Alternative to current detection of short circuit or shoot through detection for MOSFETs or IGBTs in motor drive applications

Authors: Van N. Tran  CEL Staff Application Engineer, Opto Semiconductors

Introduction
This paper intends to describe another design concept for short circuit protection scheme by monitoring the voltage across the Vds of a MOSFET or Vce of an IGBT instead of monitoring current through a shunt resistor with a differential amplifier or isolation opto, such as, PS8551A.

In this paper, LTSPICE is used to describe the circuit behavior based on:

1. The Infineon MOSFET, BCS265N10LSFG rated at Vds = 100V, Rds(on)=26.5 mΩ, and Id =40A, MMSD4148 diode rated with Vr = 100V, If = 200 mA, peak forward surge current = 1.0 A, and LT1056, high speed JFET input Opamp SPICE models.

2. Voltage source, V3: Vpk-pk = 0 to 15 V, Ton = 0.1 ms and Tperiod = 0.2 ms (switching frequency = 5KHz)

Description of the circuitry to monitor Vds of a MOSFET
The main monitoring circuit consists of the voltage source V1, R2, R3, C2, and D1. The functions of the D1 are used to monitor Vds of the MOSFET, M1 and to block the voltage, V4 from entering the monitoring circuit. The pulse input signal is provided by the voltage source, V3 to the MOSFET, M1, the motor is modeled by R1 and L1. by virtual of driving inductive loads with transistor switches often result in the high voltage resonant spikes when the coils are interrupted from their current source by the transistor. There are various ways of mitigating these undesirable spikes that cause component failures and EMI issues. The most common approach is to use snubber circuits to limit switching transients and help lower EMI. In this note, the simple RC snubber circuit is formed by the C3 and R8.

The output of the monitoring circuit is connected to the MMSD4148 acting as a comparator with reference voltage at 6V formed by V4, R6 and R7. In other words, 6V across the drain and source of M1 is the trigger point to shut down the MOSFET. This voltage can be varied by changing V4 and the ratio of R7 and R8.

The output of the opamp, MMSD4148 is connected with a low pass filter with cut off frequency = 8KHz formed by R5 and C1 with R4 acting as a load.

Note: All the components in the schematic are referred to the drain of MOSFET, M1 as a point of reference except voltage source V4 and motor ground

Operating under inductive load
The figure 1.0 through 4.0 show how the circuit behaves under normal working condition with an inductive load
Figure 2.0: Input pulse signal to MOSFET, M1 affected by RL circuit (inductive load) and snubber circuit

Figure 3.0: Voltage (green) and current (blue) at the node formed by R1 and L1 (motor load)

Figure 4.0: Output waveform at the node formed by R4, C1, and R5 under transient analysis
The figure 5.0 and 7.0 show the motor that is shorted to ground and what the output waveform looks like.

Figure 5.0: The condition where the motor is shorted to ground

Figure 6.0: Input pulse signal to MOSFET, M1 when the motor is shorted
Operating under a resistive load

The figure 8.0 through 11.0 show what the circuit and waveforms at various points under a resistive load.
Summary

The above description provides an alternative that may fit the need to detect a shoot through at the MOSFETs or IGBTs due to a short circuit condition and to protect the MOSFETs or IGBTs from damage. It also shows how the circuit behaves under inductive versus resistive load and how the snubber circuit can be implemented to reduce the voltage spike due to an inductive load. Please note that the real implementation still needs to be evaluated on the test bench.