Debugging a Current Shunt Monitor Circuit – Equipment and Settings

TI Precision Labs – Current sense amplifiers

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Sources of error

Device errors:

$$\varsigma_{RSS}(\%) \approx \sqrt{e_{Vos}{}^2 + e_{CMRR}{}^2 + e_{PSRR}{}^2 + e_{Gain\_error}{}^2 + e_{Linearity}{}^2 + e_{Shunt\_tolerance}{}^2 + e_{Bias\_current}{}^2 + e_{Other}{}^2}$$

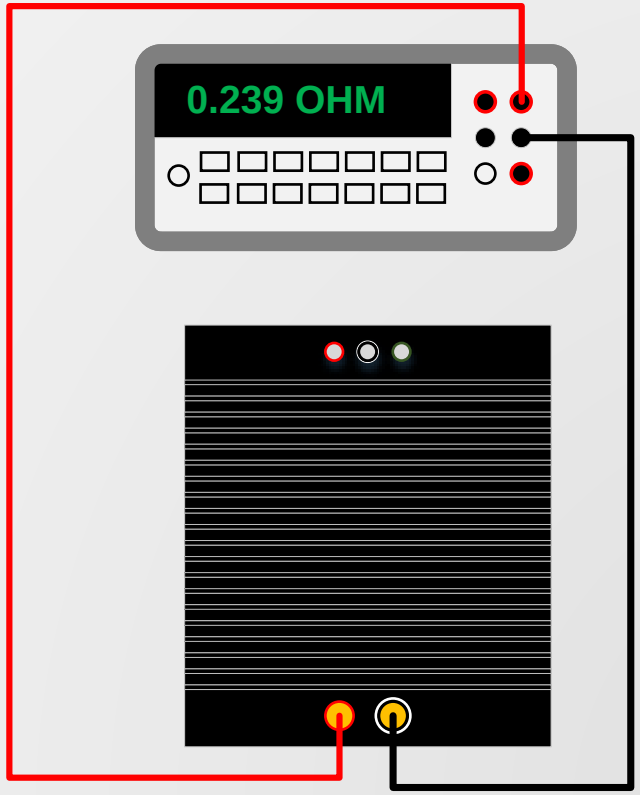
User errors:

- Improper layout
- Probe placement
- Solder issues
- Overlooking device specifications
- Downstream circuitry
- Equipment and settings
- Actual fails

Equipment and settings: Case 1

Conditions

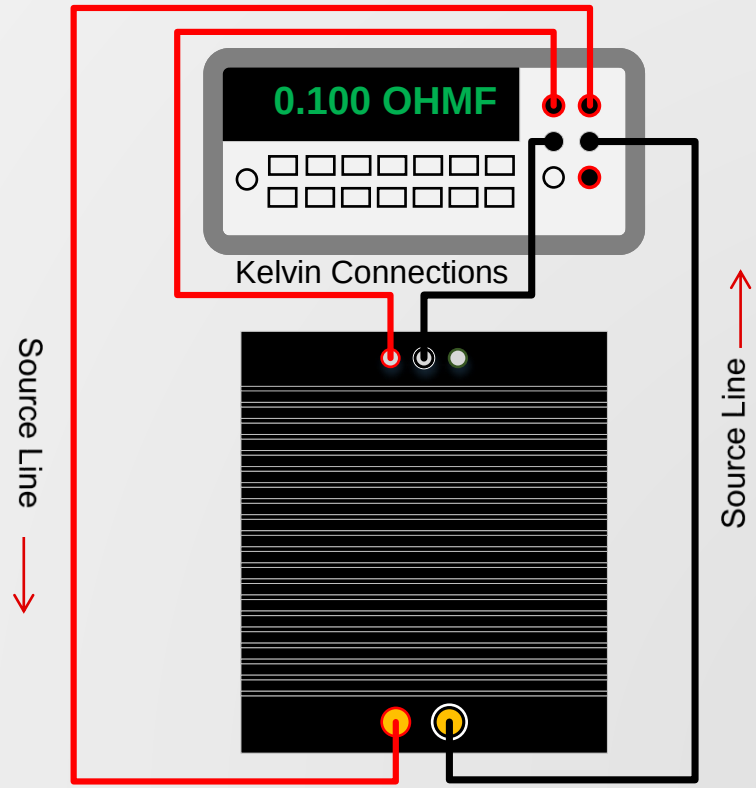
Model	Amps	Ohms	Output	Accuracy
CS-10	10	0.1	1.0 V	0.01%



Source of error

- 2-wire not as precise as 4-wire measurement

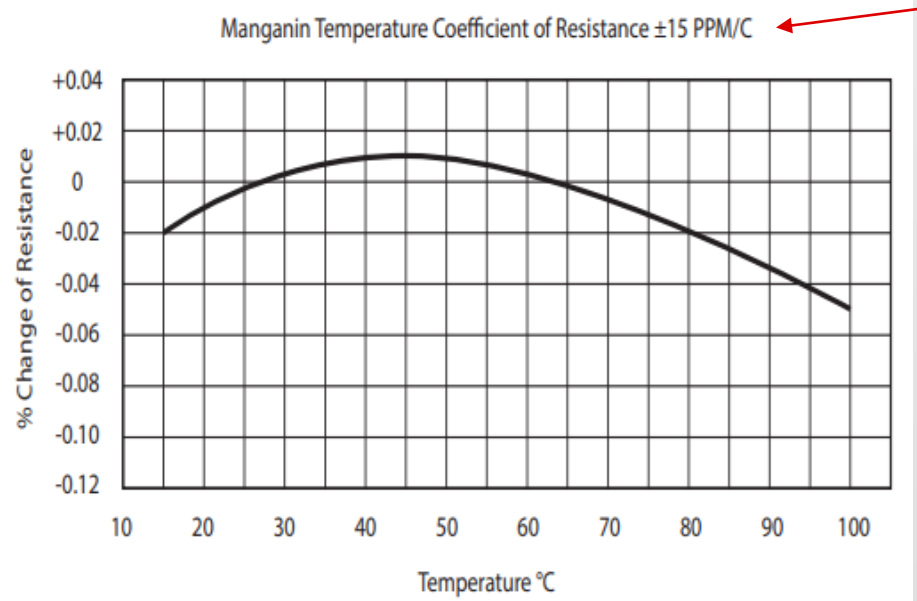
Check DMM manual for proper 4-wire setup.



Resistor temperature error

Specifications

	Parameter	Spec
Resistor	Resistance	0.333mΩ
	Tolerance	±0.1%
	Operating Current	100 A
	Coefficient of Resistance	±15 PPM/C



Examples

Given: I_{set} = 100A, R_{shunt} = 0.333mΩ, Tolerance ±0.1%

$$V_{shunt} = I * R = 100 * 0.333m = 0.0333V$$

$$R_{error-temp,95C} = (95 - 25) * 15\frac{\text{PPM}}{\text{C}} = 1050\ \text{PPM} = \pm 0.105\%$$

$$R_{shunt,\,95C} = 0.333m + \left(0.333m \times \left(\frac{0.105\%}{100} + \frac{0.1\%}{100}\right)\right) = 0.3336\text{m}\Omega$$

$$V_{shunt} = I * R = 100 * 0.3336m = 0.03336V$$

$$\%\ err_{Vshunt} = \left(\frac{0.03336 - 0.0333}{0.0333}\right) \times 100 = 0.18\%$$

$$R_{shunt,\,95C} = 0.333m + \left(0.333m \times \left(\frac{-0.105\%}{100} + \frac{-0.1\%}{100}\right)\right) = 0.3323\text{m}\Omega$$

$$V_{shunt} = I * R = 100 * 0.3323m = .03323V$$

$$\%\ err_{Vshunt} = \left(\frac{0.03323 - 0.0333}{0.0333}\right) \times 100 = -0.21\%$$

Equipment and settings: Case 2

Specifications

	Parameter	Spec
Power Supply	Voltage readback accuracy	±0.2% of full scale Voltage
	Current readback accuracy	±0.2% of full scale current
	Full scale voltage	5 V

	Function	Range	Resolution	Spec
Handheld DMM	DC voltage	200.0 mV	0.1 mV	±(0.5% + 3 digits)
		2000 mV	1 mV	
		20.00 V	0.01 V	
		200.0 V	0.1 V	±(0.8% + 3 digits)
		600 V	1 V	
	DC current	200.0 µA	0.1 µA	±(1.0% + 5 digits)
		20.00 mA	10 µA	
		200.0 mA	100 µA	±(1.2% + 5 digits)
		10.00 A	10 mA	±(3.0% + 5 digits)

Examples

Given: $V_{CC\ set}$ = 3V, I_{set} = 1A, R_{shunt} = 10mΩ

$$V_{CC\ set\ \min\ measured} = 3V - \left(5 \times \frac{0.2\%}{100}\right) = 2.99V$$

$$I_{set\ \max\ measured} = 1A + \left(900 \times \frac{0.2\%}{100}\right) = 2.8A$$

DMM ranges used: 2000mV range, 10.00A

$$V_{SHUNT\ \max\ measured} = 10mV \times \frac{(100+0.5)\%}{100} = 10.1\text{mV}$$

$$I_{VSHUNT} = \frac{10.1\text{mV}}{10\text{m}\Omega} = 1.01\text{A}$$

$$I_{Meter} = 1A \times \frac{100+3\%}{100} = 1.03\text{A}$$

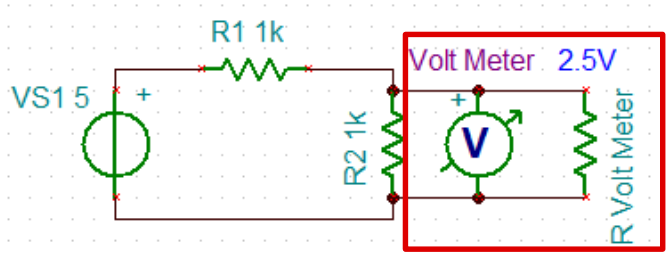
Equipment and settings: Case 3

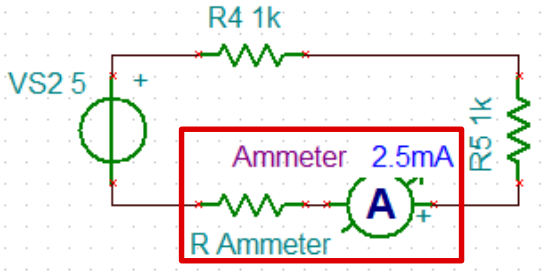
Calculations

Given: V_{out} = 5V

$$V_{\min\ meas,\,HH} = 5V - \left(5 \times \frac{0.5\%}{100} + 2 \times 0.001\right) = 4.973V$$

$$V_{\min\ meas,\,Bench} = 5V - \left(5 \times \frac{0.0025\%}{100} + 10 \times \frac{0.0004\%}{100}\right) = 4.99984V$$





Specifications

	Function	Range	Resolution	% of reading + sig digits	Nom input Z
Handheld DMM	DC Voltage	600.0 mV	0.1 mV	0.5% + 2	11.18 MΩ
		6000 mV	1 mV	0.5% + 2	11.18 MΩ
		60 V	0.01 V	0.5% + 2	10.1 MΩ
		600 V	0.1 V	0.5% + 2	10 MΩ
		600 V Zlow	0.1 V	2% + 3	3 kΩ
	Function	Range	Resolution	% of reading + % of range	Nom input Z
Bench DMM	DC Voltage	100 mV	0.1 mV	0.004% + 0.006%	10 MΩ or > 10 GΩ
		1000 mV	1 mV	0.003% +0 .0009%	10 MΩ or > 10 GΩ
		10 V	0.01 V	0.0025% + 0.0004%	10 MΩ or > 10 GΩ
		100 V	0.1 V	0.003% + 0.0006%	10 MΩ or > 10 GΩ
		1000 V	0.1 V	0.003% + 0.0006%	10 MΩ or > 10 GΩ

Equipment and Settings: E-load

Specifications

	Function	Range	Spec
E-load	Constant current mode	Low	0.05% + 820 uA
		High	0.05% + 7.2 mA
	Constant voltage mode	Low	0.03% + 4.2 mV
		High	0.03% + 15 mV

Calculations

Given: $V_{CC\ set}$ = 3V, I_{set} = 1A, R_{shunt} = 10mΩ, Range = Low

$$I_{load\ max} = 1A + \left(1 \times \frac{0.05\%}{100}\right) + 820uA = 1.00132A$$

Given: $V_{CC\ set}$ = 3V, I_{set} = 10A, R_{shunt} = 10mΩ, Range = High

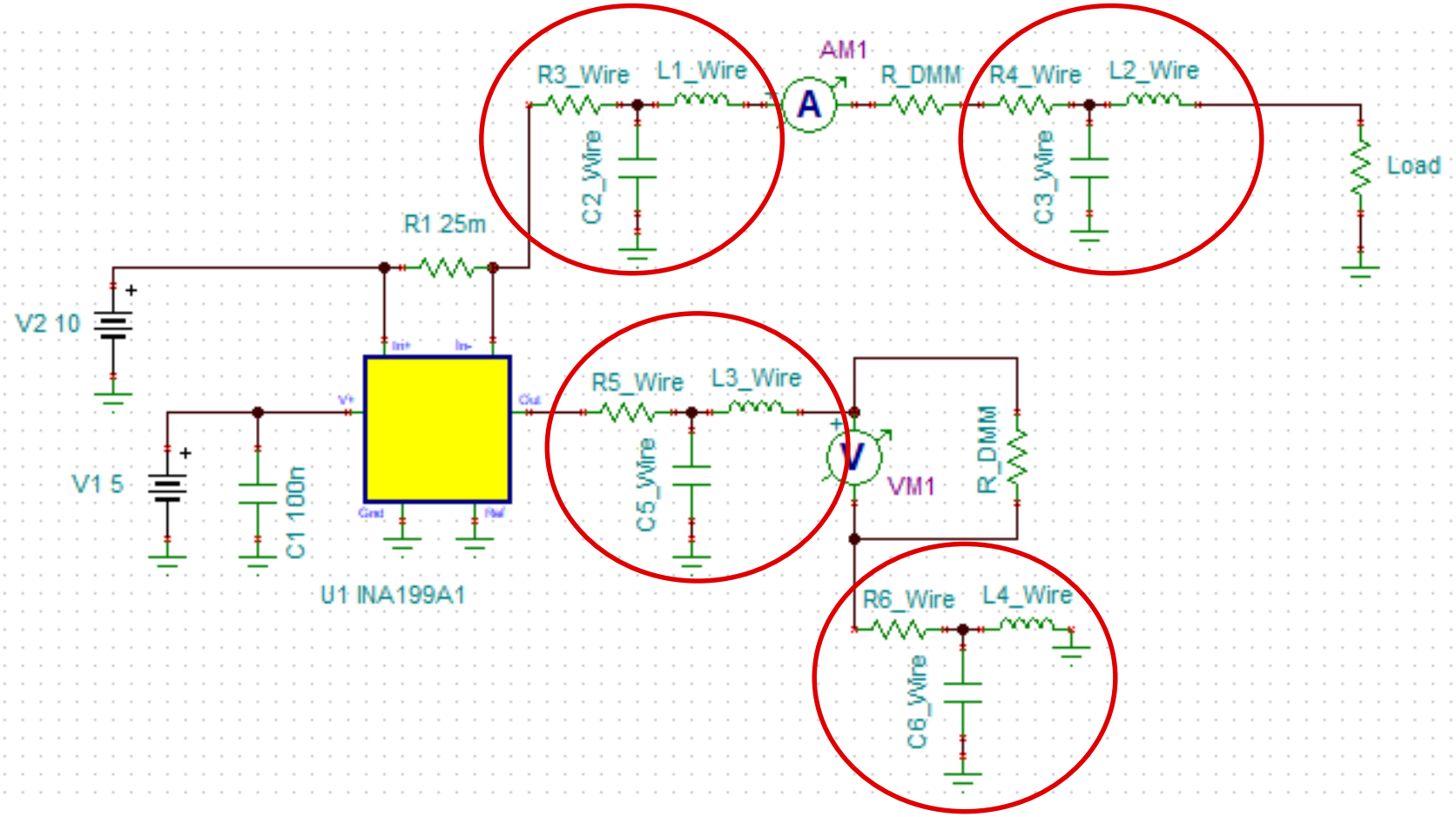
$$I_{load\ max} = 1A + \left(1 \times \frac{0.05\%}{100}\right) + 7.2mA = 1.0077A$$

Error calculations

$$\%\ err_{max,\ 1A} = \left(\frac{1.00132-1}{1}\right) \times 100 = 0.132\%$$

$$\%\ err_{max,1A} = \left(\frac{1.0077-1}{1}\right) \times 100 = 0.77\%$$

Passive elements – Equipment and parasitic



Summary

- Precision shunt resistors use 4-wire connection to make correct measurements
- Equipment is not perfect and also has measurement error
- Check equipment datasheets for settings and specifications
- Typically, handheld meters are not quite as accurate as bench meters
- Parasitic and passive elements will be present when using external equipment

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TI Precision Labs – Current Sense Amplifiers

QUIZ

Debugging a Current Shunt Monitor Circuit – Equipment and Settings - Quiz

1. When using a precision shunt resistor, measurements will be more accurate when used in the 2 wire configuration.
   a) True
   b) False

Debugging a Current Shunt Monitor Circuit – Equipment and Settings - Quiz

2. Looking at the table, we see a power supply's parameters. When setting the power supply to source 5A at 5V what would be the largest absolute measurement in the current?
   a) 5 + 0.02*5
   b) 5 + 0.002*5
   c) 5 + 0.002*900
   d) 5 + 0.002*(900+5)

	Parameter	Specifications
Power Supply	Voltage Readback Accuracy	±0.2% of full Scale Voltage
	Current Readback Accuracy	±0.2% of full Scale Current
	Full Scale Voltage	5 V
	Full Scale Current	900A

Debugging a Current Shunt Monitor Circuit – Equipment and Settings - Quiz

3. Looking at the table, we see an E-load's parameters. I would like to test my circuit under a load current of 700mA what settings should I program into the E-load?
   a) Constant Current mode Low
   b) Constant Current mode High
   c) Constant Voltage mode Low
   d) Constant Voltage mode High

	Function	Range	Specifications
E-load	Constant Current mode	Low (up to 4A)	0.05% + 820uA
		High (up to 15A)	0.05% + 7.2mA
	Consant Voltage mode	Low (up to 5V)	0.03% + 4.2mV
		High (up to 20V)	0.03% + 15mV

Debugging a Current Shunt Monitor Circuit – Equipment and Settings - Quiz

4. When working with resistors does temperature effect the voltage across the resistor?
   a) Yes
   b) No

ANSWERS

Debugging a Current Shunt Monitor Circuit – Equipment and Settings - Quiz

1. When using a precision shunt resistor, measurements will be more accurate when used in the 2 wire configuration.
   a) True
   b) False

Precision shunt resistors will be able to perform a 4-wire measurement. The 4-wire measurement is more accurate than the 2-wire measurement. The reason for this is the test leads will add series resistance changing the precisions shunt value.

Debugging a Current Shunt Monitor Circuit – Equipment and Settings - Quiz

2. Looking at the table, we see a power supply's parameters. When setting the power supply to source 5A at 5V what would be the largest absolute measurement in the current?

a) 5 + 0.02*5

b) 5 + 0.002*5

c) 5 + 0.002*900

d) 5 + 0.002*(900+5)

	Parameter	Specifications
Power Supply	Voltage Readback Accuracy	±0.2% of full Scale Voltage
	Current Readback Accuracy	±0.2% of full Scale Current
	Full Scale Voltage	5 V
	Full Scale Current	900A

The error will be +-.2% of full scale current. This corresponds to .002*900, we will need to add the original ideal value of 5. So the absolute current measurement will be 5 + .002*900.

Debugging a Current Shunt Monitor Circuit – Equipment and Settings - Quiz

3. Looking at the table, we see an E-load's parameters. I would like to test my circuit under a load current of 700mA what settings should I program into the E-load?

a) Constant Current mode Low

b) Constant Current mode High

c) Constant Voltage mode Low

d) Constant Voltage mode High

	Function	Range	Specifications
E-load	Constant Current mode	Low (up to 4A)	0.05% + 820uA
		High (up to 15A)	0.05% + 7.2mA
	Consant Voltage mode	Low (up to 5V)	0.03% + 4.2mV
		High (up to 20V)	0.03% + 15mV

The constant current mode will allow to test a circuit under a constant current load. The low mode will allow up to 4 A of current sinking and has a lower error than the high range.

Debugging a Current Shunt Monitor Circuit – Equipment and Settings - Quiz

4. When working with resistors does temperature effect the voltage across the resistor?

a) Yes

b) No

The materials resistors are made from have an electrical resistance value. This resistance value will vary with temperature differently based on the material.