Getting Started with Current Sense Amplifiers Video Series

Session 4: How To Choose An Appropriate Shunt Resistor

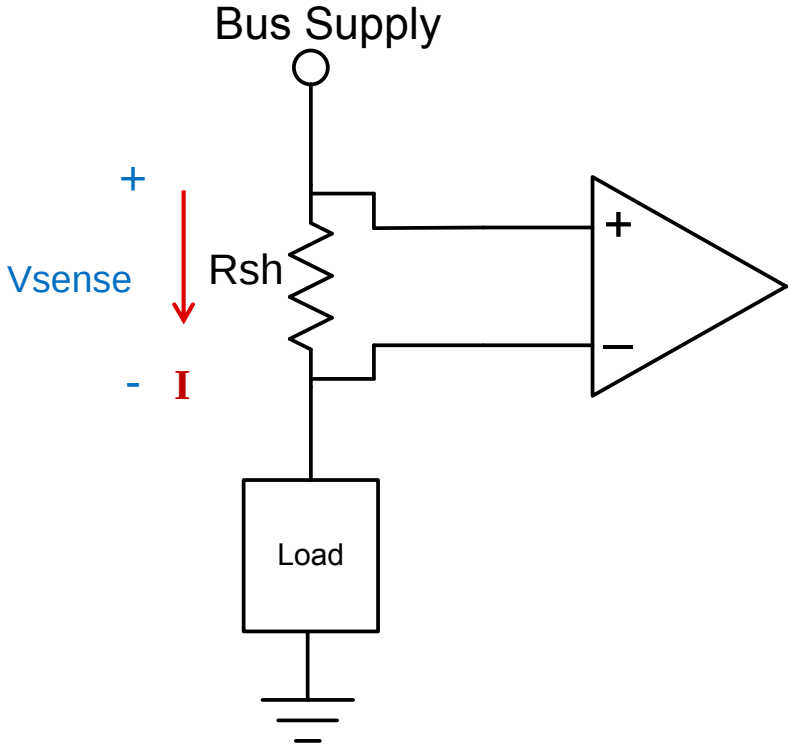
How To Choose An Appropriate Shunt Resistor

Overview

- Definition of Shunt Resistor
- Primary factors that influence the choice of the shunt resistor
- Calculating a maximum value of the shunt resistor for an application
- Shunt resistor tolerance error

How To Choose An Appropriate Shunt Resistor

What is a Shunt Resistor?



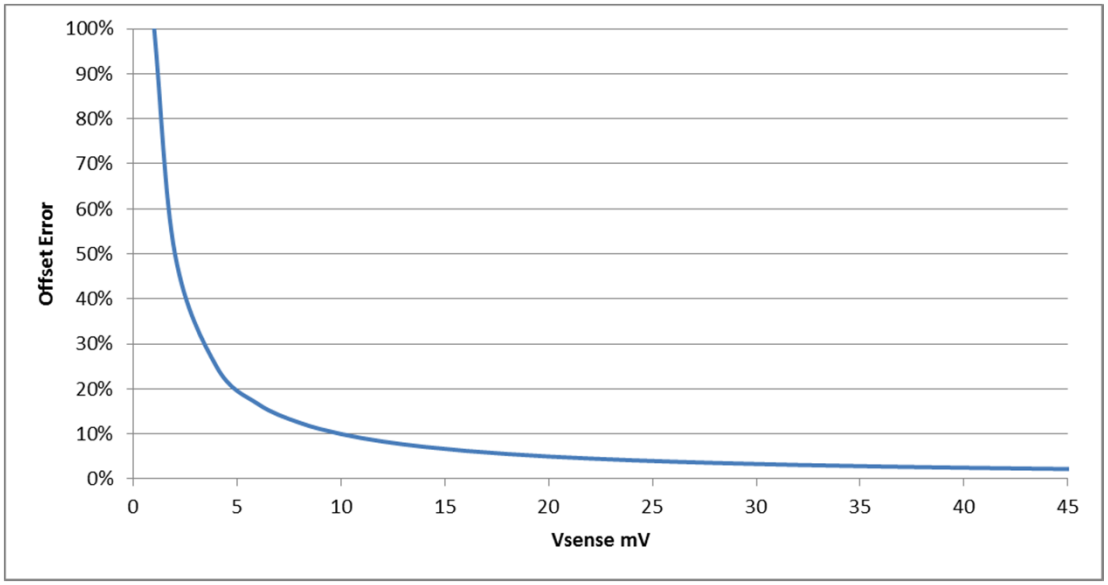
How To Choose An Appropriate Shunt Resistor

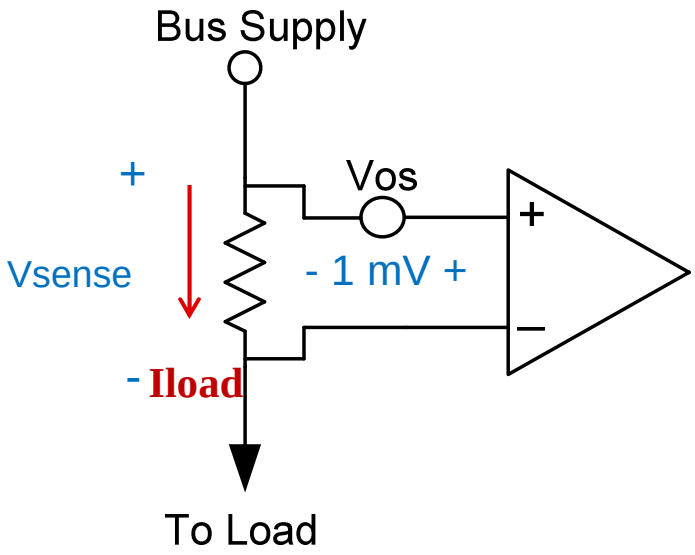
Primary Factors for choosing a Shunt

1. Minimum Current Accuracy
2. Maximum Current Power dissipation (Size and Cost)

How To Choose An Appropriate Shunt Resistor

Minimum Current Accuracy



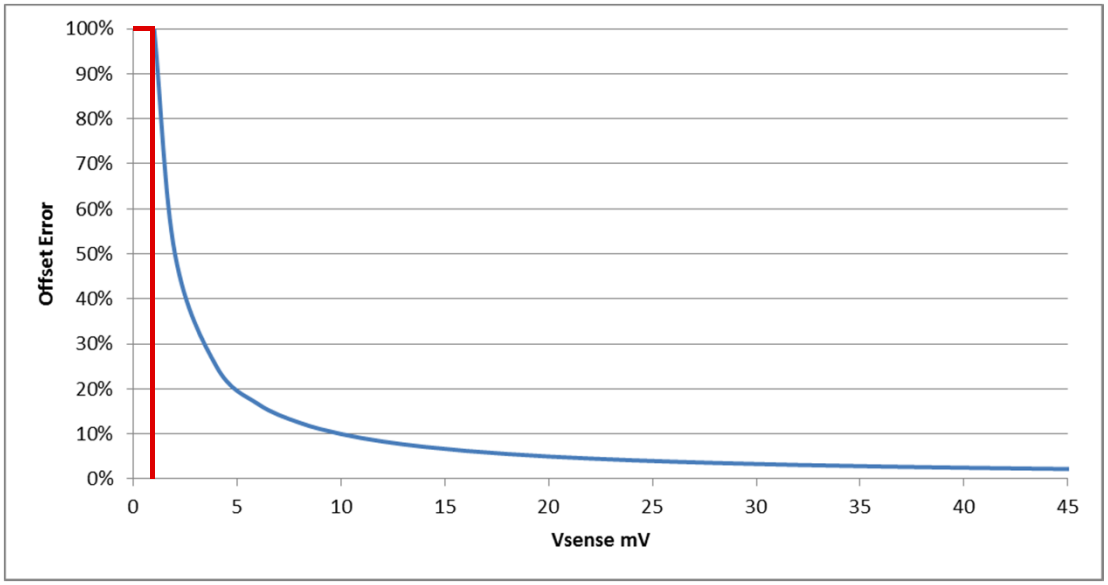


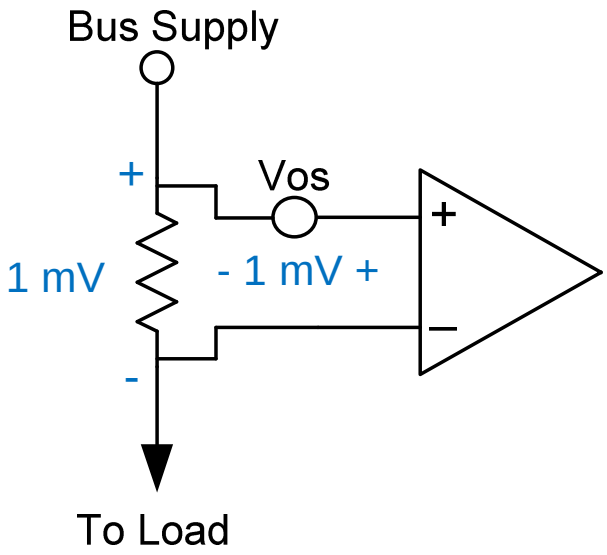
$$Offset\ Error\ (in\ percent) = \left(\frac{Vos}{Vsense}\right) * 100$$

$$Vsense = Rsh * Iload$$

How To Choose An Appropriate Shunt Resistor

Minimum Current Accuracy

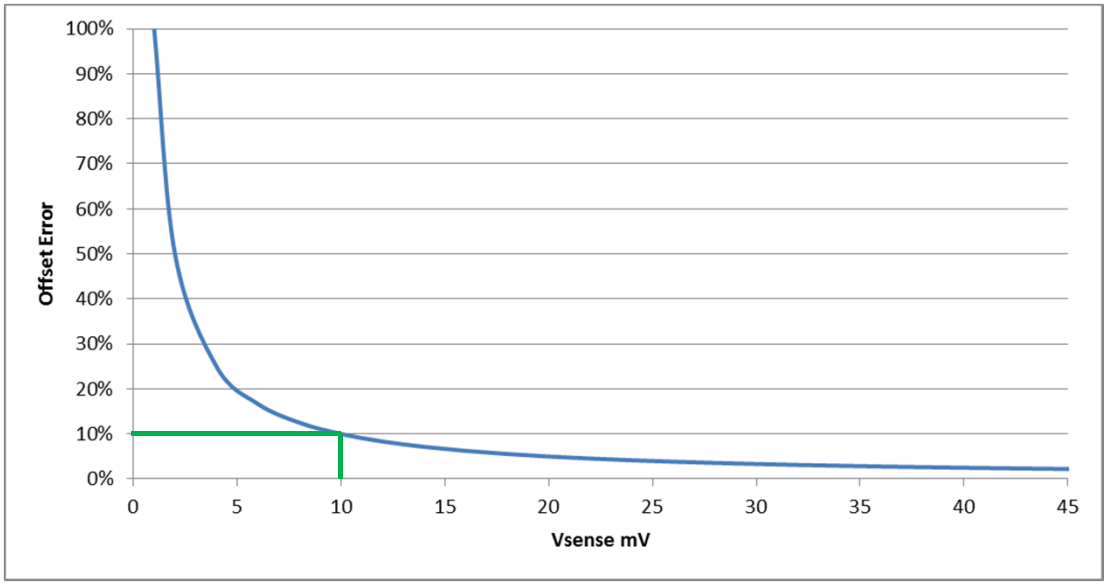


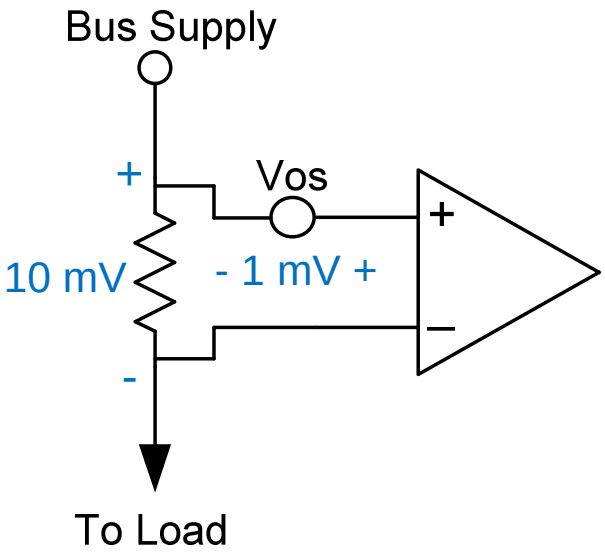


$$Offset\ Error = \frac{1\ mV}{1\ mV} * 100 = 100\ \%$$

How To Choose An Appropriate Shunt Resistor

Minimum Current Accuracy

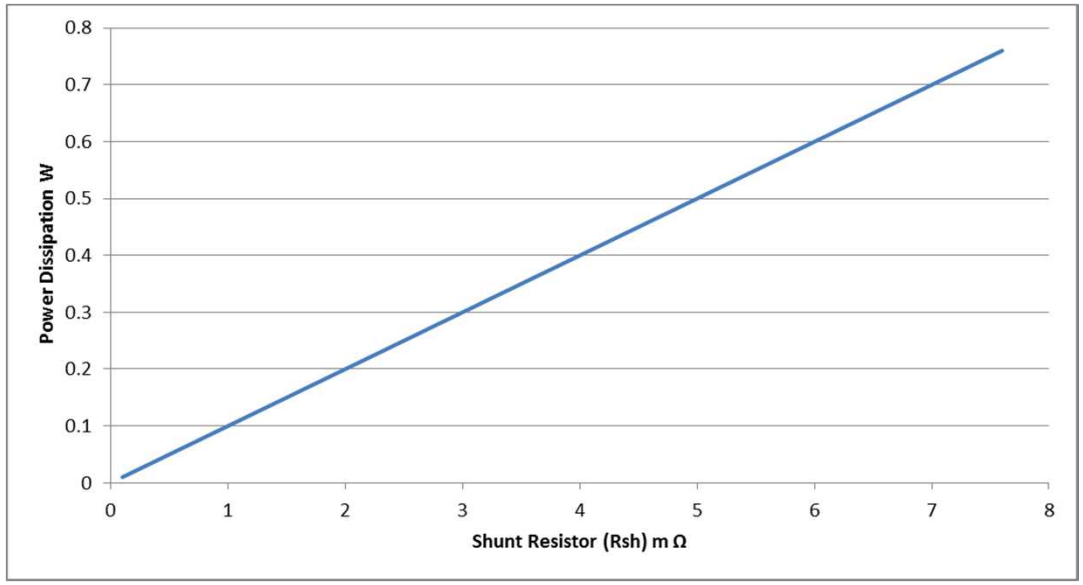


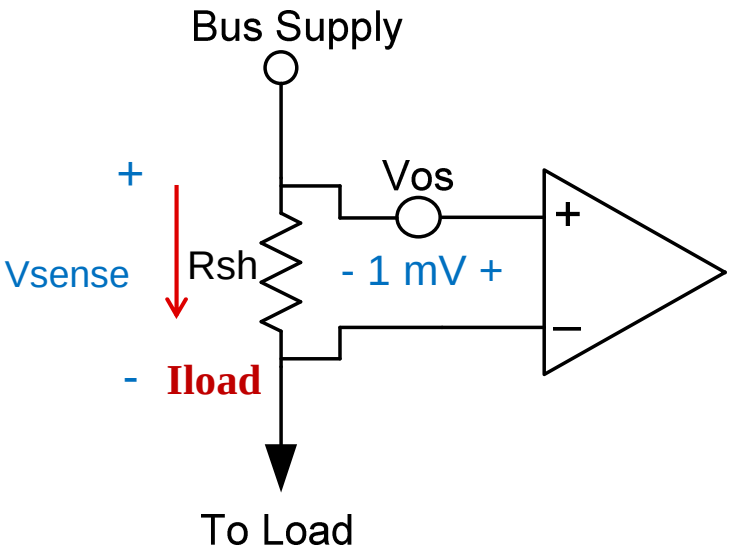


$$Offset\ Error = \frac{1\ mV}{10\ mV} * 100 = 10\ \%$$

How To Choose An Appropriate Shunt Resistor

Maximum Current Power Dissipation

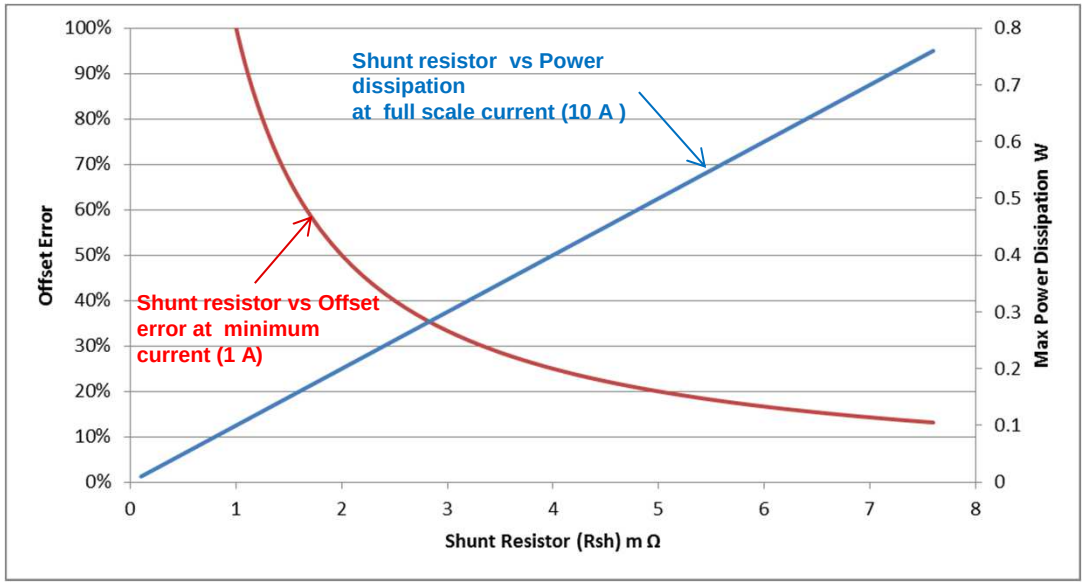


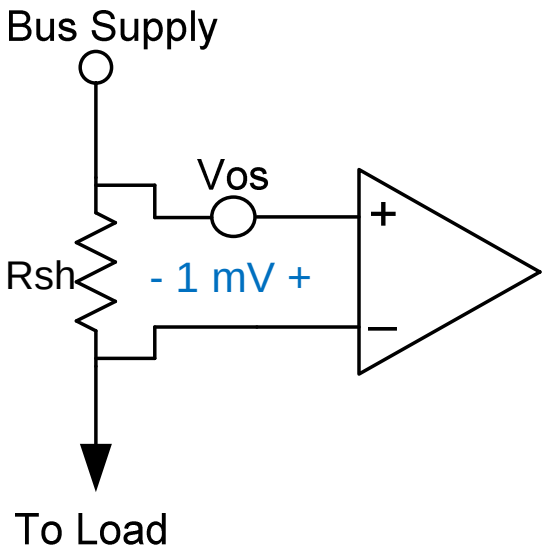


$$Power\ Dissipation = Rsh * Iload^{2}$$

How To Choose An Appropriate Shunt Resistor

Power Dissipation vs Minimum Current Accuracy tradeoff





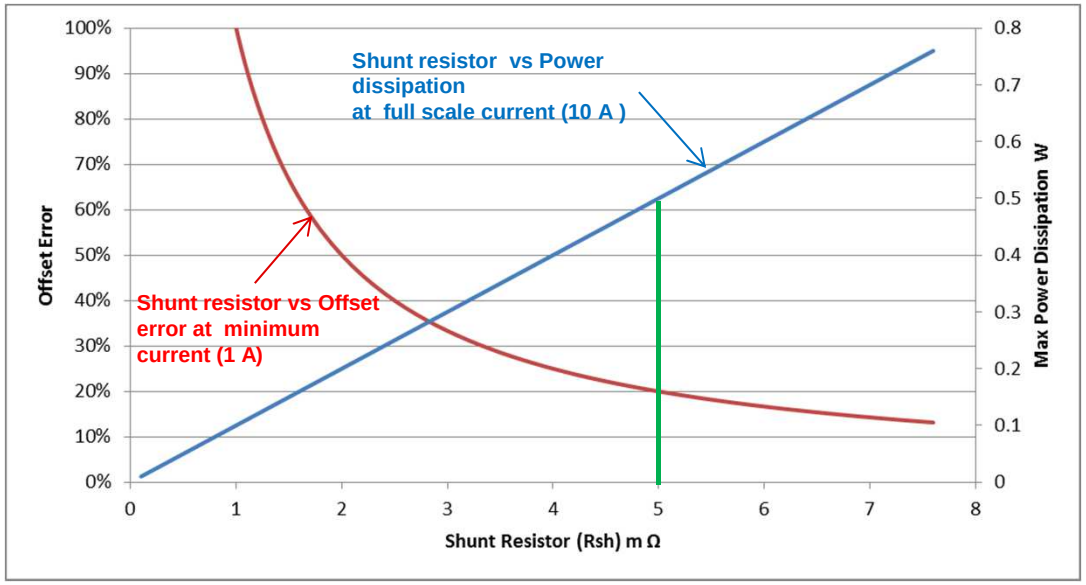
$$Offset\ Error\ (in\ percent) = \frac{Vos}{Rsh * Iload\_min} * 100$$

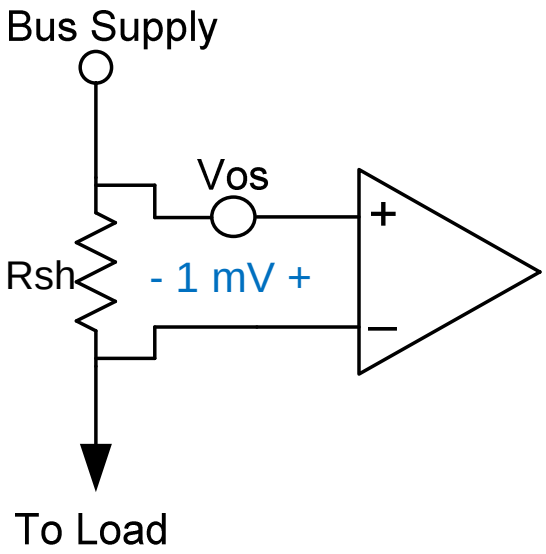
$$Max\ Power\ Dissipation\ (W) = Rsh * Iload\_max^{\,2}$$

Iload_min = 1 A; Iload_max = 10 A

How To Choose An Appropriate Shunt Resistor

Power Dissipation vs Minimum Current Accuracy tradeoff





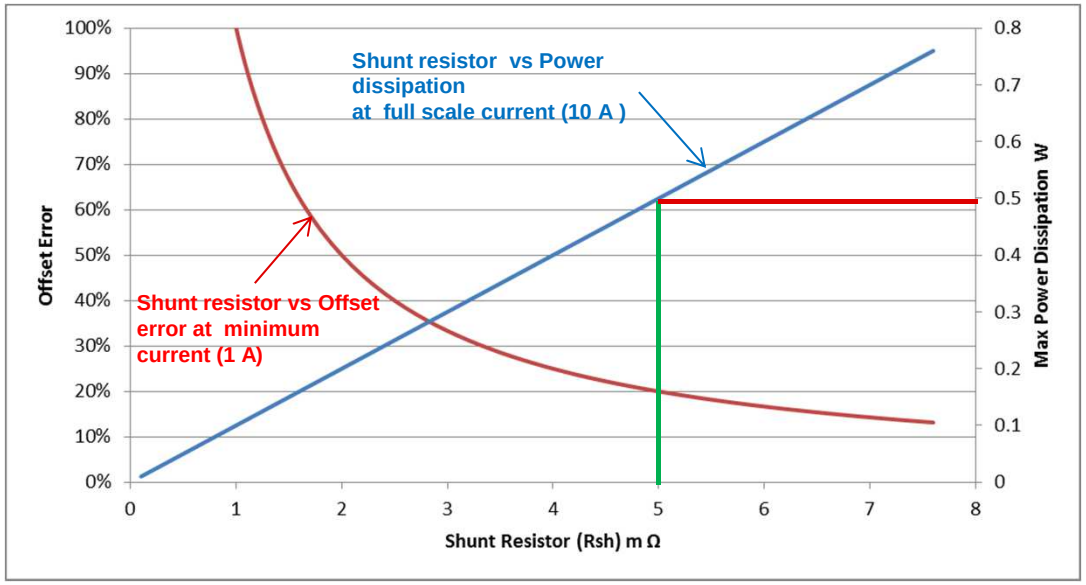
$$Offset\ Error\ (in\ percent) = \frac{1\ mV}{5\ m\Omega * 1\ A} * 100 = 20\ \%$$

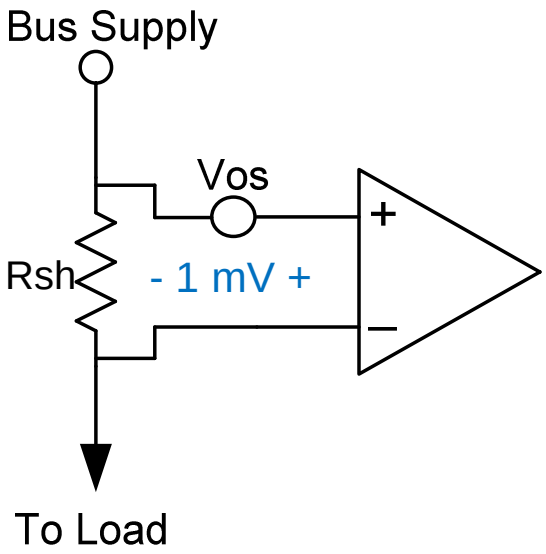
$$Max\ Power\ Dissipation\ (W) = 5\ m\Omega * \ 10\ A^2 = 0.5\ \text{W}$$

Iload_min = 1 A; Iload_max = 10 A

How To Choose An Appropriate Shunt Resistor

Power Dissipation vs Minimum Current Accuracy tradeoff





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How To Choose An Appropriate Shunt Resistor

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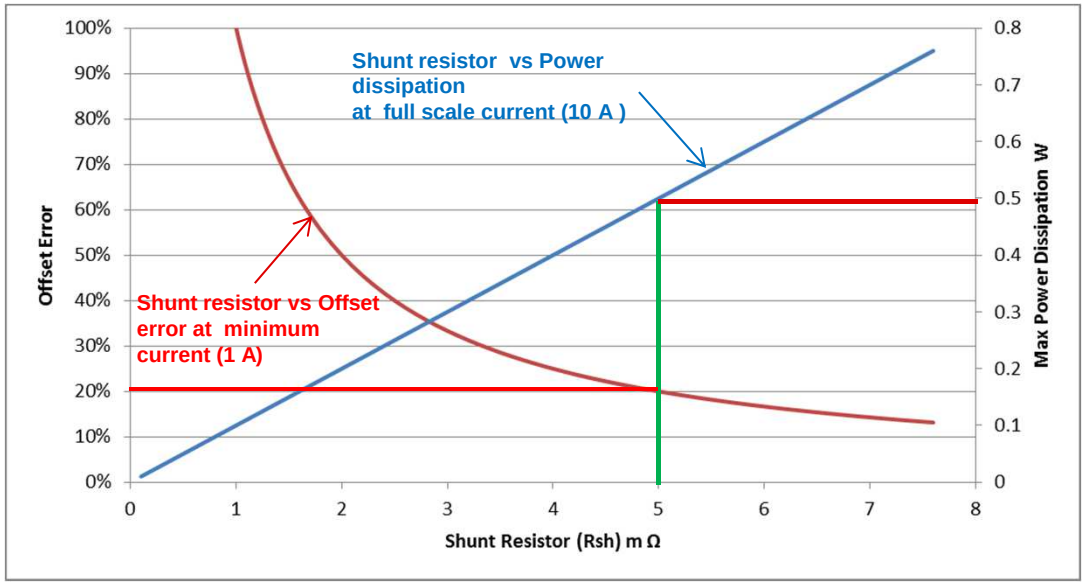

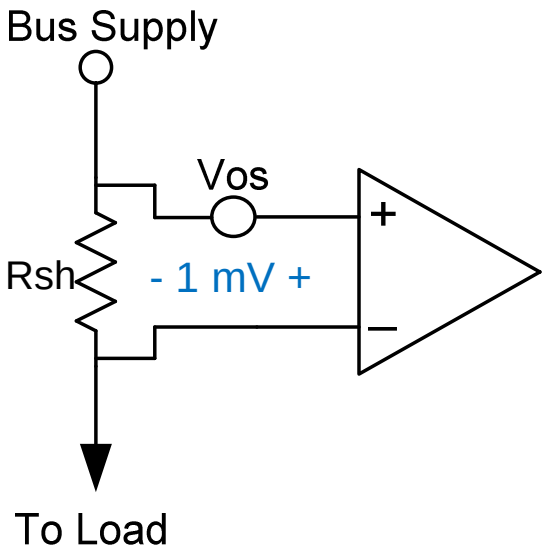

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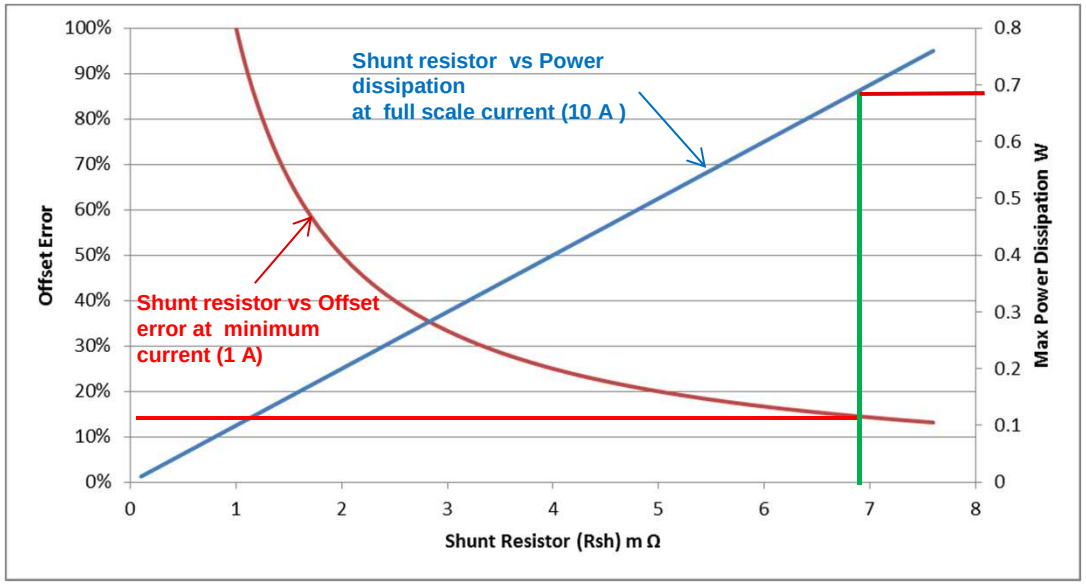
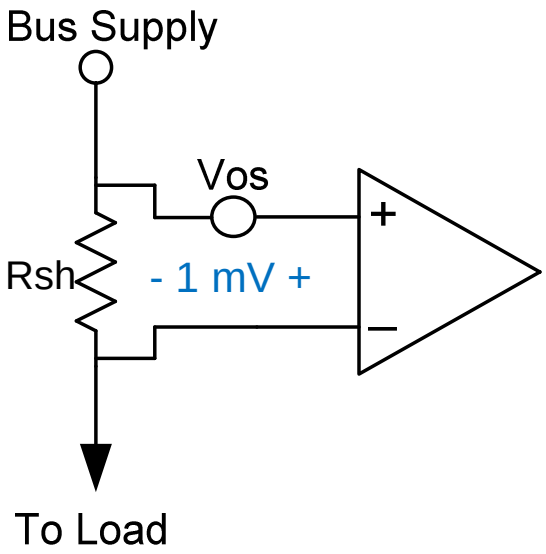
How To Choose An Appropriate Shunt Resistor

Power Dissipation vs Minimum Current Accuracy tradeoff





$$Offset\ Error\ (in\ percent) = \frac{1\ mV}{6.66\ m\Omega * 1\ A} * 100 = 15\ \%$$

$$Max\ Power\ Dissipation\ (W) = 6.66\ m\Omega *\ 10\ A^2 = 0.66\ W$$

Iload_min = 1 A; Iload_max = 10 A

How To Choose An Appropriate Shunt Resistor

Maximum value of Sense resistor

1. Maximum load current
2. Full-scale output range of the sensing device (Vout)
3. Gain

$$Maximum\ value\ of\ shunt\ resistor = \frac{Vout \div Gain}{Maximum\ load\ current}$$

How To Choose An Appropriate Shunt Resistor

Shunt Resistor Tolerance Error

- **Maximum deviation from the ideal value, expressed as a percentage.**

$$Actual\ Resistance = Ideal\ Resistance \pm \frac{Tolerance}{100} * Ideal\ Resistance$$

$$Actual\ Resistance = 10\ m\Omega \pm \frac{1}{100} * 10 m\Omega = 10\ m\Omega \pm 0.1\ m\Omega$$

9.9 mΩ ⟶ 10.1 mΩ

How To Choose An Appropriate Shunt Resistor

Example

PARAMETER	VALUES	PARAMETER	EQUATION	RESULT (INA199A1)
Iload_min	100 mA	Rsh_Max (Max Current-shunt resistor value)	$Rsh_{max} = \frac{Vout \div Gain}{Iload\_max} = \frac{5\ V \div 50\ V/V}{10\ A}$	10 mΩ
Iload_max	10 A	Psh (Current-sense resistor power dissipation at Full-scale current)	$Psh = Rsh * Iload\_max^2 = 10\ \text{m}\Omega * 10\ A * 10\ A$	1 W
Vout	5 V	Error due to offset at minimum load current	$Offset\ Error = \frac{Vos}{Rsh * Iload\_min} * 100 = \frac{150\ \mu V}{10\ m\Omega * 100\ mA} * 100$	15 %
Gain (INA199 A1)	50 V/V	Total Error at minimum load current		~15%
Gain Error (INA199 A1)	1.5 %	Error due to offset at maximum load current	$Offset\ Error = \frac{Vos}{Rsh * Iload\_min} * 100 = \frac{150\ \mu V}{10\ m\Omega * 10\ A} * 100$	0.15 %
Vos (INA199A1)	150 µV	Total Error at maximum load current	Rsh tolerance = 1%	~ 1.8 %

How To Choose An Appropriate Shunt Resistor

Shunt Resistor Pricing

Package	Tolerance (%)	Resistance (mΩ)	Power Rating (W)	Unit Price ($)
805	1	10	0.5	0.53
1206	1	10	1	0.64
2512	1	10	2	0.65
1206	0.5	10	0.5	0.74
2512	0.5	10	1	1.66
Wide 2512	0.5	10	2	2.16

How To Choose An Appropriate Shunt Resistor

- Shunt Resistor definition
- Primary factors for choosing a Shunt Resistor
  - ✓Accuracy at minimum current
  - ✓Power dissipation at maximum current

- Calculating maximum value of the shunt resistor :

$$Maximum\ value\ of\ shunt\ resistor = \frac{Vout \div Gain}{Maximum\ load\ current}$$

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Getting Started with Current Sense Amplifiers Video Series

Session 1: When to choose a Current Sense Amp
Session 2: Current Sense Amp Design Considerations
Session 3: Implementation options for both high-side and low-side monitoring
Session 4: How to choose an appropriate Shunt Resistor
Session 5: Understanding different types of error in current shunt monitor designs
Session 6: Understanding gain errors
Session 7: Understanding offset errors
Session 8: Understanding filter related error
Session 9: Understanding common mode voltage error
Session 10: Understanding temperature related error
Session 11: Understanding power supply rejection error
Session 12: Understanding shunt resistor tolerance error
Session 13: Layout considerations for a Current Shunt Monitor circuit
Session 14: Debugging a Current Shunt Monitor circuit - where to probe
Session 15: Programming Power Settings