

CHAPTER 2

Basic Electronics & Theory

(The rules behind all those little things)

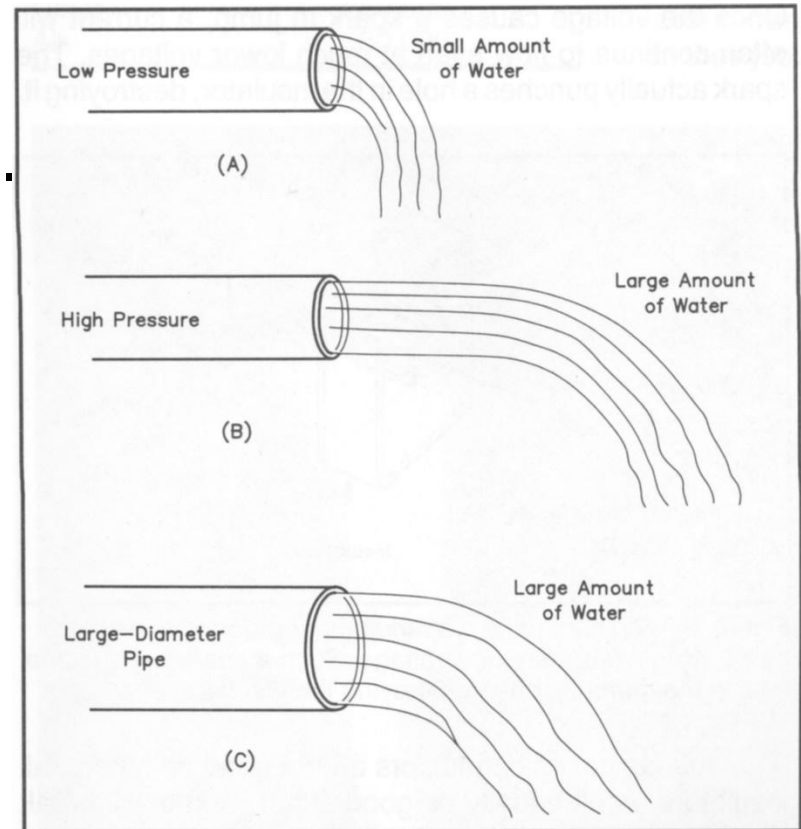
Current, Voltage, Resistance

Water flowing through a hose is a good way to imagine electricity. Water is like **Electrons** in a wire.

Flowing electrons are called **Current**

Pressure is the force pushing water through a hose – **Voltage** is the force pushing electrons through a wire

Friction against the hose walls slows the flow of water – **Resistance** is an impediment that slows the flow of electrons



Two Types of Current

- **Direct Current (DC)**
 - Flows in only one direction **from negative toward positive** pole of source
- **Alternating Current (AC)**
 - Flows back and forth because the poles of the source alternate between positive and negative

Conductors & Insulators

Electricity flows easily through some materials. These materials are called **conductors**. Most conductors are metals, and some of the best conductors are

gold, silver, aluminum and copper

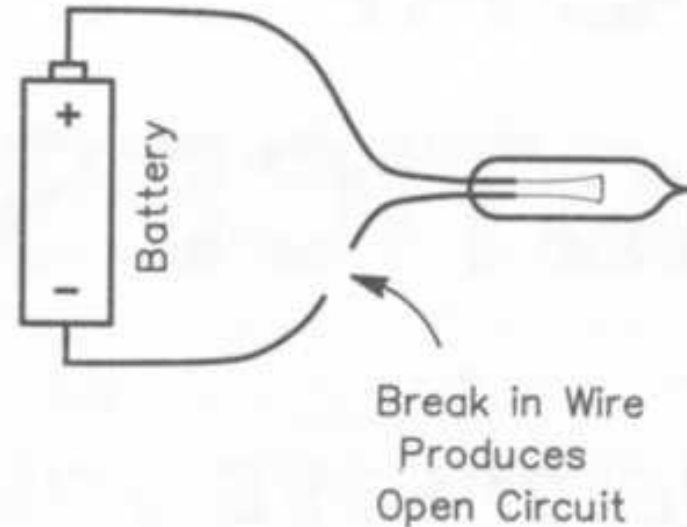
Some materials resist or prevent the flow of electricity through them. These **insulators** include such materials as

glass, air, plastic, and porcelain

Open Circuit

In an **open circuit** no current flows. A break or open in a DC circuit makes it impossible for electrons to complete a journey from negative to positive poles, so nothing flows.

For example, when a switch in a circuit is turned off, it creates an open circuit by creating a break or opening in the circuit, and current stops flowing. When it is turned on, the "path" from negative to positive poles is completed and current flows.



You probably figured that since there are "open circuits" that there are probably also "closed circuits". Well, a closed circuit is when the switch is closed and current is allowed to flow through the circuit.

A fuse is a device that is used to create an open circuit when too much current is flowing.

Short Circuit

A **short circuit** usually occurs when the intended path of electron flow is abruptly shortened, often by crossing uninsulated wires or touching other components together.

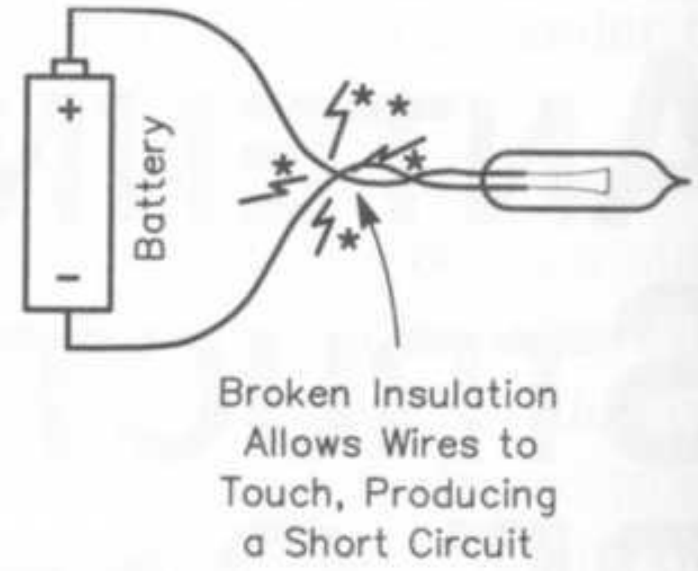
Since a circuit usually has some resistance, and the power wires or touching components that "short out" have little resistance, current will tend to flow through the path of least resistance... the location of the short circuit.

Less resistance at the same amount of voltage results in greater current flow, which can damage components not designed for it.

What is the best way to stop a short circuit from doing damage (because it is drawing too much power from the source)?

A fuse. Fuses are designed to work up to a certain amount of current (e.g. 1 amp, 15 amps, etc.)

When the maximum rated current is exceeded, the wire within the fuse burns up from the heat of the current flow, breaking the circuit and creating an open circuit... no more current flow.

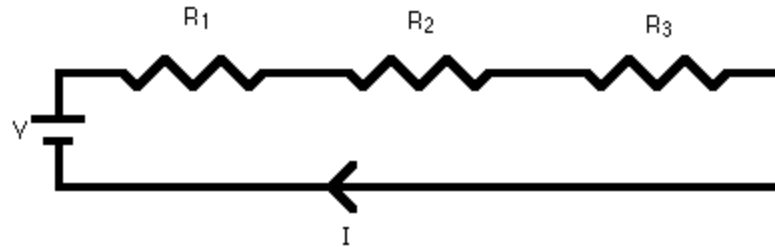


Resistors - Series Circuits

A series circuit is a circuit in which resistors are arranged in a chain, so the current has only one path to take.

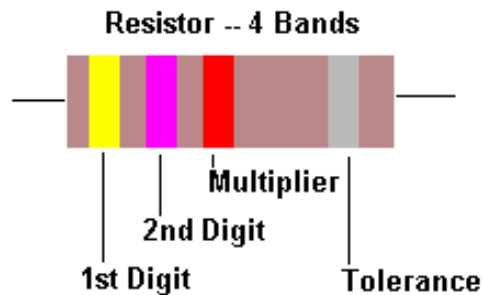
The current is the same through each resistor. The total resistance of the circuit is found by simply adding up the resistance values of the individual resistors:

$$R = R_1 + R_2 + R_3 + \dots$$



Resistor Fundamentals

Resistor Colour Codes & Tolerances



Band Color	Digit	Multiplier	Tolerance
Black	0	1	---
Brown	1	10	±1%
Red	2	100	±2%
Orange	3	1,000	±3%
Yellow	4	10,000	±4%
Green	5	100,000	---
Blue	6	1,000,000	---
Violet	7	10,000,000	---
Gray	8	100,000,000	---
White	9	---	---
Gold	---	0.1	±5%
Silver	---	0.01	±10%
None	---	---	±20%

0	1	2	3	4	5	6	7	8	9
Bad	Booze	Rots	Our	Young	Guts	But	Vodka	Goes	Well
Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White

Resistor Fundamentals

The color code chart is applicable to most of the common four band and five band resistors. Five band resistors are usually precision resistors with tolerances of 1% and 2%. Most of the four band resistors have tolerances of 5%, 10% and 20%.

The color codes of a resistor are read from left to right, with the tolerance band oriented to the right side. Match the color of the first band to its associated number under the digit column in the color chart. This is the first digit of the resistance value. Match the second band to its associated color under the digit column in the color chart to get the second digit of the resistance value.

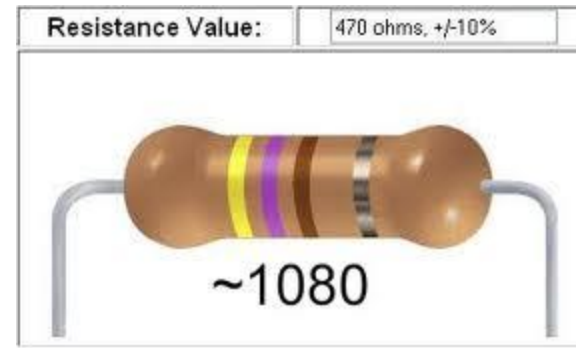
Match the color band preceding the tolerance band (last band) to its associated number under the multiplier column on the chart. This number is the multiplier for the quantity previously indicated by the first two digits (four band resistor) or the first three digits (five band resistor) and is used to determine the total marked value of the resistor in ohms.

Resistor Fundamentals

To determine the resistor's tolerance or possible variation in resistance from that indicated by the color bands, match the color of the last band to its associated number under the tolerance column. Multiply the total resistance value by this percentage.

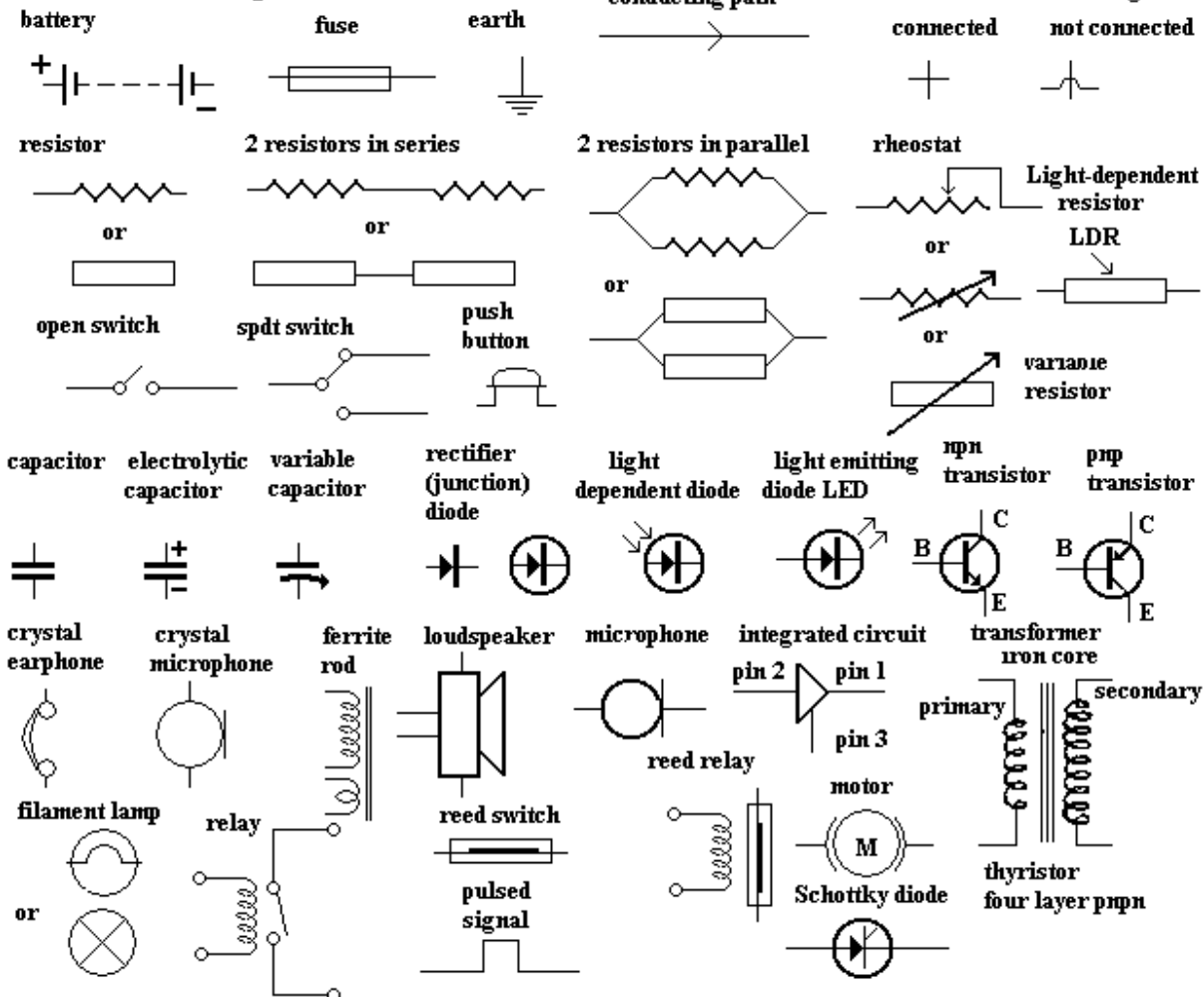
Example of a 4-Band Resistor

Colours: Band 1 (Value):	YELLOW (4)
Band 2 (Value):	VIOLET (7)
Band 3 (Multiplier):	BROWN (1)
Band 4 (Tolerance):	SILVER (10%)
Value: Resistance:	470 Ohms
Preferred Value:	470 Ohms (10%)
Tolerance:	10%



Resistor Fundamentals

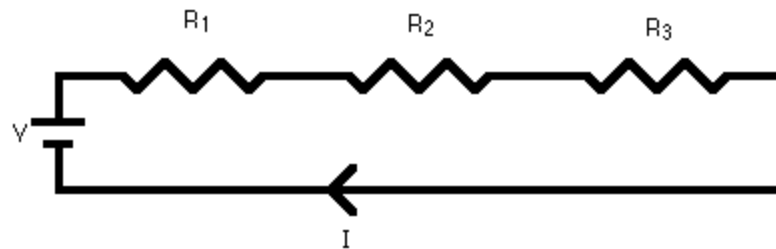
38.2.00 Circuit diagrams



Resistors – Series Circuit

A series circuit is shown in the diagram below. The current flows through each resistor in turn. If the values of the three resistors are:

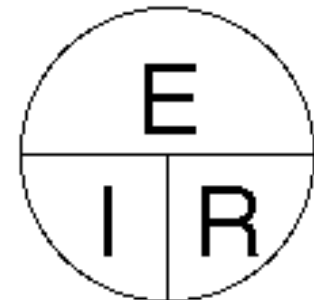
$R_1 = 8 \Omega$, $R_2 = 8 \Omega$, and $R_3 = 4 \Omega$, the total resistance is $8 + 8 + 4 = 20 \Omega$.



With a 12 V battery, by $E = I \times R$ the total current in the circuit is:

$$I = E / R = (12 / 20) = 0.6 \text{ A}$$

The current through each resistor would be 0.6 amps



Resistors – Series Circuit

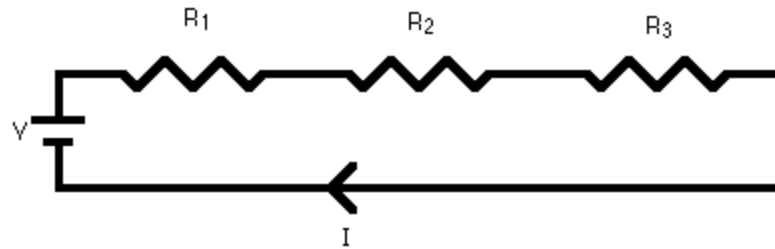
$$R = R1 + R2 + R3 + \dots$$

$$R1 = 100 \text{ ohms}$$

$$R2 = 150 \text{ ohms}$$

$$R3 = 370 \text{ ohms}$$

$$RT = ? \text{ ohms}$$



Resistors – Parallel Circuits

A **parallel circuit** is a circuit in which the resistors are arranged with their heads connected together, and their tails connected together.

The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again.

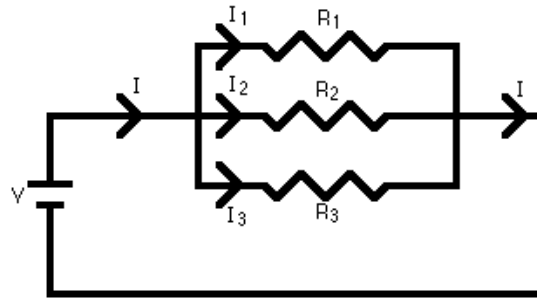
The voltage across each resistor in parallel is the same.

The total resistance of a set of resistors in parallel is found by adding up the **reciprocals** of the resistance values, and then taking the reciprocal of the total.

Equivalent resistance of resistors in parallel

$$1 / R = 1 / R1 + 1 / R2 + 1 / R3 + \dots$$

Resistors – Parallel Circuits



A parallel circuit is shown in the diagram above. In this case the current supplied by the battery splits up, and the amount going through each resistor depends on the resistance. If the values of the three resistors are:

$R_1 = 8 \Omega$, $R_2 = 8 \Omega$, and $R_3 = 4 \Omega$, the total resistance is found by:

$$1/R = 1/8 + 1/8 + 1/4 = 1/2. \text{ This gives } R = 2 \Omega.$$

With a 12 V battery, by $E = IR$ the total current in the circuit is: $I = E/R = 12/2 = 6 \text{ A}$

The individual currents can also be found using $I = V/R$. The voltage across each resistor is 10 V, so:

$$I_1 = 12/8 = 1.5 \text{ A}$$

$$I_2 = 12/8 = 1.5 \text{ A}$$

$$I_3 = 12/4 = 3 \text{ A}$$

Note that the currents add together to 6 A, the total current

Resistors – Parallel Circuits

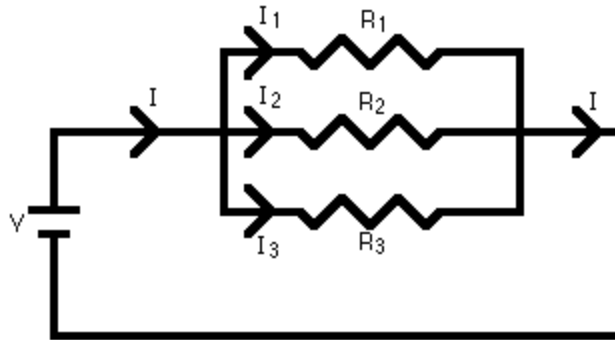
$$1 / R = 1 / R_1 + 1 / R_2 + 1 / R_3 + \dots$$

$$R_1 = 100 \text{ ohms}$$

$$R_2 = 100 \text{ ohms}$$

$$R_3 = 100 \text{ ohms}$$

$$R_T = ? \text{ Ohms}$$



$$R_T = 1 / (1 / 100 + 1 / 100 + 1 / 100) = 33.33 \text{ ohms}$$

Resistors – Parallel Circuits

A parallel resistor short-cut

If the resistors in parallel are identical, it can be very easy to work out the equivalent resistance. In this case the equivalent resistance of N identical resistors is the resistance of one resistor divided by N , the number of resistors. So, two 40-ohm resistors in parallel are equivalent to one 20-ohm resistor; five 50-ohm resistors in parallel are equivalent to one 10-ohm resistor, etc.

When calculating the equivalent resistance of a set of parallel resistors, people often forget to flip the $1/R$ upside down, putting $1/5$ of an ohm instead of 5 ohms, for instance. Here's a way to check your answer. If you have two or more resistors in parallel, look for the one with the smallest resistance. The equivalent resistance will always be between the smallest resistance divided by the number of resistors, and the smallest resistance. Here's an example.

You have three resistors in parallel, with values 6 ohms, 9 ohms, and 18 ohms. The smallest resistance is 6 ohms, so the equivalent resistance must be between 2 ohms and 6 ohms ($2 = 6/3$, where 3 is the number of resistors).

Doing the calculation gives $1/6 + 1/9 + 1/18 = 6/18$. Flipping this upside down gives $18/6 = 3$ ohms, which is certainly between 2 and 6.

Resistors – Parallel Circuits

Circuits with series and parallel components

Many circuits have a combination of series and parallel resistors. Generally, the total resistance in a circuit like this is found by reducing the different series and parallel combinations step-by step to end up with a single equivalent resistance for the circuit. This allows the current to be determined easily. The current flowing through each resistor can then be found by undoing the reduction process.

General rules for doing the reduction process include:

Two (or more) resistors with their heads directly connected together and their tails directly connected together are in parallel, and they can be reduced to one resistor using the equivalent resistance equation for resistors in parallel.

Two resistors connected together so that the tail of one is connected to the head of the next, with no other path for the current to take along the line connecting them, are in series and can be reduced to one equivalent resistor.

Finally, remember that for resistors in series, the current is the same for each resistor, and for resistors in parallel, the voltage is the same for each one

Resistors – Parallel Circuits

- Why use a parallel resistor circuit?
 - Achieve a specific resistance level not available in readily-accessible resistors
 - Reduce current through resistors

A dummy load constructed of 94 resistors configured in a parallel circuit.

The device could withstand much more current / power than any one of the resistors, or all of them in series, could withstand.



Multimeter Tool

Multimeters will measure Voltage, Current and Resistance.

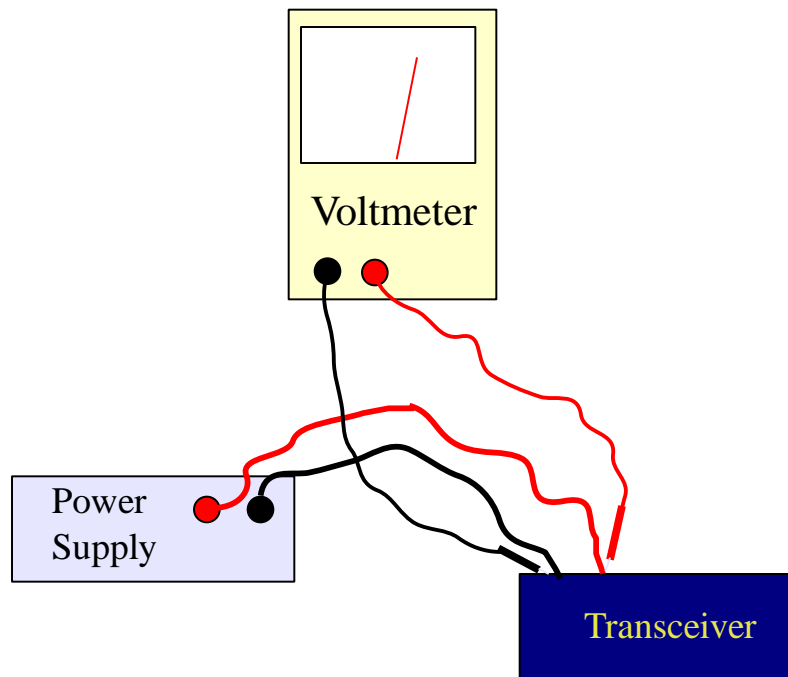
Be sure it is set properly to read what is being measured.

If it is set to the ohms setting and voltage is measured the meter could be damaged!



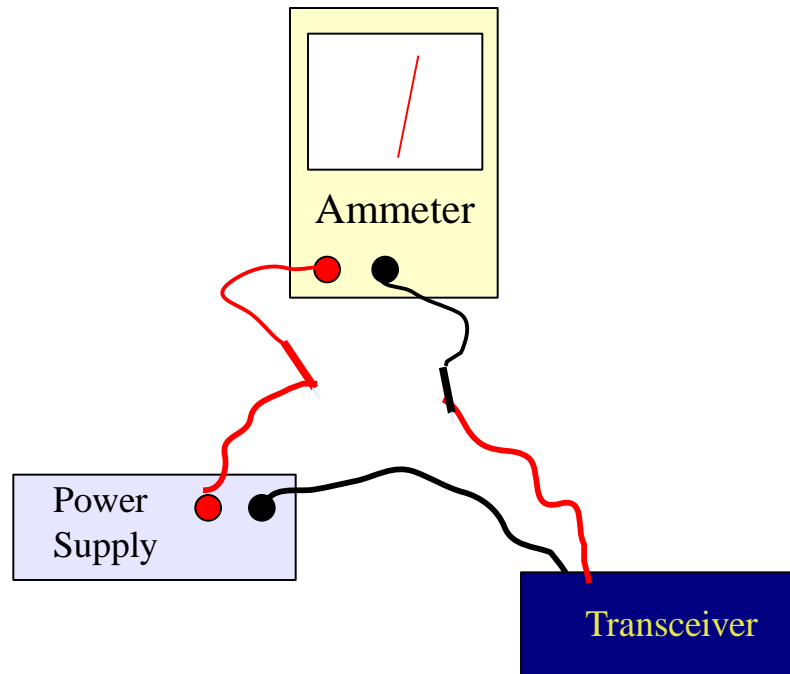
Measuring Voltage

Potential difference (voltage) is measured with a voltmeter, the voltmeter is connected to a circuit under test **in parallel with the circuit**



Measuring Current

The instrument to measure the flow of electrical current is the ammeter. An ammeter is connected to a circuit under test **in series with the circuit**



Measuring Resistance

The instrument to measure resistance is the ohmmeter. An ohmmeter is connected to a circuit under test **in parallel with the circuit**

