MICROCHIP dsPIC33EP32MC204 Drone Propeller Reference Design User Guide

Contents

MICROCHIP dsPIC33EP32MC204 Drone Propeller Reference Design

Introduction

OVERVIEW

The reference design is a low-cost evaluation platform targeted for quadcopter/drone applications with propellers driven by three-phase Permanent Magnet Synchronous or Brushless motors. This design is based on a Microchip dsPIC33EP32MC204 DSC, a motor control device.

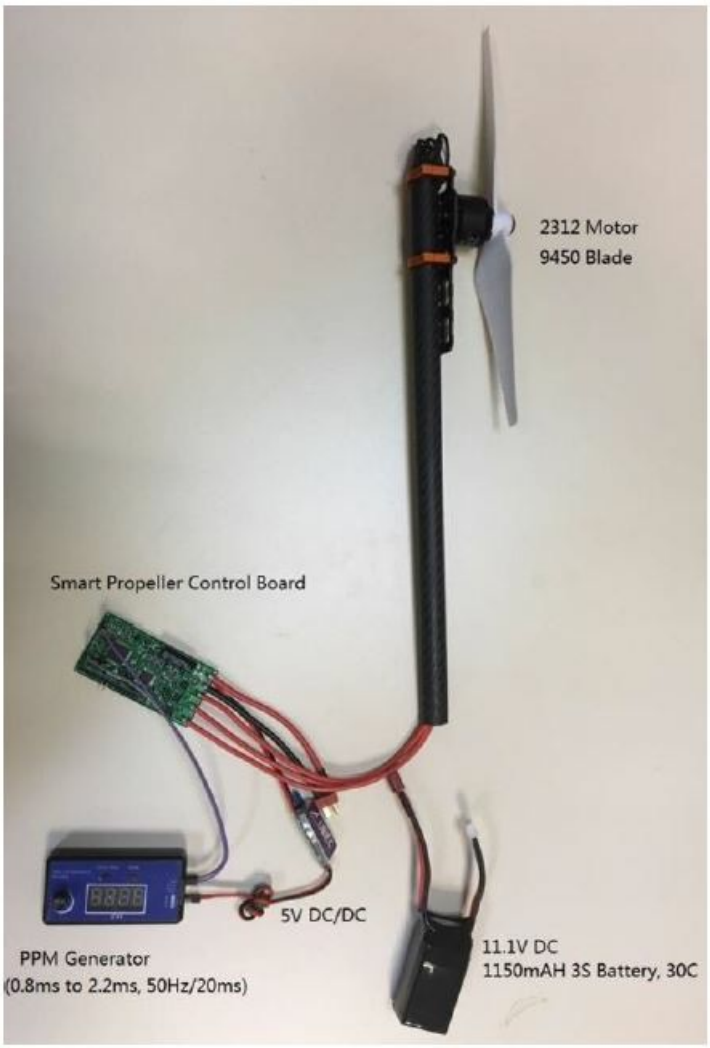


FIGURE 1-1: dsPIC33EP32MC204 Drone motor controller reference design

FEATURES

Key features of the Reference Design are as follows:

- Three-Phase Motor Control Power Stage
- Phase current feedback via the shunt method for higher performance
- Phase voltage feedback to implement sensor-less trapezoidal control or flying start
- DC Bus voltage feedback for over-voltage protection
- ICSP header for In-Circuit Serial Programming using Microchip Programmer/Debugger
- CAN Communication Header

BLOCK DIAGRAM

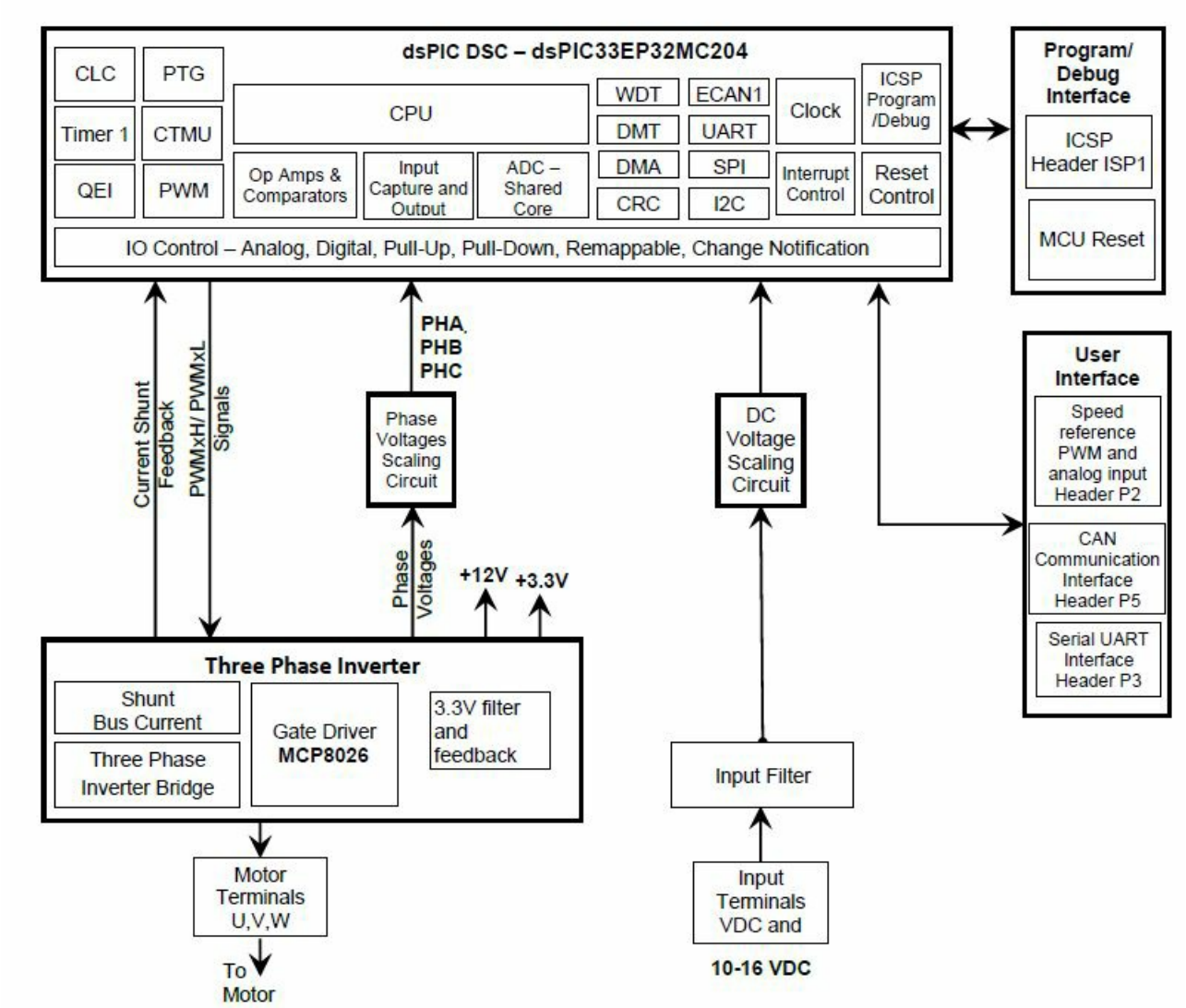
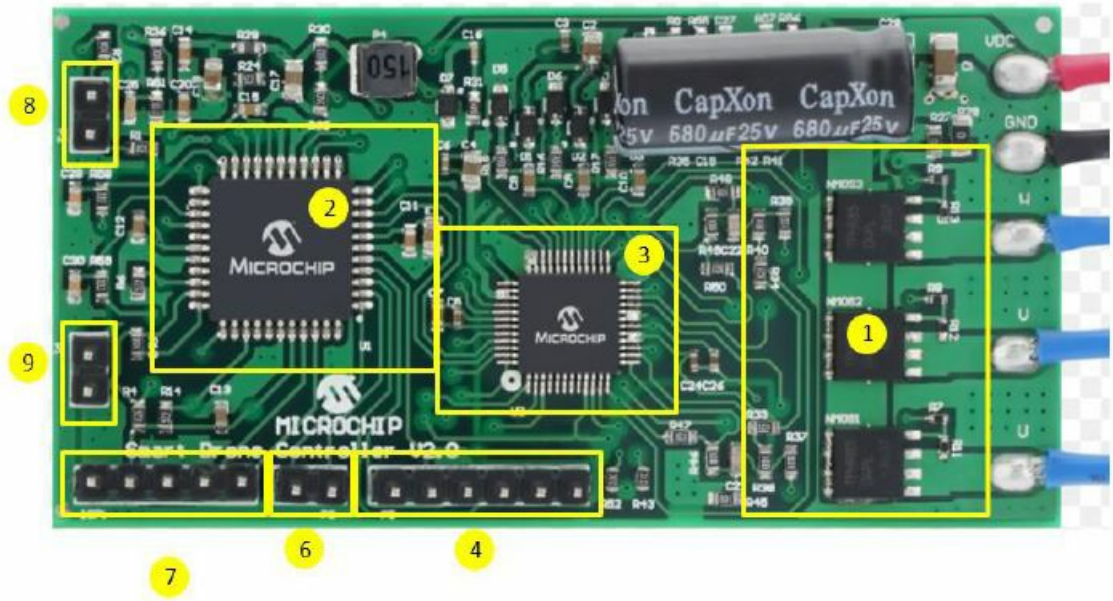
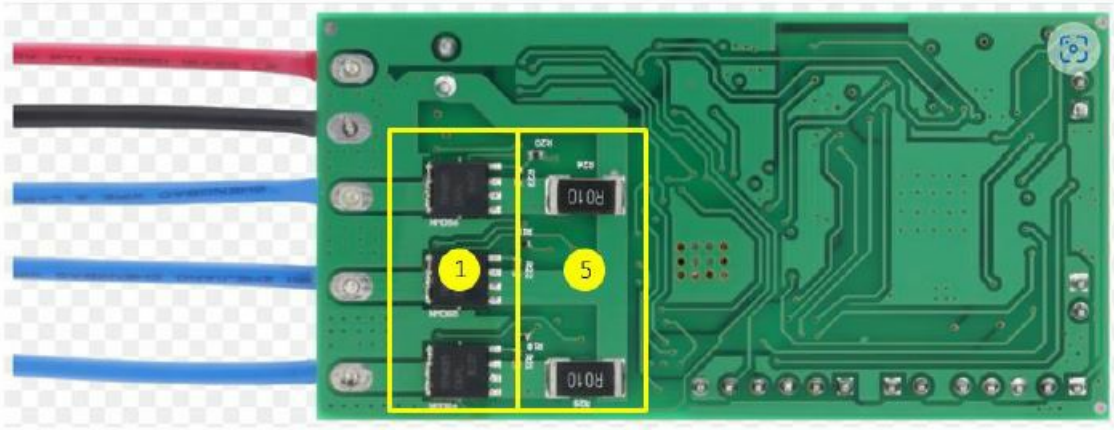


FIGURE 1-2: Block Diagram – Reference Design

The various hardware sections of the Reference Design are shown in Figure 1-3 and summarized in Table 1-1.

FIGURE 1-3: HARDWARE SECTIONS


8
9
2
3
1
MICROCHIP
CapXon
CapXon
680uF25V
680uF25V
VDC
GND
U
U
U
7
6
4


1
5
R010
R010

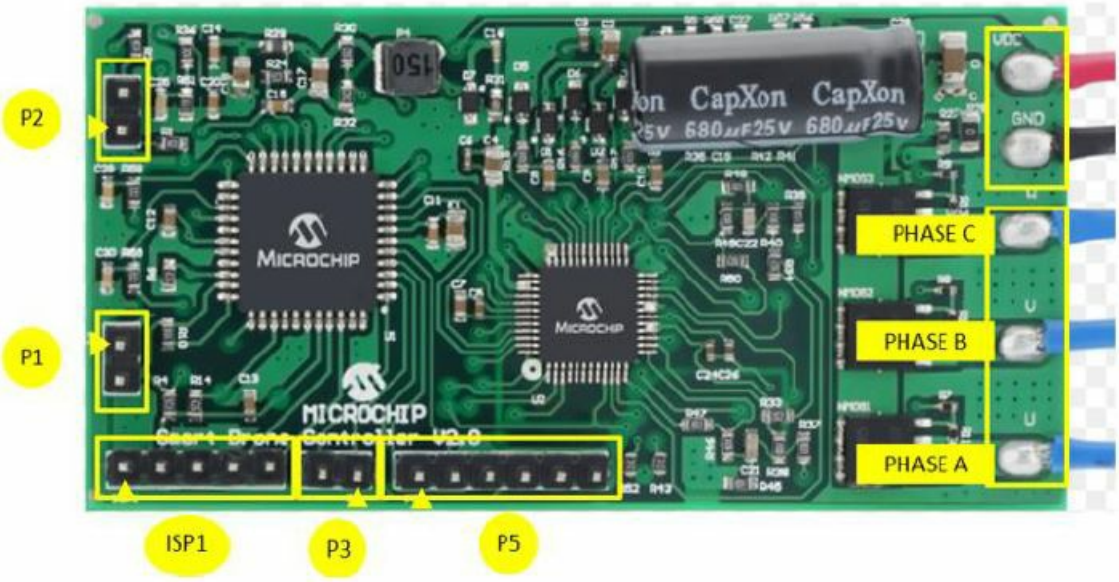

P2
P1
MICROCHIP
CapXon
CapXon
680uF25V
680uF25V
VDC
GND
PHASE C
PHASE B
PHASE A
ISP1
P3
P5

Table 1-1 Hardware Sections	
Section	**Hardware Section**
1	Three-phase motor control inverter
2	dsPIC33EP32MC204 and associated circuit
3	MCP8026 MOSFET Driver
4	CAN Interface
5	Current Sensing Resistors
6	Serial Communication Interface Header
7	ICSP™ Header
8	User Interface Header
9	DE2 MOSFET Driver Serial Interface Header

Board Interface Description

INTRODUCTION
This chapter provides a more detailed description of the input and output interfaces of the Drone motor controller Reference Design. The following topics are covered:

- Board Connectors
- Pin functions of the dsPIC DSC
- Pin functions of the MOSFET Driver

BOARD CONNECTORS
This section summarizes the connectors in the Smart Drone Controller Board. They are shown in Figure 2-1 and summarized in Table 2-1.

- Supplying input power to the Smart Drone Controller Board.
- Delivering inverter outputs to the motor.
- Enabling the user to program/debug the dsPIC33EP32MC204 device.
- Interfacing to CAN network.
- Establishing serial communication with the host PC.
- Supplying the speed reference signal.

FIGURE 2-1: CONNECTORS – Drone Motor Controller Reference Design

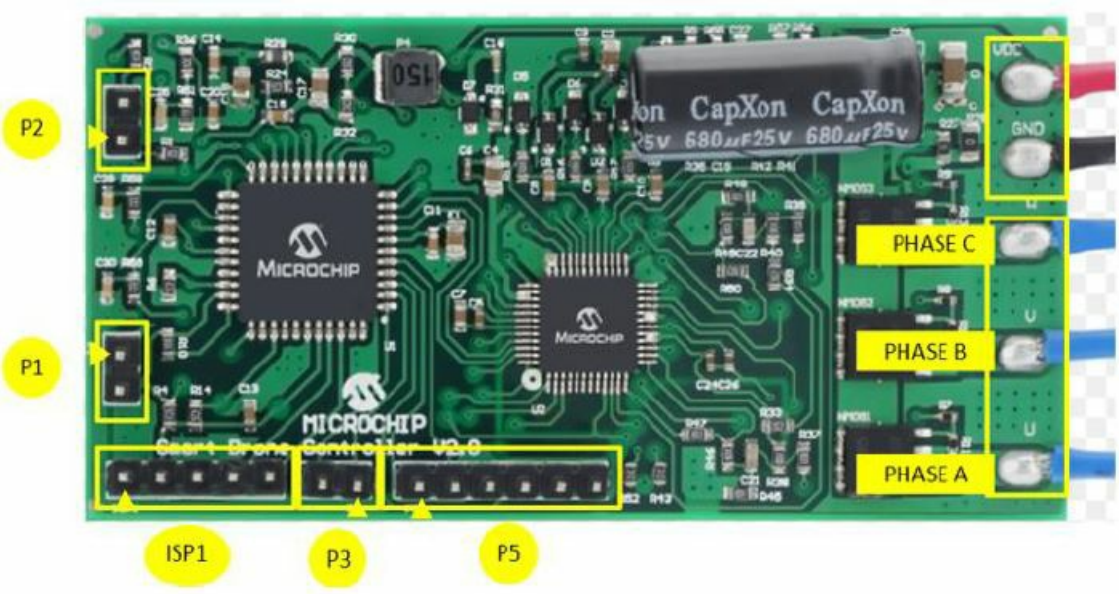


TABLE 2-1 CONNECTORS

Connector Designator	No of Pins	Status	Description
ISP1	5	Populated	ICSP™ Header – Interfacing Programmer/Debugger to the dsPIC® DSC
P5	6	Populated	CAN Communication Interface Header
P3	2	Populated	Serial Communication Interface Header
P2	2	Populated	Reference Speed PWM/Analog Interface Header
PHASE A, PHASE B, PHASE C	3	Not Populated	Three-Phase inverter outputs
VDC, GND	2	Not Populated	Input DC supply tab connector (VDC: Positive terminal, GND: Negative terminal)
P1	2	Populated	DE2 MOSFET Driver Serial Interface Header. Please refer to MCP8025A/6 data sheet for hardware and communication protocol specifications

ICSP™ Header for Programmer/Debugger Interface (ISP1)
The 6-pin header ISP1 can connect with the programmer, for example, PICkit 4, for programming and debugging purposes. This is not come populated. Populate when needed with Part Number 68016-106HLF or similar. The pin details are provided in Table 2-2.

TABLE 2-2: PIN DESCRIPTION – HEADER ISP1

Pin #	Signal Name	Pin Description
1	MCLR	Device Master Clear (MCLR)
2	+3.3V	Supply voltage
3	GND	Ground
4	PGD	Device Programming Data Line (PGD)
5	PGC	Device Programming Clock Line (PGC)

CAN Communication Interface Header(P5)
This 6-pin header can be used for interfacing to CAN network. The pin details are provided in Table 2-3.

TABLE 2-3: PIN DESCRIPTION – HEADER P5

Pin #	Signal Name	Pin Description
1	3.3 V	Supplies 3.3 volts to an external module (10 ma. Max)
2	STANDBY	Input Signal to place smart controller in standby
3	GND	Ground
4	CANTX	CAN transmitter (3.3 V)
5	CANRX	CAN receiver (3.3 V)
6	DGND	Connected to the digital ground on the board

Speed Reference UI Header (P2)
The 2-pin Header P2 is used for providing a Speed reference to the firmware via 2 methods. The pins are short-circuit protected. Details of the header P2 are given in Table 2-4.

TABLE 2-4: PIN DESCRIPTION – HEADER P2

Pin #	Signal Name	Pin Description
1	INPUT_FMU_PWM	Digital signal – PWM 50Hz, 3-5Volts, 4-85%
2	AD SPEED	Analog signal – 0 to 3.3 V

Serial Communications Header (P3)
The 2-pin Header P3 can be used for accessing unused pins of the microcontroller for function expansion or debugging, and the pin details of the header J3 are given in Table 2-4.

TABLE 2-4: PIN DESCRIPTION – HEADER P3

Pin #	Signal Name	Pin Description
1	RXL	UART – Receiver
2	TXL	UART – Transmitter

DE2 MOSFET Driver Serial Interface Header (P1)
The 2-pin Header P1 can be used for accessing unused pins of the microcontroller for function expansion or debugging, and the pin details of the header J3 are given in Table 2-4.

TABLE 2-4: PIN DESCRIPTION – HEADER P1

Pin #	Signal Name	Pin Description
1	DE2	UART – DE2 Signal
2	GND	Board Ground used for external connection

Inverter Output Connector
The reference design can drive a three-phase PMSM/BLDC motor. Pin assignments of the connector are shown in Table 2-6. The correct phase sequence of the motor must be connected to prevent reverse rotation.

TABLE 2-6: PIN DESCRIPTION

Pin #	Pin Description
PHASE A	Phase 1 output of inverter
PHASE B	Phase 2 output of inverter
PHASE C	Phase 3 output of inverter

Input DC Connector (VDC and GND)
The board is designed to operate in the DC voltage range of 11V to 14V, which can be powered through connectors VDC and GND. The connector details are given in Table 2-7.

TABLE 2-7: PIN DESCRIPTION

Pin #	Pin Description
VDC	DC Input supply positive
GND	DC Input supply negative

USER INTERFACE
There are two ways to interface to the Smart Drone Controller firmware to provide a speed reference input.

- PWM input (Digital signal – PWM 50Hz, 3-5Volts, 4-55% Duty cycle)
- Analog voltage (0 – 3.3 Volts)

The interface is done via connections to the P2 connector. See Table 2-4 for details. This reference design has an external accessory PWM controller module that provides the speed reference. The external controller has its own potentiometer and 7 segment LED display. The potentiometer can be used to adjust the desired speed by changing the PWM duty cycle that can be varied from 4% to 55%. (50Hz 4-6Volts) in 3 ranges. See Section 3.3 for more information.

PIN FUNCTIONS OF THE dsPIC DSC
The onboard dsPIC33EP32MC204 device controls the reference design's various features through its peripherals

and CPU capability. Pin functions of the dsPIC DSC are grouped according to their functionality and presented in Table 2-9.

TABLE 2-9: dsPIC33EP32MC204 PIN FUNCTIONS

Signal	dsPIC DSC Pin Number	dsPIC DSC Pin Function	dsPIC DSC Peripheral	Remarks
dsPIC DSC Configuration – Supply, Reset, Clock, and Programming				
V33	28,40	VDD	Supply	+3.3V Digital supply to dsPIC DSC
DGND	6,29,39	VSS		Digital Ground
AV33	17	AVDD		+3.3V Analog supply to dsPIC DSC
AGND	16	AVSS		Analog Ground
OSCI	30	OSCI/CLKI/RA2	External oscillator	No external connection.
RST	18	MCLR	Reset	Connects to ICSP Header (ISP1)
ISPDATA	41	PGED2/ASDA2/RP37/RB5	In-Circuit Serial Programming (ICSP™) or In-circuit debugger	Connects to ICSP Header (ISP1)
ISPCLK	42	PGEC2/ASCL2/RP38/RB6		
IBUS	18	DACOUT/AN3/CMP1C/RA3	High Speed Analog Comparator 1(CMP1) and DAC1	Amplified Bus current is further filtered before connecting to the positive input of CMP1 for over-current detection. The over-current threshold is set through DAC1. The comparator output is internally available as fault input of the PWM generators to shut down PWMs without CPU intervention.
Voltage Feedback				
ADBUS	23	PGEC1/AN4/C1IN1+/RPI34/RB2	Shared ADC Core	DC Bus voltage feedback.

Debug Interface (P3)				
RXL	2	RP54/RC6	Remappable Function of I/O and UART	These signals are connected to Header P3 to interface UART serial communication.
TXL	1	TMS/ASDA1/RP41/RB9		
CAN Interface (P5)				
CANTX	3	RP55/RC7	CAN receiver, transmitter and standby	These signals are connected to Header P5
CANRX	4	RP56/RC8		
STANDBY	5	RP57/RC9		
PWM Outputs				
PWM3H	8	RP42/PWM3H/RB10	PWM Module output.	Refer to the datasheet for more details.
PWM3L	9	RP43/PWM3L/RB11		
PWM2H	10	RPI144/PWM2H/RB12		
PWM2L	11	RPI45/PWM2L/CTPLS/RB13		
PWM1H	14	RPI46/PWM1H/T3CK/RB14		
PWM1L	15	RPI47/PWM1L/T5CK/RB15		
General purpose I/O				

I_OUT2	22	PGEC3/VREF+/AN3/RPI 33/CT ED1/RB1	Shared ADC Core	
MotorGate Dr_ CE	31	OSC2/CLKO/RA3	I/O Port	Enables or disables the MOSFE T driver.
MotorGate Drv _ILIMIT_O UT	36	SCK1/RP151/RC3	I/O Port	Overcurrent protection.
DE2	33	FLT32/SCL2/RP36/RB4	UART1	Reprogrammable port configured to UART1 TX
DE2 RX1	32	SDA2/RPI24/RA8	UART1	Reprogrammable port configured to UART1 RX
Scaled Phase voltage measurement				
PHC	21	PGED3/VREF-/ AN2/RPI 132/CTED2/RB0	Shared ADC Core	Back emf zero cross sensing PH ASE C
PHB	20	AN1/C1IN1+/RA1	Shared ADC Core	Back emf zero cross sensing PH ASE B
PHA, Feedback	19	AN0/OA2OUT/RA0	Shared ADC Core	Back emf zero cross sensing PH ASE A
No connections				
–	35,12,37, 38			
–	43,44,24			
–	30,13,27			

PIN FUNCTIONS OF THE MOSFET DRIVER

Signal	**MCP8026 Pin Num ber**	**MCP8026 Pin Function**	**MCP8026 Function block**	**Remarks**
Power and Ground connections				

VCC_LI_PO WER	38,39	VDD	Bias generator	11-14 Volts
PGND	36,35,24,20 ,19,7	PGND		Power ground
V12	34	+12V		12 Volt output
V5	41	+5V		5 Volt output
LX	37	LX		Buck regulator switch node for 3.3V out
FB	40	FB		Buck regulator feedback node for 3.3V out
PWM output				
PWM3H	46	PWM3H	Gate control logic	Refer to device datasheet for more details
PWM3L	45	PWM3L		
PWM2H	48	PWM2H		
PWM2L	47	PWM2L		
PWM1H	2	PWM1H		
PWM1L	1	PWM1L		
Current sensing pins				
I_SENSE2-	13	I_SENSE2-	Motor Control Unit	Phase A shunt -ve
I_SENSE2+	14	I_SENSE2+		Phase A shunt +ve
I_SENSE3-	10	I_SENSE3-		Phase B shunt -ve. Note this shunt is on W half bridge of the inverter.
I_SENSE3+	11	I_SENSE3+		Phase B shunt +ve. Note this shunt is on W half bridge of the inverter.

I_SENSE1-	17	I_SENSE1-	Motor Control Unit	Reference voltage -ve
I_SENSE1+	18	I_SENSE1+		3.3V/2 reference voltage +ve
I_OUT1	16	I_OUT1		Buffered output 3.3V/2 Volts
I_OUT2	12	I_OUT2		Amplified output Phase A current

I_OUT3	9	I_OUT3		Amplified output Phase B current
Serial DE2 Interface				
DE2	44	DE2	Bias generator	Serial interface for driver configuration
MOSFET gate inputs				
U_Motor	30	PHA	Gate control logic	Connects to the Motor phases.
V_Motor	29	PHB		
W_Motor	28	PHC		
High Side MOSFET gate drive				
HS0	27	HSA	Gate control logic	High side MOSFET Phase A
HS1	26	HSB		High side MOSFET Phase B
HS2	25	HSC		High side MOSFET Phase C
Bootstrap				
VBA	33	VBA	Gate control logic	Boot Strap capacitor output Phase A
VBB	32	VBB		Boot Strap capacitor output Phase B
VBC	31	VBC		Boot Strap capacitor output Phase C
Low Side MOSFET gate drive				
LS0	21	LSA	Gate control logic	Low side MOSFET Phase A
LS1	22	LSB		Low side MOSFET Phase B
LS2	23	LSC		Low side MOSFET Phase C
Digital I/O				

MotorGate Drv _CE	3	CE	Communication port	Enables the MC8026 MOSFET d river.
MotorGate Drv _ILIMIT_O UT	15	ILIMIT_OUT (Active low)	Motor Control Unit	
No connects				
–	8	LV_OUT1		
–	4	LV_OUT2		
–	6	HV_IN1		
–	5	HV_IN2		

Hardware Description

INTRODUCTION
The Drone Propeller Reference Design Board is intended to demonstrate the capability of the small pin count motor control devices in the dsPIC33EP family of single core Digital Signal Controllers (DSCs). The control board incorporates bare minimal componentry to reduce weight. The PCB area could be further shrunk in size for the production-intent version. The board can be programmed via the In System Serial Programming connector and incorporates two current sense resistors and a MOSFET driver. A CAN interface connector is provided for communication with other controllers and to provide reference speed information if needed. The controller's inverter takes an input voltage in the range of 10V to 14V and can deliver a continuous output phase current of 8A (RMS) in the specified operating voltage range. For more information on electrical specifications, see Appendix B. "Electrical Specifications".

HARDWARE SECTIONS
This chapter covers the following hardware sections of the Drone Propeller Reference Design Board:

- dsPIC33EP32MC204 and associated circuitry
- Power Supply
- Current Sense Circuitry
- MOSFET gate driver circuitry
- Three-Phase Inverter Bridge
- ICSP Header/Debugger Interface

1. **dsPIC33EP32MC204 and associated circuitry**
2. **Power Supply**

   The controller board has three regulated voltage outputs 12V, 5V and 3.3V generated by the MCP8026 MOSFET driver. The 3.3 volts is generated using the MCP8026 onboard buck regulator and a feedback

arrangement. See red box in FIGURE A-1 in the schematics section. The external power supply from the battery is directly applied to the inverter via the power connectors. A 15uF capacitor provides the DC filtering for stable operation during rapid load changes. Please see the device (MCP8026) data sheet for the output current capability of each voltage output.

3. **Current Sense Circuitry**

   Current is sensed using the popular “two shunt” approach. Two 10-milliohm shunts provide the current input to the inputs of the on-chip Op-Amps. The Op-Amps are in differential gain mode with a gain of 7.5 providing a 22Amp peak phase current measurement capability. The amplified current signal from phase A (U half-bridge) and Phase B (W half-bridge) is converted by the dsPIC controller firmware. A voltage reference with a buffered output for 3.3V / 2 provides for noise-free zero reference for the current sense circuits. See Schematics section FIGURE A-4 for details.

4. **MOSFET gate driver circuitry**

   The gate drive is handled internally except for the bootstrap capacitors and diodes which are located on the board and designed keeping in mind to adequately turn ON the MOSFETs at the lowest operating voltage. See the specifications for the MCP8026 operating voltage range in the datasheet.

   See Schematics section FIGURE A-1 for interconnect details.

5. **Three-Phase Inverter Bridge**

   The inverter is the standard 3 Half bridge with 6 N Channel MOSFET devices capable of operation in all the 4 quadrants. The MOSFET driver directly interfaces through the slew rate limiting series resistors to the Gates of the MOSFETs. A standard bootstrap circuit comprising of a network of capacitors and diodes is provided for each of the high-side MOSFETs for adequate turn-ON gate voltage. The bootstrap capacitors and diodes are rated for full operating voltage range and current. The output of the three-phase inverter bridge is available on U, V, and W for the three phases of the motor. See Schematics section FIGURE A-4 for connectivity and other details.

ICSP Header/Debugger Interface

Programming the Smart Drone Controller board: Programming and debugging are via the same ICSP connector ISP1. Use the PICKIT 4 to program with the PKOB connector, connected 1 to 1 as given in Table 2-2. You can program either with the MPLAB-X IDE or MPLAB-X IPE. Power up the board with 11-14 Volts. Select the appropriate hex file and follow instructions on the IDE/IPE. Programming is complete when a “Programming/Verifying complete” message is displayed in the output window.

- Refer to MPLAB PICKIT 4 data sheets for debugging instructions

HARDWARE CONNECTIONS

This section describes a method to demonstrate the operation of the Drone controller. The reference design requires a few extra off-board accessory modules and a motor.

- A 5V power supply to the PWM controller
- PWM controller used to supply a speed reference or a potentiometer to supply a varying voltage speed reference
- A BLDC motor with parameters as described in Appendix B
- A battery power source of 11-14V and 1500mAH capacity

Any compatible make or model can be used to replace the ones shown here for successful operation. Shown below are examples of the above accessories and motors used for this demonstration.

PWM Controller:

BLDC motor: DJI 2312

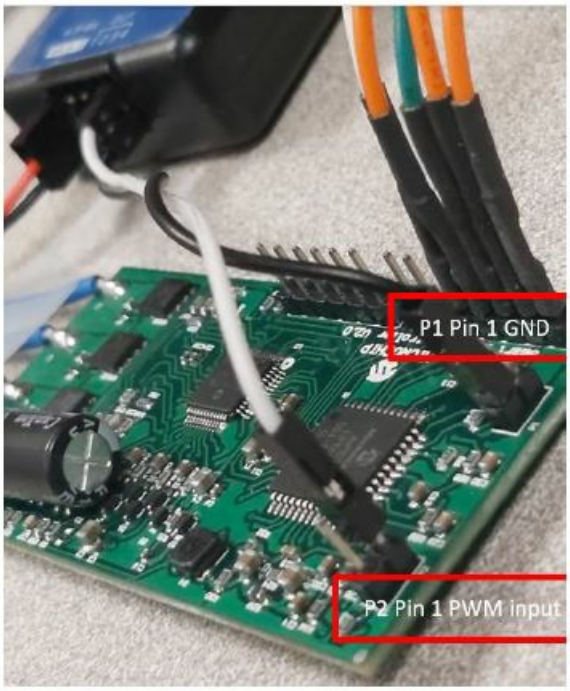
Battery:

Operating instructions: Follow the steps as below:

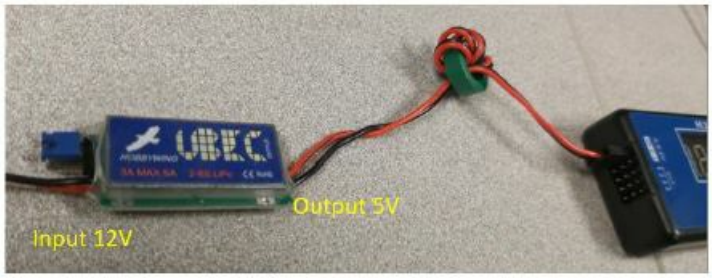
Note: DO NOT ATTACH THE PROPELLER AT THIS TIME

Step 1: Main power source connection
Connect the battery '+' and '-' to the VDC and GND terminals to power the smart controller. A DC power supply can also be used.

Step 2: Speed reference signal to the smart Drone controller.
The controller takes speed input reference from the PWM controller at 5V max peak. The output of the PWM controller provides a ground-referenced 5V signal output that connects to a 5V tolerant input pin as shown in the picture. Also shown is the location for the ground connection.



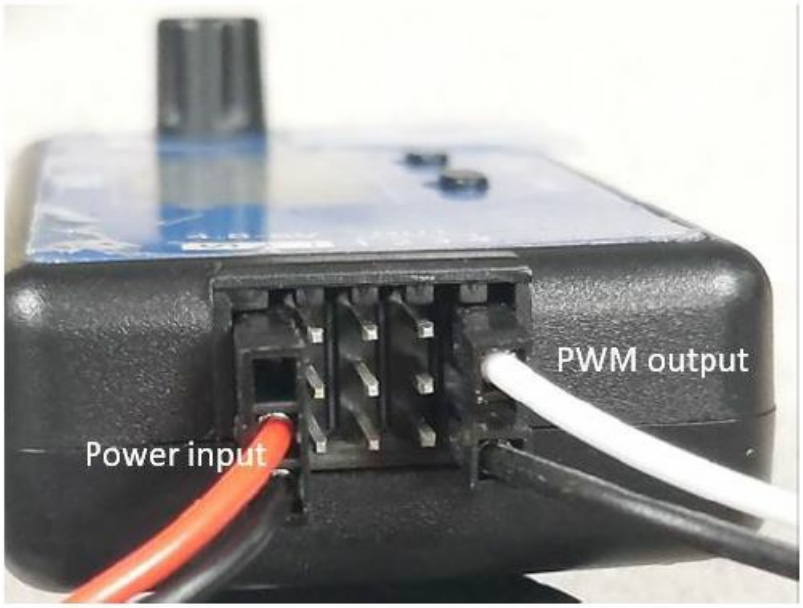
Step 3: Power supply to the PWM controller.
Connect the Switching regular input to the battery terminals and the output (5V) to the PWM controller supply.



Step 4: PWM controller configuration:
The signal pulse width from the PWM controller is validated for a valid signal in firmware to prevent spurious turn ON and overspeeding. The controller has two push-button switches. Select the manual mode of operation using the “Select” switch. Use the “Pulse Width” button to select between 3 levels of speed control. The switch cycles through 3 ranges for PWM duty cycle output with each press.

- **Range 1:** 4-11%
- **Range 2:** 10-27.5%
- **Range 3:** 20-55%

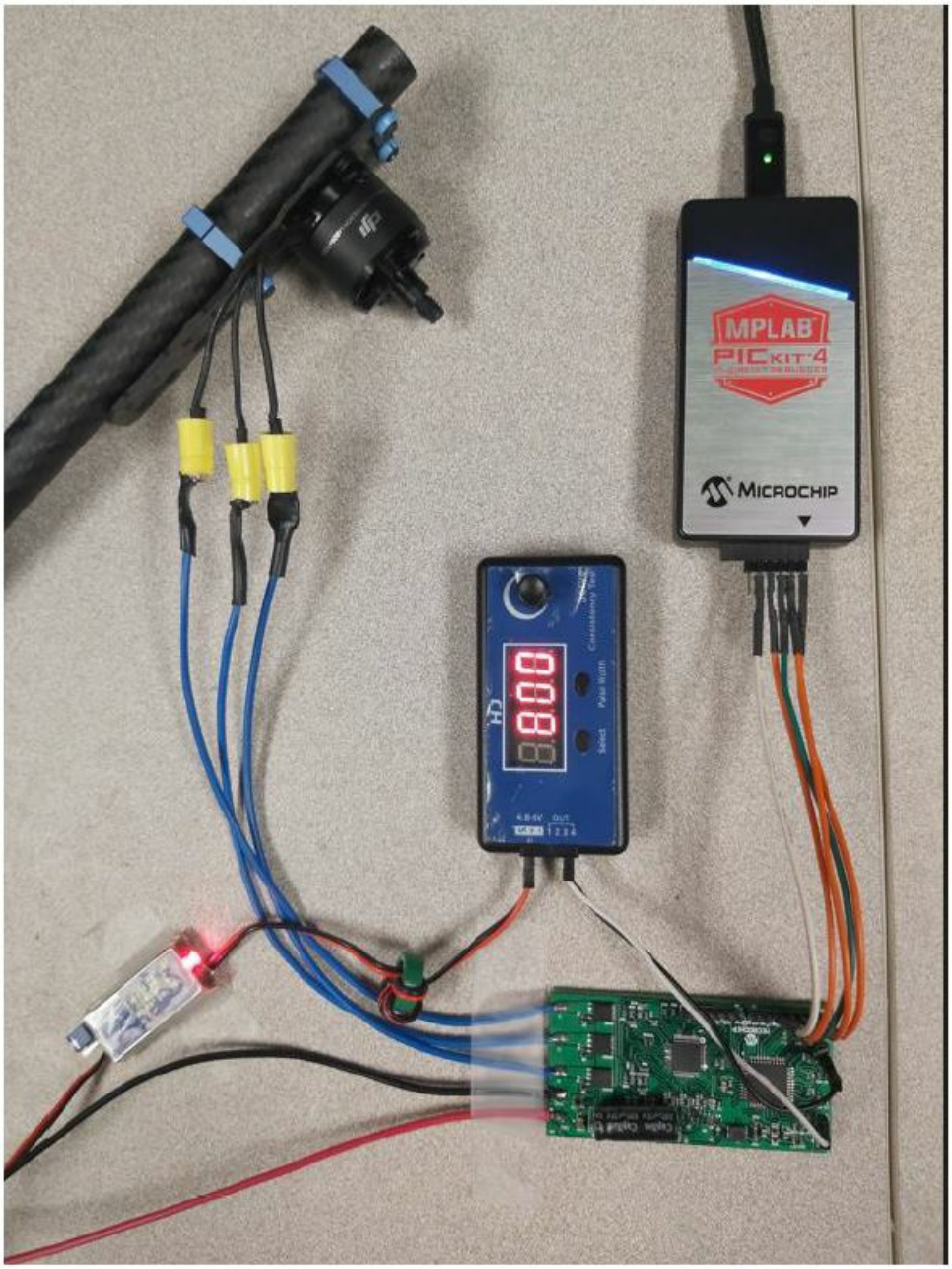
The display indication varies from 800 to 2200 for a linear change in duty cycle within the range. Turning the potentiometer on the PWM controller will increase or decrease the PWM output.



Step 5: Motor terminal connection:
Connect the motor terminals to PHASE A,B, and C. The sequence decides the direction of rotation of the motor. The desired rotation of the Drone is clockwise looking into the motor to prevent the propeller from loosening. It is therefore important to confirm the rotation direction before mounting the blades. Supply a PWM reference signal by tweaking the potentiometer on the PWM controller starting with the least pulse width position (800). The motor will start spinning at 7.87% duty cycle (50Hz) and above. The 7-Segment display shows 1573 (7.87% duty cycle) to 1931 (10.8% duty cycle) when the motor spins. Confirm the direction of rotation is counterclockwise. If not swap any two connections to the motor terminals. Return the potentiometer to the lowest speed setting.

Step 6: Mounting the Propeller:
Disconnect battery power. Mount the propeller blade by screwing it into the motor shaft in a clockwise direction. Hold the stick/motor firmly with the arm stretched out and at a safe distance from all obstacles and people while in operation. Connect the power supply. The propeller action will exert force against the hand when spinning, so a firm grip is essential to prevent bodily injury. Tweak the potentiometer to change the speed (display indicates between 1573 and 1931) This completes the demonstration.

The below picture shows the overall wiring setup for the demonstration.



Schematics

BOARD SCHEMATICS

This section provides schematics diagrams of the dsPIC33EP32MC204 Drone Propeller Reference Design. The reference design uses a four-layer FR4, 1.6 mm, Plated-Through-Hole (PTH) construction.

Table A-1 summarizes the schematics of the Reference Design:

TABLE A-1: SCHEMATICS		
Figure Index	**Schematics Sheet No.**	**Hardware Sections**
Figure A-1	1 of 4	dsPIC33EP32MC204-dsPIC DSC(U1) Interconnections MCP8026-MOSFET driver interconnections 3.3V analog and digital filter and feedback network dsPIC DSC internal operational amplifiers for amplifying Bus Current Bootstrap net work.
Figure A-2	2 of 4	In-System Serial Programming Header ISP1 CAN Communication Interface Header P5 External PWM speed control Interface Header P2 Serial Debugger Interface P3
Figure A-3	3 of 4	DC Bus voltage scaling resistor divider Back-emf voltage scaling network Op-Amp gain and reference circuitry for phase current sensing
Figure A-4	4 of 4	Motor Control Inverter –Three-phase MOSFET bridge

Figure A-1:

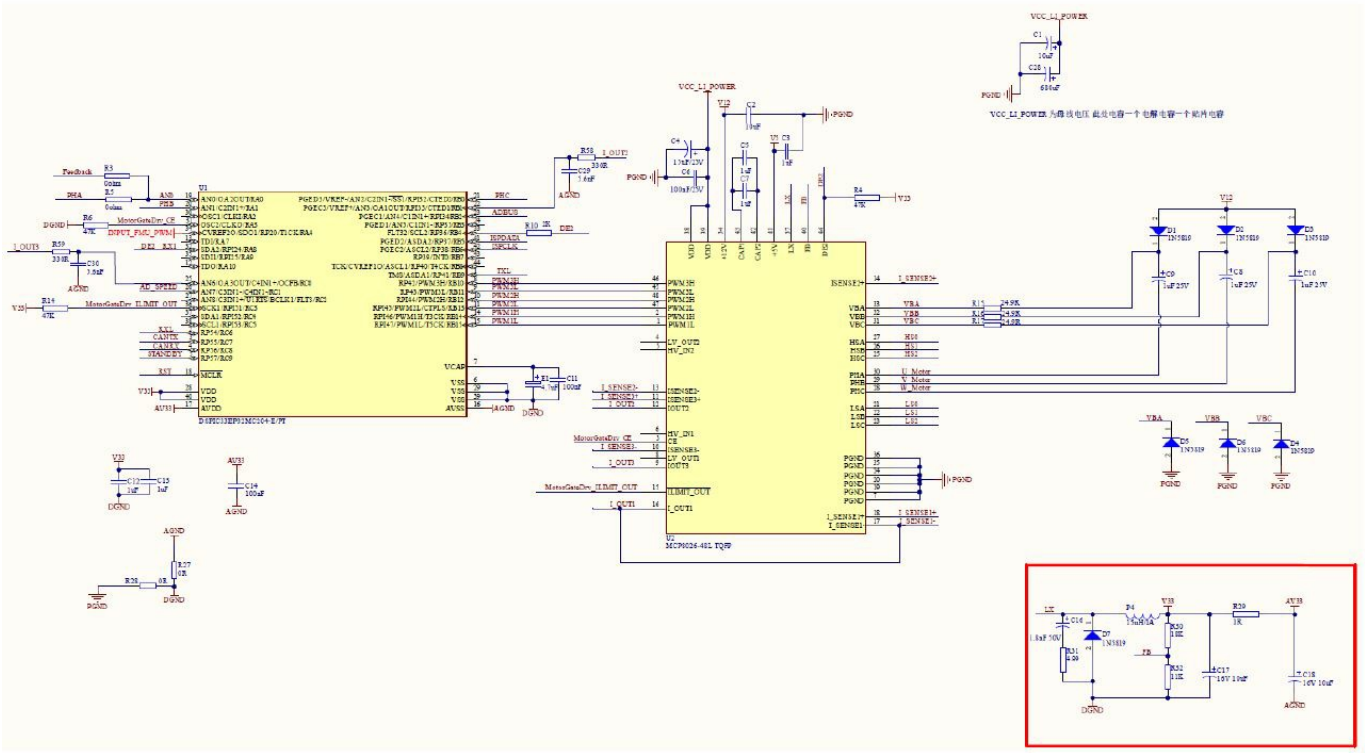


Figure A-2

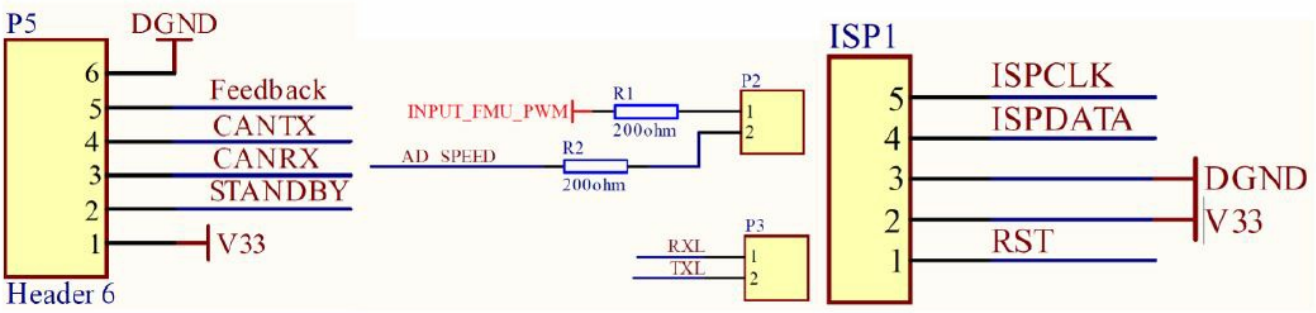


Figure A-3

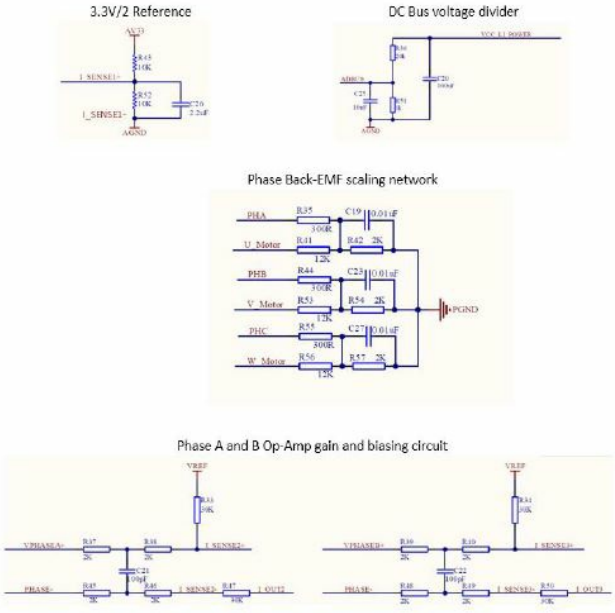
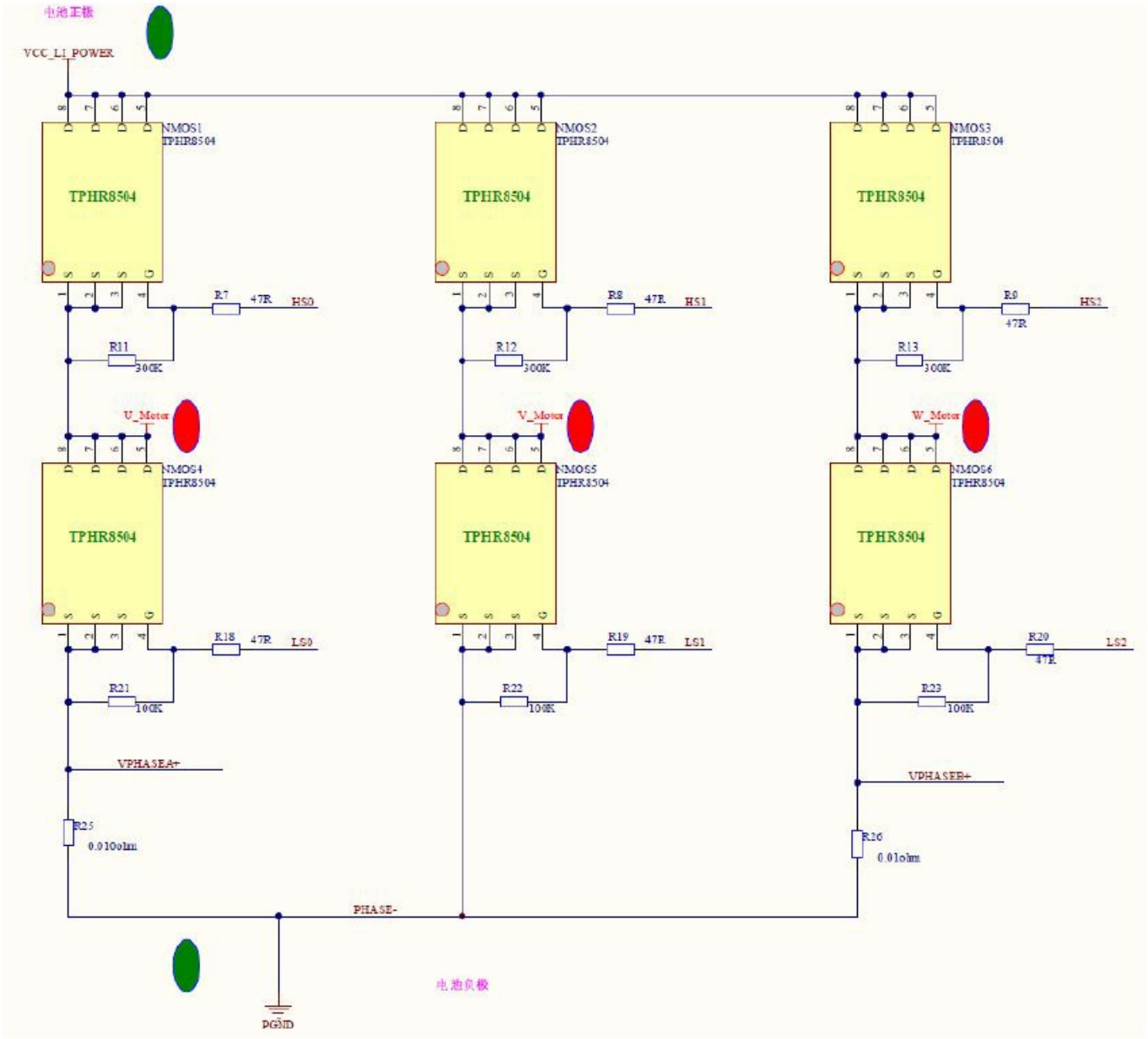


Figure A-4



Electrical Specifications

INTRODUCTION

This section provides the electrical specifications for the dsPIC33EP32MC204 Drone Motor Controller Reference Design (see Table B-1).

ELECTRICAL SPECIFICATIONS 1:

Parameter	Operating Range
Input DC Voltage	10-14V
Absolute Maximum Input DC Voltage	20V
Maximum Input Current through Connector VDC and GND	10A
Continuous Output Current per phase @ 25°C	44A (Peak)

Motor Specifications: DJI 2312	
Motor Phase Resistance	42-47 milli Ohms
Motor Phase Inductance	7.5 micro-Henrys
Motor Pole Pairs	4

Note:

1. While operating at an ambient temperature of +25°C and within the permissible Input DC voltage range the board remains within thermal limits for continuous per phase currents of up to 5A (RMS).

Bill of Materials (BOM)

BILL OF MATERIALS

Item	Comment	Designator	Quantity
1	10uF 25V 10% 1206	C1	1
2	10uF 25V 10% 0805	C2 C17, C18	3
3	1uF 25V 10% 0402	C3, C5	2
4	22uF 25V 20% 0805	C4	1
5	100nF 25V 0402	C6	1
6	2.2uF 10V 0402	C24, C26	2
7	1uF 25V 10% 0603	C7, C8, C9, C10, C12, C13	6
8	100nF 50V 10% 0603	C11, C14, C15, C20	4
9	1.8nF 50V 10% 0402	C16	1
10	0.01uF 50V 10% 0603	C19, C23, C27 C25	3
11	100pF 50V 5% 0603	C21, C22	2
12	680uF 25V 10% RB2/4	C28	1
13	5.6nF 50V 10% 0603	C29, C30	2
14	1N5819 SOD323	D1, D2, D3, D7	4
15	1N5819 SOD323	D4, D5, D6	3
16	4.7uF 25V 10% 0805	E1	1
17	TPHR8504PL SOP8	NMOS1, NMOS2, NMOS3, NMOS4, NMOS5, NMOS6	6
18	15uH 1A SMD4*4	P4	1
19	200R 1% 0603	R1, R2	2
20	0R 1% 0603	R5,R27	2

21	47K 1% 0603	R4, R6, R14, R24	4
22	47R 1% 0402	R7, R8, R9, R18, R19, R20	6
23	2K 1% 0603	R10, R37, R38, R39, R40, R42, R45, R46, R48, R49, R54, R57	12
24	300K 1% 0402	R11, R12, R13	3
25	24.9R 1% 0603	R15, R16, R17	3
26	100K 1% 0402	R21, R22, R23	3
27	0.01R 1% 2010	R25,R26	1
28	0R 1% 0805	R28	1
29	bead 1R 0603	R29	1
30	18K 1% 0603	R30	1
31	4.99R 1% 0603	R31	1
32	11K 1% 0603	R32	1
33	30K 1% 0603	R33, R34, R47, R50	4
34	300R 1% 0603	R35, R44, R55	3
35	20k 1% 0603	R36	1
36	12K 1% 0603	R41, R53, R56	3
37	10K 1% 0603	R43, R52	2
38	1k 1% 0603	R51	1
39	330R 1% 0603	R58, R59	2

40	DSPIC33EP64MC504-I/PT TQFP44	U1	1
41	MCP8026-48L TQFP48	U2	1
42	2 PIN-68016-106HLF	P1, P2, P3	3
43	5 PIN-68016-106HLF	ISP1	1
44	6 PIN-68016-106HLF	P5	1

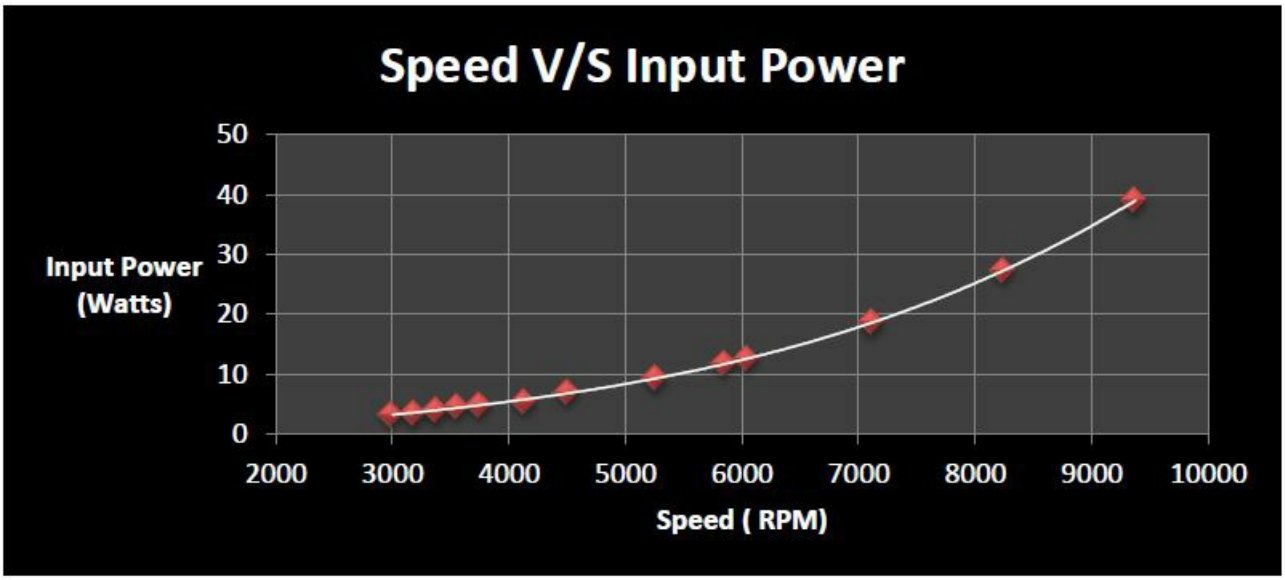
Test Results

Tests were performed to characterize the Drone Propeller Reference Design. A 12V, four pole pair three-phase PMSM Drone motor shown in the setup on page 1 was used for testing with blades attached. Table D-1 summarizes the test results. Figure D-1 shows the speed vs. input power.

Table D-1

DC Input Voltage (V)	Speed (RPM)	DC Input Current (A)	DC Input Power (W)
12	3000	0.27	3.24
	3187.5	0.28	3.36
	3375	0.32	3.84
	3562.5	0.38	4.56
	3750	0.4	4.8
	4140	0.45	5.4
	4500	0.58	6.96
	5265	0.77	9.24
	5850	0.98	11.76
	6045	1.04	12.48
	7125	1.55	18.6
	8250	2.28	27.36
	9375	3.25	39

Figure D-1



Documents / Resources

	MICROCHIP dsPIC33EP32MC204 Drone Propeller Reference Design [pdf] User Guide dsPIC33EP32MC204, dsPIC33EP32MC204 Drone Propeller Reference Design, Drone Propeller Reference Design, Propeller Reference Design, Reference Design, Design