ExtremeTech

Benjamin Heckendorn

Hacking Video Game Consoles

TURN YOUR OLD VIDEO GAME SYSTEMS INTO AWESOME NEW PORTABLES

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SAVE THE ATARI®

It's not extinct — give your classic console a new life

You and your Nintendo® — together again

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About the Author

Born in 1975, a mere two years before the Atari 2600 came out, Benjamin J. Heckendorn is a graphic artist/independent filmmaker/portable video game system builder who resides near the middle of Wisconsin, U.S.A. In his leisure moments, he enjoys actually *playing* video games (a welcome break from building them), doing karaoke, building cheap fighting robots out of remote-control cars, and working on his really low budget movies and beer. His favorite food is spaghetti and he hopes one day to visit outer space and do a voice for an animated film, but not both on the same day.

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Contents at a Glance

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Introduction

If you're reading this, we can assume one of the following:

- You have bought this book in order to make a portable.
- You are studying the contents of this book intently while contemplating its purchase.
- You have hauled all sorts of portable video game–making equipment (soldering irons, band saws, and so on) into your favorite bookstore, where you intend to "browse through" this book over and over until your portable is complete.

At any rate, you have an interest in making portables and you're in the right place! This book will give you the instructions and information required to hack up old video game systems, make them smaller, build new cases and controllers for them, run them off batteries, and transform them into awesome new portables that play all the original game cartridges and CDs.

The story of hacking portables so far...

On New Year's Eve 1999, some friends and I were wandering around downtown Madison, Wisconsin, waiting to start celebrating (typically around 3–4 p.m. in our state). During our travels, we came across a used-game store and inside, they had a glass case containing Atari 2600 cartridges. Much to my surprise, some of them were quite expensive!

"Do people actually pay *money* for Atari games?" I asked the friendly shop manager. "Oh yeah..." he replied, kindly pausing from his hamburger consumption to set my feet upon the path of knowledge. "People buy that stuff all the time."

This amazed me. You see, I've been an Atari fan as far back as I can remember, which translates to approximately 1980. Because my parents had bought into that "it will ruin your TV!" myth, I was pretty much the only person I knew who didn't have one, but I still managed to play a lot, thanks to my friends and relatives. A few years later, I managed to get an Atari 800 computer, which held me over pretty well until, one glorious day in 1994, I plunked down $20 for my first, very own Atari 2600 game system (complete with dust, grime, and flaky joysticks). Sure, I played SNES and Playstation during the 90's like everyone else, but I still kept the Atari hooked up so I could squeeze off a round of Space Invaders or Asteroids if I felt like it.

Seeing those Atari games in that store got me thinking... maybe I wasn't the last fan out there... maybe I wasn't alone. Luckily, the Internet (and the world) didn't end at the stroke of midnight as some had predicted, so I was able to do a search the next day. Sure enough, a *huge* fan base for Atari existed, with people even programming *new* games for the 2600, as well as other old systems! I felt vindicated!

At the time, I was working at a sign company, and we had recently acquired a new computer numerical control machine that could cut any shape or part that you could imagine out of a variety of materials. This got the gears in my head turning — I had always wanted to make something that would be a sort of "love letter" to the Atari, and I realized that now I could. After a few months of designing, hacking, wiring, and cutting, my first portable Atari 2600 was born!

After putting the portable on my Web site and getting deluged with fan mail, I concluded that, without a doubt, the Atari was still alive in people's hearts. I therefore designed several more models and then branched off into portable Super Nintendos and Playstation 1 consoles as well.

When I was offered the chance to write this book, I jumped at the opportunity because I knew it would answer one of the most frequently asked questions that I get: "Can you help me build my own portable game system?" Because of time constraints and the level of detail required, this was something that I had never been able to fully deliver on... until now.

Who this book is for

I wrote this book for people who love video games and want to bring their old systems back into the world in new and exciting ways. I also thought it would be neat to give video game lovers a "garage project" like those that people who work on cars have. Just think...

Guy 1: "Hey, what did you do today?"

Guy 2: "Put a 350 in my '91 Mustang."

Guy 1: "Sweet. How 'bout you?"

Guy 3: "Jacked up my '86 Metro."

Guy 1: "Cool. And you?"

You: "I stuck an '04 screen on my '81 Atari and overhauled the joystick."

All guys: "Awesome!"

I strived to write this book using the simplest terms possible, although rest assured — if I do sneak in a big word like "potentiometer," I'll tell you what it means. As for the construction of these projects, all potential problems and pitfalls have already been worked out for you — simply follow along and you should be fine. If not, each project has a troubleshooting section at the end to help you out.

Making these projects will be a test of your manual dexterity, as some of the soldering and cutting will require a good degree of accuracy. As a basic rule, just relax and be steady... take your time and remember that patience is a virtue. If you've got friends who are handy with tools or soldering, you can always ask them for help as well.

Using this book

This book contains seventeen chapters and is divided into two parts. Part 1 includes Chapters 1 through 5 and is meant as a primer to get you ready for portable building. Think of it as a boot camp, but with fewer push-ups. In Part 1:

- You'll first get an overview of the four game systems that are covered in this book:
  - 8-bit Nintendo Entertainment System
  - 16-bit Super Nintendo Entertainment System
  - Sony Playstation 1
  - Atari 2600

  The advantages and the challenges of making each into a portable will be discussed, along with a brief history of the game system itself.
- Then we'll talk about tools — what kind you need in order to make portables, and how to best use them. We'll also discuss soldering, which is pretty important when you're working with electronics!
- After that, there will be an overview of basic electronics for portable building. This is mostly so that when a term comes up in Part 2 (like "potentiometer"!), you'll know what it means.
- Following that, you'll learn how to hack up pocket televisions — including the PSOne screen — and use white LEDs to illuminate them. This prepares you for the projects in Part 2, or you can also use the hacked TVs in a custom portable of your own design.
- Finally, in Part 1 we'll discuss CNC machines. CNC stands for *computer numerical control* and refers to a type of machine that can automatically cut parts based on designs stored in a computer. Half of the projects in Part 2 are meant to be created with this type of equipment, so a basic overview of how they work will be useful.

Part 2 is the real meat of the book. This is where you'll actually hack up the game systems, make them portable, and build custom cases to put them in. Each of the four game systems has a group of three chapters devoted to it, for a total of twelve chapters in Part 2. Each chapter group is laid out something like this:

- The first chapter details how to hack up the game system itself. You learn what you need, how to run it off batteries, and how to rebuild the controller. From there, you have three choices:
  - **Make a hand-built case for the portable:** You won't need access to any fancy equipment — just a hardware store and a hacksaw. This option is always the second chapter in the group.
  - **Use a CNC machine to create a case for the portable:** This is a more advanced and expensive option, but it yields great results. This is always the third and last chapter in the group.
  - **Create a custom portable of your own design:** The system-hacking chapter will provide you with enough information to do this, and you can also use the procedures from Chapter 4 — "Hacking Pocket Televisions." Going through the other two chapters in the group will also provide hints and ideas. Let your creativity soar!

All of this yields a total of eight different portables that you can build using plans from this book, and a limitless number if you choose to use the general information to design one on your own. So dust off your old cartridges, pull those systems out of the garage, and toss their power cables in the trash... it's time to set them free!

So You Want to Make a Portable Video Game System, Eh?

part

I

in this part

Choosing a Game Console to Make Portable

chapter 1

in this chapter

- ☑ Nintendo Entertainment System (NES)
- ☑ Super Nintendo Entertainment System (SNES)
- ☑ Playstation 1 (PSOne)
- ☑ Atari 2600 (VCS)
- ☑ Chapter in Review

The purpose of this chapter is to familiarize you with each gaming system that this book covers and to explain the advantages, difficulties, and special challenges you'll encounter while making them portable. We'll discuss the best (a.k.a., cheapest) ways to acquire these old systems and estimate what you can expect to spend on a portable project.

From this, you can decide which project you'd like to tackle first, although this may also be determined by what equipment you have access to, an issue that will come up in Chapter 2, "Knowing Your Tools," and in Chapter 5, "Using Computerized Cutting Equipment." It may be tempting to just jump in and start ripping things apart, but if you don't want to end up with a pile of game-systems-turned-paperweights, it's best to plan ahead and know your systems. Let's get started!

The Nintendo Entertainment System (NES)

The year was 1984, and video games were dead. There had been good times in previous years. A company with its first factory in an old skating rink grew to become a billion-dollar behemoth; game programmers were suddenly making hundreds of thousands, if not millions, of dollars a year; and anyone with the right equipment could make games for the Atari 2600.

And therein lay the problem. Anyone could make games for the Atari 2600, and apparently everyone did. The market became flooded with a deluge of low-grade junk. Consumers didn't know how to tell the good from the bad, and they were tired of getting burned. Bargain bins began to fill with excess cartridges while systems sat unsold. The Atari 2600 was showing its age and the company was slow to create a worthy successor. They tried with the Atari 5200, but by then the public didn't seem interested. Video games seemed destined to become just another quirky footnote in history.

Meanwhile, in Japan, a playing-card company called Nintendo had moved into video amusements. In the early 1980s, they had had tremendous success with the arcade game "Donkey Kong," which starred Nintendo's mascot-to-be, Mario. By 1983 they had released their own video game console in Japan called the Famicom (short for Family Computer).

Realizing its potential, they approached Atari with the proposition of handling the worldwide release. Nintendo wanted a name synonomous with gaming on their system, and Atari seemed the perfect choice. However, in a strange twist of fate, Atari declined, and Nintendo chose to go at it alone.

Redesigned into a gray VCR-like box and renamed the "Nintendo Entertainment System" (Figure 1-1), the NES came to American shores in time for the 1985 Christmas season. Certain bundles even came with a robot, whose main purpose was to make retailers think this was something completely different from the Ataris they were having trouble selling.

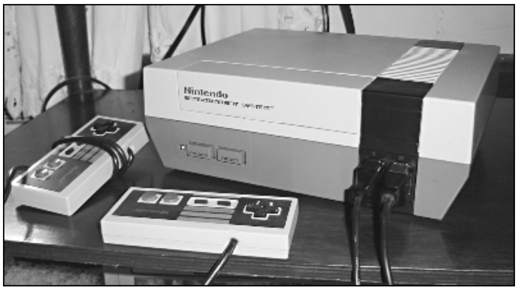


FIGURE 1-1: The Nintendo Entertainment System and two controllers (gimmicky robot sold separately).

Sales in the early years were good, propelled by the high quality of games such as The Legend of Zelda, Super Mario Bros, and Mega Man. By 1988 the NES was red-hot, with stores clamoring to keep enough games in stock to meet the demand. The NES had become more than a mere video game system — it was a cultural phenomenon that had single-handedly brought gaming from the brink of extinction to the forefront of home entertainment. And for that we should all be grateful. That said, let's rip one apart and make it portable! The NES shown in Figure 1-1 is the type you'll need for the projects in this book.

Advantages in making the NES portable

There are several advantages to making the NES portable:

- **Very popular system with a huge variety of games.** Back in the late '80s and early '90s, everybody had a NES. While it's best known for advancing the side-scroller genre with classics like Ninja Gaiden, Contra, and Castlevania, you can still find practically any type of game for the system. By the time it was officially discontinued in 1995, around 800 titles had been released.

- **Simple controllers.** The controllers for the NES are fairly simple, consisting of eight buttons (up, down, left, right, select, start, B, and A). Inside, there's a chip that sends the state of the buttons as data bits to the NES. (This is why there isn't one wire per button inside the cord, as with the Atari or the Sega Genesis.) This small number of parts allows the controllers to be hacked up quite a bit.
- **Low power requirements.** Believe it or not, the main CPU of the NES is fairly similar to the one in the Atari 2600. Therefore it doesn't use a heck of a lot of power, which gives you more play time and lets you have a nicer screen.

Challenges in making it portable

Of course, every project has potential "speed bumps" along the way, and the NES is no exception. Here are a couple to consider:

- **Abnormally large cartridges.** The NES takes some of the largest cartridges of any game system ever. Why, you ask? Well, not because they have a lot of guts in them; in fact, they're 75 percent empty space (see Figure 1-2)! Nintendo didn't want the American version of the NES to look like a video game system because video games were still considered to be dead when it was released. Therefore, the cartridge was made to insert like a VCR tape and was sized to look quite different from the Atari 2600 or the Colecovision cartridge. A portable unit can be only as small as its biggest part, and the giant NES cartridge requires the case of your portable to be bigger, and also takes up valuable space that could be used for other things, such as batteries. This creates an interesting challenge in building the portable.

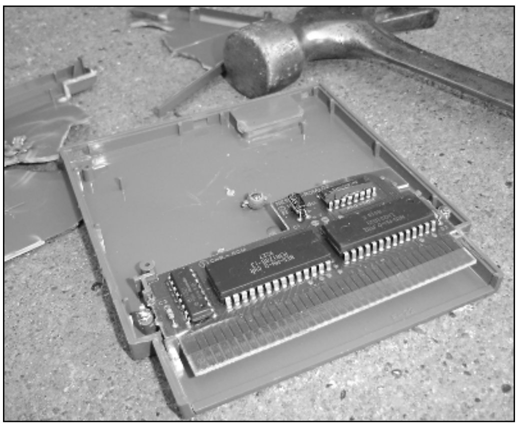


FIGURE 1-2: The guts of a NES cartridge.

- **Rewiring the cartridge slot.** The darn cartridges again! Not only are they big, but they have a lot of contacts—seventy-two of them, in fact. There are a few you can skip, but still, if you are rewiring the cartridge slot, this can be a real pain in the rear. Not to mention monotonous.

The Super Nintendo Entertainment System (SNES)

By 1990, the NES had enjoyed nearly five years of supremacy on the videogaming market. One hit game after another had been released for the system, and special cartridges were allowing them to utilize more memory and graphics than ever before. The NES was being pushed to its very limits and holding up well.

There were challengers on the horizon. The Sega Genesis had come out in 1989 and had already established itself as a worthy contender, especially with third-party developer Electronic Arts behind it. In Japan the Turbographx 16 was gaining ground, and its snazzy CD-ROM add-on gave gamers a whole new dimension of play.

To counter these scrappy newcomers, Nintendo released the "Super Nintendo Entertainment System" (SNES) in 1991 (Figure 1-3). Its processor was only a few megahertz faster than the NES, but it had vastly improved graphics that allowed for huge on-screen game characters, rich color palettes, cartoon-quality graphics, and three-dimensional immersive worlds (well, three-dimensional immersive worlds by 1991 standards).

FIGURE 1-3: The original Super Nintendo Entertainment System. (This is not the model SNES we'll be using in this book.)

The processor speed did plague the system a bit during the intial wave of games, which was jokingly referred to by some as the "free slow-motion" feature. But programmers soon learned their way around this limitation and created many fantastic games (most of them with the word "Super" in the title). Specially enhanced cartridges such as "Star Fox" gave the SNES added speed and three-dimensional graphics, prolonging the life of the system.

In 1997, Nintendo released a smaller, redesigned SNES that used a single motherboard (see Figure 1-4). This is the type of Super Nintendo that we'll be using for the projects in this book.

FIGURE 1-4: The mini-SNES we'll be using in this book.

Advantages in making the Super NES portable

The small size of the mini-SNES is a built-in advantage, but there are other great reasons to make it into a portable as well:

- **Popular system with a wide variety of games.** Having to share the market with the Sega Genesis didn't hurt the availability of games for the SNES — there are hundreds of titles available. The system really shines when it comes to role-playing and adventure games, but action and sport lovers have a lot of choices too.
- **Fairly simple controllers.** The SNES controllers have a few more buttons than the NES, but the internals are still pretty reasonable to manage. Instead of one chip to send the data, there are two, and also little subboards for the shoulder buttons.
- **Low power requirements.** One advantage to having a, hmm... "speed impaired" processor is that it doesn't take a whole lot of juice to run. Also, the second-edition SNES that you'll be using is about 6 years more modern than the original-model SNES, with increased efficiency.

Challenges in making it portable

Of course, every rose has its thorn, and the mini-SNES is no exception. Luckily, these challenges, listed below, are nothing project-threatening, just things to consider:

- **Locating a mini-SNES to use.** Of all the systems that are covered in this book, the second-edition "mini" SNES is probably the hardest to find. This doesn't mean it's overly expensive — just that you can't walk into your average used-game store or garage sale and expect to find one. I'll list places to find one later on in the chapter.

- **Working with the cartridge slot.** The cartridge slot on the SNES is pretty hard to desolder and move. I know—I've tried. The best course of action is to leave it where it is, which causes the cartridge to stick out from the board at a 90-degree angle. This will cause a few interesting challenges for the case that will have to be worked around.
- **Dealing with the shoulder buttons.** Just to forewarn you, I'm going to complain about these on the Playstation as well. The tricky thing about shoulder buttons on a portable is that you're holding a device that is heavier than just a controller alone. You need as many fingers wrapped around a portable as possible, especially a heavier home-built one. So instead of having them on top, as on the controller, we will be moving the shoulder buttons to the back of the unit (which would technically make them butt buttons, if you ask me).

Playstation 1 (PSOne)

Strangely enough, the Playstation 1 sort of began its life as a proposed add-on for the Super Nintendo Entertainment System. You see, most video game systems since the early '80s have had some sort of expansion port on the bottom or side, and this includes the SNES. However, unlike most systems with ports, plans were actually laid to use the one on the SNES to connect a CD-ROM attachment/upgrade for the system. Nintendo intended to have a partner for this new project, and they teamed with Sony to work on the tentatively titled "Playstation" add-on.

But, in a strange echo of the Atari-Nintendo nonpartnership a decade earlier, it never came to pass, and Sony decided to make the Playstation itself as a next-generation stand-alone CD-ROM–based system. (It's interesting to imagine what the video game scene would be like now if some of these near-deals had actually gone through.)

Arriving in America in the early fall of 1995, the Playstation (Figure 1-5) immediately caught the attention of the twenty-something crowd. The games were more advanced and in many cases more violent than what had typically been seen until then. Sure, there weren't a whole lot of release titles to start with, but hey, they had blood!

FIGURE 1-5: The original Playstation 1, lying on a carpet in clear defiance of the instruction manual.

A couple of years later, Final Fantasy 7 was released for the system, drawing huge new crowds of RPG fans to the Sony camp and broadening its appeal. Propelled by this and by other hit games like Resident Evil, Tomb Raider, and Gran Turismo, the Playstation sold in record numbers and Sony took the lead of the videogaming market. As of this writing (Fall 2004) it still hasn't let go.

There are two basic types of Playstation 1. The original model (as seen in Figure 1-5) came out in 1995 and ran directly off wall power. The second model (see Figure 1-6) was released in 2000. It was much smaller than the original and used a wall adapter for power, and therefore actually ran off 7.5 volts. It's commonly referred to as the "PSOne."

FIGURE 1-6: The PSOne. It's the Playstation we all know and love, only smaller. Use this one with this book.

This second, smaller model of Playstation 1 is the type that you'll need for the projects in this book. Later on in this chapter we'll discuss the best places to find one.

Advantages in making the Playstation portable

If you're wondering what's so great about making a Playstation 1 portable, consider the following:

- **Large library of great games.** As stated above, there are a lot of classic hits for the system, and chances are you're hankering to play your favorites while on the road.
- **Fairly modern 3D graphics.** The Playstation is the most advanced system covered in this book, and if you're looking for snazzy-looking portable games, this is it.
- **Makes the Gameboy Advance look like Pong.** What else can I say?

Challenges in making it portable

With all portable projects come challenges, of course, and the Playstation 1 is no exception. Some of these put the Playstation 1 project a little higher on the difficulty scale than other systems in this book, so consider the following before you begin:

- **Working with the CD-ROM drive.** As you probably remember, the Playstation 1 used regular, full-sized CDs, and so will your portable. Therefore, the challenge is to reconfigure the CD-ROM drive to work in a portable configuration and be protected from skipping. It's also going to take up more room than a typical cartridge would.
- **Rewiring and using the analog controllers.** The Playstation controller is loaded with all sorts of great buttons and analog sticks — and you'll have to rewire every one! In addition, the analog sticks take up quite a bit more depth than your average directional pad, so that must be worked around as well.
- **Working with the four shoulder buttons.** If you go back a bit, I mention this as being a problem with a portable SNES. For the Playstation, simply take that rant and multiply by 2. Not only that, but the shoulder buttons have to be out of the way of the CD-ROM drive as well.
- **Higher power requirements.** With its 33 MHz processor and CD-ROM drive, the PSOne will suck up more power than any other system we'll cover.

The Atari 2600 Video Computer System

The year was 1975. The Viking landers were on their way to Mars, the movie *Jaws* was number one at the box office, and as far as video games went, Pong was king. Atari had recently released a home version of the popular arcade game and it was a smash hit, but there was a problem. Everybody else was making it too! The market was becoming saturated with home consoles that were specialized — that is, they could play only one or two games with a few "variations" (such as select paddle length or ball speed).

Atari realized that in order to survive in the home video game business, it was going to have to come up with a machine that was programmable, meaning the owner could buy cartridges of different games and plug them into the machine to play. This may sound obvious now, but back then it was pretty revolutionary. Other programmable cartridge-based systems existed around that time, such as the Fairchild Channel F and the RCA Studio II, but Atari wanted to make something better that would hold up for the long haul.

They began development of the most advanced programmable color video game system at that time. Codenamed "Stella" after one of the engineer's bicycles, it was a make-or-break project for the company, even requiring Atari to be sold in order to obtain sufficient development funds for its completion.

Shedding the moniker of a bicycle for something far more bland, the "Video Computer System" (VCS) arrived in time for the 1977 Christmas season, with enough extras packed in to keep you busy for hours. Sales were pretty good, though not earth-shattering.

During the next few years it enjoyed continued success, but newer and more advanced systems were on the horizon. The VCS was very simplistically designed — the idea was to put most of the burden on the programmer, rather than having all of the graphical functions already built in. This proved to be the system's greatest strength, as programmers were then able to trick the system into doing things it was never intended to do.

In 1980, a programmer managed to "trick" the VCS into displaying thirty-six invaders from outer space. The resulting "Space Invaders" sold like gangbusters — people bought the system just to play the game. And with that as its stepping-stone, the VCS (now called the "Atari 2600") rocketed into to the annals of videogaming history.

The most common type of Atari 2600 is the four-switch model, as seen in Figure 1-7. It's so called because there are four silver switches on the front. This is the model of Atari 2600 you'll need to use for the projects in this book.

FIGURE 1-7: The four-switch Atari 2600 Video Computer System.

The following types of Atari 2600s will *not* work with the portable projects in this book:

- **Six-switch Atari 2600.** Has six silver switches instead of four and is somewhat heavier. This is the original model Atari from 1977. It doesn't work for these projects because the insides are completely different from the four-switch model, and it has two boards instead of just one.
- **Atari 2600 Junior.** Sleek-looking with a black shell and brushed aluminum across the front. The layout of the motherboard is quite different, however, making it unsuitable for these projects.

As mentioned before, these Ataris aren't nearly as common as the kind that *does* work, but double-check what you're getting nevertheless.

Advantages in making the Atari 2600 portable

There are actually a lot of avantages to making an Atari 2600 portable. Even if you think the system is just "too old" and out of date, consider the following:

- **It's a classic system with timeless games.** The Atari 2600 is easily the most well known and beloved classic gaming system in the current classic video game market. Anyone who was alive and beyond the pacifier-sucking age in the early '80s has memories of the system, whether it was theirs, their older brother's, or a friend's. By the same token, the games are simple and nostalgic. They weren't terribly complex, but therein lay their beauty. Unlike modern games that often get bogged down with storyline, graphics, and gore, the classic Atari games were simply about reaction, timing, and skill. They were the essence of gaming, and their universal themes still hold up today. It's like escaping your high-tech office to take a leisurely stroll through the park (but with a joystick).

- **The cartridges are small.** When you're out and about with your newly built portable system, you'll probably want to carry at least a couple games with you. The Atari 2600 has fairly small cartridges, making game toting a breeze! (In fact, the results of my personal testing show that you can fit two changes of clothes, an Atari portable, and eight cartridges in your average carry-on bag and *still* have room for deodorant. If you skip the deodorant, you can fit one more cartridge, but I wouldn't recommend it.)
- **The motherboard can become small.** The Atari 2600's motherboard (it's pretty old; shouldn't it be called a GRANDmotherboard?) starts out at a size of 10" wide by 5" high. Using the hack-and-slash methods in this book, you can get that down to a 4" × 4" square and it will still work. This allows you to build a smaller portable than the other game systems, and it's also interesting to see just how much of it can be hacked off.
- **Simple controllers.** Or "joysticks" as we called them back in the days of old. When it comes time to rewire and rebuild the controllers, the Atari 2600 joystick is the easiest because it's so simple. No special chips or anything, just five switches — up, down, left, right, and the trigger button. Just think, you'll be able to tell your grandkids/robots, "When I was your age, we had Atari. And they only had one button on 'em! And we liked it! And we didn't complain!"

Challenges in making it portable

There are a few challenges in making the Atari 2600 portable, but they're mostly things you have to do in order to get the full benefit of the system's advantages. (That makes sense, when you think about it.)

- **Working with the cartridge slot.** The Atari cartridges are small, but they have an annoying feature — the door (as seen in Figure 1-8).

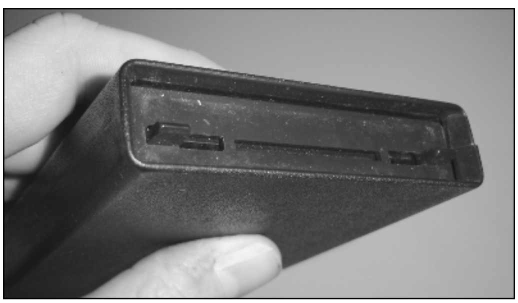


FIGURE 1-8: The pesky door that protects the Atari cartridge's guts from the outside world.

The cartridge slot on the Atari itself has two little tabs that push into the slots on either side of the door, allowing it open. Most cartridges made after 1981 don't have this door, but if you want your portable to play the older cartridges, you're going to need to either include the entire Atari cartridge slot assembly (the easiest but bulkiest method) or manually attach some tabs to make the door open (the harder but more compact method).

Note Even though the Atari cartridge slot is kind of large with a lot of excess plastic, we'll leave it intact in its original form for the two Atari 2600 projects in this book.

- **Getting a modern video signal.** If you're a fan of the Atari 2600 from "back in the day," you probably remember those RF switch box things (Figure 1-9). This took the RF signal from the Atari and channeled it into your TV. The switch was there so that you could go back to watching *The Dukes of Hazzard* or *The A-Team* when you got tired of games.

FIGURE 1-9: The RF switch box.

Although you probably could attach one of these to a pocket television, you certainly wouldn't want to. The preferred input for a pocket TV is the audio/video input jack, which uses the same kind of signals as the RCA jacks on the back of a regular TV or VCR. By default, the Atari 2600 doesn't output these types of signals, and it will have to be modified with a circuit in order to do so.

- **Slicing up and rewiring the board.** The standard Atari 2600 motherboard is too large to be used in a portable; therefore, you will need to slice it apart. This can be done with an X-Acto knife or a band saw.

Finding These Game Systems

Now that you've had an overview of each game system and its advantages and challenges, let's talk about where to find these old things. The purpose of this section is to point you in the right direction for the system you're looking for, and hopefully save you a buck or two along the way. I'll list the place, store, or resource first, followed by which video game systems you can expect to find there (in order of likelihood) and at what price (circa 2004).

- **Used–video game stores.** Large chain stores have some systems, but your best bet is a smaller, locally owned kind of place. Systems that they're likely to have include
  - **PSOne.** The previous generation of game system is always the easiest and cheapest to find. You should be able to get a PSOne and Dual Shock controller for $30 or less.
  - **Nintendo 8-bit.** Stores usually get these pretty regularly, but they also sell rather fast once they're in. Checking the store often or reserving a system is a good way to get your hands on one. They usually sell for $30–$45.
  - **Atari 2600 four-switch.** As with the NES, they sell fast when in stock, so frequent checking is a must. They're also about the same price as the NES.

  It's also not a bad idea to ask the manager of the store if they have any "broken" Nintendos or Ataris. If you can get one cheap (say, under $10), it's worth a shot, as the modifications we'll be doing on these systems in later chapters will often get them working again. This also applies to any "broken" systems you may already own.
- **Online auctions such as eBay.** These are great resources because they make it easy to find pretty much anything you might want. However, the prices can tend to be on the high side, and most game systems auctions usually include a bunch of common games you probably don't want. That said, it's a great way to find the following:
  - **mini-SNES.** An online auction is the best way to find one of these. While not the most common system, it's also not terribly rare (despite what the item description might say, of course — I've seen auctions listing the Atari 2600 version of *E.T.* as "rare"), so if bidding goes over $50 with no games, you should try another auction.
  - **Atari 2600.** Online auctions are the second-best place to purchase one of these, though you'll pretty much be guaranteed to get a load of common junk games with it. A bare-bones system usually starts around $20–$30, but if sellers think their junk games are worth anything, expect the price to be a bit more.
  - **Nintendo 8-bit.** If the used-game store fails, you can always find one online, usually for around $20–$30 with no games.
- **Garages, closets, and rummage sales.** I have a saying, "Nothing is cheaper than something you already own," and it certainly applies to any game systems you might have buried in the closet. Ask friends, relatives, and coworkers too; they're usually glad to get rid of junk. It's a great way to find the following systems:
  - **Atari 2600.** This is practically a given, but think about it. Back when people were shelving their Atari 2600s, used-game stores that bought that stuff weren't nearly as common as they are today. Therefore, instead of unloading an old system at GameStop for a couple bucks, they'd just throw it into the garage. The point of this ramble is that a lot of people still have Atari 2600s lying around their homes. They're probably not even going to put them out in rummage sales any more, so you'll have to ask. But it's definitely worth a shot.

- **Nintendo 8-bit.** Along the same lines as the Atari 2600, although by the time people started getting rid of their NES systems, there were more used-game stores around, and so the closet-to-video game ratio won't be as high as it is with the Atari.

What You Can Expect to Spend

The cost of building each of these projects varies depending on how much the game system costs, what type of screen it uses, and how you construct the case for it. This book provides two ways of creating the case for each of the four portable systems:

- Making it by hand using readily available off-the-shelf parts
- Using computer-controlled (CNC) cutting machinery, such as a router or laser engraver, to form it

This results in a total of eight portables you can build using this book. Table 1-1 provides an estimated cost per completed portable video game system. (The cost of having to buy the original game system is included, so if you already own the correct model, you'll save some money off these estimates.)

Table 1-1 Estimated Costs for Building Portables

System	*By Hand*	*By CNC Machine*
Nintendo Entertainment System	$175	$330
Super Nintendo Entertainment System	$210	$350
Playstation 1	$150	$340
Atari 2600 Video Computer System	$250	$325

Some notes regarding these price estimates:

- Actual cost will vary depending on your skill level and how easy it is to find parts.
- Estimated cost of paying to use a CNC machine is based on a rate of $60–$80 an hour. In Chapter 5, we'll discuss ways to minimize the routing and laser engraving costs.
- All of the above price estimates include batteries and charger, with the exception of the Playstation portables and the CNC-built Atari 2600.
- The Playstation portables and the CNC-built Atari 2600 will use a Sony Infolithium Type L battery for their power source. You'll also need a separate charger for the battery. The battery-and-charger combo will add, on average, about $50 to the total price. If you have a Sony camera/camcorder with this type of battery, you can use it with your

portable and charge it with your camera. Whether or not you have one of those Type L batteries or will be able to find a good deal on them online should be taken into consideration when you pick your project. (More on this in Chapter 3.)

- In general, the hand-built systems are cheaper for two main reasons:
  - No CNC machine operation time is required.
  - Most of the hand-built portables use Sony PSOne screens, which are fairly cheap (around $50–$60 each). We'll talk about these and other types of portable LCD screens in Chapter 4.

Chapter in Review

So far, we've talked about the four game systems that this book teaches you how to hack apart — the NES, SNES, PSOne, and Atari 2600 four-switch. We also discussed:

- The different versions/models of each video game system and which ones you need for the projects in this book
- Specific advantages and challenges in making video game systems portable
- Where to find the old systems at reasonable prices
- The total amount of dough you can expect to spend on each project.

In the next chapter, we'll talk about the tools you'll need for building portables and how best to use them during the construction process.

Knowing Your Tools

chapter 2

in this chapter

- ☑ Soldering Irons
- ☑ Desoldering Irons
- ☑ Multimeters
- ☑ Tweezers
- ☑ Drills and Drill Bits
- ☑ Hot Glue Guns
- ☑ Other Tools You Can't Hack Without
- ☑ Chapter in Review

Since the dawn of time, people have built and used tools to help them with their daily tasks, such as slaying saber-toothed tigers or opening jars of pickles. Portable building is no exception — you need the right tools to do things such as:

- Solder wires to motherboards and components
- Remove existing parts from motherboards
- Cut apart plastics and metals
- Glue things together and secure parts in place
- Test electronic connections and power sources

Although requirements will vary slightly from project to project, to build any portable in this book, you'll generally need access to all the tools discussed in this chapter. Don't worry, though — most of them are fairly common and may already be in your home. The ones you may need to purchase are still pretty cheap, allowing you to spend most of your money where it counts — building the portable game system itself.

Getting the small, mundane things, like how to solder, out of the way now will save us time during the big projects in Part 2. So when you're working on those and I say, "Connect this to this and desolder this," you'll already know how to do it. Sound reasonable? Cool, then let's get started!

Soldering Irons: Which End to Hold

Your first and most important weapon in the battle to free your game consoles from the bondage of their power cords is your *soldering iron.* Unless you are very skilled with matches or can shoot laser beams out of your eyes, this is one tool you pretty much have to have. In this book's projects, you'll use soldering irons to do the following:

- Connect wires to existing soldered spots on your game system's motherboard. The best way to connect things to existing solder is with more solder.
- Connect wires together or extend them. You could simply twist the ends of the wires together, but that can come loose. Wire nuts work, but they take up too much space. The best option is to twist the wires together, solder them for a tight bond, then cover the bare wires with a bit of electric tape.
- Attach components (such as resistors and switches) to copper-plated printed circuit (PC) boards: Soldering a component to a PC board not only mounts it (holds it in place), but prepares it to have wires attached as well.

In the following sections, we'll discuss types of soldering irons, what types of solder to use with them, and the best soldering techniques to use when making electrical connections.

Types of soldering irons

Not all soldering irons are created equal! Use the wrong one and your portable project could bite the dust — a $20 iron can ruin a $150 pocket TV quicker than you can say... something they won't print in this book.

The list below describes each type of iron, how much power they use, when they are useful to a portable builder, and where to find them.

High-power irons — 100-watt range

These babies are also called "soldering guns" — complete with a trigger that you pull when you want stuff to melt (Figure 2-1). They're meant to get real hot real fast and melt lots of solder when they do. Using one of these on a circuit board is usually a mistake, as the high heat can melt the solder off several things at once!

FIGURE 2-1: A high-power soldering iron, 100 watt range.

These irons are available in most retail outlets, sometimes for less than $10. Here's when one might come in handy:

- **Removing the huge amounts of solder on RF boxes.** These are the things that generate a Channel 3/4 signal in a game system, and they're always heavily soldered in place. It can be removed with a smaller iron (or blowtorch), but this will speed things up And yes, the RF box is on a circuit board, but it's usually not near anything else important.
- **Desoldering huge mistakes.** This iron is mostly meant for huge things. If you have a megaclump of solder that not even a desoldering iron can handle, the high-power iron will do the trick.

Medium-power irons — 40-watt range

This is the most common type of iron that you'll come across — you've probably got one lying in your junk drawer right next to your bent screwdriver and leaking tubes of epoxy (Figure 2-2). It's a pretty decent all-purpose tool: hot enough to melt considerable amounts of solder, but also reasonably cool enough to use on most circuit boards. The tips are usually kind of large, but you can grind them down to more of a point if you wish.

FIGURE 2-2: A medium-power soldering iron, 40-watt range.

As with the high-power irons, you can find these in your average hardware store or retail megastore for around $5–$10. Here are some situations when this type of iron will be of use:

- **Most general soldering on the NES and Atari 2600.** These systems are old enough that they're fairly simple with well-spaced parts. Therefore, you don't have to worry too much about oversoldering.
- **Soldering large connections,** such as switches, battery terminals, and ground connections. These can be done with a smaller iron, but the higher heat will make it go faster.

Low-power irons–15-watt range

Often called a "pencil iron" (Figure 2-3), the low-power 15-watt iron is usually your best bet for general-purpose portable-building work. The standard tips are generally fairly pointed (and similar in size to — get this — a pencil!), for precise connections.

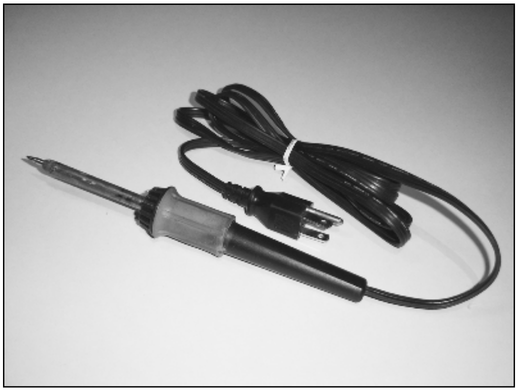


FIGURE 2-3: A lower-power "pencil" soldering iron, 15-watt range.

This type of iron costs under $10 and can be found at your local Radio Shack or a similar electronics vendor. This iron is best suited to the following tasks:

- **Soldering several connections in a row to ribbon cable.** The pencil iron will only melt the solder you want it to, without also melting excess plastic off the wire (which can cause short-circuit nightmares).
- **Attaching wires to small components** such as tact switches and LEDs (more on this later).
- **Working with surface-mount soldering on pocket TVs, the PSOne, and the SNES.** Surface-mount soldering refers to parts on a circuit board that do not have leads going through the board — rather, the part is soldered to the copper on the board surface. In most cases these connections are smaller than usual, thus requiring a fine-tipped soldering iron if you want to work with them.

Types of solder

Solder is typically made from tin and lead alloy and comes in coiled rolls. The most common type is called "rosin-core solder" because it has, well, rosin in the middle. The rosin melts with the solder, helping to make a better connection.

Solder comes in different thicknesses, typically ranging from 0.03" to 0.08" diameter. For the majority of portable-building work, I'd suggest getting an 8-oz. roll of 0.032" solder from Radio Shack, part #64-009. It's around eight bucks, which may seem like a lot for solder, but it'll last you a long time. (I'm on maybe my third roll in 3 years.)

The thicker sizes of solder may come in handy if you're making larger connections, but you'll lose accuracy. If you need more solder, just use more of the thin stuff!

Using soldering irons

The traditional way to use a soldering iron is to first heat up the spot/wire that you want to solder, and then press the solder to it so that it melts and covers the part. This works for connections that are already twisted together, but when building a portable, the majority of your soldering will involve attaching loose wires to various connections on a circuit board. Since you can't hold the solder, the wire, and the iron at the same time, I'd suggest the following method:

1. Find a spot on your workbench that you don't care about (or work over a piece of something that won't melt).
2. Pull out a good length of solder from your roll and bend it into a wiggly shape, as shown in Figure 2-4. This increases the amount available to use before you have to pull more out again. Clever, eh?

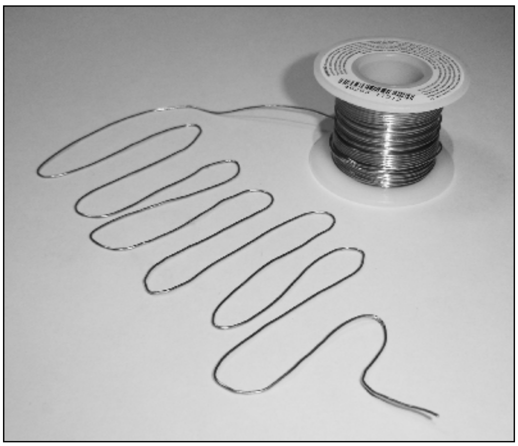


FIGURE 2-4: The solder snake.

3. Take the wire that you want to add to a connection, and make sure that its strands are twisted (Figure 2-5). This prevents loose strands from causing short circuits.

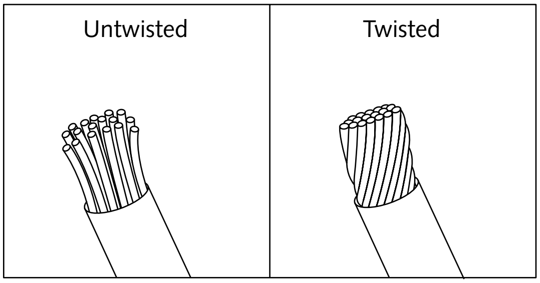


FIGURE 2-5: Stranded wire, untwisted (bad) and twisted (good).

4. Touch your soldering iron to the solder strand. If your iron is clean (the tip looks like metal, not brown gunk) a ball of molten solder will stick to it. You won't need very much.
5. Place the wire on the existing solder just to the side of the connection's lead.
6. Bring the iron over, and place the ball of solder over the strands. Press down a little. The solder will cover the wire and melt into the existing solder.
7. Hold the wire steady until the solder "glazes over." Once it looks dull, rather than shiny, it's set, and you can let go of the wire.

If you're moving the iron around with a blob of solder stuck on the tip, be warned that it can drip off, especially if it's a large blob. It could hit and damage delicate parts, such as an LCD screen, or land on your bare skin and burn you. Flying through the air for even a short distance will cool off the solder quite a bit, but it will still make you yelp if it hits your skin.

As an alternative, you may want to take the solder in one hand and the iron in the other, and first go along the board, putting new solder on all of the connections that you expect to use. This will "freshen up" the old solder. Then you can come back and attach a wire to a connection by pressing it down on the new solder with the iron until the solder remelts, and holding it in place as the solder cools again.

Here are some other general guidelines to keep in mind:

- Solder likes to stick to solder. Therefore, a bit of molten solder will gravitate toward a bigger spot of solder, much like the liquid metal that the bad guy in *Terminator 2* was made out of.
- When connecting wire, especially stranded wire, make sure that the solder completely surrounds it (Figure 2-6). This is where solder sticking to solder comes in handy, because the solder should "form around" the wire and connect to the existing solder below.

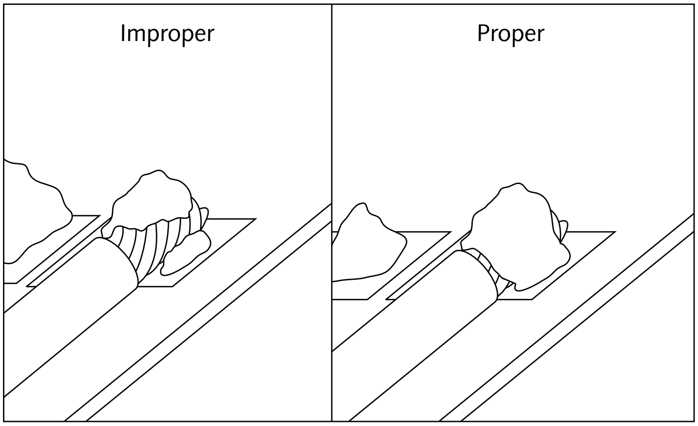


FIGURE 2-6: Improperly covered wire and properly covered wire.

- If a wire isn't completely covered with or surrounded by solder, you might as well assume that it will break loose. During the construction of a portable, you're going to be moving and flopping around these parts and wires over and over again. That's a lot of wear on the connections, so make the solder connections well the first time.

As stated earlier, a 40-watt or 15-watt soldering iron is your best choice for this type of work. Both of these irons resemble pencils, and that's exactly how you should hold one (Figure 2-7). When using it, rest your hand on the work surface for maximum steadiness. For very accurate work, you can hold your soldering hand steady with your other hand.

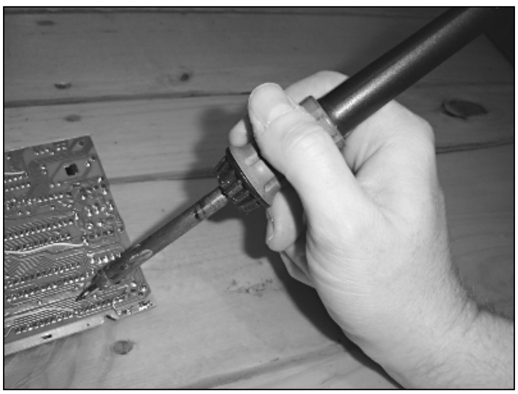


FIGURE 2-7: The proper way to hold a soldering iron. (If you're left-handed, hold this page up to a mirror.)

Try to keep the tip of the iron straight over what you're soldering. If it's tilted too far sideways, you may accidentally melt solder onto other nearby connections (Figure 2-8).

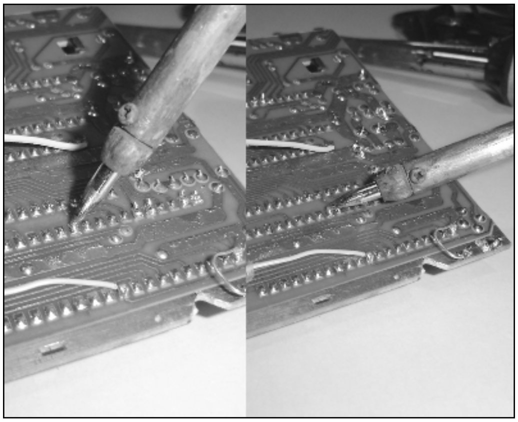


FIGURE 2-8: Tip held straight (correct), and tip tilted too far sideways (incorrect).

If you're using a lower-power iron and need some extra "oomph," try pressing the thick portion of the tip against the solder, or even the main metal part that holds the tip. This puts a greater area of heated iron against the solder to melt it faster.

"Oh no, the solder has (insert problem here)! What do I do?"

Heated solder is liquid in nature, and as we all know (especially those of us with kids), liquids can spill and make a mess. When solder spills, it can burn you or accidently connect things that you don't want it to. This can cause short circuits and in some cases even ruin parts. In this section, we'll discuss some common soldering problems and solutions in a question-and-answer format.

Q: I have accidentally soldered two connections together and I don't want to wait for the desoldering iron to heat up. Any thoughts?

A: I know the feeling! First, make sure there's no excess solder on the tip of your iron (tap the iron against the stand, then shake it off). Place the tip of the iron between the connections that you want to separate. Once the solder between them is molten, press the soldering iron down onto the board and drag it between the connections. When done correctly, this will create a clear space between the connections, and the solder will freeze before flowing back together. Also, some of the solder will stick back onto the iron. This may take a few tries, but it's faster than waiting for the desoldering iron to heat up. If you want to make sure that there's no trace of solder left between the connections, scrape the board there with a knife when you're done.

Q: I'm having trouble getting the solder to stick to a connection — it seems like the original solder on the board won't melt. Is my soldering iron too wimpy?

A: Using a higher-powered iron would do the job faster, but there are other reasons for this problem as well. If it's an old circuit board, the solder may have "rusted" a bit, which prevents new solder from sticking to it easily. The other possibility is that the connection may have a film over it. Some films are obvious, such as the usually green coating you see on most circuit-board traces (the traces are the circuit lines), while others are less noticeable; the leads may be coated as well, for example.

In either case, try one of the following:

- Scrape the connection with a knife and try again.
- Use your desoldering iron to remove the old solder so that you can start from scratch.
- Put a lot of new solder on the connection, and hold it there with the iron. Eventually, it should melt through any gunk and stick to the old solder. Don't use so much that it causes the connection to melt onto the one beside it, however (see the previous question).

Q: My connections keep breaking loose! I'm at my wit's end!

A: Sometimes solder will seem to stick to something, but not actually attach itself. This is a problem related to the previous question about the existing solder not melting. When you connect something, look and see that all of the original solder turns shiny and connects to the new solder — you may have to keep the heat on it a bit longer than you think. After soldering a wire in place, yank it around a bit to see if it's attached well (the "yank test").

Q: Um, I used my soldering iron to poke a hole through some plastic because I couldn't quite reach my drill (or didn't want to bother plugging it in). Now the iron is stinking up the place and doesn't solder well at all. What now?

A: If you're going to do this (and I think everyone does it at some point in their life), you may as well make a lot of holes because doing it even once will gunk up the tip. When you're done, you should clean the tip as described in the following section.

Keeping the tip in good condition

After a while, the tip of a soldering iron will become covered with residue, making it harder to solder. Generally, if you can't see bare metal on the tip, the solder won't stick or melt well. There are a few ways to clean it up:

- Using the blade of a dull knife that you don't care about, scrape across the tip toward the point.
- Twist some sandpaper around the tip, as if sharpening a pencil.
- Get a container of *tip tinning paste*. Available at Radio Shack (catalog #64-020), it comes in a little can that has some adhesive on the bottom so you can stick it to your work area. It's pretty solid stuff at first, but don't let that discourage you. Take the heated tip of the soldering iron and press in into the paste. Eventually it'll heat up and start to sizzle, and then the tip will sink in. Roll the tip in the bubbling paste for a bit, pull it out, wipe off the sizzling gunk, and you'll have a nice shiny soldering iron tip. Once you get your can of paste "broken in" after a few uses, the stuff will melt faster.

Desoldering Irons: Suck It Up

In this book, we'll be removing things from video game systems and their motherboards in order to make them smaller. When you need to remove a part that's been soldered to a board, you'll use a *desoldering iron* (Figure 2-9). Sure, it's basically just a hollow soldering iron with a central hole and some sort of suction device, but it's pretty much indispensible in the world of portable making. I highly recommend that you pick one up for around $10 at your local Radio Shack (catalog #62-2060).

FIGURE 2-9: Your standard-issue desoldering iron.

This is the most common type of desoldering iron. It's cheap, easy to use, and will work with every project in this book.

Using desoldering irons

All the game systems that we will discuss have circuit boards with *through-hole* parts. A system component (such as a capacitor) has leads coming from it, each of which goes *though* a *hole* in the circuit board. These are soldered in place on the back/bottom of the board (the *solder side*), and the solder flows around the lead on the front, inside, and back of the board (Figure 2-10). This is why a desoldering iron needs suction; otherwise, you wouldn't be able to get all of that solder out.

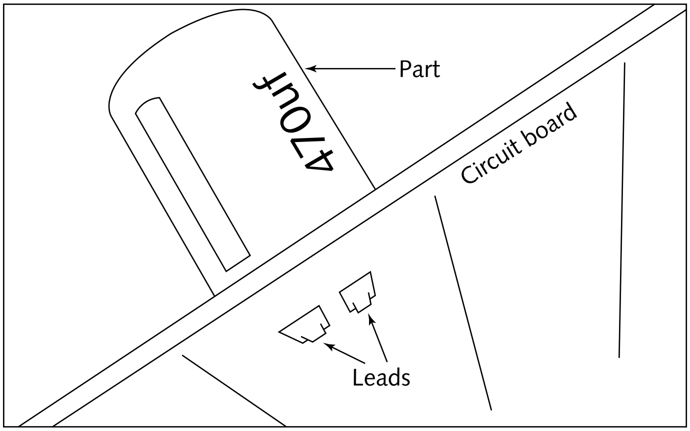


FIGURE 2-10: A part, the circuit board, and the part's leads.

To desolder a component's lead, you squeeze the bulb on the iron and then place the tip over the lead so that it's touching the solder. The solder will melt in about a second, at which point you release the bulb, which then sucks up all the solder around the lead. Finally, you hold the iron over something and squeeze the bulb again to blow the solder out (Figure 2-11).

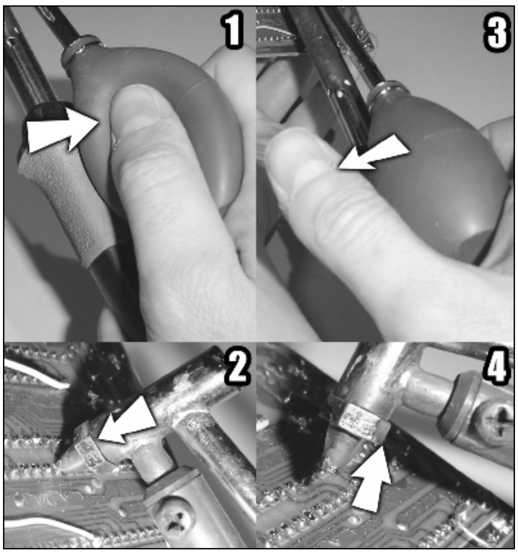


FIGURE 2-11: Desoldering something — a step-by-step pictorial guide!

Blow the excess solder into a small container, such as a plastic lid from a detergent bottle or can of spray paint. Don't blow the solder into an unmarked soda can, as you (or someone else) might accidentally drink from it — remember, solder contains lead, which is poisonous. If you want to use a soda can, cut it in half first. That'll give you a larger target to aim the solder at, as well.

If you're having trouble removing a part, especially a large part, such as a cartridge connector, try the following:

- Rock the part back and forth. If a lead moves at all when the solder is cold, then it's ready. Check which leads aren't moving, and desolder them again.
- If you've tried to desolder a lead a couple of times with no results, put new solder on it with your soldering iron. This gets all the loose bits of old solder mixed with the new. Then desolder it again (this sounds silly, but it works quite well, especially with older game systems).
- Using your free hand or a screwdriver, pull or wedge the part away from the board at one end while you desolder. Even if you don't get all the solder, this forces the leads to move. If the part seems fragile, then don't try this, but for most things, such as cartridge slots and controller ports, you're fine (especially if you're just going to throw it away after you remove it).
- If the desoldering iron's hole doesn't fit snugly around the lead you are trying to desolder, push the lead against one side of the hole. This causes heat to transfer down the lead and melt as much solder as possible.

The amount of time it takes to desolder something will vary, and for best results you should keep the iron in top shape as described in the following section.

Maintaining desoldering irons

Have you ever not changed your oil for a few years, then had your car grind to a stop one day, leaving a trail of gears behind it? Then you know that equipment maintenance is important, and this goes for desoldering irons too. As with a regular soldering iron, the main thing that will go bad is the tip. Sure, they're replaceable, but why waste them?

- Keep the surface of the tip clean and flat — when it's gunked up, it won't melt solder as fast. Scrape it clean every so often using a piece of sandpaper. As with a soldering iron, when you can see the shiny metal again, you're good to go! (See Figure 2-12.)

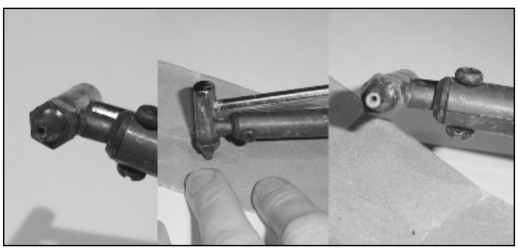


FIGURE 2-12: A desoldering iron tip before, during, and after cleaning.

- Try not to enlarge the hole — this happens when you try to cram the tip over a lead that doesn't quite fit the hole. Once it gets enlarged, it won't suck solder as well when you go back to working on normally sized leads.
- Over time the hole will enlarge regardless of how you use it. Get a new tip, but keep the old one around to desolder any thick leads you may come across, so that you won't wreck the new one.
- Over time, solder will accumulate in the iron and in the bulb. With the iron on, squeeze the bulb rapidly to blow out the excess. With the iron OFF and cold, you can pull off the bulb and dump out whatever residue may be in it.
- Don't switch tips while the iron is on! Unplug it and let it cool completely first. This may sound obvious to anyone who's made it past third-grade science class, but I've done it (um, accidentally of course!), so I just want to forewarn you. The tip and the iron will expand and contract at different rates, and you'll probably never get the tip out or completely back in again.

Multimeters: What They Are and Why You'll Need One

A *multimeter* is a device that can detect and determine the amount of electricity going through a circuit. They are encased in plastic boxes and usually have a big knob that can be switched to multiple settings (hence "multimeter"), depending on what you're trying to test. There is a display of some type that gives the reading, and two wires, usually black (negative) and red (positive), with metal leads on the ends. A multimeter usually runs off one or two AA batteries.

You'll mainly need a multimeter during these projects to test and troubleshoot your portable. It will let you check how much (if any) power is getting to certain places, whether or not things are electrically connected, how much resistance to current exists between two circuit points, and if things are shorting out. In this section, we'll discuss different types of multimeters, which kind is best for which task, the average cost of each type, and how to use one.

Types of multimeters

There are two main types of multimeters: digital and analog.

- **Digital** (see Figure 2-13). These multimeters allow for precise measurements and typically adjust the scale of measurement for you automatically, depending on what you're testing. This ensures that the decimal point is in the right place so you don't mistake 0.7 volts for 70 volts, or something like that, because you used the wrong scale. Ranging in price from $10 and up, they're a great choice for portable building, as they reduce the chance of error.

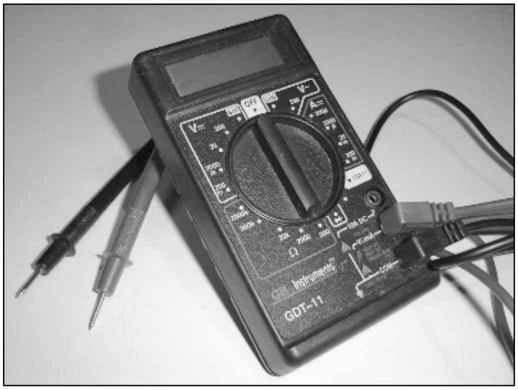


FIGURE 2-13: A digital multimeter.

- **Analog** (see Figure 2-14). These multimeters accomplish pretty much everything that digital ones do, but use the position of a needle instead of a digital display to show measurements. Check the instructions on how to correctly read the needle, as several ranges and scales appear on the face of the meter, and it's up to you to use the right one. Analog meters are cheap, usually in the $10-and-less range, and are available in most retail stores, but unless you're really trying to pinch your pennies, it's better to pop $20 more for a decent digital model.

FIGURE 2-14: An analog multimeter.

Using multimeters

Don't be intimidated by all the settings on a multimeter; it really only measures three things: voltage, resistance, and amperage. Here are explanations of what they are, and how to use them.

Testing voltage

Want to know if a battery is any good? Or if 5 volts is really getting to a spot on a board? Switch your multimeter to measure voltage, and dive in! (See Figure 2-15.)

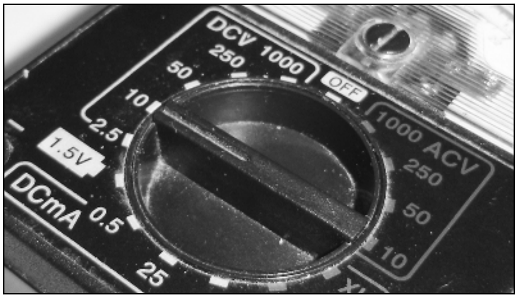


FIGURE 2-15: Multimeter set to test DC voltage.

With dial multimeters (either analog or digital), you usually have to select the range of voltage you want to test and whether it is DC (direct current, like a battery or adapter plug for your cell phone) or AC (alternating current, like a wall plug-in). In this book, we'll be DC-only, since we're building portable units that use DC batteries. If you need to test for around 5 volts, you'd set the multimeter the next highest available value up, such as 10 volts. To do this, look on the multimeter dial for the DCV (direct current voltage) section, then switch to the voltage you want in that section.

With autoranging multimeters, it's even easier. There's no dial, just a switch (see Figure 2-16) that you slide to voltage, resistance, or amps, and that's what the meter tests. It'll test both AC and DC with the same setting.

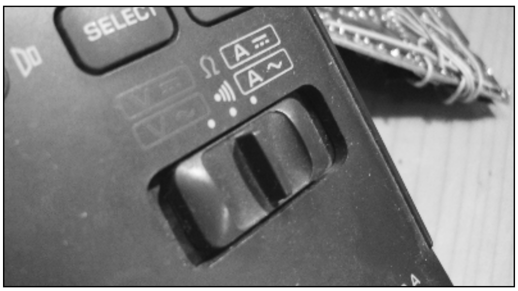


FIGURE 2-16: The selector switch on an autoranging multimeter. From left to right: voltage, resistance, and amperage.

Once you've selected the range, simply place the red prong where you want to check for positive voltage and the black prong on the negative or ground. (If you're checking a connection on a circuit board, the edges and large main areas of metal are usually ground.) Once you make both connections, the meter displays the voltage.

Keep in mind that a lot of things don't actually deliver the claimed voltage. For example, a fully charged 9.6-volt car remote control battery will read around 11.5 volts, and a regulated 5-volt power supply in a game system reads about 4.97 volts.

Testing resistance

The most common reason for testing resistance with these projects is to see if a wire or circuit is properly connected. This sounds silly, but you'll find yourself checking it a lot. (I know I do.)

Set the dial or switch to the ohm symbol, Ω (Figure 2-17). On a dial multimeter, there's usually only one or two ohm settings; use the lowest one.

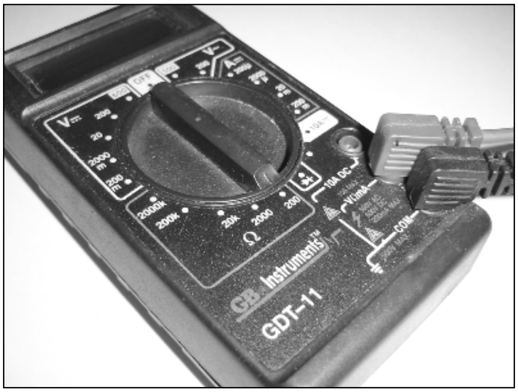


FIGURE 2-17: The dial set to ohms.

Touch the leads to the points you want to test. If there's a good connection between them, the reading will go to 0 (no resistance), or the needle on an analog meter will go all the way up with a click. Checking resistance is also useful if you've done a bunch of connections, all very close to each other, and you want to see if there are any short circuits.

Most digital multimeters have a feature where they can audibly "beep" if they detect no resistance. This is handy because you can keep your eyes on your work and not the multimeter. It's very handy when testing long rows of connections, such as those in cartridge connectors. Beep — that one's okay; beep — that one's good; dead silence — uh oh, that one's bad.

You can also place the leads on both ends of a resistor to find its rating. This works best with a digital multimeter, and is a lot faster than working out the resistor's color code.

Testing amperage

I'm not trying to teach the fundamentals of electronics in this book, so for now I'll describe amperage (or amps) simply as follows: The more amps something takes, the faster your batteries go dead. We'll talk about amps a little more in Chapter 3, but for now let's learn how to measure them.

Look for a setting on your dial multimeter that reads DCmA or DCA. This means *direct current milliamps* and *direct curent amps*, respectively. Most of the portables described in this book will use under 1 amp, so we'll deal mostly with milliamps, which is one thousandth of an amp. For this example, set it to around 500 milliamps. If you're using an autoranging multimeter, switch it to test amperage (see Figure 2-16). Note that on some multimeters, there is a different slot that you have to plug the positive lead into when you measure amperage, so check your manual.

The difference with testing amps is that you place the multimeter leads in series with the circuit. Figure 2-18 shows how the amperage of a simple motor is tested.

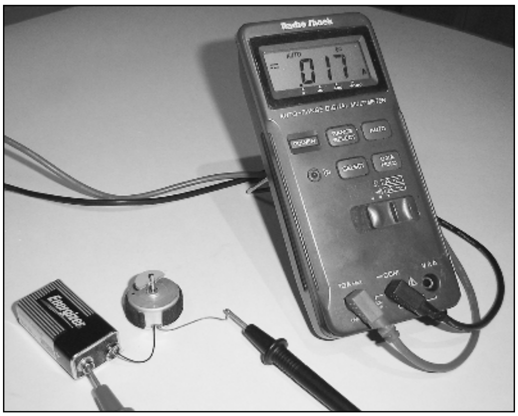


FIGURE 2-18: The current goes from the battery through the multimeter, then through the motor, and back to the battery.

This figure shows that the motor consumes around 17mA of power at 9 volts. You can hook the multimeter between the battery and your portable when it's finished to check how much power it is consuming. This, along with the mAH rating of the battery, will allow you to estimate how long the portable will run (or you can simply play the thing and time it).

Tweezers: Your Friend and Ally

The human hand is an amazing thing, but some tasks are simply beyond its abilities, such as rewiring microchips or opening CD wrappers quickly. When your fingers just aren't accurate enough, use them to reach for a pair of *tweezers*. They're of great use when you need to:

- Hold wires at a point where you're soldering. This is the most common use, and will save your fingers from many a burn.
- Make accurate bends on leads and wires. This will come in handy when you attach LEDs (light emitting diodes) to a pocket TV, as described in Chapter 4.
- Make temporary switches or electrical connections. If you want to test to see if a button works, you can just put one side of the tweezers to ground and the other side to the button. The metal tweezers will complete the connection and activate the switch.

You'll use tweezers constantly when building portables, so head down to the cosmetics section of your favorite retailer and pick some out. A pair with a rubberized coating works well and is easy to hold. If you have access to a grinding wheel (or are really diligent with sandpaper), you can sharpen the points down to make them more accurate.

Drills and Drill Bits: The Hole Story

A *drill* will come in handy when building a portable unit, mostly to make screw holes in cases and in custom circuit boards. There are also times when an existing hole on a motherboard will need to be enlarged.

Any sort of drill will work, and which one to use mostly depends on your preference. I like using chuckless drills (the chuck is the thing that tightens the collet around the screw). With a chuckless drill, you just put the bit in, hold the collet, and pull the trigger. The collet is held in place by your hand, and the teeth clamp in on the bit. You also might want to consider a cordless drill. When your soldering iron, desoldering iron, and hot glue gun are already all plugged in, the fewer additional power cords to get tangled, the better.

Also find yourself an expendable chunk of wood to drill on, or a workbench. If you're drilling holes through a circuit board and accidentally slip through and hit your heirloom dining-room table, your significant other or your mother (or your significant other's mother) might not be too thrilled.

Drill bits come in all shapes and sizes. Bits intended for metal are a good choice for building portables, as they'll go through most anything you'll need them to. If you don't want to buy a whole set of bits, here are the sizes that are most often used for video game projects:

- **1/16"** These make nice little holes for attaching things like sliding power switches and portions of a pocket TV.
- **7/64"** This is very close to 1/10" and makes holes to stick size 4 screws into.

- **1/8"** Most of the screws we'll be using are of this size, so the holes should be too!
- **1/4"** If you're using any jacks on your portable (DC power in, A/V output) this size bit will make a perfect hole for it in the side of your portable. A 15/64" bit is quite close and will work as well.

Hot Glue Guns: How Did We Ever Live Without Them?

One of the most useful tools for making portables (or for any kind of project, for that matter) is a *hot glue gun*. If you're not familiar with it, let me describe it: You put a glue stick in one end of the gun and plug the gun into the wall. The gun then heats up the glue stick and keeps it hot. When you need to secure something, you pull the trigger and hot liquid glue comes out of a nozzle on the end of the gun, allowing you to accurately deposit it. The glue adheres quite well to most anything, and if you ever need to remove it, you can pry it away with minimal damage to the surfaces underneath.

Hot glue guns are *great*—I can't stress enough how wonderful they are. In fact, if I had a chance to be on one of those "Survive Your Fear on an Idol-Filled Island" reality shows, the only thing I'd bring is a hot glue gun and a portable generator to run it (see Figure 2-19).

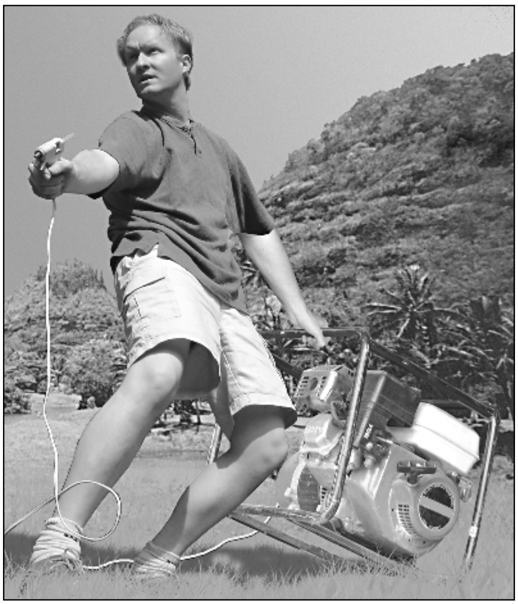


FIGURE 2-19: The author on a desert island—Week 3.

In this section we'll talk about the types of hot glue guns and all the amazing ways they can help you when building video game projects.

Types of hot glue guns

There are two basic sizes of glue gun, standard and mini (see Figure 2-20). This mostly refers to the size of the glue sticks that they use, though the regular-sized guns are a little bigger (and cost a few dollars more). Mini guns are good for portables, as they lay down a more accurate bead of glue. Most glue guns have a trigger that pushes the stick through the nozzle, but some cheaper models just have you push the end of the glue stick with your thumb.

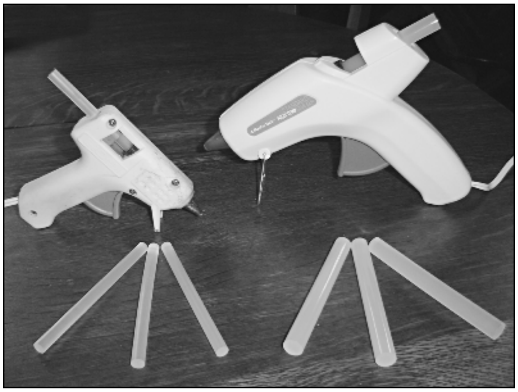


FIGURE 2-20: Mini and standard glue guns, with corresponding sticks.

Glue guns and sticks also come in *high-temperature* and *low-temperature* versions. For your portable projects, low-temperature glue works well and cools the fastest, allowing you to work more quickly. It also hurts less when it hits your fingers.

Using glue in your projects

You'll find lots of situations that call for glue, but here are some that you're sure to come across:

- Arranging wires and ribbon cables. Once you have a group of wires connected, it's helpful to get them out of the way if possible. Lay down a bead of hot glue and place the wires in it. Hold the wires down on the glue until it cools.
- Some parts are screwed in place, others soldered, and the rest — hot-glued! If you dump enough hot glue on something, it won't go anywhere — just make sure it's in the right place first. I've used hot glue to attach the screens in many of my portables, and I've never had a problem. It's much easier than trying to provide screw holes for everything.
- Making quick space-fillers. If you have a part that will be pushed or pulled on (such as a DC power input jack), and it's connected to the outer wall of a portable, glob some hot glue around it until the space between the jack and the wall of the unit is filled. It'll take a couple of minutes to dry, but will give the jack considerably more strength.
- In general, hot glue is awesome, so don't be ashamed to use it. People are only going to look at the outside of your portable. Keep that in mind.

Hot glue tips and tricks

Becoming a hot glue gun guru isn't something that just happens overnight. Here are some techniques to speed up developing your glue-wielding proficiency:

- **Avoiding those stringy things after you've glued something.** Once you start using hot glue guns, you'll notice that they leave stringy bits of glue everywhere. And they kind of stick to everything, which can be unsightly if they get on the outside of the case. (This is an ever-so-slight downside to hot glue.)

  To avoid the strings, do the following: Once you're done plopping down glue, pull the gun away just a bit. Then quickly shake it left and right. This causes a short string to form, and the motion cools it in the air and then it breaks off.

- **Removing hot glue.** There will probably be times when you'll need to remove a part that has already been locked in place with hot glue. To remove the glue, use your tweezers to bite and tear away at it (heating it back up is usually not the answer). Once you get the glue removed from at least one side of the part, the rest should pull free.

  Much like solder, it's important that the hot glue surrounds something in order to keep a good hold on it, even if it's just a thin bead (see Figure 2-21).

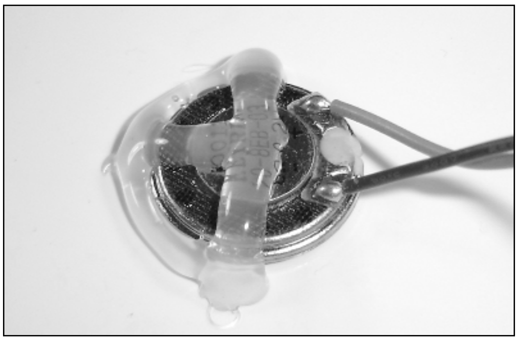


FIGURE 2-21: A small speaker held in place by the wonder of hot glue.

- **Manipulating hot glue without getting burned.** Hot glue will stick to almost anything—for example, if you touch a blob of heated hot glue with your screwdriver, it'll stick and stretch as you pull the screwdriver away. It acts a lot like the taffy you've seen them making at tourist traps, or molten glass, or tar.

  Luckily, hot glue has an Achilles' heel: water. If you want to flatten or manipulate a blob of heated hot glue, either lick your screwdriver or finger and use that. Fingers actually work best—if you get enough spit on them and you're using low-temperature glue, it doesn't really hurt any more than grabbing a hot French fry. (Hey, I've done it for years, and notice how I'm still able to type?) Just kind of tap the glue with your wet finger, and you'll barely feel it.

Caution

Remember, if you're going to squish hot glue around with your spit-covered fingers, be sure you are using a low-temperature gun and lots of spit! Higher-temperature guns *will* burn you, or at the very least make you scream an expletive.

- **Reloading the glue gun when your hands are full.** If you're going to hot-glue a whole mess of things in a row, put an extra stick of glue in your mouth before you start. When the gun runs out, just lean over and shove the new glue stick in (you'll feel just like you're on a reality game show).
- **Getting a lot of glue to spew out at once.** If you really want to flood something with hot glue, but you're using a mini glue gun, then bypass the trigger and push on the stick itself. It will melt and squirt out almost as fast as you can shove it through.

Other Tools You Can't Hack Without

Besides the major portable-building tools we've already discussed, there are several other tools you should have on hand. Most of these are fairly common household items, but check through the list anyway to see if you're missing anything.

Screwdrivers

Four kinds of screwdriver should serve you well during these projects:

- Small Phillips, with an approximately 1/8th"-wide or smaller tip. This will open most pocket TVs and game system internals. Smaller is better, as the screw shafts to open pocket TVs can be fairly narrow.
- Medium Phillips, with an approximately 1/4th"-wide or slightly bigger tip. Use this for opening up game systems, or screwing together your portable when it's finished.
- Small flat-head, with an approximately 1/8th"-wide tip. These work well as wedges. Slide the screwdriver under a part, and wedge it upward to remove the part. It's great for removing RF shields, socketed chips, and circuit board components that you're having trouble desoldering.
- Big flat-head, 1/2th" wide or so. This may seem like overkill, but a big screwdriver will come in handy more often than you might think (especially when we hack open the mini-SNES).

Pliers — Needle-Nose and Standard

These will come in handy from time to time, although you will find that a good pair of tweezers can replace needle-nose pliers in many situations. If you're going to be making a SNES portable, I would suggest having a big tough pair of regular pliers as well (more on that when we hack open the SNES).

Cutters

You'll be cutting a lot of wires for these projects so grab yourself a pair of $3 cutters/snippers at the hardware store like the ones shown in Figure 2-22.

FIGURE 2-22: A few types of cutters.

This tool is also quite useful for snipping leads off components such as resistors and capacitors, cutting through thin pieces of metal, making buttonhole openings in the cases of hand-built portable projects, and clipping components off circuit boards.

X-Acto knives

These things are right up there with tweezers and hot glue when it comes to usefulness. X-Acto is actually a specific brand of penknife, but the name is used generically (like "Jello," for gelatin). For around $2, you can buy this indispensable tool that's great for:

- Cutting apart strands of ribbon cable much better and faster than with scissors
- Shaving rough edges off your case
- Scraping connections clean for soldering
- Making an instant microsized flat-head screwdriver — just break the tip off an old X-Acto knife blade with your cutters!

Caution

X-Acto knives are sharp! I once worked at a sign shop where we used automated equipment, boom lifts, welders, and power tools of all kinds. But the worst injury that I can recall was from an X-Acto knife slip-up in the graphics room. When you're cutting something, think about where the knife will go if it slips and jumps a few inches. If you're holding something while you cut it, always keep your fingers to the side of the blade — never in its the path.

As seen in Figure 2-23, X-Acto knives come in two sizes, called 11 (small) and 2 (large). I'd suggest getting both — you'll use the small one the most, but the big one is good for more heavy-duty stuff and for when you don't want to dull the blade of the smaller one.

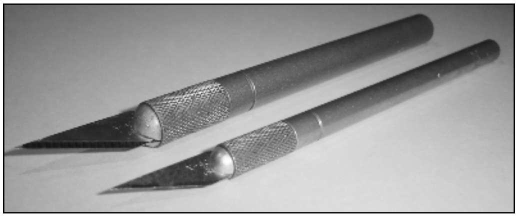


FIGURE 2-23: Both sizes of X-Acto knife.

Helping Hands

Sometimes it's hard to hold small parts steady while soldering wires to them, especially joystick ports and plug-in jacks. The answer? Find yourself a tool commonly referred to as Helping Hands! (See Figure 2-24.)

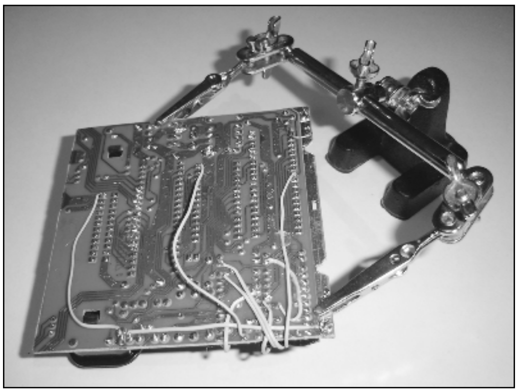


FIGURE 2-24: Helping Hands holding a hacked-up Atari motherboard.

Helping Hands is the sort of thing that you'd see on the shelf at your local hardware or electronics store for around $10 and think, "Who would buy this thing?" until you give it a try and wonder how you ever lived without. Helping Hands usually has two alligator clips on arms and a built-in magnifying glass. (I removed the magnifying glass on mine, as it got in the way far more often than I used it to view things.)

Note

Radio Shack has Helping Hands in their catalog as part #64-2063.

Wire strippers

The conventional method of stripping the plastic off wires is to use a wire stripper. There are several kinds, from the garden-variety multigauge stripper that you've probably seen before, to automatic wire strippers that bite down on the wire and pull it apart for you (Figure 2-25). In addition, a lot of cutting tools have parts meant for stripping wire.

FIGURE 2-25: Two kinds of multigauge wire strippers.

- To use a standard wire stripper, pinch the wire in the hole that best matches its size and pull the wire through. With automatic strippers, you just place the wire in the right slot and squeeze the handle — the stripper cuts, pulls, and strips the wire for you.
- To strip wire with a pair of cutters, bite the wire with the cutters so that they go through the plastic but stop at the wire, and pull to remove the plastic. To strip thicker wires, you may need to spin the cutters around the plastic to cut more of it before pulling.

Chapter in Review

Although a lot of different tools were listed in this chapter, most of them are fairly common and the ones you may not have, such as a desoldering iron or hot glue gun, are fairly cheap to buy. Even if you're only building one portable project, they'll be useful new tools to have around the house (especially the hot glue gun!).

The most common uses for each tool were descibed in this chapter. Additional ways to use them will come up in Part 2, in connection with specific projects and situations.

Learning Basic Electronics for Portables

chapter 3

in this chapter

- ☑ How I Hack Up Game Systems
- ☑ Volts and Amps
- ☑ Rechargeable Battery Types
- ☑ Power Regulators
- ☑ Wires
- ☑ Switches: Types and Uses
- ☑ Pushbuttons: Types and Uses
- ☑ Resistors
- ☑ Potentiometers
- ☑ Light-Emitting Diode (LED)
- ☑ Chapter in Review

You don't need an extensive background in electronics to build the portable projects in Part 2, because I've already done all the designing and testing for you. Instead, the purpose of this chapter is to give you a very basic overview of electronics, so that when terms and components are mentioned during the actual construction process, which starts in the next chapter, you'll be up to speed and able to follow right along. It's kind of like those movies where the gadget guy is telling the spy hero dude what everything does and how it works, so he'll be ready when the time comes!

Now that I've made it sound interesting, here are some of the top things this chapter will brief you on:

- The exact method I use to see how much of a game system's motherboard can be removed. This will give you an idea of how it's not only electronic know-how that's needed in building these projects, but also logic, testing, and patience.
- What volts and amps are and how they'll affect your portable.
- The types of batteries that will work best for these projects, and how to regulate the power coming out of them in order to avoid frying your game system.
- What kinds of components you'll use when making portables and what they do (this includes switches, LEDs, resistors, and more).
- Where to find really cheap (or even *free*) wire that works great.

When you get done with this chapter, you'll be armed with knowledge and ready to start the actual hacking, slashing, soldering, and constructing of your very first homemade portable video game system. Let's go for it!

How I Hack Up Game Systems

As I mentioned a little while ago, you don't need to know a whole heck of a lot about electronics to build portables. To demonstrate this, and to give you some insight into how I usually go about making portables, here's my step-by-step process:

1. First, I look over the game system's motherboard and see if there's any really obvious stuff that can go. Metal RF switchboxes (the things that send a Channel 3 signal of the game screen to your TV) are a common one, as are large capacitors near the power supply. Older systems often have stuff you can remove.
2. Then I start cutting components off the board with the unit running. As long as it keeps running, I keep removing parts. (Note: I can't recommend trying this yourself because of safety issues. Just rest assured that I've taken the risks for you — here's the book to prove it.)
3. Eventually the unit will stop working. I then know that whatever I just tried to remove is vital to the system's operation. I reconnect it, and then start removing other things until the unit stops working again.
4. I repeat Step 3 until I've removed (or tried to remove) every large, easy-to-remove part on the board and kept the machine running.
5. Next, I look at where removable parts were located. If there was a concentration of them all in one place, then that whole section of the motherboard can be removed. (In the case of the four-switch Atari 2600, you can remove nearly 50% of the motherboard.)
6. I then physically remove/cut off portions of the motherboard that have a lot of unnecessary parts. If the unit stops working, I simply check if any traces (the copper connection lines on a circuit) got cut, and rewire them by hand. (This will be done especially with the Atari in Chapter 15.)
7. Finally, I usually remove the existing power regulator on the motherboard and install a new one as part of my new portable design. (More on power regulators later in this chapter.)

You'll do this kind of hacking later on in Part 2, especially for the Atari 2600 (though not with the system running as you hack). The end result is a video game motherboard that works, buts needs simple support electronics (such as a new power supply and a built-in controller) and a screen to be connected to it in order to be usable. In the following sections, we'll discuss some of the concepts behind these support electronics and the components that they comprise.

Caution

Although the batteries we'll be using in this book can't shock you, tinkering with systems that are still running off their original wall adapters (as in my above story) certainly can. Take care that only low, battery-level voltages (10 volts or under) are running through a system if you're checking things. Systems that have wall power going directly into them, such as the original PS1 or N64, should be handled with extreme care, so that the power doesn't go directly into YOU.

Volts and Amps

Volts and *amps* are the two main factors to consider when powering a portable device with batteries. Before we discuss batteries themselves, we'll explain what these things are and how each of them will affect your portable building.

Volts

The *volt* is a unit of measurement for the potential difference, or *voltage,* of an electrical current. All batteries have a voltage rating—some, such as a 9-volt battery, use the rating as their common name, while for others, you have to look a little harder to find it, like in the small print on a 1.5-volt AA battery. When you test the voltage of something with a digital multimeter, you'll get a positive or negative number, depending on which way you have the test leads connected.

How volts affect your portable

The two main components of your portable will be the video display (screen) and the game system guts. Each of these takes a certain amount of voltage to run. In general, it's best to have the screen and the game system take the same voltage whenever possible, in order to reduce the number of power supply components. The power required by each of the game systems and screens used in this book is listed in Table 3-1.

Table 3-1 Voltages Used by Game Systems and Screens

System or TV Screen	*Input Voltage Required (Unregulated)*	*Actual Voltage Used Internally (Regulated)*
Nintendo 8-bit	7+ volts	5 volts
Super Nintendo 16-bit	7+ volts	5 volts
Playstation 1	7.5 volts	7.5/5 volts
Atari 2600	7+ volts	5 volts
Casio EV-680 pocket television	6+ volts (four AA batteries)	5 volts
Sony PSOne screen	7.5 volts	7.5/5 volts

The battery or power source chosen for a portable must be able to deliver enough voltage to power both the game system and the screen. This is why a battery capable of delivering at least 7.5 volts will be used by all of the projects in this book. All game systems use regulators (more on those later in the chapter) that knock the input power down to the actual voltage used internally; thus, while 7.5 volts may be the minimum input voltage required, you'll usually want to provide more in order to accommodate for the fact that the battery will slowly loose charge during play.

Note The voltage considerations and requirements have been incorporated into all the projects in this book.

Amps

The *ampere,* or *amp,* is a measurement of electrical current in a circuit. A device needs a certain amount of voltage in order to operate, but the amperage of the device indicates how much power it consumes while in operation. Let's take a house, for example: Even though everything runs on 120 volts, the more stuff you run (the more amps you use), the faster the dial on your utility meter spins and the higher your electric bill goes. An air conditioner uses the same voltage as a can opener, but a lot more amps. In a portable device, high-amp consumption drains the batteries quickly.

How amps affect your portable

Everything in your portable will consume different amount of electrical current. When designing or building a unit, you can use your multimeter to test the amp usage of each component separately, and then add them all together to see if the portable is feasible (in terms of power consumption) based on the type of battery you'll be using. Table 3-2 is an example of the parts in a typical portable, how many amps they draw, and how this affects the battery life.

Table 3-2 Amp Consumption in a Portable

Component	*Amps It Consumes*
Pocket TV, modified with white LEDs	300 mA
Atari 2600 game system	200 mA
Total amps consumed by portable components	500 mA
mAH (milliamp-hours) provided by battery	1500 mAH
Estimated playing time	3 hours (1500 mAH/500 mA)

When designing a portable, you need to figure out how much power each component is going to draw, and then determine which type of battery is going to provide the power to make your portable run for the longest time. As with the voltage, this has already been taken into consideration for this book's projects, but if you decide to build a portable on your own, it's a good thing to know.

Amp-hours

Some batteries are rated in *amp-hours,* or, more often, in milliamp-hours. A milliamp-hour (mA) rating basically says, "this battery can provide this many milliamps at this voltage for 1 hour." Example: If you take a battery that can do 1000 mAH and hook it up to a device that consumes 1 amp (1000 mA) of power, then the battery will run the device for about 1 hour. If that same battery was powering a device that consumes 500 mA, the device would run for around 2 hours.

Watt-hours

Other batteries (usually big ones, like those in a camcorder or laptop) are rated in *watt-hours.* Watts are volts multiplied by amps. Let's say that you have a portable game unit that consumes 500 mA of power at 7.2 volts. That comes to 3600 milliwatts, or 3.6 watts. To estimate the running time, you then take your battery's watt-hour rating and divide it by the watt usage of your device. So a 5.6 watt-hour battery would run the device for about 1.5 hours.

Rechargeable Battery Types

Invented long before power lines delivered electricity to the world, batteries are self-contained chemical devices that hold an electrical charge for use. In this section, we'll discuss the most common types of rechargeable batteries that you can buy, the pros and cons of each, and which are good choices for portable game building.

For each project in Part 2, a battery size has already been selected for you, although for most of them you'll still be able to choose between Ni-MH and Ni-Cd versions of each. The following is intended to familiarize you with what they are and to provide a resource for people wanting to build a portable of their own.

Nickel-cadmium batteries

Also called a "Ni-Cd" (in hip geek-speak, pronouced "Nigh-cad") battery, nickel-cadmium batteries are an older type of rechargeable battery. They are available in standard sizes (AA, D, C) as replacements for alkaline batteries, but Ni-Cd batteries are also used in older camcorders and radio-controlled toys. These are the least expensive type of rechargeable battery (around $9.99 for a standard eight-cell remote-controlled car pack), but also have the least amount of power storage — typically around 1000 mAH in a standard remote-controlled car pack. They can run a portable, but not for very long, so I'd suggest it only if you're trying to save every penny possible or the portable has low power requirements.

Note

There is a Ni-Cd pack with 2000 mAH that we'll use in the CNC-built NES project, but its extra power comes at the expense of a larger physical size.

Charging methods

Charging a Ni-Cd battery is pretty simple: basically, a plug-in wall transformer sends a low current, of a slightly higher voltage than the rating of the battery, directly into the battery. It is not an "intelligent," circuitry-controlled charging process like that used for lithium batteries. A drawback to this is that it's sometimes hard to know when the battery is charged. Some chargers have lights that indicate charge; other times, you just feel if the battery's hot or not (the battery is hot when charged).

Nickel–metal hydride batteries

Also referred to as "Ni-MH", these batteries are similar to NiCd batteries (see Figure 3-1), but have a higher energy storage capacity (about 33% more than a Ni-Cd battery of the same voltage), with a higher price to match.

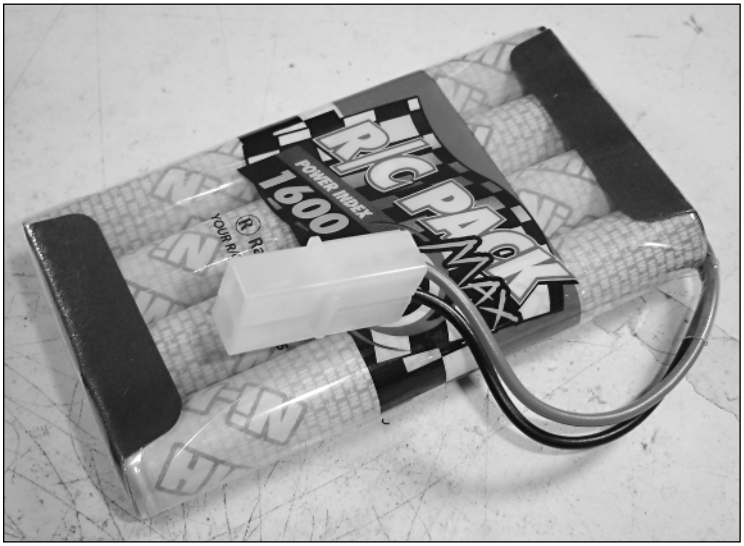


FIGURE 3-1: A remote-control car's Ni-MH battery pack, rated for 9.6 volts at 1600 mA.

These batteries cost a little more than Ni-Cd batteries, but still a lot less than lithium-ion batteries (see the section on Li-ion batteries below), making them a great choice for a portable game system. Most of the projects in this book will use Ni-MH batteries.

Charging methods

Ni-MH batteries require a Ni-MH battery charger; however, many battery chargers are dual-purpose and allow you to select whether to charge Ni-Cd or Ni-MH batteries. Ni-MH batteries also take longer to charge than Ni-Cd batteries.

Caution

If the terminals/power wires of a battery pack directly touch each other, they'll short out, which usually makes a noise as well as a spark. The spark can cause mild burns, similar to what you might get if you touch a soldering iron, so try to avoid causing short circuits. Potential short-circuit situations will be mentioned throughout Part 2.

Lithium-ion batteries

The lithium-ion battery, or "Li-ion" for short, this is one of the newest types of rechargeable batteries on the market. They aren't used as replacements for standard batteries, as Ni-Cd and Ni-MH batteries are; rather, they usually come with modern portable devices such as camcorders, laptops, and cell phones. Li-ion batteries charge faster, hold more power, and last longer than the other types of rechargeable batteries mentioned here. They basically kick butt, but the butt-kicking comes with a price tag significantly higher than that for Ni-Cd or Ni-MH batteries.

Charging methods

A Li-ion battery is usually charged inside the device that it's used in — in most cases, the battery is not removed. An example of this is when you plug a small wall adapter into your cell phone or PDA for the evening in order to recharge it.

The Sony Infolithium is a very useful, removable Li-ion battery. It comes in two main sizes, "M" for digital cameras and "L" for modern Sony camcorders. (See Figure 3-2.) Both sizes are rated at 7.2 volts, but the "L" type is larger and provides more watt-hours of power.

FIGURE 3-2: A Sony Infolithium Type "L" Li-ion camcorder battery.

If you already own a modern Sony camera, you probably already have one of these batteries, and you can just use the camera to charge it. If you don't, this type of battery is still a great choice and can be bought separately, but you'll have to get a charger as well. The retail store price of a battery and charger can be as much as $90, but if you check online auctions, you stand a good chance of finding a combo deal (battery and charger) for around $50.

Note This is the kind of battery that will be used for both Playstation projects and for the CNC-built Atari.

Power Regulators

What would happen if you hooked your electric toothbrush directly to the generators in the Hoover Dam? It'd get overloaded and melt into a pile of goo. Power needs to be regulated.

Let's take the Atari 2600 as an example. It has a power transformer that you plug into the wall. This takes the 120 volts AC and reduces it down to 9 volts DC. This then goes into the back of your Atari through a little plug. But if you took that 9 volts and pumped it into the Atari's logic circuits, it would fry the machine!

What happens is that the 9 volts first goes through what's called a *regulator* (Figure 3-3).

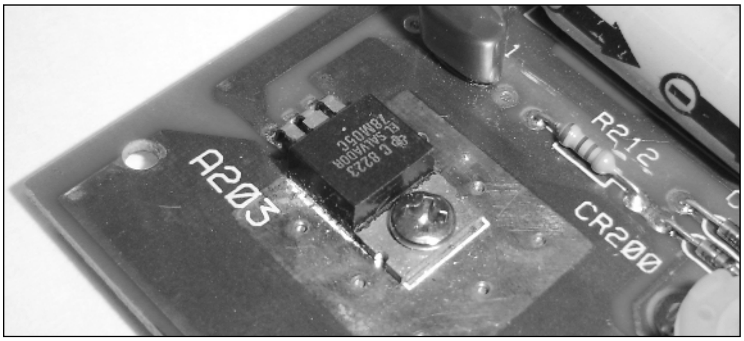


FIGURE 3-3: The power regulator in the Atari 2600.

This small device takes the 9 volts and reduces it down to 5 volts, shedding the difference as heat. Only then is the electricity piped into the main Atari circuits, allowing you to play Pac-Man (or Pac-Man Jr, hopefully)

Since the average portable-powering battery runs between 7–10 volts, you'll need some form of voltage regulation for your project. Let's take a look at what kinds of regulators are available.

Linear regulators

A *linear* regulator takes an input voltage and reduces it down to an output voltage, shedding the difference as heat (as in the Atari example above). One of the most common types is called the 7805 (Figure 3-4).

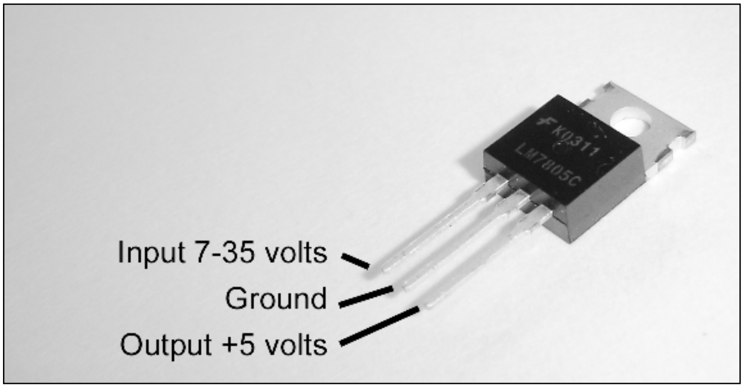


FIGURE 3-4: The 7805 linear power regulator.

This thing is also in the NES, the SNES, and many other electronic devices. It can handle up to 35 volts as input, but typically takes 9 to 12 volts. The output voltage is 5 volts. You can get a 7805 regulator off-the-shelf at Radio Shack for around $1.50 (Catalog #276-1770).

A linear regulator has what is called a drop-out point. For the 7805, it's 7 volts. This means that even though the regulator outputs 5 volts, if the battery goes below 7 volts, the regulator "drops out" and ceases to function. "Low dropout" regulators are also available, but usually have to be ordered from a place like Digikey (www.digikey.com, part #LM2940CT-5.0-ND) and require an extra part or two (usually a capacitor; check the regulator's instructions/data sheets).

As mentioned earlier, a linear regulator generates heat, which has to be dissipated. This is accomplished by a heat sink, which is basically anything that you can attach to the regulator to absorb some of the heat (an example is available as Radio Shack catalog #276-1368). The heat sink will often have fins that create a larger amount of surface area for air to pass over, thus removing more heat (just like a CPU fan or the radiator in a car).

In off-the-shelf game systems, a regulator is usually soldered directly to the board or screwed to some metal sheilding to cool it off. We'll choose the heat sink for our portables on a system-by-system basis.

Switching regulators

A *switching* regulator is a device that lowers the voltage by switching the power on and off very quickly. This allows for more efficient use of battery power and lower heat emission (usually you don't even need a heatsink). However, switching regulators aren't available from a retail place like Radio Shack, they cost a bit more than a linear regulator, and they require a few external components. As you can see in Figure 3-5, they also look different from a standard linear regulator.

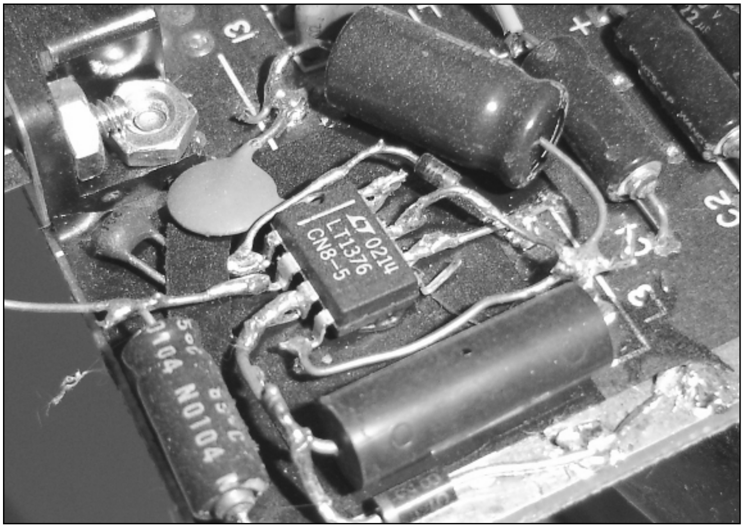


FIGURE 3-5: The eight-pin chip in the center is a switching regulator wired to provide 5 volts.

For the projects in this book, we're going to use linear regulators, but if you'd like to try your hand at using a switching regulator, go to www.digikey.com and look up part #LM2672N-5.0-ND. On the product page for this item, you can find datasheets on how to use this regulator. You can then use the circuit you build to replace any 5-volt linear regulator used in this book.

Note

You can also search the Digikey site for "regulator," by entering the following search criteria: *step-down, switching,* and *5 volts.*

Wires

A wire is a thin strand of metal that is encased in a plastic coating to insulate it. Because your portable will require connecting many separate components, you're going to be using a lot of this stuff. There are several types of wire that you can choose for your project.

Stranded wire

Stranded wire is made up of a lot of thin wires all braided together (see Figure 3-6). This allows for more flexibility, making it a great choice for most portable-building projects. A disadvantage is that stray strands may cause short circuits when not soldered properly (as mentioned in the section in Chapter 2 on using soldering irons).

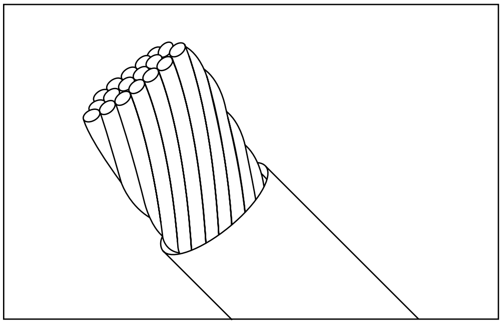


FIGURE 3-6: Stranded wire detail.

Solid wire

Solid wire is one big strand of wire in a plastic coating (Figure 3-7). It's much stiffer than stranded wire, and it will break loose at solder points if bent or moved enough. An advantage is that it's much easier to solder solid wire to parts, especially really small parts, since you don't have to worry about loose strands. If there's a connection on a portable that won't move much (or preferably not at all) after you've attached it, solid wire can be a great choice.

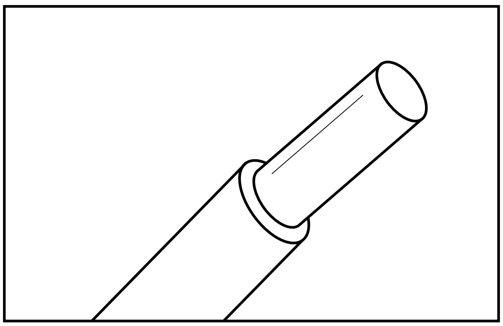


FIGURE 3-7: Solid wire detail.

Ribbon cable: Really cheap, Really great

The best, easiest, and cheapest wire for making portables is used ribbon cable. Get some from an old computer, or ask at your neighborhood computer fix-it shop. If you've got a computer-building friend, he or she is bound to have some extra.

Older hard drive cable (pre-1999) is made of stranded wire and works the best, as there's usually a fairly long stretch of uninterrupted cable between where it hooks to the computer and the first drive connection. Floppy cable is fine too, though you won't find as many long portions. With either kind, just take a pair of scissors and cut off the plugs. As a rule of thumb, you need one hard drive ribbon cable per portable.

Modern Ultra ATA hard drive cables have much thinner, solid wire and a colored plug on one end. This type of wire can be used in some situations, but cannot carry enough current in others. It will, however, come in handy when hacking pocket TVs, so you should get some. (I know, ask a friend for some and tell him or her, "I only need half a cable — you can keep the rest!")

Tip Old ribbon cable is great — almost as cool as sliced bread — but if it looks really yellowed, cracked, or otherwise deteriorated, find some that looks better. The internal stranded wires can become weak and break, causing you to have connections that look okay but don't work, which will drive you nuts during your testing and troubleshooting.

Cutting portions of ribbon cable

When we start hacking stuff apart in this book, I'll instruct you to do things like "cut a four-strand of ribbon cable 5 inches long." This means a section of ribbon cable with four wires.

Sometimes it's hard to visually count off the number of strands to cut. Instead, I suggest dragging your knife across the cable near one end, so that you can count the strands by feel. Then, make a short slice between the strands and out the end. Finally, pull the two sides of the cable apart like string cheese (or like tearing paper, if you're not a cheese aficionado).

To prepare individual strands, place the ribbon cable on something you don't care about and drag the knife between the strands, cutting about half an inch to separate them. To strip the wires, start by bending over every wire but one. Strip it, bend it down, pull another up and repeat. (See Figure 3-8.)

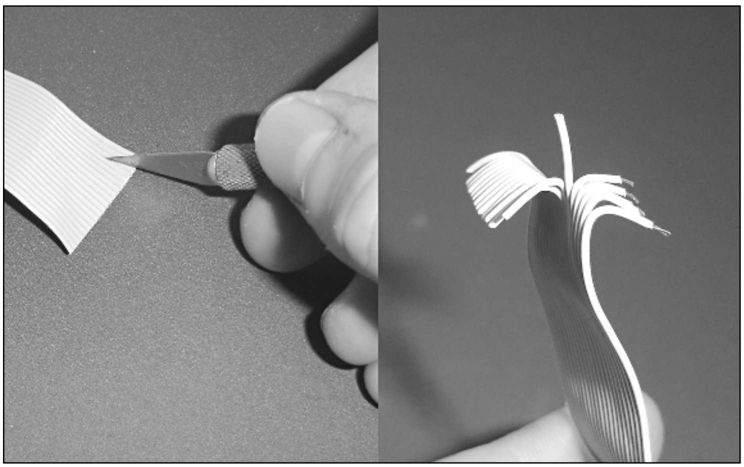


FIGURE 3-8: Slicing and stripping ribbon cable.

If you're using thin Ultra ATA cable, peel it apart more carefully, as it's very easy to rip through the plastic and expose the wire. Also keep in mind that even a low-power soldering iron will melt the plastic covering very quickly (you don't even have to touch it — the heated wire will melt it).

Switches: Types and Uses

A *switch* is basically just a mechanical device that allows or does not allow an electrical current to pass through. Even a tin foil–covered mousetrap could be a switch, but for your portable you'll probably want something more elegant (not to mention smaller). Listed below are several types of switch that you can buy and how you might use them.

SPST (single pole, single throw)

I've also seen these referred to as "single post, single terminal," which convienently uses the same first letters. (Use whichever term best rolls off your tongue.) The current waits at the post, which has two states, on and off. When the post is slid or pushed down to the "on" position, it connects to the terminal, allowing current through, as seen in Figure 3-9. The dashed lines indicate the electric current. (Example: Radio Shack catalog #275-406.)

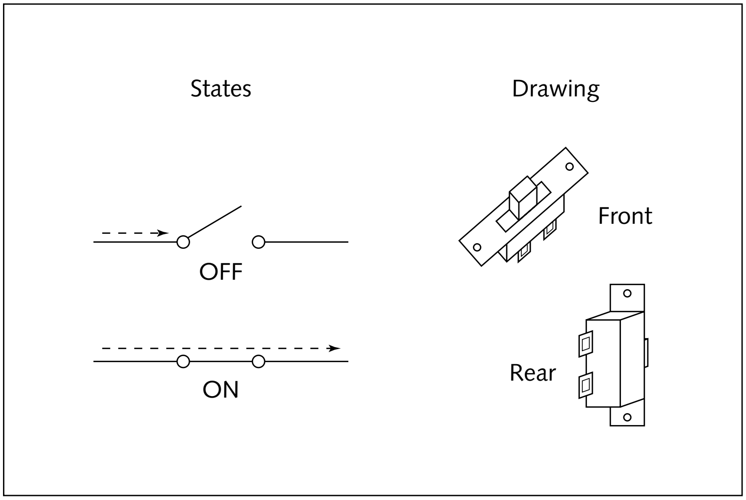


FIGURE 3-9: A SPST switch in the on and off states.

Here are some common uses for a SPST switch in a portable:

- **Power switch.** The system is either on or off. Electric current either goes in and powers the system or it doesn't. (Be sure any switch you use is rated for enough amps, as all of the system's input power will be going through it.)
- **Difficulty-setting switch on the Atari 2600.** Switches from Easy (on) to Hard (off).

SPDT (single pole, double throw)

This switch has three terminals on it, and the current waits at the center one. The switch has two states; the current can go from the center terminal to either the top or the bottom, as shown in Figure 3-10.

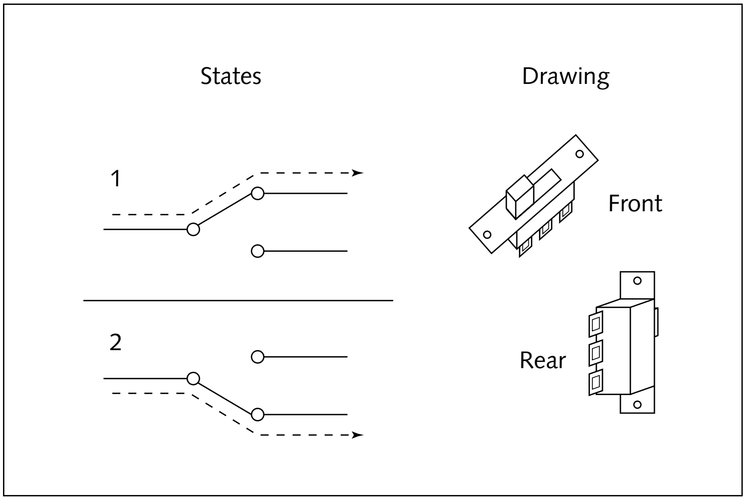


FIGURE 3-10: A SPDT switch in both states.

Here are some common uses for a SPDT switch in a portable:

- **Selection switch.** The switch will power one thing or the other, but not both at the same time.
- **Pocket TV tuner or audio/video input selector.** Almost all pocket TVs that can accept an A/V input have a small SPDT switch inside them that is pushed one way or the other by the A/V plug that you insert (more on this in Chapter 4).

DPDT (double pole, double throw)

A DPDT switch has six terminals on it. That sounds like a lot, but it's basically two SPDT switches put together and moved with the same switch, as shown in Figure 3-11. (Example: Radio Shack catalog #275-407)

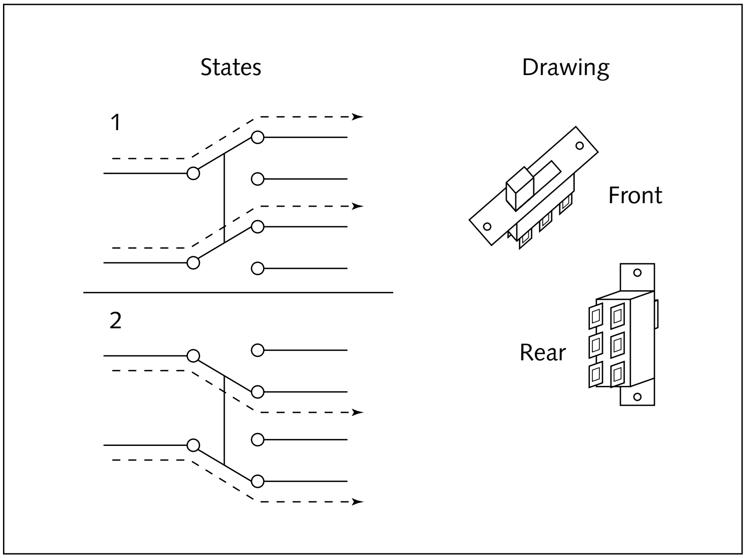


FIGURE 3-11: A DPDT switch in both states.

You might want to use a DPDT switch if, for some reason, you use two different power sources on your portable (such as 3 AAs for the screen and a 9-volt for the game system). Figure 3-12 shows an example of this. This would allow you to use a 9-volt battery for the game system and a 6-volt battery for the screen, keeping them both separate and eliminating the need for a regulator to provide different voltages from the same battery.

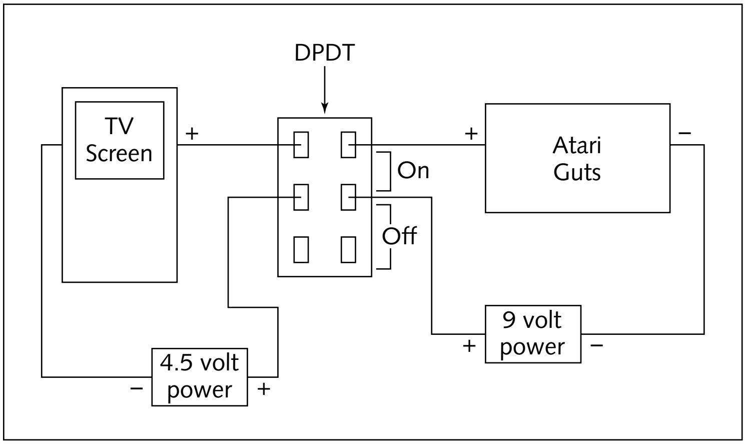


FIGURE 3-12: A DPDT switch used for a dual power supply. (Confession: I did this with the very first portable Atari that I built.)

Pushbuttons: Types and Uses

A *pushbutton* is a switch that has two states, on and off. Pushbuttons are useful for situations when you don't want to use, or don't have the room for, a slide switch, and you can also put them under things (like plastic directional pads) to create the four direction switches of a joystick.

Pushbuttons come in lots of shapes and sizes, as Figure 3-13 will attest to. There are large versions with screw threads on the sides, such as #1 in the photo (Radio Shack catalog #275-644), and smaller versions called *tact switches* that solder directly to a circuit board. (Go to `www.digikey.com`, and search for "tact switch.")

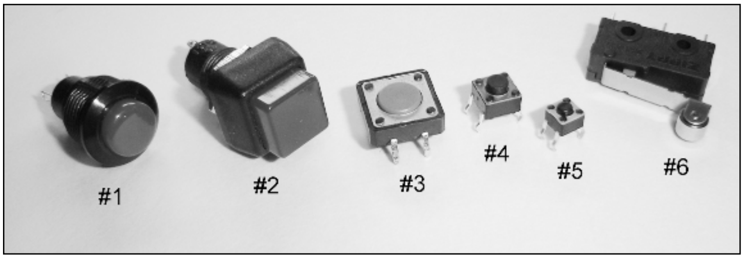


FIGURE 3-13: The pushbutton switch line-up.

If you have a dead VCR laying around, hack it up. You'll find a free tact switch (like #3–5 above) behind every button. Most buttons that make a slight "click" when pressed, from the Gameboy Advance shoulder buttons to those on a computer mouse, use a tact switch.

Note

All the projects in this book will use tact switches for the game controls.

Pushbutton switches come in two types: *normally closed* (NC) and *normally open* (NO). The difference between them is that NC switches are on by default—when you press them, they turn off. On the other hand, NO switches, which are the more common type, turn on when you press them. Some switches have three leads and allow you to wire them either way (as NC or NO), but we won't be using those in our projects.

Momentary switches

A *momentary switch* is only on while you're pressing it. Most pushbuttons, including tact switches, are momentary. These are used when you want to receive input as long as the person is holding the button down, then stop when he or she lets go. An example of this is a doorbell buzzer—it goes on ringing as long as you press the button. Here are some portable-related uses for momentary switches:

- **Joysticks.** Whether you have a gamepad-type disc (like most modern systems) or an actual joystick, you can use small tact pushbuttons to sense which direction is being pressed (Figure 3-14).

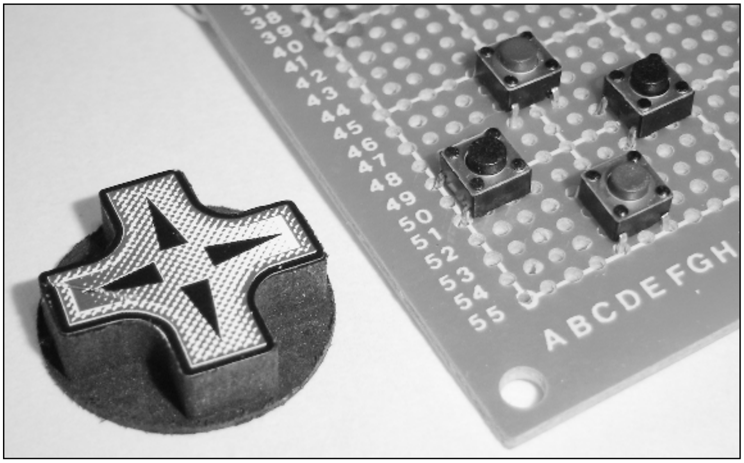


FIGURE 3-14: Tact switch pushbuttons used as an up/down/left/right gamepad.

- **Triggers.** A single pushbutton will be required for each trigger. In some cases a larger tact button (like #3 in Figure 3-13) is a good choice.
- **Physical sensors.** A small switch can be used if you want to sense if something is in a certain place, such as a cartridge or CD lid. As long as the lid is held down/closed, the system will run, but when it's not closed, the switch will open (turn off) and the Playstation will know that the lid's been lifted.

  A micro switch with a roller on it (#6 in Figure 3-13) also works well in these situations. They can also be used as a disconnect trigger. (An example is a game system that will only turn on if a cartridge is inserted, because the cartridge physically presses a switch allowing power to flow to the system.

Push On–Push Off button

This is a pushbutton that stays on after you've pressed it. It clicks in place, and then you press it again to "unclick" it and it goes off. (Radio Shack catalog #275-1565 is a good example; it's #2 in Figure 3-13.) A switch like this can be used for an on/off power switch in a portable or a difficulty-level switch in an Atari 2600 (click once: hard; click again: easy).

Resistors

A *resistor* (Figure 3-15) is a component that reduces the flow of electrical current in a circuit. In our portable projects, resistors will be used to create a video output circuit for the Atari 2600, send certain amounts of voltage to buttons on the NES and SNES, and deliver the proper amount of power to white LEDs in the modified TVs.

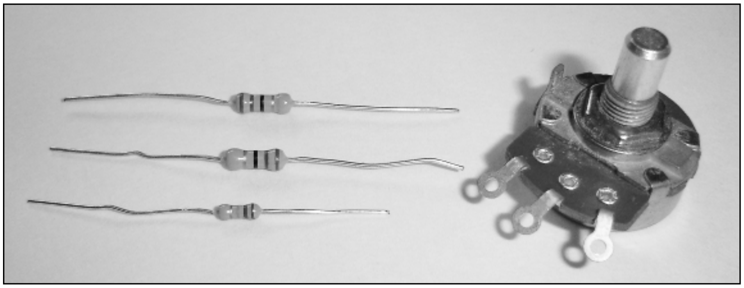


FIGURE 3-15: Some basic resistors (with a mystery guest on the right whose identity will be revealed in a couple of paragraphs...).

The color bands on a resistor indicate its rating (how much it resists) measured in *ohms*. True, the packaging for the resistor also tells you this, but you may not have it — say, if you have a loose resistor or one mounted on a circuit board. To read the bands, you can buy a small resistor-rating cheat card at Radio Shack (catalog #271-1210), or just use a digital multimeter that's set to test resistance/ohms.

Potentiometers

A *potentiometer* is a variable resistor. (See the mystery guest in Figure 3-15.) You can change the amount of resistance by turning a knob or dial of some sort. The dial contains a bit of metal inside the potentiometer, called a *wiper,* that slides over differerent sections as you turn it. As seen in Figure 3-16, the position of the wiper shortens the distance that the current must travel on one end (the terminal on that side then has a higher current), and increases it on the other (so that the other terminal has a lower current).

There are several uses for potentiometers:

- **Dial-based volume and brightness controls.** Most dial-based controls are potentiometers, including the controls on a pocket TV. We'll be rewiring these in Chapter 4, "Hacking Pocket Televisions." (Boy, Chapter 4 sounds pretty fun by now, eh?)
- **Paddle controllers for the Atari 2600.** The paddle controller for the Atari 2600 consists of a big knob with a trigger on the side, and under this knob is a potentiometer, which sends the paddle position back to the Atari.
- **Composite video circuit on the hacked-up Atari 2600 board.** Two small potentiometers allow you to fine-tune color and brightness.

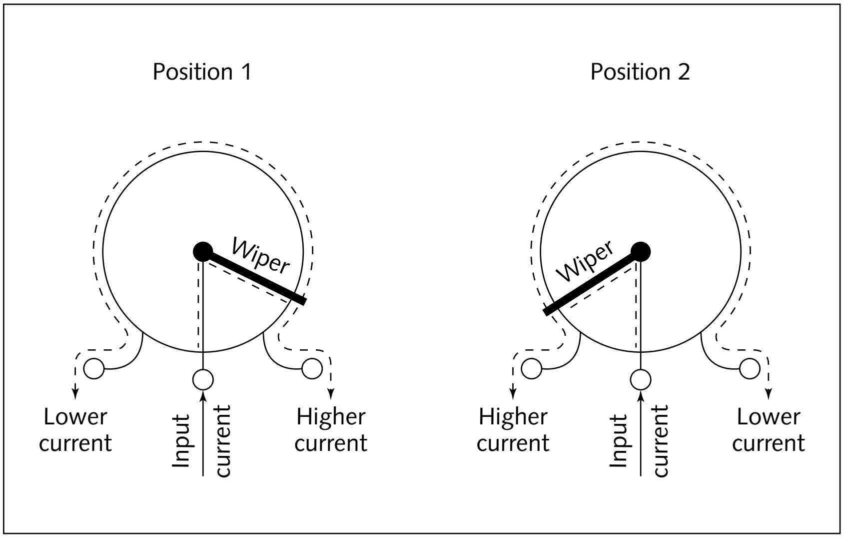


FIGURE 3-16: A potentiometer, shown at two different positions.

Light-Emitting Diodes (LEDs)

Back in the 1970s, researchers discovered that certain types of diodes (devices that allow current to flow only in one direction) emit light when a current is applied over them. This strange "feature" was transformed into the LED that we see everwhere today! (See Figure 3-17.)

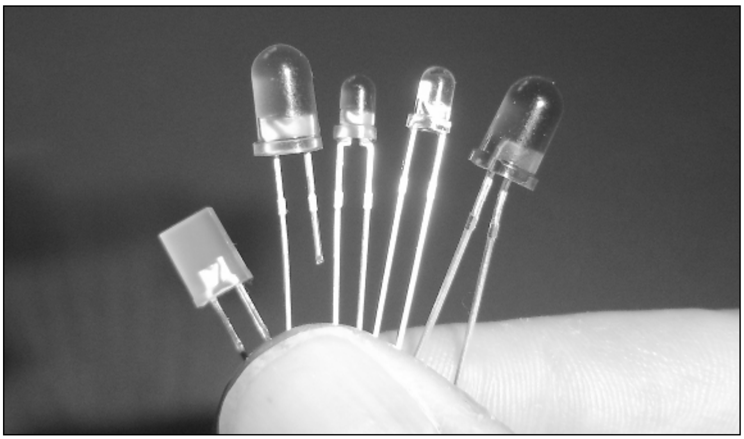


FIGURE 3-17: Several types of LEDs.

You can get pretty much any color of LED these days, and most are available off-the-shelf at Radio Shack. They typically run off only a couple of volts and use very little power. Keep in mind, an LED *is* a diode, so you have to have the positive and negative leads connected correctly in order for it to work (the long lead on an LED is always positive).

Lately, LEDs have replaced miniature light bulbs in a variety of applications, especially now that they're available in blue and white. Here are ways that we can use them:

- **Low-power pocket TV screen light.** The built-in light for a pocket TV accounts for about 50 percent of the unit's power consumption. Therefore, if you replace the existing bulb with white LEDs, the pocket TV uses a lot less power. Cool? You bet it is!
- **Indicator light.** We all gazed in awe at one of the first commercially used blue LEDs... yes, that's right — the Playstation 2 power indicator. If you'd like to have your very own mesmerizing "power on" light for your portable, an LED is the answer. Depending on the LED, you may need to put a resistor in front of it so that it won't get fried by too much voltage.

Chapter in Review

In this chapter we've discussed the basic electronic terms and components that will appear in later chapters describing how to build portable game systems. Important points to remember include:

- That a portable's volt and amp usage determines its battery life.
- That power must be adjusted using a regulator to avoid frying your game system.
- What types of batteries work well and how to charge them.
- Where to get cheap ribbon cable and how to recycle old computer parts.
- The different types of switches/buttons and how they can be used in portable building.

Hacking Pocket Televisions

chapter 4

in this chapter

- ☑ Portable Screen Overview
- ☑ Hacking a Casio EV-680
- ☑ Hacking a PSOne Screen
- ☑ Other Small Screens You Can and Can't Use
- ☑ Chapter in Review

A portable video game system is going to need a screen, video display, or TV of some kind in order for you to be able to play it. While companies that build portable game devices can get any type of screen they want (since they're loaded with dough), the casual experimenters like you and me are far more constrained. We're typically limited to using *pocket televisions* and *portable game screens* such as the white, rounded PSOne screen.

For the sake of simplicity, all eight of the portable projects in this book will use one of the following two screens:

- *Casio EV-680 screen*, a 3" diagonal pocket-television screen
- *Sony PSOne screen*, a 5" diagonal screen intended to clip onto a PSOne.

The main goal of this chapter is explain how to hack up both of these screens to prepare them for the projects in Part 2. For instance, if you decide to build a CNC Super Nintendo portable, it says in that chapter you'll need "a Casio EV-680 modified with white LEDs." This chapter tells you how to modify it. Same with the PSOne screen. You should refer back here after picking your portable project.

In this chapter, we'll start by discussing the common types of portable screens and the advantages/disadvantages of each. We'll then identify the common parts inside them. After that, we'll describe how to hack up the Casio EV-680 screen and the PSOne screen to prepare them for projects in Part 2. This includes ripping it out of the case, taking apart the guts, replacing the bulb (light source) with white LEDs in order to save power, and extending/rewiring the control dials and jacks. Finally, at the end of this chapter we'll list some other types of screens that can be used if you'd like to try making a portable of your own design.

Portable Screen Overview

Before we begin with the actual hacking of pocket TVs and screens, let's discuss some basics regarding pocket TVs. This will get you up to speed for the actual hacking and also provide information about such screens in general.

Types of portable screens

Pocket or portable TVs have been around for a while. Even back in the '60s, there were early black-and-white models, and by the '90s, they were available in color. Modern pocket TVs have a glass LCD (liquid crystal display) to display the picture and a long bulb at one end of the glass (usually the bottom) to light up the screen. A sloped piece of plastic distributes the light from the bulb evenly behind the LCD.

The main differences between modern pocket TVs are in the kind of LCD they use. There are two main types: *TFT active matrix* and *STN passive matrix.*

TFT active matrix displays are the current top-of-the-line type of LCD screen. Most modern (1995–present) devices, such as camcorders, laptops, and Gameboys, use TFT screens. TFT stands for *thin-film transistor,* as each pixel on the screen has a transistor controlling it. The advantage of the TFT screen is that it doesn't blur, like the one on an old laptop or the original Gameboy does. It provides a crisp display with bright colors and sharp edges. The disadvantage, of course, is that TFT screens are about 40 percent more expensive than the alternative.

STN stands for *supertwisted nematic*. *STN passive matrix* televisions are made from a lesser type of LCD screen that doesn't have a transistor on each pixel, so that the display does not update as fast as on a TFT screen and therefore blur. There are several disadvantages to this type of screen:

- The image blurs when there's movement.
- There is less clarity and less contrast, and the colors are muddier than on a TFT active matrix display.
- It does not work with some Atari 2600 games.
- STN display units don't always have an audio/video input jack.

The one advantage is that STNs are a lot less expensive than TFTs. If you're trying to pinch every possible penny, you might consider a STN screen, although in most cases, including the projects in this book, you'll want a TFT screen.

The parts inside a pocket TV

Let's take a look at the common parts inside a pocket TV. These will apply not only to the screens in this chapter, but to most other models of pocket TV as well. (These photos are taken from a variety of different models to illustrate the similarity of the parts.)

LCD glass (see Figure 4-1). This provides the picture. Handle it like a CD — only by the edges. Take special care not to touch the back of it, as you don't want fingerprints or dust to become trapped and mess up the image.

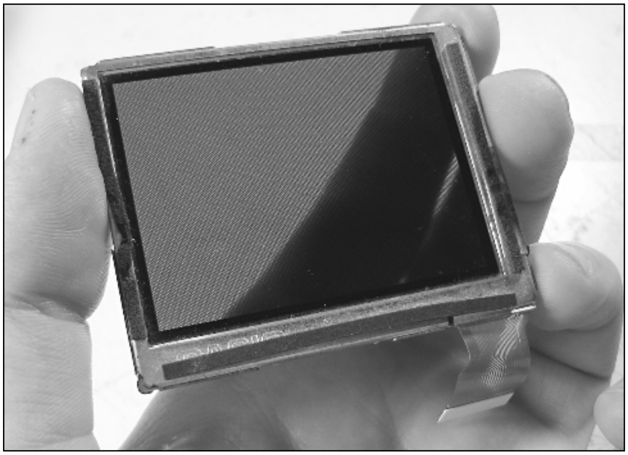


FIGURE 4-1: The LCD glass, properly held.

Light box and bulb (see Figure 4-2). The bulb lights up, and the box diffuses the light evenly behind the LCD. The box contains several layers of diffusers and pieces of plastic. It's best not to remove these, as they can be marred by the slightest touch. If you do remove this stuff, handle it by the edges or with tweezers. Do not touch the diffusing plastics with your skin. No matter how clean you think your finger is, oil will rub off on the thing.

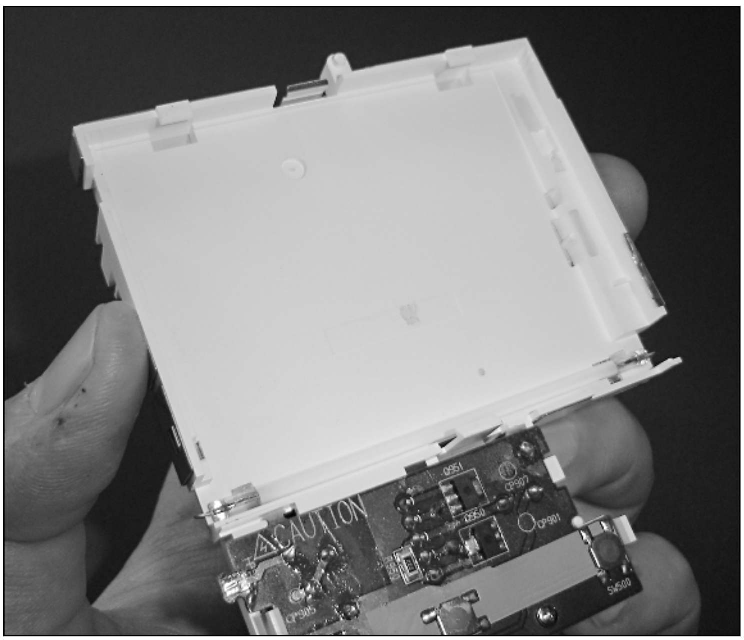


FIGURE 4-2: Light box and bulb.

Inverter (see Figure 4-3). Creates a voltage high enough to run the bulb. It can be identified by a small transformer and a few other components placed together near the bulb. The inverter and bulb consume a large percentage of the power that a pocket TV uses.

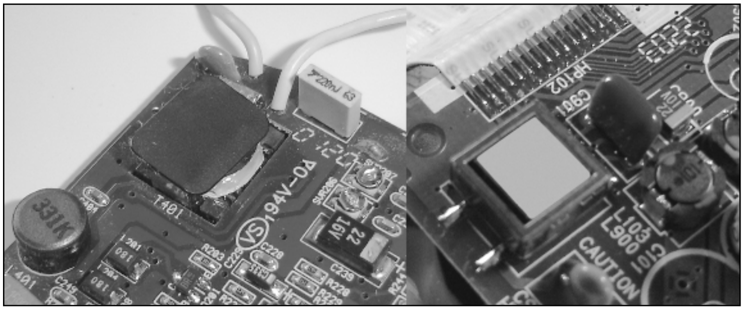


Figure 4-3: Pocket TV inverters.

Caution

The amount of voltage generated by the inverter varies from TV to TV, but it's usually around 1000 volts! Do not touch the bulb leads or the spots where they connect to the inverter if the power to the TV is on.

If you remove the bulb, the invertor will be disconnected and no longer suck up power. However, you can still get shocked by it, so it's best to remove the transformer or a few other components to "kill" it. If for some reason this "kills" the whole TV, you'd better put the parts back. On some pocket TVs (such as the older Casios we'll describe at the end of this chapter), the invertor is a separate, small circuit board, making removal easy.

Circuit boards. All pocket TVs have at least one circuit board, and a lot of them have two or more, interconnected with ribbon cable or plugs. On dual-board models, one board usually has all the jacks and controls, while the other board is connected to the screen. As a general rule, any large board with a lot of components on it cannot be removed.

The rest of the common parts are all shown in Figure 4-4.

FIGURE 4-4: Pocket TV parts.

#1 **Volume and brightness dials.** These are small potentiometers. You can remove and rewire them, but be careful with the leads, as they are pretty small and can break easily.

#2 **Audio/video input jack.** Allows a separate video input, such as a VCR or hacked-up game console. Remember, you can use the audio/video jack rewiring methods shown for the Casio TVs in this chapter for most pocket TVs, as most of them use this plug.

#3 **Headphone jack.** The audio signal goes through this. When you plug in headphones, it disconnects the audio signal from the speaker. If you remove this jack, you'll have to complete the connection with some wire in order to keep the speaker working.

#4 **TV antenna input jack (on some models).** Allows you to, for whatever reason, hook up a cable or an external antenna. This jack often gets in the way, and we'll remove it in several of our projects.

#5 **TV tuner.** Tunes in a signal. If you are on a desoldering rampage, go ahead and remove it, as this will save a little weight and power. A couple of the projects in this book require this to be removed (more on this later).

#6 **Channel selection controls.** A couple of tact switches to change the channel. You don't need to remove them.

#7 Battery connection. Springy prongs, either built into the case (as shown) or coming directly off the circuit board. If they're on the board itself, snap 'em off. These springy prongs will come in handy for the hand-built SNES project.

#8 DC auxiliary power input. This handy plug is great for all those times when you want to run your portable 2.5" TV screen for home use! Yeah, I know. Remove it!

#9 Easily blown fuse. Provides short-circuit and overload protection. Probably *too* much protection, as this fuse will sometimes get blown for no apparent reason (well, other than a person hacking up the TV). If a pocket TV stops working, try bypassing the fuse with a bit of wire or a paper clip.

Hacking a Casio EV-680

The Casio EV-680 is a pocket TV with a 3"-diameter color TFT screen (Figure 4-5). In its original, unhacked form, it takes four AA batteries to run and can tune in channels 2 through 69 with its built-in antenna. This screen will be used in this book for the CNC-built NES portable, the CNC-built SNES portable, the CNC-built PSOne portable, and both Atari portables.

FIGURE 4-5: A Casio EV-680, mint in box.

The EV-680 is available at electronics stores, such as Circuit City and Best Buy, for around $150. You can also find a Cinevision version of it at Radio Shack, catalog #16-3012. Be sure to check the polarity of the DC power input jack.

Important notice! For the CNC-built PSOne portable and the CNC-built Atari portable, special additional hacking is required for this TV. As you go through this section, keep an eye out for the special additional hacking notes and procedures that must be done, on top of the normal procedures. If you're not doing one of those two listed projects, just ignore the special additional hacking notes.

Materials you'll need

To gut the EV-680 and modify it with white LEDs, you'll need:

- Two 3-mm T1 white LEDs (`www.digikey.com`, part #CMD204UWC-ND)
- Two 10-ohm resistors (Radio Shack catalog #271-1101)
- Electric tape
- Some standard and thin ribbon cable (see the section in Chapter 3 titled *Ribbon Cable: really cheap, really great*).

Since Digi-Key adds a surcharge to orders under $25, you should order everything you need from them all at once, including any Digi-Key items required for the portable-building chapter you've chosen.

Taking apart the Casio EV-680

To begin the hacking procedure, let's take apart the TV.

1. Start by flipping the unit over and removing the battery cover. You'll see a total of five screws, including the one on the antenna and the two inside the battery compartment. Remove them all.
2. With the screws gone, use your fingernail or small flat-head screwdriver to pry the case open at the seams. There is nothing connected to the back plastic, and so it can be set aside.
3. Use a small flat-head screwdriver, your tweezers, or the edge of your knife to lift up the brackets holding the ribbon cable to the screen (Figure 4-6). Work one side up a bit, then the other, back and forth, until it's up. Grasp the sides of the cable with your tweezers, and gently pull it out.

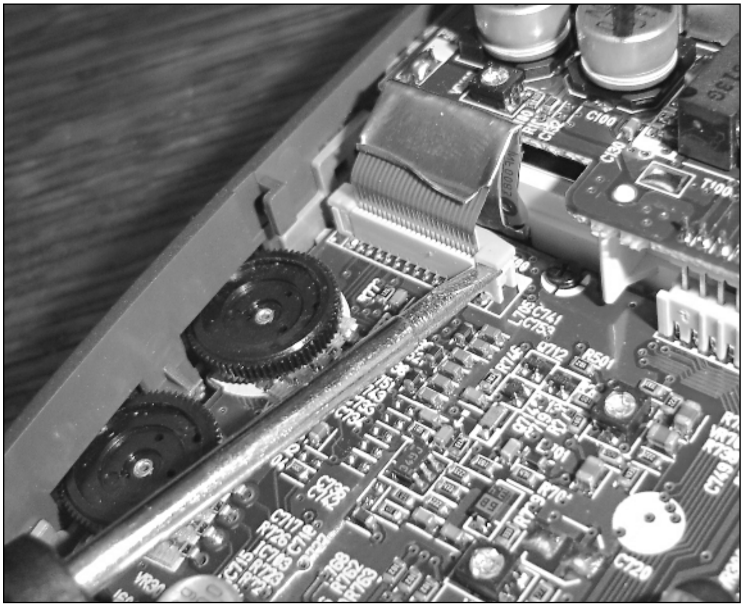


FIGURE 4-6: Releasing the ribbon cable.

4. Remove the screen assembly/upper board by pulling it out from the 17-pin beige connector in the center, and set it aside. Remove the small black screw next to the ribbon cable port on the lower board. Then desolder the two wires connected at the bottom of the board that go to the speaker.
5. Pull the left-hand side of the plastic casing (the piece with the text "Volume" and "Brightness" on it) away from the board, and pull the lower board out of the case. Remove the four screws holding the speaker in place, and pull the speaker out by lifting up the plastic surrounding it.

Note We'll call the two boards that make up the EV-680 the *screen assembly* and the *lower board* from here on out.

6. Break off the battery wire tabs from the back of the lower board. (Save them if you're ever planning to make the hand-built SNES portable.) Now flip the lower board over — it should look as shown in Figure 4-7. Desolder every highlighted lead, remove the parts that were on those leads, and set them aside.

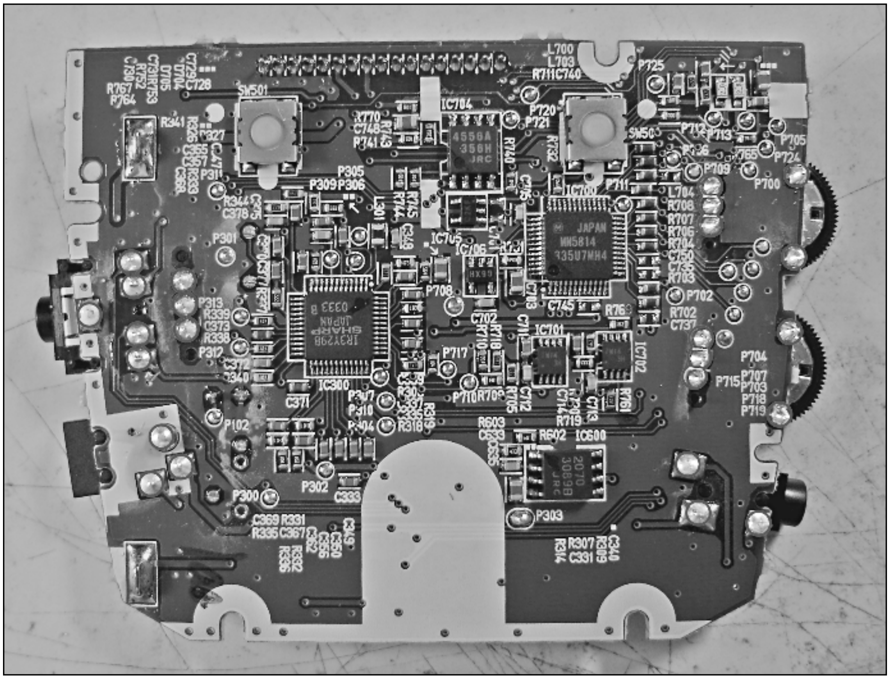


FIGURE 4-7: The front of the lower board, and what you should desolder.

The Casio EV-680 is now disassembled. In the next few sections, we'll give it a white-LED mod, and then reattach (using wires) some of the things you desoldered.

Special additional hacking (CNC PSOne and CNC Atari)

The TV tuner box needs to be removed before we continue.

1. Remove the bulb as described in the next section.
2. Desolder the metal shield around the screen from the upper board. Lift up the white plastic tabs in order to pull the screen assembly off the board. This gives you access to the TV tuner leads.
3. Remove the TV tuner box by desoldering the leads from the upper circuit board indicated in Figure 4-8. Use a flat-head screwdriver to pry the box off after desoldering.
4. Snap the screen assembly back in place and resolder the metal shield to the board.

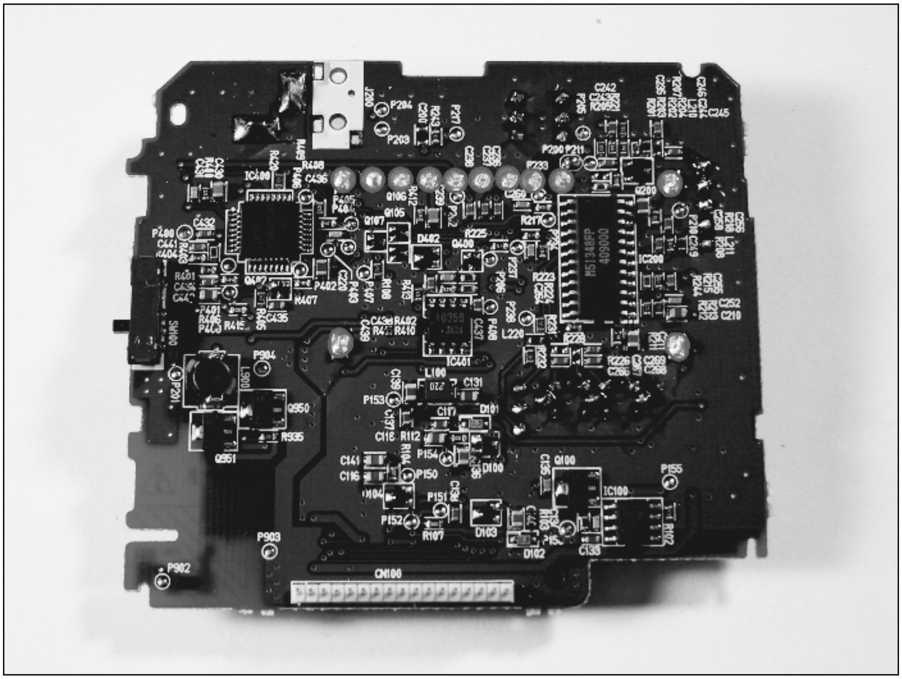


FIGURE 4-8: Desolder these leads to remove the TV tuner box.

Casio EV-680 white-LED mod

With the TV now hacked open, it's time to do the white-LED mod. This involves replacing the TV's existing light bulb with white LEDs to save power — allowing you extra playing time with your portable.

Note

Please keep the bulb safety warnings from *The parts inside a pocket TV* section in mind while you do this.

1. Snip the wires on both ends of the bulb, or desolder it from the upper board. If you snip the wires, be sure to do it right next to the solder so that no excess wire is left on the board.
2. Straighten the bulb's wires on end so that it can slide through, and then grasp the other end with your tweezers and slowly pull out the bulb. It has a couple bits of glue holding it, but they will pull loose.
3. Take one of your white LEDs and place it in the left side hole where the bulb was — it should fit in nicely. Once it is in, bend the wires back at a 90-degree angle, as shown in Figure 4-9. Keep the long lead toward the bottom of the board, as shown. Don't snip the leads off the LED yet, as you need to know which is negative and which is positive.

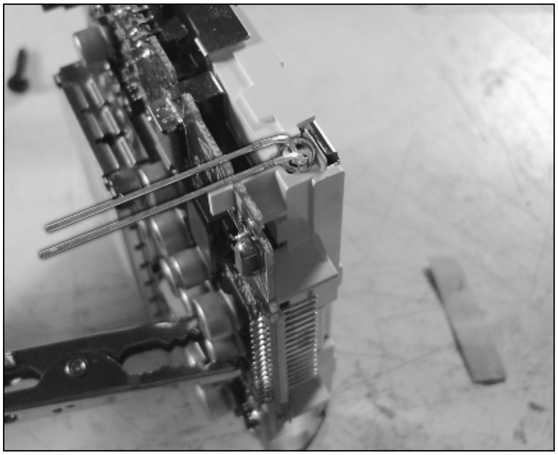


FIGURE 4-9: Placement of left LED, with bent wires.

4. Blob some hot glue over the LED itself to hold it in place. Once the glue is cold, flip the screen assembly over so that you can see the right side hole. There's a bit of white plastic in the way that you'll need to remove, as shown in Figure 4-10.

FIGURE 4-10: Snip this bit of white plastic.

5. Snip it from the side with your cutters, and then you should be able to twist it away. You can now fully insert the other white LED into the right side hole. Bend back its leads and secure it with hot glue, as you did with the first LED.
6. Place the screen assembly facedown. Cut a couple of small pieces of electric tape and place them between the LEDs, as shown in Figure 4-11. Bend the LED leads back around these pieces to keep them from touching anything that might cause a short circuit.
7. Use two strands of standard ribbon cable to connect the LEDs together in parallel (long lead to long lead, short lead to short lead).
8. Next, take your two 10-ohm resistors and wire them in series, as shown in Figure 4-11. Connect one end of the resistor pair to one of the LED's positive leads (the longer lead is positive). The back of the screen should now appear as shown in Figure 4-11.

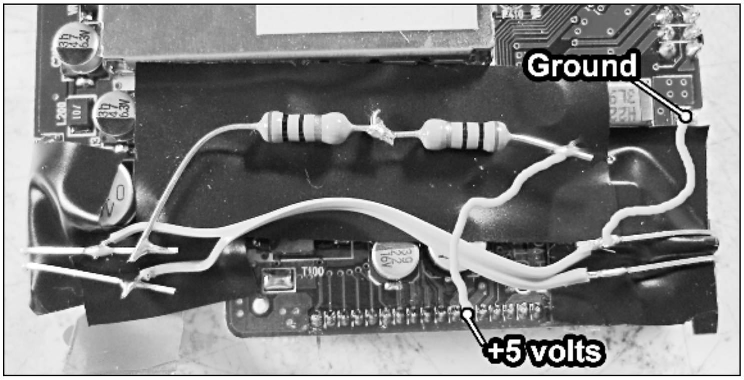


FIGURE 4-11: The LEDs connected in parallel, the resistors connected in series, and the power/ground spots.

9. Attach a short wire to the other end of the resistors (positive), and connect it to the sixth pin from the right on the main connector on the upper board (as viewed from the rear). Then attach a wire to one of the short (negative) LED leads, and connect it to the *ground* spot indicated.

Note

The metal shield on a pocket TV's LCD screen is always connected to ground. It doesn't have to be reconnected, but it does point the way to a ground connection.

Your LED backlighting mod is complete. When you've had a chance to run the TV and verify that the mod is correct, you can use hot glue to hold down the resistors and wires. It's also not a bad idea to cover them with electric tape again once the mod has been tested.

Reattaching parts to the lower board

When you took apart the Casio EV-680, I had you desolder a bunch of things from the lower board. In this section, we'll reattach those things to the board using ribbon cable. The reason for this is that those controls/jacks would be inside your portable's case and unreachable if they remained attached to the TV board. By extending them with ribbon cable, we can place them anywhere we want in our portable.

We'll reconnect all but the DC input jack. The following figures will display where to connect the wires to each part and to the board. For each part, a length of wire to use is suggested. While these may end up seeming a bit long, especially when you put them in your portable, remember that having wires too long is better than having them too short! Do the following to reconnect the parts:

1. Cut up a two-strand of ribbon cable 8" in length. Connect it to the audio/video jack and the lower board, as shown in Figure 4-12.

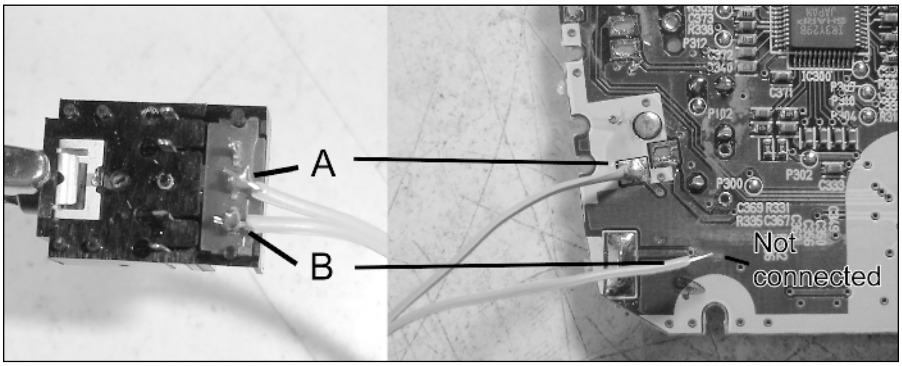


FIGURE 4-12: Connect to the plug and board as shown ("B" is not yet connected on the board side).

2. Next, cut a three-strand of ribbon cable 7" long. Connect it to the audio/video jack and the board, as shown in Figure 4-13. For best results, cut the outer wires a little shorter on the plug side.

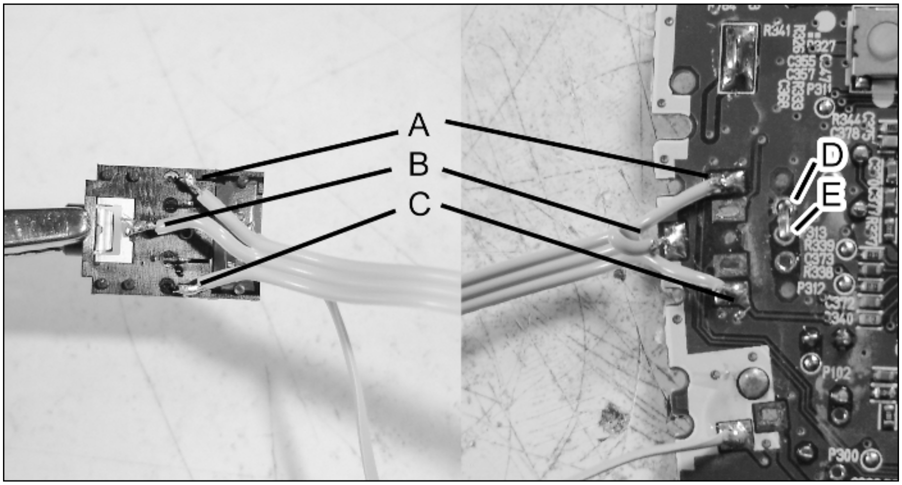


FIGURE 4-13: Connect to the plug and board as shown. (Note how wire B is longer on the plug side.)

3. Place a blob of solder between points D and E in order to connect them, as shown in Figure 4-13. This permanently sets the TV to receive audio/video input.

   Before we continue, I want to talk about what we just did here. The A/V jack has a small switch inside it that connects to the three terminals on the end (two of which were used in Step 1). When a plug is inserted, the switch goes on, telling the TV to accept an external video input. Since the switch has been removed, we had to solder spots D and E together on the board to simulate this. However, you can also use this switch to turn something off—which is what we did in Step 1. Positive voltage is sent into the unconnected wire in Figure 4-11, which then goes to the A/V jack. If no plug is inserted, the power continues through the other wire and into the TV itself, turning it on. This is useful because if you use the A/V jack for an external video output, it'll automatically turn off the system's built-in TV when you insert the plug. All right, with that off my chest let's continue.

4. Slice a three-strand of ribbon cable 9" long. Connect it to the headphone jack and the board, as shown in Figure 4-14. (I've rotated the board 180 degrees to do the soldering.) Again, if you precut some of the wires shorter, it makes for nicer connections. (You don't *have* to do it, but I do in order to make these photos look good. I guess that's my problem.)

5. Cut a four-strand of thin cable 11" long. (Ultra ATA or thin ribbon cable works best for this.) Connect it to the board and the knob as shown in Figure 4-15. (You'll notice that not all of the pins are reconnected—this is fine.) You may also want to push the wires through the holes from the other side of the board. I usually do it that way but displayed it as shown for clarity.

6. Repeat Step 5 to connect the other knob to its spot.

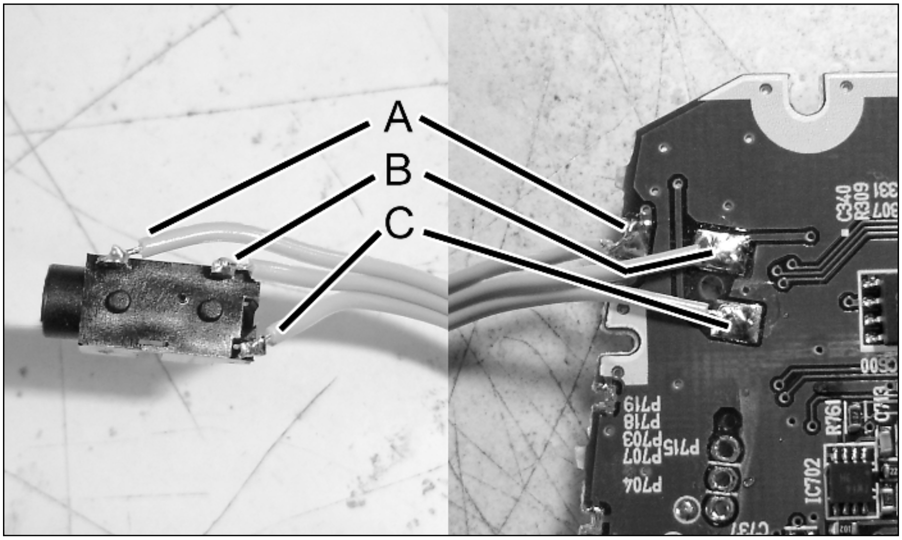


FIGURE 4-14: Connecting the headphone jack.

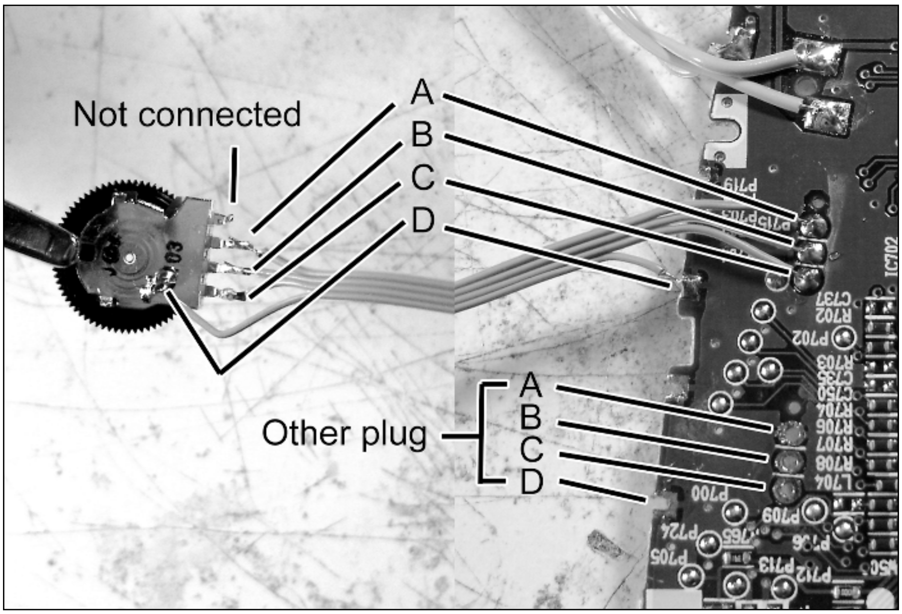


FIGURE 4-15: Reconnecting a knob. Bend out the pins on the knob as shown, using your tweezers for best results.

Reconnecting both halves of the EV-580

All right, we're almost done with this thing—we just need to reconnect the halves. However, unlike Vanessa Williams, I've saved the worst for last, because this is a bit tricky. There are three ways of doing this, and you must choose the appropriate path for the project you're doing.

- If you're not planning to use this modified TV for any portable project described in this book, then go ahead and plug the halves back together the way they came, and skip ahead to *Reconnecting the ribbon cable.*
- If you're going to build either the CNC-built PSOne or the CNC-built Atari 2600, jump ahead to the *Folded reconnecting* section.
- For all other projects in this book using this screen, continue on to the *Standard reconnecting* section below.

Standard reconnecting

Ok, before I make you do this, let me tell you why. If you recall the way this TV originally was, the lower board was fairly level with the front of the screen. This won't work for your portable because the lower board would be where the game controls should go! Therefore, we're pushing the lower board back so that it's level with the upper board. This is called *standard reconnecting*. Here's how to do it:

1. First, place the lower board just under the lip of the screen assembly and hot-glue it into place, as shown in Figure 4-16. *Make sure* the ribbon cable is behind the lower board before you attach them. Hot-glue it on both sides, keeping the boards as straight as possible.

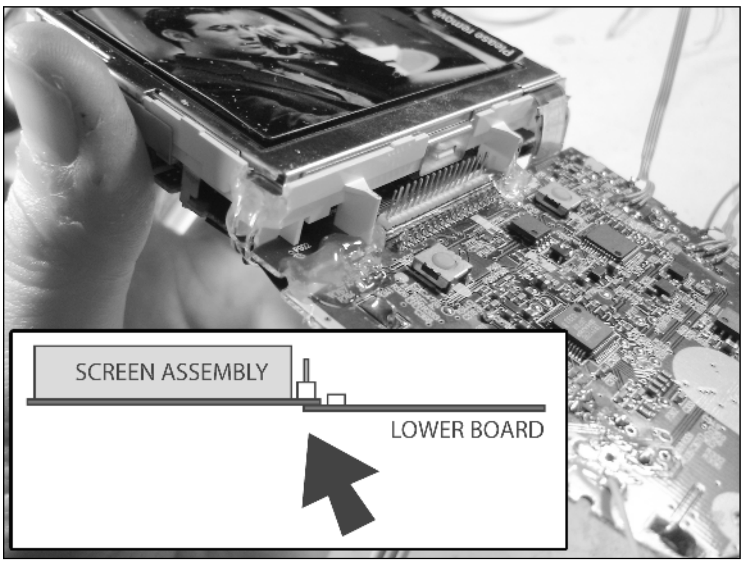


FIGURE 4-16: Placing the lower board against the screen assembly.

2. When placing the boards together, look straight down on the connector. Offset the boards just a bit so that when you bend down the pins, they'll be just to the side of the leads, not on top of them.

   Yes, that's right, we're bending all those pins. Using your tweezers, slowly bend the connection pins on the screen assembly down beside the matching leads on the lower board, one by one. Keep the following in mind:

   - Don't bend the pins too fast or they may snap.
   - You may also find it helpful to push each pin down with a small flat-head screwdriver.
   - Make sure the pins are beside the leads, not on top of them. This way you can be sure they are connected.
   - If you are near-sighted and wear glasses (like me), it sometimes helps to take them off for this sort of close-up work. Or, close one eye to help you focus (really).

3. Once all seventeen connections are bent, carefully solder each pin to each lead. (See Figure 4-17.) Make sure each pin has a sufficient amount of solder connecting it to its lead. There should be little blobs of solder on each lead, not just some "painted on" solder. Solder is like wire — if it's not thick enough, current can't flow through it correctly. Also, thin strands of solder can break, especially in this situation.

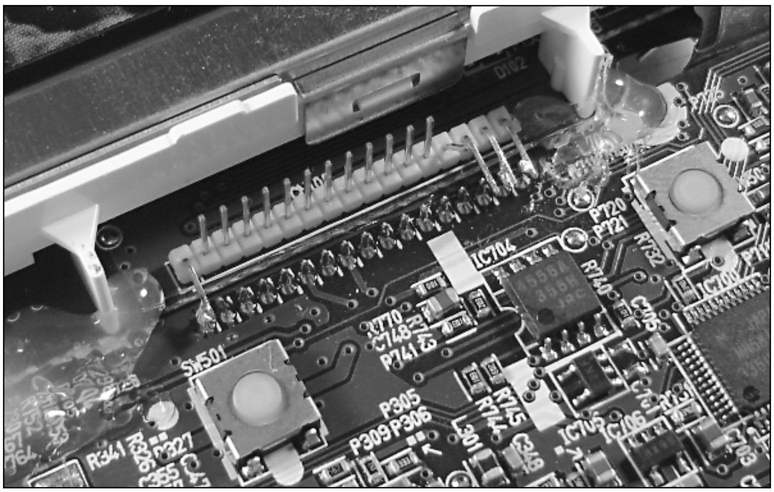


FIGURE 4-17: Bending pins and soldering them in place.

Note

Be sure to use a low-power pencil soldering iron for this task. Anything larger will spell certain doom.

The main connector is now reattached to both halves. Please jump ahead to *Reconnecting the ribbon cable* to finish this TV mod.

Folded reconnecting

The CNC-built PSOne portable and the CNC-built Atari 2600 portable require the screen to be more compact. To accomplish this, we're going to fold the lower board behind the upper board/screen assembly. This compacts the TV quite a bit, though it is a little trickier to mod. Here's how to do it:

1. Attach 10"-long *speaker wires* back to the TV ahead of time. We're doing this because the spot to wire the speakers to will become hidden after this modification.
2. Reconnect the LCD ribbon cable now, as described in the next section. Then come back here to Step 3.
3. Lay the upper circuit board screen facing down, and then lay the lower circuit board on top of it with the channel up/down tact switches facing up. Place a few layers of electric tape between the halves to prevent any possible short circuits. The two circuit boards should be pretty well-centered over one another.
4. Use bits of leads to connect the seventeen leads together, as shown in Figure 4-18. Keep all the connections on the left or right sides so that they won't bump into each other.

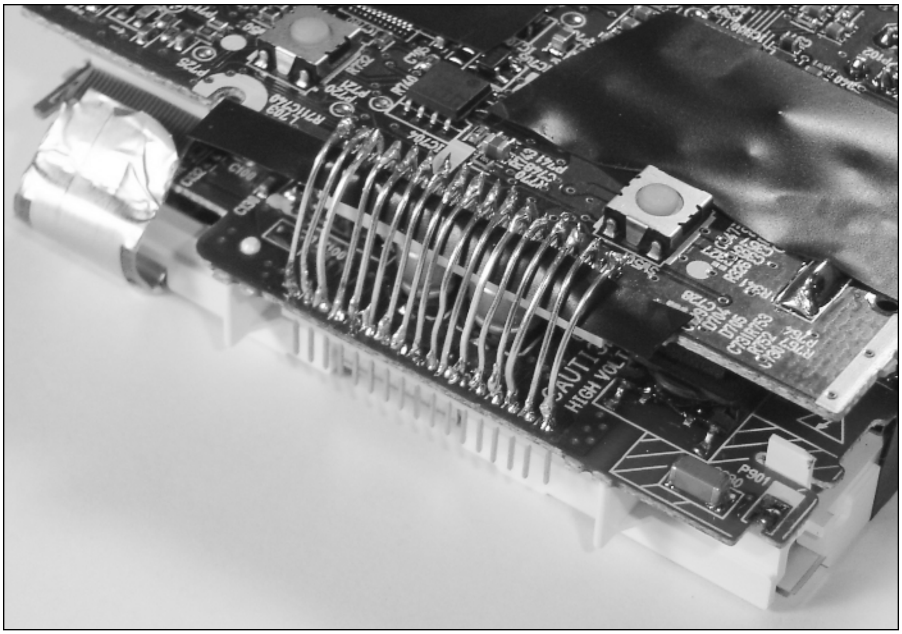


FIGURE 4-18: The seventeen leads connecting the sides together.

5. Hold the sides together using a piece of electric tape. The resulting modification should appear as shown in Figure 4-19.

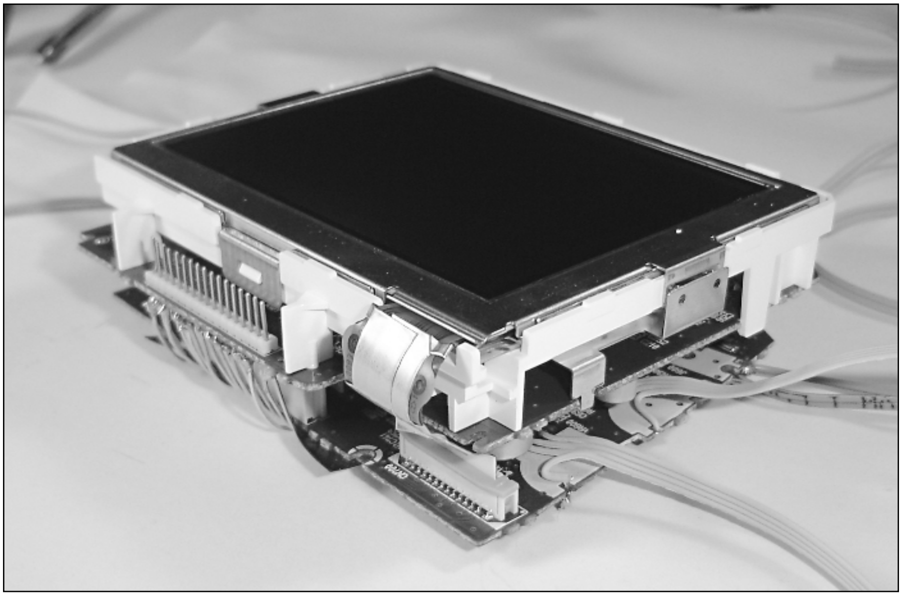


FIGURE 4-19: The completed modification of the EV-680.

Reconnecting the ribbon cable

With the main connections now reattached, the final thing that needs to be reconnected between the two halves is the ribbon cable.

1. First make sure that the plastic clamp for the connector is lifted up. Bend the ribbon cable over, and press it into the slot. Try to keep the bend rounded, not sharp.
2. Once it's all the way in the slot (so that you can't see the metal connections), alternate pushing down the sides of the clamp a little at a time, or press both sides down at the same time using tweezers. If you push one side all the way down and then the other, it tends to push the ribbon cable back out of the clamp enough to disconnect it.

With the ribbon cable reinserted, the Casio EV-680 modification is done! You can now use it with the projects in Part 2, or make your own custom portable. (Checking out the later chapters will still you give hints, of course, even if you go your own way.)

Hacking a PSOne Screen

In 2000 Sony released a redesigned Playstation 1 called the PSOne. And it had a clip-on screen available! (See Figure 4-20.)

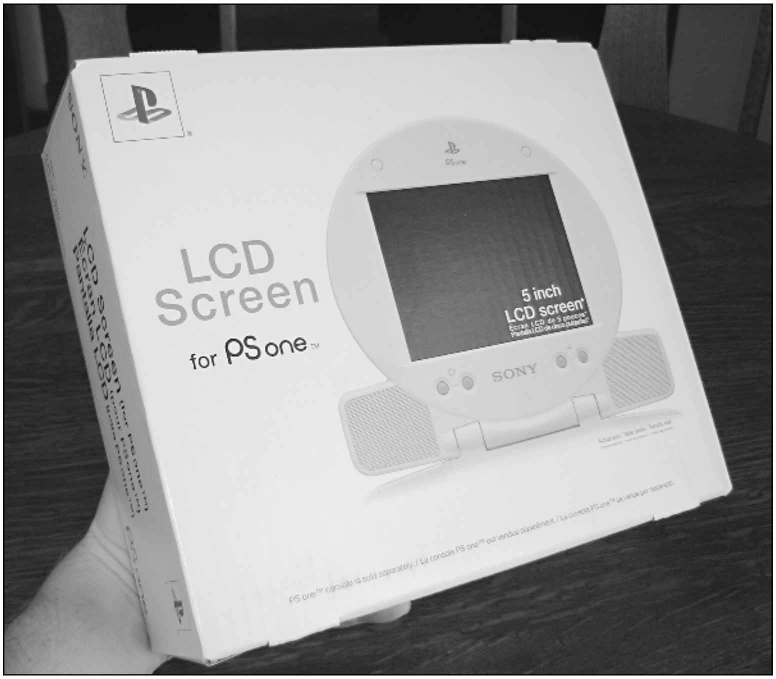


FIGURE 4-20: A PSOne screen, shown in its original retail form.

The PSOne screen was meant to plug into the back of the PSOne and replicate the ports. By this, I mean you'd then plug the power jack into the screen, thereby connecting it to the PSOne. Same with the audio/video jack. You can consider it a "pass-through" of sorts. You'd then have this little semiportable Playstation 1 unit.

I secretly think that both the PSOne and the screen were built to cater to the whims of experimenters everywhere. At $110 for a 5" LCD screen, it's a steal, and they're usually *much* cheaper if bought online. (This is your best bet for finding one, although don't rule out used game stores). The screen can accept composite video input, making it useful for a variety of purposes.

But, let's talk about your purpose, shall we? Hacking it up to make a portable! First, be aware that the PSOne screen must be converted to use white LEDs to be of any use to us. You will need:

- Three 3-mm T1 white LEDs (`www.digikey.com`, part #CMD204UWC-ND)
- One 10-ohm resistor (Radio Shack catalog #271-1101)
- A small, rather blunt Phillips screwdriver (more on this in a bit—get it, "bit"?)
- Some strands of standard-size ribbon cable

Taking apart the PSOne screen

The first step in modifying this thing is, of course, to take it apart. The screws on this screen are sometimes hidden and a little sneaky... here's how to find them:

1. Use your knife to wedge up the edges of the white speaker covers — they're just glued in place. Once you've got a bit peeled up, pull it off the rest of the way with your tweezers. You'll find two screws under each speaker cover — remove them all.
2. Using your knife again, lift off the two little rubber screw covers near the top of the unit, just above the screen. This will reveal two more screws. Remove them, along with the three exposed screws at the bottom of the unit near the plugs.

Note The screws holding the PSOne screen together have shallow groves in which to place your screwdriver. If your screwdriver is too pointy, it won't grip and will strip the screw head, making the screw even harder to remove. Use a fairly blunt-ended small screwdriver instead. Another key to removing screws like this is to push down harder when unscrewing them.

3. Use your fingernail or a flat-head screwdriver to peel the case open; there are tabs holding it on the sides and top. Set the rear plastic aside, and you'll see what looks like Figure 4-21. Remove the five indicated screws.

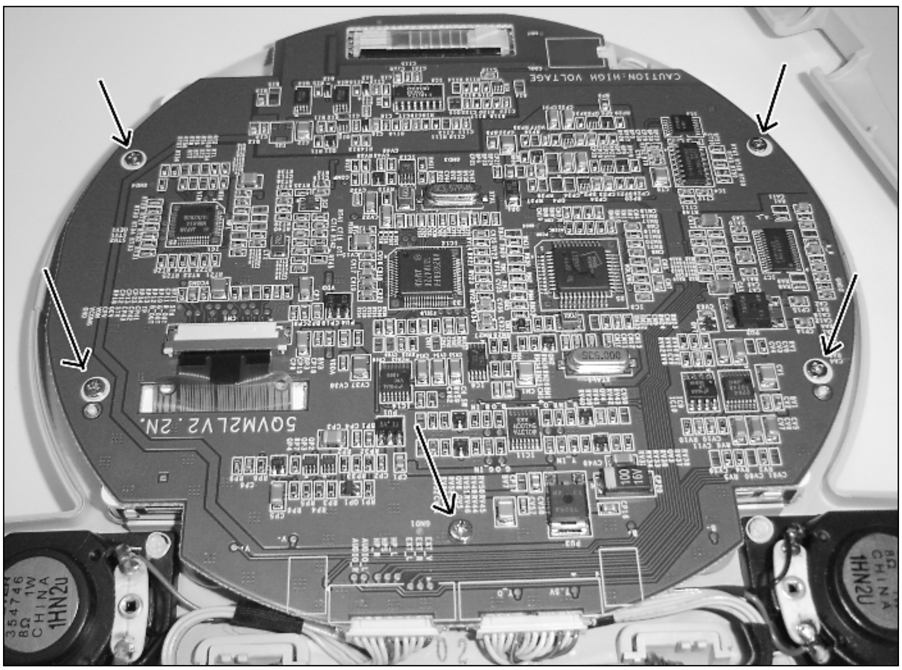


FIGURE 4-21: The next set of screws to remove.

4. Carefully flip the unit over, holding the loosened circuit board in your hand as shown in Figure 4-22. The screen is now loose and you'll want to avoid moving it around in order to protect the LCD's ribbon cable. Fold over the front plastic casing and then detach the four cable plugs, as shown in Figure 4-22.

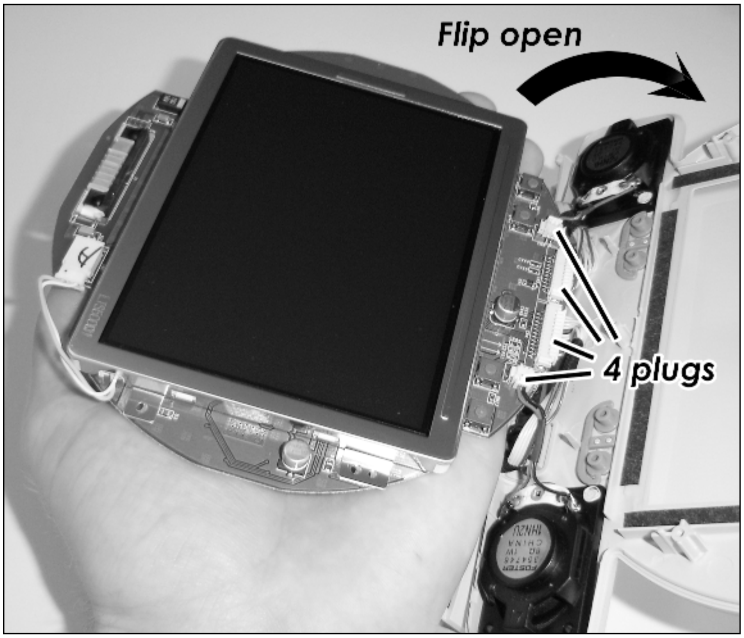


FIGURE 4-22: How to hold the unit, and which plugs to remove.

5. Set the speakers and the rear plug assembly aside for now. Unplug the two thick bulb wires coming off the inverter; they're pink and white. Flip the circuit board over, with the screen facing down (be sure it's set on something soft to avoid scratching it).

6. Look for the ribbon cable clamp on the back of the board, as seen in Figure 4-23. Place one edge of a thin flat-head screwdriver under the brown tab on one side. Slowly twist your screwdriver so that the edge of the screwdriver head lifts up the brown tab. The clamp will lift off.

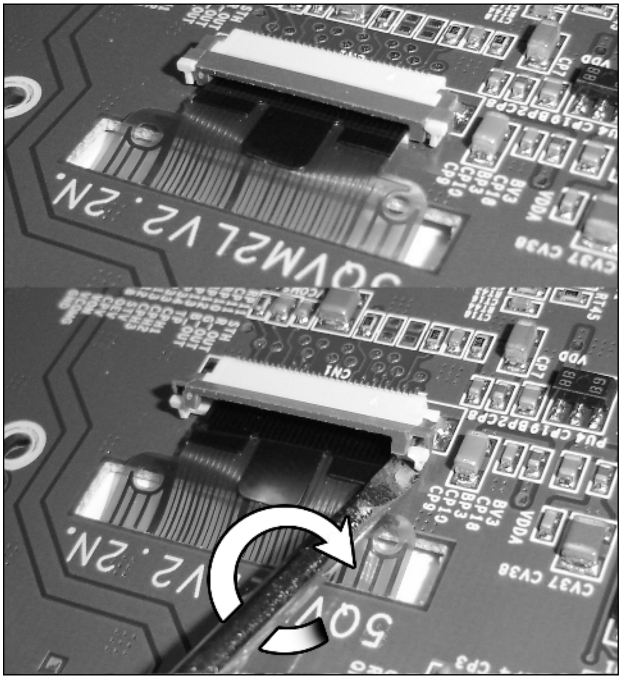


FIGURE 4-23: Unclamping the ribbon cable.

Note This kind of ribbon cable clamp is very easy to break. Take your time when opening it to avoid snapping off the white tabs on either side. If they do break, you can hot-glue the ribbon cable back in, but that's not a desirable scenario.

7. You can now remove the LCD and light assembly. Set the main circuit board aside for now. There's a metal shield around the screen that is held in place by eight tabs. Push a thin flat-head screwdriver under each tab, then pry it up to free the metal from the tab.
8. With all the tabs undone, carefully press against the screen with your thumbs and lift the side tabs with your other fingers to remove the metal shield, as shown in Figure 4-24.

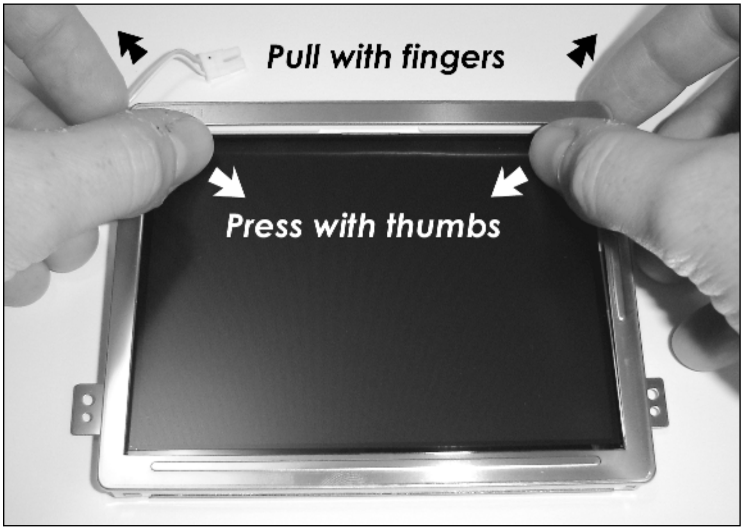


FIGURE 4-24: Removing the shield. (Don't eat potato chips just before doing this.)

9. The LCD glass is now loose. Hold the front of the LCD screen facedown against your hand and slowly lift off the plastic light box. It is not glued in any way, so if it snags a bit, tilt or shift it sideways until it comes free—do not force it.

Caution

The LCD glass is very thin and fragile. If the corners of it break, which they can during this procedure or during the reattachment, the screen will be dead.

10. Once the lightbox is detached, set the LCD glass facedown on something very clean (if you haven't already) and place a clean sheet of paper over the back of it to protect it from dust.
11. Now let's go to the lightbox. It has five plastic tabs holding the front of it in place. Open these just like you did the tabs on the metal shield. Lift carefully to avoid snapping them off. (This won't ruin anything, but the screen might reassemble a little less tightly.)
12. You can now unfold the front plastic frame. Rotate the light box so that the front portion folds down, with the bulb plug to the upper left. You'll find a thin piece of light-diffusing plastic held in place by two tabs on the left. It's actually two pieces of plastic, so try to keep them together. Using your tweezers, remove this plastic and set it aside, covering it to keep it clean. You can hold it by the edges, but do not touch the main surface with your skin. Treat this thin plastic with as much care as you do the LCD itself.

Note

You are now inside the light box. Keep everything in it clean. Whenever possible, use your tweezers or knife instead of your fingers, which can rub off oils and other mammal-based debris. (Don't worry—I won't go so far as to suggest wearing a hair net.)

Installing the white-LED mod

With the insides of the PSOne screen's lightbox breached, we can now install the white LEDs. Then we'll reassemble the light box and make the actual electrical connections for the mod as well.

1. Bend the three thin plastic strips up to reveal the bulb. Then use your tweezers to lift the bulb up from the right-hand side, tilting it toward the left. You can now pull out the bulb and the wires on the left.
2. Now it's time to insert some white LEDs! Make vertical slits in the sides of the light box plastic, as shown in Figure 4-25. These slits should be just wide enough for the LED leads and the space between them to fit through. (Remember to make a corresponding slit in the fold-down plastic frame for the upper right-hand slit.)

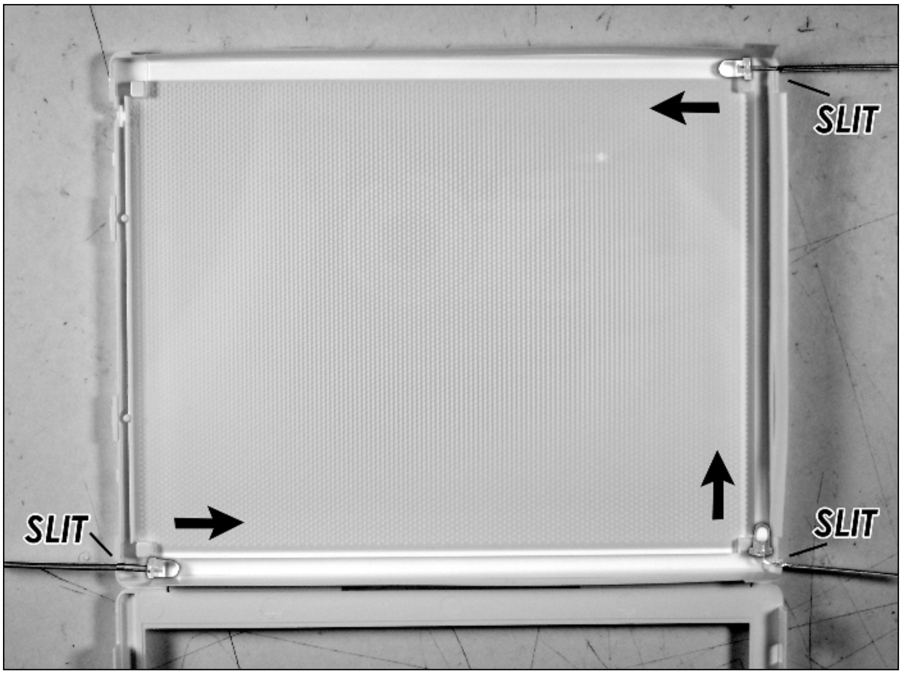


FIGURE 4-25: Where to make slits and how to place the LEDs.

3. Next, place three 3-mm white LEDs, as indicated in Figure 4-25, with the bulbs pointing in the direction of the arrows. Have the leads go through the slits and keep all of the long positive leads facing out, toward the screen side, in order to make wiring easier. Each LED should aim down the channel where the bulb once was. Once placed correctly, put some hot glue behind each LED (on its leads) to hold it. Watch out for strings of hot glue that might get on the screen. (Use your Chapter 2 skills!)

4. With the LEDs in place, fold the three thin plastic strips back down over them, and then set the thin light-diffusing plastic back over the glass. Make sure the edges of the diffusing plastic are over the thin plastic strips. This is actually kind of tricky to do, especially without touching much of the diffuser plastic, but think of it as an exercise for developing manual dexterity!
5. With everything back the way it was, fold the plastic lid back up. If you placed the LEDs well inside the channels and didn't go too wild with the hot glue, the plastic lid will snap in place nicely. If it doesn't, you may have to go back and shave off some excess hot glue with a sharp X-Acto knife.
6. Hold the LCD glass by its edges and place it back onto the light box. Finally, snap the metal frame back over both the LCD and the light box.
7. Do not force the metal frame back over the LCD. Forcing the metal frame can break the glass. If it doesn't fit quite right, there may be an unlevel LED or too much hot glue. In addition, you may want to make some cuts in the metal frame to keep it farther away from the LED leads, as shown in Figure 4-26.

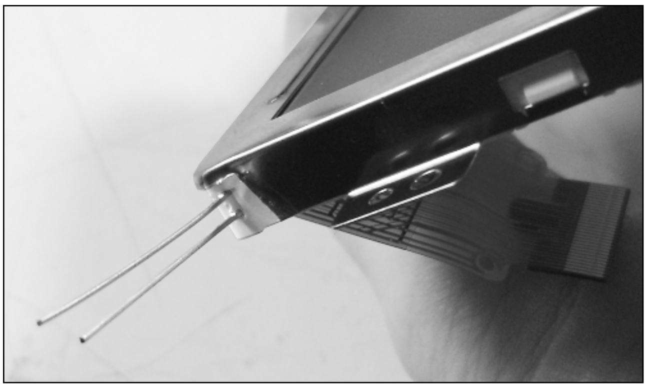


FIGURE 4-26: Where the metal frame may need cutting.

8. On the top of the main motherboard for the screen, you'll find a long transformer with six leads — two on one end, four on the other. Desolder all these leads to remove the transformer and kill the inverter circuit. This will avoid accidental shocks and also help to save power.
9. Place the screen assembly back onto the main board, sliding the ribbon cable through the slot. Push it into the ribbon cable clamp. Ensure that it's straight, level, and looks the way it did when you found it, and then press the clamp down with your finger.

10. Use a couple of small screws and nuts (size 4 at the hardware store) to temporarily secure the metal screen plate to the board until you're ready to use it in your portable. This keeps the screen from shifting around during handling. (You could also just set this thing on a shelf until you're ready to use it, I suppose.)

11. Flip to the back of the board, and look for the power regulator seen in Figure 4-27. Attach a wire to the left side lead. This will be your +5 volts for the white LEDs.

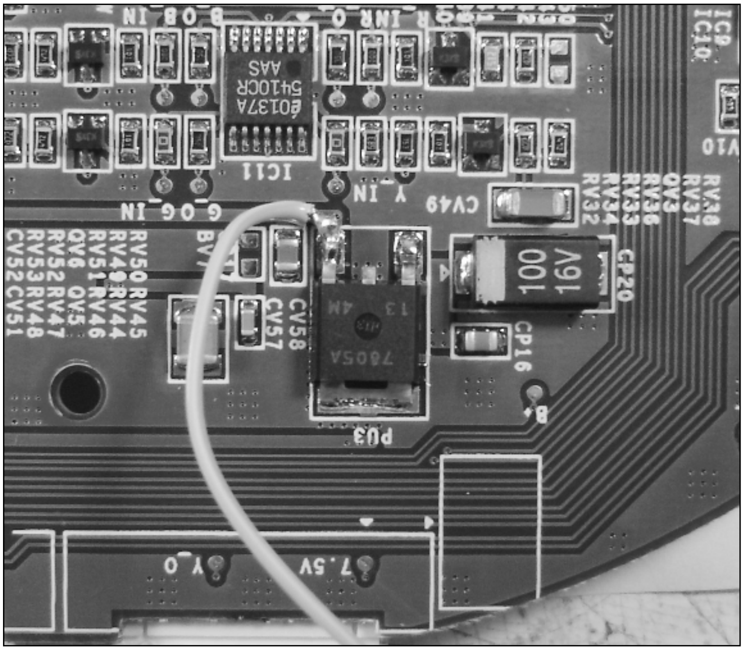


FIGURE 4-27: Where to get +5 volts. (If you look closely, you can see that the regulator is labeled "7805.")

12. Flip to the front of the board and place a piece of electric tape down as seen in Figure 4-28. Hot-glue a 10-ohm resistor on the tape and connect your +5 volt wire to one end of it.

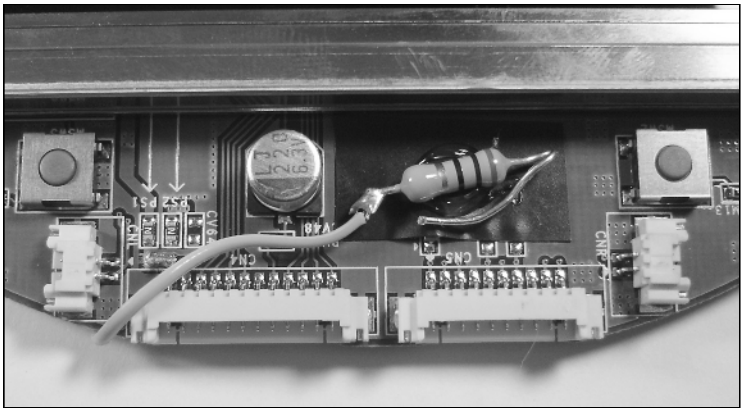


FIGURE 4-28: Placement of the 10-ohm resistor.

Note

Use more glue than shown in this picture, as the resistor can generate heat.

13. Connect the other end of the resistor to the long positive lead of each LED. Connect all the short negative LED leads to each other and then connect them to the ground spot indicated on Figure 4-29.

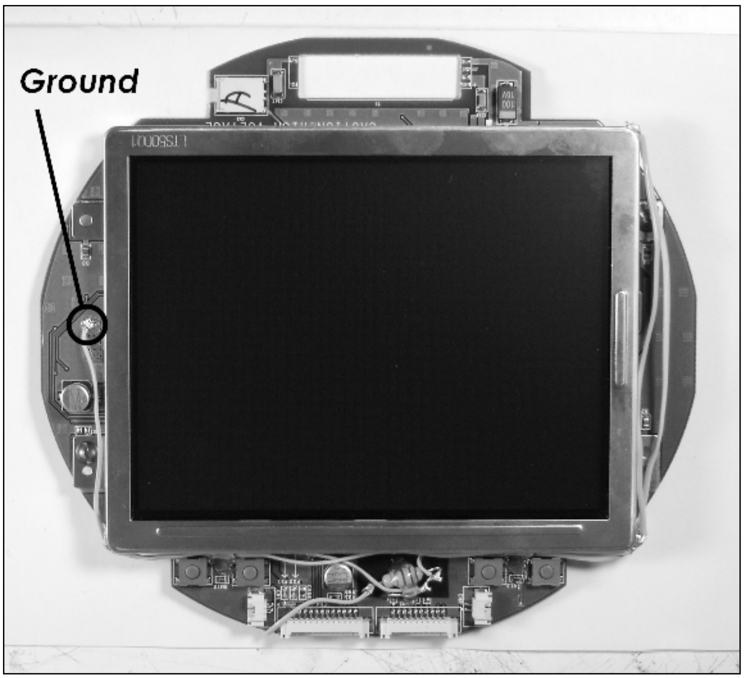


FIGURE 4-29: The completed LED mod, with ground spot indicated.

Okay, the PSOne screen is ready to go! Reattach the cables and the speakers if you like, and you can then try it out using the 7.5-volt wall adapter that came with it. Otherwise, we'll talk more about hooking stuff up to this screen during the projects that use it.

Additional PSOne screen hacking notes

If you somehow overload or fry the PSOne screen, you can jump a fuse to fix it, just like with most pocket TVs. The fuse is shown in Figure 4-30. Desolder it and put a bit of solder in its place if your screen stops working.

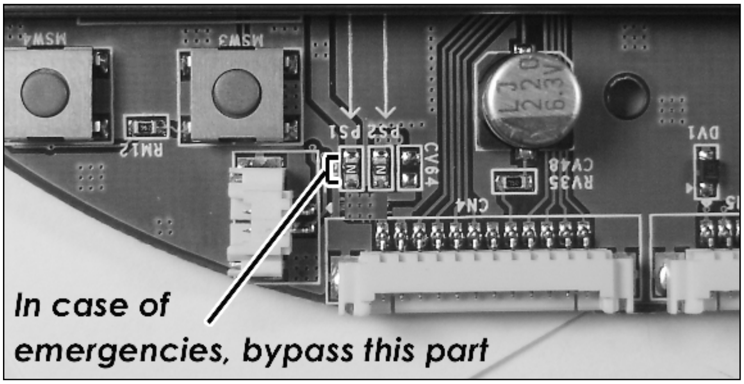


FIGURE 4-30: The fuse that you can bypass, labeled PS1 on the board.

The white-LED mod will make the screen darker than with its original bulb. You can trick the screen to get brighter by bypassing a small component on the back of the board with a thin bit of wire as shown in Figure 4-31.

It's just above the center of the board, where you'll see 10 little surface-mounted components in a row. You want to bypass the third one from the left, labeled CV30. Since it makes the screen a lot brighter, perhaps too bright for some people's taste, I'd suggest bypassing the part instead of removing it, as you may wish to change it back. (It's your call.)

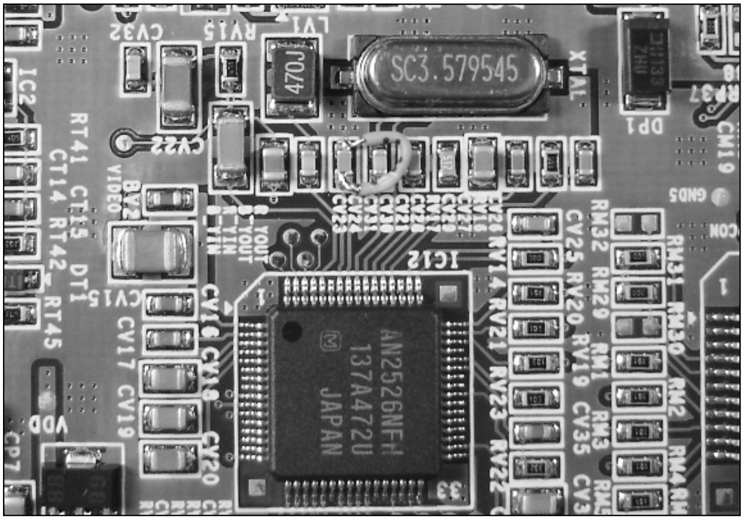


FIGURE 4-31: Bypass CV23 to make the screen brighter.

Other Small Screens You Can and Can't Use

The Casio EV-570 and EV-680 were described in this chapter because they are the most current models of pocket TV, and so the most readily available. This doesn't mean you can't use other screens — far from it!

The methods used to modify the previously mentioned screens can be applied to most pocket TVs. The parts are all the same, they're just in different places. In fact, some of the TVs I'm about to mention are actually easier to mod because they don't have as many circuit boards inside.

The white-LED mod can be used on most pocket TVs — all you need to do is use a multimeter to find a +5 volt power source on the board. Connect the +5 volts to the resistors as described previously, attach the short negative leads of the LEDs to the TV's ground, and you're set.

Note

Anything around +5 volts, like +4.6 volts, will work — this isn't rocket science, you know. Pins or connections leading to the inverter are pretty good places to find +5 volts (especially in the Casio EV-550 and 670).

The following TVs will work for portable projects:

- **Casio EV-550.** This was the predecessor to the EV-570, with the same size (2.5") screen. Inside there's a single large circuit board, which is approximately the same size as the two boards in the EV-570 put together. The inverter is attached to the light box.
    - The EV-550 has been discontinued, but there may be a few floating around as clearance items. Online outlets, such as Yahoo Shopping, can yield results.

  - The EV-550 is very similar-looking to the EV-570, but the batteries insert in the front rather than the rear, and it only takes three of them. This difference is why the EV-550 has only one circuit board. (You'd think that a single-board unit would be easier to build, but apparently Casio was really anxious to have rear-loading batteries.)
  - This unit can be used as a replacement for the EV-570 in these projects, though you may have to cut off the inverter portions of the light box to make it fit, thus requiring an LED mod for light.
- **Casio EV-670.** This model came before the EV-680 and had the same size (3") screen. It has a single large circuit board inside, with the bulb inverter connected to the light box.
  - Again, it has mostly been phased out of retail stores, but online merchants still carry them. A bonus about older models is that there's a good chance of finding refurbished units that are heavily discounted. (Who cares what the case looks like if you're removing it anyway?)
  - The EV-670 looks similar to the EV-680, but is thicker because the batteries insert in the rear. With only one circuit board inside, it is much easier to modify.
  - This unit can be used as a replacement for the EV-680 in these projects, though you may have to cut off the inverter portions of the light box to make it fit, thus requiring an LED mod for light.
- **Casio EV-4500.** This is the crown jewel of the Casio pocket TV line, with a whopping 4" screen! It also sucks up a whopping amount of power, around 750 mA.
  - The EV-4500 is still available in electronics stores for around $199.
  - You pretty much have to do the white-LED mod to use this screen with anything else; the power consumption is too high otherwise.
  - It is not compatible with the projects in this book as described — not even close, actually — but great if you want to make some kind of "super-sized" portable.
  - The display is a little crisper than the PSOne screen, but that crispness is probably not worth the price difference between the two. (Of course, this would be one of those "in the eye of the beholder" situations.)
- **RCA L2501.** This is an interesting screen. It's 2.5", but the resolution blows away the Casio EV-550 or 570. It has a main circuit board about the size of the unit, which connects with a fairly long ribbon cable to a subboard that runs the screen.
  - The L2501 has pretty much faded out of the retail scene, but you can still find them by searching online. Refurbished ones usually sell for well under $100 — a great bargain!
  - The fairly long ribbon cable allows you to move the screen portion around, or even rotate it sideways for a landscape-shaped portable.

- The wires that attach to the bulb are kind of flimsy and can break easily. And, of course, it breaks right where it connects to the bulb, leaving you with very little lead onto which to solder a fix. Either secure the wires with hot glue or replace all of it with an LED mod.
- Not directly compatible with these projects as described, but perfectly suitable for a custom portable, if you're so inclined.

I'll get the big disappointment out of the way — you can't use a Game Gear or Gameboy screen for the projects in this book. If you could, those old systems would be worth a lot more than they are — one could say they're cheap for a reason.

The general rule is that in order to be able to connect it to a video game system, a pocket TV or screen must be able to accept a composite NTSC television signal. (NTSC is the American standard; PAL and SECAM are standards used in other countries.) However, some game systems, such as the SNES and PSOne, output an RGB signal, and some screens can accept that.

Chapter in Review

In this chapter, you learned some basics about pocket TVs and portable LCD-based screens in general. You then learned how to hack up a screen for use with the portable projects in Part 2 of this book. Important points to remember include the following:

- The bulb that lights up a portable screen uses a lot of voltage. This can shock you — literally, and also metaphorically, because of how fast it eats batteries.
- Replacing the bulb with small white LEDs is easy to do and saves power. The +5 volts to run the LEDs can usually be found on the TV's motherboard.
- The LCD screen itself is thin and fragile. Care must be taken not to break it or get debris stuck in the light box behind it.
- The controls and jacks on the TV should be rewired so that they can reach the edges of your portable's case.

You can also use the information in this chapter to modify pocket TVs for your own purposes beyond making portable game systems, or use this info, along with the general hacking procedures in Part 2, to build a portable game system of your own design.

chapter 5

Using Computerized Cutting Equipment

in this chapter

- ☑ What is a CNC Machine?
- ☑ How CNC Machines Are Used
- ☑ Materials You Can Rout
- ☑ Finding CNC Machines to Use
- ☑ Chapter in Review

As mentioned earlier in this book, there are two ways for you to make the cases for your portable projects. One way is by hand, and the other is by using *CNC machinery* to cut the parts.

As you've probably guessed from the title of this chapter, this is the part where we'll be discussing the CNC (computer numerical control) machines — what they are, what types there are, how they work, and how they can be used to make parts for portables. We'll also discuss the different kinds of materials that they can cut, and the pros and cons of each.

Keep in mind that if you have parts cut by a CNC machine for your portable, you probably won't be running the machine yourself (unless you have one at school or your place of work). However, knowledge of what they are and what they can and can't do will be useful when locating one to use and explaining to the operator what you'd like done. You'll also see these terms pop up again during the CNC chapters of Part 2.

Note The project files to run the machine are all available on the companion Web site at www.wiley.com/go/extremetech. Each CNC chapter will list the correct files to use for that specific project.

What Is a CNC Machine?

CNC stands for *c*omputer *n*umerical *c*ontrol. Many machines are controlled by computers (even cars and coffee makers), but in this case, the CNC moniker is used to describe a machine that can accurately cut custom shapes out of materials placed in the machine. They have a cutting device of some sort that starts out at a home position and moves around, automatically slicing/drilling based on information sent to the machine by a separate computer.

Let's look at the two most common types that, conveniently enough, can also be used for making portable game systems.

Three-axis CNC router

Three-axis CNC routers are CNC machines that cut material using a drill bit. They're the most common type of router, consisting of a table, movable cutting head, router motor, and control box. They can be either freestanding, with a support structure under them, or designed to be placed on a table.

Three-axis means that the machine has three ways in which it can move (Figure 5-1). First, there are rails and motors on either side of the table that move the main beam back and forth along the Y axis. On the beam is the cutting head, which moves left and right on the X axis. Finally, the cutting head can raise and lower the router motor along the Z axis.

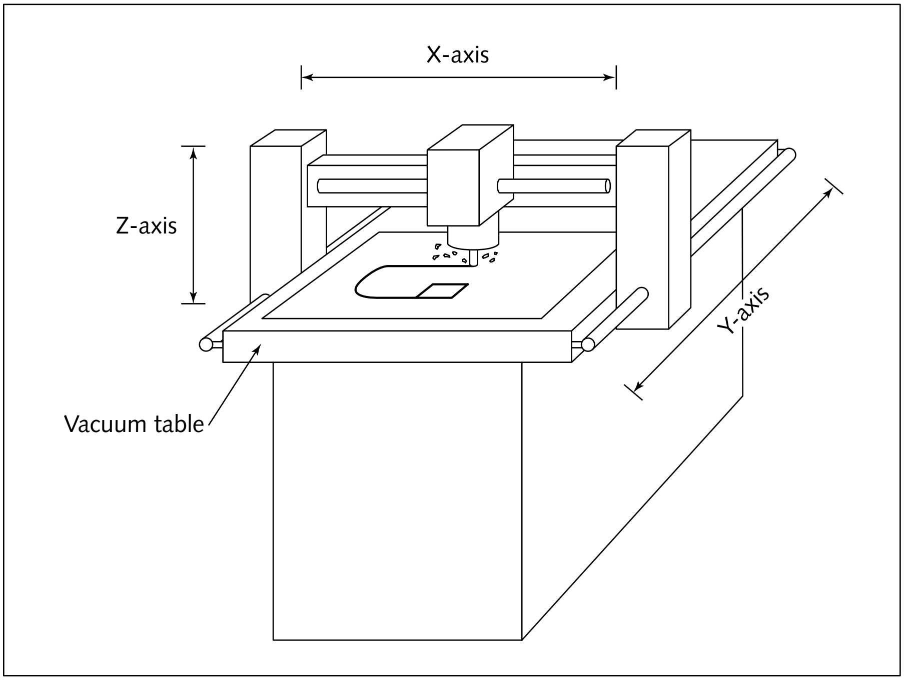


FIGURE 5-1: A three-axis freestanding router.

The router motor has a collet that holds the routing bits. These are very much like regular drill bits, but, in order to fit in the collet, they all have the same size shank regardless of the actual bit size, as seen in Figure 5-2.

Sometimes these machines have a vacuum table, which is best described as an air hockey table in reverse — it's full of little holes that suck parts down. Once you start routing using the vacuum table, you have to leave it running and sucking the whole time even if you change bits or settings, or else your material may slide around and wreck the precision alignment. As an added precaution (or if you have no vacuum table), you can also clamp things in place.

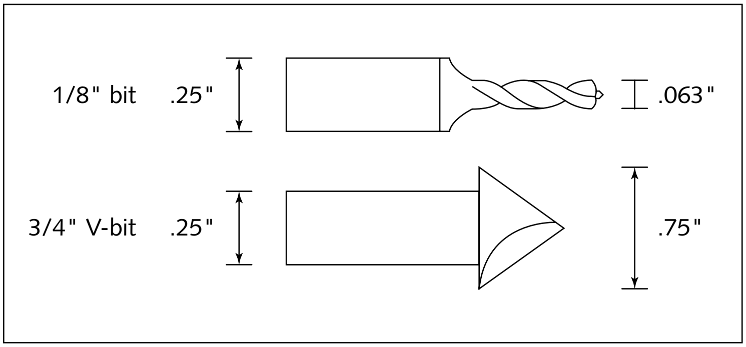


FIGURE 5-2: Examples of different router bit sizes.

When placing material to be cut on the table, you need to make the machine aware of the Z-axis depth, or table depth. This tells the machine

- Where the *surface* of the material is on the Z axis, relative to the bit
- Where the *table* is on the Z axis, relative to the bit.

Even though the machine knows how close the router motor is to the table, it has no idea what length bit you've put in until you've configured it. To set the Z depth, the bit is usually manually lowered in order to just barely touch the material or the table itself, and then the setting is locked in. If this is done incorrectly (or not at all), the machine may actually go around chewing up its own table — not a pretty sight!

You can cut a wide variety of materials with a three-axis CNC router; however, there are a few factors limiting the thickness of stuff it can cut:

- **Length of the bit.** The bit has to be as long as the material is thick in order to cut through it, and long bits are not as common and can break more easily. Long bits can "wobble" as well, causing uneven cutting. (This is when the bit actually bends a little due to the high speeds of the motor and the friction of cutting.)
- **Amount of vertical Z-axis travel that the machine is capable of.** This means how far up the machine can lift the bit; there must be enough room so that the bit can be lifted clear and moved around without cutting.

To run the three-axis CNC router, you usually use a spooling program on a stand-alone PC. After loading the shape files that you want and setting the parameters for each shape, you use the program to spool the file to the CNC machine's control box, typically over a serial port cable. Make a few final settings, press Start to begin the routing, and the CNC machine takes it from there. The chunks of waste from the drilling and cutting either pile up on the table or are sucked up by a vacuum attachment on the cutting head itself.

Laser engravers

These are CNC machines that cut material using a laser beam, like you see in all the Bond movies. The beam isn't powerful enough to shoot a hole through the moon, but it can cut thin plastics and wood with a very high degree of accuracy (Figure 5-3).

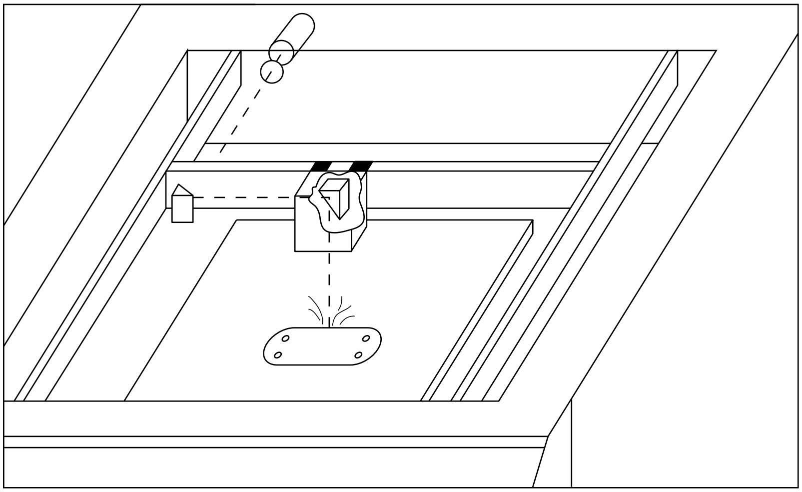


FIGURE 5-3: A laser engraver and the cutting beam.

Laser engravers range from tabletop models to versions the size of a pinball game. They are two-axis routers, with cutting motion along the X and Y axes. The Z axis, or depth of the cut, is determined by the power of the laser and how fast it moves (moving slowly gives it more time to burn through stuff).

Sometimes the table on a laser engraver can go up and down, which is like having a Z axis. However, the Z is set before the cutting begins in order to accommodate different thicknesses of material, making it similar in function to the Z-axis depth setting of a three-axis drill router.

The power of a laser engraver is measured in wattage. Lower-power engravers cannot always burn completely through material, and may only be able to engrave the surface. If you want a place to do laser cutting for you, be sure to ask about this. "Can it slice through stuff?" A machine with a 60-watt laser beam is often required.

To run the laser engraver, you use a separate computer to open your shape files in a program such as Corel Draw. The laser engraver is treated as a printer, so when you're ready, you go into the Printer Settings dialog box to set the parameters to use for the cutting. When you print the file, the data is sent to the engraver over a standard printer or ethernet cable. The engraver gets the file and waits for a final push of the START button before running it. The waste by-product of the engraving is mostly smoke, which can be downright dangerous if you're cutting certain types of plastics. For this reason there's usually at least a lid on a laser engraver, and often a ventilation system as well.

How CNC Machines Are Used

The first thing you need in order to run a CNC machine is some sort of file, or job, to send to it. The bit or laser on a CNC machine moves along a path, which is based on shapes created by a vector-editing graphics program, such as Adobe Illustrator or Corel Draw. As mentioned earlier, the files to cut the CNC projects in this book are provided on the companion Web site, but if you want to modify them or make your own, you will need access to one of the aforementioned programs. These are available in most retail software outlets, or you can visit www.adobe.com or www.corel.com for more information.

Note

You do not need to purchase vector- or raster-editing software to complete the projects in this book — all the required files are available on the Web site. The software is provided for those interested in making their own designs.

Vector versus raster

CNC machines use *vector* graphics data instead of raster graphics. Vector graphics are composed of lines, curves, and other mathematical shapes that are stored in a file (Figure 5-4). Remember the old Asteroids arcade game, and how the picture was all made of lines? That was vector graphics. Similarly, the CNC machine has to trace along continuous lines — not to draw the shapes on a screen, but to cut them out of material. This is why vector-based files are used to run a CNC machine, because there are "paths" for it to follow.

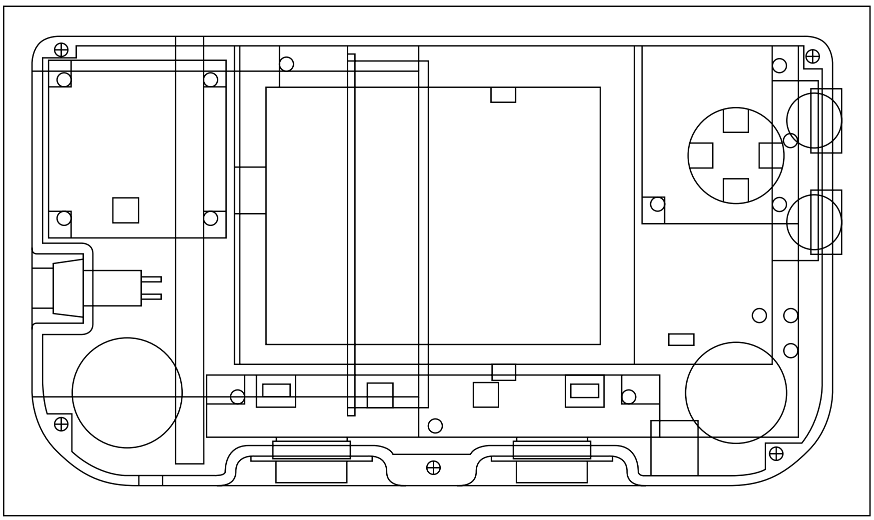


FIGURE 5-4: Vector-based graphics.

In contrast, *raster* graphics are created by scanning over the entire picture area (see Figure 5-5). A good example of this is a standard television set. Unlike the electron beam in the Asteroids game display, which traced out the individual picture elements directly, a TV beam starts at the top and scans from left to right, drawing one stripe of the picture. It then goes back to the left and down, draws another stripe, and repeats the procedure over the entire screen. This type of imaging is best for re-creating TV-like, pixel-based photographs and images, rather than simple, free-flowing line shapes, so raster graphics are typically *not* used with CNC machines.

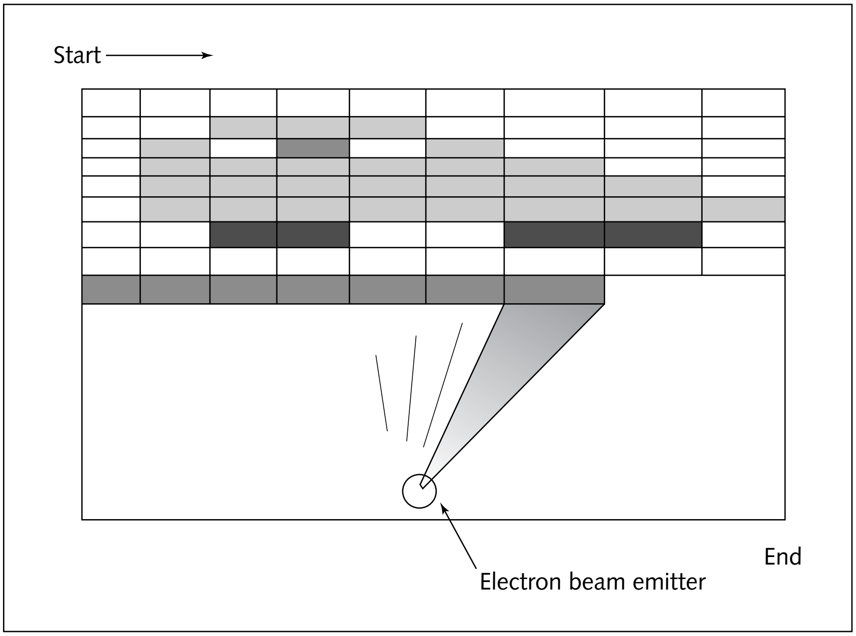


FIGURE 5-5: Raster-based graphics.

CNC machine settings

All CNC machines have settings that determine how the machine operates. You can't just set them to "automatic — go for it!" because the machine has no clue what sort of material you've put in to cut. (Sorry, it has no camera eyeballs or A.I. unit.)

Earlier we talked about settings that are entered on the CNC machine itself, such as the Z-axis depth and table height. Other settings are entered on the separate computer that sends the files to the router.

Router settings

The following parameters are set for every shape that a router cuts (the terms will vary from machine to machine). There can be many different shapes/parts on the table and different settings can be applied to each. This way, once you've got everything set up, the machine can do its thing without you having to add input for each section of the job.

- **Total depth.** This is how deep the bit will go into the material. To cut a part out or drill a hole completely through, you set the total depth to be the material's thickness.
- **Depth-per-pass.** The bit may strain and break when cutting and moving on the X and Y axes through thick material. This setting tells the machine how much to shave off at a time to protect the bit. For example, if you're cutting through 1"-thick wood, you might set the depth-per-pass to 0.25". The machine would then cut the path four times, to arrive at the total depth of 1". As a general rule, the depth-per-pass is the diameter of the bit you're using, but this can vary by material. For thin material, the depth-per-pass is usually the same as the total depth, so that just one pass is made.
- **Speed.** This is how fast the machine moves while cutting in the XY plane, typically entered in feet per minute. If the speed is set too high, the bit will break, and if it is set too low, the spinning of the bit can actually start to melt the material, which makes poor cuts (and smells bad).
- **Z-axis speed, or plunge.** This is how fast the bit is pressed down into the material along the Z axis, again expressed in feet per minute. Most of the time this parameter isn't a big deal and can be set fairly fast, but if you're drilling straight holes into a hard material, you may want to slow it down.

Laser engraver settings

Although the table of a laser engraver can move up and down, the depth of the cut is mostly determined by the power of the beam and how fast it moves. Typically a vector shape in the graphics program will be set to have a *stroke,* which is represented by a thin line of color along the edge of the shape. Let's say you make the stroke black You then enter, using the Printer dialog box, settings that are to apply to every black stroke, such as

- **Speed.** This is how fast the cutting head moves in the XY plane, typically expressed as a percentage of the top speed possible. Slow speeds allow the beam to cut deeper; however, if the beam moves too slow, it can ignite the material. Flames will actually appear where it's cutting, which looks cool, but is a little unsettling and can damage the edges and surface of the material.
- **Power.** Refers to the strength of the laser beam expressed as a percentage of the highest power the machine is capable of.

Note

The places that have CNC machines often have "cheat sheets" that tell you what settings are best for each type of material.

Engraving versus vector cutting

When the router bit is centered directly over a line (or *path*) of the shape and travels along it, cutting the material, we call this an *engrave cut*, as depicted in Figure 5-6. Note how some material on either side of the path gets chewed away because of the diameter of the bit.

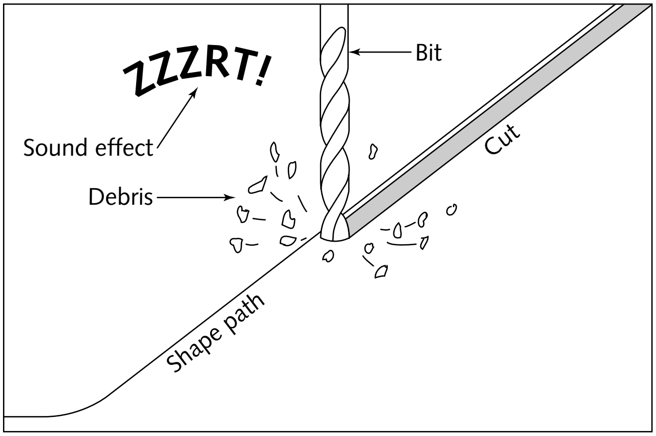


FIGURE 5-6: A bit making an engrave cut.

When you cut along a path like this with a laser engraver, it's called a *vector cut*. You can "scratch" the surface a little to show the underlying color, or cut all the way though the material to cut out the shape. Since the laser beam is very thin, it doesn't remove a noticeable amount of excess material on the sides of the path.

Male cuts

A *male cut* is used when you want the router to cut around a shape. If you simply engrave along the outside line of a shape the bit will "eat" away at the edge and reduce its total size (see Figure 5-7). This causes the dimensions of parts to deviate, which is bad for work such as ours, where accuracy is quite important.

Therefore to cut around a shape, a male cut takes into consideration the diameter of the bit. The machine creates an invisible path for the bit to follow around the existing path. This new path takes into account the width of the bit—if it's a 1/4" bit then the new path is 1/8" outside of the original path (Figure 5-7).

As a general rule, making a male cut to completely remove a part from the material is the last thing you'll want to do. Even though the vacuum table is supposed to hold things down, it doesn't always, and when the last bit of material is cut, the material will often jump or move a little, destroying any chance for further accuracy.

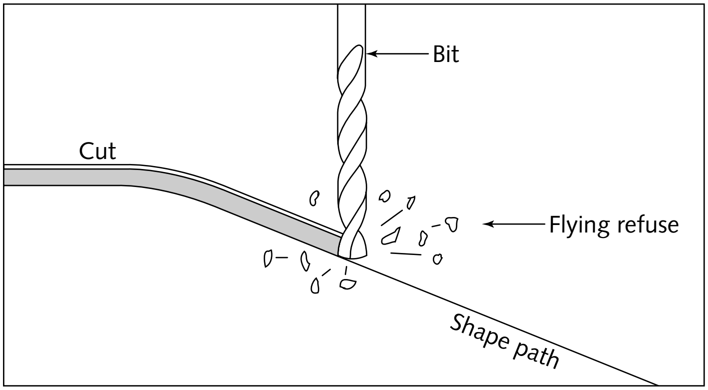


Figure 5-7: A bit making a male cut.

Female cuts

A *female cut* is the same as a male cut, except that the bit goes along the inside of a shape (Figure 5-8). The settings and considerations are the same as for the male cut.

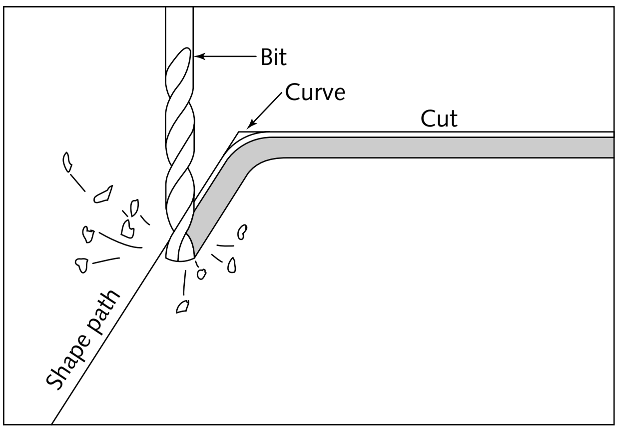


Figure 5-8: A bit making a female cut.

When using a router, a sharp 90-degree inside female cut is not possible, as the bit is rounded (as seen in Figure 5-8). This is not usually a problem unless you're expecting to fit parts inside each other. In our projects, the roundness of the bit has already been taken into consideration in order to avoid problems.

Note

Male and female cuts are not used with laser engravers since the width of the beam is too thin to eat up a noticeable amount of material around the path.

Drilling

Drilling allows you to use a router to make a regular hole the size of your bit down through the material (Figure 5-9). You usually need to have a circle shape in your drawing that is the size of the bit or the hole that you want to make.

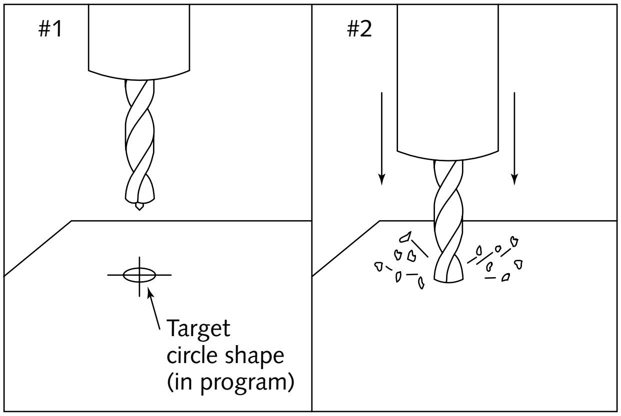


FIGURE 5-9: Drilling a hole.

If you need to make a screw hole using a laser engraver, you can simply draw a circle the size you need, and have the machine engrave it all the way through the material.

Cleanouts

Cleanouts are used by routers to hollow out thick material without cutting all the way through. It's much like making an old-time canoe: you'd hollow out the tree but leave one side intact to be the bottom. A CNC machine performing a cleanout is shown in Figure 5-10. The bit has to be long enough to reach down the sides of the cleanout without hitting the edges. For this reason, cleanouts are usually performed with a 1/4" bit, as the shank is the same thickness as the bit.

Cleanouts can allow you to make multidimensional shapes, but as you can see by the paths indicated in Figure 5-10, it can take a lot of time to do so when many passes are required.

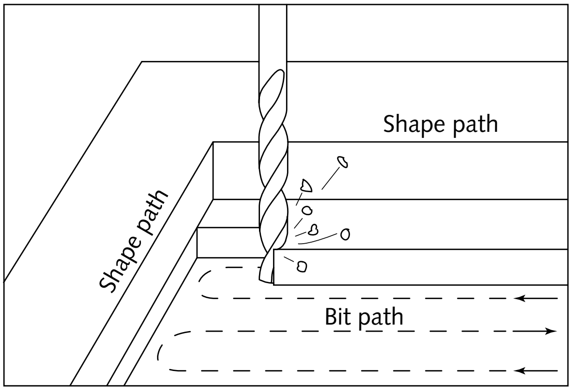


FIGURE 5-10: A bit doing a cleanout.

Choosing tool sizes for routers

Now that you've gotten the rundown on how CNC machines cut material, it's time to talk about the routing drill bits themselves, also referred to as *tools*. There are lots of kinds available, but the following will be of the most use for our projects:

- **1/4" standard bit.** This tool is mostly useful for doing fast male cuts around objects, and cleanouts inside them. It can be used for larger female-cut openings, such as cartridge slots and large holes for things like paddle controllers.
- **1/8" standard bit.** This is good for making small shapes with female cuts, such as open spots in the front of a game unit for gamepads and triggers. Most standard screws (like a size 6) are 1/8", so this bit is perfect for making screw holes in the case.
  - If you want to drill a 1/8" hole all the way through 1"-thick material, you may want to just drill 1/2" through it to get a guide hole and drill the rest later by hand. This is mostly because 1/8" router bits that are 1" long aren't as common as 1/2"-long bits.
- **1/16" standard bit.** It's easy to break these bits because they're so small, but they do have some uses. Like sugar, use sparingly.
  - If you're using small (size 4) screws, you'll need to use a 1/16" bit to make a hole small enough to work with them. A size 4 screw is actually 1/10" of an inch, so you'd have to make a female cut inside the circle using the 1/16" bit.
  - You can also use this bit to drill small holes in a grid, such as speaker openings or slits. This is really time-consuming, but looks cool.

- **V-bit (various sizes).** Shown earlier in Figure 5-2. It's got a standard shank, but then a V-shaped flat portion on the business end. The larger V-bits usually make a 45-degree cut; there are also smaller versions that are more pointed (also called engraving bits).
  - You can make a bevel around the edge of plastic by using a V-bit to engrave the outer shape before you use a male cut to remove it. This takes extra time and extra tool changes, but it does make for a nice effect (and is smoother on your hands when playing the portable).
  - A V-bit can also be used to replace small bits when cutting thin plastic. Have the V-bit make a small drill hole about 0.04" deep in places where you want the small hole to go. You can then use this indentation as a guide to drill the hole manually (you know, by hand) with the correct sized bit.

Materials You Can Rout

Laser engravers and routers can cut a variety of materials, but there are some basic limits:

- Lasers cannot cut materials that would reflect back the beam (such as metals), materials that create dangerous gases when burned (such as PVC plastics), or very thick materials. Some moderately thick materials (1/2" and up) can be cut, but it may require multiple passes, which causes the edges not to be as nice as they are in single-pass jobs.
- Routers can cut just about anything you can put on the table, with the limitations arising from the bit itself. The bit has to be long enough to cut through thick material, and it will break if you try to cut through hard material too quickly. In addition, the longer the bit is, the more likely it is to break.

Here are some materials that can be routed or laser-cut, starting with the easiest stuff:

- **Foam.** Foam usually comes in sheets at between 1/4" and 2" thick. Brands include Sign Foam and Gatorfoam. Foam is very dense (think of it as "Super-Styrofoam"), yet still softer than most other materials, allowing for very fast routing. Like PVC, it can be used for the sides and body of your portable, though it can get chipped and scratched much more easily. You could, however, paint it with enamel for protection. This material can be found at sign shops and can be a good choice if you want to minimize router time.
- **PVC plastics (routers only).** PVC comes in sheets of varying thickness, typically from 1/8" to 3/4", and in a variety of colors. Brand names of this material include Sintra and Komatex. It can be used to make the main body of a portable.

  You can find this material at most sign shops and some trophy/awards retailers.
- **Engraving stocks.** A type of plastic that comes in thin sheets, usually 1/16" thick. There's one color on the surface and a different one underneath. A machine engraves through the surface, revealing the second color in order to create letters or shapes. This type of plastic is great for making the front and back of a portable, as you have a wide variety of nice-looking textures to choose from, such as wood, marble, or glossy colors.

  The best place to find this stuff is at a trophy shop. Rowmark is a popular brand, although you can simply ask for "engraving plastic."

The following materials must be cut slower on the machine because they're denser. This doesn't mean they're bad materials to use, just that more care needs to be taken when cutting them in order to avoid damaging them or the bits.

- **Wood.** As a replacement for engraving plastic, you could use 1"-thick pieces of wood for the main body or thin laminate for the front of your game unit. Wood looks really nice, and of course you can stain it.

  Retail lumberyards are your best bet to find wood, though framing shops may have some on hand as well. For example, an oak stair step is 3/4" thick and big enough to make both the front and rear sides of a game case. Try to find the flattest wood possible, so that it'll work well in a CNC machine — warps in it will affect the Z axis and the quality of the cuts. Lay the chunk of wood in question on a table and look at it from the side. If it rocks back and forth, find a different piece.

Note

You may never find a perfect piece of wood — they'll all probably have some amount of bow to them. To compensate for this when using a router, place the outward curve down on the table with the bows up. Then, if possible, you can clamp down the bows, making the wood straight again (at least while it's being routed).

- **Acrylics.** A type of plastic used as a replacement for glass. It's brittle, meaning it can crack and break, even when just drilling holes in it. This also can cause the routed edges to be rough. It's cheaper and comes in a larger variety of thicknesses than polycarbonate.

  An advantage to acrylic is that you can laser-cut it fairly quickly, and unlike the results from the router, the edges of the parts you cut will be nice, glossy and smooth because they've been "fire-polished" by the heat of the beam. You can use clear acrylic for a see-through portable, or colored acrylic for a nice, glossy effect.

- **Polycarbonates (routers only).** Known by the brand name Plexiglas, or in slang, just "Poly". Like acrylics but harder to break — you can literally bend this stuff in half if you heat it up first. (Real-world movie example: In *Aliens,* when Sigourney Weaver got trapped and tried in vain to smash out the window, it was probably made of polycarbonate.) It's more expensive than acrylic, but is tougher and easier to work with. Although flexible, it can still be used as an engraving plastic alternative. If you're very confident of how your wiring jobs look, you could even make a portable that is see-through!

  Acrylics and polycarbonates can be found in places that sell home supplies and glass (such as lumberyards and do-it-yourself centers), or in art framing and trophy shops. You can also get "non-glare" versions of each that have a nice matte effect — they're not shiny and reflective.

- **Aluminum (routers only).** This is one of the easiest metals to rout, although the machine must spray a mixture of air and oil on the bit to keep it from overheating. The speed also has to be much slower than when cutting plastics.

  Thin, brushed aluminum can be used as a replacement for engraving plastic, although there are plastics available that simulate that texture nicely as well. You probably won't need to make the entire case out of aluminum unless you want a portable that can deflect small arms fire or survive attacks from your 5-year-old nephew.

Finding CNC Machines to Use

Unfortunately, CNC machines are not available at every corner drugstore. Laser engravers are the most common type of CNC machine in commercial use, so you may have better luck looking for them first. It may require a bit of legwork to find one, but here are a few good places to start your search:

- **Pattern shops.** Despite the sound of it, these places do not make designs for plaid shirts and oven mitts. Instead they make molds for use in casting plastic and metal parts. These molds don't grow on trees — they are created by CNC machinery!
- **Sign shops.** In the days of old, signs were all built by hand by welders and fabricators. Now many of them use a CNC machine to cut parts of aluminum frames that are then welded together to form a box. They also cut plastic letters out of PVC plastic for backlit signs and smaller sign jobs.
- **Trophy shops.** Look for ones that do laser engraving, usually the larger trophy shops.
- **Any place that advertises "laser engraving."** Be sure to ask about the power of the machine and if it can cut completely through materials.

How you can get the best rates for routing/laser work

The typical rate for renting a CNC router to cut parts ranges from $70–$90 an hour. Laser engraving costs also vary, but expect at least $1–$1.50 a minute. The amount of routing time required for each of the CNC projects in Part 2 will vary, but you may as well figure 30 minutes to an hour for everything. Setup and operator time may be either added on as extra charges or included in the hourly rate.

After buying a pocket TV and a game system, you may be looking to minimize costs, and since money doesn't grow on trees (unless you own an apple orchard), here are some suggestions:

- **Find a router owner/operator who loves video games.** Remember, there are a lot of secret Atari fans out there. (Nintendo too, but Atari has more of a cult status, much like *Star Trek.*) Find a guy in his late 20s to early 30s who does this sort of work, and you have an excellent chance of shared Atari fondness, which can work in your favor.

  When you try to explain this project to a machine operator, they may look at you like you've just arrived from Saturn, so take this book along to show them examples.
- **Know exactly what you want done.** For each CNC project in this book, the parts to be cut will all be listed, along with what type and thickness of material to use. Double-check everything and put only the required files on a disk so that they won't have to sort through looking for them. Most places that do this sort of work will use IBM-compatible computers, so Mac users should burn a CD that will work with those.
- **Have files already prepared.** Which you do, thanks to this book! This book provides multiple file types for each project, so check ahead with the place and see which kind they prefer. With these files prepared, most of the computer work is already done. The parts will be laid out in the file to use a minimum of material, but the machine operator may move stuff around anyway.

- **Use easy-to-rout materials.** Materials that rout well are faster to use and are at less risk for mistakes. If you choose foam instead of PVC, there will be less router time, although your portable will not be as tough.
- **Use a laser engraver rather than a router if possible.** There are a couple of reasons for this. The laser engraver is a cleaner machine, since it doesn't chuck bits of material everywhere and will likely require less setup time. Laser engravers are also easier to find and are more accessible to the public.

Chapter in Review

Now that you've read through this chapter, you should have at least a basic understanding of what a CNC machine is and what it can do. Here are some important points to keep in mind:

- Routers use drill bits and can cut through many types of thick material.
- Laser engravers use, well, lasers, and need to have around 60 watts of power to cut through thick material. They are more limited in material selection than routers, but do a fantastic job of cutting stuff.
- CNC machines primarily use vector graphics files to represent shapes to be cut out of material. The old Asteroids and Tempest video games used vector graphics.
- The thinner/wimpier a material is, the faster you can cut through it with the machine. The opposite is true for tough stuff.

Making Portable Game Consoles

part

II

in this part

chapter 6

Making Your Nintendo Entertainment System Portable

in this chapter

- ☑ Ripping Apart the NES
- ☑ Identifying the Internal Parts and What They Do
- ☑ Removing Stuff You Don't Need
- ☑ Fixing Questionable Cartridge Connectors
- ☑ Powering the System with Batteries
- ☑ Boosting the Video Signal
- ☑ Working with Controllers
- ☑ Chapter in Review

Inside the classic NES system we all know and love is a mere 7.6 (4.6-inch motherboard. And every small motherboard in an old game system has a common destiny — to become portable!

In this chapter, we'll take the NES apart and remove the stuff we don't need. This will prepare it for the projects in the next two chapters. We'll also talk about how to rewire the power, controllers, and audio/video. This will allow you to build a custom unit of your own design if you choose not to build the portables as described in the next two chapters. They're super-cool, of course, but some people may want to branch out and challenge themselves by having a go at it from scratch, and I applaud them!

Go bug your parents, raid the garage, hit the rummage sales... Get yourself a NES and let's get going!

Ripping Apart the NES

Let's start by ripping apart the NES and getting that motherboard out. A standard-size Phillips screwdriver is the only tool you'll need for this procedure.

1. You'll find six screw wells on the bottom of the NES. Unscrew them, and then flip the unit back over so that they fall out. You may have to whack the unit to knock them loose.

Tip Use your tweezers to remove screws your fingers can't reach.

2. Lift the top plastic case off the NES. You'll see a metal RF shield secured by eleven brass screws around the edges. Remove them, and pull off the shield.

3. You'll now see the black cartridge slot. Remove the four screws at the back holding it down.

Caution

You'll have quite a few screws rolling around and falling on the floor by this point, so I'd suggest not walking around barefoot (you've been warned!).

4. Lift off the cartridge slot assembly — you'll have to pull it forward a bit, as some of it is under the motherboard. The unit will now look as shown in Figure 6-1.

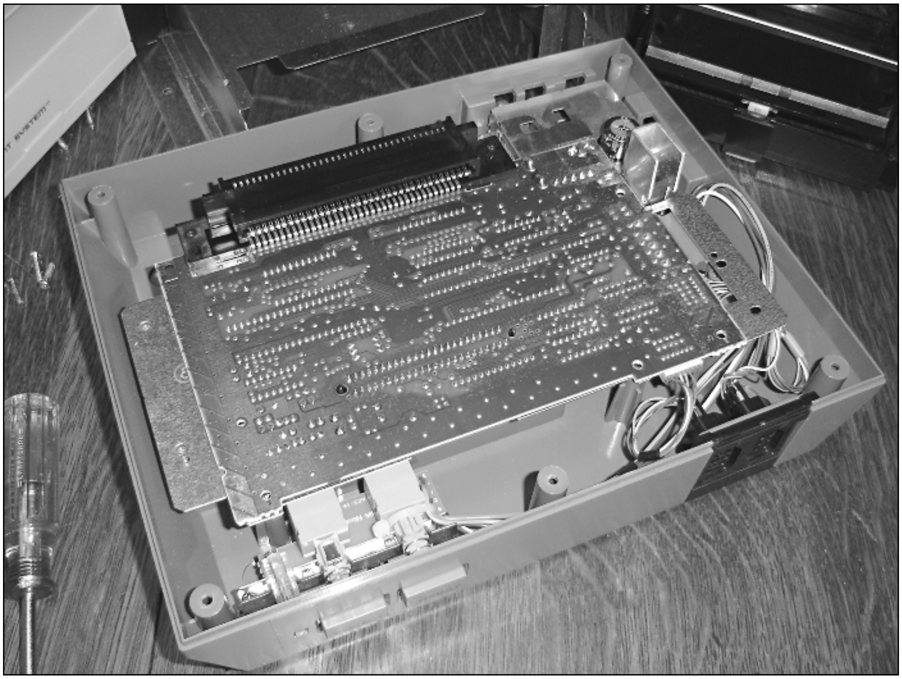


FIGURE 6-1: The NES, with its motherboard exposed to corrosion and RF signals!

5. Flip the motherboard over toward the front. You'll see the three cables attached to the upper-right — these are for the controller ports and the on/off reset switch. These cables are attached fairly tight, so brace your index finger and thumb against the NES, and pull the cables with your middle finger. You can then remove the lower bit of RF shielding.

The NES motherboard is now free from its plastic and RF shield–encrusted existence. We're now free to hack stuff off and hook other things on, but first let's review the board itself so we know what we're working with.

Identifying the Internal Parts and What They Do

In the next couple of chapters we'll be referring to the internal parts of the NES quite a bit, so let's take a moment to identify them. (Granted, these may not be the *official* Nintendo-certified names, but they'll do the job.) Figure 6-2 shows the parts side of the board along with numeric labels that match the list below.

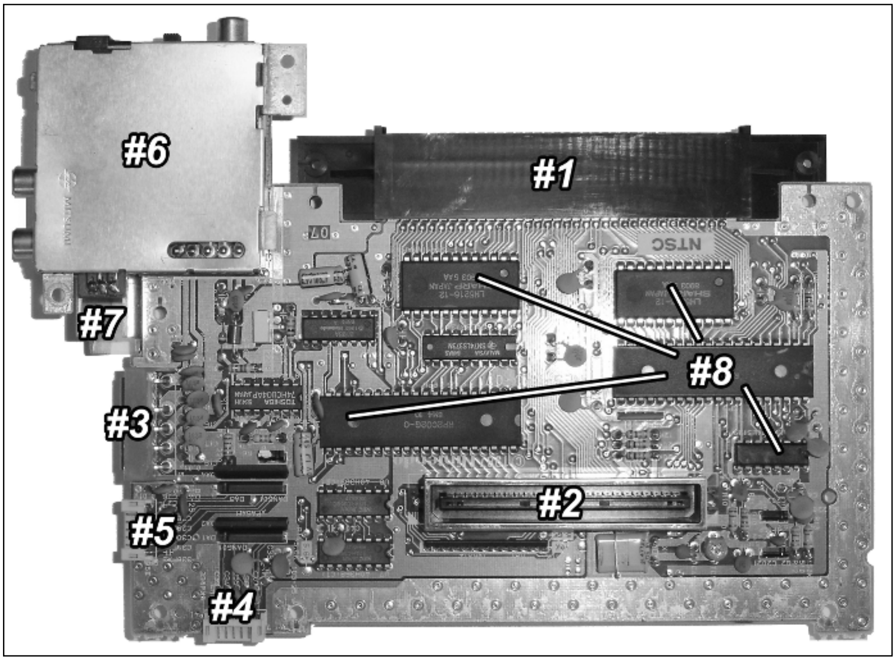


FIGURE 6-2: The NES, with parts labeled.

1. A 72-pin cartridge slot connector: This is where the game cartridge gets connected, although not all of the pins need to be hooked up.
2. Useless expansion port: It's anyone's guess what amazing add-ons were planned for the American NES. All we know is that now this port is taking up space and has to go! The pins in the center of the cartridge slot are considered unused because they go directly to this thing.
3. Power on/off and reset switch connector.
4. Player 1 controller connector.
5. Player 2 controller connector.

6. RF modulator, audio/video out, and power regulator box: We'll be removing this as well, but we'll have to re-create some of the stuff in it.
7. Power regulator and heat sink.
8. The 6502 central processing unit, picture processor, and other electronic gizmos — these run the NES.

Removing Stuff You Don't Need

Now that you know what these things are called, we can remove the ones we don't need. (Naming parts is great, since it keeps me from saying things like "remove the bluish thing to the left of the green circle-object" and confusing the heck out of you.)

1. The RF box has got to go. Start by desoldering the five main connections between it and the main motherboard.
2. There are still four metal tabs holding the RF box in place. This is a perfect time to use a large soldering gun, as mentioned in Chapter 2. Heat them up one at a time with the gun as you pry off the box.
3. If you have only a 40-watt desoldering iron to use, melt the lumps of solder around the tabs a bit at a time, sucking up what you can. Once most of the solder is removed around a lump, try prying off the box while keeping heat on the tab.

Caution

Ever thrown capacitors in a campfire? Well, I know I have, and let me tell you — those suckers explode! (Uh, kids, don't try this at camp… or anywhere, for that matter.) See that big one in the RF box? Try to keep excess heat away from it as you desolder, or better yet, remove it beforehand just to be on the safe side.

4. Next up for extraction is the useless expansion port. Flip the main board over, and you'll see two rows of leads (Figure 6-3). Desolder all of them and pry off the port. (Take care when prying that you don't smash small components on the board with your screwdriver.)

Note

The leads are a little smaller than the hole on a desoldering iron, so hold the edge of the hole against the lead to melt it properly. You need to heat up the lead, not the board.

5. Desolder the five thick leads holding the blue power on/off reset switch connector. Use a screwdriver to pry and lift the connector off.
6. Flip the board over to the parts side. See all those orange things that look like little frogs all over the board? Those are capacitors, and you can carefully bend them over to make everything thinner (Figure 6-4). Tilt them over with your fingers — try to keep their leads from touching any other metal, however. Looking at the board from the side, nothing should be much higher than the white controller connectors.

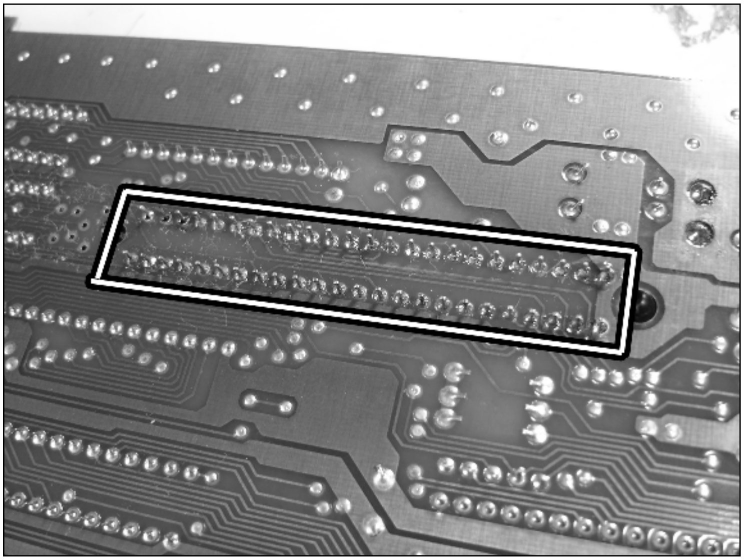


FIGURE 6-3: The leads holding the useless expansion port in place.

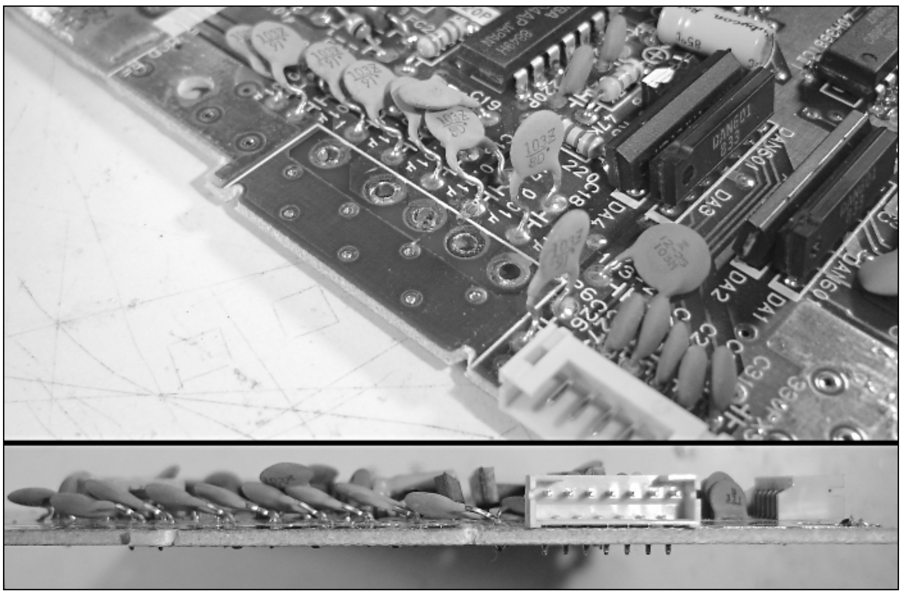


FIGURE 6-4: Bent and unbent capacitors. Also a view from the side!

Note

Some NES units have blue cylinder-shaped electrolytic capacitors on the parts side of the board. You'll have to desolder these, tilt them sideways, and then re-solder them in order to make the board flatter. They are polarized, meaning you should make sure the + and – leads end up connected to the spots where they were originally attached. (The negative lead is the one with the big black stripe near it.)

The motherboard itself is now ready to be made into a portable. However, we must also fix the worst-kept NES secret of the ages: how crummy the cartridge slot is!

Fixing Questionable Cartridge Connectors

If you're like most people, you've probably blown a lot of time trying to get your NES cartridges to work. And I do mean "blown"—you're a NES fan if you know exactly what I mean. Were we blowing dust out, blowing spit in, or casting out evil spirits? The world may never know how the practice got started, but it seemed to work and became part of the videogaming culture.

Fast-forward to present day: When your lawnmower doesn't work, you don't *blow* into it! If your cellular signal dies, no amount of hot air will help. So why should we put up with this ancient practice with the NES? How can it be fixed?

It's actually the cartridge connector inside the NES that's usually to blame. As part of their plan to make the NES look like a VCR, Nintendo came up with a "zero insertion force" cartridge slot. One might expect there to be some kind of connector that tilts when you click down the cartridge, but as you've discovered by opening up the unit, it's just a bunch of pins that bend. Over time, these pins can get pressed down and coated.

Back when I worked at a used-game store (ah, those were the days...), I got a lot of free "broken" NES units, and the majority of them could be fixed with a simple safety pin, as shown in Figure 6-5.

Simply stick a pin under each pin and pry it up a ways. Do this for the entire bottom row—you can bend the upper pins down if you want, but it's not required. Now try inserting a cartridge. It should fit very tightly and be quite firm.

You may notice that the pins are a little dirty. Back in the day, they sold cleaning kits to take care of this, but those things are probably all dried up and sold in antique stores by now. All you need to do is find something that's 1/16" thick (like a scrap of engraving plastic or the edge of a circuit board) that you can cover with a thin, tough cloth (like a baby wipe or a shirt you don't like), soak it with some rubbing alcohol and cram it between the connectors. Rub back and forth, and you'll pick up a lot of dirt and grime.

Note

If you're planning on making the CNC-built NES, don't bother fixing up the old cartridge connector because it's going to be hacked to bits (but it will still be used in some form).

You can now slide the cartridge connector back onto the NES and expect it to work much better. We're now ready to make this thing portable!

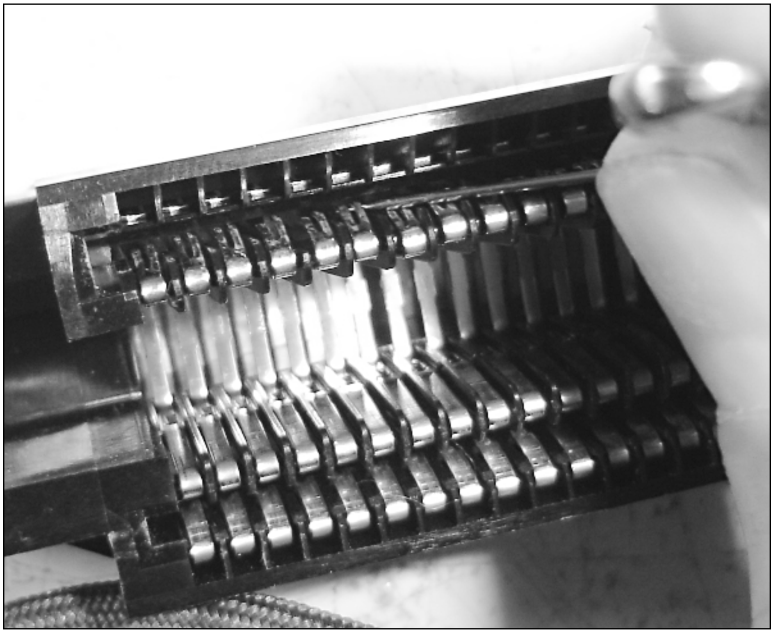


FIGURE 6-5: Using a safety pin to pull up pins.

Powering the System with Batteries

In order to be portable, a game system must have a portable power supply. In other words, it needs to run off batteries. Before we discuss how to connect batteries to the NES, let's review its power requirements.

The wall power adapter brings 9 volts into the NES, but the system only requires 5 volts. The input voltage is dropped down to 5 volts by a regulator, as mentioned in Chapter 3.

With nothing attached, the NES consumes about 350 mA of power per hour. If you figure an average of about 250 mA consumed by a white LED–modified TV, plus another 75–100 mA that will be consumed by wiring and controllers, it adds up to a grand total of around 700 mA for a portable.

Batteries you can use

Not every battery can be used to power something like the NES motherboard. There are three important things to consider:

- **The voltage that the regulator requires.** A 7805 regulator spits out 5 volts, but needs at least 7 volts as input to start running. Therefore your battery pack needs to have a starting voltage well above 7 volts.

- **How long you want the unit to run.** Considering that a portable NES consumes 700 mA, you'd need a 1500 mAH battery to get at least 2 hours of playing time, and so forth. (See my babbling in Chapter 3.)
- **The screen you'll be using.** A modified Casio pocket TV uses around 300 mA, while the amperage of something larger, like the PSOne screen, is closer to 400mA. This adds to the total power requirement, something to keep in mind if you're building a portable of your own design.

Because of these factors, I'd suggest the 7.2 Ni-MH rechargeable battery from Radio Shack (catalog #23-431). If you need more than 7.2 volts to run a higher-power screen (such as the PSOne screen), you can try the 9.6 volt Ni-MH battery from Radio Shack (catalog #23-333). Keep in mind that these batteries actually have a higher voltage than described on the label, so check them out with a multimeter after fully charging them.

You can use other batteries as well; just be sure that the starting voltage (when fully charged) is at least 3–4 volts higher than what you actually need because of the dropout limit of linear regulators (again, see Chapter 3). As a general rule, a battery to be used with a 5-volt regulator such as the 7805 should be at least 7.5 volts, and preferably closer to 9 volts. With the 7805, once the battery dips below 7 volts, the regulator will stop working (it "drops out").

Which power regulator to use

If you connect a 7- or 9-volt battery directly into the NES motherboard, it can get fried. Since this is not desirable, you'll want to reduce the higher voltages down to the proper levels before sending them into your NES. This is done using a *regulator*.

The RF box that we removed from the NES has a 7805 linear regulator in it. Since it's gone, we're going to have to replace it. You can desolder the old one from the RF box and use it for your portable if you're trying to save yourself $1.49, or you can just get a new one at Radio Shack (catalog #276-1770).

Tip

If you get a low-dropout or switching regulator, make sure it outputs 5 volts and delivers 500 mA of power. These are the requirements to run the NES motherboard.

Power and audio/video connections

The connections for power, audio, and video are found in the area where the RF box was, as shown in Figure 6-6. This is also a great place to physically attach the 7805 regulator, as described next.

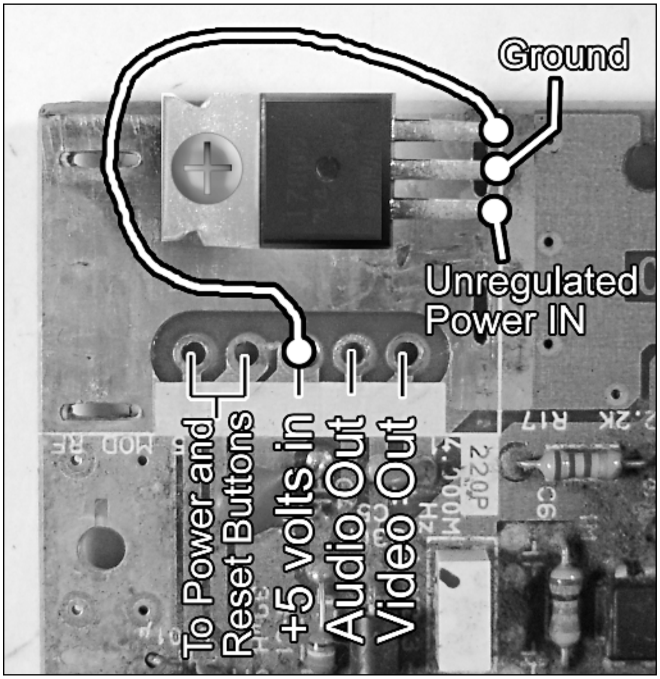


FIGURE 6-6: The audio/video power connection spot on the NES.

1. Place the 7805 regulator over the screw hole just above the five connections, with the leads going to the right. The flat metal portion of the regulator should be touching the metal on the NES.
2. Attach the 7805 regulator to the NES board using a size 6 screw and nut through the hole.
3. Solder the middle ground lead of the regulator directly to the metal on the NES board. The ground/negative connection from the battery should also connect to this metal on the NES.
4. Connect the upper lead of the regulator to the +5 volts in spot.
5. Connect the positive from your battery to a switch for turning the system on and off, then connect the other terminal of this switch to the Unregulated Power In lead of the regulator.
6. You don't need to replace the reset and power buttons, so leave those connections empty. The audio signal can go directly to the audio input of the TV. However, the video signal must be amplified, as described in the following section.

Note The NES projects in the next two chapters provide their own instructions for installing the 7805 regulator and connecting audio/video.

Boosting the Video Signal

The video coming off the video spot in the previous figure is too weak to be used with a pocket TV; therefore, we must boost it. There was a booster in the RF box, but of course it's gone now, leaving us to build one from scratch. If you're planning to make one of the portables in the next two chapters, you can skip this section, as the method of construction of this circuit is included there.

Following are the parts you'll need to create a NES video amplifier (Table 6-1) and the "how-to" instructions.

Table 6-1 Parts List for NES Video Amplifier

Part	*Quantity*	*Vendor*	*Part #*
2N4401 transistor	1	Radio Shack	276-2058
220-ohm resistor	2	Radio Shack	271-1111
33-ohm resistor	1	Radio Shack	271-1104

1. Create this circuit on a bit of circuit board, or just wire up the circuit and tape it down someplace on the NES board. Either way, connect the parts as shown in Figure 6-7.
2. Get the +5 volts and ground from the spots on the NES shown in the previous section.

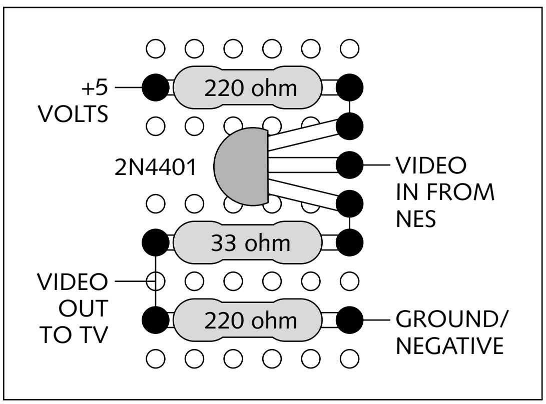


FIGURE 6-7: How to wire the video amplifier for the NES.

3. The flat portion of the transistor should face the direction shown. If you get a grab-bag of transistors instead of a single 2N4401, make sure they are "NPN" type. Even so, you may have to try a few different ones to get this circuit to work. You may also omit or change the value of the 220-ohm resistor connected to the +5 volts if the circuit needs less or more power when hooked to the pocket TV you choose. Sometimes the whites will be too bright or pixels may look "thick," requiring these adjustments.

Working with Controllers

When I was but a lad, I always wondered how there could be eight buttons on the NES controller but only seven wires on the plug. Wouldn't there have to be one wire per button, plus a ground? Wouldn't that be nine wires?

Imagine my confusion when I first saw a Nintendo 64 controller with only three wires on each plug, yet with far more buttons, and an analog stick! (Granted, I was 10 years older by then, but still befuddled).

Well, I'm not confused anymore! (At least not about that.) The NES uses a *latched* controller, seen ripped apart in Figure 6-8. There's a small IC, or microchip, in each controller that grabs the state — on or off — of all eight buttons. The NES then sends a signal down one wire to the controller saying, "What are the buttons doing?" and the IC in the controller sends back the info one bit at a time down a different wire. In fact, you don't even need seven wires — five are enough! The other two wires on a NES controller port are used for things like the light gun and the Arkanoid controller.

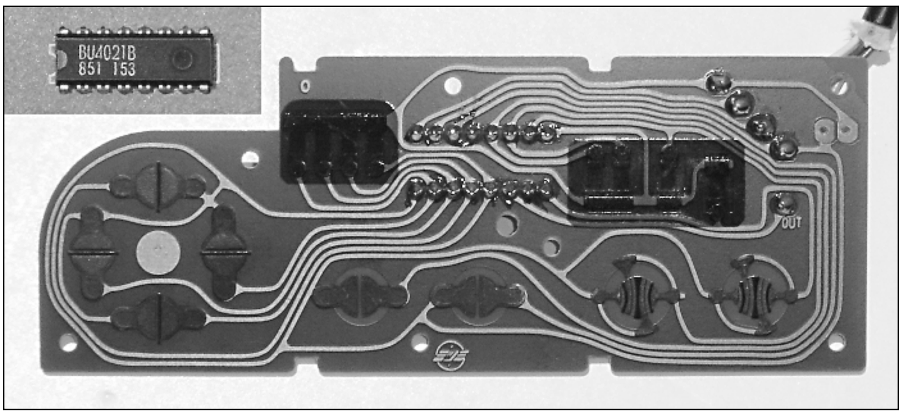


FIGURE 6-8: The inside of a standard NES controller.

Note

"IC" is not just instant-messaging slang; here, it stands for "integrated circuit." This is the more professional way to describe what laymen usually call a "microchip" (although I personally like "microchip" better, since it brings back fond memories of the '80s and cheesy robots...).

The pinouts of the IC itself are seen in Figure 6-9.

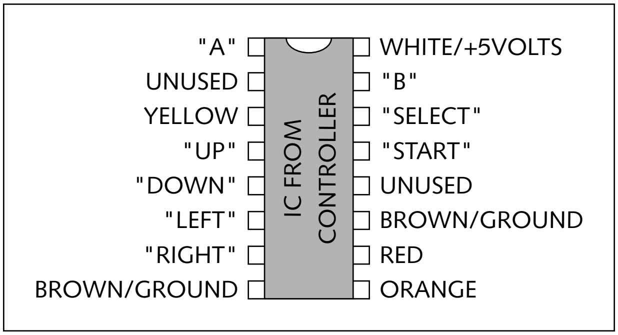


FIGURE 6-9: The pinouts of the IC inside the NES controller. Notice the groove on one end of the IC — this tells you which way to install it.

In the drawing, the wires coming off the IC are labeled by color — white, orange, red, brown, and yellow. These are the same colors as the wires attached to the NES controller circuit board. Not only that, but the plugs inside the NES that go into the motherboard use those same colors as well. This allows you to use the same color code wherever you may wish to hook up this circuit.

However, it's not enough to just hook up the buttons and wires to the IC based on the drawing. Each button needs to start out "high," so to speak. If you look at the original controller circuit board, you'll notice some weird dark rectangular-shaped areas. Those are actually some sort of strange (cough cough — cheap!) resistor that is rated at 38K ohms; +5 volts goes into each of them, and then each one goes to a button, which then goes to the appropriate pin of the IC. When the button is pressed, the 5 volts going to that particular pin is grounded out — this is called "pulling it low." When the IC detects a pin going low, it considers that button or direction pressed. Your in-game character then runs, shoots, or jumps, depending on the button.

Note In some older game systems, such as the Atari 2600, the resistors that pull a button high are inside the game console itself, not the controller.

The original NES controller uses 38K-ohm resistors; however, the closest rating you can find among the resistors at your typical Radio Shack are 33K ohms (less resistance) and 47K ohms (more resistance). I have tested both of them, and the 47K ones work fine as replacements. (The 33K ones don't — not enough resistance.) Figure 6-10 shows an example of a partially rebuilt NES controller, with only the up/down/left/right connections shown, for simplicity.

You can use this drawing as a guide for hooking up the select/start and B/A buttons. Give them each a 47K ohm–resisted 5 volts, then connect that same line to the appropriate pin on the IC, as indicated in Figure 6-9. The other side of each button goes to ground/negative/the brown wire. In short, they each hook up the same way as the directional buttons in Figure 6-10, but to different pins on the IC. You can check the wiring of the portables in the next two chapters for other examples as well.

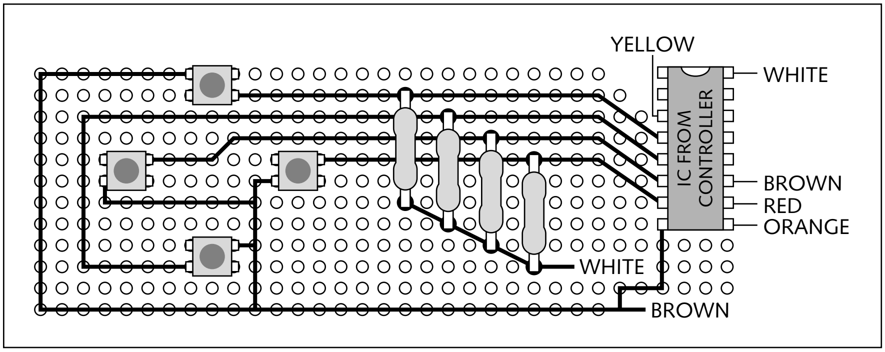


FIGURE 6-10: A rebuilt NES controller circuit. The gray things are all 47K ohm resistors. White is +5 volts, and brown is ground/negative.

The tact switch has four leads on it, and you need to use two of them for a switch. Either use two leads that are diagonal to each other or two leads both on the same side (the side-by-side pins).

As with the video amplifier, the controller rewiring will be included in each NES project. Use this for your own portables and reference (or if it ever comes up on *Jeopardy*).

Chapter in Review

Over the course of this chapter, we've taken apart the NES, removed excess things from the motherboard, given the cartridge connector new life, learned how to power it with batteries, and seen how to rebuild the controller. Where you go from here is entirely up to you ... that said, I'd suggest one of the following three options:

- Combined with the information in Chapter 4, you can now build a portable NES of your own design. Looking through the next few chapters will help guide you along with additional ideas and tips, even if you don't use those designs.
- If you don't have access to a CNC machine, such as a router or laser engraver, you can use your hacked-up NES motherboard to build a portable using common, off-the-hardware-store-shelf items as described in upcoming Chapter 7.
- Those of you who can find a CNC machine to use should jump ahead to Chapter 8. Using the information from that chapter (and the CNC machine), you can build a snazzy portable with a perfect computer-cut case.

Whichever road you choose, I wish you the best of luck with your portable Nintendo–building endeavors!

Building a Portable Nintendo By Hand

chapter 7

in this chapter

- ☑ Materials You'll Need
- ☑ Making the Front Half of the Case
- ☑ Making the Rear Half of the Case
- ☑ Wiring the Unit
- ☑ Troubleshooting
- ☑ Final Assembly and Detailing
- ☑ Chapter in Review

Here it is, a photo of the portable Nintendo Entertainment System you can build by hand! (See Figure 7-1 on the next page.)

The construction process isn't entirely by hand, and you *will* need access to a very common sort of CNC machine — a printer. (Hey, it's controlled numerically by a computer, isn't it?) As long as it can print out images at actual size (the size of the drawing or photo specified in the file), it will work for this project. Practically all modern printers should be adequate — it doesn't even need to be color!

In this chapter you'll print out templates and use them as guides to cut materials for building the front and rear halves of the portable Nintendo's case. After that, you'll install the screen and the NES parts, and then wire everything together. When you're done, you'll have a swell portable NES with a 5" screen that you can take everywhere. There's even a Player 2 port so you can take on your friends in games like Super Tecmo Bowl, or have them help you defeat the vile Red Falcon and save the universe in Contra. Sound cool? Great, let's get going!

FIGURE 7-1: A hand-built NES portable.

Materials You'll Need

Obviously you'll need an *original box-shaped Nintendo* and one *standard controller,* as seen in Chapter 1. Take apart the controller and desolder the IC. We'll be using it, the plastic buttons, and the rubber select/start button. For the display, we'll use the *Sony PSOne screen*. Perverse, I know, but in this configuration they make a pretty good team. Modify your PSOne screen with white LEDs, as shown in Chapter 4. With those two biggies out of the way, the rest of the parts are as follows.

Files

Not really a part in the physical sense, but essential nevertheless. All the files for this project are located on the companion Web site at www.wiley.com/go/extremetech, in a file called "NES by hand." Download the sixteen files from that folder so that you'll have them ready as you go through this chapter.

Electronic parts

Table 7-1 lists the electronic parts you'll need for this project. Most of them can be found at your local Radio Shack, and, for simplicity's sake, the catalog numbers are provided here. Some of the parts you'll need come in packages of more than one — the list tells you how many packages you'll need. (Example: You'll need eight 47K-ohm resistors, and there are five in a package — so two packages will be needed.)

The last two items on the list will need to be ordered from an online electronics retailer. I'd suggest Digi-Key (www.digikey.com), as they have an easy-to-use Web site and the prices are quite reasonable. There's a surcharge on orders less than $25, so you should get your white LEDs (for the TV mod) and everything else you need from them all at once.

Table 7-1 Electronic Parts List for Building a Portable NES by Hand

Part Name	*Available From:*	*Part or Catalog #*	*Quantity/ Packages Required*
Transistor 2N4401 (whole package)	Radio Shack	276-1716	1
220-ohm resistor	Radio Shack	271-1111	1
33-ohm resistor	Radio Shack	271-1104	1
47K-ohm resistor	Radio Shack	271-1130	2
3.9K-ohm resistor	Radio Shack	271-1123	1
680-ohm resistor	Radio Shack	271-1117	1
150-ohm resistor	Radio Shack	271-1109	1
Grid-style PC board	Radio Shack	276-150	1
General-purpose component PC board	Radio Shack	276-149A	1
Heat sink	Radio Shack	276-1368	1
Adjustable voltage regulator	Radio Shack	276-1778	1
7805 linear voltage regulator	Radio Shack	276-1770	1
Coaxial DC power jack (Size K)	Radio Shack	274-1565	1
Coaxial DC plug, 5 mm OD, 2.1 mm ID (Size K)	Radio Shack	274-1567a	1
Ni-MH 9.6-volt, 1600-mAH battery pack	Radio Shack	23-331	1
Ni-MH/Ni-Cd battery charger	Radio Shack	23-333	1
Phono jack	Radio Shack	274-246A	1
Tact switch, 4.5 mm H=3.8 mm	Digi-Key	CKN9018-ND	8
Speaker, 28 mm	Digi-Key	P10174-ND	1

Parts for the case

After you've acquired the electronic parts, it's time to get stuff to build the case itself. The first place to go is the hardware store. Try to find the largest store you can in order to ensure you'll be able to find all the parts, because some smaller stores don't stock certain things, such as nylon spacers.

Locate the section of the store with the steel and aluminum pieces of metal. What you're looking for is *aluminum strips* that are 1/16" thick. Here are the pieces you'll need:

- One 3/4" wide and at least 38" long
- One 1" wide and at least 27" long

The pieces I got were 4' long, so if you get those it should be O.K. Now head to the section of the store where the screws are — it should be near the aluminum section and have lots of bins of all different sizes. Pick up the items listed in Table 7-2, paying close attention to the outer diameter of the nylon spacers.

Table 7-2 Screws, Nuts, and Spacers You'll Need

Screw/Nut/Spacer Size	*Length*	*Outer Diameter*	*Quantity*
Size 4 nylon spacer	1/4"	1/4"	8
Size 4 nylon spacer	3/4"	1/4"	8
Size 6 nylon spacer	1"	1/4"	4
Size 6 screw	1 1/4"	N/A	4
Size 4 screw	1/4"	N/A	6
Size 4 nut	N/A	N/A	4

You'll also need about twelve 1/4" size 6 screws. You can get these at the hardware store, or just use the kind of computer case screws that hold in PCI cards. If you or a friend have them laying around, they're free — best of all! If not, a computer store will usually just give you some if you ask nicely.

The final things you'll need from the hardware store are rubber stoppers, which you should be able to find in the screw section. Buy four that match the dimensions shown in Figure 7-2 as closely as possible. The slice mark will come into play later.

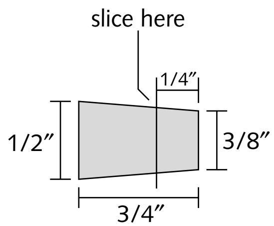


FIGURE 7-2: What size of rubber stoppers to get (side view).

Next, visit your local neighborhood trophy/awards shop. Tell them you'd like to buy some 1/16"-thick engraving plastic. (This is what they use to make plaques and things.) Pick a color that you'd like for the front and back of your portable NES, then buy a piece of it of size at least 12" × 12" (or two 12" × 6" pieces, if you want to use different colors for each side). If they have a sheet of 12" × 24" laying around, it might not be a bad idea to grab that for "coverage" (a.k.a., mistakes).

Tip

If you plan to put decal graphics on your portable, it's best to get a flat-surface piece of engraving plastic, so they will adhere well. Decals will stick to textured plastic, but may look weird.

You'll also need about 12" × 6" of 1/4"-thick *foam spacer material*. This can be anything somewhat stiff; for my portable, I used "X-Acto Foam Board" from the stationery section of Wal-Mart (look near the pens and tag board). It's cheap, easy to cut, and comes in 20" × 30" sheets for a couple of bucks.

Decal graphics

Yes, graphics, the real secret to making professional-looking portables! Putting decals on your portable will make it look great and also help label what the things on it do (like the volume and brightness controls). You've got two options for making your graphics, depending on which is easier for you:

- **Sign shops/vehicle lettering shops.** These days, most have thermal vinyl printers, which work great for this sort of thing. Take the file "NES by hand decals.plt" to them and have it printed on silver metallic vinyl. You'll get back all the decals you need for your NES portable, and they'll be quite durable.

  You'll also need some *vinyl stripes* to put along the sides of the unit — they can cut these for you at a vinyl shop as well. You'll need one 24" × 3/4" stripe for the front half and one 24" × 1" stripe for the rear half. It doesn't hurt to get extra stripes for fix-up jobs when putting the unit together. Use whatever color stripes you please — I used black and gray on my NES. Getting the stripes made from the same vinyl as the decals will most likely save you money, as the whole job can be lumped together.

- **Using your own printer.** If you have an adhesive paper kit that can be used to print rummage sale tags and the like, boot it up and print one of the following files: "NES by hand decals.wmf," "NES by hand decals.jpg," "NES by hand decals.eps," "NES by hand decals.ai," or "NES by hand decals.pdf." Print it out normal size (no scaling), and then use your X-Acto knife to cut along the buttonholes.

Note

If the vinyl shop can't open the PLT file, you can provide them with one of the alternate decal files listed above.

Some of the decals are applied halfway through the construction process, so be sure to get them made before you begin. If you're not using vinyl graphics or stripes at all, you can cover the aluminum sides of the unit with acrylic model paint or spray paint, or just leave them bare aluminum. You can even use electric tape for a covering with a "grip."

Odds and ends you'll need

As with any project, there are some odds and ends you'll need along the way. All of these things can be found at a hardware store or megamart.

- Superglue: Either the liquid kind or the gel stuff. The gel stuff takes longer to set, but it won't spill.
- Epoxy: Any type will work, including J-B Weld, but you'll probably want some 5-minute "quick" epoxy to speed things along.
- Sandpaper: You'll only need a little here and there. Any grit will work.
- Hacksaw and metal-cutting blades.
- Several hot glue sticks.
- An electric drill: Not required, but will make it much easier to thread the nylon spacers when the time comes.
- Drill bits in the following sizes: 1/8", 3/16", and 15/64".
- A package of Velcro: The thin, elongated type works fine; you can cut it to size as needed.
- Electric tape: One roll will be more than enough. If there's a used roll with any significant amount left rolling around your "junk drawer," you'll be fine.

Making the Front Half of the Case

Once all the parts are available, we can begin the construction of the portable NES's case, starting with the front half, which will contain the screen, controls, and motherboard.

Making the front plate

The front half of the case consists of a front plate cut from engraving plastic and a side wall made from bent aluminum. We'll start by cutting the front plate because the shape of it will be a guide for everything else. First, locate the file "Front plate.wmf" and double-click to open it. A PDF version is also available (called "Front plate.pdf"). Windows XP will load this file into the Picture and Fax viewer, and it can also be opened in most art programs or in a picture viewer such as ACDSee. Then, do the following:

1. In the Printer Setup, set the options to the following:
   - Scaling: None or off
   - Size: 100%, normal, or original
   - Fit to page: Off or no
   - Margins: Zero or none (this ensures that the image will fit the page)

   The size of the object on the resulting printout should be 9.25" × 5.75". If not, double-check the printer settings.
2. Lay the printout on a piece of something that is okay to damage (such as cardboard or the foam board). Using an X-Acto knife, cut out the main outer shape.
3. Tape the resulting 9.25" × 5.75" paper pattern down onto the front (color side) of your light-colored engraving plastic. If possible, line the edges of the pattern up to existing straight edges on the plastic to save yourself some cutting.
4. Using a sharp new blade in your X-Acto knife, make a groove along the inside shapes of the buttons and screen. However, do *not* make a groove around the circle in the lower-left-hand corner — this is reserved for the speaker holes, which we'll drill soon. Finally, make grooves along the outer shape.

Caution

X-Acto knives are extremely sharp, so take care when using them, especially if you'll be holding down the material with your hands near the blade as it cuts.

Here are some useful tips to keep in mind while cutting plastic in this way:

- Don't worry about what Sheryl Crow (or Rod Stewart) might say — here, the first cut isn't the deepest. But it does need to be the most accurate, so take your time.
- By the same token, the deeper you try to make the groove the first time, the greater the chance that the knife will slip because of the pressure. This can cut you, and mess up the project as well.
- You can also tape the edges of the pattern for added stability.
- Look straight down from above at what you're cutting.
- When cutting the buttons, slice just around the shape, not on it or inside it. This gives you a margin of error for things to fit. (As I always say, too much is better than not enough.)

5. Use a 1/8" or smaller drill bit to make several holes inside the aforementioned speaker circle. Sand the back of the plastic to remove any pesky hanging chads on the holes.
6. When the speaker holes are drilled and all the lines are grooved, you can remove the paper pattern. You should see all the grooves you made. Slowly and carefully re-cut along all the grooves. Two deep cuts will do it, but the more cuts you make, the easier it'll be to remove the shapes.
7. Press upward with your thumbs against the back of the plastic to bend the grooves along the sides of the main shape. The grooves will then snap open and separate the plastic, as seen in Figure 7-3.

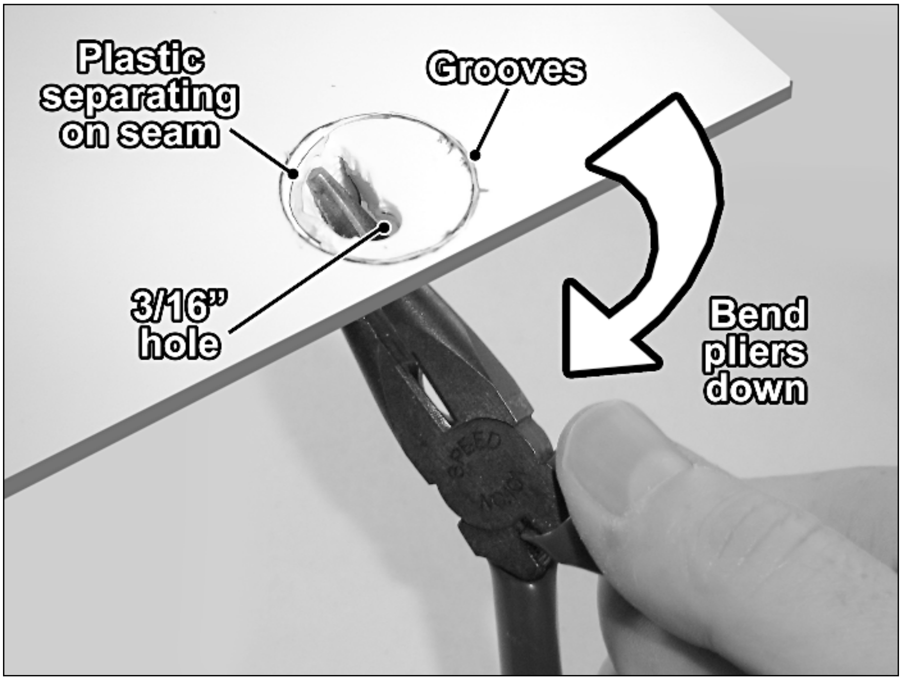


FIGURE 7-3: Bending, cracking, and separating the plastic.

Note It may seem like a good idea to pull the main piece out right away, but make sure you've re-sliced the grooves in the other shapes first. The main piece of stock gives you more to grip onto while cutting.

8. Now let's remove the screen plastic. As you did with the main shape, use your thumbs to slowly press against the back of the plastic to bend the top of the screen. A crack should appear on the back of the plastic along the line. Cut a groove along this line and bend the plastic again. The top portion should come loose. Repeat this step for the other three sides of the screen.

9. You should now be able to see the shape of the screen hole from the back of the unit. Make a few extra grooves over the four corners on both the front and back, then use your thumb to press out two corners on the same side.

You're probably already sick of me saying, "Take things slow..." —but you should! Even though you've cut guide grooves, the plastic can still rip and split more than you want it to.

10. Bend the screen plastic backward, away from the color side. It should "hinge" on the two remaining attached corners. Once it bends far enough, those will pop loose as well.

Your hands are probably pretty tired by now, so you may want to take a short break.... Done? Great! Next we'll be cutting out the buttonholes. You'll need a *3/16" bit,* which will fit inside every button shape, and a *drill.*

1. Drill a 3/16" hole inside every remaining grooved shape on the plate. For the directional pad, drill a hole inside all four corners.
2. With the holes drilled, you can remove the shapes. There are two methods for doing this, depending on the size and type of the shape:
   - Smaller shapes: Use an X-Acto knife to carve away from the pilot hole along the sides of the shape (see Figure 7-4).
   - Larger shapes: Grab onto the shape from below using your cutters or needle-nose pliers, then rotate the tool to bend the grooves open.

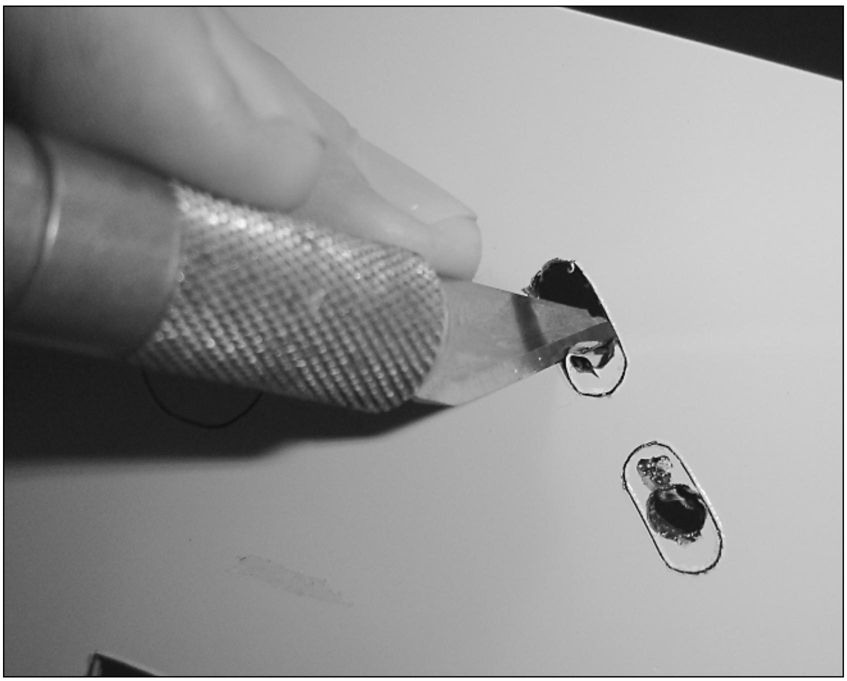


FIGURE 7-4: Grabbing through drill hole and bending plastic apart.

3. Use your X-Acto knife to shave the insides of the shapes smooth and to remove rough edges. Stick the NES buttons in and see how they fit, shaving the holes as needed.

Applying decals to the front plate

You have now completed what we'll call the *front plate*. Let's apply some graphics! This may seem like something you'd do at the end, but believe me — it's easier to get it out of the way now. (The following procedure is for vinyl graphics from a sign shop — if you printed them yourself on paper, disregard this section.)

1. Lay down some paper toweling and set your front plate on it, face up.
2. Then, take a small dish and dump in some water and a drop or two of dish detergent to make a slightly slippery mixture. Dunk each graphic in this, and then apply it to the front plate, as seen in Figure 7-10.

FIGURE 7-5: Applying graphics to the front plate.

3. Line up the holes and press down the graphics. Press a paper towel over each graphic to soak up excess water, then press them down again with a squeegee or the edge of something flexible, like a spatula or credit card.
4. After it's dry, cut out the screen portion. This was not cut earlier, because the vinyl would have been much flimsier around the edges and this would have made application more difficult.

Attaching screw posts to the front plate

In order to attach things such a circuit boards and screens to the unit, we need to provide *screw posts* for them to connect to. These will be made from *nylon spacers* of different lengths.

Once the front plate decals are good and dry, load up the "Front plate screw posts.pdf"file and print it out, using the same guidelines as for the last template. (You'll notice it's like the first pattern, but mirrored horizontally.) Cut around each double-circled screw post, as shown in Figure 7-6, and around the main outer shape. It's not a bad idea to help align the paper pattern with the front plate by cutting out some of the buttonholes and the screen.

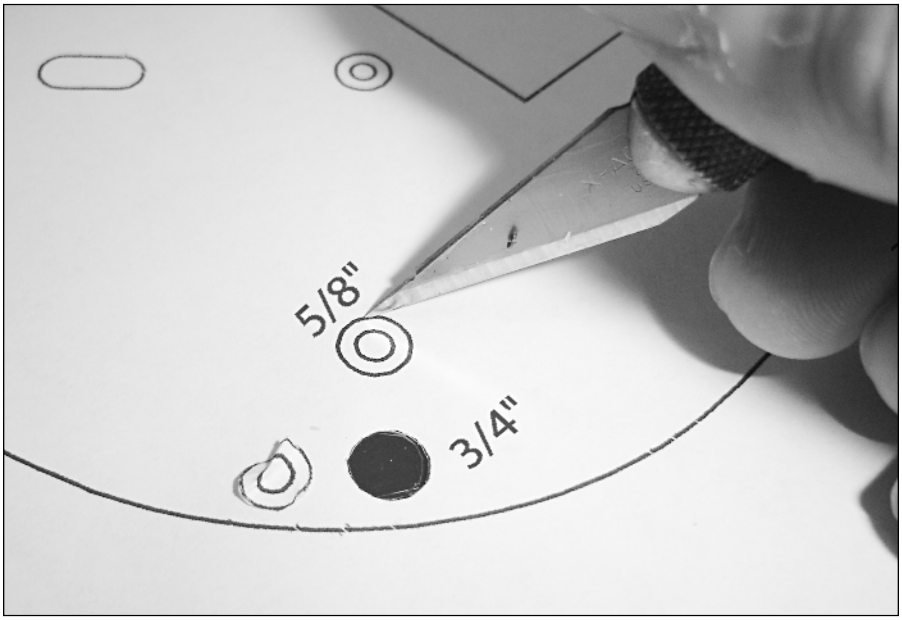


FIGURE 7-6: Cutting out the screw posts on the second pattern.

Flip the front of the case over, and sand the back of it. This will allow glue to stick to it better. Wipe off the dust from the sanding, and tape down the screw post pattern, lining up the button holes and sides as best you can. Set this aside and get your nylon spacers out.

Tip

Make a few extra slits inside the pattern so that you can tape it down in the middle as well as on the sides.

Preparing the nylon spacers

Which type of spacer and how many of them are needed was listed at the beginning of the chapter. However, some of the parts in the case need 5/8" of space, and the closest spacer is 1/2". Therefore we need to make four 5/8" spacers manually. To do this, cut 1/8" off four of the 3/4" ones using the thickest part of your X-Acto blade.

Caution As you'll be pushing down with a lot of force to cut the spacer, you should hold the spacer with needle-nose pliers when doing this in order to keep your fingers away from the blade!

Tip As an alternative, you can also use 1/2"-long spacers and glue two size-4 nylon washers to one end to make them 5/8" long. Do not drill into this glue-stacked end, however. (See the next part on threading.)

Once the spacers are all the right height, it's time to thread them. See, these spacers are intended to cover screws, not hold them. Therefore, a size-4 spacer will slide easily over a size-4 screw. But of course I'm not following those silly ordinary uses. For us, a size-4 spacer will be used to tightly hold a size-6 screw! Because of this, all the 3/4" and shorter spacers need to be threaded.

1. Hold tightly onto each spacer with your big pliers, and drill a size-6 screw in and out of it to create threads.
2. Make a mark on the end you drilled into, which should also go UP, as the end that the screw will go into.
3. Repeat Steps 1 and 2 for all the spacers except the four 1"-long ones. Those are meant to simply slide over a size-6 screw in the rear of the case, and therefore no threads are required.

Attaching the nylon spacers

You'll notice that each screw post hole on the template has a number written next to it. This tells you what size nylon spacer to place there. Put a dab of superglue in each space, and press down the appropriate length spacer on it (Figure 7-7). When placing the spacers that you cut shorter, be sure to place the original (uncut) end down on the glue, otherwise the spacer might look like the Leaning Tower of Pisa. There are also four size-4 nuts to glue down as well. Don't worry if glue gets on the paper (I sure didn't).

Let the glue set for a while, maybe even overnight. (Dream of playing your portable near a crystal blue lagoon or something.) Once you're confident the glue is set, rip and cut the paper off. After the paper is removed, put a little more glue around the base of the spacers for that extra "oomph!" You may also wish to use some epoxy. Now that the nylon spacers have been glued down, we can now call them *screw posts*.

Note Don't put any glue on the outer sides of any screw posts near the edges of the case. You need to keep 1/16" flat for the sides to be able to attach properly. While I've got your attention with this icon, try not to get any superglue on your fingers, either—not just because it causes them to stick together, but also because you might accidentally smear some on the front of the case, which would be unsightly.

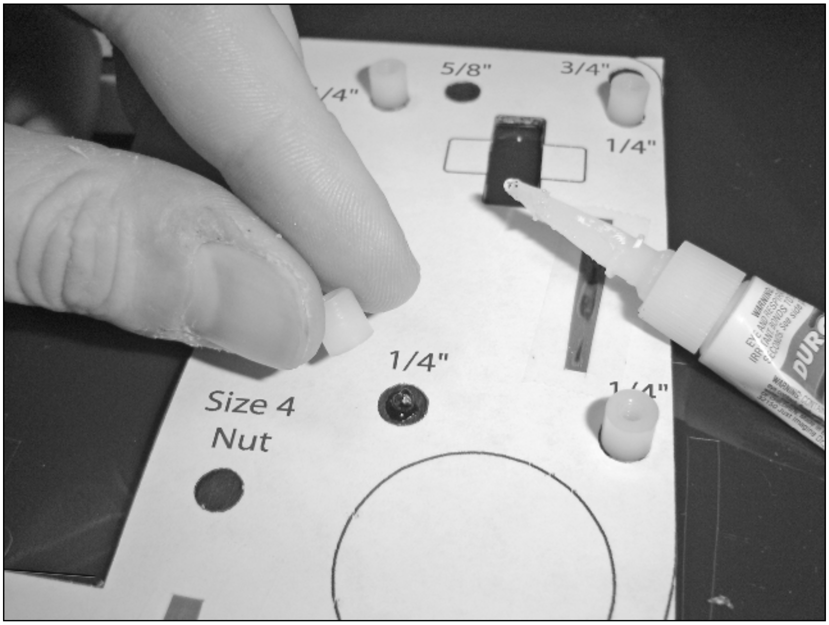


FIGURE 7-7: Placing spacers with superglue on the pattern.

Making and attaching the front walls

After the screw posts have been attached to the front plate, it's time to attach the *front walls*. These will enclose and give the proper depth to the front half of the case.

1. Take your 4'-long, 3/4"-wide, and 1/16"-thick piece of aluminum, and sand the edges and the insides. This allows glue to stick better.
2. Make an initial 90-degree bend around a pencil. This will match nicely to the upper corner of the case, as seen in Figure 7-8. Have the first edge of the aluminum go about halfway across the top of the case.

FIGURE 7-8: The first bend in the aluminum.

Tip

The aluminum strips are sure to have labels on them if they came from a hardware store. These labels are a pain to remove and always leave residue. To avoid frustration, bend the aluminum so the label ends up inside the unit. (That way nobody will see it!)

3. Before we attach the aluminum, let's make a hole for the power switch in it. Draw a small box with a felt pen, sized 5/8" wide and 3/8" high. When the aluminum is placed on the front plate, the switch hole should be just above the directional pad (Figure 7-9). Cut out the box with tin snips or a hacksaw. Take your power switch and put it in the slot, making sure it fits. Then, use a 1/16" drill bit to make screw holes in the aluminum on both sides of the switch.

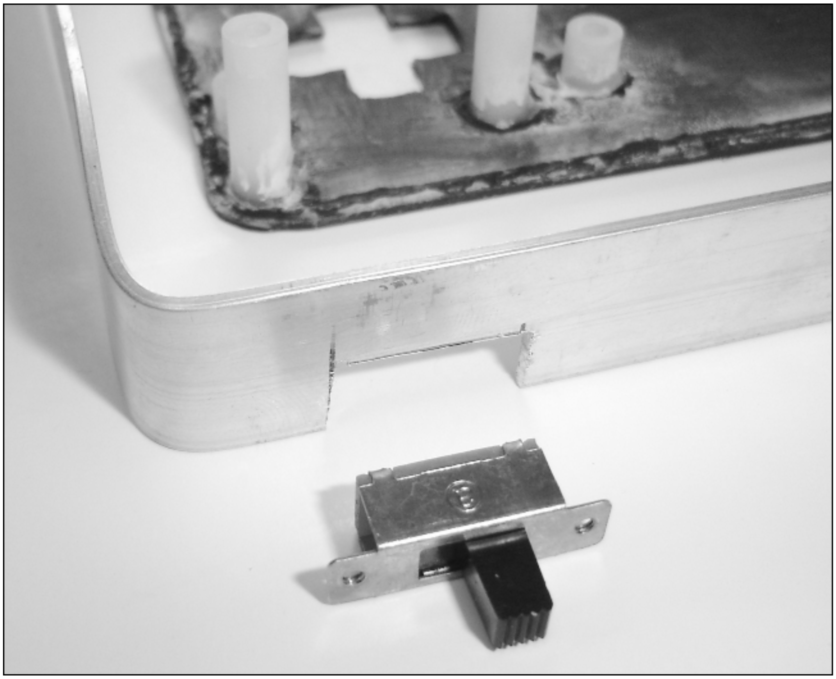


FIGURE 7-9: The power switch hole and the switch itself.

4. Place drops of superglue along the edges of the front plate and press the first bent portion of the aluminum down on it.

5. Let the glue dry, and then grip your big pliers at the last glued portion. Press down with your thumb to bend the aluminum around the first big curve, as shown in Figure 7-10.

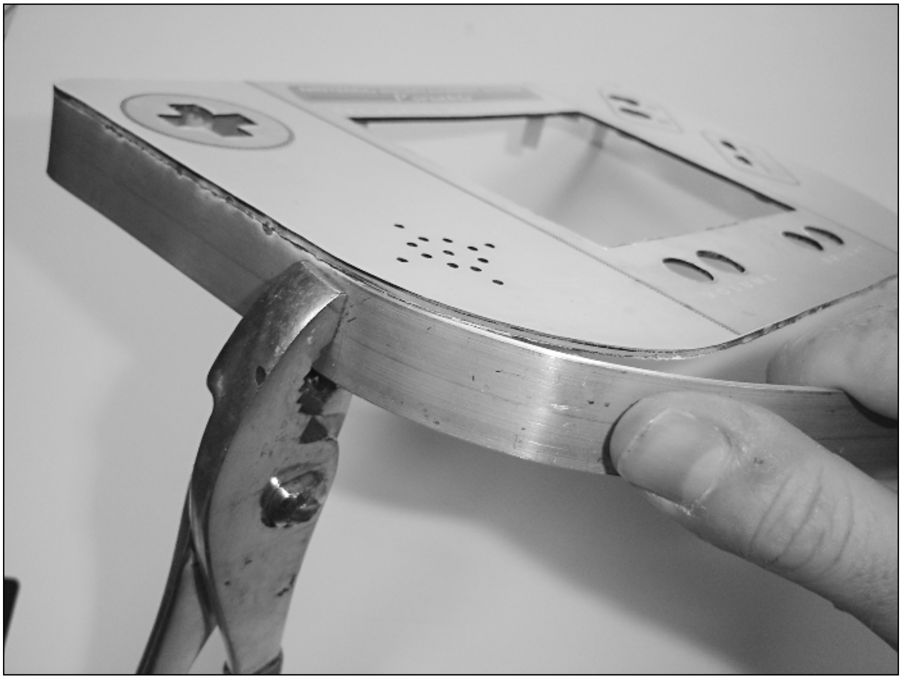
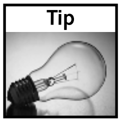


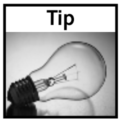
FIGURE 7-10: Bending the second curve. The pliers keep the already-glued portions from bending.



Tip

Overbend the aluminum around big curves like the one above. If you bend it exactly to the curve, it'll have tension on it, making it hard to get the glue to stick. Instead, bend it further so that when it springs back it's at the right position.

6. Continue to bend the aluminum around the unit until it reaches the beginning. Don't bother to glue as you go; just keep the first side attached for now. Make a mark where the aluminum end meets the beginning and slice it there using a hacksaw.



Tip

If anything, make the final cut a little short—it's better than too long with an overlap. You can always put a piece of vinyl over any place there's a gap. (Shh! Trade secret.)

7. You can now glue down the front walls around the unit. First attach the walls to the plate using superglue, making sure the edge of the wall is flush with the edge of the plastic.

8. Use a cotton swab to clean up any excess dust or residue that may be along the inside edges. Then lay down a thin bead of epoxy, J-B Weld, or silicone along the edge where the plate and wall meet to seal the deal. Toothpicks make good applicators for this kind of work.

9. Cover the outside of the now-attached wall with your 3/4" wide vinyl stripe or other covering of your choice (see the materials list). Cut out the power switch hole in the vinyl.

Tip It's not a bad idea to also put some epoxy at the base of the screw posts, especially the 5/8" tall ones, as these will be holding the NES motherboard, which in turn is pressured when a cartridge is inserted.

Making the Rear Half of the Case

Now that the front half of the case completed, we can build the *rear half*. It's the same size as the front half, but it will be easier because there's less stuff to cut out of it, and we've already covered a lot of the techniques. Scrape off the superglue that's probably all over your fingers by now, and let's dive in.

Making the rear plate

As with the front half of the case, the first step here is to cut a 1/16" thick *rear plate* to attach everything to.

1. Locate the file "Rear plate.wmf" and print it out as you did with the other patterns. Slice out the top and one side, and make some slits on the inside. Tape this piece to the surface of the engraving plastic that you want to be visible on the back of the unit, as seen in Figure 7-11.

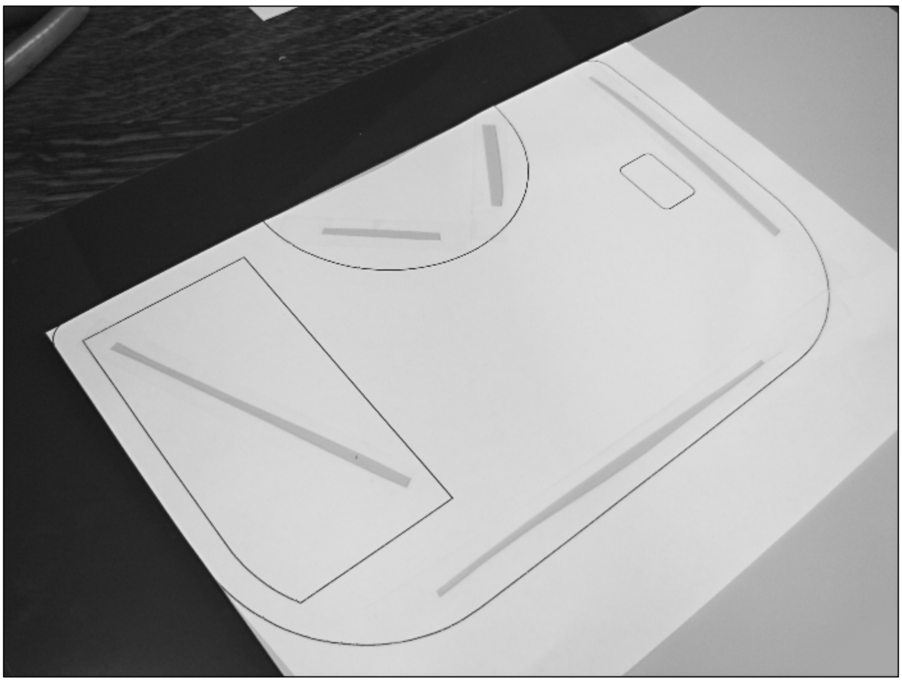


FIGURE 7-11: Taping down the rear plate pattern.

2. Make a groove along all visible lines, remove the pattern, re-cut the grooves, and snap the rear plate free. Remove the small square using drill holes, as you did with the button-holes on the front of the unit.
3. When removing the large plastic square, try to keep it intact, because the plastic you remove will be used as the battery access door. After you remove it, shave the edges of both it and the hole so that it will fit back into place easily.
4. Print out the file "Rear plate screw posts.pdf," and use your X-Acto knife to cut the shape out. Use a fine-grit sandpaper to sand the back of the rear plate, and then tape this pattern to it, as you did with the front plate screw post pattern.
5. You'll see two long, thin rectangles running alongside where the cartridge will go. Cut a groove around each of these shapes so that a reference mark will be made on the plastic beneath. (You'll notice that some of the edges of the thin rectangles run along the square holes in the plastic; obviously you won't need a mark for those parts.)
6. Next, use a 1/8" drill bit to drill holes through the plastic in the center of the four screw posts. You can then remove the pattern.

Making and attaching the rear walls

We can now attach the *rear walls* to the rear plate. Unlike the front plate, we'll do this before attaching the screw posts.

1. Grab your 4'-long, 1"-wide, and 1/16"-thick piece of aluminum, and set it against the right edge of the left thin rectangle as shown in Figure 7-12. The end of the aluminum should line up with the top of the left reference groove. This is where the cartridge opening starts.
2. Use a pencil to bend the aluminum around the first bend, and then bend it around the rest of the rear plate as you did with the front wall. The aluminum should end up at the left edge of the right thin rectangle, mirroring where the aluminum began. Make a mark at this spot.
3. Use a hacksaw to cut off the aluminum at the end spot, then superglue and epoxy the wall to the plate, as you did with the front.

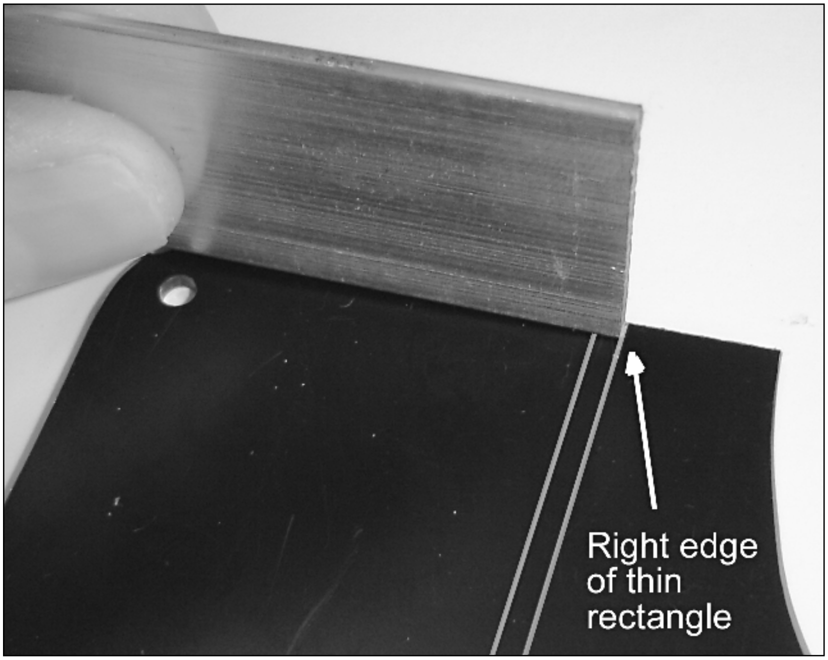


FIGURE 7-12: Initial place to line up the 1″-thick aluminum wall.

Attaching the nylon spacer screw posts

Now let's attach the screw posts to the rear plate. Grab your four 1"-long size-6 nylon washers for this. These are designed to allow a size-6 screw to move freely inside them. Since the screws only need to push the rear of the unit against the front, we can use these for the rear screw posts. (It also makes screwing the unit together much easier.)

The idea is to center these spacers over the screw holes that you drilled in the rear plate. You can eyeball this, or insert a size-6 screw partway through the hole to help guide it. (Just make sure you don't superglue the screw to the spacer!) Either way, glue down the spacers. If a spacer doesn't fit quite right because the walls are a little off, you can omit the spacer, or grind the side of it down using a grinding wheel. They're mostly for extra solidity.

Once everything is attached, go around and put a bead of epoxy around the base of the screw posts and the walls. Set it aside so that it can cure.

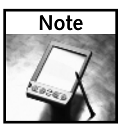
Making the battery door

While the epoxy cures on the rear half of the case, you can work on making the *battery door*. If you managed to cut out the original door shape nicely, you can use it here, but otherwise you'll have to trace the shape of the door in the rear plate onto another piece of engraving plastic and re-cut it. When the door is ready, do the following:

1. Use your X-Acto knife and a ruler to cut the following shapes out of scraps of 1/16”-thick engraving plastic:
   - Two 1/2” × 3” rectangles
   - One 1” × 3” rectangle, of a different color material (if you have any)
2. Now superglue one of the 1/2” × 3” pieces under the battery door with 1/8” exposed. Glue the other 1/2” × 3” piece under one side of the 1” × 3” piece, then attach it to the front of the battery door. The result should look as shown in Figure 7-13.

FIGURE 7-13: The assembled battery door.

You can vary a little on the vertical positions of the tabs, but try to keep them close to the photo. Place some Velcro under the upper lip, then a corresponding bit of Velcro on the back of the rear case. Your battery door is now complete, so go ahead and put the decal on it!



You may have to use more or less stacked spacers, depending on the total thickness of the Velcro pieces.

Installing the cartridge guides

To keep the cartridge straight, so that it'll plug in correctly, we need to make and install some *cartridge guides* to put on the rear plate. Do the following:

1. Use the leftovers of your 3/4"-wide aluminum strip to cut two 4-1/2"-long pieces.
2. Superglue the aluminum strips down onto the thin rectangle lines as shown in Figure 7-14. Place a very thin line of epoxy along the edges, so that no epoxy gets in the way of the battery door or the Player 2 port (which will be installed next).

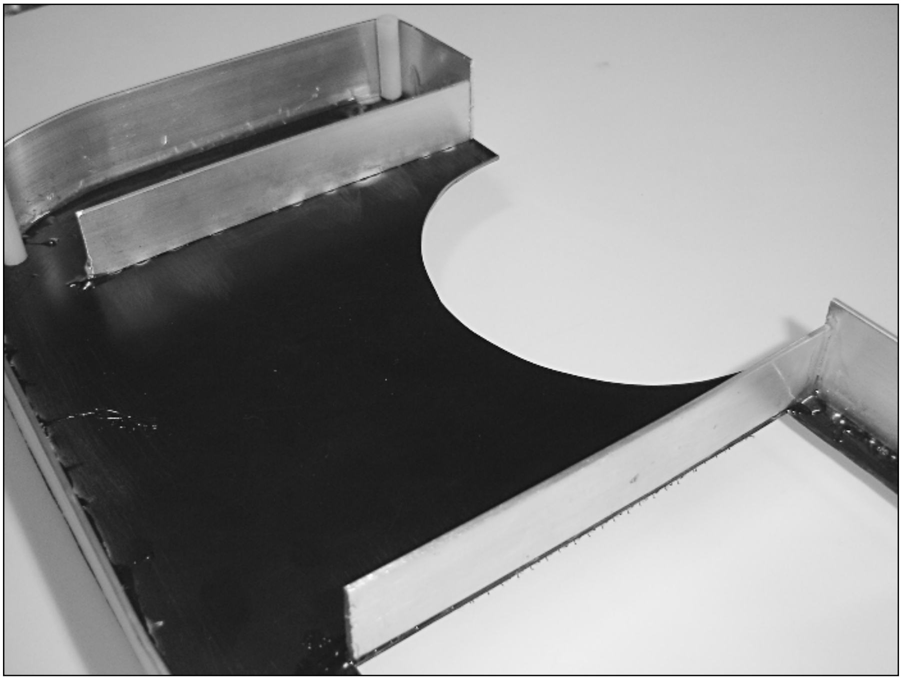
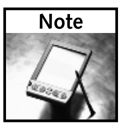


FIGURE 7-14: Inside walls attached to rear plate.



A certain margin of error has been allowed in this design to ensure that your cartridge will fit, but still try to keep the guides as straight as possible. Also, on the right-hand one, try to use a minimal amount of epoxy on the side that will touch the cartridge.

Installing the Player 2 port

As mentioned at the beginning of the chapter, this unit will have a Player 2 port so that a friend (or enemy, depending on how heated your gaming battles get) can plug in a standard NES controller and play along with you.

1. Take a controller port from your dismantled NES, and shove it into the hole of the same shape in the rear plate. It should fit pretty nicely and be flush with the back of the unit; if not, do some more shaving with the X-Acto knife.
2. Place epoxy around the sides of the port to lock it in place. Leave the original multicolored wires attached to the port—we'll extend them later.

Making the foam spacer

In order to ensure the proper positioning of the game cartridge, a 1/4"-thick foam spacer must be placed in the rear half of the case. (As mentioned in the materials list, you can use anything 1/4" thick, such as balsa wood, but the foam is very easy to cut.)

1. Print the file "NES Foam Spacer.pdf" from the companion Web site. Tape this pattern down on a piece of 1/4"-thick spacer material, and cut through the material along all lines, as seen in Figure 7-15. If you're using foam board, you can slice all the way through the pattern and the material in one pass.

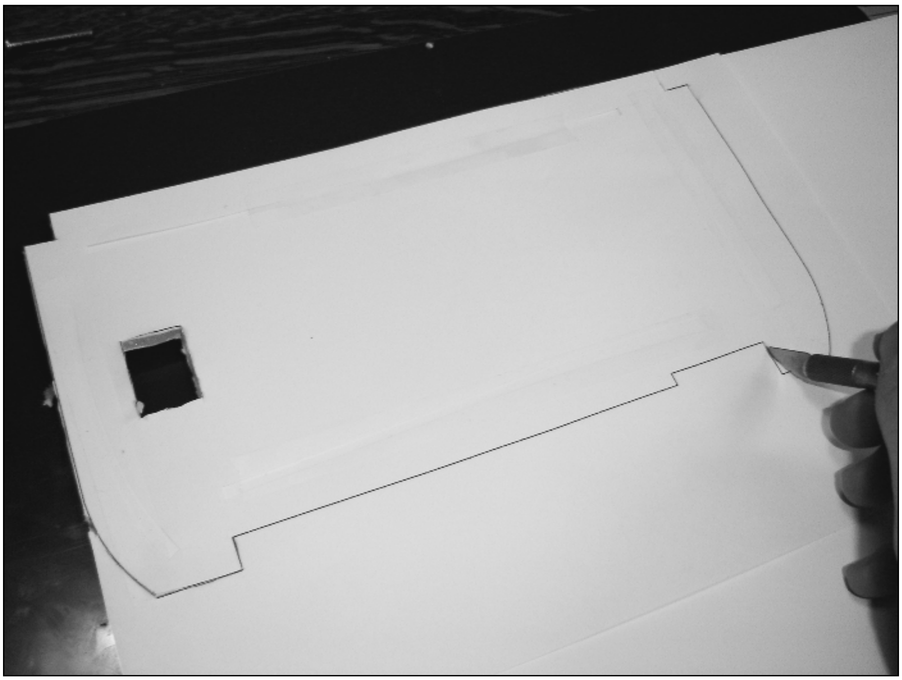


FIGURE 7-15: Cutting the 1/4" spacer. An X-Acto foam board is shown here.

2. Insert the spacer inside the walls of the rear half of the case. The square hole should go over the Player 2 port.

3. Slice away at any edges of the foam that don't quite fit. The top of the spacer should be flush and at the same level as the top edge of the aluminum walls.

4. Once you've got the spacer fitting properly inside the rear half of the case, remove it and set it aside. It will be installed during the final assembly.

Tip

The inside of the foam is a good place to write "[Your Name] was here" and the date—you know, in case aliens dig up your portable in a million years and wonder who made it.

The case for the portable NES is now complete. The majority of the remaining work for this project is wiring.

Wiring the Unit

Now that the case is built, we can start wiring the unit. This involves installing all of the electrical components and then connecting them together. This will include:

- Installing the PSOne screen and connecting it
- Making and installing printed-circuit (PC) boards for the control buttons
- Connecting the NES motherboard to the screen and PC boards
- Hooking up battery and power connections.

Set aside all the rear case parts, and get out the front case assembly and the PSOne screen (modified as per Chapter 4) in order to begin the wiring procedures.

Note

Since applying decals is best done with water, make sure they're all attached to the front of the unit before you begin wiring. Water and electricity do not mix! (Well, they do, but the result is bad.)

Installing the PSOne Screen

The first electronic component we'll install in the front of the case is the PSOne screen itself. It will attach to the inside of the front plate via four screws that will grab onto the nuts you superglued down earlier.

Before we actually install the screen, we need to make the volume and brightness control buttons. (I guess arts and crafts time isn't quite over yet—sorry.)

1. Use your X-Acto knife to cut two 1" × 0.375" rectangles out of engraving plastic. Then get out your four rubber stoppers.

2. Slice 1/4" off the small end of four stoppers to create a small button. Keep the 1/4" part. Attach a sliced stopper to each side of the plastic rectangle with superglue as seen in Figure 7-16. If you're feeling really adventurous, you can try carving small "+" and "–" marks on the ends of the buttons. A silver ink pen will also do the trick, but might look cheesy.

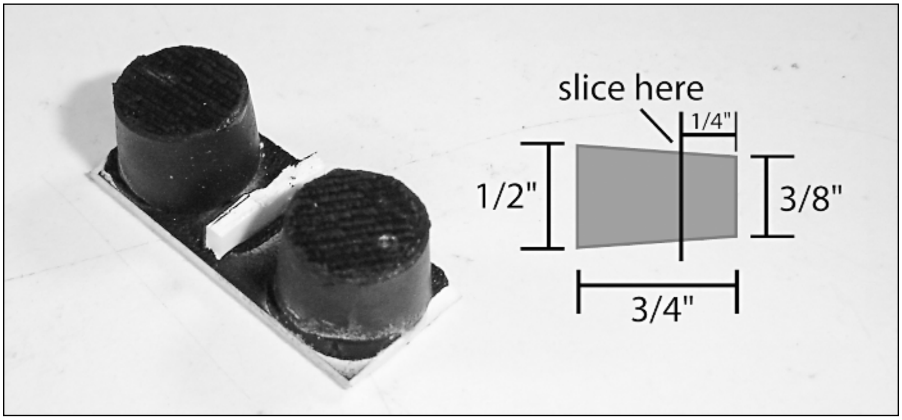


FIGURE 7-16: A rubber stopper to use for buttons.

3. As seen in the figure, place a small wedge of plastic about 1/8" high in the center of the buttons — this will hold them in position better when placed in the casing.
4. Lay the front case face down and place the button assemblies in both spots. (If you've labeled them, the "+" will be to the left here, or to the right when viewed from the front.)

With those buttons in place, we can install the PSOne screen itself into the front half of the case. To accomplish this, do the following:

1. Plug both white cables back into the bottom of the PSOne screen. Now cut off all the wires expect for the first two on the left plug and the first three on the right plug (as viewed from the front).
2. Use your cutters to snip off the old speaker plugs. The results of Steps 1 and 2 should look as in Figure 7-17.
3. Attach a 4"-long two-strand of cable to the left speaker connection as shown in the figure. This can be a difficult connection to make. Some tips:
   - Have very short lengths of exposed (stripped) wire, so it won't touch anything it shouldn't.
   - After removing the old plug, place a bit of new solder on the connections. Then hold the wire down and place a bit more solder on top of it. This will melt the solder above and below to the wire.
   - Once you've got the wires attached, secure it with a bit of glue, so it won't move around too much.
4. Remove any temporary screws that are holding the metal screen frame to the PSOne screen's motherboard. Place the screen facedown into the front of the case with the cables at the bottom. Make sure the volume/brightness buttons are "clicking" when pressed.

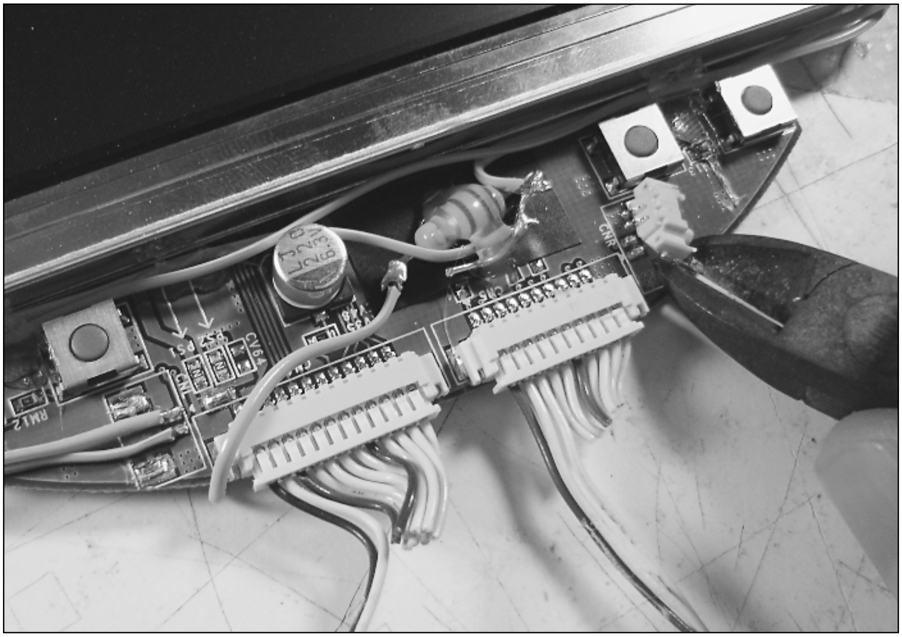


FIGURE 7-17: The cables cut, the speaker wire attached, and the old speaker plugs being removed.

5. Insert 3/8"-long size-4 screws into the four main screw holes around the screen through the back of the PSOne screen's motherboard. These screws should reach the nuts on the front plate and grab hold. Tighten until the PSOne's LCD is pressed tightly against the hole in the front plate.

Tip

If one of the nuts isn't quite in the right spot (which is possible since this was done by hand) you can either omit that screw, or pry off the nut, reposition it based on where the screw is, and glue it back down.

6. Hot-glue the *speaker* down over the speaker holes now, and connect the audio wires from the screen's left speaker connection to it. The inside of the front half of the case should now look as shown in Figure 7-18.

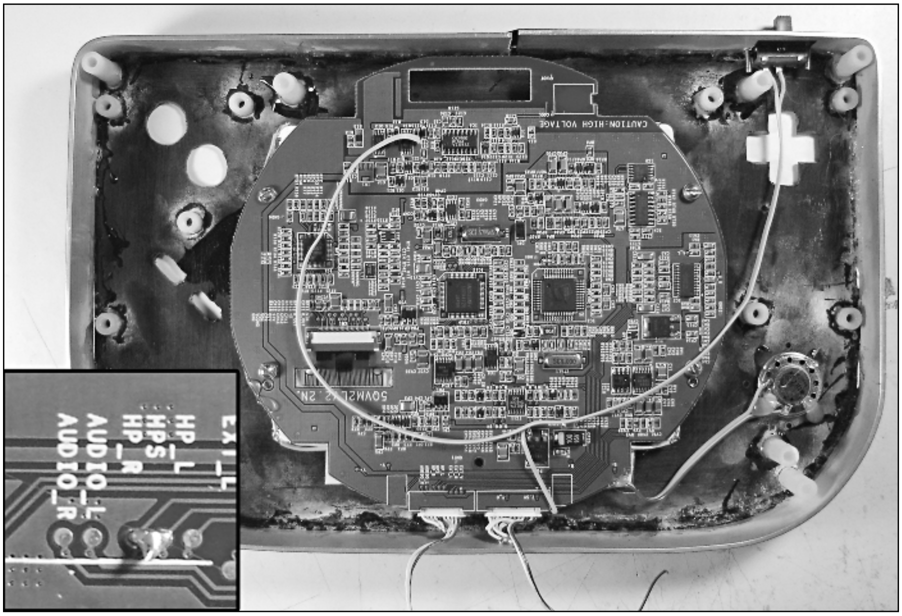


FIGURE 7-18: Attaching the screen, speaker, and power switch.

7. You'll see a close-up of the section above the left cable in Figure 7-18. Put a bit of solder down to connect the HPS and HP_R spots. This enables the speaker to work.
8. Screw the power switch into the hole we cut for it in the aluminum wall. Make sure the two terminals are to the left, so that you push the switch toward the center of the system to turn it on.

Tip

If the power switch is hard to screw in place securely, put the screws in anyway so that it looks visually correct, and dump a bunch of hot glue on the inside. (I do this more than I care to admit.)

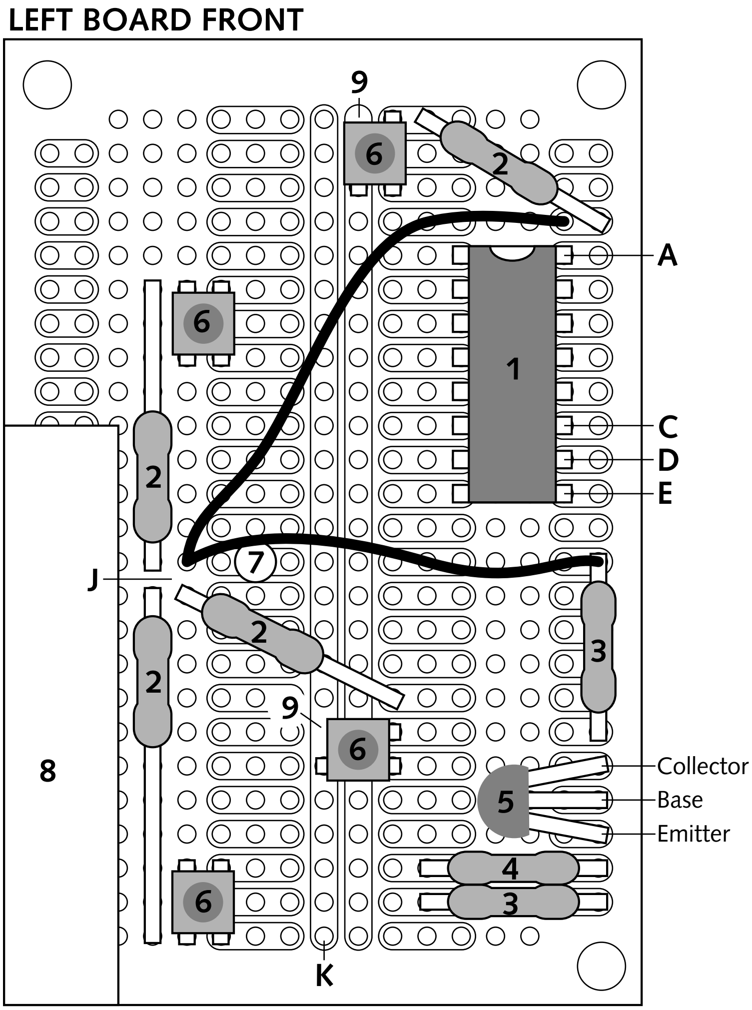
Making PC boards

There will be two PC boards in the front half of the NES portable. They contain the control buttons, the IC for the controls, a video amplifier, and a power regulator. When we refer to them as "left" and "right," this is as viewed from the rear, looking inside the unit. Here's how to put them together.

Making the left board

The left board will have the select, start, B, and A buttons, along with the controller IC and a video amplification circuit. You'll use the PC board available from Radio Shack as catalog #276-150.

Place the components listed in Figure 7-19 on the board as shown.



1) IC from NES controller
2) 48k ohm resistors
3) 220 ohm resistors
4) 33 ohm resistor
5) 2N4401 transistor
6) 4.5mm tact switches
7) Drill 1/8" hole
8) Remove this portion of the PC board
9) Leads to remove off tact switches

A) RIBBON CABLE 1
B) RIBBON CABLE 2
C) RIBBON CABLE 3
D) RIBBON CABLE 4
E) RIBBON CABLE 5

To Right Board:
F) UP
G) DOWN
H) LEFT
I) RIGHT
J) +5 VOLTS
K) GROUND

FIGURE 7-19: Where to put stuff on the left PC board.

Use a 10”-long six-strand of ribbon cable for connections F–K (this will go to the *right board*) and a 12”-long five-strand of ribbon cable for connections A–E (this will go to the *NES motherboard*). Make a black mark on the other end of the A connection wire for later reference.

As you make these boards, use the following guidelines:

- Take note of where the pre-drilled holes are on the board — they are not symmetrical, and must match the drawing. There’s a gap three holes wide on the left side, but it’s only two holes wide on the right (under the IC).
- Break off the specific leads shown on the two tact switches. All the remaining tact switch leads must be soldered to the board for the circuit to work.
- The flat portion of the 2N4401 transistor should face to the right. You can bend the transistor backward to flatten it out after soldering.
- The black lines are wires. Use pieces of ribbon cable for these connections.
- Drag an X-Acto knife along the lines to cut out the box labeled 8. Once you score the surface, you can snap the board apart, but be careful not to crack too much of it. (You may want to do this before you add the components, just in case.)

  Okay, flip the board over to the copper solder side — it’s time for more connections, as seen in Figure 7-20. For reference, the positions of the components on the other side are shown in light gray.

Some guidelines for the connections on the copper solder side:

- The straight black lines are connections that can be made with small pieces of extra leads from the components. (You can also simply blob solder directly between those connections if you wish, as there isn’t a great distance to cover.)
- The curvy black lines are connections that are best made using ribbon cable wire.
- The spots marked *Video IN from NES* and *Video OUT to screen* will be wired to things later — bookmark this page for reference.

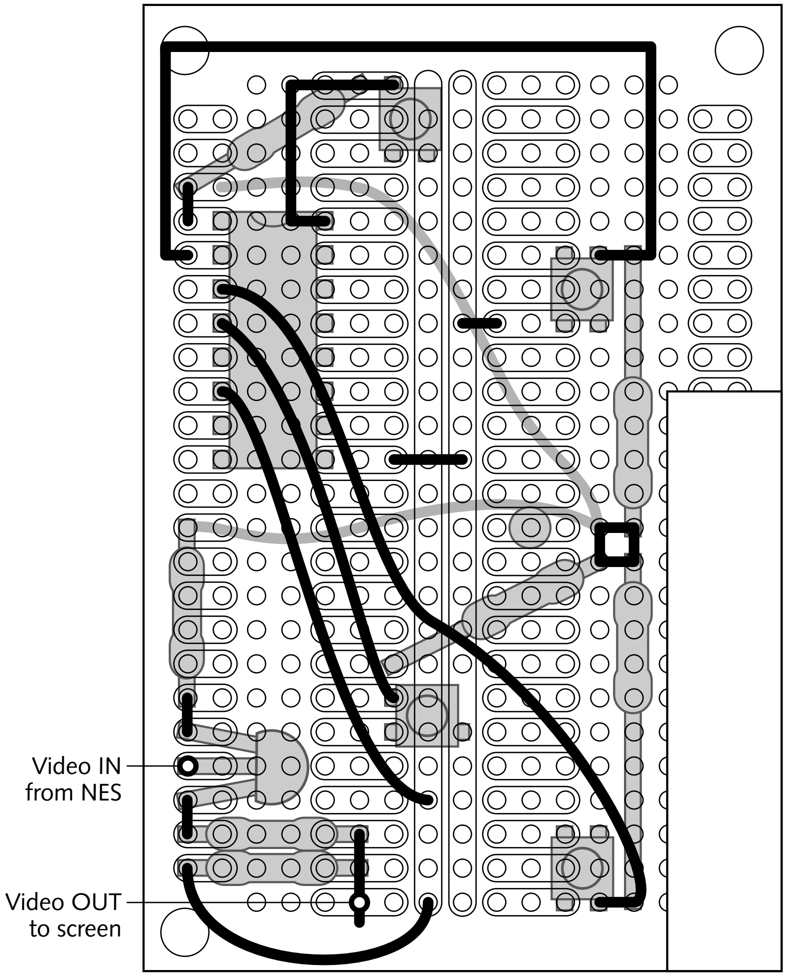


FIGURE 7-20: The left board connections, viewed from the rear.

Figure 7-21 shows what the front and back of the left board should look like after wiring.

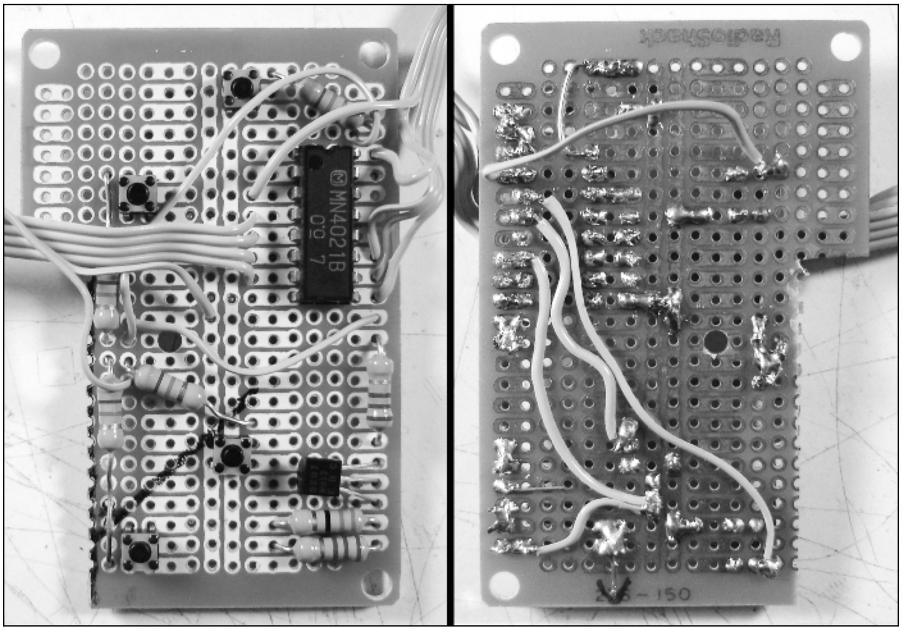


FIGURE 7-21: The completed left board, front and back.

Making the right board

The right board will contain the up/down/left/right joypad and the power regulator for the PSOne screen. Use a size-4 screw to attach the 7805 regulator to the heat sink (Radio Shack catalog #276-1368) as shown in Figure 7-22.

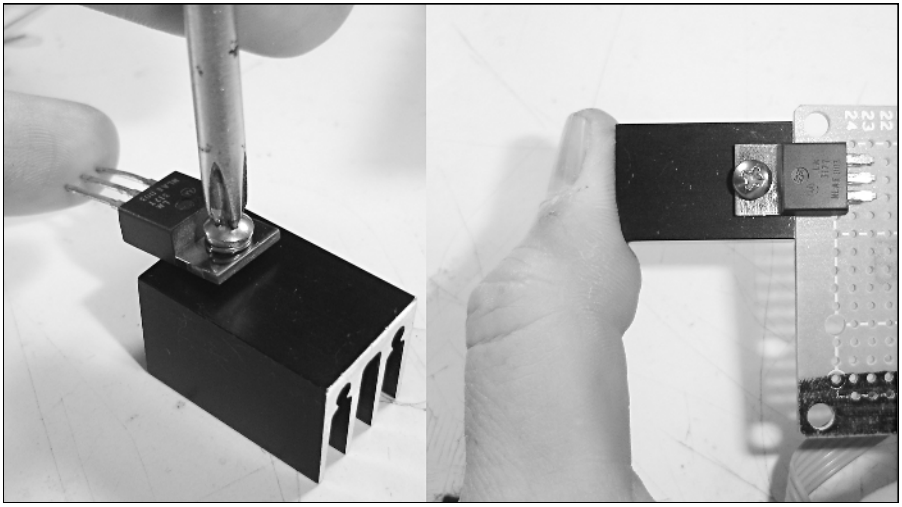


FIGURE 7-22: Attaching the heat sink and installing the regulator.

When installing the regulator, press against the heat sink so that it touches the PC board. This ensures that it will fit in the case. Place the rest of the components on the front of the board as shown in Figure 7-23.

Now flip the board over and make the connections as shown in Figure 7-24, including attaching one of the ribbon cables from the left board. The spots marked *+7.5 volts to screen* and *Ground to screen* will be wired to things later on, so bookmark this page for easy reference.

RIGHT BOARD FRONT

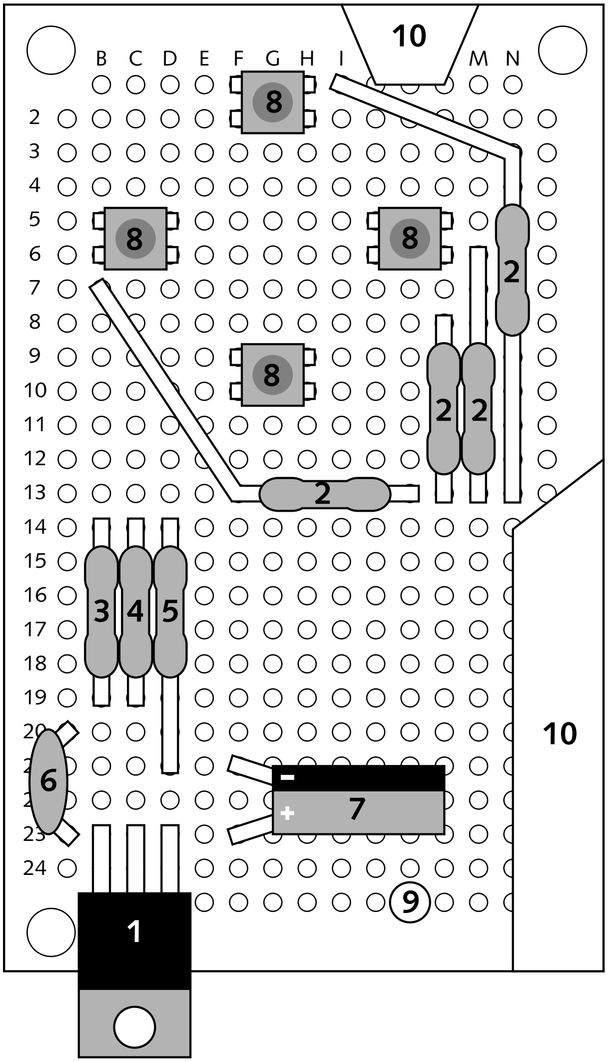
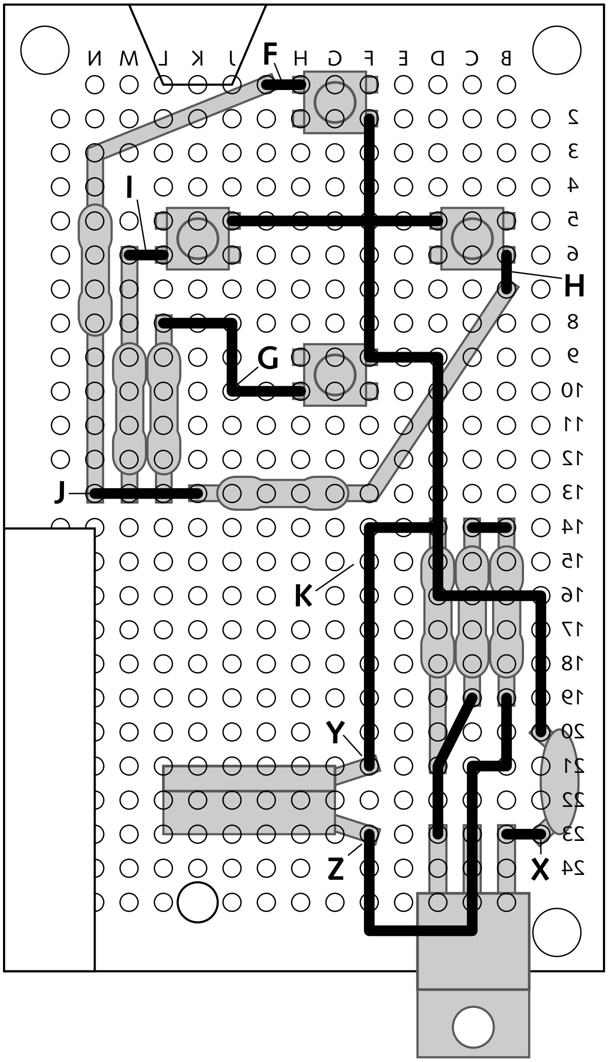


FIGURE 7-23: Installing parts on the right board.

RIGHT BOARD REAR



From Left Board:
F) UP
G) DOWN
H) LEFT
I) RIGHT
J) +5 VOLTS
K) GROUND

X) Unregulated power IN
Y) Ground to screen/NES
Z) +7.5 volts to screen

FIGURE 7-24: Connections on the rear of the right board.

Both sides of the completed right board should look as shown in Figure 7-25.

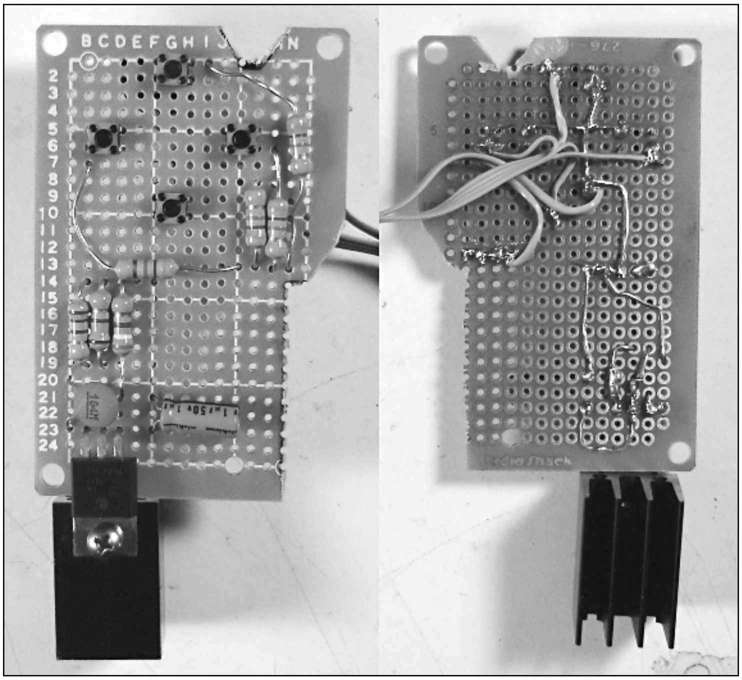


FIGURE 7-25: The front and back of the completed right board.

Installing the PC boards

The PC boards now have all the components and wiring they'll need. They're ready to be installed in the front of the case, but since the *buttons* go between them and the front plate, we'll need to prepare those now.

1. Fill the insides of both red buttons with hot glue so that the glue is level with the bottom of the button.
2. Cut a ring of very thin plastic and place it around the button, as seen in Figure 7-26.
3. Place the gray directional pad and the B, A, and select/start buttons in the appropriate holes inside the front of the case. Cover the speaker with a couple of layers of electric tape so that it won't short out against the heat sink.

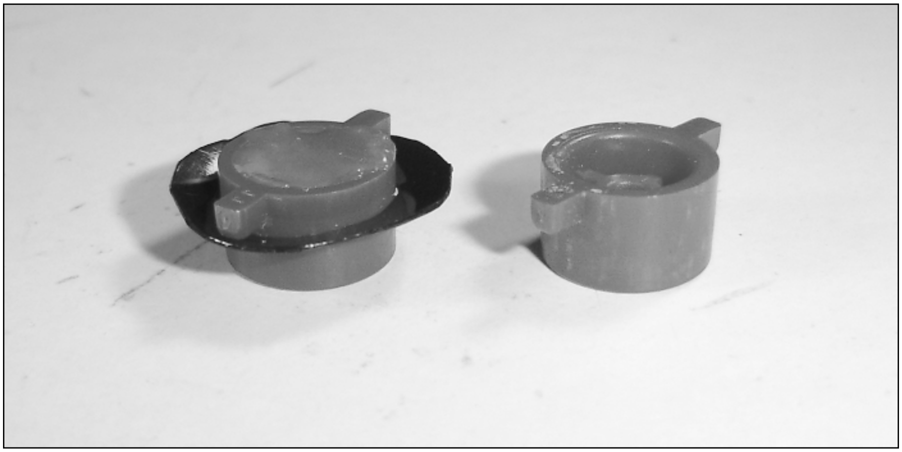


FIGURE 7-26: Modified buttons, after and before. For the ring I used the plastic from the bottom of a store-bought cake tray. (The cake was good, too.)

Now you can screw the PC boards in place. The cuts you made should allow the boards to fit around the screen, but if they don't, snip off a bit more. Screw down the PC boards with the computer case screws, as seen in Figure 7-27.

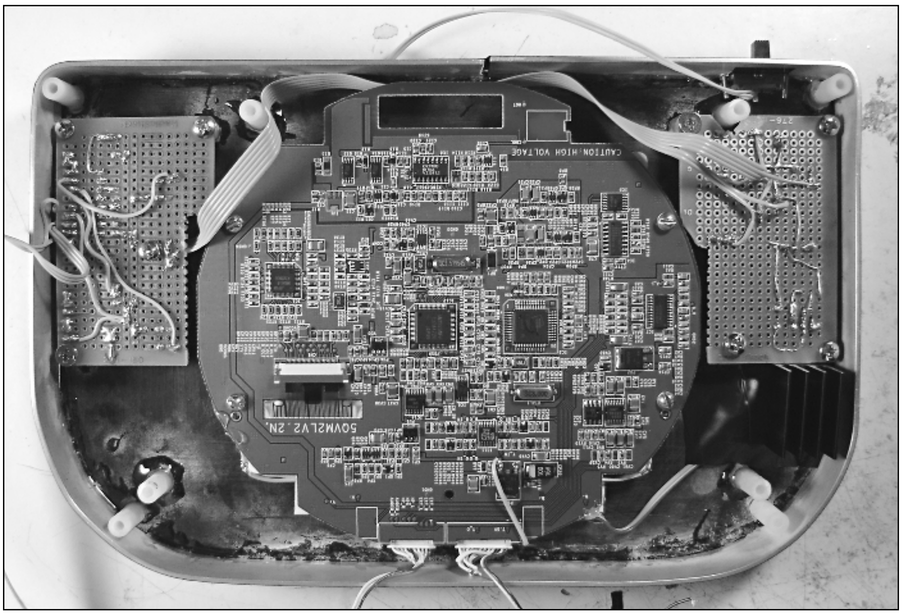


FIGURE 7-27: The PC boards attached to the case.

Please use the following guidelines when installing the boards, arranging the wires, and checking the buttons:

- Some wires may get in the way of the B and A buttons. Hot-glue these out of the way before securing the board.
- If a ribbon cable gets in the way and is hard to move, separate the strands a bit more for added freedom.
- Screw into the screw posts slowly to prevent them from snapping loose from the front plate. How much force the screw posts can take depends on the kind and amount of glue that you used on them.
- Double-check that everything under the boards is ready before you attach the boards. There's nothing more frustrating than having to remove it all because you forgot something silly, like putting in the speaker or directional pad.
- When attaching the boards, making sure the buttons are "clicking" the tact switches when they're pressed. If they don't, it's because something is too tight and the switches are stuck down. Shave off some glue or material to remedy. Add more glue if the buttons are too loose.
- Don't force screws that aren't going in easily — you can crack the PC board or mess up the screw post. Just try a different screw. (This applies particularly when using spare computer case screws, as they can vary in size.)

Wiring the PSOne Screen to the PC Boards

Flip your portable over and take a look at it. Wow, it's come a long ways, eh? After basking in its beauty, flip it back over. We're now going to connect the PSOne screen to the PC boards. This will provide power and an amplified video signal to the screen.

Go to the ribbon cables you snipped at the base of the PSOne screen. For now, we're interested in the two-strand on the right (as viewed from the rear, with the unit facedown). The blue wire is *+7.5 volts in* and the other is *ground*. Use a couple of small wires to extend these and attach them to the *+7.5 volts to screen* and *ground to screen* spots on the right PC board. These spots were indicated in Figure 7-24, back in the *Making the right PC board* section.

Now for video! Take a look at the other remaining PSOne cable, the one with three strands. If you look on the board, you'll see these labeled as EXT_V, EXT_R, and EXT_L. These are the video and right and left audio (note the letters at the end of each indicator). Twist the ends of the two white audio wires together (since the NES is mono), and extend the blue video wire in order to connect it to the *video out to screen* spot on the left PC board, as indicated in Figure 7-20 back in the *Making the left PC board* section. Connect a 10" wire to the spot marked *video in from NES* on the same board. This 10" wire, along with the combined audio wires, will connect directly to the NES motherboard.

Putting a power regulator on the NES board

Hey, it's our old friend the NES board! Remember it? Before we begin, make sure you've prepared the NES board as indicated in Chapter 6. This includes removing the expansion slot and the power on/off plug and mashing down capacitors.

1. Plug the black cartridge connector back onto NES as you originally found it. The raised portion that the cartridge sticks into should be on the solder side (the side opposite the parts on the board).
2. Set the NES board on your work surface parts-side up with the cartridge connector near the bottom of the front of the case, as seen in Figure 7-28.

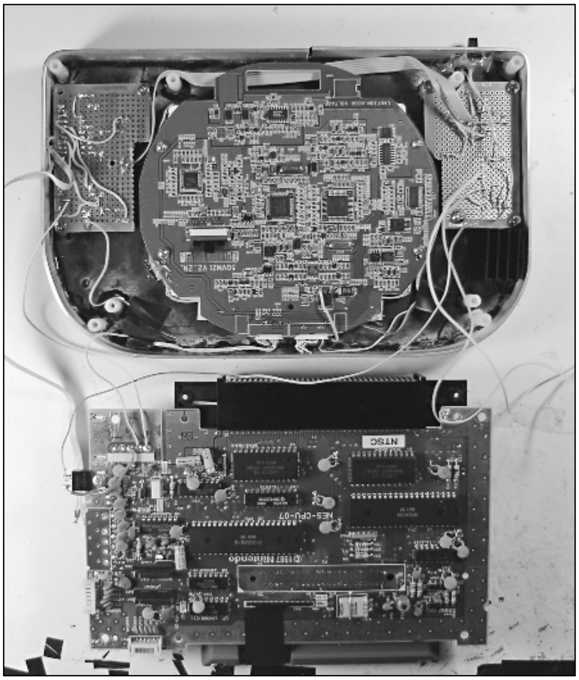


FIGURE 7-28: Proper final wiring positions.

3. Attach a 7805 regulator to the existing screw hole as shown in Figure 7-29. Use a short size-6 screw, lock washer, and nut to secure it. Bend the middle prong over backward, and use a bit of wire or paper clip to solder it to the ground (metal) portion of the other side of the board, as shown in the insert.

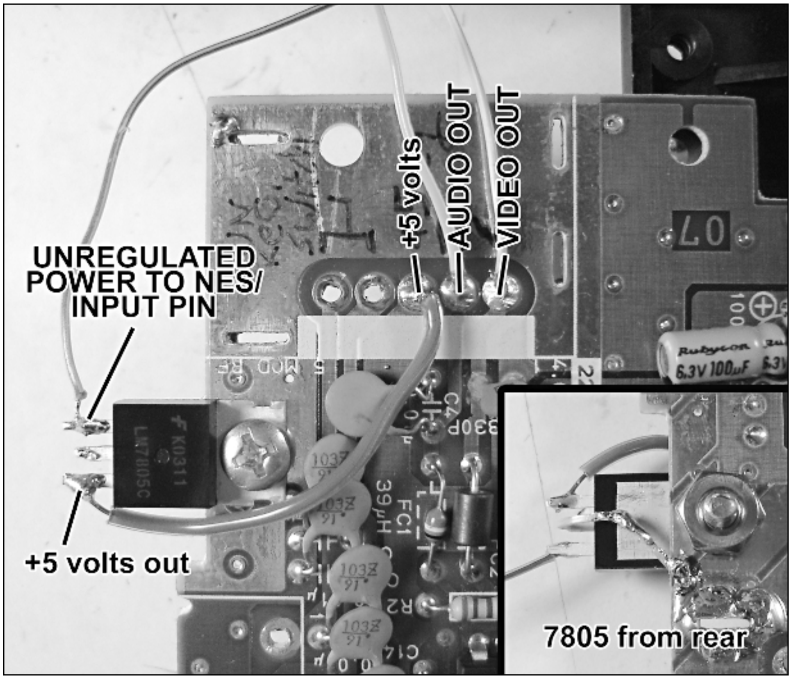


FIGURE 7-29: The 7805 regulator attached to the NES, with connections made.

4. In this same area, connect the following:
   - Connect a short, stiff solid wire from the *+5 volts OUT* on the regulator to the *+5 volts IN* spot on the NES.
   - Connect the *video IN from NES* wire from the left PC board to the *video out* spot on the NES board.
   - Connect the two interconnected audio wires from the PSOne screen to the *audio out* spot on the NES board. (They may reach already and not have to be extended, depending on how long you cut the cable.)
   - Connect an 11" wire to the input pin of the regulator. This will be the *unregulated power to NES* wire.
5. On the right PC board, there's a spot marked *unregulated power in*. (Again, look back at Figure 7-24.) Connect one wire from the on/off switch to this spot. Then connect this spot directly to *unregulated power to NES* on the 7805 regulator as indicated in Figure 7-29.
6. There should be one wire left that goes to the on/off switch. This will be called the *power switch input wire*.

7. Connect a 5” wire to the spot marked *ground to screen* on the right PC board. Connect the other end of this wire to the nearest metal edge on the NES board. Make sure to melt the solder well on the NES side for a good connection. Scrape the metal on the NES to freshen it up if necessary.

Power in, ground, audio, and video have now been connected to this NES unit.

Reattaching the controllers

All right, this is the home stretch! Getting excited? In this section, we’ll connect the built-in game controller from the PC boards to the NES motherboard. This will allow you to control your in-game character and not just watch the title screen! (Always an important ability to have.)

1. Take the five-strand of cable that’s attached to the IC on the left PC board. We made a black mark on one of the wires — this is #1 and the opposite side wire is #5. Connect them to the spots indicated in Figure 7-30.

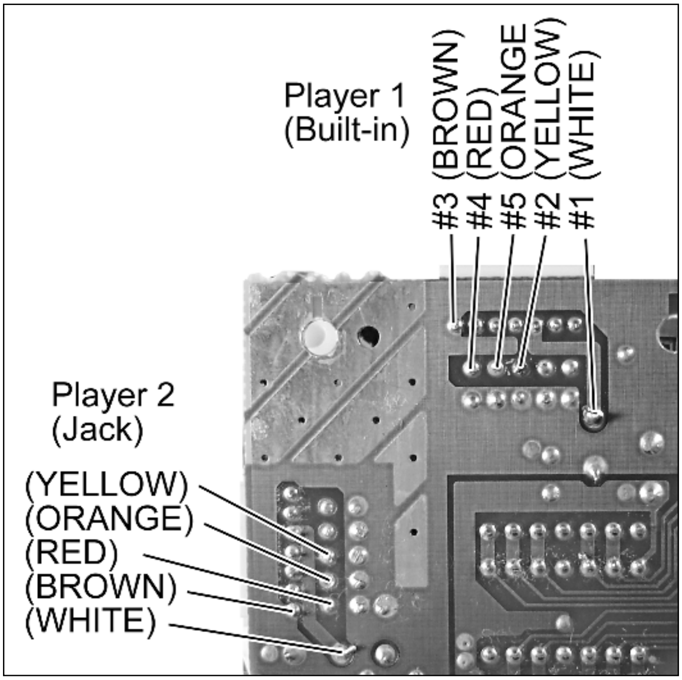


FIGURE 7-30: Reconnecting controllers.

2. Attach a five-strand of 11” ribbon cable to the spots indicated for the Player 2 port. These will be connected to the colored wires on the Player 2 port; however, this should be your final step before screwing the unit together. (Don’t worry — I’ll remind you.)

Tip

If your five-strand controller ribbon cable from the left PC board is too short to reach the NES board, you can use the original plug that goes into the NES board and the color-coding to connect it.

Let's install the NES board into the front of the case! Make sure the black cartridge slot has been reattached to the motherboard, and then place the NES into the front half of the case as shown in Figure 7-31. Do the following:

- Tuck in any excess ribbon cable below the board.
- Put a couple layers of electric tape on the right-hand side of the board so that it is insulated against that heat sink.
- Finally, make sure the loose wire going to the power switch (the power switch input wire) is above the board so that you can still get at it.

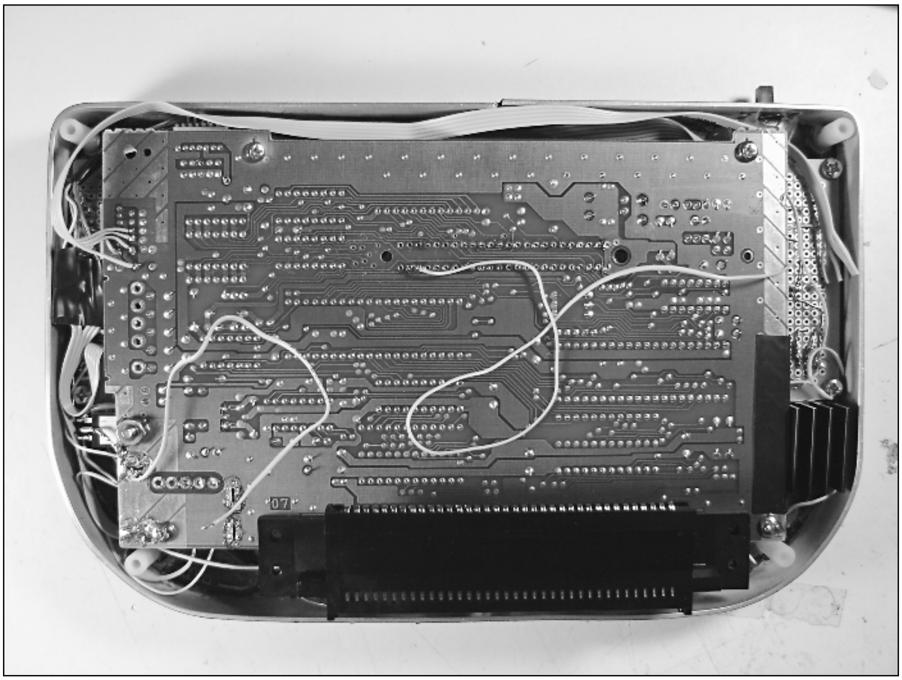


FIGURE 7-31: The installed NES board.

The length of the ribbon cables here may seem a bit long, but keep in mind that if you have to go back and fix something, or open the unit for some other reason, you'll want to be able to lay out the NES board flat. Short connections wouldn't allow this.

Note You may wish to leave the NES board loose and unscrewed until you've had a chance to see if the system is functioning correctly.

With the NES motherboard in place, use four computer case screws to attach it to the screw posts. If some aren't quite right, you can bend them a little, but otherwise, three out of four ain't bad. The bottom two near the cartridge connector are the most important. You can also use hot glue for additional impromptu connections as needed.

Attaching the power connectors

The unit is now completely wired, with the exception of the *battery connector* and the *DC auxiliary power input jack*. Because powering the unit is pretty important, we'll install these parts in this section. They install in the rear half of the case, so grab that section now.

1. Make a small 1/8" pilot hole in the metal wall just below the battery door. (The area is shown in the next figure.) Then use the pilot hole as a guide to drill a bigger 15/64" hole. After making the hole, wrap your 1"-wide vinyl (or other covering as discussed in the materials section) around the rear case wall, and then cut out the hole you just drilled.

Tip Using differently colored vinyls for the sides of the front and rear will help to hide—how shall I put this—"imperfections" in the bending of the aluminum. (I disguised my mistakes by using black for the front and gray for the rear.)

2. Insert the phono jack (Radio Shack catalog #274-246A) into the hole as shown in Figure 7-32, and screw the retaining ring on from the outside of the case. Get one of your Size K coaxial power jacks, and connect everything together as shown.
3. Get out your size K coaxial power jack (Radio Shack catalog #274-1565).
4. There are five leads on the phono jack—we'll be using four of them. The list below refers to numbered spots in Figure 7-32 and indicates how to connect the phono jack to the size K coaxial power jack and the rest of the unit:
   - (#1) To the *positive* of the battery connector jack
   - (#2) To the *negative* of the battery connector jack
   - (#3) To the *power switch input wire*
   - (#4) To the metal ground of the NES board (near the 7805 regulator is closest)

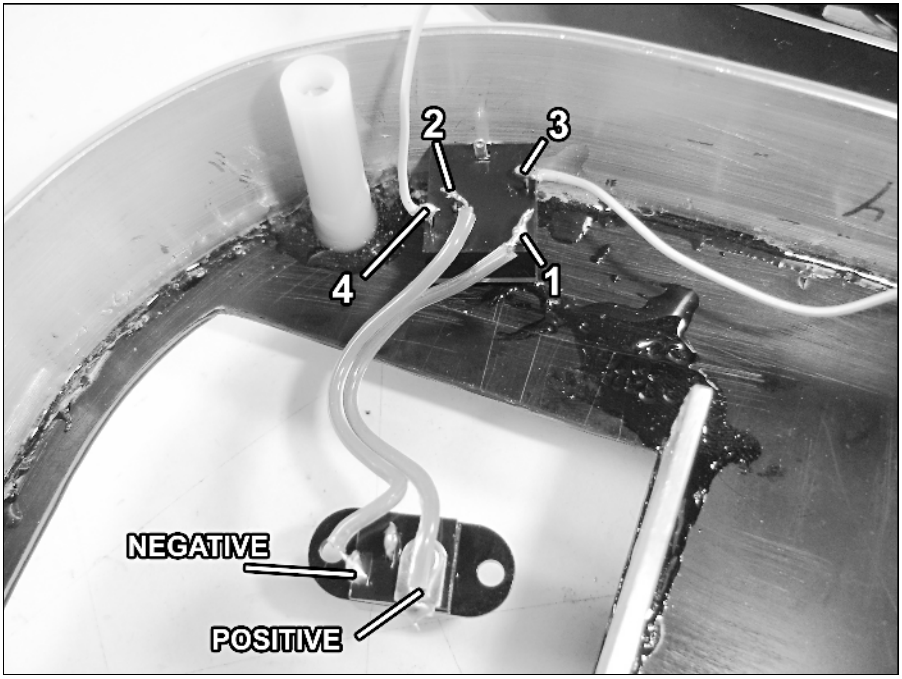


FIGURE 7-32: The auxiliary DC input jack installed in the rear of the case, along with the battery connector.

After you've tested the unit to see if it works, you can cover the plugs with glue and electric tape to avoid short circuits.

5. Now take the rechargeable battery pack itself, and snip off the white connector. Replace it with a size K coaxial power plug (Radio Shack catalog #274-1567a) as shown in Figure 7-33. The red wire goes to the center pin (positive), and the black wire to the outer pin (negative).

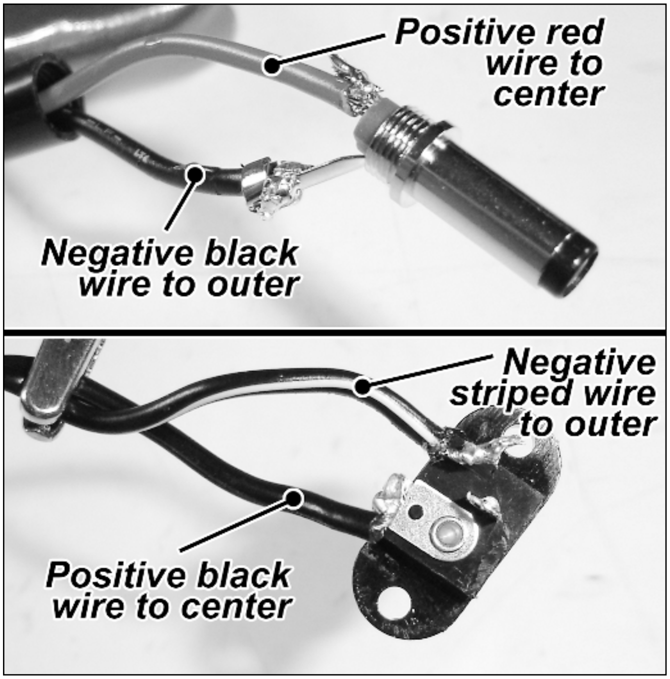


FIGURE 7-33: TOP: The plug replaced on the battery pack.
BOTTOM: The jack connected to the battery charger.

Caution

Be sure to wrap one of the leads with electric tape so it won't short out against the other. It may be hard to push the plastic sleeve back over the plug after attaching these wires, so you may wish to wrap it with electric tape instead. (Remember, it's *inside* the unit — nobody will see it.)

6. Snip the white plug off the end of your battery charger's wire. Attach the other size K coaxial jack to it as shown in the figure. The wire with the white stripe goes to the outer pin (negative), and the plain black wire goes to the inner pin (positive).

The battery and DC auxiliary power input connections are complete. Your portable NES now has the ability to be turned on and played!

Testing and Troubleshooting

Now that the unit is wired, it's time to test it out and see if everything is working. We'll take these tests step-by-step. For each step, we discuss what to check if a test fails and the most common solutions. Once we reach the end of the section, your portable will be all checked out and ready for some final assembly before closing it up.

1. Charge up the battery using the wall power charger. It doesn't have to be fully charged to do these tests, but you should keep it on the charger long enough to get 9–10 volts on the battery when you test it with the multimeter. If you're using a dual Ni-Cd/Ni-MH charger, be sure you flip the switch to the type of battery you're using.
2. Insert the battery into the size K coaxial jack inside the battery door. Be sure it's fully seated in the jack.
3. Insert a game, preferably one that plays music right away without having to press start (such as Ninja Gaiden, Zelda 2, or Mega Man 2).
4. Flip the power switch on. The screen should light up. If it doesn't, do the following:
   - First check to see that at least 9 volts are coming off the battery. The regulator that powers the screen drops out (quits) at around 8.8 volts. Is the battery adequately charged?
   - Check the spot where you hooked the blue power line coming from the PSOne screen (labeled *+7.5 volts to screen* on Figure 7-24). That spot should be spitting out 7.5 volts to send down that wire. If it's not, double-check the circuit around the regulator (the one with the heat sink attached to it).
   - See if +5 volts is going to the 10-ohm resistor that is connected to the white LEDs. Check to see that the grounded lead on each of the LEDs is properly connected to the PSOne screen's motherboard.
   - Make sure that the battery, the DC auxiliary input jack, the NES motherboard, the right PC board, and the PSOne screen all share a common electrical ground. One missing link in the chain of ground connections will stop the unit from working.
5. Once the screen lights up when the power is switched on, check that the NES's game picture shows up on the screen. If not, do the following:
   - First, press the volume or brightness control buttons. If the green-colored indicator bars for those values appear on the screen, then there's a problem with the NES or with the video connection. Skip ahead to Step 6.
   - If the volume/brightness indicators do not appear on the screen, then you need to double-check the LCD's ribbon cable. It may not have been completely reinserted (see Chapter 4).
6. If the screen is working, then the problem lies with the NES or with the video connection. Check each of the following:
   - Did you use a 2N4401 transistor for the video amplifier on the left PC board? If you got a transistor from a "grab bag," you may not have the right type. Replace the transistor with a different one from the grab bag, or get a single 2N4401 transistor.
   - Did you clean the cartridge slot and bend up the pins as described in Chapter 6? If not, the cartridge contacts might not be making good connections. Do that maintenance, and try it again.

- If the screen blinks gray (or another color), then you simply need to continue cleaning the cartridge slot (and/or the cartridges) until it works. This is a dirt-and-grime issue.
- Check that the *video out* spot on the NES motherboard is connected to the *video in from NES* spot on the left PC board. Check that the video amplifier circuit matches the drawing and instructions shown in the *Making the left PC board* section of this chapter. Finally, check that the check that the *Video out to screen* spot is connected to the blue wire on the left plug of the PSOne screen (the wire marked EX_V).
- If you have checked the wiring of the video circuit and it looks okay, but there is only a very dark picture on the screen, then the likely cause is that +5 volts isn't getting to the circuit. Double-check the part placement for the left board and that the five wires connected to the IC on that board are hooked up correctly, as they deliver the +5 volts to the video amplifier circuit. If this seems to be the only option left, skip ahead to the controller troubleshooting.

Once you've verified that the picture, sound, and controls are working, you can finish up the construction and assembly of the portable.

Final Assembly

With the portable now tested and working, you can finish assembling it. This includes installing the foam spacer, wiring the Player 2 port, closing the unit up, and adding some final decals. We'll also discuss how to use the DC auxiliary jack to run the unit off wall power.

1. Screw each of the 1-1/4"-long size-6 screws through the rear plate until they just show at the top of the rear screw posts.
2. The only wire that should be going over the back of the NES board is the power wire that goes from the phono jack to the main switch. Fix it in place with electric tape so that it doesn't float down in the way of the cartridge connector.
3. Use four computer case screws to install the NES board in place if you haven't done so already. (This was described earlier, but I suggested waiting until you'd finished tested the unit.)
4. Insert the 1/4" foam spacer into the rear case. Pull the Player 2 wires up through the square hole.
5. Attach the five-strand Player 2 ribbon cable coming off the NES to the colored wires coming off the Player 2 port, as shown in Figure 7-34. Put a small piece of electric tape around each solder connection in order to avoid short circuits (not shown in the figure).
6. Cut a 1" × 4" piece of 1/4" foam and hot-glue it against the base of the rear case (as shown in the figure). This will fit behind the cartridge connector and keep it from pulling loose from the NES motherboard.

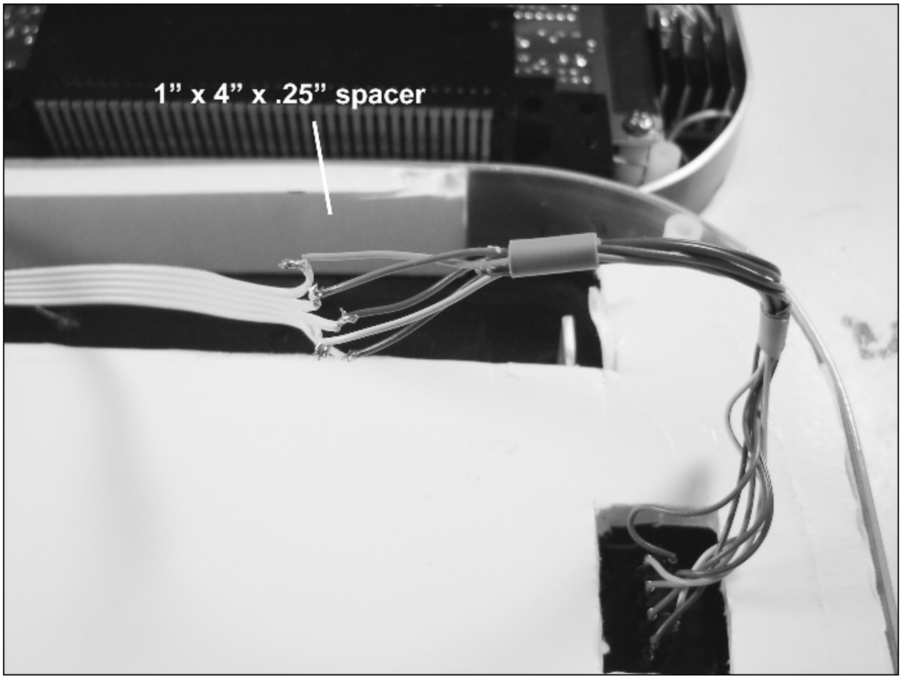


FIGURE 7-34: Attaching the Player 2 cable to the jack and the 1″ × 4″ spacer.

7. Tuck the long Player 2 ribbon cable under the top of the screen so that it goes over to the right, where the plug is on the back, and stays out of the way of the cartridge (hopefully that long cable now makes sense). This will cause the two halves to kind of pull toward each other, but that's okay because we're connecting them now. If the plastic cartridge connector bumps against the 1/4” foam spacer in the rear, it's easy enough to correct — slice away some foam. Other parts may possibly push into the foam, and you can gouge a space for them if you wish.
8. Fold the two halves of the case together and drive the four screws the rest of the way. You might notice that the aluminum walls don't quite match up in places due to the fact that this project is hand-built. The front and back screw posts should match, however, since their placement was based on a flat template.
9. Apply the final decals to the unit:
   - AUX DC 9 volts decal: Near the phono jack
   - ON/OFF decal: Below the on/off switch with the ON position toward the middle of the unit
   - Player 2: Around the player 2 port hole
   - Portable name/designed by/built by label: At the back of the unit near the base of the rear plate — write your name in the provided “Built by” spot.

10. If some edges of the aluminum overlap the engraving plastic too much, you can use a black felt-tip marker to color it so that it matches better.

11. Because of the manually bent aluminum, the front and rear of the unit may bow in or out, as seen in the upper portion of Figure 7-35. You can use pieces of vinyl to pull the sides together and reduce the amount of bowing, as seen in the lower portion of the figure.

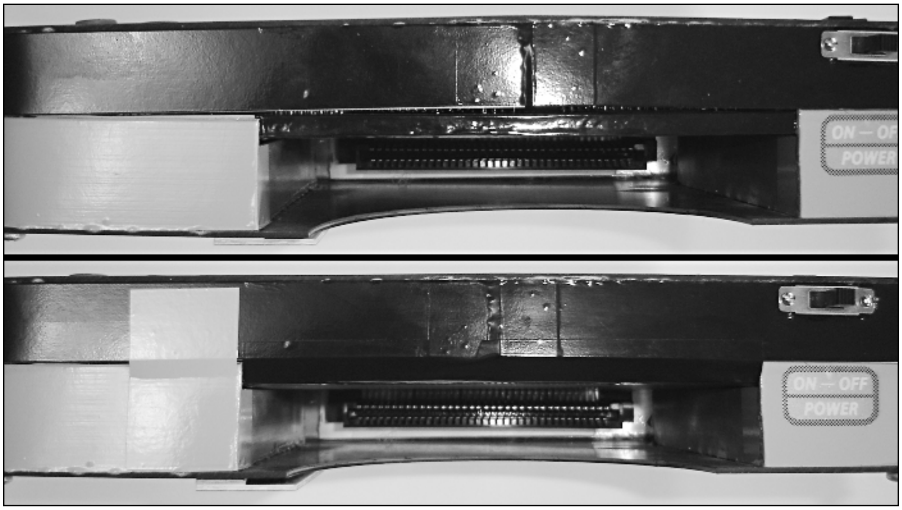


FIGURE 7-35: Using vinyl to straighten the case, before (above) and after (below).

12. If the battery pack shifts around when inserted in the unit, you may want to use a bit of Velcro to connect it to the foam spacer. To make it easy to remove after doing this, put a small tab on the front so you can pull it out (electrical tape works fine for this).

Congratulations, your hand-built portable Nintendo Entertainment System is finished and ready to be played!

Using a DC wall power adapter

Naturally, you can play your portable NES using a battery, but if you're at home or anywhere near a power outlet, you may wish to use a DC wall power adapter. You can use a multivoltage adapter or one with a fixed voltage, as long as it meets the following requirements:

- Can provide at least 750 mA of power. Most higher-power adapters provide between 800–1000 mA, which is sufficient for this portable.
- Ouputs +9 volts DC power.
- Has a 1/8" minijack (which looks like a mono headphone jack), with the center set to positive, and the outer to negative.

You can find adapters of this sort at most electronics retailers. Radio Shack stocks an adapter (catalog #273-1667) that, combined with an Adaptaplug (catalog #273-1709), will work as well.

Chapter in Review

Building a portable Nintendo Entertainment System is a great way to relive some fun gaming memories of the past, and building it by hand is within the technical and financial reach of most gamers. In this chapter, you

- Built a custom case for the NES portable by hand, using thin engraving plastic and strips of aluminum.
- Wired up new custom built-in controllers using printed-circuit boards and integrated circuits from old NES controllers.
- Attached a PSOne screen for use with a NES.
- Installed a NES motherboard (that you modified in Chapter 6) into your custom case.
- Connected all these components together, along with a battery, in order to make the unit portable.

The end result is that you now have a portable NES that you can take wherever you go. Have fun with it and show all your friends, but keep these pointers in mind:

- Don't drop the unit or allow it to get crushed — the hand-built case or the screen may get damaged. A small case, such as a camcorder or camera bag, makes a great portable transporter ("portable transporter"... that's certainly a redundant Möbius strip of a phrase).
- If you take this thing on an airplane, remove it from its bag, as you would a laptop computer, when you put it through the scanner. Be ready to turn it on and play it if they ask questions. Imagine how confusing the rat's nest of wiring inside must look on an X-ray.
- You can use a car power adapter to run the unit — just follow the same guidelines as for the DC wall power adapter.

Building a Portable Nintendo Using CNC Machinery

chapter

8

in this chapter

- ☑ Materials You'll Need
- ☑ Routing the Parts
- ☑ Hacking More of the NES
- ☑ Assembling the Parts of the Case
- ☑ Wiring the Unit
- ☑ Testing and Troubleshooting
- ☑ Final Assembly
- ☑ Chapter in Review

So you've found a CNC machine (router or laser engraver) that you can use and you're ready to try your hand at a portable NES. Well then, feast your eyes on what you can build! (Feast on Figure 8-1.)

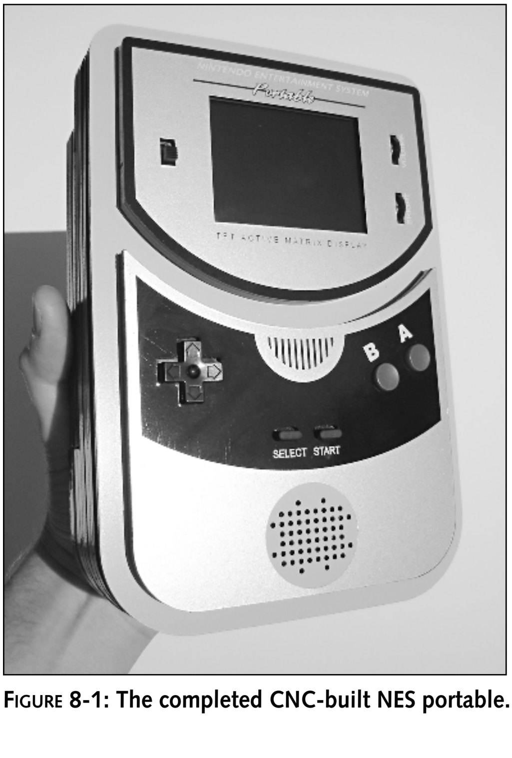


FIGURE 8-1: The completed CNC-built NES portable.

In this chapter, we'll collect the components to build this unit, get the case parts cut with a CNC machine, assemble the case, and then wire the NES board, screen, and controls into it. In Chapter 6, we already made some modifications to the NES's motherboard. We'll be doing a bit more modification to it in this chapter as well, mostly concentrating on the cartridge slot.

When you're done, you'll have a portable NES in its own perfectly formed CNC-built case. Let's get started!

Materials You'll Need

In this section, we'll list and talk about the materials you'll need to obtain in order to build this portable NES project, starting with the major components.

- A NES motherboard that has been modified, as described in Chapter 6. The motherboard should have the expansion port, the RF box, and a few of the jacks removed.
- The 16-pin IC (integrated circuit or "chip") desoldered from a standard NES controller, also described in Chapter 6.
- A Casio EV-680 pocket TV modified with white LEDs, as described in Chapter 4.

The rest of the materials you'll need are listed throughout the following sections, with the exception of the plastic for the case itself, which will be listed in the *Routing the Parts* section.

Electronics

Table 8-1 lists the electronic components you'll need for this project. Please note that this list does not include parts required to modify the pocket TV — those were covered in Chapter 4.

To make locating parts as easy as possible, I use parts from Radio Shack, even though you can get things like transistors and regulators anywhere, because most of the required electronic components are available at your local Radio Shack store. This also standardizes things, so that, for example, you'll be using the same size PC board as I did, allowing the accurate placement of parts.

Since many packages contain more than one of an item, the total number of packages you need is listed, rather than actual number of components. The tact switches can be ordered from Digi-Key, a electronics supplier whose Web site can be found at www.digikey.com.

Table 8-1 Electronic Parts List for Building a CNC NES Portable

Part Name	*Available From:*	*Part or Catalog #*	*Quantity/Packages Required*
Transistor 2N4401 (NPN-type)	Radio Shack	276-1716	1
220-ohm resistor	Radio Shack	271-1111	1
33-ohm resistor	Radio Shack	271-1104	1
47K-ohm resistor	Radio Shack	271-1130	2

Part Name	*Available From:*	*Part or Catalog #*	*Quantity/Packages Required*
Grid-style PC board (71mm × 94mm)	Radio Shack	276-147	1
7805 linear voltage regulator	Radio Shack	276-1770	1
Coaxial DC power jack (Size K)	Radio Shack	274-1565	1
Coaxial DC plug, 5 mm OD, 2.1 mm ID (Size K)	Radio Shack	274-1567a	1
Ni-Cd 7.2 volt, 2000 mAH battery pack	Radio Shack	23-330	1
Ni-MH/Ni-Cd battery charger	Radio Shack	23-333	1
Submini slide switch	Radio Shack	276-406	1
Tact switch, 6 mm	Digi-Key	EG2495-ND	8

Other suppliers, such as Digi-Key (www.digikey.com), will stock many of these parts as well, but you'll have to search by the name of the item rather than a part number. Digi-Key has a minimum order of around $25, so it's not a bad idea to stock up on whatever you need to reach that amount, such as the white LEDs for the TV mod. You may also be able to find the battery and charger at toy and hobby stores — check the photos of the battery near the end of this chapter so that you'll know what to look for. You can also use a Ni-MH version of the battery with more power (and a slightly higher price).

Screws, nuts, and washers

Take a trip to your local hardware store, and find the section with various bins filled with multiple types of screws and fasteners. Purchase the following items:

Table 8-2 Screws, Nuts, and Washers to Get

Screw/Nut Size	*Type*	*Length*	*Quantity*
Size-6 screws	Phillips, pan (round head)	1 1/4″	4
Size-6 screws	Phillips, pan (round head)	3/8″	3
Size-6 socket-head cap screw	Uses 7/64 hex wrench	1 1/4″	2
Size-4 screws	Phillips, pan (round head)	1 1/4″	2
Size-4 screws	Phillips, pan (round head)	1/2″	2
Size-4 screws	Phillips, pan (round head)	1/4″	16
Size-6 nylon washer	Nylon, 1/4″ outer diameter	N/A	16
Size-6 nut	Standard	N/A	11
Size-4 nut	Standard	N/A	2

Note

These parts are all fairly common, though you may need to visit a large hardware store to find everything in one visit.

Other stuff you'll need

The following items don't fit neatly into a category, but you'll need to get them nevertheless. All of this stuff is available at a hardware store or megamart.

- Sandpaper: Fine grit; one small sheet will suffice.
- Several glue sticks, and of course the gun.
- Superglue: One tube, either gel type or liquid. Gel is slower, but won't spill and make mistakes; liquid is faster.
- Electric tape: Have a roll on hand during this project.
- Epoxy: Used for sealing and securing things. Five-minute "quick" epoxy works best, as you won't have to wait 24 hours before continuing to work on something that you've just glued.
- Hacksaw and blade: You'll be cutting both metal and plastic with it, so get a metal-cutting blade, and you'll be covered both ways.
- Electric drill and the following sized bits: 1/10" (or the closest to that), 1/8", and 13/64"

Printing decorative decals for the unit

Nobody wants a plain-looking portable without any decoration on it! That's why I've made files available that can be used to print complementary decal graphics — visit www.wiley.com/go/extremetech (the "NES CNC" file) to download any of the following alternatives. Some of the graphics will be applied during (rather than after) the construction process, so it's best to get them made before you begin. Here are your graphic-printing options, with the appropriate file for each:

- **Using your own printer.** You can print the decal file to sticky-backed paper, and then cut the edges and holes manually with your X-Acto knife. "CNC NES decals.pdf" should open on any computer with Adobe Acrobat installed, and you can also use "CNC NES decals.wmf," "CNC NES decals.jpg," or "CNC NES decals.ai." Print the graphics at normal size, with no scaling. Please note that you may have to reduce or eliminate the page margins in order for the graphics to fit. After printing the graphics, measure the decal for the screen — it should be 5" wide. If not, check the printer settings and try again.
- **Sign shops/vehicle lettering shops.** These sorts of places are very likely to have a thermal vinyl printer, which is the kind of machine that prints the fancy graphics you see on truck doors. The advantage is these sorts of graphics are damage-resistant and therefore great for a portable that will be handled a lot. Provide the shop with the file "CNC NES decals.plt" and ask them to print it on black or somewhat dark vinyl. If they need a different type of file, offer the "CNC NES decals.ai" file or the "CNC NES decals.wmf" file.

If you're using PVC plastic for the side walls, you may also want to consider getting some vinyl stripes from the vinyl/sign shop while you're there. You can use these to cover the sides of the unit for a nice, finished look. Get the following size stripes cut in the color of your choice: two 1" × 30", one 3/4" × 20", and two 1/4" × 25". I'd suggest black, gray, or whatever color you think goes best with the engraving plastic on the fronts (more on those in the next section).

Tip

If you print your own graphics, consider using a can of clear acrylic spray (clear-coat spray paint) to coat them before applying them to your portable. This will help prevent smudging and ensure longevity.

Routing the Parts

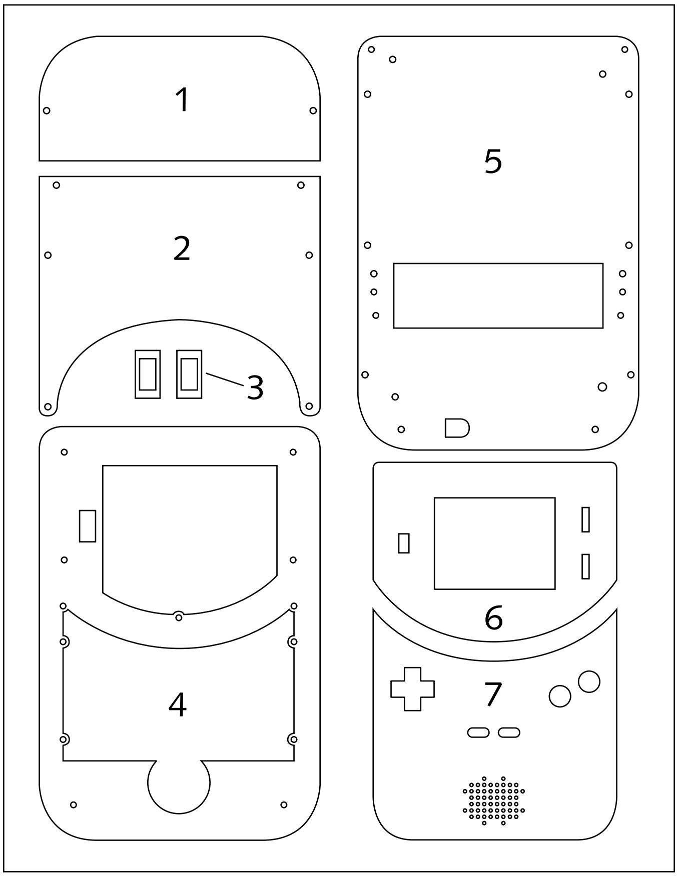
You'll need to get all the parts for the case routed before you can start building this project because the case is what everything goes into! In Chapter 5, we discussed the types of CNC machines and where to locate them, so refer back to that if you have any questions during this section.

The parts to assemble the CNC-built NES case consist of *plates* and *walls*. We'll talk about what they are and what they'll look like first, then about how to CNC-cut them.

Plates

Plates are CNC-cut from 1/16"-thick engraving plastic stock. They are used for the fronts, backs, and most of the other visible surfaces of the case. You'll need a 12" × 24" piece of it to make all the parts. I'd suggest a light gray "Nintendo" color — it'll look the best with the decals. Most places that do CNC cutting (especially laser-cutting) will want to sell you the material, rather than have you bring some in. They'll have a sample book or catalog that you can choose from, or you may want to specially order something that strikes your fancy.

Figure 8-2 displays all the plates that need to be cut for this project, and following is a list that identifies them by number. These names will come up later in the *Assembling the Parts of the Case* section, so use this drawing as your main reference.



1) Battery holder plate
2) Cartridge holder plate
3) Power switch risers
4) Front plate
5) Center match plate
6) Screen riser plate
7) Control riser plate

FIGURE 8-2: The plates for the CNC-built NES (made of 1/16"-thick engraving plastic).

Laser-cutting the plates

To CNC laser-cut the plates, provide one of the following to the laser operator, depending on what size machine they have:

- **CNC NES Plates Laser 12X12 1.cdr** and **CNC NES Plates Laser 12X12 2.cdr:** Have the laser operator cut both these files, one at a time, if they have a small 12” × 12” laser bed. This will consume two pieces of 12” × 12” material, slightly more than required when doing it all at once on a larger bed.
- **CNC NES Plates Laser NORMAL.cdr:** This has all the plates in one file, and requires material measuring about 12 1/4” × 16 1/2”. Give this file to the laser operator if the machine has a large enough bed.

Tell the operator to make vector cuts completely though the material on all black hairline strokes. If they mention that “the holes might not be accurate” or something like that, tell them you’ll be covering them all with screws anyway. It’s also not a bad idea to print out the file “CNC NES Plates Example.pdf” so that you can show the laser operator what the job looks like beforehand, or just show them Figure 8-2 and tell them that the total area used will be 12 1/4” × 16 1/2”.

Routing the plastic plates

If you’re going to have the plastic plates cut by a drill-bit router, you may need to buy the engraving stock yourself, because businesses with routers are less likely to keep it on hand, and even if they do, their selection will probably be limited. Check with the router operator first, and if they don’t have any that you like, locate some elsewhere, as described in Chapter 5, and bring it into them. You’ll need a 14” × 17” piece.

Ask the router operator what type of file they prefer, and then provide them with one of the following: “CNC NES Plates Router.plt,” “CNC NES Plates Router.eps,” or “CNC NES Plates Router.ai.” You can use the aforementioned “CNC NES Plates Example.pdf” file to print out an example, or use Figure 8-2 to show them beforehand. The total area of material that will be cut is 14” × 17”.

Have the router operator do the following with the file (remember, printing out the example file will help a lot when ordering the job):

1. Make the 1/10” holes by doing a female cut with a 1/16” bit.
2. Drill the 1/8” holes with a 1/8” bit.
3. Make all the inside shapes by doing a female cut with a 1/8” bit.
4. Cut the outsides of the shapes by doing a male cut with a 1/8” bit. This will remove the parts from the main sheet of plastic.

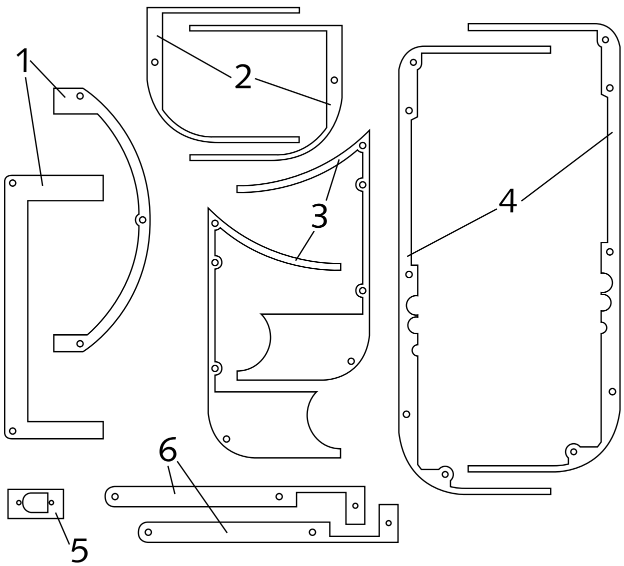
Note

Your best bet for making the plates for this project is a laser engraver. This is because of the large number and multiple sizes of screw holes — a laser can simply cut these out, whereas a router needs tool changes to accommodate the different sizes.

Side walls

Side walls are CNC-cut from 1/4” pieces of plastic. They are attached to and stacked on the sides of the plates to create the depth of the unit. You’ll need a 12” × 24” piece of 1/4”-thick material to cut them; the type of material to use depends on whether you’re using a router or laser. Suggested materials for each type of machine will be listed in the wall-cutting sections.

Figure 8-3 shows all the side walls that will need to be cut for this project. Notice that ten of them come in pairs; the name of each pair is given in the following list. Most of these pairs will be cut multiple times, so that they can be stacked to create deeper sections. The number of times each pair will be cut is also indicated.



1) Screen riser walls: one pair
2) Battery holder walls: four pairs
3) Control riser walls: one pair
4) Front side walls: four pairs
5) Battery jack riser (this is a single piece)
6) Cartridge holder walls: three pairs

FIGURE 8-3: The 1/4″-thick side wall parts for the CNC-built NES.

Most of the paired parts are symmetrical, so it doesn’t matter whether you use a piece of a pair for the right or the left. The exceptions are the screen riser walls, which I’ll remind you about when we install them.

Laser-cutting the side walls

If you’re going to cut the side walls using a laser engraver, you should first pick the type of 1/4”-thick material to use. The exact size of material required depends on what size laser-engraving bed the business has (more on that in just a bit).

- **Acrylic.** This is a fairly common type of material to cut in a laser engraver. Places with laser engravers may have some 1/4” acrylic on hand, or you may have to purchase some from a glass or sign shop. (Remember, they’ll probably want to sell you stuff they have in stock.) A free “feature” of laser-engraving acrylic is that the edges are automatically fire-polished, making them look smooth and painted. If you use clear acrylic, you could have a completely transparent unit, or cover the edges with vinyl or paint. I used black acrylic; it has a really neat look and is opaque (not see-through).
- **Wood.** This is less likely than acrylic to be available, but might be worth asking about. Again, you’d need to use 1/4”-thick pieces. Using wood will make for a more lightweight portable and will be easier to insert screws into. (It can also potentially increase the unit’s popularity in the folk-art circuit.)

Once you’ve chosen a material, provide the laser operator with the file(s) listed below, depending on what size machine they have:

- **CNC NES Walls Laser 12X12 1.cdr** and **CNC NES Walls laser 12X12 2.cdr.** This will require two 12” × 12” sheets of 1/4”-thick material. Provide these files if the laser engraver has a 12” × 12” bed.
- **CNC NES Walls Laser NORMAL.cdr.** This will require one 13” × 16” piece of 1/4”-thick material. Provide this file if the laser engraver has a larger bed.

Tell the operator to make vector cuts completely though the material on all black hairline strokes; this will cut all the required parts on the file(s). Don’t forget to print the file “CNC NES Walls Example.pdf” beforehand in order to give the laser operator an idea of what you’d like to do.

Routing the side walls

If you’re using a router to cut the side walls, you should first pick the type of 1/4”-thick material to use. (This may depend on what the business has in stock.) The three best choices, with the fastest-cutting material listed first, are as follows:

- **PVC plastic.** This can be cut through very quickly and is pretty reasonable in price. It’s also the weakest of the materials listed here, but when it’s used in a case, it will gain strength from the glue and screws.
- **Wood.** Wood can be cut at a fairly reasonable speed and is a good choice if you want to make an interesting-looking portable.
- **Acrylic.** You can use this, but it takes longer to rout (which means more cost) and won’t have the nice fire-polished edges that laser-cut acrylic does.

Whichever type of material you choose, you'll need a 20" × 12" piece of it. To have it routed, do the following:

1. Provide the router operator with one of the following files, depending on which one the software handles best: "CNC NES Walls Rout.plt," "CNC NES Walls Rout.ai," or "CNC NES Walls Rout.eps." (Ask beforehand which file types they can take.)
2. Have the router operator use the file to do the following to your chosen material:
   a. Drill the 1/8" holes with a 1/8" bit.
   b. Make the 1/10" holes by doing a female cut with a 1/16" bit.
   c. Cut the outsides of the shapes by doing a male cut with a 1/8" bit. This will remove the part from the main sheet.

Remember to print out the file "CNC NES Walls Example.pdf" beforehand to show them what you're planning to have done. As mentioned earlier, the total area of material used to cut all these side wall parts is 20" × 12".

Routing recap

In this section, we've introduced the two main types of parts for the CNC-built NES:

- *Plates*, made from 1/16"-thick engraving plastic
- *Side walls*, made from 1/4" materials.

We cut these parts using a laser engraver or a router, depending on which you have access to. The end result is a bunch of parts that look like the shapes depicted in Figures 8-2 and 8-3. Before continuing, check over your parts against these figures in order to ensure that you have all the parts you need and the proper number of each.

Hacking More of the NES

In Chapter 6, you removed quite a few things from the system and motherboard in order to prepare it for the projects in this and the previous chapter. For this particular project, however, there are a few more modifications to make on top of the ones you've already done.

1. Start by desoldering and removing the two beige controller connector jacks from the corner of the board. These were identified in Chapter 6, and have seven leads each.
2. A thin strip of the main motherboard itself needs to go as well. Use your X-Acto knife to slice several deep grooves along the line of small holes seen in Figure 8-4. You can then snap this piece off the NES board. The removed portion should measure about 1/8" × 4-3/4".

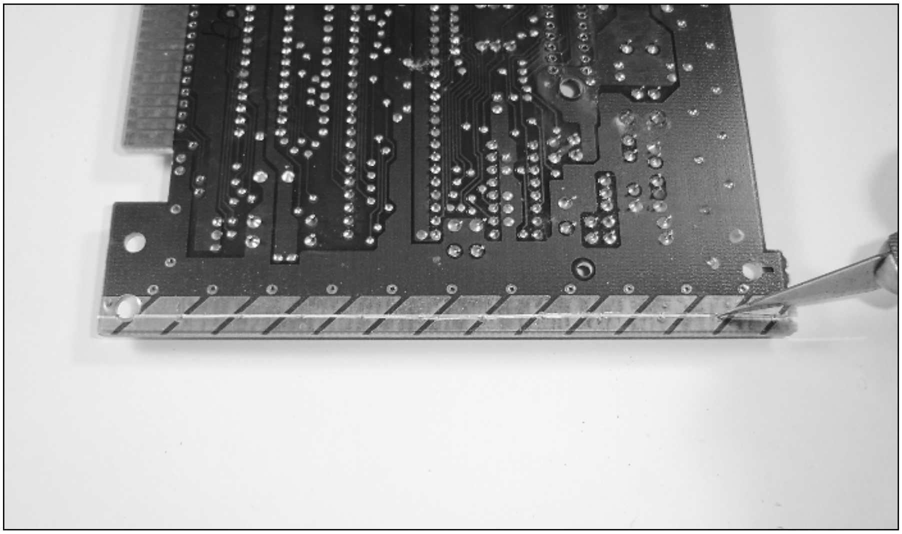


FIGURE 8-4: Where to slice off part of the NES motherboard.

Hacking the cartridge slot

I had a hard time finding a suitable replacement card-edge connector to serve as a new cartridge slot for the NES, so for this portable, we're going to have to use the existing one. Hey, look at it this way — it's free because it comes with the NES! If you recall from taking apart the NES, one end of the connector is connected to the NES, and the other to the cartridge. For this project, we're going to modify the NES end to take the cartridge, because it's got convenient screws holes around it that we can use. This will require a bit of hacking, however.

1. You'll first need to remove some plastic from the sides of the main cartridge-edge slot on the NES end (near the screw holes, as shown in Figure 8-5). The top photo shows the standard cartridge slot, and the bottom photo shows it after it's been hacked.
2. To remove the plastic portions as shown, make one slice down the side of the main cartridge slot edge with your hacksaw and another about 3/16" to the side of it. Then you can grip the little peninsula of plastic between the cuts with needle-nose pliers and break it loose. Figure 8-6 shows a close-up of how the cut-out portion looks from a different angle.
3. Insert a NES cartridge over the connector — the two cut-out portions should allow the cartridge to slide fully onto the connector. If not, or if the cartridge goes on crooked, cut away a little more plastic.

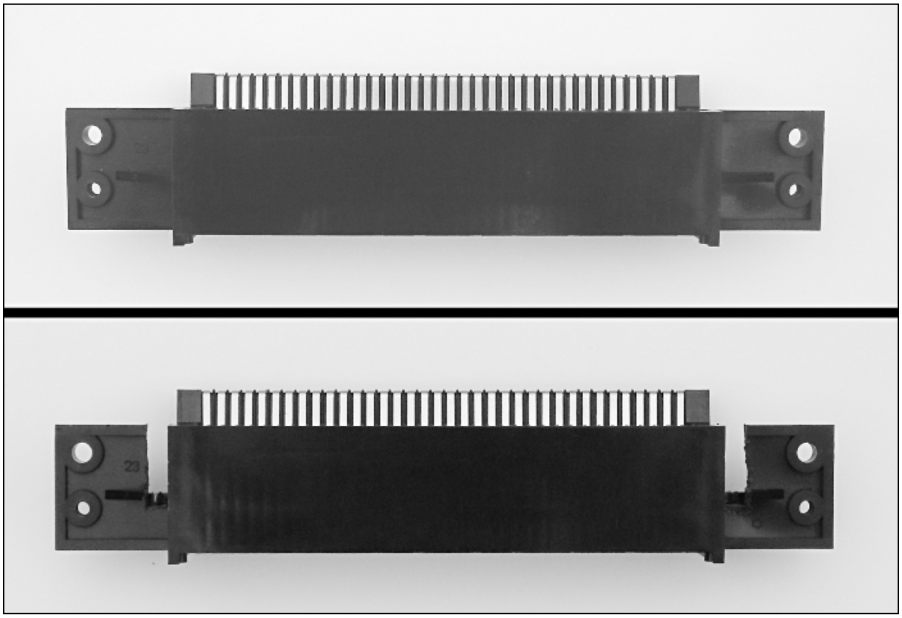


FIGURE 8-5: A NES cartridge connector, before and after hacking.

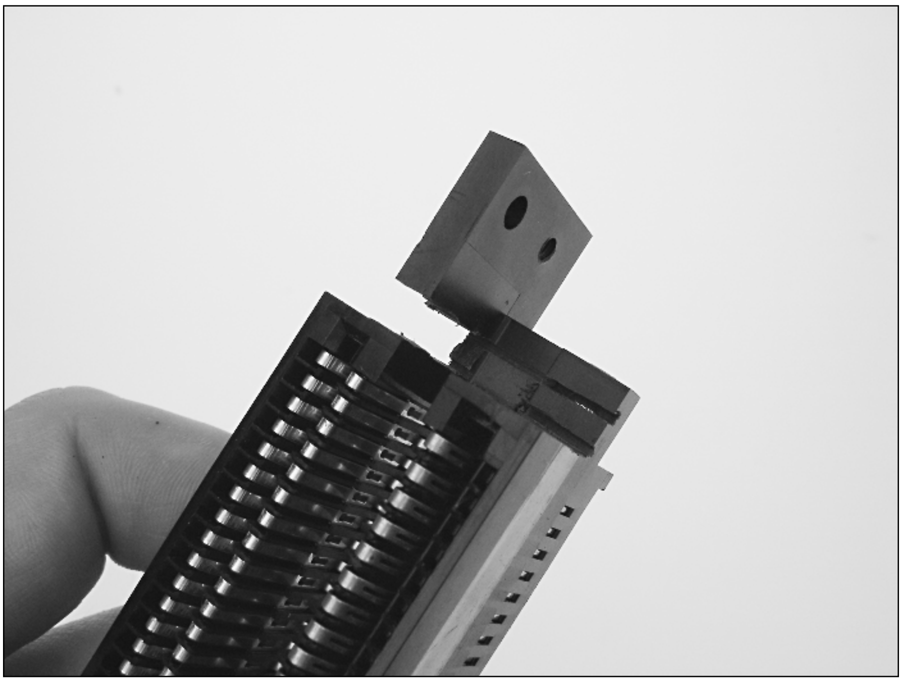


FIGURE 8-6: A close-up of one of the cut-out grooves.

4. To test if the cartridge is seated against the cartridge slot correctly, do the following:

    a. Insert what was the cartridge end of the slot back onto the NES motherboard. The cartridge itself should be on the solder (i.e., the non-parts) side of the NES board.

    b. To test the NES using the old power supply, power switch, and RF TV connection, temporarily hook the RF box and power plug back to the NES board (see Chapter 6) using some wires (rather than soldering them directly back to the board).

    c. If the cartridge does not play, cut away some more plastic, make sure that the cartridge and slot are fully inserted, and try again. Once you get it working, leave the RF box and switch connected so that you can test the board again at the end of this section.

5. Now it's time to cut the cartridge connector in half. This will remove the end that originally connected to the NES cartridge. Begin by using your hacksaw to cut both sides of the plastic as shown in Figure 8-7 below. Cut from the sides until the blade hits the first metal leads, then stop and cut the other side. The blade should be going just alongside the portion with the screw holes.

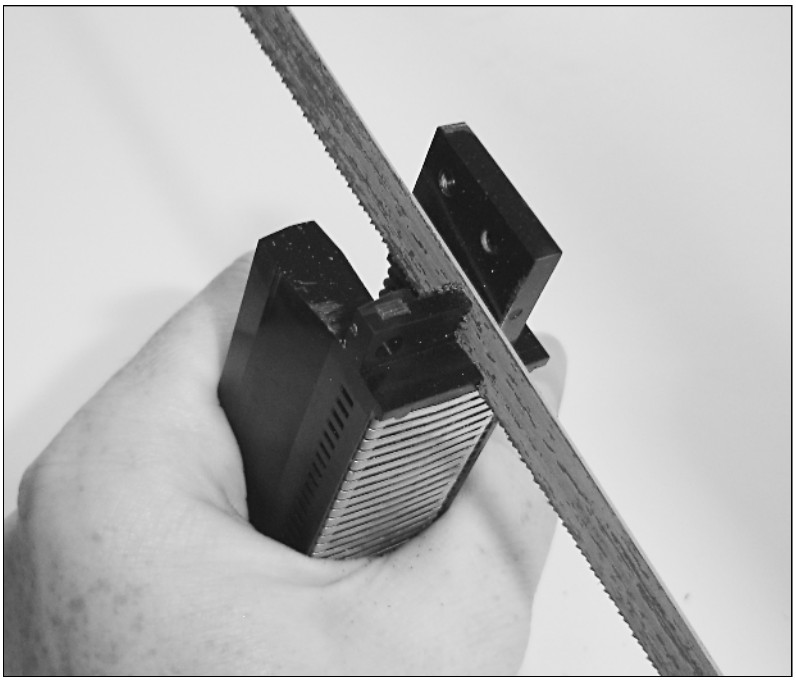


FIGURE 8-7: Where to cut the connector in half. (Don't let your old shop teacher catch you sawing like this!)

Caution Although the metal leads should stop the blade, be careful not to let it slip or you may scrape your hand. You'll probably yelp and drop the saw before it gets too deep, but it might slice you a bit anyway. If you're not comfortable with this method, you can always clamp the connector in a vise. Be careful not to overtighten the vise, as this may break the plastic.

Note The portions of plastic with the screw holes are needed for the portable. After these last few cuts, only a thin bit of plastic connects them to the main body of the cartridge connection. Be careful not to strain or push against them too much while sawing off other things.

6. It's now time to remove the first row of pins, the outer ones that are easy to get at. Use your cutters to snip each of the thirty-six outer pins, then bend them up using your tweezers or needle-nose pliers (Figure 8-8). The bent-out portion of each pin should be at least 1/4" long.

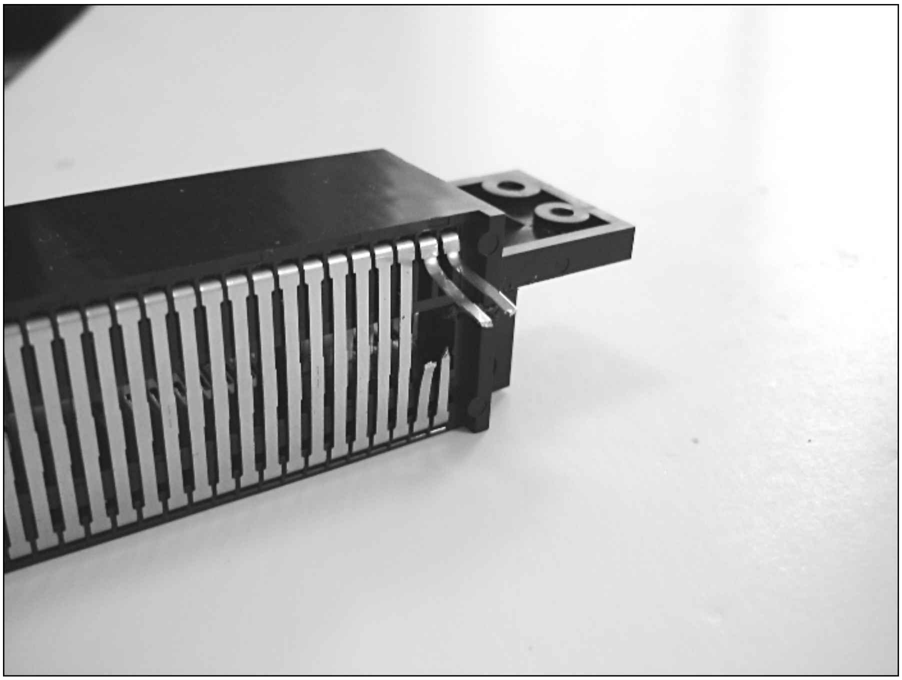


FIGURE 8-8: Snipping and bending the first set of pins.

7. You should now have discovered four black plastic pieces under this outer row of pins. Hack through them with your saw, as shown in Figure 8-9.

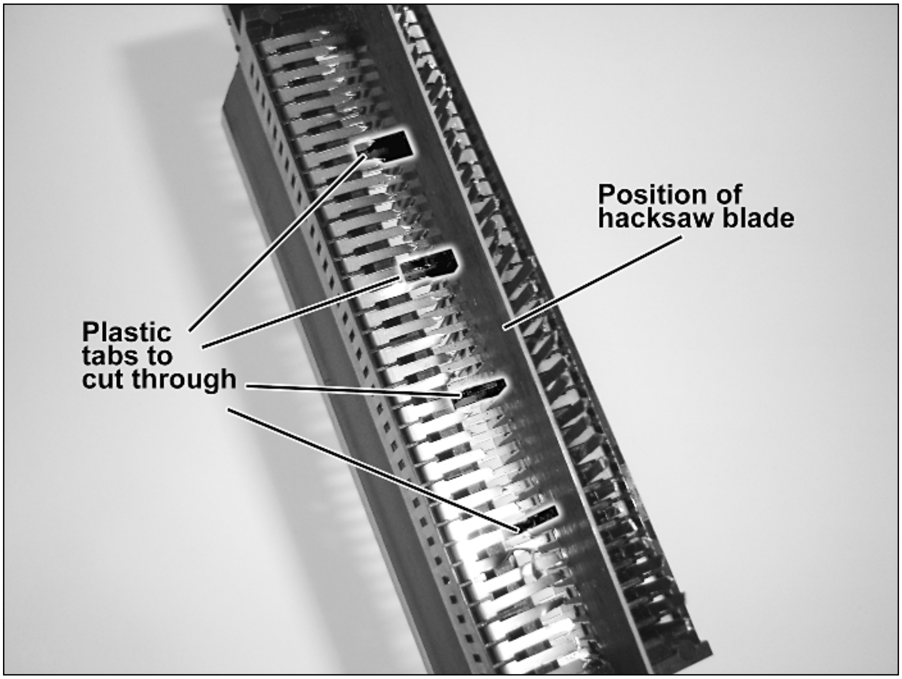


FIGURE 8-9: Yet more plastic to saw through.

8. Flip the cartridge connector around. The only thing holding the ends together now are the other thirty-six pins on the inside. Place your hacksaw blade inside the cartridge connector and saw away at the pins as shown in Figure 8-10.

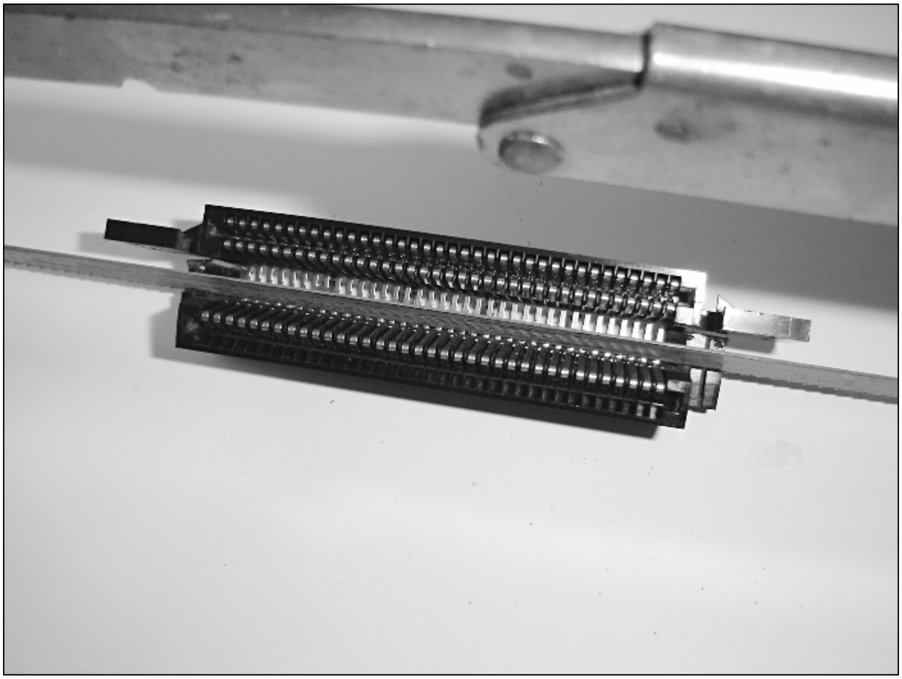
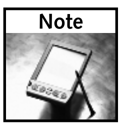


FIGURE 8-10: Saw through the pins like this.

9. Saw evenly and straight so that you hit every pin on each stroke. Stop using the saw after a couple of pins break loose. You can now bend the two sides back and forth by hand. Keep doing this — it will create strain on the weakened portions of the pins. After about 30 seconds of this "bending exercise," it'll start to get easier as more pins break loose. When only a couple of connected pins are left, snip them free manually. You have now separated the cartridge connector!



The reason you shouldn't just keep sawing until they all break loose is that the pins that break loose first will get shoved back and forth as you work on the others, causing them to weaken and possibly fall out.

10. Bend the inner row of pins back (toward the rear of the connector) as you did with the other row. What remains of the cartridge connector, and what the portable is going to use, should look like Figure 8-11.

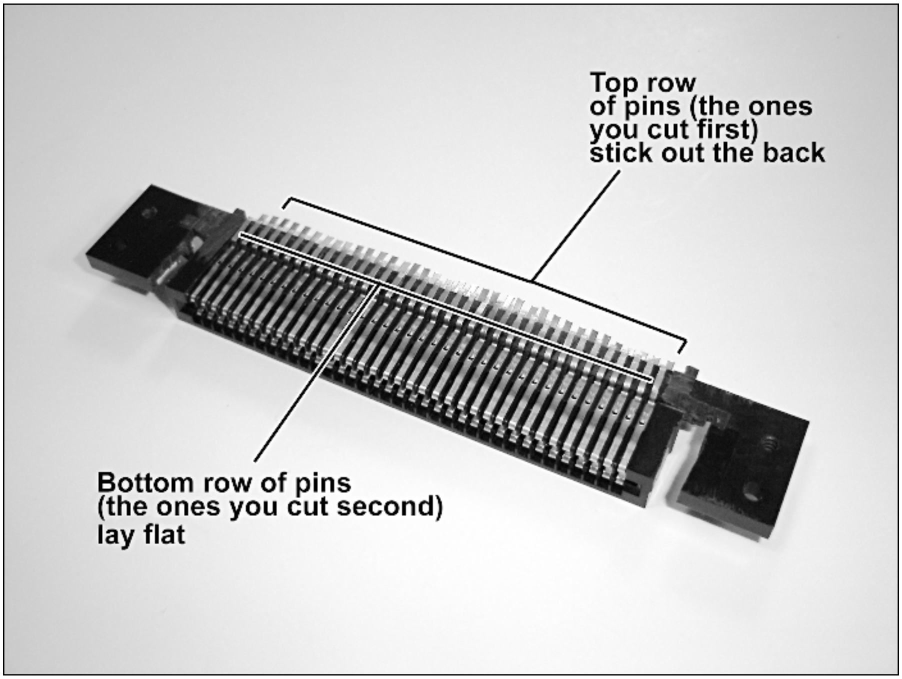


FIGURE 8-11: The completed hack on the NES cartridge connector.

11. As shown in the photo, cut off the first row of pins that you bent so that they are all about 1/4" long. Scissors work great for this — just make sure you do it outside because the pin bits will fly everywhere!

Tip

The last four bits of black plastic that you sawed through in Step 5 might have left "lumps" that will keep the second row of pins from laying flat. Sand down the lumps if they get in the way.

12. A while back, I cautioned about the strength of the plastic sides where the screw holes are. Sand down the area shown in Figure 8-12 and smear some epoxy over it to reinforce the plastic. Naturally, don't let any epoxy get where the cartridge itself might hit it.

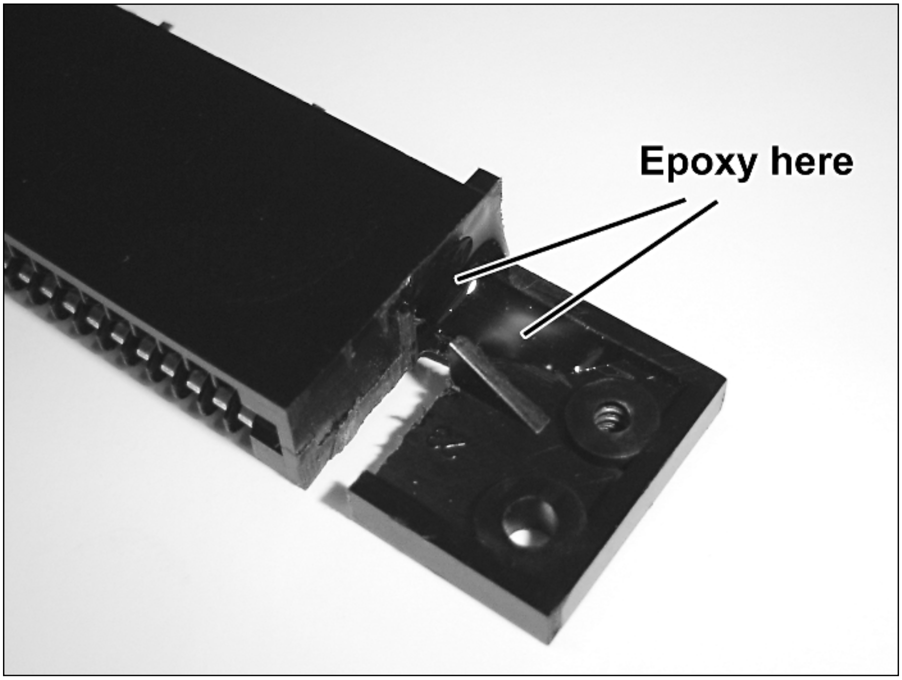


Figure 8-12: The sides of the connector with epoxy glopped on for added support.

The cartridge slot is now hacked into its new shape and is now ready to be reattached to the NES motherboard.

Reattaching the cartridge slot

Now that the cartridge slot is modified, it's time to reattach it to the NES motherboard. Since one end of the card-edge connector has been taken away, we're going to have to use wires and solder to connect the pins from the connector to the spots on the NES board. (Yes, this will be as monotonous as it sounds, but since the NES is an older system, the connections are fairly large and therefore not too hard to solder wires to.)

1. Scrape fine-grade sandpaper across the pins on the cartridge connector in order to allow solder to attach to them, then place a blob of solder on each pin so that it's ready when you attach the wires. Touching the solder strand itself to each pin and melting it there works best, as the rosin inside the solder gets to stick right to the metal pins.

2. You'll need thirty-six strands of ribbon cable per side, for a total of 72 wires. This may sound like a lot, but they're going to be fairly short pieces.
3. Start by attaching wire to the lower pins of the cartridge connectors — the ones that don't stick out the back. Strip only a little plastic off the wires in order to avoid unwanted connections. Attach the wires as shown in Figure 8-13.

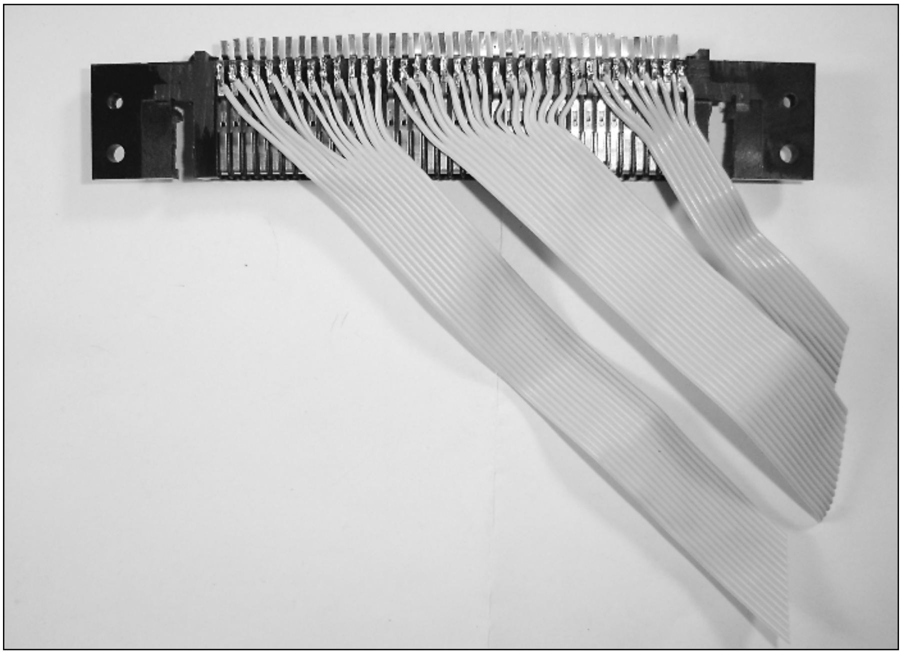


FIGURE 8-13: Attaching ribbon cable to the cartridge connector.

4. These wires should be cut at 45-degree angles. The longest wire should be 6" from end to end, and the shortest wire about 3". The rule of thumb is that if you lay the cartridge connector on the back of the NES board as shown in Figure 8-14, the wires should at least reach the cartridge connector, if not go past it a little. The NES cartridge connections are on the right side of the photo.

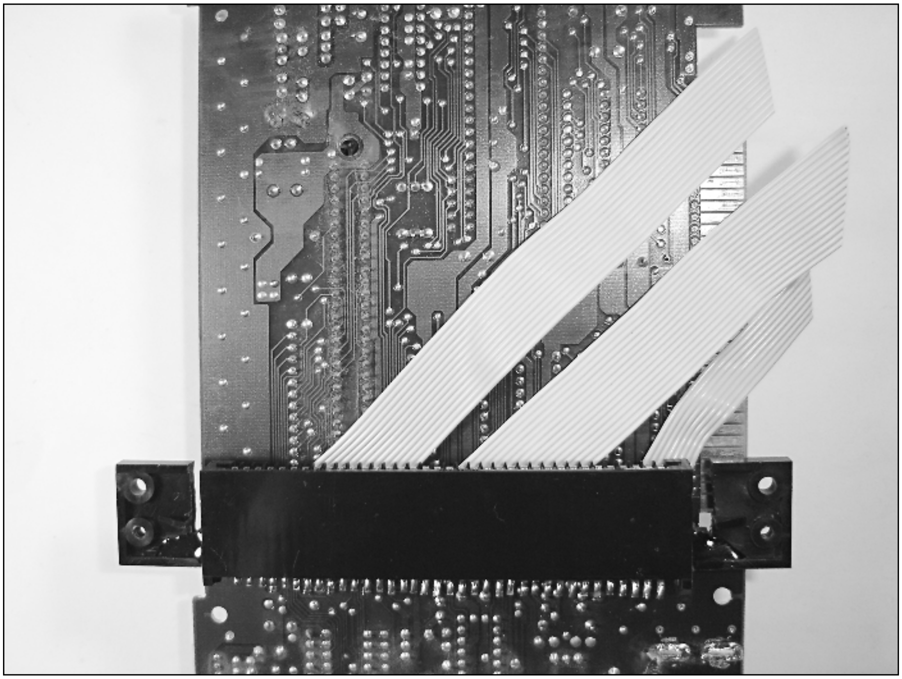


Figure 8-14: How the cartridge connector and wires are placed in relation to the NES board.

Note

The cartridge connector does not attach to the side of the board as shown in Figure 8-14 — this photo only shows a length reference.

5. Attach the other thirty-six wires to the pins on the other side of the cartridge connector. These wires should be about 1” longer than the lower ones were. Loop them around and under the back of the cartridge connector as shown in Figure 8-15.

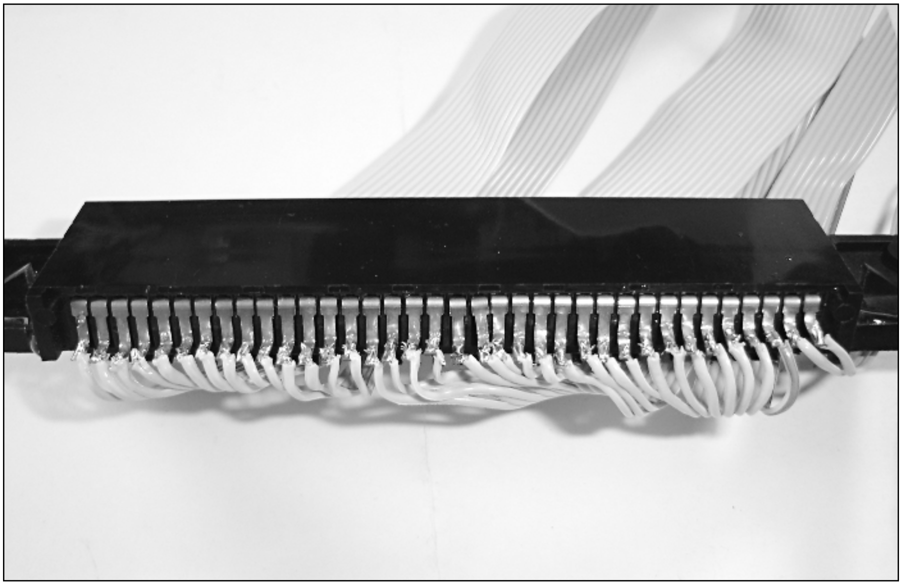


FIGURE 8-15: The second row of pins, with the wires tucked under the connector.

Tip When attaching a lot of wires that are close together like this, remember to always twist the strands. Even though only a small amount of bare wire is showing, loose strands can still be a problem.

6. Now let's attach the cartridge connector to the *center match plate*. Use two 1/2"-long size-4 screws and two 1/2"-long size-6 screws to attach it as shown in Figure 8-16. Thread all the ribbon cable through the rectangular hole. Place lock washers and nuts on the back of the plate to further secure the screws (lock washer first, nut second).

7. To ensure proper vertical spacing of the connector, place two size-6 nylon washers on each screw between the cartridge connector and the center match plate (for a total of eight nylon washers). Slide in a cartridge to test the fit. If it causes the match plate to bend, try adjusting the spacing. You can do this by trying a size-6 nut on each screw in place of the washers, or one nut and one washer.

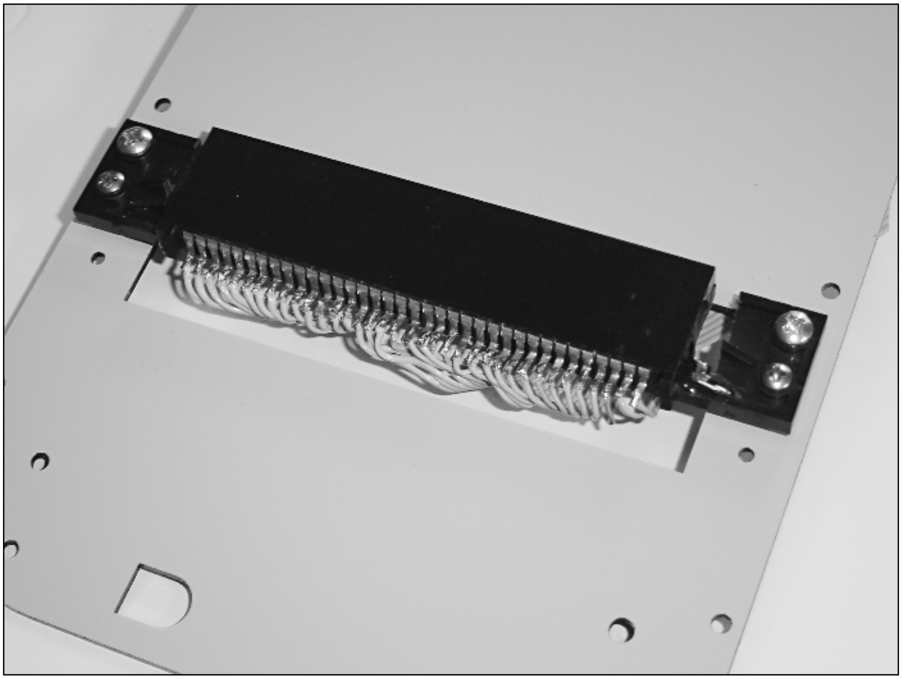


FIGURE 8-16: The placement of the cartridge connector on the center match plate.

The modified cartridge connector is now firmly attached to the center match place, and seventy-two wires have been soldered to it in preparation for attaching the cartridge connector back to the NES motherboard.

Attaching the cartridge connector to the NES board

With the cartridge connector in place, it's now time to attach it to the NES board, along with the 7805 regulator. We can use the NES board to absorb the heat coming off the regulator.

1. Get out four size-6 nuts, and sand one side of them. Then superglue them centered over the four holes shown in Figure 8-17. (Sand near the holes as well, so that the glue sticks well.). These are now the *NES board risers*.

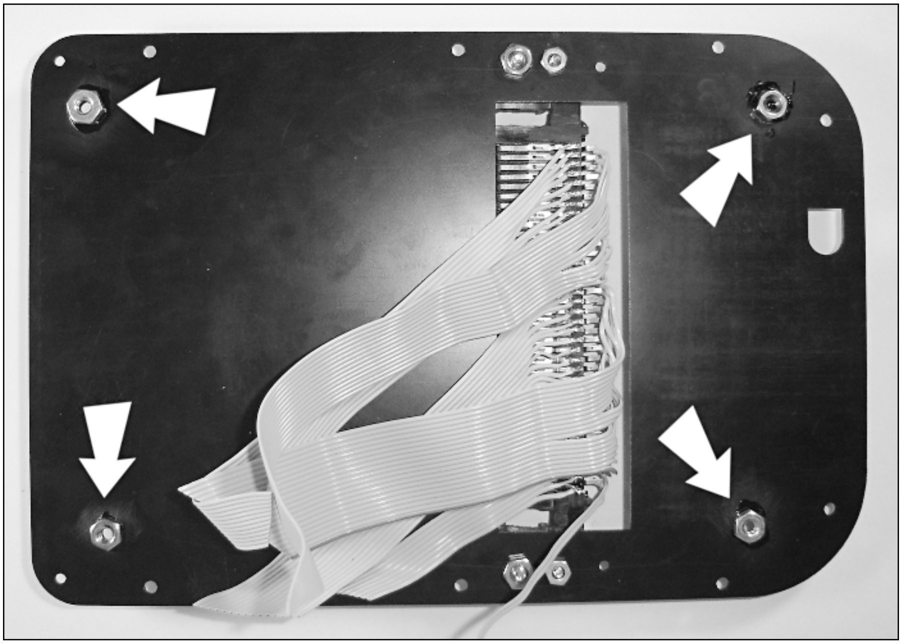


FIGURE 8-17: Where to place the NES board risers. Add a little epoxy around them for added strength.

2. Now let's attach the 7805 power regulator to the NES board. As described in Chapter 3, this takes the unregulated 7.2-volt input from the battery and knocks it down to what the NES needs to run, in this case 5 volts. Using a computer case screw and a size-6 nut, attach the 7805 regulator to the existing screw hole near where the RF box used to be, as seen in Figure 8-18.

3. Run a thick, solid wire from the top lead on the 7805 to the center spot of the five connections shown in Figure 8-18. This is *power IN to the NES*. Then solder the center lead of the regulator directly to the metal on the NES board — this is *GROUND*. We'll connect more things to this area later on.

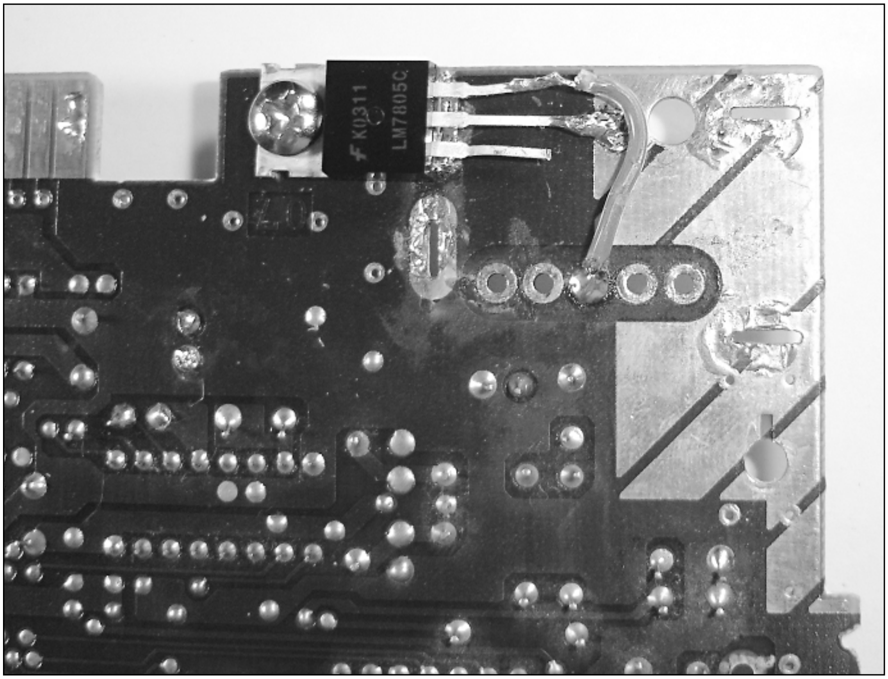


FIGURE 8-18: How to attach the 7805 regulator to the NES board.

4. Now back to the cartridge connector: Set down the NES board on the side of the center match plate as shown in Figure 8-19, and tuck the bottom pin ribbon cables under it—we'll be attaching the top ribbon cables first. Solder the thirty-six top ribbon cable wires to the NES board as shown. The wires have been numbered for reference so you can see where they go.

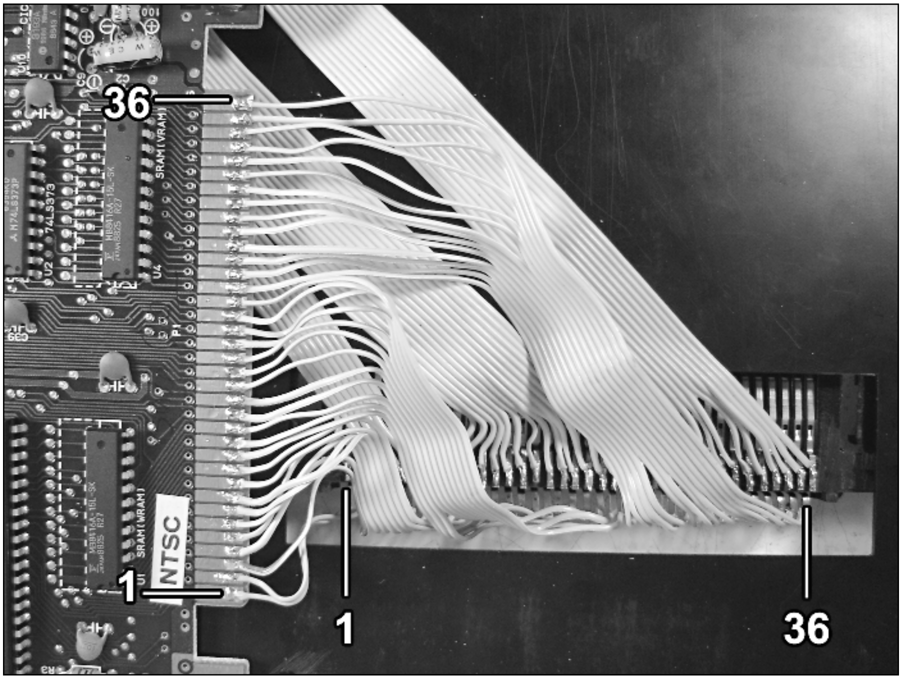
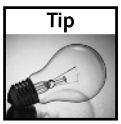


FIGURE 8-19: The top row of pins connected to the NES board.



As with the cartridge pin connections, putting solder on the NES side of these connections before attaching the wires will make this a lot easier.

5. Fold the NES board over onto the center match plate so that you can attach the remaining thirty-six wires from the bottom set of pins, as shown in Figure 8-20. The longest of the wires go to the left side, the shortest to the right. You may need to cut some of the wires shorter as you go so that they'll all fit as evenly as in the photo. (Remember, too much wire is better than not enough.)

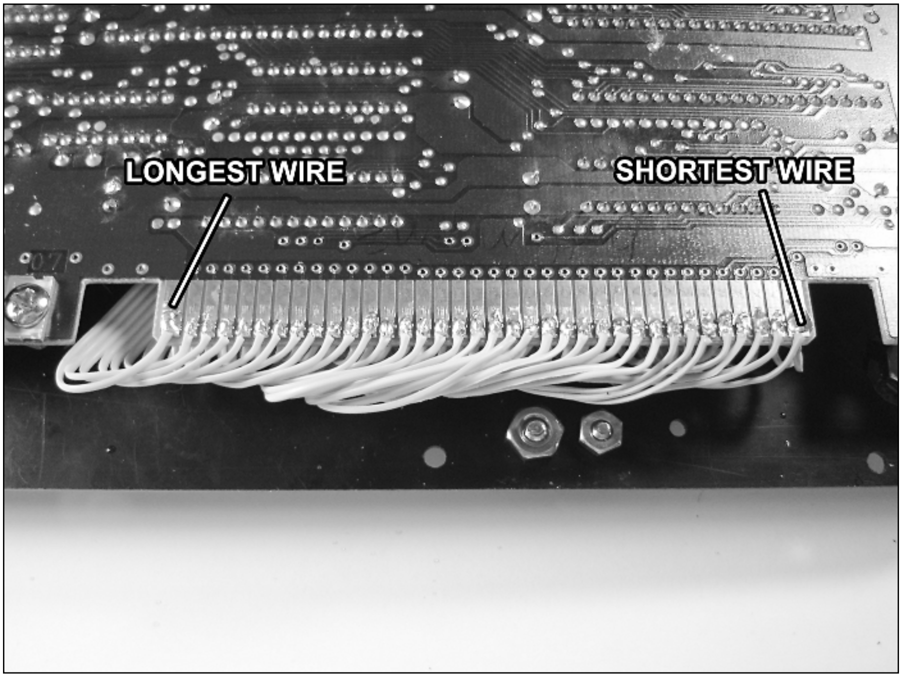


FIGURE 8-20: The bottom row of pins connected to the NES board.

The cartridge connector should now be completely reconnected to the NES. As mentioned earlier, you should test the NES using the old RF box and power switch to make sure that the cartridge slot has been properly reconnected and that the game cartridges fit and load up normally (no garbled characters, etc.). If something doesn't work, go back through this section and double-check what you did—it's a lot easier to do so now than it will be later.

Attaching the NES board to the center match plate

At this point the NES board should be completely rewired to the cartridge connecter. You can now attach the NES board to the center match plate as follows:

1. Insert four size-6 screws through the NES board and into the size-6 nuts (NES board risers) that you glued to the center match plate earlier. Screws that are 1/4"-long work best, although they are harder to find. I used a more common 3/8"-long screw to attach the board, and computer case screws may work as well. (See the following discussion.)

2. The idea is to get the NES board as close to and flat against the center match plate as possible. This will vary based on the ribbon cables, the components on the NES board, and the length of screws you use to fasten the board. Press the NES board down to flatten the ribbon cables, then see how much space is left between the NES board and the NES board risers (the nuts that we glued to the center match plate). Insert the screws, and then put nuts or washers between the NES and the center match plate to fill in the gap.

The NES board should now be firmly attached to the center match plate, along with the cartridge connector.

Note

You may want to wait until you complete the unit before you screw down the NES board, or to just use a couple of screws for now, in order to save time if you have to check under the board later.

Assembling the Parts of the Case

So far, we've attached the cartridge connector and NES board to the center match plate, which is going to be in the center of the portable. The rest of the case parts are composed of pieces of engraving plastic glued to side wall portions. This creates hollow case portions in which to place components — there are a total of five of these, and the assembly of each is described in the following sections.

Front of the unit

The *front of the unit* is the largest portion of the case — it will measure 5-3/4" × 8-1/2" × 1" when completed and will contain the TV circuit board and controls. To assemble it, do the following:

1. Sand the inside of the front plate and the top and bottom surfaces of the front side walls.
2. Stack all four layers of the front side walls and superglue them onto the front plate. The sides are symmetrical, but you should check that the screw holes line up to each other in order to make sure the edges will be even. Once the pieces are placed correctly, put a thin layer of epoxy over the inside seams to further secure things. The resulting front of the unit should look like Figure 8-21.

Figure 8-21. Attaching front walls to the front plate.

Screen riser

The *screen riser* is the portion that rises off the front of the unit and contains the LCD glass screen. It will be 1/4" thick.

Sand and glue the top and bottom *screen riser walls* to the back of the *screen riser plate.* Please note that the part of the side wall with a wider middle portion goes near the two thin slots on the screen riser plate. The finished screen riser should look as shown in Figure 8-22.

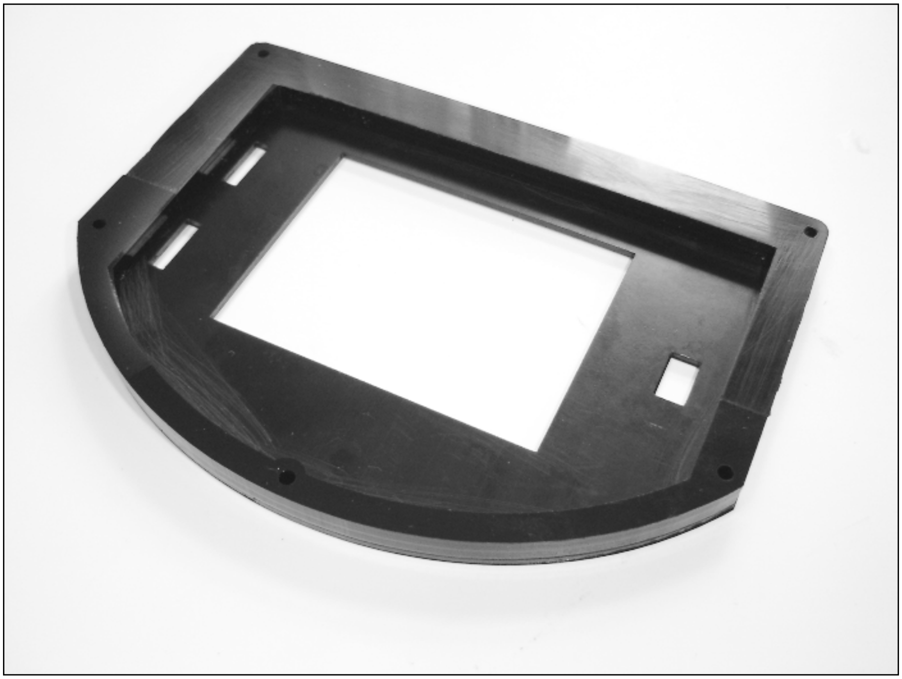


FIGURE 8-22: The screen riser walls attached to the screen riser plate.

Control riser

The *control riser* is similar to the screen riser, but holds the controller buttons and the speaker.

Sand and glue the two *control riser walls* to the back of the *control riser plate*. Both sides are the same (symmetrical), so don't worry which piece goes on which side. However, take care that the thin portions line up flush to the edges of the plate. The resulting control riser should look like Figure 8-23.

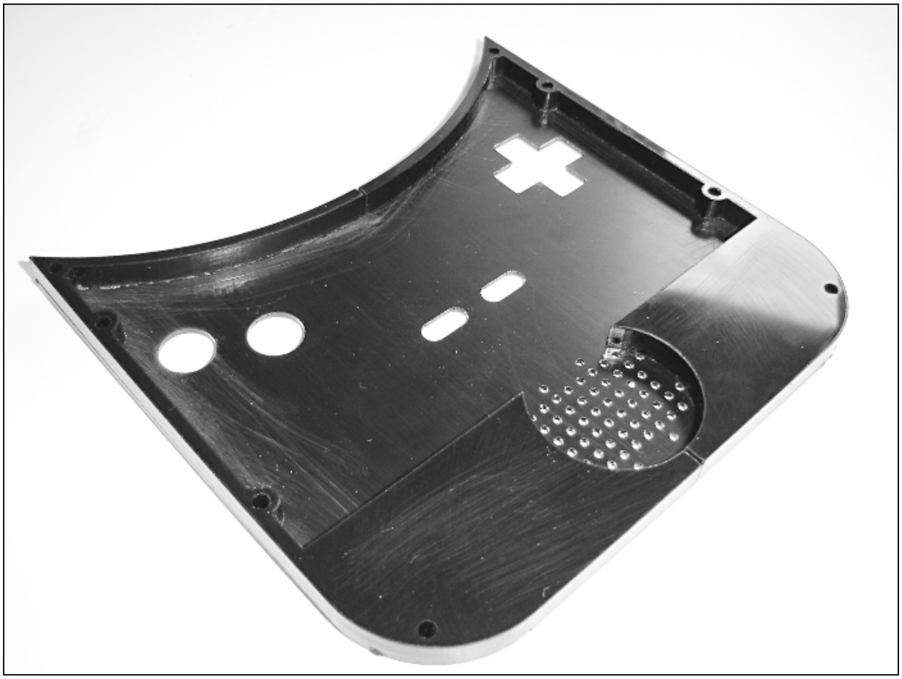


FIGURE 8-23: The control riser walls glued to the control plate.

Battery holder

The *battery holder* is a 1”-thick portion on the back of the unit that holds the battery (of course) and completely detaches from the main body for recharging.

1. Sand and glue the four layers of *battery holder walls* on the *battery holder plate*.
2. Put a thin amount of epoxy on the insides of the walls to help secure them, as they are quite thin and need extra support. Make sure it’s only a thin coat of epoxy, or the battery itself may not fit properly.

The resulting battery holder should look as shown in Figure 8-24.

FIGURE 8-24: The battery holder walls glued to the battery holder plate.

Cartridge holder

The *cartridge holder* is a 3/4"-thick section on the back of the unit with a curved piece of engraving plastic on it. Its main purpose is to decoratively cover the unsightly cartridge connector. The cartridge holder differs from the other parts of the case in that the walls are held in place by screws, not by glue.

1. Take the cartridge holder plate and insert four 1-1/4"-long size-6 screws into the four large holes and two 1-1/4"-long size-4 screws into the smaller ones.
2. Set the side wall layers on the plate one at a time and drive the screws through each, then add the next layer, for a total of three layers. Doing it this way ensures that there are no gaps between the layers.
3. Place the cartridge holder against the back of the center match plate and drive the six screws through it. Drive them just enough to grab the match plate — you'll insert them the rest of the way later.

The finished cartridge holder attached to the center match plate should look like Figure 8-25.

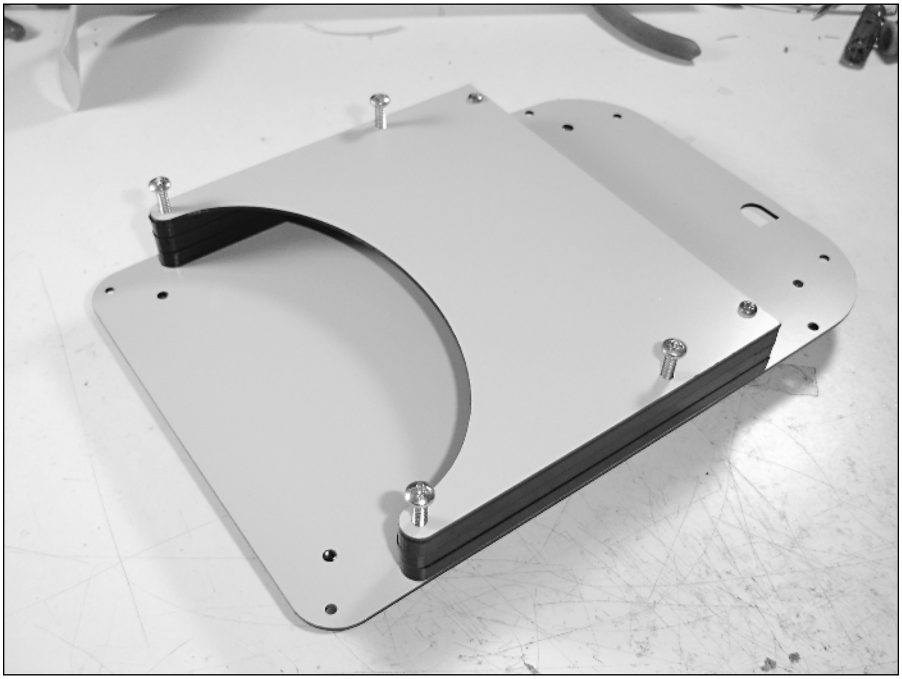


FIGURE 8-25: The cartridge holder attached to the center match plate.

Gluing and assembly tips

Here are some things to keep in mind while assembling and gluing the pieces just described:

- Be sure to sand any surfaces that will be glued together. This gives a better grip.
- If the pieces stick together and aren't quite right, bend the engraving plastic to pull the glue away from the acrylic. Do this slowly to avoid breakage. Try to keep the edges of the walls flush with the plates.
- Use small drops, not floods, of liquid superglue. Using too much makes it dry more slowly, and excess can leak out and disfigure parts of the case. If some does spill, wipe it up immediately. Gel superglue won't spill or leak as badly, but it dries more slowly than liquid superglue.

Applying the decals

The majority of the decals for this portable will be applied right here in the middle of the construction process. This is because it's hard to install graphics over raised buttons and if you use water to apply graphics from a vinyl shop, you don't want to get your electronic components wet. In this section we'll apply graphics to the screen riser, control riser, and battery holder.

If you printed the graphics yourself, apply them however your sticky-back printing-paper's instructions say to. If you got vinyl graphics from a sign shop, read on!

The decals for the screen and control risers are exactly the same size as the part, and if a vinyl shop made them, they have holes precut. The battery holder decal should be centered on the part. To apply vinyl graphics to the plates, do the following:

1. Make a solution of slightly soapy water (maybe one drop of detergent in water) and slosh the vinyl graphics through it, especially the sticky sides.

2. Slide the graphic onto the plate for proper positioning. It's helpful to do this on paper towels, so you can fold them over the graphic to soak up excess water.

3. Once the graphics are in place, use a squeegee or credit card to push the air bubbles out from under them. Let dry for an hour or two, then shave the edges of the graphics as needed with a sharp knife.

The remaining graphics can be applied later. We got the wet stuff out of the way now so it won't short-circuit things later.

Wiring the Unit

You should now have four case parts with walls, plus a flat match plate with the NES and cartridge connector attached. Now it's time to begin wiring and installing components. We'll connect the portions of the case together as we go. We'll start by wiring things into the front half of the case (such as the game controls), then install the screen, hook up battery power, and finally wire the front and rear halves of the case together.

Caution

The battery we're using for this portable stores a lot of juice. Don't let its leads or any positive/negative wiring short out, or it'll create a spark which can give you minor burns. Not life-threatening, but enough to make you jump!

Building and installing the control board

The *control board* will contain the Player 1 controls and the video amplification circuit that the NES needs in order to spit out a decent video signal. It will be installed just behind the control riser in the front half of the case.

1. Get out your 6-5/16" × 4-1/2" PC board from Radio Shack (catalog #276-147). As mentioned earlier, we're using a Radio Shack board, as it gives us a standard size that ensures your project will match the circuit layouts in this book. (See Figure 8-26.)
2. This board will need to be cut up before we can use it. To slice the PC board, firmly drag your knife along the black lines indicated in Figure 8-26. You can drag it across the holes for the bottom line, but the cuts on the sides need to be *between* holes. (Between hole lines 2 and 3, and 52 and 53.) Err, if at all, by going a little smaller than shown (so the board will fit in the case), but make sure there's enough material so that you can still drill the screw holes in the board, as described later.

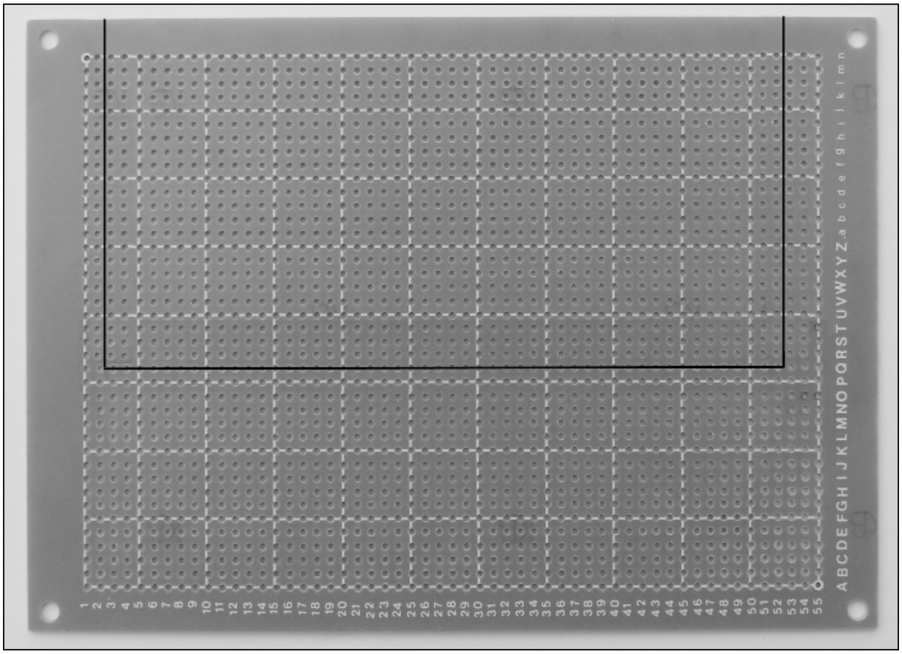


FIGURE 8-26: Where to slice down the raw PC board.

3. Check the size of the resulting piece of board — it should measure approximately 5-1/8" wide by 2-5/8" high.
4. Figure 8-27 is a drawing of the sliced-down PC board and where components should be placed on it. Install the parts as described in the following.
5. Solder all parts to the control board as shown. When placing the IC, check that the little half-circle groove is at the top.
6. The resistor leads are long enough that you can move and bend them quite a bit. Try to keep them as shown above so they won't touch anything inside the case that they shouldn't. The spots where the leads "meld" into each other on the drawing indicate that you should solder them together at that point.
7. Use a 2N4401 transistor for this board. If you get a "grab bag" of transistors at Radio Shack, they may not all work in this project. (See Chapter 6.)
8. The control pad disc should not be able to press all four directional buttons at once, only up to two at a time (for diagonal moves). To ensure this, place a small blob of hot glue in the center of the four directional tact switches. Once the glue cools, test the control pad disc on it — it may take a couple tries to get it right.
9. Use a 12"-long five-strand of ribbon cable for connections A–E. These will go to the NES motherboard later. Put a black mark on the other end of wire "A" for later reference.

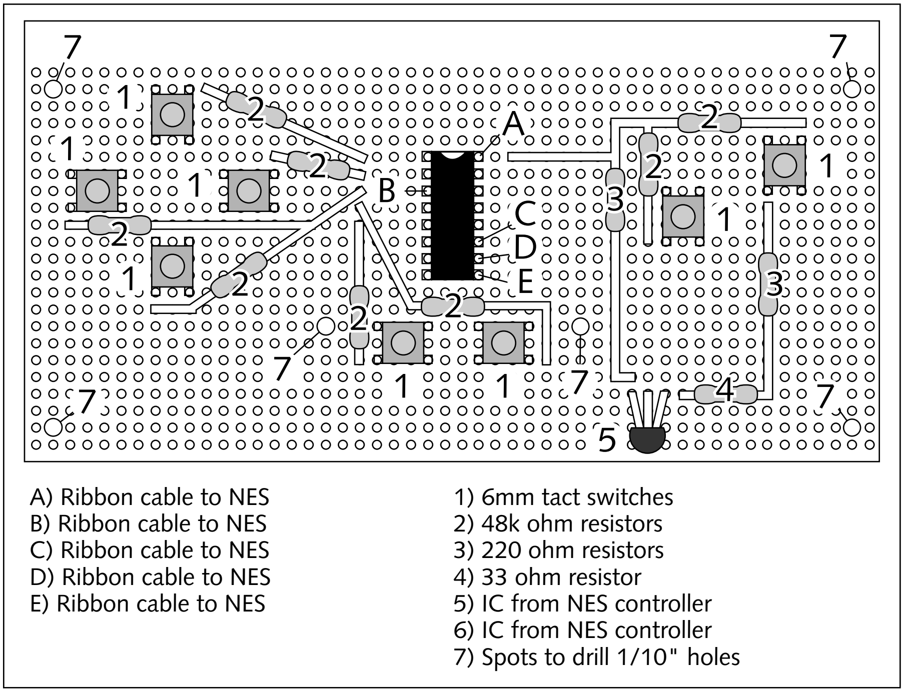


FIGURE 8-27: Where to place components on the front of the control board.

10. Use a 1/8" drill bit to drill the holes marked as spots "7" in Figure 8-27.
11. When all the components are soldered in place, flip the board over. Use ribbon cable wires or bits of extra leads to make the connections shown in Figure 8-28.

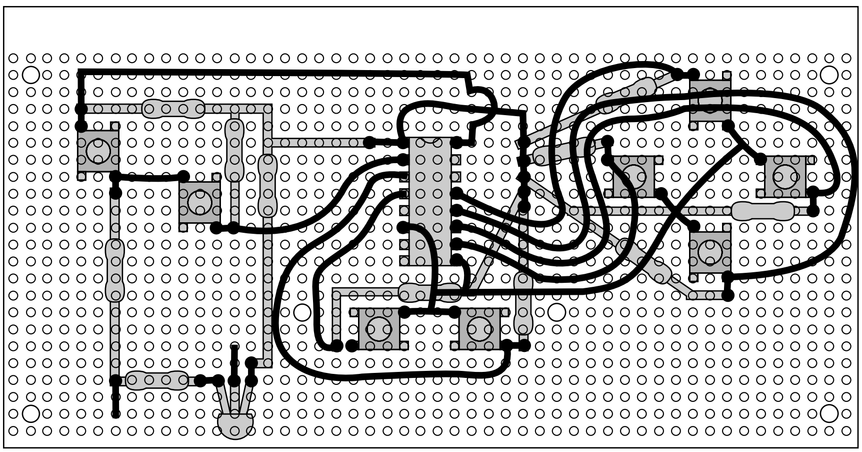


FIGURE 8-28: Connections to make on the back of the control board.

Note

In the drawing there's a gray section in one of the wires above the IC where another wire appears to cross it (that part of the other wire is drawn as a semicircle, rather than straight). These wires should not be connected at this point on your board.

The completed control board should look like Figure 8-29. Notice the two unconnected leads on the lower-left portion on the rear — these are part of the video amplification circuit, and will be connected later.

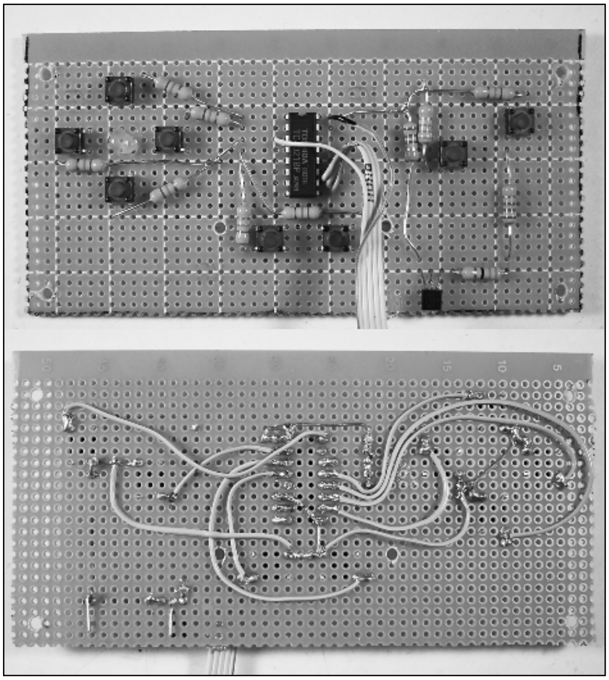


FIGURE 8-29: The completed control board, front and back.

Installing the control board and buttons

Your control board is now ready to be installed into the front of the case, along with the buttons. Please do the following:

1. Get out the plastic buttons from the NES controller that you got the IC from. You'll need the control disc, B and A buttons, and the rubbery Select/Start buttons.
2. We'll start by connecting the control board to the front plate of the unit. Insert the four 1/4"-long size-4 screws through the side holes of the PC board from the rear, and attach it as shown in Figure 8-30. Run the screws a little above the front plate, just high enough so that your finger can feel them.

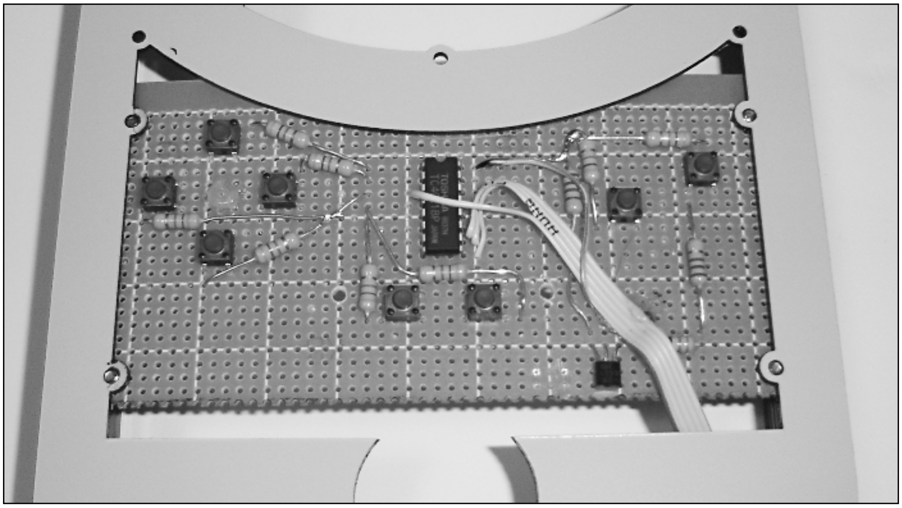


FIGURE 8-30: The control board attached to the front plate.

3. Now insert the control disc, start/select buttons, and B/A buttons through their holes inside the control riser. Press the control riser against the front plate — the four screws should line up to the correct holes. (That's why we raised them a little above the front plate — so you'd feel them "click" in place.). Screw them into the control riser to secure it to the front plate. Check to see if all the buttons are clicking correctly; if not, put some glue inside the button (to make them press against the switches more tightly) and make sure the tact switches are soldered firmly against the board. Once the buttons feel okay, insert the top two screws into the control riser as well.
4. Attach a 4"-long two-strand of ribbon cable to the connections on the TV's speaker, and hot-glue the speaker into the hole just below the controls. The front of the speaker should press against the control riser plate.

The control board, control riser, and buttons are now installed, allowing us to move on and install things on top of them.

Tip

NES controllers can be amazingly dirty, especially the control disc. Clean up the control parts with rubbing alcohol and cotton swabs before installing it in your portable. An old toothbrush works well, too.

Attaching the screen riser

Before we can install the TV screen itself, we must first attach the screen riser and the main power switch. This provides a reference guide for installing the screen. The on/off switch will be installed under the screen riser, so it must go in now as well.

1. Start by inserting five 1/4"-long size-4 screws through the back of the front plate around the screen hole until they just rise above the front surface. Take the two *power switch risers* and place them below the switch as shown in Figure 8-31. Make sure the two leads on the switch are near the top of the unit so that it slides up for on — otherwise it won't match the decals.

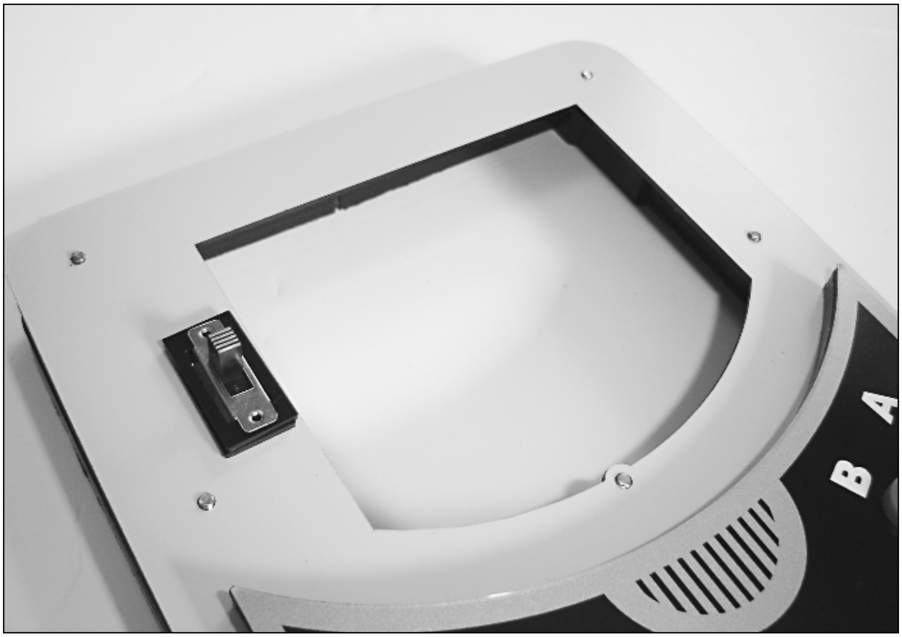


FIGURE 8-31: The five screws, two power switch risers, and the power switch itself, all in place.

2. There's a slight gap around the power switch that allows for a margin of error. However, it also requires us to manually align the switch, so get your glue gun heated up. Place the screen riser over the switch, and temporarily screw the screen riser in place.
3. Put some hot glue around the switch from the rear (inside the case). Don't get hot glue on the switch leads, as we still need to wire things to them. Now take a look at the switch from the front. Use your tweezers to center the switch in the rectangular hole — you'll have about 15 seconds before the glue becomes immobile. Let that cool, and then remove the screen riser and hot-glue/epoxy/superglue the power switch in place on the front as well. Try not to get any glue on the side that's next to the screen hole, however.

   The switch should be fairly secure by now, so you don't really need to use those two little screws that came with it. Plus, nobody is going to see that you didn't! Isn't the inside of a case great?
4. You can now reattach the screen riser by securing it with the five screws. Go ahead and take a look at the unit from the front — wow, it's actually beginning to resemble something, isn't it? Let's move onto the screen itself!

Installing the TV screen

Okay, now that the screen riser is in place, we can finally install the screen itself.

1. First, attach three wires to the spots on the front of the TV board shown in Figure 8-32. The audio wire needs to be about 8" long, and the other two can be about 4".

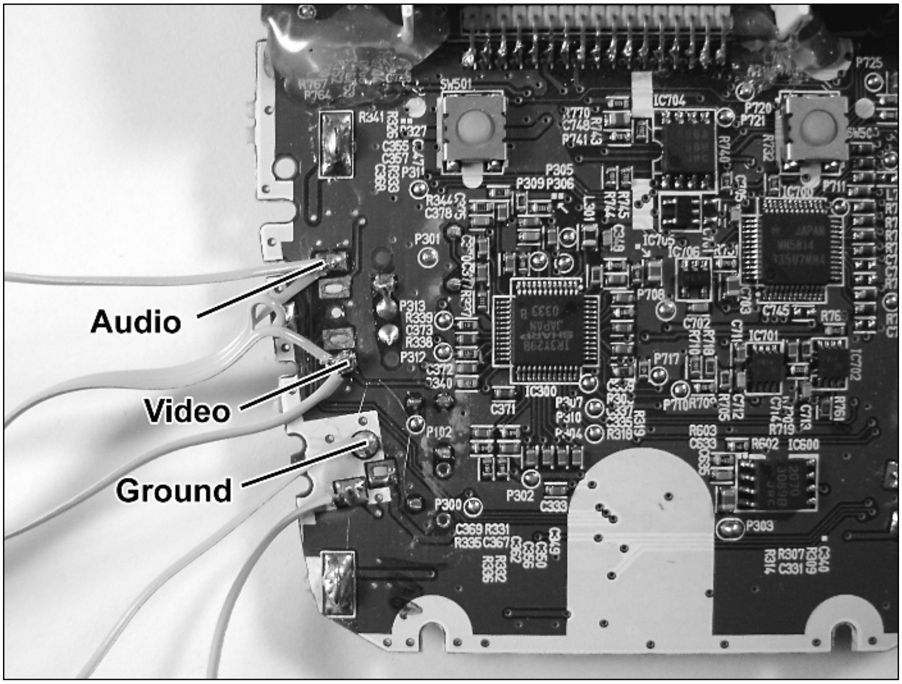


FIGURE 8-32: Attach wires to these three spots before installing the TV screen.

Tip

It's helpful to use markers to color-code the other ends of the wires, so you'll know which is which later on if one end gets hidden under something (as these TV wires will).

2. Locate the external antenna jack sticking out of the top of the TV — it's a dark gray jack that takes a 1/8" plug. Snip off the black plastic until it's flush with the edge of the circuit board. You can also desolder the entire jack if you wish.
3. There are two slots in the screen plate for the volume and brightness dials — insert them as shown in Figure 8-33. The upper volume knob on the TV goes into the upper hole here, the lower brightness knob into the lower hole. However, double-check the labeling on the plastic case of the pocket TV just to make sure. Put hot glue on the metal side and some on the top on the wires — this will hold them well enough. Use as much glue as you want; the important thing is that the dials themselves can still turn.

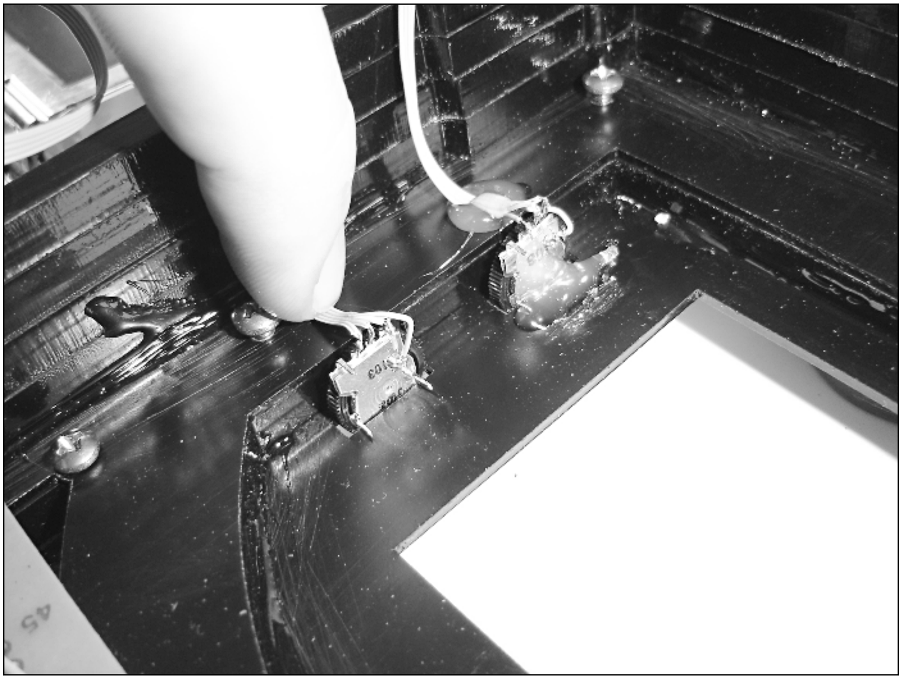


FIGURE 8-33: Inserting the volume and brightness knobs.

4. You can now install the TV itself. Place it into the front of the case as shown in Figure 8-34. There are a couple of screw holes that we drilled in the control board that you can use to install the screen, or you can just use hot glue on the top, sides, and bottom of the TV's main circuit board. Check the unit from the front and make sure the screen portion is centered in the opening of the screen plate. No metal edges should be showing.

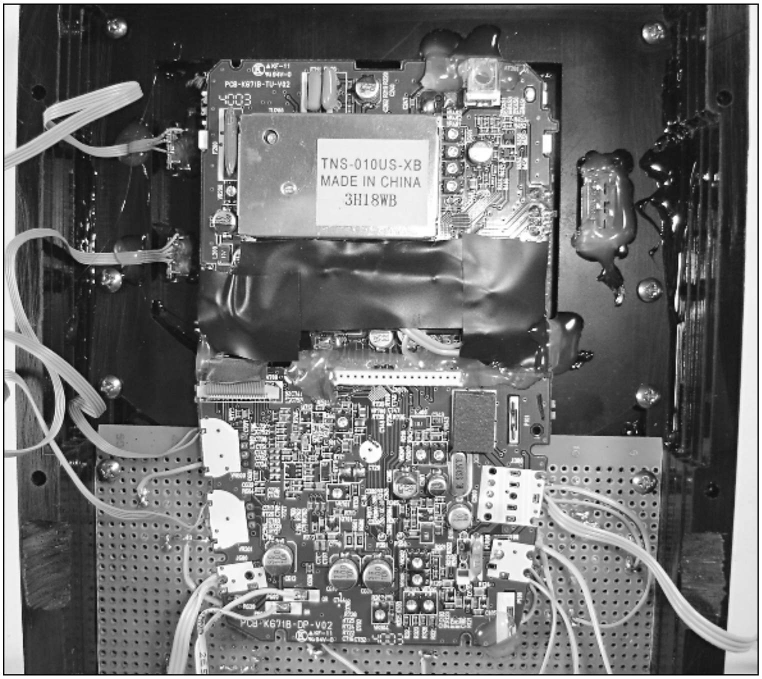


FIGURE 8-34: The TV screen installed in the front of the NES case.

Tip

You may want to leave the TV unglued/screwed to the front of the case until you've had a chance to test the unit. That way it's easier to get at things such as the control board if you need to.

5. We now need to make a few connections to the control board, as seen in Figure 8-35. Connect the TV's *video* and *ground* to the spots shown. Attach a 10" wire to the spot marked *video in from NES*. Finally, attach the two speaker wires to the TV board.

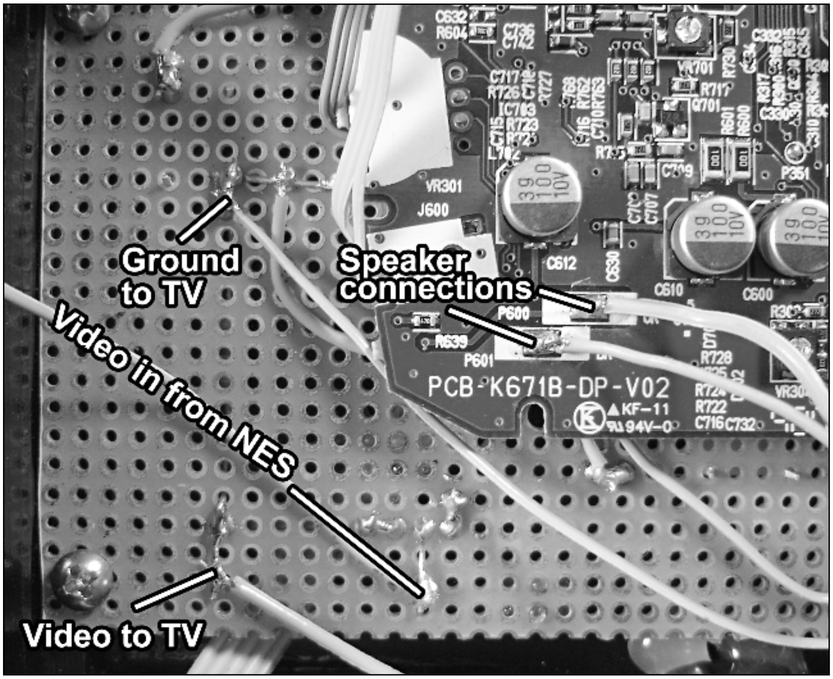


FIGURE 8-35: Connecting the TV to the control board.

The TV screen is now installed. It still has a few unconnected wires, such audio and positive power in, that will be connected in the following sections.

Connecting power to the unit

We've got enough major components installed that we can now make power-related connections throughout the unit, beginning with the power on/off switch itself and the TV.

1. Your TV should have the audio/video output jack connected to it as described in Chapter 4. The A/V jack should still have one unconnected wire, *Power into TV*. Connect it to the top lead of the power on/off switch, along with a 10" wire, which will be *Power to NES*. Finally, connect another 10" wire to the bottom pin of the power switch — this will be *Power from battery*. The power switch should now have a total of three wires connected to it, two of which are not connected on their other ends. At this point, the front half of the case is completely wired.

2. Grab the rear half of the case that contains the cartridge connector and the NES board. Take the *battery jack riser* and superglue it over the same-shaped hole in the center match plate as shown in Figure 8-36. You can then attach the *size K coaxial power jack* into it using the supplied screws (i.e., the screws that came with the jack).

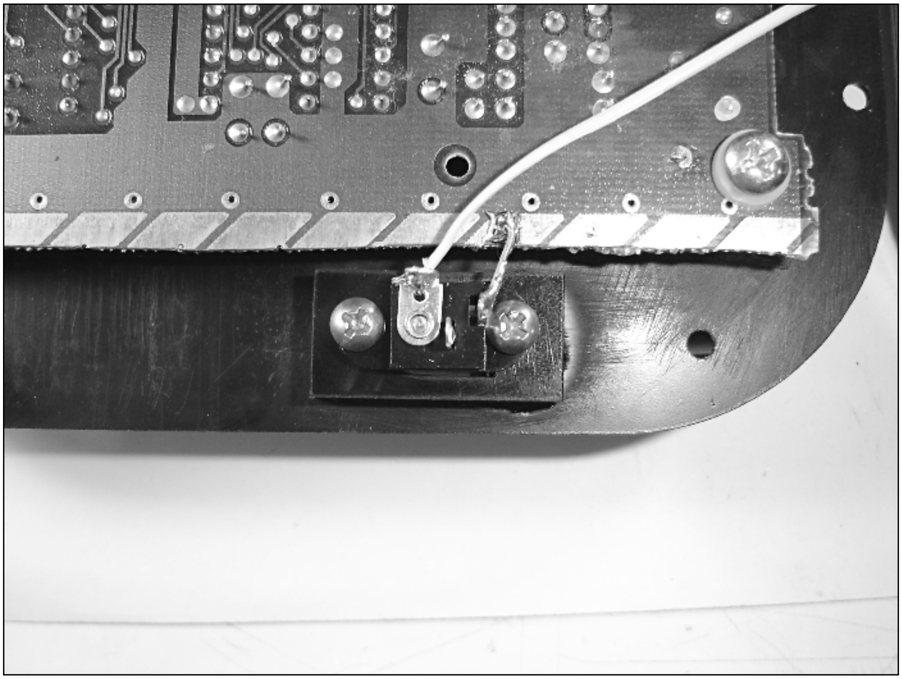


FIGURE 8-36: Where to place the battery jack riser.

3. Use a small piece of spare lead from one of the resistors (or even a bit of thin paper clip) to connect the outer terminal of the jack directly to the bare metal on the NES board—this is *ground*. Connect the center terminal of the jack to the *Power from battery wire* that goes to the power on/off switch.

4. Look back at the NES board near the 7805 regulator. Attach the three wires from the front of the case to the NES board as in Figure 8-37. *Power to NES* comes from the power ON/OFF switch, *Video* connects to the *Video in from NES* wire from the control board, and the *Audio* wire comes from the TV's lower circuit board.

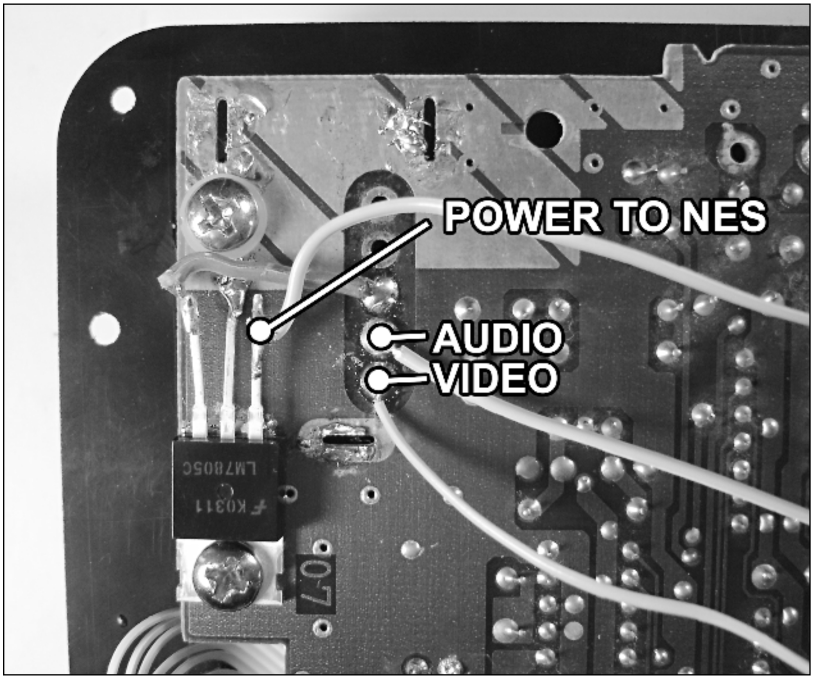


FIGURE 8-37: Attaching audio, video, and power to the NES board.

Connecting the built-in controller

The only remaining unconnected wires should be the five going to the control board — the ones that you connected when you put components in. When you connected these wires to the control board, I had you make a mark on the opposite end of one of them. That'll be wire "A," and the opposite side, the fifth wire, is wire "E." Connect them to the upper right-hand corner of the NES board as shown in Figure 8-38. The controls are now connected and ready to go, which also provides the ground wire going to the TV screen (meaning that the screen wouldn't have turned on until these five control wires were attached to the NES).

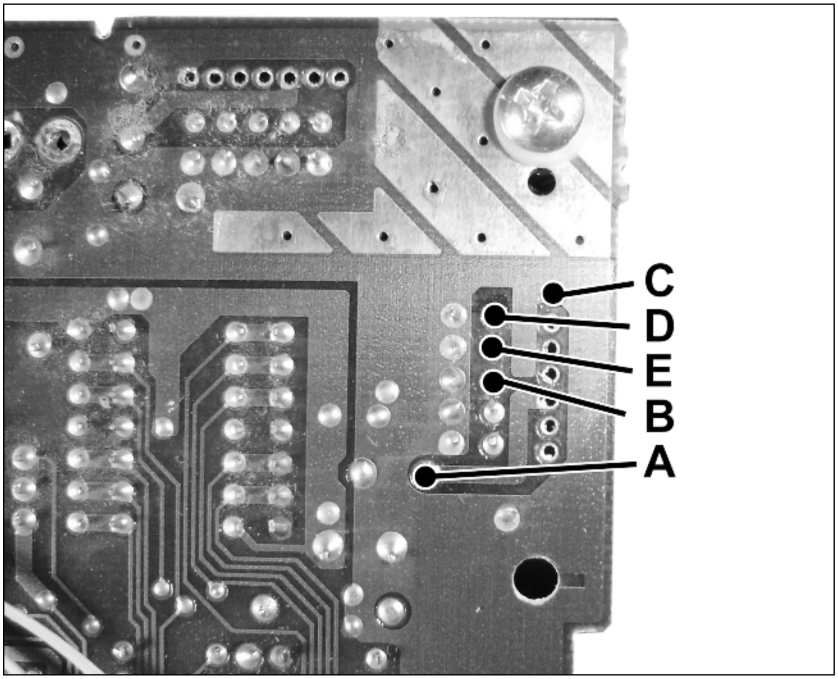


FIGURE 8-38: Attaching the control board to the NES board.

Modifying the battery pack

Yes, even the battery pack is modified for this project. In its original store-bought form, it's a bit too big to fit in the battery holder, and we'll also be giving it a new plug that's positioned in such a way as to fit into the size K coaxial power jack in the center match plate.

1. Start by using your X-Acto knife to cut through the clear plastic on the battery along the edges of the black cap where the power wires are. You can then pull off the cap to reveal the battery terminals, as seen in Figure 8-39. Draw a "+" by the red terminal and a "–" by the black terminal for reference after the wires are removed.

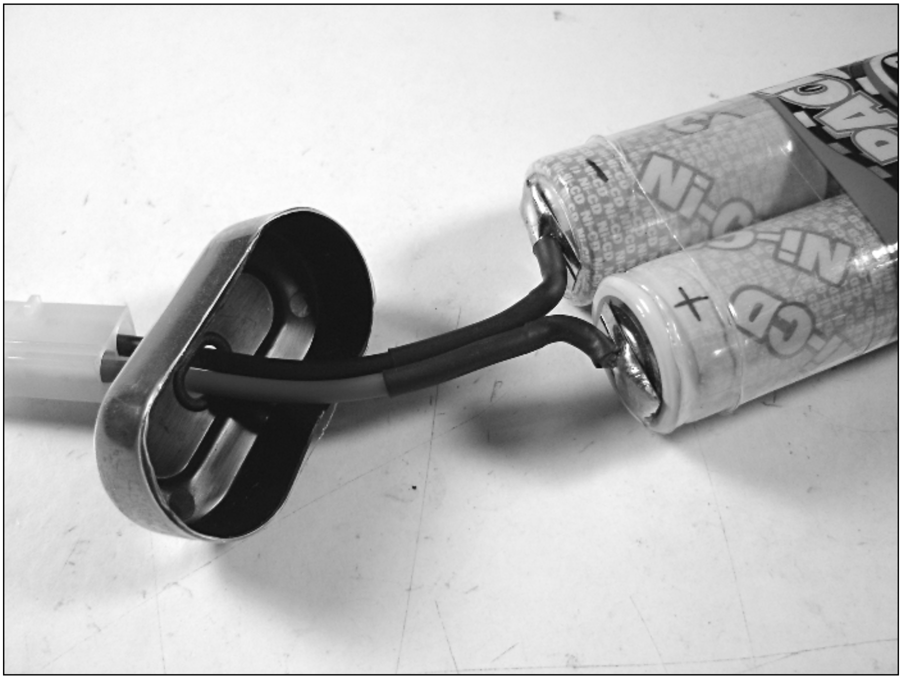


FIGURE 8-39: The cap removed from the 7.2-volt battery pack.

2. Desolder the existing wires from the battery and get out a *size K coaxial power plug*. Using a 4"-long piece of solid wire, connect the positive of the battery to the center terminal of the jack, and the negative to the outer terminal. Put a piece of electric tape around the center terminal so that it won't contact the outer terminal. Make sure to slide the cap over the wires before you attach them, so that you can screw it back onto the plug when finished. After screwing it back on, sand one side of the plug's black plastic cap so the glue will stick to it. Be careful not to short out (join) the positive and negative wires at any time, or you may get shocked or discharge the battery.
3. Make a mark 1.5" from the edge of the battery on the terminal side. Place the power plug at the edge of this mark, and vertically center the black cap portion on the battery, as shown in Figure 8-40. The idea is for the battery to plug into the back of the game unit — since that's already built, test it to see if you've got the plug in the right place. Use a multimeter to check if power is getting to the leads on the back of the coaxial jack inside the case. (Make sure the power switch is off before doing this.)
4. To attach the plug to the battery, first use a bit of superglue. Hold the plug straight and firm against the battery until the glue is dry, and then put some quick 5-minute epoxy around it. Try to keep glue off the top and bottom of the batteries, because it could create lumps, which can cause the battery holder not to fit. Finally, it's best to snake the wires around the sides of the battery, rather than the top (as shown in Figure 8-40).

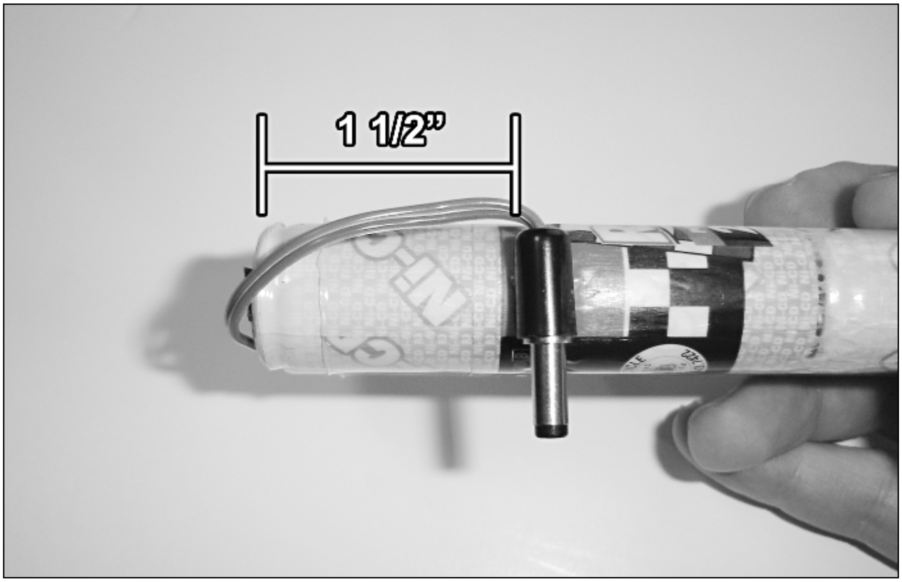


FIGURE 8-40: The power plug attached to the battery.

The battery is now modified and ready to be installed in the NES portable.

Tip

You could also insert the plug into the jack, make sure the battery holder fits over the battery, and glue the plug to the battery while it's connected to the jack. (See Figure 8-50.) This is a sure-fire way to get the plug placed correctly on the battery; just watch out for glue/epoxy dripping onto the match plate.

Attaching the battery and battery holder

You could now insert the battery into the jack and run the NES, but it wouldn't win any beauty contests. Luckily you have a battery holder! Here's how to attach it:

1. Plug the battery into the jack on the back of the NES (Figure 8-41).
2. Place the battery holder over the battery and run two 1-1/4"-long size-6 socket-head cap screws down the holes in order to hold it and the battery down. It may be helpful to bore out the side holes using a 9/64" drill bit, so that the smooth, wider part of the screw's shank will still fit. The only thing the screws really need to grip is the front half of the case. The first few times you'll probably have to use a screwdriver or small hex wrench to put them in, but after a while you should be able to do it by hand. The attached battery holder is shown in the bottom half of Figure 8-41.

FIGURE 8-41: The battery plugged into the unit and with the holder over it.

Note You don't need to actually attach the battery itself to the holder; it's designed to be held in place via *mechanical retention* (I learned that term from my dentist). If you want to attach the battery to the holder to make a kind of "battery pack," use very thin double-stick tape to do it. If you attach the battery with thicker foam-style double-stick tape or Velcro, the battery holder won't fit against the match plate.

Rewiring the battery charger plug

You're going to need to put the proper jack on the charger in order to connect it to the battery for recharging. Here's how:

Snip off the existing white plug from the charger's cable, and then attach your other size K jack to the cable as in Figure 8-42. The outer wire with a white stripe is negative, and the plain black wire in the center is positive.

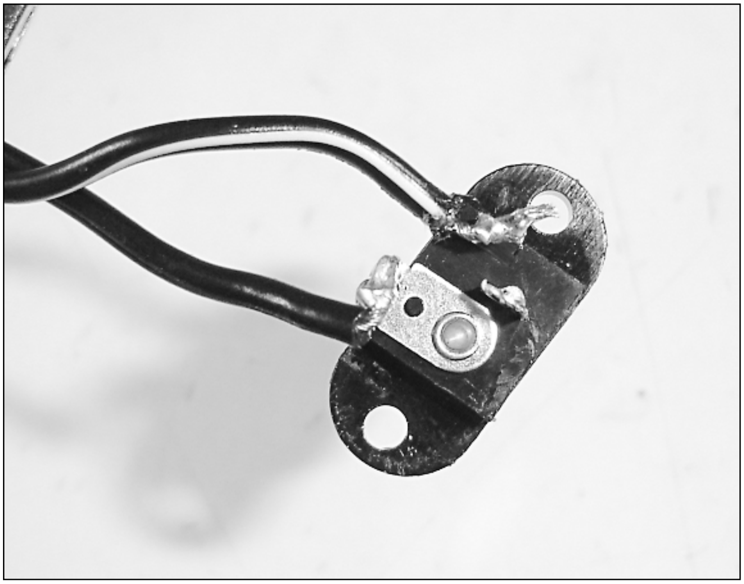


FIGURE 8-42: The new size K plug attached to the charging unit.

Using a wall power adapter to run the NES

If you'd like to make a wall power adapter for your portable NES, you'll have to get one of those universal adapters that they sell at electronic parts stores. These devices have multiple voltage settings, typically ranging from 3 volts to 12 volts. Find one that has a 7.5-volt setting, or something very close to that, but not more than 8 volts. The adapter needs to produce 650 mA of power, and most of them are rated to do 500, 800 or 1000 mA. That rating is how much the adapter *can* do, so don't worry — an 800 or 1000 mA–rated one won't fry your unit. The wrong voltage rating can ruin your unit, however, so be sure it's between 7 and 7.5 volts. Maybe even hot-glue the voltage selection switch so that it can't possibly change! (Hot glue is great!) Once you've found a wall adapter, give it a new plug to work with your NES by doing the following:

1. You should have an extra size K plug already, since they come two to a pack and you've only used one so far.
2. Test the polarity on the adapter's wires using a multimeter, and connect positive to the center terminal of the size K plug and negative to the outer terminal. (As with the battery charger, the wire with a white stripe is *probably* negative, but it's never a bad idea to check.) Cover the bare wire connections with electric tape, and slide the plug's plastic cover back over it.

You can now use this plug and the adapter in place of the battery to run your portable unit off wall power! Which kind of makes it "un"-portable — but, oh well.

Note Though it outputs the right voltage, the average battery charger doesn't provide enough amps to run your portable. (See Chapter 3 for more info on volts and amps.)

Testing and Troubleshooting

To avoid excess frustration, it's best to troubleshoot *before* closing up the unit. I try to let all the potential problems happen to me while designing and building the unit, so that I can cover them and keep them from happening to you. But some things may slip through the cracks, and that's what this section is for. We'll start with the most basic problems and work our way up.

1. Charge up the battery and insert it into the NES. Screw the battery cover over it. Insert a game cartridge, preferably one with music that plays right away. (I used Mega Man 2, also because it's one of my favorite games.)
2. Switch on the unit. The screen should light up. If it doesn't, do the following:
   - Make sure the original TV's power switch is turned on.
   - Check that +7.2 volts is going into the TV on the *Power in to TV* wire.
   - Check the polarity of the power input jack on the TV's lower board. On some TVs it's the reverse of what was indicated in Chapter 4. Check the imprint on the original pocket TV case.
3. If the TV turns on but there's no picture, only light:
   - Check the position of the brightness dial — when it's all the way up, the screen will go totally white and you won't see a thing.
   - Check that the ribbon cable from the LCD glass is properly connected to the TV's main board. (See Chapter 4.)
   - Check that +5 volts is going into the *+5 volts in* spot on the NES board.
   - Check that +7.5 volts is going into the input of the 7805 regulator on the NES board. If it is, the regulator may be bad — try replacing it. (This sounds odd, but I've wasted lots of time looking for the problem elsewhere when it was simply a defective 7805.)
   - Check the audio and video wires that are connected to the TV. As with the power input jack, the audio/video connections sometimes "flip-flop" in certain TVs. Try switching them.
   - Try connecting the *video to NES* wire to the same hole on the other side of the NES board. Sometimes when removing the RF box, the copper around the holes gets pulled off as well. If this is the case, find the closest bit of copper trace going to that connection and use it.

4. If the TV turns on but the screen blinks:
   - This means that the NES is working but the game cartridge isn't. First check that the cartridge contacts are clean. Yes, even blow on the cartridge, just like in the old days.
   - A lot of manual connections were made to the cartridge connector, and it's possible one came loose or touched another and shorted out. Check over them, looking out for loose strands of wire. Loose connections are more likely to occur on the cartridge connector itself, not on the NES board.
5. If the game picture shows up but is very weak or dark:
   - The video amplifier circuit on the control board may not be working correctly. Make sure you use a 2N4401 transistor. If you used a transistor from a grab bag, try a different one. Also double-check that the circuit is wired properly.
   - Keep in mind that the video amplifier circuit is powered by +5 volts from the control board. If the control board is not properly connected to the NES board, the video circuit may not be getting the power it needs. (See the controller issue below.)
6. If the picture is fine but there's no sound:
   - Recall that in Chapter 4, we desoldered and extended the TV's headphone jack. If the jack is removed completely or is not reconnected properly, the built-in speaker will not function. Check that chapter for more details.
   - Be sure the volume dial is turned up. If there's no sound, check that the volume dial is correctly rewired to the TV's circuit board. (Again, this is related to something in Chapter 4.)
   - Check that the audio wire from the NES is connected properly to the TV.
7. If you've made it this far, then the cartridge, picture, and sound are all working. Press Start and play the game. If the controls don't work correctly (or at all):
   - Make sure the IC from the NES controller is placed correctly. There's a groove on one end of the IC that is used for reference and can be seen in this chapter's drawings.
   - Check that the five wires are attached to the NES board in the correct order — if you forgot to make a mark indicating wire "A," they may have gotten mixed up.
   - Make sure that you soldered the correct leads on the tact switches. Soldering both leads on one side of the switch causes the switch to become "stuck on." Double-check the drawings against your PC board.
8. If the NES game picture doesn't take up the whole screen, or there's "garbage" near the edges:
   - This is caused by something called "overscan." Older game systems like the NES and the Atari 2600 were built back when most TVs still had rounded corners on the screens. Certain portions of the video picture would be off the edges of the screen, so game designers didn't extend the graphics that far, and sometimes (especially with the NES) these overscan areas had excess "garbage" characters that they didn't expect people to be able to see. The amount of screen actually used can vary from game to game. (Anyone ever notice how Star Fox on the SNES actually had a big black frame around the screen?)

Final Assembly

Now, with the portable NES tested and working properly, it's time for the final assembly. This includes securing a few more things inside the case, and screwing everything together.

1. Drill a 13/64" hole in the bottom of the front of the case (in the side walls), and put the headphone jack through it. There's plenty of space, so you could put it pretty much anywhere you want.
2. Cover the headphone jack with hot glue inside the case to secure it, and then place the "Headphones" decal on the outside of the case near the jack. Make sure there's glue behind the jack as well, so that it can withstand the pressure of the plug being inserted.
3. *Optional*: Place a bead of hot glue over the cartridge connector pins that are visible when you remove the battery door. This keeps them from getting bumped and disconnected. Be *sure* you've tested that the NES works properly before you do this. The hot glue can be removed from the wires, but it might pull off some of the pins with it.
4. Place several layers of electric tape over both the 7805 regulator and the size K coaxial power jack on the inside of the unit. This prevents them from shorting out with other wires. They shouldn't touch anything, but it's a good idea to make sure that if they do, nothing will happen.
5. Drive two 1/4"-long size-4 screws into the top two screw holes on the back of the unit.
6. Drive two 3/8"-long size-6 screws into the bottom two screw holes on the back of the unit. These will be covered by the battery holder when you screw it in place.

Tip

At first use just a couple of screws to connect the sides together, and then check to see if the unit works. Sometimes pressing the sides together can cause things to short out or become disconnected. Find out now before you go to the trouble of inserting every screw.

7. Place the "Insert Cartridge" decal just above the main curved piece of plastic on the battery holder. The curves of the decal and plastic should match.
8. Insert the battery, and screw the battery holder over it.

Congratulations, your portable Nintendo Entertainment System with a CNC-built case is done and ready for action! (If they ask what it is when going through the airport X-ray, mention this book!)

Chapter in Review

The Nintendo Entertainment System is both a classic and fun system to make into a portable, and a custom CNC-built case is a snazzy way to do it! In this chapter you accomplished this by:

- Hacking more parts from the NES above and beyond what you hacked in Chapter 6. This made the motherboard smaller so that it'd fit in the case.
- Rewiring the cartridge connector, rotated by 90 degrees so that the cartridge could be inserted differently from normal.
- Using a CNC machine to cut parts for the case, and then gluing them together to form the actual pieces.
- Making a built-in controller and wiring it to the NES, and installing a TV screen.
- Wiring the whole shebang together and testing it out.

If you're itching to build more portables, fear not — there are six more units still to come in this book!

Making Your Super Nintendo Entertainment System Portable

chapter 9

in this chapter

☑ Ripping Apart the Mini-SNES

☑ Removing Some Things, Just Moving Others

☑ Powering the SNES with Batteries

☑ Rebuilding the Controllers

☑ Chapter in Review

Let me get a big confession out of the way. I was actually a Genesis person back during the 16-bit wars of the early '90s. I didn't even own a SNES until 1998, when I saw the mini ones going for $20 on clearance at the store. If you're still reading this, I guess you didn't throw the book across the room in disgust. Thanks for understanding!

When I got into the portable-building craze, I went around looking at systems and thinking about which ones would make cool units. Even though I loved the Genesis, it never crossed my mind, because Sega themselves had released a portable version of it in 1995 — the Nomad. Not wanting to reinvent the wheel, I gazed upon my mini-SNES. Realizing the board inside must be pretty small, I ripped it apart, and a few months later, my first SNES portable was built.

And now it's your turn! In this chapter we'll open up the mini-SNES and get it ready to be used in the next two chapters. We'll also discuss the basics of running it off batteries and rebuilding controllers, in case you'd like to make a custom portable of your own design. Visit your local used-game store or buy a mini-SNES on eBay, grab your tools, and let's begin!

Ripping Apart the Mini-SNES

Of all the game consoles in this book, the mini-SNES is the hardest to open. It doesn't use normal Phillips-head screws to hold the case together. No, that'd be too easy! Instead, it uses what I refer to as "Nintendo screws." You've probably noticed them on the backs of NES and SNES cartridges — they're rounded, with little notches around the edges. Normal screwdrivers are useless against them!

Now if a person was really patient (or bored), they could slowly turn the screws on the cartridges by pressing into the side notches with a pin and twisting. (I used to do this for "fun" with my Gameboy carts in study hall long ago.) But on the mini-SNES these pesky screws are deep inside a well and can't be reached (not even by Lassie). That leaves two ways to remove them and open up the system, as described in the following sections.

Using a Nintendo screwdriver

This is the easier method, but you've got to buy a strange tool that isn't available at every corner drugstore. Instead, search an online auction site for "Nintendo screwdriver." You'll find listings either for screwdrivers or for just the bits. The size you'll need for the SNES is a 4.5 mm, but whether it's a bit or a screwdriver, make sure it's long enough to get to the bottom of the 1.3"-deep mini-SNES screw well.

The "other" ways to open the mini-SNES

If you don't want to wait for an online auction to ship, or don't feel like spending $8 on a tool you'll only use once, you can open a mini-SNES in one of the "other" ways.

Caution

I really don't want to say, "Kids—ask a grownup for help with this," as the mere mention of those words sent my eyeballs rolling when I was a lad. So I shall rephrase: If you feel you might need help hacking and slashing into a Super Nintendo, have a person who is experienced with tools assist you in the following procedures.

Grinding wheel

If you have access to a grinding wheel you can use it to open the mini-SNES using the steps listed below. (This is the preferred "other" method, so ask everyone you know if they have a grinding wheel that you can use before resorting to the screwdriver method.)

1. Hold one side of the SNES against the wheel and grind through the casing toward each screw. Figure 9-1 shows the correct "entry" points to use. Go along these lines, and I promise you won't hit anything important!

Caution

Like most spinning wheels of stone, the grinder can be dangerous. It can cut you if you touch it, cause bits of hot material to go flying into your eyes, or jerk parts out of your hands if you don't hold them tightly enough, sending them flying on dangerous trajectories. Therefore, you should always wear safety goggles when using one. If you need to hold a part close to the wheel, use a large pair of pliers, not your hands, and always wear work gloves.

2. Once you've ground a large hole near both screws on one side of the case, you should be able to see the screw posts inside. As shown in Figure 9-1, you'll only need to grind openings on one side of the case. You can now skip ahead to *Destroying the screw posts*.

FIGURE 9-1: The correct approach angles for grinding into a mini-SNES.

Using your large flat-head screwdriver

In Chapter 2, I suggested that having a big flat-head screwdriver around might be useful for portable building. Well, its time has come — if you don't have access to a grinding wheel, you can use the big screwdriver to open the mini-SNES:

1. Stick the screwdriver into the seam between the halves of the case near a screw post as shown in Figure 9-2. Twist and shove it in until you get through. Take care not to get your fingers in there, as they may get pinched or cut.
2. Once you've gotten the edge of the case open, you can push the screwdriver in and further open the case, as shown in Figure 9-3. You'll then have enough room to push the screwdriver out one of the slots on the rear, then pry up the screwdriver to pop out that section of plastic.

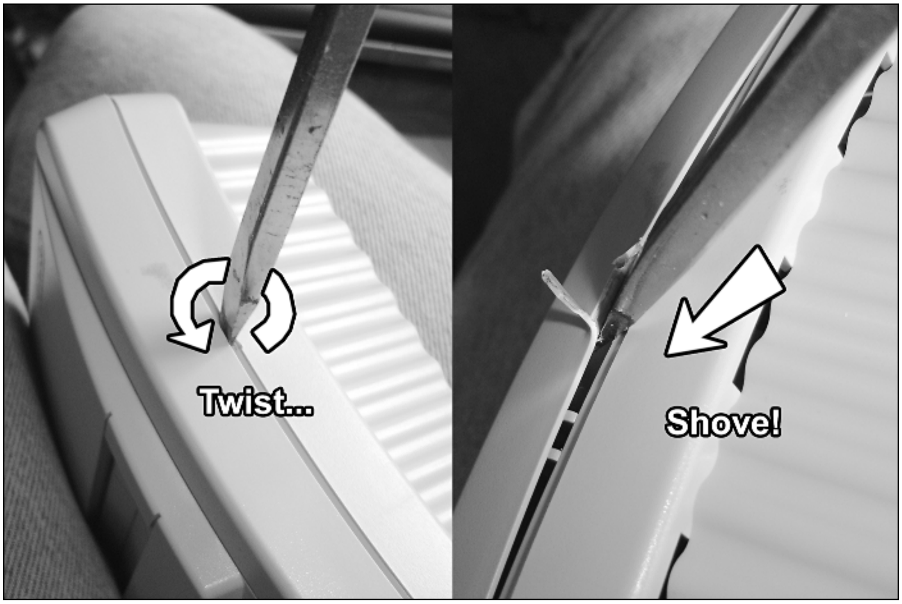


FIGURE 9-2: The screwdriver begins its attack on the mini-SNES.

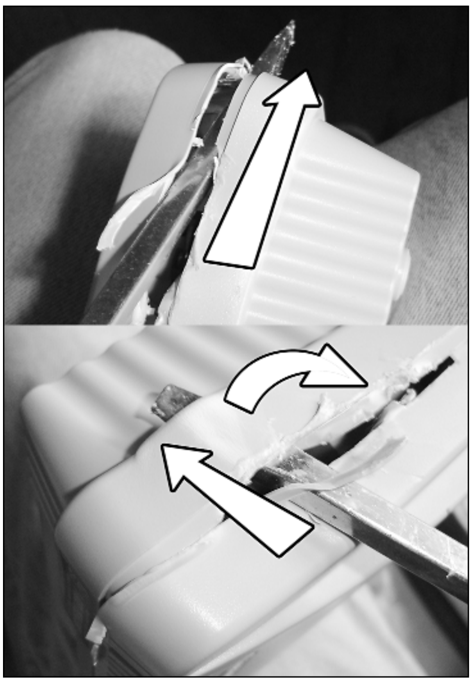


FIGURE 9-3: Separating the case further, and popping a section of plastic.

Caution

Ripped and jagged plastic can cut you, so take care while doing this.

3. Take a large pair of pliers and grip on the outer edge of the hole you've created. Bend it up and snap it open as seen in Figure 9-4. You now have access to the screw post.

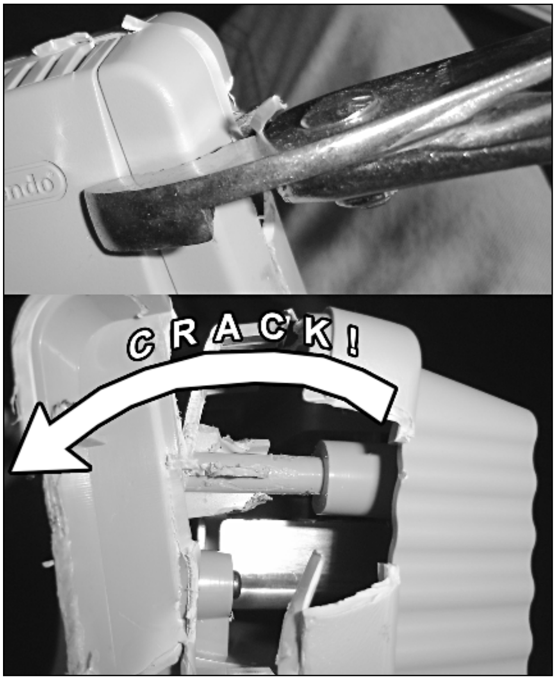


FIGURE 9-4: Prying the case open to reveal the screw posts.

4. Repeat Steps 1–3 for the other screw post on the same side — remember, you'll only have to expose the screw posts on one side of the unit. (See Figure 9-1 in the grinding wheel section.)

Tip

As a general rule, when you hack open the mini-SNES, you can smash up and wreck the front/top half of the unit all you want, but try not to bend or crack the rear half, because that is what the motherboard is attached to.

Destroying the screw posts

Using one of the previous methods, you've now exposed the plastic screw posts on one side of the mini-SNES. Time to destroy them!

1. Reach into the opening with a fairly hefty pair of pliers, and grab onto the screw post. Then bend it out (either sideways or toward the outside of the case) until the screw itself snaps free. You can also twist them to break the screw free. Do this for both exposed screw posts.
2. Now you should have one side of the SNES case unattached. If you want to go ahead and grind/pry open the other side that's perfectly okay, but a faster route is to just grab the sides, and rip it open! (See Figure 9-5.)

FIGURE 9-5: Ripping open a mini-SNES. (Be sure to yell "ARRGGHHH!" when you do this.)

The case of the mini-SNES is now open, allowing you to see the motherboard, cartridge slot, and heat sink.

Taking apart the rest of the mini-SNES

With that pesky case out of the way, we can take apart the rest of the mini-SNES in a much more traditional fashion.

1. Remove the seven Phillips-head screws that are visible on the SNES's motherboard. Four are on the lower part of the board, one is on either side of the cartridge slot, and one is up near the audio/video output jack.
2. Next, find the 7805 regulator behind the big metal heat sink. (See Chapter 3 for info on them, with pictures.) Remove the single Phillips-head screw to detach it.
3. Flip the motherboard over, and you'll see four Phillips-head screws near the top. Take them all out. You can now remove the heat sink. However, although the plastic portion will be slightly loose, it won't come off until you've done some desoldering.

The SNES motherboard is now completely free of the case.

Removing Some Things, Just Moving Others

In order to make the SNES motherboard useable for a portable, we're going to have to remove some stuff. Other things, such as those blue capacitors near the top, can't be completely removed, but rather have to be moved someplace else and reconnected. Before we begin, let's identify the internal parts of the SNES motherboard shown in Figure 9-6.

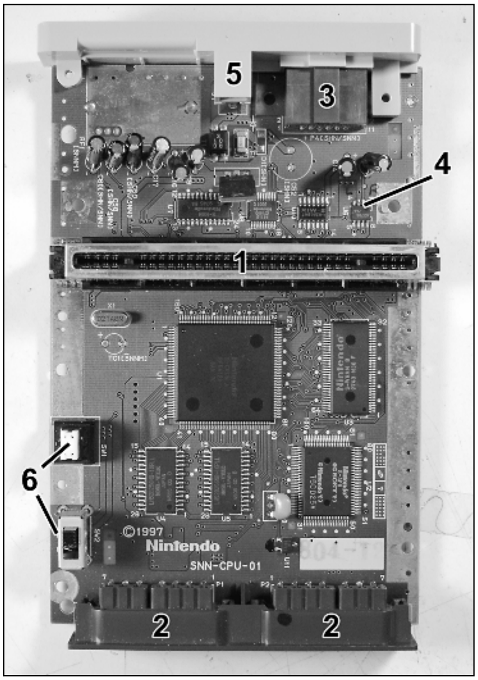


FIGURE 9-6: The SNES board with important parts labeled.

1) Cartridge slot connector
2) Controller ports
3) Audio/video output jack
4) Secret place to get left and right audio signals
5) DC power input
6) On/off power and reset switches

Now that you know what those things are, we can start removing them! Get your desoldering iron heated up and do the following:

1. Desolder the four leads on the *reset button* and the four leads on the *on/off power switch*. You can then pry these switches off the board using a thin flat-head screwdriver.
2. Put a bit of solder between the switch contacts on the front of the board as seen in Figure 9-7. (You may want to use a short bit of paper clip.) This sets the SNES switch to a permanent "on," allowing you to turn the system on and off together with the rest of a portable's guts (such as the screen). Note that there is a little bit of green between the two contacts. This is the ground — try not to hit it with the solder, because this will short out the system.

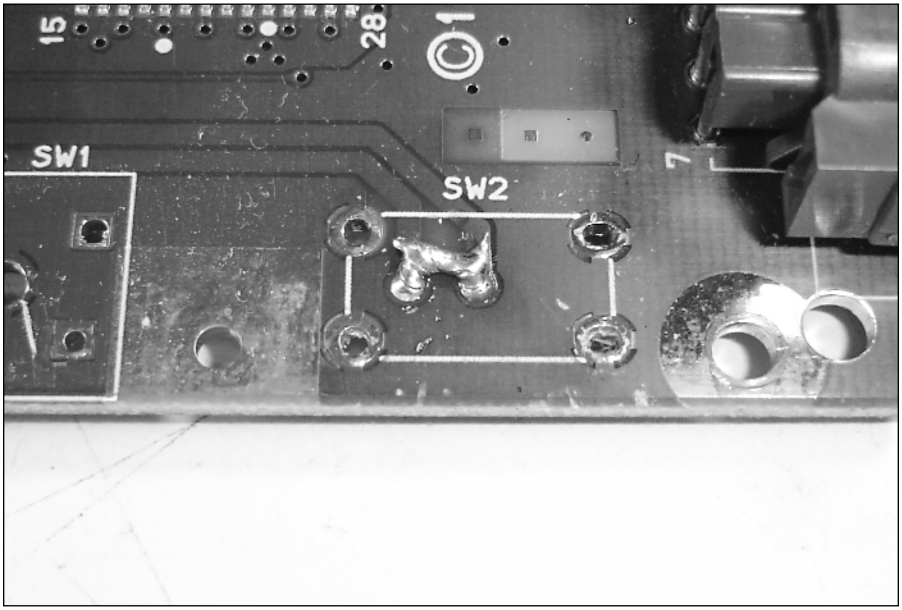


FIGURE 9-7: Jumping the power switch to be always "on."

3. Desolder the twelve leads on the *audio/video jack* and the two big leads on the *DC input jack*. For the DC input jack leads, you'll probably have to melt and suck up a little solder at a time, as there's a lot of it there. Just keep working at it, and eventually you'll remove enough solder to pry the jack free.
4. When all the solder is removed, pry the gray plastic backward, away from the main board. The DC jack will pull off with it, leaving the A/V jack behind. With the gray plastic removed, use a flat-head screwdriver to pry off the A/V jack as well.
5. Yet another overly large (and thus portable-unfriendly) part consists of the *controller jacks*. Desolder the fourteen leads on the bottom of them (seven per port). The leads are rather thick, and it won't look like much solder is coming off them — that's because there wasn't much solder there to begin with, making them actually a little easier to desolder than your average lead. With the solder gone, rock the controller jacks back and forth until they pull free. You may also need to pry them off with a screwdriver.
6. Desolder the three leads on the bottom of the 7805 regulator and remove it. Although this is an essential part — remember Chapter 3? — we'll discuss how to reconnect a new 7805 to the mini-SNES later in this chapter, and in both SNES portable projects.
7. You'll notice some dark gray tabs on either side of the cartridge slot. These originally held the unit together, but now they're merely in the way. Using a large pair of pliers, grab onto each tab and bend it forward or backward. It should snap off easily.

You've now removed everything on the mini-SNES board that you don't need. You'll need a power regulator, of course, but one can be hooked back up elsewhere so that it won't get in the way, as it would have if left in its original position. (More on this later.)

Rewiring all those darn capacitors

Take a look at the mini SNES board. Notice how pretty much everything on it is fairly flat? That's because it mostly uses modern *surface-mount* components. These are components whose connections attach to — get this — the surface, and don't go through the board itself. That makes the mini-SNES a great machine to make into a portable!

Except, of course, for the eight chunky blue capacitors near the top of the board, and unfortunately the SNES needs these to run! Therefore, in order to make the SNES board as flat and portable-friendly as possible, they must be removed and rewired elsewhere, as described below.

Note

If you're planning to use Chapter 11 to make a CNC-built SNES, then you should check the *Attaching the SNES board to the rear plate* section in that chapter to find out the slightly different way to perform the capacitor rewiring for that project. That will save you from having to do anything over.

1. Desolder the eight capacitors. Because of the nature of the mini-SNES board, this can be tricky, so here are a few tips:
   - If the capacitor won't come free after desoldering, rock it back in forth with one hand and heat up the leads. The leads will move, since they're being rocked back and forth, so that the solder won't remelt properly, thus making the capacitor loose and removable!
   - Try resoldering the leads, then melt the old solder along with the new, and desolder it all again. (This trick was mentioned in Chapter 2.)
2. The eight capacitors are all different, but luckily, their rating is listed on each of them as a "uf" number. Figure 9-8 shows where to reconnect them based on these numbers. Use a two-strand of 2" ribbon cable for each. (Make sure that there are no stray strands flailing off the ends of the wires. These can cause short-circuits.)
3. These capacitors are polarized, meaning they each have a positive and negative lead. When reconnecting the capacitors, make sure that you hook the leads up the same way you found them. To check the polarity on a capacitor, look for the white band on one side near a lead — this indicates the *negative* lead. All the negative lead wires on the capacitors should attach to the lower row of holes, the ones closest to the cartridge connector.
4. After making sure that the hacked-up SNES works (in the next section), put a thin strip of electric tape around the leads of each capacitor to keep them from touching other metal and shorting out.

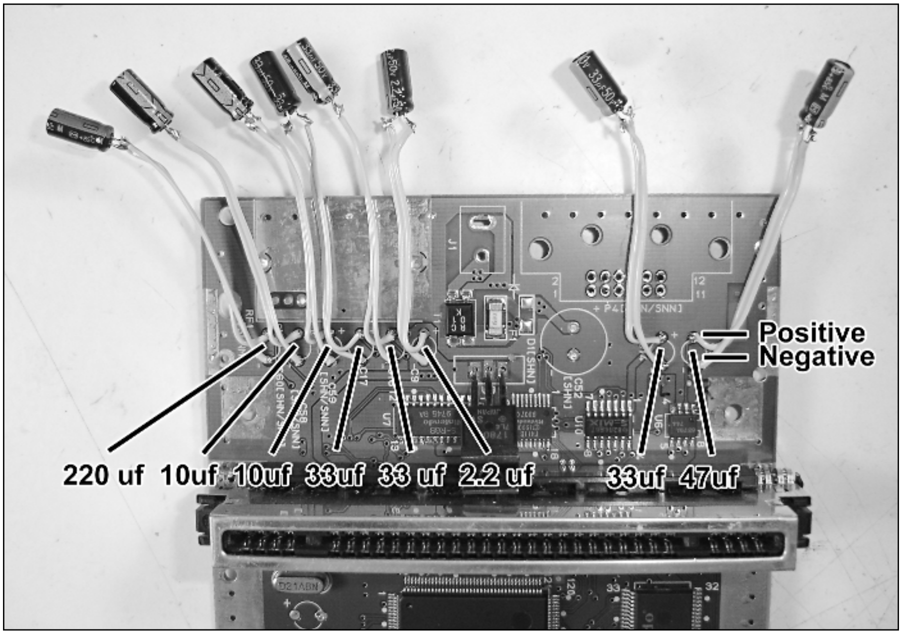


FIGURE 9-8: Reconnecting the eight capacitors.

The SNES motherboard is now a lot flatter and can fit into a portable case much better than it could have before.

> **Note** The placement of the capacitors and the length of the wires shown will work with both of the SNES portable projects I've designed for the following two chapters. If you're rolling your own SNES portable, you may need to position these capacitors in your own way, though the one here should work for most configurations.

Reconnecting the video and audio lines

Because you've removed the original audio/video jack, you're going to need a new way to get those signals off the motherboard. Figure 9-9 shows where to find the video, mono audio, and left and right audio signals on the mini SNES board.

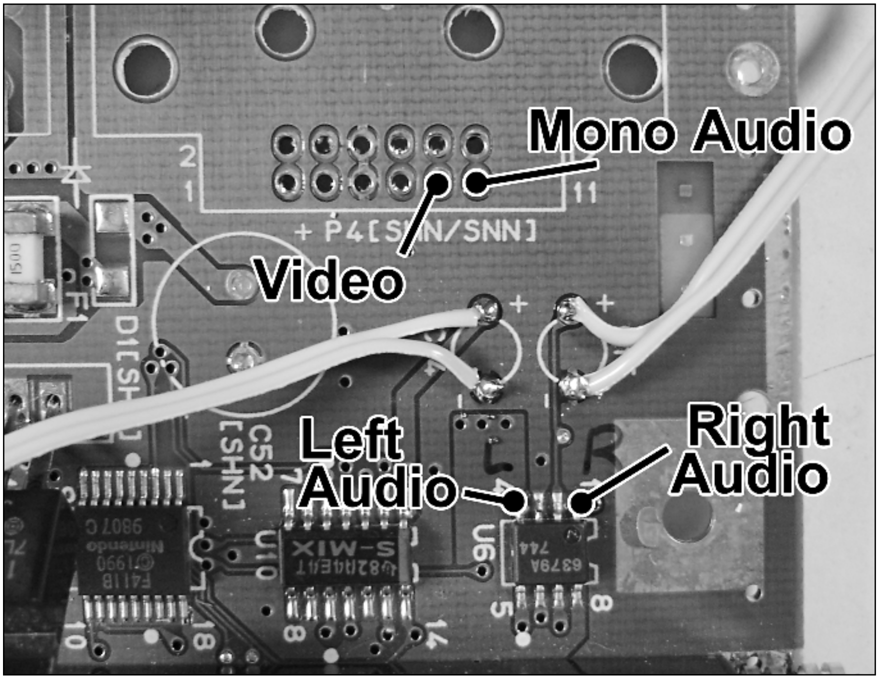


FIGURE 9-9: Video, mono audio, and left and right audio sources.

Some general notes about these connections:

- The mono audio source is for use with single-speaker pocket TVs.
- The small surface-mount IC will give you separate left and right audio signals. Use this for stereo sound when hooking up to the Sony PSOne screen. (More on this in the next chapter.)
- If the TV is hooked up to the same ground as the SNES, you won't need to attach separate grounds for the audio and video connections.

You can now hook the SNES board up to a video display, such as a pocket TV, and get the sound and picture through — except for one thing. The SNES isn't going to do squat without power going to it, so we'll discuss how to do that next.

Powering the SNES with Batteries

By this time the mini-SNES board should look pretty small and bare — but fear not, it will still work! Well, once we get some power going to it, of course.

The mini-SNES doesn't take much power, only about 350 mA at +5 volts. This can be provided to the system using a regulator, as described in Chapter 3. Here's how to hook one up to the SNES board.

1. You'll need one 7805 regulator (Radio Shack catalog #276-1770), a heat sink (Radio Shack catalog #276-1368), and a +7.5 volt (or higher) battery, as described in the next section. A piece of metal with a hole drilled in it can also be used as a heat sink.
2. Use a size-4 screw to attach a 7805 regulator to the heat sink. Insert the regulator in a piece of PC board as shown in Figure 9-10. You can mount the regulator however you like, as long as it has a heat sink and the leads don't short out against anything else. The ground (middle) connection of the 7805 can touch the heat sink, however.

Figure 9-10 shows how the 7805 regulator should be connected to the SNES.

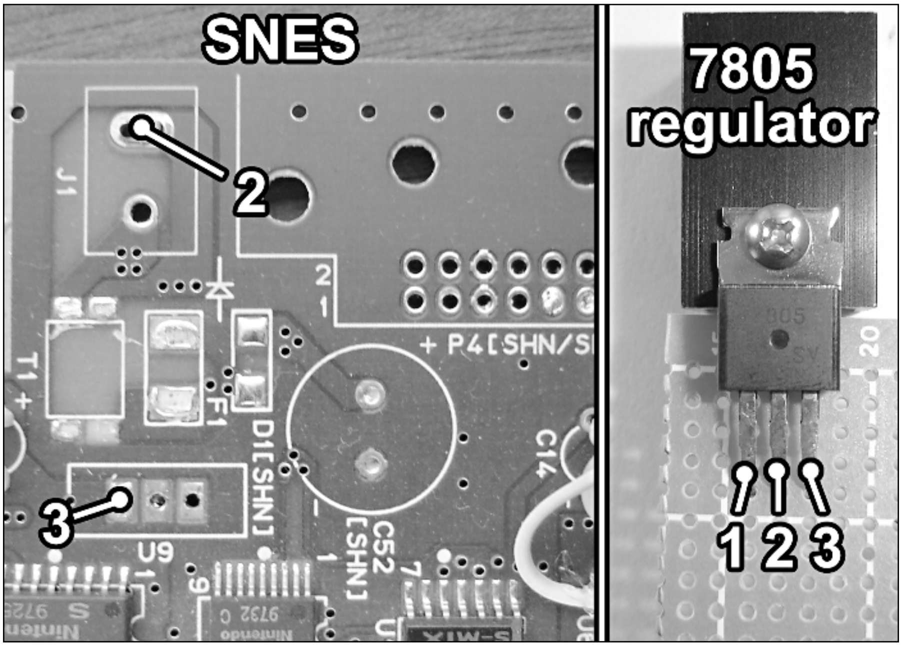


FIGURE 9-10: Hooking a new 7805 regulator and heat sink to the SNES.

- Connect spot 2 on the SNES to spot 2 on the 7805 regulator. This is *ground.*
- Connect spot 3 on the 7805 regulator to spot 3 on the SNES. This is *+5 volts out to SNES.*
- Connect the negative lead of your battery to spot 2 on the SNES and the positive lead to spot 1 on the 7805 regulator. Spot 1 is *unregulated power in*. To use a switch to turn the SNES on and off, put it between the positive battery lead and spot 1.

This simple circuit will provide the correct amount of power to run your SNES. We'll talk about which batteries are good to use in the *Batteries to run the SNES* section.

Note How to power the SNES is included in each of the SNES projects in the following two chapters. This is provided for reference or for those making their own style portables.

Easy way to power the SNES

A quick and dirty way to get a regulated power supply is to use the +5 volts coming off the pocket TV that you're using for your portable.

1. Connect a wire to the +5 volts source from your pocket TV. This spot is indicated in Chapter 4. It's the same place you get +5 volts to run the white LEDs. This wire you've just connected is the *regulated power wire.*
2. Connect the other end of the regulated power wire to spot 3 on the SNES board as indicated in Figure 9-10.
3. Connect *ground*/spot 2 from the SNES to *ground* on the TV (also indicated in Chapter 4) or to the negative lead of the battery.

The SNES will now turn on when the TV does! The TV can be powered with the normal number of batteries it takes (typically four AAs), but you'll probably want to use batteries that store a lot of mAH, since you're powering two devices now. This method of powering the SNES will be used in Chapter 10.

Note One of the reasons that this works is because by using white LEDs instead of the bulb, you're saving about 50 percent of the power the TV usually consumes. This "extra" power can then be used to run the SNES.

Batteries to run the SNES

If you're going to be powering the SNES with a 7805 regulator, then the unregulated input voltage should be at least +7 volts. This is because once the battery drains below +7 volts, the regulator "drops out" and stops working. Here are some batteries that will work:

- A 7.2-volt rechargeable battery from Radio Shack. The Ni-Cd version has 2000 mAH of power and is catalog #23-330. The Ni-MH version has 3000 mAH of power and is catalog #23-431.
- A 9.6-volt rechargeable battery from Radio Shack. The Ni-Cd version (catalog #23-329) is the most common and it provides 1000 mAH of power.
- Both of the above battery types can be charged with the dual voltage Ni-Cd/Ni-MH charger (catalog #23-333).

- As usual, a Sony Infolithium Type L battery will work great and provide lots of power, but at an added cost.
- See Chapter 3 for more information on batteries and how they compare when powering game systems.

Once you've chosen a battery, you can connect it to the 7805 regulator and the SNES as described back in the *Powering the SNES with Batteries* section.

Rebuilding the Controllers

What good is a hacked-up portable SNES if you can't control the game? This final section will discuss how to build you own custom SNES controller from scratch, and how to reconnect it to the game system.

If you take apart a standard SNES controller, you'll find some buttons with rubber things under them and a circuit board. There's an IC (integrated circuit) on the board which is used to sense the buttons. However, it's a *surface mount* chip and therefore hard to remove using standard tools. Even if you could remove it, it's very hard to resolder it and hook it back up to anything. For these projects, the only useful parts of a SNES controller are the colorful buttons themselves.

Okay, so if we can't use the guts of a SNES controller, what can we use? Why, two standard NES controllers of course! See, inside each NES controller is a 16-pin IC with the number "4021" on it. Wiring two of these together, along with buttons and resistors, recreates the hard-to-remove IC in a SNES controller, allowing you to build our own controller with ease! (You can do this because the SNES controller works just like the NES controller — it just needs that extra IC to read the extra buttons.) Here's how to make a SNES controller:

1. Get the following parts:
   - Two 4021 ICs from NES controllers.
   - A PC board (Radio Shack catalog #276-147).
   - Sixteen 10K-ohm, 1/4-watt resistors (Radio Shack catalog #271-1335).
   - Twelve 6-mm tact switches (Digi-Key part #EG2495-ND, www.digikey.com). You can also use any small switch for the buttons/directional pad.
   - Some wire.
2. Place the tact switches, 4021 ICs, and resistors on the front (non-copper side) of the PC board as shown in Figure 9-11. Note the position of the small dents on the ends of the ICs — they must be placed as shown in this drawing to work.

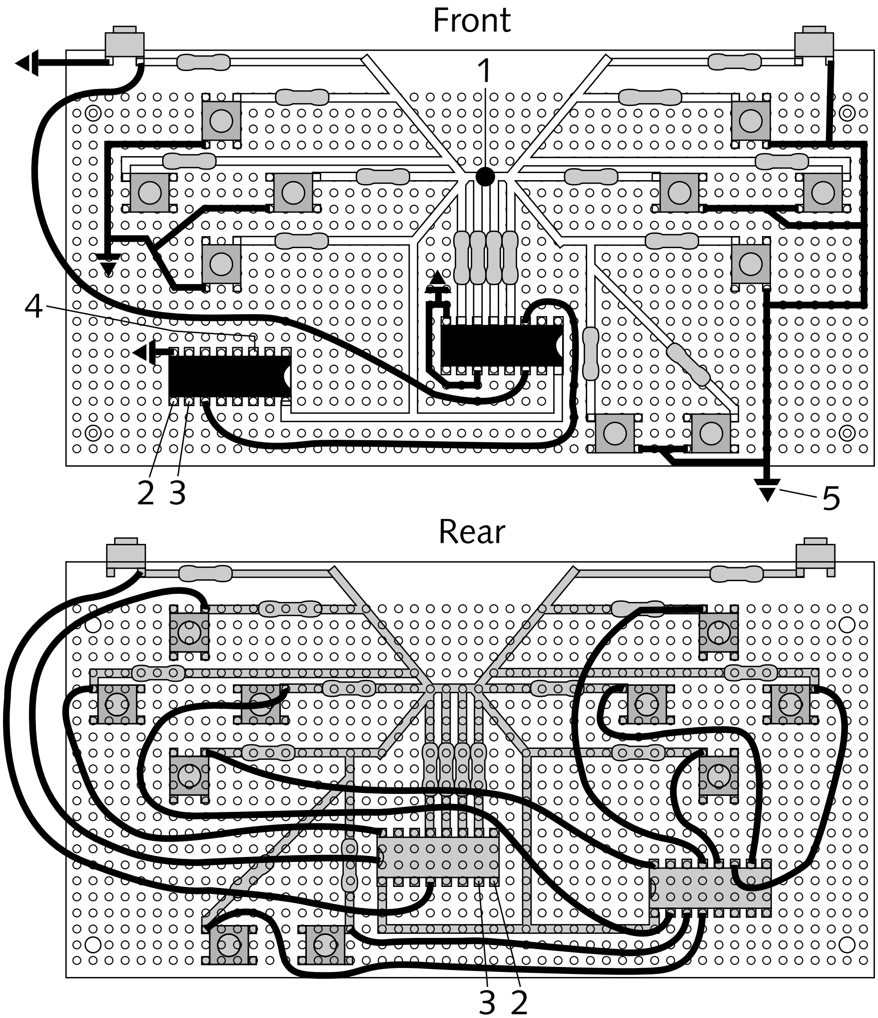


FIGURE 9-11: Wiring two 4021 ICs together to make a SNES controller.

3. Solder all components together where the leads touch each other in the drawing. As you can see, most of the wiring is done on the rear. Use the following guidelines:

- White lines indicate the leads coming off resistors. As you can see, many of these are connected together — this is the +5 volt source (same as connection #1 to SNES).
- Black lines indicate wires.
- The arrows stand for *ground*, or *negative*. All grounds in this drawing connect to wire #5 going to the SNES.

4. Connections 1 through 5 go to the Player 1 or Player 2 port on the SNES board, as shown in Figure 9-12.

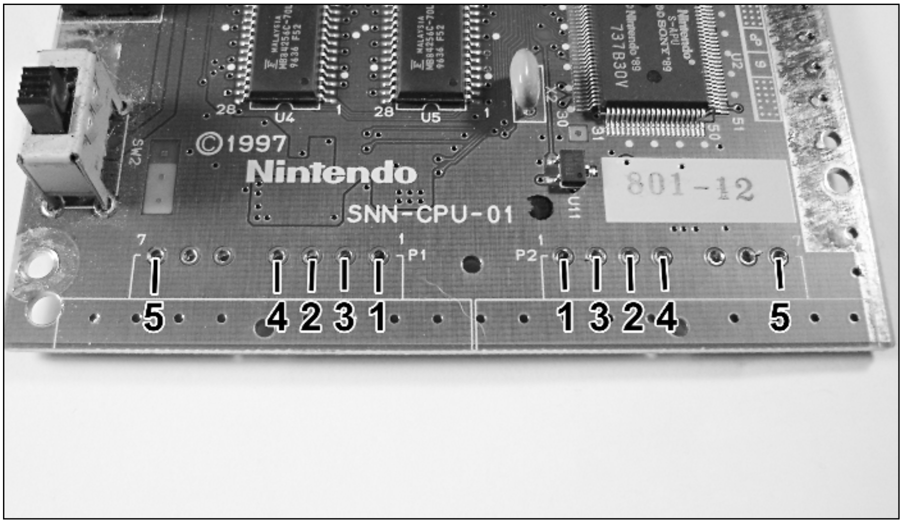


FIGURE 9-12: How the custom-made controllers hook up to the SNES board.

You can now hook this makeshift joystick up to a SNES and play games. The tact switches are positioned to fit with the plastic directional pads, and you can use the original plastic colored buttons as well. Naturally you're also free to make control buttons from any material you please.

Sometimes standard NES controllers can be hard to find, depending on the demand for them. As an alternative, you can grab two of the cheap joysticks pictured in Figure 9-13.

These were third-party joysticks released for the NES in the late 1980s. They're dirt cheap at used-game stores now ($5 at one place I checked, $2 at another), and they contain the same 4021 IC as the regular NES controllers. Buy a couple of these and you'll be set. You can also get the 4021 IC from other NES controllers, such as the NES Advantage and the MAX.

Note

The rebuilding of the controllers is discussed in the instructions in the next two chapters. This tutorial is intended for those building custom portables of their own design and explains a little about how the controllers work.

FIGURE 9-13: A cheap Quickshot joystick.

Chapter in Review

You can now play your hacked-up mini-SNES and run it off batteries! If you've got some cool ideas for a case, or want to install it in your car, or something, you should now have enough information to get you started. Otherwise, the next two chapters will take what you've learned and hacked so far, and allow you to build a complete portable SNES system out of it, either by hand or with CNC machinery.

Here's a quick recap of important stuff you've learned in this chapter:

- It's hard to open a mini-SNES case!
- You can remove a lot of stuff off the SNES board, but the blue capacitors have to be kept in order for the system to work.
- You can hook the audio, video, and power back up to the SNES after you've ripped those original parts off.
- A SNES controller works just like a NES controller except that it uses two 4021 ICs, since it has more buttons to keep track of.

Building a Portable Super Nintendo by Hand

chapter 10

in this chapter

- ☑ Materials You'll Need
- ☑ Making the Front Half of the Case
- ☑ Making the Rear Portion of the Case
- ☑ Wiring the Unit
- ☑ Troubleshooting
- ☑ Final Assembly and Detailing
- ☑ Chapter in Review

Behold Figure 10-1, the Super Nintendo Portable you can build by hand!

In this chapter we'll build the case for this portable by hand, and then install a PSOne screen and custom controls into it. We'll then install the mini-SNES you hacked in Chapter 9, and wire everything together to run off six rechargeable AA batteries. There's a lot of work involved with this project, but in the end you'll have a portable to be proud of (and of course play SNES games on).

Clear off a space on your workbench, get some fresh, sharp X-Acto knives, and let's begin!

FIGURE 10-1: The hand-built SNES portable.

Materials You'll Need

In order to build this portable SNES, you're going to need to go around collecting (and buying) materials. The first things you'll need for this project are the major ones listed below:

- A mini-SNES with all the parts removed, as described in Chapter 9.
- A 5" PSOne screen, modified with white LEDs, as described in Chapter 4.
- A standard SNES controller. Since we'll only be using the buttons and directional pad (not the electronic guts), a nonworking one is fine.
- Two standard NES controllers, either actual Nintendo models or third-party controllers, such as the Quickshot joystick. Desolder the 16-pin 4021 ICs from both controllers as described in Chapter 9.

The rest of the parts fall into three basic categories: electronics, case-building parts, and decals. There are also some miscellaneous things to pick up as well, such as glue and sandpaper.

Electronic components

Table 10-1 shows a list of the electronic parts you'll need for this project. The most convenient place to get most of this stuff is from Radio Shack. Using a common source such as Radio Shack allows us to standardize parts and layouts so that what you see in this book will match what you build yourself. (This especially applies to things such as the PC boards.) Most components at Radio Shack come in packages of more than one, so the list indicates how many packages you'll need, rather than an exact number of components.

Table 10-1 Electronic Parts List

Part Name	*Available From:*	*Part or Catalog #*	*Quantity/Packages Required*
10K ohm, 1/4-watt resistor	Radio Shack	271-1335	4
Grid-style PC board (2-3/4″ × 3-11/16″))	Radio Shack	276-158	1
1/8″ panel-mount jack	Radio Shack	274-251	1
1/8″ phone plug	Radio Shack	274-287	1
Battery holder, holds four AA batteries	Radio Shack	270-391 or 270-383	2
AA size Ni-MH rechargeable batteries	Radio Shack	2-pack: 23-525; 4-pack: 23-528	6 batteries
Ni-MH/Ni-Cd battery charger	Radio Shack	23-333	1
DPDT submini slide switch	Radio Shack	276-407	1
Battery holder, holds four AA batteries	Radio Shack	270-391a	2
Tact switch, 6 mm	Digi-Key	EG2495-ND	12

The tact switches can be obtained from Digi-Key, which has a handy Web site at www.digikey.com. They have a minimum order of $25, so it's not a bad idea to get your white LEDs at the same time.

The battery holders listed above will be used for their spring battery terminals. You can also get these from other devices such as hacked pocket TVs and old electronic devices. This will be discussed at more length in the *Attaching the battery terminals* section; you may wish to check ahead.

Parts for building the case

Now let's move on to the materials you'll need for the actual construction of this portable's case. I'll list each item, what quantity to get, and where to find it.

- **1/16"-thick engraving plastic, 12" × 12" piece.** This can be found at trophy/awards shops. (See Chapter 5 for more information.) I'd suggest a light gray SNES-style color.
- **1/16"-thick engraving plastic, 6" × 10" piece**. Dark gray or black color. This will be used for the battery covers and other assorted small pieces. 6" × 10" is the minimum size needed, but it's not a bad idea to get a little extra (or ask for some scrap) in order to allow for mistakes ... or, as I like to call it, *practice*.
- **3/8"-thick balsa wood, 3" × 5".** You can find this at hobby and model shops. It may come in a piece larger than 3" × 5", but will still be pretty cheap, and you'll have a few extra chances to cut the balsa parts correctly, which can be a little tricky.
- **Aluminum strip, 3/4" wide, 1/16" thick, and 25" long.** They have these in hardware stores near the screw aisle. Though you only need 25" of it, the stuff will likely come in a 4' or 6' length.
- **Two aluminum strips, 1/2" wide, 1/16" thick, and 12" long.** Depending on the store, these may come in the needed 12" lengths, though it's not a bad idea to pick up an extra one or two in case you need to rebend them. If you can find shiny steel strips, they'll look really cool and futuristic on your portable.

Screws, nuts, and spacers

Don't leave the hardware store yet, because you'll also need the parts listed in Table 10-2. Locate the section of the store that has a variety of screws and similar parts in a series of drawers. There's usually an entire aisle devoted to this.

Table 10-2 Screws, Nuts, and Spacers Required

Screw/Nut Size	*Type*	*Length*	*Quantity*
Size-6 screws	Phillips, pan (round head)	3/8″	4
Size-4 screws	Phillips, pan (round head)	1 1/4″	2
Size-4 screws	Phillips, pan (round head)	3/4″	2
Size-4 screws	Phillips, pan (round head)	1/4″	4
Size-4 nuts	Standard	N/A	8
Size-4 nylon washer	Nylon, 1/4″ outer diameter	1/4″	10
Size-4 nylon washer	Nylon, 1/4″ outer diameter	3/4″	2

Screw/Nut Size	*Type*	*Length*	*Quantity*
Size-6 nut	Standard	N/A	11
Size-4 nut	Standard	N/A	2
Nylon hole plugs	Fits 3/16″ hole, black	1/4″	4

In addition, you'll also need six computer case screws. These are short, 1/4"-long size-6 screws that are typically used to hold PCI cards and the motherboard in desktop computers. The reason I suggest these is because they're cheap and because 1/4"-long size-6 screws are sometimes hard to find at hardware stores.

Preparing the nylon spacers

We're going to be attaching size-4 nylon spacers to the front plate so that we can put size-6 screws into them. If this doesn't sound right, well—you're right. But if we thread the smaller size-4 spacer beforehand, it will accept a threaded size-6 screw. Here's how to thread them:

1. Grip each nylon spacer with a large pair of pliers, squeeze tight, and use a drill to drive a size-6 screw through it and back out again. This creates the threads.
2. Sand both ends of the spacer, so that glue will stick to it. Make a mark on the end that the screw entered from. This end should be up when you place these things.

Decals

The way to make your portable unit really shine is to put some snazzy graphics on it. This also helps identify things like the brightness/volume controls and power jacks. In this section we'll discuss the two different ways of making graphics for your portable and how/when to apply them. All the files are available on the companion Web site at www.wiley.com/go/extremetech, in a file called "SNES1".

- **Using your own printer.** You can get some sticky-back adhesive printer paper and use it to make your decals. Print one of the following files: "SNES by hand Decals.ai," "SNES by hand Decals.pdf," "SNES by hand Decals.wmf," or "SNES by hand Decals.jpg." Make sure the printer is set to Actual Size, 100%, or No Scaling (the exact name varies by program). This ensures the decals print at the intended size and will fit your portable. To check, measure the big circle—it should be 5-3/4" wide.

  A thin dark line has been placed in the joypad and screen decals. Use your X-Acto knife to cut out these shapes. Try to cut just on the outside of the dark line so it won't be visible on the remaining decal.

  If you're not using vinyl, you'll need something to cover the sides of your portable. You can use model paint, electrical tape, or any type of adhesive-backed colored material. (I'd highly suggest vinyl, however.)

- **Sign shops/vehicle lettering shops.** Most of these places have thermal vinyl printers these days. This is a machine that embeds color directly into sticky-backed vinyl, which can then be cut by another machine and used as decals. An advantage of decals made this way is that they are more durable and look better than ones you might print yourself. Here are the files to use:
  - The file "SNES by hand Decals.plt" will work for most shops that use the common Gerber equipment. It's all set and ready to go. I'd recommend printing it on a dark silver vinyl.
  - If they have a different system, you can provide them with one of the AI or PDF files, and they should be able to import that as an alternative. If you'd like to change some of the colors, the graphic artist on duty should be able to help you.

  While you're at the sign shop, have them make you some 3/4" × 25" vinyl stripes. You'll need at least one, but they'll probably cut ten or so at a time, because it uses the same amount of vinyl. Think of the extras as "error compensators." Pick a vinyl color that complements the engraving plastic you choose (for my portable, I used light gray). You can use these stripes to cover the sides of the unit later on, which is why the size is the same as that of the aluminum strips.

The graphics will be applied to various parts of the portable at different times during the construction procedure, so you should have them all made and ready before you begin.

Miscellaneous stuff you'll need

Below are some other items you'll need for this project that don't neatly fit into the categories above:

- Fine-grade sandpaper.
- Several glue sticks.
- Superglue: The gel stuff doesn't spill but dries slower, whereas the liquid can spill but dries faster. Use whichever you're more comfortable with.
- One tube of two-part epoxy. Any two-part mix epoxy will work, even J-B Weld. "Quick" 5-minute epoxy is handy because it won't make you wait 24 hours to cure every time you use it.
- Extra package of X-Acto knife blades: There's a lot of cutting in this chapter, so be sure you're stocked up on blades. If the tip of the blade gets dull or breaks off, your cuts won't be as accurate, which can impair your project.
- Electric tape: This is for covering connections so that they won't short each other out. It can also be used to cover the outer walls of the case if you're not using vinyl stripes.
- An electric drill and the following bit sizes: 1/10" (or the closest you can find to it), 1/8", 3/16", and 15/64".

- A package of Velcro: The thin, elongated type works fine; you can cut it to size as needed.
- A 6” × 6” piece of screen-door mesh. Hardware stores usually have a roll they can cut you a piece from. The dark-colored plastic kind works best for this project.
- A piece of 1/10”-thick (or so) hobby foam, dark-colored. Check hobby stores or the crafts section of a megamart. Any sort of flexible, easy-to-cut foam-type material will work as long as it’s close to 1/10” thick. It’s going to be used for the shoulder buttons, so pick a color you’d like for that.

Making the Front of the Case

The front of the case is only 3/4” thick, but it will contain almost all of the guts of the portable, minus the batteries. It has the big opening for the screen, as well as all of the game controls except for the shoulder buttons. The front of the case is the foundation of the entire portable.

In this section we’ll cut the *front plate* to form the shape of the case, then bend and attach the *side walls* out of 1/16”-thick aluminum to give it depth, so that it can enclose the guts.

Making the front plate

The front plate is a 1/16”-thick piece of engraving plastic that forms the main shape of the case. We’ll cut it using a printed template, then cut and drill the holes in it for the various controls and openings.

Note

All of the following files are available from this book’s companion Web site at www.wiley.com/go/extremetech, in a file called “SNES by hand.”

1. Download and print out the file “SNES by hand Front Plate.wmf” or “SNES by hand Front Plate.pdf,” depending on which file your computer can open. Make sure that it prints at actual size, with no scaling. You may need to turn off borders and margins. Measure the width of the graphic after it prints — it should be 8-1/4” wide.
2. Cut the outside main shape of the paper pattern, and tape it down to your piece of engraving plastic as shown in Figure 10-2. Make a few extra slits as shown, so that you have additional places to hold down the paper with tape.
3. Use your X-Acto knife to make grooves along all the inside shapes, then along the outer shapes. Don’t press too hard, or the knife may slip and cut too much plastic (or you).

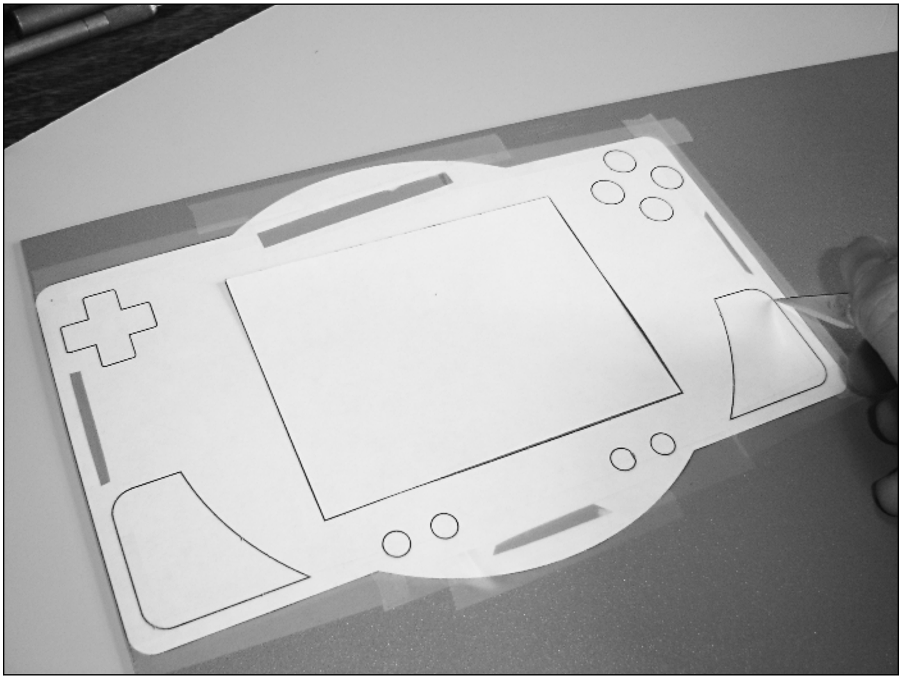


FIGURE 10-2: Cutting the first pattern.

4. Once you've made the first groove on all shapes, remove the paper pattern. Use your knife to go back over all of the cuts and make them a little deeper. Since the existing groove is guiding the knife, you can press a little harder this time. A few deep cuts over everything is fine, but the deeper you make the grooves, the easier the next steps will be.

5. Now, with all the shapes grooved at least twice (if not more), you can snap the main shape out of the plastic. Do this by bending the plastic backward, away from the colored front, along the grooved edges, with the groove on the outside of the bend. Pretend it's a sheet of paper you're trying to fold in half along the groove. Once it "folds" a certain amount, the weakened grooved portion will break.

6. Now you can remove the screen portion. Do this the same way that you removed the main shape, but only bend the edges of the screen backward until you can see a slight line appear on the back of the plastic. This line shows where the edge is. Make a few grooves along the line on the back of the plastic, and then bend the edge again. It should snap open in the middle. Repeat for each of the other four sides of the screen hole.

Caution

Bend the screen out slowly and make a lot of grooves along the edges to help it. Overbending, or bending too fast, will cause the plastic to split open past the edges of the screen. The splits can be glued back in place, but should be avoided.

7. Once all four sides of the screen hole have splits in the seams, you can slowly work toward the corners, bending the plastic open as you go. Once you reach a corner, press it with your thumb to pop it out of the plastic. Do this for both corners on one side, and you should then be able to swing the plastic open like a door and pop loose the corners on the other side.

8. With the screen plastic removed, use a 3/16" drill bit to make a hole inside each of the remaining shapes on the front plate, except for the four small holes under the screen, for which you should use a 1/8" bit. For the directional pad, it's best to drill one hole inside each of the four arms.

9. With the pilot holes drilled, you can use them to remove the shapes. There are two methods to use, depending on the size and type of the shape.
   - Smaller shapes: Use an X-Acto knife to carve away from the pilot hole along the sides of the shape. If you have a thin enough pair of needle-nose pliers, the following method will work as well.
   - Larger shapes: Using your cutters or needle-nose pliers, grab onto the shape from below through the pilot hole. Then rotate the tool to bend the grooves open. (See Figure 10-3.)

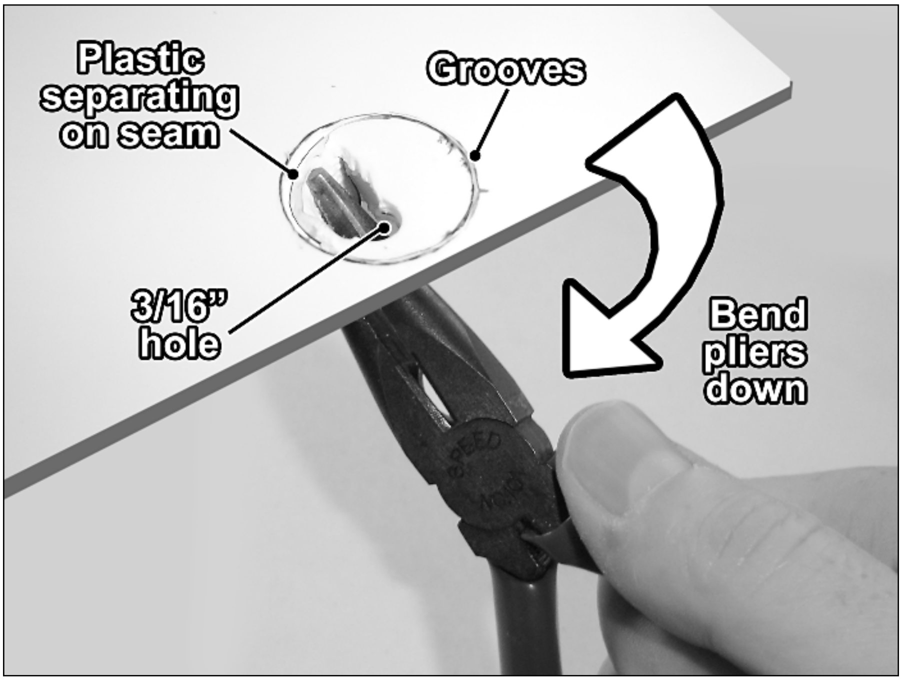


FIGURE 10-3: Bending the shapes out using the pilot holes and a pair of needle-nose pliers.

10. When removing the plastic for the two large speaker holes on the lower left and right of the front plate, use needle-nose pliers to hold the lower portion as you pull the inner plastic out. This will keep the plastic from breaking on the thin edges.

You should now have a total of fourteen openings cut in the front plate. These include the holes for the directional pad, screen, brightness controls (two), volume controls (two), the four action buttons (X, Y, B, and A), the select and start buttons, and the two speaker holes.

Tip

If the engraving plastic does crack beyond the buttons or shapes, put a little superglue inside the crack and snap it back into place. An advantage to using textured engraving plastic is that it ensures these cracks are very hard to see if you've glued them nicely.

Applying the first set of decals

Now that the front plate is cut out, it's time to apply some decals! It's easier to do this now, because there are no buttons in our way yet, and we won't have to worry about messing up the LCD glass on the screen. Place the decals as follows:

- The "X/Y/B/A" decal fits between the four button holes. (X is the top button, and B, the bottom.)
- The "Select/Start" decal goes just below this, between the tilted curved slits, with "Start" on the right and "Select" on the left.
- The decal with the "+" shape goes around the directional pad hole.
- Finally, the main screen decal centers over the screen, and the brightness/volume holes line up with the four holes near the bottom of the front plate.

If you're using graphics from a sign shop, put some water in a dish and add a drop of dish detergent. This creates a slightly soapy mixture that you can coat the sticky side of the graphics with to aid in the application.

Note

If the engraving plastic has a texture, you shouldn't use water to apply the vinyl, or it won't stick as well.

Attaching screw posts to the front plate

With the front plate cut and decaled, we can now attach screw posts to the back (inside) of it. These allow us to connect components to the front plates, and screw posts of different heights allow the components to be placed at different depths depending on how thick they are. To apply the screw posts, do the following:

1. Download and print the file SNES by hand "Front Screw Posts.pdf" or "SNES by hand Front Screw Posts.wmf." You'll see a bunch of circles with a smaller circle inside and a number next to them. Use your X-Acto knife to cut out the outer hole of each circle. The resulting holes should be 1/4" wide. You should also cut the outside main shape of the case and a few of the button holes to help you position it correctly.

2. Sand the back of the front plate and wipe off the resulting dust. This will allow the glue to stick better. Tape the front screw post pattern to the back of the front plate as shown in Figure 10-4. If you make a few extra slits near the sides of the pattern, you'll have more areas to tape down. Finally, use superglue to attach the correct length spacer into each hole. Be sure the end that you drilled into is facing upward. (See the materials list under *Preparing the nylon spacers.*)

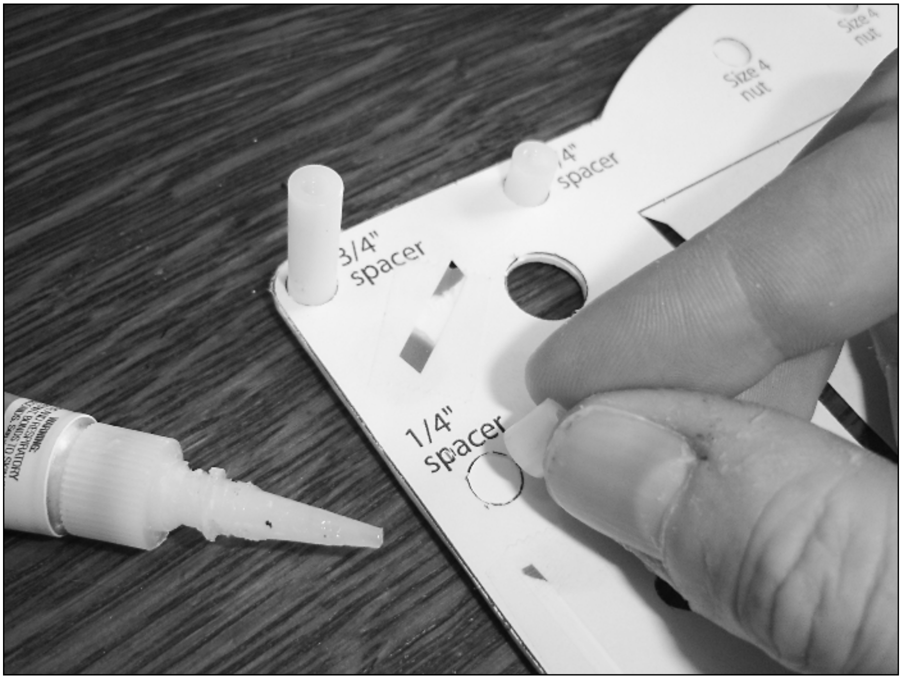


FIGURE 10-4: Parts being glued into holes.

3. There are also a total of six size-4 nuts glued onto the back of the front plate, four of them on the sides of the screen hole. Before gluing them in position, sand one side of them. (Sanding nuts may sound ridiculous and, well, it is. But it helps glue stick to them.) Place the nut so that the flat edge is parallel to the flat edge of the screen.

4. Remove the paper pattern from the front plate—you may need to cut some portions loose with your X-Acto knife.

5. Attach a size-4 nut to the top of the two lower 1/4" nylon spacers, as shown in Figure 10-5. Center it by threading a size-4 screw through and placing it in the nylon spacer below—just be sure not to glue the screw down with the nut!

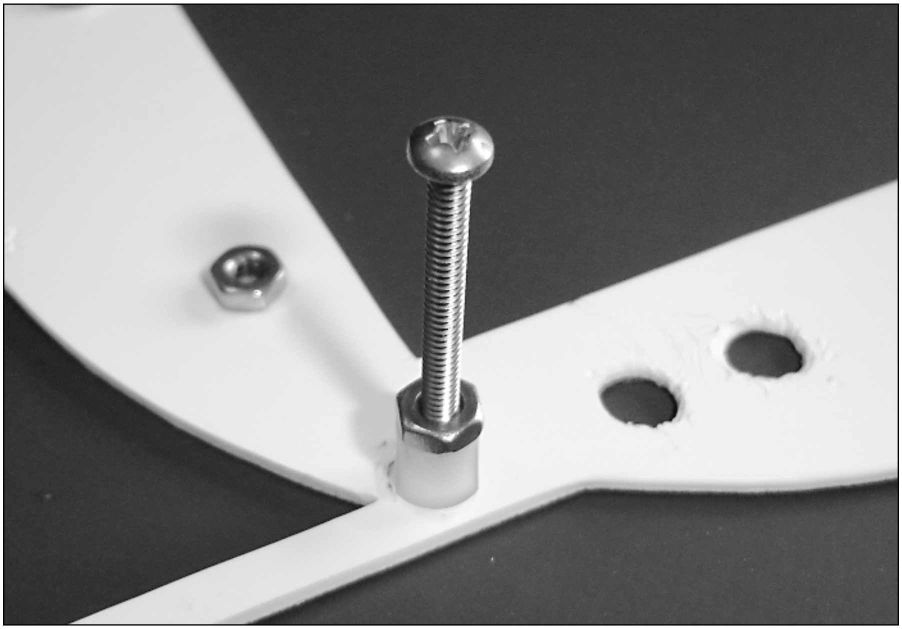


FIGURE 10-5: Attaching the size-4 nuts to nylon spacers.

Bending and attaching the front walls

Now, with all the screw posts attached to the front plate, it's time to bend the *front walls* and glue them down. This will be done in sections using your 1/16"-thick, 3/4"-wide piece of aluminum.

1. Sand the edge of the aluminum that will be touching the front plate, and make sure the edges of the back of the front plate are sanded as well — this helps the glue stick better to both surfaces.
2. Start by making a 90-degree bend around a standard pencil with 2-1/2" of aluminum remaining after the bend, as shown in Figure 10-6.
3. The bend should match the corner of the front plate near the joypad. Pencil in a 3/8"-high by 5/8"-wide rectangle on the metal, as shown in the Figure 10-6. This will be where the power switch goes. Cut down the two vertical slits with a hacksaw, and then grab the resulting tab with large pliers, and bend it out. Check that the power switch fits the hole; we'll be installing it later on.
4. To glue down the first bend, start by placing drops of superglue along the edge of the front plate. Then press the aluminum bend down and hold it for about 15 seconds. The superglue should now be holding, but take care not to let the long extending portion of aluminum hang down, or it will snap it loose. The best way is to keep everything on top of a somewhat large table. (So don't do this around dinnertime.)

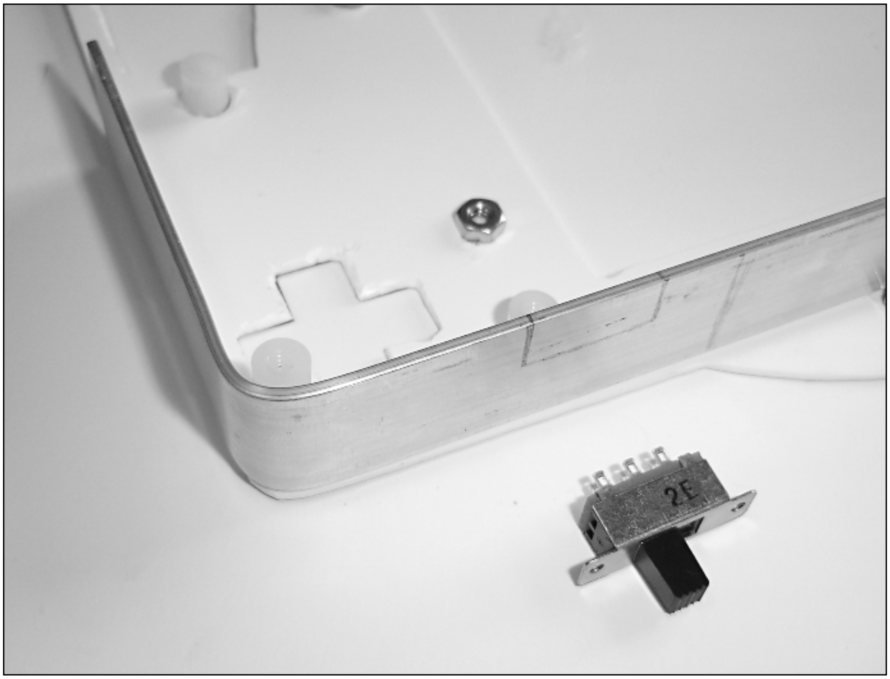


FIGURE 10-6: The first bend in the aluminum.

5. After the superglue is set, mix up a small amount of quick 5-minute epoxy. By "a small amount," I mean that when both parts are mixed together it's a blob about the size of a quarter — any more than that will be wasted. Use toothpicks to apply it to the inside seam of the first aluminum bend. This will further secure the wall. Wait 5 minutes. (This is exactly as long as Bruce Springsteen's "The River," so use that song as reference if you're a fan of The Boss.)
6. You can now make the second bend, which is along the top circular curve. Grasp the last glued portion of the aluminum with your pliers — this creates a *bend point* and keeps the glue from snapping loose. (See Spot 1 in Figure 10-7.)
7. Bend the aluminum away from the case to make the top of the circle, then back down to make the other side (Spot 2).
8. Finally, use the pliers to make a bend on the other side of the circle to match the straight portion (Spot 3).

Tip

When bending shapes such as the half-circle, it's important to bend the aluminum farther than you need. This is because when you let go, it'll spring back because it has a kind of *memory*. The idea is that if you bend it farther, it'll end up in the place you actually want it to go when it springs back. If you have to hold the aluminum in place when you glue it, then chances are it still wants to spring back, and it may break the glue bond after you let go.

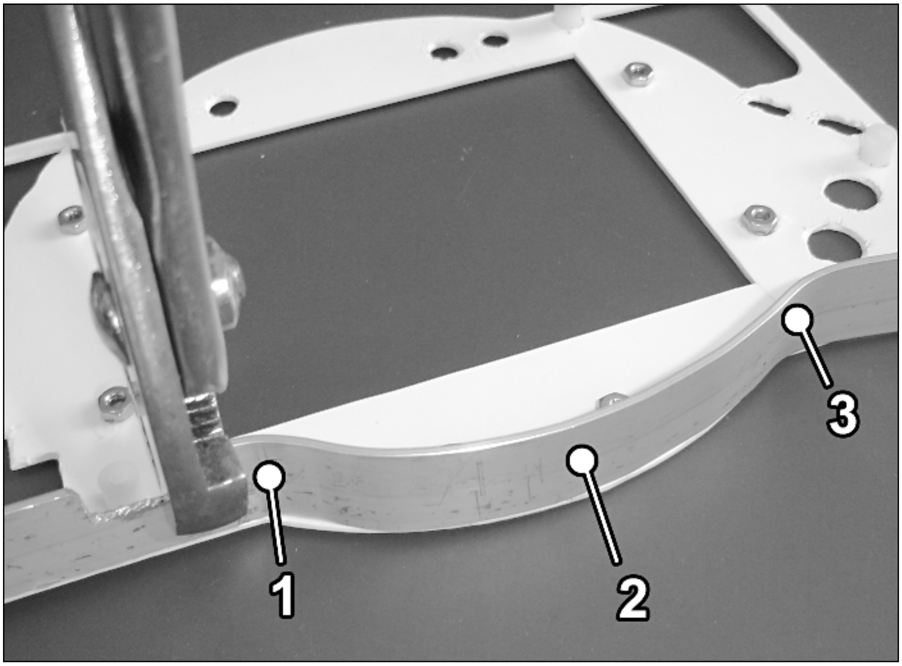


FIGURE 10-7: The second bend in the aluminum.

9. Glue this second bend down as described above. The glue should go from point 1 to 3 (as shown in Figure 10-7) but no farther. After the glue cures, it's time for bend #3! Start by gluing down the straight portion — Spot 1 in Figure 10-8. Put epoxy on the base of the 3/4" screw post to strengthen it, but only on the inside, so that it won't get in the way of the aluminum wall.

10. Let this portion set for about half and hour so that the epoxy can harden further — there's going to be a lot of strain when we make this next bend. Clamp onto the screw post and aluminum with your big pliers, and then bend the aluminum around the case, as seen in Figure 10-8.

11. Continue to bend the aluminum around the case in this fashion until it reaches where it began. Don't glue the rest of it down yet; simply check that the aluminum lines up with the edges of the engraving plastic. Make a mark where the aluminum meets the beginning, and use your hacksaw to cut it off at this point.

12. You can now glue the rest of the aluminum to the engraving plastic. First use superglue, then epoxy, as you did with the first bend.

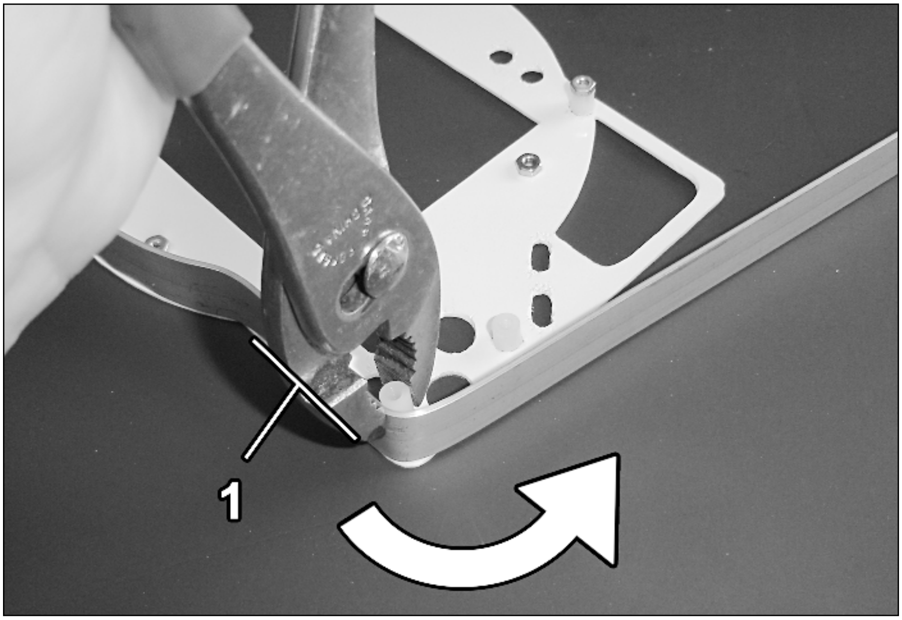


FIGURE 10-8: How to make bend #3 in the aluminum.

13. While the epoxy is curing, place a flat object over the walls (such as a big book) and a heavy object on top of that (such as more books or a bowling ball) to press down on it all. This keeps the walls as straight as possible. Even if you're using quick epoxy, it's best to leave the case to sit like this for at least a few hours so that the epoxy can cure as much as possible.

14. Take a look at the lower right-hand corner of the front half of the case, viewed from the rear, as seen in Figure 10-9. Make a mark 1/4" from the screw post, and 3/8" up from edge of aluminum. This will be where the power jack goes.

15. Use a 15/64" bit to drill out a hole on this mark.

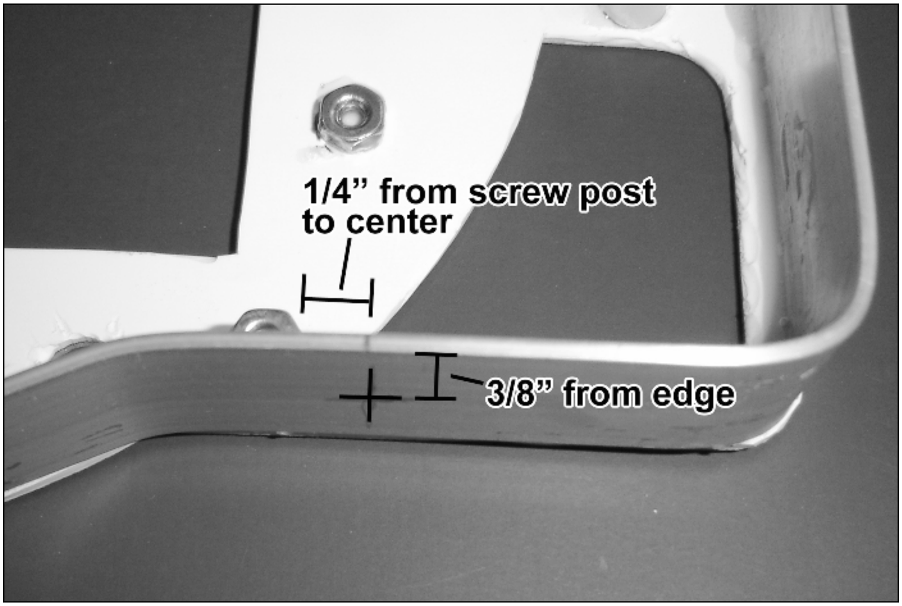


FIGURE 10-9: Target for drill hole for power jack.

Adding details to the front of the case

Now that the front half of the case is built, we'll add a few final details to it before moving on to the rear half of the case. These are mostly cosmetic, but essential nevertheless.

1. Cut small pieces of screen mesh and superglue them on the inside of the speaker holes. For best results, put two layers of mesh over each hole, one with the holes going left to right, the next with the holes going along a diagonal. This ensures a dense-looking mesh.
2. Take your 26" × 3/4" stripe of gray vinyl, and place it around the front of the case. Cut out the holes in the gray vinyl where the power switch and power jack holes are.
3. Place the on/off decal just below the power switch hole, with "ON" on the side closest to the center of the unit. Place the "Charge" decal over the power jack hole with the ends of the long decal going left and right along the wall.

Tip

Start and end the vinyl stripe at the power switch—this way the seam is mostly covered by the on/off decal.

The front half of the case is now ready to have electronics and parts installed into it.

Making the Rear Portion of the Case

We can now make the rear portion of the SNES's case. It will consist of a rear plate with a battery compartment on the back. The rear plate does not have a side wall as the front did. (Go ahead, breathe a sigh of relief.)

1. Print the file "SNES by hand Rear Plate.wmf" or "SNES by hand Rear Plate.pdf." Tape it down on some engraving plastic, as you did with the front plate pattern.
2. First, drill the holes. They are 1/10" and 1/8" in size on the rear plate. It's useful to have a decent variable-speed drill for this — the kind where the harder you squeeze the trigger, the faster the drill spins. Cheap drills have only a couple of speeds. Center the bit over the circle, and drill slowly at first for greater accuracy. Once you see plastic being chipped away, you can increase the speed and finish the hole. If you go full-speed right away, the bit may slip off the mark and put the hole in the wrong place.
3. Once you've drilled all the holes, you can make grooves along all the shapes and edges, as shown in Figure 10-10.

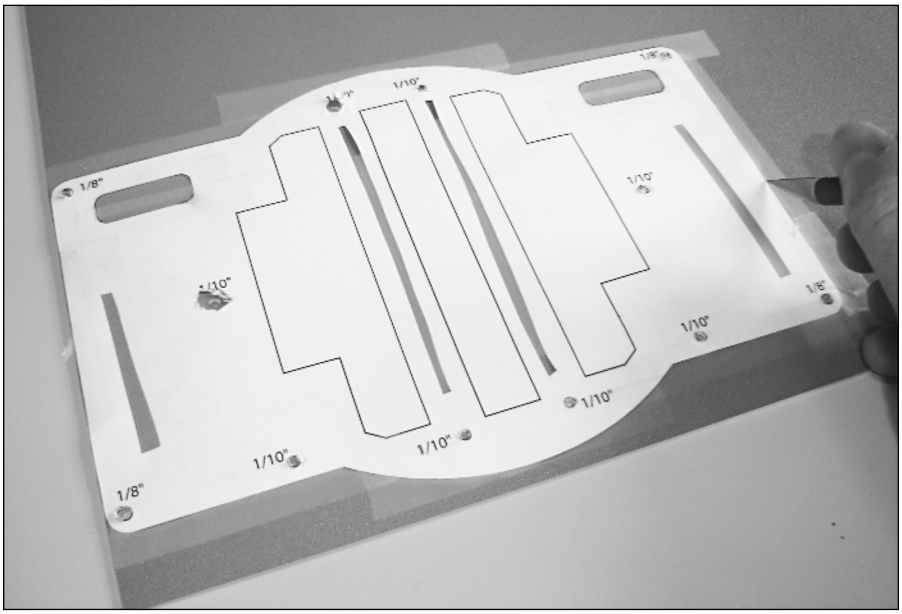


FIGURE 10-10: The rear plate being cut. Note the extra slits in the paper that allow it to be taped down in more places.

4. With all the lines sliced, remove the paper pattern. You can now drill out and remove the five inner plastic shapes, as you did with the button holes in the front plate. These shapes are the two battery holes, the cartridge slot, and the holes for the left and right shoulder buttons.
5. Print out the file "SNES by hand Rear Screw Posts.pdf" or "SNES by hand Rear Screw Posts.wmf." Cut out the outer shape, the four screw holes, and a few of the inside shapes for reference. Tape this pattern to the inside of the rear plate. Glue four 1/4"-long nylon spacers into the indicated places.

The rear plate itself is now ready to have the battery compartment attached to it.

Building the battery compartments

Now, with the rear plate cut, we can make the two battery compartments. Each holds three AA batteries, for a total of six batteries in this unit. We'll use the balsa wood to give the compartments depth, and then cover the wood with metal and engraving plastic, so that you'll only see it when the compartments are open.

Cutting the balsa wood battery risers

The first step is cutting the balsa wood battery risers. Balsa wood is fairly easy to cut with an X-Acto knife, allowing us to make compartments to hold the batteries in place. To cut the risers, follow the following procedure:

1. Print out the file "SNES by hand Battery Risers.pdf" or "SNES by hand Battery Risers.wmf." Cut out the two main shapes on the paper and tape them, one at a time, to your 3/8"-thick piece of balsa wood, as shown in Figure 10-11.
2. Start by drilling the three screw holes with a 1/10" drill bit. Then use your X-Acto knife to cut along the inside lines. Drag the knife in a smooth motion along the lines — don't "saw" with it. Every time you make a cut, the knife will go deeper. About three cuts should be enough to go completely though the material. Remove the center portion first, and then cut the outer shape. The side of the balsa wood with the pattern is the front, and you may want to make a small mark to indicate this.
3. Repeat these steps for the other battery riser.

Tip

Keep the knife as straight up and down as possible — this will ensure that the edges of your balsa wood part are straight too, and allow for better gluing when you attach the walls.

Caution

The walls are thin in some portions of these parts. However, if the wood breaks, you can easily reconnect it with superglue. Slosh a lot of glue on the thin portions even if they don't break — it will create a kind of protective "shell."

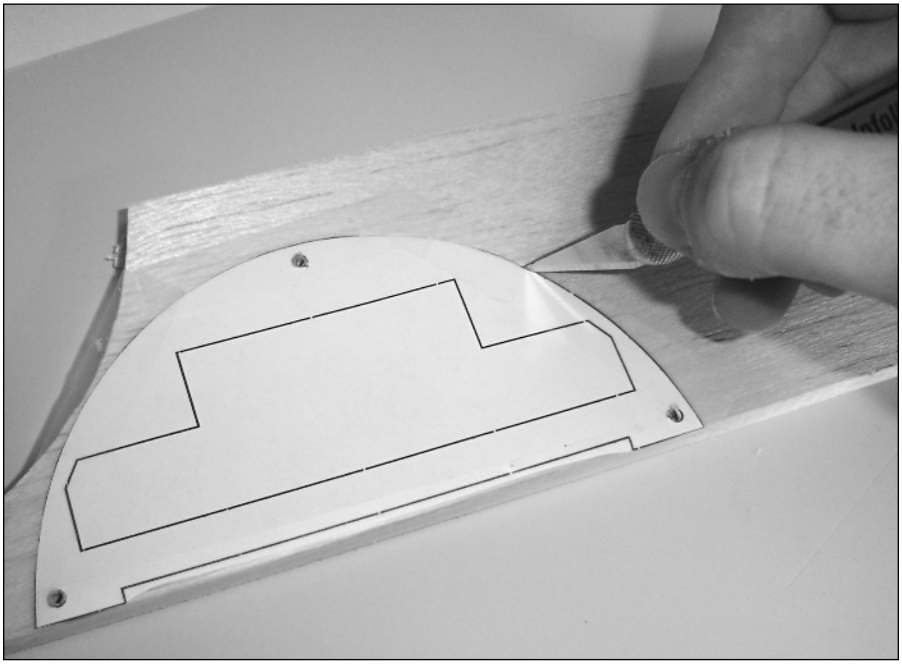


FIGURE 10-11: The battery riser pattern on 3/8″ thick balsa wood.

You should now have two balsa parts cut. One of them has the notch for the cartridge, and we'll refer to this one as the *notched battery riser* from here on out.

Applying the metal siding

Now that the balsa battery risers are cut, you can apply the metal siding to them. This covers the imperfections of the wood, and also looks cool. The method for doing this is somewhat similar to that for making the side walls for the front of the case, but the metal is glued on the sides of the balsa wood rather than the edges. We'll start by putting metal on the notched battery riser first.

1. Get out your 1/2"-wide × 12"-long thin metal strips. Sand one side of the strips with fine-grit sandpaper. If there's a plastic coating on one side, leave it on there for now and sand the other side — the plastic coating will protect the surface of the metal while you work with it. If no side comes covered with plastic, sand the side that looks the worst.
2. Make a center mark on the sanded side of each piece. The pieces that I got were 12" long, so the mark was, well, 6", of course. Place several drops of superglue on the center spot and press the notched battery riser against it, as seen in Figure 10-12. The back of the riser should be flush with the edge of the metal, and the front (the side that had the paper pattern on it) should have a 1/8" gap above it.

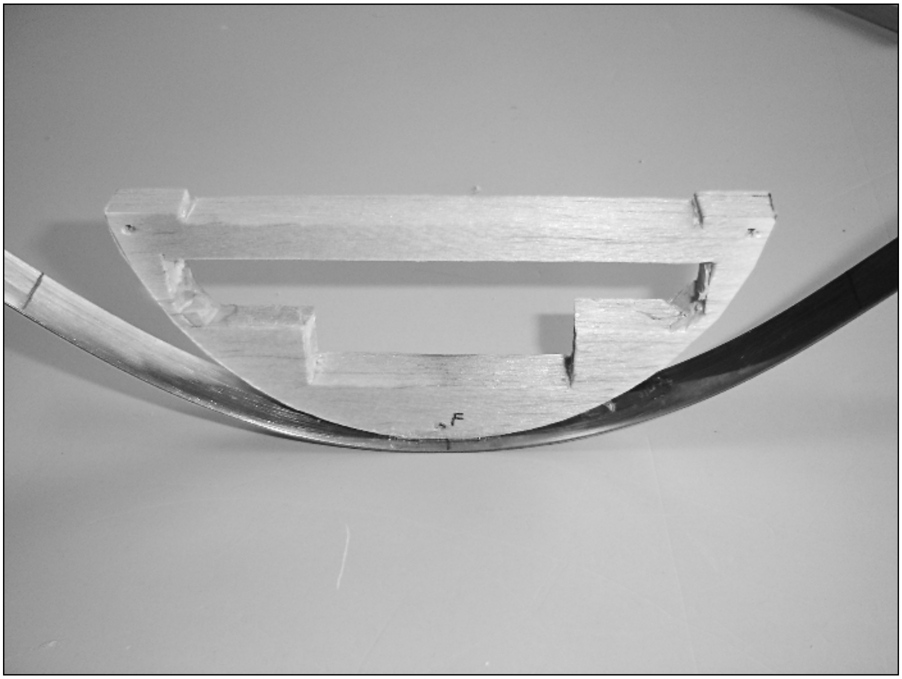


FIGURE 10-12: Attaching the metal to the notched battery riser.

3. Let this cure for a few minutes, holding the balsa firmly against the metal. If the sides of the balsa aren't perfectly straight (which is probably the case, since it was cut by a human) be sure that whatever wood is touching the metal has glue on it and the metal itself looks straight. This is why the balsa is on the inside — the metal will make it look straight when everything is done.
4. After the center point is cured and well attached, bend the metal sides up and make a mark on the aluminum where the sharp corner is, near the screw hole. Then make a mark 1/2" up from that. Cut the metal off at this second mark using tin snips or heavy scissors.

Tip

Pre-bending the metal strips can make this process easier, but it may have the side effect of not looking as even and smooth in the end.

5. Bend the metal over the wood at the sharp bend spot. There are a couple of ways you can do this, and naturally each has its own pros and cons:
   - **By hand.** Least damaging, but the corner may not be as tight.
   - **Using big pliers.** Gets a tighter bend, but might scratch the metal (although if you're covering the metal with vinyl, this isn't a problem, of course). For aesthetic protection, put some paper between the plier teeth and the metal and then bend it, even if there's a plastic coating on the metal.

- **Pre-bending the corner using a vise.** As with the pliers, this can mar the metal, so use paper or cloth to protect it. However, using a vise can result in a nice tight bend.

6. Once you've made the bend, glue down the last portions of the metal. Finally, cut a 3-3/4"-long portion of metal, and glue it inside the notch for consistency. The finished *notched battery compartment* should look as shown in Figure 10-13.

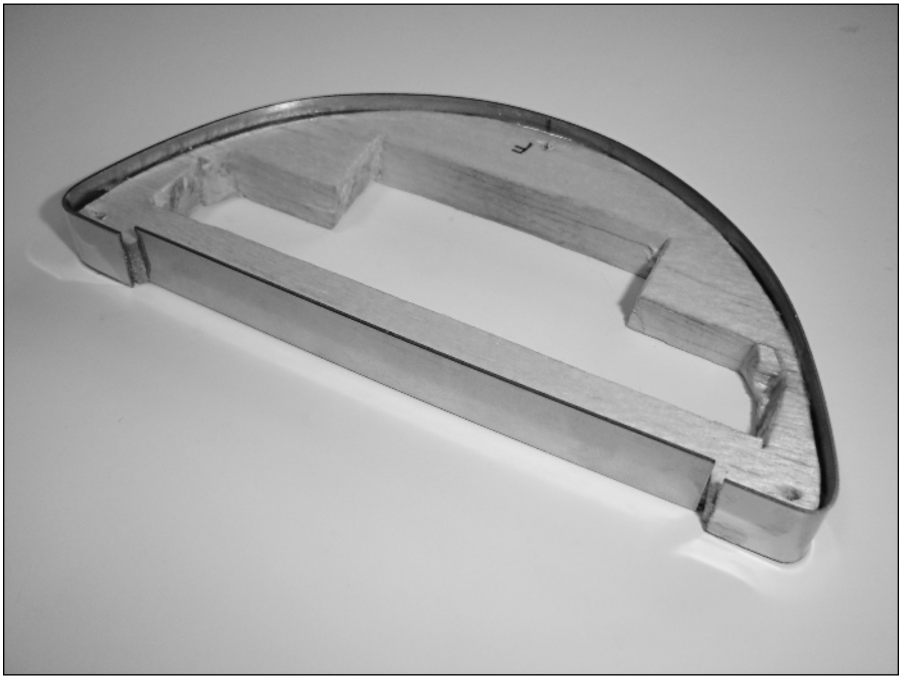


FIGURE 10-13: The notched battery riser, with metal attached.

7. Repeat the procedure for the other unnotched battery riser. If you're using a standard 12" piece of metal, you'll notice that the ends don't quite meet after being bent around the wood. Glue a small portion of metal in there to bridge the gap.

You've now built the battery compartments. In the next few sections we'll make covers for them and attach them to the rear plate.

Note

If you're concerned about how well you can manually cut these last portions of metal, keep in mind that they'll be mostly hidden when a cartridge is installed. (Shhh! Trade secret.)

Making the battery compartment covers

Okay, let's make the *battery compartment covers.* These will use Velcro stuck to the balsa wood riser to hold the batteries in place. There is no file for cutting them, so instead we'll trace the shapes by hand. The reason? The covers must fit over the battery compartments, and since those were made of balsa wood and bent metal, there's a very slim chance that a computer-designed pattern will match a human-built half-circle. Not to rip on humans (being one myself), but it's true.

1. Place the battery compartment down on the front of the engraving plastic and trace around it with a pencil. If you want to use a dark color for the battery doors, you should trace the battery compartment shapes onto a piece of paper, and then tape that to the front of the engraving stock for cutting. You could mark and cut the black engraving stock from the back, but it doesn't always make as clean of a break as doing it from the front.
2. Make grooves along the lines and snap the shape out of the engraving plastic, as you did with the plates. We'll put Velcro on the doors and battery compartments a little later on.

Tip

The shape you make by tracing will be a little bigger than the actual piece was. Because of this, cut slightly inside the line to create the correct shape in the engraving plastic. It may take a couple of tries to get it perfect but that's why I suggested getting extra engraving plastic back in the materials section.

Attaching the battery compartments to the rear plate

With the battery compartments and their covers ready, we can now start attaching things to the rear plate. Don't worry—we're in the final stretch of building the case, and we'll start the actual wiring of electronic guts very soon. With that pep talk out of the way, here's how to attach the battery compartments.

1. Place the battery risers against the rear plate of the unit. The notched battery compartment should be on the left. On the right side of the battery compartment, place the SNES "brag" label decal just to the side of the unnotched battery compartment. (There's a curve on the decal for reference.)
2. Insert 1/2"-long size-4 screws into the two side screw holes in each compartment and the two lower ones to secure the compartments to the rear plate. (We'll put screws in the top two holes later.)

Now it's time for the morale-boosting break—we've done quite a bit and you may feel weary. Go ahead and hold the rear plate against the front half of the unit. Presto! It's almost like it's actually done, isn't it? Feel the depth, the smooth lines, the sleekness of it all. Pretend you're playing your favorite SNES game . . . on a beach . . . at sunset . . . Feel better yet?

Back to reality! I had to give you a breather since this next part is a little tricky—making the *battery backers*! This sounds like an organization that collects donations door-to-door, but it's actually two parts cut out of engraving plastic that hold the battery terminals. To make them, do the following:

1. Print out the file "SNES by hand Battery Backers.pdf" or "SNES by hand Battery Backers.wmf." Cut the outside shape, and then tape the pattern down to some scrap engraving plastic. (The reason they're stuck together like two Tetris blocks that should get a room is so that you'll only have to make one cut down the middle, instead of two separate cuts.)
2. Use a 1/10" bit (or similar size, such as 5/64") to drill the holes, and then make grooves with your knife along the lines, just like when you cut the front and rear plates. Remove the paper, recut the grooves, and snap the pieces free.
3. Superglue the battery backers to the inside of the rear plate as shown in Figure 10-14 (where the four screw posts are). The long edge of each battery backer should line up with the hole, and the rest of it will overlap the hole so that the glue has someplace to stick. On the inside of the battery compartments, all the holes should be showing, at least a little. As long as you can get one wire down each, you'll be okay.

FIGURE 10-14: Gluing down the battery backers.

Attaching the battery terminals

With the battery backers in place, it's time to install the *battery terminals*. You can tear apart an old device to get these (such as a junk Walkman, flashlight, or pocket TV from one of the other projects in this book), or cut apart a battery holder from Radio Shack. A few that will work for disassembly are catalog #270-391 or catalog #270-383. (A photo of these battery holders can be seen in Chapter 11.) Snip the plastic apart on the battery holders with your cutters to get the terminals out. However you get your terminals, you'll need four of the springy negative ones and four disc-shaped positive ones. To install them on the battery backers, use the following procedure:

1. Bend the lead coming off each terminal as shown in Figure 10-15. You may notice some metal flared out on the back of the disc-shaped positive terminals — use your big pliers to squash it flat so that the disc stays on the wire.

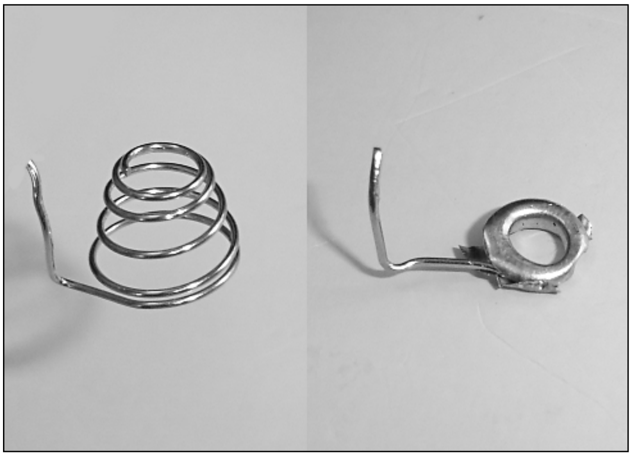
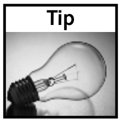


FIGURE 10-15: The bent negative and positive terminals.

2. Place the terminals and decals inside the battery compartments as shown in Figure 10-16, snaking the leads down the holes.



Tip

The best way to get the terminals in good position is to actually put batteries in, so that they will press the terminals into the proper positions. This is especially true of the positive disc-shaped terminals — they should be centered on the battery as well as possible.

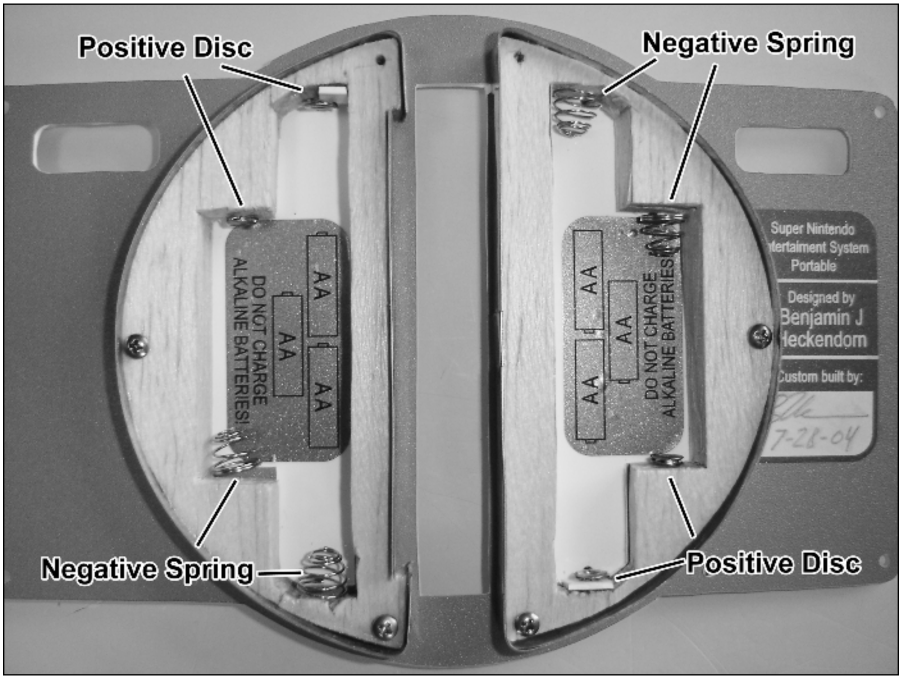


FIGURE 10-16: The placement of the battery terminals and decals.

3. Once the terminals are in place, you can then place a bit of superglue on the leads on the other side of the plate. Once the superglue dries, you can remove the batteries and use epoxy to secure the leads permanently. Just be sure that some bare metal is showing on the inside so you can still connect wires! You may also want to use small bits of engraving plastic to put behind the terminals to support them, as seen in the figure. It mostly depends on how well the balsa part ended up being cut.

4. Hey, remember your soldering iron? I know we haven't used one yet in this chapter, but now's the chance! Attach wires to the back of the rear plate as shown in Figure 10-17. Melt the solder strand directly on the terminal wires for best results — this allows the rosin core of the solder to adhere to the metal of the terminal.

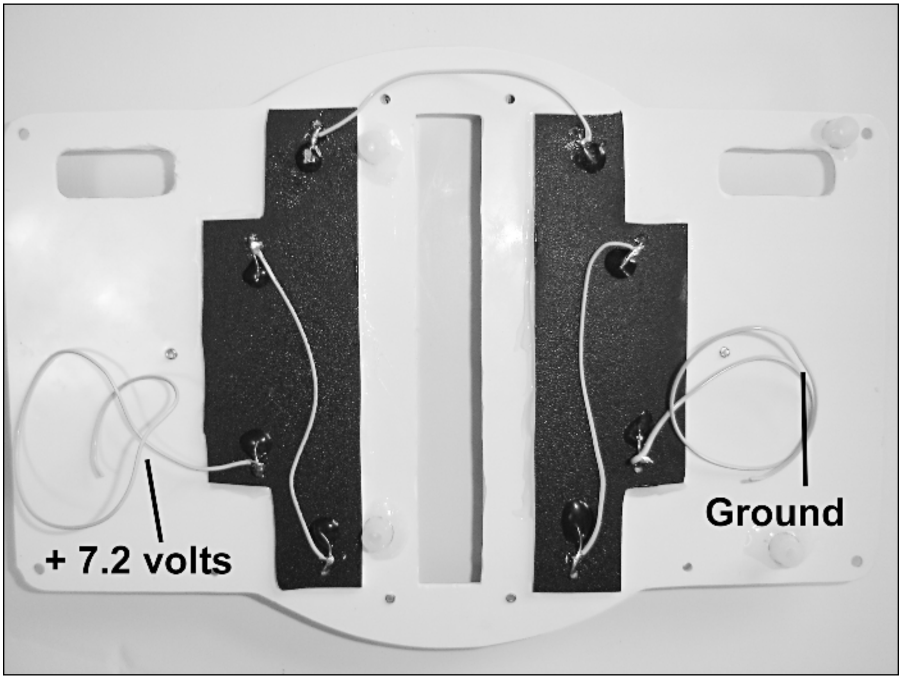


FIGURE 10-17: Attaching power wires to the battery terminals.

Use 10" wires for the positive 7.2 volts and ground wires. These will be the *positive and negative battery wires*. Color them red for positive and black for negative so that you can tell them apart after the SNES board is installed. As you can see, the battery terminals have drops of epoxy on them, and there's also a little epoxy in each drill hole.

Putting Velcro on the battery compartments and covers

The easiest way to attach the battery compartment covers is with Velcro. Here's how:

1. Cut up pieces of Velcro, and put them on the balsa as seen in Figure 10-18. Cut identical pieces for the doors themselves and place them Velcro-side down on the balsa pieces.
2. Peel the backing off, then press down the door — all the Velcro will be automatically in the right place!

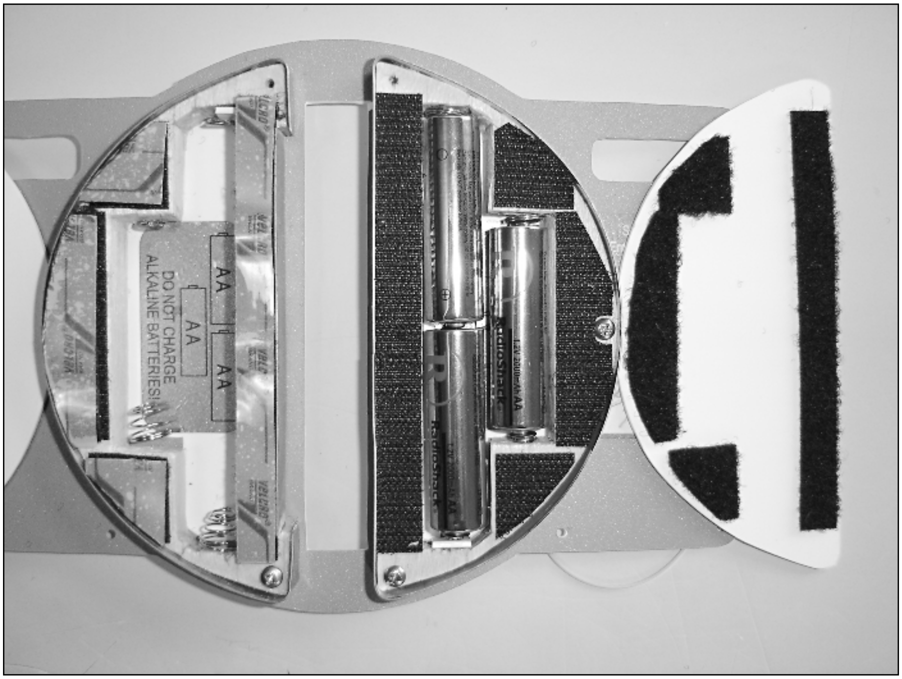


FIGURE 10-18: Velcro placement on the battery compartments and covers.

Wiring the Unit

At this point both the front and rear of the case are finished. Now we can start the actual wiring! This will involve installing the PSOne screen, making the PC boards that contain the buttons for the controls, installing the SNES board, and then wiring all of these things together so that the SNES can run.

Installing and wiring the PSOne screen

The PSOne screen will install to the inside of the front plate between the four size-6 nuts. Before it's secured in place, the new brightness and volume buttons will need to be made, since they fit between the screen and the plate.

1. Cut two pieces of 1" × 1/4" engraving plastic, and hot-glue them to the back of the front plate over the volume and brightness holes, as seen in Figure 10-19. You can then accurately superglue the *nylon hole plugs* to the engraving plastic pieces from the front. Once they're attached, remove the glue to pull the buttons free.

FIGURE 10-19: Front and back of the new brightness and volume buttons, glued in place.

2. Superglue a size-4 nut between the black caps — this will provide the proper depth when they are placed in the case.
3. We can now move onto the screen and speakers. Desolder the wires off both speakers and extend the plugs by about 2”, as shown in Figure 10-20.

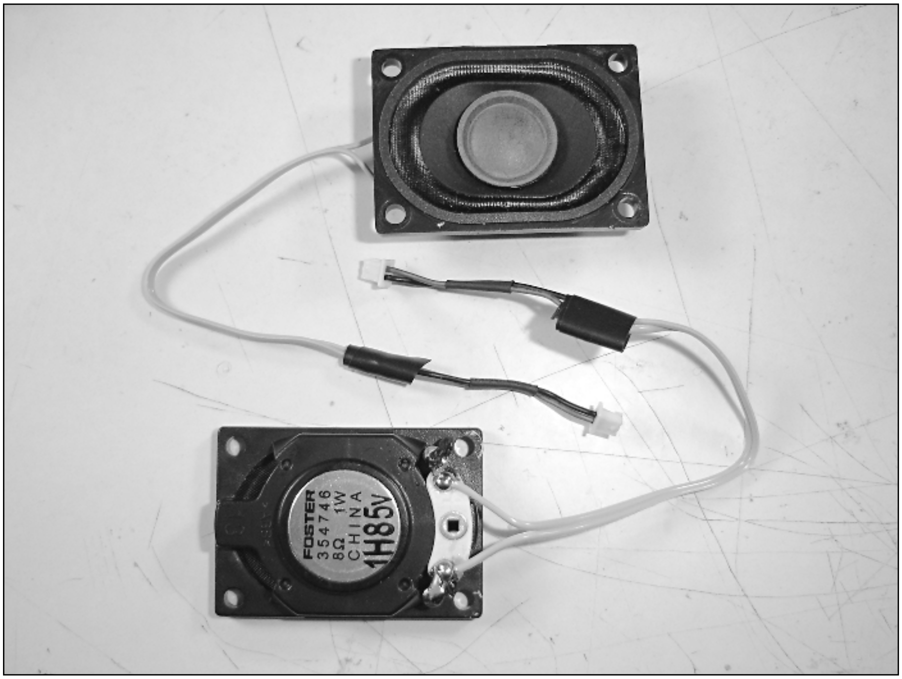


FIGURE 10-20: The PSOne speakers with new, longer plug wires.

4. Place the volume and brightness buttons into the holes on the front of the unit. Disconnect the two white plugs from the bottom of the PSOne screen. Plug the extended speaker wires into their original jacks on the screen, near the volume and brightness buttons.
5. Carefully set the screen into the front of the case as seen in Figure 10-21. Then use four 3/8"-long size-4 screws to secure it to the four nuts around the screen hole.
6. Place the speakers over the mesh and hot-glue them in place.

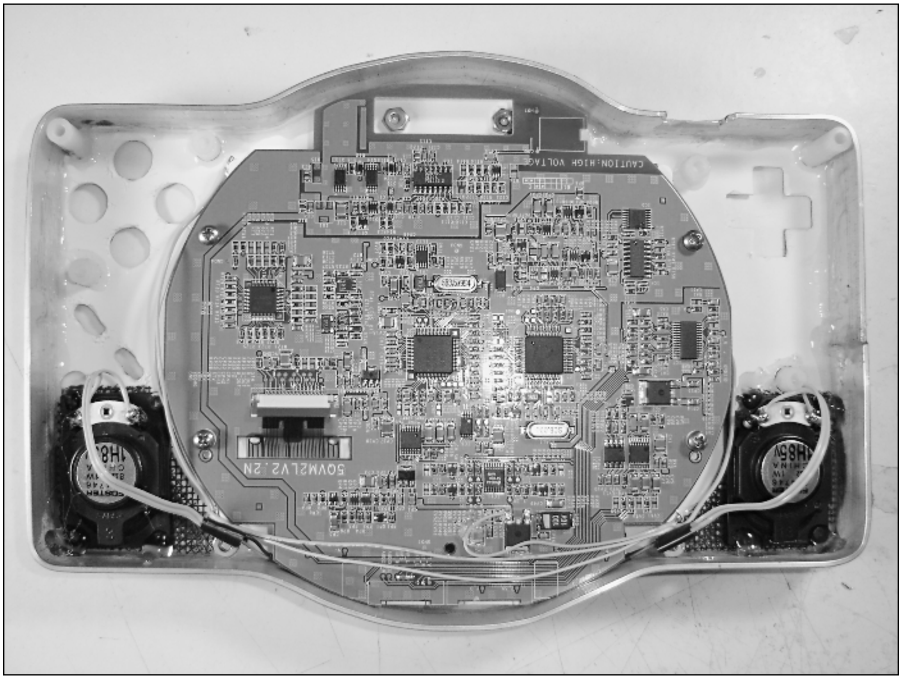


FIGURE 10-21: The PSOne screen inserted into the front of the case.

Cutting the PC boards

The hand-built SNES will have two PC boards inside it. These will be custom cut from a single PC board, catalog #276-158b from Radio Shack. Figure 10-22 shows where to slice apart this board.

Use your X-Acto to make grooves along the indicated lines. Most of them go along a series of holes, but please notice that a line on the left board goes between two rows of holes. Once you've made your first pass of cutting grooves, go over them a few more times with the knife. You should now be able to snap the excess portions of PC board off and have two separate pieces for use in this project.

Tip

To make nice clean breaks, hold each side of the groove with pliers and use them to break it apart. This prevents overbreakage.

Now that the boards are cut out, it's time to add components and wire them.

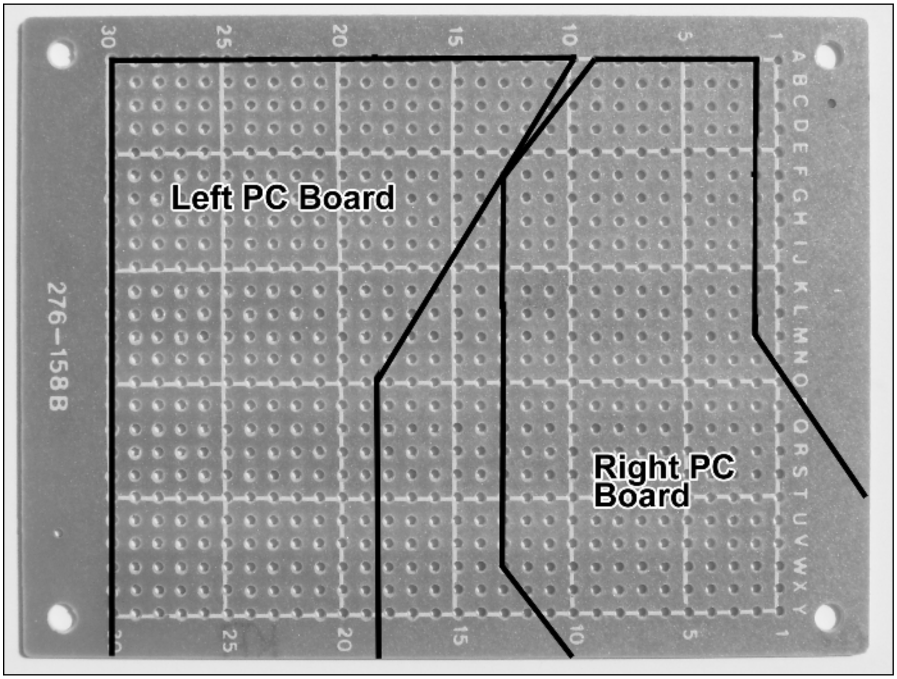


FIGURE 10-22: Where to slice the 276-158b PC board.

Left PC board

The first board we'll wire up is the *left PC board*, which is the one that goes under the up/down/left/right control pad. It also contains the two ICs that run the SNES controller, as discussed in Chapter 9. Do the following:

1. Place components on the front (non-copper side) of the board, as shown in Figure 10-23. Solder every lead on the tact switches and ICs to the copper pads on the back of the boards.
2. Use a 10K-ohm resistor for all the gray tube-like shapes. It's best to use 1/4"-watt resistors, as they're physically smaller than the 1/2-watt versions.
3. The white lines are resistor leads. There's quite a bit of extra lead on a resistor, so you can use it to make almost all of the connections required. Put the resistor leads through the holes that they're shown to end at in the drawing. Solder them to the copper on the other side, but don't snip the excess off yet, as it may be handy when wiring the back.

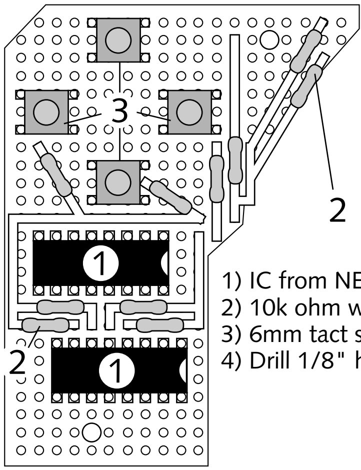


FIGURE 10-23: Placement of components on the front of the left PC board.

4. The holes on the drawing will match those on your PC board. Place the resistor leads in the holes specified, and solder them in place on the other side — you can snip off the excess lead later. The actual connections from the resistor leads to the switches and ICs will occur on the back of the board.
5. The spots where the white lines "meld" into each other indicate that you should solder the resistor's leads to each other at that point.
6. Be sure that the ICs are placed correctly, with the dents on the right-hand side (as they appear in the drawing).

Now that the components have been placed on the front of the board, it's time to make connections on the back of the board. Using wires or bits of extra lead taken off the resistors, make the connections shown in Figure 10-24.

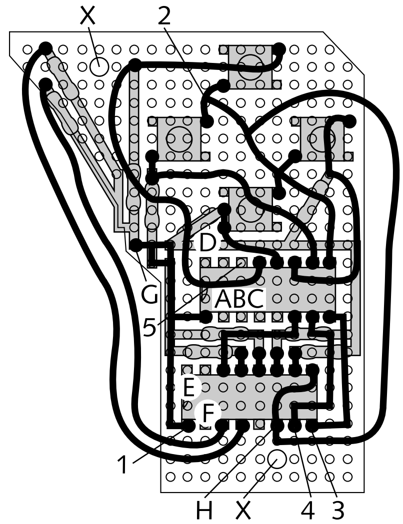


Figure 10-24: The connections on the back of the left PC board.

1. Use wires or bits of extra lead for the thick black lines. The circles at the ends of them indicate where they should be soldered to leads.
2. On the lower IC, you can see several short connections from the resistors to the IC. These can be accomplished by simply blobbing solder between the two copper pads.
3. In order to keep them from criss-crossing on the drawing, some wires are shown longer than necessary. (This excludes the connections with a labeled length of wire.)
4. The connections to the IC leads labeled 1–5 should be made to a 10"-long five-strand of ribbon cable. On the unattached end, make a mark on the #1 wire for later reference. This five-strand of cable will go to the SNES board and connect to the controller.
5. Connections A–H should be made to an 11"-long eight-strand of ribbon cable. On the unattached end, make a mark on the "A" wire for reference. This cable will connect to the buttons on the right PC board.
6. Drill 1/8" holes at the spots marked "X."
7. The two resistor connections in the upper left of this drawing will go to the left and right shoulder buttons later on.

Okay, that wraps up the left board. The front and back of it should look like what's shown in Figure 10-25. Please note, the 1–5 and A–H ribbon cable connections are not shown so as not to obstruct the rest of the board. These connections will appear in later photos, however.

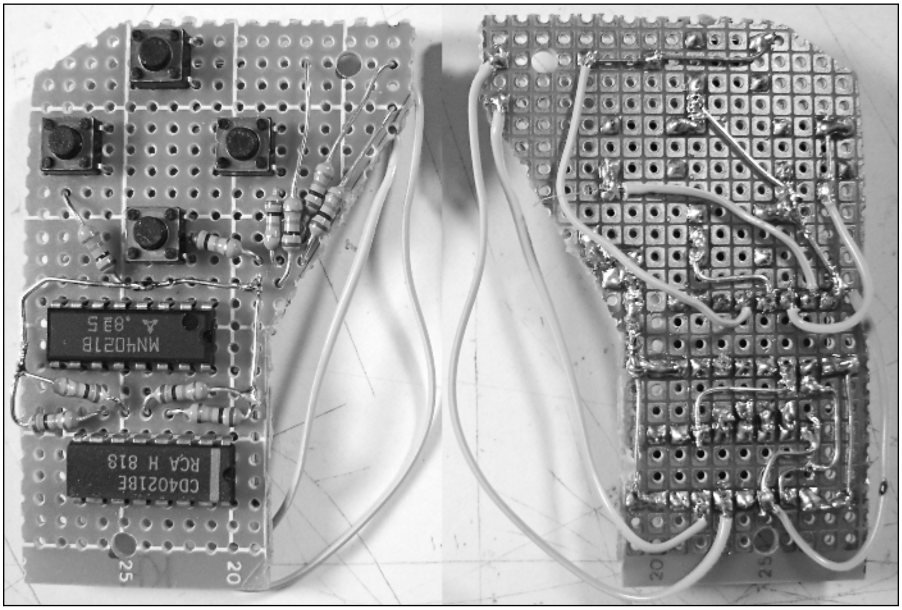


FIGURE 10-25: The front (left) and back (right) of the completed left PC board.

Right PC board

Next we'll wire up the *right PC board*, which is the one that goes under the X/Y/B/A, select, and reset buttons. Start by placing components on it as shown in Figure 10-26.

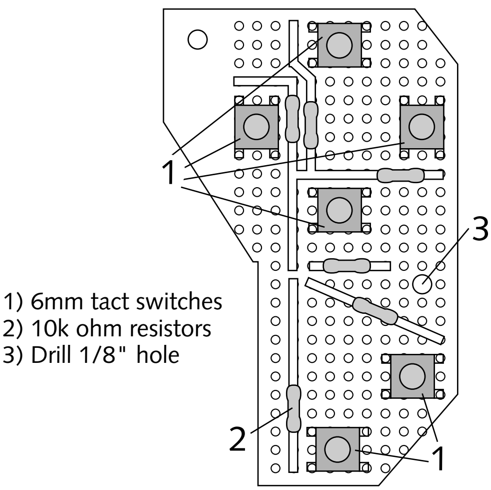


FIGURE 10-26: Placing components on the front of the right PC board.

1. Use 10K-ohm, 1/4-watt resistors for all the gray tube-like shapes. Solder their leads to the board as described in the previous section.
2. Place 6-mm tact switches in the spots marked “1.” Solder all four of their leads to the copper pads on the back of the board. (Note how the tact switches have their leads pointed in different directions. Be sure to place all the tact switches to match this drawing.)
3. Drill 1/8” holes in the spots marked “3.”

Now, with the components placed on the front of the right PC board, you can make the connections on the back of it, as shown in Figure 10-27.

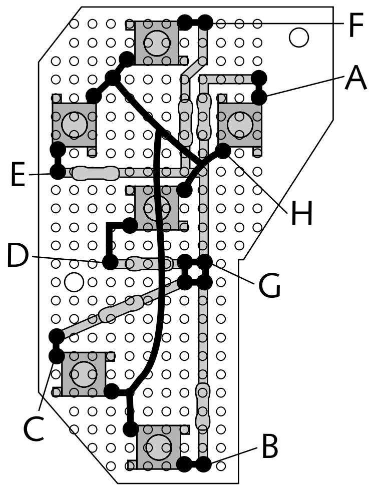


FIGURE 10-27: Connections to make on the back of the right board.

1. Use wires or bits of extra resistor lead to make the connections indicated by black lines. The circular ends show the points at which to solder the wires/leads.
2. Spots A–H should be connected to the ribbon cable coming from the spots on the left PC board with the same labels. This interconnects the boards. The ribbon length I suggested in the previous section may seem a bit long considering how close these boards will be in the case, but this length will allow us to position the cable better later on.

Figure 10-28 shows the completed right PC board (sans connections A–H).

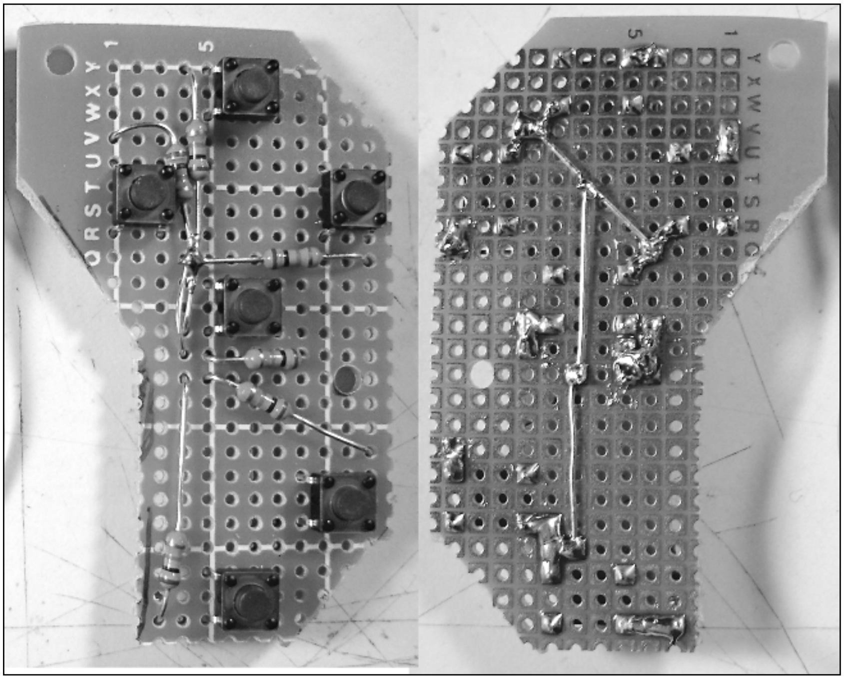


FIGURE 10-28: The front (left) and back (right) of the completed right PC board.

Installing the PC boards

Before screwing down the PC boards, you'll need to place the buttons first. The rubber select/start button will need to be modified for this. As-is, it's just too thick, and would stick above the case like a sore thumb.

1. Slice off the bottom of the select/reset buttons to leave about 3/16" of length from the tops. The actual length depends on how far you want the buttons to stick above the surface of the case. If the sliced buttons are 1/8" thick, they'll stick 1/16" above the case, and if they're 1/4" they'll be 3/16" above. A size of 1/8" is the minimum.
2. Lay the front of the case down on a flat surface, then set the select/reset buttons in their holes as shown in Figure 10-29, with the cut ends up (inside the case).
3. Next, cut a 1/4" × 1" piece of thin plastic. By "thin," I mean thin like the stuff from a soda bottle or a plastic tub-o'-margarine lid — engraving plastic is too thick for this.
4. Place a dab of superglue on each button and press the plastic piece onto them. As the cuts may not be perfect, you should keep pressure on the plastic so that as much surface contacts the buttons as possible. Hold it for a minute or two, then release. Your custom select/reset button is made!

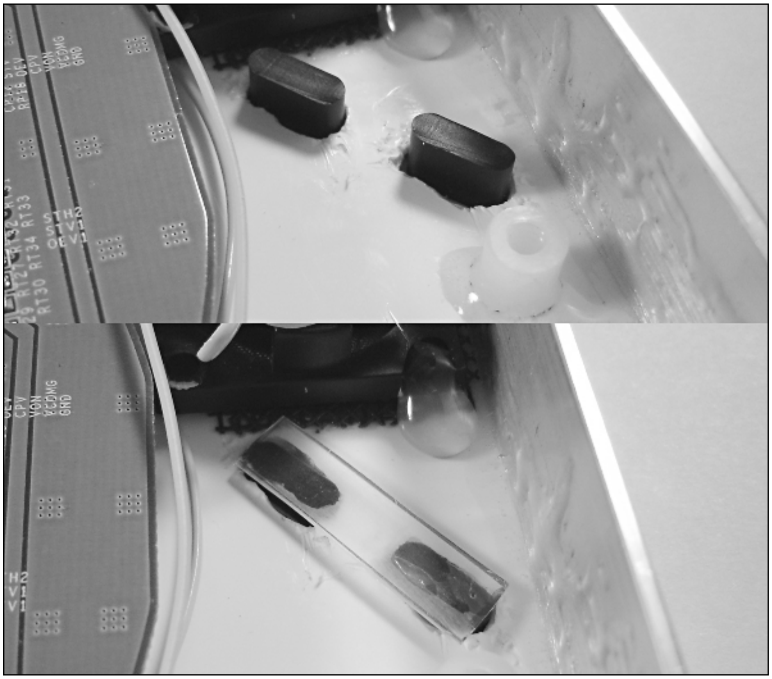


FIGURE 10-29: The select/reset buttons placed in the front of the case.

5. Place the B/A/X/Y buttons and control pad disc in their holes.
6. Use four computer case screws to attach the PC boards to the screw posts on the front plate. If one of the PC boards doesn't quite fit around the PSOne screen's motherboard, you can do one of two things:
   - Since the PC board ends up being lower (it and the PSOne board won't be level to each other), try to get it past the PSOne screen, and then secure it.
   - Use an X-Acto knife or cutters to shave off a little more of the edges of the PC board that are blocked by the PSOne screen.
7. Tuck the ribbon cable(s) between the two boards, up toward the top of the PSOne board, or even under it if that works better. (This is why I suggested overly long cables.) This gets the cables out of the way of the SNES board when it's installed.

Making the left and right shoulder buttons

The *left and right shoulder buttons* are the only buttons we're building from scratch for this unit — the original right and left shoulder buttons from a controller are too curvy to work. The new shoulder buttons need to be about 1/4" thick and have a back plate on them so that they don't fall out of the case. For easy cutting, I choose a 1/10"-thick piece of black hobby foam, available in the crafts section of your local supermart or hobby store. Here's how to make the buttons:

1. Cut and stack the foam to make a piece three layers deep. Place it under the shoulder button hole in the rear of the case, and carve out the shape with an X-Acto knife. Be sure you cut through all three layers.
2. This will create three loose pieces of foam. Superglue them together to make one solid piece. You can then trim down the sides to make it look smoother.
3. Cut a thin piece of plastic slightly larger than the foam piece, as seen in Figure 10-30. (Use the same kind of plastic that you used for the select/start button mod.)
4. Sand one side of the plastic and superglue the foam to it in order to complete the button. Repeat Steps 1–4 to make the other button.

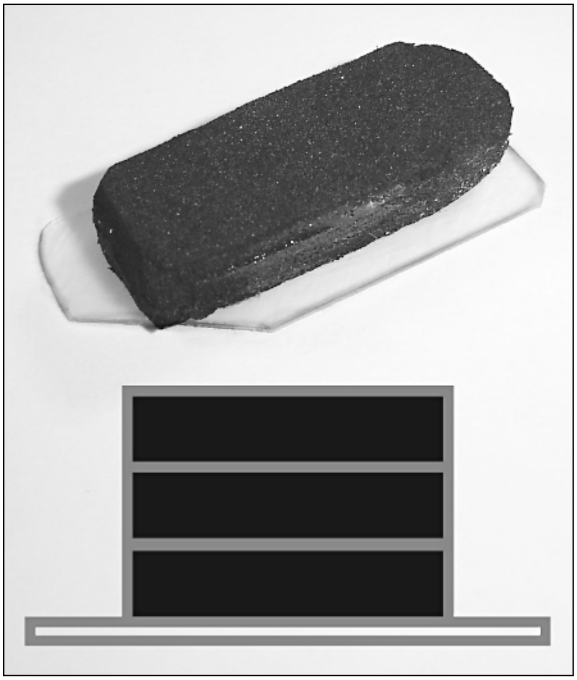


FIGURE 10-30: A completed shoulder button, with side-view cross-section.

Installing the SNES board

Now that the shoulder buttons are built, we're almost ready to attach the SNES board to the rear of the case. Desolder the 7805 regulator from the SNES if you haven't already done so (this is covered in Chapter 9). As we install the SNES board, we'll also add tact switches to it, and the rear plate to be used with the shoulder buttons we just built.

1. Take a look at Figure 10-31 — it shows the corner of the SNES board where the power switch used to be. Put a couple layers of electric tape on the board as shown, then hot-glue a tact switch in place. Bend the leads out so that the switch can sit flat.
2. Use your cutters to snip the corner of the board away, also shown in Figure 10-31. This allows the SNES board to fit in the curvy-edged case.

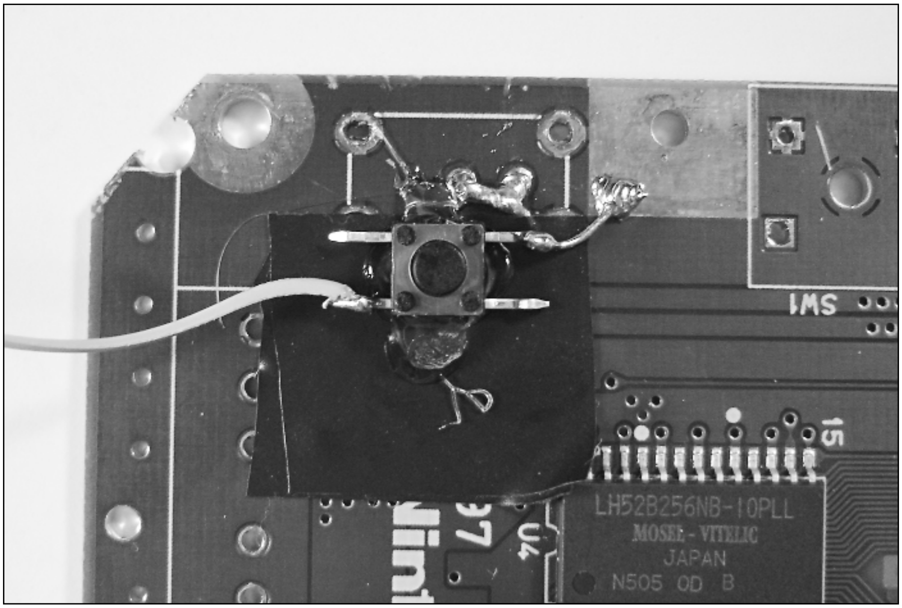


FIGURE 10-31: Placing a tact switch on SNES board and snipping the corner.

3. Connect a 10" wire to the tact switch as shown, and connect the opposite lead on the switch directly to ground (the metal edge) on the SNES board using a bit of lead or wire.

Tip

Hold the SNES board against the rear plate and line up the screw holes. You can then make sure the tact switch will be in the center of the shoulder button.

4. Before we can screw down the SNES board, we also need to connect two 10” wires to get left and right audio. Look back in Chapter 9, in the *Reconnecting the video and audio lines* section. It contains a photo of where to get both audio signals off an IC. Use this photo as reference for your connection here. Make a mark on the free end of one of the wires so that you can tell which is which later on.

5. You can now use four computer case screws to attach the SNES board to the rear plate, as shown in Figure 10-32. Make sure you get all the loose wires out from under it, including the battery wires. There are lots of holes in the SNES board, so if you want you can snake the wires through some of them. The capacitors that you rewired in Chapter 9 should all go to one side, as shown.

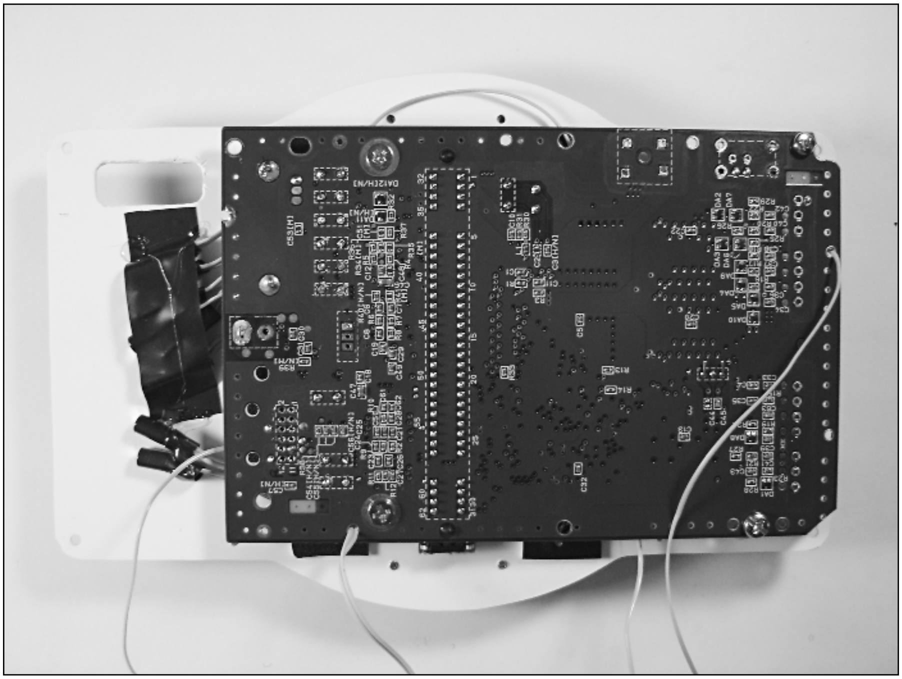
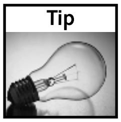


FIGURE 10-32: The SNES board screwed to the rear plate.



Tip

Use hot glue or electric tape to get the capacitors out of the way, as shown in Figure 10-32 previously.

6. Look at the right side of the SNES board in the previous photo. Note how a 1/4” × 1/4” square has been removed from the upper right corner, as well as a 1/4” × 1/4” 45-degree triangle from the lower right corner. Use your cutters to remove these same areas on your SNES board. This allows screw posts to fit past the SNES board. (As you assemble the unit, you may need to remove additional material from these spots for things to fit.)

7. Let's install the switch for the other shoulder button. Cut a piece of engraving plastic 1-5/8" wide by 1/2" high. Superglue a 1/4" nylon spacer in each corner, and hot-glue a tact switch in the middle, as shown in Figure 10-33. Solder a 2" wire to one terminal and a 10" wire to the other.

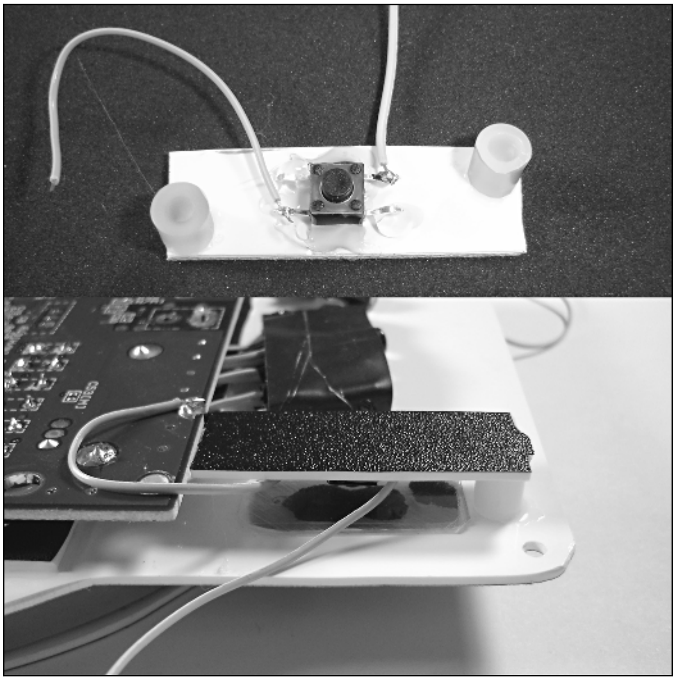


FIGURE 10-33: The tact switch and spacers attached to the engraving plastic.

8. You can then superglue this in place over the left shoulder button, as shown. Be sure it's well glued, so that it won't pop loose during an intense Street Fighter II battle. Connect the short 2" wire to ground on the SNES. Ground is any of the metal striping on the sides of the board. The SNES board and the left and right shoulder buttons are now installed onto the rear plate.

Installing the power jack and on/off switch

With the rear of the unit prepared, we can now go back to make some more connections in the front of the case, beginning with the battery charging jack.

1. Take the 1/8" panel-mount jack (Radio Shack catalog #274-251) and attach two 4" wires to it, as shown in Figure 10-34. One wire connects to the center ring; this is ground. The other wire connects to the large bending tab; this is positive.

FIGURE 10-34: Wiring the charging jack and installing it in the unit.

2. Once the jack is wired, insert it into the hole in the wall of the unit. You can then secure it with the nut on the outside. Check that the leads coming off the jack aren't touching any bare metal. You should also insert the 1/8" phono plug into the jack and make sure that the ground wire isn't touching the tip (positive) of the plug.

Caution

By installing the jack, you've made the entire aluminum wall of the unit ground, kind of like in a car. Be sure that no positive-voltage wires and no connections other than ground connections touch the outer wall. There shouldn't be any, but be aware of this in order to avoid short circuits.

3. Take your Radio Shack catalog #275-407 DPDT switch and insert it into its slot as shown in Figure 10-35. Drill two small holes in the aluminum to insert the screws. Wire the switch as described in the following steps.
4. Connect the positive and negative (ground) wires from the charge jack as shown.
5. Use a 5" wire for the *+7.2 volts to screen* wire. This will be connected to the PSOne screen soon.
6. Use a short 1" wire to make the *to ground on PC board* connection.
7. Connect a 2-1/2" wire to the ground on the PC board. This will be *ground to screen,* and will be connected to the PSOne screen soon.

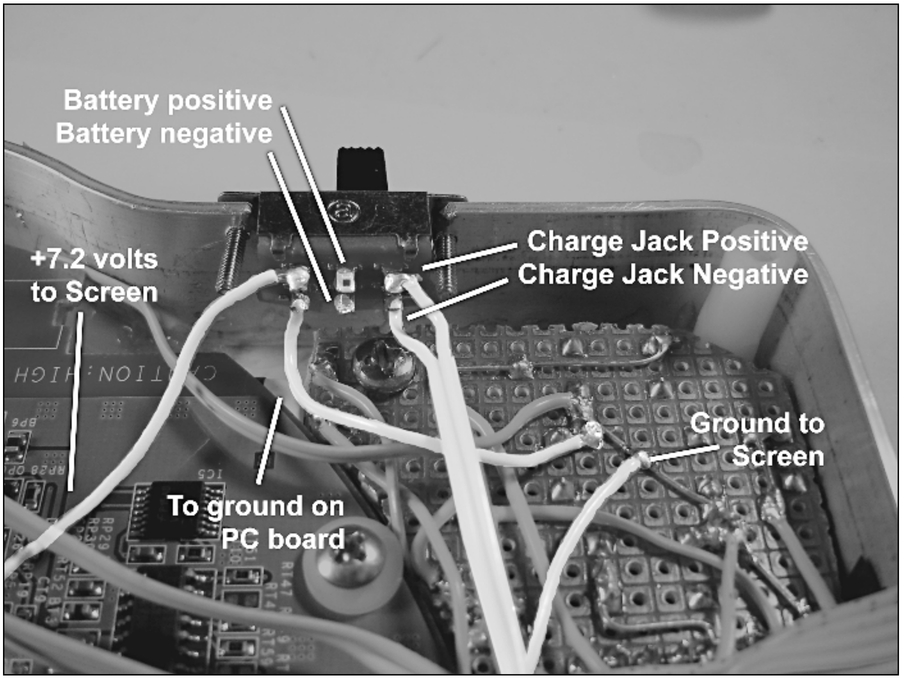


FIGURE 10-35: The ON/OFF switch installed, with wiring.

Reference Figure 10-35 when instructed to connect positive and negative from the battery to the on/off switch. If you insert the wires through the eyelet holes on the switch's leads, make sure the top and bottom ones don't touch each other. That would be bad — short-circuit city!

The charging method this unit uses is quite simple. The battery power will connect to the two center terminals. When the unit is switched on (switch goes toward the center of unit) the battery terminals are connected to the screen and SNES. When the unit is off, the battery terminals are connected to the charge jack. If there's no charger attached, then the unit is simply off. If the charger is plugged in, it sends its charge directly into the batteries.

Note

How a DPDT switch works is explained in more detail in Chapter 3.

Just below and to the left of the power switch, you'll see a small 7805A regulator on the PSOne screen board, as shown in Figure 10-36.

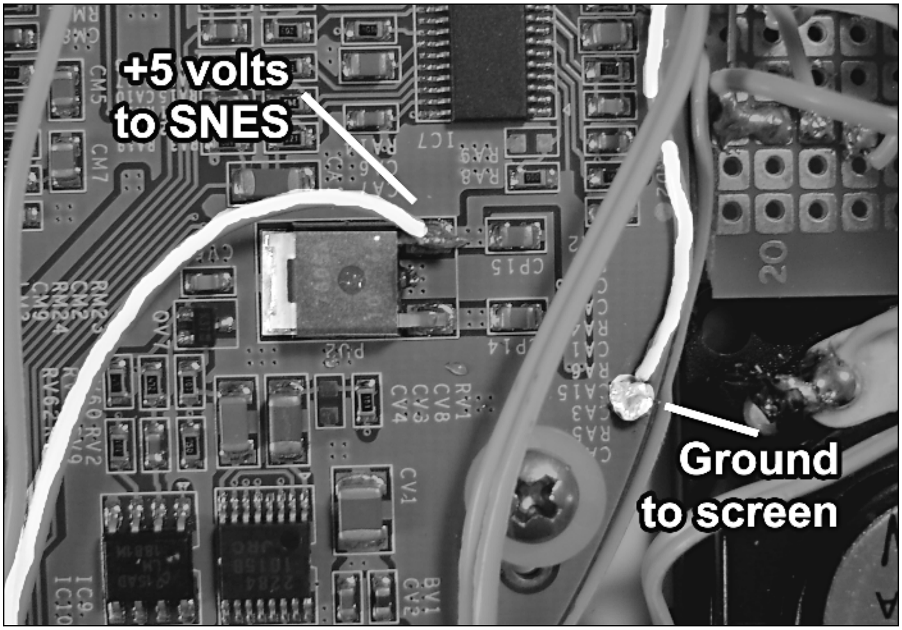


FIGURE 10-36: Connecting wires to the 7805A regulator on the PSOne screen.

1. Connect a 5" wire to the spot marked *+5 volts to SNES*.
2. To connect the *ground to screen* wire that comes from the left PC board, use your X-Acto knife to scrape away the green on the PSOne screen's board in the spot shown. Once you have a small area of bare copper showing you can solder the *ground to screen* wire to it. Tug it with your tweezers to make sure it's well attached.

Note

There are actually two 7805A regulators on the PSOne screen—this is the upper one. We used the lower one to get +5 volts to the LEDs in Chapter 4.

Wiring the two halves together

All the remaining connections involve wiring the two halves of the unit together. Yes, that's right—we're close to finishing it! To arrange the halves on your work space for the final wiring, place them as follows:

1. Lay the front half facedown and rotated 90 degrees on your work surface. The top of it should be going right, the bottom going left, and the power switch/left PC board going down/toward you. (These directions refer to your work space.)
2. Lay the rear of the case to the left of the front of the case. The bottoms of each of the halves should be touching so that you can "fold" the unit together, like closing a book. The blue capacitors should be going down/toward you.

Note You'll notice most of the wires you attach in this section will be too long. Cut them down as you make the connections so that they're only as long as they need to be. It's better to have them too long than too short!

With that positioning out of the way, let's get the wiring done, shall we?

1. We'll start by attaching the left and right shoulder button wires that are coming from the rear of the unit, under the SNES board. They connect to the left PC board just under the on/off switch, as shown in Figure 10-37.

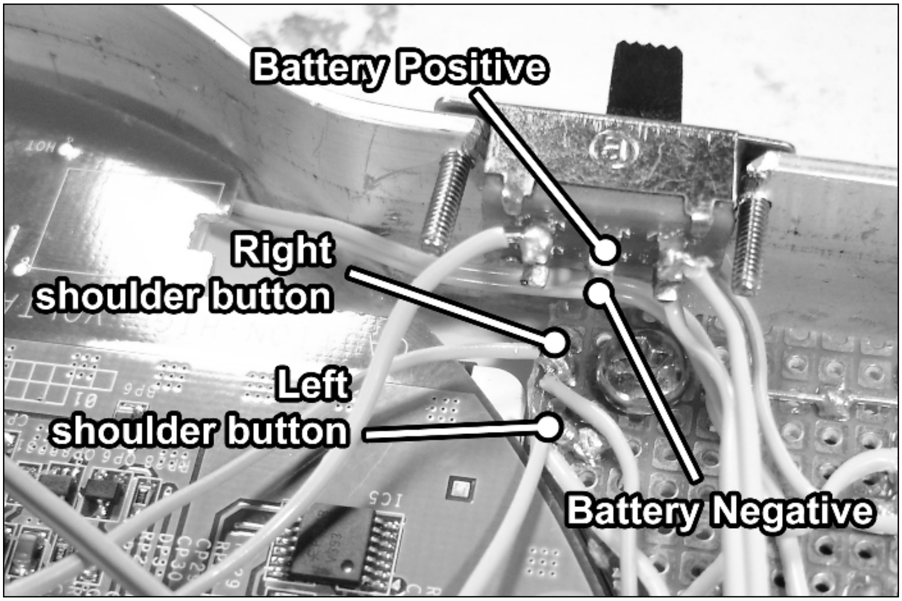


FIGURE 10-37: Connecting the right and left shoulder buttons to the PC board.

2. With the shoulder button wires attached, you can then connect the *positive and negative battery wires* to the on/off switch, also shown in Figure 10-35. If you've forgotten which wire is which (or forgot to mark them), battery positive comes out near the blue capacitors, and negative emerges from under the center of the SNES board.
3. Now let's make the power and video connections to the SNES. At the lower right-hand corner of the SNES board, you'll see the area shown in Figure 10-38. Connect the *+5 volts to SNES* wire coming from the PSOne screen to the spot shown. Connect a 4" wire to the spot marked *Video OUT*.

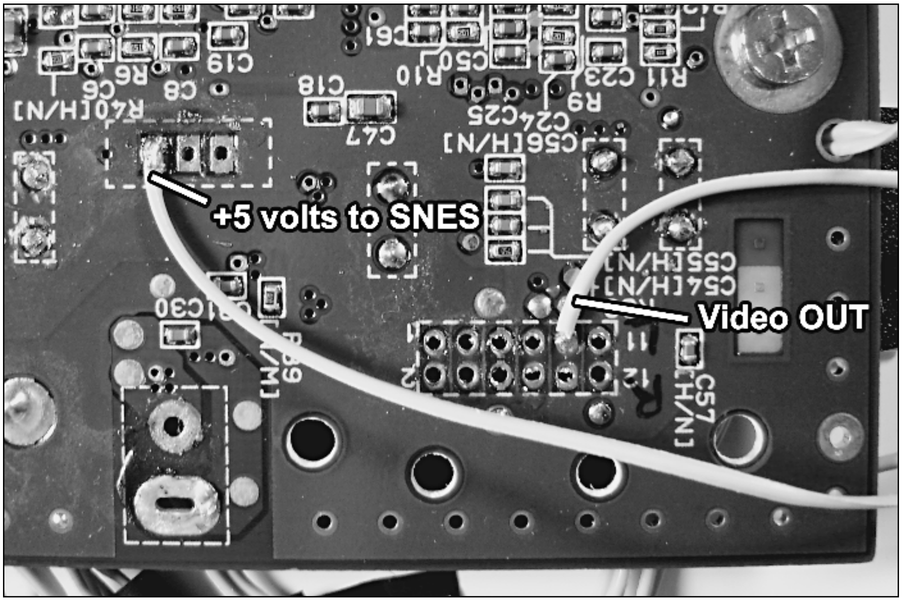


FIGURE 10-38: Connecting the power and the video wire to the SNES board.

Let's go to the PSOne screen now. Near the bottom of the main board, near where the cables were plugged in, you should see the following, as shown in Figure 10-39.

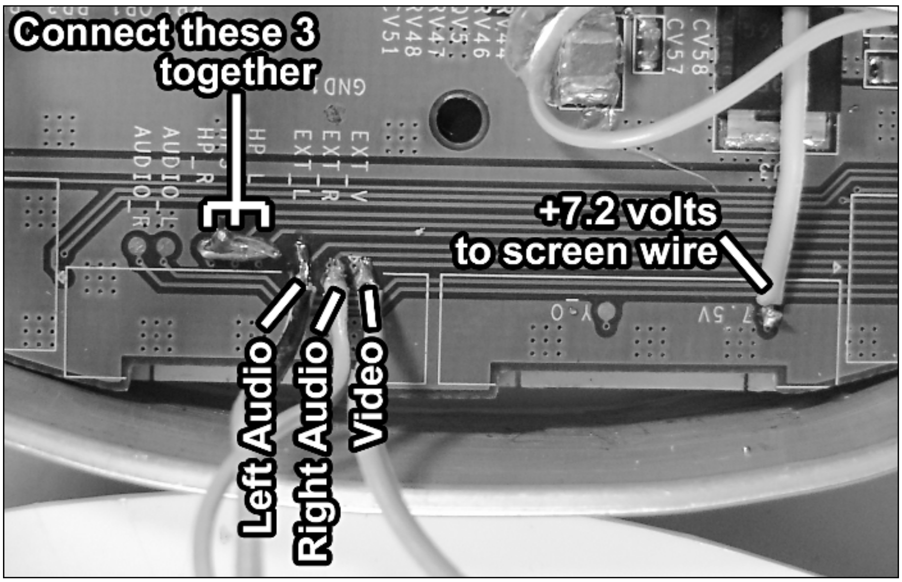


FIGURE 10-39: Connections to be made at the base of the PSOne screen.

4. The left and right audio and the video wires all come from the SNES board. Solder them to the PSOne board as shown.
5. The+*7.2 volts to screen* wire comes from the on/off switch. Connect it as shown.
6. You'll see three spots on the PSOne board, marked *HP×R*, *HPS*, and *HP×L*. Solder all three of these together to enable the PSOne speakers to work.

Note There's not much solder spot on the board to connect wires to, so be sure that they are firmly attached. Before closing up the unit, you may want to lay a bead of hot glue over these connections to protect them.

Final controller connections to the SNES board

There should now be only five unconnected wires: the ones coming from the left PC board. These were labeled 1–5 when we attached them to the PC board, and wire #1 should have a black mark on it for reference. Connect them to the Player 1 control spots on the SNES as shown in Figure 10-40.

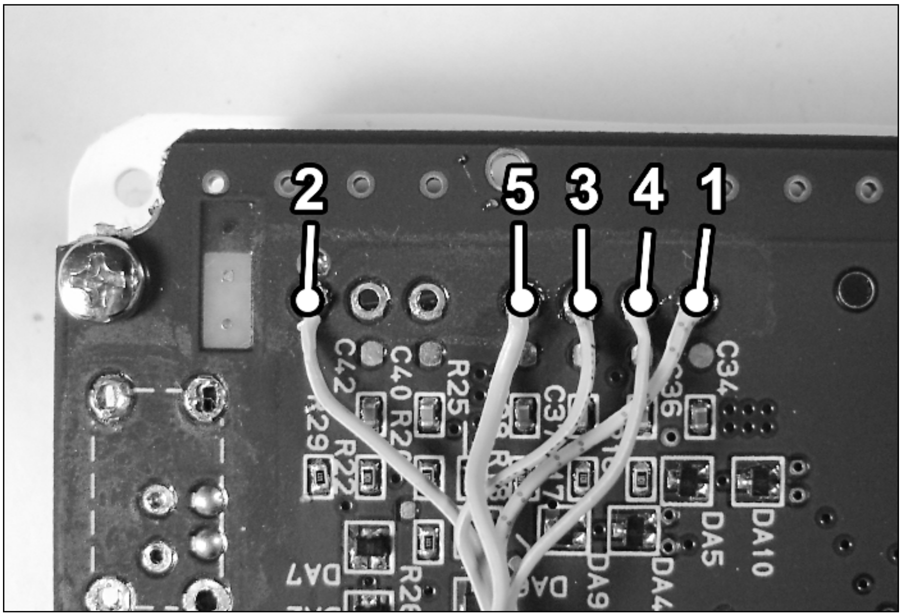


FIGURE 10-40: Connecting the built-in Player 1 controls to the SNES board.

The SNES portable is now completely wired! You can insert six AA rechargeable batteries, flip the on switch, and see what happens. We'll take a step-by-step troubleshooting walk-through in the next section to address any problems you may find.

Modifying the battery charger

The 7.2/9.6-volt battery charger will need a new plug so that it can connect to the SNES portable.

1. Cut off the existing white plug and connect the wires to the 1/8” phono plug (Radio Shack catalog #274-287), as shown in Figure 10-41.
2. The wire with the white stripe goes to the longer outer lead (negative), and the plain black wire goes to the shorter inner lead (positive).

FIGURE 10-41: Attaching a new plug on the end of the battery charger.

You can now plug it into your SNES to charge up the batteries. An indicator should light up on the charger to show that it’s, well, charging. Be sure it’s switched to the kind of batteries you have (Ni-Cd or Ni-MH).

Testing and Troubleshooting

Chances are you’re doing one of two things right now: Gleefully playing SNES games, or holding your head in despair, gazing at an unfunctional portable.

If you're in the latter category, then this is the section for you! We'll start with the biggest problems and solutions, and then go on to the minor ones. The solutions in this section for the most part tell you what to check, so be prepared to look back through the book.

1. Insert six fully rechargeable AA batteries, and switch the unit to off/charge. Plug the charger into the charge jack on the unit — it should light up indicating charging activity. If not, do the following:
   - Check the wiring of the charge plug.
   - Double-check how you wired the power on/off switch. If even one wire is wrong, the unit won't run or charge correctly.
   - Check how you wired the battery terminals. If it doesn't match the photo earlier in this chapter, the batteries may not be in the correct series, thus breaking the circuit.

   Once the charger indicates it's charging, you can move on.
2. Insert a game cartridge and switch the unit on. If nothing happens (i.e., there is no screen light or sound), do the following:
   - Make sure the batteries have been charged. Even charging them for a moment "refreshes" them and gives them enough power for a short test.
   - Check that the wires going between the battery terminals are placed correctly.
   - Check the polarity of the wires coming off the battery to see if they're reversed. Use your multimeter to check the power going into the main switch from the battery. If it reads a negative voltage, then it's reversed, and you need to switch the power wires around.
3. If the screen turns on, but the SNES doesn't, do the following:
   - Press the brightness and volume buttons to see if the indicators for them appear on the screen. This lets you know whether the screen is working properly. If you don't see the indicators on-screen:
   - Check that the LCD ribbon cable is fully reinserted into its jack. (See Chapter 4.)
   - Check that +5 volts is going to the SNES at the spot where the SNES's regulator used to be.
   - Check that the SNES's power switch has been "jumped" with a bit of wire, switching it to be "always on." (See Chapter 9.)
   - Check the five wires that connect the built-in controller to the SNES. The SNES gets its ground from these, so that if they are wired incorrectly, the whole SNES won't work, not just the controller.
4. If the screen and SNES turn on, but there's no sound, do the following:
   - In the section *Wiring the two halves together,* the audio and video were connected to some small spots near the bottom of the PSOne board. Make sure these haven't come loose.

- In that same area there were three spots on the PSOne board that were to be soldered together: *HP_R*, *HPS*, and *HP_L*. Check that they are; if not, no sound will come out of the speakers.
- Check the left and right audio connections to the small surface-mount IC on the SNES board; they may have come loose.

  Once you have picture and sound going, press Start, and try playing the game using the built-in controllers.

5. If the built-in controller doesn't work correctly, or at all, do the following:
   - The five wires going from the left PC board to the SNES board may not be in the correct order — double-check them.
   - Make sure that the two 16-pin ICs are positioned correctly. There's a small dent on the end of them; check that it matches the orientation of the ICs in the photos. If not, you've got some desoldering to do!
     - Check that every tact switch has these three things going to it:
     - Ground connection
     - 10K-ohm resistor
     - Connection to IC (on same pin as 10K-ohm resistor)
   - Each 10K-ohm resistor should have +5 volts going into it. Use your multimeter to check for this. If you find one that doesn't, find +5 volts on the PC board and connect it to the resistor.
   - Space can get tight on those PC boards, especially the left one. Make sure no connections are shorting each other out. If the controller works, but acts flaky, this is probably the reason.

Once the picture, sound, and controls are all working correctly, your SNES portable is officially completely wired, and ready for final assembly!

Final Assembly

Now that the SNES is working, we can do the final assembly. This involves adding a couple more screw posts (believe it or not!), arranging the wires inside the SNES so they'll all fit, and screwing both halves together. You're probably pretty anxious to get this thing done, so let's get started!

1. Take two 1/4"-high nylon spacers (make sure they've been threaded well), and glue them into the corners near each speaker as shown in Figure 10-42. Be sure to use epoxy on them as well, so that they don't snap loose when screwed into.
2. Flip the rear half of the case over onto the front plate to check how well the spacers line up to the screw holes, and adjust (before the epoxy dries) if necessary. Even if you use quick epoxy, I'd strongly suggest letting these cure overnight to allow maximum strength.

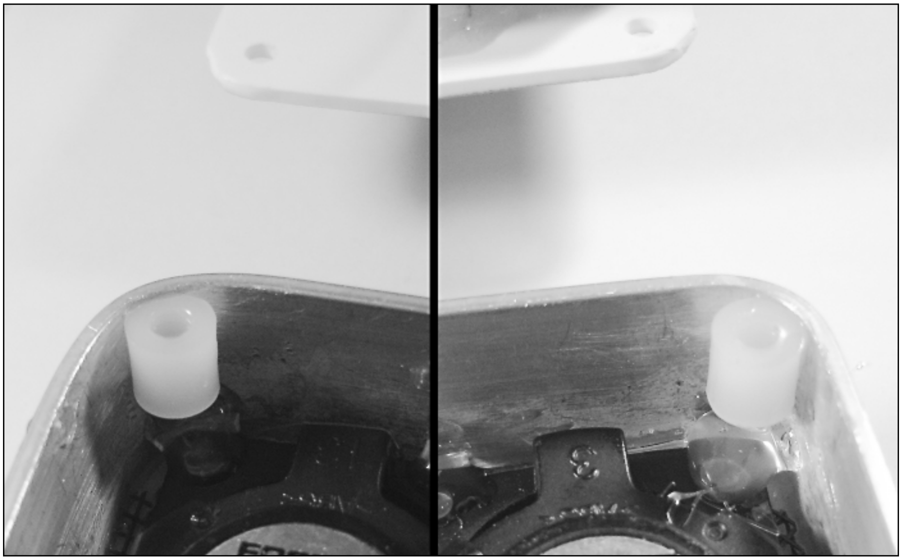


FIGURE 10-42: The final two screw posts to attach to the unit.

Whenever I design a portable, my main thought is, "It must be thin!" The hand-built SNES portable is no exception, and because of this, the insides are very tight and cramped for space! True, you can mash the halves together and get it to fit but you may also short out connections by doing that. It's best to prevent this by placing electric tape over the following areas:

1. A double-layer of tape over both rows of the SNES's cartridge connector leads.
2. A small piece over the two screws holding down the SNES board near the cartridge connector.
3. A small piece over the *+5 volt into SNES spot* (where the 7805 regulator was).
4. A small piece over the 7805A regulator on the PSOne screen that powers the white LEDs.
5. A small piece over the 7805A regulator on the PSOne screen that powers the SNES.
6. A big piece to cover the exposed leads of the power on/off switch.

Once you've placed electric tape in the indicated positions, you can press the two halves together. As you do, you'll find what wires and ribbon cables are getting in the way — press them aside or flatten them until both halves of the unit can meet. The shifting around and tucking away of various ribbon cables is vital to closing up the unit.

Remember the extra-long ribbon cable between the left and right PC boards? You can tuck that under the top of the PSOne screen's board (if you haven't already) so that it stays out of the way of the SNES board. Since it's the biggest cable (eight strands), this really saves space. With the ribbon cables in place you can now screw the halves together as follows:

1. Insert the final screws through the back of the rear plate to secure the unit, as shown in Figure 10-43.

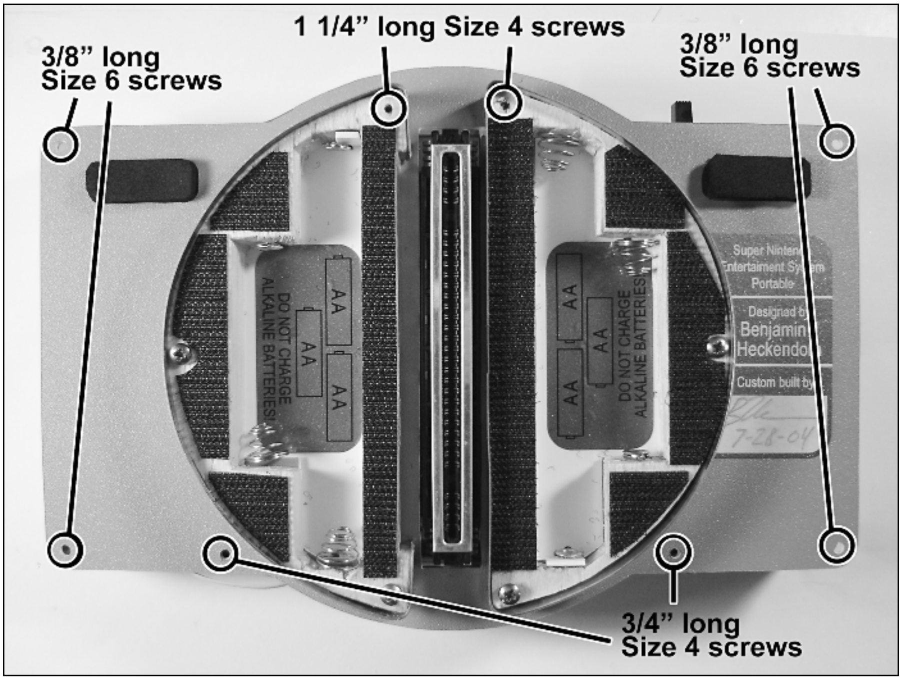


FIGURE 10-43: Which screws to use for the final assembly.

2. Fold the two halves together, like closing a book or making a sandwich. Then drive the screws from the rear half into the front to close it all up.

A few things may keep the sides from connecting properly, depending on how precisely the unit was built. Since it was done by hand, errors such as these can appear or not appear at random, and it's mostly a matter of luck.

- **The top two 1-1/4" screws that go through the balsa in the battery compartments may not line up to the top two nuts on the front plate.** To work around this problem, use your soldering iron to widen the two holes on the inside of the rear plate, as shown in Figure 10-44. Stick the iron into the holes and tilt it left and right. This melts the plastic and makes a groove, so that when you insert a screw, you can tilt it left and right and have a better aim when connecting it to the nuts on the front plate.

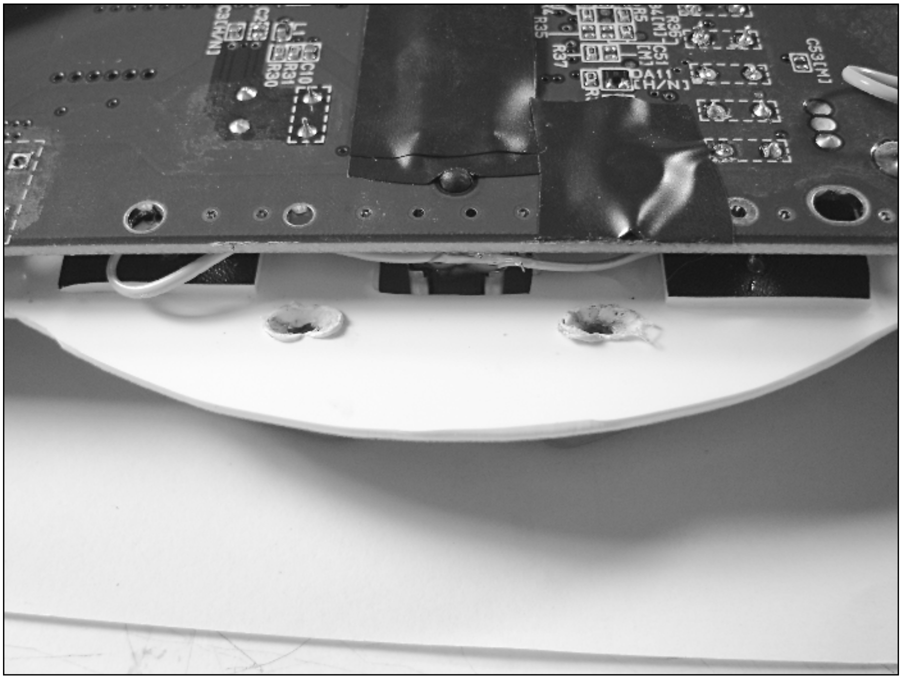


FIGURE 10-44: Making "targeting slits" in the plastic.

- **The right-hand speaker may bump against the SNES board, keeping the case from closing completely.** You can solve this problem by sanding down the front and back of the speaker. This will require you to remove the speaker from the case. Simply desolder the wires on the speaker itself, and pull it free of the glue. Fine-grit sandpaper will work, but a coarser grit will make it go faster.

  1. Lay the sandpaper on something flat and scrape the speaker across it. A good minute of sanding on each side should get the speaker thinned enough to fit. You can remove some from the front of the speaker and a lot from the back.
  2. Once the front is level with the center cone and all the text that was on the back is scraped away, you should be ready. You're actually sanding away some of the magnet, so particles of it will stick back onto it. To remove them, take the speaker outside and blow on it; they'll fly right off.

Don't sand the magnet anywhere near your portable. The magnet shards can short out circuits if they get into the case.

Note that when placing the speaker back down, you should keep it slightly away from the sides of the case. There's epoxy along that seam, and if you put the speaker on it, it may not lay as flat as possible.

- **The SNES board hits the ON/OFF switch.** Again, this depends on where you placed the switch. Regardless, only a small portion of one corner of the SNES board will hit the switch, so you can just snip that corner of the board off with your cutters. The sides of the board are just ground, and you can go up to 3/8" in from the sides with the cutting and still be safe.

Once you've made these corrections, you should be able to connect the two halves together. Congratulations, your hand-built portable Super Nintendo Entertainment System is finished! Enjoy your portable Final Fantasies and Chrono Triggering!

Chapter in Review

This chapter has been a long journey, with many complex and time-consuming steps along the way. Let's look back at the highlight reel, shall we?

- You used engraving plastic to hand-cut parts to build the SNES portable's case, much like an ancient caveman would have (except for the whole electronics thing).
- Using aluminum strips, you made walls for the unit and attached them to the plates to form the case itself.
- You made complex (yet cool-looking) battery holders for the back of the unit.
- The PSOne screen, custom controls, and SNES board were all put into the case and wired together.
- In a moment of triumph, you folded the halves together, screwed them tight, and finished your SNES portable.

What a trip! I feel winded just *reading* this recap! If you'd like to try making a somewhat easier portable SNES, the next chapter tells you how to use a CNC machine to do just that.

chapter 11

Building a Portable Super Nintendo Using CNC Machinery

in this chapter

- ☑ Materials You'll Need
- ☑ Routing the Parts
- ☑ Assembling the Case
- ☑ Wiring the Unit
- ☑ Testing and Troubleshooting
- ☑ Final Assembly
- ☑ Chapter in Review

If you have access to a CNC machine such as a laser engraver, or know of a business that has one, look at Figure 11-1 for the kind of Super Nintendo portable you can build!

FIGURE 11-1: The CNC-built Super Nintendo portable

This portable is quite small, only 4-3/4” wide by 6-3/4” tall and 1-1/2” deep. Since the case will be cut using machinery, it’s actually a fairly easy unit to build. Check Chapter 5, for more information on how these machines work and where to find them.

In this chapter we’ll CNC-cut plastic pieces, and then use them to assemble the case for this portable. After that, we’ll wire a custom built-in controller board and install it into the case along with the screen. Finally, we’ll attach the SNES board itself, along with a modified AA battery holder. In the end you’ll have a small (and compact) SNES portable you can take anywhere! Let’s get started!

Materials You’ll Need

In this section we’ll list the materials you’ll need for this project, starting with the major game-related ones.

- A mini-Super Nintendo Entertainment System, hacked as described in Chapter 9.
- One SNES controller.
- One Casio EV-680 pocket TV, modified as described in Chapter 4.
- Two regular NES controllers (any brand or type; again, check the *Rebuilding the Controllers* section in Chapter 9).

Electronic parts

The next set of materials you need will be the electronic parts. Table 11-1 lists what you’ll need. The majority of these parts are commonly available at Radio Shack stores, with the exception being the 6-mm tact switches. You’ll need to get those from an online electronics vendor such as Digi-Key (`www.digikey.com`).

Table 11-1 Electronic Parts List

Part Name	*Available From:*	*Part or Catalog #*	*Quantity/Packages Required*
10K-ohm 1/4-watt resistors	Radio Shack	271-1335	4
Grid-style PC board (71 mm × 94 mm)	Radio Shack	276-147a	1
1/8″ stereo phono plug	Radio Shack	274-246	1
7805 linear voltage regulator	Radio Shack	276-1770	1
Heat sink	Radio Shack	276-1368	1
Battery holder, holds (4) AA batteries	Radio Shack	270-391a	2
AA size Ni-MH rechargeable batteries	Radio Shack	2-pack: 23-525; 4-pack: 23-528	6 batteries

Part Name	*Available From:*	*Part or Catalog #*	*Quantity/Packages Required*
Ni-MH/Ni-Cd battery charger	Radio Shack	23-333	1
DPDT submini slide switch	Radio Shack	276-407	1
RC battery pack leads	Radio Shack	23-444	1
Tact switch, 6 mm	Digi-Key	EG2495-ND	12

Screws, nuts, and washers

Next take a trip to your local hardware store so that you can buy the screws, nuts, and washers listed in Table 11-2. Locate the section/aisle with a variety of bins filled with all sorts of screws to find this stuff.

Table 11-2 Screw, Nuts and Washers List

Screw/Nut Size	*Type*	*Length*	*Quantity*
Size-4 screws	Phillips, pan (round head)	1/4″	12
Size-6 screws	Phillips, pan (round head)	3/8″	2
Size-6 screws	Phillips, pan (round head)	1″	2
Size-6 screws	Phillips, pan (round head)	1 1/4″	4
Size-6 nuts	Standard	N/A	4
Size-6 lock washers	N/A	N/A	2

Case-building materials

To build the case itself, you'll need the materials listed in Table 11-3. These are the materials that will be cut by the CNC machine. For more information on these materials, see the last section of Chapter 5.

Table 11-3 Case-Building Materials

Material	*Size*	*Source*
1/16″-thick engraving plastic	12″ × 12″	Trophy/awards shop
1/4″-thick acrylic or wood	12″ × 12″	Lumber store, sign shop, hobby shop

The specifics of the case-building materials will be described further in the next section, *Routing the Parts.* Keep in mind that you may have to buy these materials from the business that does the CNC routing, as they may not want you to bring your own stuff in. (Again, see Chapter 5.)

Other random items you'll need

To build this portable, you should have the following items handy as well:

- Hot glue sticks.
- Fine-grit sandpaper.
- Superglue.
- Epoxy: Any two-part epoxy will work, but 5-minute "quick" epoxy will save you time.
- Extra X-Acto blades.
- Electric drill with the following bits sizes: 11/64" (or as close to it as possible) and 15/64".

Routing the Parts

Due to the nature and smallness of this project, I'm going to recommend that only a *laser engraver* be used to cut the parts. A router is just too big and cumbersome for some of the detail we'll be needing, and using one would be like inscribing a wedding ring with a jackhammer. (Well, not *quite* that bad, but it's a fun analogy.)

The parts for this project will be split into two types: *Plates*, which are pieces made from thin 1/16" engraving plastic, and *side walls*, which are 1/4"-thick portions made from acrylic or wood.

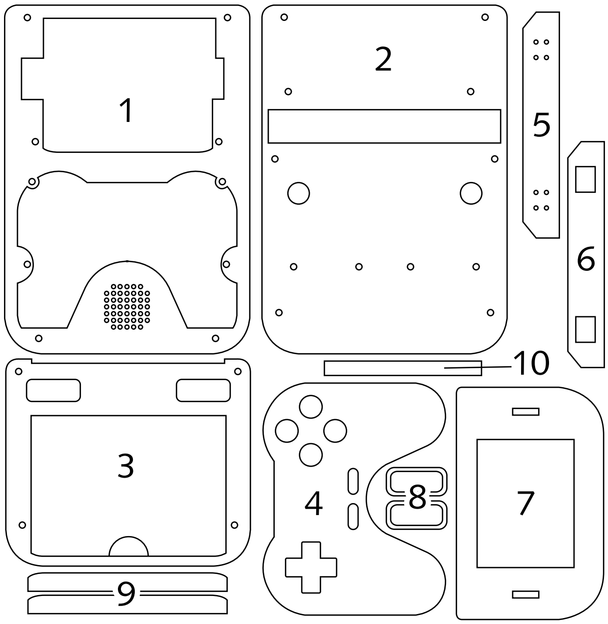
All the files mentioned in the coming pages are available on the companion Web site at www.wiley.com/go/extremetech, in a file called "SNES CNC."

Laser-cutting the plates

Most of the plates will be visible on the outside of your portable, so you should pick a color you like. I'd suggest a light gray, which will harken back to the days of the Super Nintendo's glory.

When you find a place that has a laser engraver, chances are they're not going to want you to bring in your own engraving plastic. Rather, you'll probably buy it from them along with the cutting time. They should have a good selection of colors to choose from, or you can look through a catalog and order some. As stated in Table 11-3, you'll only need 12" × 12" pieces.

Figure 11-2 shows all the parts of engraving plastic that will be cut, with their names following. These names will come up later in the *Assembling the Case* section, so use this drawing as your main reference.



1) Front plate
2) Rear plate
3) Battery compartment plate
4) Control plate
5) Shoulder button tact switch plate
6) Tact switch plate spacer
7) Screen plate
8) Shoulder button flange
9) Velcro space compensators
10) Battery door flange

FIGURE 11-2: The parts of engraving plastic.

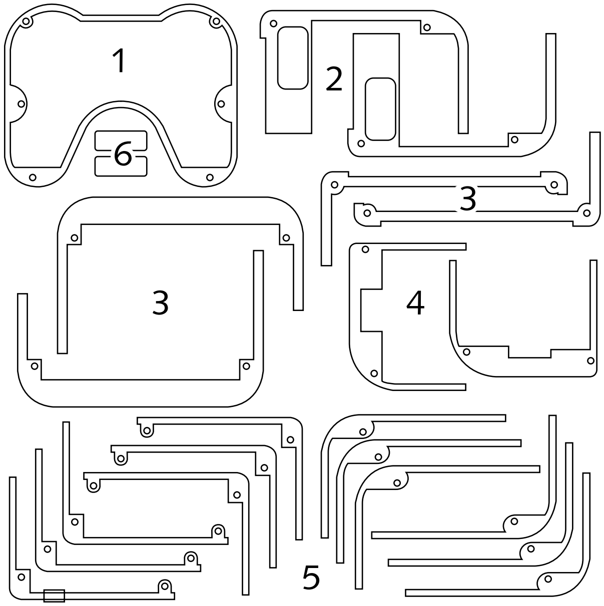
Provide the following file from the companion Web site to the laser engraver operator: "SNES CNC Engraving Plastic Material 12x12.cdr." Tell the operator to have the machine make vector cuts completely through the material on all black hairline strokes. This will cut out all the parts from the main engraving stock.

It's not a bad idea to print out the file "SNES CNC Engraving Plastic Material 12x12.pdf" before stopping by the laser engraving place. That way they'll have an idea of what you want done ahead of time.

Laser-cutting the side walls

The pieces shown in Figure 11-3 are going to be made from the 1/4"-thick material and are called the *side walls.* These pieces will be stacked and glued onto the plate in order to create the main portions and depth of the portable's case. Some of these pieces will also be used as the shoulder buttons.

Please note that most of the pieces come in pairs — the name of each pair/part is listed after the figure.



1) Control riser walls
2) Thick battery compartment walls
3) Normal battery compartment walls
4) Screen riser walls
5) Front side walls
6) Shoulder buttons. These aren't walls, but they're still 1/4" thick. They fit inside the shoulder button flanges that were cut with the plates.

FIGURE 11-3: The 1/4"-thick side wall parts.

You can use a variety of materials for the side walls, as long as it's 1/4" thick and fairly flat and solid. Whatever type of material you chose, you'll need a 12" × 12"–sized portion to create all the walls for this unit. Here are some options, along with their pros and cons. (FYI: I made my SNES portable out of balsa wood.)

- **Wood.** Fairly easy to laser-cut and work with, and it can also make for a lighter overall portable. As a drawback, wood can warp, and sometimes the drill holes will be "burned" too large, preventing size-6 screws from fitting. As a fix later on, you can use a size-8 screw in a hole that isn't grabbing the size 6.
- **Acrylic.** Takes longer to cut, and removing the pieces from the main stock afterward can be a little tricky. It's also brittle and can break. An advantage is that laser-cut acrylic has nice smooth edges from the heat-polishing, and therefore doesn't usually need additional covering or paint.
- Anything fairly solid that's 1/4" thick and can be laser-cut.

Provide the laser operator with the "SNES CNC Quarter-Inch Material 12x12.cdr" file. Have them make vector cuts completely through the material on all black hairline strokes. This will cut the side wall parts out of the main material stock. Remember, you should also print the file "SNES CNC Quarter-Inch Material 12x12.pdf" beforehand to show them what you'd like done.

Tip

Most laser engravers run off Corel Draw files, which have a CDR extension. If for some reason the place can't use a CDR file, there are AI (Adobe Illustrator) versions of the files also available on the companion Web site.

Decals

Naturally, your portable needs decals and graphics so that people know which buttons do what (and of course to make it look fancy). Here are your options for making them.

Getting graphics from a vinyl shop or sign shop

These types of businesses typically have thermal image printers that can "impregnate" color into thin adhesive-backed vinyl. This creates a very durable decal for your portable.

Provide the shop with the file "SNES CNC Decals.plt." Tell them that all the cuts and colors are already set in the file. Have them print it on a somewhat dark-colored vinyl, such as *Metallic Dark Gray* or *Slate.* If they cannot open the file with their software, offer them one of the files described in the next option.

While you're at the vinyl shop, ask them to cut you several *3/4" wide by 24" long vinyl stripes* in a color that complements the engraving plastic. (I used black, and light gray is also a good choice.) These can be used to cover the sides of your unit if you chose a material, such as wood, that doesn't have nice, uniform cut edges after being lasered.

Print the graphics yourself

If you have some adhesive-backed printer paper, you can print out the files yourself. Use one of the following files, depending on which your computer can open: "SNS CNC Decals.ai," "SNES CNC Decals.pdf," "SNES CNC Decals.wmf," or "SNES CNC Decals.jpg."

In the printer dialog box, select "No Scaling" or 100 percent size. This ensures that the size of the printed decals will match the parts of the portable. Use your X-Acto knife to cut out each decal along the edges and the thin inner black lines.

Assembling the Case

Now, with the parts routed, it's time to assemble the case. The individual parts you'll use were labeled in the previous section, *Routing the Parts.*

You may be wondering why there are so many little pieces to make this case. The idea is that the more pieces you can break the case into, the less raw material you'll use, because you can efficiently nest the parts together on a single piece of material in order to CNC cut it. It also allows you to make all the walls out of material of the same thickness (1/4"). Finally, many laser engraving machines have a table size limit of 12" × 12", so being able to fit all the parts in that area increases accessibility to an engraver.

It does make assembling the case portions a little more difficult, however. The following sections will instruct you on the assembly of each portion, using pictures of which parts to use and in what order. It's a lot like one of those TV shows where they dig up an old skeleton with its bones all over the place, then carefully reconstruct the actual shape. (Well, at least that's what it reminded me of...)

Front half of unit

The front half of the unit is the largest part of the case, measuring 4-3/4" × 6-3/4" and 3/4" thick. It will contain the controls, regulator, heat sink, speaker, and the TV screen. To assemble it, use the following procedure:

1. Sand the back of the *front plate* around the edges so that the superglue will stick well.
2. Stack and glue the three layers of *front side walls* on the back of the front plate as shown in Figure 11-4. Keep the outer edges of the walls flush with the edges of the plate of engraving plastic.

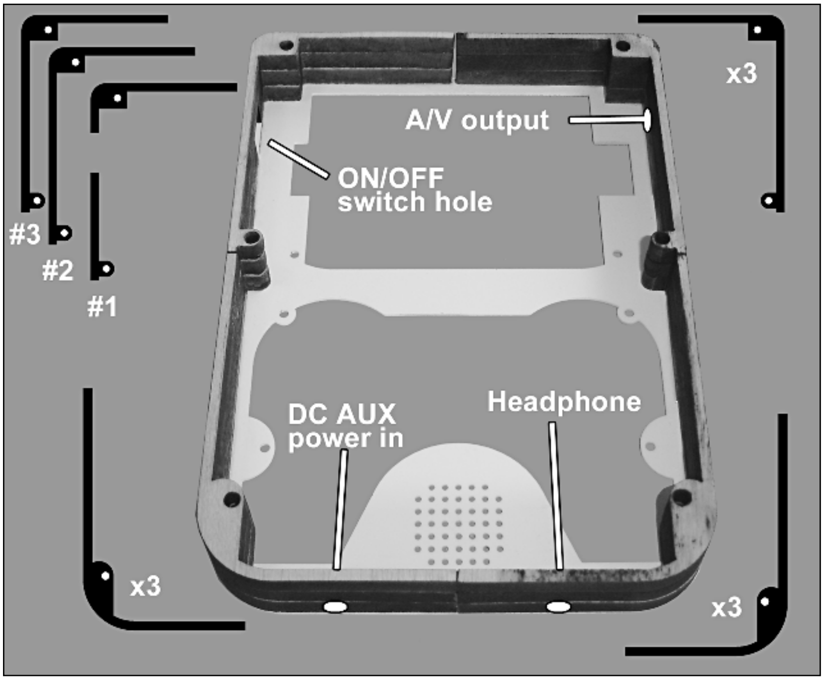


FIGURE 11-4: Which front side walls to stack and glue to the back of the front plate, and where to drill the holes.

3. Note that there's a number by each of the pieces that go on the upper left corner of the case. This indicates the order in which to glue them down:

   - Piece #1 is actually two pieces. Glue it down so that the right and bottom edges of it touch the other wall portions of the unit. This will leave about a 1/2"-wide hole in which to put the on/off switch (as labeled in Figure 11-4).
   - Pieces #2 and #3 are the same and stack on top of piece #1.

   Stacking the pieces in this order ensures that the power on/off switch is up front where it won't bump into things like the SNES board.

4. When all the walls are in place and the superglue is dry, place a bead of epoxy along the inside seam where the first layer of walls touch the front plate. Then place a thin bead of epoxy down the inside of each of the four main vertical seams (at the center of the top, left, right, and bottom). Doing this will increase the strength of the unit.

5. This SNES portable needs to have holes drilled for three jacks in the front half of the case. Each hole should be drilled in the side of the case in the first layer of walls that you glued down (at the same level as the on/off switch hole).

   - **Audio/video output jack hole.** Upper left corner, using an 11/64" bit.
   - **Headphone jack hole.** Bottom of case, right-hand side of the speaker holes. Use an 11/64" bit. Do not place the headphone jack over the large opening, as the heat sink is going to go there.
   - **DC AUX power in hole.** Bottom of case, left side of the speaker holes. Use a 15/64" drill bit. Don't put this hole over the lower left screw hole on the front plate (not shown in figure).

6. If the outer walls don't look so hot (i.e., you didn't use acrylic), then wrap a 3/4"-wide strip of vinyl around sides of the case. It should cover the walls but not the edges of the engraving plastic. Press it down so it sticks well. Once it's on, cut out the jack holes and the on/off switch space.

7. Apply the appropriate decals on the outside of the walls to label each jack. Match the decal to the jack position/description listed in Step 5.

Battery compartment

The *battery compartment* is the second largest part of the case, measuring 4-1/2" × 2-7/8" and 3/4" thick. It contains the battery holder and the left and right shoulder buttons.

Some wiring will be done while building the battery compartment, so get your soldering iron heated up. The wires we attach will all be given names here, and later in the chapter we'll refer to them as we do the final wiring. Hence, you may need to check back here for reference.

To assemble the entire battery compartment assembly, follow these steps:

1. Sand the back of the *battery compartment plate* to ensure proper gluing.
2. Glue the one layer of 1/4"-thick *thick battery compartment walls* to the back of the battery compartment plate. These walls hold the left and right shoulder buttons.
3. Glue the remaining two layers of 1/4"-thick *normal battery compartment walls* on top of the thick battery compartment walls. This will result in a total thickness of 3/4" (including the thick battery compartment walls). You'll notice that there's a gap in the normal battery compartment walls — this is for the charger jack we'll be installing shortly. Have the gap be on the right side of the unit, when viewed from the inside. (See photo in Figure 11-5.)
4. Place each 1/4"-thick *shoulder button* in each 1/16"-thick *shoulder button flange.* The flange should be level with the base of the button. Superglue the buttons to the flanges.
5. Once the glue is dry, drop the flange-equipped buttons into the holes in the thick battery compartment wall. The buttons themselves should pop out the back through the battery compartment plate, while the flanges keep them from falling completely out. Place the LEFT and RIGHT decals on them at this time.
6. Take the *shoulder button tact switch plate* and stick two 6-mm tact switches into the holes. On the opposite side, bend the tact switch leads inward to help hold the switch in place. Blob some solder onto the leads to further lock the switch down.
7. Place the *tact switch plate spacer* over the tact switch plate and superglue them together. You'll notice that the square holes allow the leads on the tact switches enough space to be wired. For simplicity's sake, both of these pieces glued together will now be referred to as the *tact switch plate*.
8. Connect a 2"-long piece of wire between the two *ground leads* on the tact switches (shown on Figure 11-5.).
9. Connect a three-strand of 10" wire to both the *left and right shoulder button leads* and the *ground leads.* The other ends of these will be connected with the rest of the game controls when you're wiring the unit. Use a marker to color-code them so you know which is left and right. Have the center wire connect to *ground.*
10. Place the *tact switch plate* over the thick battery compartment wall, with the tact switches pressing against the shoulder buttons. Hold the tact switch plate and see if the buttons are clicking on the other side. If so, superglue the tact switch plate in place. Glue it well, as the switches will be highly pressured by your fingers during all those intense Super Mario World sessions.

At this point, the battery compartment should appear as in Figure 11-5.

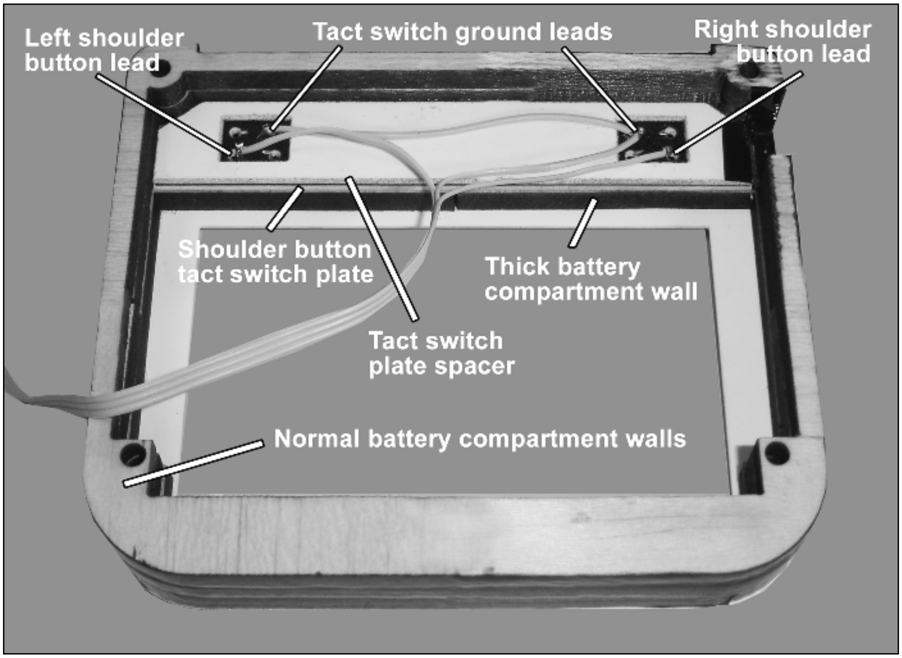


FIGURE 11-5: The battery compartment thus far, with items identified.

We'll now install the *female* RC battery pack lead, which we will call the *charge jack* (Radio Shack catalog #23-444 in the materials list). This allows you to conveniently plug a standard RC battery charger into the SNES portable. The battery lead needs a few modifications before being installed, however.

1. Cut the red and black wires so that only 1" remains connected to the white plastic portion.
2. Strip about 1/4" of plastic off the ends of each wire, and attach a 10"-long piece of wire to each. Use a magic marker to color the other ends of these wires red and black for later reference when we attach them to the power switch. These will be called the positive and negative *charge jack wires.* Finally, wrap a couple layers of electric tape around the two thick red and black wire connections so that they can't short out to anything, including each other.
3. Set the female RC battery lead down onto the tact switch plate so that it sticks out the hole in the side of the battery compartment and is flush with the edge.
4. Note that on the top and bottom of the white jack are little nubs used to connect the male jack. If this jack doesn't fit flush with the battery compartment, you can sand these down or snip them off so that it will.

5. Once you have the battery lead in the proper position, take it out and place a quarter-sized pool of hot glue down. Put the battery lead down on the hot glue and reposition it, and then let it cool. Place some hot glue behind the lead (where the red and black wires are) so that it can withstand the force of plugs being pushed into it. Don't put any hot glue on top of the switch, or the unit won't screw together correctly.
6. If you feel you need to improve the appearance of the outer walls, wrap a 3/4"-wide stripe of vinyl around the battery compartment. Cut out the portion that covers the charge jack.

Tip

The female RC plug is the kind that the RC battery charger plugs into. Make sure that the plug you used matches the photo. (See Figure 11-6.You'll also get a male plug in the plug package that you won't need, so I figured I'd better spell out the difference just to be safe.)

The installed RC battery charge jack should appear like that shown in Figure 11-6 below.

FIGURE 11-6: The charge jack installed in the battery compartment.

The last object to install is the battery compartment door and the Velcro to hold it down.

1. Take the 1/4" × 3 1/2" *battery door flange* and superglue it to the bottom (noncolor side) of the battery door on the end opposite the half-circle shape. Have 1/8" of the flange glued to the door and the other 1/8" hanging out.

2. Two pieces of standard Velcro stuck together are about 1/8” thick. Look at the battery compartment from the rear (through the door). You'll see a little ledge created by the normal battery compartment walls. This ledge is 1/4” down (the thickness of the thick battery compartment walls). Stack and glue the two *Velcro space compensators* onto this ledge. This causes the gap to be only 1/8” down.
3. Cut a 3/8” × 3-3/4” strip of Velcro, and stick it to the Velcro spacer compensators.
4. Cut the same size strip out of the opposite type of Velcro, and attach it to the back of the battery door so that it will touch the first piece of Velcro when the door is inserted.

Figure 11-7 shows the back of the battery door, the flange, and where the Velcro goes. The battery door can now be inserted into the hole and held by Velcro. (Velcro is right up there with hot glue when it comes to being useful, I think!)

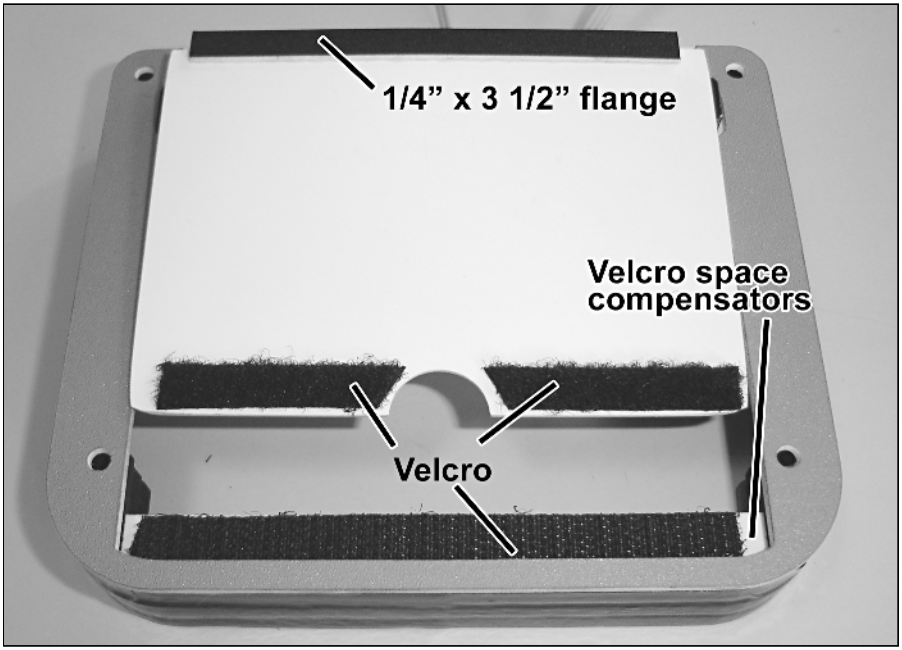


FIGURE 11-7: Back of battery door, flange, and Velcro placement.

Battery compartment to rear plate attachment

The battery compartment attaches to the rear plate to form the *rear half* of the unit. Sandwiched between them are the *battery holders* themselves, Radio Shack catalog #270-391a. The following instructions will guide you through the installation of these and the completion of the rear half.

1. Figure 11-8 shows a four–AA battery holder with the two wires positioned on the lower left. Snip the bit of black plastic so that the springy negative terminal on the top right can be rotated around to the left. Cut off most of the spring to leave only a small hook. You can then hook this into the springy terminal on the left and solder it in place.
2. Saw the battery holder in half as indicated in Figure 11-8. The saw line should be just on the right of the middle wall. We'll be keeping the left side of this holder and therefore we need that wall intact. You will find a black wire on the underside of the holder; go ahead and snip/saw through it. (Step 1 alleviated the need for this wire.)

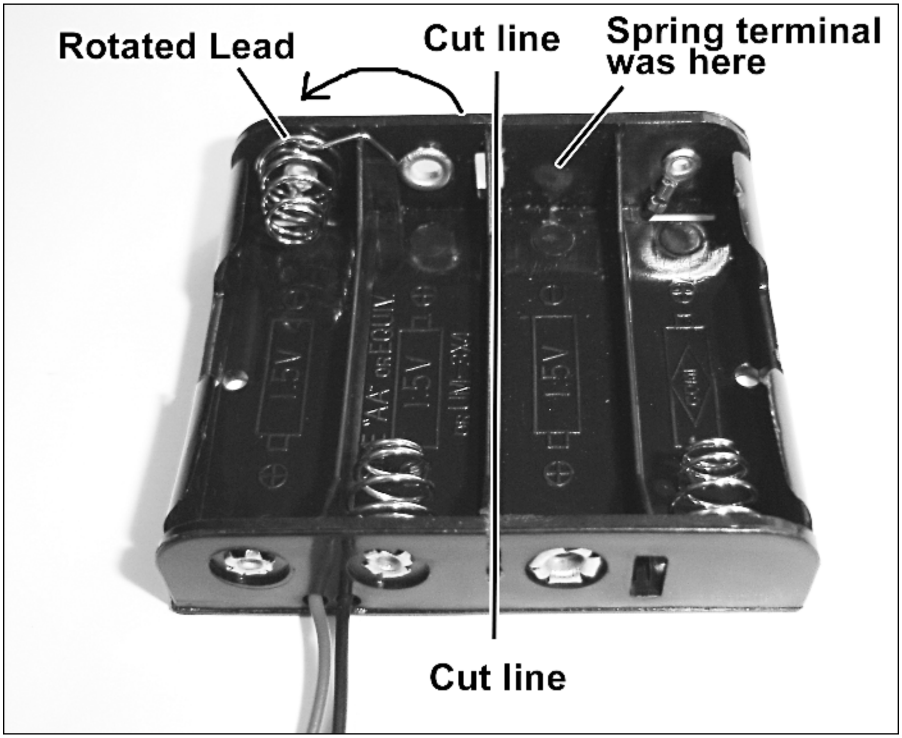


FIGURE 11-8: Modifying the battery holder.

3. Notice that there are four screw holes on the rear plate for attaching the battery holders. Place the unmodified battery holder over the leftmost screw and the one second from the right. You can then attach it using two 1/4"-long size-4 screws.
4. Place the hacked battery holder to the right of the normal battery holder with the wires at the top. The hacked edge of this holder should be touching the normal holder. Use one 1/4"-long size-4 screw to attach the hacked holder to the remaining screw hole.

Tip If the two battery holders don't press against each other closely enough, causing the screw holes to not line up, sand down the rough cut edge of the hacked battery controller until they do.

5. Snip the red wire on the unmodified battery holder and the *black wire* on the hacked battery holder down to about 1-1/2" long each, and then connect them together. This creates a serial connection between the two battery holders, causing the total power to be that of all six batteries. Cover it with electrical tape to avoid short circuits.
6. There should remain one long black wire and one long red wire. These will be called the positive and negative *battery wires*. Snake these through the two big holes in the rear plate I've provided.

The battery holders and the rear plate should now appear as in Figure 11-9.

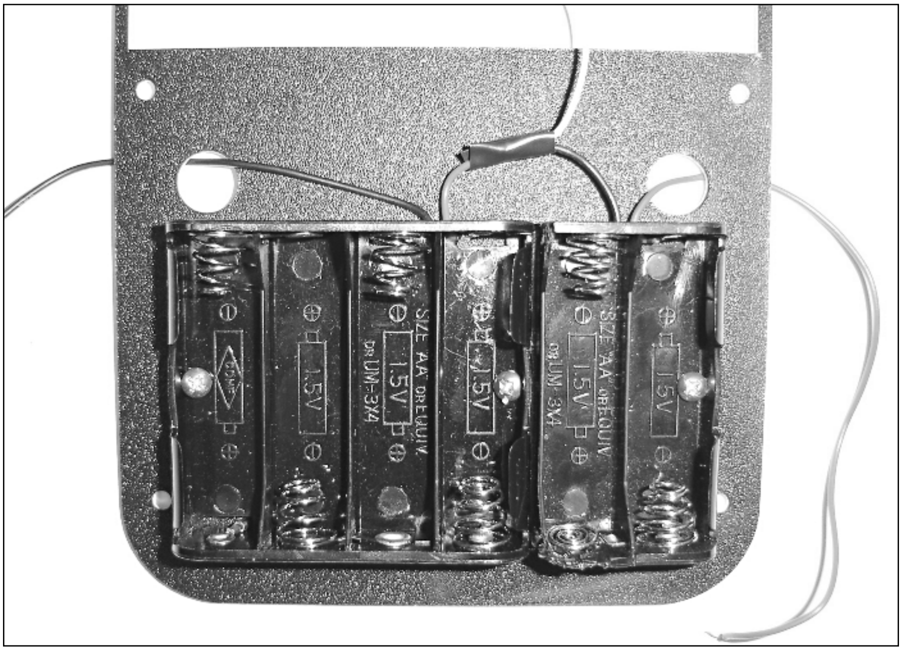


FIGURE 11-9: The battery holder attached to the rear plate.

We can now attach the battery compartment to the rear plate! Do the following:

1. Snake all the wires from the battery compartment through the right-hand hole in the figure. Make sure you've color-coded them for later reference.
2. Drive four 1-1/4"–long size-6 screws down the four screw holes on the back of the battery compartment.

3. Press the battery compartment against the back of the rear plate and drive the four screws until they come through the rear plate plastic and hold it. You may want to go a quarter-inch or so past the plate so that it doesn't fall apart while you work on it. We'll drive these screws the rest of the way when we screw the halves of the case together.

Making the screen riser

The *screen riser* is a 1/4"-thick portion that rises above the front plate and contains the LCD glass of the screen. To build it, follow these steps:

1. Sand the edges of the back of the *screen plate* for proper gluing.
2. Superglue the two *screen riser walls* down to the back of the screen plate. The curved part of the screen plate is the bottom. The screen riser wall with the bigger rectangle goes on the right-hand side, as viewed from the rear. (See Figure 11-10.)

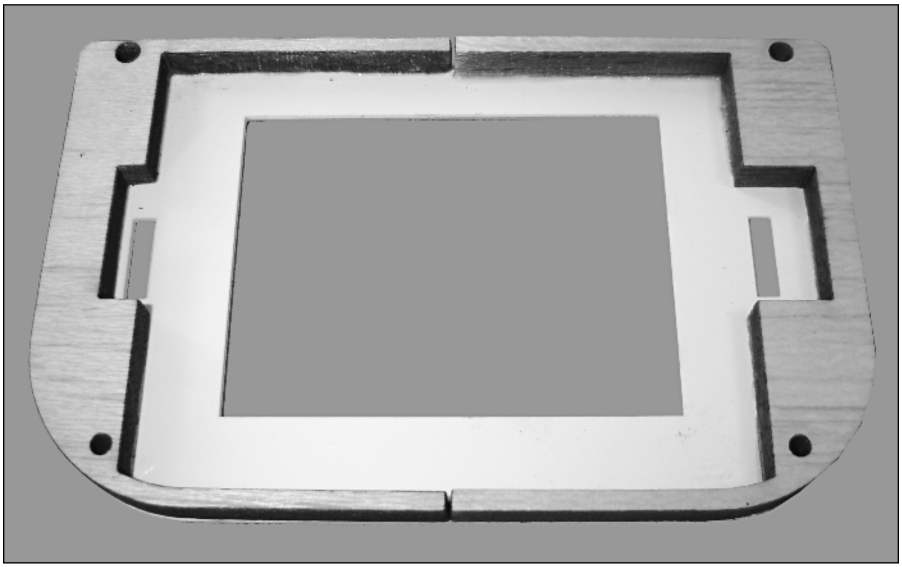


FIGURE 11-10: Completed screen riser.

3. There is one graphic decal for the screen riser that covers the entire surface of the screen plate. Apply it now.
4. Place the screen riser on the front plate and use two 1/4"-long size-4 screws to secure it from behind using the bottom two screw holes. The top two screws will be inserted later.

Making the control riser

The *control riser* is a lot like the screen riser, but the wall is one solid piece, as shown in Figure 11-11. To make it, do the following:

1. Sand the back of the *control plate*.
2. Superglue the *control riser wall* to the back of the control plate. The walls are symmetrical, so left and right don't matter, as they did with the screen riser. This wall is thin, so be careful not to break it, and keep the walls flush with the edges of the control riser.

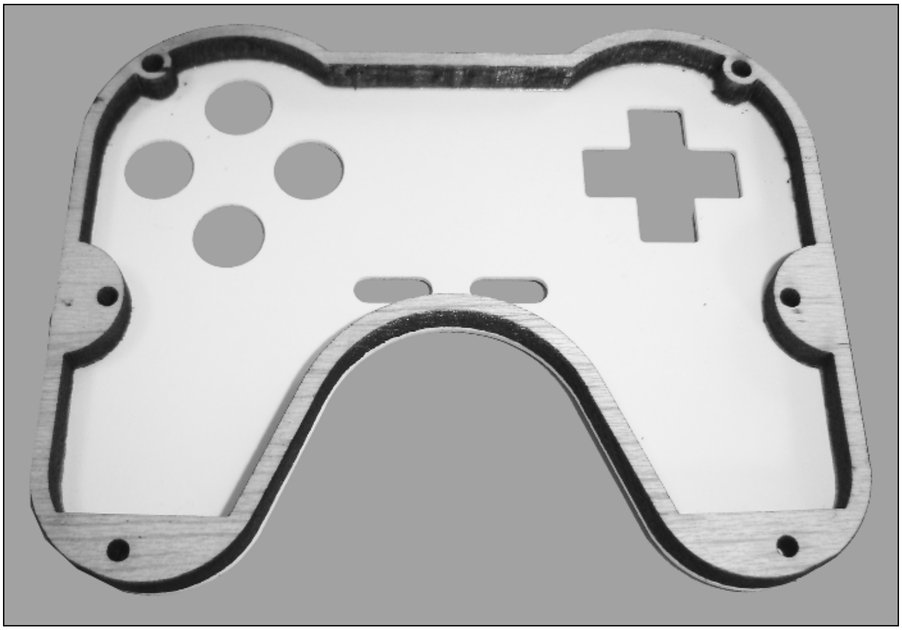


FIGURE 11-11: Assembled control riser.

3. There are three decals that should now be applied to the front of the control riser:
   - Directional pad decal: centered over the "+" shape.
   - Select/start decal: Has two holes that will match the holes on the control riser.
   - Action button decals: Centers over the four button holes. The top button is X, and the bottom is B.

Attaching the SNES board to the rear plate

The next step is to attach the SNES board to the rear plate. Practically all of the connections we need to make to the SNES board can be found on the bottom (nonparts side) of its motherboard, so they will still be accessible after we do this. The lone exception is the *audio signal.* Connect two 10" wires to the spots shown in Figure 11-12. When viewing the SNES board from the front, this is a small IC just above the cartridge slot and to the far right. You don't need to label the other ends left and right since this unit is going to have mono sound. In fact, you could hook the left and right spots on the chip together using a short wire and then connect one 10" wire to use as the audio line. (Either of these two methods is fine.)

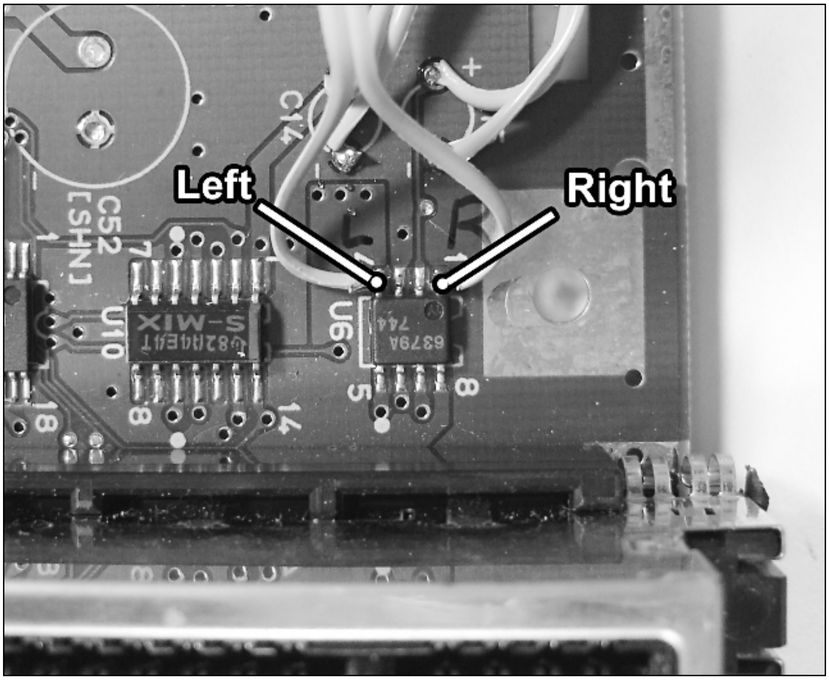
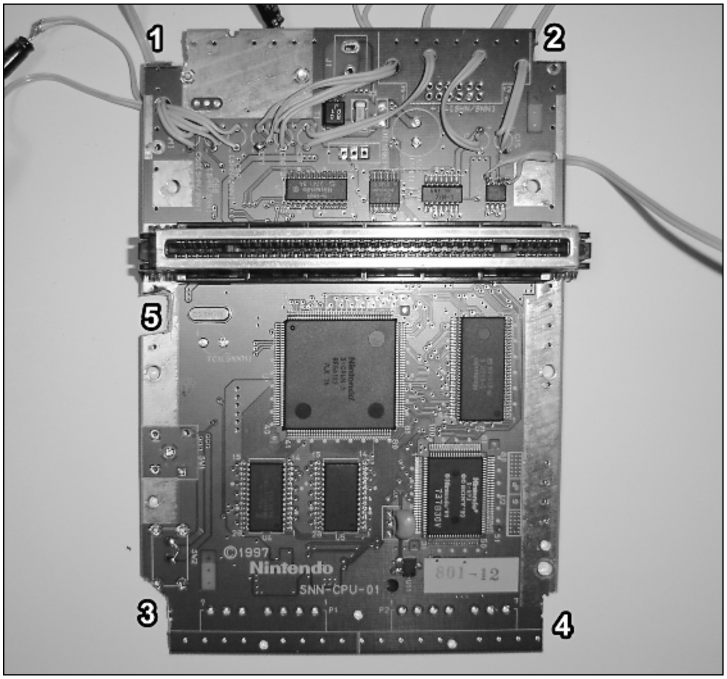


FIGURE 11-12: Where to get the left and right audio signals.

To get the SNES to fit in this case, we need to slice a few portions off the motherboard itself as shown in Figure 11-13. Following is a list that references the numbered spots in the figure and specifies the horizontal and vertical size of each hole.



1) Upper left corner:
   1/2” × 1/2”
2) Upper right corner:
   3/8” × 3/8”
3) Lower left corner:
   1/4” × 3/4”
4) Lower right corner:
   1/8” × 5/8”
5) Middle left:
   1/4” × 3/8”
   (center this square around the screw hole)

FIGURE 11-13: The SNES with portions cut off the motherboard.

To make these cuts:

1. First drag your X-Acto knife across the board a few times to make a groove. Make a groove in the same place on the other side of the board.
2. Snap the board along the grooves by bending it with your pliers or cutters. If you have tough enough cutters, or even tin snips, you can make these holes using them.

In Chapter 9, we moved a bunch of blue capacitors and rewired them so that they’d be off to the sides of the SNES board. For this particular project, we need to take this modification a step further. You see, the SNES board is going to be tight against the case on the top and left sides, so there’s no room for the wires to go around the sides. But Nintendo was thoughtful enough to provide a bunch of holes — so we’re okay!

1. Disconnect the capacitor from the end of the wire if it’s already attached.
2. Snake the wire though the nearest hole (excluding the two big ones just above the cartridge slot, because those will have screws through them), so that it sticks out the back.
3. Reattach the capacitor to the wire, making sure the negative lead is connected correctly (see Chapter 9).
4. Repeat this procedure for all eight capacitors.

The previous and next figures show the capacitor wires in this new configuration. Now only two things stand in the way of our installing the SNES board! Just above the spot where the 7805 regulator was, you'll see the two components shown in Figure 11-14: a black one with four leads and a white one with two leads. Desolder them or bite them off with your cutters, whichever works best for you.

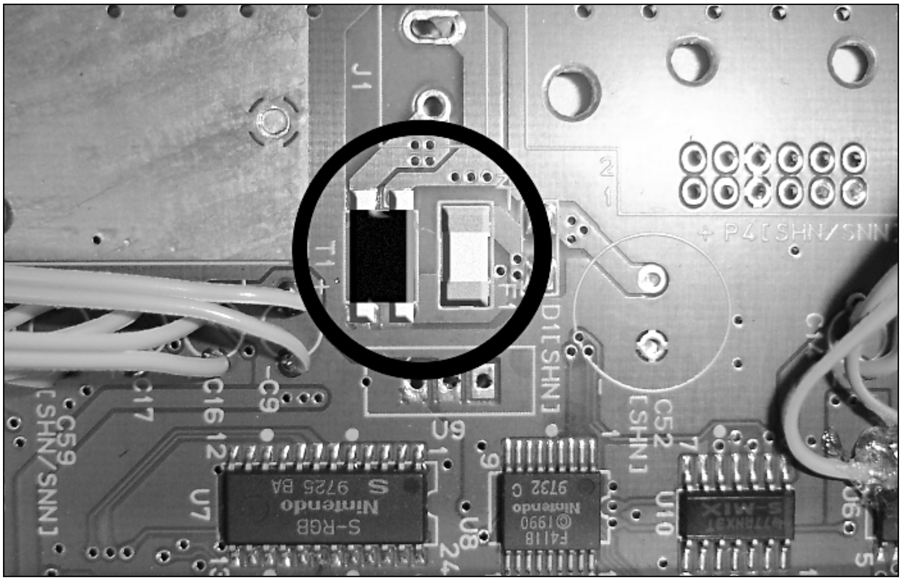


FIGURE 11-14: Remove these black and white things so that the SNES can fit.

The SNES is now ready to be installed onto the rear plate as follows:

1. Insert two 3/8"-long size-6 screws through the two holes just above the cartridge slot opening through the outside of the rear plate. Once they're inserted all the way, screw a size-6 nut down on each one.
2. Place the SNES board facedown (i.e., parts side down) onto the inside of the rear plate with the cartridge slot sticking out the back. The two screws should go into the two holes just above the SNES's cartridge slot. Press the SNES board down as far as it will go.
3. Place a lock washer and nut on each screw post to secure the SNES. (The lock washer goes under the nut.)

The attached SNES board should appear as in Figure 11-15. Try to have as many wires as possible go out the left side of the board. Note how I've used holes to snake other wires through as well, such as the black wire going to the battery.

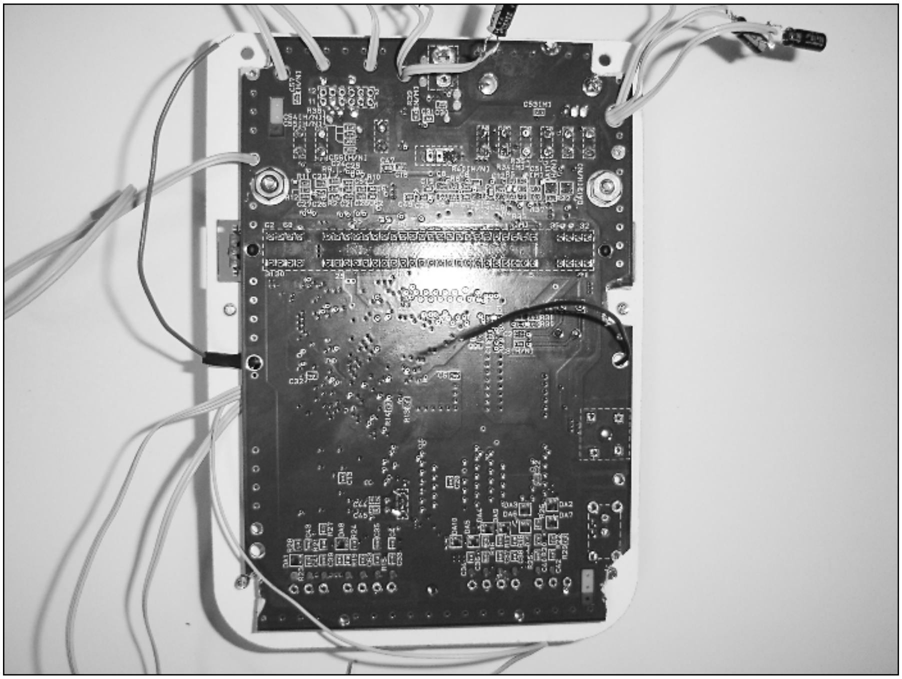


FIGURE 11-15: The SNES board attached to the rear of the case.

Wiring the Unit

With all the case parts built and the SNES board installed, it's time to start the main wiring of the unit. The physical assembly of the unit will continue as we do this.

Making and installing the control board

The *control board* contains the SNES controller tact switches, two ICs, and the unit's power regulator/heat sink. It is built from a Radio Shack component PC board, catalog #276-147a. When turned sideways, the board is the proper width we need (4-1/2"), but much too tall.

To make it the size we need, drag your X-Acto knife along rows 55 and 37 several times in order to make a groove in the board. You can then snap off the excess PC board. The cut lines are shown in Figure 11-16. This gives you seventeen rows of pins to build the board on.

Tip

You'll have a lot of PC board left over after cutting this. Place it back in the plastic bag it came in, and seal the bag with tape. Much like the Statue of Liberty, the copper on the contacts will corrode in the air, making them difficult to solder parts to, after even a few days. The bag will preserve the board for other projects you may wish to do.

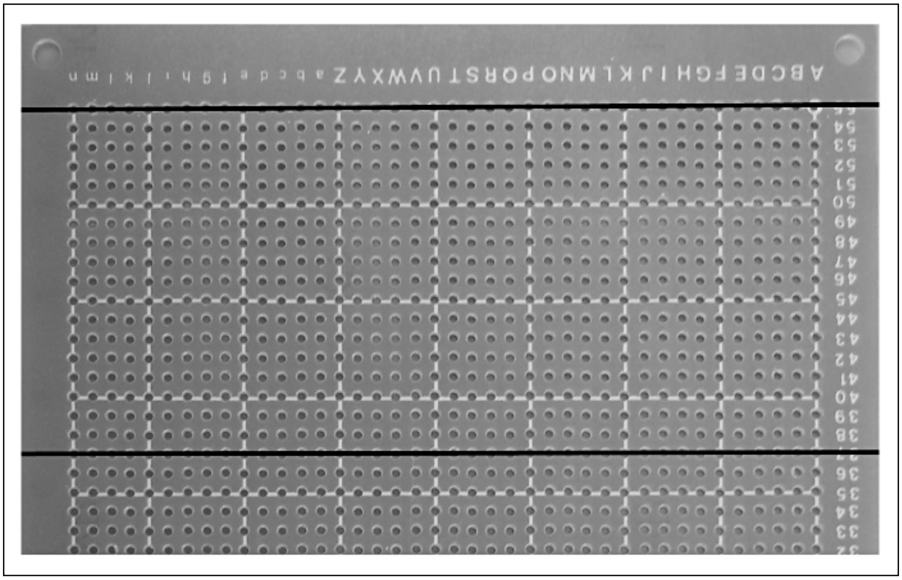


FIGURE 11-16: Where to cut apart the PC board.

To get the ICs you need for this control board, take apart two NES-compatible controllers, as described in Chapter 9, and desolder the ICs from the circuit boards inside. Then solder the ICs and the rest of the components onto the front (noncopper side) of the control board as shown in Figure 11-17.

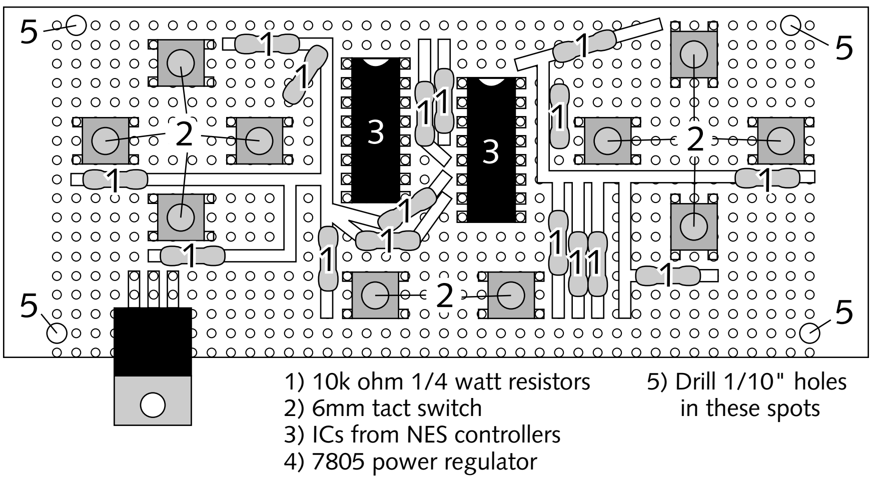


FIGURE 11-17: Where to place components on the front of the control board.

Follow these guidelines when installing the parts:

1. Use a size-4 screw to attach the heat sink to the bottom (flat portion) of the 7805 regulator. When the regulator is attached to the control board, the edge of the heat sink should touch the board.
2. The control pad disc should be prevented from pressing all four directions buttons at once. To do this, follow these steps:
   a. Place a blob of hot glue in the center of the four left tact switches.
   b. Lick the bottom of the control pad disc to put a good amount of saliva on it.
   c. Place the control pad disc on the four tact switches. The round nub under the disc should press into the glue, leaving its shape.
   d. Remove the disc. If you put enough saliva on it shouldn't pull up any glue with it. (Saliva is to hot glue as Teflon is to frying pan.)
3. The leads of the resistors are long enough to bend around and make all the connections shown. Be careful not to let the leads touch the side leads of any switches or ICs they shouldn't touch, however. (Make it look like the drawing.)
4. There are half-circle dents on the ICs, and also on this drawing. Be sure to position the ICs the same way as shown; it's a pain to have to go back and flip them around.
5. Use a 1/10" drill bit (or closest available size) to drill the four screw holes indicated as spots "5" on the corners of the board.

With the front of the board populated, it's time to work on the back. Since there are a fair number of connections to make, we'll handle it in two steps: *leads* first, and then *wires.*

Figure 11-18 shows the lead connections to make on the rear of the control board. I call these "lead connections" because you can use the leftover ends of all the resistors to do this wiring.

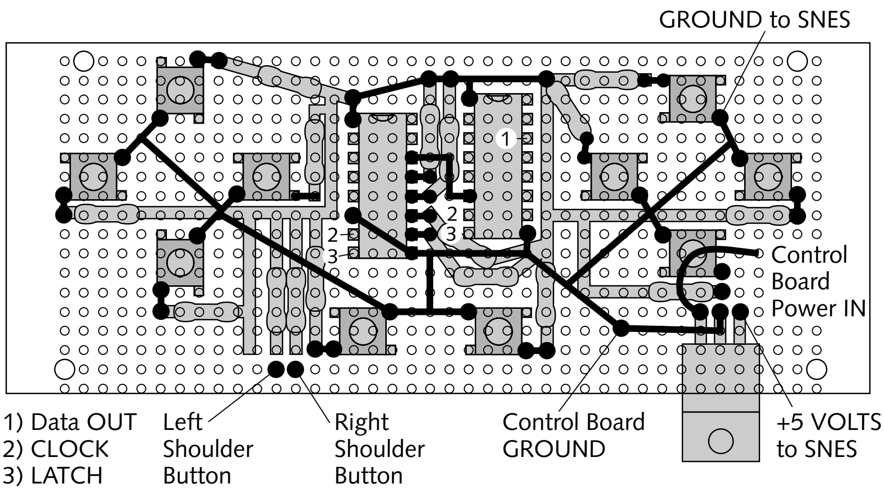


FIGURE 11-18: The first layer of things to connect on the rear of the control board.

Follow these steps to make the lead connections:

1. Use leads to make the connections indicated by the straight black lines. The circles at the ends of them indicate where they should be soldered to something.
2. Some of the connections are quite short (such as the resistor-to-tact-switches, or the four resistor-to-IC connections), so for these you can simply blob solder between the two copper points.
3. Attach a 10" wire to each of the following spots: *Control board power in*, *Control board ground*, *GROUND to SNES* and *+5 volts to SNES*. These wires will be attached to other things later on, so use these names as reference.
4. Connect a three-strand of 10"-long ribbon cable to the *Data OUT*, *CLOCK*, and *LATCH* spots. Make a mark on the other end of the *Data OUT* wire so that you know which wire is which later on when we connect these to the SNES board.
5. Note that the *CLOCK* and *LATCH* are each connected to two spots on the control board. You can attach them to the two spots on the left, and then jump some short wires over to the two spots on the right to complete the circuit.
6. Attach a 3" wire to each shoulder button spot, left and right.

You should now have a board with seven long wires and two short ones hanging off of it. Now we'll do the rest of the wire connections. These will connect the tact switches to the ICs so that the game controls (directional pad, buttons) can be sensed by them. Figure 11-19 shows how to connect the wiring on the back of the board.

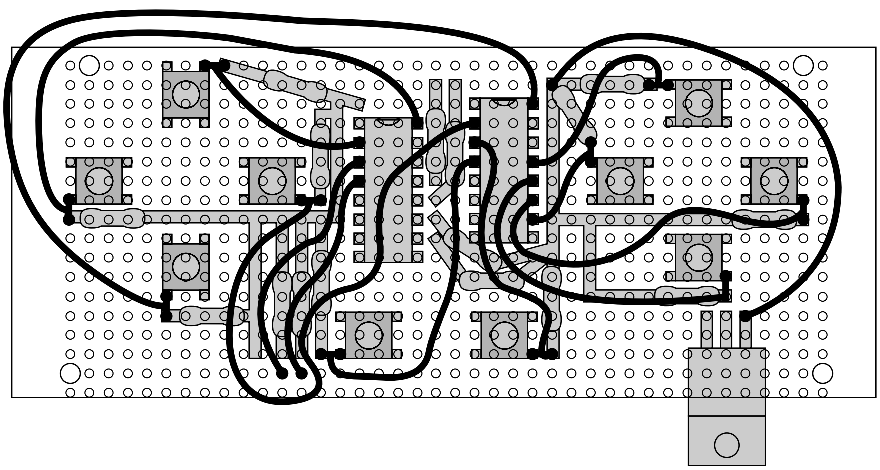


FIGURE 11-19: The remaining wire connections on the control board.

Do the following as you connect the wires:

1. Use pieces of ribbon cable wire for the gray line connections. The gray dots show where they get soldered to existing leads.
2. The wires are sometimes shown longer than needed in order to avoid having them overlap on the drawing. Yours should be only as long as necessary. (See the next figure.)
3. Note that none of these wiring connections actually leave the board. They merely connect things on the board to each other.

Figure 11-20 shows how your completed control board should look, front and rear. (The long wires are not shown so that you can see the rest of the board better.)

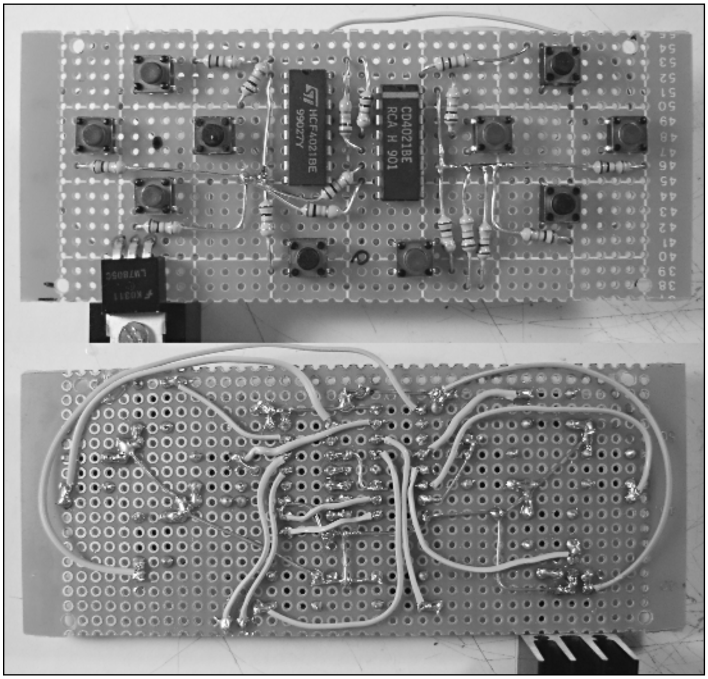


FIGURE 11-20: The completed control board.

Working with the controller buttons

The existing select/start rubber buttons from a SNES controller will have to be modified for use in this project — they're way too tall and at the wrong angle:

1. Start by cutting off the tops of the rubber select/start buttons. About 1/8" of the original tops should remain. These are the pieces that were visible on the original SNES controller, and they're all we'll be using in our project.
2. Place a couple size-6 nuts on your work area, then set the control riser facedown on those. This creates the right amount of space under it for positioning the buttons.
3. Set the sliced button tops into the holes as shown in Figure 11-21, with the cut sides up (inside the unit). Along with the nuts under the control riser, this positions these rubber pieces at the right height for the following steps. It also ensures that the pieces are glued in the correct position on the plastic to fit the holes, since they're already in the holes.
4. Cut a 1-1/4" × 1/4" piece of thin plastic, such as a chip-dip lid. (Engraving plastic is too thick.)
5. Superglue the thin rectangle of plastic to the backs of the buttons. Press it down to ensure a good bond, but be careful not to get it stuck to the control riser itself. Once the glue is dry, your modified select/start button is complete.

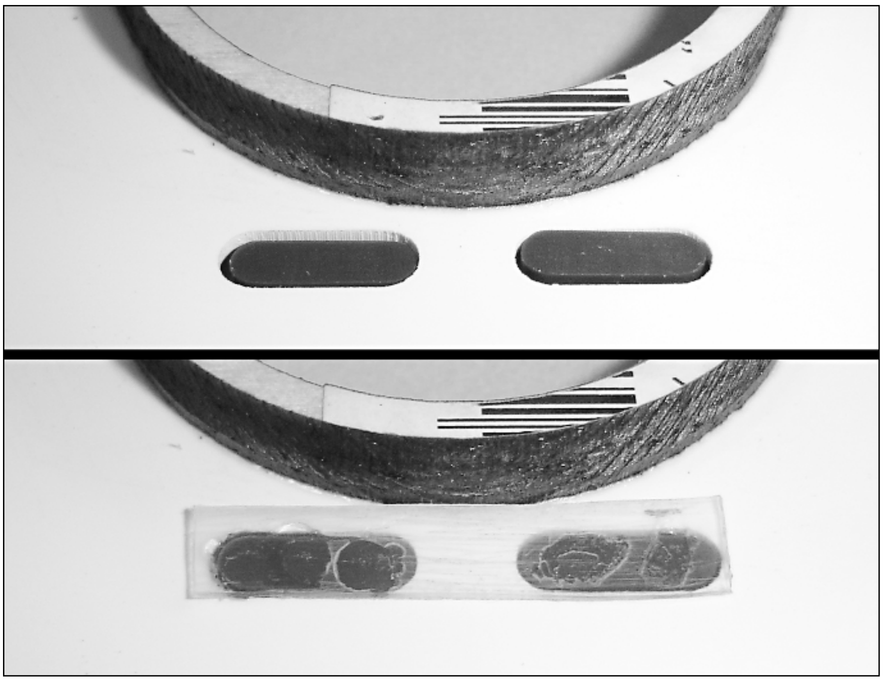


FIGURE 11-21: Installing modified select/start buttons.

The existing SNES controller buttons are not deep enough to work with this unit, so you'll have to fix them as follows:

1. Place a blob of hot glue on the back of each button, and then place them inside the control riser as shown in Figure 11-22. Place some superglue around each blob of hot glue to secure it ("it" being the glue) in place.
2. Put a blob of hot glue in each of the small circular divots on the back of the directional pad (also shown in Figure 11-22).
3. The blobs of hot glue should be about 1/16" thick on the backs of the buttons/directional pad. You can vary the amount of glue (add some or shave some off with a knife), depending on how the buttons feel when you attach the control riser to the front plate.
4. Set the buttons in the control riser as shown in Figure 11-22.

FIGURE 11-22: Placing hot glue on the backs of the buttons, inside the control riser.

Installing the control board and riser

We're now ready to install the control riser and board to the front half of the case. Here's how:

1. Place the control board against the back of the front plate. Line up the four screw holes that you drilled in the board with the top four holes around the control board opening on the front plate.
2. Drive six 1/4"-long size-4 screws into the holes around the control board opening from the inside of the case. The top four will go through the control board and then the front plate, and the bottom two only through the front plate. Screw them all through until they just pop above the surface of the front plate.
3. With all the buttons set in place, press the front of the case against the control riser, lining up its screw holes with the screws sticking out the front plate. Be sure all the buttons are in place first.
4. Squeeze the control riser, front plate, and control board. See if all the buttons are clicking correctly. If not, adjust by adding more glue or shaving some off with an X-Acto knife.
5. When you're content with how the buttons feel, drive the six size-4 screws all the way into the control riser. Check the feel of the buttons again to make sure they're okay.

The installed control riser and board should appear as shown in Figure 11-23.

FIGURE 11-23: The installed control riser and board, front and inside.

Tip If the sides of the control board don't quite fit in the case, sand them down a little. The easiest way is to place a piece of sandpaper on something hard and flat, and scrape the PC board back and forth over it.

Installing the Casio EV-680 Pocket TV

We're now almost ready to install the TV into the front of the case. In Chapter 4, we made some modifications to the TV, mainly giving it white LEDs and moving the circuit boards around. Before we can use it with this portable, there are a few more slight modifications to do.

1. At the top of the TV, you'll see a black jack that sticks out a little ways. This is *Antenna IN,* and it'll keep the screen from fitting in the case. Use your cutters to snip off the end of it so that what remains sticks out no higher than the top of the TV's circuit board. (You can also desolder the entire jack, though this would require temporarily moving the white screen plastic to get at the leads.)
2. On the front of the TV, just below the screen, you'll see two thin white rectangular plastic pieces protruding out. These will also get in the way of the screen fitting properly, so snip them both off. Once you get a grip on them, they should tear out fairly easily.
3. The original speaker was connected to the TV board by short 1-1/2" wires. These are actually long enough for this project, so go ahead and reconnect the speaker using its original orange and black wires. You'll see small little "BR"own and "OR"ange letters on the board; these tell you which wires go where.
4. Connect a 4" piece of wire to the TV's ground spot.

Figure 11-24 shows the location of these four steps for your reference.

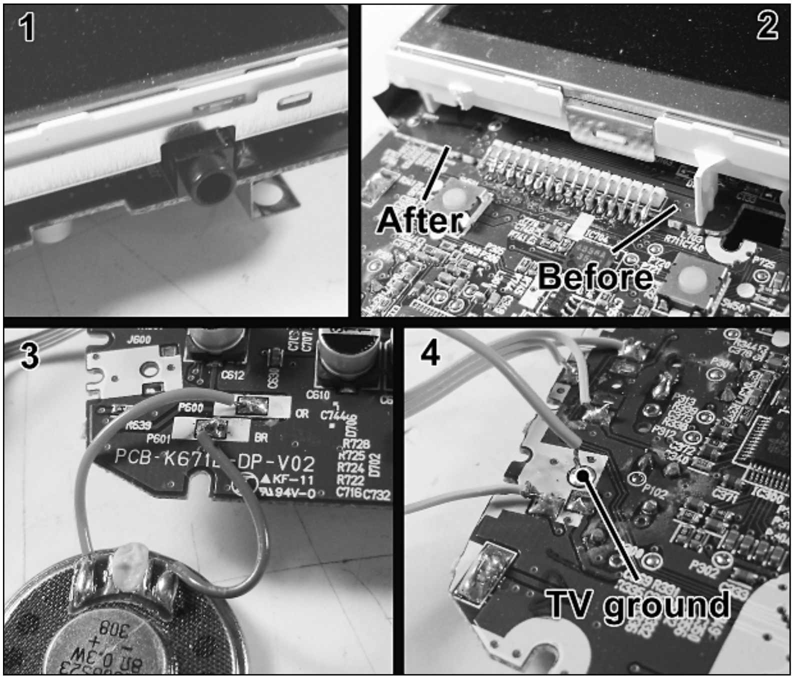


FIGURE 11-24: The four things to do before installing the pocket TV.

You can now place the TV into the front of the case. Go ahead and see how it fits. Before we permanently attach it, however, there are a few things to do.

1. There should be a total of eight wires connected to the control board at this time. Move them so they all go to the right (when viewing the front of the case from the inside). The exceptions are the two shoulder button connections; they should go toward the bottom. This ensures the wires will be long enough once the TV is in place and the two halves of the unit are being wired together.
2. When you place the TV down over the hole in the screen riser, you'll notice the lower board of the TV touches the control board. Place several rows of electric tape on the back of the control board so that it won't short out against the TV's lower board.
3. When viewed from the rear, the volume dial goes into the left hole, brightness on the right. Make sure the brightness ribbon cable, which was the lowest dial on the TV, is under the TV's board and can reach the right hole.
4. The LCD glass itself should go all the way up to the screen plate and fit against the hole provided. If it doesn't reach, check that you removed enough of the obstructing parts described earlier. Position the TV so that the metal edges around the screen aren't showing on the front of the unit.

With those items checked and ready, you can secure the TV in place by doing the following:

1. Put hot glue along the top of its circuit board and down along either side where the white LEDs were inserted.
2. Center the speaker over the grid holes, and hot-glue the edges of it to secure it in place.
3. While the glue is cooling, press the back of the TV so the screen presses flat against the screen plate. When viewed from the front, there should be no gaps or spaces around the screen.
4. Place the brightness and volume dials into the appropriate slots on the side of the screen. Double-check the plastic case that the TV came in originally to see which dial is which.
5. It's desirable to have the dials spin upward for brighter/louder and downward for darker/quieter. To ensure this, keep the silver side of each dial facing the right-hand side of the case, as viewed from the inside.
6. Once the dials are in position, put a dab of hot glue on the silver side and let it drip down onto the screen plate to secure the dial. Make sure that the dial can still spin after you've glued it. If it's spinning okay, glue the ribbon cable of the dial to the nearest portion of the case to further secure it. This keeps it from being pressed into the case.

Inserting the jacks

Before we continue wiring, let's place the three jacks in the holes we drilled back when we made the front half of the case. Here's where to place them, as viewed from the inside of the case:

1. **DC AUX input jack** (use the 1/8" stereo phono plug, Radio Shack catalog #274-246). lower left corner in the 15/64"-wide hole. Note the retaining ring for this jack won't fit on the outside due to the thickness of the case. That's okay, because we have hot glue! This jack has no wires attached to it yet; we'll attach them in the next section.
2. **Audio/video output jack** (connected to TV). upper right corner in the 11/64"-wide hole. Four wires should already be connected to this jack from when you modified the TV in Chapter 4.
   - **Audio.** This is the wire that goes to the *upper* connection on the TV where the jack used to be.
   - **Video.** This is the wire that goes to the *lower* connection on the TV where the jack used to be.
   - **Power to TV.** This goes to the TV's *power in* spot.
   - **Unconnected wire.** This will be connected to the power switch in the next section.
3. **Headphone jack** (connected to TV). Lower right corner in the 11/64"-wide hole, just over from DC AUX input jack. As with the A/V jack, it's already wired.

Secure each jack by placing hot glue around and behind it. Putting glue behind it keeps the jack from popping loose when people cram plugs into the unit. Be sure not to get hot glue on the metal leads of the DC AUX and audio/video output jacks, as we still need to make connections to those.

The front of the case with the TV, dials, and jacks installed should appear as shown in Figure 11-25.

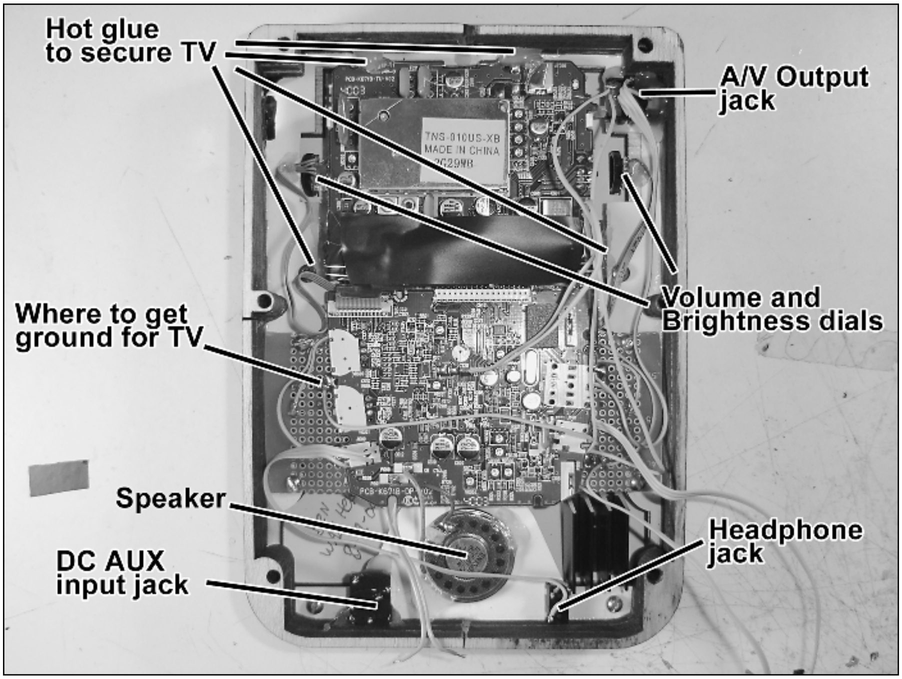


FIGURE 11-25: How the inside of the front of the case should look at this point.

Wiring the two halves together

Both the front and back halves are now ready to be wired together. Lay the halves facedown, with the front on the left and the rear on the right. It should now make sense why I had you move wires in certain directions throughout this chapter. A lot of the wires that you'll be connecting are a lot longer than they need to be. Cut them down as short as possible to make these connections with both halves of the case open. The red *positive voltage from battery* wire is the only one that will probably have to be extended. If you have to add a wire to extend it, be sure to cover the connection with electric tape so that it won't short anything out.

Power connections/switches

Get out your submini DPDT power switch (Radio Shack catalog #276-407), and place it near the hole where it goes in the front of the case—as viewed from the inside, it's the upper left corner. We don't want to install it until we've attached all the wires, but we want to keep it near its final location so that all the wires you attach will be long enough. If you have a pair of Helping Hands, they can hold this switch just above the hole while you wire it.

Figure 11-26 shows how to wire the batteries, charge jack, DC AUX input jack, audio/video output jack, and power switch together. Use regular ribbon cable wire for all these connections. The lengths will vary depending on the location of the jacks.

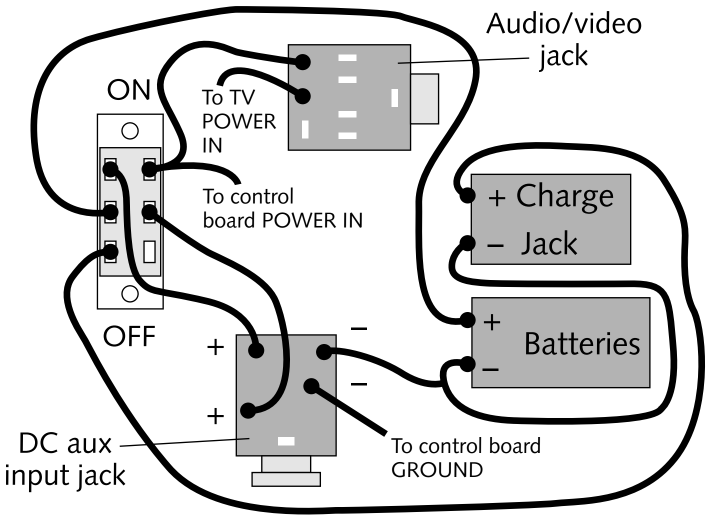


FIGURE 11-26: Power switch and battery connections.

Please note the following while doing this wiring:

- These drawings indicate how the plugs appear when looking at the inside of the unit. The *charge jack* and *battery* wires come from the rear half of the unit; they were connected back in the *Assembling the Case* section.
- The switch has the on and off positions indicated. You'll want "on" to be when the switch is pushed toward the *top* of the case, so keep this in mind when installing it.
- The *To control board power IN* and *To control board ground* connections should be made using the 10" wires you attached to the control board as shown in Figure 11-18, back in the *Making and installing the control board* section.
- The *To TV Power IN* wire coming from the audio/video jack should already be connected to the TV, as described in Chapter 4.

In case you're curious, here's how this circuit works — it's a good example of how a DPDT switch can be used, since the sides of it are isolated from each other.

1. Positive voltage goes from the batteries to the power switch. If the switch is off, the positive from the battery is connected to the positive of the charge jack. At this point, one of two things happens:
   - If a charger is plugged into the charger jack, it charges the battery. The unit is off, but charging.
   - If no charger is attached, the unit is simply off.
2. If the power switch is on, the positive voltage goes through it and into the input of the DC AUX input jack. At this point, one of two things can happen:
   - If there's no external DC adapter power plug inserted (to run the unit off wall power to avoid using the batteries), the positive voltage simply passes through the jack and back into the power switch on the other side. (See Step 3.)
   - If a power plug is inserted, providing power from a wall adapter, the lead with the positive battery power is disconnected (via a mechanical switch inside the jack), and positive voltage from the wall adapter is sent to the power switch instead.
3. Positive voltage goes back to the power switch from the DC AUX input jack, either from a wall adapter or battery. Since the switch is on, the power then goes to the lead labeled *To control board POWER IN* and the *Audio/video output jack*.
4. The power that goes to the audio/video input jack can do one of two things:
   - If there's no plug inserted into the A/V output jack, the positive voltage passes through and goes into the TV. (The connection to the TV was done in Chapter 4.)
   - If a plug is inserted, the positive voltage is disconnected. This causes the built-in screen to not turn on and the A/V signals go out the jack and to an external video source instead.

This may seem a bit elaborate, but what it does is ensure that even if you plug in the charger *and* a wall adapter, the unit will still be okay. (By "okay," I mean not spewing out smoke and burning wiring.) I know you probably wouldn't plug both things in at once, but the possibility must be safeguarded against nevertheless. The nice thing about the DC AUX input jack we're using is that it completely disconnects the battery/charger from the circuit if you plug in a wall adapter.

The battery charger you'll be using (Radio Shack catalog #23-333, from the materials list) has a small tab on the top of its male plug that you need to remove so that it can fit into the female charge jack on the SNES. Use your cutters to snip off the tab — the before and after of the plug is shown in Figure 11-27.

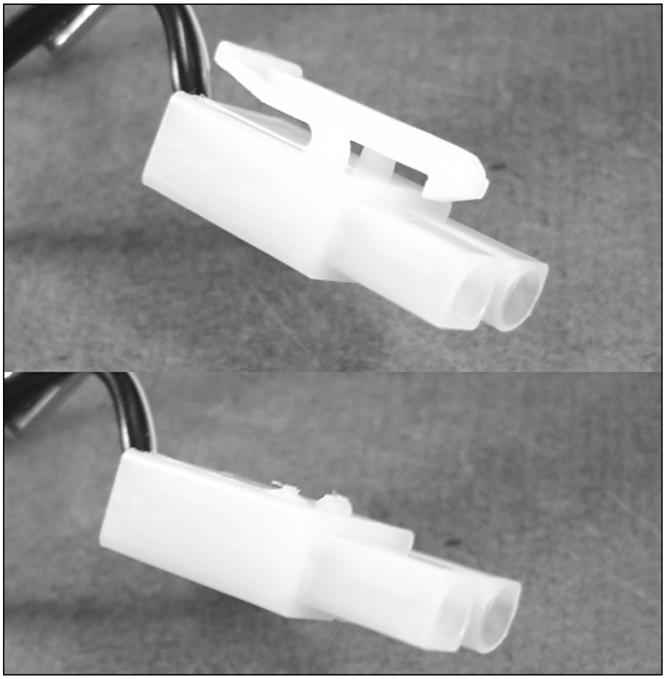


FIGURE 11-27: The charger plug, before and after snipping the tab off.

Connections to the control board

The pocket TV still needs to get a ground connection, and since it's right on top of the control board, that's a good place to get one. The ground connection in the center of the X/Y/B/A buttons should still be visible to the left of the TV. Connect the TV's ground to that, as shown in Figure 11-28.

Now connect the shoulder buttons as described.

1. Take the left and right shoulder button wires from the rear of the case, and connect them to the short left and right wires coming off the bottom of the control board. (See the Making and installing the control board section.) Cover the connections with electric tape to keep them separated.
2. Connect the center wire (ground) coming from the shoulder buttons to GROUND on the control board. Use the same spot that you just attached the TV to.

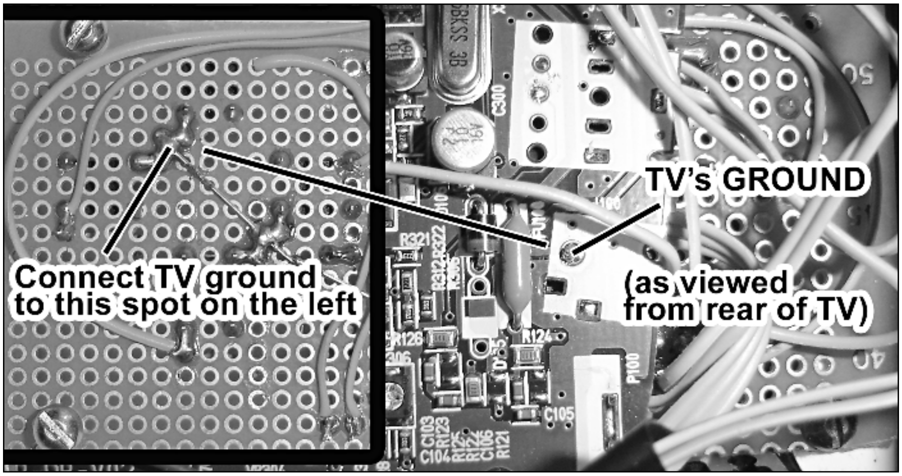


FIGURE 11-28: Connecting the TV's ground to the control board. Also shows the audio/video spots.

Audio/video and power connections to SNES

Now it's time to get video and audio off the SNES. There should already be two audio wires hanging around from when we installed the SNES to the rear of the case.

1. In Chapter 4, you attached four wires from the audio/video jack to the TV's circuit board. One of those wires was for power, and the other three were *ground, audio,* and *video*. In Figure 11-28, the audio and video spots are indicated on the back of the TV. Follow the wires connected to them up to the audio/video jack so that you'll know which is which. Make the audio/video connections in the section at the jack, since it'll be easier than trying to solder them to the TV.

2. Strip and twist the ends of the audio wires together since this unit is mono. Connect them to the *AUDIO* lead of the audio/video output jack. You can cut the audio wires fairly short, as they won't have to go very far. This will get the audio signal to the TV, as there's a wire there already. Remember, the fewer and shorter wires in this thing the better (so it'll screw together!).

3. Connect a 4” wire from the spot marked *VIDEO OUT* on the SNES to the *VIDEO* lead of the audio/video jack.
4. Connect the *+5 volts to SNES* and *GROUND to SNES* wires from the control board to the SNES as indicated in Figure 11-29. These were labeled in the *Making and installing the control board* section previously in this chapter.

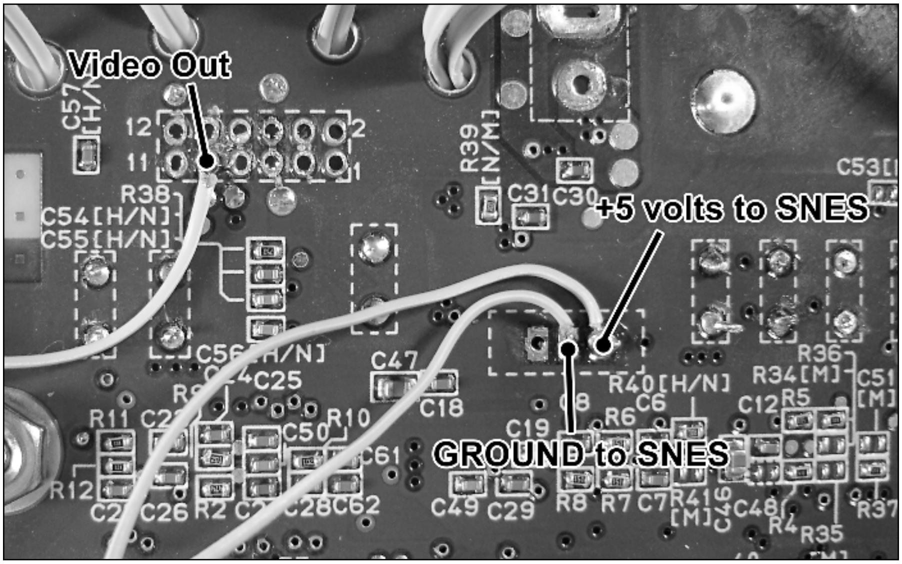


FIGURE 11-29: Connecting video, +5 volts, and GROUND to the SNES.

Controller connections

To connect the built-in controller to the SNES, attach the three remaining wires from the control board to the lower right-hand corner of the SNES as shown in Figure 11-30. When we built the control board, we made a black mark on one of these wires. Here this is wire #1, the middle wire is #2, and the other wire (believe it or not) is #3!

The CNC-built SNES portable is now ready to go! In the next section we’ll test everything out and troubleshoot any problems.

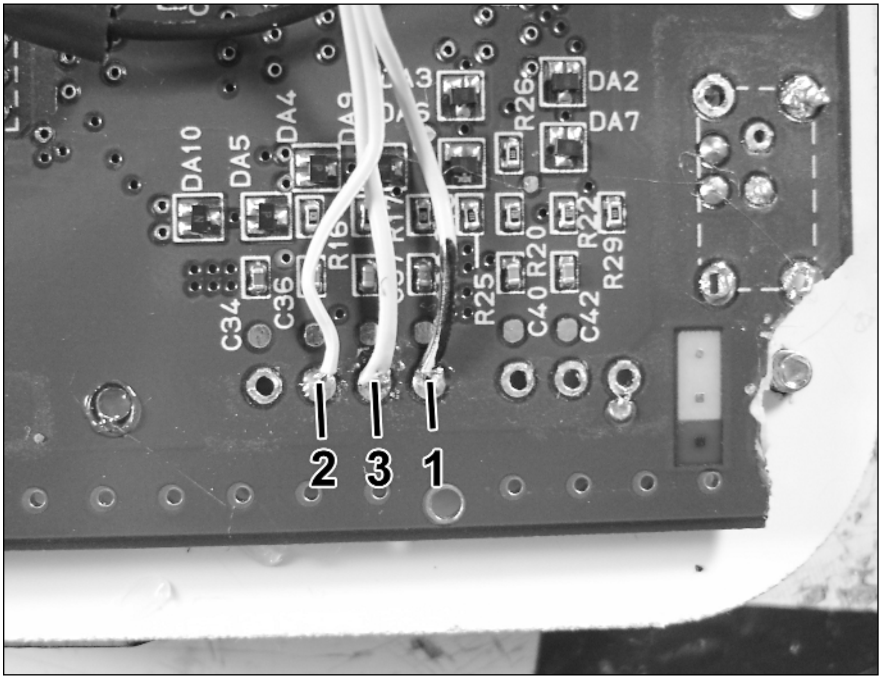


FIGURE 11-30: Attaching the controller to the SNES board.

Testing and Troubleshooting

Now that you've completed the wiring of your portable, it's time to test it out. Hopefully you won't run into any problems, but there's always a chance something may have been missed along the way. This section is here to help.

We'll take the testing step-by-step, and resolve any problems that crop up as we go.

1. Insert six rechargeable AA batteries in the unit and plug the battery charger into the side of it. Switch the SNES to off. Make sure the charger is set to the type of batteries you have (Ni-Cd or Ni-MH), and plug it into the wall. The LED on the charger should light up, indicating the batteries are charging. If it doesn't, do the following:
   - Check that the power wiring between the batteries, charge jack, power switch, and DC AUX input jack is correct, as instructed in the *Power connections/switches* section and shown in Figure 11-26.
   - Check that the battery holders were wired together correctly as explained in the *Battery compartment to rear plate attachment* section. If the battery holders aren't in the correct series, it will cause them not to charge.

- Remember when we cut the battery holder in half, and bent that one wire and connected it to another? Check that it didn't pop loose.

2. Let the batteries charge for about an hour. They don't have to fully charged in order to run these tests, and sometimes even putting them on charge for a few minutes will "refresh" them enough to work.

3. Unplug the battery charger, plug in a game cartridge, and switch the unit to on. The system should now be running off batteries. If nothing happens at all (the screen doesn't light up, no sound, etc.), do the following:
   - Check that the wiring between the two battery holders is correct.
   - Any extended wires inside the unit should have the bare metal connections covered with electric tape. If not, they may be shorting things out. (If something did get shorted out, you should recharge the batteries for a little while before trying again.)
   - Check the power wire going to the TV. Is it connected? Is there a plug in the A/V output jack, causing the TV not to turn on?
   - Is the TV's ground connection wired to ground on the control board?
   - With the RCA version of the EV-680, it's possible that the positive and negative spots are reversed (see Chapter 4). Check the original plastic case of the TV. The DC power in jack should indicate center negative, outer positive. If your TV case says differently, reverse the power wiring going to the TV.
   - Is the LED TV mod hooked up correctly? (See Chapter 4.)

4. The TV should now at least light up. If it does, but there's no SNES game picture, do the following:
   - For an all-white screen, try turning down the brightness. If it's set all the way up, it turns everything white no matter what's on the screen.
   - Is the video wire connected from the SNES to the A/V output jack? Are the audio/video wires from the jack connected to the TV?
   - Is the video wire connected to the correct lead on the A/V jack? (This is explained back in the *Inserting the jacks* and *Audio/video and power connections to SNES* sections.)
   - Much like the power connection, the audio/video spots sometimes reverse on RCA models of this TV. There's no indicator of this on the TV, but if all else fails, switch the wires around and give it a shot. If the VIDEO signal is going to the AUDIO spot, you'll probably hear "garbage noise" from the speaker, and that's usually the best indicator of this problem.
   - Is the brightness dial/ribbon cable properly attached? If it's completely detached, you can usually see a picture, but partial attachments (i.e., bad wiring) can sometimes cause the picture to disappear or go white.

It's also possible that the SNES itself isn't turning on. If the above solutions don't work, check the following:

- Is +5 volts going into the SNES, and is the *GROUND* connected? The SNES gets both of these from the control board.
- Did you try to save $1.50 by using the SNES's 7805 regulator on the control board? In my tests, it didn't work with this portable; it just created a screen full of static. For the price of three cans of pop, just buy a new 7805 from Radio Shack and use it instead. (See the electronic parts list.) This is one of those really simple fixes that's easy to miss.
- Did any of the eight rewired blue capacitors break loose? Check the connections, even the ones under the electric tape, as they may be hiding wires that have broken loose.

5. Once the game picture is showing up on the screen, turn up the volume and listen for sound. If there is none, check the following:
   - Is the volume dial/ribbon correctly wired? (See brightness dial question just above.)
   - Is the speaker attached? (This is obvious, but I have to ask. It's my job!)
   - Did you reattach the headphone jack with wires, as in Chapter 4? If you remove the headphone jack completely, the speaker won't work.
   - The left and right audio connections to the IC on the SNES are small and delicate. Check to see if they've broken loose.
6. Once the picture and sound are working, press START and try playing the game. If the buttons/controls don't work properly, or at all, do the following:
   - Double-check the wiring of the control board. Some of the connections were pretty close to each other, so see if anything is touching or shorting out that shouldn't be. This can cause erratic problems, but not total controller failure.
   - I hate to ask, but are the 4021 ICs placed correctly, with the circle dents at the tops? If not, desolder them and flip them around to match the drawings.
   - Are the three wires (*Data*, *Clock,* and *Latch*) connected to the SNES in the right order?
   - Are any of the buttons stuck down? Correct "clicking" of the buttons was checked back when we installed the control riser, but things may have been smashed into each other after assembling the rest of the case. Check that each button "clicks" when pressed.

With the picture, sound, and controls working, your SNES portable is ready to go onto the final step — final assembly!

Tip

When troubleshooting, always check the most obvious answer first. Why? Because it's the last place a person usually looks for a problem. You can waste a lot of time trying to fix things that aren't broken when it's as simple as a missing ground connection on the TV, for example.

Final Assembly

Once your SNES portable is working fine, it's time for the final assembly. While "final assembly" may sound like something you'd do at the end of a school year, here it will involve getting the wires and things inside the unit in position, and then screwing the halves together. We'll also discuss how to run the SNES off wall power to save on batteries. (Well, since they're rechargeable you don't really save *financially*, but it saves you from recharging them again. Which saves time. Yeah!)

Take a look at Figure 11-31. It shows which screws to insert into the rear of the unit to seal it all together. (Some of these you may already have inserted during the construction of the battery compartment.)

FIGURE 11-31: Final screws to use.

Check the following as you screw the unit together:

1. Make sure the eight blue capacitors end up around the screen, and not on top of it. If they're on top — especially near the big silver TV tuner box — the case won't close correctly.
2. Wires have kind of a "memory" to them. If you keep them bent a certain way they tend to stay in that shape. Move the wires around in the portable so that they stay out of the way of each other and of things inside the unit. If wires get bunched up, they can keep the thing from closing correctly.
3. With the capacitors and wires out of the way of the sides of the unit, drive the screws shown in Figure 11-31 through both sides of the portable to seal it up.
4. If you used a lightweight type of material for the side walls (such as balsa wood or foam), it's possible the screw holes may be too wide for the screws. This is due to the burning action of the laser engraver. The easy fix is to use size-8 screws instead, of the same lengths listed on the photo. This gives the screw more "bite" and fills up the hole better.
5. Place the "Built by" decal over the battery compartment door as shown in Figure 11-31.

Running the SNES portable off wall power

If you'd like to run the unit off wall power, get a multivoltage DC wall adapter that can provide 7.5 volts of power at 800 mA. (It doesn't need that many mA, but that's the closest rating on commonly available adapters.) Use the 1/8" minijack plug on the adapter, and set center (tip) to positive, outer to negative. Insert into the DC AUX input jack on your SNES portable and enjoy! (This makes the unit significantly less portable, but it saves on batteries!)

When running the unit off batteries you should always use *rechargeables*, not alkalines. Either Ni-Cd or Ni-MH will work, it just depends on how much money you want to spend. Six AA-sized Ni-MH batteries cost about $30, but you can use them for other things as well, and it'll save money in the long run.

The audio/video output jack does not work with all televisions. Using it also kind of defeats the idea of your SNES becoming portable, but since that jack came free with the TV, I included it the project anyway. If you'd like to use it, you'll need a cable with a 1/8" plug that looks like a stereo headphone jack on one end, and two RCA plugs on the other. Here are some places to find these cables:

- Digital cameras. I have a fairly generic Sony Cyber-shot camera and it came with an A/V output cable. This cable will work with your portable; you may have to switch the RCA plugs around on the TV to see which is which, however.
- Home computer to stereo speaker cables. Again, this is something you may already own. If not, perhaps a computer-building friend of yours (we all seem to have one) might be able to dig one up.
- You can also buy such a cable at Radio Shack or at most stores with electronics. Describe the plugs to them and they'll help you find the cable you need.

Chapter in Review

In this chapter you took the mini-SNES that you hacked apart in Chapter 9 and made it into a self-contained battery-powered portable gaming unit. Here's a brief recap of what was done to accomplish this goal:

- You drove around (or biked, or bused) getting parts from various places to build the project.
- You had the case parts for this unit cut using a CNC laser engraver. You then took the parts and glued them together to form the main portions of the case.
- You made a custom control board and wired it to the Casio EV-680 TV and the SNES, and then connected that stuff to a custom-hacked battery pack to power it.
- You tested the unit to see if everything worked, then screwed it together and finished it.

The end result is a fun portable that lets you play all your favorite SNES games anywhere you'd like! Enjoy your new toy and be proud, because you built it!

Making Your Sony PSOne Portable

chapter 12

in this chapter

- ☑ Ripping Apart the PSOne
- ☑ Identifying the Internal Parts and What They Do
- ☑ Powering the System with Batteries
- ☑ Working with Controllers
- ☑ Chapter in Review

The new-style Sony Playstation 1 — released in the year 2000 and typically called the "PSOne" — is much smaller than the original-model Playstation, and therefore a fairly simple system to make portable. In fact, if you were to attach a PSOne screen onto the back of a PSOne, and then hook up a 7.2-volt Sony Infolithium camcorder battery, you'd have an instant portable. It'd be the path of least resistance!

But if you're reading this book, you're probably not one of those "path of least resistance" kind of people. Instead, you want to rip the PSOne apart and configure it in ways that Sony never dreamed of! Well, you're in the right place!

In this chapter, we'll discuss the dismantling of the PSOne and what the parts inside do. We'll then run it off batteries and learn how to configure the controller. This will prepare the PSOne guts for the next two chapters, or if you're planning to make a portable of your own design, you can use this chapter as your springboard. Let's go for it!

Ripping Apart the PSOne

To rip apart the PSOne, first check to see if the used-game store left a disc in the drive, and take it out. (I think every used PSOne I've bought has had a disc inside; I don't know why.) Flip the PSOne over and remove the six Phillips-head screws from the bottom of the unit, as shown in Figure 12-1. Note that one screw is under the label marked "WARRANTY VOID IF REMOVED." Laugh for a moment, then rip through the label to find the screw.

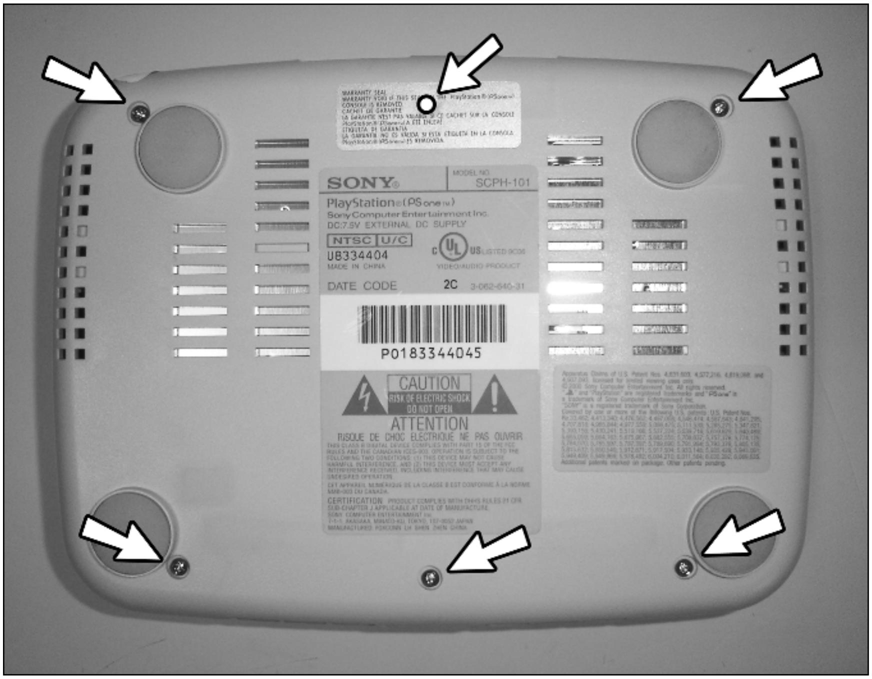


FIGURE 12-1: The first six screws to remove, including the warranty-voiding one!

You can now lift off the top half of the PSOne case. This includes the plastic buttons and the CD lid. You can now see the CD drive assembly and the metal RF shielding. Use your tweezers to carefully pull out the 4-pin *CD drive plug* and the 16-pin *CD access cable*, as shown in Figure 12-2. Grip the thin CD access cable from near the base so that you can get a good hold on it and not damage the delicate upper portions.

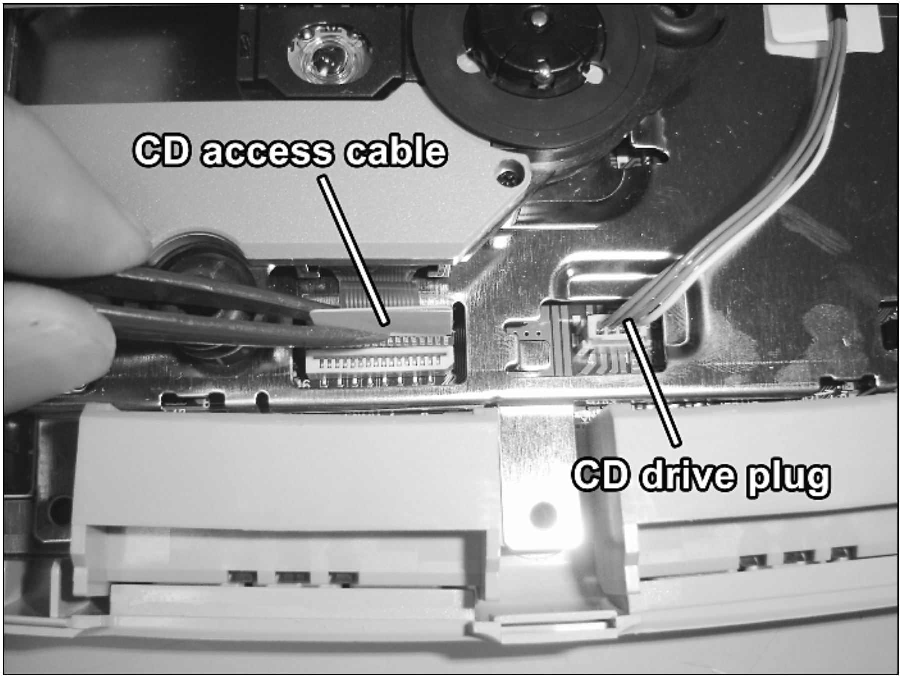


FIGURE 12-2: Removing the plugs and cables.

Lift off the top metal shield and set it aside (or keep in your suitcase to signal planes if you ever get stranded on a desert island). You can now access the motherboard. Lift the motherboard up from the rear, then pull it backward to remove. That's all there is to it!

Identifying the Internal Parts and What They Do

Before we start desoldering stuff, let's look at the board and identify the parts for later reference. Check out Figure 12-3 and the list following. We'll be using these terms quite a bit in the next few chapters, so it's a good idea to bone up on them now.

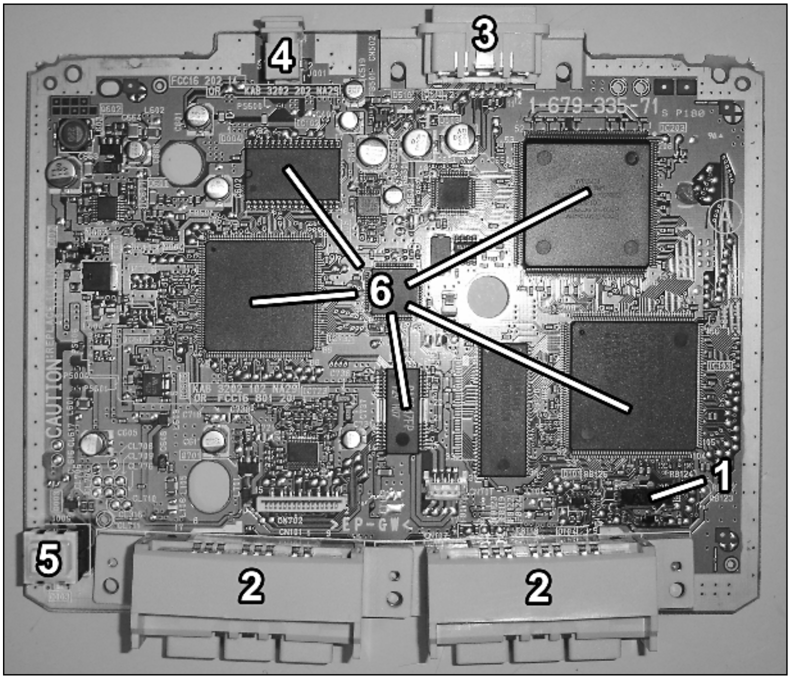


FIGURE 12-3: The internals of the PSOne.

- **Lid sensor switch.** Senses if the CD lid is closed or not. You can solder it permanently on (lid shut), but that would make it incompatible with multidisc games. (More on moving it in the next two chapters.)
- **Controller and memory card ports.** Plastic ports that accept cards and controllers. They're easy to desolder, and are actually individual pieces. This allows you to use one by itself in your PSOne portable for the memory card/Player 2 port.
- **Audio/video output jack.** Outputs signals to the screen. Pretty self-explanatory.
- **DC power input.** You hook a 7.2-volt source up to this. Conveniently enough, this is the exact voltage outputted by a Sony Infolithium camcorder/digital camera battery.

  The DC power input jack has a disconnect on the ground connection. This means that *GROUND* goes into the plug on one pin and passes through to the destination pin. If a power plug is inserted, it "disconnects" the original ground and goes to the destination pin itself.
- **ON/OFF and reset switches.** Turns the system on and off.
- **CPU and things.** The brains of the PSOne. We don't need to worry about them very much, because we're more interested in building the body!

- **CD-ROM drive assembly** (not shown, but you've already seen it in person). This unit spins and reads the disc! It has three rubber-bouncer feet that help keep the drive steady. We'll augment these in later chapters.

The components on the PSOne board are attached in one of two ways:

- **Surface-mount.** The leads are on the sides of the components, and are soldered to the surface of the motherboard (hence "surface"). We'll mostly attach things to surface-mount parts rather than remove them (which is quite difficult).
- **Through-hole.** The leads from the components go through the motherboard and out the other side. Luckily, all the parts we'll need to detach fall into this category.

Desoldering parts off the board

For both of the portables in the following chapters, all the large components need to be removed off the board. Figure 12-4 displays what to desolder, and the list tells you how.

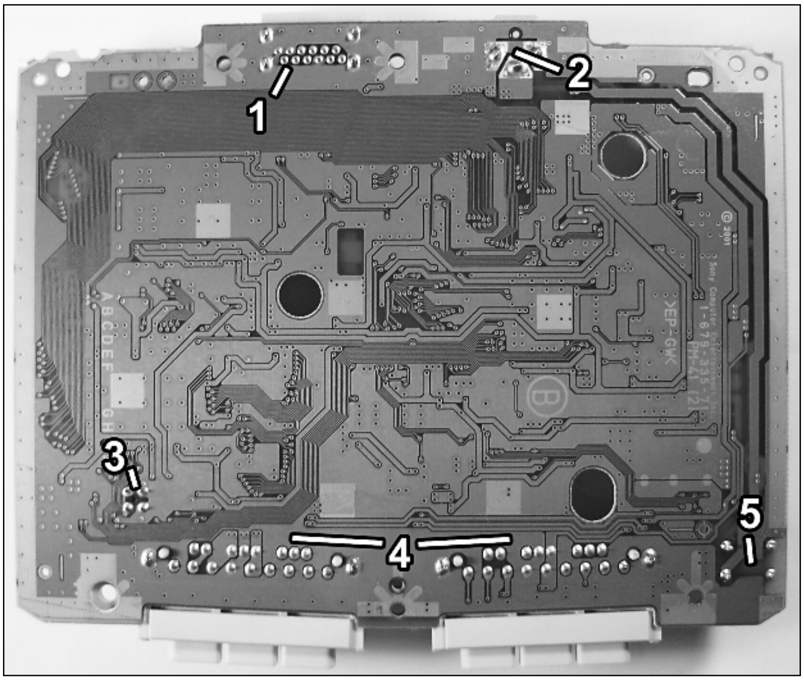


FIGURE 12-4: Desoldering spots on the back of the PSOne board.

1. **Audio/video jack.** The twelve main leads on this jack are easy to remove, but the four wide tabs on the sides are a different story. Suck up the solder a little at a time, or use an old desoldering tip that'll fit over the hole tab. Don't try to ram a new tip over tabs that won't fit, or you'll prematurely wreck it.
2. **After desoldering** the audio/video jack leads, stick a thin flat-head screwdriver under the jack near the side screw holes and twist. This will raise the jack enough to stick the screwdriver under the middle of the jack, so that you can twist it there and lift the plug enough to remove it.
3. **DC power input.** Desolder the three thick leads (again, with an older, more worn-out tip), and then rock the yellow plastic jack back and forth to snap it free.
4. **Lid sensor switch.** There are four leads to desolder in order to remove it. It may not pull free of the motherboard easily, but we'll be replacing this switch in the next few chapters, so if the switch is damaged during removal, don't sweat it.
5. **Controller/memory card ports.** Each port has two big thick pins and seventeen small pins. After desoldering them all, rock the Player 1 port forward and back with your fingers. It should pull free of the board. You can then do the same with the Player 2 port. Both ports are identical, and keep at least one handy for your portable projects. (A portable doesn't have to have a second player port, but a Playstation portable *must* have a memory card slot.)
6. **On/off switch.** Desolder the four leads from the back, and then wedge a thin flat-head screwdriver under the switch and twist to raise it off the board.

Powering the System with Batteries

Naturally, to make a game system portable, you need to run it off some batteries. The PSOne has the highest power requirements of any game system covered in this book, so the power source needs to accommodate this. Let's start by looking at how the PSOne screen and PSOne system combo works in its *original* form.

Each PSOne comes with a 7.2-volt, 2-amp wall power plug-in adapter. If you get a PSOne screen, it comes with the same adapter, but it can do 3 amps. What you do is stick the PSOne screen onto the back of the PSOne. This inserts an audio/video plug and power plug into the PSOne. You then plug the 3-amp power supply into the back of the screen, which uses that power itself, and also passes it through to the PSOne. The power adapter needs the extra amperage, since it's running two devices.

We're obviously going to use a PSOne screen that has been modified with white LEDs, so our power consumption will be about 750 mA lower overall. Despite this fact, the PSOne and screen together are still going to use a lot of power: on average, 1200 mA at 7.2 volts!

Suggested battery to use

The PSOne is a Sony product, so why not use a Sony battery? I've used the Sony Infolithium Type L camcorder battery for many a portable, as seen in Figure 12-5.

FIGURE 12-5: The Sony Infolithium Type L battery (NP-F550 shown).

Here's why it's great for a PSOne portable:

- It outputs 7.2 volts, which is exactly what the PSOne and screen run off.
- It's fairly small, yet packs a lot of power, because it's a more modern type (lithium-ion) of battery.
- It has no memory effect, like older rechargeables do, and doesn't generate heat while being charged.
- The battery has tabs on the tabs and slots in the back. This allows it to be mounted in the "open air" (such as clipped on the back of a camcorder) or inside a slot (such as inside a digital camera). The advantage of an "open air" mount is that you can clip on a physically larger battery if you wish.
- The Type L battery ranges in size from the NP-F330 (low power, the kind they include free with a camera), to the midrange NP-F550, all the way up to the megapowered NP-F960. With an open-air mount, you're only limited by how much you want to spend.

Brand-new from a retailer, these batteries can cost from $50-$150 depending on size, but if you check online auctions you can find them — and even battery/charger combos — for a lot less, usually well under $50. There are also off-brand (non-Sony) versions of these batteries.

Note

You'll need a separate charger for this type of battery, as the portable won't be able to charge them itself. If you have a Sony camera that takes this type of battery, you've already got one.

Connecting a Sony Infolithium battery

On the edge of the battery are two holes that you can use to connect positive and negative power. (The polarity is clearly labeled on the bottom of the battery.) Obviously, you'll need to stick a metal lead of some sort in there to make the connection. Your best bet is to get a "Molex-type" wire connector. These are plastic connectors that come with female or male prongs to put inside them (Figure 12-6).

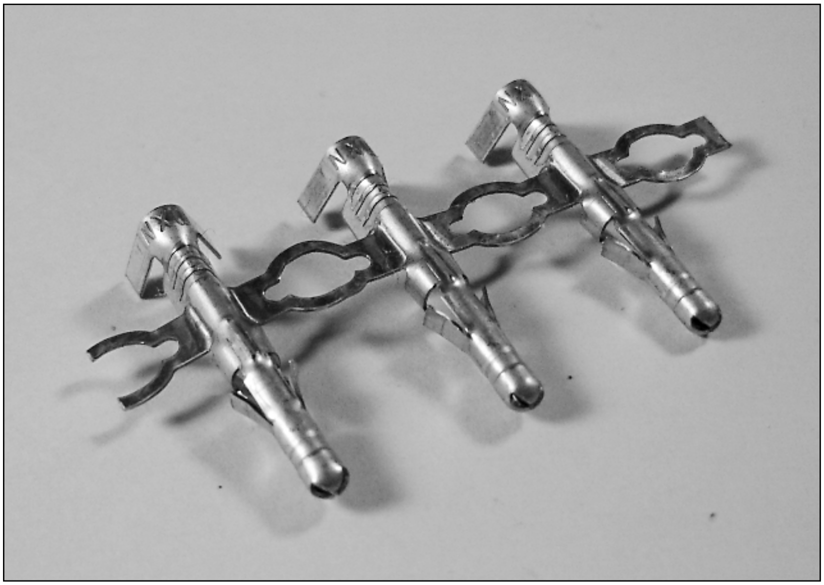


FIGURE 12-6: The male leads from inside a wire connector.

These leads fit perfectly into the battery holes on the Sony battery! Here are some places to locate connectors that have such leads in them:

- **Inside old computers, and even new ones.** If you're familiar with the guts of a PC, you know how there are lots of four-wire connectors that power things like hard drives and CD-ROMs. These all have the type of male leads that you need.
- **Connectors from a store.** Radio Shack stocks connectors that have the appropriate pins. Catalog #274-224 will work fine. You'll get the white plastic plug as well, but it's still the best way to buy the right leads.
- **RC car battery packs.** If you've done either of the NES projects from this book, you've cut off such connectors from the battery packs. Dig them out of the trash, because they've got the right male leads inside as well.

Alternative batteries to use

The power regulators in the PSOne and screen are similar to the classic 7805 regulator that we talked about in Chapter 3. A few things to note about them:

- They're smaller and the surface-mount type. There's no heat sink; instead, the heat dissipates into the motherboard itself.
- They output 5 volts and need at least 7 volts as input to keep running, because of the 2-volt "dropout" level. (This is also discussed in Chapter 3.)
- You can input higher voltages into the PSOne and screen than the suggested 7.5 volts, but don't go too far over because that extra voltage becomes heat, and as mentioned, there's no traditional metal heat sink. 9.6 volts is about the highest you'd want to go.

Based off these parameters, the following rechargeable batteries are good choices:

- 9.6 volt Ni-MH, (Radio Shack catalog #23-331): This is a smaller battery, which means you have lower total power.
- 7.2 volt Ni-MH (Radio Shack catalog #23-330) or 7.2 volt Ni-Cd (Radio Shack catalog #23-431): This is a larger battery pack, but closer to the actual voltage the Playstation stuff needs, and with a lot more mAH, even in the Ni-Cd version.

Connecting power to the PSOne

To run the PSOne, connect power from your battery of choice to the spot indicated in Figure 12-7. The same photo shows where to "jump" the power switch to be always on. Both of these locations are on the back of the motherboard.

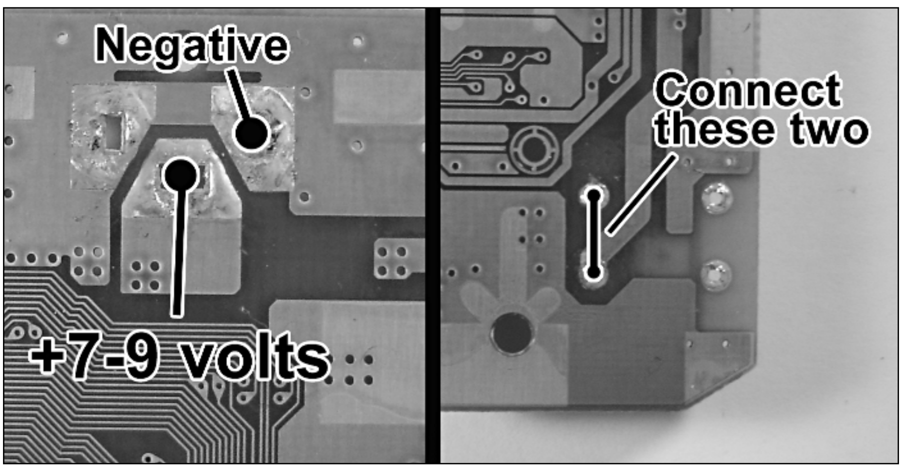


FIGURE 12-7: Where to attach power and how to jump the power switch.

The reason you'll want to wire the power switch to be always on is because you'll be running two devices off the battery (the PSOne and the screen), and you'll want a separate switch to turn them both on and off together, making one of them unnecessary.

Working with Controllers

A portable Playstation is pretty much worthless if you can't control the game or save your game progress with a memory card. Therefore we need to connect controllers! If you want to use a normal controller and plug it in the normal way, then don't desolder the controller ports and disregard this section. For all of you adventurous souls out there, read on!

Which type of Playstation controller to use

You can use pretty much any Playstation 1–compatible controller with this project, but the one we'll be covering in this and the next two chapters is the last-revision PSOne controller released, as seen in Figure 12-8. This model was typically packed with a store-bought PSOne and even says "PSOne" on it. It's got a white, rather than light gray, case and the buttons are more pastel in color than older controllers. It kind of looks like a normal Playstation controller that was left out in the sun too long.

FIGURE 12-8: The PSOne controller to use.

There are seven screws on the back. Remove then to take the controller apart. Inside you'll find a circuit board with a rumble motor on each side. Do the following:

1. Desolder the motors on either side of the board. The CNC-built PSOne does have room for rumble motors, so keep them around as an option. (Or simulate the rumble feature by playing your portable while riding a car over bad roads.)
2. Use your tweezers to pull out the flat ribbon cable on the upper right corner of the board.
3. Pull the circuit board out of the plastic controller casing. We will now refer to this 3-1/8" × 2"–sized circuit board as the *controller board*. It will still have the main controller cable attached.

Note Some of the other late-model PSOne Dual Shock controllers, such as the transparent-colored ones, will also match these instructions fairly well. If it has sixteen wires on the button connector pinout (see below), it should work.

Controller pinout

With the original cables removed (or soon to be removed), we'll need to know the pinouts of the things that connect to the controller board. (*Pinout* means a list of what each pin does.) The controller board is a bit more complex than the NES or SNES controllers, so rather than rebuild it from scratch, we'll have to simply include it somewhere in our portable.

Tip Remember that this information applies to the pastel-colored controller described above. Pinouts and connections may not match up if you use a much older controller, or a newer Dual Shock 2 (PS2).

Button connector pinouts and wiring

There are two main connections to the controller board — the *button connector* and the *controller connector.* (These aren't official names, I just made them up. But they'll work.) Figure 12-9 shows the pinout for the button connector.

You can make your own buttons for the controller by using tact switches and connecting them directly to the controller board as described above. Connect your wires just behind the beige plug. You can also attempt to stick the wires directly into the plug. Some controllers have a cable that you can desolder, which gives you easy holes to solder new wires into. (More photos and info on this are in the following two chapters.)

Since you're attaching wires to a surface-mounted component, this can be a tricky connection to make. For best results, you should use solid wire such as the thin Ultra ATA hard drive ribbon cable. If you use stranded wire, it'll be hard to keep the strands all in place, and loose strands can (and most probably *will*) short each other out, causing erratic controller action.

Figure 12-10 shows a sample portion of a custom PSOne controller made using tact switches. The four switches on the left are up/down/left/right, the middle two are select/reset, and the four on the right are square/X/circle/triangle. The left and right shoulder buttons are not shown.

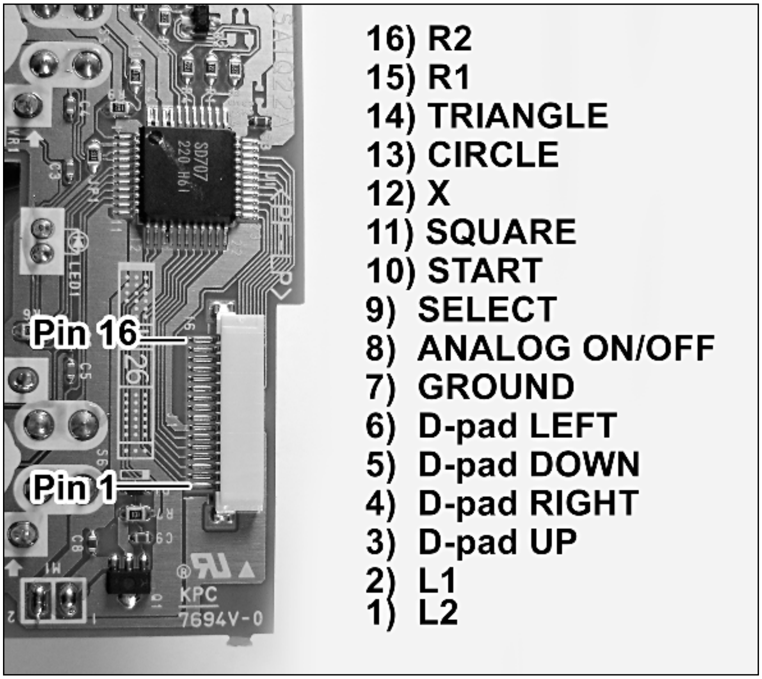


FIGURE 12-9: Button connector pinout.

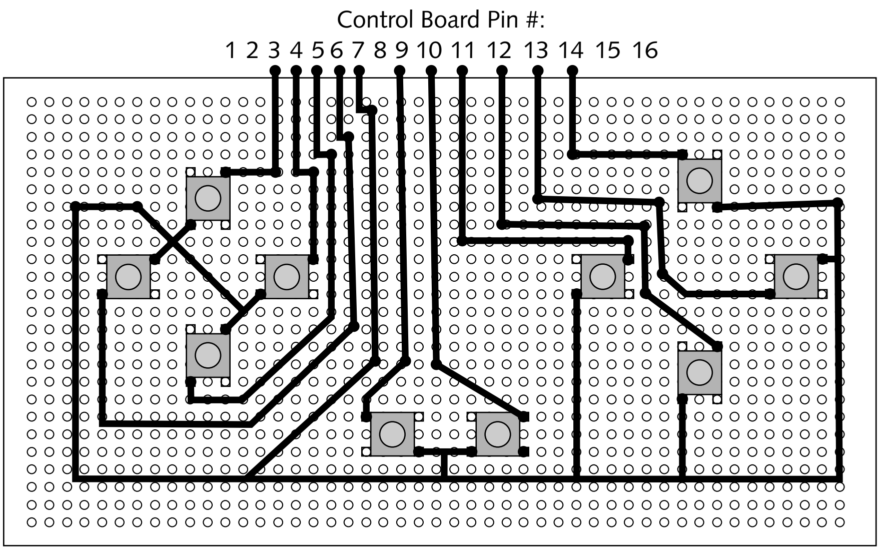


FIGURE 12-10: Sample PSOne controller on a piece of PC board.

Controller connector wiring

The other connector is used to attach the controller board to the PSOne motherboard. Since both ends use standard through-hole soldering, these connections are much easier to make. Figure 12-11 shows how to interconnect them. Notice how they switch around and aren't in the same order on each end. Also, for some reason, controller pins 2 and 8 are connected to the same spot on the PSOne board. The Player 1 connections are shown; Player 2 wires up the same way.

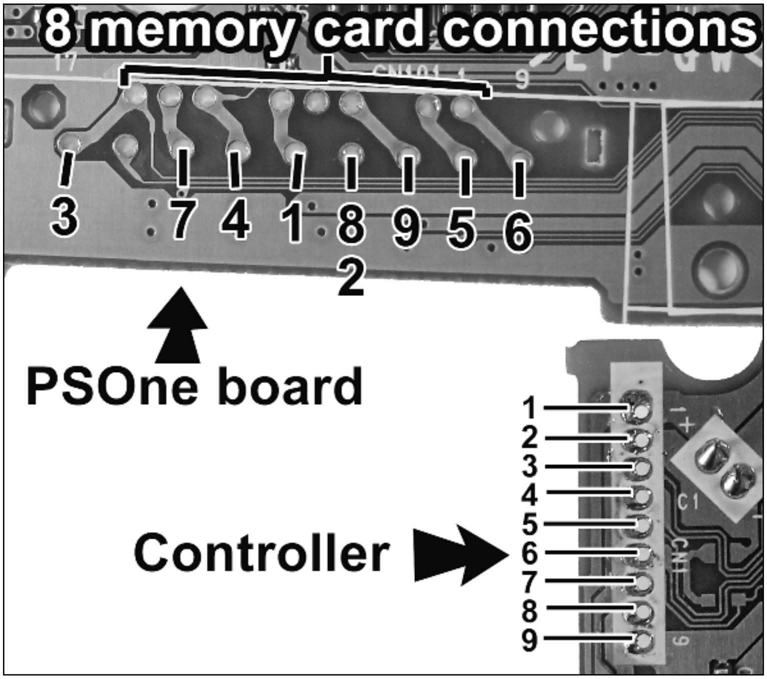


FIGURE 12-11: Controller connector pinout (lower right) and corresponding spots on PSOne board (top).

It's even easier to reconnect the memory card slot. Simply use an eight-strand of ribbon cable to connect the eight top pins on the detached controller port directly to the eight pins on the PSOne board.

Note

The reconnection of Playstation controllers is a part of the projects in the next two chapters, so if you're building one of those, simply use this information as reference.

Desoldering and reconnecting the analog control sticks

Hey look, there are tact switches on the analog control sticks! So *that's* what made them click down! See, tact switches are everywhere, but we never see them. (Much like oxygen molecules and baby squirrels.) To remove the two analog sticks from the controller board, do the following:

1. Desolder the fourteen leads on each tact switch.
2. The four biggest leads may be soldered and twisted into place. If you can't pry the stick off, check to see if that's the case. If so, use your needle-nose pliers to twist them straight so that they'll pull free of the board.
3. Use a small flat-head screwdriver to pry the analog sticks off the controller board.

To reconnect the analog sticks, simply use one ten-strand of ribbon cable per stick to reconnect the bottom three, side three, and top four leads. The big thick leads (the ones that may have been twisted) were just there for support, and do not need reconnected.

Note

If you're planning to make the CNC-built PSOne portable in Chapter 14, then *do not* desolder the analog sticks from the controller board.

You now have everything you need to make your PSOne portable! In the following chapters you can use the preparations you've made here to put the PSOne parts into custom-built cases.

Chapter in Review

Now that your PSOne is all hacked up, it's ready to be used for one of the portable projects in the next two chapters. You can also use the information from this chapter, along with the TV-hacking procedures of Chapter 4, to build a portable PSOne of your own design.

Some important stuff to remember:

- A PSOne and a PSOne screen run off the same voltage, which is also the voltage of a Sony Infolithium battery, making them a great combination.
- Male Molex connector prongs fit inside the Sony Infolithium battery holes quite well.
- You need to keep the main controller board from the Dual Shock controller, but the sub-board that contained the buttons can be recreated.
- The lid sensor switch must be hooked up to a new switch (that the CD lid clicks against), or be soldered to always on.

Additional ways to hack up and modify the PSOne and its controller will be used in the next two chapters.

Building a Portable Playstation 1 by Hand

chapter 13

in this chapter

- ☑ Materials You'll Need
- ☑ Making the Screen Assembly
- ☑ Building the Main Case
- ☑ Making the Rear Plate
- ☑ Wiring the Unit
- ☑ Testing and Troubleshooting
- ☑ Final Assembly
- ☑ Chapter in Review

Here's the portable Playstation 1 you can build by hand, shown in Figure 13-1.

Don't worry, your hands will have an important ally in the process — your printer! (Or perhaps your friend's printer you always use. You know the one.) We've come a long ways since the old dot-matrix days. Now you can print drawings and templates that exactly match the size you need, which allows you to translate the printed page into real-world parts!

In this chapter you'll cut parts out of engraving plastic and then bend and attach aluminum walls to them to form the portable's case. The screen will be built into a flip-top section that will cover the CD-ROM. After that, you'll make custom control boards that contain the analog sticks and buttons. Finally you'll install the PSOne motherboard itself and wire everything together to complete the unit.

This is probably the most difficult-to-build portable in this book, but when you're done you'll have a swell unit that can play the existing library of Playstation titles!

Without much further ado about nothing, let's get started!

FIGURE 13-1: The hand-built Portable Playstation 1

Materials You'll Need

In this section we'll list all the materials you'll need. The first set of materials are the major video game–related ones themselves.

- A **PSOne motherboard** hacked up, as described in Chapter 12.
- A **PSOne 5" screen,** modified with white LEDs, as shown in Chapter 4.
- A **PSOne Dual Shock controller,** also shown in Chapter 12. Some of the later-model Playstation 1 Dual Shock controllers will also work. If you can find one of the semi-transparent versions at a used game store, take a look through it. If you see a single circuit board with both the analog sticks connected to it and a ribbon cable connected to the upper right, you can use it with these projects. A Playstation 2 Dual Shock 2 is not appropriate for this project.

The rest of the materials you'll need can be divided into three types: *electronic parts, screws and fasteners,* and *case-building materials*.

Electronic parts

Table 13-1 is a list of electronic parts required for this project. The majority of them can be found at your local Radio Shack. This allows you to find certain parts, such as the PC boards, that will exactly match the same model PC board I used. The last two parts will need to be obtained from an online retailer such as Digi-Key (www.digikey.com).

Table 13-1 Electronic Parts List for PSOne Portable

Part Name	*Available From:*	*Part or Catalog #*	*Quantity Required*
General-purpose component PC board	Radio Shack	276-149A	2
Phono jack	Radio Shack	274-246A	1
1/8″ phono plug	Radio Shack	274-287	1
Male polarized connector (four positions, Molex type)	Radio Shack	274-224	1
5-mm red LED (or color of your choice)	Radio Shack	276-330	1
SPST pushbutton switch	Radio Shack	275-646	1
SPST submini Slide Switch	Radio Shack	275-406	1
SPDT switch with 3/4″ roller lever	Radio Shack	275-017	1
Tact switch, 6 mm	Digi-Key	EG2495-ND	8
Tact switch, 4.5 mm, H=3.8 mm	Digi-Key	CKN9018-ND	6

Note

The components required to modify the PSOne screen with white LEDs were listed and described in Chapter 4.

The Sony Infolithium battery

This portable unit will run off wall power or a Sony Infolithium battery. The type to get is Size L, which is the kind used for Sony digital camcorders (such as the Handycam) or the older Sony Mavica floppy disk–based digital cameras. These batteries come in different sizes, from NP-F330 to NP-F960. You'll need at least a middle-of-the-road battery, such as the NP-F550, in order to properly power this device.

This Playstation portable will not be able to charge its own battery, so you need a separate charging device in addition to the battery itself. If you do a search at an online auction, you can usually find pretty good deals on battery/charger combos.

Screws and fasteners

In order to assemble the case for the PSOne portable you'll need a variety of screws, fasteners, and spacers. These can be found at your local hardware store in the screw section. Look for an aisle with a bunch of bins and trays in it. There you can buy exactly as many components as you need, as listed in Table 13-2.

Table 13-2 Screw, Nuts, Washers, and Spacers

Screw/Nut/Washer/Spacer Size	*Type*	*Length/Size*	*Quantity*
Size-4 screws	Phillips, pan (round head)	1/4"	6
Size-4 screws	Phillips, pan (round head)	3/8"	4
Size-6 screws	Phillips, pan (round head)	3/8"	6
Size-6 screws	Phillips, pan (round head)	1/2"	7
Size-6 nylon screw	Slotted, pan (round head)	1/2"	2
Size-6 nut	Standard metallic	N/A	6
Size-4 nut	Standard metallic	N/A	4
Size-4 nylon spacer	1/4" outer diameter	1/4"	13
Size-6 nylon spacer	1/4" outer diameter	1/4"	1
Size-4 nylon spacer	1/4" outer diameter	1/2" long	20
Automotive panel fastener	7/64" size-hole	N/A	1
Nylon spacer	3/16" outer diameter	1"	1
Nylon spacer	3/8" outer diameter	1"	1
Size-4 nylon spacer	1/4" outer diameter	3/4"	1
Size-4 nylon washer	N/A	N/A	46
Size-6 nylon washer	N/A	N/A	1
Steel rod	3/32" diameter	2 1/8" long	1
Spring	Compression	5/32" x 9/16"	1 spring
Tubular rivet	3/16" x 1/4" size, metallic	N/A	1
Fender washer, black rubber	3/16" x 1 1/4"	N/A	1

Note

Smaller hardware stores may not stock some of the parts, such as the small spring and tubular rivet. Try a larger store (such as a large chain store), or use the closest part you can find. (More on slight deviations during the construction.)

Case-building materials

The case for this portable will be built primarily from plastic and aluminum. The aluminum parts can be found in the metal section at your local hardware store (hopefully you'll still there, wandering around with this book). The metal section is usually quite close to the screw section.

- **1" wide by 1/16" thick by 26" long aluminum strip.** This is how much you'll need, but it will most likely come in a length of 4 or 6 feet.
- **1/2" wide by 1/16" thick by 25" long aluminum strip.** You'll need this amount for the project, but it'll probably come in a 4-foot length as well. This excessive length will come in handy when you bend it (more on that later).
- **Small (4" × 4") piece of 1/4"-thick balsa wood or other easy-to-cut semi-solid 1/4"-thick material.** You can find balsa wood at a hobby shop. Whatever 1/4"-thick stuff you find, keep in mind it'll be used to make the shoulder buttons.

The plastic for the unit will be 1/16"-thick engraving plastic, as described in Chapter 5. The best place to find this material is at a trophy/awards shop. They should have quite a bit on hand for you to choose from, or you can have them order you a custom color/texture from a catalog. Here are the recommended plastic colors and amounts for this project:

- **Light blue, flat surface (no texture) piece of 1/16"-thick engraving plastic: 10" × 12" minimum.**
- **Light silver metallic, flat surface (no texture) piece of 1/16"-thick engraving plastic: 14" × 7" minimum.**
- **About 6" × 6" of spare scrap material for additional parts.** Won't be seen, so any color is fine (The shop will undoubtedly have some unwanted colors of material laying around, such as chartreuse, that you may be able to get at a substantial discount.)

Decals and graphics

One of the key elements in making a kick-butt portable is the graphics you put on it. Even a hand-built unit acquires a higher air of professionalism when you take this extra step! There are two main ways to make them:

- **Having a vinyl shop use a thermal printer.** Graphics printed directly onto adhesive-backed vinyls will have high durability and a nice glossy look. Visit your local sign or vinyl graphics shop (you know, the kind of place that puts lettering like "Sar-Nink Canoe Rentals" on truck doors), and provide them with the file "PSOne by hand Decals.plt" from this book's companion Web site. This is a fairly standard type of file for these places, but if they can't get it to load, you can provide one of the following files as an alternative. Ask them to print it on *clear enamel receptive vinyl*. This allows the natural color of the engraving plastic to show through and gives a nice effect.

While at the vinyl shop, have them also cut you the following vinyl stripes: *one 1"× 26" gray stripe,* and *one 1/2"× 20" gray stripe*. These stripes will go on the sides of the portable, so pick whatever color you think would be best. In all likelihood they'll cut several of each size to fit the piece of vinyl. This is fine, as it gives you extra chances to apply it nicely!

- **Using a printer and adhesive-backed paper.** Print out one of the following files from the companion site, depending on which loads the best with your computer: "PSOne by hand Decals.ai," "PSOne by hand Decals.eps," "PSOne by hand Decals.pdf," or "PSOne by hand Decals.wmf."

  If you're not using vinyl, you can cover the sides of your portable using electric tape, paint, or any other adhesive-backed covering you wish.

Miscellaneous tools and parts

In addition to the actual parts going into your portable, you'll need to have the following:

- **Superglue.** The liquid (non-gel) kind works best for this project. One small tube should be sufficient.
- **Hot glue sticks.** Have a well-stocked bag available, as there'll be quite a bit of hot-gluing going on during this chapter.
- **Hacksaw and blades.** Get a soft metal–cutting blade, as you'll need it for the aluminum.
- **Printer paper and ink.** The templates will be made using your printer, so be sure it's stocked up and ready to go. (This is mostly a reminder for those of use who go months — if not years — with empty ink cartridges until we really, *really* need to buy them.)
- **Workbench-mounted vise.** Not required, but will make one part in this chapter much easier to fabricate. (I'll tell you when we get to it.) A good time to visit your friend or parent/legal guardian's workshop!
- **Drill bits in the following sizes: 1/8", 1/10", 3/16", and 15/64".** (Also a good time to visit a friend with a workshop.)
- **Fine-grit sandpaper.** 220 grit should work well. A sheet or two is enough.

Files supplied on the companion Web site

This chapter will refer to files that you need to print out to build this project. All the files are available on this book's companion Web site, at www.wiley.com/go/extremetech, in a file called "PSOne By Hand." In this chapter, all the files listed have a PDF extension, meaning they open with Adobe Acrobat Reader (available free at www.adobe.com). This should cover PC and Mac users, but if for some reason you need a different file type, you can find WMF (Windows metafile) versions of each file on the companion Web site as well. When printing a file, make sure your printer settings are 100% Size, No Scaling, or Default (depending on the program). This prints the file at the original size, which is required for this project to work. Additionally, if you see a setting such as "Fit to Page," turn it off. The size of each part will be listed so you can measure the shape to double-check that the file printed properly before you start cutting anything.

Making the Screen Assembly

The screen assembly is the 6” × 6” × 1/2” portion of the unit that “pops up” and contains the screen. It will also have the select and start buttons. We won’t be using a spring to lift the screen assembly, as it’s kind of heavier than a normal CD lid and we’d need such a strong spring that it’d cause excess strain on the unit’s walls. (Of course, after you’ve installed the screen according to this section’s instructions, you’re free to try!)

Cutting the front screen plate

All right, let’s get started by making the *front screen plate*. This is the 1/16”-thick circular piece of plastic surrounding the screen. It also forms the basis for the shape of the main screen assembly itself. To cut out the front screen plate:

1. Print out the file “Front Screen Plate.pdf.” You’ll get a 6” × 6” circle with some shapes near the bottom and a big square for the screen.
2. Cut the paper about 1/2” outside of the main circle, and then tape this pattern down on a piece of engraving plastic. (For my portable I’m using silver plastic for the screen.) Figure 13-2 shows how the pattern should be taped down. Use this as a reference for all further pattern-to-plastic tapings (and believe me, there’s more coming).

FIGURE 13-2: Taping a paper pattern down to engraving plastic.

3. Using a new, sharp X-Acto knife, make a groove along the screen shape, then along the six shapes below it. Don't try to make this cut too deep, because that increases your chances of slipping and messing up the plastic (or your fingers!).
4. Make a groove along the outer circle shape, and then remove the paper pattern.
5. Deepen the existing grooves. With the existing groove acting as a guide, you can press harder with less chance of slippage. Two cuts are enough, but the more you make, the better the plastic will separate. (If you've got the patience, four grooves is groovy.)

Tip

You can't always see the grooves you're making because they're under the paper. But when the paper piece pops loose, you can be sure you've cut the entire shape.

6. You can now bend the main circle shape free of the plastic. Bend the edges of the circles backward, away from the color side of the plastic as shown in Figure 13-3. Once you've bent a certain ways, the plastic should snap open on the groove you made. Do this all around the circle to remove it.

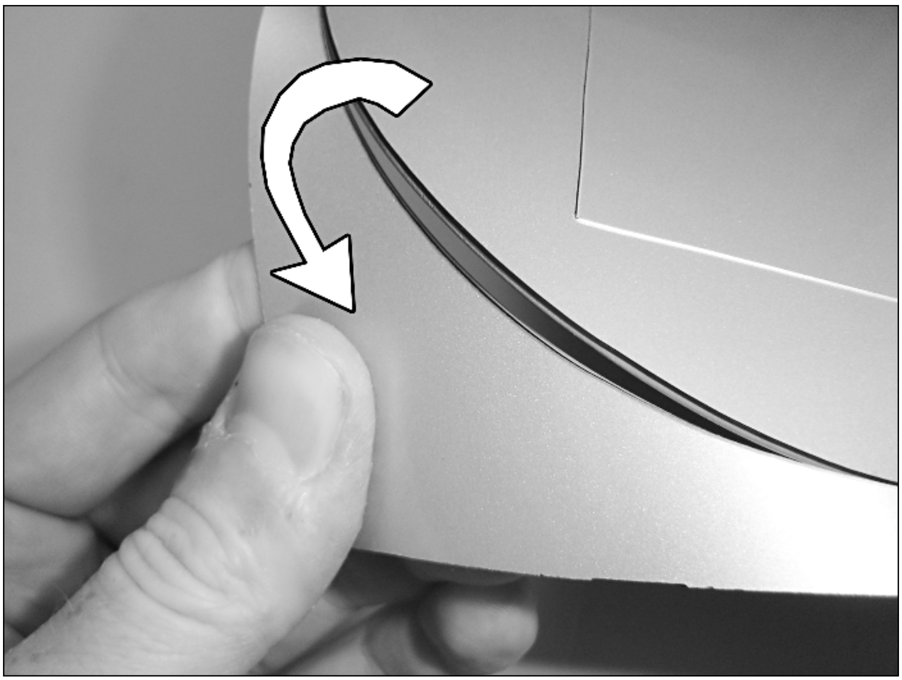


FIGURE 13-3: Bending the plastic around the edges of the front screen plate circle.

7. Depending on the original shape of the main piece of engraving stock, it may help to cut a large square around the entire circle and then remove the circle from the square. This creates a smaller area of plastic around the circle that has to be bent. Squares are easier to remove from large pieces of plastic than circles are.

8. Drill 3/16" holes in the inner shapes, such as the volume/brightness and select/start button holes. With the holes drilled, you can reach in with needle-nose pliers and bend the small shape out. (For photos of this being done, see Chapter 7.)
9. Bend the screen out the same way you bent out the main shape — with the pieces bent backward from the colored side. Since the screen is being removed from the *inside* of a piece of plastic, you should follow the following additional steps as well.
10. Once you've bent one side of the screen a ways, you'll see a line appear on the opposite side of the plastic. Cut a groove along this line, and then continue to bend the screen out.
11. When a side is bent enough that it separates, work the separation left and right toward the corners.
12. The trickiest part of the screen to remove are the corners. Bend all four sides until only the corners remain attached. You can then press on a corner from the rear, and it should pop out the front.
13. Get both corners on one side detached so that you can grab the entire screen portion and bend it backwards to easily detach the corners on the other side. (Kind of like swinging open a door, and then breaking it off at the hinges!) Save the rectangular screen shape for later use.
14. Test each hole by placing the appropriate button into it (the existing PSOne screen volume/brightness buttons and the select/start buttons from the controller). Use your X-Acto knife to "shave" the inside of the hole larger or rounder as needed. You can also drill through the four volume/brightness holes with a 1/4" bit if you wish in order to make them rounder. Cut them out as best you can with the knife first to ensure accurate hole placement.

Applying the screw posts

Now that you have the front screen plate cut, it's time to attach some *screw posts* to the back of it. Screw posts are anything that you can drive a screw into — in this case, we'll be using nylon spacers and size-4 nuts. Before we glue these down, they need to be prepared in the following manner:

1. Sand both sides of the four size-4 nuts and both ends of the four 1/2" nylon spacers. This gives them a better surface for gluing.
2. Grip each nylon spacer with large pliers, and drive a 3/8"-long size-6 screw in and out of it. This creates threads for later on. Do this for every nylon spacer screw post in the materials list.

With those items prepared, we can attach the screw posts as follows:

1. Print the file "Front Screen Plate Screw Posts.pdf." It will be a circle of the same size as the front plate (6" diameter), with the same inside shapes that you've already cut out of the plastic for reference. In addition, you'll see four double circles and four size-4 nut shapes.

2. Cut out the main circle shape, the outside of the double circles, and the outside of the nut shapes. Then cut out the four corners of the screen, and make a few slits on the sides so that you have a place to put tape.

3. Use a fine-grit sandpaper to sand the entire back of the front screen plate. Wipe off the dust.

4. Using the screen cuts and the outside shape as a guide, tape the screw post pattern to the back of the front screen plate, as shown in Figure 13-4.

FIGURE 13-4: The screw post pattern taped to the back of the front screen plate.

5. Place a dab of superglue in each spot, and glue down the appropriate item.
   - Four corner circles: 1/2” size-4 nylon spacer (threaded).
   - Four side nut-shapes: Size-4 nut. Be sure the nut is rotated in such a way that it matches the shape on the pattern.

6. Let the superglue dry, and then remove the paper pattern (you may have to cut some paper away from around the screw posts).

7. Place a thin bead of 5-minute epoxy around the four nylon screw posts to further secure them. Place some epoxy around the size-4 nuts as well, but only on the side NOT facing the screen. Otherwise the epoxy may create a lump that keeps the screen from fitting snugly against the plate.

Tip

You may want to reinforce the screw posts with epoxy after you attach the aluminum wall (coming up next).

Bending and attaching the aluminum wall

We now need to bend and attach the *aluminum wall* to the front screen plate. We will use the 1/2" wide × 1/16" thick piece of aluminum for this as described below:

1. Begin by wrapping the aluminum strip around something circular that has a smaller diameter than the front screen plate, but as close as possible without going over. (I used a normal-sized soup can, but one of those jumbo-sized beef stew cans would be the ideal choice. And tasty to boot!) Wrap the aluminum around the can at least twice, depending on how close the can size is to the front plate, holding the previous loops as tightly to the can as possible while making the new ones. Each loop should go to the side of the previous one, not on top (which is why you can't use a tuna fish can).

Caution

The aluminum strip will be building up a lot of tension energy — if you let go, it will spring back quickly. Be careful not to let it whack you in the face if it does. Keep a tight grip on it and hold it in such a way that if it does let go, it'll fly left or right, and not toward you.

2. Pull the can out of the aluminum coil. You'll now have something that resembles a very thick spring. You should have enough coils of aluminum to make the walls twice. Place the coiled aluminum over the back of the front screen plate, and widen it until it matches the size of the plate. You can put the aluminum around the plate to hold it temporarily; however, the final aluminum wall should be under the plate, not around it.
3. Adjust the aluminum by pulling, bending, and squishing it until it fits the shape of the front plate without having to be held. (Meaning the spring-back tension is gone.) The multiple coils of aluminum give you options to work with, so you can find the smoothest, roundest portion. Once you've found a good circular area, make cut marks on the coils where the ends should be.
4. Use a hacksaw to carefully cut the aluminum on the cut marks. Try not to distort the overall bend of the aluminum when you saw it. Holding it with a vise or large pliers will help.
5. The resulting cut aluminum piece should fit under the rear plate quite well. Put some electric tape at the point where the two ends meets to hold them steady, but don't let the tape go all the way down or over on edge, as you'll need that edge for gluing.
6. Pick an edge to the glued to the front plate (the one with no electric tape over it), and sand it using fine-grit paper. Wipe off the dust.

The front screen plate and wall should now appear as shown in Figure 13-5.

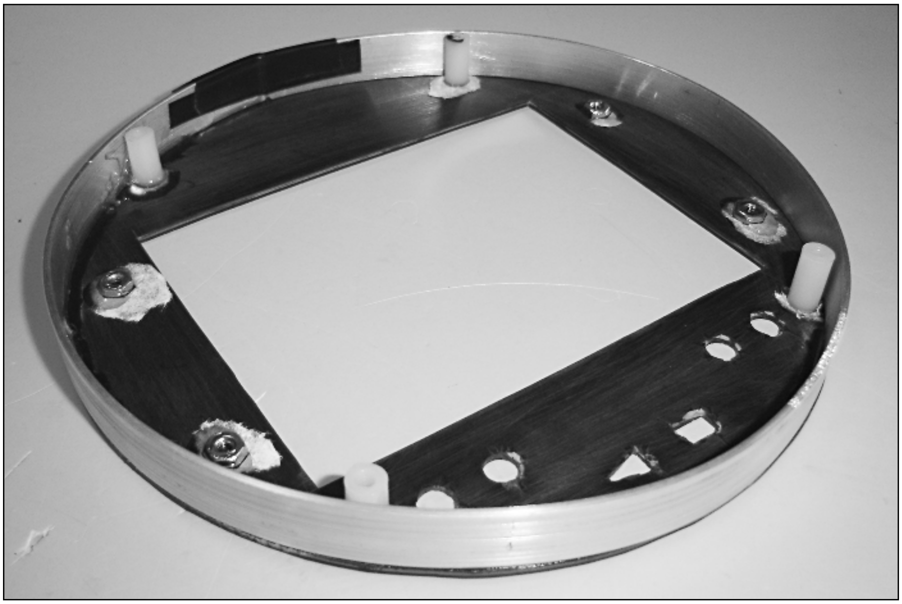


FIGURE 13-5: The front screen plate and aluminum wall thus far.

Gluing down the aluminum wall

You'll need some regular, watery superglue and 5-minute epoxy for this. Gel-type superglue will work but doesn't dry as fast. To glue down the aluminum wall, do the following:

1. Find the portion of the wall that best matches the shape of the front plate. Remember, the wall is behind the plate, not around it. (You could also say "flush.")
2. While holding the wall down onto the plate, put a bead of superglue along the inside seam a couple of inches long. Then lift up the wall a little — the watery superglue will "seep" underneath it. Place the wall back down, and hold it for about 15 seconds. Check that no glue has seeped out the sides or onto the front of the engraving plastic (It will mar that surface faster than you can say "Oh no, not my beautiful portable!")
3. Lay a bead of superglue along the next few inches. Lift the wall and hold it down. Do this for the first half of the wall.
4. Once half the wall has been glued to the plate, mix up some 5-minute epoxy. Place a bead of epoxy along the seam on top of the superglue. When you come to the nylon screw posts, place glue up and down their sides, connecting them to the wall.

5. Get something heavy and flat—like a set of encyclopedias or one Stephen King novel—and set it on top of the wall. This makes the glue dry with the wall pressed as flat as possible.
6. Repeat Steps 2–5 for the other half of the circular wall. Once it's all glued, remove the electric tape from the ends.

Applying decals

Putting decals on the unit might seem like something to do at the end of the construction process, but when raised buttons are involved, you need to get the decals down first.

- If you printed your own decals, cut out and apply the large 6" × 6" circle over the front screen plate.
- If you got printed vinyl graphics from a shop, make a mixture of slightly soapy water, peel the decal, dunk it in the water, and apply it to the front screen plate. The soapy water lets you move it around for the best positioning. Once you're satisfied, use a squeegee (or edge of credit card) to press down the vinyl and push out the water/air.
- Apply the 1/2" vinyl stripe around the side of the screen assembly. It should cover the aluminum, not the edge of the engraving plastic.
- As an alternative, you can paint the edge or cover it with electric tape.

Installing parts in the screen assembly

Before we build more of the screen assembly itself, let's install some parts into it, namely the PSOne screen!

The screen is going to be fairly detached from the rest of the unit, so cut a five-strand of 18"-long ribbon cable (*Screen Cable 1*) and a six-strand of 18"-long ribbon cable (*Screen Cable 2*). When these ribbon cables are cut, do the following to prepare the screen:

1. Plug both of the original white plugs back into the base of the PSOne screen. When viewed from the front (screen side), these will be called the *left and right plugs.* These plugs have wires to go to some separate small circuit boards containing the PSOne screen jacks (power, A/V in, etc.). Cut off all plug wires at this end so that you'll have long wires to work with.
2. Next, cut the following wires completely off the plugs at the PSOne screen end.
   - From the left plug: all but the two leftmost wires. These are, from left to right, *+7.2 volts in* and *ground.*
   - From the right plug: All but the three leftmost wires. These are, from left to right, *video in, right audio in,* and *left audio in.*
3. Place the screen inside the screen assembly, and line up the screen to the big hole. Check that you can see the four tact switches under the brightness/loudness buttonholes. Once everything is lined up okay, use a pointy felt-tip marker to reach in through the select/start holes, and make a mark in the center of each on the white plugs below. Pull the screen out of the screen assembly.

4. Get out two 4.5-mm tact switches. Place a small dot of hot glue on each mark on the white plugs, and then press a tact switch onto it, with the leads pointing left and right. Press firmly, so that the switch goes as low as possible.
5. Solder a small bit of lead between the two top inner leads on each tact switch. This will be *tact switch ground.*
6. Take your five-strand of ribbon cable and connect it to *+7.2 volts IN, tact switch ground, Video IN, Right audio IN,* and *left audio IN,* as seen in Figure 13-6. This ribbon cable will be referred to as *Screen Cable 1.* Take the remaining wire on the left plug (the second one from the left, ground) and connect it to *tact switch ground.*
7. Desolder the wires off both speakers (from the PSOne screen), and insert the plug from the wires into the left and right jacks on the front of the board.
8. Take your six-strand of ribbon cable and connect it to *left speaker* + (red wire), *left speaker* (black wire), *select, start, right speaker +,* and *right speaker.* This will be *Screen Cable 2.*
9. Make a mark on the opposite end of each ribbon cable indicating which wire is #1. Wire #1 on *Screen Cable 1* is *+7.2 volts in,* and wire 1 on *Screen Cable 2* is *left speaker +.* This will guide you later on.
10. The resulting wiring job should look like Figure 13-6. After verifying this, put small pieces of electric tape on all the exposed wire connections in order to prevent short circuits.

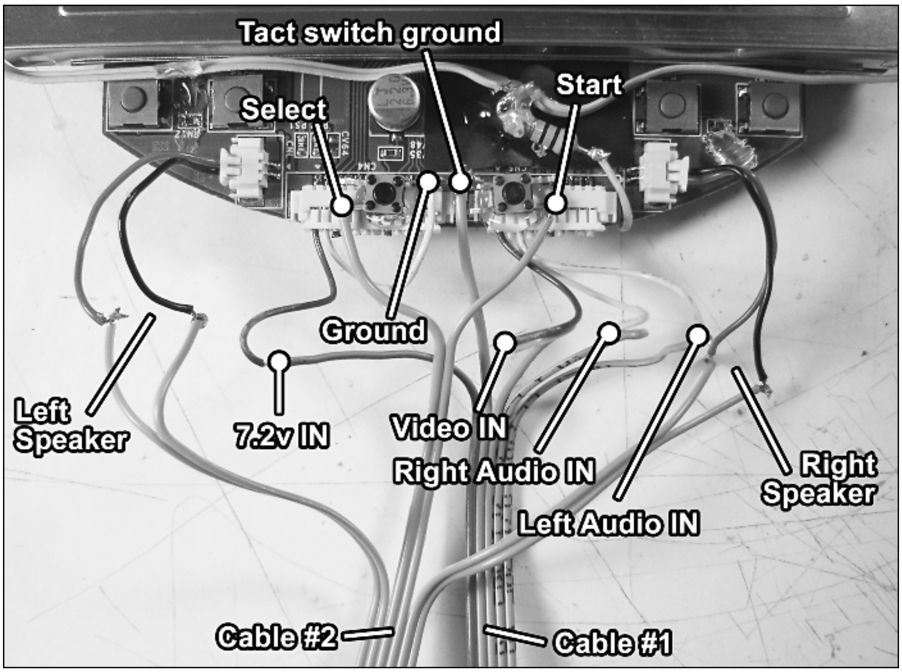


FIGURE 13-6: Both ribbon cables attached to the PSOne screen.

Tip

Be sure that no wires get in front of the select/start or brightness/loudness tact switches! Once you've got everything connected, use hot glue to secure the wires in safe places.

Installing the PSOne screen

Before we install the screen, we need to stick in the buttons that'll be under it. The select/start buttons need to be modified before we can install them. Here's what to do:

1. Start by slicing the top 1/8" off of the select/start buttons. This 1/8"-thick portion is what we'll be using.
2. Place the screen assembly facedown, and set the buttons in their holes, as shown in Figure 13-7. Once they're lined up, place a dot of superglue on the backs.
3. Cut a 1/4" × 1" piece of thin plastic. (A plastic soda bottle works well, but engraving plastic is too thick.) Sand the plastic and place it on the buttons. Press down so that the glue will set. Once they're attached, pull them and the plastic piece out, so that it won't glue to the case as it dries. Figure 13-7 shows both parts of this process.

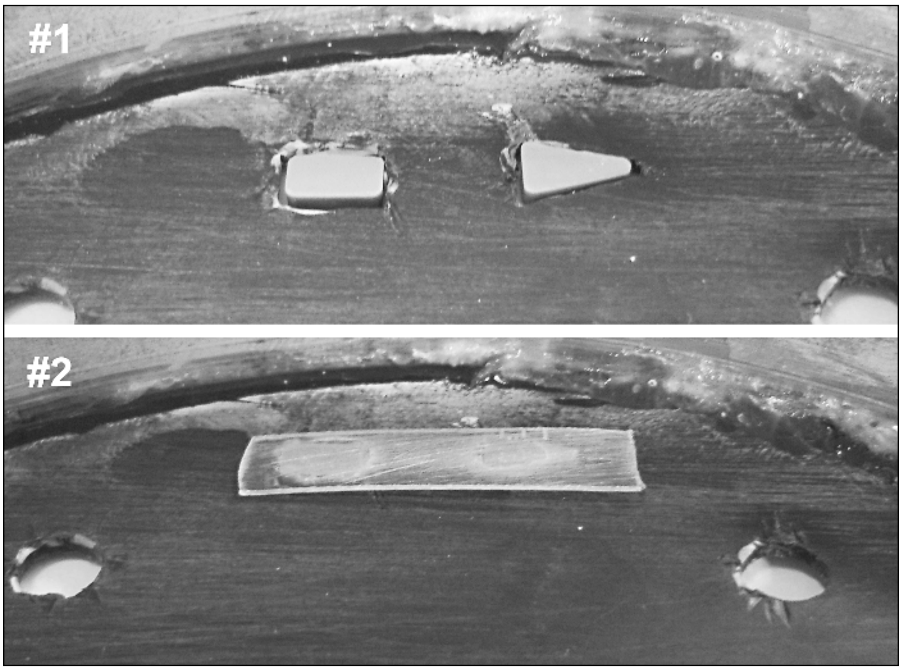


FIGURE 13-7: The select/start buttons sliced and with plastic glued behind them.

We can now proceed to install the screen. Place the select/start buttons back into their holes, and then do the following:

1. Place the existing PSOne screen brightness and volume buttons into the four holes, with the "+" mark on the right (when viewed from the front). If you'd like to make some buttons that'll stick up higher then these, use the method found in Chapter 10 in the section on *Installing and wiring the PSOne screen.*
2. Use your cutters to remove the thin top piece of circuit board from the PSOne above where the transformer used to be. (You'll see it removed in Figure 13-8.)
3. Set the PSOne screen into the screen assembly. Check that the screen is flat against the hole. If it isn't, the edges may be bumping against some excess epoxy along the inside seam. You can use an X-Acto knife to trim away any offending epoxy and allow the screen to sit flat.
4. With the screen sitting flat, use four 3/8"-long size-4 screws with a nylon washer under each to secure the PSOne. You need the nylon washer because a 1/4"-long screw is too short, and a 3/8"-long screw is too long. The washer approximates an in-between size.
5. Fold the cables up so that they go toward the top of the screen assembly, and hot-glue them in place. Keep them about 2" apart in the center so that they won't get in the way of the CD holder.

The PSOne screen and assembly should now appear as seen in Figure 13-8.

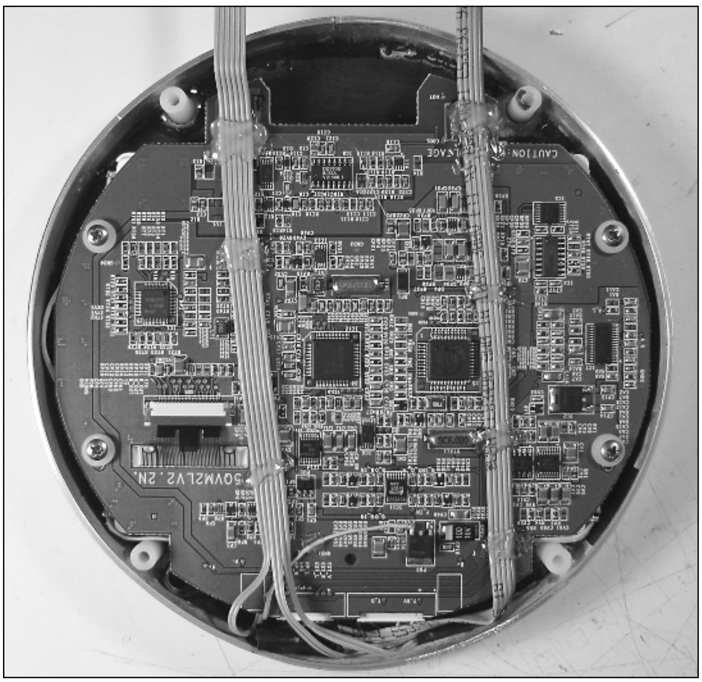


FIGURE 13-8: The PSOne screen and assembly thus far.

Cutting and attaching the rear screen plate

With the front portions of the screen assembly ready, we can now work on building the rear screen plate to close it up.

1. Print the file "Rear Screen Plate.pdf." You'll find a *hinge plate* and *teeth* on the printout as well.
2. Remove the circle from the main paper by cutting about 1/2" around it. This gives you room to tape the circle down on the same color of engraving plastic that you used for the front screen plate. Drill the four 1/8" holes first, and then cut the inside shapes and finally the main circle.
3. Cut all the grooves again, then snap the circle shape free of the plastic. (Use the same techniques you used for the front screen plate.) Drill holes to wedge out the inner square and circle shapes.
4. Sand the back (inside, noncolor side) of the rear screen plate plastic near the top where the rectangle-shaped hole is.
5. Drill the 1/10" holes in the hinge plate, and cut it out of engraving plastic. (We'll cut out the teeth later.)
6. The rectangle-shaped hole in the rear screen plate will contain the hinge. Place the hinge plate in it, and superglue a 3/4"-long, 1/4"–outer diameter nylon spacer on the top portion of the hinge plate (as shown in Figure 13-9).
7. Superglue a 1/4"-long, 1/4"–outer diameter nylon spacer on either side of the 3/4"-long spacer. Note that these two spacers are being glued to the rear screen plate.
8. Use your hacksaw to cut a 2-1/8" long piece of the 3/32"-thick steel rod. Place this through the three spacers. You now have a hinge. Tilt the hinge plate back and forth. If it hits or snags in certain places, use your X-Acto knife to shave plastic off it until it tilts smoothly. The completed hinge should appear as shown in Figure 13-9.

Caution

When making cuts on small items like the hinge plate, take extra care not to cut yourself. Whenever possible, grip the parts with pliers in order to keep your fingers away.

9. Place the rear screen plate against the main screen assembly. The hinge should be on the inside and at the opposite end of where the select/start buttons are.
10. Thread the two cables through the rectangular slots on the rear screen plate.
11. Drive a 3/8"-long size-6 screw into each of the four screw holes on the rear screen plate, checking that the two ribbon cables stay away from the hole in the middle. Again, be sure you've made reference marks on the loose ends of the screen cables before sealing up the screen. (It saves headaches later.)

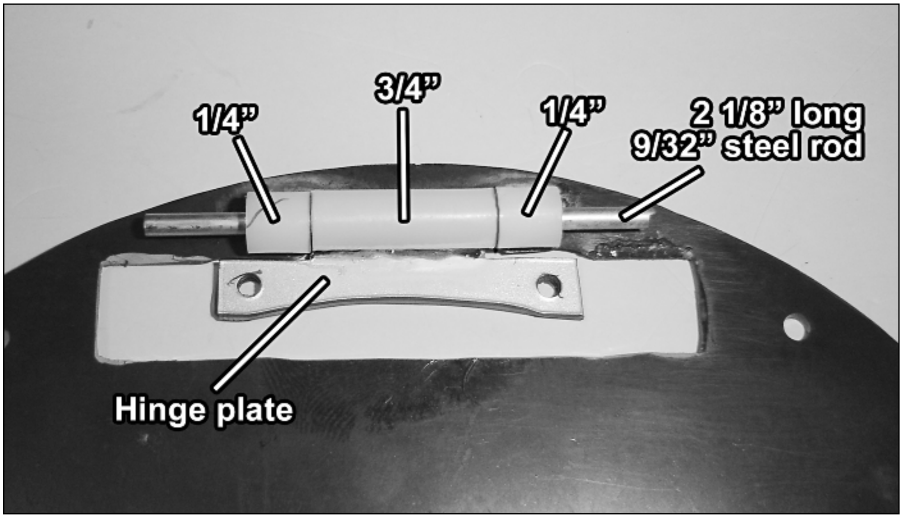


FIGURE 13-9: The nylon spacers, steel rod, hinge plate, and rear screen plate.

Building the Main Case

Once the screen assembly is done, we can start building the main case. It will be the largest part of the portable, at 8-3/4" wide, 5-1/4"tall, and 1" thick. It will contain the built-in Player 1 controls, the speakers and the simple mechanism that allows the screen assembly to pop open and reveal the disc. The screen assembly itself also attaches to the main case. (It's quite an important part of the case, as you've probably gathered!)

Cutting the front case plate

We'll start by cutting the *front case plate.* This is a 1/16"-thick piece of engraving plastic that gives the entire main case its shape. It also has several holes cut in it for the controls, speakers, and CD-ROM. To cut it, use the following procedure:

1. Print the file "Front Plate.pdf," tape it to engraving plastic, and cut the grooves as with the previous plates in this chapter.
2. There's a square on the pattern, which goes off the edge of the main shape at the bottom of the large main CD hole. For this shape, make one light *guide groove* with your knife on the up and down lines, but don't snap the shape itself out of the main plate. If you do, it'll be hard to apply to the walls correctly. We'll use these *guide grooves* for reference and removal later on.
3. Print the file "Front Plate Screw Posts.pdf " and cut out the main shapes and the double circles. Sand the back of the front plate and tape this pattern to it.

4. Since this project requires the screw posts to be of nonstandard height, superglue down nylon spacers in the following way:
   - For the 3/8" spacers, first glue down two size-4 nylon washers, and then a 1/4" spacer on top of that to make a 3/8"-tall spacer.
   - For the 5/8" spacer, glue down two size-4 nylon washers, and then top with a 1/2" spacer to make it 5/8" tall.
   - For the 1" spacers, glue two 1/2" spacers on top of each other.

Attaching the aluminum wall

The aluminum wall of the front case will be made from your 1" wide by 1/16" thick aluminum strip. To bend and attach it to the front plate, do the following:

1. Begin by using a hacksaw to remove a 3/8" × 1/4" rectangle from the corner of one end. This empty space is where the on/off switch will go.
2. Now let's start bending and attaching the aluminum to the front plate. The notched end should be touching the plastic and just to the left (when viewed from the front) of the four main buttons. Figure 13-10 shows where the notched end should start on the plate.

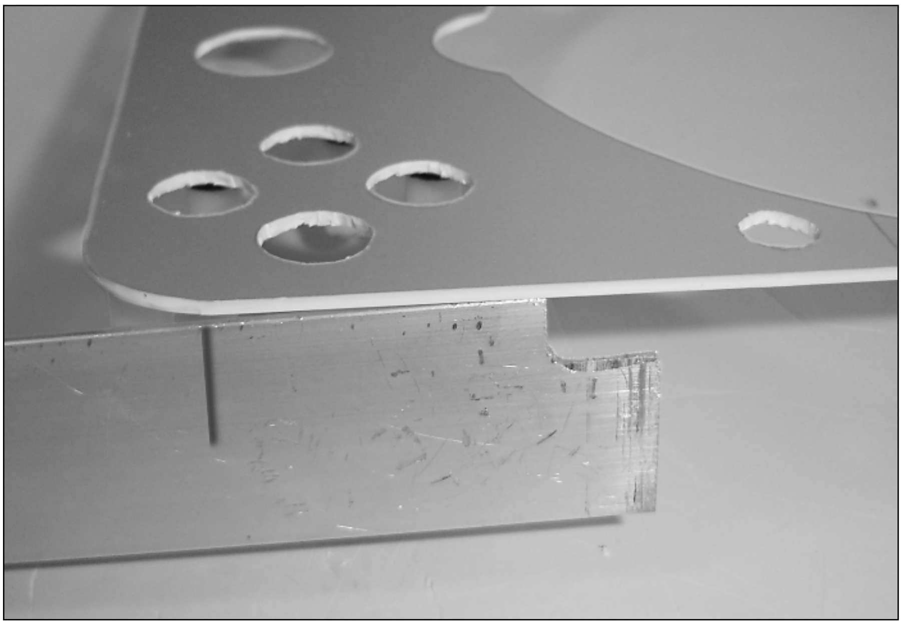


FIGURE 13-10: Where the notched end of the aluminum should start.

3. To bend the aluminum around the front plate, make a mark on the aluminum at the beginning of the first bend, as shown in the photo (the upper right-hand corner of the front plate).
4. Grip just before the mark with large pliers, and bend the aluminum to match the upper right curve of the front plate.
5. With the aluminum bent around the first curve, mark where the next curve begins.
6. Repeat Steps 3–5 for the remainder of the curves around the front plate.

Once the aluminum stripe has reached all the way back around to the beginning, it should appear as in Figure 13-11. Make a mark where the ends meet, and cut off the aluminum at that point with a hacksaw.

FIGURE 13-11: The aluminum bent around the front plate.

You can now use superglue and epoxy to attach the wall to the front plate. While this is done in a similar fashion to the gluing of the wall to the screen, you should observe these instructions as well:

1. Bend the aluminum in so that it sits in the right shape (to match the front plate) on its own. If you have to bend it and hold it in order to glue it in place, then there's a chance it may spring out of position before the glue dries.
2. When using superglue, be careful not to let any leak onto the front of the case. It's even easier to get superglue on your fingers, and then accidentally touch the front of the case without thinking! It *will* mar it, so be careful.

3. It's even more important to keep the wall flat while letting the glue dry, mostly because the more wall there is, the more it can bend. Glue one side, let it dry with a heavy flat object on top, apply epoxy, let dry with heavy flat object, and then repeat for the other side.

Tip

Have a rag or old color-striped gym sock from the '80s nearby to wipe excess superglue off your fingers before you can accidentally get it on the case.

Drilling holes in the aluminum wall

We now need to drill some precisely placed holes in the aluminum wall so that we'll have a place to attach the latch assembly. (The latch assembly will be built and attached in the next section.)

1. Print the file "Latch Assembly.pdf." We'll get to the lower portion of the printout in a minute, but for now we're interested in the *front hole template* part of it.
2. Cut out the rectangle shape of the front hole template. It should measure 1" × 2 7/8".
3. Tape the template to the bottom side of the aluminum wall. When you cut the front plate, you made some guide grooves at the bottom of the large CD hole. Line up the small rectangle on the template with the two guide grooves. The template should be exactly as tall as the wall, and centered horizontally across it.
4. Drill the four holes using the bit sizes specified on the template. Inside the larger holes are 1/8"-wide "starter holes". Drill the starter holes first, then switch to the bigger bit and use the starter holes as a guide to make the final, wider hole — this improves accuracy.
5. You can now cover the aluminum wall with your 1"-wide vinyl stripes. (Or other wall covering — see the materials list.) Keep the vinyl directly over the aluminum, and don't stray over the edges of the engraving plastic. Use your X-Acto knife to cut out the holes covered by the vinyl.

Making the latch assembly

There's one last aluminum-based part to make, and then we're done with aluminum — I promise! Called the *latch assembly*, it's a spring-based button which is connected to the aluminum walls and allows the lid of the PSOne portable to pop open.

You should have some extra 1/2"-wide aluminum strips left over from the screen assembly. Get them out, because we'll be using them here. You'll need a piece about 5" long, but bend it as directed first and cut the excess off afterward, just to be sure you use the right amount. (Too much is better than not enough, I always say!)

Figure 13-12 shows a top-down view of how the latch assembly is put together. You've already printed out this drawing (along with the front hole template), so you have an actual-size version as well. Following is the how-to list for making this thing.

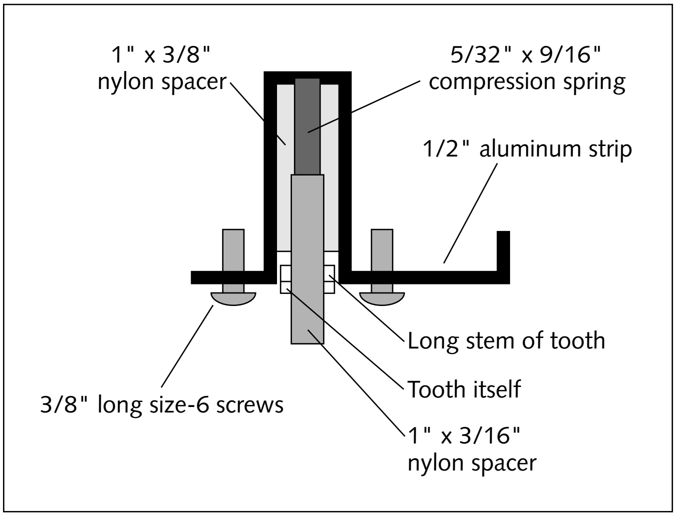


FIGURE 13-12: The latch assembly with parts labeled.

1. Start by bending the aluminum, using your actual-size printout as a guide for the sizes. From left to right, it's 1/2" over, then 1-1/4" up, 1/2" over, 1-1/4" down, 1" over, and 1/4" up.

   You won't be able to make perfect corners as shown in the drawing, but that's okay — this assembly goes in a spot that has lots of free space. (If you have a workbench-mounted vise, it will help with the bending quite a bit.) Two things are important, however:

   - The aluminum that goes along the sides of the 1" × 3/8"nylon spacer should touch it on both sides. This keeps the teeth from falling out. (More on than when we get to the teeth.)
   - The aluminum at the top of the 1" × 3/8" nylon spacer should sit as flat against it as possible so that the spring stays inside the spacer. This ensures that the button and teeth will make the right amount of movement when pressed.

2. Sand the inside of the main slot of the aluminum where the nylon spacer will go. This allows the glue to stick better.

3. Place the 1" × 3/8" nylon spacer in the main slot, and superglue it in place. Once the superglue is set, put a fine bead of 5-minute epoxy along the sides of the spacer to further adhere it to the aluminum.

4. Insert the 5/32” × 9/16” compression spring into the large nylon spacer. Insert the 1” × 3/16” nylon spacer on top of it. This is your *lid open button.*

5. Hold the latch assembly inside the front of the case and press the lid open button through the 3/16” hole you drilled in the previous section. Make a mark on the latch assembly’s aluminum through the 1/8” holes on the sides.

6. Take the latch assembly out and drill 1/8” holes on the marks. Make sure your marks are accurate and centered on the 1/2”-wide aluminum. This assembly will be very close to the CD, and if it’s not built correctly, it might hit it.

7. Use two 3/8”-long size-6 screws to attach the latch assembly to the inside of the front of the case. The tab with a hole in it should be on the right-hand side (when viewed from the front).

8. Insert the 3/16” × 1/4” *tubular rivet* in the outside end of the spacer for the lid open button. If it doesn’t fit tightly, use some superglue to affix it. Press the button in and out to see how well it’s moving. If it’s a little tight, try adjusting the two size-6 screws on either side.

Tip

If bending aluminum for the latch assembly is kicking your butt (a.k.a., not working) you can try making it out of pieces of extra engraving plastic. Use lots of epoxy and superglue for the seams, however, as they will be under considerable strain during use. (You know, with those springs and all.)

9. Before we can continue, we need to remove the engraving plastic between the lower guide grooves. Drag your X-Acto knife along the two groove lines a few more times. (Drag the knife toward the inside of the unit so that if you slip, you don’t gouge the vinyl on the outer wall.)

10. Once you’ve made the grooves deeper, crack out the 3/8”-wide section using your needle-nose pliers. Hold down the engraving plastic on either side as you do, so that it won’t crack off from the aluminum.

The latch assembly should look like what’s shown in Figure 13-13 at this point. Notice how the removed piece of plastic is the same width as the large spacer. Coincidence?

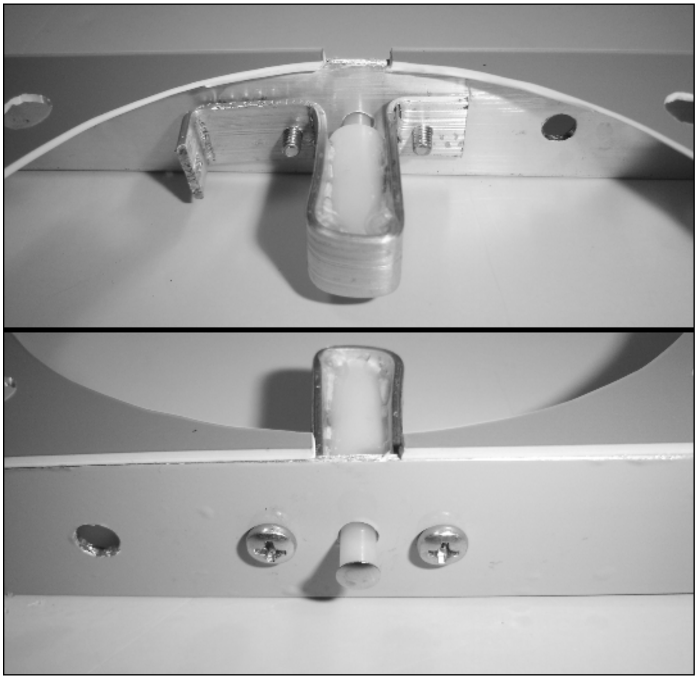


FIGURE 13-13: The latch assembly installed in the case, front and rear. (Shown with somewhat-less-than-stellar aluminum bending.)

All right, now we can apply the teeth to the lid open button. There's no real guide for this, so we have to mostly "eyeball" things. Cut out the small teeth you printed a while back (they were on the same page as the *Rear Screen Plate*) and do the following:

1. Set the teeth on the sides of the lid open button and see where it will touch the button. Sand the insides of the teeth at these spots so that glue will stick.
2. Set a piece of engraving plastic on the edge of the front plate. Fold a piece of paper over a couple of times, and set this on top of the engraving plastic. (This gives a height slightly higher than the engraving plastic alone.) The teeth should rest on the top of this, with the straight portion touching the outer aluminum wall. This ensures the teeth are at the right height to catch inside the rear screen plate.
3. Glue the teeth to the sides of the lid open button. Once they've somewhat stuck in place, press the button in and out repeatedly. This keeps the glue from sticking to the aluminum walls. Once they're superglued in, use small amounts of epoxy to further secure them. Put in as much glue as you want, as long as it doesn't stop the button from moving in and out.

The glued-in teeth should appear as shown in Figure 13-14. The engraving plastic/paper spacer is also shown.

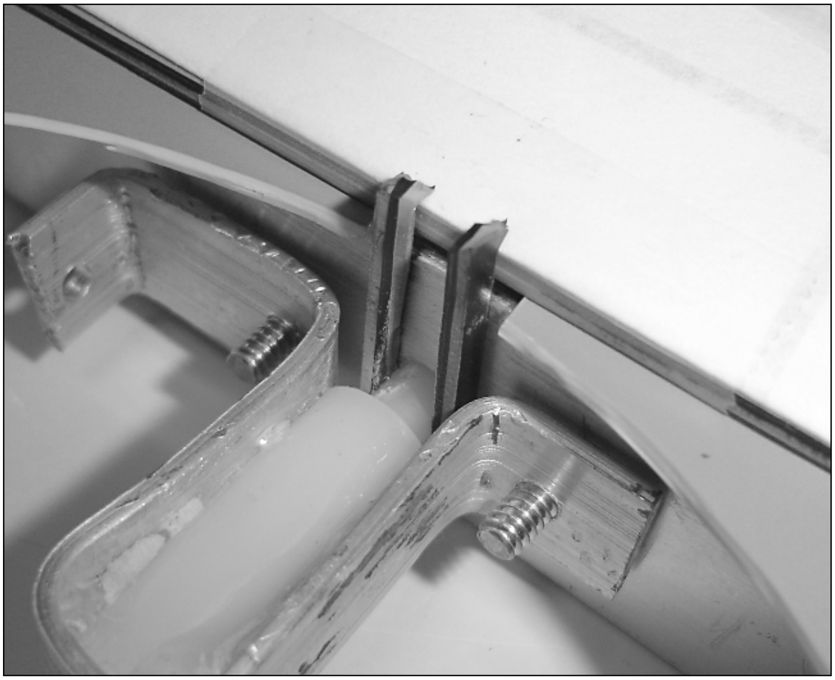


FIGURE 13-14: The teeth attached to the lid open button and resting on engraving plastic and folded paper.

Tip

If superglue does spill someplace on the lid open button where you don't want it to, quickly start pressing the button in and out. Keep doing that for a minute or two. This prevents the glue from drying correctly and sticking the moving pieces together. You may still need to go in and carve away excess glue with an X-Acto knife, however.

Installing mesh and speakers

Now that the teeth are installed, we can move onto installing the speakers. The "mesh" part is the screen-door mesh that we'll put in front of them so they'll look better.

1. Cut out four 2" × 2" pieces of the plastic screen-door mesh.
2. Place two layers of screen mesh inside each speaker hole. Have the second layer rotated at an angle so that the mesh doesn't line up to the previous layer. This creates a "denser" looking mesh.

3. Superglue the edges of the mesh to the front plate. Then cut the excess off with your X-Acto knife.
4. Place the speakers over the mesh, rotated at a 45-degree angle relative to the sides of the case. One side of each speaker should touch the lower 1” screw posts.
5. Use hot glue to secure the corners of the speakers. Be careful not to get hot glue on the main mesh portions, or it may be visible from the outside of the case.

The results of this gluing extravaganza are shown in Figure 13-15.

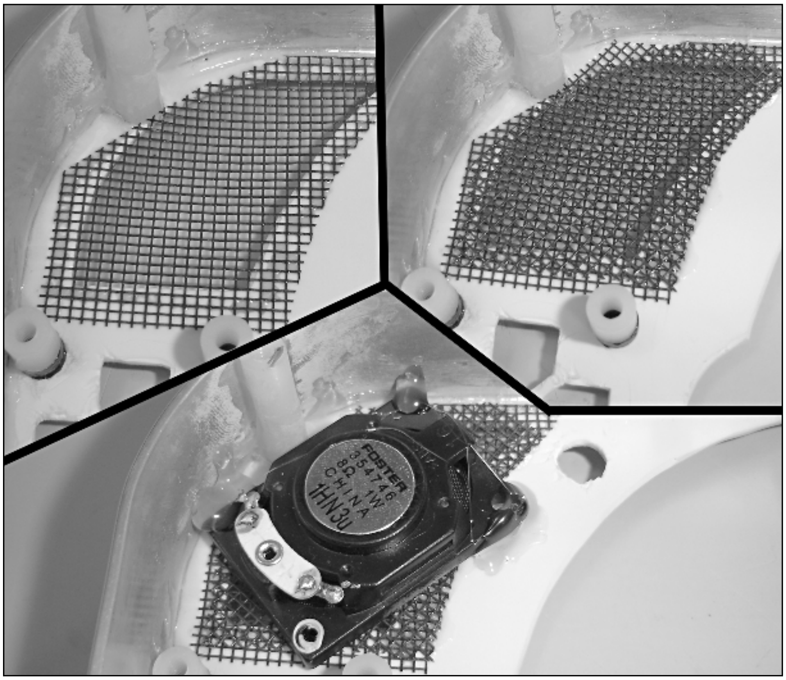


FIGURE 13-15: Speaker mesh layer 1, then with layer 2, then with speaker.

Attaching the screen assembly to the main case

With the main case built, we can now attach the round screen assembly to it. This is the last step before we start working on the rear panel (which I promise will be easier than the front has been!).

1. Tilt the hinge portion on the screen assembly down as far as it will go. Insert two 1/4”-long size-4 screws into the holes. Drive them just until they reach the other side of the hinge.

2. Set the screen assembly onto the front plate and line up the screws to the holes, and then drive them into the front plate. You may need to use a small screwdriver in order to have enough room to screw them in.
3. Bring the lid down onto the front plate. The teeth should "click" into the small rectangular opening on the screen assembly.
4. There are four holes in the front plate to receive the screws on the screen assembly. If one misses slightly, engrave the offending hole with an X-Acto knife.
5. On the inside of the main case, put a layer of epoxy over the size-4 screws and the wall. Since that piece of plastic is thin, it's going to need extra support. Even if you're using 5-minute epoxy, it's best to let it cure overnight. (While you wait, you can work on another section, like the rear panel, or watch TV — or anything, I guess.)

Making the Rear Plate

The *rear plate* will be cut from a 1/16" piece of engraving plastic and be the same size as the front plate was. However, it will not have walls attached. Instead, it simply screws directly to the back of the main case. The rear panel contains the PSOne board, shoulder buttons, Player 2/memory card port, and battery holder. To make this plate do the following:

1. Print out the file "Rear Plate.pdf" and tape it down to a piece of engraving plastic. You'll notice there are small shapes attached to the sides like parasites. They've been placed like that to reduce the total number of cuts you must make. (Aren't I nice?)
2. Drill all the holes as indicated on the pattern, then cut the grooves and remove all inner shapes, using the same method that you used for the other plates thus far in this chapter. Cut and remove the side pieces (such as the battery contact cover and shoulder button plates) from the main rear plate as well. Set them aside for later use.
3. Attach the *battery tabs* to the four 1/10" screw holes in the center of the rear plate in the following way:
   - Place a size-4 nylon washer on each 1/4"-long size-4 screw. Screw this into each hole on the battery tabs until it pokes out the other side.
   - Place another size-4 nylon washer on this side.
   - Set the battery tab against the rear plate, and drive the screws into the plate. On the other side, the end of the screws should be flush with the surface (not sticking out). The battery tabs go up and down, with the tab portions facing the center.
4. Use your two 1/2"-long size-6 nylon screws to attach the memory card/Player 2 port to the top center screw holes. Since there's a gap difference under the screw holes in the port, you'll have to put a size-6 nylon washer under the left screw. (You'll know what I mean when you see it.)

5. On the inside of the rear plate, the nylon screws will be sticking through. Use your cutters to snip them off so that there's only a slight nub of them left sticking up. (Later on you can further secure these screws with superglue if you wish.)

The rear plate, battery tabs, and memory card/Player 2 port should now appear as in Figure 13-16.

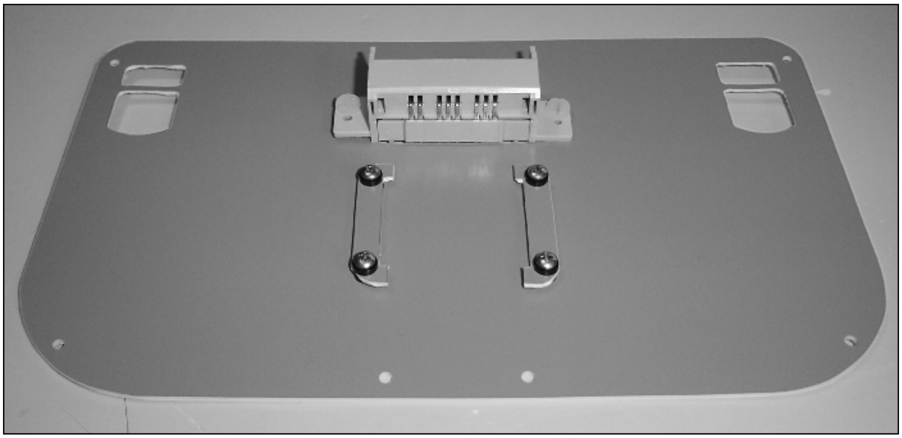


FIGURE 13-16: How the rear plate should look at the moment.

Now we need to cut some parts of out 1/4"-thick balsa wood. This will be used to make the *shoulder buttons* and a *battery contact cover* that will cover the battery terminals.

1. Print the file "Balsa Parts.pdf" and tape it down to your 1/4" piece of balsa wood. (Or other semisolid, easy-to-cut, 1/4"-thick material.) Note how everything is along a straight line, so you can put the pattern to the edge of the wood to reduce the number of cuts that you have to make.
2. Using a sharp new X-Acto blade, cut along the guidelines. When going *against* the grain it'll take a good three to four cuts to go all the way through, whereas *with* the grain you can do it in one to two cuts. You'll notice small rounded corners on the parts; just cut them straight for now.
3. Remove the parts from the main piece of balsa. Test to see how well the shoulder buttons fit through their holes in the rear plate. Sand the corners of the buttons to make them fit better. (That's why we skipped cutting rounded corners — this is much easier.)

At this point, you can paint the balsa parts if you wish. (You don't have to paint them, but as the only wooden things on this portable they may stick out like proverbial sore thumb.) A good way to do this is to small drive nails through a thin board or empty soda box, then lightly press each balsa part onto a nail. You can then spray-paint it from all angles. (I'd suggest a black or gray color.)

While the paint on your balsa parts is drying, let's insert the *battery leads* into the rear plate. To make these leads, we'll be using the male leads from a Molex connector—we talked briefly about this in a previous chapter ("Making Your Sony PSOne Portable"), but we'll get more detailed now.

1. The male Molex leads come connected together. Snip them apart, and then continue snipping, as shown in Figure 13-17. Get your soldering iron heated up, as you'll be using it very soon.

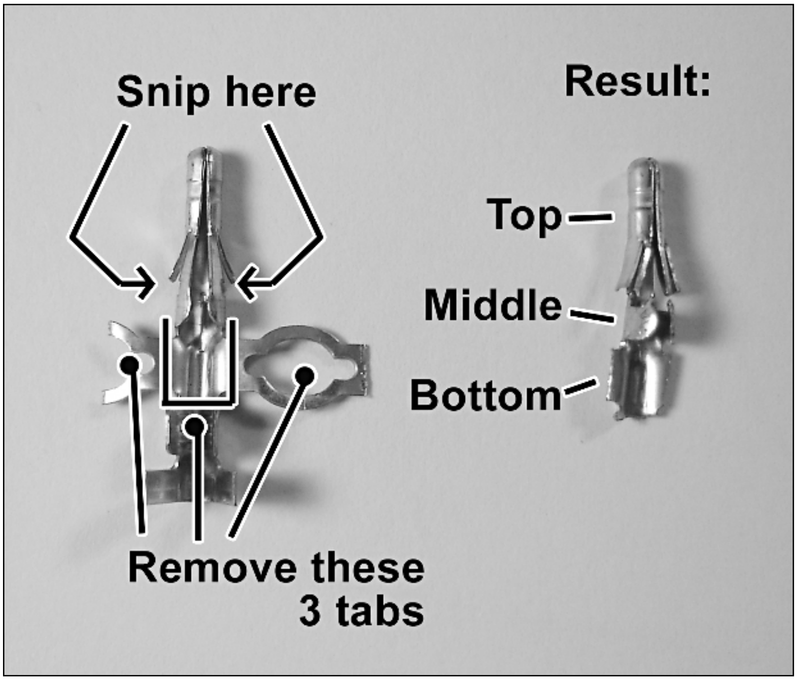


FIGURE 13-17: Where to snip the lead and what the resulting portions are called.

2. Press the lead into the rear plate from the inside. The *top* portion should be on the outside of the rear plate, the *middle* portion on the inside, and the *bottom* portion sticking out the other side of the plate.
3. Bend the *top* portion over so that it points up. This is why you needed to snip those small sections on the side.
4. Insert a Sony Infolithium battery between the battery tabs and slide it down onto the leads. If it doesn't fit between the battery tabs, use your X-Acto knife to shave the sides of them slightly. The battery should fit tightly.
5. With the battery holding the tops of the leads, bend the bottom portions so that they sit flat against the inside of the rear plate.

6. Fill the inside of the lead with solder. This will give it solidity, and also melt the plastic around the lead, helping it to hold it in place.
7. Connect a 10" wire to each of the battery leads on the inside. These will be called the *positive and negative battery wires.* When viewed from the rear, the left lead is negative, and the right lead is positive. Mark the other ends of the wires so that you can tell them apart later.
8. Superglue the 1/4" battery contact cover over the leads on the outside of the case. Then glue the thin battery contact cover over that.

Attaching the rear plate screw posts

At this point, we can attach the rear plate screw posts, as well as the shoulder button assemblies.

1. Print the file "Rear Plate Screw Posts.pdf." Cut the outside shape out of the paper and the inner circles that as labeled (such as 1/4" spacer). A few additional shapes are provided for reference when taping down the pattern.
2. Tape the pattern to the inside of the rear plate. Cut out a hole for you to snake the battery wires through so that they won't mess things up.
3. Superglue down the three 1/4" spacers. These will be called the *CD ROM drive mounts.*
4. Around the shoulder buttons, you'll see circles labeled *Size 6 Nuts & Washers.* For each of these, glue down a size-6 nut. Sand the top and bottom of the nuts first (and the washers coming up) so that they'll stick well.
5. Set (but don't glue) a size-6 washer on each size-6 nut. Then place a bit of superglue on the tops of the washers. Then take the *shoulder button plates* (these were cut along with the rear plate) and set them down on the washers, using the marks on the pattern as a guide for placement.
6. Lift the shoulder plates off — the washers should have stuck to the bottoms of them. Put some more superglue around the washers to further secure them. Press them against the plate to ensure a good bond. Do not attach the shoulder plate/washers to the rear plate yet.
7. Remove the paper pattern from the rear plate. If paper is stuck down with glue, use your knife or tweezers to remove as much of it as possible.

Making and installing the shoulder buttons

We're now ready to make the shoulder buttons themselves. Get out your painted shoulder buttons, 4.5-mm tact switches, and some thin plastic (such as that from a soda bottle or margarine tub), and do the following:

1. Cut a piece of thin plastic that fits between the three size-6 nuts around each shoulder button. Have tabs out the sides so that it holds the buttons.

2. Press the thin plastic against the rear plate, and then flip it over to view it from the outside (color side). Put a couple drops of superglue through each shoulder button hole onto the thin plastic. Press the shoulder button onto the plastic.
3. Once you've made a shape that works, place it on some thin plastic and trace it. This allows you to cut the other plastic shoulder button piece in the same shape.

Now it's time to attach the 4.5-mm tact switches to the shoulder plates:

1. Hold the shoulder plates against the size-6 nuts on the inside of the rear plate.
2. From the back, make marks through the center of each of the four shoulder button holes onto the shoulder button plates.
3. Hot-glue a 4.5-mm tact switch on each of the spots with the leads going sideways. Be sure to press them down firmly into the glue so that they're as flat against the plastic as possible.
4. Connect a three-strand of wire to each of the shoulder button plates: two going to the upper and lower leads of the tact switches, one going to a ground connection between them. (Use a bit of spare lead.) Have the wires go out on the long straight side of the shoulder button plates.

The shoulder buttons and shoulder button plates should look as shown in Figure 13-18.

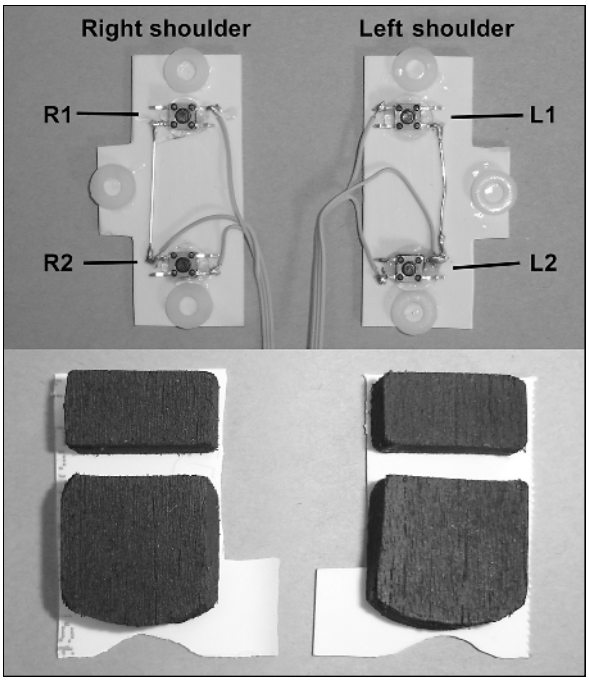


FIGURE 13-18: The tact switches on the shoulder button plates and the shoulder buttons themselves.

Note The exact shape of the thin plastic doesn't matter that much, as long as it doesn't bump into the sides (where the aluminum walls will be) or protrude toward the middle (where the PSOne motherboard will be).

Make marks on the opposite ends of the wires so that you'll know what they are later. (I used red for R1, black for ground, and no color for R2.) Set the shoulder button plates onto the nuts and superglue them in place. Make sure the buttons are clicking correctly before the final gluing. The inside of the rear plate should now look like Figure 13-19.

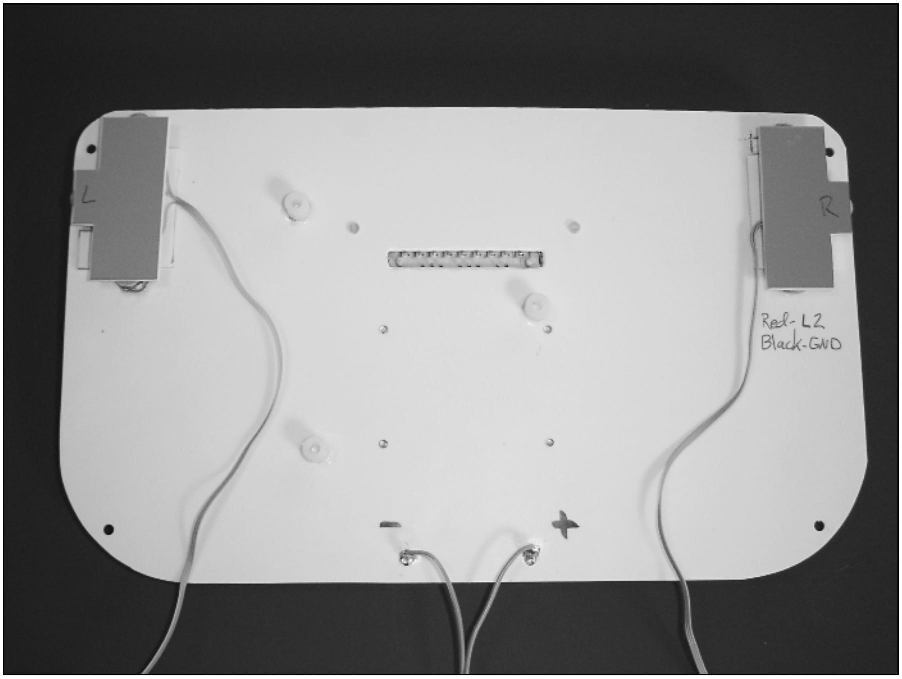


FIGURE 13-19: The inside of the rear plate thus far.

Installing the PSOne motherboard

Once the shoulder buttons and battery tabs are in place, we can install the PSOne motherboard itself. The first connections to make are from the memory card/Player 2 port to the PSOne board:

1. Lay the PSOne board, front side downward, with the Player 1/2 connections near the lower screw post on the inside of the rear plate.
2. Using solid thin ultra ATA hard drive ribbon cable, connect the eight memory card leads to the eight Player 1 memory card spots on the board. Keep these wires around 3-1/2" in length so that the PSOne board can lay as flat as possible later on.

3. Connect the nine controller leads to the nine Player 2 controller spots on the board. (For additional information on reconnecting the controller ports, see Chapter 12.) The results of both these steps should look as shown in Figure 13-20.

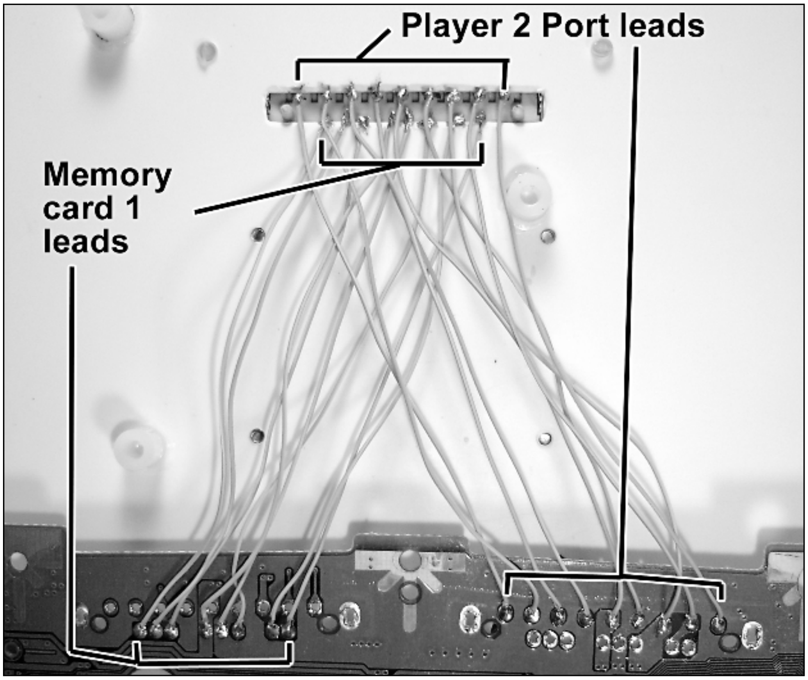


FIGURE 13-20: The memory card and Player 2 port connected to the PSOne motherboard.

Not dangerous, but may give you a headache: Make absolutely sure the memory card and Player 2 connections between the port and the board are correct here, as they'll be quite difficult to get at and fix later if they aren't. Double-check your soldering against the photos in the memory card/controller port sections of Chapter 12.

4. In Chapter 12, we identified the *positive and negative power input* spots on the PSOne board. Connect a two-strand of normal thick, stranded 10" wire to those spots, and color-code the opposite ends of the wires for later reference (*red* for positive and *black* for negative). These will be the *Positive and Negative Power to PSOne* wires. Insert them into the lead holes from the top of the board, so that the wires themselves won't be under the board after you install it.

5. Fold the PSOne board over onto the rear plate. The three nylon screw posts should go through the big holes in the board. Find the spot on the bottom of the PSOne board that touches the leads on the controller port, and cover it with a couple layers of electrical tape to avoid short circuits.

Note

You may need to bend the battery wire leads up a bit so that the PSOne board will sit down properly.

Mounting the CD-ROM drive

The CD-ROM drive and the motherboard will actually be mounted to the rear plate together. Here's how to do it:

1. Have the PSOne board folded over onto the rear plate, with the screw posts sticking through the holes. Keep the wires as flat as possible under the board. Push the PSOne board as far down toward the battery leads as possible.
2. Insert three 1/2"-long size-6 screws into the tops of the rubber feet on the CD-ROM drive. The ends of the screws won't stick out the bottom . . . yet.
3. Slide the CD read head (the thing on the drive with the glass "eye") all the way to the outer position (away from the center thing that spins the disc). If it doesn't want to move, locate the small white worm gear on the underside of the drive, and advance it manually using the tip of a small flat-head screwdriver. This will allow the CD read head to slide faster.
4. Set the CD-ROM drive onto the screw posts and drive the screws into the posts just until they make a slight grip (don't overdo it).
5. Check under the CD read head. The metallic bottom of it should be high enough that it won't touch anything on the PSOne board, with the possible exception of the 7805 surface-mounted regulator on the left. (We pushed the read head out to the farthest position in order to check this.) You can't miss it, it's got three leads, and if it graduated high school, it'd win the "Part Most Likely to Get in the Way of the CD Read Head" award. If it looks like it might collide, reverse a screw or two in order to raise the CD read head slightly.
6. Check that the shoulder button wires and buttons aren't in the way of or stuck under the PSOne board. If so, move the wires, or shave some plastic off the buttons.
7. Use our old friend — hot glue — to glue down the left and right sides of the PSOne board. Starting with the left side, place a blob under the edge of the board, press the board down firmly, and hold. Then put a good amount of glue on the top edge of the board. Repeat this for the right hand side. Put some hot glue over the battery wire leads as well.

8. At this point the PsOne board will bend slightly, up in the middle and down at the sides. This won't wreck anything, and it ensures that the 7805 regulator doesn't hit the CD read head. (You know, skyscrapers bend too — sometimes up to a foot in any direction when there's a lot of wind! So don't sweat *this* little thing.)
9. Drive down the three screws on the CD-ROM drive a little more, keeping on eye on that pesky regulator and CD read head. A gap of 1/32" between the two will be fine. Drive the three screws in by equal amounts in order to keep the CD-ROM drive level.
10. Finally, reinsert the *CD drive plug* and *access cables* onto the PSOne board. The white plastic tab at the top of the access cable shouldn't touch the disc, but you can slice it down a little if you wish.

At this point, the PSOne board, CD-ROM drive, and rear plate should look like what's shown in Figure 13-21.

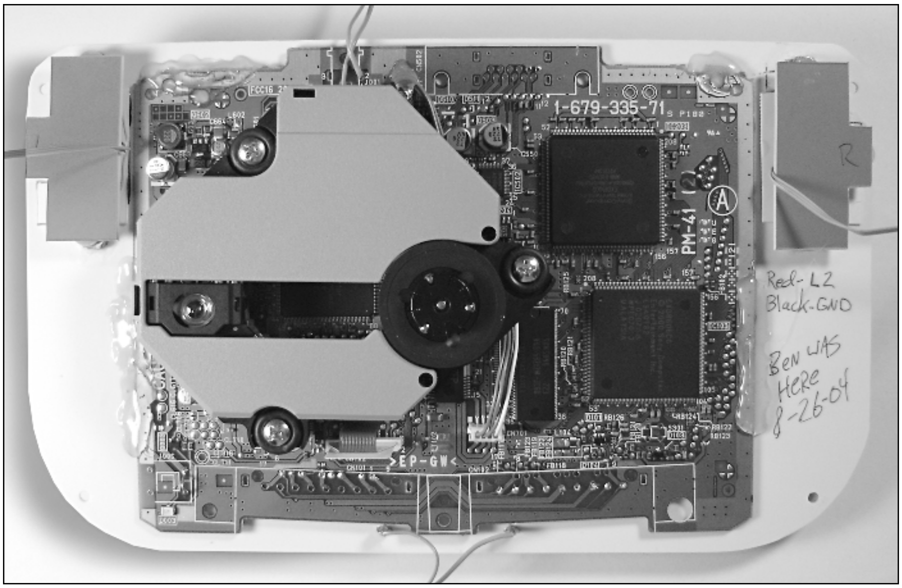


FIGURE 13-21: The rear portion of the portable at this stage of construction.

Note Remember to write *"(YOUR NAME) was here"* and the date several places inside your portable. That way if the unit ever ends up on something like PBS's *Antiques Roadshow: 2099 Edition,* the appraiser will have something to go off of.

Wiring the Unit

I'm happy to report that most of the arts-and-crafts stuff is now done, and we can concentrate on wiring the unit together. (Believe me, I'm as relieved as you are.)

We need to make four separate PC boards for this portable — the *left analog board, directional pad board, button board,* and *right analog board.* These can be cut from two PC boards, Radio Shack catalog #276-149. Figure 13-22 shows where to cut the boards and what the parts are called.

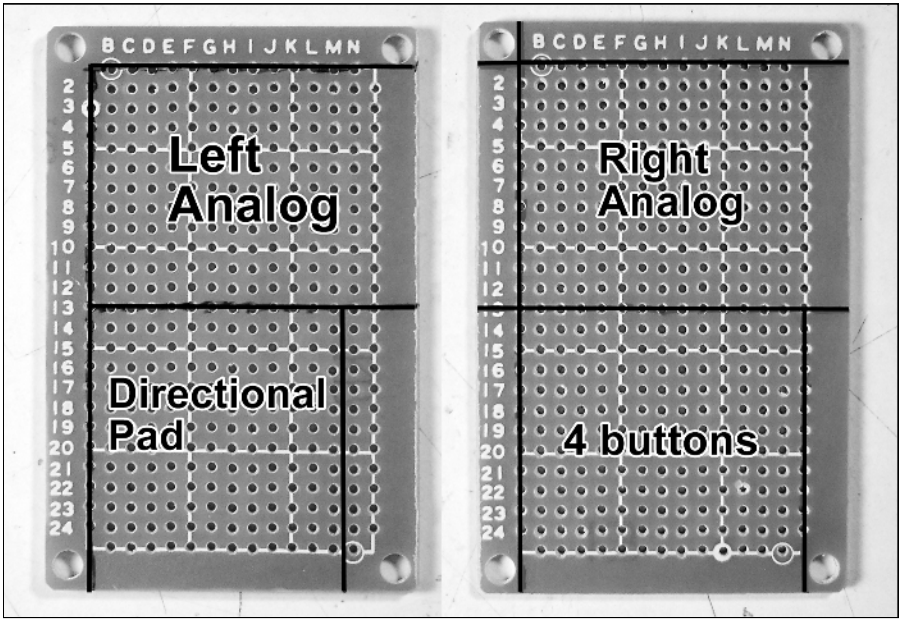


FIGURE 13-22: Where to cut the boards and what the parts are called.

To cut the PC boards, drag your X-Acto knife along the indicated lines several times to make a groove, and then snap the boards apart by bending them.

Note

The left and right analog boards are identical, and the directional pad and button boards are fairly similar, except that the button board is slightly larger.

Once you get them cut apart, it's time to place components on them, as shown in Figure 13-23.

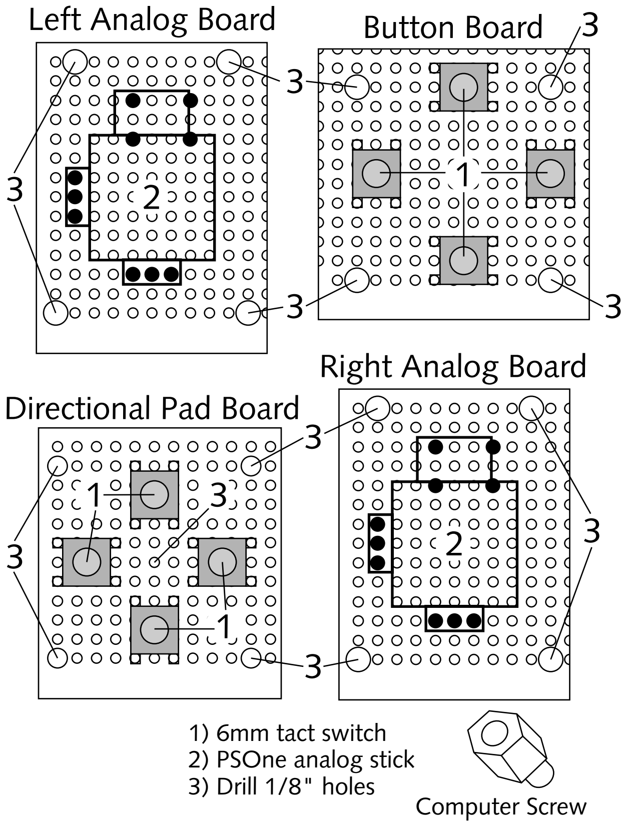


FIGURE 13-23: The placement of components on the four PC boards.

Follow these steps when placing the components:

1. Please note that the analog boards are rotated 90 degrees from their original orientation in the PC boards. The directional and button boards are not rotated. The "blank" portion of these boards (with no holes) is always toward the bottom in this portable. Mark it "bottom" and the other side "top". This will help when you install these boards in the case.

2. Remove the controller board and analog sticks from a PSOne controller as indicated in Chapter 12.

3. Remove the four big "lock down" leads that were twisted on the analog sticks. You don't need them, and they won't match the holes on the PC board anyway. Your cutters will snip them off nicely.
4. The dark circles indicate which holes the leads on the analog sticks go into. The top four tact switch leads may not fit precisely into the holes, so you may have to bend the leads around to get them to fit. As long as the six analog stick leads are in the correct position, then it doesn't matter exactly which holes the tact switch goes into.
5. When drilling the 1/10" holes, be careful not to break the edges of the PC boards. Drill straight down, slowly.
6. Drill a 1/8" hole in the center of the directional tact switches as indicated. Then screw in a computer motherboard riser screw into that spot. This is the type of screw that goes into the computer case and has a 1/4" tall hex head on it, with an opening for another screw. (A crude drawing of it is pictured in the figure.)

Making a new right analog joystick

The existing gray knob that goes over the right analog stick is too big to fit in this portable (specifically, it would hit the screen assembly when tilted left). Therefore, a new joystick must be made to fit over the right analog shaft. Don't worry — it's fairly painless.

1. Take your 1/4"-tall size-6 nylon spacer, and bore out the inside a little using a 9/64" drill bit. Hold the spacer with your large pliers, and rock the bit left and right a little. This widens the hole slightly so that it'll fit over the analog joystick shaft.
2. Remove the existing gray knob from the analog stick, and place the 3/16" × 1 1/4" *fender washer* over the shaft.
3. Place the 1/4"-tall size-6 spacer onto the shaft. It should fit tightly but still slide over it.
4. Place the 7/64" hole–size *automotive panel fastener* into the top of the spacer. The stem of the fastener will be too long, so cut off as much as necessary. Superglue the fastener on the end of the shaft.

You have now built the *right analog joystick* (new name), and it should look as shown in Figure 13-24.

Tip

You may need to cut square sides on the circular fender washer depending on how well it fits and moves in your case. In addition, if you don't like the light beige color of the washer, go ahead and paint it something to match your case. (Silver chrome might be cool!)

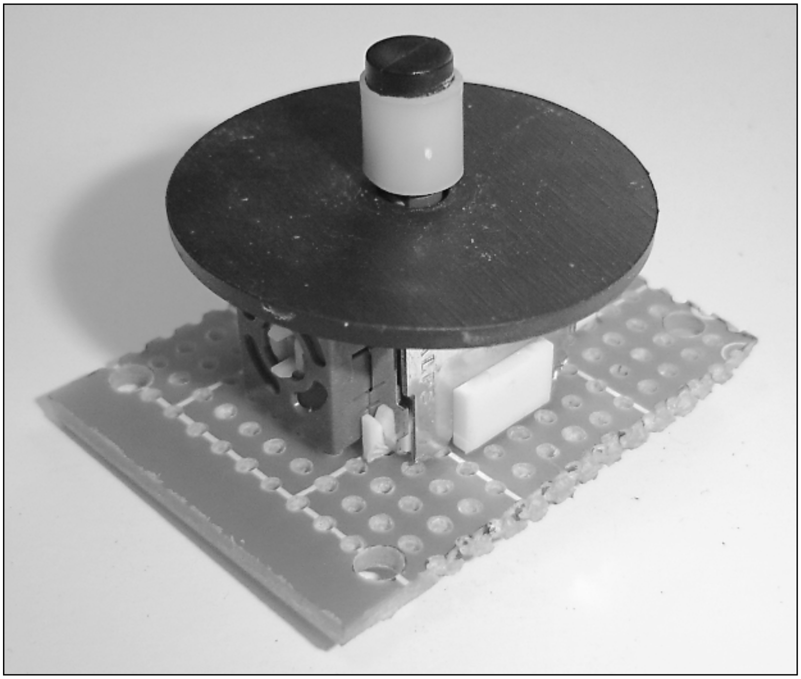


FIGURE 13-24: The right analog joystick.

Installing the PC boards

Here's the plan—we're going to install the PC boards into the front of the case, and then attach wires to the backs of them afterward. This is because these boards are fairly simple, just switches and joysticks. All connections will go directly to the controller board.

Note

The "left" and "right" directions will be as if you're looking at the unit from the front. So when looking from inside the unit, the right analog joystick goes in the left-hand slot. Also be sure to mount the PC boards with the part marked "bottom" toward the bottom of the case (where the latch assembly is).

1. Get out sixteen computer case screws. These are the stubby kind typically used to install PCI cards and to secure the motherboard down. Each PC board section will be secured with four of these screws.
2. There's a hole just to the right of the left analog stick—this is where the *Analog on/off* button will go. Remove the nut and insert the SPST pushbutton switch (Radio Shack catalog #275-646) into this hole. You won't need the put the nut back on, since it should fit tightly enough without it.

3. Just above the left analog stick is a small hole. Insert the 5-mm red LED into this hole. This is the *Analog on/off indicator light.* Cut the leads fairly short so they won't hit the left analog stick. (Just remember which lead was longer!) Connect a two-strand of 10"-long thin wire to the LED, keeping note of which wire is connected to the long (positive) lead. These are the *LED indicator wires.*
4. Okay, we can now start with actual controls! Start by installing the left analog stick in the upper left corner. The 1" screw post will most likely bump into the PC board. Use your cutter to make a small triangle-shaped indentation in the board so that it will fit. Check that the gray analog stick moves freely in all directions. If not, try shaving the hole a little bigger with an X-Acto knife. Once it fits, secure the board down with four computer screws.
5. Insert the original PSOne controller's directional pad into the four holes just below the left analog stick. Then screw the directional pad board over it. The computer screw you put on the center of the board should prevent the directional pad from pressing all four directions at once.
6. Install the right analog joystick. Check how well it moves around; you may need to trim the edges of the fender washer for best results.
7. The PSOne buttons (X, triangle, circle, and square) are hollow. Using hot glue, fill the buttons so that the glue is level with the back of the button.
8. Print the file "Button Holder.pdf." (It looks like a ninja's throwing star.) Tape it to a piece of engraving plastic and cut it out.
9. Set this *button holder* inside the four screw posts surrounding the buttons. If it's a bit tight, shave the corners with your knife.
10. Set the buttons in the holes. You may need to shave more off the button holders so that they'll fit. The important thing is that the buttons need to be quite loose.
11. The button holder keeps the buttons from flopping too far out on the unit if a person turns it upside-down. With the unit upside-down and the buttons/holder in place, move the holder up and down until the buttons stick out of the front of the case at a normal-looking distance (about 1/8" is good).
12. Once all four buttons look good, remove them, and superglue the button holder in place.
13. Place the buttons back in. Then put very small amounts of hot glue around them, but not touching them. The idea is for the hot glue to keep the buttons from rotating, so that the symbols on them always are facing the right direction. (Skip this if you wish — believe it or not, the unit will still work even if the buttons are rotated weird.)
14. Finally, screw the button board over the buttons, making sure they all click correctly. If they don't, remove some glue from inside the button.

The buttons, button holder, and hot glue drops should look as in Figure 13-25 (shown there without the button board attached).

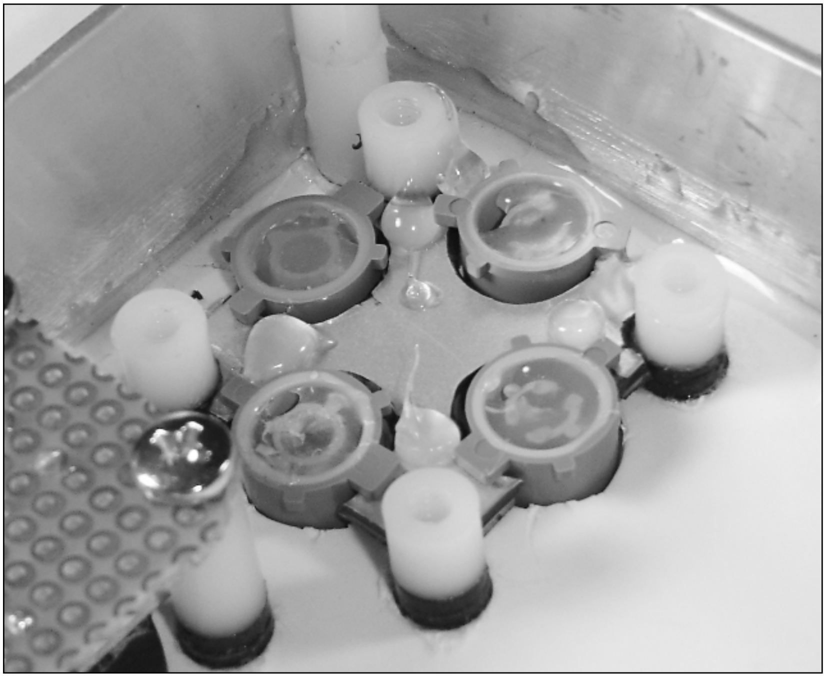


FIGURE 13-25: The buttons, button holder, and hot glue drops. (Crude, but effective.)

Wiring the two halves of the case together

We are now at the point where we can start connecting the two halves of the case together. Set the rear portion with the motherboard on your workspace, with the PSOne board facing up and the battery leads nearest you. Place the front of case (the main portion) above that, with the top of it touching the top of the rear portion and the insides up. This will allow you to fold the top down over the rear once all the connections are made.

In the following section we'll be connecting all the remaining wires. There are two rules that apply to all the wiring in this section:

1. **Keep the wires away from where the CD-ROM will be.** Hot-glue them so that they stay down, or tuck them around components, but just make sure they won't hit the CD-ROM. They won't wreck it, but could certainly kept it from spinning correctly.
2. **Keep the wires as short as possible.** Once you've figured out how to place each wire so that they don't hit the CD-ROM, cut them so that they're only as long as they need to be in order to reach their destination.

To help with this, start by hot-gluing a 4”-long 3/32” rod to the inside wall of the front case where the two ribbon cables come out of the screen assembly. (Use what’s left of the metal rod that you used for the hinge.) Place the cables under the rod, and then hot-glue the rod in place. This will now be called the *cable rod*, and the gap underneath will allow other wires to snake through as well. Figure 13-26 shows the rod and cables installed.

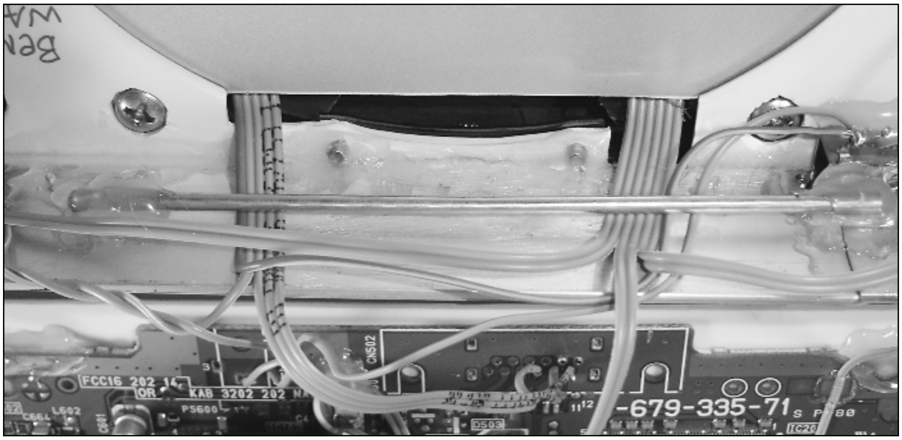


FIGURE 13-26: The rod and cables.

Note All “left” and “right” direction references will assume the case portions are laid out as described above.

Speaker wires

The left and right speaker wires come from *Screen Cable 2*. (Check back in the *Making the Screen Assembly* section to find out which wires are which.)

1. Split up the four wires into two going left and two going right from the cable rod.
2. Snake the wires around the insides of the front case until they reach the speakers. Then connect the positive and negative leads to each speaker.

Installing the DC AUX input jack

1. Get out the 1/8” phono jack (Radio Shack catalog #274-246A), and insert it into the empty hole near the lid open switch. Fasten the nut on the outside.
2. Connect wires to this plug, as shown in Figure 13-27.

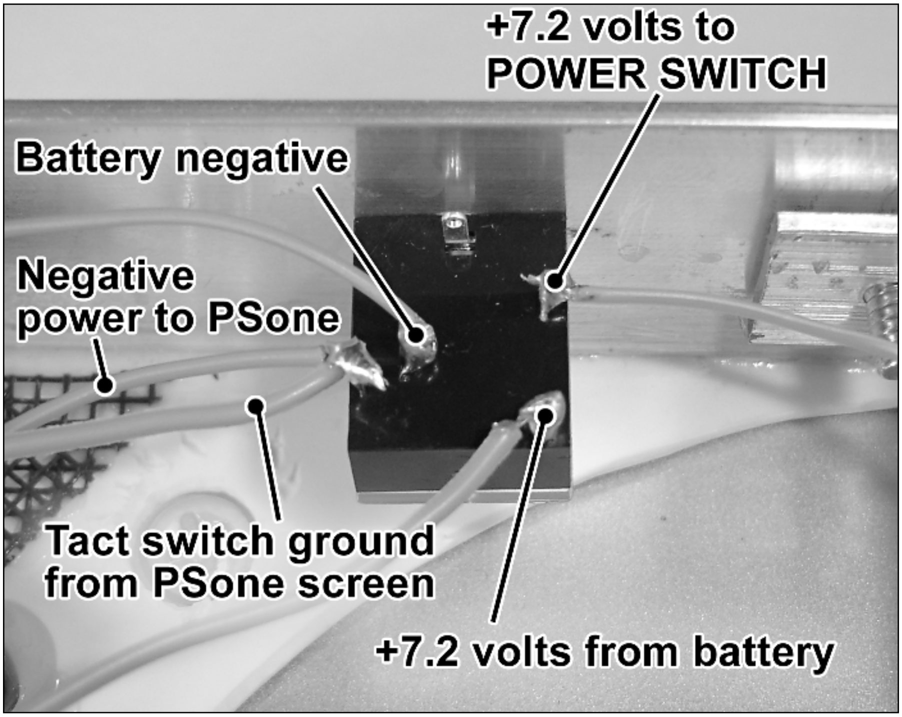


FIGURE 13-27: Connections to the 1/8″ phono jack.

- Use a 12”-long wire for the *+7.2 volts to power switch* connection. Have it go along the right side of the case (when viewed from the inside) and down along the side to the spot where the power switch will go. Use small amounts of hot glue to secure it in place along the way.
- For the rest of the wires, tuck them along the left side of the front case and down to the rear of the case. Keep them away from the left shoulder button plate.

3. Solder the *+7.2 to power switch* wire to one lead on the SPST slide switch (Radio Shack catalog #275-406).
4. Connect the other lead on the power switch to the *Positive Power to PSOne* and *+7.2 Volts to screen* wires. (A total of two wires will be attached to that lead.)
5. Place the power switch into the hole in the aluminum wall from the inside, and hot-glue it in place. You don’t need to use the side screw holes. Have the ON side (the side with the leads) going toward the center of the unit so that you flip the switch left to turn it on.

The unit now has the ability to turn on and off. Test it to see if it’s working, and if not, go back and double-check connections. If it at least turns on, then continue.

Connect audio/video to PSOne screen

There should still be three unconnected wires on *Screen Cable 1*, namely, *video in, left audio in,* and *right audio in*. Connect them to the top portion of the PSOne board as indicated in Figure 13-28. (Please note the left and right audio wires from the screen flip around when they make this connection.)

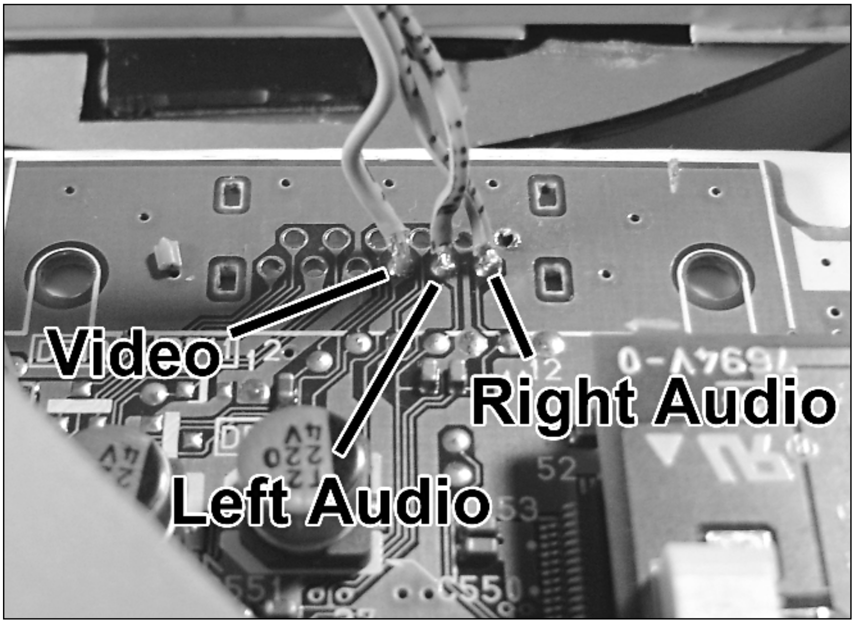


FIGURE 13-28: The video and audio connections from the PSOne board to the screen.

Installing the lid sensor switch

Get out the SPDT roller lever switch (Radio Shack catalog #275-017), and hot-glue it in the upper right corner of the front case near the right speaker. The roller part should touch the screw head through the hole and “click” when the lid is closed. Figure 13-29 shows an example of how this should look. Thus, when the lid opens, the switch opens as well.

Connect a two-strand of ribbon cable from the two right-hand leads on the switch (labeled NO and C, for “Normally Open” and “Common”) to the lid sensor switch spot on the PSOne motherboard (shown in insert on photo). This was identified in Chapter 12.

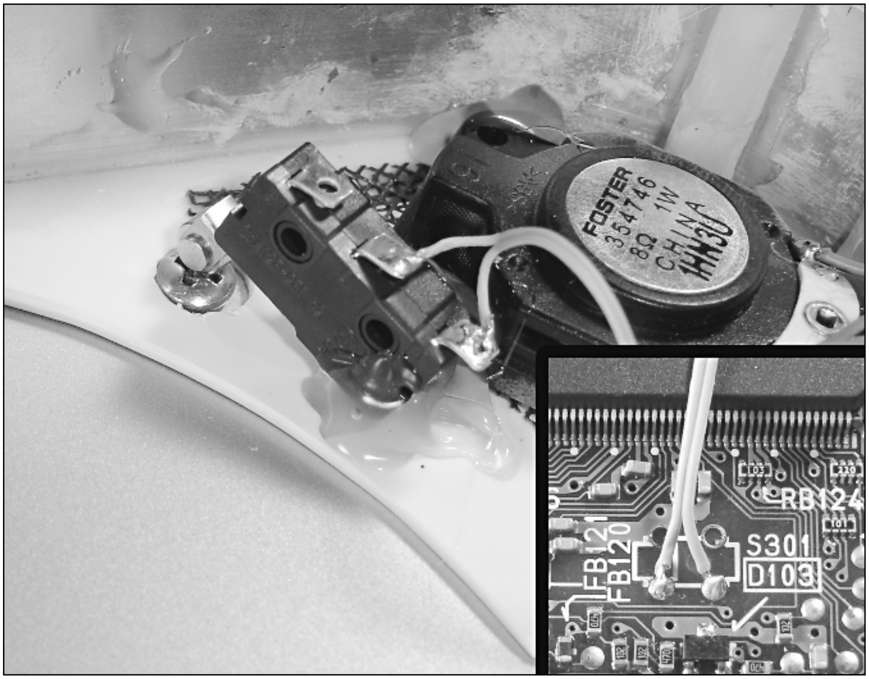


FIGURE 13-29: The lid sensor switch hot-glued in place.

Connecting the built-in controller

Okay, hooking up the built-in controller is the last of the connections, but it's a doozy! It involves wiring the PSOne controller board (from inside the controller; see Chapter 12 for more details) to all of the buttons and analog sticks.

Take the controller board from the inside of the PSOne controller, and hot-glue it just to the right of the CD-ROM drive as shown in Figure 13-30. The edge of the controller board should touch the screw post under the CD-ROM drive.

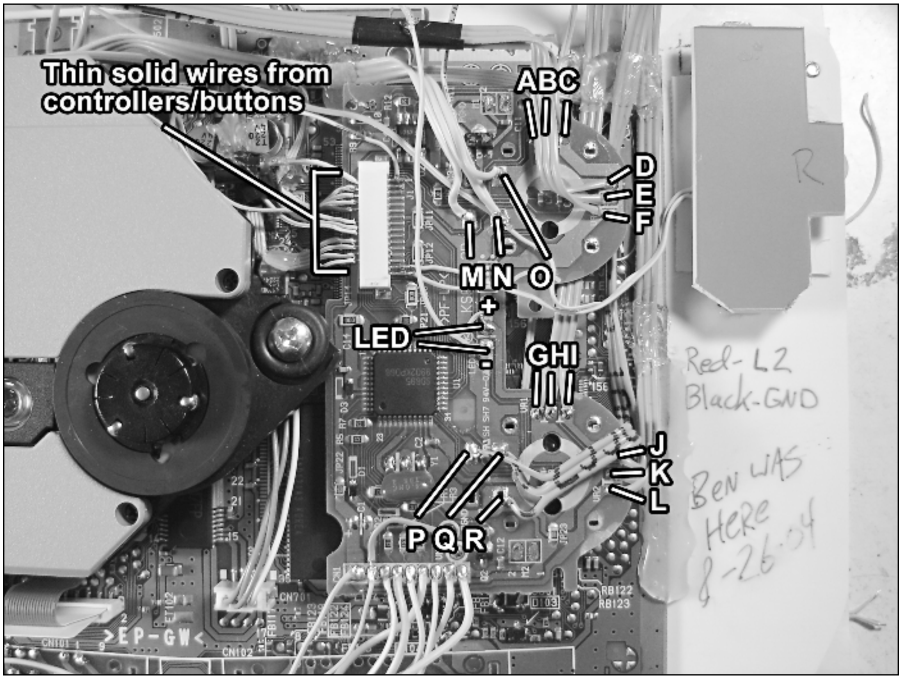


FIGURE 13-30: Placement of the controller board and pinouts.

Now it's time to connect the controller buttons to it. For everything but the analog sticks, you should use thin solid ultra ATA hard drive wire. Figure 13-31 is a drawing of how to connect these wires from the four PC boards in the front half of the case to the controller board shown in Figure 13-30. Note the ground connections going between the tact switches.

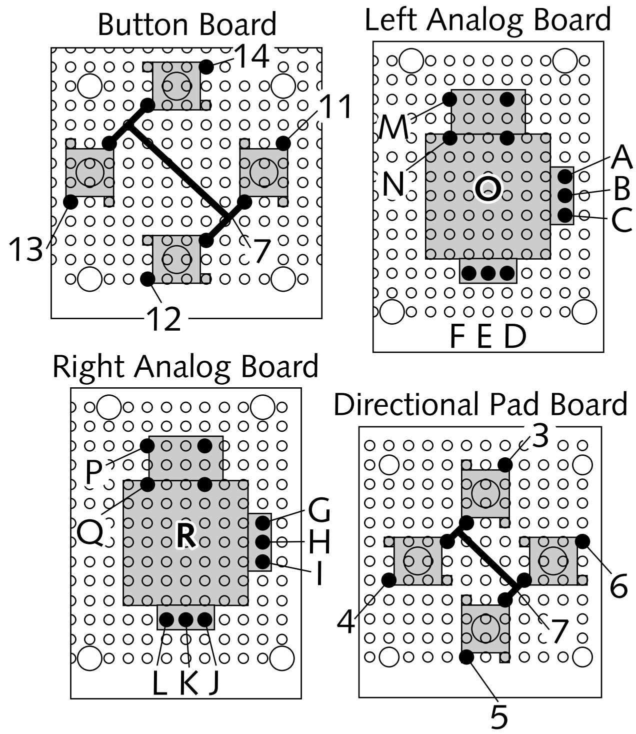


FIGURE 13-31: Wiring connections on the backs of the four PC boards.

Follow these steps and tips when wiring the controller board to the PC boards:

1. The connections on the PC boards are labeled by *numbers*. These numbers (1–16) correspond to the numbering on the controller board described in Chapter 12 (Figure 12-9, to be exact).
2. The connector on the controller board is meant to receive a flat ribbon cable. However, you can also insert thin solid wires as shown in Figure 13-30. Some models of PSOne controller boards have holes that you can solder the sixteen wires into.
3. The analog control stick connections are labeled by *letters*. Please note that you don't have to hook all four leads on the tact switches back up. You *must* use standard size ribbon cable wire for the analog stick connections in order for them to work.
4. The common ground for all the controller buttons is pin 7 on the controller board. You can also use spot "N" on the left tact switch for this connection. This way, you can hook more wires to it easily.

5. Connect the four left and right shoulder buttons to the controller board as indicated in Chapter 12. Connect the *GROUND* connections from the shoulder buttons to spot "N," as mentioned previously.
6. Connect two thin wires to the red pushbutton for the *ANALOG ON/OFF* switch. Connect one of these to the *GROUND* on the nearby directional pad PC board, and connect the other wire directly to the controller board.
7. Connect the red LED to the controller board so there's an *ANALOG ON/OFF* indicator light. Make sure the wire going to the long lead on the LED is soldered to the positive connection as indicated above.

Tip

When peeling thin ultra ATA-type ribbon cable, peel the cables alongside each other (like tearing paper), rather than AWAY from each other (like a zipper unzipping). This keeps the wiring from becoming exposed. Exposed wiring can short-circuit things!

Now, with the analog sticks and buttons connected, it's time to connect the controller board to the PSOne's motherboard. Use the wiring diagram in Chapter 12 to connect them and place the wires as shown in Figure 13-32. Be sure to connect a wire from pin 2 to pin 8 on the controller board!

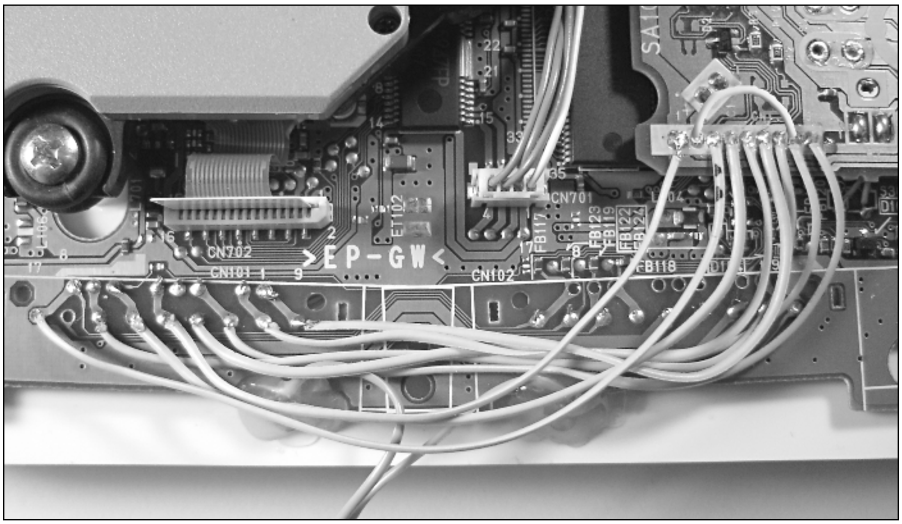


FIGURE 13-32: How to situate the wires going from the PSOne board to the controller board.

The connections are now complete! Before we close up the unit, however, we'll need to test it, which, conveniently enough, is what the next section is all about.

Testing and Troubleshooting

With the wiring complete, we can now test out the unit. In this section, I'll lead you step-by-step through what to check, and what to do if it doesn't work.

1. Start by charging up the Sony Infolithium battery. Insert it onto the battery clips and place a game disc into the CD-ROM. Make sure no wires will be brushing against the disc, and then turn the unit on. If nothing happens at all (no light, sound, disc movement, or anything), check the following:
   - Weaker Sony batteries, such as the NP-F330 they often include free with devices, aren't powerful enough to run this portable. Be sure you have a NP-F550 or better.
   - Is the white LED mod hooked up correctly? Did a power wire come loose when you connected the screen cables to the screen?
   - Check that the *+7.2 volts to screen* wire is connected to the power switch.
   - Test the wires coming off the battery leads. If you can't get a voltage reading from them, try bending the battery leads in toward each other. This creates more friction when you slide the battery on, and thus a better connection.
2. Once you get the screen to light up, see if there's a picture. The PSOne starts with a white screen and the logo along with music. If the screen lights, but there's no picture, do the following:
   - Check to see if the brightness and volume indicators appear on the screen and you can change the settings. If yes, skip the next ribbon cable–checking thing.
   - The ribbon cable attached between the LCD glass and the screen's motherboard may not be reinstalled into its jack correctly, or may have come loose during assembly. Dismantle the screen assembly and check.

     If you can see the brightness/volume indicators on the screen, but nothing else, check the following:

     Is the disc spinning? If it isn't, then the PSOne itself isn't running/getting power (see below).

     Is +7.2 volts getting to the PSOne? Use a multimeter to check the power going into the PSOne at the *Power to PSOne* spot. Also check that the polarity of the wires is correct (see Chapter 12).

     Is the *Video* wire attached correctly to the PSOne board? If so, has it come loose inside the screen assembly?
3. Once you're able to see a picture, press the + volume button to turn up the sound. If there isn't any sound, do the following:
   - Check that the volume is turned up. (I had to ask!)
   - Make sure that the left and right audio connections to the PSOne board are correct.

- Are the speaker output wires coming from the PSOne screen hooked up to the speakers with the correct polarity?
- As with the video, it's possible the connections inside the screen assembly (near the white plugs on the PSOne screen) have come loose. If the other checks fail, take apart the screen assembly and check there.

4. If picture and sound are working, the PSOne should spin the disc right away and start loading the game right after the Playstation logo appears on the screen with the black background. If it doesn't, check the following:
    - Is the CD-ROM able to spin freely? Check that wires, or the lid latch assembly, are not hitting it. If the lid latch is touching, try bending it slightly downward, away from the CD. (Note: The lid latch CAN scratch the disc if it hits it, so test the unit with a game disc that you don't care about.)
    - Are the two cables coming off the CD-ROM drive firmly and correctly plugged into the PSOne's motherboard?
    - Did you reconnect the lid sensor switch? If so, is it on the right two spots (the lower two of the four)? If so, did you connect those wires to the Normally Open and Closed spots of the level switch, as shown in the photo? If the lid is open or the switch is not attached, the PSOne goes to the CD/Memory card screen with the checkerboard background.
5. Once the disc is accessed and the game loads up, press START and try playing. It's best to use an analog-enabled game to test the controls (such as Gran Turismo or Metal Gear Solid). If the built-in controller doesn't work properly, or at all, do the following:
    - Double-check all controller connections.
    - If you inserted the thin wires into the controller board's flat ribbon cable spot, make sure none have pulled loose and are all firmly installed. (Once they all work, hot-glue them in place.)
    - Are the tact switches incorrectly rewired to the controller board?
    - Did you connect pin 2 to pin 8 on the controller board where it connects to the PSOne board?

    If all the controls work except for the analog controllers, check the following:
    - Some games require you to press the analog on button to enable it. If you can't, check that the analog on/off button (and LED indicator) are wired to the controller board properly.
    - Did you use regulator ribbon cable wires? Thin ribbon cable doesn't work when rewiring the analog sticks.
    - Check that the ribbon cables coming off the analog sticks are wired to the controller board correctly. If not, they may still work, but strangely (left goes right, or up/down and left/right may be switched around).

6. If the system switches on and off without warning or the power seems flaky, check the following:
   - As mentioned before, check that the battery leads are making good contact with the battery. Bend them up or down so that when inserted, they have more friction.
   - Also as mentioned before, be sure you're using a NP-F550 or better Sony Infolithium battery with this portable.
7. Insert a memory card in the rear slot and see if you can access it. Plug a controller in, and see if it works with a two-player game. If either or both of those tests fail, take the following steps:
   - You'll have to remove the CD-ROM drive and pry the PSOne board off the rear plate to check the connections.
   - Check the eight memory card leads under the PSOne board and see if they're all connected as described earlier in this chapter (Figure 13-20) and in Chapter 12 (Figure 12-11).
   - Check the same sections and figures if the Player 2 port isn't working.

Once you've checked over all these things, your PSOne portable is ready to be closed up and finished!

Final Assembly

Once the unit is working correctly, you can finish assembling it. This involves tucking all the wires so they'll stay put, and then screwing the halves together.

1. Begin by checking that wires will stay put and allow the case to close. Wires bunched up in certain areas, especially behind the shoulder buttons, will keep the case from closing completely.
2. Tuck the excess wires under anything possible, such as the CD-ROM drive (unless it gets in the way of the disc motion) or the cable rod.
3. Remember, the area between the shoulder button plates and the front of the case is the closet of the entire unit. Do not let stray wires sit on top of the shoulder button plates, or the unit may not close up completely.
4. Press the sides of the unit together and hold it there to allow the wires to develop a "memory" of their position. Doing this a couple of times will "tame" the wires for the final screwing-together of the sides.
5. With all the wires behaving, insert four 3/8"-long size-6 screws into the four holes in the back of the rear plate. Sandwich the two halves together and carefully drive the screws through.
6. If you're still having trouble getting the unit to close fully, insert the screws a ways and let the unit sit a while (perhaps a day or two). Then take it apart, tuck the wires down even more, screw it back together, and wait again. This will "coax" the wires into sitting properly and behaving!

Wrangling the wires to fit in the case can be one of the trickier parts of building a portable, especially one as complex as this. Once you've gotten them to behave and gotten the sides screwed together, your portable is pretty much done, though there's a couple odds and ends to take care of still. (See the following sections.)

Modifying the PSOne's AC adapter to run this unit

You can use the AC adapter you got with the PSOne screen to power this entire unit. However, you need to put a new plug on it first.

1. Snip off the old plug, and slide the cover of the new plug down the wire.
2. Solder the new 1/8" phono plug (Radio Shack catalog #274-287 on the materials list) to the wire. Connect the inside wire of the adapter to the inner lead on the plug, and the outer wires to the outer lead. The connection should look like shown in Figure 13-33.

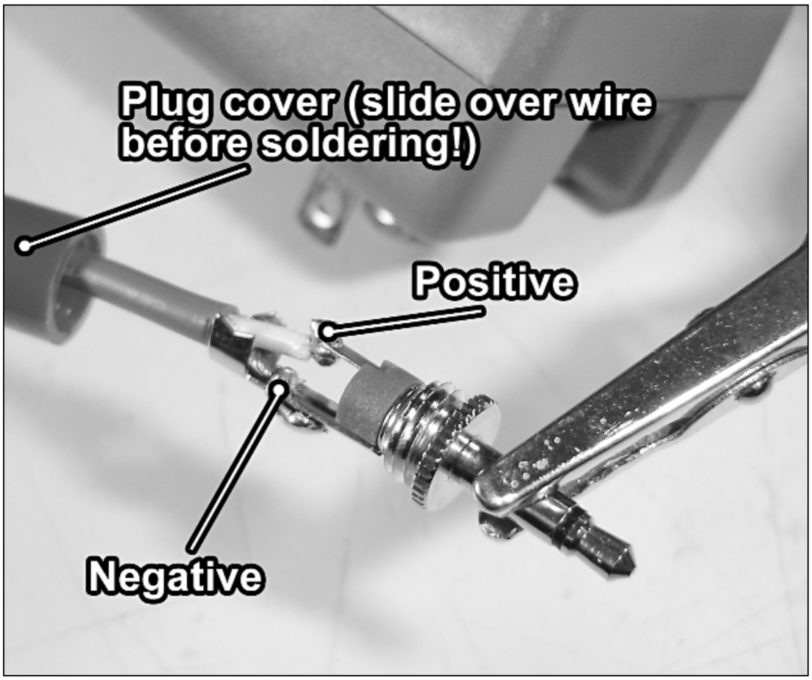


FIGURE 13-33: The wall adapter's new plug.

3. Plug in the wall adapter, and check that positive voltage is coming from the center tip of the plug, with the negative side on the outer portion.
4. Place a piece of electrical tape between them to avoid short-circuits, slide the cap back over, and screw it in place.

You can now insert this plug in the AUX DC input jack on your PSOne portable to run it off wall power. The jack will disconnect the battery when you're using the wall adapter, so don't worry about short-circuiting occurring between the two.

Placing final decals

Here we are, near the end of this long journey! All that remains is to place a few last decals on your portable in the following spots:

- **On/off label.** Just below the on/off switch. On should be facing the inside of the unit.
- **Designed/Built by label.** Just above the Player 2/memory card port, touching the top edge of the rear plate. Sign your name in the white space so you will be remembered until the end of time.
- **AUX DC input label.** Just to the left of the AUX DC input jack when viewed from the bottom.

Congratulations! With all the labels and decals applied, your PSOne portable is complete! (Remember, you'll need a big battery if you plan to cast a lot of spells in Final Fantasy VII.)

Chapter in Review

Whew! That was quite the elaborate process for making the hand-built PSOne portable, wasn't it? Let's look back at this chapter at what you did . . .

- You used patterns to cut out pieces of engraving plastic in order to form the main shapes of the case.
- Aluminum was bent (by you) around the plastic pieces to form the walls of the case.
- You installed the PSOne screen, PSOne motherboard, and the controls inside the case, and wired everything together.
- The unit was tested (again, by you) step-by-step to ensure that all of the electronics were working correctly.
- You screwed together the case and added a few final decals to finish the job.
- You're now playing your PSOne portable and enjoying every minute of it! (Except when your on-screen character dies a horrible death and you feel like throwing the controller across the room, but then hesitate, because that would be a bad idea in this case.)

Tip

If someone asks how you assembled this thing, remember—you can always recite the above recap. It's quite sufficient as-is, and won't bog them down with details.

However you use your PSOne portable and wherever you take, it I hope it provides you with lots of fun and exciting gaming action! (And if you should get bored with it, there's plenty of other projects in this book to try as well.)

Making a Portable Playstation 1 Using CNC Machinery

chapter 14

in this chapter

- ☑ Materials You'll Need
- ☑ Routing the Parts of the Case
- ☑ Assembling the Case
- ☑ Wiring the Unit
- ☑ Testing and Troubleshooting
- ☑ Final Assembly
- ☑ Chapter in Review

If you have access to a CNC machine, such as a laser engraver, and you want to make a portable PSOne, take a look at Figure 14-1 to see what you can build!

FIGURE 14-1: The CNC-built Playstation Portable.

Using a CNC machine allows us to make the case more complex than we could otherwise, while at the same time making the project easier to assemble. Since the case-building is easier, I've deferred some of the difficulty onto the wiring, but all in all, this thing isn't too hard to slap together.

In this chapter you'll collect the components needed to build this portable, and then have the parts for the case cut with a CNC machine. You'll then glue the pieces together to form the case, and then install the screen, controls, and PSOne inside of it. Finally, you'll wire everything together and test out the unit to ensure that everything's working correctly. In the end, you'll have a fun PSOne portable that you can take anywhere! Let's get started!

Materials You'll Need

Let's talk about the materials you'll need to build this portable PSOne, starting with the major game-related ones:

- A PSOne, hacked as described in Chapter 12.
- A Dual Shock PSOne controller. The kind described in Chapter 12 works fine, and you can also use later-model Playstation 1 controllers (such as the transparent Dual Shock ones from '98–'99) as well. Since those controllers are transparent, they're easy to check for compatibility — simply look to see if the controller board inside matches the photos later on in this chapter.
- A Casio EV-680, modified with white LEDs as described in Chapter 4. It will also need to be further modified to work with this project — specifically, the two circuit boards on it should be folded over one another. This is the *folded reconnecting method* that was described in Chapter 4 as being required for this CNC-built PSOne portable project.

Electronic parts

Next up are the electronic parts you'll need, listed in Table 14-1. For your convenience (and to ensure that what you buy matches what I bought), the majority of these can be found at your local Radio Shack. The final two items can be ordered from Digi-Key at `www.digikey.com`. If you're ordering white LEDs from Digi-Key, you may as well add the rest of this stuff on, and get it all at once.

Table 14-1 Electronic Parts List for CNC-built PSOne Portable

Part Name	*Available From:*	*Part or Catalog #*	*Quantity Required*
General-purpose PC board	Radio Shack	276-147	1
Phono jack	Radio Shack	274-246A	1
1/8″ phono plug	Radio Shack	274-287	1
Male polarized connector (four positions, Molex Type)	Radio Shack	274-224	1

Part Name	*Available From:*	*Part or Catalog #*	*Quantity Required*
5-mm red LED (or color of your choice, as long as it's 5 mm)	Radio Shack	276-330	1
SPST submini slide switch	Radio Shack	275-406	1
2.2K-ohm resistor	Radio Shack	271-1121	1
Tact switch, 6 mm	Digi-Key	EG2495-ND	15
Tact switch, 4.5 mm, H=3.8 mm	Digi-Key	CKN9018-ND	1

Note

This list does not include parts required to modify the pocket TV. Check Chapter 4 for those.

The Sony Infolithium battery

This portable unit will run off wall power or a Sony Infolithium battery. The type to get is Size L, which is the kind used for Sony digital camcorders (such as the Handycam) or the older Sony Mavica floppy disk–based digital cameras. These batteries come in different sizes, from NP-F330 to NP-F960. You'll need at least a middle-of-the-road battery such as the NP-F550 model in order to properly power this device.

This Playstation portable will not be able to charge its own battery, so you need a separate charging device in addition to the battery itself. If you do a search at an online auction, you can usually find pretty good deals on battery/charger combos.

Screws, nuts, and other hardware

The next step is to get some hardware parts, such as screws and nylon spacers. The screw section of your favorite hardware store should stock these, although the bigger the store, the better your chances of finding everything in one trip. Table 14-2 lists what you need to pick up.

Table 14-2 Screws, Nuts, Washers, and Spacers List

Screw/Nut/Washer/Spacer Size	*Type*	*Length/Size*	*Quantity*
Size-4 screws	Phillips, pan (round head)	1/4"	8
Size-6 screws	Phillips, pan (round head)	3/4"	7
Size-6 screws	Phillips, pan (round head)	1 1/4"	2
Size-4 nylon washers	N/A	N/A	14

Continued

Table 14-2 *(continued)*

Screw/Nut/Washer/Spacer Size	*Type*	*Length/Size*	*Quantity*
Size-6 nylon washer	N/A	N/A	6
Size-4 nylon spacer	1/4″ outer diameter	1/2″	7
Disc-shaped refrigerator magnets	1/2″ rounded	3/8″ tall	3
Automotive panel fastener	For 7/64″ size-hole	N/A	2

Case-building materials

The final type of material you'll need are things to rout the case out of. The place that does the CNC machining for you should have these available. Table 14-3 lists the amounts you'll need for this project.

Table 14-3 Case-Building Materials

Material	*Size*	*Source*
1/16″-thick engraving plastic (dark color)	12″ × 12″	Trophy/awards shop
1/16″-thick engraving plastic (light color)	10″ × 6″	Trophy/awards shop
1/4″-thick acrylic or wood	12″ × 17″	Lumber store, sign shop, hobby shop

The total area of 1/4"-thick material required is listed above, although it may need to be cut into pieces, depending on the size of the laser engraver bed. (More on this in the *Routing the Parts of the Case* section.)

Everything else

Finally, here's a list of the miscellaneous things you'll need as well:

- Hot glue sticks
- Fine-grit sandpaper
- Superglue
- Extra X-Acto blades (always a good thing to have on hand!)
- Electrical tape
- An electric drill and the following bit sizes: 1/8", 15/64", 3/16", and 1/4". (I'd suggest borrowing these from a friend, since it's better than buying them to only use this once.)

Files you'll need

This chapter will mention and require the use of several computer files. These can all be found on this book's companion Web site, at www.wiley.com/go/extremetech, in a file called "PSOne CNC."

Decals and graphics

On the companion Web site, you'll find files to use for printing decals for this project. We'll be applying these decals as we go along throughout this chapter. There are two ways of making them:

- **Using your own printer and sticky-backed paper.** For this, use one of the following files, depending on which opens best with your computer: "PSOne CNC Decals.ai," "PSOne CNC Decals.jpg," "PSOne CNC Decals.pdf," or "PSOne CNC Decals.wmf." Print it using 100% size, No Scaling, or Default (the exact choice varies by program). This ensures that the decals print at the correct size. Finally, use an X-Acto knife to cut along the lines of the decals.
- **Getting decals from a vinyl or sign shop.** Provide them with the file "PSOne CNC Decals.plt" and ask for it to be printed on clear enamel-receptive vinyl. You'll get back clear-background graphics automatically cut by them. The clear background allows the color of the engraving plastic to come through, which provides a nice effect on things like the screen (more on that later).

Tip

If the vinyl or sign shop can't use the PLT file, provide them with one of the other decal files listed in Option 1.

Routing the Parts of the Case

Once you've collected the parts to build this portable, it's time to rout the case. Because some of these parts are rather small and delicate, your best bet is to use a *laser engraver* to cut the pieces. All of the files mentioned here and throughout the rest of the chapter are available on the companion Web site, at www.wiley.com/go/extremetech.

The CNC parts for this project are divided into two types:

- **Plates.** Made from 1/16"-thick engraving plastic, they form the fronts and backs of your portable.
- **Side Walls.** Made from 1/4"-thick material, these are stacked in order to give your portable depth.

Note

If the laser engraver you find doesn't use or accept CorelDraw files for some strange reason, there are Adobe Illustrator versions of each file also available on the companion Web site. (They're the files that end in the extension AI.)

Laser-cutting the plates

In the materials lists, two types of engraving plastic were mentioned — light and dark. The light portions are used for the screen, the speaker riser, and the CD lid. The darker color is used for the main body of the unit. Pick whichever light and dark colors you like. For my portable I used a fake, plastic brushed aluminum for the light color and a medium blue for the dark color.

Figure 14-2 shows all the engraving plastic plates, both light and dark, and their names. These names will be used throughout the chapter, so dog-ear this page for later reference. (Or, if you're high-tech, use a bookmark.)

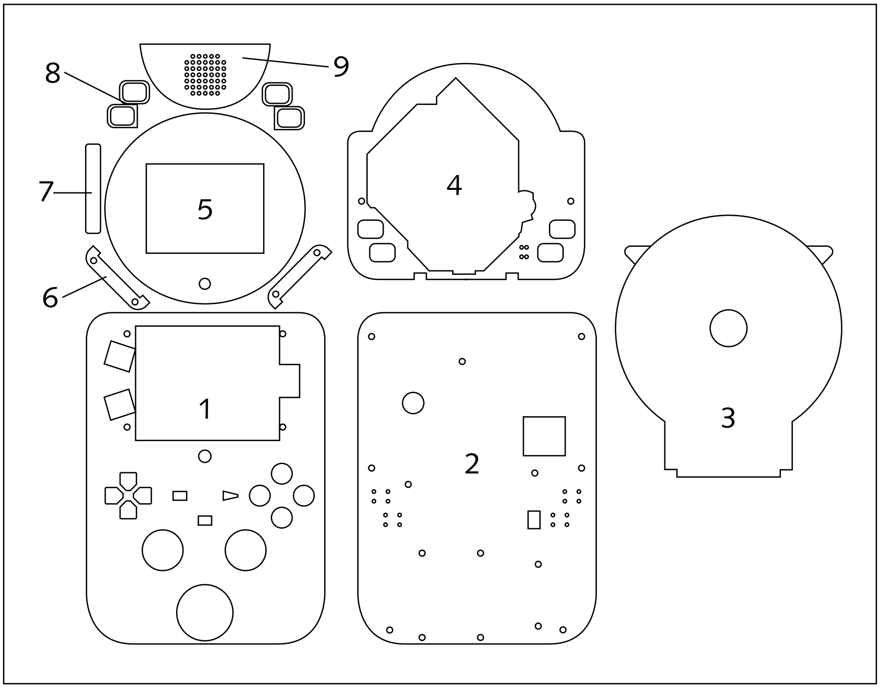


FIGURE 14-2: The engraving plastic parts.

1) Front plate
2) Rear plate
3) CD lid
4) CD drive plate
5) Screen riser plate
6) Battery tabs
7) Thin battery contact cover
8) Shoulder button flanges
9) Speaker riser plate

Provide the following files to the laser engraver operator: "Engraving Rout Dark.cdr" and "Engraving Rout Light.cdr." Each will be cut on a separate piece of colored plastic, as described above. For both files, have the operator make vector cuts completely cut through the material on all black hairline strokes. This will cut all the plates out of the plastic.

It's not a bad idea to print out the file "PSOne Engraving Plastic Material.pdf" before stopping by the laser engraving place. That way they'll have an idea of what you want done ahead of time.

Laser-cutting the side walls

The pieces shown in Figure 14-3 are called the *side walls.* These parts are all 1/4" thick and are stacked on top of each other to make the depth of the unit. For the sake of simplicity, only one set of each is shown in this figure; however, the CNC files have multiple sets of the same part, as required.

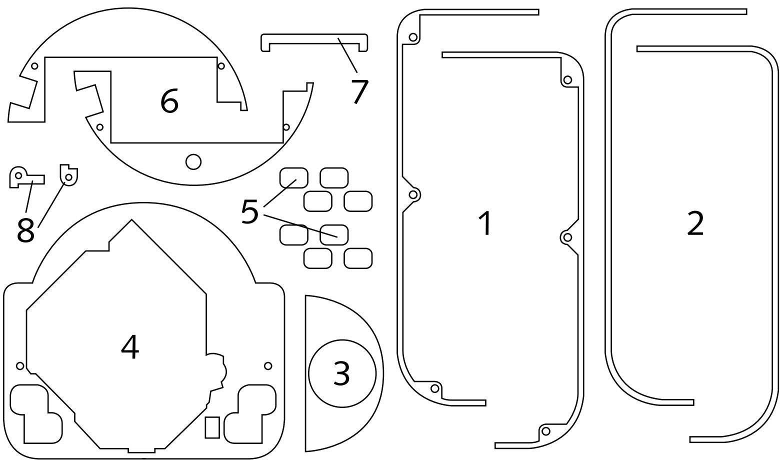


FIGURE 14-3: The 1/4"-thick side wall parts.

1) Front side walls, *Screw walls:* A total of three sets will be cut.
2) Front side walls, *Plain walls:* Two sets will be cut.
3) Speaker riser: Only one will be cut.
4) CD-ROM risers: Two of these will be cut.
5) Shoulder buttons: There are four shoulder buttons, made from two pieces each, so eight are being cut.
6) Screen risers: Only one is cut.
7) Battery contact cover: Only one is cut.
8) CD lid hinges: The smaller one is the *lower hinge*, and the larger one is the *upper hinge.* Two of each type will be cut.

Provide the laser operator with the files “Quarter-inch Plastic 1.cdr” and “Quarter-inch Plastic 2.cdr.” The reason that there are two files is because everything didn’t quite fit into a 12” × 12” area, and that’s the size of most laser engraver beds. If you find a laser engraver with a larger bed, the operator can combine these files and cut everything all at once.

In either case, have the operator make vector cuts completely through the material on all black hairline strokes. This will cut all of the side walls out of the material.

You should print the file “PSOne quarter-inch Material.pdf” beforehand to give the operator an idea of what you’d like done.

Assembling the Case

Now that we’ve gotten the parts cut, we can start assembling the case. Have your soldering iron at the ready while building the case, as we’ll be doing some wiring here and there as we go.

Preparing nylon washers and spacers

We’ll be using nylon spacers and washers throughout this chapter, so let’s talk about how to prepare them now and get it out of the way. That’ll save time later! Follow these steps for any nylon spacer or washer that is glued to something or has screws inserted into it during this chapter:

- For nylon spacers and washers: Use a fine-grit sandpaper to roughen both ends of the spacer. If only one end gets glued, don’t bother sanding the other.
- For nylon spacers: Grip them with your large pliers and use a drill to drive a size-6 screw in and out of it. This will create *threads* to allow future screws to insert into them easily. If you don’t drive the screw completely through it, make a mark in the end you did drive so that you know where the threads are.

Front half of the case

The front half of the case is the largest portion of this unit’s case, measuring 5” × 7” × 1”. It will contain the screen, controls, PSOne board, memory card/Player 2 port, and speaker. Four stacked side walls make up the depth of the unit.

Putting screw posts on the front plate

Even though the front plate was cut by a computerized machine, we need to manually attach some *screw posts* to the back (inside) of it. These screw posts are the threaded nylon spacers mentioned in the previous section.

1. Print the file “Front Plate Screw Posts.pdf.” Make sure the printer settings are 100% Size, No Scaling, or Default. This ensures that the printout will be actual size. You may also need to turn off the margins.

2. Use your X-Acto knife to cut the outer shape and the four double-circled screw post spots. You should also cut some of the other shapes (such as the analog joystick holes) for reference.
3. Lay the pattern on the back of the front plate, and tape the sides so that it stays in place.
4. Use superglue to attach two size-4 nylon washers and one 1/4" nylon spacer into each of the four screw post holes, as seen in Figure 14-4 below.

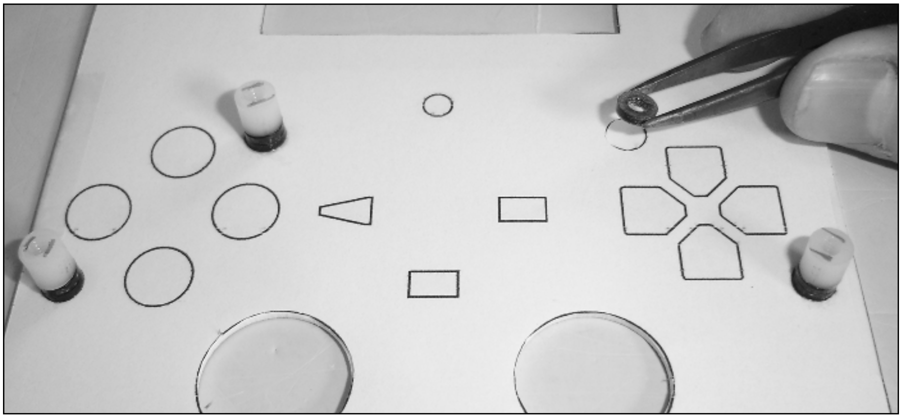


FIGURE 14-4: Gluing nylon washers and spacers into the screw post spots.

The resulting stacked screw posts should be 3/8" high. You can now tear off the paper pattern — you may need to cut around the screw posts to remove any paper that's been held by the glue.

Attaching the front side walls

The *front side walls* give the front half of the case its depth of 1". There are two types of front side walls: *screw walls* and *plain walls.* Screw walls have holes, and plain walls don't. Stack them as described below:

1. Sand the edges of the back of the front plate where the front side walls will be attached.
2. Superglue down three layers of screw walls on each side of the front plate (for a total of six pieces). Keep the sides of the walls level with the edges of the front plate as best you can. There's a gap at the bottom of the unit (where the memory card will go), so use the sides and top to align the walls.
3. Now glue down the one layer of plain walls on top of the screw walls. The result should look like what's shown in Figure 14-5.

FIGURE 14-5: The side walls attached to the front plate.

Attaching the speaker riser

The speaker riser sits on the surface of the front plate. It keeps the speaker out of the way of the memory card/Player 2 port. To attach the speaker riser, do the following:

1. Superglue down the 1/4" speaker riser wall with the circle centered over the circle on the front plate and the flat portion level with the bottom of the plate. (The circles are the same size so that it's easy to eyeball the thing.)
2. Glue the speaker riser plate on top of the speaker riser wall. Be sure to get glue near the two corners, as they are the most prone to lift back up.

Installing the screen riser

The *screen riser* is a lot like the speaker riser, but it installs a little differently, as there are some screws involved.

1. Drive four 1/4" size-4 screws into the back of the front plate until they just start to pop through the front.
2. Set the screen riser walls on top of the ends of the screws. Note that the right-hand side of the walls has a gap for the power switch. The left-hand side has the two volume and brightness holes.

3. Drive the four screws into the screen riser walls. If you used acrylic for the walls, drive the screws slowly to avoid cracking the plastic.
4. Set the screen riser plate on top of the walls and superglue it in place, with the small circle at the bottom. To make sure the rectangular screen opening is positioned straight, temporarily place the screen inside the screen riser walls so that the hole on the plate matches the screen. (Just be careful not to get glue on the screen itself!)
5. Place the screen decal on the screen riser plate. If you're using vinyl graphics, put a small bit of soapy water on the sticky side of the decal, and position it over the screen. Use a squeegee or credit card to press out the water and air bubbles, and then let it dry.

The front half of the case is now completed and ready for components to be installed. Now we can move onto making the rear half.

Rear half of the case

The *rear half of the case* will contain the CD-ROM drive, shoulder buttons, and battery. We'll start by installing the CD-ROM drive.

1. Take the three 3/4"-long size-6 screws and slide a size-6 nylon washer down each.
2. Stick the three 3/4"-long size-6 screws into the tops of the rubber feet on the CD-ROM drive.
3. Place the CD-ROM drive over the three holes on the rear plate. There are openings for the wiring attached to the CD-ROM drive — the 4-pin *drive plug* goes through the circle, and the 16-pin *flat ribbon access cable* goes through the square.
4. Put a size-6 nylon washer under each size-6 screw between it and the rear plate. Then drive all three screws down until about 1/16" of them sticks through the other side (inside) of the plate. The screw heads should be low enough that they won't scratch the disc when it's inserted and spinning. Test it by sticking in an old CD you never listen to anymore (like Hootie and the Blowfish's *Cracked Rear View*).
5. To the sides of the CD-ROM drive you'll see four sets of four small holes. Place a 6-mm tact switch in each set of holes with the leads on the left and right sides. Bend the leads on the back so that the switches will stay in place; we'll wire them in a little while.

The installed CD-ROM drive and tact switches should appear as shown in Figure 14-6.

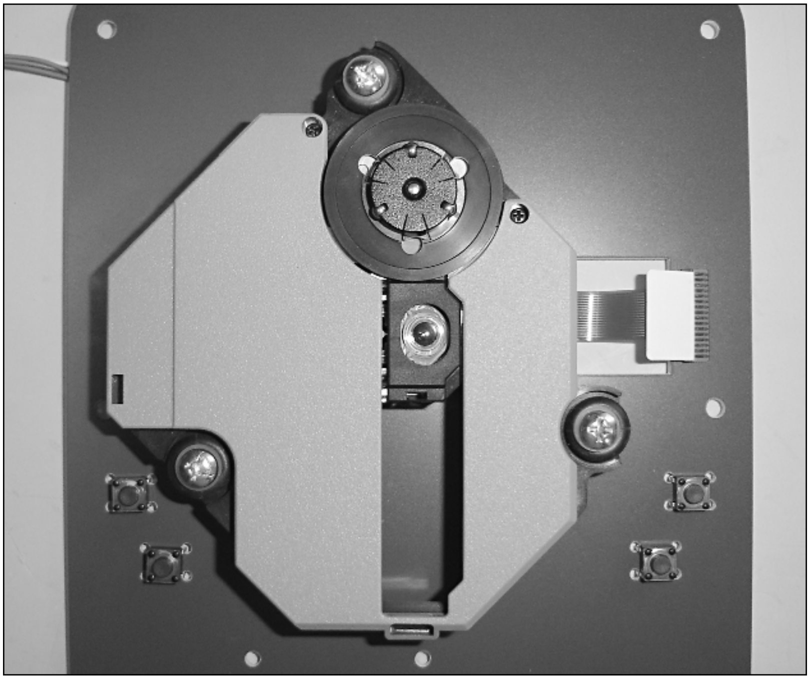


FIGURE 14-6: The CD-ROM drive installed onto the rear plate.

Next, place the two 1/4" thick *CD-ROM risers* around the CD-ROM. You may have to bend the rubber screw bumpers around to get them to fit inside. Check that the two side screw holes line up from the risers to the plate. To finish up this portion of the unit, do the following:

1. Make the left and right shoulder assemblies by first supergluing two shoulder buttons on top of each other to make a 1/2" high piece. There are a total of four of these.
2. Next, glue the 1/2"-high portions into the *shoulder button flanges,* as seen in Figure 14-7. The 1/16" shoulder button flange should sit flush with the top of the lower 1/4" shoulder button piece. If it's too high, the shoulder buttons may get stuck on.
3. Set the shoulder buttons in the holes over the four tact switches. Make sure the portion marked "top" in the above photo is on the outside.
4. There are four small holes on one side of the *CD-ROM drive plate*. Set a 4.5-mm tact switch in these holes, and solder a two-strand of 10" wire to two of the leads on the switch that are diagonal from each other (check how the other tact switches in this chapter are wired to see an example). These will be your *lid sensor wires*.

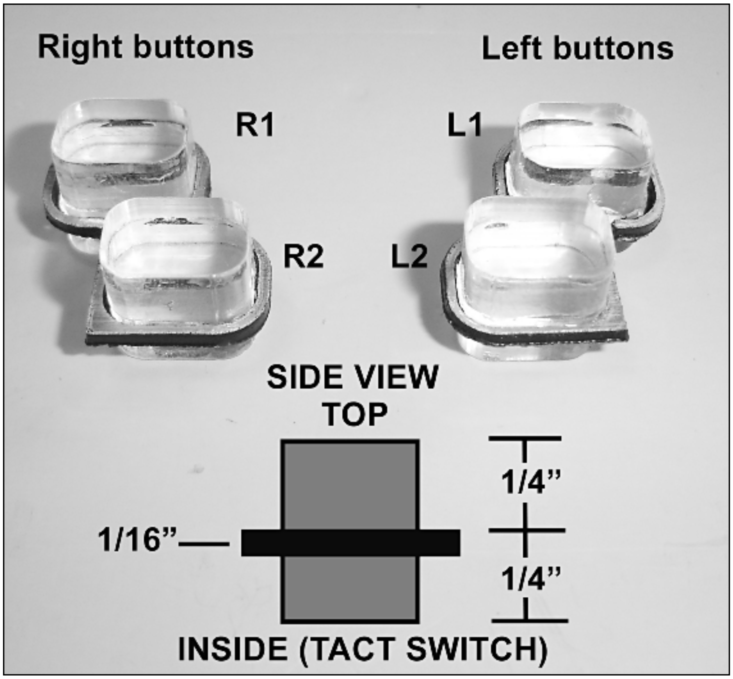


FIGURE 14-7: The shoulder buttons, with handy cross-section drawing.

5. Place the CD-ROM drive plate over the CD-ROM risers, and thread the lid sensor wires through the holes so that they come out the other side of the rear plate. Check to see that the shoulder buttons click correctly, and then drive the 1-1/4”–long size-6 screws into the side holes until they reach through the rear plate. These will be driven into the front of the case later.
6. The *lower CD hinges* have small tabs. These are meant to fit into the two slots on the CD-ROM drive plate. Superglue them in place, with the thick portion of the hinge toward the CD-ROM drive.
7. Attach the battery tabs to the four 1/10” screw holes in the bottom of the plate in the following way:
   - Screw a 1/4”-long size-4 screw into each hole on the battery tabs until it pokes out the other side.
   - Place a size-4 nylon washer over each screw between the battery tabs and the rear plate, and then drive the screws through the rear plate until the tabs are secured in place. This keeps the tabs slightly above the surface of the plate.
   - Test that the Sony Infolithium battery fits nicely between the tabs and can slide in and out.

At this point, the rear of the unit should look like what you see in Figure 14-8.

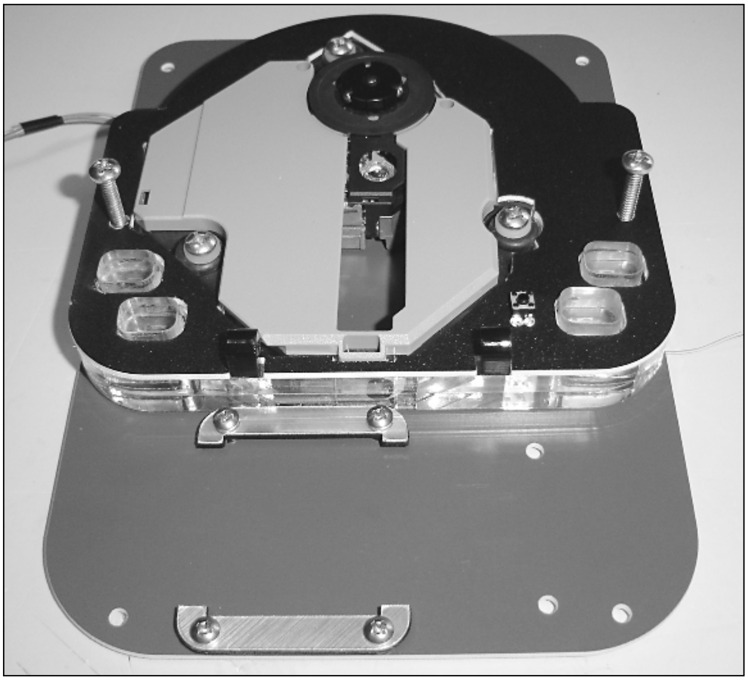


FIGURE 14-8: The rear of the unit thus far.

Tip

If you used acrylic to make the thick portions of the case, drive the screws slowly to avoid creating cracks.

Installing the battery leads

The male polarized connector that you bought comes with metal leads with rounded ends. These are what we'll use for the battery leads. Snip two of them apart from the rest, then continue snipping and bending, as seen in Figure 14-9.

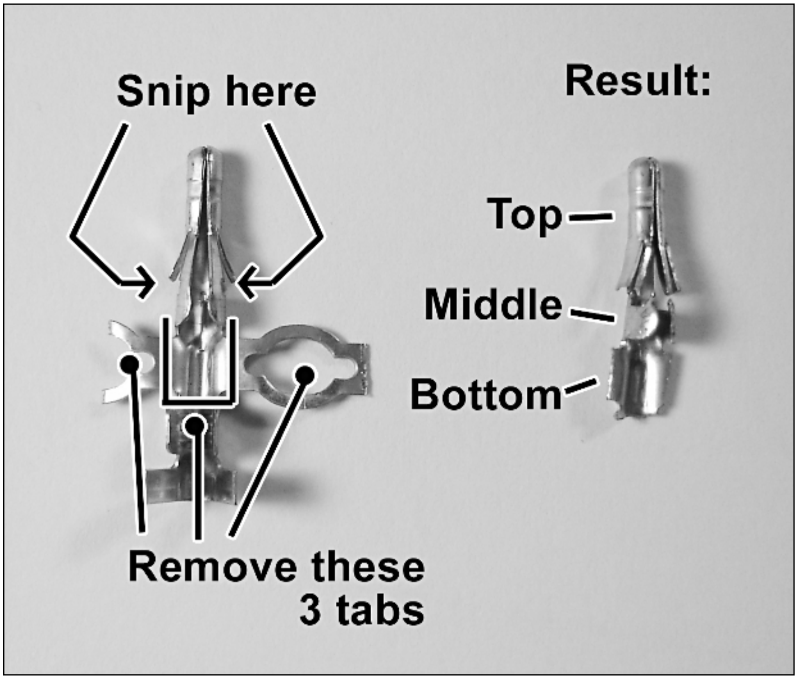


FIGURE 14-9: Where to snip the lead and what the resulting portions are called.

1. Press the leads into the rear plate from the inside. The top portion should be on the outside of the rear plate, the middle portion on the inside, and the bottom portion sticking out the other side of the plate.
2. Bend the top portion over so that it points left when viewed from the outside of the rear plate. (This is why you needed to snip those small sections on the side.)
3. Insert a Sony Infolithium battery between the battery tabs, and slide it right onto the leads. If the battery doesn't fit between the tabs, use your X-Acto to shave the sides of them slightly. The battery should fit tightly, but not so tightly that it's hard to insert or remove.
4. With the battery holding the tops of the leads, bend the bottom portions so that they sit flat against the inside of the rear plate.
5. Fill the inside of the leads with solder. This will give it solidity and also melt the plastic around the lead, helping to hold it in place.
6. Connect a 12" wire to each of the battery leads on the inside. These will be called the *positive and negative battery wires*. When viewed from the rear, the top lead is negative, and the bottom lead is positive. Mark the other ends of the wires so that you can tell them apart later.

7. Put a battery in and use the multimeter to test the other ends of the wires. If they give a voltage reading, then they're connected properly — go ahead and put some 5-minute epoxy over the battery leads on the inside of the unit. Leave the battery installed so that it holds the leads in the correct position. Even after the epoxy sets, you can still bend the ends of the leads if you need to adjust them later on.

   The front and back of the battery leads should look as shown in Figure 14-10.

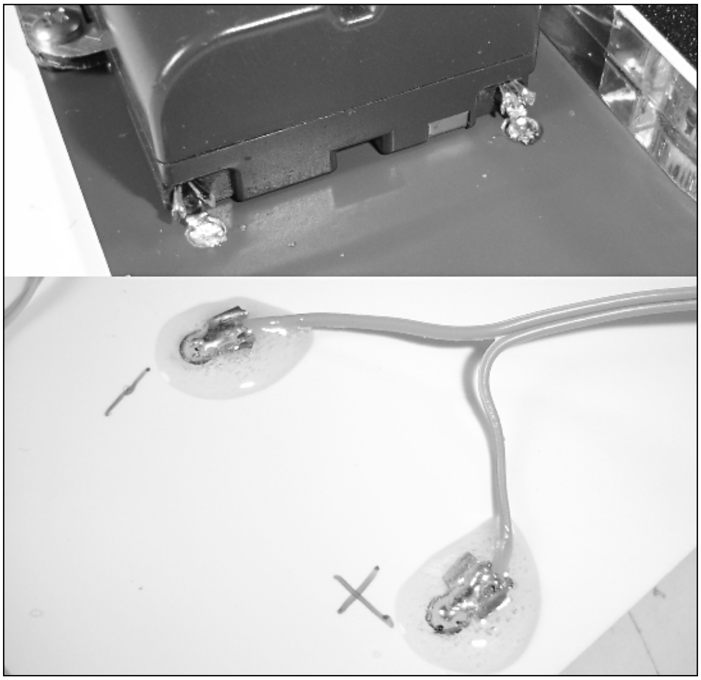


Figure 14-10: The front and back of the battery leads.

With the Sony Infolithium battery still in place, superglue the 1/4" battery contact cover over the leads on the outside of the case. Then glue the thin battery contact cover over that.

Tip

If you solder the leads while they're touching the battery terminals, it may temporarily short out the battery, causing it to read a charge of 0 volts. The battery is not wrecked, simply stick it back on the charger for a minute to restore it. This is one of those "easy" fixes that may save you troubleshooting time later on.

CD lid assembly

The CD lid assembly consists of a 1/16” plastic lid, a hinge, some nylon spacers, and magnets to secure it shut. To assemble it:

1. Glue the two upper CD hinges to the back of the CD lid, as seen in Figure 14-11. As with the lower CD hinges, there are small tabs which will fit into the notches on the lid. One of the upper CD hinges is longer. Make sure it’s on the left side of the lid (when viewed from the rear). This long hinge is meant to hit the lid sensor switch.
2. Cut a 3-1/2”–long piece of the 3/32” thick steel rod. Then set the CD lid over the CD-ROM drive plate and the hinges on it. The four hinges should fit nicely with each other. Insert the steel rod.
3. Take your two automotive panel fasteners and cut off the stem so only the top circle cap remains. Superglue these onto the ends of the hinges to cover up the unsightly steel rod. How professional this looks!

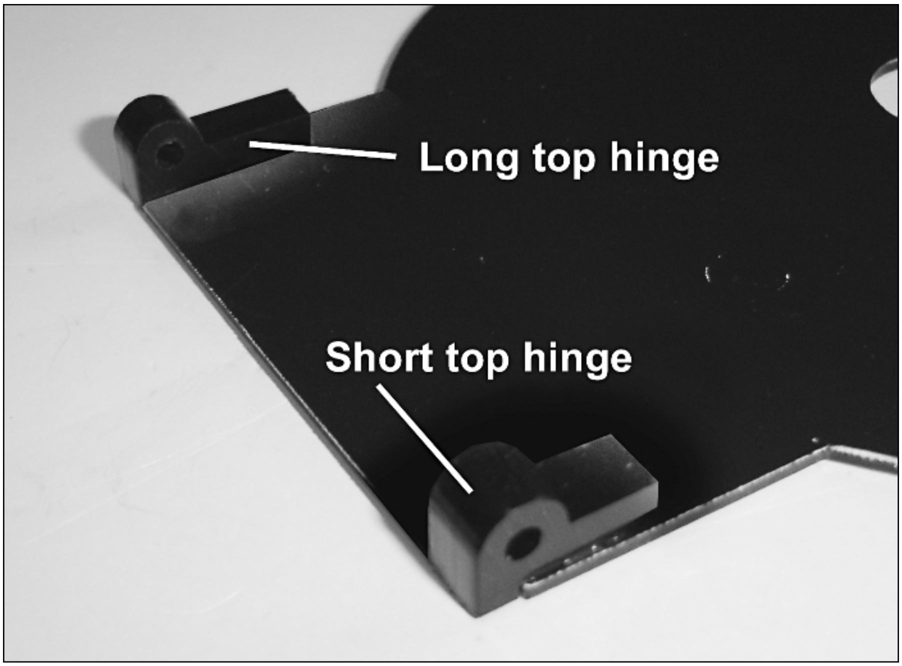


FIGURE 14-11: The hinges glued to the CD lid.

The CD lid can now open and close at will — meaning it *will* pop open when you don't want it to. So we'd best create a magnetic latch to *keep* it closed. Place that unwanted CD in the drive again for reference, then do the following:

1. Take one of the 1/2"-diameter magnets and cut it in half.
2. Stick a half magnet on top of each of the remaining two uncut magnet discs.
3. Superglue a 1/2"-long size-4 nylon spacer to the underside of the two tabs at the top of the CD lid.
4. Set a half magnet/whole magnet combo under the nylon spacer with the lid closed. The lid should be about 1/8" away from the surface of the CD. Arrange the magnets like this:
   - Half magnet should not hit the CD when the lid is lifted.
   - Whole magnet should not go over the edge of the plate.
5. Lift the lid and put some superglue on the nylon spacer. Then press it back down onto the half magnet to connect them.
6. Lift the lid again. Both magnets should lift up. Place some superglue under the whole magnet, then press the lid and magnets down onto the rear plate.
7. Lift the lid once more. The whole magnet should be stuck to the rear plate, while the half magnet comes up with the lid. Just like in Figure 14-12!

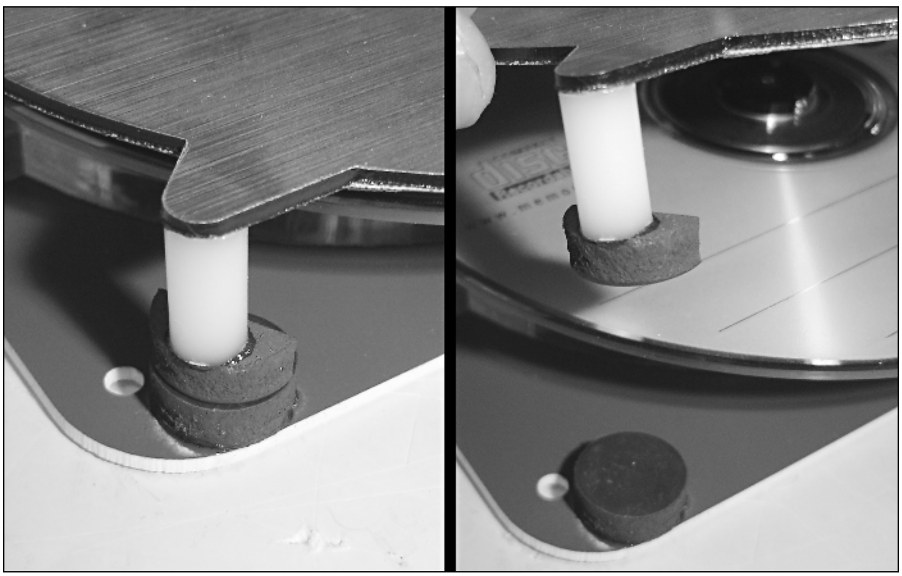


FIGURE 14-12: Magnets: An "attractive" way to make a CD lid latch.

Use your multimeter set to resistance, check that the CD lid is pressing the tact switch when it closes. If it doesn't, put a small piece of thin plastic on the hinge so that it presses against the switch more tightly. A flaky lid sensor switch will mess with your gameplay, so make sure it's working before you continue.

Attaching side walls to the rear plate

Sand the inside edges of the rear plate, and superglue the remaining plain side walls to it. This creates a depth of 1/4" for the motherboard to reside in.

Wiring the Unit

Once the main portions of the case are built, it's time to start wiring the unit! Keep your super-glue and hot glue handy, however, as they may be called into duty at any time during this section.

Making the PC control board

The PC control board will contain most of the digital controller buttons (excluding the shoulder buttons), and will be made from the Radio Shack PC board (catalog #276-147). In its native form, this board is too big, so you'll need to slice it smaller, as shown in Figure 14-13 below. To do this, firmly drag your X-Acto knife along the indicated lines several times to make deep grooves. Then snap the board apart. You'll want to keep the resulting 4-3/4" × 1-1/2"–sized inner piece.

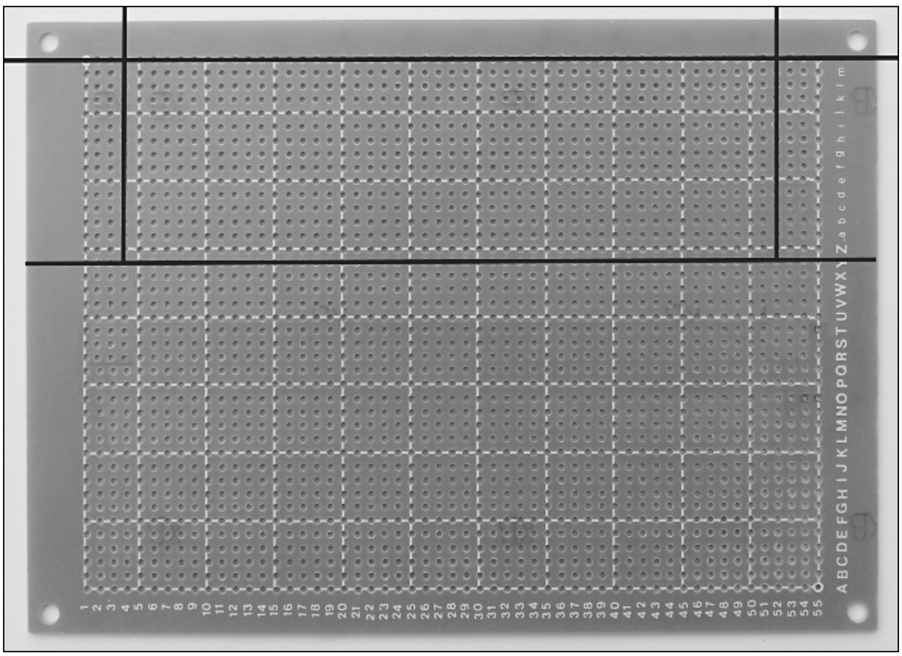


FIGURE 14-13: Where to cut the PC board.

Caution Be careful not to let the knife slip when slicing the board, or you may give yourself a nasty gash! Never drag the knife toward any part of your body.

All right, with the board safely sliced down, you can start putting components on it. Place eleven 6-mm tact switches on the PC board, as shown in Figure 14-14 below. Additional steps follow the photo.

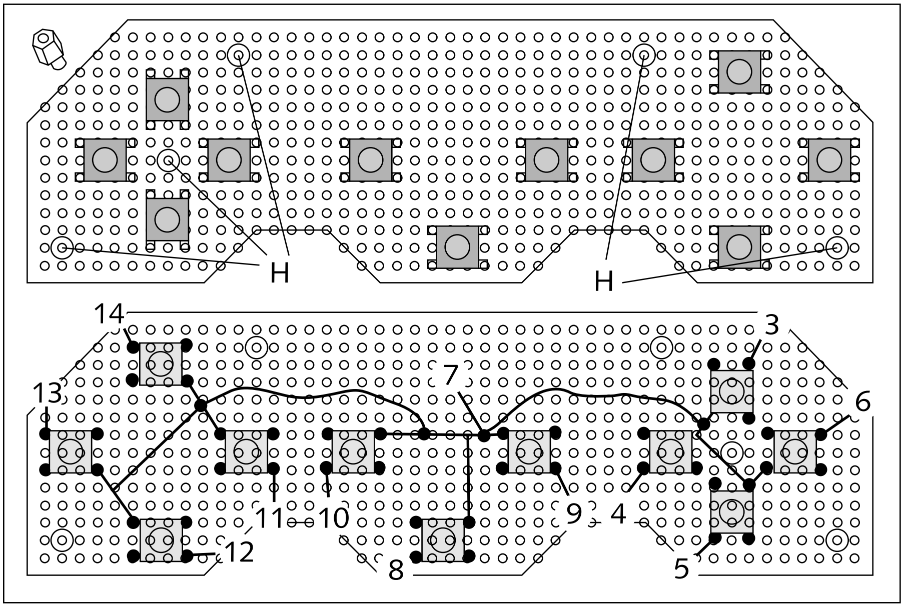


FIGURE 14-14: Placement of tact switches (top drawing) and wiring on the back (bottom drawing).

1. As you can see, more of the board needs to be clipped — specifically, the top corners, so that it'll fit in the case, and some spots at the bottom, so that the analog joysticks can rotate fully. Use your cutters to carefully bite away parts of the board a little at a time. If you try to cut large chunks, you might split the entire board. (If that occurs, fix it with superglue.)
2. Use a 1/8" bit to drill holes in the five spots marked "H" ("H" being for "hole").
3. Place a computer motherboard riser screw (pictorial example in upper left corner of the figure) into the hole between the control pad switches (the left group of four switches). This keeps the control pad disc from pressing more than two directions at once.
4. Connect a 3"-long thin stand of wire to each numbered spot so that you can connect them after installing the analog board. The numbers refer to the sixteen control board connections as described in Chapter 12. Keep in mind that four of the connections are the left and right shoulder buttons, which we'll attach later.

5. Use bits of leads or wires (whichever is handier) to connect the tact switches together on the back of the board. This is the common *GROUND* connection for all the switches, and connects to spot 7 on the controller board.

Installing the controls and board

Okay, with the PC board prepared, we can now insert the buttons into the case. The directional pad and select/start/analog rubber buttons should fit normally into the holes on the front plate. However, the four triggers (you know, the buttons with the shapes), need to be filled with glue in order to work correctly. Fill the buttons with hot glue until it's level with the bottom of the button, basically making the button solid instead of hollow. Then insert the trigger buttons into the holes.

The result of all this should look like what's shown in Figure 14-15.

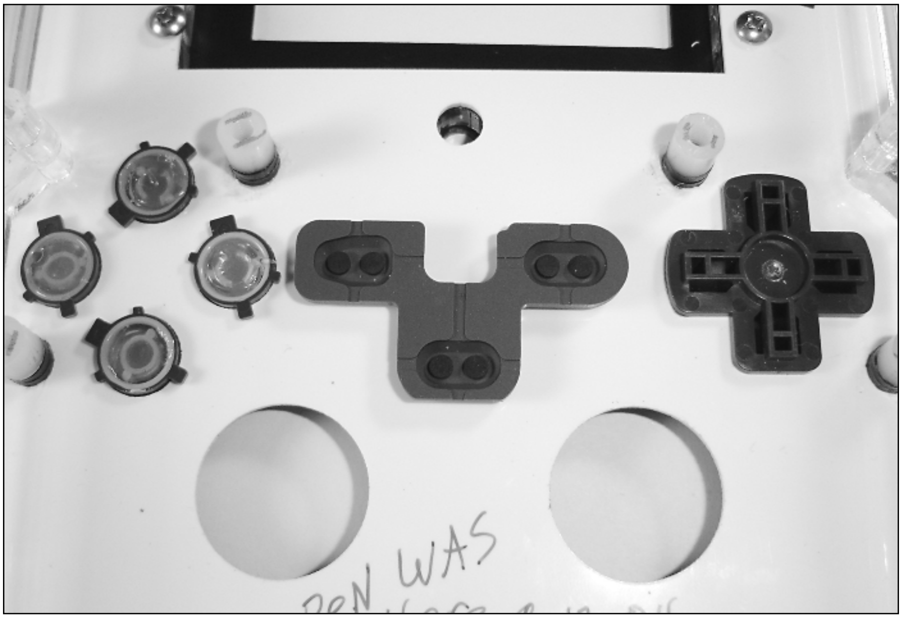


FIGURE 14-15: The glue-filled buttons inserted into the front plate.

Tip

Unless you're a die-hard Parappa the Rapper fan, you may want to check an existing Playstation controller to ensure that you've placed the trigger buttons correctly.

Place the PC board over the buttons and use four computer case screws to secure it in place. Check that the buttons are all clicking, especially the triggers. If the triggers don't feel quite right, add or remove some of the glue.

Attaching the controller board

The controller board is the thing from the original PSOne controller with the analog joysticks attached. (See Chapter 12.) Before you begin, desolder the original LED from it. With that gone, here's how to install the board:

1. Place the controller board, with analog sticks still attached, over the PC control board that you just installed. The analog sticks should fit into their holes.
2. Connect the twelve wires from the PC control board to the button connector on the controller board. The numbers on the PC control board drawing (Figure 14-14) refer to the button connector numbers seen in Chapter 12. Use the photo in that chapter as reference for the connections here. Four spots on the controller board will still be unconnected: the shoulder buttons, which we'll attach a little later.
3. Connect eight 3" wires to the controller connector spots on the left side of the controller board. (Again, for reference see Chapter 12.) However, do *not* attach a wire to spot #2. This is why there are eight wires for (9) spots.
4. Attach a short wire from spot #2 to spot #8 on the controller board. See, spot #2 does get attached to something, just not to the PSOne motherboard.
5. Lay the controller board back down, and push the analog sticks through the holes. Make a stack of two nylon washers and one 1/2" nylon spacer, and set it under the controller board between the analog sticks. This should keep the board at the proper height. Check that the joysticks rotate smoothly, then superglue and hot-glue the spacer in place.
6. Finally, put some hot glue between the controller board and the PC control board to lock it in place. (Hey, it's the easiest way!) The result should look like what you see in Figure 14-16.

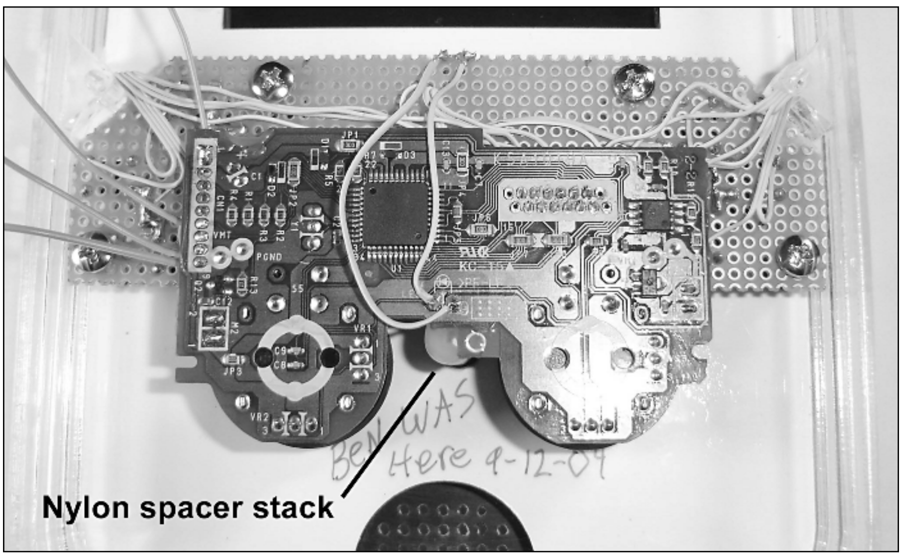


FIGURE 14-16: The controller board and nylon spacer all securely hot-glued in place!

Note

If this seems like a cheap way to secure the controller board, well, it is. However, once the unit's fully assembled, wires and things will be pressing against the controller board. So if you press down on the analog sticks, they'll be held in place regardless, and not pop loose.

Tip

By that same token, don't use too much glue to secure the controller board until you've tested this unit later on in the chapter. That way there's less to remove if you have to fix something. Once the unit's working, though, gush on the glue to your heart's content!

Inserting a new analog LED indicator

Desolder the old analog LED indicator off the controller board if you haven't already. We're going to install a new analog LED indicator that's going to be much cooler!

1. Take your 5-mm LED and insert it into the hole in the screen riser. Place it so that it sticks out however far you like, and then hot-glue it in place.
2. Attach two 4"-long wires to the LED. The long lead on your LED is positive. Connect that one to the right hand spot on the controller board where the original LED was, and connect the other wire to the left spot. (Those directions assume you're viewing the controller board from inside the case.)

Tip

To adjust the brightness of the LED so that it won't blind you during play, put a resistor between it and the positive connection on the controller board. Depending on what LED you get, between 1K ohm and 4.7K ohms should be fine. (2.2K was on the parts list.)

Power switch

Just to the side of the screen hole is a small place for the power switch. We'll need to get this thing in place before the screen, so let's do it now.

1. Take your slide switch (Radio Shack catalog #275-406) and break off the side tabs that contain the screw holes. Bending back and back with needle-nose pliers should do the trick.
2. Attach a 10"-long wire to one of the switch's leads. This is *power in.* Connect a 10" wire and a 5" wire to the other lead — this is *power out*.
3. Put some superglue on the metal side of the power switch and set it into the hole. Make sure the two leads are on the upper side, so that when you slide the switch up it's on (so it matches the decal). After the superglue is secure, lay a protective coating of hot glue over the switch to seal the deal. Don't get the glue over the leads, however, or it might get in the way of the screen.

Tip

Put a few thin layers of electric tape over the switch's leads. This prevents them from possibly shorting out to the TV, which will be quite close in proximity.

Installing the screen

Now it's time to install the screen. You can probably see now why we folded it in half—in the screen's original form, the circuit board would have bumped against the analog controller board! (I'll tell you, designing this unit really taxed my brain until I came up with the folded-screen thing. Then everything fell into place!)

1. Before actually installing the screen, do a preflight check:
   - Snip off and sand down the four plastic white tabs around the screen—two on the top and two on the bottom.
   - Carefully peel the outer layer of copper foil away from the ribbon cable going to the LCD. Even this can make the screen too thick to fit easily.
   - Make sure the hot glue over the white LEDs is flat against them and not "bulging" out. If so, flatten it with the edge of the glue gun tip, or shave some off with your knife.
2. Set the TV into the hole on the inside of the rear plate. The screen should go right up against the screen plate. How well the TV inserts will vary, since it's been modified, so if you're having trouble, try one of the following:
   - Hold the ribbon cable flat against the white plastic as you insert the TV. Be very gentle with it however; if it breaks, your TV is history.
   - There's a metal shield around the white plastic. You can bend the top portion of this shield backward so that it doesn't actually enter the main TV hole. Use needle-nose pliers to accomplish this.
   - Remove one of the size-4 screws if it bumps against a white LED. Reinsert the screw after the TV's installed. (Or just leave it out—like anyone's gonna notice?)

Now, with the TV itself properly installed, turn your attention to the volume and brightness dials. There are two slots in the screen riser for them. Install them by doing the following steps:

1. Check the original plastic shell that the TV came in to see which dial is which. The lower dial should be volume, and the upper should be brightness. Keep in mind that lower and upper refer to it in the *original form,* and now it's been flipped around.
2. Place the dials in the slots. The small tabs on the center of the dials should touch the outer edge of the hole in the front plate. This exposes just over half of the black dial on the outside of the unit. On this portable, the upper dial is volume, and the lower is brightness (check the decal).
3. Hold the dial in place, and put some hot glue between the tabs and onto the inside of the plate. Once that's dry, hot-glue the wire end of the dial. Make sure that the glue doesn't drip onto the dial itself. If it does, spin the dial until it comes free.

The installed TV, dials, and power switches should look something like Figure 14-17.

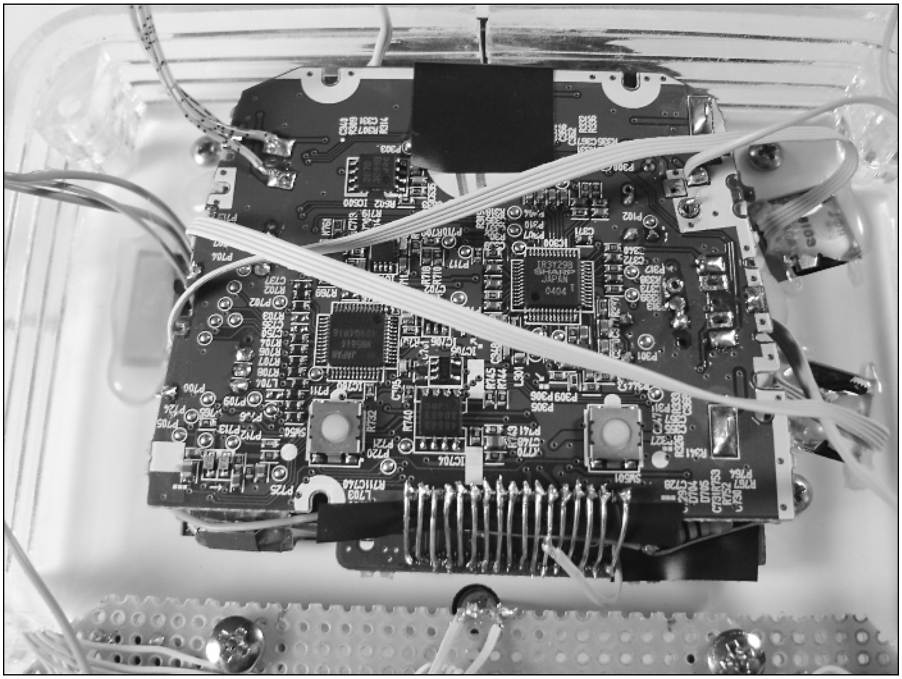


FIGURE 14-17: The area around the screen thus far.

Drilling holes for side-mount jacks

There are a total of three jacks that will stick out the sides of this unit, and we'll need to drill holes for all of them. The following lists the jacks, the hole size, and the best place to put it.

- **Audio/video output jack** (connected to the TV in Chapter 4). Drill a 13/64" hole at the top of the unit near the volume and brightness knobs. Insert the jack into it, and then hot-glue the sides and a little behind the jack so that it can take the insertion force (of a plug) without coming loose.
- **Headphone jack** (also connected to TV). Drill a 13/64" hole at the bottom of the unit about 1" away from the Player 2/Memory Card opening. Insert the jack, and secure with hot glue on the sides and behind.
- **DC AUX INPUT jack** (the phono jack from the materials list, Radio Shack catalog #274-246A). Drill a 1/4" hole at the bottom of the unit on the opposite side of the headphone jack hole. Insert the jack with the leads facing out (since we still need to attach things to them), and then screw the ring on from the outside.

Caution

If you're drilling into an acrylic case, be very careful not to crack it. Make sure the acrylic is well glued, and drill slowly. If it does crack, it'll be on the hole, so you can glue it back together and nobody will notice. You may also wish to use your soldering iron to make holes. It'll smell bad, but it won't crack! (Use an old tip, of course.)

Wiring the shoulder buttons

All right, let's start wiring more stuff on the rear half of the unit, starting with the shoulder buttons.

1. Connect a 10"-long thin wire to the L1 and L2 tact switches.
2. Connect a 7"-long thin wire to the R1 and R2 tact switches.
3. Connect the two closest leads of the L1 and L2 tact switches together, and connect a wire from that to the two closest leads of the R1 and R2 tact switches. Connect those together as well — this is *GROUND* (connects to pin #7 on the controller board).
4. A total of five wires should come from the shoulder buttons, including *GROUND,* which I included in the R1/R2 wire strand in Figure 14-18. Make a mark on the wires so that you know which is L1/R1 and which is L2/R2 later on.

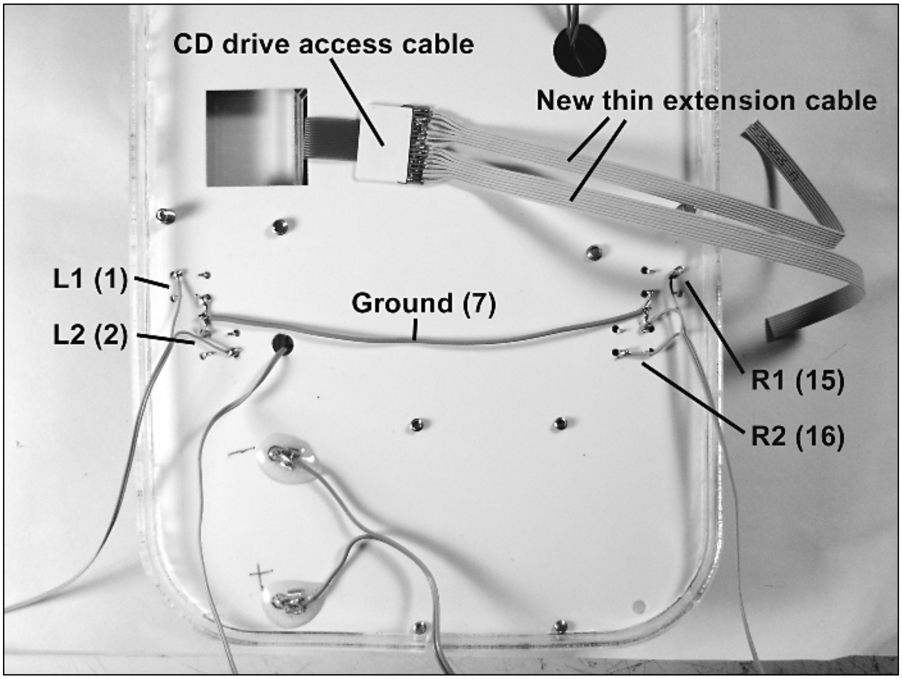


FIGURE 14-18: The wires for the shoulder buttons and the CD drive access cable as well.

Extending the CD drive access cable

I have to warn you, extending the CD drive access cable can be pretty tricky. It's one of those soldering jobs where accuracy is of utmost importance. Make sure you're using a 15-watt pencil iron, and the tip is clean and pointed (not dulled down). Then carefully follow these steps:

1. Cut a 4"-long 16-strand piece of thin Ultra ATA ribbon cable. If you can find the solid (unstranded) type of thin wire, you'll be in much better shape. (Ask at a computer parts store.)
2. Use a dab of hot glue to secure the original CD drive access cable flat against the rear plate. Angle it down slightly, as seen in Figure 14-18.
3. Dab a small bit of solder on each of the sixteen copper contacts on the original access cable.
4. Slice apart the wires on both ends so that about 1/2" is loose. Then carefully strip about 1/16"of plastic off the ends.
5. Lay each wire over each contact on the original cable. Then, lightly press the wire with the soldering iron. This will heat the solder below, and the wire will sink down into it.
6. Pull and shake the wire to test for a good connection, and then move onto the next one.
7. Use a multimeter to see if any of the connections are touching each other. Use the resistance-checking "beep" setting described in Chapter 3.
8. Once the wires are attached properly and not touching each other, use some hot glue to secure down the new ribbon cable. Do *not* hot-glue over the soldered connections, but rather place the glue just to the right of them. Hot glue can potentially pull the solder loose if you ever have to remove the glue.

Extra tips and hints

Since I'm asking you to do something rather difficult by extending this cable, it's only right of me to offer some additional tips and hints.

- You absolutely must use a small-tipped 15-watt soldering iron for accuracy. Otherwise you're doomed.
- Splitting the 16-strand ribbon cable into halves, quarters, or even sixteen individual wires will make the job easier. However, the more individual wires you have, the more chance there is of something breaking loose. You also run the risk of mixing the strands and up wiring it back to the PSOne board incorrectly.
- If you know someone who works with circuit boards for a living, or is really good with their hands, ask them for help.

- If you wear any type of corrective lenses that makes it easier to see far away rather than close up, take them off. Also, close one eye while doing this up-close stuff so that you don't see double.
- The original-model Playstations from about 1995–1996 have a really long CD drive access cable in them. If you have one of these lying about, check inside. Its CD-ROM drive is compatible with this portable, and the cable may be long enough that you don't have to extend it. Granted, the length of the cable varies by model, but it's still worth a shot to check.

Attaching the PSOne motherboard

Now that the CD access cable has been extended, we can attach the PSOne motherboard. Before you do, however, you'll need to remove a small portion of it so that it'll fit in the case:

1. Using a ruler, make a reference line across the top of the PSOne board across the extended portion near the power and audio/video connections. (See Figure 14-19.)
2. Make several grooves along this line using an X-Acto knife. Then use your large pliers to bend off the top portion.

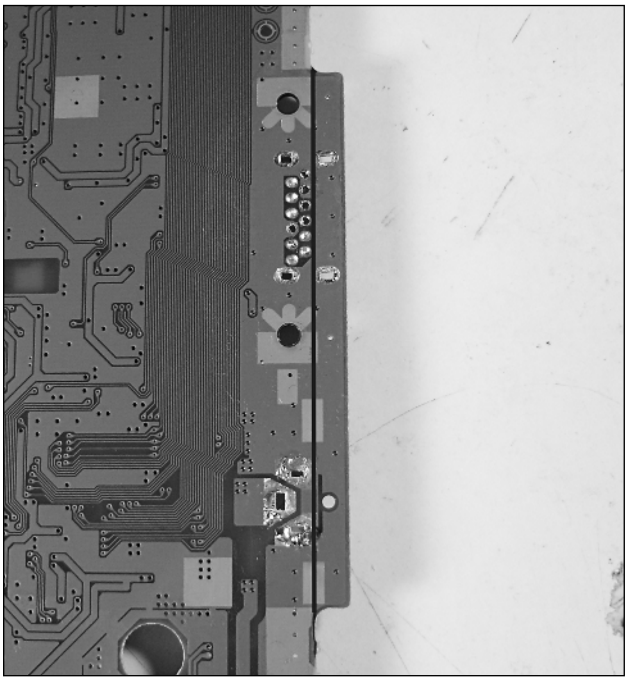


FIGURE 14-19: Where to slice off the top portion of the PSOne board.

Okay, *now* we can install it. The PSOne motherboard will be attached to the rear half of the unit, as seen in Figure 14-20. Three of the six main screws holding the unit together will go through existing holes on the board, but they need to be enlarged. You'll also need to do some corner-snipping as well. Following the figure are the steps to take when installing the board.

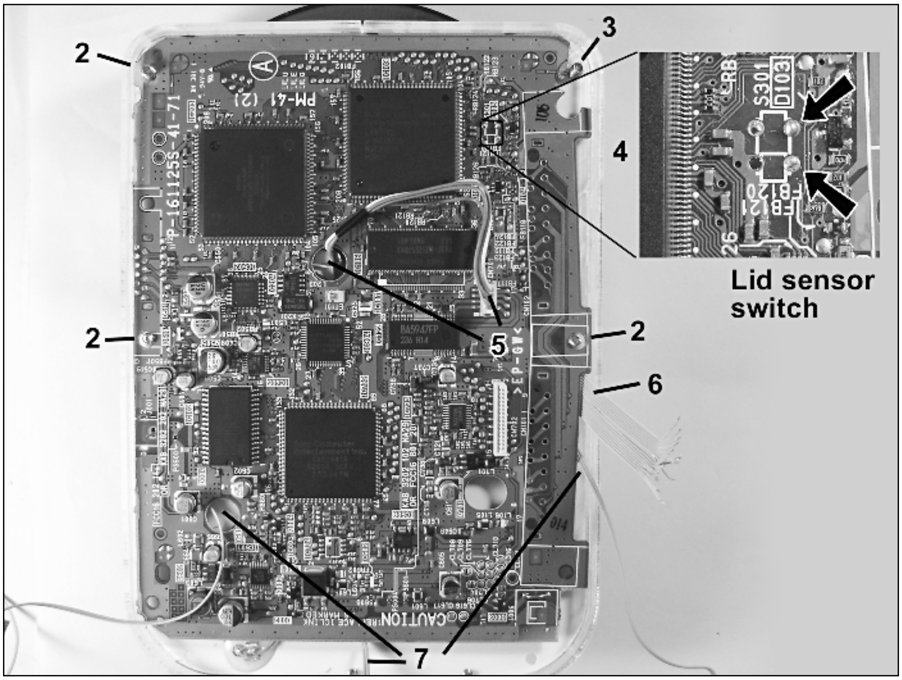


FIGURE 14-20: The PSOne motherboard set into the rear plate.

1. Note the position of the board. Parts (chips, slots) are facing out, the flat side of the board facing in (toward the CD-ROM).
2. Use a 3/16" drill bit to enlarge the upper left, middle left, and middle right holes on the boards (spots marked "2" on the figure). This will allow the 1/8" case screws to slide through easily.
3. There is no hole for the screw under the upper right corner of the board (spot 3). Instead, cut away a 1/2" high by 1/4" wide portion of the PSOne board so the screw can get through. You can also drill a hole there for the screw.
4. Connect the *CD lid sensor switch wires* to the *lid sensor switch spot* on the board from behind (Spot 4 as shown in Figure 14-20).
5. Thread the CD drive cable through the upper large hole in the board, and plug it back into its original place (Spot 5).

6. There's an indentation in the motherboard just below the right middle screw. Thread the 16-strand CD access ribbon cable through this side so that it can reach the slot (Spot 6).
7. Thread the left and right shoulder button wires and the wires to battery from under the board (Spots marked 7).
8. Note how the solder contacts for the DC power input will be hidden on the back of the board (see Chapter 12). Therefore, stick small bits of leads through the fronts of the holes, and solder them behind the board. This allows you to connect power to this spot after you've installed the motherboard. Slick, eh?
9. Set the motherboard into the rear plate. Check to see which part of it will come in contact with the *CD drive access cable soldering*, then put electric tape on the back of the PSOne board so that it won't short out against the solder. (Again, don't put anything directly on those soldered connections themselves.) The left and right edges of the board should fit tightly between the walls. If they're too tight to fit, sand them down a bit.

Connecting the halves together

Now let's start connecting the halves together. Don't worry, I haven't forgotten the CD drive access cable wires. It's just that we should connect everything else first.

Set the rear of the case on the left with the motherboard facing up. Set the front of the case just to the right of it. This will be the *assembly position***.**

Tip

I'd suggest keeping some sheets of paper under the halves of the units to avoid scuffing the front visible surfaces, especially since you'll be rotating them around as you solder.

Power, audio, and video connections

We'll start wiring the halves together by making the power, audio, and video connections as described below.

1. Connect the positive and negative battery wires to the DC AUX INPUT phono jack as shown in Figure 14-21 below.
2. Connect the *power in* wire from the on/off switch to the lead shown on the jack, and a 7"-long wire to the *To TV negative* lead.

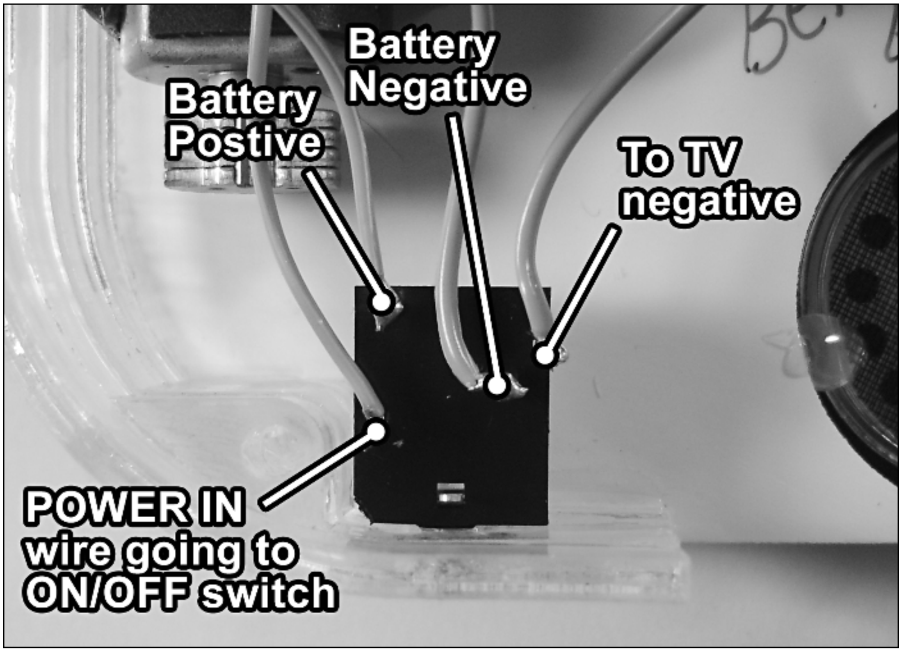


FIGURE 14-21: The DC AUX INPUT jack, with wires attached.

3. Take the *To TV negative* wire and connect it to the spot on the TV's circuit board shown in Figure 14-22. Attach another 10" wire to this same spot, and connect it to the negative DC input spot on the PSOne board.
4. Use two 10" wires to connect audio and video between the PSOne board and TV. Note that the single audio wire goes to two spots on the PSOne. Use a bit of lead to connect these spots together on the PSOne to make mono sound (since the TV is mono-only).
5. There should be two *power out* wires coming from the power on/off switch that have yet to be connected. Connect the long one to the positive DC input spot on the PSOne board, and the other one to the loose wire connected to the audio/video jack going to the TV. This then sends the power to the TV. (See Chapter 4.)

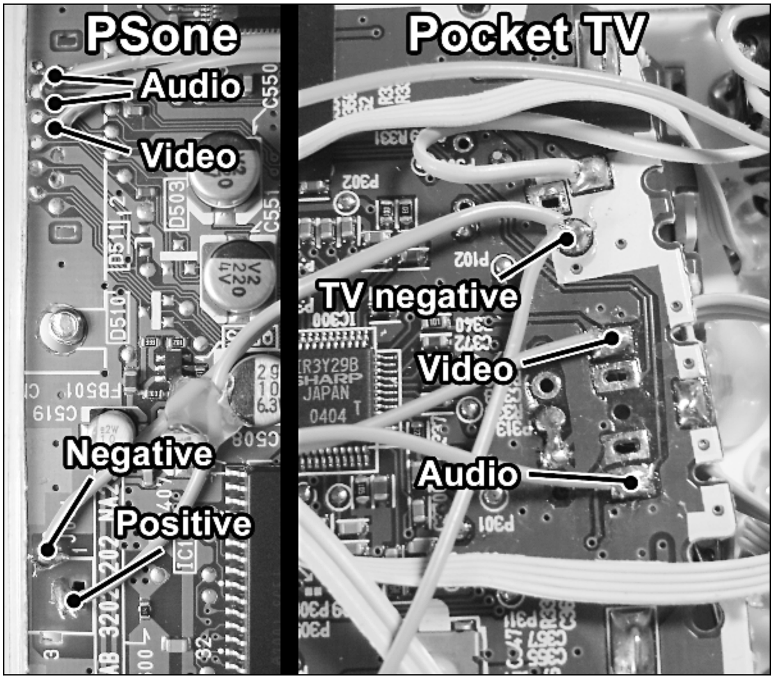


FIGURE 14-22: The audio, video, and power connections between the PSOne and pocket TV.

At this point, you can insert a charged Sony Infolithium type L battery and switch on the unit. The Playstation logo and sound should come on, and then it'll go into the memory card/CD screen. If it doesn't work, skip ahead and check the troubleshooting section to resolve the problem before continuing. (This way, there'll be less wiring in your way while you fix this problem.)

Connecting the built-in controller

With the audio, video, and power connections made, we can now connect the built-in Player 1 controller.

1. There should be eight 3"-long wires coming off the controller board. Connect these to the PSOne board as shown in Chapter 12. One of the connections on the PSOne board is labeled 8 and 2. Connect wire #8 to it (since there is no 3" wire coming from wire #2).
2. There should still be five wires loose that come from the shoulder buttons. Connect these to the controller board's button connector as indicated in Chapter 12. Connect the *GROUND* wire from the shoulder buttons to the main ground connection on the PC control board. (That's easier than connecting it to pin 7 on the controller board.)

Connecting the Player 2/memory card port

With that out of the way, we'll move on to the Player 2/memory card port that you desoldered from the PSOne in Chapter 12.

1. Start by inserting it into the gap on the bottom of the front of the case. It should fit snugly. You've got some room to work with, so slide it further in or out, depending on your taste.
2. Lay a bead of superglue along the edges of the port in order to connect it to the side walls. Then lay a bead of hot glue over that. Finally, put some hot glue behind the port so that it'll withstand the force of things being inserted into it. (Isn't hot glue great?)
3. With the port physically installed, you can make the wiring connections. Use a 5"-long 8-strand of ribbon cable to connect the memory card leads to the PSOne. Then use a 7"-long 9-strand of ribbon cable to connect the Player 2 controller leads to the PSOne.

Tip

If you don't mind the messy look, separating the ribbon cable strands for the Player 2/memory card port connections will make it a lot easier to position these wires and close up the case.

Optional: Player 1 rumble feature

As you can probably see, there's some empty space in the front of the case. Therefore, you can reinstall the rumble feature if you wish! But there's a catch, naturally... See, a Dual Shock rumble controller has two sizes of motors in it, large and small. The large one won't fit in this case. So if you'd like to do this, you'll have to gut another Dual Shock controller to get yourself a second small motor. (If you've got a friend who routinely throws controllers in frustration, why not give him or her a call now? There's probably got a smashed up "pile 'o shame" that you could plunder.)

Hot-glue the motors down on either side of the controller board. Their red and black wires should still be attached. Connect these wires back to the spots on the controller board where they originally were. (Think back to when you tore apart the controller.) There are two spots for each motor. The red wire goes to the top connection, and the black one to the bottom.

Now (sorry, I can't resist) you're ready to rumble!

Reconnecting the CD drive access cable wires

Okay, last, but certainly not least, is reconnecting the CD drive access cable to the PSOne board. There are two ways to do this, and each has its own advantages and disadvantages. Review them and decide which is best for you. (Or, just try one and if it kicks your butt, try the other.)

Inserting the wires directly into the connector

If you're using solid ribbon cable wire, this is your best bet. (I used this method in my portable.) Look inside the beige connector, and you'll see sixteen bending pins. Originally the flat ribbon cable went on the long, open side of these, but you can also cram wires down *behind* the pins.

1. Make sure about 1/8" of wire is exposed on each strand of the ribbon cable. Bend the end of the ribbon cable up away from the connector.
2. Using tweezers, bend the first strand down and stick the wire down behind the copper pin in the connector. The pin should bend forward slightly.
3. Repeat this for the remaining wires. If you keep the uninserted wires up, and bend them down one at a time to insert them, this lowers the chance of already inserting wires popping back out.
4. Do not put hot glue or anything over these connections until you've had a chance to test the unit. If you keep the motherboard in place, these connections shouldn't pop out while you test it. The stiff solid wire of the cable keeps its shape and position well.

Soldering the wires to the sides of the connector

If, for some reason, the wires and pins method isn't your bag, you can solder the wires directly to the connector's leads on the motherboard as described below.

1. Note how every other lead is on opposite sides of the connector. Because of this, split up the ribbon cable strands — bend every even lead up and every odd lead down. This allows the ribbon cable to "straddle" the connector.
2. Put a small bit of solder on each of the connector's leads. This freshens the existing solder up a bit and gets it ready to receive wires.
3. Strip only about 1/16" of plastic off the end of each wire. Bend this bare wire out away from the connector on both sides.
4. Set the strand alongside the connector, and lay the bare wire on the lead. Then touch it with your soldering iron until the solder melts. The wire will connect to the lead. (This is much like how you connected the ribbon cable to the original CD drive access cable.)
5. Repeat for the remaining wires. Keep close tabs on the odd and even sides. If you miss one, or make a mistake, heat up the solder and pull the wire free. Do *not* attempt to use your desoldering iron. It'll be overkill, and might wreck stuff.
6. As with the other method of doing this, don't hot-glue the wires in place until you've had a chance to test the unit. Just don't bump them with anything, and they should be fine.

The wiring of your PSOne portable is now complete, and should look like shown in Figure 14-23.

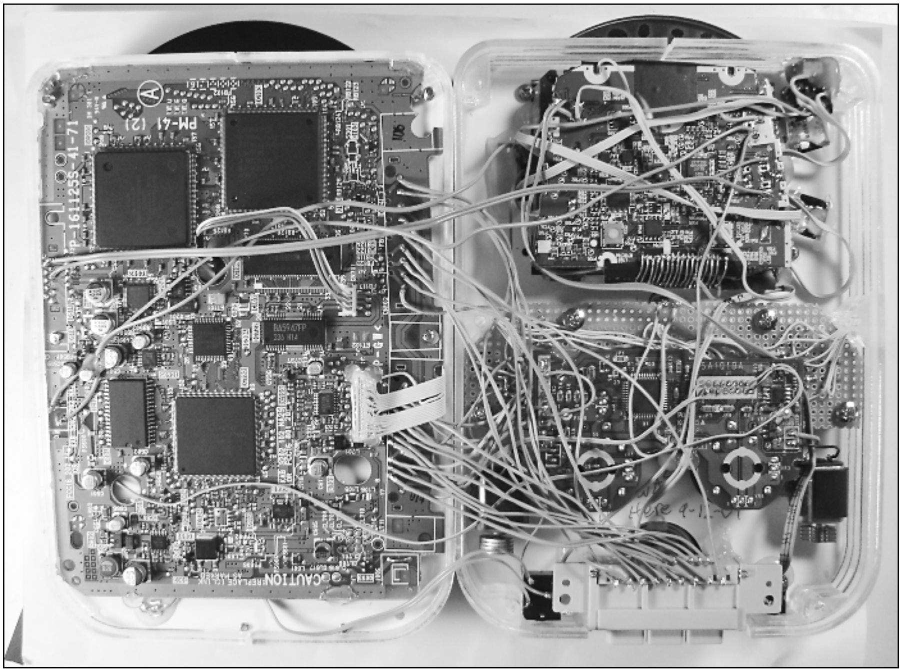


FIGURE 14-23: The insides of the PSOne portable, all wired and ready to go!

Testing and Troubleshooting

Now that the wiring of your portable is complete, it's time to test it. We'll go step-by-step on how to test out all the functions of the unit, and what to do if something doesn't work. Once everything is checked out, we'll move on to the next section where we'll close up the unit and finish it.

1. Charge up the Sony Infolithium Type L battery and slide it over the battery tabs. Insert a game disc and a memory card. Switch on the unit. If nothing happens, check the following:
   - Is the white LED mod on the TV hooked up correctly?
   - Check the polarity of the TV's jack by looking at the original plastic shell. On some models (such as the RCA Radio Shack ones), the polarity is reversed for no apparent reason.
   - Check that the battery is charged and at least +7.5 volts is coming out of it.
   - Check the connections on the DC AUX INPUT jack.

2. If the screen lights up, but there's no actual picture, check the following:
   - The ribbon cable attached between the LCD glass and the screen's motherboard may not be reinstalled into its jack correctly, or may have come loose during assembly. Dismantle the screen assembly and check.
   - Check that you've connected the audio and video wires between the PSOne and the screen correctly. Again, on some models these switch around, so you can try swapping them as well.
   - Check the seventeen connections between both halves of the TV. Did one break loose, or is one touching another?
   - If the brightness dial is turned all the way up, the screen will go completely white regardless of the picture. Spin the dial down and check if that's the problem here.
   - An incorrectly rewired brightness dial cable can also cause the picture to disappear, so check it as well.
3. If there's picture, but no sound, take the following steps:
   - Check the volume dial's ribbon cable. If even a few of the wires come loose, it can cause the sound to not work.
   - Be sure the headphone jack has been properly rewired as explained in Chapter 4. If it isn't, the sound won't work, since it passes through this jack before going to the speaker.
   - Check the audio connection between the PSOne and the TV.
4. If the PSOne starts up, with logo and sound, but doesn't continue, or just goes to the memory card screen, check the following:
   - Is the CD-ROM able to spin freely? Check that the lid (or your fingers) isn't hitting it.
   - Is the 4-strand cable coming off the CD-ROM drive firmly and correctly plugged into the PSOne's motherboard? Did any of the CD drive access wires come loose from the connector on the motherboard side? These were manually rewired, so it's quite possible.
   - Check that the lid sensor switch is being pressed when the lid is closed. Add another layer of thin plastic if you're not sure.
5. Once the disc is working correctly, the game should load upon startup. Press START to play, and try using the controls. If they don't work correctly or at all, do the following:
   - Double-check all controller connections.
   - If you inserted the thin wires into the controller board's flat ribbon cable spot, make sure none have pulled loose and are all firmly installed. (Once they all work, hot-glue them in place.)

- Are the tact switches correctly rewired to the controller board?
- Did you connect pin 2 to pin 8 on the controller board where it connects to the PSOne board?

6. Once the controls are working, try to access the memory card, and also plug in a Player 2 controller and try a two-player game. If neither works, do the following:
   - Double-check the wiring between the Player 2/memory card port and the PSOne. Make sure the wiring hasn't been accidentally reversed — they should reconnect just as they were connected when the port was on the PSOne board. Check the *Controller connector wiring* section in Chapter 12 for more information.
7. If the system switches on and off, or the power seems flaky, do the following:
   - Check that the battery leads are making good contact with the battery. Bend them down or sideways so that when they insert they have more friction.
   - Make sure you're using at least a NP-F550 Sony Infolithium battery. The smaller, weaker ones aren't really enough to power a portable like this for any length of time.

Final Assembly

Once you've got the portable PSOne working correctly, you can start the final assembly, which involves wrangling some parts and wires inside the unit so they'll fit, putting a few more decals on, and then screwing the whole thing together. Fire up the hot glue gun because we'll be starting with that.

1. Press the PSOne motherboard down along the screws against the rear plate as far as it will go. Once it's down, put some hot glue on all four corners of it to secure it. This sets you up for the next step.
2. Place a bead of hot glue over the CD drive access cable extension going to the PSOne motherboard. Let it cool a little, then get a whole bunch of saliva on your finger, and press it down over the glue. This will flatten it out over the wires, allowing more space inside the portable.
3. Put some more hot glue between the controller board (with the analog sticks) and the PC control board that you built. This will further secure the analog sticks.

Final decaling

There should be two unused decals at this point. Place the *aux power in* decal near the phono jack (the *aux power input jack*) Make sure the aux power in decal doesn't go over the edge where the halves meet.

The *Playstation Portable Designed/Built By* label goes in between the battery tabs, with the arrow pointing towards the battery leads. There's even a space to write your name so everyone will know who built your portable for all eternity (or until the ink rubs off, whichever comes first).

Screwing the unit together

We can now screw the unit together and finish it.

1. First fold the halves toward each other like a peanut butter sandwich. Imagine the wires are the peanut butter — don't let them gush out the sides. If they do, poke them back in with a small flat-head screwdriver. Also keep them away from the six screw holes. Screwing through a wire would be bad!
2. Once the sides meet and the wires are behaving, you can insert the screws. Finish driving the two middle 1-1/4" screws into the front of the case. Then, for the remaining four screw holes, insert 3/4"-long size-6 screws. The unit should now be secure.

Modifying the wall power adapter for this portable

The wall power AC to DC adapter you got with your PSOne can be used to power this unit, with a slight modification. Namely, it needs a new plug that'll fit into the DC AUX INPUT jack. Here's how to accomplish this:

1. Snip off the old plug and slide the cover of the new plug down the wire.
2. Solder the new 1/8" phono plug (Radio Shack catalog #274-287) to the wire. Connect the inside wire of the adapter to the inner lead on the plug, and the outer wires to the outer lead. The connection should look as shown in Figure 13-24.
3. Plug in the wall adapter and check that positive voltage is coming from the center tip of the plug, with the negative side on the outer portion.
4. Place a piece of electric tape between them to avoid short circuits, and slide the cap back over and screw it in place.

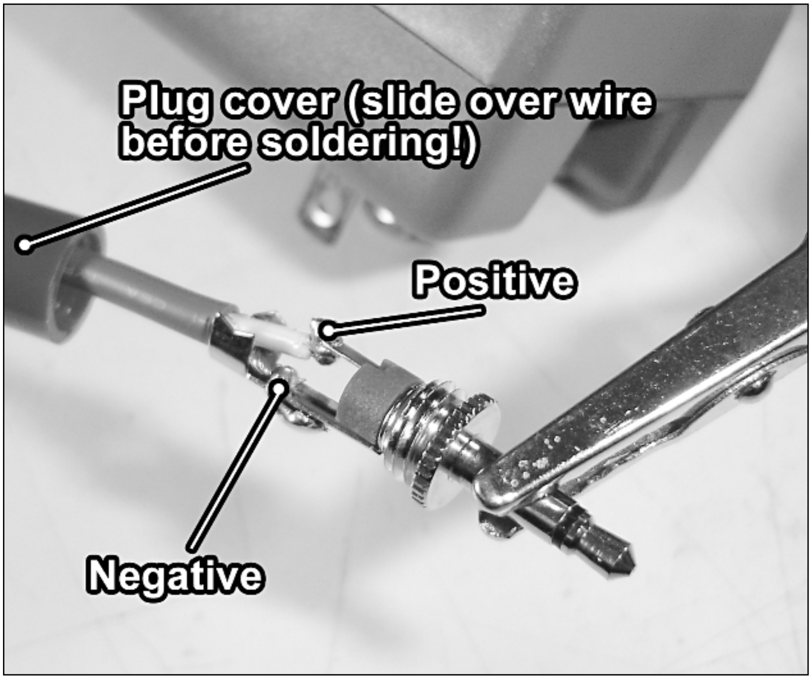


FIGURE 14-24: The wall adapter's new plug.

That's it! Your PSOne Portable is now ready for all your classic Playstation playing needs! Enjoy!

Chapter in Review

This CNC-built portable Playstation project is a fairly cool-looking unit when finished, especially if you used clear acrylic to have see-through sides! Let's look back at the major steps it took to build the thing.

- You collected components for the unit and had parts cut using a CNC machine. These parts were then glued together to form the case itself.
- A heavily-modified folded-in-half Casio EV-680 was used for the screen.
- You made and installed a custom control board that works along with part of the original controller to provide the unit with built-in game controls.

- You delicately soldered wires to extend the CD drive access cable (or used a long cable from an old Playstation).
- Finally, you installed the PSOne board itself into the case, wired everything together, tested it, and closed the unit up.
- You're now enjoying your PSOne portable and breathing new life into your Playstation 1 game collection (and maybe buying new games really cheap at the used-game store)!

Making Your Atari 2600 Portable

chapter 15

in this chapter

- ☑ Ripping Apart the Atari 2600
- ☑ Hacking Stuff Off
- ☑ Master Lead List
- ☑ Powering the System with Batteries
- ☑ Getting Audio and Video Signals to a Modern TV
- ☑ Working with Controllers
- ☑ Chapter in Review

Remember back when you were young and used to love playing Atari all the time? Just when you were about to get the new high score (that you'd write on a piece of paper), all of a sudden it would be time for bed, or the school bus would be outside honking at you?

You'd have to leave the Atari all alone, sitting there like a forlorn velveteen rabbit. Sure, it'd still be there when you got back, but didn't you wish you could take it with you?

Now, after 20 years of advances in pocket TVs and batteries, you can! In this chapter we'll hack apart your beloved Atari 2600 to make it smaller, hook up a video circuit so it can connect to modern TVs, and even give it new controllers! Let's get started before the school bus gets back!

Ripping It Apart

The first step to making your Atari 2600 portable is to rip it apart. Be sure you're using the correct type of four-switch Atari 2600, as described in Chapter 1.

1. Start by flipping the Atari 2600 over. You'll see four deep screw wells on the back. Use a long Phillips-head screwdriver to remove the screws in each.
2. Once you've gotten those pesky screws out of your way, pull the case apart. It may take a bit of gusto, but it will pop open. Remove the RF cable from the plug on the Atari board and it should look like what's shown in Figure 15-1.

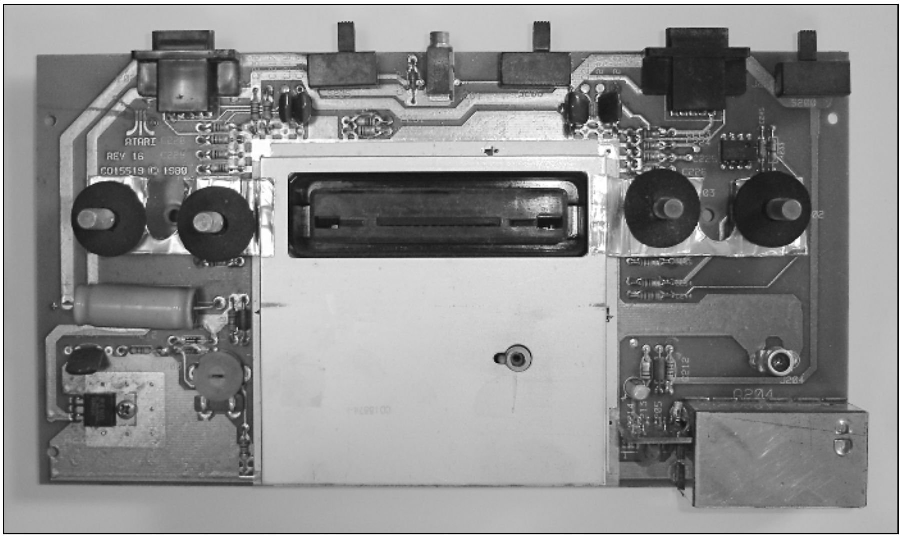


FIGURE 15-1: The main Atari 2600 board.

3. Check the upper right corner of the board. If you see a small *8-pin IC chip*, as shown in Figure 15-2, you'll need to take some additional steps when hacking up the board. (We'll do those steps later in this chapter.) This thing appears in about one out of five Atari 2600s.

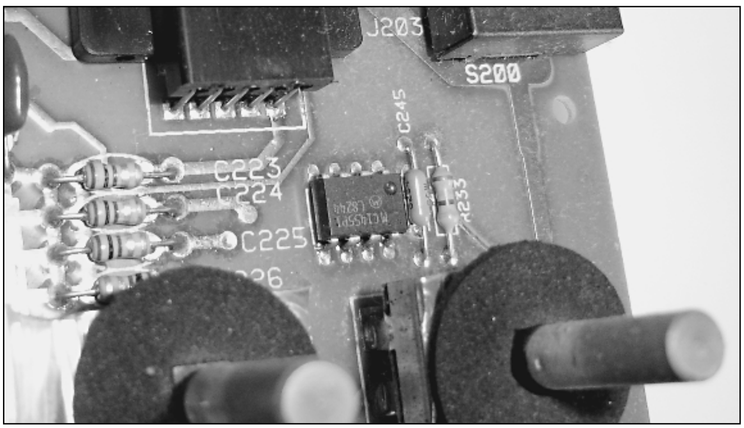


FIGURE 15-2: The small 8-pin IC chip that you may have to rewire.

4. Look around the edges of the RF shielding. You'll see little twisted tabs holding it in place. Use your tweezers or needle-nose pliers to bend these straight so that they can be pulled out. On the back side of the board, cram a flat-head screwdriver under a gap in the RF shield, and pry up to remove it.
5. Once you have the RF shielding off, you'll see the main chips and a pinkish-red thing wrapped, with copper wire sticking up. Go ahead and snip it off at the base (where its leads touch the motherboard) using your cutters.

Identifying the internal parts and what they do

Well, that wasn't too hard, getting the Atari 2600 apart, was it? Let's take a look at all this stuff on the board before we continue (see Figure 15-3).

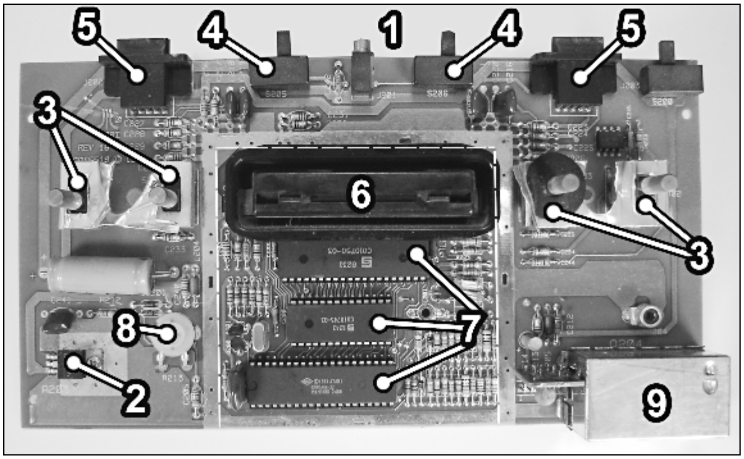


FIGURE 15-3: The Atari 2600 board with labeled parts.

- **DC input jack.** Takes a 1/8" mini plug with 9 volts DC, center positive (standard Atari 2600 wall adapter).
- **Power regulator.** Sends 5 volts DC into the Atari circuitry.
- **On/off, black/white, select, and reset switches.**
- **Difficulty switches.** Lets you make the game easy or hard (not all games use these).
- **Joystick/paddle ports.** Player 1 is on the left, Player 2 on the right.
- **Cartridge slot.** Where the game goes.
- **Main chips.** From top to bottom, RIOT, CPU and TIA.
- **Color timing potentiometer.** Adjusts the tint of the video image.
- **RF modulator.** Creates a Channel 2 or 3 television signal that goes to the RF switch.
- **Dashed lines.** This indicates where we will be slicing apart the board.

Hacking Stuff Off

The Atari 2600 board starts out as the largest of all the systems covered in this book. However, it has a secret feature — it can become the smallest! You can slice the Atari 2600 into a 4” × 4” square, and with minimal rewiring it will still function. The cut lines are shown in Figure 15-4.

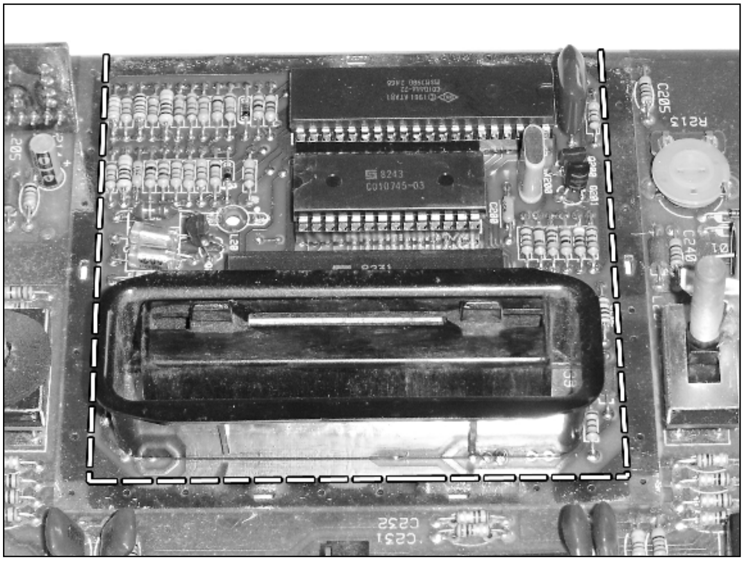


FIGURE 15-4: Where to cut the Atari 2600 board.

When cutting, stay just inside the metal band. The exception to this is the bottom piece of metal (not seen in Figure 15-4). You’ll want to leave this, in order to use it as a ground. If you’re wondering exactly *how* to cut the board, choose one of the following methods.

X-Acto knife method

Ever see one of those movies where a spy goes up to a window and scratches a circle in the glass, then pops out a perfect hole? Granted, it’s one of those “movie-isms,” like phones that ring too fast or the L-shaped bedsheet, but it illustrates a principle that actually works with a circuit board: If you scratch lines in it, you can snap it apart with minimal damage.

Place the Atari board on a table. Then, using your X-Acto knife, scratch several deep lines as indicated in Figure 15-7. Take your time to make the first line straight, because when you go back and deepen it, the knife will follow in the same groove. After you've scratched into the front for a while, make some grooves in the back as well, again just inside the metal band.

Caution If you press hard to make a groove and then reach the edge of the board, the knife will slide off and move a good 6 inches, instantly, due to the applied force. Make sure no part of your body is anywhere near this "exit area" of the knife! And do not attempt this procedure while holding the Atari board in your lap!

Once you've made grooves along the three lines in the front and back, grasp the board and push your thumbs on either side of each groove to snap it off. If the board doesn't snap, or just bends, make some more grooves. How many grooves you need to make can vary because of the age of the board and its condition.

Band saw method

If have access to a band saw, this is a much faster method. Starting with the sides, saw down each line, but try to stay on the edge of the metal line, and not go inside it (that way you won't slash into a resistor). When you get to the end of the line, just keep going — the saw should be able to plow through those green capacitor things, but keep at least one of them intact if you're planning to hook up a paddle controller. Finally, saw off the top portion, making sure not to hit the black cartridge assembly with the blade.

Caution Wear safety goggles when using a band saw, as flying debris may come off the board. Also keep your fingers well away from any blades. (Remember, skin is much softer than a circuit board.)

Master Lead List

Figure 15-5 shows a photograph of the back of the 4" × 4" square, with leads on the board labeled by letter. We'll call it the *master lead list*, and the next two chapters will refer back to this whenever a connection needs to be made on or to the Atari board. (To save wear on my keyboard, I'll simply call it the *MLL* from here on out.) For example, if there are some connections that need to be made for the Player 1 joystick, there'd be a four-strand of ribbon cable that I'll tell you to connect to spots E, F, G, and H on the MLL. Having this list/photo here will save time and space in later chapters.

So I'd suggest bookmarking this page, or if you don't have a bookmark, a classic "dog ear" will suffice. Heck, rip the page out and stick it on the wall, even!

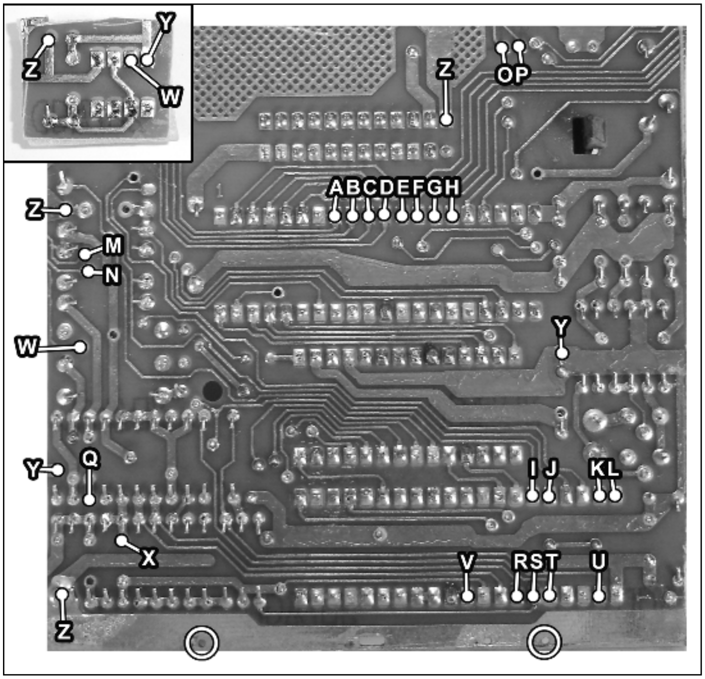


FIGURE 15-5: The 4″ × 4″ Atari 2600 Master Lead List.

Table 15-1 Legend of the Master Lead List

A	Player 2 joystick UP	J	Player 1 trigger
B	Player 2 joystick DOWN	K	Paddle 2
C	Player 2 joystick LEFT / Paddle 4 Trigger	L	Paddle 1
D	Player 2 joystick RIGHT / Paddle 3 Trigger	M	Select
E	Player 1 joystick UP	N	Reset
F	Player 1 joystick DOWN	O	Player 2 difficulty (Open=Expert, Closed=Novice)
G	Player 1 joystick LEFT / Paddle 2 Trigger	P	Player 1 difficulty (Open=Expert, Closed=Novice)
H	Player 1 joystick RIGHT / Paddle 1 Trigger	Q	Audio out
I	Player 2 trigger	R	Video circuit to 1K potentiometer

S	Video circuit to 22-ohm resistor	W	To 8-pin chip
T	Video circuit to 1K potentiometer	X	Video circuit chroma
U	Video circuit sync	Y	+5 volts in
V	Color adjust	Z	Ground

Bypassing connections

With most of the original motherboard gone, the remaining 4” × 4” square won’t work on its own. Therefore, we’re going to have to bypass some connections, and we may as well drill a couple of holes while we’re at it.

1. Connect a short wire between the three spots on the board marked “Z.”
2. Connect a wire between the two spots marked “Y.”
3. Drill a 1/8” hole into each of the two small holes circled in the above photo.

If your Atari had the 8-pin IC on the board, you’ll have to take the following steps as well:

1. Cut the circuit board around the 8-pin IC and the two components next to it to make a 3/4” × 1” piece of board (as seen in the previous figure).
2. Connect the three leads indicated on the IC to the spots on the Atari with the same letter. These are *+5 volts, Ground,* and “W.”
3. Put some electric tape on the back of the IC board to avoid short circuits, and superglue it onto the Atari board where it won’t get in the way of anything and will sit as flat as possible—just to the left of the topmost chip is a good place.

That’s it! The Atari will now run once it has batteries and a video circuit attached. You’ll need to have this bypass done for the projects in the next two chapters.

Note

You may recall that the Atari had a black and white/color switch. When that switch is disconnected the Atari defaults to color, so you won't need to reconnect it.

Getting Audio and Video Signals to a Modern TV

With the clunky RF box gone, the Atari has no way to send video signals to a TV, much less a modern one. The solution is to build a simple video circuit, as shown in Figure 15-6. (We’ll do this first, because without video, how will you know if the system is working?) As with the bypass wiring, this video mod should be done before starting the projects in the next two chapters.

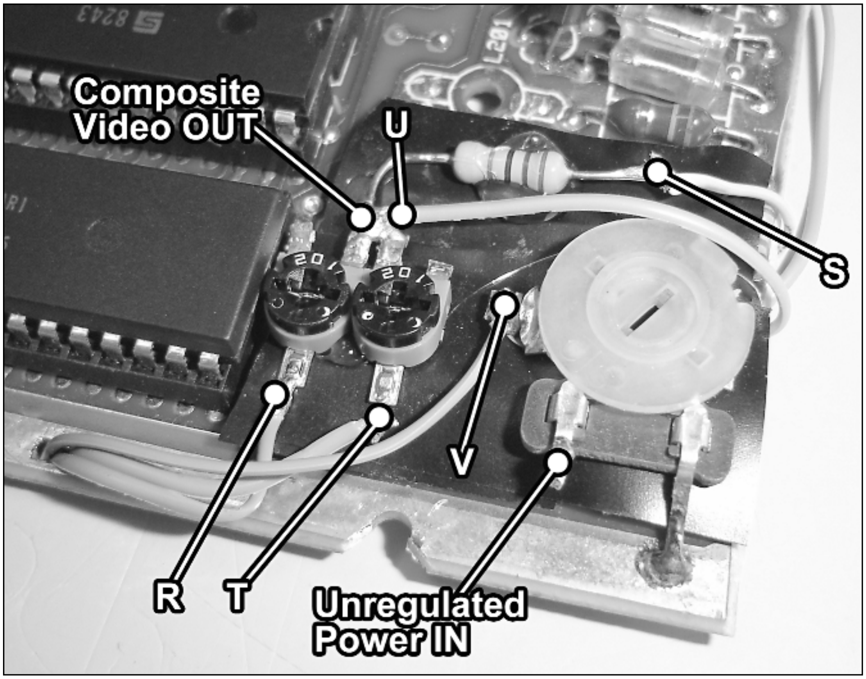


FIGURE 15-6: Atari 2600 composite video circuit.

1. Get the following parts from Radio Shack (or just about any electronics vendor):
   - Two 1K-ohm microsize PC mount potentiometers (Radio Shack catalog #271-280).
   - One 22-ohm resistor (Radio Shack catalog #271-1103).
2. Place a layer of electrical tape down over the resistors on the lower right corner of the board.
3. Desolder the color tint potentiometer (CTP) from the removed left side of the board. There's a lot of solder on it, so suck it up in sections. Once most of the solder is gone, push on the bottoms of the big tabs with the iron to make them pop out the front.
4. Hot-glue the CTP on the right side of the electric tape. Bend one of the bottom leads down and solder it to the metal stripe along the base of the board. Attach a wire from one of its side leads to spot "V" on the Atari.
5. Place both of the 1K potentiometers side-by-side on the electrical tape and solder the two closest leads of them together. This spot is *Composite video OUT.* Connect one end of the 22-ohm resistor to that and the other end of the resistor to spot "S" on the Atari.

6. Attach wires from the top leads of the potentiometers to spots "R" and "T" on the Atari.
7. Connect a wire from spot "X" to spot "U," then connect a wire from there to *Composite video OUT.* This adds *chroma* and *sync.*

That's all there is to composite video output modification! We'll attach unregulated power into the CTP in the next section.

Note

"Composite" video is the term for the kind of video signal that goes into the yellow RCA jack on your TV or VCR.

If you simply want to connect an RCA plug/cable to the Atari so that you can hook it up to a modern TV, you'll need some audio/video cables. If you have a extra set from your Playstation or N64, you can chop off the console plug ends and use them.

1. For video, connect the center wire of the cable to *Composite video OUT* and the outside to *Ground.*
2. For audio, connect the center to spot "Q" on the Atari, and the outside to *ground.* Connect the centers of the left and right (white and red) cables together to get sound going to both speakers.

Fine-tuning the picture

When you first use the Atari with the video circuit, the colors will probably look weird. You can use a thin flat-head screwdriver to turn the three capacitors to adjust it. The big CTP will adjust tint, whereas the two smaller potentiometers adjust brightness and contrast.

Table 15-2 lists the proper color schemes of several common games for your reference. The following two chapters will also refer back to this table when it comes time to adjust the color.

Table 15-2 Atari 2600 Game Color Reference Chart

Game	*Colors*
Pitfall	Dark green upper trees, light green middle, light brown ground, dark brown dirt
Frogger	Blue water (shocking), green borders, yellow middle, brown logs
Pac-Man	Blue background, puke brown maze walls, flickering ghosts
E.T. (title screen)	Grinning yellow E.T., brown "E.T." letters, blue background
Joust (title screen)	Purple-ish blue square, yellow "Joust" title. Everything else in game: Brown
Combat	Purple and blue tanks, yellow background

Powering the System with Batteries

Now that the bypassing is done, it's time to run the Atari off batteries! If you're doing one of the projects from the next few chapters, you can skip this section, but if you want to know what to do for your own custom portable, read on!

Power requirements

The Atari 2600 isn't exactly the most modern electronic device and because of that it's not terribly power-efficient, requiring around 300 mA of power at 5 volts. Since you'll be using a power regulator, this means that the battery must be at least 7 volts, if not higher. (See Chapter 3.) Here are some possible choices:

- **7.2-volt Ni-MH rechargeable, Radio Shack catalog #23-431, or the Ni-Cd version, catalog #23-330.** This type of battery has a lot of mAH, even the Ni-Cd version, but also isn't very lightweight. In fact, it'll probably comprise 50 percent of your portable's weight when done!
- **9.6-volt Ni-MH rechargeable, Radio Shack catalog #23-333.** Much lighter than the 7.2-volt version but also only about half the mAH. If you want a smaller, lighter portable, this is the way to go; it just won't run as long.
- **Sony Infolithium battery.** The best of both worlds — a long playing time, lightweight and small. The price isn't as small, although you may be able to find a good bargain from an online auction. You'll also need a separate standalone charger.

Using a power regulator

Once you've selected your battery you'll need a way to regulate its power before hooking it up to the Atari. Using unregulated power will send your Atari to the grave.

The cheapest and easiest route is to get a 7805 linear power regulator, Radio Shack catalog #276-1770. You can input any voltage from 7 to 25 volts, and the regulator will knock it down to 5 volts and turn the difference into heat. To absorb that heat, screw the regulator to a heat sink. Radio Shack catalog #276-1368 works well and fits in a variety of places.

Figure 15-7 shows a sample circuit using a 7805 to regulate power and send it to the Atari. Note how unregulated power is connected to one lead of the CTP (see the previous figure). This is the *only* place on the Atari where unregulated power should go.

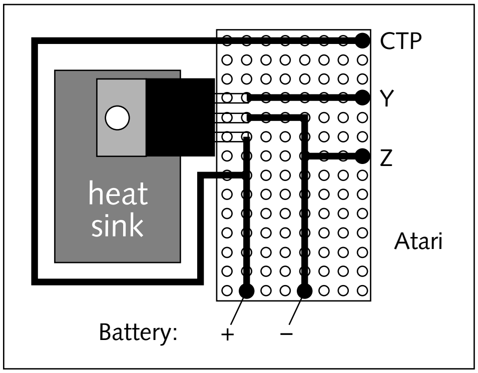


FIGURE 15-7: Sample power supply for Atari 2600.

Once you've turned on the modified Atari, you can use the CTP to adjust tint and the two 1K potentiometers to adjust brightness/contrast (see the previous section, *Fine-tuning the picture*).

Working with Controllers

By this point, you should be able to turn the Atari on and see the game. *See*, not play. That's no fun, so you're going to need a controller!

The joystick controllers for the Atari are very simple — each direction/trigger was a switch. One side of the switch was connected to the Atari (at the spots indicated on the Master Lead List), and the other side was ground. When the switch is pressed, the connection goes to ground, also called being "pulled low." The Atari then knew which direction/trigger was pressed. There were no serial latch ICs like the NES or SNES — it was simply one wire per direction/trigger, and a ground wire.

Figure 15-8 here shows a sample controller for the Atari using tact switches and a piece of PC board. The select and reset buttons have also been included. The letters refer to spots on the MLL.

Again, Frogger is a great test cartridge because you can move the frog in all four directions. Combat is good for testing both player joysticks and the triggers, since it's a two-player only game.

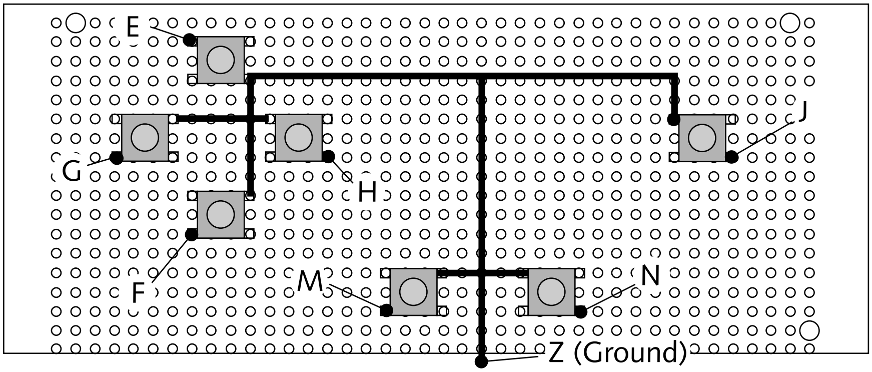


FIGURE 15-8: Sample controller for hacked-up Atari 2600.

Note

The Sega Genesis used the same single wire–per-button kind of controller/plug that the Atari 2600 did. Because of this, you can use a Genesis controller with your 2600. And if you really want to wow people, play your Genesis with an Atari controller! (A one-button game like Sonic works great, you'll have to use a Sega pad to push "Start" though.) Granted, this would have been more impressive to show off during the Sega heydays of the early '90s, but it remains an interesting historical anecdote to this day.

Difficulty switches

Since the Atari was pretty primitive, the early games for it didn't have the fancy menus and options we enjoy today. Nope, if you wanted to make the game more difficult, you'd have to get off your 1977-era corduroy couch, step over the Pet Rock, walk over to the Atari, and slide the difficulty switch from *Novice* to *Expert.* (That's a pretty extreme jump — couldn't they have had a middle position called "Journeyman," or something?)

The difficulty switch connection spots are labeled on the MLL. If you leave them open (unconnected), the games will default at Expert. You can connect each spot to a slide switch in order to be able to adjust the difficulty, or simply connect them both to the nearby ground to make all the games Novice. For the projects in this book we're going to omit the difficulty switches, so you should now wire them they way you'd like to have them.

Note

Many of the later games for the 2600 did not use the difficulty switches at all, or actually had menus! Gasp!

Wiring paddle controllers

The original Atari paddle controllers were basically big volume dials with triggers on the side. They were rather clunky, so you'll probably want to wire your own custom paddle controller for your sleek, new, modern portable. For each paddle controller you will need the following parts:

- One 1M- ohm linear taper potentiometer (Radio Shack catalog #271-211).
- A knob of some sort stuck on it. I'd suggest the chrome Radio Shack knob (Catalog #274-424), because it looks the coolest, but it's up to you of course. You could also stick the original Atari paddle knob on it, but it's awfully big.
- A desoldered fat green capacitor (FGC) from the top of the Atari board (one that you *didn't* plow the bandsaw through).

Figure 15-9 shows a sample paddle controller that can be hooked up to the Atari board.

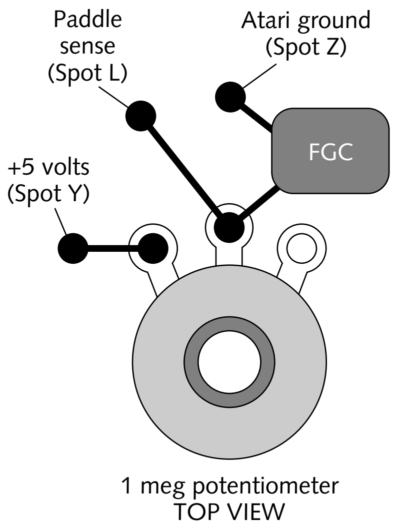


FIGURE 15-9: How to hook a paddle controller to the Atari.

Tip

You can actually hook up to four paddle controllers to the Atari—I only listed the first two on the MLL, because the pesky English alphabet ran out of letters for me to use. The next two leads going from the left of spot "K" are for paddles 3 and 4.

You now have all the stuff you need to make your Atari run off batteries, give it new controllers, and hook it up to a modern TV! Use this knowledge to create your own custom portable, or better yet, do one of the projects in the next two chapters!

Chapter in Review

In this chapter, you took apart the Atari 2600 and pulled out the motherboard. You then sliced off most of the motherboard leaving only a 4” × 4” square. Using the master lead list (MLL), you learned which spots to reconnect to get the motherboard working again. You then added a video circuit to enable the Atari to send modern composite video signals to a TV. This prepares the Atari board for use in the next two chapters.

For those of you who may be contemplating building an Atari portable of your own design, we discussed how to power the hacked-up Atari board and rebuild a joystick controller and paddle for it.

Important things to remember from this chapter include the following:

- You can cut a lot of the Atari board off and still get the “core components” working again.
- The Atari must be modified to output a normal composite video signal, unlike most video game systems from 1985 and after.
- The joystick controllers and paddles are very simple to re-create.

chapter 16

Building a Portable Atari 2600 by Hand

in this chapter

- ☑ Materials You'll Need
- ☑ Assembling the Case
- ☑ Wiring the Unit
- ☑ Testing and Troubleshooting
- ☑ Final Assembly
- ☑ Chapter in Review

As mentioned in previous chapters, the Atari 2600 VCS is a fairly simple video game system that can be hacked into a small shape. Because of this, you can make a nice, compact, simple little portable, just like the one shown in Figure 16-1!

FIGURE 16-1: A simple, compact Atari 2600 portable.

In this chapter you'll take the Atari 2600 that you hacked into a 4" × 4" square in Chapter 15 and build a custom case for it using engraving plastic and aluminum. You'll then install a screen and custom controls into the case and wire it to the Atari board along with the battery packs. The end result will be a self-contained portable Atari 2600 game system that you can take anywhere! Let's get started so that you can fulfill your dreams of playing Yar's Revenge in the break room at work (or school bus/study hall).

Materials You'll Need

We'll start with the major components of the system you'll need:

- Casio EV-680 pocket TV with white LED modification, à la Chapter 4.
- Atari 2600 four-switch, hacked up and given a video output circuit as shown in Chapter 15.
- One standard NES controller. Just for the buttons, which may seem like a waste, but it's easier than making your own. Desolder the IC (as described in Chapter 6), and it'll come in handy if you ever make a portable SNES project.

Electronic components

The Table 16-1 is a list of the electronic components you'll need. Most of these can be found at your local Radio Shack, with the tact switches needing to be ordered from an online vendor such as Digi-Key (`www.digikey.com`).

Table 16-1 Electronic Parts List for Hand-Built Atari 2600 Portable

Part Name	*Available From:*	*Part or Catalog #*	*Quantity Required*
General-purpose PC board	Radio Shack	276-147	1
Phono jack	Radio Shack	274-246A	1
Chrome knob	Radio Shack	274-424	1
SPST submini slide switch	Radio Shack	275-406	1
1M-ohm linear-taper potentiometer	Radio Shack	271-211	1
Battery holder, four AA	Radio Shack	270-391	2
7805 linear voltage regulator	Radio Shack	276-1770	1
Tact switch, 4.5 mm, H = 3.8 mm	Digi-Key	CKN9018-ND	8

Tip

If you've done other projects in this book, you may have enough of the 276-147 PC board left for this Atari portable. Check the *Wiring the Unit* section to see how much you'll need.

Screws, nuts, and spacers

Next up in your parts-finding quest are the screws, nuts, and spacers. Table 16-2 lists what you'll need — the best place to find these items is your local hardware store. The spacers, which are made of nylon, aren't always in every hardware store, but if you check a couple of places you should run across some (the bigger the store, the better).

Table 16-2 Screws, Nuts, and Spacers "To-Get" List

Screw/Nut/Washer/Spacer Size	*Type*	*Length/Size*	*Quantity*
Size-4 screws	Phillips, pan (round head)	1/4"	3
Size-6 screws	Phillips, pan (round head)	3/8"	2
Size-6 screws	Phillips, pan (round head)	1"	6
Size-6 nut	Metallic	N/A	4
Size-4 nylon spacer	1/4" outer diameter	1/4"	4
Size-4 nylon spacer	1/4" outer diameter	1/2	4
Size-4 nylon spacer	1/4" outer diameter	3/4"	6
Size-6 nylon spacer	1/4" outer diameter	3/4"	6

While you're in the hardware store, find a piece of *plastic screening*—you know, the stuff for screen doors. You only need a small 6" × 6" piece at most, so see if they have some scrap or a buy-it-by-the-foot roll that you can use, in order to avoid buying an entire roll. A dark-colored screening will look best in your portable.

Caution

Sneaking some off your neighbor's back door would be frowned upon by the general public.

Preparing the nylon spacers

The plan with the size-4 nylon spacers is to prepare them to hold a size-6 screw. How? Like this:

1. Sand both ends with fine grit paper—this allows the superglue to stick better.
2. Grip the spacer with your large pliers, and drive a size-6 screw in and out of it. This makes threads. Make a mark on the end that you drove the screw into, and make sure this end is up when placing it in the unit. The spacer is now ready for portable building!

Case-building parts

With your electronics and screws in tow, it's time to get parts to build the actual case itself. Assuming you're still in the hardware store, head over to the *aluminum and steel rack* (usually located near the screw section). Look for the following:

- **1/16"-thick × 3/4"-wide aluminum strip.** You'll need a total of 45 inches of length for the entire project, so pick up the next closest length. It'll likely be 4 or 6 feet.

Now head to the closest *awards/trophy/laser engraving place* to get some 1/16"-thick engraving plastic. (We talked about this stuff in Chapter 5.) Get the following amounts of the following colors:

- **10" × 8" of a dark color.** This will be the main color of the unit. I'd suggest a textured black or a very dark wood grain.
- **6" × 6" of a light color.** This will be used for the screen riser and the battery door. I used some faux-brushed aluminum engraving plastic, but anything that complements the main color is fine.

Keep in mind that these are the *minimum* amounts of plastic you need, based on the sizes of the parts you'll need to cut. It's not a bad idea to get extra, especially if they have pieces of scrap they'd like to get rid of, just in case something gets messed up.

Files you'll need

This chapter will have you print out several pattern and template files to be used during the construction process. These files are all located on this book's companion Web site, at www.wiley.com/go/extremetech, in a file called "Atari 2600 by hand." You can download them all at once, or just as you need them. Most of the filenames given in this chapter will have a PDF extension, meaning that they're meant to be opened with Adobe Acrobat Reader (available free at www.adobe.com), although WMF (Windows Metafile) versions of each file are also available on the site. WMF files will open automatically in modern versions of Microsoft Windows.

Graphics and decals

By applying graphics and decals, you can make your portable look quite professional, and also label which buttons and knobs do what. There are two ways of making the decals for your portable:

- **Using your own printer and sticky-backed paper.** If you've already got some sticky adhesive paper, this is the easiest (and cheapest) route. Print one of the following files: "Atari hand-built Decals.pdf," "Atari hand-built Decals.wmf," or "Atari hand-built Decals.jpg." Be sure to print it at 100% size, No Scaling, or Default (the exact option name varies by printer) in order to ensure that the graphics print out at the correct size. Use an X-Acto knife to cut along the cuts to remove the shapes from the paper.
- **Getting decals from a vinyl or sign shop.** Most sign or vinyl shops that can do vehicle graphics should be able to print some decals using a *thermal image printer.* This heat-impregnates the color right into the vinyl, creating a very durable decal. Along with that quality comes a higher price, but it shouldn't cost more than $25 for everything. For best-looking results, use two different colors of vinyl as described below.
    - "Atari hand-built Decals Clear Enamel.plt," printed on *clear enamel receptive vinyl.* This is a type of vinyl that is transparent and allows the underlying to show through material (it'll be engraving plastic in this case).

- "Atari hand-built Decals Dark Vinyl.plt," printed on *dark metallic vinyl.* However, the vinyl should be a lighter color than the main case plastic, so I'd suggest a dark gray/slate metallic. It's not a bad idea to take the engraving plastic with you and compare how it looks along with certain colors of vinyl.

While you're at the vinyl place, get some *3/4" wide × 24" long black vinyl stripes.* You only need one, but they'll probably cut you extra anyway. Think of those as being like the "extra men" in a video game, if you screw up when applying them to the case.

Tip

If the vinyl or sign shop can't use the PLT file, provide them with one of the other decal files listed in Option 1 above, or ask them to import the file "Atari hand-built Decals.ai."

Everything else

Finally, here's a list of the miscellaneous items that you'll need throughout this chapter:

- Hacksaw and fresh metal-cutting blades.
- Several hot glue sticks and a gun.
- One small tube of superglue.
- Extra X-Acto knife blades: You'll need them since you'll be doing a lot of cutting in this chapter.
- Epoxy, one tube: Any type will work (even J-B Weld!), but in this fast-paced world of ours, the quick "5-minute" kind of epoxy is preferred.
- Fine-grit sandpaper: A small piece should be sufficient.
- Various sizes of drill bit: 1/10", 1/8", 13/64", and 15/64". (You can substitute a 1/4" bit in lieu of the last two sizes.)
- Some computer-case screws: The kind that hold in expansion cards and the motherboard. (Ask a computer store guy for some, they'll know what you mean.) You'll need at least four.
- Computer case expansion slot cover: These are those metal things with a bend and screw hole on the end that insert in the rear of a computer. You'll need one, and a computer store or friend will probably give it to you for free (assuming you don't already have a drawer filled with them yourself).
- 3/4" iron-on trim, oak veneer: You can buy this stuff at a hardware store or lumber place, such as Menard's. It's meant to be attached to the edges of wood, but it'll also stick to aluminum.
- Small can of wood stain/polyurethane: Use to stain the oak veneer edging. Pick the shade you like best.

Assembling the Case

This portable Atari 2600 will be 4-1/2” × 7-1/4” × 1-1/2” in size when completed. There will be two main halves — the *front* and the *rear*. We’ll build one at a time, installing a few wires and parts as we go. Then we’ll install the major electronics in *Wiring the Unit.*

As mentioned previously, all the template files mentioned in the following section are available on the companion Web site. Some printing tips for all these template files:

- Load the PDF into Adobe Acrobat and set the printer settings to 100% size, No Scaling, or Default. This ensures the printout is actual size, which is pretty important when doing a project like this.
- If you see any “Size/Fit to Page” settings, disable them. All these graphics will fit on a standard 8-1/2” x 11”-sheet of paper.

Making the front half of the case

The *front half of the case* will measure 4-1/2” × 7-1/4” × 3/4” and contain the screen and controls. To make it, follow these steps:

1. Print the file “Front Plate.pdf.” It’ll look like the basic shape of the front of this portable. Use your X-Acto knife to cut the outside lines of the shape after making sure that the image matches the above measurements; if not, check your printer settings.
2. Lay this template on the front of the 1/16” engraving plastic you wish to use for the main case. If you have a nice square piece, you should be able to line up the pattern to at least two of the edges to save you some time. Tape the pattern to the plastic on all sides.
3. Using a sharp new X-Acto knife blade, make a light groove on all the inside shapes. Do not press too hard with the knife, as this may cause it to slip. Then cut the outside shapes. Remove the pattern.
4. Go back with your knife and make at least two more grooves on all shapes. You can press harder this time, since there’s already a “guide groove” there to help control the knife.
5. Bend the plastic backward (away from the front) to remove the main shape. To remove the smaller inside shapes, follow the following tips:
   - **Cartridge slot.** Drill a 1/4” hole inside the shape near one end, then grab through it with your cutters. Bend the plastic backward, working toward the end. Once you’ve got one end free, you should be able to pull the plastic backward (away from the front color side) to remove the piece.
   - **Screen hole.** For each of the four sides of the screen hole, bend the plastic backward to open up the groove. (Don’t bend too far, or the plastic may snap.) Now check the back of the plastic. Light lines should appear on the bends. Make a groove along these lines, and then bend the plastic again. The sides should snap loose. Then push toward the corners to release them as well.

- **Control pad and buttons.** Drill a hole in each shape, with the size of the hole depending on the shape. For the control pad, drill a hole in all four corners. Grab through the hole with your cutters and bend the plastic backward. Work around the hole until the shape comes free. Use your X-Acto knife to shave the edges of the shapes smooth.

6. Place the *select/reset decal* around the two center buttons. Select should be on the left, and reset on the right.

Caution X-Acto knives are really sharp! Take extreme care when using them and never cut toward your body. If the knife slips it could jab into you and believe me, impromptu self-surgery is not cool.

Now we're going to attach some screw posts to the back (noncolored side) of the front plate. These screw posts will be made from nylon spacers and will allow us to connect things to the case. To install them, follow these steps:

1. Print the file "Front Plate Screw Posts.pdf." As with the front plate, cut the outside shape and ensure that it's the correct size listed at the beginning of this section.
2. There are a bunch of double-circles on the pattern. For each, cut the outside circle. Cut some of the other shapes as well (screen hole, cartridge slot), to assist with alignment during the next step.
3. Tape this pattern down to the back of the front plate, lining up the sides and holes. Be sure to tape it on all four sides and even through the screen, to ensure the paper is held flat.
4. Using superglue, attach a nylon spacer of the indicated length inside each hole. Press firmly down on each spacer for about 15 seconds to ensure a good bond before moving on.
5. With all the spacers glued, remove the paper pattern. You may have to cut away at the paper in some spots, as it may be glued down as well.

Attaching the front side wall

All right, now on to the not-so-fun part: attaching the front side wall! Get out your 1/16" thick × 3/4" wide piece of aluminum for this job. Got it? Good, now do the following:

1. Cut a 5/8" long × 3/8" high notch in the beginning corner of the aluminum strip using a hacksaw. This will be the hole for the power switch. Be sure to keep the cuts as straight as possible so that the switch looks decent once installed.
2. The aluminum strip should start on the case to the left of the screen and about as high, with the notched opening against the front plate, as seen in Figure 16-2.

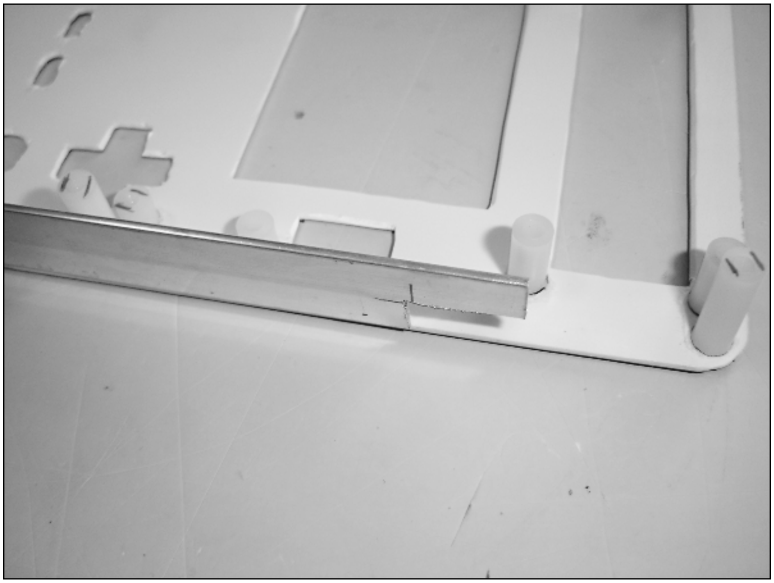


FIGURE 16-2: Where the aluminum should start and placement of the notch.

3. Make a mark where the aluminum reaches the first curve. Grip the aluminum just before the mark with larger pliers, and then bend the aluminum until it matches the curve. Some tips:
   - Once one part of the aluminum matches the curve, you can move the pliers further along the curve so that you don't rebend something that is already correct.
   - Bend the aluminum farther than it needs to go at first. This is because the aluminum will spring back after you do. The idea is that is should spring back (and stay) in the place that you intend it to be.
4. Continue bending the aluminum to match the shape of the front plate. For the tight upper curves, you can wrap the aluminum around a pencil.
5. Once the end of the aluminum reaches the beginning, make a mark and then cut it off using your hacksaw. Before cutting, check that the aluminum matches the shape of the front plate as closely as possible to avoid gaps and errors.
6. Sand the edge of the aluminum and the outer edges of the front plate for good gluing results.
7. For every 3–4 inches of aluminum, place a few dabs of superglue between it and the front plate. Press down to secure the glue. Repeat for the entire front wall.
8. Mix up some epoxy, and then use a toothpick to put a thin bead of it along the seam between the wall and plate on the inside of the case. Also put some up and down along the outer six 3/4" nylon spacers. (If you're using 5-minute quick epoxy, only mix small batches, as it'll probably cure before you can glue the entire case.)

At this point, the front half of the case should look as shown in Figure 16-3.

FIGURE 16-3: The front half of the case thus far.

Screen plate

The *screen plate* is a light-colored piece of 1/16" engraving plastic that goes over the screen and volume/brightness dials. It gives the front of the unit a little more "depth" and is also a good place to put the main unit decals. To cut and apply it, do the following:

1. Print the file "Screen Plate.pdf" and use the pattern to cut the shape as you did with the front plate. I used faux brushed-aluminum engraving plastic for mine. The two side slits for the volume and brightness dials should be cut out in the following manner:
   - Make several deep grooves into the sides of them, cutting all the way through the plastic. You can make some of the grooves on the back once the lines appear (as with the screen holes). Make only a few grooves on the top and bottom lines.
   - Set the plate face-up on something soft (like foam or cardboard), and press on the center of the slit with a small screwdriver. The slit should pop backward, allowing you to remove it.

2. Apply the graphics to the screen plate. If you're using vinyl, spray a solution of slightly soapy water on both the plate and the sticky side of the vinyl, position the vinyl, and press out the water/air bubbles using a squeegee or the edge of a credit card.
3. Set the screen plate over the front plate, lining up the screen holes. The screen plate hole is slightly smaller than the front plate hole — this gives you a margin of error to compensate for the fact that this thing is built by hand. The most important thing is for the top of the screen plate to look parallel to the cartridge slot hole. Once it looks good, superglue it down.

Note that there's a *battery door* and *flange* on the same paper pattern as the screen plate. We'll be using those when we build the rear case, so keep them handy. The next few sections cover the remaining things you need to install in the front of the case before continuing.

Speaker mesh

There's a large circular hole near the bottom of the front plate — this is the speaker hole, and we'll need to cover it with mesh, specifically with pieces of plastic screening.

1. Cut a square piece of screen-door mesh about 1-1/2" × 1-1/2" in size. Superglue it on the inside of the front plate over the 1" wide speaker hole.
2. Cut another piece the same size, then glue it over the first piece, but rotated about 45 degrees. This creates a higher visible density in the mesh.
3. Place the TV's speaker over the mesh and use about four blobs of hot glue around it to lock it in place. Point the leads/wires of the speaker towards the bottom of the case to leave room above for other stuff later on.

Paddle controller

The paddle controller will be made from the 1M-ohm potentiometer and a shiny chrome dial knob. To install it in the small hole just to the side of the speaker hole, do the following:

1. Use your cutters to snip off the small aluminum tab sticking up near the base of the shaft. You can't miss it; it's the thing that looks like it'll keep the potentiometer from sitting flush against the plate.
2. Take your hacksaw and remove the long shaft, leaving only 1/4" extending past the screw portion. If you've got a bench-mounted vise, it'll be very handy for this.
3. Remove the nut and washer, and then stick the paddle through the hole. (You may need to shave the hole a little bigger to fit the shaft.) Screw the nut and washer back on the outside. Rotate the paddle so that when looking at it from the inside, the three prongs are on the left (away from the speaker).
4. In Chapter 15, there's a drawing of how to wire the FGC (Fat Green Capacitor) to the paddle. Wire the capacitor as shown in that drawing. (Keep in mind that it's drawn as a *top view,* and you'll be looking at this one from *behind.*) You can connect the Atari ground spot "Z" to the ground on the PC controller board, since it'll be close by. Solder a 10" wire to each of the two remaining connection spots.

Tip

Don't put the knob on the paddle shaft just yet—the fine ribs of the knob will get dingy and grimy as you work on the unit.

DC AUX input jack

Since we should drill holes before we install anything delicate (like the TV screen), let's install the DC AUX input jack now.

1. Drill a 15/64" hole in the center of the front wall of the case on the left-hand side (when viewed from the rear). The hole should be just above the loudness dial slot, but about 1/2" away from the closest spacer so that the jack can fit. (Note: Making a 1/8" pilot hole will help guide the larger drill bit.)
2. Use your 3/4"-wide black vinyl stripe to cover the outside wall, cutting the vinyl around the hole and slot in the wall. Place the *DC AUX input* decal over the hole.
3. Insert the phono jack (Radio Shack catalog #274-246A from the materials list) into the hole and secure it from the outside with the nut it came with. We'll wire things to it later.

Audio/video out and headphone jack

The audio/video out and headphone jacks should already be wired to your hacked TV. The best place to drill holes for them are on the bottom of the front wall near the speaker. Keep the holes a good 1" apart so that there's enough room for both jacks.

Power switch

The *power switch* (Radio Shack catalog #275-406) fits into the slot that you cut at the beginning of the aluminum bend. The leads of the power switch should be toward the top of the unit so that pressing the switch up turns the unit on.

As for physically attaching the switch, there are two ways I'd suggest. Use whichever method works best for you, or works best with how well both ends of the aluminum came together.

- **Hot-glue it!** What else? Place the switch in the spot, and dump hot glue on top of it, keeping the glue off the leads. Glue the side tabs (with the screw holes), but don't hit the insides of the switch, or it may keep it from going back and forth.
- **Use screws.** Set the switch in place and drill two 1/16" holes through the wall to match the screw holes on the switch, and then use the supplied screws to attach it. This isn't always as easy as it sounds, so you may need to use hot glue *and* screws to make sure it's tight.

Making the rear half of the case

The *rear half of the case* is the same size as the front (4-1/2" × 7-1/4" × 3/4"), but it has far fewer screw posts and shapes. It'll be a bit of a break after the front-building ordeal, though there are still side walls to attach. To make the rear half of the case, use the following procedure:

1. Print the file "Rear Plate.pdf." Use your X-Acto knife to cut the outside lines of the shape. The resulting pattern should be the same size as the front plate.
2. Lay the paper template on some 1/16" engraving plastic of the same color that you used for the front. (You don't *have* to use the same color, but it's good for consistency.) Tape the pattern down on the sides.
3. Use a 1/8" bit to drill the eight holes in the rear plate pattern. Then use your X-Acto knife to make grooves on the inside rectangle shape (the *battery opening*), and finally make cuts on the main outside shape of the pattern.
4. Remove the pattern, regroove the cuts, and snap the shape free as you did with the front plate. If you can remove the battery hole without drilling holes, you can use that piece for the battery door later on (and save yourself some cutting!).
5. Bend and attach the aluminum side wall to the inside (noncolored side) of the rear plate, as you did with the front plate. Although it doesn't matter where the aluminum starts, you should place it to match the beginning of the front half. (In other words, put the potentially questionable-looking ends of the aluminum all in the same place.)
6. Okay, now we'll install the nylon spacers. Look at the rear half of the case from the side. Eight screw holes should be visible. The six side holes will get 3/4"-long size-6 spacers put over them. You can attach them in one of the following ways (depending on your taste and skill):
   - Put some superglue on the bottom of the spacer and just eyeball it over the hole. This will work, but the spacer may be a little off, or not quite straight.
   - Drive the 1"-long size-6 screws through the rear plate, slide a spacer over each, and glue the spacer in place. This gives better results, but you run the risk of gluing the screw in place, too.
7. Drive a 3/8"-long size-6 screw into the two center holes from the rear, and then spin a size-6 nut down to lock them in place. These screws will hold the Atari board.

At this point, the inside of the rear half of the case should look as shown in Figure 16-4 here.

Note

The reason we're using size-6 spacers on the rear half is to make it easy to insert the screws that hold the case together. They'll slide right through the rear spacers and only have to grip the front spacers a little. (This also saves you from the tedium of threading four spacers.)

FIGURE 16-4: The inside of the rear half of the case . . . so far!

Battery holder and door

The next addition to the rear half of the case are the *battery holder* and *door*. To make them, do the following:

1. Set the rear half of the case over a scrap piece of 1/16” engraving plastic, with the edge of the plastic just touching the center screw posts. Trace around the inside of the case as seen in Figure 16-5.

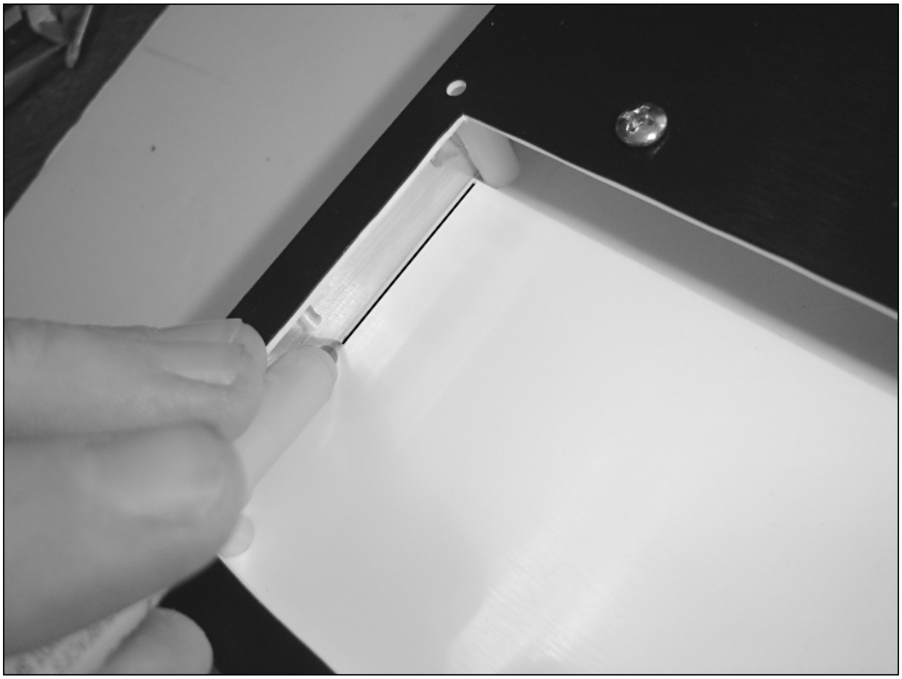


FIGURE 16-5: Tracing the shape of the case on the engraving plastic to make the battery backer.

2. Make grooves along your trace lines to snap the battery backer shape free. Insert it into the rear of the case and make sure it fits snugly. We'll attach it permanently soon.

3. Figure 16-6 shows a four-AA battery holder with the two wires positioned on the lower left. Snip the bit of black plastic so that the springy negative terminal on the top right can be rotated around to the left. Cut off most of the spring to leave only a small hook. You can then hook this into the springy terminal on the left, and solder it in place.

4. Saw the battery holder in half, as indicated in Figure 16-6. The saw line should be just on the right of the middle wall. We'll be keeping the left side of this holder, and therefore we need that wall intact. You will find a black wire on the underside of the holder. Go ahead and snip/saw through it. (Step 1 above obviated the need for this wire.)

5. Set the battery holders on the battery backer, with the complete one on the left and the split one on the right. Make marks through the three holes in the battery holders.

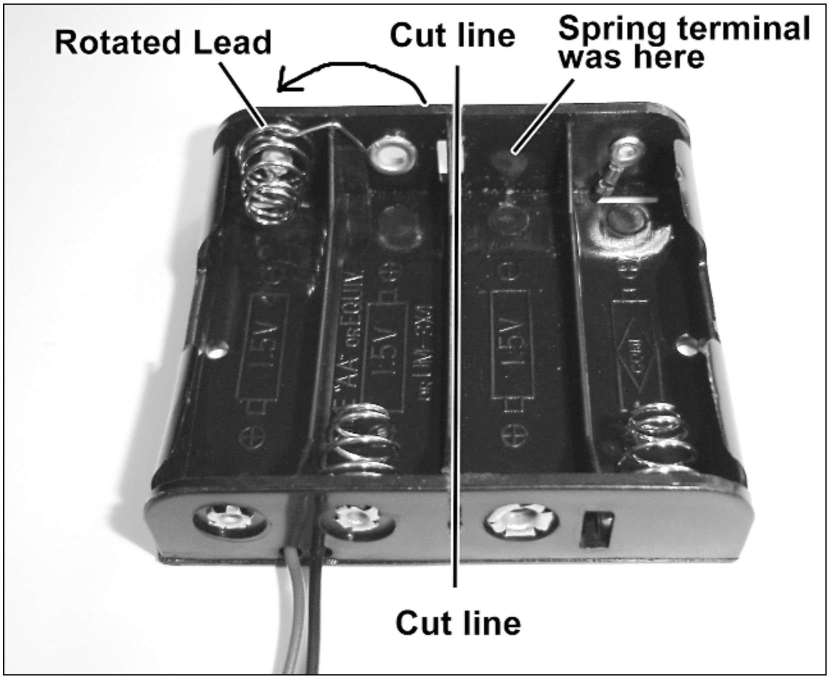


FIGURE 16-6: Modifying the battery holder.

6. Use a 3/32" bit to drill holes in the spots on the battery backer, then use 1/4"-long size-4 screws to attach the battery holders to the battery backer plate.
7. Connect the red lead from the complete battery holder, and connect it to the black lead on the split battery holder. Cut them short so that they're only as long as required, and then solder the connection and cover it with electric tape to avoid short circuits. The remaining two long wires are the *positive and negative battery wires.*
8. Insert the battery holder and plate into the rear of the case. The plate should be flush with the ends of the walls and screw posts. Use superglue to secure the plate to the side walls, and then put epoxy on the inside (around the battery holders) to secure it there as well.
9. Cut the battery door and flange from the paper pattern using 1/16" engraving plastic. Glue the flange under the top (straight) edge of the battery door. Place the *System built by* decal on the outside of the door.

The results of all this battery-related fun should end up looking like Figure 16-7.

FIGURE 16-7: The battery holder in the rear case and the door to protect it from the elements.

Tip

If you cut out the hole for the battery door cleanly enough when you made the rear plate, you can use that removed piece as the door—just add the flange and cut a half-circle in the bottom.

The final touch to the rear of the case is the *oak veneer trim.* Follow the directions on the packaging to apply it, and also follow these steps as well:

1. Start and end the trim at the same place the aluminum started. Once it's glued in place, you can apply stain or polyurethane as desired.
2. Apply the large on/off decal over the start/end spot of the trim once it's dry. The "on" position is toward the top of the unit.

Wiring the Unit

With the case-building out of the way, we can now start wiring the unit. Keep in mind that throughout this section we'll be referring back to the *MLL (Master Lead List)* from Chapter 15 quite a bit. The MLL was Figure 15-5 in that chapter.

Making the PC control board

Figure 16-8 shows where to cut the PC board (Radio Shack catalog #276-147) to make the *PC control board*. Drag your X-Acto knife along the indicated lines several times to make deep grooves, then snap the boards apart by bending them backward. Sand down or snip any rough edges.

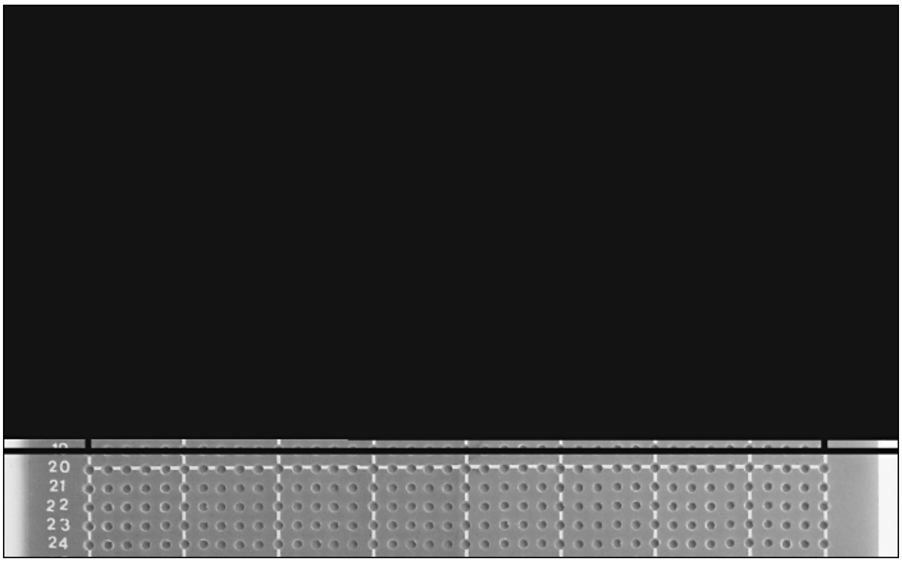


FIGURE 16-8: Where to slice the 276-146 PC board.

With the board sliced up, it's time to install the 4.5-mm tact switches on the front (noncopper side) of the board as shown in Figure 16-9 below.

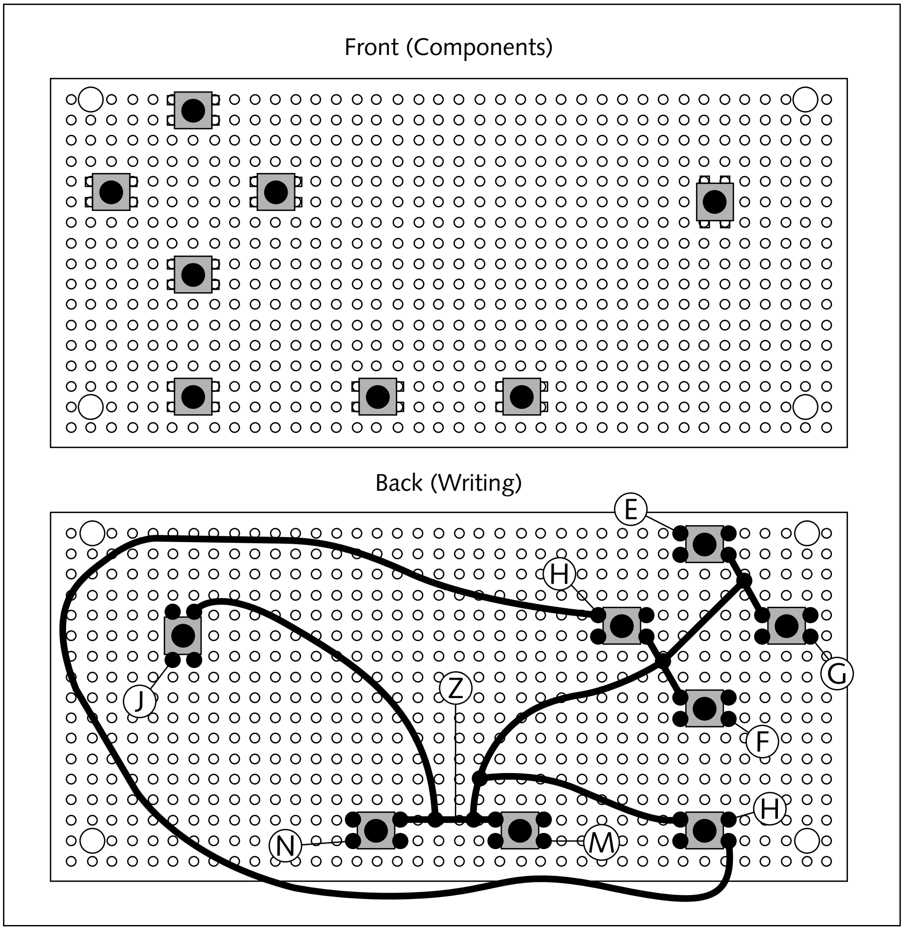


FIGURE 16-9: Placement of components (front) and wiring (back) on the PC control board.

Follow these steps when placing the components on the front and wiring them together on the back:

1. Use short wires or bits of leads to make the connections shown by the black wavy lines connecting to each switch. This is the main *ground* connection.
2. Connect a 9" wire to each of the lettered spots on the board. These letters refer to spots on the MLL to which we'll connect the other ends of these wires (later on in this section).
3. Use a 1/8" bit to drill holes in all four corners as indicated.
4. The switch directly below the joypad is the paddle trigger. It is connected to the right switch of the joypad because they both go to the same spot on the Atari.

To complete the controller area of the unit, do the following:

1. Take apart your standard NES controller and remove the red buttons, the rubber select/start thing, and the plastic joypad disc.
2. Fill the two red buttons with hot glue so that the glue is level with the back of the button.
3. Place all the NES buttons in the front of the case as shown in Figure 16-10.
4. Connect a 9" wire to each of the labeled leads on the potentiometer, as these will connect to the Atari later. The loose end of the capacitor should connect to *ground* on the PC control board.

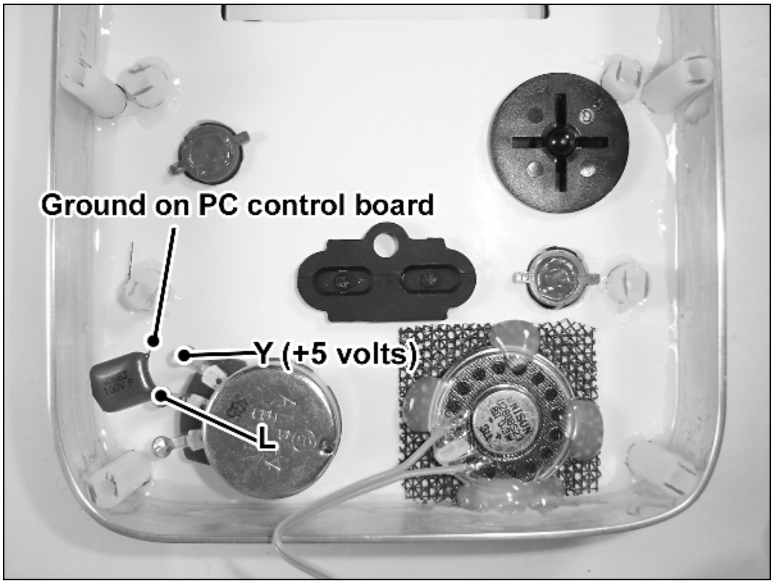


FIGURE 16-10: The case with the paddle, green capacitor, buttons, and speaker installed.

5. Use four computer case screws to attach the PC board in the case. The two upper screws are near the edge, so screw carefully to avoid cracking the board. (Even if it does crack, the screws will still hold it.)

Installing the TV screen

Next on the to-do list is installing the TV screen. Make sure it has the white-LED mod and circuit-board repositioning done as described in Chapter 4 and then do the following to install it into the front of the case:

1. Use your cutters to snip off the black plastic antenna jack at the top of the unit. This allows the TV to fit inside the case.
2. The lower circuit board is likely to touch the bare wires and solder on the PC control board. Cover these with electric tape to avoid short circuits.
3. Connect a 7" wire to the audio and video spots as shown in Figure 16-11 below. Then connect a 4" wire from the *TV ground* to *ground* on the PC control board.

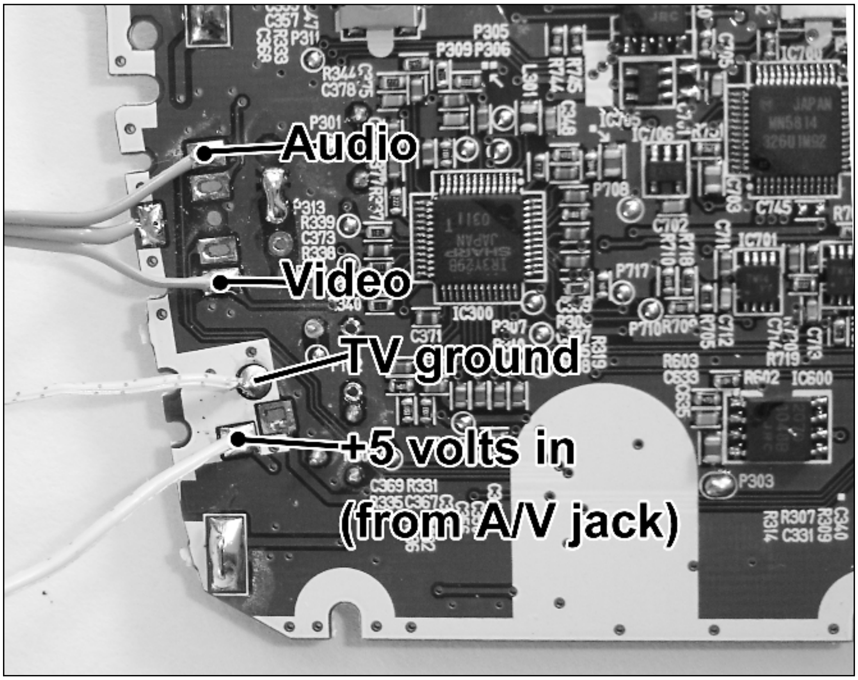


FIGURE 16-11: Audio, video, and ground connections on the EV-680.

4. Set the TV into the case. The black LCD area of the screen should match the hole you cut for it. If you look carefully and with sufficient ambient lighting, you should be able to see the pixels themselves. Around the pixels is a thin area of plain black (no picture).
5. Place blobs of hot glue on both sides of the screen (i.e., the white plastic holding it) inside the case. Then, look at the screen from the front and move the TV around until the pixel area of the LCD is centered in the hole. Do this before the hot glue dries.
6. With the screen properly aligned, put a few more blobs of hot glue around the inside edges to hold it down. Don't go overboard with the glue, however, until you've tested the unit.
7. Place the volume and brightness dials into the appropriate slots. Use a bit of hot glue on the silver side to attach them. Put some hot glue on the wires as well to secure the rear of the dials. This keeps them from being pushed around inside the case.

8. Stick the A/V output and headphone jacks into the holes we drilled for them earlier. Put hot glue around the jacks to secure them.
9. There should be a loose wire on the A/V output jack. This is *positive voltage to TV.* Connect this to the *upper lead* on the power switch. (The upper lead is the one closest to the top of the unit.)

Wiring the two halves together

We can now start wiring the two halves of the unit together. This consists mostly of wiring things from the TV and PC control board to the Atari, but we'll be doing power-related connections as well. Set the front of the case down on the left and the rear on the right, with the insides of both facing up. When making each connection, cut the wire down so that it's only slightly longer than it needs to be. Keep in mind that the Atari board will be sitting inside the rear of the case, so make sure this is accounted for when arranging any wires going there.

Built-in controller connections

1. Connect the spots from the PC control board to the Atari using the MLL as a guide. You'll be connecting the up/down/left/right pad, trigger, paddle trigger, select/reset, and ground connections.
2. Connect the two spots on the potentiometer to the Atari. For spot "Y" (*+5 volts*), you can also use the soon-to-be-placed-nearby voltage regulator.

Power connections

1. Connect the positive and negative battery wires to the DC AUX input jack, as shown in Figure 16-12. You'll have to extend the existing battery holder wires to do this. Be sure to cover the extension connection with electric tape to avoid zapping things.

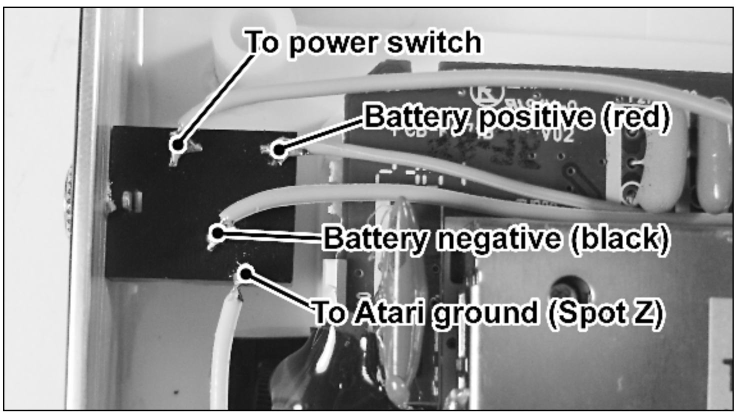


FIGURE 16-12: Connections to the DC AUX input jack.

2. *To Atari ground* can go to spot "Z" on the MLL or to ground on the PC control board.
3. Connect the wire marked *To power switch* to the lower terminal of the power switch.
4. Attach two 6" wires to the upper lead of the power switch (the TV power wire should be there as well). Connect one of these wires to the *unregulated power in* spot on the color timing potentiometer of the video circuit, as shown in Chapter 15.

The other 6" wire will be *unregulated power to 7805*. So I guess now would be a good time to install the 7805 regulator. Here's how:

1. Take the expansion slot cover and cut off the top bent end so that only 2-1/4" inches remains. Drill a 1/8" hole in the center of that. This is now the *heat sink*.
2. Snip the leads off the 7805 regulator so that only about 1/4" remains.
3. Remove the lower left screw from the PC control board and set the heat sink over the hole. Set the 7805 over that, and then reinsert the screw. Make sure the leads on the 7805 aren't touching the heat sink. It should look like Figure 16-13.

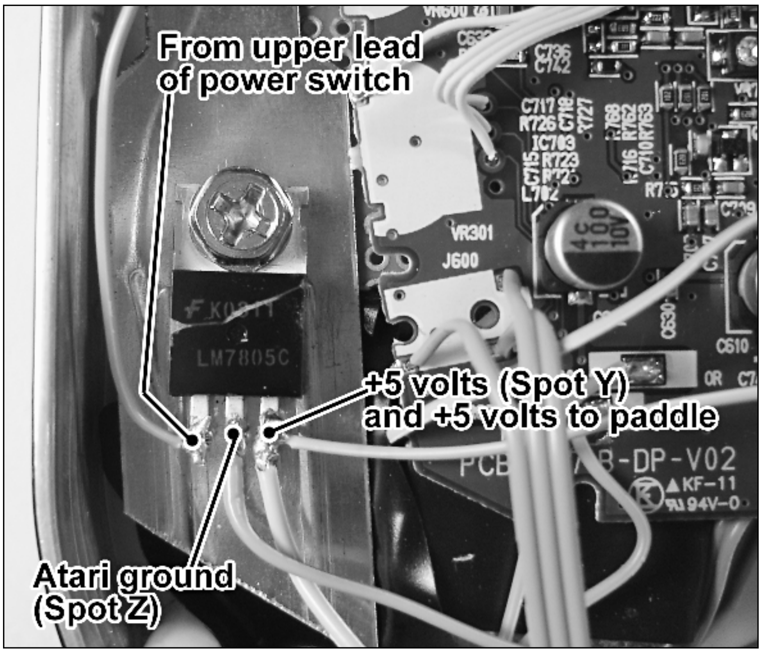


FIGURE 16-13: The installed 7805 regulator and heat sink.

4. Connect the existing wires as shown. Then run a 7" wire from the right-most lead (*+5 volts*) to spot "Y" on the Atari.

Audio/video

We connected audio and video wires to the pocket TV a ways back. Connect the video to *composite video out* on the Atari, and the audio to spot "Q."

Note

There should be a total of four wires connected to the TV's audio video spots, two going to the A/V output jack and two to the Atari.

Installing the Atari board

With all the connections made it's time to install the Atari board by doing the following:

1. Cut out the board just below the two 1/8" holes you drilled. This allows you to set the board into place rather than thread the screws through the Atari.
2. Use the cutters to snip the upper 1/4" corner of the board off so that it won't hit the screw post. Don't worry, there's nothing important there.
3. Set the Atari in the rear of the case with the two 3/8" screws going into the notches that you just cut. All of the wires should come out the left side of the board and the bottom.
4. Put a size-6 nut over each screw to secure down the Atari board.

Both completed halves of the unit should look as shown in Figure 16-14.

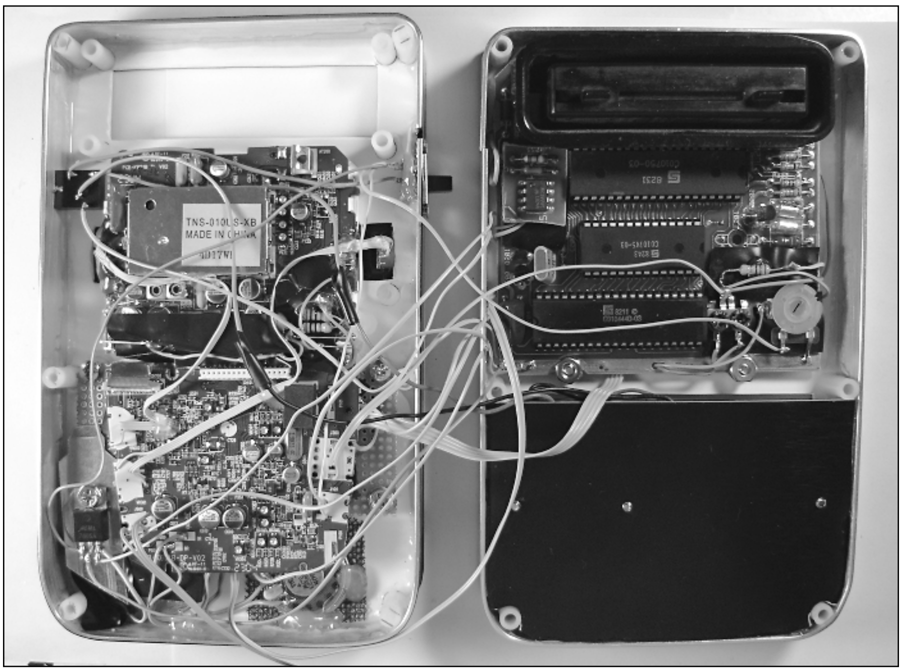


FIGURE 16-14: The completed insides of the hand-built Atari 2600 portable.

The Atari 2600 portable is now ready to run! (Or, more specifically, to be tested as described in the next section.)

Testing and Troubleshooting

In this section, we'll test out the Atari 2600 portable to ensure that everything's working before closing up the case. (Doing it now with everything still open will save you a lot of time.) We'll take the testing step-by-step to check every facet of the unit, and fix any problems that crop up along the way.

1. Insert six fully charged AA batteries into the battery holder, and insert a game cartridge into the slot. Switch on the unit. If the screen doesn't light up, check the following:
   - Is the white-LED mod hooked up correctly?
   - Check that at least +7 volts is going to the TV. If you used a RCA-model TV, the polarity of the plugs may be different than on the Casio. Check the TV's case.
2. If the screen lights up, but there's no game picture on it, do the following:
   - Check that the Atari video circuit is correctly installed.
   - On some TVs, the audio and video spots are switched around. Try switching them and see if that helps.
   - See if the small wires on the brightness dials have come loose or are touching each other.
   - Check that the brightness dial isn't turned all the way up. This creates a bright, white, blank screen regardless of what video might be displayed on it.
3. If the game video comes on the screen, but there's no sound, do the following:
   - Check the small wires on the volume dial, and see if they're all still attached. If even one comes loose, it can stop the sound from working.
   - Double-check the speaker connections.
   - Make sure the headphone jack has been properly reconnected. If it's removed completely, the speaker won't function.
   - Check that the audio connection from the Atari is properly connected to the audio connection on the TV's circuit board. As with the video, some TVs switch the audio and video around.
4. Once the sound and video are working, press Reset and try playing a game. If the controls don't work correctly, do the following:
   - Check the wiring of the PC board. Be sure that you attach wires to the tact switches exactly as shown.
   - Make sure you attached the Player 1 controls to the Player 1 spots. (See the MLL.)
   - Check where the Player 1 controls connected.

5. If the game colors are weird (you know, purple water, orange grass, etc.), do the following:
   - Use a small flat-head screwdriver to adjust the three potentiometers of the video circuit on the Atari. A color-checking table was provided in Chapter 15 in the *Fine-tuning the picture* section.

Once you've successfully worked through all these testing steps, your Atari 2600 portable is ready to go on to the final step!

Final Assembly

With the unit functioning, it's time to wrangle a few wires and parts inside the unit, and close it up. Here are the final steps to take with this portable:

1. Apply additional hot glue over the nuts holding the Atari board and around the edge of the white plastic part of the screen. Since the unit is working, you can "set in stone" these pieces.
2. Arrange the internal wires so that they stay above the battery backer and more toward the Atari board. This allows everything to fit together once you put the halves together.
3. Fold the halves of the case together like you're closing a book. Both sides should fit together. Make sure no wires are in the way of the screw posts (since you shouldn't screw through wires).
4. Drive six 1"-long size-6 screws through the rear of the case and into the front to close up the unit. Drive slowly and evenly to avoid breaking the nylon screw posts loose. (This of course also depends on how well they were glued in the first place!)

Running the unit off wall power

To run the unit off wall power (in order to avoid discharging the batteries), you'll need to find a DC wall power adapter than can do 700 mA of power at 7.5 volts. The common adapters usually come in 500, 800, and 1000 mA sizes, so you'll likely end up getting an 800 mA one. Use the 1/8" minijack plug with the center (tip) set to positive, and outer portion to negative. You can either get a multivoltage adapter that comes with a bunch of plugs at a place like Target or Wal-Mart or get a Radio Shack Adapta-plug adapter and plug (catalog #273-1667 and #273-1709).

Your portable is now ready to go, and be played anywhere! And with the wall power adapter you can play it anywhere (with a power outlet) while saving batteries at the same time!

Chapter in Review

A hand-built portable Atari 2600 is a great "toy" for anyone who wants to relive the fun and excitement of video game–playing days gone by. You can give your old system new life and bring your old games back into the world in a new and interesting way.

Looking back at this chapter, the major steps in completing this project were as follows:

- Cutting parts out of engraving plastic, and bending/attaching aluminum to them to make the bulk of the portable's case.
- Building a custom controller board and installing it, along with the modified Casio EV-680 TV screen, into the front of the case.
- Installing the Atari 2600 that you hacked up in Chapter 15 into the rear of the case, along with a custom-modified battery holder.
- Wiring both halves together to interconnect power, controls, and audio/video.
- Testing the Atari portable to see if it worked, and fixing any problems that came up.
- Arranging loose wires and parts inside the unit, and then screwing the halves together.
- Playing the completed unit to your heart's content!

Making a Portable Atari 2600 Using CNC Machinery

chapter 17

in this chapter

- ☑ Materials You'll Need
- ☑ CNC Cutting the Parts
- ☑ Assembling the Case
- ☑ Wiring the Unit
- ☑ Testing and Troubleshooting
- ☑ Final Assembly
- ☑ Chapter in Review

In Chapter 5, we discussed what CNC machines are and how they can be used to make precision-cut parts out of a variety of materials. In this chapter, you'll use a CNC machine to make the parts for the Atari 2600 shown in Figure 17-1.

Once the parts are cut, you'll glue them together to form the case itself and then install custom controls that use a Playstation Dual Shock analog controller for the system's joystick! After that, you'll install the modified Casio EV-680 pocket TV and the hacked-up Atari 2600 board along with a battery connect and Player 2 port. Finally, you'll wire everything together, test it, and complete the unit.

When you're done you'll have an awesome-looking, rather compact Atari 2600 portable that you can tote anywhere! Sound cool? Then let's get started!

FIGURE 17-1: The CNC-built Atari 2600 portable.

Materials You'll Need

You'll need to locate some materials to make this project, of course. Let's start with the main components.

- An Atari 2600 four-switch, modified as in Chapter 15.
- A Sony Playstation Dual Shock controller. Rip it apart and desolder one of the *analog sticks*. (If you've got a friend who routinely throws controllers in frustration during games, he or she may have a damaged one you can use.) A Dual Shock 2 (the kind that come with the PS2) is ideal, as the stick itself is quite dark and will complement the color scheme of the portable.
- A Casio EV-680 TV modified with white LEDs, as in Chapter 4. As mentioned in that chapter, it needs to be further modified to work with this chapter's project by doing a *folded reconnection* of the circuit boards. (This mod basically lets you fold the TV boards over themselves to make it all more compact.)

- A Sony Infolithium type L rechargeable battery and charger. If you have a digital Sony camcorder or camera, you're already set, but otherwise I'd suggest checking online auctions for "Sony NP-F550." You can usually find a pretty good deal on battery/charger combos.

Electronic parts

Let's move onto the electronic parts. The majority of this stuff can be found at your local Radio Shack; however, the last items need to come from an online vendor. I'd suggest Digi-Key (`www.digikey.com`). They've got a nice, simple site that's easy to navigate.

Table 17-1 Electronic Parts List for CNC Atari 2600 Portable

Part Name Required	*Available From:*	*Part or Catalog #*	*Quantity*
Phono jack	Radio Shack	274-246A	1
Male polarized connector (four positions, Molex Type)	Radio Shack	274-224	1
SPST submini Slide Switch	Radio Shack	275-406	1
1M-ohm linear-taper potentiometer	Radio Shack	271-211	1
7805 linear voltage regulator	Radio Shack	276-1770	1
Male 9-pin connector	Radio Shack	276-1537	1
Heat sink	Radio Shack	276-1368	1
4.7K-ohm 1/4-watt resistors	Radio Shack	271-1330	4 (1 package)
Tact switch, 6 mm	Digi-Key	EG2495-ND	4

Note

Digi-Key usually has a $25 minimum order, so you may want to get your white LEDs and some of the other parts from them, as well, to reach that amount.

Screws and fasteners

You'll need screws and such to construct your unit (even though we'll be using judicious amounts of superglue and hot glue as well). Visit the screw aisle of your local hardware store and pick up the stuff in Table 17-2:

Table 17-2 Screws, Nuts, and Washers List

Screw/Nut/Washer/Spacer Size	*Type*	*Length/Size*	*Quantity*
Size-4 screws	Phillips, pan (round head)	1/4"	5
Size-6 screws	Phillips, pan (round head)	3/8"	8
Size-6 nuts	N/A	N/A	2
Size-6 nylon washer	N/A	N/A	3
Size-4 nylon washer	N/A	N/A	4

Files you'll need

This chapter will ask you to use several files in order to have the case routed for this unit. These files are all located on this book's companion Web site, at www.wiley.com/go/extremetech, in a file called "Atari 2600 CNC." You should download all the files in that folder at once so you'll be prepared when you go to get the parts routed. Most of the router files mentioned will be CorelDraw format (CDR), since that's a very common file type for laser engravers to use. If for some reason you need a different format, there are Adobe Illustrator (AI) versions of the CDR files on the Web site, as well.

Decals (a.k.a., graphics)

In order to make this portable look professional you'll want to put some decal graphics on it. There's two ways of making your decals, and both have their pros and cons. (All of the files mentioned below can be found on this book's companion Web site, at www.wiley.com/go/extremetech, in a file called "Atari CNC.")

- **Getting decals from a vinyl or sign shop.** This is the best option, as it creates a durable decal and will also allow the natural colors of the engraving plastic to come through. It will cost you a little more, however.

  Provide the vinyl shop with the following files and have them print it on the materials specified:

  - "Atari CNC Decals Clear Enamel.plt," printed on *clear enamel receptive vinyl.* This is a transparent sort of vinyl that allows the underlying color (in this case; wood grain engraving plastic) to show through.
  - "Atari CNC Decals Metallic.plt," printed on *silver metallic vinyl.*

  If the shop can't read the PLT files, you can provide them with one from this other option:

- **Using your own printer and sticky-backed paper.** Cheaper than having vinyl decals made, but not as durable. For this, use one of the following files depending on which opens best with your computer: "Atari CNC Decals.ai," "Atari CNC Decals.jpg," "Atari CNC Decals.pdf," or "Atari CNC Decals.wmf." Print it at 100% size, No Scaling or Default (the name of the option varies by program). This ensures the decals print at the correct size. Finally, use an X-Acto knife to cut along the lines of the decals.

Tip

I'd *highly* recommend getting vinyl shop graphics unless you find it completely impossible to locate such a place. A single-person operation kind of sign place should be quite reasonable in price.

The rest of the stuff

Here's some final things to pick up that don't fit neatly into any of the above categories:

- Six computer case screws: The sort that hold in expansion cards and the motherboard. A computer store will probably just give you some, or ask a computer-building friend.
- Ribbon cable: About one IDE or floppy drive cable's worth will be enough.
- Hot glue sticks.
- A tube of superglue. The liquid type works better than the thick gel stuff.
- 5-minute epoxy. You can also use 24-hour epoxy or J-B Weld, but faster is better!
- Sandpaper (any grit is fine).
- Red paint of some sort. You only need a little for painting the trigger buttons. Model paint, automotive touch-up paint, or even fingernail polish will work. ("Look honey! My Atari matches your nails!")

Note

The plastic pieces required for the CNC-cutting will be listed in that section, since you'll probably have to buy them from the place that's doing the CNC work anyway. They usually don't want people bringing in their own material.

CNC Cutting the Parts

This Atari 2600 portable is designed with precision in mind, and some of the parts are quite small. Therefore, I'd suggest using a laser engraver to have the parts cut, as a router would be too inaccurate. (It could still be done, but the operator time would be greater.)

In this section we'll talk about what the parts are cut out of, how to get them cut, and what the name of each part is. The names will come in handy throughout the chapter as you assemble and work with things.

Engraving plastic parts

The majority of the case will be made from 1/16”-thick engraving plastic parts. I’d suggest using three different types/colors of plastic: Dark/black, light/brushed aluminum, and wood grain. The files for cutting each type and the amount of each type of plastic are:

- **“Dark engraving plastic.cdr”.** Amount required: 10” × 10”. For the front and rear plates and various small parts.
- **“Light engraving plastic.cdr”.** Amount required: 5” × 3”. For the screen plate and paddle knob top.
- **“Wood grain engraving plastic.cdr”.** Amount required: 4” × 5”. For the two side wood grain pieces.

Note

I’m listing these here because you’ll probably have to buy them from the laser engraving business anyway, rather than bring in your own for them to rout. (See Chapter 5.)

To get the engraving plastic parts cut:

1. Print out the file “Engraving plastic parts.pdf” and give it to the laser operator beforehand so they have a reference to what they’re going to be doing. It also lists the total area of engraving plastic required for all the parts, which will assist them in the time estimation.
2. Provide the laser operator the three CDR files listed above. The filenames will let them know which color/type of engraving plastic to cut with each file. Have them make vector cuts completely through the material on all black hairline strokes. This will remove the parts from the engraving stock.

Figure 17-2 shows all the 1/16”-thick engraving plastic parts that will be cut from these three files.

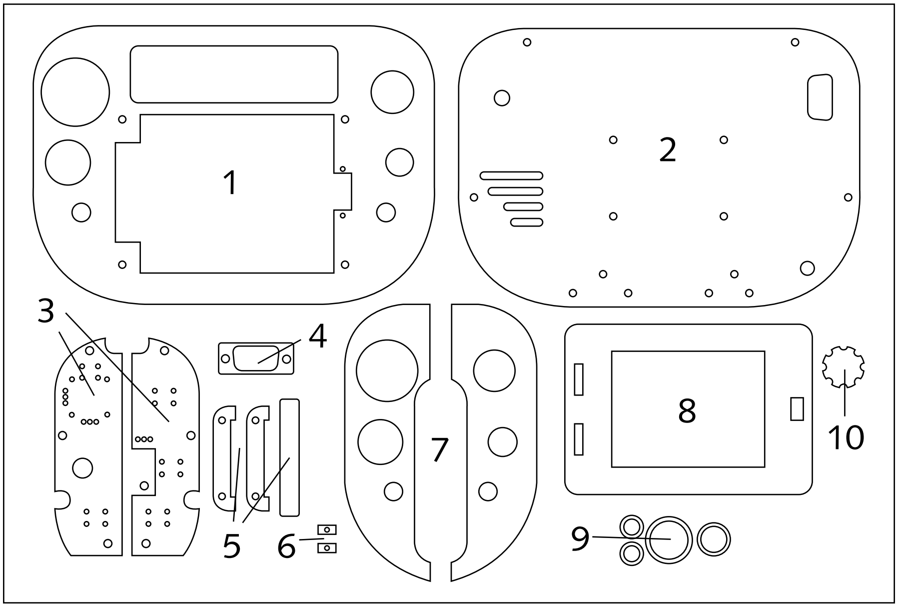


FIGURE 17-2: Engraving plastic parts.

The following list identifies the parts in the above figure by name:

1) **Front plate.** Comprises the front of the unit.

2) **Rear plate.** Comprises the rear of the unit.

3) **Left and right control boards.** Holds the tact switches and analog joystick, along with the paddle and 7805 power regulator.

4) **Joystick port riser.** Correctly spaces the Player 2 joystick port off the rear plate.

5) **Battery tabs and cover.** Tabs hold the battery in place and the cover will go over the leads.

6) **ON/OFF switch risers.** Puts the on/off switch at the correct height.

7) **Left and right button covers.** Provides a nice wood grain raised detail to the unit.

8) **Screen plate.** Covers the TV screen and holds dials and buttons.

9) **Button flanges.** These glue around the buttons to keep them from falling out of the case.

10) **Paddle knob cover.** Decorative thing for the top of the paddle knob (also covers an unsightly hole).

Quarter-inch material parts

The *main walls* of the case, *screen riser,* and *buttons* are all made from 1/4”-thick material. Anything 1/4” thick that the laser can cut through will work, such as balsa wood or acrylic. (See Chapter 5, “Using Computerized Cutting Equipment.”) I’d suggest a 1/4”-thick piece of *black acrylic*—it’ll have nice fire-polished edges when cut and look quite slick. Whatever type of 1/4”-thick material you choose, you’ll need a *12”× 12” piece* of it for this project.

To get the 1/4”- thick parts routed:

1. Print out “Quarter inch parts.pdf” beforehand to show the laser operator and give them an idea of what you want done.
2. Provide the laser operator with the file “Quarter-inch parts.cdr.” Have them make vector cuts completely through the material on all black hairline strokes. This will remove all of the 1/4”-thick parts from the material stock.

We’ll skip the photo of the main side walls, since they’ll be covered in the following section anyway. The rest of the 1/4”-thick pieces are:

- Circular things: These are the *buttons* and *paddle knob.* Multiple copies of these will be cut so you can stack them and have extras if you make a “gluing error.”
- Rectangular thing with thin walls and four screw holes: This is the *screen riser.*
- Small notched long rectangle: This is the *thick battery contact cover.*

Note Some materials may be considered 1/4″ thick, when in fact they’re slightly thinner. It depends on the manufacturer, so double-check the actual thickness of the material before you commit to using it. Even if the pieces are .275″ instead of .25″ the difference will add up once you’ve stacked them on top of each other, with the result that the electronic parts may not fit inside your case! While it may work, it all depends on the wiring inside the unit, and since this can vary I’d strongly suggest making sure the material you use is in fact exactly 1/4″ (.25″) thick.

CNC laser cutting recap

Let’s look back real quick to make sure we’ve got all the parts covered. A total of four different files should be CNC cut for this project: three out of different colors of 1/16”-thick engraving plastic (“Dark engraving plastic.cdr,” “Light engraving plastic.cdr,” and “Woodgrain engraving plastic.cdr”) and one out of 1/4”-thick material (“Quarter-inch parts.cdr”). This means a total of four laser cutting jobs should be performed, since it’s a different file and material for each job.

Assembling the Case

The case for this CNC-built Atari 2600 is fairly easy to assemble—most of the case parts are simply made by gluing the 1/4”-thick side walls to the 1/16”-thick plates. In this section, we’ll assemble the case and get it ready to have the electronic part installed.

Making the front of the case

The front of the case is the largest single section of the unit. It will measure 6 1/2” × 4 1/2” × 1 1/4” when assembled and contain the TV screen, speakers, and controls.

The most important thing to keep track of is which *wall pieces* you'll be gluing down and in what order. Figure 17-3 shows the completed front of the case, with assembly instructions following.

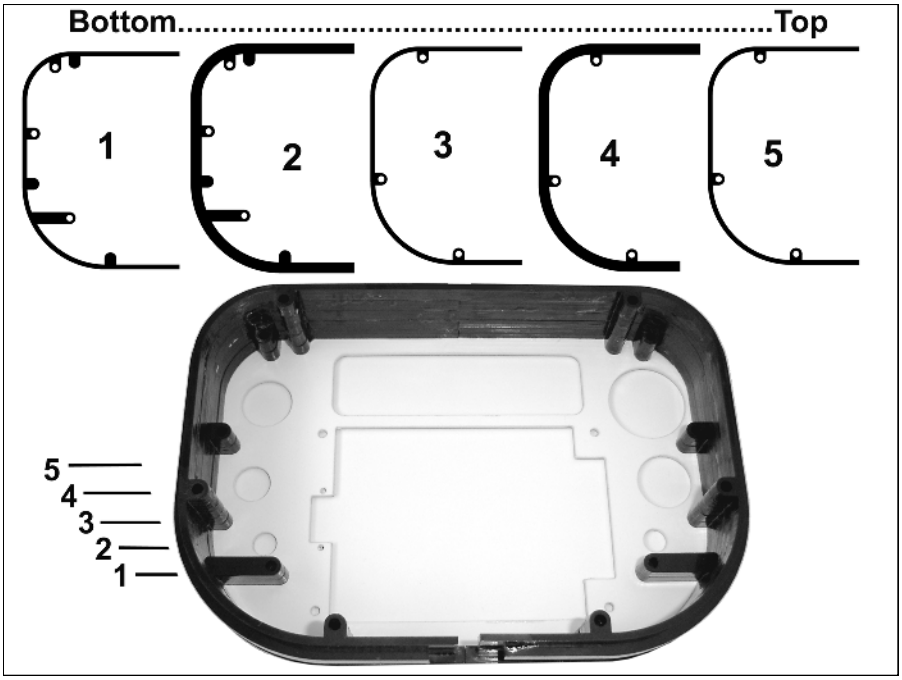


FIGURE 17-3: The front of the case and the order in which to apply wall layers.

1. Lay the front plate facedown and sand the inside edges of it where the walls will attach.
2. The case layers are labeled “1” through “5” on this drawing. This is the order in which they should be superglued to the back of the front plate.
3. Lay down the pieces in order, both the left and right sides (which are identical). One set of left and right sides composes a *layer*. The first two layers you'll glue down have six screw nubs each; the final three layers have three screw nubs.
4. Be careful not to let superglue seep outside the case, as it can make an unsightly mess and mar the surface of the engraving plastics. Wipe up any excess before it has a chance to dry. (You can make as big a mess as you want on the inside, of course.)

Note

Some of the pieces will have a gap at the bottom and not reach each other. This is not a mistake; rather it creates a "+" shaped hole for the speaker noise to get out of.

Attaching decaled front portions

With the main portion of the case built we can now attach the *decaled front portions* to it. These are the *left* and *right button covers* and the *screen plate* and *riser*. The reason I call them "decaled" is because graphics will be applied to each before they're installed. Here's the procedure:

1. Apply the decals to the left and right button covers and screen plate. "Select" is on the left, "Reset" on the right, and all the other holes in the decals will match the shapes of the plastic piece. Follow your sticky-backed paper instructions, or if you used clear enamel printed vinyl (which I highly recommend) do the following:
    a. Find an empty spray bottle and fill it with water and a few drops of dish detergent. Add half a capful of rubbing alcohol to aid in evaporation. This creates a spray mixture that is good for applying vinyl to smooth surfaces.
    b. Spray this fluid on the surface of the engraving plastic and the sticky side of the vinyl. Apply the vinyl, and then push out the water and air with a squeegee or the edge of a credit card. (Use those junk ones they're always sending in the mail!)
    c. Set the pieces on paper towels to dry — this helps soak water out of the edges of the vinyl.
2. Superglue the left and right button covers on the front plate. The holes are the same size as the ones in the front plate, with the exception of the joystick hole, which is slightly smaller on the cover. Make sure the edges of the button covers are flush (line up) with the edges of the front plate.
3. Superglue the screen plate to the screen riser. The thin wall of the riser should be at the bottom and the wide opening should be on the left for the volume and brightness dials.
4. Set the submini slide switch (Radio Shack catalog #275-406) in the slot on the right side of the main screen hole in the front plate. The screw holes should line up with the ones on the front plate. Be sure the two leads of the switch are on the top (meaning you slide the switch up to turn it on).
5. Slide the *ON/OFF switch risers* under both ends of the switch. Then drive the two switch screws (supplied with the switch) through the switch, risers, and front plate. These risers ensure the power switch sticks above the surface of the screen plate enough for you to be able to slide it.
6. Set the screen riser over the power switch — about 1/8" of it should poke through.
7. Use four 1/4"-long size-4 screws to attach the screen riser to the front plate by driving the screws through on the inside of the case.
8. Solder two 6"-long wires to the *top lead* of the ON/OFF power switch and one 9"-long wire to the bottom lead. These will be connected to things in the *Wiring the Unit* section of this chapter.

Working with the rear plate

Now let's work with the *rear plate.* It's the same size as the front plate and will contain the battery clip, DC AUX input jack, and Player 2 joystick port. The Atari board itself will also attach to it later on. Unlike the front plate, however, no side walls will be attached to the rear plate. To assemble it:

1. Attach the battery tabs to the four 1/10" screw holes in the center of the plate by doing the following:
   a. Screw a 1/4"-long size-4 screw into each hole on the battery tabs until it pokes out the other side.
   b. Place a size-4 nylon washer over each screw between the battery tabs and the rear plate, then drive the screws through the rear plate until the tabs are secured in place. The pointed parts of the tabs should face each other toward the center of the plate.
   c. Slide the Sony Infolithium battery between the tabs to check whether it fits.
2. Place the DC IN decal over the hole just over the horizontal air slits. Place the Player 2 joystick decal over the trapezoid-shaped hole. Finally, place the "built by" sticker between the battery tabs with the arrow pointing down.
3. Push the phono jack (Radio Shack catalog #274-246A) through the inside of the rear plate and screw the nut on the threaded shaft on the outside. Take care not to twist the decal when you do this. The leads on the jack should face the center of the plate. (There will be a photo of them in the next section of this chapter; *Wiring the Unit.*)
4. Superglue a *joystick port riser* to the front (the end you plug things into) of the male 9-pin connector, Radio Shack catalog #276-1537. Then place the jack through the hole on the inside of the rear plate. The riser keeps the jack from sticking too far out the back.
5. Cover the edges of the joystick port with epoxy on the inside of the plate to secure it. You can coat the entire back of the joystick port except for the nine leads.

Installing the battery leads

The male polarized connector you bought from the parts list comes with metal leads with rounded ends. These will be used to make the *battery leads*. Snip two of them apart from the rest, then continue snipping and bending, as shown in Figure 17-4.

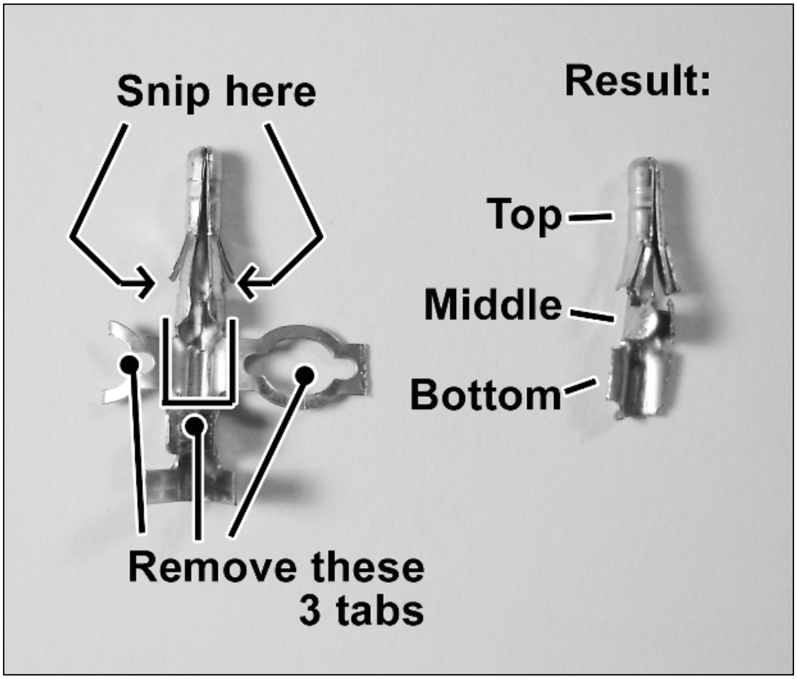


FIGURE 17-4: Where to snip the lead and what the resulting portions are called.

1. Press the leads into the rear plate from the inside. The *top* portion should be on the outside of the rear plate, the *middle* portion on the inside, and the *bottom* portion sticking out the other side of the plate.
2. Bend the *top* portion over so it points left when viewed from the outside of the rear plate. (This is why you needed to snip those small sections on the side.)
3. Insert a Sony Infolithium battery between the battery tabs and slide it down onto the leads. If the battery doesn't fit between the tabs use your X-Acto to shave the sides of them slightly. The battery should fit tightly, but not so tightly that it becomes hard to insert or remove.
4. With the battery holding the tops of the leads, bend the bottom portions so they sit flat against the inside of the rear plate.
5. Fill the inside of the leads with solder. This will make them solid, and also melt the plastic around the lead, helping it to hold it in place.
6. Connect a 5" wire to each of the battery leads on the inside of the rear plate. These will be called the *positive and negative battery wires.* When viewed from the inside, the left lead is negative, right is positive.

7. Put a battery in and use the multimeter to test the other ends of the wires. If they give a voltage reading, then the wires are okay. If they're not okay, check that the leads are inserted properly into the battery and the wires are soldered correctly to the tabs.

8. With the battery wires giving a voltage reading, you can put some 5-minute epoxy over the battery leads on the inside of the unit. Leave the battery installed so that it holds the leads in the correct position as the epoxy hardens and cures.

   The front and back of the battery leads should look like what's seen in Figure 17-5.

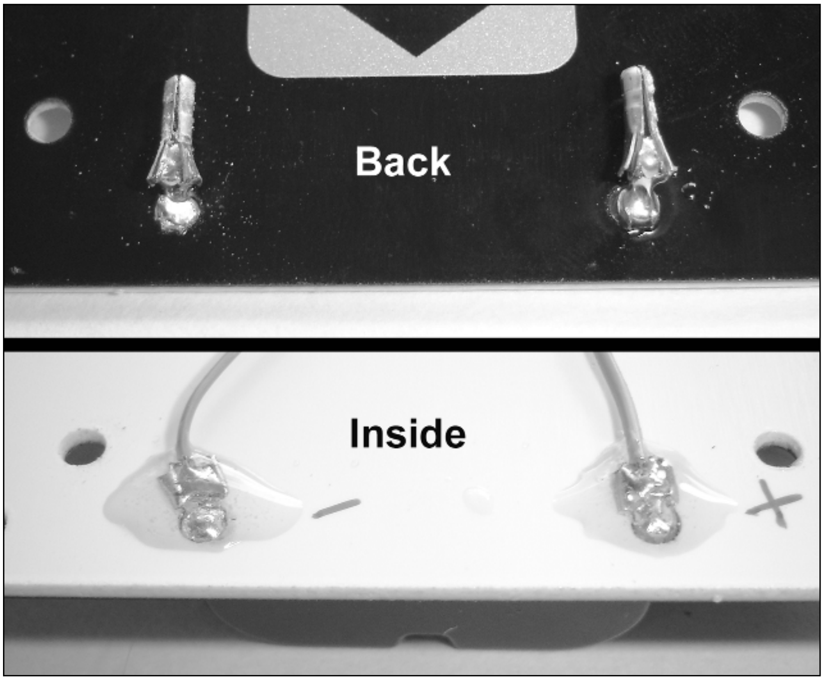


FIGURE 17-5: The front and back of the battery leads.

9. With the Sony Infolithium battery still in place, superglue the 1/4"-thick *battery contact cover* over the leads on the outside of the case. Then glue the *1/16"-thick battery contact cover* over that.

10. Drive 3/8"-long size-6 screws into the holes on either side of the battery terminal. These screws will hold the Atari board on later.

Tip

If you solder the leads while they're touching the battery terminals, it may temporarily short out the battery, causing it to read a charge of 0 volts. The battery is not wrecked; simply stick it back on the charger for a minute to "unshort" it.

The rear plate with all these things installed should now appear as shown in Figure 17-6.

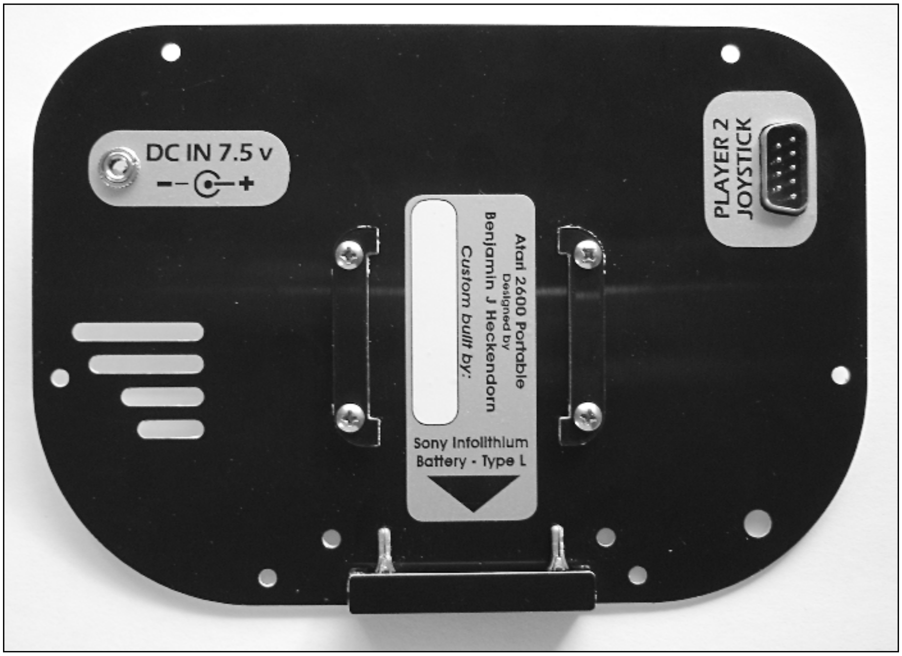


FIGURE 17-6: How the rear plate should appear at this point in time.

Wiring the Unit

With the case built we can now start wiring the unit. In this section, we'll put components on the control board, install it along with the buttons, and also put the screen in the front of the case. We'll then attach the Atari board to the rear plate and wire the two halves of the unit together.

Left and right control boards

We'll start the wiring procedures with the *left and right control boards*. Figure 17-7 shows where to install the components on the front (colored side) of them.

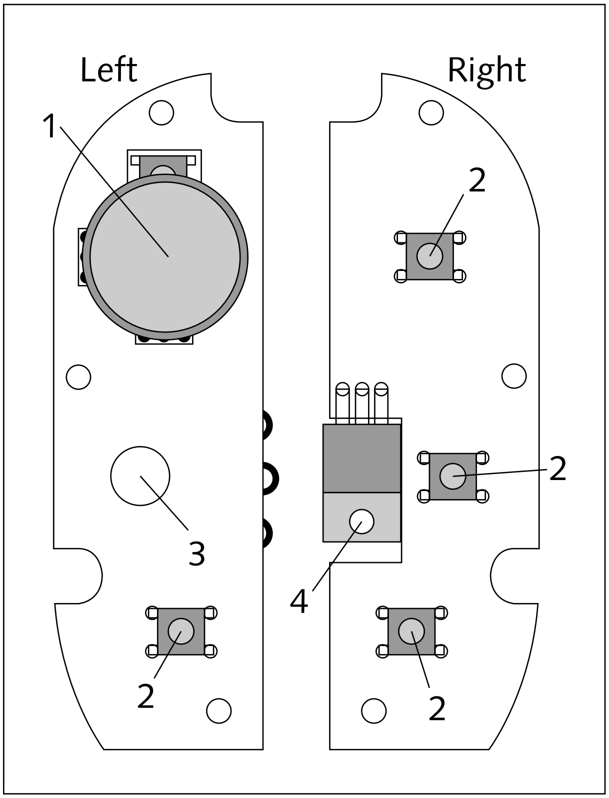


FIGURE 17-7: Parts placed on the front of the left and right control boards.

Here's a list of the parts and the steps to install them:

1. **Part 1** is the analog stick from a Dual Shock controller: The built-in tact switch should be on the top, with the other leads on the left and bottom. Press the leads through the control board as far as you can get them to go, then blob solder on the other sides. This will keep them from pulling back out.
2. **Part 2** are the 6mm tact switches: Press them firmly through the holes and blob solder on their leads in the back to hold them.
3. **Part 3** is the hole in which the paddle controller goes. Saw the shaft off the 1 meg ohm potentiometer so only 1/2" remains past the screw threads. Insert the potentiometer through the Part 3 hole with the three leads going to the right and fasten the nut and washer over the shaft. (You can see the ends of the potentiometer's three leads in the drawing.)
4. **Part 4** is the 7805 regulator. Insert it through the three holes on the right board and bend the leads up on the back to hold it partially in place. The flat portion of the regulator should face the rear (as shown in Figure 17-7).

Flip the boards over and make the connections between the components, as shown in Figure 17-8:

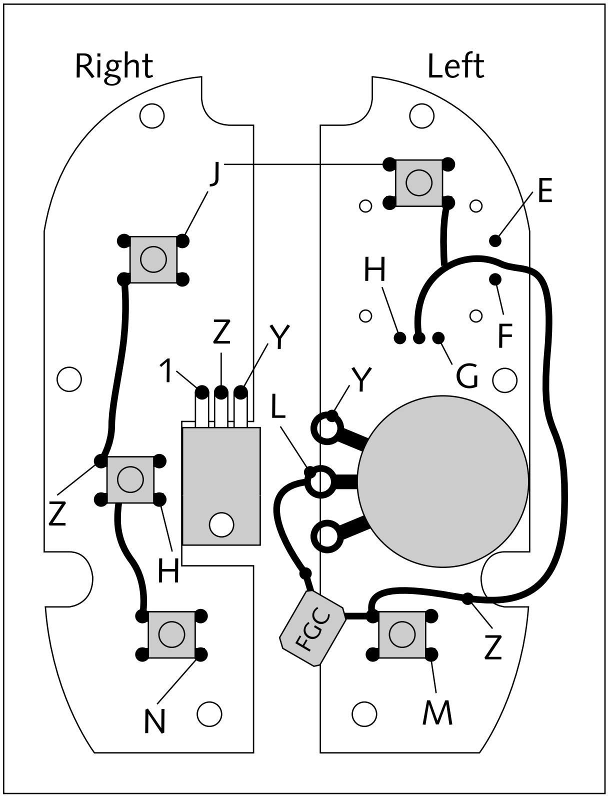


FIGURE 17-8: Wiring on the backs of the left and right control boards.

1. The lettered connections refer to Master Lead List spots on the Atari board. Connect a 9" wire to each; you can always trim them shorter later when the other ends get attached to the Atari board.
2. Connect spot "1" to the *top lead* of the power switch. A wire should already be connected to the top lead of the switch for this connection.
3. Attach the *fat green capacitor* between the middle lead of the potentiometer and the ground (Z) spot on the nearest tact switch. (See Chapter 15 for more on getting a fat green capacitor and hooking up paddles.)

4. Use a 1/4”-long size-4 screw to attach the heat sink (Radio Shack catalog #276-1368) to the flat metal side of the 7805 regulator on the back of the control board. Make sure the heat sink is tight against the regulator so it can suck heat efficiently.
5. Place a few layers of electric tape between the heat sink and the tact switch leads to avoid short-circuits. You can bend the regulator back a little if you need to. This may “tilt” the regulator a little, which can cause a problem that can be resolved by Step 7 that follows.
6. On the right control board do *not* connect the tact switch ground directly to the ground (Z) on the 7805 regulator. Connect both those spots separately to the Atari board with two pieces of wire. Otherwise, the system may reset when you press the trigger.
7. Set the right control board (the one with the regulator) in the front of the case, and then set the rear plate over that. The heat sink may press against the rear plate, keeping it from closing. If this is the case, use a coarse-grit sandpaper to sand down the fine ends of the heat sink until it fits inside the case. (A grinding wheel works great for this.)

Resisting the joystick

In the present condition, the analog joystick will work, but you’ll have to tilt it quite a ways for it to register a movement. The solution is to resist the joystick by putting a 4.7K-ohm resistor between each of the four direction leads (E, F, G, and H on the MLL) and *GROUND* (Z). The leads of the joystick should look what’s shown in Figure 17-9 after you’ve done this.

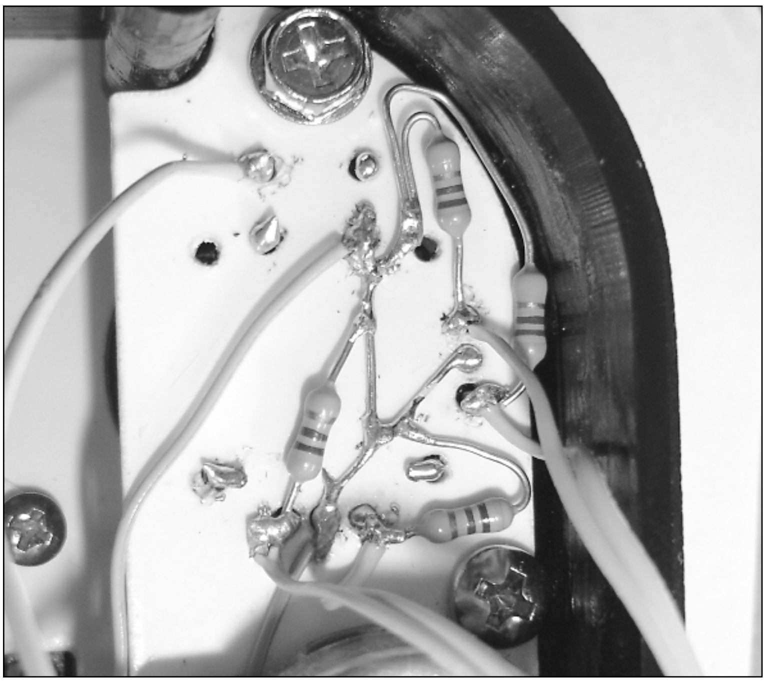


FIGURE 17-9: Resistors placed on the joystick connections.

What this does is pull each directional lead a little closer to being grounded so you don't have to tilt the joystick as far for it to register. We're using 1/4-watt resistors simply because they're physically smaller than 1/2-watt ones, and therefore they fit better.

Tip

You can use slightly higher or lower ohm resistors to adjust the sensitivity of the joystick to your liking. (More on this in the *Testing and Troubleshooting* section.)

Making buttons and installing the control boards

In the *CNC Cutting the Parts* section, some 1/4"-thick button pieces were cut along with side walls. In this section, we'll glue these pieces together along with the 1/16"-thick engraving plastic flanges to form the four buttons in this portable: *trigger*, *paddle trigger*, *select*, and *reset*. Figure 17-10 shows the completed buttons and a side view for reference.

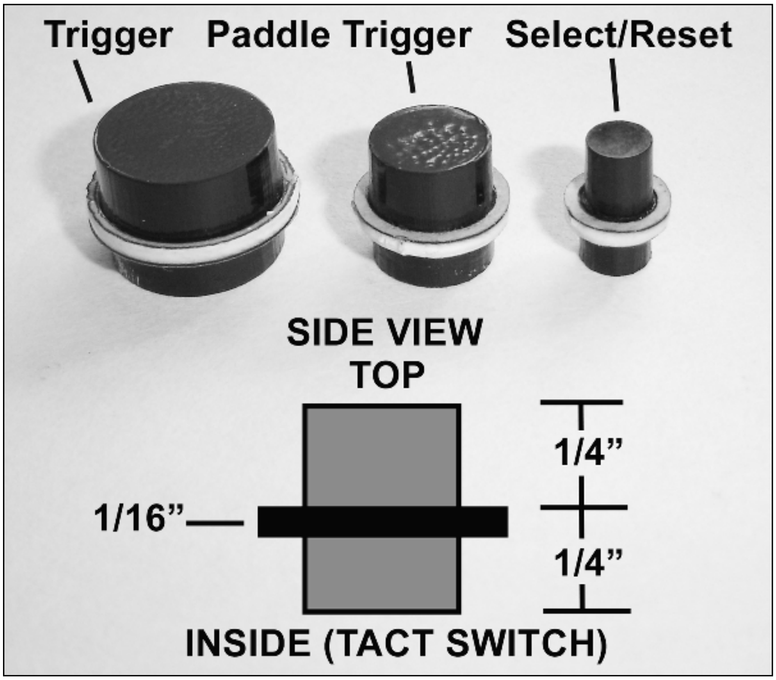


FIGURE 17-10: Top view and side view drawing of buttons/flange placement.

Each button piece is 1/4" high, but the diameter varies. The trigger is 5/8" wide, the paddle trigger is 3/8" wide, and the select/reset buttons are both 1/4". Take the following steps to glue the buttons together and then install them and the control boards into the front of the case:

1. Glue two of each size piece on top of each other to make a 1/2"-tall piece. Then glue the appropriately sized *button flange* around the piece; with the flange touching the top of one of the pieces (see preceding figure), 1/4" of the button should remain exposed on top and 3/16" on the bottom. Paint the tops of the triggers red.
2. The two) 5/8"-diameter circles with holes in them are for the paddle knob. Glue two on top of each other as you did with the buttons, and then glue the notched *paddle knob cover* on top of them. Slide the paddle knob over the potentiometer's shaft.
3. Place all the buttons in the holes in the front plate, with the thick 1/4" portion going out toward the front.
4. Set the left and right control boards into the front of the case and use computer case screws to secure them.
5. Check how well the analog control stick moves around. If it "clunks" against the sides of its hole too much, put a size-6 nylon washer under each screw to lift the left control board slightly more away from the front of the case. This gives the analog stick a little more room to move.
6. Decide how high you'd like the paddle knob to stick out (1/2" is good) and superglue it to the metal potentiometer shaft.

Installing the TV screen and speaker

You can now install the Casio EV-680 pocket TV that you modified with white LEDs in Chapter 4. Remember, you must also have the *folded reconnecting* mod done to it as well (also explained in that chapter) in order for the TV to fit inside this portable. Finally, make sure the speaker has the 5"-long extension wires and has been reattached to the TV before doing this, as it will be difficult to go back and solder it on later.

Once the modified TV is checked and ready to go, install it into the case by doing the following:

1. Place the screen into the front of the case and line up the dark area of the screen to the opening as best you can. If the screen is being "pushed up," it's probably because of the LCD ribbon cable.
2. Put some hot glue on opposite corners of the screen on the inside. (Don't get any on the LCD ribbon cable.) While the glue cools, hold the unit above your head and move the screen until it's centered as much as possible. Hold it until the glue sets.
3. Put a few more small spots of glue around the screen to hold it for now. Don't go overboard until you've tested the unit, otherwise it'll be difficult to remove the screen if you need to fix anything.
4. Set the brightness and volume dials in the appropriate slots on the side of the screen. When viewed from the rear, the lower dial is volume, and the upper is brightness.

5. Put some hot glue on the metal side of each dial to partially secure it to the case, while keeping the glue away from the dial itself. If some does hit the dial, cut it away with an X-Acto knife.
6. Blob some hot glue over the lead ends of the dials to attach the knobs to the TV screen itself. This will keep the dials from being pushed into the case.
7. Cut a square piece of screen door mesh about 1-1/2" × 1 1/2" in size. Superglue it on the bottom of the walls over the "+" shaped speaker hole.
8. Cut another piece the same size, then glue it over the first piece, but rotated about 45 degrees. This makes the mesh look thicker.
9. Place the TV's speaker over the mesh and use about four blobs of hot glue to lock it in place. Put the speaker terminals on the left so the wires going to them can be tucked along the side of the TV.

At this point, the front of the case should look like what's shown in Figure 17-11.

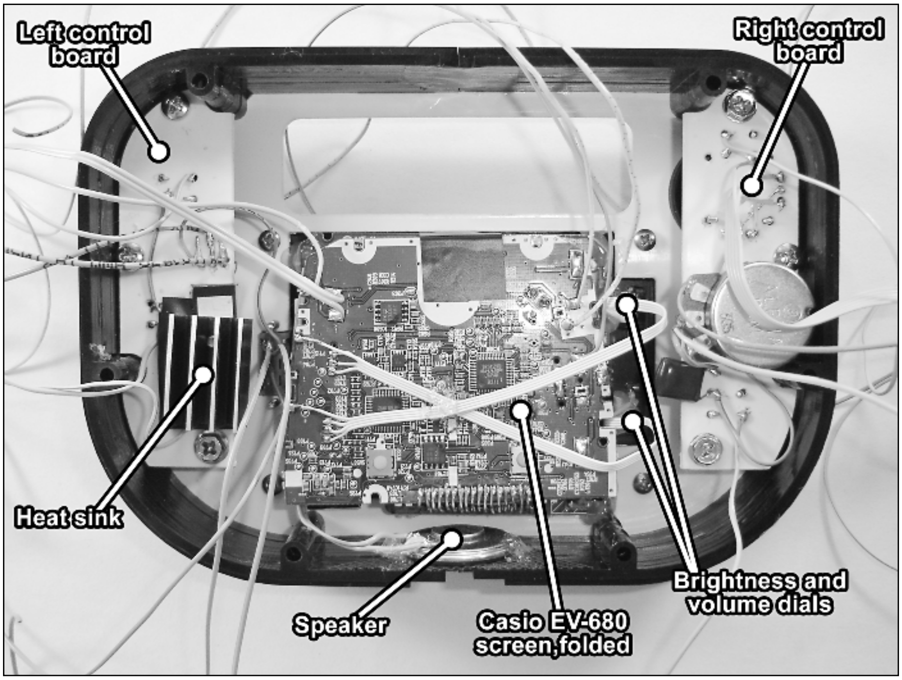


FIGURE 17-11: The inside of the front of the case with everything installed.

Tip

Keep the back of the TV's circuit board as wire-free as possible so there will be extra room when you install the Atari board.

Wiring the front and rear of the case together

We can now connect the front and rear of the case together — once we've positioned the halves for the procedure, of course. Start by laying the front half of the case facedown, with the speaker at the bottom. Set the rear of the case below it, with the battery terminals near the speaker. It's also a good idea to put a piece of paper under the unit so the engraving plastic surfaces won't get scuffed up by your work area. Okay, let's get started!

1. Set the Atari board on the inside of the rear plate. The two screws should line up to the holes you drilled on the Atari board. Check that they'll fit, but don't secure the Atari board yet. You can also snip the sides of the holes and simply slide the Atari against the screws.
2. Connect the wires from the backs of the left and right control boards to the Atari, using the letters on the *MLL* (Master lead list — Figure 15-5 in Chapter 15) as a guide. Snip the wires so they're only as long as needed, keeping in mind where the Atari board will be on the rear plate.
3. Figure 17-12 shows the connections to make from the lower TV circuit board to the Atari. The "Composite Video" refers to the output of the video circuit you built in Chapter 15.

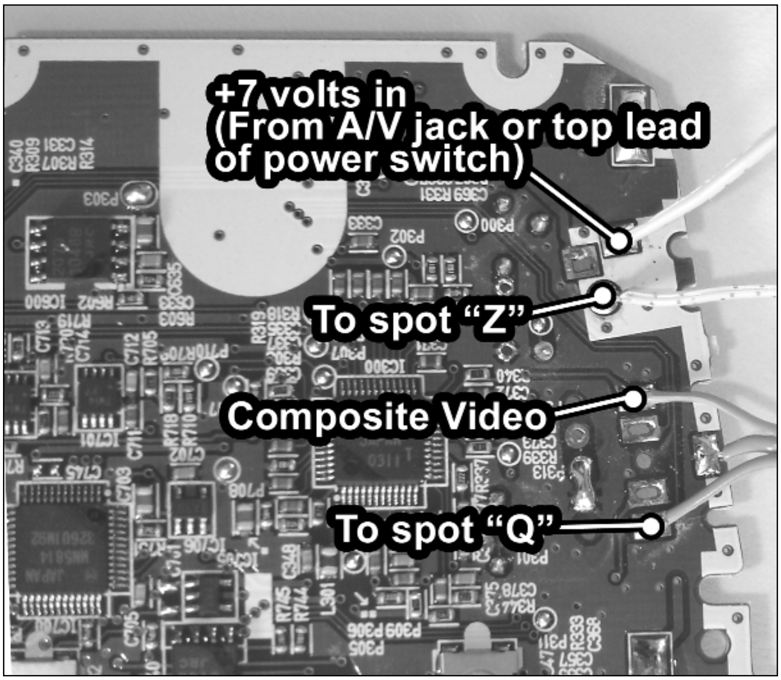


FIGURE 17-12: Audio, video, and power connections to the TV's circuit board.

4. Stick the headphone jack into the small hole in the lower left corner of the rear plate and hot-glue it in place. Keep the glue away from the edge of the plate (so the walls will fit) and the Atari board (so it will fit).

DC AUX input jack wiring

Figure 17-13 shows what wires to attach to the DC AUX input jack, followed by some steps to take when doing it.

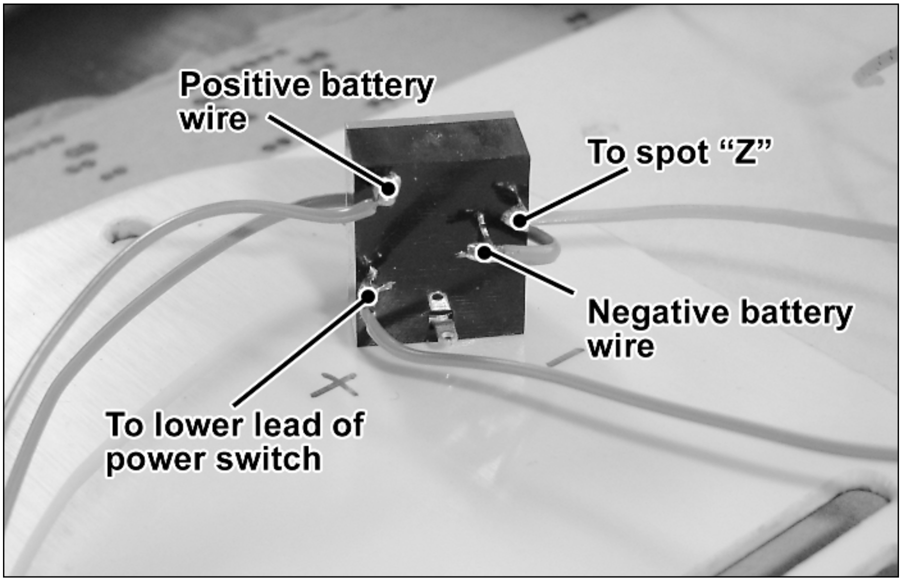


FIGURE 17-13: Wiring the DC AUX input jack.

1. The positive and negative battery wires are the ones that were connected to the battery leads on the rear plate. Connect them to the DC AUX jack as shown in Figure 17-13.
2. Keep the battery wires out from under the Atari board or they may get squished and short-circuit when the Atari board is screwed down.
3. Use a short, 3"-long wire to make the connected marked "To Spot Z." This can go to ground anywhere on the Atari board.
4. A wire should already be connected to the lower lead of the on/off power switch (from back in the *Assembling the Case* section). Connect it to the DC AUX jack, as shown.

Wiring the Player 2 joystick port

In the *Assembling the Case* section you epoxied a 9-pin connector in the rear plate. This is the *Player 2 joystick port,* and now it's time to connect it to the Atari board:

1. Figure 17-14 shows how to connect wires between this joystick port and the Atari board. These letters refer to spots on the MLL (Master Lead List).

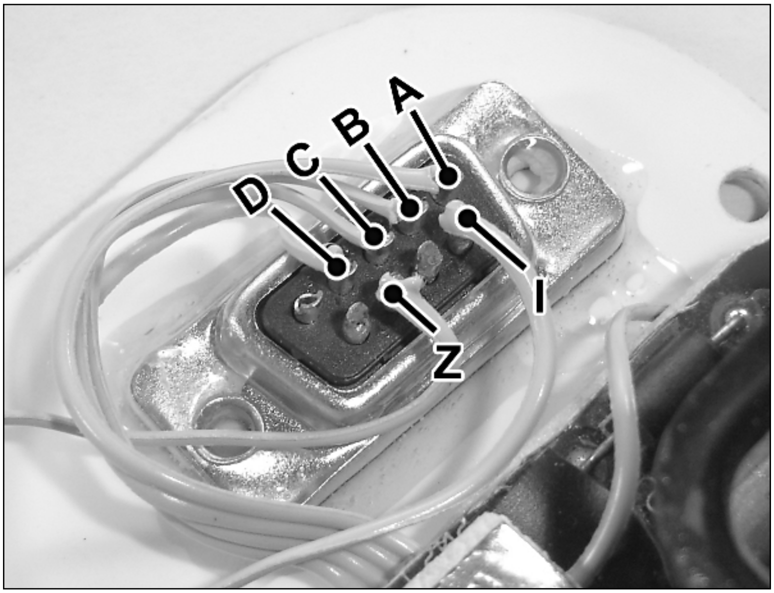


FIGURE 17-14: Connecting the Player 2 joystick port to the Atari.

2. Try to keep the four-strand of wire for the A-D connections as short as possible. It only has to go about 3" to reach the spots on the Atari board, but keep in mind that you'll want to be able to lift the Atari board to check things, so 5" is more reasonable.
3. With the Player 2 joystick port attached, you can slide the Atari board over the two 3/8"-long size screws and use two size-6 nuts on them to secure the board to the rear plate. The result should look like Figure 17-15.

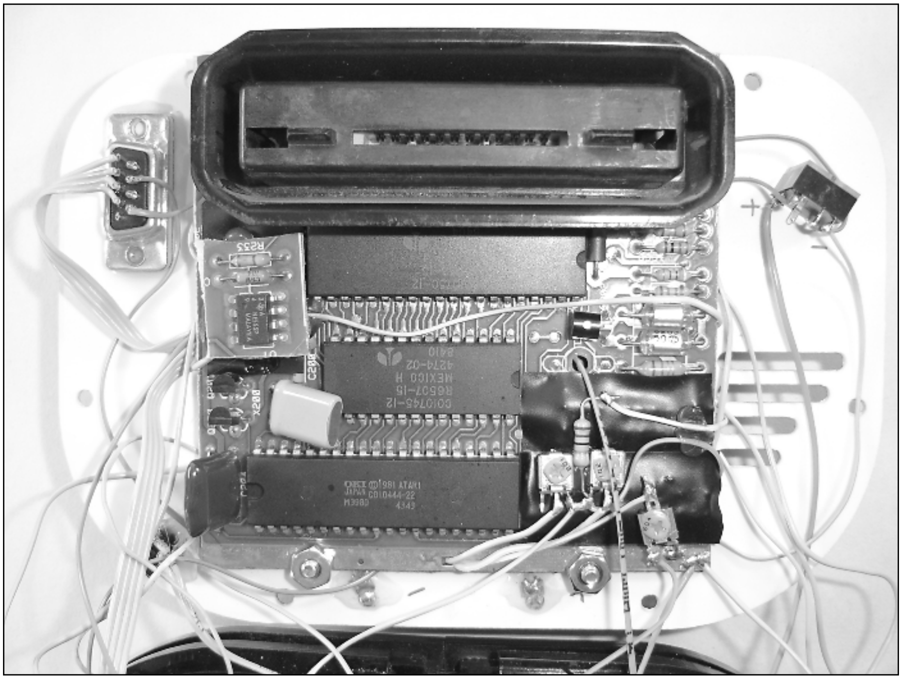


FIGURE 17-15: The completed rear half of the unit.

The parts of the Atari 2600 CNC-built portable are now completely wired together! The next step is to test it out.

Testing and Troubleshooting

In this section, we'll test out the Atari 2600 portable step-by-step and make sure everything is working before closing it up and finishing the unit. If you're one of those super lucky people (you know, the kind who never get pulled over or have to go to the dentist), everything will work great. If not, solutions and what to check for each potential problem will be listed with each test.

1. First, charge up the Sony Infolithium Type L battery and then clip it onto the back of the unit. Insert a game cartridge (one with music right away is good, such as Frogger) and switch the unit on. If nothing happens at all (no light on screen or sound), do the following:
   - Bend the battery leads either down (more toward the case) or slightly in toward one another, and try again. This gives them a better grip against the terminals inside the batteries.

- The RCA model of the Casio EV-680 almost always flips the polarity of the DC in jack. Reverse those wires and see whether it works.
- Check that the LED mod is correctly installed and +5 volts is getting to it. (See Chapter 4.)
- The fuse on the TV may have short-circuited. Bypass it as described in Chapter 4.
- Check that power is getting to the power switch (from the DC AUX input jack) and that power is going from the switch to the TV's circuit board (see Figure 17-12, earlier in this chapter).
- The positive voltage going to the TV first goes through the audio/video power jack, as explained in Chapter 4. Make sure nothing is plugged into this jack or the TV won't turn on.
- The TV gets its ground from the Atari (the spot Z connection shown in Figure 17-12). If the Atari's ground is not properly connected to the DC AUX input jack, then neither it nor the TV will work.
- Check that no positive voltage connections are shorting out to ground connections. If this occurs, you'll have to stick the battery back on the charger for a moment to reset it.

2. If the screen lights up but there's no picture or sound, take the following steps. The screen lighting up means the TV is getting the right amount of voltage. Therefore, the problem is with something else. Check the following things:
   - Check that +5 volts is getting to spot "Y" on the Atari. This allows the Atari to turn on.
   - Check that the wire between the composite video out on the Atari is connected properly to the TV's circuit board (Figure 17-12, earlier in this chapter).
   - The RCA model of the Casio EV-680 sometimes flips the audio/video connection spots. Reverse them and see whether it works.
3. If there's picture, but no sound:
   - Make sure the headphone has been properly rewired, as described in Chapter 4. If it's removed from the TV board but not reattached, the speaker will not work.
   - Check that the thin ribbon cable connecting the volume dial to the TV board is correctly wired and nothing has come loose.
   - Check that the speaker connections have not come loose, both on the speaker end and on the TV board. (As they're somewhat hidden after folding the boards, it's something you might not have noticed.)
   - Check that the audio connection from the Atari (spot "Q" on the MLL) to the TV is correct.

4. If there's sound but no picture, take the following steps:
   - Check that the LCD ribbon cable is correctly and fully inserted into the lower TV board.
   - Check the video circuit on the Atari to make sure it was wired as described in Chapter 15. Slight mistakes in the video circuit will still produce a picture, but if something major is missing (like not connecting spot U (Sync) to the composite video output; check Figure 15-6 in Chapter 15), you probably won't see anything at all.
   - If the screen is bright white, try spinning the brightness dial down.
   - Check that the thin ribbon cable connecting the brightness dial to the TV board is correctly wired and nothing has come loose.
5. If the unit resets or turns off when shaken or moved around, do the following:
   - The battery leads may not be contacting the battery well enough. Bend them slightly down or toward each to create more friction when the battery is inserted. Also check that the battery tabs and screws are tightly fastened. (This was mentioned earlier, but even if the unit is working, these tabs may still need to be adjusted to keep it working well.)
   - Check that power connections to the TV and Atari are secure. Sometimes even things that appear to be soldered are not. Resolder anything that looks questionable.
6. Once the system is on with picture and sound, go ahead and press Reset to start a game. Try NOT playing it. Just let it sit there after starting. If the game character moves without you moving the joystick:
   - It's likely that the 4.7K-ohm resistors you placed on the analog stick aren't providing enough resistance. Try swapping the offending direction's resistor with a 5.6k or 10k ohm one instead. You can also try removing the resistors completely, although this may affect the joystick's usability, especially with the diagonal movements.
   - Sometimes when you slice the Atari board apart (Chapter 15) it can cause the loose ends of the joystick traces (the circuit lines on the board) to touch each other. This causes erratic movement on-screen, usually causing your character to move weird when you press a direction. Follow the trace lines from spots E–H on the Atari board to where they get cut off at the edge of the board. If any are touching (or even look close to touching) grab the loose ends of the traces and rip them off the board. Make a deep knife cut along the traces so that when you rip them up to that point, they'll come completely off the board.
   - Loose strands on the wires connected to spots E through H on the Atari board can also make the controller act strangely. Check those spots for loose strands and remove/resolder any that you find.

7. If the controls don't work at all, take the following steps:
   - Double-check the connections on the left and right control boards and make sure all the spots are connected to the right places on the Atari board.
   - Make sure the ground connections to the left and right controller are also connected to ground on the Atari (Spot Z). Remember, don't use the middle (ground) lead of the 7805 regulator to connect ground to the left and right control boards, even though it's right there.
8. Plug in a two-player game such as *Combat* and insert an Atari joystick into the Player 2 port. Start the game and see if the Player 2 controls work okay. If they don't:
   - Check the connects A through D, I, and Z from the Player 2 port to the Atari board. If they get accidentally switched around it will cause things not to work.
   - As with the built-in Player 1 controls, check that no traces from spots A through D on the edge of the Atari board are touching. Also check for stray strands on the wire connections, both on the plug and the Atari.
9. If you've got everything working, but the game colors are weird (you know, yellow water, purple grass, etc.), do the following:
   - Use a small, flat-head screwdriver to adjust the three potentiometers of the video circuit on the Atari. A color-checking table was provided in Chapter 15 in the *Fine-tuning the picture* section.

   Once you've gotten through this checklist, your Atari portable is A-okay and ready to be closed up and finished!

Final Assembly

With the unit working properly, it's time to secure stuff down and finish up the portable. Be sure you've checked every facet of the unit before closing it up. (Sure, you can always open it again, but why go to the bother of all that screwing and unscrewing?)

1. Press the Player 1 and 2 ribbon cables flat against the back of the Atari board. Slide the Atari board over/against the two screws, and then fasten a nut over each. Don't get any wires caught under the screw end of the Atari board, or they may short out.
2. The Player 1 and 2 ribbon cables are a concern when it comes to taking up too much space. Fold them and tuck them away from things as much as you can. When you connect the halves, be sure these ribbon cables don't go over the paddle potentiometer, or the case won't fit together.
3. On the left side of the Atari board there's typically a green capacitor and a gray thing. Either bend these things so they'll fit around the screen (when the unit is closed up) or desolder and rewire them flat. (Be sure to keep the polarity the same.)
4. You can use hot glue to "wrangle" wires down and keep them in line. Be sure there's still enough loose wire that the unit can fold fully open or close, however.

5. Don't let any wires go inside or on top of the heat sink. The heat sink should touch the back plate when the unit is fully assembled and be visible through the vent holes.
6. Place a few layers of electric tape over any ground or positive voltage spots that are bare and might touch other connections when the unit is assembled, such as
   - The three leads on the potentiometer.
   - The leads on the DC AUX input jack.
   - The positive and negative battery terminals (these should already be covered with epoxy, however).
   - The power/ground connections on the TV's circuit board.
   - The leads on the Player 2 joystick port.
7. Fold the halves of the unit toward each other. Make sure wires don't go over screw posts. Fold the rear plate against the front of the case — you may have to scoot the Atari board around a little as you do this.
8. If the heat sink bumps the side of the Atari board, reach in through the vent slits on the rear plate with a thin screwdriver and pull the heat sink away from the Atari board as you press the halves together.
9. Once the halves are together, insert a battery and test the unit again. It's good to check whether anything has bumped and short-circuited before you screw things tight.
10. With the unit working properly, drive six 3/8"-long size-6 screws through the remaining holes on the rear plate to fasten the halves together.

Congratulations, your CNC-built Atari 2600 portable is complete! You can play off battery power, naturally, but if you're lounging about your pad, the following section will be of use also.

Using a DC wall power adapter

Granted, this makes the unit a little less portable, but it's still a option for powering the thing. In fact you don't even *need* the battery or charger if you do it this way.

This unit requires approximately 700 mA of power at 7.5 volts. The standard multi-voltage adapters usually come as a 500 mA, 800 mA, or 1000 mA rating, so 800 mA will be your best bet. Use the plug that looks like a mono headphone jack — it's called a 1/8" minijack — and set the voltage to center positive, outer portion negative. Radio Shack also sells DC power adapters (catalog #273-1667) that come with an "Adapta-Plug" (catalog #273-1709) that'll work with your portable.

Chapter in Review

Using this chapter, a CNC machine, some electronics parts, and a little elbow grease you have built an awesome Atari 2600 portable that will provide loads of classic videogaming fun wherever you take it. Important steps of the building process included:

- Getting the case parts routed and gluing them together.
- Installing the control boards and the modified Casio EV-680 pocket TV.
- Attaching the Atari 2600 to the rear plate and wiring both halves of the case together.
- Testing the unit to make sure everything worked before closing it up and finishing it.

Rebuilding old game systems is a great thing to do. That way, when invaders from space attack, if a frog needs to cross the road, or those pesky large asteroids have to be made smaller, the Atari 2600 will be there, now and forever, ready to answer the call!

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