Xport Robot Controller User Guide

Version 1.1, August 13, 2004

Introduction

The Xport Robot Controller (XRC) consists of both the Xport and the Robot Board. **Figure 1** below details the Robot Board and its components.

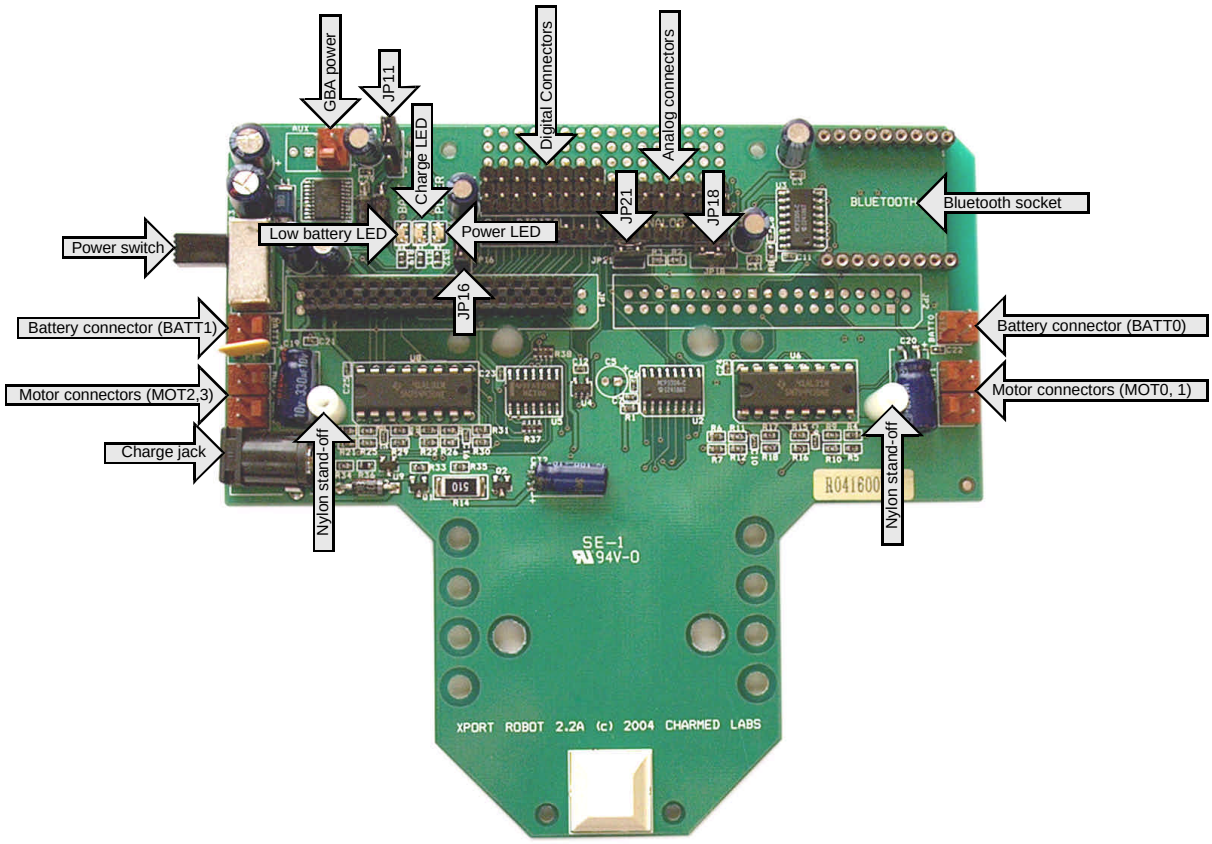

Figure 1: XRC Robot Board

Power switch	Turns the XRC on and off.
GBA power	Used to power the Game Boy via the XRC's batteries.
Power LED	Green LED that when illuminated indicates XRC is on.
Charge LED	Yellow LED that when illuminated indicates the batteries are charging.
Low battery LED	Red LED that when illuminated indicates low battery.
Digital sensor connectors	8 connectors with two digital I/O signals and power per connector.
Analog sensor connectors	8 connectors with one 12-bit analog input and power per connector.
Bluetooth socket	Socket for Class 1 Bluetooth module
Battery connectors	"BATT0" and "BATT1" connectors where 3-AA battery packs plug in.
Motor connectors	"MOT0", "MOT1", "MOT2", and "MOT3" connectors for controlling motors.

Charge jack	Connector for plugging in wall supply charger
JP11	GBA power select. Jump pins 1 and 2 to select GBA SP; jump pins 2 and 3 (default) to select regular GBA. See the section entitled *Powering the GBA.*
JP16	Selects power to all 8 digital sensor connectors. Jump pins 1 and 2 to select 5V; jump pins 2 and 3 (default) to select 3.3V. See the section entitled *Sensor Connectors*.
JP18	Selects power to all 8 analog sensor connectors. Jump pins 1 and 2 to select 5V (default); jump pins 2 and 3 to select 3.3V. See the section entitled *Sensor Connectors.*
JP21	Installing this jumper (default) enables battery monitor circuit.
Nylon stand-offs	Used to attach Xport to Robot Board.

Quickstart

The steps below will guide you through the Xport Robot Controller (XRC) setup process as well as getting a simple robotics example running. You will need the following:

- ✓ PC running Windows 9x/Me/NT/2000/XP with a parallel port, 400 Mbytes of available hard drive space and administrator privileges
- ✓ Xport software installation CD
- ✓ Xport 2.0 (included in XRC Starter Kit)
- ✓ Parallel Port Interface and 10-pin ribbon cable (also included in the XRC Starter Kit)
- ✓ Game Boy Advance (GBA) or GBA SP
- ✓ 6 NiMH or NiCd AA batteries
- ✓ Small phillips screwdriver
- ✓ Needle-nose pliers
- ✓ Wire cutters
- ✓ Wire stripper for 22 AWG wire

1. *If you ordered the XRC Starter Kit, the Xport and Robot Board are ready for use, and you can begin at step 3.* If you already have an Xport, plug the Robot Board into the Xport as shown in **Figure 2**.

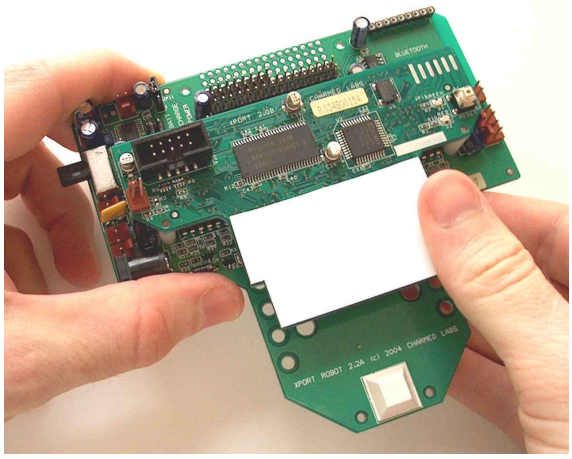

Figure 2: Attaching Xport to Robot Board

2. When the robot board is fully engaged with the Xport, it will rest upon the white nylon stand-offs (**Figure 1**) on the Robot Board. Using a small phillips screwdriver and two small 2-56 fasteners, which come in a separate bag, secure the Xport to the Robot Board as shown in **Figure 3**. Note, it is possible to plug in the Robot Board such that it is shifted 0.100". If you notice that the holes in the Xport do not line up with the holes in the nylon stand-offs, this is probably the reason. Try unplugging the Robot Board and trying to reposition.

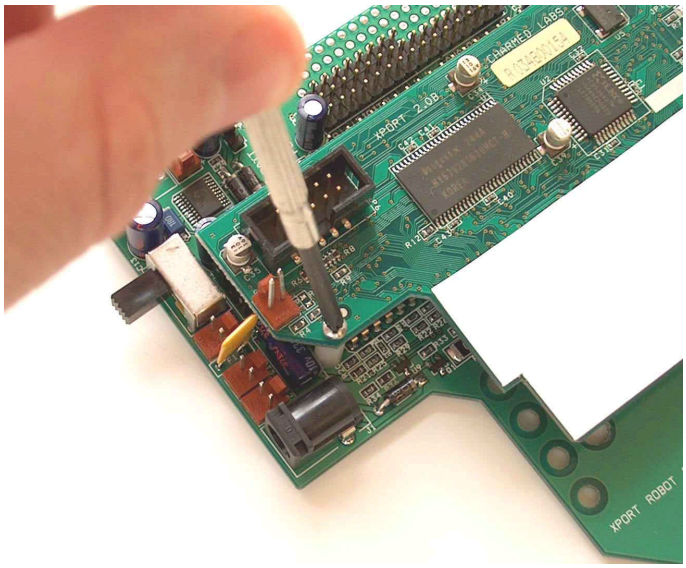

Figure 3: Secure Xport to Robot Board

3. Insert 3 AA batteries (NiMH or NiCd) into each battery holder.

4. Connect the battery holders to the Robot Board connectors that are labeled "BATT0" and "BATT1" as shown in **Figure 4**.

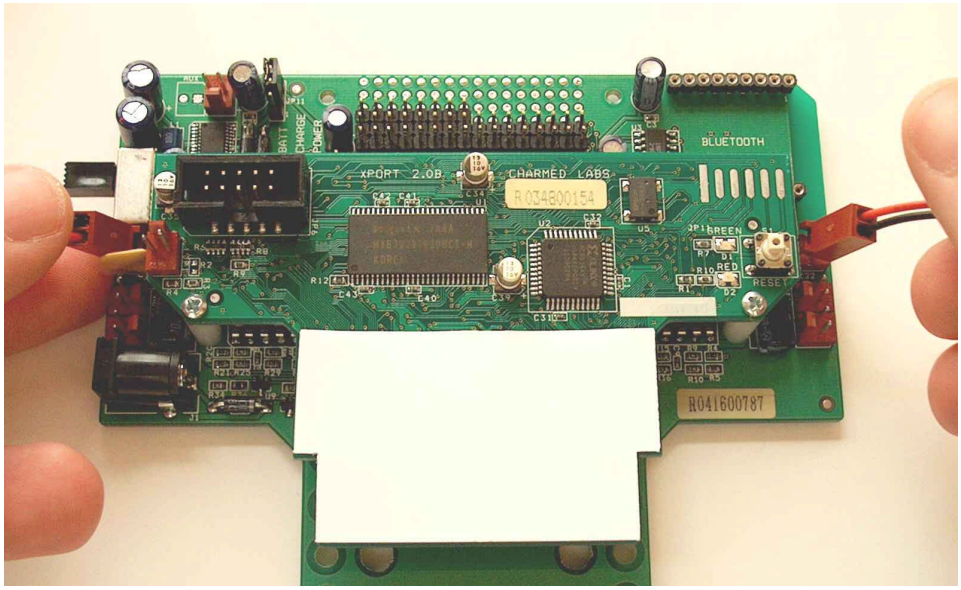

Figure 4: Connect battery holders to Robot Board

5. You can now test the power switch. Pushing it forward (toward the front of the Robot Board) will turn the XRC on, pushing it back will turn it off. When the XRC is on, you will see the green power LED illuminate.

6. For the example program, you will need to connect two motors, preferably LEGO motors, to the XRC. In order to do this, you will need to modify the LEGO wires to work with the XRC. LEGO wires have two LEGO "connectors," one at each end. With a pair of wire cutters, cut off one end of the LEGO wire, leaving plenty of wire on the other end. If the LEGO wire is sufficiently long, you may want to cut the wire in half, leaving plenty of wire on both ends. (Note, you can purchase LEGO wires through Pitsco (http://www.plestore.com/) if you wish to keep a complete set of wires to use with the LEGO RCX controller.)

7. Take one of the wires, and strip about 1/8" of insulation off each conductor.

8. With a pair of needle-nose pliers, crimp a connector pin to each conductor as shown in **Figure 5**. Note, the pin has two crimp areas: one for the conductor and one for the insulation. Be sure to crimp both areas, but the conductor area should be crimped especially tight.

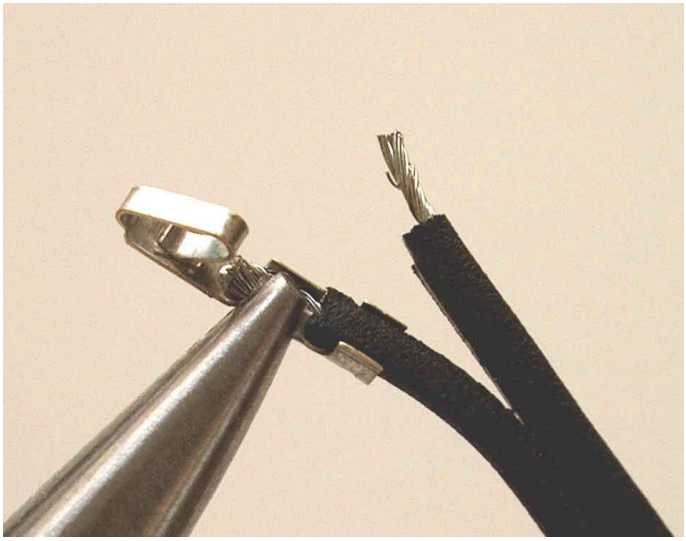

Figure 5: Crimp pin to stripped LEGO wire

9. Insert the pins into the connector housing following the orientation shown in **Figure 6**. Be sure to insert the pins fully. You may have to push them into place with a small screwdriver. The finished connector will look similar to **Figure 7**. Note the "flanges" poking through the two rectangular holes in the connector.

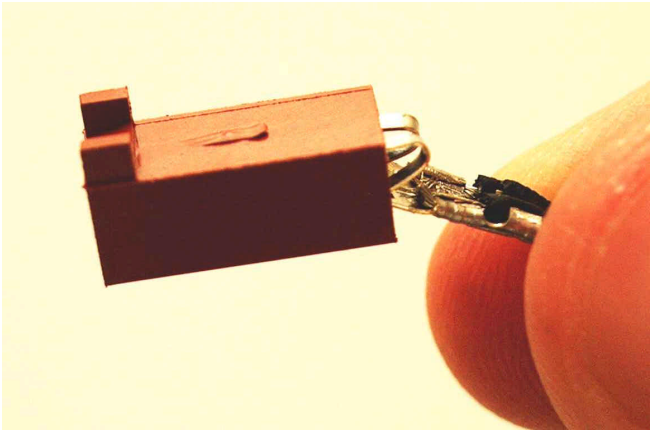

Figure 6: Insert pins into housing

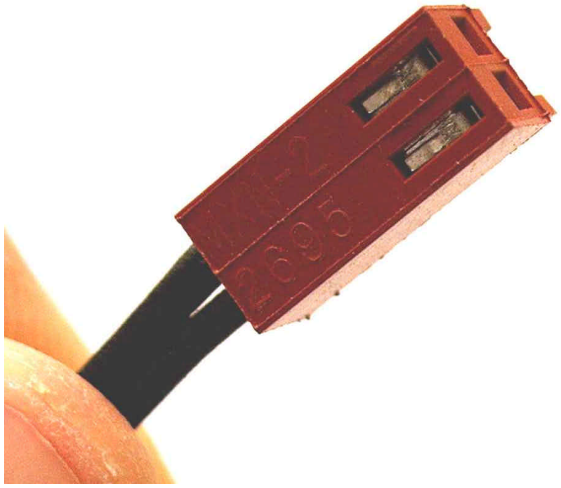

Figure 7: Completed connector

10. Repeat this process for another LEGO wire. It is a good idea to pay attention to polarity when making these wires. Mostly, you want both wires to have the same polarity, so they can be interchangeable.

11. With the two modified wires, connect two LEGO motors to the "MOT0" and "MOT1" connectors on the Robot Board as shown in **Figure 8**.

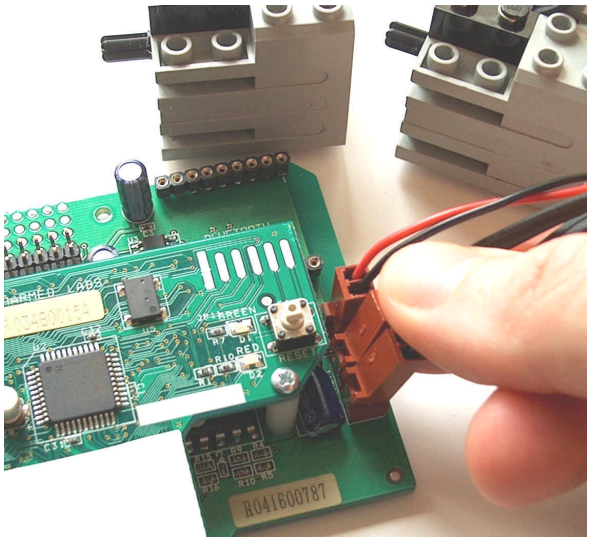

Figure 8: Insert motor connectors into "MOT0" and "MOT1" connectors on Robot Board

12. Plug the XRC into your Game Boy Advance. **Figures 9** and **10** show the XRC before and after it is fully engaged.

Figure 9: Plug XRC into GBA

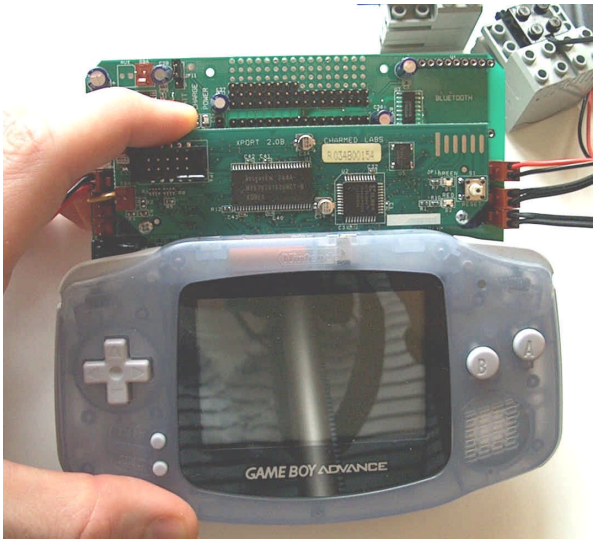

Figure 10: Fully engaged

13. *If you purchased the XRC Starter Kit, your XRC is pre-programmed with the example code and ready to run. Go ahead and skip to step 18, but return to this step later to install the software release. And if you have already installed the software release, you may skip this step and proceed to step 14.*
    Insert the Xport Software CD into your PC's CD-ROM drive and run "setup.exe". This will install the Xport utilities, Cygwin, GCC, eCos, source code and examples for the XRC.

14. Plug the Parallel Port Interface into your PC's parallel port.

15. With the GBA and XRC powered off, plug one end of the 10-pin ribbon cable into the Parallel Port Interface and the other end into the Xport's Cport. Refer to **Figures 11** and **12**.

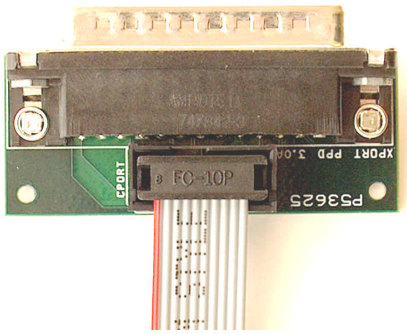

Figure 11: Plug Cport cable into Parallel Port Interface

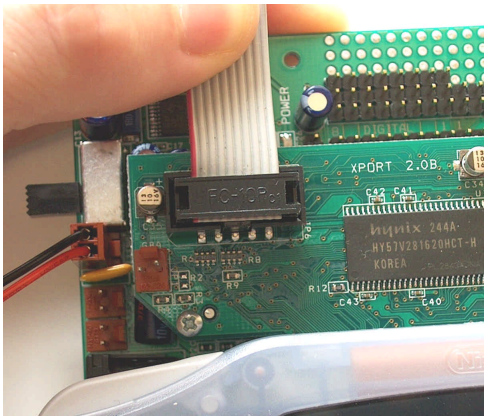

Figure 12: Plug Cport cable into Xport

16. Bring up the "Xport shell". This can either be found on the desktop or through the Start menu (Start→Programs→Xport). Change directories by typing "cd examples/xrc/robot1/haptic".

17. Run “make upload”. This will configure the Xport logic and flash, but before it does so, it will ask you to toggle the GBA power switch. Toggling the power is necessary before any programming operation.

18. Turn the XRC on and then turn the GBA on. After the GBA initializes, try turning the motor that is connected to the “MOT0” connector on the Robot Board. When you turn this motor, the other motor should turn as well.

If everything worked as described, your XRC is tested and ready for use and development. You may want to attach the battery holders to the Robot Board as described in the next section. Also note, there are several examples you may try in the ~/examples/xrc/robot1 directory. Simply type “make upload” as you did in step 17 to give each a try.

Battery Holder Attachment

Each of the two battery holders has four holes with LEGO-compatible spacing. This allows the battery holders to be placed on your robot in a variety of places where they can provide the best weight distribution, for example. However, for convenience the battery holders are often placed on the bottom of the Robot Board.

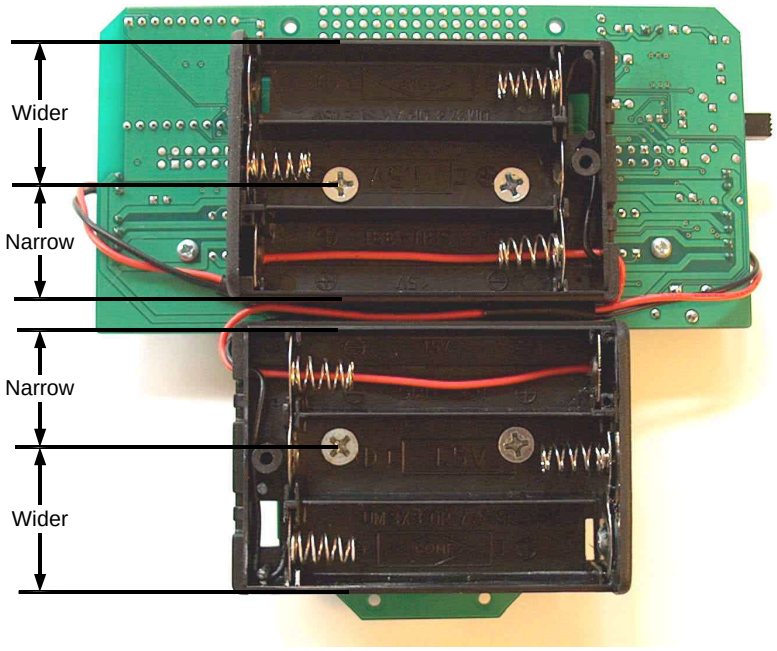

Figure 13: Battery holders mounted on the bottom of the Robot Board

Notice that each of the battery holders comes apart into two pieces: a sliding cover and the holder section. It is recommended that you attach the holder section to the Robot Board as shown in **Figure 13**. Note that the battery holders’ holes are slightly off-center. In order to get the battery holder holes to line-up with the Robot Board’s holes, the holders must be oriented with the “narrow” and “wider” dimensions of the battery holders as shown in **Figure 13**. When mounted, there should be a small gap between battery holders.

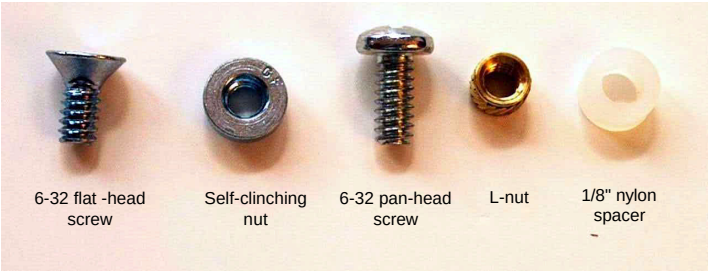

Figure 14: Some fasteners included in the XRC kit

Figure 14 shows the fasteners we will be using. To attach the holder, use the flat-head 6-32 screws on the battery holder side and the round self-clinching nuts on the Robot Board side with a 1/8" nylon spacer in between. Unfortunately, accomplishing this requires about four hands! We think the easiest method is to thread the flat-head 6-32 screws through the battery holder, hold them in place with two fingers, then flip the holder over and thread the 1/8" nylon spacers onto the screws that are sticking through the other side as shown in **Figure 15**.

Figure 15: Hold the flat-head screws in place and put spacers over screw-ends

You can then position the Robot Board on top of the battery holder, making sure to thread the screws through the Robot Board's holes and secure the self-clinching nuts with your free hand. After the nuts are somewhat secure, you can tighten them with a large phillips screwdriver. The nuts should stay in place automatically when tightening, which allows you to tighten the screws firmly. **Figure 16** shows the top side of the Robot Board after all fasteners are in place.

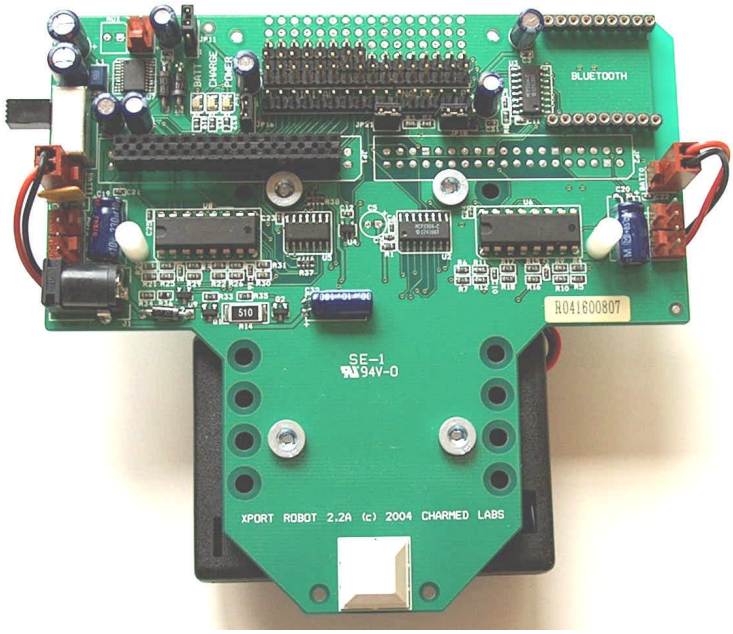

Figure 16: Top side of Robot board showing self-clinching nuts

Don't forget to plug the battery cables into the "BATT0" and "BATT1" connectors on the Robot Board. It doesn't matter which battery cable goes where, but we prefer to criss-cross the cables as shown in **Figure 13** to prevent the cables from getting in our way.

LEGO Attachment

If you completed the steps in the previous section, you may be wondering how you attach your XRC/battery holder assembly to your LEGOs. Provided in your kit are "L-nuts" (shown in **Figure 14**). These can be pressed into the "holes" of many LEGO components, and they make attaching non-LEGO pieces to LEGOs much easier. That is, no glue is required.

To illustrate, we will attach some LEGO plates to the battery holder covers as shown in **Figure 20**. To do this, we need to embed the L-nuts into a LEGO plate of our choosing. We chose a 2x8 LEGO plate with holes because they are quite plentiful in the LEGO Mindstorms Kit, but you could use a 2x6 plate, or a many other LEGO parts for that matter, depending on where or how you want to attach the XRC to your LEGO invention.

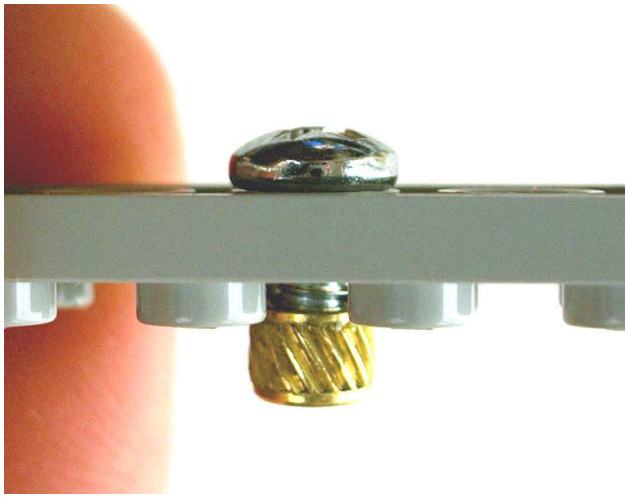

Figure 17: Thread 6-32 pan-head screw through hole in the LEGO plate and attach L-nut to the other side

With a pan-head 6-32 fastener, thread it through the hole into which you want to embed the L-nut then screw the L-nut on the other side as shown in **Figure 17**. It is important that the head of the screw is on the "flat" side of the LEGO plate, not the "bumpy" side. Next, tighten the screw with a large phillips screwdriver. The L-nut should be drawn through the hole as you turn the screw until you cannot turn the screw anymore. The L-nut is now in place. You can then loosen and remove the screw. Repeat this process with another L-nut to create a plate that looks like **Figure 18**. This plate is now ready to attach to our battery holder cover. Note, you can press the L-nuts into place by hand, but this may lead to L-nuts that are not positioned perfectly straight with respect to the hole.

Figure 18: 2x8 LEGO plate with two L-nuts

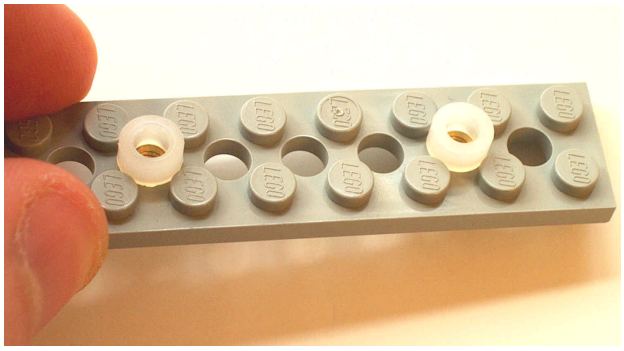

Figure 19: Place two nylon spacers on top of L-nuts

Place two 1/8" nylon spacers on top of the L-nuts as shown in **Figure 19**. They should snap and stay in place on their own. Now put the holder cover on top of the LEGO plate and use two flat-head 6-32 screws to secure the plate to the battery cover using a large phillips screwdriver. When complete, the battery holder should look like **Figure 20**.

Figure 20: Completed battery cover

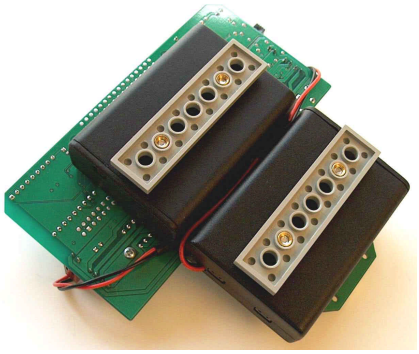

Figure 21: XRC with LEGO plates

You can now insert the batteries into the battery holders and slide the battery covers on. Your XRC is ready to attach to your LEGO invention. The complete assembly is shown in **Figure 21**.

Overview

As mentioned before, the XRC consists of both the Xport and the Robot Board. The Robot Board adds extensive robotics functionality to the Xport. It provides the following facilities that are detailed in the block diagram in **Figure 23**:

- Four, 1 Amp H-bridges (motor drivers)
- Back-EMF measuring circuitry with integrated analog-to-digital converter
- 8 channel, 12-bit analog-to-digital converter for analog sensors
- 5 Volt, 1 Amp voltage regulator
- Battery charging and voltage monitoring circuitry
- Bluetooth interface

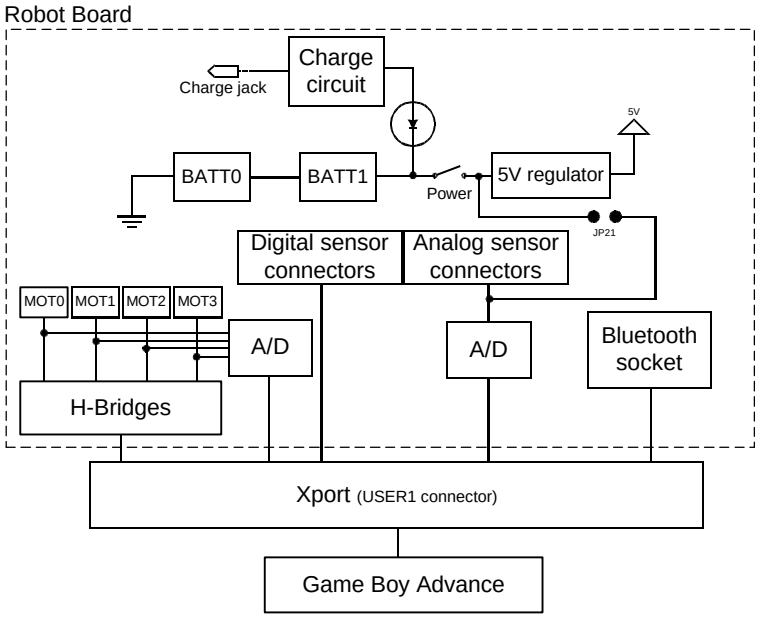

Figure 23: XRC block diagram

Back-EMF Sensing

Permanent-magnet motors, such as LEGO motors, generate a voltage when they rotate. This voltage, or "back-EMF" voltage, is directly proportional to the motor velocity. A motor controller that can accurately sense the back-EMF voltage can determine the motor's velocity. And if the back-EMF voltage is integrated (summed) over time, the motor's position can be determined as well.

The XRC determines both the motor position and velocity in this manner, which makes closed-loop control possible. The XRC can determine the position, velocity and torque of up to 4 independent motors simultaneously.

One big advantage of back-EMF sensing is that it does not require any additional mechanical complexity such as optical/mechanical encoders. The same two wires that supply power to the motors are used for back-EMF sensing.

Robot Board Signals

Table 1: Robot Board signals

Name	Function	Xport USER1 pin	Xport USER1 name	FPGA pin
DS0A	Digital sensor 0 channel A	2	PA0	20
DS0A	Digital sensor 0 channel B	3	PA1	21
DS1A	Digital sensor 1 channel A	4	PA2	22
DS1A	Digital sensor 1 channel B	5	PA3	23
DS2A	Digital sensor 2 channel A	6	PA4	24
DS2A	Digital sensor 2 channel B	7	PA5	27
DS3A	Digital sensor 3 channel A	8	PA6	29
DS3A	Digital sensor 3 channel B	9	PA7	30
DS4A	Digital sensor 4 channel A	10	PA8	31
DS4A	Digital sensor 4 channel B	11	PA9	33
DS5A	Digital sensor 5 channel A	12	PA10	34
DS5A	Digital sensor 5 channel B	13	PA11	35
DS6A	Digital sensor 6 channel A	14	PA12	36
DS6A	Digital sensor 6 channel B	15	PA13	37
DS7A	Digital sensor 7 channel A	16	PA14	41
DS7A	Digital sensor 7 channel B	17	PA15	42
M0A	Motor 0 control channel A	18	PA16	43
M0B	Motor 0 control channel B	19	PA17	206
M1A	Motor 1 control channel A	20	PA18	18
M1B	Motor 1 control channel B	21	PA19	16
M2A	Motor 2 control channel A	22	PA20	16
M2B	Motor 2 control channel B	23	PA21	15
M3A	Motor 3 control channel A	24	PA22	14
M3B	Motor 3 control channel B	25	PA23	10
ADDATA	A/D converter data	26	PA24	9
ADCS	A/D converter chip select	27	PA25	8
ADCLK	A/D converter clock	29	PA27	6
BTTX	Bluetooth data transmit	28	PA26	7

BTRX	Bluetooth data receive	33	CLKINA	77
BTRTS	Bluetooth request-to-send	30	PA28	5
BTCTS	Bluetooth clear-to-send	31	PA29	4
BTRESET	Bluetooth reset	32	PA30	3

Sensor Connectors

The sensor connectors located toward the front of the Robot Board (**Figure 1**) are arranged in a grid. As **Figure 24** shows, each "column" is a different connector. Each of the 8 digital sensor connectors has two I/O "channels" for a total of 16 I/Os. Each of the 16 I/Os is controlled directly by the FPGA (Table 1), which makes it possible to interface a wide variety of devices to the digital sensor connectors. The digital sensors will accept from 0 to 5V as input and output 3.3V LVTTL logic, which is compatible with standard TTL.

Each of the 8 analog sensor connectors has a single analog input. The analog inputs are connected to an 8-channel 12-bit analog-to-digital converter that can be read by the GBA. The analog inputs will accept voltages between 0 to 3.3V, which correspond to readings between 0 and 4095, respectively.

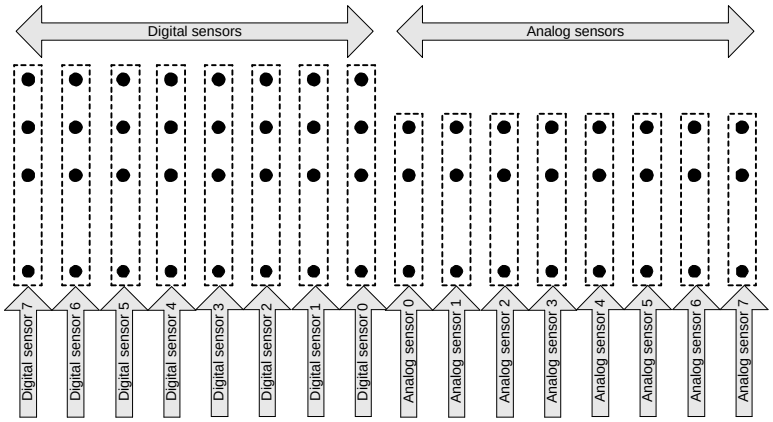

Figure 24: Each "column" of the sensor connector area is a different connector. There are 8 digital and 8 analog sensor connectors.

Sensor power

Each of the sensor connectors as **Figure 25** shows has a GND and power pin. JP16 (see **Figure 1**) selects between +5V and 3.3V for the 8 digital connectors. JP18 selects between +5V and 3.3V for the 8 analog connectors. Shorting pins 1 and 2 with a jumper will select 5V, and shorting pins 2 and 3 will select 3.3V for either JP16 or JP18.

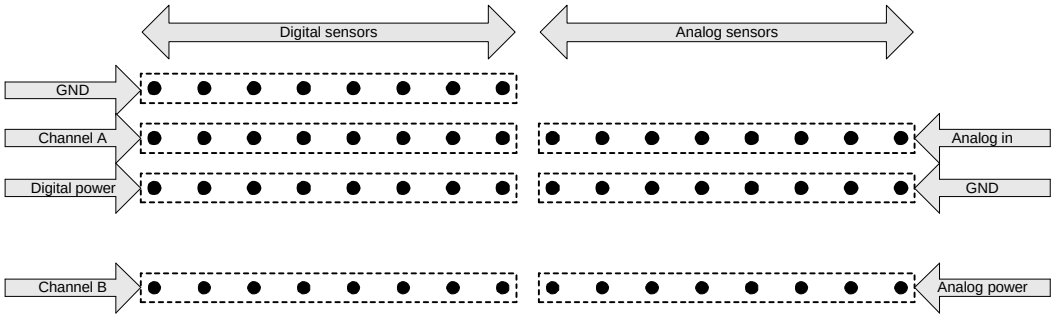

Figure 25: The "rows" of the sensor connector area

Battery Charging

Charging the batteries entails powering the XRC off and plugging the wall supply that comes the XRC kit into the charge jack shown in **Figure 1**.

IMPORTANT: do not use any other wall supply. Use only the wall supply that came with the XRC. Using another wall supply with a different voltage or current rating will likely damage the charge circuit.

While the batteries are charging, the yellow "CHARGE" LED (**Figure 1**) will be illuminated. The LED will turn off when the batteries are fully charged. It takes 6 hours to fully charge a set of drained batteries.

Powering the GBA

The Game Boy Advance is a portable device that has its own battery supply. When using the GBA with the XRC it is convenient to power the GBA through the XRC's batteries so that there is a single set of batteries that needs to be recharged or replaced. It is also convenient to control the GBA and XRC power through a single power switch.

Accordingly, the XRC has a power connector that is designed to power the GBA. **It is important when using the power connector to set the correct voltage via JP11 (Figure 1).** Namely, jump pins 1 and 2 if you have a GBA SP and pins 2 and 3 (default) if you have a regular GBA.

Using this connector entails making a power cable that is compatible with your GBA. The GBA SP comes with a battery charger that can be modified to plug into the XRC's power connector. That is, simply cut the cable and crimp a connector to the GBA SP's charger cable. Extra connectors are supplied in the XRC kit for this purpose.

The regular GBA (not GBA SP) requires the "AC Adapter Set" from Nintendo, which allows the GBA to be powered externally. With this component it is straightforward to make a cable that plugs into the power connector.

When making a power cable it is important to observe the correct polarity between the power connector and the GBA. The polarity is marked in embossed lettering on the GBA SP and on the AC Adapter Set. **Figure 26** shows the polarity of the XRC power connector.

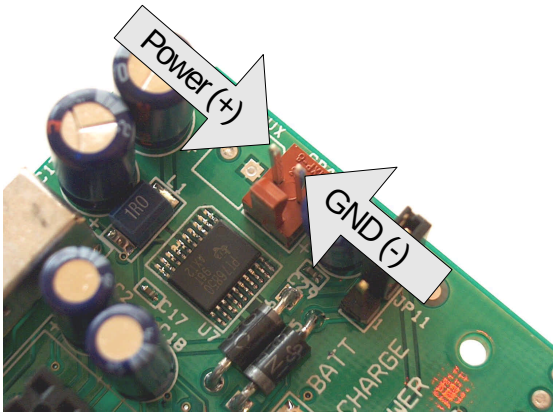

Figure 26: GBA power connector polarity

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