Sensors are critical in a motor control application. Sensors provide valuable information such as torque, temperature, position and speed. Today’s advancements in sensor technologies have enabled improvements in accuracy, performance, cost and reliability. Today’s technology also allows for integration of multiple features within a sensor that are focused on solving system level challenges. In motor control, several sensors are being used for feedback and protection. One of the key components for motor control feedback and protection is the current sense amplifier.

**Low-side Phase Current Sensing**

In a motor control for DC brushed or brushless drive architectures, low-side current sensing is one of the most cost effective solutions to measure currents due to lower common mode. Low-side sensing is accomplished using an external shunt connected between the controller ground and the system ground as shown in Figure 1. One of the fundamental requirements for using low-side sensing is that the amplifier should be able to support common mode voltages below ground. As the external shunt is connected between the controller ground and system ground, its is critical that the layout of the shunt and current sense amplifier be optimized to maximize current measurement accuracy. Current sense amplifiers from Texas Instruments are specifically designed and factory trimmed to ensure the overall system errors.

**Over Current Protection**

One of the key features that is implemented in motor control circuitry is over current protection (OCP). In the system the output current from low-side is sampled by the ADC in the processor. If the processor detects the sampled output current has exceeded the threshold, the controller can be shutdown. While this is the simplest approach to achieve OCP the disadvantage with this implementation is the latency added by the ADC conversion. If faster protection is needed a dual comparator can be connected as shown in Figure 3. The two outputs of the comparator can easily be connected to the GPIO to trigger a shutdown command sequence or action when an alert is identified. One of the drawbacks of using the low-side sensing with dual comparator is the increase in the number of components needed to accomplish OCP.
The INA303 includes a high common-mode, bi-directional current-sensing amplifier and two high-speed comparators configured to detect overcurrent conditions. The INA303 comparators are in a window configuration. The device features an adjustable limit threshold range for each comparator set using an external limit-setting resistor. This current-shunt monitor can measure differential voltage signals on common-mode voltages that can vary from 0 V up to 36 V, independent of the supply. The open-drain alert outputs can be configured to operate in either a transparent mode (output status follows the input state) or in a latched mode (alert output is cleared when the latch is reset). The alert response time for comparator one is under 1 µs while the alert response for comparator two is set through an external capacitor ranging from 3 µs to 10s.

Figure 4 describes the configuration of INA303 in a low-side motor drive application for phase1. For phase2 and phase3 measurements two additional INA303 will be required. The INA303 has a maximum offset voltage of 35µV and a drift of 0.5µV/°C. Low offset, drift and gain error enable accurate measurements across temperatures. With an output slew rate of 4V/µs, the phase currents can be measured accurately at lower duty cycles with narrow pulses. A 1µs delay on ALERT1 and an adjustable delay on ALERT2 pin from 3µs to 10s enables optimization for various applications. The Analog output of INA303 can be connected to the ADC of the processor. While the two comparator outputs can be connected to GPIOs of the processor. The threshold of the comparator1 can be set by RLIMIT1 resistor. The lower threshold for comparator2 can be set using RLIMIT2 resistor. This configuration can ensure that the motor and the controller can be protected against damage by ensuring the current remains within the safe operating region.

<table>
<thead>
<tr>
<th>Device</th>
<th>Optimized Parameter</th>
<th>Trade-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>INA300</td>
<td>Package</td>
<td>No analog output, slower response</td>
</tr>
<tr>
<td>INA301</td>
<td>Response time, Package</td>
<td>Single alert</td>
</tr>
<tr>
<td>INA302</td>
<td>Warning &amp; Critical Alert Capability</td>
<td>Not configured as a window comparator</td>
</tr>
<tr>
<td>INA181</td>
<td>Package: SC70-6 &amp; SOT23-6, Lower Cost</td>
<td>Amplifier only</td>
</tr>
</tbody>
</table>

Table 2. Related TI TechNotes

- SBOA162 Measuring Current To Detect Out-of-Range Conditions
- SBOA163 High-Side Motor Current Monitoring for Over-Current Protection
- SBOA168 Monitoring Current for Multiple Out-of-Range Conditions
- SBOA190 Low-Side Current Sense Circuit Integration
- SBOA192 External Current Sense Amplifiers vs Integrated On-Board Amplifiers for Current Sensing
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