CURRENT SENSING USING RESISTIVE SHUNTS
What is current sensing?
Common Methods of Current Sensing
High/Low Side Resistive Sensing
Challenges of Resistive Sensing
A method of determining the current drawn to a load

Not necessarily measuring current

- Voltage
- Magnetic Field

Large range of measurements

- μA to kA
- Requires different techniques depending on what level of current is being drawn
USES OF CURRENT SENSING

- Over-current Protection
  - Prevents equipment failure
  - Helps ensure safety

- Performance Monitoring
  - Improves throughput
  - Reduces waste

- Power Consumption
  - Monitoring of current draw can help improve efficiency
  - Can be useful in trend analysis of a system
A flux field is generated, the toroid senses the field, special IC measures and amplifies induced voltage.

Advantages:
- Handles high currents
- No insertion loss

Disadvantages:
- Large Size
- Expensive

http://www.allegromicro.com/en/Products/Design/unipolar/images/fig2.jpg
Uses transformer to read current in one winding induced by the other

Advantages:
- No offset voltage
- No external power required

Disadvantages:
- Large Size
- Expensive
- Requires AC

http://www2.electronicproducts.com/images2/F64DATAD0506.gif
RESISTIVE SHUNT CURRENT SENSING

- Ohm’s Law used to create voltage drop
- Voltage drop is measured by an IC
- IC amplifies voltage drop
- Can use high or low side
- Advantages:
  - Speed
  - Size
  - Accuracy
- Disadvantages:
  - Insertion loss
  - Low current
Places shunt resistor between the power source and the load

- Advantages:
  - Can trigger necessary action before current flows through the load
  - Does not add any disturbance to ground

- Disadvantages:
  - Requires very careful resistor matching to ensure the differential amplifiers have a precise measurement
  - Eliminated with the use of a current shunt monitor

HIGH SIDE MEASUREMENT

TI INA138

Low Side Measurements

- Places shunt resistor from the load to ground.

**Advantages**
- Simple and low cost
- Most accurate current sensing method

**Disadvantages**
- Adds unnecessary resistance in the ground path
- Circuit faults may occur before being noticed by the sensing instrument
- Current sent to an antenna in the load may not be measured

[Diagram of Low Side Measurement](http://focus.ti.com/en/graphics/aap/general/figure2.gif)
LOW SIDE MEASUREMENT

CHALLENGES OF RESISTIVE SHUNT SENSING

- Low resistance
- Offset voltage
- Noise
- Finite gain
CHALLENGE: LOW RESISTANCE

- Minimize impact
  - Maintain original signal to load
  - Typically 10 – 100m Ω
  - Keep voltage drop within IC rails
  - Resistor value depends on expected current
  - Choose smaller for portable devices, higher for accuracy

- Parasitics
  - PCB traces
  - Solder joints
  - Wires
  - Tolerance
CHALLENGE: OFFSET VOLTAGE

- All amplifiers have an offset
  - Input same voltage in positive and negative terminals
  - Output is ideally zero
  - In practice, it is non-zero
  - Typical op-amp can be 10 mV, even precision can have 30 µV
- Small offsets can lead to large errors
- Voltages can also drift
  - Aging of device
  - Temperature
Voltage drop is a differential signal
- ICs require a high common mode rejection ratio
- Placement in devices may lead to noise coupling on a single input

Thermal noise requires consideration

High currents may create undesirable magnetic fields

High frequency signals on the line can cause problems
Consider a 1mΩ resistor with 1 mA of current; this is a 1 uV drop
- Typical precision chips may only have a gain of 500
- 500 uV is still a very small signal
- This may present problems in converting to a digital signal
- As an analog signal, it is not robust
- Using an ideal op-amp would fix this problem
  - Operational Amplifier
  - Shunt Monitor
  - Instrumentation Amplifier
  - Chopper Amplifier
CONCLUSION

- Current sensing basics and methods
- Resistive shunt monitoring
  - High side
  - Low side
- Design considerations