OTHER ST PRODUCTS TO CHECK

ADC120 ADC1283	ISOSD61	STISO621
12-bit ADC converter 8 channels Speed 50ksps to 1Msps ENOB 11.7 bits	16-bit isolated Sigma-Delta modulator Input range ±320mV Output 25Msps 1-bit stream	Digital isolator Dual channel for UART Up to 100Mbps

GLOSSARY

Bidirectional – Ability of the device to measure current in both negative and positive directions.

Unidirectional – Unidirectional current sensing measures current in one direction only. The opposing direction is sensed as zero.

Output common mode – Shift of the output voltage by a certain Vref in order to allow bidirectional measurement. When using op amps, a small output common mode also prevents output from entering saturation and therefore provides better response to small currents.

Input Common mode voltage – Common voltage which is applied to both inputs of the circuit. This voltage is not part of the useful signal and should not be amplified.

Common mode rejection ratio (CMRR) – Measure of a device's ability to filter out the common mode voltage. This is important for high-side or in-line current sensing.

H-bridge – Transistors connected in such a way as to control voltage and its polarity applied to the load.

Gain bandwidth product (GBP) – Product of the gain and maximum small signal frequency. A circuit able to amplify 10kHz with 40dB gain has the same GBP as a circuit amplifying 100kHz with 20dB gain. This parameter is specified in op amp datasheet.

Bandwidth (BW) – Signal frequency at which the amplitude drops by 3dB. This is specified in datasheets for current sense monitors.

Input offset voltage (Vio) – Differential input voltage of the In+ and In- pins to obtain the output at the mid-range of the supply voltage. It originates from the matching of internal transistors.

Input offset voltage drift (dVio/dT) – Drift of the input offset voltage with temperature. This might be important for motor control applications.

Input bias current (Iib) – Current flowing through device inputs. Due to device biasing requirements and normal operation leakage, a very small amount of current (pA or nA range, depending on the technology) flows through its inputs.

Zero drift – Technology designed to self-correct device parameters by compensating Vio errors and those occurring with temperature and with time. Zero drift or chopper devices have their Vio in the order of microvolts and nanovolts per Celsius degrees drift. Zero drift virtually cancels 1/f noise and mitigates aging over time.

Rail-to-rail input – An op amp with a high-rail input can work with input signals up to Vcc+, while a low-rail input is able to deal with signals down to Vcc-. Rail-to-rail input op amps can handle input signals from Vcc- to Vcc+.

EMI filter – filter to suppress the impact of electromagnetic interferences. As current sensors are always connected to external wires, some external sources may produce EMI disturbance. Current sense monitors and some high-performance op amps usually feature embedded EMI filters.

For more information, visit us on http://www.st.com/current-sense-amplifiers and www.st.com/opamps

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Current Sensing
Quick reference guide

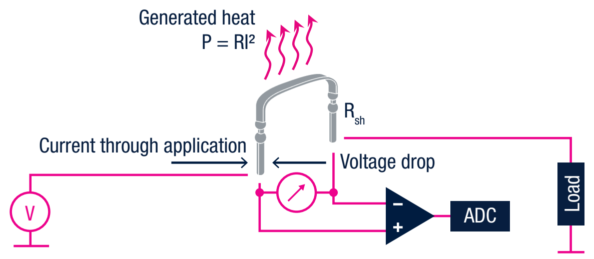
Current sensing is important in many industrial and automotive applications like motor control, battery management, power management, and many others.

ST provides solutions for these applications based on operational amplifiers and integrated current monitors for shunt current sensing.

HOW DOES IT WORK ?

Our current sensing solution involves a shunt resistor and the straightforward application of Ohm's law. A tiny resistance is placed on the current path and the linear voltage drop is amplified to derive a precise current measurement.

All resistors dissipate power in the form of heat, and this unwanted effect is also present to some extent in shunt resistors. While a lower shunt resistance will minimize the impact, the drawback is that higher amplification gain will be required, which lowers overall measurement precision.



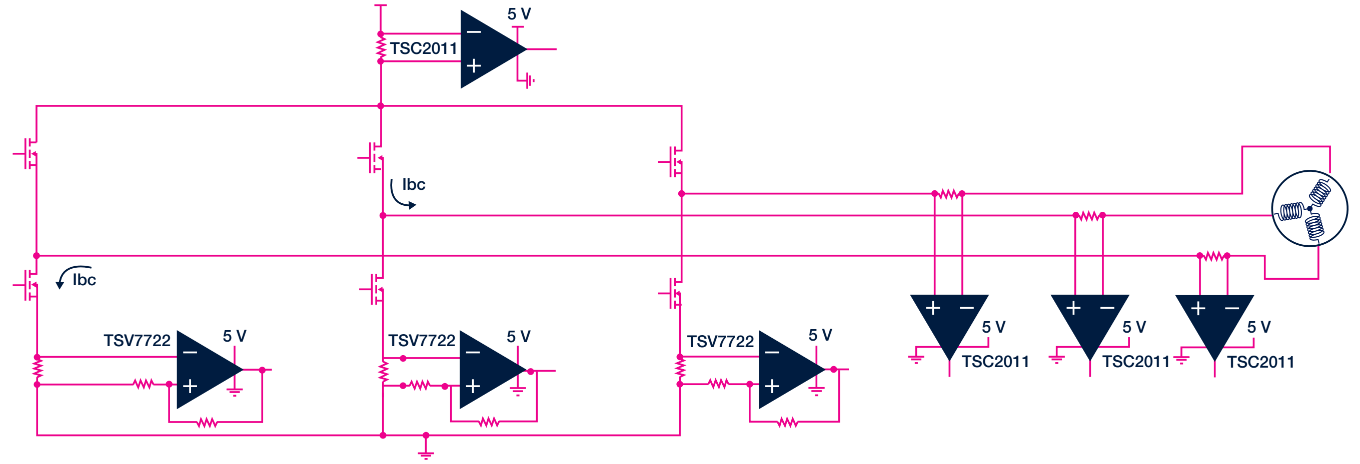
POSITION OF THE SHUNT

Shunt resistors can be placed in several different locations to measure current through an application. Each of them has certain advantages and disadvantages.

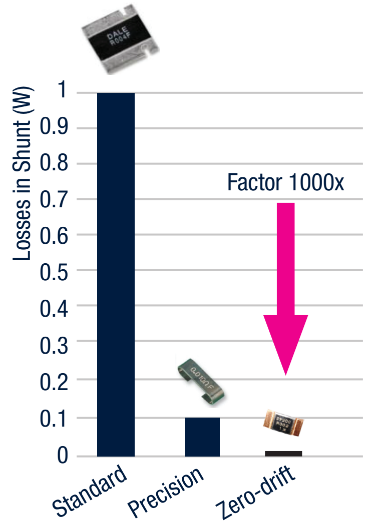
High-side – Shunt resistor is placed on the power rail. In this case, the current sensor is directly on the supply voltage, so its maximum input common mode voltage needs to be high enough to manage the supply voltage. High-side shunt resistors are used in applications where ground cannot be cut for mechanical reasons, RF disturbances, or other currents flowing to ground.

In-line – Also called phase current sensing. Shunt resistors can be placed in line with motors in motor control applications, but this requires bidirectional current sense monitoring. While it offers the advantage of tracking current all the time, fast voltage transients will be present due to the switching activity of the H bridge, and the device must be able to recover quickly after such common mode voltage shifts.

Low side – In this case, the shunt is place on the ground line, so the common mode voltage is close to 0V, and low voltage technology is sufficient. This is a popular solution because simpler and cheaper op amps can be employed.



SHUNT RESISTOR VALUE AND SIZE



Note: output precision is the same

Shunt value selection involves balancing dynamic range and power dissipation. Lower shunt values inflict smaller losses, but higher amplification gain is needed, and devices having a certain gain bandwidth product (GBP) incur a slower response dealing with higher gains.

The precision of current amplifiers have a large impact on final shunt values and power dissipation. High precision devices can work with higher gain to maintain the same output accuracy as standard components, while allowing smaller shunt values.

To calculate critical shunt values and sizes, the total current range must be known. While the range is simply the maximum current for unidirectional measurement, the maximum currents in each direction must be summed for bidirectional readings. Given the current range, along with the maximum output voltage and gain, the following equations provide the maximum value of the shunt and its power dissipation.

$$R_{sense} \leq \frac{V_{outMax}}{I_{range} \cdot Gain} \qquad P_{Max} \geq R_{sense} \cdot I^2_{max}$$

The final shunt value should always be smaller than the theoretical value to account for imperfections and errors. A smaller shunt value also gives some margin to measure overcurrent and prevent saturation. The maximum power dissipation of the shunt resistor must be higher than the calculated value.

ST PRODUCT AND PORTFOLIO

Unidirectional current monitors	TSC101A TSC101B TSC101C SOT23-5 Operating 2.8 to 30V Gain x20 x50 x100	TSC888A TSC888B TSC888C SOT23-5 Operating 2.8 to 24V Gain x20 x50 x100	TSC102 TSSOP8 SO8 Operating 2.8 to 30V Gain x20 adj. TSC1021 TSSOP8 Operating 2.8 to 30V Gain x20 x50	TSC103 TSC1031 TSSOP8 SO8 Operating 2.9 to 70V AMR -16 to 75V Gain x50 x100 TSC200 MiniSO8 SO8 Operating 2.7 to 18V Gain x20
Bidirectional current monitors	TSC2010 TSC2011 TSC2012 MiniSO8 SO8 Operating -20 to 70V Bandwidth 600kHz Gain x20 x60 x100	TSC210 TSC211 TSC212 SC70-6 QFN10 Operating -0.3 to 26V Gain x200 x500 x1000 Vio max 35µV	TSC214 TSC215 SC70-6 QFN10 Operating -0.3 to 26V Gain x100 x75 Vio max 60µV	TSC213 SC70-6 QFN10 Operating -0.3 to 26V Gain x50 Bandwidth 100kHz Vio max 100µV
Operational amplifiers	TSV7722 TSV772 Dual Operating 2.0 to 5.5V Low rail/R2R input Vio max 200µV GBP typ 20MHz	TSV782 TSV792 Dual Operating 2.2 to 5.5V R2R input Vio max 200µV GBP 30/50MHz	TSZ181 TSZ182 Single / dual Operating 2.2 to 5.5V Vio max 35µV (44µV) GBP typ 3MHz	TSB7191A TSB7192A Single / dual Operating 2.7 to 36V Vio max 300µV GBP typ 22MHz

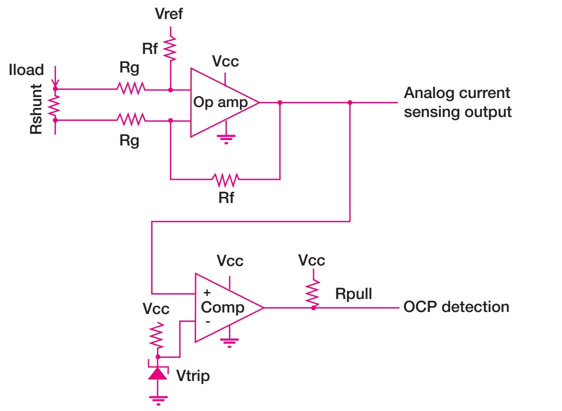
Automotive-grade version available

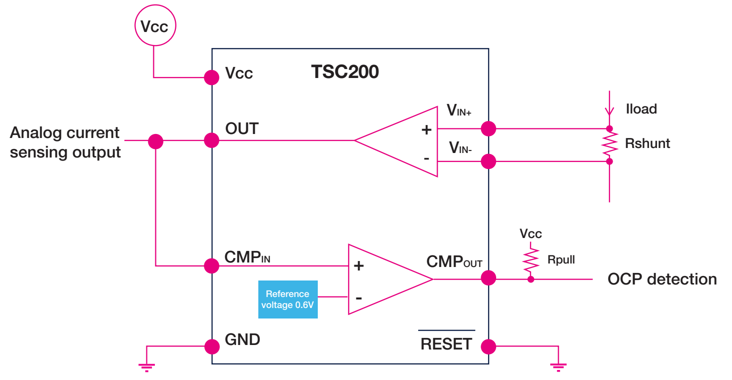
Extended temperature range (-40 to+150°C) available

INTEGRATED OVERCURRENT PROTECTION (OCP) VS OP AMPS

One of the key points in preventing damage in an application is the ability to measure current variations very quickly and accurately.

Current sensing with a comparator circuit is a method commonly used to detect an overcurrent. In many applications with input common mode voltage below 30V, the choice between a current sense monitor or operational amplifier is a matter of designer preference.





Op-amp OCP

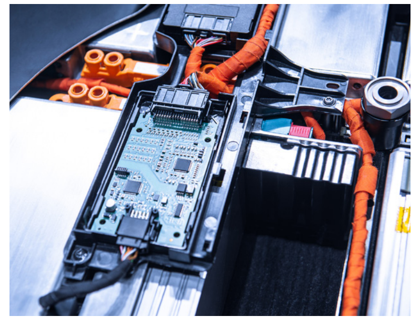
- Flexible solution
- External components needed
- Common mode voltage limited to Vcc
- Can be costly if accuracy and speed are expected

Integrated OCP

- Only one device so BOM and PCB area saving
- Fast response time
- Low-side and high-side with common mode higher than Vcc

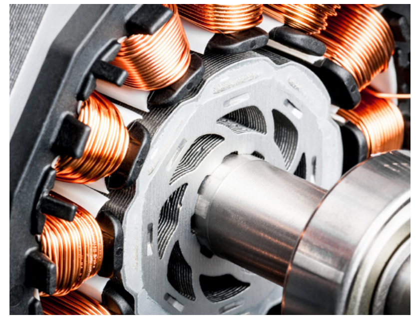
APPLICATIONS

Battery management systems



Battery management systems require bidirectional and very high precision current sensing to minimize energy losses. The sensing rate is usually low, and both high-side and low-side can be adopted. Isolated current sensing is not required up to 48V.

Low voltage motor control



Driving a motor requires sufficient sensing rates for correct operation. Shunt power dissipation is negligible with respect to the consumption of the motor, so some energy losses can be sacrificed for faster sensing. Bidirectional in-line or unidirectional high-side current sensing is usually preferred.

Wireless infrastructure

Current sensing is important in power amplifiers to monitor the performance and to maximize the efficiency. It also helps reduce overall energy consumption of base stations, as well as their environmental impact and cost of use. The integrated comparator can detect overcurrent events and switch off the power amplifier, preventing damages.