UM11550

EV-INVERTERHD SiC MOSFET enablement kit

Rev. 2 — 20 October 2022 User manual

Document information

Information	Content
Keywords	automotive, inverter
Abstract	This user manual describes the EV-INVERTERHD enablement kit for SiC MOSFET with GD3160 gate drive devices. The kit can be purchased with only power board and microcontroller board and accessories directly from NXP. Or, a complete kit with power board, controller board, and SiC MOSFET, and DC link all enclosed in water cooling housing case from Vepco Technologies.

Revision history

Rev	Date	Description
2	20221020	update for new EV-INVERTERHD SiC MOSFET enablement kit
1	20210308	initial version

IMPORTANT NOTICE

For engineering development or evaluation purposes only

NXP provides the product under the following conditions:

This evaluation kit is for use of ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY.

It is provided as a sample IC pre-soldered to a printed-circuit board to make it easier to access inputs, outputs and supply terminals. This evaluation board may be used with any development system or other source of I/O signals by connecting it to the host MCU computer board via off-the-shelf cables. This evaluation board is not a Reference Design and is not intended to represent a final design recommendation for any particular application. Final device in an application heavily depends on proper printed-circuit board layout and heat sinking design as well as attention to supply filtering, transient suppression, and I/O signal quality.

The product provided may not be complete in terms of required design, marketing, and or manufacturing related protective considerations, including product safety measures typically found in the end device incorporating the product. Due to the open construction of the product, it is the responsibility of the user to take all appropriate precautions for electric discharge. In order to minimize risks associated with the customers' applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards. For any safety concerns, contact NXP sales and technical support services.

1 Finding Kit Resources and Information on the NXP Web Site

The NXP analog product development boards provide an easy-to-use platform for evaluating NXP products. The boards support a range of analog, mixed-signal and power solutions. They incorporate monolithic integrated circuits and system-in-package devices that use proven high-volume technology. NXP products offer longer battery life, a smaller form factor, reduced component counts, lower cost and improved performance in powering state-of-the-art systems. NXP Semiconductors provides online resources for this reference design and its supported devices at http://www.nxp.com. The information page for electric vehicle (EV) traction motor reference designs is here. The information page provides a product overview, specifications, ordering information, documentation, and software. The Documents and Software tab offers quick-reference information applicable to using the EV-INVERTERHD SiC metal-oxide-semiconductor field-effect transistor (MOSFET) Enablement Kit, including the downloadable assets referenced in this document.

1.1 Collaborate in the NXP community

The NXP community is for sharing ideas and tips, ask and answer technical questions, and receive input on just about any embedded design topic.

The NXP community is at https://community.nxp.com/community/s32.

2 Overview

NXPs EV-INVERTERHD SiC MOSFET Enablement Kit is designed for customers using IGBTs or SiC MOSFETs modules to develop the power inverter module (PIM) that control electric vehicle traction motors. The kit consists of two boards, the EV-CONTROLEVMHD MCU control board and the EV-POWEREVBHD driver control board for HybridPACK Drive modules. The EV-CONTROLEVMHD MCU control board supports motor control, current sensing, and interface connectivity functions. The EV-POWEREVBHD driver control board controls power to the IGBTs or SiC MOSFETs.

The kit also includes all of the software needed to configure the system basis chip, control a 3-phase inverter for traction motors, and operate and monitor the inverter platform. The software includes software device drivers and inverter services, Automotive Math and Motor Control Library Set (AMMCLiB) motor control software libraries, motor control application tuning (MCAT), code examples, and FreeMASTER graphical user interface of NXP.

For customers who purchase the kit, schematics, Gerber files, user guides, and the System Safety Concept Application Note are available online.

Customers can choose two paths in using the EV-INVERTERHD SiC MOSFET Enablement Kit with an insulated gate bipolar transistor (IGBT) or SiC MOSFET module. For customers interested in an off-the-shelf solution, NXP has partnered with Vepco Technologies Inc. to offer a self-contained PIM that integrates the EV-CONTROLEVMHD and the EV-POWEREVBHD boards within a single unit (available here). In addition to the two NXP boards, the Vepco product includes a StarPower MD816HTC120P6HE SiC Module using Wolfspeed SiC die, link capacitors, a bus bar, and a cooling plate. All of the components within the module are connected and ready to use. Figure 1 shows the Vepco PIM with the bottom removed to expose the EV-CONTROLEVMHD board. (The EV-POWEREVBHD board is hidden below the EV-CONTROLEVMHD board in this photograph.)

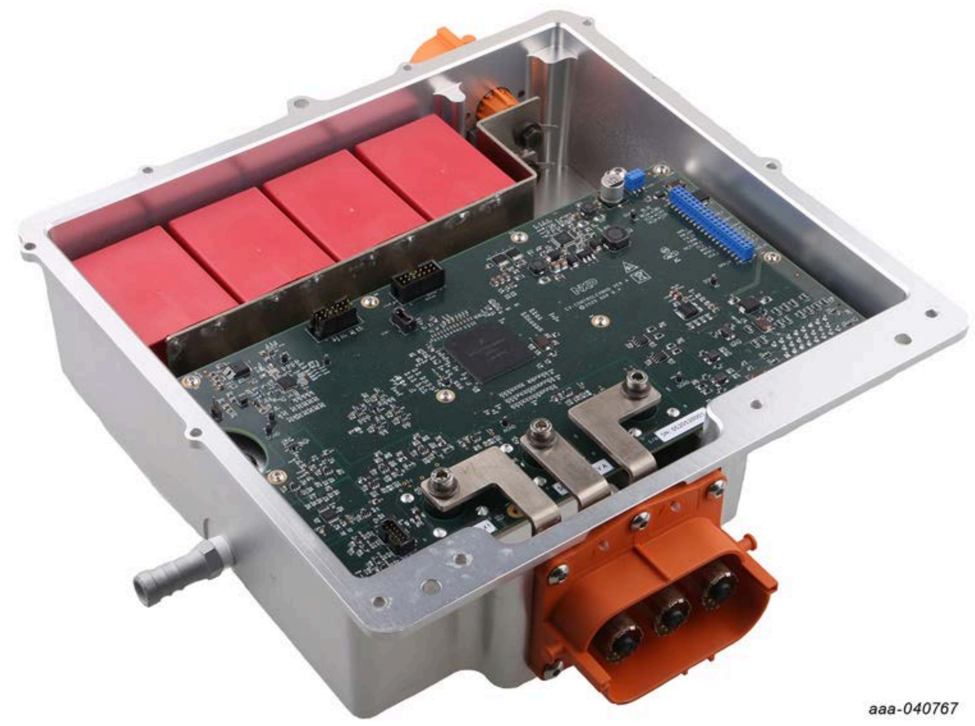


Figure 1. Vepco PIM with bottom removed

The EV-INVERTERHD SiC MOSFET Enablement Kit can also be purchased directly from NXP Semiconductor. However, customers who choose to do so are responsible for providing all of the additional required components (PIM housing, link capacitors, cooling plates, connectors, bus bar, and so on) for configuring and debugging their platform.

3 Getting started

NXP analog product development boards provide an easy-to-use platform for evaluating NXP products. These development boards support a range of analog, mixed-signal, and power solutions. The boards incorporate monolithic integrated circuits and system-in-package devices that use proven high-volume technology. NXP products offer longer battery life, a smaller form factor, reduced component counts, lower cost, and improved performance in powering state-of-the-art systems.

Note:

Read this manual in its entirety before connecting the power inverter module (PIM) to any power source. When operating in a lab environment, make sure all high-voltage connections are secured, and the operator is properly protected from any shock hazard.

3.1 Kit contents

The enablement kit (EV-INVERTERHD) kit includes:

- MCU control board (EV-CONTROLEVMHD)
- Driver control board (EV-POWEREVBHD)
- 3-phase output bus bars for LEM current sensors

- 6 pin and 40 pin header connectors for interfacing between EV-CONTROLEVMHD and EV-POWEREVBHD

3.2 Additional hardware

In order to use the EV-INVERTERHD SiC MOSFET Enablement Kit, customers must provide some additional hardware beyond what is contained in the kit. The amount of additional hardware required depends on whether the customer is using the Vepco PIM or is designing their own EV Inverter platform.

All customers (Vepco PIM users included) must provide the following items:

- **Low-voltage DC power supply:** A 12 VDC power supply for the inverter
- **High-voltage DC power supply:** Up to 800 VDC, 400 A (or similar) for the motor
- **Kvaser Leaf Light HS v2 USB-controller area network (CAN) interface** or comparable USB-CAN interface adapter (available here)
- **PEmicro multilink debug probe:** To connect the EV-CONTROLEVMH board to the PC-based GUI (available here)
- **Motor:** A 3-phase permanent magnet synchronous motor.
- **High-voltage cabling (2-wire):** For high-voltage connections from high-voltage DC power supply into the PIM link capacitors
- **High-voltage cabling (3-wire):** For high-voltage phase connections from the PIM to the motor
- **Low-voltage cabling:** For low-voltage connections from the 12 VDC power supply to the PIM

In addition to the required equipment listed above, customers who choose to design their own inverter platform must also provide the following:

- **StarPower SiC MD816HTC120P6HE Module using Wolfspeed SiC MOSFET die or Infineon FS03MR12A6MA1B CoolSiC MOSFET HybridPACK Drive module.**
- **Cooling plate or water jacket for SiC or IGBT HybridPACK footprint module:** The cooling plate serves as the cooling structure interface for the SiC or IGBT module.
- **Bus bar:** Used to connect the DC link capacitors to the SiC MOSFET module and to provide links to the DC high-voltage/high current power supply
- **DC link capacitor:** Four KEMET C4AQIEW6100A3BJ 100UF 800 VDC radial capacitors (available here) connected in parallel are used for inverter baseline performance measurements. The selected capacitors must be compatible with the SiC MOSFET listed above and its intended operating voltages.
- **23-position signal connector** (optional) AMPSEAL (PN 770680-1) connector (available here) to connect the PIM to a 3-phase motor.
- **High-voltage shielded cable (2-wire):** Used to connect the 23-position signal connector to the motor resolver connections excitation signals
- **Low-voltage shielded cable (21-wire):** Used to connect the 23-position signal connector to the motor resolver sense signals, CAN, signals, and so on
- **40-pin cable:** 40-pin flat ribbon cable with male-to-female connectors to connect the EV-CONTROLEVMHD MCU control board to the EV-POWEREVBHD driver control board.
- **Board stand-offs:** To provide mechanical support for the components.

3.3 Interface connections

High-voltage interface: Requires a minimum distance of 8 mm away from any other terminals and between each terminal:

- Two-terminal DC connection – inputs V+ and V– from the high-voltage power supply connected via the bus bar to the SiC MOSFET or IGBT module.
- Three-terminal AC connection – outputs are U, V, W phase from the SiC MOSFET or IGBT module.

3.4 Windows PC workstation

This evaluation board requires a Windows PC workstation.

- Windows 10 or 8 compatible PC with two available USB ports.

3.5 Software

The software listed below must be installed prior to working with this reference design. All listed software is available on an NXP secured site. To gain access to the secured site, use the registration code provided in the hardware shipment. The software bundle includes the actual application software that runs on the EV-INVERTERHD SiC MOSFET enablement kit. Customers who purchase the EV-INVERTERHD enablement kit receive instructions on how to download the software.

- S32 Design Studio IDE V2.1 for Power Architecture
- Automotive Math and Motor Control Library Set (AMMCLiB)
- FreeMASTER 3.1 runtime debugging tool
- Motor control application tuning (MCAT)
- Example code, GD3160 Device Driver notes and GD3160 Device Driver Reference notes

4 Getting to know the hardware

4.1 SiC enablement kit overview

The EV-INVERTERHD SiC MOSFET is a reference design enablement kit containing NXP content to develop an EV 3-phase traction motor inverter. The system is designed to drive the StarPower MD816HTC120P6HE footprint module using Wolfspeed SiC MOSFETs die or Infineon FS03MR12A6MA1B CoolSiC HybridPACK module. This kit includes two printed-circuit boards (PCBs) (see Section 3.1) and basic configuration and drive software. PCB layout, schematics, and Gerber files are available on an NXP secured website. (To gain access to the secured site, use the registration code provided in the hardware shipment.)

Customers must obtain the additional inverter components. These components include the SiC MOSFET or IGBT module, link capacitor, bus bar, cooling plate, mounting hardware, and so on. Customers can select their own components when designing and assembling a complete PIM to work with the NXP EV-CONTROLEVMHD and EV-POWEREVBHD boards. As an alternative, a complete pre-assembled reference PIM platform is available through NXP partner Vepco Technologies. The SiC MOSFET module using the Wolfspeed die is available from StarPower Semiconductor Ltd.

4.2 EV-INVERTERHD SiC MOSFET enablement kit features

Benefits:

- Increases speed of development
- Offers a full platform solution
- Provides functional safety options
- Optimizes performance

Featured products:

- GD3160 isolated SiC MOSFET or IGBT ASIL D gate driver
- MPC5775E advanced motor control ASIL D MCU
- FS65XX robust ASIL D system basis chip (SBC)
- TJA1051 redundant CAN bus interface
- TJA1100 IEEE 100BASE-T1 compliant Automotive Ethernet physical interface of the OSI model (PHY) transceiver interface
- Capability to connect to StarPower MD816HTC120P6HE or Infineon FS03MR12A6MA1B CoolSiC HybridPACK footprint power module for 3-phase evaluations and development

4.3 EV-INVERTERHD enablement kit block diagram

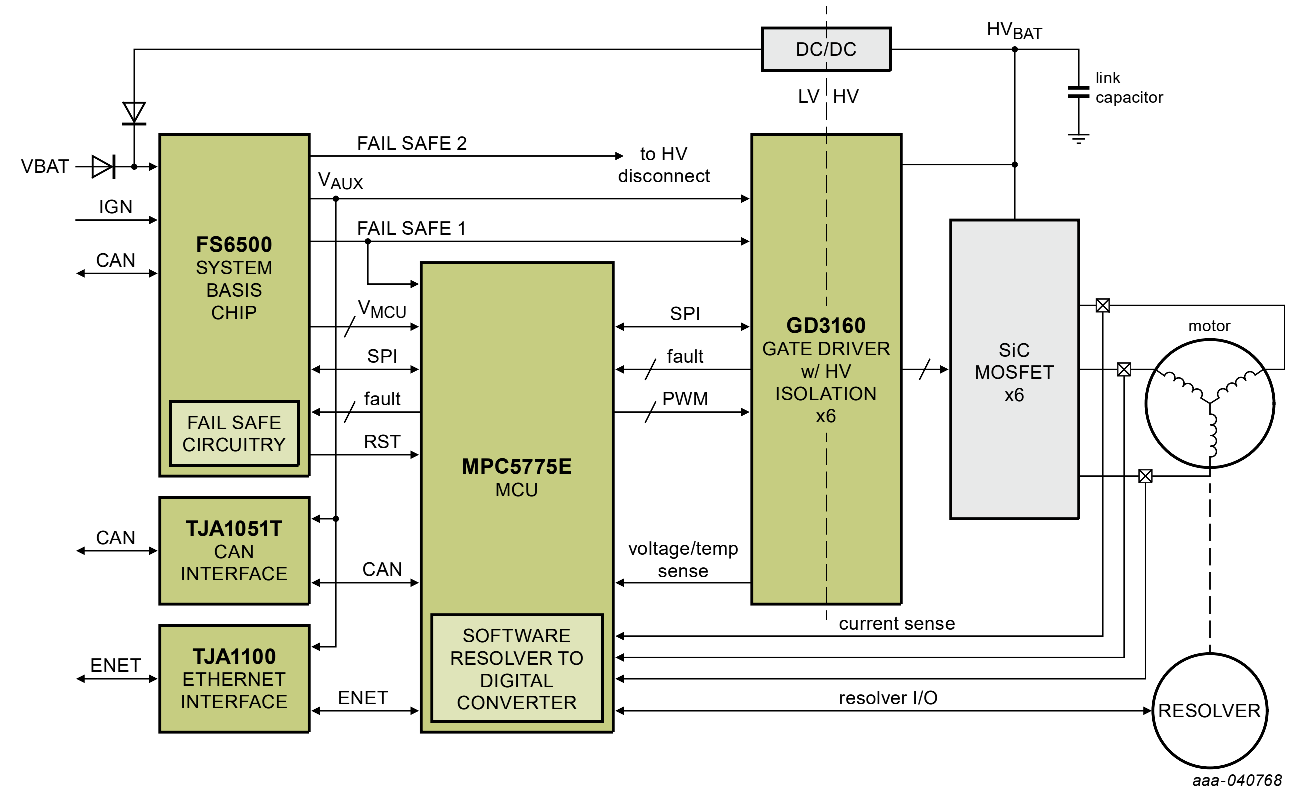


Figure 2. Enablement kit block diagram

4.4 Board descriptions

4.4.1 EV-CONTROLEVMHD board connectors

The EV-CONTROLEVMHD MCU control board supports motor control, current sensing, and interface connectivity functions. The board includes an NXP MPC5775E 32-bit dual-core ASIL D MCU targeted for motor control. An NXP FS65xx system basis chip (SBC) powers the MCU. High-speed CAN support is provided by an NXP TJA1051 transceiver device. In addition, the board includes an NXP TJA1100HNZ Ethernet PHY chip with a 100BASE-TI single-port PHY.

This section describes the internal signals connecting to the control board. Notice that there are connectors on both the top and the bottom of the board.

4.4.1.1 EV-CONTROLEVMHD top of board connectors

Figure 3 shows the connectors on the top of the EV-CONTROLEVMHD board. The pin definitions for the connectors are included in the subsections below.

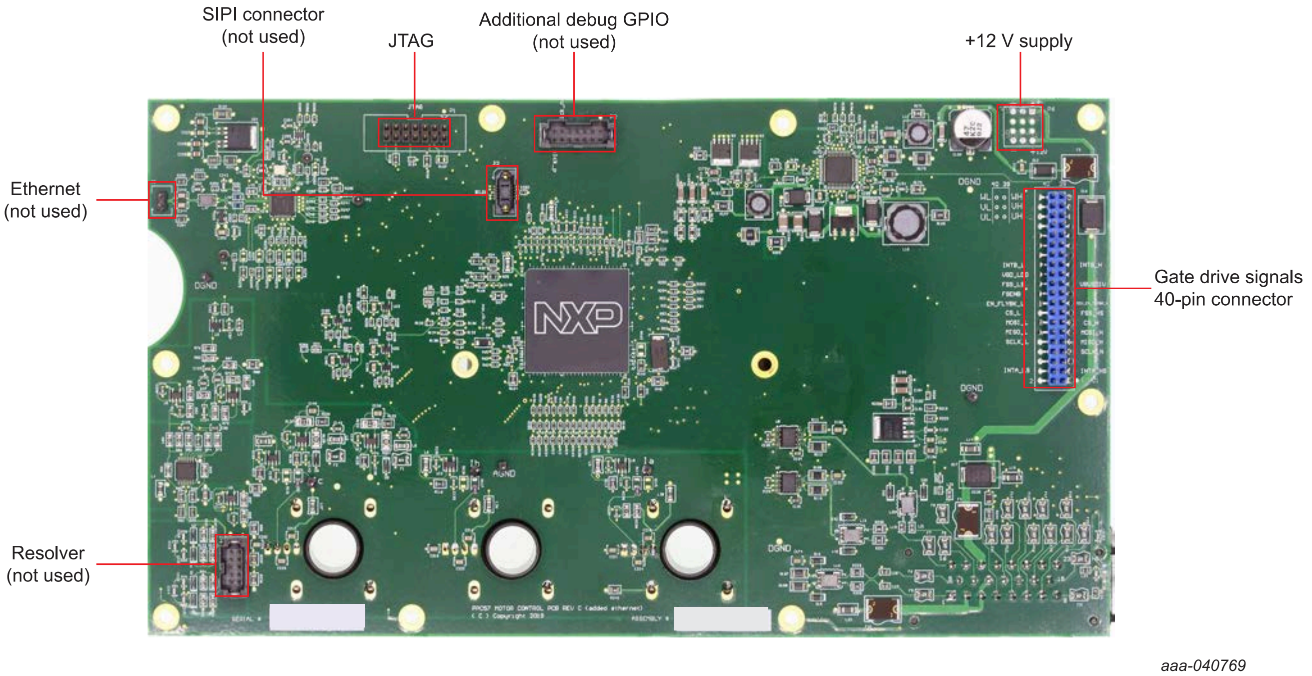


Figure 3. EV-CONTROLEVMHD connectors – top of board

4.4.1.1.1 Gate drive signals 40-pin connector definitions

Table 1. Driver signals 40-pin connector (J1) definitions

Connector: Samtec 2 mm, 2 x 20

Pin	Symbol	Type	Range	Memo
1	NC	—	—	For clearance
2	NC	—	—	For clearance
3	INTA_HS	Digital input	0 V to 5 V	Fault Indicator HS
4	INTA_LS	Digital input	0 V to 5 V	Fault Indicator LS

Table 1. Driver signals 40-pin connector (J1) definitions*...continued*

Connector: Samtec 2 mm, 2 x 20

Pin	Symbol	Type	Range	Memo
5	NC	—	—	For clearance
6	NC	—	—	For clearance
7	SCLK_GD_HS	Digital output	0 V to 5 V	SPI_HS clock
8	DGND	—	—	—
9	MISO_GD_HS	Digital input	0 V to 5 V	SPI_HS MISO
10	SCLK_GD_LS	Digital output	0 V to 5 V	SPI_LS Clock
11	MOSI_GD_HS	Digital output	0 V to 5 V	SPI_HS MOSI
12	MISO_GD_LS	Digital input	0 V to 5 V	SPI_LS MISO
13	CS_HS	Digital output	0 V to 5 V	SPI_HS CS
14	MOSI_GD_LS	Digital output	0 V to 5 V	SPI_LS MOSI
15	FSS_HS	Digital output	0 V to 5 V	Fail-safe state high-side; active low
16	CS_GD_LS	Digital output	0 V to 5 V	SPI_LS CS
17	EN_FLYBK_HS	Digital output	0 V to 5 V	Enables flyback for high side
18	EN_FLYBK_LS	Digital output	0 V to 5 V	Enables flyback for low side
19	VDDA	Power	5 V	Analog supply for Vdc measurement
20	FSENB	Digital output	0 V to 5 V	Enables safe state; active low
21	VbusDivByX	Analog input	0 V to 5 V	Bus voltage measurement
22	FSS_LS	—	—	Fail-safe state low side; active low
23	AGND	—	—	—
24	VGD_LDO	Power	5 V	Power supply for LS Logic
25	INTB_GD_HS	Digital input	0 V to 5 V	Fault Indicator HS
26	INTB_GD_LS	Digital input	0 V to 5 V	Fault Indicator LS
27	DGND	—	—	—
28	VDDIO	Power	5 V	Power supply for HS Logic
29	AOUT_UH	Digital input	0 V to 5 V	—
30	AOUT_UL	Digital input	0 V to 5 V	—
31	AOUT_VH	Digital input	0 V to 5 V	—
32	AOUT_VL	Digital input	0 V to 5 V	—
33	AOUT_WH	Digital input	0 V to 5 V	—
34	AOUT_WL	Digital input	0 V to 5 V	—
35	PWM_UH	Digital output	0 V to 5 V	—
36	PWM_UL	Digital output	0 V to 5 V	—
37	PWM_VH	Digital output	0 V to 5 V	—
38	PWM_VL	Digital output	0 V to 5 V	—
39	PWM_WH	Digital output	0 V to 5 V	—

Table 1. Driver signals 40-pin connector (J1) definitions*...continued*

Connector: Samtec 2 mm, 2 x 20

Pin	Symbol	Type	Range	Memo
40	PWM_WL	Digital output	0 V to 5 V	—

4.4.1.1.2 +12 V supply connector definitions

Table 2. +12 V supply connector (P6) definitions

Connector: Samtec 2 mm, 3 x 6

Pin	Symbol	Type	Range	Memo
1, 2	12V UNSWTCHD	POWER	8 V to 16 V	—
3, 4	NC	—	—	For clearance
5, 6	GND 12V RTRN	analog ground	—	—

4.4.1.1.3 JTAG connector definitions

Joint Test Access Group (JTAG) connector is compatible with PEmicro multilink debugger 2x7 connector.

Table 3. JTAG connector (P1) definitions

Connector: Samtec 2 mm, 2 x 7

Pin	Symbol	Type	Range	Memo
1	TDI_R_PPC	Digital input	0 V to 5 V	Connects to TDI pin on SPC5775E
2	EN_FS65_DEBUG	Digital input	0 V to 5 V	Puts SBC input Debug mode upon power-up
3	TDO_R_PPC	Digital output	0 V to 5 V	Connects to TDO pin on SPC5775E
4	DGND	—	—	Digital ground
5	TCK_R_PPC	Digital output	0 V to 5 V	Connects to TCK pin on SPC5775E
6	DGND	—	—	Digital ground
7	NC	—	—	No connection
8	NC	—	—	No connection
9	RSTB_JTAG	Digital output	0 V to 5 V	Connects to the RSTB pin (reset MCU on safety block failure) on MC33FS6523CAE CAN transceiver
10	TMS_R_PPC	Digital output	0 V to 5 V	Connects to TMS pin on SPC5775E
11	NC	—	—	Connects to VDDIO power rail - Not used with PEmicro
12	DGND	—	—	Digital ground
13	NC	—	—	No connection
14	JCOMP_R_PPC	Digital output	0 V to 5 V	Connects to JCOMP (JTAG Compliance) pin on SPC5775E

4.4.1.1.4 Unused connectors

The EV-CONTROLEVMHD board has four connectors that are intended for internal purposes or are reserved for future releases. Those connectors are:

- P2 – Additional debug general-purpose input/output (GPIO): For internal debugging only.
- J2 – SIPI connector: For internal use only.
- P5 – Ethernet connector: Reserved for future releases.
- P4 – Resolver connector: For internal use only.

For additional information regarding these connectors, contact a local NXP representative.

4.4.1.2 EV-CONTROLEVMHD bottom of board connectors

As shown in Figure 4 there are four connectors on the bottom of the EV-CONTROLEVMHD board.

The 23-pin connector and the three motor phase current sense connectors on the bottom of the EV-CONTROLEVMHD board are typically in use.

The AMPSEAL signal connector is intended for connecting to a PIM traction motor and is used for monitoring and control signals. The corresponding connections are shown in Table 6 and Table 7.

The three motor phase current sensors connect the EV-CONTROLEVMHD board to the SiC MOSFET power module to provide motor phase and current sense information. These connectors are pre-installed in the Vepco PIM. Customers who chose not to use the Vepco PIM must pass cables through the motor phase current sensors when connecting the SiC MOSFET power module to a motor. (See Section 5.2 "Assembling the hardware – non-Vepco procedure")

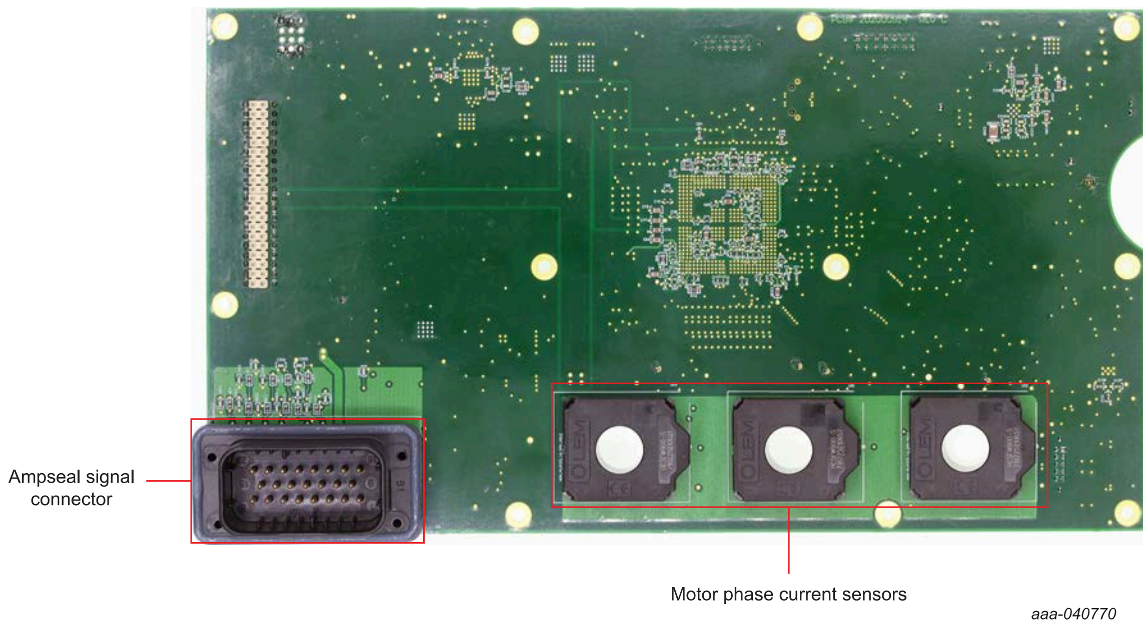


Figure 4. EV-CONTROLEVMHD connectors – bottom

4.4.2 EV-POWEREVBHD board connector

The EV-POWEREVBHD driver control board controls power to the IGBTs or SiC MOSFETs. The board features six NXP GD3160 single-channel gate drivers.

This section describes the internal signals connecting to the power board. All of the connectors are on the top of the board.

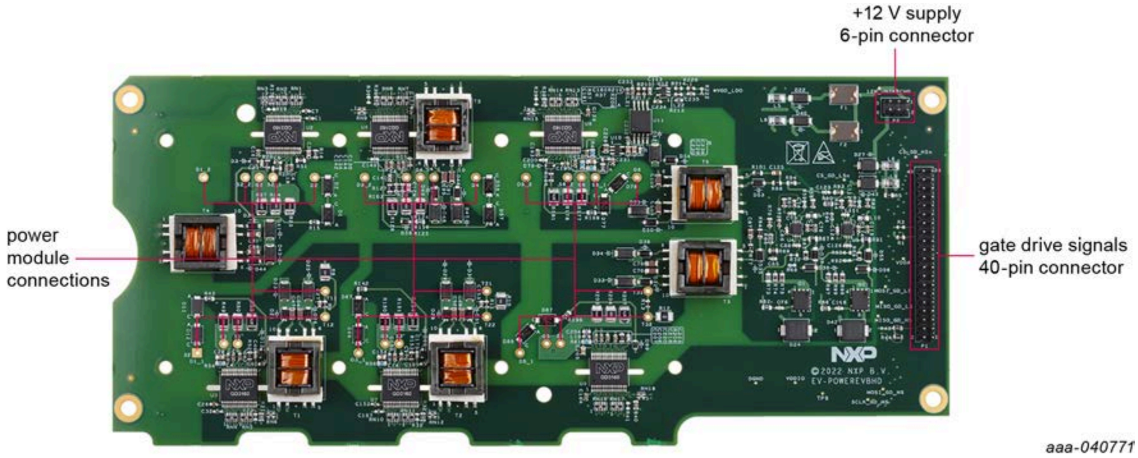


Figure 5. EV-POWEREVBHD connectors

4.4.2.1 Driver signals connector definitions

Table 4. Driver signals 40-pin connector definitions
Connector: Samtec 2 mm, 2 x 20

Pin	Symbol	Type	Range	Memo
1	NC	—	—	For clearance
2	NC	—	—	For clearance
3	INTA_HS	Digital input	0 V to 5 V	Fault indicator HS
4	INTA_LS	Digital input	0 V to 5 V	Fault indicator LS
5	NC	—	—	For clearance
6	NC	—	—	For clearance
7	SCLK_GD_HS	Digital output	0 V to 5 V	SPI_HS clock
8	DGND	—	—	—
9	MISO_GD_HS	Digital input	0 V to 5 V	SPI_HS MISO
10	SCLK_GD_LS	Digital output	0 V to 5 V	SPI_LS Clock
11	MOSI_GD_HS	Digital output	0 V to 5 V	SPI_HS MOSI
12	MISO_GD_LS	Digital input	0 V to 5 V	SPI_LS MISO
13	CS_HS	Digital output	0 V to 5 V	SPI_HS CS
14	MOSI_GD_LS	Digital output	0 V to 5 V	SPI_LS MOSI
15	FSS_HS	Digital output	0 V to 5 V	Fail-safe state high side; active low
16	CS_GD_LS	Digital output	0 V to 5 V	SPI_LS CS
17	EN_FLYBK_HS	Digital output	0 V to 5 V	Enables flyback for high side

Table 4. Driver signals 40-pin connector definitions...*continued*

Connector: Samtec 2 mm, 2 x 20

Pin	Symbol	Type	Range	Memo
18	EN_FLYBK_LS	Digital output	0 V to 5 V	Enables flyback for low side
19	VDDA	Power	5 V	Analog supply for Vdc measurement
20	FSENB	Digital output	0 V to 5 V	Enables safe state; active low
21	VbusDivByX	Analog Input	0 V to 5 V	Bus voltage measurement
22	FSS_LS	—	—	Fail-safe state low side; active Low
23	AGND	—	—	—
24	VGD_LDO	Power	5 V	Power supply for LS logic
25	INTB_GD_HS	Digital input	0 V to 5 V	Fault indicator HS
26	INTB_GD_LS	Digital input	0 V to 5 V	Fault indicator LS
27	DGND	—	—	—
28	VDDIO	Power	5 V	Power supply for HS Logic
29	AOUT_UH	Digital input	0 V to 5 V	—
30	AOUT_UL	Digital input	0 V to 5 V	—
31	AOUT_VH	Digital input	0 V to 5 V	—
32	AOUT_VL	Digital input	0 V to 5 V	—
33	AOUT_WH	Digital input	0 V to 5 V	—
34	AOUT_WL	Digital input	0 V to 5 V	—
35	PWM_UH	Digital output	0 V to 5 V	—
36	PWM_UL	Digital output	0 V to 5 V	—
37	PWM_VH	Digital output	0 V to 5 V	—
38	PWM_VL	Digital output	0 V to 5 V	—
39	PWM_WH	Digital output	0 V to 5 V	—
40	PWM_WL	Digital output	0 V to 5 V	—

4.4.2.2 +12 V supply connector definitions

Table 5. +12 V, 6 pin connector (P2) definitions

Connector: Samtec 2 mm, 2 x 3

Pin	Symbol	Type	Range	Memo
1, 2	12 V UNSWTCHD	POWER	8 V to 16 V	—
3, 4	NC	—	—	For clearance
5, 6	GND 12 V RTRN	analog ground	—	—

4.4.2.3 Power module connections

These 30 connectors connect the the EV-POWEREVBHD board to the corresponding pins on the surface of the P6HE or CoolSiC module [gate, drain, source, negative temperature coefficient (NTC)] for each phase. These connectors align with the power module pins so that the EV-POWEREVBHD board can be mounted directly on top of the power module.

5 Assembling the hardware

The procedure for assembling an inverter platform that uses the EV-INVERTERHD SiC MOSFET Enablement Kit differs depending on whether the Vepco PIM is employed or whether the customer has chosen to configure their own platform. The following sections cover both procedures.

5.1 Assembling the hardware – Vepco procedure

The assembly instructions in this section apply to users who have elected to use the Vepco PIM.

The following hardware, described in Section 4 "Getting to know the hardware", is required for this procedure.

- Vepco power inverter module (PIM)
- High-voltage cabling for inverter DC link supply (2-wire)
- High-voltage cabling for motor phase connection (3-wire)
- Low-voltage 12 V power supply (inverter)
- High-voltage power supply (PIM DC link)
- 3-phase motor
- PEmicro multilink debugger probe
- Kvaser Leaf Light v2 USB – CAN interface adapter

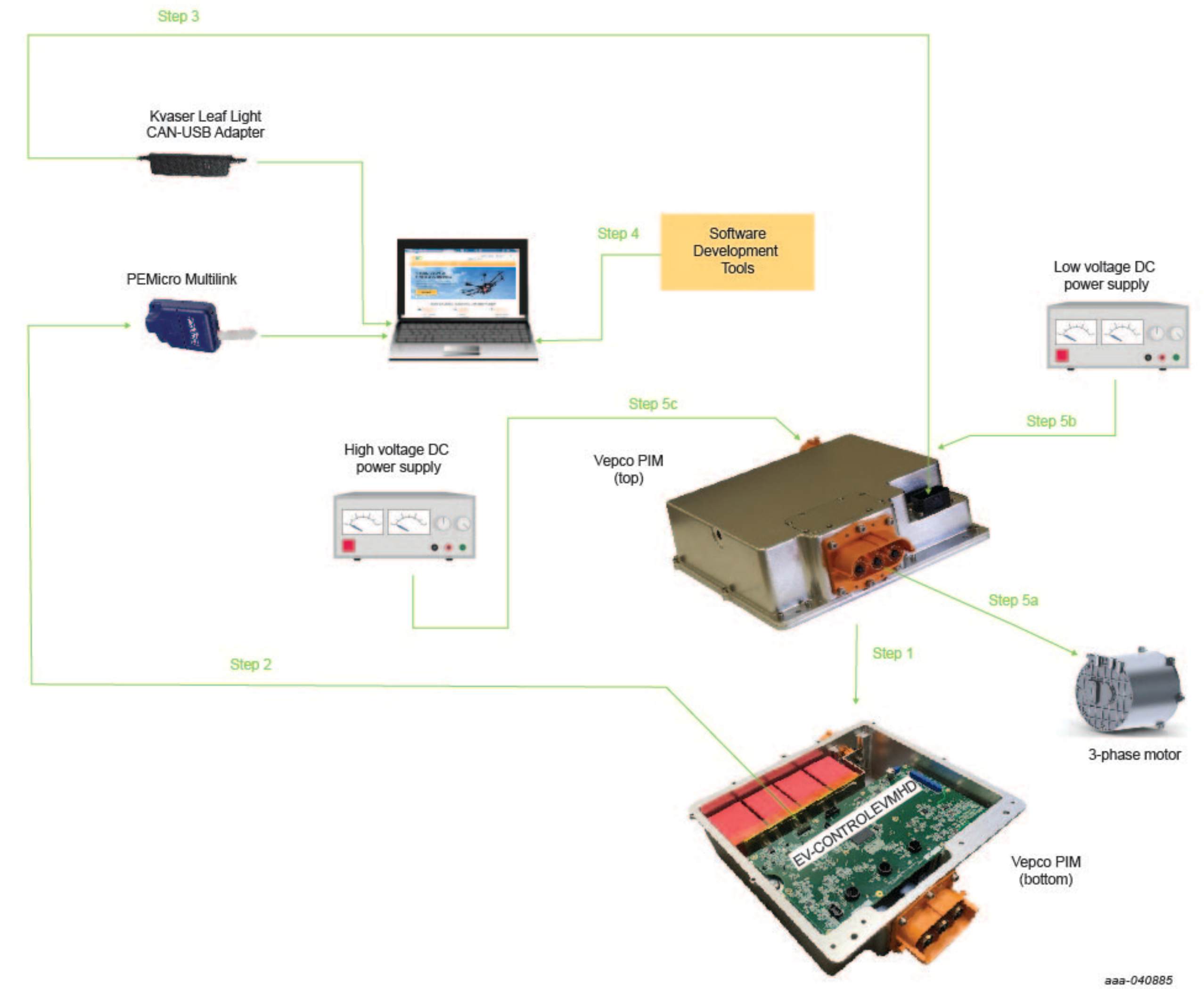
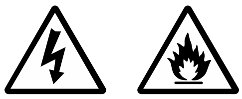


Figure 6. Assembly procedure using the Vepco PIM with the EV-Inverter HD SiC MOSFET Enablement Kit

1. Turn the Vepco PIM upside down and remove the bottom plate. Removing this plate exposes the EV-CONTROLEVMHD board with EV-POWEREVBHD board, link capacitors, and power module mounted inside the unit.
2. Connect the 14-pin PEmicro multilink debugger header to connector P1 on the EV-CONTROLEVM with the pin 1 marks aligned. Connect a USB cable from the PEmicro multilink to the host PC. Both LED lights on the PEmicro multilink should be on, indicating that the JTAG bus is live and ready to communicate. For information on installing the PEmicro software and debugging with the PEmicro probe, consult the PEmicro documentation (available here).
3. Route the Kvaser Leaf Light USB-CAN Interface Adapter from the 23-pin connector on the bottom of the EV-CONTROLEVMHD board to a USB port on the Windows PC. See Section 6.2 "Installing the USB – CAN interface adapter" for detailed instructions on making the connection.

4. Install the software development tools. See Section 3.5 "Software"
5. **WARNING**

   Lethal voltage and fire ignition hazard

   The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire. This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

   Follow the instructions in the Vepco PIM documentation to make the following connections (see Figure 6):

   a. 3-phase motor
   b. Low-voltage DC power supply
   c. High-voltage DC power supply. Warning: HIGH DC VOLTAGES CAN BE FATAL. Use extreme caution.

5.2 Assembling the hardware – non-Vepco procedure

The following assembly instructions apply to users who have elected to design their own inverter control platform instead of using the Vepco module. The instructions cover electrical connectivity only. The customer is responsible for assembling the physical structures (bus bar, mounting hardware, and so on) required to support and connect the components in their platform.

- EV-INVERTERHD SiC MOSFET Enablement Kit
- StarPower P6HE module or Infineon CoolSiC HybridPACK module
- Cooling plate
- A bus bar compatible with a HybridPACK module
- DC link capacitors
- High-voltage cables for inverter DC link supply (2)
- High-voltage cables for motor phase connection (3)
- High-voltage shielded cable (2-wire) for motor resolver connections
- Low-voltage shielded cable (21-wire) for motor resolver connections
- 23-position AMPSEAL signal connector (optional)
- Low-voltage 12 V power supply (inverter)
- High-voltage power supply (DC link)
- 40-pin flat ribbon cable with one male and one female connector (optional)
- Board stand-offs - 0.5 in (optional)
- Motor
- PEmicro multilink debugger probe
- Kvaser Leaf Light v2 USB – CAN interface adapter

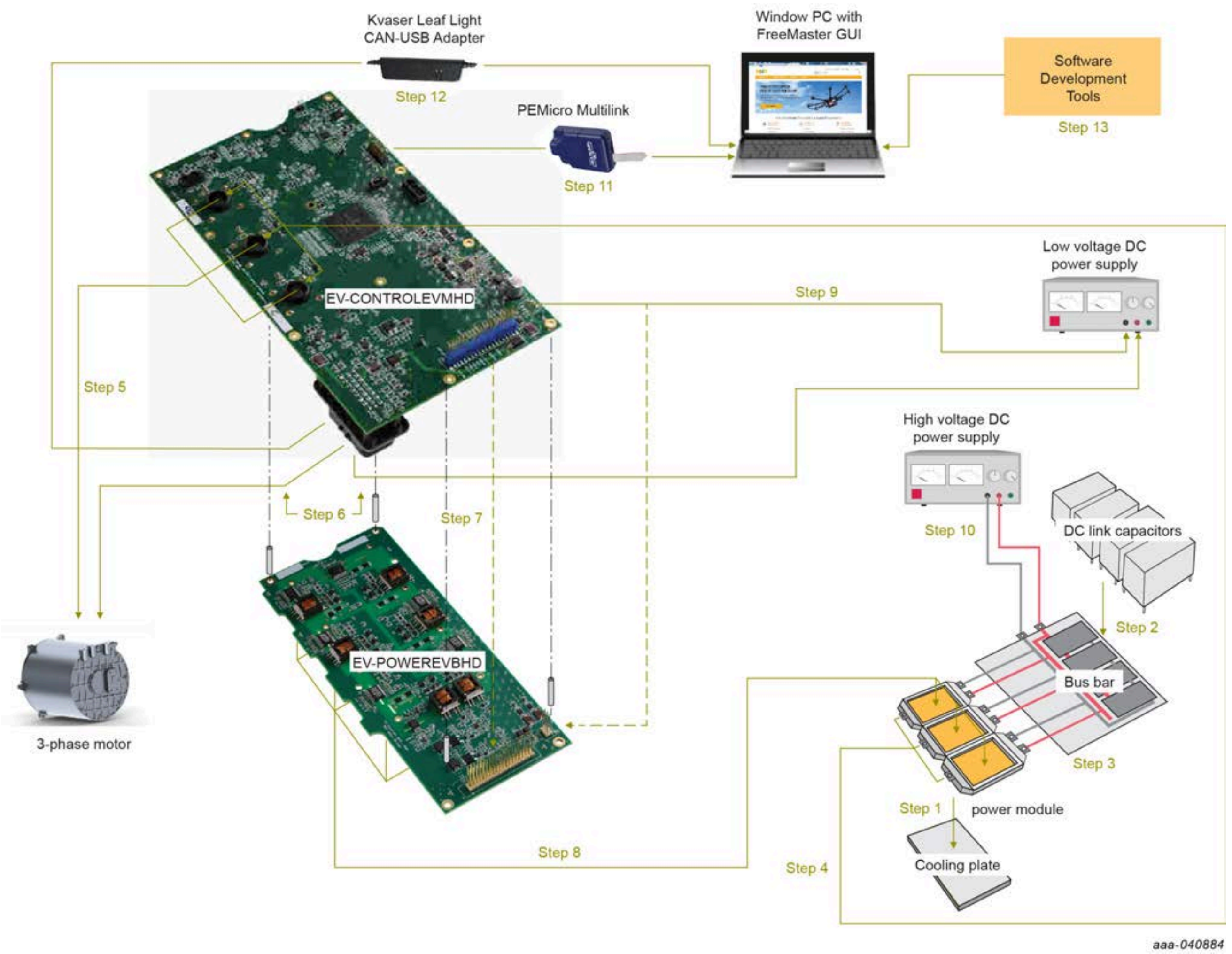
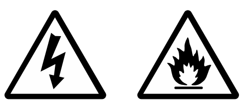


Figure 7. Assembly procedure using the EV-INVERTERHD SiC MOSFET Enablement Kit with a non-Vepco HybridPACK module

1. Attach the MD816HTC120P6HE or FS03MR12A6MA1B CoolSiC power module to the cooling plate.
2. Attach the DC link capacitors to the bus bar.
3. Connect the three positive DC power connectors on the power module to the corresponding connectors on the bus bar. Connect the three negative DC power connectors on the power module to the corresponding connectors on the DC link bus bar
4. Connect high-voltage cables to the 3-phase output connectors on the power module. Then route each wire through the one of the three motor phase current sensors (U21, U22, U23) on the EV-CONTROLEVMHD board.
5. Connect the 3-phase motor to the three cables that were routed through the current sensors in the previous step. Make sure that the U, V, and W connections match.
6. Connect the motor resolver to the 23-pin connector on the EV-CONTROLEVMHD board. The connections are made as follows:
   - Using the two-wire high-power shielded cable, connect pin 14 and pin 21 (resolver excitation signals) on the 23-pin connector to the corresponding connections on the motor. Connect the shield ground to pin 6 on the 23-pin connector.

   - Using the low-power cable, connect pins 8, 15, 22, and 23 (resolver sense signals) on the 23-pin connector to the corresponding connections on the motor. Connect the shield ground to pin 7 on the 23-pin connector.
   - Using the low-power cable, make all remaining connections (CANH, CANL, and so on) according to Table 6 and Table 7.
   - Connect the EXT_DGND to 12 V GND
7. Connect the two enablement kit boards. The connection can be made using two different methods:
   - Method A: Mount the EV-CONTROLEVMHD board on top of the EV-POWEREVBHD board by directly connecting the 40-pin connectors (J1 and P1) and the +12 supply connectors (P6 and P2). Make sure that the pins on the lower board are completely inserted into the connectors on the upper board. Use stand-offs to provide structural support between the two boards. Notice that connecting the boards in this fashion blocks access to the test points and components on the top of the EV-POWEREVBHD board.
   - Method B: Connect the two boards with cables. To do so, connect a 40-pin ribbon cable between connector J1 on the EV-CONTROLEVMHD board and connector P1 on the EV-POWEREVBHD board. In this configuration, the EV-POWEREVBHD board must be powered independently from the EV-CONTROLEVMHD board. (See step 9)
8. Connect the EV-POWEREVBHD board to the power module. Aligning the power module is best done by aligning the pins on the surface of the power module with the power module connectors on the bottom of the EV-POWEREVBHD board (see Figure 5) and mounting the two units together.
9. Connect the low-voltage DC power supply (12 V) to connector P6 on the EV-CONTROLEVMHD board. If Method B in step 7 was used to connect the EV-CONTROLEVMHD board to the EV-POWEREVBHD board, an additional connection must be made from the low-voltage DC power supply to the +12 supply connector (P2) on the EV-POWEREVBHD board. (When the two boards are mounted, as in Method A, step 7, the EV-POWEREVBHD draws power directly through the +12 supply connector on the EV-CONTROLEVMHD board.)
10. **WARNING**

    Lethal voltage and fire ignition hazard

    The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire. This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

    Using the 2-wire high-voltage cable, connect the positive connector on the high-voltage/high-current DC supply to the positive DC link capacitor connectors on the bus bar. Then connect the negative connector on the high-voltage/high current DC supply to the negative DC link capacitor connectors on the bus bar. Warning: HIGH DC VOLTAGES CAN BE FATAL. Use extreme caution.
    Before applying high voltage (>300 V) to the DC connection, use a current limited (1 A) power supply and apply 15 V to 30 V to the DC connection to make sure that there is no excessive leakage current.
11. Connect the 14-pin PEmicro multilink debugger header to connector P4 on the EV-CONTROLEVM with the pin 1 marks aligned. Connect a USB cable from the

PEmicro multilink to the host PC. Both LED lights on the PEmicro multilink should be on, indicating that the JTAG bus is live and ready to communicate. For information on installing the PEmicro software and debugging with the PEmicro probe, consult the PEmicro documentation (available here).

12. Attach the Kvaser Leaf Light USB-CAN Interface Adapter to the 23-pin connector on the bottom of the EV-CONTROLEVMHD board and a USB port on the Windows PC. See Section 6.2 "Installing the USB – CAN interface adapter" for detailed instructions on making the connection.
13. Install the software development tools. See Section 3.5 "Software"

5.3 Using a motor not from Vepco Technologies

The application software in the PIM was developed for a 4-pole pair, 3-phase permanent magnet synchronous motor. The PIM expects a 4-pole 6-wire position resolver sensor to provide the rotor position information. If the custom motor is the same configuration, then the speed and position information in the software are correct.

If there is a different number of pole pairs or resolver configurations, reconfigure or rewrite the PCS.c application programming interface (API) void Get_RotorPos(T_S16* Pos) to calculate the position (0 to 4095) based on the resolver configuration. The PCS.c file is located at Source>App>foc>PSC>PSC.c.

The connectors shown in Figure 8 and in Table 6 and Table 7 are used to bring in signals from CAN, the resolver, and the motor.

Note that, depending on how the motor is wound, the positive direction of the motor may be different from the definition of the PIM.

- **Calibration table**
  A custom motor table is often required for optimization. The format of the table is presented in LookupTable.c. The lookup tables are two-dimensional (2D) tables. These tables request torque (Tq_cmd) and rpm/Vdc ratio (rpm_Vdc) inputs. The outputs are Id, Iq, Ld, Lq, and Lambda; each output has its own table.
  It is possible to bypass the lookup tables by operating the motor in the Id Iq reference mode instead of Torque reference mode.
- **Faults and warnings**
  The faults and warnings are handled in the FTM module. A few examples are provided in the module.
- **Speed mode**
  The speed reference mode is implemented as an outer loop of the torque reference mode. Depending on the inertia and other characteristics of the motor, it may require some tuning to the speed loop parameters. These parameters can be found in the MSC module.

Figure 8. 23-position signal connector AMPSEAL PN 770680-1

The EV-interface 23-pin connector is used to bring in signals from the CAN, resolver, and motor. Connections for the 23-position signal connector on the backside of the EV-CONTROLEVMHD are described in Table 6.

1. Unlatch the handle, insert the cable assembly into the header, and relatch the handle. **Note:** depending on how the motor is wound the positive direction of the motor may be different from the definition of the PIM.
2. The PIM rB is preloaded with demo software that does not require resolver and motor current feedback signals to be connected. The demo software runs open-loop controls once the logic power is supplied.
3. The following are required connections for the demo software:
   - Ground: EXT_DGND must be connected to 12 V GND
   - Power supply: unswitched 12 V and ignition may be tied together.

Table 6. EV-CONTROLEVMHD bottom interface connections

Connector: TE Connectivity Ltd. 4 mm, 2 3 plug

Pin	Symbol	Description	Value
1	EXT_CANH_A	CANA High	transistor-transistor logic (TTL) 0 V to 5 V
2	EXT_DGND	Digital Ground	0 V, 100 mA
3	EXT_DGND	Digital Ground	0 V, 100 mA
4	EXT_12V_IGNIT	Ignition	0 V to 16 V, 100 mA
5	EXT_MTRTD1_RTN	Motor RTD 1 Return	Resistor –
6	EXT RSLVR_DRV_SHIELD	Resolver Excitation Shield	0 V
7	EXT_RSLVR_SNS_SHIELD	Resolver Sense Shield	0 V
8	EXT_RSLVR_S1	Resolver sense S1	Analog 100 mA
9	EXT_CANL_A	CANA Low	TTL 0 V to 5 V
10	EXT_FLT_OUT	Fsb1	TTL
11	NC	—	—
12	EXT_MTRRTD1_SIG	Motor RTD 1 Signal	Resistor +
13	EXT_MTRRTD2_SIG	Motor RTD 2 Signal	Resistor +
14	EXT_RSLVR_R1	Resolver excitation R1	Analog 100 mA
15	EXT_RSLVR_S3	Resolver sense S3	Analog 100 mA
16	NC	—	—
17	NC	—	—
18	EXT_12V_UNSWTCHD	Unswitched 12 V	10 V to 16 V, 2 A
19	EXT_12V_RETURN_GND	12 V GND	0 V, 2 A
20	EXT_MTRRTD2_RTN	Motor RTD 2 Return	Resistor –
21	EXT_RSLVR_R2	Resolver excitation R2	Analog 100 mA
22	EXT_RSLVR_S2	Resolver sense S2	Analog 100 mA
23	EXT_RSLVR_S4	Resolver sense S4	Analog 100 mA

Refer to Table 7 for connections. For advanced operation of the PIM, it is required to have a motor with a resolver and resistance temperature detector (RTD) sensing connections. Connect CANA_H CANA_L resolver signals to x6 RTD1 signals x2 for proper operation of the PIM.

Table 7. Optional connections

PCB	Device	Color	Molex 33472-1206
P1	RTD1 +	RD	1
P2	RTD –	RD-BK	2
P3	RTD2 +	YL	3
P4	RTD2 –	YL-BK	4
P10	RSLV S1	BL	7
P6	RSLV S3	BL-BK	8
P5	RSLV S2	GN	9
P9	RSLV S4	GN-BK	10
P8	RSLV R1	WT	11
P7	RSLV R2	WT-BK	12
n.a.	n.a.	n.a.	5
n.a.	n.a.	n.a.	6

6 Software requirements and installation

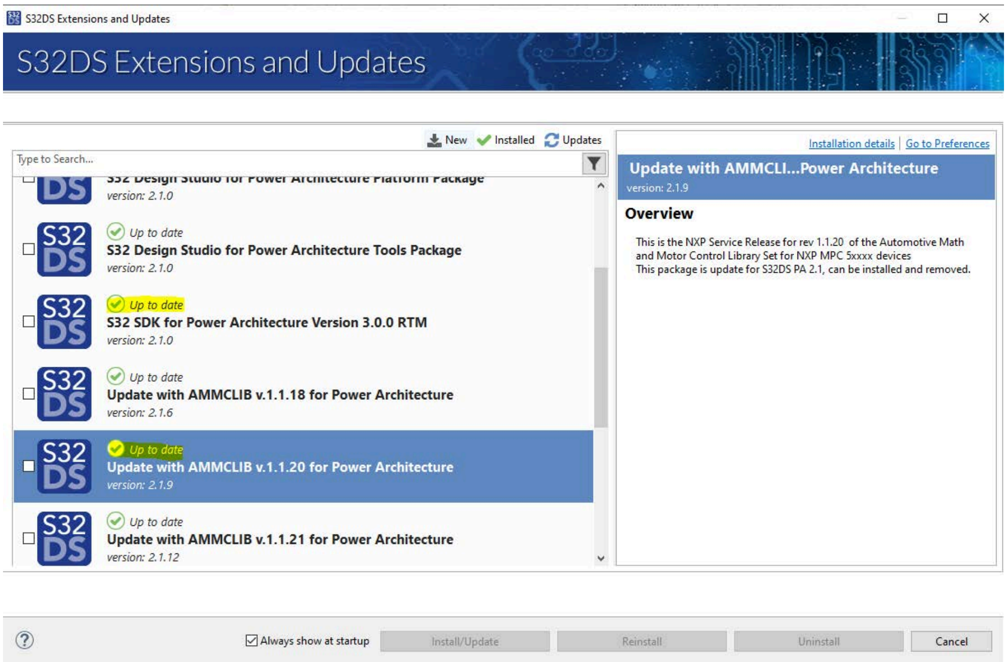
Table 8. Software descriptions

Name	Source	Use
S32 Design Studio for Power Architecture V2.1	nxp.com	integrated development environment (IDE) and debugger toolchain
Kvaser drivers for Windows	kvaser.com/download	GUI toolchain
FreeMASTER 3.1	nxp.com	GUI toolchain
AMMCLIB_1.1.20 or greater	nxp.com	Motor control libraries

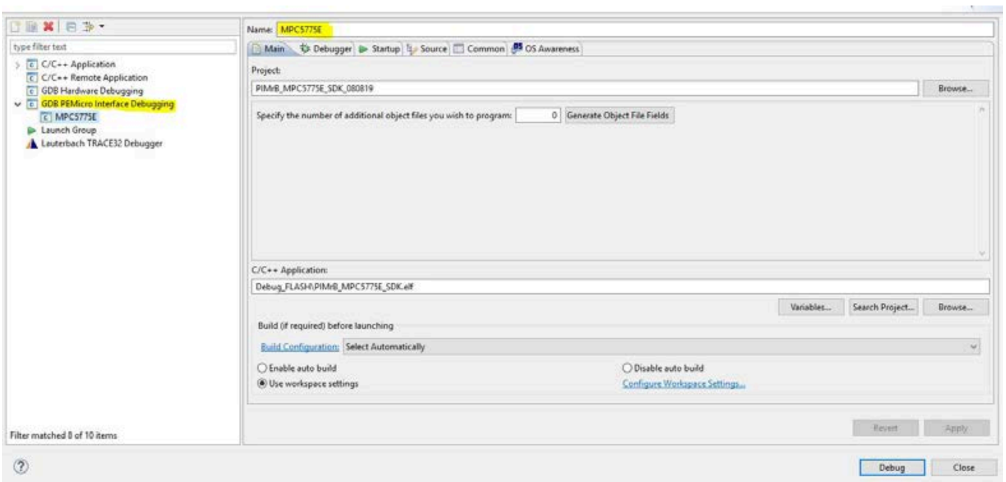
6.1 S32 Design Studio for Power Architecture V2.1

The S32 Design Studio IDE is a complimentary integrated development environment for Automotive and Ultra-Reliable MCUs that enables editing, compiling, and debugging of designs.

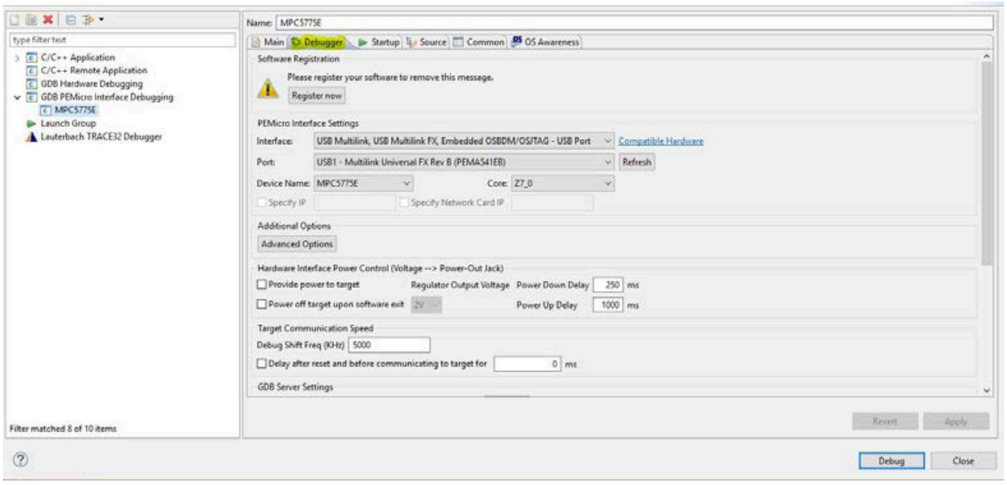
1. Go to https://www.nxp.com/design/software/embedded-software/s32-design-studio-ide/s32-design-studio-ide-for-power-architecture-based-mcus:S32DS-PA and click **User Guide**.
2. Follow the instructions within the S32 Design Studio for Power Architecture 2.1 Installation Guide.
3. Run the S32 Design Studio by clicking the S32 Design Studio for Power Architecture V2.1 icon
4. Before flashing the device, verify that the updates have been installed on the S32 design studio for AMMCLIB_1.1.20 or later. To do so, go to **Help** and check for S32DS extensions and updates. It should be up to date with AMMCLIB v.1.1.20 for power architecture.



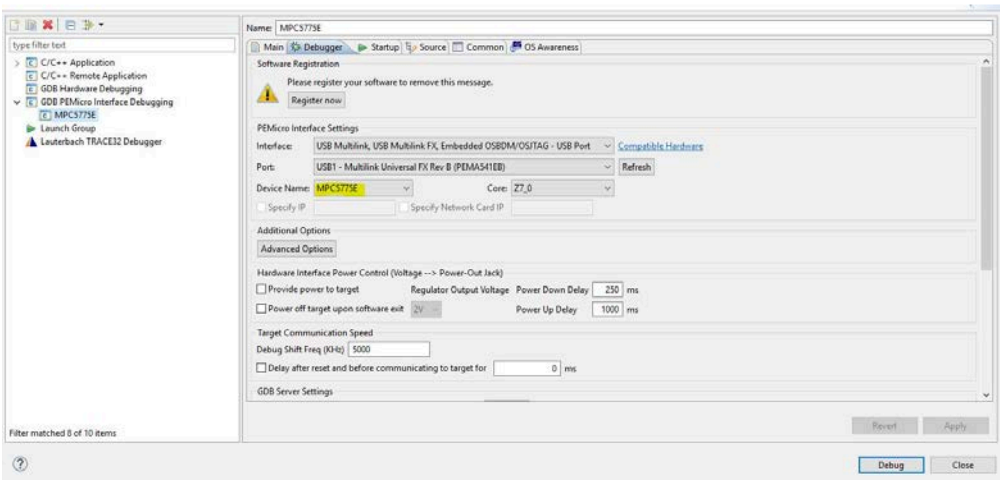
5. Click **Run** > **Flash from file...**
6. Double-click the **GDB PEmicro Interface Debugging** icon
7. Change the name of the new configuration to **MPC5775E**.



8. Click the **Debugger** tab



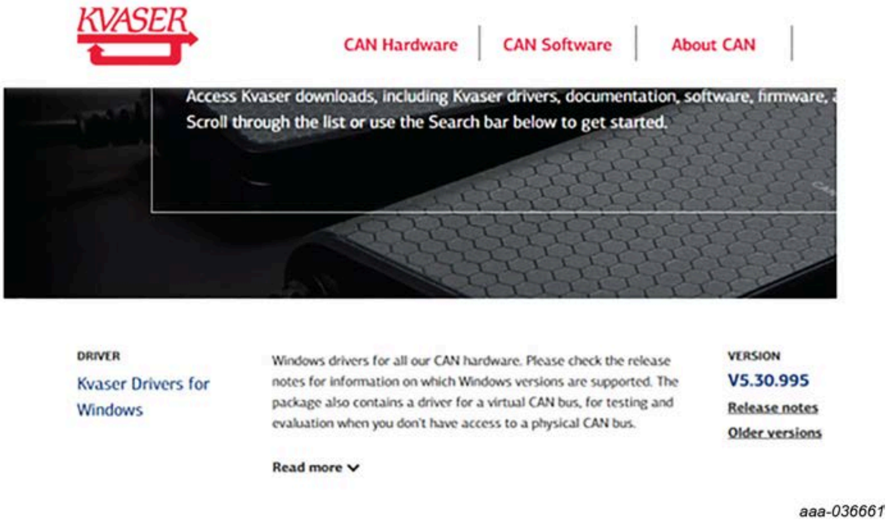
9. Click the **Device Name** drop-down menu and select **MPC5775E**



10. Click **Apply**
11. Flash the .elf file.

6.2 Installing the USB – CAN interface adapter

1. Browse to https://www.kvaser.com/download/.
2. Download the latest Kvaser drivers for Windows and install them. The driver page is shown below.



3. Connect the USB-CAN interface adapter to a USB port on the computer.

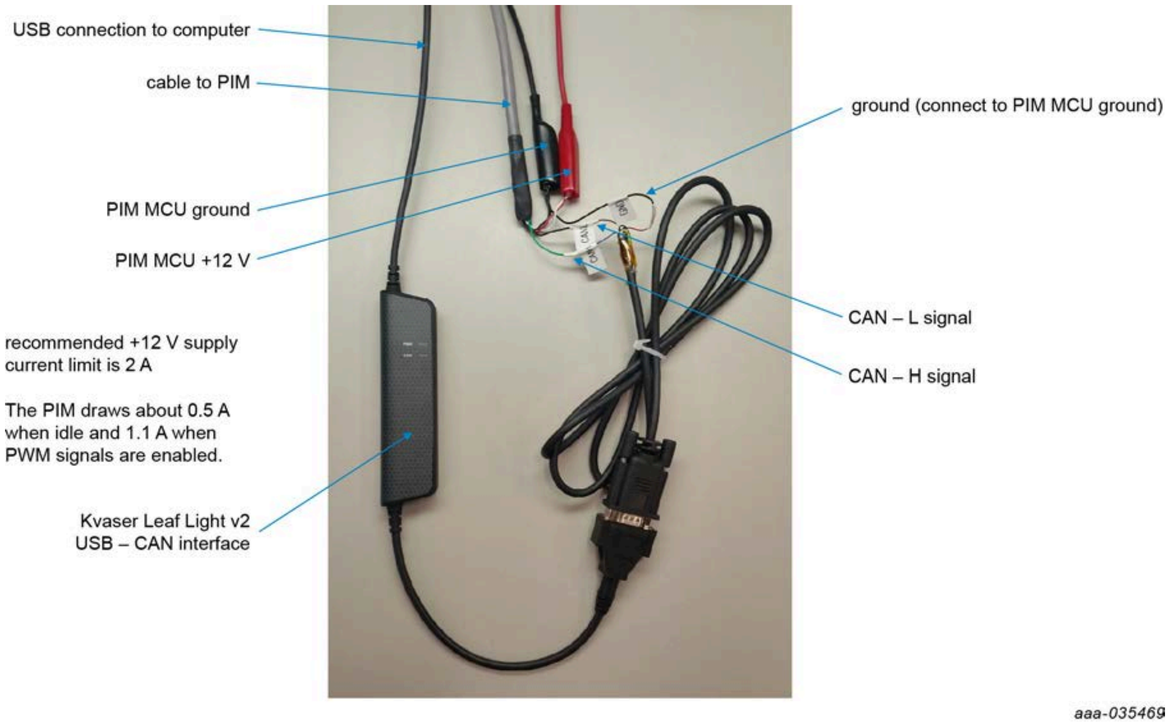


Figure 9. Connecting the USB-CAN interface adapter to a USB port on the computer

6.2.1 Kvaser leaf light v2 9-pin connector pinout

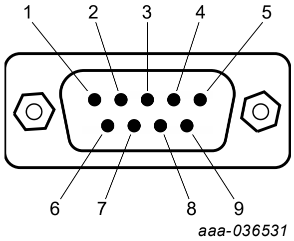


Figure 10. D-SUB 9 connector pin numbers

Table 9. Pinning

Pin	Description
1	not connected
2	CAN_L
3	GND
4	not connected
5	shield
6	not connected
7	CAN_H
8	not connected
9	not connected

6.3 FreeMASTER setup

Refer to UM11551 PIM FreeMASTER GUI user guide for information on connecting to the PIM and using the FreeMASTER tool to monitor and control the inverter application demo.

7 Operation of the power inverter module (PIM)

After completing the steps in Section 5 and Section 6 "Software requirements and installation", you are now ready to operate the PIM.

7.1 Demo software

1. The EV-CONTROLEVMHD board is preloaded with DEMO software that does not require resolver and motor current feedback signals to be connected. The Demo software runs open loop controls once the logic power is supplied.
2. Required connection for demo software:
   - Ground: EXT_DGND must be connected to 12 V GND
   - Power supply: Unswitched 12 V and ignition may be tied together.
   - Optional connection:
   - CANA_H CANA_L

- Refer to Table 7 for connection:
- For advanced operation of the PIM, a motor with resolver and RTD temperature sensing connections is required: The following signals must be connected for proper operation of the PIM.
  - CANA_H CANA_L
  - Resolver signals x6
  - RTD1 signals x2

3. Apply 30 VDC on the TE DC connector.
4. Apply 12 V logic power supply and observe the motor as it begins spinning and ramping up speed until it is stable.

8 MPC5777C software development tools

NXP has software development tools available for use with the NXP MPC5777C development board (DEVB). The development board is intended to provide a platform for easy customer evaluation of the MPC5777C microcontroller and to facilitate hardware and software development. The development board can be used for powertrain/inverters/battery management system (BMS)/automotive Ethernet, and so on. The latest product information is available at http://www.nxp.com/MPC5777C.

Development software, available at http://www.nxp.com:

- **S32S Design Studio IDE for power architecture:**
  The S32S design studio for power architecture IDE installed on a Windows PC workstation enables editing, compiling, and debugging of source code designs. Software development kit (SDK) supports several devices including MPC5777C.
- **Automotive Math and Motor Control Library Set (AMMCLiB):**
  The AMMCLiB is a precompiled software library containing the building blocks for a wide range of motor control and general mathematical applications.
- **FreeMASTER 3.1 runtime debugging tool:**
  FreeMASTER runtime debugging tool is a separate download and can also be used with the MCU code developed with S32DS as a user-friendly real-time debug monitor, graphical control panel, and data visualization tool for application development and information management.
- **Motor control application tuning (MCAT):**
  The MCAT is a FreeMASTER plug-in tool intended for the development of permanent magnet synchronous motor (PMSM) field oriented control (FOC) and brushless direct current (BLDC) motor control applications.
- **Example code, GD3160 device driver notes and GD3160 device driver reference notes:**
  GD3160 device driver example code REV1.1, or later, provides a basis to get started and begin software development for the desired motor control.

9 Schematics, board layout, and bill of materials

The board schematics, board layout, and bill of materials are available with purchase of the EV-INVERTERHD SiC MOSFET Enablement Kit.

10 References

[1] Tool summary page for EV-INVERTERHD SiC MOSFET Enablement Kit – https://www.nxp.com/design/designs/sic-ev-power-inverter-control-reference-platform:EV-INVERTERHD

[2] Product summary page for GD3160 – http://www.nxp.com/GD3160

[3] GD3160 fact sheet – https://www.nxp.com/docs/en/fact-sheet/GD3160FSA4.pdf

[4] Product summary page for MPC5775E – http://www.nxp.com/MPC5775B-E

[5] Product summary page for FS6500 – http://www.nxp.com/FS6500

[6] Product summary page for TJA1042 – http://www.nxp.com/TJA1042

[7] Vepco Technologies – http://www.vepcotech.com/

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Date of release: 20 October 2022
Document identifier: UM11550