SCUTTLE Robot Wiring Guide

Revision 2022.04.24

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Good Practices

- Keep Wire sets bonded together.
- Use colors which are found in the common sequence
  - makes it easy for others to repeat your trials
  - makes it easy to document
- Eliminate individual pins
  - replace them with multi-position housings
- Use black colored wire for ground
  - whenever possible
- Dupont Housings: align the arrow to ground pin
  - whenever possible
- Use 90-degree headers where appropriate
- Hot glue backs of through-hole pins
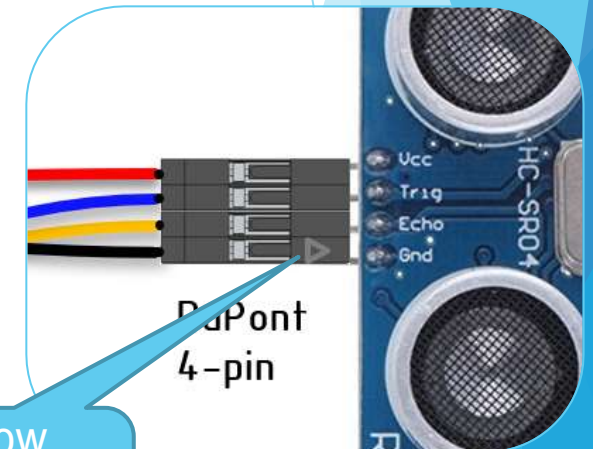 - reduce chance of short circuit
  - hot glue is removable if necessary
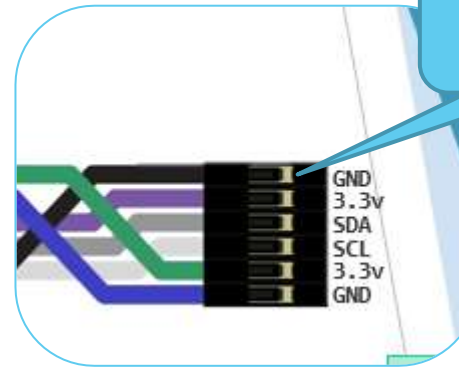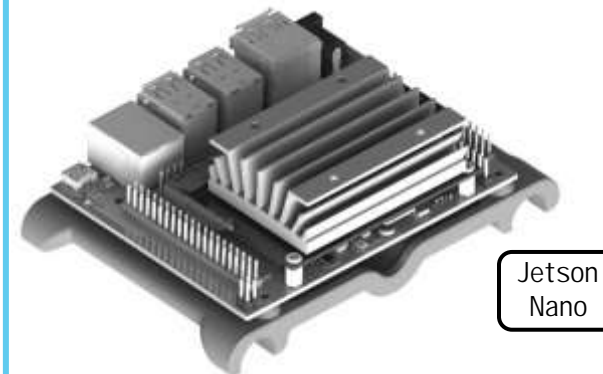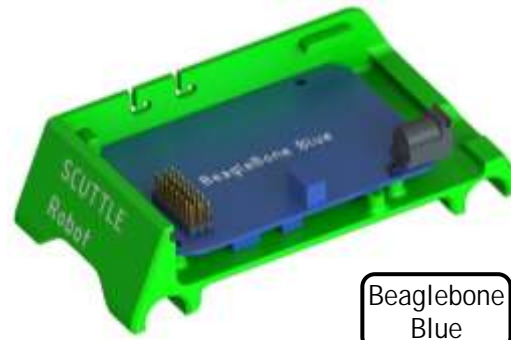
space for probing

cover pins with hot glue

straight pin

90 degree pin
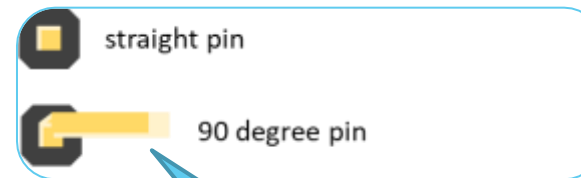
choose appropriate male pins

Arrow aligns with ground

SCUTTLE Supports various CPUs

SCUTTLE Chassis

Raspberry Pi

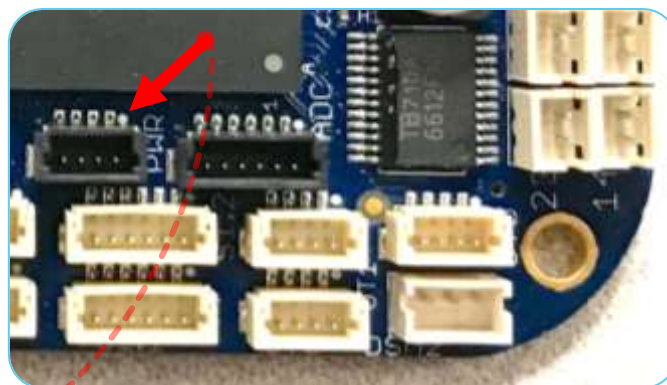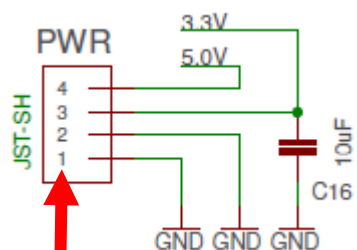Beaglebone Blue

Jetson Nano
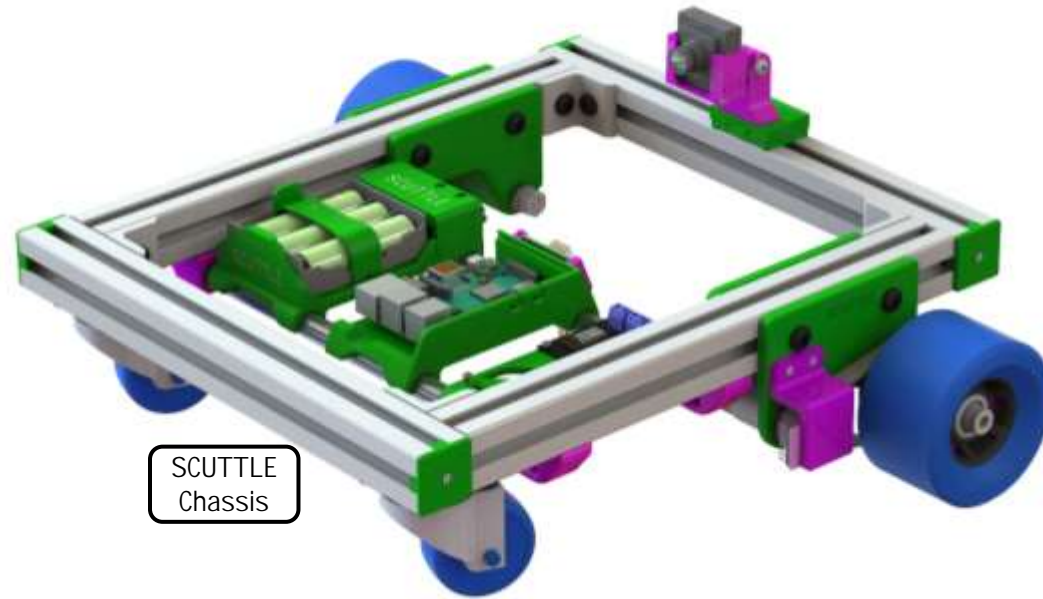
Before You Begin:

Important Info:

To match the beaglebone pins to the pin numbers on the diagram:

The tiny white circle on the silkscreen at each connector indicates "pin1"

images of this style are copied directly from the beaglebone schematic

Validated Sensors & Actuators

Encoders

Microsoft camera

Audio Amplifier

Ultrasonic Sensor

HC-SR04

i2C

GP1

Pwr

Dual Motor Driver

Gamepad
Controller

Gamepad
USB

M2

M1

Connection Map

I2C	4 GPIOs (GP0)	SPI (S1.2)	UART (UT1)	UART (UT5)
4 GPIOs (GP1)	UART (GPS)	SPI (S1.1)	UART (UT0)	UART (DSM)

Servos
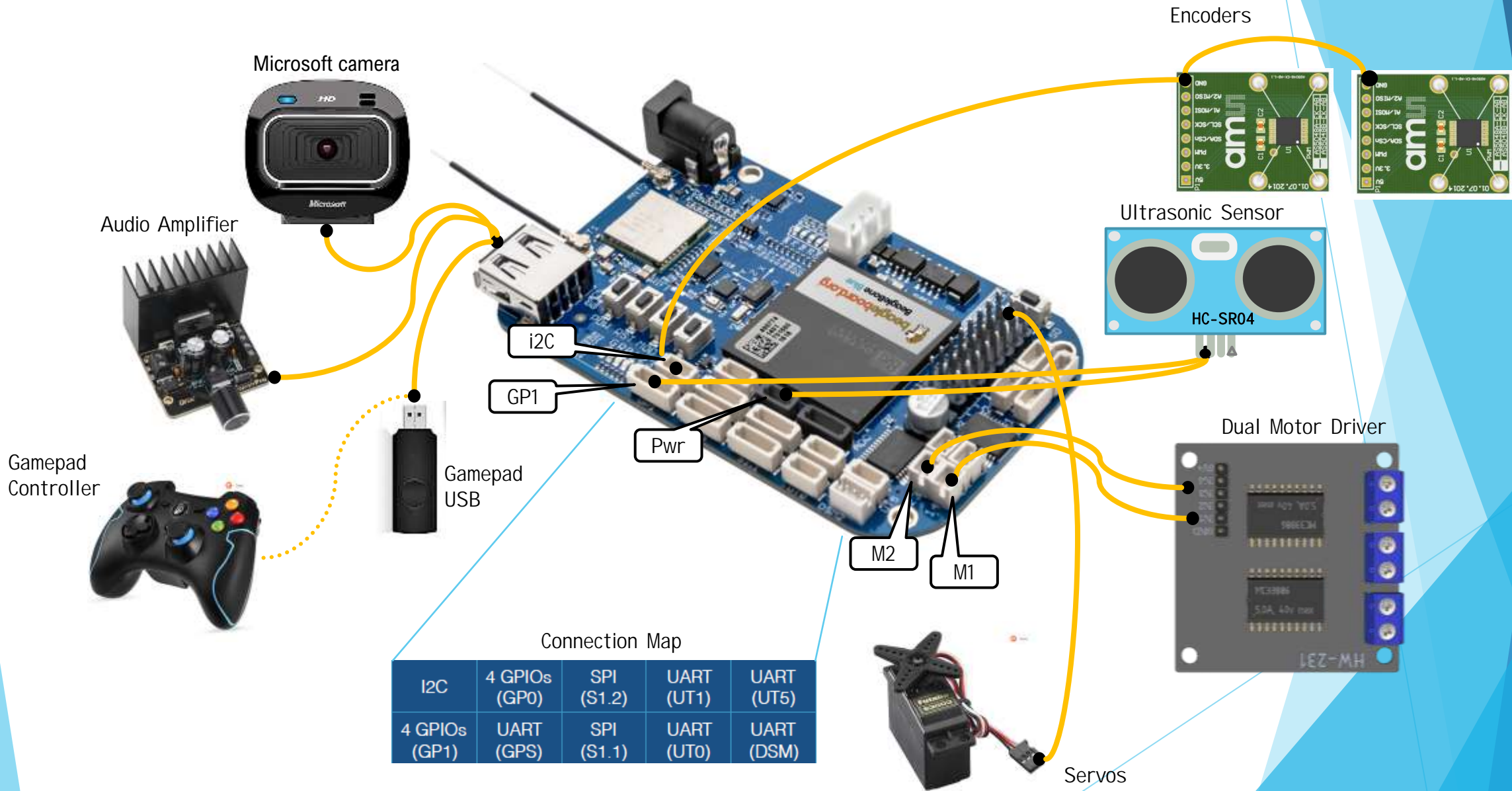
Motor Driver Signal Wires
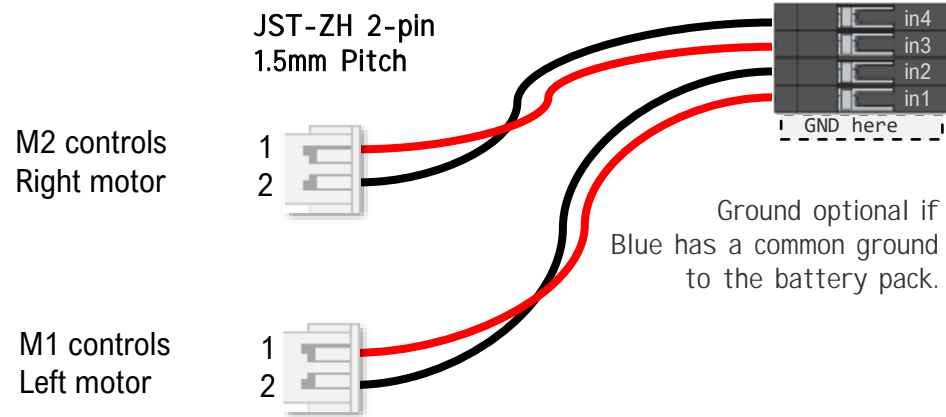
Motor Driver Top View
HW-231 Motor Driver

JST-ZH 2-pin
1.5mm Pitch

in4
in3
in2
in1

GND here

M2 controls
Right motor

1
2

M1 controls
Left motor

1
2

Ground optional if
Blue has a common ground
to the battery pack.

Right

Input
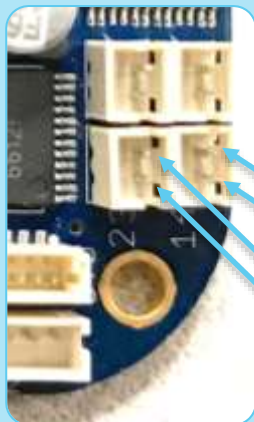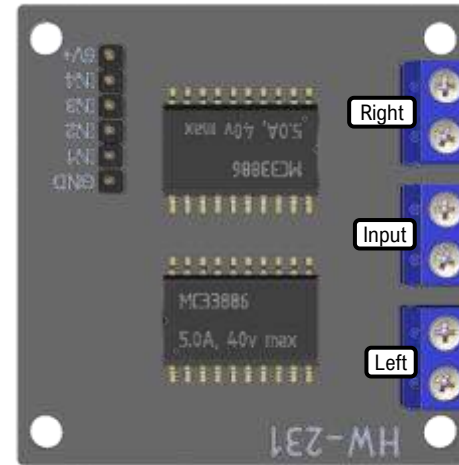
Left

Pin 1 should be HIGH when
motor is driven FORWARD

Motor1 Pin1
Motor1 Pin2

Motor2 Pin1
Motor2 Pin2

Hardware design convention:
Pin 1 uses the square solder pad.

Motor Direction:
Left-hand: Drives CCW on positive command.
Right-hand: Drives CW on positive command

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Motor Driver Power Wires

Power wires are 18 AWG

Motor Driver Top View
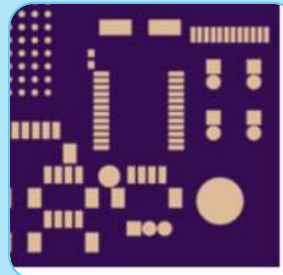*HW-231 Motor Driver*

To Power Supply

Right

(24cm)

To Power Supply

Input

(26cm)

Left

(10cm)

(Strip 6mm & tin this end)

Solder & heat shrink this end
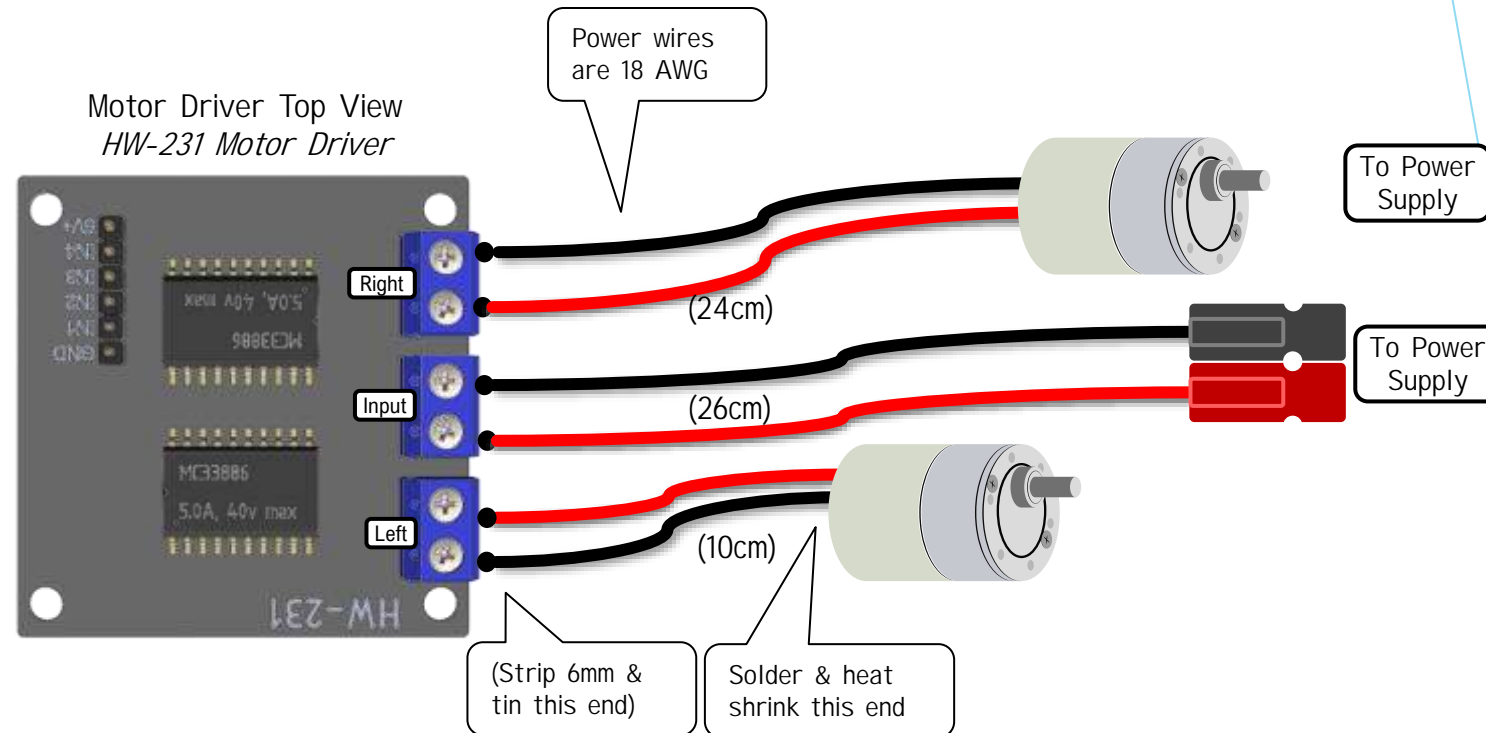
Motor Direction:
Left-hand: Drives CCW on positive command.
Right-hand: Drives CW on positive command

Encoder Details

Left Encoder

Front View   Side View

For the left-hand encoder, A1 AND A2 solder is bridged.

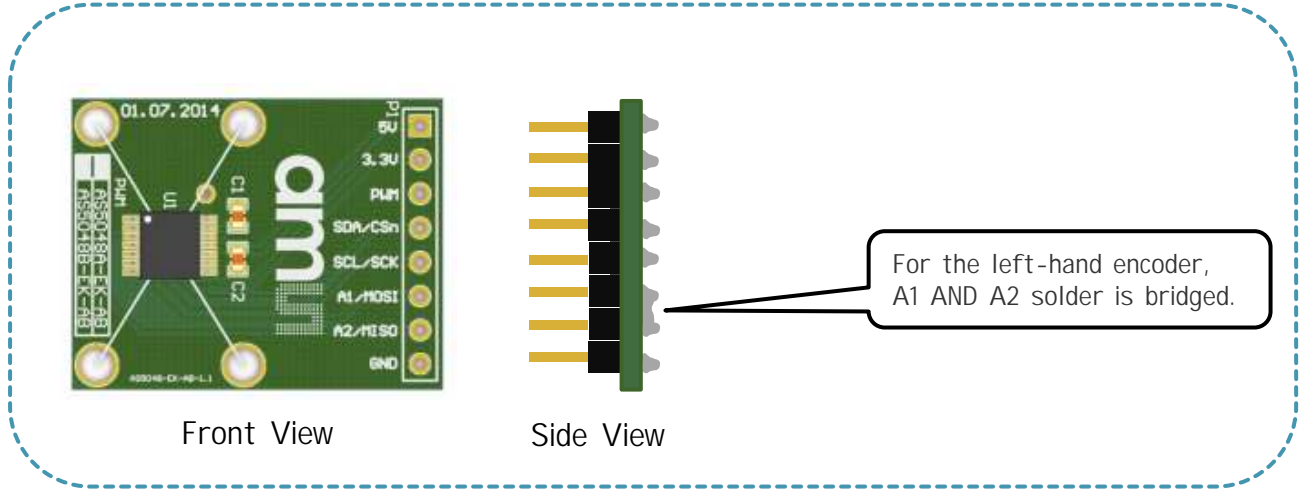The i2c address is determined by the signals on A1 and A2 pins.
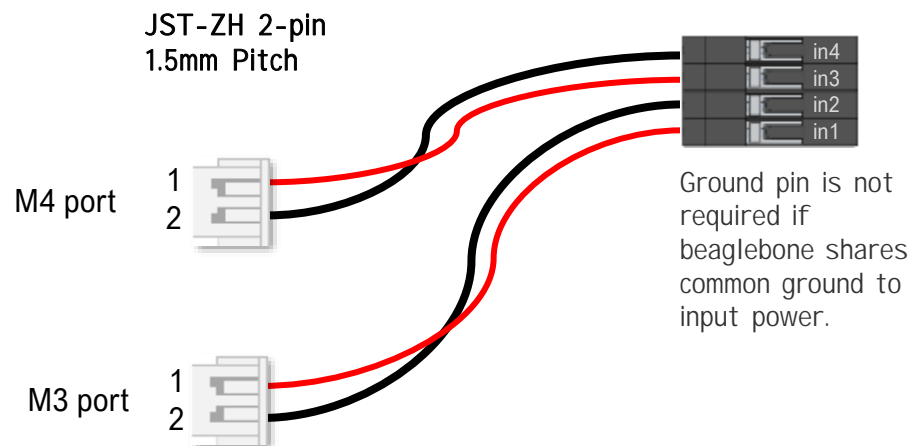
Left Hand Encoder A1 is pulled **down** to GND. I2C address is 0x40

Right Hand Encoder pin A1 is pulled **up** to 3.3v. I2C address is 0x41

	Pin A1	Pin A2	Resulting i2c address
Left Encoder	LOW	LOW	0x40
Right Encoder	LOW	HIGH	0x41

H-Bridge L298N (optional)

A versatile and cheap device for delivering variable voltage to low-powered DC actuators.

Connect any actuator
(below 2A)

L298N DUAL H-BRIDGE

JST-ZH 2-pin
1.5mm Pitch

in4
in3
in2
in1

M4 port
1
2

M3 port
1
2

Ground pin is not
required if
beaglebone shares
common ground to
input power.

output

Input
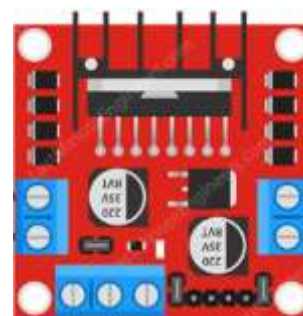
To Power
Supply

Image (and more great info!) adapted
from LastMinutEngineers.com
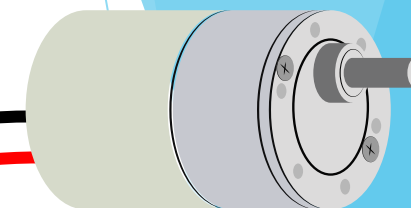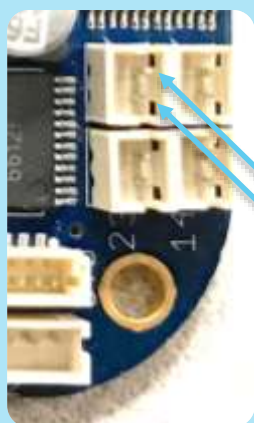
Pin 1 should be HIGH when
motor is driven FORWARD

Motor3 Pin1
Motor3 **Pin2**

More information about the 5v regulator
Found on the datasheet (L78M05)

Ultrasonic Distance Sensor (GPIO)

JST-SH 4-pin
(CONNECT TO PWR)

5.0V
3.3V
GND
GND

JST-SH 6-pin
(CONNECT TO GP0)

3
2
1
0
3.3V
GND

DuPont
4-pin

HC-SR04

Vcc
Trig
Echo
Gnd

PWR

JST-SH
4
3
2
1

3.3V
5.0V

C16
10uF

GND GND GND

GP0

GND
3.3V
GPIO1_25
GPIO1_17
GPIO3_20
GPIO3_17

JST-SH
1
2
3
4
5
6
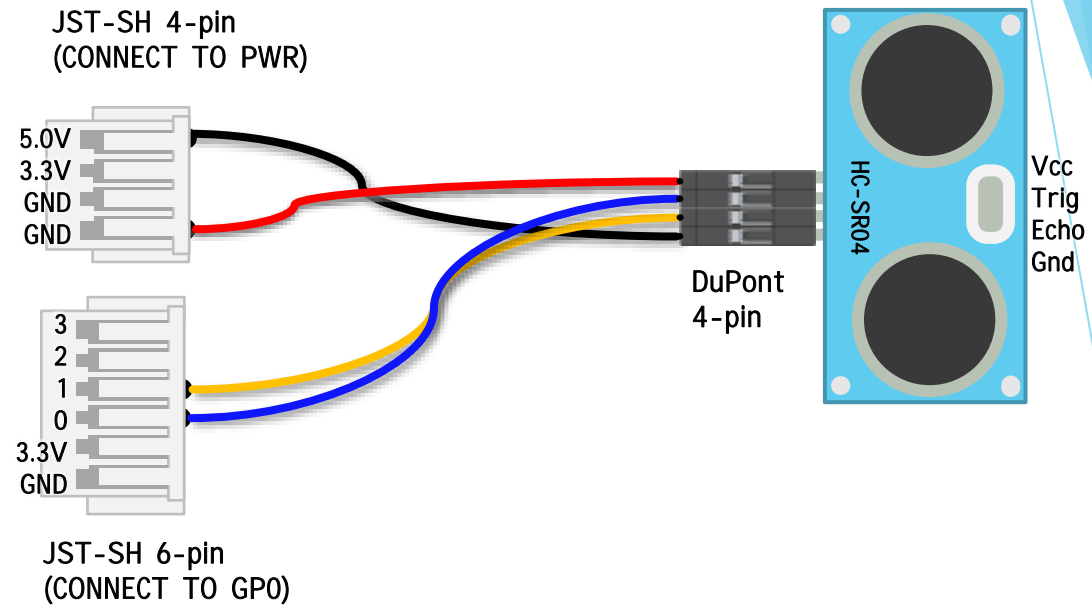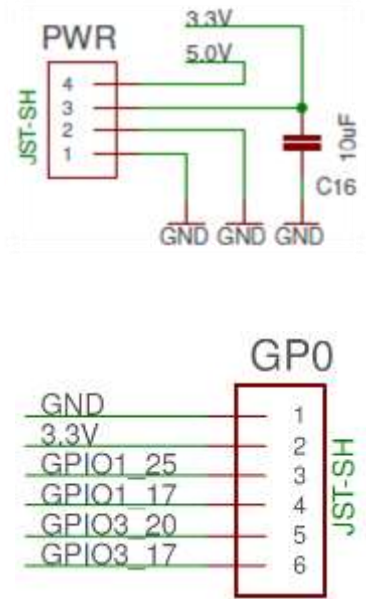
NOTE: For JST connectors out-of-box,
the colors are not in the correct order.
You need to rearrange them.

Cable Design

(I2C port on Beagle)
Style: JST-SH 4-pin

DuPont style
2.54mm female 4-pin
(plugs into bus
board)

Pin 1: GND
3.3V
SCL
SDA

Plugs into I2C Bus PCB
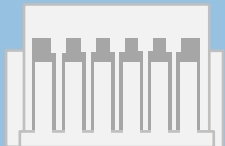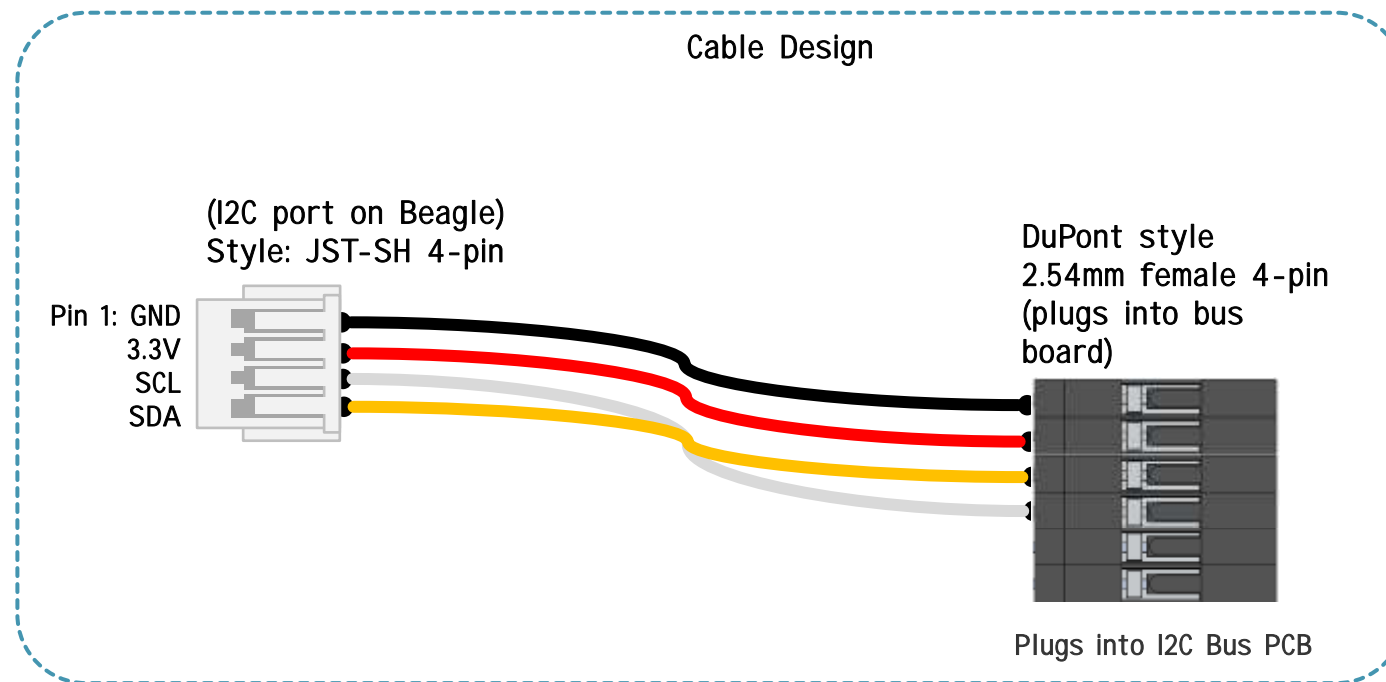
Compass CMPS or CMPS2 (I2C)

Compass Signal Cable

Compass

I2C bus board

Gnd   Gnd
3.3v 3.3v
SDA   SDA
SCK   SCK
3.3v
Gnd
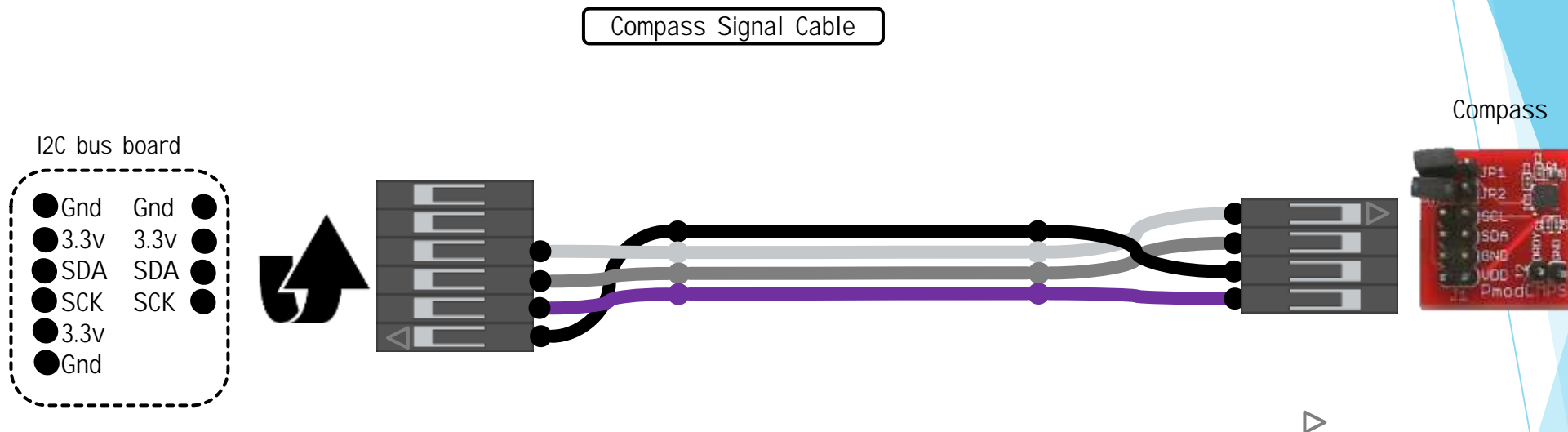
This compass is not necessary since you can access the compass on the beaglebone blue. Be sure to calibrate the compass on the blue since it lies within close proximity of magnetic hardware on the robot.

I2C Bus Board

Option A:
solder a perfboard / breadboard

The board is made from a breadboard and soldered manually. The board can be cut between rows J & K. The solder bridges all pins from left to right.

Enc R · (spare) · CPU · CMPS · Enc L

GND
3.3v
SDA
CLK
3.3V
GND

Screw Hole

□ straight pin

⌐ 90 degree pin
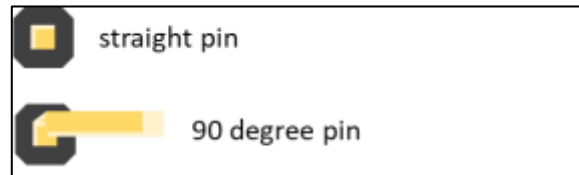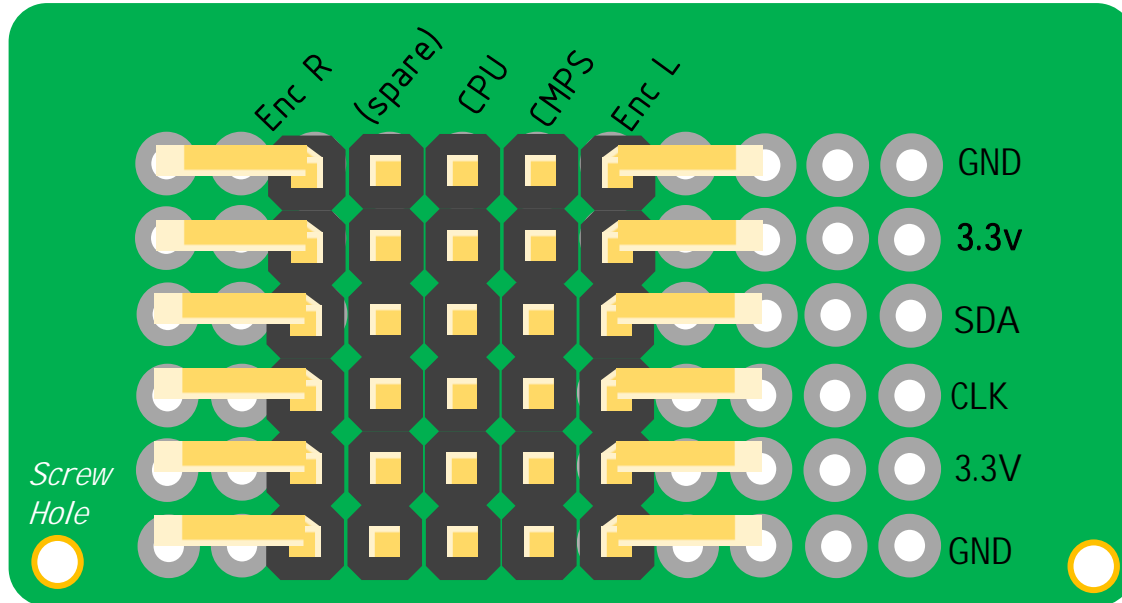
Option B:
Order the custom PCB

You can order the custom PCB from JLCPCB.com or any other service. We have posted the design files on our github under electronics hardware.
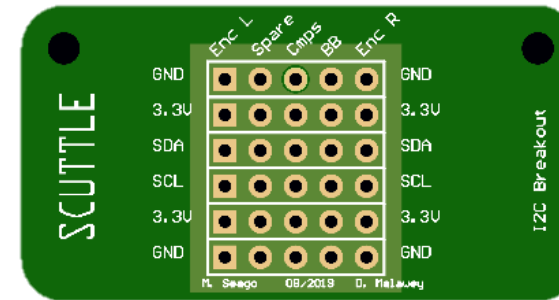
Encoder AMS AS5048 (I2C)

Left Hand Encoder
A1 is pulled **down** to GND
I2C address is 0x40
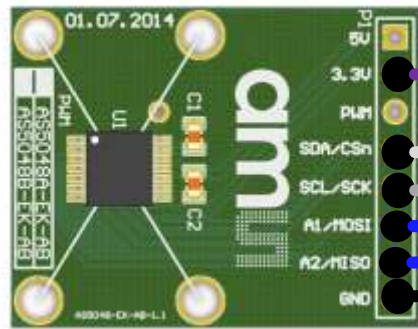
Nodes on the I2C bus board are indicated here
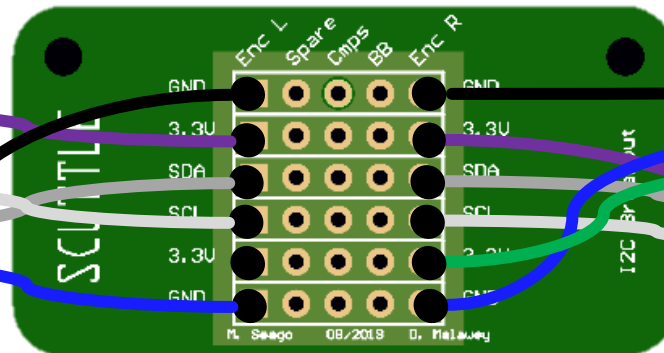
Right Hand Encoder
A1 is pulled **up** to 3.3v
I2C address is 0x41
(Note mounting orientation on robot)

Left
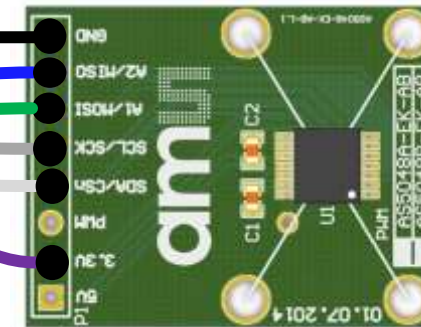
Right

Also see: Encoder Details Slide

Encoder Cables

NC

Left
Hand

20cm from tip to tip

NC
3.3v
NC
SDA
SCL
NC
A2
GND

GND
3.3v
SDA
SCL
3.3v
GND

A1 & A2 soldered together on pcb
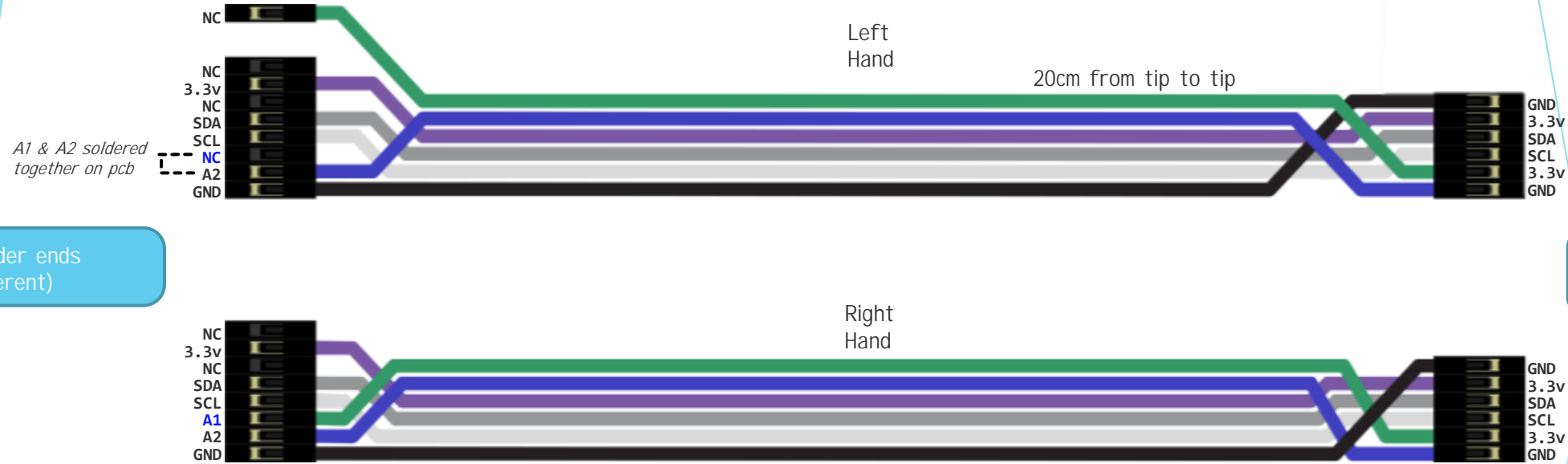
Encoder ends (different)

Bus Board Ends (matching)

Right
Hand

NC
3.3v
NC
SDA
SCL
A1
A2
GND

GND
3.3v
SDA
SCL
3.3v
GND

15

Connects to battery Pack

As an option, bridge LiPo terminal to 12v positive terminal (see Servo Slide)

Battery Connector

LIPO   V_BATT   DO

1
2   BATT_MID
3   BATT_MINUS

JST XH

Q1
MOSFET-N   GND

Barrel Connector
Center Positive
5.5x2.1mm

VCC

R107
.1, 0805

CGND   GND
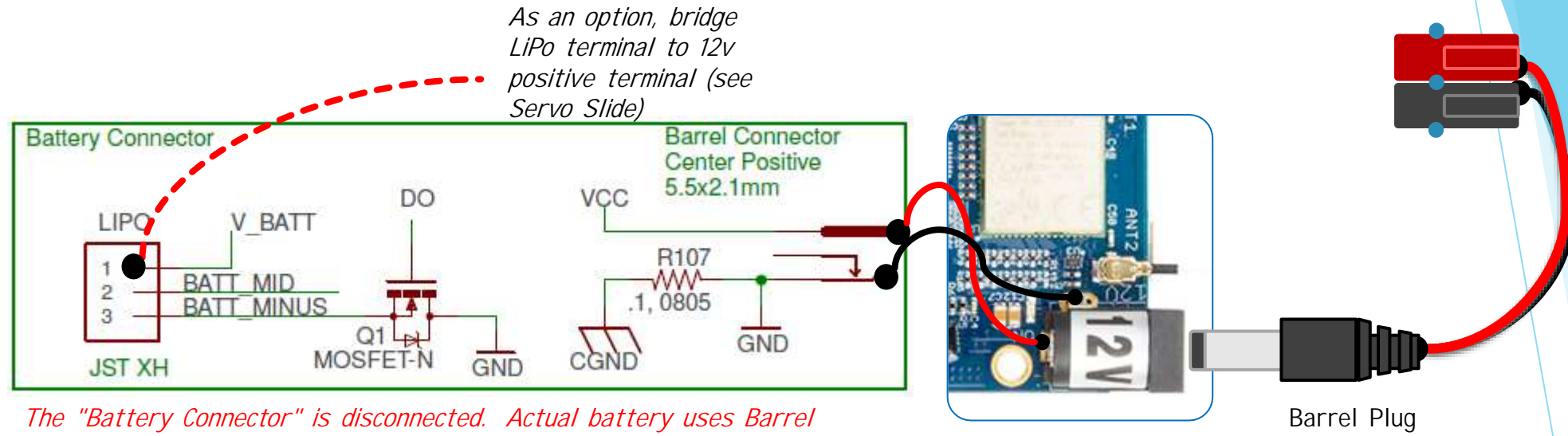
The "Battery Connector" is disconnected. Actual battery uses Barrel Connector.

12 V

Barrel Plug

Battery Pack (version1 configuration)

Bottom Side

11.1v

7.4v

3.7v

0.0v

3-Cell 18650 holder
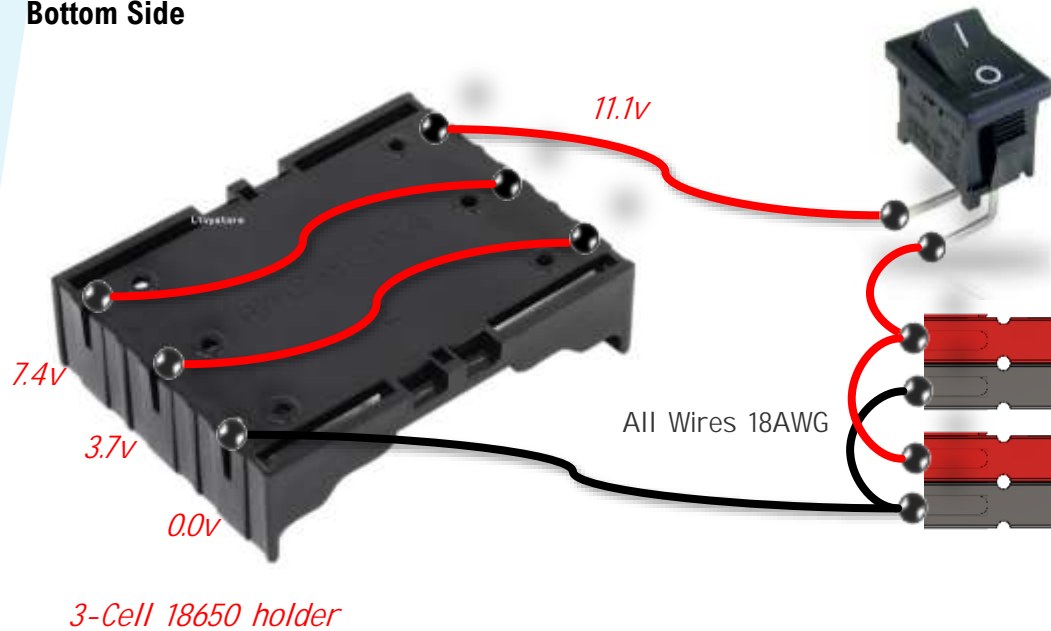
Switch PN:SRB22A2FBBNN
Carries 10A max

Two pairs of Anderson connectors are attached here.

All Wires 18AWG

This battery pack was used through 2020.09. The wires are appropriate for the CAD designs posted prior to version 2.1.

You may build a battery pack without a Battery Management System (BMS) as shown here, or copy our latest design which includes BMS. See next slide.

Pack version 1
BMS: does not fit
Model on GrabCAD
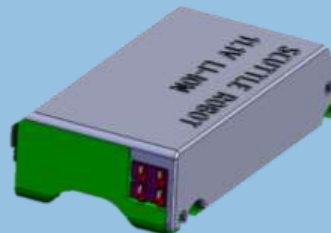
Pack version 2
BMS: optional
Model on GrabCAD
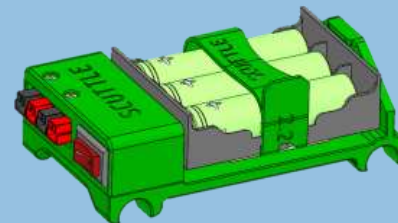
Battery Pack (v2, enhanced with BMS)

The BMS adds several functions to the battery pack. Look out for a Youtube video covering the SCUTTLE BMS soon (-DM 2020.11)

Anderson connectors, 35A contacts

55mm

55mm

90mm

65mm

Switch
PN:SRB22A2FBBNN
10A max current

70mm

10A 125v

7.4v   3.7v   0.0v

55mm

90mm   90mm

3-Cell 18650
Tray bottom side

25mm

4.2V

R003
E003

0V

430

430

430

12.6V

40A

8.4V

25mm

Leave this hole clear for a screw

35mm

11.1v   7.4v   3.7v
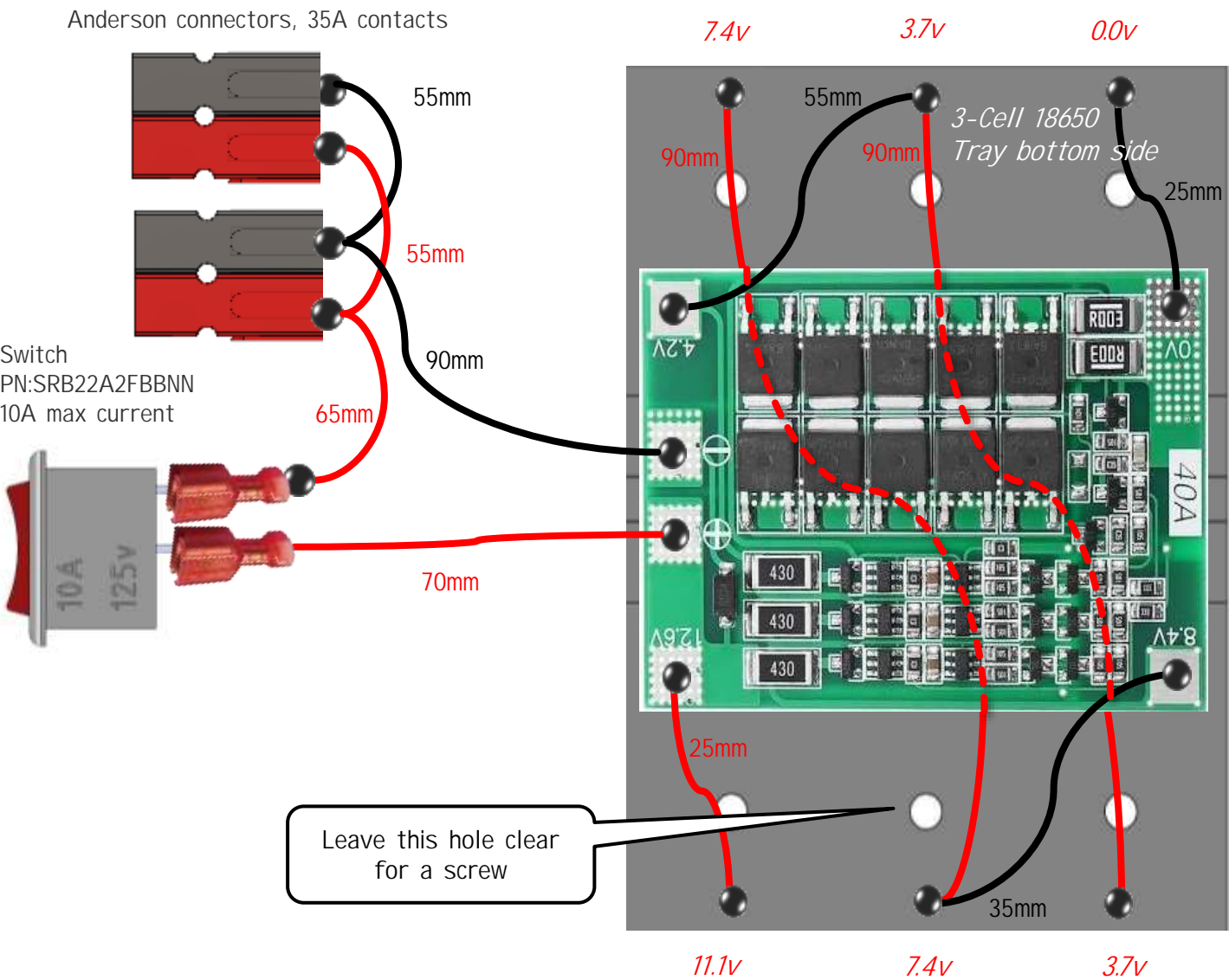
Table of wires to cut (11 total)

Length (mm)
25, 25
35, 35
55, 55
65
70
90, 90, 90

Battery Pack Styles

Pack version 1
- BMS: does not fit
- Model on GrabCAD
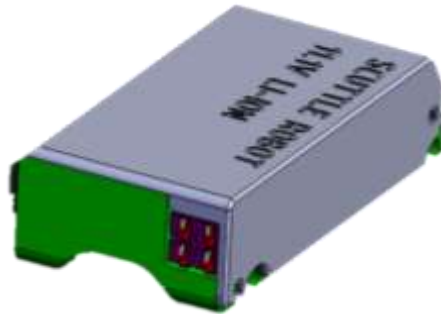- Access CAD model from within SCUTTLE assembly

Pack version 2
- BMS: optional
- Model on GrabCAD
- Access the model as a standalone assembly
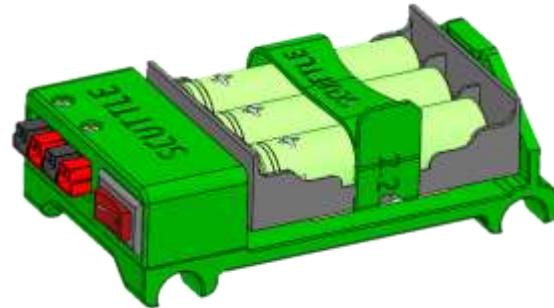
Lidar Device

SICK TiM 561

Power Connector Diagram (lidar side)

POWER connection (supply voltage)

Connection "Power"
5-pin M12 plug

Power Cable:
(brown)
(white)
(blue)

Pin	Function
1	DC 9 ... 28 V
2	SYNC/DEVICE READY
3	GND
4	n.c.
5	n.c.
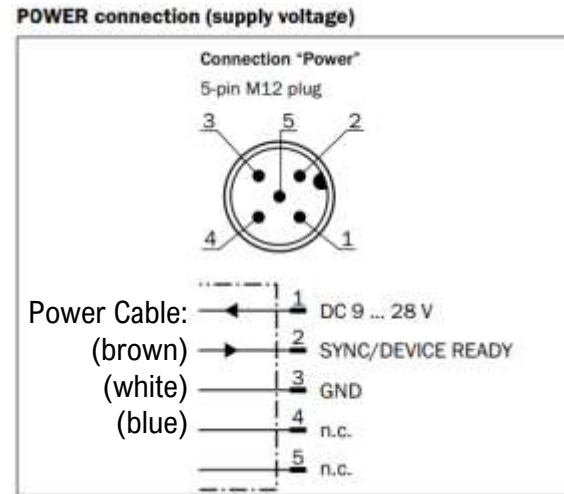
LIDAR-side connector (male pins)

Power Cable Diagram (plugs into lidar)
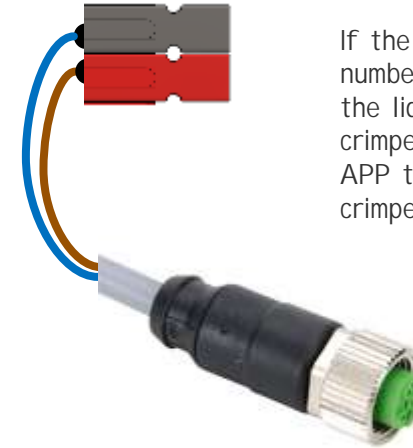
If the indicated cable part number is used for power to the lidar, brown will be crimped into the 12v positive APP terminal and blue is crimped into the negative.

Cable: 7000-12241-2150300

Cable-side connector (female pins)

Typical Lidar power consumption: 2.1w

GamePad

Gamepad Controls Mapping

Trigger: B6   Trigger: B7

B4   B5

B10   axis 0+   select proper mode   B0

B8   B9   B3

axis 1+   B1

B2

B11   axis 2+

axis 3+
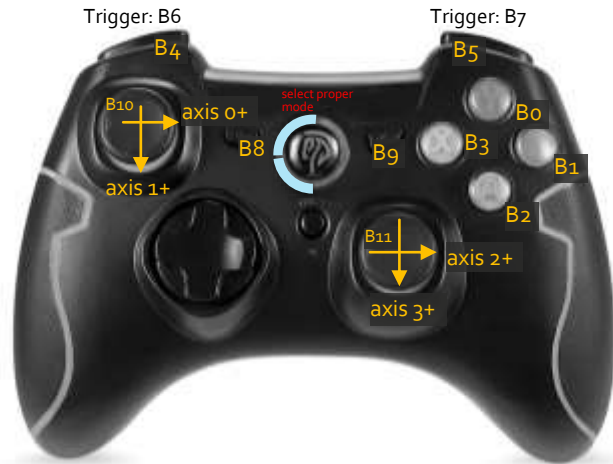
Button Behavior:
- not pressed: 0
- Pressed: 1

Axis behavior:
- Right returns positive values
- down returns positive values

- Outputs:
- Analog axes return values between -1 and 1
- These axes reach their limits before the hard-stop.
- To discover the behavior graphically, visit the html graphical test page [here](#)

Servos

Bridge Power to the liPo connector

positive terminal

solder to third pin

Without a power source available at the positive (third pin) input of the liPo connector, the board has insufficient current available to the servos to drive servos at full torque or to drive multiple servos.

A safe fix is to solder the positive terminal of the DC jack to the third pin of the connector shown. When a battery is connected, the pins correspond to 0.0v, 3.7v, and 7.2v terminals of a 2-cell lipo.

Servo Channel 8

Servo Channel 1

Read the silkscreen to see correct connector orientation for positive, negative, and signal.
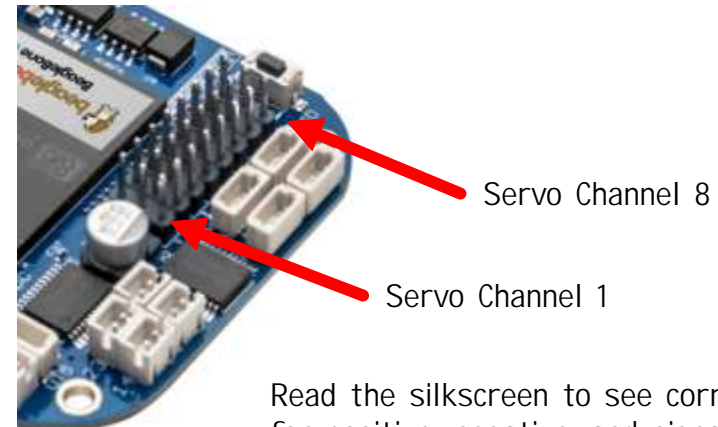
RC522 low-cost
RFID Scanner
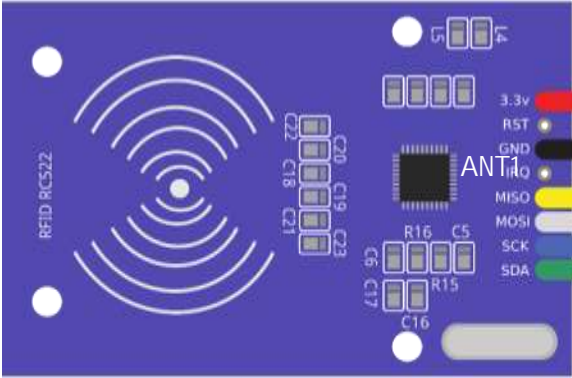
Plug into 6-pin JST-SH
port on bbb.

ANT1

3.3v
RST
GND
IRQ
MISO
MOSI
SCK
SDA

SPI1_SS1
SPI1_SCK
SPI1_MISO
SPI1_MOSI
3.3v
GND

Pyle PCB3BK

PAM8610 D Amp Board

22AWG or larger wires

1-speaker is OK.

To 12v power

Aux cord

usb adapter

To Beagle USB
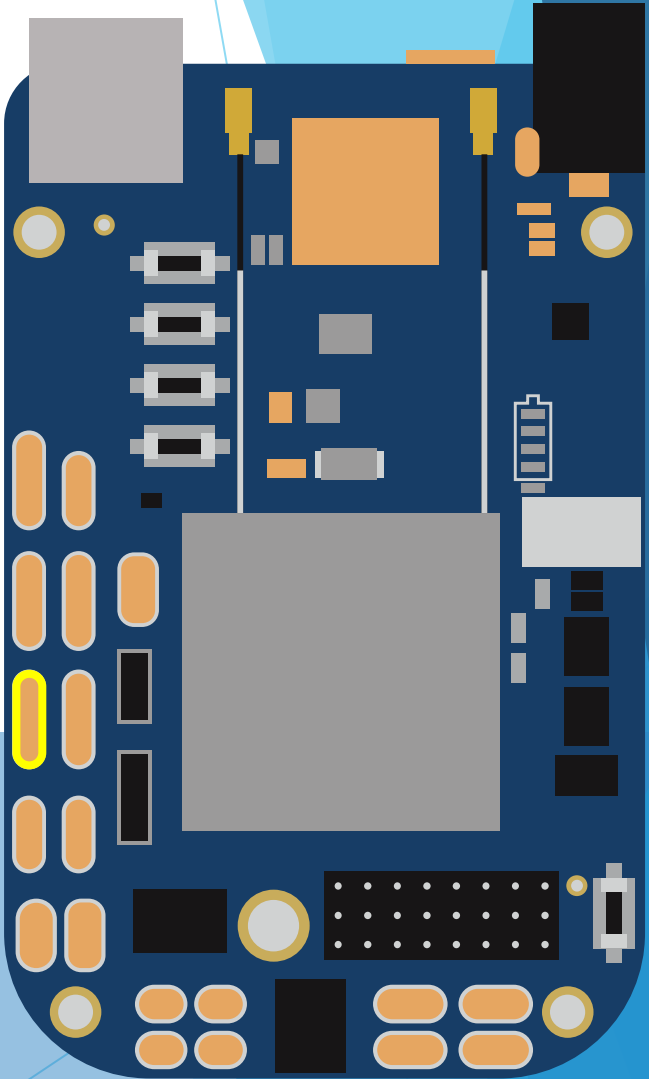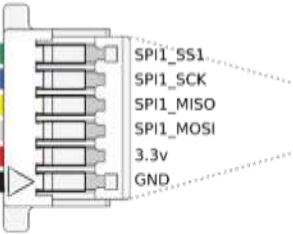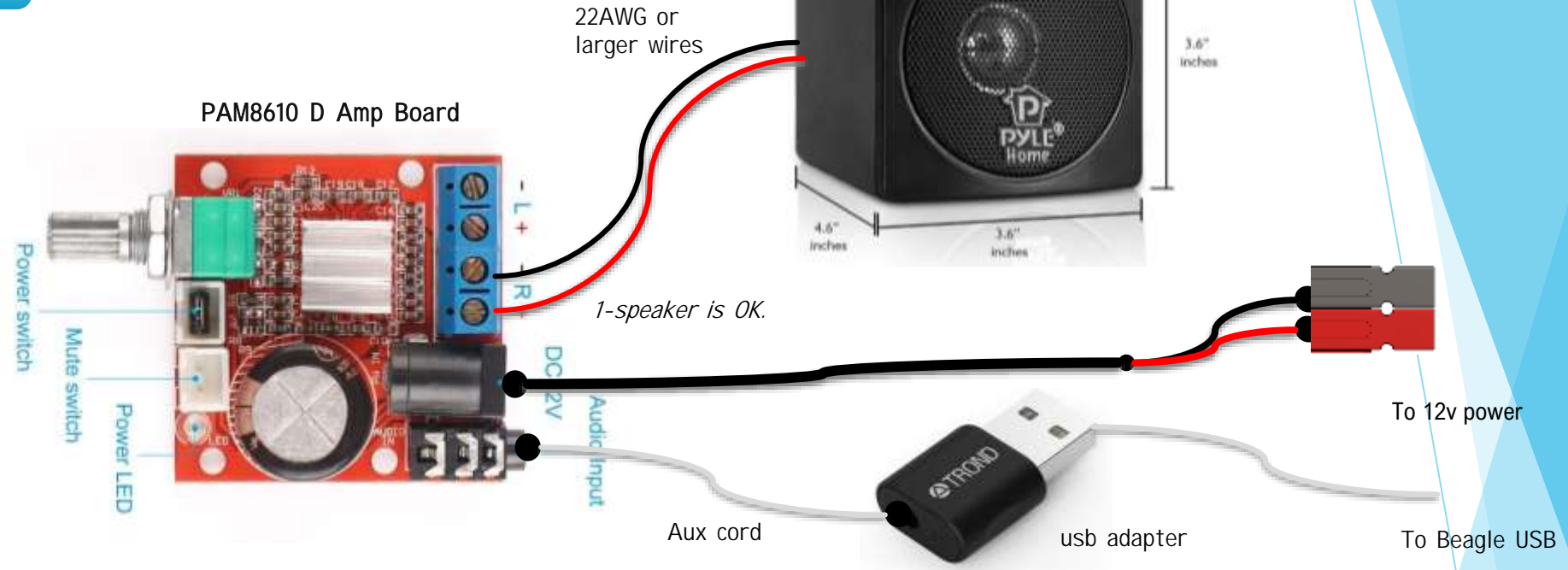
Alternative:

The above setup will support at least 10 watts (this is actually quite loud — easy to hear in a crowded room).

It is also possible to find a speaker which receives BOTH power AND signal over USB. These will be more compact but less powerful. (The speaker shown is 3w max)

GPIO connectors:
JST-SH 6-pin

Example call for writing to this pin:
write(1,3,1) # arguments: port, pin, state

Default Config

output / Controls Green LED
output /   Controls Red LED
output
output
3.3V
GND

3
2
1
0
3.3V
GND

GP1

Example call for reading this pin:
read(0, 1) #arguments: port, pin

iput
output
input
output
3.3V
GND

3
2
1
0
3.3V
GND

GP0

SCUTTLE naming convention (used in L1_gpio.py)
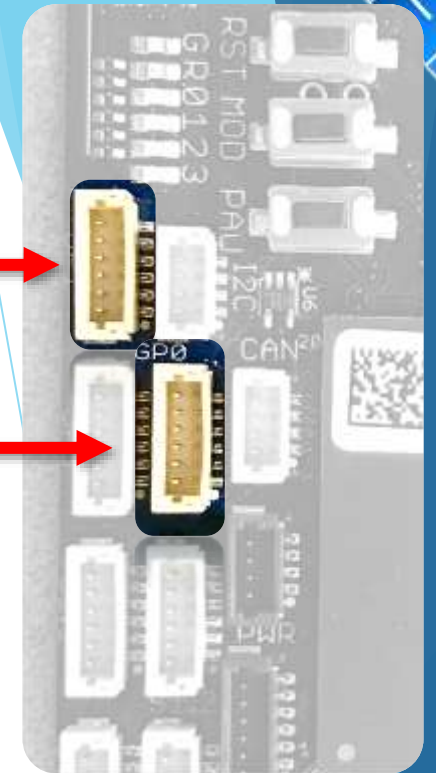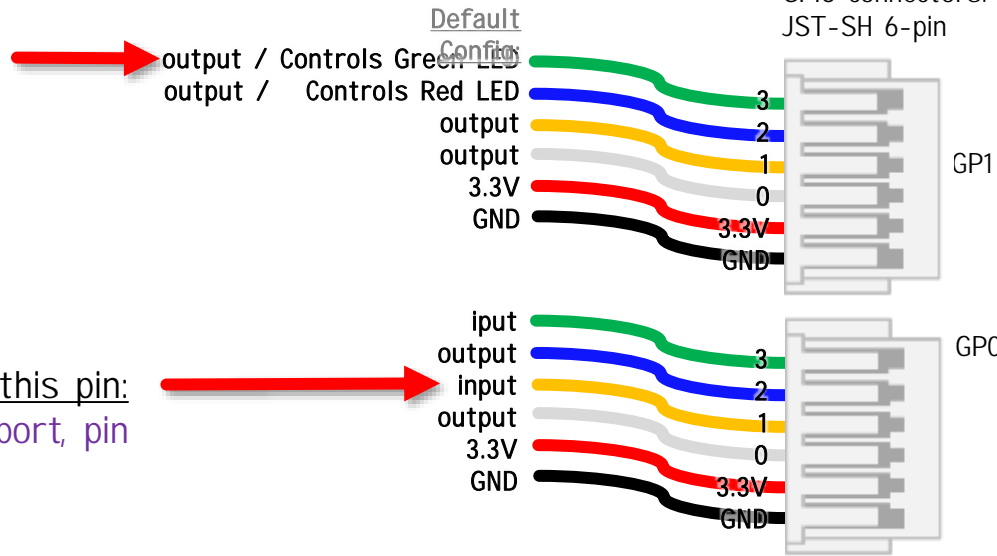
Connector vector image preserved for later use.

Note: JST wires don't come with the proper color sequence. They must be rearranged.

3
2
1
0
3.3V
GND

GP0 connector
JST-SH 6-pin on
Beagle

Relays are appropriate for switching of high powered devices. For heavy pumps, motors, fans, or floodlights, it may be best to add a dedicated power source such as an ancilliary battery. Then, control the power to the device using logic-level signals and a relay or solid-state relay.
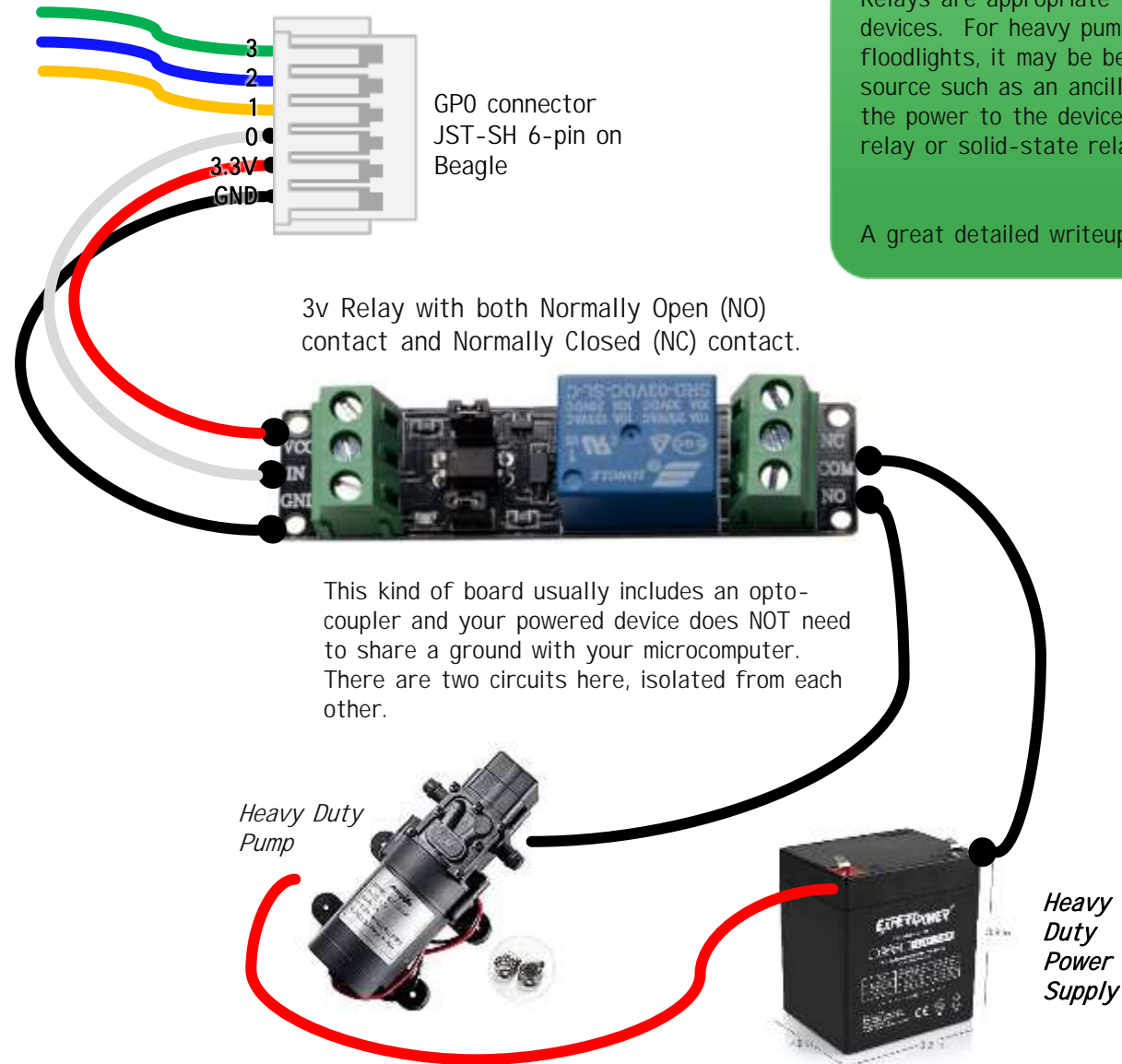
A great detailed writeup is here.

3v Relay with both Normally Open (NO) contact and Normally Closed (NC) contact.

VCC
IN
GND

NC
COM
NO

This kind of board usually includes an opto-coupler and your powered device does NOT need to share a ground with your microcomputer. There are two circuits here, isolated from each other.

Heavy Duty Pump

Heavy Duty Power Supply

Twin Relays (tested)

Successfully tested setup 2020.10.10
- Jumper pin is removed from Vcc pins
- Send GND and 5v to the device from Beaglebone PWR
- In our test, the 3.3v from Beagle was insufficient to drive the relays
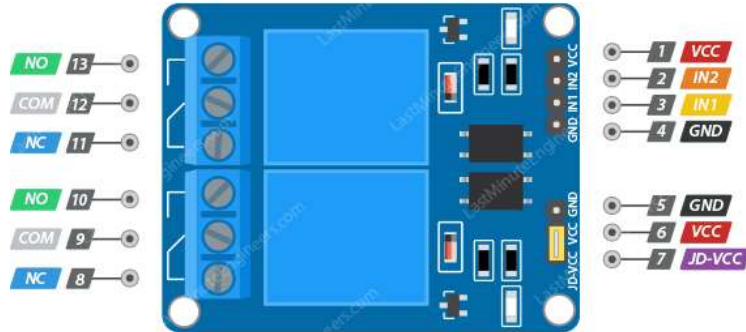- Our device was found to be active low although advertised as active high

Image credit: Last Minute Engineers (visit)

The problem with active-low relays:
If you have an actuator which must not be actuated until the right moment, (such as a car horn we tested indoors) an active-low device may cause you trouble.

Unless the coil power is provided at the exact moment that the signal pin is driven high, there will be an actuation during startup. Consider this when you shop for a relay.

JST-SH 6-pin

in2
in1
Vcc
GND
1
0
3.3V
GND

JST-SH 4-pin

5.0v

GND
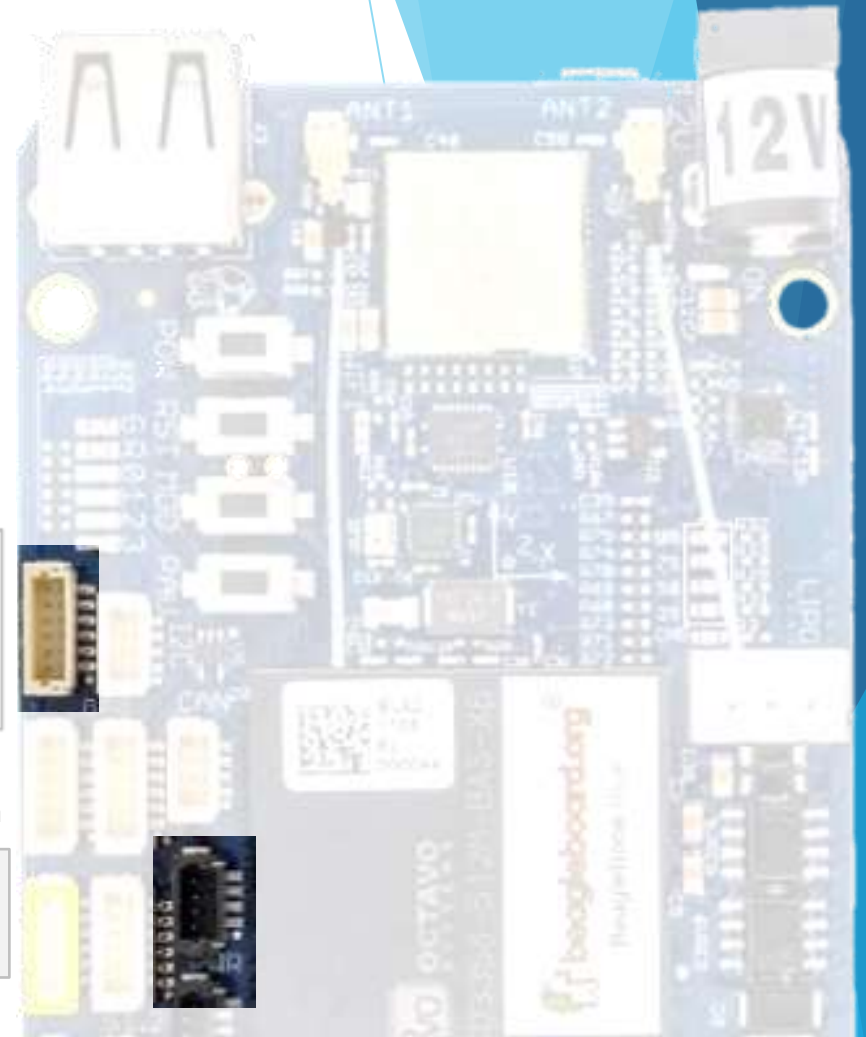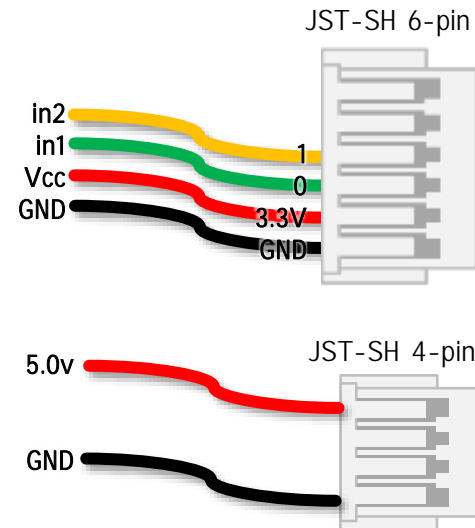
Wifi Antenna

Users can replace the small onboard antenna with their own selected antenna.

Antenna1 is used for WiFi

Antenna2 is used for Bluetooth

U.FL mini pci to SMA pigtail

6dBi antenna offers improved RSSI if pointed properly.

ANT1

ANT2

SCUTTLE Wire Routing

SICK Lidar

USB (data)

USB splitter

LIDAR USB:

i2c cable

motor signals

USB splitter

3-Cell Li-ion Pack

12V JUMPER

Beagle Pwr

Motor Pwr

BB Blue

L PWR R

GamePad USB dongle

Camera USB

LH encoder

i2c to bb

RH encoder

LIDAR POWER

i2C Bus Board

Left Encoder

8-pin duPont

Right Encoder

8-pin duPont
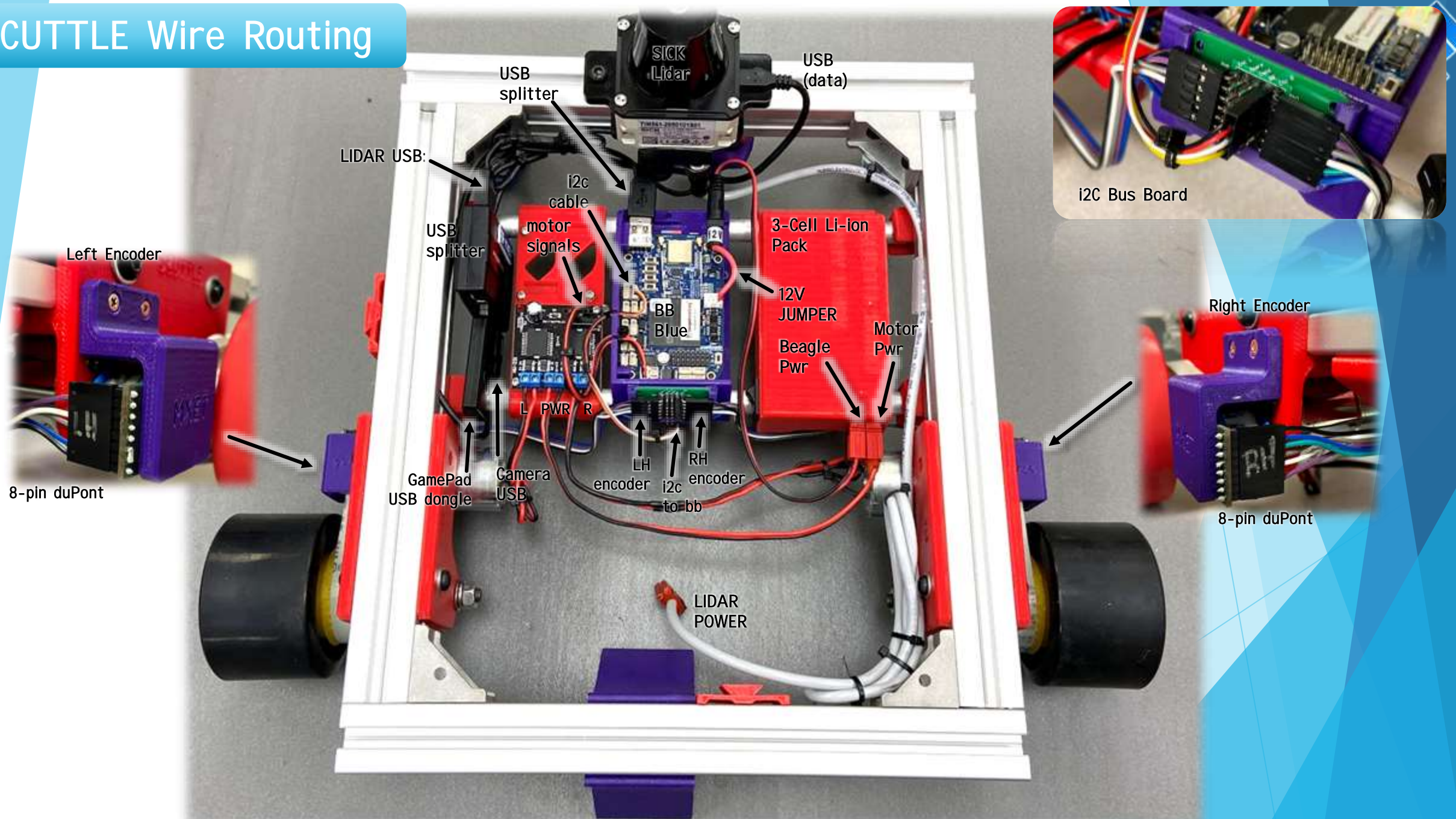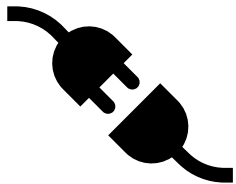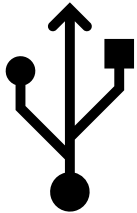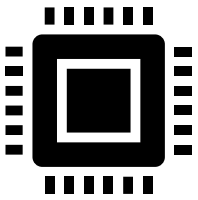
Wiring Guide Section 2

[Raspberry Pi] [Jetson Nano] [Edge AI]

Pi Wiring Guide

Contents:

This section covers single board computers (SBCs) that conform to the 40-pin header design from Raspberry Pi

Note: Raspberry Pi was integrated after Beaglebone Blue. For wiring elements corresponding purely to the chassis, see Part 1.

SCUTTLE Chassis
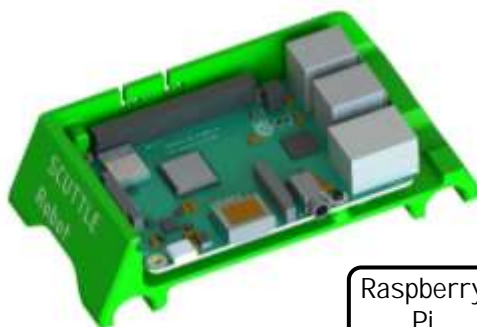
Raspberry Pi

Beaglebone Blue

Jetson Nano

Pi version 3B shown
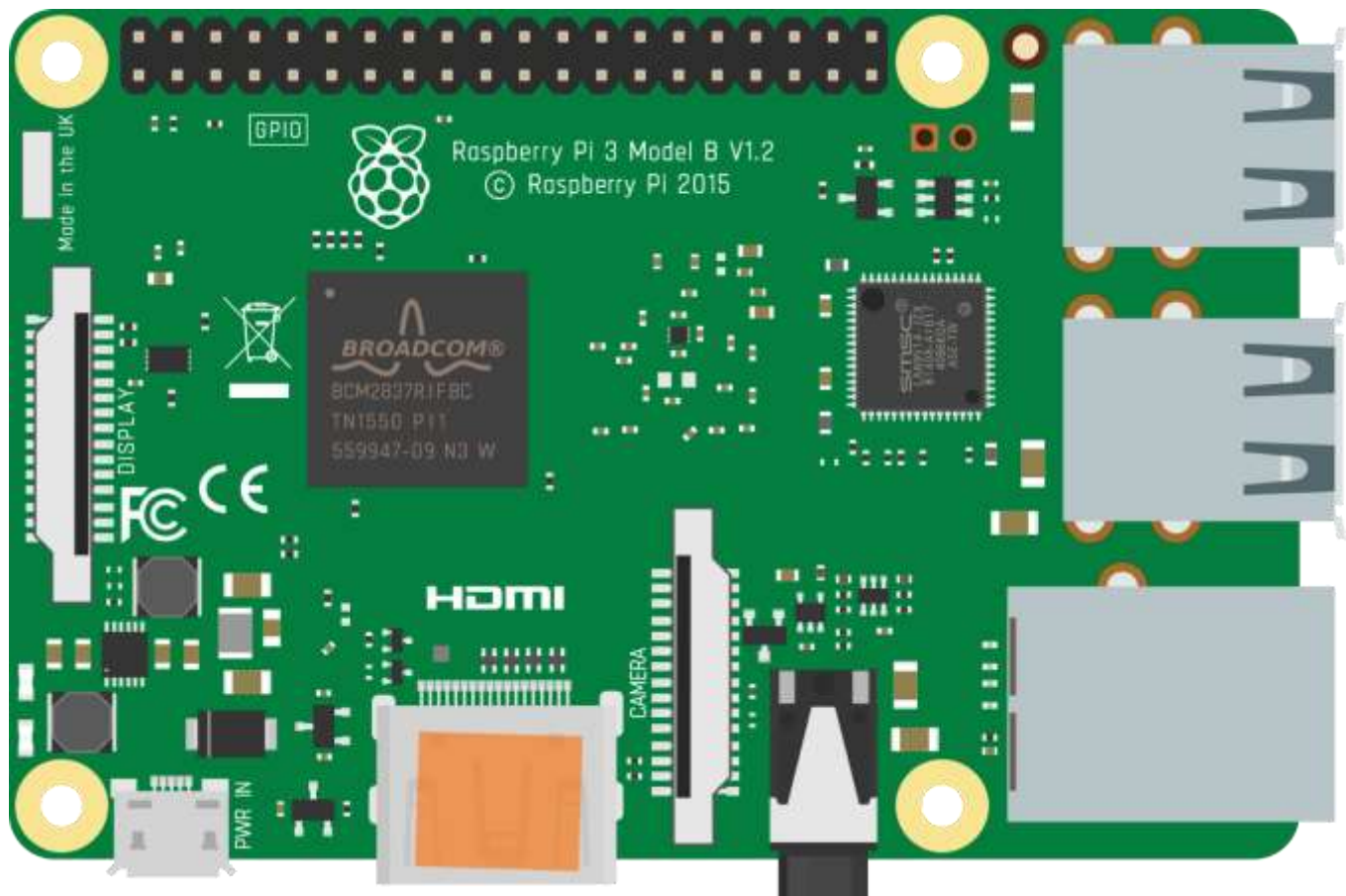
Pin Number Convention

Keep the wires bonded
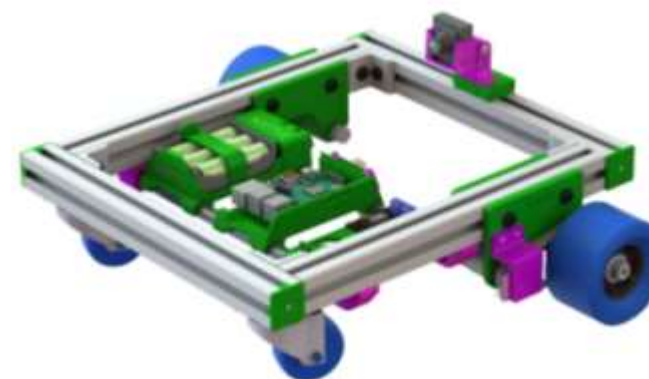to each other, if possible.

Top View
HW-231 Motor Driver

Pins on RasPi

GPIO17 11 12 GPIO18
GPIO27 13 14 GND
GPIO22 15 16 GPIO23
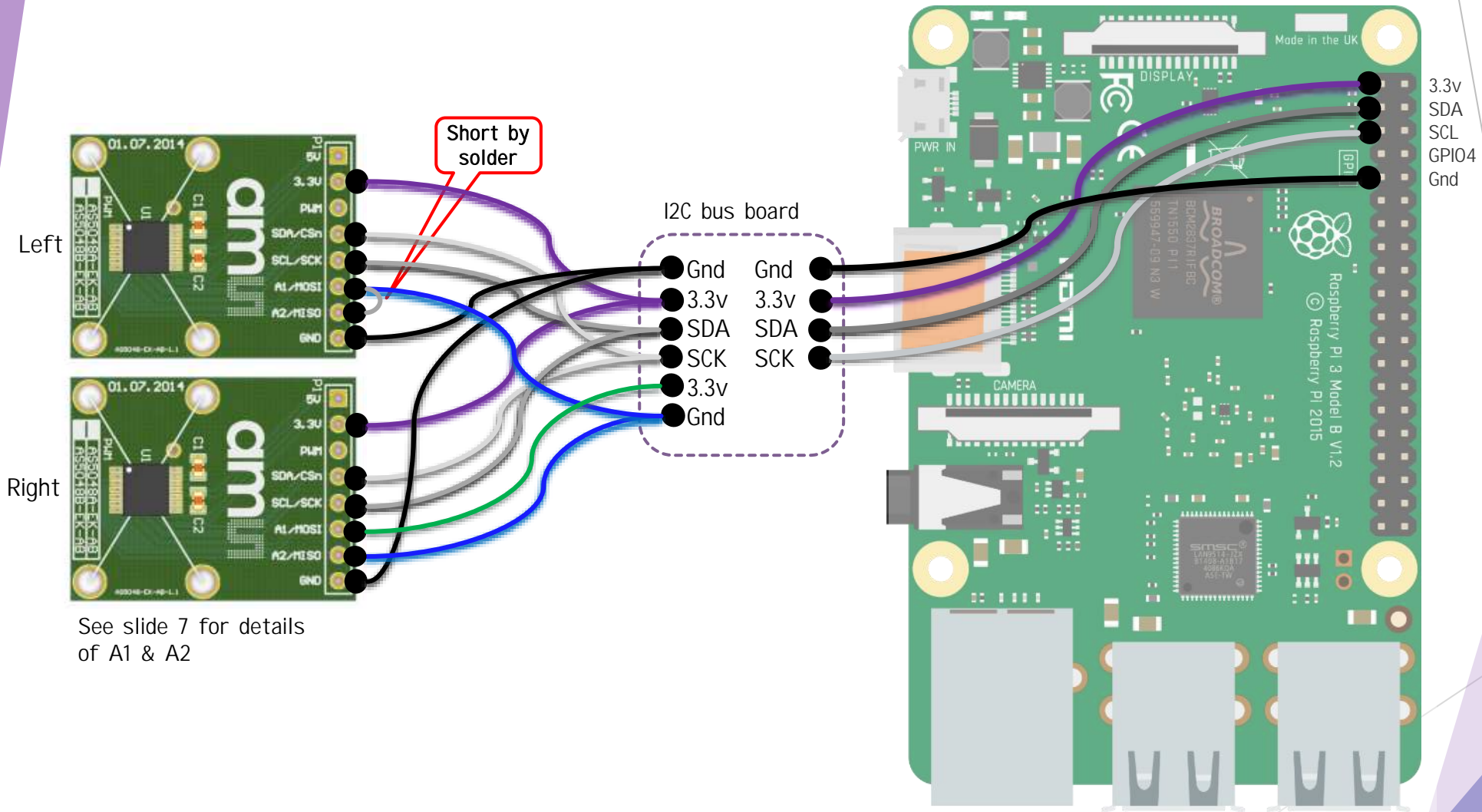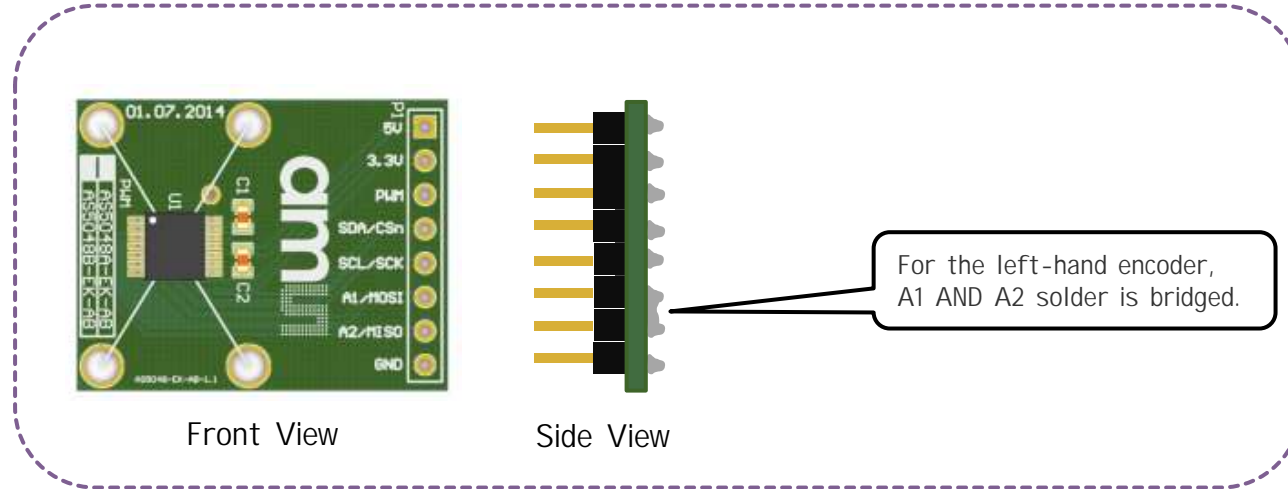
Ground is *optional* if the
Pi and Motor Driver have
a common ground to the
battery pack.

Left   Input   Right

See Motor Driver
Power Wires slide for
these connections.

Left

Right

See slide 7 for details
of A1 & A2

Short by solder

I2C bus board

Gnd Gnd
3.3v 3.3v
SDA SDA
SCK SCK
3.3v
Gnd

3.3v
SDA
SCL
GPIO4
Gnd

Encoder Details

Left Encoder

Front View

Side View

For the left-hand encoder,
A1 AND A2 solder is bridged.

The i2c address is determined by
the signals on A1 and A2 pins.

Left Hand Encoder A1 is pulled
down to GND. I2C address is 0x40

Right Hand Encoder pin A1 is pulled
up to 3.3v. I2C address is 0x41

	Pin A1	Pin A2	Resulting i2c address
Left Encoder	LOW	LOW	0x40
Right Encoder	LOW	HIGH	0x41

Pi - Power Supply

5.0v regulator

DC-DC 15W Converter
IN   **OUT**
12V   **5V 3A**
+ -   **- +**

To battery (12v)

5v
5v
Gnd

Dupont Cables

Motor Signals Cable

motor driver

Pi

i2c Signal Cable

i2c board

Pi

Pi Power Wire

Soldered to 5.0v power wires

Pi

100mm
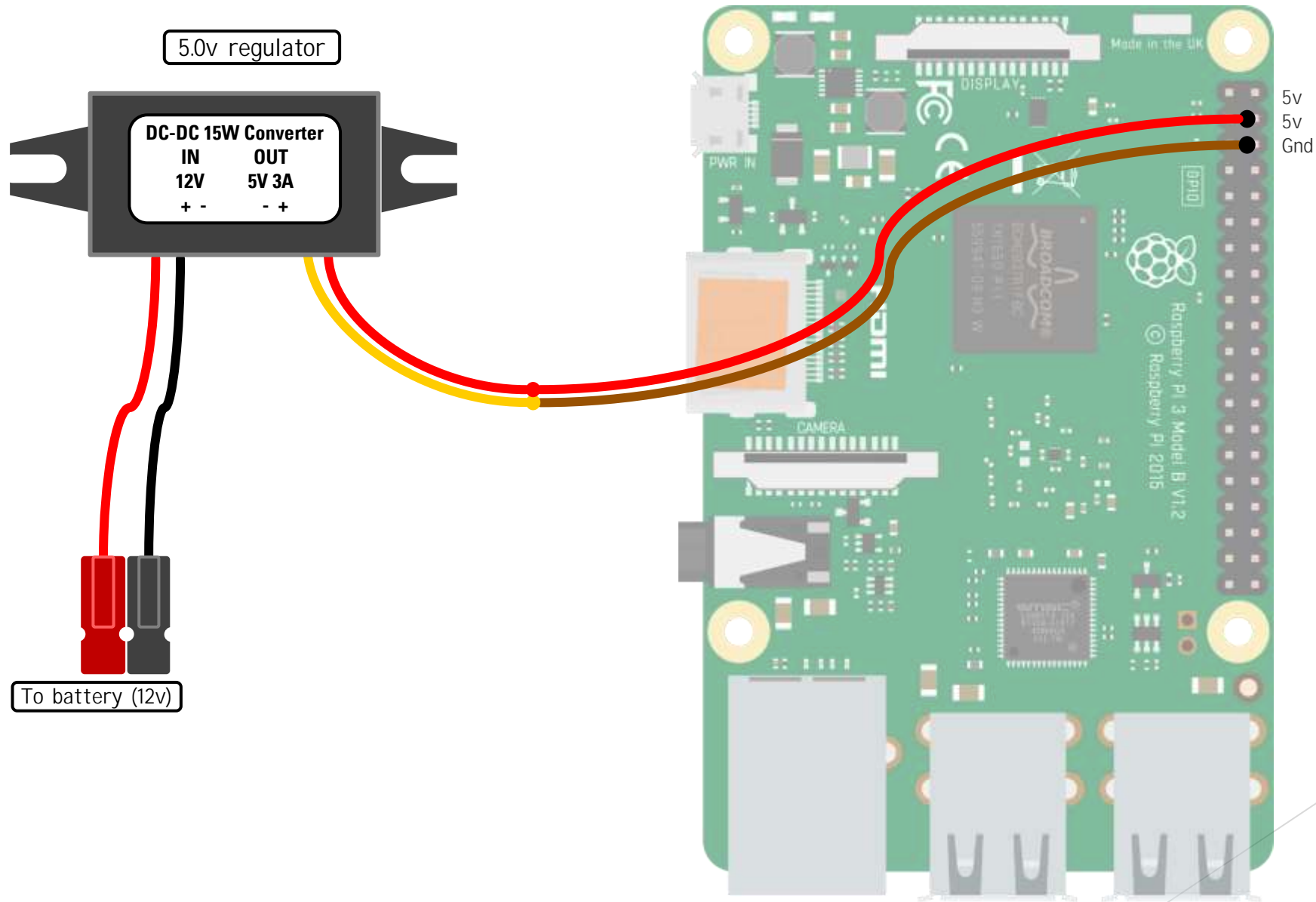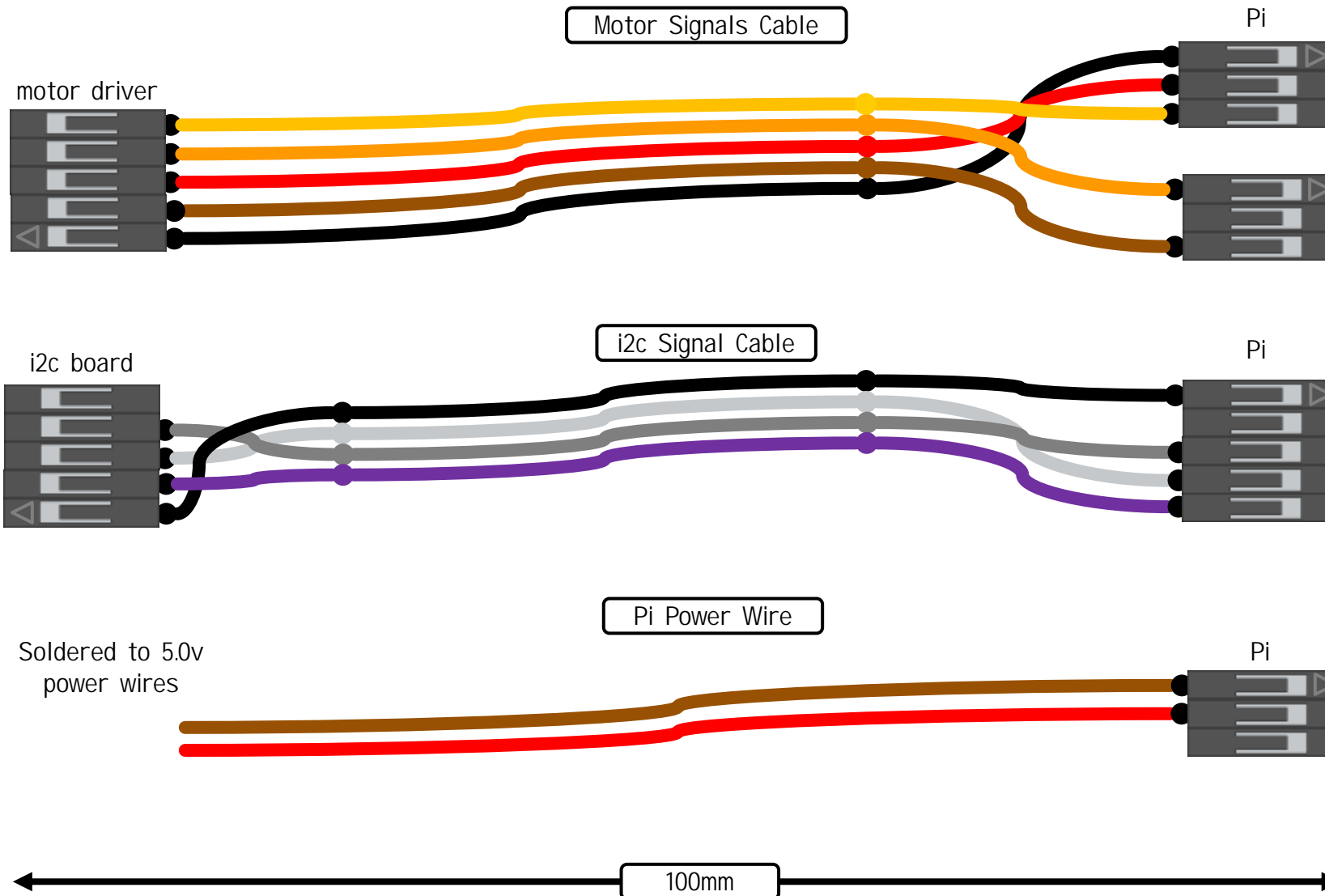
Guidelines:

Ground: When possible, insert the ground in the housing pin with the arrow.

Opening: Make the opening face the outside of the Pi headers when plugged in. This makes it easier to probe.

Bonding: Do not peel the wires apart unless you must. Keep wires bonded for strength

Pin Groups: Always use grouped housings instead of individuals. Then, the cable resists tugging, unplugging, and bending male pins.

Tug Test: After inserting pins into housings, lightly tug each pin to ensure it is locked in.

Voltage Meter — Adafruit INA219

This sensor can measure current and voltage.

To Battery Positive

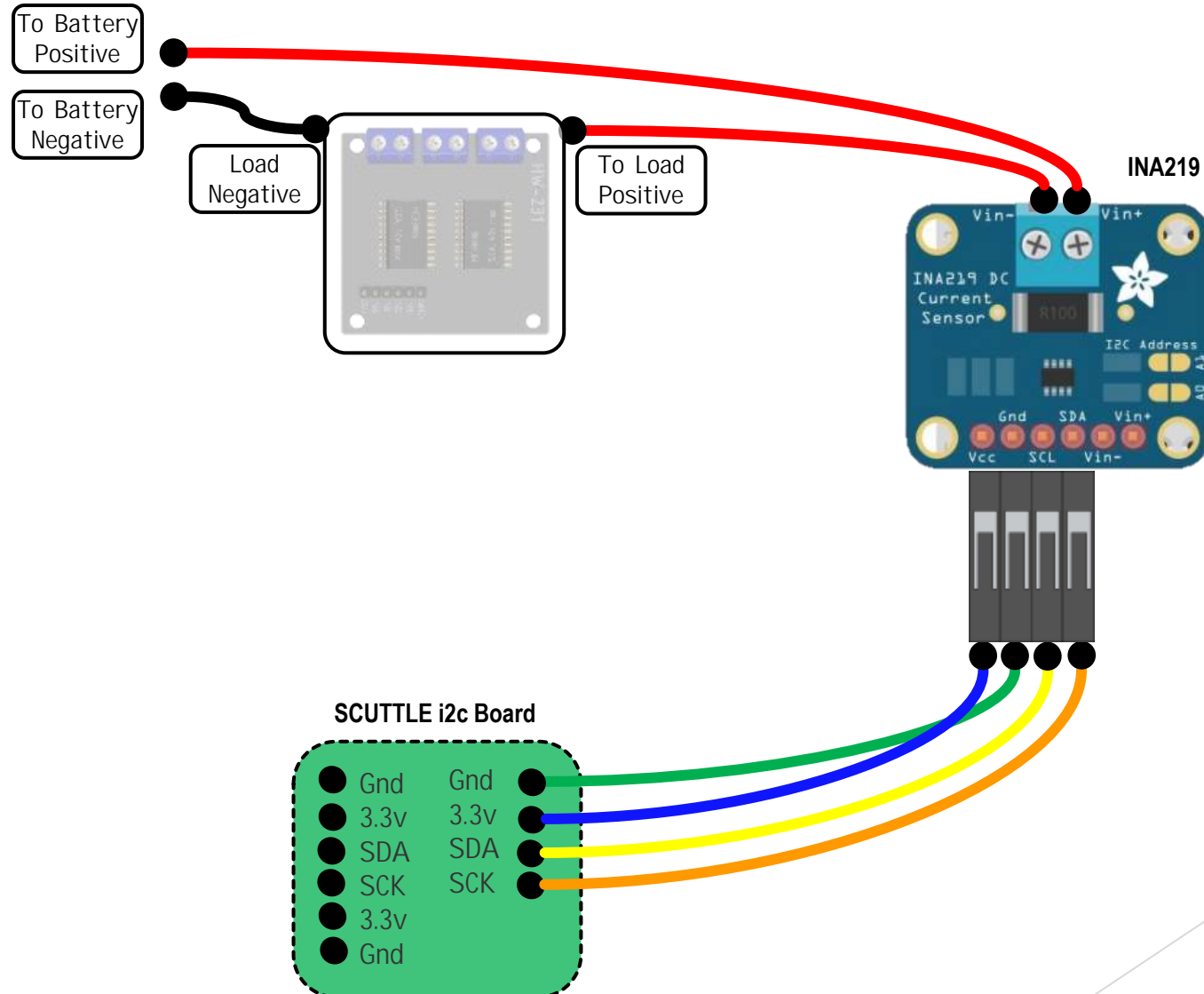To Battery Negative

Load Negative

To Load Positive

INA219

Vin- Vin+

INA219 DC Current Sensor

R100

I2C Address

A0 A1

Gnd SDA Vin+
Vcc SCL Vin-

HW-231

SCUTTLE i2c Board

| Gnd | Gnd |
3.3v	3.3v
SDA	SDA
SCK	SCK
3.3v	
Gnd	

Study an Example like this one if you plan to measure current

Set the i2c address to 0x44 by bridging the A1 contact with solder. See this guide for details.

The default Address of 0x40 would interfere with the encoders.

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Distance Sensor — VL53L0X

This is a time-of-flight distance sensor.

VL53L0X

SCUTTLE i2c Board
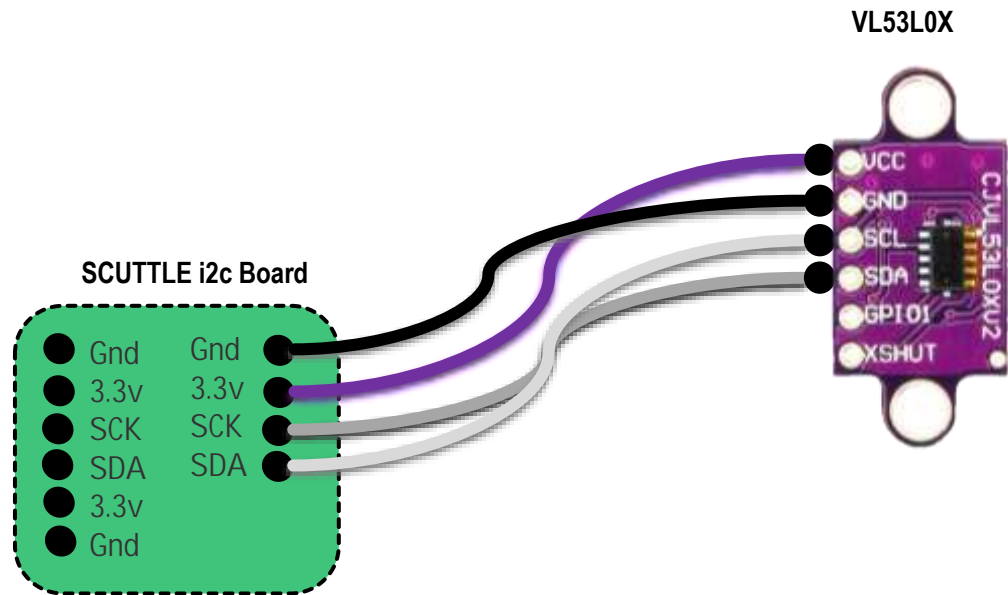
Pi - Configuration for remo.tv

Coming for this slide: configuration of hardware on RasPi B 3+, Linux default device numbers for branded speakers, and text-to-speech selection (ie, alsamixer).
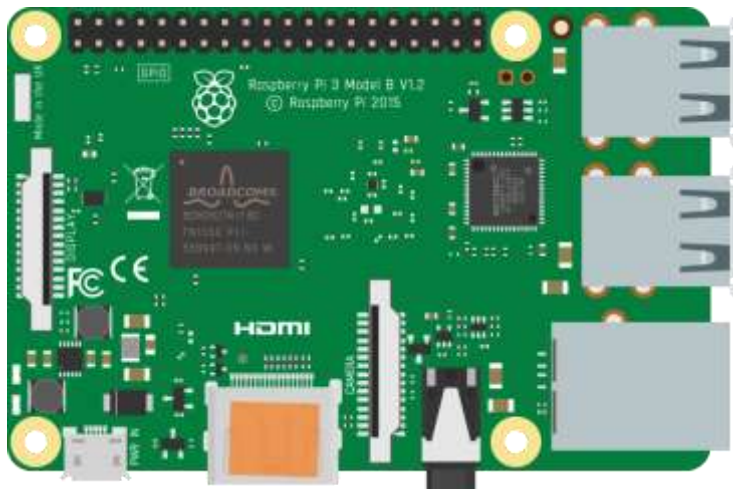
We recommend a speaker that receives power AND signals from the USB port.

If you need to use an Aux cord, a right-angle adapter can keep your wires neat.
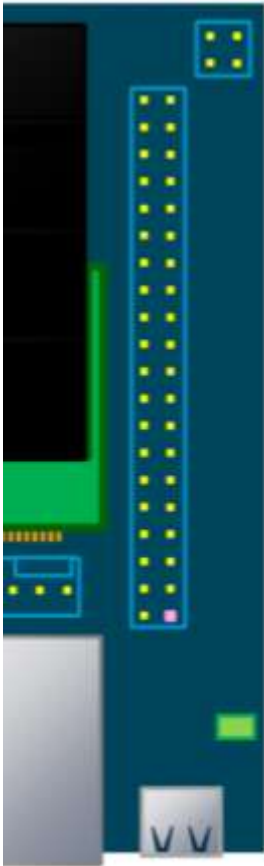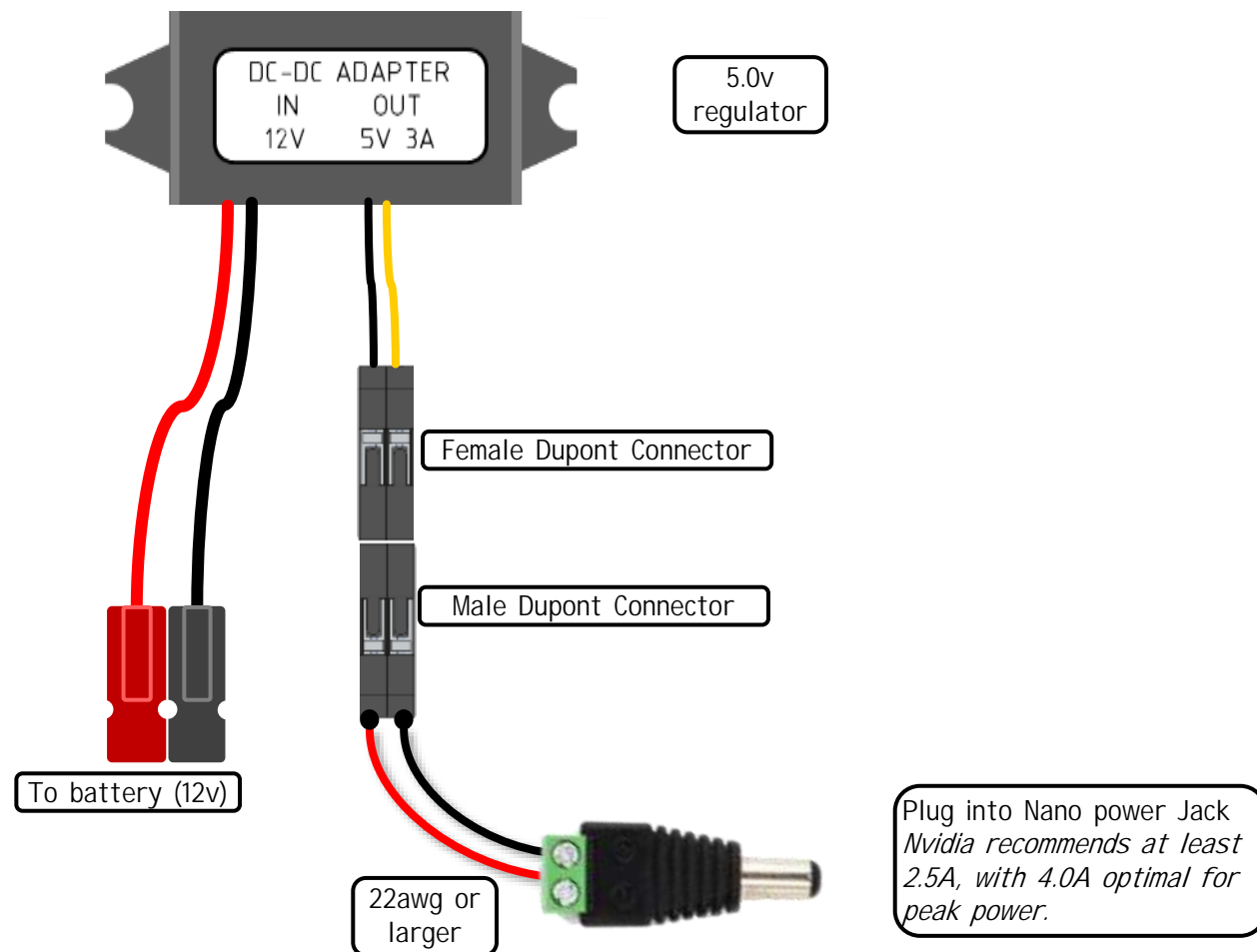
Jetson Nano Wiring

Diagram from Jetsonhacks.com

Sysfs GPIO	Name	Pin	Pin	Name	Sysfs GPIO
	3.3 VDC *Power*	1	2	**5.0 VDC** *Power*	
	I2C_2_SDA *I2C Bus 1*	3	4	**5.0 VDC** *Power*	
	I2C_2_SCL *I2C Bus 1*	5	6	**GND**	
gpio216	**AUDIO_MCLK**	7	8	**UART_2_TX** */dev/ttyTHS1*	
	GND	9	10	**UART_2_RX** */dev/ttyTHS1*	
gpio50	**UART_2_RTS**	11	12	**I2S_4_SCLK**	gpio79
gpio14	**SPI_2_SCK**	13	14	**GND**	
gpio194	**LCD_TE**	15	16	**SPI_2_CS1**	gpio232
	3.3 VDC *Power*	17	18	**SPI_2_CS0**	gpio15
gpio16	**SPI_1_MOSI**	19		**GND**	
gpio17	**SPI_1_MISO**	21	22	**SPI_2_MISO**	gpio13
gpio18	**SPI_1_SCK**	23	24	**SPI_1_CS0**	gpio19
	GND	25	26	**SPI_1_CS1**	gpio20
	I2C_1_SDA *I2C Bus 0*	27	28	**I2C_1_SCL** *I2C Bus 0*	
gpio149	**CAM_AF_EN**	29	30	**GND**	
gpio200	**GPIO_PZ0**	31	32	**LCD_BL_PWM**	gpio168
gpio38	**GPIO_PE6**	33	34	**GND**	
gpio76	**I2S_4_LRCK**	35	36	**UART_2_CTS**	gpio51
gpio12	**SPI_2_MOSI**	37	38	**I2S_4_SDIN**	gpio77
	GND	39	40	**I2S_4_SDOUT**	gpio78

40 Pin Array on Jetson Nano

Diagram for powering Jetson Nano

DC-DC ADAPTER
IN   OUT
12V   5V 3A

5.0v regulator

Female Dupont Connector

Male Dupont Connector

To battery (12v)

22awg or larger

Plug into Nano power Jack
Nvidia recommends at least 2.5A, with 4.0A optimal for peak power.

Jetson Nano – i2c

Diagram for connecting i2C to SCUTTLE
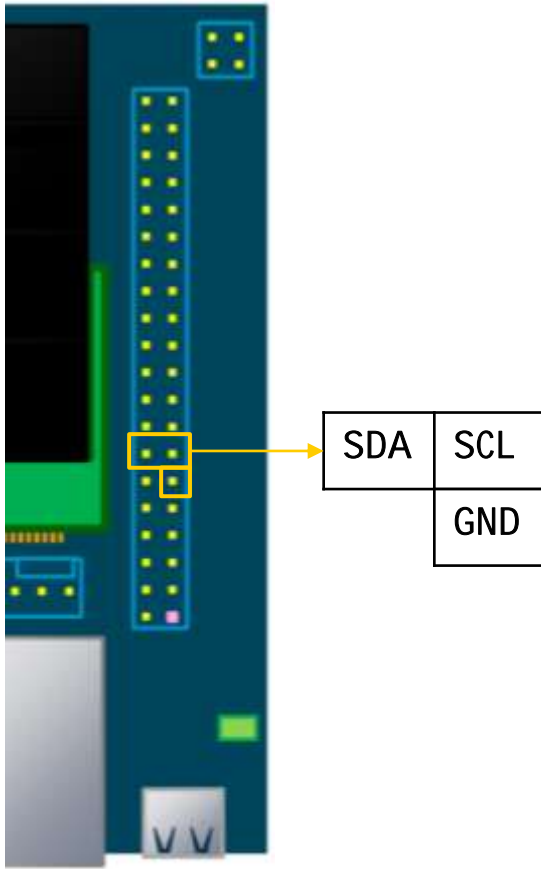
TO BE COMPLETED...

SDA	SCL
	GND

TDA4VM Edge AI Board

▶ Wiring section in progress... to be completed in May 2022!