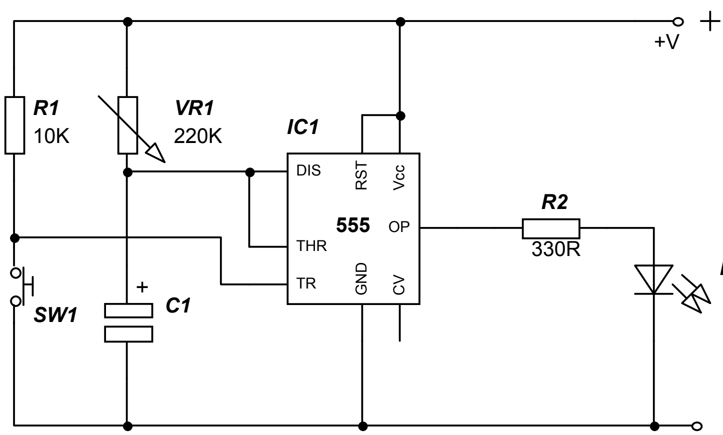
UNDERSTANDING ELECTRONICS



N Humphrey

UNDERSTANDING ELECTRONICS

Basic Electrical Principles

Objectives

After working through this chapter, you should be able to do the following:

1. Define what voltage is, know the symbol for voltage and the units used.
2. Understand the basic difference between AC and DC voltages.
3. Define the meaning of an electric current, know the symbol for current and the units used.
4. Know what conductors and insulators are and be able to give examples.
5. Use the formula from Ohms law to calculate resistance, voltage or current.
6. Know how voltages and currents can be measured.
7. Know what power dissipation is and the unit for power.
8. Be able to calculate power dissipation.

What is Electronics?

When we talk about electronics we are normally referring to low currents and in many cases to low voltages as well. But what are currents and voltages?

What is Voltage?

Voltage or **electro motive force** (e.m.f), pushes or forces an electric current through a closed circuit. It can be compared with the domestic water supply in a home. The pressure in the pipe forces the water along, in electronics, voltage forces the electric current along. The unit of voltage is the **Volt** and the symbol used is **V**.

What is Current?

When a battery is connected to a light bulb, it lights up. The applied voltage forces the electric current from the battery, through the bulb and then back to the battery. But there is a little bit more to the story. What is actually happening is electrons are moving from the positive terminal of the battery, through the bulb, and then back to the negative terminal of the battery.

Scientists assumed in the early days that electrons move from positive to negative. They have since discovered that in fact electrons move from negative to positive. However we accept what is known as convention, i.e. that electrons move from positive to negative. So **current** is the flow of electrons through a closed circuit. The unit of current is the **ampere**, sometimes written as **amps**. The symbol used is **I**.

AC and DC voltage

There are two types of voltage, **alternating current** (ac) voltage and **direct current** (dc) voltage. The voltage in a mains plug is 240v AC. This means that the voltage changes from +240v to –240v, and back to 240v and so on. It changes from +v to –v fifty times a second. Anything that changes with time has a frequency. In this case mains voltage has a frequency of 50Hz.
DC voltage remains constant at a given voltage. For example our 9v battery would show a constant line at 9v if plotted against time. In electronics our circuits are supplied with a dc voltage.

Resistance

The final part of the story was discovered by a scientist called Ohm. Some materials allow the flow of electrical currents through them. They are known as **conductors.** Examples include gold, silver, copper and aluminium. Although these material are conductors they have some resistance to the flow of electrical currents. Other materials totally resist the flow of electrical currents. These are known as **insulators.** Examples include dry wood, paper, plastics and air. **Resistance** is the property of a material to restrict the flow of electric current. The unit of resistance is the **ohm**. The symbol used is Ω. However we tend to use the letter **R**.

Ohm's law

Ohm discovered that there was a relationship between an **applied voltage**, the **current** flowing through the wire, and the **resistance** of the wire. His law states that" the current flowing in an electrical conductor is proportional to the voltage across it at constant temperature". From Ohm's law we can say that

V (volts) = **I** (amps) x **R** (ohms)

There are also divisions of these units. For example, we may have 1000R which can be written as 1K, the K representing kilo or a thousand. We could have 10mA, which can be written as 0.01A, the mA representing milliamps.
When performing calculations, every time you must ensure that your values are in the units of the formula given above.

Conversion of units

1mA = 0.001A
1uA = 0.000001A

Example

An e.m.f. (voltage) of 9v is applied to a light bulb of resistance 100R. What current is flowing in the circuit?

Using the formula	**V** = **I** x **R**
	9 = **I** x 100
Therefore	**I** = 9/100
	I = 0.09A

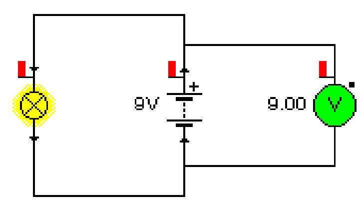
This can also be written as 90mA. (milliamps)

Exercise 1.1

1. A 9v battery is connected to a bulb rated at 60mA. What is the resistance of the bulb?
2. An e.m.f. of 12v is applied to a bulb of resistance 250R. What current is flowing in the circuit?

Measuring voltage

If we want to measure the voltage at a given point in a circuit we use a

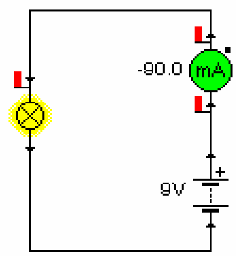


voltmeter. The symbol for a voltmeter is **V**.

If for example, we want to check the voltage of our 9v battery, we would connect the **red** lead of the **voltmeter** to the **positive** terminal of the battery. The **black** lead of the **voltmeter** would be connected to the **negative** terminal.

Measuring current

To measure the current flowing in a circuit we use an **ammeter**. The symbol is **A**. The ammeter has to be part of the circuit, so for example, if we were trying to find the current flowing in a bulb connected to a battery, we would connect the **red** lead of the **ammeter** to the **positive** terminal of the battery.



The **black** lead of the **ammeter** is connected to one side of the **bulb**, the other side of the bulb is connected to the negative terminal of the battery.

In electronics workshops we tend to use multimeters rather than separate volt and ammeters. Multimeters can measure AC and DC voltages, current and resistance.

Power

When for example, you run, your body generates heat. When an electric current flows in a circuit, the components in the circuit generate heat. If you consider a bulb connected to a battery. The bulb emits light, but in doing so, it also generates heat. If the bulb was to overheat it would be destroyed. When we talk about this generated heat, we call it the **power dissipated** or **power rating**. The symbol for power is **P** and the unit is the **Watt**.

(1) **P** (watts) = **V** (volts) x **I** (amps)

(2) **P** (watts) = $\mathbf{I^2}$ (amps) x **R** (ohms)

Either formula can be used according to the information available.

Example

A 6v bulb is rated at 0.06A. What is the power rating of the bulb.

P = V x I
P = 6 x 0.06
P = 0.36W

Exercise 1.2

1. A bulb has a voltage rating of 240v, and a power rating of 60W. What current would flow once it is connected to the voltage supply?
2. A bulb has a resistance of 10R and the current flowing through it is 0.5A. What is the power rating of the bulb?

UNDERSTANDING ELECTRONICS

Resistors

Objectives

After working through this chapter, you should be able to do the following:

1. Define what a resistor is and recognise the circuit symbol.
2. Know what is meant by the term preferred values.
3. Know what is meant by the term tolerance.
4. Be able to use the resistor colour code to identify 4 colour band resistors.
5. Be able to calculate the total resistance of resistors connected in series.
6. Be able to calculate the total resistance of resistors connected in parallel.
7. Be able to calculate power dissipation.
8. Know what a variable resistor is and recognise the circuit symbol.

In electronic circuits there are many occasions where we want to be able to control or restrict the current flowing, or to fix the voltage at a given point. To achieve this we used a **fixed resistor**.

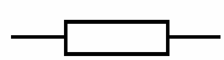


Fig 2.1 Symbol for a Resistor

Resistors are constructed from one of the following materials, carbon film, metal film, metal oxide or are wirewound. They come in a range of values, typically from 4R7 to 1M, although values as low as 0.47R and as high as 10M are available. Resistors also come in a range of power ratings, typically from 0.25W up to 50W. Again lower and higher power ratings are available.

Preferred values

With such a wide range of potential values, it would be very expensive and uneconomic to manufacture every single value. To overcome this a range of **preferred values** has been created. The most common ranges are known as the E12 and E24, although others are available.

E12 range 10R, 12R, 15R, 18R, 22R, 27R, 33R, 39R, 47R, 56R, 68R, 82R and their multiples.

E24 range 10R, 11R, 12R, 13R, 15R, 16R, 18R, 20R, 24R, 27R, 30R, 33R, 36R, 39R, 43R, 47R, 51R, 56R, 62R, 68R, 75R, 82R, 91R and their multiples.

When choosing a resistor we always choose the preferred value that is higher than that calculated. For example if our calculated value for a resistor was 50R, we would use a 56R resistor. (Based on the E12 range)

Exercise 2.1

Using the E12 range chose the nearest resistor to the values below.

1. 30R
2. 110R
3. 620R
4. 4K3
5. 91K
6. 160K
7. 510K

Tolerance

Resistors also come in a range of **tolerances**. Tolerance means how accurate or close the measured resistance would be to the stated value of the resistor. Typical **tolerances** are 5%, 2% and 1%

Colour coding

Due to the small physical size of a resistor, a unique **colour coding** system has been devised. The table on the next page shows the **colour code** for a four band resistor.

Colour	1st Band	2nd Band	3rd Band
Black	O	0	-
Brown	1	1	0
Red	2	2	00
Orange	3	3	000
Yellow	4	4	0000
Green	5	5	00000
Blue	6	6	000000
Violet	7	7	0000000
Grey	8	8	
White	9	9	

To read the **colour code**, begin by identifying the 4th band on the resistor which is coloured Gold. This indicates the tolerance of the resistor. Most of the resistors used in schools are 5%. Once you have done this, keep the 4th band to your right. You can now start on the left hand side with the 1st band and begin to identify the resistor.

Example

1. A resistor is coded orange, orange, brown and gold. What value is this resistor?
Having identified the 4th band as the tolerance band, we will start with the first colour which was orange. Orange represents the number 3. The 2nd colour is also orange, so we have another 3. The third band is the most important. It tells us how many zero's to add. So our third brown means that we need to add a zero.

So our resistor Orange Orange Brown gold is 330 Ohms with a 5% tolerance.

2. This time we need to identify the colours of a 1K resistor to ensure that the one we have taken out of the tray is the correct value.
Firstly convert 1K to ohms

1K = 1000R (kilo = 1000)

Now we cans start to work out the colours. Our first digit is 1, so from the table the colour of the first band is brown. The 2nd digit is 0, so the colour is black. The remaining digits represent the third band, which is the number of zero's. For this resistor we need two zero's so the colour is red.

Exercise 2.2

Using the above examples to guide you, work out the value of the following resistors.

1. Brown, black, orange, gold?
2. Yellow, violet, black, gold?
3. Red, red, red, gold?
4. Green, blue, yellow, gold?
5. Blue, grey, brown, gold?

From the stated value, work out the correct colour code for each resistor. Remember to convert each value into ohms first.

6. 100R
7. 2k2
8. 33k
9. 180k
10. 1M

Resistors in series

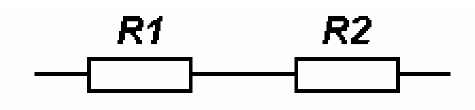


Fig 2.2 Resistors in Series

When you start to look at circuits, you will often see resistors connected together one after another as if they were in a continuous chain. We say they are connected in **series**.

When resistors are connected in this way, the overall resistance can be found by

$\mathbf{R}_{total}= \mathbf{R1} + \mathbf{R2} + \mathbf{R3}$ and so on.

All you have to do is simply add all the resistances together. Note that the use of R1, R2 etc refers to the identification of each resistor, it is not a value.

Example

What is the overall resistance of a circuit if R1 is 22R and R2 is 56R?

$\mathbf{R} = \mathbf{R1} + \mathbf{R2}$
$\mathbf{R} = 22 + 56$
$\mathbf{R} = 78R$

You may be wondering why we connect resistors in series. One reason is that sometimes we require a resistor value that is not manufactured or within the preferred range. By combining resistors, we can often obtain the required value. Another use is to drop or reduce voltages in a circuit.

Resistors in parallel

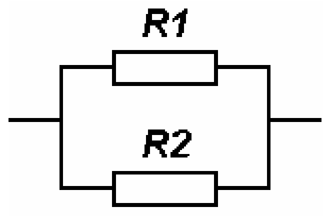


Fig 2.3 Resistors in Parallel

When two or more resistors lay side by side with their ends connected together, we say they are connected in **parallel**.

When resistors are connected in this way, the overall resistance can be found by

$\mathbf{R_{total} = R1 \times R2 / (R1 + R2)}$

Or

$\mathbf{1/R_{total} = 1/R1 + 1/R2 + 1/R3}$

Example

1. Two resistors are connected together in parallel. R1 is 8R and R2 is 8R. What is the total resistance?

$\mathbf{R_{total} = R1 \times R2 / (R1 + R2)}$
$\mathbf{R}_{total} = 8 \times 8 / (8 + 8)$
$\mathbf{R}_{total} = 64 / 16$
$\mathbf{R}_{total} = 4R$

2. Two resistors are connected together in parallel. R1 is 8R and R2 is 6R. What is the total resistance?

$\mathbf{R_{total} = R1 \times R2 / (R1 + R2)}$
$\mathbf{R}_{total} = 8 \times 6 / (8 + 6)$
$\mathbf{R}_{total} = 48 / 14$
$\mathbf{R}_{total} = 3.43R$

This can also be written as 3R43. This way is normally used so as to save any confusion with decimal points.

Looking at the two examples you may have noticed a couple of patterns. Firstly with example 1, if both resistors are of equal value then the total resistance will always be exactly half the value of one of the resistors.

In example two where we had two resistors of different values, the total resistance will always be less than the lowest value resistor.

If you apply these two rules when looking at your answer you should never miscalculate the total resistance.

Exercise 2.3

Calculate the total resistance of the following resistors connected in series.

1. When R1 is 100R and R2 is 220R?
2. When R1 is 1K and R2 is 680R?
3. When R1 is 10K and R2 is 330R?

Calculate the total resistance of the following resistors connected in parallel.

4 When R1 is 16R and R2 is 16R?
5 When R1 is 1K and R2 is 1K?
6 When R1 is 100R and R2 is 47R?
7 When R1 is 27R and R2 is 22R?

Power Dissipation

In chapter 1 you came across the term **Power dissipated** or **Power rating**. In restricting the flow of electric current, resistors generate heat. All resistors have a power rating the most common is 0.25W. If you are unsure how to calculate power dissipation, look back at chapter 1.

Variable Resistors

You have already come across **variable resistors** in your home without knowing it. The volume control on your Hi-Fi is a variable resistor as are the tone controls or graphic equaliser. A variable resistor can be adjusted from 0R to its stated value.

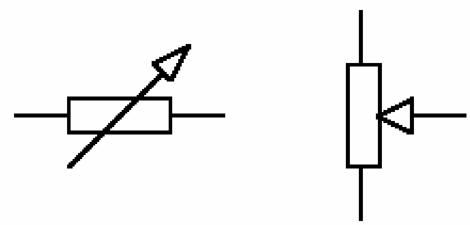


Fig 2.4 Symbols for variable resistors

On circuit boards a smaller variable resistor called a **pre-set** is used. These are variable resistors which once adjusted usually do not need to be adjusted again.

Potential (Voltage) divider

Very often in circuits you will see two resistors connected together as shown below.

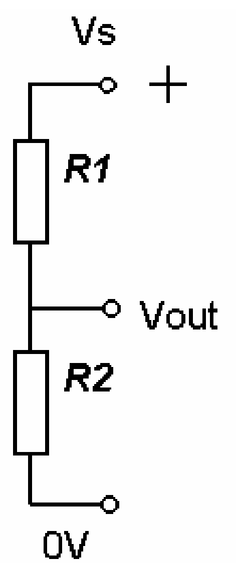


Fig 2.5 Potential divider

Each of the resistors has the same value of current flowing through it. For example if there is 10mA flowing through R1 then there will be 10mA flowing through R2.

However a portion of the supply voltage is dropped across each resistor. For example if each resistor is 100R and the supply voltage Vs is 9V then because each resistor is of the same value they will each drop half the supply voltage i.e. 4.5V. Indeed if you measured the voltage across either of the resistors you would find it was half the supply voltage. But what happens when the two resistors are of different values.

The current through each resistor is the same but to find the voltage at V_{out} the formula below is used.

$V_{out} = V_{supply} \times R2 / (R1 + R2)$

For example if R1 is 5R, R2 is 10R and the supply voltage Vs is 9V find the output voltage.

$V_{out} = Vs \times R2/ (R1 + R2)$

$V_{out} = 9 \times 10 / (5 + 10)$

$V_{out}= 6V$

Exercise 2.4

Find the output voltage V_{out} if

1. Vs = 9V, R1 = 100R, R2 = 75R
2. Vs = 9V, R1 = 50R, R2 = 75R
3. Vs = 9V, R1 = 25R, R2 = 25R
4. Vs = 9V, R1 = 40R, R2 = 30R

Although we have considered two fixed resistors for our potential divider they could be any two resistive components. For example one of the two resistors could be a preset and the other could be a light or heat sensor. You will meet the potential divider again in the chapter on sensors.

Capacitors

Objectives

1. Know what a capacitor is.
2. Know the symbol used and the units of capacitance.
3. Understand what is mean by the term polarised and non-polarised.
4. Know what capacitors are used for.
5. Be able to calculate the time constant of a simple circuit.

What is a Capacitor?

A capacitor consists of two conducting surfaces (plates) separated by a thin layer of insulation called a **dielectric.** This layer of insulation can be ceramic, polystyrene, polyester, polycarbonate, mica, air, paper or electrolyte.

How does it work?

When a battery is connected to a capacitor the voltage does not reach the plates straight away. To achieve this difference in potential between the plates of the capacitor, electrons have to be supplied to the more negative plate and removed from the more positive one. This takes time, the time is dependent on the size of the current carrying the electrons. A capacitor stores an electrical charge.

Symbols

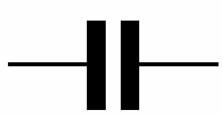


Fig 3.1
Capacitor symbol

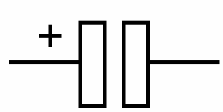


Fig 3.2
Electrolytic

The circuit symbol for a capacitor is shown above.

The symbol in fig 3.1 is used to indicate a **non-polarised** capacitor. This means that it can be connected either way round. The symbol in fig 3.2 is used to indicate a **polarised** capacitor. This means that the + lead has to be connected to the + side of the circuit. This type of capacitor is normally an electrolytic type and is very common in electronic circuits.

The scientist who discovered what we call capacitors was Michael Farraday. The unit of capacitance is named after him and is called the **Farrad**. The symbol is **F**.

The Farrad is a very large unit so we tend to use the sub divisions µF, nF and pF.

The smallest capacitors are usually ceramic plate or disc types with their value measured in pF. Electrolytic capacitors are the largest in terms of their value which is measured in µF. Polyester capacitors can be in nf or µF and fall between ceramic types and electrolytic types.

What are capacitors used for?

As you have already discovered a capacitor takes time to achieve a difference in potential between the plates. So a capacitor can be used to create a **time delay**. But capacitors can be used for other applications.

Another feature of a capacitor is that it allows AC voltage to pass through it but stops DC voltage from doing so. You will find capacitors used extensively in circuits because of this especially in audio equipment and in power supplies.

Capacitors are also used in filters to get rid of unwanted signals or frequencies. An example of this is in tone controls or graphic equalisers.

Time Delay

A circuit showing a resistor and capacitor connected together to create a time delay is shown below.

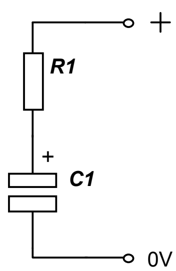


Fig 3.3

TC = C x R x 1.1

As the last part of the formula 1.1 makes very little difference we tend to ignore it so the formula becomes

TC = C x R

The units are seconds for time, Farrads for capacitance and Ohms for resistance.

Example

If R1 is 100K and C1 is 100µF what is the time constant of the circuit?

T = C x R
T = 100µF x 100K
T = 0.000100 x 100 000
T = 10 seconds

What this actually means is that the capacitor will take 10 seconds to become charged.

Exercise 3.1

1. If R1 is 47K and C1 is 470µF what is the time constant?
2. If R1 is 1M and C1 is 10µF what is the time constant?
3. If the time constant is 20 seconds and C1 is 100µF what value of resistor is required?

You will find out more about time constants in the chapter on timers.

Capacitors in series and Parallel

Capacitors can be connected in series and parallel just like resistors. However connecting two capacitors in series is like connecting resistors in parallel.

For capacitors in series

C = C1 x C2 / (C1 +C2)

For capacitors in parallel

C = C1 + C2

We rarely need to use these formulas.

Transistors

Objectives

1. Know the symbols for an NPN and PNP transistor
2. Be able to label the connections.
3. To be able to say what the arrow on the symbol indicate.
4. To be able to state what a transistor is used for.
5. To know what the “switch on” voltage is.
6. To understand the term Threshold.
7. To understand why a resistor is connected to the base of a transistor.
8. To know the symbol and connections for a FET

Introduction

The transistor was invented in December 1947 by William Shockley, John Bardeen and Walter Brattain at Bells laboratory in New Jersey. The transistor has revolutionised electronics leading to the invention on integrated circuits and the microprocessor. Transistors come in different sizes either in a metal package or a plastic package. They can cost from a few pence to as much as £50 for specialist devices.

Bi-polar transistors

The first transistors were manufactured from geranium (types beginning with AC in their part number), now transistors are manufactured from silicon. There are two types of transistor, NPN and PNP. These refer to the type of construction of the transistor.

N	P	N

Fig 4.1

Fig 4.1 shows the construction of an NPN transistor. Imagine it is like a hamburger. A piece of N type material (top of the bun) joined to a thin piece of P type material (the burger), then joined to a piece of N type of material (bottom part of the bun). The PNP type can be seen in the same way with the N type material being the burger.

Symbols

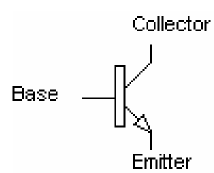


Fig 4.2
NPN

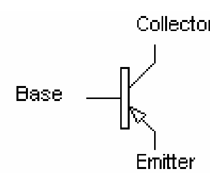


Fig 4.3
PNP

There are three connections on a transistor. **Collector**, **Base** and **Emitter**. With an NPN transistor the **Collector** is connected to the +v part of the circuit. The **Base** is connected to the input of the circuit and the **Emitter** is connected to 0v. With a PNP transistor, the **Collector** is still connected to the more positive part of the circuit which is 0v. The **Base** is connected to the input and the **Emitter** is connected to -V

The **arrow** on the transistor symbol indicates the **direction of current flow**.

What is a transistors used for?

A transistor has two uses:
1. As an electronic switch.
2. As an amplifier.

How do transistors work?

In this chapter we are only going to consider the transistor as an electronic switch.
The transistor will "switch on" when the difference in voltage between the **Base** and the **Emitter** is 0.65V. In other words if we connected the red lead of a voltmeter to the **Base** leg, and the black lead to the **Emitter** leg, the voltage would have to be a minimum of 0.65V. This voltage can be up to approximately 3 to 4 volts. If it is any greater than this the transistor can be damaged. When a transistor has switched on it is said to have reached **Threshold**.

When the transistor has reached **Threshold** almost all of the current will flow through the transistor from the collector to the emitter. A very small amount will be present at the base.

Current limiting

If too much current flows through the **Base** of a transistor, the transistor will be damaged. To prevent this from happening, a resistor is connected in series with the **Base** of the transistor.

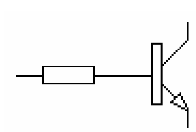


Fig 4.4
Current limiting resistor

A typical value for the **current limiting resistor** is 1K

Field Effect Transistors (FET)

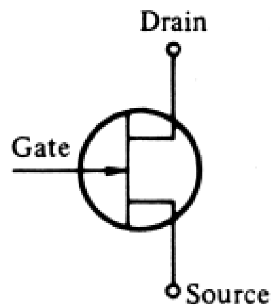


Fig 4.4

A field effect transistor (FET) has two layers of semiconductor material, one on top of the other. Current flows through one of the layers which is called the channel. A voltage is connected to the other layer, called the gate which interferes with the current flowing in the channel. The voltage connected to the gate controls the current in the channel.

There are two types of FET. The Junction Field Effect Transistor (JFET) and the Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

In summing up the difference between a Bi polar transistor and a FET is that a Bi polar transistor is current controlled whilst a FET is voltage controlled.

Timers

Objectives

1. Know what is meant by the term Monostable.
2. Know how a Monostable timer works.
3. Be able to divide the circuit into Input, timing, Process, Output.
4. Know what is meant by the term Astable.
5. Know how an astable timer works.

Tme

All around us we are surrounded by products which rely on or use time in their operation. Examples of products that use time include microwaves, videos and security lights. All of these products operate for a period of time and then switch off.

Monostable timer

A timer that switches on for a period of time and then switches off again remaining off until it is reset is called a **monostable timer**. **Monostable** means single state. A circuit using a 555 timer IC in monostable mode is shown below.

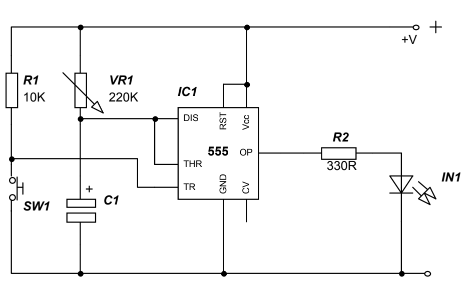


Fig 5.1 Monostable timer circuit

Input/timing/process/output

R1 and SW1 are the **input** components of the circuit. VR1 and C1 are the **timing** components. The **process** component is the IC and the **output** components are R2 and IN1.

How does it work?

When switch SW1 is pressed the voltage at pin 2 of IC1 becomes 0V. This then triggers the IC into life and C1 is discharged, the output becomes high or on. C1 then starts to charge through VR1. When the voltage across the capacitor reaches 2/3 of the supply voltage the IC then changes the output to low or off.

If SW1 is pressed once the timer has been activated the time period is not affected.

Timing

In the chapter on capacitors you found out how to calculate the time constant. To alter the time period all you need to do is change the value of either VR1 or C1, or both components. If you increase the values of these components you lengthen the time period. The formula is given below

T = C x R

Where time is in seconds, capacitance is in Farrads and resistance is in Ohms.

When choosing values for C1 and VR1 we tend to use the highest value of resistance and lowest value of capacitance. There are a number of reasons for this. A resistor of 10R is the same physical size as one of 1M and all values cost the same. With capacitors as the value increases so does the physical size. As size increases so does the cost.

Connecting the output

There are two ways of connecting the output. In the circuit shown the output is connected from pin 3 of the IC to the 0V supply via R2 and IN1. In this case the output is said to be connected to sink. There is no output voltage present until SW1 is pressed so IN1 will be off.

If the output is connected from the +V supply to pin 3 of the IC via R2 and IN1, there will be a voltage difference between these connections and IN1 will be on. When SW1 is pressed the voltage at pin 3 is high so there will be no voltage difference and IN1 will be off. IN1 will be on again once the time period has elapsed. If the output is arranged in this way it is said to be connected to source.

Astable timer

A timer that is not in one state or another is called an **astable**. Simply an astable circuit switches pin 3 high (on) then low (off), then high again and so on. It keeps on doing this until it is stopped. A circuit is shown below.

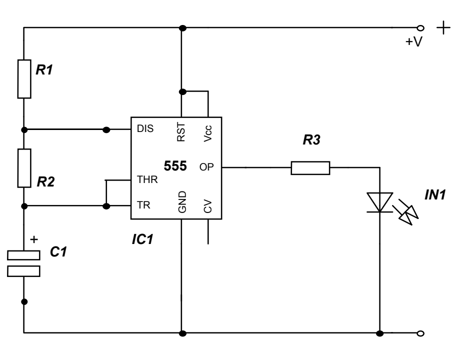


Fig 5.2 Astable timer circuit

R1, R2 and C1 are the timing components.

How does it work?

When the circuit is connected to a power source it triggers itself and free runs as a **multivibrator**. The capacitor C1 charges through R1 and R2 and discharges through R2 only. The duty cycle may be precisely set by the ratio of these resistors.

C1 charges and discharges between 1/3 Vcc and 2/3 Vcc (If Vcc is 9V then the two values are 3V and 6V)

The charge time (output **High** (on) state) is given by:

t1 (seconds) = **0.693** x **(R1 + R2)** x **C1** (farads)

The discharge time (Output **Low** (off) state) is given by:

t2 (seconds) = **0.693 x (R2) x C1** (farads)

Thus the total period T is given by:

T = t1 + t2 = 0.693 x **(R1 x 2R2)** x **C1**

The frequency of oscillation is then:

F = 1/T = 1.44/ ((R1 +2R2) x **C1)**

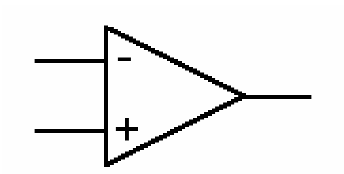
Although it would appear that there is a lot of maths involved in a nutshell you can vary the time that the circuit is high and the time that the circuit is low. This involves the values of R1, R2 and C1.

This comparison between the on period and the off period is called the **mark to space ratio** or **mark space ratio.**

Operational Amplifier

An operational amplifier is an IC that performs complex mathematical operations

The symbol for a Operational amplifier is shown below



As you can see the Operational Amplifier or Op amp for short has two inputs marked + and -. The + input is called the non-inverting input and the – input the inverting input.

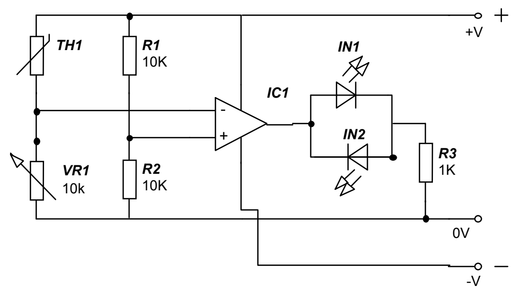
This can appear confusing at first.

The op amp has a number of features. Firstly it has a very high gain (Ao) up to 100 000. However the output voltage cannot be higher than the supply voltage and in practice as a maximum 2 volts less than the supply voltage.

The op amp depending on the device used and the application will require a dual power supply. This is a +V, -V and 0V. To achieve this two batteries will have to be used.

The obvious use of an op amp is as an amplifier but it also can be used as a comparator.

Op Amp as a comparator



Operational Amplifier as a Comparator

If you look at the input to the op amp you will see that there are two potential dividers. The first potential divider is formed by R1 and R2. As the values are identical the voltage at the non-inverting input will be half the supply voltage. Assuming you are using a PP3 battery then the voltage will be 4.5V.

The second potential divider is formed by the Thermistor TH1 and by the varaible resistor VR1. The thermistor has a value of 4K7

A Thermistor is a resistor whose resistance changes when the temperature increases. So as the resistance changes the voltage at the junction of TH1 and VR1 also changes.

When the batteries are connected the green LED lights. The voltage at pin 3 is 4.33V. The voltage at pin 2 is 4.6V. When the thermistor detects an increase in temperature the red LED now lights. The voltage now at pin 3 is 4.44V.

The voltage at pin 3 is compared with the voltage at pin 2 hence the op amp is used as a comparator.

Logic Gates

Objectives

1. Know what is meant by High and Low states.
2. Know the numbers that represent each state.
3. To be able to recognise the symbols for the different logic gates.
4. To be able to construct the truth tables for each logic gate.
5. To be able to design simple logic gate circuits to solve problems.

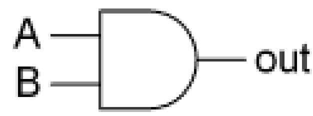
Digital Electronics

Digital electronics could be described as the switching on or off of an output from an input pulse. An output that is on is said to be **high**. An output that is off is said to be **low**. An output can only be in one **state** or the other. A **high state** is represented by the number **1**, a **low state** by **0**.

Logic Gates

There are a range of Logic Gates where the output will only go High once the input criteria is fulfilled. One of the popular series of Logic Gates is the 4000 series. Most are available as 14pin integrated circuits. Logic gates can have 2, 3 or 4 inputs. To find out which combination of inputs are needed to produce an output a truth table is constructed. In this chapter we are only going to consider 2 input gates. To know how many possible input combinations are possible the expression 2^n is used, where 2 represents the number of possible states (high or low). n refers to the number of inputs.

AND Gate



A	B	OUT
0	0	0
0	1	0
1	0	0
1	1	1

If you look at the above truth table you can see that the only time the output is High, both inputs have to be High. This gate could be represented by two switches connected in series as shown below in fig 7.1. The circuit is only complete when both switches are closed.

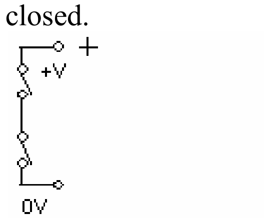
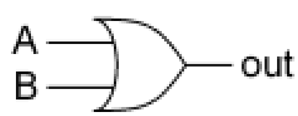


Fig 7.1

OR Gate



A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	1

With this truth table as long as either of the inputs is High, then the output will be High. This gate could be represented by two switches connected in parallel as shown in fig 7.2. As long as one of the gates is closed the circuit is completed.

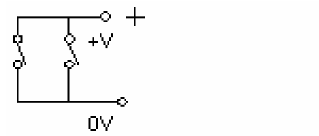
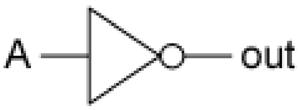


Fig 7.2

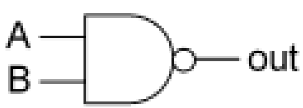
NOT Gate



A	Out
0	1
1	0

The **NOT** gate is often referred to as an inverter. The symbol is easily recognisable from the circle on the output. The output is the opposite to the input.

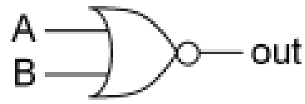
NAND Gate



A	B	OUT
0	0	1
0	1	1
1	0	1
1	1	0

The Not-And or **NAND** gate is an **AND** gate with an inverter on the output. It is one of the more popular gates and can be used to construct some of the other logic gates.

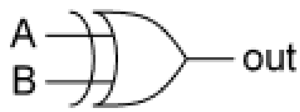
NOR Gate



A	B	OUT
0	0	1
0	1	0
1	0	0
1	1	0

The NOT-OR or **NOR** gate is an **OR** gate with an inverter.

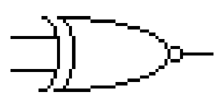
XOR Gate



A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	0

With the **XOR (**exclusive **OR)** gate the output is only high when either of the inputs is High. If both inputs are High the output is Low.

XNOR Gate



A	B	OUT
0	0	1
0	1	0
1	0	0
1	1	1

With the XNOR (Exclusive **NOR**) gate the output is only high when both inputs are Low or both inputs are High.

Delay propagation

When designing circuits using logic gates it is worth considering the time it takes for the output of a logic gate to change from a **Low** state to a **High** state. Although the time taken may only be nano seconds, you have to add up the number of logic gates from the original input to the final output to obtain the overall **propagation delay.**

Very often when using a circuit simulation program this delay will not be highlighted. It is only when a circuit is built on breadboard or on a PCB and it does not quite work as planned that this **propagation delay** comes to light.

Designing Logic gate circuits

Logic gates can be used to solve problems in electronics. For example, design a circuit using two input logic gates when either
A. The pressure mat is stepped on
B. The PIR detects movement
C. The window contact is broken

The first stage is to draw a truth table. As there are 3 inputs with each input having a high or low state then there are a total of 2^3 or 8 possible combinations.

A	B	C	OUT
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

From the truth table it can be seen that output is **High** when any of the inputs is also **High.**

The solution to the problem is to use 2 input **OR** gates as shown below.

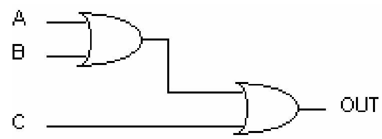


Fig 7.3

Ex 7.1

Using 2 input logic gates design a circuit for a plant watering system that will water plants when

A. It is dark and
B. When the plant is dry or
c. When the override is operated