

UM12210

EV Traction Inverter Gen 3 SiC MOSFET Enablement Kit

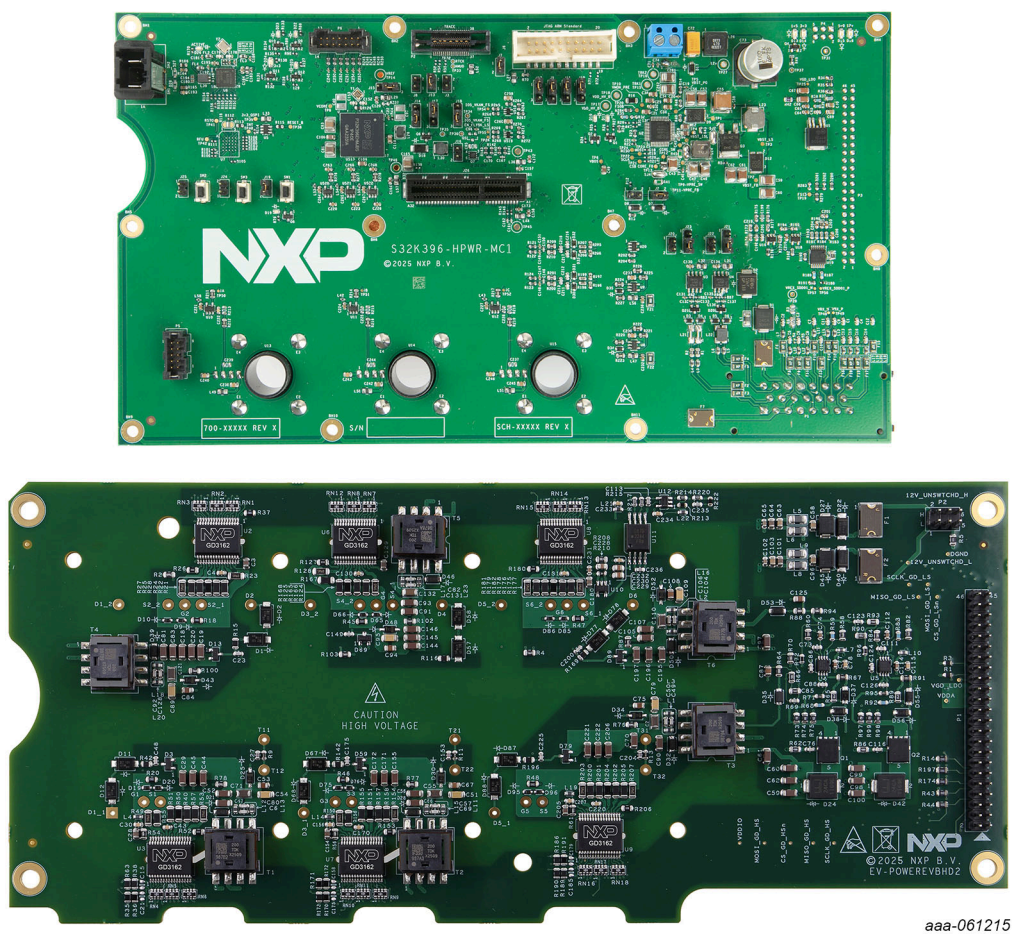
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User manual

Document information

Information	Content
Keywords	automotive, inverter, S32K396, GD3162
Abstract	This user manual describes the EV Traction Inverter Gen 3 SiC MOSFET Enablement Kit (EV-INVERTERGEN3) featuring GD3162 gate drive devices and S32K396 Microcontroller. The kit can be purchased with only the power board and microcontroller board and accessories directly from NXP. Alternatively, a complete kit with power board, controller board, SiC MOSFET, and DC link, all enclosed in a water cooling housing case, can be purchased from Vepco Technologies.





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1 Finding kit resources and information on the NXP website

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. These boards incorporate monolithic integrated circuits and system-in-package devices that use proven high-volume technology. NXP products offer

- Longer battery life
- Smaller form factor
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NXP Semiconductors provides online resources for this reference design and its supported devices at <http://www.nxp.com>. See the information page for electric vehicle (EV) traction motor reference designs at <https://www.nxp.com/products/power-management/motor-and-solenoid-drivers/powertrain-and-engine-control:PWRTRAIN-ENGCONTROL>. 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 Traction Inverter Gen 3 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, asking and answering technical questions, and receiving input on just about any embedded design topic.

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

2 Overview

NXP's EV Traction Inverter Gen 3 SiC MOSFET Enablement Kit is designed for customers using SiC MOSFETs modules to develop the traction inverter module that controls electric vehicle traction motors. The kit consists of two boards, the S32K396-HPWR-MC1 MCU control board featuring the S32K396MCU, FS26 SBC, TJA146X CAN, TJA1103 Ethernet interface and the EV-POWERVEVBHD2 driver control board featuring GD3162 gate drive devices with dynamic gate strength for HybridPACK Drive power modules. The S32K396-HPWR-MC1 MCU control board supports motor control, current sensing, and interface connectivity functions. The EV-POWERVEVBHD2 driver control board controls power to the 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 tool (MCAT), code examples, and the FreeMASTER graphical user interface from NXP.

Customers who purchase the kit have access to the schematics, Gerber files, user guides, and the SW Application Note which all are available online in a secured site.

Customers can use the EV Traction Inverter Gen 3 SiC MOSFET Enablement Kit with a SiC MOSFET module [1]. For customers interested in an off-the-shelf solution, NXP has partnered with [Vepco Technologies Inc.](#) to offer a self-contained ECU that integrates the S32K396-HPWR-MC1 and the EV-POWERVEVBHD2 boards within a single unit. In addition to the two NXP boards, the Vepco product includes a compatible SiC Module, DC link capacitors, a busbar, and a cooling plate. All of the components within the ECU are connected and ready to use. [Figure 1](#) shows the Vepco ECU with the bottom removed to expose the S32K396-HPWR-MC1 MCU board.



Figure 1. ECU made in collaboration with Vepco based on EV-INVERTGEN3 boards

The EV Traction Inverter Gen 3 SiC MOSFET Enablement Kit can also be purchased directly from NXP Semiconductor. However, customers who choose to do so are responsible for providing all the additional required components (ECU housing, power module, DC link capacitors, cooling plates, connectors, busbar, and so on) for configuring and debugging their platform.

3 Getting started

Read this manual in its entirety before connecting the traction inverter module 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-INVERTERGEN3) includes:

- MCU control board (S32K396-HPWR-MC1)
- Driver control board (EV-POWЕРЕVBHD2)
- 3-phase output busbars for LEM current sensors
- 6-pin and 46-pin header connectors for interfacing between S32K396-HPWR-MC1 and EV-POWЕРЕVBHD2 boards

3.2 Additional hardware

To use the EV Traction Inverter Gen 3 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 ECU [\[11\]](#) or is designing their own EV inverter platform.

All customers (Vepco ECU 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 (or similar) for the motor
- **PCAN-USB CAN Interface for USB:** or comparable USB-CAN interface adapter [\[5\]](#)
- **PEmicro multilink debug probe:** Connects the S32K396-HPWR-MC1 [\[4\]](#) board to the PC-based GUI [\[6\]](#)
- **Motor:** A 3-phase permanent magnet synchronous (PMSM) motor.
- **High-voltage cables (2-wire):** For high-voltage connections from high-voltage DC power supply into the ECU DC link capacitors.
- **High-voltage cables (3-wire):** For high-voltage phase connections from the ECU to the PMSM motor
- **Low-voltage cables:** For low-voltage connections from the 12 VDC power supply to the ECU

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

- **SiC HybridPACK footprint module**
- **Cooling plate or water jacket compatible for SiC HybridPACK footprint module:** The cooling plate serves as the cooling structure interface for the SiC module.
- **Busbar:** 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 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 [\[7\]](#).
- **23-position signal connector** (optional) AMPSEAL (PN 770680-1) connector to connect the ECU to a 3-phase motor [\[8\]](#).
- **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
- **46-pin cable:** 46-pin flat ribbon cable with male-to-female connectors to connect the EV-CONTROLEVMHD MCU control board to the EV-POWЕРЕVBHD 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 eight 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 busbar 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 11 or 10 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 Traction Inverter Gen 3 SiC MOSFET Enablement Kit. Customers who purchase the EV-INVERTERGEN3 enablement kit receive instructions on how to download the software.

- S32 Design Studio for S32 Platform
- Automotive Math and Motor Control Library Set (AMMCLiB)
- FreeMASTER 3.2 runtime debugging tool
- Example code, GD31xx Device Driver notes and GD31xx Device Driver Reference notes

4 Getting to know the hardware

4.1 SiC enablement kit overview

The EV-INVERTERGEN3 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 Wolfspeed ECB2R1M12YM3L footprint module, Infineon FS03MR12A6MA1B CoolSiC HybridPACK module, or Leapers Semiconductor DFS02FB12HDB1. 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. Use the registration code provided in the hardware shipment to gain access to the secured site.

Customers must obtain the additional inverter components. These components include the SiC MOSFET or IGBT module, link capacitor, busbar, cooling plate, mounting hardware, and so on. Customers can select their own components when designing and assembling a complete ECU to work with the NXP S32K396-HPWR-MC and EV-POWЕРЕVBHD2 boards. As an alternative, a complete preassembled reference ECU platform is available through NXP partner Vepco Technologies. The SiC MOSFET module installed will be one of the compatible modules as listed in [Section 3.2](#).

4.2 EV Traction Inverter Gen 3 SiC MOSFET Enablement Kit features

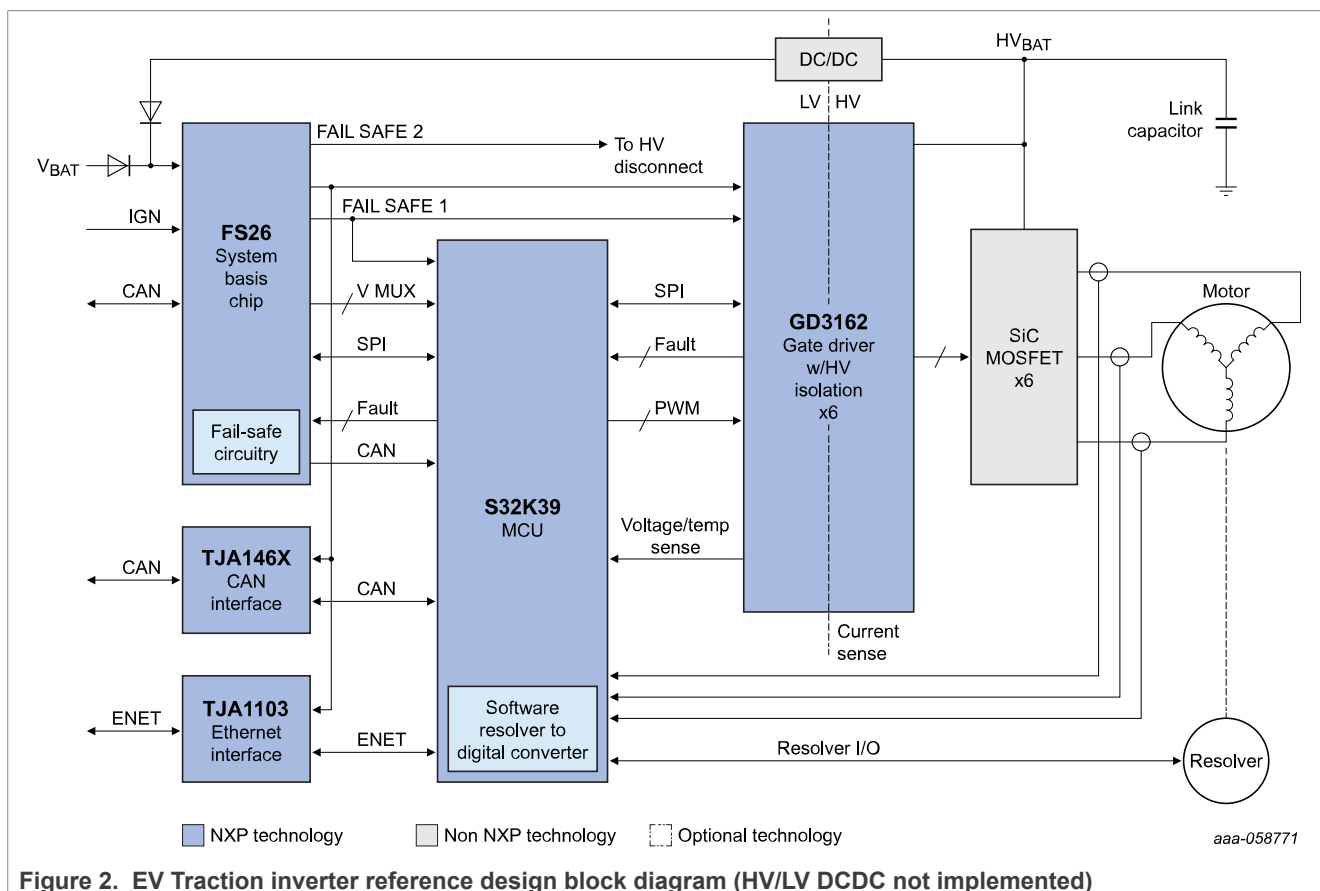
4.2.1 Benefits

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

4.2.2 Featured products

- S32K396 advanced motor control ASIL D MCU
- GD3162 isolated SiC MOSFET or IGBT ASIL D gate drivers with dynamic gate strength. [\[2\]](#)[\[3\]](#)
- FS26XX robust ASIL D system basis chip (SBC)
- TJA1462AT/0Z redundant CAN bus interface [\[10\]](#)
- TJA1103AHN/0Z IEEE 100BASE-T1 compliant Automotive Ethernet physical interface of the OSI model (PHY) transceiver interface
- Capability to connect Wolfspeed ECB2R1M12YM3L, StarPower MD816HTC120P6HE or Infineon FS03MR12A6MA1B CoolSiC HybridPACK, Leapers Semiconductor DFS02FB12HDB1 footprint power module for 3-phase evaluations and development

4.3 EV-INVERTERGEN3 enablement kit block diagram



4.4 Board descriptions

4.4.1 S32K396-HPWR-MC1 board connectors

The S32K396-HPWR-MC1 MCU control board supports motor control, current sensing, and interface connectivity functions. The board includes an NXP S32K396 32-bit dual-core ASIL D MCU targeted for motor control. An NXP FS26xx [9] system basis chip (SBC) powers the MCU. High-speed CAN support is provided by an NXP TJA1462AT/0Z transceiver device. In addition, the board includes an NXP TJA1103AHN/0Z Ethernet PHY chip with a 100BASE-T1 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 S32K396-HPRW-MC1 top of board connectors

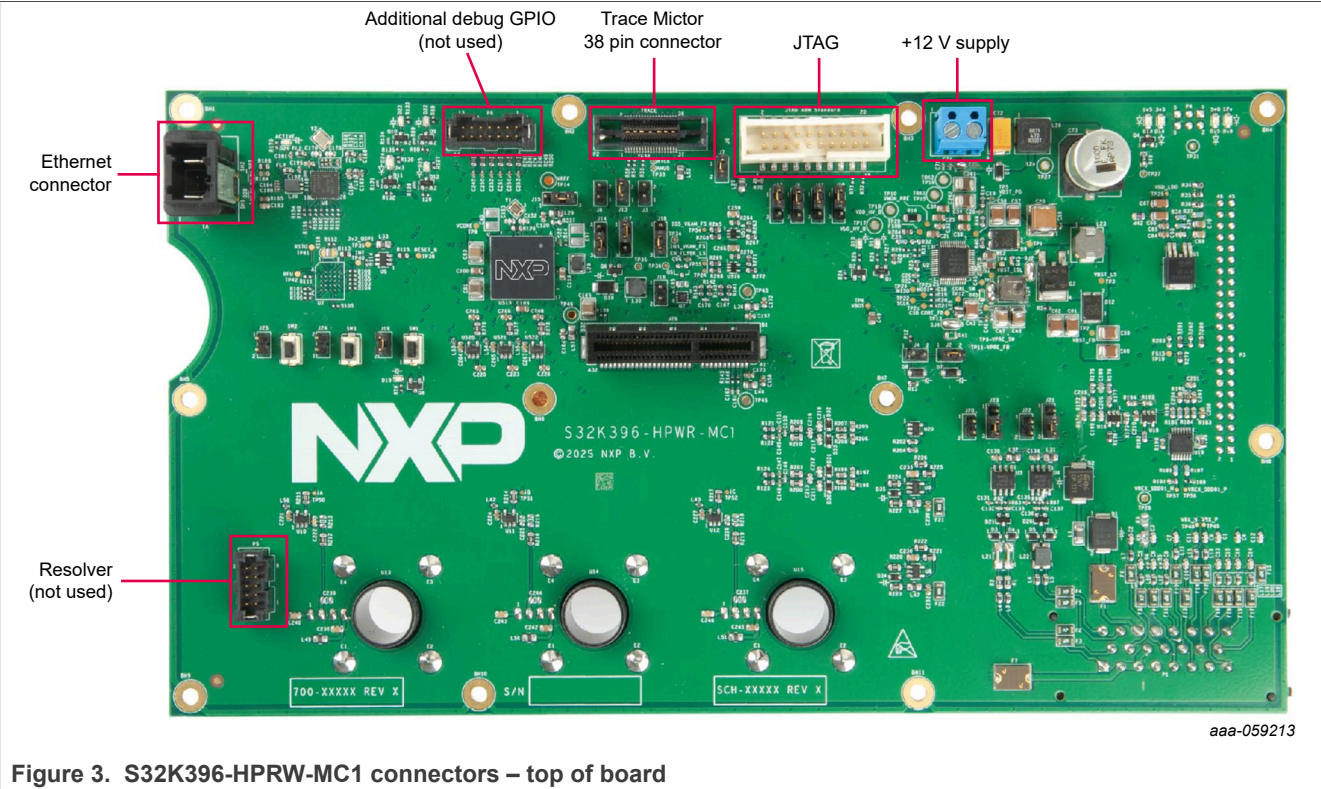


Figure 3. S32K396-HPRW-MC1 connectors – top of board

Figure 3 shows the connectors on the top of the S32K396-HPWR-MC1 board. The pin definitions for the connectors are included in the subsections below.

4.4.1.1.1 +12 V supply connector definitions

Table 1. +12 V supply connector (P4) definitions

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

4.4.1.1.2 JTAG connector definitions

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

Table 2. JTAG connector (J6) definitions

Pin	Symbol	Type	Range	Memo
1	VCC	—	5 V	—
2	GND	—	—	—
3	NC	—	—	—
4	GND	—	—	—
5	TDI_ARM	Digital output	0 V to	Connects to TDI pin

Table 2. JTAG connector (J6) definitions...continued

Pin	Symbol	Type	Range	Memo
			5 V	
6	GND	—	—	—
7	TMS	Digital output	0 V to 5 V	Connects to TMS pin
8	NC	—	—	—
9	TCK_ARM	Digital output	0 V to 5 V	Connects to TCK
10	GND	—	—	—
11	RTCK	—	—	—
12	DGND	—	—	—
13	TDO	Digital output	0 V to 5 V	Connects to TDO pin
14	GND	—	—	—
15	RESET	—	—	—
16	GND	—	—	—
17	NC	—	—	Connects to PTF23
18	GND	—	—	—
19	NC	—	—	Connects to PTF25
20	GND	—	—	—

4.4.1.1.3 Unused connectors

The S32K396-HPRW-MC board has four connectors that are intended for internal purposes or are reserved for future releases. Those connectors are:

- P6 – Additional debug general-purpose input/output (GPIO): For internal debugging only.
- P5 – Current sensing and calibration: Reserved for future releases.

4.4.1.2 S32K396-HPWR-MC1 bottom of board connectors

As shown in [Figure 4](#) there are four connectors on the bottom of the S32K396-HPWR-MC1 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 ECU traction motor and is used for monitoring and control signals. The corresponding connections are shown in [Table 5](#) and [Table 6](#).

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 ECU. Customers who chose not to use the Vepco ECU must pass cables through the motor phase current sensors when connecting the SiC MOSFET power module to a motor. See [Section 5.2](#).

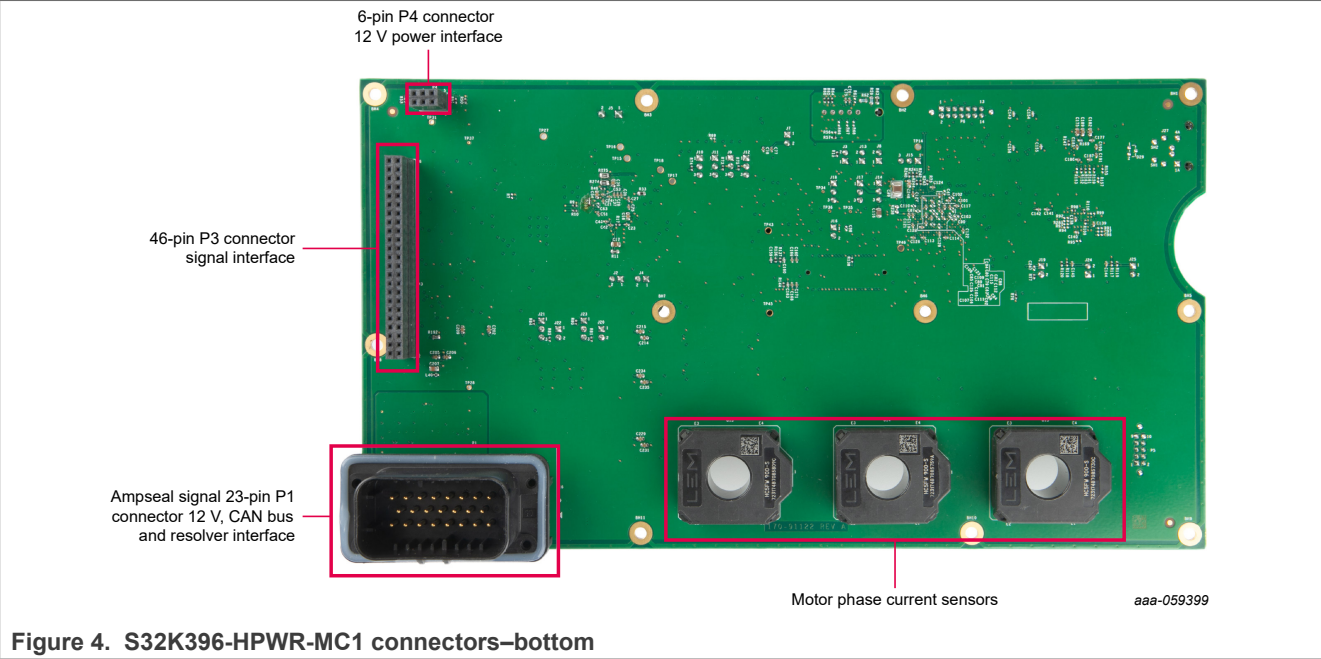


Figure 4. S32K396-HPWR-MC1 connectors–bottom

4.4.2 EV-POWERVEBHD2 board connector

The EV-POWERVEBHD2 driver control board controls power to the SiC MOSFETs. The board features six NXP GD3162 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.

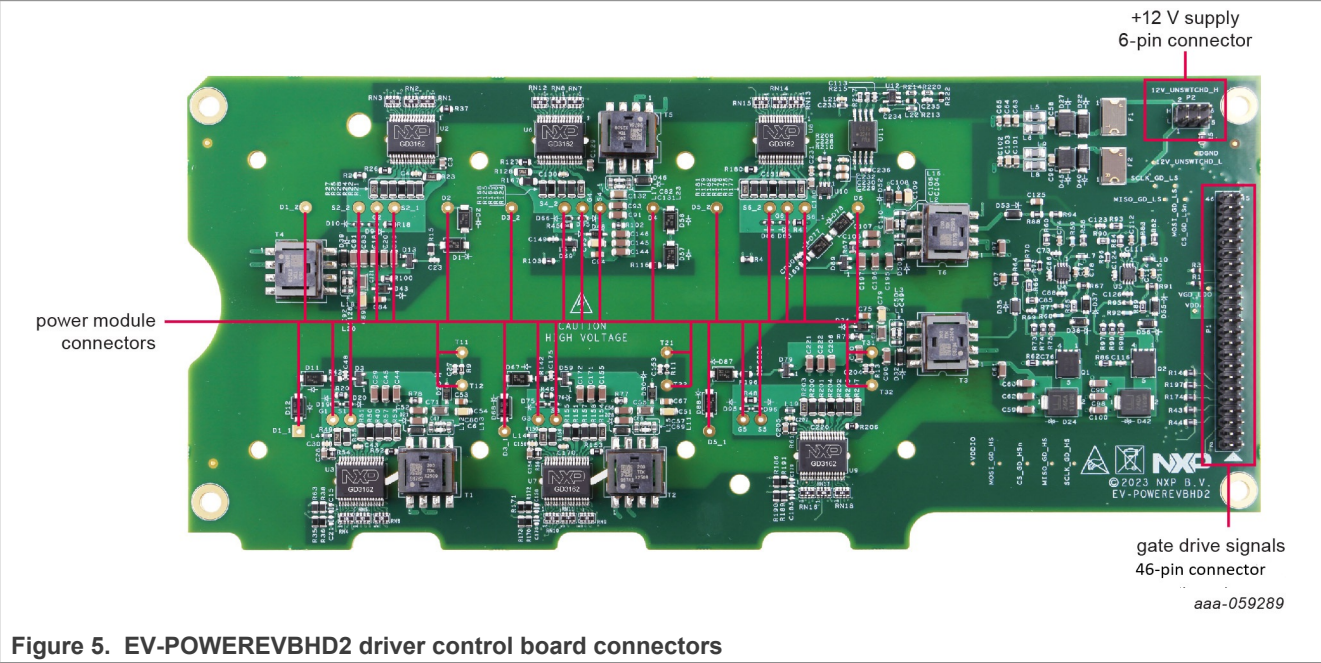


Figure 5. EV-POWERVEBHD2 driver control board connectors

4.4.2.1 Driver signals connector definitions

Table 3. Driver signals 46-pin connector definitions

Connector: Samtec 2 mm, 2 x 23

Pin	Symbol	Type	Range	Memo
1	GSENHU	Digital input	0 V to 5 V	Gate Strength Enable HS phase U
2	GSENLU	Digital input	0 V to 5 V	Gate Strength Enable LS phase U
3	GSENHV	Digital input	0 V to 5 V	Gate Strength Enable HS phase V
4	GSENLV	Digital input	0 V to 5 V	Gate Strength Enable LS phase V
5	GSENHW	Digital input	0 V to 5 V	Gate Strength Enable HS phase W
6	GSENLW	Digital input	0 V to 5 V	Gate Strength Enable LS phase W
7	INTA_GD_UH	Digital output	0 V to 5 V	Fault indicator HS phase U
8	INTA_GD_UL	Digital output	0 V to 5 V	Fault indicator LS phase U
9	INTA_GD_VH	Digital output	0 V to 5 V	Fault indicator HS phase V
10	INTA_GD_VL	Digital output	0 V to 5 V	Fault indicator LS phase V
11	INTA_GD_WH	Digital output	0 V to 5 V	Fault indicator LS phase W
12	INTA_GD_WL	Digital output	0 V to 5 V	Fault indicator LS phase W
13	SCLK_GD_HS	Digital input	0 V to 5 V	SPI_HS clock
14	DGND	—	—	—
15	MISO_GD_HS	Digital output	0 V to 5 V	SPI_HS MISO
16	SCLK_GD_LS	Digital input	0 V to 5 V	SPI_LS Clock
17	MOSI_GD_HS	Digital input	0 V to 5 V	SPI_HS MOSI
18	MISO_GD_LS	Digital output	0 V to 5 V	SPI_LS MISO
19	CS_HS	Digital input	0 V to 5 V	SPI_HS CS
20	MOSI_GD_LS	Digital input	0 V to 5 V	SPI_LS MOSI
21	FSS_HS	Digital input	0 V to 5 V	Fail-safe state high side; active low
22	CS_GD_LS	Digital input	0 V to 5 V	SPI_LS CS
23	EN_FLYBK_HS	Digital input	0 V to 5 V	Enables flyback for high side
24	EN_FLYBK_LS	Digital input	0 V to 5 V	Enables flyback for low side
25	VDDA	Power	5 V	Analog supply for Vdc measurement
26	FSENB	Digital input	0 V to 5 V	Enables safe state; active low
27	VbusDivByX	Analog output	0 V to 5 V	Bus voltage measurement
28	FSS_LS	Digital input	—	Fail-safe state low side; active Low
29	AGND	—	—	Analog ground
30	VGD_LDO	Power	5 V	Power supply for LS logic
31	INTB_GD_HS	Digital output	0 V to 5 V	Fault indicator HS
32	INTB_GD_LS	Digital output	0 V to 5 V	Fault indicator LS
33	DGND	—	—	Digital ground
34	VDDIO	Power	5 V	Power supply for HS Logic

Table 3. Driver signals 46-pin connector definitions...continued

Connector: Samtec 2 mm, 2 x 23

Pin	Symbol	Type	Range	Memo
35	AOUT_UH	Digital output	0 V to 5 V	AOUT pin output HS phase U
36	AOUT_UL	Digital output	0 V to 5 V	AOUT pin output LS phase U
37	AOUT_VH	Digital output	0 V to 5 V	AOUT pin output HS phase V
38	AOUT_VL	Digital output	0 V to 5 V	AOUT pin output LS phase V
39	AOUT_WH	Digital output	0 V to 5 V	AOUT pin output HS phase W
40	AOUT_WL	Digital output	0 V to 5 V	AOUT pin output LS phase W
41	PWM_UH	Digital input	0 V to 5 V	PWM input HS phase U
42	PWM_UL	Digital input	0 V to 5 V	PWM input LS phase U
43	PWM_VH	Digital input	0 V to 5 V	PWM input HS phase V
44	PWM_VL	Digital input	0 V to 5 V	PWM input LS phase V
45	PWM_WH	Digital input	0 V to 5 V	PWM input HS phase W
46	PWM_WL	Digital input	0 V to 5 V	PWM input LS phase W

4.4.2.2 +12 V supply connector definitions

Table 4. +12 V, 6 pin connector (P2) definitions

Connector: Samtec 2 mm, 2 x 3

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

4.4.2.3 Power module connections

These connectors connect the EV-POWЕРЕVBHD2 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-POWЕРЕVBHD2 board can be mounted directly on top of the power module. Socket pins (not included) can be used to attach the EV-POWЕРЕVBHD2 board to the SiC MOSFET power module to easily attach and de-attach board from power module if desired. Mill-Max part# 0405-0-15-15-34-27-04-0.

4.4.2.4 EV-POWЕРЕVBHD2 Gate Resistor Selection:

Choosing proper gate resistor values on the gate drive power board (EV-POWЕРЕVBHD2) is important to optimize switching losses while staying within the Safe Operation Area (SOA) of the SiC MOSFET power module reducing Voltage Drain to Source (Vds) overshoot.

Worse case conditions of high voltage and high current were used across temperatures (-15C, 25C, and 125C) to optimize gate resistor values on the EV-POWЕРЕVBHD2 power board using GD3162 gate drive devices with dynamic gate strength. Resistor values were determined for Resistance Gate On (RGon) and Resistance Gate Off (RGoff) at 800 volts DC link Bus voltage with high current 800A using low gate strength, and lower current 200A using medium gate strength. Measurements were taken with various resistor values to maintain Vds overshoot below maximum voltage rating of SiC MOSFET power module at 1200V.

Double Pulse tests were performed on Low-Side switch and High-Side switch independently using medium gate strength at 200A and 800V and low gate strength at 800A and 800V to determine highest gate resistance value needed to keep maximum overshoot below 1200V maximum power module rating SOA while using the lowest R_{Gon} and R_{Goff} resistor value possible to optimize switching losses.

5 Assembling the hardware

The procedure for assembling an inverter platform that uses the EV Traction Inverter Gen 3 SiC MOSFET Enablement Kit differs depending on whether the Vepco ECU 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 ECU.

The following hardware, described in [Section 4 "Getting to know the hardware"](#), is required for this procedure.

- Vepco power inverter module (ECU)
- 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 (ECU DC link)
- 3-phase motor
- PEmicro multilink debugger probe
- PEAK USB – CAN interface adapter

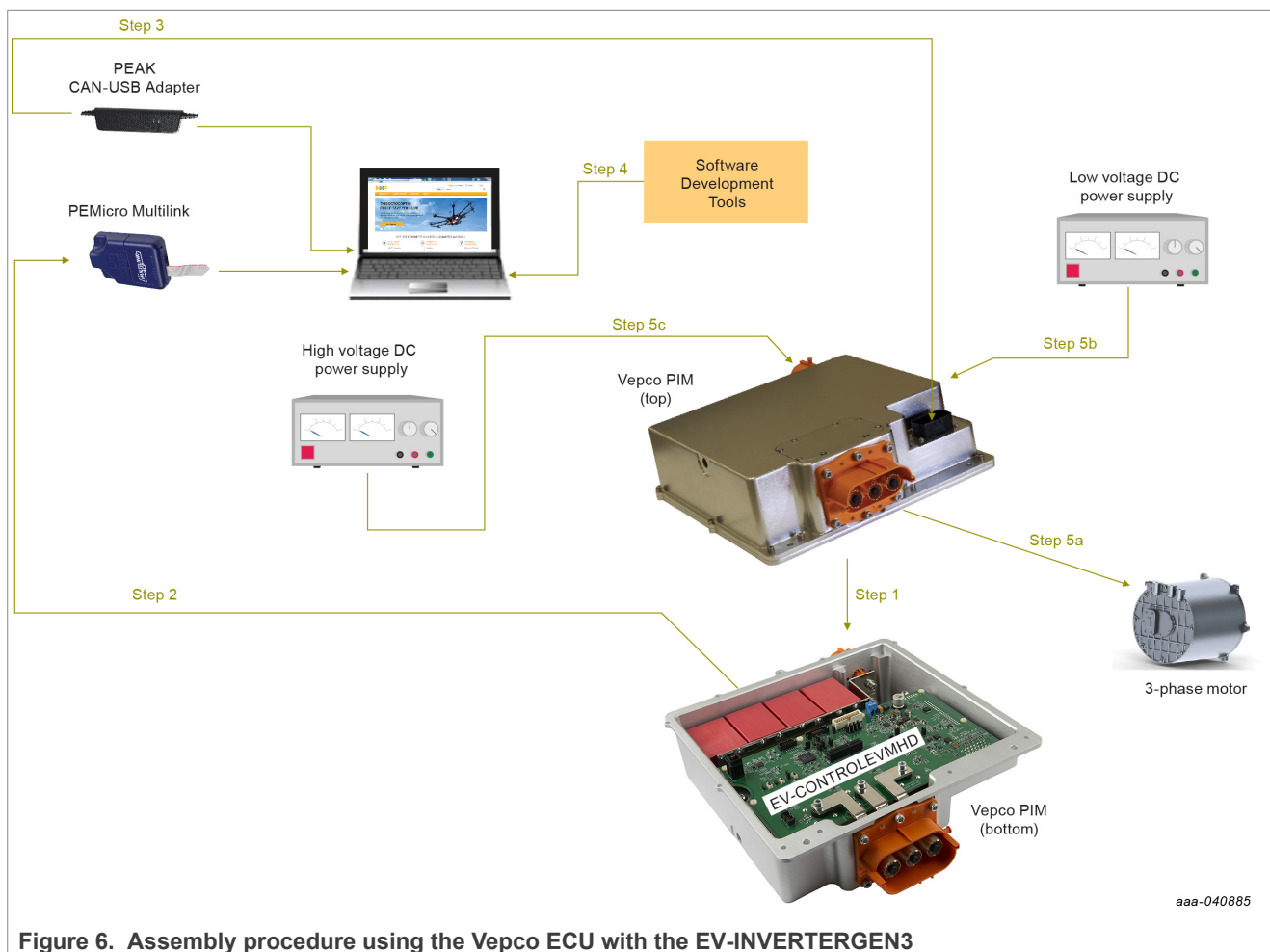


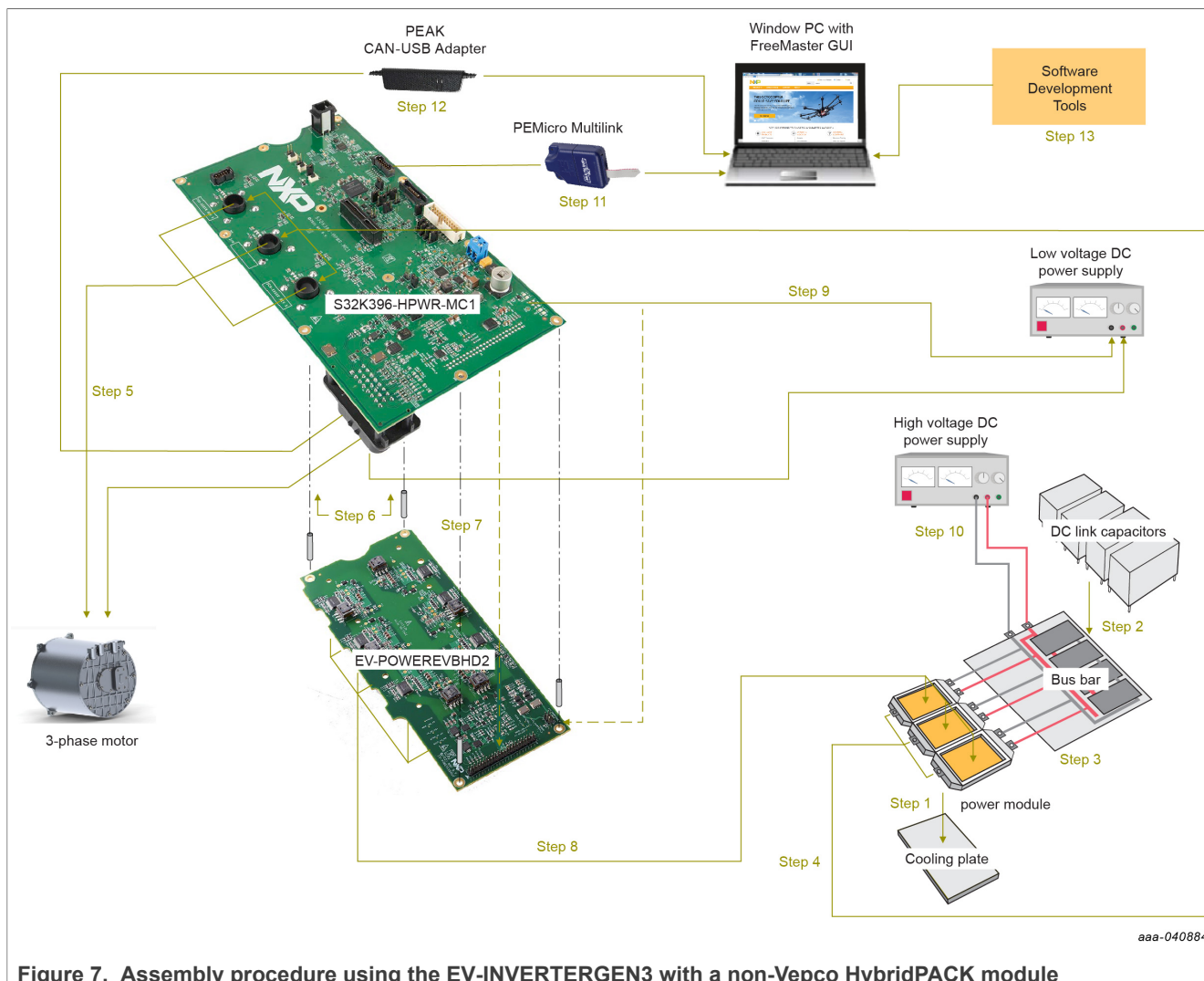
Figure 6. Assembly procedure using the Vepco ECU with the EV-INVERTERGEN3

1. Turn the Vepco ECU upside down and remove the bottom plate. Removing this plate exposes the S32K396-HPWR-MC1 board with EV-POWERVEVBD2 board, link capacitors, and power module mounted inside the unit.
2. Connect the PEmicro multilink debugger header to connector J6 on the S32K396-HPWR-MC1 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 PEAK USB-CAN Interface Adapter from the 23-pin P1 connector on the bottom of the S32K396-HPWR-MC1 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. Follow the instructions in the Vepco ECU documentation to make the following connections, see [Figure 6](#):
6. 3-phase motor
7. Low-voltage DC power supply
8. 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 (busbar, mounting hardware, and so on) required to support and connect the components in their platform.

- EV-INVERTERGEN3 SiC MOSFET Enablement Kit
- StarPower P6HE module or Infineon CoolSiC HybridPACK module
- Cooling plate
- A busbar 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
- PEAK USB – CAN interface adapter



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1. Attach the ECB2R1M12YM3LISiC power module to the cooling plate.
2. Attach the DC link capacitors to the busbar.
3. Connect the three positive DC power connectors on the power module to the corresponding connectors on the busbar. Connect the three negative DC power connectors on the power module to the corresponding connectors on the DC link busbar
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 (U13, U14, U15) on the S32K396-HPWR-MC1 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 P1 connector on the S32K396-HPWR-MC1 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 P1 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 9 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_12V_UNSWTCHD to EXT_GND_12V_RETURN
7. Connect the two enablement kit boards. The connection can be made using two different methods:
 - Method A: Mount the S32K396-HPWR-MC1 board on top of the EV-POWERVEBHD2 board by directly connecting the 46-pin connectors (P3 and P4) and the +12 supply connectors (P4 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-POWERVEBHD2 board.
 - Method B: Connect the two boards with cables. To do so, connect a 46-pin ribbon cable between connector P3 on the S32K396-HPWR-MC1 board and connector P1 on the EV-POWERVEBHD2 board. In this configuration, the EV-POWERVEBHD2 board must be powered independently from the S32K396-HPWR-MC1 board. See step 9.
 8. Connect the EV-POWERVEBHD2 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-POWERVEBHD2 board (see [Figure 5](#)) and mounting the two units together.
 9. Connect the low-voltage DC power supply (12 V) to connector P4 on the S32K396-HPWR-MC1 board. If Method B in step 7 was used to connect the S32K396-HPWR-MC1 board to the EV-POWERVEBHD2 board, an additional connection must be made from the low-voltage DC power supply to the +12 supply connector (P2) on the EV-POWERVEBHD2 board. (When the two boards are mounted, as in Method A, step 7, the EV-POWERVEBHD2 draws power directly through the +12 supply connector on the S32K396-HPWR-MC1 board).

Using the two-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 busbar. Then connect the negative connector on the high-voltage/high current DC supply to the negative DC link capacitor connectors on the busbar. 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.

1. Connect the 20-pin PEmicro multilink debugger header to connector J6 on the S32K396-HPWR-MC1 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](#)).
2. Attach the PEAK USB-CAN Interface Adapter to the 23-pin connector on the bottom of the S32K396-HPWR-MC1 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.
3. Install the software development tools. See [Section 3.5 "Software"](#).

5.3 Using a motor not from Vepco Technologies

The application software in the ECU was developed for a 4-pole pair, 3-phase permanent magnet synchronous motor (PMSM). The ECU 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 appconfig.h or use MCAT for sensor parameters modifications.

The connectors shown in [Figure 8](#) and in [Table 5](#) and [Table 6](#) are used to bring in signals from CAN, the resolver, and the motor.

Note: Depending on how the motor is wound, the positive direction of the motor may be different from the definition of the ECU.

- **Calibration table**
A custom motor table is often required for optimization. The format of the table is presented in main.c. The lookup tables are two-dimensional (2D) tables. These tables describe dependencies Ld, Lq, and Lambda and Id, Iq currents; each output has its own table.
- **Faults and warnings**
The faults and warnings are handled in the MCAT.



Figure 8. 23-position signal connector [8]

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 S32K396-HPWR-MC1 are described in Table 5.

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 ECU.
2. The ECU3 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_12V_UNSWTCHD must be connected to EXT_GND_12V_RETURN
 - Power supply: EXT_12V_UNSWTCHD unswitched 12 V and ignition EXT_12V_IGNIT may be tied together

Table 5. S32K396-HPWR-MC1 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
5	EXT_MTRTD1_RTRN	Motor RTD 1 Return	Resistor –
6	EXT_RSLVR_DRIVE_SHIELD	Resolver Excitation Shield	0 V
7	EXT_RSLVR_SENSE_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_FAULT_OUT	Fsb1	TTL
11	EXT_DGND	—	—

Table 5. S32K396-HPWR-MC1 bottom interface connections...continued

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

Pin	Symbol	Description	Value
12	EXT_MTRTD1_SIG	Motor RTD 1 Signal	Resistor +
13	EXT_MTRTD2_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	EXT_CANH_B	—	—
17	EXT_CANL_B	—	—
18	EXT_12V_UNSWTCHD	Unswitched 12 V	10 V to 16 V, 2 A
19	EXT_GND_12V_RETURN	12 V GND	0 V, 2 A
20	EXT_MTRTD2_RTRN	Motor RTD 2 Return	Resistor –
21	EXT_RSLVR_R2	Resolver excitation R2	—
22	EXT_RSLVR_S2	Resolver sense S2	—
23	EXT_RSLVR_S4	Resolver sense S4	—

Refer to [Table 6](#) for connections. For advanced operation of the ECU, 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 for proper operation of the ECU.

Table 6. Optional connections

PCB	Device	Color	Molex 33472-1206
P12	RTD1 +	RD	1
P5	RTD –	RD-BK	2
P13	RTD2 +	YL	3
P20	RTD2 –	YL-BK	4
P8	RSLV S1	BL	7
P15	RSLV S3	BL-BK	8
P22	RSLV S2	GN	9
P23	RSLV S4	GN-BK	10
P14	RSLV R1	WT	11
P21	RSLV R2	WT-BK	12

6 Software requirements and installation

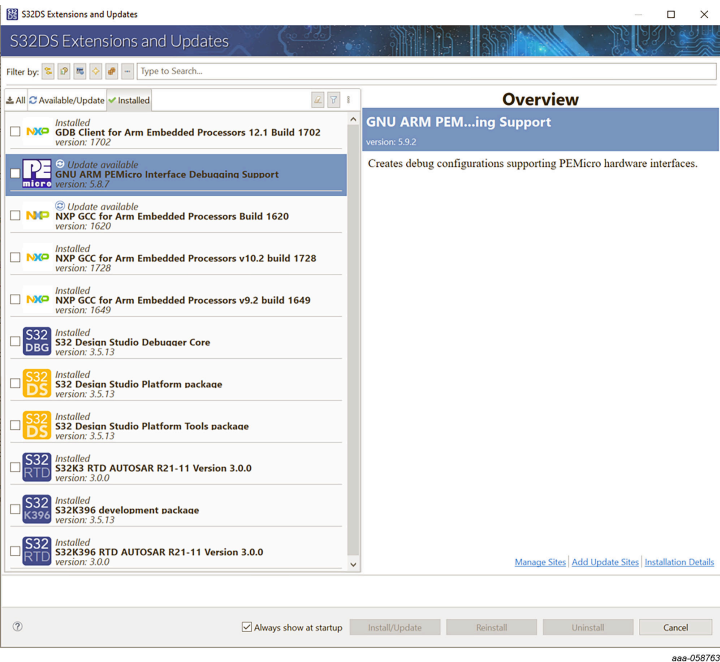
Table 7. Software descriptions

Name	Source	Use
S32 Design Studio for S32 Platform Version: 3.5 Build id: 240726 (Update 13)	nxp.com	integrated development environment (IDE) and debugger toolchain
PEAK USB drivers for Windows	PCAN-USB	GUI toolchain
FreeMASTER tool 3.2	nxp.com	GUI toolchain
S32K3xx_AMMCLIB_v1.1.31	nxp.com	Motor control libraries

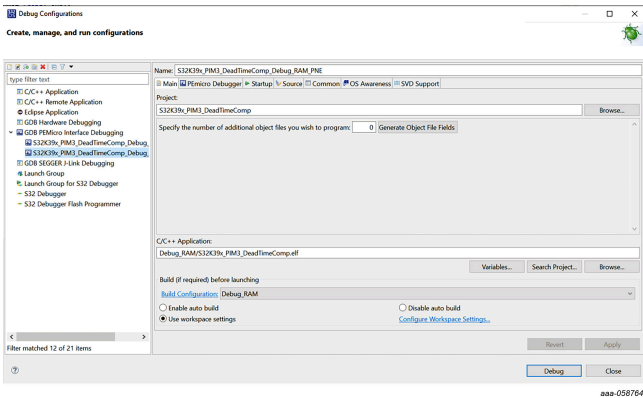
6.1 S32 Design Studio for S32 platform

S32 Design Studio for S32 platform is a complimentary, integrated development environment for automotive and ultrareliable MCUs that enables editing, compiling, and debugging of designs.

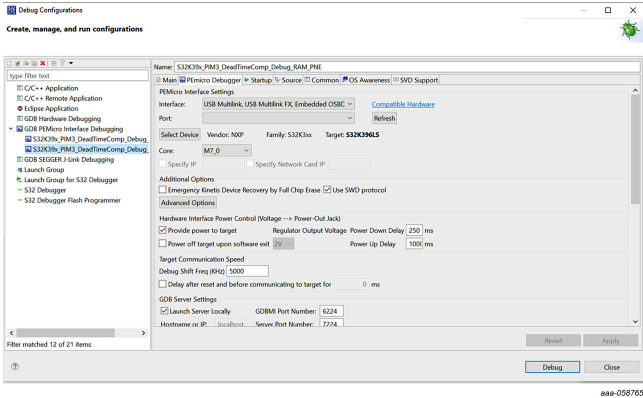
1. Go to S32 Design Studio | NXP Semiconductors and click <https://www.nxp.com/webapp/Download?colCode=S32DSIG> - **User Guide**.
2. Follow the instructions within the S32 Design Studio for S32 Platform Installation Guide.
3. Run the S32 Design Studio by clicking the S32 Design Studio for S32 Platform icon
4. Before flashing the device, verify that the updates have been installed on the S32 design studio. To do so, go to **Help** and check for S32DS extensions and updates.



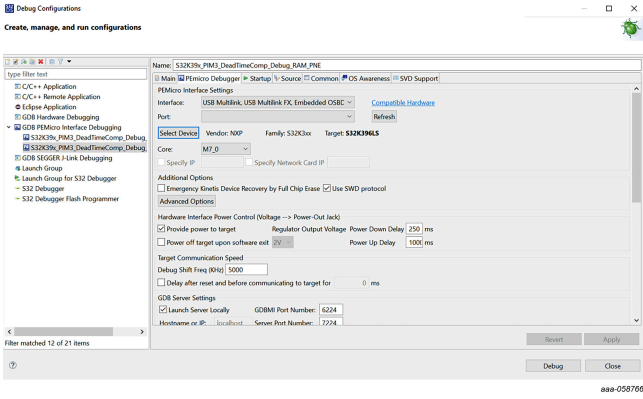
5. Click **Run > Flash from file...**
6. Double-click the **GDB PEMicro Interface Debugging** icon
7. Change the name of the new configuration to **S32K39x**



8. Click the **Debugger** tab



9. Click the **Device Name** drop-down menu and select **S32K396LS**

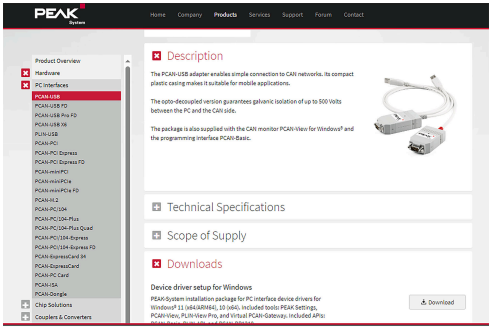


10. Click **Apply**

11. Flash the .elf file.

6.2 Installing the USB – CAN interface adapter

1. Browse to [PCAN-USB: PEAK-System](#)
2. Download the latest PEAC 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.

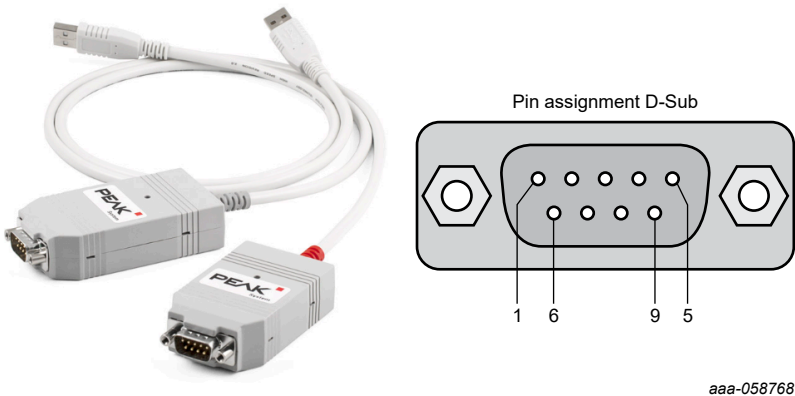


Table 8. USB-CAN interface adapter pinning

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

6.3 FreeMASTER setup

Refer to the ECU3 SW application note user guide for information on connecting to the ECU and using the FreeMASTER tool to monitor and control the inverter application demo.

7 Operation of the power inverter module (ECU)

After completing the steps in [Section 5](#) and [Section 6](#), you are now ready to operate the ECU.

7.1 Demo software

1. The S32K396-HPWR-MC1 board is preloaded with demo software that does not require a resolver and motor current feedback signals to be connected. The demo software runs open loop controls once the logic power is supplied.
2. Required connections 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 6](#) for connection:
 - For advanced operation of the ECU, a motor with resolver and RTD temperature sensing connections is required: The following signals must be connected for proper operation of the ECU.
 - CANA_H CANA_L
 - Resolver signals x6
3. Apply 30 VDC on the TE DC connector.
4. Apply a 12 V logic power supply and observe the motor as it begins spinning and ramping up speed until it is stable.

8 S32K396 software development tools

NXP has software development tools available for use with the NXP S32K396 development board (DEVB). The development board is intended to provide a platform for easy customer evaluation of the S32K396 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 [S32K39/37/36 Electrification MCUs | NXP Semiconductors](#).

Development software is available at <http://www.nxp.com>:

- **S32 Design Studio for S32 Platform**

The S32 Design Studio for S32 Platform IDE installed on a Windows PC workstation enables editing, compiling, and debugging of source code designs. Software development kit (SDK) supports several devices including the S32K396.

- **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 controls and general mathematical applications.

- **FreeMASTER 3.2 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.

8.1 Example code, GD31xx device driver notes and GD31xx device driver reference notes

GD31xx 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 Traction Inverter Gen 3 SiC MOSFET Enablement Kit.

10 References

- [1] Tool summary page for EV-INVERTERGEN3 – <https://www.nxp.com/design/designs/sic-ev-power-inverter-control-reference-platform:EV-INVERTERHD>
- [2] Product summary page for GD3162 – <http://www.nxp.com/GD3160>
- [3] GD3162 fact sheet – <https://www.nxp.com/docs/en/fact-sheet/GD3160FSA4.pdf>
- [4] Product summary page for S32K396-HPWR-MC1 – <http://www.nxp.com/MPC5775B-E>
- [5] PCAN-USB CAN Interface for USB – <https://www.peak-system.com/PCAN-USB.199.0.html>
- [6] PEmicro multilink debug probe – https://www.pemicro.com/products/product_viewDetails.cfm?product_id=15320180
- [7] DC link capacitor – <https://www.digikey.com/en/products/detail/kemet/C4AQIEW6100A3BJ/10442849>
- [8] 23-position signal connector – <https://www.te.com/en/product-770680-1.html>
- [9] Product summary page for FS6500 – <http://www.nxp.com/FS6500>
- [10] Product summary page for TJA1462AT/0Z – <https://www.nxp.com/part/TJA1462ATK>
- [11] Vepco Technologies – <http://www.vepcotech.com/>

11 Revision history

Document ID	Release date	Description
UM12210 v. 2.0	29 May 2025	<ul style="list-style-type: none">• Global: replaced <i>S32K396-HPWR-MC</i> with <i>S32K396-HPWR-MC1</i>• Updated abstract for NXP style and grammar• Updated the unnumbered figure above the Important Notice• Updated Section 4.4.1: corrected MCU board part number• Updated Figure 1• Updated Figure 3• Removed section (with table) <i>Gate drive signals 46-pin connector definitions</i> (redundant with Section 4.4.2.1 and its table)• Updated Figure 5• Updated Table 3• Updated Table 4• Updated Figure 4• Updated Figure 6• Updated Figure 7• Updated Section 5.2 to remove <i>Leaf Light</i> in the second procedure• Updated legal information
UM12210 v. 1.0	06 February 2025	Initial version

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