

3-Phase Power Stage with DC/DC Inverter Lite

User's Manual

56800
Hybrid Controller

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3-Phase Power Stage with DC/DC Inverter Lite

User's Manual

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The following revision history table summarizes changes contained in this document. For your convenience, the page number designators have been linked to the appropriate location.

Revision History

Date	Revision Level	Description	Page Number(s)
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Chapter 1

Introduction and Setup

1.1 Introduction

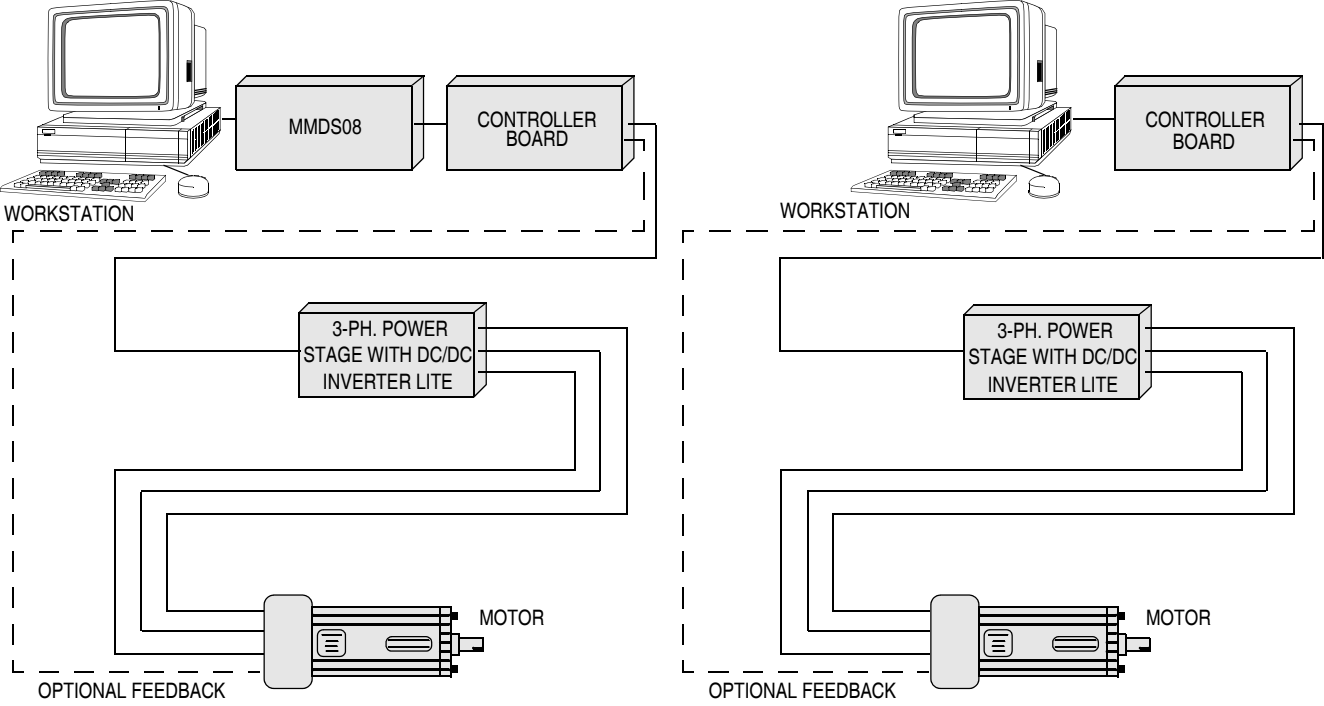
Freescale Semiconductor's 3-Phase Power Stage with DC/DC Inverter Lite is a 12V – 42V, 10A power stage integral to Freescale Semiconductor's embedded motion control series of development tools. It provides a power stage to control 3-Phase BLDC, PMSM and ACIM motors operating at voltages ranging up to 42V. It is supplied with a 40-pin ribbon cable, interconnecting with, among others, one of the embedded motion control series control or evaluation boards, providing a ready-made software development platform for small brushless DC motors. A new feature, different from the usual 3-phase power stage, consists of a DC/DC step-down inverter. This inverter is capable of reducing the voltage level and can even brake the motor by transferring energy to the higher voltage input side. An illustration of system configurations is delineated in [Figure 1-1](#). [Figure 1-2](#) is an illustration of the board.

1.2 About this Manual

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

- Setup instructions are found in [1.3 Setup Guide](#).
- Schematics and board circuitry description are found in [4.2 Schematics](#).
- Pin assignments are shown in [Figure 3-1](#), and a pin-by-pin description is contained in [3.2 Signal Descriptions](#).

Introduction and Setup



a) MC68HC08 MICROCONTROLLER

b) MCF523xEC, MPC555, 56800/E HYBRID CONTROLLER, S12Exx MICROCONTROLLER

Figure 1-1. System Configurations

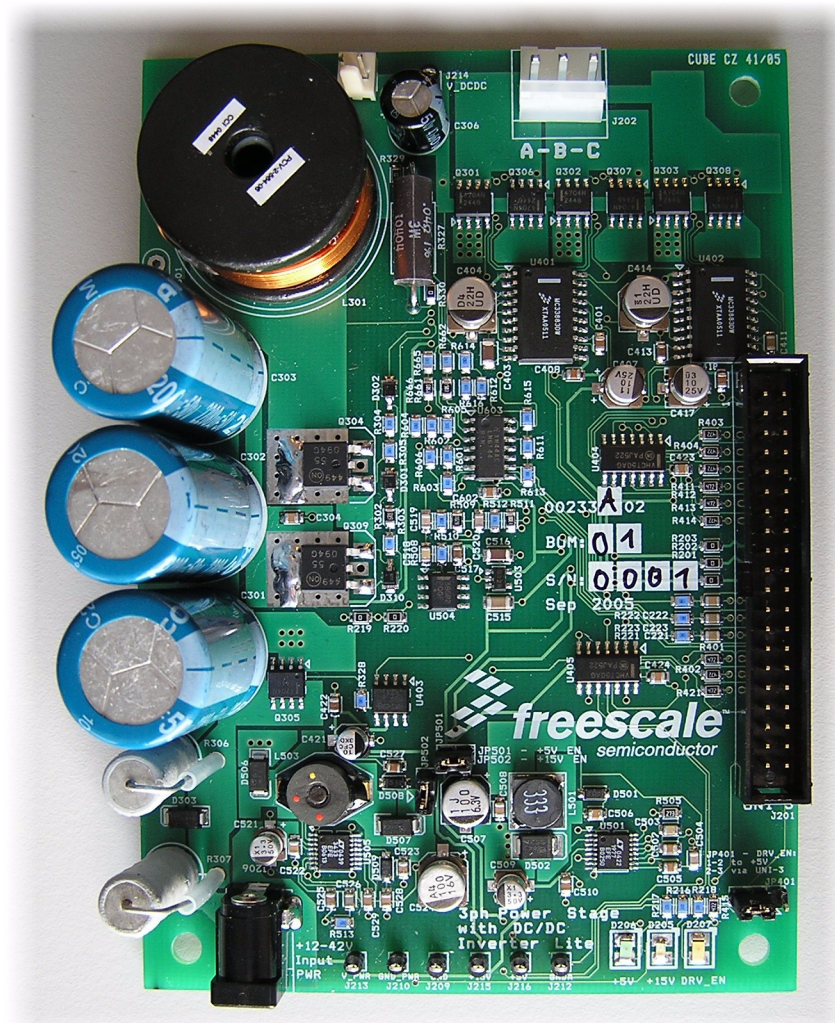


Figure 1-2. 3-Phase Power Stage with DC/DC Inverter Lite

WARNING

The 3-Phase Power Stage with DC/DC Inverter Lite includes power components able to reach temperatures hot enough to cause burns. For safe operation, the 12V – 42V input power should come from a DC laboratory power supply current-limited to less than 10A.

Before moving scope probes, making connections, etc., it is advisable to power down the 12V – 42V supply.

Operation in lab setups with grounded tables and/or chairs should be avoided.

Also advisable: wear safety glasses; avoid wearing ties and jewelry; use shielding; and operate only by personnel trained in power electronics lab techniques.

1.3 Setup Guide

Setup and connections for the 3-Phase Power Stage with DC/DC Inverter Lite are straightforward. The 3-Phase Power Stage with DC/DC Inverter Lite connects to a Freescale Semiconductor embedded motion control series control board via a 40-pin ribbon cable. The motor’s power leads plug into output connector J206, and its Hall sensors or encoder plug into the control board’s Hall sensor/encoder input connector. [Figure 1-3](#) depicts a complete setup.

Follow these steps to set up the board:

1. Plug one end of the 40-pin ribbon cable (supplied with Freescale Semiconductor embedded motion control series control boards) into the input connector J201, located at the edge of the board. The other end of this cable goes to the control board’s 40-pin output connector.
2. Plug the free end of the cable connected to the input connector J201 into the control board’s 40-pin connector.
3. Jumper configuration is required to be able to use the 3-Phase Power Stage with DC/DC Inverter Lite. JP501 and JP502 must be closed to provide the +5V and +15V supply. JP401 must be set up according to whether the MOSFET pre-drivers should be enabled/disabled using a UNI-3 signal and/or whether it should be permanently turned on. See [Table 1-1](#) for details.
4. Connect a 12V – 42V DC power supply to the power jack J206. This connector is located in a corner of the 3-Phase Power Stage with DC/DC Inverter Lite. The input power supply should be rated for at least 5A and should have its current limit set to 10A depending on needs.
5. If protection features are desired, set the control board’s overcurrent and overvoltage detection comparators according to your needs. These values limit the DC bus current and voltage. For the current, 1.65V corresponds to 0A, and 3.3V corresponds to 14.025A. Regarding voltage, 0.2V corresponds to 0V, and 3.3V corresponds to 47.5V.
6. Apply power to the 3-Phase Power Stage with DC/DC Inverter Lite. The green power-on LEDs D205 (+15V) and D206 (+5V) are lit when power is present.

Table 1-1. 3-phase Power Stage with DC/DC Inverter Lite Jumper Options

#	Function	Connections
JP401	Pre-driver enabled by the UNI-3 signal	2-3
	Pre-driver permanently enabled	1-2
JP501	+5V voltage generation enabled	closed
	+5V voltage generation disabled	open
JP502	+15V voltage generation enabled	closed
	+15V voltage generation disabled	open

CAUTION

Do not enable the +15V generation on the 3-Phase Power Stage with DC/DC Inverter without enabling the + 5V generation. The gate signals use buffers to be converted from the 3.3V to the 5V logic. As the brake resistance pre-driver is always enabled the absence of +5V could turn on the brake resistance.

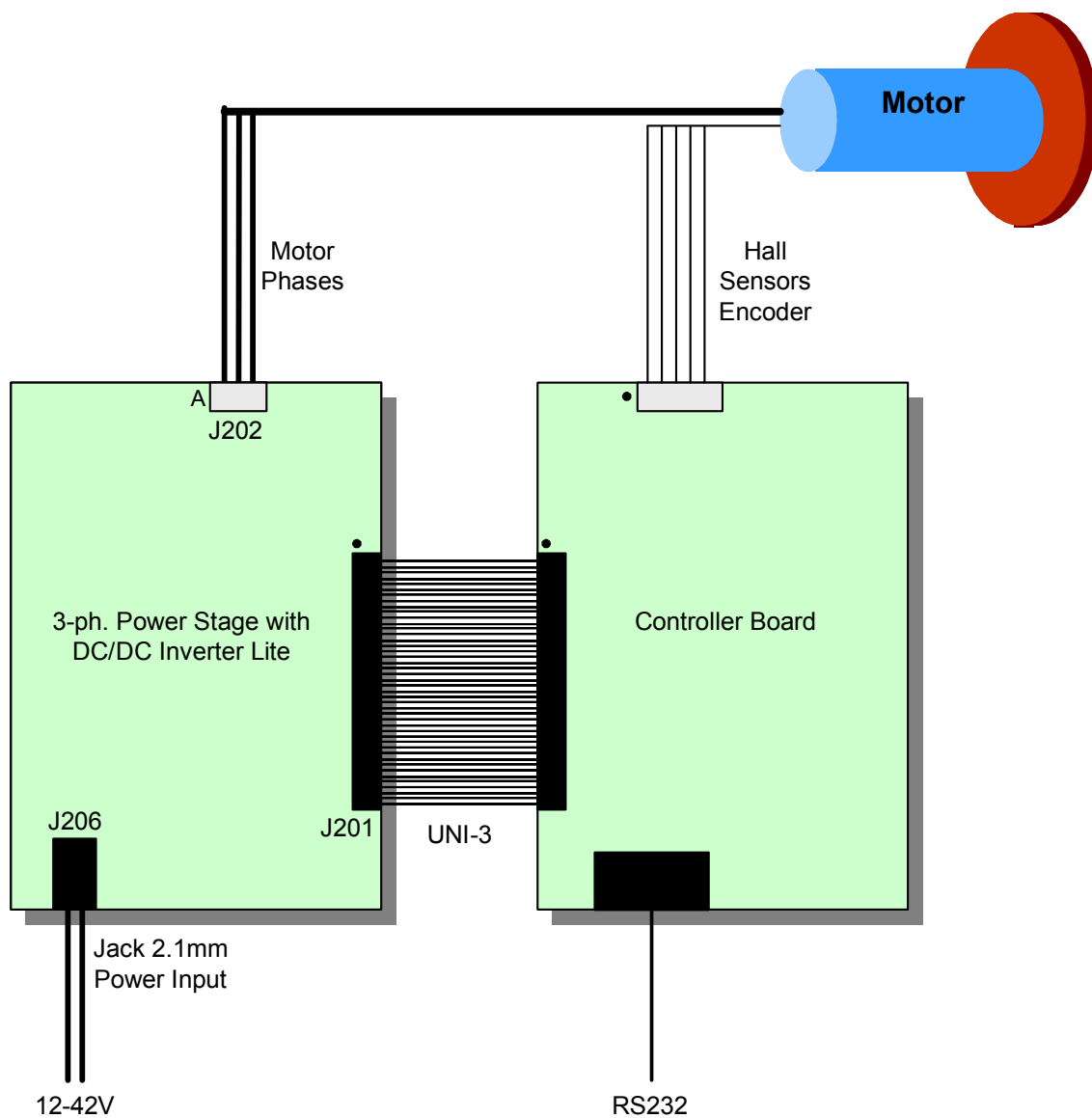


Figure 1-3. 3-Phase Power Stage with DC/DC Inverter Lite Setup

Chapter 2

Operational Description

2.1 Introduction

Freescale Semiconductor's embedded motion control series 3-Phase Power Stage with DC/DC Inverter Lite is a 12V – 42V, 10A, surface-mounted power stage. In combination with one of the embedded motion control series control boards, it provides a software development platform allowing algorithms to be written and tested without the need to design and build a power stage. It supports algorithms using Hall sensors, an encoder and back electromotive force (EMF) signals for sensorless control.

The 3-Phase Power Stage with DC/DC Inverter Lite does not have any overcurrent protection independent of the control board; therefore, it must be set up and used with care, when driving low impedance motors. The current measuring circuitry is set up for $\pm 14.025\text{A}$ full scale. At ambient temperature (25°C), the board will remain within thermal limits when operating with output currents up to 9A continuous RMS (12A for 10 seconds).

Input connections are made via the 40-pin ribbon cable connector J201. Pin assignments for the input connector are illustrated in [Figure 3-1](#). Power connections to the motor are made on a 3-way output connector J202. Phases A and B are labeled on the board. The input current requirements are met by a single DC power supply capable of supplying 5A. However, it is recommended to use a more powerful power supply. The voltage requirements are met by a power supply of 12V – 42V. The voltage should be within these limits. The board sustains a voltage of at least 9V with a maximum of 50V. The input power is supplied by means of a 2.1mm jack connector J206.

A summary of the information required to use the 3-Phase Power Stage with DC/DC Inverter Lite follows. For design information, see [Chapter 4 Schematics](#).

2.2 Electrical Characteristics

The electrical characteristics in [Table 2-1](#) apply to operation at 25°C .

Table 2-1. Electrical Characteristics

Characteristic	Symbol	Min	Typ	Max	Units
Power Supply Voltage	V_{DC}	9	12, 24, 42	50	V
Quiescent Current ⁽¹⁾	I_{CC}	—	1.7	—	mA
Quiescent Current: +5V Generation on ⁽¹⁾	I_{CC5V}	—	4.8	—	mA
Quiescent Current: +15V Generation on ⁽¹⁾	I_{CC15V}	—	5.9	—	mA
Quiescent Current: +5V, +15V Generation on ⁽¹⁾	I_{CCSPL}	—	8.9	—	mA
Quiescent Current: +5V, +15V, Drivers On Signal ⁽¹⁾	I_{CCALL}	—	30.0	—	mA
Min Logic 1 Input Voltage	V_{IH}	2.4	—	—	V
Max Logic 0 Input Voltage	V_{IL}	—	—	0.8	V
Input Logic Resistance	R_{In}	—	4.7	—	k Ω
Analog Output Range	V_{Out}	0	—	3.3	V
Bus Current Sense Voltage	I_{Sense}	—	118	—	mV/A
Bus Current Sense Offset	I_{offset}	—	1.65	—	V
Bus Voltage Sense Voltage	V_{Bus}	—	153	—	mV/V
Bus Voltage Sense Offset	V_{OFFSET}	—	0.2	—	V
Power MOSFET On Resistance	$R_{DS(On)}$	0.25	0.85	1.4	m Ω
Continuous Output Current ⁽²⁾	I_D	—	9	12	A
Pulsed Output Current	I_{DM}	—	—	50	A
Total Power Dissipation (per MOSFET) ⁽²⁾	P_D	—	1.85	3.75	W
Required Deadtime (generated by processor)	t_{OFF}	200	400	—	ns

1. Measured with an input power of 24V.

2. The values are measured at 25°C. Values may differ for other temperatures.

Chapter 3

Pin Descriptions

3.1 Introduction

Inputs and outputs are located on four connectors available on the board:

- 40-pin UNI-3
- 3-pin motor power
- 2.1mm jack type power Input
- 2-pin DC/DC inverter output

Pin descriptions for each of these connectors are provided and test points identified in the following sections. Pin assignments for the UNI-3 connectors are illustrated in [Figure 3-1](#). Signal descriptions are provided in [Table 3-1](#) through [Table 3-2](#).

3.2 Signal Descriptions

Pin descriptions are identified in this subsection.

3.2.1 J206 Input Power Connector

Connector J206 is provided for the 12V – 42V power supply. This connector is a 2.1mm power jack for plug-in type 12V – 42V power supply connections. The power supply should be able to deliver at least 5A.

3.2.2 J201 UNI-3 40-Pin Ribbon Connector

Signals are grouped together on the 40-pin ribbon cable connector, J201, located at the edge of the board. Pin assignments are shown in [Figure 3-1](#). Pin descriptions are listed in [Table 3-1](#).

Table 3-1. The J201 Connector Signal Descriptions

Pin No.	Signal Name	Description
1	PHA_T	The non-inverting gate drive signal for the top half-bridge of phase A.
2	Shielding	Connected to a shield wire in the ribbon cable and ground on the board.
3	PHA_B	The non-inverting gate drive signal for the bottom half-bridge of phase A.
4	Shielding	Connected to a shield wire in the ribbon cable and ground on the board.
5	PHB_T	The non-inverting gate drive signal for the top half-bridge of phase B.
6	Shielding	Connected to a shield wire in the ribbon cable and ground on the board.
7	PHB_B	The non-inverting gate drive signal for the bottom half-bridge of phase B.
8	Shielding	Connected to a shield wire in the ribbon cable and ground on the board.
9	PHC_T	The non-inverting gate drive signal for the top half-bridge of phase C.
10	Shielding	Connected to a shield wire in the ribbon cable and ground on the board.
11	PHC_B	The non-inverting gate drive signal for the bottom half-bridge of phase C.
12	GND	Digital power supply ground
13	GND	Digital power supply ground, redundant connection
14	+5V	+5V digital output, supplied from this board
15	+5V	+5V digital output, supplied from this board
16	+3.3V_A	+3.3V analog output, supplied from this board
17	GND_A	Analog power supply ground
18	GND_A	Analog power supply ground, redundant connection
19	+15V	Low current +15-volt output, supplied from this board
20	NC	No connection
21	S_VDCDC	The analog sensing signal measuring DC bus voltage at the DC/DC inverter output. It is scaled at 0.065 volts per volt of DC bus voltage and shifted by 0.2V.
22	S_I_DCBUS	The analog sensing signal that measures DC bus current. It is scaled at 0.118 volts per amp of DC bus current and shifted by 1.65V
23	NC	No connection.
24	+1.65V_REF	+1.65V reference for current sensing offset.
25	+0.2V_REF	+0.2V reference for voltage sensing offset.
26	S_VPWR	The analog sensing signal measuring power input voltage at the DC/DC inverter input. It is scaled at 0.065 volts per volt of DC bus voltage and shifted by 0.2V.
27	NC	No connection
28	Shielding_A	Pin 28 is connected to a shield wire in the ribbon cable, and ground to the analog ground on the board.
29	BRAKE	The non-inverting gate drive signal controlling the brake resistance at the DC/DC inverter input.
30	NC	No connection

Table 3-1. The J201 Connector Signal Descriptions (Continued)

Pin No.	Signal Name	Description
31	DCDC_T	The non-inverting gate drive signal for the top half-bridge of the DC/DC inverter. Creates voltage at the output of the DC/DC inverter, step-down.
32	DRV_EN	The non-inverting signal controlling the MOSFET pre-drivers on/off state. Can be overridden by the on-board jumper to permanently turn on the pre-drivers. (This signal is not applied to the brake resistance pre-driver, i.e., if +15V is present the brake resistance driver is ready to operate.)
33	DCDC_B	The non-inverting gate drive signal for the bottom half-bridge of the DC/DC inverter. Brakes the output of the DC/DC inverter by transforming the energy to the input of the DC/DC inverter.
34	NC	No connection
35	NC	No connection
36	NC	No connection
37	Shielding_A	Connected to a shield wire in the ribbon cable and ground to the analog ground on the board.
38	S_BEMF_PHA	The analog sensing signal measuring phase A back EMF. It is scaled at 0.065 volts per volt of DC bus voltage and NOT shifted by 0.2V.
39	S_BEMF_PHB	The analog sensing signal measuring phase B back EMF. It is scaled at 0.065 volts per volt of DC bus voltage and NOT shifted by 0.2V.
40	S_BEMF_PHC	The analog sensing signal measuring phase C back EMF. It is scaled at 0.065 volts per volt of DC bus voltage and NOT shifted by 0.2V.

Pin Descriptions

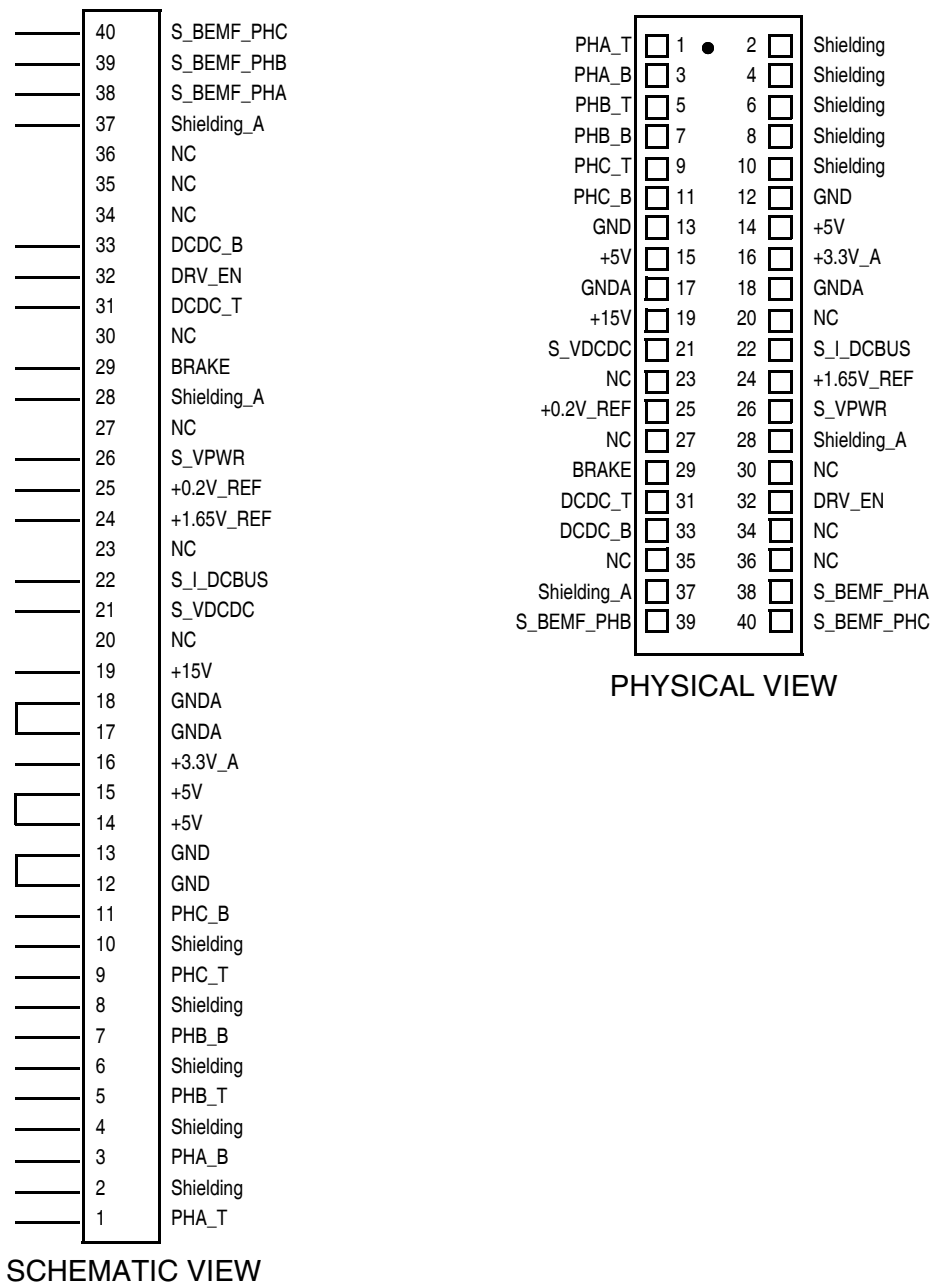


Figure 3-1. 40-Pin Connector J201

3.2.3 J202 Motor Power Connector

The board contains a 3-way connector, J202. A pin description of this J202 connector is provided in [Table 3-2](#).

Table 3-2. The J202 Connector Signal Descriptions

Pin No.	Signal Name	Description
1	Phase_A	Phase_A supplies power to motor phase A
2	Phase_B	Phase_B supplies power to motor phase B
3	Phase_C	Phase_C supplies power to motor phase C

3.2.4 J217 DC/DC Inverter Output Connector

The board contains a 2-way connector (J217) connected to the DC/DC inverter output. This connector is only an auxiliary for testing and tuning purposes. A pin description of the J202 connector is provided in [Table 3-3](#).

Table 3-3. The J217 Connector Signal Descriptions

Pin No.	Signal Name	Description
1	V_DCDC	DC/DC inverter output voltage
2	GND_PWR	Power ground

Chapter 4 Schematics

4.1 Overview

Schematics for the 3-Phase Power Stage with DC/DC Inverter Lite are provided in this chapter.

Unless otherwise specified, resistor values are in ohms (Ω), resistors are specified as 1/8W $\pm 5\%$, and interrupted lines coded with the same letters are electrically connected.

4.2 Schematics

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

4.2.1 Power and Motor Connection

The 3-Phase Power Stage with DC/DC Inverter Lite contains several connectors for the power supply and motor phases.

The input power supply must not be less than 9V nor higher than 50V. There is a 2.1mm jack connector (J206) for the power supply connection.

The output for the motor is achieved via a 3-way connector (J202). See [Figure 4-1](#) for more details.

The output of the DC/DC inverter is connected to the J217 connector.

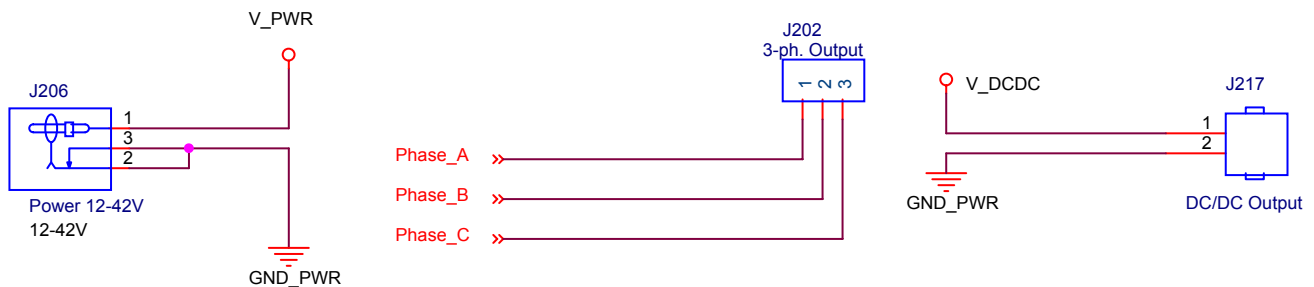


Figure 4-1. Power and Motor Connection

4.2.2 Test Points and LED Indication

The 3-Phase Power Stage with DC/DC Inverter Lite contains eight test points to allow easy voltage checks at important points:

- GND_PWR – the power ground is connected to the power supply. All other grounds are derived from this ground.
- GND – the digital ground for ICs connected to the UNI-3 connector. This ground is connected to the GND_PWR through R219.

Schematics

- G_NDA – the analog ground serves for the analog sensing and is connected to the UNI-3 connector. It is connected to the GND through R220.
- V_PWR – this point is connected to the power supply positive terminal. All other voltage levels are derived from this point.
- V_DC/DC – this point is found at the output of the DC/DC inverter and the input to the 3-phase inverter.
- +15V – this point is the output of the U505 switching regulator. It serves the U401 and U402 MOSFET pre-drivers and is connected to the UNI-3 connector too.
- +5V – this point is the output of the U501 switching regulator. It serves as the power supply for other ICs and is connected to the UNI-3 connector. It is also used for analog 3.3V generation.

This board also contains three LEDs as indicated:

- D205 – indicates the +15V level was properly generated.
- D206 – indicates the +5V level was properly generated.
- D207 – indicates the U401 and U402 MOSFET pre-drivers are turned on.

For more details see [Figure 4-2](#).

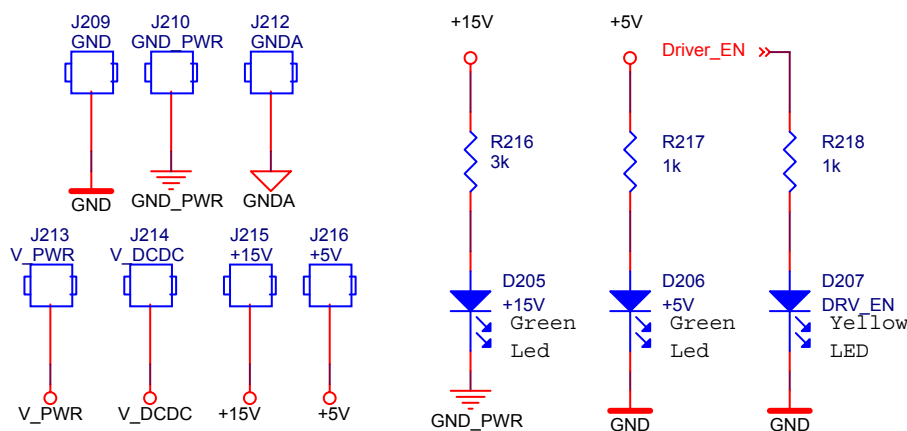


Figure 4-2. Test Points and LED Indication

4.2.3 UNI-3 Connector

The J201 UNI-3 connector serves for interconnection with a controller or EVM board. Its connection is illustrated in [Figure 4-3](#).

4.2.3.1 Changes to Standard UNI-3 Connection

The 3-Phase Power Stage with DC/DC Inverter Lite board does not use the standard UNI-3 interface. It does bring a few UNI-3 signals changes. One signal change is in DC bus voltage sensing. Pin 21 does not sense the board power supply voltage as in the standard UNI-3, but senses the voltage at the DC/DC inverter output and the 3-phase inverter input. The board power supply sensing is connected to pin 26 (instead of the standard temperature sensing).

This board does not have phase currents measurement signals in the standard UNI-3. Instead, pin 25 provides a 0.2V voltage offset reference, and pin 24 provides a 1.65V current offset reference. The remaining pin 23 is unconnected.

Pins 31 and 33 originally aimed for PFC control are used for the DC/DC inverter control where pin 31 controls the DC/DC inverter top switch. Pin 32 controls the bottom switch.

Pin 32 enables or disables the MOSFET pre-drivers for the DC/DC inverter and the 3-phase inverter. The brake MOSFET pre-driver is permanently turned on if a +15V voltage is present.

The serial communication pin 30 is not connected.

The -15V (-12V) pin 20 is not connected.

The +5V analog voltage supply pin 16 provides a +3.3V level instead.

The +15V pin 19, the +5V pins 14 and 15, and the +3.3V pin 16 are connected by means of 0Ω resistors R201, R202, and R203 for possible disconnection in case it is desired to supply the controller or EVM board independently.

See [Figure 4-3](#) for more details.

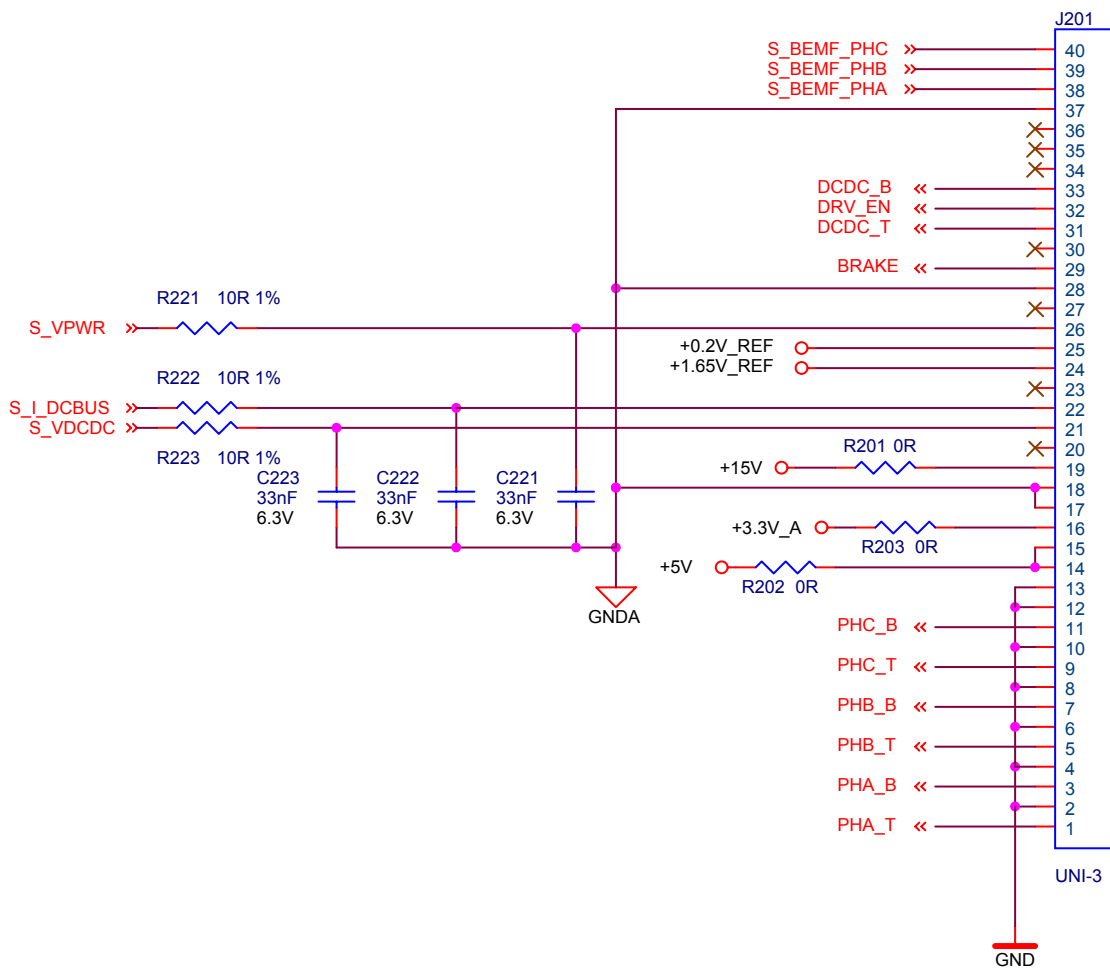


Figure 4-3. UNI-3 Connector

4.2.4 Ground Connection

As previously mentioned, the 3-Phase Power Stage with DC/DC Inverter Lite board contains more ground points. These grounds are connected into one point by means of 0Ω resistors in a 0805 case (see [Figure 4-4](#)). Where necessary, remove these resistors to disconnect the grounds or to replace them with other components.

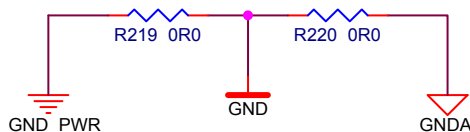


Figure 4-4. Ground Connection

4.2.5 Power Components

The 3-Phase Power Stage with DC/DC Inverter Lite is composed of a 3-phase inverter designed to drive a 3-phase motor output and a step-down DC/DC inverter (see [Figure 4-5](#)). This board uses either two DPAK N-channel MOSFETs or two TO-220 N-channel MOSFETs, depending on the BOM. In the case of the TO-220, a heatsink can be mounted if required.

The DC/DC inverter serves to decrease the voltage level, i.e., it can control its output from 0V to the input power supply voltage level. Its output is controlled by switching the Q309 MOSFET – the PFC_PWM pin 31 of the J201 UNI-3 connector. Thus, the inverter uses the L301 inductor and the C306 capacitor to keep desired output voltage level. The L301 inductor footprint contains two types of inductor shape in order to select from more inductors. The two basic types used are:

- Coilcraft PCV2-564-06 – 560μH, 6A
- Coilcraft PCV1-394-05 – 390μH, 5A

The inductor should be within the range of 250 – 600μH according to the desired current rippling and the inverter response. Current is another criteria for inductor selection.

This DC/DC inverter can also work in the opposite direction, i.e., if we want to brake the load and transfer its energy to the power supply’s input voltage level. To reduce the load voltage level, the Q304 MOSFET is used – the PFC_z_c pin 33 of the J201 UNI-3 connector. Therefore, if this MOSFET is turned on, the L301 inductor is charged, and in the instant when the MOSFET is turned off the energy accumulated in the inductor is transferred to the DC/DC inverter’s input. This temporarily causes a higher voltage at the board input. If this operation goes on longer, the input capacitors does not absorb all the energy and the input voltage is higher. In this case, care must be taken and the Q305 brake MOSFET must be turned on while the voltage is higher. Voltage must not go higher than 50V. The brake resistors are designed to absorb the power of 10W. When insufficient, these resistors must be replaced by resistors with a higher rating.

The Q304 MOSFET operates in a different way to the Q309, i.e., whereas the Q309 can be switched from 0 – 100% of the duty cycle, the Q304 cannot. It can only be switched from 0 to a certain percentage because the inductor is discharged when the MOSFET is turned off. This maximum duty cycle depends on the voltages both at the input and at the output.

The DC/DC inverter can be bypassed by the J201 short-circuit jumper.

The 3-phase inverter (see [Figure 4-6](#)) is connected to the output of the DC/DC inverter. It contains six N-channel MOSFETs controlled by the UNI-3 pins 1, 3, 5, 7, 9, and 11. The MOSFETs must be switched properly to avoid hardware damage. At least 200ns of deadtime must be inserted.

The 3-phase inverter contains a shunt resistor for current sensing. The shunt has a dual footprint, i.e., one can populate it with an Isabellenhutte PMA SMD resistor and/or a Vishay VLR-3 TH resistor. The PMA resistor contains special terminals for precise gate measurement and the TH resistor output is led from its terminals. If the TH is used the R329 and R330 0Ω resistors must be populated, otherwise they must be left vacant. See [Figure 4-6](#) and [Figure 4-16](#).

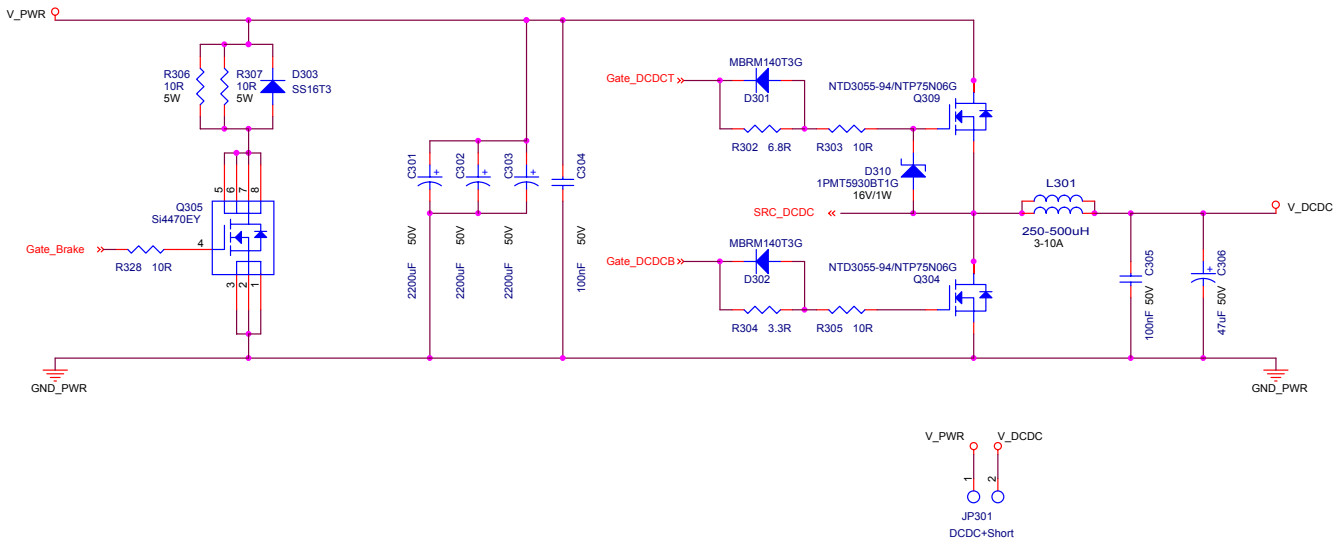


Figure 4-5. DC/DC Inverter

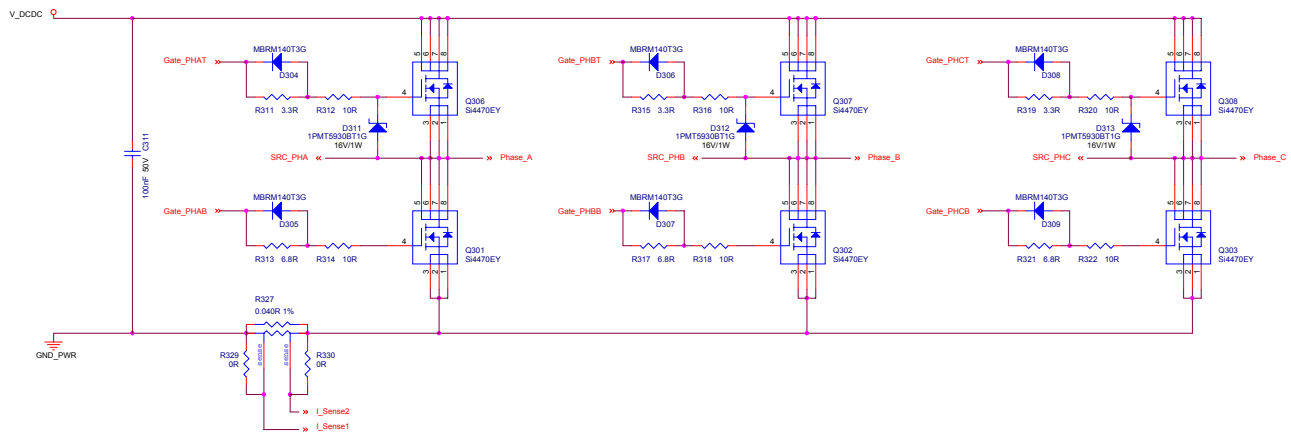


Figure 4-6. 3-phase Inverter

4.2.6 MOSFET Pre-driver

The 3-Phase Power Stage with DC/DC Inverter Lite contains two Freescale Semiconductor MC33883 pre-drivers and one MAX628 MOSFET pre-driver. The MC33883 is a full-bridge pre-driver able to work up to 55V. This board contains two MC33883 ICs – U401 and U402 (see [Figure 4-7](#)). One half of the U401 is dedicated to the DC/DC inverter while the other half is dedicated to phase A of the 3-phase inverter.

Schematics

The U402 drives the B and C phases of the 3-phase inverter. This driver must be enabled in order to be able to drive the MOSFETs. It is controlled by the UNI-3 pin 32 and/or it can be permanently enabled by moving the JP401 jumper to the 1-2 position (see [Figure 4-8](#)). If the drivers are enabled, the D207 LED is lit.

The MAX628 is a dual MOSFET pre-driver of up to 18V. This board uses its non-inverting channel to drive the low-side braking resistance MOSFET. It can also be replaced by the MAX627.

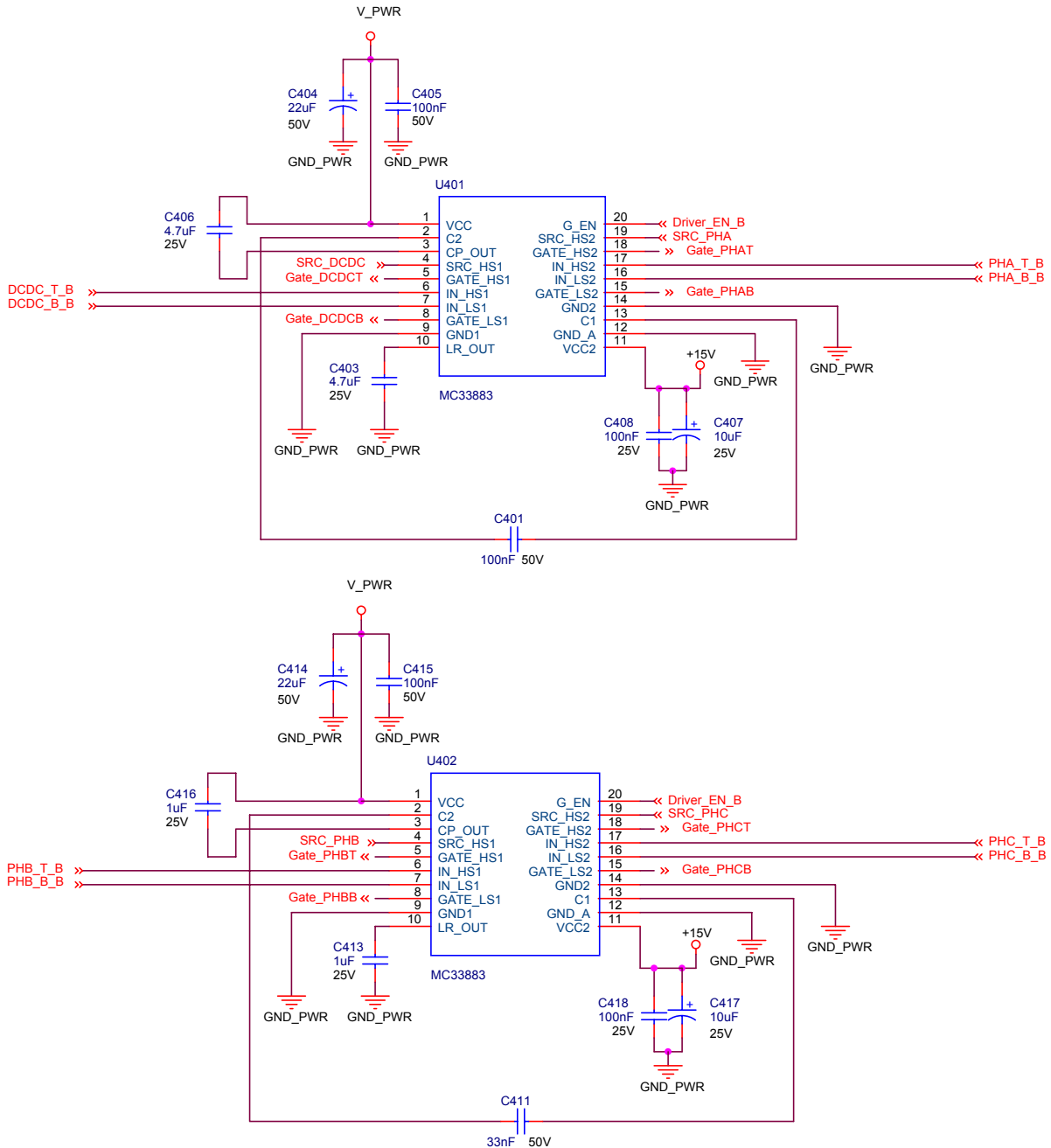


Figure 4-7. MC33883 MOSFET Pre-driver

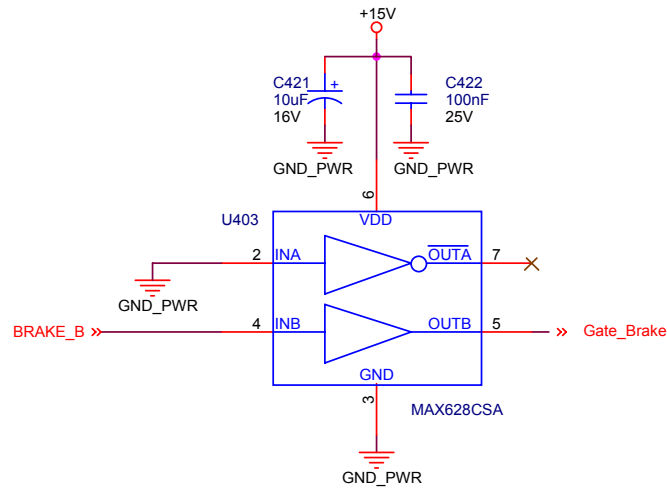


Figure 4-8. MAX628 MOSFET Pre-driver

The MC33883 pre-driver requires a 5V logical signal, so a 3.3V – 5V buffer is used between the UNI-3 connector and the MOSFET pre-drivers.

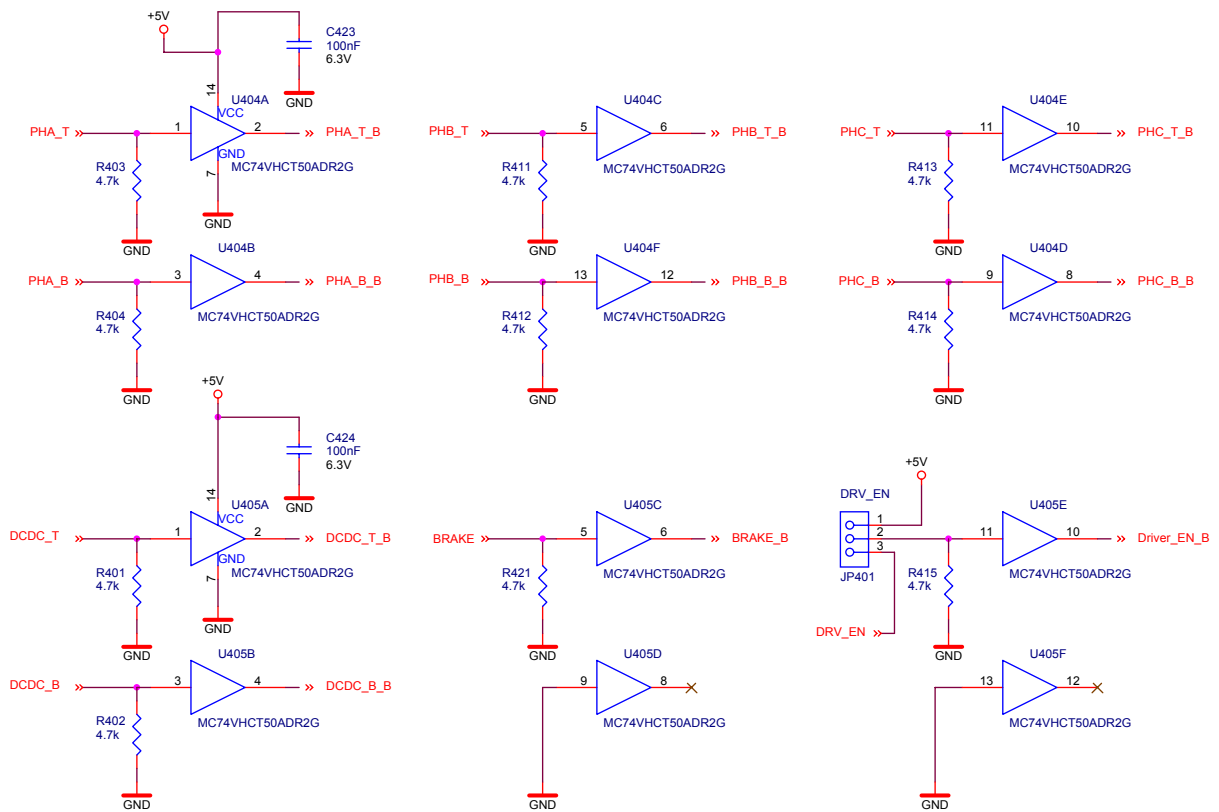


Figure 4-9. 3.3V-to-5V Buffer

4.2.7 Power Supply

The 3-Phase Power Stage with DC/DC Inverter Lite contains devices requiring various voltage levels: +15V, +5V, +3.3V, +1.65V and +0.2V.

4.2.7.1 +15V Power Supply

The +15V level is generated by means of the LT3433 switching step-up/down inverter (see [Figure 4-10](#)) generating this voltage from the input power supply of 9V – 50V. This regulator is capable of supplying at least 100mA, up to 500mA with respect to input voltage. This voltage level provides power to the MC33883 MOSFET pre-drivers and charge pump, and the MAX628. It is also connected to the UNI-3 pin 19.

To connect this voltage level further into the heart of the board, it is necessary to connect jumper JP502. If the LT3433 voltage regulator operates properly and the JP502 jumper is shorted, the D205 LED will light.

This driver adjusts the shut-down level to 8.6V, i.e., when the input power supply drops below 8.6V, the regulator shuts down.

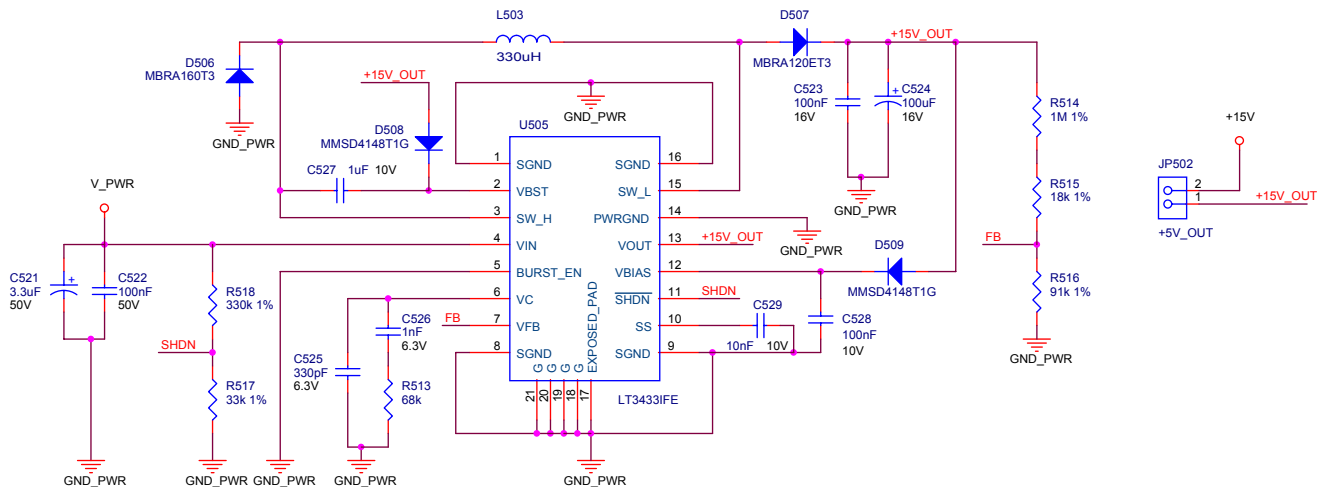


Figure 4-10. +15V Power Supply

4.2.7.2 +5V Power Supply

Another very important voltage level for this board is the +5V. This voltage level is obtained from the LT1977 switching step-down inverter, and provides up to 1.5A (see [Figure 4-11](#)). The +5V level supplies on-board logic ICs, the 3.3V linear voltage regulator, and is connected to the UNI-3 pins 14 and 15 to supply the connected EVM or controller board.

To connect this voltage level further into the heart of the board, jumper JP501 must be connected. If the LT1977 voltage regulator operates properly and the JP502 jumper is shorted, the D206 LED will light.

This driver adjusts the shut-down level to 7V, i.e., when the input power supply drops below 7V this regulator shuts down.

4.2.7.3 +3.3V Power Supply

The 3.3V power supply is generated from the +5V level by means of the MC78PC33NTR linear voltage regulator (see Figure 4-12). It is capable of sinking 150mA. This voltage level serves the on-board op-amp power supply and the voltage reference IC supply. It is also connected to the UNI-3 pin 16 as an analog voltage supply for the EVM or controller board.

4.2.7.4 +2.5V Reference

The 2.5V reference is generated from the +3.3V level by means of the LM385BD-2.5G linear voltage reference (see Figure 4-13). This reference serves the +1.65V and +0.2V reference resistor dividers. It can sink up to 20mA.

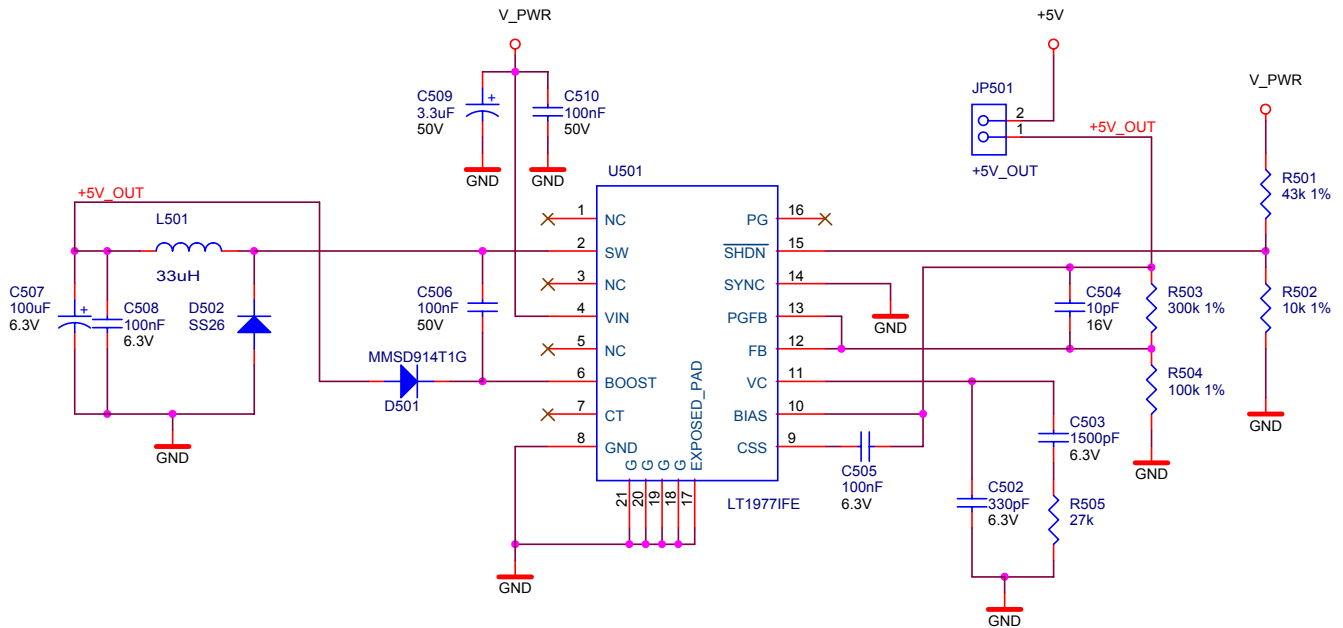


Figure 4-11. +5V Power Supply

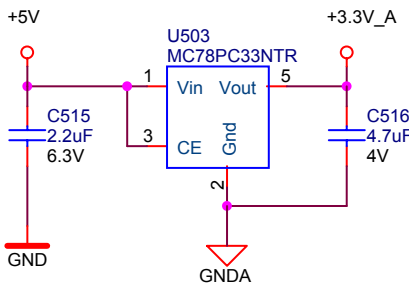


Figure 4-12. +3.3V Power Supply

Schematics

4.2.7.5 +1.65V Reference

The +1.65V is provided by the R510 and R509 resistor divider from the +2.5V reference voltage (see [Figure 4-13](#)). The resistors are calculated for 42 μ A where the reference is at its most precise. The divider shifts the current sensing value.

4.2.7.6 +0.2V Reference

The +0.2V is provided by the R512 and R511 resistor divider from the +2.5V reference voltage (see [Figure 4-13](#)). The resistors are calculated for 42 μ A where the reference is at the most precise. The divider shifts the voltage sensing value according to AD converter offset.

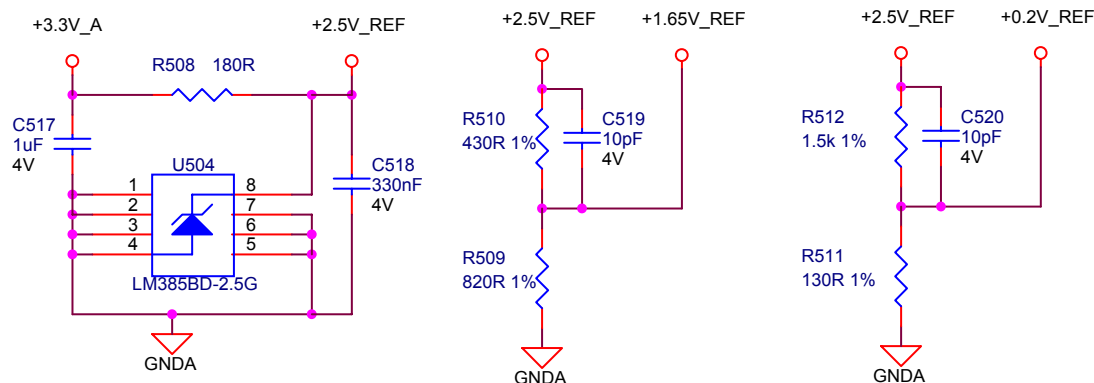


Figure 4-13. Voltage Reference

4.2.8 Analog Signals Sensing

Some voltages and currents in the 3-Phase Power Stage with DC/DC Inverter Lite can be sensed, i.e., they are connected to the UNI-3 pins. Those are: input power voltage, the voltage at the DC/DC inverter output, and 3-phase inverter current (to the motor).

4.2.8.1 Input Power Voltage Sensing

The input power voltage is measured at the input to the DC/DC inverter by means of the R604 and R605 voltage divider. The divider voltage is led to the U603-2 LM6144 op-amp channel (see Figure 4-14). The gain of the op-amp is 1. Its aim is to shift the output by 0.2V according to some ADC offset, so an output of 0.2V – 3.3V corresponds to an input of 0V – 47.5V. If the board is used with a voltage below 31V, the R604 resistor can be changed to 27kΩ 1% in order to change the measurement scale to 0V – 31V. The output is connected to the UNI-3 pin 26.

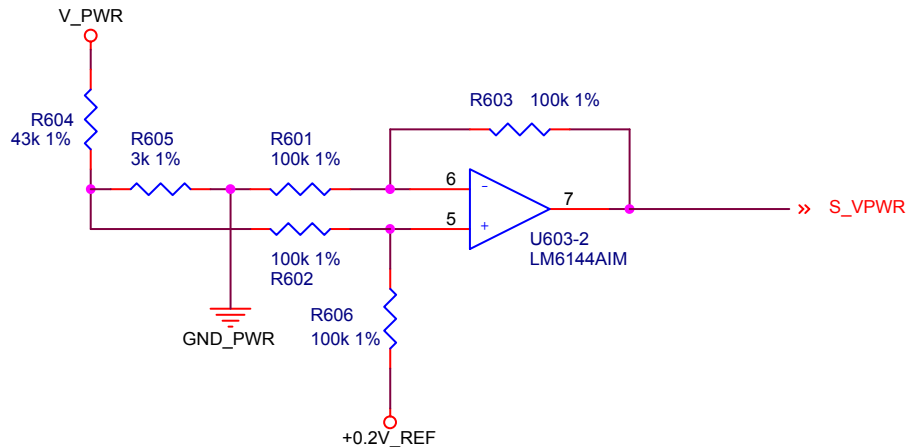


Figure 4-14. Input Power Voltage Sensing

4.2.8.2 DC/DC Inverter Output Voltage Sensing

The DC/DC inverter output voltage is measured by means of the R614 and R615 voltage divider. The divider voltage is led to the U603-3 LM6144 op-amp channel (see Figure 4-15). The gain of the op-amp is 1. Its aim is to shift the output by 0.2V according to some ADC offset. So an output of 0.2V to 3.3V corresponds to an input of 0V – 47.5V. If the board is used with a voltage below 31V, the R614 resistor can be changed to 27kΩ 1% in order to change the measurement scale to 0V – 31V. The output is connected to the UNI-3 pin 21.

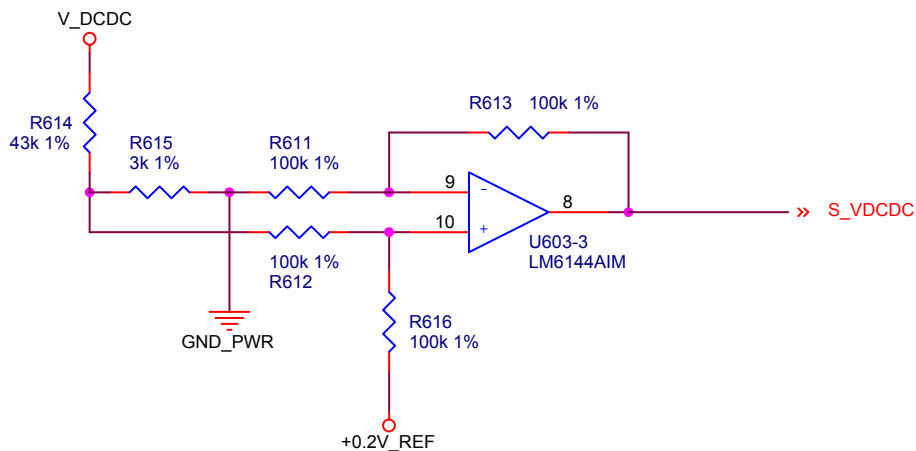


Figure 4-15. DC/DC Inverter Output Voltage Sensing

4.2.8.3 3-phase Inverter Current Sensing

The 3-phase inverter current is sensed at the R327 shunt resistor. The current observed here represents all the current flowing to (from) the 3-phase inverter, i.e., to the motor. The shunt resistor is represented by a 0.040Ω resistor, either an Isabellenhutte PMA SMD resistor or a Vishay VLR-3 TH resistor. The PMA resistor contains Kelvin terminals for precise current measurement, while the VLR-3 senses at its pins. If the TH is used the R329 and R330 0Ω resistors must be populated, otherwise they must be left vacant (see [Figure 4-6](#), [Figure 4-16](#)). The gain of this op-amp is 2.94 with a 1.65V offset, i.e., output of 0V – 3.3V corresponds to -14.025A – 14.025A, where 1.65V represents zero current. The output is connected to the UNI-3 pin 22.

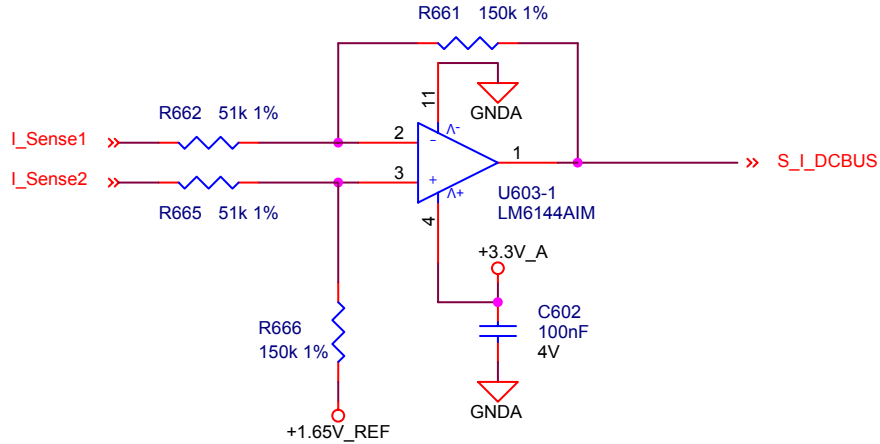


Figure 4-16. 3-phase Inverter Current Sensing

4.2.8.4 BEMF Voltage Sensing

The BEMF voltages are measured by means of the R624 and R625, R634 and R635, R644 and R645 voltage dividers. The divider voltages are led directly to the UNI-3 pins 38, 39 and 40 without any offset correction (see [Figure 4-17](#)), so the output 0V – 3.3V corresponds to 0V – 50.6V. If the board is used with a voltage below 33V, the R624, R634, R644 resistors can be changed to 27k 1% for the scale 0V – 33V.

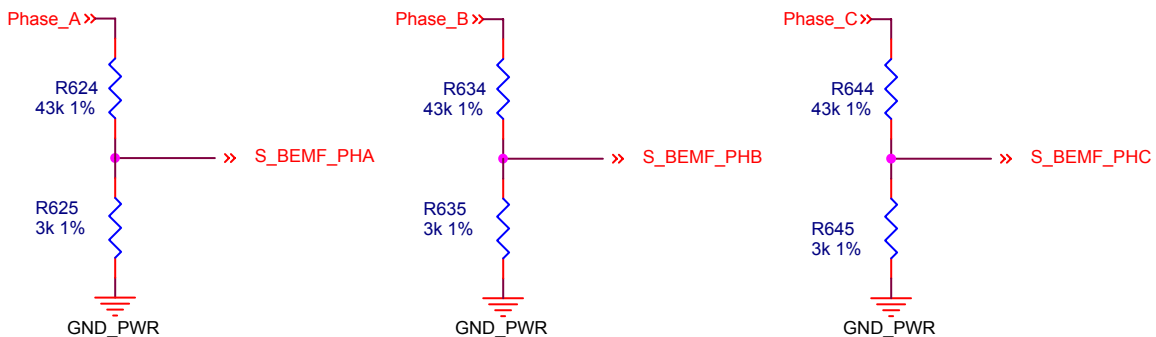


Figure 4-17. BEMF Voltage Sensing

4.3 Motor Connections

Proper motor connection is provided in [Figure 4-18](#). The 3-Phase Power Stage with DC/DC Inverter Lite should be connected to the EVM, or controller board via the J201 UNI-3 connector. This connector transfers all necessary power to supply the connected board, so 12V – 42V is supplied to the 3-Phase Power Stage with DC/DC Inverter Lite. The phases of the motor are connected to the output and the motor sensor is connected to the EVM or controller board.

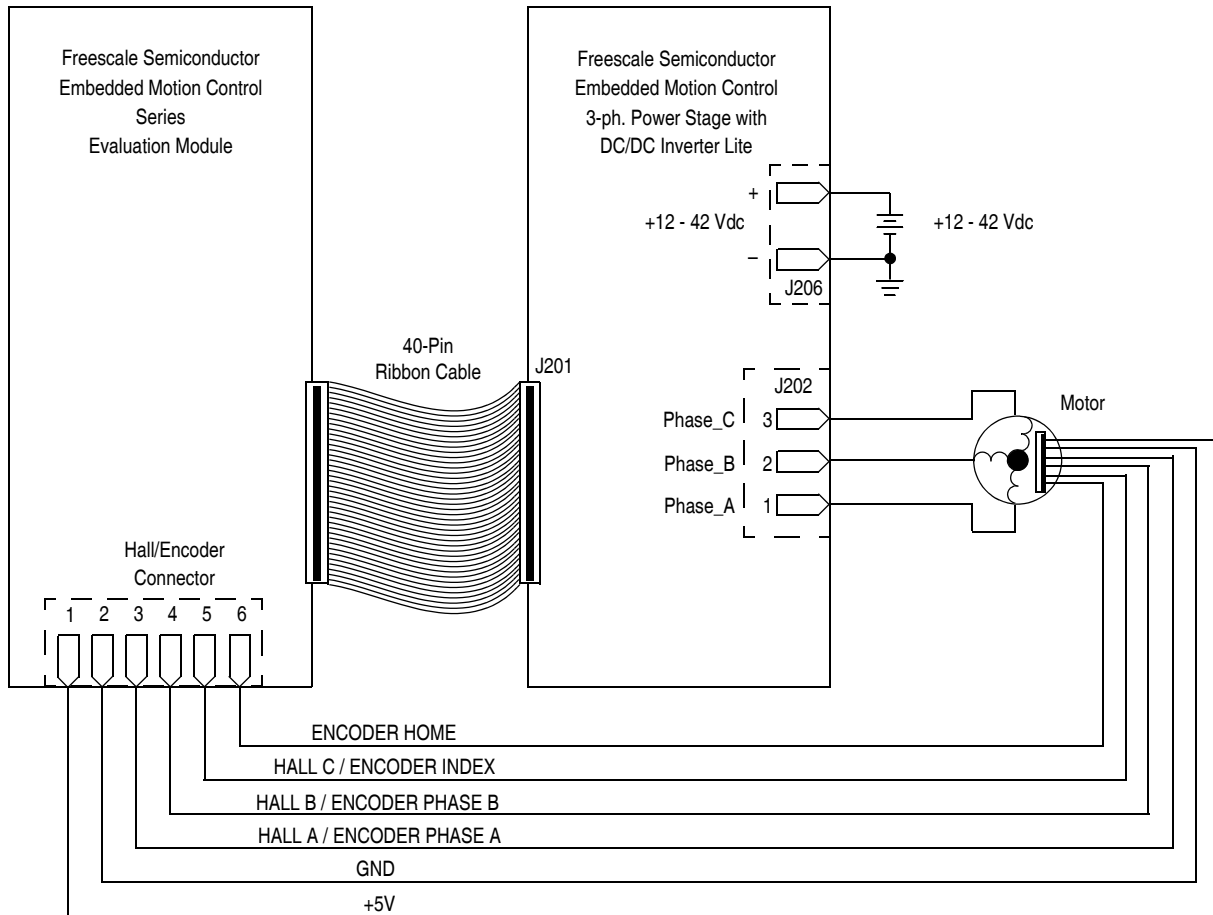


Figure 4-18. Motor Connections — Schematic View

Appendix A

Bill of Materials

The 3-Phase Power Stage with DC/DC Inverter Lite's bill of materials is described in the following parts list.

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

Qty.	Reference	Part Value	Description	Mfg.	Mfg. Part No.
3	C221, C222, C223	33nF/25V	Ceramic capacitor, 0805, 33nF/25V	Phycomp	2238 910 15643
3	C301, C302, C303	22000µF/50V	Electrolytic Capacitor 16mm, 2200µF/50V	Panasonic	ECA1HHG222
19	C304, C305, C405, C408, C311, C401, C415, C418, C422, C423, C424, C505, C506, C508, C510, C602, C522, C523, C528	100nF/50V	Ceramic capacitor, 0805, 100nF/50V	AVX	08055C104KAT2A
1	C306	47µF/50V	Electrolytic Capacitor 8mm, 47µF/50V	Rubycon	50RX3047MEFG8X11.5
2	C403, C406	4.7µF/25V	Ceramic capacitor, 1206, 4.7µF/25V	Kemet	C1206C475K3PAC
2	C404, C414	22µF/50V	Electrolytic capacitor, SMD 6.3mm, 22µF/50V	Nichicon	UUD1H220MCR1GS
2	C407, C417	10µF/25V	Electrolytic capacitor, SMC 5mm, 10µF/25V	Nichicon	UWX1E100MCR1GB
1	C411	33nF/50V	Ceramic capacitor, 0805, 33nF/50V	Phycomp	2238 580 15643
2	C413, C416	1µF/25V	Ceramic capacitor, 0805, 1µF/25V	Multicomp	T0805F105ZNT
1	C421	10µF/16V	Electrolytic capacitor, SMB 4mm, 10µF/16V	Panasonic	EEVFC1C100R
2	C502, C525	330pF/100V	Ceramic capacitor, 0805, 330pF/100V	Multicomp	A0805C331JNT
1	C503	1500pF/50V	Ceramic capacitor, 0805, 1500pF/50V	Phycomp	2238 5871 5625
3	C504, C519, C520	10pF/100V	Ceramic capacitor, 0805, 10pF/100V	Multicomp	A0805C100JNT
1	C507	100µF/6.3V	Electrolytic capacitor, SMD 6.3mm, 100µF/6.3V	BC COMPONENTS VISHAY	2222 1536 3101
2	C509, C521	3.3µF/50V	Electrolytic capacitor, SMB 4mm, 3.3µF/50V	Nichicon	UWX1H3R3MCR1GB

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

Qty.	Reference	Part Value	Description	Mfg.	Mfg. Part No.
1	C515	2.2 μ F/16V	Ceramic capacitor, 1206, 2.2 μ F/16V	Murata	GRM31MR71C225KA35L
1	C516	4.7 μ F/16V	Ceramic capacitor, 1206, 4.7 μ F/16V	Murata	GRM31MF51C475ZA12L
1	C517	1 μ F/16V	Ceramic capacitor, 0805, 1 μ F/16V	Murata	GRM21BR71C105KA01L
1	C518	330nF/16V	Ceramic capacitor, 0805, 330nF/16V	Multicomp	B0805R334KNT
1	C524	100 μ F/16V	Electrolytic capacitor, SMD 6.3mm, 100 μ F/16V	Nichicon	UWX1C101MCR1GB
1	C526	1nF/50V	Ceramic capacitor, 0805, 1nF/50V	Phycomp	2238 580 15623
1	C527	1 μ F/10V	Ceramic capacitor, 0805, 1 μ F/10V	Multicomp	N0805R105KNT
1	C529	10nF/50V	Ceramic capacitor, 0805, 10nF/50V	Multicomp	U0805R103KNT
2	D205, D206	SMD LED Green	LED, green, 0805	Fairchild Semiconductor	QTLP630C-4
1	D207	SMD LED Yellow	LED, yellow, 0805	Fairchild Semiconductor	QTLP630C-3
8	D301, D302, D304, D305, D306, D307, D308, D309	MBRM140T3G	Diode 1A/40V, CASE457	On Semiconductor	MBRM140T3G
4	D310, D311, D312, D313	1PMT5930BT1G	Zener diode 16V/3W	On Semiconductor	1PMT5930BT1G
1	D303	SS16T3	Diode 1A/60V, SMA	On Semiconductor	SS16T3
1	D501	MMSD914T1G	Diode 200mA/100V, SOD-123	On Semiconductor	QTLP630C-4
1	D502	SS26T3	Diode 2A/60V, SMB	On Semiconductor	SS26T3
1	D506	MBRA160T3	Diode 1A/60V, SMA	On Semiconductor	MBRA160T3
1	D507	MBRA120ET3	Diode 1A/20V, SMA	On Semiconductor	MBRA120ET3
2	D508, D509	MMSD4148T1G	Diode 200mA/100V, SOD-123	On Semiconductor	MMSD4148T1G
1	HS301	TV101	Heatsink for TO220	AAVID Thermalloy	TV101
1	J201	CON/40	Header 40 pins breakaway connector	Multicomp	MC9A12-2034
1	J202	3-way connector	3-way straight connector	Molex	39-26-3030
1	J206	Power Jack	Power Jack type connector 2.1 mm	Switchcraft	RAPC722
7	J209, J210, J212, J213, J214, J215, J216	Test point	Test point	Keystone	5002
1	JP401	Header 2.54mm, 3x1	Header 2.54mm, 3x1	Molex	90120-0763
2	JP501, JP502	Header 2.54mm, 2x1	Header 2.54mm, 2x1	Molex	90120-0762

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

Qty.	Reference	Part Value	Description	Mfg.	Mfg. Part No.
1	L301	560 μ H/6A 390 μ H/5A	Power Inductor	Coilcraft	PCV2-564-06 PCV1-394-05
1	L501	33 μ H/1.5A	SM Power Inductor	Coilcraft	MSS7341-333MXB
1	L503	330 μ H/0.6A	SM Power Inductor	Coilcraft	DO3316P-334
7	Q301, Q302, Q303, Q305, Q306, Q307, Q308	Si4470EY	N-channel SO8 MOSFET, 60V/12.7A	Vishay	Si4470EY
2	Q304, Q309	NTP75N06G	N-channel TO220 MOSFET, 60V/75A	On Semiconductor	NTP75N06G
7	R201, R202, R203, R219, R220, R329, R330	0R0	Resistor 0 Ω , 0805	Multicomp	MC 0.1W 0805 0R
1	R216	3k	Resistor 3k Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 3K
2	R217, R218	1k	Resistor 1k Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 1K
3	R221, R222, R223	10R-1%	Resistor 10 Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 10R
4	R302, R313, R317, R321	6.8R	Resistor 6.8 Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 6R8
4	R304, R311, R315, R319	3.3R	Resistor 3.3 Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 3R3
9	R303, R305, R312, R314, R316, R318, R320, R322, R328	10R	Resistor 10 Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 10R
2	R306, R307	10R/5W	Power Resistor 10 Ω , 5W	Welwyn	MO5S-10RJI
1	R327	0.040R 1%	Shunt Resistor 40m Ω , 1%	Vishay (Isabellenhuetten)	LVR-3 0.040 1% (PMA-A-R040-1)
10	R401, R402, R403, R404, R411, R412, R413, R414, R415, R421	4.7k	Resistor 4.7k Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 4K7
6	R501, R604, R614, R624, R634, R644	43k-1%	Resistor 43k Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 43K
1	R502	10k-1%	Resistor 10k Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 10K
1	R503	300k-1%	Resistor 300k Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 300K
9	R504, R601, R602, R603, R606, R611, R612, R613, R616	100k-1%	Resistor 100k Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 100K
1	R505	27k	Resistor 27k Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 27K
1	R508	180R	Resistor 180 Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 180R
1	R509	820R-1%	Resistor 820 Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 820R
1	R510	430R-1%	Resistor 430 Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 430R
1	R511	130R-1%	Resistor 130 Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 130R
3	R512, R615, R617	1.5k-1%	Resistor 1.5k Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 1K5
1	R513	68k	Resistor 68k Ω , 5%, 0805	Multicomp	MC 0.1W 0805 5% 68K
1	R514	1M-1%	Resistor 1M Ω , 1%, 0805	Multicomp	MC 0.1W 0805 1% 1M

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

Qty.	Reference	Part Value	Description	Mfg.	Mfg. Part No.
1	R515	18k-1%	Resistor 18kΩ, 1%, 0805	Multicomp	MC 0.1W 0805 1% 18K
1	R516	91k-1%	Resistor 91kΩ, 1%, 0805	Multicomp	MC 0.1W 0805 1% 91K
1	R517	33k-1%	Resistor 33kΩ, 1%, 0805	Multicomp	MC 0.1W 0805 5% 33K
1	R518	330k-1%	Resistor 680kΩ, 1%, 0805	Multicomp	MC 0.1W 0805 1% 330K
5	R605, R615, R625, R635, R645	3k-1%	Resistor 3kΩ, 1%, 0805	Multicomp	MC 0.1W 0805 1% 3K
2	R661, R666	150k-1%	Resistor 150kΩ, 1%, 0805	Multicomp	MC 0.1W 0805 1% 150K
2	R662, R665	51k-1%	Resistor 51kΩ, 1%, 0805	Multicomp	MC 0.1W 0805 1% 51K
2	U401, U402	MC33883	Full bridge MOSFET pre-driver	Freescale Semiconductor	MC33883
1	U403	MAX628CSA MAX627CSA	MOSFET pre-driver	Maxim	MAX628CSA MAX627CSA
2	U404, U405	MC74VHCT50AD R2G	Hex buffer	On Semiconductor	MC74VHCT50ADR2G
1	U501	LT1977EFE	Step-down switching regulator	Linear Technology	LT1977EFE
1	U503	MC78PC33NTR	Linear regulator 3.3V	On Semiconductor	MC78PC33NTR
1	U504	LM385BD-2.5G	Linear voltage reference 2.5V	On Semiconductor	LM385BD-2.5G
1	U505	LT3433EFE	Step-down/up switching regulator	Linear Technology	LT3433EFE
1	U603	LM6144AIM MC33204D	Quad channel rail-to-rail operational amplifier	National Semiconductor On Semiconductor	LM6144AIM MC33204D

Appendix B

PCB

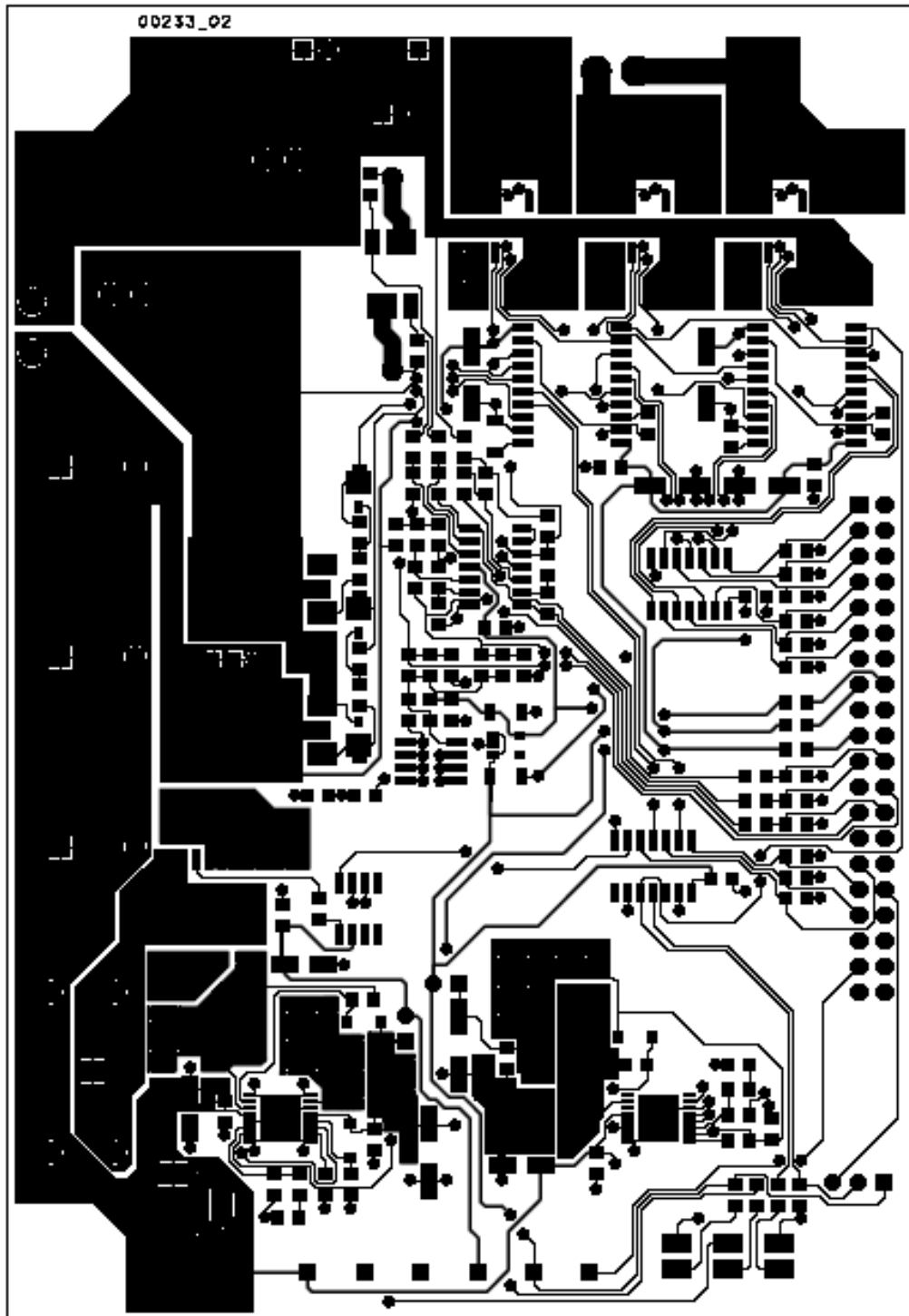


Figure B-1. Top Copper Layer

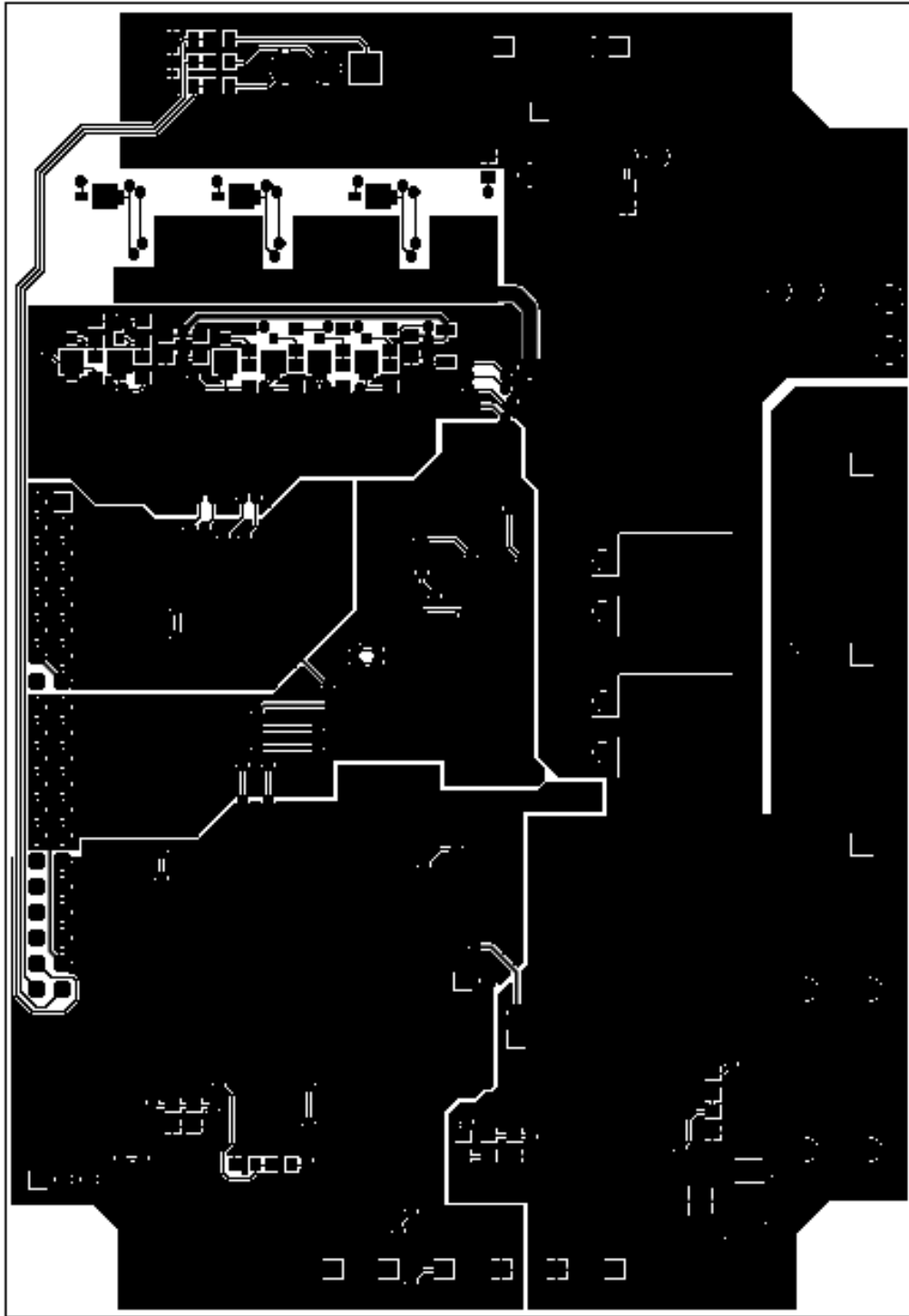


Figure B-2. Bottom Copper Layer (from bottom)

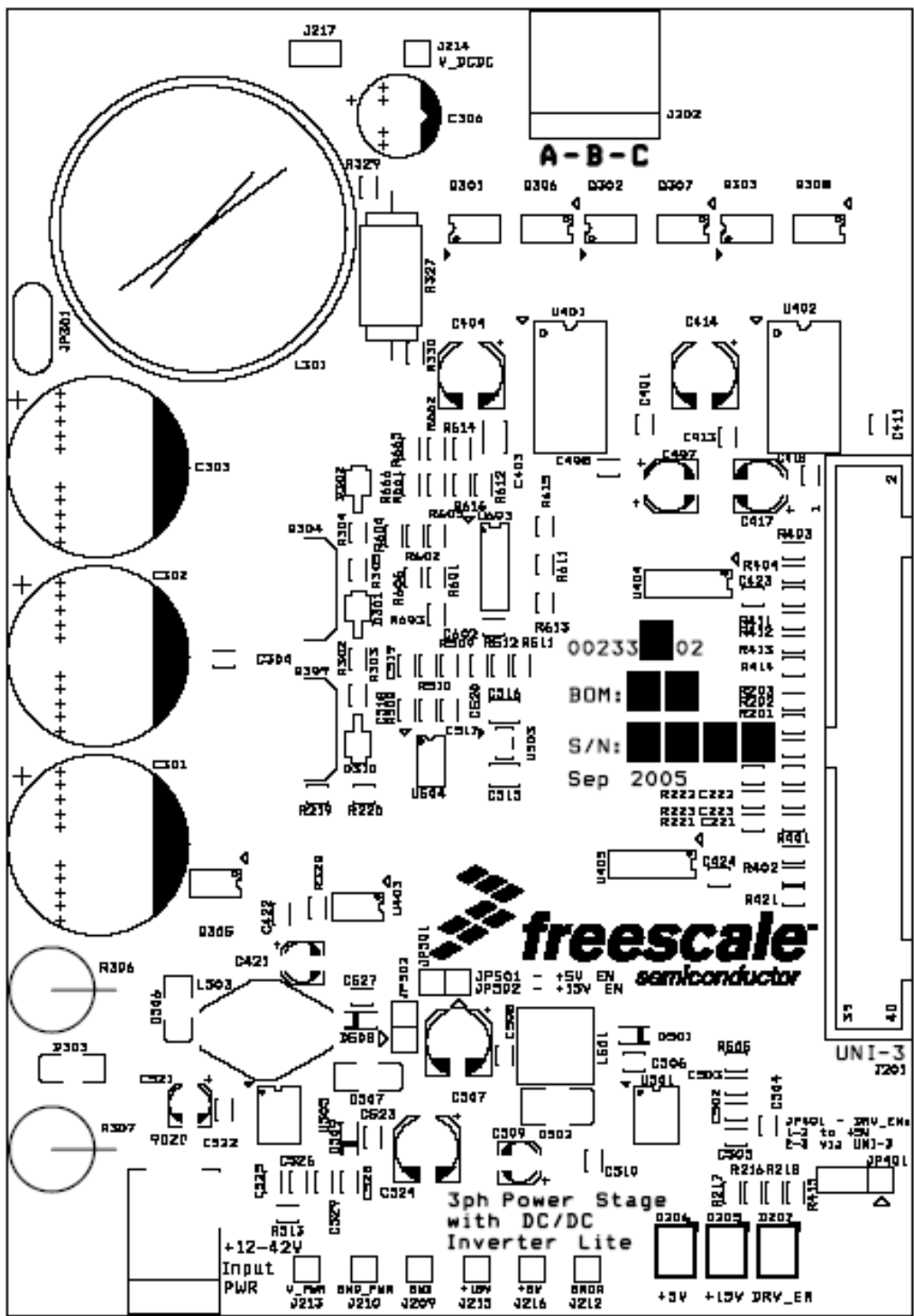


Figure B-3. Top Silkscreen Layer

3-Phase Power Stage with DC/DC Inverter Lite, Rev. 0

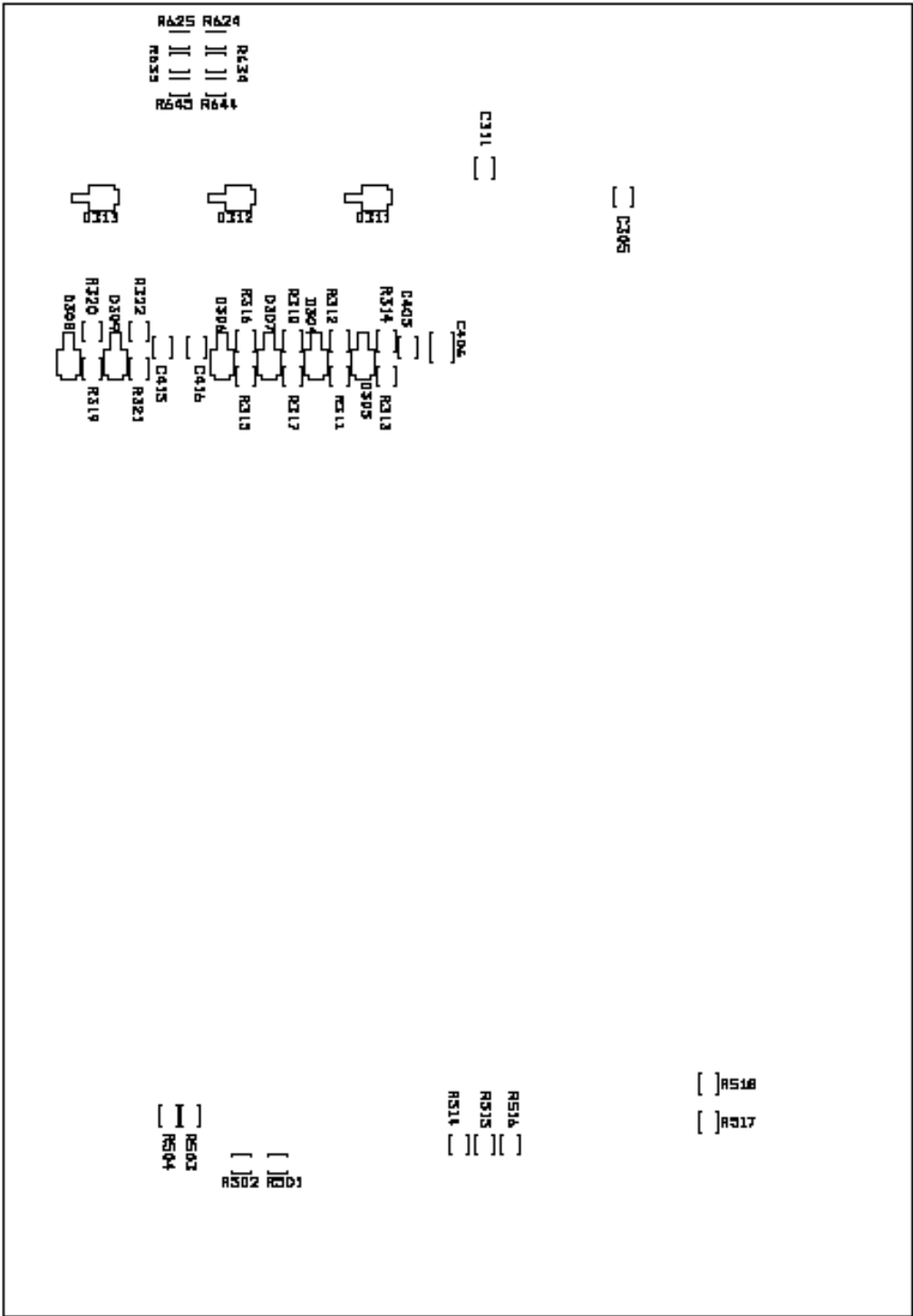


Figure B-4. Bottom Silkscreen Layer (from bottom)

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