MEMCEVMBUM/D

Motorola Embedded Motion Control

Evaluation Motor Board

User's Manual

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Section 1. Introduction and Setup

1.1 Contents

1.2 EVM Motor Introduction

Motorola's evaluation motor board (EVM motor board) is a 12-volt, 4-amp power stage that is an integral part of Motorola's embedded motion control series of development tools. It is supplied in kit number ECMTREVAL, along with a small brushless dc motor, an encoder, an encoder cable, a 40-pin ribbon cable, and mounting hardware. In combination with one of the embedded motion control series control or evaluation boards, it provides a ready-made software development platform for small brushless dc motors. The motor is capable of being controlled with either Hall sensors, an optical encoder, or with sensorless techniques. An illustration of the systems' configurations is shown in **Figure 1-1**. **Figure 1-2** is an illustration of the board.

1.3 About this Manual

Key items can be found in the following locations in this manual:

- Setup instructions are found in **1.5 Setup Guide**.
- Schematics are found in **4.3 Schematics**.
- Pin assignments are shown in **Figure 3-1. 40-Pin Input Connector J1**, and a pin-by-pin description is contained in **3.3 Signal Descriptions**.
- For those interested in the reference design aspects of the board's circuitry, a description is provided in **Section 5. Design Considerations**.

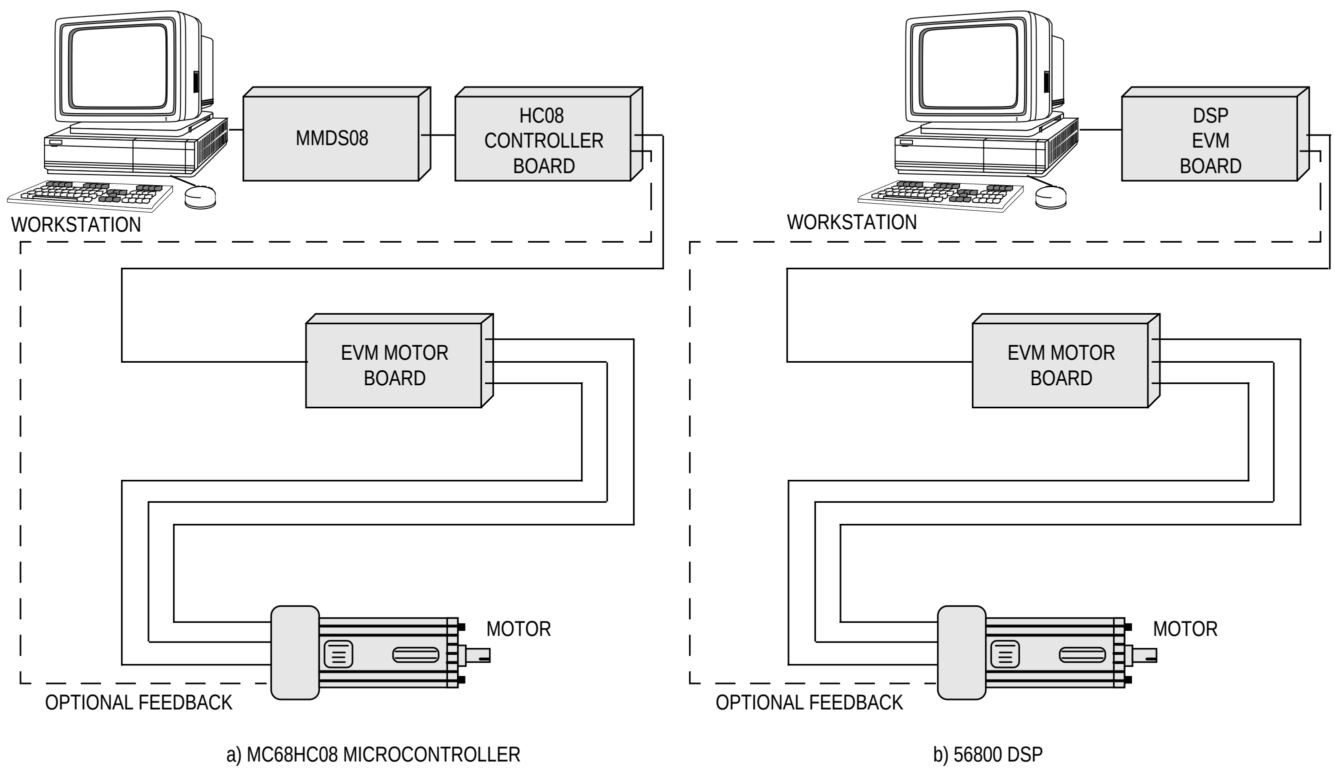


Figure 1-1. Systems' Configurations

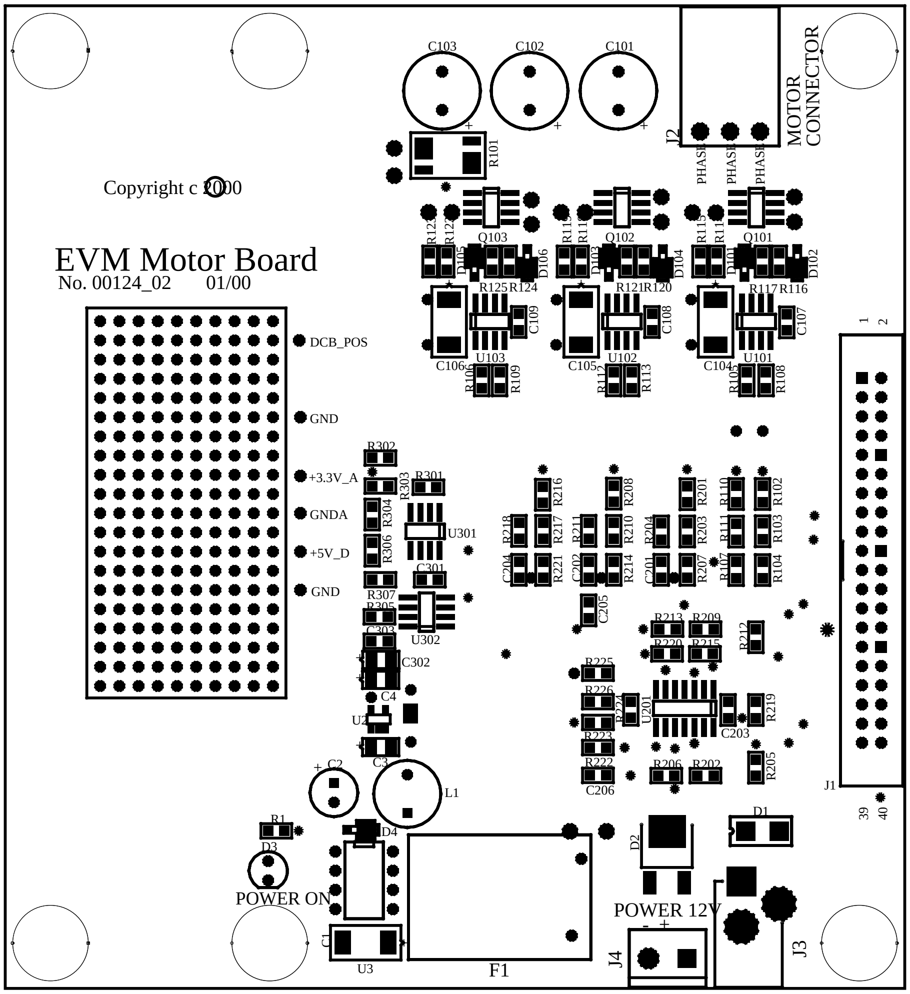


Figure 1-2. EVM Motor Board

1.4 Warnings

The EVM motor board kit includes a rotating machine and power transistors. Both can reach temperatures hot enough to cause burns. To facilitate safe operation, 12-volt input power should come from a dc laboratory power supply that is current limited to no more than 6 amps.

The user should be aware that:

- Before moving scope probes, making connections, etc., it is generally advisable to power down the 12-volt supply.
- Operation in lab setups that have grounded tables and/or chairs should be avoided.
- Wearing safety glasses, avoiding ties and jewelry, using shields, and operation by personnel trained in power electronics lab techniques are also advisable.

1.5 Setup Guide

Setup and connections for the EVM motor board are straightforward. The EVM motor board connects to a Motorola embedded motion control series control board via a 40-pin ribbon cable. The motor's power leads plug into output connector J2, and its Hall sensors plug into the control board's Hall sensor/encoder input connector. **Figure 1-3** depicts a completed setup.

Follow these steps to set up the board:

1. Mount four standoffs to the EVM motor board at the locations indicated in **Figure 1-3**. Standoffs, screws, and washers are included in the kit. This step and step 3 are optional when making connections with DSP control boards such as the DSP56F805EVM. The DSP boards may be placed flat on a bench, next to the EVM motor board.
2. Plug one end of the 40-pin ribbon cable that is supplied with Motorola embedded motion control series control boards into input connector J1, located on the right-hand side of the board. The other end of this cable goes to the control board's 40-pin output connector.
3. Mount the control board on top of the standoffs with screws and washers from the ECMTREVAL kit. This step is optional with DSP control boards.
4. Plug the free end of the cable connected to input connector J1 into the control board's 40-pin connector.
5. Connect a 12-Vdc power supply either to connector J3, labeled "Power 12V," or power jack J4. Either one, but not both, may be used. These connectors are located on the front right-hand corner of the board. The 12-volt power supply should be rated for at least 4 amps and have its current limit set between 4 and 6 amps.
6. If protection features are desired, set the control board's overcurrent detection comparator to 2.8 V and its undervoltage detection comparator to 1.24 V. These values limit dc bus current to 2.8 amps and turn off drive signals if bus voltage falls below 6 volts.
7. Apply power to the EVM motor board. The green power-on LED lights when power is present. Note that the EVM motor board powers the control board, making only one power supply necessary to run a complete system.

CAUTION: ***Since the control board is powered by the EVM motor board, it is imperative that only one power supply is used.***

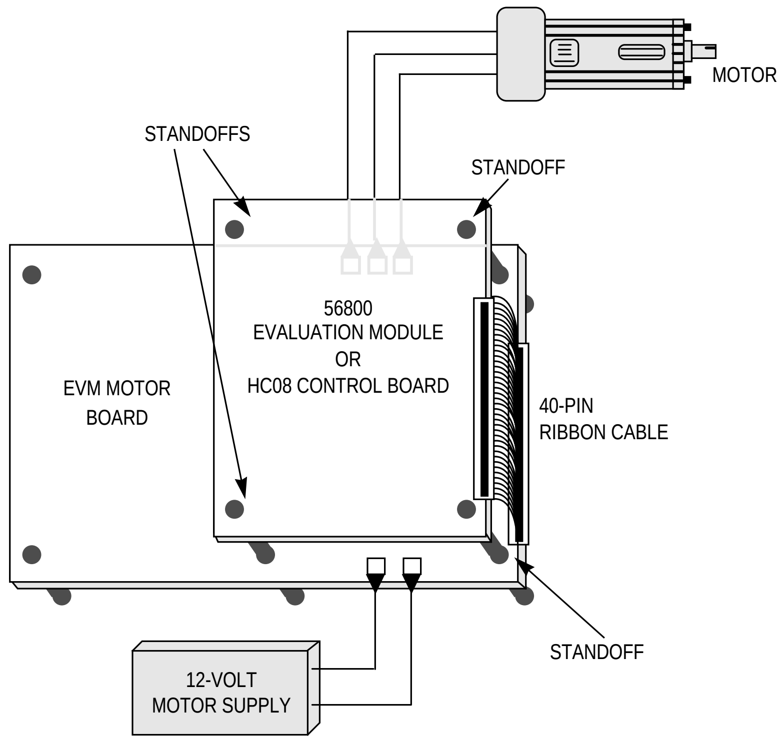


Figure 1-3. EVM Motor Board Setup

Section 2. Operational Description

2.1 Contents

2.2 Introduction

Motorola's embedded motion control series EVM motor board is a 12-volt, 4-amp, surface-mount power stage that is shipped with an MCG IB23810-H1 brushless dc motor. In combination with one of the embedded motion control series control boards, it provides a software development platform that allows algorithms to be written and tested without the need to design and build a power stage. It supports algorithms that use Hall sensors, encoder feedback, and back EMF (electromotive force) signals for sensorless control.

The EVM motor board does not have overcurrent protection that is independent of the control board, so some care in its setup and use is required if a lower impedance motor is used. With the motor that is supplied in the kit, the power output stage will withstand a full-stall condition without the need for overcurrent protection. Current measuring circuitry is set up for 4 amps full scale. In a 25^{O}C ambient operation at up to 6 amps continuous RMS output current is within the board's thermal limits.

Input connections are made via 40-pin ribbon cable connector J1. Pin assignments for the input connector are shown in **Figure 3-1. 40-Pin Input Connector J1**. Power connections to the motor are made on output connector J2. Phase A, phase B, and phase C are labeled on the board. Power requirements are met with a single external 12-Vdc, 4-amp power supply. Two connectors, labeled J3 and J4, are provided for the 12-volt power supply. J3 and J4 are located on the front edge of the board. Power is supplied to one or the other, but not both.

A summary of the information needed to use the EVM motor board follows. For design information, see **Section 5. Design Considerations**.

2.3 Electrical Characteristics

The electrical characteristics in **Table 2-1** apply to operation at 25°C and a 12-Vdc power supply voltage.

Table 2-1. Electrical Characteristics

Characteristic	Symbol	Min	Typ	Max	Units
Power Supply Voltage	Vdc	10	12	16	V
Quiescent Current	I_{CC}	—	50	—	mA
Min Logic 1 Input Voltage	V_{IH}	2.4	—	—	V
Max Logic 0 Input Voltage	V_{IL}	—	—	0.8	V
Input Resistance	R_{In}	—	10	—	kΩ
Analog Output Range	V_{Out}	0	—	3.3	V
Bus Current Sense Voltage	I_{Sense}	—	412	—	mV/A
Bus Voltage Sense Voltage	V_{Bus}	—	206	—	mV/V
Power MOSFET On Resistance	$R_{DS(On)}$	—	32	40	MΩ
RMS Output Current	I_M	—	—	6	A
Total Power Dissipation	P_{diss}	—	—	5	W

2.4 Motor Characteristics

The motor characteristics in **Table 2-2** apply to operation at 25°C.

Table 2-2. Motor Characteristics

Characteristic	Symbol	Min	Typ	Max	Units
Terminal Voltage	V_t	—	—	60	V
Speed @ V_t		—	5000	—	RPM
Torque Constant	K_t	—	0.08	—	Nm/A
Voltage Constant	K_e	—	8.4	—	V/kRPM
Winding Resistance	R_t	—	2.8	—	Ω
Winding Inductance	L	—	8.6	—	mH
Continuous Current	I_{cs}	—	—	2	A
Peak Current	I_{ps}	—	—	5.9	A
Inertia	J_m	—	0.075	—	$kgcm^2$
Thermal Resistance		—	—	3.6	°C/W

Section 3. Pin Descriptions

3.1 Contents

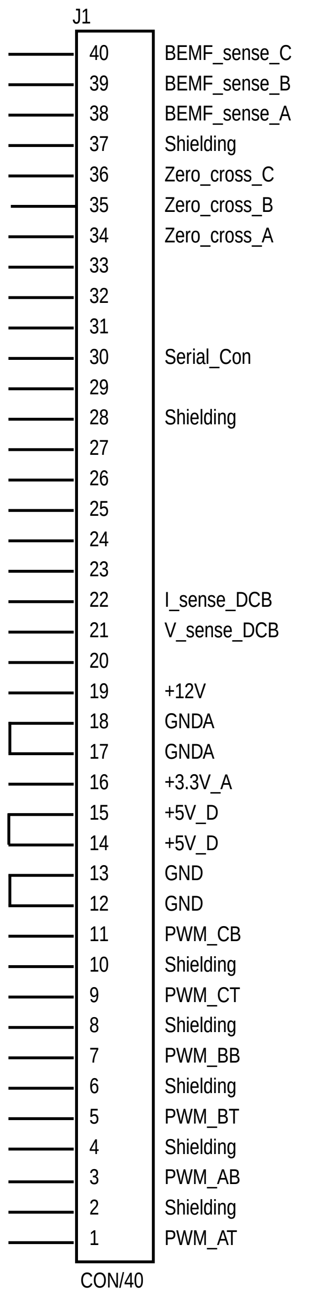
3.2 Introduction

Inputs and outputs are located on eight connectors:

- Three connectors are located on the board.
- Three connectors are associated with the motor.
- Two connectors are attached to a cable for the encoder.

In addition, six test points are located on the right-hand side of the EVM motor board's breadboard area.

Pin descriptions for each of these connectors and the test points are identified in the following information. Pin assignments for the input and output connectors are shown in **Figure 3-1**. Signal descriptions are provided in **Table 3-1** through **Table 3-5**.



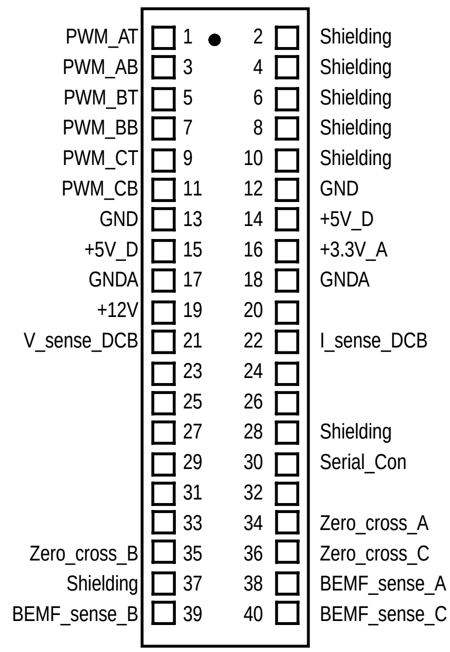


Figure 3-1. 40-Pin Input Connector J1

3.3 Signal Descriptions

Pin descriptions are identified in this subsection.

3.3.1 EVM Motor Board Power Connectors J3 and J4

Two connectors, labeled J3 and J4, are provided for the 12-volt power supply. J3 and J4 are located on the bottom right-hand corner of the board. Connector J3 is a 2.1-mm power jack for plug-in type 12-volt power supply connections. Connector J4 has screw terminal inputs labeled + (plus) and – (minus), for accepting wire inputs. Power is supplied to one or the other, but not both. The power supply should be able to deliver at least 3.5 amps. For power supplies that can supply larger currents, 4 amps is the default current limit setting.

3.3.2 EVM Motor Board 40-Pin Ribbon Connector J1

Signal inputs are grouped together on 40-pin ribbon cable connector J1, located on the right side of the board. Pin assignments are shown in **Figure 3-1**. Pin descriptions are listed in **Table 3-1**.

Table 3-1. Connector J1 Signal Descriptions (Sheet 1 of 3)

Pin No.	Signal Name	Description
1	PWM_AT	PWM_AT is the gate drive signal for the top half-bridge of phase A. A logic high at input connector J1 turns on the phase A top switch.
2	Shielding	Pin 2 is connected to a shield wire in the ribbon cable, and ground on the board.
3	PWM_AB	PWM_AB is the gate drive signal for the bottom half-bridge of phase A. A logic high at input connector J1 turns on the phase A bottom switch.
4	Shielding	Pin 4 is connected to a shield wire in the ribbon cable, and ground on the board.
5	PWM_BT	PWM_BT is the gate drive signal for the top half-bridge of phase B. A logic high at input connector J1 turns on the phase B top switch.
6	Shielding	Pin 6 is connected to a shield wire in the ribbon cable, and ground on the board.
7	PWM_BB	PWM_BB is the gate drive signal for the bottom half-bridge of phase B. A logic high at input connector J1 turns on the phase B bottom switch.
8	Shielding	Pin 8 is connected to a shield wire in the ribbon cable, and ground on the board.

Table 3-1. Connector J1 Signal Descriptions (Sheet 2 of 3)

Pin No.	Signal Name	Description
9	PWM_CT	PWM_CT is the gate drive signal for the top half-bridge of phase C. A logic high at input connector J1 turns on the phase C top switch.
10	Shielding	Pin 10 is connected to a shield wire in the ribbon cable, and ground on the board.
11	PWM_CB	PWM_CB is the gate drive signal for the bottom half-bridge of phase C. A logic high at input connector J1 turns on the phase C bottom switch.
12	GND	Digital power supply ground
13	GND	Digital power supply ground, redundant connection
14	+5V_D	Digital +5-volt power supply
15	+5V_D	Digital +5-volt power supply, redundant connection
16	+3.3V_A	Analog +3.3-volt power supply
17	GNDA	Analog power supply ground
18	GNDA	Analog power supply ground, redundant connection
19	+12V	+12-volt power supply
20	—	No connection
21	V_sense_DCB	V_sense_DCB is an analog sense signal that measures dc bus voltage. It is scaled at 0.206 volts per volt of dc bus voltage.
22	I_sense_DCB	I_sense_DCB is an analog sense signal that measures dc bus current. It is scaled at 0.412 volts per amp of dc bus current.
23	—	No connection
24	—	No connection
25	—	No connection
26	—	No connection
27	—	No connection
28	Shielding	Pin 28 is connected to a shield wire in the ribbon cable, and ground on the board.
29	—	No connection
30	Serial_Con	Serial_Con is an identification signal that lets the controller know which power stage is present. It is nominally a 600-Hz square wave.
31	—	No connection
32	—	No connection
33	—	No connection

Table 3-1. Connector J1 Signal Descriptions (Sheet 3 of 3)

Pin No.	Signal Name	Description
34	Zero_cross_A	Zero_cross_A is a digital signal that is used for sensing phase A back-EMF zero crossing events.
35	Zero_cross_B	Zero_cross_B is a digital signal that is used for sensing phase B back-EMF zero crossing events.
36	Zero_cross_C	Zero_cross_C is a digital signal that is used for sensing phase C back-EMF zero crossing events.
37	Shielding	Pin 37 is connected to a shield wire in the ribbon cable, and ground on the board.
38	BEMF_sense_A	BEMF_sense_A is an analog sense signal that measures phase A back EMF. It is scaled at 0.206 volts per volt of dc bus voltage.
39	BEMF_sense_B	BEMF_sense_B is an analog sense signal that measures phase B back EMF. It is scaled at 0.206 volts per volt of dc bus voltage.
40	BEMF_sense_C	BEMF_sense_A is an analog sense signal that measures phase C back EMF. It is scaled at 0.206 volts per volt of dc bus voltage.

3.3.3 EVM Motor Board Output Connector J2

Power outputs to the motor are located on connector J2, labeled “Motor Connector.” Pin assignments are described in **Table 3-2**.

Table 3-2. Connector J2 Signal Descriptions

Pin No.	Signal Name	Description
1	Phase_A	Phase_A supplies power to motor phase A. The motor wire color is white/red.
2	Phase_B	Phase_B supplies power to motor phase B. The motor wire color is white/yellow.
3	Phase_C	Phase_C supplies power to motor phase C. The motor wire color is white/black.

3.3.4 Motor Power Connector

Motor power connections are grouped into a connector that plugs into the EVM motor board’s motor connector, J2. Pin assignments are identical to EVM motor board output connector J2.

3.3.5 Motor Hall Sensor Connector

Hall sensor connections are made with a connector that plugs into the control board’s Hall sensor/encoder connector. Pin assignments are described in **Table 3-3**.

Table 3-3. Motor Hall Sensor Connector

Pin No.	Signal Name	Description
1	+5V	+5V supplies power from the control board to the Hall sensors. The wire color is red.
2	GND	GND is the Hall sensor ground. The wire color is black.
3	Hall A	Hall A is an open collector output from Hall sensor A. The wire color is green.
4	Hall B	Hall B is an open collector output from Hall sensor B. The wire color is white.
5	Hall C	Hall C is an open collector output from Hall sensor C. The wire color is blue.

3.3.6 Motor Encoder Connector

The encoder connector has five pins. Pin 1 orientation is shown in **Figure 4-6. Encoder Connector — Physical View**. Pin assignments are described in **Table 3-4**.

Table 3-4. Motor Encoder Connector

Pin No.	Signal Name	Description
1	GND	Pin 1 is the encoder's ground.
2	Index	Pin 2 is the index output.
3	Channel A	Pin 3 is the channel A output.
4	+5V	Pin 4 supplies +5 volts from the control board to the encoder.
5	Channel B	Pin 5 is the channel B output.

3.3.7 Motor Encoder Cable Connectors

The encoder cable has two connectors, one at each end. They assume the pin assignments of their respective mating connectors, one on the EVM motor board and the other on the control board.

3.3.8 Test Points

Six test points provide easy access to power supply and ground voltages. They are listed in **Table 3-5** as they appear from top to bottom on the board.

Table 3-5. Test Points

Pin No.	Signal Name	Description
1	DCB_POS	Test point DCB_POS is connected to the +12-volt motor bus.
2	GND	Test point GND is connected to the 12-volt power supply and motor bus ground.
3	+3.3V_A	Test point +3.3V_A is connected to the 3.3-volt analog power supply voltage.
4	GNDA	Test point GNDA is connected to analog ground.
5	+5V_D	Test point +5V_D is connected to the 5-volt digital power supply voltage.
6	GND	Test point GND is an additional connection to the 12-volt power supply and motor bus ground.

Section 4. Schematics and Parts List

4.1 Contents

4.2 Overview

A set of schematics for the EVM motor board appears in **Figure 4-1** through **Figure 4-5**. An overview of the whole board is shown in **Figure 4-1**. The 3-phase H-bridge, including gate drivers, appears in **Figure 4-2**. Bus current feedback is shown in **Figure 4-3**. Back EMF signals appear in **Figure 4-4**. The brushless dc motor is shown in **Figure 4-5**.

Unless otherwise specified, resistor values are in ohms, resistors are specified as 1/8 watt ±5%, and interrupted lines coded with the same letters are electrically connected.

4.3 Schematics

The schematics for the evaluation motor board appear on the following pages.

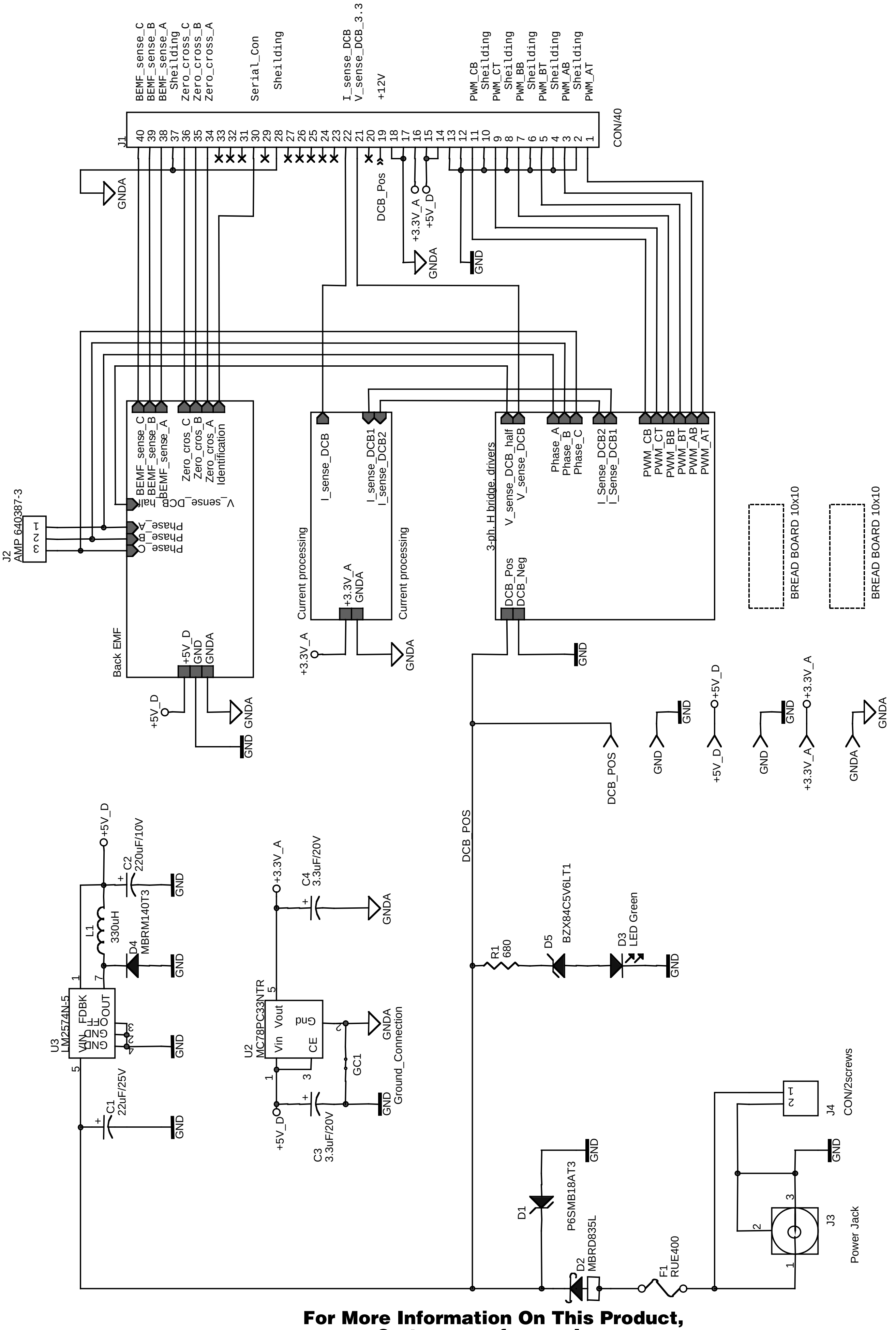


Figure 4-1. Motor Evaluation Module Overview

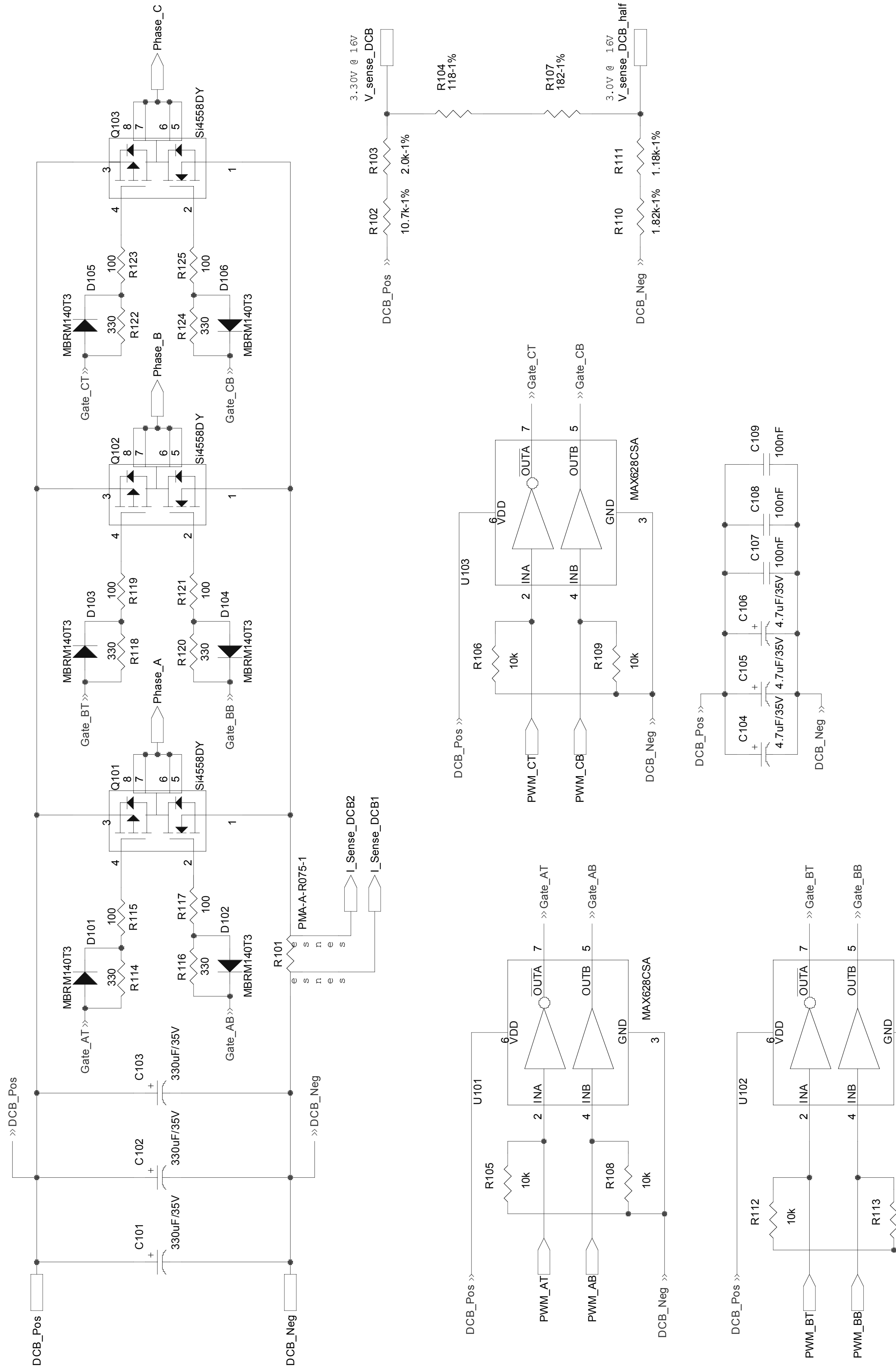


Figure 4-2. 3 Phase H-Bridge

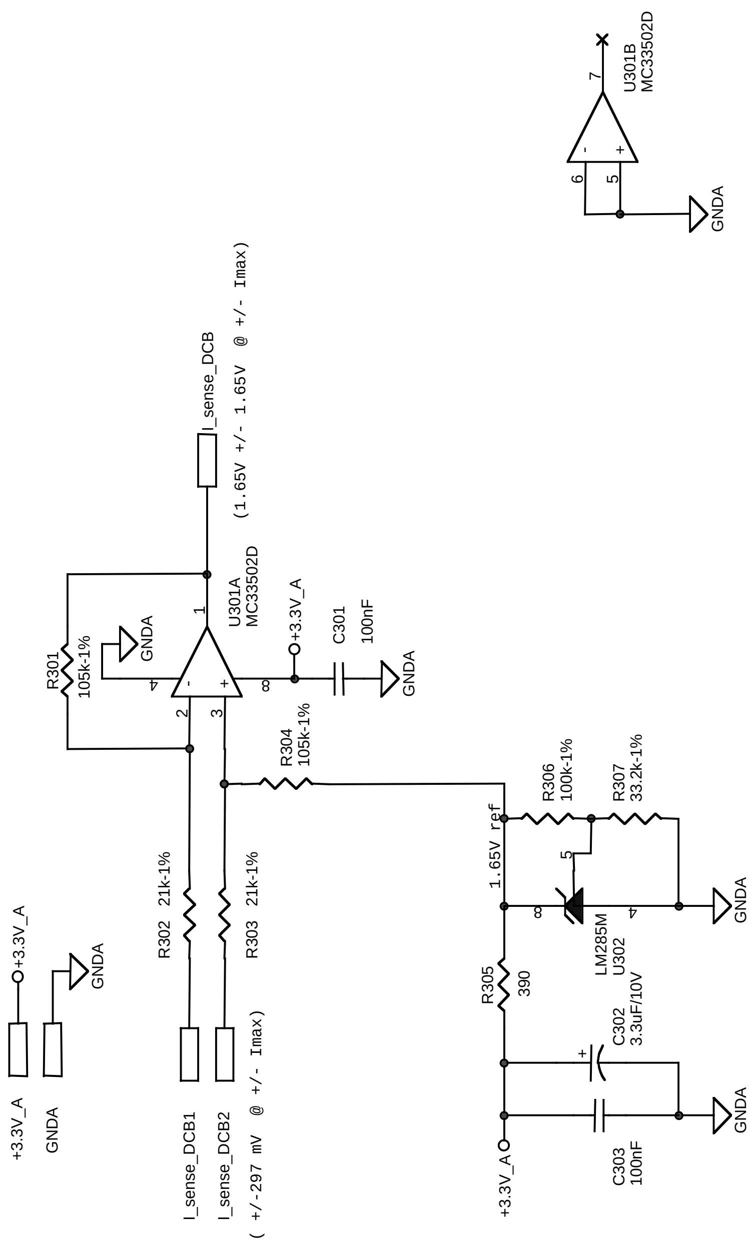


Figure 4-3. Bus Current Feedback

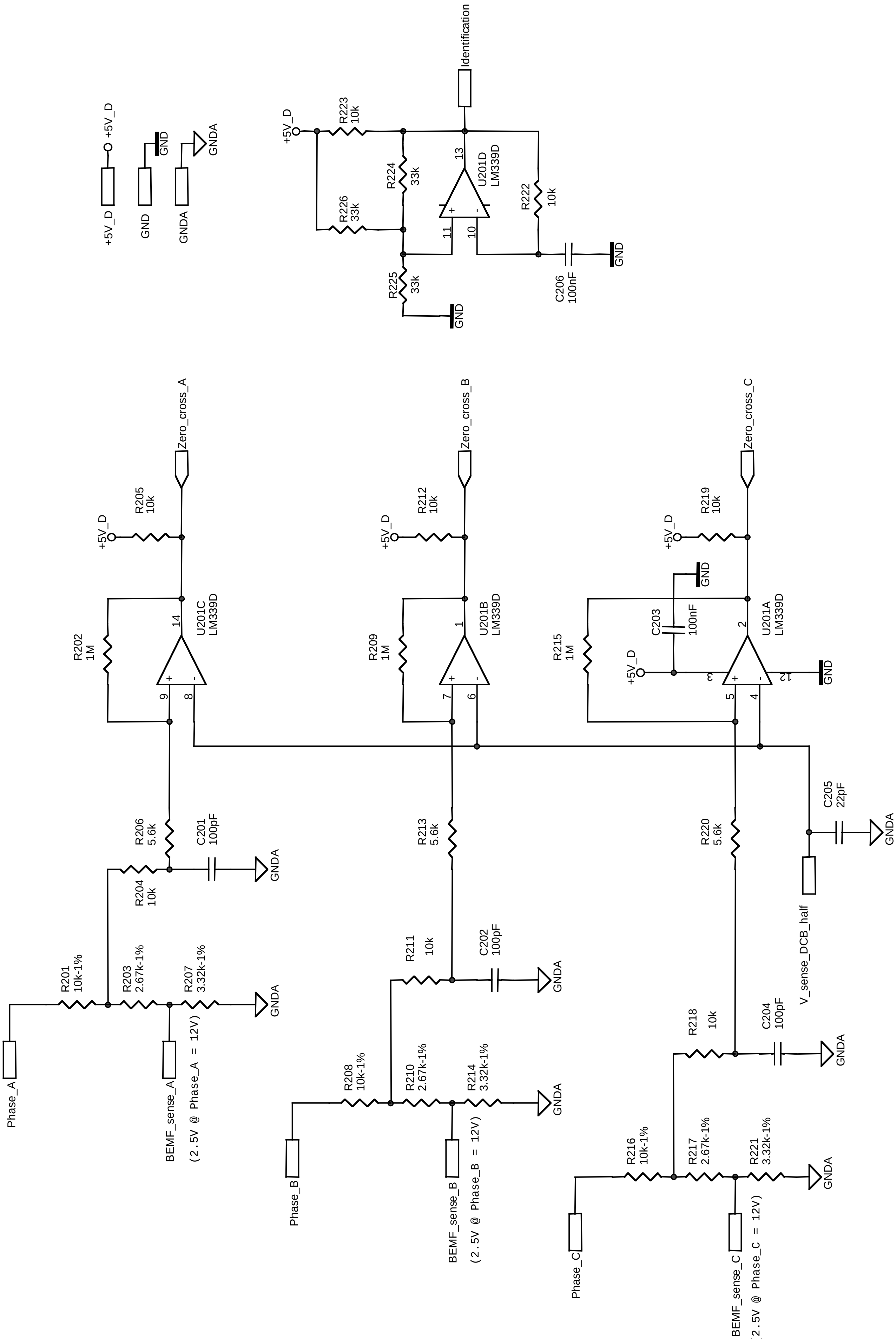


Figure 4-4. Back EMF Signals

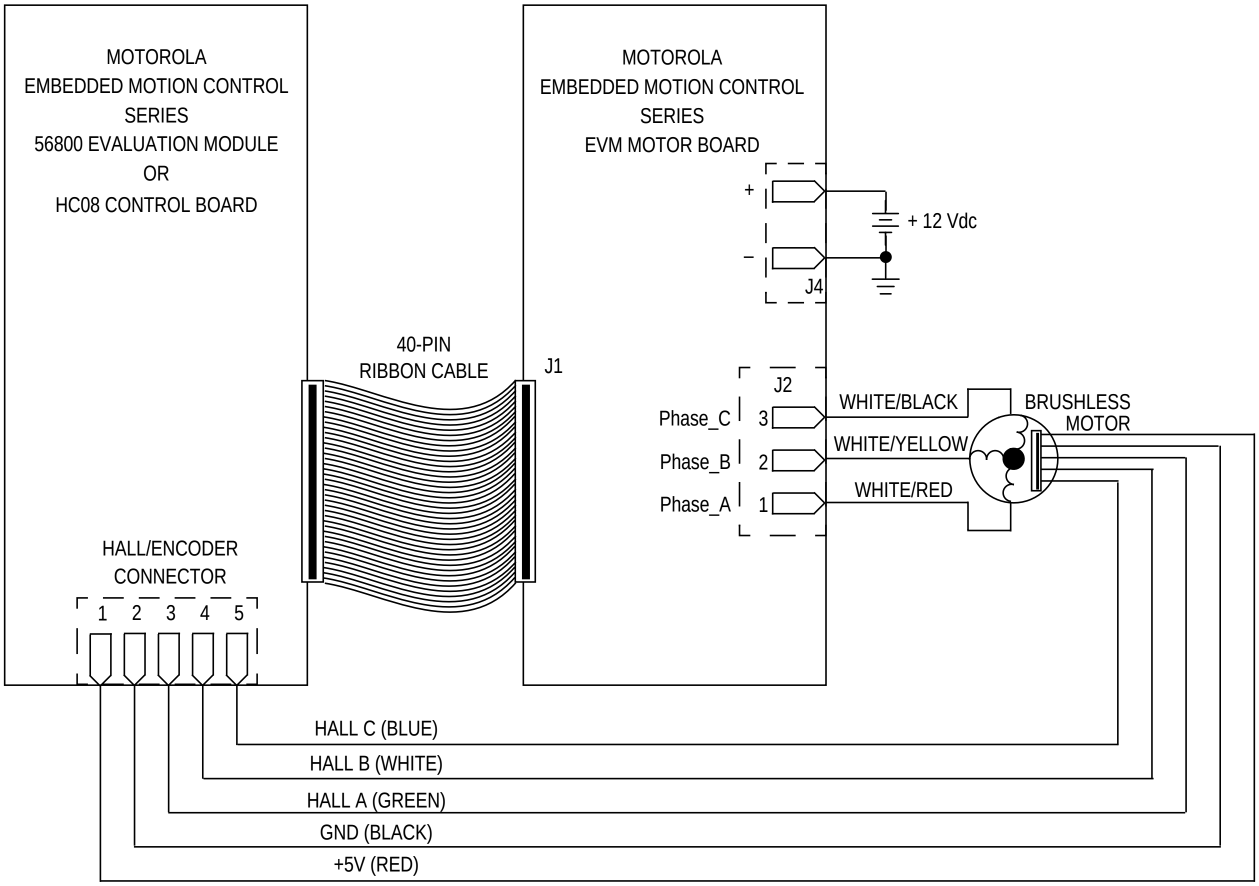


Figure 4-5. Brushless dc Motor Connections — Schematic View

4.4 Encoder Connector

The encoder is shown in **Figure 4-6**. The mark on the motor in this view indicates pin 1 on the encoder's 5-pin connector.

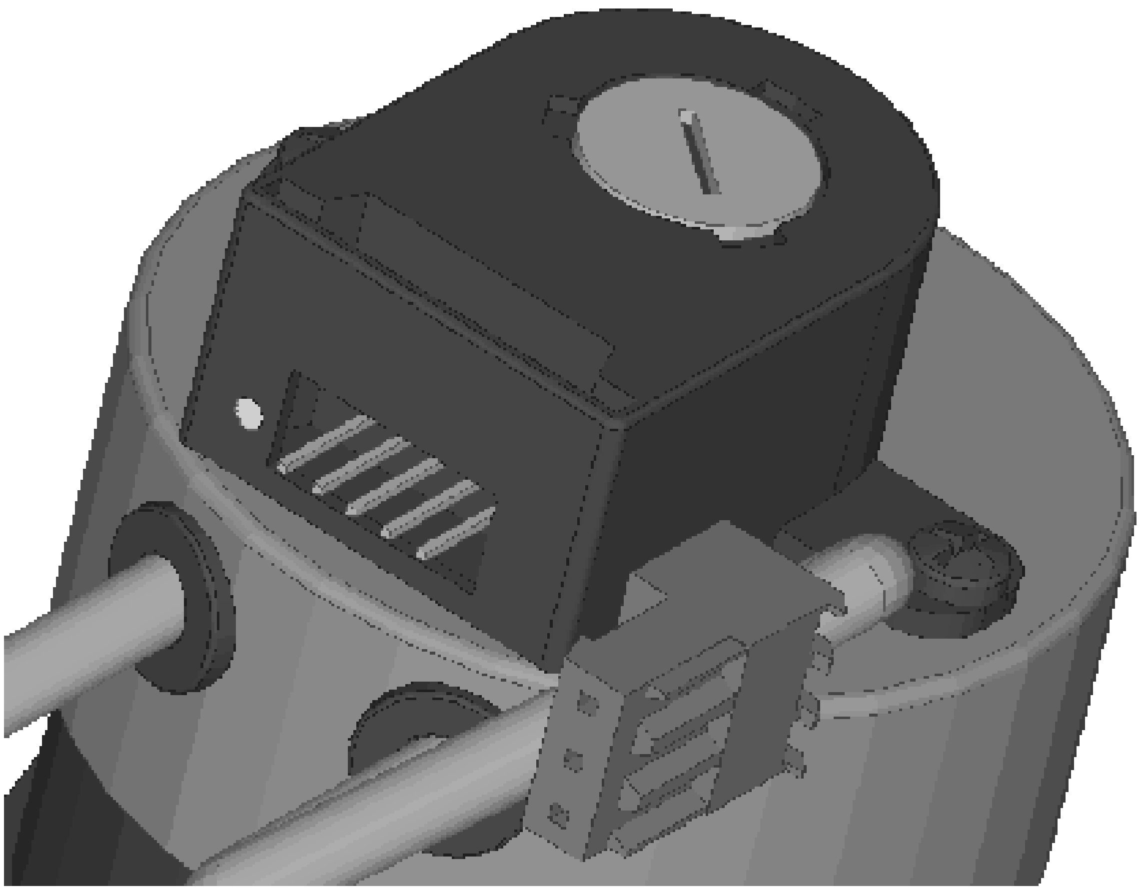


Figure 4-6. Encoder Connector – Physical View

4.5 Parts List

The EVM motor board's parts content is described in the following parts list.

Table 4-1. Parts List (Sheet 1 of 3)

Qty.	Reference	Part Value	Description	Mfg.	Mfg. Part No.
1	C1	22 µF/25 V	Tantalum capacitor, D, 22 µF/25 V, ±10%, ESR 0.2	AVX	TPSD226K025R0200
1	C2	220 µF/10 V	Electrolytic Capacitor 220 µF/10 V, Type RE2	ELNA	RE2-10V221MMA
2	C3, C4	3.3 µF/ 20 V	Tantalum Capacitor, A, 3.3 µF/20 V, ±10%	Vishay Sprague	293D335X_010A2
3	C101, C102, C103	330 µF/35 V	Electrolytic Capacitor 330 µF/35 V, Type RE2	ELNA	RE2-35V331MMA
3	C104,C105,C106	4.7 µF/35 V	Tantalum Capacitor, D, 4. 7µF/35 V, ±10%	Vishay Sprague	293D475X_035D2
7	C107, C108, C109, C203, C206, C301, C303	100 nF	Capacitor, 805, Ceramic 100 nF/25 V, Z5U, ±20%	Vishay Vitramon	VJ0805U104MXXA
3	C201, C202, C204	100 pF	Ceramic capacitor, 0805, 100 pF, ±5%	Vishay Vitramon	VJ0805A101JXA
1	C205	22 pF	Ceramic capacitor, 0805, 22 pF, ±5%	Vishay Vitramon	VJ0805A220JXA
1	C302	3.3 µF/10 V	Tantalum capacitor, A, 3.3 µF/10 V, ±10%	Vishay Sprague	293D335X_010A2
1	D1	P6SMB18AT3	Transient voltage suppressor 18 V	ON Semiconductor	P6SMB18AT3
1	D2	MBRD835L	Low VF Shottky Rectifiers 35 V, 8 A	ON Semiconductor	MBRD835L
1	D3	LED Green	LED diode, 3mm, 10 mA, green	Kingbright	L-934GT
7	D4, D101, D102, D103, D104, D105, D106	MBRM140T3	Shottky Rectifiers 40 V, 1A	ON Semiconductor	MBRM140T3
1	D5	BZX84C5V6LT1	Zener diode 5.6 V	ON Semiconductor	BZX84C5V6LT1
1	F1	RUE400	Resetable fuse	Raychem	RUE400
1	J1	CON/40	Header 40 pins breakaway connector	Fischer Elektronik	ASLG40G
1	J2	AMP 640387-3	Header 3 pins	AMP	640387-3
1	J3	Power Jack	Power Jack type connector 2.1 mm	CUI Stack	PJ-002A

Table 4-1. Parts List (Sheet 2 of 3)

Qty.	Reference	Part Value	Description	Mfg.	Mfg. Part No.
1	J4	CON/2screws	2 screws PCB terminal, 200 mils	WAGO	237-132
1	L1	330 µH	Inductor 330 µH, 0.5 A, thruhole, d = 9mm	Bourns	RLB0914-331K
3	Q101, Q102, Q103	Si4558DY	P+ N MOSFET transistor, 30 V, 6 A	Vishay	Si4558DY
1	R1	680	Resistor 680 Ω, 5%, 0805	Vishay Dale	CRCW0805-681J
1	R101	PMA-A-R075-1	Sensing resistor with Kelvin terminals, 75 MΩ, 1%	Isabellenhutte	PMA-A-R075-1
3	R201, R208, R216	10 k-1%	Resistor 10 kΩ, 1%, 0805	Vishay Dale	CRCW0805-1002F
3	R203, R210, R217	2.67 k-1%	Resistor 2.67 kΩ, 1%, 0805	Vishay Dale	CRCW0805-2671F
1	R104	118-1%	Resistor 118 Ω, 1%, 0805	Vishay Dale	CRCW0805-1180F
14	R105, R106, R108, R109, R112, R113, R204, R205, R211, R212, R218, R219, R222, R223	10 k	Resistor 10 kΩ, 5%, 0805	Vishay Dale	CRCW0805-103J
1	R107	182-1%	Resistor 182 Ω, 1%, 0805	Vishay Dale	CRCW0805-1820F
1	R110	1.82 k-1%	Resistor 1.82 kΩ, 1%, 0805	Vishay Dale	CRCW0805-1821F
1	R111	1.18 k-1%	Resistor 1.18 kΩ, 1%, 0805	Vishay Dale	CRCW0805-1181F
3	R202, R209, R215	1 M	Resistor 1 MΩ, 5%, 0805	Vishay Dale	CRCW0805-105J
3	R206, R213, R220	5.6 k	Resistor 5.6 kΩ, 5%, 0805	Vishay Dale	CRCW0805-562J
3	R207, R214, R221	3.32 k-1%	Resistor 3.32 kΩ, 1%, 0805	Vishay Dale	CRCW0805-3321F
3	R224, R225, R226	33 k	Resistor 33 kΩ, 5%, 0805	Vishay Dale	CRCW0805-333J
2	R301, R304	105 k-1%	Resistor 10 5kΩ, 1%, 0805	Vishay Dale	CRCW0805-1053F
2	R302, R303	21 k-1%	Resistor 21 kΩ, 1%, 0805	Vishay Dale	CRCW0805-2102F
1	R305	390	Resistor 390 Ω, 5%, 0805	Vishay Dale	CRCW0805-391J

Table 4-1. Parts List (Sheet 3 of 3)

Qty.	Reference	Part Value	Description	Mfg.	Mfg. Part No.
1	R306	100 k-1%	Resistor 100 kΩ, 1%, 0805	Vishay Dale	CRCW0805-1003F
1	R307	33.2 k-1%	Resistor 33.2 kΩ, 1%, 0805	Vishay Dale	CRCW0805-3322F
6	R114, R116, R118, R120, R122, R124	330	Resistor 330 Ω, 5%, 0805	Vishay Dale	CRCW0805-331J
6	R115, R117, R119, R121, R123, R125	100	Resistor 100 Ω, 5%, 0805	Vishay Dale	CRCW0805-101J
1	U2	MC78PC33NTR	Linear voltage regulator	ON Semiconductor	MC78PC33NTR
1	U3	LM2574N-005	Switching voltage regulator	ON Semiconductor	LM2574N-5
3	U101, U102, U103	MAX628CSA	MOSFET driver	Maxim	MAX4428CSA
1	U201	LM339D	Comparator	ON Semiconductor	LM339D
1	U301	MC33502D	Operational amplifier, rail to rail	ON Semiconductor	MC33502D
1	U302	LM285M	Adujstable voltage reference	National Semiconductor	LM285M
1	R103	2.0 k-1%	Resistor 2.0 kΩ, 1%, 0805	Vishay Dale	CRCW0805-2001F
1	R102	10.7 k-1%	Resistor 10. 7kΩ, 1%, 0805	Vishay Dale	CRCW0805-1071F

Section 5. Design Considerations

5.1 Contents

5.2 Overview

From a systems point of view, the EVM motor board kit fits into an architecture that is designed for code development. In addition to the hardware that is needed to run a motor, a variety of feedback signals that facilitate control algorithm development are provided.

The EVM motor board's power output stage is a complementary MOS field effect transistor (MOSFET) 3-phase bridge that is capable of supplying and sensing 4 amps of continuous current. Feedback signals include bus voltage, bus current, back EMF (electromotive force), and zero crossing. Descriptions of each of these blocks are contained in **5.3 3-Phase H-Bridge**, **5.4 Bus Voltage and Current Feedback**, and **5.5 Back EMF Signals**.

5.3 3-Phase H-Bridge

The output stage is configured as a 3-phase H-bridge with complementary MOSFET output transistors. It is simplified considerably by dual integrated gate drivers that each have one inverting and one non-inverting driver. A simplified schematic that shows one phase is illustrated in **Figure 5-1**.

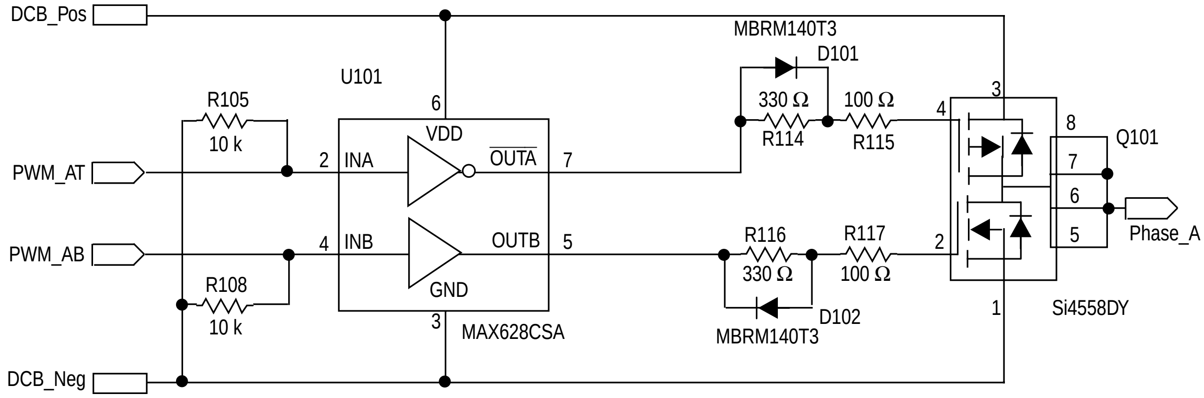


Figure 5-1. Phase A Output

At the input, pulldown resistors, R105 and R108, set a logic low in the absence of a signal. Open input pulldown is important, since it is desirable to keep the power transistors off in case of either a broken connection or absence of power on the control board. Gate drive is supplied by a Maxim MAX628CSA. This part has a minimum logic 1 input voltage of 2.4 volts and maximum logic 0 input voltage of 0.8 volts. The EVM motor board will, therefore, accept inputs for either 3.3- or 5-volt logic. Under voltage lockout is not included in the gate drive. If this feature is desired, the control board's under-voltage detection comparator can be set for 1.24 volts.

One of the more important design decisions in a motor drive is selection of gate drive impedance for the output transistors. In **Figure 5-1**, resistors R116, R117, and diode D102 determine gate drive impedance for the lower half-bridge transistor. A similar network is used on the upper half-bridge. These networks set turn-on gate drive impedance at approximately 430 Ω and turn-off gate drive impedance at approximately 100 Ω. These values produce transition times of approximately 60 ns.

Transition times of this length represent a carefully weighed compromise between power dissipation and noise generation. Generally speaking, transition times longer than 250 ns tend to get power hungry at non-audible PWM rates; and transition times under 50 ns create di/dt's so large that proper operation is difficult to achieve. The EVM motor board is designed with switching times at the lower end of this range to minimize power dissipation.

5.4 Bus Voltage and Current Feedback

Feedback signals proportional to bus voltage and bus current are provided by the circuitry shown in **Figure 5-2**. Bus voltage is scaled down by a voltage divider consisting of R102, R103, R104, R107, R110, and R111. The values are chosen such that a 16-volt maximum bus voltage corresponds to a 3.3-volt maximum analog-to-digital (A/D) input. Bus current is sampled by resistor R101 in **Figure 4-2** and amplified by the circuit in **Figure 5-2**. This circuit provides a voltage output suitable for sampling with A/D inputs. An MC33502 is used for the differential amplifier. The gain is given by:

$$A = R301/R302$$

The output voltage is shifted up by 1.65 V, to accommodate both positive and negative current swings. A ±300-mV voltage drop across the shunt resistor corresponds to a measured current range of ±4.0 amps.

Note that the EVM motor board measures, but does not limit, current. Current limiting is performed on the control board, where a 2.8-volt setting for the overcurrent detection comparator produces a 2.8-amp current limit.

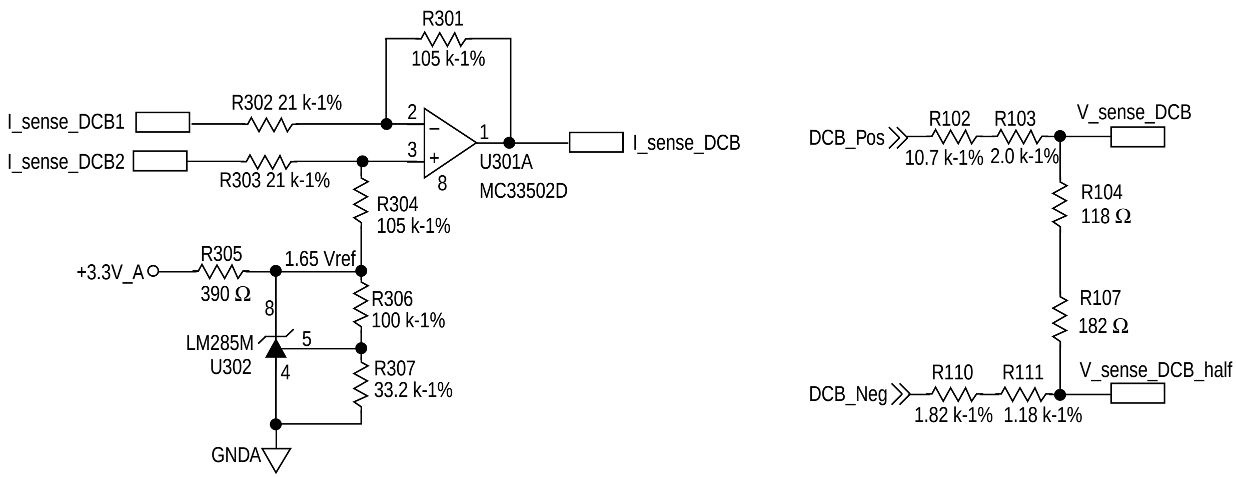


Figure 5-2. Bus Feedback

5.5 Back EMF Signals

Back EMF and zero crossing signals are included to support sensorless algorithms for brushless dc motors. Referring to **Figure 5-3**, which shows circuitry for phase C, the raw phase voltage is scaled down by a voltage divider consisting of R216, R217, and R221. One output from this divider produces back EMF sense voltage BEMF_sense_C. Resistor values are chosen such that a 16-volt maximum phase voltage corresponds to a 3.3-volt maximum A/D input.

A zero crossing signal is obtained by comparing motor phase voltage with the motor bus voltage. Comparator U201A performs this function, producing zero crossing signal Zero_cross_C.

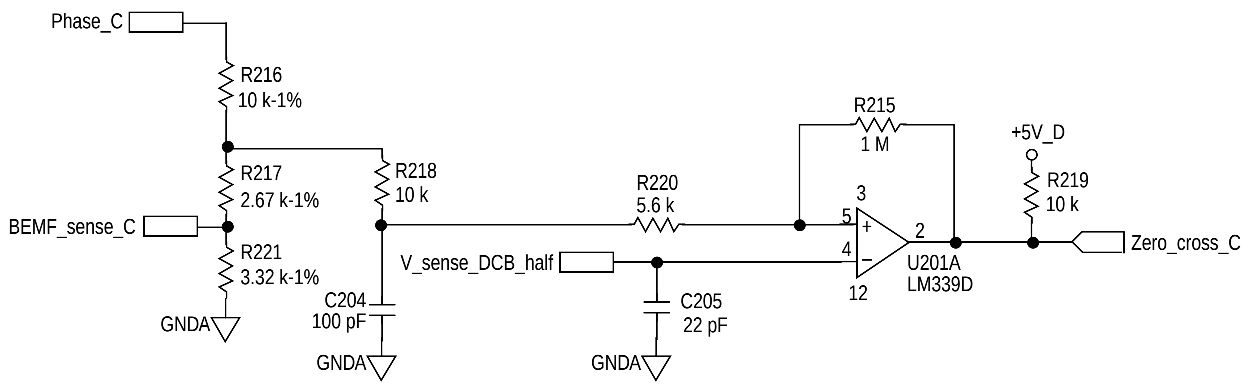


Figure 5-3. Phase C Back EMF Feedback

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