Using fixed power supplies – Part 1

Calculations for figure 5

I published a construction article in the March 2024 edition of Practical Wireless Magazine. Electronic viewing of the magazine, as part of a subscription, is here: https://pocketmags.com/eu/practical-wireless-magazine

In that article appears figure 5 – as shown here:

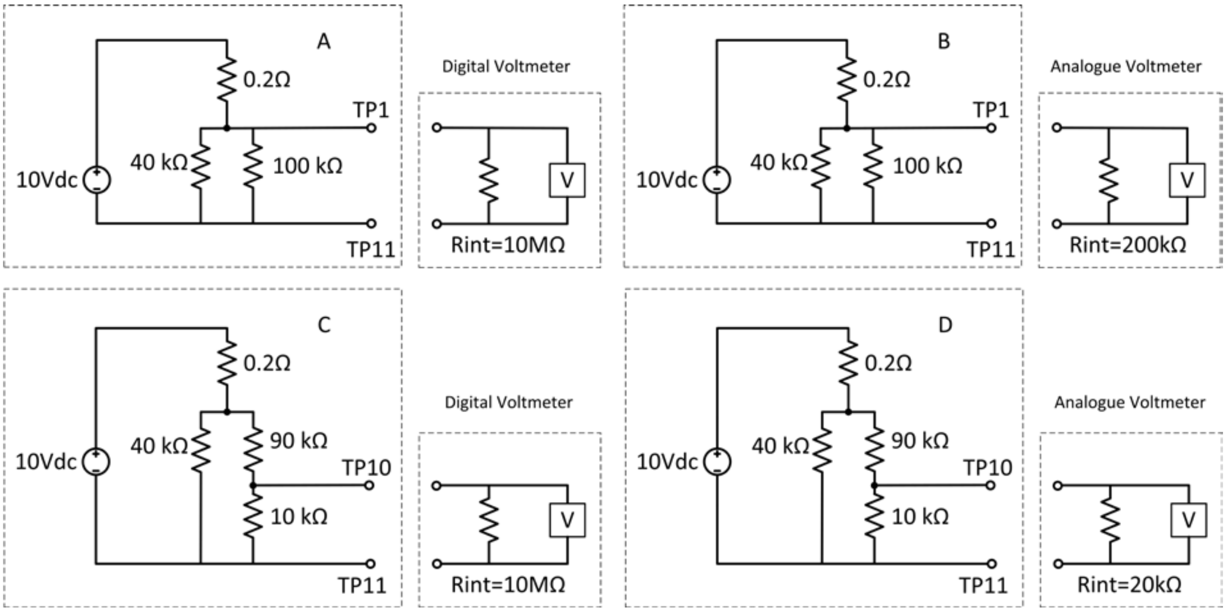


Figure 1. Be aware of different multimeter input resistances

I want to demonstrate, if you use an analogue multimeter with a low input impedance as opposed to using a digital multimeter with a high input resistance, that you must be aware of how errors may occur.

In all the blocks (A – D) in Figure 5, the 0.2 ohm resistor represents the output resistance of the 78L05 (U2). The 0.2 ohm resistor is in series to ground with R1A, R1B, R1C and R2 which make up the 40 kΩ resistor which has in parallel a 100 kΩ resistor made up from R3 to R12. At each tap (TP1 to TP10) you place the multimeter in parallel with all or a portion of that 100 kΩ resistor.

In block A of Figure 5 we have the digital multimeter, with an input impedance of 10 MΩ (called Rint), measuring at TP1 (where we expect to measure 10 Volts).

The formula you use is:

$$V_{measured} = V_m = \frac{R_T}{R_T + R_s} \times V_T$$

For figure 5 block A we have:

$$V_m = \frac{40k \parallel 100k \parallel 10M}{[40k \parallel 100k \parallel 10M] + 0.2} \times 10$$

The term $40k \parallel 100k \parallel 10M$ indicates a 40kΩ resistor is in parallel with a 100kΩ resistor which is also in parallel with a 10MΩ resistor.

$$V_m = \frac{28490}{28490.2} \times 10$$

$$V_m = 9.999929\ volts$$

Which is 10 volts for all practical purposes.

In block C of Figure 5 we have the digital multimeter, with an input impedance of 10 MΩ, measuring at TP10 (where we expect to measure 1 Volt).

For figure 5 block C we have:

$$V_m = \frac{10k \parallel 10M}{[10k \parallel 10M] + 90k} \times 10$$

$$V_m = \frac{9990}{99990} \times 10$$

$$V_m = 0.9990999\ volts$$

Which is 1 volt for all practical purposes.

In both cases the high input impedance of the digital multimeter does not materially affect the circuit it is coupled to and for all practical purposes measures 10V at TP1 and 1V at TP10.

In block B of Figure 5 we are using the analogue multimeter on the 10V range and as its input impedance specification is 20 kΩ per volt, the actual input impedance on the 10V range is 200 kΩ.

For figure 5 block B we have:

$$V_m = \frac{40k \parallel 100k \parallel 200k}{[40k \parallel 100k \parallel 200k] + 0.2} \times 10$$

$$V_m = \frac{25000}{25000.2} \times 10$$

$$V_m = 9.99992 \; volts$$

Which is 10 volts for all practical purposes.

In block D of Figure 5 we are using the analogue multimeter on the 1V range and as its input impedance specification is 20 kΩ per volt, the actual input impedance on the 1V range is 20 kΩ.

For figure 5 block D we have:

$$V_m = \frac{10k \parallel 20k}{[10k \parallel 20] + 90k} \times 10$$

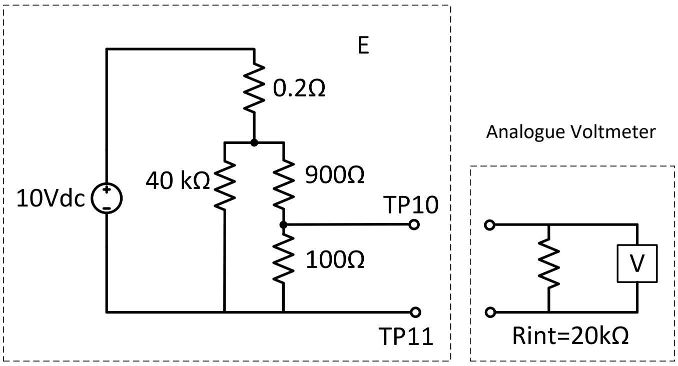
$$V_m = \frac{6666.7}{96666.7} \times 10$$

$$V_m = 0.689 \; volts$$

Which is not 1V, is an error of 31.1% and demonstrates how a low impedance input multimeter can cause incorrect measurements.

I go on to say in the article that "*If you do have an analogue meter that has a low Ω/V specification then consider replacing R3 - R12 with 100 Ω 1% resistors. On the 1 Volt scale this will reduce your error to less than 0.5%*".

This changes the schematic to:



For the figure E above we have:

$$V_m = \frac{100 \parallel 20k}{[100 \parallel 20] + 900} \times 10$$

$$V_m = \frac{99.5}{999.5} \times 10$$

$$V_m = 0.9955\ volts$$

This is an error of 0.45%.

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