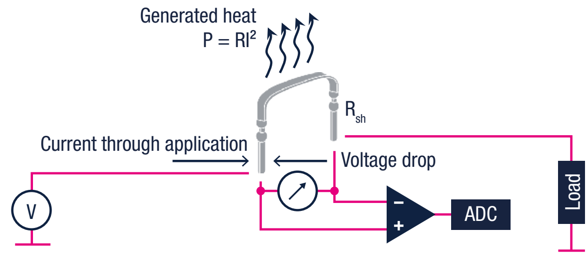
Current Sensing
Quick reference guide

Current sensing is critical in industrial and automotive applications such as motor control, battery management, and power management.

ST offers solutions based on **operational amplifiers** and integrated current monitors for shunt current sensing.

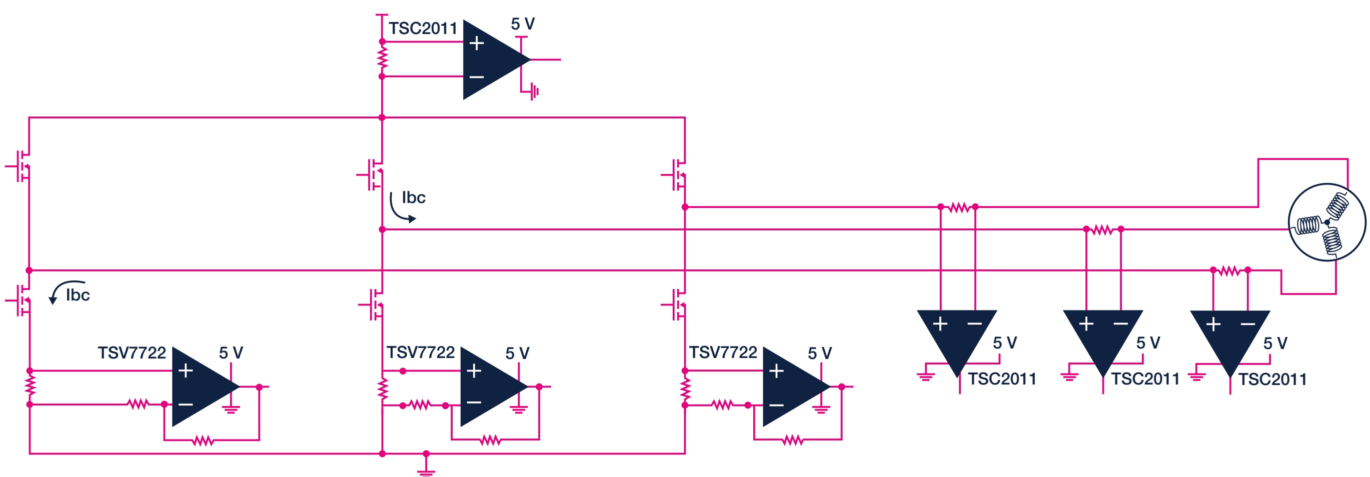
HOW DOES IT WORK ?

Our current sensing solution involves a shunt resistor and Ohm's law to obtain an accurate current measurement. Shunt resistors dissipate power in the form of heat, which affects measurement precision. Lower shunt resistance minimizes the impact, but higher amplification gain is required, which lowers overall measurement precision.

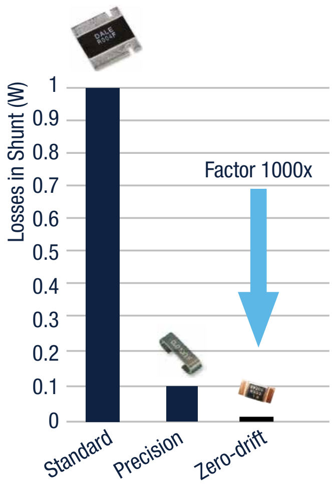


POSITION OF THE SHUNT

Shunt resistors can be placed in different locations to measure current through an application, each with its advantages and disadvantages. High-side shunt resistors are used when ground cannot be cut, in-line shunt resistors require bidirectional current sense monitoring, and low-side shunt resistors are popular due to the use of simpler and cheaper op amps.



SHUNT RESISTOR VALUE AND SIZE



Note: output precision is the same

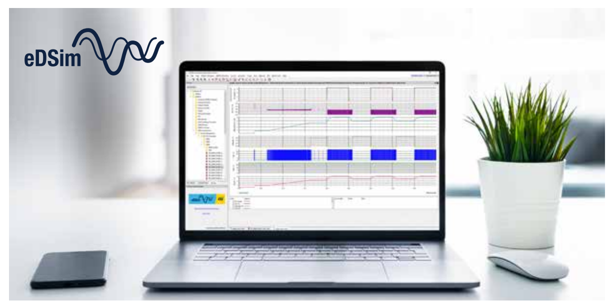
Selecting the appropriate shunt value involves balancing dynamic range and power dissipation. Lower shunt values result in smaller losses but require higher amplification gain, which may decrease measurement precision. High precision current amplifiers allow for smaller shunt values. To calculate critical shunt values and sizes, the total current range must be known, and equations can provide the maximum shunt value and 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 be smaller than the theoretical value to account for imperfections and errors, and to prevent saturation. A smaller shunt value also provides a margin to measure overcurrent. The maximum power dissipation of the shunt resistor must be higher than the calculated value.

SIMULATION TOOL

Design and simulate your current sensing circuits with ease using the powerful **eDesignSuite** and **eDSIM** tools.



APPLICATIONS

Battery management systems

To minimize energy losses, battery management systems require bidirectional and highly precise current sensing. While the sensing rate is typically low, both high-side and low-side sensing can be used. Additionally, isolated current sensing is not necessary for systems with voltage levels up to 48 V.

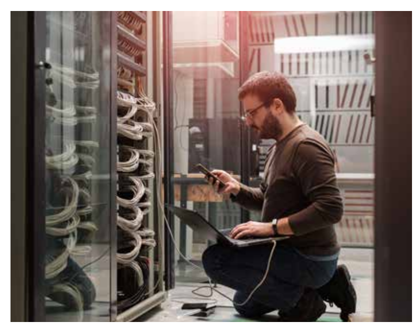
Learn more about **current sensing for battery management system**

48 V motor control

To drive a motor correctly, it is necessary to have sufficient sensing rates. While some energy losses can be sacrificed for faster sensing, shunt power dissipation is typically negligible compared to the motor's consumption. For current sensing in motor applications, bidirectional in-line or unidirectional high-side sensing is often preferred.

Discover **current sensing solutions for motor control**

Server power



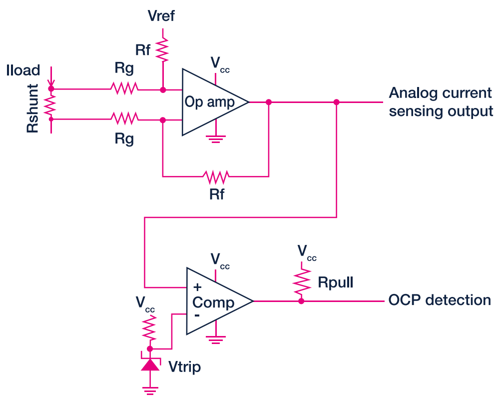
Current sensing is very important for server power management, enabling efficient operation and energy savings. High-side sensing is favored for its non-intrusive measurements. Fast sensing rates are essential to accommodate the dynamic power requirements of servers, ensuring consistent performance and system stability.

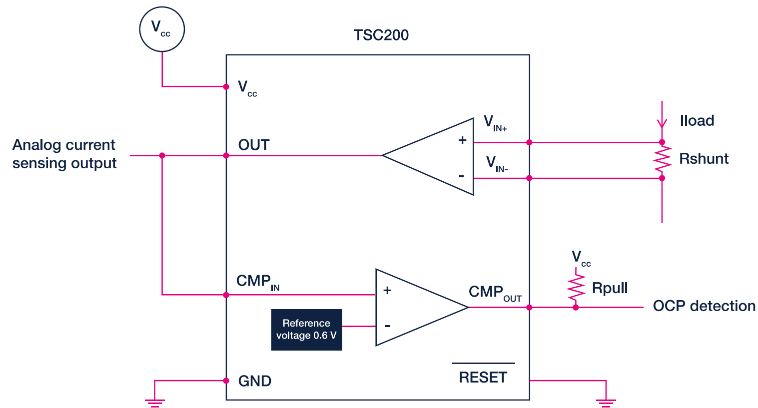
Learn more about **general compute servers**

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 30 V, the choice between a current sense monitor or operational amplifier is a matter wwof designer preference.





Op-amp OCP

- Flexible solution
- External components needed
- Common mode voltage limited to V_{cc}
- 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 V_{cc}

ST PRODUCT AND PORTFOLIO

Unidirectional current monitors

TSC101	TSC888	TSC102 / TSC1021	TSC103 TSC1031	TSC200 TSC201 TSC202
SOT23-5 Operating 2.8 to 30 V Gain x20 x50 x100	SOT23-5 Operating 2.8 to 24 V Gain x20 x50 x100	TSC102 TSSOP8, SO8 Operating 2.8 to 30 V Gain x20 adj. **TSC1021** TSSOP8, SO8 Operating 2.8 to 30 V Gain x20 x50	TSSOP8, SO8 Operating 2.9 to 70 V Gain x20 x25 x50 x100	MiniSO8, SO8 Operating -16 to 80 V Gain x20 x50 x100

Bidirectional current monitors

TSC2010 TSC2011 TSC2012	**TSC210 TSC211/12 TSC213/14/15	TSC2020 TSC2021 TSC2022	TSC240	TSC1801
MiniSO8, SO8 Operating -20 to 70 V Gain x20 x60 x100 Vio max 200 µV	SC70-6, QFN10 Operating -0.3 to 26 V Gain x200 x500 x1000 x50 x100 x75 Vio max. 35, 60, 100 µV	MiniSO8, SO8, TSSOP8 Operating -4 to 100 V Gain x20 x50 x100 Vio max. 150 µV	SO8, TSSOP8 Operating -4 to 100 V Gain x20 x50 x100 x200 Vio max. 25 µV	SOT23-6 Operating 2.0 to 5.5 V Gain x20 Vio max. 200 µV

Operational amplifiers

TSV77 series	TSV79 series / TSV78 series	TSZ18 series / TSZ15 series	TSZ901 / TSB719 series	TSB18 series
Operating 2.0 to 5.5 V Vio max. 200 µV GBP 20 MHz	TSV79 series Operating 2.2 to 5.5 V Vio max. 200 µV GBP 50 MHz TSV78 series Operating 2 to 5.5 V Vio max. 200 µV GBP 30 MHz	TSZ18 series Operating 2.2 to 5.5 V Vio max. 25 µV GBP 3 MHz TSZ15 series Operating 1.8 to 5.5 V Vio max. 7 µV GBP 1.6 MHz	TSZ901 Operating 2.5 to 5.5 V Vio max. 5 µV GBP 10 MHz TSB719 series Operating 2.7 to 36 V Vio max. 300 µV GBP 22 MHz	Operating 4 to 36 V Vio max. 20 µV GBP 3 MHz

Automotive-grade version available

STEVAL-AETK2V1 (TSC210/13)
STEVAL-AETK1V2 (TSC210/11/12)
STEVAL-AETKT3V1 (TSC200/1/2)
STEVAL-AETKT4V1 (TSC2020/21/22)

Extended temperature range -40 to +150°C and 175 °C available for op amp

- Available in KIT24O PAMP
- Available in KIT2407AUTOSC

** Product available in training kit

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 V_{ref} 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 10 kHz with 40 dB gain has the same GBP as a circuit amplifying 100 kHz with 20 dB gain. This parameter is specified in op amp datasheet.

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

Input offset voltage (V_{io})–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 (dV_{io}/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 V_{io} errors and those occurring with temperature and with time. Zero-drift or chopper devices have their V_{io} 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 V_{cc+}, while a low-rail input is able to deal with signals down to V_{cc-}. Rail-to-rail input op amps can handle input signals from V_{cc-} 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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