CURRENT SENSING USING RESISTIVE SHUNTS

ECE 480 Design Team 5
Joshua Myers
Ryan Laderach
Stephen England
Kenji Aono
4/1/2011

OUTLINE

- What is current sensing?
- Common Methods of Current Sensing
- High/Low Side Resistive Sensing
- Challenges of Resistive Sensing

CURRENT SENSING

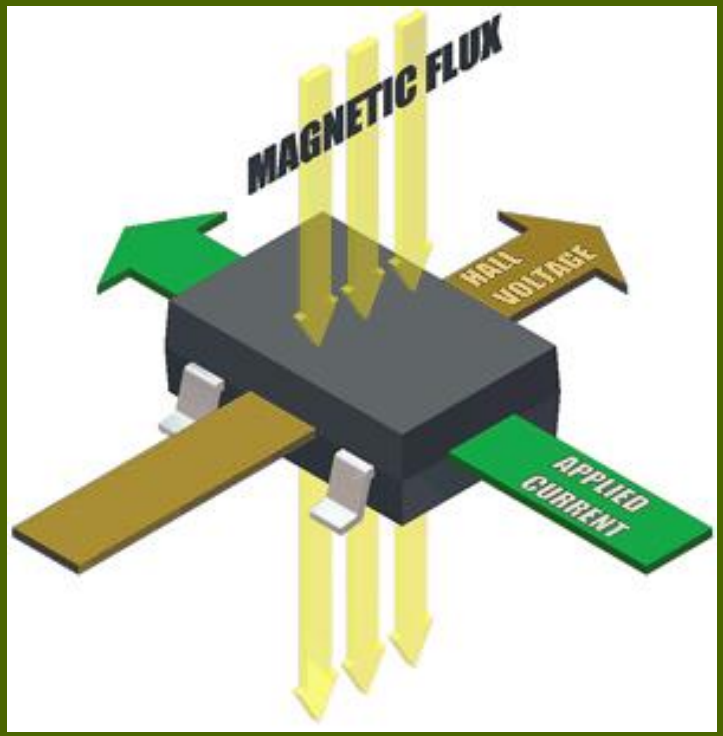
- A method of determining the current drawn to a load
- Not necessarily measuring current
  - Voltage
  - Magnetic Field
- Large range of measurements
  - μA to kA
  - Requires different techniques depending on what level of current is being drawn

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

HALL EFFECT CURRENT SENSING

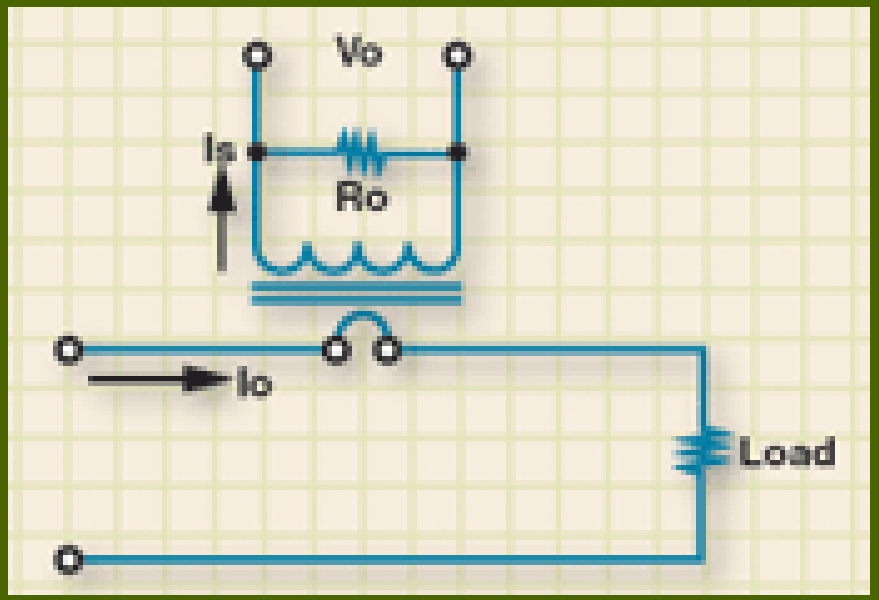
- A flux field is generated, the toroid senses the field, special IC measures and amplifies induced voltage
- Advantages:
  - Handles high currents
  - No insertion loss
- Disadvantages:
  - Large Size
  - Expensive



http://www.allegromicro.com/en/Products/Design/unipolar/images/fig2.jpg

CURRENT TRANSFORMER SENSING

- 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

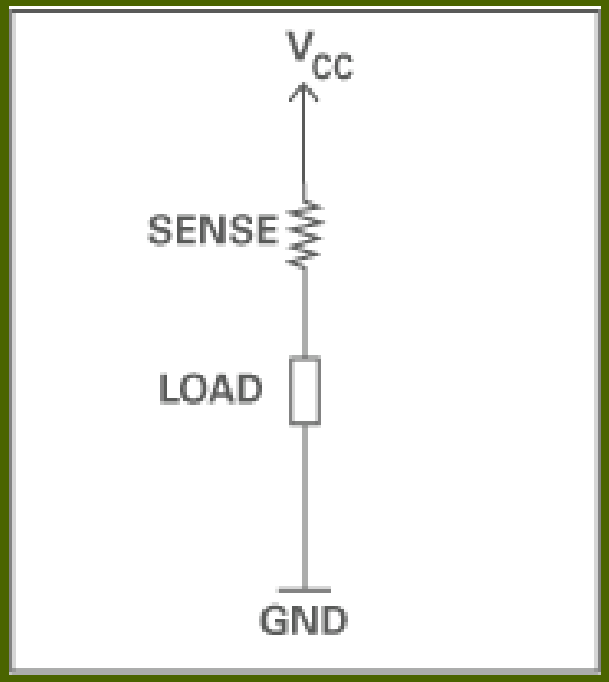


http://www2.electronicproducts.com/images2/F64DATAD0506.gif

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

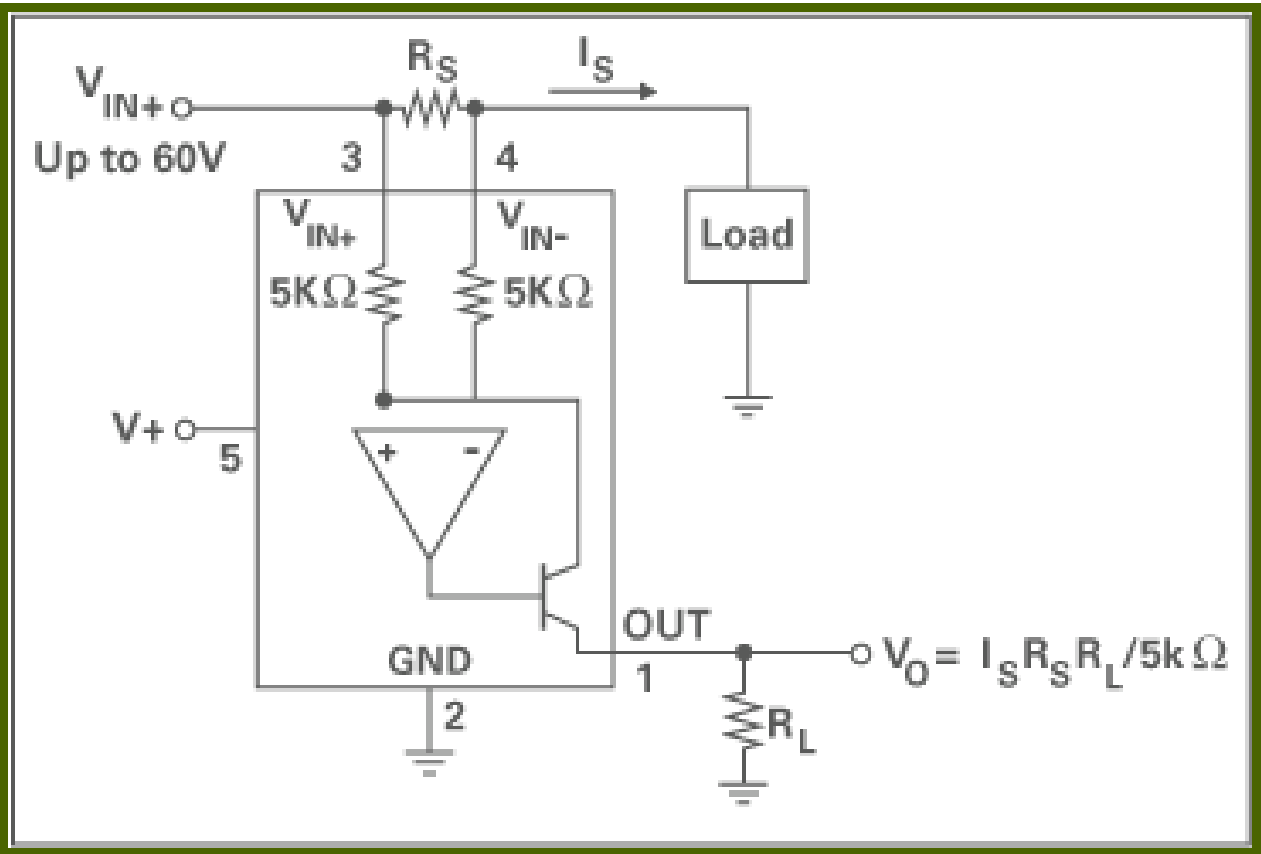
HIGH SIDE MEASUREMENTS



- 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

http://focus.ti.com/en/graphics/aap/general/figure4.gif

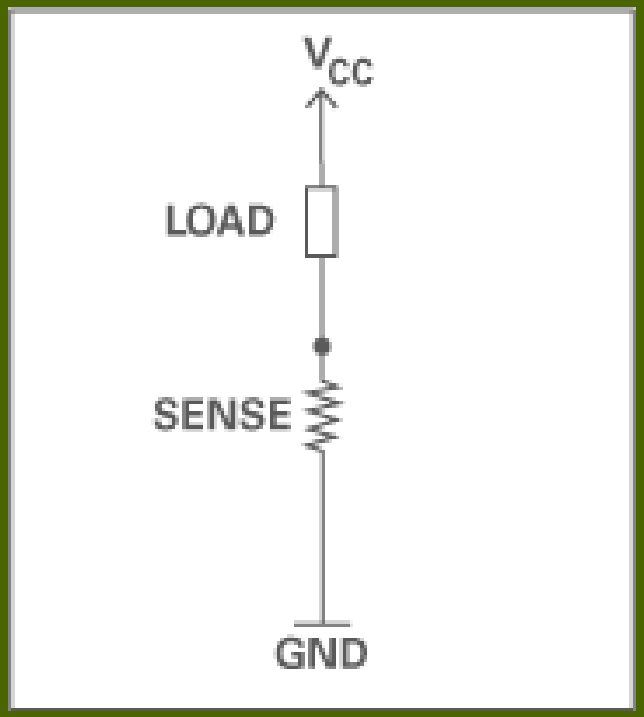
HIGH SIDE MEASUREMENT



TI INA138

http://focus.ti.com/en/graphics/aap/general/figure6.gif

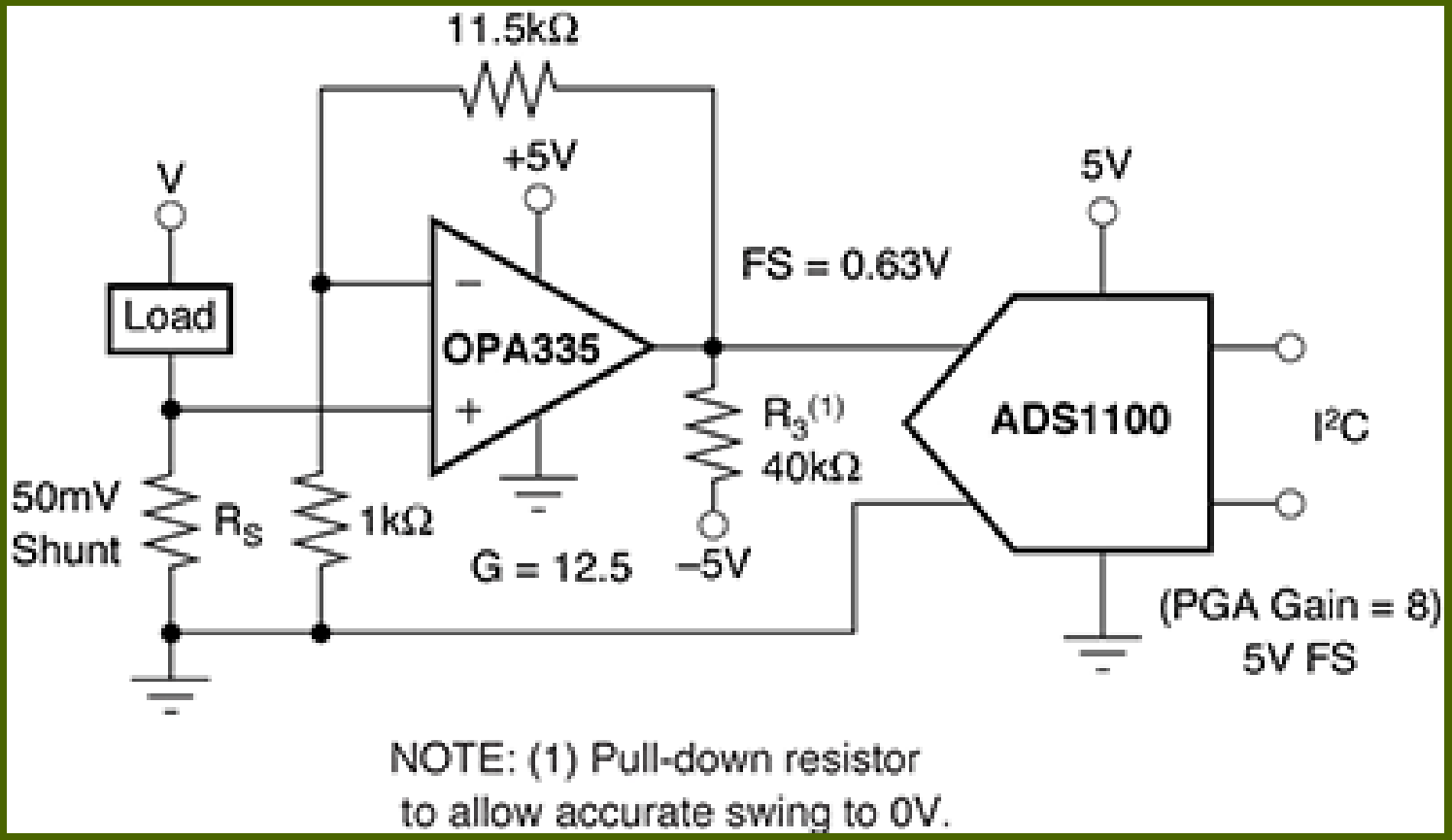
LOW SIDE MEASUREMENTS



http://focus.ti.com/en/graphics/aap/general/figure2.gif

- 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

LOW SIDE MEASUREMENT



http://focus.ti.com/en/graphics/aap/general/figure3.gif

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

CHALLENGE: NOISE

- 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

CHALLENGE: FINITE GAIN

- 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

QUESTIONS