GAL Build Guide

Introduction

The Gun Aiming Laser, or GAL, is a battery-powered, hand-operated, multi-spectrum target pointer, illuminator, and aiming laser system.

Battery: 1x 18650 or 1x CR123
Activation: On-board momentary pushbutton, Crane/Laser plug or 2.5mm jack (or neither), double-tap for 'hold on', 5-minute timeout
Illumination: 850 or 940nm 3W LED
Visible Laser: 5mW 650nm TTL Laser
IR Laser: 5mW 850nm TTL Laser
Height: 1.7" (1.4" above rail)
Width: 2.9"
Length: 4.2"
Weight: 4.9oz (138g) (without battery)
Battery Life: >6 hrs on DUAL HIGH mode (2000 mAh 18650)

Parts List

Parts Kits

Parts kits are available at knacktactical.com. These parts kits have everything you'll need to build the GAL including a pre-soldered, pre-programmed, and tested PCB. The only things you will need are the 3D-printed parts and the tools for assembly.

Hardware

4x M4x6mm Button Head Hex Drive Screw - Securing Lid to Body
4x M4x4mm Short Threaded Heatset Inserts - Securing Lid to Body
1x M3x45mm Socket Head Screw - Pic Rail Screw
2x M3x6mm Flat-Tip Set Screw - Laser Adjustment Screw
2x M3 Hex Nut - Laser Adjustment Lock
3x M3x4mm Short Threaded Heatset Inserts - Laser Adjustment, Pic Rail Nut
1x Number 0, 3/16 Long Screw - Selector Knob Securing
2x AAA **Negative** (Spring) Battery Terminal - Negative terminal for battery, rear spring for laser
1x 0.5" x 0.148" OD Compression Spring - Laser retention spring
1x 16" of thin wire (26 or 28 AWG), paired wire makes things much neater
1x 3.5" of 22 AWG Solid Core Wire
1x US Nickel Coin (or another 21mm metal coin/disc)
(Optional) 1x AAA Positive Battery Terminal - For 18650 batteries without a nipple
1x Laser Hole Cover - Covers the Laser Hole
    This can be laser cut/CNC'd from 1/16" polycarbonate or acrylic, or made by hand.

If using a Crane-style tape switch:

1x 6.1mm ID Unthreaded Spacer - 1st Stage of Crane Connector
1x 0.198" ID Unthreaded Spacer - 2nd Stage of Crane Connector
(Optional) 1x Crane-style tape switch - Activates Device

If using a 2.5mm Jack:

1x 2.5mm Audio Jack
(Optional) 1x 2.5mm Jack tape switch - Activates Device

Electrical Components

1x 19mm Momentary Press Button - Internal Activation Button
1x 940nm or 850nm 3W LED - Illuminator LED
1x 20mm Lens for 3W LED - Illuminator LED Lens
1x 850nm 6x23mm TTL Driven Laser - IR Laser
1x 650nm 6x23mm TTL Driven Laser - Visible Laser
1x Red Diffused Flat Top LED - Indicator LED

1x Rotary Switch - Mode Selection
The rotary switch is a C&K A Series Rotary Switch. The models that will work are:

A**XXX**<u>YY</u>RNC**<u>Z</u>**
XXX can be 109, 110, or 112
<u>YY</u> can be 15, 03, or 05
<u>Z</u> can be Q, B, or G (you will probably only find Q)

The variance in the model number is because only 9 positions are used (hence XXX must be greater than or equal to 9) and the length of the knob doesn't matter, as it is shortened to around 3 mm, so any of the knobs will work. Pick whichever is the cheapest.

PCB

These parts are not needed if purchasing a parts kit from knacktactical.com as the PCB is included and already populated.
1x GAL v2 PCB
1x ATTINY84A-SSU
1x MMBT2222A-TP
8x 10kΩ 1/8W 0805 Resistor
2x 10Ω 1/4W 0805 Resistor
1x 3.3kΩ 1/8W 0805 Resistor

3D Printed Parts

1x Body
- See the Printing>Body section for more info on body variations

1x Lid
1x Laser Base
1x Laser Housing
1x Pic Rail Clamp
1x Lens Cap
1x Battery Cap

1x Selector Knob
2x Adjustment Locking Knob
1x Vertical Adjustment Support
1x Rotary Switch Jig (Optional)

ATtiny84 Programming

These parts are not needed if purchasing a parts kit from knacktactical.com as the ATtiny84 on the PCB will already be programmed.
1x Any Arduino with SPI capabilities (Nano, Uno, Micro, Due, etc.) (knockoffs will work)
1x Breadboard
1x 10 to 22 µF Electrolytic Capacitor
6x Jumper Cables/wires (will need to temporarily solder 4 of them to the PCB)

Tools for Assembly

- Soldering Iron and solder
- Needle nose pliers
- Tweezers
- Wire strippers
- Super glue
- Hot Glue/Epoxy
- 2mm, 6mm, and 8mm drill bits (an entire metric drill bit kit is nice to have for many FOSSCAD projects)
- 1 or 2mm dia Heatshrink tubing

Body Variations

Choosing a Battery

The GAL is designed for a single Lithium battery. The operating voltage of the ATtiny84 is between 2.7 and 5.5V, which is the perfect range for an 18650 or CR123! The only other minimum voltage requirements are for the lasers, which operate between 3 and 5V. While the idea originally started with 2 CR123s and a 5V regulator, I found that the entire device worked on 3V which is simpler and cheaper.

That being said, **if you print the 18650 body and put two CR123s down the hatch, you will likely fry your board, which is both sad and not good.** So don't do that. I prefer the 18650 as it provides a brighter illuminator, longer runtime, and rechargeability. But you might already have CR123s on your kit, so that could be more convenient. Up to you.

Externally Activating your GAL

After choosing your battery, you'll need to choose how you want to externally activate your GAL. As there is an on-board button, you don't *have* to run an external switch if you don't want to, but these leave options for upgrades. There are currently two options: Laser/Crane style plug or 2.5mm jack. There are pros and cons to both.

The pros of the Laser/Crane-style plug is that your GAL will work with the same switches that work with the PEQ15, MAWL, and DBAL. Switches with this plug style can be found all over the internet. I may have some in stock in my store.
The cons of the Laser/Crane-style plug is that the female part of the plug is not easy to find, so it must be made using spacers from McMaster-Carr. It isn't the prettiest solution, but it works. It can also be water-tightened from the inside with epoxy, silicone, or even hot glue for those with commitment issues.

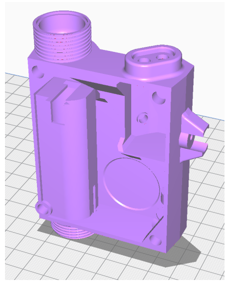
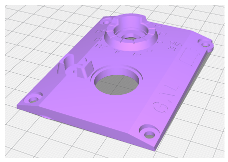
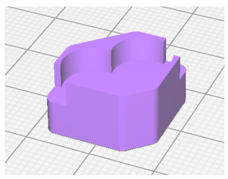
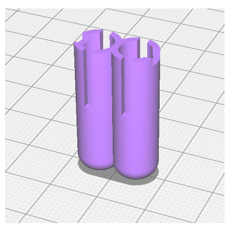
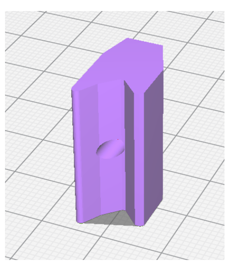
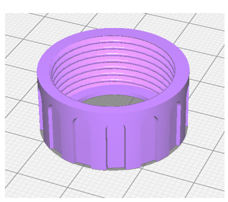
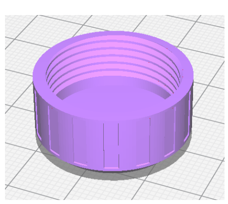
The pros of the 2.5mm jack are that it is very easy to install, as it's an actual part from DigiKey.
The cons of the 2.5mm jack are that it simply isn't as cool and male 2.5mm jacks from AliExpress tend not to inspire a lot of confidence in their construction quality.

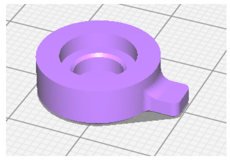
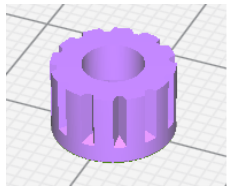
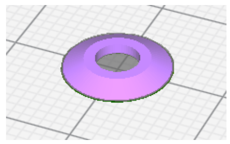
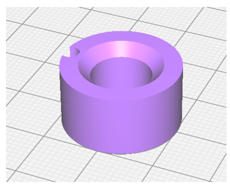
Switches for both types can be found on AliExpress or other places on the internet.

Printing

This section contains the suggested print orientations and whether supports are needed, as well as any notes, for each of the required printed parts. In general, the settings will depend on the material you are printing with. All of my prints are with PLA+, but I would imagine better materials would result in a better device. Regardless, you'll probably want:

- Walls: 4+
- Infill: 40+%

Printed Parts			
Part	Orientation	Supports	Notes
Body		Yes	4 Body Variations: ● Crane | CR123 ● Crane | 18650 ● 2.5mm Jack | CR123 ● 2.5mm Jack | 18650
Lid		Yes	
Laser Base		No	
Laser Housing		No	
Pic Rail Clamp		Yes	
Lens Cap		No	
Battery Cap		No	

Selector Knob		No	
Adjustment Locking Knob		Yes	2x needed
Vertical Adjustment Support		No	
Rotary Switch Jig		No	

Programming the ATtiny84

Programming the ATtiny84 on the PCB is required for the device to function. To program the ATtiny, you will need your Arduino, breadboard, capacitor, and jumper wires. The program can be found on GitHub.

A majority of the steps can be found in this guide, however, steps 1, 2, 5, and 6 will be different.

Step 1: Go Get Stuff

We will be working with the ATtiny84, not the ATtiny85, but that difference will be accounted for later. You will also not need the LEDs or resistors.

Step 2: Wire the Circuit

Since our ATtiny is not on a breadboard (and also is surface mount), we cannot use a breadboard to program it. Instead, solder pads have been added and labeled for the necessary pins. The pinouts listed below are accurate for the Arduino Uno and Nano. If using something else, ensure you use the correct pins for SS, MOSI, MISO, and SCK. The connections are as follows:

- Arduino +5V (or +3.3V, doesn't matter) → Any VCC Pin on the PCB (see Figure 1)
- Arduino GND → Any GND Pin on the PCB (see Figure 1)
- Arduino Pin 10 (SS) → RST pad on PCB
- Arduino Pin 11 (MOSI) → MOSI pad on PCB
- Arduino Pin 12 (MISO) → MISO pad on PCB
- Arduino Pin 13 (SCK) → CLK pad on PCB

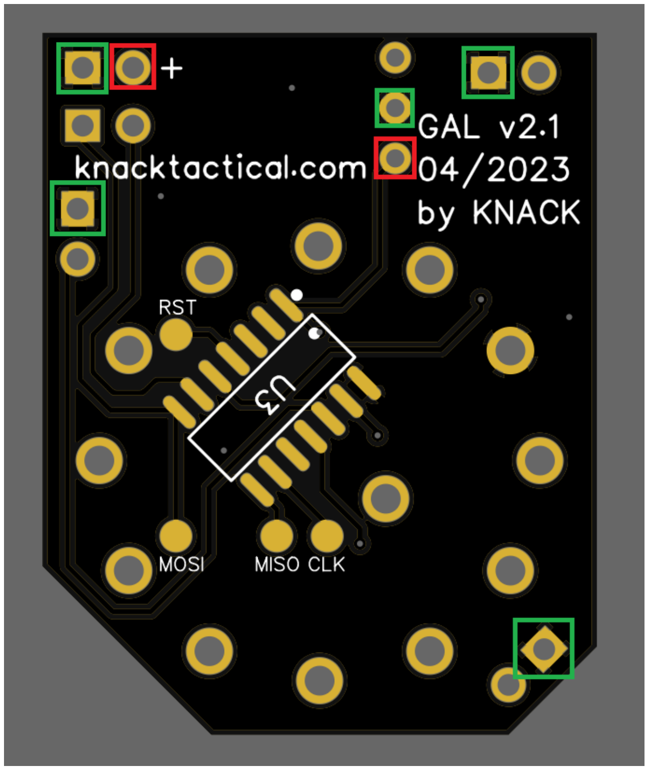


Figure 1
Green squares mark GND pins and red squares mark VCC pins

Step 3: Program the Arduino

This step is unchanged. The reason we need to do this step is to tell the Arduino that it will be used as a programmer rather than an executor of the code we give it.

Step 4: Filter Capacitor

This step is unchanged. The purpose of the capacitor is to prevent the Arduino from restarting itself. Be mindful of the polarity on the capacitor!

Step 5:

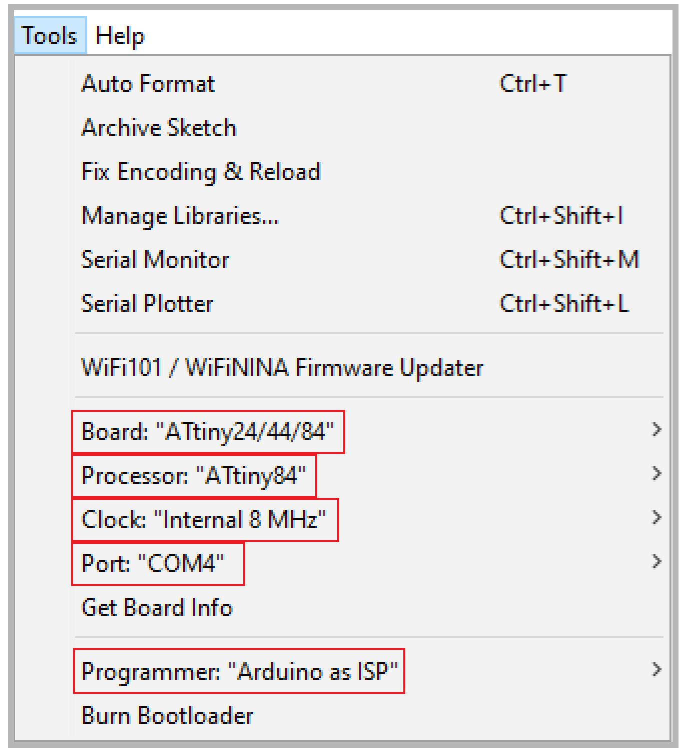
The guide is outdated on this step and there is a much easier way to do it now.

1. Open 'File>Preferences' in the Arduino IDE.
2. Paste the following link into the 'Additional Boards Manager URLs' section:
   - https://raw.githubusercontent.com/damellis/attiny/ide-1.6.x-boards-manager/package_damellis_attiny_index.json
   - Sidenote: If you already have something in this field, add a comma after the current entry or click the icon next to the entry and add the link below what is currently there.
3. Click OK, close the Arduino IDE, and reopen the Arduino IDE for the changes to take effect.

Step 6: Program the ATtiny84

With everything connected properly, you should now be able to program the ATtiny. First, ensure that the options under tools are correct. They should be:

Board: "ATtiny24/44/84"
Processor: "ATtiny84"
Clock: "Internal 8 MHz"
Port: Whatever port your Arduino is
Programmer: "Arduino as ISP"



Click 'Burn Bootloader' and it will burn the bootloader to the ATtiny. **If you miss this step,** the ATtiny will not run correctly. Ensure the 'Burn Bootloader' step completes. If not, make sure your connections are correct and try again.

Open the 'firmware.ino' file in the Arduino IDE, double-check the 'Tools' settings are correct, and upload the code to the ATtiny. Congrats, the ATtiny is now programmed!

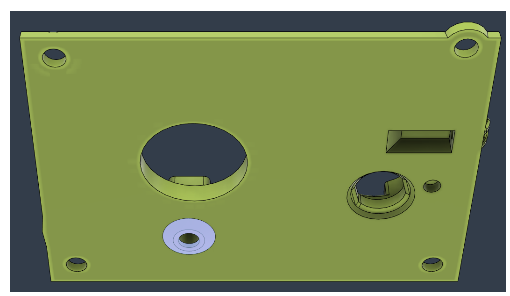
Assembly

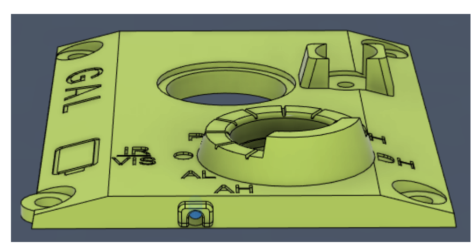
Printed Parts

Vertical Adjustment Support

Parts needed:
1x Lid
1x Vertical Adjustment Support
A few dabs of superglue

The only assembly of printed parts needed is attaching the Vertical Adjustment Support to the Lid. This can be done with a ***few*** dabs of superglue and a T20 screwdriver bit or anything round you can find that fits in the heatset hole. The T20 screwdriver bit works well because it is tapered which applies downward pressure and keeps the piece centered. Try not to use too much superglue, as you will be putting a very hot heatset next to this and burning superglue isn't good for you. You should be soldering in a well-ventilated area anyway, but be mindful. The reason for this piece is to prevent needing supports on the entire underside just for that piece.



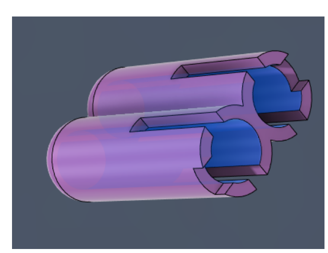


Lid

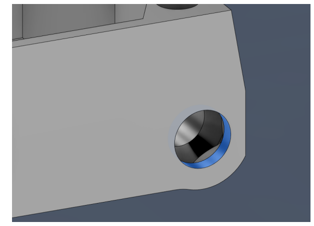
You will need to drill out the Indicator LED hole with a 2mm drill bit.

Laser Housing

It might be necessary to ream the two holes for the lasers with a 6mm drill bit, as it is designed to be a very snug fit.



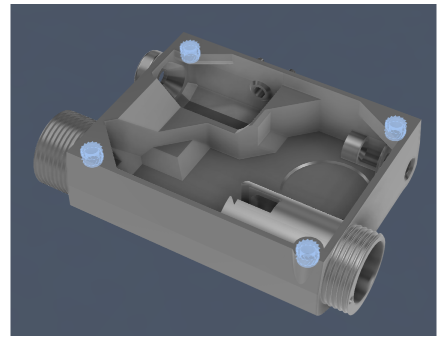
2.5mm Jack Hole



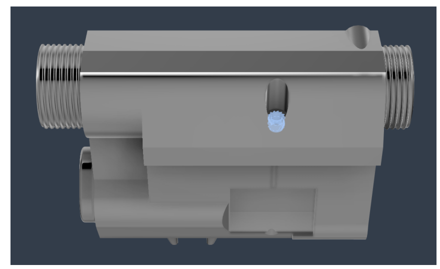
If using the 2.5mm jack for external activation, you may need to ream the hole with an 8mm drill bit for the jack to fit.

Hardware

Heatsets



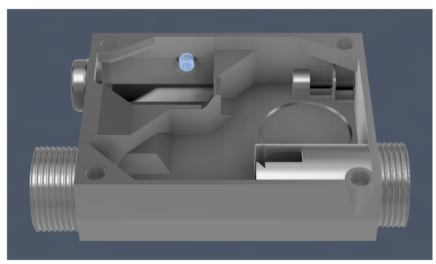
Parts needed:
1x Body
1x Lid with Vertical Adjustment Support
4x M4x4mm Heatset Threaded Insert
3x M3x4mm Heatset Threaded Insert
Soldering Iron



There are 4 M4 heatsets and 3 M3 heatsets. The 4 M4 heatsets go on top of the body and are used to attach the lid to the body. These should go just under flush and may need sanding to get rid of the bump squeezed out.

1 M3 heatset goes in the outside hole for the Pic Rail Clamp.

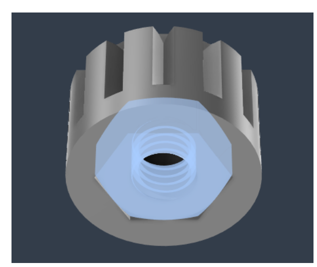
1 M3 heatset goes in the Horizontal Adjustment hole. You can use an M3 screw to help align the heatset. This should be flush with the bump.



1 M3 heatset goes into the lid but only after the Vertical Adjustment Support has been installed. This should be flush with the Vertical Adjustment Support.

Adjustment Locking Knob

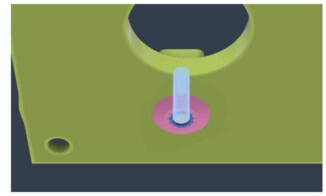
Parts needed:
2x M3 Hex Nut
2x Adjustment Locking Knob



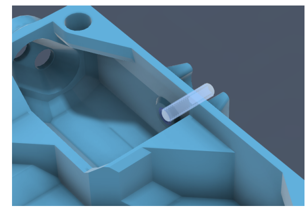
This one is pretty self-explanatory. All you need to do is put an M3 Hex Nut in the nut hole of each Adjustment Locking Knob. You may need to use a soldering iron similar to inserting a heatset, but it may also press fit in.

Screws

Parts needed:
2x M3x6mm Flat-Tip Set Screws
1x Lid
1x Body
1x Assembled Adjustment Locking Knob

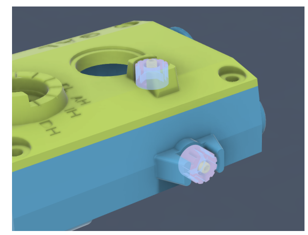


There are 4 M4x6mm Button Head Hex Screws which secure the Lid to the Body, but these should be installed towards the end of the build



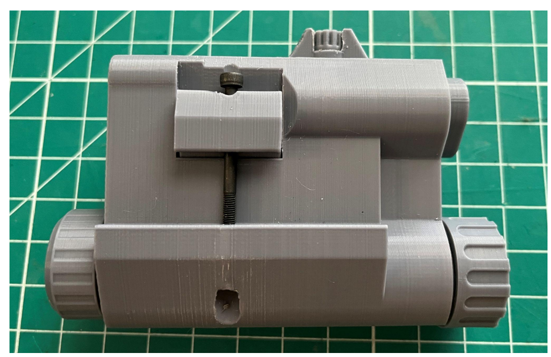
There are 2 M3x6mm Flat-Tip Set Screws which are used to adjust the windage and elevation of the lasers. These can simply be screwed in from the outside and left flush with the heatsets.

You may find that threading the screw from the inside for the first time will make threading the screw from the outside easier, as it cuts the thread pattern into the plastic between the heatset and the outside of the Body/Lid.



The Adjustment Locking Knobs can be screwed on over the protruding portion of the Set Screws. The purpose of the Adjustment Locking Knob is to protect the set screw and help lock the adjustment screw to prevent it from moving and losing zero.

Pic Rail Clamp



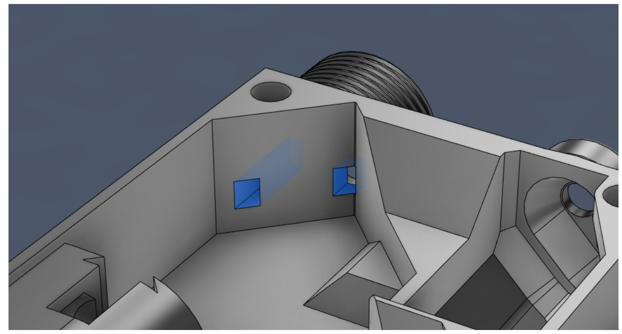
Parts needed:
1x M3x45mm Socket Head Screw
1x Pic Rail Clamp

The M3 screw should easily slip through the Pic Rail Clamp. If it doesn't, ream the hole with a 3mm drill bit. Now, screw the screw into the heatsink on the other side of the channel. ezpz

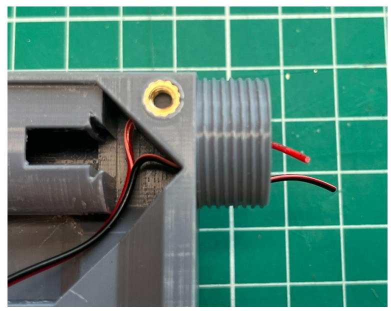
Wiring and Soldering

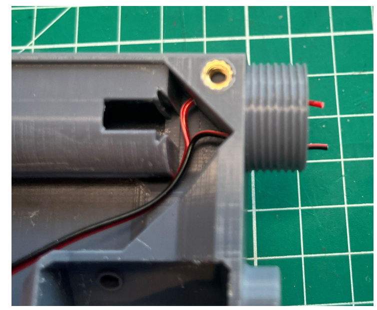
A quick tip, all of the square through-hole pins on the PCB are GND except the VIS Laser pin. See Figure 1.

Illuminator LED

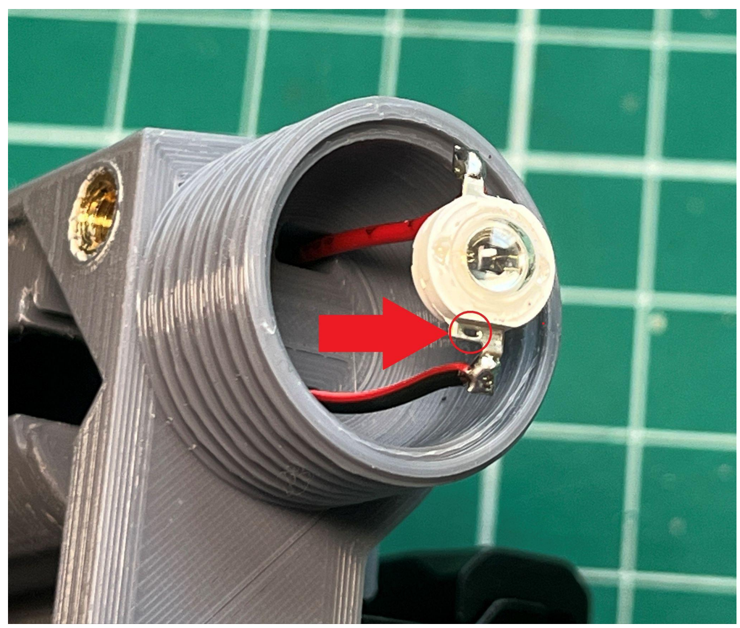


Parts needed:
1x Body
1x Lens Cap
1x 940nm or 850nm 3W LED
1x 20mm Lens for 3W LED
1x 4" length of paired 28 AWG wire
Soldering iron and solder
Wire strippers



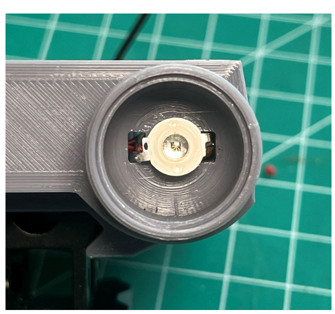


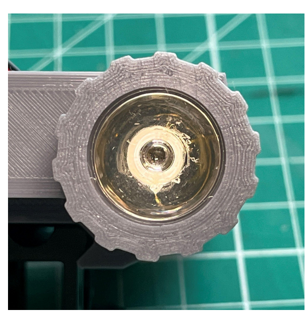
To assemble the Illuminator LED, first split about 1" of the paired wire. Feed a wire through each of the holes on the back face of the Illuminator LED housing. If using the 18650 Body, you may need to use tweezers to help guide the wires in as there is less space between the holes and the battery compartment.

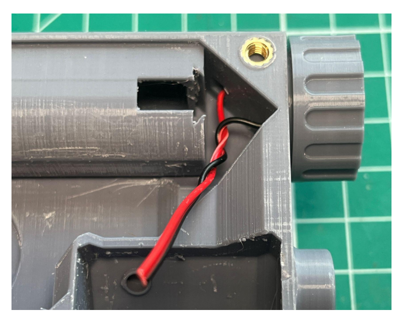


Once the wires are fed through, you can shorten whichever wire is longer, then strip and tin them. Using tweezers to hold the LED, solder the red wire to the positive leg and the black wire to the negative leg. The negative leg can be identified by the stamped minus symbol on the leg, circled in the picture to the right. Try to solder the wires so they are in line with the center of the LED, so they fit nicely in the holes. Bend the legs 90° towards the back of the LED and pull the wires from the back so the LED sits in place. I like to twist the separated wires to keep them neat. Place the 20mm lens in the lens housing and thread the Lens Cap on. The Lens Cap should press against the lens and hold the LED in place in the middle.

You can separate the other ends of the paired wire a small amount, strip, and tin them in preparation for final assembly.

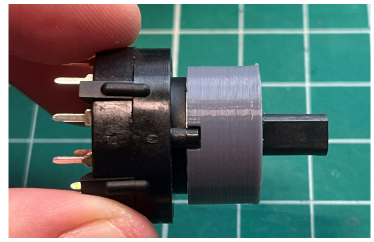


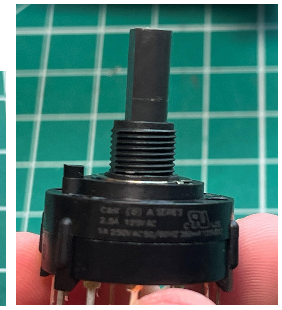




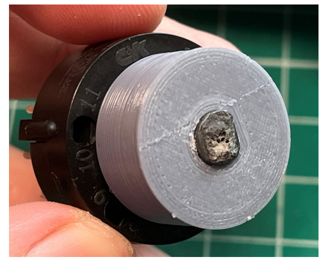
Rotary Switch

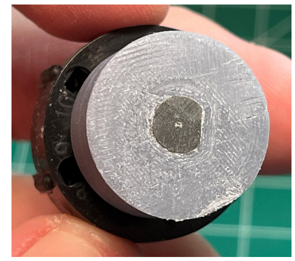
Parts needed:
1x GAL v2 PCB with SMD components soldered
1x Rotary Switch as described in the parts list section
1x Rotary Switch Jig
Wire cutters and a file/sandpaper
Soldering iron and solder



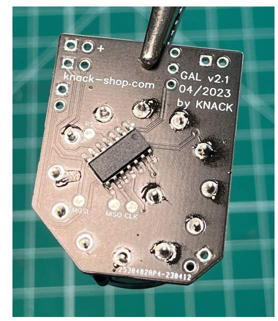


Without modification, the rotary switch's actuator would stick well beyond the top of the GAL, which would look weird. To fix this, you will need to shorten it. The Rotary Switch Jig helps with that. First, remove the nut and washer. Then, slide the jig over the actuator until it is seated at the bottom, rotating the actuator until the alignment pin lines up with the slot (should be all the way counterclockwise). Use a knife to scribe a line around the actuator, take the jig off, and make sure the line you scribed is about 3mm above the start of the actuator. Put the jig back on and then using strong wire cutters or a saw, shorten the actuator to the top of the jig. Use sandpaper or a flat file to shorten the actuator until it is flush with the jig.

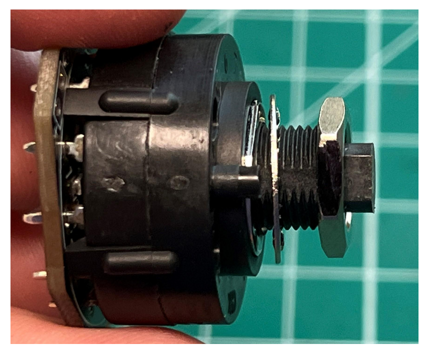




After your PCB is programmed, you will need to solder the Rotary Switch onto it. There is only one way the switch can fit into the PCB due to the 'A' pin. Make sure that the ATtiny is on the bottom.



Take this time to familiarize yourself with how the nut threads onto the rotary switch. Since the threads are plastic, they are ***VERY EASILY*** cross-threaded, especially when you are using needle nose pliers to install the nut, as you will have to when installing the switch into the Lid. What I have found helps is to mark the face that the threads start on. I do this by having the actuator all the way counterclockwise and threading the nut on by hand. There should be very little resistance when threading the nut on. If you feel any resistance, stop and unthread. A good way to find the start of any thread is to push the nut onto the threads while unscrewing the nut; you will feel a click when the threads are at the start. Once you've confirmed you've found where the threads start, mark the face of the nut that is parallel to the flat face of the actuator with a marker. Use this mark to help you when installing the switch into the Lid.



Battery

Parts needed:
1x Battery Cap
1x Body
1x US Nickel (or other 21mm disc/coin)
1x AAA Negative Battery Terminal (Spring)
1x AAA Positive Battery Terminal (only if your battery does not have a nipple on the positive terminal - e.g. most 18650s)
3.5" of 22 AWG Solid Core wire
3" of wire (26 or 28 AWG stranded is fine for this purpose)
Soldering iron and solder
A few dabs of superglue

Battery Positive Terminal

Nippleless-Batteries

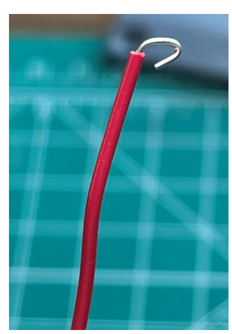
If your battery source does not have a nipple on the positive terminal, you will need to add one to the Nickel before installing it into the Battery Cap. If it does, you can skip the next section, although you may want to clean the gunk off your coin with sandpaper while the nippleless people read it.

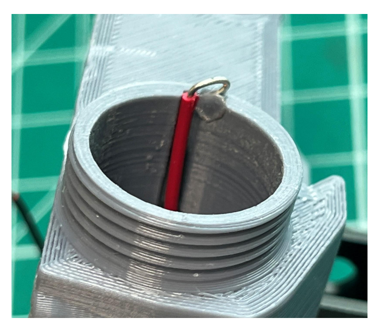
Since most coins are absolutely filthy, it may be necessary to scuff the surface with a file or sandpaper until you reach clean metal. You can cut the solder tab off if you want, but leaving it on doesn’t hurt anything. You will then need to solder the AAA Positive Terminal to the Nickel. The coin will be very hot, so helping hands or pliers will be necessary so you don’t burn yourself. Make sure the Positive Terminal is centered as well as you can get it. Make sure not to have any sharp blobs of solder on the face of the battery terminal that will mate with the 18650, as they might damage your battery. Just run your finger over the face of the terminal and if there are any sharp solder blobs, sand them off. Once the coin cools down, you can move on to the next step.

Battery Cap

Welcome back, nippled-battery-havers. With everyone’s coin clean, you can super glue your coin into the inside of the Battery Cap.

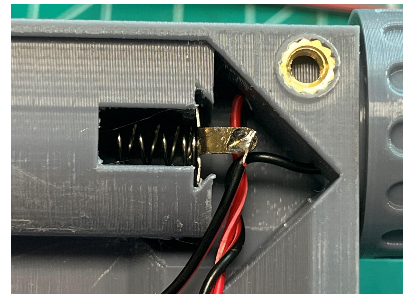
Battery Positive Wire





In order to get the positive connection to the PCB, we will need to run the 22 AWG Solid wire from the face of the battery threads to the inside of the Body. The reason for the solid wire is that we need to make a contact of sorts that will contact the Nickel in the Battery Cap which contacts the battery’s positive terminal, which is pushed into the Nickel by the AAA Negative Terminal’s spring. To do this, strip about 1cm of the wire and use some small pliers to fold the stripped end of the wire into a shepherd's hook of sorts, which prevents the wire from falling into the hole and provides the contact as listed above. Shove the wire through the wire hole and feed it out the other side into the middle of the body. I like to press the shepherd’s hook into the plastic a bit with a soldering iron so it stays put. You can also make a kink right where the wire exits the wire hole for the same reason.

Battery Negative Terminal



Now we are going to install the AAA Negative Battery Terminal. Using a pair of needle nose pliers, firmly press the Negative Terminal into the slot at the end of the battery hole. Make sure the solder tab is facing up. Once it is fully seated in the slot (ensure by looking from the opening of the battery hole; the spring should be centered), bend the solder tab away from the battery compartment. Solder the 3" length of wire to the solder tab. This will be your GND Wire.

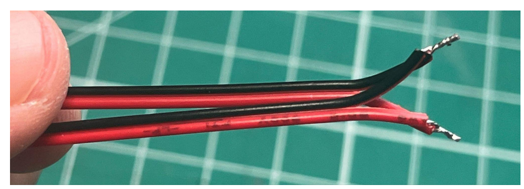
Testing

Now is a good time to test that your battery compartment works as intended. Insert your battery with the negative terminal going in first (so the positive terminal is towards the back) and screw the Battery Cap on. Use a multimeter on the two wires and check that you read a voltage. If you don’t, the most likely culprit is that the shepherd's hook isn’t touching the nickel. The easiest way to fix that is to make the shepherd’s hook larger so it sticks up more. Once you read a voltage across the two wires, unscrew the Battery Cap and remove the battery.

External Activation

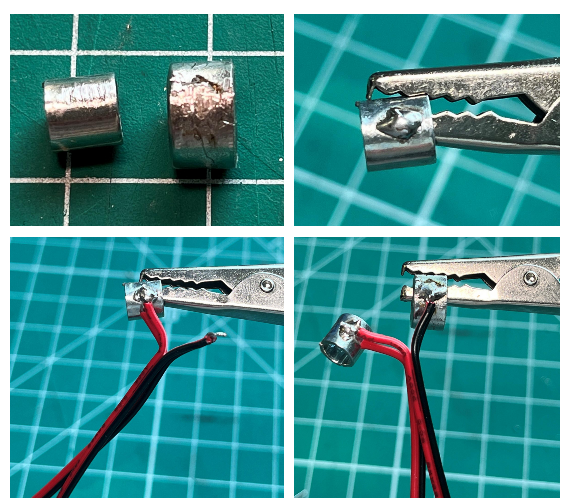
Parts needed:
1x 3.5" length of paired 28 AWG wire
1x 2.5" length of paired 28 AWG wire
Soldering iron and solder

Wires



Split an end of each length of wire, about a ½" down. Strip a ¼" off each wire. Twist the black and black wires together and solder them; repeat with the red wires. This junction will go to whatever external activation method you choose. The shorter length of wire will go to the two pins on the PCB labeled ‘Button’. The longer length of wire will go to the Internal Activation Button. Since the activation method is just a switch to ground, which wire goes to which pin/spacer doesn’t matter.

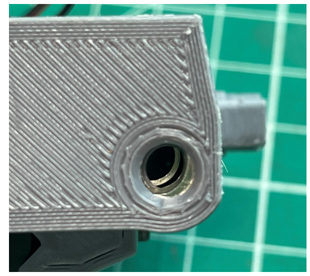
Crane Connector

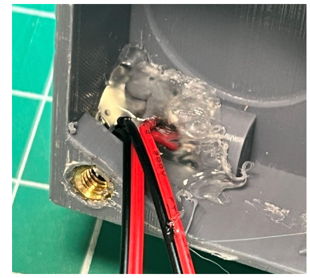


Parts needed:
1x 6.1mm ID Unthreaded Spacer
1x 0.198" ID Unthreaded Spacer
Soldering iron and solder

Since there isn’t a female Crane connector (at least that I could find), we have to make our own. Using two different ID metal spacers, we have a cheap and reliable solution. To create the connector, all we need to do is solder the wires we created in the last section to the two spacers. The smaller ID spacer will be towards the front (if looking at the slots where the spacers will go, the smaller will be on the left). The spacers don’t seem to like getting soldered to, so I’ve found that roughing them up a bit with a file helps. But essentially all you have to do is solder the pair of wires to the two spacers.

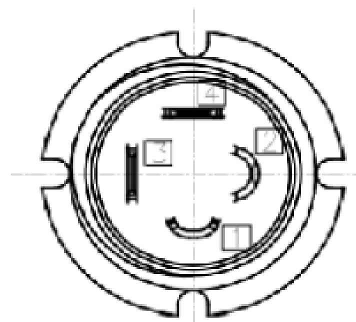
There is no retention (or water-tightness) for the spacers when they're in the body, so I like to use either epoxy, hot glue, or melted filament (via my soldering iron) to lock them in place. When locking them into place, make sure they are fully seated in the slots. You can check this by looking through the back hole and making sure you don't see any metal (the picture to the right shows an example of incorrect alignment). You can also make sure they are fully seated by inserting your Crane-style switch, but this could lock your switch in place if using a thin enough epoxy.





After installation, ensure the connector works with your Crane switch with a multimeter set on continuity. There should be a short between the two spacers when the switch is pressed, and not when it is not.

2.5mm DC Jack Pinout

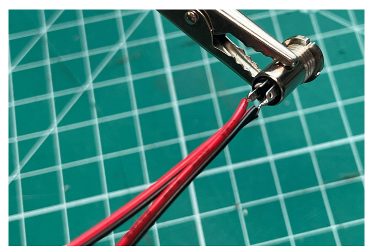


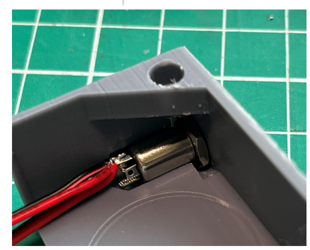
2.5mm Jack

Parts needed:
1x 2.5mm Jack with included 8mm nut
Soldering iron and solder

Solder one wire to pin 2 on the jack and the other wire to any of the other pins. Just to be safe, you can solder only to the curved pins on the jack (pins 1 and 2).

Once the wires are soldered, you can install the jack into the body. First, place the nut on the inside of the body, feed the wires and jack through the outside, and tighten the jack with a pair of pliers. You will need to spin the jack as the nut shouldn't be able to rotate.





Laser Assembly

Parts needed:
1x 850nm 6x23mm TTL Driven Laser
1x 650nm 6x23mm TTL Driven Laser
1x Laser base
1x Laser Housing
1x AAA Negative Battery Terminal
1x 0.5" x 0.148" OD Compression Spring
Soldering iron and solder
Super glue
Hot Glue

Assembling the Laser Assembly

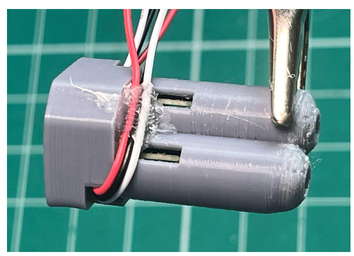
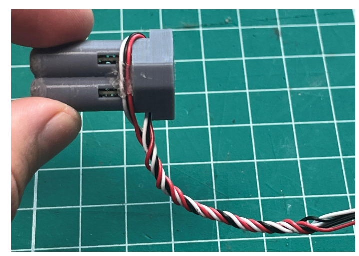
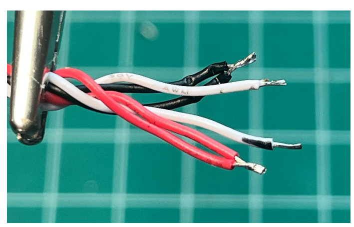
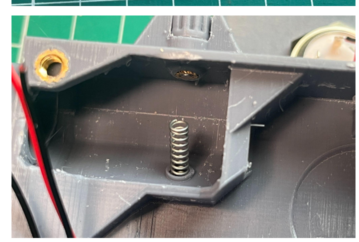
First, take this time to mark the white wire of the VIS laser with a marker so you can easily differentiate them later. The easiest way to tell the difference between the IR and VIS laser is that the IR laser's lens has a blue tint whereas the VIS laser's does not. When shortening the wires later on, remember to remark the white wire.

When buying the lasers from the linked seller, you can purchase a non-adjustable version, which you will tell them the focal distance, or you can buy the adjustable version and do it yourself. To set the focal distance of the VIS laser, you will need some sort of 3-5V power supply (any lithium battery will work). On these TTL-driven lasers, there are 3 wires. Black is ground, red is positive voltage, and white is the signal wire. When given a PWM signal to the white wire, the laser will run at a perceived lower power (equal to the duty cycle of the PWM signal). But back to setting the focal distance, while the laser is pointed not at your face, connect the red and white wires to the positive supply voltage and the black wire to ground. Now, loosen or tighten the front lens portion of the brass body until you've found the best focal distance for you; use a very small dab of super glue to lock it in place. Be careful not to use too much as it might inhibit inserting the laser into the Laser Housing.

The IR Laser's focal distance can be set using the same method as above but with something that can see IR light.

Once the focal distances are set, use side cutters or scissors to remove the heatshrink from each laser. Be careful not to damage the electronics underneath the heatshrink. Insert the two lasers into the Laser Housing, making sure they are fully seated. I like to put the side of the PCB that the wires are soldered to towards the opening in the Laser Housing. If they don't go all the way in (the PCB should be flush with or below the opening), make sure there isn't anything from the printing process blocking them. Once they are fully seated, bend the wires 90° so they are sitting in the openings in the Laser Housing. Then drop a dab of hot glue on the back of each laser PCB and press the Laser Base onto the Laser Housing.

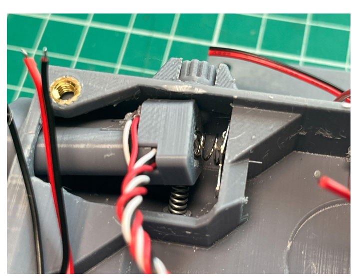
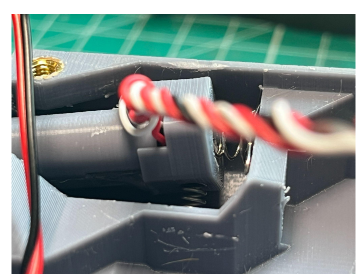
Take the set of wires from the left laser (if looking from the emitter side with the Laser Base's hump on top) and cross them over the top to join them with the right laser's wires. A dab of hot glue in the corners between the Laser Base and Laser Housing helps keep everything tight.

Twist the 6 wires together for about 2". Cut the wires about 1⁄2" after the twist ends. Strip the two white wires just enough to tin them, about ⅛". Strip the black and red wires ¼" so that you can twist them together before soldering, black to black and red to red, obviously. Solder the two pairs and shorten them to about ⅛".

Installing the Laser Assembly

Before starting, make sure the horizontal adjustment screw is at least flush with the heatset. If it is protruding, it will be much more difficult to install the Laser Assembly. Start by placing the compression spring into its hole. Then place the Laser Assembly into its area. You will need to compress the spring a bit with tweezers while making sure the emitter side of the laser is nestled into the chamfered slot towards the front of the Body, where the two holes are.

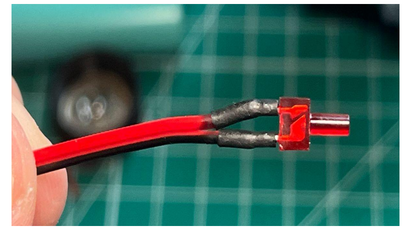



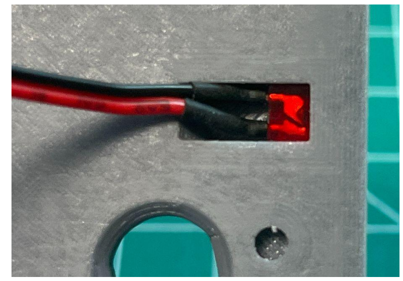
Once the compression spring is in the hole on the Laser Base, install the AAA Negative Battery Terminal behind the Laser Base so the spring sits in the hole.

Indicator LED

Parts needed:
1x Red Diffused Flat Top LED
3" length of paired 28 AWG wire
Soldering iron and solder
Thin heatshrink

Split an end of the length of wire about ½". Strip and tin around ⅛" of that. Take note of the polarity of the LED; the longer leg is the anode (positive lead). Shorten the legs of the LED with wire cutters to around a ¼". If you forgot which leg is which after cutting them to the same length, the leg attached to the smaller of the two pieces of metal inside the plastic is the positive leg. Before soldering the wires to the LED, put two small pieces of heatshrink on each wire. Tin the LED legs and then solder the red wire to the positive leg and the black wire to the negative leg. After letting the solder joints cool, pull the heatshrink over the solder joint and use a lighter or your soldering iron to shrink it. Slide the LED into the slot on the underside of the Lid and lock it in with a dab of hot glue.



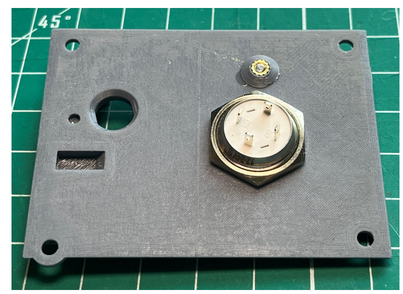


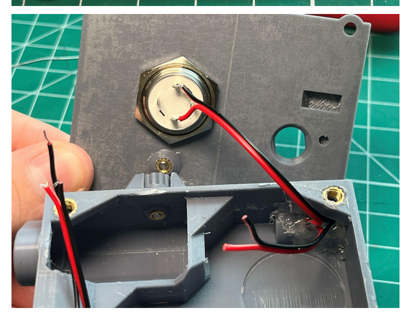
Internal Activation Button

Parts needed:
1x 19mm Momentary Press Button
1x Lid
Soldering iron and solder

Remove the nut from the button and install it on the Lid. You can leave the O-ring on, but it looks better when removed and should be still water-resistant since it is a tight fit. Pliers are helpful when tightening the nut.

The button listed in the parts kit includes an LED onboard, but we won't be using that. Split, strip, and tin the longer of the two wires from the External Activation section and solder them to the 'NO' (Normally Open) pins on the button.

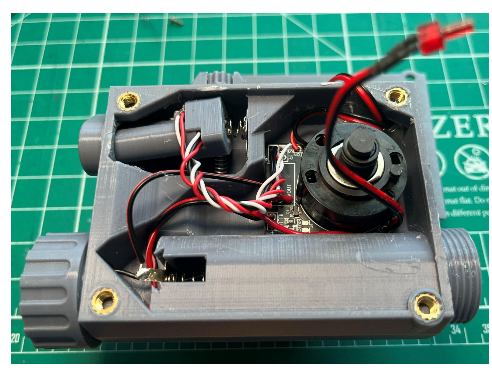




PCB

Parts needed:
Soldering iron and solder

It's finally time to wire up the PCB. This part is fairly straightforward - solder the wires to their respective pins on the PCB. Having helping hands to hold the PCB makes things much easier, but they are not necessary. I found that holding the PCB so that the Rotary Switch shaft is pointing the same way as the lasers helps since you can put the wires in the pin holes on the top (front) and solder from the bottom (back).



A pinout diagram for the PCB can be found in Figure 2. For the next section, I will assume that GND is the black wire and VCC is the red wire unless otherwise stated. A basic rundown of connections is:

- Illuminator wires
  - GND to square pin in ‘ILLUM’ area
  - VCC to circle pin in ‘ILLUM’ area (next to ‘+’)
- Laser wires
  - GND to square pin in unmarked area next to ‘VIS IR’ area
  - VCC to circle pin in unmarked area next to ‘VIS IR’ area (next ‘+’ on back side)
  - VIS TTL (white) wire to square pin in ‘VIS IR’ area (under ‘VIS’)
  - IR TTL (white) wire to circle pin in ‘VIS IR’ area (under ‘IR’)
- Activation wires
  - Either wire to either pin in ‘BUTTON’ area
- Indicator LED wires
  - GND wire to square pin in ‘LED’ area
  - VCC wire to circle pin in ‘LED’ area (next to ‘+’)
- Power wires (from battery)
  - GND wire to ‘GND’ pin
  - VCC wire to ‘VOUT’ pin
    - This area was originally for a Pololu 5V buck regulator but was removed when the design was switched from two lithium batteries (6~8V) to one lithium battery (3~4V)

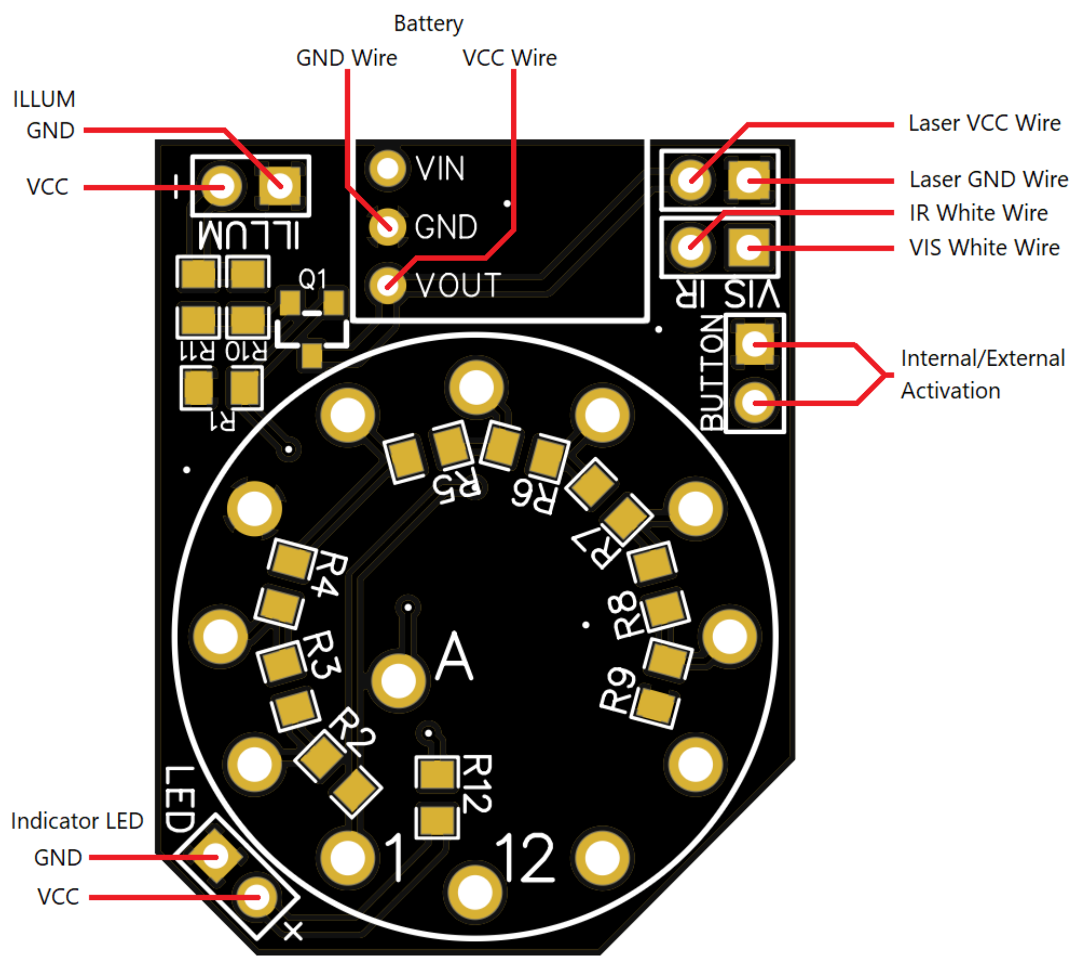


Figure 2
Pinout diagram of the Gal v2.1 PCB

Putting It All Together

Testing

I know, you thought we were done. I'm sorry. But before you close everything up, you should test to make sure everything works as intended. There's a chance you assembled or soldered something incorrectly and rather than find that out later, we'll do that now. When testing, I like to have the Rotary Switch in the furthest counterclockwise position (VIS High). Insert your battery and screw on the Battery Cap. If you've done everything right, nothing should happen.

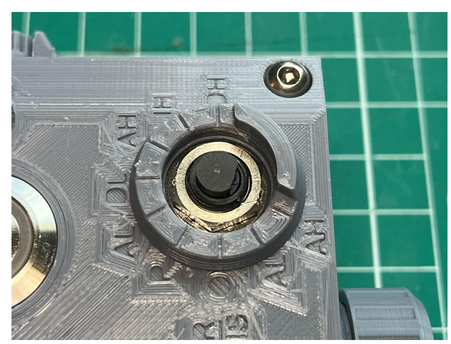
With the device pointed at something that isn't your face, press the Internal Activation Button. The red laser should shine and the Indicator LED should light up. If it does, great! If it doesn't, go to the 'Troubleshooting' section.

Next, move the selector knob one position clockwise (VIS Low). Press the button; the red laser should shine but dimmer and the Indicator LED should light up. Any time you activate the device, the Indicator LED should light up, so, going forward, if it doesn't, something is wrong.

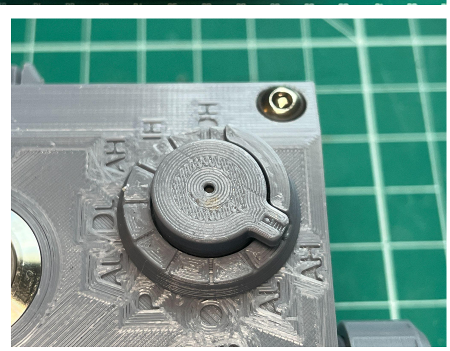
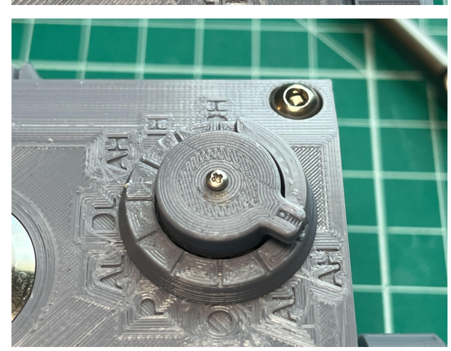
Using the chart in the 'What Happens When I Press the Button?' section, go through each setting and test the functionality. If any problems arise, go to the 'Troubleshooting' section.

Finally putting it together

Parts needed:
4x M4x6mm Button Head Hex Drive Screw
1x Number 0, 3/16 Long Screw
1x Selector Knob
1x Pic Rail Clamp
1x M3x45mm Socket Head Screw
Needle nose pliers
PH00 screwdriver



Ok, now it's finally time to finish this up. The lid should press fit over the Rotary Switch quite snugly. You should then be able to screw the 4 M4 screws through the Lid into the Body.

Place the Rotary Switch's washer on it and then use the needle nose pliers to thread on the nut. Remember the mark we made on the nut to help start the threads. Also remember that it is very easy to cross-thread this nut, so take your time. Once the nut is on, press the Selector Knob on and using the PH00 screwdriver, screw the #0 screw into the top of the shaft. Congrats, you now have your own GAL!

What Happens When I Press the Button?

Great question. That depends on what mode the device is set to. Regardless of the mode, the Indicator LED should light. If it does not light when you press the button, something is wrong. It could be a power issue, wiring issue, or programming issue (I would check in that order). But that's for the troubleshooting section. Assuming your GAL is activated and your Indicator LED is on, we can turn our attention to the Selector Knob.

There are 9 modes the GAL can be in:

- VIS AIM HIGH
    - Denoted as AH in the VIS section
    - Full brightness 650nm (Red) Laser
- VIS AIM LOW
    - Denoted as AL in the VIS section
    - 20% brightness 650nm (Red) Laser
- OFF
    - Denoted as O
    - Does nothing, but uses a small amount of juice when the device is activated
    - Prevents NDs when not in use, I guess
- PROGRAM
    - Denoted as P
    - Used to program Illuminator Flash Speed
    - First, the Indicator LED will flash twice
    - After 5 seconds, the device will time out and return to 'standby' mode
    - During that 5 seconds, you can turn the Selector Knob to different modes to choose your desired flash speed (seen in the table below)
        - Once you have turned the Selector Knob to the mode that corresponds with your desired flash speed, release the button
        - The Indicator LED will blink a number of times per second corresponding to the Flash Speed
            - e.g. 4 flashes per second, the Indicator LED will blink 4 times
    - Change the mode to DL, AL, IH, or DH and the illuminator will flash at the selected rate
    - To return to a constant illumination (i.e. 0 flashes per second), move the Selector Knob to P, activate the device, and deactivate the device

Mode	PROGRAM (P)	DUAL LOW (DL)	AIM HIGH (AH)	ILLUM HIGH (IH)	DUAL HIGH (DH)
Flashes/sec	0	1	2	4	8

- AIM LOW
    - Denoted as AL in the IR section
    - 20% brightness 850nm (IR) Laser
- DUAL LOW
    - Denoted as DL in the IR section
    - 20% brightness 850nm (IR) Laser
    - 20% brightness 850/940nm LED
- AIM HIGH
    - Denoted as AH in the IR section
    - Full brightness 850nm (IR) Laser

- ILLUM HIGH
    - Denoted as IH in the IR section
    - Full brightness 850/940nm LED
- DUAL HIGH
    - Denoted as DH in the IR section
    - Full brightness 850nm (IR) Laser
    - Full brightness 850/940nm LED

You can also double-tap for ‘hold on’ in whatever mode the selector is set to.

If the device is activated for a continuous 5 minutes (by double tap, manual, or accidental activation), it will automatically deactivate the device until the next button press.

A Few Things to Note

Why Are The Lasers Only 5mW?

Firstly, I don’t have a way to test the power of the lasers, but the VIS laser is much brighter than your average cat toy and the IR laser can be seen under PVS69s hundreds of yards away.

Secondly, I don’t really like Chinese deathbeam lasers. I’ve seen enough StyroPyro videos to know not to mess with them. “But KNACK, I can’t see my VIS laser 100 meters away in direct sunlight!” Good, now you won’t commit war crimes by giving the 14-year-old kid on the other team Lasik. The beauty of open source is that if you reaaaaallly want to blind yourself looking at your cool new GAL in the mirror, you certainly can go for it.

Water-Tightening

Lid to Body

While I haven’t personally done it, a bead of silicone caulk around the edge of the Lid would create a better seal than nothing. This is still to be explored.

Laser/Crane-style female plug

Since the Crane-style female connector is handmade, it will not be watertight, which could be a problem since it is a large hole in the side of the body. Even with the male connector inserted, water could still make its way into the housing through the port, so this is probably the most important spot to water-tighten. In the installation instructions, I showed how I use hot glue to cover up the spacers used as the female connector. This could also be done with epoxy.

Rotary Switch Hole

The rotary switch fits pretty tightly in the hole, so it should be fairly water-tight, but you could also drop a bead of silicone before installing the nut, or even after, so long as it doesn’t interfere with the Selector Knob’s movement.

Laser Adjustment Holes

These are also a pretty tight fit and should be fairly water-resistant.

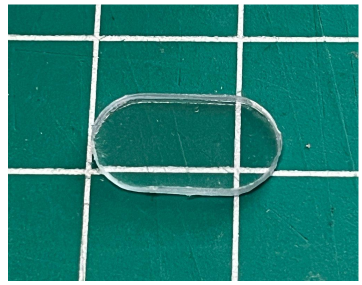
Battery and Lens Caps

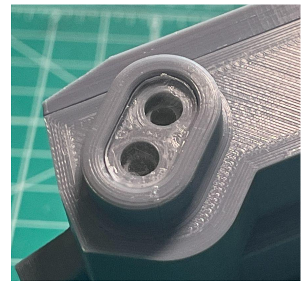
These are also a pretty tight fit and should be fairly water-resistant. Silicone grease on the threads might help. This is still to be explored.

Laser Hole Cover

Parts needed:
1x Laser Cover Hole
Super glue

This step is mostly for water-tightening your GAL. Since there are two open holes for the lasers to emit from, water could make its way into the body. To prevent this, as well as dust and debris, a clear cover should be installed.





You should know that the Laser Hole Cover that comes in the parts kit does create a small amount of speckle in the laser dot. Before gluing the cover onto the body, place the cover into the slot on the Body and (while not pointing it at your face), activate the device. If you like the way the laser looks through the cover, then you can use it. If not, leave it off. I've found that the IR laser is affected less than the VIS laser.

If you decide to install the Laser Hole Cover, first, clean the cover with glasses cleaner and a microfiber cloth to make sure there aren't any marks. Then apply a ***very*** thin bead of super glue around the edge. If you can apply the glue on just the edge, that is ideal. Less is more in this instance because the cover is a pain to remove once glued in and if the glue spreads over where the laser shines through, it will distort the beam. Simply press the cover into place.

Current Draw and Battery Life

If a battery is connected, the device will automatically go into 'standby' mode. While in 'standby' mode, the device will draw current (listed below for the given battery voltages) until the battery is disconnected or dead. At that current, it may take a while but it will happen eventually (2500mAh at 1.8mA is only 1388 hours and 52 minutes). It's best to loosen the battery cap a smidge, click the button to ensure the indicator light doesn't light, and then go about your day. Or just remove the battery when not in use.

Mode	Current @ 4V (mA) (18650 Battery)	Current @ 3V (mA) (CR123 Battery)
Standby	1.8	1.4
VIS High	24.4	25.8
VIS Low	10.4	8.8
Off	6.5	4.6
Program	6.5	4.5
IR Aim Low	9.2	7.3

IR Dual Low	63.5	35.4
IR Aim High	19.1	18.2
Illum High	280.3	151.2
IR Dual High	290.2	162.1

Troubleshooting

My GAL isn't doing anything

When testing the functionality of the GAL, I like to work in the VIS Aim Low mode, so I don't have to work with NVGs on. Your goal is to see the laser (don't point it at your face please) when you press the button. You should also see the Indicator LED when you press the button.
When doing any checks after step 3, disconnect your battery to prevent shorts. Obviously, don't forget to reconnect it when testing if the device is working after any changes are made.

1. Check that your battery is installed correctly (there isn't any reverse voltage protection, so you might be boned if it isn't). The negative terminal should always go in first, as denoted on the lid.
2. Check that your battery isn't dead. The GAL operates between 3-5V, so make sure you're in that range.
3. With the Lid off, use a multimeter to check that your PCB is getting the voltage by probing the VOUT and GND pins on the v2.1 boards. If not and you passed steps 1 and 2, then your wiring is likely at fault.
4. Check that your button/external activator is actually shorting when pressed using the continuity setting on your multimeter. Check at the 'Button' pins on the PCB as well.
5. Check that your Rotary Switch is soldered properly. You can also check that the switch is working properly by testing the continuity between the pins.
6. Check that your lasers and LEDs are soldered properly. The Indicator LED will not light if installed backwards (just diode things). The same goes for the Illum LED and the lasers.
7. If you've reached this state, your issue is most likely with the ATtiny84. Your best bet is to redo the Programming the ATtiny84 steps.
8. At this point, something terrible has happened. Feel free to reach out for help.

You can reach me by (in the preferred order):
- Discord (knack_tactical)
- Opening an issue on GitHub
- email (knack.tactical@gmail.com)
- Reddit (u/knack_tactical)

Changelog

10/02/2023	Initial Release