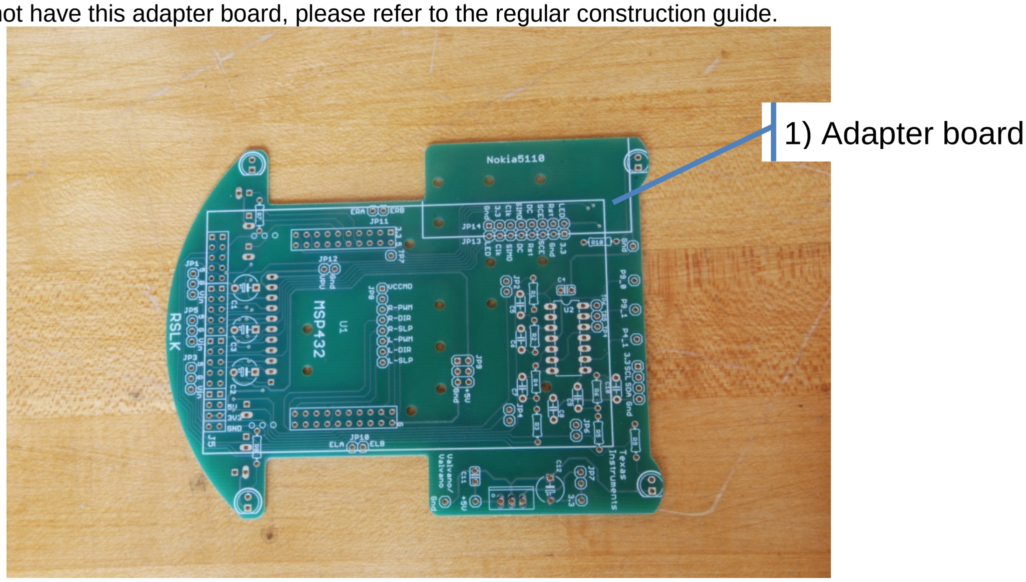
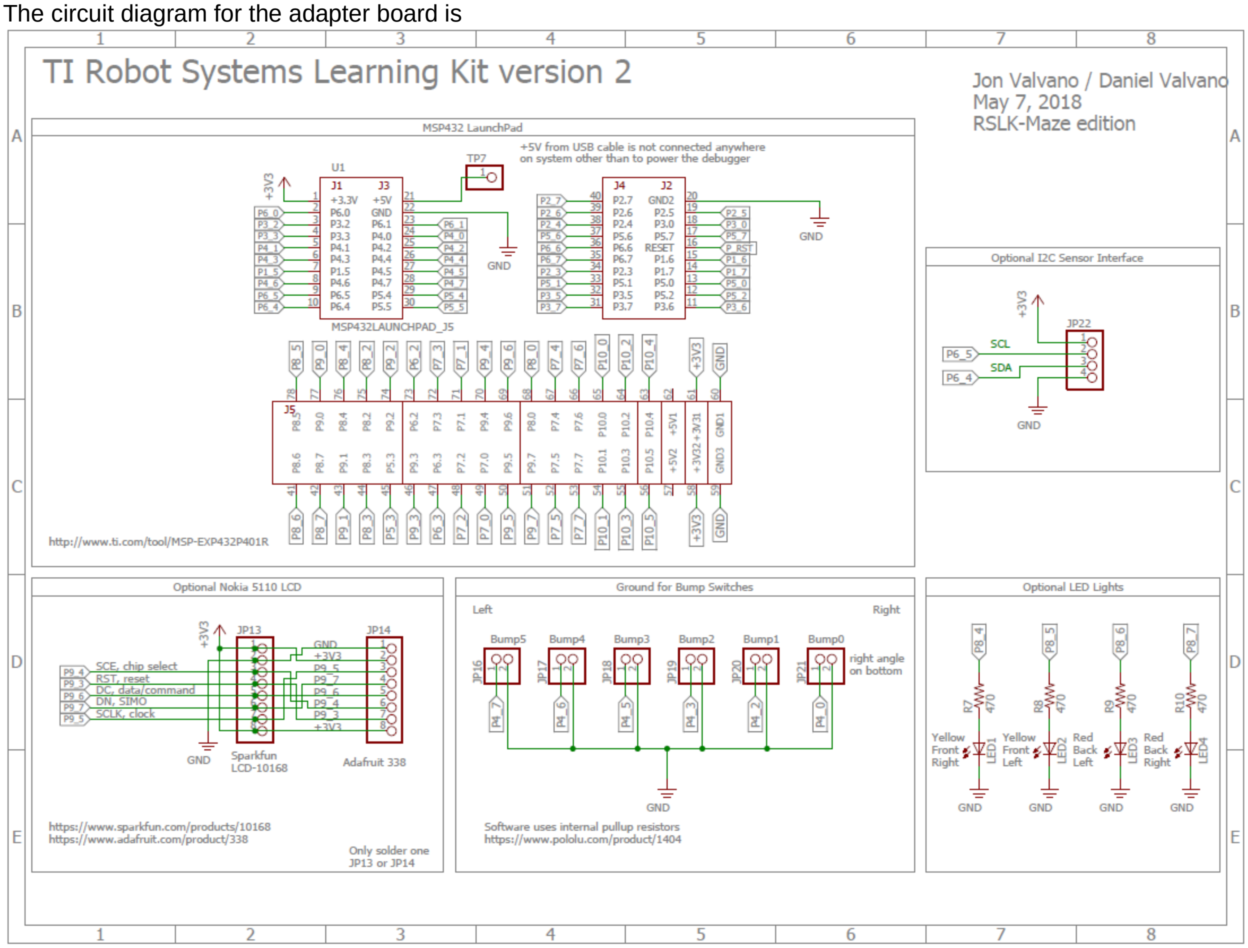
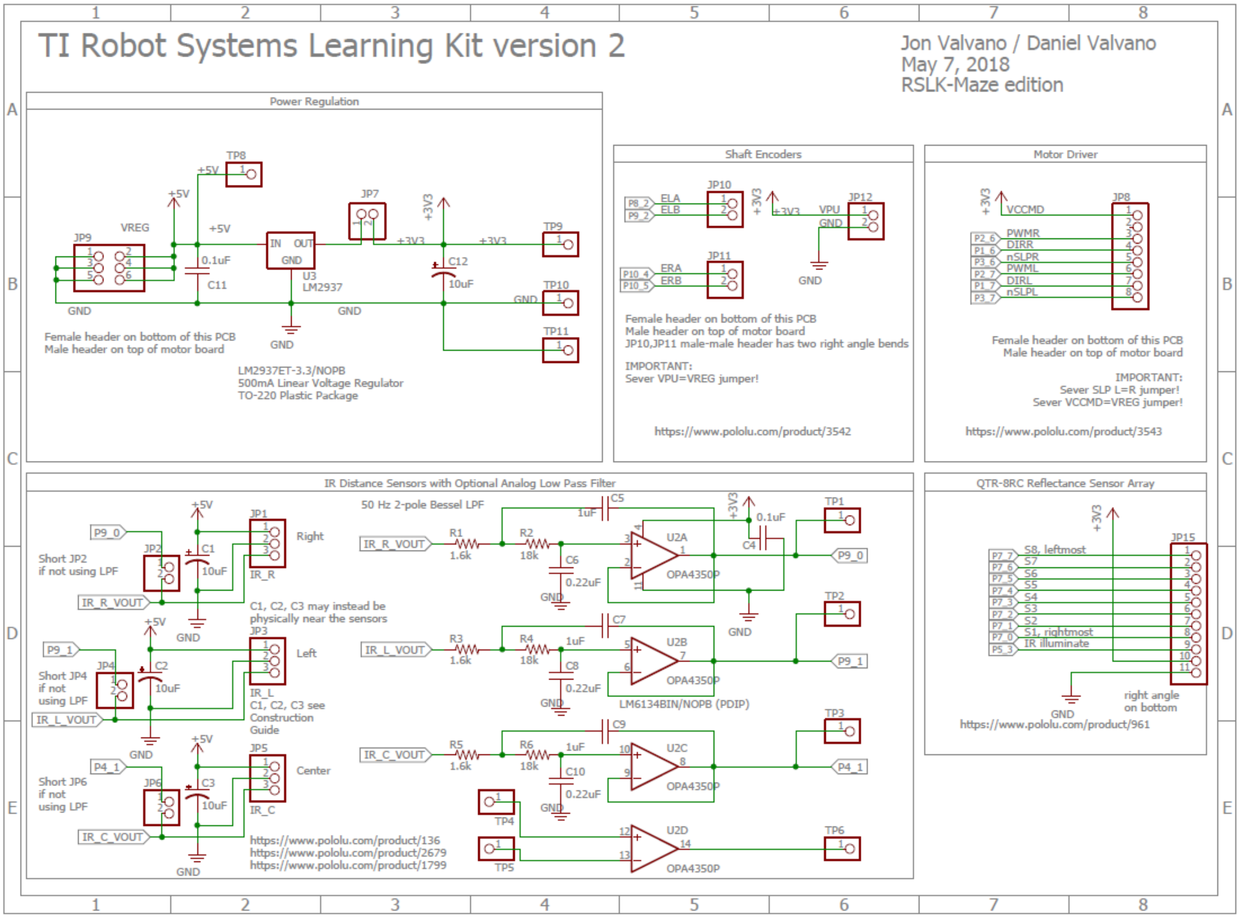
Robot Systems Learning Kit Construction Plan

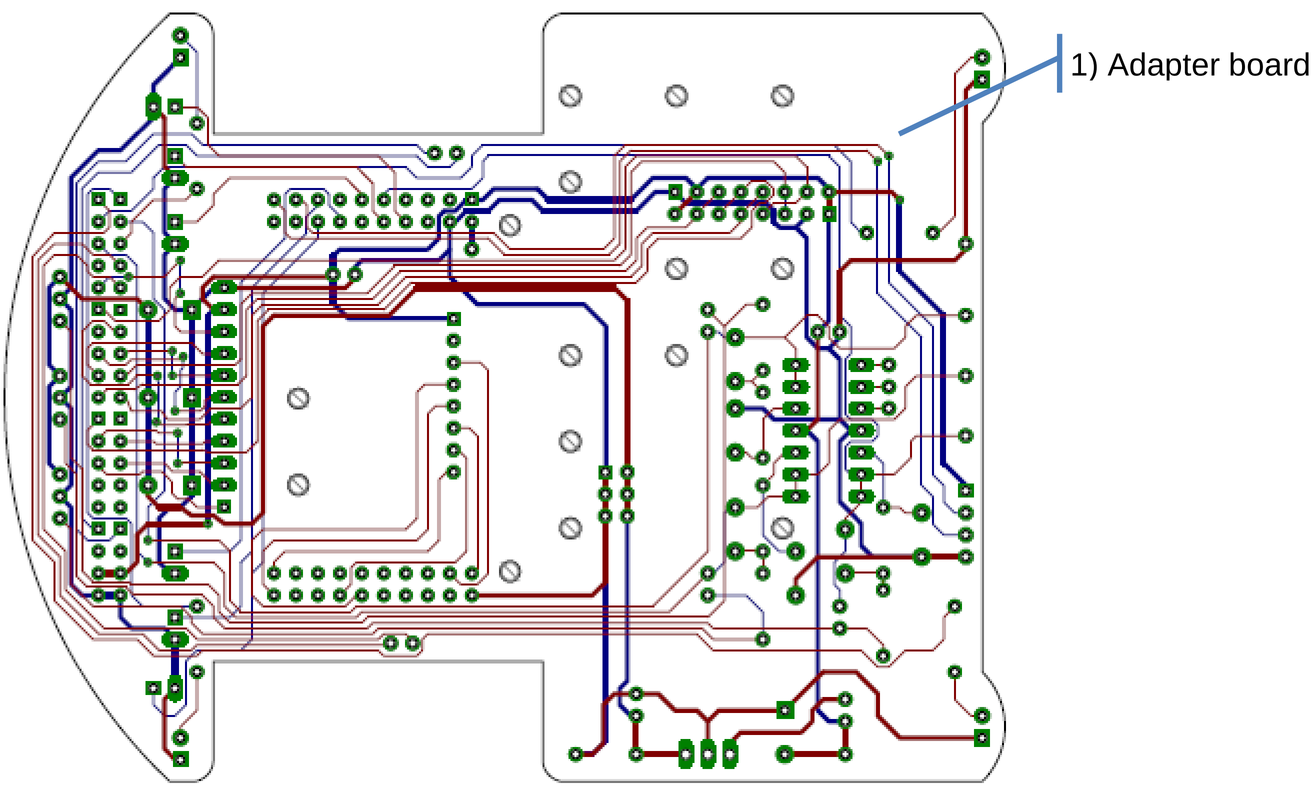
This is a guide to build the TI-RSLK Robot using the TI-RSLK kit purchased for the curriculum, plus the RSLK adapter board shown below. This board is optional. You can download, edit, and use the Eagle design files for this board. If you do not have this adapter board, please refer to the regular construction guide.



The circuit diagram for the adapter board is




TI Robot Systems Learning Kit version 2
Jon Valvano / Daniel Valvano
May 7, 2018
RSLK-Maze edition
Power Regulation
Female header on bottom of this PCB
Male header on top of motor board
LM2937ET-3.3/NOPB
500mA Linear Voltage Regulator
TO-220 Plastic Package
Shaft Encoders
Female header on bottom of this PCB
Male header on top of motor board
JP10,JP11 male-male header has two right angle bends
IMPORTANT:
Sever VPU=VREG jumper!
https://www.pololu.com/product/3542
Motor Driver
Female header on bottom of this PCB
Male header on top of motor board
IMPORTANT:
Sever SLP L=R jumper!
Sever VCCMD=VREG jumper!
https://www.pololu.com/product/3543
IR Distance Sensors with Optional Analog Low Pass Filter
50 Hz 2-pole Bessel LPF
Short JP2 if not using LPF
C1, C2, C3 may instead be physically near the sensors
Short JP4 if not using LPF
C1, C2, C3 see Construction Guide
Short JP6 if not using LPF
LM6134BIN/NOPB (PDIP)
https://www.pololu.com/product/136
https://www.pololu.com/product/2679
https://www.pololu.com/product/1799
QTR-8RC Reflectance Sensor Array
S8, leftmost
S1, rightmost
IR illuminate
right angle on bottom
https://www.pololu.com/product/961


1) Adapter board

Below is the **bill of materials** for the various options of the kit.

Adv	Basic	Upgrade	Part
1	1	0	red chassis
1	0	1	shaft encoder pair
1	1	0	Motor Driver and Power Distribution board
1	1	0	line sensor array with 8 sensors
2	0	2	IR bracket pair with 4 bolts and 4 nuts
3	0	3	IR sensors
3	0	3	IR cables
6	6	0	bump switches
1	1	0	LaunchPad: MSP-EXP432P401R
1	0	1	BLE: BOOSTXL-CC2650MA
1	0	1	Wifi: CC3120BOOST
1	1	0	Wire/ cables
1	1	0	8 - AA batteries
6	6	0	0.5in 4-40 plastic machine screw
1	1	0	3.25in white solderless breadboard
2	2	0	0.75in 4-40 metal standoff
8	8	0	0.187in 4-40 metal nut
4	4	0	1.375in 4-40 plastic standoff
2	2	0	0.5in 2-56 metal standoff
1	1	0	2x30, 0.1in male header
1	1	0	1x20, 0.1in, straight male header
1	0	0	1x8 straight male header (for Nokia 5110)
1	1	0	Heat Shrink Tubing, Flexible 0.175" Black 3.28'
1	1	0	1x14 right-angle male header
12	12	0	0.5in 2-56 screw for bump switches
3	0	0	10 µF Tantalum capacitors, 10% 20V (on IR sensors)
12	12	0	2-56 nuts for bump switches
1	1	0	Carbon 1/6W, 5%, 470, CFR-12JB-52-470R (used for lab, not robot)
1	1	0	Carbon 1/6W, 5%, 22k, CFR-12JB-52-22K (used for lab, not robot)
1	1	0	Carbon 1/6W, 5%, 33k, CFR-12JB-52-33K (used for lab, not robot)
1	1	0	Wirewound 5W, 5%, 10 ohm (used for lab, not robot)
2	2	0	Ceramic, Z5U, -20/+80%, 0.47 uF,C320C474M5U5TA (used for lab, not robot)
3	3	0	B3F-1052 tactile push button switch (used for lab, not robot)

In addition to the RSLK kit components you will need this parts to use with the adapter board

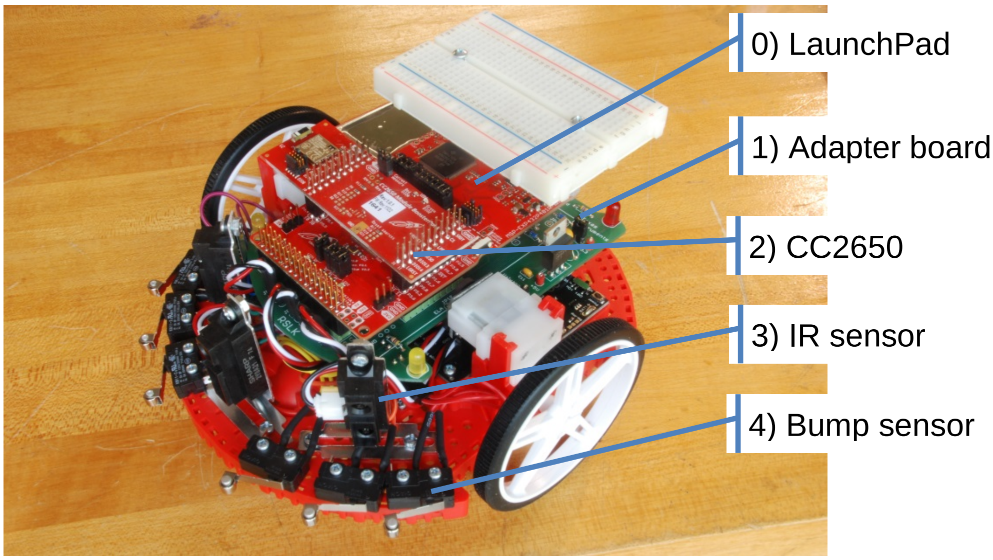
Components	Quantity	Description	Vendor	Part
U3	1	3.3v linear regulator, 500mA	TI	LM2937ET-3.3/NOPB
U2	1	quad op amp (PDIP)	TI	LM6134BIN/NOPB
LED3,LED4	2	Red LED HLMP-4700	Newark	40K0080
LED1,LED2	2	Yellow LED HLMP-4719	Newark	40K0081
J5	1	2 by 16 male/female header	Samtec	SSW-116-03-G-D
JP8	1	8 pin female	Samtec	SSW-108-01-G-S
JP9	1	2 by 3 female	Samtec	SSW-103-01-G-D
JP10,JP11,JP12	3	1 by 2 female	Samtec	SSW-102-01-G-S
R1,R3,R5	3	Carbon 1/8W, 1%, 1.6k resistor	Newark	38K5427
R2,R4,R6	3	Carbon 1/8W, 1%, 18k resistor	Newark	38K5433
R7,R8,R9,R10	4	Carbon 1/8W, 5%, 470, resistor	Newark	58K5123
C6,C8,C10	3	0.22 µF XR7 ceramic capacitor	Newark	18K5773
C5,C7,C9	3	1 µF ceramic capacitor	Newark	97M4165
C1,C2,C3,C12	1	10 µF tantalum (3 in kit)	Newark	26H0166
C4, C11	2	0.1 µF ceramic capacitor	Newark	76K4123
TP10,TP11	2	Black test points, Keystone 5001	Newark	62W5135
TP8,TP9	2	Red test points, Keystone 5000	Newark	07J9695
TP1,TP2,TP3	3	Orange test points, Keystone 5003	Newark	62W5137
JP7	1	2-pin shunt, 382811-6	Newark	91C5937 (JP2,JP4,JP6 are not used)
	3	1 by 12 male RA header, breakable	Newark	08N6738
	2	1 by 20 male header, breakable	Newark	08N6754
	3	2 by 20 male header	Newark	53K9098
	2	7/16 male-female spacer, 2-56	Newark	27T8851 or 27T8849

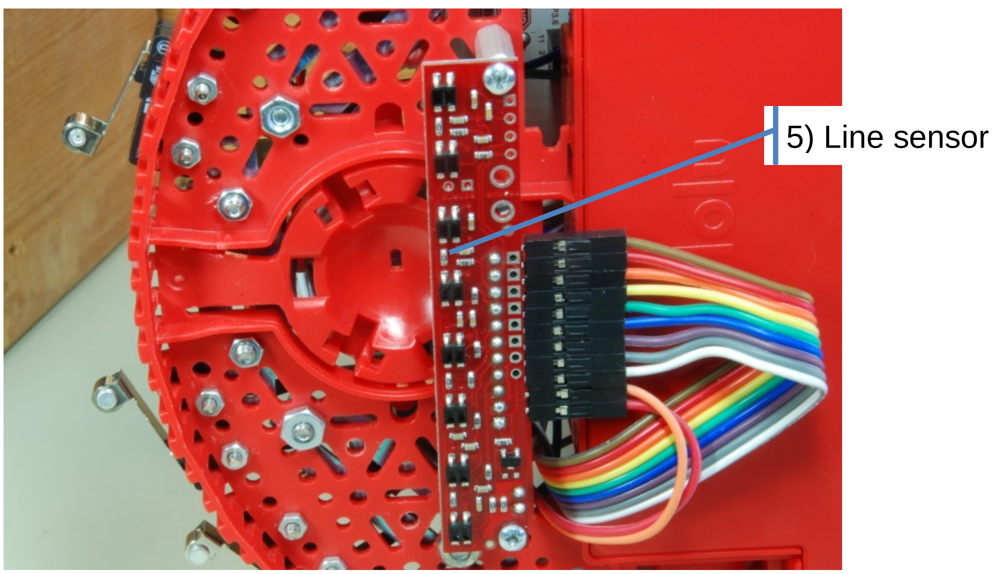
There are two TI-RSLK kits available: the TI- Basic and the Advanced. This adapter board can be used with either kit. This guide will help you build a robot and control its movements through BLE on your phone. For more infornation on the robot chassis, please go to www.polulu.com

https://www.pololu.com/product/3502

The following figure shows a completed robot with the adapter board. The TI RSLK robot will have

LaunchPad (0), which includes the MSP432 microcontroller,
Adapter board (1), which simplifies robot construction
CC2650 (2), which implements BLE
IR sensors (3), which measure distance
Bump sensors (4), which detects collisions, and
Line sensor (5), which can detect lines.



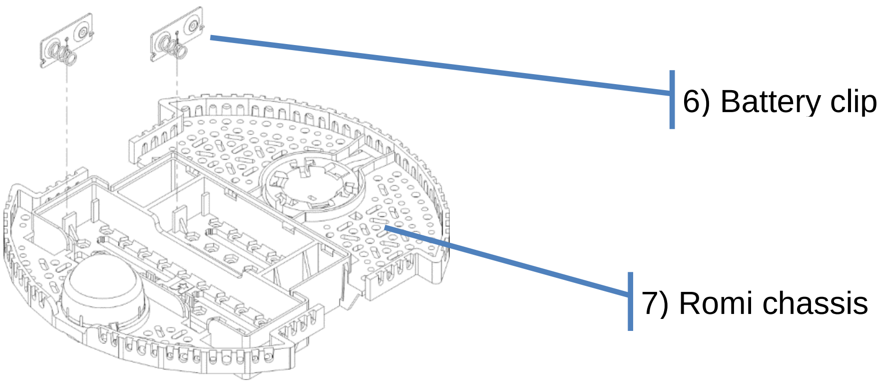


Stage 1) Configure the Romi chassis with snap-together steps.

Useful video: https://youtu.be/0MP7cw9P4x8

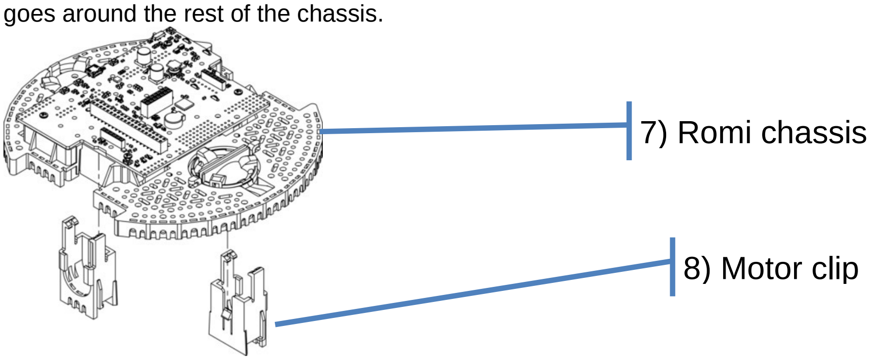
Step 1) Double-sided battery terminals

Attach the two double-sided battery terminals (6) into the chassis (7) by pressing them into their indentations inside the battery compartment. Be sure that the spring matches with the flat (negative) side of the battery. The battery polarity can be seen as outlines cut through the chassis. The Pololu website has a very detailed assembly guide on their website at: https://www.pololu.com/docs/0J68/4



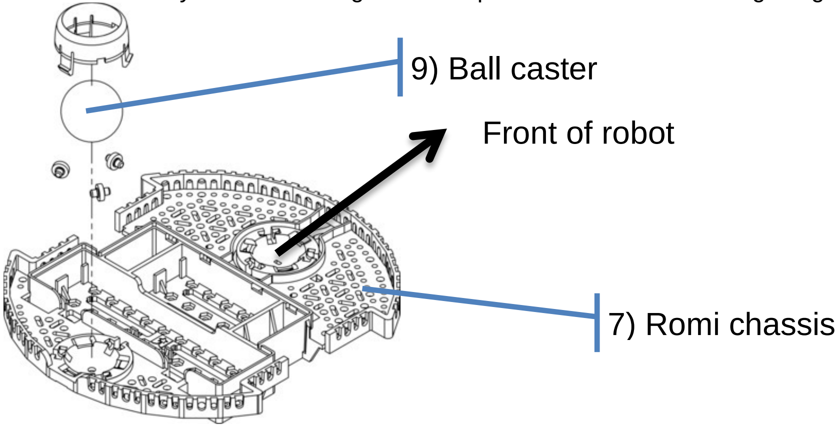
Step 2) Motor clips

Attach the two motor clips (8) to the chassis (7). They should slide into place from the bottom and hold snugly without needing glue. The clip part will point up, where it will eventually fit around the rectangular part of the motor gear box. The side that faces out towards the wheels has three little indentations that continue the same pattern that goes around the rest of the chassis.



Step 3) The ball caster

Attach the ball caster (9) to the back of the chassis (7). Be careful to use the slot in the back of the chassis; it will be the rigid one without the suspension. This provides the robot with stability with minimal additional friction. You might consider attaching the ball caster at the end of the robot construction, since it might be more convenient if the chassis can sit flat while you are attaching other components. See the following image from Pololu:

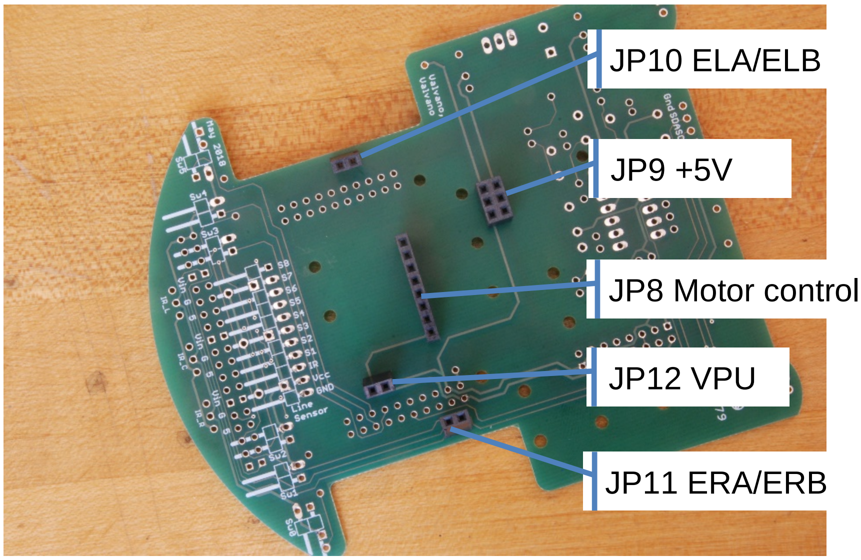


Stage 2) Configure the adapter board allowing it to connect to the MDPDB

Before you solder, you should position the MDPDB, the male headers, the corresponding female sockets, and the adapter board to verify proper orientation of all parts.

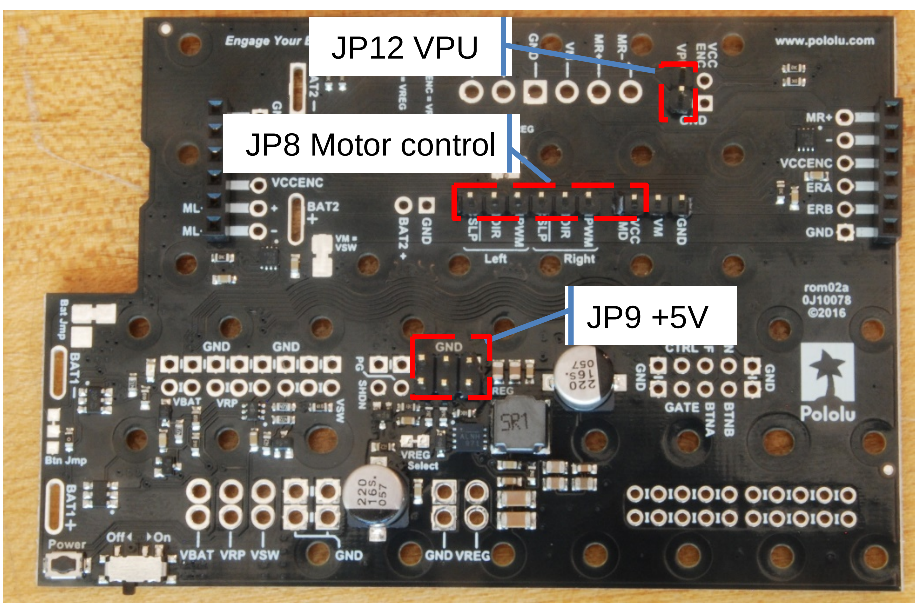
Step 1) Solder the 3 female sockets (JP8, JP9 and JP12) on the bottom of the adapter board.

The JP10 ERA/ERB and JP11 ELA/ELB sockets will be attached later.

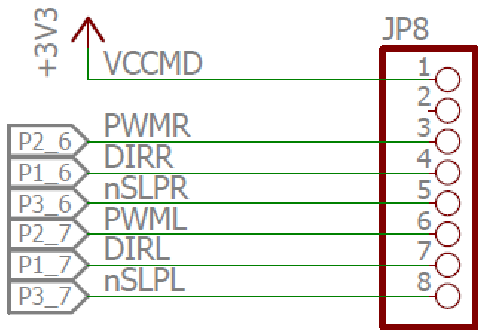


Step 2) Solder the corresponding 3 sets of male pins onto the MDPDB

ERA/ERB, ELA/ELB will be attached later. The JP8 male pins are 1 by 6 and 1 by 3, plugging into the 1 by 8 female header on the adapter board. The VM and ground pins to the right of JP8 will not be connected to the adapter board. The figure shows a 1 by 3 male soldered on the MDPDB. However, you could solder a single male pin into VCCMD and leave VM and GND without male pins. Notice there will be a single female socket on the adapter board JP8 between VCCMD and PWM(right) that is not connected.



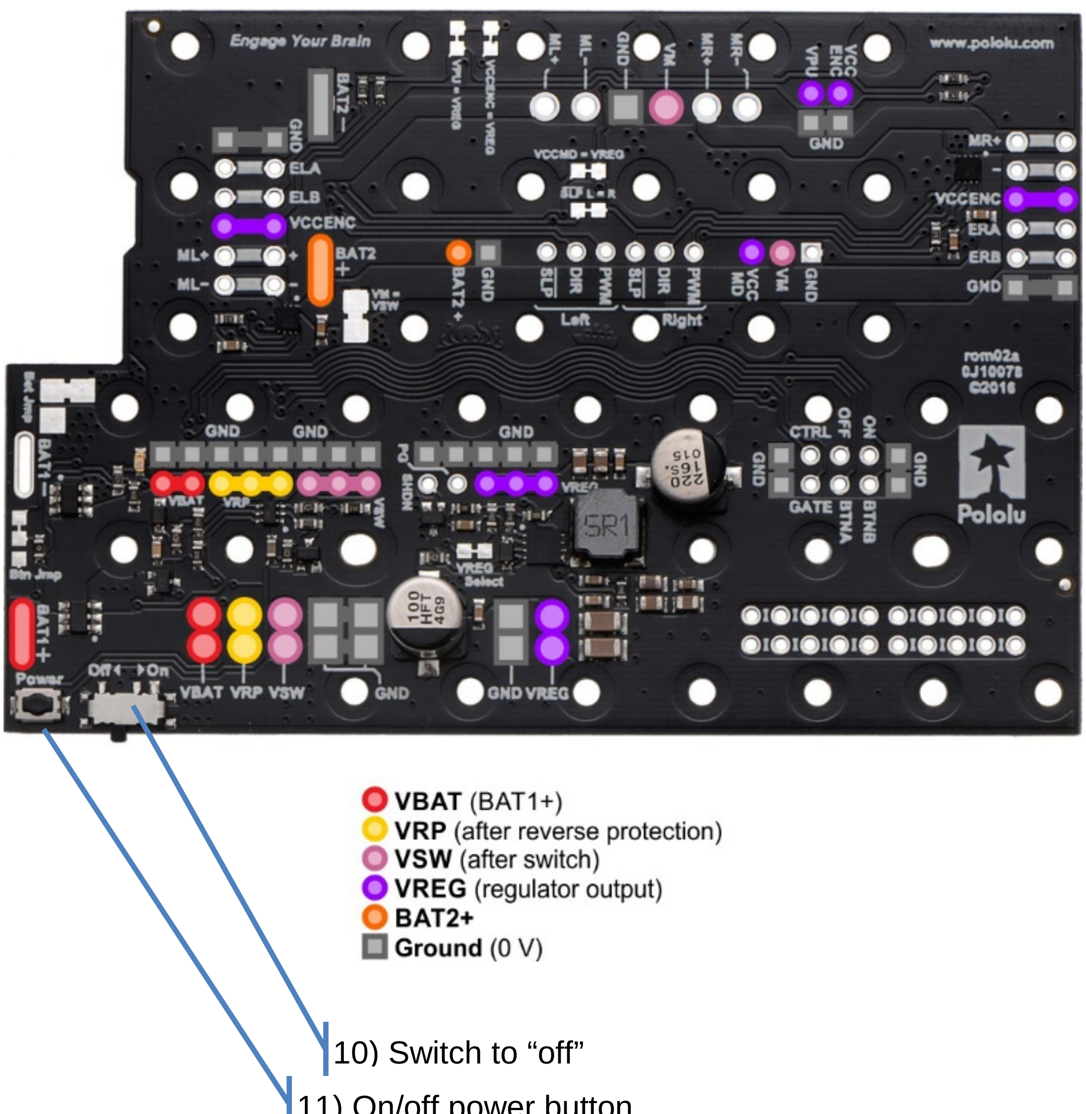
The adapter board will route the motor control pins to the appropriate pins on the MSP432



Stage 3) Configure the MDPDB for use on the robot.

Step 1) The Two Power switches

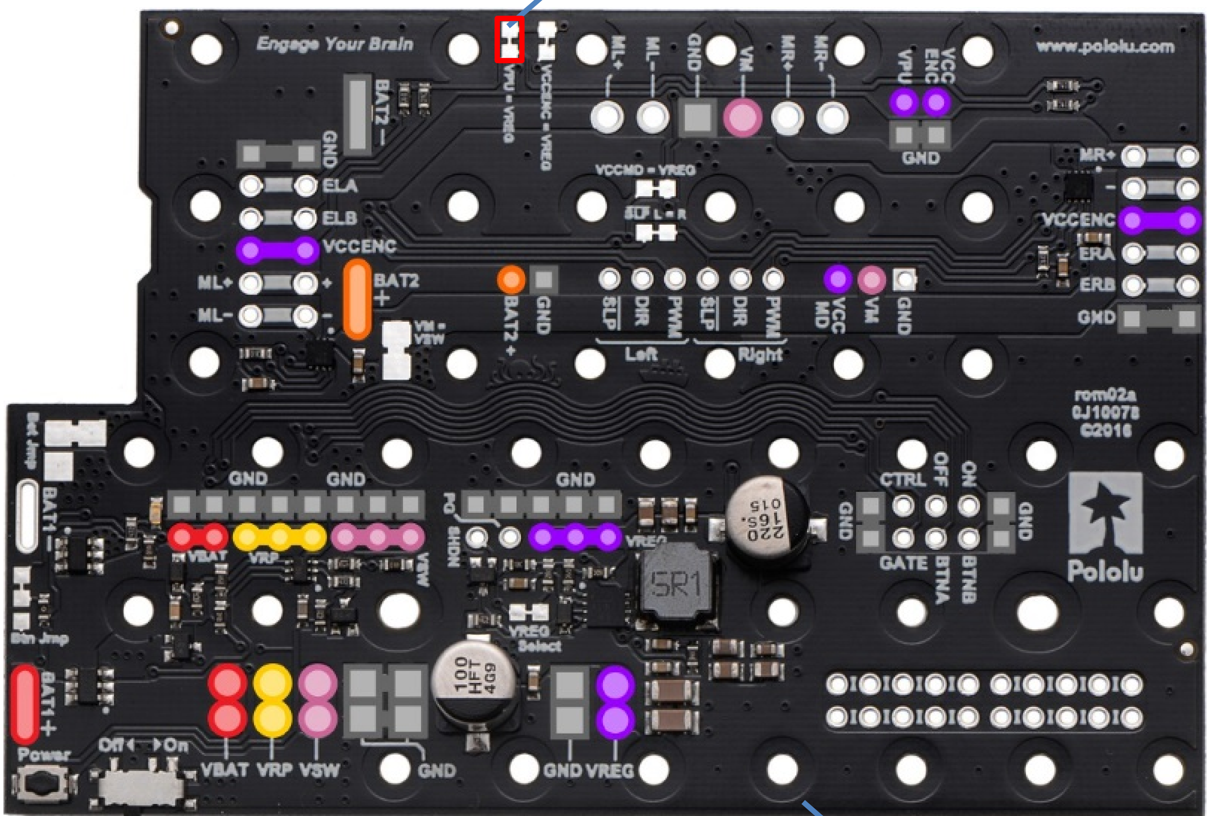
Move the switch to “Off” (10) and leave it in the “Off position” for the entire project. You will be pressing the “Power” button (11) to turn on and off the battery power to the robot.



Step 2) The VPU-VREG trace

Cut the **VPU—VREG** trace (12) on the **MDPDB** (13). This will allow the shaft encoders to run at 3.3V as required by the LaunchPad.

12) VPU-VREG trace

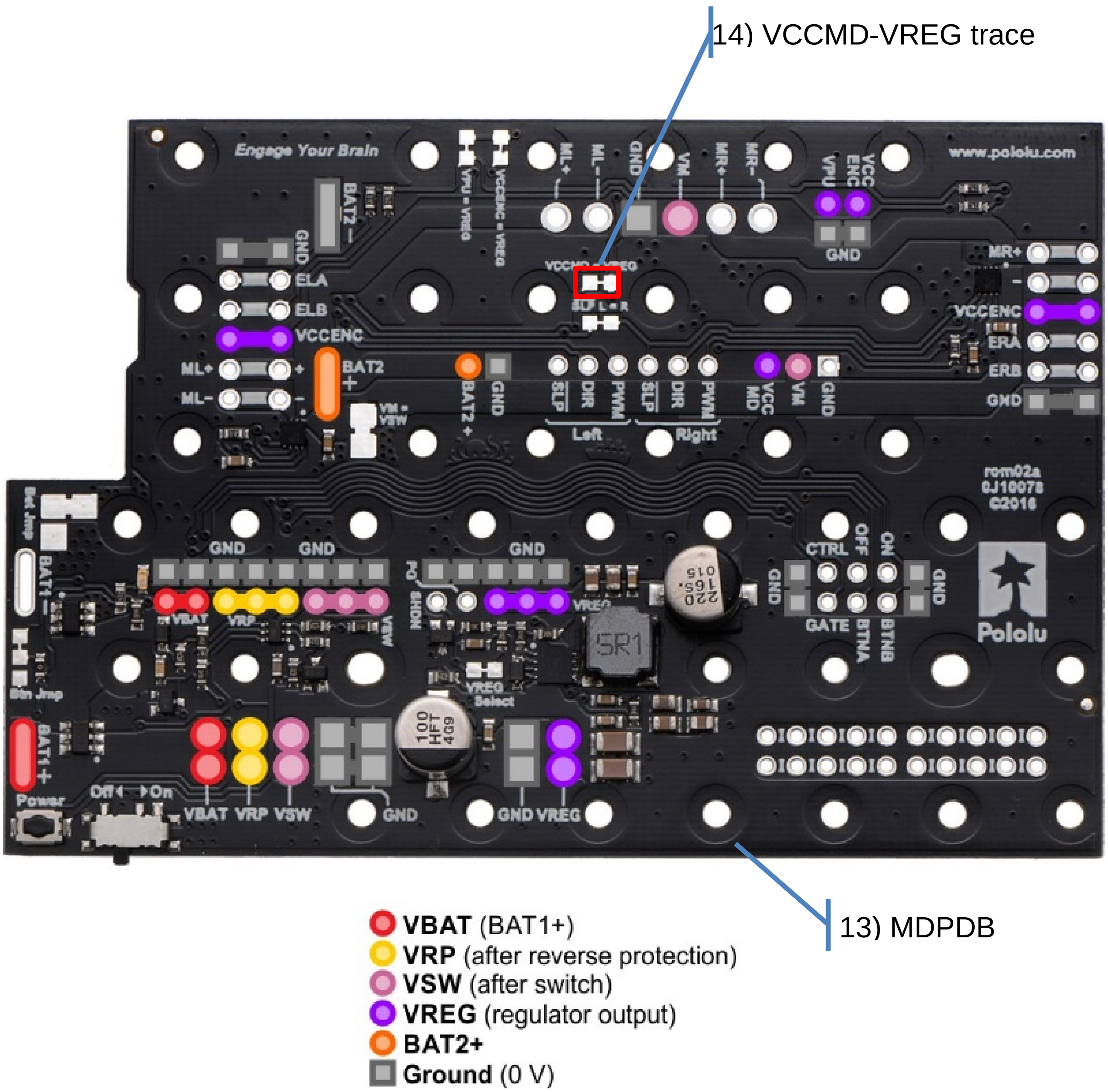


13) MDPDB

VBAT (BAT1+)
VRP (after reverse protection)
VSW (after switch)
VREG (regulator output)
BAT2+
Ground (0 V)

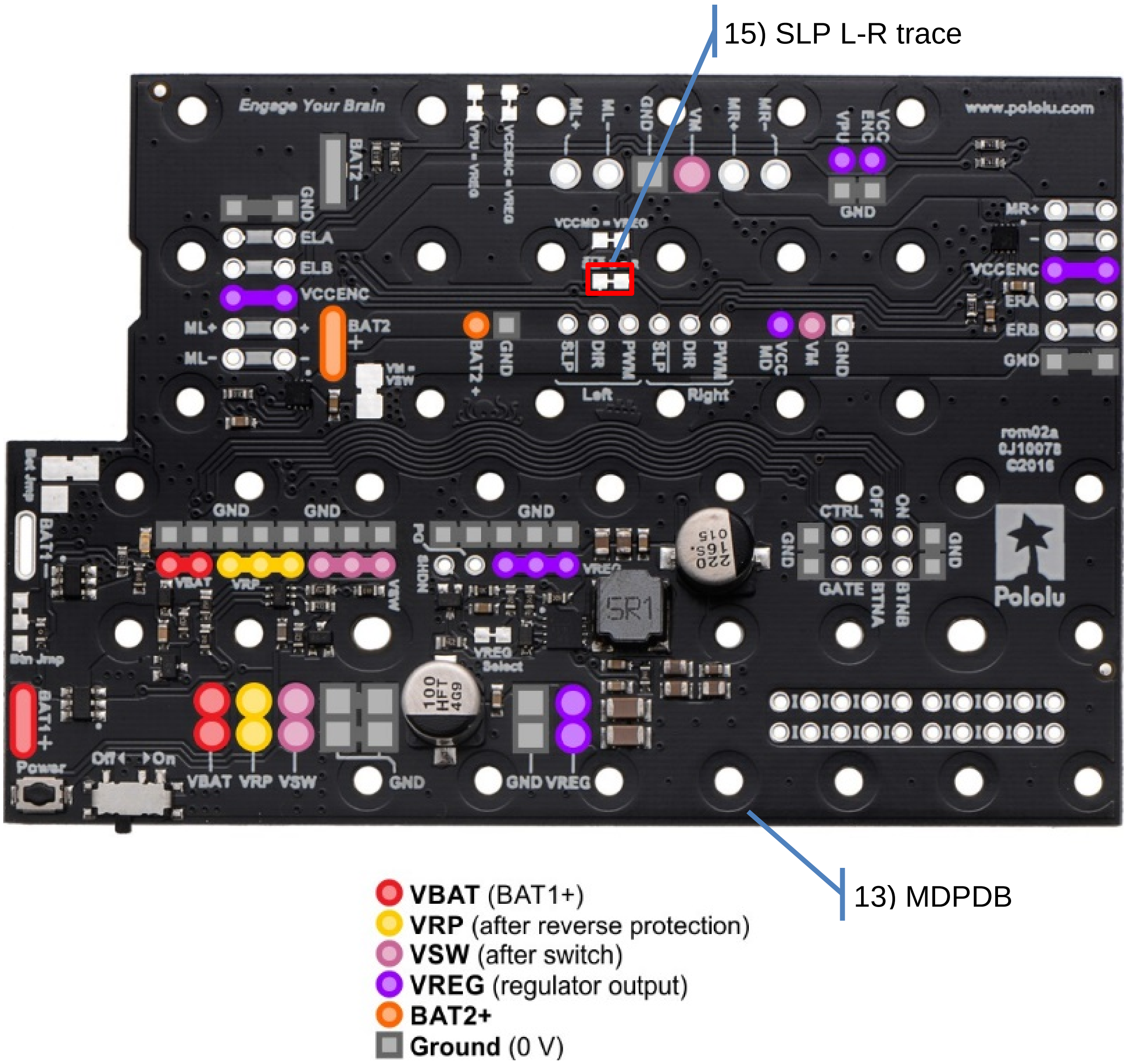
Step 3) The VCCMD-VREG trace

Cut the **VCCMD-VREG** (14) trace on the **MDPDB** (13). This will allow the DRV8838 motor driver chips to run at 3.3V to accept 3.3V inputs so the LaunchPad can control the motors.



Step 4) The SLP L-R trace

Cut the **SLP L-R** trace (15) on the **MDPDB** (13). This will allow the left and right motor driver chips to sleep separately from each other. Each of the sleep pins will be tied to a separate GPIO pin, so this trace must be cut.



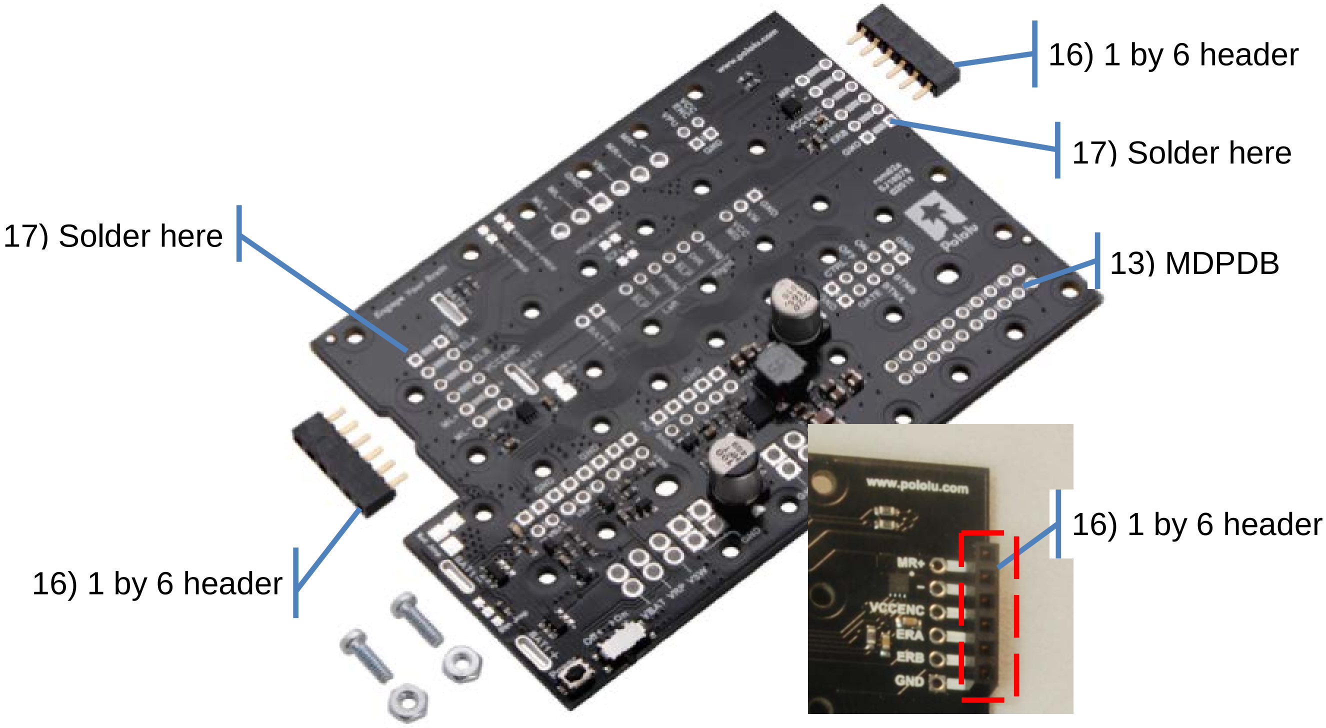
Step 5) Test the trace cuts

Use an ohmmeter to verify that the traces have been successfully cut.

Warning: double check the cut traces to make the exact one are cut and not any additional traces. You should have cut **VPU—VREG**, **VCCMD-VREG**, and **SLP L-R** traces.

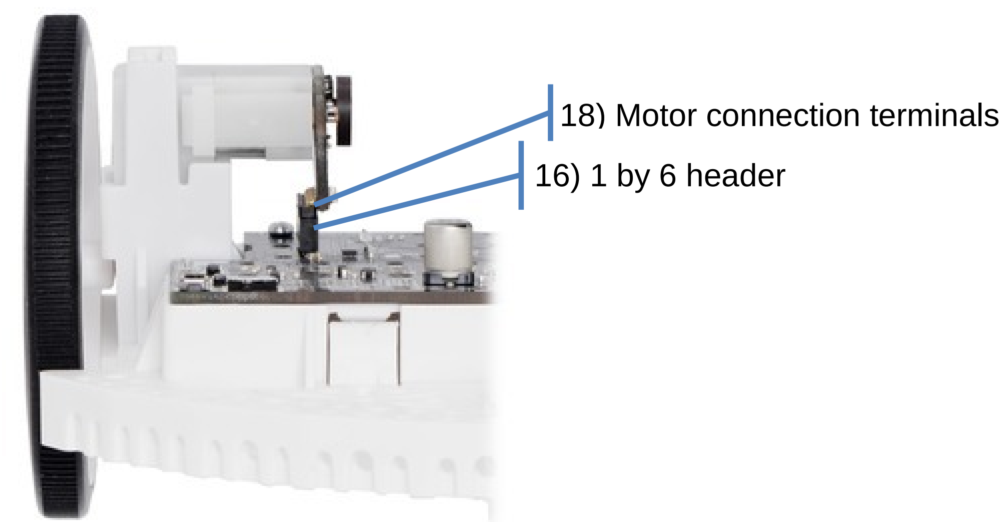
Step 6) Motor connection headers

Both the **MDPDB** (13) board and the **Romi Encoder Pair Kit** came with a pair of 1x6 female headers (16). Solder one pair in each column of motor connection terminals closest to the edge (17) of the **MDPDB** (13).



Motor Driver and Power Distribution Board for Romi Chassis with included hardware.

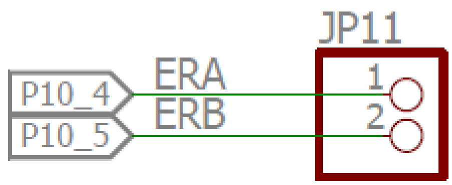
The motor connection terminals (18) are where the motors will physically plug in once they are inserted into the Romi chassis. The other pair of female headers is extra. Ultimately, it should look like this image from Pololu:



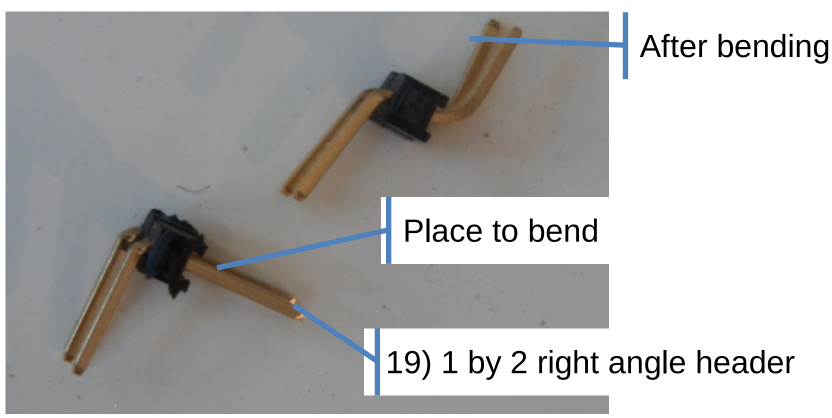
Before soldering anything together, it might help to arrange the components to visualize how it will ultimately look. Also consider Step 6):

Step 7) Shaft encoder headers

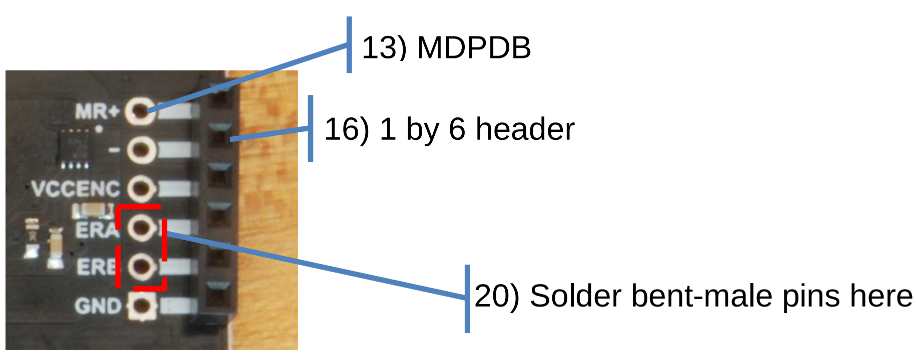
Basically, you need to connect ERA, ERB, ELA, and ELB from the MDPDB to the adapter board. The adapter board will route these four signals to the appropriate pins on the MSP432.

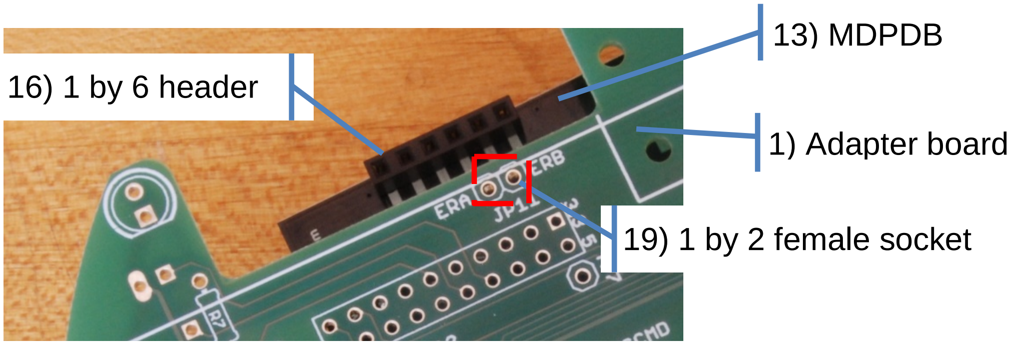


Break off two 1x2 male right-angle headers (19), and using two pliers make an additional 90 bend in each header so the male pins are parallel, but offset as shown in the figure.

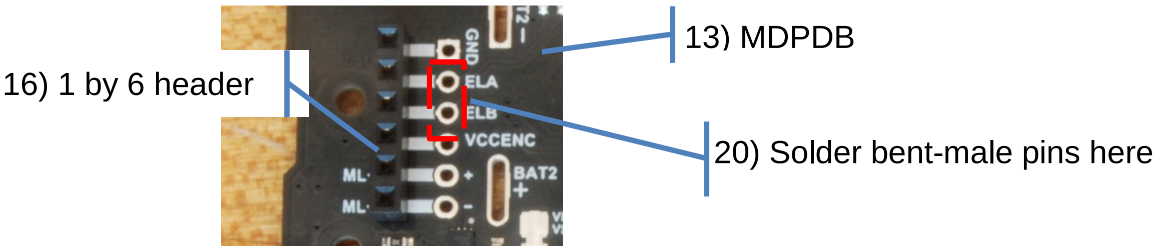


Solder the 2-pin header into the ERA/ERB position (20) not occupied by the 1 by 6 female header (16). The bends allow the connection to the adapter board to move away from the sides towards the center of the robot. Before you solder, you should position the MDPDB, the bent-male header, the 2-pin female socket, and the adapter board to verify proper orientation.

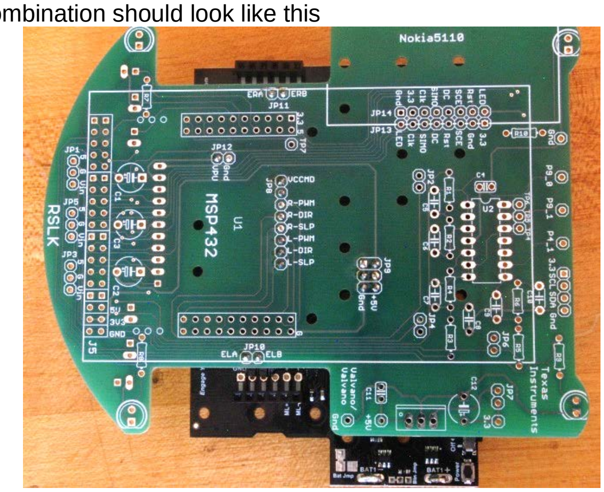




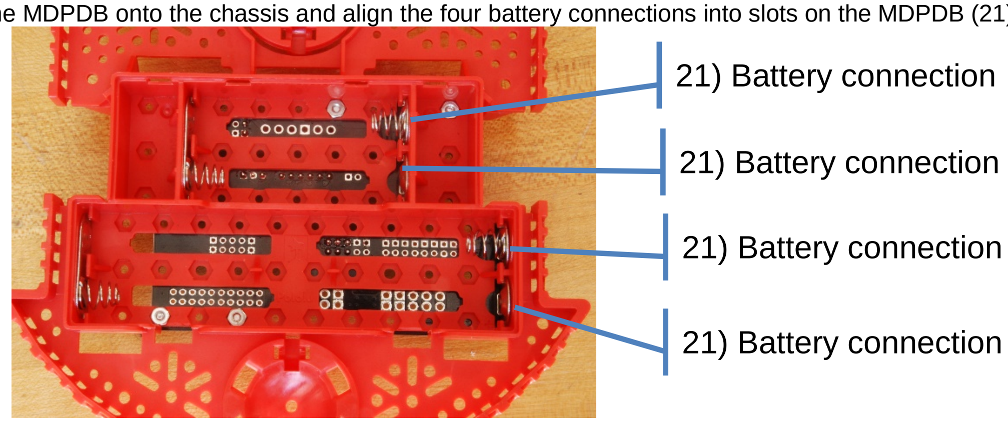
Repeat the process for the left side, connecting ELA and ELB. Again, before you solder, you should position the MDPDB, the bent male header, the 2-pin female socket, and the adapter board to verify proper orientation.



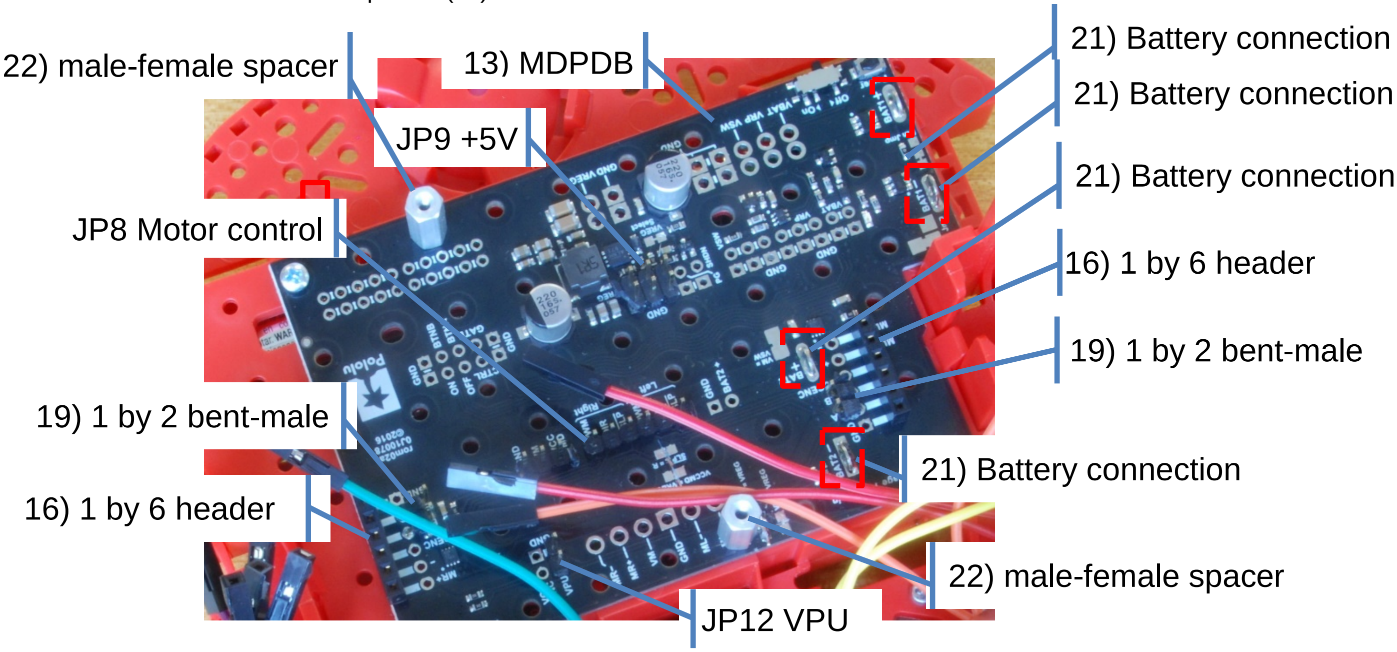
The resulting combination should look like this



Step 8) Solder the battery connectors onto the MDPDB
Place the MDPDB onto the chassis and align the four battery connections into slots on the MDPDB (21).

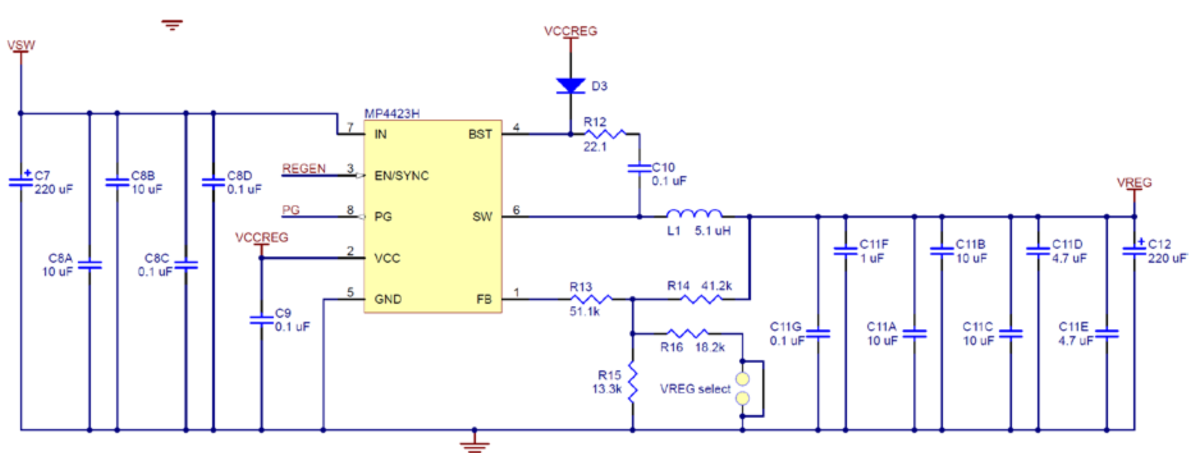


Solder the four connections (21). Mount the MDPDB to the chassis using two screws/nuts from the Pololu kit, and two 7/16 2-56 male-female spacers (22). The chassis MDPDB combination should look like this

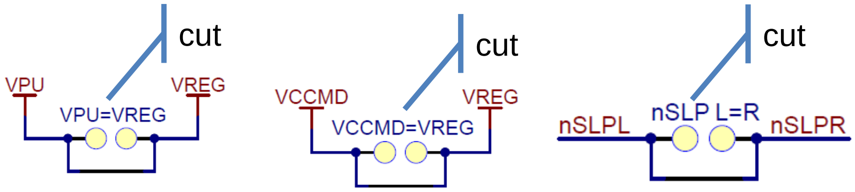


Step 9) Verify power on the MDPDB

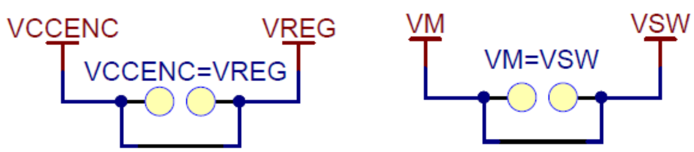
Place the 6 NiMH batteries in the storage area under the robot. At this point do not attach the adapter board, the motors, or the LaunchPad. Fully charged the 6 batteries will generate from 7.2 to 9 V, which is called VSW on the MDPDB. Each cell has about 1.5 V if fully charged, 1.25 V if 50% charged, and 1.0 V if almost fully discharged



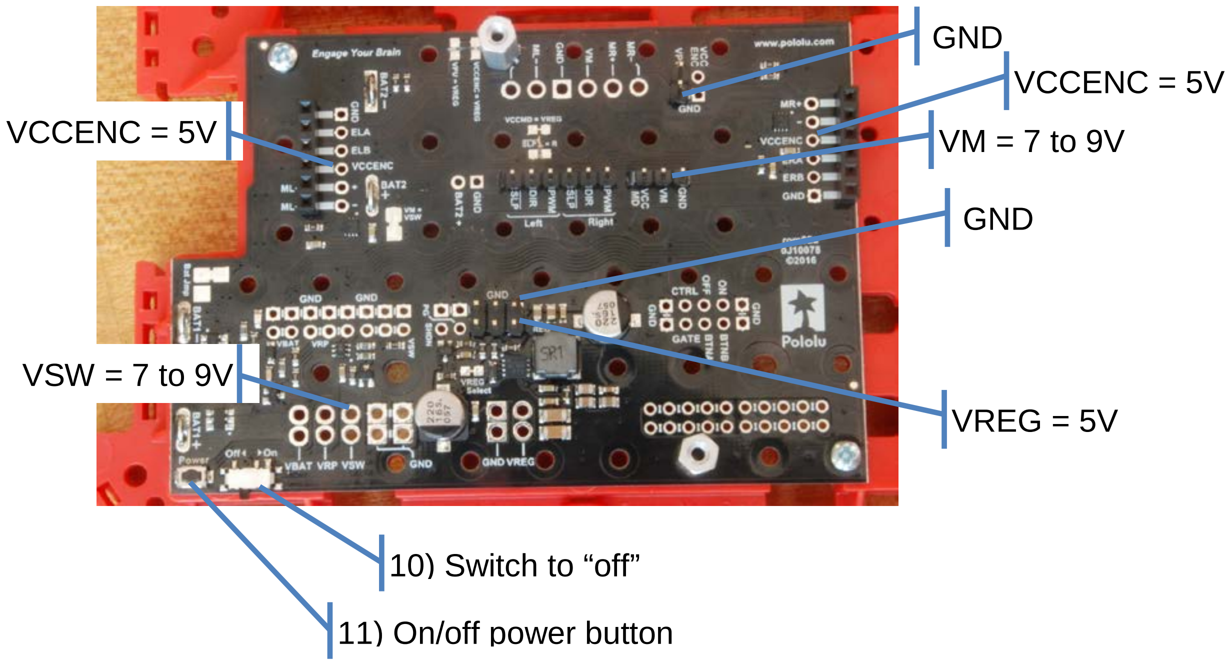
Recall, we cut the **VPU—VREG**, **VCCMD-VREG**, and **SLP L-R** traces. Therefore, at this point, VPU and VCCMD will not have power. VPU and VCCMD will eventually be 3.3V once the robot is complete.



We did not cut the **VCCENC-VREG** or **VM-VSW** traces.



Connect the ground probe of a voltmeter to ground on the MDPDB. Slide the power switch (10) to “off”. Placing the switch (10) in the off position allows the power button (11) to turn on and off the power. Press the power button (11) and probe the MDPDB for the expected voltages as shown in the following figure.



Stage 4) Complete the adapter board

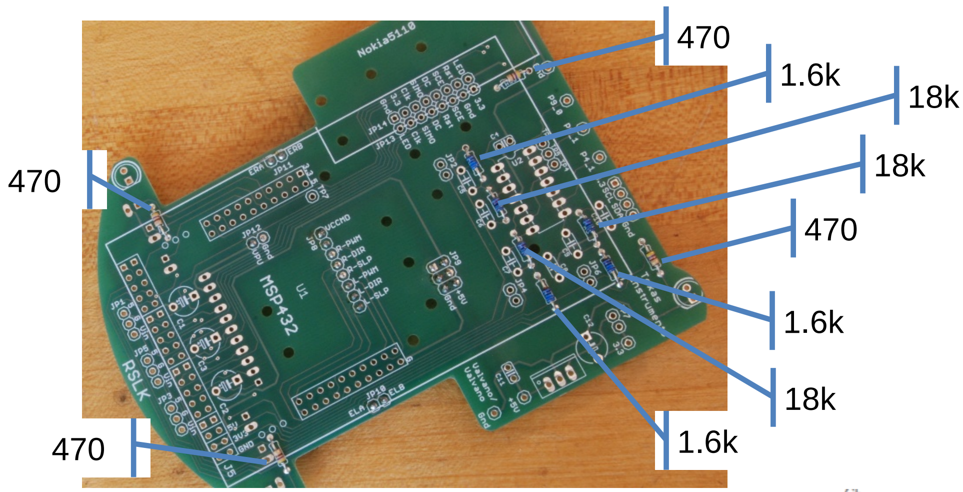
There are a couple of strategies for soldering a PCB. One approach is to solder components from bottom to top (connect components positions on the bottom side, then the top side). A second approach is to solder components from smallest (shortest) to largest (tallest). This approach prevents the large components from obstructing the soldering of the small components. We will follow the smallest to largest strategy in this guide. We suggest you assemble all the remaining components to be soldered onto the adapter board, and create your own strategy. I.e., read through the steps of this stage before soldering.

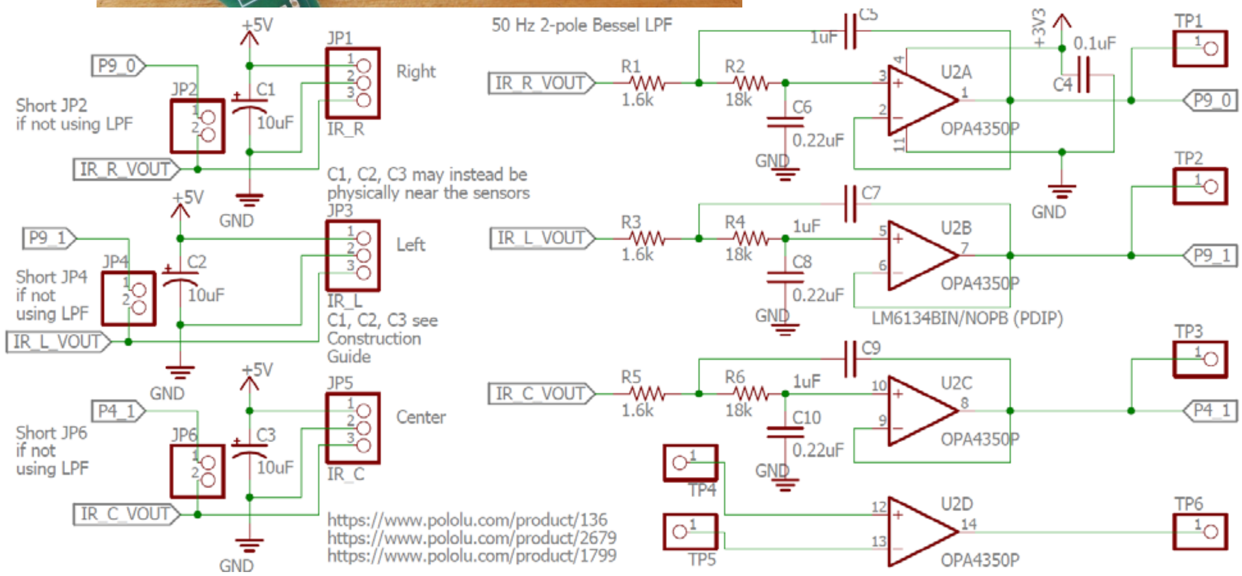
If you do not plan to implement the low-pass analog filter with the op amp you can jumper JP2, JP4, JP6 and not connect R1, R2, R3, R4, R5, R6, C4, C5, C6, C7, C8, C9, C10, U2, TP1, TP2, and TP3. The low-pass analog circuit uses three of the four op amps on U2. If you wish to use the fourth op amp, you can connect to TP4, TP5 and TP6.

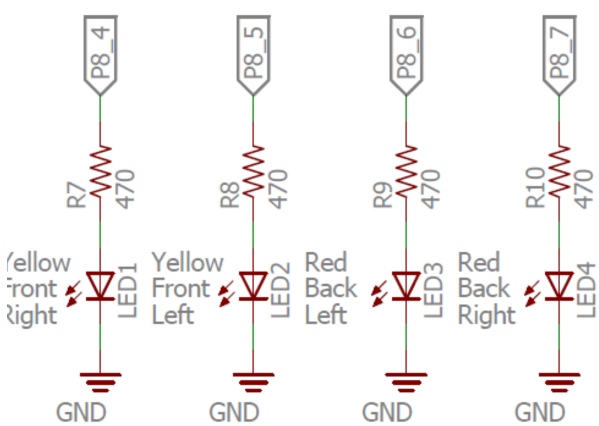
Step 1) Resistors

Solder the 10 resistors first, because they are the smallest components

R1,R3,R5	Carbon 1/8W, 1%, 1.6k resistor
R2,R4,R6	Carbon 1/8W, 1%, 18k resistor
R7,R8,R9,R10	Carbon 1/8W, 5%, 470, resistor



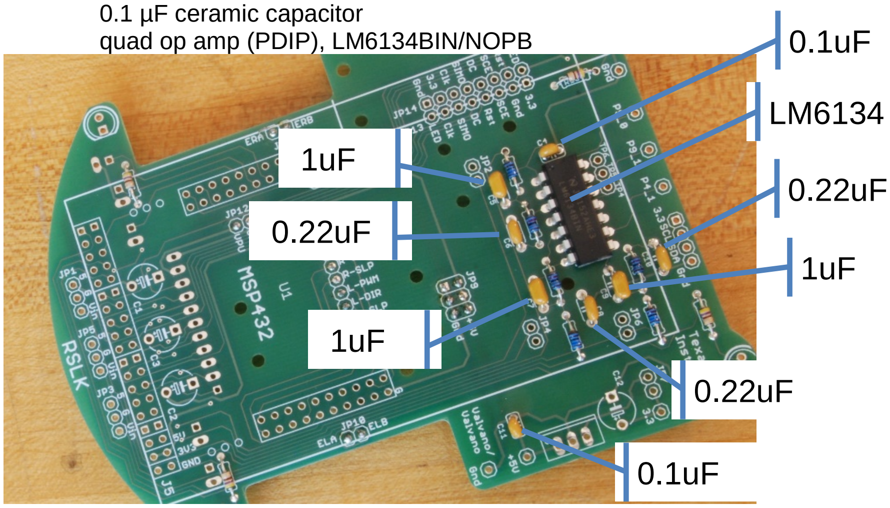




Step 2) Ceramic capacitors and op amp

Solder the 8 ceramic capacitors and the op amp. Make sure pin 1 of the op amp is aligned to pin 1 on the board

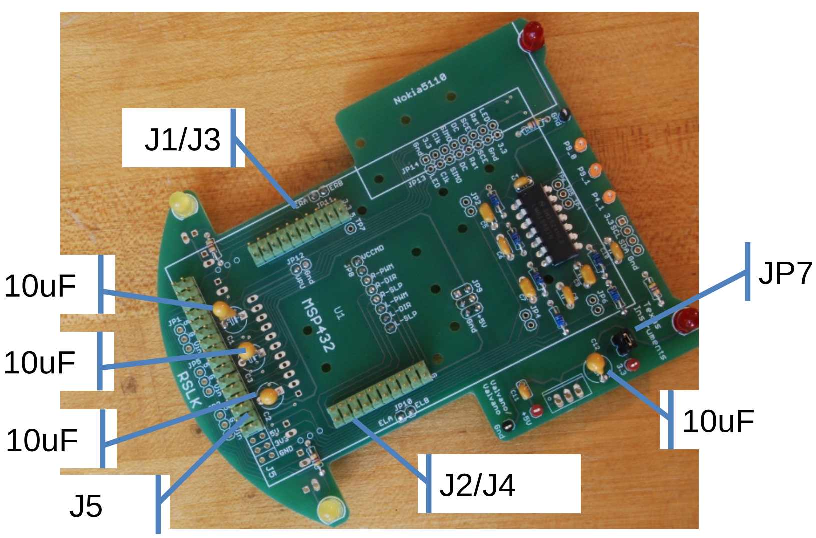
C6,C8,C10	0.22 µF XR7 ceramic capacitor
C5,C7,C9	1 µF ceramic capacitor
C4, C11	0.1 µF ceramic capacitor
U2	quad op amp (PDIP), LM6134BIN/NOPB



Step 3) Tantalum, LED, test points and headers.

Solder the tantalum capacitors, LEDs, LaunchPad headers, power shunt, and test points. JP2,JP4,JP6 are not connected if using the op amp circuit. Make sure the tantalum capacitors are soldered with the + terminal of the capacitor aligned with the +terminal of the adapter board. The top of the adapter board has male pins that will connect to the female sockets on the bottom of the MSP432 LaunchPad. Notice, 6 pins on the left side of the adapter board J5 will not be connected (5V, 3V3, GND)

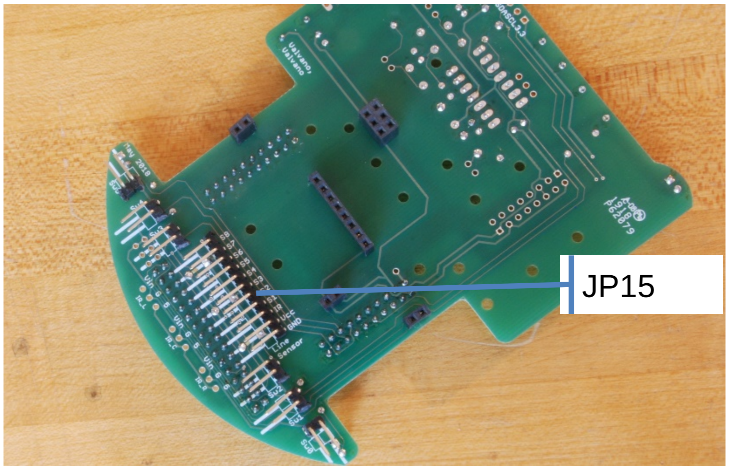
C1,C2,C3,C12	10 µF tantalum
LED3,LED4	Red LED HLMP-4700 (in back)
LED1,LED2	Yellow LED HLMP-4719 (in front)
TP10,TP11	Black test points, Keystone 5001
TP8,TP9	Red test points, Keystone 5000
TP1,TP2,TP3	Orange test points, Keystone 5003
JP7	2-pin shunt, 382811-6
J1/J3, J2/J4	2 by 10 male headers
J5	2 by 16 male headers

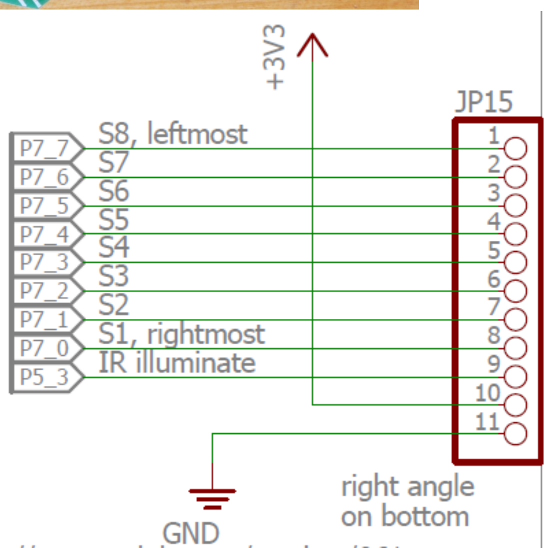


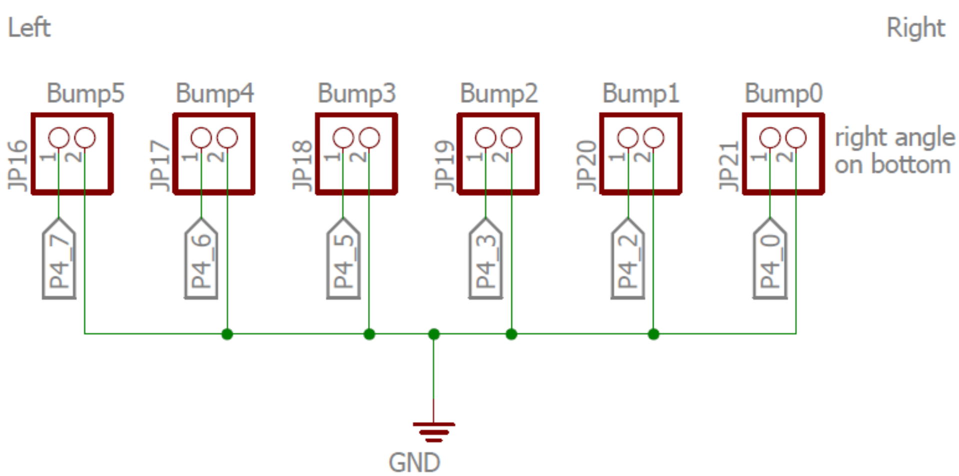
Step 4) Right-angle sensor headers.

Solder the right angle headers on the bottom of the adapter board. These will allow connection to the 6 bump sensors and the line sensor. The adapter board will route the sensor signals to the appropriate pins on the MSP432.

JP15	1 by 2 right angle male header for line sensor
JP16, JP17, JP18, JP19, JP20, JP21	Six 1 by 2 right angle male headers for bump switches



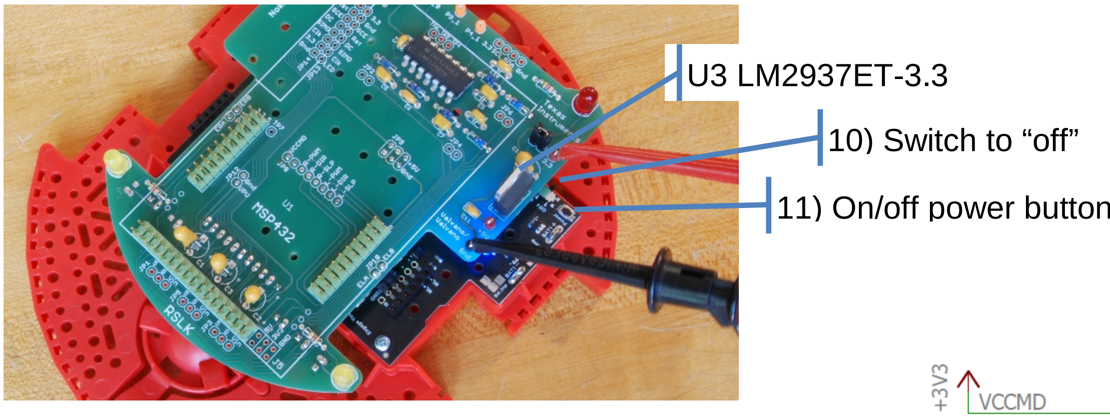


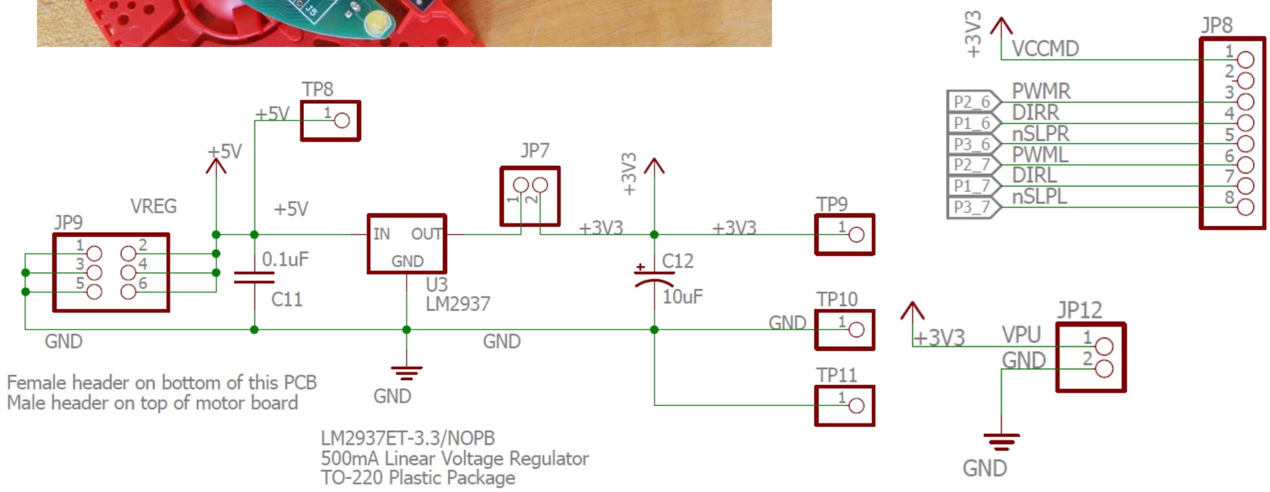


Step 5) +5V regulator.

Solder the U3, 3.3v linear regulator, LM2937ET-3.3/NOPB. This regulator takes the +5V from the MDPDB (VREG) and creates +3.3V for the MSP432, Nokia 5110, and the op amp. 3.3V will also be routed back into the MDPDB on the VPU and VCCMD lines. At this point you can test the regulator, by combining the 6 NiMH batteries (7.2V), the chassis, the MDPDB, and the adapter. When the power button is activated (11), the LED on the MDPDB should activate, the +5V pin on the adapter should be 5V, and the +3.3V pin on the adapter should be 3.3V.

If the 3.3V line measures 5V, double check the connections which should have been cut in Stage 3 step 2.

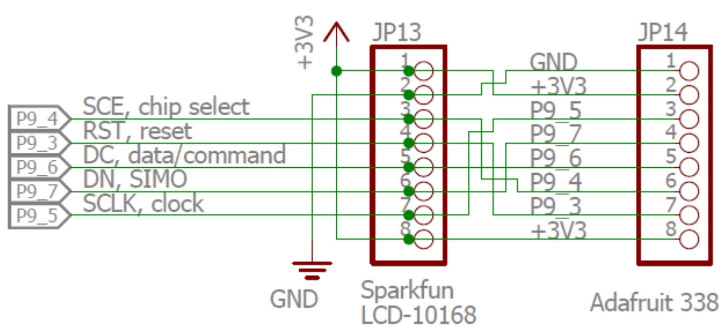




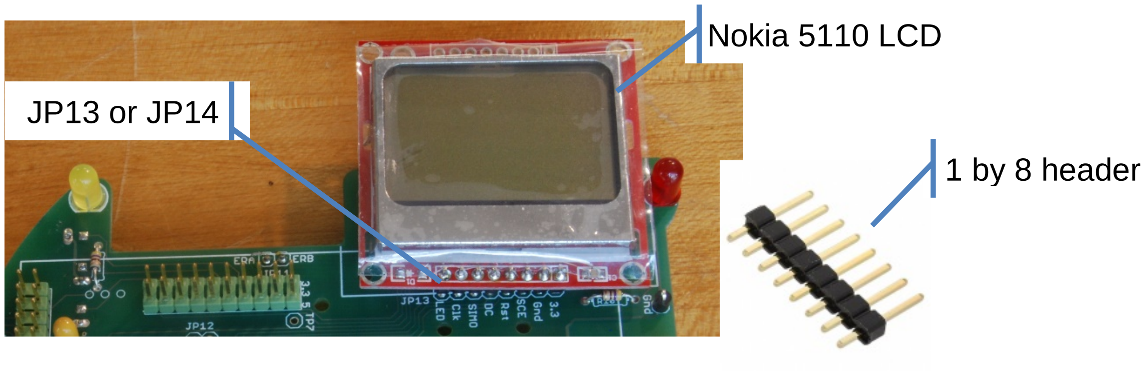
Step 6) Nokia 5110.

If you have a Nokia 5110, it can be directly soldered to the adapter board. Notice there are two places JP13 or JP14 into which you could connect the LCD. The Nokia 5110 will also have two rows of 8 holes. In general, the two sets of holes allow the screen to be installed in different orientations. However, there will only be one configuration that will be correct. Double check the datasheet for your specific part to avoid soldering your display in a manner that will not operate. After you are sure of the connections, break off a 1x8 male header and solder it into the row of terminals on the **Nokia 5110**.

Please test your LCD on a solderless breadboard connected to a MSP432 LaunchPad before soldering it to the adapter PCB. This way you can make sure your LCD works and double check the pin connections between the LaunchPad and the LCD. Bad contact between red PCB and metal cased LCD causes 5110 screen flicker and continual contrast variation, or bad contact can cause it to not work at all.



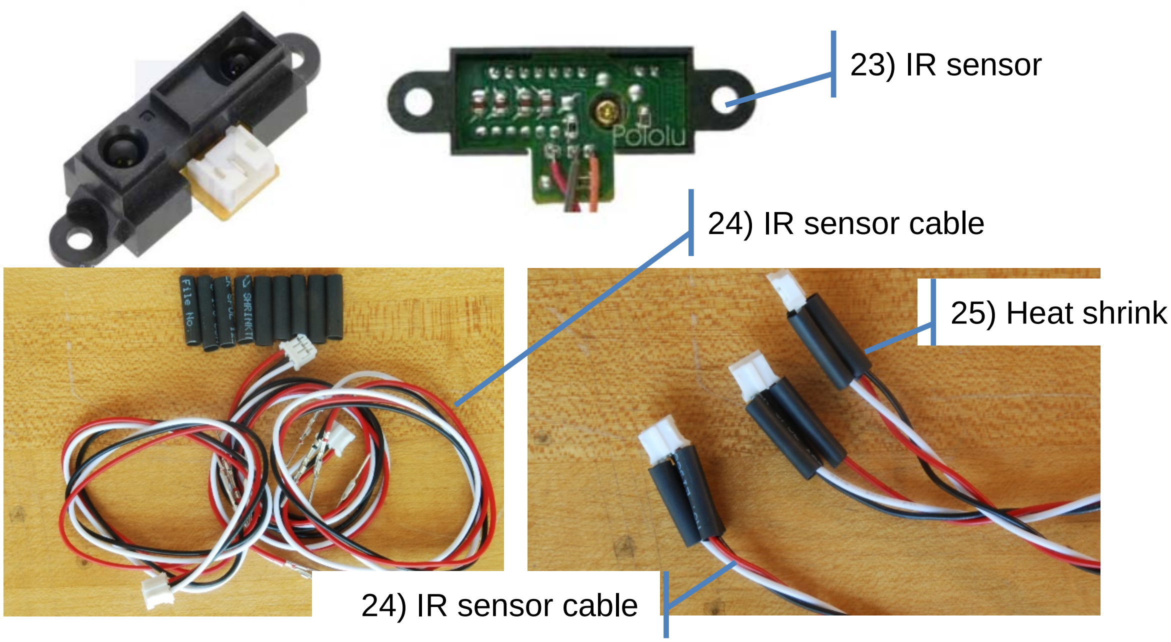
https://1111zz.wordpress.com/2017/11/30/nokia-5110-bad-contact-between-pcb-and-lcd/



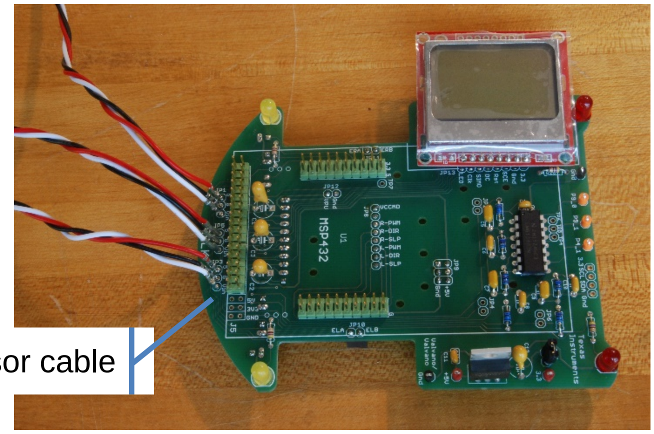
Stage 5) Interfacing the sensors

Step 1) Prepare the IR sensor cables

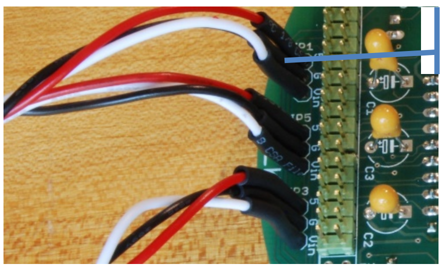
You will interface the IR sensors (23) using the IR sensor cables (24). Cut 9 pieces of heat shrink (25) and thread them onto the 9 wires of the three cables. Braid each three-wire cable to minimize surface area between ground and signal on the cable.



Solder the 9 sensor wires to the top of the adapter board. Make sure the +5V, ground and signal wires are appropriately connected.



Slide the 9 pieces of heat shrink over the 9 pins and use a heat gun to shrink the tubing

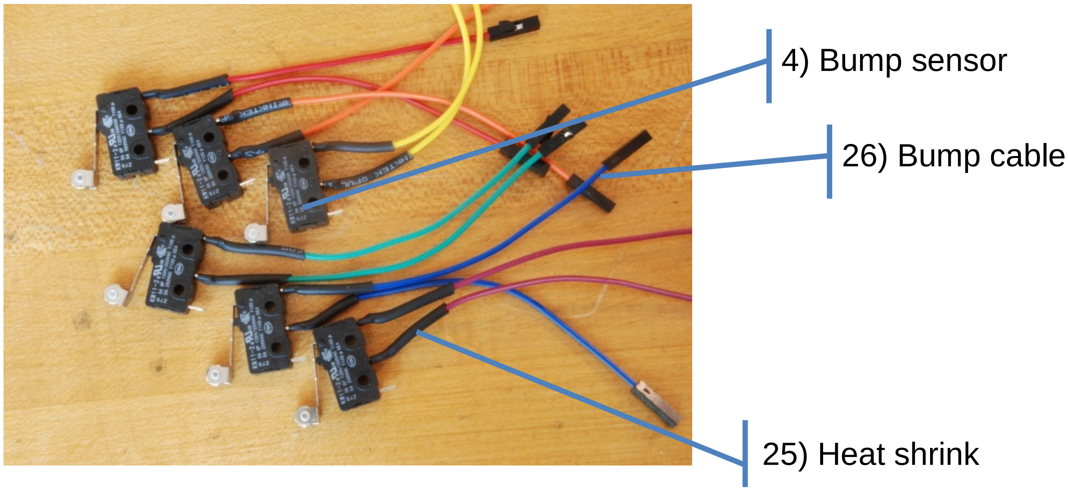


Step 2) Prepare the bump switches

Cut 12 pieces of heat shrink (25) about 3/4 inch long. Separate 12 individual wires (26) from the ribbon cable. In this guide, we cut 6 female-female wires in half to create the 12 individual wires.

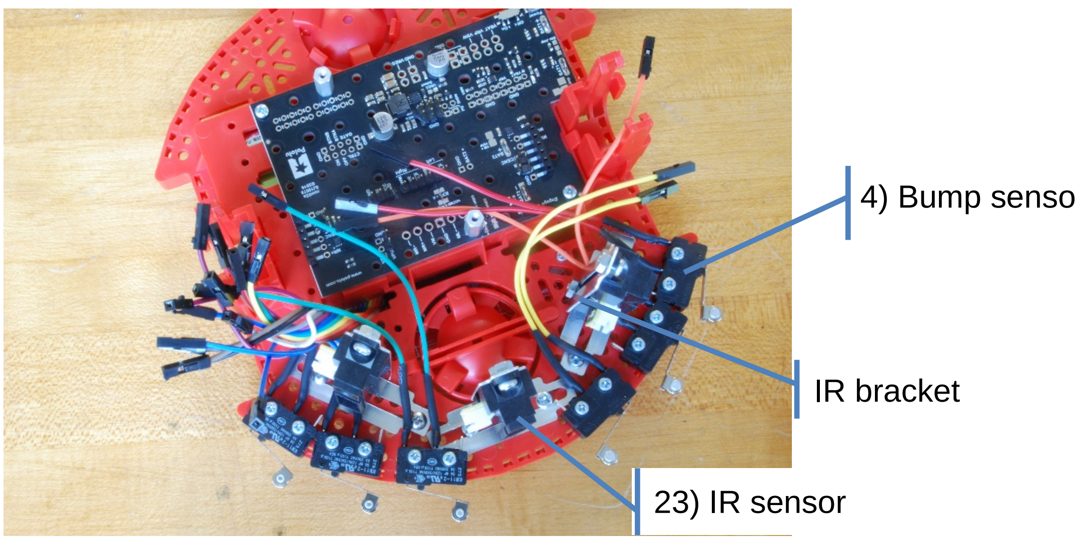
It might be easier to follow the connections if you use six pairs of the same color wires. The heat shrink will cover the solder joints, providing a little bit of mechanical and electrical stability. Test if the heat shrink tubes fit over the ends of the ribbon cable. If not, you must now slip them over the cut ends of each of the 12 wires. Otherwise, you can apply the heat shrink tubes at your convenience later. Strip away about 1/8 inch of the insulation and solder the 12 wires onto the 6 bump switches (4). Thread the heat shrink over the solder joints and use a heat gun to shrink the tubing.

For the example code in the labs to work without modification, wire the switches in normally open configuration. This means to solder one wire to the terminal marked “1” or “C” and to solder the other wire to the middle terminal marked “3” or “NO”. Use an ohmmeter if you are still not sure which terminal is which. “Normally open configuration” means high impedance when the switch is released and low impedance when the switch is pressed. The software will convert the touch (0 ohms, robot crash) into logic 0, and high impedance (no crash) into logic 1.

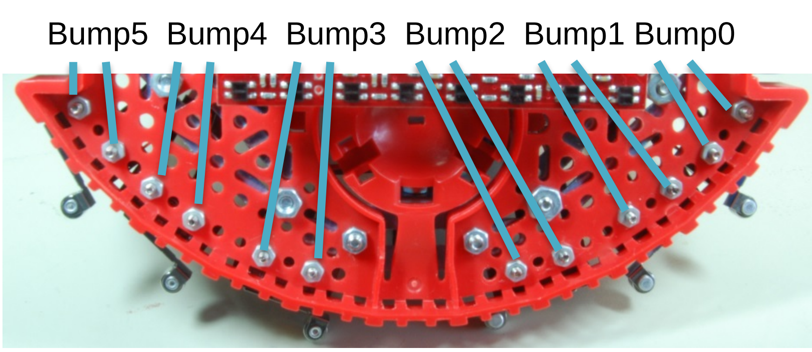


Step 3) Attach the IR sensor and bump sensors to the chassis

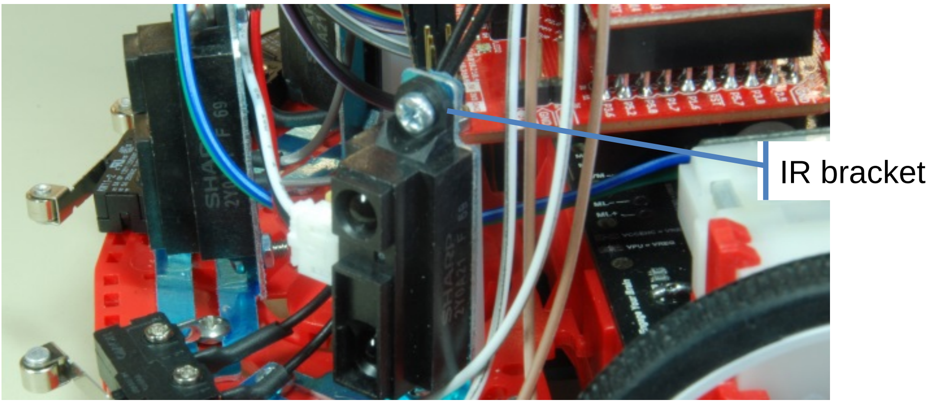
Connect the three IR sensors (23) and six bump sensors (4) to the chassis.



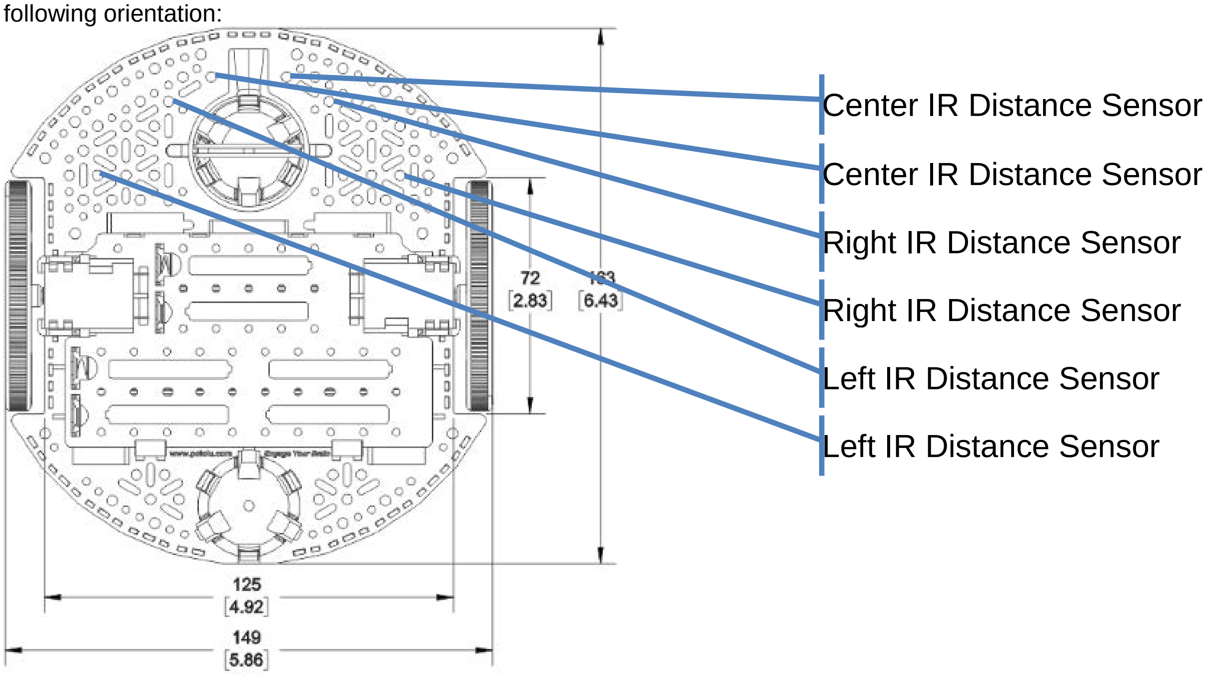
Bolt the six bump switches to the Romi chassis. Consider all the different angles from which the robot can hit the wall, and attach the switches so that each collision presses at least one switch. The twelve 0.5in 2-56 (or M2) screws and 2-56 (or M2) nuts fit through the holes along the edge of the chassis. Mounting half of the switches “upside down” relative to the others allows the arms to stick out in the following configuration:



Bolt the three **Sharp GP2Y0A21YK0F** IR distance sensors to three of the **Bracket Pairs** from Pololu. The **Bracket Pairs** come with 4 or 5 pairs of 4-40 screws and nuts that work well here. There will be one completely extra bracket but not enough 4-40 screws and nuts. There will be 4-40 screws and nuts in the RSLK kit that can be used.



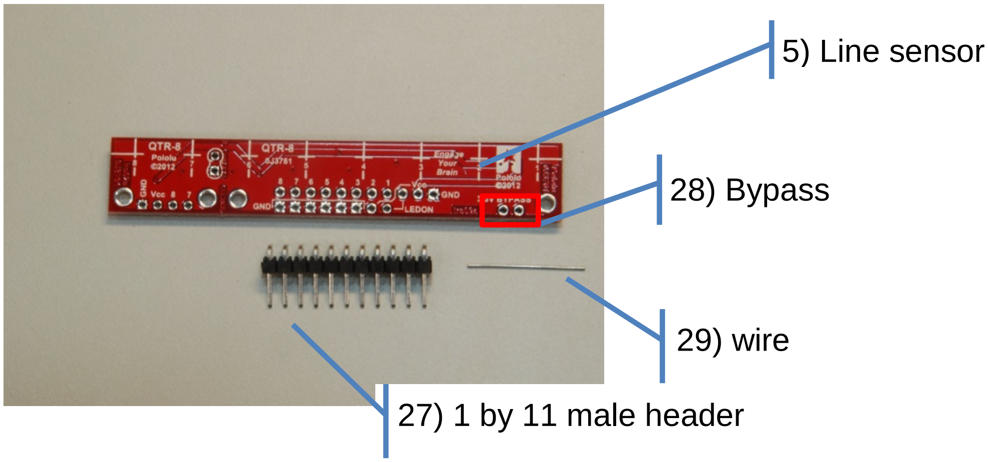
In theory, these should be as close to the center of the robot as possible (due to the 10 cm "blind spot" of the sensor) and looking forward and at 45 degrees. In practice, there are not many places where they fit, but they fit well in the following orientation:

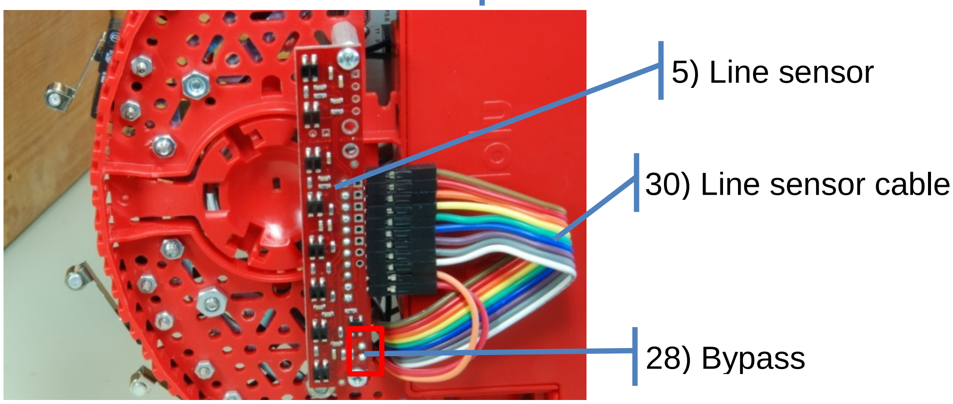


Step 4) Prepare the line sensor

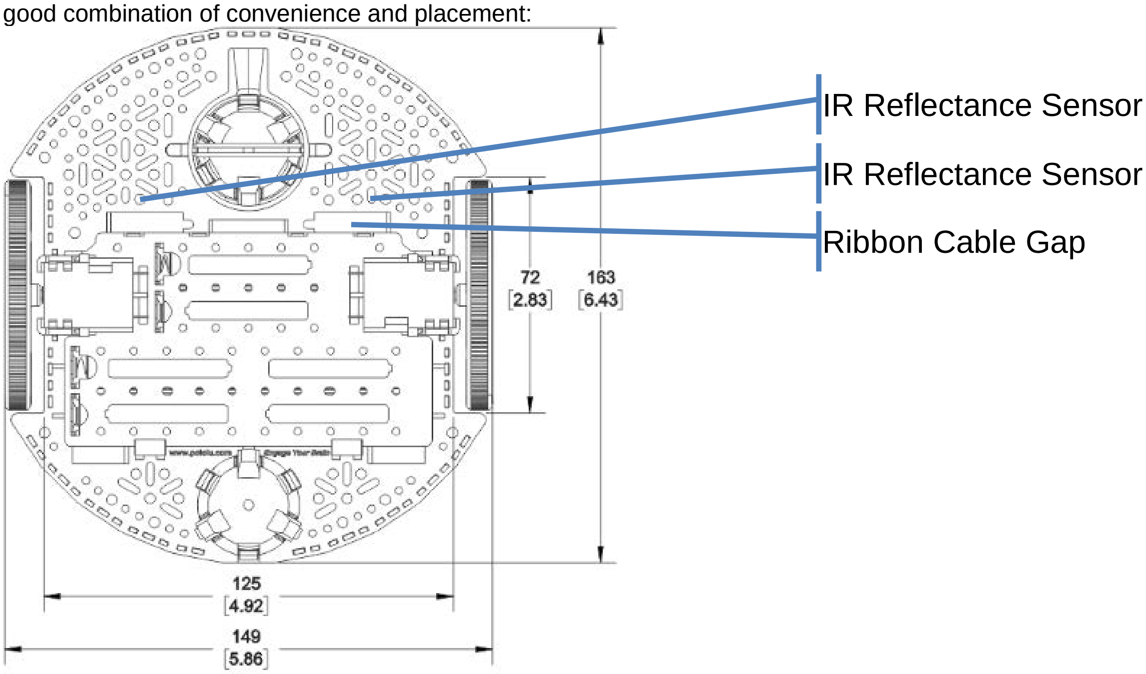
Solder a short piece of wire (29) between the two terminals labeled "**3.3V BYPASS**" (28). This will make the IR reflectance sensor 3.3V compatible. A single piece of solid wire bent into a 'U'-shape will work. Alternatively, you could use a 1 by 2 male header and a shunt to connect the two pins of Bypass (28).

Break the right-angle male header into 1x11 (27) and solder it into the long row of terminals on the line sensor (5). These 11 singles include the 8 sensor outputs, the IR illumination LED input, power, and ground. To prevent the wires (30) from dragging on the ground below the robot, attach it so the bulk of the header is on the flat side of the PCB, the side opposite the components.





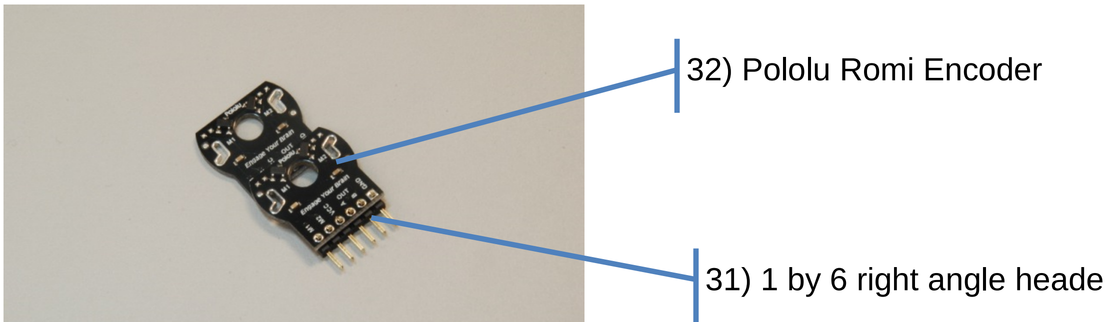
Bolt the two 0.5in 2-56 metal standoffs to the bottom of the Romi chassis. In theory, these should be as close to the wheels as possible and centered equally between them. The optimal distance from the **QTR-8RC Reflectance Sensor Array** to the track is 0.125in (3mm), and the maximum distance is 0.375in (9.5mm). The battery cover and low robot clearance make it difficult to mount the sensor exactly between the wheels, but the following orientation is a good combination of convenience and placement:



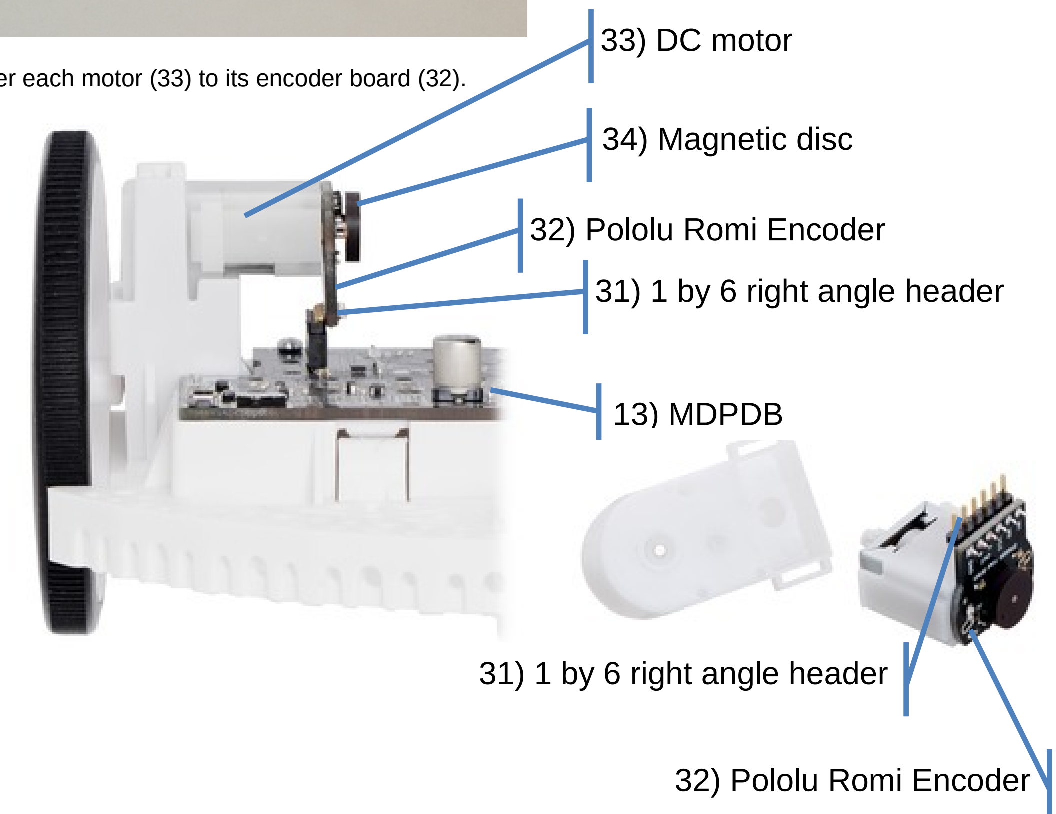
Stage 6) Prepare the motor gearboxes

Step 1) The right-angle headers

Solder the 6-pin right-angle male headers (31) to both PCBs in the Pololu **Romi Encoder Pair Kit** (32). The right-angle male header is not exactly symmetrical, so note the location of the black plastic piece in these images from Pololu. The bulk of the header will be on the flat side of the shaft encoder PCB, the side without the silkscreen and without the components.



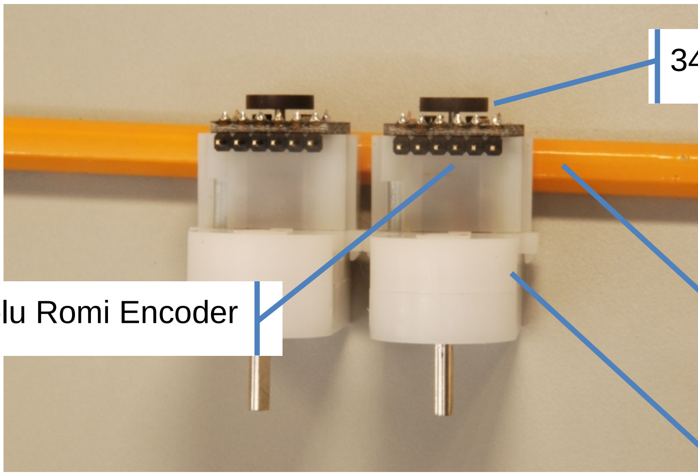
Solder each motor (33) to its encoder board (32).



Step 2) The motor connections

Slide the shaft encoder PCBs (32) over the motor (33) shafts and motor power wires and align them to be straight and snug with the motor housings. The Hall Effect sensors should be on the opposite side of the board as the motors. The Pololu assembly instructions suggest,

"One way to achieve good alignment between the board and the motor is to tack down the board to one motor pin and to solder the other pin only when the board is flat and well aligned. Be careful to avoid prolonged heating of the motor pins, which could deform the motor case or brushes."
https://www.pololu.com/product/3542



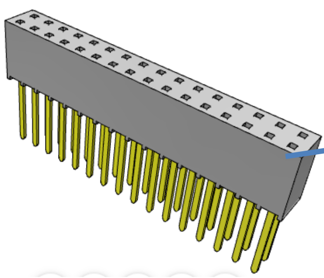
Step 3) The magnetic disc

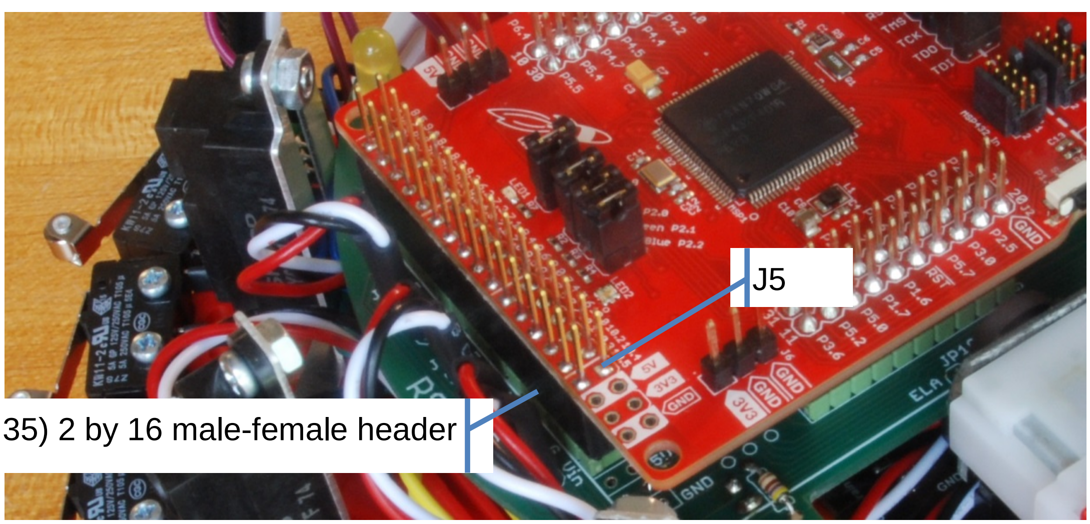
Gently press the 6-pole magnetic discs (34) onto the exposed motor shafts.

Stage 7) Prepare the LaunchPad

Step 1) J5 header

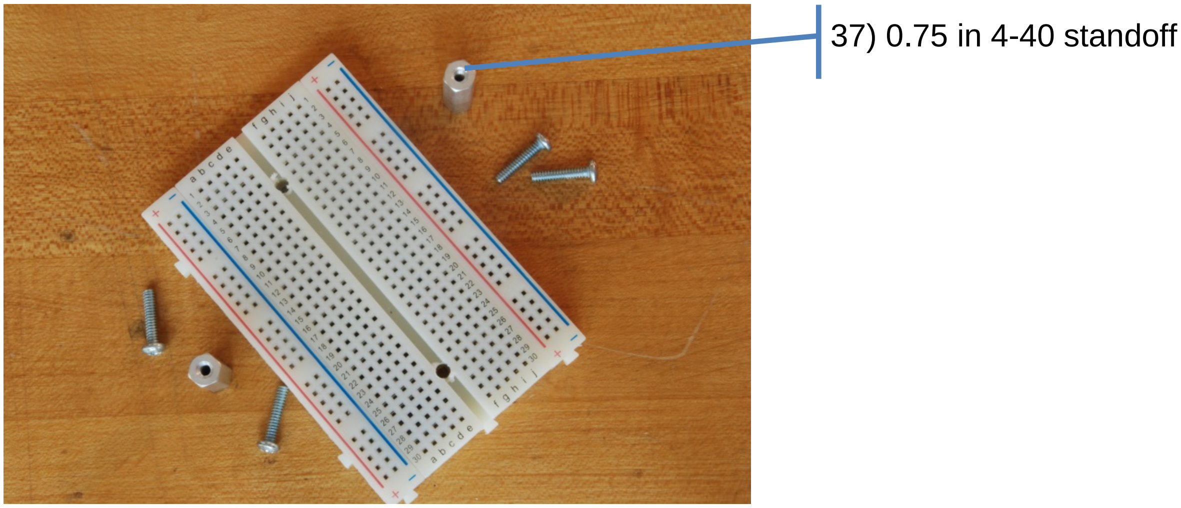
Solder the Samtec SSW-116-03-G-D 2x16 male-female connector (35) into J5 of the LaunchPad. Notice, 6 pins on the left side of the adapter board J5 will not be connected (5V, 3V3, GND). As always, it is good practice to visually inspect how the pieces will fit together before soldering.





Step 2) Attach the breadboard to the LaunchPad

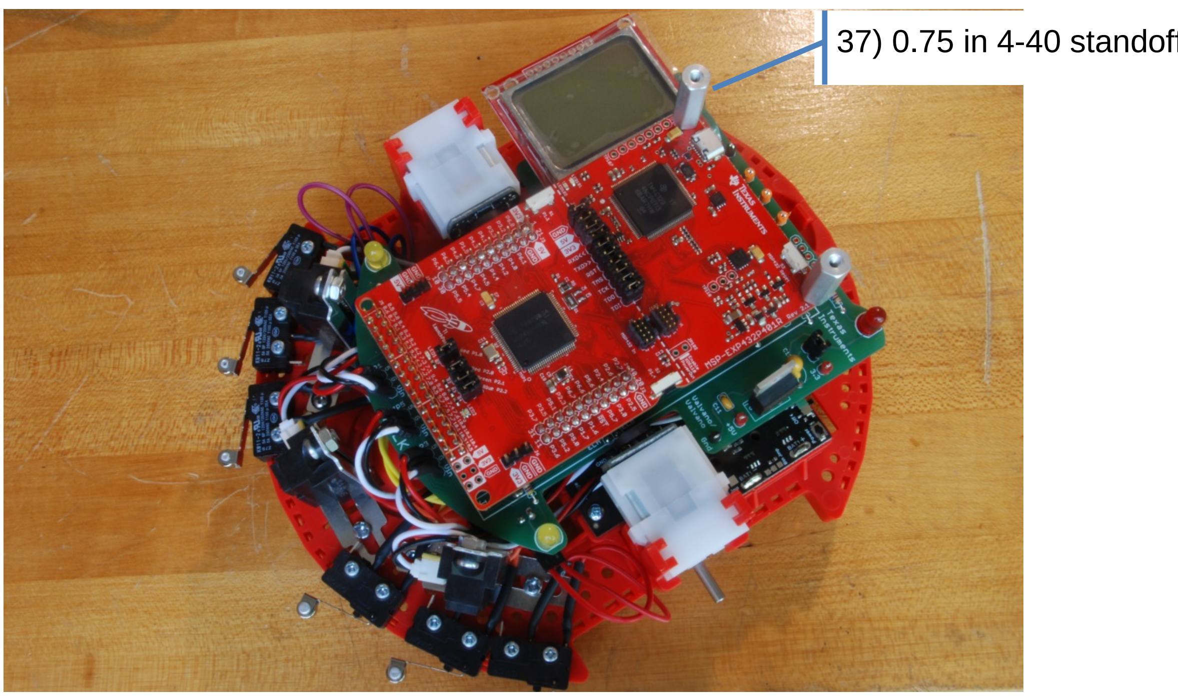
Drill two holes in the center of the wireless breadboard at the “5” and “26” positions.



Use the two 0.75in 4-40 metal standoffs (37) and four 4-40 screws to attach the breadboard to the LaunchPad

Step 3) Attach the LaunchPad

The LaunchPad can now be attached to the adapter board.



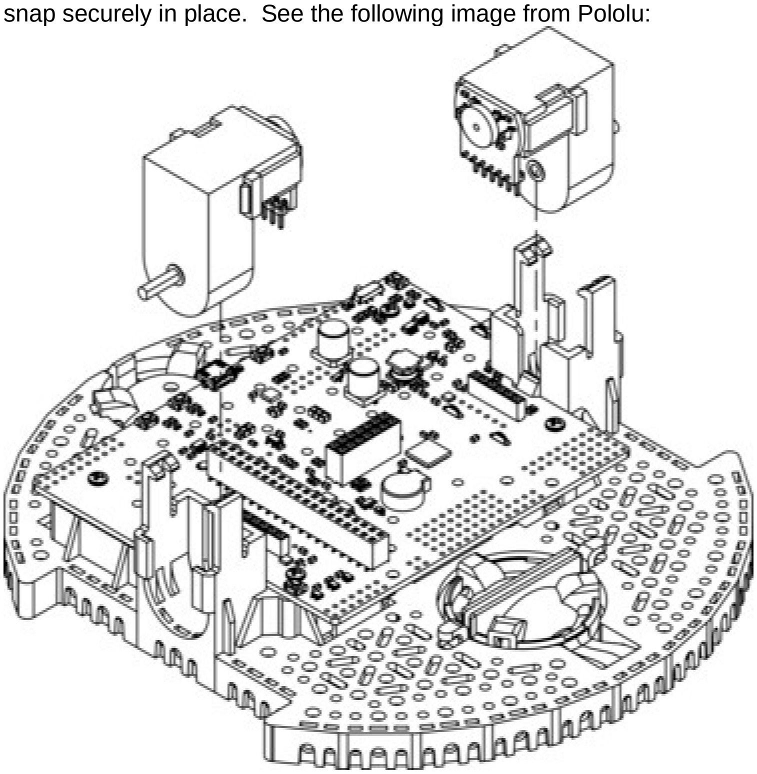
Stage 8) Attach the motor gearboxes

Step 1) The tires

Gently stretch the rubber tires over the plastic wheel frames. Be careful and patient; the tire is only barely stretchy enough to go around the wheel, and it will be a snug fit.

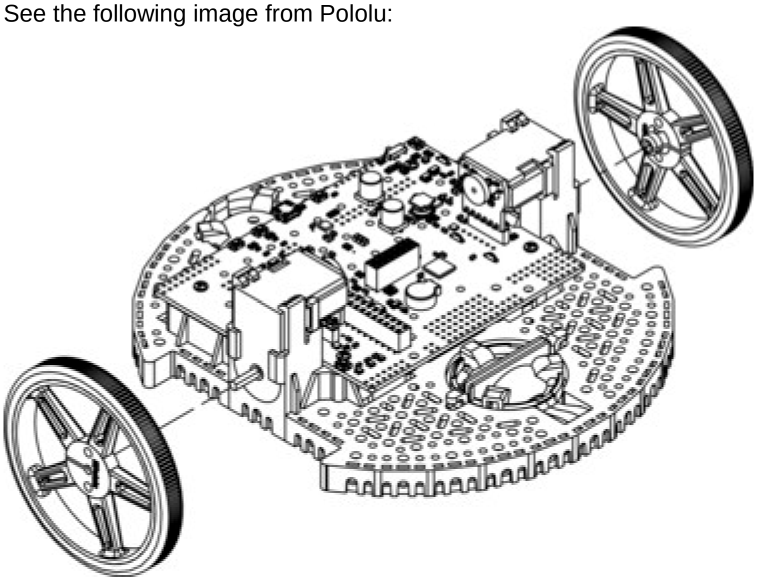
Step 2) Snap into place

Gently lower the motor gearboxes into the motor clips with the wires and the round side down. The right-angle male headers on the **Romi Encoder Pair Kit** should plug into the female headers on the **MDPDB**. The motor gearboxes snap securely in place. See the following image from Pololu:



Step 3) The wheels

Gently press the plastic wheel frame onto the metal shaft that extends out of the motor gearbox until the motor shaft is flush with the outer face of the wheel. Notice that the holes are 'D' shaped, so they need to be aligned properly. See the following image from Pololu:

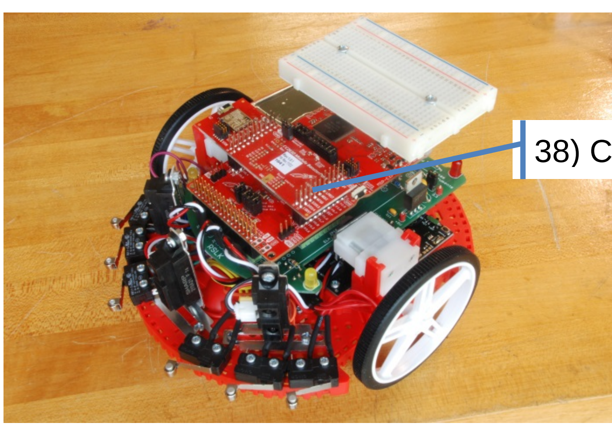


The Pololu assembly instructions suggest,

"One way to do this is to set the wheel on a flat surface and line the chassis up with it so that the flat part of the motor's D-shaft lines up correctly with the wheel. Then, lower the chassis, pressing the motor shaft into the wheel until it contacts the surface."
https://www.pololu.com/docs/0J68/4 (Step 12)

Stage 9) Attach the wireless CC2650 Booster Pack

If you are going to use a CC2650 Bluetooth Booster Pack (38), attach it to the top side of the LaunchPad. Be careful because these modules can easily physically fit together in a way that is electrically incorrect. The text on the silkscreens should be facing the same direction on the LaunchPad as on the Booster Pack, and some Booster Packs have additional pins labeled to help show the proper alignment. Make sure ground is connected to ground and 3.3V is connected to 3.3V. Also verify that the connection is not "off by one".

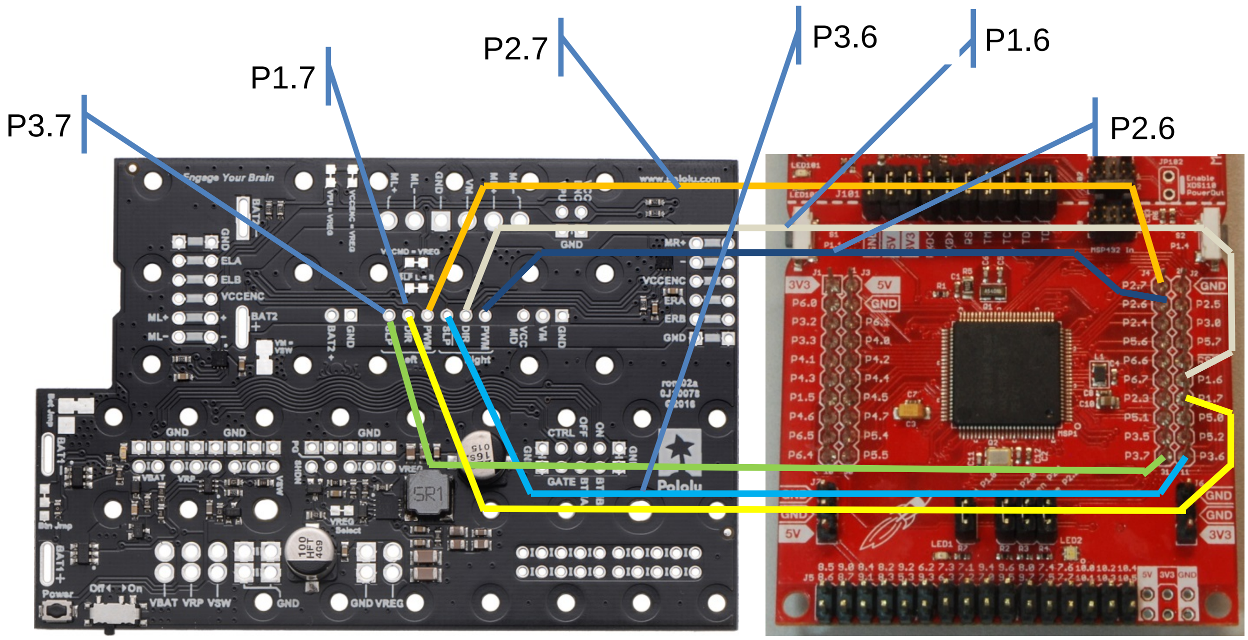


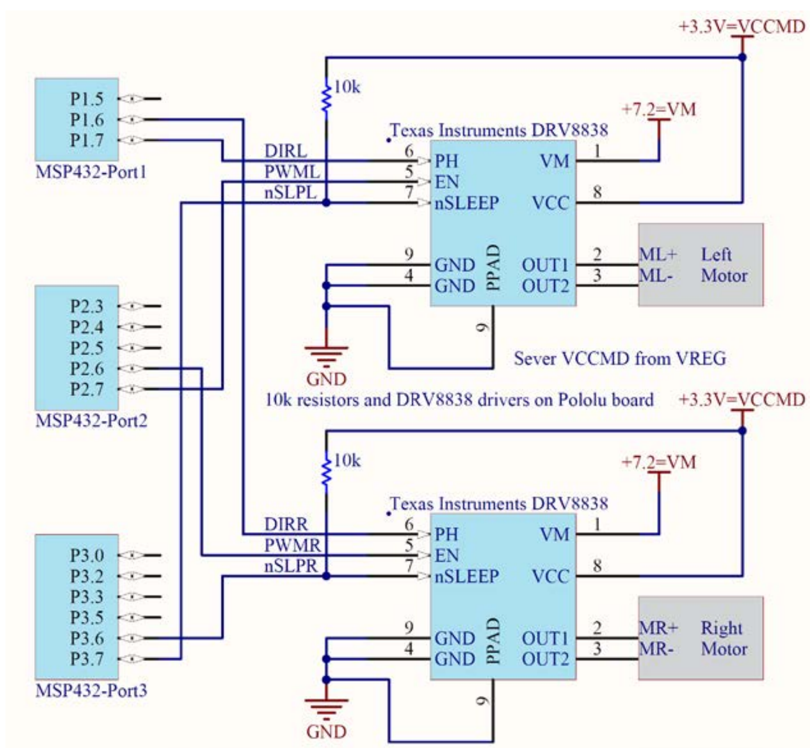
Stage 10) Double check final electrical connections

Before powering the robot, double check the connections between the MSP432 and the **MDPDB**. You may have to partially disassemble the robot to verify these connections.

Step 1) Verify the motor control wires

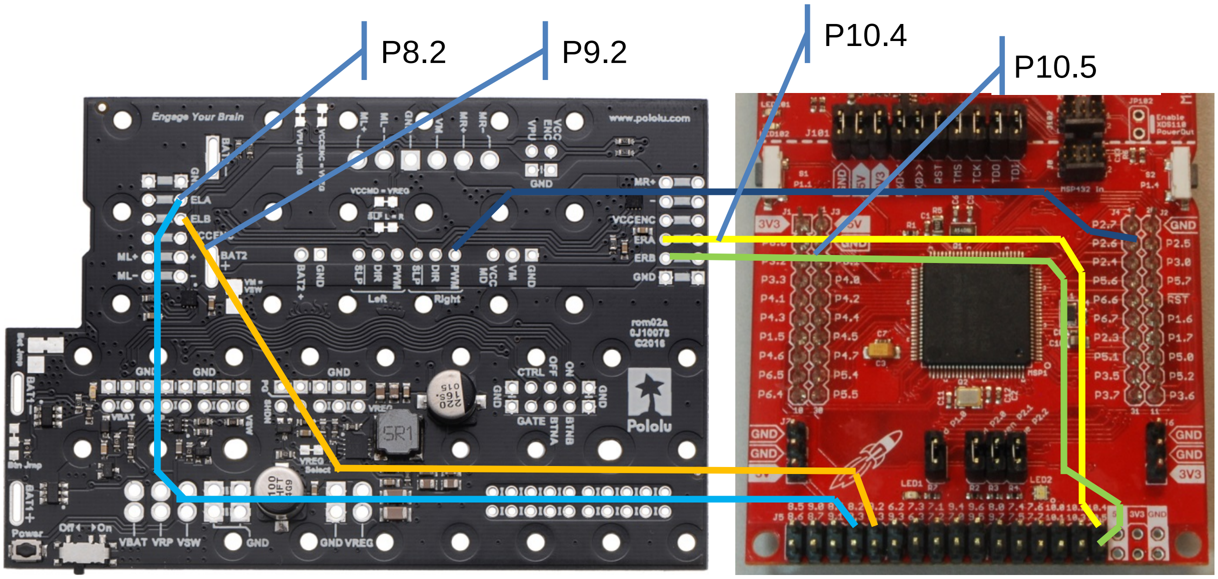
Check the 6 connections between the MSP432 and the **MDPDB**. Refer to the data sheet of the DRV8838 to see how the software output values to these six signals affect motor behavior.

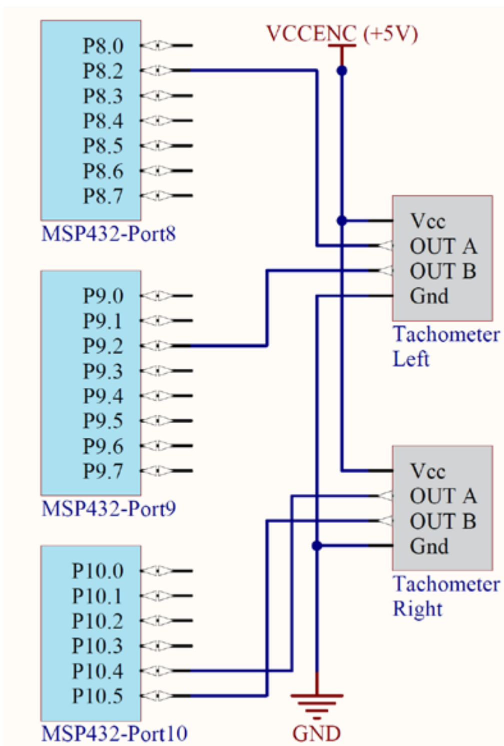




Step 2) Verify the shaft encoder wires

Check the 2 connections from the left wheel such that ELA is connected to P8.2 and ELB is connected to P9.2. Check the 1x2 ribbon cable from the right wheel such that ERA is connected to P10.4 and ERB is connected to P10.5.



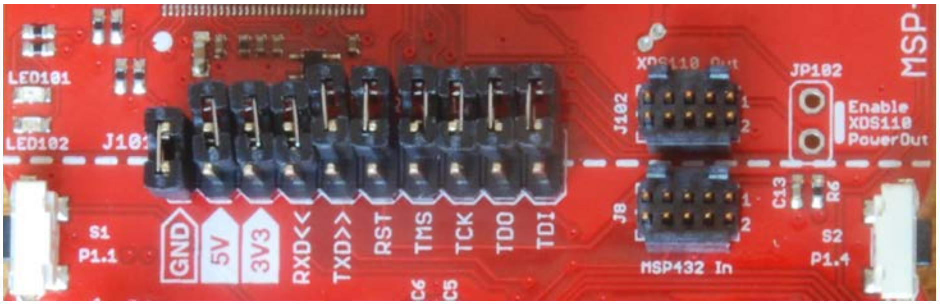


The line sensor, IR distance sensor, LCD, and bump switches can be verified later during the software testing stage.

Step 3) Verify power connections between the MDPDB, adapter board, and the LaunchPad

1) Grounds must be connected between the **MDPDB** and the LaunchPad. The GND jumper on the LaunchPad between the debugger and MSP432 will always be inserted. However, the 5V and 3V3 jumpers will always be removed.

2) When running the entire system from the battery power, the USB cable is not connected to the PC, and the nine jumpers on the LaunchPad must be removed (5V, 3V3, RXD, TXD, RST, TMS, TCK, TDO and TDI). Removing these jumpers will prevent bad currents from flowing between the powered MSP432 and the unpowered debugger.



With the USB cable disconnected and the nine jumpers removed, power up the robot and check the 3.3V line on the adapter board and on the MSP432. You will have VREG=5V on the MDPDB and the adapter board, but the 5V line on the MSP432 half of LaunchPad is not connected to anything. Recheck the +5V on the adapter board. Turn off the power before going to the next test.

To run stand alone: Disconnect the USB cable and remove the 5V, 3V3, RXD, TXD, RST, TMS, TCK, TDO and TDI jumpers on the LaunchPad. You can then activate or deactivate the robot with the power button

3) Debugging requires plugging the USB cable to the PC, which will bring 5V into the debugger half of the LaunchPad. The 3.3V to the debugger comes from the regulator on debugger half of the LaunchPad. Separately, the 3.3V on the MSP432 will come from the regulator on the adapter board, which is why we always remove the 5V and 3V3 jumpers on the LaunchPad to separate these two sources. When debugging, the 7 jumpers (RXD, TXD, RST, TMS, TCK, TDO and TDI) must be inserted.

First turn off the battery power and insert the RXD, TXD, RST, TMS, TCK, TDO and TDI jumpers. Next, connect the USB cable, and lastly power up the robot from the batteries. Again check the 3.3V line on the adapter board and on the MSP432. Recheck the +5V on the adapter board. Turn off the power before going to the next test.

To run in debug mode: First, insert the 5V, 3V3, RXD, TXD, RST, TMS, TCK, TDO and TDI jumpers. Second, connect the USB cable. Lastly, activate the battery power on the robot.

To end debugging session: First, turn off the battery power on the robot. Second, disconnect the USB cable.

There is a detailed testing procedure as part of Lab 5.

Stage 11) Software

Developing the software to operate the robot involves a bottom-up process over the course of 20 individual modules. Each module has an introduction, a lecture, a lab, a quiz, some optional activity, and some videos. However, if you do not care to learn how the low-level details of the robot works, and would rather develop high-level software, there are two projects that you can use. You can also use these projects to test the IR distance sensor, the LCD, the bump sensors, and the line sensor.

Step 1) Install Code Composer Studio and the ti_rslk_maze software

Follow the directions in Lab 1 to download and configure the software development system.

Step 2) Find the documentation of the software system

Within the **ti_rslk_maze** folder you will find **tirslk_maze_1_00_00_Software_Documentation.html**. Double-click this link to open the documentation. The software is divided into modules, and each of the function is described in detail.

Step 3) Competition projects

The **Competition** project allows you to develop high-level software by providing object-code implementations of low-level functions (the functions that would have been developed as part of the 20-module learning kit). The **Competition_BLE** project allows you to develop high-level software with Bluetooth.