BASIC ELECTRICS FOR MODEL BOATS

INTRODUCTION

This tutorial, prepared for the **Model Ship World** members, gives an overview of the steps required to undertake to wire up their model boats. The fitting of the main drive electric motors will be covered in another tutorial; this one applies to lights, smoke generators, small motors for Radars and the like. It is divided into 10 Sections, and each one follows on from the previous, so if you work your way through them all in sequence you will have an understanding of what you need to do to wire up your boat.

At the end of the tutorial I will give a list of useful internet links, some of these are very easy to use and are good to check your calculations (or do them for you!)

SI UNITS

Also keep in mind that you have to make sure all the units are the same, we use the SI System for electrics and the table below shows the most commonly used.

Prefix	Symbol	Factor	Numerically	Name
giga	G	10^{9}	1,000,000,000	billion
mega	M	10^{6}	1,000,000	million
kilo	k	10^{3}	1,000	thousand
centi	c	10^{-2}	0.01	hundredth
milli	m	10^{-3}	0.001	thousandth
micro	µ	10^{-6}	0.000 001	millionth
nano	n	10^{-9}	0.000 000 001	Billionth

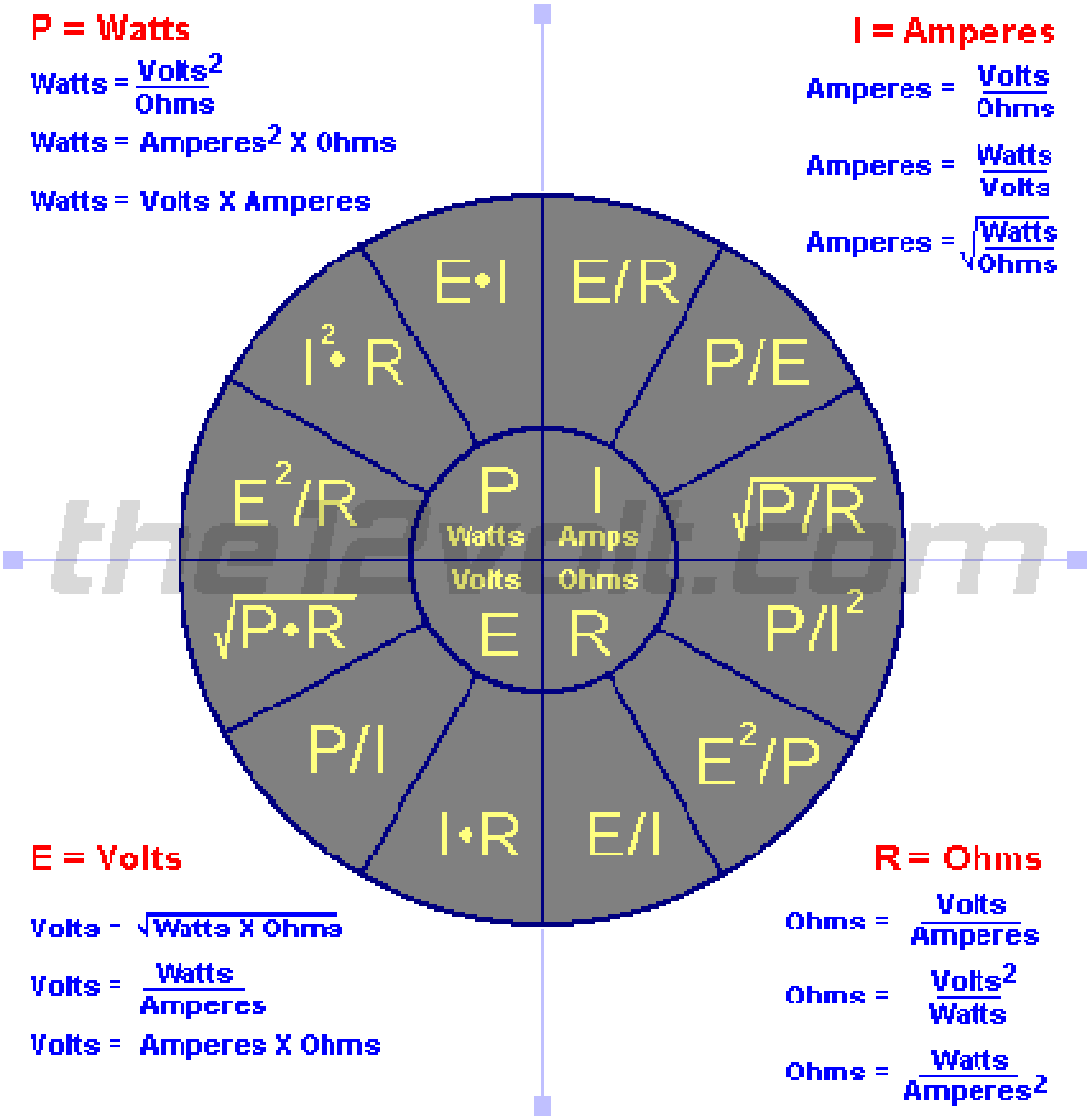
We also use these common SI units in electrical circuits. For this tutorial we will only use volts, amps and ohms.

Quantity	Unit	Symbol
Electric capacitance	farad	**F**
Electric inductance	henry	**H**
Electric current	ampere	**A**
Electric p.d., emf	volt	**V**
Electric resistance	ohm	**Ω**
Luminous flux	lumen	**lm**
Power, radiant flux	watt	**W**

This all seems very complicated, but isn't really. Most of us will remember these from our dim distant school / college days!

1 OHMS LAW

All electrical circuits have to comply with same basic rules – these are known as Ohms Law and are best illustrated by Figure 1. A circuit has a power source, in our case usually a battery, which supplies a voltage and a current. As these pass through our resistors (which are the lights, radar motors, winches etc) they use up the power, and the trick is to make sure that all the circuit balances itself. This is not as hard as it sounds if we follow some basic rules.



2 RESISTORS IN SERIES

Resistors (Lights, motors etc) can be connected in series; that is, the current flows through them one after another. The circuit in Figure 1 shows three resistors connected in series, and the direction of current is indicated by the arrow.

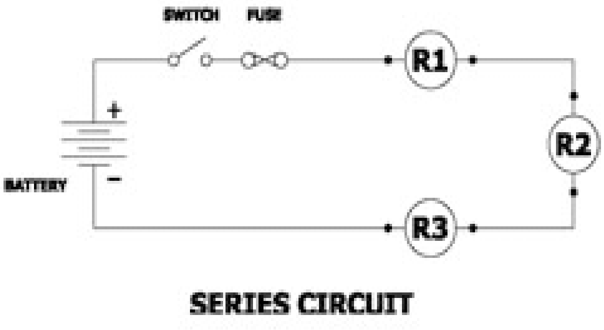


Figure 1 Example of circuit with 3 resistors connected in series

Note that since there is only one path for the current to travel, from + to – of the battery, the current through each of the resistors is the same.

$$I = I_1 = I_2 = I_3$$

Also, the voltage drops across the resistors must add up to the total voltage supplied by the battery:

$$V_{total} = V_1 + V_2 + V_3$$

Since **V** = **I R**, then

$$V_{total} = I_1 \cdot R_1 + I_2 \cdot R_2 + I_3 \cdot R_3$$

But Ohm's Law must also be satisfied for the complete circuit:

$$V_{total} = I \cdot R_{equivalent}$$

So the currents cancel on both sides, and we arrive at an expression for equivalent resistance for resistors connected in series.

$$R_{equivalent} = R_1 + R_2 + R_3$$

In general, the equivalent resistance of resistors connected in series is the sum of their resistances.

3 RESISTORS IN PARALLEL

Resistors (Lights, motors etc) can also be connected such that they branch out from a single point and join up again somewhere else in the circuit. This is known as a **parallel** connection. Each of the three resistors in Figure 1 is a path for current to travel between points + and – of the battery.

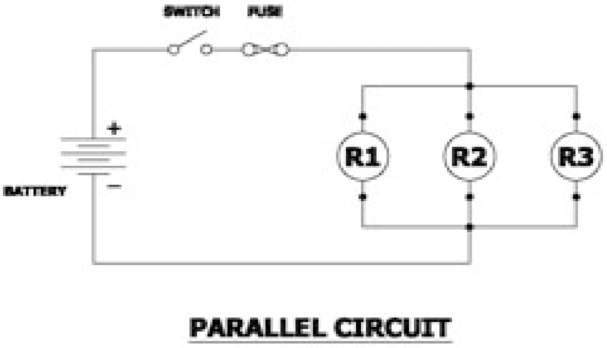


Figure 1 Example of circuit with 3 resistors connected in parallel

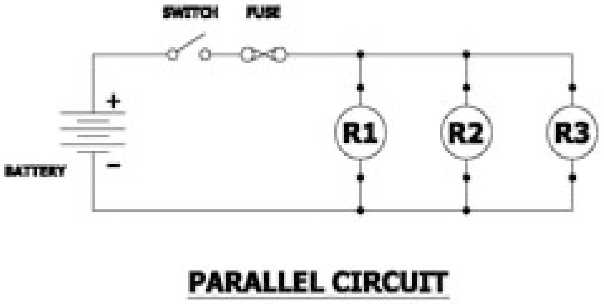


Figure 2 Another example of circuit with 3 resistors connected in parallel.

Note that the current has several alternate paths to follow, then that part of the circuit is considered to be parallel. Figures 1 and 2 are identical circuits, but with different appearances.

At + the potential must be the same for each resistor. Similarly, at - the potential must also be the same for each resistor. So, between points + and -, the potential difference is the same. That is, each of the three resistors in the parallel circuit must have the same voltage.

$$V_1 = V_2 = V_3 = V$$

Also, the current splits as it travels from + to -. So, the sum of the currents through the three branches is the same as the current at + and at - (where the currents from the branch reunite).

$$I = I_1 + I_2 + I_3$$

By Ohm's Law, equation is equivalent to:

$$\frac{V}{R_{equivalent}} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

By equation, we see that all the voltages are equal. So the V's cancel out, and we are left with

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

4 WORKING OUT THE CIRCUIT

Ok, so with all the math theory sorted out, we can get down to designing our circuits. We will have a good idea of what we want on our model, and the best way is to write a list and draw a sketch of these items, grouping them together if they are to run simultaneously. For example, all the running lights would be on at the same time, but the internal lights we may wish to be able to switch on and off independently, along with the other items like the radar or guns.

The list could look like this:

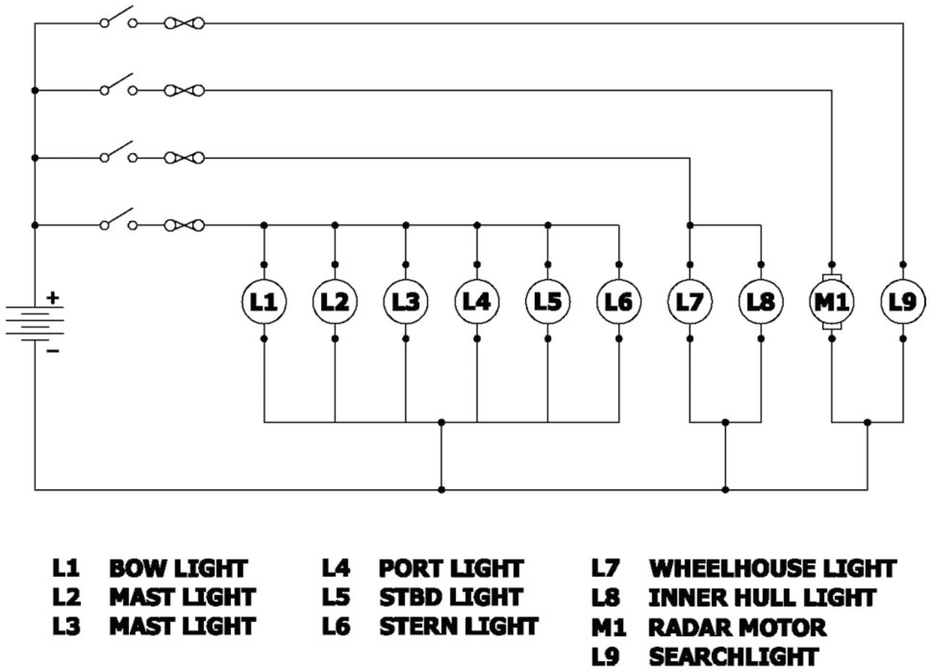
Running Lights
    Bow lamp
    Stern lamp
    Mast lamp
    Mast lamp
    Port lamp
    Starboard lamp

Independent Lights
    Wheelhouse lamp
    Inner Hull lamp

Radar Motor

Searchlight

And our circuit sketch would look like this (Ignore the switches and fuses for the time being):



The next step is to go and find all the electrical information on our items. A word here regarding the pros and cons of series versus parallel circuits. In general, I use parallel circuits, should one light blow, or a motor fail, the rest of the circuit will still operate. In a series circuit, once one item has gone, they all stop working. It is also more convenient to protect the circuit with individual fuses, important if the model is likely to get wet…

The electrical information will be got from the packaging, the catalogues, etc, and if at all possible keep them around the same voltage – don’t mix a 28V DC lamp in with a bunch of 6V ones – makes sense, doesn’t it!

We then tabulate all this information in the same format as our preliminary circuit diagram. In this case there are 3 ‘Legs’ to the circuit, 1 for all the running lights, 1 for the Radar motor and one for the searchlight

Our table would look like this:

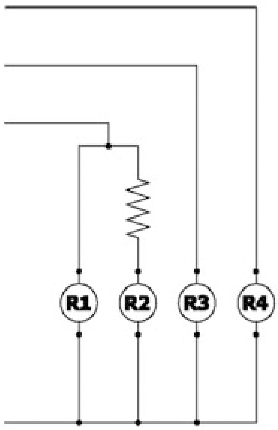
Secondary Circuit 1				
L1	Bulb xxx	6V	0.2A	**30 Ω**
L2	Bulb xxx	6V	0.15A	**40 Ω**
L3	Bulb xxx	6V	0.15A	**40 Ω**
L4	LED xxx	3.3V	0.02A	**165 Ω**
L5	LED xxx	3.3V	0.02A	**165 Ω**
L6	Bulb xxx	6V	0.2A	**30 Ω**
Secondary Circuit 2				
L7	Bulb xxx	6V	0.2A	**30 Ω**
L8	Bulb xxx	6V	0.2A	**30 Ω**
Secondary Circuit 3				
M1	Motor xxx	6V	0.25A	**24 Ω**
L9	Bulb xxx	6V	0.2A	**30 Ω**

The total current draw is 1.59A

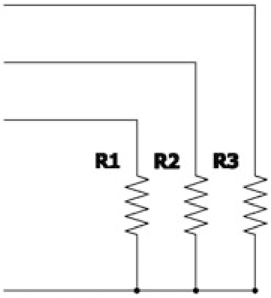
From Ohms Law, we know that R = E/I, so we go back to our list and tabulate the item resistances. Shown in RED. Remember to keep the same units (0.02A is 20 mA)

A note about LEDs, (and other lights, for that matter), if you have 6 in series, they will take (6 x 3.3) 19.8V to drive them and they will draw 20mA, but if you have them in parallel, it takes 3.3V to drive them and they draw 120mA. It is easier to increase the current than the voltage with modern batteries.

Immediately obvious is the fact that the secondary circuit 1 has a 3.3V component to it, so we will have to insert a resistor to drop the voltage from 6 to 3.3 volts in this leg. We can also now simplify the circuit to equivalents, and the sketch would look like this:



R1 L1, L2, L3, L6
R2 L4, L5
R3 L7, L8
R4 M1, L9



EQUIVALENT CIRCUIT

We can calculate now, on the left hand diagram

R1 = 8.57 **Ω**,
R2 = 300 **Ω**, (135**Ω** +165 **Ω** = 300 **Ω)**
R3 = 15.01 **Ω**,
R4 = 13.33 **Ω**,

And therefore the total equivalent resistance (for the right hand diagram) is

R1 = 2570.69 **Ω**
R2 = 15.01 **Ω**
R3 = 13.33 **Ω**

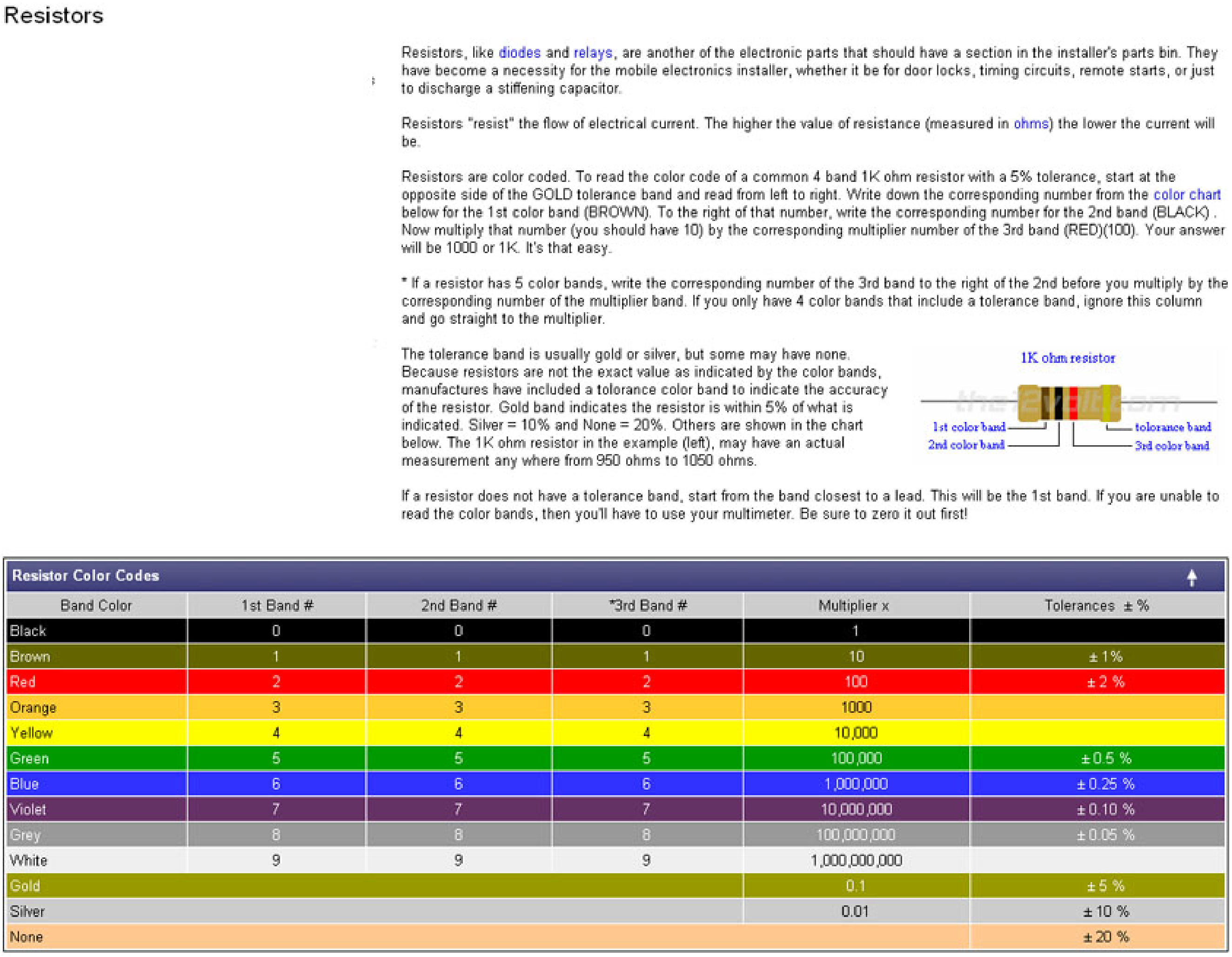
If we wish to run everything together we will need a 6V 850mA Battery

5 RESISTOR RATINGS

Now that we have worked out the circuit and know the value of the resistor we need to use, (in the last section it was 135 Ω) we can use the following chart to determine the closest.

The standard 5% Resistor values for one group are as follows, (multiply by 1, 10, 100 etc):

10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, and 91



Resistors

Resistors, like diodes and relays, are another of the electronic parts that should have a section in the installer's parts bin. They have become a necessity for the mobile electronics installer, whether it be for door locks, timing circuits, remote starts, or just to discharge a stiffening capacitor.

Resistors "resist" the flow of electrical current. The higher the value of resistance (measured in ohms) the lower the current will be.

Resistors are color coded. To read the color code of a common 4 band 1K ohm resistor with a 5% tolerance, start at the opposite side of the GOLD tolerance band and read from left to right. Write down the corresponding number from the color chart below for the 1st color band (BROWN). To the right of that number, write the corresponding number for the 2nd band (BLACK). Now multiply that number (you should have 10) by the corresponding multiplier number of the 3rd band (RED)(100). Your answer will be 1000 or 1K. It's that easy.

* If a resistor has 5 color bands, write the corresponding number of the 3rd band to the right of the 2nd before you multiply by the corresponding number of the multiplier band. If you only have 4 color bands that include a tolerance band, ignore this column and go straight to the multiplier.

The tolerance band is usually gold or silver, but some may have none. Because resistors are not the exact value as indicated by the color bands, manufactures have included a tolorance color band to indicate the accuracy of the resistor. Gold band indicates the resistor is within 5% of what is indicated. Silver = 10% and None = 20%. Others are shown in the chart below. The 1K ohm resistor in the example (left), may have an actual measurement any where from 950 ohms to 1050 ohms.

If a resistor does not have a tolerance band, start from the band closest to a lead. This will be the 1st band. If you are unable to read the color bands, then you'll have to use your multimeter. Be sure to zero it out first!

Resistor Color Codes

Band Color	1st Band #	2nd Band #	*3rd Band #	Multiplier x	Tolerances ± %
Black	0	0	0	1	
Brown	1	1	1	10	± 1%
Red	2	2	2	100	± 2 %
Orange	3	3	3	1000	
Yellow	4	4	4	10,000	
Green	5	5	5	100,000	± 0.5 %
Blue	6	6	6	1,000,000	± 0.25 %
Violet	7	7	7	10,000,000	± 0.10 %
Grey	8	8	8	100,000,000	± 0.05 %
White	9	9	9	1,000,000,000	
Gold				0.1	± 5 %
Silver				0.01	± 10 %
None					± 20 %

So we will select the closest - 150 Ω

6 WIRE SIZING

There are two important factors to be considered when sizing the wire to be used. These are:

How much current does the wire have to carry?

How long is the wire run?

The first factor is the most important. The more current drawn, the larger the wire you will need. Wire size (diameter) is specified in terms of "AWG" (American Wire Gauge) which is more commonly known just as "Gauge". A point to keep in mind is that as the wire diameter gets larger; its gauge number gets smaller. (All back to front!).

For our models, we will generally use wires in the 12 to 30 Gauge range. Before you can select the proper size wire, you will need to know how much current the wire is required to carry. You know (or can measure) the current use of each item used in your model, then it is a simple matter to add these numbers up to get the total amount. Most items tell you the current draw on their packaging.

For those that give a range like motors, select a value that is 75% of the max. Once all of these individual amounts are known, you can add them up to determine the total amperage.

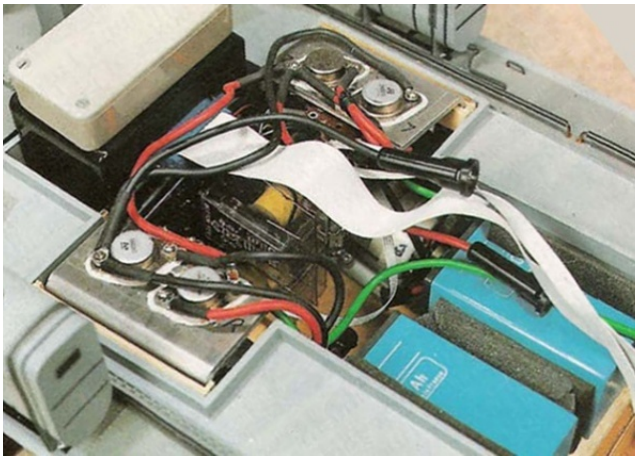
From the chart provided below, you can now select the size of wire required. To be on the safe side, select a size that will carry your total load plus an additional 25%, this will be the size wire needed to run from your battery to your terminal block. From the terminal block to each individual item, select the wire according to the current draw of that specific device.

Longer runs of wire cause voltage drops due to the resistance of the wire, so the longer the run, the more voltage is lost. To overcome this, a larger wire is used as the larger the wire the less the resistance. For any wire run over about 4 feet (1200mm), use the next size larger wire than what the current draw requires.

Wire Sizing Chart.

WIRE GAUGE	CURRENT CAPACITY
12 Gauge	41 Amps
14 Gauge	32 Amps
16 Gauge	22 Amps
18 Gauge	16 Amps
20 Gauge	11 Amps
22 Gauge	7 Amps
24 Gauge	3.5 Amps
26 Gauge	2.2 Amps
28 Gauge	1.4 Amps
30 Gauge	0.9 Amps

In our circuit in Section 4, we would use a 26 Gauge wire for the main power to the terminal block, then 30 Gauge thereafter. I have used computer ribbon cable for runs where I need to have quite a few wires running to the same place, but be very careful here, they can only carry low currents and MUST NOT get hot. They have an added advantage in that you can 'split' them – see picture adjacent. The downside is the connectors at either end. I just strip the existing ones off and solder the ends to spade connectors.!



7 SWITCHES AND FUSES etc

There is an extremely large selection of switches and fuses available today, and all at very reasonable prices. I tend to use rocker switches. These are available as:

SPST, Single Pole, Single Throw

SPDT, Single Pole, Double Throw

DPST, Double Pole, Single Throw

You can also get miniature switches, but these all tend to have lower ratings than the rocker switches mentioned above. Always try to have them where they are easily accessible, as they need to be ‘not stuck in a corner‘ where you can’t get your fingers to them.

Creativity can also play a part here – a good example was a tiller that operated a micro switch for on/off. However, remember that they do break down and you wouldn’t want to demolish half a model to get at a switch to replace it.

When selecting fuses, the fuse rating should be 125% of the normal operational current and should be of the fast acting type. Once again, position it where it can be easily got at.

If your model goes on the water you should always use A waterproof fuse holder, otherwise, an ordinary inline fuse holder will do fine.

Car type fuses are not suitable for model boats, even though they are less expensive – they are generally too high a rating and they are difficult to replace in tight confines. If you put the fuse holder on a ‘flying lead’ it can be best positioned to suit the model.

It is good practise to use spade connectors, or similar, to make the connections to all switches and fuses, again, for accessibility and ease of replacement

8 GOOD WIRING PRACTICE

As electricity and water do not mix very well, it is important to take all the care we can when connecting up all our wiring.

Soldering

First, let's look at soldered joints. Make sure that all the parts (wire, connectors splices and terminals) are good and clean. If we pulled them out of our junk box, chances are that they won't be. As the old saying goes, cleanliness is next to Godliness – this is certainly true when it comes to soldering.

After cleaning, flux all the parts to be soldered. Flux is an acid that removes the oxides caused by heat giving a better hold for the capillary action of the solder. It is also better to use flux paste then fluxed solder.

When soldering, tin both ends of the part to be joined, this eases the actual time the heat is applied during the jointing – less heat – better joint. The final soldered joint should be shiny and free from any bubbles or lumps.

When soldering next to electronic componentry, use heat shunt tweezers, available from electronic suppliers. These locking tweezers take heat from the soldering iron/gun away from the components.

Not difficult, but as all the items are inexpensive, it pays to practice for an hour before commencing the model soldering, especially if you haven't done it for a while.

Once all the joints have been soldered, tests run the circuit before applying a waterproof coating, better to make repairs now than later.

Water Proofing

Now we will waterproof the joints. This should be done even if the model is for display purposes only, as there is often dampness in the atmosphere. There are 3 ways of doing this, select which one is better for you

Heat Shrink Tubing

This is available in a variety of sizes from Ø1.5mm up to Ø13mm. It halves its diameter when heated and gives a fully waterproof cover. Heat Shrink should be slipped over the wire BEFORE soldering the joint. To shrink, heat the tubing with a hot air gun to 115°C. a hair drier does not work as it does not get hot enough. Heat shrink is suitable for all cable types and is permanent

PCB Lacquer

This is available in aerosol tins and is fine for waterproofing static display model electrics. The film can be soldered through for repairs, but requires a solvent for removal. Use in a well ventilated area and follow instructions supplied with the product

Car Paint Lacquer

This is similar to PCB Lacquer, but leaves a heavier film. It is fairly permanent, but not rated to as high a temperature as PCB Lacquer and is not easy to solder through. OK for small circuits if you don't want to go to the expense of the proper spray

Finally, when you have test run the electrics, waterproofed the circuit, test run again and then install them in your model. Test run again, and then tidy up all the cabling with cable ties, tighten any mounting screws and congratulate yourself on a job well done.

9 BATTERY CHARGING

LEAD ACID

The lead acid batteries we use in our models are really no different than the battery in our car. The Chemical properties and reactions are the same with the only real difference being the form of the electrolyte and how it is held in suspension.

The electrolyte in our model boat battery has been produced as a Gel (Hence “Gel Battery”). The Gel electrolyte allows the battery to be mounted in any position without the worry of leaking.

The drawbacks are that the gel electrolyte batteries are more sensitive to an over charging, and that they are more expensive.

These batteries need to be charged at a constant voltage of 2.3 to 2.4 V per Cell. When charging at this fixed voltage, you will notice that the charge current will vary from being high when the charging starts, then slowly it drops to nothing when the battery is fully charged. If you use the correct electronic battery chargers, you will not do the battery any harm and it will last a long time. If you overcharge (from a car Lighter socket – I’ve seen it done!) the battery will deteriorate rapidly.

Remember to charge them every month (during winter) and after you use them.

NICAD

These are the usual battery for small power applications such as our lights and smaller motors. They are inexpensive, a large range of battery holders are available, and they can be banked up to give the voltages we require.

I prefer to have 2 sets of batteries, both fully charged, so that when 1 set has run down I can quickly use the reserve set, and charge them both when I return home. Once again, using the correct charger (try to get the batteries and charger in the same pack) will ensure a long service life for them.

With all batteries, do not leave them in your model for long periods without use, remove them, wipe them with petroleum jelly or spray with CRC, and store them in a safe place. Check them periodically, and give them a full charge prior to wanting to use them.

10 BASIC PRODUCTS

Lights and Bulbs

Incandescent:	usual bulb type, drawback is that they generate heat in the larger sizes
sub miniature:	with fly leads 2.4V – 12V also available coloured, different varieties
wire ended filament:	6v, 12v clear, long life
MES type:	all voltages, needs separate holder, good all round light, but not long life
miniature krypton	2.4v, 3.6V, 4.8V, very bright light
MCC tubular	all low voltages, a larger bulb
LED:	wide range available, very long life, 2.5v, 3.3V, 5V 6v, 12V available. All need to be connected correctly (anode to +ve). Coloured, white and flashing
Constant Current	a very versatile LED with ic, 4V to 30V operating range, can be connected with other LEDs in series, great all rounder
Luxeon III	1W very bright LED, 3.7V, New product…
Cold Cathode tubes	not used often as require dedicated power supply, generate some heat and tend to be too large, but can be used for lighting inside of hull
Lightsheet	also requires dedicated power supply, can be cut to suit space, fairly expensive,
Fibre Optic cable	an easy way of getting a small light to many places from the same light source, needs care with handling, available now as starter kits, all the bits you need

Power Sources

Mains ac power	unsuitable and not safe – do not use
AC adapters	suitable for static displays, available with wide range of DC outputs from 3V to 24V, also available with adjustable output voltages, usually mains fused, needs cable to socket which can be an inconvenience
Batteries	Best option, add in series for extra voltage, parallel for extra current, nicads 1.2V, drycells 1.5V, 3V, 4.5V, 6V and 12V, lead acid batteries tend to be too large, gel batteries 6V, 8V, 12V.

All the other products you will need to light up your model ship can be found in your local electronic shop, or via the internet. If you have any questions, also talk to them – they are a mine of information. Spend some time looking at what is available, it will be an interesting exercise and will amaze you!

10 MULTIMETERS

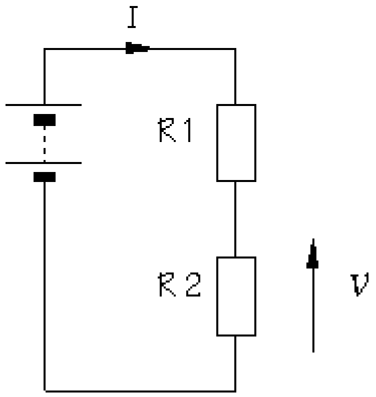
thanks to Doctronics, UK

What do meters measure?

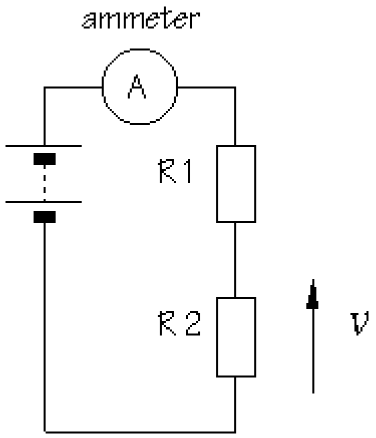
A meter is a measuring instrument. An **ammeter** measures current, a **voltmeter** measures the potential difference (voltage) between two points, and an **ohmmeter** measures resistance. A **multimeter** combines these functions and possibly some additional ones as well, into a single instrument.

Before going in to detail about multimeters, it is important for you to have a clear idea of how meters are connected into circuits. Diagrams *A* and *B* below show a circuit before and after connecting an ammeter:

A



B



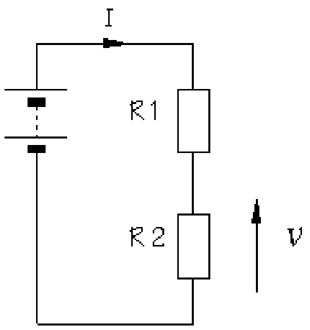
to measure current, the circuit must be broken to allow the ammeter to be connected in series

ammeters must have a LOW resistance

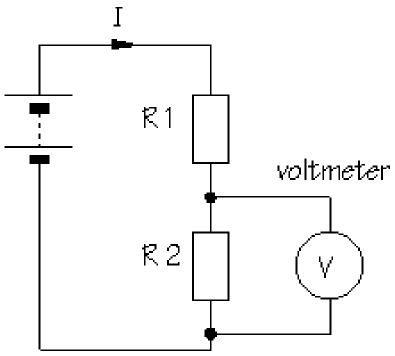
Think about the changes you would have to make to a practical circuit in order to include the ammeter. To start with, you need to *break the circuit* so that the ammeter can be connected in series. All the current flowing in the circuit must pass through the ammeter. Meters are not supposed to alter the behaviour of the circuit, or at least not significantly, and it follows that an ammeter must have a very LOW resistance.

Diagram *D* shows the same circuit after connecting a voltmeter:

C



D



to measure potential difference (voltage), the circuit is not changed: the voltmeter is connected in parallel

voltmeters must have a HIGH resistance

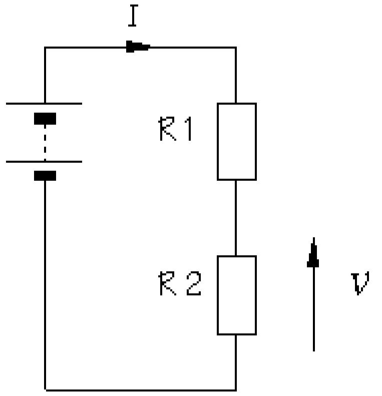
This time, you do not need to break the circuit. The voltmeter is connected in parallel between the two points where the measurement is to be made. Since the voltmeter provides a parallel pathway, it should take as little current as possible. In other words, a voltmeter should have a very HIGH resistance.

Which measurement technique do you think will be the more useful? In fact, voltage measurements are used much more often than current measurements.

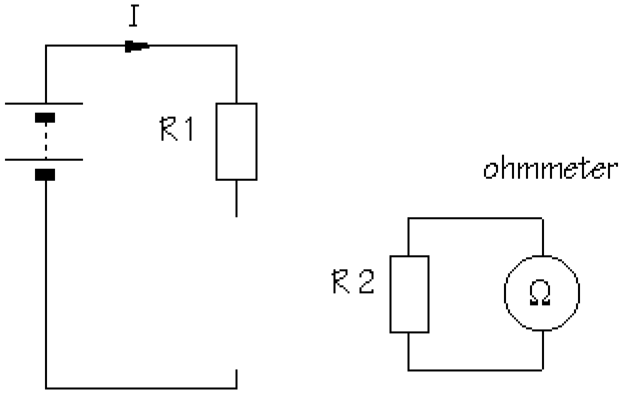
The processing of electronic signals is usually thought of in voltage terms. It is an added advantage that a voltage measurement is easier to make. The original circuit does not need to be changed. Often, the meter probes are connected simply by touching them to the points of interest.

An ohmmeter does not function with a circuit connected to a power supply. If you want to measure the resistance of a particular component, you must take it out of the circuit altogether and test it separately, as shown in diagram *D*:

A

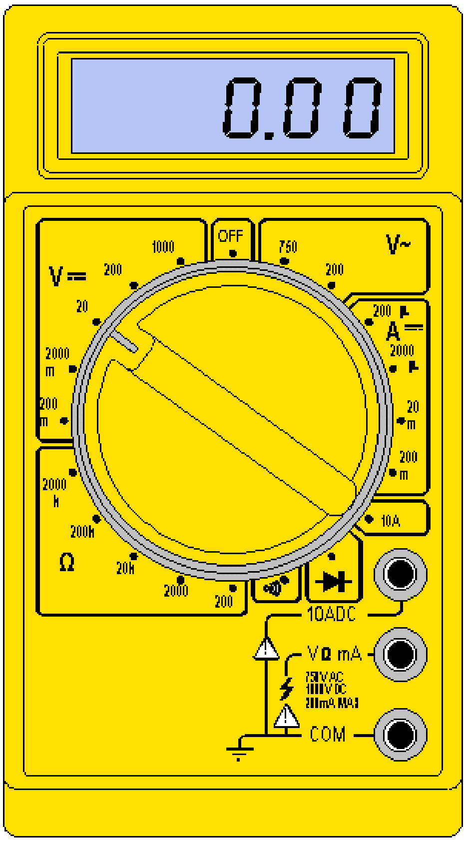


D



to measure resistance, the component must be removed from the circuit altogether

ohmmeters work by passing a current through the component being tested



Ohmmeters work by passing a small current through the component and measuring the voltage produced. If you try this with the component connected into a circuit with a power supply, the most likely result is that the meter will be damaged. Most multimeters have a fuse to help protect against misuse.

Digital multimeters

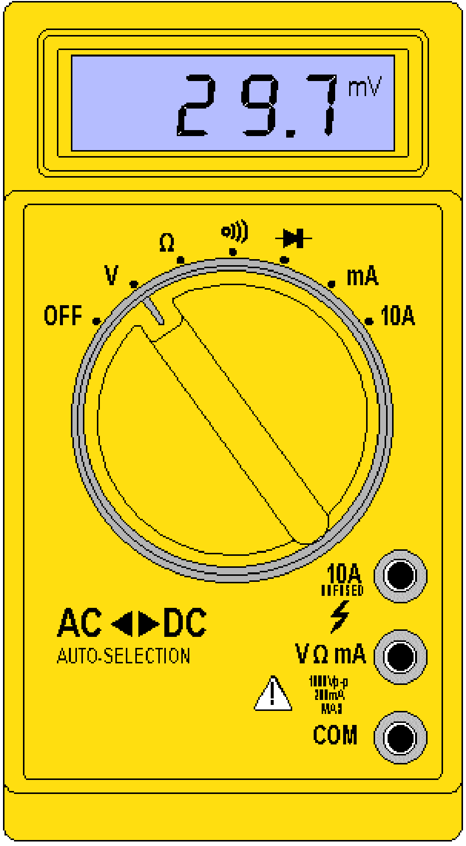
Multimeters are designed and mass produced for electronics engineers. Even the simplest and cheapest types may include features which you are not likely to use. Digital meters give an output in numbers, usually on a liquid crystal display.

The diagram shows a **switched range multimeter**:

The central knob has lots of positions and you must choose which one is appropriate for the measurement you want to make. If the meter is switched to 20 V DC, for example, then 20 V is the maximum voltage which can be measured, This is sometimes called 20 V **fsd**, where fsd is short for **full scale deflection**.

For circuits with power supplies of up to 20 V, which includes all the circuits you are likely to build, the 20 V DC voltage range is the most useful. DC ranges are indicated by V= on the meter. Sometimes, you will want to measure smaller voltages, and in this case, the 2 V or 200 mV ranges are used.

What does DC mean? DC means **direct current**. In any circuit which operates from a steady voltage source, such as a battery, current flow is always in the same direction. Every constructional project described in Design Electronics works in this way.



AC means **alternating current**. In an electric lamp connected to the domestic mains electricity, current flows first one way, then the other. That is, the current reverses, or alternates, in direction. With UK mains, the current reverses 50 times per second.
You are not at all likely to use the AC ranges, indicated by V~, on your multimeter.

An alternative style of multimeter is the **autoranging multimeter**:

Autoranging multimeter

The central knob has fewer positions and all you need to do is to switch it to the quantity you want to measure. Once switched to V, the meter automatically adjusts its range to give a meaningful reading, and the display includes the unit of measurement, V or mV. This type of meter is more expensive, but obviously much easier to use.

Where are the two meter probes connected? The **black** lead is always connected into the socket marked COM, short for COMMON. The **red** lead is connected into the socket labelled VΩmA. The 10A socket is very rarely used.

Analogue multimeters

An analogue meter moves a needle along a scale. Switched range analogue multimeters are very cheap but are difficult for beginners to read accurately, especially on resistance scales. The meter movement is delicate and dropping the meter is likely to damage it!

Each type of meter has its advantages. Used as a voltmeter, a digital meter is usually better because its resistance is much higher, 1 MΩ or 10 MΩ, compared to 200 kΩ for a analogue multimeter on a similar range. On the other hand, it is easier to follow a slowly changing voltage by watching the needle on an analogue display.

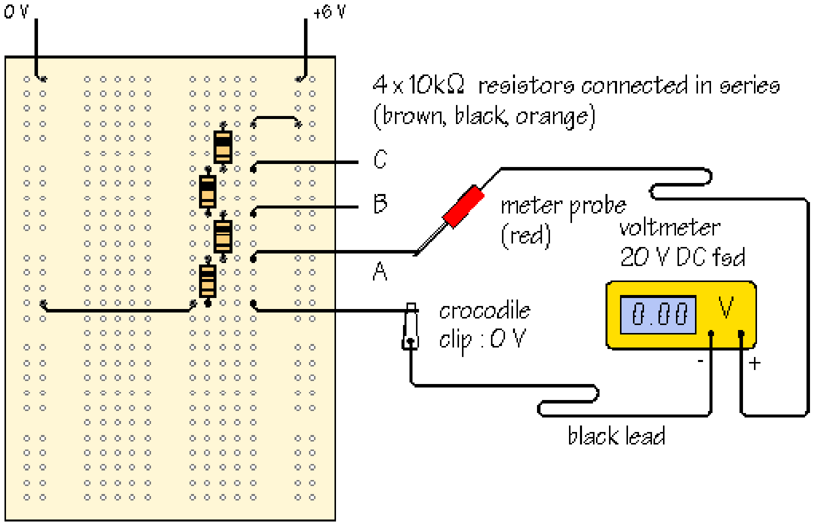
Used as an ammeter, an analogue multimeter has a very low resistance and is very sensitive, with scales down to 50 µA. More expensive digital multimeters can equal or better this performance.

Most modern multimeters are digital and traditional analogue types are destined to become obsolete.

Making measurements

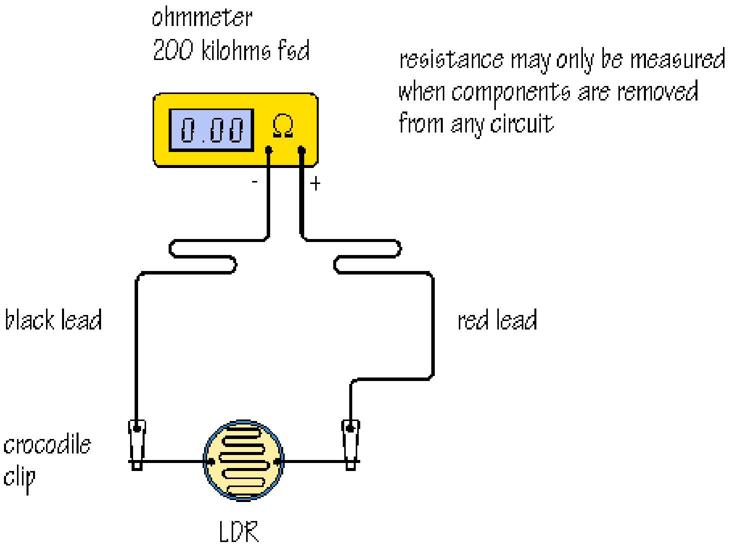
1. *Voltage measurements*:

Build the circuit shown below using prototype board and four 10 **kΩ** resistors:

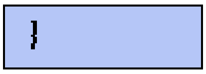


Using the multimeter as a voltmeter, measure the power supply voltage and then measure the voltages at points A, B and C.

2. *Resistance measurements*:



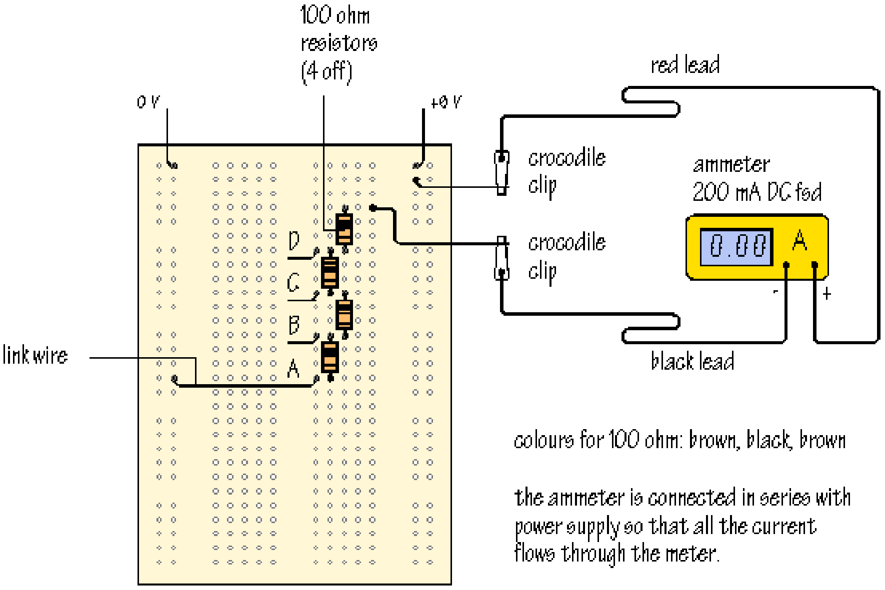
To get the multimeter to function as an ohmmeter, you will need to select a resistance range. With a switched range meter, the 200 k position is usually suitable. You will see the resistance measurement change as the light level changes. Covering the LDR with your hand increases the resistance of the LDR.

If the meter reads  this means that the resistance is more than the maximum which can be measured on this range and you may need to switch to a new position, 2000 k, to take a reading. (How many megohms is 2000 k?)

You can check the value of any fixed value resistor in the same way, and confirm that you have worked out the colour code correctly.

3. *Current measurements*:

The diagram below shows a prototype board set up for the measurement of current:



colours for 100 ohm: brown, black, brown

the ammeter is connected in series with power supply so that all the current flows through the meter.

Note that the current must flow *through* the ammeter in order to reach the circuit.

Some useful links

http://www.maplin.co.uk/	Online component supplier - Uk
http://www.radioshack.com	Online component supplier - UK
http://rswww.com	Online component supplier - USA
http://www.the12volt.com	Ohms Law Calculator
http://www.dannyg.com	Resistor Value Calculator
http://www.webcalc.net	Battery sizing Calculator
http://www.webcalc.net	Resistor series/parallel sizing Calculator
http://www.doctronics.co.uk	Multimeter information