MSE-5: A Light- and Sound-Sensing Robot

Written By: Sean Michael Ragan

SUMMARY

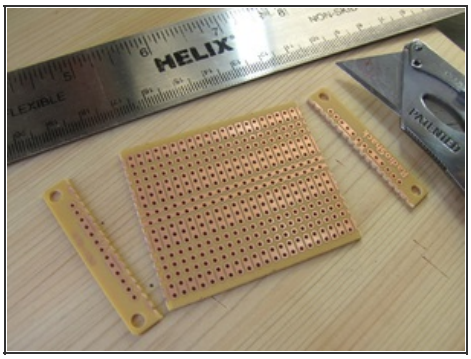
MSE-5 is a direct descendant of Gareth Branwyn's *Mousey the Junkbot*, as published in MAKE Volume 02. Like Mousey, MSE-5 uses a simple circuit to drive two small electric motors, varying the voltage between them depending on the amount of light shining on its two "eyes" (which are really just small IR phototransistors). The robot always tries to turn toward whichever side of its body is exposed to more light, and thus "seeks out" the brightest IR source in its environment, which is often the light source, whether it's a light bulb or sunlight through a window. Mousey and MSE-5 belong to a class of light-sensitve robots called "phototropes." They'll happily wander around in a sunbeam, or chase a flashlight across a darkened floor, as long as the batteries hold out.

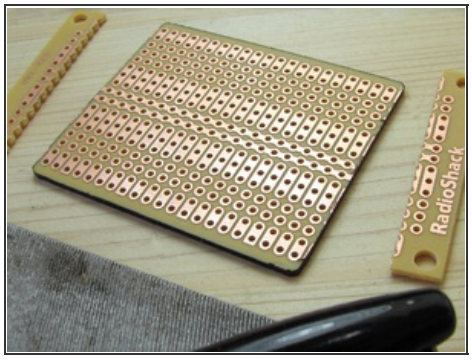
Like Mousey, MSE-5 also has a "backpedal" reflex that temporarily reverses its motors in response to certain environmental stimuli. In Mousey, the reflex is tripped by a simple mechanical "bump switch" positioned at the front of the body: if Mousey runs into something, the switch is depressed, a relay is triggered, and the motors run in reverse for a few seconds, causing Mousey to back away from the obstacle.

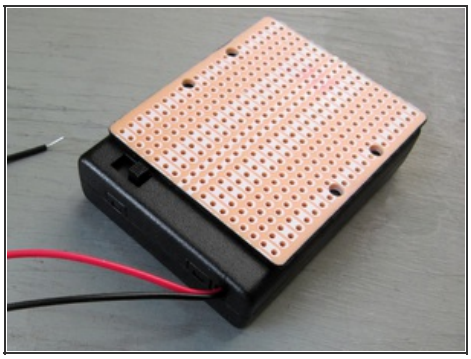
MSE-5 replaces Mousey's bump switch with a microphone and a simple circuit that amplifies sound, filters it, and activates a relay in response to any sharp, loud noise like a clap or a shout. Interestingly, the acoustic shock of an impact on the robot body is often sufficient to trigger the circuit, so MSE-5 replicates Mousey's impact-reversing behavior, to some

degree, while adding a more general responsiveness to sound.

Step 1 — Prepare the perf board.

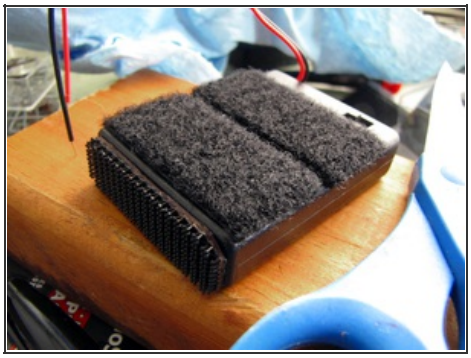
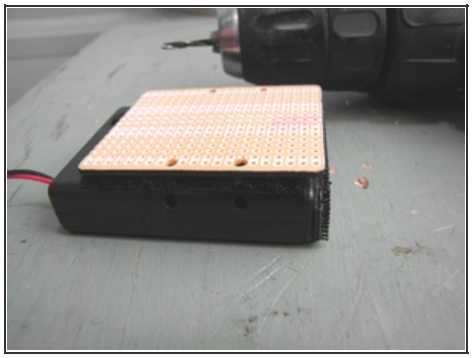






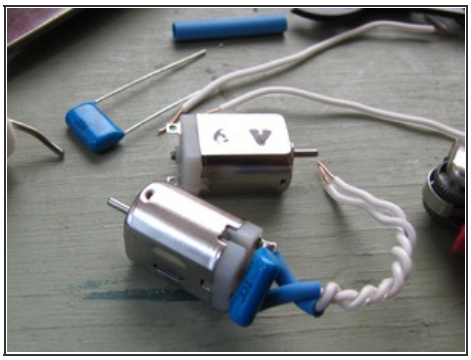
- We'll be using a piece of pre-etched printed perforated board ("perf board") to build MSE-5's electronics. First, we need cut it down to size.
- Use a straightedge and a sharp knife to score the perf board along the first *full* row of holes at each end (you'll discard the short rows on the ends). For each cut, score the board 3 times on one side, flip it over, score it 3 times on the other side, then snap it along the line. The finished piece has 21 full rows.
- Smooth the snapped edges with a small file. You might also round off the corners, just for looks. I also finished the edges with a permanent marker.
- **NOTE:** The perf board is not symmetric from left to right. Orient it so that from the *component* side (without copper traces), the group of 3 columns of unconnected holes is on the *right,* as shown in the third photo. In this position, the "top" of the board, as I use the term, is as the top of a page.
- Use a drill with a 7/64" bit to carefully enlarge the first and last holes in the perf board's 7th and 13th rows down, as shown. If your electric drill has a slow setting, use it. These holes will be used to mount the finished circuit to the robot body.
- The finished perf board should fit neatly on the battery holder, as shown, with the top of the board flush with the front edge of the battery holder. There should just be room to still operate the switch, which will be at the rear of the robot.

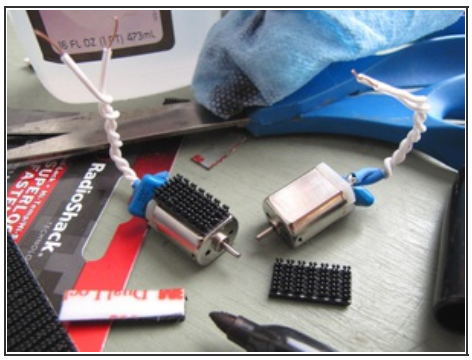
Step 2 — Mod the battery pack.


- Clean the the battery pack with rubbing alcohol. Pad the top of the pack with 2 strips of "soft" velcro, placed forward of the power switch. Cover the front end of the pack with a piece of "Superlock" fastener tape.
- The adhesive foam on the Superlock tape is white; color it with a permanent marker if you don't like the way it looks.
- **NOTE**: After applying Superlock tape, let the adhesive cure for 2–3 days before removing any Superlocked items that may be attached. Superlock is *strong,* so let the adhesive cure well before you try to remove them, otherwise that bond might break first.
- Put the PCB on top of the velcro padding, as shown, and use it as a template to drill 4 matching 7/64" holes through the velcro and the top of the battery pack. You might want to remove the battery cover to make sure you don't damage it by drilling too far.
- Drill 2 more holes on each side of the battery pack, directly aligned with the mounting holes in the topside of the case, and in the PCB, as shown in the second photo. Drill these as close to the top of the case as you can get without drilling into the rounded edge.
  PHOTO: ADD YELLOW CIRCLES TO INDICATE
- **NOTE:** These holes will be used to mount the circuit board using small zip ties. If you drill them too far down, the zip ties might interfere with loading batteries into the case. Before continuing, put a small zip tie through each pair of holes and check that the batteries still fit.
- Finally, trim the 2 battery pack leads to 1¾" long and strip ¼" of insulation from the ends. Tin the stripped ends with your soldering iron, then twist the 2 leads together and secure with a short piece of heat-shrink tubing.

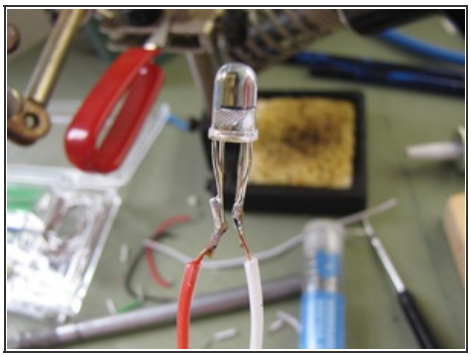
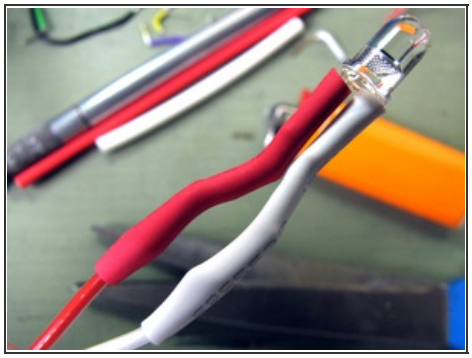
Step 3 — Prep the motors.





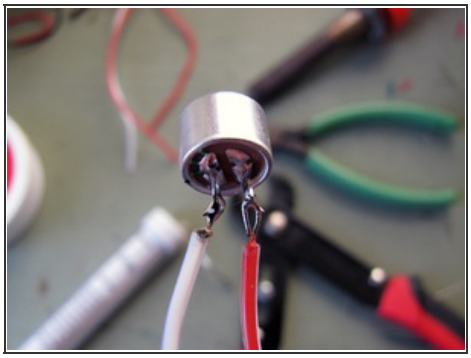
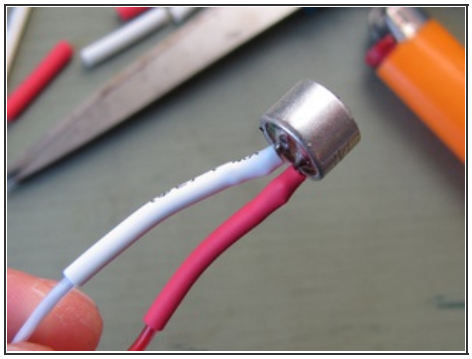
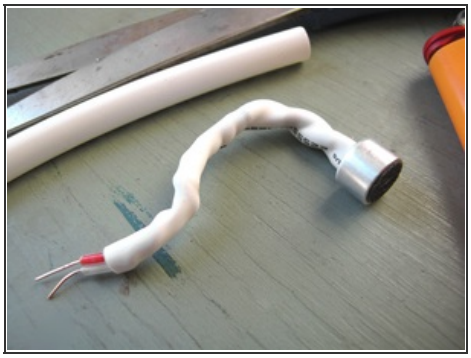
- Run the legs of a 0.1 F metallized polyester film capacitor into the wiring holes in the terminals of each motor. Even with the capacitors in place, there should still be enough room leftover in each hole for a 24 AWG wire lead. These capacitors will help prevent electrical noise from the motors from entering MSE-5's power supply.
- Cut four 2" lengths of 24 AWG wire and strip ¼" of insulation off each end. Solder a wire to each of the 2 terminals on each of the 2 motors, insulate the solder joints with heat-shrink tubing, and twist the leads together as shown.
- Cut two 3/8" x ¾" pieces of Superlock tape to fit the flat sides of the motors. As before, you can color the white edge if you don't like the way it looks. Clean the flat, smooth side of each motor with rubbing alcohol or acetone, and apply a Superlock strip to each motor.
- MSE-5's wheels are made from pencil erasers! Cut 2 fresh erasers down to about 5/16" long, center them over the motor shafts, and push them on. Be sure to leave a bit of clearance between the eraser and the motor body so the wheels can spin without binding.

Step 4 — Make the eyestalks.

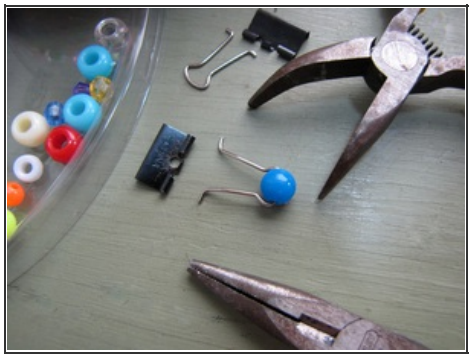

- Cut four 3" lengths of 24-gauge solid-core wire, 2 in red and 2 in white. Strip ¼" of insulation off all the ends.
- Solder a red lead to the shorter, "collector" leg of each of your IR phototransistors, and solder a white lead to each of the longer, "emitter" legs. Insulate the connections with heat-shrink.
- Twist the red and white leads from each phototransistor around each other, leaving about ½" of untwisted pair at the end.
- Cover the twisted pairs from each phototransistor with heat-shrink tubing to make 2 "eyestalks." These can be mechanically adjusted to change how MSE-5 responds to light.

Step 5 — Make the "earstalk."

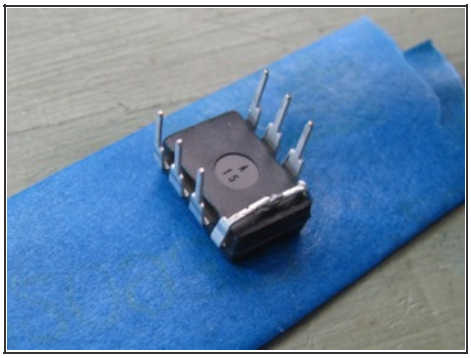
- Cut two 3" lengths of 24-gauge solid-core wire, 1 in red and 1 in white. Strip ¼" of insulation off all the ends.
- Solder a red lead to the negative leg of each of your microphone element, and solder a white lead to the positive leg, as shown. Insulate the connections with heat-shrink.
- Twist the red and white leads from the mic around each other, leaving about ½" of untwisted pair at the end.
- Cover the twisted pair from the mic with heat-shrink tubing to make an "earstalk." This can be adjusted as needed to change how MSE-5 responds to sound.

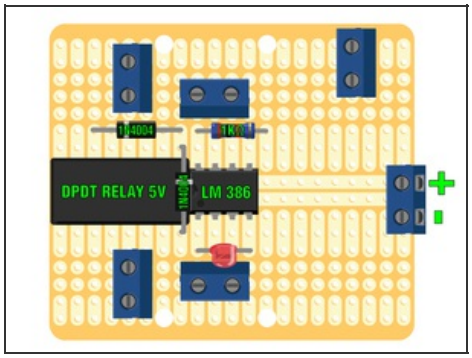
Step 6 — Build the tailwheel.

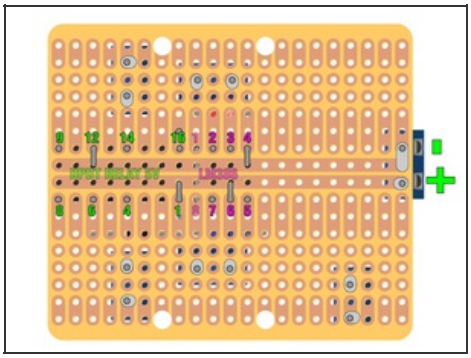




- Clip a 5/8"-wide binder clip to the edge of a piece of scrap wood about ¼" thick. Flip the handles up out of the way, then drill a 3/32" hole through one side, centered, as close to the mouth of the clip as you can without hitting the little curled tab in the middle.
- **TIP:** The spring steel in a binder clip is very hard, but fortunately it's also very thin. Use a drop of oil on the tip of a sharp bit, drill at higher rather than lower speed, with a bit of force, and take your time. The tool may smoke or chatter a bit before breaking through. Don't be alarmed. Wear goggles.
- Cut the clip in half by filing along the edge of the wood scrap with a small 3-corner file. This doesn't take long; after a minute or so, the clip will simply fall in half. Smooth over the cut edge with more filing, or use a pair of nibblers. Be aware that it will probably be sharp, at first. You want to leave a little bit of a "lip"
- Thread a small plastic bead onto the binder clip handle, as shown. You'll need to use a couple pairs of small pliers to unbend the clip, here and there, to get the bead in place.
- Bend the wire handle back into shape, make sure the bead can still spin, and put the handle back onto the halved clip. There's your tailwheel!
- Mount the tailwheel to the bottom edge of the battery pack using the battery pack's case screw, which is long enough to secure both the tailwheel and the battery cover as normal. The lip indexes against the back edge of the battery pack to keep the tailwheel from spinning about the mounting screw.

Step 7 — Place the phototrope components.

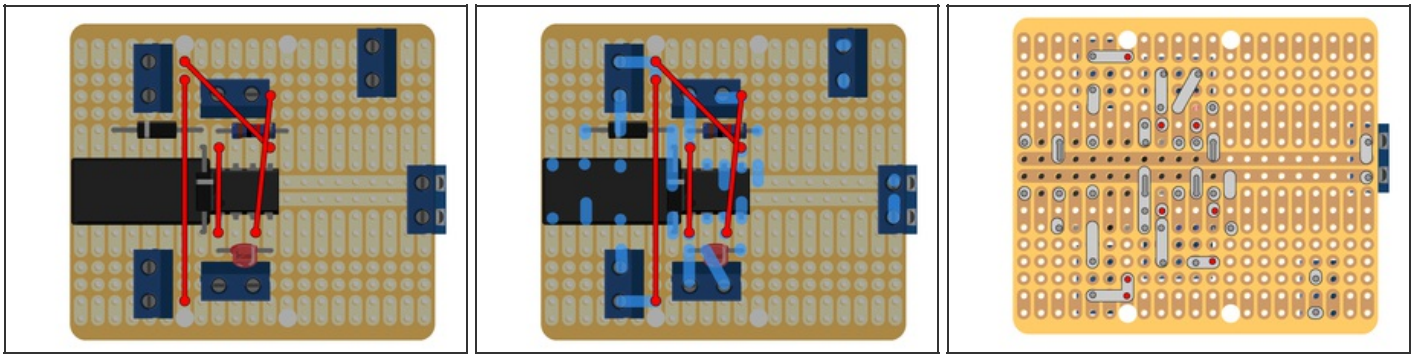






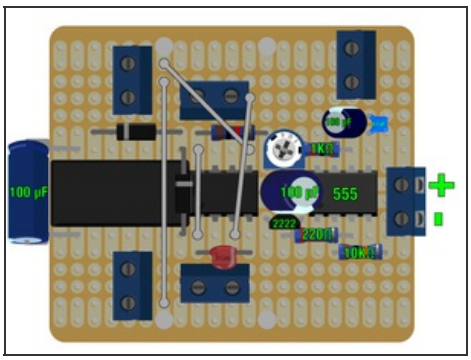
- First, identify pins 1 and 8 on your LM386 IC. Use small pliers to bend them around so that they just contact each other underneath the IC package, as shown, and solder them together. Shorting pins 1 and 8 like this sets the LM386 to "high gain" mode.
- Position the 6 screw terminals as shown. Secure them in place, as you go, by soldering their pins on the underside of the board. Note the solder-side connection from the power connector to the negative power bus.
- Position the LM386, relay, LED, and 2 rectifier diodes as shown, noting the correct orientation of the pins in each case. It doesn't matter which direction the 1K resistor is pointing. Don't solder them just yet.
- **NOTE:** The shorter, negative lead on the LED goes toward the *bottom* of the perfboard, in the same row as pin 4 of the amplifier IC.
- The relay and ICs in the MSE-5 design make their connections to positive and negative power through the central power bus traces on the solder side of the PCB. Bend relay pins 1 and 12, and LM386 pins 4 and 6, inward toward the power bus traces, as shown. You'll solder these in the next step.

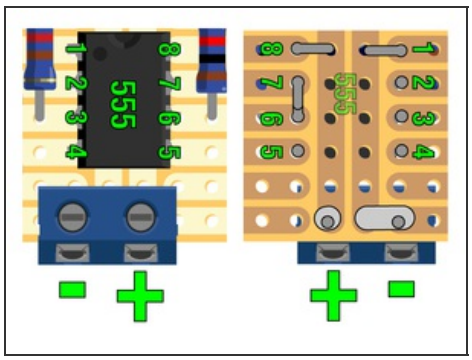
Step 8 — Wire the phototrope circuit.

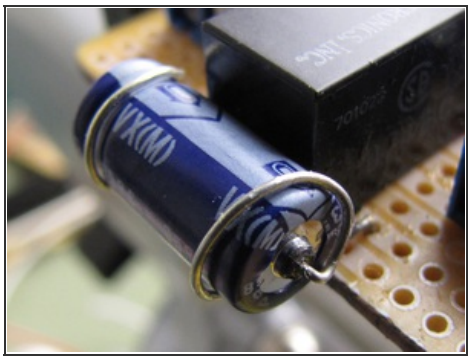


- Cut 4 jumper wires from 24 AWG solid-core copper wire: one ¾" long, two 1.5" long, and one 2".
- Strip about 0.2" of insulation from each end of each jumper. For the shortest wires, you may find it easier to use a sharp hobby knife instead of stripping pliers.
- Connect the 4 jumper wires as shown. Put the stripped ends through the perf board holes on the component side where indicated by the red dots, and bend them on the solder side so they stay in place.
- Flip the board over and solder each of the bent leads or pins indicated by the blue traces on the component-side view. On the solder-side view, component legs are indicated by dark gray dots, wire leads by red dots, and solder traces by light gray ovals.
- When you've got solder in all the right places, use diagonal cutters to trim any excess lead, wire, or pin.
- **NOTE:** The ¾" jumper goes across the holes beneath pins 1 and 8 of the LM386 chip, *but does not connect to the chip itself*. Remember, we folded and soldered these pins earlier, so the holes beneath them are vacant. We use them to jump power across the chip from the 1K resistor to the LED and port-side phototransistor.

Step 9 — Place the "reflex" components.

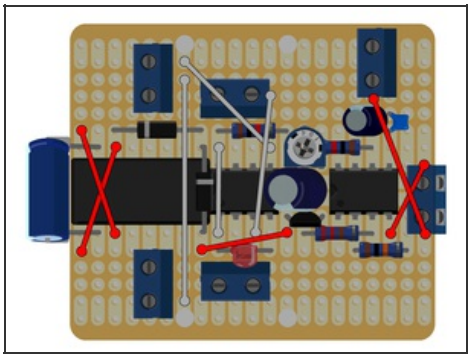
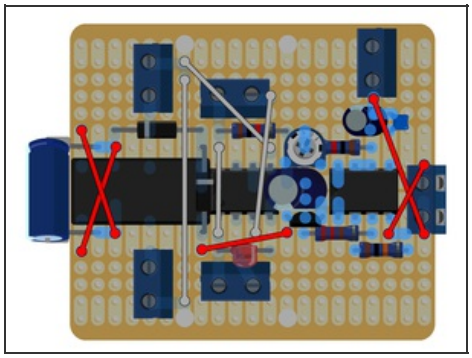
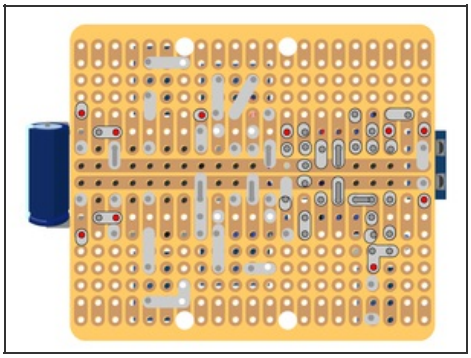






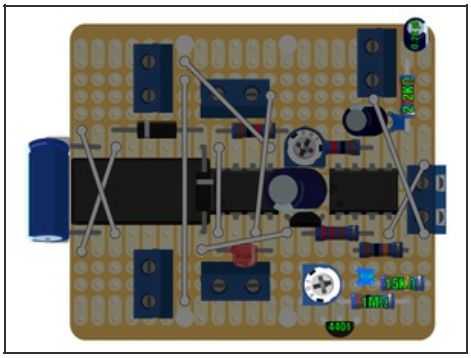
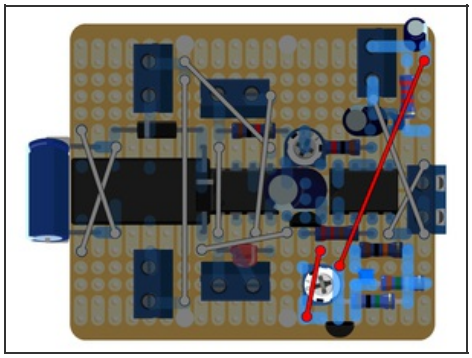
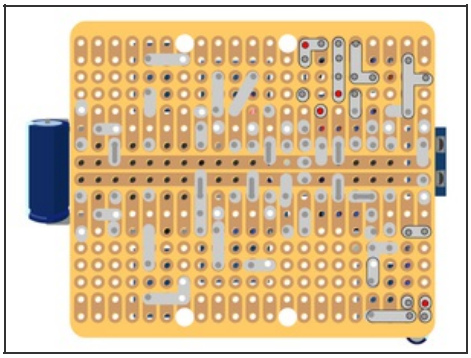
- These components control MSE-5's "reversing" reflex. The relay is already in place from the previous step, but now we are going to hook up the timer chip that controls how long it stays on, as well as the capacitor and variable resistor that set the delay period, and the transistor that actually switches the power.
- Position the 555 timer IC, the 100K variable resistor ("trimpot), the three 100 F electrolytic capacitors, and the 2N2222 transistor as shown, noting their orientations from the diagram. The 0.1 F capacitor and the three resistors are not polarized, and it does not matter which way they go in.
- As before, bend 555 timer pins 1 and 8 in to contact the negative and positive power buses, respectively. Also, bend pins 6 and 7 up and down, respectively, to contact each other.
- The axial-lead electrolytic capacitor is positioned across relay pins X and Y, and hangs off the front of the perfboard as shown. The capacitor is slightly wider than the relay, but you can curl the long leads around the capacitor body, as shown, to close the gap.
- If you don't like the way the capacitor looks, you can cover it in heat shrink tubing before installing it on the perfboard, like I did. If you do this, be careful not to lose track of which end is which! Electrolytic caps can burst if wired backwards.

Step 10 — Wire the "reflex" circuit.

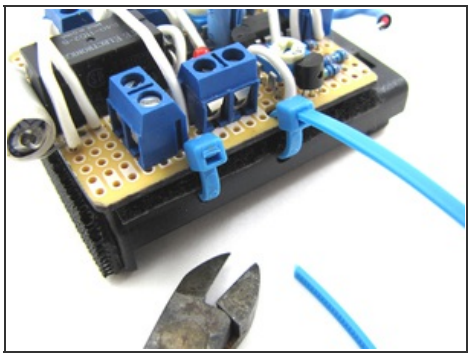
- Cut 5 jumper wires from 24 AWG solid-core copper wire: one about 1" long, three 1.25" long, and one 1.5". Strip about 0.2" from each end, as before.
- Place the 5 jumpers as indicated by the red lines. Bend the stripped leads underneath the perfboard, as before, and solder to make the connections indicated by the blue traces in the component-side diagram.
- For your reference, a circuit diagram is attached to this project as a PDF. Check each connection against it as you go.

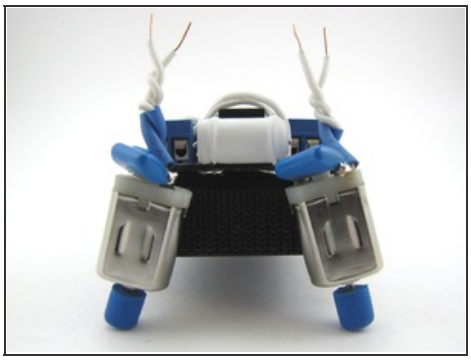
Step 11 — Add the audiotrope circuit

- With MSE-5's "fleeing" reflex wired, we can trigger it by grounding 555 timer pin 2. To make the reflex audiotropic, we now add a very simple amplifier circuit that will trigger pin 2 in response to a sufficiently loud sound.
- Position the 0.22 F electrolytic capacitor, the 2N4401 transistor, and the second 100K trimpot as shown, noting the correct orientation of each. The 0.1 F capacitor and the remaining three resistors are not polarized, so it does not matter which way they go in.
- Prepare two jumpers - one 2" long and one ¾" long - and wire them to the perfboard as indicated in red.
- Flip the board over and solder each component leg and wire lead as needed to make the connections indicated in blue.

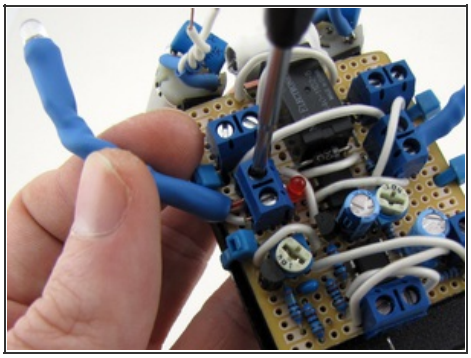
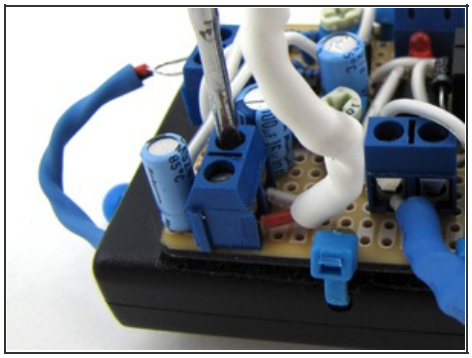
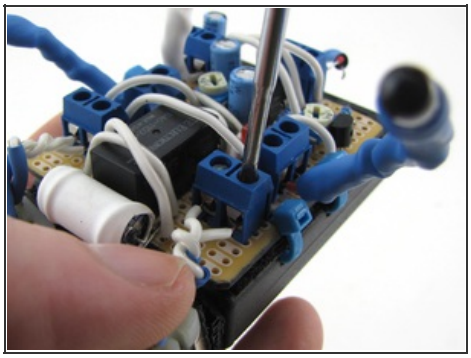
Step 12 — Assemble the robot.





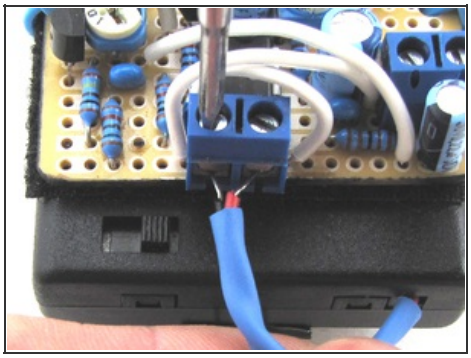
- Remove the battery cover, position the perf board solder-side down on the velcro padding, and align the mounting holes in board and pack. Thread a small zip tie through each pair of holes, as shown, adjust to light tension, and clip off the excess.
- Load four AAA batteries into the pack and close it up again, fixing the tailwheel in place with the battery cover screw.
- Position the 2 motors on the front corners of the battery pack using the Superlock tape. Try to get them symmetric in both height and angle.
- The motor angle will affect how fast MSE-5 moves. Closer to vertical lowers the speed, and closer to horizontal increases it. Try starting with a "splay" of about 20° off vertical for each motor.

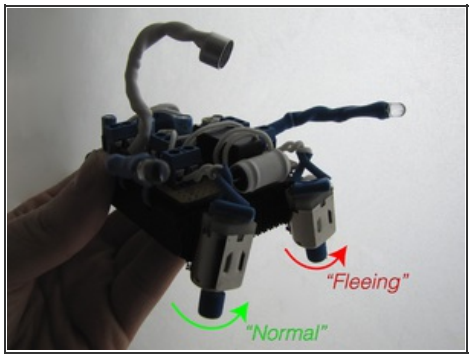
Step 13 — Connect the eyes, ears, and motors.

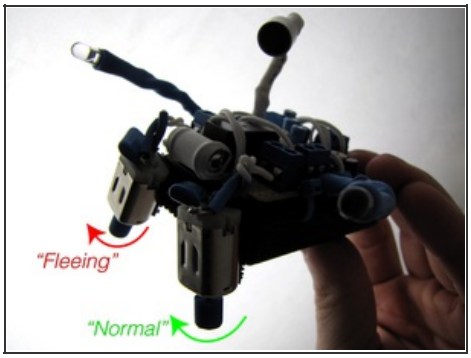




- Slip the stripped ends of the motor wires into the front right and left motor mounting terminals, as shown. (For now, it doesn't matter which wire goes in which port.) Tighten down the terminal post screws to secure each wire firmly.
- Adjust MSE-5's eyestalks to a rakish angle and connect them to the right and left eye mounting terminals, as shown. The red lead goes in the *front* terminal on each side.
- The heat-shrink tubing on MSE-5's eyestalks gives them some shape "memory." This makes them more resilient in impacts, but also slightly harder to bend. If they won't hold your favorite shape, try warming them gently over a candle flame before bending.
- Install the microphone element in MSE-5's "head" terminal by inserting the leads into the ports and tightening the screws. Condenser mic elements are polarized, so check the photo to make sure you've got it the right way 'round: the longer lead goes on MSE-5's right.

Step 14 — Test and adjust your robot.







- Making sure the power switch is in the inboard/OFF position, connect the battery pack power leads to the tail terminal block, as shown. The red lead goes in the left port, the black lead in the right. Tighten down the screws and make sure both leads are firmly seated.
- Hold the robot up off the floor, facing a sunny window, a flame, or an incandescent light bulb. With your fingers clear of the motors, flip the battery pack power switch. The red LED should come on, and one or both of the motors should start to spin.
- Test MSE-5's phototropism by angling the body so that first one eye, then the other, is pointed at the light. Then try covering each eyestalk with your hand. The motor *opposite* the eye that sees the brightest light should be much more active, and it should be rotating in the forward direction, as indicated by the green arrows.
- If a motor is turning in the wrong direction, simply turn off the power, disconnect its leads from the terminal block, and connect them the other way around.
- If the *wrong* motor is turning in response to light, i.e. the motor on the same side as the light source, the sensitivity of the audiotropic circuit may be set too low. Use a small screwdriver to adjust the port-side trimmer as needed.
- Finally, test MSE-5's audio response by blowing into the microphone element or loudly clapping your hands. When the "backpedal" circuit is tripped, the relay flips and reverses both which motor is active in response to light, and which direction that motor spins. This "fleeing" response is indicated by the red arrows.
- You can adjust the duration of the "fleeing" response using the starboard-side trimpot.

To show off MSE-5's light-seeking behavior, turn it loose on any smooth surface near a bright light source. A sunbeam on a kitchen floor is a great spot; MSE-5 will happily wander around

inside it as long as the batteries hold out. You can also lead it around with a bright flashlight beam, so long as there are not too many competing IR sources around. The sun is hard to beat, as IR sources go, and you'll find that, like a cat, MSE-5 is easily distracted by windows.

To observe the sound-reactive behavior, "startle" the 'bot with any loud sound like a clap or a shout. The condenser mic element has some directionality, so sounds in front of the robot are more likely to trigger the "flight" reflex than sounds from the rear. Hard impacts will often trigger the reflex as well, though not as reliably as the original Mousey's mechanical bump switch.

Speaking of, it would not be difficult to add a Mousey-style contact switch to the MSE-5 platform and turn it into a light-, sound-, and contact-responding design. The timing circuit that mediates the sound-activated "startle" response could easily be tripped by a mechanical switch, as well, and there's plenty of room right below MSE-5's "head," between the motors, to mount an additional small accessory with Superlock tape, and electrical access to the startle reflex through the microphone port immediately above.

Hmmmm...I wonder what else we could put there...

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