**INTRODUCTION**

Current sense amplifiers are used in a variety of applications, such as motor or solenoid control, load current monitoring, and fault detection. In such applications, it is typical for the input common-mode voltage to swing from ground to a certain high-side supply. However, while a user may work with the assumption that the input common-mode swings are limited to this high-side supply, there are transient voltages that must be considered. The result of these transients is that a supposed low voltage application tends to appear as a high voltage application, and the current sense amplifier must be robust enough to handle these occurrences.

**TRANSIENT VOLTAGES IN A MOTOR DRIVE CIRCUIT**

One can consider a motor drive circuit to gain insight into these transient voltage events. The circuit shown in Figure 1 uses the ADuM3223 to drive the gates of two MOSFETs in a half-bridge configuration. The inputs of the ADuM3223 are driven with inverted pulse-width modulation (PWM) signals with duty cycles of 50%, enabling switching between the two MOSFETs.

The node between the emitter of the high-side FET and the collector of the low-side FET is the half-bridge point of the motor drive circuit. This node becomes the connection to the shunt resistor, \( R_{SH} \), and the motor load, represented by an inductance, \( M \). In this circuit, the AD8418, a current sense amplifier, is used to monitor the differential voltage across the shunt resistor. Since this differential voltage is typically a small value in the range of millivolts, the common-mode voltage seen by the current sense amplifier is essentially the voltage at the half-bridge point, and is denoted as \( V_{CM} \) in Figure 1.

When the low-side FET turns on, the half-bridge point is pulled down to ground. When the low side FET switches off and the high side FET turns on, the half-bridge point switches to the bus voltage, \( V_{BUS} \). It is during this momentary switching that transients become apparent. These transients are caused by the fast switching speed of the load, along with the reactive nature it presents to the driver.

![Figure 1. Motor Drive Circuit with the ADuM3223 and the AD8418](image-url)
Figure 2. Common-Mode Voltage at the Half-Bridge Point

Figure 2 shows the common-mode voltage taken at the half-bridge point with a switching frequency of 10 kHz and a bus voltage of 15 V. A close look at the plot shows transients at both swings of the common-mode voltage. The transient at the rising edge reaches almost 8 V, which is more than 50% of the bus voltage. At the falling edge, there is a transient of about −2.5 V. For applications where higher bus voltages and faster switching frequencies are used, the transients may effectively become higher.

CHOOSING AN AMPLIFIER

Figure 3 and Figure 4 show the typical response of the AD8418 to the common-mode voltage transients from the ADuM3223 motor drive circuit. The AD8418 output deviates from the expected voltage by about 30 mV to 40 mV as the common-mode voltage switches, then settles back to the expected output in a few microseconds. The capability of the current sense amplifier to handle these high transients is dictated by its input common-mode voltage range specification. Other amplifiers may have an absolute maximum specification, shown either as the common-mode voltage survival range or the continuous input common-mode voltage.

The Analog Devices, Inc. line of current sense amplifiers are designed to operate with a wide range of input common-mode voltages. The AD8418, for example, has a common-mode voltage survival range from −4 V to +85 V. For applications with larger negative transients, current sense amplifiers such as the AD8202 can survive common-mode voltages down to −8 V.

CONCLUSION

Amplifier choice ultimately depends on the requirements of the current sense application. It is important for the user to recognize the occurrence of common-mode transient voltages and to accommodate these when choosing the appropriate amplifier. The varied input common-mode voltage ranges of the line of current sense amplifiers from Analog Devices provide the user with flexibility for these considerations.