Reliably Detect Faults In Circuit Breakers with Contactless Inductive Switches

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Circuit breakers are commonly used to manage the flow of electricity within a home or office but their reliable functionality is often taken for granted. Circuit breakers rely on making a solid electrical contact between the AC mains and the rest of the circuitry with the ability the open the circuit in the case of a short circuit or power surge. While this is a very robust method towards managing the flow of electricity, there is no inherent indication when the electrical connection is solid or barely making contact. Over time, the mechanical portion of the circuit also wears down making it more likely to get stuck halfway or make a marginal contact representing a potential failure point in the system.

Through the use of contactless inductive switches, the state of the circuit breaker can be remotely monitored regardless if a solid electrical contact is being made or not. This TechNote covers the basics of implementing inductive switches in a side-by-side configuration that can be used to reliably detect the health of circuit breakers and give the user a warning to take action.

**Desired Circuit Breaker States for Detection**

Figure 1 shows an example of the normal engaged/disengaged states as well as the undesirable region in the middle where a typical circuit breaker would fail or improperly work.

![Figure 1. Circuit-breaker States](image)

By using a contactless switching technology such as the LDC0851 differential inductive switch, you can detect the position of the metal lever itself rather than requiring the electrical contact. Thus, if the switch wears down, gets stuck in the middle or creates a partial contact, the LDC0851 will still be able to detect this state and alert users to take action through a simple LED warning or message. Note that this contactless approach also means that the LDC0851 is not affected by any of the AC or DC currents that are flowing in the system.

**Inductive Switch Implementation**

A 3-state slider switch can be implemented with two LDC0851 devices as shown in Figure 2.

![Figure 2. Dual LDC0851 Configuration](image)

Since the latch of the circuit breaker is made of metal it can be reused as the target for the LDC0851 to sense its position. The orientation of the coils can be adjusted to align the desired angle of the circuit breaker to a predetermined LDC0851 output state.

**Sensor Orientation for 3-State Switching**

With the switch fully engaged, both reference coils (LREF #1 and LREF #2) are covered, causing the push/pull outputs of both LDC0851 devices to have a high output state. When the switch is fully disengaged, both sense coils (LSENSE #1 and LSENSE #2) are covered, causing both LDC0851 devices to have a low output state.
output state. When the switch is anywhere in the middle, representing an unintentional state, LREF #1 and LSENSE #2 are covered, causing one LDC0851 to have a high output and the other LDC0851 output to have a low output respectively. These states are represented with a simple yellow and red LED display, but a more sophisticated message display is possible. Figure 3 shows the functional operation.

### Circuit Breaker State

<table>
<thead>
<tr>
<th>Circuit Breaker State</th>
<th>Output Pattern</th>
<th>Coil with most metal coverage/least inductance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully disengaged (Tripped)</td>
<td>0</td>
<td>LSENSE #1</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>LSENSE #2</td>
</tr>
<tr>
<td>Partially engaged (Fault)</td>
<td>1</td>
<td>LREF #1</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>LSENSE #2</td>
</tr>
<tr>
<td>Fully engaged (Normal operation)</td>
<td>1</td>
<td>LREF #1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>LREF #2</td>
</tr>
</tbody>
</table>

Figure 3. LDC0851 Coil-target Orientation

### Prototyping with the LDC0851

In order to test the concept, I 3-D printed a circuit breaker mockup and added copper tape to the lever to simulate a metal target; see Figure 4. I used two of the LDC0851EVMs configured as side-by-side coils with coil E from the LDCCOILEVM (1). Note that the inductor coils do not need to make electrical contact with the lever, so they are placed at a nominal 1mm distance from the lever. Additionally, the LDC0851 provides stable operation over temperature and is not affected by environmental contaminants. A video of this circuit breaker prototype can be found online (2).

Figure 4. Circuit Breaker Prototype with LDC0851

### Alternative Device Recommendations

For applications that need high resolution output data, the previous generation of LDC devices (LDC1612, LDC1312, and LDC1101) can also be used to implement the slider functionality. The LDC1612 and LDC1312 devices are general purpose inductance-to-digital converters that offer multiple channels and enable linear position sensing with a single device. The LDC1101 is a single channel, high speed general purpose device that can sample up to 180 ksps.

(1) See blog [Prototype side-by-side coils in four easy steps](#) for guidance on quick prototyping for the LDC0851.

(2) [Circuit breaker video](#)

### Table 1. Device Recommendations

<table>
<thead>
<tr>
<th>Device</th>
<th>Optimized Parameter</th>
<th>Performance Trade-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDC0851</td>
<td>No registers to program, simple push/pull interface, lower power (for duty cycled applications)</td>
<td>Requires multiple devices to achieve more than 2 states</td>
</tr>
<tr>
<td>LDC1612, LDC1312</td>
<td>Multiple channels, higher resolution</td>
<td>Higher power consumption and requires microcontroller to program device and process data</td>
</tr>
<tr>
<td>LDC1101</td>
<td>Highest sample rate</td>
<td>Higher power consumption and requires microcontroller to program device and process data</td>
</tr>
</tbody>
</table>
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