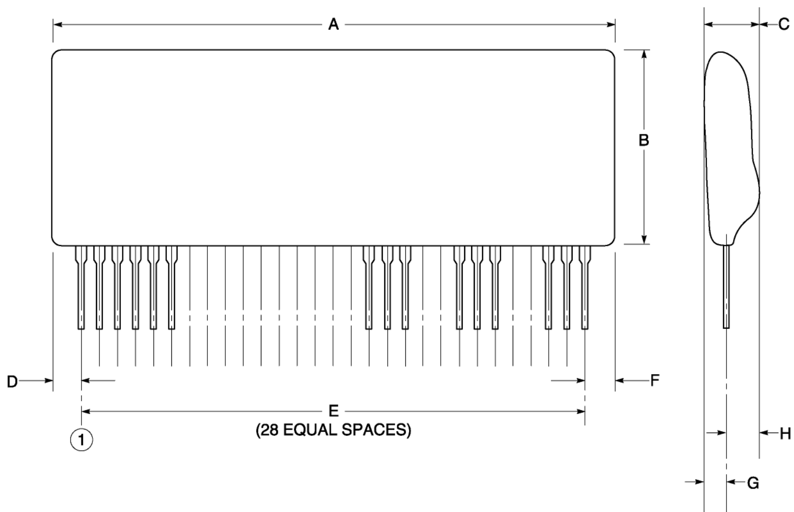
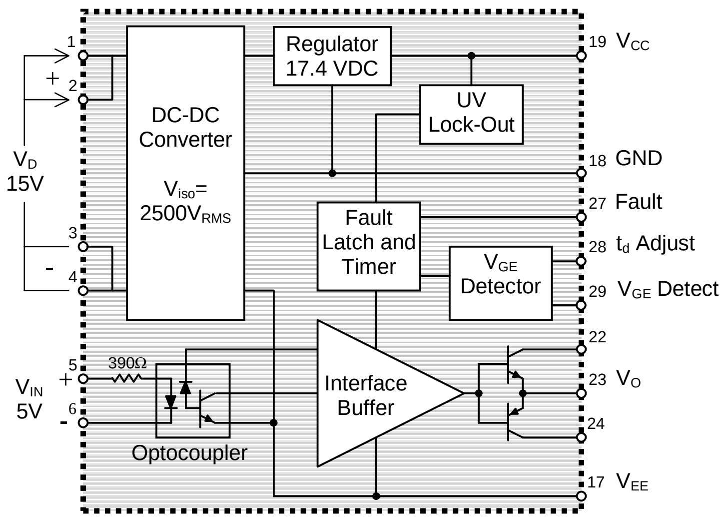
Powerex, Inc., 200 E. Hillis Street, Youngwood, Pennsylvania 15697-1800 (724) 925-7272

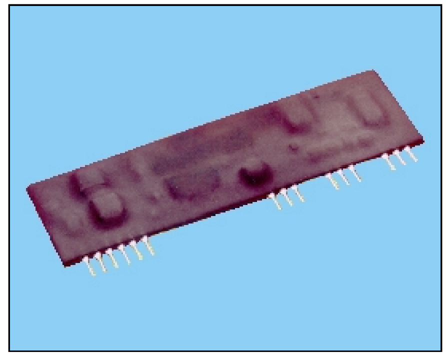
Gate Driver



Block Diagram



Dimensions	Inches	Millimeters
A	3.27 Max.	83.0 Max.
B	1.18 Max.	30.0 Max.
C	0.59 Max.	15.0 Max.
D	0.24 Max.	6.0 Max.
E	2.80	71.12
F	0.22 Max.	5.5 Max.
G	0.18 Max.	4.5 Max.
H	0.43 Max.	11.0 Max.



Hybrid Integrated Circuit For Driving IGBT Modules

Description:

M57161L-01 is a hybrid integrated circuit designed for driving Powerex F-Series IGBT modules. This gate driver converts logic level control signals into high current gate drive with suitable on and off bias voltages. Electrical isolation of the input control signal is provided by an integrated high-speed optocoupler. A built-in isolated DC-DC converter supplies gate drive power. The driver has short-circuit and undervoltage protection and provides a fault status feedback signal.

Features:

- ☐ High output current (±) 7A peak
- ☐ Isolated DC-DC converter provides +15.5V/-5V drive
- ☐ High-speed optocoupler isolates input signal
- ☐ Short-circuit and undervoltage protection

Application:

Gate drive for IGBT modules with internal RTC circuit in motor drive, UPS, welder, etc.

Recommended Modules:

Powerex 600V and 1200V F-Series IGBT Modules

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M57161L-01
Hybrid IC for IGBT Gate Driver

Absolute Maximum Ratings, T_a = 25°C unless otherwise specified

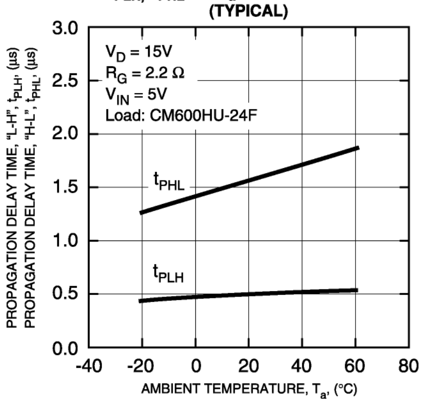
Item	Symbol	Test Conditions	Ratings	Units
Supply Voltage	V_D		16	Volts
Input Voltage	V_{IN}	Applied between: Pin 5 - Pin 6	-1 ~ +7	Volts
Output Voltage	V_O	ON State, V_D = 15.7V	16.5	Volts
Output Current	I_{OHP}	Pulse Width 1 µs,	-7	Amperes
	I_{OLP}	f ≤ 20kHz	7	Amperes
Isolation Voltage	V_{iso}	Sine Wave Voltage, 60Hz, 1 minute	2500	V_{rms}
Case Temperature	T_C		85	°C
Operating Temperature	T_{opr}		-20 ~ +60	°C
Storage Temperature	T_{stg}		-25 ~ +100	°C
Fault Output Current	I_{FO}	Sink Current Pin 27	25	mA
Applied 29 Pin	V_R		V_{CC}	Volts

Electrical Characteristics, T_a = 25°C, V_D = 15V, V_{IN} = 5V, f = 20kHz, R_G = 2.2Ω, CM600HU-24F unless otherwise specified

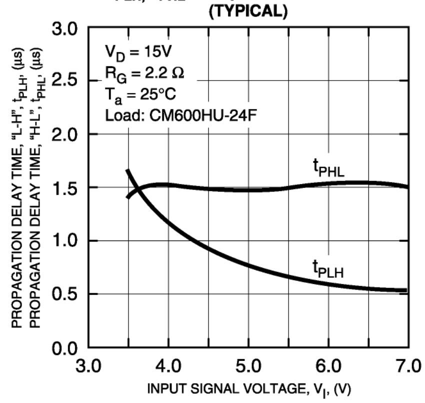
Item	Symbol	Test Conditions	Limits			Units
Supply Voltage	V_D	Recommended Range	14.3	15.0	15.7	Volts
Input Voltage	V_{IN}	Recommended Range	4.5	5.0	5.5	Volts
"H" Input Current	I_{IH}	Recommended Range	9	10	11	mA
Switching Frequency	f	Recommended Range	—	—	20	kHz
Gate Resistor	R_G	Recommended Range	2.2	—	—	Ω
"H" Input Current	I_{IH}	V_{IN} = 5V	—	10	—	mA
Gate + Supply Voltage	V_{CC}	V_{IN} = 0V, f = 0Hz	17.0	17.4	17.8	Volts
Gate - Supply Voltage	V_{EE}	V_{IN} = 0V, f = 0Hz	-5.5	-6.5	-7.5	Volts
"H" Output Voltage	V_{OH}		14	15.5	16.5	Volts
"L" Output Voltage	V_{OL}		-4.0	-5.0	-6.0	Volts
"L-H" Propagation Time	t_{PLH}	I_{IH} = 10mA	—	0-.4	1	µs
"L-H" Rise Time	t_r	I_{IH} = 10mA	—	0.4	0.5	µs
"H-L" Propagation Time	t_{PHL}	I_{IH} = 10mA	—	1.3	2.0	µs
"H-L" Fall Time	t_f	I_{IH} = 10mA	—	0.4	0.5	µs
Timer	t_{timer}	Duration with Input Signal in OFF State	1.5	—	2.5	ms
Fault Output Current	I_{FO}	Applied Pin 27, R = 470Ω	—	12	—	mA
Short-circuit Detect Delay Time	t_{TRIP}	Pin 29: 11V,	—	3.5	—	µs
Total Shut-down Time	t_d	Pin 28: Open	—	6.5	—	µs
V_{CC} at UV Protect	V_{CL}	Measured at Pin 18 – Pin 19	14.2	15.2	16.2	Volts
Short-circuit Detect Voltage	V_{SC}		11.0	11.6	12.2	Volts

M57161L-01
Hybrid IC for IGBT Gate Driver

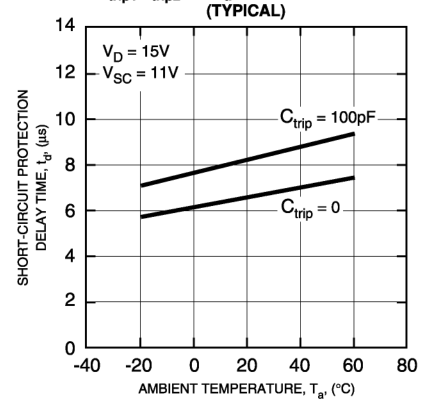
t_{PLH}, t_{PHL} VS. T_a CHARACTERISTICS (TYPICAL)



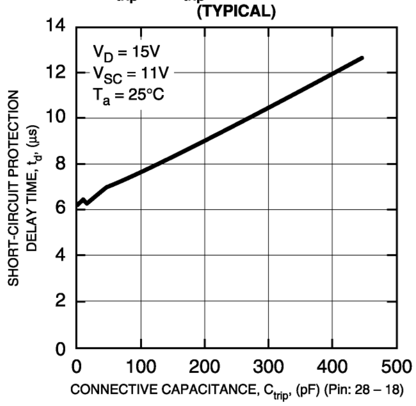
t_{PLH}, t_{PHL} VS. V_I CHARACTERISTICS (TYPICAL)



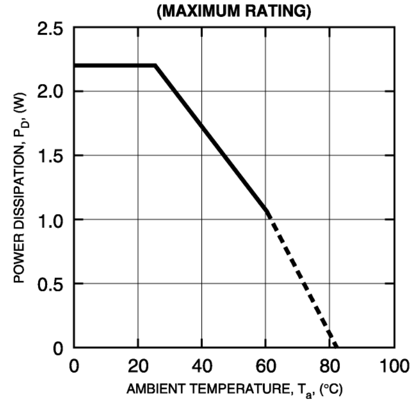
t_{trip1}, t_{trip2} VS. T_a CHARACTERISTICS (TYPICAL)



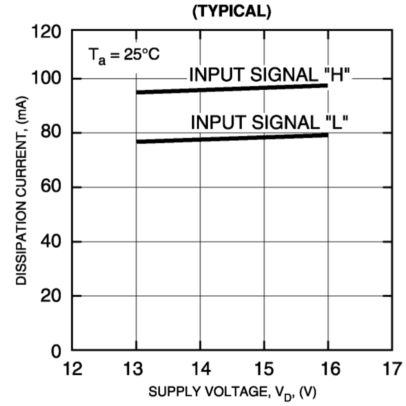
t_{trip} VS. C_{trip} CHARACTERISTICS (TYPICAL)



POWER DISSIPATION VS. AMBIENT TEMPERATURE (MAXIMUM RATING)



DISSIPATION CURRENT VS. SUPPLY VOLTAGE (TYPICAL)



1. Principle of Operation – RTC Detection and Short-Circuit Protection

Powerex F-Series (trench gate) IGBT modules have a built-in RTC (Real Time Control) circuit. The purpose of the RTC is to limit short-circuit current and maintain a 10µs short-circuit withstanding capability. The RTC circuit limits the current by actively reducing the gate voltage when excessive collector current is present. The M57161L-01 gate driver uses a gate voltage detection circuit to sense the activation of the RTC circuit inside the F-Series IGBT module. A simplified schematic of the RTC detector circuit is shown in Figure 1.

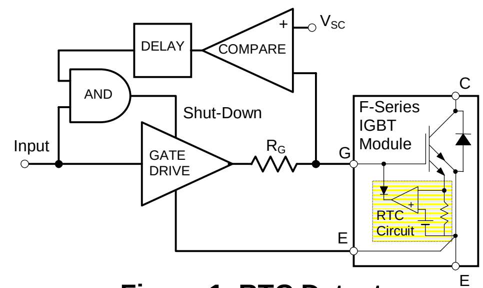


Figure 1 RTC Detector

This circuit consists of a comparator with its (-) input connected to the gate of the IGBT module and its (+) input supplied with a fixed reference voltage of V_{SC}. In the normal ON state, the voltage on the gate of the IGBT is nearly equal to the positive gate drive supply voltage, which exceeds V_{SC} and makes the comparator output low. In the normal OFF state, the gate voltage is nearly equal to the negative gate drive supply voltage, which is less than V_{SC} making the comparator output high. If a short circuit occurs, the RTC circuit inside the F-Series IGBT module will activate and pull the gate voltage down below the V_{SC} reference. This abnormal presence of a gate voltage less than V_{SC} when the IGBT is supposed to be on indicates that the module's RTC has been activated. This condition is identified by a logical AND of the gate driver's control input signal and the comparator's output as shown in Figure 1. The output of the AND will go high when a short-circuit condition is detected. The output of the AND is then used to command the IGBT to shut down in order to protect it from the short circuit. A delay is provided after the comparators output to prevent the circuit from indicating a short-circuit condition during the normal transition of gate voltage at turn-on.

2. Operation of the M57161L-01 RTC Detector

The Powerex M57161L-01 hybrid gate drive circuit implements RTC detection as described above. A flow chart for the logical operation of the short-circuit protection is shown in Figure 2. When the IGBT module's RTC is activated the hybrid gate driver performs a soft shut-down of the IGBT and starts a timed lock-out, t_{timer}, typically 2.0ms. The soft turn-off helps to limit the transient voltage that may be generated while interrupting the 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.

This protection scheme is superior to conventional desaturation detection because it avoids the need for a high voltage detection diode, and reduces spacing requirements on the gate drive printed circuit board. In addition, noise immunity is improved because the driver is not connected to the high voltage on the IGBT's collector.

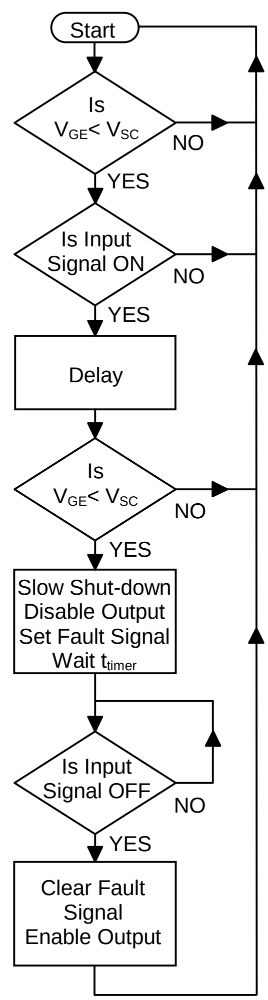
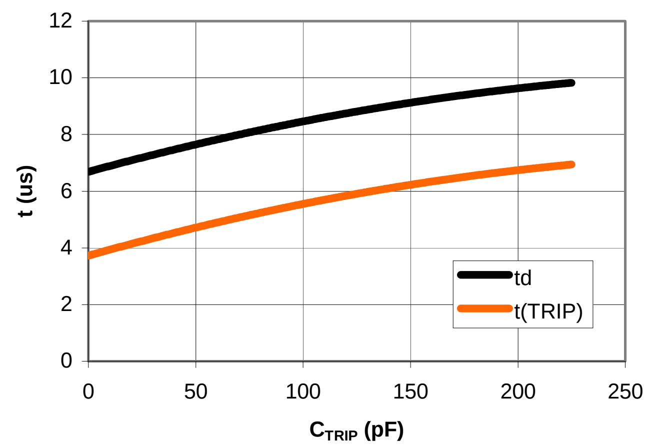


Figure 2 Flow Chart

3. Adjusting Protection Delay Time

The M57161L-01 has a default short-circuit detection time delay (t_{TRIP}) of approximately 3.5µs. This will prevent erroneous detection of short-circuit conditions as long as the series gate resistance (R_G) is near the minimum recommended value for the module being used. The 3.5µs delay is appropriate for most applications so adjustment will not be necessary. However, in some low frequency applications it may be desirable to use a larger series gate resistance to slow the switching of the IGBT for reduced noise and turn-off transient voltages. As the R_G is increased, the rise of gate voltage is slowed and in some cases it may not exceed V_{SC} before the t_{TRIP} delay expires. If this happens the driver will erroneously indicate that a short circuit has occurred. To avoid this condition the M57161L-01 has provisions for extending the t_{TRIP} delay by connecting a capacitor (C_{TRIP}) between pins 28 and 18. If t_{TRIP} is extended care must be exercised not to exceed the short-circuit withstanding capability of the IGBT module. Normally this will be satisfied for Powerex F-Series IGBT modules as long as the total shut-down time (t_d) does not exceed 10µs. The total shut down time (t_d) consists of the t_{TRIP} delay plus a propagation delay of approximately 2.5µs. A curve showing the relationship between t_d, t_{TRIP} and C_{TRIP} is shown in Figure 3. The C_{TRIP} capacitor must be selected so that the gate voltage exceeds V_{SC} before the short-circuit detection time t_{TRIP} expires.

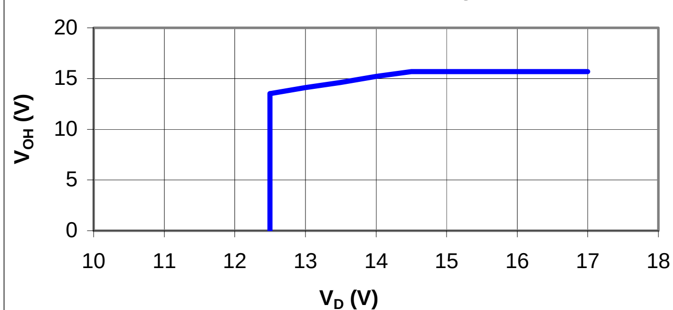
Figure 3 C_{TRIP} versus t_{TRIP} and t_d



4. Undervoltage Lock-out

The M57161L-01 hybrid gate driver is designed to operate from a single 15V control power supply, V_D. For proper operation this supply should be between 14.3V and 15.7V. If the V_D supply becomes low, then the on-state drive voltage for the IGBT will also decrease. In order to prevent dangerously low drive voltages the M57161L-01 has an undervoltage protection circuit. If the output voltage of the DC-DC converter at pin 19 (V_{CC}) becomes less than the data sheet specified trip level (V_{CL}), the output will turn off and a fault signal will be generated. Figure 4 shows the effect of the UV lock-out on the gate voltage as a function of input voltage. In order for normal operation to resume, the V_{CC} voltage must exceed the undervoltage trip level (V_{CL}). Operation of the undervoltage protection circuit may also occur during power up and power down. The system controller's program should take this fault into account.

Figure 4 Supply Voltage versus On-State Gate Voltage

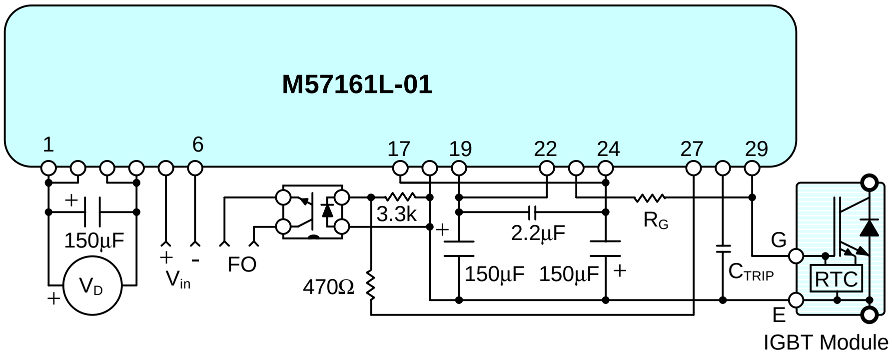


5. Application Circuit for M57161L-01

An example application circuit for the M57161L-01 hybrid gate driver is shown in Figure 5. The input circuit between pins 5 and 6 consists of the built-in optocoupler's LED in series with a 390Ω resistor. This combination is designed to provide approximately 10mA of drive current for the optocoupler when a control signal of 5V is applied. If another control voltage is desired then an external current limiting resistor can be added. The value of the external resistor can be calculated by assuming the forward voltage drop of the optocoupler's photodiode is 2V. For example, if 15V drive is desired the required external resistor would be: (15V-2V)÷10mA - 390Ω = 910Ω.

The hybrid circuit operates from a single 15V control power supply (V_D) that is connected at Pins 1,2 and 3,4. The control power supply must be decoupled with a capacitor connected as close as possible to the driver's pins. This decoupling capacitor is included to provide a stable, well-filtered voltage for the primary side of the driver's built-in DC-DC converter. When selecting the input decoupling capacitor it is important to insure that it has a

Figure 5 M57161L-01 Typical Application Circuit



sufficiently high ripple current rating. The example circuit in Figure 5 uses a 150µF low impedance type electrolytic for the input decoupling capacitor.

The driver's built-in DC-DC converter produces isolated +17.4V and -6.5V outputs at pins 19 and 17 with respect to the common pin 18. These voltages are supplied to driver's output stage on pins 22 and 24 to provide high current gate drive with on and off driving voltages of +15.5V and –5V. In order to deliver the pulse current necessary for efficient switching, the output of the isolated DC-DC converter (pins 17, 18 and 19) must be decoupled using a combination of low impedance electrolytic and film capacitors. In Figure 5 the 150µF low impedance electrolytics and a 2.2µF stacked film or multi-layer ceramic are included for this purpose. These capacitors should be located as close as possible to the pins of the hybrid gate driver. When driving small modules it is usually acceptable to use smaller capacitors provided that that they have sufficient ripple current capability and low enough impedance. However, very large modules and parallel module applications may require 500µF or more to achieve low enough impedance and high enough ripple current capability.

The series gate resistor (R_G) should be selected based on the application requirements and module type being used. Details for selecting R_G can be found in Powerex IGBT module application notes. The minimum allowable R_G for the M57161L-01 is 2.2Ω. If a smaller value is desired, a booster stage must be added. (See Section 7.) The back-to-back zener diodes from G to E that are normally recommended are not required with F-Series IGBT modules because they are included as part of the modules internal RTC circuit.

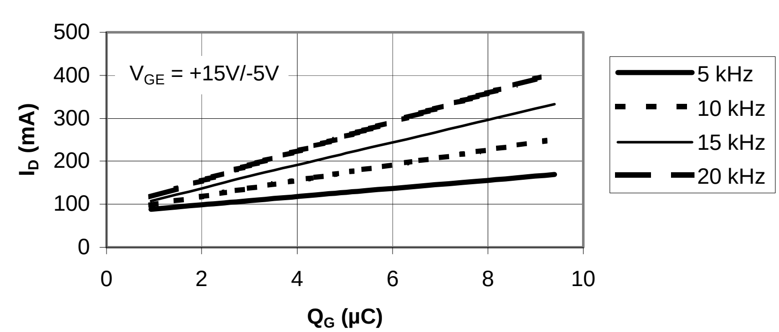
Pin 28 is used to adjust the RTC detection time and total shut-down time. This adjustment was described in detail in Section 3. To extend the trip time, C_{TRIP} can be connected as shown in Figure 5. This capacitor should be located as close as possible to the pins of the gate driver.

Pin 27 is an active low fault status signal. When a fault (short circuit or undervoltage) is detected this pin is pulled down to the V_{EE} supply. In Figure 5 a low speed optocoupler is utilized to provide isolation of the fault feedback signal. The optocoupler is connected from the common of the isolated power supply (pin 18) to the fault signal pin using a 470Ω current limiting resistor. When a fault occurs a current of approximately 10mA will flow in the optocoupler's LED. A 3.3kΩ resistor connected across the opto's photodiode helps to improve noise immunity.

6. Control Power Supply Requirements

The control power supply current required for the M57161L-01 is primarily a function of the gate charge (Q_G) of the IGBT module being driven and the switching frequency. Figure 6 shows the 15V control power supply current (I_D) as a function of IGBT module gate charge for various switching frequencies. This curve provides an estimate of the required current. The actual current will vary depending on the operating conditions of the IGBT module. To accommodate these variations, it is recommended that the 15V supply be designed to provide 150% - 200% of the value indicated in Figure 6.

Figure 6 Supply Current versus Gate Charge



7. Driving Large IGBT Modules

In order to achieve efficient, reliable operation of large IGBT modules or multiple parallel connected modules, a gate driver with high pulse current capability is required. The M57161L-01 hybrid gate driver is designed to perform this function as a stand-alone unit in most applications. However, for optimum performance with very large modules, it may be necessary to add an output booster stage to the hybrid gate driver. A booster stage is required when the desired series gate resistance is lower than the minimum R_G specified on the gate driver's data sheet.

Figure 7 M57161L-01 Typical Application Circuit With Booster Stage

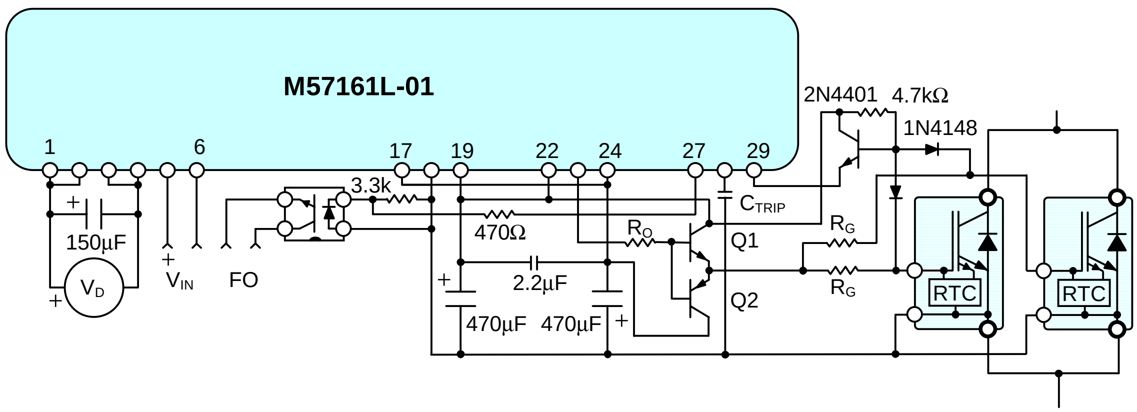


Figure 7 is a schematic showing the M57161L-01 with an added booster stage consisting of a complimentary transistor pair driving two parallel connected IGBT modules. The NPN and PNP booster transistors (Q1, Q2) should be fast switching (t_f < 200nS) and have sufficient current gain to deliver the desired peak output current. Table 1 lists some combinations of booster transistors that can be used in the circuit shown in Figure 7. The series resistor (R_O) connected from the driver's output on pin 23 to the booster stage is used to limit the peak base current and help to damp oscillations in the booster stage. In most applications R_O should be set so that $R_O = h_{fe} \times R_G$, where h_{fe} is the minimum gain of the booster stage transistors and R_G is the series gate resistance. Note that if the application has parallel modules then the effective R_G must be used in the above equation. For example, if there are 2 modules in parallel then $R_O = h_{fe} \times R_G/2$. When parallel connected modules are used with the M57161L-01 it is also necessary to include a diode OR circuit so that the gates of the paralleled modules can be independently monitored. An example of the diode OR is also shown in Figure 7.

Table 1 Booster Stage Transistors

Q1 NPN	Q2 PNP	Peak current	V_{CEO}	Manufacturer	Package
MJD44H11	MJD45H11	15A	80V	ON Semiconductor	D2-Pac
D44VH10	D45VH10	20A	80V	ON Semiconductor	TO-220
MJE15030	MJE15031	15A	150V	ON Semiconductor	TO-220
2SC4151	2SA1601	30A	40V	Shindengen	Isolated TO-220
ZTX851	ZTX951	20A	80V	Zetex	TO-92