UM11299

RDGD3100F3PH5EVB three-phase inverter reference design

Rev. 1 — 24 September 2019 User manual

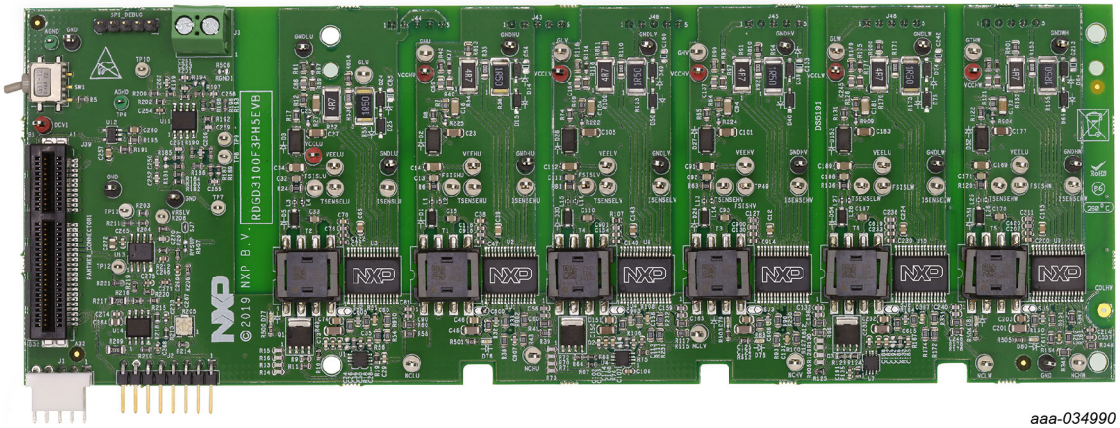

Figure 1. RDGD3100F3PH5EVB

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This reference design is intended 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 reference design may be used with any development system or other source of I/O signals by simply connecting it to the host MCU or computer board via off-the-shelf cables. Final device in an application will be heavily dependent on proper printed circuit board layout and heat sinking design as well as attention to supply filtering, transient suppression, and I/O signal quality.

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1 Introduction

This document is the user guide for the RDGD3100F3PH5EVB reference design. This document is intended for the engineers involved in the evaluation, design, implementation, and validation of single-channel gate driver for IGBT, GD3100.

The scope of this document is to provide the user with information to evaluate the single channel gate driver for IGBT, GD3100. This document covers connecting the hardware, installing the software and tools, configuring the environment and using the kit.

The RDGD3100F3PH5EVB is a fully functional three-phase inverter evaluation board populated with six GD3100 gate drivers with fault management and supporting circuitry. This board supports SPI daisy chain communication for programming and communication with three high-side gate drivers and three low-side gate drivers independently.

This board has low-voltage and high-voltage isolation in conjunction with gate drive integrated galvanic signal isolation. Other supporting features on the board include IGBT current sense and desaturation short-circuit detection, IGBT temperature sensing, DC Link bus voltage monitoring, phase current sensing, and motor resolver excitation and signal processing connection circuitry. See GD3100 data sheet for additional gate drive features.

2 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 device(s) on http://www.nxp.com.

The information page for RDGD3100F3PH5EVB reference design is at http://www.nxp.com/RDGD3100F3PH5EVB. The information page provides overview information, technical and functional specifications, ordering information, documentation, and software. The **Get Started** provides quick-reference information applicable to using the RDGD3100F3PH5EVB reference design, including the downloadable assets.

2.1 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 http://community.nxp.com.

3 Getting started

Working with the RDGD3100F3PH5EVB requires the kit contents, additional hardware, and a Windows PC workstation with installed software.

3.1 Kit contents

- Assembled and tested RDGD3100F3PH5EVB (three-phase inverter populated with 5.0 V compatible gate driver devices) board in an anti-static bag
- One PCIe cable (S32SDEV-CON18) for connection to MCU board (MPC5777C-DEVB or MPC5744P)
- Quick Start Guide

3.2 Additional hardware

In addition to the kit contents, the following hardware is necessary or beneficial when working with this kit.

- Microcontroller for SPI communication, PWM generation, and current and fault monitoring.
- IGBT module Fuji Electric M653
- DC link capacitor compatible with IGBT part M653 Series
- HV power supply with protection shield and hearing protection
- Current sensors for monitoring each phase current
- 12 V, 1.0 A DC power supply
- TEK MSO 4054 500 MHz 2.5 GS/s 4-channel oscilloscope

3.3 Windows PC workstation

This reference design requires a Windows PC workstation. Meeting these minimum specifications should produce great results when working with this reference design.

- USB-enabled computer with Windows 7 or Windows 10

3.4 Software

Installing software is necessary to work with this reference design. All listed software is available on the reference design's information page at http://www.nxp.com/RDGD3100F3PH5EVB.

- S32S Design Studio IDE for power architecture
- Automotive Math and Motor Control Library (AMMCL)
- FreeMaster 2.0 runtime debugging tool
- Motor Control Application Tuning (MCAT)
- Example code, GD3100 Device Driver notes and GD3100 Device Driver Reference notes

4 Getting to know the hardware

4.1 Kit overview

4.1.1 RDGD3100F3PH5EVB features

- Capability to connect to Fuji Electric M653 Series IGBT modules for full three-phase evaluation and development
- Daisy chain SPI communication (three high-side and three low-side gate drivers)
- Power supply which is jumper configurable for VEE negative or GND reference

- Easy access power, ground, and signal test points
- 2×32 PCIe socket for interfacing to MCU control
- Optional connection for DC bus voltage monitoring
- Compatible with MPC5777C-DEVB

4.1.2 Voltage domains

The low-voltage domain is an externally supplied 12 V DC (VSUP) primary supply for non-isolated circuits, typically supplied by the vehicle battery. The low-voltage domain includes the interface between the MCU and GD3100 control registers and logic control. See the area outlined in yellow in Figure 2.

Low-side driver and high-side driver domains are isolated high-voltage driver control domains for IGBT single phase connections and control circuits. Pins on bottom of board are designed to easily connect to three-phase IGBT module. See the areas outlined in red, white, and blue in Figure 2.

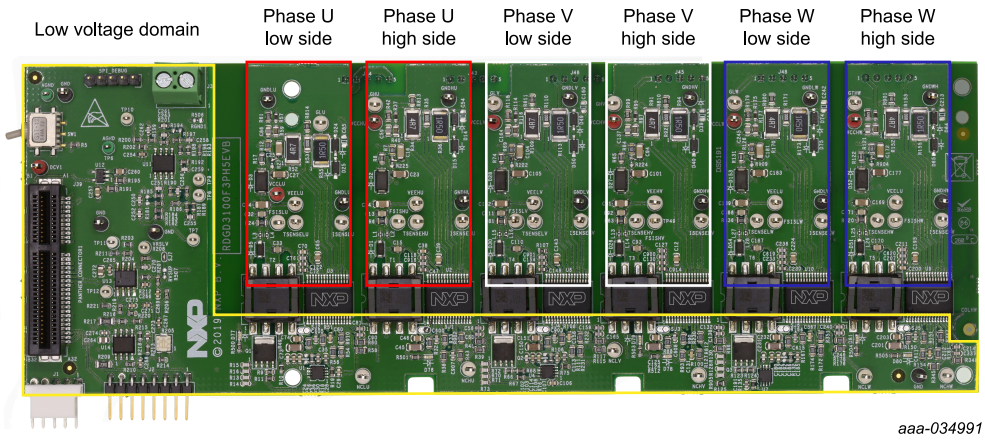

Figure 2. RDGD3100F3PH5EVB three-phase inverter board voltage domains and interface

4.2 Featured components

4.2.1 Advanced IGBT gate driver

4.2.1.1 General description

The GD3100 is an advanced single channel gate driver for IGBTs. Integrated Galvanic isolation and low on-resistance drive transistors provide high charging and discharging current, low dynamic saturation voltage, and rail-to-rail gate voltage control.

Current and temperature sense minimizes IGBT stress during faults. Accurate and configurable under voltage lockout (UVLO) provides protection while ensuring sufficient gate drive voltage headroom.

The GD3100 autonomously manages severe faults and reports faults and status via INTB pin and a SPI interface. It is capable of directly driving gates of most IGBTs. Self-test, control, and protection functions are included for design of high reliability systems (ASIL C/D). It meets the stringent requirements of automotive applications and is fully AEC-Q100 grade 1 qualified.

4.2.1.2 GD3100 features

- Compatible with current sense and temp sense IGBTs
- Fast short-circuit protection for IGBTs with current sense feedback
- Compliant with ASIL D ISO 26262 functional safety requirements
- SPI interface for safety monitoring, programmability, and flexibility
- Integrated Galvanic signal isolation
- Integrated gate drive power stage capable of 10 A peak source and sink
- Interrupt pin for fast response to faults
- Compatible with negative gate supply
- Compatible with 200 V to 1700 V IGBTs, power range > 125 kW
- AEC-Q100 grade 1 qualified

4.2.2 GD3100 pinout and MCU interface pinout

See GD3100 advanced IGBT gate driver data sheet for specific information about pinout, pin descriptions, specifications, and operating modes.

VSUP DC supply terminal is a low voltage input connection for supplying power to the low voltage non-isolated die and related circuitry. Typically supplied by vehicle battery +12 V DC.

The MCU connector is a 2×32-pin PCIe interface connector for use with either MPC5744P or MPC5777C 32-bit MCU board or any other MCU of preference. An MCU is needed for SPI communication and control of advanced IGBT gate drive devices (GD3100).

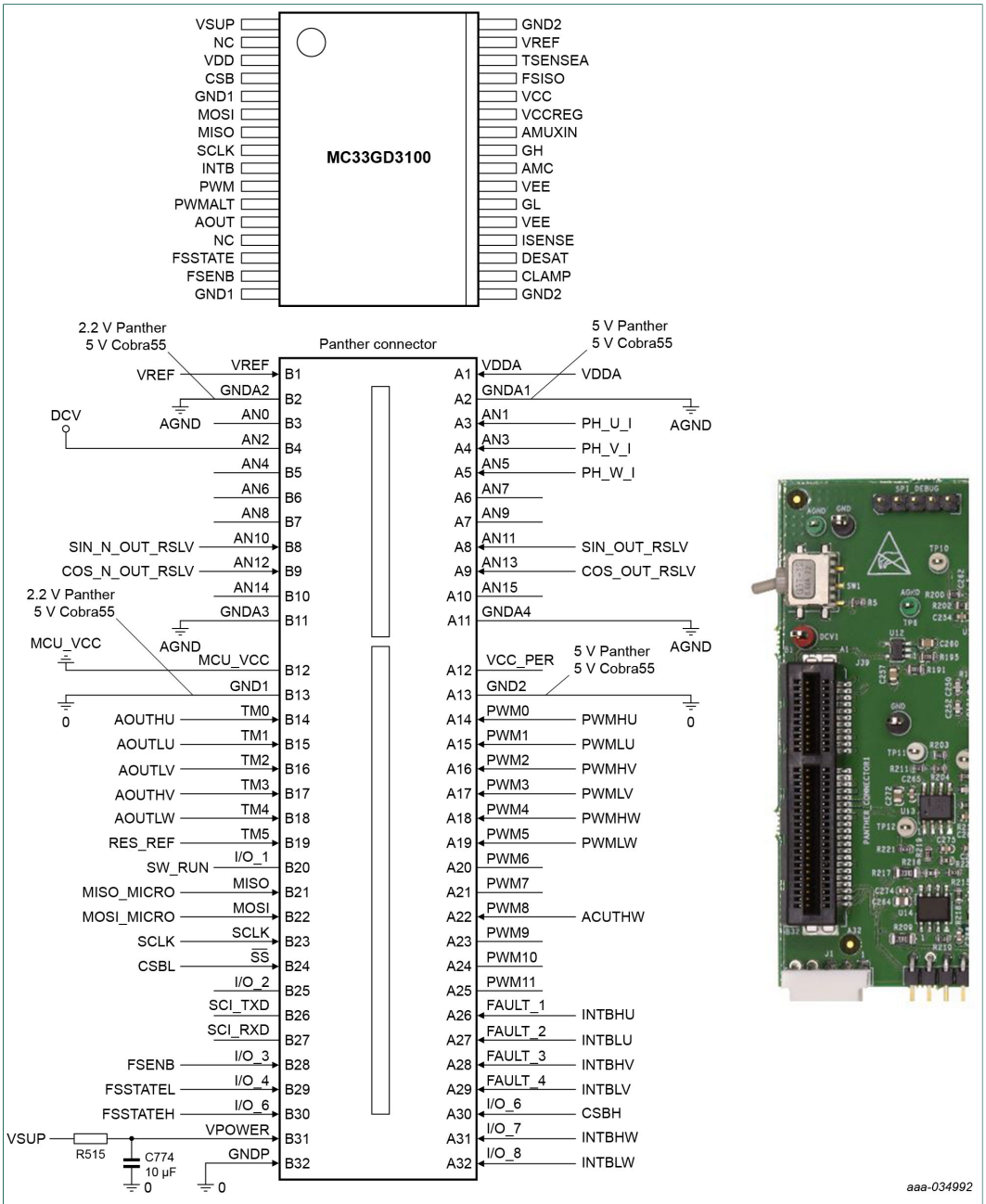

Figure 3. Gate driver pinout and board interface connection PCIe 2×32

Table 1. PCIe connector pin definitions

Pin	Name	Function
A1	VDDA	Voltage reference resolver circuit
A2	GNDA1	Analog ground
A3	PH_U_I	Current feedback phase U
A4	PH_V_I	Current feedback phase V
A5	PH_W_I	Current feedback phase W
A6	n.c.	not connected
A7	n.c.	not connected

Pin	Name	Function
A8	SIN_OUT_RSLV	Sine resolver signal
A9	COS_OUT_RSLV	Cosine resolver signal
A10	n.c.	not connected
A11	GNDA4	Analog ground
A12	n.c.	not connected
A13	GND2	Ground
A14	PWMHU	Pulse width modulation high-side phase U
A15	PWMLU	Pulse width modulation low-side phase U
A16	PWMHV	Pulse width modulation high-side phase V
A17	PWMLV	Pulse width modulation low-side phase V
A18	PWMHW	Pulse width modulation high-side phase W
A19	PWMLW	Pulse width modulation low-side phase W
A20	n.c.	not connected
A21	n.c.	not connected
A22	AOUTHW	Analog output signal high-side phase W
A23	n.c.	not connected
A24	n.c.	not connected
A25	n.c.	not connected
A26	INTBHU	GD3100 fault reporting pin for high-side phase U
A27	INTBLU	GD3100 fault reporting pin for low-side phase U
A28	INTBHV	GD3100 fault reporting pin for high-side phase V
A29	INTBLV	GD3100 fault reporting pin for low-side phase V
A30	CSBH	Chip select bar to high gate drive devices
A31	INTBHW	GD3100 fault reporting pin for high-side phase W
A32	INTBLW	GD3100 fault reporting pin for low-side phase W
B1	VREF	Voltage reference from MCU
B2	GNDA2	Analog ground
B3	NC	not connected
B4	DCV	Optional DC bus voltage monitoring (not used by default)
B5	n.c.	not connected
B6	n.c.	not connected
B7	n.c.	not connected
B8	SIN_N_OUT_RSLV	Sine resolver signal
B9	COS_N_OUT_RSLV	Cosine resolver signal
B10	n.c.	not connected
B11	GNDA3	Analog ground
B12	MCU_VCC	MCU VCC regulator voltage
B13	GND1	Ground
B14	AOUTHU	GD3100 analog output signal high-side U phase
B15	AOUTLU	GD3100 analog output signal low-side U phase
B16	AOUTLV	GD3100 analog output signal low-side V phase

Pin	Name	Function
B17	AOUTHV	GD3100 analog output signal high-side V phase
B18	AOUTLW	GD3100 analog output signal low-side W phase
B19	RES_REF	Resolver reference voltage
B20	SW_RUN	Signal from onboard switch demo mode
B21	MISO_MICRO	SPI slave out signal
B22	MOSI_MICRO	SPI slave in signal
B23	SCLK	SPI clock
B24	CSBL	Chip select bar to low-side gate drivers
B25	n.c.	not connected
B26	n.c.	not connected
B27	n.c.	not connected
B28	FSENB	Fail-safe state enable bar
B29	FSSTATEL	Fail-safe state low-side
B30	FSSATEH	Fail-safe state high-side
B31	VSUP	12 V voltage supply (low voltage domain)
B32	GNDP	Ground connection (low voltage domain)

4.2.3 Test points

All test points are clearly marked on the board. The following figure shows the location of various test points.

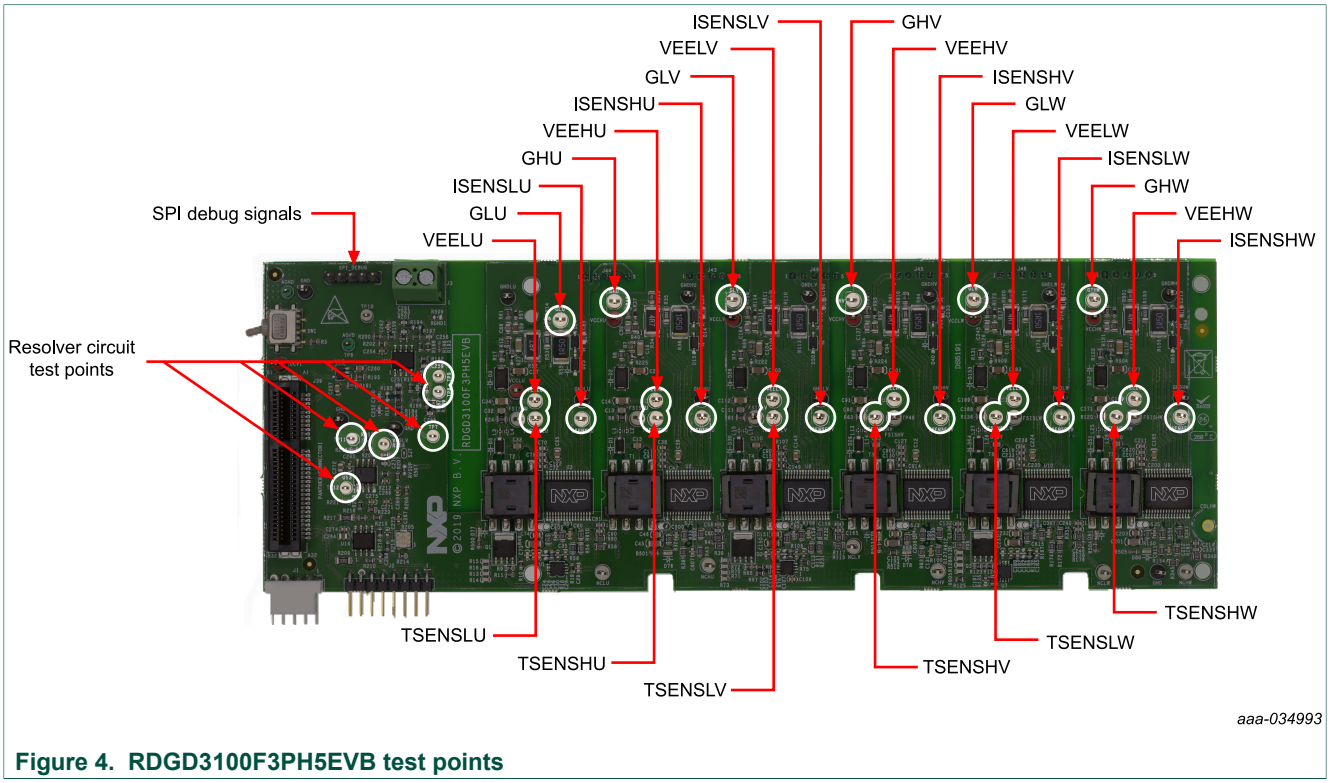

Figure 4. RDGD3100F3PH5EVB test points

Test point name	Function
DCV	Micro DC voltage
DSTHU	DESAT high-side U phase V_{CE} desaturation connected to DESAT pin circuitry
DSTHV	DESAT high-side V phase V_{CE} desaturation connected to DESAT pin circuitry
DSTHW	DESAT high-side W phase V_{CE} desaturation connected to DESAT pin circuitry
DSTLU	DESAT low-side U phase V_{CE} desaturation connected to DESAT pin circuitry
DSTLV	DESAT low-side V phase V_{CE} desaturation connected to DESAT pin circuitry
DSTLW	DESAT low-side W phase V_{CE} desaturation connected to DESAT pin circuitry
FSISHU	Not used – for test purposes only
FSISHV	Not used – for test purposes only
FSISLU	Not used – for test purposes only
FSISLV	Not used – for test purposes only
FSISLW	Not used – for test purposes only
GHU	Gate high-side U phase which is the charging pin of IGBT gate
GHV	Gate high-side V phase which is the charging pin of IGBT gate
GHW	Gate high-side W phase which is the charging pin of IGBT gate
GLU	Gate low-side U phase which is the charging pin of IGBT gate
GLV	Gate low-side V phase which is the charging pin of IGBT gate
GLW	Gate low-side W phase which is the charging pin of IGBT gate
NCLU – NCHW	Not used – for test purposes only
Resolver circuit	Test points for internal signals of resolver circuit (see schematic for more information)
SPI DBG	SPI signal port for analyzing SPI signals (see schematic for signals)
TSENSEHU	TSENSE high-side U phase connected to NTC temperature sense
TSENSEHV	TSENSE high-side V phase connected to NTC temperature sense
TSENSEHW	TSENSE high-side W phase connected to NTC temperature sense
TSENSELU	TSENSE low-side U phase
TSENSELV	TSENSE low-side V phase
TSENSELW	TSENSE low-side W phase
VEELU	Negative voltage supply test point for low-side driver gate of IGBT phase U (pre-configured to –8 V) See schematics for alternate configuration
VEEHU	Negative voltage supply test point for high-side driver gate of IGBT phase U (pre-configured to –8 V) See schematics for alternate configuration
VEELV	Negative voltage supply test point for low-side driver gate of IGBT phase V (pre-configured to –8 V) See schematics for alternate configuration
VEEHV	Negative voltage supply test point for high-side driver gate of IGBT phase V (pre-configured to –8 V) See schematics for alternate configuration
VEELW	Negative voltage supply test point for low-side driver gate of IGBT phase W (pre-configured to –8 V) See schematics for alternate configuration
VEEHW	Negative voltage supply test point for high-side driver gate of IGBT phase W (pre-configured to –8 V) See schematics for alternate configuration
ISENSLU	ISENSE test point connected to IGBT current sense and GD3100 gate driver Isense pin low-side phase U
ISENSHU	ISENSE test point connected to IGBT current sense and GD3100 gate driver Isense pin high-side phase U

Test point name	Function
ISENSLV	ISENSE test point connected to IGBT current sense and GD3100 gate driver Isense pin low-side phase V
ISENSHV	ISENSE test point connected to IGBT current sense and GD3100 gate driver Isense pin high-side phase V
ISENSLW	ISENSE test point connected to IGBT current sense and GD3100 gate driver Isense pin low-side phase W
ISENSHW	ISENSE test point connected to IGBT current sense and GD3100 gate driver Isense pin high-side phase W

4.2.4 Indicators

The RDGD3100F3PH5EVB evaluation board contains LEDs as visual indicators on the board.

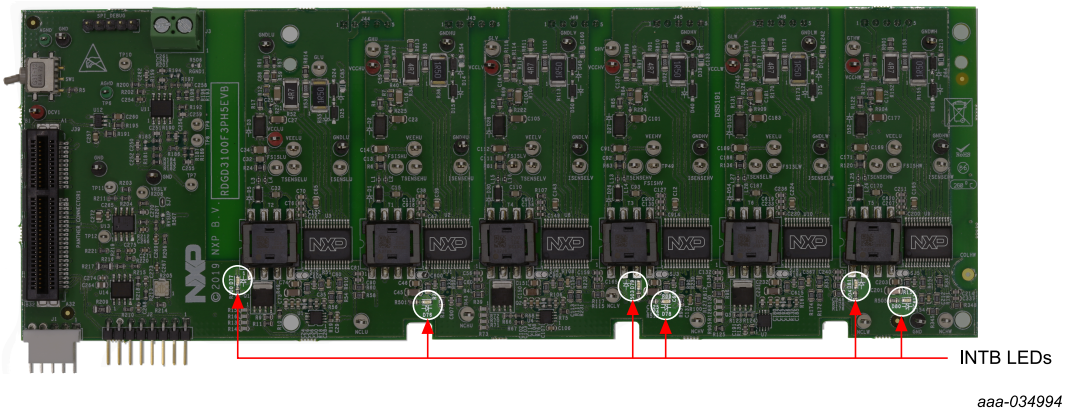

Figure 5. RDGD3100F3PH5EVB indicator locations

Table 2. RDGD3100F3PH5EVB indicator descriptions

Name	Description
INTB LEDs	Indicate a GD3100 interrupt has occurred on that gate drive device

4.2.5 Connectors

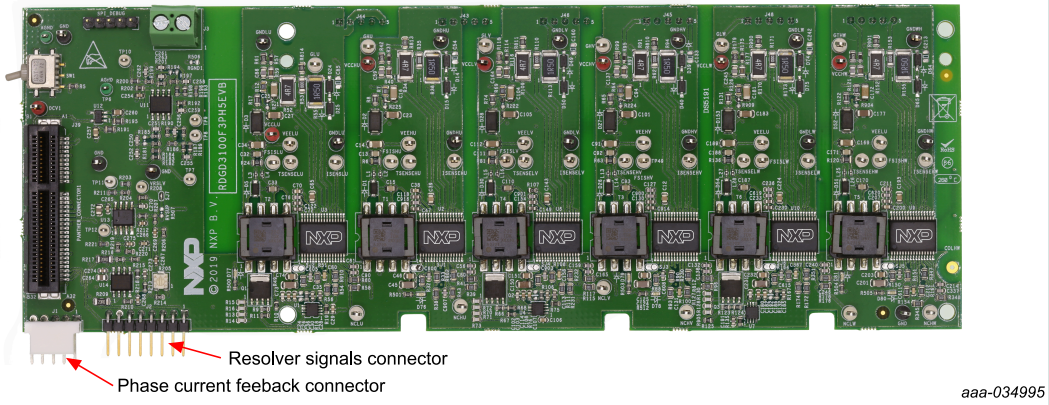

Figure 6. RDGD3100F3PH5EVB connector locations

Table 3. RDGD3100F3PH5EVB connector descriptions

Name	Description
Phase current feedback connector	Current feedback connections from U, V, and W phases (see schematic for detailed information)
Resolver signals connector	Resolver excitation signals (see schematic for more information)

4.2.6 Power supply and jumper configuration

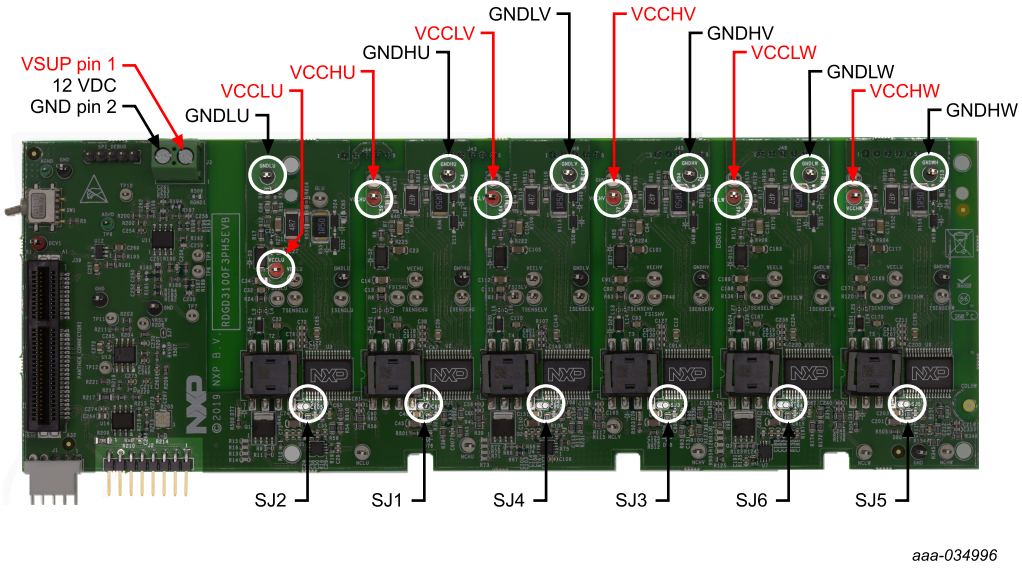

Figure 7. Power supply test points and jumper locations

Name	Function
SJ1 to SJ6	Solder jumpers used for 5.0 V operation connecting VSUP to VDD on each gate drive device
SW1	Not used (internal purposes only)
VCCHU	High-side phase U VCC voltage test point Isolated positive voltage supply (15 V to 18 V)
VCCHV	High-side phase V VCC voltage test point Isolated positive voltage supply (15 V to 18 V)
VCCHW	High-side phase W VCC voltage test point Isolated positive voltage supply (15 V to 18 V)
VCCLU	Low-side phase U VCC voltage test point Isolated positive voltage supply (15 V to 18 V)
VCCLV	Low-side phase V VCC voltage test point Isolated positive voltage supply (15 V to 18 V)
VCCLW	Low-side phase W VCC voltage test point Isolated positive voltage supply (15 V to 18 V)
VSUP +12 V DC	VSUP low voltage positive supply connection (+12 V DC)
VSUP GND	VSUP low voltage supply ground connection (GND1)

4.2.7 Gate drive resistors

See Figure 8 for the locations of the following gate drive resistors.

- RGH - gate high resistor in series with the GH pin at the output of the GD3100 high-side driver and IGBT gate that controls the turn on current for IGBT gate.
- RGL - gate low resistor in series with the GL pin at the output of the GD3100 low-side driver and IGBT gate that controls the turn off current for IGBT gate.
- RAMC - series resistor between IGBT gate and AMC input pin of the GD3100 high-side/low-side driver for gate sensing and Active Miller clamping.

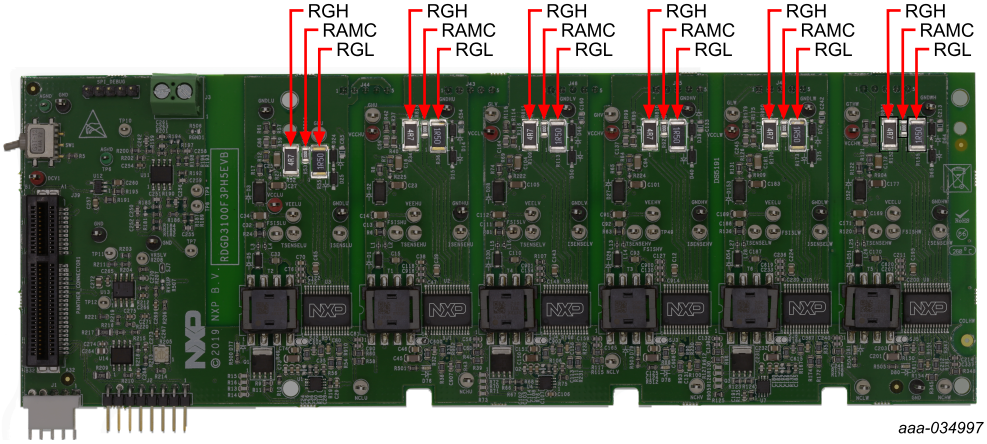

Figure 8. Gate drive resistors for each phase high-side and low-side

4.2.8 IGBT pin connections

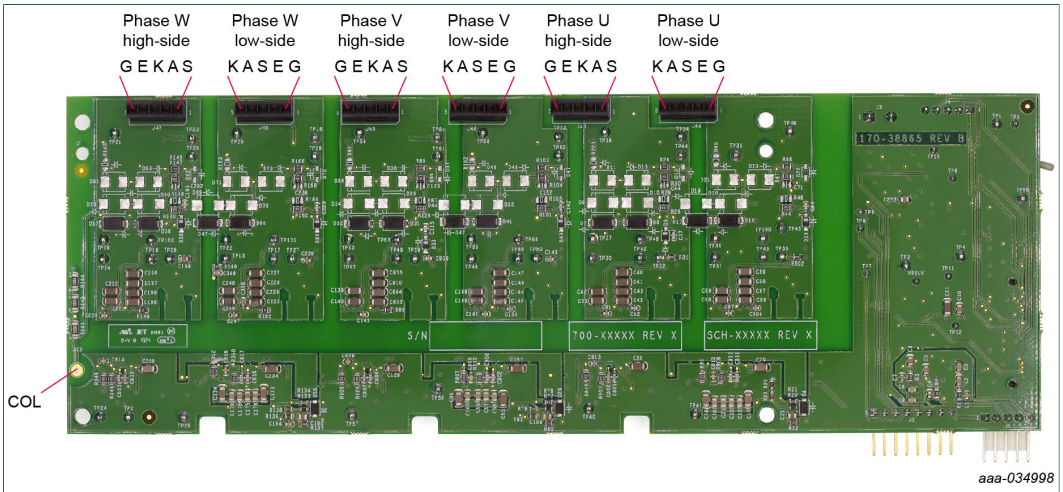

Figure 9. IGBT connection pins

Connection name	Pin description
COL	Collector (high-side W phase only)
G	Gate (IGBT gate)
E	Emitter (IGBT emitter)

Connection name	Pin description
K	Kathode (temperature sensing diode)
A	Anode (temperature sensing diode)
S	Sense (IGBT emitter current sensing)

4.3 Schematic, board layout, and bill of materials

The schematic, board layout, and bill of materials for the RDGD3100F3PH5EVB reference design are available at http://www.nxp.com/RDGD3100F3PH5EVB.

5 Configuring the hardware for startup

Figure 10 presents a typical hardware configuration.

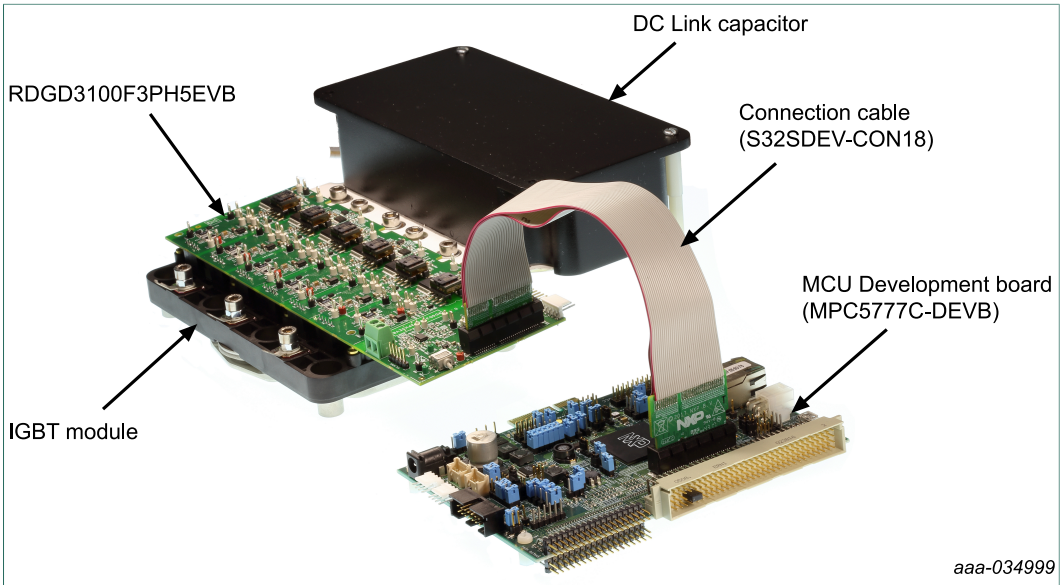

Figure 10. Typical configuration

To configure the hardware as illustrated in Figure 10, complete the following procedure:

1. Assemble IGBT module with water cooling jacket if desired and properly attach to DC Link capacitor positive and negative high-voltage supply connections across U, V, and W phases.
2. Attach RDGD3100F3PH5EVB to the IGBT module. Ensure that all board socket connection pins are properly seated onto the IGBT pin connections. The board socket connectors are intended for easy attachment and detachment to the IGBT module without damaging the IGBT connection pins.
3. Connect motor:
   a. Connect output of the IGBT module each phase U, V, and W to each of the respective U, V, W connections on the desired three-phase motor.
   b. For running the motor in closed-loop motor control, connect resolver signals from the motor resolver connection to the resolver pin connections on the RDGD3100F3PH5EVB. See schematics for J2 header signal connections on the RDGD3100F3PH5EVB board.

c. For running the motor in closed loop motor control, connect current sensors from each phase U, V, and W (current sensors are not included with RDGD3100F3PH5EVB) and connect the respective signals from the current sensors to the phase current feedback pin connections of the RDGD3100F3PH5EVB. See schematics for J1 header signal connections on the RDGD3100F3PH5EVB board.

4. Connect DC power:
   a. Connect a low voltage DC power supply to the RDGD3100F3PH5EVB at the VSUP connection terminal (12 V DC with a minimum 1.0 A supply).
   b. Connect a low voltage DC supply to the MCU controller board and connect a USB cable from the MCU controller to a computer for software driven motor control.
   c. Connect a high voltage/high current DC supply (use recommended voltage and current for desired motor) to the positive and negative connections on the DC Link capacitor to supply three-phase motor DC link voltage.
5. Attach the 2x32 PCIe cable (S32SDEV-CON18) supplied with kit to the RDGD3100F3PH5EVB and MCU controller board such as the MPC5777C-DEVB. This cable is keyed and is compatible with interface port on MPC5777C-DEVB.

6 Installing and configuring software and tools

6.1 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/BMS/Automotive Ethernet, etc. The latest product information is available at www.nxp.com/MPC5777C.

List of Development software:

- 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. The SDK supports several devices including the MPC5777C. For more information, refer to the S32DS-PA SDK for power architectures at http://www.nxp.com/S32SDK-PA.
- Automotive Math and Motor Control Library (AMMCL):
  Automotive Math and Motor Control Library (AMMCL) is a precompiled software library containing the building blocks for a wide range of motor control and general mathematical applications. For more information and to download the AMMCL, refer to the Automotive Math and Motor Control Library Set for MPC577xC at http://www.nxp.com/AUTOMCLIB.
- FreeMaster 2.0 runtime debugging tool:
  FreeMASTER runtime debugging tool is a separate download and can also be used in conjunction 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. See FreeMASTER runtime debugging tool at http://www.nxp.com/freemaster.
- Motor Control Application Tuning (MCAT):
  Motor Control Application Tuning (MCAT) is a FreeMASTER plug-in tool intended for the development of PMSM FOC and BLDC motor control applications. For more information and to download MCAT, refer to MCAT at http://www.nxp.com/MCAT.

- Example code, GD3100 Device Driver notes and GD3100 Device Driver Reference notes:
  GD3100 Device Driver example code REV1.2 provides sample code that shows how to configure and monitor the GD3100 gate driver device. See GD3100 Device Driver Example Code (REV 1.2 or later) at http://www.nxp.com/GD3100-DRIVER.

7 References

[1] **RDGD3100F3PH5EVB** — detailed information on this board, including documentation, downloads, and software and tools
http://www.nxp.com/RDGD3100F3PH5EVB

[2] **GD3100** — product information on Advanced single-channel gate driver for Insulated Gate Bipolar Transistors (IGBTs)
http://www.nxp.com/GD3100

[3] **MPC5777C** — ultra-reliable MCU for automotive and industrial engine management
http://www.nxp.com/MPC5777C

[4] **MPC5744P** — ultra-reliable MCU for automotive and industrial safety applications
https://www.nxp.com/MPC574xP

8 Revision history

Revision history

Rev	Date	Description
v.1	20190924	Initial version

9 Legal information

9.1 Definitions

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