DRV830x-HC-C2-KIT Hardware Reference Guide

1 Introduction

The Medium Voltage Digital Motor Control (DMC) kit (DRV830x-HC-C2-KIT, Figure 1), provides a great way to learn and experiment with digital control of medium voltage brushless motors to increase efficiency of operation. The board is available in two configurations, the DRV8301-HCEVM or the DRV8302-HC-EVM. This document goes over the kit contents and hardware details, and explains the functions and locations of jumpers and connectors present on the board.

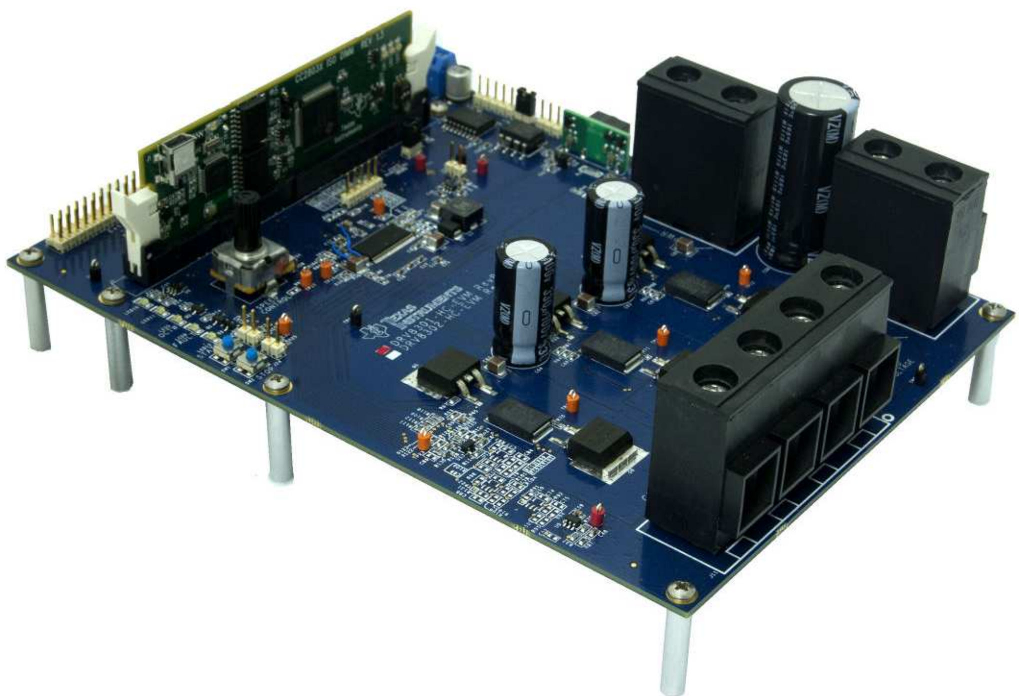

Figure 1. The Evaluation Board

WARNING

This EVM is meant to be operated in a lab environment only and is not considered by TI to be a finished end-product fit for general consumer use. It is the user's responsibility to confirm that the voltages and isolation requirements are identified and understood, prior to energizing the board and or simulation. When energized, the EVM or components connected to the EVM should not be touched.

General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines

WARNING

Always follow TI’s setup and application instructions, including use of all interface components within their recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and those working around you. Contact TI's Product Information Center http://support/ti./com for further information.

Save all warnings and instructions for future reference.

Failure to follow warnings and instructions may result in personal injury, property damage, or death due to electrical shock and burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is **intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments**. If you are not suitable qualified, you should immediately stop from further use of the HV EVM.

1. Work Area Safety
   (a) Keep work area clean and orderly.
   (b) Qualified observer(s) must be present anytime circuits are energized.
   (c) Effective barriers and signage must be present in the area where the TI HV EVM and its interface electronics are energized, indicating operation of accessible high voltages may be present, for the purpose of protecting inadvertent access.
   (d) All interface circuits, power supplies, evaluation modules, instruments, meters, scopes and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
   (e) Use stable and nonconductive work surface.
   (f) Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
2. Electrical Safety
   As a precautionary measure, it is always a good engineering practice to assume that the entire EVM may have fully accessible and active high voltages.
   (a) De-energize the TI HV EVM and all its inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   (b) With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment connection, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   (c) After EVM readiness is complete, energize the EVM as intended.

   WARNING: WHILE THE EVM IS ENERGIZED, NEVER TOUCH THE EVM OR ITS ELECTRICAL CIRCUITS AS THEY COULD BE AT HIGH VOLTAGES CAPABLE OF CAUSING ELECTRICAL SHOCK HAZARD.
3. Personal Safety
   (a) Wear personal protective equipment (for example, latex gloves or safety glasses with side shields) or protect EVM in an adequate lucent plastic box with interlocks to protect from accidental touch.

Limitation for safe use:

EVMs are not to be used as all or part of a production unit.

2 Getting Familiar with the Kit

2.1 Kit Contents

The DRV830x Digital Motor Control Kit contains:

- F28035 controlCARD
- DRV830x DMC board with slot for the controlCARD
- USB Cable
- USB Stick with CCStudio IDE, GUI, Quick Start Guide, and controlSUITE installer for further documentation

The DRV830x-HC-EVM board can accept any of the C2000 series controlCARDs, but we recommend using the CC28035 ISO DIMM control card with the onboard JTAG emulator shipped with the kit. The F28035 controlCARD has the source code already pre-flashed in memory to allow it to work out of the box with the Quick Start GUI.

2.2 Kit Features

The kit has the following features:

- Three-Phase Power Stage, DRV830x capable of driving 3-phase brushless DC motors and Permanent Magnet Synchronous Motors.
  - 60V DC max input voltage
  - 60A peak output current per phase
  - Up to 200KHz driver switching frequency
  - Integrated 1A buck converter to provide logic and analog power
  - Dual integrated current sense amplifiers
- Isolated CAN and SPI communication
- Closed-loop digital control with feedback using the C2000's on-chip PWM and ADC peripherals
- On-board isolated JTAG emulation through the SCI peripheral and the FTDI chip.
- JTAG connector for external emulators
- Quadrature Encoder Interface available for speed and position measurement
- Hall Sensor Interface for sensored three-phase motor control
- High precision low-side current sensing using the C2000's high-performance ADC and current sense amplifiers integrated into the DRV830x
- Four PWM DAC's generated by low pass filtering the PWM signals to observe the system variables on an oscilloscope to enable easy debug of control algorithms.
- Over current protection on the inverter stage, DRV830x
- Hardware Developer's Package that includes schematics and bill of materials is available through controlSUITE.

The software available with the kit is completely open source, and hence can be easily modified to tune and run a customer's motor.

2.3 Warning Regarding Low Switching Frequencies on the DRV830x

When the DRV830x runs at a low switching frequency (e.g. less than 20 kHz with 100 nF bootstrap capacitor), the bootstrap capacitor voltage might not be able to maintain a proper voltage level for the high-side gate driver. A bootstrap capacitor under voltage protection circuit (BST_UVP) will start under this circumstance to prevent the potential failure of the high-side MOSFET.

In this circumstance, both the FAULT and OTW pins should pull low and the device should selfprotect itself. The motor's inductance and the inverter's bootstrap capacitance will allow the DRV830x to run efficiently until approximately 10 kHz (with margin). Setting the PWM switching frequency below 10 kHz may cause issues on the inverter output and is not recommended. Please reference the datasheet.

3 Hardware Overview

Figure 2 illustrates a typical motor drive system running from a laboratory power supply. The DRV830x-HC-C2-KIT's motor control board has all the power and control blocks that constitute a typical motor drive system for a PMSM or BLDC motor.

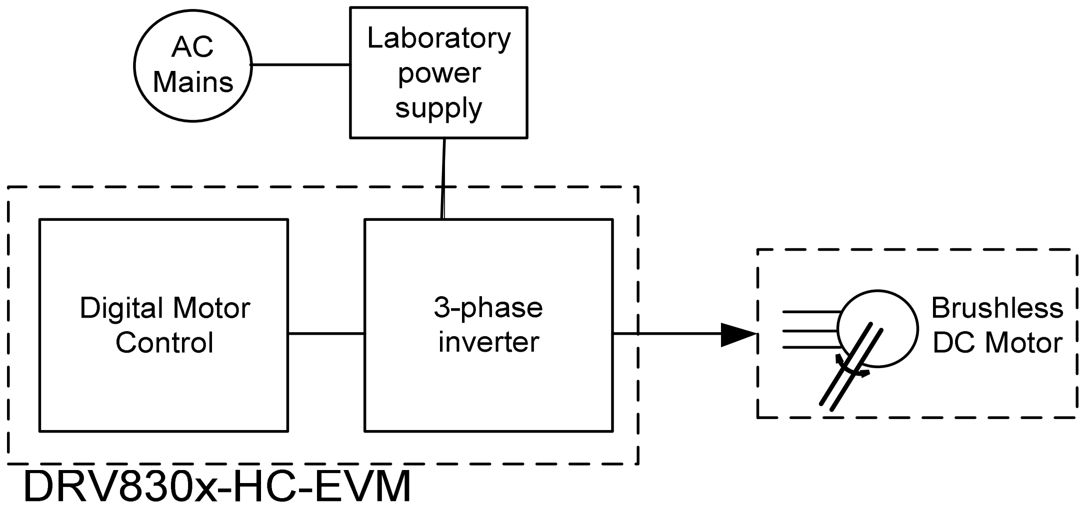

Figure 2. Block Diagram for a Typical Motor Drive System Using

3.1 Macro Blocks

The motor control board is separated into functional groups that enable a complete motor drive system, these are referred to as macro blocks. Following is a list of the macro blocks present on the board and their functions:

- ISO controlCARD socket – Socket for a C2000 controlCARD with a built-in isolated XDS100 emulator.
- DC Bus Connection
  - "PVDD/GND" Terminals – Connect an external 8-60V DC lab supply here making sure to observe correct polarity.
- DRV830x – This module includes either the DRV8301 or DRV8302 Three Phase Pre- Driver as well as all of the necessary external passive components.
- Current Sense – Low-side shunt current sensing on each half-bridge.
- Quadrature Encoder Connections – Connections are available for an optional shaft encoder to interface to the MCU's QEP peripheral.
- Hall Effect Sensor Connections – Connections are available for optional Hall Effect Sensors.

Figure 3 illustrates the position of these macro blocks on the board. The use of a macro block approach, for different power stages enables easy debug and testing of one stage at a time. All the PWM's and ADC signals which are the actuation and sense signals have designated test points on the board, which makes it easy for an application developer to try out new algorithms and strategies.

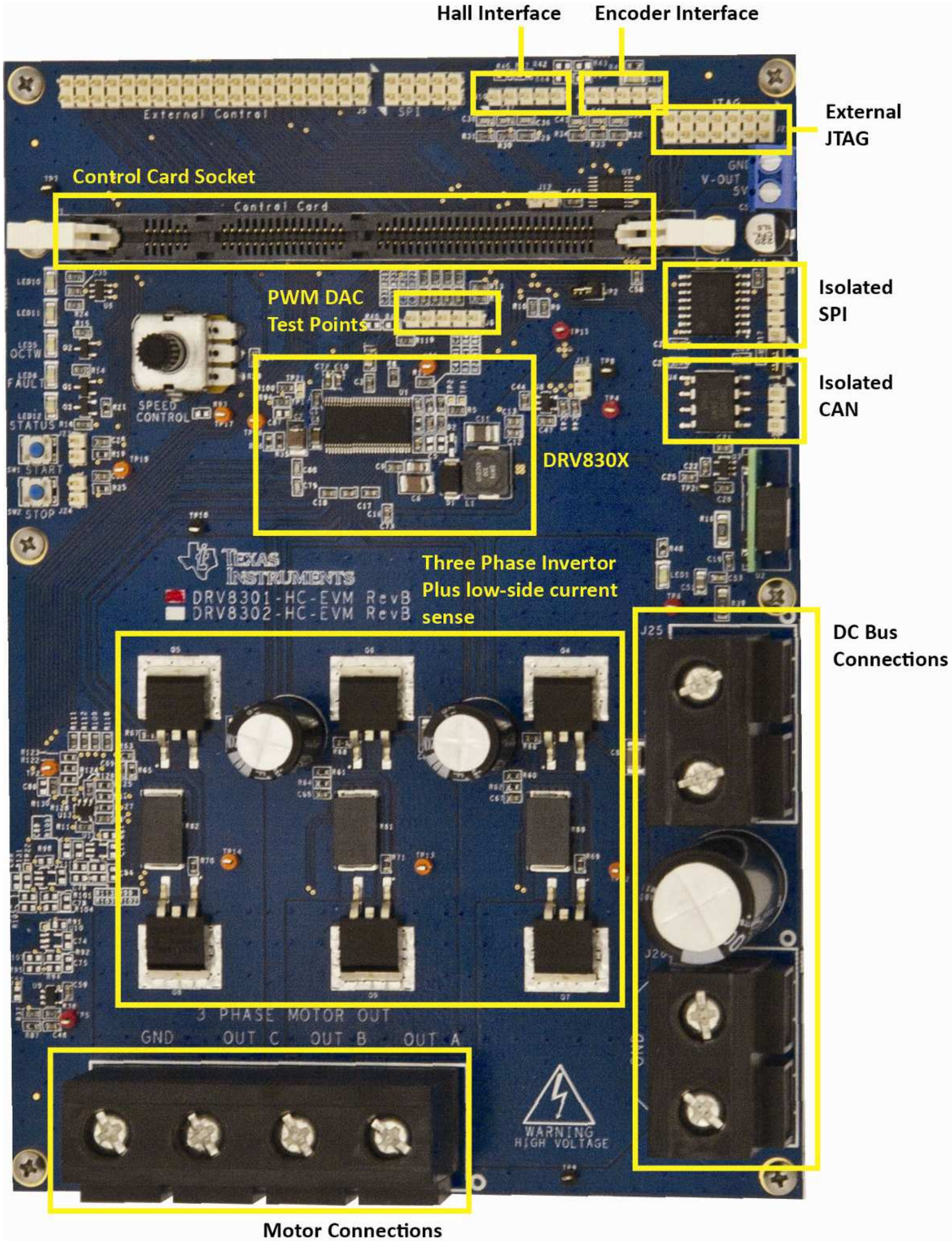

Figure 3. DRV830x-EVM Board Macros

3.2 Powering the Board

The board is separated into two power domains*, the low voltage Controller Power domain that powers the controller and the logic circuit present on the board, and the medium voltage power delivery line that is used to carry the medium voltage and current like the DC power for the Inverter also referred to as DC Bus.

1. Controller Power comprises of the 5V and 3.3V that the board uses to power the controller and the logic and sensing circuit present on the board. This power is regulated from the DC bus by the DRV830x integrated buck converter.
2. DC Bus Power is the medium voltage line – up to 60V - that provides the voltage to the inverter stage to generate 3 phases to control the motor

NOTE: Do not apply power to board before you have verified these settings!

The kit ships with the control card inserted and the jumper and switch settings pre done for connecting with the GUI. However the user must ensure that these settings are valid on the board.

1. Make sure nothing is connected to the board, and no power is being supplied to the board.
2. Insert the Control card into the controlCARD connector if not already populated.
3. Make sure the following jumpers & connector settings are valid i.e.
   - JP2 is installed
4. Make sure that the following switches are set as described below on the F28035 control card to enable boot from flash and connection to the SCI
   - SW3 is in the UP (OFF) position (towards top of control card)
   - SW2 on controlCARD, Position 1 = UP (ON), Position 2 = UP (ON)
5. Connect a USB cable from computer to USB connector on control card
6. Connect the motor you want to spin to the “MOTOR” terminal block as shown inFigure 4.

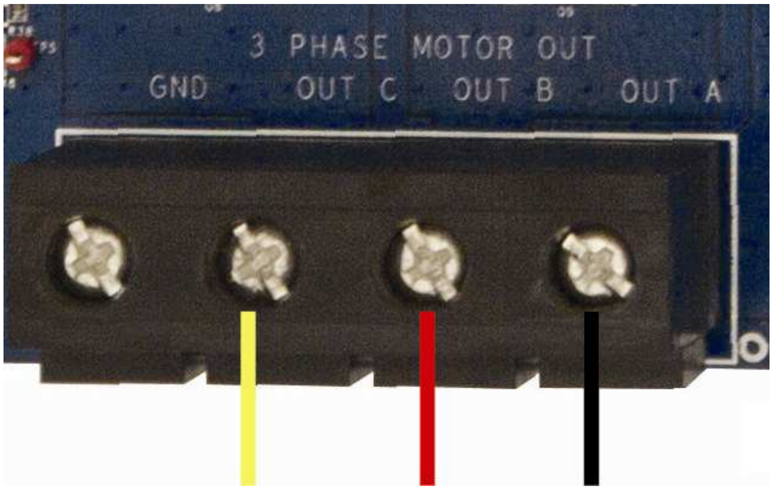

Figure 4. DRV830x-HC-EVM Motor Connections

7. Connect an 8-60V DC power supply to the PVDD and GND terminals

3.3 controlCARD Settings

- LD1 – Turns on when controlCARD is powered on
- LD2 – controlled by GPIO-31
- LD3 – controlled by GPIO-34
- LD4 – USB-mini connection
- SW2 – controls the boot options of the F28035 device

Table 1. controlCARD Boot Options

Position 1 (GPIO-34)	Position 2 (TDO)	Boot from
0	0	Parallel I/O
0	1	Wait mode
1	0	SCI
1	1	(default) Get mode; the default get mode is boot from FLASH

- SW3 – TRSTn Control

  This switch is used to connect or disconnect the TRSTn pin that is used for the JTAG emulation. When JTAG connection is needed for the board the SW3 should be in ON position. For booting from FLASH or other boot options (no JTAG connection needed) this pin should be in the OFF (UP) position.

3.4 GUI Connection

The FTDI chip present on the controlCARD can be used as an isolated SCI for communicating with a HOST i.e. PC. The following jumper settings must be done to enable this connection.

As the GUI software is provided for F28035 controlCARD only, F28035 settings are discussed below:

1. For F28035, put SW3 on the F28035 Control Card to UP position (towards top of card)
2. Connect a USB cable from J1 (on control card) to host PC.

NOTE: If you are going to boot from Flash & connecting using the GUI, you would need to do the Boot from Flash settings as described in the Table 1.

4 Hardware Resource Mapping

4.1 Resource Allocation

Table 2 lists the GPIO and ADC resource allocation for the board.

Table 2. GPIO and ADC Resource Allocation

J1 Pin no.	GPIO	Signal Name	Function (DRV8301/DRV8302)
23	GPIO-00	PWM_AH	DRV830x Phase AH PWM input
73	GPIO-01	PWM_AL	DRV830x Phase AL PWM input
24	GPIO-02	PWM_BL	DRV830x Phase BH PWM input
74	GPIO-03	PWM_BL	DRV830x Phase BL PWM input
25	GPIO-04	PWM_CH	DRV830x Phase CH PWM input
75	GPIO-05	PWM_CL	DRV830x Phase CL PWM input
26	GPIO-06	DAC_PWM4	PWM DAC
76	GPIO-07	STOP	Push button input
28	GPIO-08	DAC_PWM3	PWM DAC
78	GPIO-09	START	Push button input
29	GPIO-10	DAC_PWM1	PWM DAC
79	GPIO-11	DAC_PWM2	PWM DAC
33	GPIO-12	LED-1	User LED
83	GPIO-13	OCTWn	Over-temperature warning
84	GPIO-14	FAULTn	Over-current fault
34	GPIO-15	LED-2	User LED
38	GPIO-16	SPI-SIMO	Isolated SPI Interface
88	GPIO-17	SPI-SOMI	Isolated SPI Interface
39	GPIO-18	SPI-CLK	Isolated SPI Interface
89	GPIO-19	SPI-STE	Isolated SPI Interface
40	GPIO-20	QEPA	Encoder A
90	GPIO-21	QEPB	Encoder B
41	GPIO-22	STATUS	User LED
91	GPIO-23	QEPI	Encoder Index
35	GPIO-24	SDI	SPI Data In/M_DC
85	GPIO-25	SDO	SPI Data Out/GAIN
36	GPIO-26	SCLK	SPI ClockDC_ADJ
86	GPIO-27	/SCS	/SCS/M_PWM
44	GPIO-30	CAN-RX	Isolated CAN Interface
94	GPIO-31	CAN-TX	Isolated CAN Interface
30	GPIO-40	CAP1	Hall Input 1
80	GPIO-41	CAP2	Hall Input 2
31	GPIO-42	CAP3	Hall Input 3
81	GPIO-43	DC-CAL	Short DC current sense amplifier inputs to ground, calibrate offset
59	ADC-A1	IA-FB	Current sense phase A
61	ADC-A2	I-TOTAL	DC Bus current sense

Table 2. GPIO and ADC Resource Allocation (continued)

63	ADC-A3	IC-FB	Current sense phase C
67	ADC-A5	IC-FB	Current sense phase C
71	ADC-A7	ADC-Vhb2	Phase Voltage sense B
7	ADC-B0	TSI	Tach/Pot input
9	ADC-B1	IB-FB	Current sense phase B
11	ADC-B2	VDCBUS	DC Bus voltage sense
13	ADC-B3	IA-FB	Current sense phase A
15	ADC-B4	ADC-Vhb3	Phase Voltage sense C
17	ADC-B5	IB-FB	Current sense phase B
21	ADC-B7	ADC-Vhb1	Phase Voltage sense A

4.2 Jumpers and Connectors

The tables in this section show the various connections available on the board.

Table 3. List of Connectors

Connector Reference	# of Pins	Name
J2	2	HEADER2x1
J4	5	HEADER5x1
J5	40	HEADER20x2
J6	5	HEADER5x1
J7	3	HEADER3x1
J8	5	HEADER5x1
J10	5	HEADER5x1
J11	4	TERM BLOCK HEADER4x1
J12	2	HEADER2x1
J13	2	HEADER2x1
J20	10	HEADER5x2
J21	14	HEADER7x2
J23	2	HEADER2x1
J24	2	HEADER2x1
J25	2	TERM BLOCK HEADER2X1
J26	2	TERM BLOCK HEADER2X2

Table 4. Board Connections

Pin #	Signal
J2 (User Power Access)	
1	VCC_5V
2	GND
J4 (Optional Encoder)	
1	E1A
2	E1B
3	E1C
4	VCC_5V
5	GND
J6 (PWM DAC)	
1	DAC1
2	DAC2
3	DAC3
4	DAC4
5	GND
J7 (CAN)	
1	CAN-H
2	CAN-L
3	IGND
J8 (User SPI)	
1	iSD-O
2	iCLK-O
3	iSD-I
4	iGPIO
5	IGND
J10 (HALL Sensor)	
1	E2A
2	E2B
3	E2C
4	VCC_5V
5	GND
J11 (Motor)	
1	Phase A
2	Phase B
3	Phase C
4	GND
J12 (GPIO/SCI)	
1	GPIO-28
2	GPIO-29
J13 (User Power Access)	
1	VCC_3.3V
2	GND
J20 (DRV8301 SPI)	
1	NC
2	GND
3	NC
4	NC
5	SDO

Table 4. Board Connections (continued)

6	NC
7	SCLK
8	SDI
9	SCS
10	GND
J23 (Push Button)	
1	START
2	GND
J24 (Push Button)	
1	STOP
2	GND
J21 (External JTAG)	
1	TMS
2	TRSTn
3	TDI
4	GND
5	VCC_3.3V
6	NC
7	TDO
8	GND
9	TCK
10	GND
11	TCK
12	GND
13	EMU0
14	EMU1
J25 (Power Input)	
1	PVDD
2	PVDD
J26 (Power Input)	
1	GND
2	GND
J5 (External Controller Access)	
1	VCC_5V
2	GND
3	VCC_5V
4	GND
5	STATUS
6	EN_GATE
7	QEPA
8	QEPI
9	FAULTn
10	QEPB
11	CAP3
12	OCTWn
13	DC_CAL
14	CAP1
15	DAC_PWM1

Table 4. Board Connections (continued)

16	CAP2
17	DAC_PWM3
18	DAC_PWM2
19	GND
20	GND
21	DACE_PWM4
22	PWM_CL
23	PWM_AL
24	PWM_BL
25	PWM_AH
26	PWM_CH
27	GND
28	PWM_BH
29	ADC-Vhb1
30	GND
31	ADC-Vhb2
32	ADC-Vhb3
33	IC-FB
34	VDCBUS
35	I_TOTAL
36	IB-FB
37	IA-FB
38	TSI
39	GND
40	GND

Table 5. Test Points

Test Point	Net Connection
TP1	VCC_5V
TP2	VCC_5V_R5
TP3	PWRGD
TP4	VCC_3.3V
TP5	REF_1.65V
TP6	PVDD
TP7	GND
TP8	GND
TP9	GND
TP10	GND
TP11	VCC_5V
TP12	SH_A
TP13	SH_B
TP14	SH_C
TP15	S02
TP16	IB-FB
TP17	IA-FB
TP18	U10_1
TP19	IC-FB

Table 5. Test Points (continued)

TP20	IGND
TP21	S01
TP22	U11_1
TP23	I-TOTAL

Table 6. Jumpers

Reference	Function
JP2	VCC_5V to controlCARD
JP4	CAN termination

Schematic Disclaimer and Warnings

Texas Instruments provides the DRV8430x-HC-C2_KIT schematic drawings and other design files to help users develop DRV8430x & C2000 based reference design products. These design files can be found at www.ti.com/tool/TIDM-THREEPHASE-BLDC-HC. Application safety, safety of the Medium Voltage DMC kit and design integrity of such reference designs are solely responsibility of the user. Any reference designs generated off these schematics must take into account necessary product safety design requirements, including interface components and load motors in order to avoid user risks including potential for fire hazard, electrical shock hazard and personal injury, including considerations for anticipated agency certification compliance requirements. Such product safety design criteria shall include but not be limited to critical circuit creepages and clearances, component selection, ratings compatibility of controlled motor loads, and required protective means (ie output fusing) depending on the specific loads being controlled. TI accepts no responsibility for design integrity of any reference designs based on supplied schematic drawings and the schematics are strictly for development purposes.