

## SiC MOSFET Isolated Gate Driver

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This article describes an implementation of an isolated gate driver suitable for testing and evaluating SiC MOSFETs in a variety of applications. This design replaces previous versions of this application note and include new enhancements. The enhancements are as follows:

- The circuit board has been extended so that now 2 watt as well as 1 watt DC-DC converters can be used. This enables driving larger MOSFETs or driving of smaller MOSFETs at higher frequency.
- The creep/strike clearance has been significantly increased.
- A separate regulator has been added for the opto-isolator. This allows simpler bypassing of the DC-DC converters when non-isolated operation is desired.
- The output resistor network has been modified with an additional diode to allow separate optimization of turn-on and turn-off transitions.

The top and bottom view of the enhanced gate driver is shown in Figures 1 and 2. The enhanced creep distance is accomplished with the groove in the printed circuit card. Some of the components are not populated because of the added flexibility in setting up the output network.

Figure 1: Isolated Gate Driver Top View

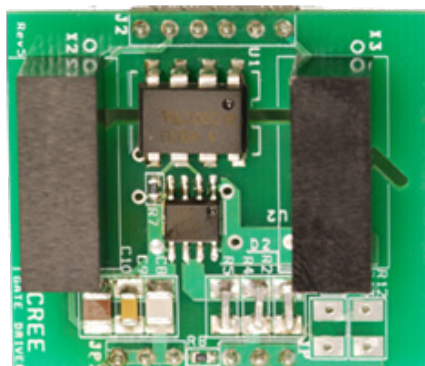
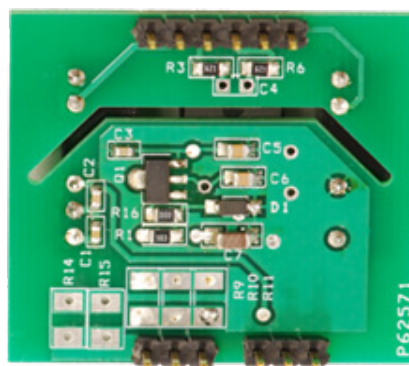


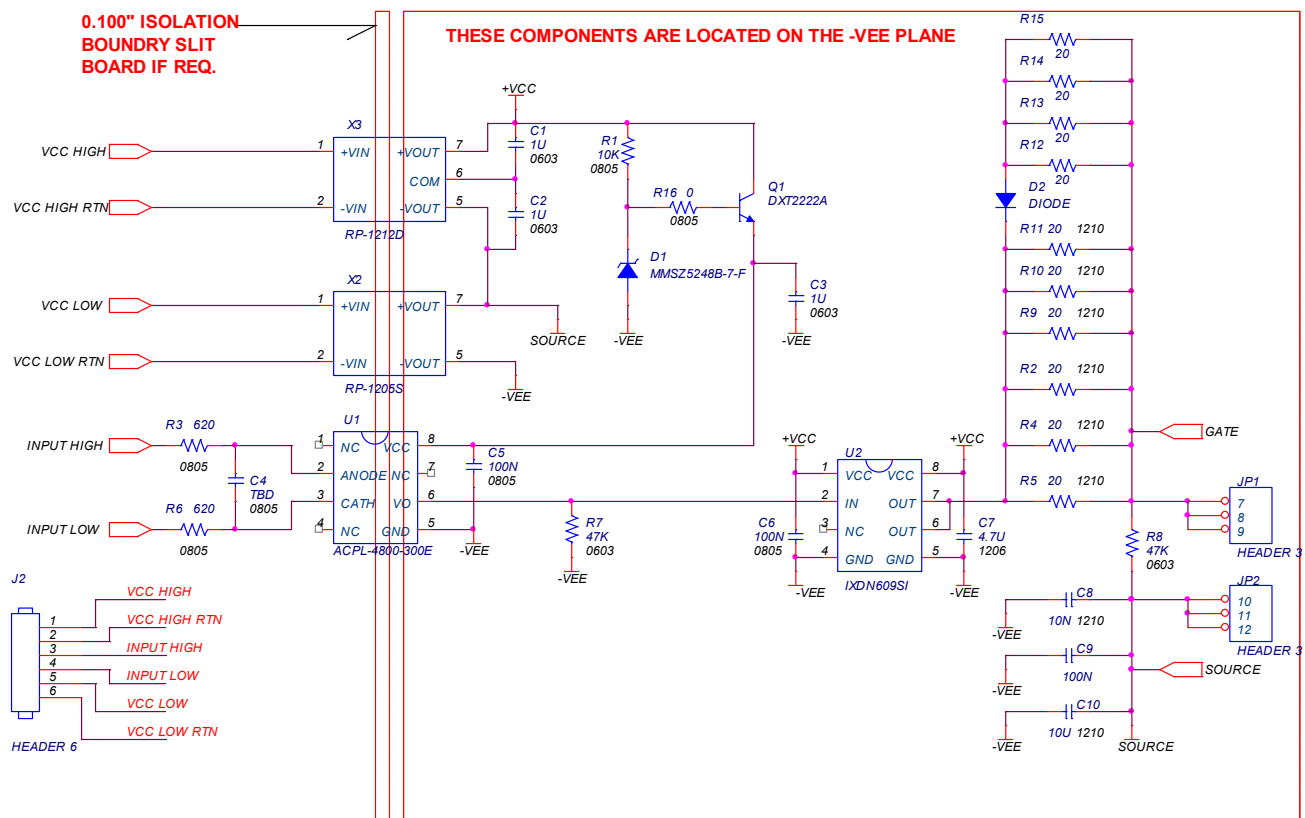
Figure 2: Isolated Gate Driver Bottom View



The new schematic for the enhanced gate driver is shown in Figure 3. The circuit consists of two isolated DC-DC converters (X2 and X3), an opto-isolator (U1) and the gate driver integrated circuit (U2). This integrated circuit, the Clare/IXYS IXDN609SI can provide 35V output swing and up to 9A of current with a typical output resistance of 0.8  $\Omega$ . The opto-isolator, the Avago ACPL-4800-300E, has high common mode transient immunity (30kV/ $\mu$ sec) and can operate from 4.5 to 20V. A provision for an input filtering capacitor (C4) has been included if needed. Power is provided by isolated DC-DC converters; one for the positive bias and the other for negative bias. X2 and X3 are both from the Recom RP series of 1 watt unregulated isolated DC-DC converters or the Recom [1] RxxP2xx series of 2 watt DC-DC converters. Either type can be accommodated depending on the application.

These converters are inexpensive with an isolation voltage rating of 5.2kV and also have very low isolation capacitance. In this particular configuration, X2 is a 12V in 5V out converter and X3 is a 12V in, +/-12V out converter. As shown in the schematic, the outputs of the converters are series connected and the common connection is referenced to the source terminal. Therefore, VCC determines the gate pulse positive voltage and -VEE determines the negative gate pulse voltage. The -VEE node is used as the ground reference for opto-isolator and the gate driver. The opto-isolator's maximum operating voltage is 20V which can be greater than the voltage appearing at VCC. An emitter follower clam consisting of Q1 and D1 has been added to limit the voltage to the opto-isolator to 17.3V nominal. A base resistor (R16) was included if additional dampening is desired for the emitter follower. In practice, a zero ohm resistor works fine. Resistors R2, R4, R5, R9-R15 and diode D2 can be populated to provide optimum turn-on and turn-off performance. In this case, only R2, R4 and R5 are populated with 20 ohm 1/3 watt resistors. To minimize stray inductance, capacitors C8-C10 are located very close to the source output pin and the gate driver to provide very tight coupling between the source output terminal and the -VEE node.

**Figure 3: Isolated Gate Driver Schematic**



Operation of the gate driver is as follows. A +10 to +12V pulse is applied to the opto causes the gate terminal to go high. The intent of this circuit is to afford the maximum flexibility. Therefore, unregulated DC-DC converters were used so that the output gate pulse positive and negative voltage levels can be adjusted at ground level. The gate voltage positive level is adjusted by varying the voltage between the VCC HIGH and VCC HIGH RTN and the negative pulse level is adjusted by varying the voltage between the VCC LOW and VCC LOW RTN pins. The procedure is to observe the output of the gate driver board with an oscilloscope and adjust VCC HIGH and VCC LOW input voltages until the gate pulse is set to the desired values. Care must be taken during adjustment to insure that the voltage between the VCC and -VEE nodes does not exceed the maximum ratings of U2, which is 35V.

The circuit can be modified to remove the isolated DC-DC converters to allow direct connection of VCC, source, and -VEE directly to external power supplies. This is accomplished by removing the converters and replacing them with jumper wires. The schematic of this change is shown in Figure 4. Notice that X2 and X3 have been removed and replaced by jumpers shown as the dark blue nets. Also note, the gate driver can also be configured for no negative gate bias by not populating the negative gate bias DC/DC converter as shown in Figure 5. Notice that DC-DC converter X3 is not populated and a jumper is placed as shown in the dark blue net.

Non-regulated DC-DC converters are used in this design to allow convenient adjustment of the high and low gate pulse amplitudes at ground level. The VCC high input sets the high level and the VCC low input sets the low level. The procedure is to observe the output of the gate driver board with an oscilloscope and adjust VCC high and VCC low until the output pulse high and low levels are set to the desired values.

**Figure 4: Non-Isolated Configuration Schematic**

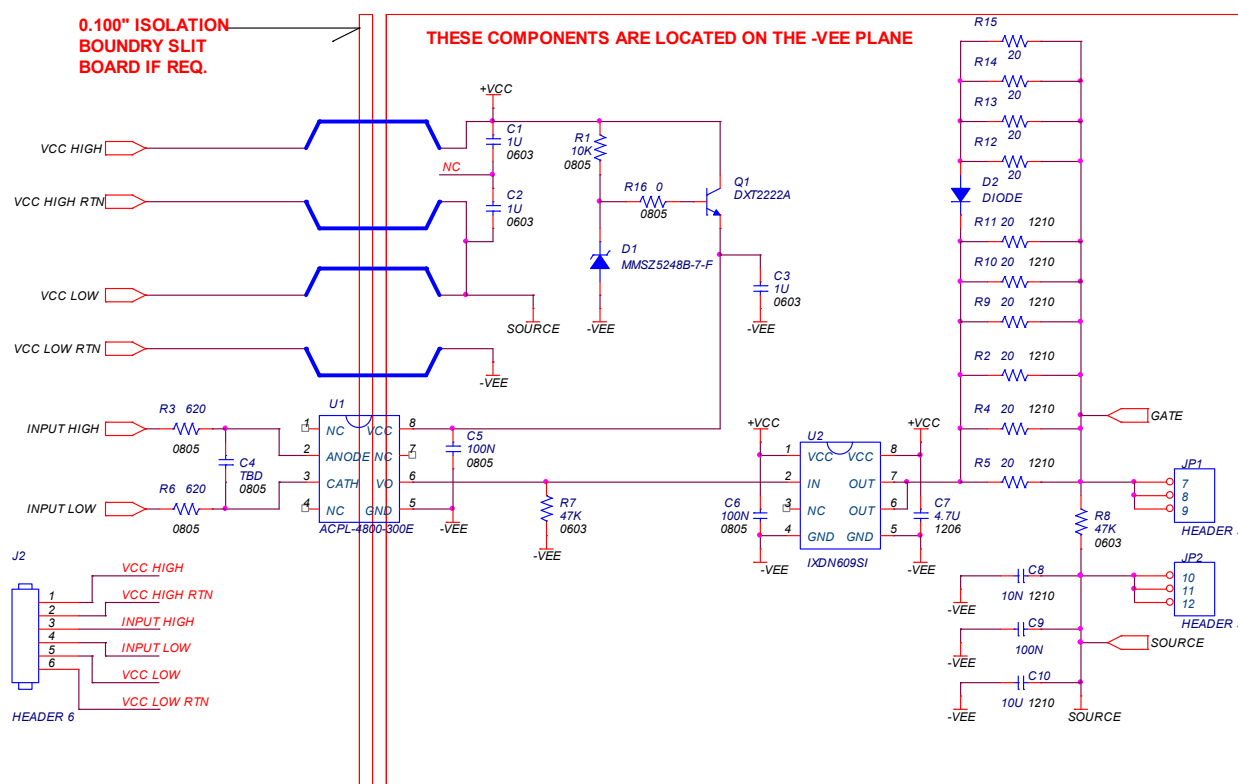
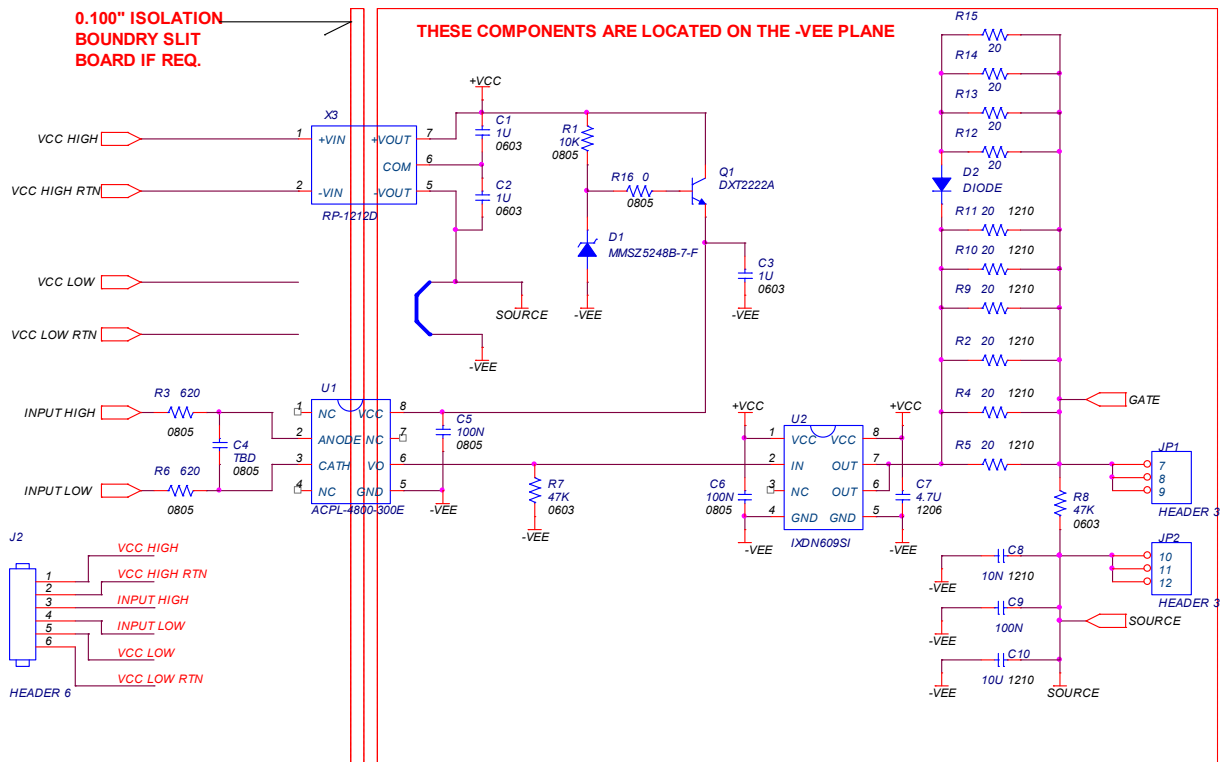


Figure 5: Isolated Configuration Schematic - No Negative Bias



The bill of materials for the isolated gate driver is shown in Table 1. Please note that different Recom isolated DC-DC converters can be used. Also note that the photographs of the populated board shown in Figures 1 and 2 are for reference only and does not correlate to this BOM. Also, C4, D2 and R9-R15 are not populated so they are listed as TBD. It is up to the user to select these parts depending on the application.

**Table 1: Isolated Gate Driver Bill of Materials**

| Item | Quant. | Ref. Des. | Value          | Description                                 | Manufacturer                | Manufacturer P/N |
|------|--------|-----------|----------------|---------------------------------------------|-----------------------------|------------------|
| 1    | 3      | C1,C2,C3  | 1U             | Capacitor, Ceramic 1UF 25V X5R 0603         | AVX                         | 06033D105MAT2A   |
| 2    | 1      | C4        | TBD            | Capacitor, Ceramic TBD 0805                 |                             |                  |
| 3    | 2      | C5,C6     | 100N           | Capacitor, Ceramic 100n 50V X7R 0805        | Kemet                       | C0805C104K5RACTU |
| 4    | 1      | C7        | 4.7U           | Capacitor, Ceramic 4.7UF 50V X5R 1206       | Kemet                       | C1206C475K5PACTU |
| 5    | 1      | C8        | 10N            | Capacitor, Ceramic 10n 50V NP0 1210         | Kemet                       | C1210C103J5GACTU |
| 6    | 1      | C9        | 100N           | Capacitor, Ceramic 100n 50V X7R 1206        | Kemet                       | C1206C104K5RACTU |
| 7    | 1      | C10       | 10U            | Capacitor, Ceramic 10UF 16V X5R 1210        | Kemet                       | C1210C106K4PACTU |
| 8    | 1      | D1        | MMSZ5248B-7-F  | DIODE ZENER 18V 500MW SOD-123               | Diodes Inc.                 | MMSZ5248B-7-F    |
| 9    | 1      | D2        | DIODE          | Diode, TBD SOD-123AC                        |                             |                  |
| 10   | 2      | JP1,JP2   | HEADER 3       | 3 Pins Cut to length                        | Sullins Connector Solutions | PBC36SAAN        |
| 11   | 1      | J2        | HEADER 6       | 6 Pins Cut to length                        | Sullins Connector Solutions | PBC36SAAN        |
| 12   | 1      | Q1        | DXT2222A       | Transistor, NPN General Purpose, 40V SOT-23 | Diodes Inc.                 | DXT2222A-13      |
| 13   | 1      | R1        | 10K            | Resistor, 10k 1/8W 5% 0805                  | Vishay/Dale                 | CRCW080510K0JNEA |
| 14   | 3      | R2,R4,R5  | 20             | Resistor, 20 Ohm 1/3W 5% 1210               | Vishay/Dale                 | CRCW121020R0JNEA |
| 15   | 7      | R9-R15    | TBD            | Resistor, TBD 1/3W 5% 1210                  |                             |                  |
| 16   | 2      | R3,R6     | 620            | Resistor, 620 Ohm 1/8W 5% 0805              | Vishay/Dale                 | CRCW0805620RJNEA |
| 17   | 2      | R7,R8     | 47K            | Resistor, 47k 1/10W 5% 0603                 | Vishay/Dale                 | CRCW060347K0JNEA |
| 18   | 1      | R16       | 0              | Resistor, 10k 1/8W 5% 0805                  | Vishay/Dale                 | CRCW08050000Z0EA |
| 19   | 1      | U1        | ACPL-4800-300E | Opto-Isolator                               | Avago                       | ACPL-4800-300E   |
| 20   | 1      | U2        | IXDN609SI      | Gate Driver Non-Inverting                   | IXYS                        | IXDN609SI        |
| 21   | 1      | X2        | RP-1205S       | DC/DC Converter, 1W 12V in<br>5V out        | Recom                       | RP-1205S         |
| 22   | 1      | X3        | RP-1212D       | DC/DC Converter, 1W 12V in<br>+/-12V out    | Recom                       | RP-1212D         |
| 23   | 1      | -         | -              | ISOLATED GATE DRIVER REV5 PCB               | Cree                        |                  |

[1] <http://www.recom-power.com/>

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