# *Series Parallel Circuits*

Series-parallel circuits contain combinations of both series and parallel components. The principles used to analyse series and parallel circuits are also utilized to analyse basic series-parallel circuits.

These principles are used to simplify the portions of the circuit that are purely parallel or purely series. These simplifications usually leave other pure parallel or pure series portions. The circuit is repeatedly simplified until the entire circuit is resolved.

Figure 1 shows the resistors $R_3$ and $R_4$ are connected in parallel and can be combined into one resistance ($R_3||R_4$) using the parallel resistance equation.

Looking at Figure 2., it is obvious that $R_2$ to using series with ($R_3||R_4$). This gives us Figure 3 with $\mathbf{R_{234} = R_2 + (R_3||R_4)}$

Figure 4 shows the final simplification. From figure 3 we can see that the two remaining resistors are in parallel. This gives us $\mathbf{R_T = R_1||(R_2 + (R_3||R_4))}$

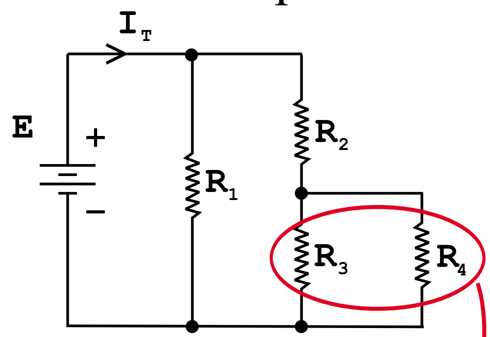


Figure 1 - The original circuit

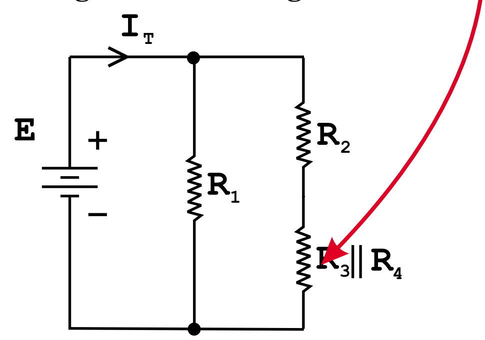


Figure 2 - The 1st Simplification

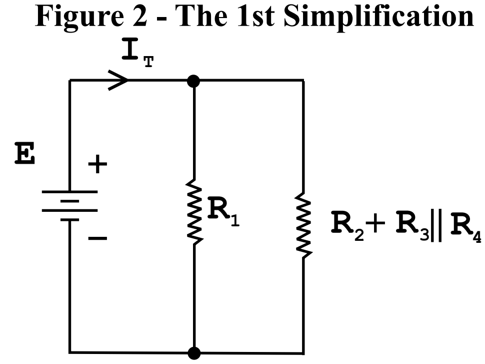


Figure 3 - The 2nd Simplification

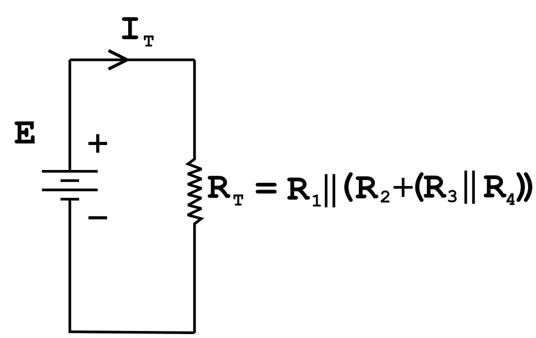


Figure 4 - The Final Simplification

## Power In Series Parallel- Circuits

Power calculations for series parallel circuits are identical to those in series or parallel circuits.

## Power Dissipated by Each Resistor

The power dissipated by each resistor in a series - parallel network is determined by the same formulas as before:

$$P_1 = V_1 I = \frac{V^2}{R_1} = I^2 R_1 \quad \text{[watts,W]}$$

$$P_2 = V_2 I = \frac{V_2^{\,2}}{R_2} = I^2 R_2 \quad \text{[watts,W]}$$

$$P_n = V_n I = \frac{V_n^{\,2}}{R_n} = I^2 R_n \quad \text{[watts,W]}$$

The power delivered by a voltage source of the circuit is given as:

$$P_T = EI \quad \text{[watts,W]}$$

The power delivered by the voltage source, must be completely dissipated by all the resistors in the network.

Each resistor in a network dissipates some of the power. The total power used by the network is the addition of the power used by each resistor.

$$P_T = P_1 + P_2 + \cdots\cdots + P_n \quad \text{[watts,W]}$$

**Example 7-1 to 7-4 page 222-228**

## Analysis Of Series Parallel Circuits

When analyzing series parallel circuits remember to use the following rules:

***Remember that:***

- ***The same current occurs through all series elements.***
- ***The same voltage occurs across all parallel elements.***
- ***Kirchhoff's Voltage Law and Kirchhoff's Current Law applies for all circuits regardless of whether the circuits are series, parallel, or series parallel.***

The following steps will help simplify the analysis of series parallel circuits:

1. Whenever necessary, redraw complicated circuits showing the source connection at the left-hand side.
2. Examine the circuit to determine the strategy which will work best in analyzing the circuit for the required quantities. If possible, start the analysis of the circuit with the components most distant from the source.
3. Simplify recognizable combinations of components wherever possible, ***redrawing the resulting circuit as often as necessary.***
4. Determine the equivalent circuit resistance $R_T$.
5. Solve for the total circuit current. Indicate the directions of all currents and label the correct polarities of the voltage drops on all components.
6. Calculate how currents and voltages split between the elements of the circuit.
7. Check your result by using a different approach.

## Potentiometers And Rheostats

Sometimes it is desirable to change the value of the resistor once it has been installed in a circuit. For these applications, we use a variable resistor.

The resistance of a variable resistor can be adjusted by turning a knob, rotating the screw, or adjusting a slider. There are two major classes of variable resistors: ***rheostats and potentiometers.***

***Often these two classes are actually the same physical device; it is the electrical connection that distinguishes the two types of variable resistors.***

The volume control on a receiver or amplifier is an example of variable resistor used as a potentiometer.

As a general rule, potentiometers are used to control voltage levels and rheostats are used to control current levels.

## Potentiometers

Figure 4 shows a cutaway view of potentiometer. A sliding contact is moved along the strip of resistive material to adjust the value of the component.

The 2 outer solder terminals (A & C) are fixed to the end of the resistive material.

The sliding contact can be set anywhere along the resistive material.

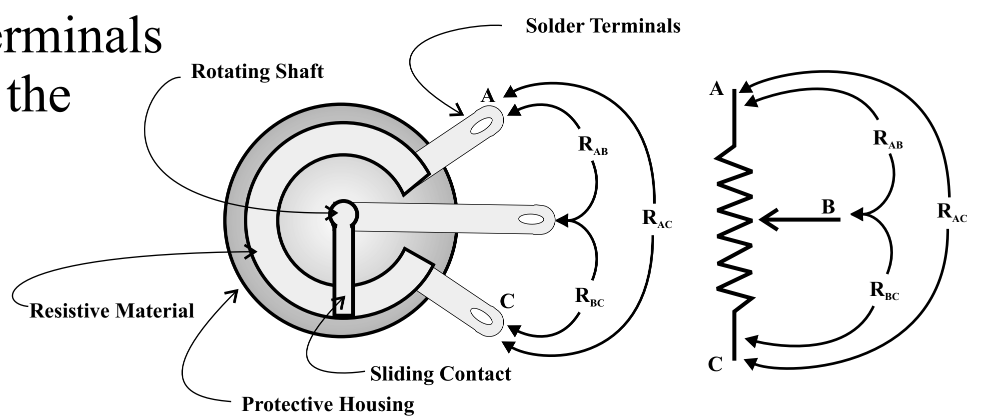



**Figure 4 Cut-away view of a potentiometer and its schematic symbol**

## Potentiometers How they Work

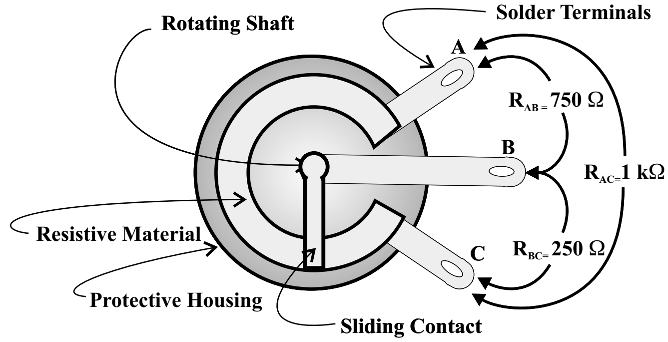



**Figure 6 - 1 kΩ Pot**

With potentiometers, the resistance between terminals A and C ($R_{AC}$) is always constant.

As an example, let's say that the resistive material between terminals A and C has a resistance of 1k Ω. ***See Figure 6***.

As you can see in Figure 6, the slider (or wiper arm) is closer to terminal C than it is to terminal A. In our example, approximately 75 percent of the resistive material is between the wiper arm and terminal A with the remaining 25% between the wiper arm and terminal C.

If we were to take an ohmmeter and measure the resistance between terminals A & B ($R_{AB}$), we would read approximately 750Ω. The resistance between terminals B & C ($R_{BC}$)would read approximately 250 Ω.

If we were to move the slider, we would find that ($R_{AB}$) and ($R_{BC}$) will change however they will always add up to 1kΩ.

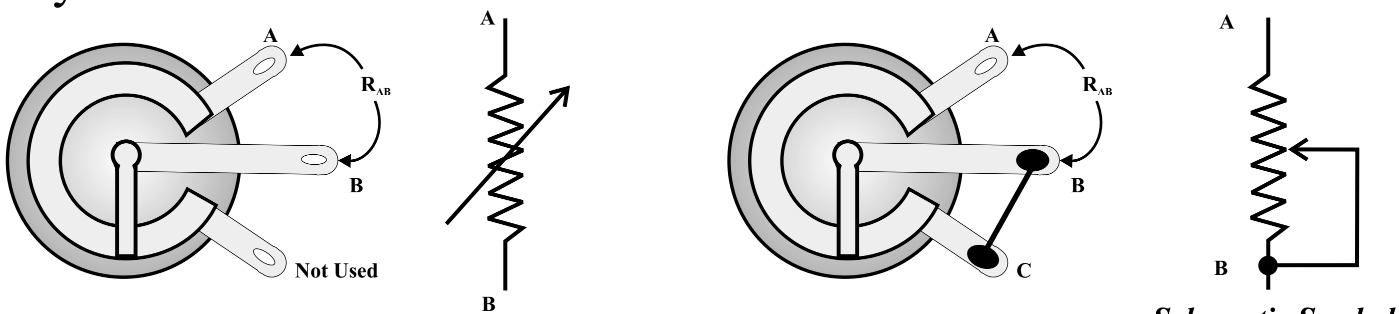
If we moved the wiper arm towards terminal A, then ($R_{AB}$) would decrease. At the same time ($R_{BC}$)would increase by the same amount.

Added together, $R_{AB} + R_{BC}$ always equal $R_{AC}$, in this case 1kΩ.

## Rheostats

Figure 6 shows two ways to wire a variable resistor has a rheostat.

Note that the rheostat has only 2 terminals.  Here we are using only terminals A and B.




*Schematic Symbol*

*Schematic Symbol*

*Use only Terminals A & B.*

*Connect terminals  B & C together with a wire.*

**Figure 6      Two Ways to wire a Potentiometer as a Reostat**

## The Loading Effect of Instruments

Now we have studied series parallel circuits, this would be a good time to introduce instrument loading effects.

## Voltmeter Loading Effect

Iin the lab, we have used two different voltmeters. They were the Triplett VOM and the Fluke DMM.

We know that the DMM has a 10 MΩ input resistance on dc volts while the VOM has a much lower input resistance that changes with a range we are using.

Now would be a good time to see what effect this input resistance has on our circuit.

Consider Figure 7, a simple series circuit. We are trying to measure $V_{R2}$

## Voltmeter Loading Effects

Figure 7 shows a simple series circuit. by calculation, the voltage appearing across $R_2$ is 5 V.

This is the voltage that we should be able to measure with our voltmeter.

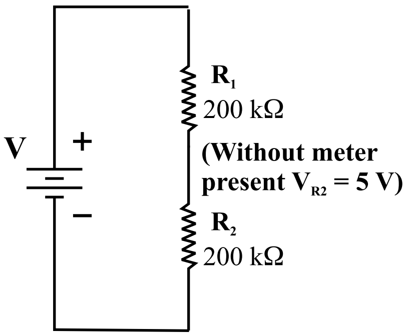



Fig. 7 A simple series circuit

In Figure 8, we are attempting to measure the voltage across $R_2$ with a **Triplett VOM**. Note that voltmeter is reading 3.33 V, substantially below the real value of 5 v.

This is because the **VOM** has a lower input resistance. The meter appears as a resistance that is in parallel with $R_2$.

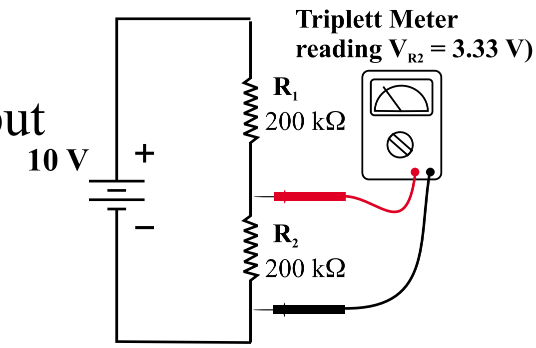



Fig. 8 Measuring $V_{R2}$ with a Triplett VOM on the 10 V range

This lower input resistance is drawing energy out of the circuit and is causing the erroneous reading of 3.33 V. The meter is loading down the circuit. This is called the loading effect.

In Figure 9, the Fluke voltmeter is measuring the voltage across $R_2$. This meter has a 10 MΩ input resistance.

Because the input resistance is so high, the meter is actually reading very close to the real voltage value of 5 V. The loading the effect presented by this meter is very small and in most cases is negligible..

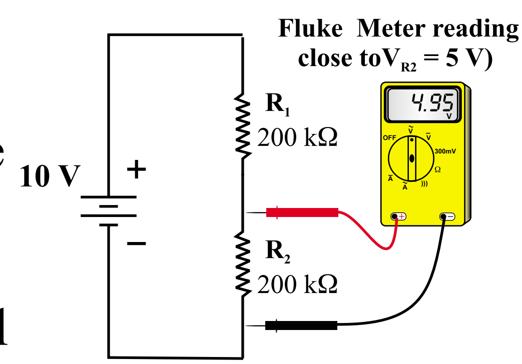



Fig. 8 Measuring $V_{R2}$ with a Triplett VOM on the 10 V range

## Voltmeter Loading Effects

The important thing to remember is that the higher the voltmeter's internal resistance, the less loading effect it has on the circuit you are measuring.

## Ammeter Circuit Effects

An ideal ammeter has zero resistance but a real ammeter always has a small resistance that alters the actual circuit current.

The actual circuit current is always decreased due to the additional resistance.  The amount the current decreases is usually negligible however when measuring the currents for low resistance components, the effect can be substantial.

## A Case in Point

In Figure 10 (a), we are measuring the current through $R_{2.}$

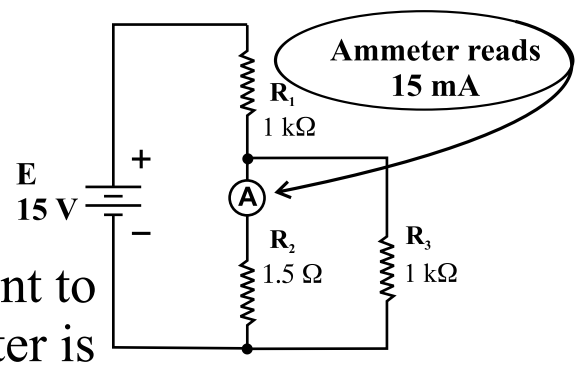


Figure 10 (a)   The "Ideal"  Ammeter

By calculation, you would find the current to be very close to 15 ma. The Ideal ammeter is measuring 15 mA as it should be.

Figure 10 (b) shows a more real life situation. In this case the ammeter is not totally "transparent". It has an internal resistance of 5 Ω.

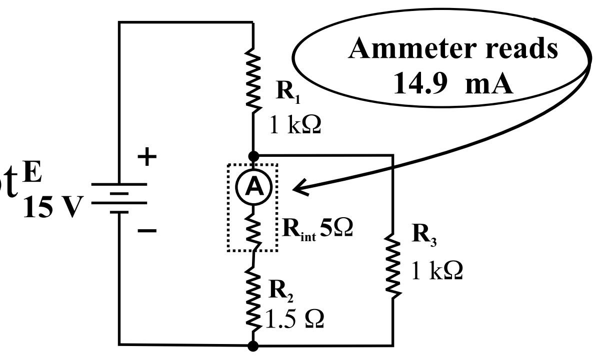


Figure 10 (b)   The "Real" Ammeter

The ammeter inserts this extra resistance into the circuit and the circuit current is affected. It is now 14.9 mA. The important thing to remember is that all ammeters have some internal resistance and in some circuits, this resistance can cause a substantial error.