

E11: Autonomous Vehicles

Lab 4: Robot Assembly

In this lab, you'll put together your very own robot! You should have a Mudduino and a chassis, as well as your kit of parts. Now it's time to put them all together.

This lab can take a while. Read through the lab in advance so it will go faster. If you can build your gearbox before lab, you are more likely to finish by the end of the lab period.

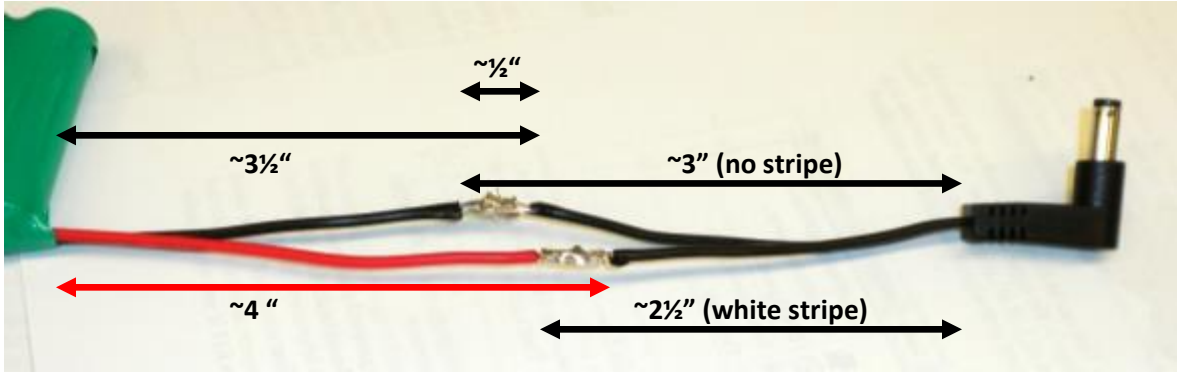
Preparing the Battery

The robot is powered by a 7.2V RC car battery. Before it can be used, you need to solder a barrel jack to the battery wires. The barrel jack has two leads that will be soldered to the battery wires.

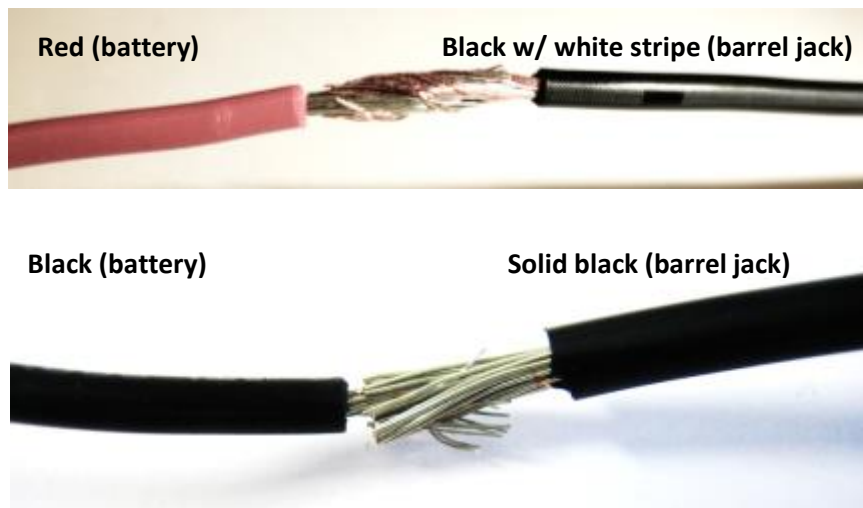


WARNING: The battery is designed for high current output. If you accidentally create a direct path between power and ground, the battery will start smoking in about four seconds. There is also the possibility of sparking between power and ground, which can cause small burns. If you take care to keep power and ground separated, you won't have any problems.

Now that we've gotten the scary warnings out of the way, here's how to attach the connector. Cut the wires so that about 4" emerge from the battery, and 3" emerge from the barrel jack leads (clip one of the leads about half an inch shorter than the other to prevent electrical contact between the wires). If you leave too much wire, it will drag behind your robot and might get caught on things. **SEE FIGURE ON NEXT PAGE!**



Strip about 1/2" off of the red wire from the battery and barrel jack lead with the white stripes along the wire. Intertwine the wires, as shown below. Make sure you have a good mechanical connection before you solder.



Heat the junction, and apply copious amounts of solder. Make sure that the solder is actually soaking into the connection, rather than just wetting the surface (if this isn't happening, keep heating the wires). You should also flip over the wires and solder the other side. You want to make a very strong electrical and mechanical connection.



To check that the polarity of the battery is correct, use a multimeter and two red and black multimeter probes to measure its voltage. Set your multimeter to measure DC voltage in the 10 volt range. Place the red probe inside the barrel jack, and use the ground black probe to make contact with the outer sleeve, as seen in the image here below. You should see a **positive** voltage value roughly between 4-8 volts. However, if you see a **negative** voltage you've soldered your wires backwards! Yikes! This means you should unsolder your wires, swap them, and redo the previous steps.



Once you're satisfied, clean up any stray wires with the cutters and wrap electrical tape around the junction. Then, repeat with the black wire from the battery pack and the solid black wire on the barrel jack leads. Remember that it is very important the two solder joints do not make contact or else power will be shorted to ground. **Write your initials on your battery pack.**

Preparing the Battery Charger

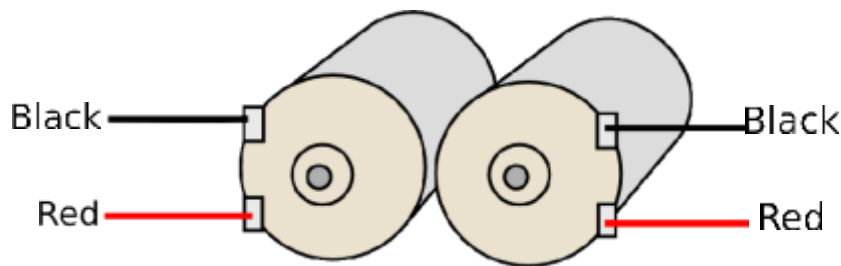
Connect the large round jack to the battery charger in the same fashion. Chop the incompatible connectors off of the battery charger so that you can solder on the round jack instead. The red wire on the charger goes to the black and white wire on the jack. The black and red wire on the charger goes to the solid black wire on the jack.

Plug your battery pack into the charger and the charger into the wall. You should see a red light on the charger indicating that the battery pack is charging. The light will turn green when the battery is fully charged. It is a good idea to recharge your battery before each of the future labs so that it remains at full strength.

Preparing the Motors

You will find two pairs of motors in your kit. They look deceptively similar and are important not to mix up. The motors that come with the gear box kit are only rated for 3-6 V and could burn out if connected to your 7.2 V battery pack. Discard them or mark them with a sharpie and set them aside in a way that you will not mix them. Instead, you'll be using the other pair of motors in your kit rated for 3-12 V.

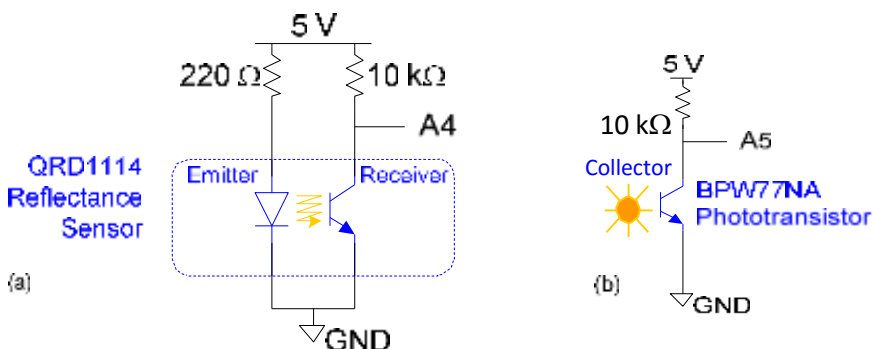
Use four pieces of the 6" single or multi-stranded wires to connect the 3-12 V motors to the Mudduino board (single stranded wires are suggested or you will need to solder a male header to the multi-stranded wires not connected to the motor). Strip 1/3" of insulation off the ends and solder a red and black wire to each of the motors. Take electrical tape and tightly wrap one layer around the motor and wires for strain relief so that the wires won't rip off the motor's lugs if jostled. Twist the wires together to keep them neat. Note that since the motors are driving wheels on opposite sides of the bot, you will want the wire colors to be mirrored.



This will make programming the robot's driving more intuitive.

Wiring up the Sensors

The standard robot is equipped with two different sensors: a phototransistor, and a reflectance sensor. The sensors require supporting circuitry to operate. The circuit diagrams of the phototransistor and reflectance sensor are shown below:

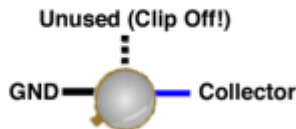


The component terminals are identified in the following image, looking down on the components from above with the leads coming out the bottom.

Reflectance Sensor

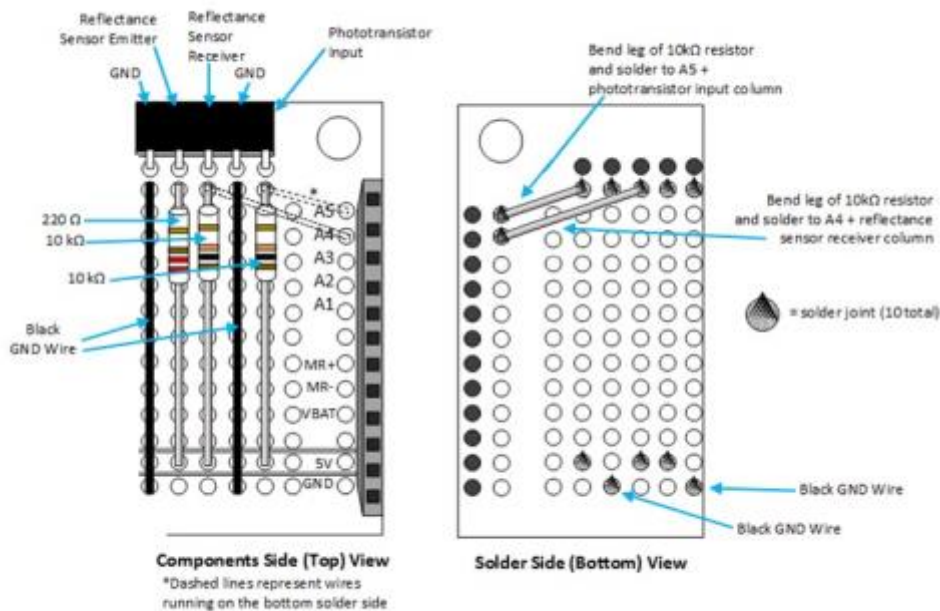


Phototransistor



The middle pin of the phototransistor is the base terminal. It will interfere with the transistor's operation if it touches the other terminals, so snip it off close to the package to prevent such problems. The two reflectance sensor ground pins (the short ones) need to be connected together. Bend one over and wrap it around the bottom of the other one, solder, and trim off the excess from the first one while leaving the second one at full length.

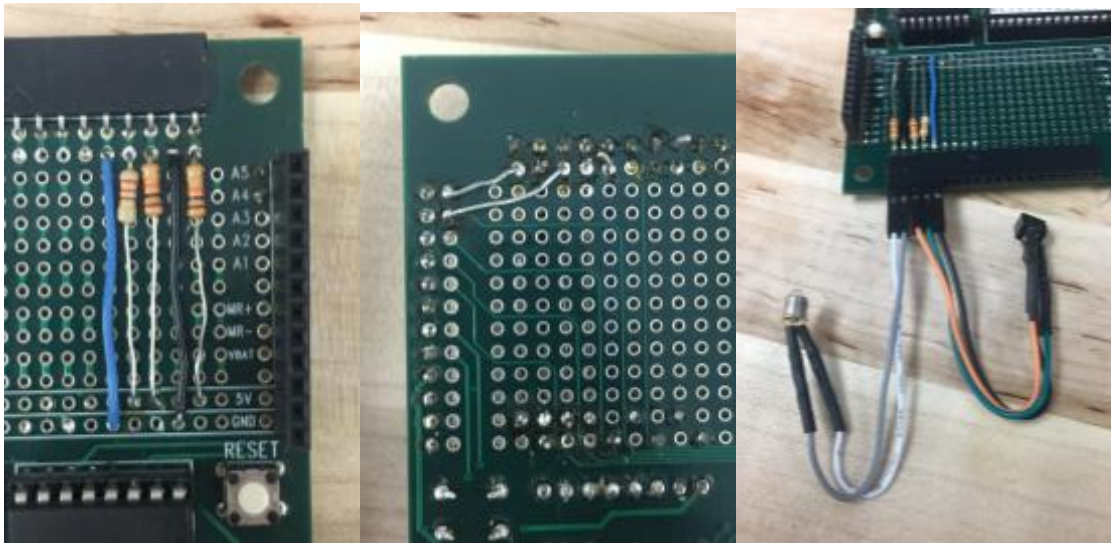
The required resistors will be soldered onto the perfboard on the top half of the Mudduino board. While there are many ways to do this, we recommend the layout below because it can be done simply with only three resistors and two wires. Study the wiring diagram and pictures provided below (**especially the resistors**), and relate them to the schematic so you see how each connection is made. There should be two pieces of wire that make the ground connection. Take your time and get it right the first time; it's easy to goof up and fairly time consuming to redo if you make the wrong connections.



Remember that the resistor codes are:

- 220 Ω : red-red-brown (1x)
- 10 k Ω : brown-black-orange (2x)

You will need to make a 2-wire cable and a 3-wire cable with two male header pins and three male header pins, respectively, at one end. These cables will plug into the female right angle connector at the front of the robot. The following diagram shows which pins on the sensors connect to the headers on the Mudduino. A common mistake is to wire the reflectance sensor incorrectly. (Note that the phototransistor diagram is shown from below, looking up at the pins.) Slide $\frac{3}{4}$ " of 1/8" diameter heat shrink tubing over each wire before soldering to the components, then slide the tubing over the solder joint and use a heat gun to shrink the tubing to cover the joint and prevent it from touching adjacent joints.



Attaching the Servo Motor

Notice how the circuit board has a notch in the back of the robot for mounting the servo motor. Place the servo in the notch (this is a very tight fit), such that the gear is closer to the power jack. Secure the servo motor to the board using a pair of 2-56 x 3/16" nylon machine screws. The screws should hold to the flanges on the servo so that you do not need nuts. The nylon screws prevent you from shorting the power to ground planes inside your circuit board.

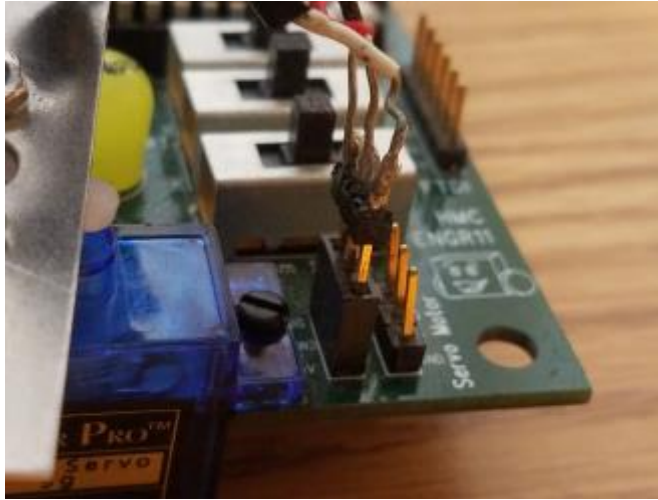
The servo motor female header pins should mate with the corresponding male header pins on the circuit board. Polarity matters! The brown wire should connect to the GND pin, red to VDD, and yellow to SIG.

Mounting the Distance Sensor

Attach your distance sensor assembly to your servo motor. The distance sensor assembly includes the distance sensor, the mounting bracket, and the double horn arm. Place the arm on the servo with the sensor facing forward (toward the bumper in the front of the robot). Use a small pan-head screw in the servo kit to affix the arm to the servo.

Make sure that no wires or other parts can get in the view of the distance sensor or it will interfere with the distance readings.

To prepare the distance sensor for mounting on the robot, attach the distance sensor cable to the sensor. Take the opposite ends of this cable and solder them to a three-pin male header that you will use to attach the cables to the female header on the Mudduino.



Attaching the Gearbox

Take the gearbox you assembled in Lab 2 (if you haven't assemble it, do so now). Plug the motors into the gearbox. The electrical tape should be tight enough around the motors so that the motors are snug in their housing without the electrical tape bunching up. For the sake of consistency between robots, put the red wires on the bottom. Bolt the gear box to the chassis using the nuts and bolts from the gear kit.

Put tires on your two wheels and mount them to the gear box using the hex shaft plates. A big Phillips screwdriver will be helpful.

Bolt your gear box to your chassis using two machine screws and nuts that came with the gear box.

Robot Assembly

You can think of the robot as a delicious sandwich: crunchy gearboxes and tangy batteries squished in between the chassis and the Mudduino. The entire thing is bolted together, with standoffs preventing you from smashing the sandwich.

Attach the ball caster to the front of the robot. Place the thicker black plastic standoff between the caster and the chassis to level the robot. The chassis holes are slightly too small for the screws, so the process of screwing them in will tap threads into the chassis.

Mount the sensor tower on the chassis with an 8-32 ½” machine screw.

Place the phototransistor in the sensor tower facing forward. Place the reflectance sensor in the square hole in the chassis.

The battery pack could be damaged if the sharp pins on the bottom of the Mudduino board were to pierce the pack. To prevent this risk, attach two 3” strips of foam tape to the side of the battery pack with no label.

Add the battery (foam side up) and Mudduino. Make sure that the battery cable is coming out in a convenient location.

There should be 4 metal standoffs, one in each corner that will hold the entire thing together. Secure the standoffs by fastening 8-32 machine screws on top through the holes in the Mudduino and on the bottom through the chassis. The standoffs are threaded inside so the screws should screw in place.

Connect the 3-wire and 2-wire cables from the sensors to the right-angle headers on the front of the Mudduino. Plug the motor wires into the MR+/- and ML+/- header pins on the sides of the Mudduino.

Congratulations! You have just made your delicious robot sandwich!