MCP8048 QFN48 BLDC Motor Driver Evaluation Board User Guide

EV80M48A

Introduction

The MCP8048 QFN48 BLDC Motor Driver Evaluation Board is used to demonstrate the driver capabilities offered by the MCP8048 variant with LIN and a VIO voltage of 3.3V in BLDC/PMSM motor applications.

The two-layered, high current board is designed to be very versatile, low cost, and easily configurable to meet as many customer preferences as possible. It uses the MCP8048 as a 3-phase Brushless DC (BLDC) motor gate driver and the dsPIC33CK256MP205 Motor Control DIM provided by Microchip. In order to implement different types of algorithms, like the sinusoidal dual/single shunt FOC or the trapezoidal motor control algorithm in sensored or sensorless mode, the board can be easily configured by using the jumpers and connectors located on the board. Furthermore, the desired firmware should be implemented accordingly to the desired hardware configuration.

As provided, the MCP8048 QFN48 BLDC Motor Driver Evaluation Board is ready to drive a BLDC motor using the FOC method in sensorless mode. The board is equipped with a Start/Stop button and a potentiometer that can be used to adjust the speed of the motor. The evaluation board can drive a BLDC motor with a supply voltage of up to 32.5V and a motor current up to 35A RMS. For higher load currents, a custom heat sink can be attached on the bottom side. The MCP8048 QFN48 BLDC Motor Driver Evaluation Board provides user selectable 3.3V/5V/100 mA LDOs, a 3.3V Buck Regulator, a LIN communication interface, a USB Serial connection, a MikroE connector, an Xplained Pro extension header, three current sense operational amplifiers, and Hall-effect sensors inputs. Moreover, the MCP8048 has many configuration capabilities for OCP/Limit, Overvoltage, Undervoltage, Overtemperature protections due to its internal dedicated registers that are available via its SPI interface.

Several key test points are available on the board in order to facilitate user measurements, tuning or motor control optimization.

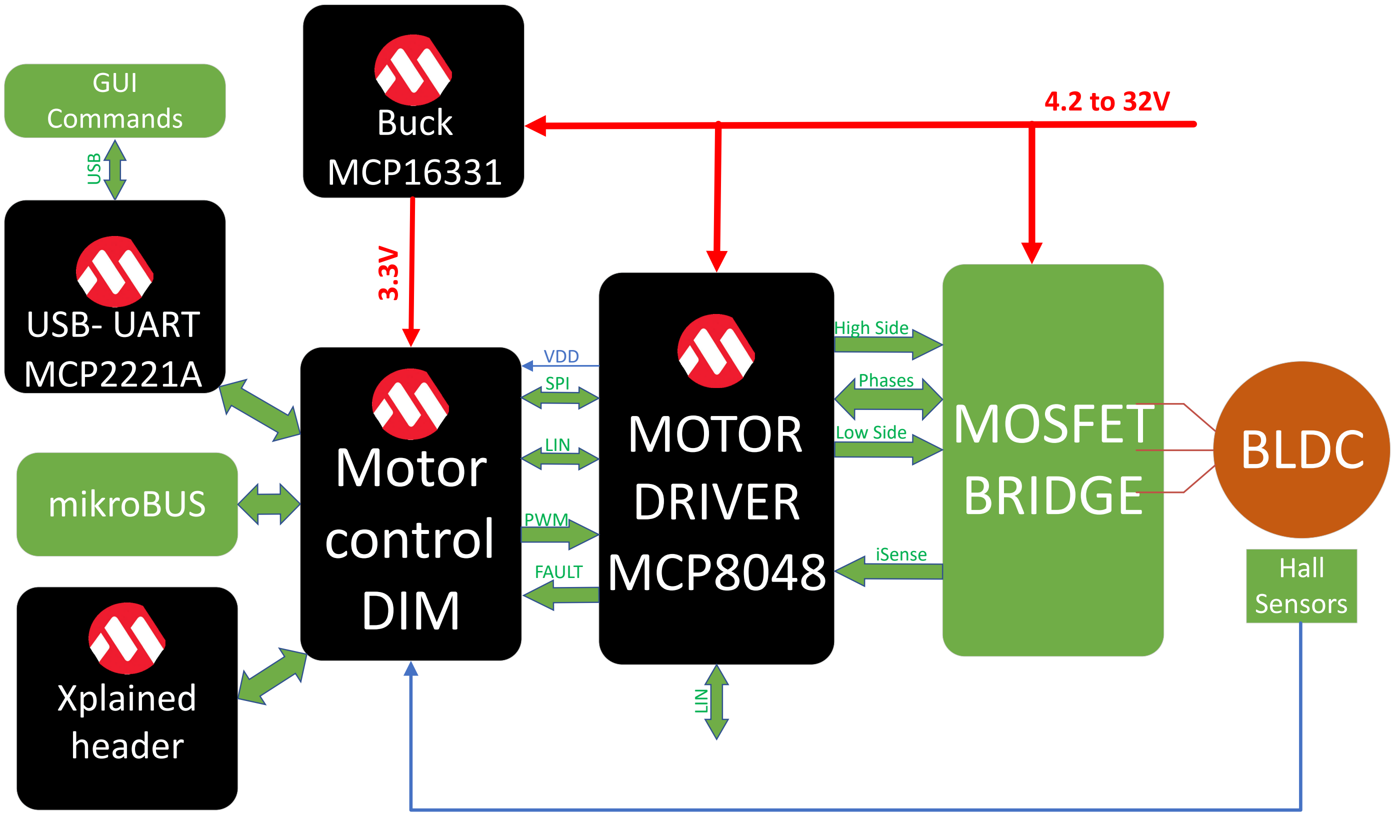
The evaluation board provides several optical indicators, such as RunLED, FltLED for the status indication, PwLED for voltage presence, VDD1 and VDD2 for LDO voltage presence, RX and TX indication of serial connection to computer and six on-board LEDs for Pulse-Width Modulation (PWM) inputs.

Features

The MCP8048 QFN48 BLDC Motor Driver Evaluation Board is a complete motor controller for brushless DC motors (BLDC). The board can drive a three-phase brushless DC motor rated at up to 35A and 32.5V. The input voltage motor operating range for the board is +4.9V to +32.5V. The board consists of three main units:

- MCP8048 QFN48 Motor Driver
- DIM connector to attach one of the compatible motor control DIMs, like dsPIC33CK256MP205 Motor Control DIM
- Three phases MOSFET Bridge

Figure 1. MCP8048 QFN48 Motor Driver Block Diagram



The on-board MCP8048 generates 3.3V using internal voltage regulators (VDD2) for the attached host microcontroller (or 5V for other microcontroller type/Hall sensors). The MCP8048 also contains two charge pumps for the low and high side of the Gate Driver Unit to allow operation up to 100% duty cycle.

A LIN communication interface included by MCP8048 gives the possibility for external systems interfacing that use this communication protocol.

An input terminal block connector is provided to apply the input voltage to the board, and another output connector is provided to attach the BLDC.

A programming header connector is available for programming/updating the firmware contained in the dsPIC33CK256MP205 Motor Control DIM, using a PICkit™ programmer/debugger.

An input terminal block is supplied on the board, to allow users to connect the Hall sensors with selectable voltage supply (5V/3.3V).

Four push buttons (**RST**, **PB1**, **RUN** and **WAKE**) are available for different events generation (such as start, stop, direction change, reset, etc). A reference speed potentiometer is available to set the desired motor velocity.

An optional spare buck power supply is available for MCP8048-3333 which has INH signal for external source activation or for external interfaces if the required current exceeds the device capability.

Finally, the PCB layout design can serve as reference for a robust, low-cost, two-layered, low-voltage, high-current board.

The MCP8048 QFN48 BLDC Motor Driver Evaluation Board has the following features:

- Input operating voltage range: 4.9V to 32.5V
- Maximum of 10/27Ω of gate drive sink/source resistance for external N-Channel MOSFETs and programmable LS/HS slew rate control: 12.5%, 25%, 50%, 100%
- Drives up to a 35A RMS BLDC motor

- Three programmable gain/offset current sense amplifiers (G = 8, 16, 32, 64)
- ON/OFF push button (RUN)
- Reset push button (RST)
- PB1 user-programmable push button (μC/Wk)
- Wake-up push button
- PWM signal LED indicators
- Fault signal LED indicator
- IRQ signal LED indicator
- PICkit debugger interface
- Speed control potentiometer
- Terminal block for 3.3V and 5V Hall-effect sensors
- UVLO, OVLO and DUVLO protections
- Programmable external MOSFET overcurrent protection 125 mV to 1.75V
- Programmable PWM dead-time protection 100 ns to 6.3 μs (100 ns step)
- Thermal shutdown protection
- Programmable timing filters for current and voltages
- Complete “C” source code (provided on the Motor Driver Evaluation Board webpage)

Kit Contents

The MCP8048 QFN48 BLDC Motor Driver Evaluation Board kit includes:

- MCP8048 QFN48 BLDC Motor Driver Evaluation Board (EV80M48A)
- dsPIC33CK256MP205 Motor Control DIM (EV53A92A)

1. Setup and Configuration

The MCP8048 QFN48 BLDC Motor Driver Evaluation Board demonstrates the features of Microchip's 3-Phase Brushless DC (BLDC) Motor Driver with Power Module, MCP8048, used in a BLDC motor driver application. When used in conjunction with a microcontroller, the MCP8048 will provide the necessary drive signals to drive a 3-Phase BLDC motor.

The MCP8048 contains all necessary functional blocks for developing high performance BLDC/PMSM motor drivers: high and low-side MOSFET drivers, three gain/offset configurable Op Amps, protection circuity and SPI interface for the configuration of the internal registers.

The board is equipped with a DIM slot for one of Microchip's motor control DIMs and is compatible with the dsPIC33CK256MP205 Motor Control DIM high performance Digital Signal Controller (DSC) and can handle simple motor control algorithms like the six-step or high-performance algorithm like the Field Oriented Control (FOC). The dsPIC (DSC) present on the Motor Control DIM is used to provide the PWM inputs to the MCP8048, as well as handle the high-speed Analog-to-Digital Conversion (ADC), supporting up to 50 kHz PWM operation for the FOC motor control technique or higher for trapezoidal. The microcontroller supports a large range of motor control applications due to its specific synchronization between different peripherals.

The motor current can be measured using the dual or single-shunt techniques described in AN1078. A high-performance current sense amplifier is implemented using two of the three of the MCP8048's internal Op Amps. The third internal OPAMP can be configured either as BEMF or current sense amplifier.

1.1. Getting Started

The MCP8048 QFN48 BLDC Motor Driver Evaluation Board board is fully assembled and tested for driving a BLDC motor. The board can be easily configured to drive a BLDC motor in sensored or sensorless mode, as well as for sinusoidal single-shunt FOC or trapezoidal motor control algorithm.

An external voltage source capable of supplying 5V to 32.5V at the rated motor current is required. The board is presented in Figure 1-1. A BLDC motor is also required to evaluate the board motor driver.

The board can be easily configured for different types of motor and control algorithms:

- PMSM, FOC, single-shunt sensorless (with/without wind milling)
- PMSM, FOC, single-shunt based on sensor position detection
- BLDC trapezoidal sensorless based on BEMF null cross detection

Each type of motor control can be configured in firmware through the proper assignation of controller ports to the available signals. These signals are hard routed to the controller ports and can be considered depending on the chosen motor control type.

The IBus and BEMF signals are simultaneously available at the controller input ports, allowing any of the control algorithms mentioned above to be implemented.

The Hall sensors or BEMF can be hardware-configured through J5, J7 and J9, by placing the jumpers in the appropriate position.

Figure 1-1. MCP8048 QFN48 BLDC Motor Driver Evaluation Board Top

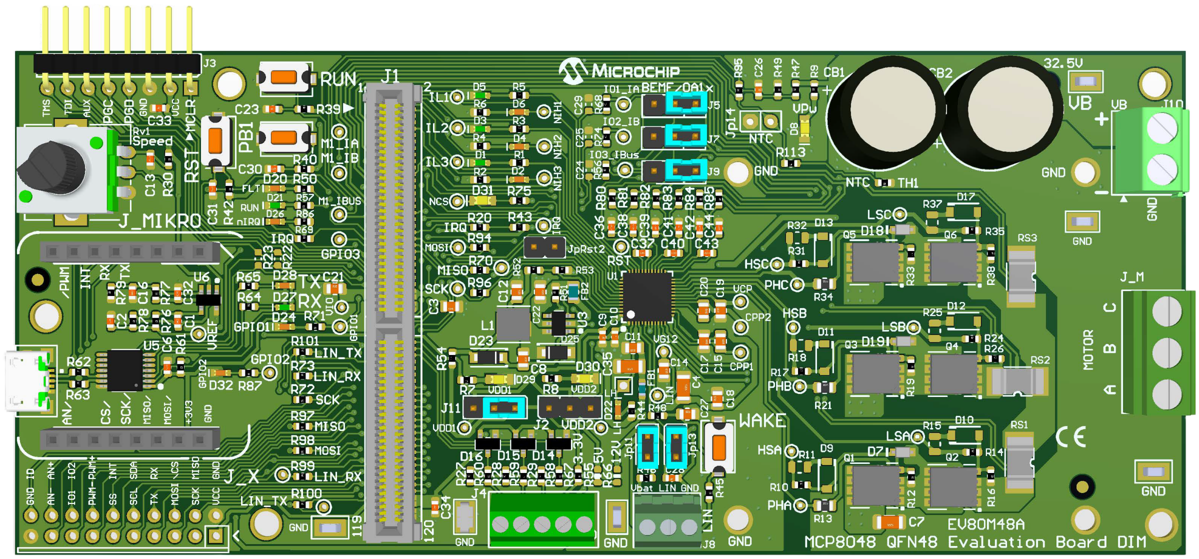
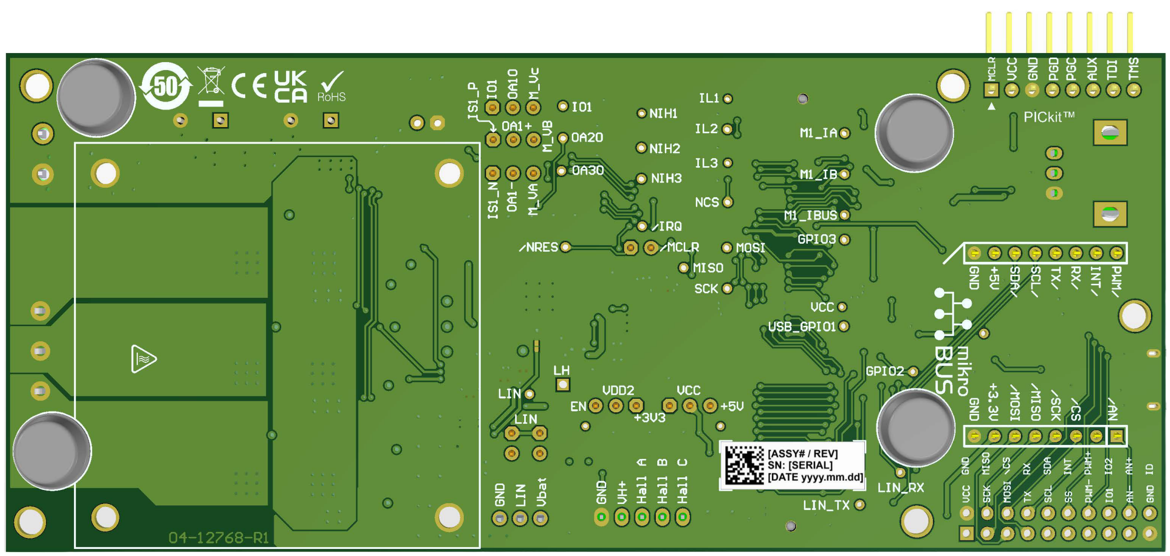


Figure 1-2. MCP8048 QFN48 BLDC Motor Driver Evaluation Board Bottom



1.2. Headers, Connectors, Jumpers

1.2.1. Jumper Settings

The MCP8048 QFN48 BLDC Motor Driver Evaluation Board has several user-configurable jumpers. The jumpers are described in Table 1-1 below. The configuration jumpers positioning is illustrated in Figure 1-3.

Table 1-1. MCP8048 QFN48 BLDC Motor Driver Evaluation Board Jumpers

Jumper	Positions	Function Description
JpRst2	On/Off	Connect/Disconnect MCLR and nRST signals (for WDT operation).
J5,7,9	BMFx/OAx	BMF block signals/OpAmp1 hardware configuration.
R55/R66/R67	5V/12V/3.3V	5V/12V/3.3V Hall power voltage selection.
Jp11	On/Off	Connect/Disconnect LIN bus to an external Battery.
Jp13	On/Off	Connect/Disconnect LIN bus to Commander LIN capacitor.
J2	VDD2/INH	Route VDD2 to DSP PwS or INH to Auxiliary Buck (MCP8048-3333). Do not place the jumper if powered from the buck.
J11	3V3/5V	Power microcontroller with 3.3V or 5V.
R54	SMD Resistor 0Ω	Populate if auxiliary buck is used and J2 = INH or not placed.
R113	SMD Resistor 0Ω	Populate if the surface mounted NTC "TH1" is used.
R20/R69	On/Off	Connect/Disconnect IRQ line.
R70/R97	On/Off	Connect/Disconnect MISO line.
R94/R98	On/Off	Connect/Disconnect MOSI line.
R72/R96	On/Off	Connect/Disconnect SCK line.
R73/R99	On/Off	Connect/Disconnect LIN_RX line.
R100/R101	On/Off	Connect/Disconnect LIN_TX line.

Figure 1-3. MCP8048 QFN48 BLDC Motor Driver Evaluation Board Jumpers Positioning

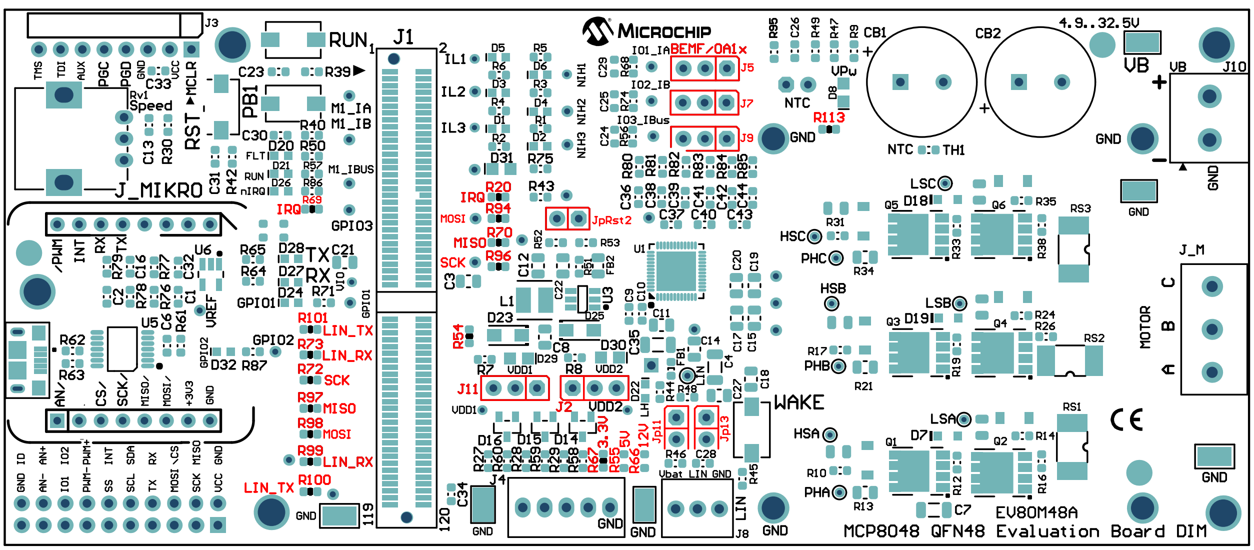
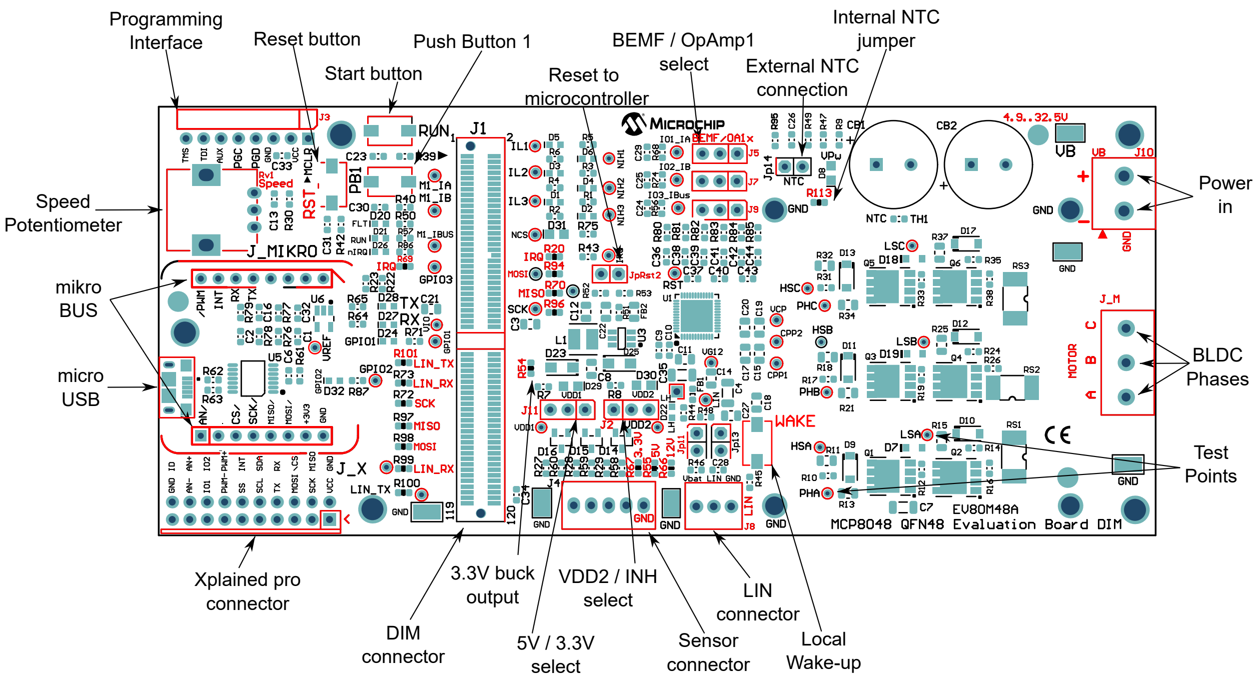


Figure 1-4. MCP8048 QFN48 BLDC Motor Driver Evaluation Board Features



The board can be easily configured for different types of motor and control algorithms:

- BLDC Trapezoidal sensorless based on B-EMF null cross detection
- BLDC Trapezoidal based on sensor position detection
- PMSM, FOC, three shunt sensorless (with/without wind milling)
- PMSM, FOC, three shunt based on sensor position detection

Table 1-2 describes the jumpers' settings, for different motor control modes.

Table 1-2. Hardware Motor Control Mode Setup

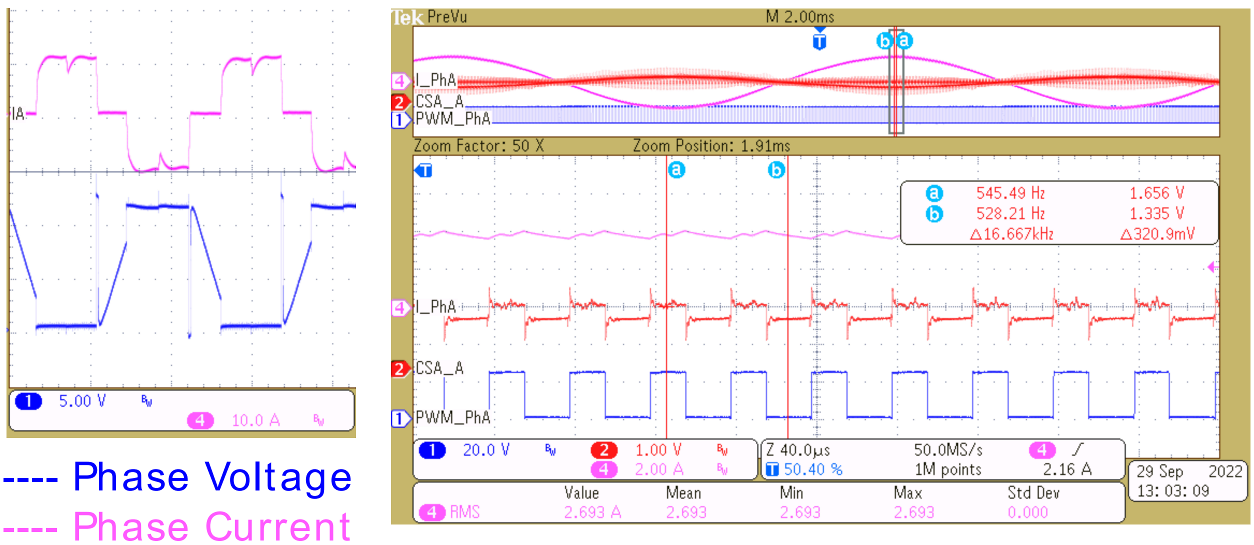
Jumper	Positions	Description
Trapezoidal Sensorless Mode		
J5	BEMF3	Route OPO1 as BEMF3 ZCD output to DSC.
J7	BEMF2	Route OPP1 as BEMF2 ZCD output to DSC.
J9	BEMF1	Route OPN1 as BEMF1 ZCD output to DSC.
FOC Sinusoidal Sensorless Mode		
J5	IO1	Route OPO1 CSA output to DSC.
J7	In1+	Route OPP1 as CSA to IS+.
J9	In1-	Route OPN1 as CSA to IS-.
Trapezoidal Sensored Mode		
R67	HALL 3.3V	Route 3.3V to power Hall sensors.
or		
R55	HALL 5V	Route 5V to power Hall sensors.
or		
R66	HALL 12V	Route 12V to power Hall sensors.
FOC Sinusoidal Sensored Mode		
J5	IO1	Route OPO1 CSA output to DSC.
J7	In1+	Route OPP1 as CSA to IS+.

Table 1-2. Hardware Motor Control Mode Setup (continued)

Jumper	Positions	Description
J9	In1-	Route OPN1 as CSA to IS-.
R67	HALL 3.3V	Route 3.3V to power Hall sensors.
or		
R55	HALL 5V	Route 5V to power Hall sensors.
or		
R66	HALL 12V	Route 12V to power Hall sensors.

For the same motor, Figure 1-5 shows the currents for sensorless trapezoidal and sensorless sinusoidal modes, taken on this board.

Figure 1-5. Trapezoidal and Sinusoidal Motor Control Modes



Pressing the Sw1 (WAKE) push button wakes the system up.

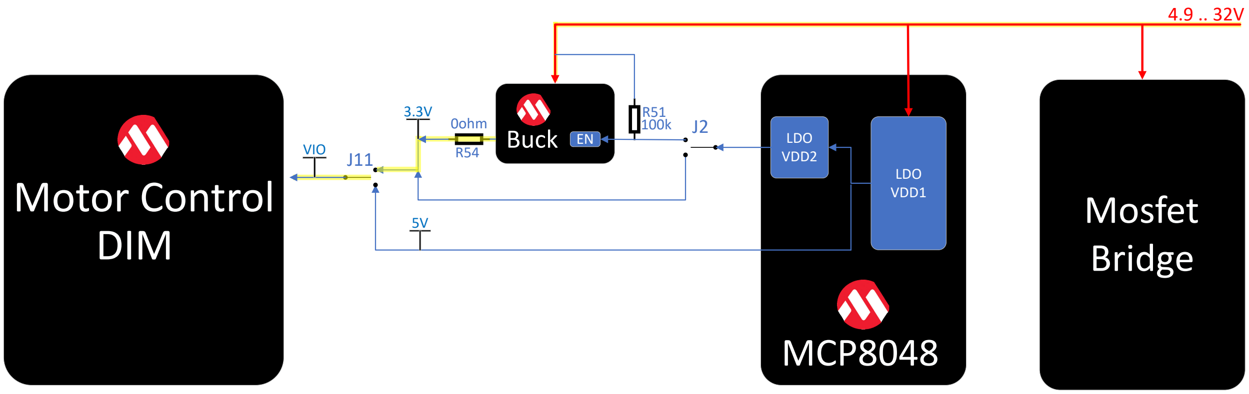
Pressing the ST3 (RST) push button forces a host controller reset.

Jp11 and **Jp13** are used to pull up LIN to the external battery voltage and to add a LIN commander capacitor, respectively.

J2 is dedicated for the VDD2/INH pin and, when the board is equipped with the MCP8048-3333, must be put in the **INH** (right) position, to be used as external power supply activator (the second LDO is not available for this variant). At the same time, R54 (0Ω) has to be populated to tie the external power supply output to the +3.3V line, in order to supply the dsPIC33CK256MP205 Motor Control DIM.

The INH jumper should be skipped if R51 - Enable PullUp - is present on the board.

Figure 1-6. Evaluation Board Power Supply Diagram



1.2.2. Available Interfacing Connectors

For external board interfacing, there are several connectors/pads available.

- J3 is dedicated for microcontroller programming/debugging. After programming, it can be used for other purposes, e.g., for rotary encoder interfacing, due to the microcontroller pin remapping feature.
- J_M is the motor driver output. This is the connection to the BLDC motor.
- J10 is the power supply connection. The board needs to be connected to a power supply with an output range of 4.9 to 32.5V, according to the voltage ratings of the motor utilized by the user.
- J4 connects the Hall effect sensors to the dsPIC33CK256MP205 microcontroller. Before connecting the Hall effect sensors, the user must make sure that the Hall effect sensors are powered with the right voltage, by putting the 0R resistor in location R67 for 3.3V, in location R55 for 5V or in location R66 for 12V.

Interface Connectors

Table 1-3. J10 (**VPwS**) Input Power Supply Connector

Pin	Name	Description
1	GND	Power Supply Ground
2	VPwS	+Power Supply Voltage

Table 1-4. JM (**MOTOR**) Three Phases Output Connector

Pin	Name	Description
1	A	Motor A Phase
2	B	Motor B Phase
3	C	Motor C Phase

Table 1-5. J3 (**PICKITProg**) is mainly dedicated for microcontroller programming/debugging

Pin	Name	Description
1	MCLR	Master Clear Pin
2	VPP	+3.3V Power-programming
3	VSS	Microcontroller GND
4	PGD	Programming Data
5	PGC	Programming Clock
6	Aux	Not used
7	TDI	Not used
8	TMS	Not used

Table 1-6. J6 (**Sensors**) Hall Sensors Interfacing Connector (could be also used for Other Interfacing Sensors, e.g., QEI)

Pin	Name	Description
5	VH-	Hall GND
4	VH+	Hall Power Supply +3.3/5V/12V
3	HallA	HallA Sensor Output
2	HallB	HallB Sensor Output
1	HallC	HallC Sensor Output

Table 1-7. J8 (**LIN**) Can be Used to Communicate with External Systems Based on LIN Protocol or for External Wakeup Command when SLEEP Mode was Induced

Pin	Name	Description
1	VBAT	External Battery LIN Biasing
2	LIN	LIN Bus Signal
3	GNDLIN	LIN Ground Reference

1.2.3. Powering the MCP8048 QFN48 BLDC Motor Driver Evaluation Board

Apply the input voltage to the input power terminal block, **VB**, with respect to polarity. The input voltage source should be limited to +32.5V. For proper operation with a common motor, the input voltage should be between +4.9V and +32.5V,in concordance with the motor rated voltage. Connect the positive side of the input power source (+) to pin 1 of **VB**. Connect the negative or return side (-) of the input source to pin 2 of **VB**. Refer to Figure 1-3.

1.2.4. Connecting a Motor to the MCP8048 QFN48 BLDC Motor Driver Evaluation Board

Connect each phase winding of a three-phase BLDC motor to the appropriate terminal of the motor terminals (PhA, PhB, PhC).

1.3. Operating a Motor

1. Turn the SPEED adjust potentiometer (RV1) fully counterclockwise to obtain the slowest speed setting. Next, turn the speed adjust approximately ¼ turn clockwise to allow for 25% motor speed.
2. Turn on the power supply. At this moment, the red Fault LED is blinking at around 10 Hz.
3. Press and release the RUN push button (ST1) to start the motor. In this moment, the PWM's LEDs indicate the motor powering.
4. Turn the Speed potentiometer clockwise to increase motor speed and counterclockwise to decrease motor speed. The Speed Adjust changes the PWM duty cycle of the PWM signals being sent to the MCP8048.
5. Press and release the RUN push button again to stop the motor.

1.4. Indicator LEDs

The MCP8048 QFN48 BLDC Motor Driver Evaluation Board has eight LEDs to indicate the system status. Table 1-8 lists the LED indicators and their description.

Table 1-8. LED Indicators

PCB Location	Name	Description
D1, D3, D5	PWMxL	PWM Phase x low–side.
D2, D4, D6	PWMxH	PWM Phase x high–side.
D8	VPw	Indicates power supply presence.
D21	Run	Motor running state.
D20	Flt Fault	Indicates FAULT status.

Table 1-8. LED Indicators (continued)

PCB Location	Name	Description
D22	LH	Optical indicator for Limp Home, VDD independent high voltage failure output.
D24	GPIO1	LED connected to debugging pin. Used by user for code debugging purposes.
D26	nIRQ	Indicates nIRQ status.
D27	RX	Data activity received by MCP2221A on RX line.
D28	TX	Data activity transmitted by MCP2221A on TX line.
D29	VDD1	Presence of voltage on the VDD1 line.
D30	VDD2	Presence of voltage on the VDD2 line.
D31	NCS	Indicates chip select status.
D32	GPIO2	LED connected to debugging pin. Used by user for code debugging purposes.

1.5. Test Points

There are several test points on the board that allow probing of voltages, currents and signals (see Table 1-9).

Table 1-9. Test Points Description

Test Point Name	Description
+4.9...32V	Power Supply (+)
GND	Power Supply Ground (-)
VDD2	3.3V LDO Output Voltage
VDD1	5V Internal LDO Output
VIO	Microcontroller supply voltage
VG12	12V internal low side LDO output
CPP1	Charge Pump Positive 1
CPP2	Charge Pump Positive 2
VCP	Output Charge Pump 2 output (respect with VDH)
MOSI	SPI Host Output Client Input
MISO	SPI Host Input Client Output
SCK	SPI Serial Clock
NCS	SPI Chip Select
IRQ	Interrupt request
IL1...3	PWMs Low driver inputs
IH1...3	PWMs High driver inputs
GL1...3	A/B/C Phase Low driver outputs
GH1...3	A/B/C Phase High driver outputs
SH1...3	A/B/C motor/driver phase signals
RST	MCP8048 reset Host
LIN	LIN Bus in/output
RX	LIN Rx (MCP8048 Out)
TX	LIN Tx (MCP8048 In)
LH	Limp Home MCP8048
GPIO1	Spare dsPIC test signal (debugging purposes)
GPIO2	Spare dsPIC test signal (debugging purposes)
GPIO3	Spare dsPIC test signal (debugging purposes)
IO1_IA	opAmp1 output (current through phase 1)
IO2_IB	opAmp2 output (current through phase 2)
IO3_IBus	opAmp3 output (current through phases)

Table 1-9. Test Points Description (continued)

Test Point Name	Description
M1_IA	DIM Internal opAmp output (current through phase 1)
M1_IB	DIM Internal opAmp output (current through phase 2)
M1_IBUS	DIM Internal opAmp output (current through phase 3)

1.6. Reprogramming the dsPIC33CK256MP205 Motor Control DIM

The dsPIC33CK256MP205 Motor Control DIM can be reprogrammed with the user's desired firmware. The processor may be programmed by using an external power source and a PICkit™ 3, MPLAB® REAL ICE in-circuit emulator, PICkit™ 4 or PICkit™ 5 programmer.

1. Connect the power source to the board, as explained in Section 1.1.
2. Connect a PICkit 3, PICkit 4, or PICkit 5 to the **J3** header.
3. Start up the MPLABX Integrated Development Environment (IDE) and load the EV80M48A_ck_205.X Motor Driver Evaluation Board firmware project.

In the "MCP8048.h" file, configure the desired application parameters.

1. In the "UserParms.h" file, the desired motor parameters can be configured (see Chapter 5. Software).
2. Build the project.
3. Program the device.
4. Press the RESET switch on the board to reset the processor and allow it to execute the new firmware program.

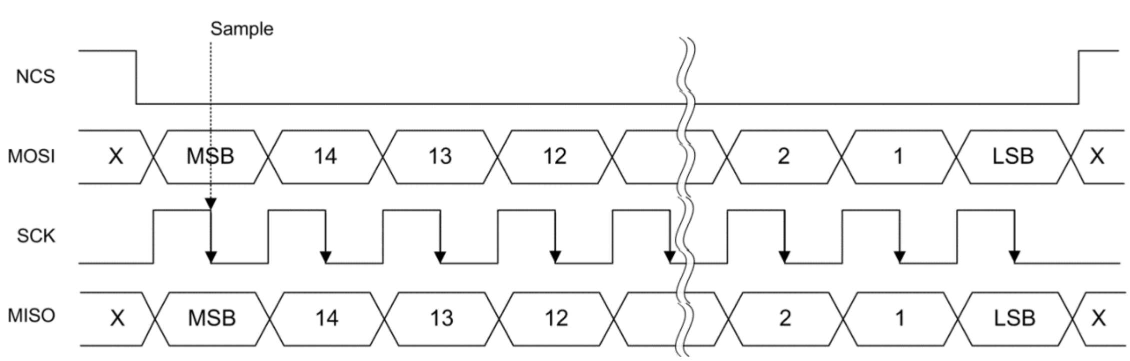
Note:
The following project options may need to be changed for the computer used to build the firmware:

- Add Library `libdsp-elf.a` located in the XC16 `???\src\Libdsp\lib\directory.`
- Add XC16-as ASM. Include Directory in XC16 `???\src\Libdsp\asm`.
- Set hardware tool to "PICkit 3", "PICkit 4", "PICkit 5" or "REAL ICE."

1.7. Configuring the MCP8048

The MCP8048 has configuration registers that may be used to modify the operating parameters of the device. The parameters are modified by sending commands to the MCP8048 using the SPI communication interface. Bit sampling is performed on the falling edge of the clock and data is shifted in/out on the rising edge, as illustrated in Figure 1-7. 16 bits must be transmitted to the device for a single register write operation. The first byte contains the 7-bit address along with a 'read/write' bit (the LSB). The second byte contains the data to be written to the register. If the R/W bit is 0, it is a write operation, otherwise, a read one.

Figure 1-7. SPI Timing Protocol



The user may add code to the evaluation board firmware to communicate with the registers. The evaluation board software contains a subroutine which initializes the MCP8048 registers. The configuration registers are summarized in Table 1-10. Detailed information is available in the datasheet. An example of waveforms SPI communication is shown in Figure 1-8.

Figure 1-8. SPI Registers Configuration - Waveform Example

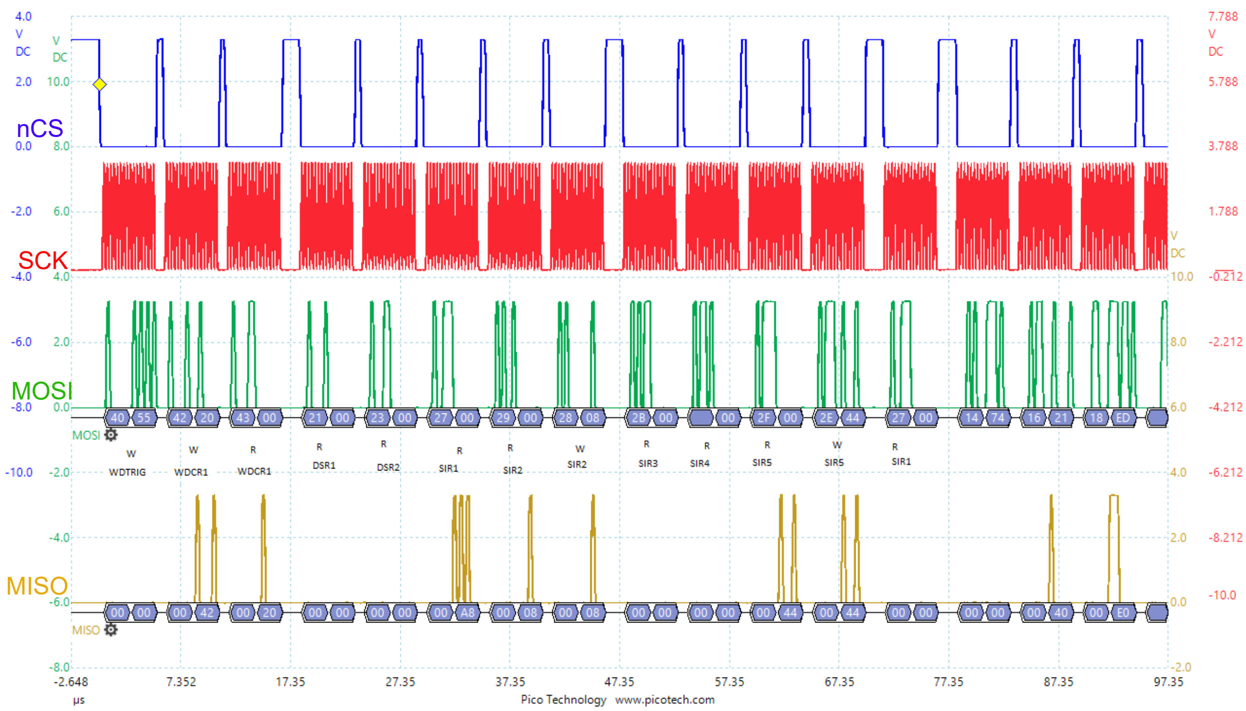


Table 1-10. Configuration Message Commands (XXXXXXXX = By Default)

Register	Address	Description	Asserted Parameters/Modes
DOPMCR	0x01	Device Operation Mode Control Register	Deep Sleep Mode
			Sleep Mode
			Standby Mode (by default)
			Normal Mode
LOPMCR	0x02	LIN Operation Mode Control Register	LIN Standby Mode
			LIN Normal Mode
GOPMCR	0x03	Gate Driver Unit Operation Mode Control Register	GDU OFF Mode
			GDU Standby Mode
			GDU Normal Mode
WUCR	0x04	Wake-up Control Register	Local Wake-up Enable
			LIN Bus Remote Wake-up Enable
GDUCR1	0x05	GDU Control Register 1	BEMF det. Enable/Disable Bit
			Cross Conduction Enable/Disable Bit
			TCC=100 ns ×N, N= 0 to 63
GDUCR2	0x06	GDU Control Register 2	Edge Blanking Time Control Bits
			Cross Conduction Protection Time
			LSOFF, LS= 0 when GDU = Standby
			HSOFF, HS = 0 when GDU = Standby

Table 1-10. Configuration Message Commands (XXXXXXXX = By Default) (continued)

Register	Address	Description	Asserted Parameters/Modes
GDUCR3	0x07	GDU Control Register 3	Low Side Slew Rate Control
			High Side Slew Rate Control
			Low Side Adaptive Dead Time
			High Side Adaptive Dead Time
GDUCR4	0x08	GDU Control Register 4	VGS Under-voltage Filter Time
			VGS/VGUVLO Level Selection
			VGSUVLO Detection Enable/Disable Bit
			Complementary Control Enable/Disable bit
ILIMCR	0x09	Current Limitation Control Register	Current Limit Shutdown Enable/Disable Bit
			Current Limitation Filter Time
			Current Limits Enable/Disable Bit
ILIMTH	0x0A	Current Limitation Threshold Register	VILIM_TH= 5/3.3V/128 ×DAC
SCPCR	0x0B	Short Circuit Protection Control Register	Short Circuit Detection Threshold
			Short Circuit Filter Time
			Short Circuit Shutdown Enable/Disable Bit
CSCR	0x0C	Current Sensing OpAmp Control Register	CS OpAmp Gain Control
			CS OpAmp Output Offset Control
			Enable CS OpAmp1 Enable/Disable Bit
			Enable CS OpAmp2 Enable/Disable Bit
			Enable CS OpAmp3 Enable/Disable Bit

1.8. MCP8048 Message Responses

When a fault event occurs, depending on the desired protections that have been enabled, the driver generates an interrupt to the host controller, by pulling down the **NIRQ** line. At this moment, the host should initiate the SPI communication to read the status registers (DSR1, 2) and the system interrupt registers (SIR1...5), and to find out the fault cause. Table 1-11 summarizes the registers that should be read.

Table 1-11. Configuration Message Responses

Register	Address	Description
DSR1	0x10	Device Status Register 1
DSR2	0x11	Device Status Register 2
SIR1	0x13	System Interrupt Register 1
SIR2	0x14	System Interrupt Register 2
SIR3	0x15	System Interrupt Register 3
SIR4	0x16	System Interrupt Register 4
SIR5	0x17	System Interrupt Register 5
SIECER1	0x18	System Interrupt Event Capture Enable Register 1
SIECER2	0x19	System Interrupt Event Capture Enable Register 2

2. Schematic Features

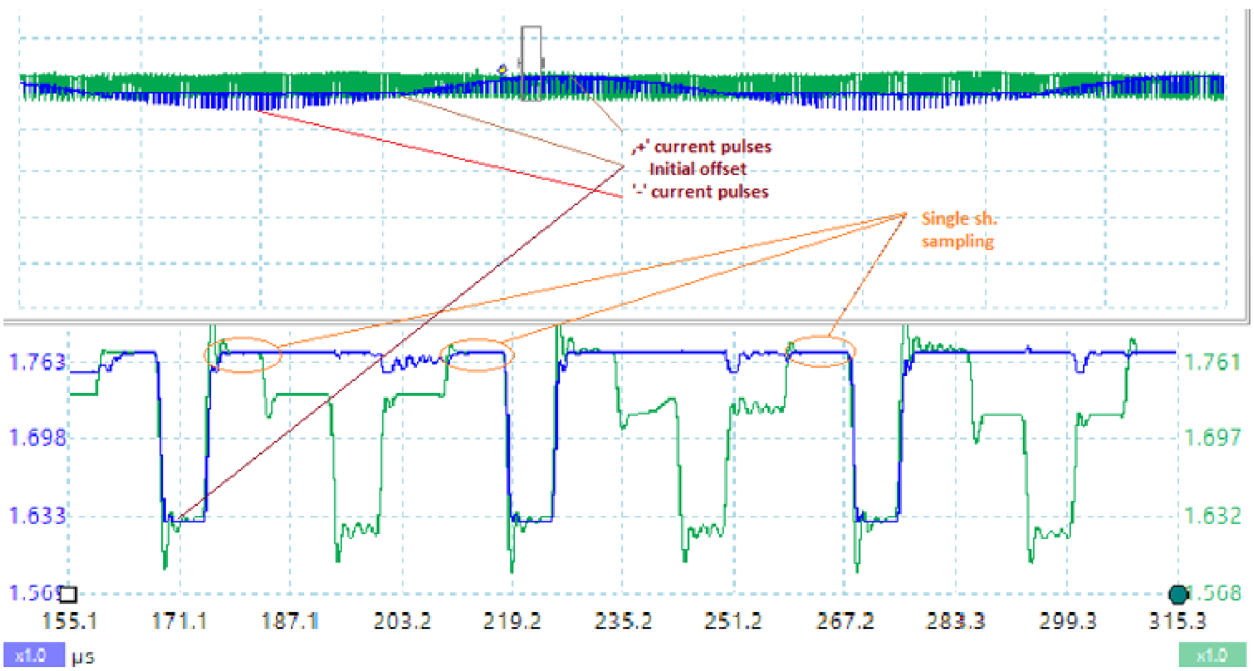
2.1. Shunt Topology

The evaluation board is designed in a combined shunt configuration. Two CSAs are connected on two of the three phases, while the third is summing all three phases in single shunt configuration. See the complete shunt topology used on this board in Figure 3-6.

For taking maximum advantage of the part's features, the evaluation board is configured as illustrated in Figure 2-2 and Figure 2-3 below, which summarize the connections between external current sense resistors and the internal available CSAs and GDU - External MOSFETs bridge. In this configuration, the evaluation board offers the option of evaluating either a combined shunt topology or a single shunt topology. The third CSA can monitor the bus current so it can be used for single shunt mode or for limitation of the maximum motor current in FOC or Trapezoidal control mode.

Generally, the motor phases are equilibrated, so only two-phase current are required to be measured, while the third will be the algebraic sum of the other two. This gives the possibility to use the third CSA to evaluate the current pulses across the summing shunt. The main advantage is that these pulses are only in positive range related to the initial offset and could be directed to the internal current limit comparator, without any particular software/hardware processing.

Figure 2-1. CSA's Outputs in Combined Shunts Topology

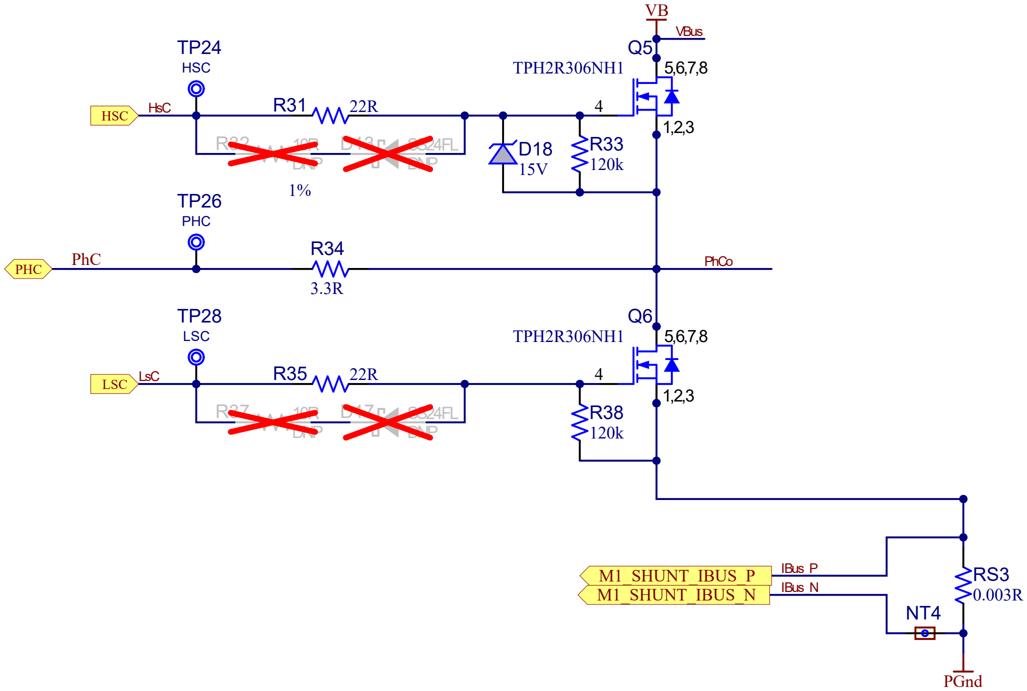


Finally, by applying the procedure for currents reconstruction, the evaluation board offers the possibility to develop and evaluate the single shunt configuration with MCP8048 QFN48 Motor Driver.

2.2. Asymmetric Turn On/Off External MOSFET Bridge

The evaluation board offers an additional feature - to configure an asymmetric on/off for both H/L side external MOSFET bridge, by populating R32+D13 and R37+D17 groups for all three phases, in order to achieve a slowdown turn-on MOSFET commutation and fast commutation of the MOSFET gates to the lowest potential. Furthermore, the part could be configured to sink/surge 25%, 50%, 75% or 100% slew rate speed for LS and HS independently.

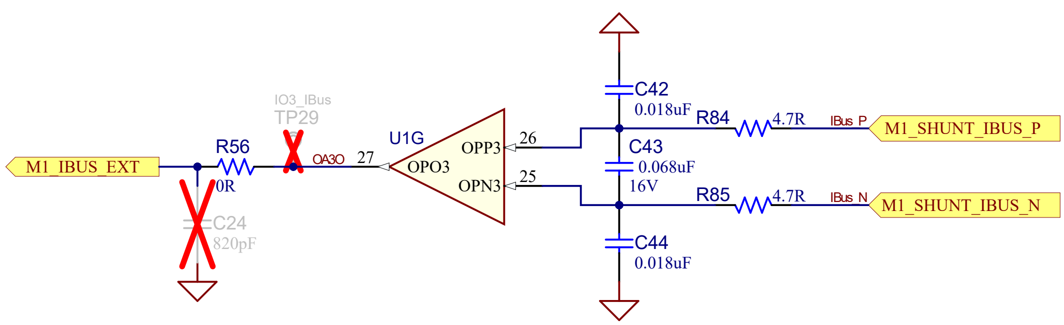
Figure 2-2. Optional Asymmetric Turn On/Off



2.3. Current Sense Amplifier (CSA)

To ensure the ADC range conversion, the initial offset of CSA is set to approximately 1.65V. The total gain of the CSA is Gt = 16. For high motor currents, it is necessary to decrease the equivalent shunt resistor value, in order to avoid CSA output limitation. This reduces the losses and avoids analog limitation or overflows in numerical computation. For sense current detection, the available internal operational amplifiers are configured as presented in Figure 2-3, for a high-speed and robust operation of the CSA.

Figure 2-3. Current Sense Amplifier from MCP8048



3. Board Design

This section contains the following schematic and layouts for the MCP8048 QFN48 BLDC Motor Driver Evaluation Board (EV80M48A).

- Schematic 1
- Schematic 2
- Buck Converter
- DIM
- Hall Effect Sensors Connector
- 3-Phase Inverter
- LIN Interface Connector
- Power Input Connector
- Input Voltage Divider
- Push Buttons
- Speed Potentiometer
- NTC Thermistor
- USB UART Converter
- VREF opAmp
- Top Silk
- Top Copper and Silk
- Top Copper
- Bottom Copper
- Bottom Copper and Silk
- Bottom Silk

3.1. Schematics

Figure 3-1. Schematic 1

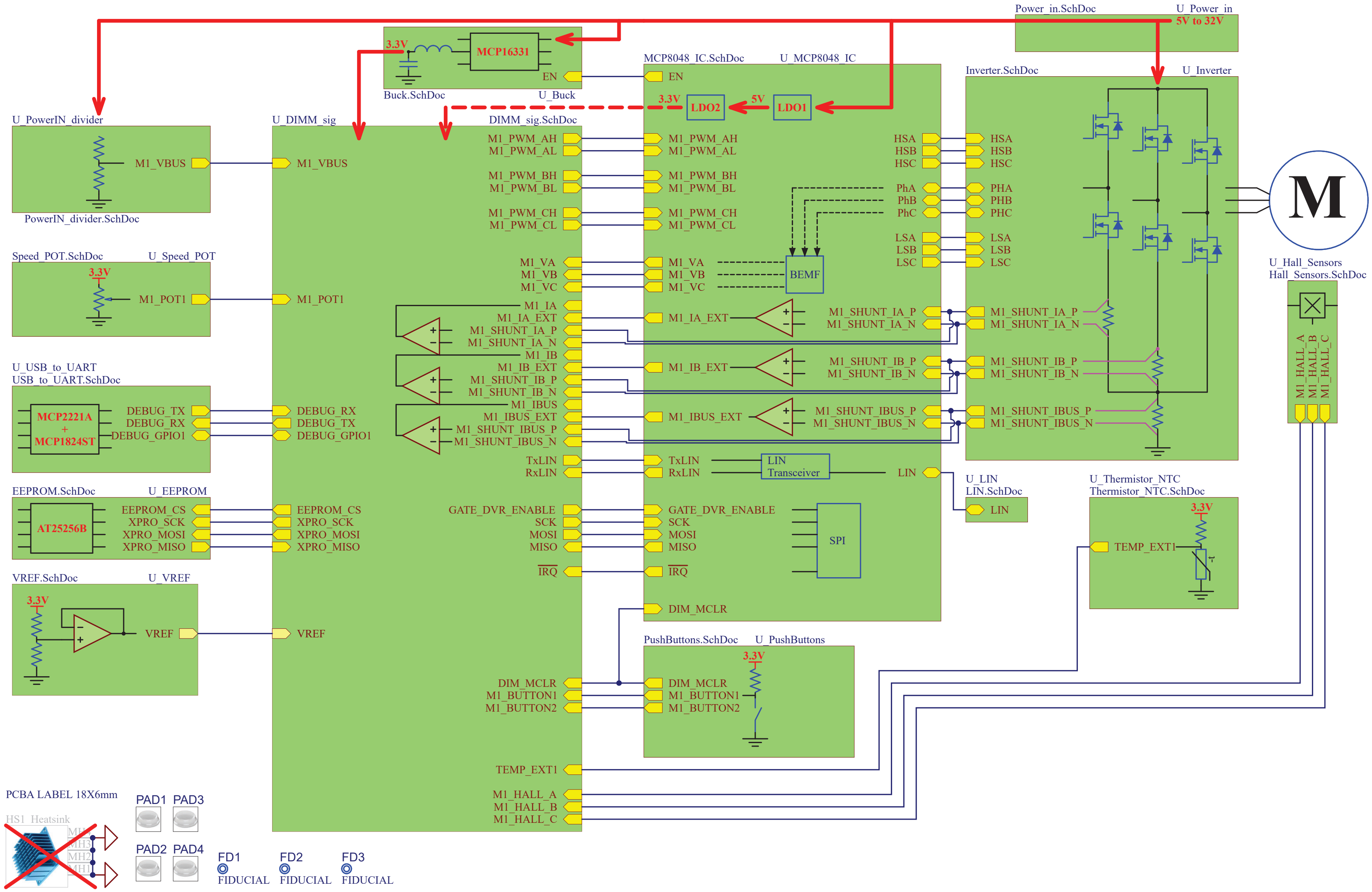


Figure 3-2. Schematic 2

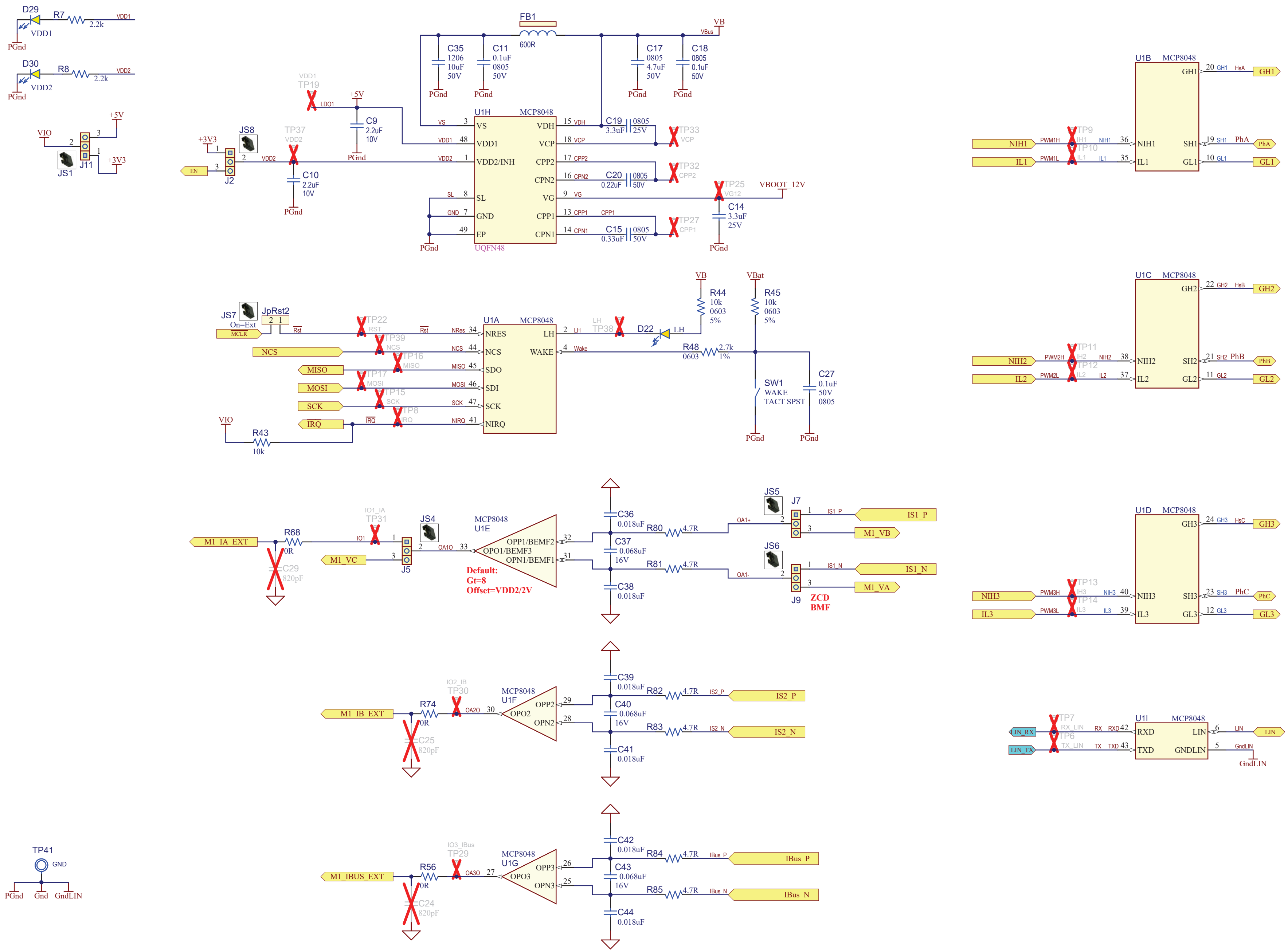


Figure 3-3. DIM

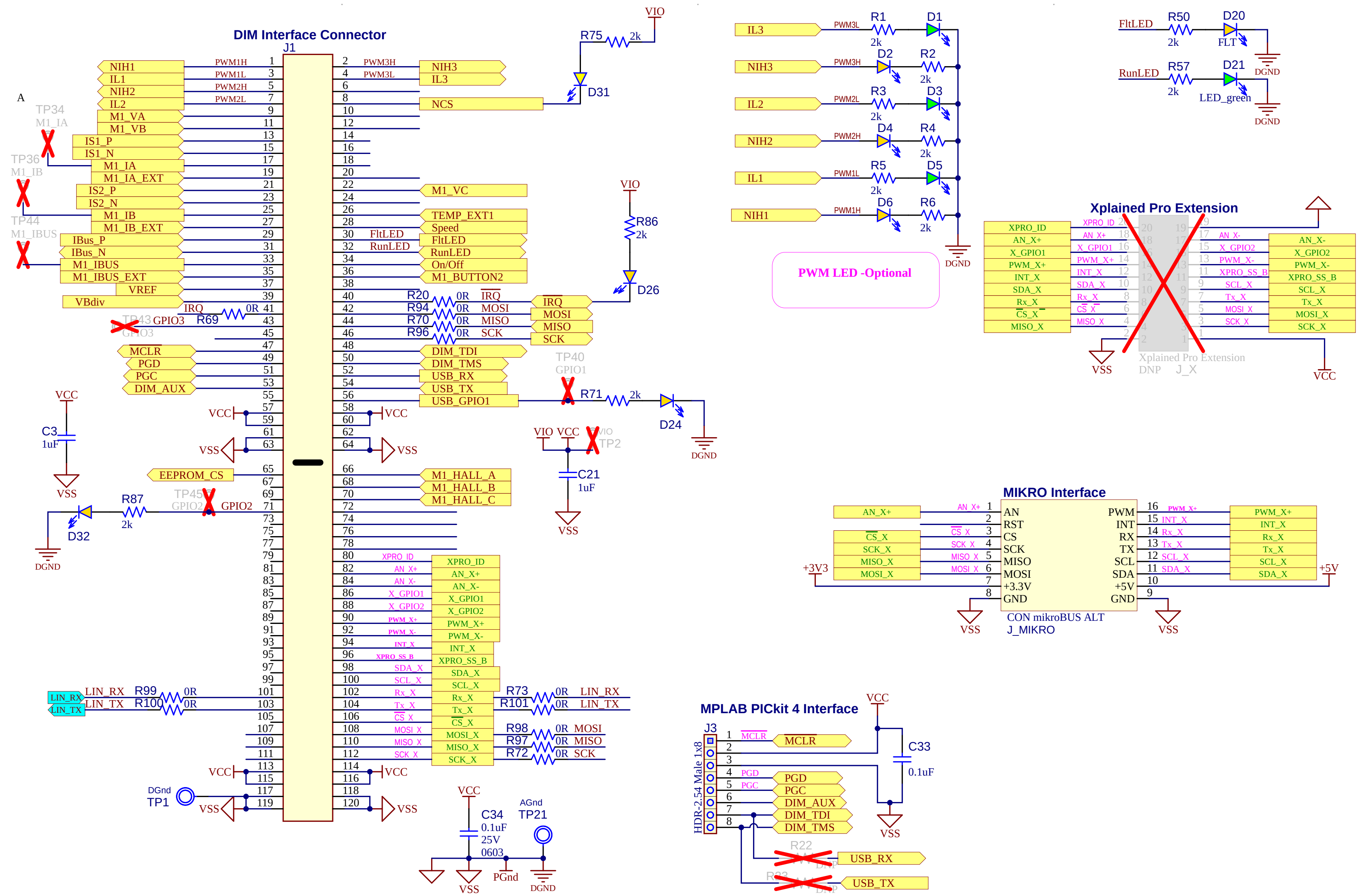


Figure 3-4. Buck Converter

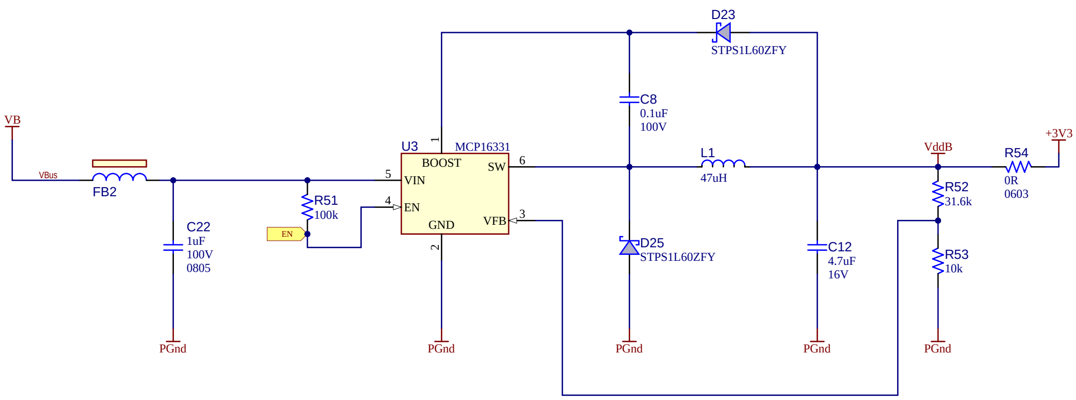


Figure 3-5. Hall Effect Sensors Connector

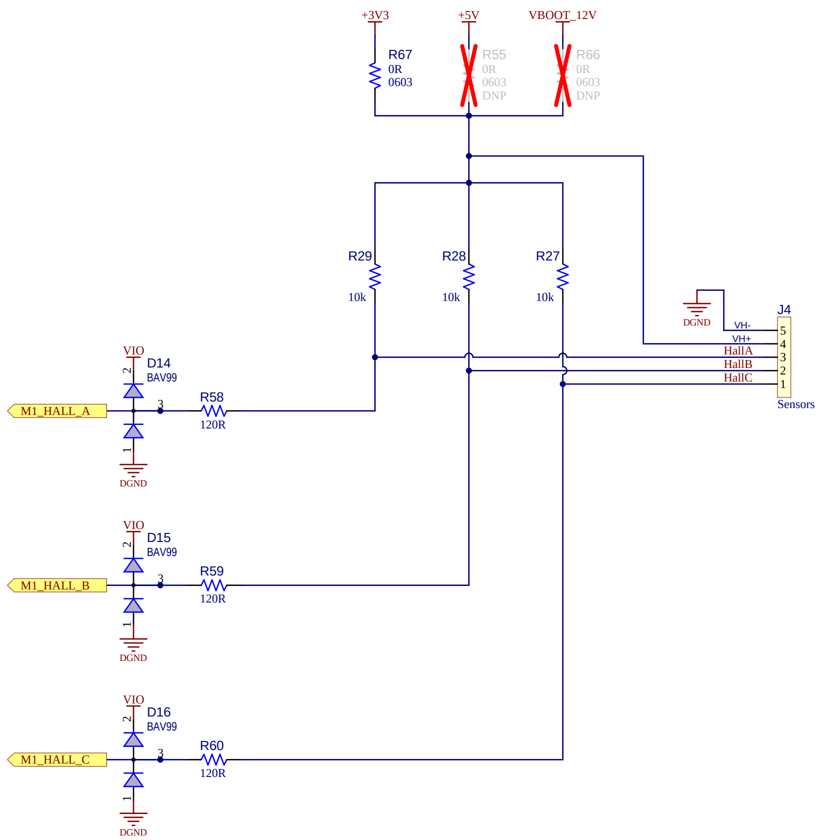


Figure 3-6. 3-Phase Inverter

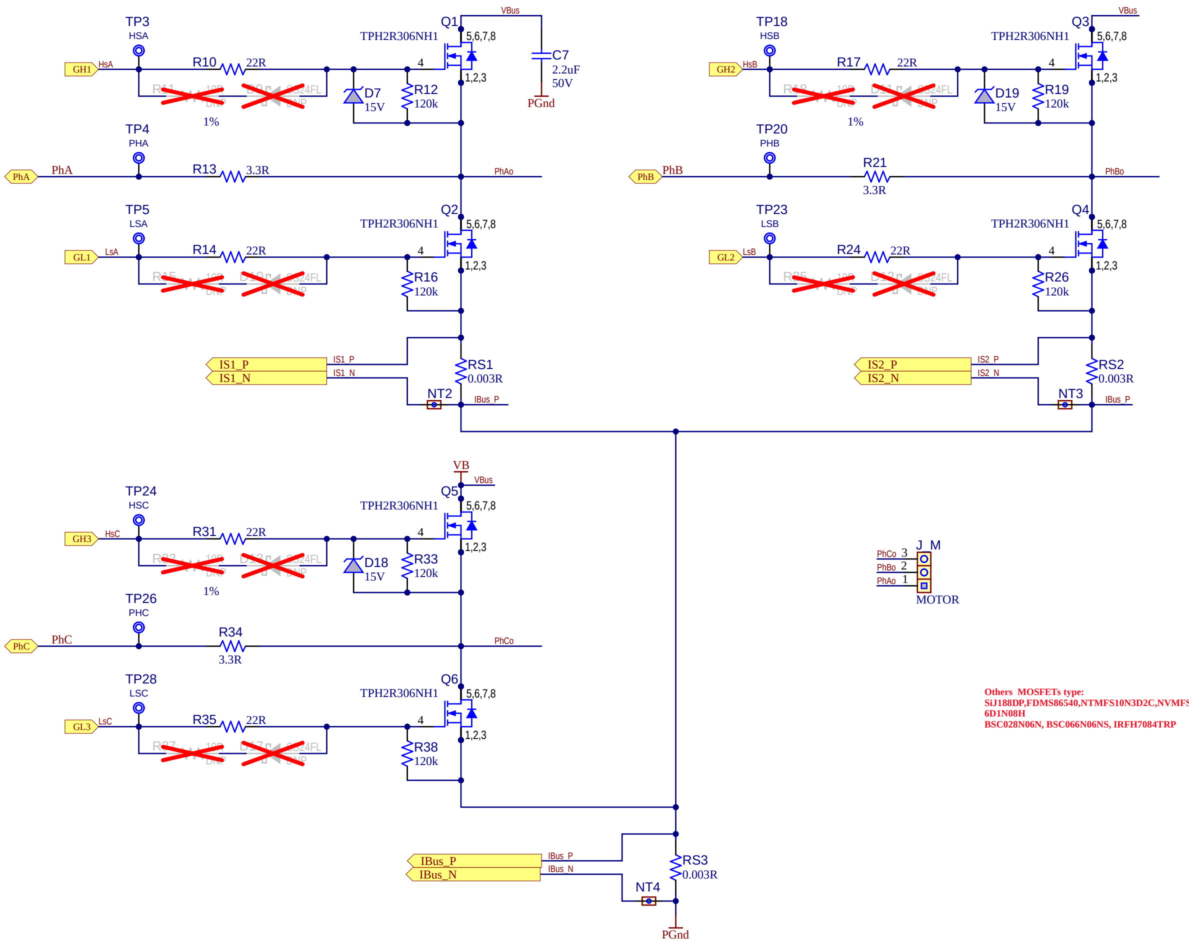


Figure 3-7. LIN Interface Connector

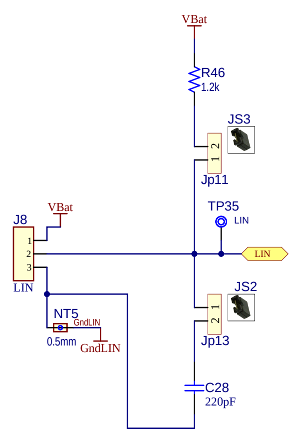


Figure 3-8. Power Input Connector

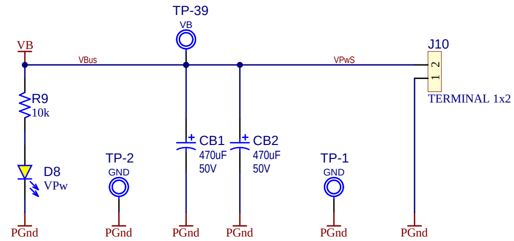


Figure 3-9. Input Voltage Divider

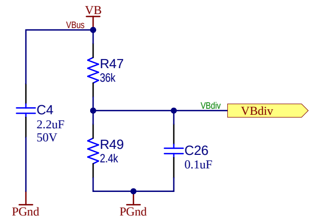


Figure 3-10. Push Buttons

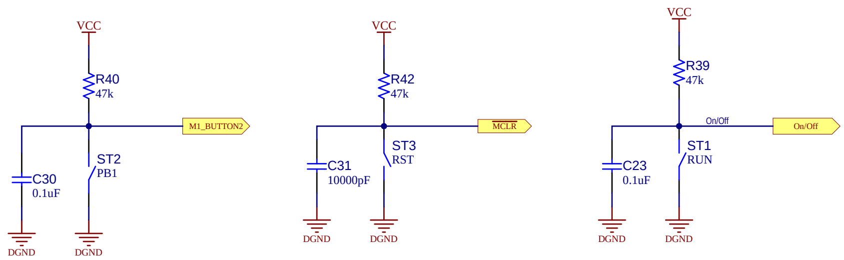


Figure 3-11. Speed Potentiometer

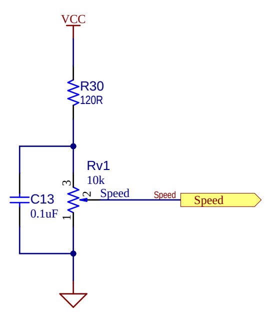


Figure 3-12. NTC Thermistor

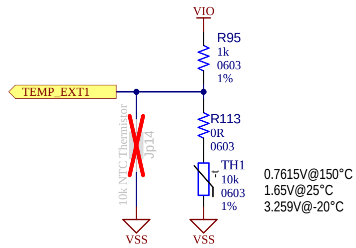


Figure 3-13. USB UART Converter

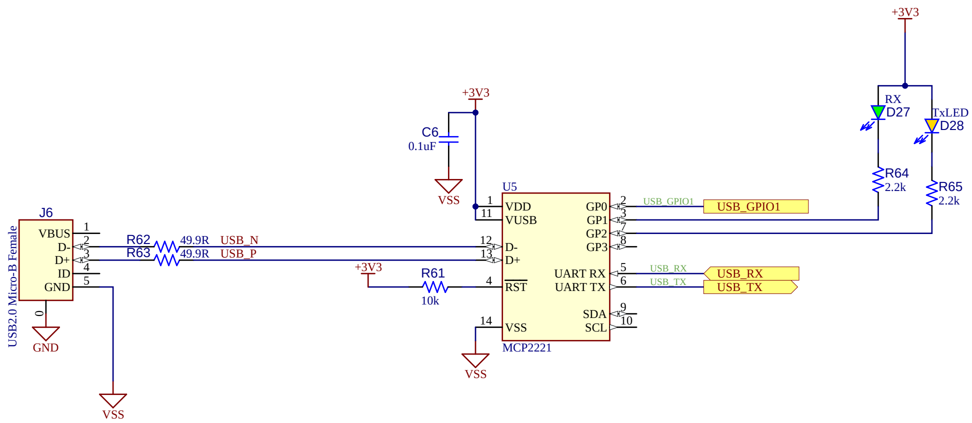
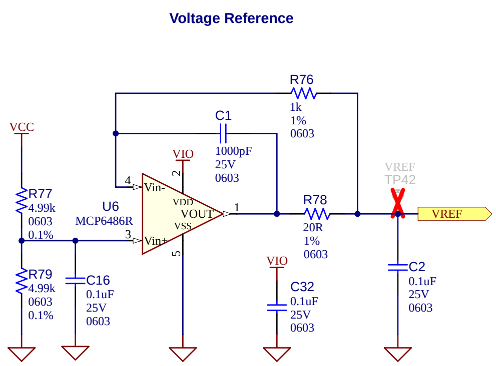


Figure 3-14. VREF opAmp



3.2. Layouts

Figure 3-15. Top Silk

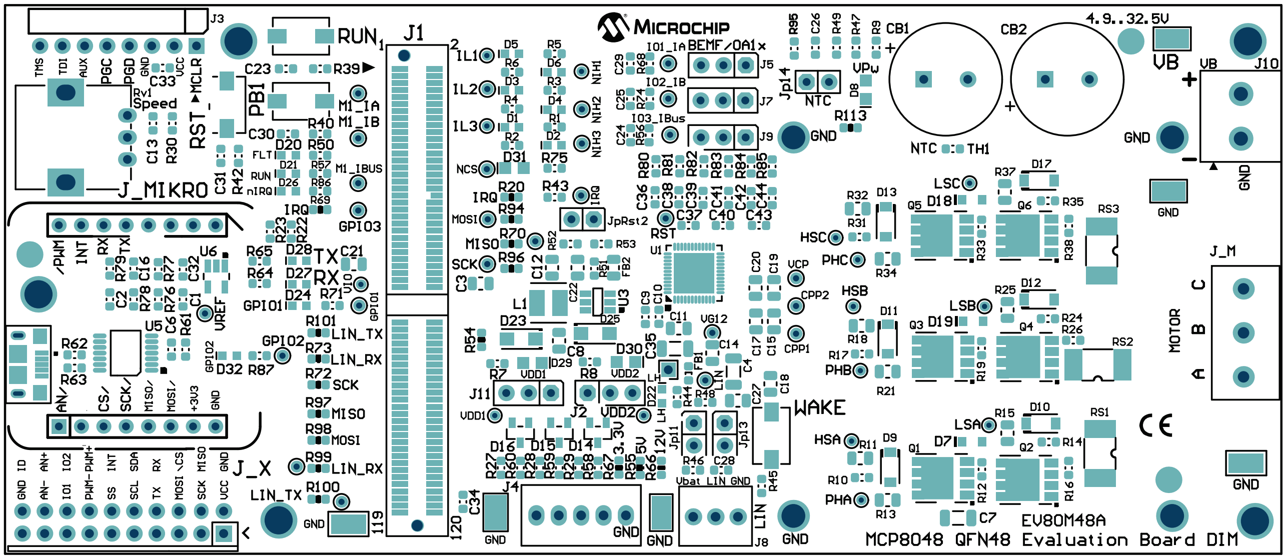


Figure 3-16. Top Copper and Silk

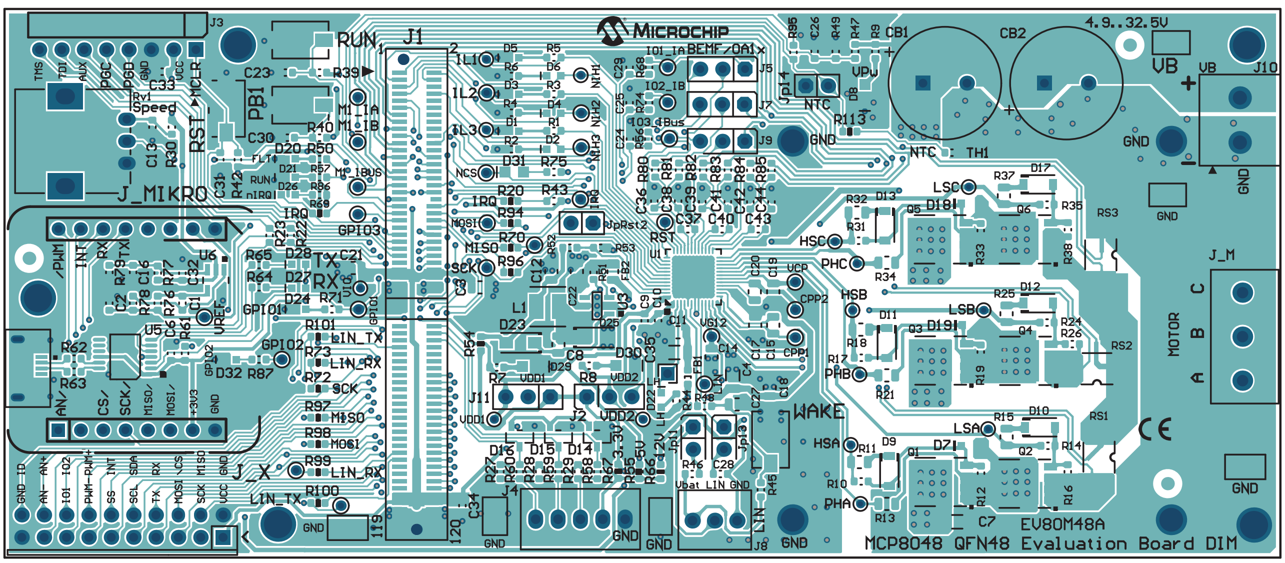


Figure 3-17. Top Copper

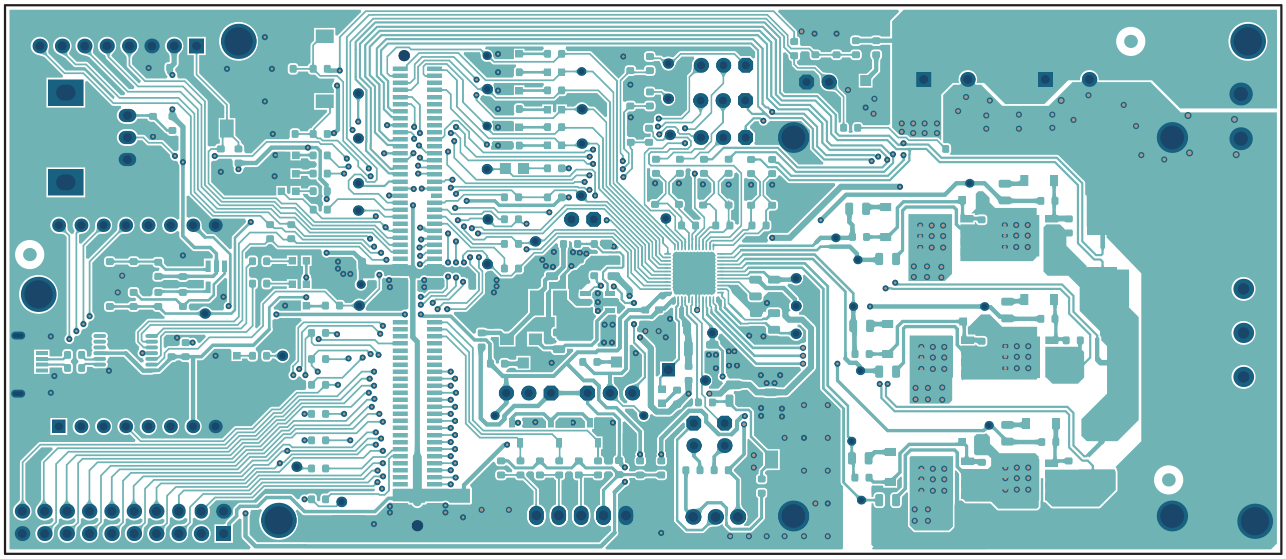


Figure 3-18. Bottom Copper

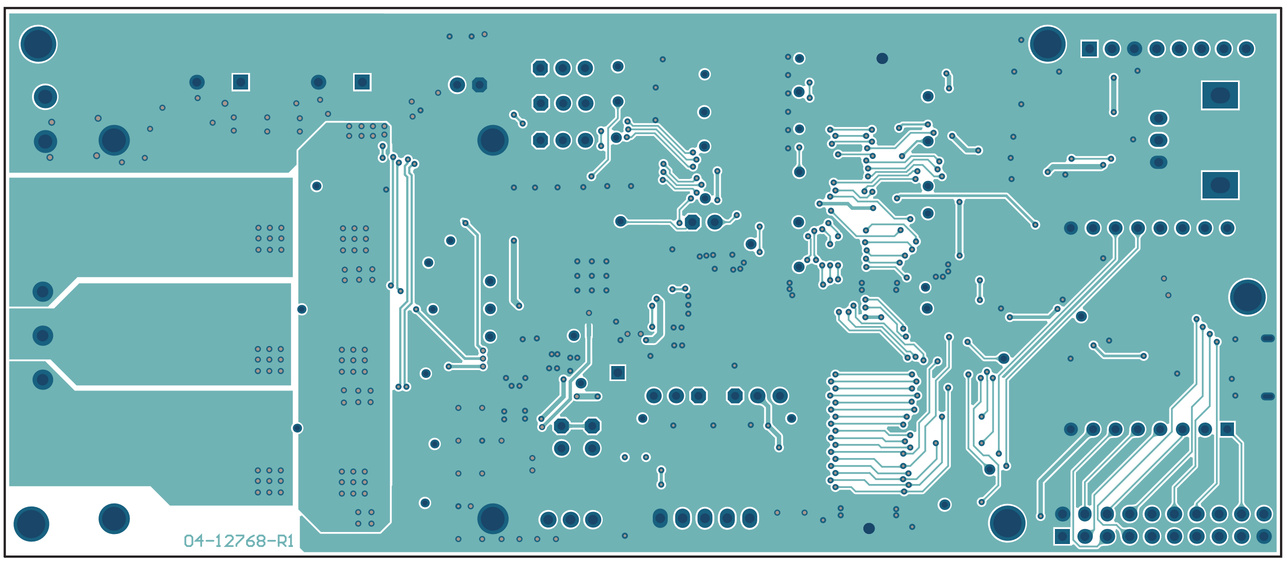


Figure 3-19. Bottom Copper and Silk

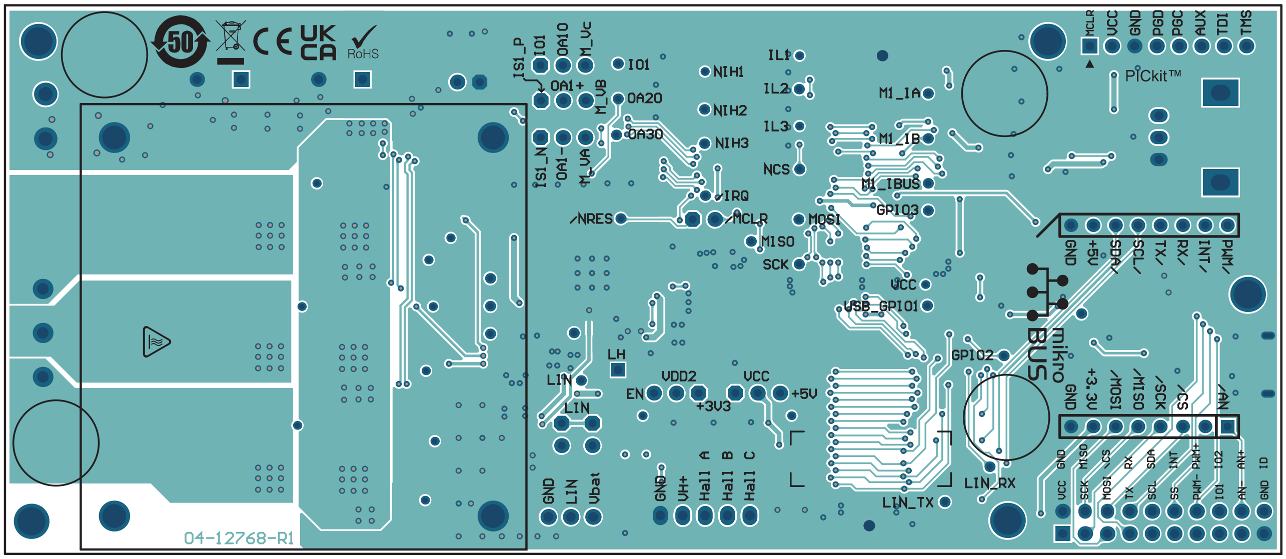
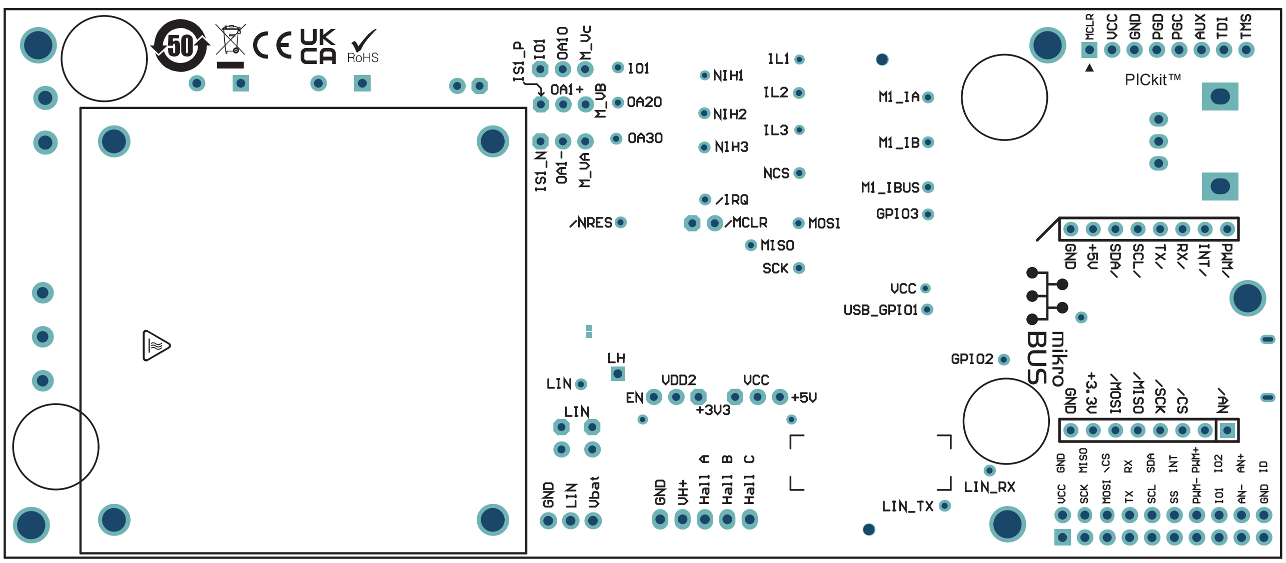


Figure 3-20. Bottom Silk



4. Bill of Materials (BOM)

Table 4-1. Bill of Materials (BOM)

Qty	Reference	Description	Manufacturer	Part Number
1	C1	Capacitor, Ceramic, 1000 pF, 25V, 5%, C0G/NP0, SMD, 0603	KEMET	C0603C102J3GACTU
10	C2, C6, C13, C16, C23, C26, C30, C32, C33, C34	Capacitor, Ceramic, 0.1 µF, 25V, 10%, X7R, SMD, 0603	Kyocera AVX, AVX Corporation	06033C104KAT2A
2	C3, C21	Capacitor, Ceramic, 1 µF, 25V, 10%, X7R, SMD, 0805	AVX	08053C105K4Z2A
2	C4, C7	Capacitor, Ceramic, 2.2F, 50V, 10%, X7R, SMD, 1206, AEC-Q200	TDK Corporation	CGA5L3X7R1H225K160AB
1	C8	Capacitor, Ceramic, 0.1 µF, 100V, 10%, X7R, SMD, 0805	AVX	08051C104K4T2A
2	C9, C10	Capacitor, Ceramic, 2.2 µF, 10V, 10%, X7R, SMD, 0603	Taiyo Yuden Co., Ltd.	LMK107B7225KA-T
3	C11, C18, C27	Capacitor, Ceramic, 0.1 µF, 50V, 10%, X7R, SMD, 0805	KEMET, Cal-Chip	C0805C104K5RACTU, GMC21X7R104K50NTLF
1	C12	Capacitor, Ceramic, 4.7 µF, 16V, 20%, Y5V, SMD, 0805	Samsung Electro-Mechanics	CL21F475ZOFNNNE
2	C14, C19	Capacitor, Ceramic, 3.3 µF, 25V, 10%, X7R, SMD, 0805	TDK Corporation	C2012X7R1E335K125AB
1	C15	Capacitor, Ceramic, 0.33 µF, 50V, 10%, X7R, SMD, 0805	Samsung Electro-Mechanics	CL21B334KBFNNNE
1	C17	Capacitor, Ceramic, 4.7 µF, 50V, 10%, X5R, SMD, 0805	TDK Corporation	C2012X5R1H475K125AB
1	C20	Capacitor, Ceramic, 0.22 µF, 50V, 10%, X7R, SMD, 0805	Murata Manufacturing Co., Ltd.	GCM21BR71H224KA37L
1	C22	Capacitor, Ceramic, 1 µF, 100V, 10%, X7S, SMD, 0805	TDK Corporation	C2012X7S2A105K125AB
1	C28	Capacitor, Ceramic, 220 pF, 50V, 10%, X7R, SMD, 0603	TDK Corporation	C1608X7R1H221K
1	C31	Capacitor, Ceramic, 10000 pF, 50V, 20%, X7R, SMD 0603	Kyocera AVX	06035C103KAT2A
1	C35	Capacitor, Ceramic, 10 µF, 50V, 10%, X7R, SMD, 1206	TDK Corporation	C3216X7R1H106K160AE
6	C36, C38, C39, C41, C42, C44	Capacitor, Ceramic, 0.018 µF, 16V, 10%, X7R, SMD, 0603	KEMET	C0603C183K4RAC7867
3	C37, C40, C43	Capacitor, Ceramic, 0.068 µF, 16V, 10%, X7R, SMD, 0603	Panasonic® - ECG	ECJ-1VB1C683K
2	CB1, CB2	Capacitor, Aluminium, 470 µF, 50V, 20%, RAD, P5D12.5H20	United Chemi-Con	EKZE500ELL471MK20S
5	D1, D3, D5, D21, D27	Diode, LED Green, 1.7V, 20 mA, 3.92mcd, Diffuse, SMD, 0603	OSRAM Opto Semiconductors GmbH.	LP L296-J2L2-25-0-20-R18-Z
9	D2, D4, D6, D20, D22, D24, D26, D28, D32	Diode, LED Amber, 2.1V, 25 mA, 2mcd, Clear, SMD, 0603	Lite-On®, Inc.	LTST-C190AKT
3	D7, D18, D19	Diode, Zener, 15V, 310 mW, SMD, SOD-323	Nexperia USA Inc.	PZU15B,115
4	D8, D29, D30, D31	Diode, LED, Yellow, 2.1V, 30 mA, 10mcd, Diffuse, SMD, 0805	Lumex® Inc.	SML-LXT0805YW-TR

Table 4-1. Bill of Materials (BOM) (continued)

Qty	Reference	Description	Manufacturer	Part Number
3	D14, D15, D16	Diode, Rectifier Array, 1.25V, 200 mA, 70V, SOT-23-3	Micro Commercial Components (MCC)	BAV99-TP
2	D23, D25	Diode, Schottky, 570 mV, 1A, 60V, SMD, SOD-123F	STMicroelectronics	STPS1L60ZFY
1	FB1	Ferrite, 600R@100 MHz, 300 mA, SMD, 0603	Laird Technologies®	HZ0603C601R-00
1	FB2	Ferrite, 30R@100 MHz, 8.5A, AEC-Q200, SMD, 0805	Murata Electronics® North America	BLM21SN300SH1D
1	J1	Connector, Edge, HTEC8, 0.80 mm, 120P, Female, SMD, Vertical	Samtec, Inc.	HTEC8-160-01-L-DV-A-K-TR
5	J2, J5, J7, J9, J11	Connector, HDR-2.54, Male, 1x3, Tin, 5.84MH, TH, Vertical	Samtec, Inc.	TSW-103-07-T-S
1	J3	Connector, HDR-2.54, Male, 1x8, Gold, 5.84MH, TH, R/A	Sullins Connector Solutions	PBC08SBAN
1	J4	Connector, Terminal, 2.54 mm, 1x5, Female, 20-30AWG, 6A, TH, R/A	Phoenix Contact	1725685
1	J6	Connector, USB2.0, Micro-B, Female, SMD, R/A	FCI	10118193-0001LF
1	J8	Connector, Terminal, 2.54 mm, 1x3, Female, 20-30AWG, 6A, TH, R/A	On-Shore Technology, Inc.	OSTVN03A150
1	J10	Connector, Terminal, 5.08 mm, 1x2, Female, 12-28AWG, 16A, TH, R/A	On-Shore Technology, Inc.	OSTVI022152
1	J_M	Connector, Terminal, 5 mm, 1x3, Female, 12-30AWG, 16A, TH, R/A	Wurth Electronics	691137710003
2	J_MIKRO	Connector, Header, 8 Position 0.100" (2.54 mm), Tin Through Hole	Sullins Connector Solutions	PPTC081LFBN-RC
3	Jp11, Jp13, JpRst2	Connector, HDR-2.54, Male, 1x2, Tin, 6.75MH, TH, Vertical	Molex	0901200122
1	L1	Fixed Inductor, 47 µH, 450 mA, 834 mΩ	Wurth Elektronik	74406032470
1	LABEL1	Label PCBA 18x6mm Datamatrix Assy# / Rev / Serial / Date	ACT Logimark AS	505462
6	Q1, Q2, Q3, Q4, Q5, Q6	Transistor, FET, N-CH, TPHR8504PL,L1Q 60V, 136A, 0.0023R, 800 mW, VDFN-8	Toshiba	TPH2R306NH1,LQ
12	R1, R2, R3, R4, R5, R6, R50, R57, R71, R75, R86, R87	Resistor, Thick Film, 2k, 1%, 1/10W, SMD, 0603, AEC-Q200	Vishay/Dale	CRCW06032K00FKEA
4	R7, R8, R64, R65	Resistor, Thick Film, 2.2k, 5%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3GSYJ222V
9	R9, R27, R28, R29, R43, R44, R45, R53, R61	Resistor, Thick Film, 10k, 5%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3GEYJ103V
6	R10, R14, R17, R24, R31, R35	Resistor, Thick Film, 22R, 1%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3EKF22R0V
6	R12, R16, R19, R26, R33, R38	Resistor, Thick Film, 120k, 1%, 1/10W, SMD, 0603, AEC-Q200	Panasonic® - ECG	ERJ-3EKF1203V
3	R13, R21, R34	Resistor, Thick Film, 3.3R, 1%, 1/8W, SMD, 0805	Vishay/Dale	CRCW08053R30FKEA
18	R20, R54, R56, R67, R68, R69, R70, R72, R73, R74, R94, R96, R97, R98, R99, R100, R101, R113	Resistor, Thick Film, 0R 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3GEY0R00V, ERJ-3GSY0R00V

Table 4-1. Bill of Materials (BOM) (continued)

Qty	Reference	Description	Manufacturer	Part Number
4	R30, R58, R59, R60	Resistor, Thick Film, 120R, 1%, 1/10W, SMD, 0603	Stackpole Electronics Inc	RMCF0603FT120R
3	R39, R40, R42	Resistor, Thick Film, 47k, 1%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3EKF4702V
1	R46	Resistor, Thick Film, 1.2k, 1%, 1/10W, SMD, 0603	Stackpole Electronics Inc	RMCF0603FT1K20
1	R47	Resistor, Thick Film, 36k, 1%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3EKF3602V
1	R48	Resistor, Thick Film, 2.7k, 1%, 1/10W, SMD, 0603, AEC-Q200	Vishay/Dale	CRCW06032K70FKEA
1	R49	Resistor, Thick Film, 2.4k, 1%, 1/10W, SMD, 0603	Yageo Corporation	RC0603FR-072K4L
1	R51	Resistor, Thick Film, 100k, 5%, 1/10W, SMD, 0603 (Don't Use, Duplicate, Use RSMT0026)	Panasonic® - ECG	ERJ-3GEYJ104V
1	R52	Resistor, Thick Film, 31.6K, 1%, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3EKF3162V
2	R62, R63	Resistor, Thick Film, 49.9R, 1%, 1/10W, SMD, 0603, AEC-Q200	Vishay/Dale	CRCW060349R9FKEA
2	R76, R95	Resistor, Thick Film, 1k, 1%, 1/10W, SMD, 0603	Panasonic® - ECG, Vishay/ Dale	ERJ-3EKF1001V, CRCW06031K00FKEA
2	R77, R79	Resistor, Thick Film, 4.99k, 0.1%, 1/10W, SMD, 0603, AEC-Q200	Panasonic® - ECG	ERA-3AEB4991V
1	R78	Resistor, Thick Film, 20R 1%, 1/10W, SMD, 0603, AEC-Q200	Panasonic® - ECG	ERJ-3EKF20R0V
6	R80, R81, R82, R83, R84, R85	Resistor, Thick Film, 4.7R, 1%, 1/10W, SMD, 0603	Vishay/Dale	CRCW06034R70FNEA
3	RS1, RS2, RS3	Resistor, Shunt ME, 0.003R, 1%, 4W, AEC-Q200, SMD, 2512	Vishay/Dale	WSLF25123L000FEA
1	Rv1	Resistor, Variable, 10k, 20%, TH, P090S	BI Technologies/TT Electronics	P090S-14T20BR10K
4	ST1, ST2, ST3, SW1	Switch, TACT, SPST, 24V, 50 mA, KSR231GLFS, SMD, 6X3.5mm	TE Connectivity Alcoswitch Switches	147873-2
1	TH1	Resistor, Thermistor, 10k, 1%, SMD, 0603	TDK Corporation	NTCG163JF103FTDS
2	TP1, TP21	Connector, Test Point, TAB, Silver, Mini, 3.8x2.03, SMD	Keystone® Electronics Corp.	5019
4	TP41, TP-1, TP-2, TP-39	Connector, Test Point, TAB, Silver, Mini, 3.8x2.03, SMD	Keystone® Electronics Corp.	5019
1	PCB1	Printed Circuit Board	Microchip Technology Inc.	04-12768-R1
1	PCBA1	PCB Assembly	Microchip Technology Inc.	02-01785-R1

Table 4-2. Microchip Parts

Qty	Reference	Description	Manufacturer	Part Number
1	U1	Analog Motor Driver, UQFN-48, AEC-Q100	Microchip Technology Inc.	MCP8048T-5033H/ZWXVAO
1	U3	Analog Switcher Buck, 2 to 24V, SOT-23-6	Microchip Technology Inc.	MCP16331T-E/CH
1	U5	Interface, USB, I2C, UART, TSSOP-14	Microchip Technology Inc.	MCP2221-I/ST
1	U6	Analog OpAmp 1-Ch, 10 MHz, SOT-23-5	Microchip Technology Inc.	MCP6486RT-E/OT

Table 4-3. Mechanical Parts

Qty	Reference	Description	Manufacturer	Part Number
8	JS1, JS2, JS3, JS4, JS5, JS6, JS7, JS8	Mechanical Hardware Jumper, 2.54 mm, 1x2	FCI	63429-202LF
4	PAD1, PAD2, PAD3, PAD4	Mechanical Hardware Rubber Pad Cylindrical Flat Top D9.5 H4.8 Clear	Bumper Specialties Inc.	BS35CL01X02RP

Table 4-4. Do Not Populate

Qty	Reference	Description	Manufacturer	Part Number
0	C24, C25, C29	Capacitor, Ceramic, 820 pF, 50V, 10%, X7R, SMD, 0603	Murata Electronics®	GRM188R71H821KA01D
0	D9, D10, D11, D12, D13, D17	Diode, Schottky, 40V, 2A, SOD-123F	Fairchild/ON Semiconductor®	SS24FL
0	HS1	Mechanical Hardware Heatsink	Advanced Thermal Solutions Inc.	ATS-CPX050050025-124-C1-R0
0	J_X	Connector, HDR-2.54, Female, 2x10, Gold, TH, RT Angle	Sullins Connector Solutions	PPPC102LJBN-RC
0	Jp14	Connector, HDR-2.54, Male, 1x2, Tin, 6.75MH, TH, Vertical	Molex	0901200122
0	R11, R15, R18, R25, R32, R37	Resistor, Thick Film, 10R, 1%, 1/8W, SMD, 0805	ROHM Semiconductor	MCR10EZHF10R0
0	R22, R23, R55, R66	Resistor, Thick Film, 0R, 1/10W, SMD, 0603	Panasonic® - ECG	ERJ-3GSY0R00V

5. Software

5.1. Software Location

The application software can be downloaded from the MCP8048 web page located on the Microchip website at www.microchip.com.

More details related to the Motor Control algorithm in the Single-Shunt mode FOC can be found in **AN1299 – *"Single-Shunt Three-Phase Current Reconstruction Algorithm for Sensorless FOC of a PMSM"* (DS01299A).** In addition, a more detailed description of sensorless FOC MC, position and speed estimation, field weakening, and other motor control topics, can be found in **AN11078 – *"Sensorless Field Oriented Control of a PMSM"* (DS01078B).**

*The following sections highlight only the specific implementation details for this application using the **MCP8048** motor driver and a **dsPIC -CK** controller.*

5.2. Selected Firmware Constants and Definitions

The desired driver application parameters can be set in "MCP8048.h" file. Below are defined the driver registers and their specific properties.

```
//**** MCP8048 Application Limit Values settings **************************//
#define VRefDAC     3300    // [mV] or 5000[mV] //
#define CCPT_nS     700    // Cross conduction protection time= 0,100,..6300[nS]
#define EGBLTime_nS     750    // Edge blanking time, 250 (default)
#define AdTSWO_nS     250    // Ad Force time switch, 250 (default)
#define VGSUVFLT_nS     1250    // VGS under-voltage filter time=500..7500, 2000[nS] (default)
#define ILIMFLT_nS     1000    // Current limitation filter time=2000 (default)
#define MOS_OCL     1890    // MOSFET Overcurrent Limit=[0..VRefDAC] [mV]
#define SCThrVal_mV     250    // Short circuit detection threshold 125mV to 1750mV
#define SCFLT_nS     1000    // Short circuit filter time,2000 (default)
```

All required configuration functions are implemented in the "MCP8048.c" file and can be called in the main application function after the power-up sequence.

```
////////////////// Functions conversion prototype ////////////////////////////
inline uint8_t SetCCPTime( unsigned CCPTime );
inline uint8_t Set_VGSUVFLT( unsigned Time_nS );
inline uint8_t TimeConversion( unsigned Time_ns );
inline uint8_t SetSCThrVal( unsigned SCThrVal );
inline uint8_t SetCurrLim( long unsigned CurrThrVal );
inline uint8_t SetAd_TSWO( uint8_t Ad_TSWO_ns );
```

```
////////////////// Prepare registers content for writing //////////////////////
void ATA6847_Reg_Init(void);
```

```
///////////////// Write command, configures register content /////////////////
void MCP8048_Write_Reg( uint8_t reg_address,uint8_t reg_config );
```

```
///////////////// Read command, returns register content //////////////////////
uint8_t MCP8048_Read_Reg( uint8_t reg_address );
```

```
///////////////// Usefull functions ////////////////////////////////////////////
uint8_t    ATA6847_Init_Normal_Mode( void );
void    MCP8048_Init_Standby_Mode( void );
void    MCP8048_Reg_Write_Init_Regs( void );
void    MCP8048_Reg_Read_Init_Regs( void );
inline void ClearFaults( void );
inline void Fault_manage( void );
```

The implementation of the internal MCP8048 registers and bitwise definition can be found in the "MCP8048.h" file.

```
//***************************************************************************//
// MCP8048 registers bitwise definition
//***************************************************************************//

/////////////////////////////////////////////////////////////////////////////////
#define DOPMCR (0x01)//    // Device operation mode control register
////////////////////////////////////////////////////////////////////////////////
typedef union {
struct{
uint8_t DvOpMd :3;    // Select Device Operation Mode, Default=1
uint8_t    :3;    // Unused (read as 0)
uint8_t VdIOOVSD:1;    // Vdd
uint8_t RSTLVL :1;    // Under-voltage (UVDD1 < UVDD1_UV_Set)
};
BYTE CFG;
} tDOPMCR;

#define DOpM_DSleep 0b001    // Deep sleep mode
#define DOpM_Sleep 0b010    // Sleep mode
#define DOpM_St_By 0b100    // Standby mode (default)
#define DOpM_Normal 0b111    // Normal mode

//    76543210
#define DOpM_Sleep_or_DSleep_MASK    0b00000100
```

```
/////////////////////////////////////////////////////////////////////////////////
#define LOPMCR (0x02)    // LIN TRX operation mode control register
////////////////////////////////////////////////////////////////////////////////
typedef union {
struct {
uint8_t LOPM    :2; // Select LIN Transceiver operation modes
uint8_t    :6; // Unused (read as 0)
};
BYTE CFG;
} tLOPMCR;
#define LIN_St_By 0b01    // 2'b01     LIN Standby mode (default)
#define LIN_Normal 0b10    // 2'b10    LIN Normal mode
// Other    Invalid mode selection
```

```
/////////////////////////////////////////////////////////////////////////////////
#define GOPMCR (0x03)    // GDU operation mode control register
/////////////////////////////////////////////////////////////////////////////////
typedef union {
struct {
uint8_t GDUOPM    :3;    // Select GDU operation modes
uint8_t    :5;    // Unused (read as 0)
};
BYTE CFG;
} tGOPMCR;

#define    GDU_OFF    0b001    //    GDU    OFF mode    1 (default)
#define    GDU_St_By    0b100    //    GDU    Standby mode    4
#define    GDU_Normal    0b111    //    GDU    Normal mode    7
// Other Invalid mode selection
```

The configuration functions are called by the **MCP8048_Drv_Init()** function, as shown in following example.

```
//////////////// Registers content initialization /////////////////////////////
// In this function the registers are configured
// with application required configuration
/////////////////////////////////////////////////////////////////////////////////
void ATA6847_Reg_Init( void )    // Registers content initialization
{
/////////////////// WatchDog-disabling /////////////
ATA6847_REGS.REG_VAL.WDTRIG_CFG.WD_TRIG = 0x55;    //-- valid WWD trigger
ATA6847_REGS.REG_VAL.WDCR1_CFG.WDC    = WGD_OFF ; //-- keep WWD off // WGD_TOM (default) //
WGD_WOM
```

```
//////////// LIN TRX operation mode control ////////////
ATA6847_REGS.REG_VAL.LOPMCR_CFG.LOPM    = LIN_Normal; //LIN_St_By;// Operation mode

///////////// GDU operation mode control /////////////
ATA6847_REGS.REG_VAL.GOPMCR_CFG.GDUOPM    = GDU_OFF;//GDU_Normal;    // Operation mode

///////////// Wake-up control register /////////////////////////
ATA6847_REGS.REG_VAL.WUCR_CFG.LINWUE    = Active;//Inactive;// // Operation mode
ATA6847_REGS.REG_VAL.WUCR_CFG.LOCWUE    = Active;    // Operation mode

//////////// GDU control register 1, Back-EMF, Cross conduction filter time
ATA6847_REGS.REG_VAL.GDUCR1_CFG.BEMFEN    = Inactive;
ATA6847_REGS.REG_VAL.GDUCR1_CFG.CCEN    = Active; // cross-conduction timer and adaptive dead-
time
ATA6847_REGS.REG_VAL.GDUCR1_CFG.CCPT    = SetCCPTime( CCPT_nS ); // 100 {nS]

//////// Edge blanking time, Cross conduction time,/////////////
ATA6847_REGS.REG_VAL.GDUCR2_CFG.EGBLT    = TimeConversion( EGBLTime_nS );
ATA6847_REGS.REG_VAL.GDUCR2_CFG.TSWTO    = SetAd_TSWO( AdTSWO_nS );
ATA6847_REGS.REG_VAL.GDUCR2_CFG.LSOFF    = Active; //Inactive; // 0, LS=TrS or 1, LS=0 when
GDU= Standby
ATA6847_REGS.REG_VAL.GDUCR2_CFG.HSOFF    = Active; //Inactive; // 0, HS=TrS or 1, HS=0 when
GDU= Standby

////////// GDU Control Register 3, Adaptive dead-time, Slew rate
ATA6847_REGS.REG_VAL.GDUCR3_CFG.ADDTHS    = AdDT_Dis ; // Adaptive dead-time HS disabled;
ATA6847_REGS.REG_VAL.GDUCR3_CFG.ADDTLS    = AdDT_Dis ; // Adaptive dead-time LS disabled;
ATA6847_REGS.REG_VAL.GDUCR3_CFG.HSSRC    = FullS_50_0; //FullSpeed;//FullS_12_5;// Slew rate
HS
ATA6847_REGS.REG_VAL.GDUCR3_CFG.LSSRC    = FullSpeed;// FullS_25_0; //FullS_12_5;// Slew rate
LS

////////// GDU Control Register 4 //////////////////////////
UVVGSLVL ATA6847_REGS.REG_VAL.GDUCR4_CFG.VGSUVFLT = Set_VGSUVFLT( VGSUVFLT_nS );
ATA6847_REGS.REG_VAL.GDUCR4_CFG.UVVGSLVL = Active;    // VGS/VG under-voltage detection level
selection(default=1)
ATA6847_REGS.REG_VAL.GDUCR4_CFG.UVVGSSEN = Active;    // VGS under-voltage detection enable,
default=1)
ATA6847_REGS.REG_VAL.GDUCR4_CFG.VDHOVSD    = Active;
ATA6847_REGS.REG_VAL.GDUCR4_CFG.COMPEN    = Inactive; // Complementary control enable,
default=0 IL+IH

//////////// Current limitation control /////////////////////////
ATA6847_REGS.REG_VAL.ILIMCR_CFG.ILIMSDEN = Active ;
ATA6847_REGS.REG_VAL.ILIMCR_CFG.ILIMFLT    = TimeConversion( ILIMFLT_nS );
ATA6847_REGS.REG_VAL.ILIMCR_CFG.ILIMEN    = Inactive; //Active ;

///////// Current limitation threshold ////////////////////////
ATA6847_REGS.REG_VAL.ILIMTH_CFG.DAC    = SetCurrLim( MOS_OCL );

//////////// Short circuit protection ///////////////////////
ATA6847_REGS.REG_VAL.SCPCR_CFG.SCTHSEL    = SetSCThrVal( SCThrVal_mV );
ATA6847_REGS.REG_VAL.SCPCR_CFG.SCFLT    = TimeConversion( SCFLT_nS );
ATA6847_REGS.REG_VAL.SCPCR_CFG.SCSDEN    = Active ;//Inactive; // Short circuit shutdown
enable

/////////////// Current Sensing OpAmp control register ///////////
ATA6847_REGS.REG_VAL.CSCR_CFG.CSAxEN    = CSCR_ALL_CSAX_DISABLED;
ATA6847_REGS.REG_VAL.CSCR_CFG.GAIN    = Gain_16;    // Gain=8,16,32,64 0b01
ATA6847_REGS.REG_VAL.CSCR_CFG.OFFSET    = VRef_2 ;    // VRef/2/4/8/16, 0b11

////// System Interrupt Mask Register1, activates interrups /////
ATA6847_REGS.REG_VAL.SIECER1_CFG.OTPWM    = Active; // Over temperature pre-warning
ATA6847_REGS.REG_VAL.SIECER1_CFG.SPIFM    = Active; // SPI failure interrupt
ATA6847_REGS.REG_VAL.SIECER1_CFG.VSUVM    = Active; // VS UV failure interrupt mask (VVS<
VVS_UV_Set)
ATA6847_REGS.REG_VAL.SIECER1_CFG.ILIMM    = Active;    // Current limitation event
ATA6847_REGS.REG_VAL.SIECER1_CFG.VDHOVM    = Active;    // VDH OV failure interrupt
ATA6847_REGS.REG_VAL.SIECER1_CFG.GSCM    = Active;    //Inactive// General short circuit
failure

////// System Interrupt Mask Register2, activates interrupts /////
ATA6847_REGS.REG_VAL.SIECER2_CFG.VDD1OVM    = Active;    // VDD1 overvoltage event interrupt
ATA6847_REGS.REG_VAL.SIECER2_CFG.VDD2OVM    = Active;    // VDD2 over-voltage event interrupt
ATA6847_REGS.REG_VAL.SIECER2_CFG.VDD1UVLM    = Active;    // VDD1 IO under-voltage interrupt
(VVDD1< VVDD1_IO_UV_Set) event interrupt mask bit
ATA6847_REGS.REG_VAL.SIECER2_CFG.VDD1UVHM    = Active;    // VDD1 under-voltage interrupt
(VVDD1< VVDD1_UV_Set) event interrupt mask bit
```

```
ATA6847_REGS.REG_VAL.SIECER2_CFG.VDD2UVM    = Active;    // VDD2 under-voltage event interrupt

////// Init default register with default startup value //////////
ATA6847_REGS.REG_VAL.RWPCR_CFG.CFG = 0x00; ATA6847_REGS.REG_VAL.MLDCR_CFG.CFG = 0x00;

////////// Test Device operation mode control ////////
ATA6847_REGS.REG_VAL.DOPMCR_CFG.DvOpMd    = DOpM_Normal;//DOpM_St_By;// Operation mode
ATA6847_REGS.REG_VAL.DOPMCR_CFG.RSTLVL    = Active;//Inactive;
}
```

To write the parameters in the driver, a Write SPI function will be called:

```
///////////////// Write command, configures register content //////////////////
void ATA6847_Write_Reg( uint8_t reg_address, uint8_t reg_config )
{
SPI_Command SPI_WORD;
SPI_WORD.ADDERSS = reg_address;
SPI_WORD.W_R = Write;
SPI_WORD.Reg_Config = reg_config;
SPI1_Exchange16bit(SPI_WORD.SPI_Command);
}
```

To get a specific register content, a particular read function is implemented.

```
///////////////// Read command, returns register content //////////////////////
uint8_t ATA6847_Read_Reg( uint8_t reg_address )
{
SPI_Command SPI_WORD; SPI_WORD.ADDERSS    = reg_address;
SPI_WORD.W_R     = Read;
SPI_WORD.Reg_Config = 0x00;
SPI_WORD.Reg_Config = ( uint8_t )(SPI1_Exchange16bit(SPI_WORD.SPI_Command));
return SPI_WORD.Reg_Config;
}
```

5.3. BLDC User Parameters

```
/////***************** HURST Big************************//
#ifdef    HURST_Big
#define    NOMINALSPEEDINRPM 3150
#define    MINSPEEDINRPM    550 // 500
#define    INITIALTORQUE    1.5    // Initial torque current
#define    POLEPAIRS    5        // Number of pole pairs
#define    PHASERES    ((float)0.35)        // Phase resistance in Ohms.
#define    PHASEIND    ((float)0.00033) // Phase inductance in Henrys
#define    FILTERDELAY    90        // 90-(1...7) advance
//*** Velocity Control Loop Coefficients *****
#define    WKP    Q15(0.11751)//Q15(0.3657)//
#define    WKI    Q15(0.01025)//Q15(0.0285)//
```

```
////////////////////////////////////////////////////
//******** Q Control Loop Coefficients *******
#define    QKP    Q15(0.09275)    //Q15(0.0975)//
#define    QKI    Q15(0.00725)    //Q15(0.0095)//
#define    QKC    Q15(0.995)
#define    QOUTMAX    Q15(0.725)
//******** D Control Loop Coefficients *******
#define    DKP    QKP
#define    DKI    QKI
#define    DKC    QKC
#define    DOUTMAX    QOUTMAX
#define    SMCGAIN    0.525
#define    MAXLINEARSMC    0.475    //
#endif
```

5.4. dsPIC33CK256MP205 Port Usage

5.4.1. Port Mapping

Onboard Buttons:

```
#define On_Off_Set_Input()    (_TRISD11 = 1)
#define On_Off_GetValue()    (_RD11)
```

```
#define On_Off      !(_RD11)     //SW1 - BTN_1
#define SPB_Set_Input()     (_TRISE10 = 1)
#define SPB_GetValue()     (_RE10)
#define SPB     !(_RE10)     //SW2 - BTN_2
```

BEMFs / Hallsensors:

```
// Halls or BEMF inputs
#define BMF_A_SetDigitalInput()  (_TRISC6 = 1)
#define BMF_B_SetDigitalInput()  (_TRISC7 = 1)
#define BMF_C_SetDigitalInput()  (_TRISD10 = 1)

#define HallA_SetDigitalInput()  (_TRISD5 = 1)
#define HallB_SetDigitalInput()  (_TRISD6 = 1)
#define HallC_SetDigitalInput()  (_TRISD7 = 1)

#define HallA_GetValue()     _RD5
#define HallB_GetValue()     _RD6
#define HallC_GetValue()     _RD7
```

5.4.2. A/D Mappings

```
/*****************************************************************************
* Setting the Analog/Digital Configuration SFR(s)
****************************************************************************/
ANSELA = 0x0013;
ANSELB = 0x009F;
ANSELC = 0x0048;
ANSELD = 0x0400;
ANSELE = 0x000F;

I_Bus_SetAnalogInput();// (_ANSELA0 = 1)
I_B_SetAnalogInput() ;// (_ANSELA4 = 1)
I_A_SetAnalogInput() ;// (_ANSELB2 = 1)
V_Bus_SetAnalogInput();// (_ANSELC3 = 1)
SpRef_SetAnalogInput();// (_ANSELC6 = 1)
// TempS_SetAnalogInput();// (_ANSELC6 = 1)

HallA_SetDigitalInput();
HallB_SetDigitalInput();
HallC_SetDigitalInput();
```

5.4.3. Communications Mappings

```
/////// SPI selection pin -> ATA6847L ///////////////////
#define nCS_SetOutput()     (_TRISD2 = 0)
#define nCS     _LATD2
#define nCS_Enable()     nCS = 0
#define nCS_Disable()     nCS = 1
#define SCK_Set_Output()     (_TRISD12 = 0)
#define MISO_Set_Input()     (_TRISC4 = 1)
#define MOSI_Set_Output()     (_TRISC5 = 0)

////// UART1 pin selection -> ATA6847L LIN UART /////////
#define RX_Set_Input()     _TRISC8 = 1 //EvBComb
#define TX_Set_Output()     _TRISC9 = 0
```

5.4.4. Used Peripherals Mappings

```
/*********************************************************
* Set the PPS for used peripherals
********************************************************/
_builtin_write_RPCON( 0x0000 );     // unlock PPS
RPINR20bits.SCK1R = 0x004C;         // RD12->SPI1:SCK1OUT
RPOR22bits.RP76R = 0x0006;     // RD12->SPI1:SCK1OUT
RPOR10bits.RP53R = 0x0005;     // RC5->SPI1:SDO1
RPINR20bits.SDI1R = 0x0034;         // RC4->SPI1:SDI1
RPINR19bits.U2RXR = 0x004D;     // RD13->UART2:U2RX
RPOR23bits.RP78R = 0x0003;     // RD14->UART2:U2TX
_builtin_write_RPCON( 0x0800 );     // lock PPS
```

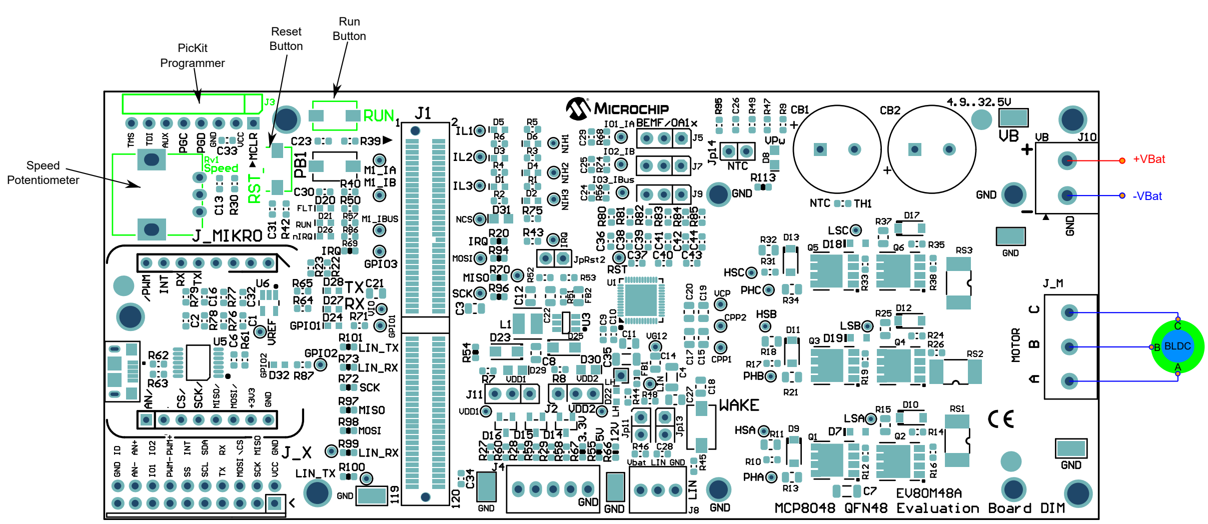
5.5. MPLAB X COMPILER STARTUP

1. Start up the MPLAB® X compiler (not supplied, available on the Microchip web site).
2. From the toolbar, select *File>Open Project*.
3. Browse to the evaluation board source code path.
4. Select the existing project file, named **MCP8048_RD.X**
5. In the Projects window, right-click on `MCP8048_RD.X` and select Properties. The page contains the project properties. Processor, Compiler, Hardware and Config settings may be changed here. **Note:** The user may need to modify the paths to the source files and linker files for PID controller implementation, based upon their locations on the host computer. Be sure to verify the Libraries contain the correct path to `libdsp-elf.a`
6. Right-click on **MCP8048_RD.X** again and select "Make and Program Device." This will compile the firmware and download it to the programming hardware.
7. The compiler results will be displayed in the Output window frame. Verify success.

5.6. MPLAB® X IDE and PICkit™ 4/5 Exercise

1. Start up the MPLAB® X (not supplied, available on the Microchip web site).
2. From the toolbar, select *File>Open Project*.
3. Browse to the evaluation board source code path.
4. Select the existing workspace directory, named `MCP8048_RD.X`, or create a new one.
5. Align Pin 1 of the header with the Pin 1 mark on the programmer Connect the PICkit™.
6. Set the bench power supply voltage control to minimum voltage output.
7. Turn on the power supply and set the output voltage to 13-14V. Turn off the power supply.
8. Connect the bench power supply to the board as in next figure

Figure 5-1. External Connections



9. Turn on the power supply.
10. Right-click on `MCP8048_RD.X` in the *Projects* window and select "Make and Program Device." This will compile the firmware and program the dsPIC33CK256MP205 processor.
11. The compiler results will be displayed in the Output window frame. Verify success.
12. Connect a Brushless DC (BLDC) motor to the board motor connections. Connect the motor phase wires to the PhA PhB, and PhC as in Figure 5-1.

13. Momentarily press the RESET switch on the board. This step is required to reset the dsPIC MCU device after programming.
14. Turn the SPEED adjustment fully counterclockwise. This sets the motor to the slowest speed.
15. Momentarily press the RUN switch to start the motor.
16. Momentarily press the RUN switch again to stop the motor.
17. Momentarily press the RUN switch again to start the motor.
18. Turn the SPEED adjustment clockwise. The motor speed should increase.
19. The used may probe the different test points on the board to see the various signals being generated. The LSA, HSA, LSB, HSB, LSC, HSC test points will show the external MOSFET gate drive signals.
20. Stop the motor by pressing RUN again.

5.7. MPLAB® X DMCI Window Exercise

For debugging purposes in MPLAB® X IDE, a plug-in tool is available.

As provided, the board implements a single-shunt FOC motor control algorithm and has been tested on two motor types: ANAHEIM BLY343S-30V-3000 440/W and HURST DMA0204024B101 /24V/3.4A.

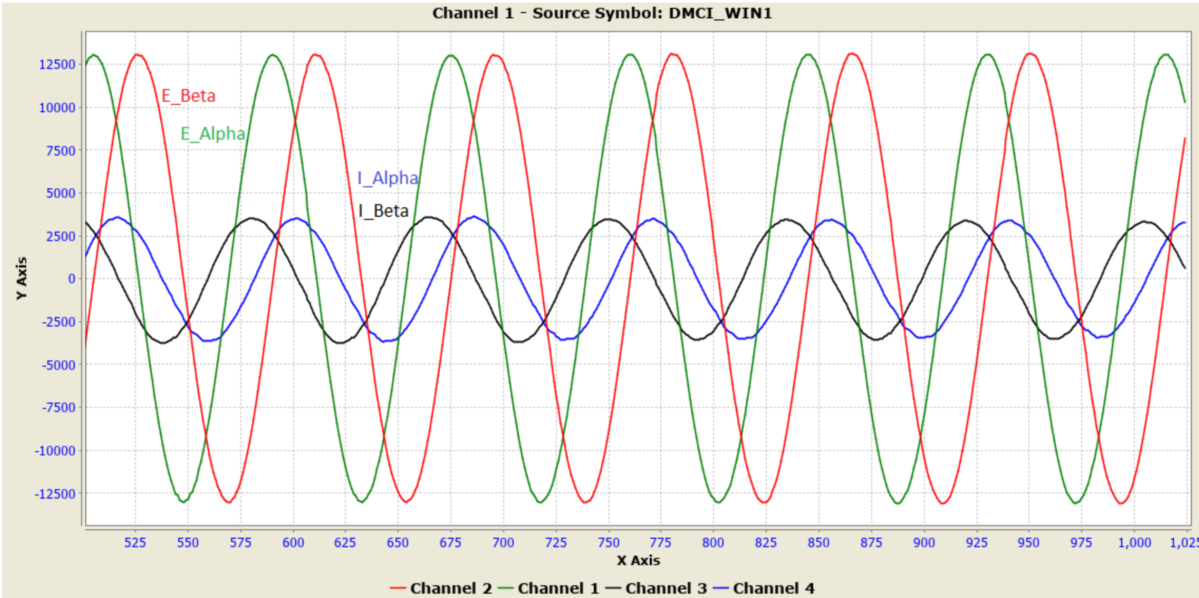
The motors were controlled in normal and field-weakening modes. Several images based on DMCI window are presented below.

1. In the opened project, open the **MCP8048.h** header file and find the line where the processor directive `#undef DMCI_WIN`, which undefines the DCMI window. Comment this line.
2. In the **MCP8048_RD.c** file, the sections related to DMCI will become active.
3. Find the section where the desired variables are assigned to the DMCI-declared vectors. For example, the figure shows the wanted variables:

```
#ifdef DMCI_WIN     // For test pourposes
    DMCI_WIN1[indx]= SMO_est.Ialpha;//SVG_PWM.PWM_DC_A;//SMO_est.Theta;
    DMCI_WIN2[indx]= SMO_est.Ibeta;//SVG_PWM.PWM_DC_B;//AngleEst.CurrTheta;
    DMCI_WIN3[indx]= OMEGA_RPM; //SVG_PWM.PWM_DC_C;//I_dq.d;//
    DMCI_WIN4[indx]= AngleEst.CurrTheta ;//I_dq.q; //
    indx++;
    if(!(indx<WIN_DIM))
    {indx=0;}
#endif
```

4. The PICkit™ 3/4 should be attached at the J1 evaluation board connector.
5. From the toolbar, select *Debug->Debug Project*. Wait for compilation and debug launching and running.
6. After successful project compilation and board programming, press the RUN button and increase the speed at around 80% of full scale. Stop the motor by pressing again the RUN button.
7. Stop debugging by pressing Pause icon or <Ctrl+Alt+8>.
8. From the toolbar, select *Tools->Embedded->DCMI-> DCMI Window.*
9. In the *Dynamic Data View* right-click on each Data Source window and assign one of **DMCI_WIN1[]** to **DMCI_WIN4 []** vector for each of Data Source windows. In each Data source window will appear the evolution of the assigned variable. By merging the Data Source windows, all data can be displayed on the same or two graphs.

Figure 5-2. DMCI Window



10. Notice that, after closing the debugging session, the board must be reprogrammed in the normal way as, with the #undef DMCI_WIN line uncommented described above, in the MPLAB® X IDE and PICkit™ 4/5 Exercise section, in the desired motor control mode.

6. References

Table 6-1. Recommended Reading

Source	Document Title	Literature Number	Available
Microchip Technology, Inc.	MCP8048/MCP8049 Data Sheet	.....	www.microchip.com/en-us/product/MCP8048
Microchip Technology, Inc.	dsPIC33CK256MP508 Data Sheet	DS70005349K	www.microchip.com/en-us/product/dspic33ck256mp508
Microchip Technology, Inc.	Sensorless Field Oriented Control of a PMSM using a Sliding Mode Observer (SMO)	AN1078	www.microchip.com/en-us/application-notes/an1078
Microchip Technology, Inc.	Sensorless BLDC Control with Back-EMF Filtering Using a Majority Function	AN1160	www.microchip.com/en-us/application-notes/an1160
Microchip Technology, Inc.	Sensorless BLDC Motor Control Using dsPIC30F2010	AN992	www.microchip.com/en-us/application-notes/an992
Microchip Technology, Inc.	Sensorless Field Oriented Control (FOC) for a Permanent Magnet Synchronous Motor (PMSM) Using a PLL Estimator and Field Weakening (FW)	AN1292	www.microchip.com/en-us/application-notes/an1292
Microchip Technology, Inc.	Using the dsPIC30F for Sensorless BLDC Control	AN901	www.microchip.com/en-us/application-notes/an901

7. Revision History

Doc. Rev.	Date	Comments
A	7/2026	Initial release of this document.

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