DATE	COURSE/YEAR/GROUP	NAME

UNIVERSITY OF PLYMOUTH

Department of Communication & Electronic Engineering

COMPUTER SIMULATION USING "ELECTRONICS WORKBENCH"

METER LOADING

Learning Objectives

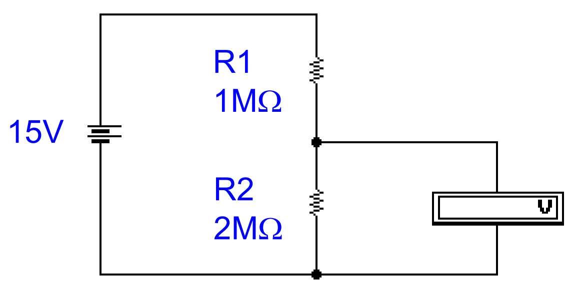
To study the way the inclusion of a voltmeter, ammeter or oscilloscope in a circuit will actually affect the quantity being measured.

To establish the conditions under which meter loading is significant.

Introduction

When instruments are used in a practical circuit to measure voltages, currents or observe wave forms using a CRO, some loading effect will take place. This disturbs the circuit and causes a change in the voltages and currents of the circuit. The degree of distortion will depend on the circuit parameters and the characteristics of the instruments used. Some of these loading effects are considered in the simulations below.

The circuit shows two resistors in series connected to a 15V supply. Calculate the voltage you would expect to see on the voltmeter. Show your working



Voltmeter Reading:

V_{CALC} =

Simulate the circuit using Electronic Workbench and measure the voltage using one of the voltmeters from the Parts Bin.

Voltmeter Reading: V_{SIMUL} =

Access the voltmeter label window and note the meter internal resistance (i.e., ‘double click’ on the voltmeter).

R_{in} =

Now change this meter resistance to 20 MΩ, which is typical of a Digital Multimeter. Repeat the simulation.

Voltmeter Reading: V_{SIMUL} =

Again access the voltmeter label window and reset the meter internal resistance to 200kΩ. This would be typical of a common analogue voltmeter e.g., an Avo. Repeat the simulation and record the voltage.

Voltmeter Reading: V_{SIMUL} =

Discuss the results obtained and explain the variation of the voltmeter readings.

Hint: you will need to calculate the (equivalent) resistance, of the meter’s resistance (200kΩ) and R_2 in parallel, then use the potential divider formula to calculate the theoretical voltage. The 200 kΩ calculation is given below as an example.

Discussions and Calculations:

Resistance of meter, R_{in} = 200 kΩ. This is in parallel with R_2 = 2 MΩ

Combined resistance R_T $\frac{R_{in}R_2}{R_{in}+R_2} = \frac{0.2*2}{0.2+2} = 0.182M\Omega$ =

So the voltage showing on the $V_s\frac{R_2}{R_1+R_2} = 15\frac{0.182}{0.182+1} =$ voltmeter = 2.31V

This is much less than the calculated value of 10V because the meter resistance is so low compared to the resistor R_2 across which it is placed. The current through the voltmeter is actually much greater than that through R_2, whereas the simple calculation assumes no current through the meter.

Repeat the calculation for the other two cases, and compare with the figures from the simulation. Discuss the results with your tutor. Can you come to a general conclusion on when meter loading is going to be a problem?

Calculations of V for meter resistance’s Rin = 1MΩ and 20MΩ.

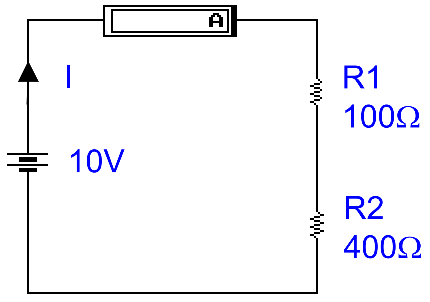
Modify the circuit to replace the MΩ resistors with kΩ resistors of the same value (i.e., 1 & 2kΩ). Repeat the investigation of the measured voltage using the same range of meter internal resistance's and comment on the new results.

Results:

Comments:

Ammeter Loading:

The current in the circuit below, is measured using an ammeter. Simulate the circuit.



Theoretical circuit current (Ohm's Law)

I_{CALC}=

Measured current in simulation

I_{SIMUL} =

Internal resistance of ammeter used in simulation

R_{METER} =

Now access the Label window for the ammeter ('double click' on the ammeter) and modify the ammeter internal resistance to 10 Ω. This would represent a typical value for many practical ammeters. Run the simulation again and measure the new circuit current.

New circuit current = % change in current value =

Why has the current value changed?

Under what conditions is ammeter loading going to be significant?

Answer:- when the ammeter resistance is compared to the circuit resistance

Conclusion – Ideal Meters

A simpler way of expressing the conclusion to these investigations is to say that:-

- An ideal voltmeter would have no loading effect if its resistance was: INFINITE/ ZERO
- An ideal ammeter would have no loading effect if its resistance was: INFINITE/ ZERO

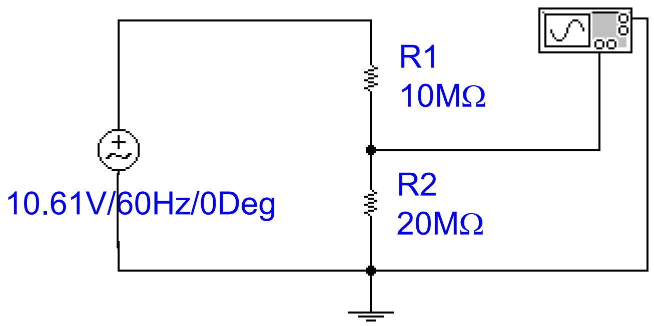
Select the correct answer above in each case.

Oscilloscope Loading

Connect up the voltage divider circuit with an AC voltage source, and an oscilloscope connected across R_3

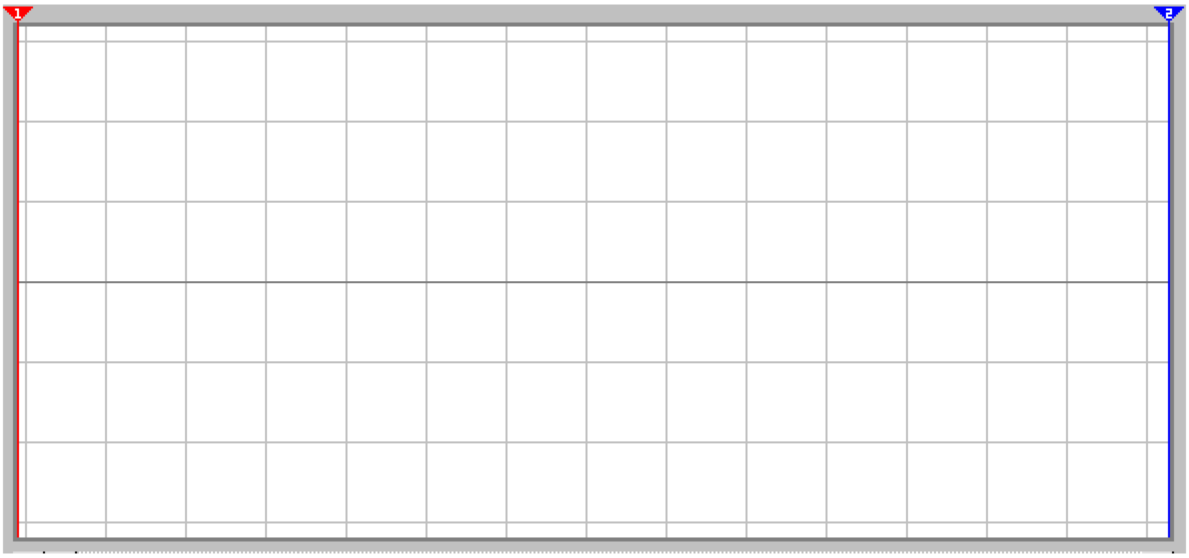
The voltage is set at 10.61V (rms), because this has a peak value of 10.61 x 1.414 = 15.0 V

Thus, you can compare the loading effect directly with the DC circuit, where we used a 15V battery.



Hint: Colour the wires to the oscilloscope, to get different colour traces i.e., 'click' on the wire to highlight it,then choose Circuit & Wire Colour.

Run the simulation and record the peak voltage across R_2



Can you deduce the effective resistance of the CRO ?

Humm!! The simulation seems somewhat inadequate. Typically, a real CRO has a resistance of only 1 MΩ, and a X10 probe often has to be used. This increases the resistance to 10 MΩ, though at the expense of reducing the gain by 10.

The moral is that simulations are always, to some degree, a simplified view of reality. They are very useful, but results from them should always be taken with a pinch of salt.