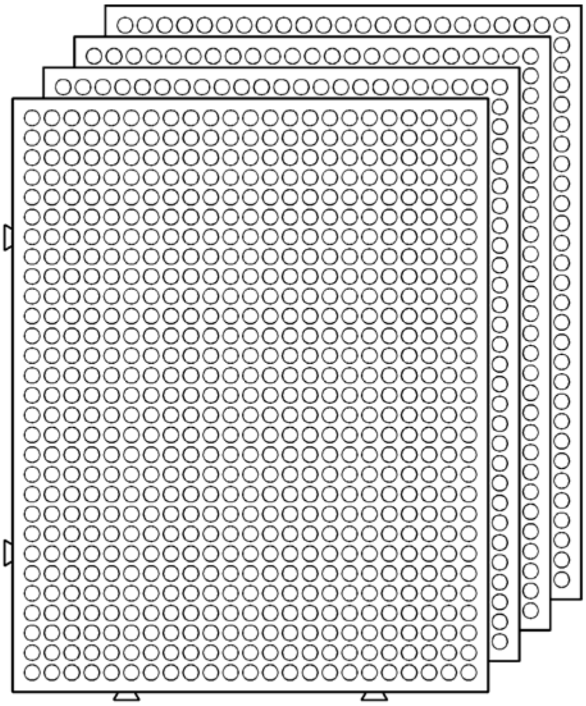
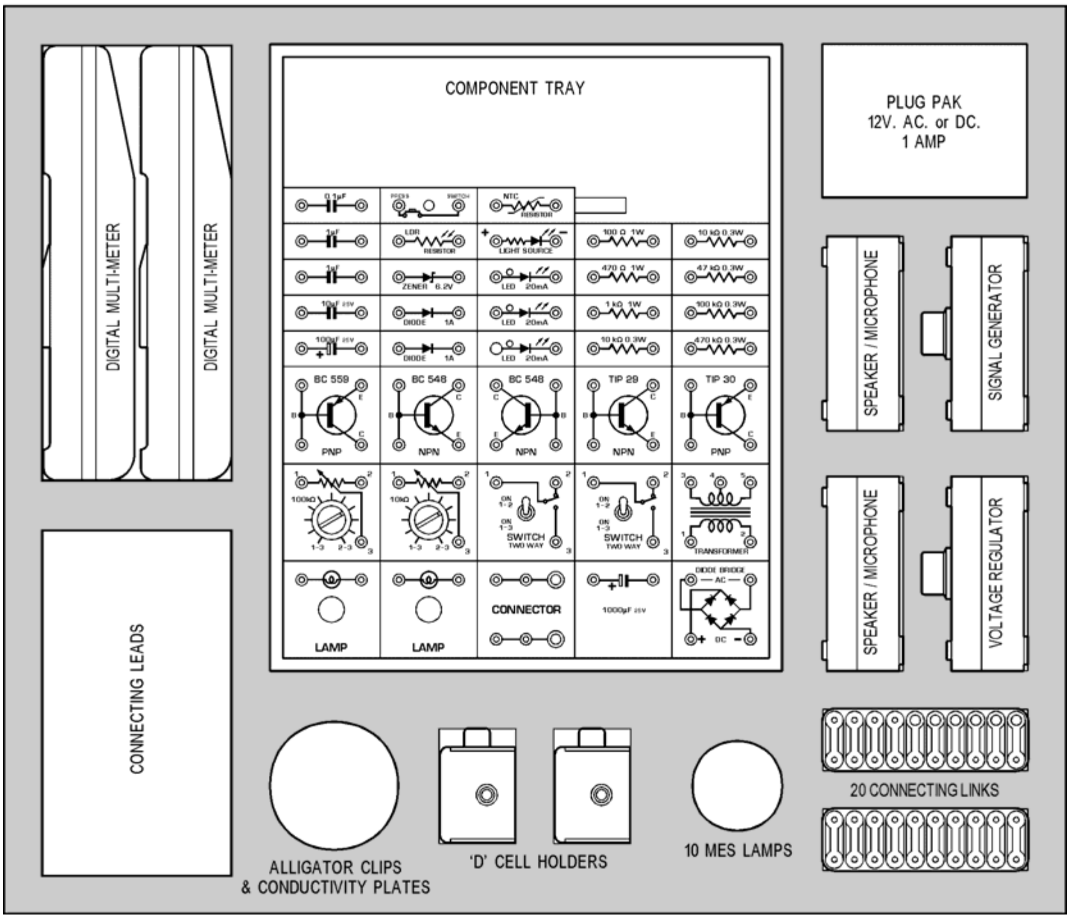
THE 'IEC' ELECTRONICS KIT

Cat: EM1764-001



4 BASE PLATES STORED UNDER COMPONENT TRAY



I N D U S T R I A L E Q U I P M E N T & C O N T R O L P T Y . L T D .
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GENERAL DESCRIPTION:

This kit is designed to perform important basic electronic experiments. To study electric and electronic circuits, resistors, capacitors, diodes, transistors, LEDs, lamps, principles of rectification and filtering, voltage regulators, measuring techniques and on and on. Working circuits can be created to excite the students into learning more effectively and to explore electronics further.

The equipment is designed for a long life in the classroom and all items in the kit are of high quality.

A separate but compatible kit will soon be available for the teaching of Digital Electronics, which is a natural follow on from the basic electronics course.

NOTE: The Mains Adaptor for operating the Power Source converts Mains Power to 12V.AC at a current of 1amp. The standard low voltage plug on the low voltage cable is 5.5mm outside diameter and must be suitable for a 2.5mm diameter pin size. To conform to safety regulations in each country, this adaptor is normally sourced locally within that country.

HOW TO USE THE KIT:

- Remove the tray of components and use the support plates below. These plates can be locked together to form larger plates. Most experiments can be done with only one plate but two or more students can perform experiments at the same time.
- Each component housing has flexible feet that press firmly into the holes in the base and hold the components in their desired positions for connection by links or by cables.
- One of the vials contains 4x adaptors from 4mm banana plug to 2mm banana socket. These are for plugging into the meters to allow 2mm banana plugs to be used for connections.
- The **Voltage Regulator** is used as the adjustable power supply in almost all experiments. The 12V.AC. Mains PlugPak is plugged directly into the socket on the face of the regulator.
- The **Signal Generator** connects directly to the Voltage Regulator with 2x 2mm links. It has choice of sine or square wave signal and choice of slow (1Hz-100Hz) or fast (100Hz-10,000Hz) frequency signal.
- Cables may be extended in length by plugging into one another. Cables can be 'piggy-backed' and 2mm cables can be changed to 4mm cables by using the 2mm links with the 2mm and 4mm holes in the top face.
- After choosing an experiment, lay out and connect the components as shown in the experiment drawing. The schematic drawing of the circuit is shown also. After some experience and understanding, the students will lay out the components to suit themselves.

DESIGN FEATURES OF THE KIT:

- The various components are in transparent ventilated housings to be easily visible to the students. Each housing is clearly marked with the name, symbol and rating.
- The kit is complete with 2x holders for 'D' cell, an adjustable voltage regulator and an adjustable sine and square wave signal generator.
- The components fit easily but firmly into a back panel which holds all components in correct relative position. These back panels can lock together to make larger working areas.
- Components are soldered into printed circuits for extreme reliability.
- Connections are made by 2mm banana plugs on small 'links' that connect one component to another. Short cables with moulded plugs are provided for connections further apart.
- Special features permit the compact 2mm system to be adapted to the 4mm system. The use of the compact 2mm system permits easy entry into Digital Electronics where many more connections are required for each component.
- The high quality digital meters in the kit are complete with 9V batteries fitted. The ranges are both AC and DC Volts and Amps together good Ohms ranges. Capacitance up to 20uF can be measured directly.

KIT CONTENTS: 23 mini transparent housings for components:

- 5x Resistors: 1x 100 ohm, 1x 470 ohm, 1x 1,000 ohm (1k), 2x 10,000 ohm (10k),
- 3x Resistors: 1x47,000 ohm (47k), 1x 100,000 ohm (100k), 1x 470,000 ohm (470k)
- 5x Capacitors: 1x 0.1uF, 2x 1uF, 1x 10uF, 1x 100uF (electrolytic)
- 3x Light Emitting Diodes (LEDs) 1 ea. red, yellow, green
- 2x Diodes 1 Amp
- 1x Zener diode 6.2V 400mW
- 1x Light source (white LED)
- 1x Light dependent resistor (LDR)
- 1x Temperature dependent resistor (NTC)
- 1x Press switch

15 small transparent housings for components:

- 1x Transistor NPN (high power TIP30)
- 1x Transistor PNP (high power TIP29)
- 2x Transistors NPN (low power BC548)
- 1x Transistor PNP (low power BC559)
- 2x Potentiometers 0.5W 10k ohm 100k ohm
- 2x Toggle switch, two way (SPDT)
- 1x Transformer, 8 ohm / 1,000 ohm CT
- 1x Bridge rectifier (with LED monitor)
- 1x Capacitor 1,000uF (electrolytic)
- 2x Lamp holders for MES globes
- 1x Connector box (for alligator clips etc.)

4 large transparent housings for components:

- 1x Regulated power supply, 0-12V.DC. 1 Amp
- 1x Signal generator, sine & square, adjustable 1–10,000Hz, 50mA max.
- 2x Speaker or Microphone 1,000 ohm impedance

Hardware:

- 4x Base plates for mounting and connecting components
- 2x Sets of 10x 2mm banana plug connection links with 4mm banana plug adaption
- 1x Set of 15x 2mm banana plug cables with moulded & stackable 2mm banana plugs
- 1x Set of 6 cables with moulded & stackable 4mm banana plugs
- 2x Digital multimeters with connection cables
- 2x Battery holders for “D” cells
- 1x Vial containing 10x lamps, 6V 50mA.
- 1x Vial containing 4x alligator clips to fit 4mm banana plugs, 4x alligator clips with 4mm banana plugs attached, 4x 4mm/2mm banana plug adaptors, 2x conductivity plates, stainless steel, size 70 x 20mm.
- 1x Instruction and experiment book
- 1x Mains adaptor (Plug Pak), 220/240V.AC. 50/60Hz / 12V.AC. 1 Amp. **To conform to safety standards around the world, this Mains Adaptor is normally sourced locally within the country of purchase.**

GLOSSARY OF ELECTRICAL & ELECTRONIC TERMS:

AC: Means Alternating Current. This is current that flows both forward and backwards following a sine wave waveform. AC does not have a + and - polarity so red and black terminal and wire colours are usually not used.

AMPLIFIER: An amplifier is an electronic circuit that changes a small signal of current or voltage into a much larger signal. A microphone provides a very small signal but, after passing through several amplifiers, the power of the signal is amplified to run large loud speakers of maybe hundreds of watts of power. Transistors can be used as amplifiers.

AMPS: This is the name or unit given to the flow of electricity or electrical current. If one Volt of potential is applied to one Ohm of resistance, then one Amp of current flows. If currents are small, the unit can be milliamps or 'mA' (one thousandth of an amp). If currents are very small, the unit can be microamps or 'uA' (one millionth of an amp).

BOOST: Term used to indicate that two separate windings on a transformer are connected so that one voltage adds to the other.

BRIDGE: This is the name given to 4 devices connected in a square formation. Power or signal is applied to one pair of diagonal corners of the square and the desired result is taken from the other diagonal corners of the square. A common bridge is a Rectifier where 4 diodes are connected as a square and AC is connected to 2 corners and DC is taken from the other 2 corners.

BUCK: Term used to indicate that two separate windings on a transformer are connected so that one voltage subtracts from the other.

CAPACITOR: A capacitor is a device that can store electric charge (something like a battery). The energy is stored as voltage is applied and current flows into it until it is 'charged'. At a later time, this energy can be released, or 'discharged' again to perform a function. These are commonly used in circuits that rectify AC to DC to try to make rectified DC smoother. When the AC waveform falls to zero, the energy stored in the capacitor is discharged to try to fill the gaps in the AC waveform. As the AC waveform rises again, the capacitor is re-charged. This occurs 100 times per second and when used in this manner, they are called 'filter capacitors'. Large filter capacitors are polarised and are designed to be connected only to a DC voltage source. They are called 'electrolytic' capacitors. CAUTION::: If electrolytic capacitors are connected to AC or if they are connected backwards to the DC voltage, they get hot and burst with a loud 'bang'. Some capacitors are designed for AC but these are not electrolytic and are much smaller capacitance. There are many types of capacitors for various voltages and uses.

CHOKE: This is an AC device and is sometimes called an 'Inductor'. It is an iron core with only one coil fitted. The magnetic field in the iron caused by the current through the coil also cuts the turns of wire in the same coil and causes a reverse voltage in the winding that opposes the applied voltage. This tries to stop the flow of current through the coil. The AC current flowing through any coil without iron core is greatly reduced when an iron core is fitted.

CORE: Means the iron shape that is used to couple the magnetic field between two or more coils. A magnetic field can exist much more easily in an iron core than it can in air. When an iron core is used inside the coils, the induction effect is much more efficient. See 'Reluctance'.

CURRENT: This is the conventional flow of electricity through a conductor. It is caused by an EMF or voltage causing electrons to flow in a conductor if a circuit is closed. In DC circuits, the current flows in a conductor 'in phase' (see glossary) with the voltage. In AC circuits this is not always the case, but this phenomenon is reserved for more advanced AC studies.

DC: Means Direct Current. This is current that flows in one direction only. It might be a smooth, non-varying current from a battery, or it might be a pulsating current which is obtained when AC is rectified to DC. The AC sine wave is converted by the rectifier to flow in one direction, but rises and falls 100 times per second from zero to maximum in the shape of half of a sine wave. DC has a polarity and normally red means positive and black means negative. Current flows in a DC circuit from positive to negative.

DIODE: A diode is an electronic device that conducts current in one direction but blocks current flow in the other direction. The current flows in the direction of the arrow normally marked on the device. When conducting, a small ‘forward voltage’ must be exceeded before a diode fully conducts.

DISTORTION: This term means that the output signal from an electronic circuit is not a faithful reproduction of the input signal. It can be caused by driving an amplifier too hard and causing saturation in the components or inductors. Most electronic devices have a normal operating region where they can be driven at the correct levels and they operate with distortion within acceptable limits.

DPST or DPDT: Used when describing switch operation. Means ‘Double Pole Single Throw’ or ‘Double Pole Double Throw’. The number of ‘poles’ is the number of circuits being controlled through the switch. One, two or 3 poles is usual but multi-pole is quite common. The number of ‘throws’ is the number of selections that the switch has (normally one or two). For example, if the switch was ON/OFF, it would be Single Throw. If the switch selects ON in one direction and ON to a different circuit in the other direction, it is Double Throw. See also SPST & SPDT switch.

EMF: Means Electro Motive Force. This is the voltage generated in a conductor when it moves within a magnetic field. Voltage is like the pressure of electricity and, when the circuit is closed, a current is forced through the conductors because of the presence of an EMF. The amount of current flowing depends on the magnitude of the EMF and the resistance of the circuit (Ohm’s Law).

EMITTER: This is one of the layers inside a transistor. In an NPN transistor the emitter is connected to the negative line and current flowing from positive into the base makes a much larger current flow into the collector and out the emitter of the transistor. In a PNP transistor the emitter is connected to the positive line and current flowing from the base into the negative makes a much larger current flow into the emitter and out the collector of the transistor.

FEEDBACK: Feedback is the name given to the condition where part of the output of a system is fed back into the input of the system. If the Feedback is POSITIVE (in phase with the signal), the signal fed back will reinforce the original signal. If the Feedback is NEGATIVE (out of phase with the signal), the feedback will reduce the signal into the system. Positive feedback causes oscillations in a system. Negative feedback reduces gain, reduces distortion and improves stability in a circuit.

FIELD: This is a general name given to magnetic lines of force either in an iron core or in air.

FILTER: When AC voltage is rectified to create DC, the DC is not smooth like a battery. It follows the AC sine wave shape and, although it does not reverse direction, it rises from zero volts up to a peak and falls again 100 times per second (full wave rectification) or 50 times per second (half wave rectification). A filter, which is usually a large value capacitor connected across the DC, charges up to the peak voltage and discharges into the load to try to level out the humps and make it closer to a smooth DC. The effect is best seen on an oscilloscope.

FLUX: Is a general term meaning the magnetic field present usually in an iron core.

FREQUENCY: This is the number of times per second that the AC wave passes through one full cycle of rising from zero to maximum, then falling through zero to minimum and then rising to zero again. The unit is Hertz. Normal mains power in Australia has a frequency of 50Hz. Other countries such as USA and Canada (and many others) use a 60Hz power system.

GAIN: The ‘gain’ of a circuit is the amplification or a circuit or condition. It is used mainly in electronics for amplification but can be used in mechanical circuits too. There can be current gain or voltage gain or mechanical gain (mechanical advantage).

IMPEDANCE: In the world of DC, resistance (ohms) is the factor that controls the current in a circuit. In the world of AC, there is a mixture of both Resistance and Reactance which alter the flow of current through an AC circuit. The term Impedance means the combination of these two phenomena. The term ‘Low Impedance’ means a circuit that has only small total resistive effect to an AC current flow.

INDUCTANCE: This is the measurement of a coil's inductive effect in Henrys. Inductance depends on the number of turns in the coil and the amount of iron in the core. Coils of low inductance (micro Henrys) are used in radio sets for tuning stations and coils of larger inductance (millihenrys or Henrys) are used as Chokes for power supply filters or high power oscillators and special equipment.

INDUCTION: Means the inducing of a voltage in a coil of wire by the application of a magnetic field from either a magnet or another coil of wire. The coils of wire are usually not electrically connected.

INDUCTOR: An inductor is a coil of many turns of wire mounted on an iron core (see Choke).

INTEGRATED CIRCUIT: An integrated circuit, or IC, is a modern device that contains thousands of resistors, capacitors, diodes and transistors on a very small chip of silicon. Sometimes they have many pins for soldering into circuit boards and sometimes they are bonded and soldered directly without pins. This is called 'surface mounting'. Their small size is amazing and complete computers can be made on a single chip a few millimetres square. When ICs were invented, the size of all electronic devices became much smaller.

LAMINATIONS: Iron cores in an AC device are made from thin strips of iron instead of from solid blocks of iron. These thin strips are called laminations and are insulated electrically so current cannot flow from one to another. This is to reduce or eliminate wasteful and unwanted circulating currents in the iron.

LDR: An LDR is a Light Dependent Resistor. This is a special resistor that changes its value when light shines upon it. It is used for light meters (for measuring the intensity of light) and in cameras for adjusting the flash or camera settings to suit the light conditions.

LEAKAGE: This is stray magnetic field that appears outside the iron core. Any field leaking outside the iron core cannot be used by the transformer in driving the secondary coil. Transformer design tries to keep magnetic leakage to a minimum.

LED: An LED is a Light Emitting Diode. The behave in a similar way to normal diodes except when they carry current the give off light. There is almost zero heat generated so they are very efficient. First LEDs were very dull and low power, but nowadays, they are very bright and come in all colours. They are used in motor car tail lamps and in traffic lights and in street speed signs. They do not have a filament to break and this makes them much more reliable and much more efficient than normal lamps.

LOAD: The term 'load' is used for any circuit that draws power from a power source. If a resistor is connected to a battery so that current flows, the resistor can be called the 'battery's load'. The current drawn by the resistor can also be called the 'load' on the power source.

In the case of a transistor, the load of the transistor is the resistor or device connected into the collector circuit. Sometimes the load is in the emitter circuit depending on the circuit function.

LOSSES: This is the name given to energy provided by the Primary coil to the system but not available as usable energy from the secondary coils. Transformer losses include:

- The energy required in magnetising and de-magnetising and reversing the magnetisation in the core 100 times per second. Special iron used for transformers has low losses.
- Resistance in the copper wire of the windings causing voltage loss and heat generated.
- Circulating currents in the iron core causing heating of the iron.
- Loss of magnetic field (leakage) into the air from the iron core.

MAGNETISING CURRENT: This is the current drawn from the power source by the primary coil required to magnetise the iron core and to overcome leakage and losses. Transformer design tries to keep the magnetising current as small as possible because it is wasted energy from the power source and causes unwanted heating in the primary coil.

MES: This is a size of lamp connection base. When Thomas Alva Edison invented the electric light globe, at around the same time a thread was invented for screwing lamps into sockets. It is called the 'Edison Screw'. The different sizes are: Miniature Edison Screw (MES), Small Edison Screw (SES) the Edison Screw (ES), the Giant Edison Screw (GES).

MULTIVIBRATOR: This is a very common form of 2x transistor oscillator. There are 3 types: Mono-stable, Bi-stable and A-stable, each of which has an very important and useful function in many electronic circuits. Mono-stable has one stable state and when disturbed, executes a time delay and returns to that state. Bi-stable has 2x stable states and each must be disturbed for it to 'flip' to the other stable state. A-stable is a free running oscillator with no stable states. Each type of Multivibrator involves capacitors and resistors in the circuits.

NTC: An NTC resistor is a special resistor with a Negative Temperature Coefficient. This means that when they heat up, the value of their resistance falls. They have a special characteristic that is set by their construction and they are used for circuits like temperature controllers.

OPERATING REGION: The 'Operating Region' of a device is the set of conditions that are correct for the device so that a signal applied to the device will cause the normal and expected behaviour in the device. In the case of a transistor, the adjustment of the amount of base current flowing before the signal is applied is called 'setting the operating region'. When correct, the input signal will create an output signal with minimum distorting.

OSCILLATOR: An oscillator is an electronic circuit that creates a constantly and repetitively changing output voltage. See Signal Generator. A signal generator creates its signals by using oscillator circuits and by adjusting their speed and voltage. Oscillator circuits are made by using transistors in certain configurations.

OSCILLOSCOPE: This is a very useful instrument with a screen (like a small TV) that allows voltages to be seen as they change. If a Signal Generator is connected to an Oscilloscope, the wave shape and the frequency and the voltage can all be seen and measured. It can be used to measure DC voltages or oscillations up to hundreds of millions of Hz.

PARALLEL CONNECTION: When two or more devices are connected so that the current divides and flows through side-by-side paths, they are said to be connected 'in parallel'. The total current from the source is the sum of the parallel currents.

PEAK VOLTAGE: Unfiltered DC voltage is a sine wave shape that rises to a peak value and falls to zero volts 100 times per second. When a DC voltmeter meter is placed on the DC, it shows the average DC voltage (not the peak voltage). If a capacitor is placed on the output when there is no load connected to the power supply, it will charge to the peak value which is the highest point of the sine wave. The voltmeter will show this higher peak voltage (average x approx.1.4). When a load is placed on the power supply, the capacitor will discharge this extra energy into the load as the sine wave falls 100 times per second and the voltmeter will then show the average voltage again. But this will be a higher average than before because the capacitor adds extra energy to the load.

PHASE: If you raise both arms and lower them together, they are 'in-phase'. If one arm rises as the other arm falls, they are 'out of phase'. The timing relationship of two voltages or two currents or a voltage compared to a current is called the 'phase relationship'. In the world of DC, currents and voltages are usually 'in phase'. This is not always the case in the world of AC.

As an AC voltage rises in a coil with an iron core, the current through the coil rises slightly later than the voltage. Therefore the magnetic field also rises slightly later than the voltage. The voltage induced in a secondary coil therefore appears at a different instant when compared to the applied voltage. Look at these voltages on a double beam oscilloscope. If a secondary coil is wound the same direction (clockwise or anti-clockwise) as another secondary coil, the AC voltage on these two coils will be rising and falling at exactly the same time. This means they are 'in phase'. If they are connected in series, their voltages will add (see 'boost' in the glossary). If one coil is wound in the opposite direction, they will be 'out of phase' and their voltages will subtract (see 'buck' in the glossary). Phase angle is from 0 to 360 degrees. The term 'in phase' means a shift of zero degrees in phase. 'out of phase' means a shift of 180 degrees in phase.

POTENTIOMETER: A potentiometer is a device that can be applied at each end across a voltage and can be adjusted to supply from zero up to that voltage to another circuit. It is usually a resistor with a sliding contact that can be moved from one end to the other. When the resistor is applied across the supply voltage and the sliding contact is at the 'low' end, the voltage on the slider is zero. When it is half way along the resistor, it is said to be 'tapping' half the supply voltage .. and so on.

PRIMARY; The name given to the transformer winding that is connected to the power source. It provides the energy to both magnetise the iron core and to transfer to the secondary winding(s).

PTC: A PTC resistor is a special resistor with a Positive Temperature Coefficient. This means that when they heat up, the value of their resistance rises. They have a special characteristic that is set by their construction and they are used for circuits like temperature controllers or where a rise in current must be protected against (the extra current heats the PTC and the rise in resistance limits the current).

PULL-UP: A pull-up is normally a resistor that is used to pull part of an electronic circuit up towards the positive line. It can be for many reasons, but is often is to hold a transistor ON so the negative going signal can switch it off. If there was no pull-up, the transistor might already be OFF and the signal would try also to turn it OFF and the circuit could not work.

PULL-DOWN: A pull-down is normally a resistor that is used to pull part of an electronic circuit down towards the negative line. It can be for many reasons, but is often is to hold a transistor OFF so the positive going signal can switch it ON. If there was no pull-up, the transistor might already be ON and the signal would try also to turn it ON and the circuit could not work.

REACTANCE: The world of DC has Resistance (Ohms) that controls the flow of DC current in a circuit and generates heat (Watts). In the world of AC, resistance exists but, in addition to resistance, AC circuits have Reactance. It behaves like resistance but does not generate heat. Reactance depends on the Inductance (Henrys) of a coil or Capacitance (microfarads) of a capacitor and the Frequency (Hertz) of the AC current flowing through it.

RECTIFIER / RECTIFICATION: AC can be changed to DC by 'rectification'. If a single diode is used, only one half of the AC waveform passes through the diode as DC and the voltage appears as 50 humps per second. If 4 diodes are connected in a 'bridge' configuration 'full wave' rectifier, both halves of the AC waveform are rectified and the DC appears as 100 humps per second. If a transformer winding has a 'centre tapping', only 2 diodes are required to create 'full wave' rectification. Rectification is reserved for electronic study and is not covered in this booklet.

REGULATOR: A regulator can be a voltage or a current regulator. A voltage regulator is a device that provides exactly the same voltage whether it is supplying zero or maximum current to the load. It is sometimes adjustable for voltage value, but when it is set, it does not change its voltage with load. A current regulator retains the set current and if the resistance of the load changes the current remains constant.

RELUCTANCE: The ability of a material to support a magnetic field is called the 'reluctance' of the material. Air has a very high reluctance and iron has a low reluctance. The special laminated iron used to make transformer cores usually has a very low reluctance.

RESISTANCE: Means the ease or difficulty that electrons have in flowing through a circuit. Glass does not conduct electricity, so it can be said that it has an extremely high resistance. Metals allow easy flow of electrons, and can be said to have a very low resistance. Every material has resistance value in OHMS. 'Kilohms' means thousands of ohms. 'Megohms' means millions of ohms.

Ohm's law: 1 volt EMF causes 1 AMP of current to flow through 1 OHM of resistance.

RESISTOR: This is a device that has a specific resistance. They are used in all electronic circuits to control the flow of electricity. Resistors can be seen as small dots on a printed circuit or as small tubular devices with 2 wires or as much larger devices that are too large to carry. As they carry current they emit heat, so the rating of a resistor includes the OHMS of resistance and the WATTS that can be dissipated as heat.

RESONANCE: When a capacitor and an inductor are connected in series or in parallel, at certain frequencies the reactance of the capacitor and the reactance of the inductor are exactly equal but are 180^o out of phase. When this occurs in the series circuit, there is a sudden fall in overall reactance and a heavy current flows. When this occurs in the parallel circuit, there is a sudden rise in overall reactance and current falls. The phenomenon of resonance is used for tuning radio or TV stations.

RHEOSTAT: A rheostat is a resistor with a sliding contact so the value of the resistor can be smoothly adjusted from zero ohms to maximum. It is similar to a Potentiometer but only one end of the resistor and the moving contact are connected.

ROTOR: The rotor of a motor is the part that rotates

SATURATION: This means that a device is supplied with so much energy that it can accept no more. In the case of an Inductor or Transformer, if the iron becomes saturates (too much magnetic field created by the primary coil), the transformer primary coil carries high current and does not create the correct voltage in the secondary winding. In the case of an electronic device, an excess of current will saturate a device so it can no longer change is current in sympathy with the input signal. Saturation causes electrical distortion and often causes physical damage to components.

SECONDARY: The name given to winding(s) of a transformer that are not the 'Primary' winding.

SERIES CONNECTION: When two or more devices are connected so the current must pass from the end of one into the beginning of the next so that the same current flows through all of them, they are said to be connected 'in series.

SIGNAL GENERATOR: This is a very useful instrument that provides an adjustable frequency wave to a circuit. The wave type is usually either sine wave or square wave. The frequency depends on its use. It can be an 'audio oscillator' where the frequency might be from 1Hz to 20kHz (within the frequency range of human hearing). It can maybe be a high frequency of 10kHz to 10MegHz for radio work. A switch usually selects the shape of the wave (sine, square, triangular, sawtooth and more) and another knob adjusts the frequency and another knob may adjust the voltage of the output signal.

SPST or SPDT: Used when describing switch operation. Means 'Single Pole Single Throw' or 'Single Pole Double Throw'. The number of 'poles' is the number of circuits being controlled through the switch. The number of 'throws' is the number of selections that the switch has (normally one or two). For example, if the switch was ON/OFF, it would be Single Throw. If the switch selects ON in one direction and ON to a different circuit in the other direction, it is Double Throw. See also DPST & DPDT.

STATOR: The stator of a motor is the part that does not rotate.

TAPPING: If a coil is wound part way (say 20 turns) and the wire is then looped from the bobbin to a connection point and then returned to the coil and the coil wound further, the coil is said to have a tapping. Transformer coils can have as many tappings as desired to provide many voltages from the one coil. If two coils of say 50 turns are connected in series, this is the same effect as one 100 turn coil tapped at the mid point.

TRANSFORMER: This is a device where two or more coils of wire are coupled by an iron core so that the magnetic field in the iron created by one of the coils (the primary coil) induces a voltage in the other coils. The coils are not normally electrically connected to each other. Depending on the number of turns of wire on the coils, the voltage applied to the primary coil can be changed or transformed to a different voltage on the secondary coil(s). The thickness of the wire forming the coils has no effect on the voltages created. The wire thickness should be calculated to suit the current flows in and out of the transformer to avoid overheating of the wire.

TRANSISTOR: A transistor is an electronic device consisting of 3 layers of semi conducting material forming a Collector, Base and Emitter. Transistors can be NPN or PNP type depending on the way the layers are manufactured. When a small current flows from the collector into the base, a much larger current flows in the collector / emitter circuit. They are used in almost all electronic circuits for amplifiers and for many other purposes.

UNITS: Most electrical units have prefixes that mean fractions or multiples of the basic unit.

Greater than 1x: Deca: 10x Kilo: $x10^3$ Mega: $x10^6$ Giga: 10^9 Terra: $x10^{12}$

Less than 1: Deci: $1/10^{th}$ Centi: $1x\ 10^{-2}$ Milli: $1x\ 10^{-3}$ Micro: $1x\ 10^{-6}$ Nano: $1x\ 10^{-9}$ Pica: $1x\ 10^{-12}$

VOLTAGE: This is the electrical 'pressure' that is created in a conductor when a conductor moves relative to a magnetic field to cut the lines of magnetic force. The voltage cannot cause current to flow until the circuit is closed. The voltage is dependent on the strength of the field and the speed of motion of the conductor. Voltage can be created also chemically as in a battery or by heat or light or by electric charge as in static electricity, lightning and similar. To understand voltage, it can be considered to be similar to pressure of water in a pipe. Pressure of water is present in a pipe but the flow of water (like electrical current) cannot occur until a circuit is made with pipes (like electrical wires) and until the tap is opened (like an electrical switch turned on).

VOLTS: This is the name or unit given to the potential of electricity or electrical pressure. If one Volt of potential is applied to one Ohm of resistance, then one Amp of current flows. If voltages are small, the unit can be millivolts or 'mV' (one thousandth of a volt). If voltages are very small, the unit can be microvolts or 'uV' (one millionth of a volt).

WATTS: When a voltage causes a current to flow through a resistance, heat is generated in the resistance. The unit of the power generated is Watts. If powers are small, the unit can be milliwatts or 'mW' (one thousandth of a watt). If powers are very small, the unit can be microwatts or 'uW' (one millionth of a watt). For a DC circuit, Volts x Amps = Watts. For AC circuits it is more complicated and this is reserved for later study.

METERS: There are several different common types of measuring meters.

Meaning of Analogue: All analogue meters move in the same way as an electric motor turns in a magnetic field. A very fine coil of wire is held in pivots in a very strong magnetic field. If any current flows in the coil, it tries to twist in the magnetic field against springs that are trying to keep it stationary. A pointer is attached to the coil and the pointer moves on the scale to indicate a reading or measurement. Being mechanical, analogue meters can usually be repaired. Analog meters clearly show voltages changing as the pointer moves back and forth.

Meaning of Digital: Digital meters provide a numeric reading and there are no moving parts. They are normally more accurate than analogue types. Digital meters require batteries to operate and the main difficulty is that digital meters do not clearly indicate voltages that are changing because it is impossible to follow the numbers changing. Digital meters are not easily repaired.

Analogue student meters: These are used commonly in classrooms and are individual meters with terminals. They can be either AC or DC meters and are usually made from plastic and have either one or two ranges for either Volts or Amps. They have pointers that pass over a scale, are low cost and are very good for student experiment work.

Analogue demonstration meters: These are very large meters used in a classroom for all the students to see from a great distance. They have a long and fat pointer and the large scale can often be interchanged to change the meter from AC to DC and from Volts to Amps and to change the measuring ranges.

Analogue multimeters: An analogue multimeter is one that has a pointer that passes over a scale and has many ranges and functions that can be selected by a switch on the meter. The one meter can usually read many ranges of Amps, Volts and Ohms. They are sometimes called AVO meters.

Mirror backed scale: Most analogue meters have a strip of mirror below the scale to that the user can place the pointer over the reflection of the pointer to be sure the eye is exactly vertically over the pointer. This eliminates errors due to reading the pointer at an angle (called parallax).

Digital multimeters: The kits contain digital multimeters. They are usually accurate and have no moving parts. They use 9 Volt batteries internally and have many AC and DC Amps, Volts and Ohms ranges. Often they can measure also Capacitance, Inductance, Temperature, Transistor Gain and Frequency.

The small student series digital meters in the kit measure AC or DC Amps (up to 10A), AC or DC Volts (up to 1000V), Ohms (up to 200 megohms), Capacitance up to 20uF and Transistor Gain.

USING METERS:

Always be careful to select AC or DC correctly. Think about the values you are measuring and always be sure to select a range higher that the readings you expect. It is always better to begin on a high range and reduce it than to start at a low range and damage the meter. The meters are supplied with instruction sheets and connection cables with 4mm banana plug connectors.

MEASURING CAPACITANCE: The meters supplied in the kit can read capacitance to 20 microfarads (uF). The connection for capacitance is by a small socket on the front of the meter because usually capacitors have wires at each end of their bodies to place into the small sockets. This kit however has all 4mm banana socket connections.

To connect cables to the meter for capacitance, the kit contains some short lengths of tinned copper wire to press into the socket and for attachment of alligator clips.

<u>ALWAYS TURN DIGITAL METERS OFF AFTER USE.</u>

Experiment list:

RESISTORS:

R1	Measuring resistance. Ohm's law.
R2	Resistors in series
R3	Resistors in parallel
R4	Variable resistance (or Rheostat)
R5	Potentiometer (or Voltage Divider)
R6	Resistor that changes with temperature. Negative Temperature Coefficient (NTC)
R7	A lamp is a resistor with a Positive Temperature Coefficient (PTC)
R8	Resistor that changes with light intensity. Light Dependent Resistor (LDR)
R9	Measuring light intensity using an LDR

DIODES:

D1	Diode, direction of conduction
D2	Forward voltage of a silicon diode
D3	Characteristic curve of a silicon diode
D4	Diodes as protection devices. (e.g. meter protection)
D5	Light Emitting Diodes (LED)
D6	Forward Voltage of a Light Emitting Diode (LED)
D7	Using diodes and lamps to indicate polarity
D8	Using AC. Show reversal of current using LEDs
D9	Operation of a Zener Diode
D10	Zener Diode as a voltage regulator (stabiliser)
D11	Half wave rectifier using 1 diode (with filtering)
D12	Full wave rectifier using 2 diodes (with filtering)
D13	Full Wave rectifier using 4 diodes (Bridge rectifier)

CAPACITORS:

C1	Capacitor DC charge and discharge
C2	Capacitor AC charge and discharge
C3	Capacitor behaving as an 'AC resistor'
C4	Capacitors in series
C5	Capacitors in parallel

INDUCTORS:

I1	Inductor as an AC resistor

TRANSISTORS:

T1	Construction of NPN and PNP transistors and diodes.
T2	An NPN transistor behaves like 2 diodes
T3	A PNP transistor behaves like 2 diodes (PNP)
T4	Operating an NPN transistor
T5	Operating a PNP transistor
T6	Transistor (NPN) & capacitor as a pulse timer
T7	Transistor (PNP) & capacitor as a ‘delay off’ timer
T8	Transistor (NPN) as a current amplifier with collector load
T9	Transistor (NPN) as a voltage amplifier with collector load
T10	Transistor (NPN) as a current amplifier with emitter load
T11	Transistor (NPN) as a voltage amplifier with emitter load
T12	PNP type transistor compared to NPN transistor. When to use ?
T13	Filter to select high and low frequencies to be heard in speaker

OSCILLATORS:

O1	Multivibrator, ‘bi-stable’ type (has two steady states)
O2	Multivibrator, ‘mono-stable’ type (has one steady state)
O3	Multivibrator, ‘a-stable’ type (free running with no stable state)
O4	Oscillator, tone generator, manual control, using a speaker
O5	Oscillator, tone generator, controlled by light, using a speaker
O6	Oscillator using inductor and speaker
O7	Series Resonance using voltmeter as detector.
O8	Parallel Resonance using a speaker as a detector.
O9	Oscillator, sine wave, ‘Wien Bridge’ type

AMPLIFIERS:

A1	One transistor controls the next transistor
A2	Amplifier, single stage, using microphone and speaker
A3	Amplifier, two stage, AC coupled, using microphone and speaker
A4	Amplifier, differential pair

LOGIC CIRCUITS:

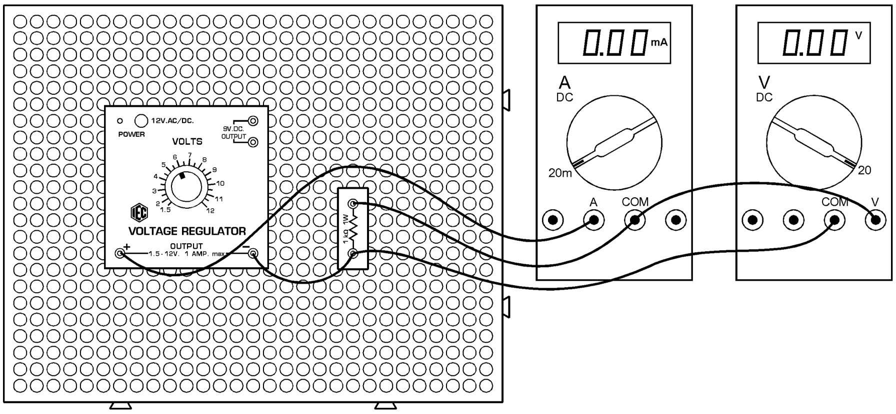
L1	AND gate (switch logic)
L2	OR gate (switch logic)
L3	Exclusive OR (XOR) gate (switch logic)
L4	NOT gate (switch logic)
L5	AND gate (diode logic)
L6	OR gate (diode logic)
L7	NOT gate (transistor logic)
L8	NAND gate (diode logic)
L9	NOR gate (diode logic)

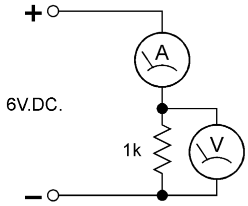
PROJECTS:

P1	Liquid level control circuit
P2	Automatic Night Light (using a Schmitt Trigger)
P3	‘Shop Entry’ door alarm

EXPERIMENTS.

R1: Measuring resistance. Ohm's Law





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Resistor 1,000 ohms

Connect the circuit as shown above

Aim: To study the function of a resistor. To prove Ohm's Law. R(ohms) = V(volts) / A(amps)

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above. Set regulator to 6V.DC. Set voltmeter to 20 volts DC. Set ammeter to 20mA range.

Experiment: Adjust regulator to say 6.0V. If 6 volts is applied to a resistance of 1,000 ohms, the current flowing should be: 6/1000 = 0.006 amps (6.0mA).

Now adjust the voltage regulator to say 12V.DC. Check and note the current flowing through the resistor at this higher voltage.

Now change the resistor to a different value (say 100 ohms). Check voltage and current.

Using the voltage and current measured, calculate the exact value of the resistor in Ohms.

Ohms = Volts / Current

What is the difference between the calculated value of the resistor and the marked value of the resistor ?

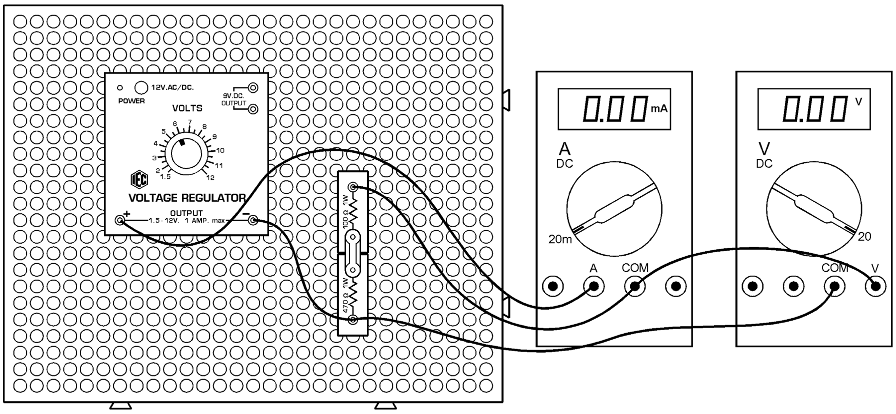
What is the percentage error ?

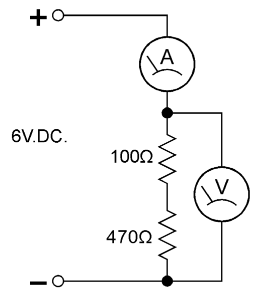
Using a graph pad, plot a graph of volts against amps for several resistors. What do you notice about the graphs ? Is the relationship between volts and amps 'linear' ? Can you use the graph to predict the current that would pass through a resistor at different voltages ?

Disconnect the power source and use the multimeter set to 'ohms' and measure the value of the resistor. Compare this value with your exact measured value. What is the percentage error ?

Conclusion: There is a relationship between Volts, Amps and Ohms. The law that relates them is called 'Ohm's Law'.

R2: Resistors in series





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 2x Resistors: 100 ohms and 470 ohms

Connect the circuit as shown above

Aim: To discover the total resistance of 2x resistors in series. To discover the voltages appearing across each resistor.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above. Set regulator to 6V.DC. Set voltmeter to 20 volts DC. Set ammeter to 20mA range.

Experiment: Adjust regulator to say 6.0V. If 6 volts is applied to the 2x resistances in series, measure the current flowing in the circuit.

Use Ohm's law to calculate the ohms value of the 2x resistances connected in series (R=V/A). Look at the values marked on the resistance housings and discover if the resistance you calculated equals the two added together.

Choose 2x different resistances and change the voltage. Measure volts and amps and calculate ohms again to discover if the ohms is the addition of the two resistors.

Take note of the voltage and remove the voltmeter from the power source. Connect the voltmeter across one of the resistors. Use this voltage with the current flowing and calculate the value of this single resistor. Note the voltage measured.

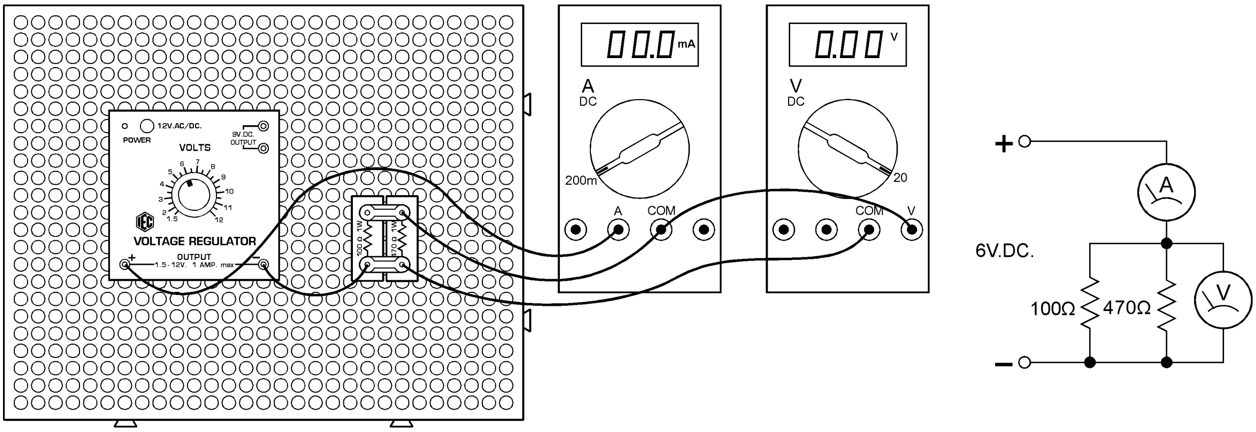
Do the same with the second resistor. Note the voltage across this second resistor.

If you add the two voltages together, what do you notice the result equals ?

Disconnect the power source and use the multimeter set to 'ohms' and measure the value of the two resistors in series. Compare this value with your exact measured value. What is the percentage error ?

Conclusion: The value of resistors in series add together to make the total resistance. Adding the separate voltages across each resistor equals the total voltage supplied from the power source.

R3: Resistors in parallel



Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 2x Resistors 100 ohms and 470 ohms

Connect the circuit as shown above

Aim: To discover the total resistance of 2x resistors in parallel. To discover the voltages appearing across each resistor.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above. Set regulator to 6V.DC. Set voltmeter to 20 volts DC. Set ammeter to 200mA range.

Experiment: Adjust regulator to say 6.0V. If 6 volts is applied to the 2x resistances in parallel, measure the current flowing in the circuit.

Use Ohm's law to calculate the ohms value of the 2x resistances connected in parallel (R=V/A). Look at the values marked on the resistances and discover the total resistance is **lower** than either of the resistors. If R is the total resistance, discover that 1/R = 1/ r1 + 1/ r2

If 1/100 + 1/470 = 1/R the value of R calculates to 82.45 ohms. How does this compare with your calculated resistance value using volts and amps ?

Place the ammeter into each resistor circuit and measure the current in each resistor. Notice that the two currents add to equal the total current.

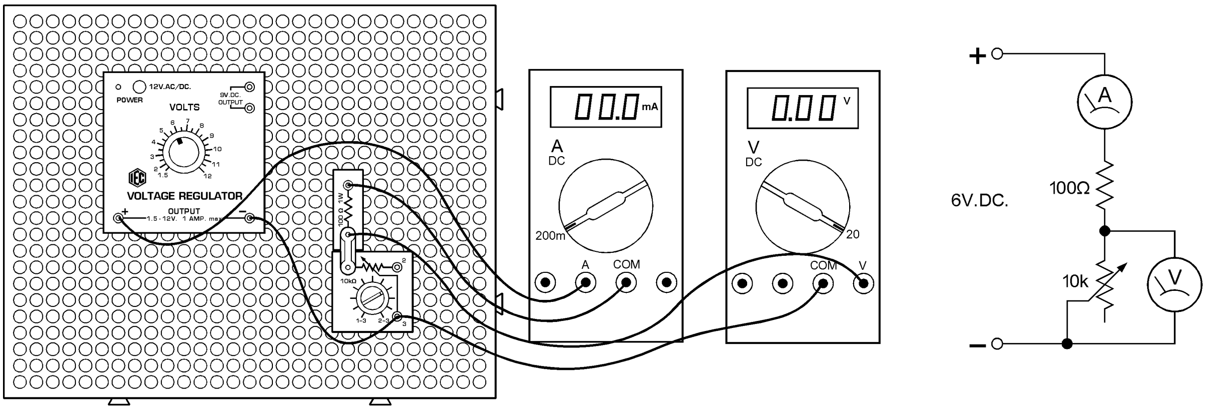
Ohm's law can be written also V = A x R. Multiply the current value through each resistor by the resistance value of each resistor and see that it equals the volts applied to each resistor.

Add another resistor, say 1000 ohms, to the existing ones to make 3 resistors in parallel. Using volts and amps again calculate to total resistance. Now use the formula 1/R = 1/ r1 +1/ r2 + 1/ r3. Does the formula still work ?

Conclusion: When resistors are connected in parallel, each resistor carries a share of the current depending on its ohms value. The total resistance is lower than any of the resistors connected. Each resistor has the same voltage applied to it.

NOTES: For 2x resistors in parallel, another way of calculating the total resistance is by using the simple rule of: "product / sum". This means multiply the 2x resistance values together and divide the result by the sum of the 2x resistors. For 100 and 470 ohms, this would be (100 x 470) / (100 + 470) = 82.45 ohms. **This formula works only for 2x resistors.**

R4: Variable resistance (or Rheostat)



Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Resistor 100 ohm
- 1x Potentiometer 10k ohm

Connect the circuit as shown above

Aim: To create a 'variable resistor'. To learn the difference between a variable resistor (rheostat) and a voltage divider (potentiometer). To vary the resistor to observe the results.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a 100 ohm resistor is series with a 10,000 ohm variable resistor. Set regulator to 6V.DC. Set voltmeter to 20 volts DC. Set ammeter to 200mA range.

Experiment: A voltage divider or potentiometer is a 3 connection device (each end of the resistor and the 'slider' that moves around the length of the resistor). A variable resistor is a voltage divider with only 2 connections used (one end of the resistor and the 'slider'). As the knob is turned, the 'slider' changes the value of the resistance from zero to maximum. The next experiment will use all 3 connections as a voltage divider or potentiometer.

Adjust regulator to say 6.0V. Use the voltmeter to check the voltage.

Set the variable resistor to zero value and measure the current flowing in the circuit with only the 100 ohm resistor remaining. The current should be V / R = 6 / 100 = 0.06 amps (60 mA).

- **Question:** Why did we put the 100 ohm resistor in series with the variable resistor ?

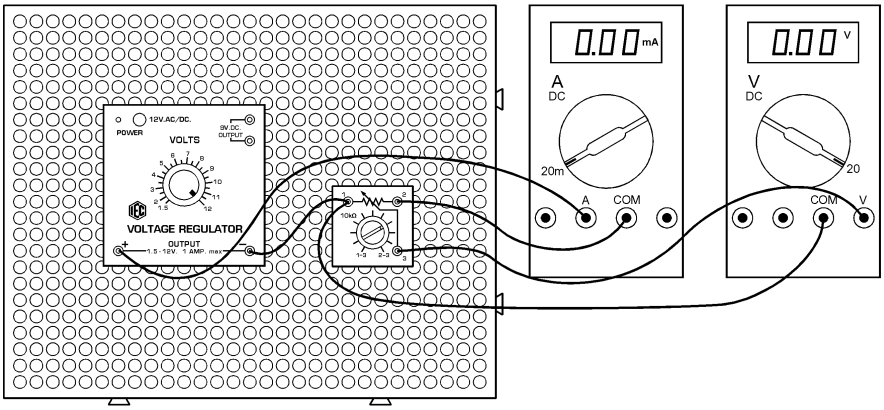
Answer: If there was no resistor in series, the variable resistor could be adjusted to zero ohms and this would be a 'short circuit' across the regulator, a large current would flow and the volts would be forced to be zero.

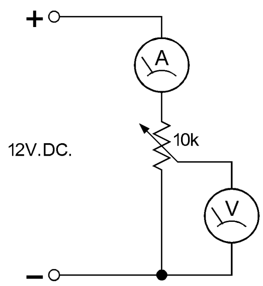
Observe the applied voltage and the current flowing through the circuit and increase the value of the variable resistor. If the variable resistor was turned to maximum, the total resistance would be 10,100 ohms. Calculate the current that should be flowing. Remember a milliamp (mA) is A/1000. Look at the ammeter and see if you are correct. A = V / R

Adjust to other values of resistance and check volts and amps. Use the Ohms range on your multimeter to check if your resistance calculations are correct.

Conclusion: A smoothly changing resistor is called a variable resistance or rheostat and is useful for changing current in a circuit or for providing many different resistance values in a circuit.

R5: Potentiometer (or Voltage Divider)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Potentiometer 10k ohm

Connect the circuit as shown above

Aim: To create a 'voltage divider' or Potentiometer. To learn the difference between a variable resistor (rheostat) and a voltage divider (potentiometer). To adjust voltages and observe effects.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a 10,000 ohm variable resistor. Set regulator to 12V.DC. Set ammeter to 20mA range and voltmeter to 20V.DC.

Experiment: A voltage divider or potentiometer is a 3 connection device (each end of the resistor and the 'slider' that moves around the length of the resistor). We discovered in the experiment with resistors in series that the supply voltage can be divided between the resistors. If the resistance can be smoothly divided at any value, it follows that the voltage can be smoothly divided.

The 10,000 ohm resistance is connected across the power source and a current flows through the resistance. Place a voltmeter between the 'slider' connection and the negative end of the resistance. Turn the knob so the 'slider' rotates to touch the same end of the resistor. The output voltage should be zero.

Now gradually turn the knob so the 'slider' moves around the resistor. Notice that the voltage now increases as the 'slider' touches further along the resistor. As the 'slider' touches along the 10,000 ohm resistor, actually two resistors are created in series and we are measuring the volts between zero and the connection point between them. At the middle point around the resistor the two resistors would be 5,000 ohms each and the voltage should be half of the applied voltage (6V).

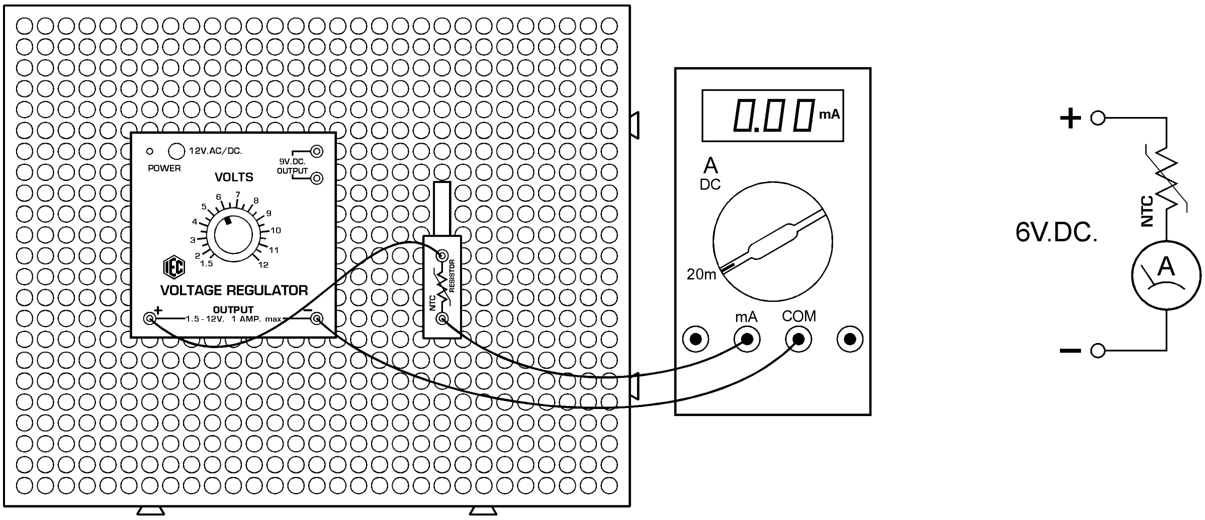
When the 'slider' reaches the other end of the resistor, the output volts is the same as the power supply (input) volts.

So, we can change the output volts from maximum to zero by using a potentiometer.

Conclusion: If a voltage is applied across a resistor and a sliding connection can be made to touch at any point along the resistor, a fully adjustable voltage (or potential) can be obtained which can be adjusted from zero volts to the full applied voltage. This is very useful in electronic circuits like volume controls or brightness controls on lights.

R6: Resistor that changes with temperature

Negative Temperature Coefficient (NTC)



Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Ammeter & cables
- 1x NTC Resistor

Connect the circuit as shown above

Aim: To demonstrate a special type of resistor that can change its resistance with a change in temperature. As temperature rises, its resistance falls.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a NTC resistor. Set regulator to 6V.DC. Set ammeter to 20mA DC.

Experiment: Take a piece of ice and place it against the metal rod protruding from the NTC resistor. As the rod cools, notice the change in current passing through the resistor. The resistance rises and the current falls.

Now take a hot piece of metal and place it against the rod to heat the NTC resistor. Or, use longer cables for connection and, very carefully, place the metal rod into very hot water. Notice the change in resistance that causes a change in current flow.

Negative Temperature Coefficient (NTC) means that the resistance is reduced as the temperature rises. If the resistance was rising as the temperature rises, it would be called a Positive Temperature Coefficient (PTC).

Knowing the voltage being applied and knowing the current flowing, use Ohm's Law to calculate the resistance when it was cold and the resistance when it is hot. R = V / A

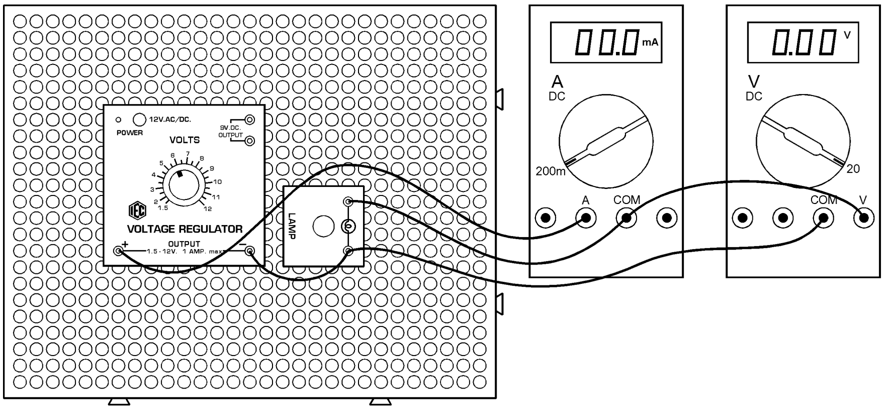
Conclusion: In an earlier experiment, we have seen a resistance change by turning a knob and moving a 'slider'. In this case we have seen resistance change by using heat. This means we can make a voltage divider or a variable resistance that works with heat.

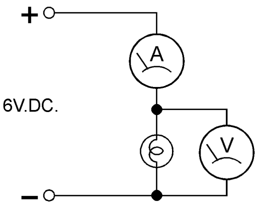
In electronic circuits, this would be useful to control temperature in a room or to turn off a heater if the temperature became too high etc..

Think of other uses.

R7: A Lamp is a resistor that changes with temperature

Positive Temperature Coefficient (PTC)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Ammeter & cables
- 1x Voltmeter & cables
- 1x Lamp (behaves as a PTC resistor)

Connect the circuit as shown above

Aim: To demonstrate that a lamp behaves as a PTC resistor. It changes its resistance with a change in temperature and as temperature rises, its resistance rises.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a lamp. Set regulator to 6V.DC. Set ammeter to 200mA.DC. range and voltmeter to 20V.DC. range.

Experiment: Reduce the voltage to minimum and take note of the current flowing through the lamp and the voltage across the lamp.

Gradually raise the voltage in 0.5V steps and, each time, note the current flowing through the lamp. Take a graph pad and plot a graph of volts on the 'X' axis and amps on the 'Y' axis. When all the plots are on the page, draw a graph best fitting the position of the plots.

If the resistor was not changing, the graph would be a straight line which relates volts and amps to follow Ohm's Law. If the graph is not a straight line, it means that the resistance value is changing as the volts and amps are increased. As the current increases through the lamp, you can see the filament getting hotter and glowing brighter.

Therefore we can see that the resistance of a lamp increases as the filament becomes hotter and this makes it a temperature dependent resistor with a Positive Temperature Coefficient.

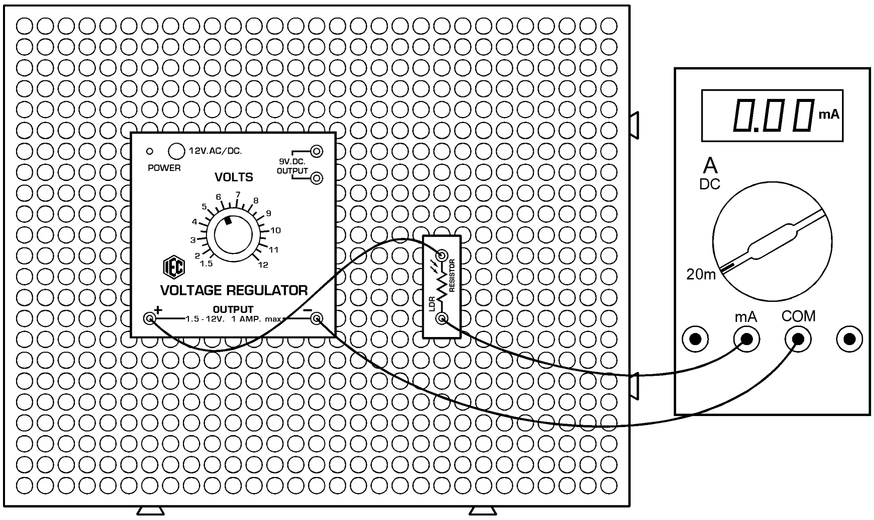
Conclusion: In the earlier experiment, we have seen a resistance change by turning a knob and moving a 'slider'. In this case we have seen a lamp's resistance change as it begins to glow. This means we can make a voltage divider or a variable resistance that works with heat.

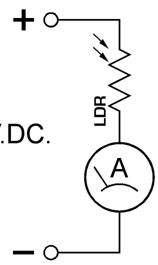
In electronic circuits, this would be useful to limit the current flowing as the current rises enough to make the lamp glow.

Think of other uses.

R8: Resistor that changes with light intensity.

Light Dependent Resistor (LDR)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Ammeter & cables
- 1x LDR Resistor

Connect the circuit as shown above

Aim: To demonstrate a special type of resistor that can change its resistance with a change in illumination. As light falls upon the resistor it changes it value.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a LDR resistor. Set regulator to 6V.DC. Set ammeter to 20mA DC.

Experiment: Cover the LDR with a piece of cardboard and check and note the current flowing through it. Remove the cardboard and check and note the current flowing through it. Notice that the resistance is reduced which causes the current to rise when the light increases.

The white LED light source in the kit: Note that this 'light source' is an LED and it has a resistor built into it to limit the current but the other LEDs do not have resistors inside their housings.

Now take the 'Light Source' from the kit and take two 2mm banana plug cables to connect it to the power source. Plug the banana plugs into the top of the existing plugs in the power source (piggy-back the plugs) and check the polarity (the + and – connections). Position the Light Source so the bright white light falls on the face of the LDR. Check and note the current through the LDR.

Knowing the voltage being applied and knowing the current flowing, use Ohm's Law to calculate the resistance of the LDR: a) when it was dark b) when it was illuminated by the room light and c) when it was illuminated by the bright light source. Ohm's Law is: R = V / A

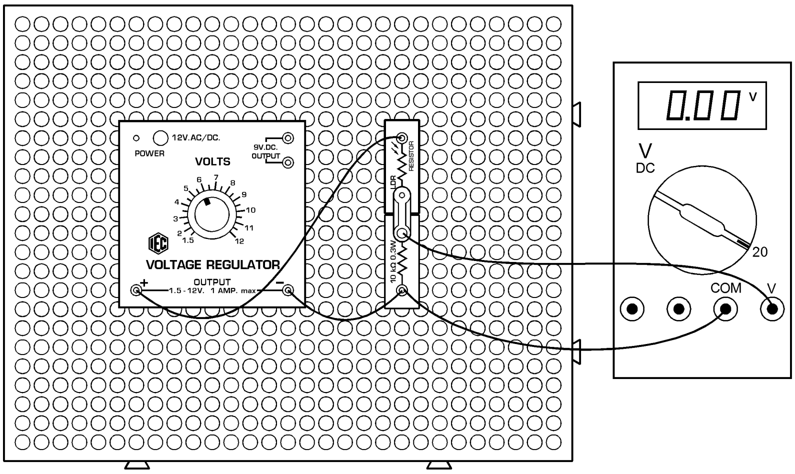
Conclusion: In earlier experiments, we have seen a resistance change by turning a knob and moving a 'slider'. In this case we have seen resistance change by using different intensities of light. This means we can make a voltage divider or a variable resistance that works with the amount of light falling on an LDR.

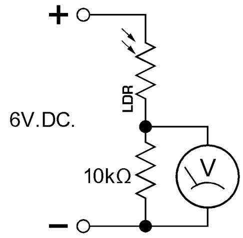
In electronic circuits, this would be useful to automatically turn lights on and off when it becomes dark or light. Or to ring a bell if a light beam were broken across the entry door to a shop, or to make a burglar alarm if the burglar walked through the light beam and stopped the light reaching the LDR.

Think of other uses.

R9: Measuring light intensity using an LDR

Light Dependent Resistor (LDR).





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Resistor 10k (10,000 ohm)
- 1x LDR Resistor

Connect the circuit as shown above

Aim: To make an electronic circuit that will measure the brightness of a light by using a voltmeter. To connect an LDR in series with a fixed value resistor to create a voltage divider. To measure the voltage across the fixed resistor which will change as the LDR changes its resistance with the brightness of the light.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a LDR resistor. Set regulator to 6V.DC. Set multimeter to 20V DC.

Experiment: Cover the LDR with a piece of cardboard and check and note the voltage appearing across the fixed resistor. Remove the cardboard and check and note the voltage across the fixed resistor.

Now take the 'Light Source' from the kit and take two 2mm banana plug cables to connect it to the power source. Plug the banana plugs into the top of the existing plugs fitted to the power source (piggy-back the plugs). Check the polarity (the + and – connections). Position the Light Source so the bright white light falls on the face of the LDR. Check and note the voltage across the fixed resistor.

Move the light source further away from the LDR. Try different positions.

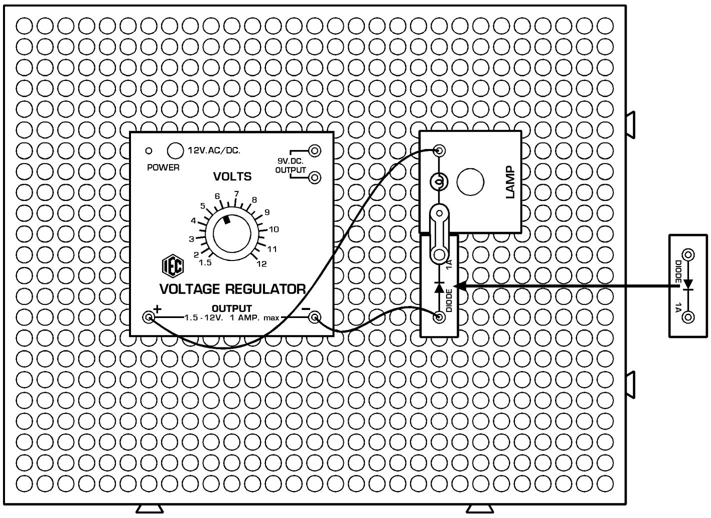
Measure the voltage across the resistor and then measure the voltage across the LDR too. Notice the two voltages add together to equal the power source voltage (a voltage divider).

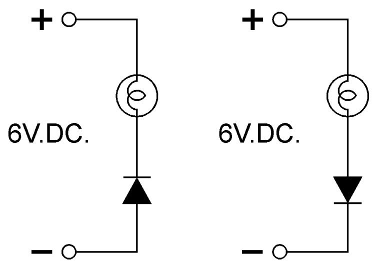
Conclusion: In earlier experiments, we have seen a voltage change by turning a knob and moving a 'slider'. In this case we have seen voltage change by using different intensities of light. This means we can make an instrument to measure the amount of light present.

In electronic circuits, this would be useful to measure the amount of light in an office to check if there is enough light to work and read properly.

Think of other uses.

D1: Diode, direction of conduction





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Diode
- 1x Lamp

Connect the circuit as shown above

Aim: To discover the function of a Diode. A diode carries current in one direction only and blocks the flow of current in the opposite direction. If current flows, the lamp should come on and if blocked the lamp should be off. Also to discover if it is important which direction current flows through a lamp.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a lamp and a diode in series. Set regulator to 6V.DC.

Experiment: Turn off the power (or remove one plug from power source) and connect the circuit with the positive (+ve) connection of the power source connected to the lamp and the other side of the lamp connected to the diode with the arrow pointing towards from the lamp. The current from the power source will always try to flow from the positive connection to the negative connection.

Turn ON the power source (insert the plug) and check if the lamp glows or not.

If NO, the current cannot flow in this direction through the diode.

Now turn off the power source, remove the diode and reverse its position so the arrow points away from the lamp. Turn ON the power source and check if the lamp glows or not.

If YES, the current can pass through the diode in that direction.

Leave the connections as they are and reverse the positive and negative connections from the power source. The current will now try to flow the opposite direction around the circuit.

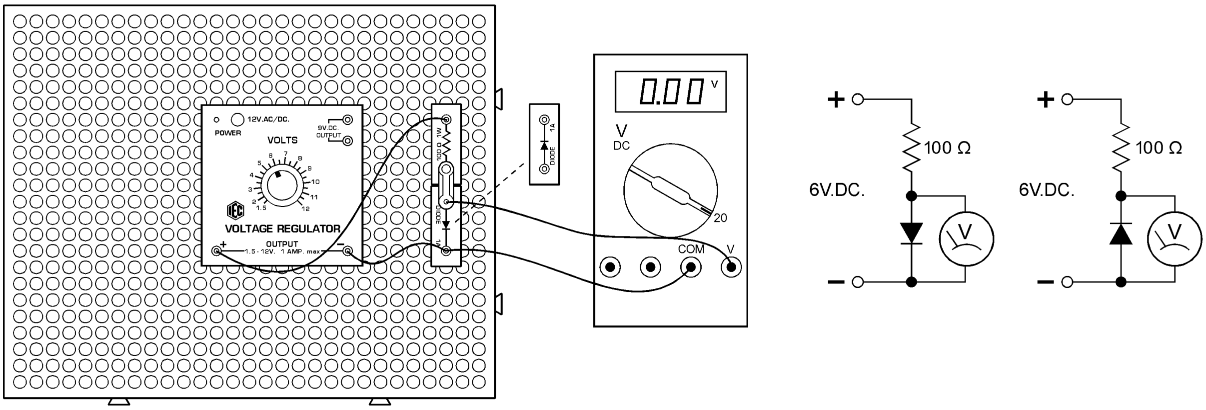
Check if the current flows. If NOT, reverse the diode like before. If the current flows now the lamp will glow.

What have you noticed about the arrow direction on the diode ?

Conclusion: We have made the current flow in both directions in the circuit and the lamp can glow either way. This means the lamp does not change its behaviour in either direction that the current flows. But the diode can carry current only in one direction and it stops the current flow in the other direction.

The ARROW symbol on the diode shows the direction that the current can flow.

D2: Forward voltage of a silicon diode



Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Resistor 100 ohms
- 1x Diode

Connect the circuit as shown above

Aim: To check if a diode completely blocks current in the reverse direction and to check if a silicon diode completely conducts current in the forward direction. Most diodes are made from silicon and are called 'Silicon Diodes'. Other types of diodes are made from Germanium and various other semiconductor materials.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a resistor and a diode in series. Set regulator to 6V.DC.

Experiment: Turn off the power source (or remove one banana plug). Check the circuit and notice that the direction of the diode and the connections to the power source are made so the current will flow from the positive connection of the power source, through the resistor and through the diode in the direction of the arrow symbol.

If the diode conducts current perfectly (say like a piece of wire), there should be zero resistance in the diode and there should be zero volts measured across the diode.

Turn on the power source and measure the voltage across the diode. Is it zero volts ? Therefore, does the diode conduct perfectly ?

This voltage across the diode in the conducting direction is called the 'Forward Volt Drop' of a diode.

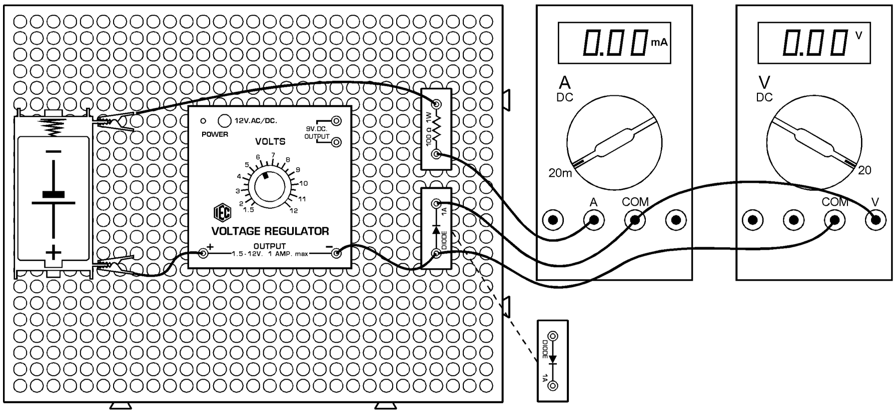
Now turn off the power source and reverse the diode in the circuit. Turn on the power source. What is the voltage across the diode ? Use the voltmeter to check the power source voltage. Notice they are exactly the same. This means there is zero current flowing through the fixed resistor and the diode is completely blocking the flow of current in this reverse direction. Check the voltage across the fixed resistor – it should be zero.

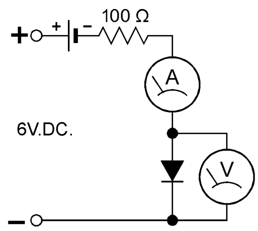
Conclusion: We have discovered that the diode is a perfect block for reverse current direction but is not a perfect conductor in the forward direction (direction of the arrow).

The forward voltage drop of about 0.6V to 0.7V means that full current will not flow through a diode in the forward direction until it exceeds this voltage. If 0.5V is applied to a silicon diode, full current will not flow through it, but if 0.8V is applied, full current will flow.

Also in any electronic circuit that has a silicon diode, there will always be a loss of voltage of about 0.6V to 0.7V across each diode. Two diodes in series require 1.2V to 1.4V before current can flow through them ….. etc..

D3: Characteristic curve of a silicon diode





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Dry cell battery
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Resistor 100 ohms
- 1x Diode

Connect the circuit as shown above

Aim: In the previous experiment, we saw that full current cannot flow through a silicon diode until the voltage reaches about 0.6 to 0.7V. But very small current does flow below this voltage and the aim of this experiment is to investigate this small current. We will be taking several readings of the very small current flowing through a silicon diode in the forward direction up to the point where it begins to fully conduct (up to 0.7V).

We will then make a graph of the voltage (X axis) against the current (Y axis).

Settings: The power source has a minimum voltage of 1.3V, so we are placing a dry cell backwards into the circuit to subtract 1.5 volts from the power source to cause the voltage go to below zero volts. Connect circuit as shown above with a 100 ohm resistor and a diode in series. Set voltmeter to 20V and ammeter to 20mA ranges.

Experiment: Turn the power source voltage slightly so the voltmeter reads exactly zero volts and the ammeter reads zero mA. Slowly raise the voltage to 0.1V and take note of the volts and the mA. Then raise the volts to 0.2V and take note of the mA. Continue in 0.1V increments up to 1.5V.

Take a graph pad and plot the points you have measured. Use volts on the X axis against the current in milliamps (mA) on the Y axis.

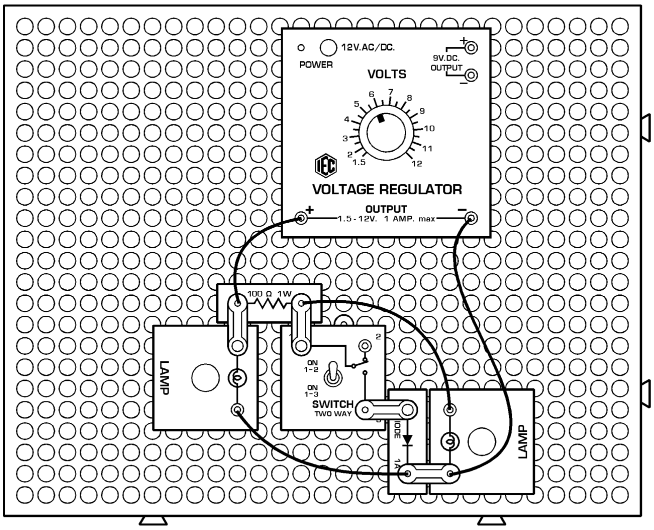
Join the plotted points to form a graph of the voltage / current characteristic curve of a silicon diode.

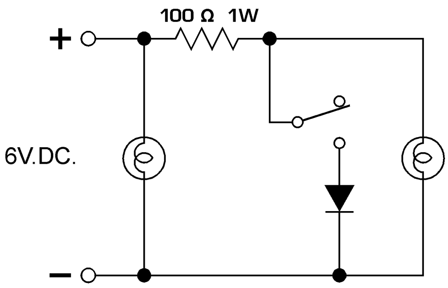
If a Germanium diode were used instead of a silicon diode, the current begins to rise rapidly at about 0.2V instead of 0.6 / 0.7V. This means that Germanium diodes have a much lower forward volt drop than silicon diodes.

Conclusion: In silicon diodes, below 0.7V, a very small current flows in the forward direction and it increases with voltage. At about 0.6V to 0.7V the diode begins to conduct fully and current rises very quickly as the voltage increases slightly.

The relationship between the current and the voltage across a diode is called the **Characteristic Curve** of the diode.

D4: Diodes as protection devices





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Switch
- 2x Lamps
- 1x Diode
- 1x Resistor 100 ohms

Connect the circuit as shown above

Aim: To use a diode as a protection device to ensure that the voltage applied to a device cannot rise above the forward voltage of a silicon diode (0.7V). With the switch open, there is no protection applied to the second lamp. With the switch closed a diode is placed in parallel with the second lamp.

Settings: The voltage source is set to about 6V.DC

Experiment: Turn the switch OFF (open circuit) so the diode is not connected across the second lamp. Turn on the power source and see that both lamps glow with close to equal brightness. Each has about 6V applied.

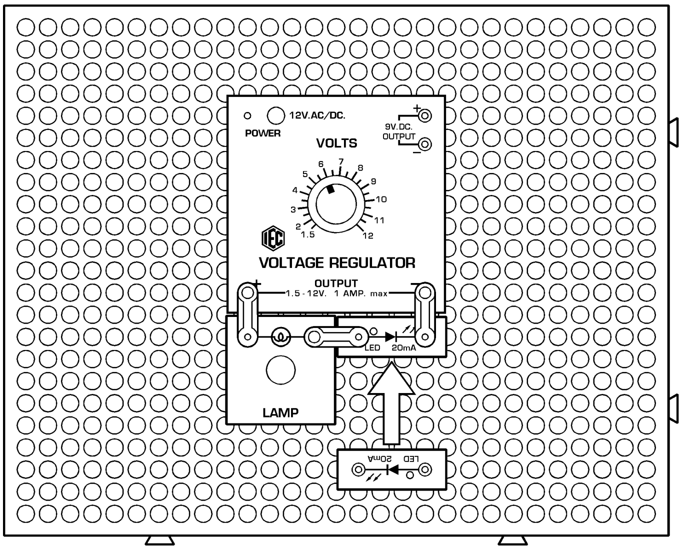
Note that the second lamp has the 100 ohm resistor in series but the voltage drop caused by this resistor is small and its effect can be ignored.

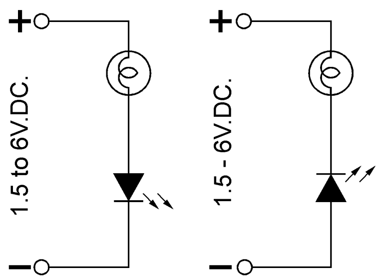
Now switch the diode into circuit across the second lamp. See that the lamp goes OFF. The diode carries the current and only the forward drop of the diode (0.7V) is being applied to the lamp.

Explanation: When this can be used ? If the second lamp was an ammeter and if there was no diode, a voltage of about 6V would be applied to it and a heavy current would flow which would damage the meter. With the diode connected, the diode carries the heavy current and protects the meter by limiting the voltage to the meter to 0.7V. Meters often have protection diodes connected internally because, when measuring, the voltage across the meter's sensitive circuits is always much less than 0.7V and the diode does nothing. If the voltage rises however, the diode begins to conduct to protect the meter from higher voltages.

Conclusion: Diodes have several uses. Mainly they are used to carry current in one direction only. They do not conduct perfectly and this small voltage that is always across a diode can be used as a protection for other devices.

D5: Light Emitting Diode (LED)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Lamp
- 1x LED (Light Emitting Diode) any colour.

Connect the circuit as shown above

Aim: To show the behaviour of a Light Emitting Diode when connected in the forward and in the reverse directions.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. The voltage source is set to minimum (about 1.5V.DC.).

Experiment: With the LED connected in the forward direction (current flowing in the direction of the arrow), raise the voltage slowly from minimum and note that both the lamp and the LED begins to glow when the voltage reaches about 3V.DC. **Do not raise the voltage any higher than about 6V.DC. or the current will damage the LED.**

Now reverse the connection of the diode and try again. Note that there is no current flowing and the LED does not glow.

Normally, an LED always has a resistor in series to limit the current through it. If a 1k (1,000 ohm) resistor is used instead of the lamp, the voltage can be raised to about 12V safely because only about 10mA will be flowing through the LED.

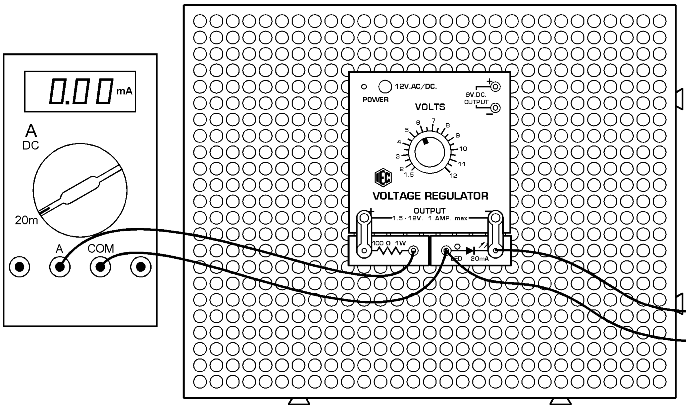
Try it and see.

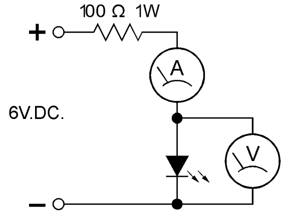
Conclusion: An LED is a diode that behaves similar to a normal diode except that light is emitted when current flows in the conducting direction. The current through an LED should be limited by a resistor so it cannot exceed say 10 to 20mA.

Notice that there is no heat generated and the efficiency of an LED is very high because almost all the electrical energy is converted to light instead of heat.

Notice that when a lamp is run at full voltage (6V) heat can be felt coming from the lamp.

D6: Forward voltage of a Light Emitting Diode (LED)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Resistor 100 ohms
- 1x LED (Light Emitting Diode) any colour

Connect the circuit as shown above

Aim: To check if a Light Emitting Diode (LED) completely conducts current in the forward direction or is there a forward voltage drop, similar to a normal silicon diode.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with a resistor and an LED in series. Set regulator to 6V.DC. Set the ammeter to 20mA.DC. and voltmeter to 20V.DC.

Experiment: Turn off the power source (or remove one banana plug). Check the circuit and notice that the direction of the LED and the connections to the power source are made so the current will flow from the positive connection of the power source, through the resistor and through the LED in the direction of the arrow symbol.

If the diode conducts current perfectly (say like a piece of wire), there should be zero resistance in the LED and there should be zero volts measured across the LED.

Turn on the power source and measure the voltage across the LED. Is it zero volts ? Therefore, does the LED conduct perfectly ?

This voltage across the LED in the conducting direction is called the 'Forward Volt Drop' of an LED. Different colours of LED have different forward voltage drops.

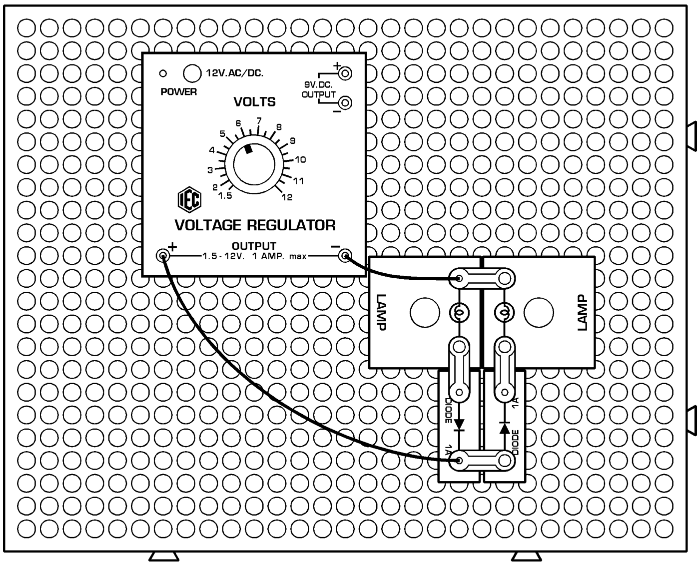
Now turn off the power source and reverse the LED in the circuit. Turn on the power source. What is the voltage across the LED ? Use the voltmeter to check the power source voltage. Notice they are exactly the same. This means there is zero current flowing through the fixed resistor and the LED is completely blocking the flow of current in this reverse direction. Check the voltage across the fixed resistor – it should be zero.

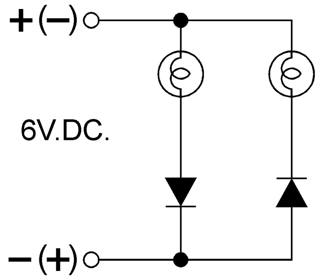
Conclusion: We have discovered that the LED is a perfect block for reverse current direction but is not a perfect conductor in the forward direction (direction of the arrow).

The forward voltage drop of about 1.5V means that full current will not flow through an LED in the forward direction until it exceeds this voltage. If 1.2V is applied to an LED, full current will not flow through it, but if 1.5V or more is applied, full current will flow.

Also in any electronic circuit that has an LED, there will always be a loss of voltage of about 1.5V across each LED. Two LEDs in series require 3V before current can flow through them … etc..

D7: Using Diodes and Lamps to indicate polarity





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Lamps
- 2x Diodes

Connect the circuit as shown above

Aim: To apply forward polarity and then reverse polarity to the circuit to show that lamps can be used to detect polarity applied to a circuit.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Connect circuit as shown above with diodes facing opposite ways and with lamps in series with the diodes. Set regulator to 6V.DC.

Experiment: First apply power with the positive terminal from the power source connected to the top connection of the circuit. Notice that one lamp is ON and the other lamp is OFF.

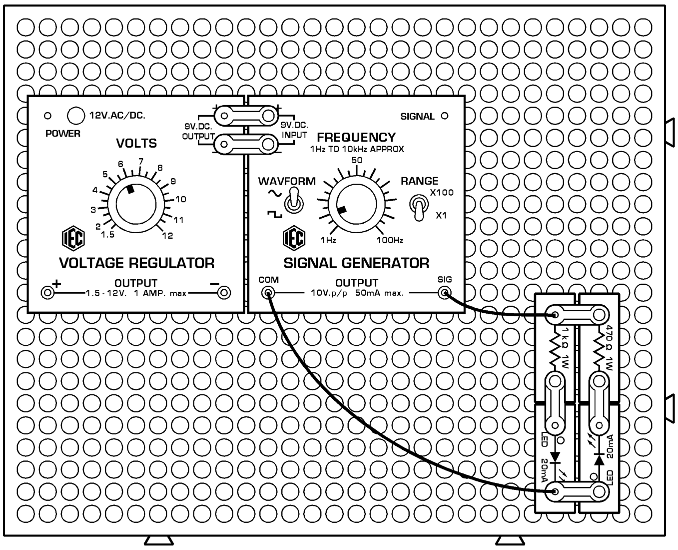
Notice that the lamp that is ON is carrying current in the same direction as the arrow marking on the diode.

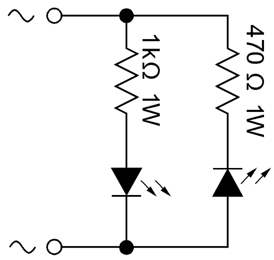
Now disconnect and reverse the connections from the power source to the circuit.

Notice that the other lamp is now ON and the first lamp is now OFF. Note that the current is now flowing in the arrow direction of the second diode.

Conclusion: We have discovered that that 2x lamps and 2x diodes can be used as a polarity checker.

D8: Using AC. Show reversal of current by using LEDs





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator to provide AC sine wave.
- 2x Resistors 1k and 470 ohm
- 2x LEDs (Light Emitting Diodes) any colour.

Connect the circuit as shown above

Aim: To apply Alternating Current (AC) to the circuit to show the forward and reverse sections of the AC wave passing through the two LEDs. To see effects at different frequencies.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. Use 2x links to connect 9V.DC. from the Voltage Regulator to the Signal Generator. Connect circuit from the Signal Generator as shown above with 2x LEDs with resistors in series. There is no need to set the regulator.

Experiment: Turn Signal Generator to the lowest frequency and select X1 on frequency switch and 'Sine' on the waveform switch. With these settings, the markings around the knob will show directly the frequency supplied to the circuit.

If you have access to an Oscilloscope, connect the Signal Generator and inspect the two types of wave (sine and square). See the frequency of the wave change as the knob is turned.

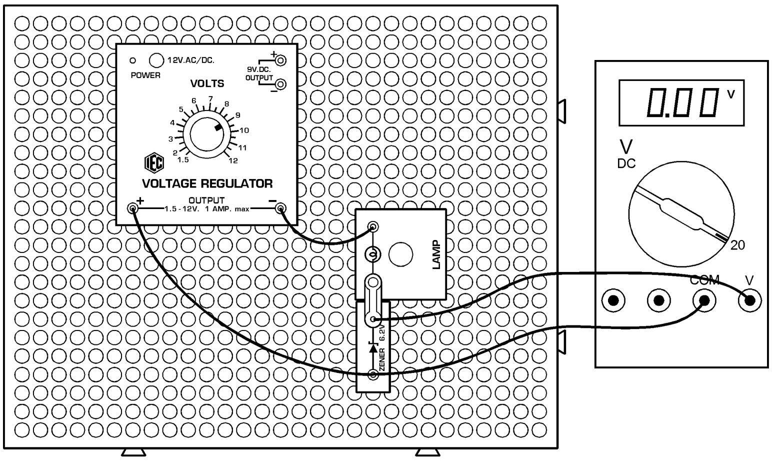
As the AC wave of the applied voltage rises, passes through zero to a positive peak, then falls and passes through zero to a negative peak and the rises again over and over, each LED will indicate the direction that the current is flowing in the circuit. Notice the LEDs glow gradually as the current rises to follow the sine shaped wave.

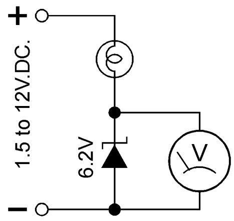
Change the Signal Generator wave form to be a 'Square Wave'. A square wave rises to maximum suddenly, remains at maximum for a period then suddenly falls to minimum for period, the rises suddenly to maximum etc….. Notice the LEDs suddenly switching ON and OFF as the square wave reverses polarity.

Raise the frequency and notice that the LEDs blink faster but will appear to be on steady as the human eye cannot respond quickly enough to the switching.

Conclusions: In an AC circuit, current moves forward and reverse through the components. Two LEDs can be arranged to monitor this effect. A sine wave changes the voltage gradually and a square wave changes voltage suddenly from froward to reverse. The human eye cannot respond to rapid blinking and, as the frequency rises, the blinking blurs into a steady glow.

D9: Operation of a Zener Diode





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Lamp
- 2x Zener diode 6.2V

Connect the circuit as shown above

Aim: To learn the differences between Zener Diodes and normal diodes. To monitor the voltage across a zener diode as the voltage is raised to examine its behaviour.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. With volts on minimum, connect the power to the lamp and zener in series.

Explanation: With voltage applied to a zener diode in the forward direction (current flowing in the direction of the arrow), it behaves like a normal diode and conducts with a forward volt drop of about 0.7V. In the reverse direction, the current is blocked like a normal diode, but only up to a certain voltage. After this voltage, the zener diode will conduct heavily in reverse.

Experiment: Observe the volts on the meter with the power source on minimum. Observe also if the lamp glows. Gradually raise the voltage to the circuit until the lamp suddenly glows. This observation tells us that current cannot flow until a certain voltage is reached.

What voltage must be applied to this zener diode before current can flow ?

Increase the voltage further.

What do you notice about the voltage across the zener diode ?

Although the voltage across the zener remains constant, the current through the lamp increases as the power source voltage increases because the zener diode will carry current providing the applied voltage exceeds its ‘zener voltage’.

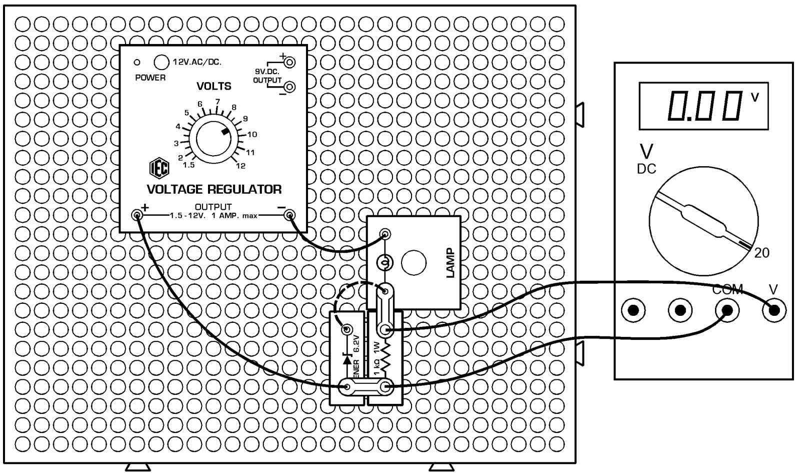
NOTE: Zener diodes can be obtained for many different ‘zener voltages’ up to hundreds of volts.

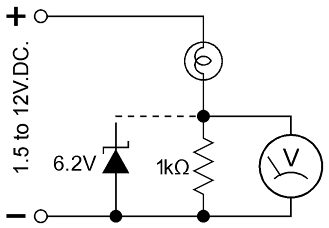
Conclusions: A zener diode is a special diode that ‘breaks over’ in the reverse direction at a particular voltage. This behaviour make them very useful for:

1) Protecting circuits from damage due to excessive voltages

2) For creating steady voltages from varying voltages (stabilised voltage).

D10: Zener diode as a Voltage Regulator (stabiliser)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Lamp
- 1x Resistor 1k (1,000 ohm)
- 1x Zener diode 6.2V

Connect the circuit as shown above

Aim: To connect a lamp and resistor in series and measure the voltage across the resistor as the supply voltage is varied. Then to apply a zener diode across the resistor to make a voltage regulator (voltage stabiliser). Then check that voltage across the resistor remains steady even when the supply voltage varies.

Settings: Voltage regulator is the power source and is powered from 240/12V Plug Pack. With volts on minimum, connect the power to the lamp and resistor in series.

Experiment: With the zener diode NOT connected, raise the supply voltage and check the voltage across the 1k resistor. Note that the voltage changes with the applied voltage and is almost the same as the supply voltage. Note also that there is not enough current flowing through the 1k resistor to illuminate the lamp.

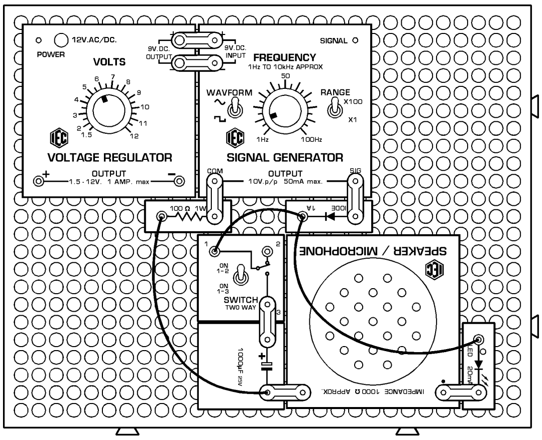
Now reduce the voltage and connect the zener diode across the resistor.

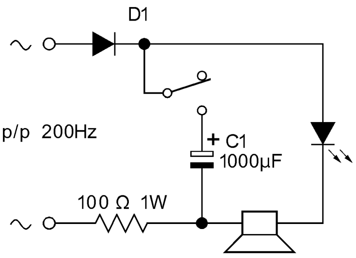
Again measure the voltage across the resistor as the supply voltage is raised. Note that when the voltage rises above the ‘zener voltage’, a heavier current flows through the zener diode to make the lamp glow. The lamp is behaving as a ‘dropping resistor’ to permit the supply voltage to fall to the ‘zener voltage’ of the diode. Note that the voltage across the resistor remains at the ‘zener voltage’ providing the supply voltage is always higher.

NOTE: Our circuit used a lamp as a dropping resistor to the zener diode so that current can be seen to flow and to change, but normally a fixed resistor would be used.

Conclusions: A zener diode is a special diode that ‘breaks over’ in the reverse direction at a particular voltage. If a dropping resistor and a zener diode is applied in a circuit, a steady voltage (the ‘zener voltage’) can be created to operate another circuit that requires a steady or stabilised voltage.

D11: Half Wave rectifier using diode (with filtering)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator for sine & square waves
- 1x Speaker
- 1x Resistor 100 ohm
- 1x Capacitor 1,000uF
- 1x Switch
- 1x LED (any colour)
- 1x Diode

Connect the circuit as shown above

Aim: To feed AC current into one diode to make 'half wave' DC current. Then pass this current through a speaker so we can hear the pulses. As the speaker pulses, the LED in series with the speaker should blink ON and OFF.

Explanation of 'Half Wave' and 'Full Wave' rectification: When the positive half of the AC wave passes through the diode and the speaker, a pulse can be heard and seen on the LED. The LED does not pulse during the negative half of the AC cycle. Therefore, since only one half of the AC wave passes through the diode, this type of rectification is called 'Half Wave' rectification.

NOTE: Other types of rectifier arrangements (see later diode experiments) can pass both the positive and negative halves of the AC wave but they change the negative half wave to a positive half wave. So, all half-waves become positive and therefore they are Direct Current. This is called 'Full Wave' rectification.

Settings: Set the Signal Generator to the slowest frequency and select sine waveform. See the LED on the output pulse once per positive half of the AC cycle.

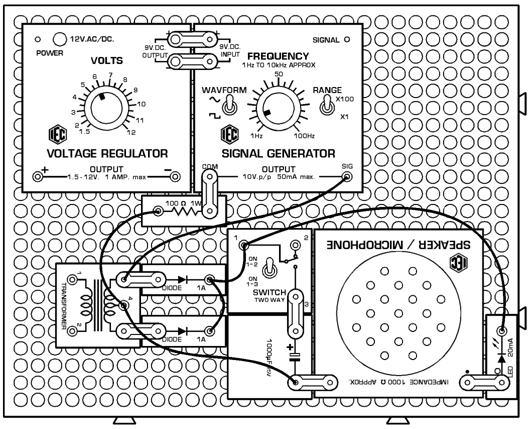
Experiment: Raise the Signal Generator sine wave frequency to hear the pulses (a tone) in the speaker. Change to square wave output to hear the sharper tone because the speaker cone moves more suddenly.

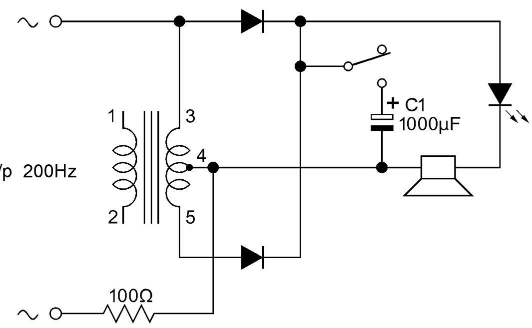
Experiment for filtering: Turn the Signal Generator to about 50Hz so that there are 50 pulses heard in the speaker per second. Close the switch so the capacitor is connected across the speaker. The capacitor absorbs the pulses of energy and releases this stored energy when the pulse is not there. In this way, it 'smooths out' the DC half wave. The speaker should sound much softer.

Conclusions: A single diode can change AC (Alternating Current) into DC (Direct Current) but only half of the AC wave passes and the other half is lost.

A large value capacitor can be used to absorb the peaks and fill the troughs of the waveform to 'smooth' the voltage to become closer to a battery (which is perfectly smooth DC).

D12: Full Wave rectifier using 2 diodes (with filtering)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator for sine & square waves
- 1x Transformer with centre tap winding
- 1x Speaker
- 1x Resistor 100 ohm
- 1x Capacitor 1,000uF
- 1x Switch
- 1x LED (any colour)
- 2x Diodes

Connect the circuit as shown above

Aim: To feed the centre point of a transformer coil with AC current to create two positive pulses from the positive and negative AC waveform. Then to rectify BOTH halves of the AC wave to form a 'full wave' DC rectifier. Then to apply a capacitor to filter the full wave DC waveform to make it smoother.

Settings: Set the Signal Generator to the slowest frequency setting and select Sine wave output. As in the previous experiment, the LED will monitor current through the speaker and the capacitor can be switched to 'smooth' the DC waveform.

Experiment: The positive half of the AC wave passes through diode, the LED, the speaker and back to the power source through the resistor. The current passes also through the half of the transformer winding between 3 & 4 which induces a reverse voltage on the other half of the transformer between 4 & 5. This reverse voltage cannot pass through diode #2.

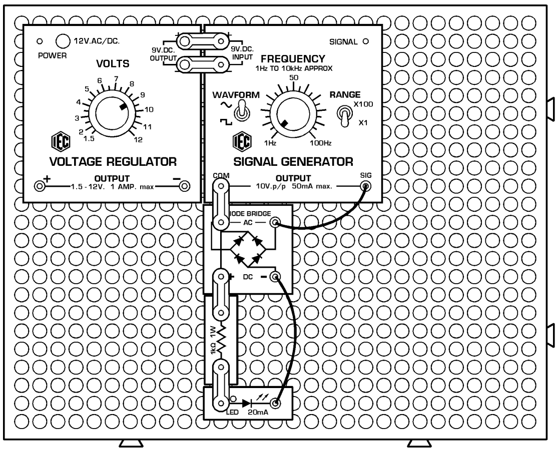
When the AC wave reverses, the current cannot pass through diode #1 but the reverse voltage appearing between 4 & 5 can pass through diode #2. Therefore, BOTH halves of the AC waveform have passed through diodes to become DC. This is called 'full wave' DC.

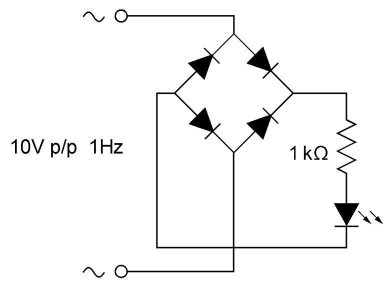
If the Signal Generator is increased to 50Hz, the speaker will sound a tone of 100Hz because both halves of the AC wave are present. Remember in the previous experiment that half wave rectification provided only 50 pulses/second in the speaker.

Switch in the capacitor and the speaker will be quite silent because it is easier to filter full wave DC to be 'smooth' than half wave DC.

Conclusions: A full wave rectifier is more efficient that a half wave rectifier because BOTH halves of the AC wave pass and all the energy available in the AC wave can be used. Also it is easier to filter full wave DC than half wave DC because it has more pulses and less empty spaces to fill.

D13: Full Wave rectifier using 4 diodes (Bridge Rectifier)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator for sine & square waves
- 1x Resistor 1,000 ohm
- 1x Bridge Rectifier (made from 4x diodes)
- 1x LED (any colour)

Connect the circuit as shown above

Aim: The kit has a bridge rectifier made with LEDs monitoring each of the 4 diodes. When current flows through a diode, its LED glows. The LED on the output will glow each time current passes. We will use the Signal Generator as the power source and set very slow so the pulses of current can be easily seen.

Settings: Set the Signal Generator to ‘sine’ wave and select the x1 (slowest) frequency. The 1,000 ohm resistor is there to limit the current through the LED.

Experiment: AC (Alternating Current) is applied to a bridge rectifier and when the sine wave is positive, the current passes through one diode, passes through the circuit and returns back to the power source through another diode. This means that 2 diodes in the bridge are conducting at the one time. Look at the LEDs indicating which diodes are conducting.

When the sine wave is negative, the current passes through the other 2 diodes in the bridge.

Start the Signal Generator at the slowest speed and follow the path of the current for the positive and negative halves of the AC sine wave. **NOTE:** If the reversals of the AC are too quick for study, use the Regulator or batteries instead of the Signal Generator to provide a steady voltage, then reverse the connections to simulate the reversal of the AC sine wave. The LEDs will show which diodes are conducting at any time. When the bridge rectifier circuit is understood, the Signal Generator can be reconnected.

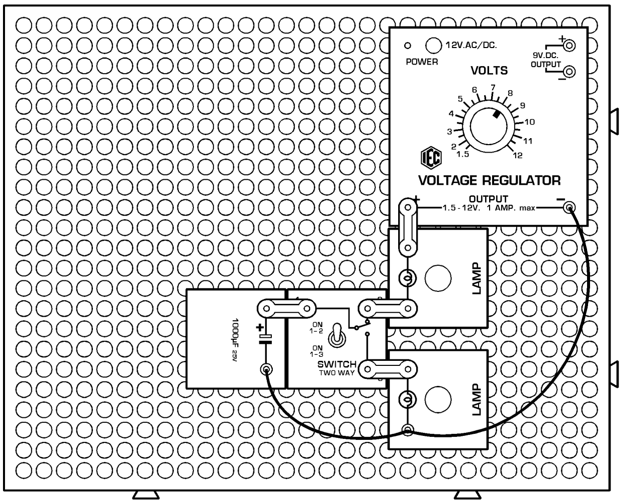
The LED demonstrates that the current flowing OUT of the bridge rectifier is always flowing in the same direction to make the LED glow for each pulse. It proves that the bridge is converting AC into full wave DC current.

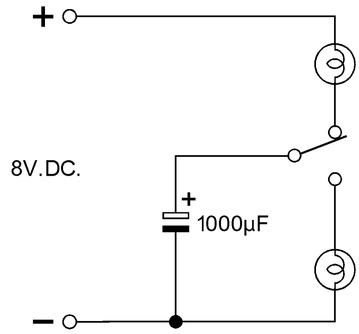
EXTRA: If an Oscilloscope is available, examine the AC sine wave into the bridge and see the DC wave out of the bridge to fully understand the meaning of ‘full wave’ rectification.

Conclusions: A bridge rectifier is made from 4 diodes and there are always 2 diodes in series. This means there is a forward volt drop in the bridge of 1.4 volts (2x diode drops).

A bridge rectifier permits a full wave rectification with the simplest connection of 2 terminals for AC IN and 2 terminals for DC OUT.

C1: Capacitors, DC charge and discharge





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Switch
- 1x Capacitor 1,000uF
- 2x Lamps

Connect the circuit as shown above

Aim: To demonstrate the charging of a capacitor from a power source and the discharging of a capacitor into a load (a lamp).

Settings: Set the Regulator to about 8V.DC. Take care regarding the polarity of the capacitor.

Note: This large capacitor is NOT bi-polar. This means it has a polarity and must be charged in one direction only. The +/- marking is on the capacitor label and be sure polarity is correct.

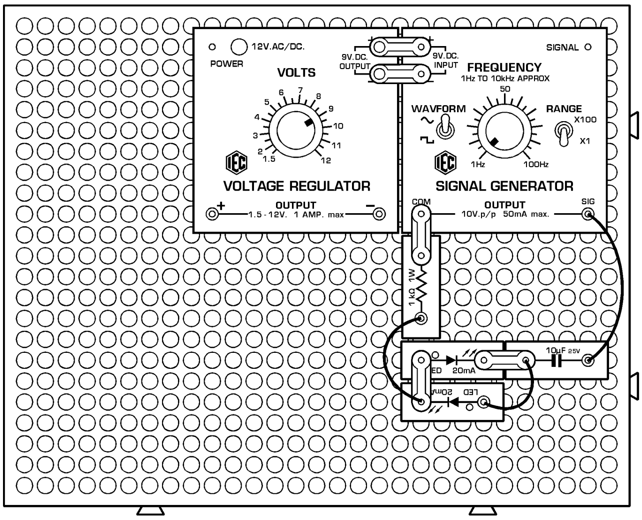
Experiment: Select to connect the capacitor to the lamp from the power source. This lamp limits the current into the capacitor during charging. A pulse of current will flow into the capacitor and it will charge up to the same voltage as the power source. It will store this electrical energy.

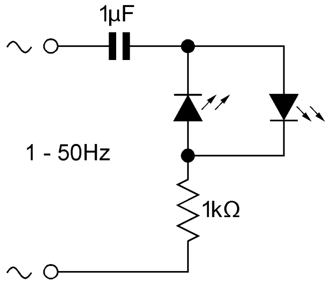
Switch the charged capacitor to connect with the other lamp. The energy stored inside the capacitor will discharge through the lamp and it will be seen to blink ON momentarily as the capacitor dumps its charge.

Note that the blink of the lamp when charging the capacitor is about the same as the blink during discharging the capacitor.

Conclusions: A capacitor is a device that can be charged with electrical energy and can store it. This energy can be recovered by discharging the capacitor into a load.

C2: Capacitors, AC charge and discharge





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator for sine & square waves
- 1x Capacitor 1uF
- 1x Resistor 1k (1,000 ohm)
- 2x LEDs (any colour)

Connect the circuit as shown above

Aim: To use the Signal Generator as an AC power source. To very slowly repetitively charge and discharge a capacitor while watching the LEDs to check the direction of the current flow.

Settings: Set the Signal Generator to the slowest frequency (x1) and select 'sine' waveform.

Note: This capacitor is bi-polar. This means it does not have a polarity and can be charged in either direction. This must not be done with capacitors that have + / - polarity marked on the label.

Experiment: Apply the AC sine wave signal from the signal generator and see the LEDs blink on and off as the direction of the current in and out of the capacitor changes. The LEDs are monitoring the currents flowing for charging to one polarity of the AC waveform and then discharging and recharging to the opposite polarity of the AC waveform.

Increase the frequency gradually and notice that the charging and discharging continues but at a faster and faster rate.

Increase the frequency until your eye can no longer see the blinking and the LEDs appear to be on continuously.

Change the signal generator to 'square wave' and see if there is a difference in the current flow.

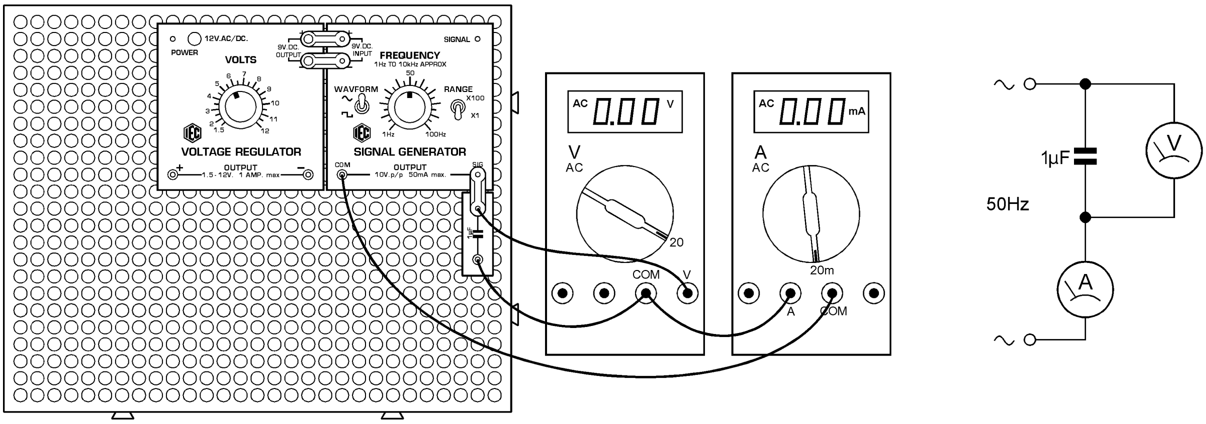
Explanation: The LEDs are still blinking ON and OFF, but the human eye has 'persistence'. This means it takes some time for the human eye to respond to a change in image. For this reason, the blinks appear to run together into a continuous blur.

Check the frequency that makes your eyes see a continuous light from the LEDs.

Check different students to see if everyone's eyes have the same persistence.

Conclusions: A capacitor is a device that can be charged and discharged repetitively. We have proved that current flows into the capacitor as it charges and current flows out of the capacitor as it discharges to charge the opposite direction.

C3: A Capacitor behaving as an 'AC resistor'



Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator for sine & square waves
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Capacitor 1uF

Connect the circuit as shown above

Aim: To use the Signal Generator as an AC power source. To repetitively charge and discharge a capacitor while measuring the AC voltage across it and measuring the AC current flowing through it. To use Ohm's Law to calculate the 'AC resistance' of a capacitor. The correct name for this is 'Reactance' of the capacitor.

Settings: Set the Signal Generator to about 50Hz and select 'sine' waveform. Select 20V.AC. on the voltmeter and 20mA.AC.on the ammeter.

Note: This capacitor is bi-polar. This means it does not have a polarity and can be charged in either direction. This must not be done with capacitors that have + / - polarity marked on the label.

Experiment: Apply the AC power and measure the AC volts and the AC amps. Use Ohm's Law to calculate the AC resistance of a 1uF capacitor. R (ohms) = V / A (1mA = 0.001Amp)

The result is in Ohms and is called the 'Reactance' of the capacitor.

The formula for calculating the Reactance of a capacitor is: $R = 1 / (2\pi\ f C)$, where R is the reactance in ohms, f is the frequency in Hz and C is the capacitance in **Farads.**

Note: 1,000,000uF (microfarad) = 1F (Farad)

R (ohms) = 1 / (2π x 50 (Hz) x 0.000001F (1uF)) = 3,183 ohms

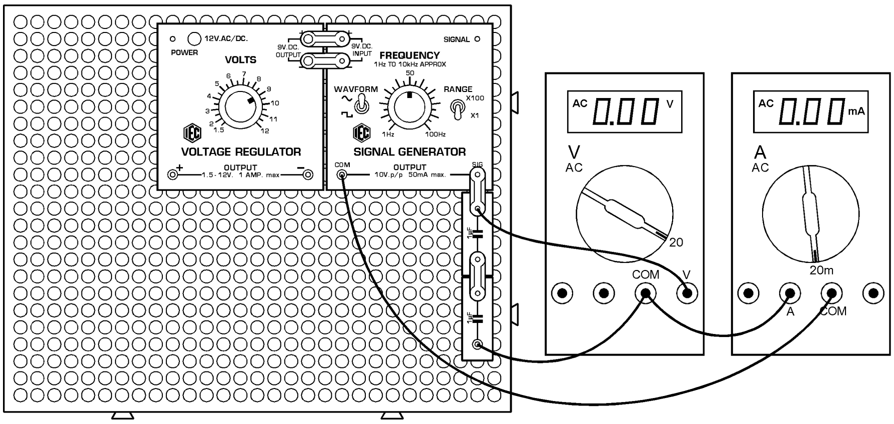
Compare this result with the result you obtained by using the meter readings and Ohm's Law.

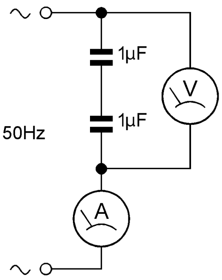
NOW, increase the frequency from the Signal Generator to 100Hz and repeat the above measurements and calculations. What do you notice ? Try other frequencies.

Now reduce the frequency to zero. What do you notice ?

Conclusions: A capacitor is a device that can be charged and discharged repetitively and the reactance in the circuit depends on the Capacitance (uF) and Frequency (Hz). If the frequency is increased, the reactance falls. If the capacitance is less, the reactance rises. If the frequency is decreased to zero, this is DC and the capacitor blocks completely (reactance becomes infinity).

C4: Capacitors in series (capacitive reactance)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator for sine & square waves
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 2x Capacitors 1uF

Connect the circuit as shown above

Aim: To use the Signal Generator as an AC power source. To repetitively charge and discharge two capacitors in series while measuring the AC voltage across them and measuring the AC current flowing through them. To use Ohm's Law to calculate the 'AC resistance' of the two capacitors in series. The correct name for this is 'Reactance' of the capacitor.

Settings: Set the Signal Generator to about 50Hz and select 'sine' waveform. Select 20V.AC. on the voltmeter and 20mA.AC.on the ammeter.

Experiment: Apply the AC power and measure the AC volts and the AC amps. Use Ohm's Law to calculate the AC resistance of 2x 1uF capacitors in series. R (ohms) = V / A (1mA = 0.001Amp)

Refer to the previous experiment and refer to the formula for capacitive reactance.

Question: Is your measured reactance larger or smaller than 1uF capacitor in the previous experiment ?

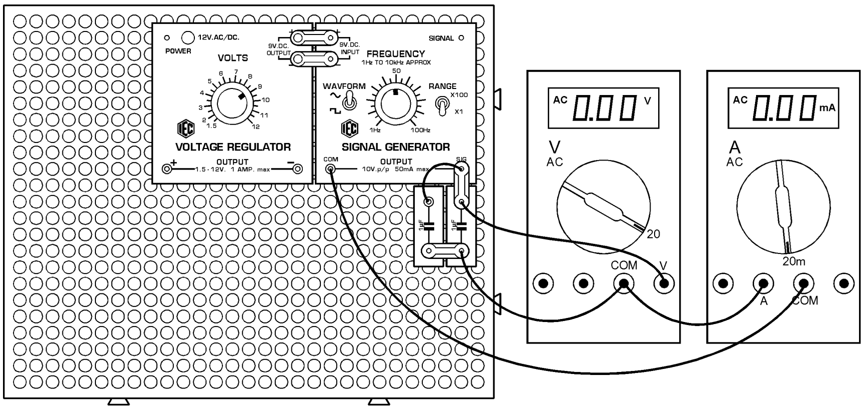
Look carefully at the formula $R = 1 / (2\pi\ f C)$. If the reactance R is larger, the capacitance C must be smaller. If the reactance is about double, this means the capacitance must be about half.

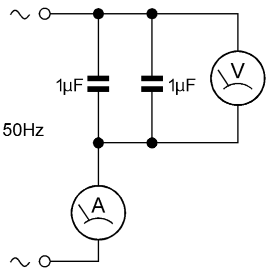
RULE: If capacitors are placed in series the capacitance value reduces in uF. This is the opposite to resistors in series where the resistors combine to become a larger value.

For Example: If 3x equal value capacitors are placed in series, the total capacitance becomes 1/3rd of the one capacitor. But the reactance becomes 3 times the reactance of one capacitor.

Conclusions: Capacitors in series reduce the total capacitance. If the capacitance reduces, the reactance (in ohms) increases. Therefore, capacitance value behaves the opposite to resistors, but the reactance value behaves the same as resistors.

C5: Capacitors in parallel (capacitive reactance)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator for sine & square waves
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 2x Capacitors 1uF

Connect the circuit as shown above

Aim: To use the Signal Generator as an AC power source. To repetitively charge and discharge two capacitors in parallel while measuring the AC voltage across them and measuring the AC current flowing through them. To use Ohm's Law to calculate the 'AC resistance' of the two capacitors in parallel. The correct name for this is 'Reactance' of the capacitor.

Settings: Set the Signal Generator to about 50Hz and select 'sine' waveform. Select 20V.AC. on the voltmeter and 20mA.AC.on the ammeter.

Experiment: Apply the AC power and measure the AC volts and the AC amps. Use Ohm's Law to calculate the AC resistance of 2x 1uF capacitors in parallel. R (ohms) = V / A (1mA = 0.001Amp)

Refer to the previous experiment C3 and refer to the formula for capacitive reactance.

Question: Is your measured reactance larger or smaller than 1uF capacitor in the previous C3 experiment ?

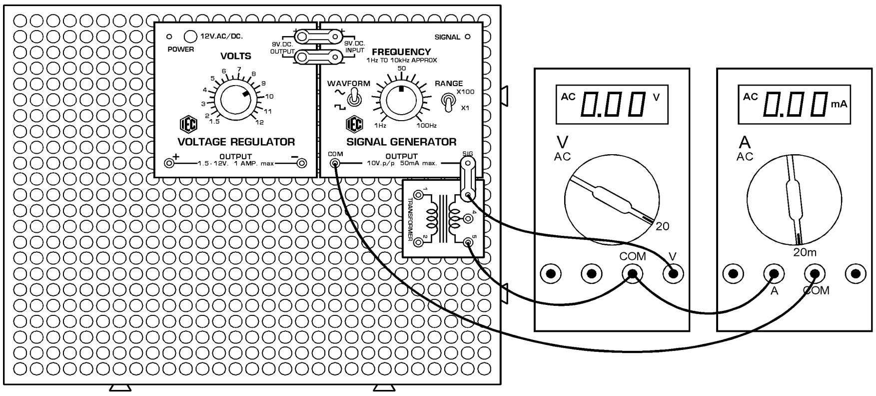
Look carefully at the formula $R = 1 / (2\pi\ f C)$. If the reactance R is smaller, the capacitance C must be larger. If the reactance is about half, this means the capacitance must be about double.

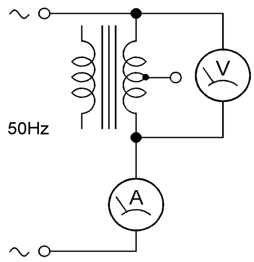
RULE: If capacitors are placed in parallel the capacitance value increases in uF. This is the opposite to resistors in parallel where the resistors combine to become a lower value.

For Example: If 3x equal value capacitors are placed in parallel, the total capacitance becomes 3 times the value of one capacitor. But the reactance becomes 1/3rd the reactance of one capacitor.

Conclusions: Capacitors in parallel increase the total capacitance. If the capacitance in uF increases and the reactance (in ohms) decreases. Therefore, capacitance value behaves the opposite to resistors, but the reactance value behaves the same as resistors.

I1: Inductor (inductive reactance)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator for sine & square waves
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Inductor (using 1x winding of the transformer)
- 1x Resistor 1k (1,000 ohm)

Aim: To use the Signal Generator as an AC power source. To pass AC through an inductor (a coil on an iron core) while measuring the AC voltage across it and measuring the AC current flowing through it. To use Ohm's Law to calculate the 'AC resistance' of the inductor in ohms. The correct name for this is the 'Reactance' of the inductor.

Settings: Set the Signal Generator to about 50Hz and select 'sine' waveform. Select 20V.AC. on the voltmeter and 20mA.AC.on the ammeter. Note: 1,000mH (millihenrys) = 1H (Henry)

NOTE: The resistor in the circuit is to limit the current through the inductor and stop the inductor from saturating the iron core. If the iron core saturates (becomes full of magnetic field) the calculations are not valid

Experiment: Apply the AC power and measure the AC volts and the AC amps. Use Ohm's Law to calculate the total AC resistance of the inductor. R_L (ohms) = V / A (1mA = 0.001Amp)

The result is in Ohms and is called the 'Impedance' of the circuit. The impedance is the addition of the fixed resistor, the ohms reactance of the Inductor and the ohms resistance of the copper wire that makes the inductor coil.

The formula for calculating the Reactance of an inductor is: $R_L = (2\pi\ f\ L)$, where R is the reactance in ohms, f is the frequency in Hz and L is the inductance in Henrys. Taking the inductor as having an inductance of ….mH and a DC resistance of …ohms. R_L (ohms) = (2π x 50 (Hz) x 0.035H (35mH)) = 3,183 ohms reactance + …ohms DC resistance = ? ohms impedance.

Compare this result with the result you obtained by using the meter readings and Ohm's Law.

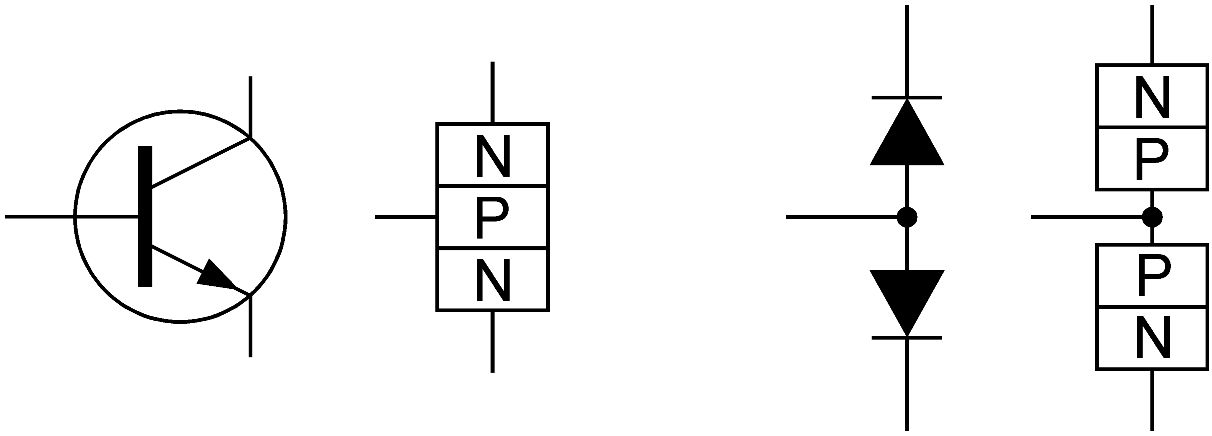
NOW, increase the frequency from the Signal Generator to 100Hz and repeat the above measurements and calculations. What do you notice ? Try other frequencies.

Now reduce the frequency. What do you notice ?

Conclusions: An Inductor is a device that consists of a coil of copper wire wound on an iron core so that a magnetic field is created. It can be fed with AC current and a reactance appears in the circuit. The reactance value depends on the Inductance (H) and frequency (Hz). If the frequency is increased, the reactance rises. If the Inductance is less, the reactance falls. If the frequency is decreased to zero, this is DC and the inductor conducts completely (reactance becomes zero). Only the fixed resistor and the ohms resistance value of the copper wire will limit the current flowing.

T1: Construction of a Transistor and Diode.

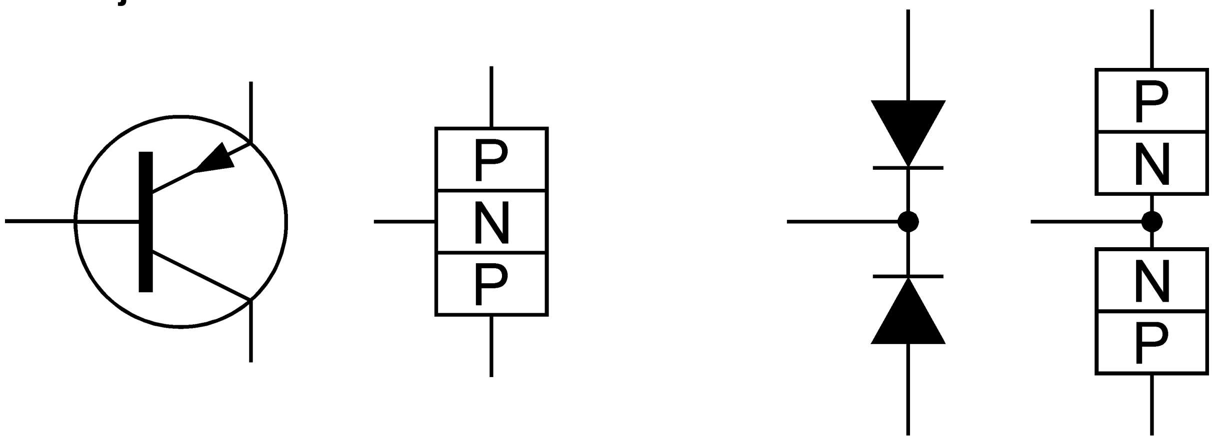
NPN junction



A Diode consists of a junction between 2 different layers of semiconducting material. The semiconductor is sometimes silicon and sometimes germanium. The material is manufactured with a very small amount of impurities added (called ‘doping’) so that an ‘N’ type and a ‘P’ type material is created. When a small voltage is applied to the junction (forward drop voltage), current flows easily from the P to the N materials but cannot flow from the N to the P materials.

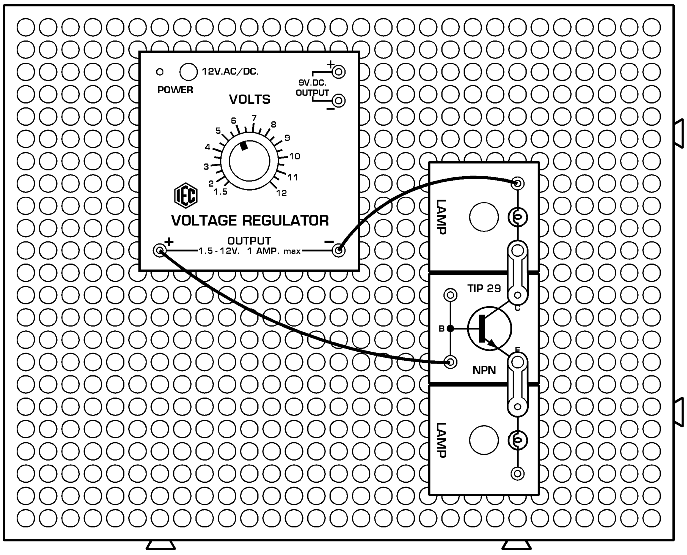
A Transistor is similar to a Diode but 3 layers are used instead of 2 layers. In an NPN Transistor the collector and emitter are both N material and the base is P material. See in the drawing above that the transistor is really 2 diodes joined in series with the mid point being the base. But the transistor junctions are special because when a small current flows from the base to the emitter (P-N), a larger current can flow through the collector to emitter N-P-N junction.

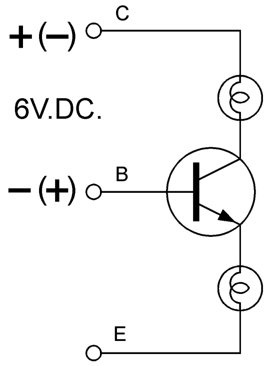
PNP junction:



The drawing above is of the PNP transistor showing that the PNP transistor is exactly the same as the NPN except that the layers are reversed. See in the drawing above that the transistor is really 2 diodes joined in series with the mid point being the base. But the transistor junctions are special because when a small current flows from the emitter to the base (P-N), a much larger current can flow through the emitter to collector P-N-P junction.

T2: A Transistor behaves like 2x diodes (NPN)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor TIP29 (NPN)
- 2x Lamps

Connect the circuit as shown above

Description of a Transistor: A 'semiconductor' is a material that is not an insulator (like plastic) and is not a conductor (like metal). A transistor is made from 3 layers of semiconducting material and the 3 connections of a transistor are connected to each layer. The 3 connections are called the EMITTER, the BASE and the COLLECTOR and the behaviour of the junction between the base and the emitter is like a diode. The behaviour of the junction between the base and the collector also is like a diode. Depending on the arrangement of these 3 layers, a transistor can have the emitter connected to the negative supply if it is an NPN type transistor, or the emitter can be connected to the positive supply if it is a PNP type transistor. The symbol of a transistor always has an arrow head on the emitter. If it is NPN type, the arrow head faces away from the base and towards the negative supply. If it is a PNP type, the arrowhead faces towards the base and away from the positive supply.

Aim: To prove that the junctions between the base and the emitter and base and the collector of a Transistor is like a diode in each case.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a lamp in series with its collector and a lamp in series with its emitter.

Experiment: Refer to the previous experiment T1. Apply the DC positive (+) to the collector C and negative (-) to the Base B. Voltage is applied in the N-P direction and current cannot flow.

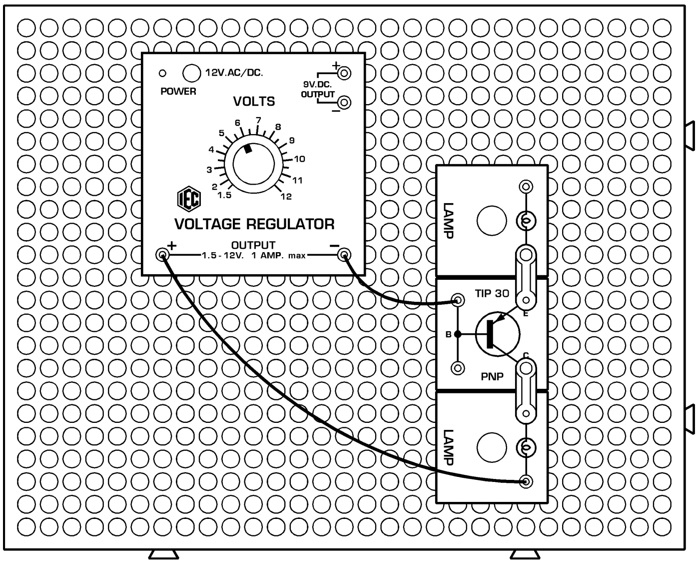
Now reverse these connections so voltage is applied in the P-N direction. Current flows.

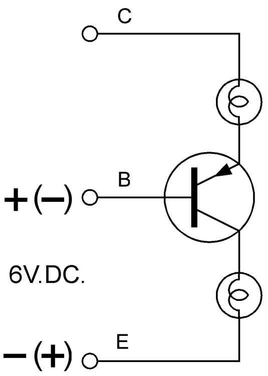
Now apply the DC positive (+) to the base B and negative (-) to the Emitter E. Voltage is now applied in the P-N direction and current flows.

Now reverse these connections so voltage is applied in the N-P direction. Current cannot flow.

Conclusion: Your results show that the transistor behaves like 2x diodes joined back to back in series. Current cannot flow from collector to emitter or from emitter to collector. It will be discovered later that for a NPN transistor, the base must be connected to the positive through a resistor to control the current for the transistor to conduct from the collector to the emitter.

T3: A Transistor behaves like 2x diodes (PNP)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor TIP30 (PNP)
- 2x Lamps

Connect the circuit as shown above

Description of a Transistor: A ‘semiconductor’ is a material that is not an insulator (like plastic) and is not a conductor (like metal). A transistor is made from 3 layers of semiconducting material and the 3 connections of a transistor are connected to each layer. The 3 connections are called the EMITTER, the BASE and the COLLECTOR and the behaviour of the junction between the base and the emitter is like a diode. The behaviour of the junction between the base and the collector also is like a diode. Depending on the arrangement of these 3 layers, a transistor can have the emitter connected to the negative supply if it is an NPN type transistor, or the emitter can be connected to the positive supply if it is a PNP type transistor. The symbol of a transistor always has an arrow head on the emitter. If it is NPN type, the arrow head faces away from the base and towards the negative supply. If it is a PNP type, the arrowhead faces towards the base and away from the positive supply.

Aim: To prove that the junctions between the base and the emitter and base and the collector of a Transistor is like a diode in each case.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a lamp in series with its collector and a lamp in series with its emitter.

Experiment: Refer to the previous experiments T1 and T2. Apply the DC positive (+) to the collector C and negative (-) to the Base B. Voltage is applied in the P-N direction and current flows.

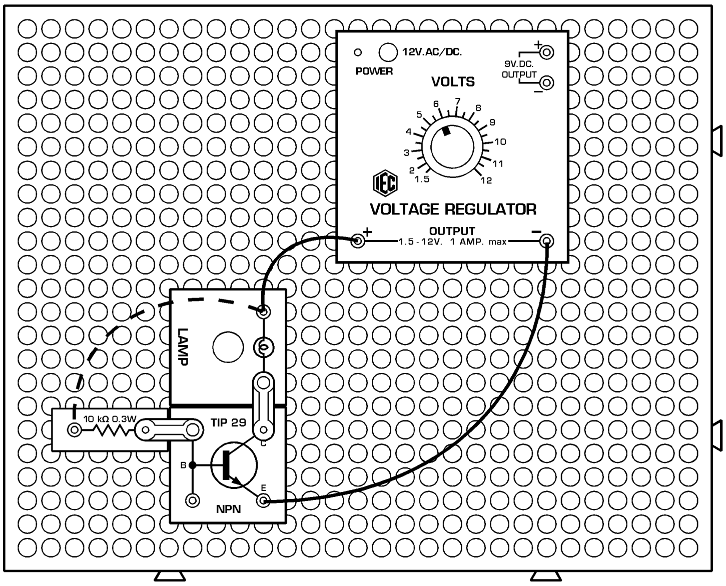
Now reverse these connections so voltage is applied in the N-P direction. Current cannot flow.

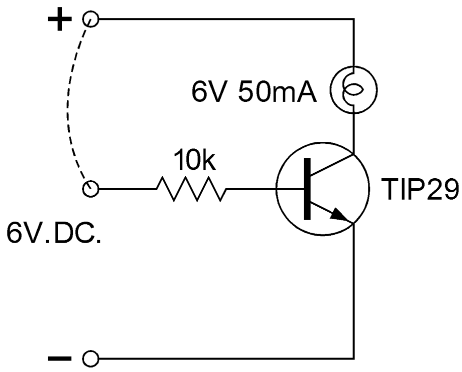
Now apply the DC positive (+) to the base B and negative (-) to the Emitter E. Voltage is now applied in the N-P direction and current cannot flow.

Now reverse these connections so voltage is applied in the P-N direction. Current flows.

Conclusion: Your results show that the transistor behaves like 2x diodes joined back to back in series. Current cannot flow from collector to emitter or from emitter to collector. It will be discovered later that for a PNP transistor, the base must be connected to the negative through a resistor to control the current for the transistor to conduct from the emitter to the collector.

T4: Operating an NPN Transistor





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor TIP29 (NPN)
- 1x Resistor 10k (10,000 ohm)
- 1x Lamp

Connect the circuit as shown above

Aim: We have seen that a transistor can be seen as 2x diodes back to back so that current cannot pass from collector to emitter. The aim is to make a transistor conduct current from collector to emitter.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a lamp in series with its collector only.

Experiment: With the resistor in the base circuit not connected (open circuit), current does not flow through the collector to the base and the lamp is off.

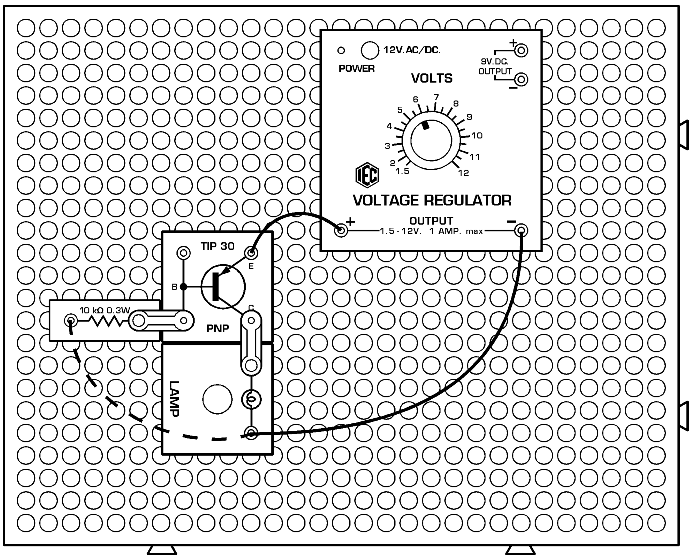
Now join the resistor to the positive supply as shown by the dotted line. The 10k (10,000 ohm) resistor limits the current into the base to a very small current (about 0.6mA) but a much larger current now flows through the collector to the emitter to make the lamp come on (about 50mA).

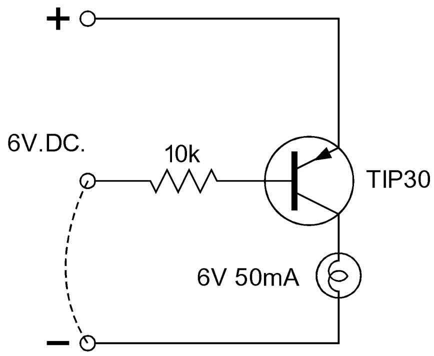
This is the normal function of an NPN transistor where a very small base to emitter current flowing causes a much larger collector to emitter current through the transistor.

Explanation: When the P-N base to emitter junction carries a small current, it changes the behaviour of the collector to base N-P junction to make it conduct.

Conclusion: The transistor is behaving as a CURRENT AMPLIFIER because the small base to emitter current causes an AMPLIFIED collector to emitter current.

T5: Operating a PNP Transistor





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor TIP30 (PNP)
- 1x Resistor 10k (10,000 ohm)
- 1x Lamp

Connect the circuit as shown above

Aim: We have seen that a transistor can be seen as 2x diodes back to back so that current cannot pass from emitter to collector. The aim is to make a transistor conduct current from emitter to collector.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a lamp in series with its collector only.

Experiment: With the resistor in the base circuit not connected (open circuit), current does not flow through the collector to the base and the lamp is off.

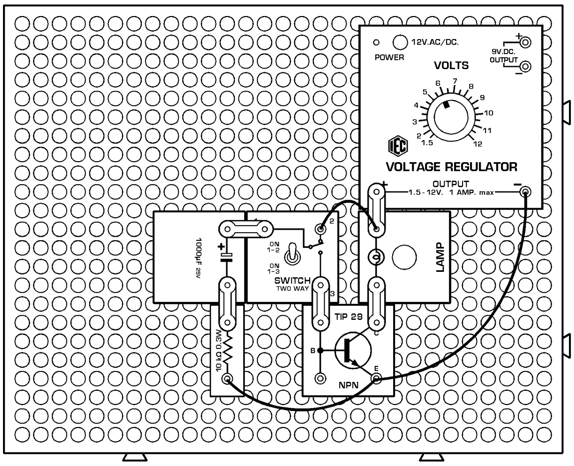
Now join the resistor to the negative supply as shown by the dotted line. The 10k (10,000 ohm) resistor limits the current from the base to a very small current (about 0.6mA) but a much larger current now flows through the emitter to the collector to make the lamp come on (about 50mA).

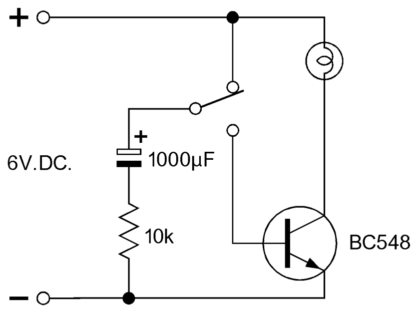
This is the normal function of a PNP transistor where a very small base to collector current flowing causes a much larger emitter to collector current through the transistor.

Explanation: When the P-N emitter to base junction carries a small current, it changes the behaviour of the collector to base N-P junction to make it conduct.

Conclusion: The transistor is behaving as a CURRENT AMPLIFIER because the small base to collector current causes an AMPLIFIED emitter to collector current.

T6: Transistor (NPN) & capacitor as a pulse timer





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor BC548 (NPN)
- 1x Resistor 10k (10,000 ohm)
- 1x Capacitor 1,000uF (careful of polarity)
- 1x Switch (2 way)
- 1x Lamp

Connect the circuit as shown above

Aim: To operate a switch to charge a capacitor, then operate the switch to make a transistor turn on its load for a time then automatically turn off.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a lamp in series with its collector only. This lamp, or any other device controlled by the transistor is called the 'LOAD' of the transistor.

Experiment: When the switch is turned one way, the capacitor is charged from the positive line through the 10,000 ohm (10k) resistor. This resistor limits the current, so allow about 10 seconds for the capacitor to fully charge, however, the circuit will work with partially charged capacitor.

Now switch the capacitor to the base of the transistor. Current will flow through the base to emitter P-N junction to cause the transistor to conduct from collector to emitter. The lamp will go ON full.

As the capacitor discharges through the 10k resistor, the current into the base will fall until the transistor turns off and the lamp will go OFF.

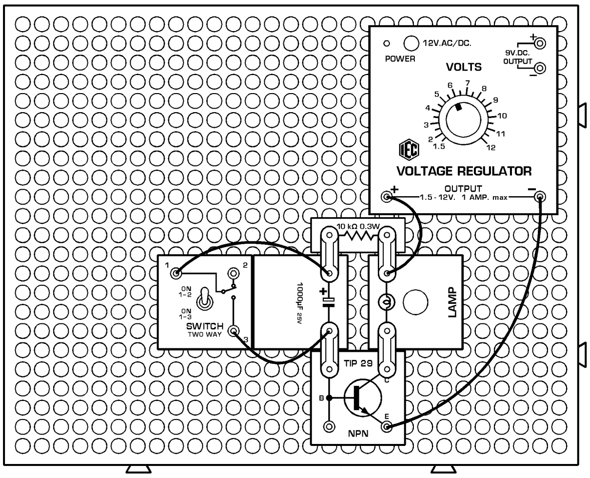
To change the pulse time, try different values of resistors and capacitors. If the capacitor is larger or if the resistor is higher resistance, the pulse time will be longer. If the capacitor is smaller value or if the resistance is a lower value, the pulse time will be shorter. Try it and see.

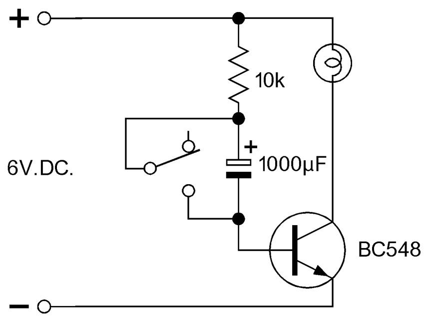
Timing information: When a Resistor and a Capacitor is combined in a circuit to control timing of any circuit, it is called an 'RC' circuit. In simple circuits, it can be said that 1 Farad charging or discharging through 1 ohm will take 1 second. Therefore, 1uF and 1,000,000 ohm (1 Megohm or 1M) will also charge or discharge in 1 second. 1,000uF and 1k should also be 1 second, therefore, in the circuit above, 1,000uF and 10k should take about 10 seconds to charge or discharge. Check the time delay with a stop watch.

Exercise: Change the position of the resistor in the circuit above so the capacitor will charge very quickly (instantly) but will still produce the timed pulse through the transistor. Test it.

Conclusion: The transistor can be turned on by a small base current stored in a capacitor. RC circuits can be used to make many different types of timers.

T7: Transistor (PNP) & capacitor as a 'delay off' timer





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor BC548 (NPN)
- 1x Resistor 10k (10,000 ohm)
- 1x Capacitor 1,000uF (careful of polarity)
- 1x Switch (connect as 1 way)
- 1x Lamp

Connect the circuit as shown above

Aim: To turn on a switch to turn on a transistor and lamp, then turn off the switch but the transistor and lamp remain on and have a time delay before the transistor and lamp turn off.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a lamp in series with its collector only. This lamp, or any other device controlled by the transistor is called the 'LOAD' of the transistor.

Experiment: When the switch is turned on, the capacitor is short circuited and must discharge. The 10k resistor is connected to the base so that base to emitter current will flow and the transistor will turn ON. The collector load lamp will be ON.

When the switch is turned off, the capacitor will placed into the base circuit and will begin to charge. The charging current will remain flowing into the base to emitter junction until the capacitor becomes almost fully charged and the current will reduce towards zero. Just before the capacitor is fully charged, there will be insufficient base current to turn on the transistor and it will turn OFF.

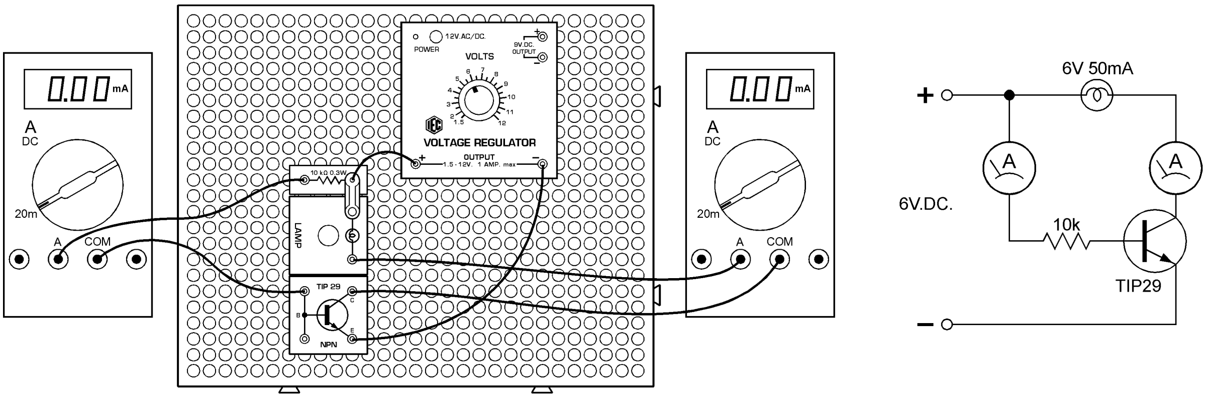
Therefore, when the switch is turned on, the lamp is ON immediately. When the switch is turned off, the lamp turns off several seconds afterwards.

Can you think of a use for this type of circuit ?

Timing information: When a Resistor and a Capacitor is combined in a circuit to control timing of any circuit, it is called an 'RC' circuit. In simple circuits, it can be said that 1 Farad charging or discharging through 1 ohm will take 1 second. Therefore, 1uF and 1,000,000 ohm (1 Megohm or 1M) will also charge or discharge in 1 second. 1,000uF and 1k should also be 1 second, therefore, in the circuit above, 1,000uF and 10k should take about 10 seconds to charge or discharge. Check the time delay with a stop watch.

Conclusion: The transistor can be turned on by a current charging a capacitor. RC circuits can be used to make many different types of timers.

T8: Transistor (NPN) as a current amplifier with collector load



Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Ammeters & cables
- 1x Transistor TIP29 (NPN)
- 1x Resistor 10k (10,000 ohm)
- 1x Lamp

Connect the circuit as shown above

Aim: To connect a transistor so that it conducts through collector to emitter to operate a load. To measure the base current and compare it to the collector current and to calculate the current 'gain'.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a lamp and ammeter in series with its collector and resistor and ammeter in series with its base.

Explanation 1): Current 'Gain' means the amplification or the comparison of current from the base circuit to the collector circuit. If the base current is 1mA and the collector current is 30mA, it can be said that the current gain of the circuit is 30.

Experiment: Apply power and notice that the lamp will turn ON. Current will be flowing in the base circuit and a much heavier current will be flowing in the collector to emitter circuit.

Measure and note the base and collector currents in the above circuit.

What is the ratio between them ? What is the current gain of the TIP29 transistor in this circuit ?

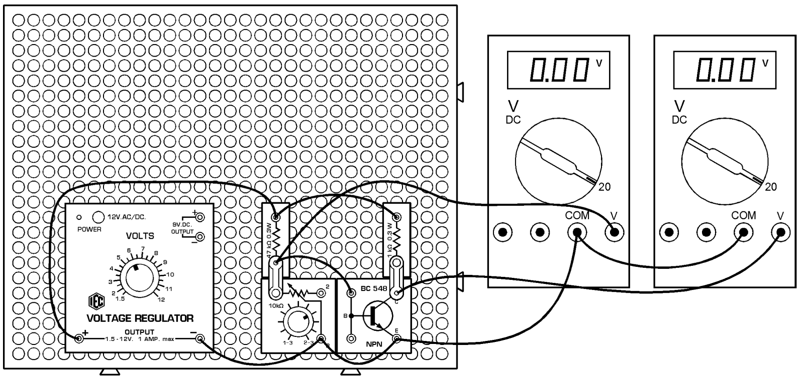
Explanation 2): All transistors have an 'operating region' where the current into the base relates to the current through the collector/emitter circuit. If the current into the base is too high, the transistor junction 'saturates' and the collector current no longer follows the base current in a linear manner. When this occurs, the output does not follow the input signal and this is called "distortion".

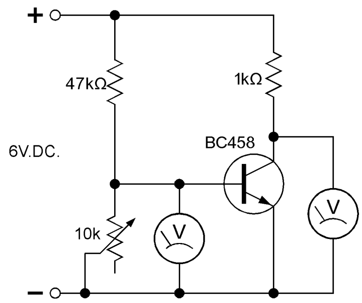
For example: If a sine wave signal is applied to the base and the current is controlled so it is within the normal operating region of the transistor, there will be a current change in the collector/emitter circuit which will also be a sine wave of exactly the same shape, but much larger. If the current is permitted to exceed or fall below the operating region, the output signal will be a badly shaped wave with flat tops. If it was an audio (sound) wave, it would sound very bad to the ear (distorted).

All transistors have 'data sheets' available that tell the designer of electronic equipment all the information required to be sure the operating voltages and currents are not exceeded.

Conclusion: The transistor is behaving as a CURRENT AMPLIFIER because the small base to collector current causes an AMPLIFIED collector to emitter current. It can be said also that it is behaving like an ON/OFF switch because the base current is not being altered by a signal (like a signal generator or microphone etc.)

T9: Transistor (NPN) as a voltage amplifier with collector load





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Voltmeters & cables
- 1x Transistor BC548 (NPN)
- 2x Resistors 1k (1,000 ohm) 47k (47,000 ohm)
- 1x Potentiometer 10k (10,000 ohm)

Connect the circuit as shown above

Aim: To connect a transistor so that it conducts through collector to emitter to operate a load in the collector circuit. To measure the base voltage and compare it to the voltage across the transistor and to calculate the voltage 'gain'. See previous experiment for explanation of 'gain'.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a load resistor in the collector circuit and a voltmeter across the collector-emitter and a voltmeter measuring the base voltage from the negative line. The base is fed from an adjustable voltage divider made by a resistor and a potentiometer (connected as a variable resistance).

Experiment: Turn the variable resistance so that the transistor base voltage becomes say 0.5V. so that the transistor is just on the point of turning ON. Measure the voltage across the transistor.

Now turn the potentiometer so the voltage from negative line to base is slightly higher. Measure the voltage across the transistor. This circuit inverts the signal voltage and, as the base voltage rises the transistor voltage falls. Raise the base voltage again slightly and measure the collector volts.

Note the CHANGE in base voltage and note the CHANGE in transistor voltage. Notice that the change in base voltage is very much less than the change in collector to emitter voltage, therefore this configuration has a voltage gain (or amplification). Divide the CHANGE in collector volts by the CHANGE in base volts. This is the voltage gain of the transistor.

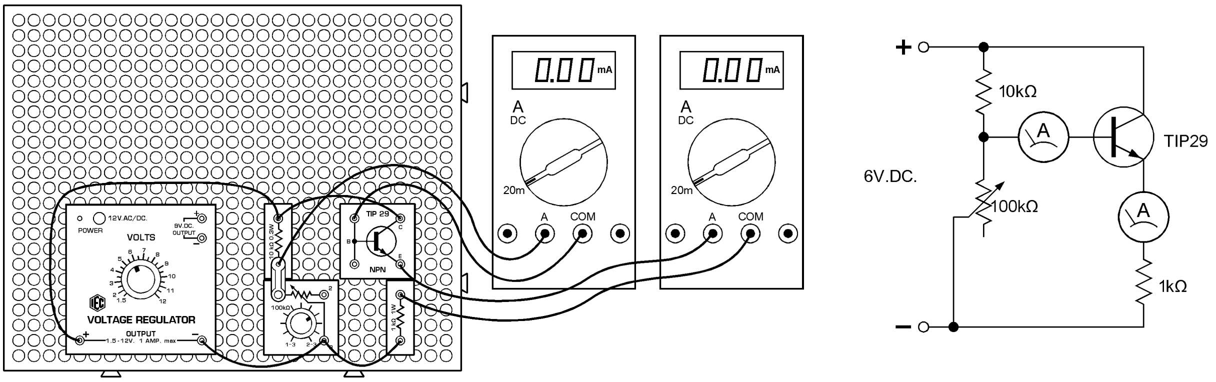
NOTE: It is the CHANGE in voltage that is important and the inversion of the voltage from base to collector/emitter is not relevant to the gain of the circuit.

Conclusion: The transistor is behaving as a VOLTAGE AMPLIFIER because a change in base voltage (between negative line and base) causes a voltage change across the transistor (from collector to emitter). The 'gain' of a transistor depends on the transistor characteristics and the configuration of the circuit. This circuit provides a positive gain and the signal is inverted. If the base voltage increases, the transistor voltage decreases.

T10: Transistor (NPN) as a current amplifier with emitter load

'Emitter Follower' current amplifier

Plot characteristic curve of current gain



Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Ammeters & cables
- 1x Transistor TIP29 (NPN)
- 2x Resistors 1k (1,000 ohm) 10k (10,000 ohm)
- 1x Potentiometer 100k (100,000 ohm)

Connect the circuit as shown above

Aim: To connect a transistor so that it conducts through collector to emitter to operate a load. To measure the base current and compare it to the collector current and to calculate the current 'gain'. See previous experiment for explanation of 'gain'.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a resistor and an ammeter in series with its emitter and an ammeter in series with its base. The base is fed from an adjustable voltage divider made by a resistor and a potentiometer (connected as a variable resistance).

Explanation: When the load resistor is placed in the emitter circuit instead of the collector circuit, it is sometimes called an 'Emitter Follower'. As the current flows in the load resistor, the voltage drop across the load raises the emitter voltage above the negative line which tries to turn the transistor OFF. Because of this, the amplification of an Emitter Follower' is normally very low and is usually has a gain of less than 1.

The advantages of the Emitter Follower circuit is that it is a current amplifier that changes a high resistance, very low current signal into a low resistance, large current source maybe for operating a speaker or similar. The Emitter Follower amplifier does not invert (reverse) the input. This means the output current rises and falls in phase with the input signal current.

Experiment: Turn the variable resistance so that the transistor base current becomes zero. The base will now be connected to the negative supply and the transistor current will also be zero.

Gradually increase the value of the variable resistor to increase the voltage feeding the base so that base current begins to flow. Take note of the base current when emitter current JUST begins to flow. Then note each base current and emitter current over say about 10 steps.

Document these 10 or more readings of base and emitter current.

Take a graph sheet and, using X axis for base current and Y axis for emitter current, plot the curve for current gain for a NPN transistor with emitter load. This is called the characteristic curve.

T10: Transistor (NPN) as a current amplifier with emitter load

‘Emitter Follower’ current amplifier

Plot characteristic curve of current gain

……….. continued …………

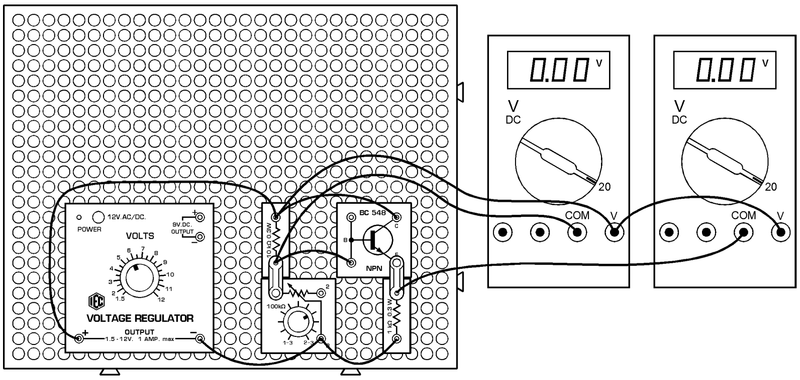
Current gain is emitter current / base current. Check the current gain from the graph you drew. Is the current gain the same all over the graph ? Is there a ‘window’ (this means a low and a high limit) of base current where the graph is the straightest line ?

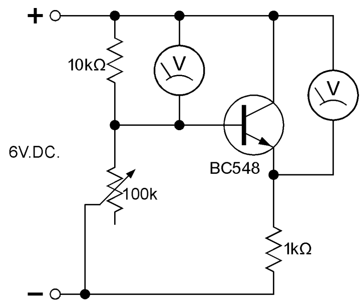
For minimum distortion, the transistor should be operating in the straight line region of the graph. When a signal is applied to the base and the transistor is amplifying, for minimum distortion, the maximum and minimum base currents should not be outside these limits.

Conclusion: The transistor is behaving as a CURRENT AMPLIFIER because the small base to collector current causes an AMPLIFIED collector to emitter current. The current into the base is controlled manually to find out the emitter current that relates to the base current (its current gain). A graph of the current gain is useful for a designer to know what values to use in a circuit using this TIP29 transistor.

T11: Transistor (NPN) as a voltage amplifier with emitter load

'Emitter Follower' voltage amplifier





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Voltmeters & cables
- 1x Transistor BC548 (NPN)
- 2x Resistors 1k (1,000 ohm) 10k (10,000 ohm)
- 1x Potentiometer 100k (100,000 ohm)

Connect the circuit as shown above

Aim: To connect a transistor so that it conducts through collector to emitter to operate a load in the emitter circuit. To measure the base voltage and compare it to the voltage across the transistor and to calculate the voltage 'gain'. See previous experiment for explanation of 'gain'.

Settings: Set the Voltage regulator to about 6V.DC. The transistor has a load resistor in the emitter circuit and a voltmeter across the collector-emitter and a voltmeter measuring the base voltage from the positive line. The base is fed from an adjustable voltage divider made by a resistor and a potentiometer (connected as a variable resistance).

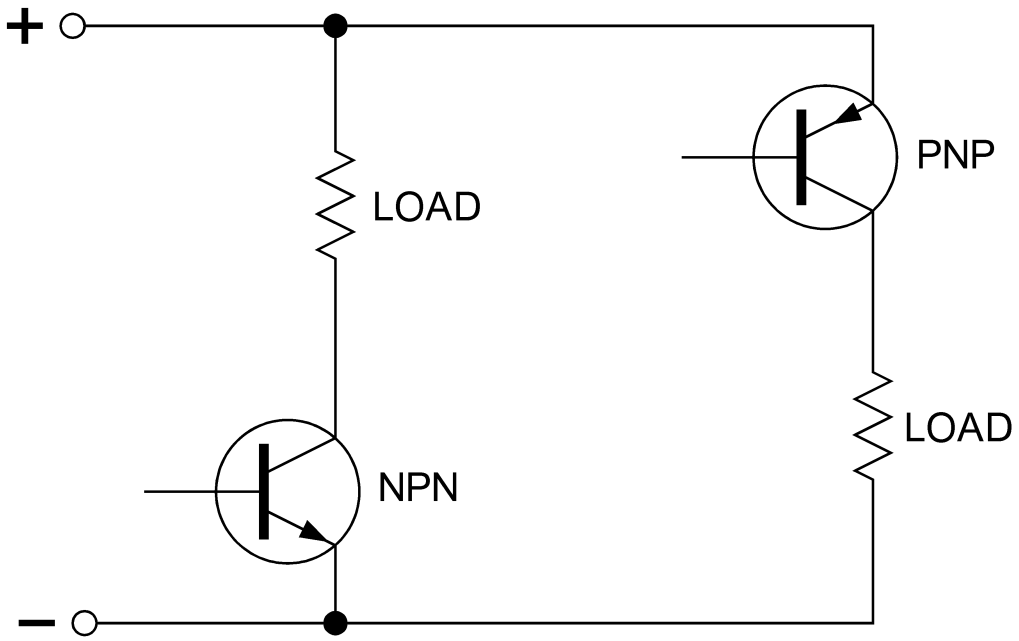
Experiment: Turn the variable resistance so that the transistor base voltage becomes 2V. Measure the voltage across the transistor. When the emitter has a resistor, the emitter voltage rises with the base voltage.

Now turn the potentiometer so the voltage from positive line to base is say 5V. Measure the voltage across the transistor.

Note the CHANGE in base voltage and note the CHANGE in transistor voltage. Notice that the change in base voltage is slightly more than the change in emitter voltage, therefore this configuration has a gain of less than 1 (sometimes called 'less than unity gain').

Conclusion: The transistor is behaving as a VOLTAGE AMPLIFIER because a change in base voltage (between positive line and base) causes a voltage change across the transistor (from collector to emitter). The 'gain' of a transistor depends on the transistor characteristics and the configuration of the circuit. This circuit provides a gain of less than one and it inverts the signal. If the base voltage increases, the transistor voltage decreases.

T12: Transistors PNP type and NPN type. When to use ?



The above circuit shows an NPN transistor with a collector load and a PNP transistor with a collector load. Many circuits use transistors with loads in their emitter circuits, but usually this is for special purposes of the circuit. It is more common for collector loads to be used.

BASE CURRENT:

The base of any transistor is a sensitive circuit and requires a very small current. Too much current can easily destroy the transistor. The base circuit is normally fed through a resistor to control the current or is fed from a voltage divider between positive and negative lines to set the current passing into the base before a signal is applied. This steady current flowing before the signal is applied is called the 'quiescent current' and this preset voltage to the base is called the 'base bias'.

IS THE BASE CONNECTED TO pos OR neg ?

For the NPN transistor to conduct, the base must have current passing through the P-N junction from the base to the emitter. This means the base must be connected towards the positive line before the transistor can conduct

For the PNP transistor to conduct, the base must have current passing through the P-N junction from the emitter to the base. This means the base must be connected towards the negative line before the transistor can conduct.

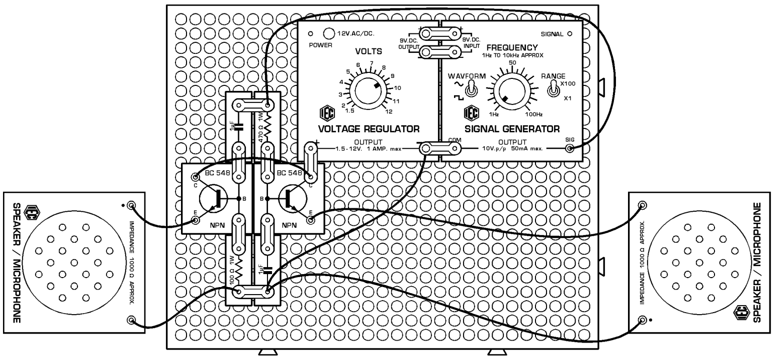
TYPE OF SIGNAL:

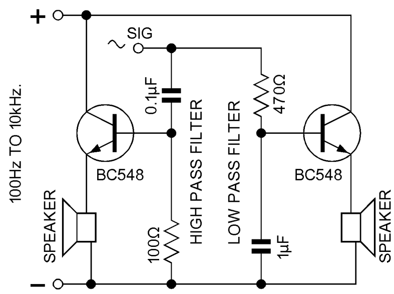
The choice of using an NPN or PNP type transistor in a circuit depends on the function of the circuit and the type of signal that is to be applied to the base.

If a signal source is held to negative line but rises above negative when energised, this signal would normally be connected to a NPN transistor for the circuit to operate correctly.

If a signal source is held to positive line but falls below positive when energised, this signal would normally be connected to a PNP transistor for the circuit to operate correctly.

T13: Audio 'High Pass' and 'Low Pass' filter using transistors.





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator, set to sine wave and range x10.
- 2x Transistors BC548 (NPN)
- 2x Resistors 100 ohm 470 ohm
- 2x Capacitors 0.1uF 1.0uF
- 2x Speakers

Connect the circuit as shown above

Aim: To apply a signal to a circuit where the lower frequencies come from one speaker and the higher frequencies come from another speaker. This circuit is called a 'Filter' and if low frequencies are passed and high frequencies are blocked, it is called a 'Low Pass' filter. If high frequencies are passed and low frequencies are blocked, it is called a 'High Pass' filter.

Settings: Set the Signal Generator to 'sine' wave and set the range switch to x10.

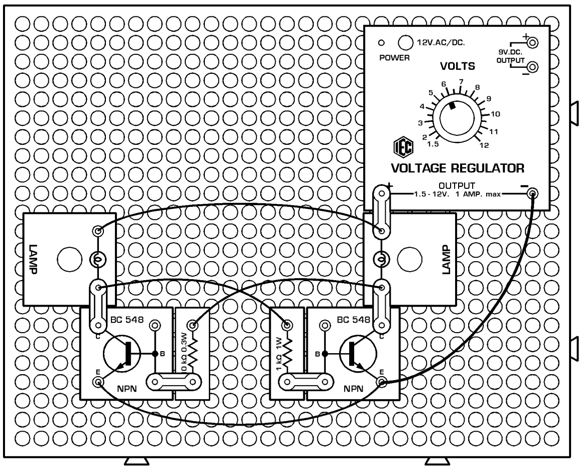
Experiment: While listening to the speakers, raise the frequency from the Signal Generator. Notice that the low frequencies can be heard from one speaker. As the frequency rises, the tone can be heard equally from both speakers. As you reach high frequency, the sound is heard mostly from the other speaker.

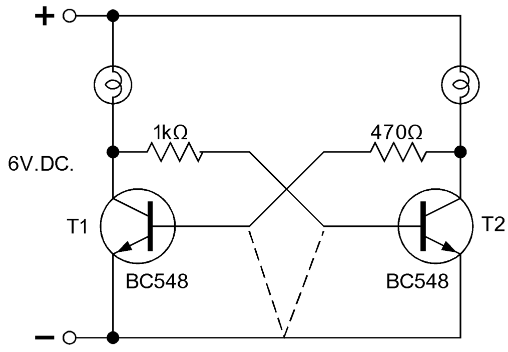
Look at the circuit. The left speaker is driven by a transistor where the base circuit has a capacitor in series with the base. We know that capacitors have a high reactance (AC resistance) at low frequencies, so this must be the filter that passes high frequencies better. Check it and see.

Look at the other base circuit. In this case, the base is fed by a resistor and a capacitor passes the signal to the negative line. Again, we know the capacitor has a low reactance with high frequencies so they will be bypassed to the negative line. So this must be the circuit that passes low frequencies better (because high frequencies are bypassed).

Conclusion: Capacitors are useful because of their characteristic of changing their reactance with frequency. The change from open circuit (blocking) at DC (zero frequency) to a low reactance (close to a short circuit) at high frequencies.

O1: Oscillator. Multivibrator, 'bi-stable' type (two steady states)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Transistors BC548 (NPN)
- 2x Resistors 1k (1,000 ohm) 470 ohm
- 2x Lamps

Connect the circuit as shown above

Aim: To make a circuit where one lamp is on and remains on in a stable condition. Then by joining 2 points momentarily makes the circuit 'flip' the other way to make the other lamp come on and the first lamp go off and remain in this new stable condition. Then when another two points are joined momentarily, the circuit immediately returns to its original stable state.

Settings: Set the Voltage regulator to about 6V.DC.

Experiment: Notice that in the circuit, the 2 transistors T1 and T2 have the same circuits except that T1 has a 470 ohm base resistor and T2 has a 1k base resistor. When power is turned on, probably T1 will turn on first because it has larger current into its base circuit.

Question: When first powered, if the 2 base resistors were exactly the same value, which transistor would turn on first. Can you predict ?

Exercise: To try it, you can take a potentiometer and add 530 ohms to the 470 ohm resistor to make 1k (same as the other resistor). To set the correct value, measure the resistance with one of the multimeters set to 'Ohms' range.

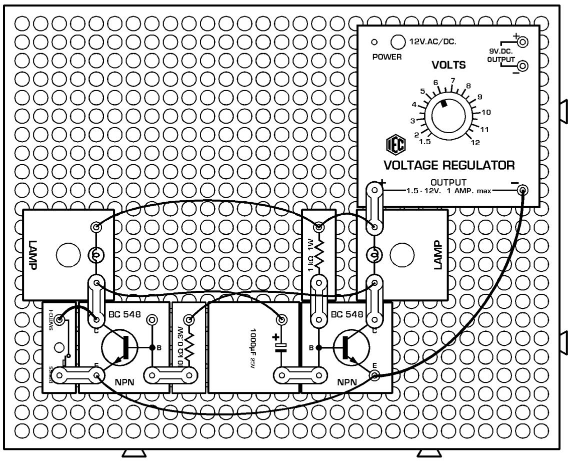
When T1 turns on, its lamp load will come on and its collector will fall almost to negative line because T1 is turned hard on. This low voltage at collector of T1 will be applied to T2 through its 1k base resistor and T2 will be held off.

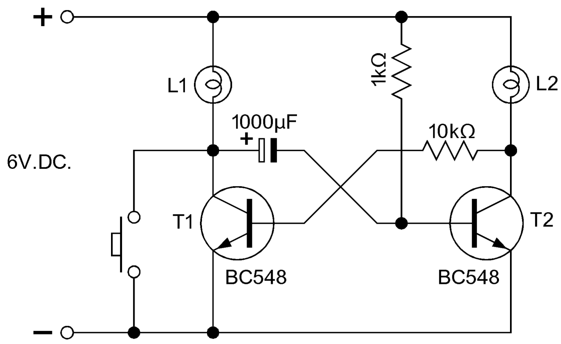
Now momentarily join the base of T1 to negative to force it off. Immediately, the collector of T1 will rise and the lamp will be off. This high voltage on T1 collector will be passed to the base of T2 and it will immediately turn hard on and its lamp will be on. The collector of T2 will fall almost to negative line and this will hold off T1 by pulling its base low through its 470 ohm base resistor.

Note that no matter how quick you are and how short a time you join a base to negative, the circuit always flips over. The circuit has 2 steady states.

Conclusion: A bi-stable multivibrator is a type of oscillator with two stable states. It can be disturbed momentarily to flip one state to the other state Could be used to turn off a light in a room and turn on a light in another room by pressing a button once. Another button could be used to return the lights to their original rooms.

O2: Oscillator. Multivibrator, 'mono-stable' type (one steady state)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Transistors BC548 (NPN)
- 2x Resistors 1k (1,000 ohm) & 10k (10,000 ohm)
- 1x Capacitor 1,000uF (careful of polarity)
- 2x Lamps
- 1x Press button

Connect the circuit as shown above

Aim: To make a circuit where one lamp is on and remains on in a stable condition. Then a press button closing momentarily makes the circuit 'flip' the other way to make the other lamp come on and the first lamp go off. After a predictable time delay, the circuit returns to the original condition.

Settings: Set the Voltage regulator to about 6V.DC.

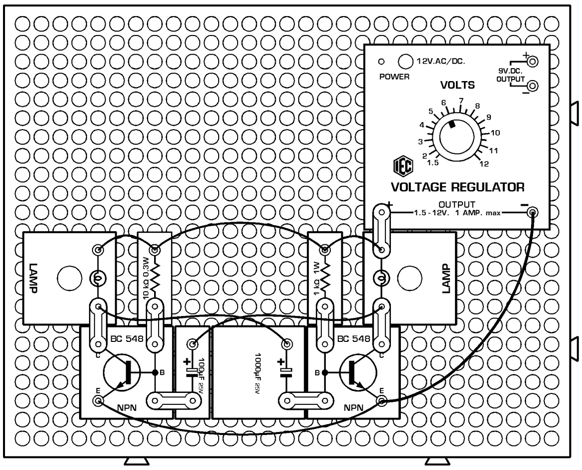
Experiment: When power is turned on, T2 immediately turns on its load lamp because its base is connected to the positive line with a 1k resistor. The collector of T2 falls almost to negative line because the transistor is fully on. Therefore the T1 is turned off by the 10k resistor to its base. The capacitor is at line voltage and it fully charges through the P-N emitter junction of T2.

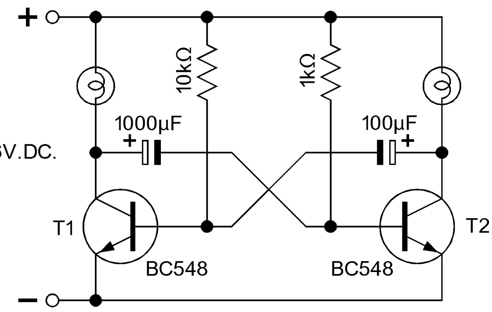
When the press button is MOMENTARILY pressed, it pulls the collector of T1 instantly to negative line. This change in voltage is transferred to the base of T2 which is pulled down lower than the emitter and is quickly forced OFF. The collector of T2 rises to positive line and forces T1 heavily ON.

The capacitor now discharges through the 1k resistor to the positive line. After a time delay, depending on the value of the capacitor and its discharge resistor, the base of T2 will begin to rise slightly towards positive line and, at about 0.6V to the emitter, it will begin to turn ON. The collector of T2 will begin to fall and turn off T1 through the 10k resistor. The collector of T1 will rise and the capacitor will again charge through the base to emitter junction of T2 to turn it ON harder.

Conclusion: A mono-stable multivibrator is a type of oscillator with only one stable state. It can be disturbed to take the other state, but, after a preset delay must return to its stable state. Could be used to turn off a light in a room and turn on a light in another room by pressing a button once. After a certain time the room lights would change back to original conditions.

O3: Oscillator. Multivibrator, 'a-stable' type (no steady states)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Transistors BC548 (NPN)
- 2x Resistors 1k (1,000 ohm) & 10k (10,000 ohm)
- 2x Capacitors 100uF & 1,000uF
- 2x Lamps

Connect the circuit as shown above

Aim: To make a circuit where lamps flip on and off without any stable state. This is sometimes called a 'free-running' oscillator.

Settings: Set the Voltage regulator to about 6V.DC.

Experiment: When power is turned on, one of the transistors will turn on first but which one will turn on first is difficult to predict. Probably the transistor with the lower base resistor will turn on first.

When T1 turns on, its collector will fall almost to negative line and its load lamp will be on. The low voltage on the collector of T1 will be transferred to the base of T2 by the capacitor and T2 will be held off.

The base resistor of T2 will begin to charge up the capacitor from the collector of T1 until it rises enough to turn on T2. When T2 turns on, the collector of T2 will fall almost to negative line and will force off T1 by transferring the low voltage to the base of T1 through its capacitor.

Then the base resistor of T1 will charge up the capacitor through the base resistor of T1 until it rises enough to turn on T1 ….. and so on. The circuit will flip back and forth freely.

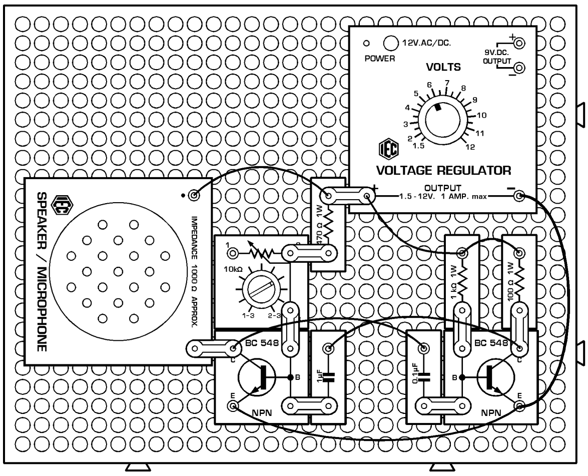
The load lamps in the collectors of T1 and T2 will flash on and off continuously.

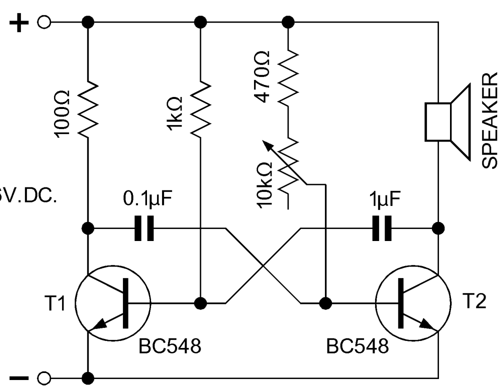
The frequency of oscillation depends on the values of the base resistors and the capacitors. Try using higher values for the 2 base resistors. Try using smaller values for the capacitors. If the oscillator vibrates fast, the lamps will appear to be on steady because of the persistence of the human eye.

Conclusion: An 'a-stable' or 'free running' multivibrator oscillator is commonly used in electronics.

Can be useful for creating a Signal Generator or for making an audible tone in a speaker or for making a lamp flash on and off for a danger signal etc.etc..

O4: Oscillator. Tone generator with manual control & speaker





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Transistors   BC548 (NPN)
- 3x Resistors 100 ohm   470 ohm   1k (1,000 ohm)
- 1x Potentiometer 10k (10,000 ohm)
- 2x Capacitors   0.1uF & 1uF
- 1x Speaker

Connect the circuit as shown above

Aim: To make a circuit that generates a musical tone in a speaker and to change the pitch (or frequency) of the tone by rotating a knob.

Settings: Set the Voltage regulator to about 6V.DC.   One transistor has a 100 ohm collector load and the other has the speaker as its collector load.

Experiment: If you refer to the previous experiment, you will see that this is the circuit of an 'a-stable' or 'free running' multivibrator. The difference is that one of the transistors has a speaker for the load instead of the lamp and the other transistor has a resistor.   As the current goes on and off through the speaker it will produce a tone.   The resistor and capacitor values have been chosen to produce a frequency in our audible range.

Questions: What frequency is required so the human ear can hear a tone ?   What is the lowest frequency we can hear ?   What is the highest frequency we can hear ?   Can the humans hear the highest frequencies or do some animals hear higher frequencies than we do ?

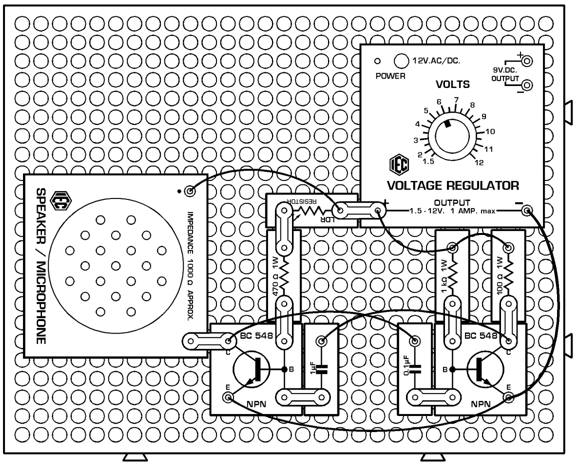
When power is turned on, the multivibrator oscillator should freely run and we should hear a tone from the speaker.

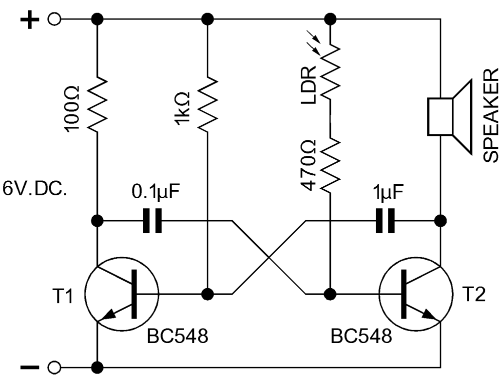
Change the value of the potentiometer (used here as a variable resistance) to change the charging time for one of the capacitors (refer to the previous experiment).   If the resistance is increased, the frequency should fall because it takes longer for the capacitor to charge through a higher resistor. If it takes longer for the capacitor to charge, the oscillator will slow down.

Conclusion: An 'a-stable' or 'free running' multivibrator oscillator is commonly used in electronics. It is used to make oscillations of various waveforms for making audio alarms or for generating signals.

This experiment demonstrates one use for the circuit.

O5: Oscillator. Tones controlled by light





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Transistors   BC548 (NPN)
- 3x Resistors 100 ohm   470 ohm   1k (1,000 ohm)
- 1x LDR
- 2x Capacitors   0.1uF & 1uF
- 1x Speaker

Connect the circuit as shown above

Aim: To make a circuit that generates musical tones in a speaker that change their pitch (or frequency) by the brightness of a light.

Settings: Set the Voltage regulator to about 6V.DC.   One transistor has a 100 ohm collector load and the other has the speaker as its collector load.

Experiment: If you refer to the previous experiment, you will see that this is the same circuit but, instead of a potentiometer, we have used an LDR. The LDR changes its resistance with light. The resistor and capacitor values have been chosen to produce a frequency in our audible range.

When power is turned on, the multivibrator oscillator should freely run at a frequency within the human hearing audible band and we should hear a tone from the speaker.

Change the amount of light reaching the LDR and let it change its resistance value. As it changes its resistance value, the tone will change because the multivibrator oscillator will run faster and slower.

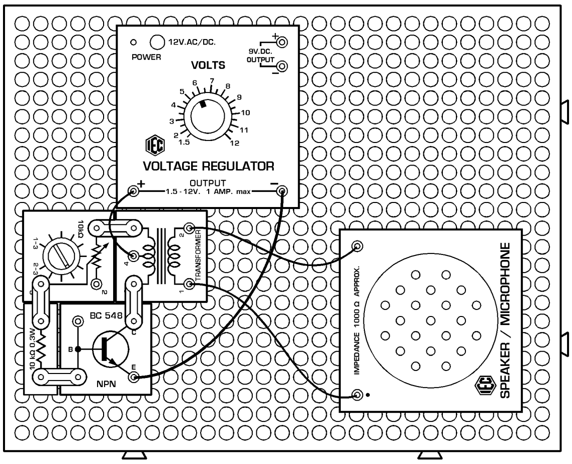
If the light is increased, The value of the LDR will reduce.

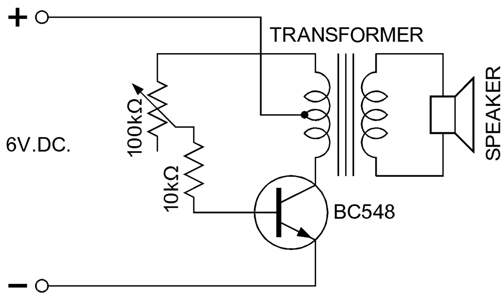
Question: Will more light make a higher pitch or a lower pitch ?   Why ?

Conclusion: An ‘a-stable’ or ‘free running’ multivibrator oscillator is commonly used in electronics. It is used to make oscillations of various waveforms for making audio alarms or for generating signals.

This experiment demonstrates one use for the circuit.

O6: Oscillator. Inductive, free running





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor   BC548 (NPN)
- 1x Resistor 10k (10,000 ohm)
- 1x Potentiometer 100k (100,000 ohm)
- 1x Transformer (one coil with centre tap)
- 1x Speaker

Connect the circuit as shown above

Aim: To make a circuit that freely oscillates using only the inductance of a transformer, a transistor and speaker. There are no capacitors.

Settings: Set the Voltage regulator to about 6V.DC.   The transistor has the transformer coil as its collector load.   The centre tap on the coil is fed back to the base.   As the collector current changes it automatically changes the current into the base. This is called ‘feedback’.

Experiment: When the power is applied, the base of the transistor is joined to the positive line through the transformer coil.   The transistor will immediately turn on.

As current flows from positive line to the collector, it passes through half of the coil. The other half of the coil generates a negative voltage because of transformer action. This negative voltage connected to the base turns off the transistor.

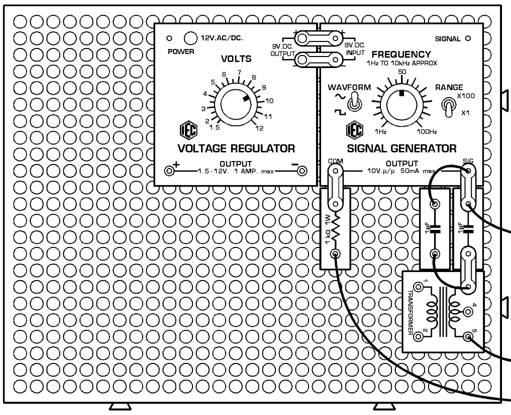
The current through the transformer coil stops so the base is again fed current from the positive line so the transistor turns on again ….. and so on. It oscillates.

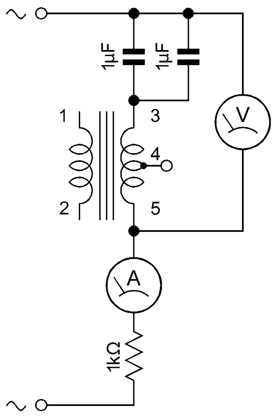
The other winding on the transformer is connected to a speaker. As the current goes on and off through half of the coil (or winding) in the collector circuit, a voltage is created in the speaker’s winding by transformer action. The speaker is driven by this current and a tone can be heard.

The potentiometer changes the current than can flow into the base and this will need to be adjusted to allow this circuit to freely oscillate. Remove power, adjust resistance value and re-apply power. When the value is correct, the tone will be heard in the speaker when the power is applied.

Conclusion: An oscillator does not need a capacitor to work.   Oscillators can have either capacitors or inductors or both.

O7: Oscillator. Series Resonance (natural oscillations)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Signal Generator, set to sine waveform.
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Resistor 1k (1,000 ohm)
- 2x Capacitors 1uF
- 1x Transformer

Connect the circuit as shown above

Aim: To demonstrate series 'resonance' where an inductance and a capacitance react against one another at one particular frequency when connected in series. This principle is used in 'tuning' radio and TV circuits so they receive only one station and reject all the others.

Settings: Set the Signal Generator to the x1 setting for frequency. Set the voltmeter to 20V.DC. and set the ammeter to 20mA.DC.

Experiment: The simple circuit has a capacitor (2x 1uF capacitors in parallel make a total of 2uF) in series with a small inductor. When the power is applied, the AC coming from the Signal Generator will pass through the series connection of capacitor and inductor. The 1k resistor is there only to limit the current so the Signal Generator is not too heavily loaded.

On AC, a capacitor creates a type of resistance called 'reactance' and this value in ohms reduces as the frequency rises.

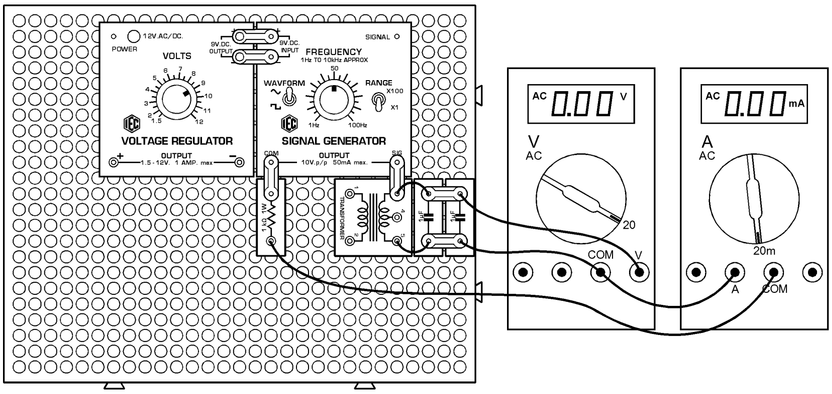
On AC, an inductor also creates a type of AC resistance and this value in ohms increases as the frequency rises.

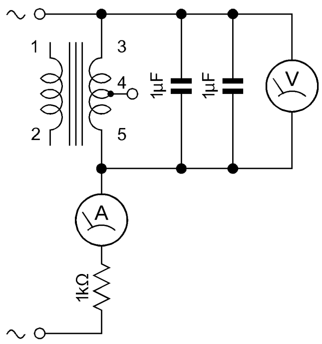
If a capacitor and an inductor are placed in series, there is always a frequency where the two reactances are exactly equal but are 180^o out of phase (reacting against each other). When this occurs, the total reactance falls to zero and a very heavy current flows. The current is limited by the 1k resistor.

Raise the frequency of the signal generator and watch the voltmeter. The voltage across the two devices will show when this 'resonance' point is reached. At series resonance, the voltage across both devices will fall suddenly. It cannot fall to zero because there is always some normal resistance in capacitors and inductances to cause some voltage reading. At resonance, the reactance of the capacitor equals the reactance of the inductor.

Conclusion: Resonance is a natural oscillation when reactances of capacitance and inductance are equal. It occurs also when sound frequency matches a length of tube (like a trumpet) or when a particular frequency in a room sounds louder than normal.

O8: Oscillator. Parallel Resonance (natural oscillations)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 1x Inductor (one half of the transformer)
- 2x Capacitors 1uF
- 1x Resistor 1k (1,000 ohm)

Connect the circuit as shown above

Aim: To demonstrate parallel 'resonance' where an inductance and a capacitance react against one another at one particular frequency when connected in parallel. This principle is used in 'tuning' radio and TV circuits so they receive only one station and reject all the others.

Settings: Set the Signal Generator to the x1 setting for frequency. Set the voltmeter to 20V.DC. and set the ammeter to 20mA.DC.

Experiment: The simple circuit has a capacitor (2x 1uF capacitors in parallel make a total of 2uF) in parallel with a small inductor. When the power is applied, the AC coming from the Signal Generator will split and some will pass through the inductor and some will pass through the capacitor. The 1k resistor is there only to limit the current so the Signal Generator is not too heavily loaded.

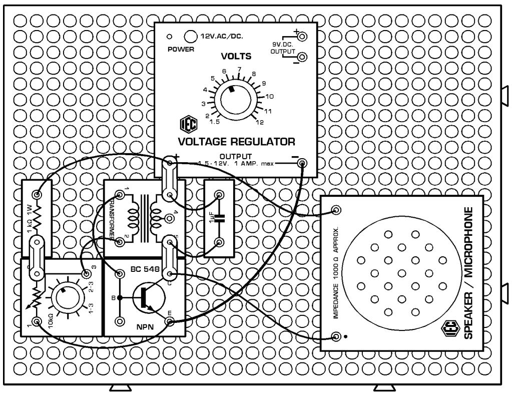
On AC, a capacitor creates a type of resistance called 'reactance' and this value in ohms reduces as the frequency rises.

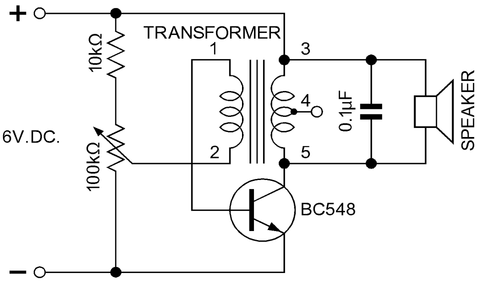
On AC, an inductor also creates a type of AC resistance and this value in ohms increases as the frequency rises.

If a capacitor and an inductor are placed in parallel, there is always a frequency where the two reactances are exactly equal. When this occurs, the total reactance increases to maximum and a very small current flows.

Conclusion: Resonance is a natural oscillation when reactances of capacitance and inductance are equal. It occurs also when sound frequency matches a length of tube (like a trumpet) or when a particular frequency in a room sounds louder than normal.

O9: Oscillator. Parallel Resonance with speaker.





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor (NPN) BC548
- 1x Resistor 10k (10,000 ohm)
- 1x Potentiometer 100k (100,000 ohm)
- 1x Capacitor 0.1uF
- 1x Transformer

Connect the circuit as shown above

Aim: To demonstrate parallel 'resonance' where an inductance and a capacitance react against one another at one particular frequency when connected in parallel. This principle is used in 'tuning' radio and TV circuits so they receive only one station and reject all the others.

Settings: Set the Voltage regulator to about 6V.DC.

Experiment: The circuit has a transformer winding as the collector load and a capacitor connected across the winding to form a parallel resonant circuit. The other winding on the transformer feeds the base of the transistor and turns it off when the collector current rises. This arrangement causes a natural oscillation.

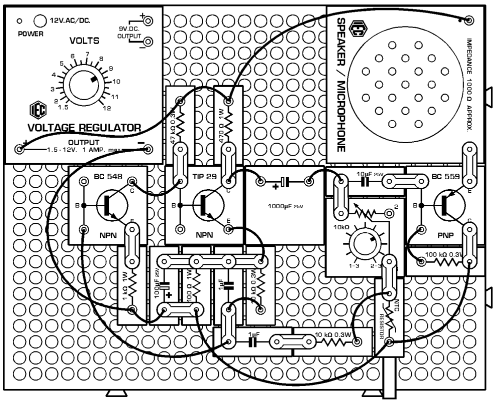
The resistors form a voltage divider to adjust the DC voltage at the base and to make the transistor biased slightly ON so it will respond to small signals. This setting must be adjusted carefully to make the circuit oscillate. If the feedback circuit is not set to permit the correct feedback current the system will not oscillate.

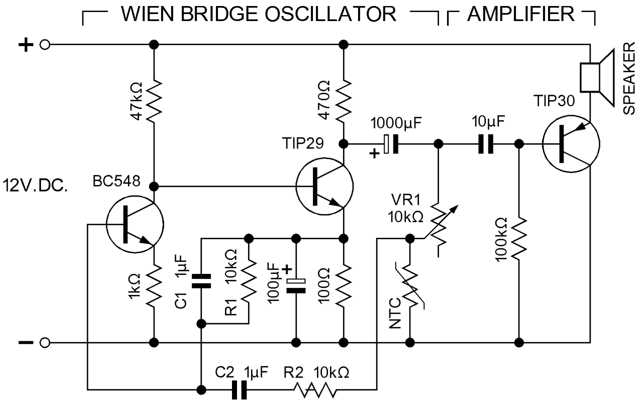
When the feedback circuit is the correct balance, the system will naturally resonate. As the frequency rises, there will be a point where the reactance of the capacitor and the reactance of the transformer coil are equal. We know from the previous experiment that series resonance causes a sudden reduction in total reactance of the circuit and a high current flows. With parallel resonance it is the opposite.

At the resonant frequency, the resistance through the parallel circuit rises greatly. The speaker is monitoring this voltage by sounding a tone and, since the voltage on the speaker should rise suddenly, the tone should become much louder.

Conclusion: Resonance is a natural oscillation when reactances of capacitance and inductance are equal. It occurs also when sound frequency matches a length of tube (like a trumpet) or when a particular frequency in a room sounds louder than normal.

O10: Oscillator.   'Wien Bridge' sine wave oscillator.





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 3x Transistors   (NPN) BC548   (NPN) TIP29   (PNP) TIP30
- 7x Resistors 100 ohm, 470 ohm, 1k, 10k, 10k, 47k, 100k,
- 1x Potentiometer 10k (100,000 ohm)
- 5x Capacitors 1uF, 1uF, 10uF, 100uF, 1,000uF
- 1x Speaker
- 1x Resistor (NTC)

Aim: To demonstrate a special type of oscillator (Wien Bridge) that generates 'sine' waves and, in this case, allows the oscillations to be heard through a speaker.

Settings: Set the Voltage regulator to about 12V.DC.

Experiment: The circuit is more complex than previous circuits.   The second transistor feeds its output signal from the emitter back to the base of the first transistor (feedback) but this circuit is a combination of a 'high pass' and a 'low pass' filter.   These filters form 2 legs of a 'bridge.

The collector output of the second transistor, which is the inversion of the emitter output, also feeds back to the first transistor but is modified by the value of the NTC resistor as current through this resistor changes its temperature and therefore its resistance.   The amount that this NTC resistor changes the feedback is adjusted by the variable resistance feeding the NTC.

The final stage of the circuit is a simple PNP transistor amplifier to drive the speaker. The speaker is the emitter load of this PNP transistor.

Using the components shown, this oscillator will run at about ???? Hz and, if an oscilloscope is available, look at the shape of the oscillation at the terminals of the speaker. The Variable resistance will adjust the quality of the sine wave to make the top and bottom halves of the wave the same shape. This should be close to a 'sine' wave.

The 'Bridge' is made up from:

Leg 1:   Resistor R1 and capacitor C1 in parallel 1uF and 10k

Leg 2:   Resistor R2 and capacitor C2 in series 1uF and 10k.

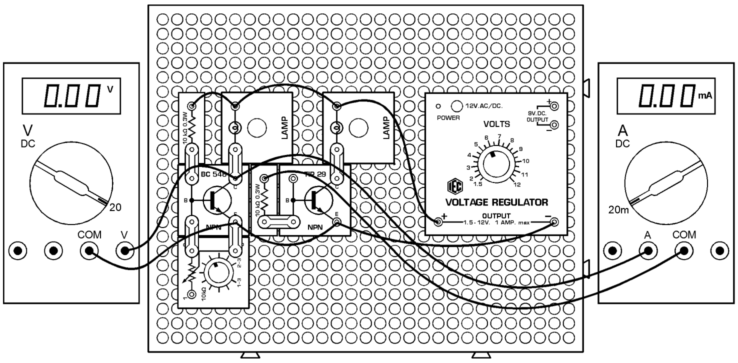
Leg 3:   Variable resistor VR1 10k

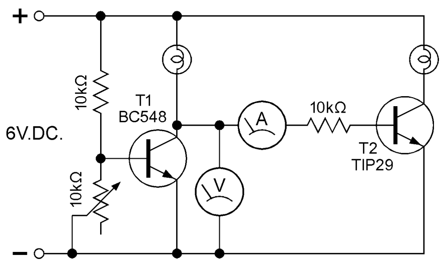
Leg 4:   NTC resistor

The exact description of how the circuit creates a sine wave is complex and goes beyond the study level of this electronics kit.

Conclusion: We have made a free running oscillator with special characteristics.

A1: Amplifier. One transistor controls the next transistor





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Ammeter & cables
- 2x Transistor (NPN) BC548   (NPN) TIP29
- 2x Resistors 10k (10,000 ohm) 10k
- 1x Potentiometer 10k (10,000 ohm)
- 2x Lamps

Connect the circuit as shown above

Aim: To control one transistor by adjusting base current and see that transistor control another transistor.   As one turns on gradually, the other turns off gradually.   We use the meters to monitor the collector voltage of the first transistor and the base current into the second transistor.

Settings: Set the Voltage regulator to about 6V.DC.   Each transistor has a lamp as its collector load. Set the adjustable resistor to maximum resistance.

Experiment: The current into the base of the first transistor is controlled by adjusting the voltage applied to it.   The voltage divider formed by the 10k resistor and the 10k potentiometer provides this adjustable voltage.

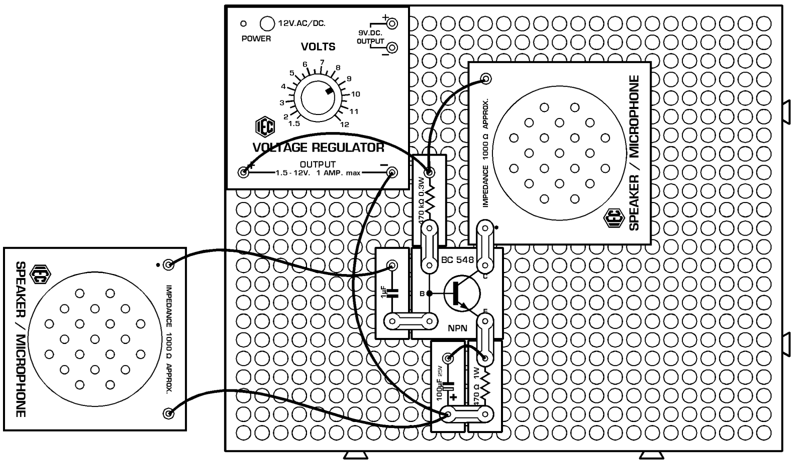
With the adjustable resistor on maximum resistance the voltage to the base is highest and the first transistor is turned on and its load lamp is on.   When the first transistor is turned on, its collector voltage is low.

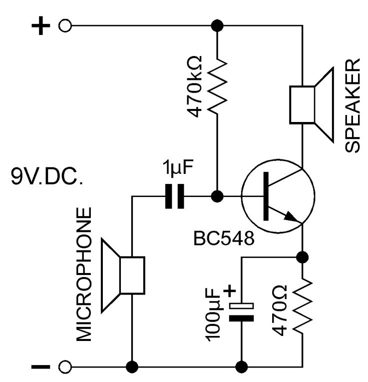
As the adjustable resistor is reduced, the base voltage of the first transistor is reduced towards negative line, the base current falls, it turns off and its collector voltage rises. This collector voltage feeds the base of the second transistor and the current into the second transistor base rises and this transistor turns on.

Repeat the action several times and monitor the collector voltage and the base current in the second transistor.   Follow what is happening.   This is the basic action of a 2 transistor amplifier.

Conclusion: In an NPN transistor, as the base voltage falls, the base current falls and the transistor turns off causing the collector voltage to rise. This means the transistor inverts the signal voltage.   The second transistor **inverts again** so the output voltage from the collector of the second transistor is in phase with the signal applied to the first transistor.

A2: Amplifier. Single stage using microphone & speaker





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Transistor (NPN) BC548
- 2x Resistors 470k (470,000 ohm) 470 ohm
- 2x Capacitors 1uF 100uF
- 1x Microphone
- 1x Speaker

Connect the circuit as shown above

Aim: To apply a microphone signal to change the transistor base current and drive the speaker from the transistor collector current.

Settings: Set the Voltage regulator to about 9V.DC.

Experiment: The base of the transistor is pulled up to the positive line and a small steady base current will flow which will cause some steady collector current to flow. This brings the transistor into its 'operating region'. A small rise and fall in base current will now cause a much larger rise and fall in collector current. The microphone's signal rapidly changes the base current when sound waves are converted into electrical signals by the microphone.

We cannot connect the microphone directly from the base to the negative line or it will pull the base to negative line and turn the transistor off. We need the electrical signal from the microphone but we do not want the resistance of the microphone to pull the base to negative line.

To isolate the microphone from pulling the base to negative, we use a small capacitor which blocks any DC current but will allow an AC current to flow from the microphone into the base. The microphone, when energised by sound, will cause a small additional signal current into the base and this current will change the collector current of the transistor.

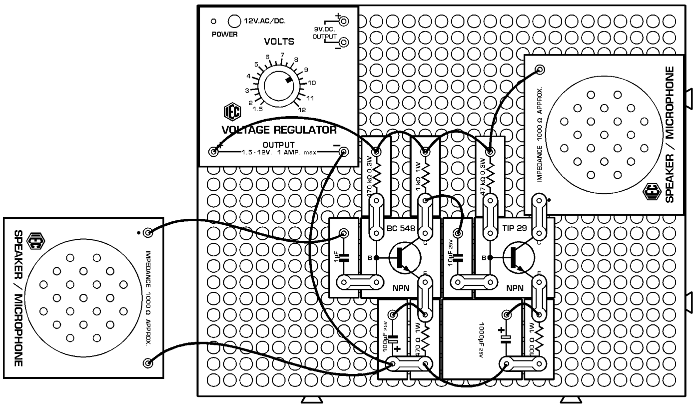
A resistor is used in the emitter line so that as transistor DC current flows, the emitter rises above the negative line. This stabilises the circuit and allows the output voltage to swing up and down without reaching the negative line.

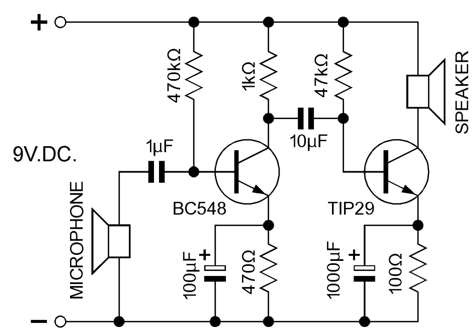
We do not want the CHANGE in collector current to change this emitter resistor value so it is BYPASSED with a large capacitor. This allows a change in collector current to flow through the capacitor and not flow through the emitter resistor. The steady DC current flows through the emitter resistor but cannot flow through the 'bypass' capacitor.

Turn on the power source and talk into the speaker. You should hear your voice coming from the speaker. A single stage amplifier will not drive the speaker very loudly.

Conclusion: You have built your first amplifier for sound. Later you will build a 2 stage amplifier which will be much louder.

A3: Amplifier. Two stage, AC coupled, using microphone & speaker





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Transistors (NPN) BC548 TIP29
- 5x Resistors 470k, 470 ohm, 1k, 47k, 100 ohm
- 4x Capacitors 1uF, 100uF, 10uF, 1,000uF
- 1x Microphone
- 1x Speaker

Connect the circuit as shown above

Aim: To apply a microphone signal to the base of the first transistor and drive the speaker from the collector current of the second transistor. Notice the first transistor is low power type and the second transistor is a high power type.

Settings: Set the Voltage regulator to about 9V.DC.

Experiment: The circuit of the first transistor is the same as the previous experiment except the collector load is a resistor instead of the speaker. The circuit works exactly the same as described in the previous experiment.

The output from the first transistor comes from the collector and is coupled to the second transistor by a capacitor. This capacitor blocks the DC voltage at the collector of the first transistor from reaching the base of the second transistor.

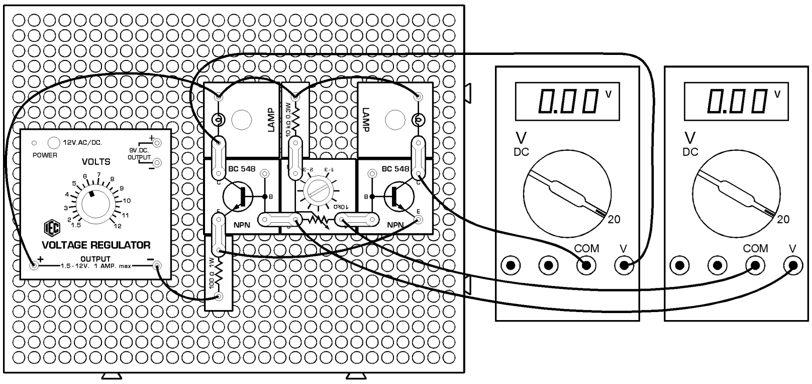
The base of the second transistor is biased to the positive line, similar to the first transistor and the emitter has a resistor and a bypass capacitor the same as the first transistor.

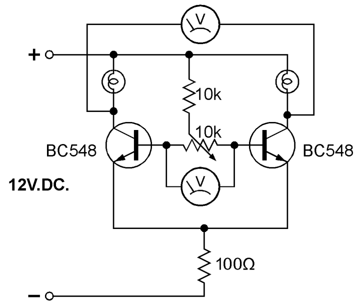
The signal from the collector of the first transistor is much stronger than the original signal from the microphone and it drives the base of the second transistor much harder. Therefore the current through the collector to emitter in the second transistor is greater and the speaker sounds much louder.

If the microphone and speaker are too close together, sound from the speaker will be picked up by the microphone and will be amplified. The amplified sound will be picked up be the microphone easier and it will be amplified again. This is called 'positive feedback' and will make the amplifier begin to oscillate and make a squealing sound. To stop this, keep the microphone well away from the speaker.

Conclusion: You have built your first 2 stage amplifier for sound. You have experienced unwanted 'positive feedback' oscillation. This is often heard when someone is speaking in a microphone when standing too close to the speakers.

A4: Amplifier. Differential pair (sum & difference amplifier)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Voltmeters & cables
- 2x Transistors (NPN) BC548
- 2x Resistors 10k   100 ohm
- 2x Lamps
- 1x Potentiometer 10k

Connect the circuit as shown above

Aim: To connect two transistors so that the voltage between them is the amplification of the difference between their base voltages. This is the principle used in many operational amplifiers (sometimes called op-amps).

Settings: Set the Voltage regulator to about 12V.DC.

Experiment: As the potentiometer is turned from one end to the other end, one transistor turns on its lamps and the other turns off its lamp. The difference between the base voltages is measured by one voltmeter and the difference between the collector voltages is measured be the other voltmeter.

When turning the potentiometer, it can be seen that the voltage difference between the voltages on the two bases is amplified as the difference between the collectors.   When the difference between the base voltages is zero, the difference between the collector voltages is also close to zero volts.

Starting at zero volts between the collectors, turn the potentiometer so exactly 1 volt is measured between the collectors. Measure and note the voltage (in mV) between the bases.

Now turn the potentiometer to obtain exactly 3 volts between the collectors. Again measure and note the voltage between the bases in mV.

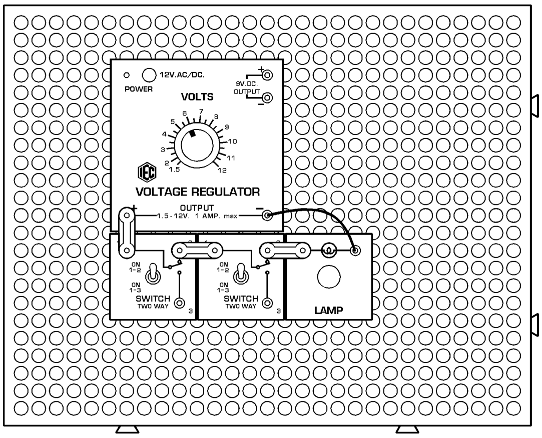
The CHANGE in the collector to collector voltage was exactly 2 volts.

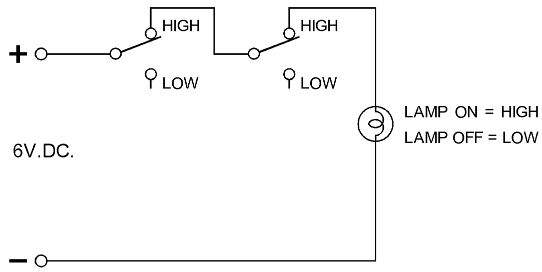
What was the CHANGE in base to base voltage ?

Divide the CHANGE in collector volts (2.0V) by the change in base volts (??mV). This number is the 'gain' of the system.

Conclusion: This is a special amplifier that amplifies the difference between 2 voltages and it is a very common type of amplifier.   In an operational amplifier, there are 2 inputs and the voltage difference between them is amplified by the 'gain' of the device and causes the output to rise in voltage.

L1: Logic circuit. AND gate (using switch logic)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Lamp
- 2x Switches

Connect the circuit as shown above

Explanation: A 'gate' is a device that has one or more inputs and only one output. The condition of the inputs controls the condition of the output. The status of inputs and outputs can be either ON or OFF. This is sometimes called 'HIGH' and 'LOW' or '1' and '0' or 'YES' and 'NO' or 'TRUE' and 'FALSE'.

Digital electronics is a form of electronics where only 'HIGH' and 'LOW' conditions are used to perform logical functions. Computers work only on these conditions. A 'HIGH' condition is value '1' and a LOW condition is value '0'. Counting is performed in a counting system called 'BINARY' where any numeric value can be expressed as a series of '1s' or '0s'.

Example: The value 183 is expressed in BINARY counting as 10110111

This example is called an '8 bit word' because there are 8 binary bits to make the value. **Each bit has a value that is 2x times the value of the previous bit.** This method of counting can be called 'counting to the base 2' or 'Binary'. Our normal way of counting is called 'counting to the base 10' or 'Decimal' counting.

For an 8 bit word, the right hand bit is value 1 or 0, the next bit is 2 or 0, the next bit is 4 or 0, the next bit is 8 or 0, the next bit is 16 or 0, the next bit is 32 or 0, the next bit is 64 or 0, the left bit is 128 or 0.

Therefore the value 10110111 is value 128+0+32+16+0+4+2+1 = value 183

It can be seen that 'gate logic' creates sets of 'ON' or 'OFF' conditions that can be used for mathematical calculations inside computer chips. The 'ON' and 'OFF' conditions occur very quickly (millions of times per second) which makes computers so fast at calculating.

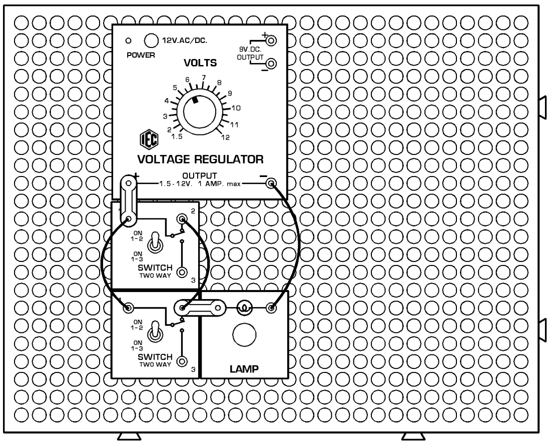
Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits. To understand the AND gate when using switches for the inputs.

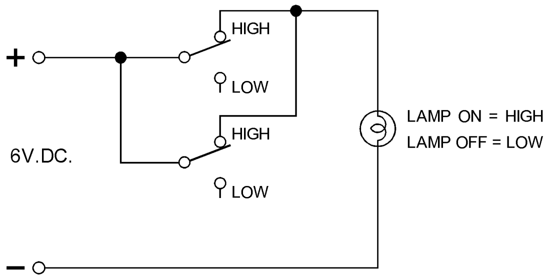
Settings: Set the Voltage regulator to about 6V.DC.

Experiment: It is obvious that the lamp can be ON only if switch 1 AND switch 2 are both ON. Any other combination of switch settings will make the lamp go OFF. This can be written ON+ON=ON or 1+1=1, 0+1=0, 1+0=0, 0+0=0

This list of conditions is called a 'Truth table'.

L2: Logic circuit. OR gate (using switch logic)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Lamp
- 2x Switches

Connect the circuit as shown above

See experiment L1 for explanation of ‘digital logic’.

Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits.   To understand the OR gate when using switches for the inputs.

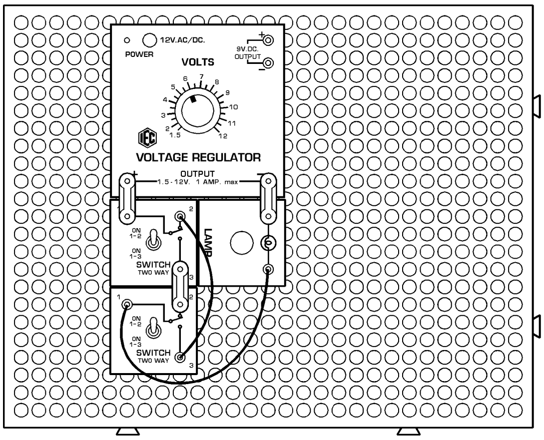
Settings: Set the Voltage regulator to about 6V.DC.

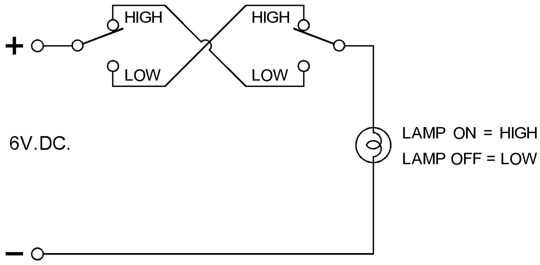
Experiment: It is obvious that the lamp can be ON if either switch 1 OR switch 2 are ON. It will be ON also if both switch 1 AND switch 2 are ON.   If both switches are OFF, lamp will be OFF.

Truth table: 1+0=1   0+1=1 0+0=0   1+1=1

There is another gate called an Exclusive OR gate (XOR gate). This means the gate is on when one OR the other switch is on but the gate is off if both switches are either ON or OFF.   See the next experiment.

L3: Logic circuit. Exclusive OR gate (XOR, using switch logic)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Lamp
- 2x Switches

Connect the circuit as shown above

See experiment L1 for explanation of 'digital logic'.

Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits. To understand the Exclusive OR gate (XOR gate) using switches for the inputs.

Settings: Set the Voltage regulator to about 6V.DC.

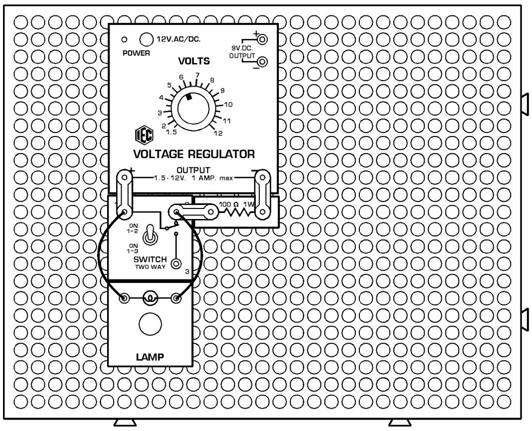
Experiment: In the previous experiment, we saw the OR gate. It is possible to make an OR gate that does not include the AND condition too. It is called 'Exclusive OR'.

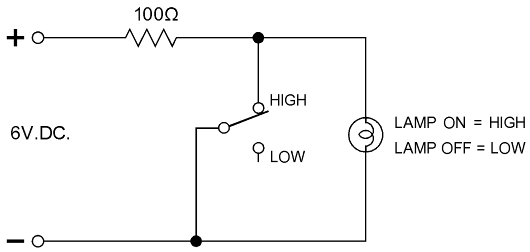
This circuit is the same as used when wiring up a house when 2 switches must control the one light in a room. The light will be ON only if one or the other switch is ON. If both switches are ON, the light is OFF.

Follow the circuit as shown to check the operation of an 'Exclusive OR' gate (XOR gate).

Truth table: 1+0=1 0+1=1 1+1=0 0+0=0

L4: Logic circuit. NOT gate (using switch logic)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Lamp
- 1x Switch
- 1x Resistor 100 ohm

Connect the circuit as shown above

See experiment L1 for explanation of ‘digital logic’.

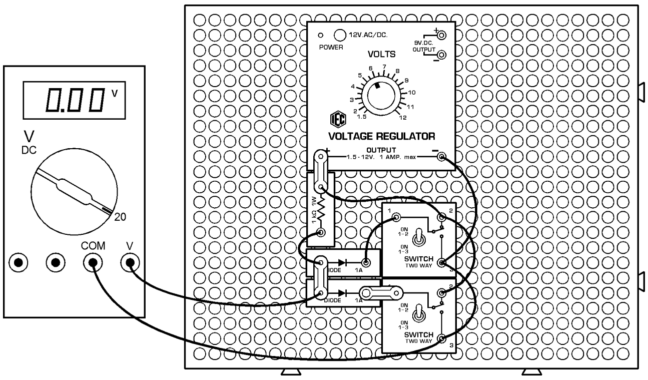
Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits. To understand the NOT gate (or INVERTER) using a switch for the input.

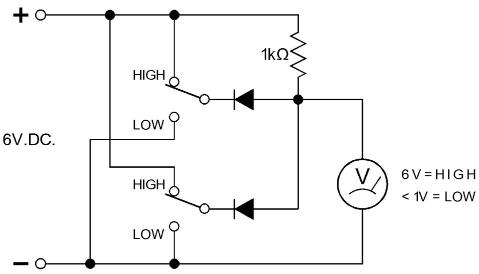
Settings: Set the Voltage regulator to about 6V.DC.

Experiment: When switch is ON, it makes the gate OFF. When switch is OFF, makes gate ON. This is the function of the NOT gate (or INVERTER).

Truth table: 0=1   1=0

L5: Logic circuit. AND gate (using diode logic)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 2x Switches
- 2x Diodes
- 1x Resistor 1k (1,000 ohm)

Connect the circuit as shown above

See experiment L1 for explanation of 'digital logic'.

Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits. To understand the AND gate using diodes for the inputs.

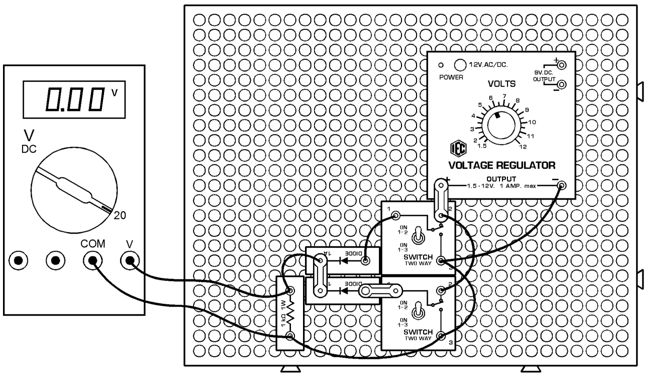
Settings: Set the Voltage regulator to about 6V.DC.

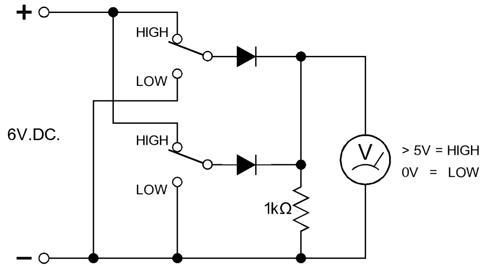
Experiment: The resistor is used to limit the current through the diodes. The voltmeter is monitoring the gate status.

If either input is LOW, a diode shorts the voltmeter to negative line and the gate is OFF. The gate is ON only of input 1 AND input 2 are ON. This is therefore an AND gate.

Truth table: 1+1=1   1+0=0   0+1=0   0+0=0

L6: Logic circuit. OR gate (using diode logic)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 2x Switches
- 2x Diodes
- 1x Resistor 1k (1,000 ohm)

Connect the circuit as shown above

See experiment L1 for explanation of 'digital logic'.

Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits. To understand the OR gate using diodes for the inputs.

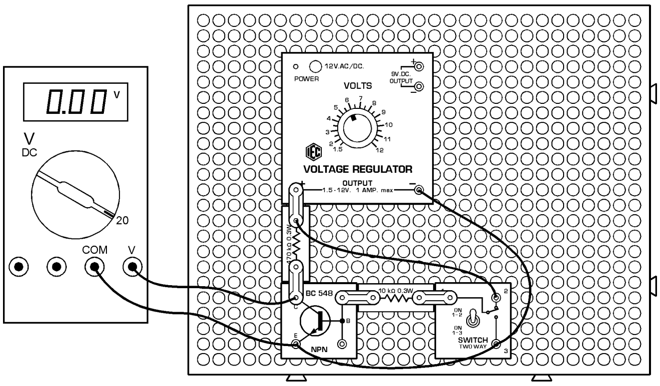
Settings: Set the Voltage regulator to about 6V.DC.

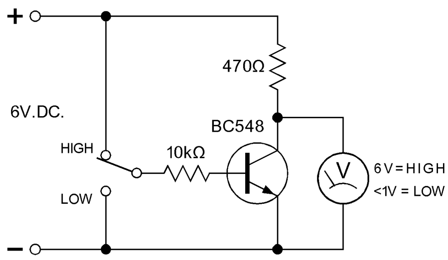
Experiment: The resistor is used to limit the current through the diodes. The voltmeter is monitoring the gate status.

If either input is HIGH with the other input LOW, the voltmeter is HIGH. If both inputs are HIGH, output is HIGH. If both inputs are LOW, output is LOW. This is therefore an OR gate – but it is not an Exclusive OR gate.

Truth table: 1+0=1 0+1=0 0+0=0 1+1=1

L7: Logic circuit. NOT gate (using transistor logic)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 1x Switch
- 1x Transistor (NPN) BC548
- 2x Resistors 470 ohm 10k

Connect the circuit as shown above

See experiment L1 for explanation of ‘digital logic’.

Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits.   To understand the NOT gate using a transistor for the input.

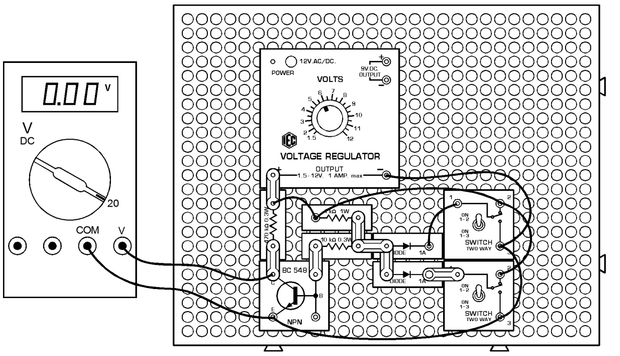
Settings: Set the Voltage regulator to about 6V.DC.

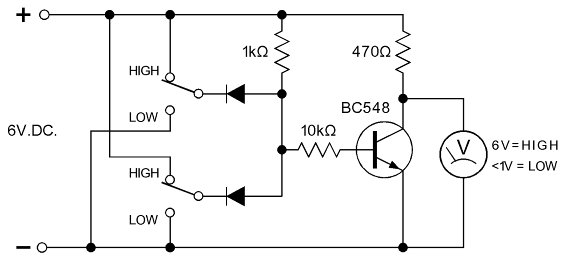
Experiment: The resistors are used to limit the current through the base and collector of the transistor. The voltmeter is monitoring the gate status.

If input is HIGH, base current flows and the transistor turns ON. The collector voltage falls close to the negative line and becomes LOW. This is therefore a NOT gate or INVERTER.

Truth table: 1=0   0=1

L8: Logic circuit. NAND gate (using diode logic & inverter)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 2x Switches
- 2x Diodes
- 1x Transistor (NPN) BC548
- 3x Resistors 470 ohm 1k 10k

Connect the circuit as shown above

See experiment L1 for explanation of 'digital logic'.

Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits. To understand the NAND gate using diodes for the inputs and a transistor for the inverter. 'NAND' is the combination logic for a NOT and an AND together. Its logic is the reverse of the AND gate.

Settings: Set the Voltage regulator to about 6V.DC.

Experiment: The resistors are used to limit the current through the diodes, the base and collector of the transistor. The voltmeter is monitoring the gate status.

The first part of the circuit is the same as the AND gate in experiment L5. The result of the logic is fed to a transistor which inverts the logic because when the base is HIGH the collector goes LOW.

Therefore, the transistor converts the AND gate to a NAND gate.

Truth table: 1+1=0 1+0=1 0+1=1 0+0=1

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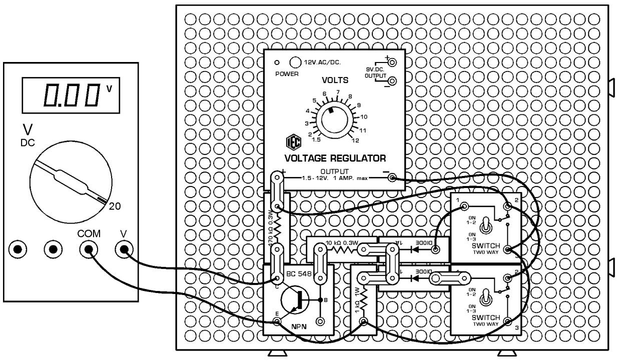
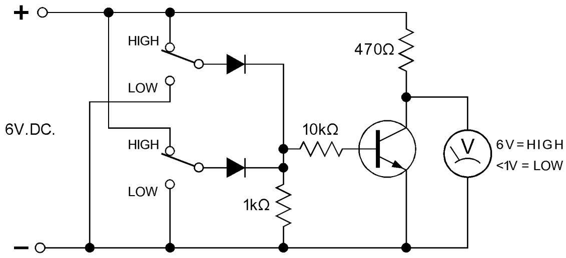
L9: Logic circuit. NOR gate (using diode logic & inverter)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Voltmeter & cables
- 2x Switches
- 2x Diodes
- 1x Transistor (NPN)   BC548
- 3x Resistors 470 ohm 1k   10k

Connect the circuit as shown above

See experiment L1 for explanation of 'digital logic'.

Aim: Introduction to Digital Electronics. To learn the different types of gates used in digital logic circuits.   To understand the NOR gate using diodes for the inputs and a transistor for the inverter. 'NOR' is the combination logic for a NOT and an OR together.   Its logic is the reverse of the OR gate.

Settings: Set the Voltage regulator to about 6V.DC.

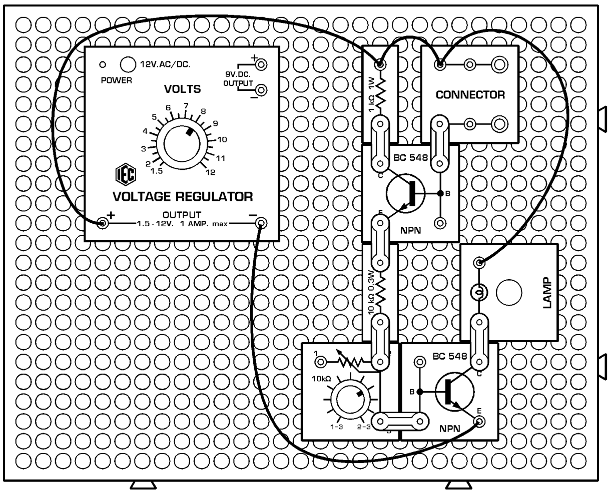
Experiment: The resistors are used to limit the current through the diodes, the base and collector of the transistor. The voltmeter is monitoring the gate status.

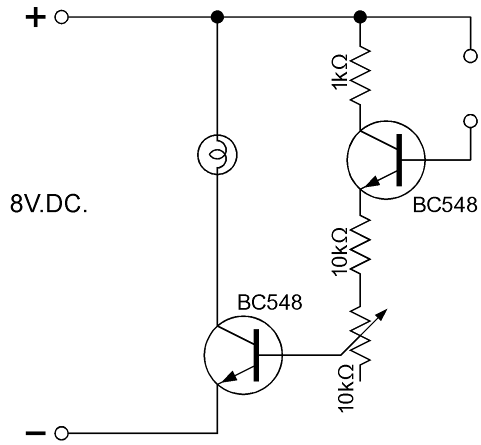
The first part of the circuit is the same as the OR gate in experiment L6.   The result of the logic is fed to a transistor which inverts the logic because when the base is HIGH the collector goes LOW.

Therefore, the transistor converts the OR gate to a NOR gate.

Truth table: 1+0=0   0+1=0   1+1=0   0+0=1

P1: Project: Liquid Level switch





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 2x Transistors (NPN) BC548
- 3x Resistors 1k 10k 10k
- 1x Lamp
- 1x Connector block
- 2x Alligator clip to banana plug adaptors.
- 2x Stainless steel electrodes.

Connect the circuit as shown above

Aim: To make a practical circuit that lights a lamp when the level of a liquid reaches 2x electrodes.

Settings: Set the Voltage regulator to about 8V.DC.

Experiment: This amplifier has very highly sensitive input. The current in the collector to emitter circuit of the first transistor is fed directly into the base of the second transistor. So there is a very high current gain for the circuit. A very small current through the electrodes will make the lamp glow.

Hold the electrodes between your fingers and see if enough current flows through your skin to operate the circuit. Wet your fingers to increase the conduction to your skin.

Note that there is no need for a base current limiting resistor because the emitter circuit has high resistance and a heavy current cannot flow from base to emitter.

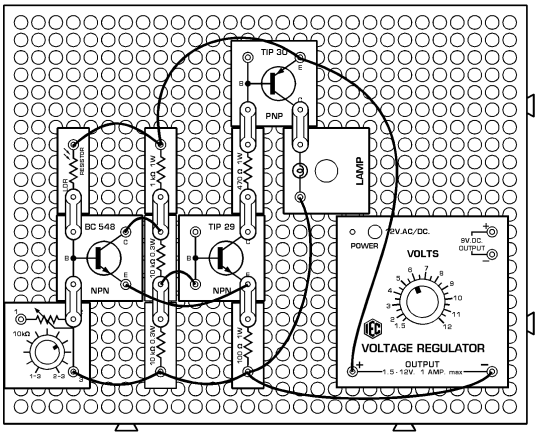
The sensitivity of the circuit can be adjusted by the variable 10k resistor. If this resistance is set to a higher value, the current into the base is reduced and the first transistor will need to turn on harder to make the second transistor turn on. If the variable resistor is changed to be a low value, more current will flow into the base of the second transistor and the first transistor needs to turn on less to make the lamp glow.

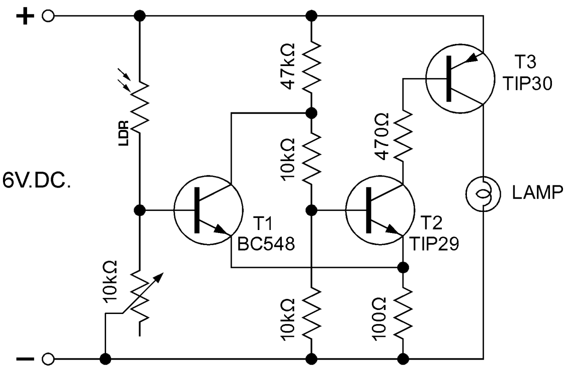
NOTE: If plain water does not make the circuit work, add a ‘pinch’ of table salt to the water to make the water more conductive.

Conclusion: Feeding the base of a transistor directly from the collector to emitter circuit of another transistor provides a very high current gain in the circuit.

This is one form of a direct coupled (or DC coupled) transistors to amplify steady voltages or DC signals. For microphones and speakers, the signals are a type of AC signal and the coupling between the stages is usually by capacitors to pass the AC signal and to block DC voltages.

P2: Project: Automatic 'Night Light' (using a Schmitt trigger)





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Light source
- 3x Transistors (NPN) BC548 (NPN) TIP29 (PNP) TIP30
- 5x Resistors 100 ohm 470 ohm 10k 10k 47k
- 1x Light Dependent Resistor (LDR)
- 1x Potentiometer 10k
- 1x Lamp

Connect the circuit as shown above

Aim: To make a practical circuit that brings on lights when the surroundings become too dark. Automatic exterior garden lights are available for gardens in homes and for security in businesses. The darkness approaches slowly, so to make the lights turn on instantly, a 'Schmitt Trigger' circuit is used.

Settings: Set the Voltage regulator to about 6V.DC.

Explanation: A 'Schmitt Trigger' is a very common form of electronic switch. It changes a slowly changing signal into a very fast ON/OFF function. In the case of the Shop Alarm, the change in light may be gradual but we want a definite ON/OFF switching action for the light (or audible alarm).

In the Schmitt, the gradual turning on of one transistor begins to turn off a second transistor which strongly reinforces the turning on of the first one. In this way the system tuns on fully and very fast. The signal must then change a certain amount (hysteresis) to start to turn off the first transistor which begins to turn on the second transistor which strongly reinforces the turning off of the first one.

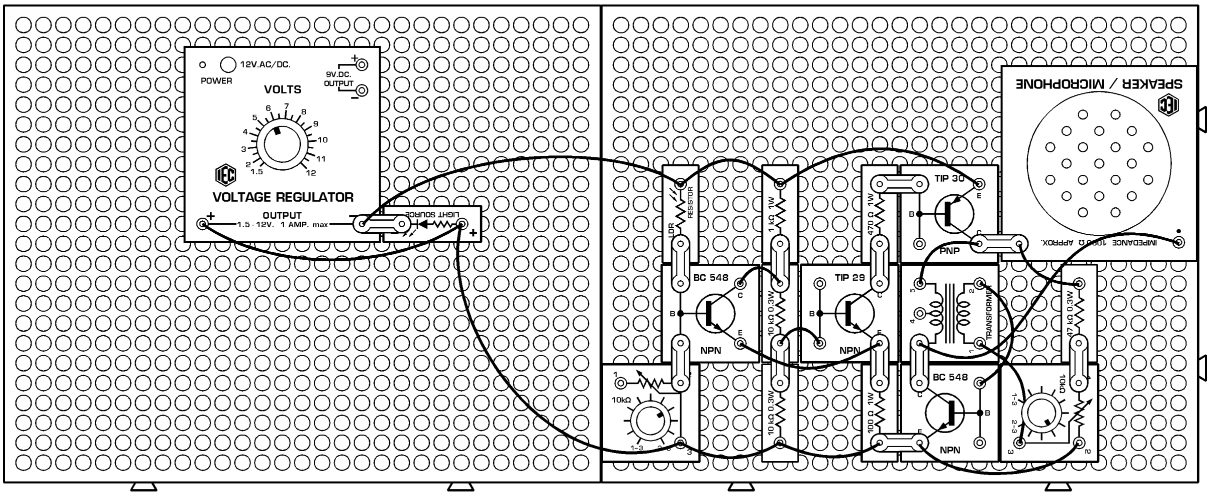
Experiment: The base of T1 is fed from the connection of the LDR and the potentiometer connected as a variable resistor. The variable resistor is set to adjust the sensitivity of the light sensing. When the light is removed from the LDR, its resistance rises and the base current into T1 falls. T2 is held on by a voltage divider made by the 3 resistors between the positive and negative lines. The emitter of the T2 is raised from negative line and this raises the emitter also of T1 which forces it off harder.

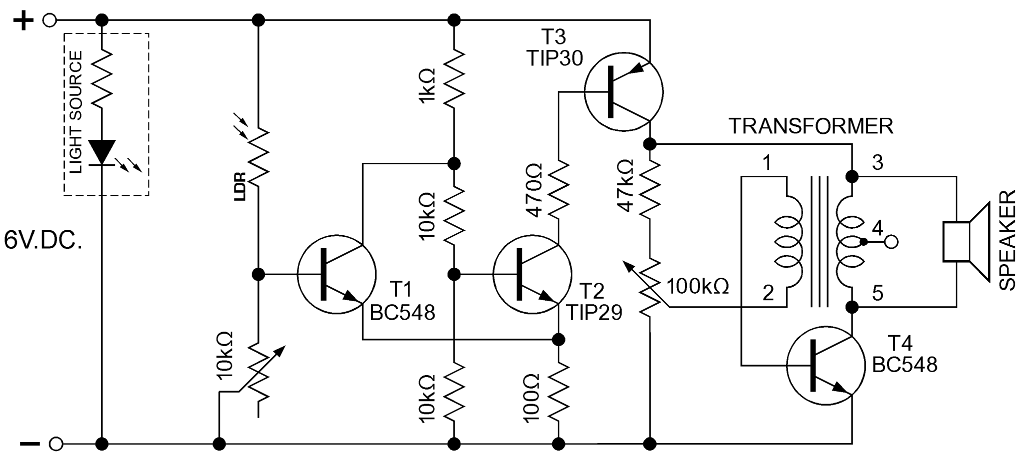
When the light beam is restored, the system reverses, T1 is on, T2 is off and the emitter voltage of T2 falls. This reinforces the turning on of T1.

The third transistor is a PNP current amplifier and the emitter to base junction and the 470 ohm resistor are the collector load of T2. T3 does not invert the switching of T2.

Conclusion: A simple DC coupled 3 stage amplifier can be used to operate a shop door alarm and, although the light might vary gradually, the switching action is sharply ON or OFF. The sensitivity can be changed to stop normal surrounding light from making the system give false alarms.

P3: Project: A ‘Shop Entry’ door alarm.





Equipment required:

- 1x Voltage regulated power supply powered by 240/12V.AC. PlugPak
- 1x Light source
- 4x Transistors (NPN) BC548 (NPN) TIP29 (PNP) TIP30 (NPN) BC548
- 1x Transformer
- 1x Speaker
- 6x Resistors 100 ohm 470 ohm 1k 10k 10k 47k
- 1x Light Dependent Resistor (LDR)
- 2x Potentiometers 10k 100k
- 1x Light source (white LED with integral resistor)

Connect the circuit as shown above

Aim: To make a practical circuit that sounds an audible alarm when a light beam is broken. Maybe the beam can be across the doorway of a shop and as a person enters the shop, the beam is broken.

Settings: Set the Voltage regulator to about 6V.DC.

P3: Project: A 'Shop Entry' door alarm.

……… continued ………..

Experiment: The first part of this circuit is the same as the previous experiment. Refer to the previous experiment for explanation for the operation of the 'Schmitt Trigger' circuit.

The second part of the circuit is an oscillator to make the tone for the speaker. Refer to oscillator experiment O9.

When the light beam is broken, T3 turns on in the same way as the previous experiment. But this time it does not make a lamp glow. It provides the power for an oscillator (same as experiment O9) which makes a tone in the speaker.

The 100k potentiometer in the oscillator changes the frequency of the oscillator and therefore changes the sound of the tone from the speaker.

Conclusion: A simple DC coupled 3 stage amplifier can be used to operate a shop door alarm. When an oscillator is added, it can become an audible alarm. The sensitivity can be changed to stop normal surrounding light from making the system give false alarms and the pitch of the tone coming from the speaker can also be adjusted.

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EXPERIMENT NOTES