TECHNOLOGY
SUBJECTS
SUPPORT
SERVICE

Leaving Certificate

# Technology

## Electronics and Control

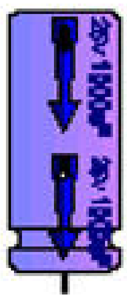
# Contents

# Electrical Measurement

## Measuring Capacitance


Measuring capacitance can be carried out by using a multimeter or by reading the value from the component itself. Allowing for the fact that capacitors may have a tolerance value +/- 20% of the expected capacitance, using a meter may be a preferred option. The capacitor is simply connected to the meter which has been set to measure capacitance in farads/microfarads.

Note that not all digital multimeters allow the user to measure capacitance and this function is generally only found in more expensive meters.



Capacitors may either electrolytic or non-electrolytic (also called electrostatic). Electrolytic capacitors have polarity which means they must be placed in a circuit the correct way around or they will not work or will become damaged. Electrolytic capacitors are generally quite big and we can easily read the value from the component - 1000µF for example.

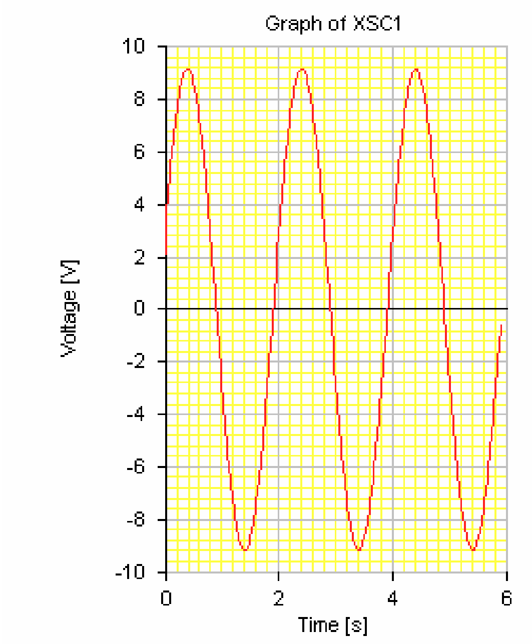
Generally capacitors have small values of values other than Farads.
The following terms are commonly used:-

1µF = 1 microFarad = $1\text{x}10^{-6}$ Farads = 1 millionth of a Farad
1nF = 1 nanoFarad = $1\text{x}10^{-9}$ Farads = 1 billionth of a Farad
1pF = 1 picoFarad = $1 \text{ x } 10^{-12}$ Farads = 1 trillionth of a Farad

**Exercise**
Convert 2200µF to (a) Farads,
(b) nanoFarads and
(c) picoFarads.

## Frequency

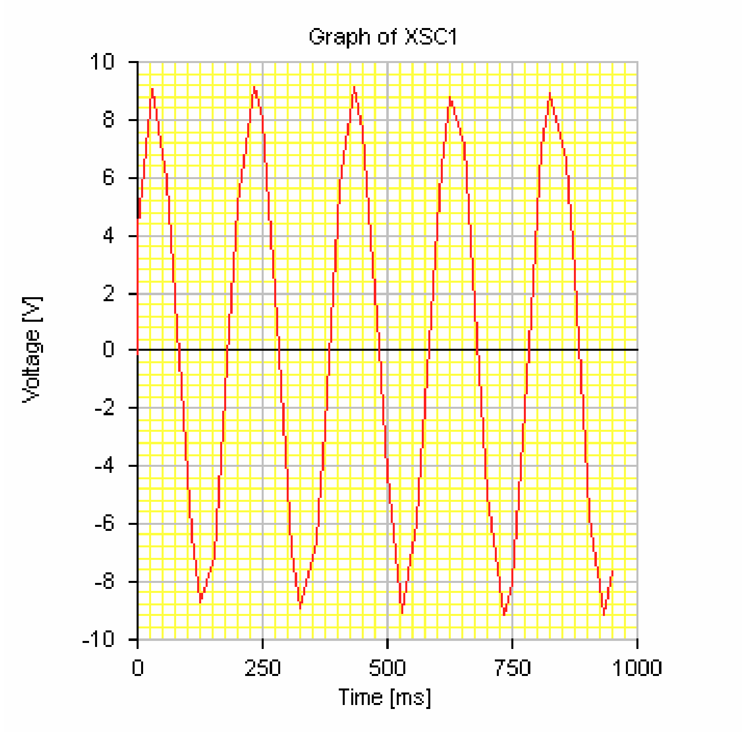
The voltage trace shown on the graph below is produced by an oscilloscope when an alternating current (AC) is connected to a 1k resistor.




As the name suggests alternating current (AC) flows in one direction and then in the other. It can be seen that the waveform flows from an initial value of 0V to a maximum value of 9V after half a second. The voltage value then drops to 0V after a time of one second before reaching another maximum of 9V, termed minus 9v (time = one and a half secs). Note that one complete cycle takes exactly two seconds. Negative voltage can sometimes seem very confusing while really it is not. Just remember that in the minus part of the graph the current continues to flow only this time in the opposite direction.

An ammeter inserted in the circuit will record a PLUS and MINUS READING. **Which means the current is flowing in the opposite direction.**

In most cases many cycles of the waveform occur in one second and the number of cycles which occur per second is known as the FREQUENCY – Symbol (f). Frequency is measured in HERTZ - (Hz).




In the diagram above there are five cycles occurring in one second and hence :-
Frequency f = 5 Hz

Relationship between frequency and period (time):-

(a) $f = \frac{1}{T}$ Hz OR (b) $T = \frac{1}{f}$ Sec

Where T is the PERIOD (i.e. the time taken to complete one waveform )

Examples

1. A waveform has a frequency of 5 Hz, calculate the period of the waveform.

$$T = \frac{1}{f} = \frac{1}{5} = 0.2 \text{ sec}$$

(This means 1 waveform will be traced every 0.2 seconds)

2. If the period of an AC waveform is 5milli seconds , find the frequency

5 milli seconds = 0.005 seconds

$$f = \frac{1}{T} = \frac{1}{0.005} = 200 \text{ Hz}$$

**Exercise**

1. Given the following frequencies, calculate the period of the waveform.
   (a) f = 100Hz
   (b) f = 5Hz
   (c) f = 20Hz
   (d) f = 100Hz
   (e) f = 1Hz

2. Given the following periods of each cycle calculate the frequency of the waveforms.
   (a) T = 0.05 seconds
   (b) T = 2 seconds
   (c) T = 25 milliseconds
   (d) T = 125 milliseconds
   (e) T = 5 milliseconds

## Power

In the study of electricity the word power has a specific meaning, usually to do some form of work. Examples include:

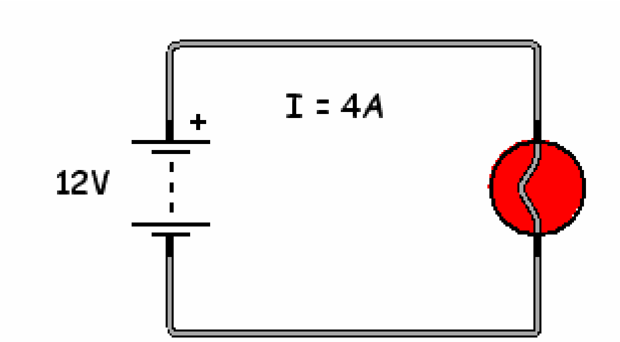
- to move something
- to generate heat
- to produce sound
- to produce light

Power may be defined as the rate at which energy is converted into work and it is measured in watts, symbol W. Large electric motors are sometimes rated in horsepower in the same way that car engines are. One horsepower = 746 watts. There are three formulae which can be used to calculate power in an electrical circuit.

**Formula 1**

P = I x V Watts. Where I is the current flowing through an electrical component and V is the voltage across it.

(a) Calculate the power developed by the bulb if a current of 4 amps is flowing in the circuit.

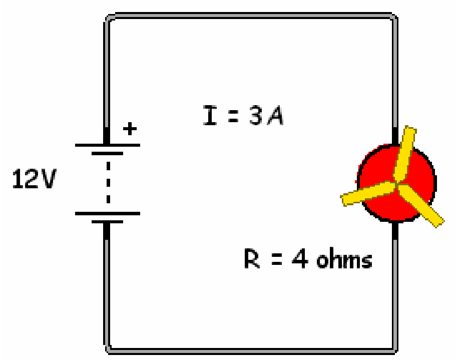



Voltage across bulb = V = 12 volts
Power = I x V = 4 x 12 = 48 watts

**Formula 2**

$P = I^2 \times R$ where I is the current flowing through a component and R is the resistance of the component.

(b) Find the power developed by the motor if the current flowing in the circuit is 3 amps and the resistance of the motor is 4 ohms?



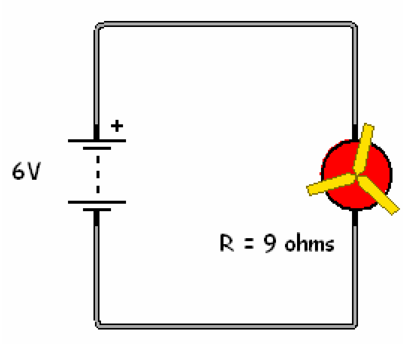

Power = $I^2$ x R = I x I x R = 3 x 3 x 4 = 36 Watts

**Formula 3**

$$P = \frac{V^2}{R} \text{ Watts Watts}$$

Where V is the voltage across the component and R is the effective resistance.

(c) Find the power developed by the motor in the circuit shown below.




$$P = \frac{V^2}{R} = \frac{6x6}{9} = 4watts$$

**Exercise**

1. A lamp is connected to a 10 volt supply and is drawing a current of 3 amps. Calculate the power developed by the lamp.

2. A lamp connected to a supply is drawing a current of 6 amps. If the resistance of the lamp is 2 ohms calculate the wattage of the lamp.

3. A motor of resistance 5Ω is connected to a 20 volt battery. Calculate the power output of the motor.

4. An 8 volt power supply is supplying a current of 250 mA to a relay. Calculate the power dissipated in the relay.

5. The current and resistance is known in a circuit. What formula can be used to determine the power dissipated in the resistor?

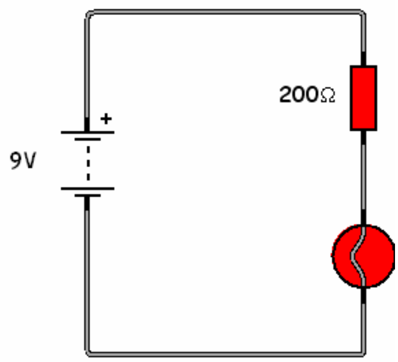
6. A resistor has 20V dropped across it and 2 amps of current flowing through it. What power is dissipated in the resistor?

7. A circuit has 120V applied to a motor that has 10Ω of resistance. How much power is developed by the motor?

**Power Dissipation**
All components have resistance so when a current flows through them power is dissipated in most cases in the form of heat. It is something to be aware of in the selection of components to be used in a circuit that the power ratings are not exceeded, examples are bulbs and resistors.

Example 1

Find the power dissipated by the bulb (Resistance of bulb = 100 ohms)

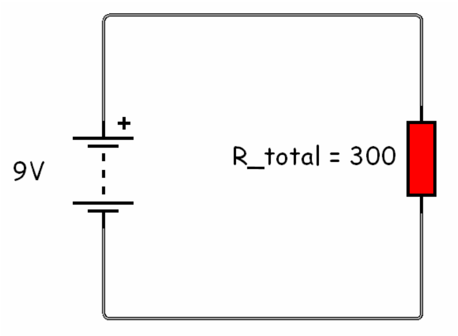



To find the power dissipated in the bulb which has a resistance of 100Ω.

If the formula Power = I x V watts is to be used the following data must be known: current flowing through the bulb and voltage across the bulb.

As the 200 ohm resistor and the lamp are in series then:

$$R_t = 200 + 100 = 300\Omega$$




So now having one voltage and one resistance the current flowing in the circuit can be calculated:

$$I = \frac{V}{R_t} = \frac{9}{300} = 0.03 Amps$$

The voltage across the bulb can be found:

V (bulb) = I x R   where R = the resistance bulb and I is the current

Vd = 0.03 x 100 = 3volts

We now have values for both the current through the bulb and the voltage across it.

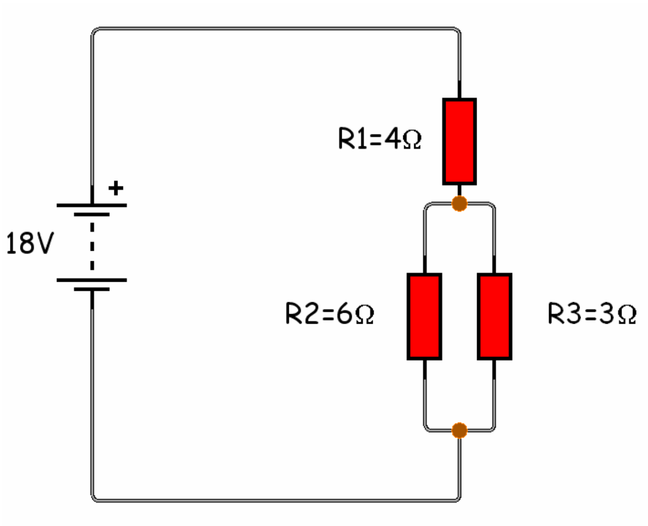
P = I x V = 0 .03 x 3 = 0 .09W or 90mW.

The power could also be calculated using the formula

$$\text{Power } = \frac{V^2}{R} = \frac{9}{100} = 0.09 \text{ Watts}$$

Example 2

In the circuit shown calculate the power dissipated in the 3 Ω resistor.

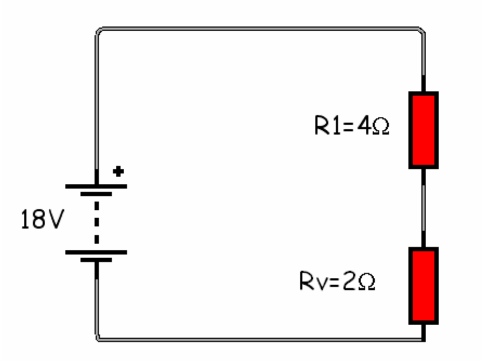



The first step is to find the total resistance of the circuit.

R2 and R3 are in parallel and this parallel arrangement is in series with R1

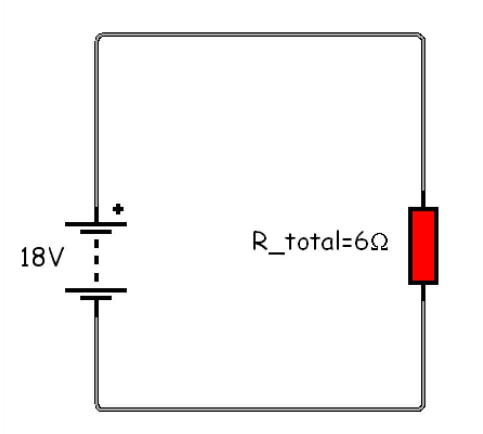
To calculate the parallel pair R2 || R3 (let equivalent resistance = Rv)

$$\text{Rv} = \frac{\text{R2 x R3}}{\text{R2 + R3}} = \frac{6 \text{ x } 3}{6+3} = \frac{18}{9} = 2\Omega$$




Circuit now reads R1 and R2 in series.

$$R_{Total} = R1 + Rv = 4 + 2 = 6\Omega$$

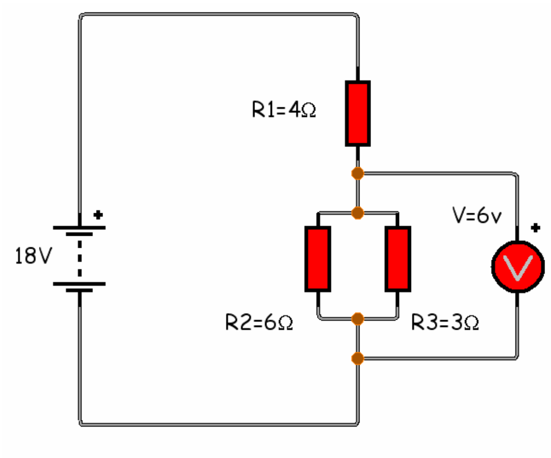



From having one voltage and one resistance the current flowing in the circuit can be found:

$$I = \frac{V}{R_{total}} = \frac{18}{6} = 3\,Amps$$

Knowing there is 3Amps flowing in the circuit we can now calculate the voltage across the two resistors in parallel. Remember that their effective resistance is 2Ω.

Voltage across parallel block: I x Rv = 2 x 3 = 6volts




Voltage = 6V

Resistance = 3Ω

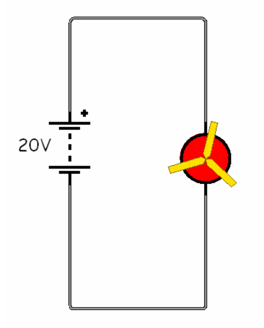
Power dissipated by the resistor:

$$Power = \frac{V^2}{R} = \frac{6x6}{3} = 12\,Watts$$

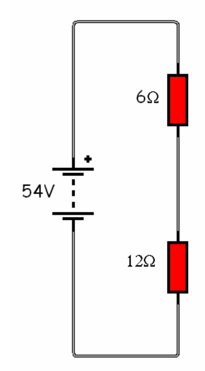
 

**Exercises**

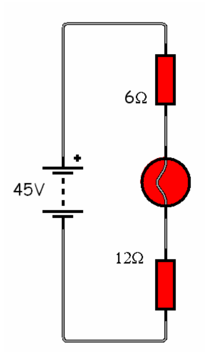
(a) In the circuit shown the motor has an internal resistance of 10Ω. Find the power developed by the motor.




(b) Calculate the power dissipated in the 12Ω resistor.

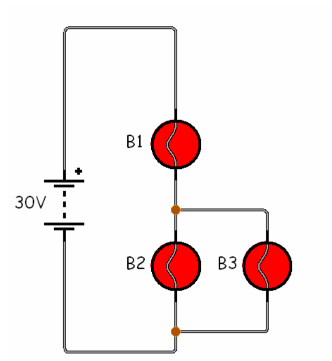



(c) The bulb shown has a filament resistance of 12 ohms. Calculate the output power.




ulb.

(d) In the circuit shown all the bulbs have a resistance of 10Ω. Find the output power of B3.

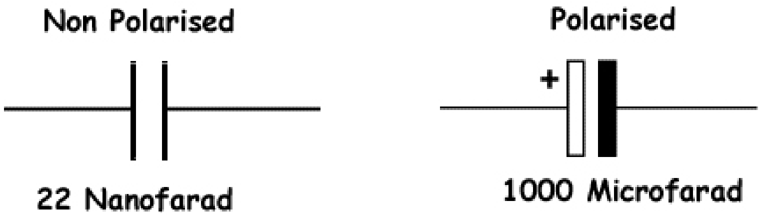


# Components and Circuit Design

## Components

### Capacitors

- Used to store electricity
- Capacitance (C) measured in  micro , nano and pico  Farads
- Two types: polarised and non-polarised




Capacitors symbol and typical value

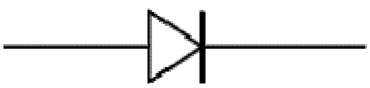
### Inductors (chokes)

- Consists of a coil of wire
- Used to block any unwanted AC signal circulating in a DC circuit
- Non polarised
- Inductance  (L) measured in  micro and nano Henrys


Inductor symbol and typical value

### Diode

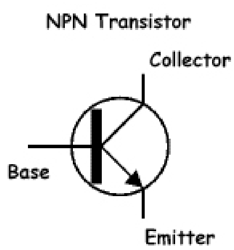
- Used primarily in AC circuits
- Diodes will pass current easily in one direction (forward mode) but will allow only a very tiny amount of current to pass when reversed (reverse mode)
- Diodes are polarised
- Used in rectification circuits (changing AC to DC)



Diode Symbol

### Transistor

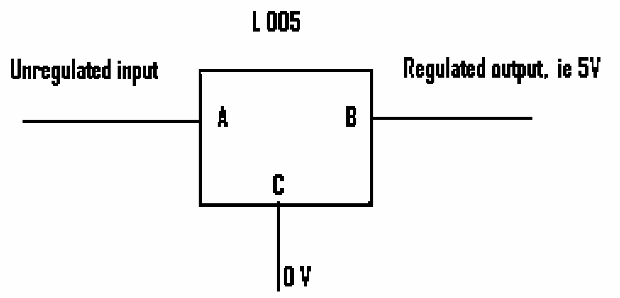
- Two types   NPN and PNP
- Polarised
- Transistors can operate in two modes:
    - as an electronic switch
    - as an amplifier




Symbol (for transistor)

**Voltage Regulators**

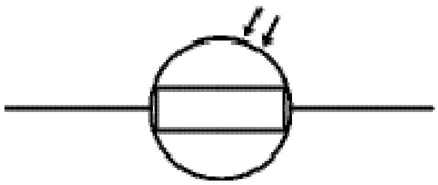
- Used primarily in POWER SUPPLY UNITS
- Function is to retain a constant output voltage irrespective of the amount of current drawn from the PSU




Symbol for voltage regulator (type L005)

**Light Dependent Resistor**

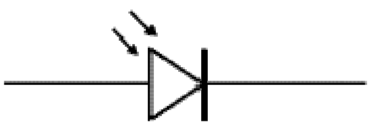
- The resistance of the component will fall as the intensity of the light falling on it increases
- Used mainly in sensor circuits in conjunction with a resistor to form a voltage divider circuit
- The varying voltage produced at the junction of the two components is used to switch on and off a transistor



Symbol (LDR)

**Photo Diode**

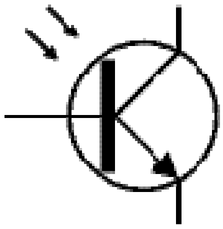
- Polarised
- Similar in operation to the LDR
- Operates in the reverse mode: the reverse current flowing through it increases in proportion to the amount of light striking the transparent window
- The one advantage to using a photodiode as opposed to the LDR is that its speed of operation is much faster



Symbol (photo diode)

**Phototransistor**

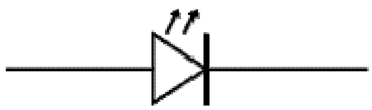
- Polarised
- Very similar in operation to the photodiode but in this case the current produced when light strikes the transparent window is amplified
- The photo transistor is about 100 times more sensitive than the photo diode



Symbol (for phototransistor)

**Ligtht Emitting Diodes (Leds)**

- Polarised
- When the P-N junction is forward biased in a circuit the LED will emit light
- The two points to remember is that the LED operates from a 2V supply and can only pass a maximum current of 20 milliamps it is for this reason in most instances a resistor is placed in series with the LED



Symbol (LED)

**Variable Resistors**

- Non polarised
- As their name implies the resistance of these components can be varied from zero ohms to any predetermined value
- Used mainly as volume and other control in radio and TV sets
- Usually contains three terminals but when used as a variable resistor one of the outside and the middle connection are used

Fig.1 depicts the symbol for a variable resistor and fig.2 demonstrates the variable resistor used in a circuit to control the brightness of the lamp.

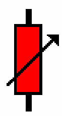


Fig.1

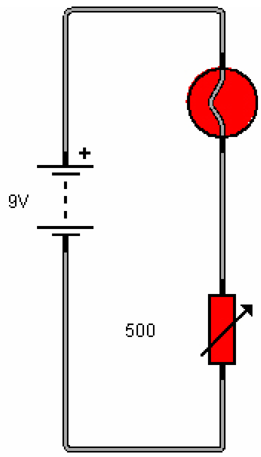
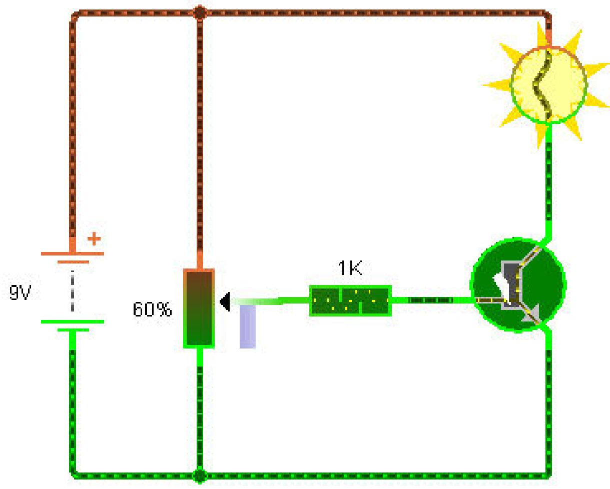



Fig.2

**Potential Divider Circuit (Potentiometer)**

- Non polarised
- Three connections

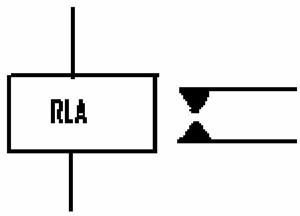
The circuit shown below shows a variable resistor operating as a potential divider. Assemble the circuit using appropriate soft ware to verify the lamp can be switched on and off by varying the wiper arm of the potential divider circuit. The wiper splits or divides the 9V which is available in the circuit. The variable resistor should have a value of 10k.




A 1K ohm resistor is connected in series with the base. This resistor does not contribute to the operation of the circuit; its function is simply to prevent damage to the transistor in the event that the base is exposed to a high voltage.

**Relay**

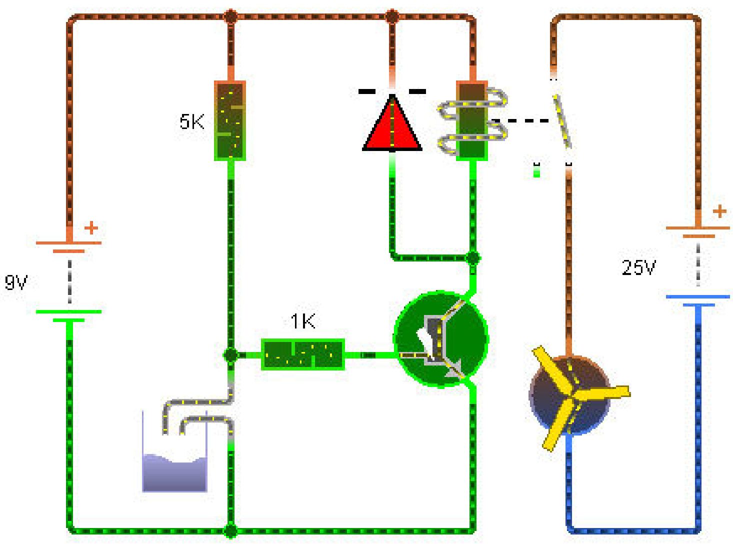
- Used mainly as an interface
- Most electronic sensor circuits (primary circuits) cannot provide sufficient current to drive power components. For this reason a secondary circuit capable of providing sufficient current must be assembled (secondary circuit) and an interface is therefore required to link the two circuits
- Relays are usually non polarised but exercise care as some relays incorporate a diode to prevent damage to other components due to rapid switching
- There is no electrical connection between primary and secondary circuits



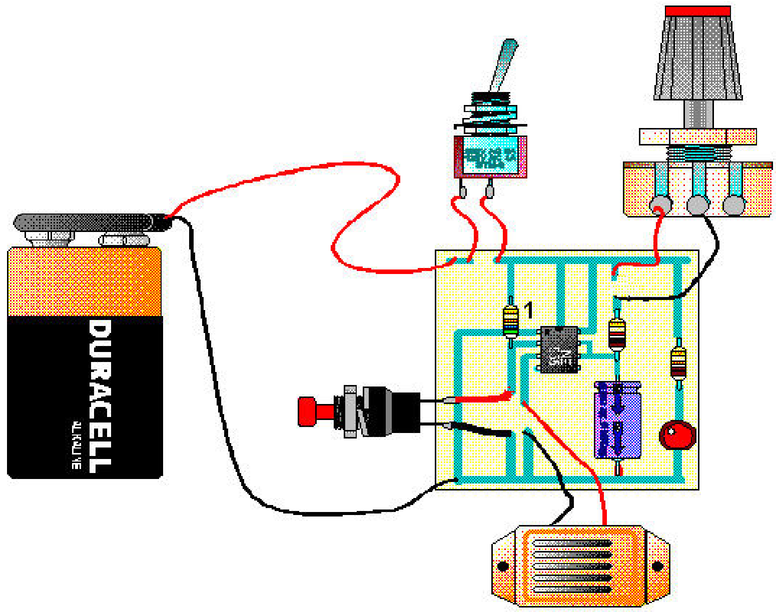
In the circuit below the motor will rotate and drive the fan until the water level reaches a certain level and the motor will switch off. The primary sensor circuit is operating from a 9V supply whereas the secondary driver circuit is operating from a 25 V supply, there is no electrical connection between the two circuits.

Note: the direction of the diode placed across the coil of the relay to prevent damage to the transistor.

Now using appropriate software assemble the circuit and verify its operation.



**Circuit Testing** – 555 Monostable Circuit



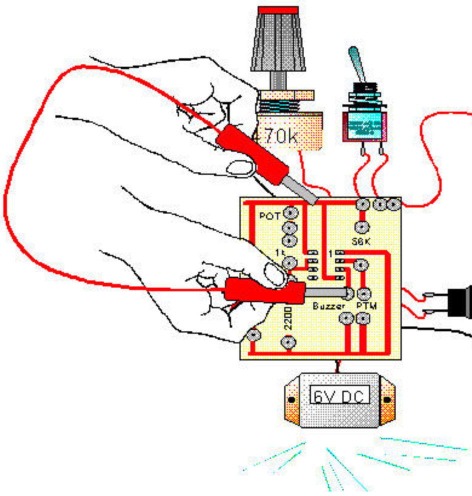

The above circuit shows a 555 timer arranged in monostable mode. This means that if the PTM switch is pressed and then released, the buzzer should sound for a period of time and then switch off.

In the event that the circuit fails to function:-

- Begin by carrying out a visual check to ensure that the components are of the correct value and have been placed correctly into the circuit, ensuring all joints have been soldered.

- Place the toggle switch in the ON position and the LED should light. Used like this the LED is simply an indicator to show that the battery and switch are working correctly. Let us assume the LED does in fact light. The PTM (red top) switch has been pressed but the buzzer does not sound. If the LED failed to light then go to step 8.

**Step 1** – Test the buzzer

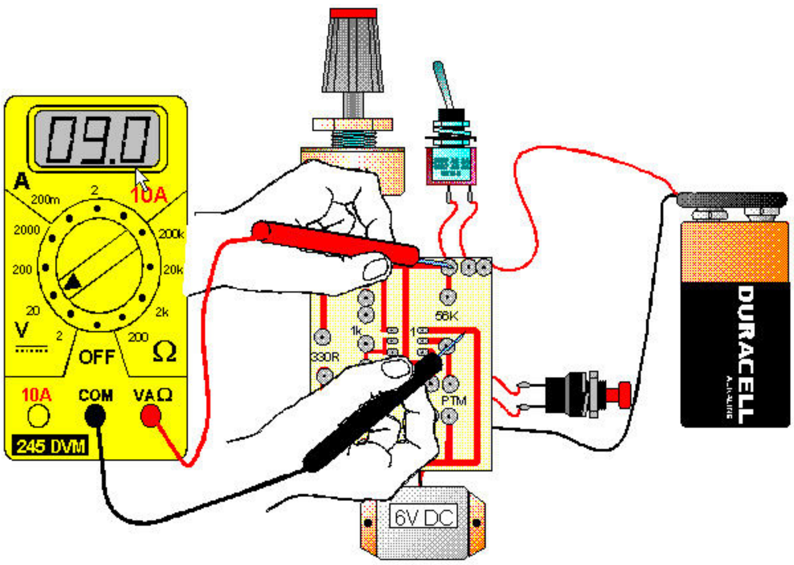



- Temporarily remove the 555 IC from the holder and connect a wire as shown. If the buzzer sounds by connecting it directly to the positive rail then the problem is elsewhere in the circuit.

- If it does not sound then the problem is with the buzzer or how it is soldered into the circuit.

Assume the buzzer sounds. Replace the 555 timer IC back into the circuit.

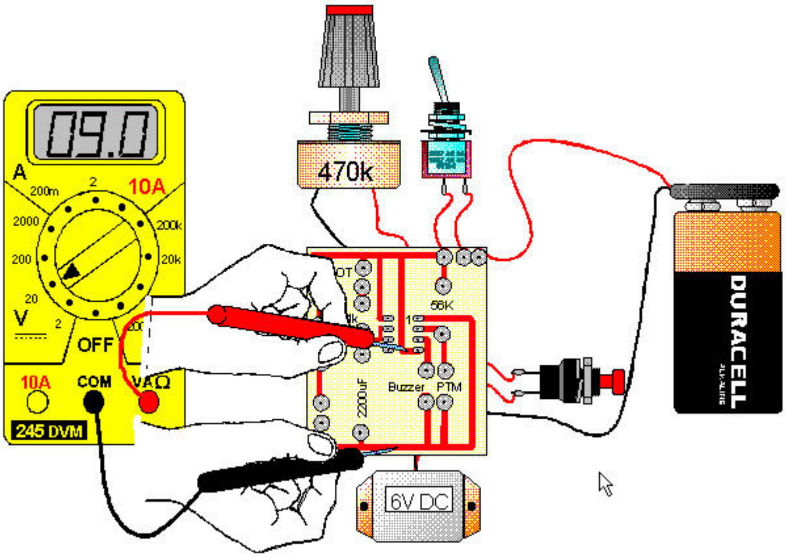
**Step 2** - Test the voltage at pin 1




- With the multimeter set to 20V DC, the reading should be 9V. This means that the positive rail is at 9V and pin 1 is connected to 0V. Remember that the toggle switch can be placed in either of two positions.

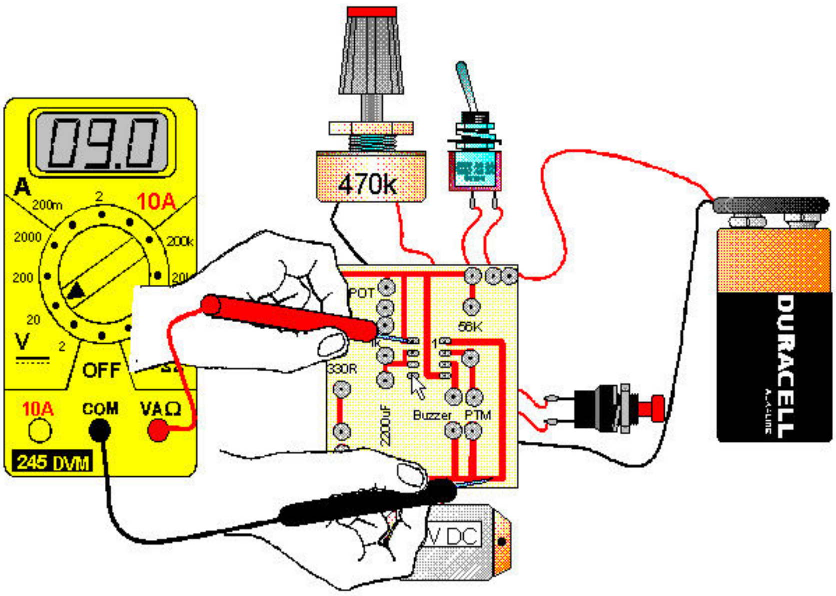
Let us assume that the meter does in fact read 9V.

**Step 3** - Test pin 4



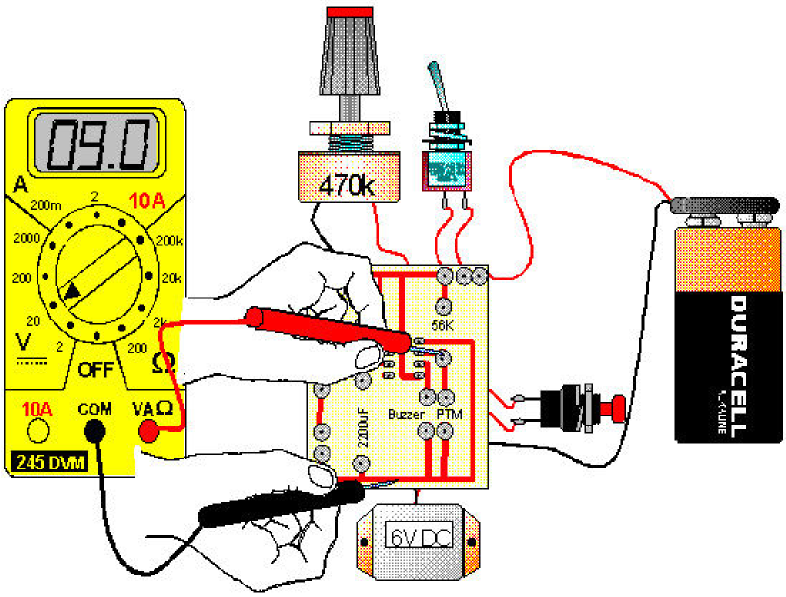

- With the multimeter in the position shown pin 4 is connected to the positive rail and the voltage should be around 9 volts.

**Step 4** – Test pin 8



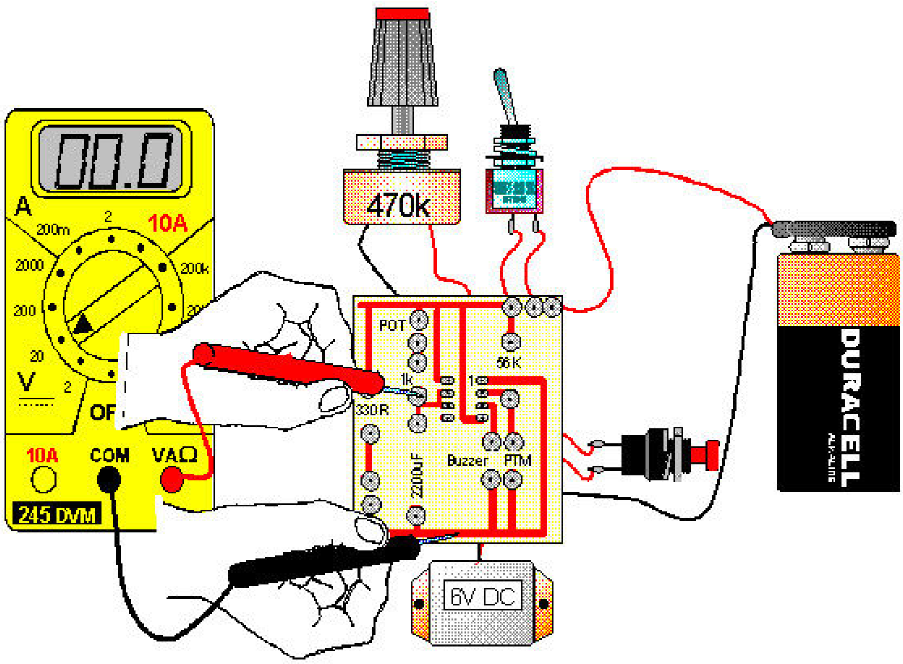

- Pin 8 is also connected to the positive rail and as such the multimeter should read 9 volts.

**Step 5** – Test the PTM (push to make switch)



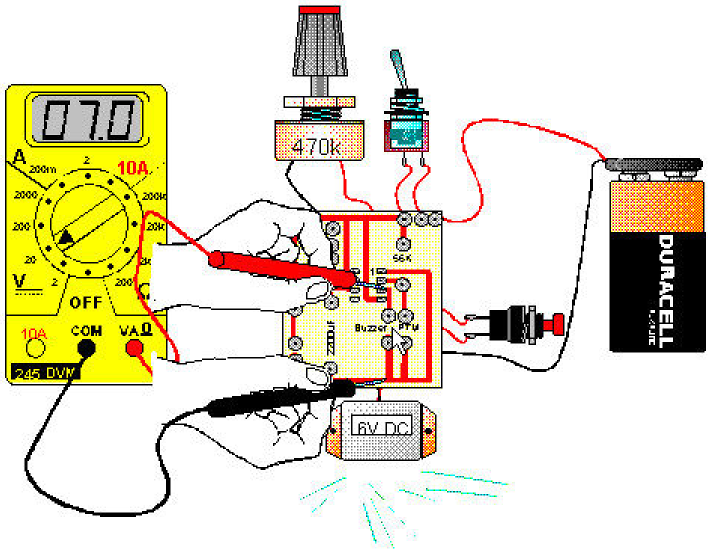

- With the multimeter arranged across the switch as shown the meter should read 9 volts? When the switch is pressed the voltage should fall to 0V.

**Step 6** – Testing the capacitor



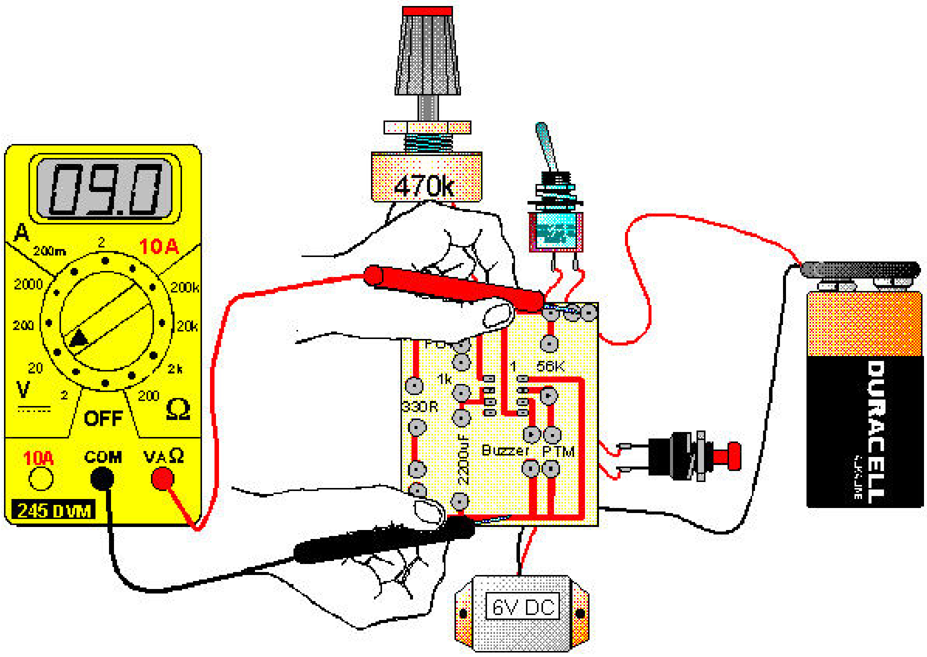

- If the PTM switch is pressed and released then the following sequence should be noted. When working correctly the multimeter should read 0 volts to begin. The capacitor should begin to charge and the voltage will rise accordingly. In a properly functioning circuit the voltage will rise to 6V before falling back to 0V again, after a time.

**Step 7** – Testing pin 3




- With the positive probe of the meter placed as shown and the PTM pressed then pin 3 should go high, in or around 7 volts. This in turn should cause the buzzer to sound.

**Test 8** – Testing power before the toggle switch




- Assume we tested the buzzer using the wire link in test 1 and the buzzer did not sound. This means a number of things might be wrong. The buzzer is faulty, the toggle switch is broken or the battery is flat. Let us try and eliminate these in order.
- Testing as shown and obtaining a voltage of 9V proves that the battery is operational.

- If we check the voltage on the other side of the switch and it is still at 9 volts then the switch is also operating correctly. Remember the switch can be in either of two positions.

- If we obtain 9 volts at this point we would assume the likely problem is with the buzzer.

Fault finding requires patience and a systematic approach. You must understand fully how the circuit behaves, only then can we begin to fix the problem.

In the event of all these tests having been carried out and the circuit still malfunctions, it can be assumed the timer chip is faulty and thus must be replaced. Note that this is the last option, not the first.

# Power Supplies and Safety

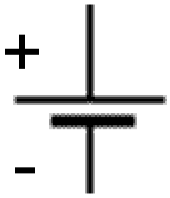
## Power Supplies

All electronic circuits designed to carry out a particular function require a power supply to deliver an output. In the case of non-mobile equipment (such as pedestal drill or circular saws) these devices are connected directly to the mains supply.

This system of mains operated equipment has three advantages:-

- Regulation is good, this means the voltage will remain constant irrespective of the amount of current drawn from the supply
- It will continue to supply the desired voltage, current indefinitely
- Power produced by this method is much cheaper than battery power

Mobile equipment by its nature needs a mobile power supply and in most cases BATTERY POWER is used, although with the advance of technology solar power is becoming more available.




The term cell was used to denote a component producing an output voltage ( usually 1.5V ) whereas the battery is a number of these cells connected in series or parallel to output a higher current or voltage, but at present the two terms have been blurred and a cell can represent a battery and vice versa .

There are several disadvantages to using batteries as a form of power supply:-

- Batteries can only supply a finite amount of current for a finite time
- Regulation is poor, i.e. as more current is drawn the output voltage of the battery will fall, and also as the battery ages the output voltage will fall
- As the battery ages the amount of current which can be drawn from the battery will fall until a point is reached when the battery can no longer supply sufficient current to drive the equipment and subsequently the battery must be replaced
- Batteries even when not in use have a shelf life
- Equipment which is not in use for extended periods should have the batteries removed as corrosion can occur

The size of the battery determines the amount of current the battery can supply (capacity measured in AMPERE HOURS) and the time the battery can continue to supply the said current. Obviously the size of the equipment determines the size of the battery which can be used. For example a hearing aid can only accommodate an extremely small button type battery whereas a portable radio can accommodate a much larger battery or bank of batteries

## Types of batteries (cells) and their uses

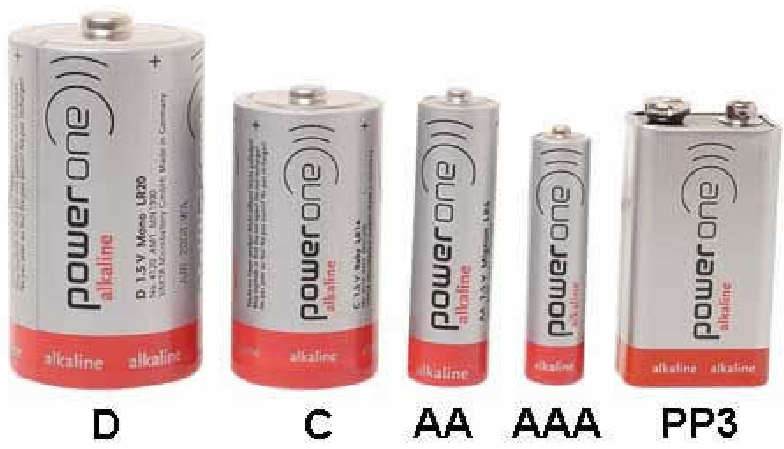
Alkaline button cells usually come in four sizes, nominal voltage 1.5V, and a capacity of 35mA hours. Reasonably priced and used extensively in cameras, calculators, stop watches etc.

Silver Oxide button cells again come in four sizes, nominal voltage 1.55V. Applications include watches clocks, calculators, cameras, and other miniaturised equipment where size and performance are important factors. May be used as superior replacements for the above mentioned ALKALINE button cell but are much more expensive.

There is a very wide range of coin and button cells available. However, to be of practical value in school electronics, they need to be fitted into specialised battery holders and only a limited range of these are available.


Zinc air batteries are compatible with silver button cells but have a nominal voltage 1.4V. These cells offer a high capacity and a flat discharge profile and are ideally suited for medical electronics, e.g. hearing aids and other applications where precise operational life is required. In comparison to other button type cells, this type is very expensive. The above types of button cells are not rechargeable and they can only produce very tiny current in the region of micro amps.

In circuits where a larger flow of current is required (in the milliamp range) Zinc chloride batteries (types D, C, AA, AAA, PP3) are used. Types D, C, AA, AAA all output a nominal voltage of 1.5V.



- Type AAA is the smallest of the above batteries and also produces the smallest amount of current (somewhere in the region of 10 milliamps over an extended period). Used in musical IPODS, and infra red controllers for televisions etc.
- Type AA one of the most used batteries, can be found in small radios, torches, toys, cassette players etc. This type can readily supply current of 40 milliamps over long periods.
- Types C, D can provide a much larger current region of 100 milliamps over extended periods and are used  in power torches and large portable musical centres. Note the above batteries can provide much larger current over shorter periods.
- The PP3 battery has an output voltage of 9V. It is used extensively in small radios and also in smoke alarms. It can provide a continuous current output of 20 milliamps.

The above types of the ZINC CHLORIDE BATTERIES are all of the non rechargeable type although ALKALINE types (D, C, AA, AAA, and PP3) are being produced which are rechargeable.

For other types of equipment where a large power output is required (i.e. large current drain) e.g. motors, actuators heavy duty lamps, then two options are available. Rechargeable lead acid batteries such as those used in cars can produce considerable currents.


A more viable solution for classroom use however is a power supply such as that shown opposite. Theses come with various voltage and current limits.


The advantage of this particular unit is that the voltage can be adjusted and the maximum current is 1500 milliamps.

Voltage and current requirements for all circuits should be ascertained and the correct size battery or power supply ordered.

There are a number of ways to ascertain the current value flowing in any given circuit:-

- Use a multimeter, highly accurate
- Some power packs give a readout of the current in a circuit
- Mathematically calculate the value. This is not easy to do in some case, such as motors. In the case of seven segment displays however we can assume that as a maximum value 20 milliamps may flow through each LED. This gives a value of 140 milliamps and if a double display is used a possible 280 milliamps will flow. Could you use a PP3? The answer is yes; just don't expect it to run for several hours' usage. A power supply as shown may be a better option although the cost of such a unit will be between €10-15.

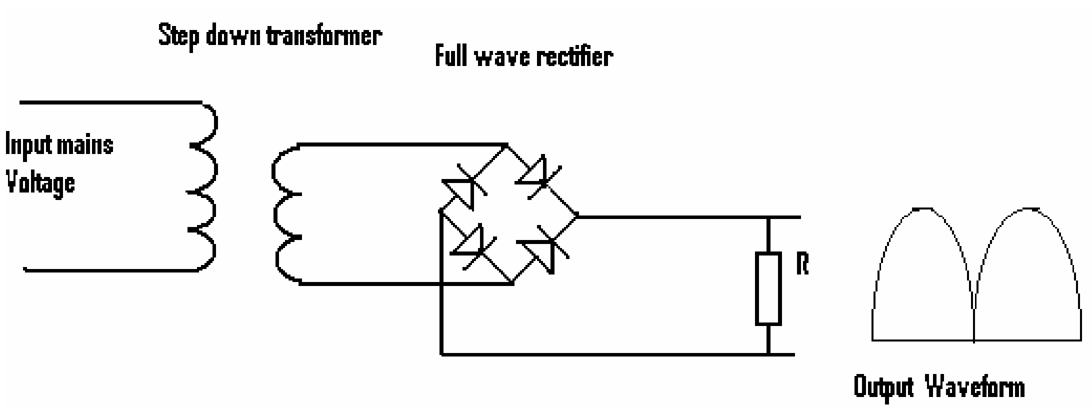
## Mains Power Supplies

***Never try and link any circuit to a mains electricity supply. This operates at a voltage of around 230V and the consequences of misuse are fatal. Only connect your project through a mains adapter supplied by a recognised manufacturer which reduces the voltage to a suitable working value.***

Circuits containing transistors and ICs may operate from voltages as high as 30 volts and as low as 1 volt. The current demand can vary from a few micro amps (electronic watches, etc) to several amps (motorised circuits).

Batteries are suitable for low power portable equipment which draws a small current (usually in the region of milliamps). One drawback of the battery is the decrease of the battery output voltage as increased current is drawn from the battery, the greater the decrease the poorer is said to be the REGULATION

Regulation can be termed as the difference in output voltage between no load and full load conditions. In general most equipment is designed to operate from power supply units (PSU) which operate from the mains supply. These units can supply very steady voltages over a wide current range. A PSU consists of a step down transformer and a rectifier. The transformer reduces the 230V AC mains supply to a low voltage AC supply. The rectifier then converts the low AC voltage to a low DC voltage.

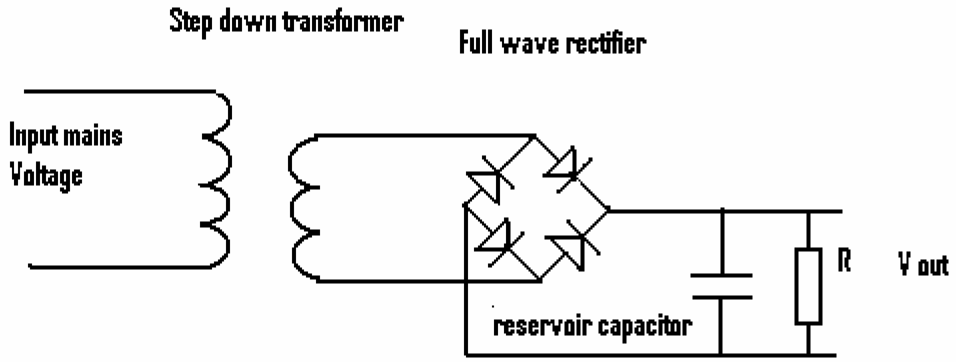



The sketch shown above represents a full wave rectifier (unsmoothed) circuit. Note the current flowing through R which represents the load/electronic component is in the same direction during both half cycles.

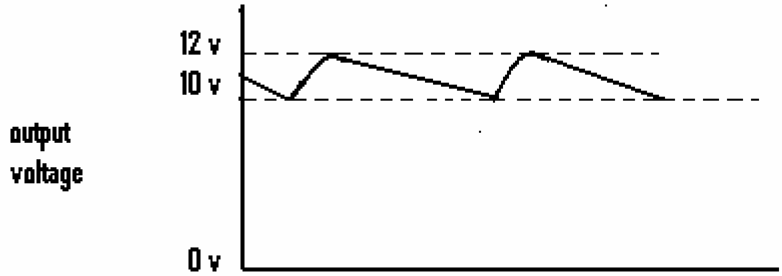
 

Thus a fluctuating direct voltage is developed across the output resistor as shown
The voltage is fluctuating from zero volts up to its maximum (say 12 volts) and thus is not suitable to power an electronic circuit requiring a stable voltage. The only use to which the above circuit could be put is to the charging of a battery.

The diagram below illustrates the effect of adding a capacitor in parallel with the load. A capacitor used in this way is often referred to as a smoothing capacitor.



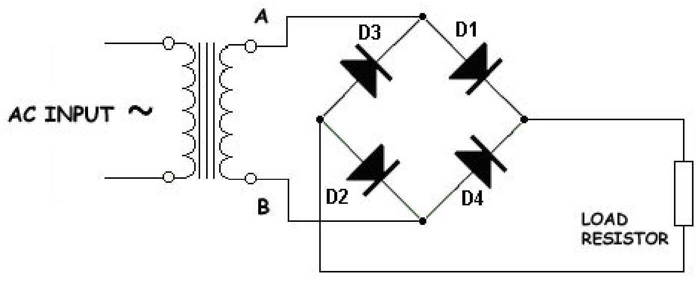

The output waveform now consists of a nominal 10V DC level and a 2V ripple voltage. In reality this ripple voltage might be bigger or smaller depending on the size of the capacitor. This ripple voltage has a frequency of 100 Hz 9 i.e. **twice** the frequency of the mains supply. This phenomenon is explained in some detail later on.




This type of POWER SUPPLY UNIT (PSU) is quite satisfactory to use in simple transistor circuitry such as switching circuits, light circuits etc. It is not suitable for use in circuits which produce a sound out put as the 100 Hz ripple produced by the power supply will be superimposed on the resultant output sound.

It is also not suitable for use in circuits using chips as these chips can be adversely affected by the ripple voltage. Other faults with the full wave bridge rectifiers is that as the current drawn from the PSU is increased the amplitude of the ripple voltage will increase and consequently the DC output voltage will fall, i.e. VOLTAGE REGULATION is poor.

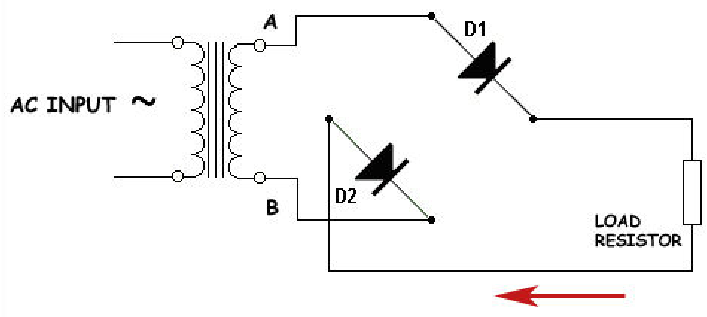
## The operation of the bridge rectifier



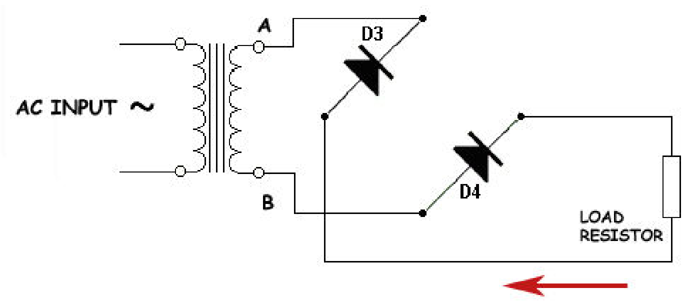

A bridge rectifier consists of four diodes arranged as shown The voltage has already been reduced from 230V to a smaller voltage using a step down transformer,

The voltages at points A and B on the transformer are changing in opposite directions. When A is increasing in a positive direction, B is increasing negatively. It is like the opposite ends of a see-saw. During the first half cycle, A is positive and B is negative.

D1 has positive on its anode, D2 has negative on its cathode and as such both are forward biased. Current flows around the circuit formed by these diodes, the load and the transformer winding, as shown in the diagram below.

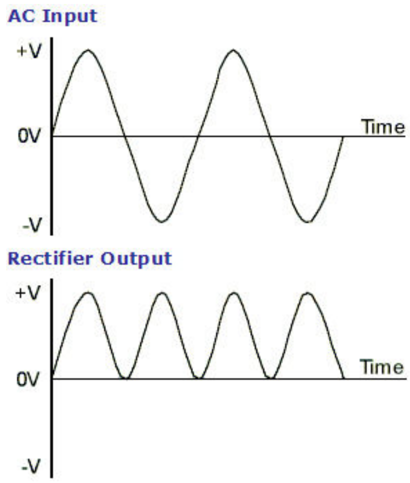



During the next half cycle, A is negative and B is positive. D4 has positive on its anode, D3 has negative on its cathode and as such both are forward biased. Current flows around the circuit as shown in the diagram below, again flowing in the same direction through the load and producing another pulse of voltage.




Since the full cycle is used this circuit is called a FULL-WAVE rectifier.

Assume the frequency of mains AC to be 50Hz, there are two pulses for each cycle of input, there are 100 pulses per second out. This is explained by the fact that the positive half of the AC waveform causes one pulse and the negative half forms the other pulse. There are 2 complete waveforms on the AC input side of the circuit but four peaks on the rectified output. The pulsating DC can be smoothed with a reservoir capacitor, as in the half-wave rectifier circuit.




## Voltage Regulation

Regulation can be defined as the change in output voltage when the load current varies between its maximum and minimum values. As electronic equipment becomes more complex it becomes necessary to produce power supply units which can produce a constant DC voltage. Many mains operated DC supplies are sold as “battery replacements” but in some cases do not live up to expectations.

The mains supply can vary by some 10 % and in a simple transformer/rectifier circuitry this deviation would be reflected in the output DC supply. For example in gate circuits when using the 74 series chips ( TTL logic circuits) a voltage supply of 5 volts plus or minus half a volt is required. Also for variations of current drawn a constant voltage is desirable. The simplest form of regulator is the ZENER DIODE REGULATOR.

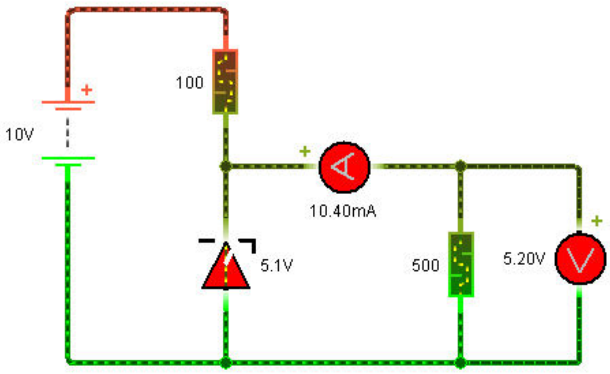
## Properties of a Zener Diode

If the ordinary diode is placed in a circuit in the reverse mode and the input voltage is increased, a point is reached when the diode will rupture and the diode is destroyed With the ZENER diode in the reverse mode, similar to the ordinary diode it will not pass current

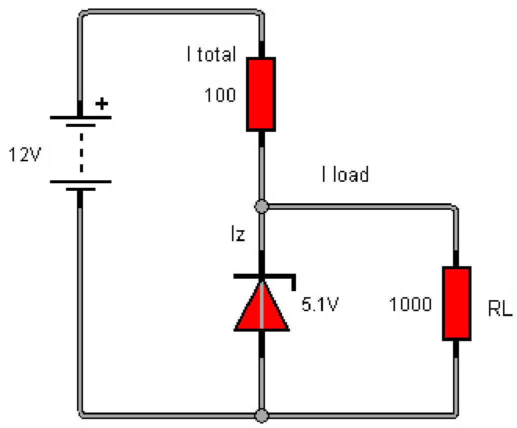
As the voltage is increased, at a particular voltage, known as the BREAKDOWN REGION the diode will pass current but more importantly its voltage will remain rock steady even with a further increase in the input voltage (breakdown region is perhaps misleading as it could convey the impression of permanent damage to the diode, this is not so).

This property is utilised in the voltage regulator circuit below. In this circuit a zener diode having a zener voltage of 5.1 volts is used. An ammeter is inserted in the circuit to monitor the current flowing,

- The zener diode will maintain a very steady voltage of 5.1V even if the input voltage is increased
- The zener diode will maintain a steady voltage even if the load is increased or decreased.




**Caution when using zener diodes**




The current drawn from the battery (I total) flows through the 100 ohm resistor. The current now splits and a % flows through the zener (Iz) and the majority of the current flows through the load resistor (RL).

Power dissipated by the zener diode can be calculated from the formula:-
P = Iz x Vz watts, (where Iz is the current through the zener diode and Vz is the zener voltage ).This power is dissipated in the form of heat.

If the load resistance (RL) is removed then I total has to flow through the zener diode. This means the power developed in the diode is very much increased as the current value is much bigger and could lead to the destruction of the zener diode.

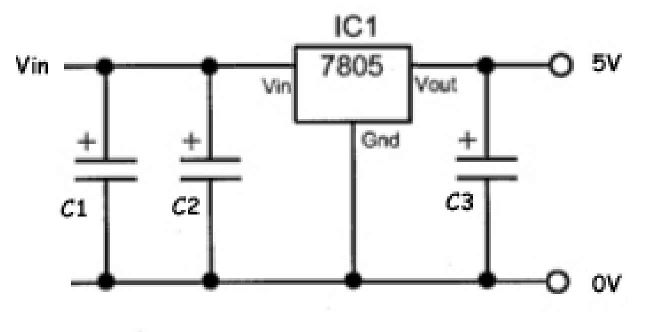
 

## Integrated Circuit Regulators

It is becoming increasingly less economic to design and build a regulator circuit and a variety of integrated circuit regulators are now available. These are very simple to use since they have only three terminals labelled IN, OUT, COMMON.

These IC regulators are normally sold in fixed voltages 5V for TTL circuitry, 12V for general use and 15V for operational amplifiers.

A typical circuit diagram of 5V IC regulator is shown below:-




The circuit is to provide a stable 5V, 1000 mA (1 amp) supply using the 7805 regulator. C1 is a reservoir capacitor in the order of 1000 micro farads to provide a smoothed input voltage. C2 and C3 are not essential but improve the performance of the regulator. The regulator should be connected to a heat sink to dissipate heat, especially if the current drawn is close to the maximum value for the component.


A 7805 regulator showing the three connectors. Note that the maximum current, in this case 1 amp, should not be exceeded. A datasheet is used to determine the pin configuration and the threshold values for the different sizes and type of regulator.

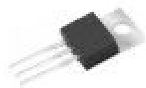
# TruSemi

**DE7805**
**DE7805A**

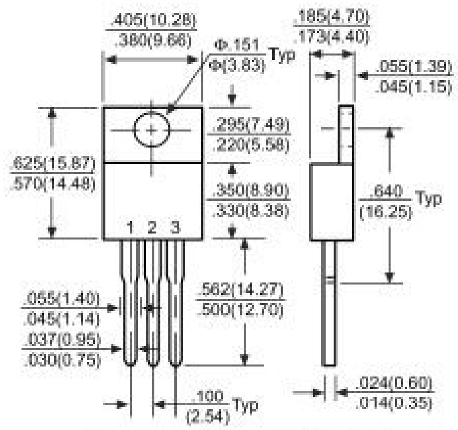
## TECHNICAL SPECIFICATIONS OF 3-TERMINAL POSITIVE VOLTAGE REGULATOR

### Description

These regulators empoly internal current limiting and thermal shutdown, making them essentially indestructible. They can deliver over 1A output current with adequate heatsinking. They are intended as fixed voltage regulators in a wide range of applications including local, on-card regulation for elimination of noise and distribution problems associated with single-point regulation.



TO-220AB




Dimensions in inches and (millimeters)

### Pinning

1 = Input
2 = Ground
3 = Output

### Absolute Maximum Ratings ($T_A$=25°C)

| Characteristic | Symbol | Rating | Unit |
|---|---|---|---|
| Input Voltage | $V_I$ | 35 | V |
| Total Power Dissipation | $P_D$ | Internal limit | W |
| Operating Temperature Range | $T_{opr}$ | 0 to +125 | °C |
| Maximum Junction Temperature | $T_J$ | 125 | °C |
| Storage Temperature Range | $T_{STG}$ | -55 to +150 | °C |
| Lead Temperature(Soldering 10 Sec.) | $T_L$ | 230 | °C |

### Electrical Characteristics

($V_{in}$=10V, $I_{out}$=500mA, 0°C≦$T_J$≦125°C, unless otherwise specified)

| Characteristic | | Symbol | Min | Typ | Max | Unit | Test Conditions |
|---|---|---|---|---|---|---|---|
| Output Voltage | DE7805A | $V_O$ | 4.85 | 5.00 | 5.15 | V | $T_J$=25°C |
| | DE7805 | | 4.80 | 5.00 | 5.20 | | |
| | DE7805A | | 4.85 | 5.00 | 5.15 | | $P_D$≦15W, 5mA≦$I_O$≦1A |
| | DE7805 | | 4.75 | 5.00 | 5.25 | | |
| Line Regulation | DE7805A | $Reg_{line}$ | - | 4.0 | 50 | mV | $T_J$=25°C, 7V≦$V_{in}$≦25V |
| | DE7805 | | - | 4.0 | 100 | | |
| | DE7805A | | - | 1.6 | 25 | | $T_J$=25°C, 8V≦$V_{in}$≦25V |
| | DE7805 | | - | 1.6 | 50 | | |
| Load Regulation | | $Reg_{load}$ | - | - | 100 | mV | $T_J$=25°C, 5mA≦$I_O$≦1.5A |
| | | | - | - | 50 | | $T_J$=25°C, 250mA≦$I_O$≦750mA |
| Input Bias Current | | $I_{IB}$ | - | 5.5 | 8.0 | mA | $T_J$=25°C, $I_O$≦1A |
| Input Bias Current Change | | $\Delta I_{IB}$ | - | - | 0.5 | mA | 5mA≦$I_O$≦1A |
| | | | - | - | 1.3 | | 7V≦$V_{in}$≦25V |
| Output Noise Voltage | DE7805A | $V_n$ | - | 40 | 200 | μV | $T_A$=25°C, 10Hz≦f≦100KHz |
| | DE7805 | | - | 100 | 300 | | |
| Ripple Rejection | DE7805A | RR | - | 68 | - | dB | 8V≦$V_{in}$≦18V, f=120Hz |
| | DE7805 | | 62 | 73 | - | | |
| Dropout Voltage | DE7805A | $V_D$ | - | 2.0 | - | V | $T_J$=25°C, $I_O$=1A |
| | DE7805 | | - | 2.5 | - | | |
| Short Circuit Current | | $I_{SC}$ | - | 1.5 | - | A | $T_J$=25°C |
| Peak Output Current | | $I_{max}$ | 1.7 | - | - | A | $T_J$=25°C |
| Average $T_C$ of $V_{out}$ | | $\Delta V_O/\Delta T$ | - | -0.8 | - | mV/°C | 0°C≦$T_J$≦+125°C, $I_O$=5mA |

# Electric Motors

## Electric motors and motor reversal - DC motors

An electric motor is a device which converts electrical energy into motion. The sketch below shows an arrangement of two magnets placed some distance apart with the north and south poles adjacent to each other. Lines of magnet flux will radiate from the north pole and enter the other magnet via the south pole.

If a conductor is placed in the magnetic field and a current is passed through it then it will move upwards and if the current is reversed (flows through the conductor the other way) then the conductor will move downwards through the magnetic field Fig.1

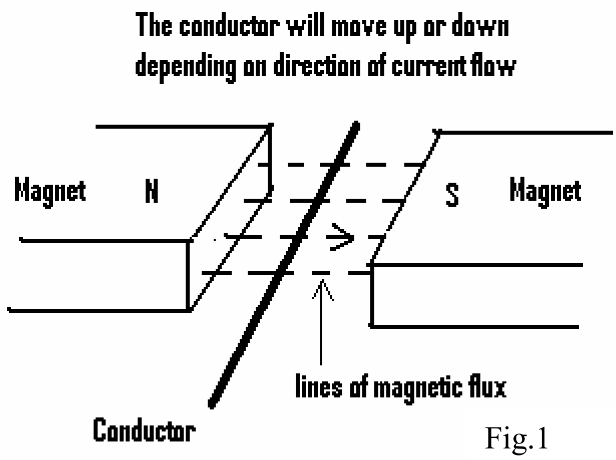


Fig.1

Now consider the arrangement shown in Fig.2.

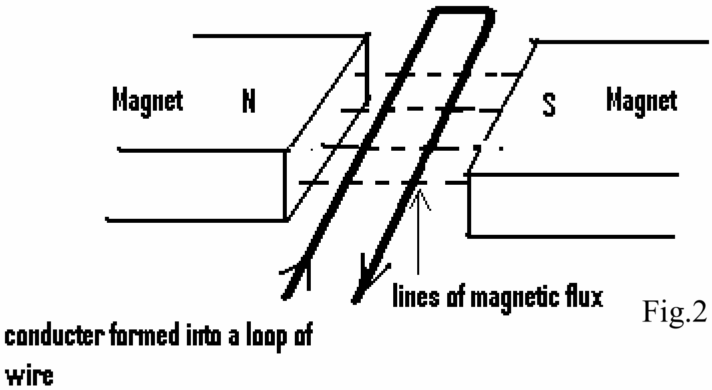


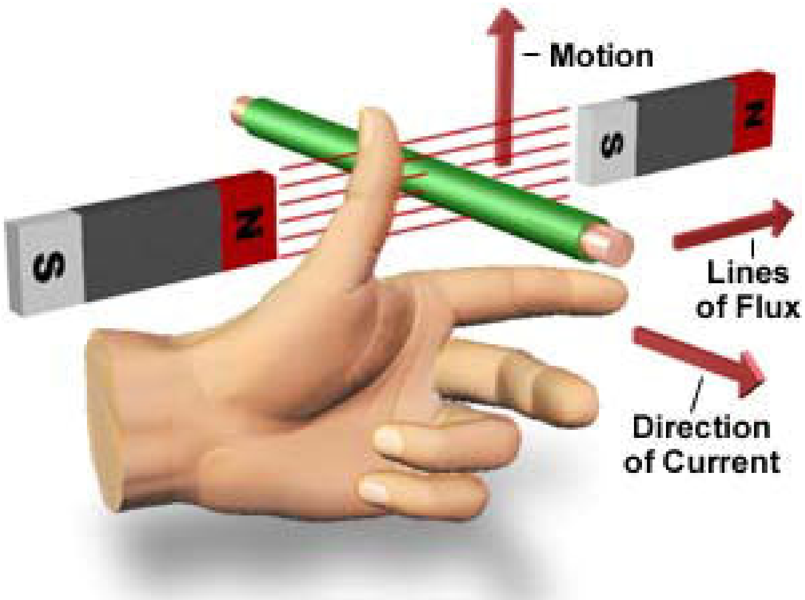
Fig.2

The wire has been bent into the form of a loop (note directions of current flow in each leg the loop). Current flowing in the left leg of the loop will cause that leg to move downwards whereas the current flowing in the right leg will cause that leg to move upwards, thus the loop of wire in the magnetic field will tend to spin.

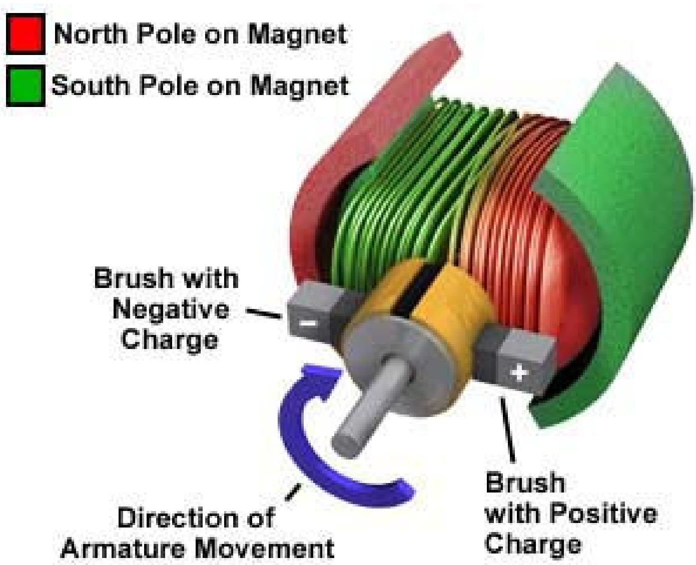
The left hand rule, established by Fleming, can be used to predict the direction the conductor will move.

- Place the thumb, first finger and middle finger of the left hand at right angles to each other as shown below.
- The Thumb represents thrust or motion, the First finger is aligned with the magnetic field and the seCond finger is aligned with the direction of the current.

***Diagrams below have been reproduced with the kind permission of The Florida State University (Michael W Davidson)***




The problem now is to get the current into the loop when it is spinning. Consider the arrangement shown below.



Current flows from the battery through the right hand brush though the right hand section of the slip ring which is soldered to the armature winding. Note the small slit in the slip ring, usually filled with insulating material

Current now flows through the loop of wire out through the left hand side of the slip ring and out through the left hand brush and hence back to the battery, so current is constantly being applied to the loop of wire which is rotating in the magnetic field

Note: a practical motor contains many loops of wire thus the slip ring is segmented into many sections. The loops of wire are called the armature windings and the slip ring arrangement is known as the commutator which is assembled on a shaft allowing the whole assembly to rotate.

The magnetic field is produced in two ways

- Permanent magnets (this method used only in the cheaper type of motors)
- Field coils which are wound around soft iron cores known as the FIELD POLES.

Thus when current is passed through the field coil the soft iron core is magnetised. Motors must have a least two field poles to have a north/south pole arrangement.

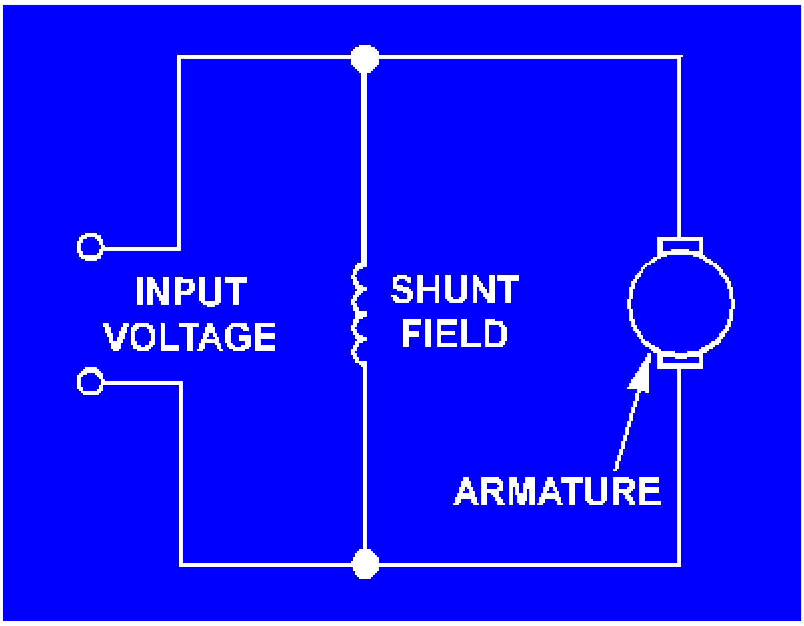


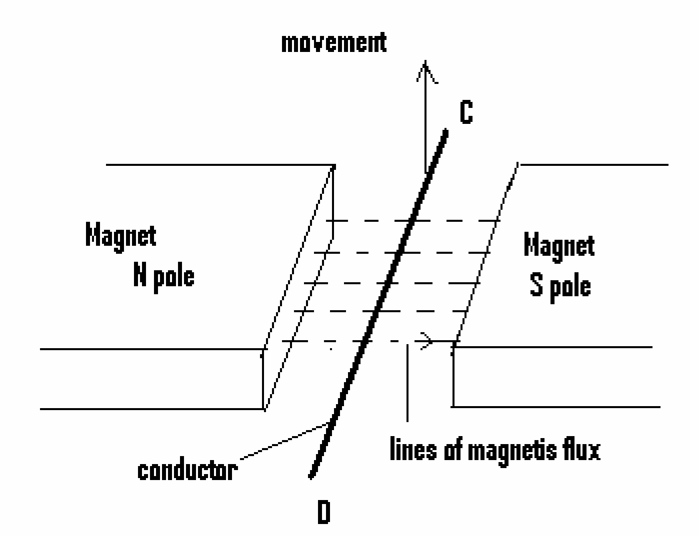

Fig.5

Fig. 5 shows arrangement of field winding and armature attachment known as a SHUNT MOTOR where the field coils are in parallel with the armature. A small % of the current flows through the field coils to produce the magnetic field. Most of the current flows through the armature windings thus producing the turning effect of the motor (known as the TORQUE).

## Back EMF (voltage) produced in the armature of a motor

When a conductor is moved down through (or up through) the magnetic field as shown in fig.6 then an EMF (a voltage) is developed across the conductor.

Fig.6




Note the polarity is dependent in the direction the conductor is moved. In the case of a motor the current flowing through the conductor in the magnetic field is caused due to the external voltage applied by the battery. But now the conductor is moving through the magnetic field another voltage will be induced in the conductor caused by this movement. This voltage will oppose the applied voltage and is thus known as the Back EMF (or back voltage). Thus the BACK EMF must always be smaller than the applied voltage or no current would flow in the loop and all movement would cease.

Once you adjust the speed of a dc shunt motor, the speed remains relatively constant even under changing load conditions. One reason for this is that the field flux remains constant. A constant voltage across the field makes the field independent of variations in the armature circuit. If the load on the motor is increased, the motor tends to slow down. When this happens, the back EMF generated in the armature decreases. This causes a corresponding decrease in the opposition to battery current flow through the armature. As a result the armature current increases, causing the motor to speed up. The conditions that established the original speed are established again, and the original speed is maintained.

Conversely, if the motor load is decreased, the motor tends to increase speed; back emf increases, armature current decreases, and the speed decreases. In each case, all of this happens so rapidly that any actual change in speed is slight. There is instantaneous tendency to change rather than a large fluctuation in speed.

## Relationship between Torque, Armature current and Magnetic flux

The TORQUE or turning moment produced by each conductor is measured in NEWTON METRES.

It can be seen that the current through the field coils is reasonably constant so therefore the **MAGNETIC FLUX IS CONSTANT** and we can restate that torque is proportional to MAGNETIC FLUX x ARMATURE CURRENT

So as magnetic flux is constant, **the torque is proportional to the amount of current flowing through the armature.**

Consider the current flowing in the armature, call it IA. All conductors in which current is flowing have resistance, call resistance of the armature RA.

THUS VOLTAGE DROP ARMATURE = IA x RA Volts (ohm's law)

If the input battery voltage is V volts:

BACK EMF symbol E = V – ARMATURE VOLTAGE
E = V – IA x RA Volts
Where E = BACK EMF measured in volts
IA = ARMATURE CURRENT measured in AMPS
RA = Resistance of the armature

Example 1
A 500 V DC motor takes an armature current of 50 A and has an armature resistance of 0.6Ω. Calculate the BACK EMF.

E = V – IA x RA = 500 – 50 x 0.6 = 500 - 30 = 470 volts
BACH EMF = 470 Volts

Example 2
A 300 V DC motor takes an armature current of 30 Amps. If the armature resistance is 0.5Ω calculate the BACK EMF.

E = V – IA x RA , E = 300 –( 30 x 0.5 ) = 300 – 15 = **285 Volts**

## Efficiency

Is the measure of output power to the input power usually expressed as a percentage.

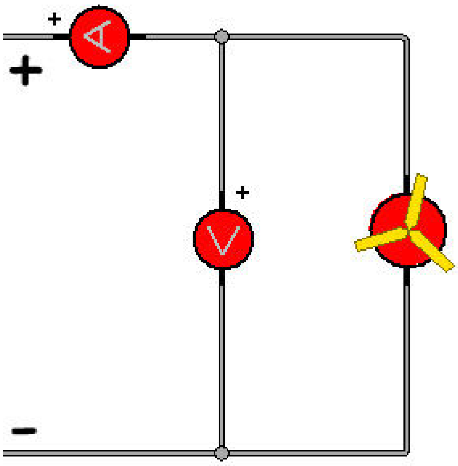
$$\text{EFFICIENCY} = \frac{\text{OUTPUT POWER}}{\text{INPUT POWER}} \times 100\%$$

Due to the fact there are always losses within a machine, i.e. friction, noise, power losses due to the resistance of the field and armature windings, the output power must always be less than the input power, thus the efficiency must always be less than 100 %.

There are a number of ways of measuring efficiency of a motor but as the output power of a motor is always stated, then the input voltage and the input current must be measured to calculate the input power and hence efficiency.

A voltmeter is connected across the input supply and an ammeter is inserted in the input line (see fig.7) and thus knowing the input voltage and current the input power can be calculated.

INPUT POWER = V x I Watts



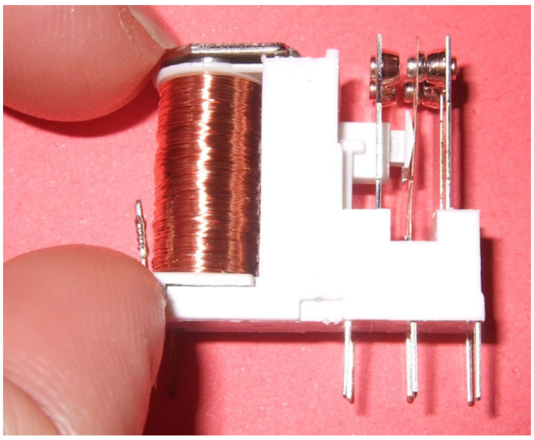

If we assume this DC motor is rated at 2kW (2000 watts ).This is a statement of the output power of the motor.

If the supply voltage is 250 Volts and the current drawn from the supply is 10 amps, calculate the efficiency of the machine?

INPUT POWER = V in x I in
= 250 x 10
= 2500W.

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}} x100 = \frac{2000}{2500} x100 = 80\%$$

## Motor Reversal

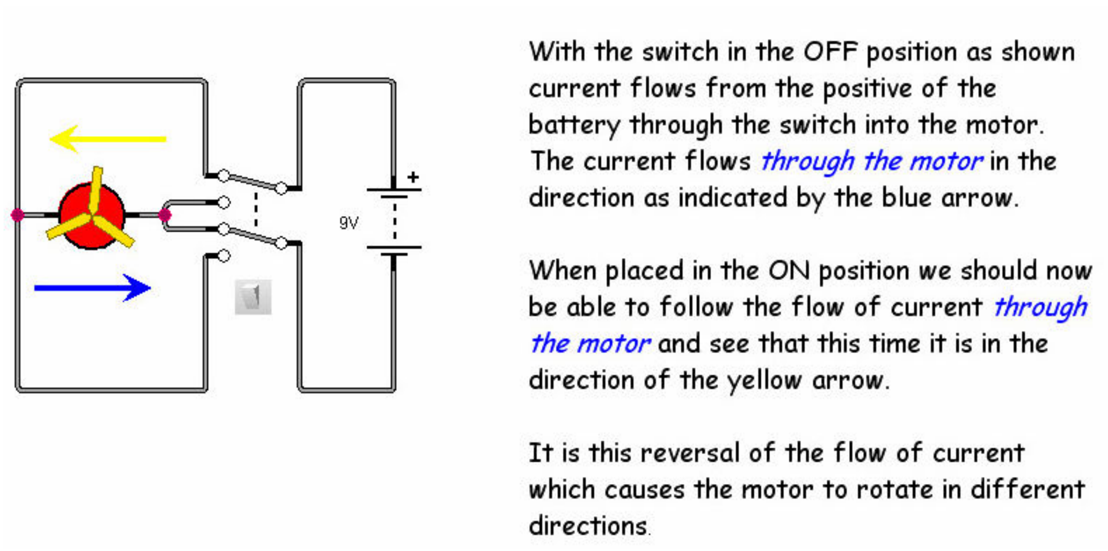


It is often necessary to reverse the direction of rotation of an electric motor. This is achieved using a double pole double throw switch or double pole double throw (DPDT) relay. A diagram of a relay is shown above.

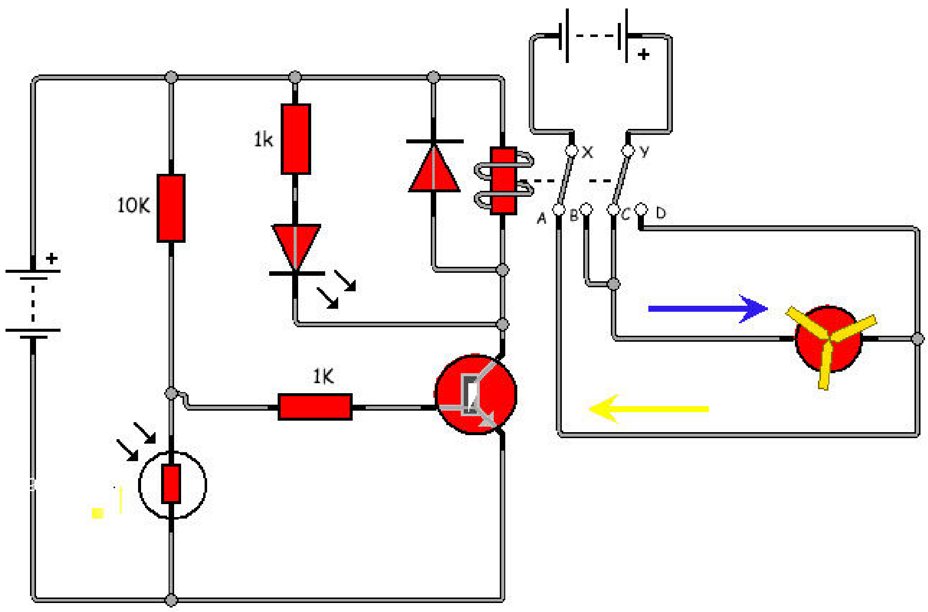
Whether using a DPDT switch or relay the principle of operation is always the same. If we reverse the direction of the current through the motor then it will rotate in a different direction.

## Controlling a Motor using a DPDT Switch




The diagram below shows the arrangement to reverse the motor using a DPDT relay. The light sensor and transistor are used to turn the relay from one state to another. Model the circuit on appropriate software.




There are a number of observations you should make:-

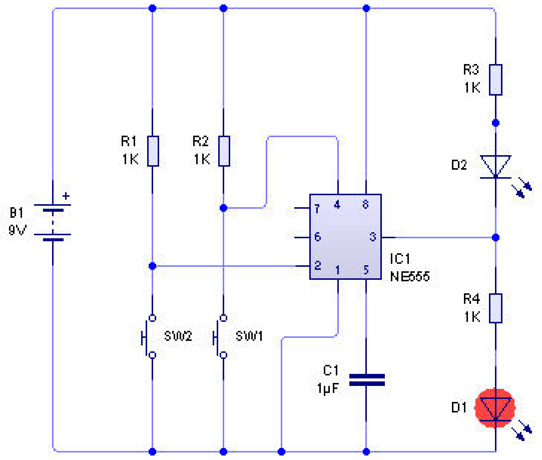
- In daylight the contacts are arranged as shown.
- In the position shown (daylight) current flows from Y -C –Motor- A- X. It can be seen Y is connected to the positive side of the battery and X to the negative.
- In dark conditions the current now flows Y-D-Motor-B-X.
- As a result the current is now flowing through the motor in a direction opposite to daylight conditions.
- The two power supplies are separate. This means that the light sensing circuit might operate at safe 9V but the motor could operate from a 240V supply.

***Never use a mains operated motor for any classroom projects.***

# Assembly of Pre-designed Circuits

**The Bistable Circuit**

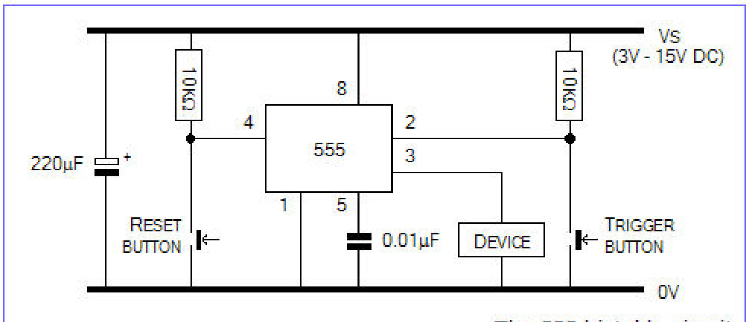
The 555 can be arranged as a bistable circuit, as the name suggests it has two stable states- high and low. Pressing one switch and then releasing it will cause the output of the 555 timer to go to a high state and it will remain in this state until the other switch is pressed, then released. To demonstrate this action two LEDs have been added and one led will light if one switch is pressed and the other when the opposite switch is pressed. Essentially we have constructed a 'memory circuit' as the last input pressed is remembered until the other input has been pressed. This type of arrangement is commonly referred to as a flip-flop.



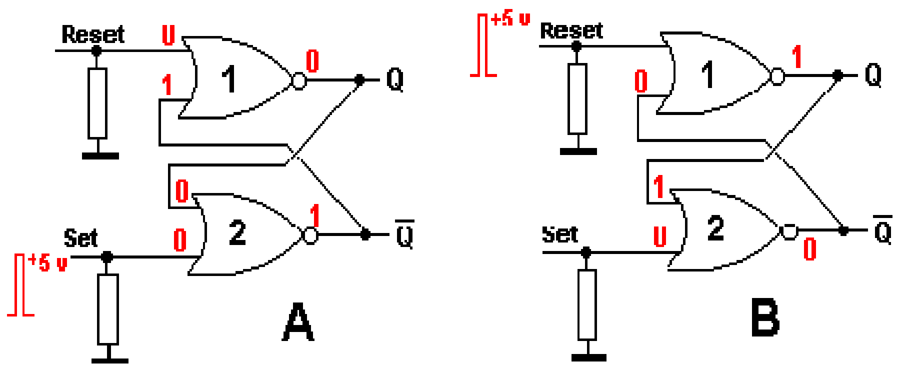

A practical application is a cat flap circuit. Two switches are arranged either side of a cat flap. When the cat goes out one switch is pressed and the appropriate led switched on. On re-entering the house the other switch is pressed and the opposite led is switched. Using different colours of led we can determine if the cat is in or out.

***Caution***

It is possible to simulate this arrangement using appropriate software as shown above. Software packages are often configured differently and you may experience problems using some of the more basic packages. Note however that this circuit works well in real life using the physical components arranged as shown below. For those familiar with astable or monostabe circuits these configuration will seem odd. Pins 6 and 7 are disconnected.




The 555 bistable circuit




- A similar outcome would be achieved using logic gates, in this case NOR gates in the configuration shown above. Here one input of each gate is held LOW by "pull down" resistors. The other input is cross-coupled to the output of the other gate. Initially, as shown in diagram A, gate 2 has two LOW inputs, so its output is HIGH.

- This HIGH output is one input of gate 1, so the output of gate 1 is LOW. When the SET input of gate 2 is momentarily pulsed HIGH, the output of gate 2 goes LOW. This means that both inputs of gate 1 are LOW, so its output is HIGH, which is coupled to an input of gate 2. Even though the pulse has finished, the output of gate 2 stays LOW because of this HIGH input.

- The gates are now in the state shown in diagram B. We say that the circuit has remembered or LATCHED and is in the SET state. If the SET is pulsed again, nothing happens, the circuit stays in the SET state. If the RESET on gate 1 is now pulsed HIGH, the output of gate 1 goes LOW. This is coupled to gate 2 which now has two LOW inputs, so its output goes HIGH. The gates have been RESET to their original states.

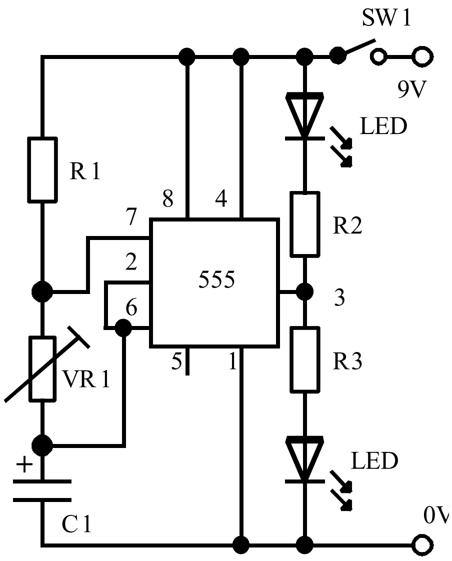
- If the RESET is pulsed again, nothing happens, the circuit stays in the RESET state. Note that when one output is HIGH, the other is LOW and vice-versa. If both inputs are taken LOW simultaneously, then there is no change; both inputs are already LOW. If both inputs are taken HIGH simultaneously, then the result is INDETERMINATE and is to be avoided.

- A similar circuit can be constructed using NAND gates and pull up resistors. The inputs are pulsed low to change states.

## The Astable Circuit

Astable means not stable, i.e. the outputs are continuously changing from one condition to another. In one instance the output of the circuit is low and the next instance the output is high - similar to flashing Christmas tree lights where the lights are continuously switching on and off.

This condition can be illustrated by connecting a 555 timer in the astable mode as shown by the circuit below where two LEDs will be made to flash on and off at a predetermined rate.




The heart of the circuit is a 555-timer chip configured in astable mode. This means the output at pin 3 is constantly changing, i.e. the output goes high (9V) for a specified time and then low (0V) for a specified time, before again switching high.

The transition from high to low is called a cycle, and the number of cycles that occur in one second is called the frequency, measured in hertz (symbol Hz). The frequency is controlled by the size of R1, VR1, and C1. Formula to calculate the frequency:-

$$FREQ = \frac{1.414}{(2VR1 + R1) \times C1} Hz$$

With VR1 adjusted to its maximum value.

$$FREQ = \frac{1.414}{21000 \times 0.001} Hz$$

FREQ= 0.06 Hz

The time taken to complete one cycle (known as the PERIOD symbol T) can be calculated from the formula.

$$T = \frac{1}{FREQ} \sec s$$

T = 16 seconds

If R1 is made much smaller than VR1, (i.e. R1 is approximately one tenth VR1) then the time the LED is lit, will be the same as the time unlit i.e. lit for 8 seconds, unlit 8 seconds. This time can be made shorter by reducing the value of VR1.

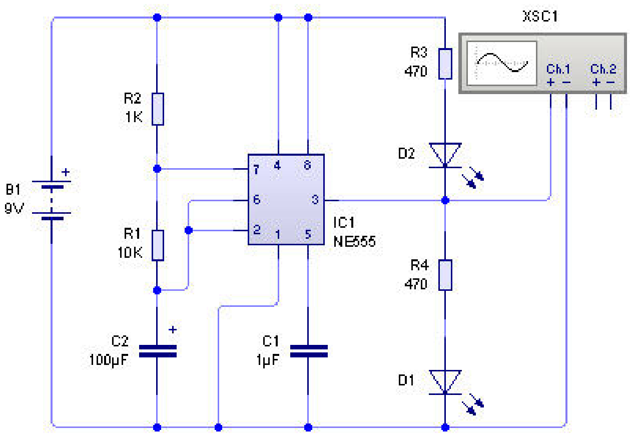
**Operation of LEDs**
Consider the output pin 3 (555 timer) is low 0V, the "top" LED in series with R2 is connected from the 9V rail to pin 3, therefore this LED is lit. The "Bottom" LED in series with R3 is connected from pin 3 (0V) to the bottom rail (0V), therefore this LED is unlit.

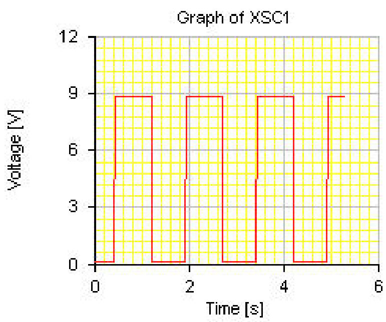
Consider now output (pin 3) goes high (9V). With 9V on the top rail and 9V on pin 3, there is no voltage drop across R2 in series with the "top" LED, so it is unlit. With 9V on pin 3 (astable) and 0V on the bottom rail, the "bottom" LED is therefore lit. Thus both leds flash on and off alternately at a predetermined rate.

**Calculation of Voltage Dropper Resistors R3 and R2**
It is most important an LED must not have any more than 2V dropped across it. Also the current flowing through it should not exceed 20 mA. The LEDs are connected to the (9V) outputs of the astable circuit to 0V rail, and also from the 9V supply rail to the 0V output of pin 3 of the astable circuit. Therefore 7V must be dropped across a resistor called a voltage drop resistor. As max current permissible through an LED is 20 mA, **Ohms Law** can be used to calculate value of resistor.

$$R = \frac{7}{0.020} = 350 ohms$$

It is not good practice to have components operating at their upper limits i.e. 20 mA. Therefore make resistor larger, say 470 ohms. This has the dual advantage of protecting the LED, and also drawing less current from the battery, thus prolonging its life at the expense of the LED being a little less bright.




The astable circuit was assembled using appropriate software. When the circuit was switched on the red and green leds flashed alternately, see the resultant output trace below.

The output (pin 3) is switching HIGH for a period (0.7 secs) and then switching LOW for the same period.

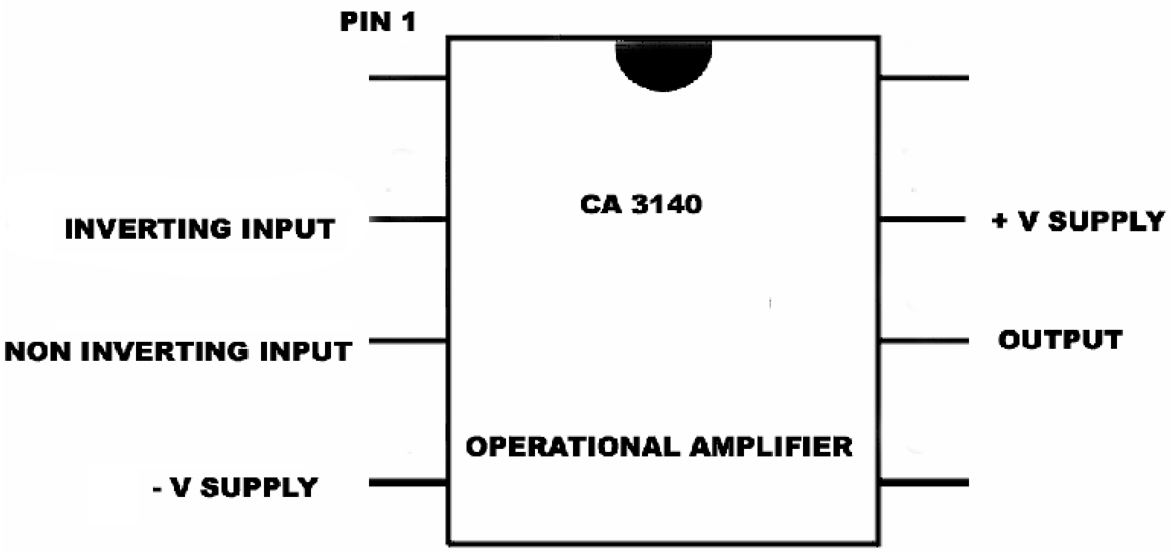
Note the much smaller time period as the capacitor has been reduced from 1000µF to 100µF.

## The Operational Amplifier

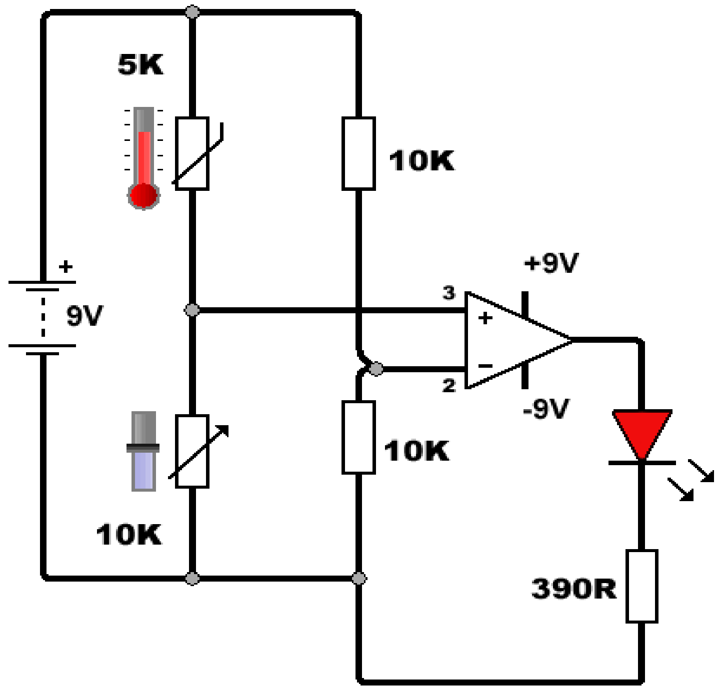
The operational amplifier was originally designed in the early 1960s to perform mathematical operations such as addition, subtraction, integration and so on by manipulating voltages. The earliest amplifiers were soon superseded by another type called the 741, first introduced in 1965. It is still one of the most common used components found in electronic circuits. The 741 has been developed over time but does however have a number of shortcomings and a simpler device known as the CA3140 is much easier to use in school based work.

Differential Amplifier (Comparator Circuit) is one of the most common configurations found in school based project work. The pinout on the 741 and the CA3140 are identical as shown below.

Pin 1 is found in the position marked, with pin eight opposite. –v supply is therefore pin 4; output is pin 6 and so on.

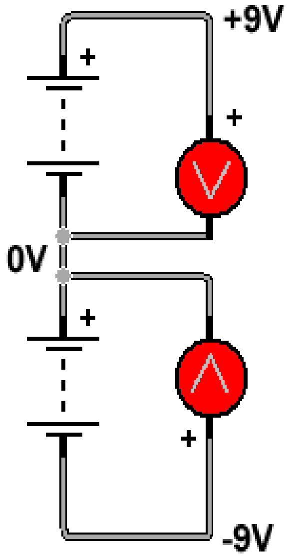


**Operation**




- Two 10K resistors are set up in a potential divider arrangement feeding to the inverting pin (2) as shown. This voltage therefore is 4.5V, commonly referred to as the threshold or reference voltage. This voltage remains constant.
- We have a second potential divider consisting of a 5K (at 25°C) thermistor and a 10K variable resistor. Adjust the variable resistor so the LED is off.
- If the thermistor is heated then its resistance goes down and so does the voltage across it. This causes a rise in voltage across the 10K variable.
- The voltage at pin 3 (non-inverting pin) will rise above the inverting voltage (pin 2) and the output goes high, to around 7V. The LED is now lit.
- Note that the Op Amp has an extremely high gain, commonly 100,000. Since the output goes to 7V by division (7/100000) we can see that a voltage difference of only 70uV is needed to switch the Op Amp from off to fully on. In other words we have an extremely sensitive circuit. A tiny change in temperature will bring about an immediate effect.
- Remember if the voltage at pin 3 is greater than the voltage at pin 2 then the output pin is high (7V), otherwise it is low (0V). 3>2

## Operational Amplifier – Gain

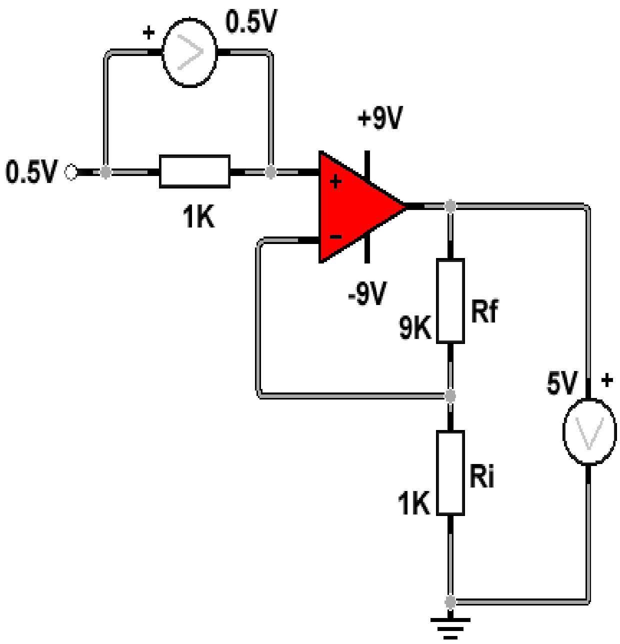



In order to achieve gain (increasing the size of a voltage) from an Op Amp we need to set up a dual rail power supply. Normally pin 7 is connected to the positive supply and pin 4 to the negative.

To achieve a dual rail supply we arrange two batteries as shown opposite. The positive of one battery is connected to the negative of another. The mid point is therefore at 0V. This means that the top rail is at + 9V relative to the junction of the two batteries. The bottom rail is at -9V relative to the junction. This can be quite a confusing concept but essentially the only thing we have to remember is that the current flows from +9V to 0V ***and*** from 0V from -9V, opposite of what we might expect.

It is usual to use two PP3 batteries in series to achieve the dual rail arrangement thus giving a power supply of + - 9 volts.

### Circuit arrangement for non-inverting gain




$$\text{Gain} = 1 + \frac{Rf}{Ri}$$

$$= 1 + \frac{9000}{1000}$$

$$= 1 + 9$$

$$\text{Gain} = 10$$

***Hence 0.5V in : 5V out***

# Logic Gates

Systems constructed so that all inputs and outputs can only take either one of two states are termed logic systems or logic circuits.

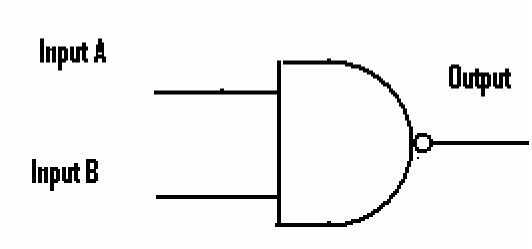
## The NAND gate

Is in fact a combination of two gates, an AND gate followed by a NOT (inverter) gate.

Truth table for NAND gate

| Inputs | | Output |
|---|---|---|
| A | B | |
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

Symbol for a NAND gate

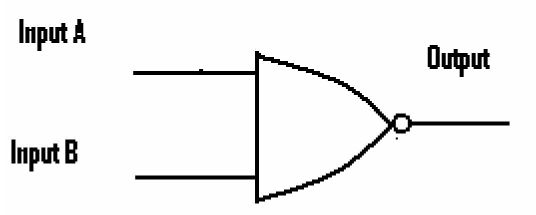



## The NOR gate

Is a combination of an OR gate followed by a NOT gate.

| Inputs | | Output |
|---|---|---|
| A | B | |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

Symbol for NOR gate



## 3 Inputs

For a circuit having three inputs a table must be made out for all the conditions of the inputs which might be either sensors or switches. See the table below which gives all the conditions of the switches, starting with all switches open and ending with all switches closed. There are 8 possible combinations which equates to $2^{3}$.

| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |
| 1 | 1 | 1 |

## 4 Inputs

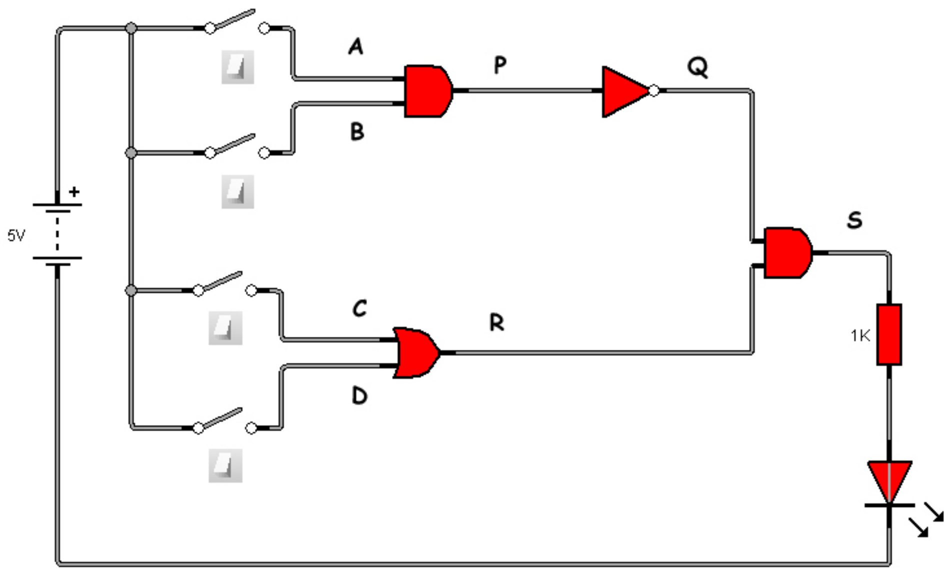
Note that in this case there are 16 possibilities or $2^4$

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 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 |

## Defining the outcome of a particular gate system

Assume the following circuit showing 2 AND gates an OR gate and a NOT gate arranged as shown.




| A | B | C | D | P | Q | R | S |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |

Let us examine line 2 and line 12 from the table.

***Line 2***

- A = 0 B = 0 is fed into an AND gate so output P = 0
- Since Q is an inverter (NOT) then this 0 becomes a 1 at Q
- C = 0 D = 1 is fed into an OR gate so R = 1
- R and Q are fed into an AND gate and since both are at level 1 then the output will be a 1 hence S = 1

***Line 12***

- A = 1 B = 0 is fed into an AND gate so output P = 0
- Since Q is an inverter (NOT) then this 0 becomes a 1 at Q
- C = 1 D = 1 is fed into an OR gate so R = 1
- R and Q are fed into an AND gate and since both are at level 1 then the output will be a 1 hence S = 1

Try to work through further lines of the table and see how they various outcomes are arrived at.

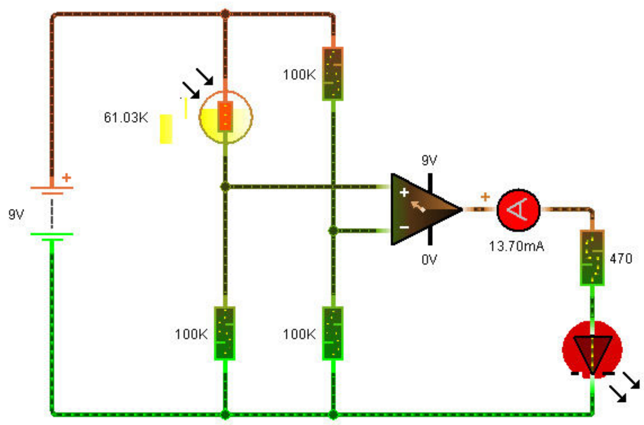
 

# Inputs and Outputs

## Buffers and Fan out

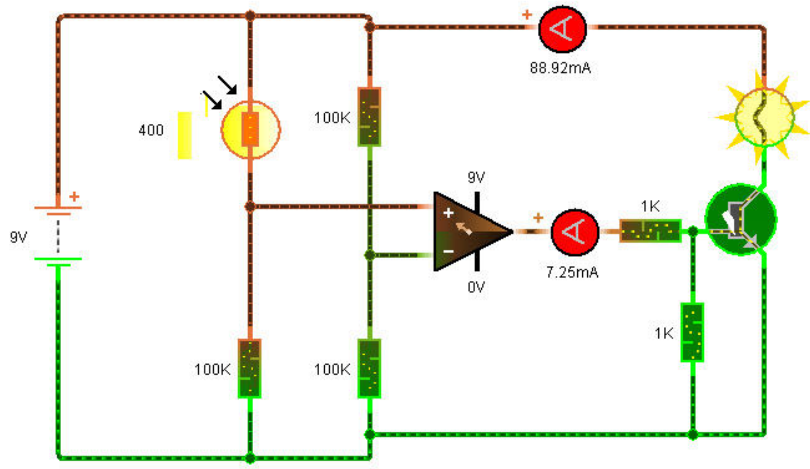
Most electronic circuits have a relatively low voltage source, typically 9volts and most small component have the capacity to pass a low current, usually in the region of milliamps. For this reason if the circuit is being asked to drive a piece of equipment delivering an output measured in watts an interface must be employed to connect the low voltage, low current source (the primary circuit) to the power circuit (the secondary circuit).

The interface component can be in the form of a transistor, relay, thyristor etc. Consider the circuit below which is a temperature sensitive circuit being used to switch on the LED .




The op amp is being asked to deliver a current of 18 milliamp which it is quite capable of doing, so the circuit operates satisfactorily, no buffer circuit is required.

Now connect the bulb to the op amp and the circuit will not operate, the op is being asked to deliver a current much in excess of that which it is capable of delivering. The bulb will draw somewhere in the region of 100 milliamps.




The op amp this time is switching a transistor to operate the bulb. Note the current being drawn from the op amp is merely 7.2mA whereas the current supplied to the bulb is 89mA.

**Caution**
When selecting a transistor to switch the lamp ensure the transistor is capable of passing sufficient current. It is therefore wise when selecting a transistor to carry out a particular function to consult a transistor selector manual.

This manual will give the relevant parameters , the two most important being:-
(a) IC MAX / mA the collector current which transistor can safely pass
(b) hFE the gain of the transistor, the relationship of base current to collector current

## Quick reference data

Table 2: Quick reference data

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{CEO}$ | collector-emitter voltage | open base; $I_C$ = 10 mA | - | - | 45 | V |
| $I_C$ | collector current (DC) | | - | - | 500 | mA |
| $I_{CM}$ | peak collector current | | - | - | 1 | A |
| $h_{FE}$ | DC current gain | | - | - | - | |
| | BC817; BC817W; BC337 | | 100 | - | 600 | |
| | BC817-16; BC817-16W; BC337-16 | | 100 | - | 250 | |
| | BC817-25; BC817-25W; BC337-25 | | 160 | - | 400 | |
| | BC817-40; BC817-40W; BC337-40 | | 250 | - | 600 | |

The above datasheet refers to the BC337-40. In this case a transistor which can pass 100mA will be sufficient, regarding the gain, in this case it is not important, and since the chosen transistor can handle 500mA then we can proceed.

**Using differing op amps**
Different op amps when operating in the single rail mode have different output voltages when in the “low” condition.

- CA 3140 output “low” condition = 0V
- LM 741 output “low” condition = 1.6 V

The software package used to assemble the op-amp circuits has a “low” of 0.9V, this would be sufficient to switch on the transistor without any changes to the input so to overcome this problem a voltage divider circuit is used, i.e. a 1KΩ resistor in series with another 1kΩ resistor.

Thus when the output from op amp is 0.9 V the voltage at the base

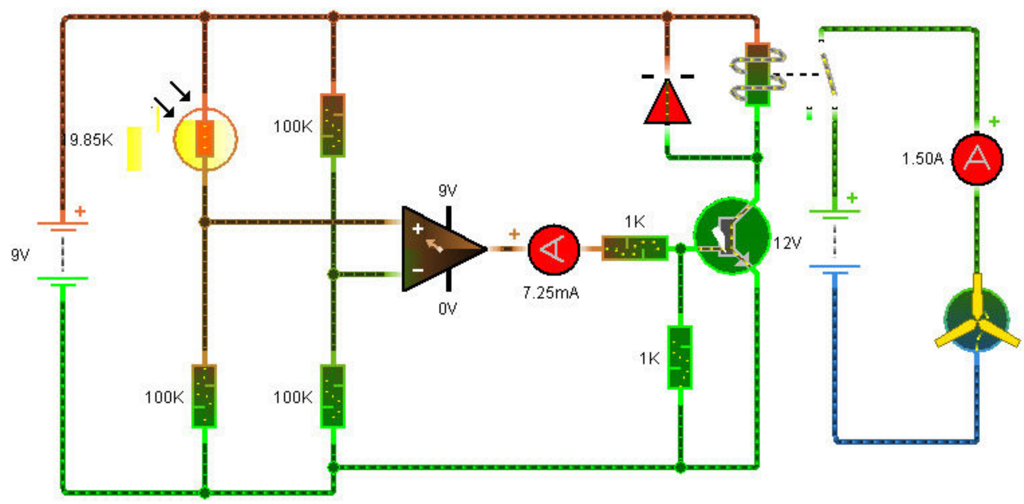
$$Vb = 0.9 \times 1000 / 2000 = 0.45 \text{ V}$$

When output of the op amp is “high“ (8.1 V) , base voltage

$$Vb = 8.1 \times 1000 / 2000 = 4.05\text{V}$$

Thus when the output of op amp is “low” the transistor is switched off, and the LED remains unlit. When the output of op amp is “high” the transistor is switched on and LED now be lit.

When a much higher current is required to drive a piece of equipment , as is required to drive a fan which requires a current of 1.5 A, then a relay may be a more suitable option.




This circuit is much the same as the previous one with the exception the bulb has been removed and a relay installed instead. When inserting a relay into the circuit it is imperative a diode is fitted in parallel with the relay as shown. The relay contains a coil of wire and when current in a coil changes rapidly, it produces a very high voltage, which may result in damage to the transistor. The diode is placed in the circuit to provide a low resistance path.

When the output of the op amp goes “high” the transistor is switched on, the relay is energised and the points of the relay will “make” thus producing a path for the current from the 12 V supply to flow through the motor. There is no electrical connection between the sensor circuit, (primary circuit) and the motor driver circuit (secondary circuit).

## Fan out

This can be termed as the number of similar logic gates which can be connected to the output of a gate without adversely affecting the output level of the said gate. As the two types of logic gates (TTL logic 74 series ) and (CMOS logic) have differing parameters, both must be considered separately.

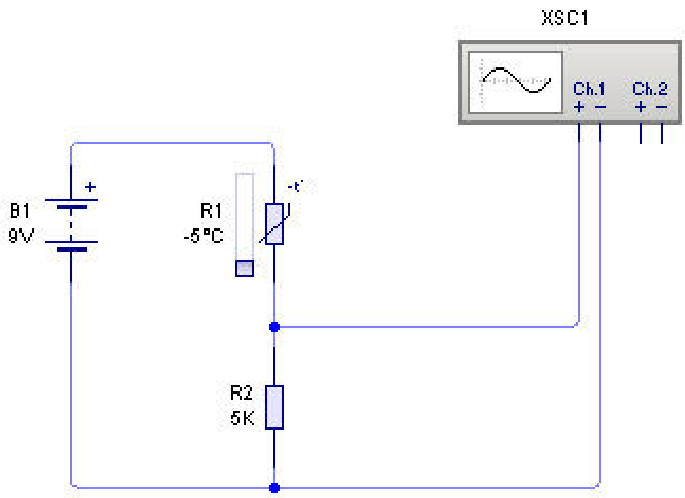
The FAN-OUT of the TTL logic gate is 10 which means the output of a particular gate can be connected to ten inputs of similar gates without damage being sustained by the driver gate. An output from the said chip in the “high” state can source 40 micro amps. An output in the “low” state can sink 16 milliamps

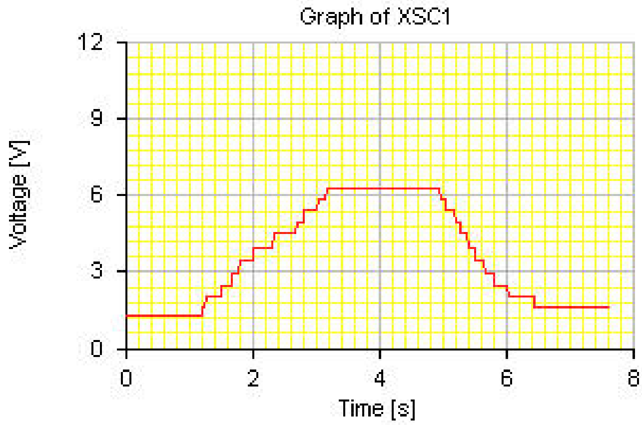
The FAN-out of the CMOS type chip is much higher, in the region of 50. The CMOS chip can sink or source roughly the same amount of current dependent on the applied voltage for example when operating from a 5V supply it can sink/source 5mA. When operating from a 10V source it can sink/source 10mA.

## The Schmitt Trigger

Most sensors, for example the thermistor and light dependent resistor have a similar property in that their resistances vary with the environmental conditions. This property is used to produce a voltage which will vary as the environmental conditions change using a voltage divider circuit. Consider the circuit shown in fig.1.

Fig 1



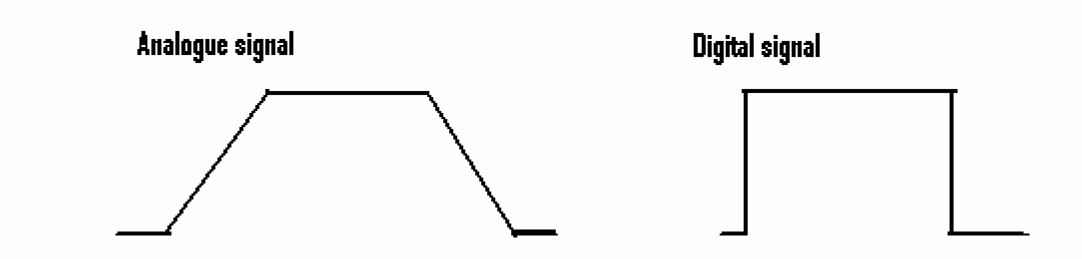




The circuit consists of a thermistor connected in series to a 5Kohm resistor. An oscilloscope is connected across the 5Kohm resistor to register the output voltage.

The temperature of the thermistor is increased and then again decreased. Under cold conditions the voltage registered on the oscilloscope is approximately 1.5 Volts.

- As the thermistor is heated then the resistance of the thermistor will decrease and hence the voltage drop across the 5K ohm resistor will rise.
- As the thermistor is cooled again then the voltage across the 5K ohm resistor will fall as shown on the trace.

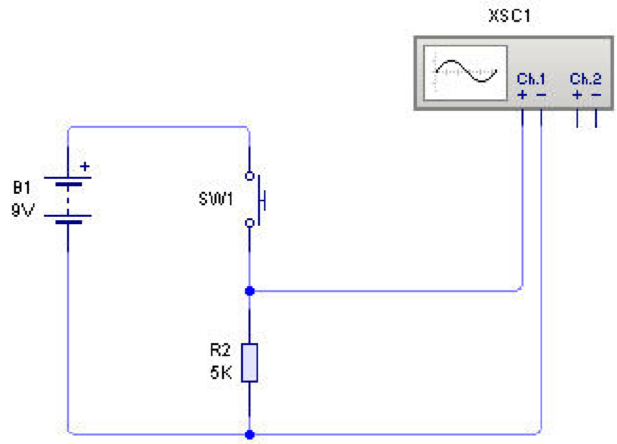
Thus the signal which initially was 1.5V increased to a voltage of 6V and then decreased again to 1.5V. This signal which is constantly changing has an infinite number of voltage values is called an analogue. This signal is not suitable to operate a digital circuit and must therefore be converted to a digital signal.

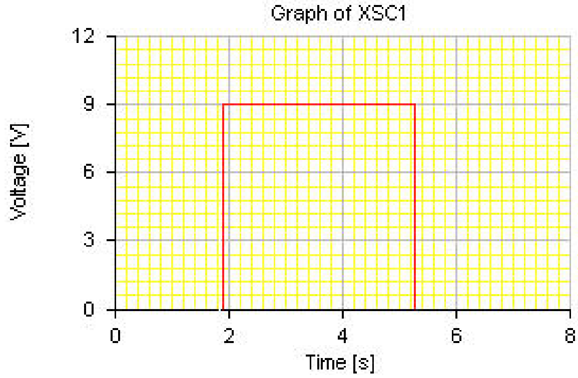


Digital signals, (see fig.2) can be produced using a simple switch type circuit whose output signal can exist in only two states, i.e. and can only have one of two values (there are various ways of describing this digital output , in this case 9V or 0V, High or Low, 1 or 0). Note the system shown in fig.2 to produce a square wave pulse is not recommended as an input device to a logic circuit, without safeguards, as a condition known as “switch bounce” can occur.

Fig 2

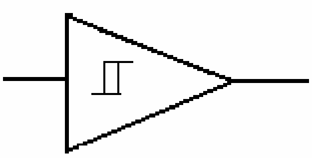



Thus if it is required to feed an analogue signal to a digital circuit then the relevant analogue signal must be converted to a digital form. To carry out this conversion a circuit known as a SCHMITT TRIGGER can be inserted between the analogue circuit and the digital circuit.

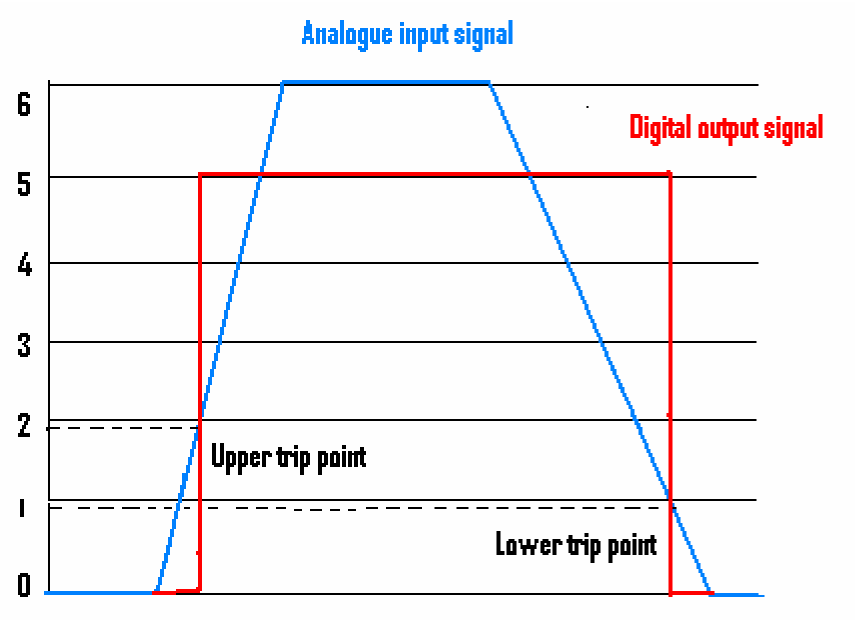
Note the Schmitt trigger can also be used to remove unwanted “noise” from a digital signal. Schmitt triggers can be manufactured using transistor circuit but special dedicated chips are now manufactured to simulate Schmitt trigger operation.

Schmitt trigger symbol



A typical Schmitt trigger will recognise a logic 1 (high) if the input signal goes above 1.7 V (This voltage is called the UPPER TRIP POINT - UTP). Once having recognised this signal the input must drop below 0.9V (this voltage is called the LOWER TRIP POINT - LTP) before the output signal of the Schmitt trigger again drops to 0 (low). This action is illustrated in fig3

Fig 3

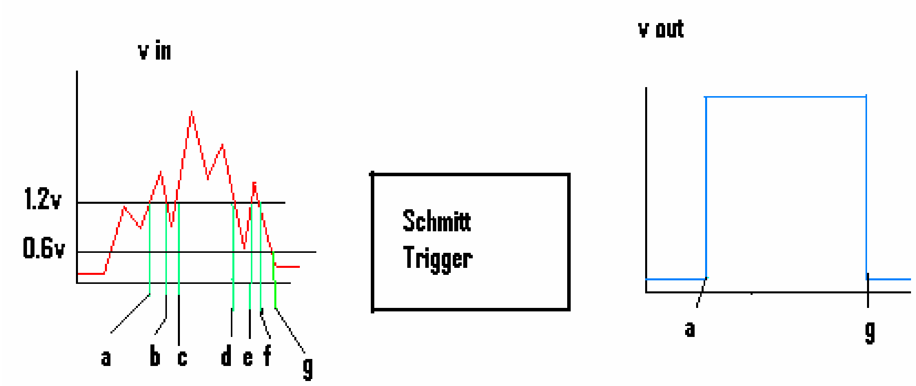



The action of the Schmitt trigger is further illustrated in fig 4 where a signal containing "noise" (a series of spikes) is passed through a Schmitt trigger producing a perfect square wave signal. Note in this case the IC (Schmitt trigger) selected has an UTP of 1.2 V and a LTP of 0.6 V.

**Action**

Up until the input voltage increases to 1.2 V the output of the Schmitt trigger is "low". At point ***a*** the UTP voltage has been reached so output of the trigger goes "high". Although from period (b to c) the voltage in the form of a spike has dropped to 0.9 V the output of the trigger remains high as the LTP has not been reached (0.6V ). From period (c to f) again a series of spikes have occurred but output voltage has remained unchanged (as LTP has not been reached). It is not until point (g) has been reached which is the LTP that the output voltage of the Schmitt trigger circuit goes "low". Thus the signal has been effectively "cleaned" and suitable for use in a digital circuit.

Fig 4

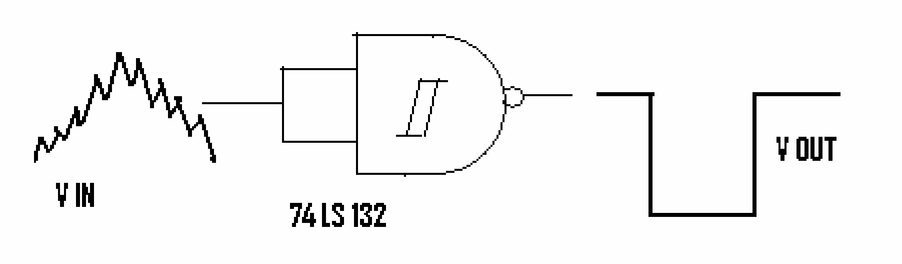


Thus when the analogue signal input reaches a value of 1.2 V the Schmitt trigger will switch from LOW to HIGH and output of the Schmitt trigger will remain HIGH until input voltage drops to 0.6 V when the output will drop to LOW.

**Schmitt trigger integrated circuits**
Two chips are generally used for this purpose, TTL 74 LS132 and CMOS 4093B. Note in this case as well as producing a Schmitt Trigger action the signal is also inverted - see fig.5

Fig 5




Data for the said ICs:-

| | | |
|---|---|---|
| 74 LS 132 | UTP = 1.7 V | LTP = 0.9 V |
| 4093 B | UTP = 2.9 V | LTP = 2.3 V |

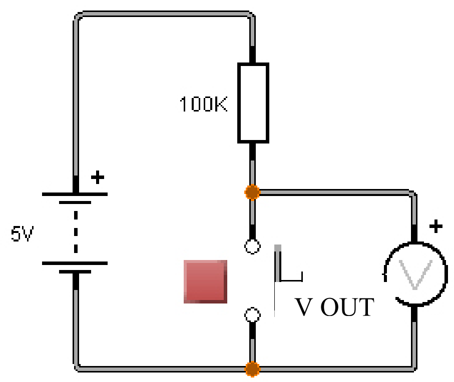
# Counters

## Counting Circuits

Counting circuits usually consist of two sections, a sensor section and a counter section. This sensor section can take many forms from a simple push switch to a more sophisticated light or infra red beam which is broken by some method. All the sensor sections should be designed to have one thing in common, the production of a clean square wave pulse which is then fed to the counter section. It is vitally important the sensor produces a “clean “single square pulse for each count else erroneous counts will occur. There are a number of ways this can be achieved.

**Method 1**

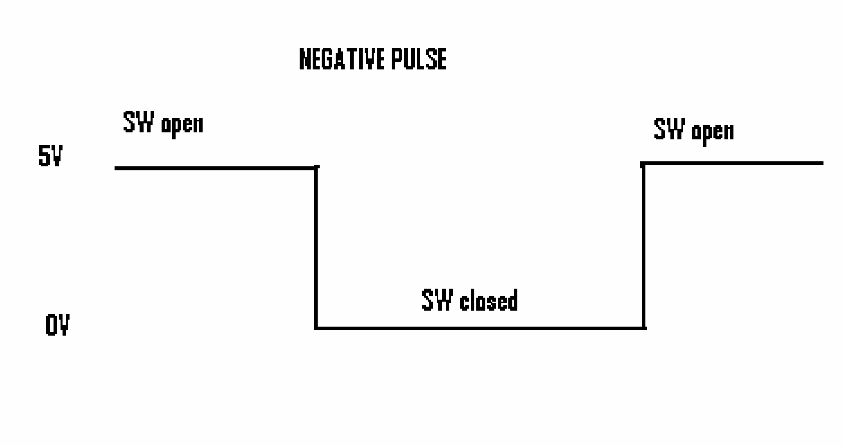
Consider using a simple push switch to produce a square wave pulse as shown in the diagram below.




With the switch not pressed, no current can flow in the circuit so there is no voltage difference across both sides of the 100K ohm resistor and hence V OUT = 5V.

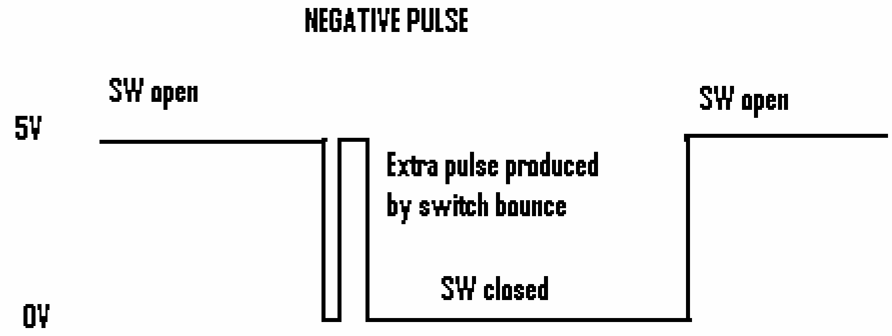
When switch is pressed, current can flow around the circuit so now we find a voltage difference across the 100K ohm resistor is 5 V so V OUT = 0V

When switch is again released the voltage again returns to 5V, a negative pulse has been produced. Note that a 5 volt supply is used to illustrate the concept of a negative pulse as this is used often in TTL logic ( gate circuits operating the 74 series of chips).

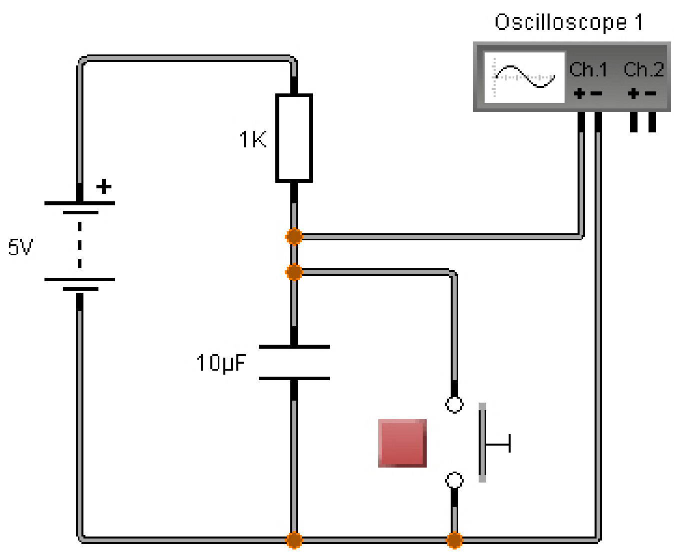



Unfortunately the inside of switches contain springs which means when closed a condition known as “switch bounce“ can occur. This means when the switch is closed we do not get a single contact being made but rather a series of contacts, this will of course change V OUT from 0V to 5V a number of times. This will often result in an incorrect number of pulses getting sent to the counter. Remember we want one push of the switch to increment the counter by one.

The effect of bounce can be shown in the diagram below.




One way of counteracting this problem is to insert a DEBOUNCE CIRCUIT after the switch. A simple example of this is shown below.



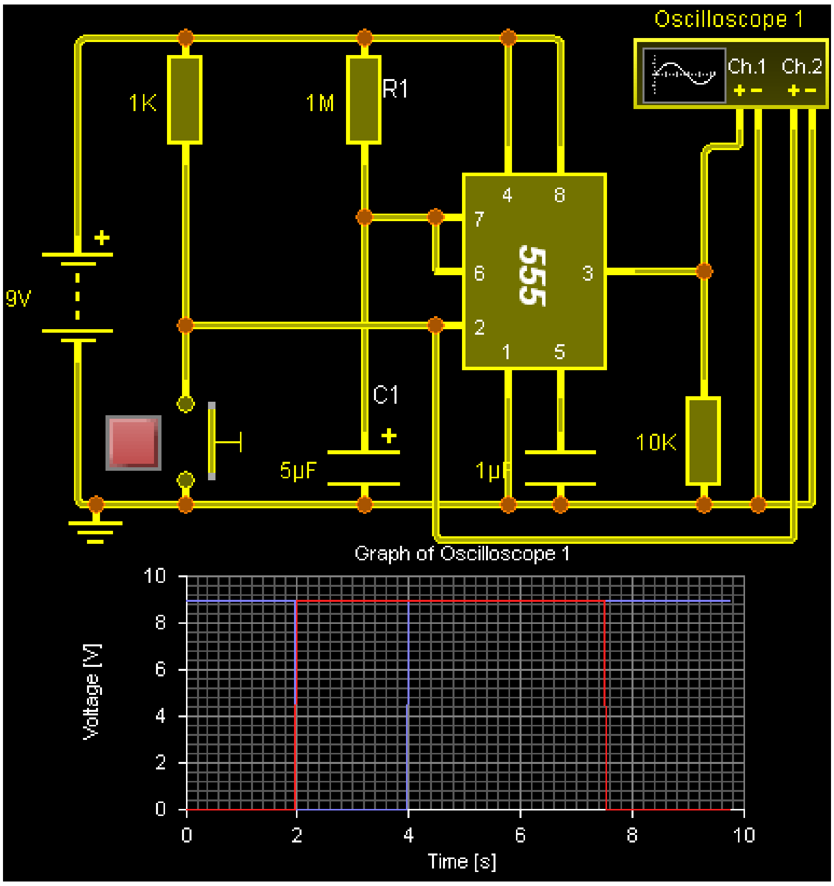

The inclusion of the capacitor has the effect of only allowing a single pulse to pass. The capacitor then must recharge before the next pulse can be sent.

The capacitor and resistor network should be used to form an RC circuit and as long as the TIME CONSTANT is higher than the 'bounce' period then this is a fairly effective circuit.

The wave produced is not a true square wave and it can be shown that by creating a true square wave we in fact improve the performance of the circuit.

**Method 2**

A simple yet effective method of producing clean square waves is by using a 555 timer set up in monostable mode. This arrangement produces a perfect square wave pulse when a negative pulse is applied to pin 2.




The oscilloscope (Channel 2) has been connected to the input pin 2 to monitor the input pulse and Channel 1 has been connected to the output pin 3 to record the output trace. The switch arrangement used to produce the negative pulse is connected to pin 2. The timing arrangement (i.e. time the output at pin 3 is high) depends on the following formula:

TIME HIGH = 1.1 x R1 * C1 secs
TIME high =1.1 x 1000000 * 0.000005 (remember uF changed to Farads)
= 5.5s as seen from graph

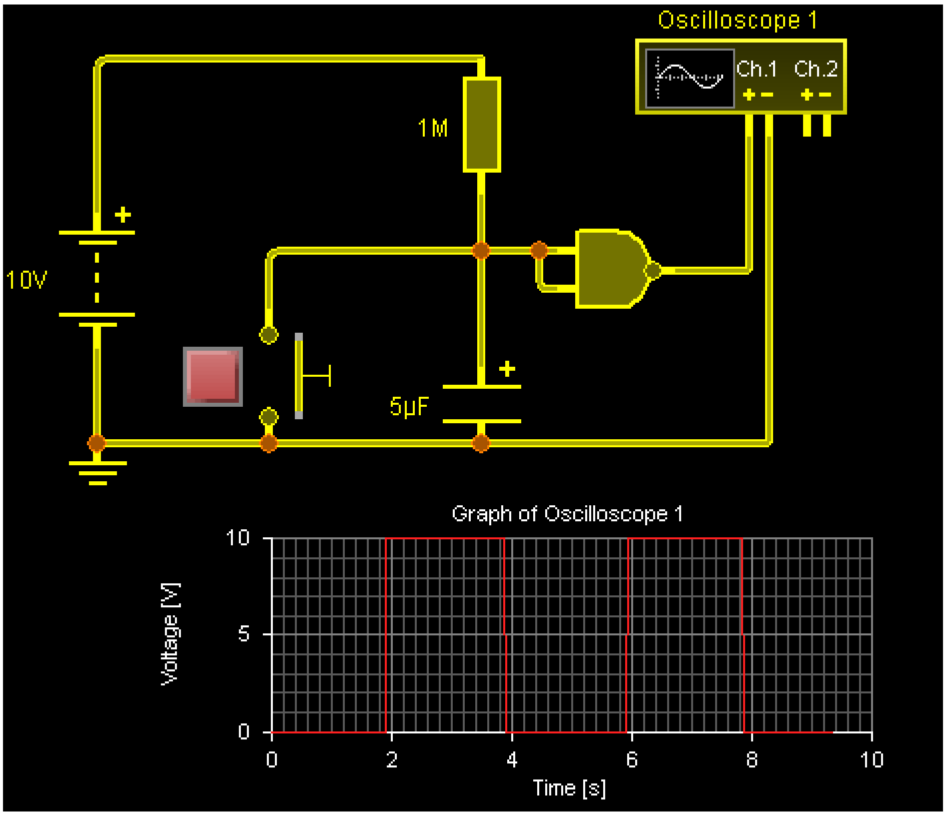
Negative pulse is applied at time 2 seconds (duration of negative pulse = 2s). Output Pin 3 goes high at time 2s and remains high to 7.5s (duration of "time high" = 5.5s).

To illustrate the circuit works effectively as a debounce circuit, assemble the above circuit using the appropriate software and insert a second negative pulse a very short period after the first pulse, the output at Pin 3 should be unaffected. Note also the perfect square waveform obtained from Pin 3.

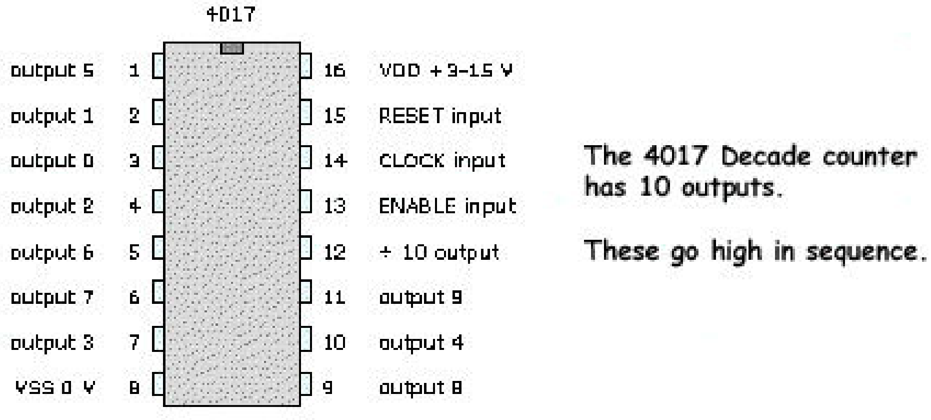
**Method 3**
The gate circuit shown below will carry out the same function as the 555 monostable timer circuit. The switch has been pressed twice to give two square wave outputs. Note increasing the value of R or C will increase the "time high" period
Although the square wave output produced by an ordinary NAND GATE is perfectly adequate for a counting circuit.

To produce a perfect wave form use either of the quad two input Schmitt trigger chips 74 LS 132 (5V operation) or the 4093 chip (+ 3 to + 15 V operation).



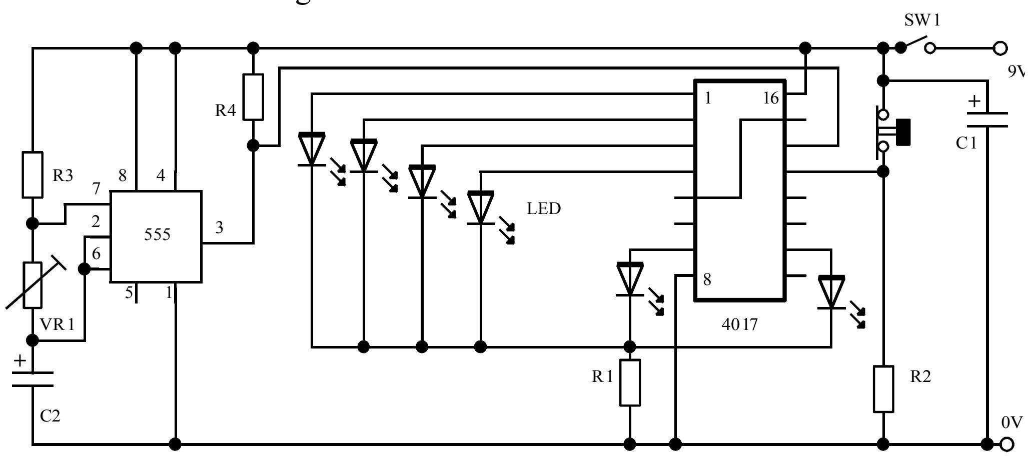
## Counters - Decade Counter

As the name suggests the counter can count up to 10. The IC used is the CA 4017 BE (16 pin DIL operating voltage 3 to 15 volts), pin 8 is connected to 0V and pin 16 to the positive rail. Pin 14 is the clock pin where the square wave pulses are input, usually from a 555 timer.




When pulse number one is applied to pin 14 the output 0 (pin 3) will go high and remain high until pulse number two is applied at which time output 1 (pin 2) will go high and output 0 will drop low or back to 0V. Thus with each square wave pulse applied to pin 14 the respective output will go high and the preceding output pin will drop to 0V until output 9 ( the tenth pulse ) is reached. The circuit diagram below demonstrates the use of the 4017B when used as a dice.

See circuit 51 – 112 Working circuits

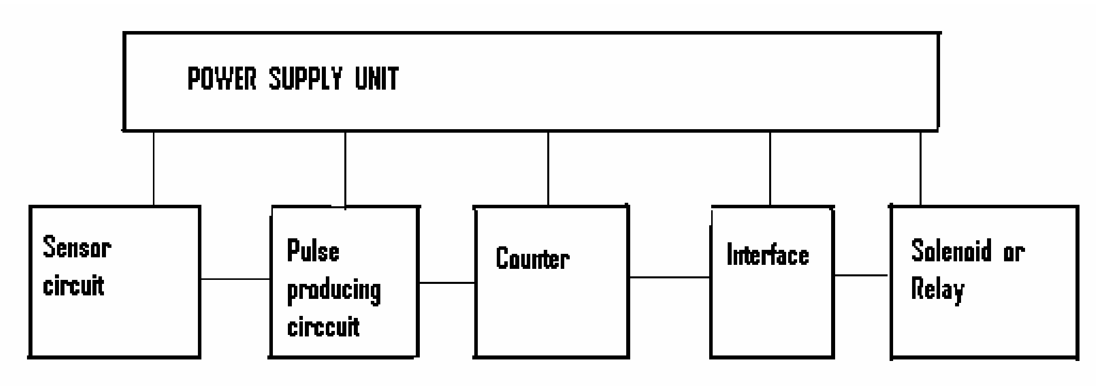



### Operation as dice

(a) Ensure that the IC is connected to the 0V and +V rails as shown.
(b) Pulses are provided from a 555 timer which has been set up in astable mode.
(c) Pin 13 is the IC enable and it must be at 0V to allow the pulses through to the counter. We have a PTB switch connected in series with a resistor, the midpoint of which is connected to pin 13. In other words pin 13 is held high, the dice will only operate when the switch has been held ***open*** for a random period.
(d) When the switch is released again the counter will stop and one particular LED will be lit.
(e) Pin 5, (the $7^{th}$ ouput), is connected to pin 15 or the reset pin. This means when a seventh pulse is sent the decade counter resets, ensuring only 6 LEDs have a random chance of being lit.

**To design a circuit using the counter**

Design an arrangement to shut the trap door of a rabbit hutch when the nine rabbits have gone in for the night. When an infra red beam is broken nine times a solenoid is to be activated to allow a trap door to fall. Block diagram of overall circuit



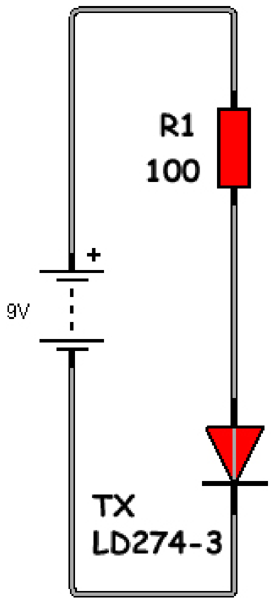

It is good policy to assemble one section of the circuit and fully test before progressing to the next session. As explained the pulses being fed to the counter must be “clean”, so the sensor circuit will be designed to produce a series of negative pulses which can be fed to a 555 circuit in monostable mode the pulse which are output can be fed to a counter circuit.

**The Sensor Circuit**

An infra red beam will be produced by means of an infra red transmitter diode. As the beam is expected to be effective over a range of 300mm a current of 75mA should be sufficient:

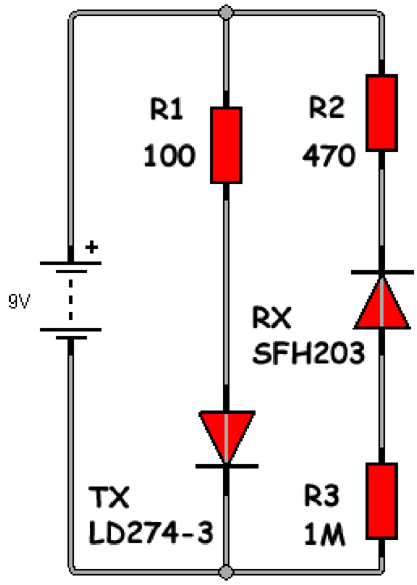
$$R1 = 7.7 / 0.075 = 100\Omega$$

**Transmitter/Receiver**



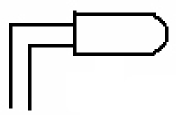

After assembly, using a voltmeter check the voltage across the IR diode is in the range of 1.3 volts.
Now assemble the receiver circuit which is in effect the receiver diode.

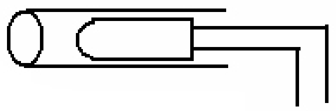
The receiver should be aligned with the transmitter at a distance approximately 300 mm apart.




With circuit assembled, now check the voltage at the junction between the diode and R3 (remember all voltages with respect to earth or 0V). The voltage at this point somewhere in the region of 4 volts.

Now break the beam, by placing a piece of metal between the two diodes, and the voltage should be somewhere in the region of 0.7 volts.

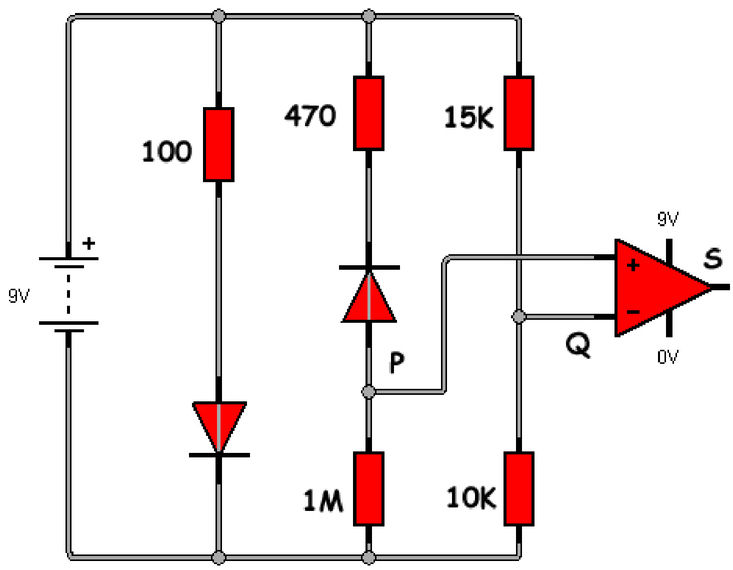




Tx - Transmitter    Rx - Receiver

The completed circuit of transmitter receiver arrangement (remember to screen the receiver diode against stray IR radiation by housing it in a black container)

The change in voltage from 4V to 0.7V is a useful change in voltage which can now be fed to an operational amplifier set up in comparator mode. If we connect the receiver to pin 3 of the operational amplifier, we will set the reference voltage just below 4V.



By use of the formula V=R2/R1 + R2 * Vin

≈ Voltage at point Q = 9 x 10000 / (10000 + 15000 ) = 3.6 V

With beam unbroken voltage at point P (from reading above) = 4 V. Thus voltage at point Q (+ terminal op amp) is less than voltage at P. Thus the voltage at Q = 3.6 V (- TERMINAL OP AMP) is less than the voltage at P (P = 4 V). Since the voltage at the positive pin is greater than that at the negative pin so the output at point S should be high (in the region of 8 V).

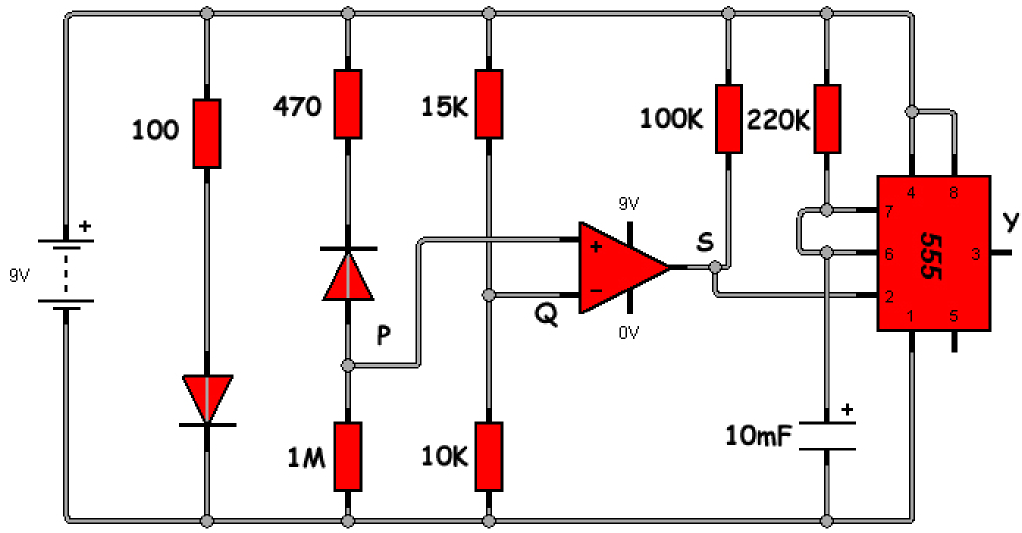
Now break the beam and the voltage at point P now drops to 0.7 V. The voltage at point Q is now greater than voltage at P so the output at S now goes LOW (0V). Thus when the beam is unbroken the output is "high" when the beam is "broken" output is low and will again return " high" when the beam is returned to the unbroken state- ( a NEGATIVE PULSE has been produced). All the above voltages can be verified using the voltmeter.

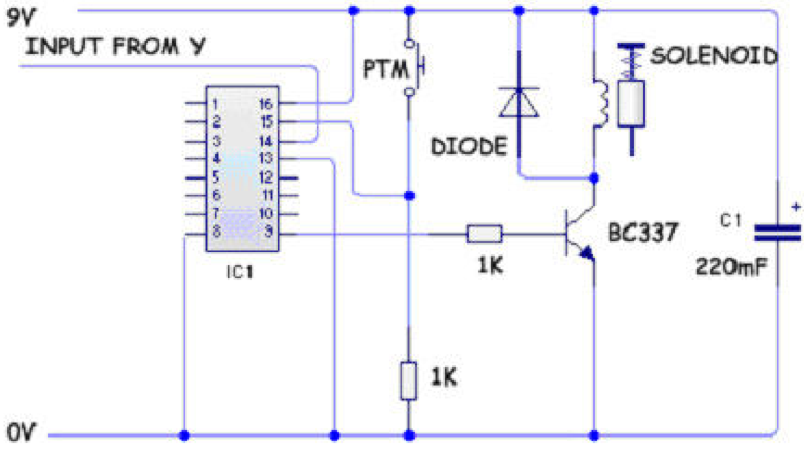
If the circuit is operating correctly the monostable circuit can be added to produce "clean" train of pulses necessary to drive the counter circuit. A 555 timer configured in the monostable mode is used to produce the perfect square wave to feed the counter. The counter section of the monostable circuit is configured to give a "high" time of approximately 2. 5 seconds,

TIME HIGH = 1.1 x R x C1 = 1.1 x 220000 x 0.000010 = approx 2.5 SECS

Note this "time high" can be shortened or lengthened by changing either the size of the resistor or the size of the capacitor. Note a 100K ohm resistor is connected to the output of the operational amplifier. This resistor is called a "pull up" resistor as it is not good policy to connect a "raw" voltage to pin 2 of the monostable circuit.

**Testing procedure**
Connect the voltmeter to point Y (pin 3) of the 555 timer. The meter should record 0V with the beam unbroken. Now break the beam and return again to the unbroken state The meter should now record a voltage of 8 volts for a period of 2.5 seconds and then again return to 0V. Now the pulse producing and the pulse shaping circuit (555 monostable) is completed it only remains to complete the counter section.

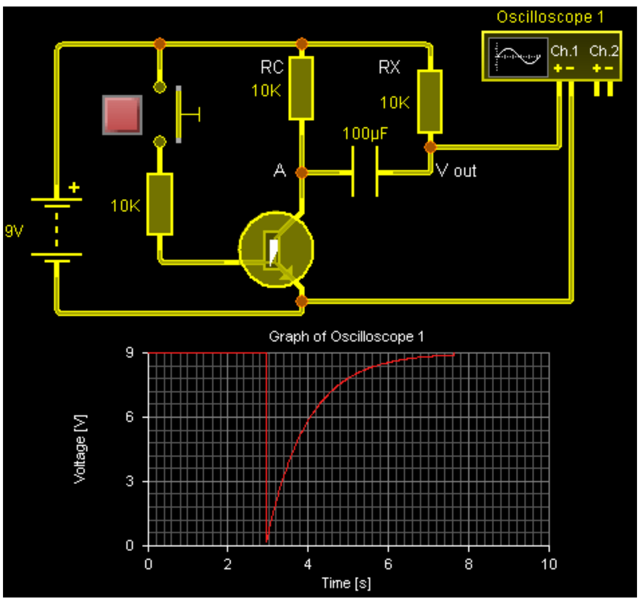





The output from the pulse shaping circuit is connected to pin 14 of the 4017 chip. On the ninth pulse the output pin 9 will go “high”, the transistor (BC337) will switch on and the solenoid will be activated. Note the solenoid contains a coil of wire so it is necessary to place a diode in parallel. A IN4001 diode is suitable.

To reset the circuit the reset switch is pressed pulling pin 15 high. All chips are prone to produce “noise” which is unwanted signals which can inadvertently trigger the circuit, it is therefore good practice to insert a large capacitor (220 μF) between the positive and 0V rail to filter this from the circuit. A IN4001 diode is suitable.

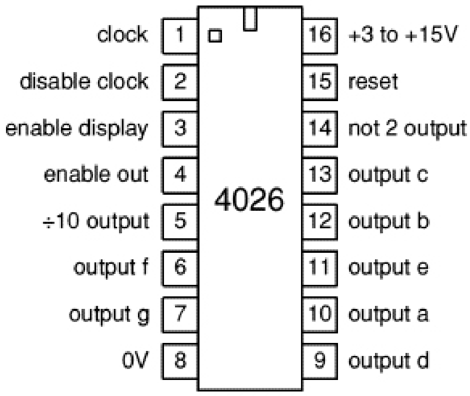
**Alternative method of producing a clean pulse.**
One draw back of the previous circuit is the beam must be broken and then returned to its unbroken state very quickly to produce the negative pulse necessary to trigger the monostable circuit to produce the “clean” pulse which is then applied to the counting circuit. Essentially this means that a 555 timer can only perform a timing function when the trigger has been pressed and allowed to return to the original state. To overcome this, the following circuit can be used and the output, V OUT fed into pin 2 (trigger) of a 555 timer. This circuit is called a pulse shaping circuit and will produce a negative pulse when switch is closed.



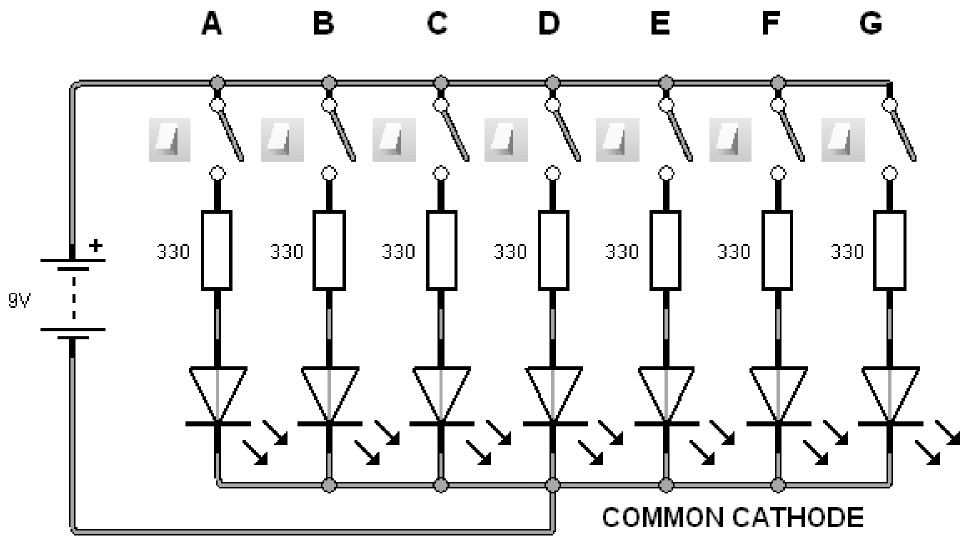

 

Using the appropriate software package, the oscilloscope has a time base in the region of 10 seconds. Verify that when the switch has been pressed a negative pulse is formed as shown. The pulse is formed even if the switch remains pressed, differing from all other switched inputs.

**Counter – Numerical Counter**



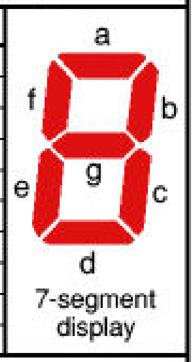

Using the 4026B Decimal counter with decoded 7 segment output allows us to display a numerical value. It operates on exactly the same principle as the 4017B IC with the exception that the outputs (a, b, c, d, e, f, g) are connected to a common cathode seven segment display which essentially is an array of 7 LEDs.



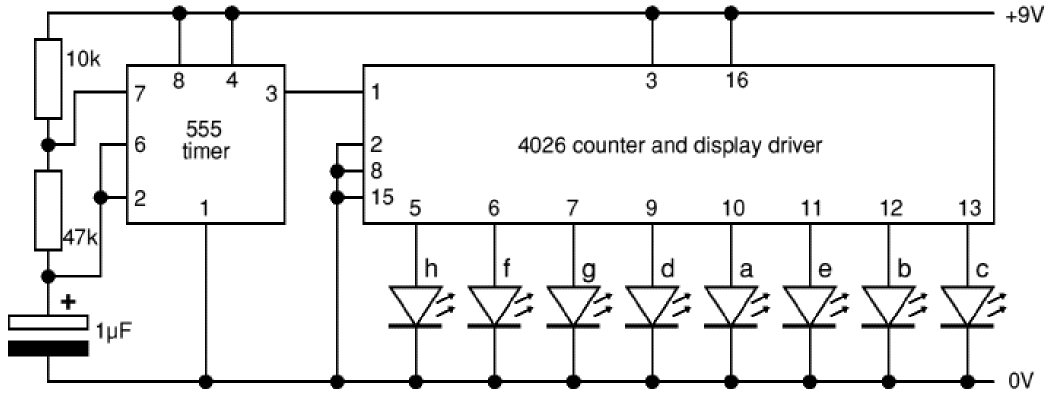

Common cathode refers to the fact that all the negatives of each of the 7 segments are commonly joined. From the table below we can see that to create the number 5 on the display segments a,c,d,f and g must be high or at supply voltage. Note that in a 4026 IC circuit the seven resistors are not needed as they are packaged into the chip itself.

**Outputs from the 4026 counter and display driver IC**

| Count | a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|---|
| 0 | ● | ● | ● | ● | ● | ● | |
| 1 | | ● | ● | | | | |
| 2 | ● | ● | | ● | ● | | ● |
| 3 | ● | ● | ● | ● | | | ● |
| 4 | | ● | ● | | | ● | ● |
| 5 | ● | | ● | ● | | ● | ● |
| 6 | ● | | ● | ● | ● | ● | ● |
| 7 | ● | ● | ● | | | | |
| 8 | ● | ● | ● | ● | ● | ● | ● |
| 9 | ● | ● | ● | ● | | ● | ● |

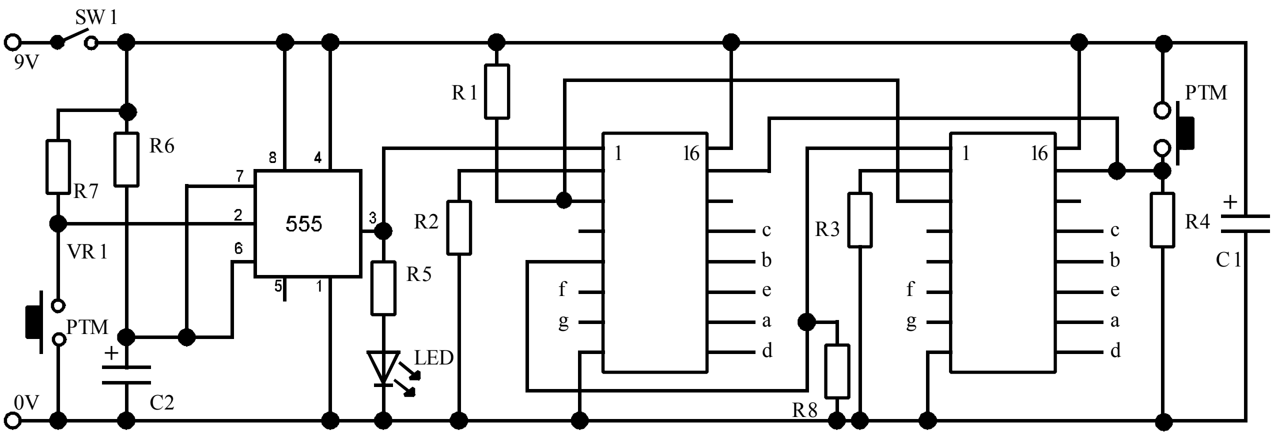



● = segment on.



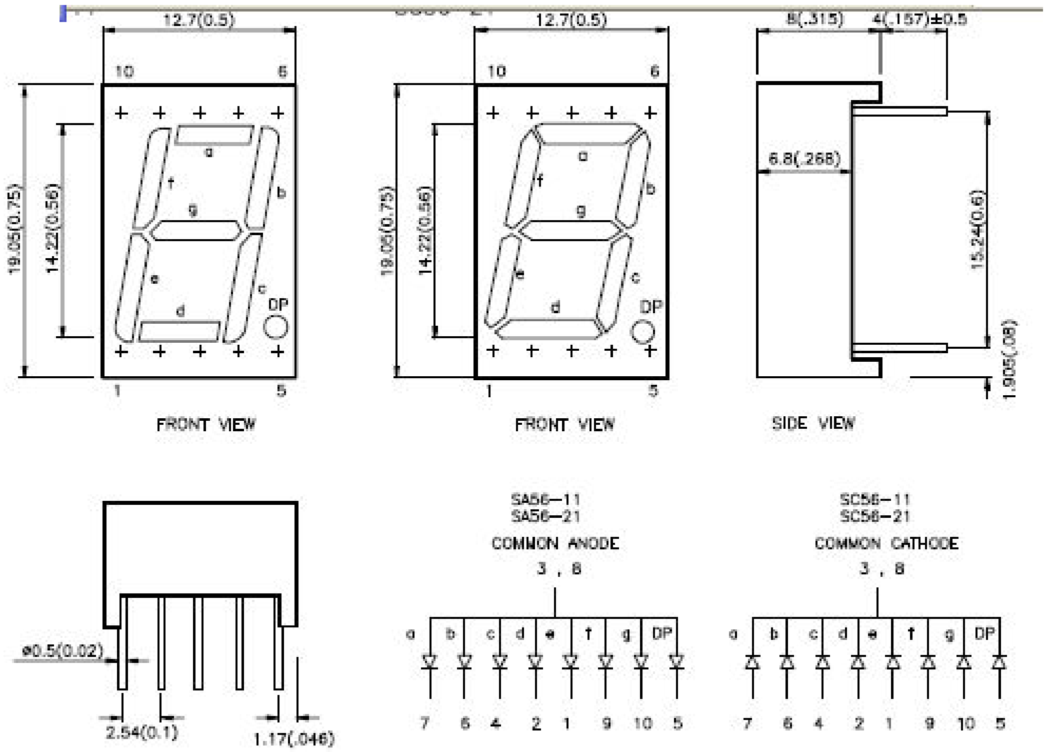

The diagram above shows the general layout and method of connecting a 555 in astable mode to a 4026 counter. We know that the arrangement is astable as pins 2 and 6 are connected together. As each high pulse is sent through from the 555 the numbers 1 through to 9 are displayed on the counter. The arrangement shown is very basic and a much improved circuit is shown below. The diagram shows a two stage circuit, the counter on the left shows units and the counter on the right displays tens. The improvement includes the ability to reset and the ability to use the divide by 10 output (pin 5) to send a pulse to the tens module after 9 units have been counted. This time we have used a monostable circuit and clock pulses are generated from pressing the 555 timer switch.

For the purpose of clarity the 7 segment displays have not been shown on this circuit, these have to be connected to the points a-g as shown. Remember there will be two 7 segment displays, one for the units and one for the tens.




**See circuit 94 -112 Working Circuits**

The following information has been obtained from a data sheet and is vital we understand what it means before attempting to connect in a 7 segment display to our circuit.




We can see that the pins are numbered from 1-5 on the bottom and 6-10 in the top of the display. Note this is being viewed from the front and not from the pins side. Our circuits are designed to use common cathode and so all component numbers should begin with SC and NOT SA. Once we have identified the pins the rest is quite easy really.

Pin 7 –a on the display connects to pin 10 on the 4026b etc. Either pin 3 or 8 or both must be connected to the negative rail. The decimal point is pin 5 and can usually be ignored unless you are designing a stop watch. Note that the 4026 can also be clocked using a PIC microcontroller.