DRV8412-C2-KIT Hardware Reference Guide

1 Introduction

The Medium Voltage Digital Motor Control (DMC) kit, DRV8412-C2-KIT, provides a great way to learn and experiment with digital control of medium voltage motors to increase efficiency of operation (see Figure 1). This document describes the kit contents and the hardware details, and explains the functions and locations of the jumpers and connectors on the board.

Figure 1. DRV8412-C2-KIT

WARNING

This EVM is meant to be operated in a lab environment only and is not considered by Texas Instruments 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

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 DRV8412 Digital Motor Control Kit contains:

- F28035 controlCARD
- DRV8412 DMC board with slot for the controlCARD
- 2 brushed DC motors
- 8-wire bi-polar stepper motor
- USB Cable
- 24V AC/DC supply with 2.5A of current
- USB Stick with CCStudio IDE v4, GUI, Quick-Start Guide, and controlSUITE installer

The DRV8412EVM board can accept any of the C2000 series controlCARDs, but sinceJTAG is not included on the board, we recommend using a CC28035 ISO DIMM control card with the onboard JTAG emulator that is shipped with the kit. The F28035 controlCARD has the source code preflashed in memory, so it will work out of the box with the Quick Start GUI.

Figure 2 shows a kit assembly with 24V AC/DC supply, stepper motor, brushed DC motors, and the installed controlCARD.

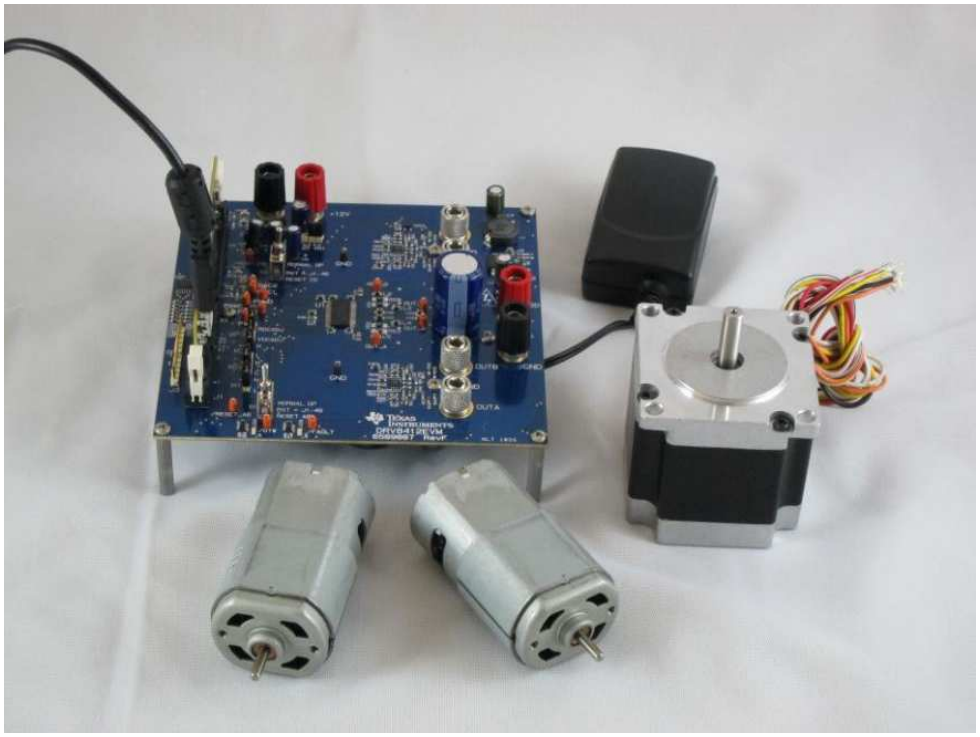

Figure 2. Kit Assembly

2.2 Kit Features

The kit has the following features:

- Dual H-Bridge Power Stage, DRV8412 capable of stepper motor control, dual brushed DC motor control or control of a single larger DC motor with a parallel H-bridge configuration
  - 52V DC max input voltage
  - 6A peak with a 3.5A max continuous output current
  - Up to 500khz driver switching frequency
- 12V control voltage can be supplied externally or regulated from the DC bus, and can be selected using JP1
- 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
- Quadrature Encoder Interface available for speed and position measurement
- High-precision, low-side current sensing using the C2000's high-performance ADC, the Texas Instruments OPA2350 high speed op-amps, and the Texas Instruments REF3025 high-precision voltage reference chip
- Two PWM DACs generated by low-pass filtering the PWM signals to observe the system variables on an oscilloscope to enable easy debugging of the control algorithms.
- Over-current protection on the inverter stage, DRV8412
- Hardware Developer's Package that includes schematics and bill of materials (BoM) is available through the controlSUITE.

The software available with the kit is pre-optimized for the motors that are available with the kit. The software is completely open source and can be easily modified to tune and run a different motor. The following motors are available with the kit:

Bi-polar Stepper Motor *(4.2A/phase (parallel) , 8-wire, 1.8°*/step)	
Brushed DC Motor *(12V, 0.92A)*	

(1) For more information, see *Microstepping of Bi-polar Stepper Motors* (Literature Number: TIDA013)

(2) For more information, see *Dual-Axis Current Control of Brushed DC Motors* (Literature Number: TIDA012)

Figure 3. Available Motors

2.3 Warning Regarding Low Switching Frequencies on the DRV8412

When the DRV8412 runs at a low switching frequency (for example, running at less than 20 kHz with a 47 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 case, both the FAULT and OTW pins will pull low and the device will self-protect itself. The motor's inductance and the inverter's bootstrap capacitance allows the DRV8412 to run efficiently until approximately 10 kHz (with margin). Setting the PWM switching frequency to below 10 kHz may cause issues on the inverter output and is not recommended.

3 Hardware Overview

Figure 4 shows a typical motor drive system that is running from either a laboratory power supply or from the 24V supply delivered with the KIT. The DRV8412-C2-KIT's motor control board has all the power and control blocks that constitute a typical motor drive system for a step motor or for a 2 brushed DC motors (Figure 3).

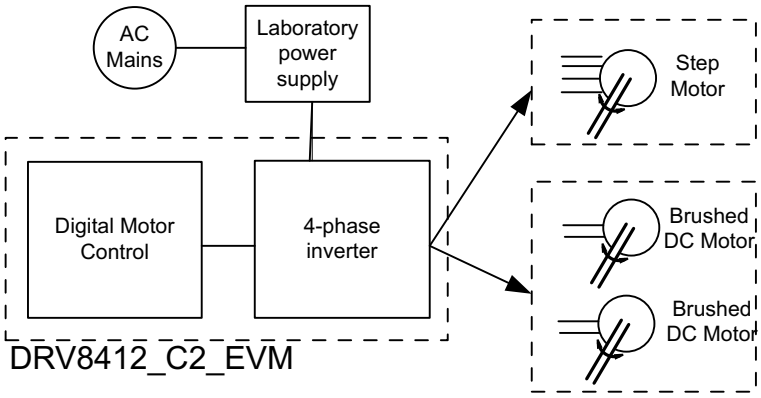

Figure 4. Block Diagram for a Typical Motor Drive System Using

3.1 Macro Blocks

The motor control board is separated into functional groups, referred to as macro blocks, that enable a complete motor drive system.

The macro blocks present on the board, and their functions, are listed here:

- **DC Bus Connection, "PVDD/GND" –** Connect the supplied +24V power supply here, while ensuring the power supply's polarity is correct
- **+12V Control Power Entry –** Connectors to optionally provide an external 12V supply for logic and gate drive power. The 12V supply can also be regulated on-board from the DC bus, depending on the setting of the JP1 jumper. Set to position "VR1" to use the on-board regulator. Set to position "+12V" to use an external regulator.
- **DRV8412 –** This module includes the DRV8412 Dual Full-Bridge PWM Motor Driver as well as all of the required, external passive components.
- **Current Sense –** Low-side shunt current sensing on each half-bridge.
- **Reset Switch –** Individual reset for each H-bridge. Reset can be forced manually from the 3-position switch or through a GPIO from the MCU. Setting the switch to the down position, "RESET AB, RESET CD" will disable the H-bridge outputs. Setting the switch to the middle position will allow control through a GPIO on the MCU. Setting the switch to the up position, "NORMAL OP", will disable control from the MCU and enable the H-bridge outputs.
- **Quadrature Encoder Connections –** Connections are available for an optional shaft encoder to interface to the MCU's QEP peripheral.
- **Mode Jumpers –** DRV8412 mode can be set to enable or disable the cycle-by-cycle current limit, latched over-current, and parallel or dual full-bridge mode. See Table 1.

Table 1. Mode Jumper Settings.

Mode Pins			Output Configuration	Description
M3	M2	M1		
0	0	0	2 full-bridge or 4 half-bridge	Dual full bridges (two PWM inputs for each full bridge) or four half bridges with cycle-by-cycle current limit
0	0	1	2 full-bridge or 4 half-bridge	Dual full bridges (two PWM inputs for each full bridge) or four half bridges with OC latching shutdown (no cycle-by-cycle current limit)
0	1	0	1 parallel full-bridge	Parallel full bridge with cycle-by-cycle (connect OUTA and OUTB together at terminals and connect OUTC and OUTD together at terminals)
0	1	1	2 full-bridge	Dual full bridges (one PWM input each full bridge with complementary PWM on second half bridge) with cycle-by-cycle current limit
1	x	x	Reserved	Reserved

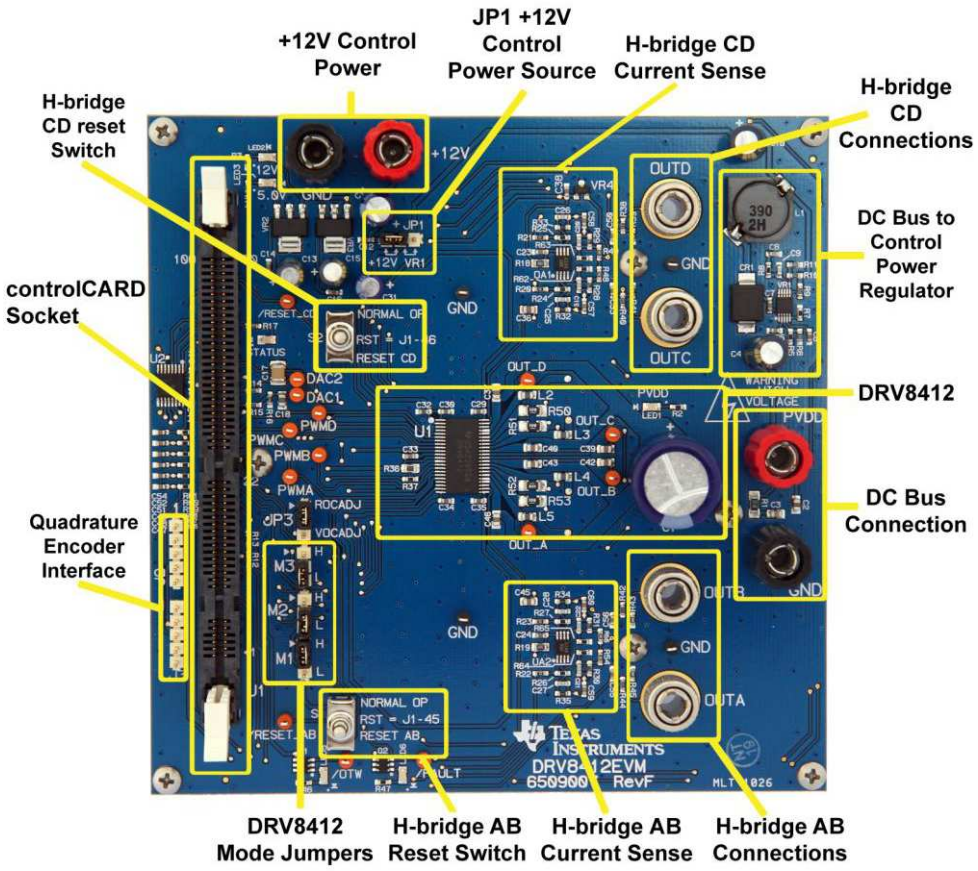

Figure 5. DRV8412-EVM Board Macros

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 on the board. The **medium-voltage power delivery line** that carries medium-voltage and current like the DC power for the inverter, also referred to as a DC Bus.

1. Controller Power cosists of the 12V, 5V and 3.3V that the board uses to power the controller, and the logic and sensing circuit on the board. This power can be sourced from one of two places, selected through the JP1 Jumper:
   - The +12V DC control power entry: Connect an external bench supply with 1A current limit here

     or
   - The on-board regulator, VR1: +12V is regulated from DC bus power via on board buck.
2. DC bus power is the medium-voltage line, carrying up to 52V, that provides the voltage to the inverter stage that is necessary to generate the 4 phases to control the motors.
   - Connect the supplied 24V-regulator to the PVDD and GND connectors.

CAUTION

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. Ensure nothing is connected to the board, and that power is not being supplied to the board.
2. Insert the control card into the J1 controlCARD connector, if not already populated.
3. Ensure the following jumpers and connector settings are valid on the DRV8412 base board:
   - JP1 is in the VR1 position
   - JP3 is in the ROCADJ position
   - M1 is in the H position, M2 is in the L position, and M3 is in the L position
   - Switches S1 and S2 are in the middle position
4. Ensure the following switches are set on the F28035 control card, as described below, to enable a boot from flash and a connection to the SCI
   - SW3 is in the OFF position (towards top of control card)
   - SW2 on controlCARD, Position 1 = ON, Position 2 = ON
5. Connect a USB cable from your computer to the USB connector on control card
6. Connect the motor you want to spin to the OUTA-OUTD terminals on the base board, as shown in Table 2.

Table 2. Motor Connection Table

Terminal	Brushed DC	Stepper
OUTA	Motor 1 +	Black,Orange/White
OUTB	Motor 1 -	Orange, Black/White
OUTC	Motor 2 +	Red, Yellow/White
OUTD	Motor 2 -	Yellow, Red/White

7. Connect power.

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 3. 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 that is on the board can be used as an isolated SCI for communicating with a HOST (such as a PC). The following jumper settings must be set to enable this connection.

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

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

NOTE: If you are going to boot from Flash and you are connecting using the GUI, you need to complete the "Boot from Flash" settings, as described in the Table 3.

4 Hardware Resource Mapping

4.1 Resource Allocation

Figure 6 shows various stages of the board in a block diagram format, and shows the major connections and feedback values that are being mapped to the C2000 MCU. Table 4 lists these resources.

Table 4. PWM and ADC Resource Allocation

J1 Pin no.	Signal Name	PWM Channel/ ADC Channel No Mapping	Function
23	GPIO-00	PWM-1A	Input to OUTA half-bridge
73	GPIO-01	PWM-1B	Input to OUTB half-bridge
24	GPIO-02	PWM-2A	Input to OUTC half-bridge
74	GPIO-03	PWM-2B	Input to OUTD half-bridge
29	GPIO-10	DAC1	Monitor input to channel 1 (low-pass filtered)
79	GPIO-11	DAC2	Monitor input to channel 2 (low-pass filtered)
83	GPIO-13	TZ-OTW	LOW = Over-temperature warning
			HIGH = Normal operation
84	GPIO-14	TZ-FAULT	LOW = Device fault condition
			HIGH = Normal operation
45	GPIO-32	RESET_AB	Resets OUTA/OUTB outputs
89	GPIO-19	RESET_CD	Resets OUTC/OUTD outputs
41	GPIO-22	Status LED	
40	GPIO-20	S1A	Encoder 1A
90	GPIO-21	S1B	Encoder 1B
91	GPIO-23	S1C	Encoder 1C
35	GPIO-24	S2A	Encoder 2A
85	GPIO-25	S2B	Encoder 2B
36	GPIO-26	S2C	Encoder 2C
57	ADC-A0	ID_FB	Current sense phase D
59	ADC-A1	IC_FB	Current sense phase C
61	ADC-A2	IB_FB	Current sense phase B
63	ADC-A3	IA_FB	Current sense phase A
65	ADC-A4	VDCBUS	PVDD supply sense
15	ADC-B4	ADC-Vhb1	Phase Voltage sense A
17	ADC-B5	ADC-Vhb2	Phase Voltage sense B
19	ADC-B6	ADC-Vhb3	Phase Voltage sense C
21	ADC-B7	ADC-Vhb4	Phase Voltage sense D

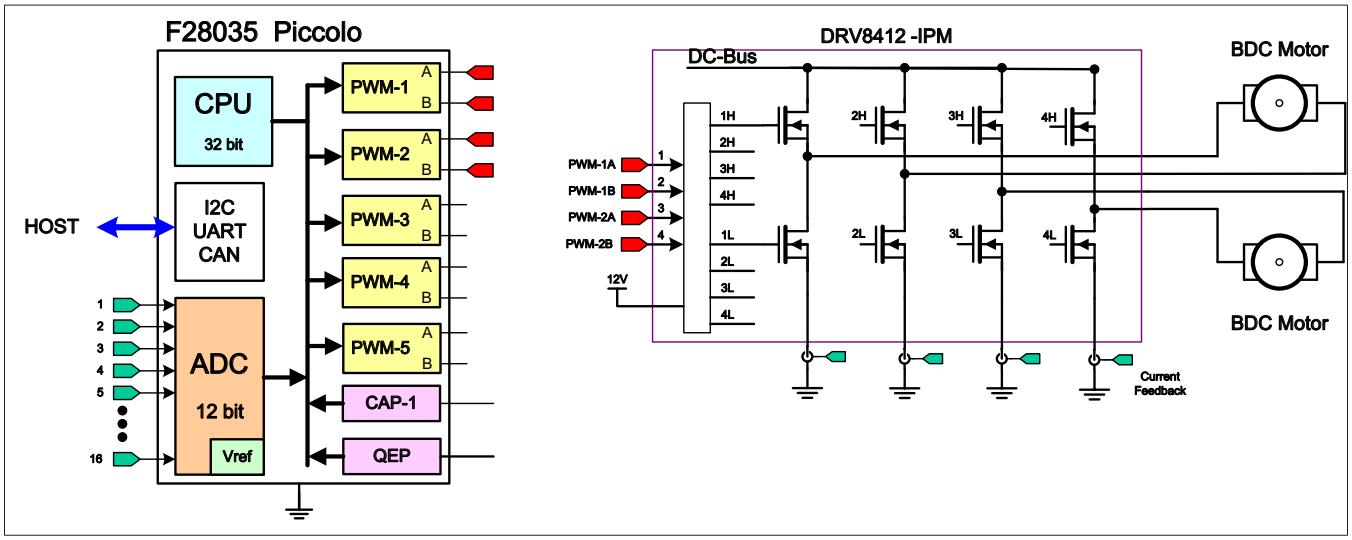

Figure 6. Medium Voltage DMC board Block diagram with C2000 MCU

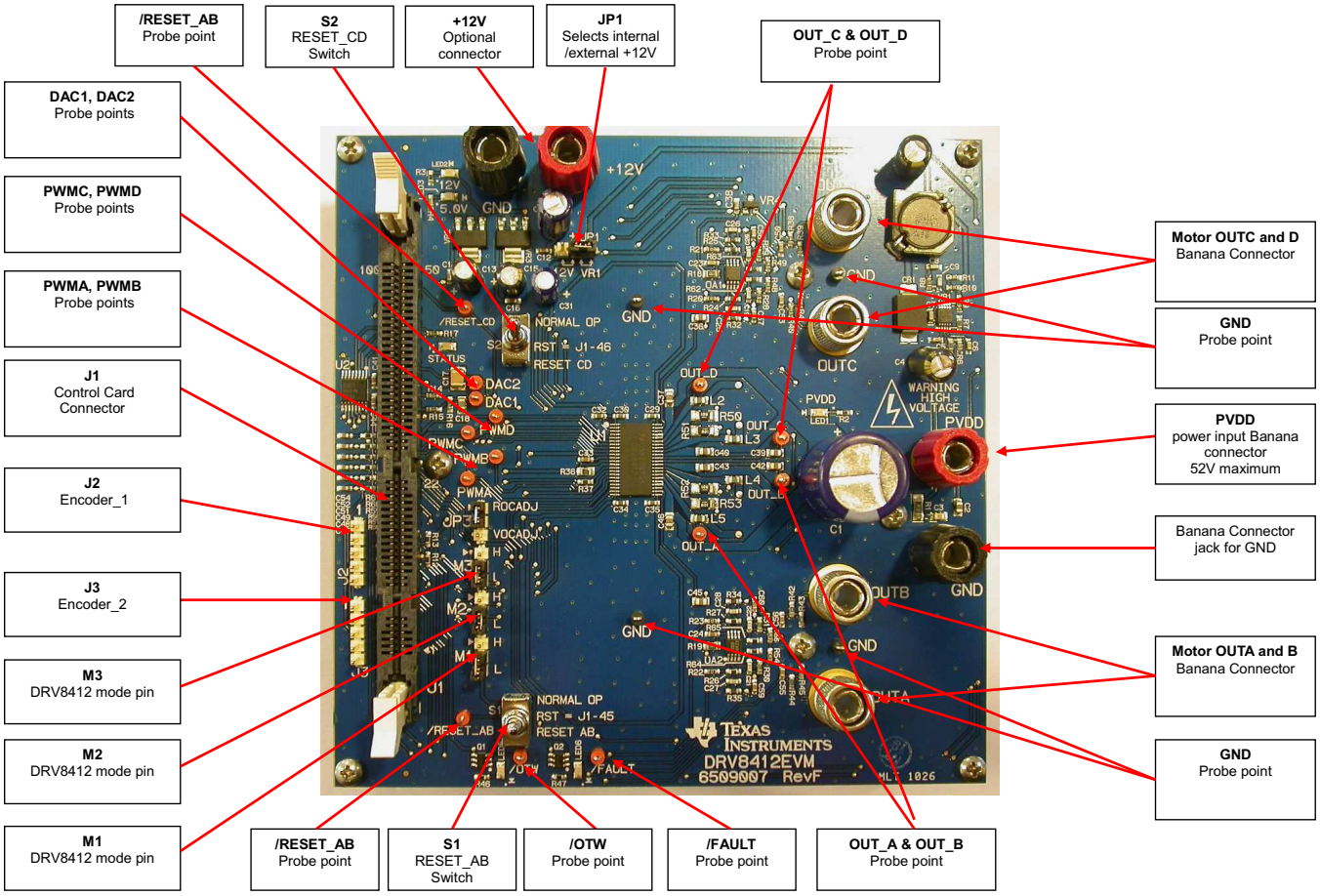

Figure 7. DRV8412_C2_ Kit Jumpers and Connectors Diagram

Schematic Disclaimer and Warnings

Texas Instruments provides the DRV8412_C2_KIT schematic drawings and other design files to help users develop DRV8412 & C2000 based reference design products. These design files can be found at located in the Design Tools Folder: www.ti.com/tool/TIDM-THREEPHASE-BSDC. 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.

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12. User shall be solely responsible for proper disposal and recycling of EVMs consistent with all applicable federal, state, and local requirements.

Certain Instructions. User shall operate EVMs within TI's recommended specifications and environmental considerations per the user's guide, accompanying documentation, and any other applicable requirements. Exceeding the specified ratings (including but not limited to input and output voltage, current, power, and environmental ranges) for EVMs may cause property damage, personal injury or death. If there are questions concerning these ratings, user should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the applicable EVM user's guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using EVMs' schematics located in the applicable EVM user's guide. When placing measurement probes near EVMs during normal operation, please be aware that EVMs may become very warm. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use EVMs.

Agreement to Defend, Indemnify and Hold Harmless. User agrees to defend, indemnify, and hold TI, its directors, officers, employees, agents, representatives, affiliates, licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of, or in connection with, any handling and/or use of EVMs. User's indemnity shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if EVMs fail to perform as described or expected.

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General Statement for EVMs including a radio

User Power/Frequency Use Obligations: For EVMs including a radio, the radio included in such EVMs is intended for development and/or professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability in such EVMs and their development application(s) must comply with local laws governing radio spectrum allocation and power limits for such EVMs. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by TI unless user has obtained appropriate experimental and/or development licenses from local regulatory authorities, which is the sole responsibility of the user, including its acceptable authorization.

U.S. Federal Communications Commission Compliance

For EVMs Annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. Changes or modifications could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at its own expense.

FCC Interference Statement for Class B EVM devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Industry Canada Compliance (English)

For EVMs Annotated as IC – INDUSTRY CANADA Compliant:

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Concerning EVMs Including Radio Transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs Including Detachable Antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Canada Industry Canada Compliance (French)

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

Concernant les EVMs avec appareils radio

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

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If user uses EVMs in Japan, user is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after user obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after user obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless user gives the same notice above to the transferee. Please note that if user does not follow the instructions above, user will be subject to penalties of Radio Law of Japan.

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