Measurements

Accuracy–how close the measured value is to the actual value

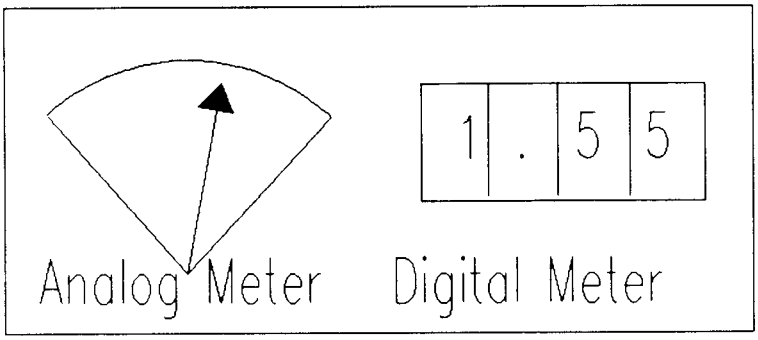
$$\% \; error = 100 \; \frac{Measured \; Value - Actual \; Value}{Actual \; Value}$$

if Actual Value $\neq 0$

Resolution–the smallest change that can be measured

Precision–repeatability of measurements

Range–Difference between the maximum and minimum values of the parameter that can be measured



Analog Instrument–A/D Conversion Performed by User

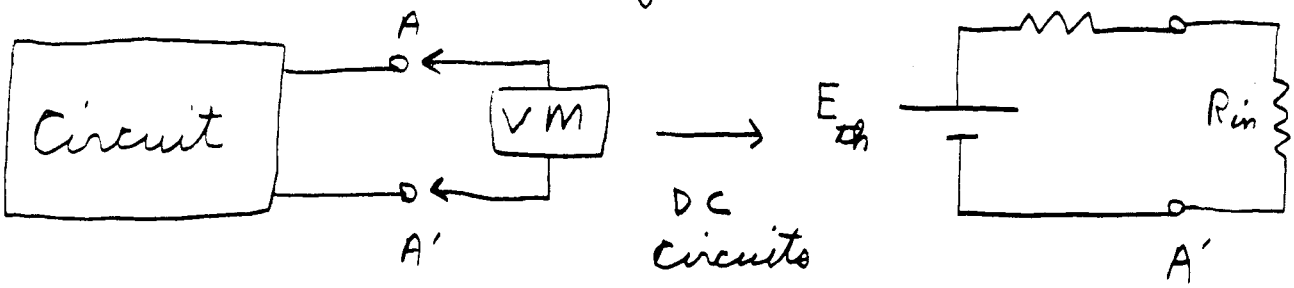
Digital Instrument–A/D Conversion Performed by Instrument

Calibration–A perfectly calibrated instrument is one that measures the parameter that it is designed to measure with perfect accuracy, infinite resolution, and total precision. The actual and measured values are the same when the instrument is connected to the system in which the parameter is to be measured.

Even if the instrument is perfectly calibrated and the user reads the measured value with infinite resolution there may still be an error in measuring the desired parameter due to meter or instrumentation loading.

Meter or instrumentation loading is the alteration of the parameter to be measured by the insertion of the meter or instrument. The instrument or meter may change the parameter being measured to a different value.

Voltmeter Loading



Before VM is connected $V_{AA'} = V$

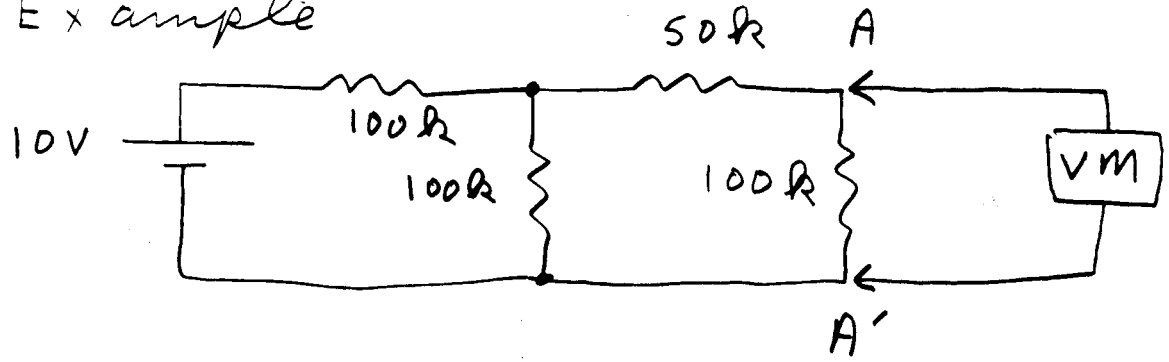
After VM is connected $V_{AA'} = V'$

$$\% \text{ error due to voltmeter loading} = 100 \frac{V' - V}{V}$$

$$V = E_{th} \qquad V' = E_{th} \frac{R_{in}}{R_{in} + R_{th}}$$

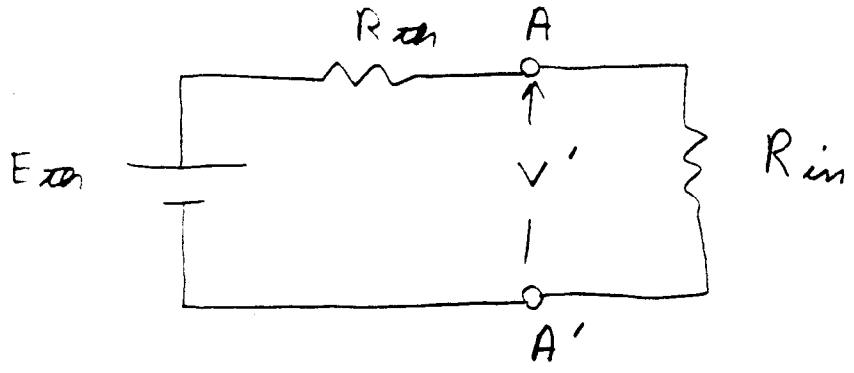
$$\% \text{ error} = -100 \frac{R_{th}}{R_{in} + R_{th}}$$

Example



$$E_{th} = 10 \frac{100 \| (150)}{100 + 100 \| (150)} \frac{100}{100 + 50} = 2.5\,V$$

$$R_{th} = 100 \| (50 + 100 \| 100) = 50\,k\Omega$$



$E_{th} = 2.5\,V$

$R_{th} = 50\,k\Omega$

HP34401A DMM $R_{in} = 10\,M\Omega$

$$V' = E_{th}\,\frac{R_{in}}{R_{in}+R_{th}} = 2.487562\,Volts$$ [6 ½ digits]

$$\%\ error = -100\,\frac{R_{th}}{R_{th}+R_{in}} = -0.49751\,\%$$

1% error | < 1 accurate

Fluke 73 HH DMM $R_{in} = 10\,M\Omega$

$V' = 2.487\ Volts$ [3 ½ digits]

Simpson Model 260-7 Analog Multimeter

$R_{in} = S\,V_{fs}$

$S = 20\,k\Omega / Volt$, V_{fs} = range

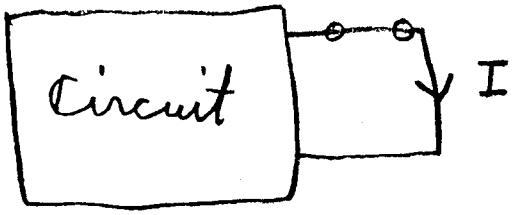
On the 10 Volt range $R_{in} = 20 \cdot 10 = 200\,k\Omega$

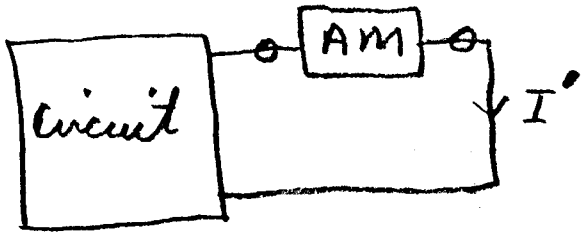
$V' = 2\ Volts$ % error = −20 %

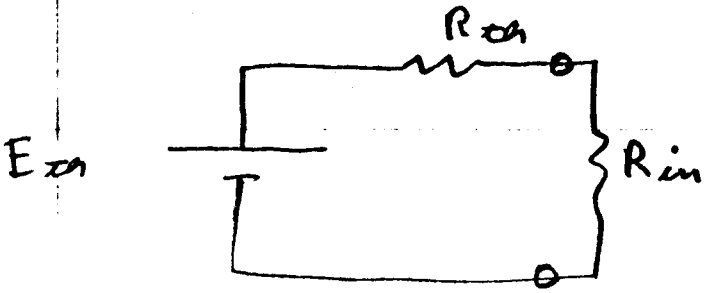
On the 2.5 Volt range $R_{in} = 2.5 \cdot 20 = 50\,k\Omega$

$V' = 1.25\ V$ % error = −50 %

Ammeter Loading





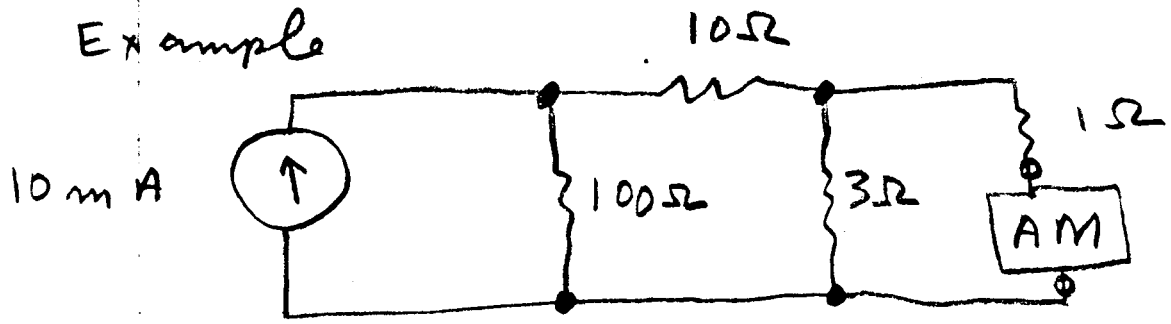


$$I = \frac{E_{th}}{R_{th}}$$

$$I' = \frac{E_{th}}{R_{th} + R_{in}}$$

$$\%\ \text{error} = 100\ \frac{I' - I}{I} = -100\ \frac{R_{in}}{R_{in} + R_{th}}$$

Example



$$E_{th} = 10\ mA\ \frac{100}{100+10+3} \cdot 3 = 26.5\ mV$$

$$R_{th} = 1 + 3 \,\|\, (10+100) = 3.92\ \Omega$$

If $R_{in} = 2\ \Omega \Longrightarrow$

$$\%\ \text{error} = -100\ \frac{2}{2+3.92} = -33.8$$