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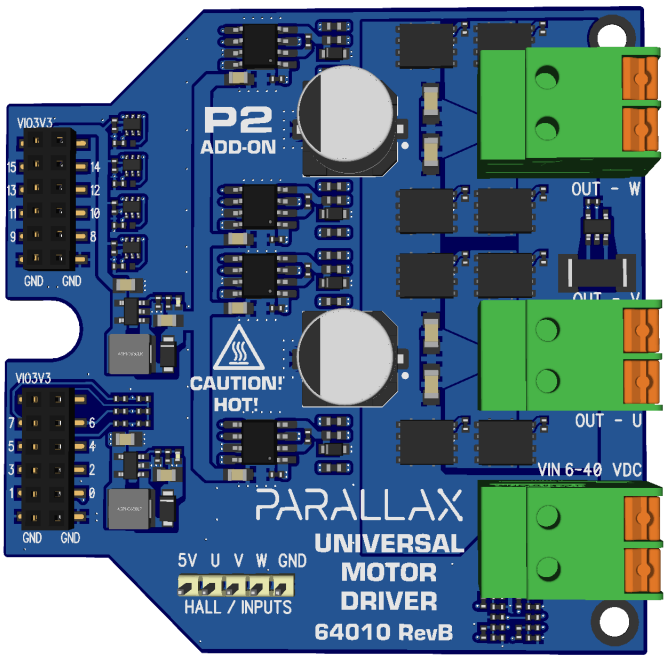
Universal Motor Driver P2 Add-on (Rev B, #64010)

The Universal Motor Driver P2 Add-on Board (Rev B) from Parallax was designed as an accessory for the Parallax Propeller 2 8-core microcontroller. It is compatible with standard P2 dual-port accessory headers found on many Propeller 2 development boards.



This 4-phase motor driver add-on supports experimentation and development with many motor types, including brushed and brushless motors. For example, it could support a single brushless 3-phase Hub Brushless DC (BDLC) motor, a 4-phase stepper motor, two brushed bi-directional DC motors or four brushed uni-directional DC motors. With a 3-phase motor, both sinusoidal 180° and classic 120° drive techniques are supported.

The open design and standard 0.1" connectors allow the Universal Motor Driver P2 Add-on Board to be used with other microcontrollers as well.

Features

- Universal 4-phase motor driver using four UCC27211D MOSFET drivers
- Phases can be controlled individually or in groups to support many motor types including single or 3-phase motors, single/dual DC motors or 4-phase stepper motors
- Sinusoidal 180° or classic 120° drive topology
- Each phase allows individual control of High and Low sides
- High and Low sides protected against simultaneous activation
- On-board Hall effect sensor connector for motor control feedback
- Common current feedback signal for motor control and over-current protection
- Independent voltage feedback signals for each phase, for motor control and over-voltage protection
- Under-voltage lockout protection built into MOSFET drivers
- High-current spring terminal connectors for quick and robust connections to high-current motors
- Two grounded 0.125 inch (3.2 mm) mounting holes

Specifications

- Input voltage range: 6–40 VDC
- Maximum continuous supply current: 20A
- Maximum surge motor current: 60A
- P2 board connector: dual 2x6 pass-thru headers with 0.1" spacing
- Power and motor cable connection method: Push-in spring connection, nominal 2.5 mm^2
- Communication Interface: 3.3V TTL, PWM
- VIN and Output Channel Spring Terminal Blocks: 32A 400V rated
    - Conductor cross section solid : 0.2 mm^2 ... 4 mm^2
    - Conductor cross section AWG : 24 ... 12
    - Stripping length : 10 mm
- Operating temperature range: -40 to +185 °F (-40 to +85 °C)
- PCB dimensions: 2.75 x 2.75 in (70 x 70 mm)

Quick Start Guide

WARNING: Ensure the motor controller PCB is not installed on a conductive surface which may short out the high-current pins on the bottom of the board!

WARNING: Use of an inline fuse close to the VIN terminal is highly recommended when operating from a power source without fault protection, such as from a battery pack!

WARNING: Only connect to a power source that is capable of providing the current requirements of your motors! An overloaded power source might drop voltage in a way that risks damage to the motor MOSFETs or drivers.

The P2 Edge Mini Breakout Board (#64019) is used in the simple wiring diagrams below. For projects that require more space, more headers for additional add-ons, or a breadboarding area, we recommend either the P2 Edge Breakout Board (#64029) or P2 Edge Module Breadboard (#64020).

Typical connections for Motor Mount and Wheel Kit - SKU 28962

Parts required:

- Motor Mount and Wheel Kit - Aluminum (#28962)
- Universal Motor Controller P2 Add-on Board (#64010)
- P2 Edge Mini Breakout Board (#64019)
- P2 Edge module (#P2-EC), not shown
- Prop Plug (#32201), not shown

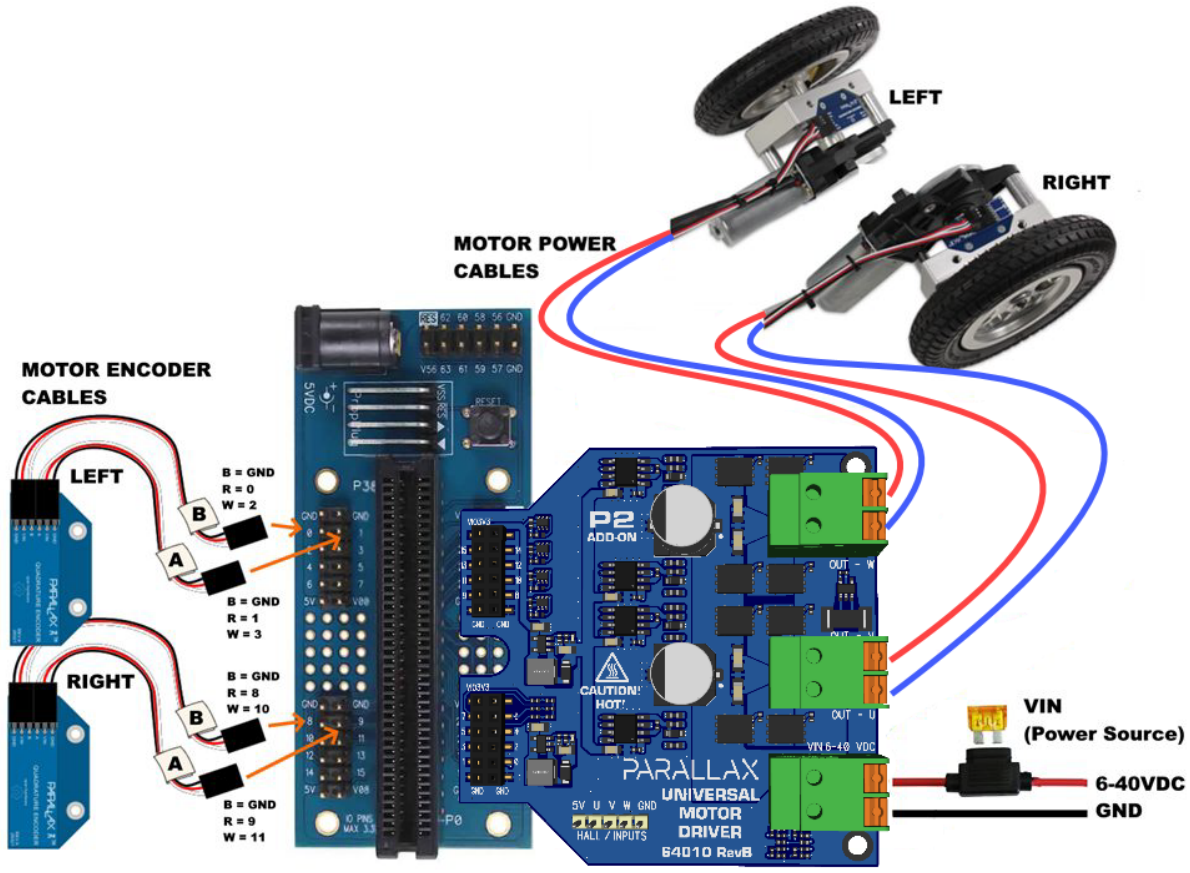


Diagram notes:

- Fuse and power cables shown at VIN are not supplied.
- Fuse is optional, but recommended when operating the motor controller from a battery power source.
- P2 Edge module and P2 Edge Mini Breakout Board board power source not shown.
- A Prop Plug #32201 (not shown) is typically required for programming the P2 Edge module.
- Motors, motor power cables, motor encoders and encoder cables are included in the Motor Mount and Wheel Kit (#28962).

Typical connections for 6.5" Hub Motor with Encoder - SKU 27860

The following instructions are for a single Hub Motor. To operate two Hub Motors. add a second Universal Motor Driver P2 Add-on Board to the unused headers on the P2 Edge Mini Breakout Board.

Parts Required:

- 6.5" Hub Motor with Encoder (#27860)
- Universal Motor Driver P2 Add-on Board (#64010)
- P2 Edge Mini Breakout Board (#64019)
- P2 Edge module (#P2-EC), not shown
- Prop Plug (#32201), not shown

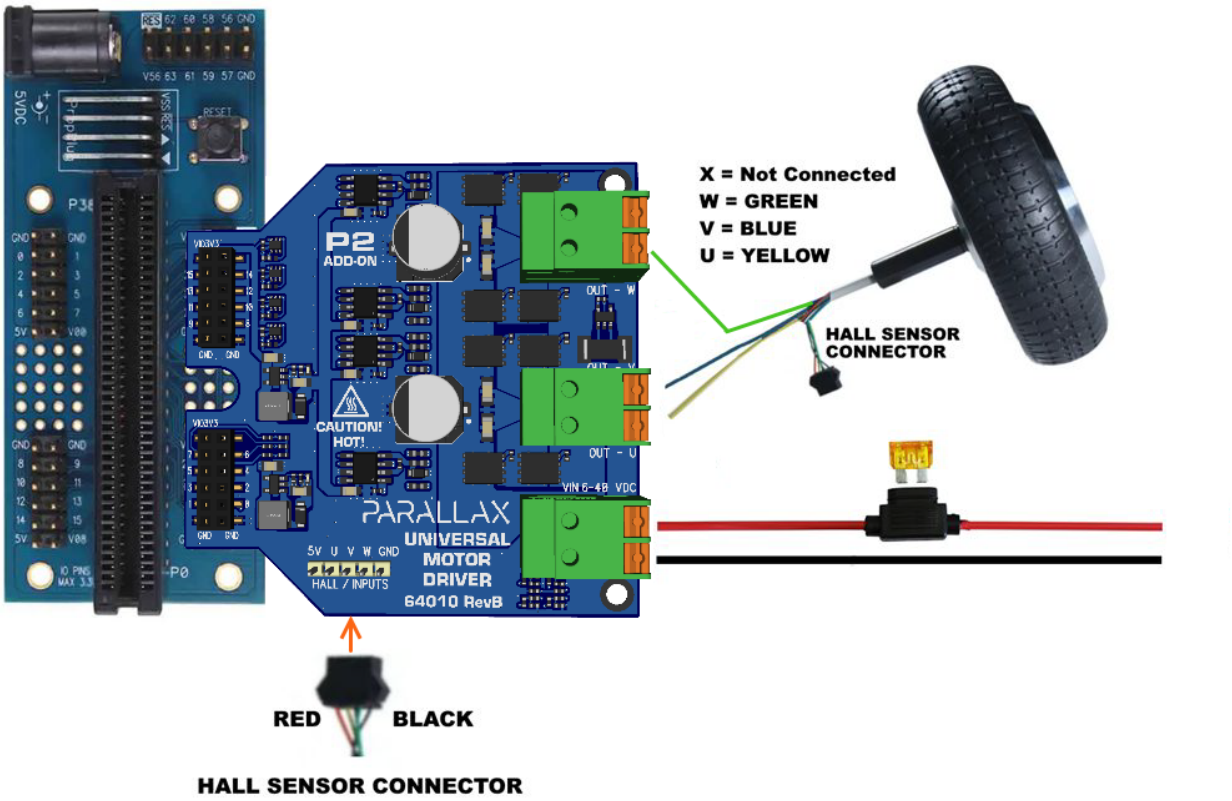
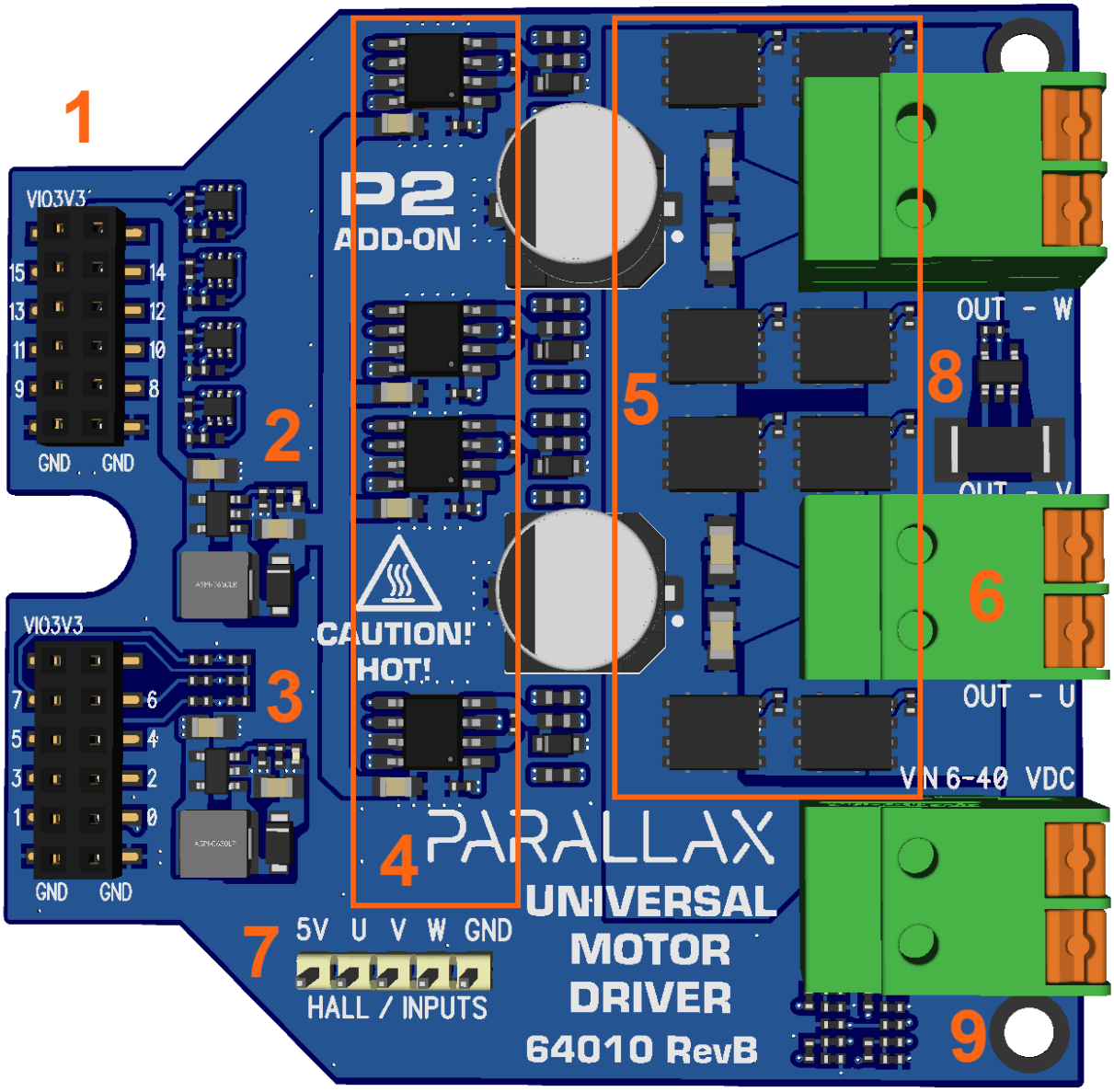


Diagram Notes:

- Fuse and power cables shown at VIN are not supplied.
- Fuse is optional, but recommended when operating the motor controller from a battery power source.
- P2 Edge module and P2 Edge Mini Breakout Board board power source not shown.
- A Prop Plug (not shown) is typically required for programming the P2 Edge module.
- Hall sensor connector is included with the 6.5" Hub Motor with Encoder (#27860).

Feature Descriptions



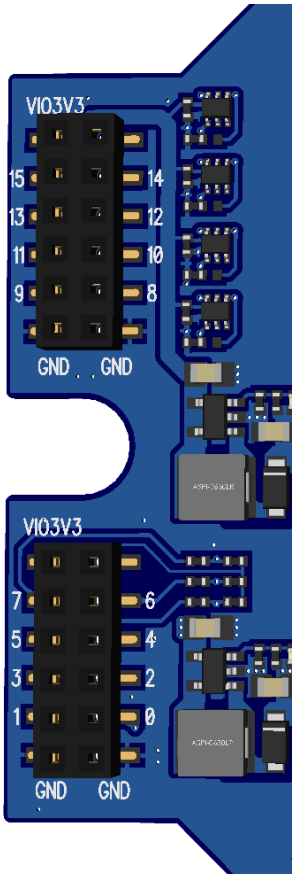
1. Dual 2x6 way P2 Accessory Headers

The 2x6 way accessory headers follow the standard P2 header pinout, and are ready to stack on top of the P2 Eval Board or any of the P2 Edge module breakout boards that include dual accessory header locations.

The headers are standard 0.1” pitch, making this add-on board a convenient rapid solution for integration in custom user applications.

3.3V	VIO3V3	5V	Not Connected
PWM_XH	15	14	PWM_XL
PWM_WH	13	12	PWM_WL
PWM_VH	11	10	PWM_VL
PWM_UH	9	8	PWM_UL
GND	GND	GND	GND

3.3V	VIO3V3	5V	Not Connected
HALL_W	7	6	HALL_V
HALL_U	5	4	SENSE_COMMON
SENSE_X	3	2	SENSE_W
SENSE_V	1	0	SENSE_U
GND	GND	GND	GND



2. 12 V Power Supply

The 12 V power supply is based on a switching boost regulator and is capable of delivering up to 50 mA to the MOSFET driver circuits. Power to the boost circuit comes from the VIO3V3 pin on the upper P2 Accessory Header.

3. 5 V Power Supply

The 5 V power supply provides power to the HALL/INPUTS header, and is available for user attached sensors. This onboard power supply is based on a switching boost regulator and is capable of delivering up to 100 mA. Power to the boost circuit comes from the VIO3V3 pin on the lower P2 Accessory Header.

4. MOSFET Drivers

This board has four Half-Bridge MOSFET drivers, part number Texas Instruments UCC27211D. One driver controls each of the 4 output channels labeled: U, V, W, X.

The drivers allow independent control of the high and low channels, and there is an added logic buffer before each MOSFET driver to ensure that the high side MOSFET can only be turned on when the low side MOSFET is turned off. The independent control ensures compatibility with a wide range of loads, including brushed and brushless motors.

The UCC27211D MOSFET driver has internal protection against large negative spikes, at least down to -10V on the HS pin (high-side feedback). To further protect the MOSFET Drivers against negative voltage spikes there is a fast-acting reversed-biased diode between each common switching node and ground. The protection against large negative spikes makes this motor controller particularly suitable for driving large BLDC type hub motors.

TIP: Even though the MOSFET Drivers feature a fast ~20ns propagation delay and typically 7.2ns rise, 5.5ns fall time, the MOSFETs also require some time to respond to the control signal from the MOSFET Drivers. This means it is possible, for fractions of a second during fast switching, that both high and low MOSFETs might be partially on and causing momentary overcurrent. Therefore, the recommended minimum pause (deadtime) is 250 ns after switching off one MOSFET and before switching on the other MOSFET in the same channel. Using a deadtime pause is standard practice for Half-Bridge motor controllers, and ensures the highest efficiency and lowest power losses, including lower current-surge requirements from the power source and overall cooler operation of the motor controller PCB.

5. MOSFETs

Each of the four channels have two high-power N-Channel MOSFETs in a common Half-Bridge arrangement. The MOSFETs have large internal body diodes to provide maximum protection from back EMF. Refer to the manufacturer datasheet for full details, Micro Commercial MCAC85N06Y-TP.

The MOSFETs are controlled by the MOSFET Drivers, typically with a PWM signal driving the high and low sides on/off alternately for a brushless motor, or asserting the MOSFETs either on or off when driving a brushed DC motor. Refer to the **MOSFET Drivers** Tip above about minimum deadtime when designing the code to run the motor controller.

6. VIN and Motor Channel Connectors

The large spring-operated terminal block connectors are convenient and quick to use. They have a nominal 32 A rating and accept solid or flexible conductors in the range 0.2 mm²–4mm² (24–12 AWG). Recommended conductor stripping length is 10 mm.

WARNING: Use of an inline fuse close to the VIN terminal is highly recommended when operating from a power source without fault protection, such as from a battery pack !

WARNING: Always use VIN and Motor channel cables that are rated for the maximum total power requirements of your installation.

WARNING: Ensure your power source is capable of providing the maximum voltage and current requirements of your motors, including during startup and when under full load. Surge current requirements are significantly higher at start-up and when motors change direction!

7. Hall Effect or General Purpose Feedback Inputs

The HALL/INPUTS header is populated with a standard 5 way 0.1" male header, and is typically used to connect the Hall effect sensor cable of a 3-phase Hub (BDLC) type motor, such as our Hub Motor #27860.

The 5V output is provided to power a low current hall sensor (or similar sensor up to 100 mA), and the three signal pins (U, V, W) are each pulled up to 3.3 V via a 3.9 kΩ resistor and are each connected to the P2 Accessory Header via a series 3.9 kΩ resistor to protect the microcontroller from 5 V signals.

8. Current Sense Resistor with Amplifier

Total MOSFET load current can be measured with the current sense resistor, and the data is typically used to determine system load and provide overcurrent protection.

This board uses a low-side sensing technique with a 3 mΩ current sense resistor connected between common MOSFET GND and common system GND.

A dedicated current sense amplifier beside the shunt resistor (INA180B2) boosts the signal with a gain of 50 V/V. Refer to the Texas Instruments INAx180 datasheet, and in particular the section "Precise Low-Side Current Sensing" to help with interpreting the current sense readings. In addition the same datasheet has an elaborated Typical Application for Low-Side Sensing in section 9.2.

The voltage level can be measured across this sense resistor and converted to current with this formula:

Vsense = 3mOhms * 50V/V gain = 150mV per Amp (mV/A)

This can be simplified as: Isense = Vsense / 150

Example: If the voltage measured at Sense Common (Vsense) = 1500mV then the MOSFET current would be 1500mV / 150 (mV/A) = 10 Amp.

Refer to the schematic diagram available on the product page downloads for more information.

9. Mounting Holes

The two plated mounting holes are 3.2 mm in diameter and connected to the board GND (ground) plane.

If desired, with the board plugged into a P2 Eval or P2 Edge breakout with rubber feet, use 3 mm diameter standoffs with 8 mm or 9 mm length to provide support for the add-on board, or to mount it to a base.

Specifications

Symbol	Quantity	Minimum	Typical	Maximum	Units
VIN	Supply Voltage	6	-	40	V
Ic	Continuous current all phases			20	A
Is	Surge current all phases			60	A
Pmax*	Continuous power all phases		240	800	W
Icp	Continuous current per phase			20	A
Icpp	Pulse current per phase			60	A
IO+[0…15]	Logic Voltage	0	-	3.3	V
PWM LO	Low-Level Input Voltage	-		0.8	V
PWM HI	High-Level Input Voltage	2.2	-	-	V
PWM Q	PWM Frequency		20	50	kHz

*Typical rating based on 50% duty cycle without external cooling. Maximum rating based on 50% duty cycle with external cooling.

Absolute Maximum Ratings

Symbol	Quantity	Maximum	Units
VIN	Supply Voltage	50	V
VIO3V3	Logic Supply Voltage	3.3	V
IO+[0…15]	Logic Voltage	3.3	V

Pin Definitions for the P2 Dual Accessory Header Block 15–8

Pin Offset	Pin Label	Pin Function	Pin Description
15	PWM_XH	PWM input for **X** channel **High**-side MOSFET driver.	The PWM H (high) and PWM L (low) pins control the MOSFET drivers on each channel. Signal logic is active high. When both signals are driven high, PWM L has priority. PWM H will only operate the high MOSFET when PWM L is turned off (driven low). Both the H and L pins have pull-down resistors to keep the signal default state low and ensure the MOSFETs remain off if the PWM signal is unconnected or floating. Refer to the schematic diagram and the Texas Instruments UCC27211D datasheet for further information.
14	PWM_XL	PWM input for **X** channel **Low**-side MOSFET driver.	
13	PWM_WH	PWM input for W channel **High**-side MOSFET driver.	
12	PWM_WL	PWM input for **W** channel **Low**-side MOSFET driver.	
11	PWM_VH	PWM input for **V** channel **High**-side MOSFET driver.	
10	PWM_VL	PWM input for **V** channel **Low**-side MOSFET driver.	
9	PWM_XH	PWM input for **X** channel **High**-side MOSFET driver.	
8	PWM_XL	PWM input for **X** channel **Low**-side MOSFET driver.	

Pin Definitions for the P2 Dual Accessory Header Block 7–0

Pin Offset	Pin Label	Pin Function	Pin Description
7	HALL_W	Output from the Hall Sensor Header, channel **W**.	Typically used to connect to feedback sensors/encoders to determine position and direction of a motor, the Hall Sensor Header pins could also be repurposed as general Inputs or Outputs. Each of the three channel pins (U, V, W) has a series 3.9 kΩ resistor for compatibility with 5 V sensors, and also a 3.9 kΩ pull-up to 3.3 V for compatibility with active-low open-drain sensors. Refer to the schematic diagram for further information.
6	HALL_V	Output from the Hall Sensor Header, channel **V**.	
5	HALL_U	Output from the Hall Sensor Header, channel **U**.	
4	SENSE_ COMMON	Current feedback from all four Channels (U, V, W, X).	The common Sense signal is typically used to determine overall system load and provide overcurrent protection. The common Sense feedback uses a low-side current sensing technique, and is connected to one side of a 3 mΩ current sense resistor in the common GND path of all channel low-side MOSFETS. A current sense amplifier (INA180B2) boosts the signal with a gain of 50 V/V. The voltage level measured across the current sense resistor can be converted to current with this formula: **Isense = Vsense / 150** Example: If the voltage measured at Sense Common (Vsense) = 1500mV then the MOSFET current would be 1500mV / 150 (mV/A) = 10 Amp.
3	SENSE_X	Output voltage feedback from Channel **X**.	The Sense signals are typically used to determine motor position and provide over-voltage protection. Sense feedback voltage is in the ratio 13.1:1 (± 5%) of the voltage at the motor output on each channel. Example: If the motor voltage is 40 V, this feedback voltage will be 3.05 V ±5%.
2	SENSE_W	Output voltage feedback from Channel **W**.	
1	SENSE_V	Output voltage feedback from Channel **V**.	
0	SENSE_U	Output voltage feedback from Channel **U**.	

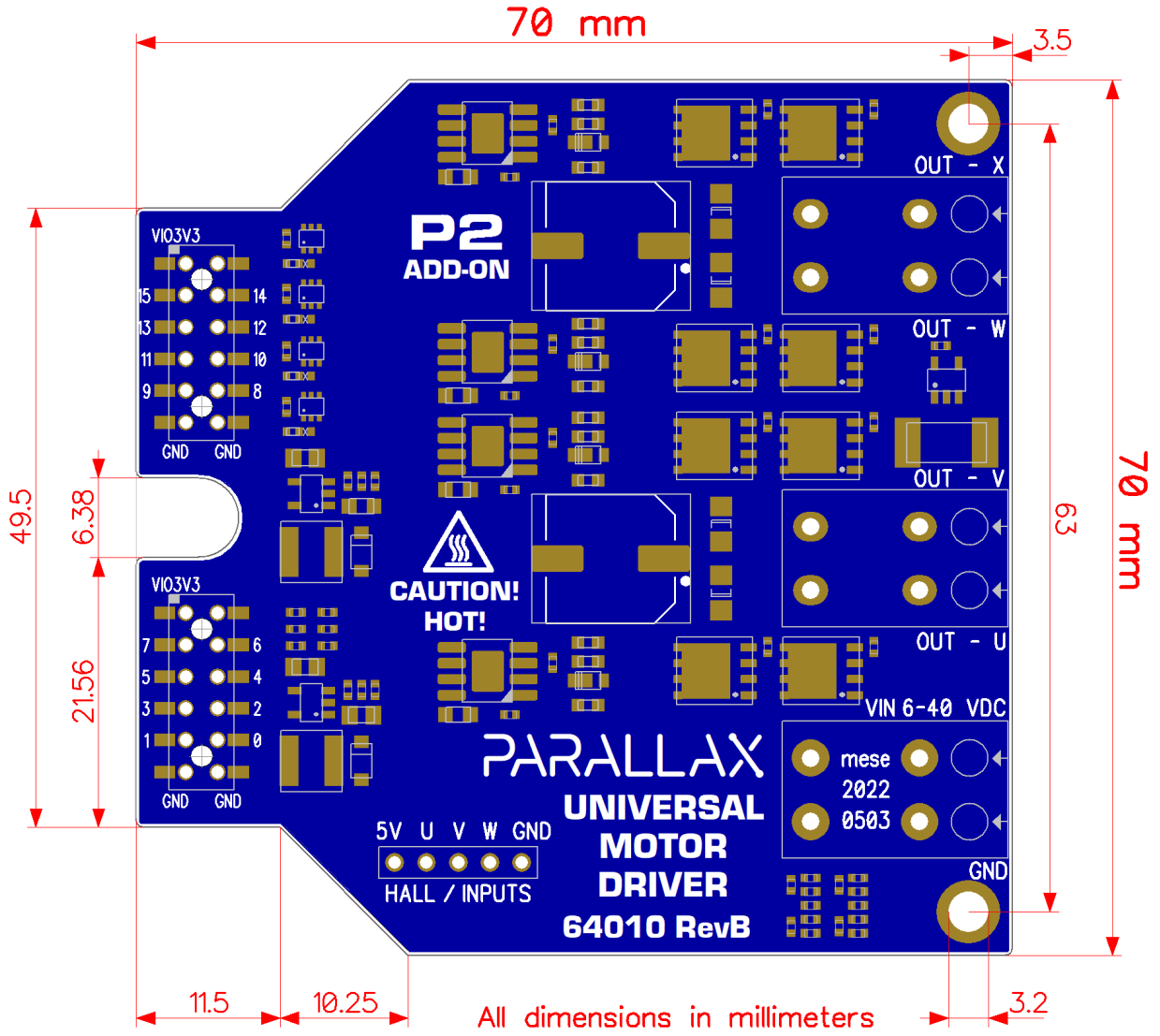
Pin Definitions for the Hall Sensor Header

Hall Sensor Header **HALL / INPUTS**	**Pin Description**
5V	5V output for external sensor, maximum 100 mA.
W	Typically used to connect to feedback sensors, hall sensors or encoders to determine the position and direction of a motor. For compatibility with 5V sensors, each of the three channel inputs (U, V, W) has a series 3.9 kΩ resistor between the Hall Sensor Header and the corresponding HALL output pin on the P2 Accessory Header. Each channel also has a 3.9 kΩ pull-up resistor to 3.3 V for compatibility with active-low open-drain sensors. Refer to the schematic diagram for further information.
V	
U	
GND	Common GND

Resources and Downloads

Check for the latest version of this document, free software, and example programs from the Universal Motor Driver P2 Add-on Board product page. Go to www.parallax.com and search 64010.

Module Dimensions



Revision History

Version 2.0: Product Guide updated for Rev B hardware release.

- PCB size change from 80 x 64 mm to 70 x 70 mm
- MOSFET drivers upgraded for improved reliability with hub wheel motors
- Current sense amplifier added to low-side shunt resistor

Version 1.0: Original Rev A hardware release. v1.1: fixed typo in PCB dimensions.