High-Side Motor Current Monitoring for Over-Current Protection

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High power, precision motor systems commonly require detailed feedback such as speed, torque and position to be sent back to the motor control circuitry in order to precisely and efficiently control the motor's operation. Other motor control applications, such as fixed motion tasks, do not require the same level of system complexity in order to carry out their jobs. Ensuring that the motor has not stalled or encountered an unintended object in the motor's path or that a short in the motor's winding exists can frequently be all of the information provided back to the motor control circuitry. More complex motor control systems implementing dynamic control and active monitoring can also benefit from adding simple out-of-range detection function because of the faster indication of out-of-range events.

By placing a current sense amplifier in series with the DC power supply driving the high side of the motor drive circuitry as shown in Figure 1, the overall current to the motor can be measured easily detecting out-of-range conditions. To detect small leakages the low-side return current can also be measured. A difference between the high-side and low-side current levels indicates a leakage path exists within the motor or motor control circuitry.

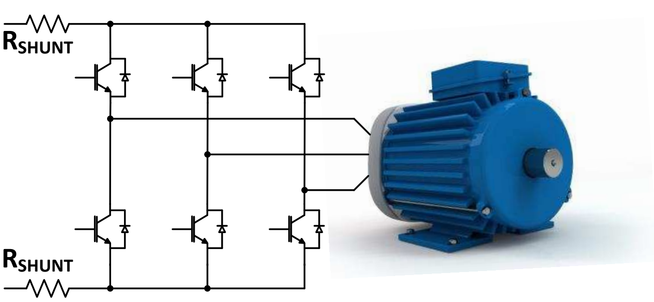

Figure 1. Low & High-Side Current Sensing

The DC voltage level varies depending on the voltage rating of the motor leading to multiple current measurement solutions to accommodate the corresponding voltage levels. For low voltage motors (~5V) the selection of a circuitry to monitor this current is much simpler with multiple amplifier types (current sense, operational, difference, instrumentation) are able to perform the current measurement function to support this common-mode input voltage range.

For larger voltage motors (24V and 48V for example), the available options decrease down to dedicated current sense and differential amplifiers. As the voltage requirements continue to increase, measurement errors begin to impact the ability to effectively identify out-of-range conditions. One specification that describes an amplifier's effectiveness at operating at high input voltage levels is the common-mode rejection (CMR) term. This specification directly describes how well an amplifier's input circuitry can reject the influence of large input voltages.

Ideally, an amplifier is able to completely reject and cancel out any voltage common to both input pins and amplify only the differential voltage seen between them. However, as the common-mode voltage is increased, leakage currents in the amplifier's input stage result in additional input offset voltage. Larger input range levels being monitored will create proportionally larger measurement errors.

For example, an amplifier (difference amplifier or current sense amplifier) that has a CMR (Common-Mode Rejection) specification of 80dB will have a significant offset voltage introduced in the measurement based on the input voltage level. An 80dB CMR specification corresponds to an additional 100µV of offset voltage induced into the measurement for every volt applied to the input.

Many devices are specified under defined conditions (V_{CM} = 12V and V_S = 5V for example) which establishes the base-line for the default specifications (CMR and PSRR specifically). In this example operating at 60V common-mode voltage creates a change in V_{CM} of 48V (60V-12V). A 48V change with a 80db CMR results in an additional 4.8mV of offset voltage in addition to the specified input offset voltage found in the device's datasheet.

Applications employing calibration schemes are less concerned by this additional induced offset voltage. However, for applications where system calibration cannot account for this shift in offset, selection of an amplifier with better common-mode voltage rejection is required.

The INA240 is a dedicated current sense amplifier with a common-mode input voltage range of -4V to +80V and a worst case CMR (Common-Mode Rejection) specification of 120dB over the entire input and temperature range of the device. 120dB of CMR corresponds to an additional 1µV of input offset voltage induced for every 1V change in common-mode voltage. The temperature influence on the amplifier's ability to rejection common-mode voltages is not well documented in many product datasheets so it should be evaluated in addition to the room temperature specification. The INA240 maintains a guaranteed 120dB CMR specification over the entire -40ºC to +125ºC temperature range. The typical CMR performance for the INA240 over the entire temperature range is 135dB (less than 0.2µV for every 1V change) as shown in Figure 2.

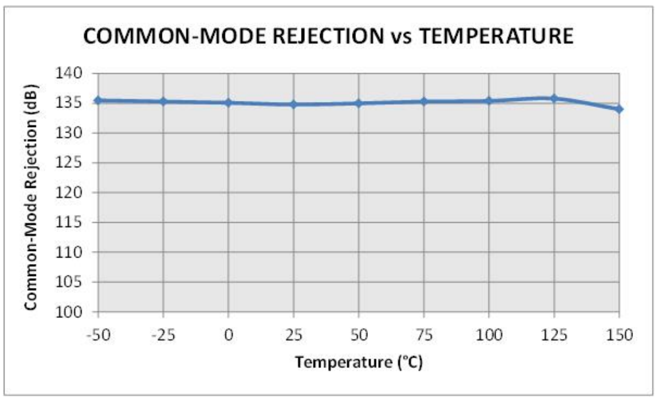

Figure 2. Common-Mode Rejection vs. Temperature

A system controller has the ability to utilize the current sense amplifier's measurement to evaluate the operation of the system. Comparing the current information to pre-defined operating threshold allows for detection of out-of-range events. A comparator following the high-side current sense amplifier can easily detect and provide alerts quickly to the system allowing for corrective actions to be taken.

Figure 3 illustrates the signal chain path for monitoring and detecting out-of-range excursions when measuring currents on a high voltage rail driving the motor drive circuitry. The output signal proportional to the measured input current is directed to the ADC in addition to be sent to the comparator to detect overcurrent events. The comparator alert will assert if the input current level exceeds the predefined threshold connected as the comparators reference voltage.

A key requirement for over-current detection circuitry is the ability to detect and respond quickly to out-of-range conditions. A signal bandwidth 100kHz and 2V/µs allows for the INA240 to accurately measure and amplify the input current signal, send the output to the high-speed comparator for an alert to be issued based on a shorted condition in the span of a few microseconds. This fast response ensures other critical system components are not damaged by the unintended excess current flowing in the system.

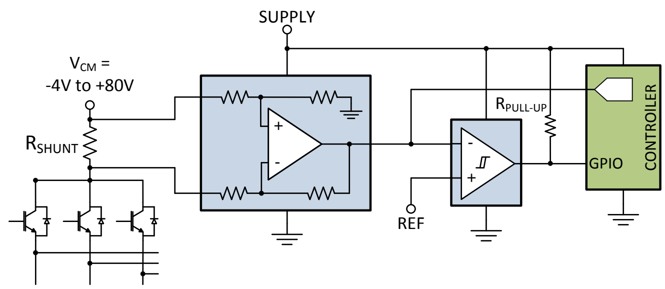

Figure 3. High-Side Over-Current Detection

Alternate Device Recommendations

For applications measuring high voltage capability needing a faster signal bandwidth or smaller package, use the LMP8640. For applications requiring higher voltage capability, the INA149 is a high performance difference amplifier capable of interfacing with common-mode voltages up to +/-275V off of a +/-15V supply and has a guaranteed CMR of 90dB (or 31.6µV for every 1V input change). The INA301 is a precision current sense amplifier with an on-board comparator that is ideal for detecting over-current events on common-mode voltages up to 36V.

Table 1. Alternate Device Recommendations

Device	Optimized Parameter	Performance Trade-Off
LMP8640HV	Package: SOT23-6, Signal Bandwidth	Accuracy
INA149	V_{CM} Range: +/-275V	CMR, Gain
INA301	On-Board Comparator; 35µV V_{OS}	V_{CM}: 0V to 36V

Table 2. Related TI TechNotes

SBOA160	High Precision, Low-Drift In-Line Motor Current Measurements
SBOA161	Low-Drift, Low-Side Current Measurements for Three-Phase Systems
SBOA162	Measuring Current To Detect Out-of-Range Conditions
SBOA165	Precision Current Measurement On High Voltage Power Rail

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