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MOTION CONTROL

# Short-Circuit Protection for Three-Phase Power Inverters

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## INTRODUCTION

The light industrial and appliance markets are becoming more and more demanding in terms of performance and safety features. These requirements are frequently at odds with the need for lower costs due to the higher circuit complexity required. The IR2x381 gate driver family is designed specifically to protect full inverter systems composed of a three-phase output bridge and brake, replacing at least seven traditional optocoupler gate drivers with one monolithic high voltage IC. Desaturation detection of the power switch is fully integrated, increasing system reliability and drastically reducing part count and layout space. Gate driving capability is up to 540mA. The full-featured design makes this device particularly well suited for motor drive applications.

## MONOLITHIC 1200V THREE-PHASE GATE DRIVING CAPABILITY

IR monolithic high voltage technology allows the IR2x381 ICs to safely drive 110Vac to 380Vac motor drive applications capable of withstanding voltages up to 1200Vdc. The IR2x381 can drive a configuration of a three-phase power bridge with brake consisting of seven power switches (Figure 1).

With gate driving capability of 20V, the 350mA source-current and 540mA sink-current allow for driving a wide range of low power switches without connecting external buffer stages. The gate driver has separate outputs in each channel but brakes to add flexibility in configuring the gate charge profile. In addition, the device features a two-stage turn-on capability to achieve finer gate control.

Seven separate channels allow safe inverter control resulting from an anti-shoot-through input circuit and a programmable deadtime of up to 5 ms. The floating channels can be easily supplied by the widely used bootstrap technique because of low quiescent current (250mA max). Under-voltage conditions in floating and low voltage circuits are managed independently and, when an under-voltage occurs, the power switches that are under that supply are turned off. The gate driver I/Os are 3.3V CMOS/TTL compatible to ease communication with the system controller. For each power switch, a signal is provided that feeds back the status of its collector. The collector voltage feedback is particularly key in applications in which accurate control algorithms are used, i.e. deadtime compensation. Separate inputs are available for controlling all the high-, low-side and brake drivers. A shutdown pin is also available for switching off all the power devices. An open drain fault output is provided that becomes active (low) in case of under-voltage or a desaturation detection event.

Logic ground and common emitter ground are separated to decouple the large amount of noise caused by inverter switching.

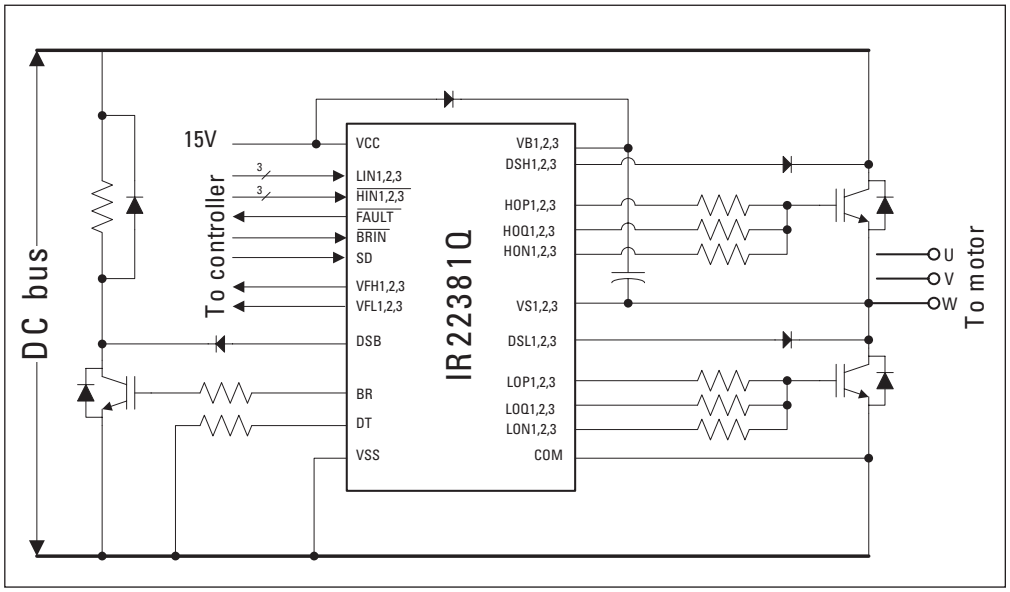


*Figure 1: Typical application.*

## DESATURATION PROTECTION

IGBT protection is fully integrated for any kind of short circuit. In fact, every single power device is monitored for desaturation. Figure 2 shows an example of a phase-to-phase short-circuit. A desaturation detection circuit is embedded in both the high- and low-side output stages for each of the three inverter legs and for the brake driver. The IGBT collector is monitored to emitter voltage by means of an external high voltage diode.

Diode sensing is achieved by an internal circuit that compares the anode voltage with an internal reference voltage of 8V. The same circuit also manages high frequency spikes, rejecting noise coupling and provides an active diode biasing by means of a patented structure.

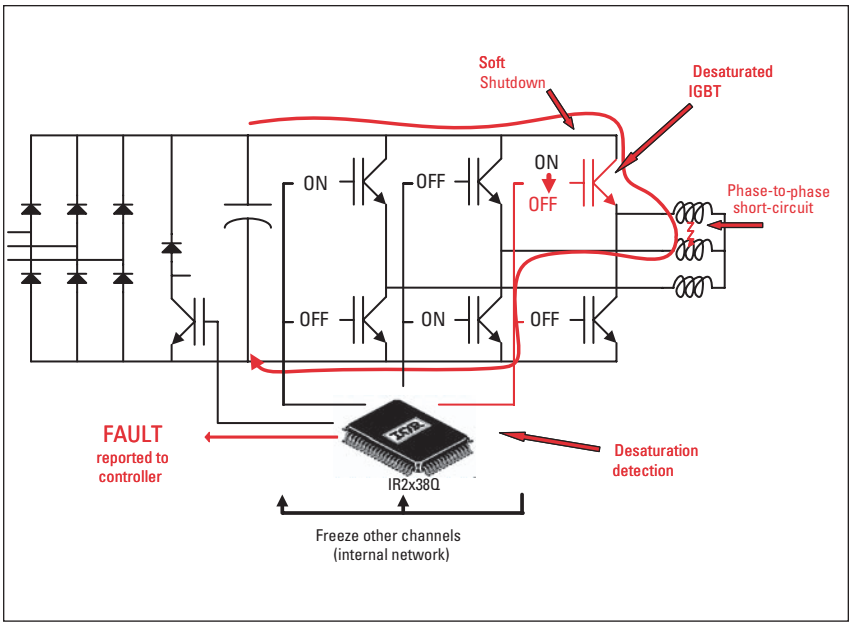


*Figure 2: Phase-to-phase short circuit.*

Under short-circuit conditions, current in the power switch can be as high as 10 times the nominal current (Figure 3 shows phase-to-dc minus short circuit with 30A power module). Whenever the switch is turned-off to block the current path, this high current generates relevant voltage transients in the power stage that need to be smoothed out to avoid definitive inverter failure. The gate driver accomplishes the transients' control by smoothly turning off the desaturated switch by means of the double function LON/HON pin (typ 500Ω series resistor internally provided) or the BR pin for brake.

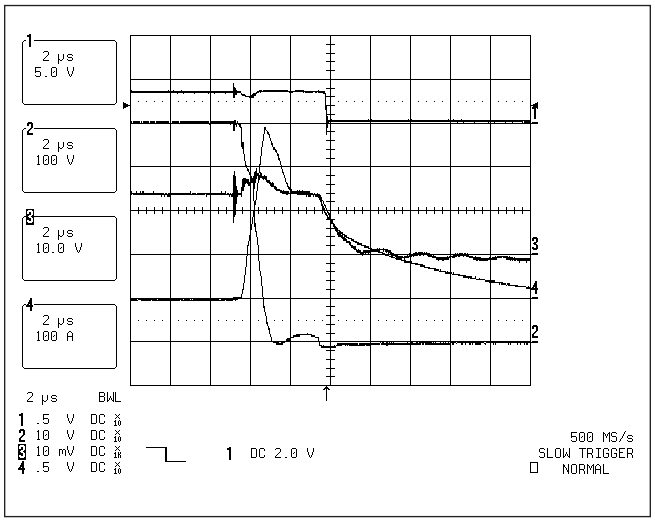


*Figure 3: Short-circuit (phase-to-dc minus) condition:*
*CH1: FAULT*
*CH2: phase voltage*
*CH3: desaturated IGBT gate*
*CH4: phase current (100A/div)*

An internal network manages phase-to-phase short-circuits. The gate drivers synchronize to freeze their state, becoming insensitive to input commands, until the short-circuit current is exhausted. This procedure is necessary to avoid an undesired hard shutdown due to controller command during the soft shutdown sequence. Hard shutdown follows after the soft shutdown procedure has been accomplished. At this time, the fault pin becomes active. The fault clear pin is used to restore the normal operation mode.

## CONCLUSION

The IR2x381 3-phase + brake gate driver family is well suited to light industrial and appliance designs up to 3.5kW, providing valuable protection and control features such as desaturation detection and voltage feedback. The MQFP-64 23.2x17.2 $mm^2$ footprint makes it the smallest full-featured gate driver in the market.

IRMD22381Q Reference Design Kits are also available at www.irf.com.