Design and Applications of HCPL-3020 and HCPL-0302 Gate Drive Optocouplers

Application Note 5004

Introduction

The HCPL-3020 (DIP-8) and HCPL-0302 (SO-8) consist of GaAsP LED optically coupled to an integrated circuit with a power output stage. The current rating, combined with the high common mode rejection (CMR), fast switching and latch-up performance uniquely qualify these optocouplers to be the ideal choices in low power inverter gate drive applications. The high operating voltage ranges of the HCPL-3020 and HCPL-0302 output stages provide the drive voltages required by MOS-gated devices like IGBTs or MOSFETs. The voltage and current provided by these optocouplers make it suitable for driving IGBTs with rating up to 1200V/20A.

The HCPL-3020 and HCPL-0302 represent one of the cheapest solutions to drive MOS-gated devices in safe, efficient, reliable and cost–effective manner. Besides its ease of implementation, the HCPL-3020 and HCPL-0302 also excel in power consumption. HCPL-3020 and HCPL-0302 will please all designers in the motor control or inverter arena as the following features demonstrate:

- Low power consumption: Low supply current of 3mA, which allows powering HCPL-3020 and HCPL-0302 using bootstrap technique. This eliminates the need of an isolated power supply or dc-to-dc converter and a smaller V_{CC} capacitor can be used. This not only reduces the printed circuit board space but also total system cost.
- External gate resistor connection: Designer can control the gate signal flow, and have an option to slow down the device commutation, therefore reducing the amount of Electro-Magnetic Interference (EMI) compared to intelligent power module (IPM) solution.
- Low level output voltage, V_{OL}: The V_{OL} of HCPL-3020 and HCPL-0302 is specified at 1.0V maximum. This low voltage possibly eliminates the need of negative gate drive for many applications.
- Low external part–count: by integrating the gate driver and isolation function in one package, the final HCPL-3020 and HCPL-0302 implementation reveals an obvious gain in component reduction compared to other competing technologies, such as transformer and high voltage integrated circuit.

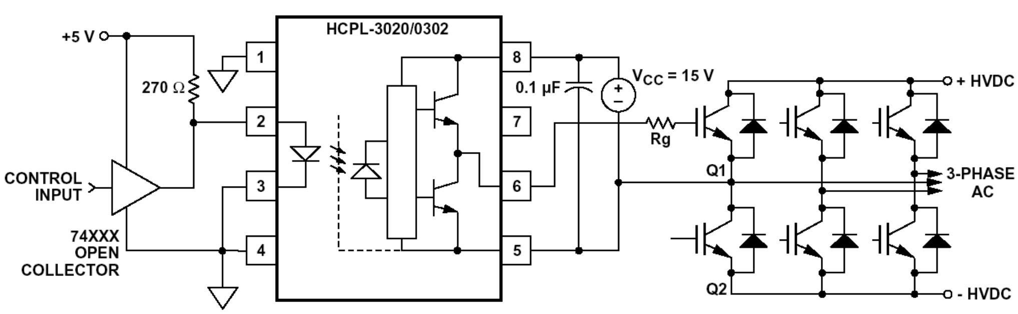

Figure 1. Recommended LED Drive and Application Circuit for HCPL-3020 and HCPL-0302.

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Bootstrap Power Supply Circuit

Figure 2 shows a bootstrapped power supply circuit. This circuit includes a bootstrap circuit for providing output power to the HCPL-3020 or HCPL-0302 gate drive optocouplers, thereby eliminating the need for isolated power supplies or dc-to-dc converters. It can be modified to suit other Agilent Technologies' gate drive optocouplers and current/voltage sensing isolation amplifiers.

In this basic bootstrap topology, when the lower IGBT, Q_2 in the bridge is turned on, the emitter of Q_1 is pulled to -HV. Similarly, when the upper IGBT, Q_1 is turned on, the collector of Q_2 is pulled to +HV. This charges C_{BSH} and C_{BSL} up to the supply voltage V_{CC} minus the voltage drop across the diodes D_H and D_L. The energy stored in C_{BSH} and C_{BSL} can then be used to turn on Q_1 and Q_2. 3 mA low supply current of HCPL-3020 and HCPL-0302 minimizes the value of C_{BSH} and C_{BSL}. The V_{CC} voltages are clamped by Zener Diodes, D_{ZH} and D_{ZL}.

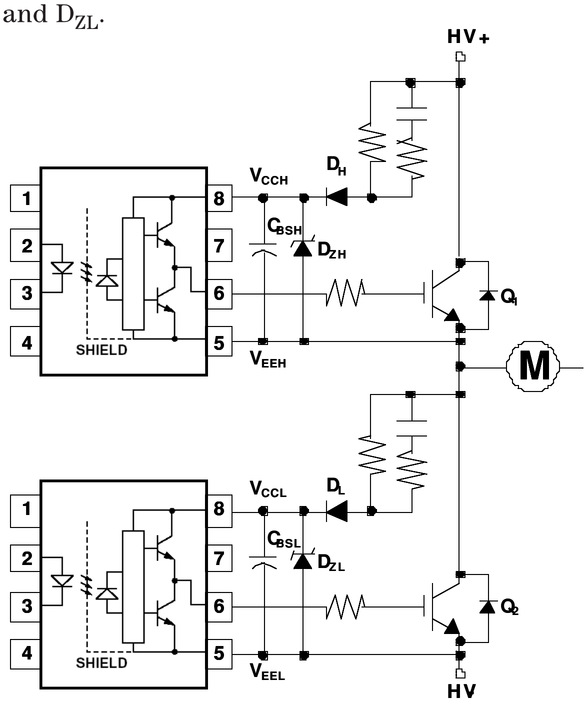

Figure 2. Bootstrap Circuit for Power Control System.

Influence of Gate Resistor

With external gate resistor connection, designers can control the IGBT gate signal flow, and have an option to slow down the device commutation; therefore reducing the amount of Electro-Magnetic Interference (EMI) compared to intelligent power module (IPM) solution.

Series gate resistor is typically used for both turn-on and turn-off of MOS-gated devices. It is commonly implemented using only a resistor. Advance gate control usually realized using different resistors for turn-on and turn-off.

A small gate resistor will help in avoiding cross conduction, limiting IGBT switching losses and improve di/dt. On the other hand, large gate resistor can help to avoid ringing, limiting the free wheeling diode losses and reverse recovery voltage. Designers need to balance the trade-off in selecting an optimize gate resistor.

Calculation selection of gate resistor, based on limiting the gate current and power dissipation can be found in application section of HCPL-3020 and HCPL-0302 data sheet.

Speed Improvement Circuit

Designers typically focus more on turn-off process of MOS-gated devices. This is because the turn-on speed is generally satisfactory to drive the MOS-gated devices.

The circumstance is very much different during turn-off. Theoretically, the turn-off speed of MOS-gated device depends only on the gate drive circuit. A high current turn-off circuit can discharge the input capacitors more rapidly, providing shorter switching times and as a result lower switching losses. Higher discharge current can be accomplished by using a low output impedance gate driver and/or a negative turn-off voltage.

Low switching losses can be achieved by having faster switching, but it comes with a trade-off of increase ringing in the waveforms due to the higher turn-off di/dt and dv/dt. This must be taken into consideration in view of EMI concern.

A. Anti-Parallel Diode Turn-Off Speed Improvement Circuit

One of the simplest turn-off speed improvement techniques is the anti-parallel diode, as shown in Figure 3. This simple circuit allows tuning of the IGBT turn-on speed by varying R_{GATE}. During turn-off, the anti-parallel diode, D_{OFF} shunts out the resistor, R_{GATE}. D_{OFF} will be forward biased and starts to conduct only when the voltage drops across the gate resistor, is higher than forward voltage of D_{OFF}:

$$I_G \times R_{GATE} > V_{FDOFF}$$

Therefore, as the gate-to-emitter voltage approaching zero, the effect of anti-parallel diode becomes less significant. Consequently, turn-off delay time is reduced, but improvement switching times and dv/dt immunity is only incremental.

B. PNP Turn-Off Speed Improvement Circuit

One of the most popular arrangements to improve turn-off speed is the pnp turn-off speed improvement circuit illustrated in Figure 4.

In this simple circuit, during the turn-on, the input capacitor of IGBT is being charged through gate resistor, R_{GATE} and turn-on diode, D_{ON}. D_{ON} also prevent reverse breakdown of the base-emitter junction of Q_{OFF} during the initial stage of the turn-on process.

During turn-off, the pnp transistor, Q_{OFF}, is being turned-on, and gate turn-off current is being discharges through Q_{OFF} to emitter of IGBT. With this simple circuit configuration, the area enclosed by high turn-off discharge current loop is being minimized.

The speed improvement circuit minimizes ground-bouncing problem by not discharging the turn-off current through the gate driver. Simultaneously, the power dissipation of the gate driver is cut to half.

C. Negative Gate Drive Turn-off Speed Improvement Circuit

Low level output voltage, V_{OL} of HCPL-3020 and HCPL-0302 of 1.0V maximum possibly eliminates the need to negative gate drive for many applications. Under certain circumstances, a negative gate voltage as shown in Figure 5 can be applied to reduce the switching losses during turn-off.

Negative gate drive also help to ensure IGBTs in off state during turn-off process even with the present of high dv/dt noise in collector-emitter voltage.

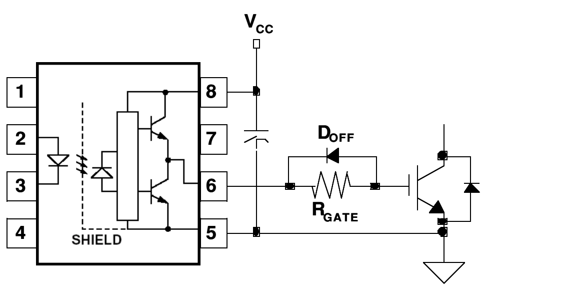

Figure 3. Anti-Parallel Diode Turn-Off Speed Improvement Circuit.

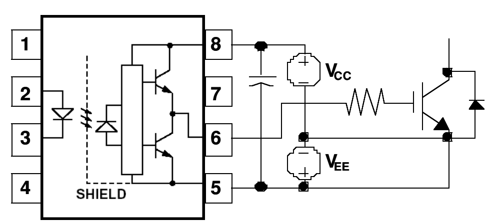

Figure 5. Negative Gate Drive (V_{EE}) for Fast Turn-off.

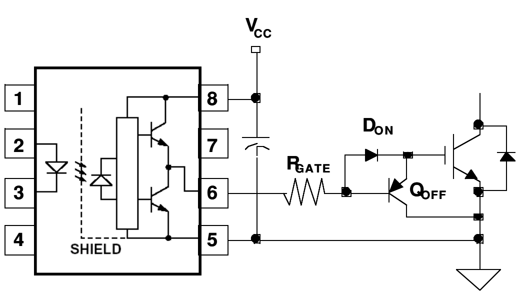

Figure 4. PNP Turn-Off Speed Improvement Circuit.

Common Mode Transient Immunity

In motor drives and inverters, there are large voltage transient generated by switching of the transistors. Common Mode Transient Immunity of gate drive optocouplers is the key attribute that allow the transmit of accurate information across the isolation barrier. All Agilent Technologies' gate drive optocouplers rely on two key technical strengths to achieve high Common Mode Transient Immunity. The first is use of a proprietary, low-cost Faraday shield, which decouples the optocoupler input side from the output side. The second method is by unique package design, which minimizes input-to-output capacitance. For proper LED circuit consideration for ultra high Common Mode Transient Immunity performance, please refer to application section of HCPL-3020 and HCPL-0302 data sheet.

Driving Higher Power IGBT

A non-inverting current buffer, as illustrated in Figure 6 can be used to boost the IGBT gate drive current of HCPL-3020 or HCPL-0302. Even though the driver is built from discrete components, it is necessary to have its own bypass capacitor placed across the collectors Q_1 and Q_2. Preferably, a smoothing resistor, R is inserted between the bypass capacitor of HCPL-3020 or HCPL-0302 and the bypass capacitor of the current buffer can improve noise immunity. The R_{BIAS} can be selected to provide the required gate impedance based on the large signal beta of the driver transistors, Q_1 and Q_2.

This current buffer should be placed as close as possible to IGBT to minimize the parasitic inductance of the gate charging and discharging current loop.

If need of higher current arise, as a leading supplier of gate drive optocouplers, Agilent Technologies offers gate drive optocouplers with output current as high as 2.A offer in various packages to meet the requirements. These higher output current gate drive optocouplers help to:

- reduce external components needed for current buffer
- reduce printed circuit board space for discrete components
- reduce system cost

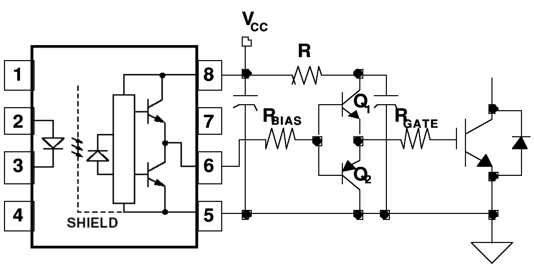

Figure 6. Current Buffer for Increased Drive Current.

Table 1. Agilent Technologies Gate Drive Optocouplers Portfolio.

Part Number	Description	Package
HCPL-316J	Highly Integrated Single Channel 2.0A Gate Drive Optocoupler	SO-16
HCPL-3120	2.0A IGBT Gate Drive Optocoupler	DIP-8
HCPL-J312	2.0A IGBT Gate Drive Optocoupler	DIP-8
HCNW-3120	2.0A IGBT Gate Drive Optocoupler	8-pin Widebody
HCPL-3150	0.5A IGBT Gate Drive Optocoupler	DIP-8
HCPL-315J	0.5A IGBT Gate Drive Optocoupler, Dual Channel	SO-16
HCPL-0314	0.4A IGBT Gate Drive Optocoupler	SO-8
HCPL-3140	0.4A IGBT Gate Drive Optocoupler	DIP-8
HCPL-J314	0.4A IGBT Gate Drive Optocoupler	DIP-8
HCPL-314J	0.4A IGBT Gate Drive Optocoupler, Dual Channel	SO-16
HCPL-0302	0.2A IGBT Gate Drive Optocoupler	SO-8
HCPL-3020	0.2A IGBT Gate Drive Optocoupler	DIP-8

Conclusion

Agilent Technologies' HCPL-3020 and HCPL-0302 enables designers to meet stringent requirements of high Common Mode Rejection (CMR), wide operating temperature range and fast switching in low power inverter gate drive applications, specially targeting at low power industrial inverters and inverter controlled consumer appliances. Low I_{CC} supply current also allows the use of smaller V_{CC} capacitor, and use bootstrap technique eliminating costly isolated power supply. A few speed improvement circuits for HCPL-3020 and HCPL-0302 are recommended. Though current buffer can be used to increase driving current, Agilent Technologies does offer higher output current gate drive optocouplers up to 2.0A, which help to reduce external components, PCB space and system cost.

References

1. "Agilent HCPL-3020/HCPL-0302 0.2 Amp Output Current IGBT Gate Drive Optocoupler Data Sheet", Agilent Technologies Publication Number 5988-9290EN (4/03)
2. J. N., Khan, "Optocouplers for Variable Speed Motor Control Electronics in Consumer Home Appliances", Agilent Technologies Publication Number 5980-1297 (5/00)
3. "Optocoupler Designer's Guide", Agilent Technologies Publication Number 5988-4082EN (6/02)

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