1.0 Driving IGBT Modules

When using high power IGBT modules, it is often desirable to completely isolate control circuits from the gate drive. A block diagram of this type of gate drive is shown in Figure 1.1. This circuit provides isolation for logic level control and fault feedback signals using opto-couplers and separate isolated floating power supplies for each gate drive circuit. There are a number of advantages to this type of gate drive topology including:

(1) Stable on and off driving voltages that are independent of the power device switching frequency and duty cycle.
(2) Easily adapted to provide very high output currents for large IGBT modules.
(3) Power circuit switching noise and high voltages are isolated from control circuits.
(4) Local power is available for protection circuits such as desaturation detectors.

To help simplify design of fully isolated gate drive circuits, Powerex provides a family of hybrid circuits that supply the required gate drive, short circuit protection, and isolated power for efficient reliable operation of Powerex IGBT modules.

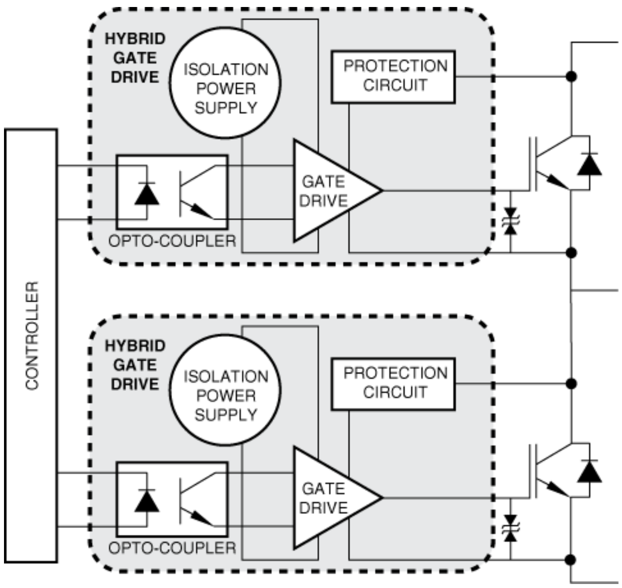


Figure 1.1 Fully Isolated Gate Driver

1.0.1 Hybrid Gate Drivers

Powerex offers nine hybrid SIP (single-in-line-package) circuits recommended for IGBT module gate drives. All nine circuits provide isolation for control input signals by means of built-in, high speed opto-couplers. All of the opto-couplers have been selected to provide from 2500V_{RMS} to 3750V_{RMS} isolation and immunity to power circuit common mode transient noise of better than 15kV/µs. This feature allows convenient common referencing of high and low side control signals. The high speed types, VLA502-01 and VLA513-01, are designed for applications with operating frequencies up to 60 kHz. The hybrid gate drivers feature output stages designed to provide the pulse currents necessary for efficient switching of Powerex IGBT modules. All drivers are designed to provide a substantial off-state bias of -5V to -12V in order to ensure robust noise immunity. Hybrid gate drivers simplify gate drive design by minimizing the number of components required. In addition to high performance gate drive, many of the drivers also provide short circuit protection.

For optimum performance, parasitic inductance in the gate drive loop must be minimized. This is accomplished by connecting decoupling capacitors as close as possible to the pins of the hybrid driver and by minimizing the lead length between the drive circuit and the IGBT. Back-to-back zeners rated at about 18V should be connected between the gate and emitter terminals as closely as possible to the pins of the device as shown in Figure 1.1. These zeners protect the gate during switching and short circuit operation. The gate drivers have a built-in 180 ohm input resistor that is designed to provide proper drive for the internal opto-isolator when V_{IN} = 5V. If other input voltages are desired, an external resistor should be connected between the logic control signal and pin 1 to maintain the proper opto-drive current of 16mA. The value of the required external resistor can be computed by assuming that the forward voltage drop of the opto-diode is 2V.

For example:

If 15V drive is required then

Rext = (15V - 2V)/16mA - 180Ω ≈ 630Ω.

Table 1.1 lists the key features and typical application range for Powerex's family of hybrid gate drivers. Figure 1.2 is a photograph of a VLA503-01 gate driver with built-in short circuit protection. The pin layout of the VLA503-01 and VLA504-01 gate drivers is equivalent while the VLA503-01's package is slightly larger.

Table 1.1 Hybrid Gate Drivers and Features

TYPE	INTEGRATED DC-DC CONVERTER	SHORT CIRCUIT PROTECTION	SOFT SHUTDOWN	OUTPUT CURRENT	USABLE RANGE
VLA504-01	No	V_{CE} Desaturation	Yes	+/-3A	600V, 400A, 1200V, 200A
VLA503-01	No	V_{CE} Desaturation	Yes	+/-5A	600V, 600A, 1200V, 400A
M57962K	No	V_{CE} Desaturation	Yes	+/-5A	600V, 400A, 1200V, 200A, 1700V, 400A
M57159L-01	No	V_{CE} Desaturation	Yes	+/-1.5A	600V, 150A, 1200V, 75A
VLA500-01	Yes	V_{CE} Desaturation	Yes – Adjustable	+/-12A	600V, 800A, 1200V, 1400A
VLA500K-01R	Yes	V_{CE} Desaturation	Yes – Adjustable	+/-12A	600V, 800A, 1200V, 1400A 1700V, 1000A
VLA502-01	Yes	V_{CE} Desaturation	Yes – Adjustable	+/-12A	600V & 1200V High Frequency Modules
VLA507-01	No	None	No	+/-3A	600V, 200A 1200V, 150A
VLA513-01	No	None	No	+/-5A	600V, 600A, 1200V, 400A + High Frequency Modules

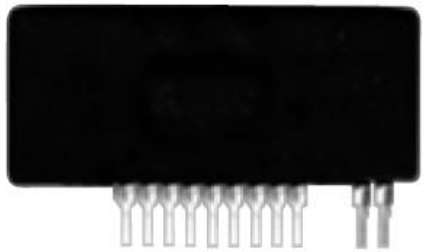


Figure 1.2 Photograph of the VLA503-01

1.0.2 Hybrid DC-to-DC Converters

Power is usually supplied to hybrid IGBT gate drivers from low voltage DC power supplies that are isolated from the main DC bus voltage. Isolated power supplies are required for high side gate drivers because the emitter potential of high side IGBTs is constantly changing. Isolated power supplies are often desired for low side IGBT gate drivers in order to eliminate ground loop noise problems. The gate drive supplies should have an isolation voltage rating of at least two times the IGBTs V_{CES} rating (i.e. V_{ISO} = 2400V for 1200V IGBT).

In systems with several isolated supplies, inter-supply capacitances must be minimized in order to avoid coupling of common mode noise. The recommended power supply configuration for Powerex hybrid IGBT gate drivers is shown in Figure 1.3. Two supplies are used in order to provide the on- and off-bias for the IGBT. The recommended on-bias supply (V_{CC}) voltage is +15V and the recommended off-bias supply voltage (V_{EE}) is -8V. These supplies should be regulated to within +/-10%. The range indicated on the individual driver datasheets is acceptable.

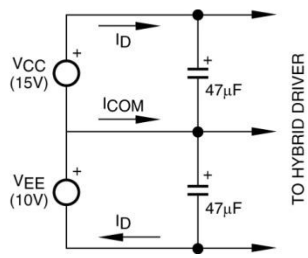


Figure 1.3 Hybrid Driver DC-to-DC Converter

Electrolytic or tantalum decoupling capacitors should be connected at the power supply input pins of the hybrid driver. These capacitors supply the high pulse currents required to drive the IGBT gate. The amount of capacitance required depends on the size of the IGBT module being driven.

Powerex provides two isolated DC-to-DC converters for use with gate drivers that do not have built in power supplies. The characteristics of these DC-to-DC converters are summarized in Table 1.2. Powerex DC-to-DC converters are designed with minimum inter-winding capacitance in order to minimize dV/dt coupled noise. The VLA106-15242 is a single-in-line isolated DC-to-DC converter that produces a regulated +15.8V/-8.2V output from an input of 12V to 18V DC. The VLA106-24242 produces a regulated +15.8V/-8.2V output from an input of 21.6V to 26.4V DC. A photograph of the VLA106-15242 is shown in Figure 1.4 and has the same package and footprint as the VLA106-24242.

Table 1.2 DC-to-DC Converters for Hybrid Gate Drivers

TYPE	INPUT (VOLTS)	OUTPUT CURRENT	POWER (WATTS)
VLA5106-15242	12 – 18	1 @ +24V, 100MA	2.4
VLA106-24242	21.6 – 26.4	1 @ +24V, 100MA	2.4

The gate drive DC-to-DC converters are decoupled using low impedance electrolytic capacitors. It is very important that these capacitors have low enough impedance and sufficient ripple current capability to provide the required high current gate drive pulses.

Figure 1.4 VLA106-15242

1.1 Basic Gate Drivers (VLA507-01, VLA513-01)

Powerex offers two basic opto-isolated hybrid gate drivers. These drivers consist of a high speed opto-coupler for input signal isolation followed by a current boosting output stage. The output stage is designed to provide the high pulse currents necessary for efficient switching of high current IGBT modules.

1.1.1 Applications for the VLA507-01 and VLA513-01

Photographs of the VLA507-01 and VLA513-01 are shown in Figures 1.5 and 1.6. These gate drives are designed to drive modules that require peak gate currents of 3A and 5A respectively. The internal schematic and application circuit are shown on their respective datasheets. The pin layout is the same for these two devices.

Figure 1.5 VLA507-01

Figure 1.6 VLA513-01

1.2 Gate Drivers with Short Circuit Protection

Standard Powerex IGBT modules are designed to survive low impedance short circuits for a minimum of 10 µs. In many cases, it is desirable to implement short circuit protection as part of the gate drive circuit in order to provide the fast response required for reliable protection against severe low impedance short circuits. Several Powerex hybrid gate drivers provide this type of protection as shown in Table 1.1. The VLA500 series (VLA500-01, VLA502-01 and VLA500K-01R), VLA504 and VLA503 all use desaturation detection as described in Section 1.2.1.

1.2.1 Desaturation Detection

Figure 1.7 shows a block diagram of a typical desaturation detector. In this circuit, a high voltage fast recovery diode (D1) is connected to the IGBT's collector to monitor the collector-to-emitter voltage. When the IGBT is in the off-state, D1 is reverse biased and the (+) input of the comparator is pulled up to the positive gate drive power supply which is normally +15V.

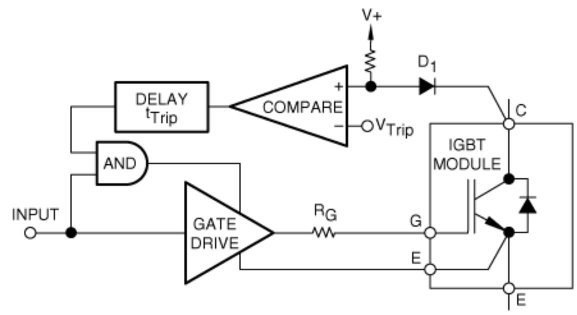


Figure 1.7 Desaturation Detector

When the IGBT turns on, the comparators (+) input is pulled down by D1 to the IGBT's $V_{CE(sat)}$. The (–) input of the comparator is supplied with a fixed voltage (V_{TRIP}) which is typically set at about 8V. During normal switching, the comparators output will be high when the IGBT is off and low when the IGBT is on. If the IGBT turns on into a short circuit, the high current will cause the collector-emitter voltage to rise above V_{TRIP} even though the gate of the IGBT is being driven on. This presence of high V_{CE} when the IGBT is supposed on is called **desaturation**.

The detect diode (D1) must be an ultra fast recovery diode with a current rating of at least 100mA and a blocking voltage equal to or greater than the V_{CES} rating of the IGBT module being used.

Desaturation can be detected by a logical AND of the driver's input signal and the comparator output. When the output of the AND goes high, a short circuit is indicated. The output of the AND is used to command the IGBT to shutdown in order to protect it from the short circuit. A delay (t_{TRIP}) must be provided after the comparator output to allow for the normal turn on time of the IGBT. The t_{TRIP} delay needs to be set so that the IGBTs V_{CE} has enough time to fall below V_{TRIP} during normal turn on switching. If t_{TRIP} is set too short, erroneous desaturation detection will occur. The maximum t_{TRIP} delay is limited by the IGBT's short circuit withstanding capability. The driver's default settings are sufficient for many applications and therefore these capacitors can be omitted. For Powerex A-Series and NF-Series IGBT modules, the maximum safe limit is 10µs.

1.2.2 Operation of Powerex Desaturation Detectors (VLA500 series, VLA504-01, VLA503-01)

Powerex offers four SIP hybrid integrated circuit gate drivers that implement desaturation detection. A photograph of the VLA502-01 is shown in Figure 1.8. The VLA500 series drivers all have the same pin layout and approximate dimensions. Both have a built-in DC-to-DC converter that provides isolated gate drive power consisting of +15.3V (V_{CC}) -7.6V. Transformer coupling provides $2500V_{RMS}$ isolation between the 15V control supply (V_D) and the gate drive power. This feature allows the drivers to provide completely floating gate drive that is suitable for high or low side switching.

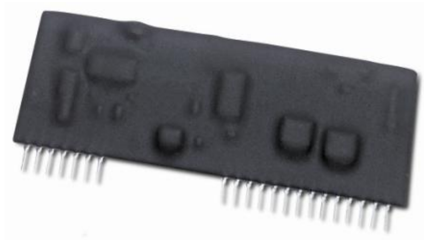


Figure 1.8 Photograph of a VLA500 Series Gate Driver

Figure 1.9 is a flow diagram showing the logical operation of Powerex desaturation detectors. A block diagram for the Powerex desaturation detector operation is shown in Figure 1.10.

As described, the driver monitors the V_{CE} of the IGBT. The driver detects a short circuit condition when V_{CE} remains greater than V_{TRIP} for longer than t_{TRIP} after the input on signal is applied. The trip time (t_{TRIP}) can be adjusted with an external capacitor. A relationship between the capacitor value and the trip time can be found on the driver datasheet and an example is shown in Figure 1.11 of Section 1.2.3. When a desaturation is detected, the hybrid gate driver performs a soft shutdown of the IGBT and starts a timed (t_{RESET}) 1.5ms lock-out. The soft turn-off helps to limit the transient voltage that may be generated while interrupting the large short circuit current flowing in the IGBT. During the lock-out, a fault feedback signal is asserted and all input signals are ignored. Normal operation of the driver will resume after the lock-out time has expired and the control input signal returns to its off-state.

1.2.3 Trip Time Adjustment

The desaturation trip time (t_{TRIP}) can be adjusted in the gate drivers that offer desaturation protection by connecting C_{TRIP} as shown in the application example circuits found on the device datasheets. Figure 1.11 shows the relationship between C_{TRIP} and t_{TRIP} for the VLA500-01. Similar curves for the other gate drivers can be found on the individual detailed datasheets. The driver's default trip time (no C_{TRIP} connected) will work for most applications. However, when modules are used with relatively large $R_{G,}$ the driver may incorrectly detect a short circuit. The false trip occurs because it takes longer than t_{TRIP} for the device to reach an on-state voltage less than V_{TRIP}. For these applications, extending t_{TRIP} may be necessary.

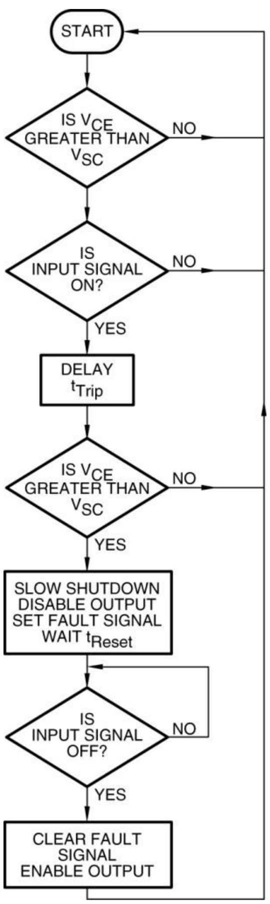


Figure 1.9
Protection Circuit Operation

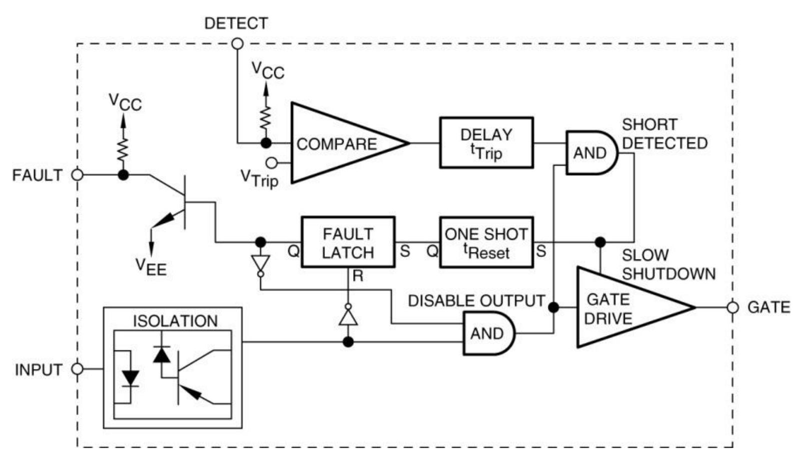


Figure 1.10 Block Diagram for Desaturation Detector

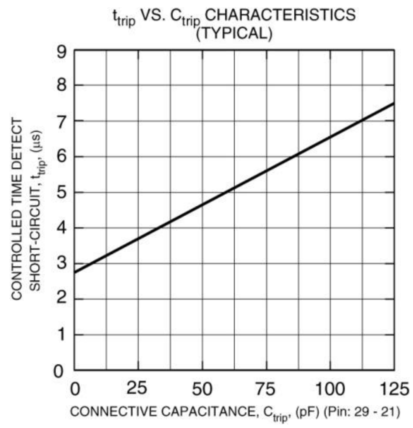


Figure 1.11 Adjustment of t_{TRIP} for the VLA500-01

In addition to being able to adjust the trip time, the shutdown speed can be adjusted in the VLA500 series devices. This adjustment may be necessary in some applications to limit transient voltages during a short circuit shutdown. Usually, this is only necessary when a booster stage is being used with the driver to drive large modules. More information about this adjustment can be found on the detailed datasheets and application notes.

1.3 Selecting the Gate Resistor

R_G must be selected such that it falls within the range specified on the IGBT module datasheet and the output current rating (I_{OP}) of the hybrid gate driver is not exceeded. If R_G is computed using Equation 1.1, then I_{OP} will not be exceeded under any condition.

Equation 1.1 Conservative Equation for Minimum R_G

$$R_G(MIN) = (V_{CC} + |V_{EE}|)/I_{OP}$$

Example:
With V_{CC} = 15V and $-V_{EE}$ = 10V R_G(MIN) for VLA503-01 will be:
R_G = (15V + 10V)/5A = 5 Ω

In most applications, this limit is unnecessarily conservative. Considerably lower values of R_G can usually be used. The expression for R_G(MIN) should be modified to include the effects of parasitic inductance in the drive circuit, IGBT module internal impedance and the finite switching speed of the hybrid drivers output stage. Equation 1.2 is an improved version of Equation 1.1 for R_G(MIN).

Equation 1.2 Improved Equation for $R_{G(MIN)}$

$$R_G(MIN) = (V_{CC} + |V_{EE}|)/I_{OP} - (R_G)INT – Ø$$

Large IGBT modules that contain parallel chips have internal gate resistors that balance the gate drive and prevent internal oscillations. Table 1.3 lists the internal R_G values for modules containing parallel chips. The value of Ø depends on the parasitic inductance of the gate drive circuit and the switching speed of the hybrid driver. The exact value of Ø is difficult to determine. It is often desirable to estimate the minimum value of R_G that can be used with a given hybrid driver circuit and IGBT module by monitoring the peak gate current while reducing R_G until the rated I_{OP} is reached. The minimum restriction on R_G often limits the switching performance and maximum usable operating frequency when large modules outside of the driver's optimum application range are being driven. Further steps to address this issue are provided in Section 1.7.

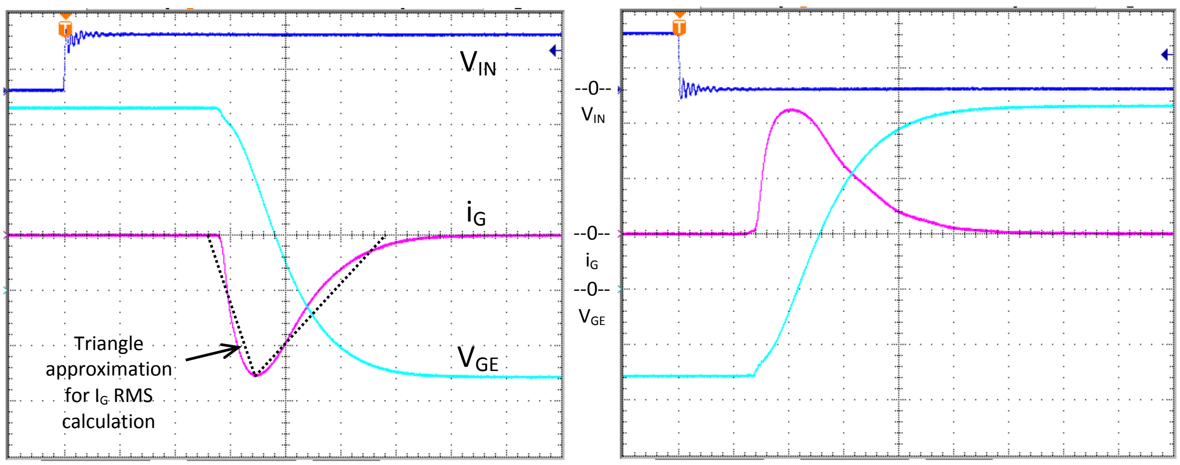
The RMS gate current is used to determine the power requirements for R_G by the equation $P=i^2R$ where i is the RMS gate current. When measuring RMS gate current, be certain that the instrument has a sufficiently high sampling rate to accurately resolve the relatively narrow gate current pulses. Most "true RMS" DMMs are not capable of making this measurement accurately. The RMS gate current can also be estimated from the gate drive waveform.

Figure 1.12 shows a typical gate current waveform. If we assume the turn-on and turn-off pulses are approximately triangular we can estimate RMS gate current using the equations given in Figure 1.13. In most applications, the peak gate current is much larger than the average current supplied by the DC-to-DC converter so it is reasonable to assume that the RMS ripple current is roughly equal to the RMS gate current. The RMS ripple current can be estimated using Equations 1.4 and 1.5 from Figure 1.13. For example, if we use a triangular approximation to estimate the RMS current of the turn-off pulses shown in Figure 1.12, we see that $i_p(off)=12A$ and $t_p(off)=1440ns$.

Table 1.3
Internal Gate Resistance

PART NUMBER	INT. R_G (Ω)
CM400DY-12NF	0.8
CM600DY-12NF	0.8
CM200DU-12NFH	1.6
CM300DU-12NFH	1.6
CM200DY-24NF	3
CM300DY-24NF	2
CM400DY-24NF	2
CM600DU-24NF	1.5
CM300DY-24A	3
CM400DY-24A	2
CM600DY-24A	2

PART NUMBER	INT. R_G (Ω)
CM900DU-24NF	1
CM1400DU-24NF	0.67
CM200DU-24NFH	1.6
CM300DU-24NFH	1.6
CM400DU-24NFH	1.6
CM600DU-24NFH	1.6
CM600HU-24NFH	1.6
CM900HU-24NFH	1.6
CM400HA-24A	1.5
CM600HA-24A	1



V_{IN}:5V/div, V_{GE}: 5V/div, i_G:5A/div, t:400ns/div, R_G=1.0ohm, C_L=0.33μF

Figure 1.12 Typical Gate Current Waveform

If the switching frequency f = 20 kHz and assuming that the on- and off-gate drive pulses are equivalent, then the RMS gate current will be approximately 1.57ARMS.

Eqn. 1.3 RMS Current for Repetitive Triangular Pulses

$$i_{RMS} = i_p \sqrt{\frac{t_p \cdot f}{3}}$$

Where:
i_p = Peak Current
t_p = base width of pulse
f = frequency

Eqn. 1.4 RMS Current for Turn-on Gate Pulses

$$i_{G(on)}(RMS) = i_p(on) \sqrt{\frac{t_p(on) \cdot f}{3}}$$

Where:
$i_p(on)$ = Peak Turn-On Current
$t_p(on)$ = Base width of On pulse
f = frequency

Eqn. 1.5 RMS Current for Turn-off gate Pulses

$$i_{G(off)}(RMS) = i_p(off) \sqrt{\frac{t_p(off) \cdot f}{3}}$$

Where:
$i_p(off)$ = Peak Turn-Off Current
$t_p(off)$= Base width of Off pulse
f = frequency

Eqn. 1.6 Total RMS Gate Current

$$i_G(RMS) = \sqrt{i_{G(on)}(RMS)^2 + i_{G(off)}(RMS)^2}$$

Or assuming $i_{G(off)} = i_{G(on)}$
(On and Off current pulses are symmetric) the RMS gate current is:

$$i_G(RMS) = i_p \sqrt{\frac{2 \cdot t_p \cdot f}{3}}$$

Where:
i_p = Peak Gate Current
t_p = base width of gate drive pulse
f = frequency

Figure 1.13
Equations for Measuring RMS Current

1.4 Supply Current

The current that must be supplied to the IGBT driver is the sum of two components. One component is the quiescent current required to bias the driver's internal circuits. The current is constant for fixed values of V_{CC} and V_{EE}. The second component is the current required to drive the IGBT gate. This current is directly proportional to the operating frequency and the total gate charge (Q_G) of the IGBT being driven. With small IGBT modules and at low operating frequencies, the quiescent current, I_H, will be the dominant component. The amount of current that must be supplied to the hybrid driver when V_{CC} = 15V and V_{EE} = -10V can be determined from Equation 1.7.

Equation 1.7
Required Supply Current for Hybrid Drivers

$$I_D = Q_G \times f_{PWM} + I_H$$

Where:
I_D = Required supply current
Q_G = Gate charge
f_{PWM} = Operating frequency
I_H = "H" input current maximum for driver

1.4.2 Single Supply Operation

Using a dual supply as in Figure 1.3, the current drawn from V_{CC} (I_D+) is nearly equal to the current drawn from V_{EE} (I_D-). Only a small amount of current flows in the common connection (I_{COM}). In many applications, it is desirable to operate the hybrid driver from a single isolated supply. An easy method of accomplishing this is to create the common potential using a resistor and a zener diode. In order to size the resistor for minimum loss, we must first determine the current flowing in the common connection (I_{COM}). A circuit diagram showing how the hybrid drivers can be used with a single supply is shown on Figure 1.14 and a complete schematic is shown on each driver's datasheet.

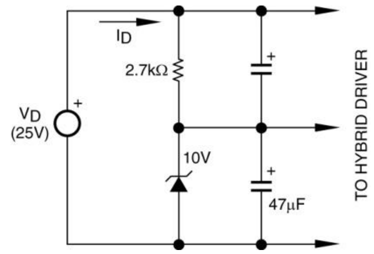


Figure 1.14 Single Supply Operation of IGBT Hybrid Drivers

The voltage of the single supply and the zener diode can be varied to allow use of standard supplies. For example, if a 24V DC-to-DC converter is to be used, then a 9V zener diode would give +15V/-9V which is acceptable for all of the hybrid gate drivers. The two limiting factors that need to be observed if changes are made are:

(1) Voltages must be within the allowable range specified on the gate driver data sheet and
(2) The turn-on supply should be 15V +/-10% for proper IGBT performance.

1.5 Total Power Dissipation

The hybrid IGBT driver has a maximum allowable power dissipation that is a function of the ambient temperature. With V_{CC} = 15V and V_{EE} = -10V, the power dissipated in the driver can be estimated using Equation 1.8.

Equation 1.8 Total power Dissipation

$$P_D = I_D \times (|V_{CC}| + |V_{EE}|)$$

The power computed using Equation 1.8 can then be compared to the derating curves shown on the driver datasheet. The derating curve for the VLA503-01 is shown in Figure 1.15 and shows a maximum allowable ambient temperature of 60°C. The power computed using Equation 1.8 includes the dissipation in the external gate resistor (R_G). This loss is outside the hybrid driver and can be subtracted from the result of Equation 1.8. The dissipation in R_G is difficult to estimate because it depends on drive circuit parasitic inductance, IGBT module type and the hybrid driver's switching speed. In most applications, the loss in R_G can be ignored. Direct use of Equation 1.8 will result in a conservative design with the included loss of R_G acting as a safety margin. When operating large modules at high frequencies, the limitations on ambient temperature may be significant. Additional derating information for other hybrid gate drives can be found on the individual detailed data sheets.

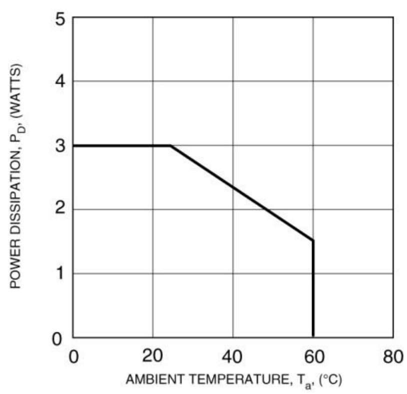


Figure 1.15 Derating Curve for VLA503-01

1.6 Operational Waveforms

Figure 1.16 is a typical waveform showing the gate-to-emitter voltage during a slow shutdown in the VLA500-01 driver. Approximately 2.8µs after the detect input pin (pin 1) voltage exceeds $V_{SC,}$ the gate-to-emitter voltage is slowly brought to zero in about 6µs. This slow shutdown is very effective in protecting IGBT modules having a minimum short circuit withstand time of 10µs which includes the entire A and NF-Series IGBT module line-up. Figure 1.17 shows the collector-emitter voltage (V_{CE}) and collector current (I_C) for an IGBT module during a short circuit. This waveform shows the effectiveness of the slow shutdown in controlling transient voltage.

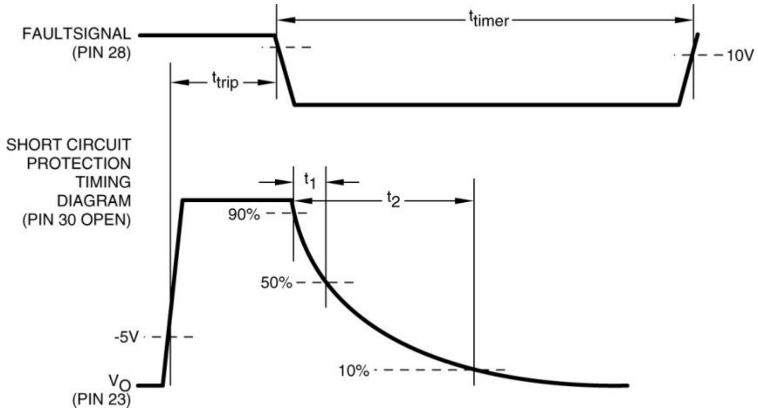


Figure 1.16 Fall Time Characteristics

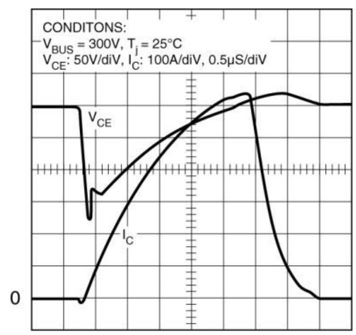


Figure 1.17 Short Circuit Shutdown Waveform

1.7 Driving Large IGBT Modules

In order to achieve efficient and reliable operation of high current, high voltage IGBT modules, a gate driver with high pulse current capability and low output impedance is required. Powerex hybrid gate drivers are designed to perform this function as stand-alone units in most applications. The VLA500-01 and VLA502-01 are capable of driving modules with ratings up to 1400A and 1200V while the VLA500K-01R is capable of driving 1700V modules with 1000A current ratings. In cases where gate drive is needed for parallel operation of large modules, it may be necessary to add an output booster stage to the hybrid gate driver for optimum performance.

When using the hybrid gate drivers as stand-alone units with IGBT modules outside the range specified in Table 1.1, three things must be considered. First, the maximum peak output current rating of the hybrid gate driver places a restriction on the minimum value of R_G that can be used. For example, the minimum allowable R_G for VLA500-01 is 1 ohm. (For additional information, refer to Section 1.3.) This value is higher than what would be required for several large IGBT modules running in parallel. Using R_G larger than the datasheet value will cause an increase in t_d(on), t_d(off), t_r and switching losses. In high frequency (more than 5 kHz) applications, these additional losses are usually unacceptable. Even if the additional losses and slower switching times are acceptable, the driver's allowable power dissipation or drive current capability must be considered. At an ambient temperature of 60°C, the VLA500-01 can provide about 150mA of gate drive current. If a CM1400DU-24NF module is being used, the driver will be required to use its entire output current capability at a switching frequency of about 16 kHz. In this case, operation at a higher frequency than 16 kHz will cause the driver to overheat. Lastly, the driver's slow shutdown becomes less effective when it is used with large devices. This occurs because current that flows to the gate through the relatively high reverse transfer capacitance (C_{res}) of large devices cannot be absorbed by the driver. Its output impedance is not low enough. The slow shutdown may become less slow and a larger turn-off snubber capacitor may be required. This third limitation is perhaps the most serious. In some cases, the hybrid driver may completely lose control of the gate voltage and allow it to climb above 15V. If this happens, the short circuit durability of the IGBT module may be compromised.

In cases where more than 12A of peak output current are required, a discrete npn/pnp complimentary output stage can be added to the hybrid driver. One possible implementation is shown in Figure 1.18. The NPN and PNP booster transistors should be fast switching (t_f < 200ns) and have sufficient current gain to deliver the desired peak output current. The circuit shown in Figure 1.18 shows the output booster being used with the VLA503-01 driver. Table 1.4 lists some combinations of booster transistors that can be used in the circuit shown in Figure 1.18.

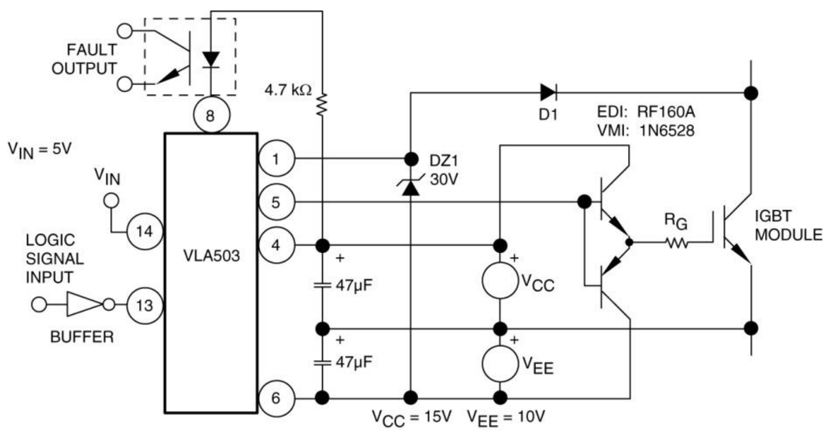


Figure 1.18 Example Circuit for Driving Large IGBT Modules

Normally, either the VLA503-01 or VLA513-01 is used to drive the booster stage. However, if the gain of the booster transistors is sufficiently high, the lower current VLA504-01 and VLA513-01 can be used. If very high gain transistors are used in the booster stage, care must be exercised to avoid oscillations in the output stage. It may become necessary to add resistance from base-to-emitter on the booster transistors as shown in Figure 1.19. This output booster stage can be used with the VLA513-01 if short circuit protection is not needed.

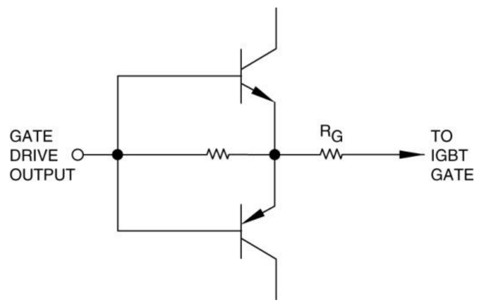


Figure 1.19 Alternate Booster Stage Configuration

1.8   Application Examples

Fully isolated gate drive circuits can be easily designed by combining hybrid gate drive circuits with hybrid DC-to-DC converter modules. Combining these circuits typically involves designing a printed circuit board with appropriate shielding and support components. Figure 1.20 shows two examples of prototype circuit boards that demonstrate how a fully isolated gate driver can be implemented with hybrid circuits. The following sections describe three examples of fully isolated gate drive.

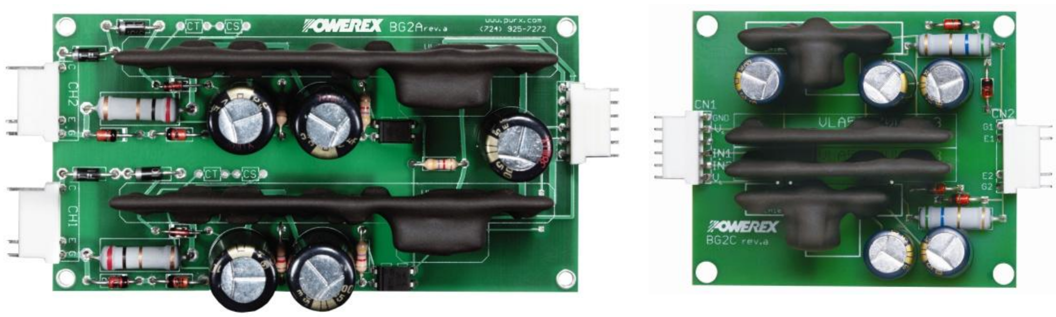


Figure 1.20 Populated BG2A and BG2C Gate Drive Prototype Boards

1.8.1 Fully Isolated Gate Drive for Dual IGBT Modules

The Powerex BG2A, BG2B, BG2C and BG2D driver boards are prototypes of fully isolated gate drive circuits designed to drive IGBT modules. The BG2D is made specifically for mounting directly to the NX-series dual IGBT modules. The BG2A and BG2C are shown on the left and right side of Figure 1.20 respectively. Table 1.4 gives a complete listing of available prototype boards and the other accessory products that are used in each.

Table 1.4 Prototype Boards

Prototype Board	Gate Driver Part No.	Peak Drive Current (I_{OP})	Minimum R_G	Desat Detection	Typical Application* (IGBT Module Rating)	Recommended DC/DC Converter
BG2B/D	M57159L-01	+/- 1.5A	4.2 Ω	Yes	Up to 100A	VLA106-15242 for 15VDC Input VLA106-24242 for 24VDC Input
BG2B/D	VLA504-01	+/- 3A	3.0 Ω	Yes	Up to 200A	
BG2B/D	VLA503-01	+/- 5A	2.0 Ω	Yes	Up to 600A	
BG2C	VLA507-01	+/-3A	3.9 Ω	No	Up to 200A	
BG2C	VLA513-01	+/-5A	2.0 Ω	No	Up to 600A	
BG2A	VLA500-01	+/- 12A	1.0 Ω	Yes	Up to 1400A	Included in gate driver
BG2A	VLA500K-01R	+/- 12A	1.0 Ω	Yes	Up to 1000A - 1700V	Included in gate driver
BG2A	VLA502-01	+/- 12A	1.0 Ω	Yes	Up to 600A - NFH Series	Included in gate driver

The BG2C incorporates the lowest cost gate drivers VLA507-01 and VLA513-01. The VLA513-01 has +/-5A output current capability and is also capable of switching high frequency NFH-Series modules. The VLA513-01 is capable of driving standard speed 600V and 1200V modules up to 600A and 400A respectively and High Frequency NFH series modules at 60 kHz switching up to 200A or at 30 kHz switching up to 400A.

Control on/off signals are optically isolated using the hybrid gate drivers built-in optocoupler. Optocouplers are also provided to isolate the fault feedback signal. All isolation is designed for a minimum 2500VRMS between the input and output. Full schematics for the gate drive boards are given on the board’s application note.

1.9 Related Application Notes

Table 1.5 lists additional application notes relevant to IGBT module accessories including gate drivers and development boards. Clicking on the application note name will bring up the associated pdf document. The datasheets for the specific gate drivers include more information such as product specifications and application circuit examples.

Table 1.5 Additional Reading

Application Note	Product Type	IGBT Module Application
VLA500	Gate Driver IC	600V Module up to 600A 1200V Module up to 1400A
VLA502	Gate Driver IC	High Frequency NFH series 600V and 1200V Modules
BG2A	Gate Drive Development Board	600V Module up to 600A 1200V Module up to 1400A
BG2B	Gate Drive Development Board	600V Module up to 600A 1200V Module up to 400A
BG2C	Gate Drive Development Board	600V Module up to 600A 1200V Module up to 400A And High Frequency NFH series 60kHz switching up to 200A 30kHz switching up to 400A

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