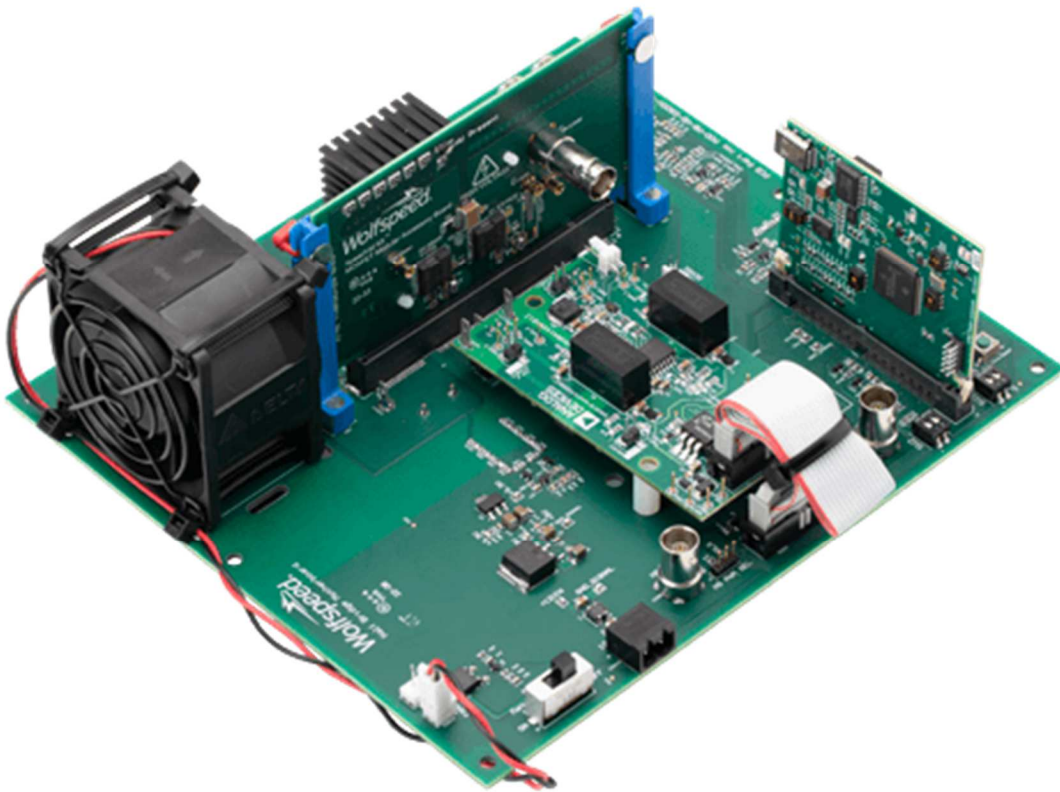


**MOD-MB-HB-0900V-40A**  
**SpeedVal Kit™ Half-Bridge**  
**Motherboard User Guide**



# MOD-MB-HB-0900V-40A SpeedVal Kit™ Half-Bridge Motherboard User Guide

The SpeedVal Kit™ is a modular evaluation platform that enables the user to perform testing and evaluation on a wide variety of SiC MOSFETs and gate drivers. The platform can be used for device selection, gate drive optimization, as well as early controls development using an optional control card. This document provides an overview of the SpeedVal Kit half-bridge motherboard and provides testing guidance for various modes of operation. The MOSFET power daughter cards, gate driver cards, and control cards have separate user guides with the information specific to those components. Additional details on the platform and other compatible boards can be found at <https://www.wolfspeed.com/products/power/evaluation-kits/speedval-kit-modular-evaluation-platform/>.

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All parts of this application note are provided in English, and the Cautions are provided in English, Mandarin, and Japanese. If the end user of this board is not fluent in any of these languages, it is your responsibility to ensure that they understand the terms and conditions described in this document, including without limitation the hazards of and safe operating conditions for this board.

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**CAUTION**

**PLEASE CAREFULLY REVIEW THE FOLLOWING PAGES, AS THEY CONTAIN IMPORTANT INFORMATION REGARDING THE HAZARDS AND SAFE OPERATING REQUIREMENTS RELATED TO THE HANDLING AND USE OF THIS BOARD.**

**警告**

请认真阅读以下内容，因为其中包含了处理和​​使用本板子有关的危险隐患和安全操作要求方面的重要信息。

**警告**

ボードの使用、危険の対応、そして安全に操作する要求などの大切な情報を含むので、以下の内容をよく読んでください。



## CAUTION

**DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD. THERE CAN BE VERY HIGH VOLTAGES PRESENT ON THIS EVALUATION BOARD WHEN CONNECTED TO AN ELECTRICAL SOURCE, AND SOME COMPONENTS ON THIS BOARD CAN REACH TEMPERATURES ABOVE 50° CELSIUS. FURTHER, THESE CONDITIONS WILL CONTINUE FOR A SHORT TIME AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED.**

**Please ensure that appropriate safety procedures are followed when operating this board, as any of the following can occur if you handle or use this board without following proper safety precautions:**

- **Death**
- **Serious injury**
- **Electrocution**
- **Electrical shock**
- **Electrical burns**
- **Severe heat burns**

You must read this document in its entirety before operating this board. It is not necessary for you to touch the board while it is energized. All test and measurement probes or attachments must be attached before the board is energized. You must never leave this board unattended or handle it when energized, and you must always ensure that all bulk capacitors have completely discharged prior to handling the board. Do not change the devices to be tested until the board is disconnected from the electrical source and the bulk capacitors have fully discharged.

### 警告

请勿在通电情况下接触板子，在操作板子前应使大容量电容器的电荷完全释放。接通电源后，该评估板上通常会存在危险的高电压，板子上一些组件的温度可能超过50摄氏度。此外，移除电源后，上述情况可能会短时持续，直至大容量电容器电量完全释放。

操作板子时应确保遵守正确的安全规程，否则可能会出现下列危险：

- 死亡
- 严重伤害
- 触电
- 电击
- 电灼伤
- 严重的热烧伤

请在操作本板子前完整阅读本文件。通电时禁止接触板子。所有测试与测量探针或附件必须在板子通电前连接。通电时，禁止使板子处于无人看护状态，且禁止操作板子。必须确保在操作板子前，大容量电容器已释放了所有电量。只有在切断板子电源，且大容量电容器完全放电后，才可更换待测试器件。

### 警告

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ボードを操作するとき、正確な安全ルールを守るのを確保すべきです。さもないと、以下の危険がある可能性があります：

- 死亡
- 重症
- 感電
- 電撃
- 電気の火傷
- 厳しい火傷

当ボードを操作する前に、完全に当書類をよく読んでください。通電している時にボードに接触する必要がありません。通電する前に必ずすべての試験用のプローブあるいはアクセサリをつないでください。通電している時に無人監視やボードを操作するのは禁止です。ボードを操作する前に、大容量のコンデンサーで電力を完全に釈放するのを必ず確保してください。ボードの電源を切った後、また大容量のコンデンサーで電力を完全に釈放した後、試験設備を取り換えることができます。



## 1. Introduction

The purpose of the SpeedVal Kit™ platform is to provide a single evaluation platform that allows almost all discrete Wolfspeed® SiC MOSFETs and diodes (650 V to 1200 V) to be evaluated and tested in a common platform. The half-bridge motherboard supports testing that measures switching energy using double-pulse testing (DPT) as well as system testing in many common topologies including buck and boost, both synchronous and asynchronous. Each power daughter card comes fully assembled with its own thermal management system comprised of a heatsink and thermal isolator.

The SpeedVal Kit platform allows different Wolfspeed SiC MOSFETs and diodes to be swapped in a matter of seconds. Moreover, by testing different devices on the same platform, with the same layout and gate driver, any measured differences can be correctly attributed to the device itself. Historically, testing MOSFETs in different packages required testing on different boards which may have different gate drivers. It was impossible to know what, if any, of the measured differences were due to the MOSFET itself or due to other variables such as the layout and gate driver. The SpeedVal Kit platform allows users to swap out not only MOSFETs of different  $R_{DS(ON)}$  but also MOSFETs in different packages.

The SpeedVal Kit platform has many compatible gate driver cards available from carefully selected partners that allow users to compare device performance with different gate drivers while holding all other variables constant. This allows users to quickly select the best combination of device and gate driver for their application. This pairing can be carried into the user's own design, reducing design risk and shortening the product development cycle time.

The SpeedVal Kit platform built on the half-bridge motherboard works with the following other building blocks:

1. Power Daughter Card (1 required) – Half-bridge configuration of two MOSFETs or a MOSFET and a diode
2. Gate Driver Card (1 required) – Two-channel driver card including gate power supplies
3. Control Card and User Interface (optional)
4. Buck Boost Filter Board (optional)
5. Air Core Inductor (optional) – For double-pulse testing

## Kit Contents

The SpeedVal Kit motherboard comes with all necessary hardware to set the board on a bench and attach the gate driver and power daughter cards. The kit contains all required gate driver cables and MMCX to BNC adapters to simplify probing the  $V_{GS}$  and  $I_{DS}$  test points on the power daughter card. Also included is a surface mount (SMT) current transformer that can be used for  $I_{DS}$  measurement on the power daughter cards and an adapter board for compatibility with the NXP® control card.

Table 1: Motherboard Evaluation Kit Contents

| Item | Qty | Description                                   | Mfg.        | Part No.           | Notes         |
|------|-----|---|-------------|--------------------|---------------|
| 1    | 1   | Half-Bridge Motherboard PCB Assembly          | Wolfspeed   | MOD-MBHB-0900V-40A |               |
| 2    | 2   | Desat Cable Assembly                          | Wolfspeed   | -                  |               |
| 3    | 6   | Standoff, Nylon, 8-32, MF, 1.75 in, off-white | Essentra    | 36832MF175         | or equivalent |
| 4    | 8   | Machine Screw Pan Phillips 8-32, 0.25 L       | Essentra    | NSP-8-4-01         | or equivalent |
| 5    | 2   | Washer, Nylon, #8, 0.055-0.070                | Essentra    | 16FW008062         | or equivalent |
| 6    | 2   | Screw, 8-32, 0.250, PPH, Nylon                | Essentra    | 010832PW025        | or equivalent |
| 7    | 2   | Hex Standoff, 8-32, 0.375                     | Essentra    | 36832MF037         | or equivalent |
| 8    | 8   | Hex Nut 8-32 Thread .170 height               | Essentra    | 0400832HNS         | or equivalent |
| 9    | 2   | Cable Assembly Coaxial BNC to MMCX 6.00"      | Amphenol RF | 095-850-207-006    | or equivalent |
| 10   | 1   | Cable Assembly, Ribbon, 16P                   | -           | -                  |               |
| 11   | 1   | Current Transformer                           | Sumida      | T93020             |               |
| 12   | 1   | Interposer PCB Assembly                       | Wolfspeed   | -                  |               |

Each SpeedVal Kit motherboard has a unique part number that follows the convention listed in **Error! Reference source not found.** below.

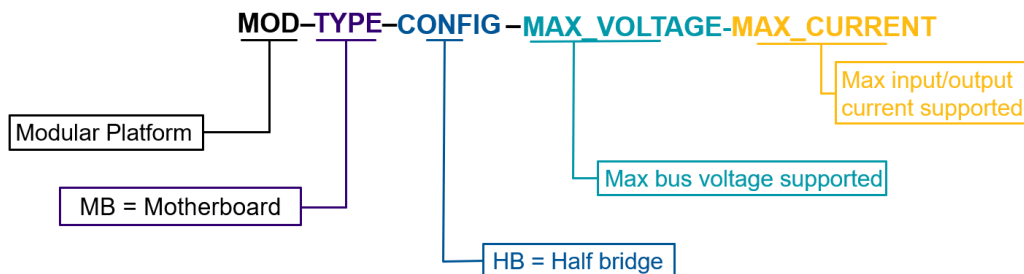


Figure 1: Motherboard Naming Convention

Maximum Bus and Power Terminal Ratings:

- The maximum continuous voltage rating for the DC bus is 900 V.
- The maximum continuous RMS current rating for the DC bus and switch node terminals is 40 A.

## 2. Board overview

### Size

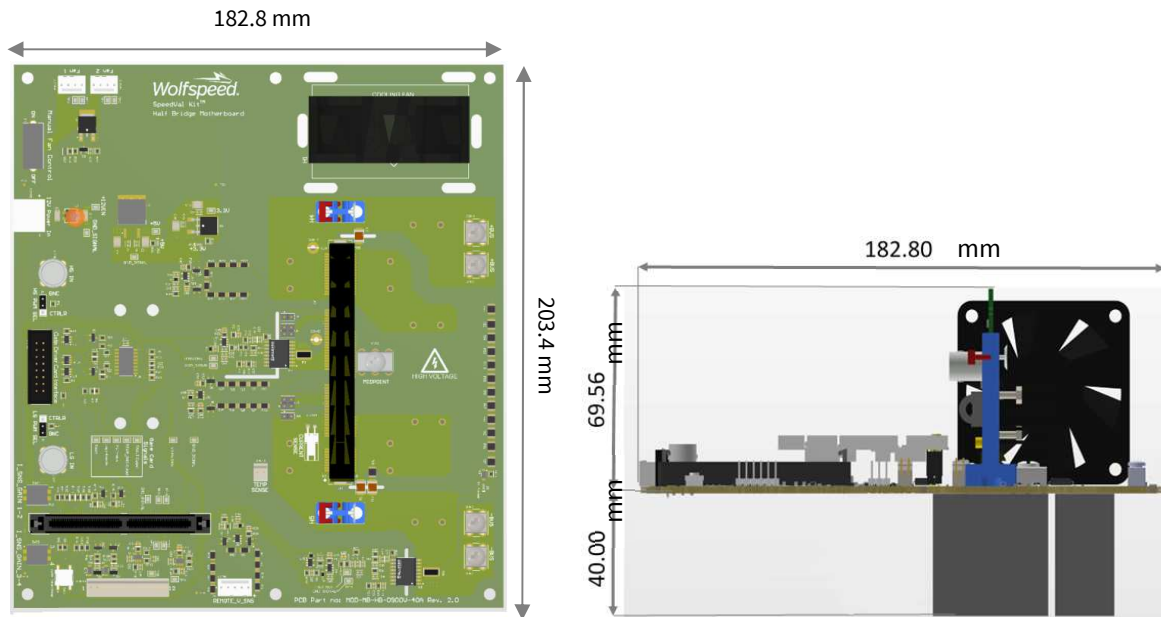


Figure 2: Product dimensions MOD-MB-HB-0900 V-40 A: Top view (left) and Front view (right)

## Motherboard overview

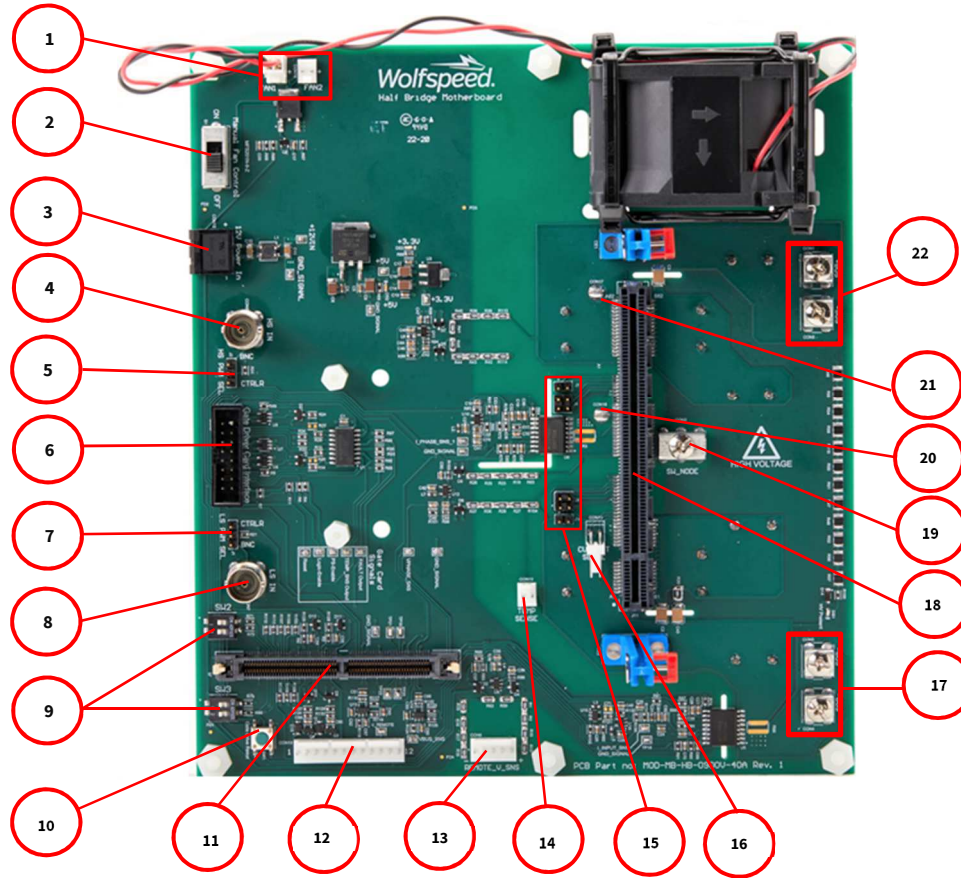


Figure 3: SpeedVal Kit™ Motherboard Overview

Table 2: Motherboard List of Connections

| Item | Description                         | Item | Description                          |
|------|-------------------------------------|------|--------------------------------------|
| 1    | Fan Power Connectors                | 11   | Optional Control Card Slot           |
| 2    | Manual Fan Power Switch             | 12   | External Digital I/O Connector       |
| 3    | 12V Logic Power Input               | 13   | Remote Voltage Sensing Connector     |
| 4    | High-Side PWM Input (BNC)           | 14   | NTC Temperature Sensor Connector     |
| 5    | High-Side PWM Selector              | 15   | Gate Driver Board Output Connectors  |
| 6    | Gate Driver Interface Connector     | 16   | Current Transformer Output Connector |
| 7    | Low-Side PWM Selector               | 17   | Negative DC Bus Terminals            |
| 8    | Low-Side PWM Input (BNC)            | 18   | Power Daughter Card Connector        |
| 9    | Current Sensor Sensitivity Selector | 19   | Switch Node (midpoint) Terminal      |
| 10   | Gate Driver Reset Switch            | 20   | Lower Drain Sense Tab                |
| 21   | Upper Drain Sense Tab               | 22   | Positive DC Bus Terminals            |

### 3. SpeedVal Kit™ Daughter Card Connectors

Figure 4 shows where the SpeedVal Kit daughter cards plug into the half-bridge motherboard. Depending on the gate driver card selected, there may or may not be Miller clamp connections (J7, J14).

The optional control card plugs into connector J5. If the NXP® card is used, the interposer card included with the kit plugs into J5 and the control card plugs into the interposer. The 16-pin ribbon cable plugs into the gate driver connector CON9 and the corresponding header on the gate driver daughter card.

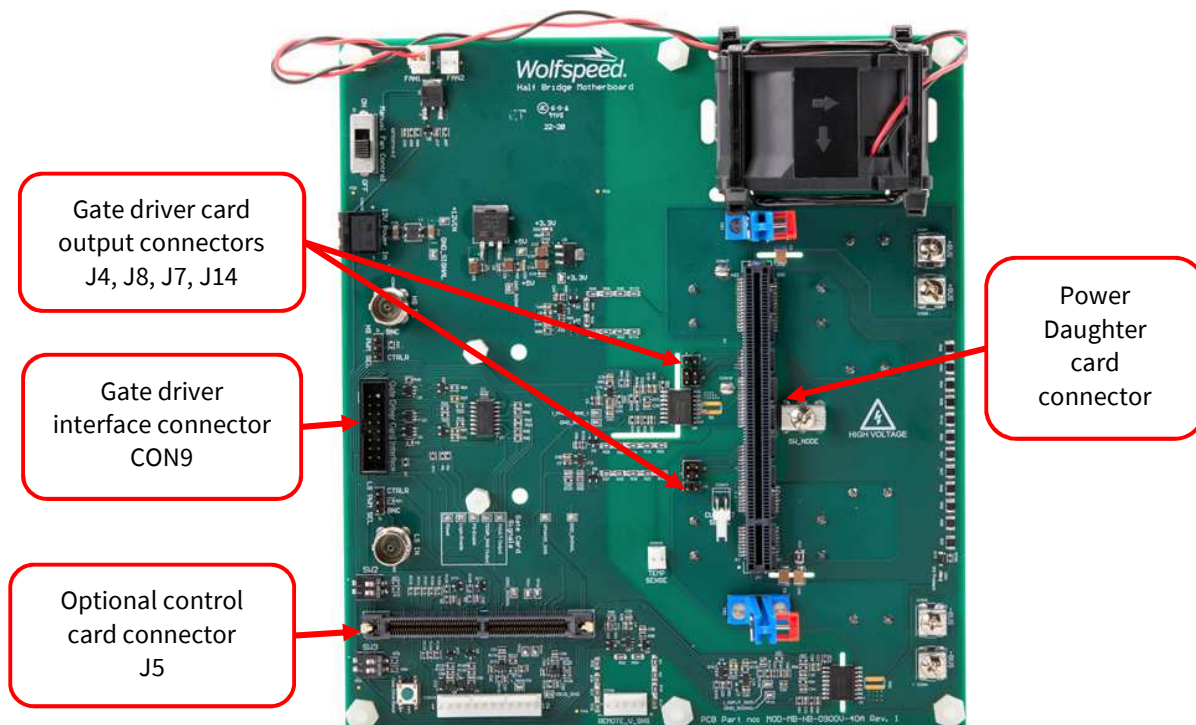


Figure 4: SpeedVal Kit™ Card Connectors

#### 3.1 Gate Driver Card Connectors

This section describes the interface between the gate driver card and the half-bridge motherboard. A 16-pin interface on the input side of the gate driver card carries the input power, PWM signals, fault signals, and other logic signals between the motherboard and gate driver. Table 3 list the signals for this 16-pin interface.

Note that some gate driver cards may not contain all of the features listed in Table 3. The optional signals are indicated by a “N” in the “Required” column of Table 3. The input/output designation is from the perspective of the gate driver card, not the motherboard.

Table 3: Gate Driver Card Interface Definition (CON9)

| Pin | Name                        | Description   | Type   | Required |
|-----|-----------------------------|---|--------|----------|
| 1   | V <sub>DC</sub>             | Power supply input pin. Nominally 12 V. Current rating will primarily depend on gate power DC/DC selected.  | Power  | Y        |
| 2   | COM                         | Ground reference for input-side power and signals   | Power  | Y        |
| 3   | HS+                         | Positive line of differential high-side PWM   | Input  | Y        |
| 4   | HS-                         | Negative line of differential high-side PWM   | Input  | N        |
| 5   | LS+                         | Positive line of differential low-side PWM  | Input  | Y        |
| 6   | LS-                         | Negative line of differential low-side PWM  | Input  | N        |
| 7   | $\overline{\text{FAULT}} +$ | Positive line of differential fault output. The FAULT output is the combined representation of any faults on the daughter card. If any fault is detected, /FAULT+ will be pulled low.   | Output | N        |
| 8   | $\overline{\text{FAULT}} -$ | Negative line of differential fault output.   | Output | N        |
| 9   | TEMP+                       | Positive line of differential temperature output. The TEMP output signal is a digital representation of the NTC reading. This may be encoded as a frequency, duty cycle, or a bit-stream and should be defined in the daughter-card datasheet/application note. Alternatively, this channel can be used to represent another analog signal such as bus voltage. | Output | N        |
| 10  | TEMP-                       | Negative line of differential temperature output  | Output | N        |
| 11  | PS_ENA                      | Gate power supply enable signal. Drive high to enable isolated power supply outputs.  | Input  | N        |
| 12  | COM                         | Ground reference for input-side power and signals   | Power  | Y        |
| 13  | PWM_ENA                     | Enable input for gate signals. Drive high to enable gate driver outputs.  | Input  | N        |
| 14  | COM                         | Ground reference for input-side power and signals   | Power  | Y        |
| 15  | $\overline{\text{RESET}}$   | Reset input to clear latched faults. Pull low to reset.   | Input  | N        |
| 16  | COM                         | Ground reference for input side power and signals   | Power  | Y        |

All gate driver cards will have two 4-pin connectors for the isolated gate output connections. One connector is for the high-side device and one is for the low-side. Using two pins per signal helps to reduce the inductance in the connection and provides redundancy.

Table 4: Gate Connections

| Pin | High Side (J4) | Low Side (J8) |
|-----|----------------|---------------|
| 1   | 0VB (source)   | 0VA (source)  |
| 2   | HS_Gate        | LS_Gate       |
| 3   | 0VB (source)   | 0VA (source)  |
| 4   | HS_Gate        | LS_Gate       |

Some gate driver cards have two additional 2-pin connectors for a Miller clamp signal as shown in Table 5.

Table 5: Miller Clamp Connections

| Pin | High Side (J7)       | Low Side (J8)        |
|-----|----------------------|----------------------|
| 1   | Miller_Clamp_Gate_HS | Miller_Clamp_Gate_LS |
| 2   | Miller_Clamp_VSS_HS  | Miller_Clamp_VSS_LS  |

### 3.2 Power Daughter Card Connector (CON16)

Figure 5 shows the pinout for the 164-pin edge card connector between the motherboard and power daughter card. The red pins are +BUS, the blue pins are -BUS, and the yellow pins are the switch node. The remaining pins are for the gate drive circuits, Miller clamp, temperature feedback and current sensing. The dark grey areas are pins that are unused in order to provide adequate voltage spacing between nets at different potentials.

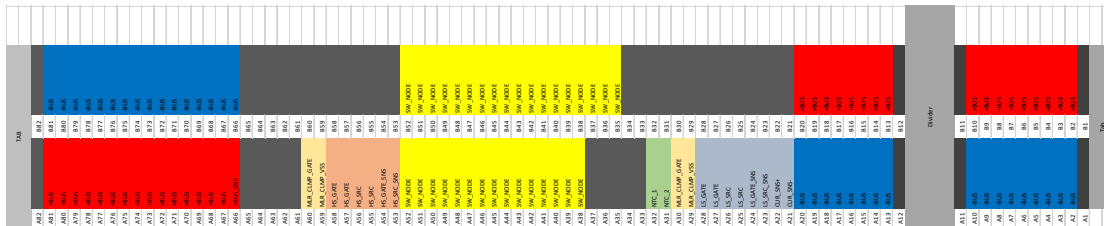


Figure 5: Pinout For 164-Pin Card Connector

### 3.3 Control Card Connector (J5)

The motherboard supports control cards from industry-leading partners. The Texas Instruments® control card can plug directly into the motherboard (Figure 6), while the NXP® board requires the use of the included interposer board (Figure 7).

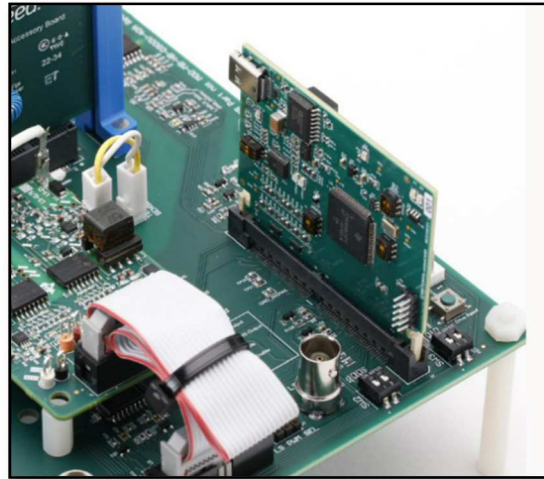


Figure 6: Texas Instruments® Control Board



Figure 7: NXP® Control Board with Interposer

## 4. Control Cards and Graphical User Interface (GUI)

Basic firmware and a computer based graphical user interface (GUI) are available for use with the control cards. The firmware incorporates basic functionality to provide gate signals for all of the supported test modes (Double Pulse, buck, boost) on the half-bridge platform and provides voltage, current, and temperature monitoring. This enables the user to easily test different configurations without an external



function generator. It can also serve as the basis for the user to develop additional firmware on a known test platform before developing custom hardware. Additionally, the GUI provides helpful notes and diagrams for each test configuration to streamline the test setup in the lab as shown in Figure 8: GUI connection diagram example. Installation and user guides are available as part of the firmware download from the SpeedVal Kit control card webpage.

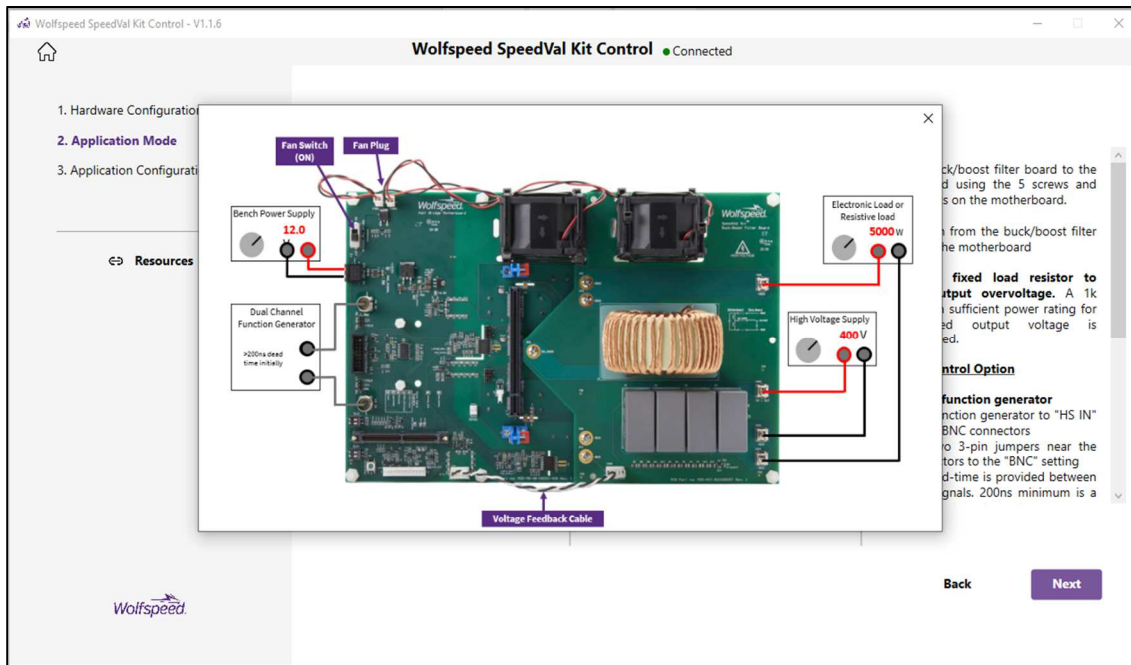


Figure 8: GUI connection diagram example

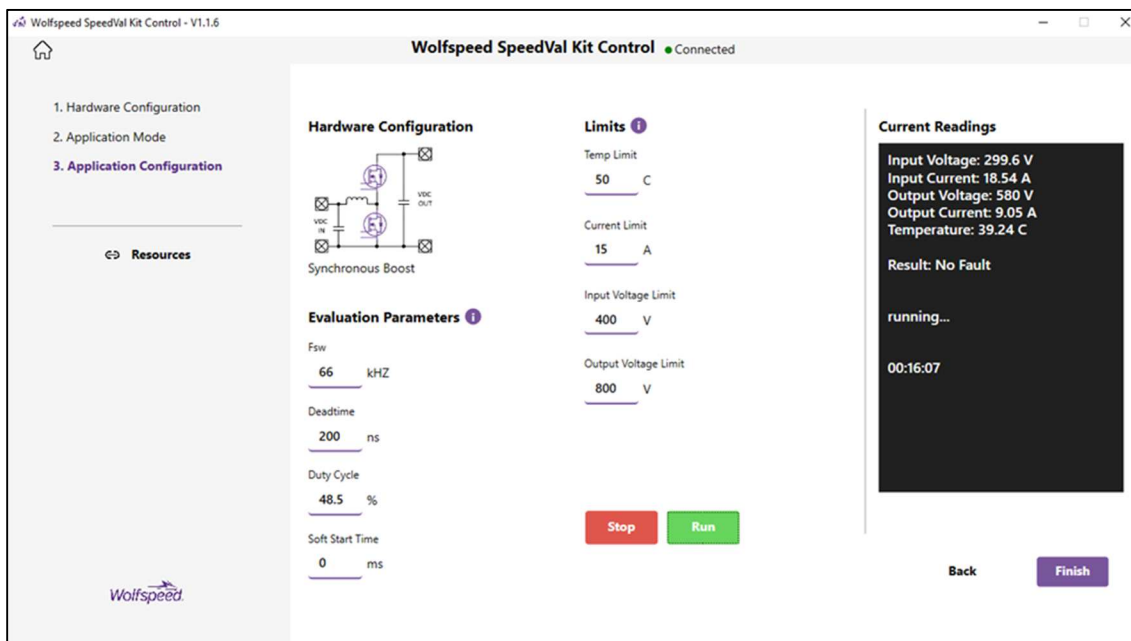


Figure 9: GUI operating configuration and status monitoring

## 5. Electrical Features



### **CAUTION**

**IT IS NOT NECESSARY FOR YOU TO TOUCH THE BOARD WHILE IT IS ENERGIZED. WHEN DEVICES ARE BEING ATTACHED FOR TESTING, THE BOARD MUST BE DISCONNECTED FROM THE ELECTRICAL SOURCE AND ALL BULK CAPACITORS MUST BE FULLY DISCHARGED.**

**SOME COMPONENTS ON THE BOARD REACH TEMPERATURES ABOVE 50° CELSIUS. THESE CONDITIONS WILL CONTINUE AFTER THE ELECTRICAL SOURCE IS DISCONNECTED UNTIL THE BULK CAPACITORS ARE FULLY DISCHARGED. DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW THE BULK CAPACITORS TO COMPLETELY DISCHARGE PRIOR TO HANDLING THE BOARD.**

**PLEASE ENSURE THAT APPROPRIATE SAFETY PROCEDURES ARE FOLLOWED WHEN OPERATING THIS BOARD AS SERIOUS INJURY, INCLUDING DEATH BY ELECTROCUTION OR SERIOUS INJURY BY ELECTRICAL SHOCK OR ELECTRICAL BURNS, CAN OCCUR IF YOU DO NOT FOLLOW PROPER SAFETY PRECAUTIONS.**



#### 警告

通电时不必接触板子。连接器件进行测试时，必须切断板子电源，且大容量电容器必须释放完所有电荷。

板子上一些组件的温度可能超过50摄氏度。移除电源后，上述情况可能会短暂持续，直至大容量电容器完全释放电荷。通电时禁止触摸板子，应在大容量电容器完全释放电荷后，再操作电路板。

请确保在操作电路板时已经遵守了正确的安全规程，否则可能会造成严重伤害，包括触电死亡、电击伤害、或电灼伤。

#### 警告

通电している時にボードに接触する必要がありません。設備をつないで試験する時、必ずボードの電源を切ってください。また、大容量のコンデンサーで電力を完全に釈放してください。

ボードのモジュールの温度は50度以上になるかもしれません。電源を切った後、上記の状況がしばらく持続する可能性がありますので、大容量のコンデンサーで電力を完全に釈放するまで待ってください。通电している時にボードに接触するのは禁止です。大容量のコンデンサーで電力をまだ完全に釈放していない時、ボードを操作しないでください。

ボードを操作している時、正確な安全ルールを守っているのを確保してください。さもないければ、感電、電撃、厳しい火傷などの死傷が出る可能性があります。

## 5.1 Main Power Terminals, Logic Power, Cooling Fan

Terminals CON1 and CON5 are the +DC Bus connections. Terminals CON3 and CON4 are the -DC Bus connections. CON2 is the switched node or midpoint connection.

The SpeedVal Kit platform only requires a single 12VDC 3A power supply for control power, which is connected to CON12. The negative rail of the 12V supply should be connected to earth ground to prevent leakage currents from pulling the low-voltage side of the board away from ground. The current drawn from the power supply will vary based on the selection of gate driver cards, control board, power daughter card, and test conditions.

There are two fan power connectors included on the motherboard. One is to power the onboard fan, and the other is to power the fan on the optional buck boost filter board. The fan power can be controlled manually with switch S1 or automatically with one of the optional control cards. If one of the optional control cards is plugged into the motherboard, the fans will turn on automatically whenever power tests are run. More detailed specifications on the fan and fan power capacity is contained in the thermals section of this document.

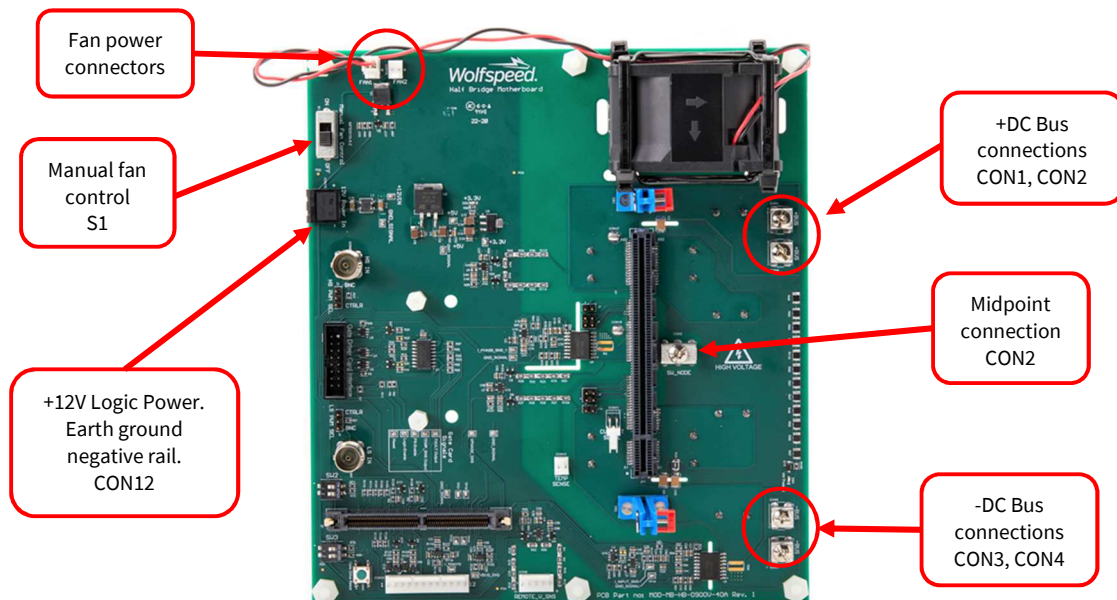


Figure 10: Main Power Terminals, Logic Power Input, and Cooling Fan Locations

## 5.2 Digital IO and Remote Sensing Connector

Header CON13 contains two digital input signals and two digital output signals that can be programmed to interact with external circuits using one of the control cards. Refer to Figure 11 for pin mappings.

CON13 also contains both a DC link voltage test point and a remote voltage test point that provide an easy way to monitor the DC link voltage and the remote voltage. Both voltages are scaled 100:1 and are referenced to the low voltage ground, resulting in a 9V full scale signal for a 900V bus.

The digital outs are open drain signals and require an external pullup for proper operation. The maximum voltage to which the signals can be pulled is 24V and the maximum sink current is 20mA.

| Pin | Function                   |
|-----|----------------------------|
| 1   | Ground                     |
| 2   | External digital output 0  |
| 3   | Ground                     |
| 4   | External digital output 1  |
| 5   | Ground                     |
| 6   | External digital input 0   |
| 7   | Ground                     |
| 8   | External digital input 1   |
| 9   | Ground                     |
| 10  | Remote voltage test point  |
| 11  | Ground                     |
| 12  | DC Link voltage test point |

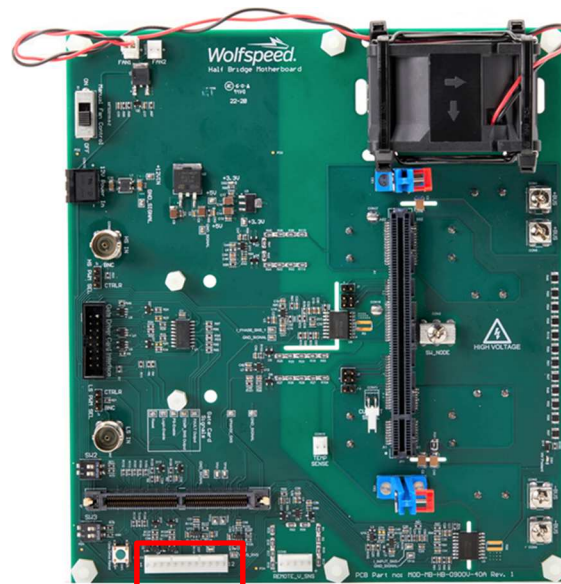


Figure 11: CON13 Digital I/O and Remote Sensing Connector Location and Pin Definitions

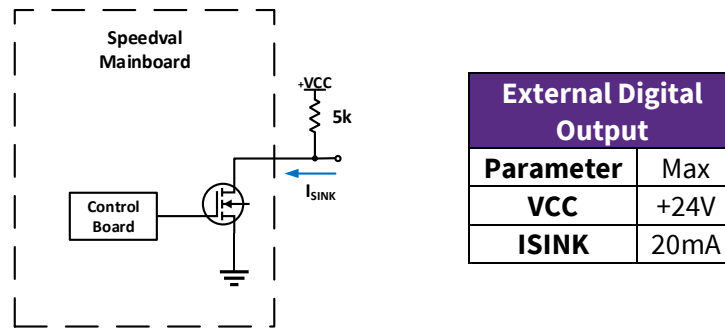


Figure 12: External digital output

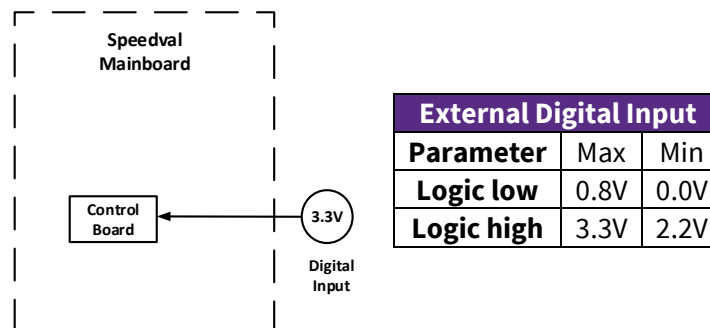


Figure 13: External digital input

### 5.3 Current Sensor and Scaling

The SpeedVal Kit half-bridge motherboard comes equipped with two current sensors for sensing the DC bus current and the switched node current. If one of the optional control boards is installed when running power tests, the graphical user interface (GUI) will display the DC link and switched node current feedback from these sensors. The sensitivity of the current sensors is adjustable.

Table 6: Current sensor sensitivity DIP settings

| DIP POS_2 | DIP POS_1 | Sensitivity (mV/A) | Maximum Current (A) |
|-----------|-----------|--------------------|---------------------|
| 0         | 0         | 26.4               | 50                  |
| 0         | 1         | 33                 | 40                  |
| 1         | 0         | 39.6               | 33.3                |
| 1         | 1         | 19.8               | 66.7                |

shows the DIP switch settings and the maximum current and gain for each setting. The default is highlighted in grey. If the current to be sensed will exceed 33.3A, the gain must be adjusted using one of the DIP switches. For best performance, the sensitivity should be set to the highest setting where the max current will not be exceeded. The control board reads the position of the DIP switches only when control power is first applied. If the DIP switches are changed while control power is present, the control power must be cycled for the new gain to take effect.

Table 6: Current sensor sensitivity DIP settings

| DIP POS_2 | DIP POS_1 | Sensitivity (mV/A) | Maximum Current (A) |
|-----------|-----------|--------------------|---------------------|
| 0         | 0         | 26.4               | 50                  |
| 0         | 1         | 33                 | 40                  |
| 1         | 0         | 39.6               | 33.3                |
| 1         | 1         | 19.8               | 66.7                |

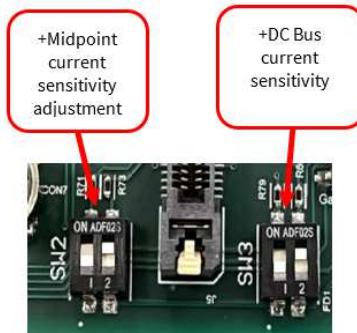


Figure 14: Current Scaling and DIP Switch Position for Current Sensors

## 5.4 Current Transformer Output

A 10:1 SMT current transformer (CT) is included with the half-bridge motherboard. This CT can be mounted on any of the power daughter cards instead of using the SMT shunt resistors as shown in Figure 15. The output of this CT is fed through CON11. A wire harness is needed to connect pin 1 of CON11 through the aperture of a high-bandwidth current transformer and back to pin 2 of CON11. Figure 16 shows the wire harness and a high-bandwidth AC current transformer connected.

Using the CT to sense the current provides highly accurate switching loss measurements and dynamic waveform analysis (rise and fall times,  $di/dt$ ,  $dv/dt$ ,  $Q_{RR}$ ); however, it cannot be used for power testing. The current waveforms during power testing contain a significant DC component so only the low-resistance shunt method can be used. See Section 8 for a detailed explanation of the different current sensing methods supported in the SpeedVal Kit platform.

**CAUTION! When the CT is installed on the power daughter card, connector CON11 should not be left open or damage to the components and SpeedVal Kit™ PCBs can occur. The two terminals at CON11 must be tied together after passing through the high-bandwidth AC current transformer.**

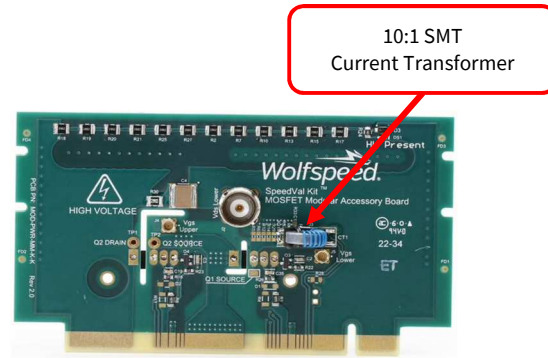


Figure 15: Power daughter card with CT

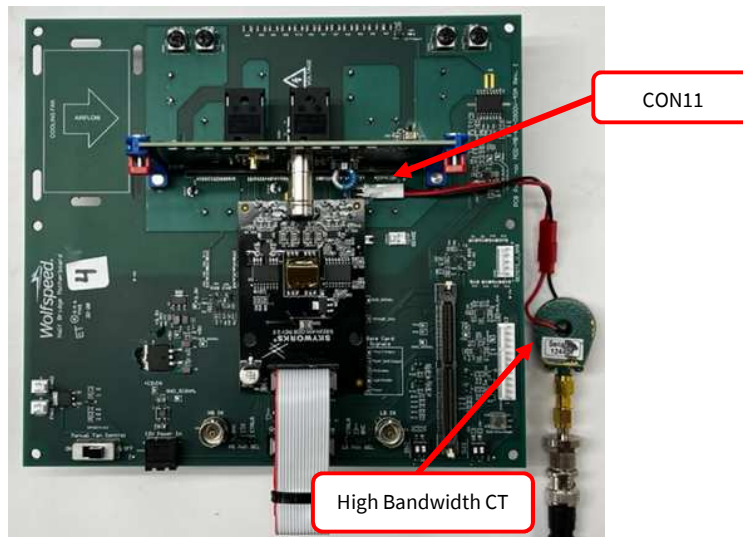


Figure 16: CON11 connected with high bandwidth CT

## 5.5 NTC temperature sensing

Each power daughter card contains or has provisions for a negative temperature coefficient (NTC) resistor for sensing either the heatsink temperature (through-hole device daughter cards) or a location on the PCB near the devices (SMT device daughter cards). Some of the available gate driver cards contain NTC temperature sensing circuitry to sense this NTC's resistance and convert this into a digital representation of the NTC reading. This may be encoded as a frequency, duty cycle, or a bit-stream and will be defined in the applicable gate driver user manual.

Figure 17 shows the NTC signal connector (CON10) on the motherboard and how it connects to two different gate driver cards that include an NTC temperature-sensing circuit.



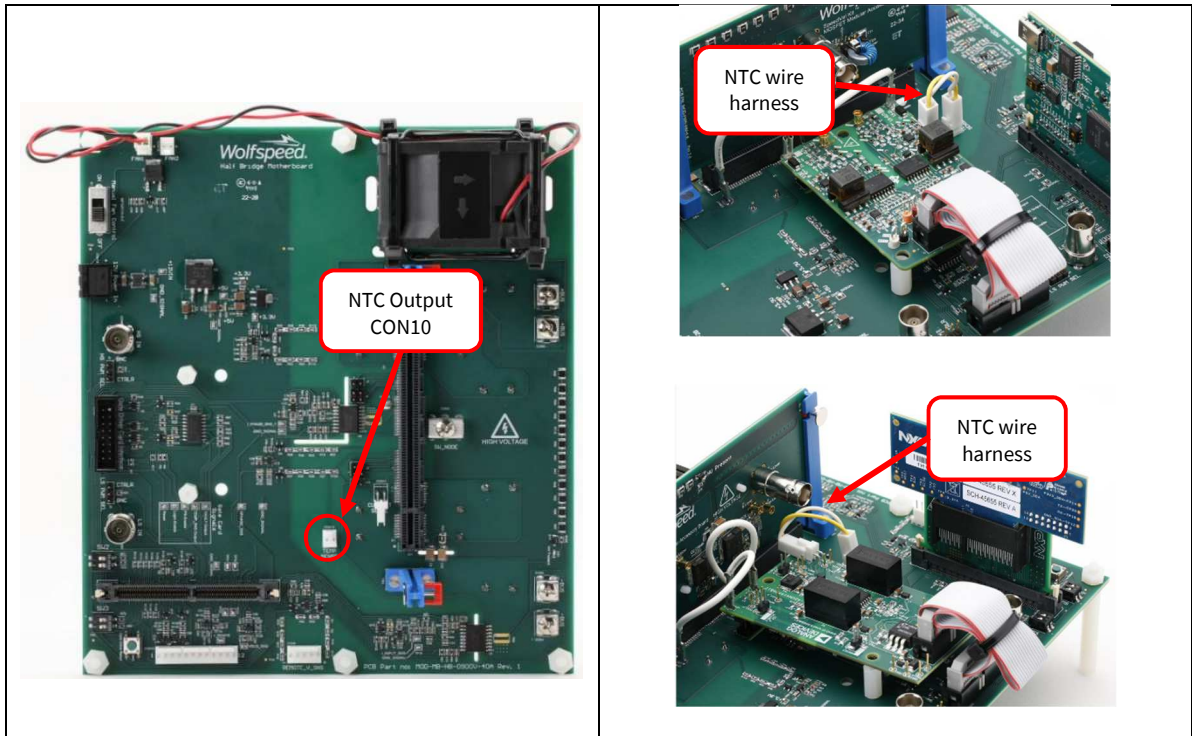


Figure 17: TO-247-4L Power Daughter Card with NTC Sensing Connections

## 5.6 Overcurrent Protection (OCP)

Many of the gate drivers compatible with SpeedVal Kit platform feature overcurrent protection (OCP, also commonly referred to as desat protection) to protect the MOSFETs in the event of a shoot-through event or short-circuit scenario. This protection requires the drain voltage of both MOSFETs be monitored. The SpeedVal Kit motherboard includes jumpers to make the connections from the MOSFET drain sense points to the gate driver. Figure 18 shows the jumpers and drain sense connections.

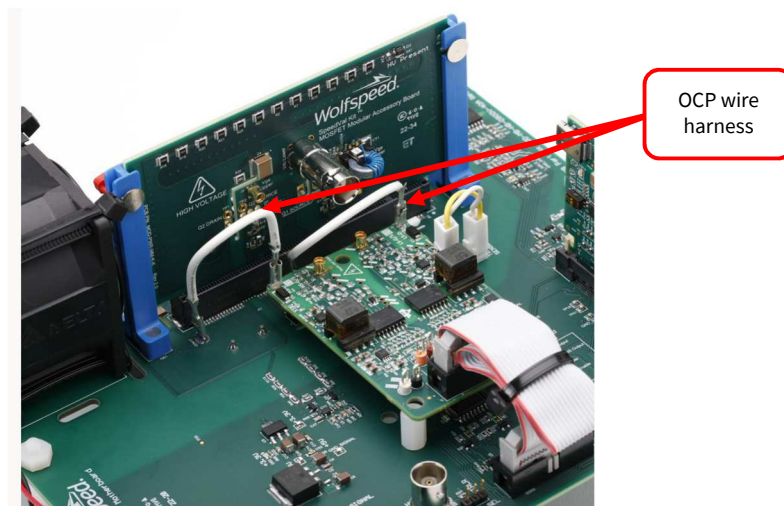


Figure 18: TO-247-4L Power Daughter Card with Drain Sense Connections

## 5.7 PWM Input

The SpeedVal Kit platform has an optional control card to generate the PWM signals for the high-side and low-side gate drive channels, or the PWM signals can be supplied externally via the BNC connectors located on the motherboard (Figure 20).

If the motherboard is outfitted with one of the optional controller cards, as shown in Figure 19, jumpers J1 & J2 should both be in the “CTRLR” positions. To supply the PWM signals externally through the BNC inputs, jumpers J1 & J2 should be in the “BNC” positions shown in Figure 20.



Figure 19: Jumper set to CTRLR input



Figure 20: Jumper set to BNC input

The motherboard contains an interlock circuit to prevent accidentally commanding a shoot-through, which can occur if both PWM signals are high. This would turn on both MOSFETs at the same time, resulting in extremely high currents through the MOSFETs by effectively shorting out the DC bus. The circuit in Figure 21 sets both LS-PWM and HS-PWM signals low if the incoming signals are both high, preventing the two MOSFETs from being gated on at the same time. If you want to test the short-circuit protection of the gate driver to protect against this condition, you will need to remove U4 and U9 and install R9 and R49 to bypass the interlock circuit. There may be additional interlocking on the gate driver card that would need to be bypassed as well to allow for overlapping PWM signals.

Note that this should only be done when using a gate driver that provides short-circuit protection. The short-circuit protection on the gate driver cards may require tuning of the trip level and timing in order to provide adequate protection of the SiC MOSFETs during a short-circuit test. It is highly recommended to start this testing at a low voltage (approximately 100-200 V) and verify proper functionality before increasing the bus voltage to reduce the possibility of damage to the board or devices. The short circuit protection should be tuned to provide turn-off of the MOSFET such that the total duration of the short-circuit current is approximately 1 $\mu$ s or less.

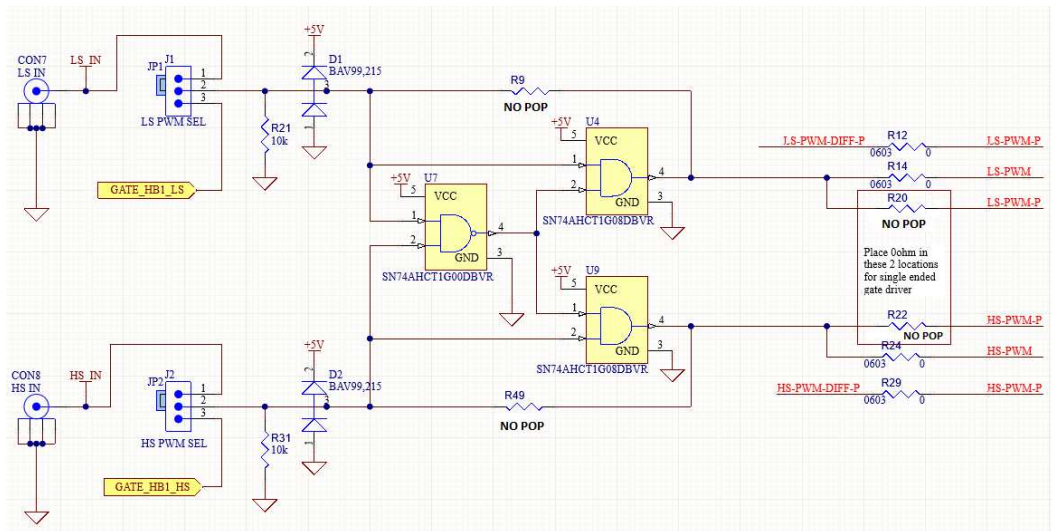


Figure 21: PWM Interlock Circuit

## 6. Layout

Best practice when designing power converters with SiC is to keep the gate drivers as close to the MOSFETs as possible and minimize the parasitic inductance between the MOSFETs and DC bus capacitors. This limits parasitic inductance in the power loop and gate loop, which is detrimental to switching performance. The SpeedVal Kit platform features a novel card edge system that creates a flexible modularity that does not sacrifice switching performance. The SpeedVal Kit platform's novel card edge approach utilizes these features:

- Thirty-three pins for each bus connection to the daughter card
- Wide copper areas on top and bottom of daughter card to mimic a laminated bus structure with small loop area
- Four-layer design on the motherboard and power daughter card allowing for interleaved bus connections to minimize inductance

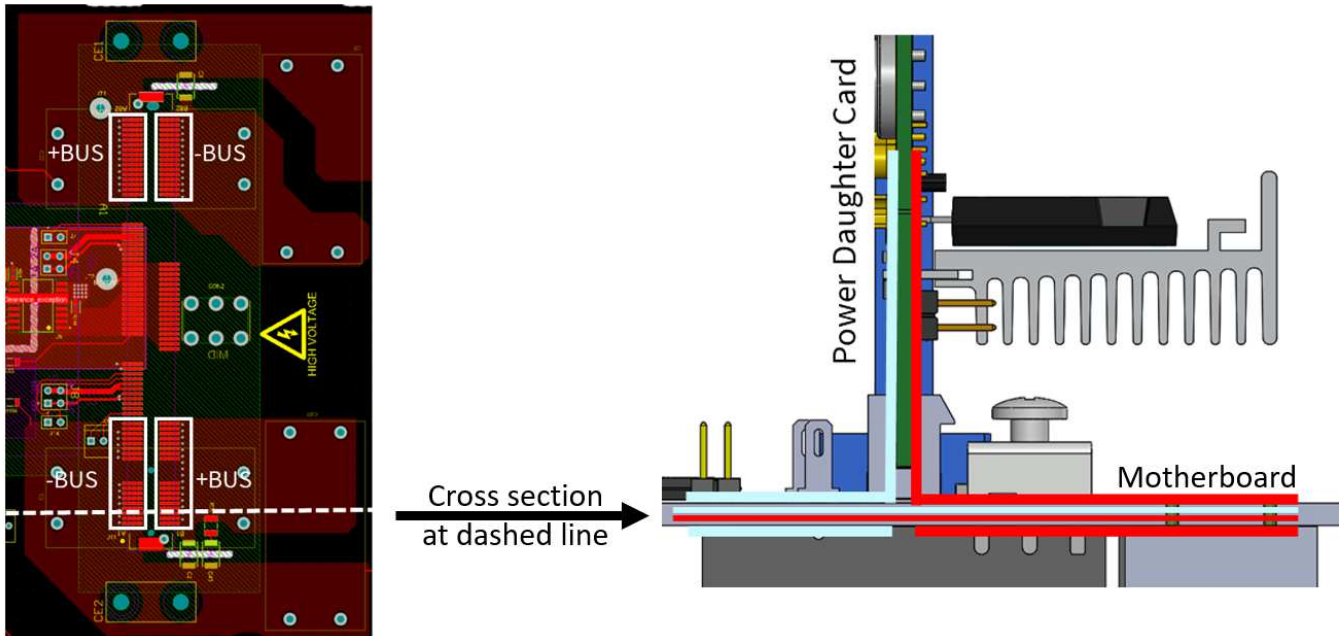


Figure 22: Cross-sectional View of SpeedVal Kit™ Main Connector and DC Bus Connections

## 7. Thermal Management

The SpeedVal Kit half-bridge motherboard comes equipped with a cooling fan (Sanyo® # 9G0612P4S0011 or equivalent). The cooling fan can be controlled manually with switch S1. If one of the optional control boards is installed, the control board will start the fan automatically when a power test is run.



|                |             |
|----------------|-------------|
| Supply Voltage | 12 VDC      |
| Power Rating   | 8.04 W      |
| Current Rating | 670 mA      |
| Size           | 60x60x25 mm |
| Air Flow       | 49.4 CFM    |

Figure 23: Cooling Fan and Specifications

The motherboard has two connectors to power fans. Fan 1 (CON14) connector provides power to the included fan. Fan 2 (CON15) connector provides power to the optional buck boost filter board.

### Fan Connector

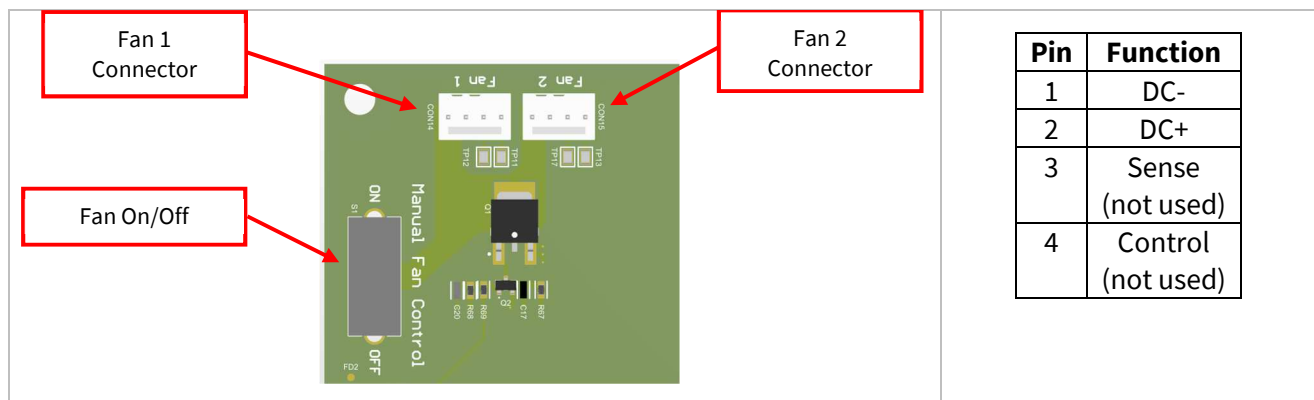


Figure 24: Fan Connector Pinout

The maximum combined fan current for both connectors is 3A.

### Heatsink

Each power daughter card comes with a heatsink and insulator. The user guide for each power daughter card contains detailed information including the thermal impedance, assembly instructions, and information on the PCB thermal vias (SMT packages).

## 8. Double Pulse Measurements and Current Sensing

This section shows how to set up the SpeedVal Kit platform to take accurate switching energy measurements using a double pulse test (DPT). Each power daughter card comes with a current shunt for sensing  $I_{DS}$ , but the resistance value with which it comes preinstalled may be optimized for power testing rather than switching energy measurements. This is because the overall shunt resistance must be kept very low ( $\leq 10$  m $\Omega$ ) to keep power dissipation to a minimum when running power tests.

The power daughter card may need the current sense circuit to be modified before taking switching energy measurements. There are two acceptable modifications to support accurate switching energy measurements. Consult the user guide of the selected power daughter card to determine what value shunt resistors are preinstalled and to review the procedure to change the value if necessary.

### 8.1 High Resistance Shunt

One method for accurate switching loss measurements is to use a shunt with a relatively high shunt resistor value. Many daughter cards have eight (0603 footprint) shunt resistors. Setting these resistors to  $1\Omega$  each gives an overall shunt resistance of  $125$  m $\Omega$  and very good signal-to-noise ratio for taking accurate switching loss measurements. The RC filter network may need to be modified from the preinstalled values as well. The typical shunt circuit and filter components for DPT are shown in Figure 25. Consult the power daughter card manual for the board being tested to see the specific component designators that may need to be modified. The system should not be run in a continuous power test with this configuration, as the power rating of the resistors is not sufficient to support operation beyond DPT.

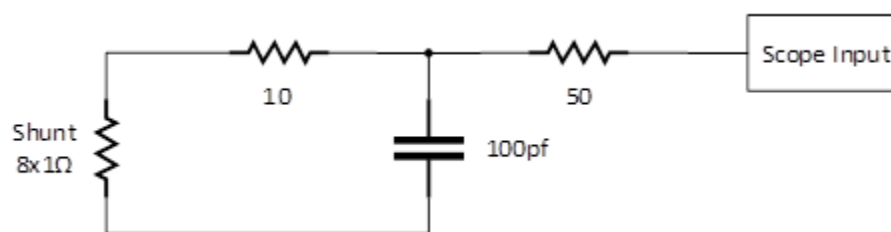


Figure 25: High Resistance Shunt Circuit

### 8.2 Two Stage Current Transformer

Another current sensing method is to implement a two-stage current transformer. The first stage consists of a 1:10 turn surface mount transformer that is included with the motherboard kit which must be soldered onto the power daughter card. The daughter card comes prepopulated with surface mount shunt resistors, which must be removed to populate the current transformer. There is also a RC compensation network and MMCX connector that must be removed as well. Please refer to the specific power daughter card user manual for reference designators of the components that must be removed.

Figure 26 shows a power daughter card with the shunt resistors and Figure 27 shows it with the shunt resistors and MMCX connector removed and the CT populated.



Figure 26: Daughter Card with Shunt Resistors

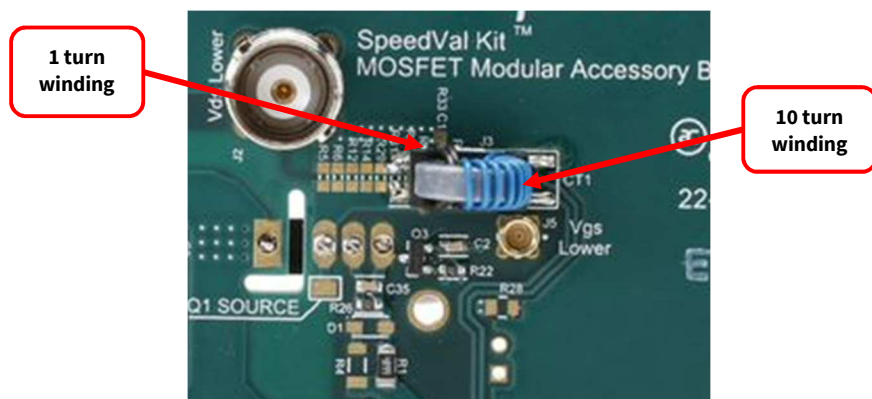


Figure 27: Daughter Card with Current Transformer

The second stage is a shielded high-bandwidth current transformer that the output of the first 1:10 transformer is passed through. This high-bandwidth current transformer is not included with the kit.

Table 7 lists two models that may provide acceptable performance, but this is not an exhaustive list. Figure 28 shows the high-bandwidth current transformer connected to the SpeedVal Kit motherboard and Figure 29 shows the schematic for the circuit.

Table 7: Recommended High-Bandwidth Current Transformers

| Manufacturer    | Model     | CT Gain (V/A) | Overall Attenuation |
|-----------------|-----------|---------------|---------------------|
| <b>Pearson</b>  | 2878      | 0.10          | 100:1               |
| <b>Magnelab</b> | CT-B_0.25 | 0.25          | 40:1                |



Figure 28: High-Bandwidth CT Connected to CON11

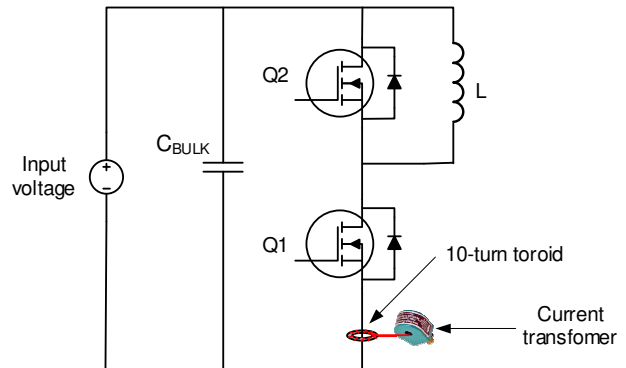


Figure 29: Circuit Schematic With CT

**Note! When using the CT method, it is critical that a user does not operate with the current signal output connector, CON11, left open. CON11 will act as a current source so it must be shorted or else it can result in damage to the SpeedVal Kit™ platform.**



### 8.3 Comparing Two Stage CT and Shunt Performance

Figure 30 shows switching energy measured on a 1200 V, 32 mΩ TO-263-7L MOSFET using the two methods. The dashed lines are the measurements taken with the double CT method and the solid lines are the measurements taken with the shunt method (1 Ω resistors). Both methods yield very similar results.

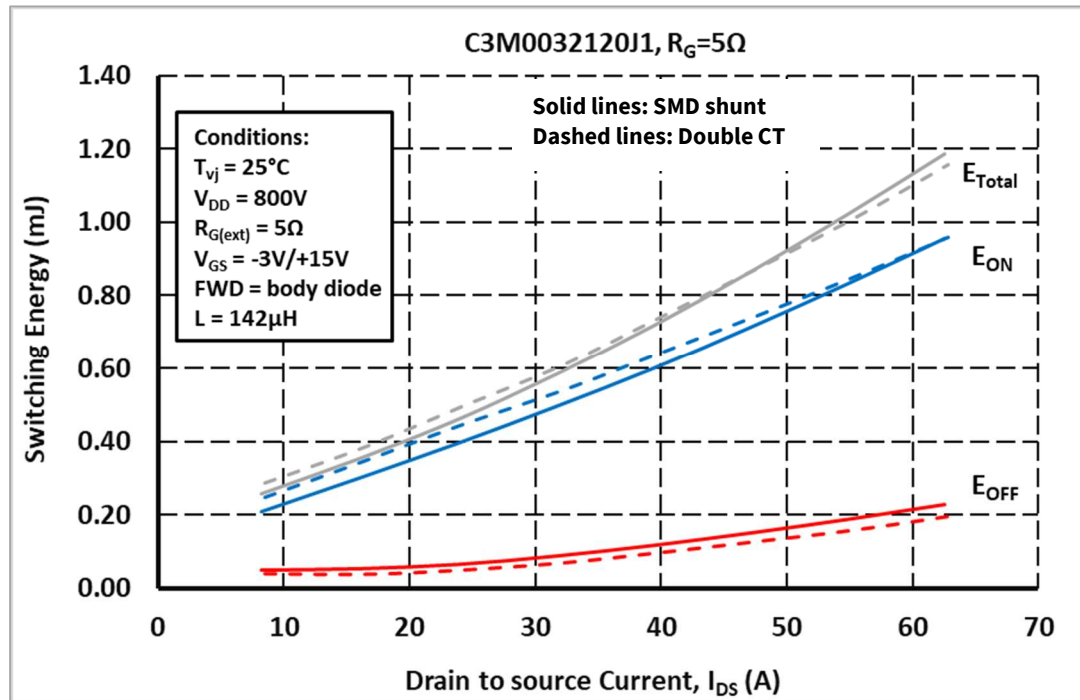


Figure 30: CT vs Shunt Switching Energy Measurements

Figure 31 shows the measured turn-on waveforms using the two methods. The solid lines are the measurements taken using the high-resistance shunt and the dashed lines are the measurements taken using the CT. The blue waveforms are  $V_{DS}$  on the lower switch. The red waveforms are  $I_{DS}$  through the lower switch. The shunt method has lower insertion inductance into the power loop than the CT method. The lower insertion inductance results in slightly higher peak currents due to a slightly increased reverse recovery current (Figure 31). The lower insertion inductance also results in lower peak  $V_{DS}$  overshoot at turn-off (Figure 32).

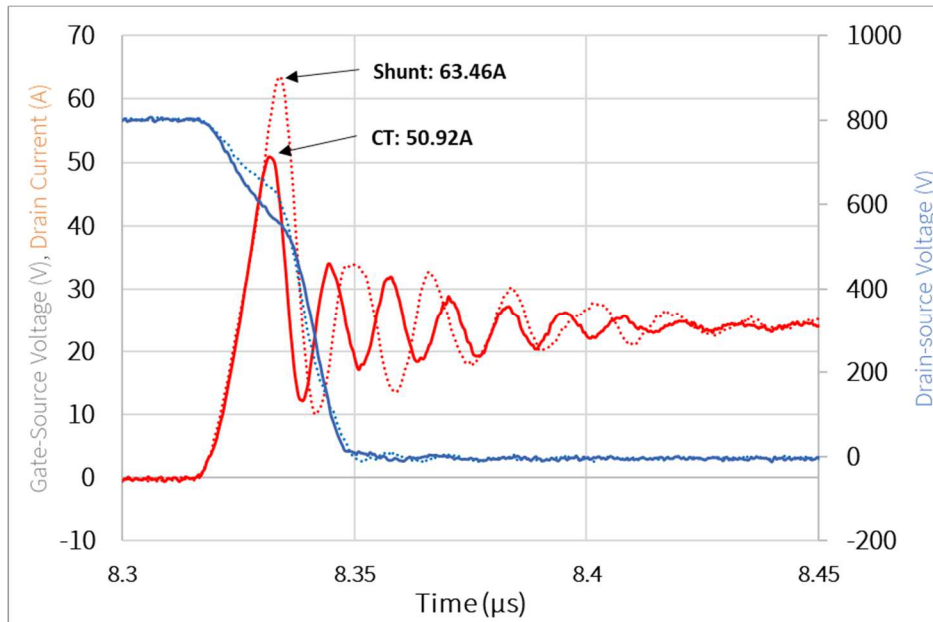


Figure 31: CT vs Shunt Turn-on Waveforms

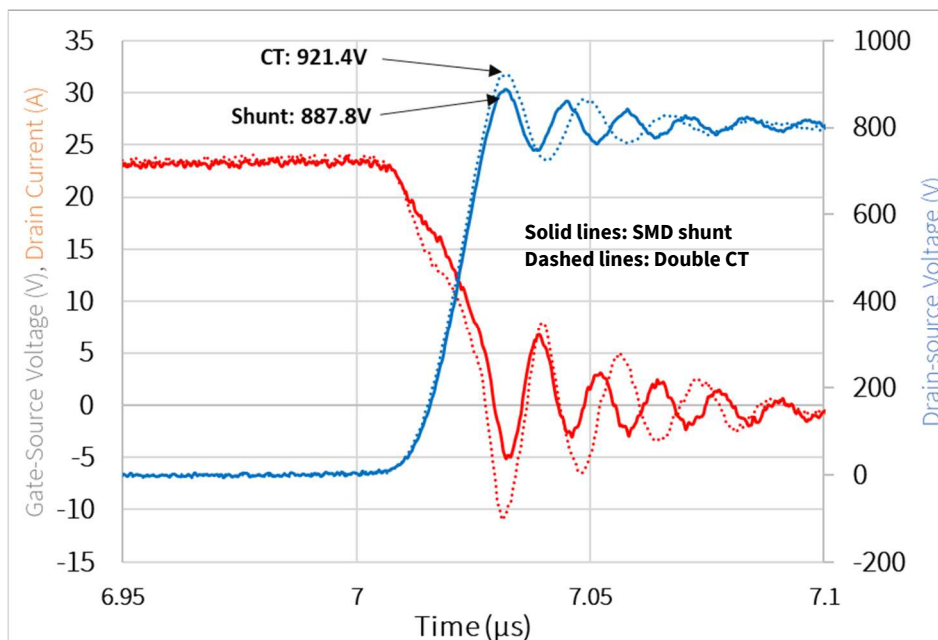


Figure 32: CT vs Shunt Turn-off Waveforms

## 8.4 Double Pulse Measurements

This section shows how to set up the SpeedVal Kit platform to take double pulse measurements. Figure 33 shows the SpeedVal Kit platform with an air core inductor and all probes in place. The necessary equipment is listed below (Figure 34). Note, if one of the optional control cards is being utilized, a function generator is not needed.

### Equipment needed for double pulse measurements:

- Digital oscilloscope (350 MHz or greater)
- x100 oscilloscope voltage probe for measuring  $V_{DS}$  (350 MHz or greater)
- x10 oscilloscope voltage probe for measuring  $V_{GS}$  (350 MHz or greater)
- 50  $\Omega$  BNC cable for measuring  $I_{DS}$
- High voltage power supply for charging DC bus
- 12 V, 3 A power supply
- Function generator for generating PWM or optional control card
- Air core inductor

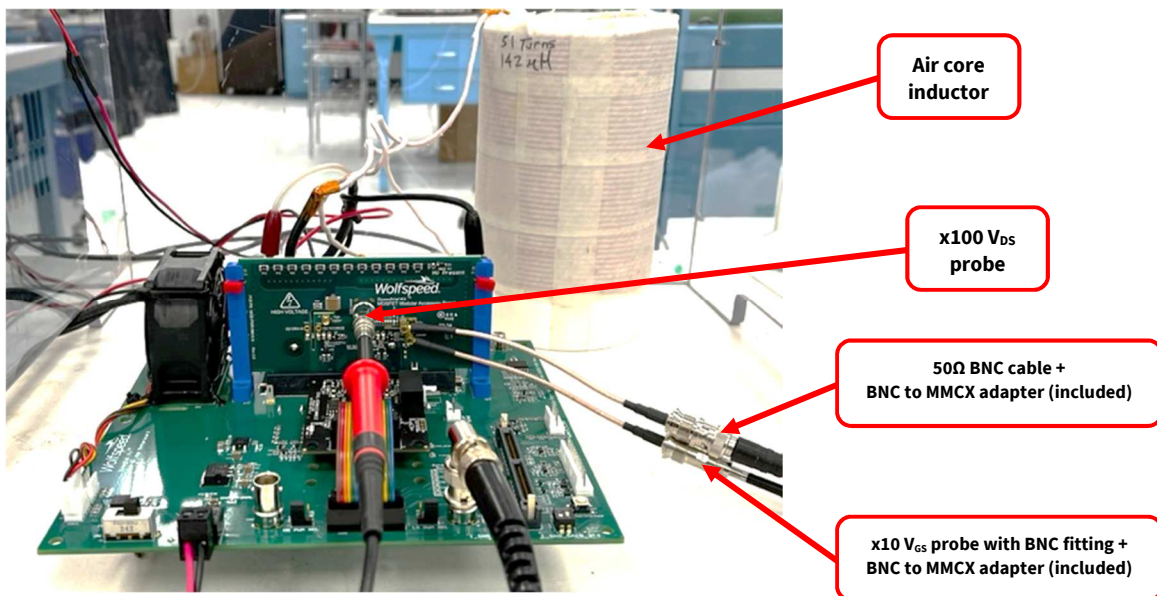


Figure 33: SpeedVal Kit™ Platform Setup for Taking Double Pulse Measurements

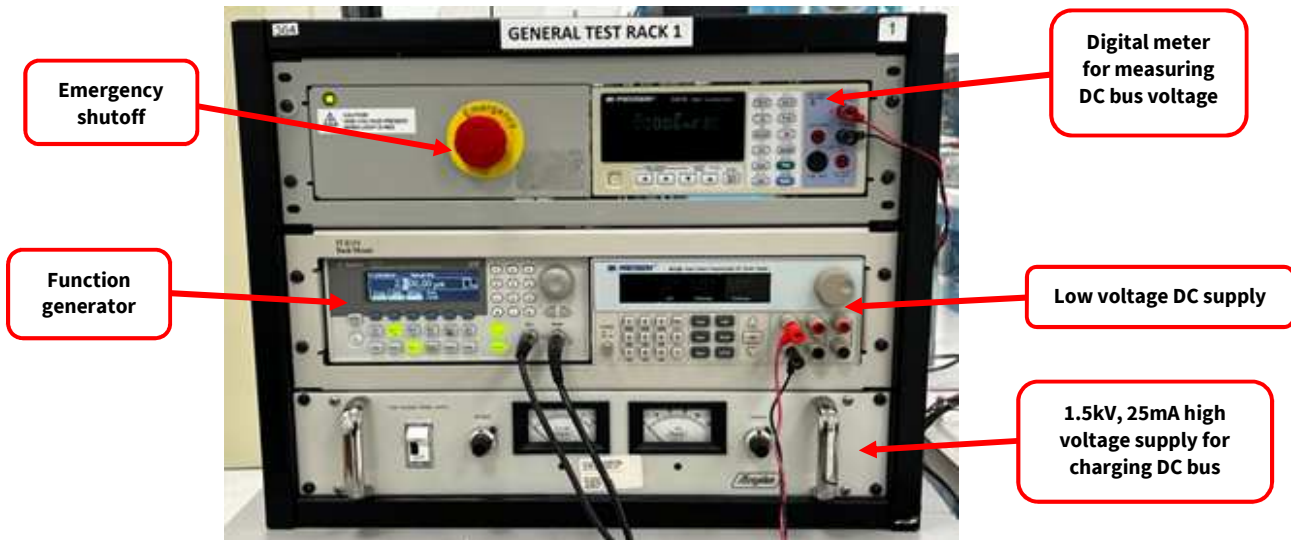


Figure 34: Test Rack with Necessary Equipment

Figure 35 shows each probe cable with several turns on nanocrystalline cores to serve as a common mode filter. The nanocrystalline cores are recommended to reduce common mode artifacts that are sometimes generated due to high  $dv/dt$ .



Figure 35: Oscilloscope Shown with Nanocrystalline Common Mode Cores

### 8.4.1 Deskew

Deskewing is critical to making accurate double pulse measurements. Taking double pulse measurements on a setup that has not been properly deskewed can result in errors of more than 100%. Figure 36 shows the connections for deskewing the setup.

#### Control Options

##### 1. External Function Generator

- Connect function generator to “LS IN” BNC connector
- Set the two 3-pin jumpers near the BNC connectors to the “BNC” setting

##### 2. Control Card

- Plug a control card into the control card slot. Ensure firmware has been loaded per instructions in user guide.
- Connect control card to PC to operate the program
- Set the two 3-pin jumpers near the BNC connectors to the “CTRLR” setting

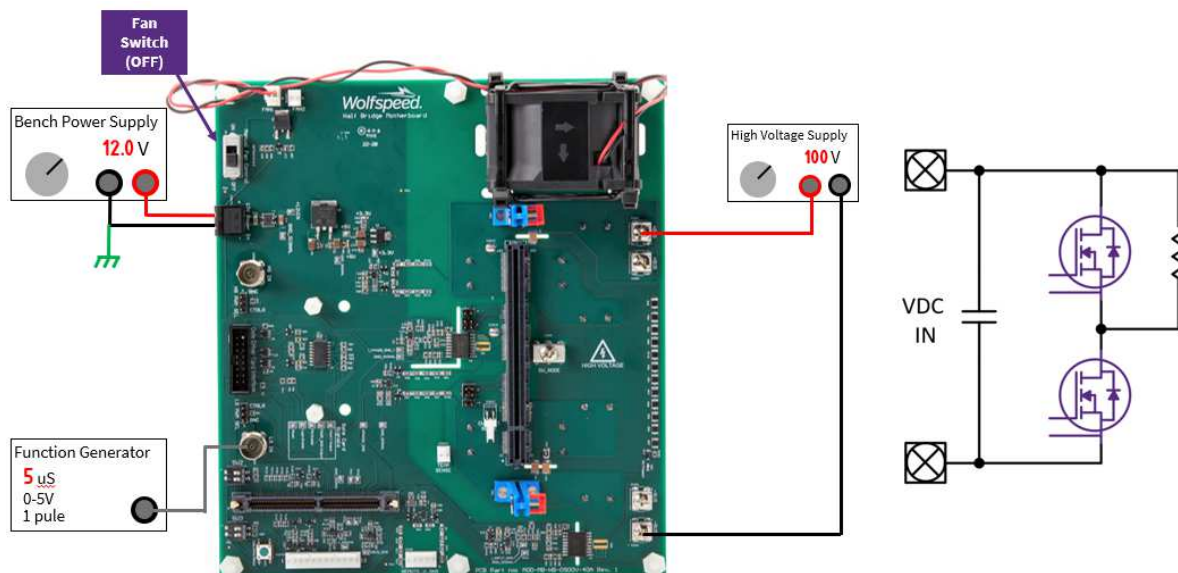


Figure 36: SpeedVal Kit™ Connections for Deskew

### 8.4.2 Deskew Procedure

The deskew test is necessary to perform before running DPT to ensure  $V_{DS}$  and  $I_{DS}$  scope channels are time-aligned to get accurate switching loss measurements.

- Ensure the power daughter card has been configured per the daughter card user guide to use a high-resistance current shunt or two-stage CT to get accurate results.

- Follow the instructions in the power daughter card user guide to place the supplied low-inductance resistor across the upper switch position.
- Use 125 V maximum DC link voltage.
- The air core inductor should be disconnected from the motherboard.
- The fan does not need to run for this test.
- Depending on the selected control method, either use the GUI to generate a deskew pulse, or the external function generator to create a 1-5us single pulse on the low-side PWM input.

### 8.4.3 Deskew Waveforms

The current shunt monitoring connector is installed on the power daughter card with the polarity reversed. This is so the  $V_{DS}$ ,  $V_{GS}$ , and  $I_{DS}$  commons will all be tied to the same node (source of lower MOSFET). During normal operation, the oscilloscope will need to invert  $I_{DS}$  so that it is displayed properly.

During deskew,  $I_{DS}$  should be inverted so that  $I_{DS}$  will be in phase with  $V_{DS}$  and the timings can be aligned (deskewed). The scale and offsets of  $V_{DS}$  and  $I_{DS}$  are adjusted so that the waveforms appear to lie on top of each other (Figure 37). Once the scales and offsets are properly adjusted, the oscilloscope's zoom function should be utilized so that small timing differences can be seen (Figure 38).

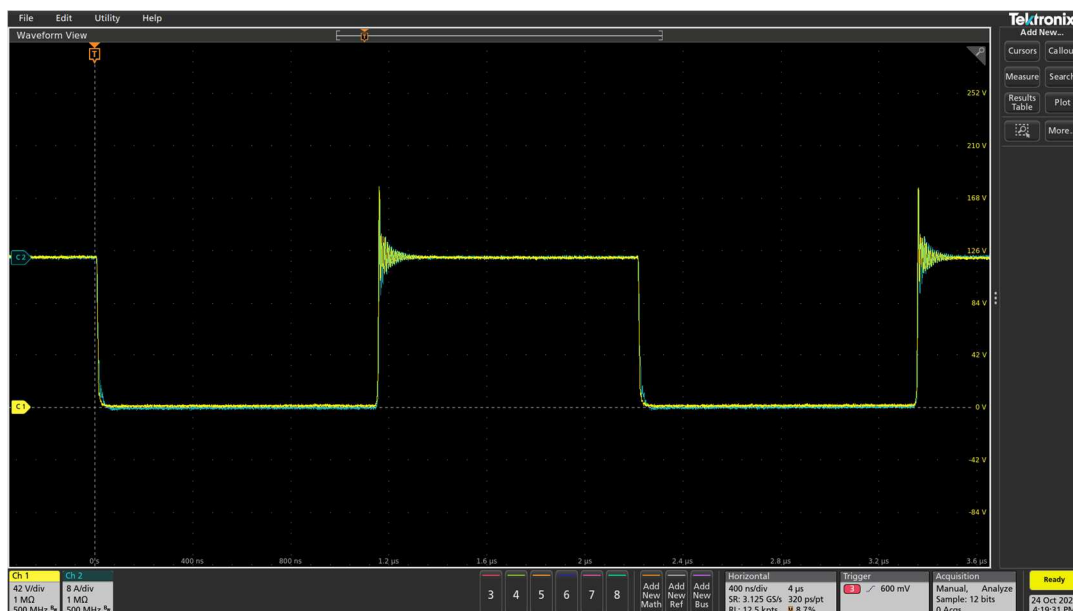


Figure 37:  $V_{DS}$  and  $I_{DS}$  Waveforms

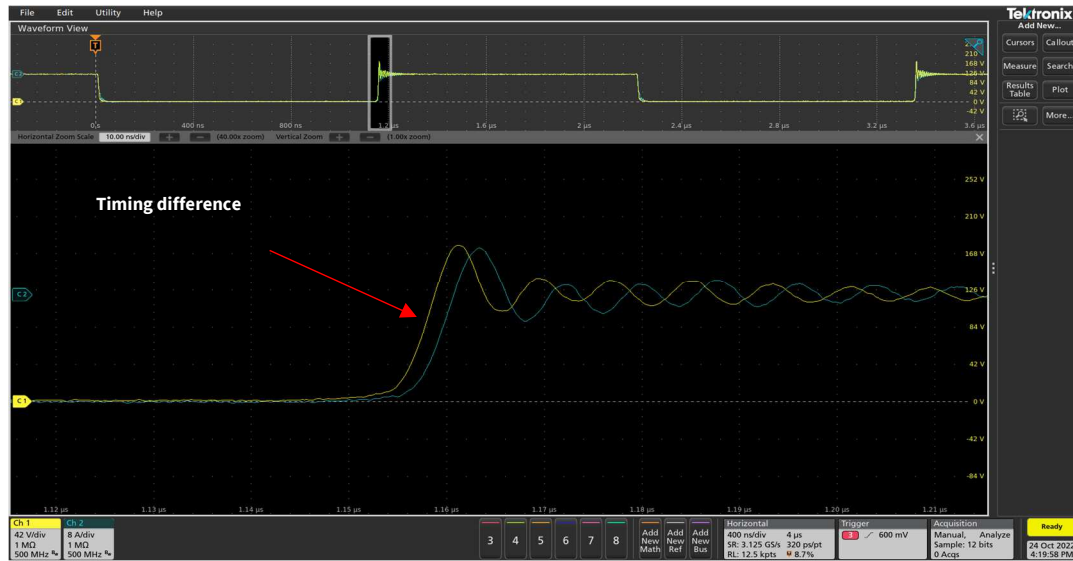


Figure 38:  $V_{DS}$  and  $I_{DS}$  Waveforms Zoomed

Figure 38 shows that the  $I_{DS}$  waveform is lagging behind the  $V_{DS}$  waveform by approximately 2ns. Two nanoseconds of deskew is added to channel 2 ( $I_{DS}$ ).

Figure 39 and Figure 40 show the  $V_{DS}$  and  $I_{DS}$  waveforms at both switching edges are well aligned after the deskew has been properly adjusted. Now that the scope setup has been deskewed, the resistor must be removed and replaced with an inductor.

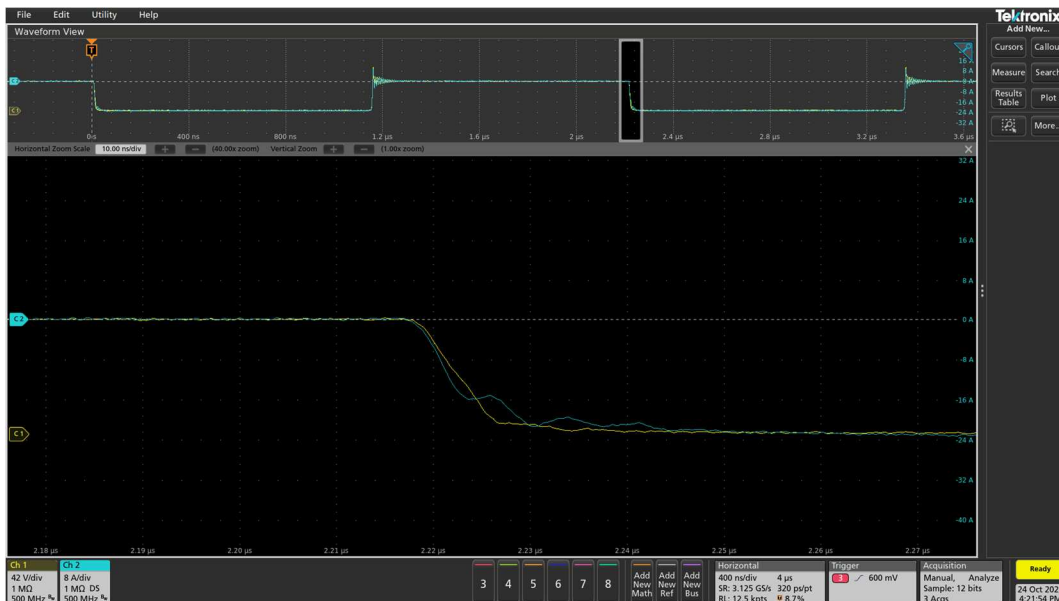


Figure 39:  $V_{DS}$  and  $I_{DS}$  Waveforms Zoomed

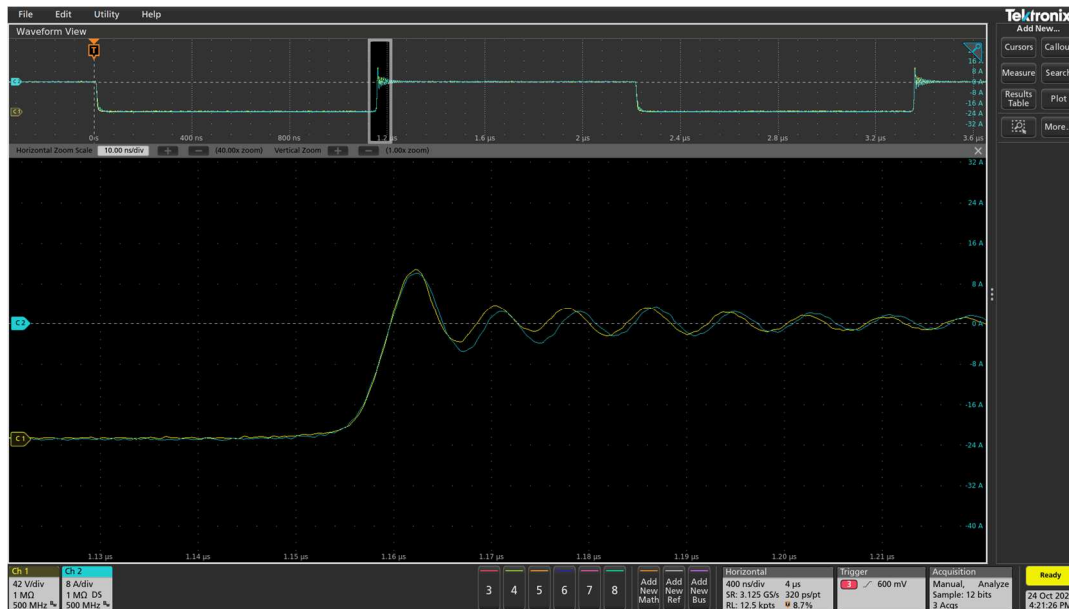


Figure 40:  $V_{ds}$  and  $I_{ds}$  Waveforms Zoomed

### 8.4.4 Switching Loss Measurements

Once the circuit has been deskewed, remove the deskew resistor and replace with the air core inductor.

#### Switching Energy Measurement Setup

- Ensure the power daughter card has been configured per the user guide to use a high-resolution current shunt or two-stage CT in order to get accurate results.
- It is recommended to use the SpeedVal Kit air core inductor that has been optimized to have low parallel capacitance.
- Select an inductance value to achieve the desired switching current using a pulse width of 15us or less to avoid self-heating the part.
- The fan does not need to run for this test.

#### Inductor Selection

The value of the inductor should be selected to provide the desired test current levels based on the test voltage and pulse width. Short pulses should be used for DPT measurements to limit the self-heating of the MOSFET, and to avoid saturating the CT or overheating the shunt resistors. A good practice is to use total on-time of the lower MOSFET between 5 and 15us time ( $T_1+T_2$  in Figure 42). Table 8 shows calculated inductance values for 10us on-time for several voltages and currents to use as a reference value when selecting an inductor for DPT. It is important to consider the final current during the DPT is higher than the current where  $E_{on}$  and  $E_{off}$  are



measured because the current continues to rise during the 2<sup>nd</sup> pulse. Ensure that the final current is within the rating of the shunt resistors and the MOSFET under test.

*Table 8: Example Inductance Values*

| Test Current | 400V  | 600V  | 800V  |
|--------------|-------|-------|-------|
| <b>20A</b>   | 200uH | 300uH | 400uH |
| <b>40A</b>   | 100uH | 150uH | 200uH |
| <b>60A</b>   | 67uH  | 100uH | 133uH |
| <b>80A</b>   | 50uH  | 75uH  | 100uH |

The inductor should be an air-core construction to avoid any effects of the core material affecting the switching behavior. It is also important to minimize the shunt or parallel capacitance by winding only a single layer and leaving a gap between the turns of approximately the diameter of the wire. Due to the short pulse duration of the DPT, the wire can be relatively small gauge such as 18-22AWG.

## Control Options

### 1. External Function Generator

- Connect function generator to “LS IN” BNC connector
- Set the two 3-pin jumpers near the BNC connectors to the “BNC” setting

### 2. Control Card

- Plug a control card into the control card slot. Ensure firmware has been loaded per instructions in user guide.
- Connect control card to PC to operate the program
- Set the two 3-pin jumpers near the BNC connectors to the “CTRLR” setting

## Switching Energy Measurement Procedure

Figure 41 shows the connection diagram for taking double pulse measurements.

- Depending on the selected control method, either use the GUI, or the external function generator to generate a two or more pulses for the low-side PWM.
- Refer to the power daughter card user guide for limitations on peak current levels and pulse duration based on the current sensing element.

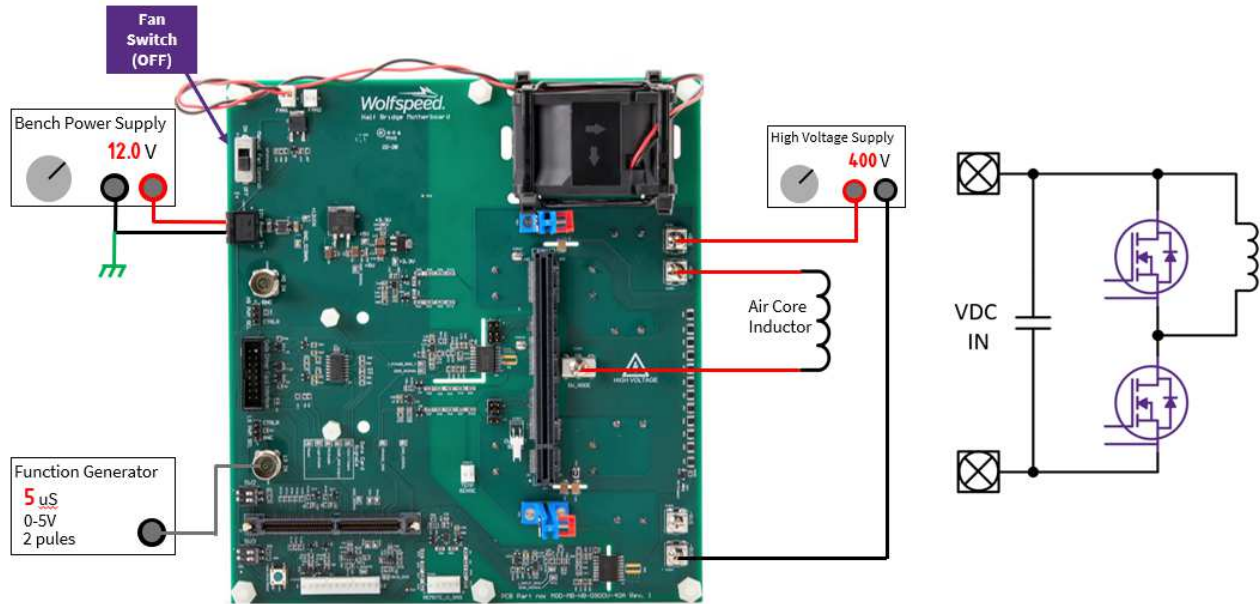


Figure 41: SpeedVal Kit™ Connections for Taking Switching Energy Measurements

Once the setup has been pulsed, the user needs to zoom in on the waveforms to measure the switching losses. Figure 44 shows the turn-on waveforms. To measure the turn-on switching energy ( $E_{ON}$ ),  $V_{DS}$  and  $I_{DS}$  are multiplied to give the instantaneous power as shown in Figure 43.  $E_{ON}$  is defined as the integral of the instantaneous power beginning when  $I_{DS}$  is at 10% of the target current and ending when  $V_{DS}$  has fallen to 10% of the DC bus voltage. This calculation can be done on most oscilloscopes using the integral function or by solving for the area underneath the power curve between the 10% boundary points. Figure 44 and Figure 45 show measured test data for the configuration shown in Table 9.

Table 9: DPT Devices Tested and Conditions

| Items                   | Parameters  |
|-------------------------|-------------|
| <b>DC Link Voltage</b>  | 400 V       |
| <b><math>R_G</math></b> | 5 $\Omega$  |
| <b>Inductor</b>         | 142uH       |
| <b>High-Side MOSFET</b> | C3M0045065L |
| <b>Low-Side MOSFET</b>  | C3M0045065L |

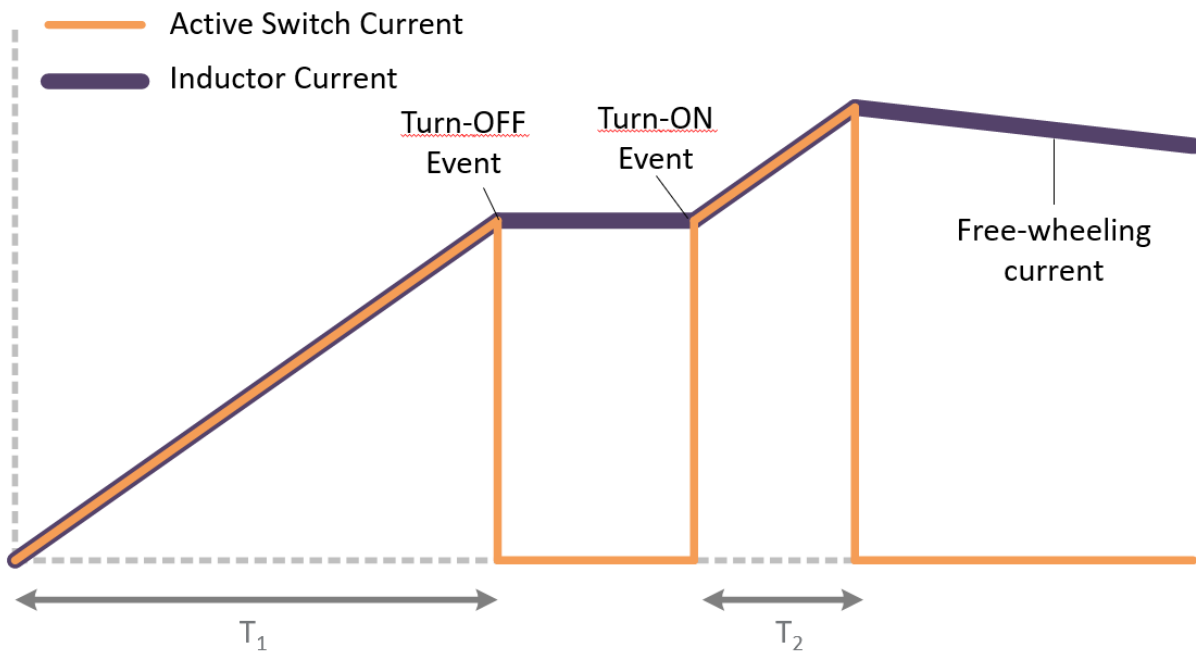


Figure 42: Double Pulse Waveform Diagram

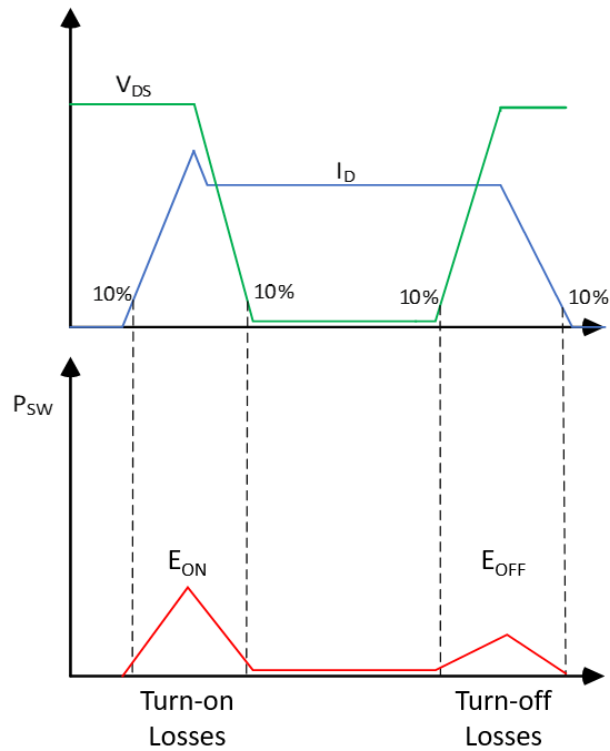


Figure 43: Switching Energy Measurement Definitions

Figure 44 shows an example turn-on energy measurement. The cursors and the cursors are set at the 10% boundary points, resulting in an  $E_{ON}$  measurement of 89.12uJ.

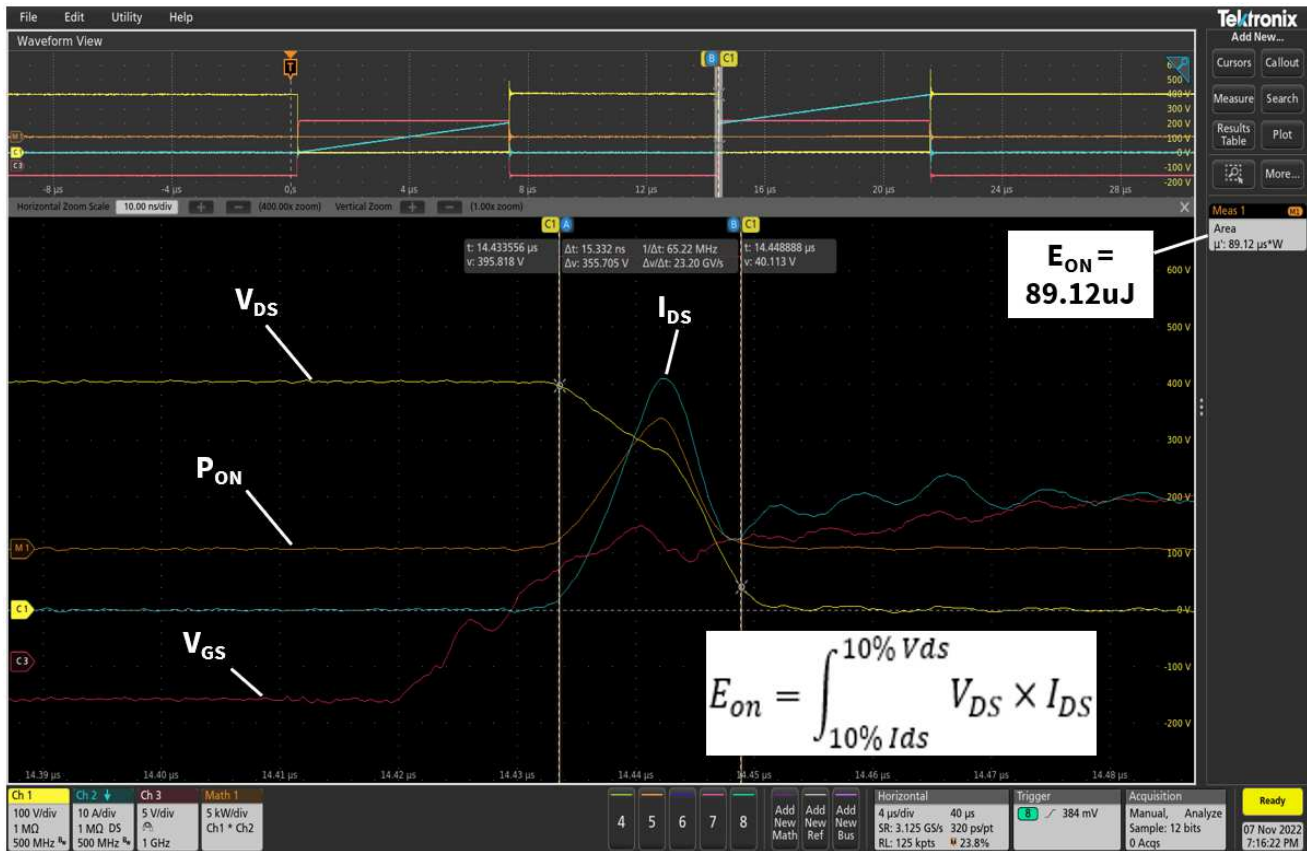


Figure 44: Zoomed in View of Turn-on Waveforms

To measure the turn-off switching energy ( $E_{OFF}$ ), the user must zoom in on the waveform at the turn-off event. Figure 45 shows the zoomed turn-off switching waveforms.

$E_{OFF}$  is defined as the integral of the instantaneous power beginning when  $V_{DS}$  is at 10% of the DC bus voltage and ending when  $I_{DS}$  has fallen to 10% of the target current.

Figure 45 shows an example turn-off energy measurement. The cursors are set at the 10% boundary points, resulting in an  $E_{OFF}$  measurement of 16.95uJ.

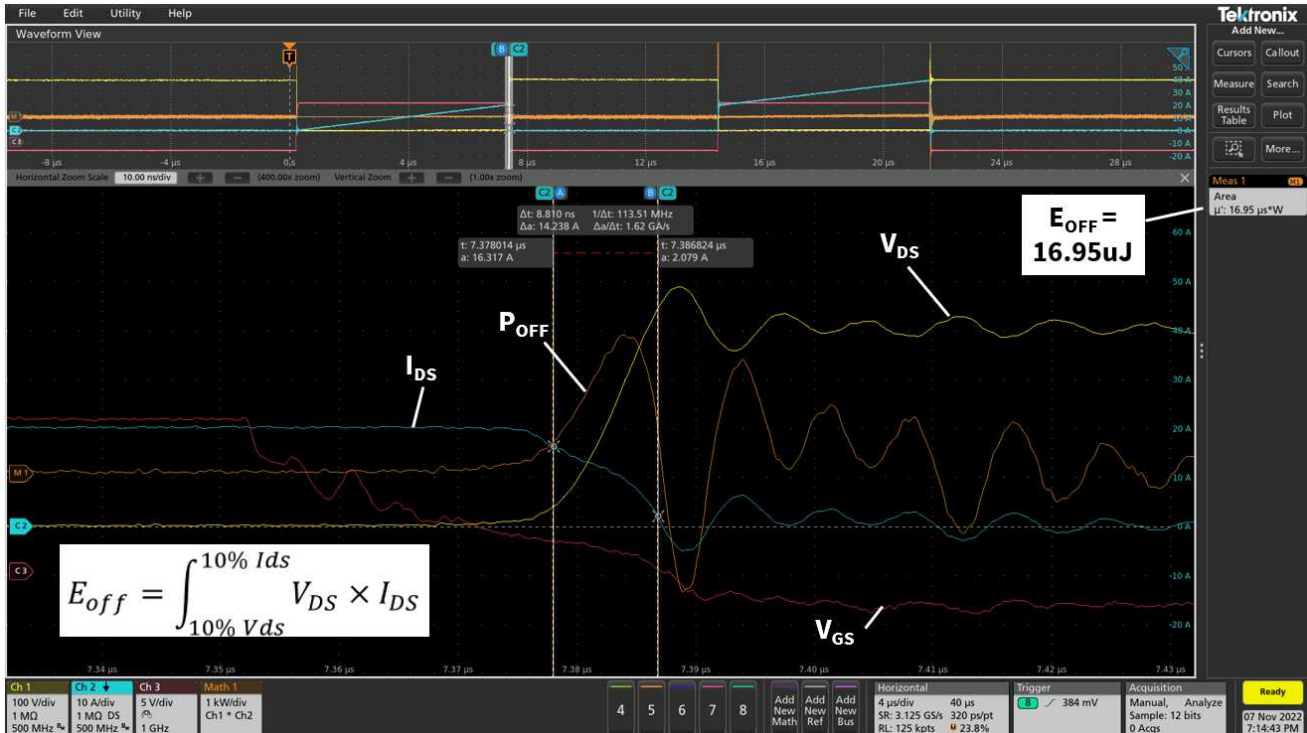


Figure 45: Zoomed in View of Turn-off Waveforms

### 8.4.5 Reverse Recovery Charge ( $Q_{RR}$ )

Perform a deskew test first before running DPT to ensure voltage and current probes have been time-aligned. Significant error will result from even a few ns of misalignment.

- Ensure the power daughter card has been configured per the user guide to use a high-resolution current shunt or two-stage CT to get accurate results.
- It is recommended to use the SpeedVal Kit air core inductor which has been optimized to have low parallel capacitance.
- Select an inductance value to achieve the desired switching current utilizing a pulse width of 15µs or less to avoid self-heating the part.
- The fan does not need to run for this test.

#### Control Options

1. External Function Generator
  - Connect function generator to “HS IN” BNC connector
  - Set the two 3-pin jumpers near the BNC connectors to the “BNC” setting
2. Control Card
  - Plug a control card into the control card slot. Ensure firmware has been loaded per instructions in user guide.

- Connect control card to PC to operate the program.
- Set the two 3-pin jumpers near the BNC connectors to the “CTRLR” setting.

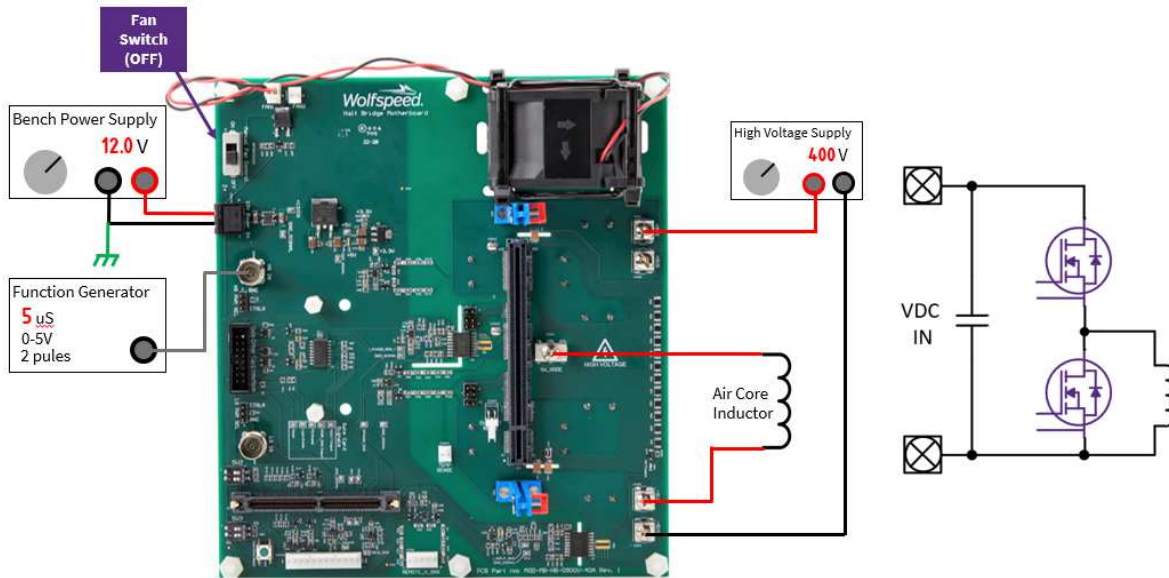


Figure 46: Connection Diagram for  $Q_{RR}$  Measurement

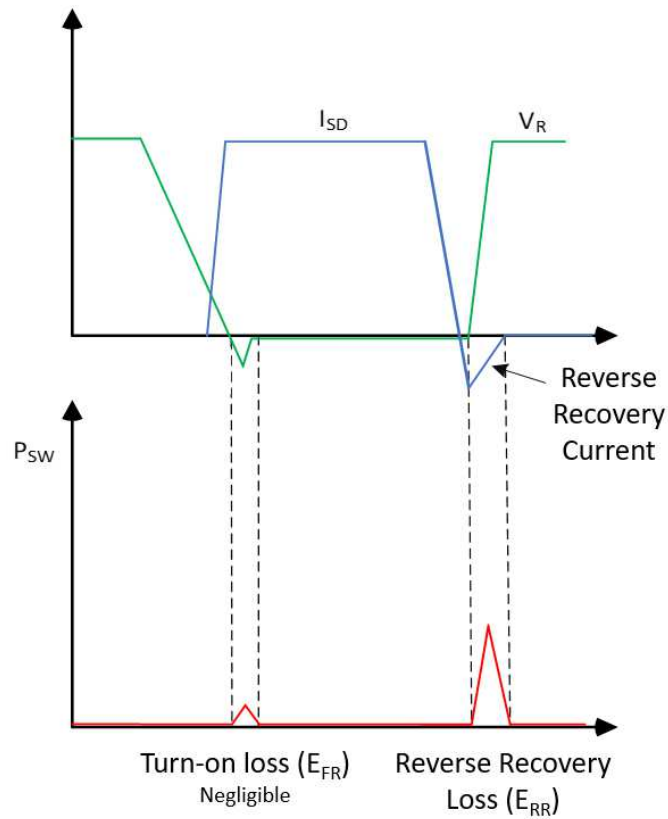


Figure 47:  $Q_{RR}$  Measurement Definitions

Figure 48 shows a zoomed in view of  $I_{DS}$ . To measure  $Q_{RR}$ ,  $I_{DS}$  is integrated from the point that  $I_{DS}$  goes through zero to when it returns to zero. This is the period of time when reverse recovery current is flowing backwards through the body diode of the lower device.

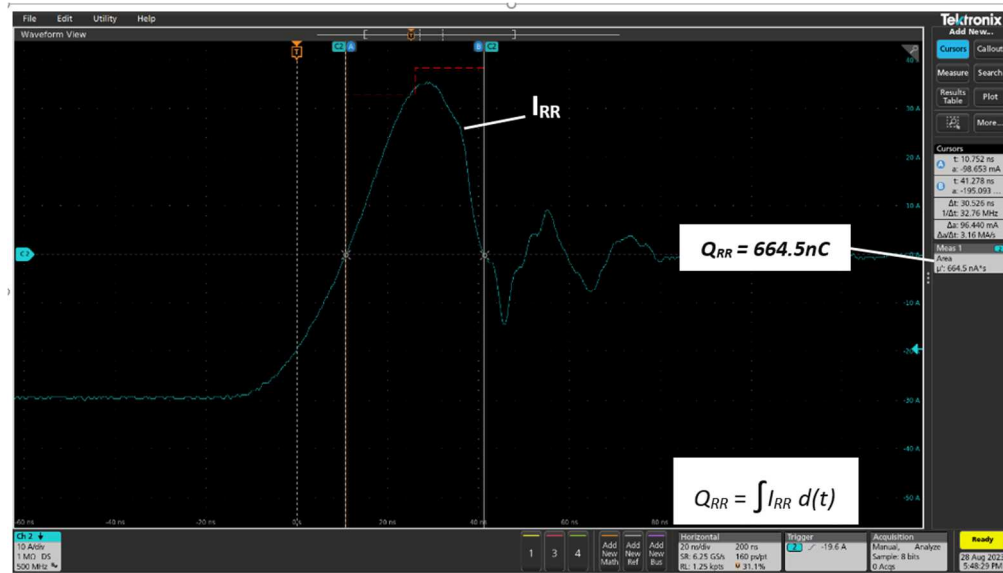


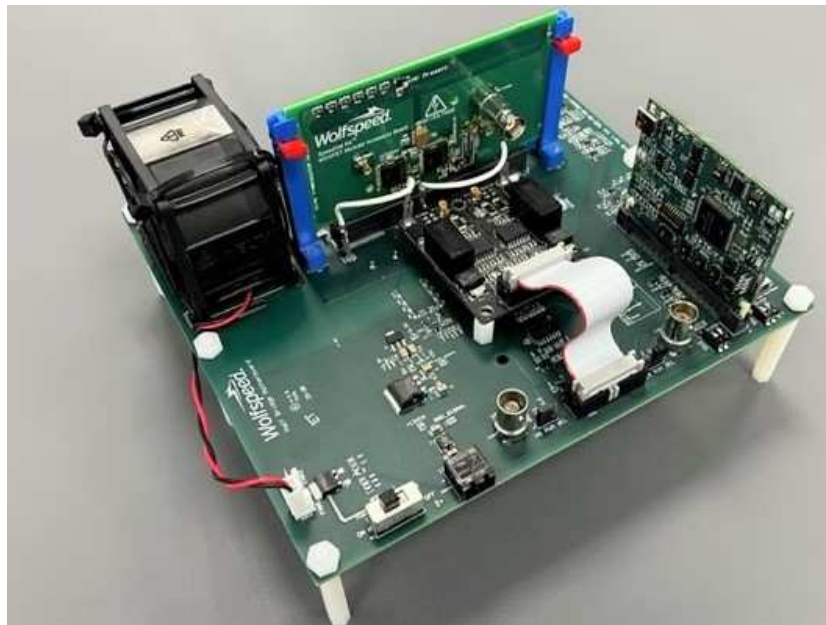
Figure 48: Zoomed in view of  $Q_{RR}$  measurement

## 9. Short Circuit Testing

Some applications require the power converter to withstand a short-circuit applied to the output, between phases, or between a switch node and bus rail. Several of the gate driver daughter cards in the platform support short-circuit protection. The SpeedVal Kit platform can be used to test and adjust the timing of the protection to provide fast response time to a short circuit event but avoid false triggering fault protection. During a short circuit event, the  $di/dt$  is extremely high, as it is limited only by the stray inductance of the DC bus and the short itself, along with the transconductance of the MOSFET that is turning on.

Due to the high peak currents, which can exceed 1000A, the shunt resistors on the power daughter card need to be shorted out to prevent damage. Refer to the power daughter card user guide for the shunt resistor reference designators. It is recommended to remove the resistors and place a copper jumper or solder bridge between the pads. In order to measure current during the short-circuit event, a Rogowski coil can be placed around the shorting wire, or around the drain lead of the MOSFET if using a through-hole device.

Use the two jumper wires provided with the motherboard kit to connect the gate driver daughter card to the drain voltage sense tabs on the motherboard as shown in Figure 49.



*Figure 49: Drain Voltage Sense Jumpers*

Short circuits in the application can occur in two different ways, referred to as type 1 and type 2. A type 1 event is when the MOSFET turns on into an existing short circuit. In a type 2 event, the MOSFET is fully on at the time a short circuit occurs in the system. A type 2 short circuit can be easily tested on the SpeedVal Kit platform. The gate driver protection behaves differently in these two cases. In type 1, the gate driver will have an initial delay time after applying the gate signal before it begins monitoring the drain voltage to detect a short circuit event



in order to allow the MOSFET to fully turn on and avoid false triggering during normal operation. This is referred to as blanking time and is one of the parameters that can be adjusted during testing to optimize the response. In a type 2 event, since the MOSFET is already on, and the blanking time has expired, the short circuit detection can happen more quickly as the delay is no longer present.

A type 1 short circuit can be tested on either the high or low side MOSFET. To test the low-side device, connect a shorting wire between the switch node terminal and the positive DC bus terminal using a 14 AWG wire or larger. The length of this wire can be adjusted to provide different amounts of inductance in the short circuit to represent the expected condition in the application. Then apply a single 5V pulse to the low-side PWM input BNC to gate the low-side device on. It is recommended to start the testing with a 500ns pulse, and gradually increase it while observing the short-circuit behavior. Apply only one pulse at a time, and then allow the device to cool for at least 30 seconds before testing again. As the commanded pulse width is increased above the gate driver short-circuit protection time, the gate driver will respond and turn the device off. This timing depends on the gate driver daughter card. Refer to the user guide for the gate driver card for more details and how to adjust the timing. The total duration of the short circuit current (starting at 0A, and returning to 0A) should be approximately 1 $\mu$ s. This duration is a good balance to avoid false tripping while providing robust short-circuit protection. If the gate driver is not responding within this time, adjust the settings on the gate driver card to reduce the response time, or increase the turn-off gate drive strength.

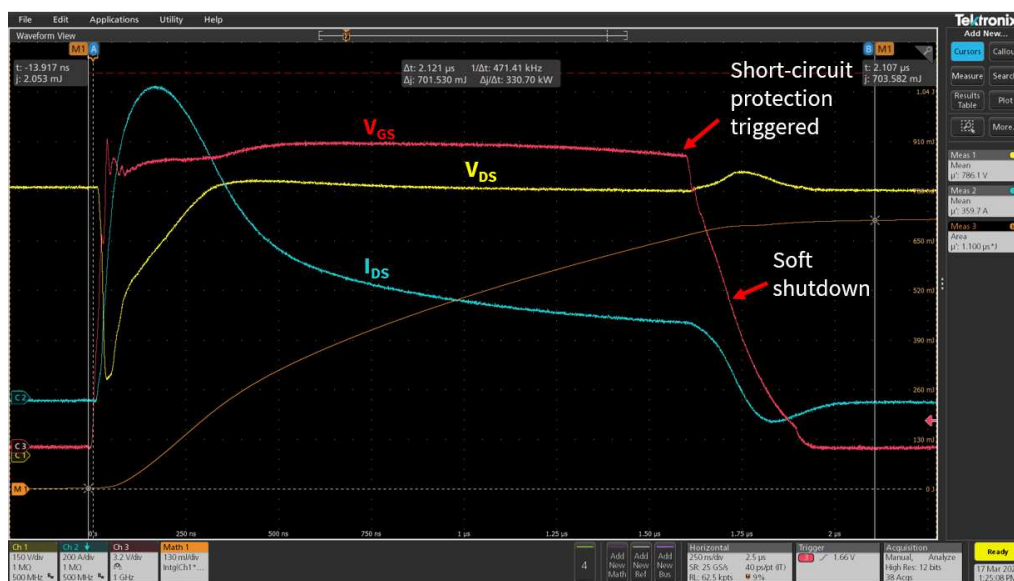


Figure 50: Example short-circuit behavior

## 10. Power Topologies and Connection Diagrams

The half-bridge SpeedVal Kit motherboard supports several different continuous power testing configurations. A separate buck-boost filter board equipped with an inductor and film capacitor bank can be attached to the

motherboard to enable a quick way to run the system as either a buck or boost converter. The user can also attach other loads to the motherboard as long as the voltage and current limits of the motherboard and the thermal limits of the MOSFETs are observed.

## 10.1 Synchronous Boost Converter

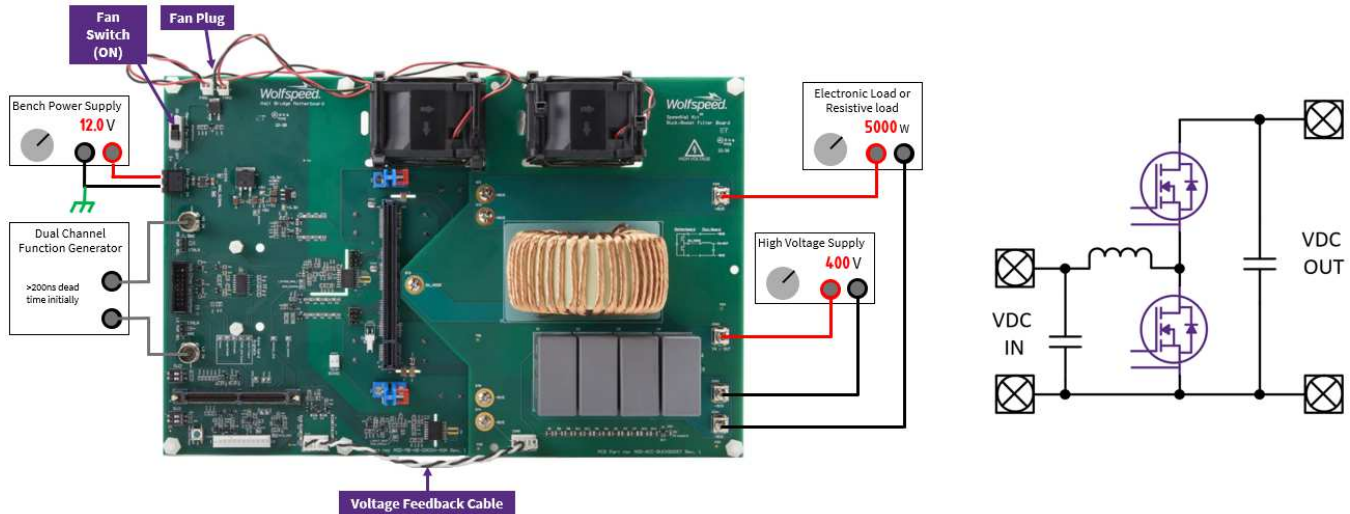


Figure 51: Connection Diagram for Synchronous Boost Converter

### Equipment Setup

- Connect buck/boost filter board to the motherboard using the 5 screws and terminal nuts on the motherboard (Figure 51).
- Plug the fan from the buck/boost filter board into the motherboard.
- **Connect a fixed load resistor to prevent output overvoltage.** A maximum 1k resistor with sufficient power rating for the desired output voltage is recommended.

### Control Options

1. External Function Generator
  - Connect function generator to “HS IN” and “LS IN” BNC connectors
  - Set the two 3-pin jumpers near the BNC connectors to the “BNC” setting
  - Ensure dead-time is provided between the input signals. 200 ns minimum is a recommended starting point.
  - Turn on the fan switch before running, and ensure both fans are operating
2. Control Card

- Plug a control card into the control card slot. Ensure firmware has been loaded per instructions in user guide.
- Connect control card to PC to operate the program.
- Attach the voltage feedback cable between the buck/boost filter board and motherboard
- Set the two 3-pin jumpers near the BNC connectors to the “CTRLR” setting
- Fans should operate automatically when testing starts. Ensure both fans are operating

## 10.2 Asynchronous Boost Converter

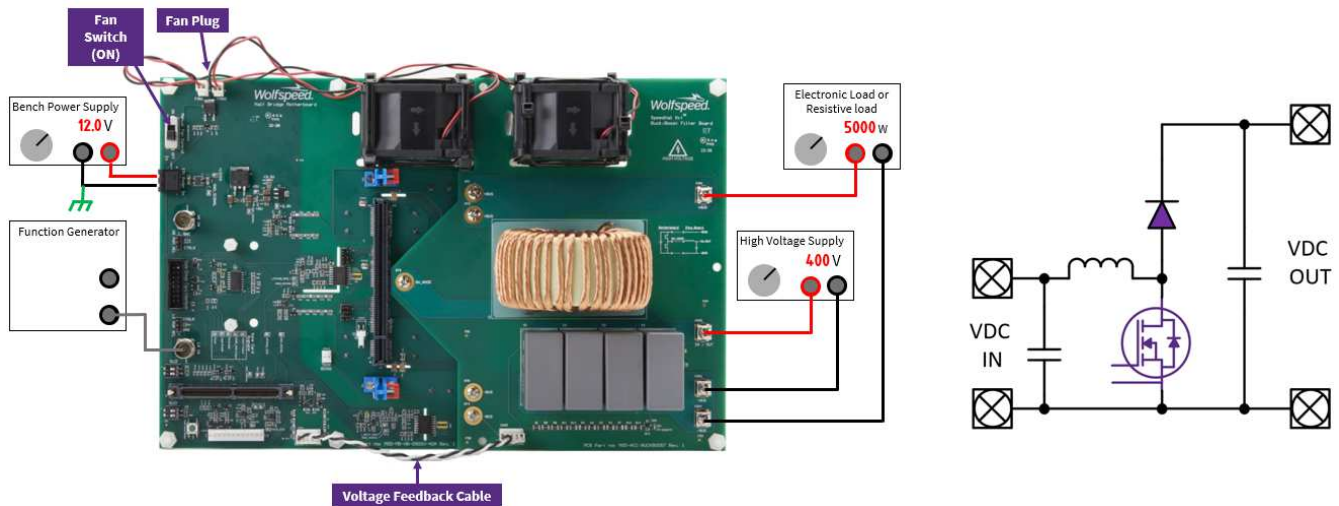


Figure 52: Connection Diagram for Asynchronous Boost Converter

### Equipment Setup

- Connect buck/boost filter board to the motherboard using the 5 screws and terminal nuts on the motherboard (Figure 52).
- Plug the fan from the buck/boost filter board into the motherboard.
- **Connect a fixed load resistor to prevent output overvoltage.** A 1k resistor with sufficient power rating for the desired output voltage is recommended. It is recommended to maintain the load level high enough to maintain continuous current in the inductor or the output voltage may exceed the targeted voltage. There is no overvoltage protection available when driving the PWMs with a function generator.

### Control Options

1. External Function Generator
  - Connect function generator to “LS IN” BNC connectors
  - Set the two 3-pin jumpers near the BNC connectors to the “BNC” setting

- Turn on the fan switch before running, and ensure both fans are operating
2. Control Card
    - Plug a control card into the control card slot. Ensure firmware has been loaded per instructions in user guide.
    - Connect control card to PC to operate the program
    - Attach the voltage feedback cable between the buck/boost filter board and motherboard
    - Set the two 3-pin jumpers near the BNC connectors to the “CTRLR” setting
    - Fans should operate automatically when testing starts. Ensure both fans are operating

### 10.3 Synchronous Buck Converter

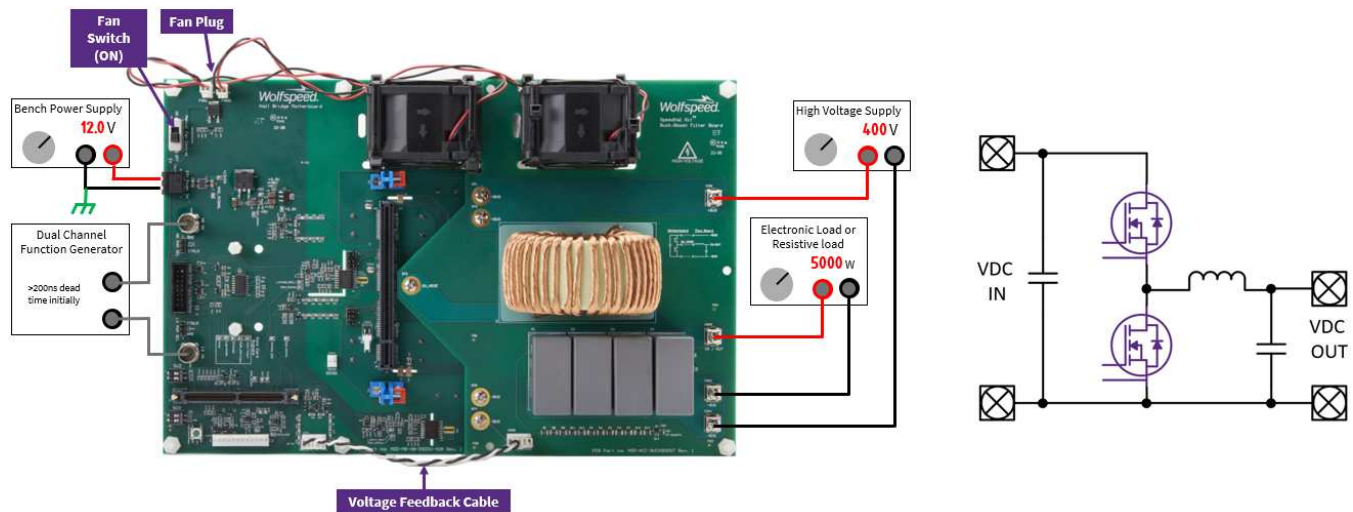


Figure 53: Connection Diagram for Synchronous Buck Converter

#### Equipment Setup

- Connect buck/boost filter board to the motherboard using the 5 screws and terminal nuts on the motherboard (Figure 53).
- Plug the fan from the buck/boost filter board into the motherboard.

#### Control Options

1. External Function Generator
  - Connect function generator to “HS IN” and “LS IN” BNC connectors
  - Set the two 3-pin jumpers near the BNC connectors to the “BNC” setting
  - Ensure dead-time is provided between the input signals. 200 ns minimum is a recommended starting point.

- Turn on the fan switch before running, and ensure both fans are operating
- Control Card
    - Plug a control card into the control card slot. Ensure firmware has been loaded per instructions in user guide.
    - Connect control card to PC to operate the program
    - Attach the voltage feedback cable between the buck/boost filter board and motherboard
    - Set the two 3-pin jumpers near the BNC connectors to the “CTRLR” setting
    - Fans should operate automatically when testing starts. Ensure both fans are operating

## 10.4 Asynchronous Buck Converter

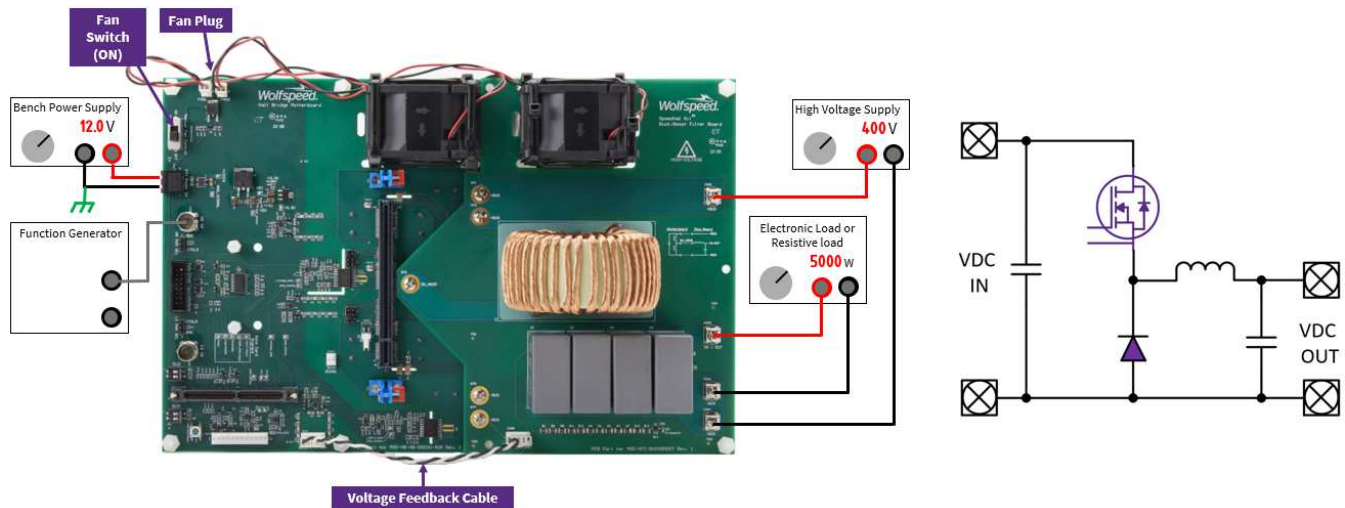


Figure 54: Connection Diagram for Asynchronous Buck Converter

### Equipment Setup

- Connect buck/boost filter board to the motherboard using the 5 screws and terminal nuts on the motherboard (Figure 54).
- Plug the fan from the buck/boost filter board into the motherboard.

### Control Options

- External Function Generator
  - Connect function generator to “HS IN” connector
  - Set the two 3-pin jumpers near the BNC connectors to the “BNC” setting
  - Ensure dead-time is provided between the input signals. 200 ns minimum is a recommended starting point.

- Turn on the fan switch before running, and ensure both fans are operating

## 2. Control Card

- Plug a control card into the control card slot. Ensure firmware has been loaded per instructions in user guide.
- Connect control card to PC to operate the program
- Attach the voltage feedback cable between the buck/boost filter board and motherboard
- Set the two 3-pin jumpers near the BNC connectors to the “CTRLR” setting
- Fans should operate automatically when testing starts. Ensure both fans are operating.

## 11. Application Example – Synchronous Boost Converter

This section shows how to set up the SpeedVal Kit platform to run as a synchronous boost converter. Figure 55 shows the SpeedVal Kit platform outfitted with the optional control board to supply the PWM pulses and the buck/boost filter board. An external function generator could have been used instead of the control board.

Table 10 shows the parameters for the test. The load for this test was a combination of an electronic and resistive load. **It is advised to always include some fixed resistive load when running in boost configurations. This prevents the output voltage from increasing to dangerous levels if an electronic load were to shut off unexpectedly.**

Table 10: Test Conditions

| Items               | Parameters   |
|---------------------|--------------|
| Input Voltage       | 200 V        |
| Output Voltage      | ≈385 V       |
| Output Current      | 11.7 A       |
| Output Power        | 4560 W       |
| Switching Frequency | 66 kHz       |
| Duty Cycle          | 48.5%        |
| Deadtime            | 200 ns       |
| Inductor            | 450 uH       |
| Output Capacitor    | 48 uf        |
| Input Capacitor     | 48 uf        |
| High-Side MOSFET    | C3M0045065J1 |
| Low-Side MOSFET     | C3M0045065J1 |

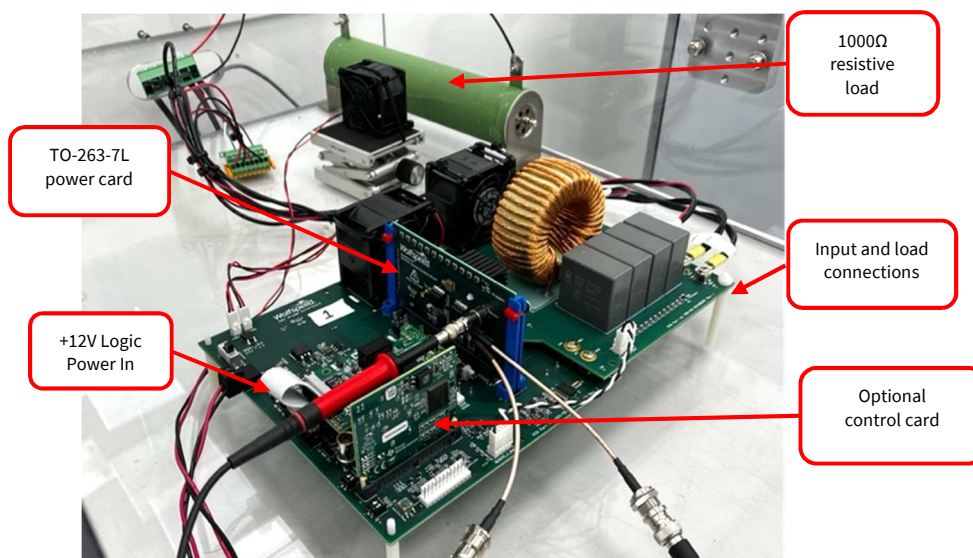


Figure 55: SpeedVal Kit™ Platform Setup for Synchronous Boost Setup

Figure 57 shows the oscilloscope probes connected to the power daughter card. A 100X passive probe is connected to J2, which measures  $V_{DS}$  on the lower switch. A 10X passive probe is connected to J5, which measures  $V_{GS}$  on the lower switch.

The power daughter card used here comes with a low-inductance surface mount shunt which is used to measure the current in the lower MOSFET. On this power daughter card, eight 40 mΩ 0603 resistors are paralleled to form the low-inductance shunt (5 mΩ). The voltage across the shunt resistors (J3) will be monitored and multiplied by 200 (scope multiplier setting) to give the correct shunt current,  $I_{DS}$  (Figure 56). The scope multiplier setting will vary depending on which power daughter card is being tested. Refer to the power daughter card user guide for the proper multiplier.

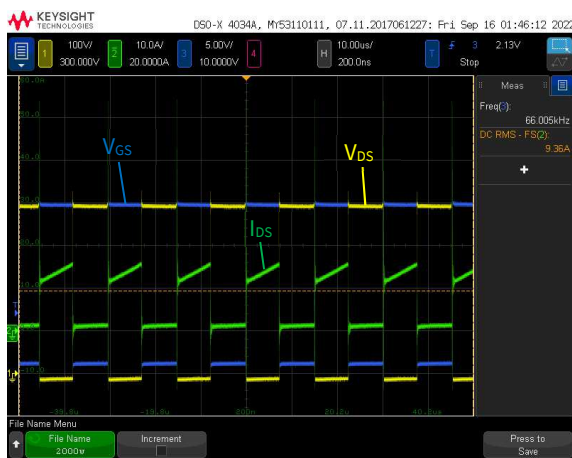


Figure 56: Oscilloscope Waveforms

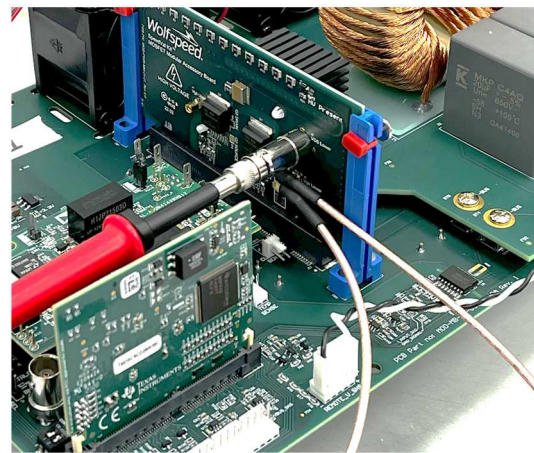


Figure 57: Oscilloscope Probe Connections

The board in the example was run and loaded at various power levels while the efficiency (as shown in Figure 58) was tracked using a power analyzer and the MOSFET package temperature (as shown in Figure 59) was tracked using an IR camera.

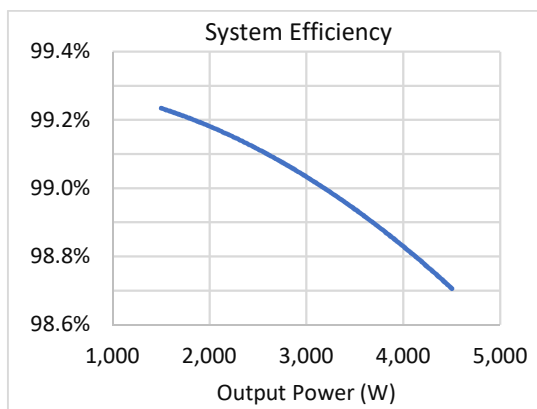


Figure 58: System Efficiency

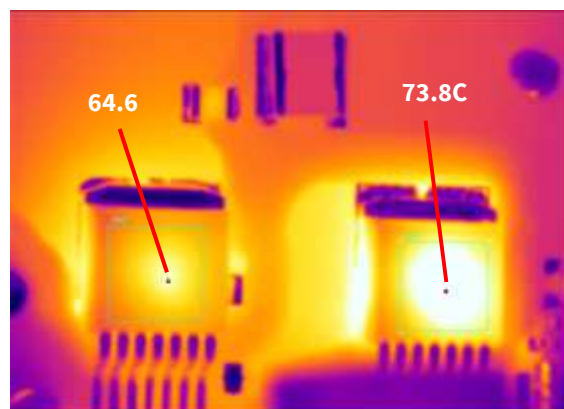


Figure 59: IR scan of MOSFETs at 4500 W



## 12. Troubleshooting

### No gate pulses

Check the PWM selection jumper position (J1 & J2). If supplying PWM pulses with an external function generator, the jumpers need to be in the “BNC” position. If using one of the optional control cards, both jumpers should be in the “CTRLR” position. Refer to section 5.7 for a picture of the jumpers in the correct positions.

### Distorted current waveforms when performing double pulse tests (switching energy)

The power daughter cards are shipped ready for high-power testing. Before performing double pulse tests, the board must be modified. There are two modifications (high-resistance shunt and current transformer) to choose from to take accurate double pulse measurements. Refer to section 6 for details. Figure 60 shows the waveforms with the power daughter card in its stock configuration, which has been optimized for high-power testing. The fast switching speeds of SiC devices can create noise and ringing in the measurement circuit. With low-resistance shunts, the signal-to-noise ratio is relatively low, so parasitics in the measurement circuit significantly change the measured waveform causing excessive peaks and ringing.

Figure 61 shows the waveforms with the power daughter cards modified for double pulse measurements. The current waveform is much cleaner, and the ringing is less pronounced, allowing for more accurate double pulse measurements.

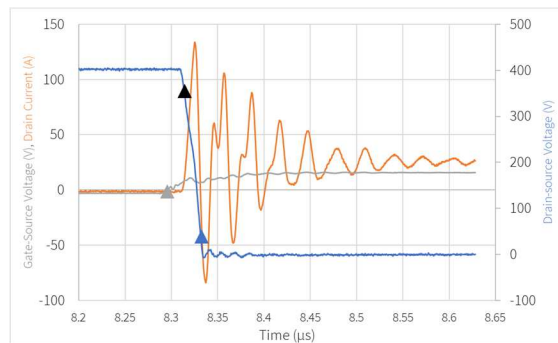


Figure 60: Power Daughter Card Waveforms Optimized for Power Testing

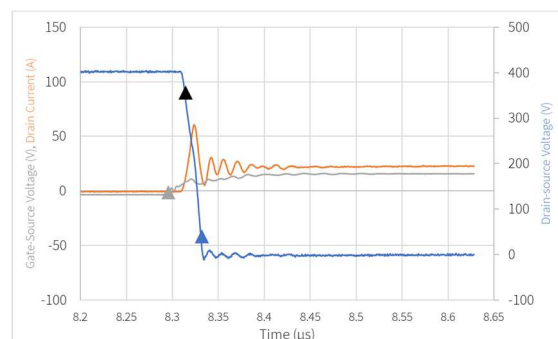


Figure 61: Power Daughter Card Waveforms Optimized for Double Pulse Testing

## No current waveform

If utilizing the CT method for measuring  $I_{DS}$ , confirm that connector CON11 is mated with a plug that passes the current through one of the recommended high-bandwidth current transformers. See section 5.4 for further instructions.

If using the high-resistance shunt method, verify that the MMCX to BNC adapter is connected to the  $I_{DS}$  test point on the power daughter card.

## Distorted gate waveforms seen on oscilloscope

On occasion,  $V_{GS}$  or gate waveforms may appear distorted (Figure 62). There are several connections in the gate measurement path. If one is not solidly connected, it may result in distorted gate waveforms. Check the following:

- X10 oscilloscope probe tip to BNC coupling
- Probe BNC coupling to 6" BNC to MMCX adapter
- 6" MMCX adapter to power daughter card MMCX test point

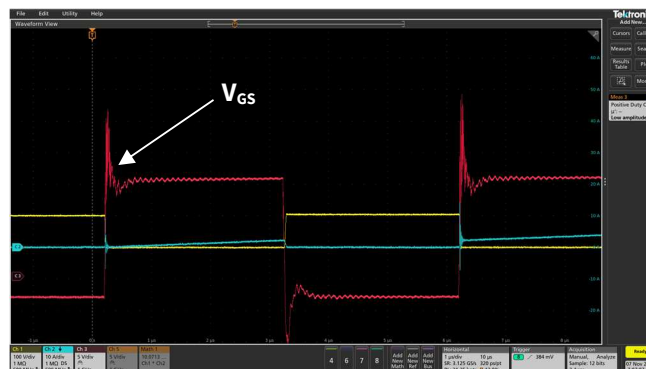


Figure 62: Distorted  $V_{GS}$  Waveform

## Measuring high voltage on the control side of the board or getting an overvoltage warning from the function generator.

The return (negative) terminal of the 12V power to the motherboard must be tied to earth ground. The voltage sensing circuits present on the motherboard provide a leakage path between the high voltage bus and the low-voltage control circuits. When a grounded high-voltage power supply or grounded oscilloscope probe is used for measuring on the high-voltage side of the system, it completes the leakage path circuit. The high impedance of these sense circuits results in less than 0.5mA of leakage current, however, in an ungrounded system this can cause the control side of the motherboard to float up in voltage relative to earth ground. Connecting the negative rail of the 12V input to earth ground, the potential of the control circuit will remain referenced to ground.

### 13. Revision history

| Date                 | Revision | Changes   |
|----------------------|----------|---|
| <b>December 2022</b> | Rev. 1   | 1st Issue   |
| <b>November 2023</b> | Rev. 2   | Added note to earth ground +12V power supply. Added short-circuit section. Various other clarifications and formatting updates. |

## 14. Important Notes

### Purposes and Use

Wolfspeed, Inc. (on behalf of itself and its affiliates, “Wolfspeed”) reserves the right in its sole discretion to make corrections, enhancements, improvements, or other changes to the board or to discontinue the board.

THE BOARD DESCRIBED IS AN ENGINEERING TOOL INTENDED SOLELY FOR LABORATORY USE BY HIGHLY QUALIFIED AND EXPERIENCED ELECTRICAL ENGINEERS TO EVALUATE THE PERFORMANCE OF WOLFSPEED POWER SWITCHING DEVICES. THE BOARD SHOULD NOT BE USED AS ALL OR PART OF A FINISHED PRODUCT. THIS BOARD IS NOT SUITABLE FOR SALE TO OR USE BY CONSUMERS AND CAN BE HIGHLY DANGEROUS IF NOT USED PROPERLY. THIS BOARD IS NOT DESIGNED OR INTENDED TO BE INCORPORATED INTO ANY OTHER PRODUCT FOR RESALE. THE USER SHOULD CAREFULLY REVIEW THE DOCUMENT TO WHICH THESE NOTIFICATIONS ARE ATTACHED AND OTHER WRITTEN USER DOCUMENTATION THAT MAY BE PROVIDED BY WOLFSPEED (TOGETHER, THE “DOCUMENTATION”) PRIOR TO USE. USE OF THIS BOARD IS AT THE USER’S SOLE RISK.

### Operation of Board

It is important to operate the board within Wolfspeed’s recommended specifications and environmental considerations as described in the Documentation. Exceeding specified ratings (such as input and output voltage, current, power, or environmental ranges) may cause property damage. If you have questions about these ratings, please contact Wolfspeed prior to connecting interface electronics (including input power and intended loads). Any loads applied outside of a specified output range may result in adverse consequences, including unintended or inaccurate evaluations or possible permanent damage to the board or its interfaced electronics. Please consult the Documentation prior to connecting any load to the board. If you have any questions about load specifications for the board, please contact Wolfspeed for assistance.

Users should ensure that appropriate safety procedures are followed when working with the board as serious injury, including death by electrocution or serious injury by electrical shock or electrical burns can occur if you do not follow proper safety precautions. It is not necessary in proper operation for the user to touch the board while it is energized. When devices are being attached to the board for testing, the board must be disconnected from the electrical source and any bulk capacitors must be fully discharged. When the board is connected to an electrical source and for a short time thereafter until board components are fully discharged, some board components will be electrically charged and/or have temperatures greater than 50° Celsius. These components may include bulk capacitors, connectors, linear regulators, switching transistors, heatsinks, resistors and SiC diodes that can be identified using board schematic. Users should contact Wolfspeed for assistance if a board schematic is not included in the Documentation or if users have questions about a board’s components. When operating the board, users should be aware that these components will be hot and could electrocute or electrically shock the user. As with all electronic evaluation tools, only qualified personnel knowledgeable in handling electronic performance evaluation, measurement, and diagnostic tools should use the board.

### User Responsibility for Safe Handling and Compliance with Laws

Users should read the Documentation and, specifically, the various hazard descriptions and warnings contained in the Documentation, prior to handling the board. The Documentation contains important safety information about voltages and temperatures.

Users assume all responsibility and liability for the proper and safe handling of the board. Users are responsible for complying with all safety laws, rules, and regulations related to the use of the board. Users are responsible for (1) establishing protections and safeguards to ensure that a user's use of the board will not result in any property damage, injury, or death, even if the board should fail to perform as described, intended, or expected, and (2) ensuring the safety of any activities to be conducted by the user or the user's employees, affiliates, contractors, representatives, agents, or designees in the use of the board. User questions regarding the safe usage of the board should be directed to Wolfspeed.

In addition, users are responsible for:

- compliance with all international, national, state, and local laws, rules, and regulations that apply to the handling or use of the board by a user or the user's employees, affiliates, contractors, representatives, agents, or designees.
- taking necessary measures, at the user's expense, to correct radio interference if operation of the board causes interference with radio communications. The board may generate, use, and/or radiate radio frequency energy, but it has not been tested for compliance within the limits of computing devices pursuant to Federal Communications Commission or Industry Canada rules, which are designed to provide protection against radio frequency interference.
- compliance with applicable regulatory or safety compliance or certification standards that may normally be associated with other products, such as those established by EU Directive 2011/65/EU of the European Parliament and of the Council on 8 June 2011 about the Restriction of Use of Hazardous Substances (or the RoHS 2 Directive) and EU Directive 2002/96/EC on Waste Electrical and Electronic Equipment (or WEEE). The board is not a finished end product and therefore may not meet such standards. Users are also responsible for properly disposing of a board's components and materials.

### **No Warranty**

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