SHORT CIRCUITS

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VOLUME III

Second Edition

Cat. BJ-8505

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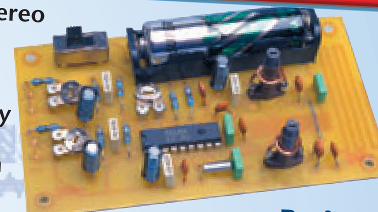
Dazzling display using 10 LEDs that appear to chase each other. Build for a shop, theatre or advertising display.

- Kit includes PCB, LEDs & electronic components.
- 12VDC power required.

Project # 8

Cat. KJ-8064

MINI FM TRANSMITTER



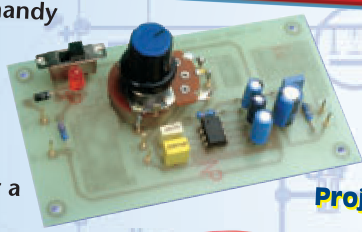
Transmit stereo audio from your tape deck or CD player to any FM radio elsewhere in your house. You could even tune in on a portable walkabout radio.

- Kit supplied with PCB, 1 x AA battery and electronic components.

Project # 15

Cat. KJ-8114

THE CHAMP AMPLIFIER



A cheap and handy amplifier that can improve low-level signal sources so they can be heard on headphones or a speaker.

- Kit includes PCB, volume potentiometer and all electronic components.
- 12VDC power required.

Project # 11

Cat. KJ-8072

GUITAR WAA WAA

Add the popular Waa-Waa effect to your guitar to sound really distinctive.

- Kit supplied with PCB, 6.5mm sockets and electronic components.
- Amplifier and 12VDC power required.

Project # 24

Cat. KJ-8096

GUITAR PRACTICE AMP

This low cost amplifier allows you to practice your guitar without annoying the neighbours. It has a guitar type input socket, small speaker and volume control.

- Kit supplied with PCB, speaker, socket and electronic components.
- 12VDC power required.

Project # 22

Cat. KJ-8092

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SHORT CIRCUITS

By Gary Johnston

VOLUME 3: SECOND EDITION

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The Jaycar website – www.jaycar.com.au

There is only so much information that will fit in a book, so we have placed a lot more information on our website. If you want to know more or download a program or file, it is free to readers of this book. Just point your web browser to **www.jaycar.com.au** and follow the prompts.

Where to buy the kits

All of the parts for every project described in this book (and far more) are available from Jaycar Electronics stores and dealers all over Australia and New Zealand. There are special deals on kits of parts for each individual project in the book, bulk rates for schools and all the tools you will need. See the inside front cover of this book for details on this.

Welcome to Short Circuits Vol. III

Welcome to Short Circuits Vol III completely updated second printing.

This is the revised 2nd edition of the successful original launched back in 2000. It retains all the features of the original book that made it a success – modern components, circuits and techniques. It still retains the user-friendly aspects, as well.

Many people have graduated from the spring-clip baseboard introduced in Short Circuits I. If you have already read Short Circuits II you will be familiar with the printed circuit board (also known as a PC board or PCB for short). PC boards are great because most of the complicated wiring is done for you. Indeed, it is "printed" in copper on the baseboard!

We will show you how to solder – properly – in this book. Yes, we did say that soldering can be dangerous in Short Circuits Vol I and it still is if you are silly. In reality though, soldering is no more dangerous than, say, using an electric drill.

We assume in this book that you are over 12 or that you are working under the supervision of a parent or teacher. If you do not fall into any of these categories, we suggest that you have a look at Short Circuits Vol I first.

Apart from the soldering – which is fun in itself – the complicated wiring together of the various components is done on a PC board. Most electronic devices use some sort of PC board – your computer, DVD player, iPod®, TV, stereo etc are full of them. The best part about PC boards is convenience. The wiring between the components is almost completely done for you and they offer a stable place to mount most of the parts.

By the way, many of the projects in this book can be made to run from mains (240V) power via a plugpack supply. This is perfectly safe as we use a fully-enclosed Electricity Authority approved adaptor. Your fingers will never touch anything higher than around 12 volts.

You will still find the "Tech Talk" panels as you did in Short Circuits Vol I & II. Again you will receive a complete explanation giving a full technical description, along with individual explanations of component functions in the context of the overall circuit.

Phew! Dont worry, you can skip over the "Tech Talk" and still get your project going. It's there for those who just need to know all the "gory details"! We also have sections which describe the components you will encounter in this book, including the microchip or integrated circuit (IC).

When you encounter a term thats foreign to you, you can look it up in the glossary – it will be explained unless the term is more appropriate to your dictionary. Throughout the text, we suggest how to substitute components if you need or want to. We also show you how to use some simple test equipment and how to "read" component values

The best part, though, is that you get to keep and actually use projects built on PC boards. You can make an electric guitar practice amplifier, an intercom, a burglar alarm, a light flasher or heaps of other things that work really well. You'll impress your parents and friends with how clever you are!

You never know, the buzz you get from this book might just tip you into a lucrative career in electronics or even computing. I turned something I did for fun in my free time into a career but as far as I am concerned, I am still getting paid to pursue a hobby.

Thats right, getting paid to have fun! You can do this too. Happy soldering!

Gary Johnston
Managing Director
Jaycar Electronics Group.

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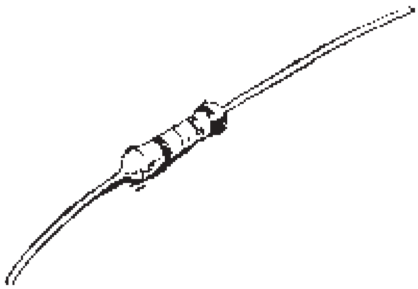
How to recognise components . . .

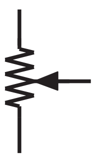
Resistors – fixed and variable

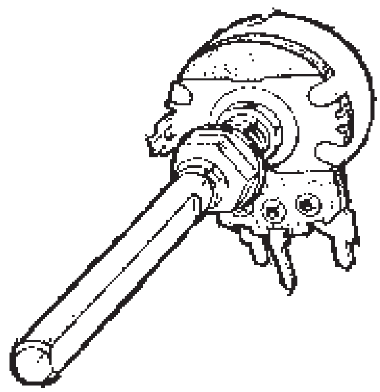
RESISTOR



Resistors are used to limit the amount of current flowing in a circuit – the higher the resistance, the less current that flows & vice versa. Resistor values are measured in ohms (Ω) and are identified by the colour bands on their bodies (see page 43). They may be connected into circuit either way around (ie, they are not polarised).

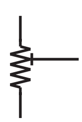
POTENTIOMETER





A potentiometer (or pot.) is basically a variable resistor. It has three terminals and is fitted with a control shaft. Rotating this shaft varies the position of a metal wiper on a carbon resistance track inside the pot. body and this in turn determines the resistance between the wiper (centre terminal) and the two outer terminals. Potentiometers are commonly used as volume controls.

TRIMPOT



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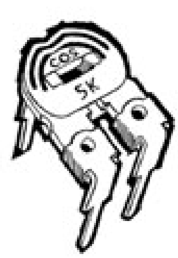
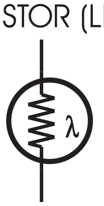
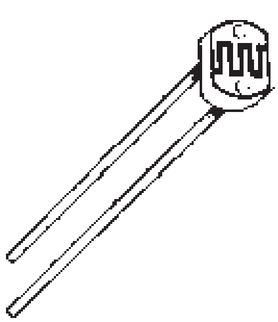


A trimpot is a special type of potentiometer which, while variable, is intended to be set once (or seldom) and left. For this reason, a shaft is not included but instead a screwdriver is used to adjust the "wiper" or variable portion. Some trimpots are made with their total resistive element and wiper exposed, others are enclosed in a plastic case.

LIGHT DEPENDENT RESISTOR (LDR)

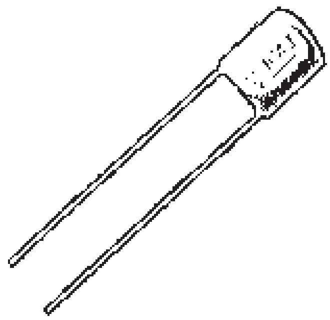




A light dependent resistor (LDR) is a special type of resistor that varies its resistance according to the amount of light falling on it. When it is dark, an LDR will have a very high resistance (typically many millions of ohms) but this will fall to just a few hundred ohms in the presence of strong light. They are not polarised.

Capacitors – fixed and variable

POLYESTER
CAPACITOR
(GREENCAP)

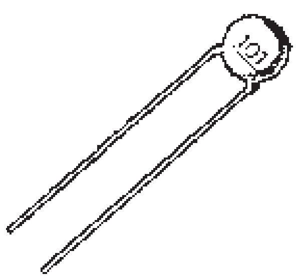


Capacitors block DC (direct current) while allowing varying or AC (alternating current) signals to pass. They are commonly used for coupling signals from one part of a circuit to another and in timing circuits. Some polyester capacitors are called "greencaps" since they have green bodies. Their values are specified in microfarads (µF) and range from .01µF up to about 2.2µF – see page 55 for capacitor codes. They are not polarised.

MKT POLYESTER
CAPACITOR

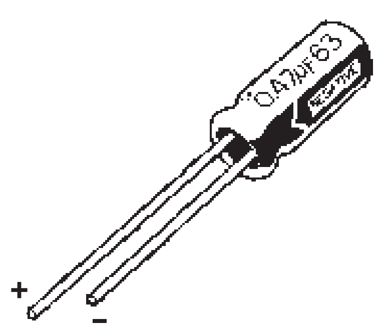
Another type of polyester capacitor but these are normally yellow and have a block shape. One of the major advantages of MKT capacitors is a more standardised pin spacing, making them more useful for PC boards. Most small fixed capacitors in this book are MKT types, though greencaps can be substituted if you wish.

CERAMIC
CAPACITOR



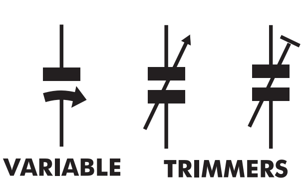
Ceramic capacitors range in value from 1pF (picofarad) to about 0.47µF and are often used in RF (radio frequency) tuned circuits and filter circuits. Like greencaps, they are not polarised – see page 55 for code markings.

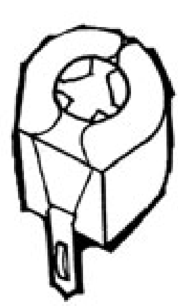
ELECTROLYTIC
CAPACITOR



Electrolytic capacitors are commonly used to filter power supply rails, for coupling audio signals and in timing circuits. They range in value from about 0.1µF up to hundreds of thousands of microfarads. These capacitors are polarised and the positive and negative leads are clearly marked on their bodies. Be sure to connect them correctly.

VARIABLE OR
TRIMMER CAPACITOR

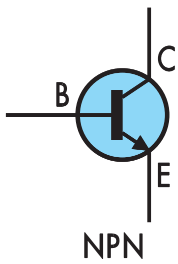


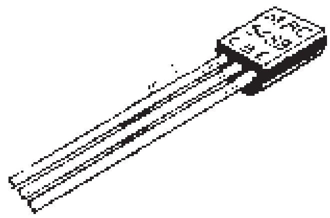


Sometimes the amount of capacitance needs to be adjusted or "trimmed" – changing the frequency of a tuned circuit, for example.
A variable capacitor has one set of fixed plates and one set which can be moved with either a knob (like a pot) or a screwdriver (similar to a trimpot). Because of their construction, most variable capacitors have quite low values – up to a few tens or at most hundreds of picofarads (pF).

Semiconductors: Transistors & Diodes

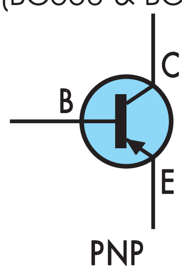
NPN TRANSISTOR
(BC548 & BC338)

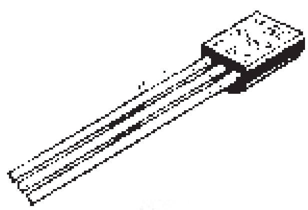




Transistors are semiconductor devices that can either be used as switches or to amplify signals. They have three leads: *collector, base* and *emitter*. A small current flowing in the base-emitter junction causes a much larger current to flow between the collector and the emitter. Two types of transistors are used in this book – NPN types and PNP types. Transistors are labelled with "Q" numbers (Q1, Q2, etc) on the circuits, so as not to confuse them with transformers.

PNP TRANSISTOR
(BC558 & BC328)

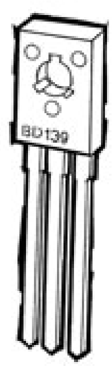




The PNP transistors used in this book mostly look identical to the NPN types specified, so be careful when selecting them. You can easily recognise a PNP transistor on a circuit, because the arrow at the emitter points towards the base junction. Be sure to always use the exact type specified and always connect their leads exactly as shown in the wiring diagrams.

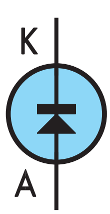
POWER TRANSISTOR
(PNP or NPN)

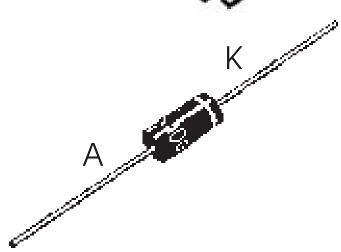
(Symbols
as above)



Power transistors are (usually) larger than the "small signal" types above and, as their name suggests, are capable of handling higher currents and voltages. Most power transistors have an exposed metal tab (or part of the case exposed) to enable a close thermal bond to be made to a heatsink, thereby enabling heat to be conducted away from the transistor.

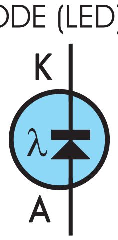
SILICON DIODE

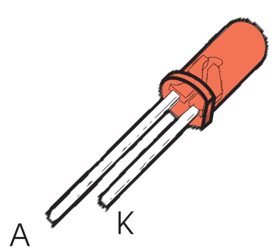




A diode can pass current in one direction only but in order for current to flow, the anode (A) must be positive with respect to the cathode (K). In this condition, the diode is said to be *forward biased* and a fixed voltage of at about 0.6V appears across its A and K terminals. If the anode is less than +0.6V with respect to the cathode, negligible current flows and the diode effectively behaves as an open circuit.

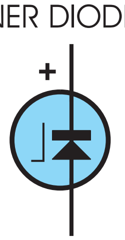
LIGHT EMITTING
DIODE (LED)

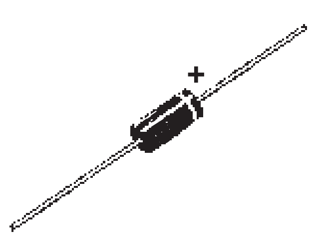




These special diodes have a plastic translucent cover (usually clear, red, green or yellow) that houses a small semiconductor element. When a small current is passed through the LED, it glows brightly. LEDs must be forward-biased to operate. They are available in red, orange, yellow, green, and blue colours as well as two-colour.

ZENER DIODE

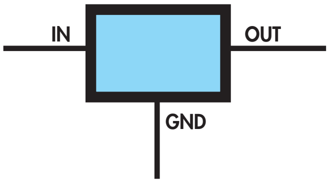


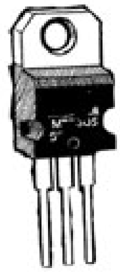


The Zener is another special type of diode which, under certain conditions, develops a quite constant voltage across its junction. This voltage is often used as a reference voltage in power supply circuits. The striped end of a Zener is its positive end (this is opposite to normal diodes).

Other Semiconductors

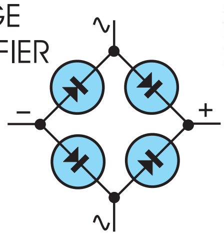
3-TERMINAL REGULATOR

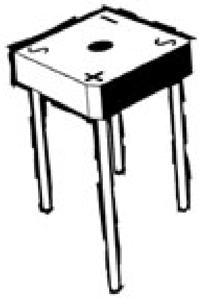




A special type of integrated circuit which supplies a regulated, or accurate, voltage from its output regardless (within limits) of the voltage applied to its input. They are most often used in power supplies. Most regulators give a specific voltage (eg, a "7812" regulator gives 12 volts out) but some are adjustable via an external potentiometer.

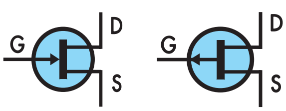
BRIDGE RECTIFIER



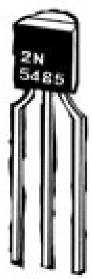


Bridge rectifiers consist of four diodes connected in a "diamond" pattern. This type of rectifier takes the output voltage from a transformer (AC) and converts it into pulsating DC. A smoothing capacitor connected between "+" and "-" helps make this a more constant DC. See page 111 for a more detailed explanation.

FET - JUNCTION TYPE

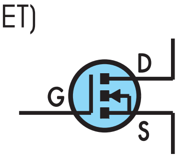


n-channel p-channel

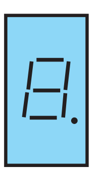


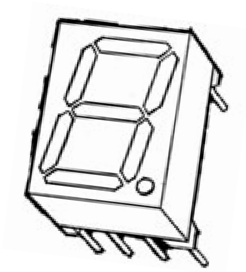
The voltage applied to a FET's control element (the "gate") controls the current flowing between its other two elements – the "source" and the "drain". This behaviour is in contrast to "ordinary" transistors where the current through the base controls the collector/emitter current. In many ways, FETs behave more like old-time valves rather than modern transistors. Like transistors, though, FETs can be used as amplifiers or switches. They come in both "P-channel" and "N-channel" (similar to PNP and NPN transistors) and are available in both small signal and power types.

FET - POWER TYPE (MOSFET)



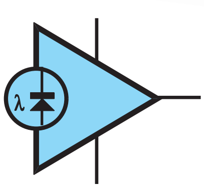
LED DISPLAY

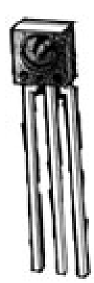




A LED display has seven elongated LEDs arranged in an "8" pattern. By choosing which LEDs are lit, any number from 0 through to 9 can be formed. Most LED displays also contain another small LED which can be used as a decimal point.

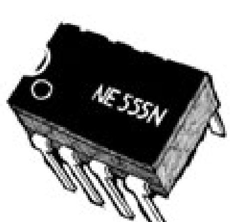
INFRARED DETECTOR





A device which has a "window" through which infrared light can pass and be detected by sensing circuitry within.

INTEGRATED CIRCUIT

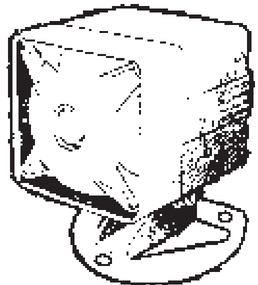


(ICs have many symbols, usually depicting the function or circuit use)

Integrated circuits (ICs) contain all, or most, of the components, necessary for a particular function – in one package. There are many shapes and styles but the three shown here are the most common in hobby electronics. Pin 1 of the IC is usually marked with a spot of paint, a notch cut in the end of the IC or sometimes with the number 1 above it. Looking down on the IC, the numbering is always anticlockwise from that point.

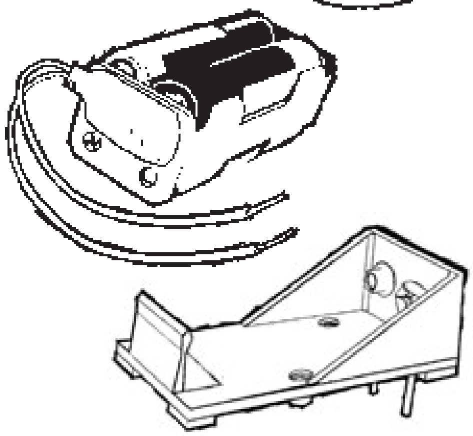
Hardware

ALARM SIREN



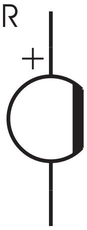
A very high intensity piezoelectric siren intended for warning and alarm applications. Because of its very high output level, while working on this type of siren it is strongly recommended that you "muffle" the output by placing it under, say, a pillow or blanket. Hearing damage could occur at close range.

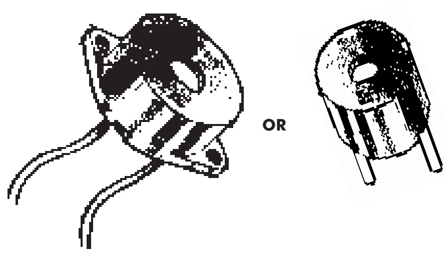
BATTERY/ HOLDER



The battery supplies power to the circuit. Many of the projects described in this book use a 12V supply which can be made up from two of these packs, each containing four 1.5V penlight (AA) cells in series. The illustration at left also shows a battery snap connector. Some projects use a 9V battery while one uses just a single AA cell. Be sure to always connect batteries the right way around.

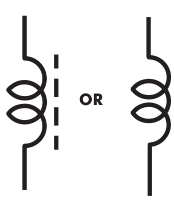
BUZZER





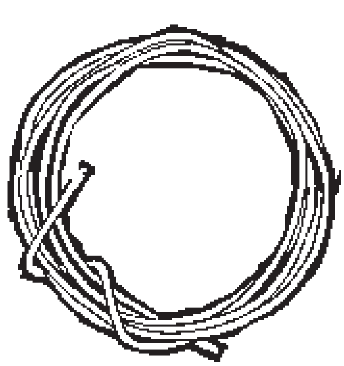
The buzzer specified in the projects in this book is a self-oscillating piezoelectric type. It uses a piezoelectric diaphragm which is flexed when varying voltages are applied to it. A small circuit inside the buzzer generates a tone signal (the varying voltage) and this is converted to sound via the diaphragm. This device is polarised.

COIL AND FORMER



Consists of a base with mounting pins, a coil former and sometimes an internal threaded ferrite core or "slug". The coil is wound on the former and the ferrite core is adjusted to achieve the exact inductance required. A dotted line alongside the coil symbol indicates a ferrite core. A solid line normally indicates an iron core while no line indicates no core or a core which does not affect inductance. Sometimes the coil does not need to be adjusted so no adjustable ferrite slug is necessary.

COPPER WIRE – ENAMELLED

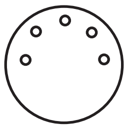


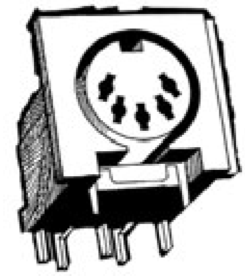
Copper is almost always used for wire because of its excellent conductivity. Sometimes, though, there is a probability of short-circuiting (for example in a coil) so the copper must be insulated. A very fine coating of enamel is applied (like varnish or clear paint). Unless the wire gets too hot or the design voltage is exceeded, this will continue to insulate the wire.

COPPER WIRE – TINNED

Often used for links on PC boards where there is no danger of short circuits. Plain copper wire cannot be used because it will oxidise or tarnish in the presence of air. A thin alloy coating is therefore applied to the copper – not just of tin as the name suggests, but an alloy of tin and lead which is easy to solder but doesn't oxidise as easily as copper.

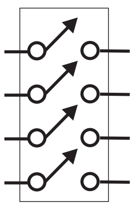
DIN SOCKET

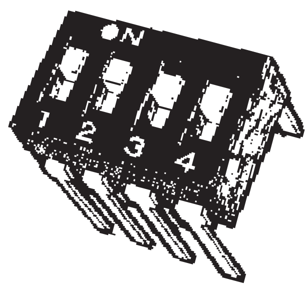




DIN is an international set of standards which originated in Germany (it stands for Deutches Industrie Normales). Many devices conform to a DIN standard – in this book it is the 3-pin or 5-pin socket which is normally used for audio inputs and outputs but in our case we are connecting a transformer fitted with a DIN plug to a regulated supply circuit.

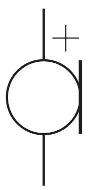
DIP SWITCH

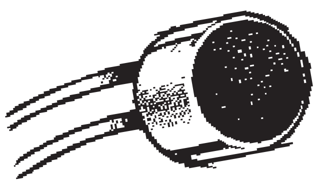




A number of single pole, single throw switches (in our case four but can be more or less) moulded into a "case" the same size as an integrated circuit. DIP, by the way, stands for Dual-Inline Plastic, which describes the way the pins connect to the case and the case's material.

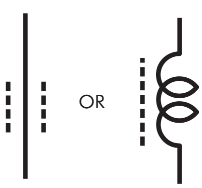
ELECTRET MICROPHONE

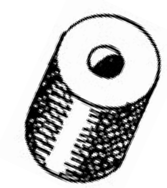




An electret microphone converts audible sound waves into electrical signals. These signals can then be amplified (eg, in a public address system), fed to a transmitter, or processed in some other way (eg, to operate a sound-triggered switch). All electret microphones contain a field effect transistor (FET) which acts as a buffer and this means that they must have a DC supply of a few volts. This device is polarised.

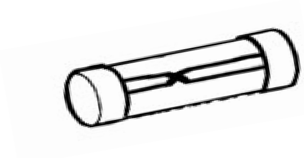
FERRITE BEADS





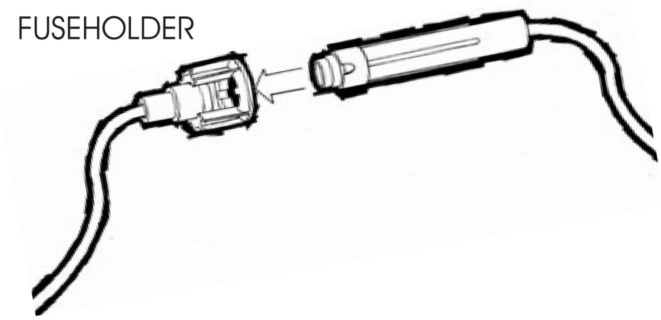
Made from a ceramic material, ferrite beads help to eliminate or minimise RF interference which might be picked up by sensitive circuitry. A typical way to use the beads is simply to thread component leads through their holes.

FUSE



A fuse protects a circuit from damage if too much current flows by destroying itself or "blowing" (see page 86) Most of the fuses used in electronics consist of a fine wire enclosed in a glass tube with metal caps. The current rating of fuses varies from a few milliamps to many, many amperes. The two common sizes of glass fuse are the 3AG, which is 32mm long x 6mm in diameter and the M205, which is 20mm long x 5mm in diameter.

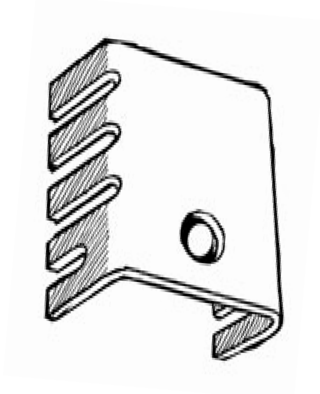
FUSEHOLDER



To connect a fuse, a fuseholder is required. Some fuseholders are simply metal clips which solder directly onto a PC board but where access is required, an external fuseholder is used. These generally fit together by pushing in and twisting, much like replacing a light globe in a light socket. You can also get chassis-mounting or case-mounting fuseholders where just the cap is removed to access the fuse.

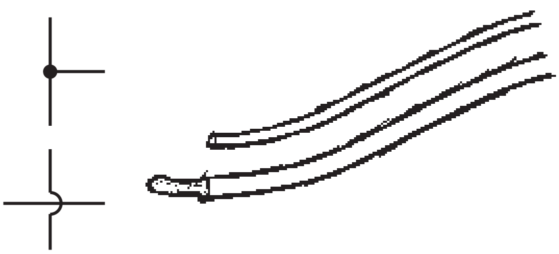
Hardware

HEATSINK



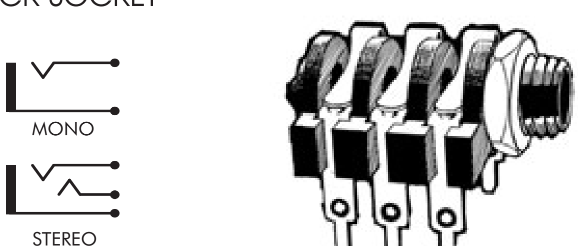
Virtually all components generate some heat. While most can cope with this heat some are not capable of removing all the heat they generate and may eventually be damaged or destroyed. A heatsink is a device which makes intimate thermal contact with the device (most likely a semiconductor) and draws the heat from it, keeping it cool and radiating its heat to the surrounding air.

HOOK-UP WIRE



Hook-up wire is used to make circuit connections. Single-strand tinned copper wire (non-insulated) can sometimes be used but multi-strand insulated hook-up wire is often necessary to prevent shorts (remove about 3-5mm of insulation from each end of the wire). You can also use plastic sleeving (called "spaghetti") to insulate bare wires where they cross over each other, to prevent shorts. On a circuit diagram, a solid dot indicates that the leads are connected or joined, while a "loop-over" means that the wires are not joined and must be insulated from each other.

JACK SOCKET

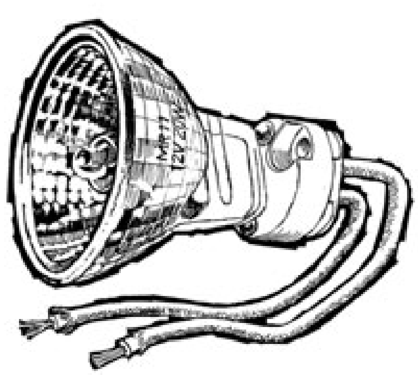


A very widely-used type of plug and socket system, particularly in audio applications. The plug can have two sections, a body and an insulated end, for mono use, or it can have an additional insulated ring for stereo use. The socket has contacts which touch the appropriate portion of the plug when fully inserted. We use sockets intended for 6.35mm plugs in this book, although similar sockets (and plugs) are available in 3.5mm and 2.5mm diameter.

LAMP - BULB

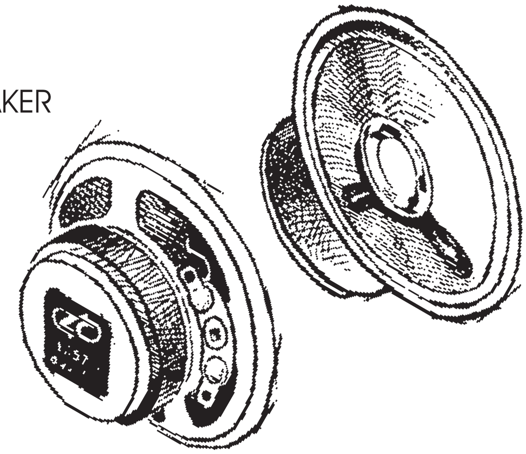
A tiny light globe, similar to those used in torches except that this particular device has two long leads to make the connections. It is not polarised and can be connected either way around.

LAMP - HALOGEN



A high-current bulb which operates from 12V AC or DC, giving a very bright and quite "white" light output. It has a tungsten filament, similar to a conventional bulb but instead of a vacuum inside it has one or more of the "halogen" gases. Up close, these bulbs can give a burn similar to sunburn. They also operate at a very high temperature, especially the 50W types. They are not polarised.

LOUDSPEAKER

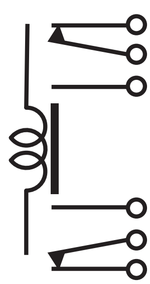


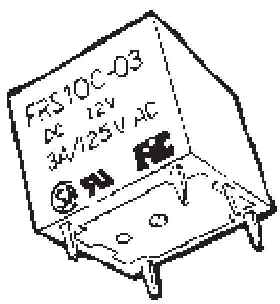
A loudspeaker converts electrical signals into sound waves. It has two terminals which go to a "voice coil" (essentially a coil of wire) attached to a cardboard paper cone. When electrical signals are applied to the voice coil, it creates a varying magnetic field which interacts with an adjacent permanent magnet at the back of the speaker. As a result, the cone vibrates in sympathy with the applied signal to produce sound waves. The terminals are marked with "+" and "–" signs but a speaker can be considered non-polarised as used in these projects.

PC STAKE

A small (10mm long) metal "pin" which is soldered into a PC board, making it much simpler and easier to connect and disconnect external wires. The PC stake has a collar closer to one end – this is the end which goes into the board.

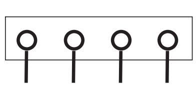
RELAY

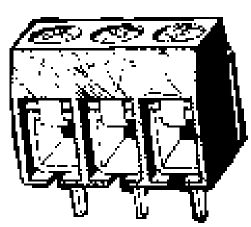




Many electronic components are not capable of switching the required voltages or currents, so a relay is used. This has a coil which forms an electromagnet, attracting a steel "armature" which itself pushes on one or more sets of switching contacts. When the coil is energised, these disconnect from one set of contacts and connect to another. When de-energised the contacts return to their original position. In most cases, the relay coil needs a diode across it to prevent damage to sensitive semiconductors.

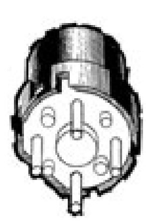
SCREW TERMINAL BLOCK





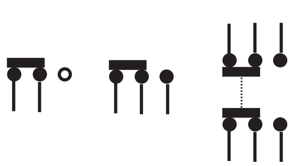
Another method for easily connecting – and disconnecting – external wiring to a PC board. The terminal block has pins which solder to a PC board and wires are inserted into their appropriate holes and made fast by tightening a grub screw in the terminal block.

SWITCH - PUSHBUTTON

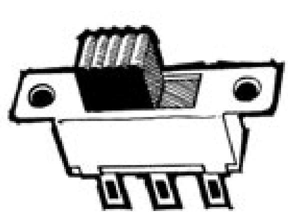


A switch which is actuated by pressing it. Some pushbutton switches are "push on, push off" but most are "momentary action" – when the button is released the switch opens. The pushbutton switches used in this book which solder directly to the PC board must be inserted the right way around for the switching action to occur (note the flat surface on one side).

SWITCH - SLIDER



SPST SPDT DPDT



Slider switches work exactly as their name implies – you slide it to switch positions. Almost all power switches in this book are slider switches. Most projects require only a single pole, single throw (SPST) function but slider switches are usually made double pole, double throw (DPDT) so the PC boards can accommodate either type in the same hole positions.

BONUS!

Soldering: how it's done

All the projects in this book use printed circuit (PC) boards. These are fibreglass or phenolic boards which have etched copper tracks on one side and the components which make up the circuit on the other side. The leads from the components poke through holes drilled in the board.

It's easy to understand why they're called "printed circuit boards" – it looks as though the tracks are "printed" on.

To make the PC boards work, you have to make metal-to-metal connections between the PC board tracks and the component leads, so that electrical currents can flow easily between them. This is done by making the joins using *solder* – an alloy of two metals (lead and tin) which melts at a relatively low temperature.

You'll need to be able to solder properly to assemble these projects, which means that they are not just good fun but a great way to learn about soldering, as well as electronics. Don't worry, soldering is easy once you get the hang of it.

The basic idea is that the two metal surfaces to be joined (say the lead or "pigtail" of a resistor and a copper "pad" on the PC board) are brought together and both heated up quickly using the tip of an electric soldering iron. They're heated to above 183°C, which is the melting temperature of the '60/40' solder alloy (60% tin, 40% lead) used in most electronic work.

Then the solder (usually in the form of fairly fine wire with a resin core) is touched on both surfaces. The solder melts and the resin acts as a 'flux' which dissolves any oxide on the metal surfaces so that the molten solder can "wet" them to form a good permanent bond. Finally, the soldering iron tip is removed carefully, allowing the solder to solidify again as a smooth and relatively strong metal "joint".

Sound easy? It really isn't hard, although it is a bit like riding a bike: you generally have to practice a while before you can make good solder joints without even thinking about it. Here are some practical tips, to get you off to a good start with your soldering:

TIP 1. Get yourself a good lightweight "electronics" type soldering iron, with a small tip and not too much heating power. An iron rated at 20 watts is more than enough for building any of the projects in this book and for most general electronics work. A good example is the Jaycar Cat. TS-1554. This is also available as part of the Jaycar Soldering Iron Starter Kit (Cat. TS-1651) which comes complete with a stand (to hold it when it's hot), a spare tip, some resin-cored solder and a metal solder sucker to suck up solder if you make a mistake and need to remove a component.

Even better, if your budget will stretch that far, is a temperature-controlled soldering station like the Jaycar Cat. TS-1620. This has a professional-type low voltage soldering iron with an adjustable thermostat to control tip temperature, plus a really solid stand and cleaning sponge, etc.

Don't try to use a heavyweight plumber's soldering iron – it'll not only make your arm and hand tired but also risk overheating your delicate electronic parts and PC board. The same applies to gas-fired soldering torches and irons – although when you get skilled, one of the very small gas-fired soldering pencils is OK.

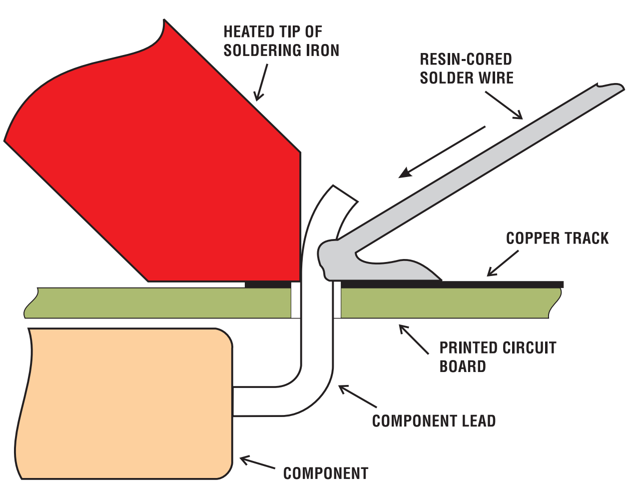


Fig.1: how to solder a component lead to its copper pad on the PC board. The tip of the iron heats both the lead and the copper pad, so the end of the solder melts when it's touched against them.

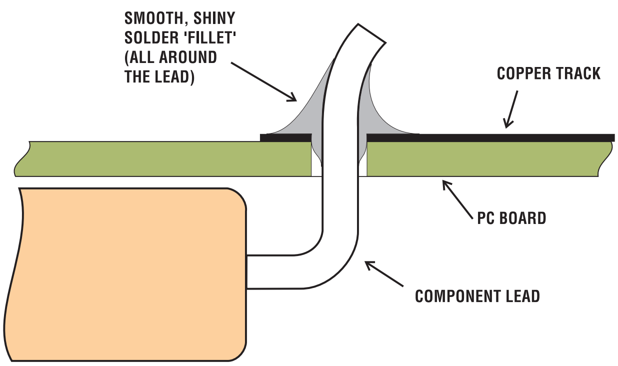


Fig.2: a good solder joint has a smooth and shiny 'fillet' of metal, bonding all around both the lead and the copper pad.

TIP 2. The two metal surfaces to be soldered need to be clean and preferably already "tinned" – either plated with pure tin, like the leads of many components or cleaned and given a thin coating of solder using a soldering iron and solder.

TIP 3. The tip of your soldering iron needs to be clean too and it should have a coating of tin or solder. Most modern iron tips are tin plated but before making each joint it's a good idea to clean off any gunk by wiping it over a small piece of sponge which is moistened with water. The hot tip turns some of the water to steam, which in turn "steam cleans" the iron tip.

TIP 4. Make sure the soldering iron tip has reached the correct temperature. If it isn't hot enough, you won't be able to make a good joint. If you're using a soldering station or iron with a thermostat, this usually begins ticking when the correct temperature is reached. Otherwise, try touching the end of the solder wire against the (cleaned) tip – it should flow easily.

TIP 5. Try to touch the iron tip to both metal surfaces together, so they both heat up to soldering temperature in the shortest time. Otherwise one might get too hot before the other gets hot enough. This can damage delicate parts like ICs and it may overheat the copper pad so that it lifts away from the board.

TIP 6. Almost immediately after applying the iron tip, touch the end of the solder wire to both metal surfaces. That way, the solder itself will melt and flow into the joint the instant the right temperature has been reached. Push just enough solder into the joint to produce a nice "fillet" of molten solder around the two surfaces, then remove the solder wire. Finally move the iron away too, taking care not to bump the joint before the solder solidifies again.

Mind you, you'll solder each joint much quicker than the time it takes to read these few lines of text. The secret of good soldering is to do it quickly – heat up the joint, touch the solder to it so that it wets the component leads and flows nicely, then pull the iron tip away without bumping the joint as it solidifies. It takes just a second or two to do each connection.

If the solder doesn't seem to want to melt against one of the metal surfaces, a good trick is to brush the end of the solder wire against the tip of the iron – so it starts to melt and flow between the surfaces. The molten solder itself will help bring the two metal surfaces up to temperature and "start the ball rolling".

TIP 7. As we said, try to make the joint as quickly as possible, because the longer you take, the more likely that the component itself and the copper pad and track will overheat and be damaged. But don't work so quickly that you can't make a good joint – having to do it over again will also increase the risk of damage. So "speed with care" is the motto.

TIP 8. As the solder solidifies, take a careful look at the joint you've made, to make sure there's a smooth shiny metal "fillet" around it. This should be broadly concave in shape, showing that the solder has formed a good bond to both metal surfaces. If it has a rough and dull surface or just forms a "ball" on the component lead, or a "volcano" on the copper pad with the lead emerging from the "crater", you have a "dry joint" which needs doing again – perhaps after cleaning one of the metal surfaces again. See the drawings for what to look for.

TIP 9. For projects that use a number of ICs, you may find it easier to use a fine-gauge solder (less than 1mm diameter). This reduces the risk of applying too much solder to each joint and forming "bridges" to adjacent copper pads or tracks.

Well, that's the basics of soldering. But if you're new to soldering, why not get a bit of practice before you start work on your first real project? Find yourself a piece of old PC board and a few surplus resistors or bits of hookup wire and try making a few solder joints.

You'll soon get the hang of it.

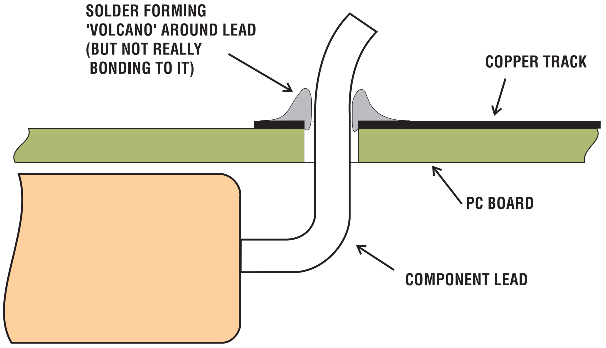


Fig.3: one kind of 'dry' joint. The solder has bonded to the copper pad but isn't bonded at all to the component lead. It'll cause trouble if it isn't re-soldered properly, so that it looks like Fig.2.

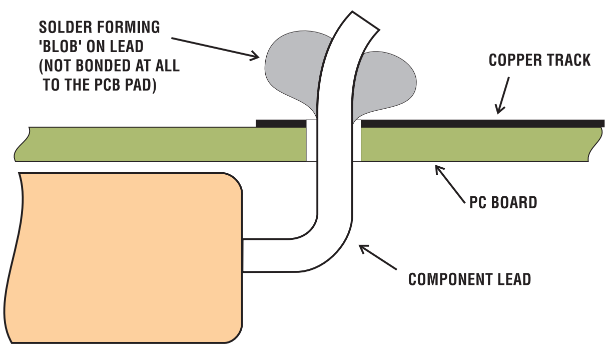


Fig.4: another kind of dry joint. Here the solder has bonded to the component lead but not to the PC board pad. Again it needs to be re-done to look like Fig.2.

BONUS!

Your Multimeter . . .

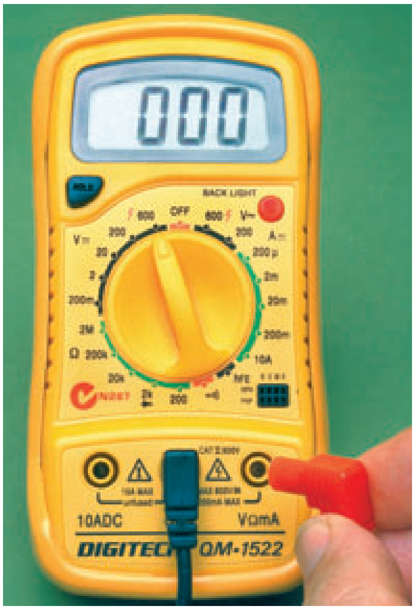
Multimeters are great tools for checking how well a circuit is operating or for tracking down the cause of the problem if it *isn't* working. But there are some basic DOs and DON'Ts to bear in mind, to ensure you take accurate measurements and do not damage either your meter or the circuit you're testing. Follow this easy pictorial guide and you shouldn't strike any problems.

The main thing to remember when you're using a multimeter is that before you connect the probes to the circuit or component to be tested, make sure you have set it for:

(a) the correct KIND of measurement – in the main, **VOLTS DC** if you're measuring DC voltages, **VOLTS AC** if you're measuring AC voltages or you are not sure if they are AC or DC voltages, **AMPS** (or more likely MILLIAMPS) if you're measuring current, or **OHMS** if you're measuring resistance.

(b) the right range – that is, a range *higher* than the highest voltage, current or resistance you're likely to measure (if you don't know, select the highest range). Otherwise there could be an expensive BANG when the probes touch!

For checking any of the circuits and components in this book (and in fact for most electronics work), a digital multimeter (DMM) or an analog type (as shown above right) are equally suitable. A wide range of digital multimeters is available from Jaycar stores, along with the QM-1020 analog multimeter shown in the above picture.



For most measurements, the black probe lead's plug goes into the multimeter's 'COM' (common) socket and the red lead's plug into the 'V-Ω-mA' socket. Push them as far into the socket as they'll go to make sure there's a good connection and no exposed metal (which could allow accidental shocks if you're measuring high voltage).

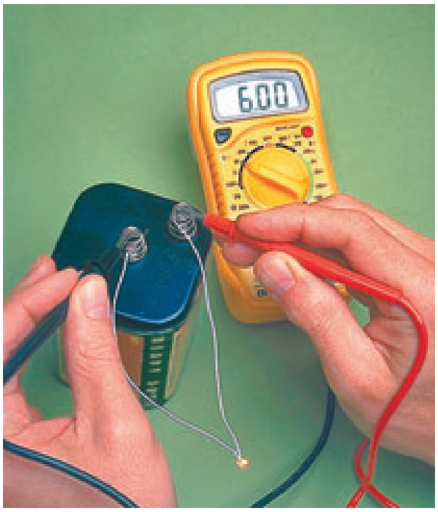
Before measuring a DC voltage, set the meter to its highest DC voltage range (here 600V). That way, there shouldn't be any damage done if the voltage is higher than you expect. You can always click down a range or two to make the measurement more accurately, if you need to.

The same applies when you're about to measure an AC voltage – set the meter to its highest AC voltage range first, to avoid mishaps. Here the switch is set to 600V again but this time on the AC voltage scale (the V with a ~, a small sinewave 'wiggle', indicates AC voltage).

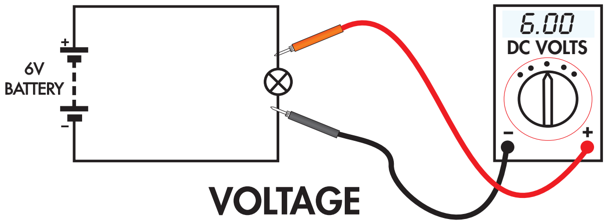
and how to use it

Measuring VOLTAGE – volts (V) and sometimes millivolts (mV)

Voltage is measured by connecting the meter across the component or circuit under test while power is connected. In other words, the meter is in PARALLEL with the circuit or part of the circuit under test.



When you're measuring voltage (also known as potential difference), the two meter probes are simply connected between the two points concerned – such as the terminals of a battery or the terminals of a lamp.



VOLTAGE

IN PARALLEL WITH COMPONENT UNDER TEST

Let's start by measuring the terminal voltage of a battery. Turning the pointer from "off" to any other position (in this case the 200V DC range) also turns the digital multimeter on. Connect the red (positive) meter probe to the positive battery terminal and the black (negative) meter probe to the negative battery terminal. Here a fresh lantern battery reads just over 6V.

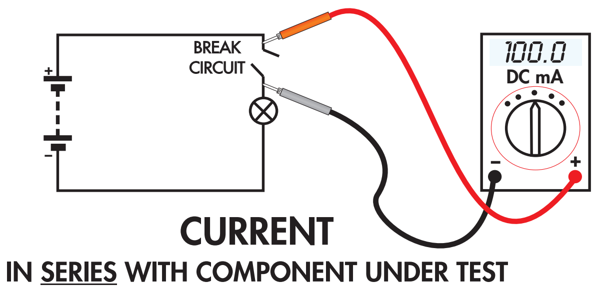
As we now know the reading is below the maximum limit of the next range down (ie, 6V is less than 20V), we can click the pointer to that range and the reading will be one digit more accurate. Note that it now says 6.21V – before it was 6.2V. Sometimes that extra accuracy is very important.

If you accidentally connect a digital multimeter's test probes to the battery terminals the wrong way around (red to negative, black to positive), it will still read the correct voltage – but with a minus sign to show the reversed polarity. No harm done – but it's important to know what that minus sign means. With an analog meter you should never connect the probes back to front.

Measuring CURRENT – amps (A), milliamps (mA) or microamps (μA)

Current is measured by making the current flow from the circuit, through the meter and then back to the circuit. In other words, the meter is in SERIES with the circuit or part of the circuit under test.

When you want to measure the current in a circuit, you need to break the circuit at that point and connect the probes so that the current to be measured flows THROUGH the meter – switched to the correct current range, of course. Here the small lamp is seen to be drawing close to 100mA.



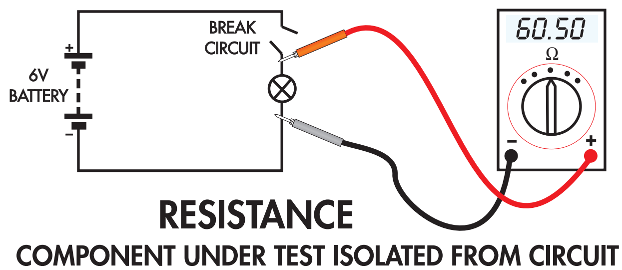
When you are going to measure a current, it's again important to switch to a higher range than you expect before hooking the meter into circuit, to prevent accidental overloads. Here the meter has been switched to the 200mA range, before making the measurement of lamp current which, according to the manufacturer's data, should be about 100mA.

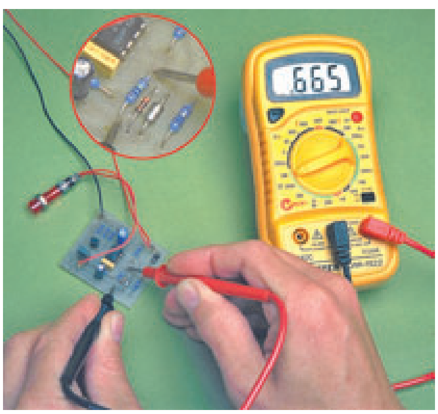
With many multimeters, the red (positive) probe lead needs to be changed over to a special "high current" socket before you can measure currents of more than a few hundred milliamps – as well as switching to the appropriate range. Here the red lead has been plugged into the '10A DC' socket on the left, to measure currents up to 10A. Just remember to change the lead back to the 'V-Ω-mA' socket before you try to make any other kinds of measurement!

Measuring RESISTANCE – ohms (Ω), kilohms (kΩ) and megohms (MΩ)

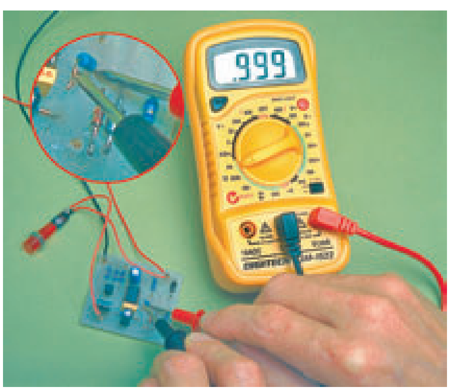
Resistance is measured by passing a tiny current (provided by a battery inside the meter) through the component under test. The component must be isolated from other components and any source of current.

When you switch to any of the resistance ranges on a DMM and before you make a measurement, it generally gives this kind of "over range" indication with no connection between the probes. If it doesn't, the battery inside the meter may need replacing.

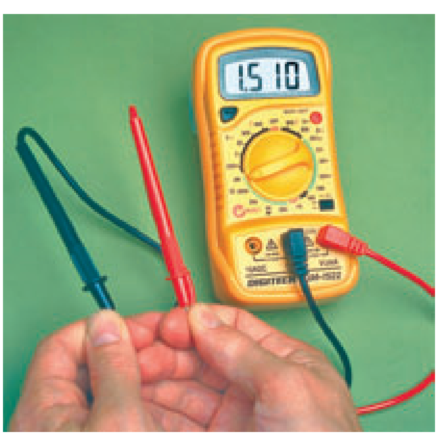




Although you can measure the value of resistors that are soldered into a PC board, by simply connecting the meter probes across them, this can give a false lower reading due to the board's tracks connecting other components in parallel. Here a 1MΩ resistor is reading only 665kΩ, because of this problem.



To make an accurate measurement of a resistor on a PC board, one end is carefully unsoldered from under the board, and lifted so the meter can measure just the resistor by itself. As you can see the 1MΩ resistor is now reading 999kΩ (well within its tolerance).

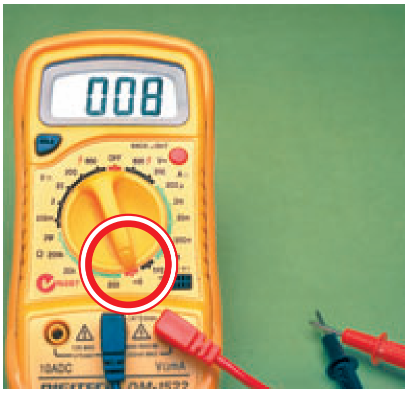


When you're trying to measure fairly high resistances, make sure you don't cause errors by connecting yourself in parallel with the probes. As you can see, the human body is not a good insulator; here the resistance between the user's hands reads only 1.51MΩ.

With the user's hands well back from the probe tips, behind the guard rings on the plastic sleeves (the correct position for safety in all measurements), the meter reads 'over range' as it should with an open circuit between the probes.

Other ranges: diode/transistor checking, continuity, etc

Many modern meters, even low-cost models, have a handy selection of other ranges which are used to check other components – semiconductors, especially. Some have inbuilt buzzers to help check continuity.

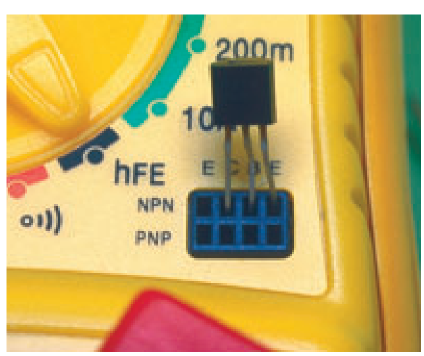


Many meters have a 'continuity' range, a low resistance setting which is used to check for breaks in cables and PC board tracks. When the two probes are touched together (or connected via a low-resistance circuit), the meter reads the approximate resistance between them. A buzzer or beeper may also sound, so that you don't have to look at the meter to know that the circuit is OK.

Checking the forward conduction of a silicon diode is very easy using the "diode check" function. With the switch in the diode position, you simply place the test leads across the diode one way – here the positive lead is on the cathode (striped end) which reverse-biases the diode. The meter reads "1" or over-range, just as a reverse-biased diode should read.

Reversing the leads forward-biases the diode, with the meter reading the forward voltage drop for a specified small current in the forward direction. Here the silicon power diode has a drop of 0.741V, showing that it's fine. Silicon diodes can be expected to show a forward voltage drop of between about 0.5V and 0.8V, depending on their type.

Many multimeters can also be used to measure the current gain (also called the h_{FE} or "beta") of bipolar transistors. In most cases, it's just a matter of switching the meter to the h_{FE} range and plugging the transistor into a multi-way transistor socket on the front panel.



Just how the transistor is plugged into the meter to measure h_{FE} depends on whether it's an NPN or PNP type and the way its 'works' are connected to the three leads. As you can see both rows of holes have an emitter (E) socket at both ends, to allow for almost any possible combination of connections.

With the transistor plugged in correctly, the meter reads its h_{FE} current gain directly (in this case, 461). If you get a very low reading, the transistor may be a dud, or you might have accidentally swapped the collector and emitter connections. If changing them over gives a much higher reading, that was the problem and your transistor is OK.

Project 1

Dasher Flasher

Discourage crooks from breaking into the family car with this lamp flasher on the dashboard. They'll think that there's an alarm installed and go somewhere else. It can be built in a flash, too!

What does it do?

The Dasher Flasher uses a very popular integrated circuit or IC, the 555 timer, to control a transistor which flashes a bright light.

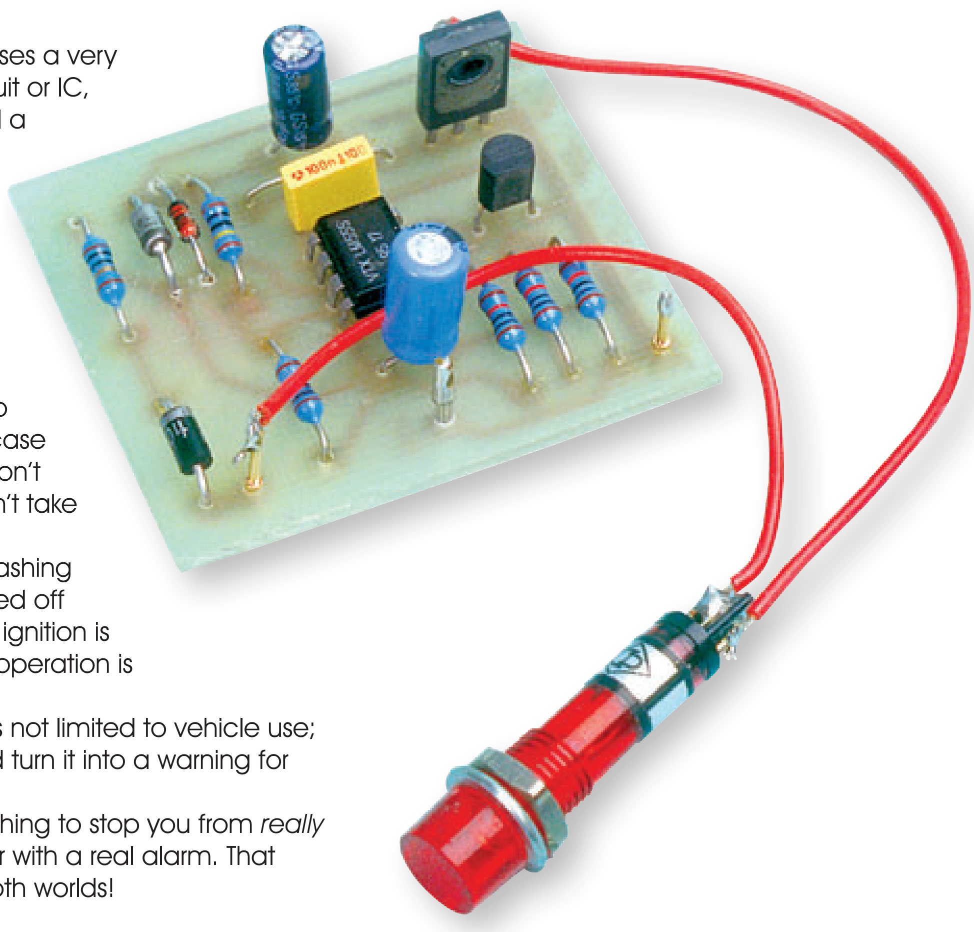
Normally, this light is mounted on the dashboard of a vehicle to warn people that an alarm is operational.

Of course, there is no alarm attached in this case – or is there? The thief won't know and hopefully won't take the risk!

The light only starts flashing when the ignition is turned off and goes out once the ignition is turned on. Therefore its operation is fully automatic.

This warning flasher is not limited to vehicle use; with ingenuity you could turn it into a warning for lots of other situations.

Naturally, there is nothing to stop you from *really* using the Dasher Flasher with a real alarm. That would be the best of both worlds!



You will need these parts

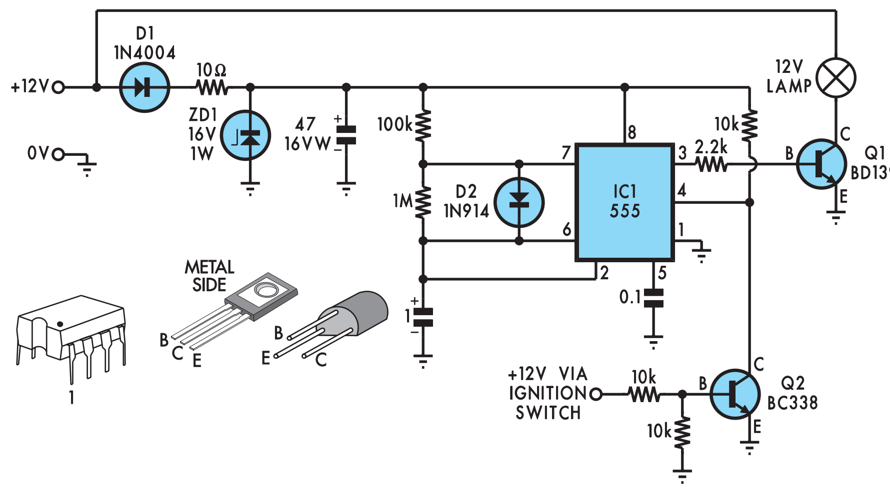
Resistors (0.25W, 1%)
1 1MΩ
1 100kΩ
3 10kΩ
1 2.2kΩ
1 10Ω

Capacitors
1 47µF 16VW PC electrolytic
1 1µF 16VW PC electrolytic
1 0.1µF MKT polyester

Semiconductors
1 555 timer (IC1)
1 1N4745 16V 1W zener diode (ZD1)
1 1N4004 1A diode (D1)
1 1N914 or 1N4148 signal diode (D2)
1 BD139 NPN transistor (Q1)
1 BC338 NPN transistor (Q2)

Miscellaneous
1 Dasher Flasher PC board
1 12V indicator lamp
4 PC stakes
1 1m length of black hookup (automotive) wire
1 1m length of red hookup (automotive) wire

Putting it together



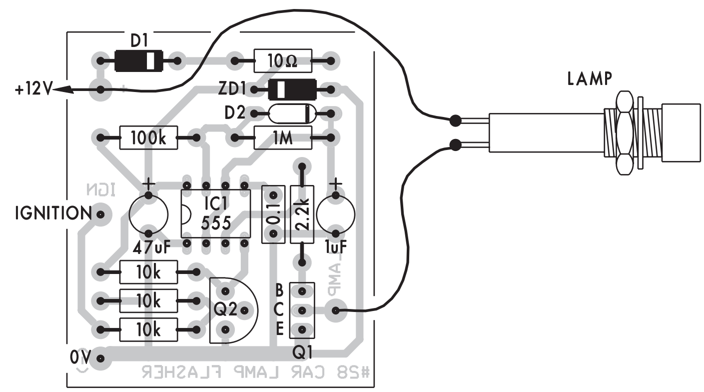
All components apart from the lamp mount on the Dasher Flasher PC board.

If you haven't soldered electronic components before, we suggest you read the section on soldering (page 12) before commencing construction.

Start by installing and soldering in all the resistors (these can go in either way around) and then the PC stakes.

IC1 can be inserted now – make sure it is oriented with pin 1 in the position shown. Check twice before soldering – it's very hard to remove without damaging the PC board! Insert diodes D1, D2 and ZD1 and the electrolytic capacitors (they're the ones with a "–" mark down their sides) with the orientation shown.

Transistor Q1 is mounted with its metal tab facing Q2. Mount both transistors so that there is just enough of their leads poking through the PC board to solder – unlike most components, these do NOT go all the way down to the board.



Checking it out

Connect the lamp to the +12V and output (lamp) PC stakes (either way around) and a 12V supply (either a battery or a plugpack adaptor) to the appropriate +12V and 0V PC stakes .

If the lamp fails to flash, check your board for faults, including shorts between tracks or breaks. Also check that all the components are in their correct place and oriented as shown.

The supply to IC1 should be about 11.5V (measured between pins 8 and 1 of IC1). If you are measuring voltage with a multimeter, be careful not to short between the pins of the IC with the probes.

Check that the lamp stops flashing when the ignition input is connected to the +12V supply. You can do that by connecting a wire between the "ignition" pin and the +12V supply PC stake.

Finally, if you're installing this flasher in a car, be sure to obtain the +12V supply via a fuse. The connection is usually best made at the fusebox. The ignition supply should also come via an existing fuse.

TECH TALK

The 555 timer (IC1) produces continuous pulses about one second apart from its output at pin 3 (see page 23 for a more detailed explanation of 555 timer operation). These pulses turn transistor Q1 on and off, which in turn turns a lamp on and off.

We also need to stop it working (so that the lamp stops flashing) when the ignition is turned on. Another transistor, Q2, is used to do this. When the ignition is turned on, Q2 turns on and pulls pin 4 (reset) of IC1 low. This "stops" the 555.

12V power is taken from any of the car's circuitry which stays live when the ignition is turned off. The input for Q2 is taken from an "Accessories" circuit which is only on when the ignition is on (eg, the car radio supply rail).

Diode D1 isolates the timer circuitry from the somewhat higher currents of the lamp circuit for reliability and, as a bonus, stops you doing any damage if you accidentally reverse the battery connections.

The IC is protected against voltage spikes above 16V by the 10Ω series resistor and another specialised component, a 16V zener diode (ZD1). The 47µF capacitor also helps smooth the supply.

Want To Know How A 555 Timer IC Works?

The 555 timer can be made to operate in various ways. The most common are to supply continuous pulses (called an astable or oscillator) or to supply single pulses (called a monostable or one-shot).

Astable mode

A 555 will oscillate over a very wide range, from seconds or even minutes per cycle up to about 100kHz or so. This, together with its wide operating voltage and low cost, has made it a very popular IC.

Looking at the diagrams below you can see several similarities between the basic astable and the circuit of our lamp flasher. The main difference, which we'll explain in a moment, is the diode between pins 7 and 6.

When power is first applied, C1 starts to charge towards the supply voltage via R1 and R2. The output, pin 3, is high.

C1 continues to charge until it reaches two thirds of the supply voltage. Pin 6 detects when the voltage reaches this threshold and it tells the output to go low. At the same time, pin 7 goes low and the capacitor starts discharging (the discharge current flows via R2 and the IC itself).

Pin 2 detects when the capacitor voltage drops to one third of the supply voltage, at which time it triggers the IC into action again. The output (pin 3) goes high again, as does the discharge (pin 7), allowing C1 to start charging once again.

This process repeats itself for as long as power is applied or something else is done to stop it. In the case of the Dasher Flasher, that involves taking the reset (pin 4) low. Pin 4 is normally held high via the 10kΩ resistor to the positive supply but when the ignition is switched on, Q2 is turned on via the 10kΩ base resistor. This pulls the reset low and turns off the IC.

We mentioned diode D2 before in our flasher circuit. What this does is change the duty cycle, or the output high to output low ratio, by allowing the capacitor to charge quickly when the diode is forward biased (pin 7 high) but discharge slowly when the diode is reverse biased (pin 7 low).

We do this because we want the lamp on-time to be very much shorter than its off time, to best simulate "real" alarm flashers.

With the values of resistance and capacitance in this circuit, the capacitor charge time is about 0.1s when the lamp is on. The discharge time for the capacitor is about 1.1s.

The ratio of the two resistors (R1 and R2) and the values of R1, R2 and C1 normally determine both the frequency of oscillation and the duty cycle. The formulas are:

Output high time (t1) = 0.693 x (R1 + R2) x C1
Output low time (t2) = 0.693 x R2 x C1
Oscillation frequency (f) = 1.44/((R1 + 2R2) x C1)
where R is in Ohms, C is in Farads and T is in seconds.

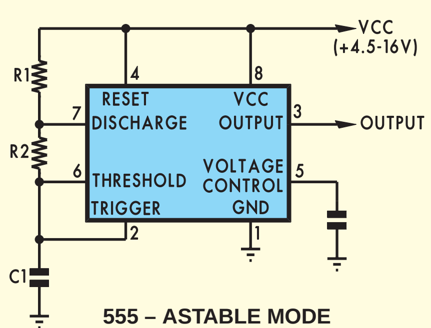
Note that in our Dasher Flasher circuit R2 is effectively shorted when D2 is forward biased, hence the output high time is close to (0.693 R1 C1).

Monostable mode

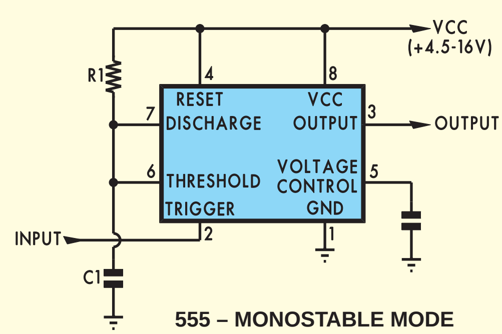
One of the main uses for a monostable (also known as a one-shot) is to stretch pulses. The 555 is very good at this, enabling very short duration pulses to be lengthened so that slower circuitry can handle them. The circuit delivers a single pulse at pin 3 each time a trigger pulse is applied to the input.

At the same time, the design of the 555 allows the IC to invert the pulse if the circuit calls for it – that is, a negative going pulse can become a positive-going pulse.

Again, the IC uses the one third supply and two thirds supply voltages as trigger points. The external components are chosen to give the required length of pulses as the external capacitor (C1) charges and discharges through these thresholds. Time delays ranging from microseconds to seconds are possible.



555 – ASTABLE MODE



555 – MONOSTABLE MODE

Project 2

Ding Dong Doorbell

It's that classic "ding dong" sound everyone loves – but this one is electronic, of course. Why not build one for your front door?

What does it do?

This electronic doorbell simulates the sound of the electromechanical ding-dong doorbell.

The latter uses two plates which resonate when struck by a small soft hammer, one plate producing a "ding" sound and the second plate the "dong". When the doorbell switch is pressed, current flows through a solenoid which activates the hammer to strike the "ding" plate. When the doorbell switch is opened, the solenoid plunger returns by a spring and strikes the second "dong" plate.

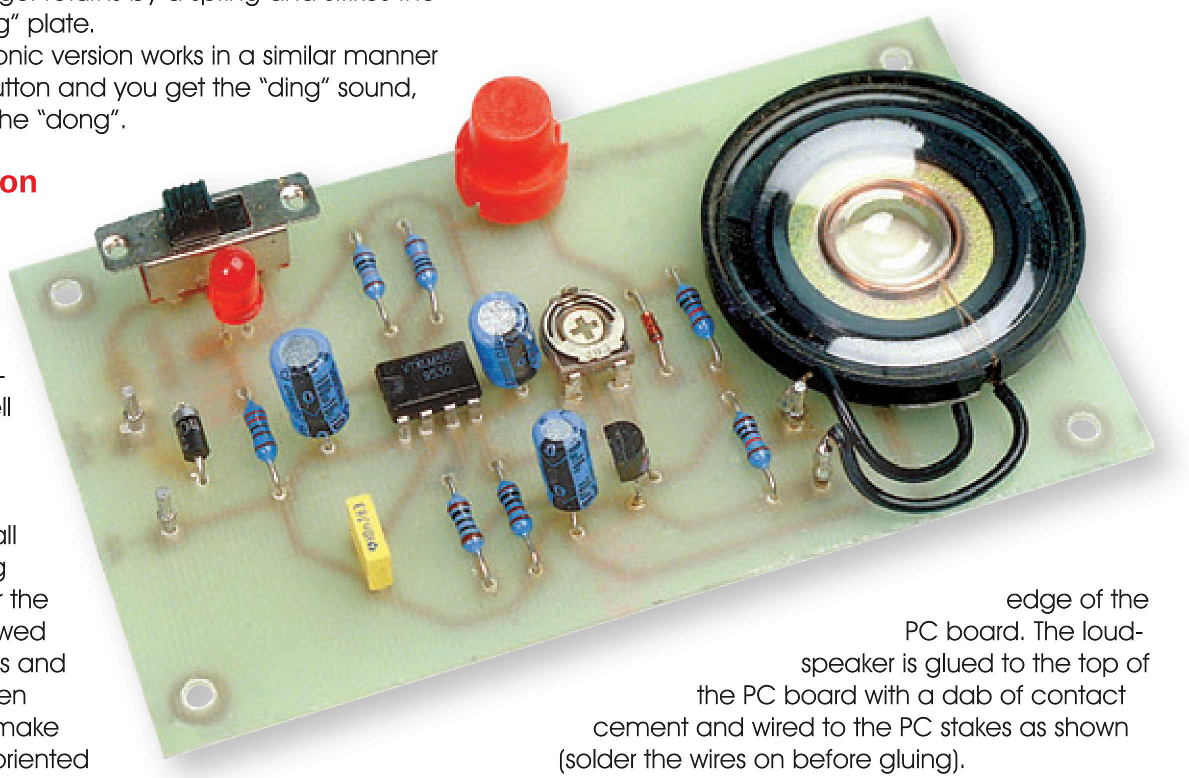
The electronic version works in a similar manner – press the button and you get the "ding" sound, release it for the "dong".

Construction

All parts except the remote loudspeaker are mounted onto the Electronic Doorbell PC board.

Start by installing the PC stakes at all external wiring points and for the speaker, followed by the resistors and then VR1. When inserting IC1 make sure that it is oriented with pin 1 in the position shown. Diode D1 mounts with the cathode (striped end) towards S1 and D2 with the cathode towards Q1.

Install the electrolytic capacitors, LED1 and transistor Q1 with the polarity shown. S1 is installed by inserting the switch pins into the PC board and soldering in place. Switch S1 may be a DPDT type; this doesn't matter. Switch S2 must be correctly oriented with the "flat" side of the switch body towards the



edge of the PC board. The loudspeaker is glued to the top of the PC board with a dab of contact cement and wired to the PC stakes as shown (solder the wires on before gluing).

You will need these parts

Resistors (0.25W, 1%)
2 100kΩ   2 10kΩ   1 2.2kΩ
1 1kΩ   1 100Ω
1 20kΩ horizontal trimpot (VR1)

Capacitors
1 100µF 16VW electrolytic
1 47µF 16VW electrolytic
1 10µF 16VW electrolytic
1 .01µF MKT polyester

Semiconductors
1 555 timer (IC1)
1 BC548 NPN transistor (Q1)
1 1N4004 1A diode (D1)
1 1N914, 1N4148 signal diode (D2)
1 red 5mm LED (LED1)

Miscellaneous
1 Electronic Doorbell PC board
1 SPDT slider switch (S1)
1 momentary PC-mount pushbutton switch (S2)
4 PC stakes
1 40mm 8Ω Mylar cone speaker

TECH TALK

The electronic doorbell circuit is based around a 555 timer IC, set up as an oscillator. Its basic operation is similar to the 555 oscillator in project 1, however here there are two tones.

As you may recall from project 1, the oscillation frequency of the 555 depends on the time it takes the capacitor connected to the trigger input (pin 2) to charge and discharge between 2/3rds and 1/3rd the supply voltage.

But there is also another way to control the frequency of oscillation and this is to adjust the voltage at the control pin (pin 5). If we adjust this voltage we also alter the voltage range over which the capacitor is charged and discharged and this changes the frequency of oscillation.

Remember that the reset (pin 4) must be high for the 555 to operate. Normally it is held low by a 1kΩ resistor so the doorbell remains silent.

When pushbutton switch S2 is pressed, it pulls pin 4 high via diode D2 and discharges the 100µF capacitor. IC1 then begins oscillating. Switch S2 also provides base current to transistor Q1 via a 10kΩ resistor.

The transistor turns on, effectively connecting a 20kΩ variable resistance between pin 5 and earth. This resistance alters the pin 5 voltage, so the oscillation frequency is higher than normal. For as long as S2 is closed, the pin 3 output of IC1 drives the loudspeaker to produce a "ding" tone.

When S2 is released, two things happen. First, transistor Q1 switches off since its base is pulled low via the 10kΩ resistor to ground. With Q1 off, VR1 has no effect on pin 5 and IC1 oscillates at its normal frequency. This produces the "dong" tone.

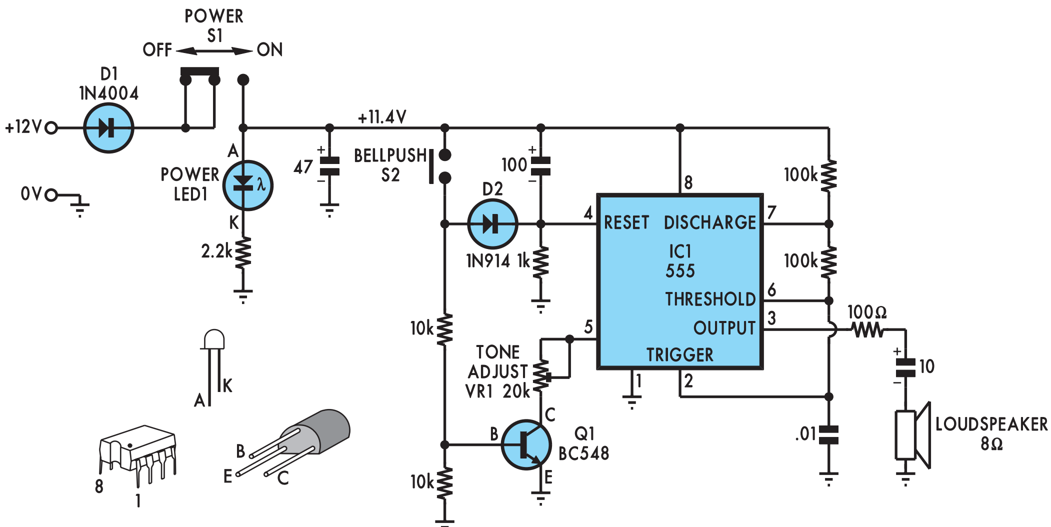
Second, the 100µF capacitor connected to pin 4 starts to slowly charge via the 1kΩ resistor to earth. When the voltage on pin 4 falls to about 1V, the 555 resets and the "dong" tone ceases.

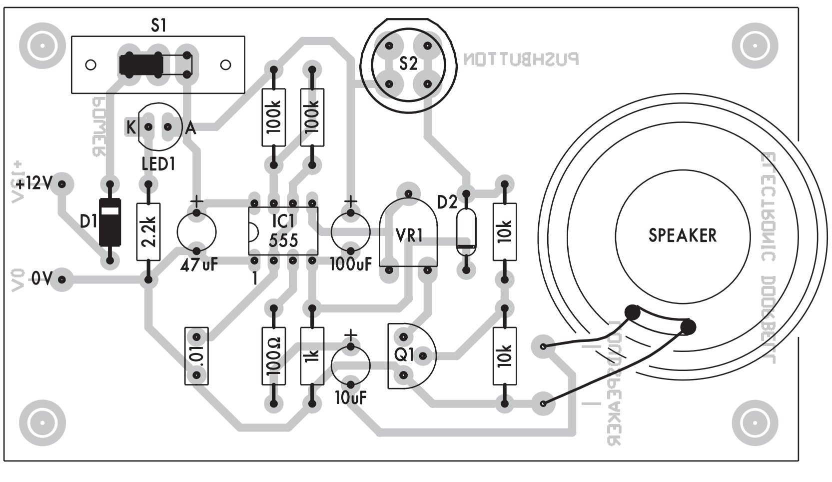
VR1 can be a fixed value resistor but we made it variable so you can set the "ding" frequency which sounds best with the "dong" tone.

Diode D1 is included to provide reverse polarity protection for the circuit. Switch S1 is to connect power, while LED1 indicates when power is applied. The 47µF capacitor smooths the supply rails for reliable operation of IC1.

Checking It Out

Apply power to the circuit and switch on. Check that there is an initial tone from the loudspeaker which lasts for around one second as the 100µF capacitor at pin 4 of IC1 charges. Press the pushbutton switch S2 and check that it "dings", then release it and you should get the "dong". Adjust VR1 for best sound balance between ding and dong.





What to do next

You could use a standard doorbell switch in place of switch S2. This can be wired to S2's copper pads (or to PC stakes in that position) once the switch has been removed. More volume can be obtained by reducing the value of the 100Ω resistor in series with the speaker. Alternatively, or as well, you can use a larger speaker mounted on a panel or in a box.

Project 3

Electronic Eye

Warning! Warning! Strangers approaching! It's battle stations . . . you can't see them yet but the electronic eye tells you they're coming!

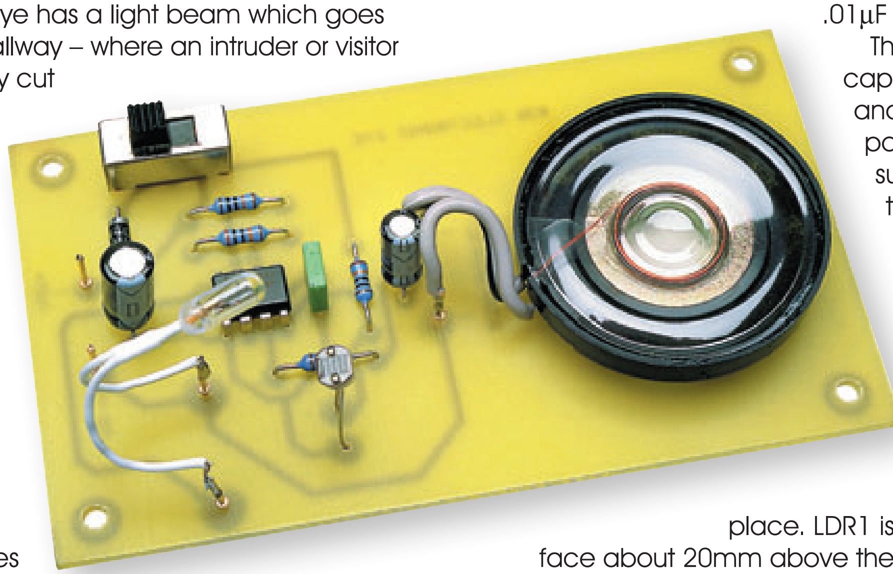
What does it do?

Have you ever gone through a doorway and heard a bell ring or a buzzer sound? You've been spotted by an electronic eye which you probably didn't even know was there. Now you can make your own to detect strangers – or friends – approaching!

The electronic eye has a light beam which goes across a path or hallway – where an intruder or visitor must go. When they cut the beam by walking through it, the circuit detects the break and produces a tone in a loudspeaker.

The circuit actually detects the absence of light. It is based on a component called a light dependent resitor (LDR) which changes its resistance according to the amount of light that shines on its active surface. With no light, the resistance of the LDR is very high – several megohms – but this resistance rapidly drops as the amount of light upon it increases. In bright light or daylight, the resistance can be as low as a few hundred ohms or so.

We use this resistance change to control an oscillator which drives a loudspeaker whenever the LDR resistance is high.



Construction

All parts, with the possible exception of the lamp (see comments below), are mounted onto the Electronic Eye PC board.

Start by installing and soldering in PC stakes at all external wiring points, followed by the four resistors and .01µF capacitor.

The electrolytic capacitors, diode and IC are all polarised so make sure you insert them with the polarity shown. Switch S1 is installed by inserting the switch pins into the PC board and then soldering them in place. LDR1 is mounted with its face about 20mm above the PC board.

The 12V lamp, LP1, can be mounted directly to the PC stakes. For more practical use, though, you'll probably want to mount the lamp off the PC board. In this case, connect LP1 via a length of twin insulated (figure-8) wire. A 1-metre length is included in the parts list for this purpose.

The loudspeaker can be glued to the top of the PC board with a dab of contact adhesive and wired to the PC stakes as shown. Solder its connecting wires before gluing!

You will need these parts

Resistors (0.25W, 1%)
3 100kΩ 1 100Ω

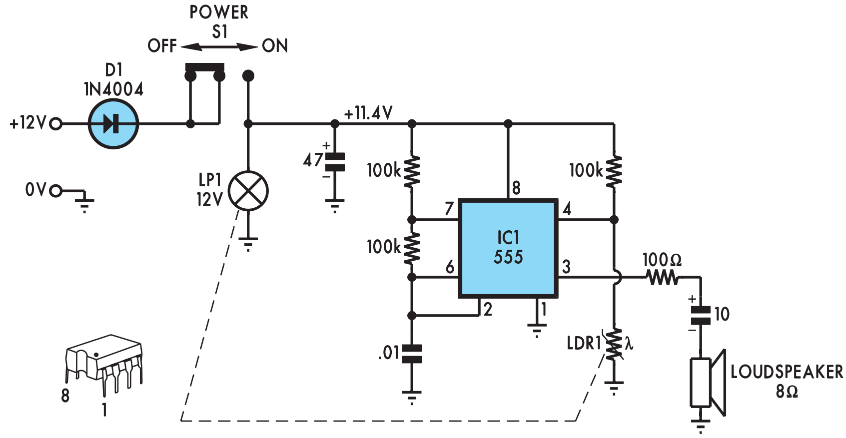
Capacitors
1 47µF 16VW electrolytic
1 10µF 16VW electrolytic
1 .01µF MKT polyester

Semiconductors
1 555 timer (IC1)
1 1N4004 1A diode (D1)

Miscellaneous
1 Electronic Eye PC board
1 SPDT slider switch (S1)
1 light dependent resistor (LDR1)
1 12V 100mA miniature globe (LP1)
6 PC stakes
1 40mm Mylar cone loudspeaker
1 1m length twin insulated (figure-8) wire

Testing

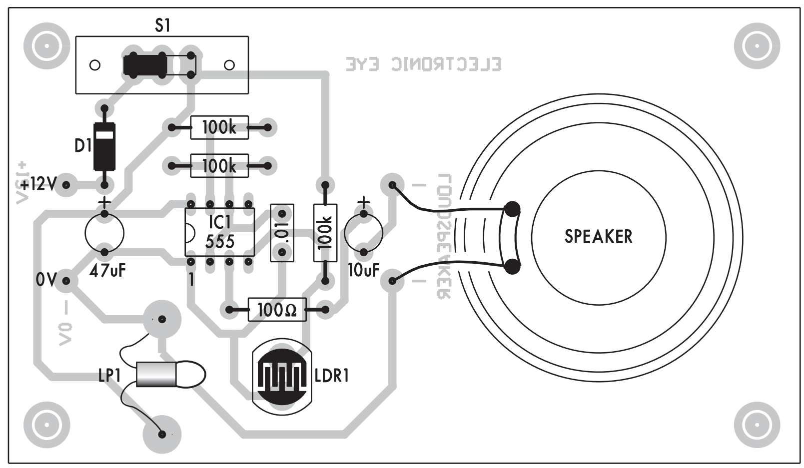
Connect power to the circuit, switch on and check that lamp LP1 lights up. Bend the LDR over so that its top face collects the light from LP1. Now break the light between the LP1 lamp and LDR and check there is a tone from the loudspeaker. If there is no tone, you may need to shield LDR1 from all external light sources as well.



What to do next

If the LDR and lamp are mounted on the PC board, the only practical way to detect someone passing through a doorway, for example, would be to shield the LDR from the lamp and set the PC board up on one side and a mirror on the other, to reflect the light back to the LDR.

However, you could mount the lamp further away from the LDR by connecting either to some long leads. (LDRs and lamps are not polarised so there's no worry about mixing up the connections at the other end).



The lamp is best focused within a torch reflector and can be aimed at the LDR. A brighter bulb will also give you a longer range. Be warned, though – the brighter the bulb, the higher the current drain – a typical 12V "dial" lamp (as specified) draws only 100-200mA or so but a 12V 20W lamp such as a halogen with its own reflector will draw nearly 2A. They're bright, though!

The pickup can also be increased by placing LDR1 at the focal point of a parabolic torch reflector.

For best range and most secrecy, try "shrouding" both your light/reflector and LDR/reflector by mounting them deep inside blackened cardboard or plastic tubes. You'll need to carefully aim them but you should find that the range is greatly increased.

As a bonus, the electronic eye will work much better in daylight. Even better, if you can find some small glass (or even plastic) lenses, try putting these in the tubes at the focal point of the LDR and lamp.

With all of these improvements, we've been able to increase the range from a few centimetres to more than 10 metres!

TECH TALK

The electronic eye is another example of a 555 timer in action. As you can see, this is one versatile little chip! For a more detailed explanation of 555 operation, see page 21.

We use the reset pin (pin 4) of the 555 timer to control whether it oscillates or not. As you may remember, pin 4 must be held high (at least above about 0.7V) or the 555 will sit there doing nothing.

But that's just what we want the 555 to do – most of the time. It's only when someone breaks that electronic eye that we want it to react. We do this with the LDR connected between pin 4 and earth.

When bright light shines on LDR1 from lamp LP1, its resistance drops and pulls pin 4 of IC1 below 0.7V. This resets IC1 and stops it oscillating so that there is no tone from the loudspeaker.

However, when someone walks into the beam, the resistance of LDR1 rises and so the voltage at pin 4 of IC1 also rises. This means that IC1 now oscillates and so a tone is produced from the loudspeaker.

Power for the circuit is from a 12V source. Diode D1 is included to provide reverse polarity protection for the circuit. If the voltage applied to the circuit is the incorrect polarity then the diode will not conduct, preventing any damage.

The 47µF capacitor filters the supply to provide reliable operation of IC1.

Project 4

Simple FM Alarm

Imagine if someone pinched your sports bag and ran off. Imagine their shock when a little later a big burly police officer taps them on the shoulder . . .

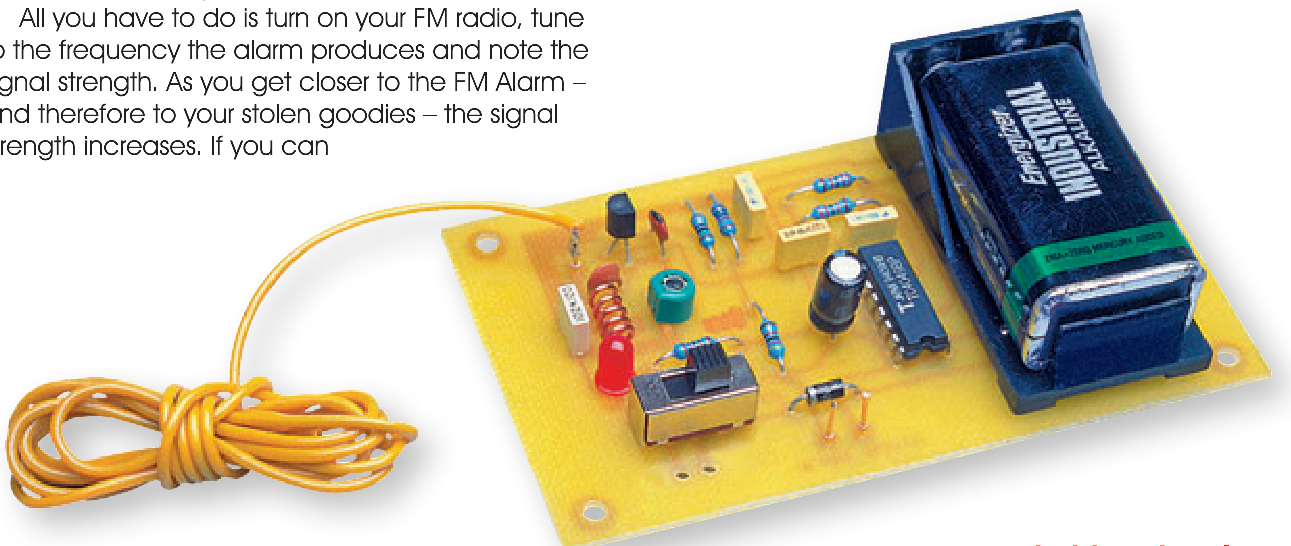
What does it do?

This FM alarm transmits a tone to any FM radio enabling it to be tracked and located. It's easy to build and the alarm signal can be received on any radio with the standard 88-108MHz FM band.

When a switch closes, the FM Alarm goes off, except there's no noise; nothing to let the crook know they've been caught in the act.

All you have to do is turn on your FM radio, tune to the frequency the alarm produces and note the signal strength. As you get closer to the FM Alarm – and therefore to your stolen goodies – the signal strength increases. If you can arrange for a couple of friends to help you with radios on the same frequency, catching the crook is much easier.

FM Alarms are a good way to provide temporary protection for your valuables – say in a locker or room where you do not want to keep a constant lookout yourself.



You will need these parts

Resistors (0.25W, 1%)
1 47kΩ
2 22kΩ
1 10kΩ
1 2.2kΩ
1 150Ω

Capacitors
1 47µF 16VW PC electrolytic
2 0.1µF MKT polyester
1 .022µF MKT polyester
1 .001µF MKT polyester
1 6.8pF NP0 ceramic
1 3.9pF NP0 ceramic
1 30pF trimmer (VC1)

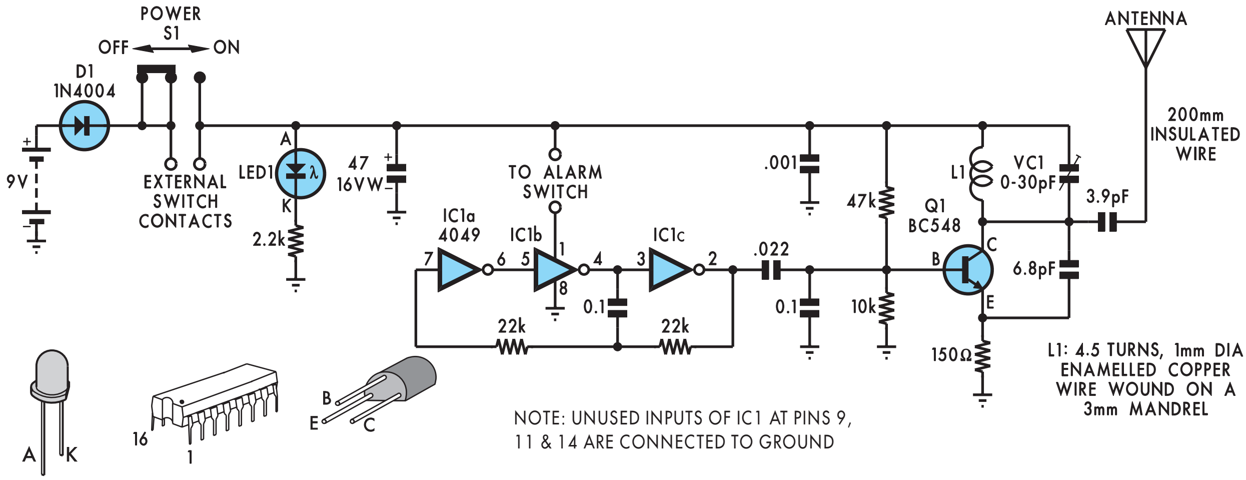
Semiconductors
1 4049 hex inverter (IC1)
1 BC548 NPN transistor (Q1)
1 5mm red LED (LED1)
1 1N4004 1A diode (D1)

Miscellaneous
1 FM Alarm PC board
1 SPDT slider switch (S1)
1 9V battery holder
1 60mm length of 1mm-dia. enamelled copper wire
1 200mm length of medium-duty hookup wire
3 self tapping screws
5 PC stakes

Switching the alarm

There are two ways provided to trigger the alarm. One is to switch only the oscillator on and off, for FM receivers without a muting facility, while the other is to switch the whole circuit on and off, for FM receivers which can mute the audio if there is no signal being received.

The latter is the preferred method since the current drawn from the battery will be zero until the switch is closed. The former method will keep the receiver quiet but will be much heavier on the batteries powering the FM Alarm.



Construction

The Simple FM Alarm is one project where literally everything – battery included – mounts on the PC board.

Begin construction by winding the coil, L1, from 1mm diameter enamelled copper wire. Four and a half turns are wound on a 3mm mandrel (eg, the end of a 3mm or 1/8in drill). Wind from left to right in an anticlockwise direction, keeping the windings fairly close together. When completed, remove the mandrel and trim the ends of the wire.

Put the coil to one side while you start soldering the other components onto the PC board. Begin with the PC stakes, resistors and non-polarised capacitors.

Q1, D1, IC1 and the electrolytic capacitor are all polarised – mount them with the orientation shown. Finally, mount the hardware: the 9V battery holder is secured to the PC board with self-tapping screws as well as being soldered, then S1 (if required), VC1 and last of all, the coil L1 can be soldered in place.

The coil is soldered to the PC board like other components but first you will need to strip the enamel from the ends of the wire. The easiest way to do this is to scrape the enamel away with sand paper then "tin" the bare wire with solder.

Insert the coil into the PC board holes – it may be a tight fit with the wires "tinned" with solder but the tinning will make soldering the coil to the copper pads much easier.

The antenna is made with a 200mm length of hookup wire connected to the antenna terminal PC stake.

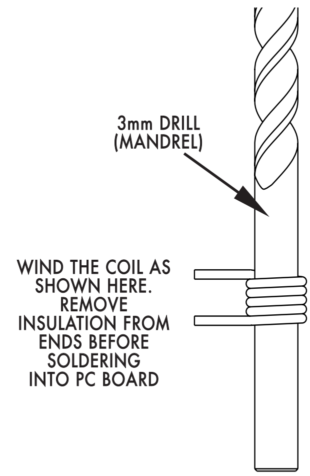
Testing

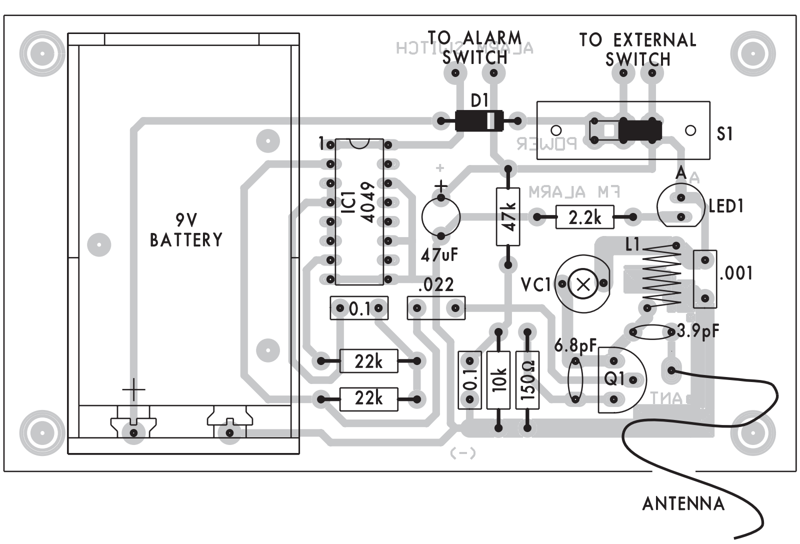
Regardless of which method of triggering you will eventually use, temporarily connect a link across the "to alarm switch" contacts. We will look at the triggering options shortly.

Connect the battery and check that the LED lights with S1 closed or the external switch contacts closed.

Now switch on an FM radio receiver and tune it to a quiet section of the FM band. With the radio close by, try to tune the transmitter by adjusting trimmer capacitor VC1. If you do not hear a tone from the radio adjust coil L1 by opening up the gap between the windings with your fingernails.

Do this by small amounts at a time and vary VC1





TECH TALK

This alarm is quite similar to the FM Radio Microphone (Project 14). Instead of an electret microphone to pick up sound, though, we have an audio oscillator which modulates the transmitted signal.

For an explanation of how the transmitter section works, refer to Project 14.

As mentioned, the main difference is the audio oscillator, made up of three gates from a 4049 quad inverter. IC1a, IC1b and IC1c are three inverters connected end to end.

When the output at pin 2 of IC1c is high the output of IC1b is low and conversely, when the output of IC1c is low the output of IC1b is high. The 22kΩ resistor at the pin 2 output of IC1c charges the 0.1µF capacitor at pin 3 and when the voltage reaches the high threshold of IC1a's input, the inverters swap their outputs from a low to a high and from a high to a low.

The 0.1µF capacitor then discharges via the now low pin 2 output. When the capacitor voltage reaches the lower threshold input of IC1a, the inverters again change state and the process repeats. The frequency of oscillation is about 500Hz.

The output from IC1c is a square wave. The waveform is AC-coupled to the base of Q1 via a .022µF capacitor. The 0.1µF capacitor between the base of Q1 and earth filters the sharp edges off the square wave. This helps to produce a more pleasant sound in the receiver.

To make the circuit completely portable, a 9V battery supplies power. Diode D1 provides reverse polarity protection so that the circuit will not be damaged if the battery is incorrectly connected.

Switch S1 turns power on and off while LED1 provides power on indication.

each time until you are tuned in. Now move the radio some distance away from the transmitter and readjust the tuning for best sound quality.

Triggering the alarm

As mentioned previously, two methods are provided to switch the alarm, depending on the type of FM radio you will be using to track it down.

If your FM radio cannot mute on receive (that is, it hisses loudly between stations), you will need to connect the alarm trigger switch across the contacts marked "to alarm switch" on the circuit diagram.

However, if your FM radio can mute, or go silent, when there is no received signal, your alarm trigger switch can be connected across the power switch contacts. In fact, the power switch itself becomes redundant and could be left out. In this case, you will need to solder a link between the "to alarm switch" contacts.

So much for switching the alarm on and off – whether by switching the whole alarm or switching the oscillator only. But which type of switch is suitable as a trigger for the alarm?

There are many different types of alarm switches to choose from to trigger your FM Alarm, depending on your application and what you want to protect. Basically, all you want to do is ensure that the switch closes when you want the alarm to start working.

You could use reed switch/magnet pairs, microswitches, mercury ("tilt") switches, even push button switches. The latter could be used through the bottom of a case or bag, for example, with the switch held open while ever the bag rested a certain way on the ground. If it was raised or moved, the switch would close and the alarm would start.

The same idea can be used on a door or window. The one thing you don't want, though, is a momentary-type switch which will only give very brief alarm operation; eg, some types of motion and movement detectors.

The alarm switch should be installed so that it closes and stays closed when you want the alarm to sound.

Mounting the alarm

The way the alarm is mounted – and in what – depends on where you are going to use it. Being fully self-contained it doesn't really need a case but it does need some form of protection.

If you were going to use it in a sports bag or case, for example, you might want to protect it from weighty objects such as shoes, balls or books. The same comments apply to the alarm switch itself.

"Fox hunting"

We briefly mentioned how an alarm such as this could be used. Amateur radio operators regularly enjoy a pastime called "fox hunting" where they endeavour to track down a small hidden transmitter using receivers and directional antennas.

The same technique can be used with the FM Alarm: if you can fit a directional antenna to your FM receiver you will find the signal very strong in one direction but dropping off markedly as the antenna swings away from the signal source.

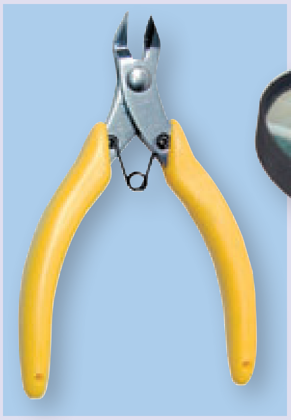
With practice, you can become very skilled at determining the direction of the transmitter. Using the combination of direction AND signal strength is one way to find out not just which way the transmitter is but how far. Enlisting the help of a couple of similarly-equipped friends and a local map makes the task that much easier!

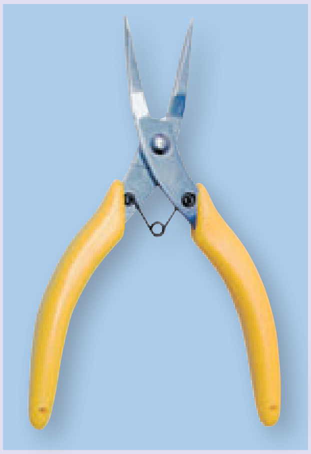
The Tools You're Going To Need

If the projects in this book are your first experience with "hands on" electronics experimenting and construction, here's a quick guide to the basic hand tools you'll need for this kind of work. There are quite a few other tools which will make things even easier (including a multimeter, which is discussed separately) but these are the ones you'll use the most often.

A set of small screwdrivers is essential for all kinds of jobs: loosening and tightening terminal blocks, opening and reassembling instrument boxes, fitting printed circuit boards and other parts inside boxes, fitting cables with plugs and sockets and so on. The Jaycar TD-2017 Precision Screwdriver Set gives you four flat-bladed drivers plus two cross-blade drivers for Phillips-head screws, all mounted in a handy wall holder.

Small side cutters or "nippers" are almost essential. You use them to trim off the excess component leads, cut wire links to length, remove outer insulation from cables and so on. These are the Jaycar TH-1890 cutters, which are 115mm long.



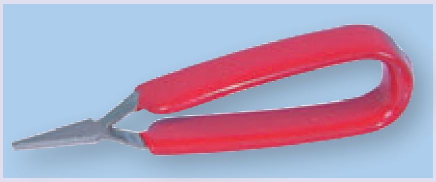


Small long-nose pliers are also very useful for jobs like bending component leads correctly, forming wire links and also holding small items like nuts in confined spaces. The Jaycar TH-1893 pliers shown here are spring-loaded and just the shot for most electronics work.

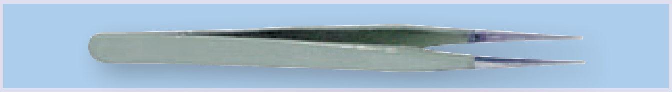
A properly designed wire stripper makes removing insulation from wires much easier, faster and safer. The Jaycar TH-1824 stripper shown here automatically adjusts to the insulation diameter and is well worth adding to your toolbox.

A low-power, electronics type soldering iron is a must. In the Jaycar TS-1651 Soldering Kit shown here, you get the soldering iron, a stand (to hold it when it's hot), some resin-cored solder wire and even a solder sucker to suck up solder if you make a mistake and need to unsolder a component.

A PC board holder can make things much easier when you're soldering components to a printed circuit board, holding it in place while leaving both of your hands free to hold the solder and the hot iron: an artificial 'third hand'! This is the Jaycar TH-1983, which is easily adjustable, has a magnifying glass and features a solid cast-iron base for stability.



A clip-on heatsink is handy when you're soldering small components, especially semiconductors. It prevents overheating by drawing the heat away from the body – and frees up your hands as well! This Jaycar TD-2122 is low in cost but all you need.



Pointed-end tweezers can help hold wires and component leads while you're soldering them, or small nuts while you're trying to fit them to screws. The low-cost Jaycar TH-1754 tweezers shown here are a good choice.

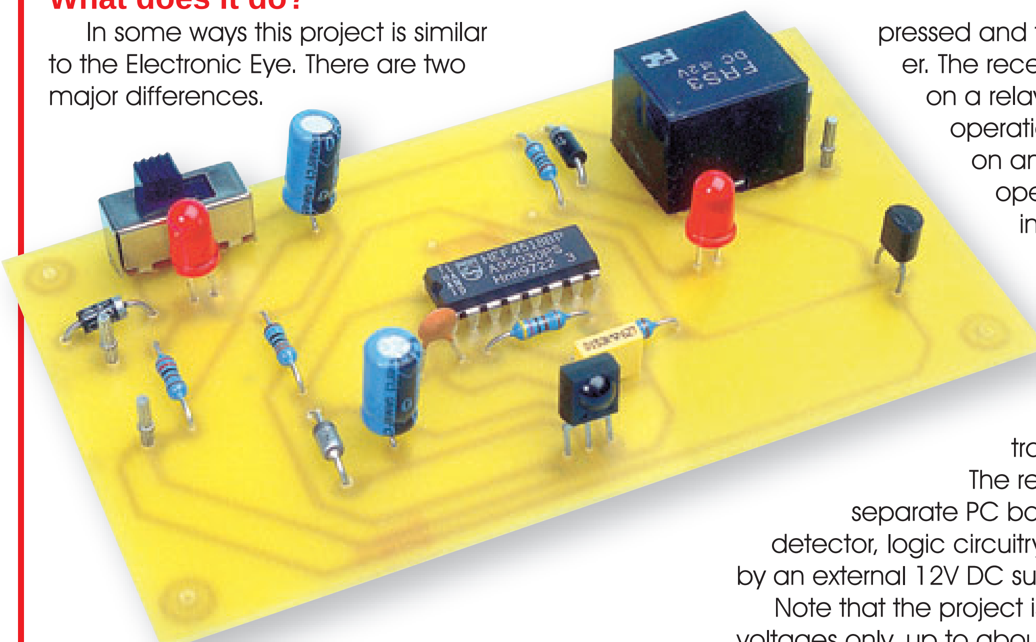
Project 5

Infrared Remote Link

If you want to remotely switch low-voltage equipment on and off across a room, this project will do it for you. It uses an invisible infrared beam so it can't be seen.

What does it do?

In some ways this project is similar to the Electronic Eye. There are two major differences.



One is that infrared, not visible, light is used. The other difference is that a special infrared receiver module is used which is much quicker to trigger than an LDR and can have much greater range.

Infrared remote links are used for many electronic applications but are commonly used to remotely operate equipment. Sometimes (but not in this project), infrared links can carry intelligence such as telephone or television signals.

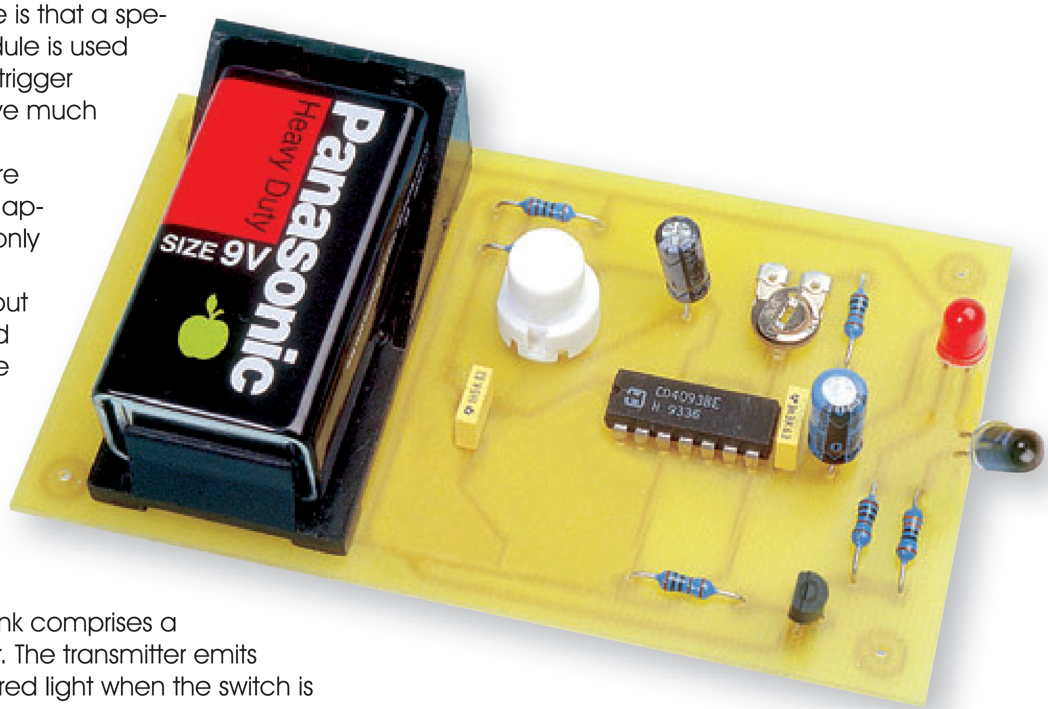
You could even add a Morse key to this project and use it to transmit secret Morse code messages!

This Infrared Remote Link comprises a transmitter and a receiver. The transmitter emits a pulsating beam of infrared light when the switch is pressed and this is detected by the receiver. The receiver can be arranged to turn on a relay momentarily ("momentary" operation) or it can turn the relay on and off alternately ("alternate" operation) on receipt of each infrared signal transmission.

The transmitter is mounted on a small PC board which carries the necessary components, a 9V battery, a transmit switch and the infrared transmitter LED.

The receiver is mounted on a separate PC board. It contains the infrared detector, logic circuitry and the relay. It is powered by an external 12V DC supply.

Note that the project is suitable for switching low voltages only, up to about 30V DC. **DO NOT try to use it to switch the 230VAC mains – that would be much too dangerous.**



You will need these parts

INFRARED TRANSMITTER

Resistors (0.25W, 1%)
1 100kΩ   3 1kΩ
1 330Ω   1 100Ω

Capacitors
1 47µF 16VW PC electrolytic
1 2.2µF 16VW PC electrolytic
1 .0033µF MKT polyester
1 .0015µF MKT polyester

Semiconductors
1 4093 quad Schmitt trigger (IC1)
1 BC338 NPN transistor (Q1)
1 5mm infrared LED (IRD1)
1 5mm red LED (LED1)

Miscellaneous
1 Infrared Transmitter PC board
1 50kΩ horizontal trimpot (VR1)
1 momentary PC mount pushbutton switch (S1)
1 9V battery holder
3 small self-tapping screws

INFRARED RECEIVER

Resistors (0.25W, 1%)
2 4.7kΩ   1 2.2kΩ   1 1kΩ
1 330Ω

Capacitors
2 47µF 16VW PC electrolytic
1 .015µF MKT polyester
1 47pF ceramic

Semiconductors
1 infrared receiver (IR1)
1 4518 dual 4-bit counter (IC1)
1 BC338 NPN transistor (Q1)
1 5.1V 1W zener diode (ZD1)
2 1N4004 1A diodes (D1, D2)
2 5mm red LEDs (LED1, LED2)

Miscellaneous
1 Infrared Receiver PC board
1 3A SPDT 12V DC relay (RLY1)
1 DPDT slider switch (S1)
5 PC stakes

Putting it together

The receiver and transmitter have their own PC boards, so they can be used at some distance from each other.

In each case, the order for construction should be: PC stakes (2 on transmitter, 5 on receiver), resistors, trimpots, capacitors (take care with electrolytic capacitor polarity), semiconductors (again, note polarities) and finally hardware. The 9V battery holder is attached to the transmitter board with small self-tapping screws and the terminals are soldered in position. S1 on the transmitter is installed with its flat side facing the 9V battery holder.

The infrared LED will be a grey or bluish colour and is mounted side on so that it can transmit parallel to the PC board surface. These components must be oriented as shown on the overlay diagram.

On the receiver board, IR1 is mounted with its lens towards the outside edge of the PC board. The relay can only be oriented one way – see the layout diagram. Also, you may need to squeeze S1's pins with a pair of pliers to get them to fit – or you can slightly enlarge the PC board holes.

Note that you only install either R1 or R2 on the receiver board, depending on whether you want the relay to latch on (alternate mode) or be momentary in operation. If you wish, instead of mounting R1 or R2, you can drill the four holes slightly larger and fit PC stakes. Then it will be simple to change from momentary to alternate mode and back again simply by soldering the 4.7kΩ resistor to the appropriate stakes.

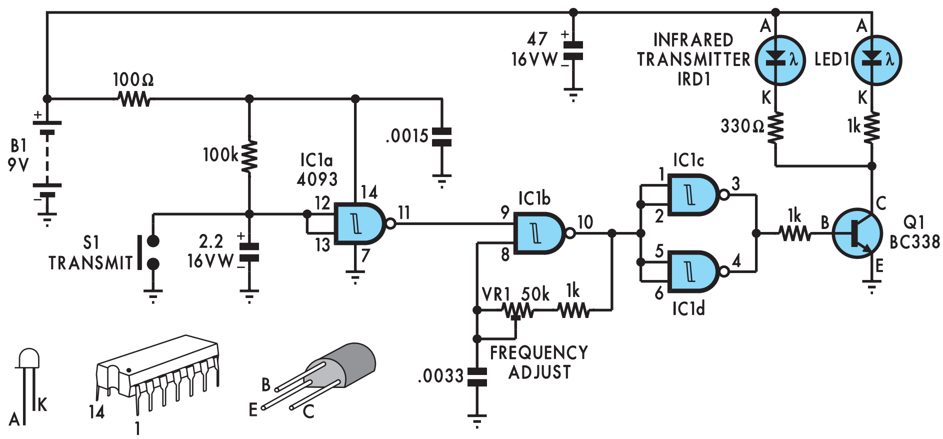
Checking it out

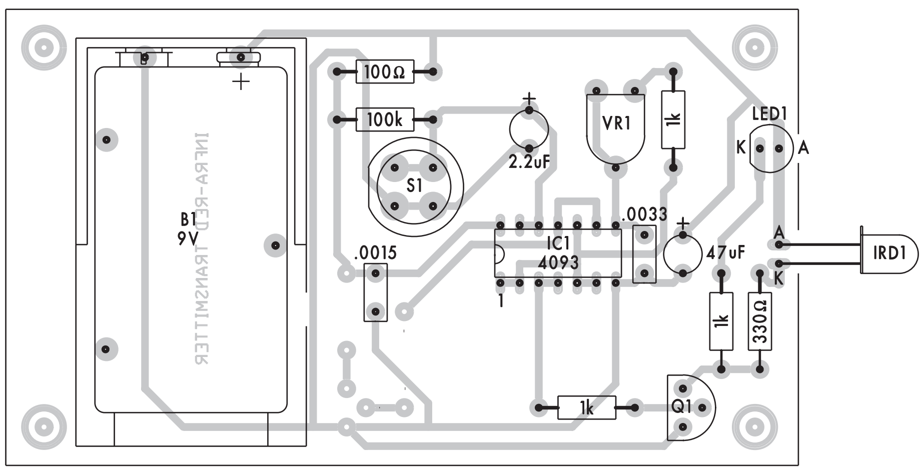
Insert a 9V battery in the holder on the transmitter and check that the transmit LED lights when switch S1 is pressed. If so, that implies that the IR LED is receiving power and transmitting too.

Aim the IR LED on the transmitter at the IR receiver and apply power to the receiver. Check that the acknowledge LED on the receiver board lights when you press the button on the transmitter board.

You will need to adjust VR1 on the transmitter so that the receiver will have the best range. The acknowledge LED actually indicates the state of the relay. When the relay is on, the LED lights and when the relay is off, the LED is also off.

So if you have R1 installed, the LED will light in an alternate fashion and when R2 is installed the LED will light upon reception of a signal.





What to do next

You can extend the range of the transmission by installing reflectors on the transmitter LED and the receiver lens. You could use small torch reflectors with the LED and receiver mounted at the focal point. Make sure that the transmitter LED and receiver lens are lined up correctly.

You can also extend the range with glass lenses placed at the focal points in front of the transmitter IR LED and the receiver detector.

Because the transmitter and receiver are working on a data stream at a specific frequency and not simply the absence or presence of light you should find that this unit is not as affected by daylight as the simple Electronic Eye light beam relay. However, strong sunlight will tend to "swamp" the infrared receiver so it is best to shield it from direct light.

TECH TALK

Infrared transmitter

The infrared transmitter has four basic sections: a switch circuit (1) which controls an oscillator(2), the output of which is buffered (3) and then fed to an infrared transmitter (4).

The switch, oscillator and buffer are all based around IC1, a 4093 quad Schmitt NAND gate, which contains four logic gates. These gates have a high output when either of their inputs is low. However, when both inputs are high the gate output is low.

The "Schmitt" part of the name refers to a special characteristic of such gates: their switching action, high or low, is more controlled and accurate than a standard gate. Schmitt triggered gates are often used to produce a sharply defined transition from high to low (or vice versa) when the input level is gradually changing.

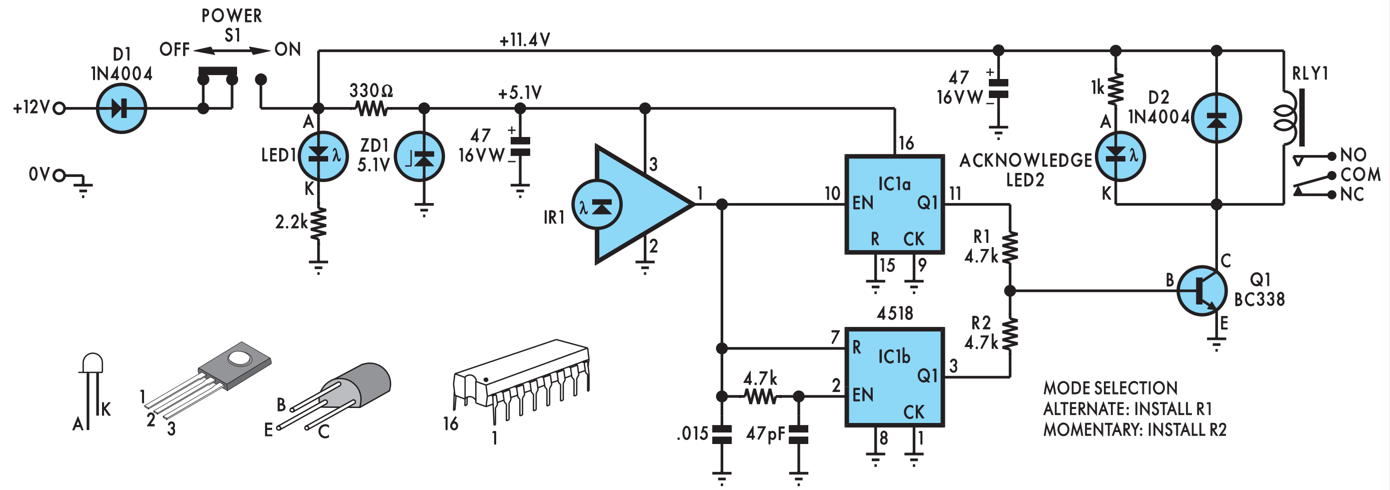
The circuit is powered from a 9V battery. There is no need for a power switch because the standby current is so low that it does not affect battery life.

IC1a has its inputs connected together and so acts as an inverter. Initially, the 2.2µF capacitor at its inputs is charged to the full 9V supply via the 100Ω and 100kΩ resistors. When transmit switch S1 is pressed it discharges the 2.2µF capacitor, taking both inputs low and IC1a's output high.

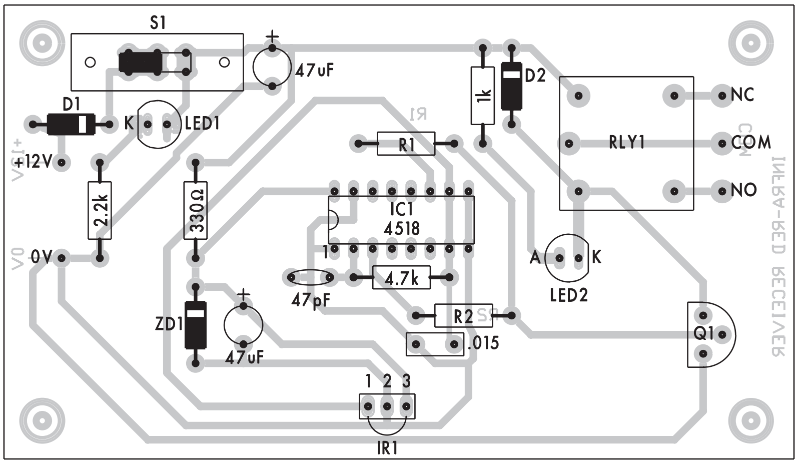
When IC1a's output goes high, it pulls pin 9 of IC1b high and the output (pin 10) goes low. The .0033µF capacitor at pin 8 now begins to discharge via the 1kΩ resistor and VR1. When the capacitor voltage reaches the lower threshold of the input, the output goes high and the capacitor now charges up via the resistors. When the capacitor reaches the upper threshold of the input, pin 10 goes low again.

Thus the output oscillates at a rate set by the resistance of VR1. This rate is adjusted to about 20kHz which is the operating frequency of the detector in the receiver circuit.

IC1c and IC1d are connected in parallel and buffer the oscillator signal from IC1b. They drive transistor Q1 via a 1kΩ base resistor which switches on and off at about 20kHz. This in turn powers IRD1 (the infrared LED) and LED1 (the transmit indicator) at the same frequency. These two LEDs are driven directly from 9V while a 47µF capacitor



On the facing page are the circuit and PC board layout diagrams for the transmitter, while above and at right are the circuit and PC board layout for the receiver. You will need both for the Infrared Remote Link.



Note: install R1 for alternate operation or R2 for momentary operation.

decouples the supply. The 330Ω and 1kΩ resistors limit the current through the LEDs to a safe value.

When the transmit switch is released, the 2.2µF capacitor at IC1a's inputs charges very quickly, sending the inputs high once again. This stops transmission of the infrared signal, with IC1b ceasing to oscillate.

Infrared receiver

The receiver circuit is based around an integrated infrared detector, IR1, which comprises a detector diode, amplifier, detector and demodulator. If IR1 detects a 20kHz infrared signal then the output at pin 1 will go low. The output will go high again when the infrared signal ceases.

The output of IR1 drives both IC1a and IC1b. IC1 is a dual 4-bit binary counter.

The Q1 output of IC1a switches its state, from low to high or high to low, each time a low-going pulse is received by its pin 10 enable input. If resistor R1 is connected in circuit, the high Q1 output drives the base of transistor Q1.

This in turn powers both the relay coil and the acknowledge LED (LED2). Thus, with R1 installed, the relay is turned on for one infrared transmission and off on the next transmission. This is the "alternate" selection.

The "momentary" selection is slightly different and is based on the other 4-bit binary counter. The Q1 output of IC1b is normally low because the reset input (pin 7) is normally high. When the pin 7 input goes low, the reset is released and the IC is clocked via the low-going signal at the enable input at pin 2. This enable input signal is delayed slightly using the 4.7kΩ resistor and 47pF capacitor to ensure that the reset is released before clocking occurs.

Thus the Q1 output at pin 3 goes high and, with R2 installed instead of R1, drives transistor Q1 which powers the relay. When the output of IR1 goes high again, IC1b is reset via pin 7 and the Q1 output goes low. Thus the relay is only on during transmission of the infrared signal, as detected in IR1.

The relay coil is powered from the +11.4V rail. The rest of the circuit is powered from a regulated 5.1V supply via the 330Ω resistor, zener diode ZD1 and the 47µF capacitor.

D1 provides reverse-polarity protection while D2 suppresses the reverse voltage which occurs when transistor Q1 turns off and the relay coil is de-energised. LED1 indicates when power is switched on via S1.

Project 6

Simple Intruder Alarm

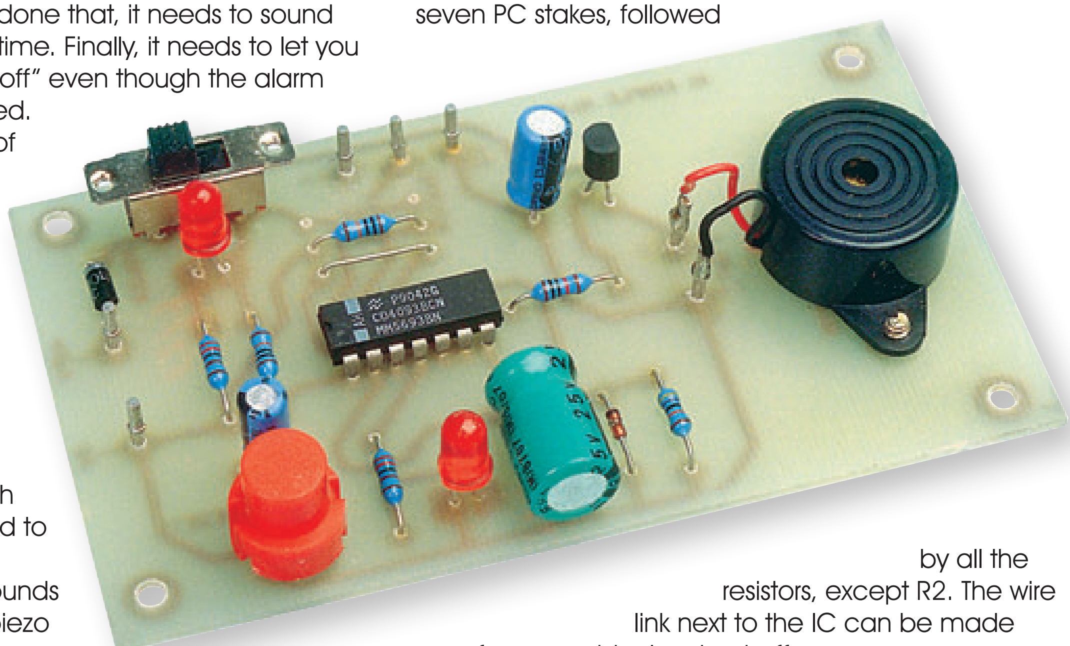
Some alarms give false alarms because they are so complex a lot can go wrong. This one is really simple – just one IC – but it works really well! It can also be used as a car alarm.

What does it do?

All intruder alarms need to do three things. The first, and most obvious, is to detect when an intrusion has occurred. When it has done that, it needs to sound an alarm for a certain time. Finally, it needs to let you know that it has "gone off" even though the alarm siren might have ceased.

This circuit does all of those but it manages to do it without the complexity of many systems. In fact, there is just one integrated circuit and a few other components. It can detect using either "normally closed" or "normally open" sensors (see Tech Talk) which can be fitted to a door or window.

When triggered it sounds a small but very loud piezo alarm. At the same time a LED lights and even though the piezo alarm turns off after a fixed delay of about 40 seconds, the LED stays on until you press a reset button or turn off the power.



Construction

Apart from the alarm switches, all components mount on the Simple Alarm PC board. Start with the seven PC stakes, followed by all the resistors, except R2. The wire link next to the IC can be made from a resistor lead cut-off.

The next step is to install the capacitors – all are electrolytic types and are therefore polarised. The 100µF low leakage (LL) capacitor is mounted on its side, as shown in the photograph and PC board

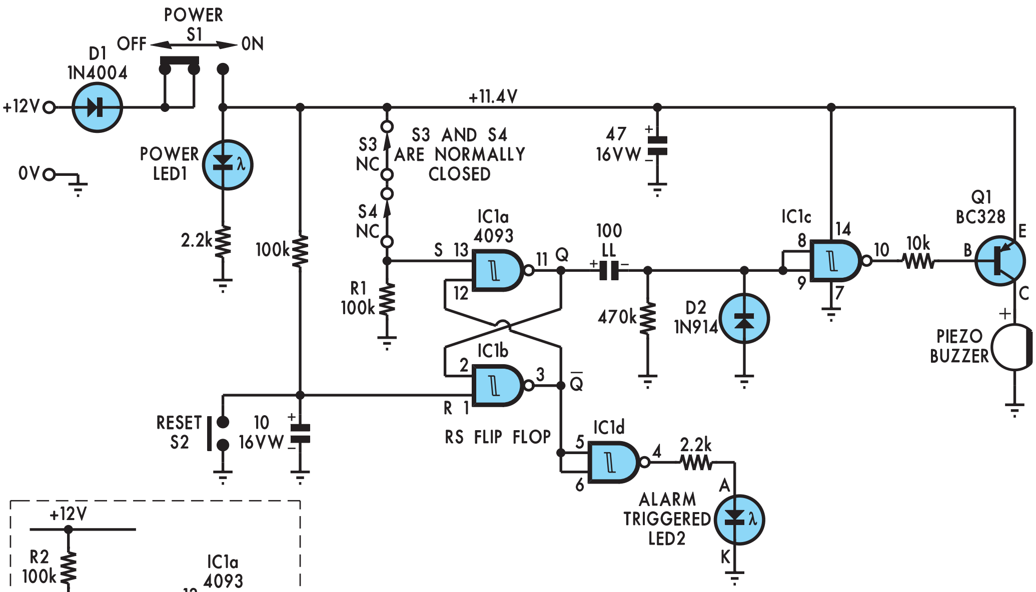
You will need these parts

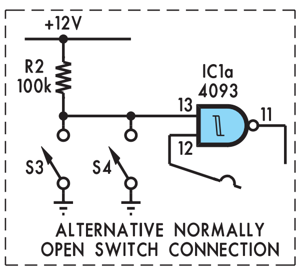
Resistors (0.25W, 1%)
1 470kΩ
2 100kΩ
1 10kΩ
2 2.2kΩ

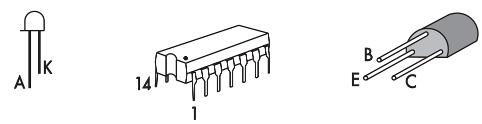
Capacitors
1 100µF low leakage (LL) electrolytic
1 47µF 16VW electrolytic
1 10µF 16VW electrolytic

Semiconductors
1 4093 quad Schmitt trigger NAND gate (IC1)
1 BC328 PNP transistor (Q1)
1 1N4004 1A diode (D1)
1 1N914, 1N4148 signal diode (D2)
2 red 5mm LEDs (LED1, LED2)

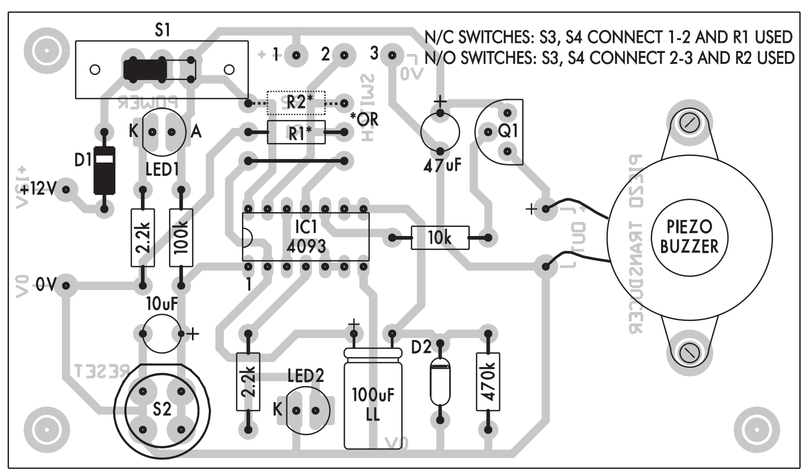
Miscellaneous
1 Simple Alarm PC board
1 SPDT slider switch (S1)
1 momentary PC-mount pushbutton switch (S2)
1 piezo buzzer
7 PC stakes
2 self-tapping screws







Note: a newer type of piezo buzzer may be supplied – it is much smaller and solders directly to the PC board in the position where the PC stakes are shown. Both types have about the same output.



layout. All the semiconductors are also polarised – follow the layout carefully. Mount both LEDs about 7mm or so above the surface of the PC board.

The hardware is mounted last. The piezo buzzer is secured with self-tapping screws from the underside of the board and its wires are soldered to the PC stakes. Make sure that the red wire connects to the PC terminal marked with a "+" sign.

Both switches are mounted directly on the PC board, with the flat side of S2 closest to the 10µF electrolytic capacitor. If S1 is difficult to fit, crimp or squeeze the pins slightly with pliers.

Testing

With S3/S4 and R2 still not connected, apply power and switch S1 on. LED1 should light and the siren should sound after about 1 second. Check that the alarm stops after about 40 seconds and that the alarm triggered LED (LED2) lights. Try the reset switch to check that LED2 is extinguished and that the alarm resounds after one second.

You can short the two lefthand PC stakes near S1 to check that the alarm does not sound unless this short is open.

If you are going to use normally open alarm (sensing) switches, R1 must be removed. It isn't wasted; it becomes R2 and can now be soldered into position.

Installation

This alarm does not have an exit or entry delay time before the alarm sounds. This means that you will not be able to exit from or enter the room or vehicle if the alarm is set, without sounding the siren.

The way around this is to have a hidden or key-operated power switch on the outside of the alarm protected area. This external switch can either replace S1 (you could put some extra PC stakes in the appropriate holes for connection) or it could be wired in series with S1, between the 12V power source and the PC board. It doesn't matter that D1 is on the other side of the switch – either position is fine.

The alarm triggered LED should also be visible from

TECH TALK

Inside the IC are four NAND gates, each with two Schmitt inputs. These gates have a high output when either input is low (0V or ground). If both inputs go high, the output goes low.

The Schmitt input is a special type which gives the gate cleanly defined switching points. It logic high and logic low switching points are further apart than for a standard gate and this eliminates uncertainty with slowly varying signals.

Two of the gates in IC1 are connected together to form an R-S flipflop. This is the simplest form of flipflop with two separate inputs (in this case pin 13 of IC1a and pin 1 of IC1b).

When you first turn on the power switch, pin 1 of IC1b is held low via the discharged 10µF capacitor connected across the reset switch S2. Since pin 1 is low, the output (pin 3) is high and this is connected to pin 12 of IC1a.

Assuming that switches S3 and S4 are closed, pin 13 of IC1a is also high and so the pin 11 output is low. The 100µF capacitor at IC1a's output is discharged and the pin 8 and 9 inputs of IC1c are held low by the 470kΩ resistor to ground. IC1c's output is high and Q1 is off.

The 10µF reset capacitor at pin 1 of IC1b now charges up to the full supply via the 100kΩ resistor and so pin 1 of IC1b goes high. IC1b's output remains high, however, since the low pin 11 output of IC1a connects to pin 2.

When either or both switches S3 and S4 are opened, pin 13 of IC1a is pulled low via the 100kΩ resistor connecting to ground. IC1a's output goes high and the 100µF capacitor at pin 11 pulls IC1c's inputs high. IC1c's output goes low and turns on PNP transistor Q1 via the 10kΩ resistor at its base. Q1 supplies current to the piezo buzzer which sounds the alarm.

Since pin 11 of IC1a is high, the pin 2 input of IC1b is also high and IC1b's output goes low. IC1d is connected as an inverter and its high output at pin 4 drives LED2 via the 2.2kΩ resistor. This LED indicates that the alarm has triggered.

Meanwhile, the voltage at the input to IC1c begins to fall as the 100µF capacitor at IC1a's pin 11 output charges via the 470kΩ resistor connecting to ground. When this voltage reaches the low threshold of IC1c's input, its output goes high and transistor Q1 switches off to stop the alarm.

The circuit stays in this state until switches S3 and S4 are closed and the reset switch is pressed. The reset pulls pin 1 of IC1b low to set IC1b's output high and IC1a's output low. Thus the output of IC1d goes low to switch off LED2.

Diode D2 prevents pins 8 and 9 of IC1c being taken negative with respect to ground when the charged 100µF capacitor is discharged by the low-going IC1a output.

Supply to the circuit is a nominal 12V from a plugpack, battery or our regulated supply (Project 27). Diode D1 protects the circuit from reverse supply connection since it will only conduct with the correct polarity voltage. The supply is decoupled (or smoothed) with a 47µF capacitor and LED1 indicates when power is on.

Switches S3 and S4 detect an intrusion. These switches can be normally open or normally closed but both must be the same type; that is both normally open or both normally closed.

Normally open switches are connected in parallel, with the 100kΩ resistor on pin 13 connected to the positive supply. The normally closed switches are connected in series, with the 100kΩ resistor to ground.

outside so that it can be seen if an intrusion has been detected. You may wish to use some PC stakes and run a pair of wires to LED2 but if you do, be careful you keep the polarity the same.

A pair of wires will also have to be run to the alarm trigger switch(es). The circuit shows only two switches but in theory there is no limit to the number of alarm switches you can include.

In practice though, you should keep the number of alarm trigger switches to the minimum you need because faulty switches are a common cause of false alarms.

Just remember, whatever type you choose they must all be the same, either normally open or normally closed. In addition, R1/R2 on the PC board must be selected as appropriate for the type of switch chosen.

Alarm Switches

There is a large variety of suitable alarm switches available – for the best guide, see the alarm pages of the latest Jaycar Electronics catalog.

Most of the switches (also called sensors) will state whether they are normally open (NO) or normally closed (NC) devices. Some, such as a mercury switch, (Jaycar Cat. SM1035) can be mounted so that they can be used either way.

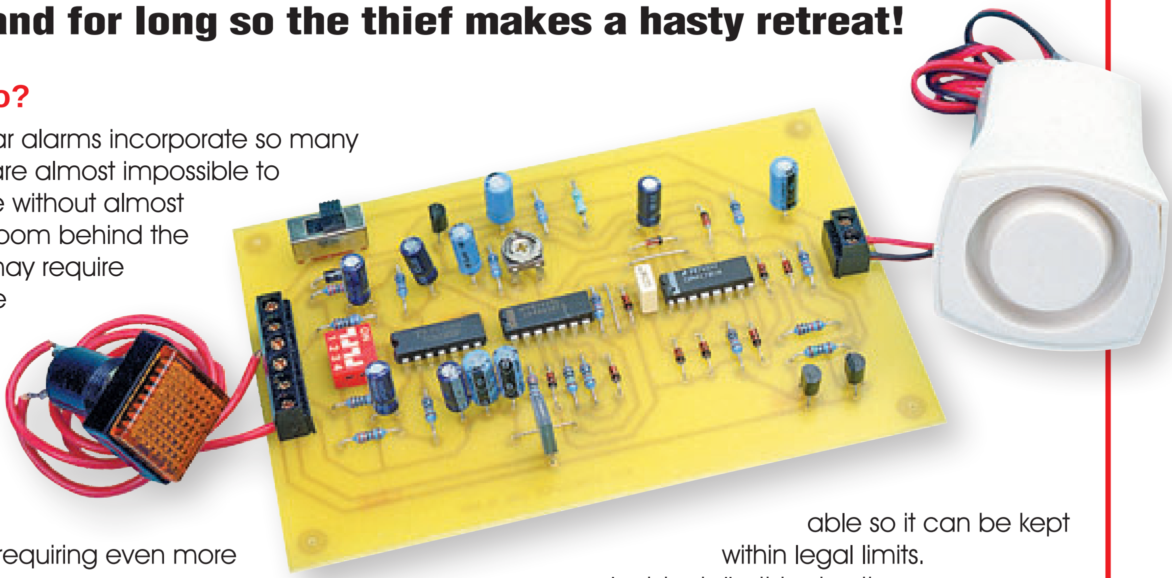
Other popular alarm switches include the reed switch and magnet assemblies (Jaycar Cat. LA5070 or LA-5075) or tamper switches (Jaycar Cat. LE8775).

If you want to get really tricky, you could use a movement sensor such as a passive infrared detector (Jaycar Cat. LA5036). Key-operated switches (for turning the alarm on and off externally) are also available (Cat. SM1027 and SM1030).

Project 7

Screamer Car Alarm

At last! A practical car alarm which is effective, yet easy to build and install. But this one is a bit different: when triggered it emits a deafening shriek *inside* the car. It's far too loud to stand for long so the thief makes a hasty retreat!



What does it do?

Many current car alarms incorporate so many features that they are almost impossible to install into a vehicle without almost rewiring the wiring loom behind the dashboard! They may require connection into the electronic ignition, the blinkers, horn, separate battery, central door locking and ignition. They can even incorporate ultrasonic sensing, requiring even more wiring and installation.

The Screamer Car Alarm requires only three connections to the car wiring, namely the 12V supply, chassis (0V) and a door switch. Yet it doesn't skimp on features – they include entry and exit delays, a flashing light to warn of the alarm operation, a soft warning alarm just in case you forget to turn the alarm off, and (most important) an ear-splitting main alarm.

The siren really is that loud – far too loud for a thief to stay in the vehicle. It could even cause ear damage with long exposure. The alarm will switch off and rearm itself after a set time. The alarm "on" time is variable so it can be kept within legal limits.

Incidentally, this circuit appears very complex but it really is quite simple to build because all the hard wiring is taken care of by mounting components on the PC board. Just take care and take your time!

Construction

All components except the alarm siren are mounted on the Screamer Car Alarm PC board.

Begin construction by installing the resistors and links. The links can be made from cut-off resistor leads. The diodes can be mounted next – all except

You will need these parts

Resistors (0.25W, 1%)
1 10MΩ 1 1MΩ 5 100kΩ
5 10kΩ 3 2.2kΩ 1 390Ω
1 150Ω 2 100Ω
1 500kΩ horizontal trimpot (VR1)

Semiconductors
1 4030 quad exclusive-OR gate (IC1)
1 4093 quad 2-input Schmitt NAND gate (IC2)
1 4017 decade counter (IC3)
1 BD139 NPN transistor (Q1)
3 BC338 NPN transistors (Q2-Q4)
1 1N4004 1A diode (D1)
10 1N914 or 1N4148 signal diodes (D2-D11)

Capacitors
1 100µF 16VW PC electrolytic
2 47µF 16VW PC electrolytic
1 22µF 16VW PC electrolytic
5 10µF 16VW PC electrolytic
1 1µF 16VW PC electrolytic
1 0.1µF MKT polyester

Miscellaneous
1 Screamer Car Alarm PC board
1 SPDT slider switch (S1) (or alarm switch – see text)
1 4-way DIP switch
1 6-way PC terminal strip
1 2-way PC terminal strip
1 12V indicator lamp
1 alarm siren (see text)

one are small signal diodes which are usually smaller than the power diode, D1. As usual, take care with their orientation – one mounts with its stripe opposite to all the rest.

Likewise, when mounting the capacitors, make sure the electrolytics are inserted the right way around. Q1-Q4 can now be inserted and soldered in position followed by VR1 and the three ICs – they all mount with their notch or dot facing the same direction.

If you are fitting switch S1 to the PC board (see note at end) it is installed by crimping the mounting pins before inserting it into position. If using an external switch, S1 can be replaced by a wire link.

Finally, the DIP switches and the PC board mounting terminals can be inserted and soldered.

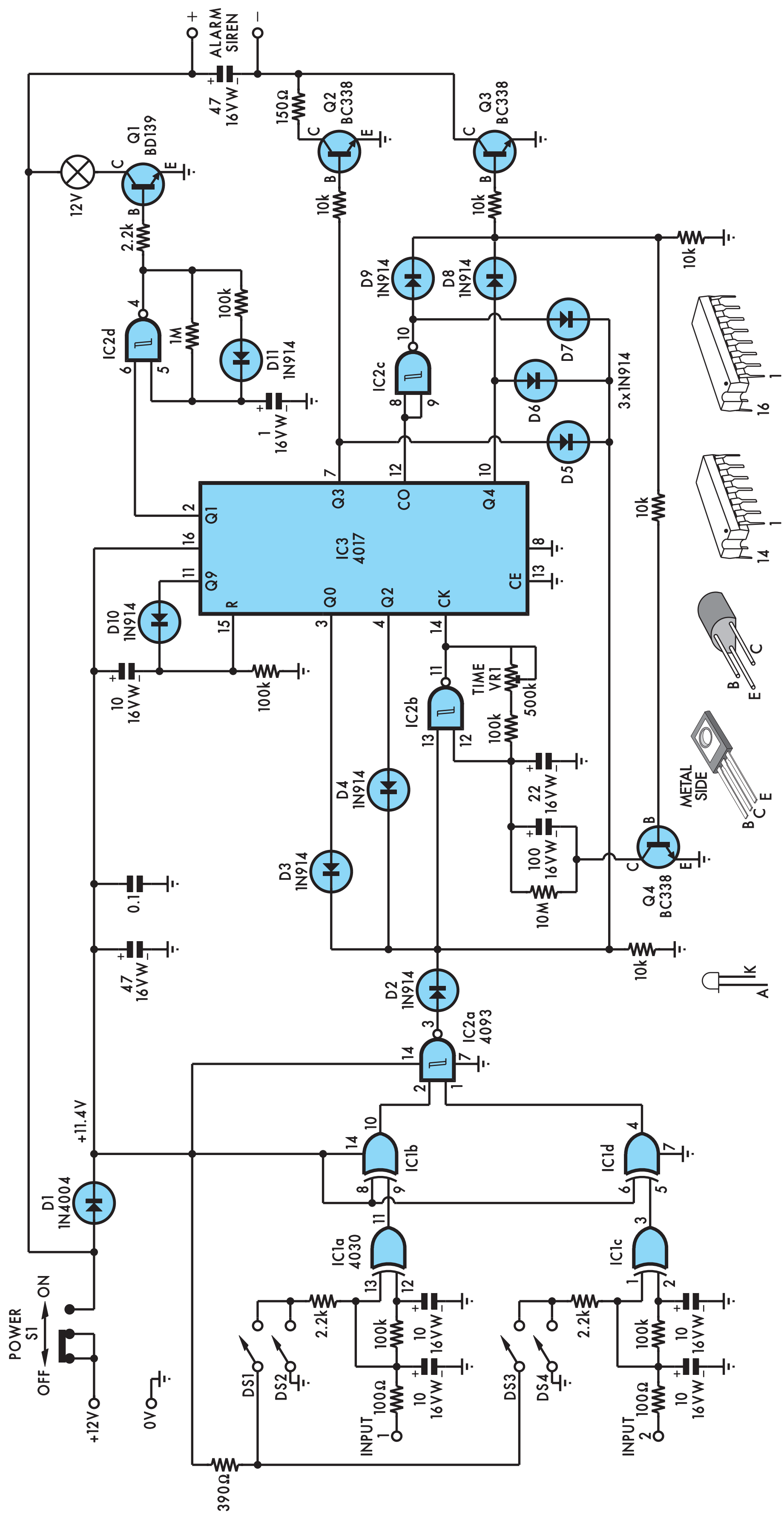
Testing

This is probably the most complex project in this book, so very carefully check your component placement and soldering. It is very easy, especially around ICs, to accidentally bridge between adjacent pads with solder.

Fortunately, the alarm can be tested without connecting the alarm siren – you wouldn't be able to stand the noise for very long!

First, wire up the indicator lamp and close DS1 and DS3. Set VR1 fully anticlockwise then connect a 12V battery or plugpack supply to the circuit and turn on. The lamp should initially light and after a few seconds it should begin to flash. If you temporarily connect Input 1 to 0V with a short length of wire, the lamp should stop flashing after a few seconds. If you wait for about one minute the lamp should again begin flashing after the alarm period.

You can adjust the alarm time by adjusting VR1. It can be varied from about 60 seconds to 180 seconds. A word of warning, though: in NSW at least, it is illegal for a car alarm to sound for more than 90 seconds, even "in cabin" alarms such as this. You may have to reduce the 47µF capacitor at the collector of Q4 to



ensure that this time cannot be exceeded. Anywhere between 22µF and 47µF would be appropriate values to try. The unit should be tested with the siren suitably muffled – eg, by placing the siren under a pillow!

Installation

Before you install the alarm you need to determine which type of courtesy light you have fitted. The vast majority of cars have the switch on the chassis, or negative, side of the light but there are some exceptions. If in doubt, try asking a friendly auto electrician.

The alarm can be installed in a car by accessing the 12V supply via a fuse and the vehicle earth or -ve. Inputs are required from at least one door switch. The second input can be left open provided that one of the DIP switches for it is closed. DS1 should be closed when Input 1 is used with a ground (chassis) connecting door switch. DS2 should be left open. If Input 2 is used on a ground connecting door switch, then close DS3 and open DS4. For a positive connecting door switch, close DS2 for Input 1 and DS4 for Input 2. DS1 and DS3 should be left open.

Alternatively, you may wish to wire the other alarm input to protect the bonnet or boot. If either of these has a light fitted, you can tap into that – or fit a boot or bonnet light yourself (they're very handy).

You can also choose whether you fit the on/off switch on the battery side or the earth side of the light. Alternatively, you can fit a switch which connects the alarm input to chassis when the boot or bonnet are opened (there are many types of switches available).

Mounting the lamp and on/off switch

You will need to install the lamp in the dashboard so that it can be seen readily. The on/off switch, on the other hand, must be well hidden, mounted somewhere so that you can turn the alarm on and off on exiting the vehicle and on your return. The main points to remember about the switch are that:

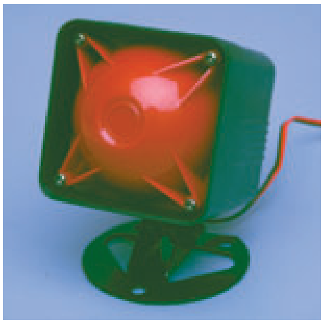
(a) it must be accessible – you don't want to have to go into contortions to reach it before the alarm goes off.

(b) it must be not only difficult to spot from outside the car but difficult to spot you reaching for it. If you park in the same position each day or night there could be someone watching you.

The best place to locate the PC board and alarm siren is probably under the dashboard. Make sure the alarm siren is aimed into the car and not muffled by under-dash material.

Even if you forget to switch the alarm off when you enter the car the softer warning siren will sound to give you a chance to switch it off – or get out of the car – before the full volume siren sounds.

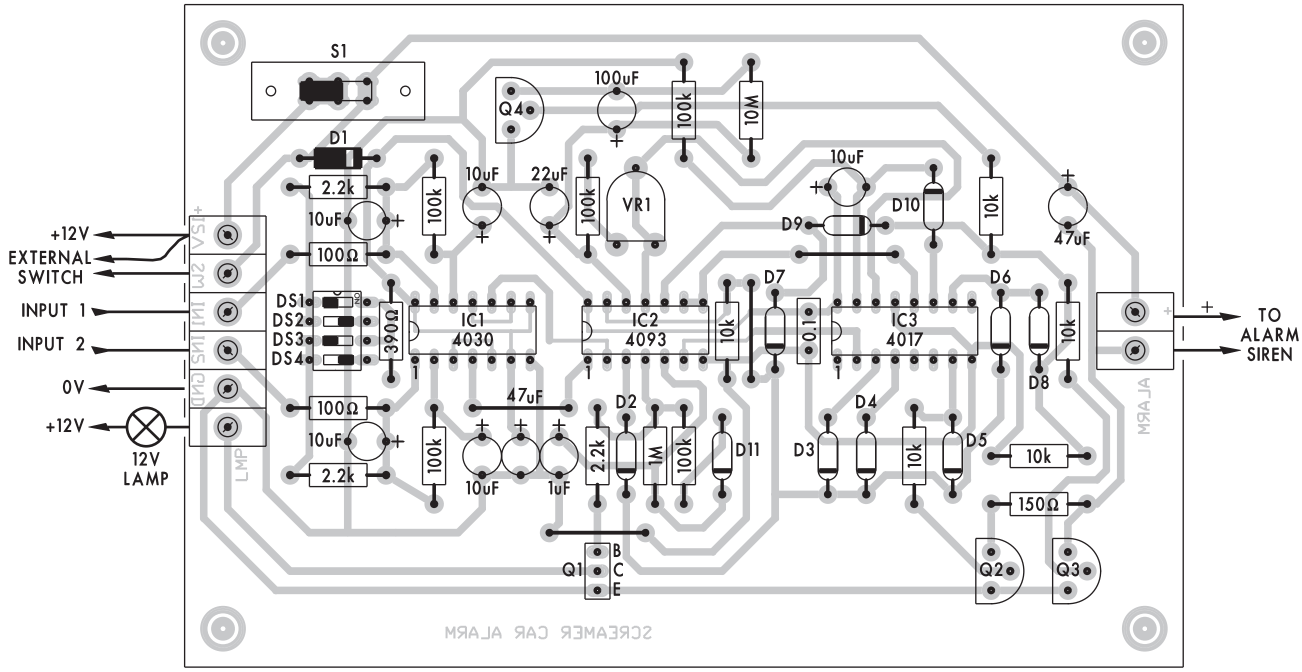
About the siren



There are many types of siren suitable for this alarm. You should look for a siren which operates from 12V and has a sound output of around 115-120dB or so (at close range, that's almost as loud as a jet aircraft).

Suitable sirens from the Jaycar catalog include the Car Alarm Electronic Siren (125dB, Cat. LA8908), Piezo Siren (120dB, Cat. LA5258), Tweetie Pie (116dB, Cat. LA5255) and Large Tweetie Pie (119dB, Cat. LA5254).

See next page for Tech Talk



The alarm circuit is based around three low-cost CMOS ICs – a 4030 quad exclusive-OR gate, a 4017 decade counter and a 4093 quad Schmitt NAND gate. The 4030 detects door openings, the 4093 acts as a timer and the 4017 causes various events to occur such as the exit and entry period, the soft alarm, the loud alarm and so on.

A door opening is detected by Input 1 or 2. To account for both types of door switching used for car courtesy lights, these can be set to respond to a high- or a low-going signal using DIP switches DS1-DS4. For simplicity, we will only look at what happens around Input 1. Input 2 operation is identical.

Most cars have low-going switching – the door switch connects the negative side of the light to the chassis. In this case DS1 is closed and DS2 is open. In the few cars where the door switch is on the battery side of the courtesy light, DS2 is closed and DS1 is open.

IC1a is an exclusive-OR gate which has a high output at pin 11 only when one input is high and the other low. If DS1 is closed and DS2 open then the pin 13 input is normally held high via the 2.2kΩ resistor and the pin 12 input is held high via the 100kΩ resistor. The output (pin 11) is therefore low.

Opening a door will take Input 1 low, taking pin 13 low immediately. However, the pin 12 input stays high for a moment because of the charged 10µF capacitor connected to it. Thus the pin 11 output goes high. The 10µF capacitor discharges via the 100kΩ resistor, soon reaching the pin 12 low trigger threshold. The pin 11 output then goes low again.

When the door closes, pin 13 goes high and pin 12 stays low until the 10µF capacitor is charged via the 100kΩ resistor, which means pin 11 goes high during this period as well.

The output of IC1a is inverted by IC1b and is monitored, along with the output from input 2 (IC1c&d), by Schmitt NAND gate IC2a. Normally, when neither input is detecting a door opening or closure, the inputs to IC2a are both high and its output is low.

IC2a's output controls the operation of the clock oscillator formed around IC2b, via diode D2. When IC2a's output is low, the pin 13 input of IC2b is held low via the 10kΩ pull-down resistor (next to Q4 on the circuit diagram), so IC2b cannot oscillate.

IC3 is a 4017 decade counter which has 10 separate outputs designated Q0, Q1, Q2 and so on up to Q9, as well as a carry out (CO). The IC counts the clock input signal to pin 14 and sequentially places a high on each of the outputs in turn. We have used five of the outputs and the carry out to control the entry and exit delays, the soft alarm time and the main alarm time period.

When power is applied, the pin 15 reset input to IC3 is held high via a 10µF capacitor. This holds the IC reset so any clocking pulses from oscillator IC2b are ignored. After a short time, pin 15 is pulled low as the 10µF capacitor charges via the 100kΩ resistor. IC3 is now ready for operation, with the Q0 output at pin 3 high and other outputs low.

Diode D3 pulls the pin 13 input high on timer oscillator IC2b and the 22µF capacitor at its pin 12 input begins to charge via trimpot VR1 and the 100kΩ series resistor. When the capacitor voltage reaches the upper threshold of the pin 12 input, the output goes low. The 22µF capacitor then discharges via VR1 and the 100kΩ resistor and when the voltage reaches the lower threshold of the pin 12 input, the output again goes high and clocks IC3's pin 14 input. The next output (Q1) at pin 2 now goes high. The pin 13 input to IC2b is held low again via the 10kΩ pull down resistor and so pin 11 stays high.

The period between when power is applied until the output of IC2b goes high again is the exit period. The doors can be opened and closed during this period without triggering the alarm.

IC3's pin 2 output controls another oscillator based on IC2d. This oscillator drives the dashboard indicator lamp via transistor Q1. During the reset and exit periods, IC2d's pin 6 input is low and so the pin 4 output is high. Therefore transistor Q1's base is held high to light the lamp.

When the Q1 output at pin 2 of IC3 goes high, the IC2d flasher oscillator operates. It operates as follows: when the pin 4 output is high, the 1µF capacitor at pin 5 is charged via a 100kΩ resistor and diode D11. When the 1µF capacitor reaches the upper threshold of pin 5, the output goes low and the capacitor is discharged via the 1MΩ resistor.

This discharge period is much longer than the charge time. Thus IC2d drives transistor Q1 and the lamp flashes in brief bursts to indicate that the alarm is set.

The alarm will stay in this state until a door is opened or closed to trigger timer oscillator IC2b via D2. If this happens, the pin 11 output will go low and begin to discharge the 22µF capacitor. When the capacitor is discharged, the pin 11 output of IC2b goes high and clock IC3 so that the Q2 output goes high. This holds the pin 13 input of IC2b high via diode D4 and so IC2b continues to oscillate.

The period from when IC2b is triggered and the time that the Q2 output is high is the entry delay. It gives sufficient time to enter the car and switch off the alarm before the siren sounds.

The next high-going pulse from IC2b clocks IC3 again so that the Q3 output goes high. This high output holds the pin 13 input to IC2b high via D5 to maintain the oscillation and also drives transistor Q2. This transistor drives the alarm siren via a 150Ω resistor. The resistor limits the voltage applied to the siren so that it is not particularly loud. This is the warning alarm.

When the IC2b oscillator clocks IC3 again, the Q4 output goes high. This holds the oscillator on via D6 and drives transistor Q3 via diode D8. Transistor Q3 now drives the alarm siren at full voltage for maximum sound output.

The Q4 output from IC3 also drives transistor Q4 via diode D8. This transistor connects an extra capacitor to the pin 12 input of IC2b, to slow the oscillation rate and to increase the alarm time.

When the oscillator triggers IC3 again, the unused Q5 output goes high but more importantly the CO (Carry Out) from pin 12 goes low. This is buffered and inverted by IC2c and the high output from pin 10 of IC2c drives transistors Q3 and Q4 via diode D9, along with the pin 13 input of IC2b via D7. The CO output stays in the low state for a further three clock signals from IC2b which are effectively ignored.

When the next clock pulse to IC3 occurs, the Q9 output goes high which resets IC3 via D10. Thus the Q0 output goes high. All other outputs go low except the carry out, which goes high and the alarm siren turns off. After a delay, the Q1 output again goes high and the circuit is ready to sound the alarm when a door is opened or closed.

Power for the circuit is from the 12V car battery with diode D1 providing reverse polarity protection. A 47µF capacitor across the supply provides a reservoir for transient loads and the second 47µF capacitor across the alarm siren provides added supply filtering.

A more convenient switch than the one on the PC board can be fitted to switch the alarm on and off. This must be hidden within the car but be within reach to turn the alarm off before it goes off.

Resistors And Their Colour Coding

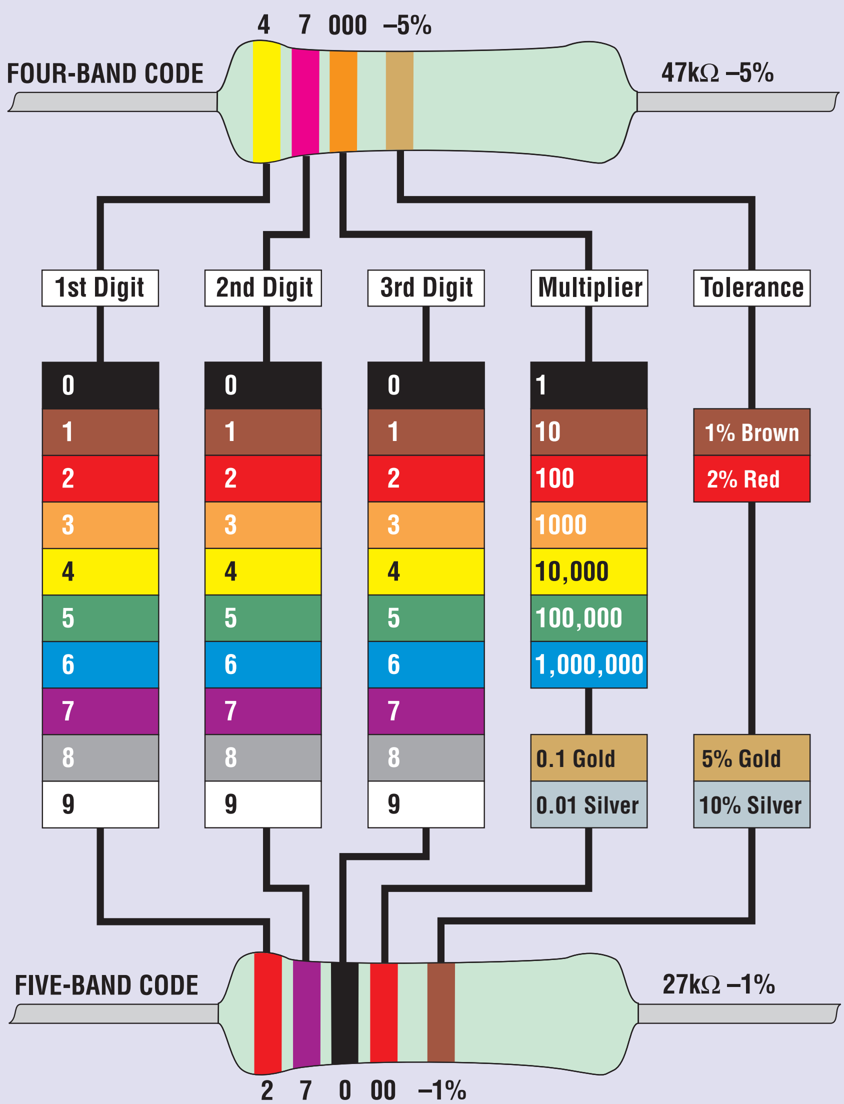
Resistors usually have their value shown as a colour code with bands of coloured paint. Each colour band is used to represent a numeral or a decimal multiplier.

The bands are normally nearer one end of the resistor than the other and they're read from that end. They can have four or five bands. With a 4-band type, the first two bands show the basic value, while the third band shows the 'number of zeros' and the fourth band (often spaced slightly further away) shows the tolerance – ie, how close to the specified 'nominal value' the actual value is likely to be.

With 5-band resistors, the first three bands are used to show the basic value. In this case the fourth band signifies the number of zeros and the fifth band gives the tolerance.

Note that the '0' represented by a black third band on a five-band resistor doesn't mean it's ignored. That nought is still counted, so that a black third band followed by a red fourth band means there are THREE noughts – the equivalent of an orange third band on a four-band resistor (see example).

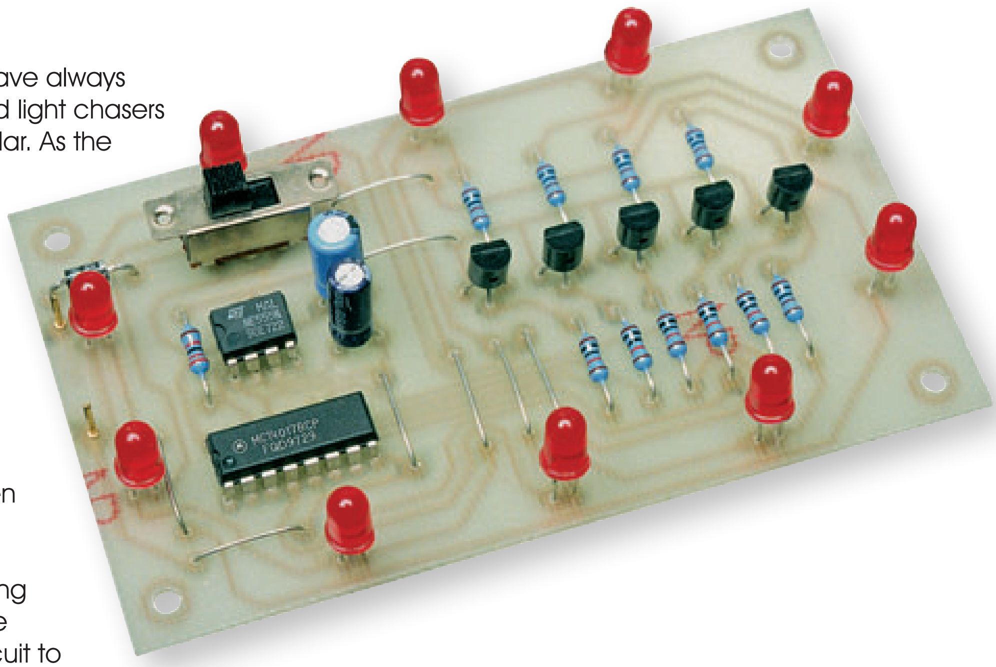
Sometimes the body of the resistor can have a colour which makes it hard to decide the exact colour of some bands by eye. The best plan here is to check the resistor value with a multimeter, before wiring it into your circuit. The same applies if the bands seem to be equally spaced from both ends, so you don't know which end to start from. Where there's a gold or silver band, though, this will help work that one out – these bands always go at the end of the code.



Project 8

Light Chaser

Everyone has seen a chaser, where lights are turned on and off in such a way as to make them appear to "chase" each other. They're very popular in shops, theatres and advertising displays. Here's one you can make yourself!



What does it do?

Moving light displays have always been attention getters and light chasers are one of the most popular. As the name suggests, the lights appear to chase each other around. It's an optical illusion – but it works!

In the days before semiconductors, chasers were made with an electric motor moving a switch contact from one light circuit to the next, then the next, and so on.

These days, it's much easier with electronics doing both the switching and the moving from one light circuit to the next.

It might surprise you to know that even large commercial chasers involving hundreds or even thousands of lights start with a circuit essentially the same as this one. They simply add the components necessary to switch mains voltages!

Construction

All components for the Light Chaser mount onto the LED Chaser PC board.

Begin construction by inserting and soldering the PC stakes, followed by the resistors and wire links. The wire links may be a little too long for resistor lead cut-offs: use tinned copper wire instead.

The two electrolytic capacitors, the ICs, transistors and LEDs are polarised devices so ensure they are inserted the correct way around. The transistors are soldered in place so that they are about 5mm above the PC board.

Similarly, the LEDs should stand above the PC board – about 5-10mm should look about right.

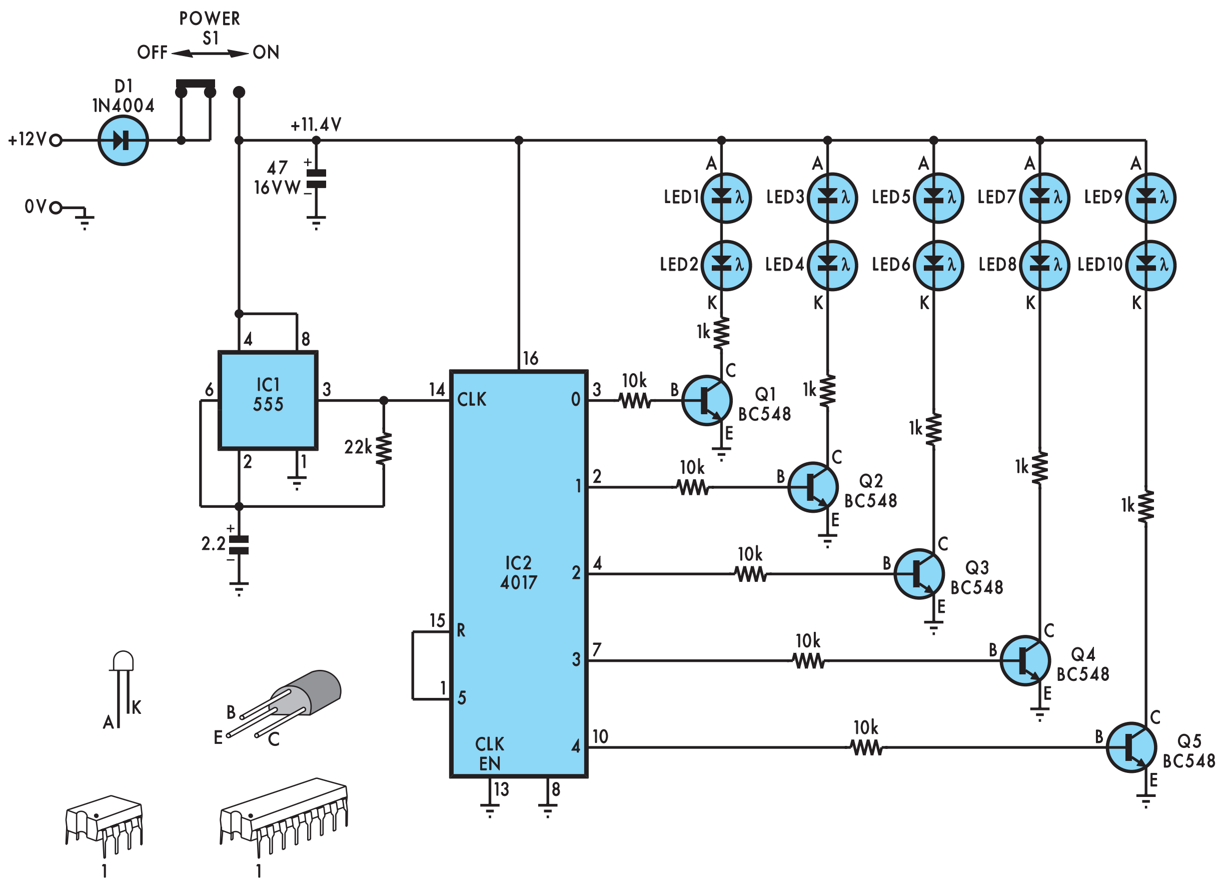
You will need these parts

Resistors (0.25W, 1%)
1 22kΩ   5 10kΩ   5 1kΩ

Capacitors
1 47µF 16VW PC electrolytic
1 2.2µF 16VW PC electrolytic

Semiconductors
1 555 timer (IC1)
1 4017 decade divider (IC2)
1 1N4004 1A diode (D1)
5 BC548 NPN transistors (Q1-Q5)
10 5mm red LEDs (LED1-LED10)

Miscellaneous
1 LED Chaser PC board
1 SPDT slider switch (S1)
2 PC stakes
1 150mm length of tinned copper wire



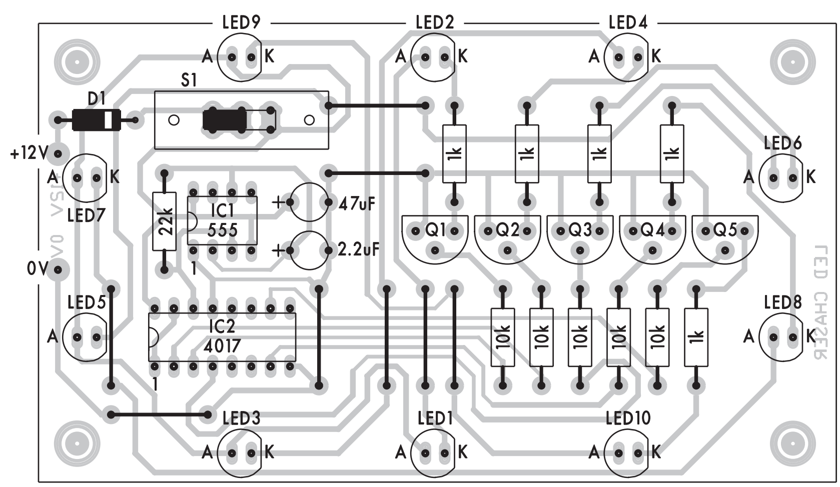
Testing

The circuit is designed to operate from a 12V battery or plugpack but will also work with a 9V battery.

Just remember the life of a 9V battery will be rather short so if you are planning to use a battery, do all your troubleshooting with a power supply beforehand!

First of all, check your soldering, especially around the ICs, LEDs and transistors. Some pads are very close together and it's easy to bridge across them.

Checking the circuit is very simple: apply power, turn it on and see if it works!



Each of the LEDs should light up in the sequence detailed in the circuit description, appearing to be travelling in a clockwise direction.

If it doesn't work, check the voltage between the anode of any odd-numbered LEDs and 0V – it should be about half a volt or so less than the supply voltage.

If this is OK, check the voltage between pins 8 and 1 of IC1, and pins 16 and 8 of IC2. They should be the same as the previously measured voltage. If it still doesn't work, check your soldering carefully. Poor solder joints are responsible for 95% of the faults in electronic projects!

If you want to change the speed of rotation, you can change either the 2.2µF capacitor or the 22kΩ resistor. Use a larger value for either component to slow it down and smaller values to speed them up.

Keep the value of the resistor above about 1kΩ though, or the circuit may not operate correctly. Not only that but unless you use a larger capacitor the LEDs will flash too fast to get the chasing effect – they'll simply appear permanently on.

What to do next

For a really bright display you could substitute high brightness LEDs. Be aware, though, that high brightness LEDs are normally quite dim unless you are looking straight into them.

As we said in the explanation, we use the IC to count to five (0, 1, 2, 3, 4) before resetting – but it can count to 10. If you'd like to add more LEDs in the ring, you can use the IC to count to 5, 6, 7, 8 and 9 by adding extra output resistors, transistors and LED strings.

Naturally, you won't be able to use the PC board pattern as it is but with a little ingenuity you could come up with a really impressive chaser!

The 5 count output comes from pin 1, with pin 5 connected to the reset (pin 15). Similarly, the 6 count comes from pin 5, with 6 to the reset; the 7 count from pin 6, pin 9 to reset; the 8 count from pin 9, pin 11 to reset. And to count all the way, the 9 count comes from pin 11, with the reset pin earthed.

If you wish, you could have only one LED chasing (simply drop one of the LEDs in the pair) but again, the PC board pattern won't be usable as is. Alternatively, you could add another one, two, perhaps even three LEDs to each string to have even more LEDs chasing each other around. You may need to reduce the 1kΩ resistors but don't go below 330Ω.

Finally, how about using small 12V lamps instead of LEDs? You can do this by replacing the BC548s with higher rated transistors (perhaps BD139s rated at 1.5A) and connecting suitable lamps in the collector circuits instead of the LEDs and 1kΩ resistors.

Typical small lamps (often called "dial lamps") draw about 100mA or so; brighter or larger lamps considerably more.

There are a few wrinkles to take into account. First, the pinouts of a BD139 are quite different from a BC548 so make sure you get them correct.

Second, BD139s cannot pass 1.5A without adequate heatsinking. And there is another problem: when many filament globes are turned on, their "cold surge" current can be 8-10 times their rated current for a brief instant. This could destroy a transistor.

Third, and possibly most serious, the BD139 gain could be inadequate for high current lamps. Lowest spec gain is only 40, so if the 4017 IC is supplying about 5mA base current, that allows only about 200mA collector current.

To be safe, for a higher current lamp, a higher rated Darlington transistor such as a BD681 (4A max, gain = 750) would be a better choice.

Finally, you'll need a larger power supply, capable of driving the lamps you choose.

TECH TALK

The circuit for the Light Chaser comprises two cheap and readily available integrated circuits (ICs): a 555 timer and a 4017 decade counter.

The 555 is wired as an astable oscillator in just about the simplest configuration possible: only two additional components. When power is applied, pins 6 and 2 are low due to the discharged 2.2µF capacitor. The pin 3 output, therefore, goes high. As well as providing a clock pulse for IC2, this starts to charge the capacitor via the 22kΩ resistor.

When the capacitor charges to 2/3 the supply voltage, pin 6 detects this and sends the output low. The capacitor then discharges via the 22kΩ resistor through pin 3 until it reaches 1/3 the supply voltage. Pin 2 detects this and sends the output high.

The process continues at about 18Hz for as long as power is applied, with the output from pin 3 fed to the clock input of IC2.

IC2 is called a "decade" counter (normally counting to 10) but we are using it to count to only 5. As it counts the clock pulses at its pin 14 input, each of its outputs goes high in turn for one clock period. As each output goes high, it turns on an associated transistor and two LEDs. For example, when the first output ("0") at pin 3 goes high, Q1 is switched on via the 10kΩ base driver resistor. This transistor powers LED1 and LED2 via the 1kΩ current limiting resistor.

The process continues as the "1" output at pin 2 goes high and the "0" output goes low. The output sequence follows with the "2" output going high, then the "3" output and finally the "4" output. At the sixth count the "5" output at pin 1 goes high and pulls the reset input at pin 15 high. This clears the counter so that it returns with the "0" output high, ready to start over.

The rotating effect of the LEDs is achieved by placing the LEDs in a somewhat rectangular shape, with the 1, 3, 5, 7 & 9 LEDs in order followed by the 2, 4, 6, 8 & 10 LEDs. Thus LEDs 1 & 2 light up, then LEDs 3 & 4, followed by LEDs 5 & 6, LEDs 7 & 8 and finally LEDs 9 & 10 before LEDs 1 & 2 light again. As a result, we get two LEDs on opposite sides of the "ring" appearing to "chase" each other.

The circuit is powered from 12V, although it will work happily from a 9V battery if you want to make it portable. Diode D1 provides reverse polarity protection in case you get the battery connections reversed. The supply rail is bypassed with a 47µF capacitor, located near IC1.

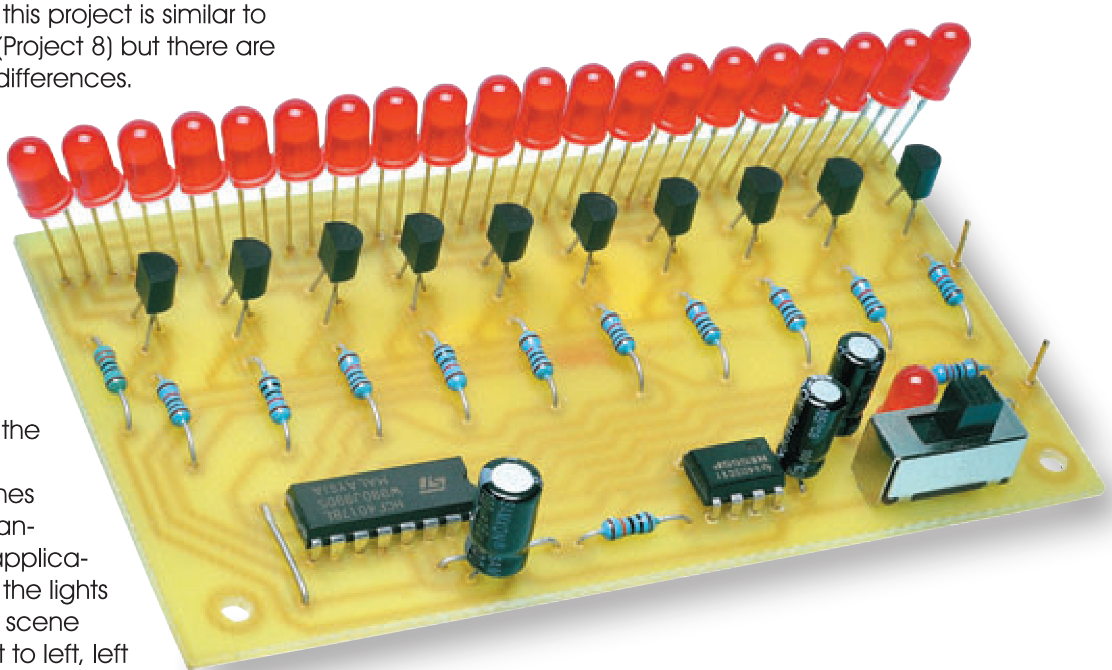
Project 9

Light Scanner Chaser

Do you like to see a row of lights chase each other? This one does even more: the row of lights chases forwards AND backwards! It's just like a scanner from a space movie!

What does it do?

In many ways this project is similar to the Light Chaser (Project 8) but there are some important differences. Instead of lights chasing each other around a ring, these ones chase each other from the middle of a string to the outsides, stop, then turn around and chase back the other way.



This is sometimes described as "scanning" – in some applications, it looks as if the lights are scanning the scene – left to right, right to left, left to right and so on . . .

Whether you build this simple scanning circuit as a novelty (it's great on toys and models!) or just to look at the neat effect, you can have a lot of fun. Or maybe you want an alarm warning light with a difference; with this circuit the thieves could even think that THEY are being scanned!

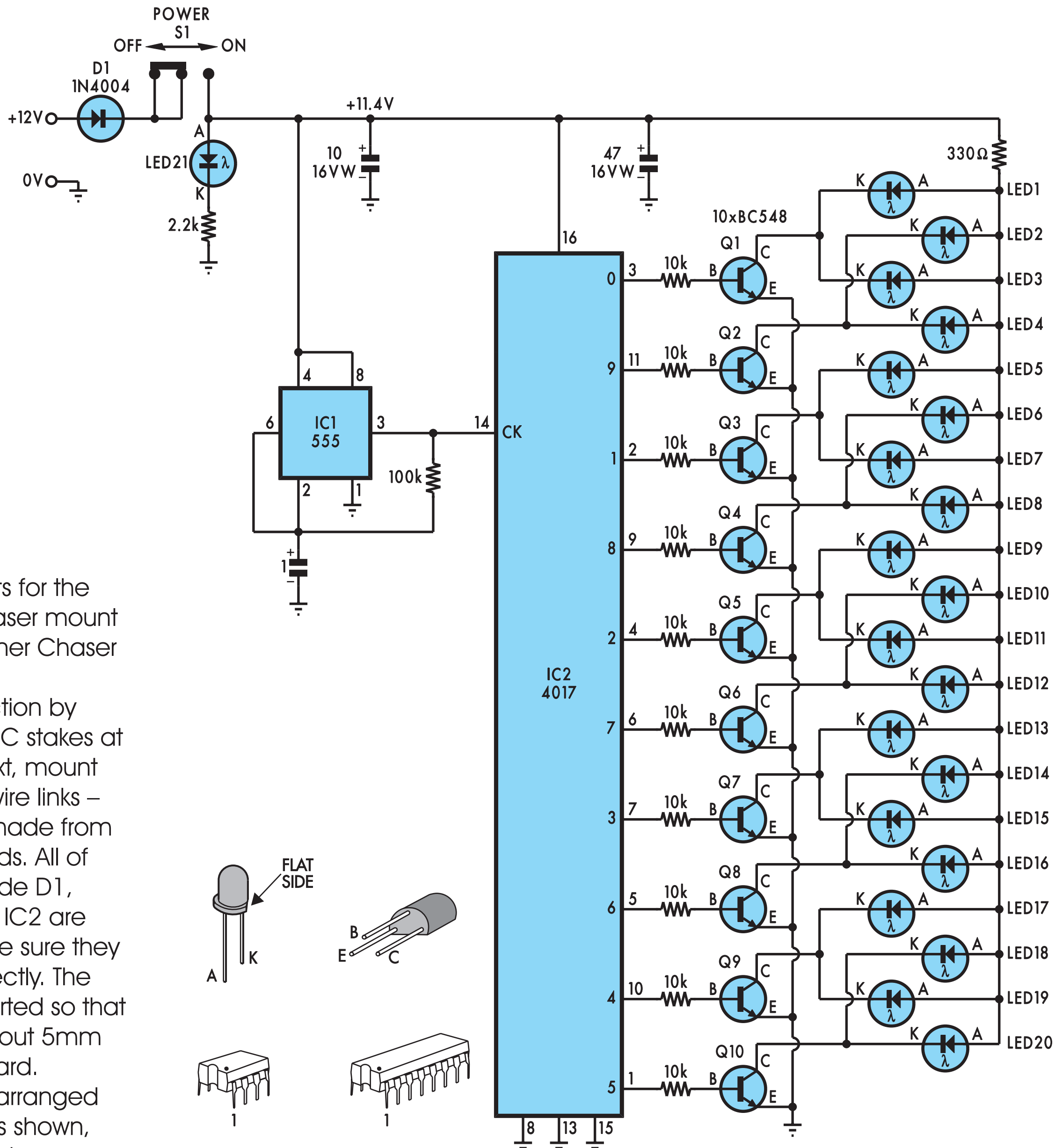
You will need these parts

Resistors (0.25W, 1%)
1 100kΩ
10 10kΩ
1 2.2kΩ
1 330Ω

Capacitors
1 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 1µF 16VW PC electrolytic

Semiconductors
1 555 timer (IC1)
1 4017 decade counter (IC2)
1 1N4004 1A diode (D1)
10 BC548 NPN transistors (Q1-Q10)
21 5mm red LEDs (LED1-LED21)

Miscellaneous
1 Light Scanner Chaser PC board
1 SPDT slider switch (S1)
2 PC stakes



Construction

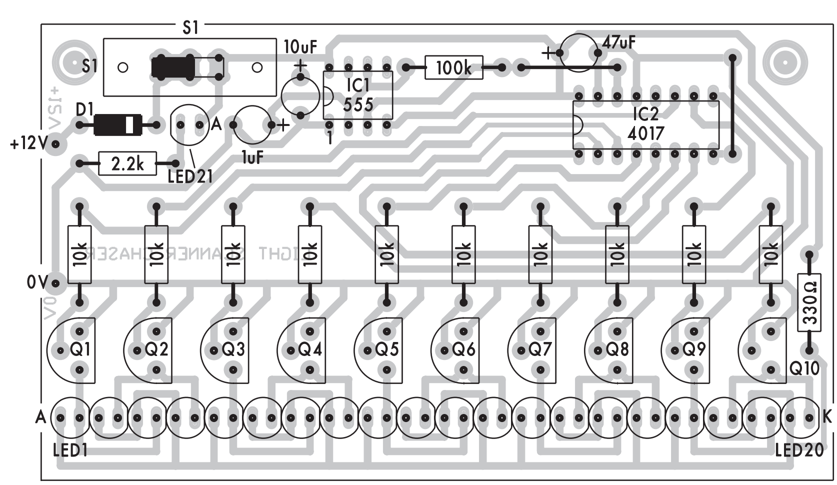
All components for the Light Scanner Chaser mount on the Light Scanner Chaser PC board.

Begin construction by inserting the two PC stakes at +12V and 0V. Next, mount the resistors and wire links – the links can be made from cut-off resistor leads. All of the transistors, diode D1, the LEDs, IC1 and IC2 are polarised, so make sure they are oriented correctly. The transistors are inserted so that they are each about 5mm above the PC board.

LEDs 1-20 are arranged in a straight line as shown, about 10-15mm above the PC board. Once again, watch the polarity: all these LEDs mount the same way so if one looks back to front, it probably is!

If you wish, they can be bent over at right angles so that they are parallel to the PC board surface. (It is best to do this before soldering them in place to avoid undue stress on the soldered joints and PC board tracks).

Because the LEDs will start flashing as soon as power is switched on, LED21 and its associated 2.2kΩ resistor could be left out. If used, LED21 is left facing upward from the PC board.



TECH TALK

Once again, the circuit for the Light Chaser Scanner comprises two inexpensive but versatile integrated circuits, a 555 timer (IC1) and a 4017 decade counter (IC2).

The oscillator, based on the 555 timer, operates the same way as in the light chaser except that the speed is about half – 9Hz. The output of IC1 (pin 3) is again fed to the clock input of IC2.

Again like the Light Chaser, IC2 is a decade counter but this time it is used to count all the way to 10. (For an explanation of the oscillator and decade counter operation, see "Tech Talk" for that project.)

So how does the 4017 count backwards to get the reverse direction pattern?

It doesn't! Like the magician and his mirrors, it's an illusion. It's all in the way the LEDs are connected – it just appears that the LEDs are scanned from left to right and right to left.

What we do is actually count from 0 to 4 with the LEDs arranged in a left to right pattern and then count from 5 to 9 with the LEDs arranged in a right to left pattern. Presto – the LEDs operate one way and then in a reverse direction!

If you look at the outputs of the 4017 we have shown them in a strange order: rather than a straight counting sequence from 0-9 we have arranged them in the sequence 0, 9, 1, 8, 2, 7, 3, 6, 4 & 5. This arrangement is the same on the printed circuit board.

So the LEDs are scanned from left to right for the 0-4 counts and from right to left with the 5-9 counts.

The connection of the LEDs is also unusual. When the "0" output is high for instance, LED1 and LED3 light up and there is a separation of LED2 between them. When the "1" output goes high, LED2 lights as well as LED4.

The circuit is powered from a 12V supply and diode D1 provides reverse polarity protection. Switch S1 applies power to the circuit and this is indicated with LED21.

Since the circuit should start flashing immediately power is applied, though, LED21 and its associated 2.2kΩ resistor could be regarded as optional.

The power supply rail is bypassed using 10µF and 47µF capacitors, located near IC1 and IC2 respectively.

Testing

The circuit can be operated from a 12V battery or plugpack. Before you connect power, though, check your soldering thoroughly, especially around the IC pins and the LEDs.

Some tracks are pretty close together and you could have a solder bridge between them.

Connect power to the PC board and check that LED21 lights (if fitted). The LEDs should light up in the sequence described above. If the LEDs do not light, they may be back to front.

To check that the circuit is oscillating, a multimeter on a 10V DC or higher range connected between pin 3 of IC1 (most easily accessed by the link next to the 100kΩ resistor) and 0V should show a continually changing reading. 9Hz is getting a bit fast for most analog multimeters but you should see the pointer "vibrating".

If it doesn't work, measure the voltage between pins 16 and 15 of IC2 – it should be around 11.5V to 12V or so, depending on the output voltage of your plugpack. If using a 12V battery, the voltage should be close to 11.4V.

If all else fails, check your soldering once again. Even though a soldered joint may look OK, it might be a "dry joint." Its a good idea to resolder any suspect joints just in case.

What to do next

You can change the speed of the scanning motion by altering the 100kΩ resistor or 1µF capacitor value.

Use a larger component value to slow the scanning motion down and a smaller value to speed it up. A 1MΩ resistor will give close to 1 pulse per second. Don't reduce the resistor value below about 10kΩ, though.

While you can make the circuit run as slowly as you like (within reason!), speeding the oscillator up has its limitations. If it's too fast the LEDs won't appear to chase each other, they'll just appear as a blur with all on at once.

If you want a brighter display you could use some of the ultra-bright LEDs now available. The major problem with these LEDs is that off-axis they're not very bright at all.

Or you could experiment with using higher rated transistors and using globes instead of LEDs (naturally, the globes would have to be connected in the same sequence as the LEDs).

Also, you'll need to ensure that the power supply you use is capable of handling the higher currents of globes (there are two on at any one time).

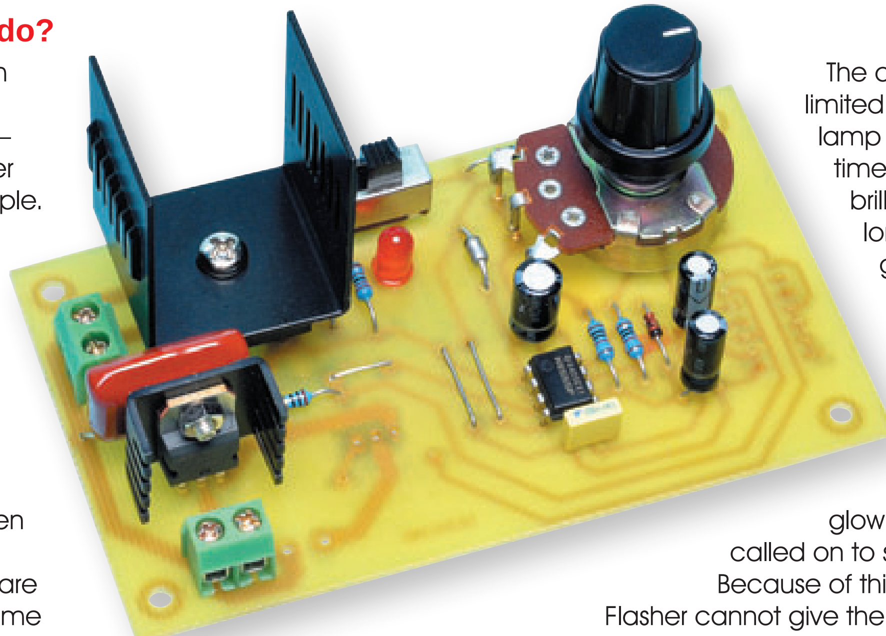
For more information, see the discussion on using lamps in the Light Chaser project (page 44).

Project 10a

A Really Bright Flasher!

A bright flashing light is a real attention getter – for emergencies, in advertising, as a party light . . . or just for fun. This one is really versatile and is easy to build.

What does it do?



It's fine to flash a small globe as a warning signal – just like our Dasher Flasher, for example. But if you really want to be noticed, you need a really bright lamp to flash. That's what this project does – flashes a low-cost but very bright 12V halogen globe.

These globes are often used for home or display lighting and are rated at either 20 or 50 watts.

The lamp flashes on and off with a fixed on time of about half a second and an off time which is variable from 0.5s to about 3.5s.

The actual flash rate is limited by the halogen lamp itself. It takes a short time to come up to full brilliance and even longer to completely go out. This is called thermal lag. If we were to flash the lamp too fast, the filament would not have time to cool and stop glowing before being called on to start glowing again.

Because of this, the Very Bright Flasher cannot give the effect of stopped or jerky movement which true "strobe lights" can. But strobe lights usually use a special flash tube which requires dangerous voltages. Our Very Bright Flasher operates from a safe 12V and even with these limitations, is a real attention-getter!

You will need these parts

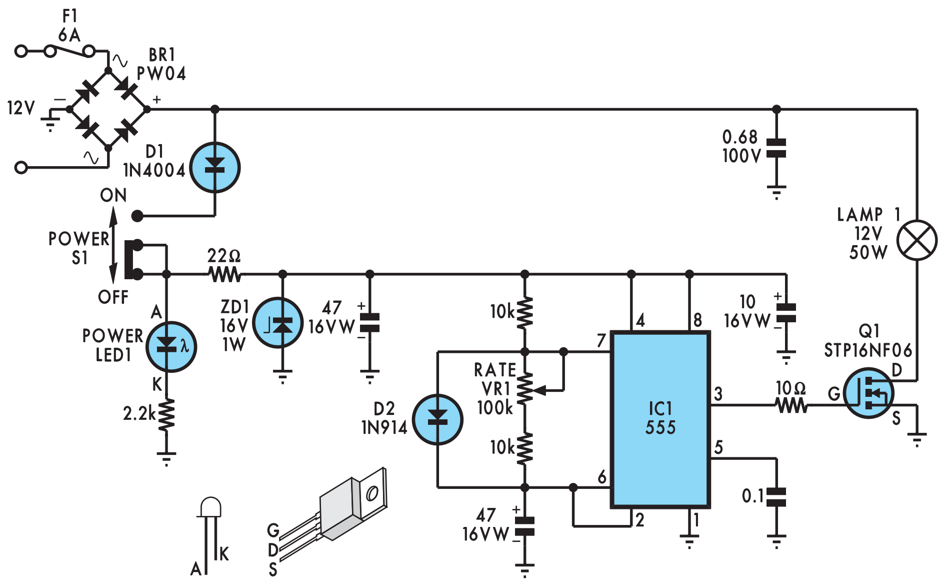
Resistors (0.25W, 1%)
2 10kΩ   1 2.2kΩ
1 22Ω   1 10Ω
1 100kΩ linear pot (VR1)

Miscellaneous
1 Very Bright Flasher PC board
2 2-way PC-mount terminal strips
1 SPDT miniature slider switch (S1)
1 12V 50W or 20W halogen lamp (Lamp1)
1 base to suit halogen lamp
1 mini heatsink, 20 x 20 x 10mm
1 mini U heatsink, 28 x 25 x 34mm
2 3mm screws and nuts
1 knob for VR1
1 3AG in-line fuseholder with 6A fuse
3 PC stakes plus tinned copper wire for links

Capacitors
2 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 0.68µF 100VDC greencap
1 0.1µF MKT polyester

Semiconductors
1 555 timer (IC1)
1 PW04 10A 400V bridge rectifier (BR1)
1 1N4004 1A diode (D1)
1 1N914, 1N4148 signal diode (D2)
1 16V 1W zener diode (ZD1)
1 STP16NF06 16A 60V MOSFET (Q1)
1 5mm red LED (LED1)

Construction



All components with the exception of the fuseholder and halogen lamp mount on the Very Bright Flasher PC board. In fact, this board can be used to construct two versions – this single lamp flasher or the next project, a two-lamp flasher.

Start with the three PC stakes which connect to VR1, followed by all the resistors and links. Use cut-off resistor leads for the links.

IC1, the four diodes (D1, D2, ZD1 and LED 1), the bridge rectifier and the three electrolytic capacitors are all polarised so follow the PC board layout carefully when placing them. S1 mounts directly onto the PC board – if the pins are difficult to insert, crimp them with pliers first.

The PC mounting terminal blocks are fitted with the wire entry points facing outwards. VR1 mounts with its terminals soldered to the top of the PC stakes (a drop of super glue under the back of the pot will secure it more firmly to the PC board). The MOSFET heatsink is simply screwed to the MOSFET so that metal touches metal (no insulation is required if the heatsink doesn't touch anything else).

Bridge rectifier BR1 requires a larger U-shaped heatsink, secured using a 3mm screw and nut before soldering the bridge into place. Make sure you have identified the terminals of the bridge before the heatsink obscures them!

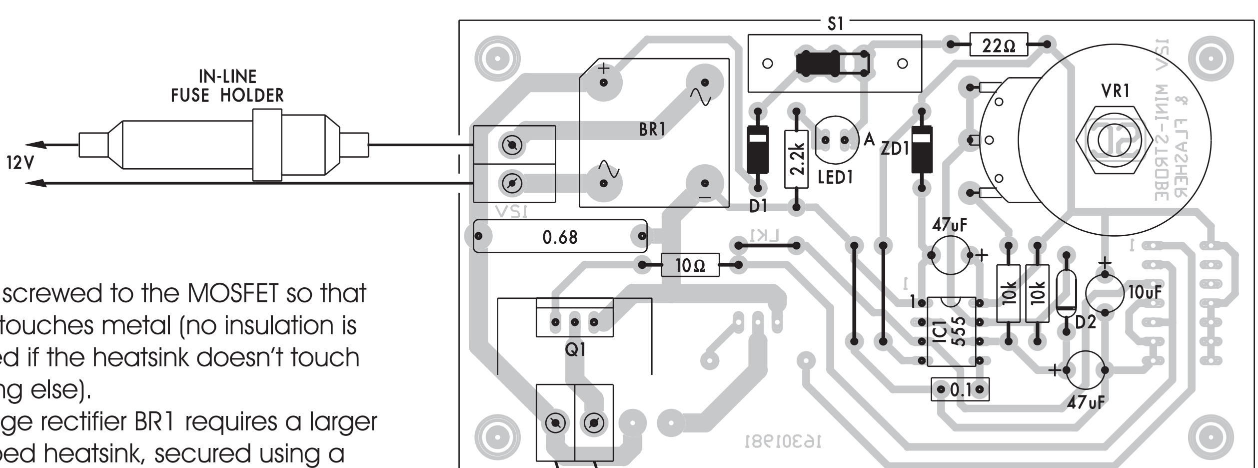
Apply a smear of heatsink compound between the top of the bridge rectifier (BR1) and the heatsink before securing in place. The bridge is inserted with the plus terminal, usually also identified by a cut-off corner, oriented towards the corner of the PC board as shown.

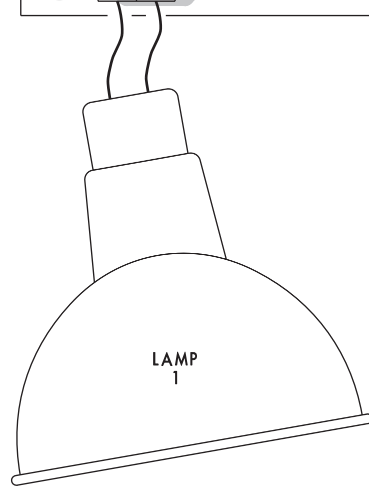
A lamp base connector is specified for this project because it is quite difficult to successfully solder wires to the lamp pins. The lamp simply pushes into the base and the wires connect to the PC board terminal block.

If you need longer lamp leads you can solder a suitable length of figure-8 cable to the base connector wires and insulate the joins with insulation tape.

Do Not Use An Electronic Transformer

This circuit can be powered from either a 12V car battery or from a conventional 12VAC transformer as used with halogen downlamps (see text). The newer electronic (switchmode) transformers are NOT suitable for use with this project, as their high switching frequency will cause the bridge rectifier and electrolytic capacitors to overheat.





TECH TALK

The circuit comprises a timer (IC1) which sets the flash rate and Mosfet (Q1) which drives the halogen lamp.

The timer is a 555 IC, connected as an astable. By now, you're probably getting pretty familiar with the way a 555 operates. This one has the familiar resistor between pin 7 and the positive supply and the capacitor between pins 6/2 and the negative supply.

Between pins 7 and 6/2, though, it's a little different. First of all, there's a variable resistor (a 100kΩ potentiometer) which varies the frequency of oscillation. The 10kΩ resistor ensures there is always some resistance in circuit.

Second, there's a diode connected right across the pot and resistor. This makes the capacitor charge time fixed, independent of the setting of VR1. The discharge time is variable, as set by VR1. Because the charge time is fixed, the output "high" is also fixed. This sets the lamp "on" time.

The pin 3 output of IC1 drives Mosfet Q1 via a 10Ω resistor. You can think of a Mosfet as a switch: with the gate high, it turns on (turning on the lamp). With the gate low, it turns off.

The advantage of using a Mosfet instead of a bipolar transistor is that its transition from off to on and off again is very rapid, which means that it doesn't have to dissipate a lot of heat. It also has a very low "on" resistance, thus saving dissipation problems. Even so, it requires a small heatsink for reliability.

The power supply for this circuit is also a little different because it can work from DC or AC. A DC supply can be connected either way around because the bridge rectifier (BR1) ensures that the polarity becomes correct.

Using a bridge rectifier like this is a handy trick to keep in mind if there is ever a danger of reverse connection. A single diode provides reverse polarity protection but stops the circuit working. A bridge rectifier provides reverse polarity connection AND the circuit keeps working. The only major drawback is that 0.6 volts is lost across each diode so the circuit needs to be happy working from a slightly reduced voltage.

The supply can be either 12VDC from a battery or 12VAC from a conventional halogen lamp transformer. Because the lamp draws over 4A, the battery or supply must be capable of high current output. The 12V Regulated Supply (Project 28) is *NOT* suitable, nor can you use an electronic (switchmode) transformer.

BR1 rectifies the output if an AC supply is used while D1 isolates the lamp supply from the supply to IC1. LED1 indicates when power is on.

The supply to the IC is protected against transients above 16V by the 22Ω series resistor and zener diode ZD1. The 47µF and 10µF capacitors decouple the supply, while the 0.68µF capacitor between the lamp supply and ground minimises voltage fluctuations when Mosfet Q1 turns off.

Power supply

The supply needs to be capable of delivering over 2A with a 20W lamp and 4A with a 50W lamp. A car battery is suitable or, for AC operation, use a conventional halogen lamp transformer such as the Jaycar MP-3044. **This transformer includes a wired-in mains lead and plug, making it safe from the mains voltage. If you use a different transformer, make sure that it's supplied with the mains lead and plug already fitted.**

Do not use a switchmode transformer and note also that the transformer used in our Regulated 12V Supply is definitely not suitable for this project.

Checking it out

Connect the lamp and wired base connector to the output terminals and apply power. If the lamp fails to flash, check the board for faults, including shorts between tracks and breaks. Also check that all the components are in their correct place and oriented as shown.

The supply to IC1 (between pins 8 and 1) should be around 11V, or about 1.2V less than the supply to the lamp.

A multimeter connected between the gate and source of the MOSFET (careful you don't short out the pins!) should show a continually changing voltage, depending on where you have VR1 set. If the lamp doesn't flash, either the MOSFET must be faulty or the lamp has blown.

Want coloured globes? There are several options available. If you are using 20W halogen lamps with an integral glass cover, you can cover them with Cellophane. **Don't try this with 50W lamps, though; they get too hot and could start a fire.** Coloured 50W halogen globes are available from Jaycar or you can buy transparent glass paint in many colours which isn't troubled by heat at craft or art shops.

If you want to change the flash rate from the available range with VR1, change the 47µF capacitor to a smaller value for faster rates and a larger value for slower flashes. Remember, though, if you make it too fast, the lamp will not have time to go out between flashes and will simply vary in brightness.

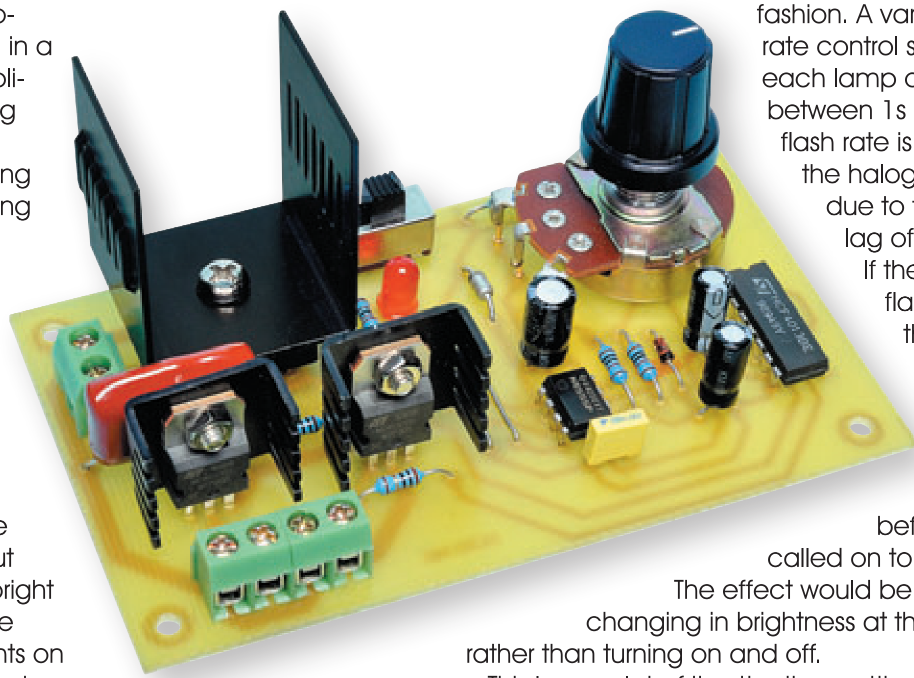
Project 10b

Two-Lamp Flasher

One flashing lamp is a great attention getter – but two lamps flashing alternately is even better!

What does it do?

You've seen two-lamp flashers used in a wide variety of applications – everything from school bus flashers to advertising signs to level crossing warnings. Whether you have a warning application or just want to liven up a party with flashing lights, this project is the one to build.



It is similar to the previous project but features two very bright halogen lamps. The circuit turns two lights on and off in an alternate fashion. A variable flash rate control switches each lamp on from between 1s and 4s. The flash rate is limited by the halogen lamp itself due to the thermal lag of its filament. If the lamp was flashed too fast the filament would not have time to cool and cease glowing before being called on to glow again. The effect would be a lamp changing in brightness at the flash rate rather than turning on and off. This loses a lot of its attention-getting impact.

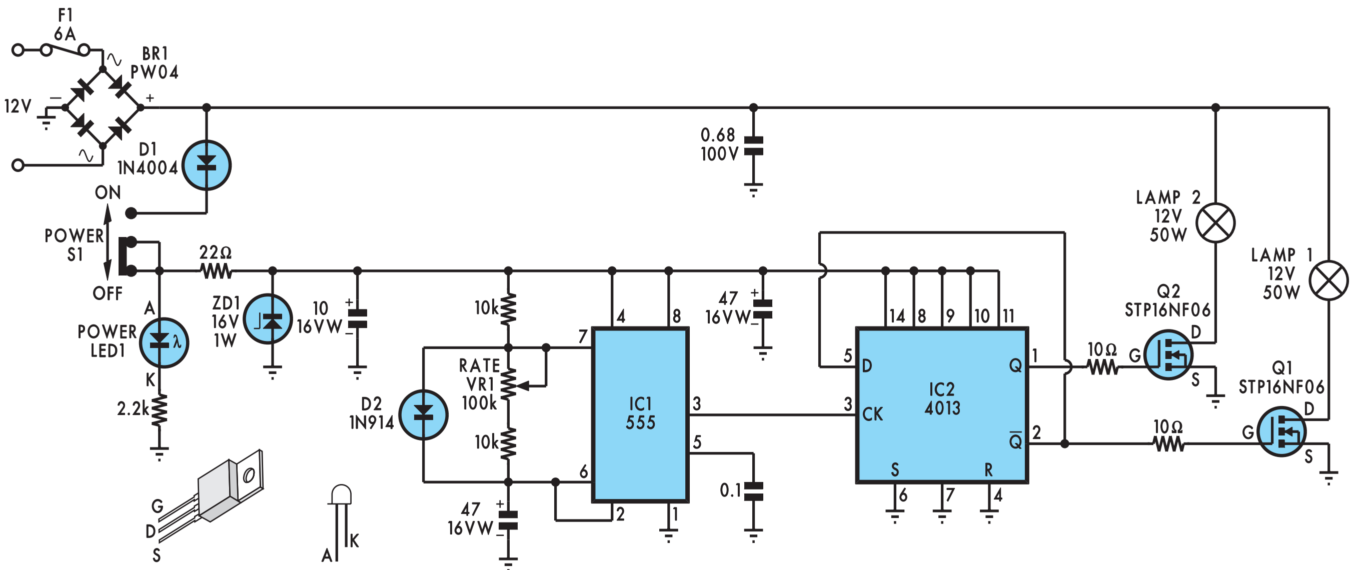
You will need these parts

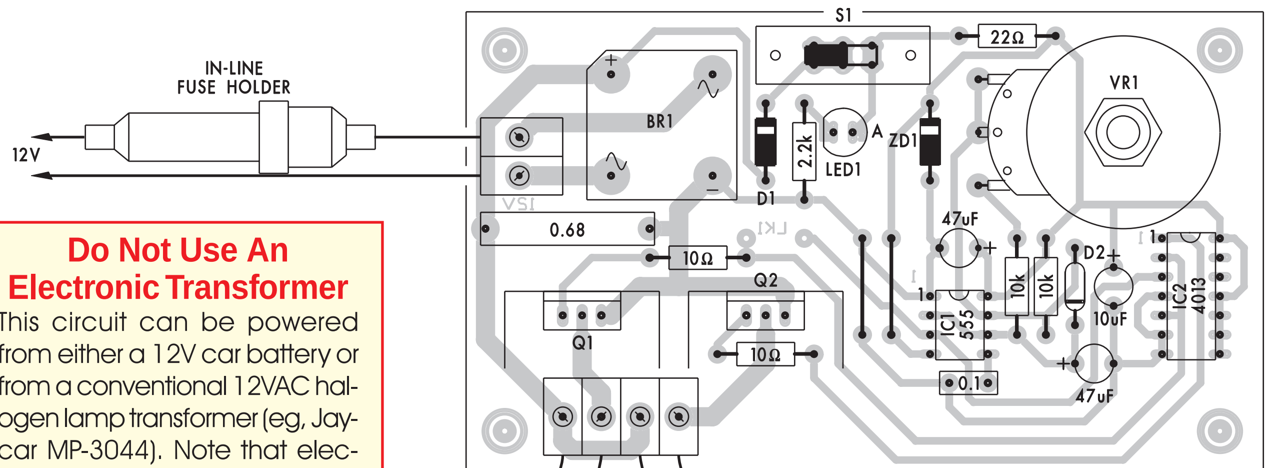
Resistors (0.25W, 1%)
2 10kΩ 1 2.2kΩ
1 22Ω 2 10Ω
1 100kΩ linear pot. (VR1)

Miscellaneous
1 Very Bright Flasher PC board
1 2-way PC-mount terminal strip
1 4-way PC-mount terminal strip
1 SPDT miniature slider switch (S1)
2 12V 50W or 20W halogen lamps with base connectors (Lamp1 & Lamp 2)
2 mini heatsinks, 20 x 20 x 10mm
1 mini U heatsink, 28 x 25 x 34mm
3 3mm screws and nuts
1 knob for VR1
1 3AG in-line fuseholder with 6A fuse
3 PC stakes

Capacitors
2 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 0.68µF 100VDC greencap
1 0.1µF MKT polyester

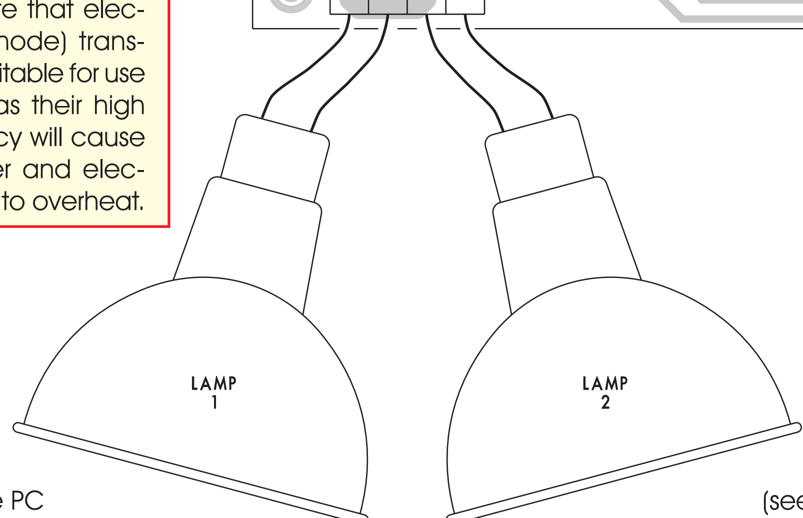
Semiconductors
1 555 timer (IC1)
1 4013 dual D-flipflop (IC2)
1 PW04 10A 400V bridge rectifier (BR1)
1 1N4004 1A diode (D1)
1 1N914, 1N4148 signal diode (D2)
1 16V 1W zener diode (ZD1)
2 STP16NF06 16A 60V Mosfets (Q1, Q2)
1 5mm red LED (LED1)





Do Not Use An Electronic Transformer

This circuit can be powered from either a 12V car battery or from a conventional 12VAC halogen lamp transformer (eg, Jaycar MP-3044). Note that electronic (ie, switchmode) transformers are NOT suitable for use with this project, as their high switching frequency will cause the bridge rectifier and electrolytic capacitors to overheat.



Construction

All components apart from the in-line fuse and two halogen lamps mount on the PC board, the same one as used in the single lamp flasher.

The only differences are the inclusion of the 4013 flipflop IC and the additional MOSFET/resistor to drive the second lamp, another terminal block to connect the second lamp and the removal of a link.

Follow the same order of assembly as for the single lamp flasher.

Testing

Follow the same setup and testing procedure as for the single lamp version (see page 52). Even though this circuit has two lamps, the power supply requirements are much the same because only one lamp is on at any time.

If you want a single flashing light with the same on and off times (also known as a 50% duty cycle), you can build this version of the flasher circuit but only install one Mosfet and one lamp. The speed will still be variable.

TECH TALK

Most of the circuit for the Two Lamp Flasher will look quite familiar as it's based on the Single Lamp Flasher described in Project 10a.

In fact, the only difference – apart from the obvious addition of a second lamp and Mosfet – is the inclusion of a 4013 dual-D flipflop (IC2).

This flipflop has two outputs, called Q and Q-bar. If Q is high, Q-bar will be low and if Q is low, Q-bar will be high. In other words, the Q-bar output is always the complement (or opposite) of the Q output.

Because one output is the inverse of the other, at all times (while ever power is applied, of course) one of these outputs must be high and the other low.

In our case, the flipflop is connected so that each clock pulse from the 555 timer flips the high output from one to the other, while the next clock pulse flops it back again.

That's how the flipflop got its name – flip, flop, flip, flop . . .

The connection between the Q-bar output (pin 2) and the data input (pin 5) ensures that the outputs are changed on the positive-going edge of the clock pulse.

The Q and Q-bar outputs drive power MOSFETS Q1 and Q2 via 10Ω resistors. When the Q-bar output is high, Q1 turns on, turning on lamp 1, a high brightness halogen bulb. At the next pulse, the Q-bar output goes low, turning Q1 and its lamp off, while the Q output goes high, turning on Q2 and its lamp. This will continue as long as power is applied.

The speed at which the lamps flash can be adjusted by VR1, which controls the clock speed, or rate of oscillation, of the 555 timer.

The power supply requirements are the same as for the single lamp flasher (see page 52). The circuit can be operated from either a 12V battery or, because of the bridge rectifier (BR1), a conventional 12VAC halogen lamp transformer **(be sure get one with a wired-in mains cord and plug).** Do NOT use an electronic transformer.

Remember that if 50W lamps are used, the current drawn from the supply is over 4A at all times. That's a lot of current!

Know Your Capacitors

There are five types of capacitor you'll commonly meet in electronics. Most of the differences between them are due to their ***dielectric*** (the insulation between the capacitor's two plates).

One very common type is the ***metallised polyester***, either dipped in green-coloured plastic to become a 'greencap' (they can also come in brown and red) or potted in a small rectangular box of yellowish plastic to become an 'MKT' capacitor. They typically range from about 1000pF (.001µF, or 1nF) to 0.47µF.

Another type is the ***multilayer monolithic ceramic***, with very thin layers of ceramic material (like porcelain) used as the dielectric, between thin layers of metal film. Called just 'monolithics' for short, this type is common in digital circuits. Values range from about .01µF (10nF) to 0.22µF.

For use at high frequencies and with values from 1pF to 1000pF, the ***ceramic disc*** type is usually best. These have metal electrodes on either side of a small ceramic disc. As the electrical behaviour of the ceramic tends to vary with temperature, they're available with different types of ***temperature coefficient***. The 'NP0' type varies least with temperature.

Last are ***electrolytic*** capacitors, often called 'electros' for short. These use a very thin layer of insulating metal oxide as the dielectric but a small quantity of conducting liquid is used inside to make electrical contact with the surface of the oxide. Electros are made in high values (from about 0.1µF up to 10,000µF or more).

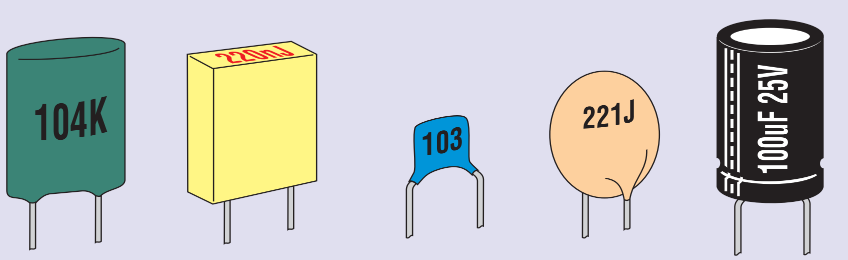
Capacitors generally have their value printed directly on them but it can be a bit tricky to work out their value, because a coding system is often used. One code is similar to the resistor code, with two value digits followed by a third digit giving the multiplier or 'number of zeros'. So '104' decodes as 10 and four zeros, or 100,000. '221' means a value of 220. When this coding system is used, you can almost always assume that the value is being given in ***picofarads*** — so '104' means 100,000pF or 0.1µF, '103' means 10,000pF (or 0.01µF) and '221' means 220pF.

Another code uses three digits followed by an 'n', and it's all in ***nanofarads*** rather than picofarads. So '220n' means 220nF (or 0.22µF).

Low-value ceramic capacitors generally have their full value given in picofarads, like '15' (for 15pF) or '47' (for 47pF), and might even have a decimal point – such as '5.6' (for 5.6pF).

Electrolytics generally have their full value and voltage rating on their case. Because they're polarised they also have a band to indicate the negative or positive electrode lead.

Other letters on the capacitor's body may be codes for the tolerance. K means ±10%, J means ±5%, G means ±2% and E means ±1%.



GREENCAP MKT MONOLITHIC CERAMIC ELECTROLYTIC

Project 11

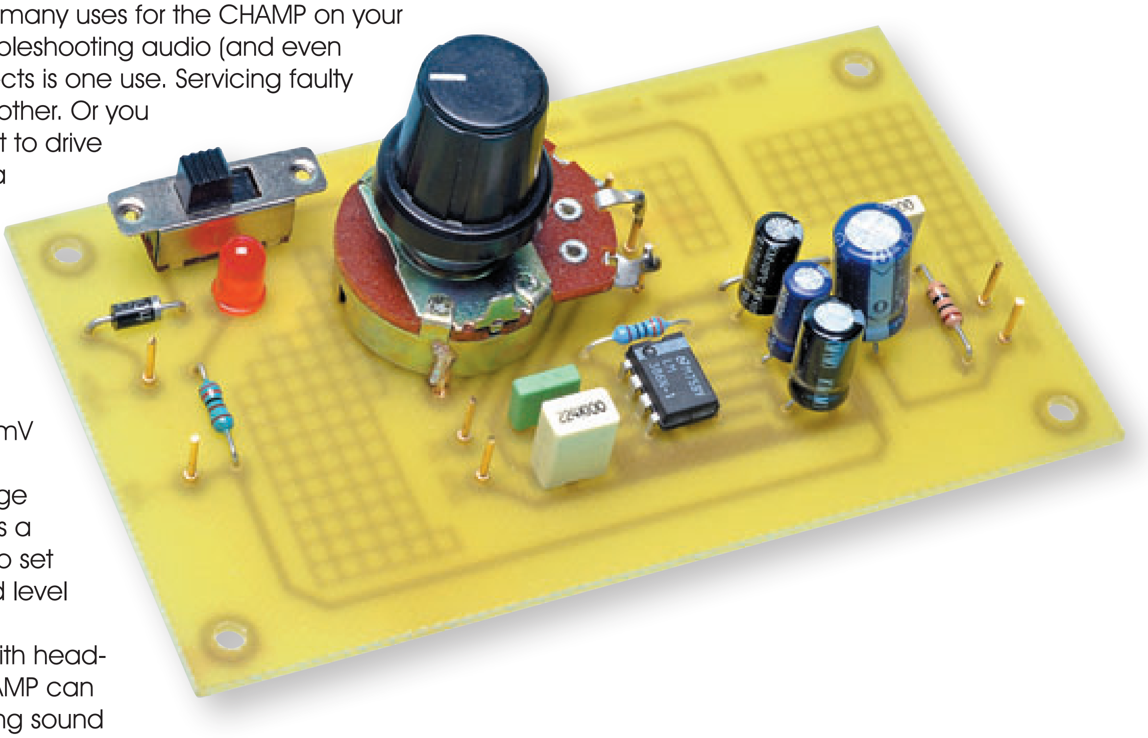
The CHAMP

If you're into electronics, sooner or later you'll need a small amplifier for testing, development or just for listening. This project really is a CHAMP – a Cheap, Handy AMPlifier. In fact, this is one project every electronics enthusiast should build.

What does it do?

The CHAMP has only one use – to amplify low level audio signals to a level where they can drive a speaker or set of headphones.

Yet you'll find many uses for the CHAMP on your workbench! Troubleshooting audio (and even non-audio) projects is one use. Servicing faulty equipment is another. Or you could even use it to drive a speaker from a personal cassette, radio or CD player.



The CHAMP can be used with virtually any signal source ranging from 50mV up to one or two volts. That's a huge range! It includes a volume control to set the output sound level to your liking.

When used with headphones, the CHAMP can give ear-shattering sound without disturbing anyone around you. With a speaker connected it will provide sufficient output for personal listening.

You will need these parts

Resistors (0.25W, 1%)
1 2.2kΩ 1 330Ω 1 10Ω

Miscellaneous
1 Champ Audio Amplifier PC board
1 SPDT slide switch (S1)
1 10kΩ log pot. (VR1)
1 knob
9 PC stakes
1 8Ω speaker or headphones
1 length shielded audio cable (input)
1 length mini figure-8 cable (output)

Semiconductors
1 LM386N-1 single chip amplifier (IC1)
1 1N4004 1A diode (D1)
1 5mm LED (LED1)

Capacitors
1 470µF 16VW PC electrolytic
2 47µF 16VW PC electrolytic
1 22µF 16VW PC electrolytic
1 0.22µF MKT polyester
1 0.1µF MKT polyester
1 .047µF MKT polyester

Construction

All components for the CHAMP, including the volume control, are mounted on the CHAMP PC board.

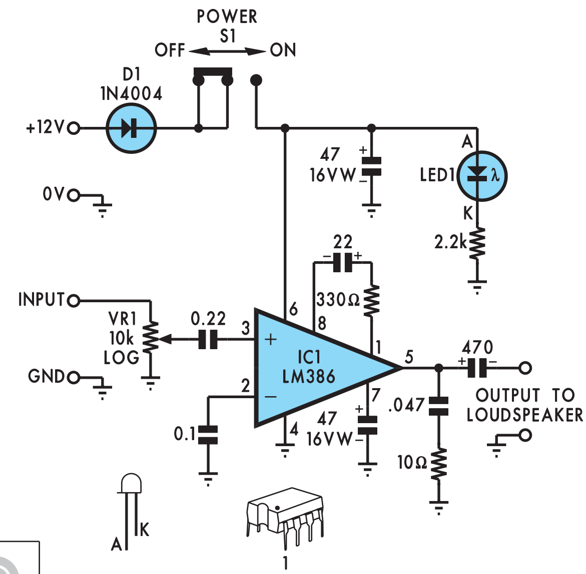
Begin construction by installing the PC stakes. There are nine of these including the three which connect to the volume control potentiometer. The resistors and the wire link can be inserted next, with the wire link made from a cut-off resistor lead.

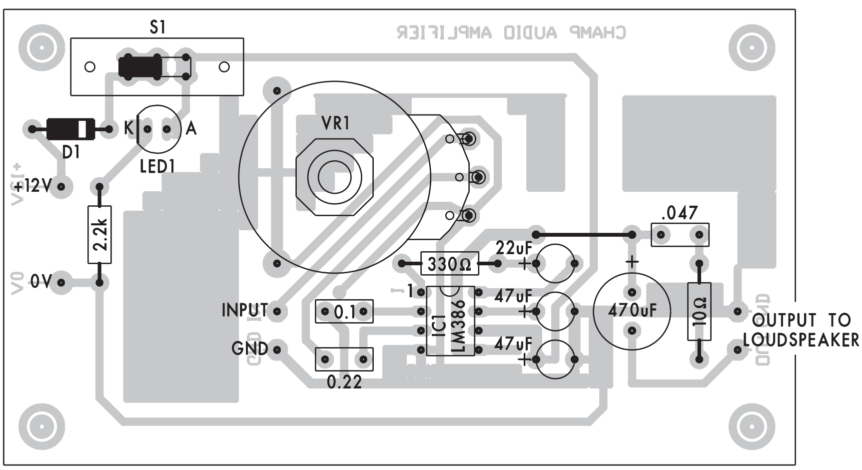
Install the capacitors, taking care with the electrolytic capacitors which must be inserted with the correct polarity.

Insert semiconductors IC1 and D1, noting the orientation of both from the component overlay (the notch on the IC is closest to VR1).

Speaking of VR1, it mounts with its terminals soldered to the allocated PC stakes. A dab of contact adhesive under the potentiometer body will secure it to the PC board so it does not rely on the PC stakes for rigidity.

Switch S1 mounts with its terminals inserted through the allocated holes. If they're a tight fit, crimp or squeeze the terminals slightly. LED1 mounts about 10-15mm above the PC board; again ensure that the polarity is correct before soldering.





TECH TALK

The amplifier is based on a National Semiconductor LM386 amplifier IC. Indeed, there are very few extra components; just about everything is taken care of by the IC.

Signal is directly coupled to volume control VR1 while output from the pot wiper is AC-coupled via a 0.22µF capacitor to the non-inverting input of IC1 at pin 3. AC coupling achieves two results. First, it prevents any DC at the input flowing through the pot (DC in pots often causes "scratchiness" or noise when they are rotated). Second, AC coupling minimises any offset at the output of the amplifier which would reduce the usable peak-to-peak voltage and therefore the power output.

The input impedance of the LM386 is 50kΩ so the 0.22µF capacitor rolls off signals below 15Hz. The 0.1µF capacitor at pin 2 grounds this inverting input to AC signals.

The gain is 60, as set by the 330Ω resistor between pins 1 and 8. The 22µF capacitor in series prevents any DC flow between the pins which could hinder amplifier operation.

The amplifier is internally biased so that the output at pin 5 sits at half the supply voltage. This allows maximum output swing and therefore maximum power output. A 470µF DC blocking capacitor couples the output signal to the loudspeaker or headphone load.

Some amplifiers are prone to high frequency oscillation, especially when connected to long speaker lines. To help prevent this, a .047µF capacitor in series with a 10Ω resistor (known as a Zobel network) is connected between the output and earth.

Power supply ripple rejection is vastly improved by including the 47µF capacitor between pin 7 and ground. Another 47µF capacitor is used to decouple the supply rail to pin 6.

The best source of power for the circuit would be our regulated 12V supply (Project 28) . A 12V battery or plugpack will also work. In fact, the circuit will operate, with reduced output, down to about 4-5V.

Accidental reverse-polarity connection is prevented by diode D1. Switch S1 lets you turn the CHAMP on and off and LED1 indicates when power is on.

Testing

Apply power and check that the LED lights. Now measure the voltage between a GND PC stake and pin 6 of IC1. It should be about 11.4V. The pin 5 output voltage should measure half this supply at +5.7V.

If all seems OK, there's a highly technical check often used in electronics called the "blurt" test. You connect a speaker to the output, turn the amplifier on with the volume control at say half-way, and apply your finger to the input terminal. All being well, you'll hear a healthy "blurt" from the speaker! (It is just the hum and noise being picked up by your body).

Final testing can be done with a signal connected to the input (don't forget to turn the amplifier off before connecting the signal!).

To minimise noise pickup, use screened cable for the connection from the signal source to the amplifier. The inner conductor connects to the signal input terminal and the screen, or braid, connects to the ground terminal.

When soldering to the braid, it's important to apply heat only long enough to make a connection and NOT to melt the inner insulation. Once soldered, check the resistance between the input and ground terminals on the board. It should be somewhere near 10kΩ. If it's close to zero, you've shorted the inner conductor to the braid. The only way around this is to cut a short length off and re-solder it more carefully!

To connect a loudspeaker or headphones to the output, ordinary "figure 8" cable or two individual wires are fine. Virtually any 8Ω or 16Ω loudspeaker will work fine with The CHAMP.

Switch the amplifier on and adjust the volume control to give the level required.

What to do next

If you find the output from a small speaker is insufficient for your needs, try connecting a larger speaker. Contrary to what you might think, larger speakers usually don't need more power to drive them. They are usually more efficient at converting electrical energy into sound and therefore most large speakers will sound louder than most small speakers when driven from the same amplifier.

There is nothing to stop you connecting a hifi speaker box to this amplifier, as long as it is rated at 8Ω or more (most are). Remember, though, a 16Ω speaker will not give as much sound output as an equivalent 8Ω speaker.

Do you want to use the CHAMP to listen to your personal portable stereo cassette, radio or CD player on a pair of speakers instead of its headphones? Just build another CHAMP and test it as outlined above.

The portable stereo almost always has a 3.5mm stereo output jack. Looking at the matching 3.5mm stereo plug, you'll see it has three connections. One goes to the tip of the plug, one to the body and the third to the ring between the tip and the body (you can check these with your multimeter).

Connect one CHAMP input to the tip connection with its earth (that's the braided part of the cable) to the body connection; the other CHAMP has its input connected to the ring connection and the earth also to the body connection.

First make sure you have output from your portable stereo (check with your headphones) and then, without changing any settings, swap the headphone plug for the CHAMP input plug. Power up both CHAMPS and you should hear sound from both speakers.

Preferred Resistor Values – The "E" Series

It is very difficult to make any component to an exact value. Fortunately, in the vast majority of cases, it doesn't matter – near enough really is good enough.

Resistors, especially, are unlikely to be the exact value indicated by their colour codes – instead, they are made to a "tolerance" or percentage range within which they are guaranteed to fall. They are sorted into an "E" series according to their tolerance. For example, in the E6, or 20% tolerance series, there are six values between 1 and 9 (or between 10 and 99, 100 and 999, and so on). These values are shown in the accompanying table.

A 100Ω 5% resistor (E24 series) may have a value anywhere from 95Ω (100Ω - 5%) to 105Ω (100Ω + 5%). The next resistor value up, 110Ω, may be anywhere from 104.5Ω to 115.5Ω. As you can see, the ranges overlap.

These days, resistors are mostly made to 2% or even 1% tolerance (E96 series). In most cases, the values now sold belong to the E96 series.

Preferred Resistor Values (in each decade)

E6 Series (20% Tolerance)	E12 Series (10% Tolerance)	E24 Series (5% Tolerance)
10	10	10
		11
	12	12
		13
15	15	15
		16
	18	18
		20
22	22	22
		24
	27	27
		30
33	33	33
		36
	39	39
		43
47	47	47
		51
	56	56
		62
68	68	68
		75
	82	82
		91

Project 12

Universal Preamplifier

If your amplifier doesn't have the oomph! you think it should, maybe it's not being driven hard enough. That's when a preamplifier comes in handy. This little beauty is ready for just about any application you can think of.

What does it do?

This preamplifier increases the output level of a signal source so that it can drive another device, such as an amplifier, to full output. With a number of variations possible by changing components on the PC board, it can accept most types of signal sources in common use and even some not-so-common, such as the magnetic cartridge from a record player.

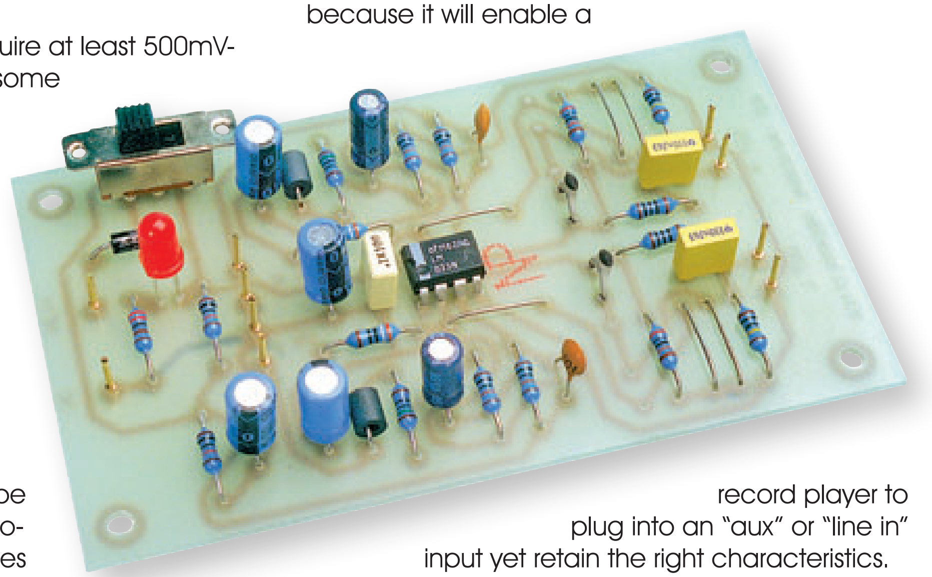
Most modern amplifiers require at least 500mV-1000mV or so to drive them – some much more. Most microphones, electric guitars and record players deliver much less than this – so a preamplifier is required.

This is a stereo preamplifier, based on a dual low-noise op amp. Performance can be very good – at least as good as many commercial preamplifiers.

The requirements of a preamplifier depend on the type of source. For example, a microphone or guitar normally requires a "flat" frequency response but a magnetic cartridge needs a preamp which boosts the signal at low frequencies. Above all, though, the preamplifier should have low noise and low distortion.

Since the advent of compact discs, vinyl records have all but disappeared. Because of this, very few hifi systems these days have a magnetic cartridge preamp (a magnetic cartridge was/is by far the most common type of high performance cartridge used to play records). However, there are countless millions of vinyl records in private collections.

This preamp is a viable way to provide the link between the record player and the hifi system, because it will enable a record player to plug into an "aux" or "line in" input yet retain the right characteristics.



The "RIAA" and "IEC" equalisation needed by a magnetic cartridge preamp are standards originally set by the Record Industry Association of America and the International Electrotechnical Commission. These standards help the preamp to compensate for the characteristics of the magnetic cartridge.

You will need these parts

Note: this parts list contains all the components necessary to build any one of the three versions of the preamp.

Resistors (0.25W, 1%)
- 2 1MΩ
- 4 100kΩ
- 2 10kΩ
- 1 2.2kΩ
- 2 200Ω
- 2 100Ω
- 2 200kΩ
- 2 16kΩ
- 2 3.6kΩ
- 2 390Ω
- 2 150Ω

Capacitors
- 3 100µF 16VW PC electrolytic
- 3 47µF 16VW PC electrolytic
- 2 0.33µF MKT polyester
- 1 0.1µF MKT polyester
- 2 .015µF MKT polyester
- 2 .0047µF MKT polyester
- 2 100pF ceramic
- 2 22pF ceramic

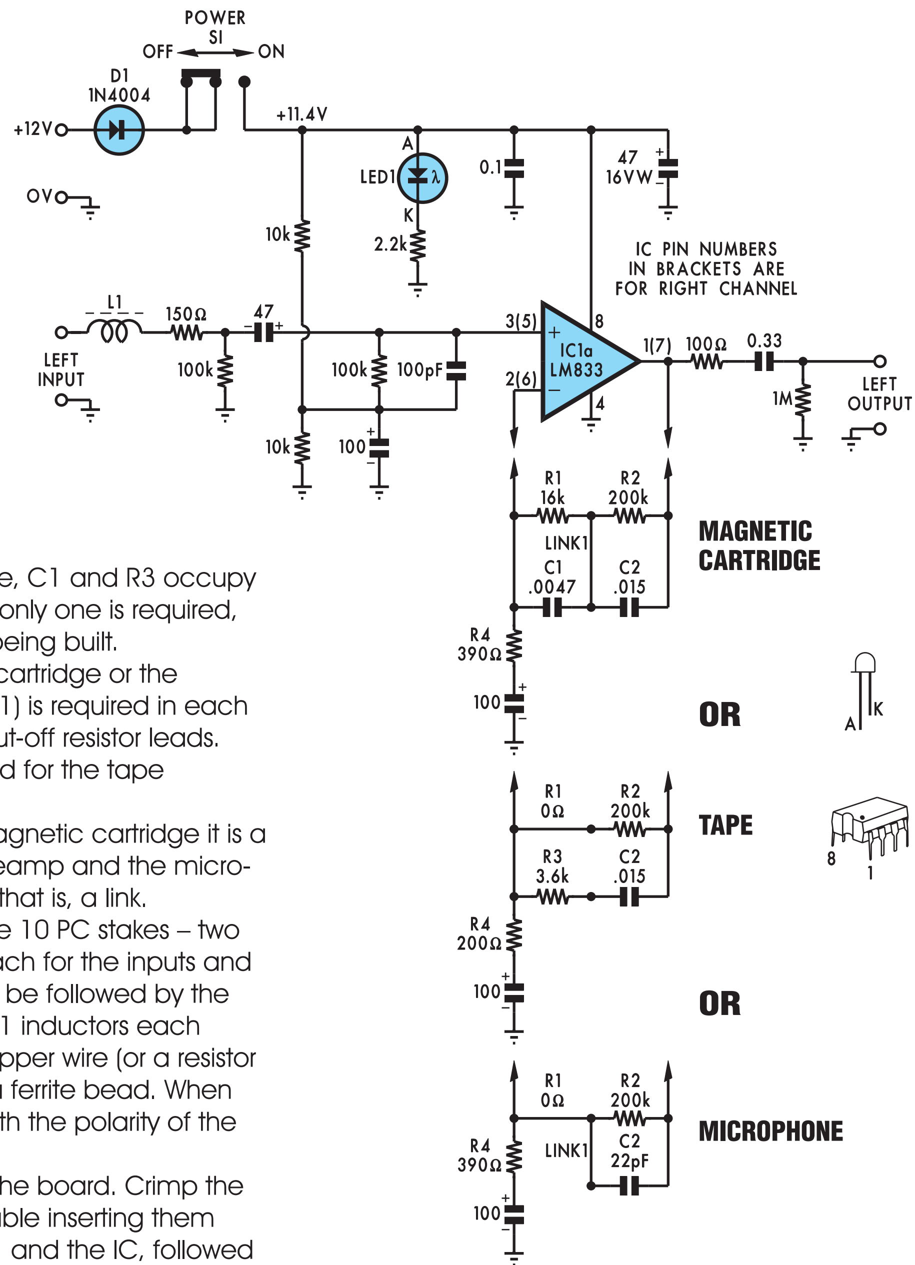
Semiconductors
- 1 LM833 dual op amp (IC1)
- 1 1N4004 1A diode (D1)
- 1 5mm LED (LED1)

Miscellaneous
- 1 Universal Preamplifier PC board
- 1 SPDT slider switch (S1)
- 2 5mm long ferrite suppression beads (L1)
- 10 PC stakes

Construction

All the components for the Universal Preamplifier are mounted onto a PC board.

Note that only one version of the amplifier can be built at one time and the feedback components – C1, C2, R1, R2, R3 & R4 – will need to be chosen as indicated on the circuit diagram. Because it is a "universal" preamplifier, the PC board pattern can accommodate various components in various positions. Be very careful when selecting which components go in which places for which version. For example, C1 and R3 occupy the same position on the PC board; only one is required, depending on the type of preamp being built.



If you are building the magnetic cartridge or the microphone preamplifier, a link (LINK1) is required in each channel. Links can be made from cut-off resistor leads. It is essential that LINK1 is NOT installed for the tape preamplifier.

Take special note of R1: in the magnetic cartridge it is a 16kΩ resistor but in both the tape preamp and the microphone preamp R1 is shown as 0Ω – that is, a link.

Begin construction by installing the 10 PC stakes – two for power (+12V and 0V) and two each for the inputs and outputs of each channel. These can be followed by the resistors and links as necessary. The L1 inductors each consist of a short length of tinned copper wire (or a resistor lead cut-off) passing once through a ferrite bead. When installing the capacitors take care with the polarity of the electrolytic types.

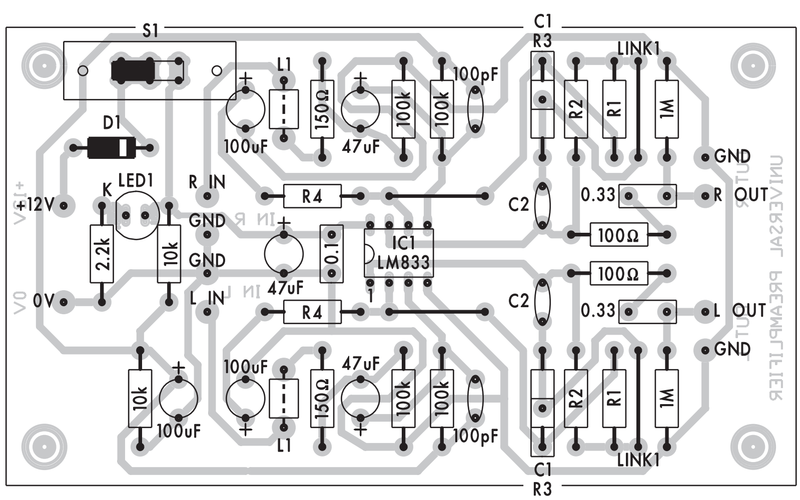
Switch S1 is mounted directly on the board. Crimp the switch pins with pliers if you have trouble inserting them into the holes. Finally, install diode D1 and the IC, followed by LED1 which sits about 15-20mm above the PC board. Again, make sure all semiconductors are oriented correctly. It does matter!

Testing

After checking your component placement and soldering carefully, connect a 12V battery or supply and check that the LED lights when S1 is turned on.

You should also be able to measure about 11.4V between pins 8 and 4 of IC1. The voltage between pin 1 (or 7) and pin 4 of IC1 should be about half supply at +5.7V.

If the voltages check out, you're ready to connect it to your signal source and to your amplifier.



What to do next

Because of the low signal levels involved and the amount of amplification, there is a very real chance that hum will be picked up and amplified.

To prevent this, or at least minimise its effects, it is always advisable to use screened cable when connecting either a signal source to the preamp or the preamp to an amplifier.

Screened cable has an inner conductor surrounded by insulation, surrounded by a braid (normally of copper wire or tinned copper wire), surrounded by outer insulation.

The outer insulation is stripped back to expose the braid and the braid cut back a little to expose the inner insulation. The inner insulation is then removed to expose the inner conductor and allow soldering.

In all cases, the inner conductor is soldered to the input or output PC stakes while the braid is soldered to the earth or ground ("GND") stakes. If your signal source or amplifier input has sockets (often "RCA" types are used) you will need to solder suitable plugs onto the screened cable to connect to them.

Best results – that is, minimum hum and noise pickup – will be achieved if you also mount the preamplifier in a grounded metal case (to ground it, use a single wire to connect the metal case to the ground track on the PC board).

If you wish to build a microphone preamplifier with different gain, simply change the ratio of the resistors in the feedback network. For example, substituting a 100kΩ resistor in place of the 200kΩ resistor will decrease the gain by half (to 257). Reducing it to 47kΩ will make the gain 121 times; 39kΩ will make it 101 times, and so on.

There are not many applications where more gain would be required but the theory is the same.

However, too high a gain could make the preamplifier unstable. This could cause damage to an amplifier.

TECH TALK

For simplicity, only the left side of the preamplifier is shown in the circuit diagram – the right side is identical except for the pin numbering of IC1 (right side numbering is in brackets).

We have also shown three preamplifier versions – one for a magnetic cartridge, one for a tape head and the other for a dynamic-type microphone. In fact, most of the circuit is identical for all three; only the feedback components around IC1 are changed for the various versions.

If you want a preamp for other devices, the microphone preamp can be used, with an adjustment to the preamplifier gain if required.

The input passes through a small inductor (L1), a 150Ω resistor and a 47µF capacitor to the non-inverting input at pin 3 of IC1. The inductor, resistor and 100pF shunt capacitor form a filter to remove RF interference signals which may be picked up by the input leads.

Op amp IC1a is biased at half supply voltage using two series 10kΩ resistors between the positive supply and earth, with a 100µF capacitor to filter out any ripple which may be present. The pin 3 input, called the non-inverting input, connects to this half supply via a 100kΩ resistor.

The gain of the circuit is set by the components between pins 2 and 1 and the components connecting from pin 2 to ground. These are the "feedback" circuits and as you can see are slightly different between versions.

Only one of the three feedback circuits is connected and the circuit in the right channel must be the same.

In the magnetic cartridge version, the RIAA time constants of 3180µs (50Hz), 318µs (500Hz) and 75µs (2122Hz) are provided by R1, R2, C1 and C2. The IEC recommendation of a rolloff below 7950µs (20Hz) is provided by the 0.33µF capacitor at the preamplifier's output when it is driving a 50kΩ load.

A further rolloff below 4Hz is provided by the 100µF capacitor in series with the 390Ω resistor. This 390Ω resistor sets the maximum gain of the amplifier for AC signals while the 100µF capacitor ensures that the DC gain is one.

The tape equalisation provides a 3000µs (53Hz) rolloff, due to the 200kΩ resistor and .015µF capacitor. The 3.6kΩ resistor limits the effect of the .015µF capacitor at frequencies above 2.95kHz so that the gain remains flat from this frequency onward. Low frequency rolloff is set by the 200Ω resistor and 100µF capacitor at about 8Hz.

For the microphone version of the preamp, the gain is set at 514 by the 200kΩ and 390Ω resistor (gain = R2/R4 +1). The high frequency rolloff is at 72kHz and the low frequency rolloff is at 4Hz. The preamplifier has a flat response from 10Hz to 20kHz.

Power for the circuit is from a nominal 12V supply via reverse protection diode D1. LED1 indicates when power switch S1 is on. It's quite important in a high-gain circuit such as this that the power supply is as noise and hum-free as possible. For this reason, we suggest using the 12V regulated supply described in this book.

If you are building the unit into an amplifier, it might be possible to obtain power from an existing supply rail, regulated to 12V if necessary.

Project 13

High Power 12V Amplifier

This amplifier-on-a-chip delivers much more power than is normally available from a 12V supply – almost four times, in fact. If you want lots of power, this is the one to build.

What does it do?

It pumps out a lot more power than you'd normally expect, that's what!

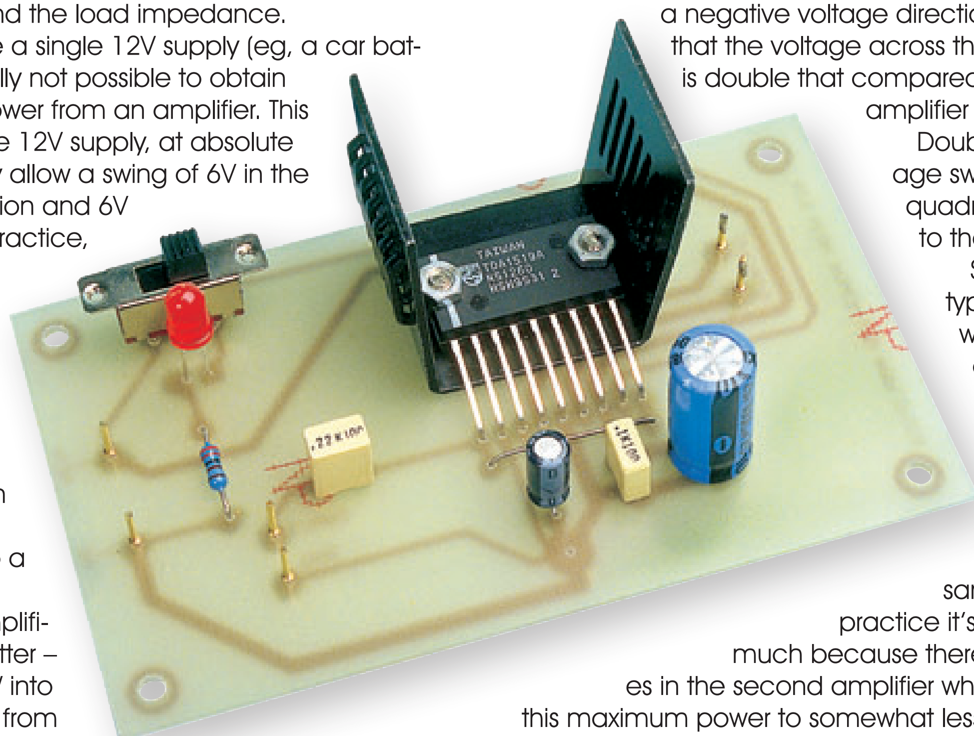
The amount of power available from an amplifier depends basically on two things: the voltage applied to the load and the load impedance.

If you have a single 12V supply (eg, a car battery), it is usually not possible to obtain very much power from an amplifier. This is because the 12V supply, at absolute best, can only allow a swing of 6V in the positive direction and 6V negative. In practice, it's even less than this.

Typically, a power amplifier operating from a single 12V supply rail can only deliver about 4W into a 4Ω load.

But this amplifier is much better – around 13.5W into a 4Ω speaker from a 12V supply! So how can it produce so much more output power?

Have you heard the magician's explanation of magic tricks? "It's all done with mirrors," they say. Believe it or not, that's how we get the extra power, except that our "mirror" is electrical. It's actually inside the special IC we use – there is not one, but two amplifiers in one package. Effectively, one amplifier drives the loudspeaker in a positive voltage direction while the second amplifier drives the loudspeaker in a negative voltage direction. This means that the voltage across the loudspeaker is double that compared to a single amplifier driver.



Doubling the voltage swing effectively quadruples the power to the loudspeaker.

So if we use two typical amplifiers which on their own can only deliver 4W into 4Ω, we would expect to obtain about 16W into the same load. In practice it's not quite that much because there are extra losses in the second amplifier which will reduce this maximum power to somewhat less than four times the power – in this case, 13.5W into 4Ω.

But you'd have to agree that 13.5W is a lot better than 4W!

And just as important for us, all the hard work is done by the power amplifier package: all we have to do is add a few capacitors and a speaker to make it sing – loudly!

You will need these parts

Resistors (0.25W, 1%)
1 2.2kΩ

Semiconductors
1 TDA1519A audio amplifier (IC1)
1 5mm red LED (LED1)

Capacitors
1 1000µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 0.22µF MKT polyester
1 0.1µF MKT polyester

Miscellaneous
1 High Power 12V Amplifier PC board
1 SPDT slider switch (S1)
1 mini U heatsink, 28 x 25 x 34mm
2 small screws and nuts
6 PC stakes
1 length tinned copper wire (for link)
1 portion of heatsink grease

Construction

The High Power 12V Amplifier is constructed on a PC board. The amplifier package is placed over a U-shaped heatsink and secured to the PC board with two screws and nuts.

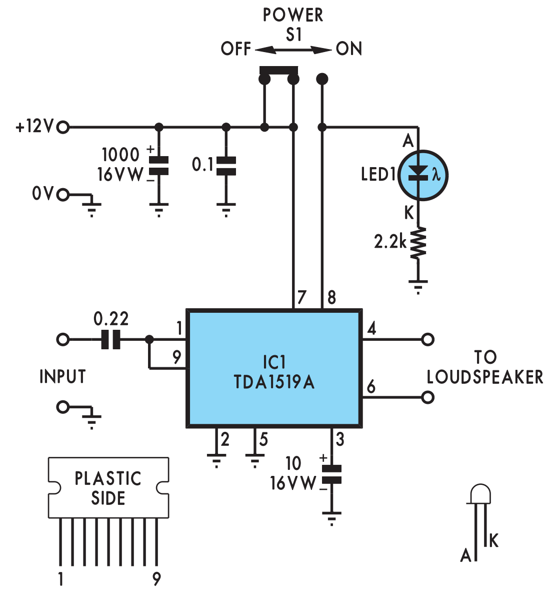
Begin by installing the PC stakes – there are six of them; two for power connection, two for speaker connection and the remaining two for signal input. The LED, resistor, capacitors and wire link are next – take care with the polarity of the LED and electrolytic capacitors.

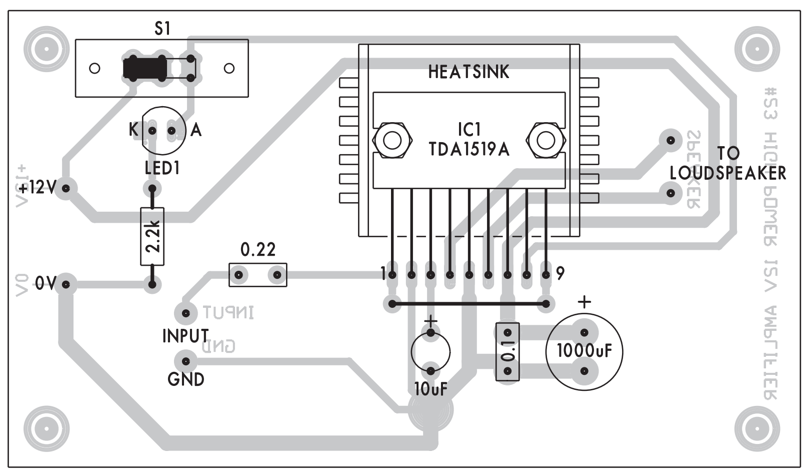
Normally, we make a wire link from a cut-off resistor lead but in this case it is probably too long, so you will need a short length of tinned copper wire.

Switch S1 mounts directly on the PC board but you may need to squeeze its pins with a pair of pliers to fit them in the PC board holes. Alternatively, you could slightly enlarge the holes with a fine drill, taking care that you don't remove the copper pads which the pins are soldered to.

The amplifier is mounted by first bending the leads at 90° about 12mm away from the body of the package so that these can be inserted into the PC board holes. Now place the heatsink in position and place the amplifier package over this.

Before securing the module to the heatsink with screws and nuts, place a smear of heatsink compound between the two mating surfaces of the heatsink and amplifier package to help heat transfer.





Testing

After checking your component placement and soldering, apply power. With the switch off, the LED should be off. Switch on and check that the LED lights. Very carefully measure the supply rails between pins 7 and 2. These should be at 12V. A second check is the voltage between pins 3 and 2 – it should be about 6V.

If all appears well, disconnect power and connect a speaker to the outputs and a signal to the input. Be warned when you reconnect power and turn it on, though: it could be very loud!

The amplifier needs about 1V RMS to drive it to full power. That's a fair amount of signal; much more than you will get from a microphone, guitar pickup or similar source. If you need more signal level the easiest approach is to build a preamplifier, such as the Universal Preamplifier in Project 12.

However, 1V RMS is a fairly typical output level for such things as tuners, cassette decks, CD players and so on – any of these should be able to connect to this amplifier directly.

What to do next

What if you want to drive the amplifier from your personal portable CD player or cassette player which only has a headphone socket, not a "line out" socket?

If you think about it, the headphone socket is in a way a "line out" socket – it is providing audio signals to power the headphones.

You can drive this amplifier directly from the headphone socket (using a suitable plug, of course – most use a 3.5mm stereo plug). But what do you do with the stereo signal when this is a mono amplifier?

You could either build a second amplifier . . . or you can combine the stereo signal into a mono signal by connecting the two channels together via, say, 100Ω resistors (see diagram on page 64).

The volume control on the personal portable will then control the volume from the amplifier.

Ahh! What if you are using a line output from a CD or cassette player, as previously discussed? Very few of these have any form of level control.

TECH TALK

The High Power 12V Amplifier is based on a Philips TDA1519A power amplifier module. It was originally intended for car radios – hence the need for a single 12V supply rail.

This module incorporates all the complexity of two power amplifiers and has output protection against short circuits, good supply ripple rejection, overheating protection, reverse polarity protection and overvoltage shutdown. It is also protected against static discharge.

Overall, it is virtually indestructible within its limits.

One power amplifier is non-inverting and has its input at pin 1 and its output at pin 4. The second amplifier is inverting and its input is at pin 9 while its output is at pin 6. The pin 3 input is for supply decoupling of a half-supply rail internal to the amplifier module. Pin 7 is the positive supply input while pins 2 and 5 are the signal and power supply earths.

The signal input to the amplifier is applied to both the non-inverting and inverting inputs (pins 1 & 9) via a 0.22µF coupling capacitor.

The input impedance is 25kΩ for this bridged mode of operation and so the low frequency rolloff is at 28Hz.

Pin 8 is a mute and standby input which turns the amplifier on when connected to the pin 7 supply. When pin 8 is open circuit, the amplifier is effectively turned off and the quiescent current drawn by the circuit is around 100µA. This input is best used to provide the on and off switching and since pin 8 draws a low current we can use a low-cost switch.

If we were to switch the 12V supply on and off with a switch, then we would need a switch rated at 1.5A or more. LED1 lights when S1 is switched on.

The 12V supply is decoupled with a 1000µF capacitor and a 0.1µF capacitor connected in parallel.

It might seem strange to have a small capacitor in parallel with a much larger one. The reason is that a large electrolytic capacitor unfortunately also has some inductance, which slows down its response to transients.

In an audio circuit, this may allow noise to get into the system. The small value capacitor has virtually no inductance and therefore helps the larger capacitor to do its job.

Incidentally, just in case you were wondering how some car hifi systems deliver awesome amounts of power (many hundreds of watts in some systems), in every case the 12V DC from the car battery is stepped up to a much higher level – perhaps ±100V or more.

Therefore the voltage swing of the amplifier could be 200V or more: no wonder some systems are so ear-splitting!

All is not lost because it's easy to add a volume control to the amplifier. Strictly speaking, it should be a "logarithmic" or "log" potentiometer because this type will give the most natural change in level. However you won't do any damage with another type of pot (eg, a linear pot).

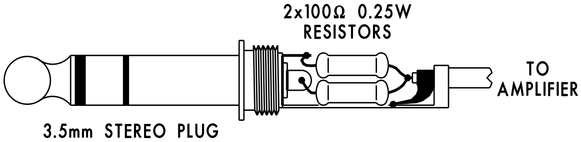
A potentiometer of about 100kΩ can be connected to the input of the amplifier. This is fed via a 0.22µF capacitor which eliminates the possibility of any direct current flowing through the potentiometer from the output of the CD or cassette deck.

To work out which terminals to use: with the pot standing upright on its back and the three terminals facing you, the one on the left side is the "earth" or "ground" terminal (the screens of the screened cables should be soldered to this). The middle terminal connects to the "input" PC stake on the amplifier, while the right side terminal is the one to which the signal source connects via the 0.22µF capacitor.

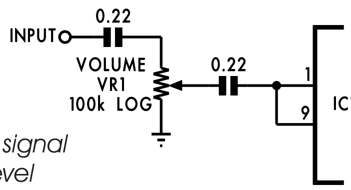
Finally, as far as speakers are concerned, this amplifier is capable of giving very good performance into a good speaker. A speaker mounted in an enclosure will be best – a typical home hifi speaker can be used if you can find a spare one.

The speaker should be rated at 4Ω but an 8Ω speaker can be used if you are prepared to accept reduced volume.

Can you work out the power you'd deliver into the 8Ω speaker? If you said about 6.75W (or about half the power into the 4Ω speaker), well done!



Here's how to combine a stereo headphone or speaker output into a mono signal suitable for the high power amplifier. It can all fit inside a 3.5mm plug but be careful to insulate the various connections from each other!



Use this circuit to connect a volume control between the signal source and the amplifier input if the signal source doesn't have a level control of its own.

Project 14

Simple FM Microphone

Want to build a radio microphone just like you see performers use on TV? Here's one you can build yourself – and you can pick up the signal on any FM-band radio.

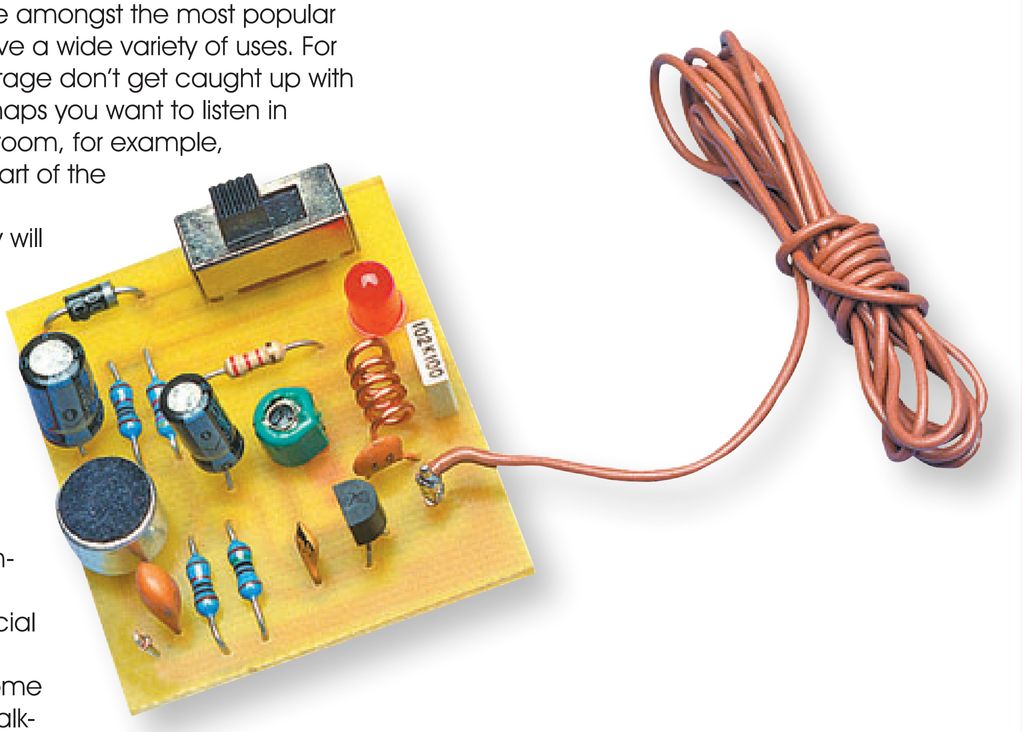
What does it do?

Radio microphones are amongst the most popular projects because they have a wide variety of uses. For example, performers on stage don't get caught up with connecting leads. Or perhaps you want to listen in on something – a baby's room, for example, while you are in another part of the home.

And as every good spy will tell you, the heart of most "bugs" is, surprise surprise, a radio microphone!

A radio microphone has essentially three parts – a microphone, an amplifier and a transmitter. Our radio microphone actually combines the amplifier and transmitter, with its output on the commercial FM radio frequencies.

This means that any home hifi receiver, portable or walkabout type radio which can receive FM stations will also be able to receive this radio microphone's signal. Just tune the radio in to the transmitted frequency.



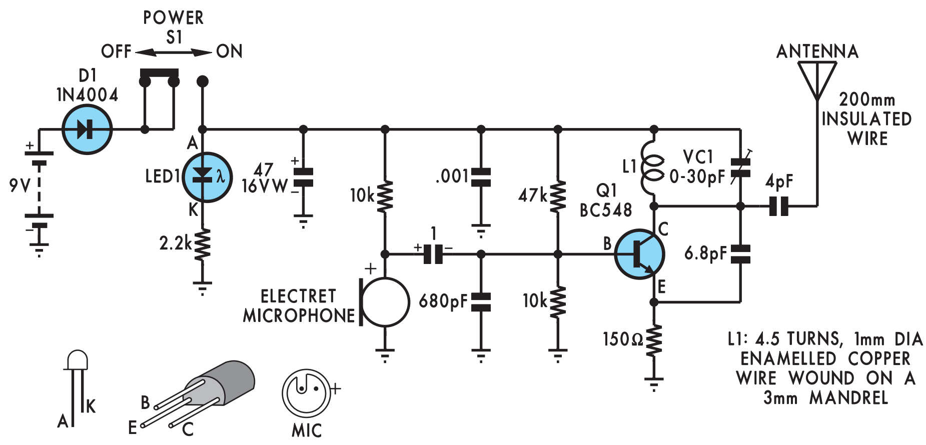
You will need these parts

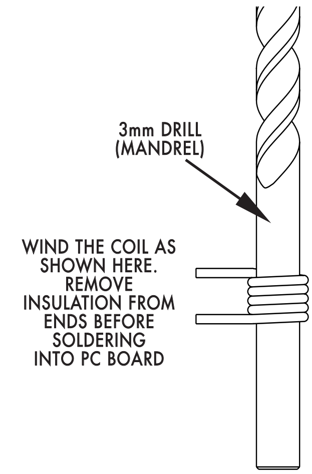
Resistors (0.25W, 1%)
1 47kΩ
2 10kΩ
1 2.2kΩ
1 150Ω

Capacitors
1 47µF 16VW PC electrolytic
1 1µF 16VW PC electrolytic
1 .001µF MKT polyester
1 680pF ceramic
1 6.8pF NP0 ceramic
1 4pF (or 3.9pF) NP0 ceramic
1 30pF trimmer (VC1)

Semiconductors
1 BC548 NPN transistor (Q1)
1 5mm red LED (LED1)
1 1N4004 1A diode (D1)

Miscellaneous
1 FM Microphone PC board
1 electret microphone
1 SPDT slider switch (S1)
1 9V battery clip lead
1 50mm length of 1mm enamelled copper wire
1 200mm length of light-duty hookup wire
3 PC stakes





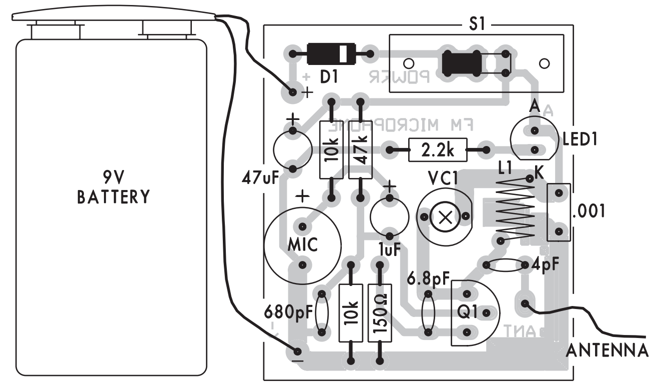
Construction

The Radio Microphone is constructed on one PC board.

Begin construction with the three PC stakes (+ & - battery and antenna connection points), followed by the resistors, diode and capacitors. Make sure that the electrolytics are placed with the polarity shown. Now insert and solder S1 and VC1 (you may need to squeeze S1's pins with pliers to get them to fit the holes).

Q1 mounts with the orientation shown. The microphone is also polarised – it needs to be connected with the correct polarity.

The circuit diagram shows how to select the positive terminal which is then inserted into the PC board hole marked with a "+".



TECH TALK

To make a transmitter, we first need an oscillator. Transistor Q1 is made to oscillate by the 6.8pF capacitor connected between its collector and emitter. But at what frequency?

That's the job of inductor L1 and variable capacitor VC1. They form a tuned circuit (or, if you like, a bandpass filter) which passes signals at a particular frequency.

Oscillation is maintained at about 100MHz but is adjustable between about 88MHz and 108MHz – the commercial FM band – by varying VC1 over its range.

Some of the signal at the collector is coupled to the antenna by the 4pF capacitor. The antenna (actually a 200mm length of insulated wire) radiates the signal which can be received some distance away.

The 4pF capacitor isolates the antenna from the tuned circuit so that any movement of the wire does not greatly affect the oscillator's frequency.

So far, so good. But all you would hear would be a hiss on many FM receivers and nothing at all on others. For an FM transmitter to send any useful information, its oscillator frequency must be shifted up and down marginally from its centre value. This is called "modulation" and it is this change in frequency that is detected in the receiver.

In our circuit, an electret microphone, powered from the positive supply via a 10kΩ resistor, produces a voltage change as we talk into it. This varying voltage is then fed to the base of transistor Q1 via a 1µF capacitor. When we change the base voltage on Q1 we also alter the capacitance as seen at the collector and this varies the frequency of oscillation.

Q1 is biased using a voltage divider consisting of 47kΩ and 10kΩ resistors. The 680pF capacitor grounds the base at high frequencies.

A 9V battery powers the circuit. Diode D1 provides reverse polarity protection so that the circuit will not be damaged if the battery is incorrectly connected (it's easy to touch a 9V battery onto a battery snap connector the wrong way around).

The circuit is turned on and off with switch S1, while LED1 provides power on indication.

Inductor (or coil) L1 is made using 1mm diameter enamelled copper wire. Four and a half turns are wound on a 3mm mandrel (eg, the top end of a 3mm or 1/8 inch drill).

Wind from left to right in an anticlockwise direction, keeping the windings fairly close together. When completed, remove the mandrel and trim the ends of the wire.

The coil is soldered to the PC board like other components but first you will need to strip the enamel from the ends of the wire. Don't try to strip the enamel with the coil in place – all you will succeed in doing is lifting the copper pads from the PC board.

The antenna consists of a 200mm length of hookup wire which is soldered to the antenna terminal PC stake.

Checking it out

Connect the battery and check that the LED lights. So far, so good!

Now switch on an FM radio receiver and tune it to a quiet section of the FM band – that is, away from any station. With the radio close by the transmitter, try to tune the transmitter by slowly adjusting VC1.

If you do not hear a howl from the radio, adjust the coil (L1) by opening up the gap between the windings with your fingernails. Do this in very small amounts at a time and vary VC1 each time until you are tuned in. Now move the radio away from the transmitter and readjust the tuning on the FM radio for best sound quality as you talk.

What to do next

As you have found, adjusting the coil changes the operating frequency of the FM Microphone. Rather than run the risk of having an accident and having to readjust L1, it's wise to protect the circuit by putting it in some form of case.

The entire PC board and battery can be housed in a small plastic utility box. Mount it so that the PC board is protected from the battery – perhaps with plastic foam – and drill a couple of holes in the case so that the microphone insert and the power switch are both outside the case.

Using it

Once set up, using the FM Microphone is as simple as turning it on and tuning in your FM receiver to the correct frequency.

You should find that most of the time the tuning on the receiver will stay the same between uses because FM receivers have what is called "capture effect". This allows them to adjust automatically for a slight change in the received frequency.

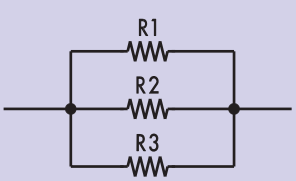
As the 9V battery is used up, though, its voltage will drop and this will cause the frequency to drift a little too far, requiring you to re-tune the receiver. You should not have to adjust L1 again.

Understanding Series & Parallel Circuits

(1). When **resistors are connected in series,** their resistances add. The total resistance (R) is given by the formula:

R = R1 + R2 + R3

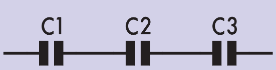
Example: if R1 = 47kΩ, R2 = 100kΩ and R3 = 470kΩ, the total resistance R = 617kΩ.



(2). When **resistors are connected in parallel,** the resulting resistance (R) is determined as follows:

1/R = 1/R1 + 1/R2 + 1/R3

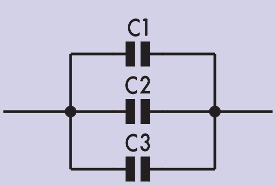
Example: if R1, R2 and R3 are all 100kΩ, then 1/R = 3/100kΩ and R = 33.3kΩ.



(3). When **capacitors are connected in series,** the total capacitance (C) is determined as follows:

1/C = 1/C1 + 1/C2 + 1/C3

Example: if C1, C2 and C3 are all 10µF, then 1/C = 3/10µF and C = 3.3µF.



(4). When **capacitors are connected in parallel,** their capacitances add. The total capacitance (C) is:

C = C1 + C2 + C3

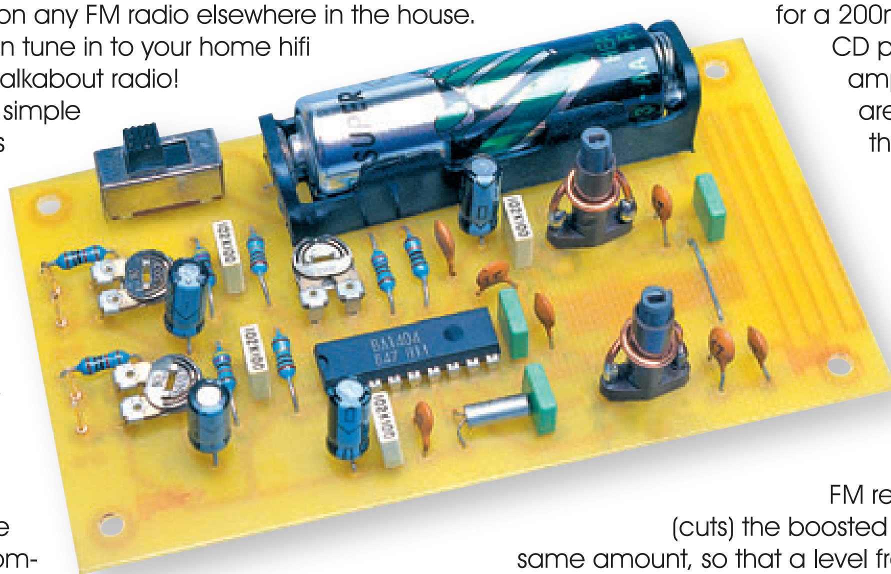
Example: if C1 = 10µF, C2 = 22µF and C3 = 47µF, the total capacitance C = 79µF.

Mini-mitter (FM Stereo Transmitter)

"Wannabe" a disk jockey and transmit full stereo music around your house? Build this and you can!

What does it do?

The Mini-mitter is a small stereo FM transmitter powered by a single 1.5V battery. You can connect a CD or tape player to the Mini-mitter and then listen to your favourite CDs on any FM radio elsewhere in the house. You could even tune in to your home hifi system on a walkabout radio!



While most simple FM transmitters only send a monophonic signal to a receiver, this one transmits genuine stereo. Now you can enjoy the whole performance!

FM stereo transmitters are usually very complex devices but in this case a special IC is used to make it very simple indeed.

The Mini-mitter transmits on the standard FM broadcast band from about 88MHz to 108MHz and provides good clean stereo over a 20 metre range. And the sound quality is very good, with distortion below 3% for a 200mV input signal (most CD player, tape deck and amplifier "line out" sockets are capable of at least this level).

To minimise hiss and improve the signal-to-noise ratio, FM radio stations apply what is known as pre-emphasis – they apply treble boost to the audio signal before transmission. The FM receiver de-emphasises (cuts) the boosted frequencies by the same amount, so that a level frequency response in maintained.

The Mini-mitter applies the standard 50ms pre-emphasis. The separation between channels is quite good at 45dB.

You will need these parts

Resistors (0.25W, 1%)
1 100kΩ 2 47kΩ 2 10kΩ
1 2.7kΩ 2 10Ω
2 2kΩ horizontal trimpots (VR1, VR2)
1 100kΩ horizontal trimpot (VR3)

Capacitors
2 10µF 16VW PC electrolytic
2 4.7µF 16VW PC electrolytic
3 .01µF MKT polyester or ceramic
4 .001µF MKT polyester or ceramic
1 330pF ceramic
2 47pF NP0 ceramic
2 15pF NP0 ceramic
1 10pF ceramic
1 4.7pF NP0 ceramic

Semiconductors
1 BA1404 integrated circuit (IC1)

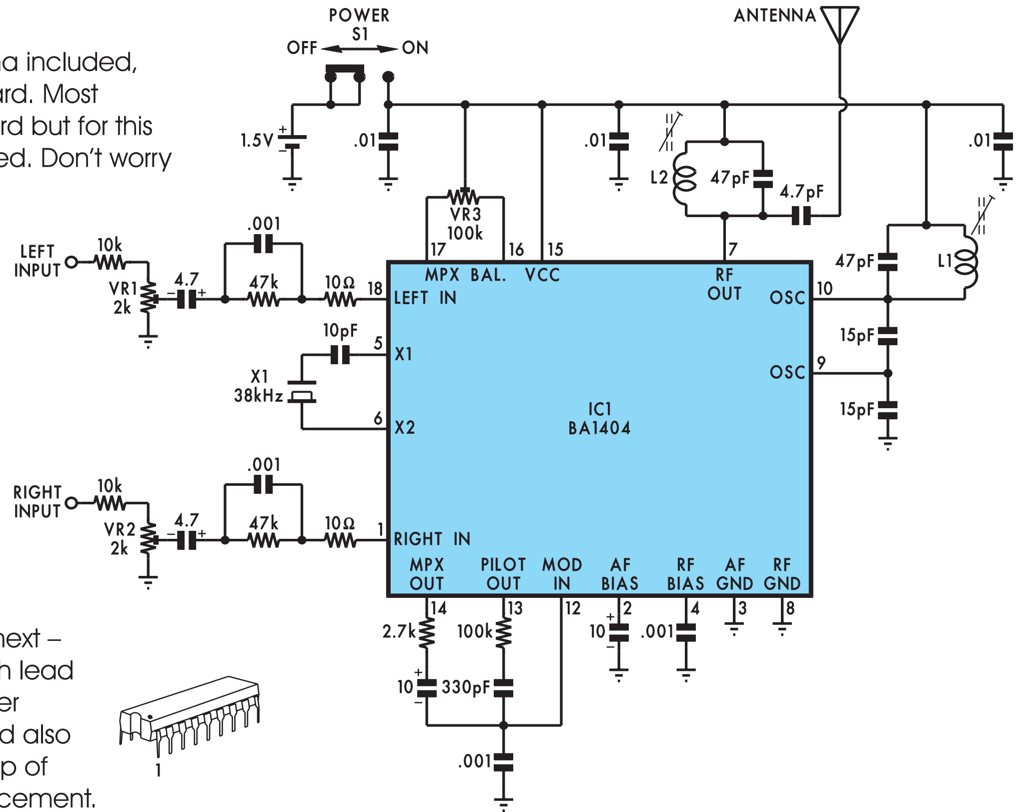
Miscellaneous
1 FM Stereo Transmitter PC board
1 AA cell holder
1 1.5V AA cell (preferably alkaline)
1 SPDT slider switch (S1)
1 38kHz crystal (X1)
2 4mm coil formers (L1, L2)
2 4mm ferrite slugs (screws) to suit
1 100mm length of 1mm diameter enamelled copper wire
4 PC stakes

Construction

The entire circuit, antenna included, is built onto a single PC board. Most construction is straightforward but for this project, two coils are required. Don't worry – they're easy to wind!

As usual, start by soldering the four PC stakes into their positions, followed by the resistors and trimpots. Using one of the resistor lead cut-offs, solder in the single link.

Next, insert and solder the capacitors, ensuring that the electrolytic types are the right way around. The crystal can be soldered in next – it is best if you leave enough lead length so it can be bent over parallel to the PC board and also secured in place with a drop of silicone sealant or contact cement.



TECH TALK

Most of the work is done by the BA1404 IC which is a chip specifically designed for use as an FM transmitter. All it needs are a few external components to make it fully operational.

The left and right stereo audio signals can be taken from just about any source. These signals are connected to trimpots VR1 and VR2 via 10kΩ series resistors. The 10kΩ resistors ensure the input to the IC cannot be overloaded (which would result in severe distortion) while the trimpots allow the left and right signal levels to be matched (and further attenuated if necessary).

The signal is then AC-coupled via 4.7µF capacitors to the pre-emphasis networks, each comprising a 47kΩ resistor and .001µF capacitor in parallel. This gives the audio signal a higher level from about 3.1kHz. This is the Australian standard 50µs pre-emphasis.

The 10Ω resistors at pins 18 and 1 act as stoppers to prevent RF signals entering, which can be picked up via the audio supply leads and input components. RF signals can cause the IC to operate in an unpredictable manner.

The signal is then fed into audio amplifiers inside the IC. The supply for these amplifiers is filtered by the 10µF capacitor connected to pin 2 of the IC.

As there are two (stereo) audio channels but only one transmitted channel, the audio signals must be specially mixed, or encoded. This is called "multiplexing" and requires the use of a frequency generated by the 38kHz crystal and 10pF capacitor between pins 5 and 6.

A 19kHz "pilot" tone is also required – this is created by dividing the 38kHz by two inside the IC. The oscillator's bias supply is decoupled with the .001µF capacitor connected to pin 4.

Stereo encoding is done in the IC's internal multiplexer and this is balanced using trimpot VR3. The multiplexer output at pin 14 and the 19kHz pilot signal at pin 13 are mixed using series resistors and capacitors to set the correct phase and level for the modulation input at pin 12.

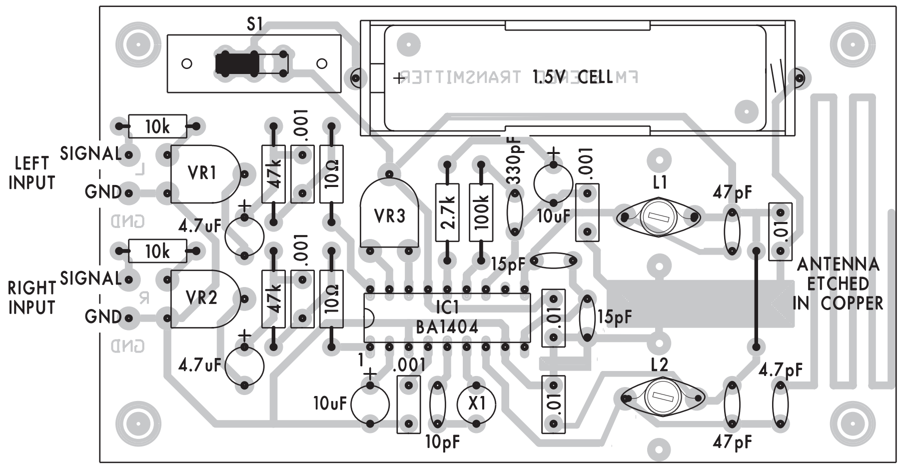
The IC and the tuned circuit components around pins 9 and 10 generate the RF signal at around 100MHz (adjustable between 88MHz and 108MHz by moving the slug inside L1).

The frequency is normally very stable. However, when an audio signal is fed into pin 12, the frequency varies up and down slightly in accordance to the audio signal. This is called frequency modulation or FM.

The modulated RF signal appears at pin 7 and is fed to a parallel tuned circuit consisting of inductor L2 and a 47pF capacitor. The output signal is then coupled to the antenna via a 4.7pF capacitor. The antenna is actually a track on the PC board so you don't need a trailing wire antenna.

The only components left now are the coils, the switch and battery holder and the IC itself. We'll leave the coils and the IC for a moment but the switch and battery holder can be soldered in now. Switch S1 is specified as an SPDT type but a DPDT type will also fit in the PC board holes. Either will work fine.

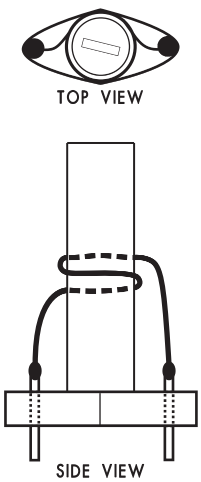
Mounting the battery holder is a little tricky. The negative, or spring contact end, is located towards the antenna end of the PC board. It is attached with a short length of tinned copper wire at each terminal end into the PC board holes. It can be secured to the PC board with some contact adhesive or double sided tape.



Winding the coils

The two coils, L1 and L2, are not available as a finished component so you have to wind them yourself. Both are the same, wound with 1.5 turns of 1mm enamelled copper wire on 4mm diameter formers. The diagram shows how this is done.

First, very carefully scrape some of the insulation from the end of a 100mm length of wire with fine sandpaper or a utility knife. On some wire, the insulation can be removed with a very hot soldering iron – just heat and apply solder to the wire as if you are soldering it.



L1, L2: 1.5 TURNS, 1mm DIA ENAMELLED COPPER WIRE ON A 4mm DIA FORMER WITH F29 SLUG

Solder the end of the wire to one of the two pins, then wind on the 1.5 turns tightly, in a clockwise direction. Before soldering the other end of the coil to the opposite pin, you will need to strip the insulation from the end as described above.

Insert the finished coil into the "L1" position on the PC board. Repeat the complete process for the other coil (L2).

Insert the threaded ferrite slugs into L1 and L2 and adjust both so that the top of each slug is about 2mm below the top of the former.

The two spare holes adjacent to each coil are for fitting shielding cans around the coils, if required. Strictly speaking, the coils should be shielded from each other but we found cans unnecessary.

To complete your PC board, insert IC1 (taking care with polarity) and solder its pins carefully.

Checking it out

You'll need an FM radio or tuner to test the transmitter out, preferably one with a tuning meter (signal strength) or at least a stereo indicator light. Set it to an unused frequency around the centre of the band (100MHz). The exact frequency isn't important.

After thoroughly checking your component placement and soldering, install a 1.5V battery and turn S1 on. Adjust the slug in L1 until the FM radio receives the signal. You should see a sudden rise in the signal strength meter. Alternatively, you can check to see that the stereo indicator lights.

Apply a stereo audio signal (eg, from a CD player or other source) to the left and right inputs and adjust VR1 and VR2 so that the signal is not distorted. Adjust L1 for best tuning and L2 for best transmission range. Ideally, L1 & L2 should be adjusted using a non-metallic tool, to avoid placing more metal inside the coil which would change its inductance.

Note that some slugs may include a strip of rubber down one side which prevents movement in the former. If your slugs do not have this they can be secured with a short length of dental floss down one side of the slug to stop any movement.

Trimpot VR3 can be adjusted for best balance between left and right channels. Normally, VR3 is best left in its centre position.

What to do next

Perhaps you would like to mount the Mini-mitter in a small box. If you do, make sure it's a plastic one or the transmitter won't do much transmitting! Radio waves can easily pass through most plastics but metals stop them dead in their tracks!

Mounting the PC board in a case shouldn't prove too difficult. You will need to provide input sockets for your stereo signal. Also, if you want to change frequency, you will need to drill a hole in the case immediately above L2 so that the slug in the coil can be adjusted.

Project 16

A Low-Cost Intercom

Want a low cost method to communicate between rooms? Here's one that fits the bill – it's easy to build and easy to use.

What does it do?

The word "intercom" is a contraction of two words: internal and communication. What you hear is what you get – the means of communicating within a building where walls or even floors would normally make speech impossible.

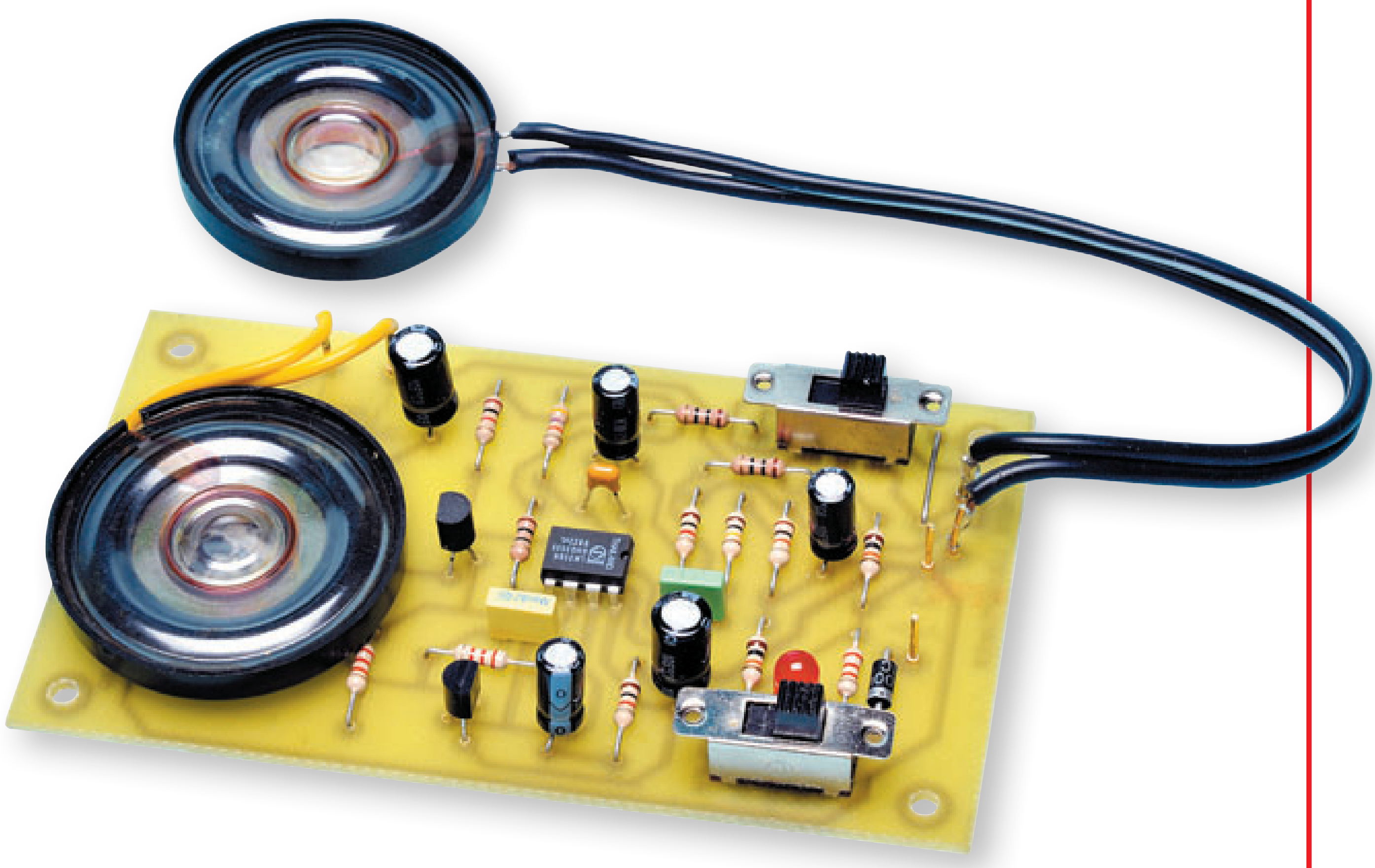
The intercom has two sections: a master unit including an amplifier, loudspeaker and switch and a remote unit simply comprising a loudspeaker.

The remote unit is "hands free" – the local unit can listen in on everything picked up by the remote unit (so be careful!). To talk from the remote unit to the local unit, you simply talk! To talk from the local unit to the remote unit, you flick a switch; to listen, you flick the switch back again.

Because no action is necessary at the remote unit, it's great as a baby monitor: mum can continue working without having to check on baby all the time – if bub cries, the remote unit will pick up the noise!

This type of intercom is called "half duplex" due to the fact that only one party can talk at one time. The advantage of this type of system is that it is simple; the disadvantage is that you need to develop a certain protocol when talking so that the listening party can know when they can speak. One method is to say "over" when you finish talking and the intercom is switched in reverse for the listener to talk.

This type of communication is used in radio communications. Incidentally, a "full duplex" intercom allows both parties to talk at once, as on the telephone.



Construction

All parts except the remote loudspeaker are mounted onto the Low Cost Intercom System PC board.

Start by installing and soldering the PC stakes at all external wiring points, followed by the resistors and the link. The link can be made from a resistor lead cut-off.

When inserting IC1 and the electrolytic capacitors make sure that they are oriented as shown. Diode D1 mounts with its cathode (K) or striped end toward S1. LED1 and transistors Q1 and Q2 mount onto the PC board with the orientation shown.

S1 and S2 are installed by inserting the switch pins into the PC board and soldering in place.

This is one of the few projects in this book where a “DPDT” (double pole, double throw) switch is required (S2). The two halves of the switch, S2a and S2b, are switched at the same time by the same slider. This is what changes the intercom from talk to receive.

In the photograph, the local loudspeaker is shown attached to the top of the PC board with a dab of contact cement. This is fine if you’re not planning on mounting the intercom in a pair of jiffy boxes (see “installing and using your intercom”

You will need these parts

Resistors (0.25W, 1%)

1 100kΩ	1 47kΩ	3 10kΩ
3 2.2kΩ	3 1kΩ	2 10Ω

Capacitors

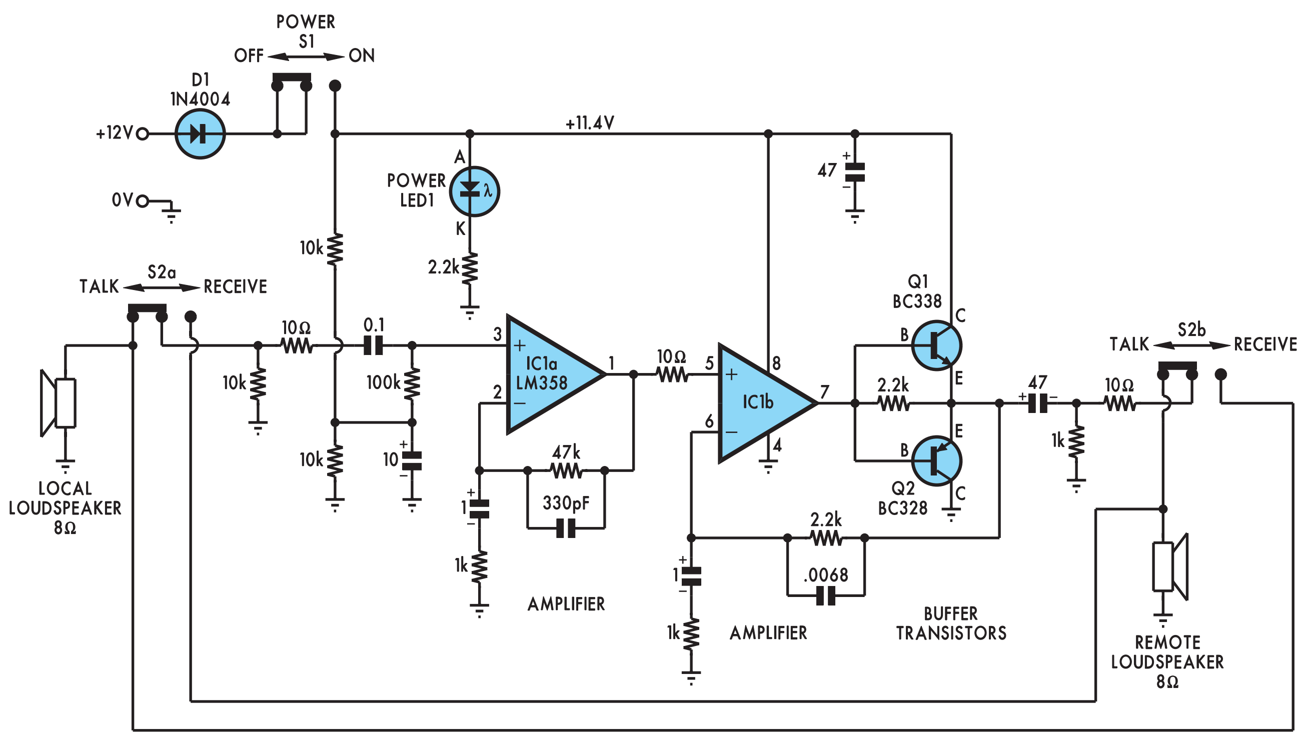
2 47µF 16VW electrolytic
1 10µF 16VW electrolytic
2 1µF 16VW electrolytic
1 0.1µF MKT polyester
1 .0068µF MKT polyester
1 330pF ceramic

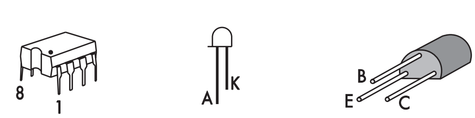
Semiconductors

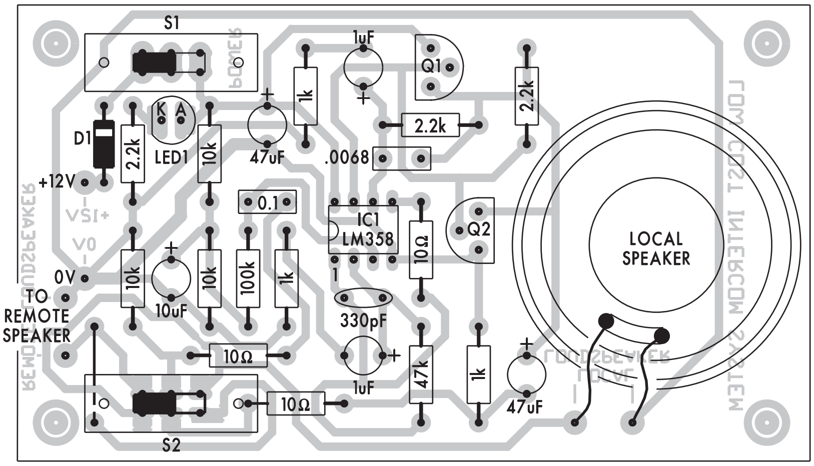
1 LM358 dual op amp (IC1)
1 BC338 NPN transistor (Q1)
1 BC328 PNP transistor (Q2)
1 1N4004 1A diode (D1)
1 red 5mm LED (LED1)

Miscellaneous

1 Low Cost Intercom System PC board
1 SPDT slider switch (S1)
1 DPDT slider switch (S2)
2 40mm Mylar cone loudspeakers
6 PC stakes
1 5m length of twin speaker wire (mini figure-8)







below). Just remember, before you glue the speaker in place, to solder a pair of wires to the speaker terminals so it can be connected to the PC stakes when the glue has set.

If you are planning on mounting the intercom in boxes, connect the local speaker to the same PC stakes via a suitable length of thin twin insulated wire (figure-8 is ideal).

The remote loudspeaker is similarly wired using twin wire to the remote speaker PC stakes on the PC board.

Testing

Apply power to the circuit, switch on and check that the LED lights. If so, it's time to enlist the aid of a friend. With switch S2 in the "listen" position, get them to talk into the remote speaker while you listen to the local speaker. You should hear your friend talk.

Now move the switch to the "talk" position and check that your friend can hear you as you talk into the local speaker. If so, all is well.

If not, check the supply voltage across the +12V and 0V terminals. If this is OK, check the 11.4V rail and the half-supply voltage at pin 1 of IC1. If all else fails, check your soldering again!

You will find that if the loudspeakers are brought in close proximity to each other they will produce a howl. This is because the speaker that is used as the microphone picks up sound from the other speaker which is then amplified and further detected in the microphone speaker. This process is repeated again and again, resulting in an unpleasant howl known as acoustic feedback.

Naturally, that means you cannot mount the two intercom "stations" too close together. But then again, if they are that close, you wouldn't need an intercom, would you?

Installing and using your intercom

Simply run twin wire from the appropriate points on the PC board to the remote speaker, wherever that may be located. Remember, though, that the speaker wiring should not be obtrusive, nor stretched across doorways, steps or paths, etc where people might trip over it. We have nominated a distance of up to 5m apart because we know that works well. You could find that it works over a lot longer distance.

The remote speaker can be mounted in a small box with appropriate holes drilled for the sound to get to and from the speaker cone.

The circuit can be run from a 12V battery but a 12V plugpack would be more appropriate for long-term use. That way, the intercom could be always left "on" as required without worrying about flattening batteries.

Just remember, though, that very few "12V" plugpacks deliver exactly 12V. Almost invariably they are above that figure – up to about 16V or even more in many cases, dropping close to 12V only when delivering their full rated output. In most cases, this circuit included, the extra volt or two doesn't cause any problems.

Also note that there is about 0.6V "lost" due to the voltage drop across the polarity protection diode, D1. So when measuring the "half supply" voltage mentioned above, it is not half of 12V but half of the voltage measured after D1 (ie, half of 11.4V = 5.7V).

Finally, switch S2 has been chosen to match S1 but you might find it more convenient to wire in a push-button, momentary-action switch.

That way, S2 becomes a true "push to talk" switch. The only requirement for S2 is that it is a double pole changeover-type switch. You wire it so that in its normal or "rest" position, the receive contacts are connected.

See next page for Tech Talk

TECH TALK

Like many commercial intercoms, in our version there are no microphones as such to pick up sound. So how is the intercom able to detect sound, convert it to an electrical signal and then transfer it to the other station?

To understand this, let's first consider how a microphone works.

In the case of a "dynamic" type, a diaphragm moves in sympathy with the vibrations of sound in the air around it. This diaphragm is attached to a coil of wire suspended in a magnetic field.

As you probably know, moving a coil in a magnetic field generates electric currents relative to the movement.

The tiny electric currents generated by the microphone are a representation of the sound waves which struck the diaphragm.

In each of the intercom stations, though, there is only a speaker. But we can use the speaker "back to front" as a microphone.

Normally, the electrical energy produced by an amplifier is converted into sound by the speaker. Inside the speaker is a coil of wire called a voice coil which is suspended in a magnetic field.

It is a type of electromagnet – the electrical energy fed into the coil causes it to move in and out very quickly. The voice coil is attached to the speaker cone, so it moves too. The moving cone in turn vibrates the air around it, resulting in sound we can hear.

But what happens if sound vibrations strike a speaker?

Exactly the reverse happens: the cone vibrates the voice coil, which moves in its magnetic field. The result: tiny electric currents are generated in the speaker coil.

In normal use (as a speaker), these currents are so tiny they are ignored but here, if we amplify them enough, we can use them.

And that's just what we do in this circuit – the dual operational amplifier (IC1) provides the high amount of amplification (or gain) required to boost the signals to and from the speakers in the intercom.

IC1a is the first op amp. It has the non-inverting input (+) biased at half-supply using two 10kΩ resistors connected in series across the 11.4V supply. The 10µF capacitor decouples this supply and ensures it is smooth DC. A 100kΩ resistor feeds this nominal 6V (it will actually be about 5.7V) to pin 3 of IC1a.

The input signal from the local loudspeaker is also coupled to pin 3 of IC1a via a 10Ω resistor and 0.1µF capacitor.

It is possible that the long cables between the local and remote units may act as an antenna and pick up radio frequency signals. The 10Ω resistor between the speaker and the IC will help prevent these from getting through. The capacitor isolates the 6V DC level on pin 3 from the input loudspeaker.

The gain of the op amp is 48, set by the 47kΩ feedback resistor and 1kΩ resistor (gain = 47,000/1000 +1). The 1µF capacitor in series with the 1kΩ resistor sets the low frequency rolloff of the amplifier at 159Hz. This means that frequencies below this will not be amplified by the full 48 times. The upper frequency rolloff is set at just over 10kHz by the 330pF capacitor across the 47kΩ resistor.

The amplified signal then passes to op amp, IC1b, via another 10Ω RF stopper resistor. The output of IC1b is buffered using transistors Q1 and Q2. These transistors act as complementary emitter followers, so called because the emitter voltage "follows" the base signal.

When the pin 7 output of IC1b goes above the half-supply voltage by about 0.6V, Q1 turns on to assist drive to the load. Similarly, when IC1b's output goes negative by 0.6V below half supply, Q2 turns on to assist the op amp in driving the speaker.

The feedback signal from the emitters passes back to the inverting pin 6 input via a 2.2kΩ resistor.

The gain of this second stage is 3.2, set by the 2.2kΩ and 1kΩ resistors (2200/1000 +1). The low frequency rolloff is 159Hz as before while the upper frequency rolloff is set at 10.6kHz by the 2.2kΩ resistor and .0068µF capacitor.

Op amp IC1b and transistors Q1 and Q2 drive the speaker via a 47µF AC-coupling capacitor and 10Ω resistor. The capacitor prevents the 5.7V DC present at the op amp output from driving the load while the series 10Ω resistor prevents the output signal from overloading the small loudspeaker.

Switches S2a and S2b select which unit, local or remote, can talk. Normally, the local unit is in the receive mode, listening in to the remote unit. When the switch is changed over, the local unit can answer (ie, send) and the remote unit receives.

Power for the circuit is from a nominal 12V DC supply via reverse polarity protection diode D1 and power switch S1. If power is reverse connected, the diode will not conduct.

LED1 lights to indicate when the power is on, while the 47µF capacitor filters and smooths the supply rail.

Project 17

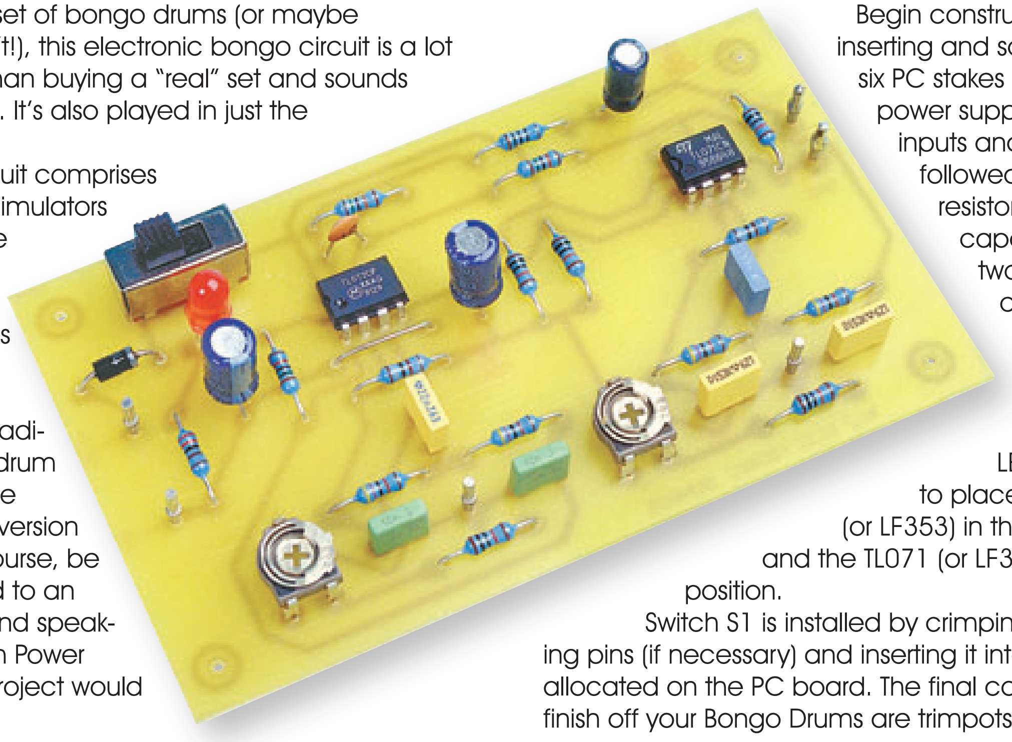
Electronic Bongos

Bongo drums are traditionally played with the hands and give many types of music an unmistakable sound. Here's an electronic version which sounds remarkably like the "real thing".

What does it do?

The bongo drum produces a characteristic background beat in many types of music. If you always wanted a set of bongo drums (or maybe you haven't!), this electronic bongo circuit is a lot cheaper than buying a "real" set and sounds very similar. It's also played in just the same way.

The circuit comprises two drum simulators which have slightly different frequencies from each other. This matches traditional two-drum bongos. The electronic version must, of course, be connected to an amplifier and speaker. The High Power Amplifier project would be ideal.



Putting it together

All components for this project mount on the Electronic Bongos PC board.

Begin construction by inserting and soldering the six PC stakes (for the power supply, the two inputs and the output), followed by all the resistors and capacitors. The two electrolytic capacitors are polarised, as are IC1 and IC2, D1 and LED1. Be sure to place the TL072 (or LF353) in the IC1 position and the TL071 (or LF351) in the IC2 position.

Switch S1 is installed by crimping the mounting pins (if necessary) and inserting it into the position allocated on the PC board. The final components to finish off your Bongo Drums are trimpots VR1 and VR2.

You will need these parts

Resistors (0.25W, 1%)

1 150kΩ	4 47kΩ	2 15kΩ
5 10kΩ	1 2.2kΩ	2 1.8kΩ
1 100Ω		

2 20kΩ horizontal trimpots (VR1, VR2)

Capacitors

2 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 .033µF MKT polyester
1 .022µF MKT polyester
2 .015µF MKT polyester
2 .01µF MKT polyester
1 10pF ceramic

Semiconductors

1 TL072 or LF353 dual op amp (IC1)
1 TL071 or LF351 op amp (IC2)
1 1N4004 1A diode (D1)
1 5mm red LED (LED1)

Miscellaneous

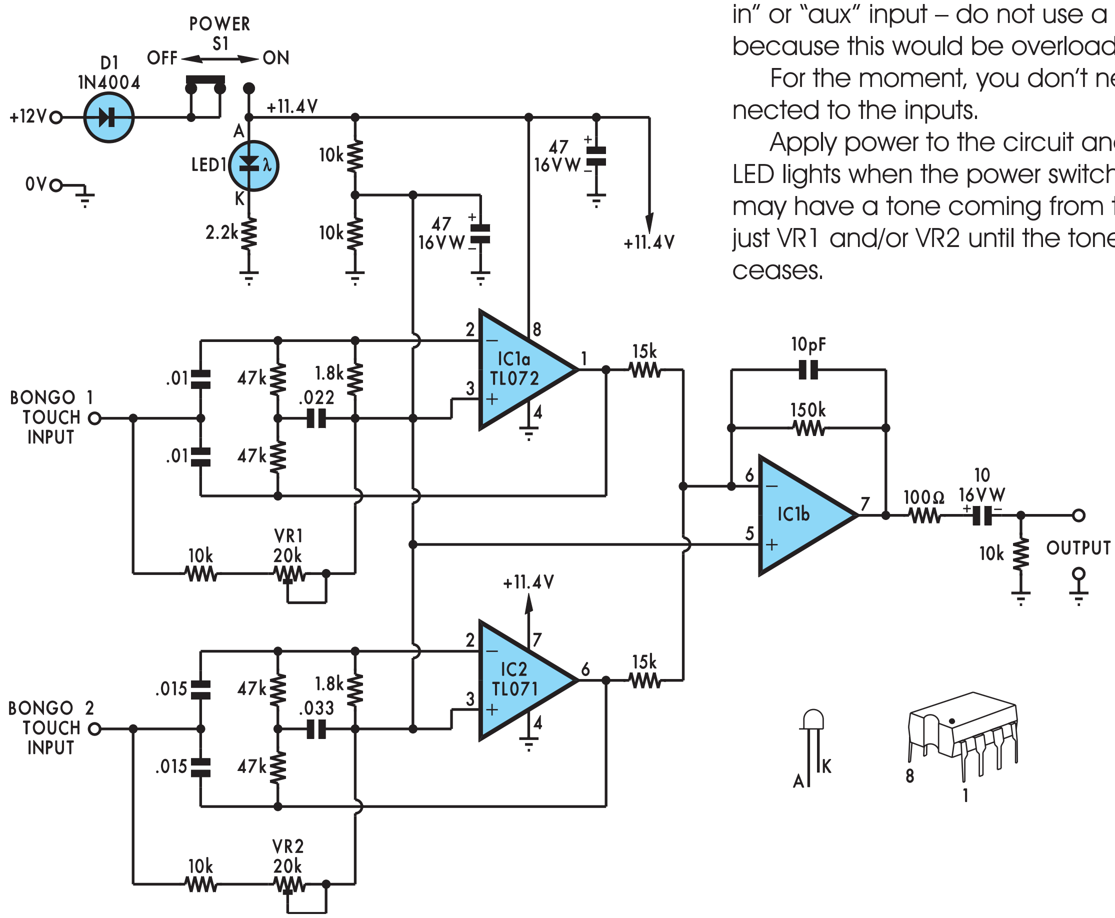
1 Electronic Bongos PC board
1 SPDT slider switch (S1)
6 PC stakes
1 short length of tinned copper wire

Checking it out

Connect the output of the Electronic Bongos to the input of a power amplifier using a suitable length of screened cable. The braided screen connects to the ground terminal. The other end of the screened cable will require a suitable plug to connect to the amplifier signal input. On most amplifiers, this will be the "line in" or "aux" input – do not use a microphone input because this would be overloaded.

For the moment, you don't need anything connected to the inputs.

Apply power to the circuit and check that the LED lights when the power switch is turned on. You may have a tone coming from the speaker – adjust VR1 and/or VR2 until the tone just, and only just, ceases.



TECH TALK

As you might expect, the bongo sound is produced by oscillators, based around op amps IC1a and IC2. However, these oscillators are quite different from others we have used because they have to work a special way: we want them to produce the "bong" sound but then quickly die away. This is called a "ringing" oscillator.

The oscillators are actually "Twin T" types. If you look at IC1a, for example, the two .01µF capacitors form the top of one T and the 10kΩ resistor & VR1 form the stem. The other T is formed by the two 47kΩ resistors and the .022µF capacitor.

We have described these as oscillators but in truth most of the time they are not. They are very high gain bandpass filters – the gain being so high that they could burst into oscillation if not controlled. That's the job of trimpots VR1 and VR2 – they vary the filter gain so that both IC1a and IC2 are just on the verge of oscillation.

When either of the bong "plates" is touched, the extra capacitance of your body to earth is enough to push the oscillators over the threshold. But the oscillation doesn't last long, it dies away; exactly what we want it to do!

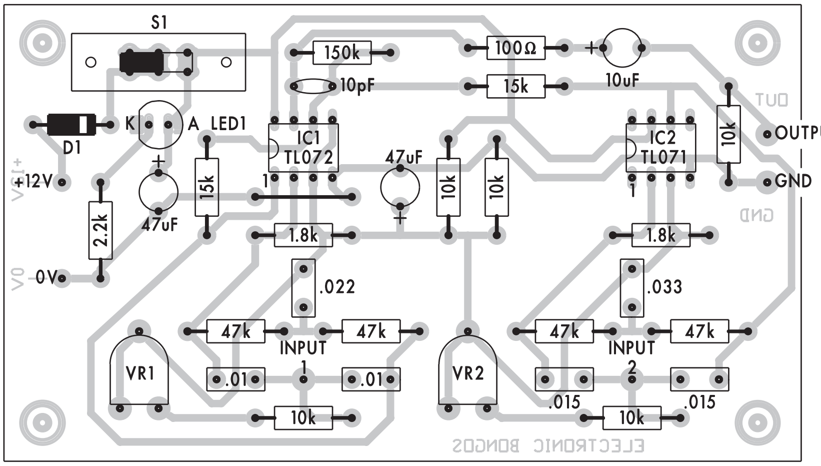
The outputs from IC1a and IC2 are mixed in amplifier IC1b which has a gain of -10 for each input. The minus sign simply means that the output signal is inverted compared to the input. The pin 7 output from IC1b is coupled to the output terminals via a 100Ω resistor and 10µF AC-coupling capacitor.

The signal from the output terminals can be connected to any appropriate amplifier.

Each of the op amps is biased at half supply via the two series 10kΩ resistors across the supply. This half-supply rail is decoupled or smoothed with a 47µF capacitor. Incidentally, the op amps inside the TL071 and TL072 packages are identical but the TL072 contains two op amps while the TL071 contains one.

Power for the circuit is from a nominal 12V source with diode D1 providing reverse polarity protection. S1 applies power and LED1 indicates whenever power is on.

Now touch the bongo 1 input PC stake and adjust VR1 for a tone. Check that the sound dies away when your finger is removed. You may need to readjust the trimpot slightly for best results. Similarly, adjust VR2 for the bongo 2 input.



What to do next

Now that you've finished the board assembly, you're going to need some form of plate to play on. You could make up some using small pads of metal which are soldered to the bongo inputs.

For example, the lids cut from a large tin can could be soldered to wires connected to the inputs. Be careful of sharp edges, though!

Better still, use the lid of a large, self-sealing tin such as a powdered milk tin. Maybe you could even use an upside-down tin can decorated as a bongo drum. (You may want to fill the can with paper or some other material to deaden any "real" sound it makes).

If you use a long run of wire from your "bongos" to the PC board inputs you may find hum is being picked up – in this case, use screened cable. The screens should be connected to the "GND" terminal on the PC board, with the inner conductors soldered to their respective input stakes. Leave the screen unconnected at the "drum" (metal plate) end – solder the inner conductors only to the "drums".

One thing to remember – if you make any significant changes to the amount of metalwork connected to the input, you're going to change the capacitance of the circuit. This may or may not affect operation but you should be able to adjust VR1 and/or VR2 to get everything working properly.

Ohm's Law

Back in 1827, German physicist George Simon Ohm made a discovery that has become fundamental to electronics.

Ohm found that there was a simple relationship between the **current** that flows in an electrical circuit and the potential difference or **voltage** that must be applied to the circuit in order to make that current flow. The two are directly proportional – doubling the voltage produces double the current and so on.

The ratio between voltage and current depends on a fundamental circuit property – the amount of **resistance** to the flow of current through the circuit.

Ever since, resistance and resistors have been measured in basic units called 'ohms'.
The relationship between volts, current and ohms has long been known as **Ohm's Law**. It can be written as a formula, in three ways:

$$V = I \times R \qquad I = V/R \qquad R = V/I$$

where V is the potential difference in volts; I is the current in amps; and R is the resistance in ohms.

As you can see, when you know any two of these quantities you can easily work out the third one.

Power In A Circuit

In 1845, the British physicist James Joule discovered another basic fact about electrical circuits: when a current flows, the circuit's resistance converts the electrical energy into heat energy. The amount of heat produced each second is called the **power** and is proportional to both the resistance of the circuit and the *square* of the current.

This is known as **Joule's Law,** and can again be written as a formula:

$$P = I^2 \times R$$

where **P** is the power in watts (W); **I** is again the current in amps; and **R** is the resistance in ohms.

By using Ohm's Law, we can substitute for either R or I to get two further versions of this formula:

$$P = V \times I \qquad P = V^2/R$$

Strictly speaking these formulas only apply to circuits with DC (direct current) flowing. However, you can often use them in AC circuits providing you work with the RMS (root-mean-square) value of the AC voltage and current.

Project 18

VOX – Sound Switch

Look mum – no hands! This circuit lies in wait, listening for any sound. When it hears something it springs into life . . . and when the sound passes, it goes back to sleep.

What does it do?

This is a sound-activated switch which closes a relay whenever a loud-enough sound is detected by an on-board microphone. Both the level of sound which triggers the switch and the delay before the switch turns off again when no sound is received can be set to suit the circumstances.

You can use this to switch on other devices such as a cassette recorder or even a video camera. This type of circuitry is often used in surveillance and security applications: instead of using endless amounts of cassette or video tape, no recording is done until there is a sound. Gotcha!

It's also used a lot by amateur radio operators and others using transmitters. Often called a VOX (which stands for voice-operated switch), the circuit switches from receive to transmit when the person speaks into the microphone. It's much more convenient than manually flicking a switch – and this circuit never forgets to switch back!

You will need these parts

Resistors (0.25W, 1%)
1 1MΩ 4 100kΩ 1 47kΩ
1 10kΩ 2 4.7kΩ 3 2.2kΩ
2 1kΩ
1 500kΩ horizontal trimpot (VR1)
1 100kΩ horizontal trimpot (VR2)

Capacitors
2 47µF 16VW PC electrolytic
1 4.7µF 16VW PC electrolytic
1 2.2µF 16VW PC electrolytic
2 0.1µF MKT polyester
1 47pF ceramic

Semiconductors
1 LM358 op amp (IC1)
1 BC338 NPN transistor (Q1)
2 1N4004 1A diodes (D1, D4)
2 1N914, 1N4148 signal diodes (D2, D3)
2 5mm red LEDs (LED1, LED2)

Miscellaneous
1 Voice Operated Relay PC board
1 3A SPDT 12V DC relay (RLY1)
1 electret microphone
1 SPDT slider switch (S1)
7 PC stakes
Short lengths of insulated hookup wire (for microphone)

Putting it together

All components, including the electret microphone and relay, mount on the Voice Operated Relay PC board.

Begin construction by installing PC stakes at the +12V and 0V positions, at the relay outputs – NC (normally closed), NO (normally open) and COM (common) – and for the electret microphone. This done, install the resistors and trimpots.

IC1, the transistor, diodes D1-D4, LED1 and LED2 are all polarised, as are the electrolytic capacitors. Take care to orient them correctly. Diodes D2 and D3 are small signal diodes and are usually significantly smaller than the power diodes (D1 and D4).

Switch S1 is installed by crimping the mounting pins and inserting it into the position allocated on the PC board. If you have difficulty with this, the holes can be enlarged very slightly, making sure you do not remove the copper pad below.

The electret microphone is best mounted on short lengths of hookup wire (eg, 10-20mm) which will help to isolate it from any vibrations from the relay.

Checking it out

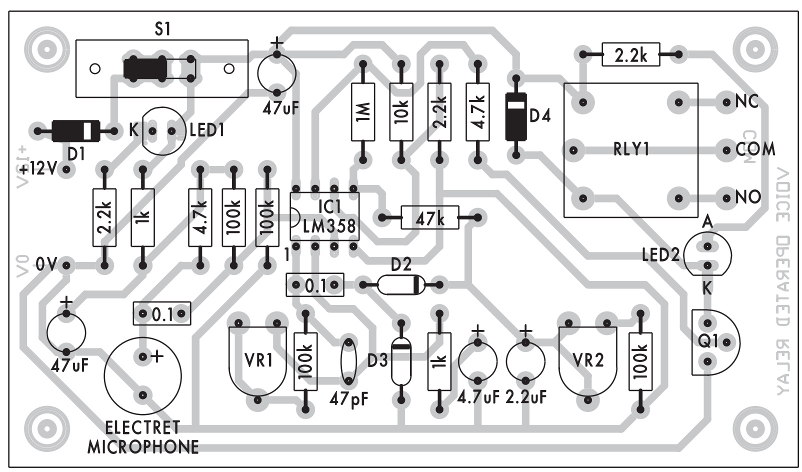
After checking your component placement and soldering, apply power to the circuit and check that LED1 lights when S1 is turned on.

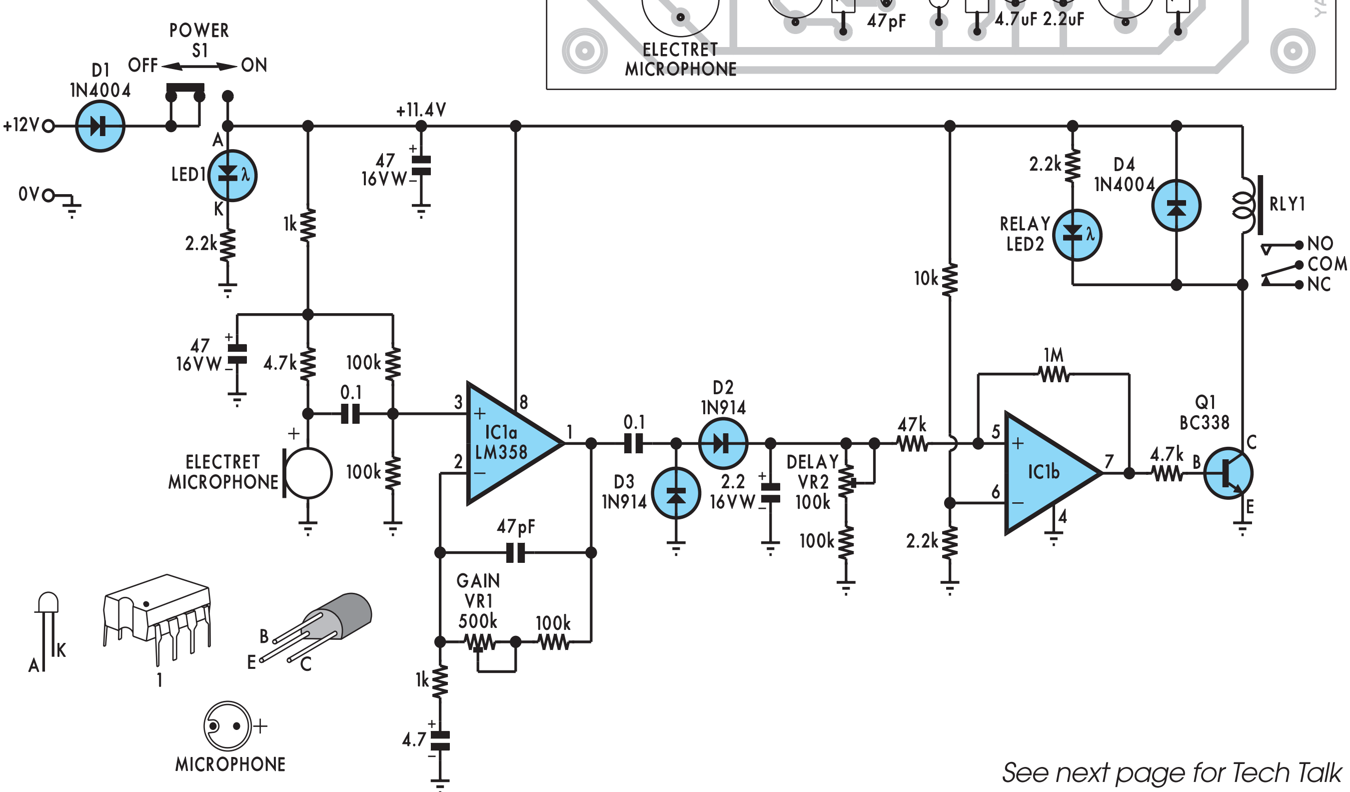
Speak into the microphone and check that the relay closes whenever you speak and releases when you stop talking. The sensitivity is adjusted using VR1 – fully clockwise, the relay will trigger very easily on small sounds (perhaps too easily). Adjust VR1 to the level that suits you best.

If you adjust VR2 for a too-short time delay after sound has ceased, you may find a tape recorder cuts words off. A short delay – say half a second or so – is better.

Remember that the PC board mounting relay is rated for only 3A at 12VDC – it is not suitable for switching mains-operated devices.

Besides, that's too dangerous!





See next page for Tech Talk

TECH TALK

A tiny microphone picks up sound waves and converts them to electrical signals. These signals are amplified and then fed into a comparator. As its name suggests, a comparator compares things – in this case, a reference voltage and the levels of sound picked up by the microphone. If the comparator decides the level is high enough, it turns on a transistor which in turn drives a relay.

The microphone is a special type called an electret. Apart from being very small (and easily hidden!) and sensitive, one big difference between the electret and other types of microphone is that it requires a power supply to function. This is supplied via series 4.7kΩ and 1kΩ resistors connected to the positive supply. The 1kΩ resistor and the 47µF capacitor decouple the microphone supply from the remainder of the circuit.

Decoupling is necessary because when the relay switches off, the collapsing magnetic field of the coil can generate a spike or transient on the supply. This can be big enough to retrigger the circuit. Decoupling reduces this possibility significantly.

IC1a is connected as an amplifier with variable gain as set by VR1, the microphone sensitivity control. At its minimum resistance the gain is 101 [gain = (VR1 + 100kΩ)/1kΩ +1]. With VR1 at its maximum (500kΩ), the gain is increased to 601.

IC1a amplifies the signal coupled to its non-inverting input via a 0.1µF capacitor. The amplifier is biased to about half-supply using the two 100kΩ resistors from the electret supply to ground.

Following IC1a, the signal is coupled via another 0.1µF capacitor to a rectifier comprising diodes D2 and D3. These act to provide a DC voltage, at the positive side of the 2.2µF capacitor, which follows the signal level from IC1a's output.

The capacitor is discharged by the 100kΩ trimpot (VR2) and series 100kΩ resistor. These components set the delay before the relay turns off in the absence, or too low a level, of sound input to the microphone.

IC1b is connected as a comparator, with signal applied to the non-inverting input (pin 5). This is compared with a reference voltage on the inverting input (pin 6), set by the 10kΩ and 2.2kΩ voltage divider. The reference voltage at pin 6 is about 2V (2.2kΩ/(2.2kΩ+10kΩ) x 11.4V). When the voltage at pin 5 exceeds the reference, the output (pin 7) goes high.

The 1MΩ resistor between the non-inverting input and the output, along with the 47kΩ resistor on the input, provide a small amount of "hysteresis". This means that when the output goes high the pin 5 input is also pulled up by an extra 0.6V. This ensures the output remains high until the non-inverting input voltage drops well below its 2V trigger voltage. When IC1b's output goes high, transistor Q1 is turned on, which in turn energises the relay coil and lights LED2.

Power for the circuit is from a 12V source with diode D1 providing reverse polarity protection. LED1 indicates whenever switch S1 is on.

A 47µF capacitor across the supply provides a reservoir for transient loads and helps prevent oscillation of IC1.

Why the diode across the relay?

In this and other projects involving relays, there is normally a power diode connected directly across the coil. Why? What does it do?

For most of the time, it does absolutely nothing. That's because it's reverse biased and, as we all know, a reverse biased diode is turned off.

However, there are times when the diode is absolutely essential for circuit protection. That's when the current through the relay coil is turned off.

First, though, think about the relay when it is on: a current flows through the coil, creating a magnetic field around it (the same magnetic field which pulls in an actuator to make the relay work).

But what happens when the current stops flowing? We have a coil surrounded by a magnetic field. Then the magnetic field collapses as there is no current to sustain it (therefore the relay opens).

Followed it so far? OK, for a brief instant we have a coil of wire in a collapsing magnetic field. By the process of induction, a high voltage "spike" is generated across the coil, with a polarity opposite to the original voltage applied to the coil. This spike, while very short in duration, can do a lot of damage to sensitive components such as some semiconductors whose voltage ratings might be exceeded many times over.

Because of the polarity of the spike, the diode across the coil suddenly becomes forward biased and conducts. This effectively short-circuits the coil (and the voltage spike) so no harm can be done.

Once the voltage spike disappears, the diode again is reverse biased and does nothing . . . until the next time the relay is de-energised.

By the way, if you don't believe the spike is high voltage, try holding onto a relay coil's terminals (without a suppression diode) with bare, moist fingers while connecting and disconnecting a 9V or 12V battery to the terminals.

You should be able to feel the tickle.

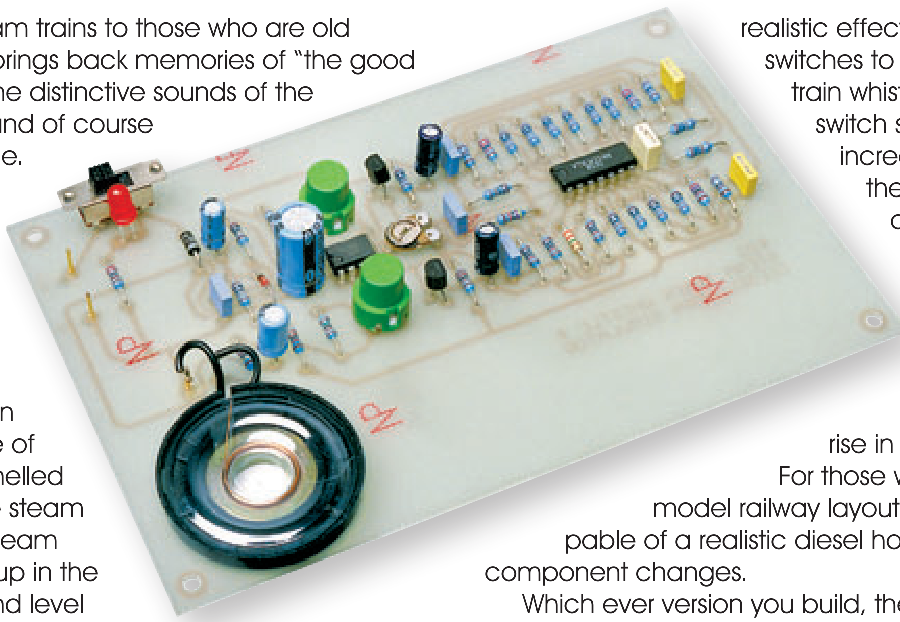
Project 19

Train Sound FX

Do you have a model railway setup? Wouldn't it be great to have authentic sounding train whistle and horn sound effects? Hey, even if you don't have model trains you can still build this one just for fun!

What does it do?

Mention steam trains to those who are old enough and it brings back memories of "the good old days" with the distinctive sounds of the steam engine and of course the steam whistle.



The steam whistle is basically a by-product of the engine itself. Because there is steam under pressure in the boiler, some of it can be channelled off to power the steam whistle. As the steam pressure builds up in the whistle, the sound level rises until it reaches its maximum intensity. When the steam valve is released, the sound level drops off quickly.

Because the whistle is driven by steam, there is a significant amount of background noise or hiss evident in the steam whistle sound.

The Steam Train Whistle duplicates all the requisite notes, noises and level changes to produce a realistic effect. It includes two switches to initiate the steam train whistle sound. One switch simulates the slow increase in volume of the whistle as the operator pulls the valve open; the other provides an instant steam train whistle without the initial slow rise in volume.

For those with more modern model railway layouts, the circuit is capable of a realistic diesel horn with just a few component changes.

Which ever version you build, the Train Sound FX will sound impressive and add realism to your model train layout.

Construction

All components including the speaker mount on the Train Sound FX PC board.

As usual, start with the PC stakes for the 12V supply and the loudspeaker output, followed by the resistors

You will need these parts

Resistors (0.25W, 1%)

- 1 2.2MΩ
- 1 120kΩ
- 14 100kΩ
- 1 47kΩ
- 1 33kΩ
- 1 27kΩ
- 2 22kΩ
- 1 15kΩ
- 3 10kΩ
- 1 2.2kΩ
- 3 1.8kΩ
- 1 1kΩ
- 1 390Ω
- 1 22Ω
- 1 10Ω
- 1 50kΩ horizontal trimpot (VR1)

Capacitors

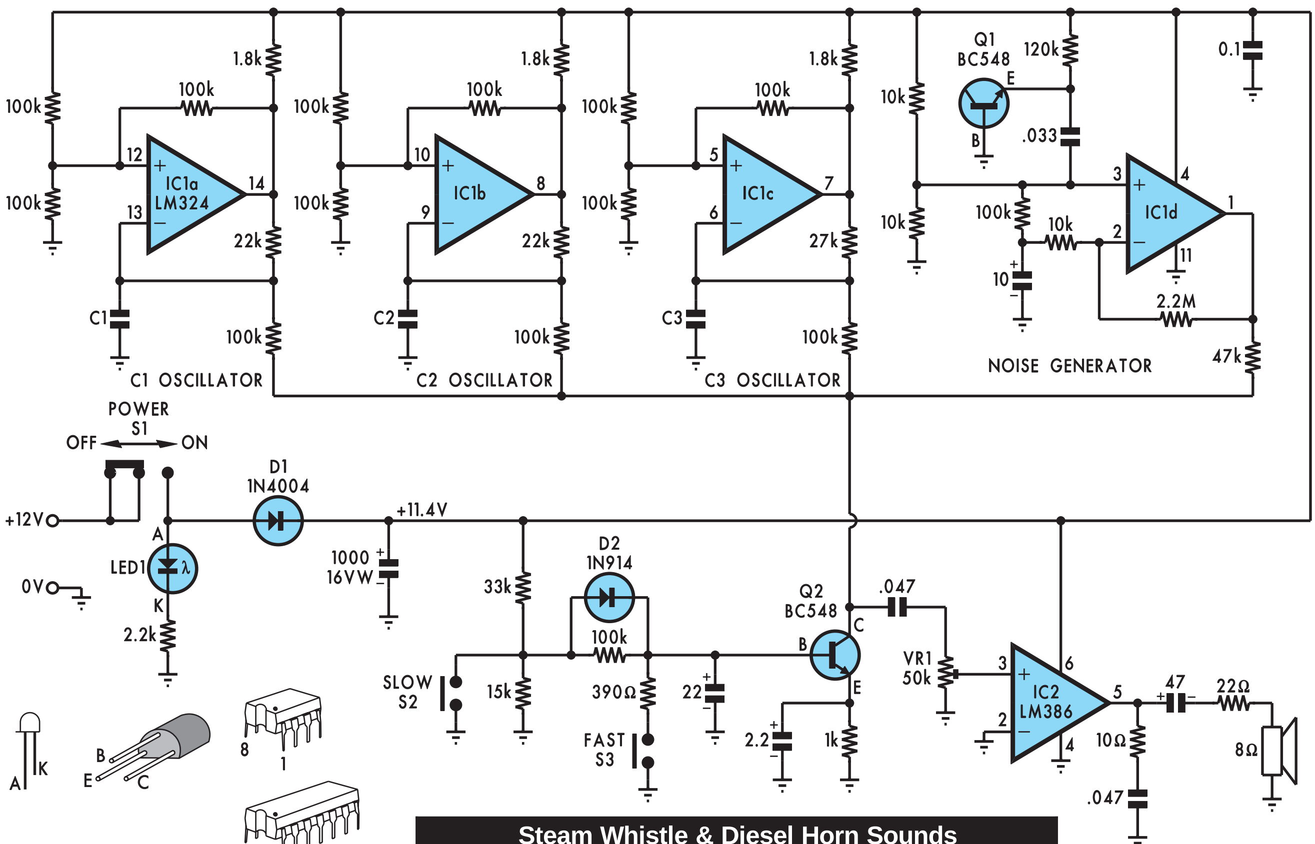
- 1 1000µF 16VW PC electrolytic
- 1 47µF 16VW PC electrolytic
- 1 22µF 16VW PC electrolytic
- 1 10µF 16VW PC electrolytic
- 1 2.2µF 16VW PC electrolytic
- 1 0.12µF MKT polyester
- 2 0.1µF MKT polyester
- 2 0.056µF MKT polyester
- 3 0.047µF MKT polyester
- 1 0.039µF MKT polyester
- 1 0.033µF MKT polyester

Semiconductors

- 1 LM324 quad op amp (IC1)
- 1 LM386 audio power amplifier (IC2)
- 2 BC548 NPN transistors (Q1, Q2)
- 1 1N4004 1A diode (D1)
- 1 1N4148, 1N914 diode (D2)
- 1 5mm red LED (LED1)

Miscellaneous

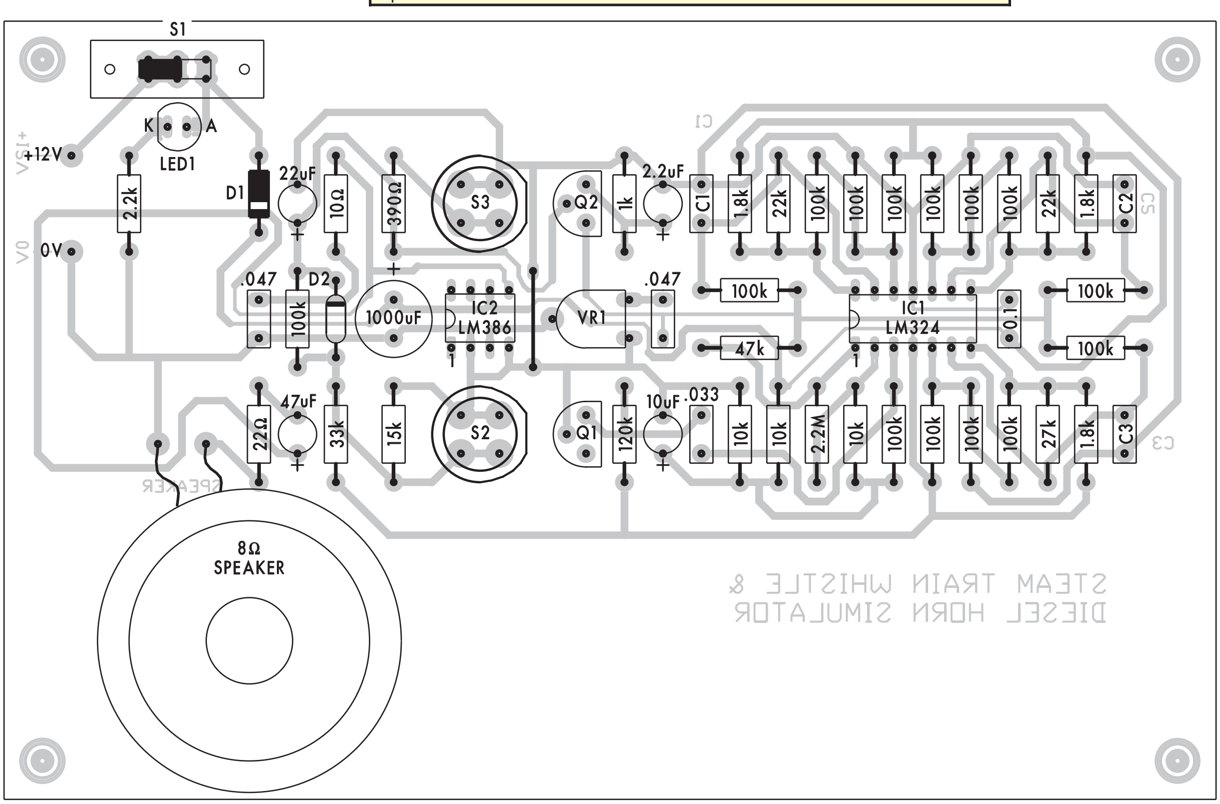
- 1 Train Sound FX PC board
- 1 40mm 8Ω Mylar loudspeaker
- 1 SPDT slider switch (S1)
- 2 momentary PC-mount pushbutton switches (S2, S3)
- 4 PC stakes



Steam Whistle & Diesel Horn Sounds

	Capacitors (µF)			Resulting Frequencies (Hz)		
	C1	C2	C3	IC1a	IC1b	IC1c
Steam	.039	.056	.056	740	525	420
2-Car Diesel	.047	.056	.056	600	525	420
40-42,4401-4440 Diesel	0.1	0.12	.056	280	330	420
422,442,47,73,48126	.056	0.12	.056	525	330	420

Note: for diesel horns, remove the 47kΩ resistor near pin 1 of IC1 to prevent noise input to the mixer.



TECH TALK

To produce the steam whistle sound, the outputs of three oscillators and a white noise source are mixed together. The oscillators have frequencies of 740, 525 and 420Hz and do not produce pure sinewaves but include second harmonics or multiples extending up to 1480Hz.

White noise is a signal composed of not one frequency but (theoretically) ALL frequencies.

The three oscillators are Schmitt trigger types which use three of the four op amps from an LM324 quad package. The operation of each stage is virtually identical except that different value capacitors set their different frequencies. Oscillator 1 (based on IC1a) operates as follows:

Initially capacitor C1 at the inverting input (pin 13) is discharged and so the output (pin 14) is high. The capacitor begins to charge via the 22kΩ resistor until the voltage reaches +8V which is the upper threshold of pin 12.

The output now goes low and the capacitor discharges via the 22kΩ resistor until it reaches 4V, the lower threshold of pin 12. The output again goes high and the process repeats.

The waveforms across C1, C2 and C3 are all triangular, whereas the waveform at the output of each op amp is a square wave. In this case, a triangular wave is preferable to a square wave since it has less harmonic content, which is what we want for the whistle. Therefore, the outputs are taken from the capacitors.

The remaining op amp (IC1d) is used to amplify the white noise generated by the reverse-biased base/emitter junction of Q1.

A resistive mixer combines the oscillator signals and white noise to make a composite sound which is fed to the envelope shaper, Q2. The envelope shaper is triggered with either S2 or S3 to provide a slow or fast rise time respectively.

Normally, transistor Q2 is biased on via the 33kΩ/15kΩ voltage divider and 100kΩ resistor in parallel with diode D2. Because Q2 is on, any signal coming from the oscillators or noise generator is effectively shunted to earth.

When S2 is pressed and held, bias is removed but the transistor stays on until the 22µF capacitor discharges via the 100kΩ resistor and S2.

As it turns off, the signal at the collector increases until it reaches full volume. This takes around 100ms.

When S2 is released, bias is restored, the capacitor rapidly charges via D2 and transistor Q2 turns on, again shunting the signal to earth.

If S3 is pressed and held, Q2's base is taken almost immediately to earth via the 390Ω resistor and Q2 turns off virtually straight away. Upon release, Q2 can turn on again.

The output from Q2's collector is AC-coupled to volume control VR1 and then fed to IC2, an LM386 audio amplifier which provides sufficient power to drive the loudspeaker.

A Zobel network (10Ω resistor and .047µF capacitor) at the output of the amplifier helps prevent high-frequency instability. The 47µF capacitor prevents DC reaching the speaker while the 22Ω resistor limits power to the speaker.

For diesel horn sounds, the oscillator frequencies are altered and the noise generator output is disconnected from the mixer.

and the link (use a cut-off resistor lead for the link).

Before soldering in the capacitors you will need to select the appropriate values from the table, depending on whether you are building the steam whistle or the various types of diesel horn. Also, if building the diesel horn, the 47kΩ resistor near pin 1 of IC1 is left out (this disconnects the noise generator). Obviously, IC1d cannot be left out but if you want to, Q1 and its associated components around IC1d can be omitted.

Take care when mounting the ICs, transistors, diodes and electrolytic capacitors as all these components are polarised. When soldering in the LED, leave about 15-20mm of its leads so it stands up off the PC board.

Note that there are only two connections to Q1 even though it looks like a mistake!

Switch S1 is installed by inserting its pins into the holes allocated. Switches S2 & S3 are oriented with their flat sides towards Q1 and Q2 respectively. The 8Ω speaker can be attached to the board with a dab of contact cement and soldered to the appropriate PC stakes.

Testing

After checking your soldering and component placement, set VR1 to its mid-point, apply power to the +12V & 0V terminals and switch on. If all is well, the LED should light but you should hear nothing!

Press one of the switches (S2 or S3) and you should hear the right sound from the loudspeaker. Adjust VR1 for volume level.

If the sound output from the onboard speaker is too low, you could use a larger speaker, especially one housed in an enclosure, to obtain more volume.

Alternatively, you could use the circuit to drive a larger amplifier. You could leave out IC2, its associated components and the speaker and take the output from the wiper and ground side of VR1.

Project 20

Wind & Rain SFX

Relax to the soothing sounds of rain pattering on the roof. Or sit by the warm fire as the howling wind whistles through the trees. But wait! It's not raining . . . or even windy!

What does it do?

This project simulates the sound of falling rain or howling wind. SFX is an acronym (or abbreviation) used a lot in the film industry for "sound effects".

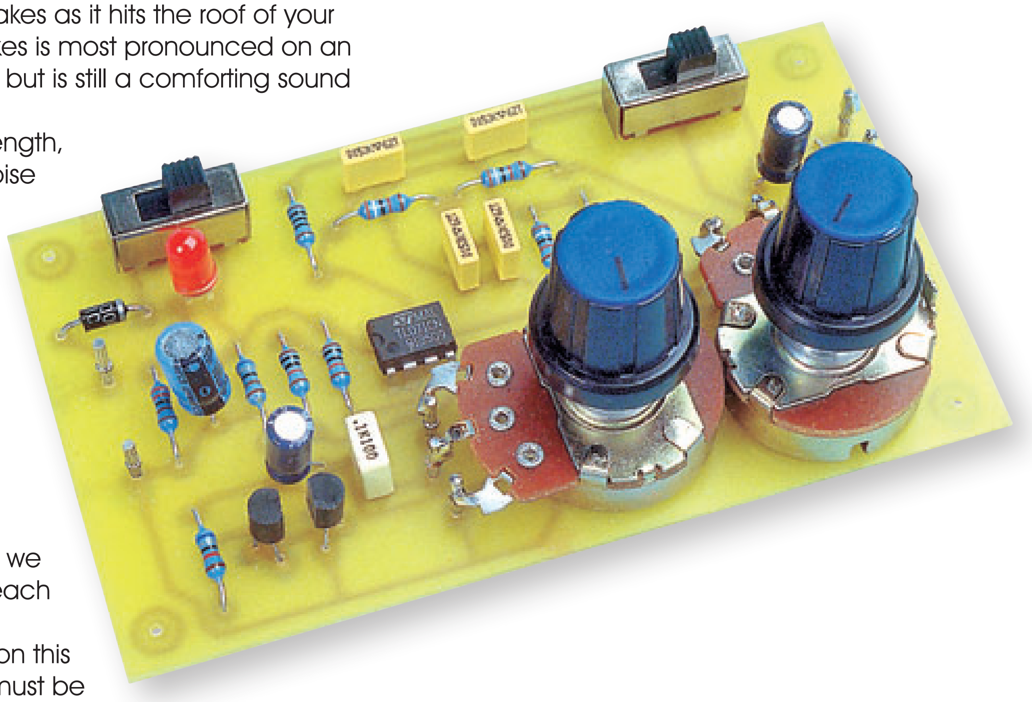
It is well known that the sound of rain is very soothing. It relaxes you as you listen to the irregular noise patterns that the rain makes as it hits the roof of your house. The sound it makes is most pronounced on an old corrugated-iron roof but is still a comforting sound on other materials.

Depending on its strength, wind usually makes a noise as it passes through the leaves of the trees or as it enters your house through gaps in the doorways.

With this circuit we electronically generate signals that sound very much like falling rain or howling wind. We can select between the two sounds via a switch and we can adjust the level of each sound individually.

There is no amplifier on this PC board – the output must be connected to an amplifier and speakers.

Your home hifi amplifier is ideal because a reasonable amount of power is required to make the sound effects realistic. However, it will work with the amplifiers described in this book.



You will need these parts

Resistors (0.25W, 1%)

1 68kΩ	4 39kΩ	3 10kΩ
1 6.8kΩ	1 2.2kΩ	1 100Ω

Capacitors

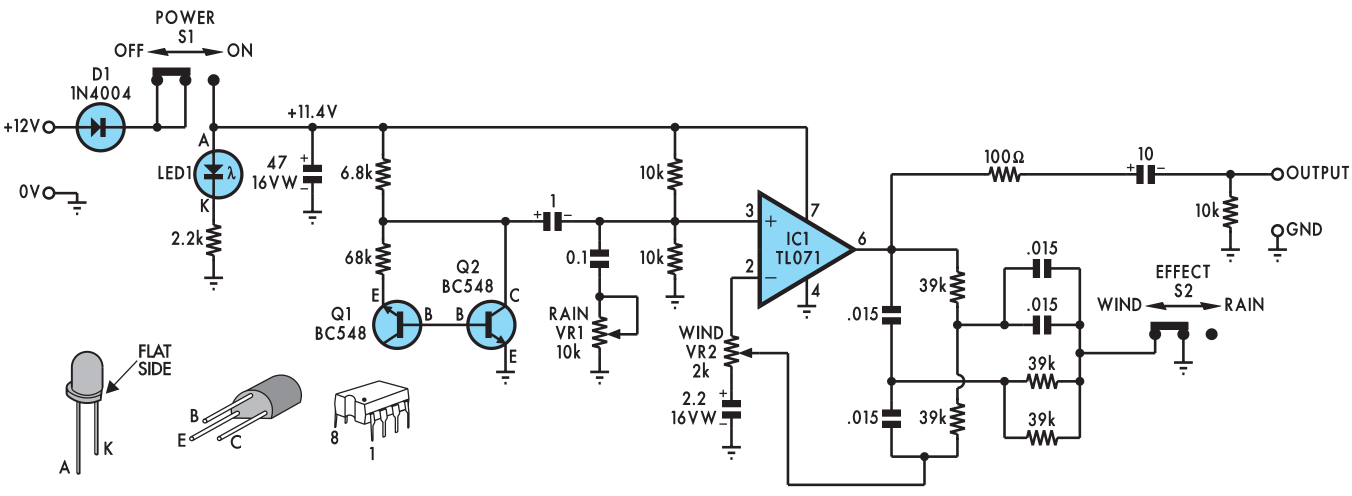
1 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 2.2µF 16VW PC electrolytic
1 1µF 16VW PC electrolytic
1 0.1µF MKT polyester
4 .015µF MKT polyester

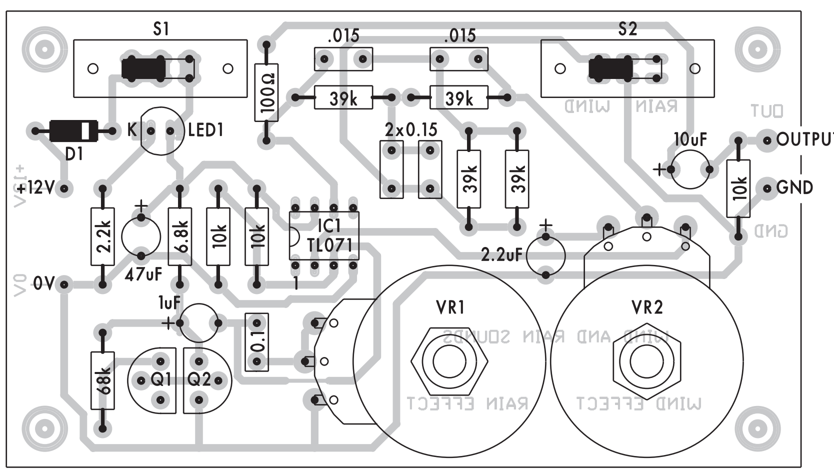
Semiconductors

1 TL071 op amp (IC1)
2 BC548 NPN transistors (Q1, Q2)
1 1N4004 1A diode (D1)
1 5mm red LED (LED1)

Miscellaneous

1 Wind and Rain Sounds Effects PC board
1 10kΩ linear pot. (VR1)
1 2kΩ linear pot (VR2)
2 knobs
2 SPDT slider switches (S1, S2)
10 PC stakes





Construction

All components are mounted on the Wind and Rain SFX PC board.

Begin construction by installing all the PC stakes – at +12V and 0V, at the output and for the two potentiometers (VR1 and VR2).

The resistors and capacitors can be installed now, taking care to orient the electrolytic capacitors correctly. Insert and solder diode D1 and the LED, followed by Q1, Q2 and IC1. Again, make sure these components are correctly fitted.

Switches S1 & S2 are specified as SPDT types but the PC board pattern will also accommodate DPDT types. Either can be used.

Finally, VR1 and VR2 are mounted by soldering their terminals to the PC stakes. A dab of contact adhesive on the PC board under VR1 & VR2 before soldering will help make them even more rigid (but you won't be able to get them off again).

Checking it out

Before connecting it to an amplifier, apply power to the circuit and check that the LED lights when S1 is turned on. If not, check your power supply, the connections and your component placement.

If the LED lights, turn S1 off and solder a suitable length of screened cable to the output terminals. The earth or braid of the cable connects to the GND terminal on the PC board.

The other end of the cable will require a suitable plug for your amplifier input. If connecting to a hifi amplifier, use the "aux" or "line in" input, which is usually an "RCA" type connector.

Turn the volume of your amplifier down and turn S1 on again. You should be able to hear rain sounds with S2 in one position and wind sounds with S2 in the other. Adjust the potentiometers to obtain different effects.

What to do next

You might like to mount the Wind & Rain Sound FX in its own case – one of the small plastic jiffy boxes would be ideal. Naturally, you'll need to drill holes in the case for VR1 and VR2 and possibly fit S1 and S2 off the PC board so they are accessible.

You will also need an output socket. A single RCA type is cheap and you could then use standard RCA-to-RCA leads if your amplifier is fitted with this type of socket.

Some provision will also have to be made for power. A suitable DC power socket would be the logical choice (suitable for a 12V DC plugpack supply) but you might also consider using a 9V battery inside the case – the circuit will work quite happily from the reduced voltage.

TECH TALK

The circuit comprises a white noise generator to produce the rain sound, an amplifier to increase the signal level and a filter to pass only the wind howling sounds.

We are using the reverse-biased base/emitter junction of transistor Q1 as the noise source. Reverse bias means that the voltage applied to the emitter is positive with respect to the base. Note that the collector is not connected.

The transistor junction breaks down at about 5V and current then flows from the emitter to the base. This would probably destroy the transistor if it wasn't limited by the 68kΩ resistor. The transistor breakdown produces random electrical noise over a wide frequency range. This is called "white noise" and when amplified, sounds very much like rain.

In this case, the white noise is amplified by transistor Q2. The signal at Q2's collector is then AC-coupled (via a 1µF capacitor) to amplifier IC1 which is biased at half supply using the 10kΩ divider resistors at pin 3. The noise signal is filtered using a 0.1µF capacitor and potentiometer VR1 to reduce high frequencies in the noise source.

The filtering effect is least when VR1 is at its maximum resistance. VR1 thus controls the noise sound to simulate either heavy rain when set at maximum or light rain when set at minimum.

The signal from the filter is amplified by IC1. This amplifier operates in one of two modes. First, when switch S2 is in the rain position (open), the gain is set by the two 39kΩ resistors in series along with the setting of VR2.

When switch S2 is in the wind position (closed), IC1 acts as a sharp bandpass filter. The filter components comprise the 39kΩ resistors and .015µF capacitors. They form what is called a "Twin-T" filter, with the filter output connecting back to the inverting input of IC1 via VR2. The filter has little effect on the output if the wiper of VR2 is at minimum, that is towards the 2.2µF capacitor connected to ground.

Conversely, when the potentiometer is at its maximum setting, the filter allows only a narrow band of frequencies centred around 270Hz to pass through the IC. This simulates the howling wind sound and VR2 controls the effect.

The signal from pin 6 of IC1 is fed to the output via a 100Ω resistor and 10µF capacitor. This output can be connected to an audio power amplifier.

Finally, the circuit is powered from a 12V DC supply or battery with diode D1 providing reverse polarity protection. A 47µF capacitor across the supply provides a reservoir for transient loads and prevents IC1 from oscillating.

Why a FUSE can be your BEST FRIEND...

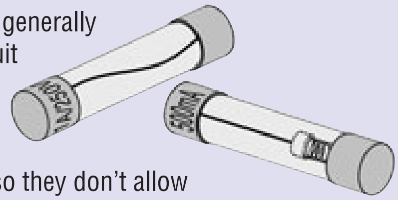
Fuses are one of the most misunderstood components in electronics. Many people curse them when they "blow" and stop a piece of equipment from operating.

If they don't have the correct replacement fuse they may replace it with a short length of metal rod or heavy wire "to get things going again". However, this is really very dangerous. Fuses are an extremely important part of most equipment and the correct fuse can protect both the equipment and YOU from damage, serious injury and even loss of life.

A fuse is basically a short piece of wire, carefully chosen in terms of its diameter and composition (and sometimes the physical tension applied to it as well) so that it will conduct current continuously up to a certain level but melt or "fuse" if the current rises above that level. When the fuse blows, the circuit is opened, which automatically switches off the current before serious damage is done.

In many of the fuses used in electronic equipment, the fuse wire is mounted in a small glass tube, fitted with metal end caps which form the electrical connections. The glass tube forms a physical guard, so that when it does blow the molten metal can't fly off and cause damage or injury. The glass also generally lets you see when the fuse has blown.

Fuses are always marked with the current level they're designed to fuse at and generally with the maximum circuit voltage they're designed to work at too. Fuses for high-voltage circuits must be made so they don't allow an 'arc' to occur when they fuse. For maximum protection it's very important to replace them with a new fuse of exactly the same rating.



You shouldn't use a fuse of lower rating, because it will probably blow during normal circuit operation and be a nuisance. And you certainly shouldn't use one of higher rating (or even worse, a piece of wire) because this means it may not blow even if the current should increase to a dangerous level.

If the fuse is a special "fast blow" or "slow blow" type, it's also important to replace it with the same type, again for maximum protection.

It's quite possible for electronic equipment to overheat and catch fire without the protection that a fuse can give. This risk isn't just confined to equipment operating from 240V AC mains power, either — there's enough energy stored in a 12V car battery and even in a couple of heavy-duty lantern batteries to start a fire. A blown fuse gives you the opportunity to find the real cause of the trouble and fix it before any further damage occurs. So don't see fuses as a nuisance; they're an essential safety device.

Project 21

Guitar Link

Want to play a guitar without buying a guitar amplifier and speakers? This neat preamplifier will let you plug your guitar into virtually any amplifier – your home hifi included.

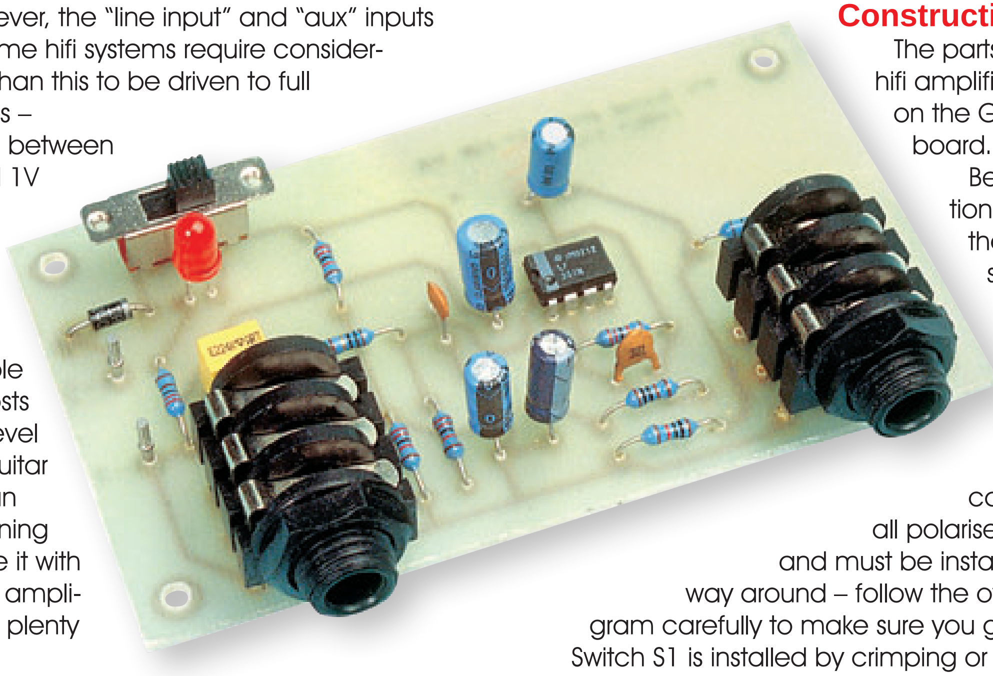
What does it do?

Plugging an electric guitar directly into the "line in" or "aux" input of a home hifi system or even a ghetto blaster may work but it won't work very well.

The output from a typical electric guitar is about 50mV. However, the "line input" and "aux" inputs on most home hifi systems require considerably more than this to be driven to full output levels – somewhere between 250mV and 1V or even more, depending on the amplifier.

This simple project boosts the 50mV level from your guitar to more than a volt, meaning you can use it with virtually any amplifier and get plenty of oomph!

It's not limited to your home hifi system, either. You can use this to plug an electric guitar into virtually any device with a "line in" or "aux" input socket. That includes cassette recorders and even PC sound cards, so if you want to record your guitar playing, this project will help you do it.



Construction

The parts for the guitar/hifi amplifier link mount on the Guitar Link PC board.

Begin construction by installing the two PC stakes and the resistors. IC1, diode D1, the LED and the four electrolytic capacitors are all polarised devices and must be installed the right way around – follow the overlay diagram carefully to make sure you get them right.

Switch S1 is installed by crimping or squeezing its mounting pins with a pair of pliers before inserting it into the position allocated on the PC board.

The 6.35mm jack sockets also mount directly on the PC board.

You will need these parts

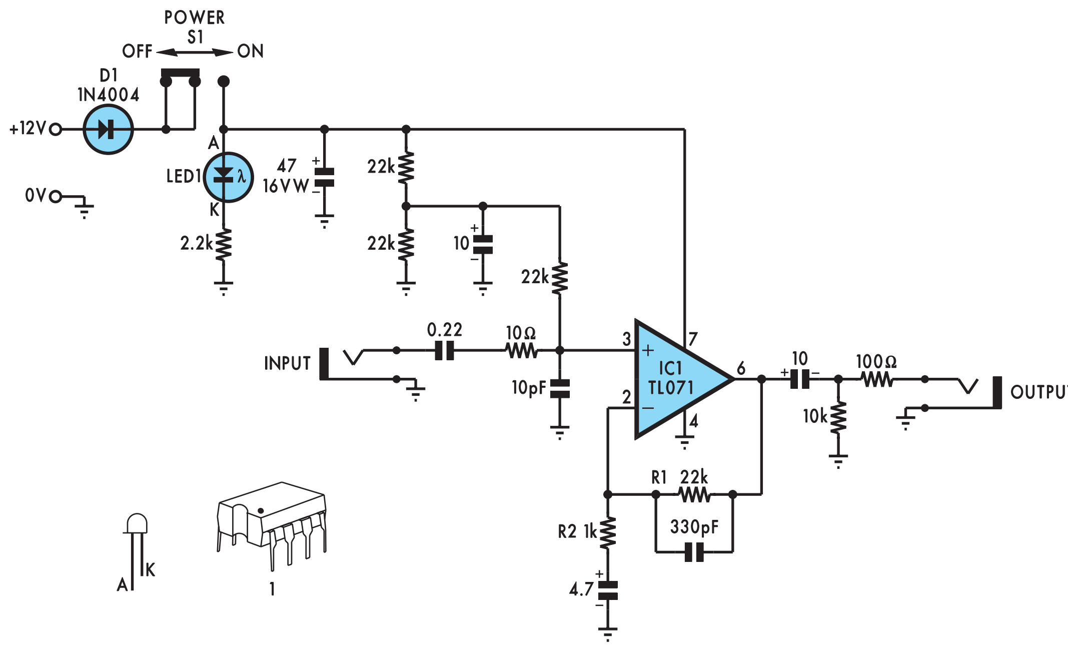
Resistors (0.25W, 1%)

4 22kΩ	1 10kΩ	1 2.2kΩ
1 1kΩ	1 100Ω	1 10Ω

Capacitors
- 1 47µF 16VW PC electrolytic
- 2 10µF 16VW PC electrolytic
- 1 4.7µF 16VW PC electrolytic
- 1 0.22µF MKT polyester
- 1 330pF ceramic
- 1 10pF ceramic

Semiconductors
- 1 TL071 op amp (IC1)
- 1 1N4004 1A diode (D1)
- 1 5mm red LED (LED1)

Miscellaneous
- 1 Guitar Link PC board
- 1 SPDT slider switch (S1)
- 2 6.35mm PC-mount jack sockets (mono or stereo)
- 2 PC stakes



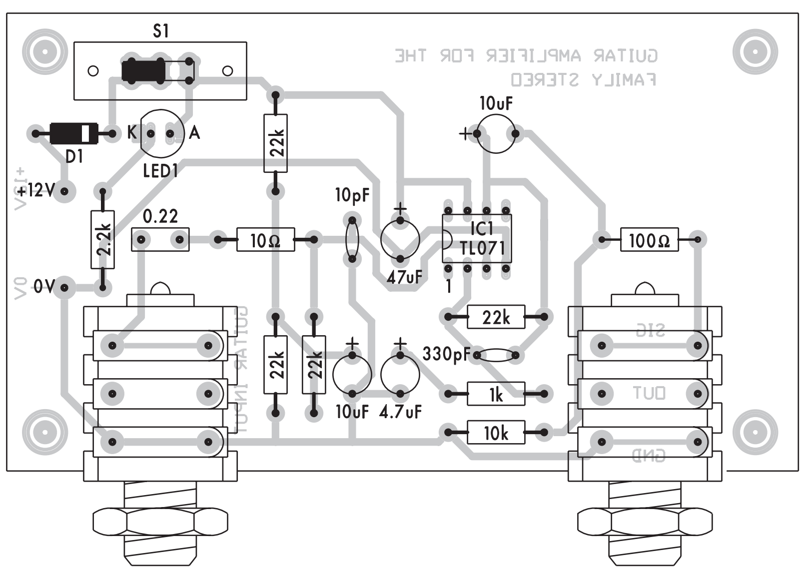
Testing

When you have thoroughly checked your soldering and component placement, connect your guitar to the input socket and from the output connect a 6.35mm jack-to-RCA lead. The RCA end of the lead is plugged into the "aux" (auxiliary) or "line in" socket of your stereo amplifier – either the left or right channel input. If you cannot identify which input to use, you should be able to use virtually any spare input except for phono and microphone inputs.

If a 6.35mm-to-RCA plug lead is unavailable, you can use a 6.35mm jack-to-RCA socket converter so that an RCA-to-RCA standard lead can be used.

Turn the volume control on the amplifier to near minimum and turn it on. Then apply power to your circuit and test that the guitar can be played through the amplifier, adjusting the volume as required.

Note that if you want the sound from both loudspeakers you will need to switch the stereo amplifier to "mono". If your stereo amplifier doesn't have a stereo/mono switch, there are "Y" adaptors available which convert a single 6.35mm plug to two RCA sockets, or one RCA socket to two RCA plugs.



TECH TALK

The circuit is basically an amplifier – or more specifically a preamplifier – with a gain of 23 which boosts the 50mV output from the guitar to about 1.15V. The resulting amplified signal can be connected to the auxiliary input of a home stereo amplifier or virtually any other amplifier. The output level is adjusted in the normal fashion using the volume control on the amplifier.

IC1, a TL071 operational amplifier (or op amp), is connected as a non-inverting amplifier. That means the signal at the output of the op amp has the same phase as, or is a replica of, the signal at the input, albeit greatly increased in level.

The guitar signal is applied to the pin 3 input via the 0.22µF capacitor and 10Ω resistor. The 0.22µF capacitor allows the AC signal to pass while stopping any DC getting back to the guitar (where it might interfere with the guitar pick-up). The 10Ω resistor and its 10pF capacitor help prevent any RF interference which may have been picked up by the long guitar lead acting as an antenna.

Normally, op amps require a positive and negative supply but in this case we trick the op amp into believing it has this by biasing the input to half the supply voltage with the two 22kΩ resistors forming a voltage divider. The 10µF capacitor decouples, or helps smooth, this "6V" supply. The op amp doesn't know it is operating with supply rails of 0, 6 and 12V – it thinks it is operating with -6, 0 and +6V rails.

One of the neat things about op amps is that it is really easy to set their gain merely by choosing appropriate resistor values in their feedback loops. These are the resistors between output and input (R1) and pin 2 and earth (R2) via the 4.7µF capacitor.

The formula is simple: **Gain = R1/R2 +1**. So with a 22kΩ and 1kΩ resistor, the gain is 22/1 + 1 = 23. This means that if your guitar produces a 50mV signal, you multiply that by 23 and get 1.15V output.

In a perfect world, an amplifier would operate from 0Hz to infinity. However, it's not a perfect world! Due to limitations in the devices themselves and external causes, it is desirable for an amplifier to "roll off", or reduce gain, above and below certain frequencies.

That's the purpose of that 4.7µF capacitor we mentioned a moment ago: it sets the low frequency rolloff at 34Hz. Below 34Hz the amplifier gain drops off rapidly.

Similarly, high frequency rolloff is set at 22kHz by the 330pF capacitor across the 22kΩ feedback resistor.

The signal from pin 6 of IC1 is AC-coupled to the output via a 10µF capacitor (that means AC can get through but not DC). The 10kΩ resistor to ground provides a charging path for the 10µF capacitor while the 100Ω resistor in the output isolates any capacitive loads which may be connected. Capacitive loads such as from shielded guitar leads could otherwise cause oscillation in the amplifier.

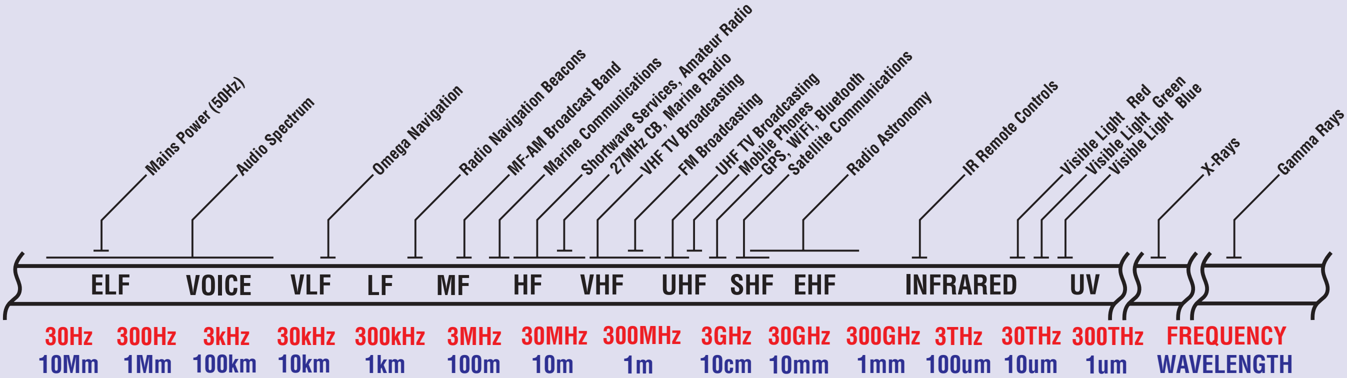
Power for the circuit is from a 12V supply with diode D1 providing reverse polarity protection. The 47µF capacitor decouples or smooths the supply.

The power indicator, LED1, is driven from the positive supply and the 2.2kΩ resistor to ground.

Wavelength, Frequency & the EM Spectrum

Radio waves, light and heat radiation are all examples of electromagnetic (EM) radiation and differ only in terms of their wavelength (W) and frequency (F).

You can convert from one to the other very easily. The formula is: **W = 300/F** where W is the wavelength in metres and F is the frequency in MHz.



Project 22

Guitar Practice Amp

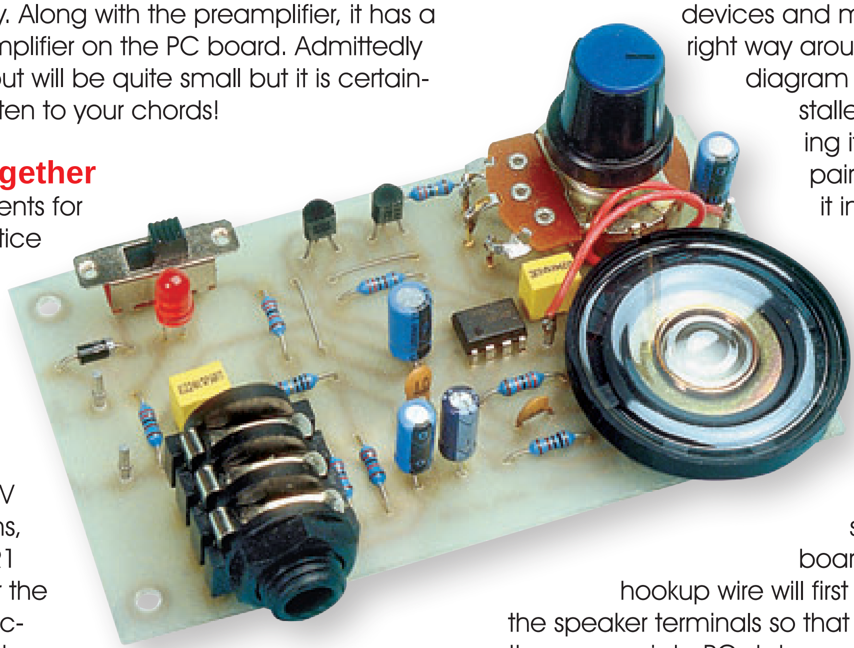
When you want to practise your guitar but not disturb others, this amplifier will be ideal. It mightn't shake the ground but it's cheap & easy to build!

What does it do?

This amplifier is similar to the hifi amplifier Guitar Link (Project 21) but it has the advantage that it will drive a speaker directly. Along with the preamplifier, it has a small power amplifier on the PC board. Admittedly the sound output will be quite small but it is certainly enough to listen to your chords!

Putting it together

All components for the guitar practice amplifier are mounted on the PC board.



Begin construction by installing all the PC stakes: the two at the +12V and 0V positions, the three for VR1 and the two for the speaker connections. Next are the resistors and non-polarised capacitors. There are two links to be soldered in on this PC board – they can be made from suitable lengths of resistor pigtail.

IC1, diode D1, transistors Q1 and Q2, the LED and the four electrolytic capacitors are all polarised devices and must be inserted the right way around – follow the overlay diagram carefully. Switch S1 is installed by crimping or squeezing its mounting pins with a pair of pliers before inserting it into position on the PC board. The 6.35mm jack socket is mounted directly on the PC board.

The speaker can be mounted by applying a spot of super glue to its magnet side and sticking it onto the PC board. Short lengths of flexible hookup wire will first need to be soldered to the speaker terminals so that they can be soldered to the appropriate PC stakes.

VR1 is mounted by soldering its pins to the PC stakes. A knob isn't essential but adds class to the project.

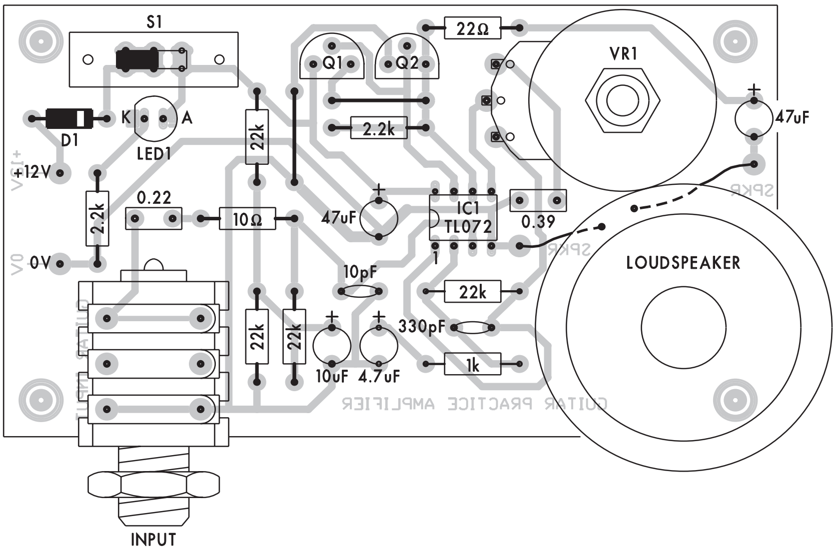
You will need these parts

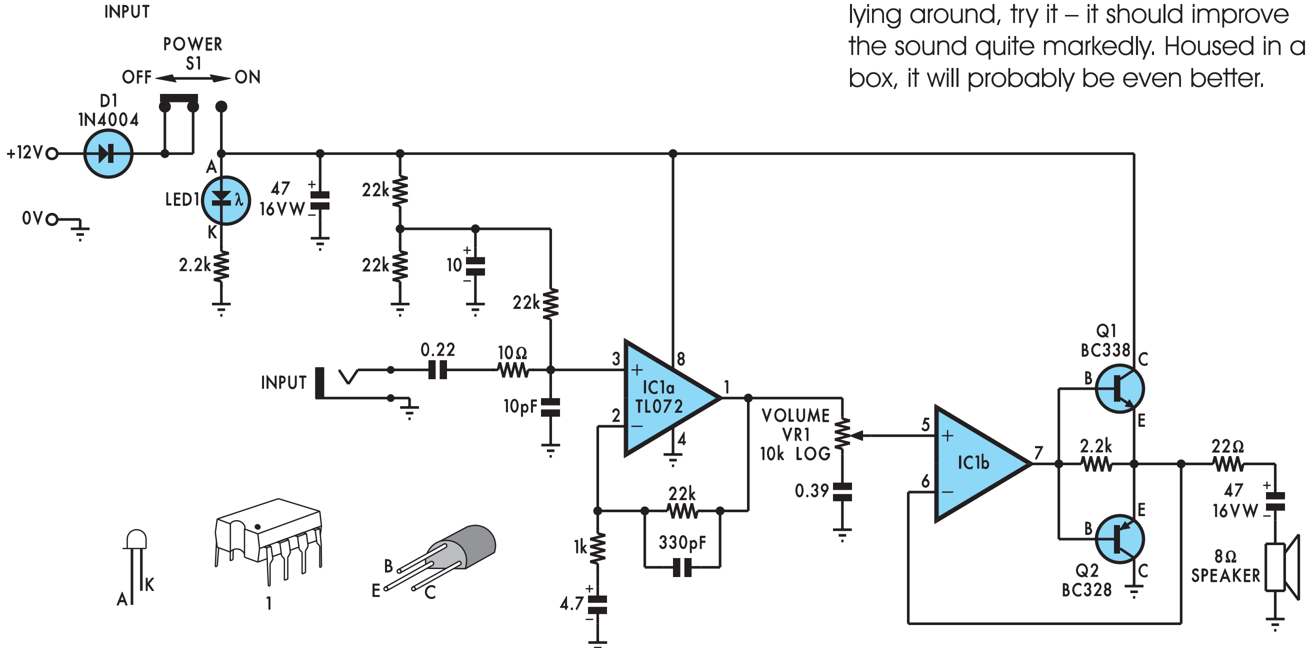
Resistors (0.25W, 1%)
4 22kΩ   2 2.2kΩ   1 1kΩ
1 22Ω   1 10Ω
1 10kΩ log potentiometer (VR1)

Capacitors
2 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 4.7µF 16VW PC electrolytic
1 0.39µF MKT polyester
1 0.22µF MKT polyester
1 330pF ceramic
1 10pF ceramic

Semiconductors
1 TL072 dual op amp (IC1)
1 1N4004 1A diode (D1)
1 BC338 NPN transistor (Q1)
1 BC328 PNP transistor (Q2)
1 5mm red LED (LED1)

Miscellaneous
1 Guitar Practice Amplifier PC board
1 SPDT slider switch (S1)
1 6.35mm PC-mount jack socket (mono or stereo)
1 40mm 8Ω Mylar cone loudspeaker
7 PC stakes
1 knob





Testing

There's not much to test – if the LED comes on when the power switch is turned on it should work.

Connect your guitar to the input socket and 12V to the power terminals. Turn it on and twang away! The volume can be adjusted with VR1. If the circuit doesn't work, re-check your component placement and soldering.

What to do next

One of the limiting factors of this amplifier is the very small and therefore rather inefficient speaker. If you have a larger, more efficient speaker lying around, try it – it should improve the sound quite markedly. Housed in a box, it will probably be even better.

TECH TALK

The circuit is basically the preamplifier from Project 21 with a power amplifier added to the output. We use a second op amp and a couple of transistors to drive a loudspeaker.

For an explanation of how the preamplifier section works, refer to Project 21. The main difference is that instead of a single op amp we use two op amps in one package.

The gain of the first op amp remains the same at 23 but instead of a coupling capacitor and socket, the output (now from pin 1) goes to the volume control potentiometer (pot). This pot is coupled to ground via a 0.39µF capacitor which prevents any direct current (DC) flowing through it. DC can make a pot go noisy. The wiper of the pot connects directly to the non-inverting input of IC1b (pin 5).

The output of IC1b drives complementary transistor pair Q1 and Q2. These transistors act as emitter followers, so called because the emitter voltage follows the base voltage. When the signal at the pin 7 output of IC1b swings above half-supply by about 0.6V, Q1 turns on and drives the 8Ω loudspeaker via a 22Ω resistor and 47µF capacitor. Similarly, Q2 turns on and drives the speaker when the signal on pin 7 of IC1b swings 0.6V below half-supply.

A 12V supply powers the circuit and diode D1 provides reverse polarity protection. Power is applied via switch S1 and a 47µF capacitor decouples or smooths the supply. The power indicator, LED1, is driven via a 2.2kΩ resistor to earth.

As with other audio projects, the best choice of 12V supply would be the regulated supply (Project 28). Using a 12V DC plugpack will probably result in hum and noise from the speaker as most plugpacks have poor filtering.

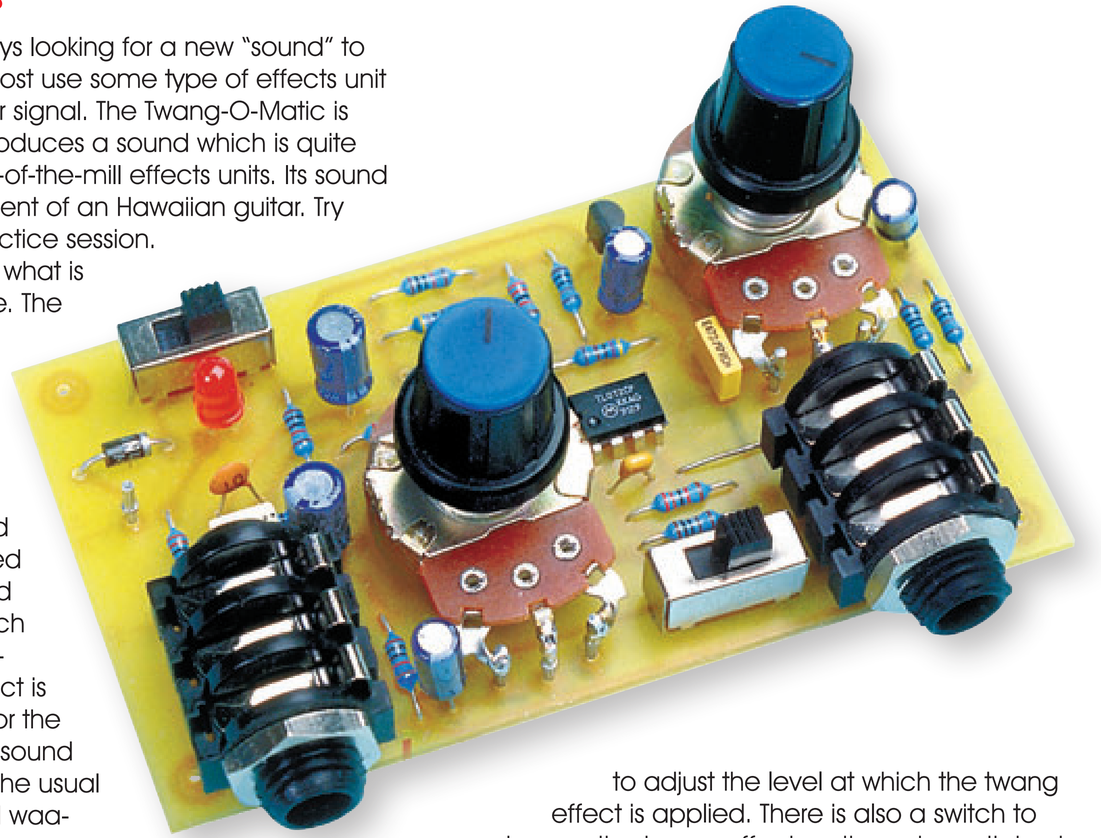
Guitar Twang-O-Matic

Looking for that distinctive guitar sound which will make your group different from all the rest? Try the Twang-O-Matic and the talent scouts will come running!

What does it do?

Guitarists are always looking for a new "sound" to add to their music. Most use some type of effects unit which alters the guitar signal. The Twang-O-Matic is one of these but it produces a sound which is quite different from the run-of-the-mill effects units. Its sound is somewhat reminiscent of an Hawaiian guitar. Try it out at your next practice session.

A guitar produces what is essentially a sinewave. The Twang-O-Matic unit alters the waveform to what only can be described as a severe type of distortion. The output waveform is amplified and half wave rectified and has a narrow and spiky waveshape which should sound particularly bad. But the effect is something different for the guitarist who wants a sound that stands out from the usual distortion, sustain and waa-waa units.



There is an "effect" control to adjust the level at which the twang effect is applied. There is also a switch to bypass the twang effect, so it can be switched in and out.

You will need these parts

Resistors (0.25W, 1%)

2 100kΩ	3 22kΩ	3 10kΩ	2 4.7kΩ
1 2.2kΩ	1 1kΩ	1 100Ω	1 10Ω

1 100kΩ log potentiometer (VR1)
1 10kΩ log potentiometer (VR2)

Capacitors

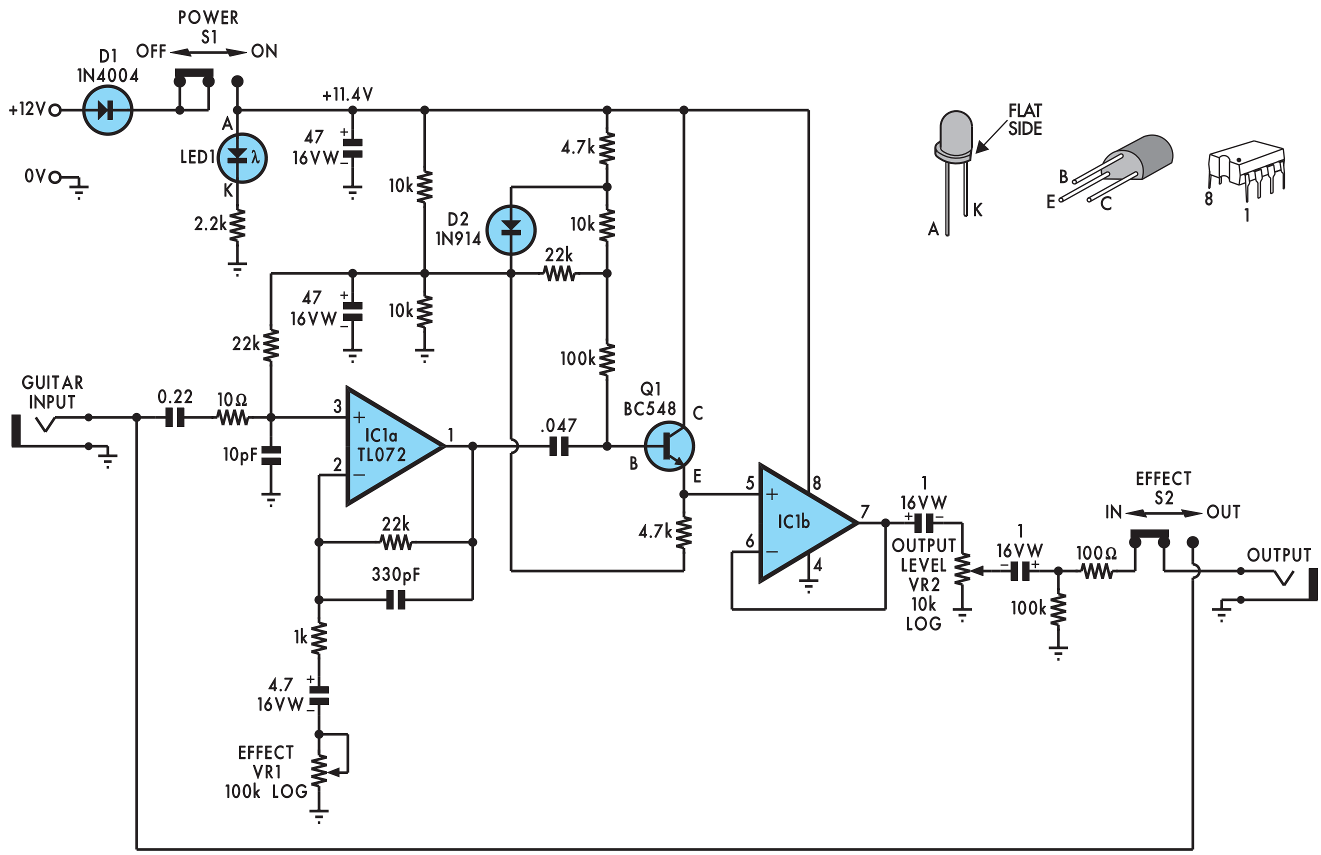
2 47µF 16VW PC electrolytic
1 4.7µF 16VW PC electrolytic
2 1µF 16VW PC electrolytic
1 0.22µF MKT polyester
1 .047µF MKT polyester
1 330pF MKT polyester or ceramic
1 10pF ceramic

Semiconductors

1 TL072 op amp (IC1)
1 BC548 NPN transistor (Q1)
1 1N4004 1A diode (D1)
1 1N914, 1N4148 signal diode (D2)
1 5mm red LED (LED1)

Miscellaneous

1 Twang-O-Matic PC board
2 knobs
2 SPDT slider switches (S1, S2)
2 6.35mm PC-mount jack sockets
8 PC stakes



Putting it together

All components are mounted on the Twang-O-Matic PC board.

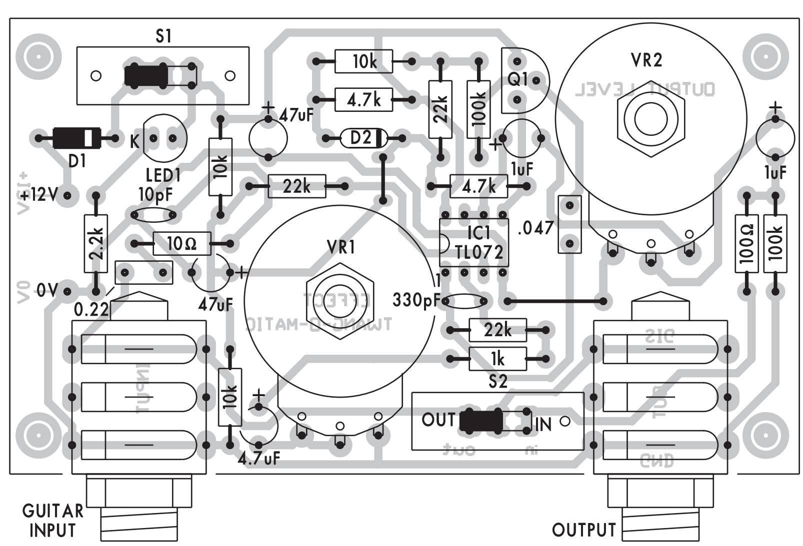
Begin construction by installing the PC stakes at the +12V and 0V positions and for the VR1 & VR2 potentiometer terminals, followed by the resistors. There are two links to be soldered in – these can be made from resistor lead cut-offs.

There are seven capacitors to be installed, some of which are electrolytic types and must go in the right way around. Similarly, the two diodes and the LED are also polarised. D2 is a small-signal diode and will usually be smaller than D1, a power diode.

IC1 can be mounted next, again taking care to orient it correctly.

Now we move on to the "hardware": switches S1 & S2 and the two 6.35mm jack sockets. All mount directly on the board. If any of these are difficult to insert, you may need to crimp or squeeze their mounting pins with a pair of pliers first.

Finally, VR1 and VR2 can be mounted as shown by soldering their terminals to the PC stakes. They are different values so be careful to ensure they aren't swapped! Soldering them to the PC stakes will be more than adequate in most cases but you could make them even more secure by placing a drop of contact cement or silicone sealant underneath them.



Checking it out

All you need to test the Twang-O-Matic is a guitar, a guitar amplifier and a 12V supply (and, of course, connecting leads). We've used 6.35mm sockets on the PC board because these are virtually the standard for guitar connection.

After checking your component placement and soldering carefully, connect a lead from the Twang-O-Matic output to your guitar amplifier input. Set the amplifier to minimum volume and apply power to both the Twang-O-Matic and your amplifier.

As you turn up the amplifier volume, you should hear virtually nothing until the volume control is well advanced, when you might hear some hum. If so, that's OK – hum is to be expected, especially when the Twang-O-Matic is not mounted in a metal box.

Turn both devices off and turn the volume control down on your amplifier. Connect your guitar to the input socket of the Twang-O-Matic.

Switch the bypass switch (S2) to "out" and reapply power to the circuit and your amplifier. Check that the guitar can be played and heard in the normal way.

Now switch the bypass switch to "in" and check that varying VR1 gives you the twang effect.

Adjust VR2 so that the same sound level from your amplifier is obtained when the effects switch is either in or out.

What to do next

As mentioned before, you may experience some hum or noise through your guitar amplifier.

The most practical way to minimise hum is to mount the Twang-O-Matic in a small metal case "earthed" to the 0V supply. This simply means connecting a short length of insulated wire between the 0V PC stake and a spade lug fixed to the box with a suitable screw, nut & washer.

You will need to drill appropriate holes in the top of the box for VR1 and VR2, along with holes in the side of the box for the input and output sockets.

The input and output sockets are robust enough to support the whole board "hanging" off them. Drill 13mm holes for the sockets and attach them to the case with their nuts.

There is no need to use nuts on VR1 and VR2 so 6.5mm holes for the pot shafts will be enough. S1 and S2 will need to be mounted off the PC board and connected to their appropriate pads with leads. LED1 could also be mounted on the top of the box instead of on the PC board.

Some provision for power will also need to be made. A small DC power socket could be fitted to the box with a matching plug on your 12V supply. If a metal socket is used, the earth wire described above is not needed as the socket earths the box.

TECH TALK

The circuit comprises an amplifier and a half-wave rectifier which only allows positive signal excursions to pass through.

Signal at the guitar input is AC-coupled via a 0.22µF capacitor to the non-inverting input of amplifier IC1a. Most op amps require positive and negative supply rails but this op amp is tricked into believing it has these rails by the voltage divider across the 11.4V supply (the two 10kΩ resistors and 47µF smoothing capacitor). The midpoint of this divider is used as a virtual earth and biases pin 3 of IC1 via a 22kΩ resistor.

The gain of this amplifier is set by the 1kΩ resistor at the inverting input (pin 2) plus the value of VR1 at the time, along with the 22kΩ resistor between pins 1 and 2. The maximum gain (when VR1 is set to minimum resistance) is 22k/1k + 1 = 23. When VR1 is set to its maximum (100kΩ), the amplifier has a gain close to unity: 22k/(1k+100k) + 1 = 1.2

The signal from the amplifier output (pin 1) is AC-coupled to transistor Q1 via the .047µF capacitor. This transistor, connected as an emitter follower (that is, the emitter voltage follows the base voltage), is partially biased on by D2 and the resistors around it.

The transistor needs to be almost turned on because if it wasn't, low level signals from IC1a would not be able to pass through and would be lost – ie, there would be gaps in the notes.

Because Q1 is biased to just on the point of conducting, even tiny positive-going signals from IC1a will make it conduct so nothing (except negative-going signals!) is lost.

This is exactly what we want – a transistor which turns on with positive-going signals and turns off with negative-going signals – in other words, it is behaving as a half-wave rectifier.

Op amp IC1b is connected as a buffer, passing the AC signal from the emitter of Q1 through to the output level potentiometer, VR2, via a 1µF capacitor. The output level pot allows you to match the Twang-O-Matic output level to that of the normal output from the guitar. That way, you can switch between straight guitar and Twang-O-Matic (using switch S2) without having to adjust the volume control on your guitar amplifier each time.

Power for the circuit is from a 12V supply with diode D1 providing reverse polarity protection. A 47µF capacitor across the supply provides a reservoir for transient loads and prevents IC1 from oscillating.

Project 24

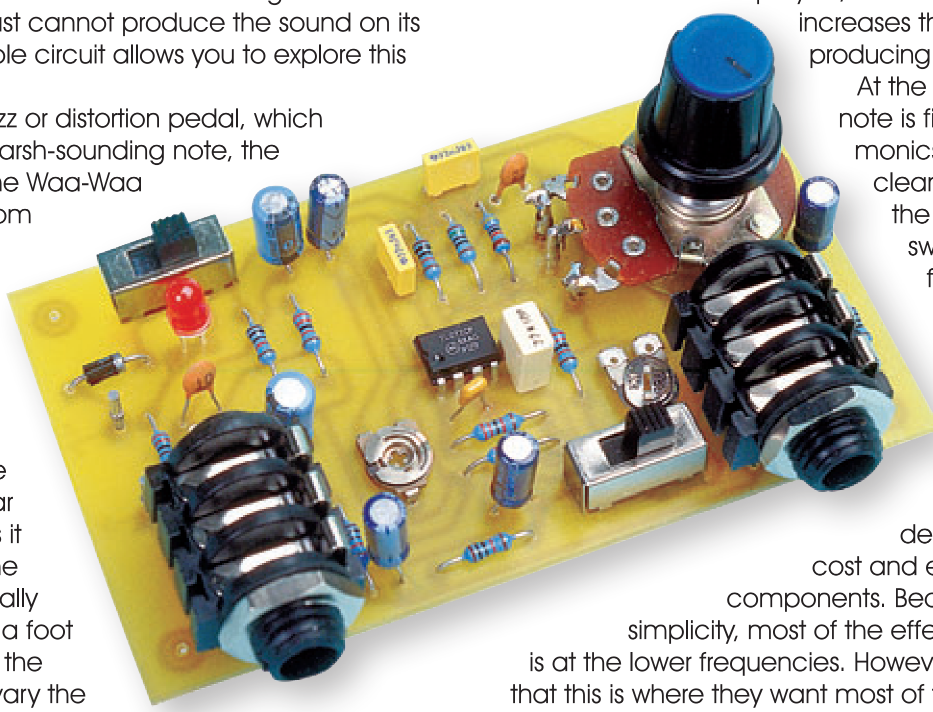
Guitar Waa-Waa

It's not the sound of a baby crying . . . but it does have some similarities. It's yet another way a guitarist can sound really distinctive!

What does it do?

Waa-Waa has always been a popular effect with guitarists. It is one of the classic guitar sounds but a guitar just cannot produce the sound on its own. This simple circuit allows you to explore this sound effect.

Unlike a fuzz or distortion pedal, which produces a harsh-sounding note, the sound from the Waa-Waa circuit is far from harsh. The name "Waa-Waa" really expresses just how it does sound.



The circuit takes the note from the guitar and reshapes it to produce the effect. It's usually controlled by a foot pedal so that the guitarist can vary the amount of "waa" to suit the music or the mood while playing.

The foot pedal controls the centre frequency of a sharp bandpass filter. When this filter is moved over the frequency of the note being played, the volume suddenly increases then decreases, producing the "Waa" sound. At the same time, the note is filtered of harmonics, making it a cleaner sound. But as the bandpass filter is swept higher up the frequency band, those harmonics can be heard again.

The filter circuit in this Waa-Waa unit is a very simple design, using low-cost and easily obtainable components. Because of its simplicity, most of the effect on the sound is at the lower frequencies. However, guitarists say that this is where they want most of the Waa-Waa effect.

This project presents only the electronics, not the foot pedal. This is available as a commercial item, or you could make your own.

You will need these parts

Resistors (0.25W, 1%)

1 470kΩ 4 22kΩ
4 10kΩ 1 2.2kΩ
1 150Ω 1 100Ω
1 10Ω
1 10kΩ linear potentiometer (VR1)
1 100kΩ horizontal trimpot (VR2)
1 10kΩ horizontal trimpot (VR3)

Semiconductors

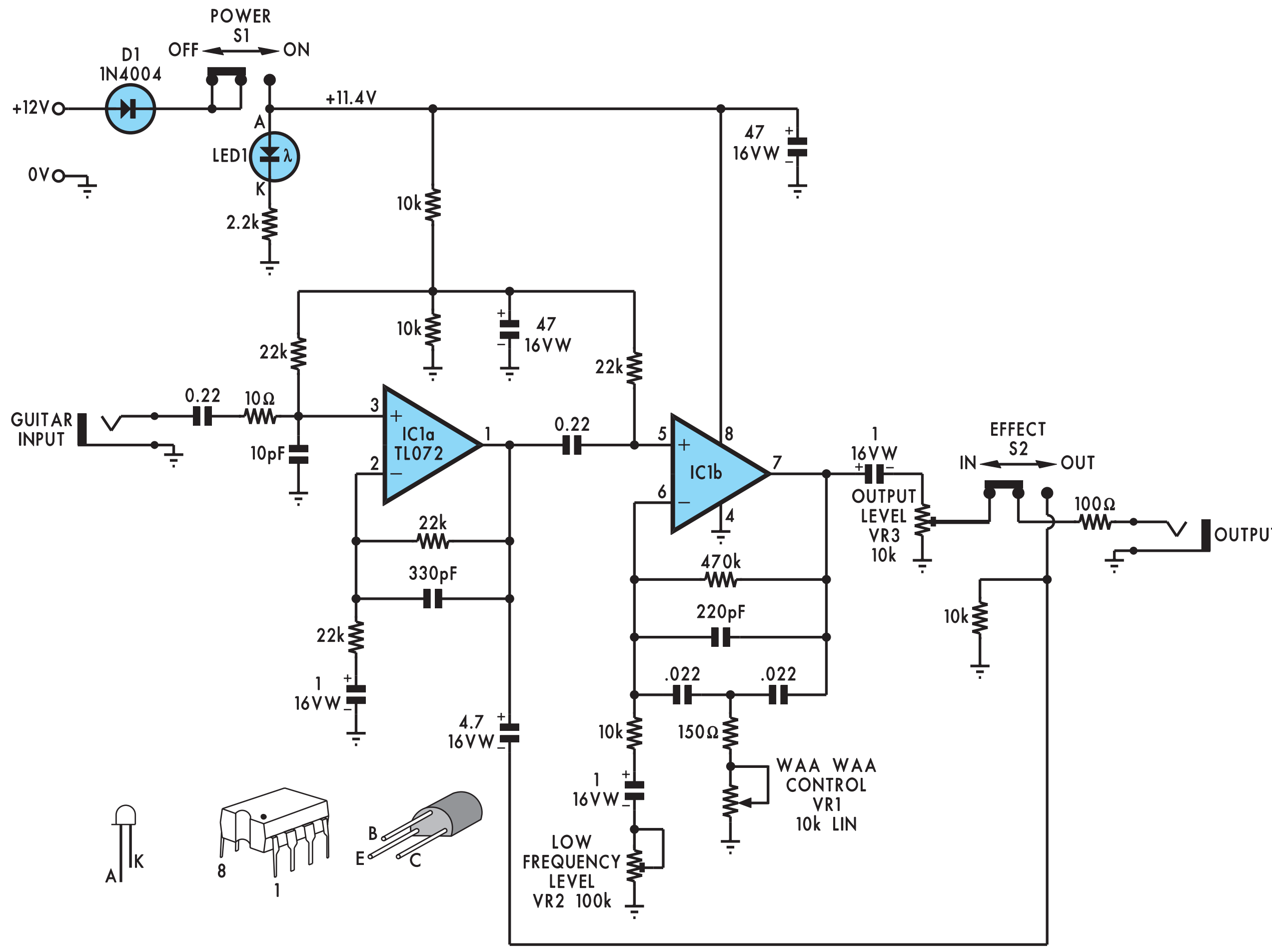
1 TL072 op amp (IC1)
1 1N4004 1A diode (D1)
1 5mm red LED (LED1)

Capacitors

2 47µF 16VW PC electrolytic
1 4.7µF 16VW PC electrolytic
3 1µF 16VW PC electrolytic
2 0.22µF MKT polyester
2 .022µF MKT polyester
1 330pF ceramic
1 220pF ceramic
1 10pF ceramic

Miscellaneous

1 Waa-Waa PC board
2 SPDT slider switches (S1, S2)
2 6.35mm PC-mount jack sockets (mono or stereo)
5 PC stakes



Construction

All components are mounted on the Waa-Waa PC board.

Begin construction by installing all the resistors, followed by the five PC stakes (at the 12V, 0V and VR1 terminals).

The capacitors can be installed next, taking care to orient the electrolytic types correctly. When these are in, you can install trimpots VR2 & VR3. Note that these have different values – the 100kΩ trimpot is usually marked with a 104 designation, while the 10kΩ trimpot usually has a 103 marking.

You can now install the three semiconductors: the diode, the LED and the IC. All of these are polarised so double check that they have been installed the right way around before soldering.

Finally, the "hardware" is mounted. First, switches S1 & S2 and the two 6.35mm jack sockets are placed on the PC board and soldered in.

Potentiometer VR1 is left until last as it is the largest component. Its terminals are soldered to the PC stakes but for additional security, a dab of super glue or contact cement on the PC board under the back of the pot would be a good idea.

Checking it out

First, plug your guitar into your guitar amplifier to make sure it can be heard (that is, used in the normal way – just to make sure).

Now disconnect the guitar lead from the amplifier and plug it into the input socket on the Waa-Waa unit. Connect another 6.35mm jack lead (ie, standard guitar lead) from the output socket to your amplifier.

Now connect 12V DC power to the circuit, switch S2 to "effect out", switch S1 on and check that the guitar can still be heard from your guitar amplifier speaker. If not, check that the power LED is on and that your plugs are all the way in. If it still doesn't work, have a closer look at your soldering and component placement and orientation.

Assuming you can hear your guitar through the speaker, switch S2 to "effect in" and adjust VR1 as you play to obtain the waa-waa effect.

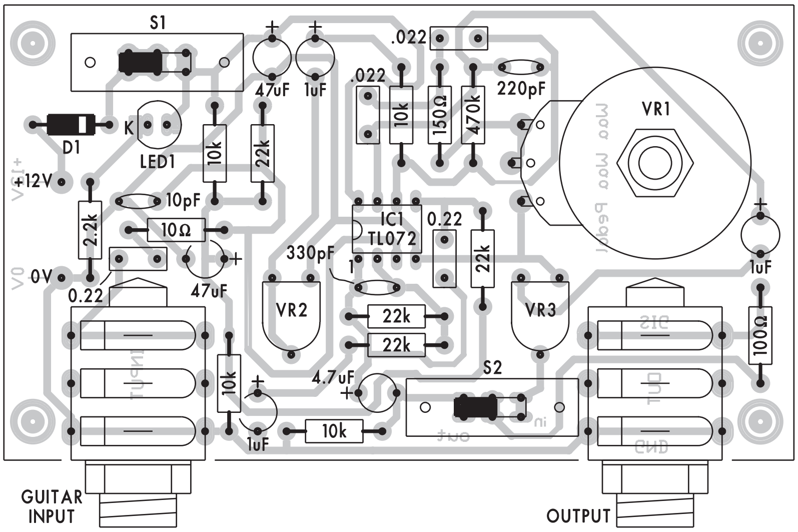
Adjust VR2 so that the waa-waa volume at low frequencies is at about the same level as obtained for the higher frequencies.

When VR1 and VR2 are set up, adjust VR3 so that the same sound level is obtained when the effects switch (S2) is in either position.

What to do next

Using a knob to control the amount of waa-waa is OK in theory but in practice, you'll find you suddenly need to grow a third hand!

That's why most waa-waa units use a spring-loaded foot pedal to control them. Foot pedals are not particularly difficult to make – all you need to do is convert the up-down action of the pedal to control a potentiometer. The easiest way to do this is to use a "slider" potentiometer which can be linked directly to the pedal .



Alternatively, some pedals have the potentiometer mounted as the "axle" between the moving and non-moving parts of the pedal. Keep in mind, though, that you are probably only going to get about 30° of movement in the pedal whereas the pot might have nearly 300° of rotation.

Possibly the easiest way around the problem is to buy a cheap commercial foot pedal (maybe a secondhand one from a music store or pawn shop) and if necessary change its potentiometer for the correct value used in this Waa-Waa circuit (10kΩ linear).

In some cases, you may even be able to fit the guitar Waa-Waa PC board inside the foot pedal, obviously with suitable holes drilled for the input and output sockets and switches S1 and S2. Otherwise, the board should be mounted in a case, preferably metal, for protection.

The case should be earthed back to the 0V PC stake via a short length of hookup wire (the input and output sockets are plastic and will not earth the case).

TECH TALK

The circuit has two parts, each based around half of a TL072 dual op amp. The first amplifier, IC1a, is just that; an amplifier. The second amplifier, IC1b, and its associated components form the bandpass filter.

Signal from the guitar is AC-coupled to amplifier IC1a via a 0.22µF capacitor. The gain for this stage is set at two by the 22kΩ resistors connected to the inverting input, pin 2. The 10Ω resistor and 10pF capacitor at pin 3 suppress any radio frequencies which may be picked up by the guitar leads.

The 1µF capacitor connecting one of the 22kΩ resistors to ground provides AC-coupling, which allows the amplifier to be biased at about half-supply. The half-supply is derived by two 10kΩ resistors connected in series across the 11.4V supply. This is decoupled or smoothed by a 47µF capacitor.

The output from IC1a is AC-coupled via a 0.22µF capacitor to pin 5 of IC1b. This input is also biased to the same half-supply rail as IC1a, via a 22kΩ resistor. The gain of the filter is set by the 470kΩ feedback resistor and the components from pin 6 to ground. VR2 is used to adjust the gain of the amplifier at low frequencies so that it matches the gain at high frequencies.

The filter section comprises the two .022µF capacitors and the 150Ω resistor in series with VR1. This is called a half-T filter (see how the two capacitors form the top of the letter "T" while the resistor and pot form the leg). It can be tuned over the range from about 50Hz to 1.4kHz by adjusting VR1.

The 220pF capacitor across this filter rolls off the high frequency response in an effort to provide a similar filter bandpass response across the usable frequency range. VR2 is adjusted to boost gain at low frequencies to match the gain provided at the high frequency end.

The output from the filter is AC-coupled via a 1µF capacitor to trimpot VR3. This is adjusted so that the signal level from the waa-waa filter matches the "bypass" signal from IC1a's output. That way, when you switch between waa-waa and bypass with switch S2, you don't have to adjust the volume of your guitar amplifier.

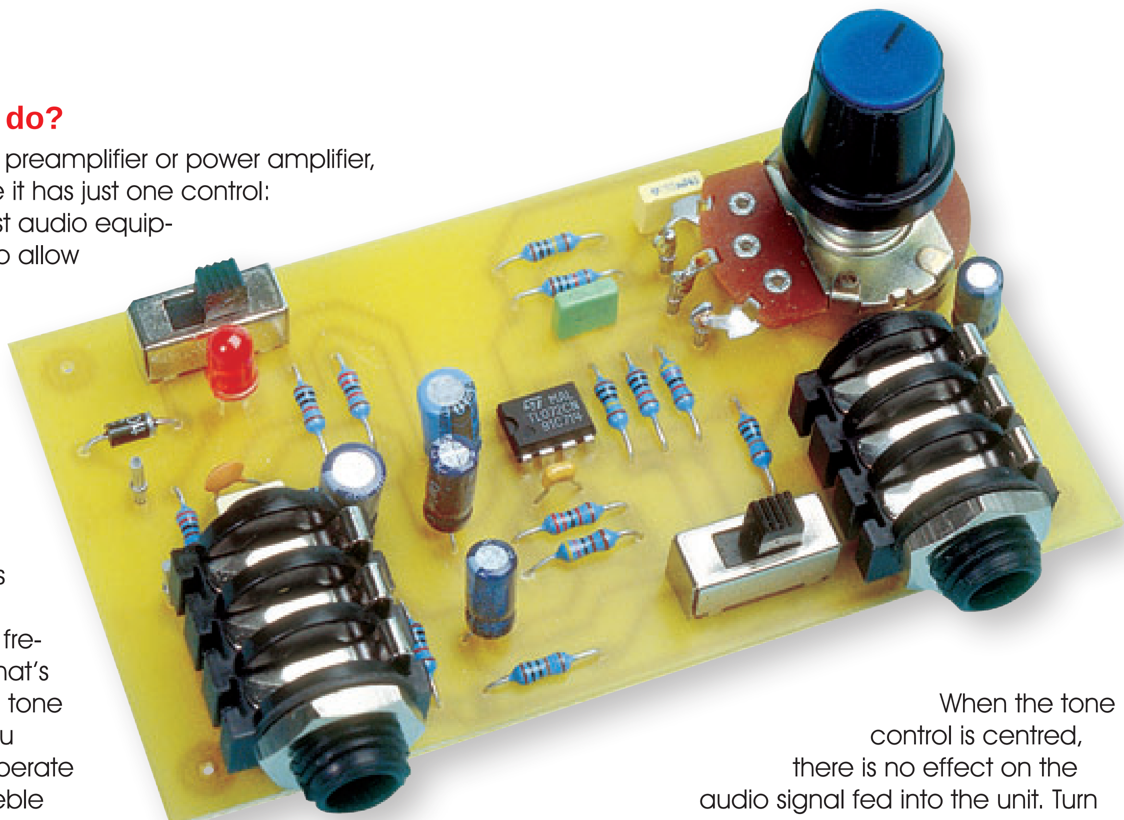
Power for the circuit is from a 12V source, with diode D1 providing reverse polarity protection. Switch S1 applies power and LED1 indicates when the power is on.

Finally, the 47µF capacitor across the supply provides a reservoir for transient loads and helps prevent IC1 oscillating.

Project 25

Universal Tone Control

Is the sound from your guitar or other source not quite the way you like it? Add a tone control and adjust it to what you want!



What does it do?

If you build a preamplifier or power amplifier, the chances are it has just one control: volume. Yet most audio equipment should also allow you to adjust the tone as well.

Adding a tone control can enhance the sound by brightening up or cutting the high frequencies and boosting or cutting the bass frequencies. And that's exactly what this tone control does: you can build it to operate at the bass or treble frequencies by changing two component values.

This tone control is intended mainly for guitar use but there is absolutely nothing to stop you from using it with any other audio source.

When the tone control is centred, there is no effect on the audio signal fed into the unit. Turn the control clockwise and the bass or treble will be boosted; anticlockwise and the bass or treble level will be reduced.

You can obtain a maximum boost or cut of 12dB at either the 64Hz bass frequency or the 8kHz treble frequency.

You will need these parts

Resistors (0.25W, 1%)

2 1MΩ	2 100kΩ
1 47kΩ	2 22kΩ
4 10kΩ	1 4.7kΩ
1 2.2kΩ	1 100Ω
1 10Ω	

1 100kΩ linear pot. (VR1)

Capacitors

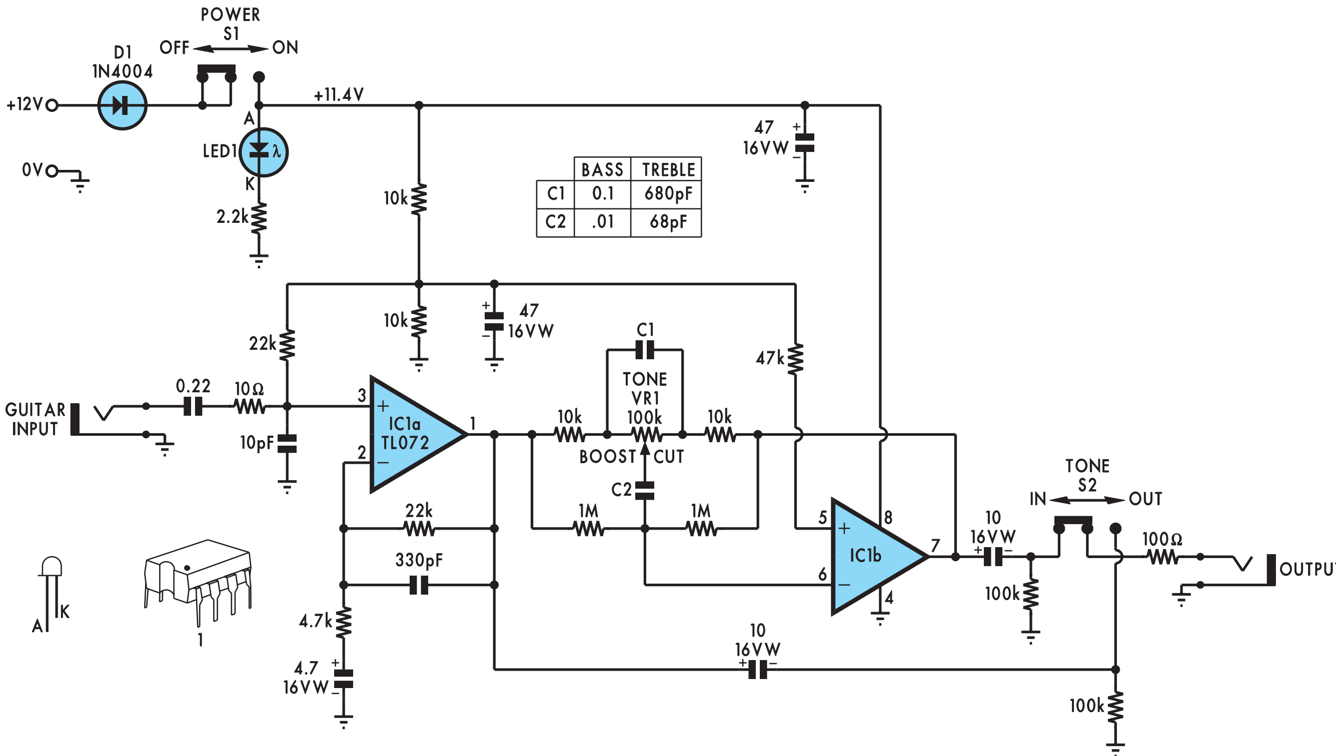
2 47µF 16VW PC electrolytic
2 10µF 16VW PC electrolytic
1 4.7µF 16VW PC electrolytic
1 0.22µF MKT polyester
1 0.1µF MKT polyester
1 .01µF MKT polyester
1 680pF MKT polyester or ceramic
1 330pF MKT polyester or ceramic
1 68pF ceramic
1 10pF ceramic

Semiconductors

1 TL072 op amp (IC1)
1 1N4004 1A diode (D1)
1 5mm red LED (LED1)

Miscellaneous

1 Tone Control PC board
2 SPDT slider switches (S1, S2)
2 6.35mm PC mount jack sockets (mono or stereo)
5 PC stakes



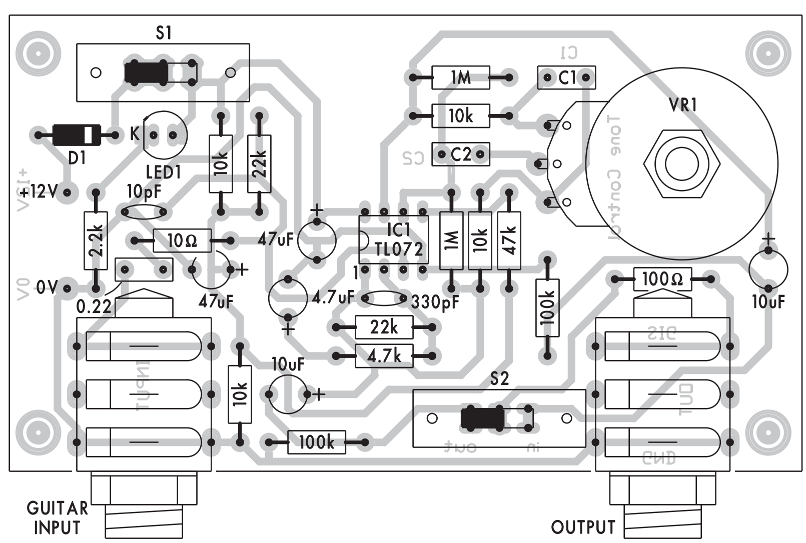
	BASS	TREBLE
C1	0.1	680pF
C2	.01	68pF

Construction

All components mount on the Tone Control PC board. If you wish, you could mount the PC board in its own plastic case but the more usual approach would be to mount it in the same case as the amplifier or preamplifier.

Begin construction with the five PC stakes (12V and 0V plus the three for the potentiometer connections), followed by the resistors.

Before any of the capacitors are inserted, you need to decide whether you are building a treble tone control or a bass tone control. For the bass version, C1 and C2 need to be 0.1μF and .01μF respectively, while the treble version has C1 and C2 as 680pF and 68pF respectively. Fit these and then install all the other capacitors.



There are five electrolytic capacitors so be careful with polarity.

Next come the diode and LED and finally, as far as the small devices are concerned, the IC. Once again, take care with the polarity of these components.

Switches S1 & S2, along with the two 6.35mm jack sockets, are mounted directly on the PC board. While the parts list calls for SPDT (single pole, double throw) switches, in all likelihood DPDT (double pole, double throw) types will be supplied in a kit. The PC board pattern can accommodate either type – the DPDT contacts are bridged to effectively make the switch an SPDT type. The 6.35mm jack sockets actually sit proud of the board.

Finally, VR1 is mounted as shown by soldering its terminals to the PC stakes. If you wish, a drop of contact adhesive on the PC board under the back of VR1 will make it even more rigid.

Testing

Before connecting the tone control to your amplifier, apply power to the circuit and make sure LED1 lights when the switch is turned on. Now turn the tone control off.

Most guitars use a standard 6.35mm jack lead to connect to an amplifier input, so the tone control uses the same size leads. You will need a second lead to connect the tone control to the amplifier.

Turn the tone control back on and check that the guitar can still be heard through the amplifier (or any other audio source can be heard).

Adjust VR1 to ensure that the tone changes. If it doesn't, the chances are you have S2 switched to the "out" position.

The final check is that S2 does indeed switch the tone control in and out of circuit without the volume significantly changing.

What to do next

To complete your project and add that "professional" touch, you could mount the tone control in its own plastic or metal case. Like all projects in this book, the PC board is designed to fit into the standard Jaycar 130 x 67 x 44mm Jiffy box (Cat. HB-6013).

The most logical method of mounting would be with the shaft of VR1 emerging through the top and the input and output sockets from the side. If you do this, you will also need to mount S1, S2 and the LED on the top of the box on flying leads. Keep the leads as short as practical to make sure they don't tangle on anything inside the case.

However, the more usual method of mounting would be to place the tone control in the same case as the amplifier. You may even be able to obtain the 12V power source from the amplifier.

If your amplifier doesn't have 12V available but has, say, 15V or 18V (very common in preamplifier stages), you could add a 12V regulated supply to the amplifier – see Project 28.

Naturally, if building the tone control into your amplifier, you would need to make some arrangement for access to the switches, input socket and of course the tone control pot itself. The output could be wired direct to the amplifier input using screened cable.

What if you want bass AND treble control . . . or stereo? The first is easy! Build another tone control and run the output from one into the input of the other.

The second is even easier – simply build a second tone control for the other channel.

TECH TALK

Signals from the audio source (eg, guitar, preamplifier, etc) are AC-coupled to op amp IC1a via a 0.22µF capacitor and 10Ω resistor. IC1a's gain is set at 5.6 by the 22kΩ and 4.7kΩ feedback resistors at the pin 2 inverting input.

High-frequency rolloff at 21kHz is provided by the 330pF capacitor across the 22kΩ feedback resistor while the low frequency rolloff at 7Hz is set by the 4.7µF capacitor connecting the 4.7kΩ resistor to ground. The 10Ω resistor and 10pF capacitor at the input suppress any radio frequencies which could otherwise enter via the input leads.

Op amps generally need to operate from a positive and negative supply rail. Here, though, the op amp is tricked into believing that to be the case by the half-supply rail formed by the two 10kΩ resistors between the positive supply and ground. This rail is decoupled, or smoothed, with a 47µF capacitor.

As well as connecting to the signal input, pin 3 also connects to the half-supply rail via a 22kΩ resistor.

The output from IC1a is applied to op amp IC1b via the tone control circuitry. Effectively, this circuitry is connected in the feedback loop for IC1b, between its output at pin 7 and the inverting input at pin 6.

The values used for C1 and C2 determine the frequency of operation for the tone control, VR1. When VR1 is centred, the circuit is balanced and so no boost or cut is provided. When VR1 is adjusted either up or down, there is an imbalance in the circuit and so more or less boost or cut can be obtained at the tone control frequency.

This circuit arrangement is called a "gyrator" and is used in graphic equalisers to obtain the required boost or cut for each band of frequencies.

The output from IC1b is AC-coupled to switch S2, which selects between tone in and out: tone in when IC1b's output is selected and tone out when the output from IC1a is connected to the output, effectively bypassing the tone control stage.

You can also effectively bypass any tone control effects by centring VR1. However, having a separate switch means that you can quickly switch it in and out at will.

Project 26

Guitar Sustain Unit

Playing an electric guitar without a sustain unit is like eating icecream without the chocolate topping. Add this sustain unit now and make your guitar sound more fulfilling.

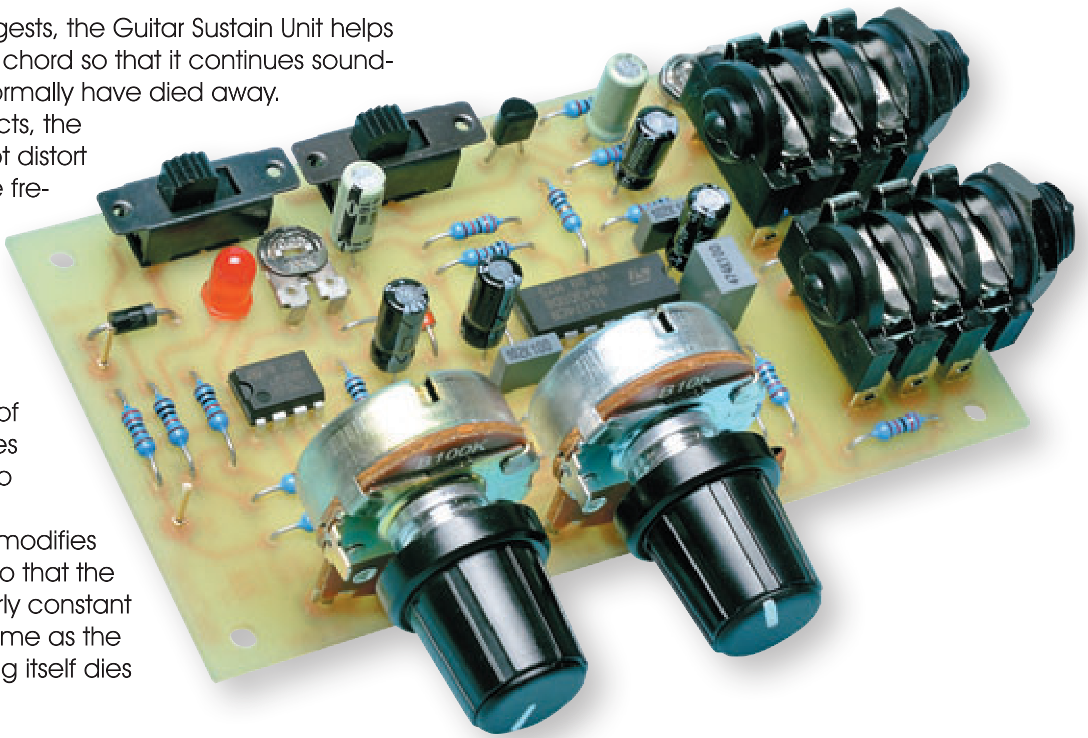
What does it do?

As its name suggests, the Guitar Sustain Unit helps to sustain a note or chord so that it continues sounding after it would normally have died away.

Unlike other effects, the sustain unit does not distort the tone, shape the frequency response or modulate the envelope.

When you pluck the string on your guitar, it initially produces a high level of oscillation which dies away fairly quickly to nothing.

A sustain pedal modifies this natural decay so that the volume remains fairly constant for a set period of time as the sound from the string itself dies away to nothing.



You will need these parts

Resistors (0.25W, 1%)

1 100kΩ	1 47kΩ	3 22kΩ
3 20kΩ	6 10kΩ	1 2.2kΩ
1 1kΩ	2 100Ω	1 10Ω

1 10kΩ linear PC-mount pot. (VR1)
1 100kΩ linear PC-mount pot. (VR2)
2 100kΩ linear trimpots (VR3, VR4)

Capacitors

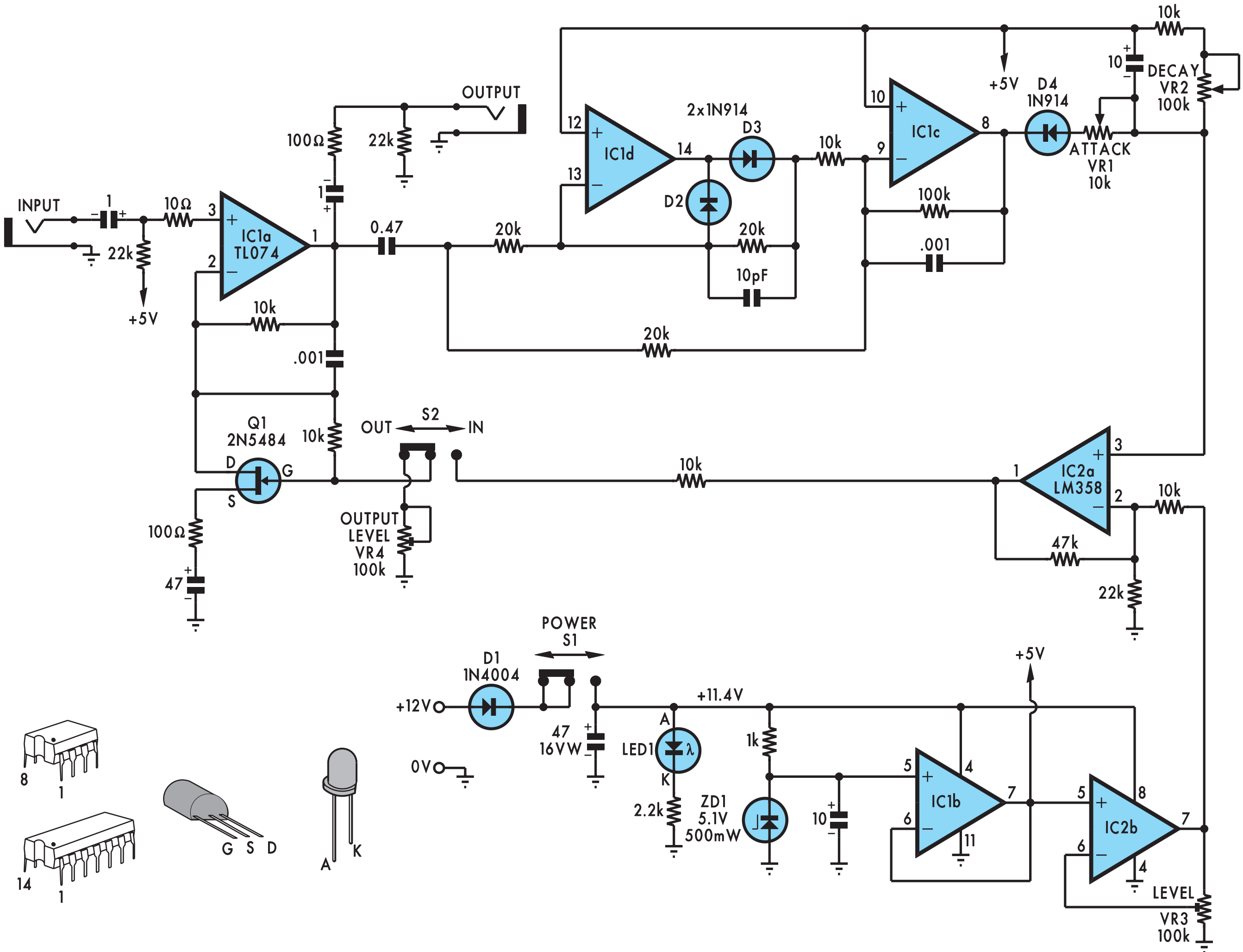
2 47µF 16VW PC electrolytic
2 10µF 16VW PC electrolytic
2 1µF 16VW PC electrolytic
1 0.47µF MKT polyester
2 .001µF MKT polyester
1 10pF ceramic

Semiconductors

1 TL074, LF347 quad op amp (IC1)
1 LM358 dual op amp (IC2)
1 2N5484 Mosfet (Q1)
1 1N4004 1A diode (D1)
3 1N914, 1N4148 signal diodes (D2-D4)
1 5.1V 400mW zener diode (ZD1)
1 5mm red LED (LED1)

Miscellaneous

1 Guitar Sustain Unit PC Board
2 SPDT slider switches (S1, S2)
2 6.35mm PC-mount mono unswitched sockets
2 knobs
2 PC stakes



Construction

All components mount onto the Guitar Sustain PC board. Start by installing and soldering in all the resistors and the two links, which can be made from resistor lead cutoffs. Next, insert and solder the two PC stakes, followed by all the capacitors. Ensure the electrolytic types go in the right way around.

The semiconductors can be installed next – diodes D1-D4, zener diode ZD1, the FET and the ICs.

Finally, mount the hardware – trimpots VR3 and VR4, switches S1 and S2, the input and output sockets and finally the attack and decay pots, VR1 and VR2. These pots mount side-on to the PC board as shown.

Testing

It's always wise to first connect your guitar to your amplifier in the normal way just to make sure that it is working properly.

If all is OK, take a few minutes to check your PC board to ensure that there is nothing inserted in the wrong place or with the wrong polarity and, just as important, that your soldering is up to scratch. There are some very close pads on this PC board and it would be easy to get a solder bridge between them. Remember the old saying: faulty components are rare; faulty soldering is not!

Once checked visually, connect a 12V supply to the appropriate PC stakes. Without connecting your guitar just yet, turn S1 on and check that the LED lights. Measure the voltage between pin 4 of IC1 and the 0V stake to ensure that there is about +11.4V. The same reading should be made between pin 8 of IC2 and 0V – but don't short any IC pins together with your multimeter probe!

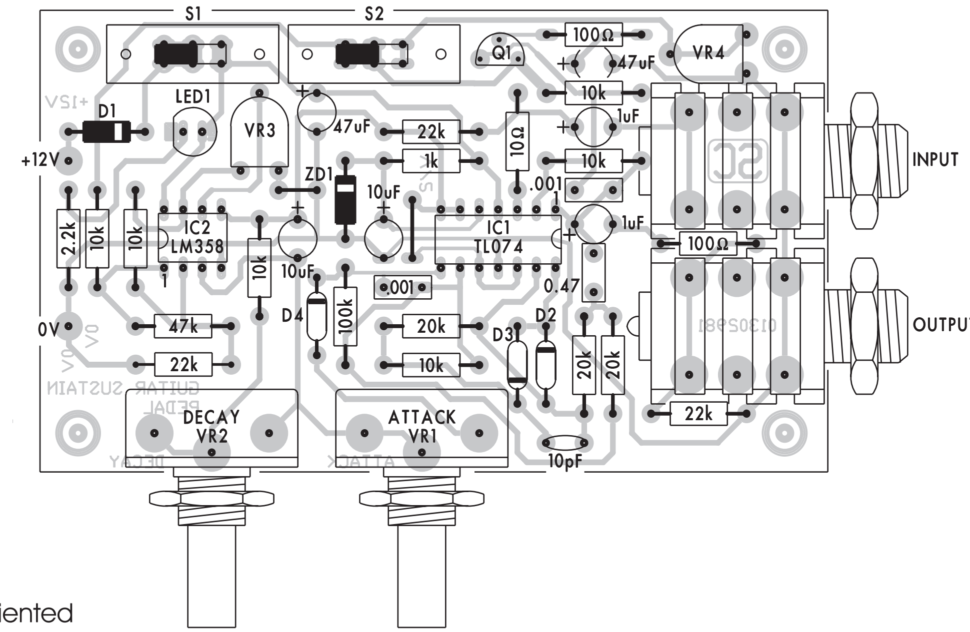
There should be about +5V between each of pins 6, 7, 10 & 12 of IC1 and 0V and between pin 5 of IC2 and 0V.

You are now ready to test the sustain unit with your guitar. Plug your guitar into the input socket and connect a standard (6.35mm) lead between the output socket and your guitar amplifier.

Switch slider S2 away from S1 and play a few notes. You may need to adjust VR4 to get the same volume as before. Now slide S2 towards S1 so that the sustain unit is in circuit.

Adjust VR3 for best effect on sustain. You may also need to adjust the volume level from your guitar to suit the input range of the sustain unit, which operates best between 10mV and 200mV.

Adjust the attack control to set the rate at which the note is reduced in volume when the string is first plucked. Also adjust the decay rate to ensure that the note volume is maintained throughout most of its decay.



What to do next

As with all of these guitar-oriented projects, the PC board really needs to be housed in a case (preferably metal) for protection – especially if you play in a band!

A metal case will also help to shield the unit from hum and noise pickup (and RF, too, especially if you use radio microphones). Any metal case should be earthed back to the "0V" stake via a suitable (short) length of hookup wire.

While you don't need to adjust the attack and decay controls once set, different styles of music and indeed playing call for different rates. That's why the attack and decay controls are adjustable.

To finish them off properly, cut the shafts to suitable length (clamp the shafts in a vyce to cut them) and fit a couple of knobs to suit.

The effects in-out switch can be replaced by a foot switch to make it easy to operate; indeed the whole unit can be built inside a foot switch case. Or you could even build this unit into the same foot pedal case as the Waa-Waa Unit (Project 24), sharing the same 12V power supply. The effects in-out switch can be mounted on the non-moving part of the foot pedal case so that you can simply tap it with your foot to turn the unit on and off. Just make sure you use a heavy duty foot switch!

TECH TALK

This is a fairly complex circuit. To make it easier to understand, the block diagram below shows the circuit broken down into its various circuit sections.

The signal from the guitar is applied to a gain controlled amplifier. This is an amplifier whose gain is controlled by an external voltage.

As well as providing the output to the guitar amplifier, this also provides a signal which is full-wave rectified and then filtered to produce the DC control voltage. This voltage depends on the signal level at the output of the gain controlled amplifier and is compared in an error amplifier to a reference voltage set by potentiometer (VR3). The output from the error amplifier is applied back to the gain controlled amplifier which uses this to maintain a constant output.

There are six op amps in the circuit, four in IC1 and two in IC2. Q1 is a junction FET which varies the gain of IC1a in response to the control voltage.

Unlike other op amps used in projects in this book, the op amp circuitry here is biased at a fixed 5V using zener diode ZD1. This is supplied with current via a 1kΩ resistor from the 11.4V rail.

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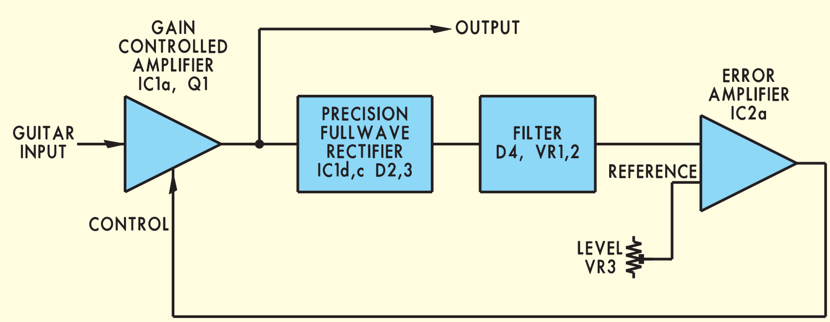


TECH TALK CONTINUED

This results in a regulated supply, much better than one derived from a voltage divider. The regulated supply is filtered with a 10µF capacitor and then buffered with op amp IC1b. This results in a very stable bias supply.

Signal input from the guitar is AC-coupled to the non-inverting input of IC1a via a 1µF capacitor. The 22kΩ resistor biases the pin 3 input to 5V while the 10Ω resistor at IC1a's input helps prevent any radio frequency pick-up from the guitar leads.

In most circuits, the gain of the amplifier is set by the ratio of two resistors. In this circuit, the gain of IC1a is not fixed but is set by the 10kΩ feedback resistor and the value of the resistance between the drain and source of Q1 which is in series with a 100Ω resistor and 47µF capacitor. The resistance between Q1's drain and source varies in accordance with the voltage applied to the gate.

The 47µF capacitor provides low frequency rolloff, while high frequency rolloff above about 16kHz is provided by the .001µF capacitor between pins 1 & 2.

The output signal from IC1a goes to two places. First of all, it is AC-coupled via a 1µF capacitor and 100Ω resistor to the output socket. But it is also connected to the rest of the circuit via the 0.47µF capacitor. Nothing after this point changes the signal; rather the signal itself is monitored by the rest of the circuit.

IC1c and IC1d in conjunction with diodes D2 and D3 and associated resistors form the full-wave rectifier. When the input signal goes negative, the output of IC1d goes high, forward biasing D3. The gain, as set by the 20kΩ input and 20kΩ feedback resistors, is -1 (ie, unity gain but the signal at the output is inverted with respect to the input).

Because D3 is forward biased, this signal is seen at the cathode of D3 and is coupled to the inverting input (pin 9 of IC1c) via the 10kΩ resistor. The gain for IC1c is set at -10 by this 10kΩ input resistor and the 100kΩ feedback resistor (100kΩ/10kΩ). The overall gain for the input signal is therefore -1 x -10 = +10.

However, there is an extra path for the input signal, via the 20kΩ resistor connected to pin 9 of IC1c. This signal path gives a positive signal at the output of IC1c with a gain of -5 (100kΩ/20kΩ).

Adding the two gains, +10 and -5, gives us +5. Since the input signal is negative, the voltage at the pin 8 output is also negative.

For positive signals, the output of IC1b is clamped because D2 conducts. The signal then passes via the 20kΩ resistor connecting to pin 9 of IC1c. IC1c inverts this signal and provides a gain of -5. Since the input signal is positive the signal at pin 8 of IC1c is negative.

Thus for positive inputs, the output goes negative with a gain of 5, and for negative signal inputs, the output also goes negative with a gain of 5. Therefore we have a full-wave rectifier.

The 10pF capacitor across the 20kΩ feedback resistor for IC1d prevents instability, while the .001µF capacitor across the 100kΩ feedback resistor of IC1c gives a measure of filtering.

The full-wave rectified signal is filtered using D4, VR1, VR2, the 10kΩ resistor and the 10µF capacitor. Diode D4 allows the 10µF capacitor to be charged via VR1 but only discharged using VR2 and the series 10kΩ resistor. This allows separate control over the attack and decay times.

Attack is the time the circuit waits after the note is plucked before acting; decay is the length of time for which the circuit maintains the note volume.

IC2a is the error amplifier and its pin 3 input monitors the rectified signal from D4 and the 10µF capacitor. Its pin 2 input is connected to the reference level voltage from trimpot VR3 and op amp IC2b. VR3 sets the level of the "sustained" signal and IC2a drives the gate of FET Q1 so that this "sustained" signal is maintained by IC1a.

If that sounds confusing, let's summarise the circuit operation.

IC1a handles the signal from the guitar and its gain is controlled by FET Q1 which acts like a variable resistor in the feedback network of Q1. The precision rectifier circuit monitors the signal output from IC1a and the DC voltage from it is compared by the error amplifier against the reference level from IC2b, as set by VR3.

If the output from IC1a is too low, IC2a drives the gate of Q1 harder to increase the signal gain. Conversely, if the signal output from IC1a is too high, IC2a reduces the drive to Q1. This increases its resistance, and so the signal output is reduced.

Obviously, this process can't go on forever, because eventually the guitar signal drops right away. But the sustain circuit does maintain the signal for much longer than would otherwise occur.

Switch S2 selects sustain in or out. When set to the "in" position, the voltage from pin 1 of IC2a controls Q1's gate. When S2 is in the "out" position, the gate is held at a voltage set by VR4 and the 10kΩ resistor between gate and drain.

In use, trimpot VR4 is adjusted to give the same volume when the guitar string is first plucked, regardless of switch position.

Power for the circuit is derived from a 12V source. Diode D1 protects against accidental reverse polarity connection, while the 47µF capacitor decouples the supply. LED1 indicates that power is present when S1 is switched on.

Project 27

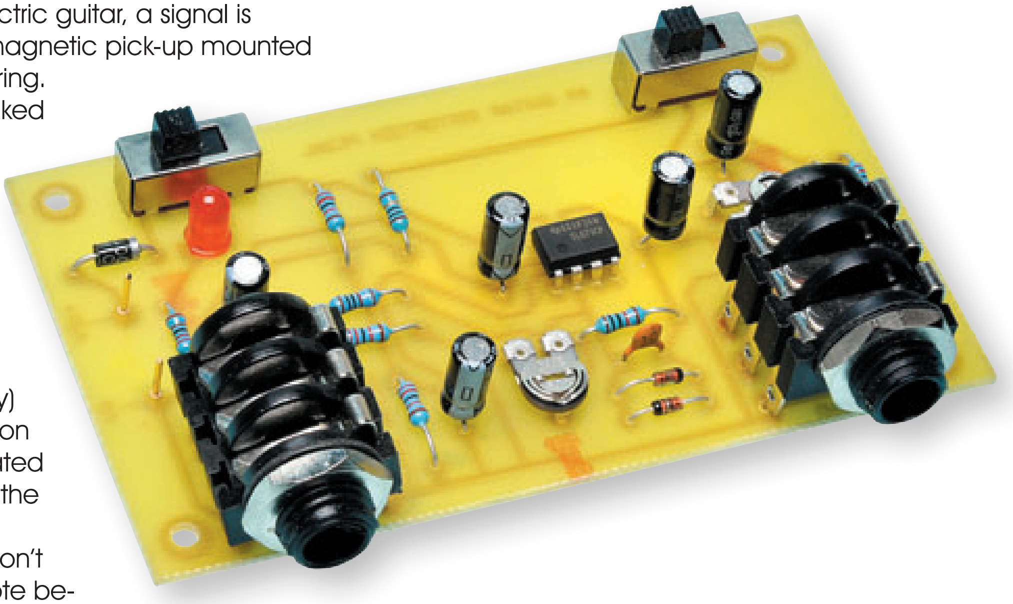
Guitar Distortion Unit

Distortion is something we try very hard to eliminate in hifi amplifiers. But guitarists love adding a bit of distortion to make their music sound a bit different.

What does it do?

When you play an electric guitar, a signal is induced into an electromagnetic pick-up mounted immediately under the string.

When the string is plucked or struck, it vibrates – strongly at first, then dies away. This is called "decay" – the frequency remains the same but the vibration decreases over time.



The signal generated by the pick-up is (normally) a quite faithful reproduction of the acoustic note created within the hollow body of the guitar – except that most modern electric guitars don't produce any acoustic note because they are solid!

The guitar output signal is usually a fairly low level (about 50mV or so) and requires a significant amount of amplification to enable it to be heard. It is also mostly a fundamental tone, approaching a sinewave in pattern. Because of this, there isn't much in the way of harmonics, or multiples of the fundamental tone, in the signal.

Between the guitar and the amplifier, we can play a few tricks with the signal to make it sound quite different. One of those tricks is distortion.

In this case, we deliberately create a "third harmonic" of the original signal and add it back in, creating a note which sounds rather harsher than the original.

At the same time, we can introduce some sustain effect, which keeps the signal at much the same level for much of the time that the guitar string is vibrating even though the sound level is decaying away.

A depth control trimpot changes the sustain threshold signal level and the amount of distortion produced.

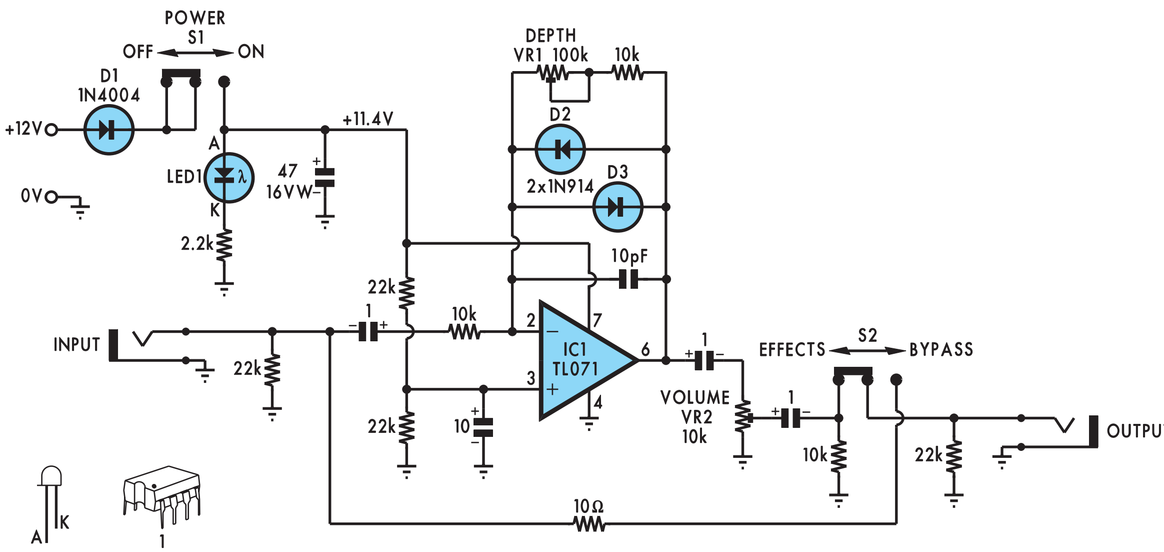
You will need these parts

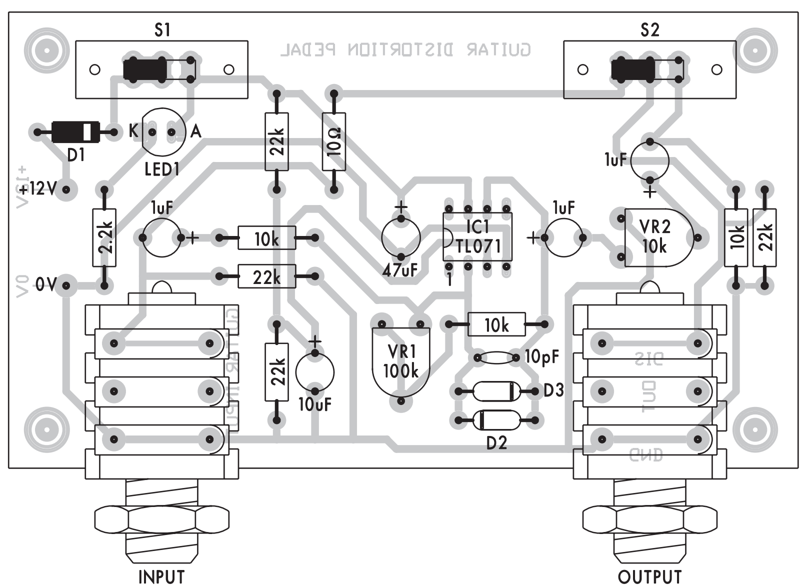
Resistors (0.25W, 1%)
4 22kΩ 3 10kΩ
1 2.2kΩ 1 10Ω
1 100kΩ horizontal trimpot (VR1)
1 10kΩ horizontal trimpot (VR2)

Capacitors
1 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
3 1µF 16VW PC electrolytic
1 10pF ceramic

Semiconductors
1 TL071 op amp (IC1)
1 1N4004 1A diode (D1)
2 1N914, 1N4148 signal diodes (D2, D3)
1 5mm red LED (LED1)

Miscellaneous
1 Guitar Distortion Unit PC board
2 SPDT slider switches (S1, S2)
2 6.35mm PC-mount jack sockets (mono or stereo)
2 PC stakes





Construction

All the parts for the Guitar Distortion Unit are mounted on a PC board.

Begin by installing PC stakes for +12V and 0V supply connections, then install all the resistors and capacitors (take care with the polarity of electrolytics) and the two trimpots (VR1 & VR2).

Note that the trimpots have different values; the 10kΩ volume control (usually labelled 103) is the one immediately above the output socket while the trimpot labelled 104 is the 100kΩ depth control in the middle of the PC board.

When mounting the semiconductors (D1-D3, IC1 and the LED), again watch the polarity. The small signal diodes, which mount the opposite way around to each other, are smaller than the power diode.

Finally, mount the hardware. You may need to crimp or squeeze the switch mounting pins with pliers if you find they don't fit properly. The PC board pattern allows for left or right mounting sockets – only one set is used, depending on which type of socket you have.

Checking it out

After carefully checking both your component placement and soldering, connect a 6.35mm lead (standard guitar lead) from the output socket to your guitar amplifier, connect 12V power to the appropriate PC stakes, turn the volume control on your guitar amplifier to minimum and turn the distortion unit on.

When you turn up the amplifier volume control, you will probably hear some hum and noise. That's OK. Turn the volume control back down, turn the distortion unit off and plug your guitar into the input socket.

Set S2 to "bypass" and, even with the unit turned off, you should be able to play your guitar in the normal way. Now turn the unit on, switch S2 to "effects" and with suitable adjustment to VR1, you should find the guitar sounds completely different. It might take some experimentation to find the right position for VR1 – that's entirely a matter of taste. Finally, adjust VR2 so that the same sound level is obtained when the effects switch (S2) is either in or out.

TECH TALK

The circuit is basically an amplifier (op amp IC1) which begins to clip the signal when it reaches a certain level. This clipping introduces distortion by rounding off the positive and negative excursions of the original waveform.

A half-supply rail for the op amp is produced by the two 22kΩ resistors in series across the supply rails. This connects to IC1's non-inverting input and is bypassed with a 10µF capacitor.

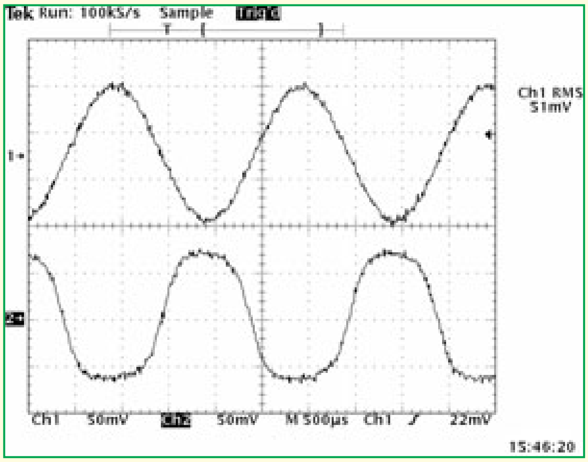
The signal input is AC-coupled to the amplifier via a 1µF capacitor. The gain is set by the 10kΩ resistor at the inverting input (pin 2) and the feedback components between pins 2 and 6.

At low signal levels the gain is set by the 10kΩ resistor and the setting of VR1. When VR1 is set to minimum (0Ω), the amplifier has a gain of -1 (10kΩ/10kΩ) and when set to its maximum (100kΩ), the gain is increased to -11 (110kΩ/10kΩ). Note that the minus sign of the gain only refers to the fact that the signal is inverted compared to the original; it does not mean a loss.

When the signal level between pins 2 and 6 reaches about 0.7V peak in the positive or negative direction, diodes D2 & D3 begin to conduct, reducing the gain of the amplifier. The result is a signal that appears clipped because of the variation in the gain of the amplifier as the signal level is increased.

The accompanying oscilloscope waveforms demonstrate this effect by showing what happens to the waveform before and after passing through the distortion unit.

The top waveform is a sinewave with a level of about 50mV RMS. The peak-to-peak amplitude of the waveform is 150mV. The lower waveform shows the output of the distortion unit.



Note how the peaks and troughs of the waveform are more rounded off compared to the original waveform and that the actual peak-to-peak level is reduced to about 140mV.

Trimpot VR1 varies the gain of the amplifier at low levels, thus setting the signal level at which clipping commences. The higher the gain setting, the greater the lower signal levels will be distorted. Therefore this trimpot can be regarded as an adjustment for distortion depth.

The output from IC1 is AC-coupled via a 1µF capacitor to volume trimpot VR2. This allows the distorted signal level to be matched to the original signal level, which in turn allows distortion to be switched in or out (using switch S2) without affecting the signal level driving the amplifier. Without this control, the amplifier volume would need to be adjusted each time S2 was moved.

Power for the circuit is from a nominal 12V source with diode D1 providing reverse polarity protection. S1 switches the power on and off and LED1 indicates when the power is on.

What to do next

Like similar guitar projects, hum and noise might be a problem. The most practical way to minimise hum is to mount the Guitar Distortion Unit in a small metal case "earthed" to the 0V supply. This simply means connecting a short length of insulated wire between the 0V PC stake and a spade lug fixed to the box with a suitable screw, nut & washer.

The metal box could be a sloping foot-pedal type box with S2 being a heavy duty push on/push off switch actuated by the guitarist's foot. You will need to drill appropriate holes in the side of the box for the input and output sockets. These sockets are robust enough to support the whole PC board "hanging" off them. Drill 13mm holes for the sockets and attach them to the case with their nuts.

S1 and S2 will need to be mounted off the PC board and connected to their appropriate pads with leads. LED1 could also be mounted on the top of the box instead of on the PC board. S1 and LED1 could be left out if you want to make the wiring simpler (don't forget to put a short across S1's pads on the PC board).

Some provision for power will also need to be made. A small DC power socket could be fitted to the box with a matching plug on your 12V supply.

If a metal DC power socket is used, the earth wire described above is not needed as the socket earths the box. The metal body must connect to 0V.

Project 28a&b

Regulated 12V Supplies

Most circuits don't care what the exact supply voltage is – near enough is good enough. But there are some circuits where it really does matter and that's where a regulated supply is required.

What does it do?

Most power supplies do not give a particularly constant output voltage. They either vary over time (usually because the voltage from a power point varies over time) or they vary as the current drawn from them varies (as the current goes up, the voltage usually goes down). In most cases, this doesn't matter because the circuit is designed to take these variations into account.

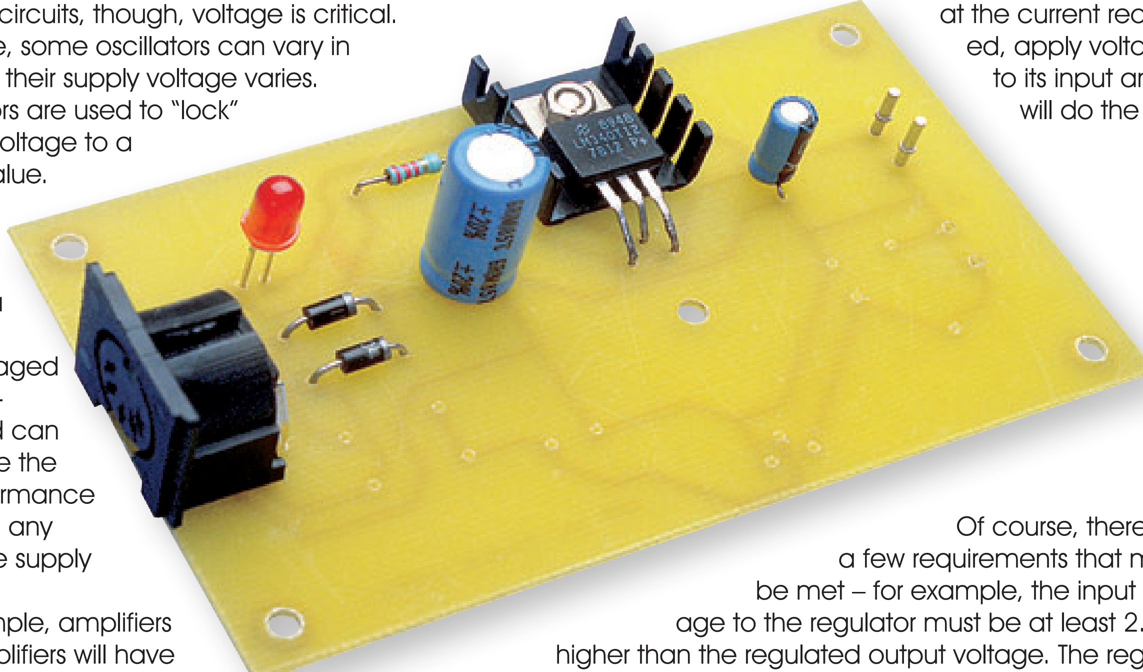
In some circuits, though, voltage is critical. For example, some oscillators can vary in frequency if their supply voltage varies.

Regulators are used to "lock" the supply voltage to a particular value. Regulators can also be used to prevent a circuit from being damaged due to overvoltage and can also improve the circuit performance by reducing any ripple on the supply rails.

For example, amplifiers and preamplifiers will have less hum in the signal output if powered from a regulated supply rather than from a DC plugpack, many of which have considerable ripple on the supply rail. DC plugpacks are also notorious for output voltage variations with load variations.

There are regulated DC plugpacks available – you might be surprised to find most would have a circuit almost identical to the one we are building here, crammed inside the case.

Building a fixed-voltage regulated supply these days is very easy through the use of 3-terminal regulators. You simply select the regulator which gives the output voltage required at the current required, apply voltage to its input and it will do the rest!



Of course, there are a few requirements that must be met – for example, the input voltage to the regulator must be at least 2.5V higher than the regulated output voltage. The regulator shouldn't be overloaded but even if it is, no harm will be done – the regulator will simply shut down until the overload is removed or it cools down to a safe level, after which it will continue working normally.

Providing we keep the regulator operating within its limits, it will keep working away.

You will need these parts

Resistors (0.25W, 1%)
1 2.2kΩ

Capacitors
1 1000µF 25VW PC electrolytic
1 10µF 16VW PC electrolytic

Semiconductors
1 7812 or LM340T12 12V regulator (REG1)
2 1N4004 1A diodes (D2, D4)
1 5mm red LED (LED1)

Miscellaneous
1 12V Power Supply PC board
1 mini heatsink, 20 x 20 x 10mm
1 3-pin or 5-pin PC-mount DIN socket
1 screw and nut
4 PC stakes
Small amount of heatsink grease

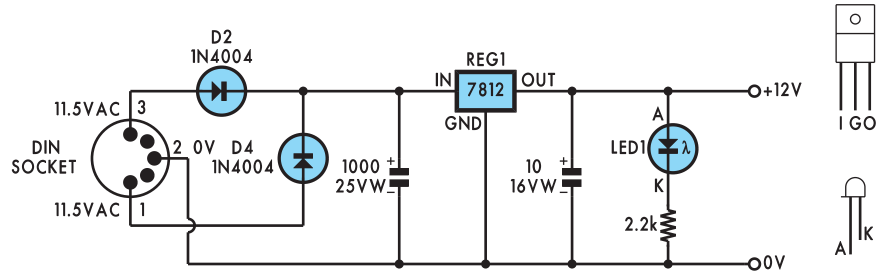
Construction

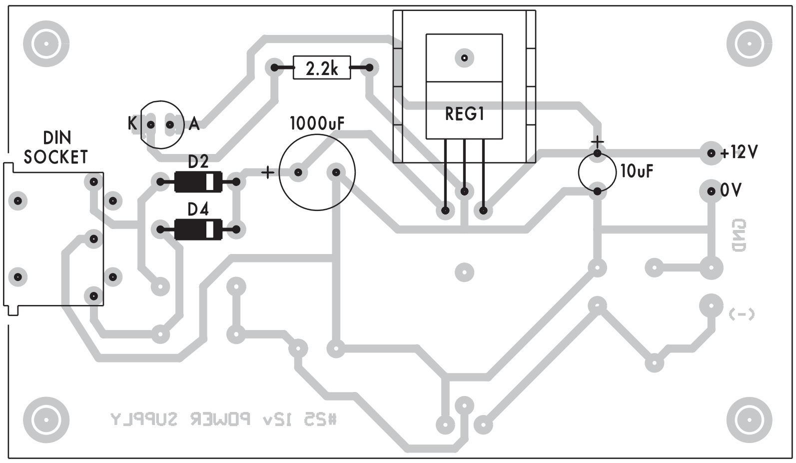
The parts for the 12V Power Supply are mounted on the Power Supply PC board. This board is designed to accommodate some extra components which we'll talk about shortly. So for this project, expect a few spare holes when assembling the board.

Start by inserting the PC stakes for the DC output. The only non-polarised component is the 2.2kΩ resistor, so make sure that all the other components are oriented as shown. Check that the pins of the DIN socket are all the way through the PC board before soldering them.

The regulator is mounted onto the small heatsink and secured to the board with a 3mm screw and nut which goes through both the heatsink and regulator. Bend the leads of the regulator so that they fit into their mounting holes. As with any component fitted to a heatsink, a smear of heatsink compound (or thermal grease) between the mating surfaces will assist heat transfer.

No insulation is required between the regulator and the heatsink as long as nothing else touches the heatsink.





Testing

After checking component placement and soldering, plug the transformer (see Tech Talk) into the input socket and check that the LED lights when the mains power is on and that you obtain a 12V output. Due to manufacturing tolerances, the output can be from 11.5V to 12.5V but we've found they are usually close to 12V.

TECH TALK

This circuit is designed to use the Jaycar MP-3055 transformer (pictured) which has two 11.5V AC, 1.25A secondary windings. It has the advantage that all the wiring is pre-connected and enclosed, making it very safe to use. The output comes from a 3-pin DIN plug with the two windings connected to form a centre tap (at pin 2).

Diodes D2 & D4 form a full-wave rectifier to produce a DC voltage across the 1000µF capacitor. This capacitor ensures a relatively smooth DC rail and the voltage across it with the specified transformer is around 16VDC.

That's right, the DC output voltage across the smoothing capacitor is higher than the AC voltage from the transformer. How come? All is explained in the panel "Where Do the Extra Volts Come From?"

This DC voltage is applied to the regulator input and a smooth 12V DC comes from the output. If you like, the regulator simply "lops the top" off the applied voltage, giving an output free of the variations at the top of the applied-waveform.

The LED and its associated resistor have a dual purpose: as well as indicating power on, they also give the regulator a minimum load at all times.

The only other component is a 10µF capacitor across the output. This is called a "bypass" capacitor and it helps further smooth the output of the regulator and also prevents the regulator from oscillating. One disadvantage of these regulators is that they are prone to high frequency oscillation if very small values of capacitance are connected to the output. This can even be in the form of the leads connecting the output of the regulator to your circuit (all leads have some capacitance). The 10µF capacitor effectively swamps the effect of the small capacitance.

What to do next

What if you need a positive and negative supply? Many circuits require positive and negative (dual) supply rails – that is, one supply rail is +12V with respect to the 0V terminal and the other supply rail is -12V with respect to 0V.

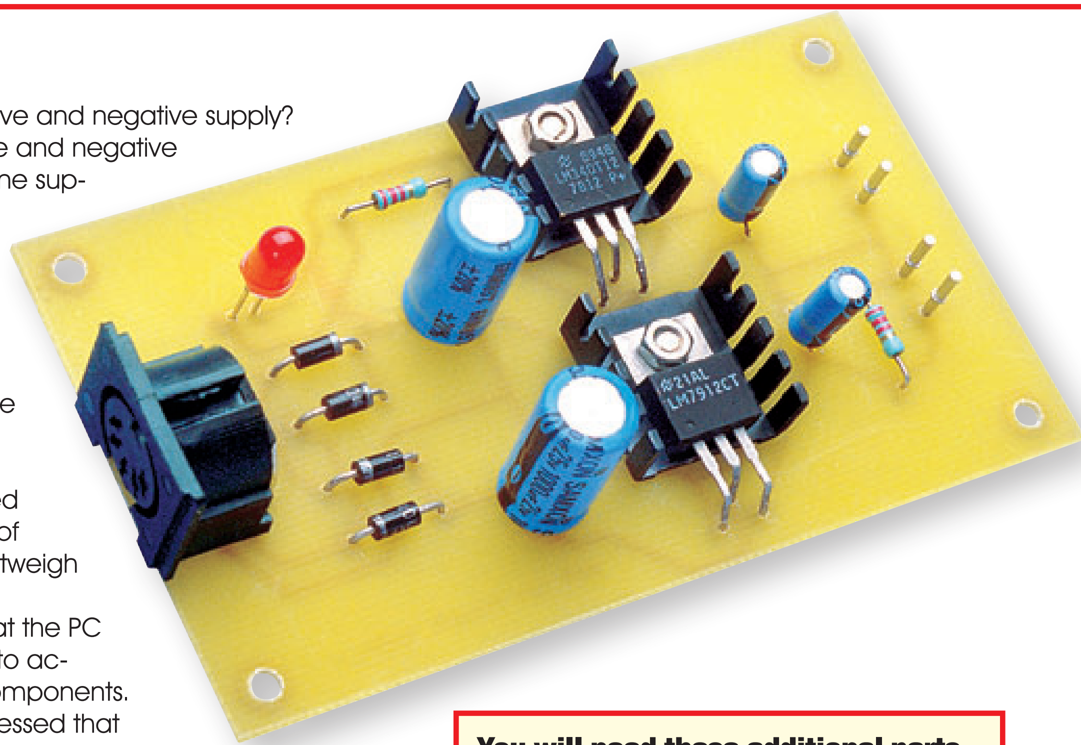
Op amps and amplifiers are examples of circuits which usually need a positive and negative supply rail.

Sometimes circuits can operate from an unregulated supply but the advantages of adding a regulator often outweigh the extra cost.

We mentioned earlier that the PC board had been designed to accommodate a few extra components. You've probably already guessed that those components might be for a dual regulated supply.

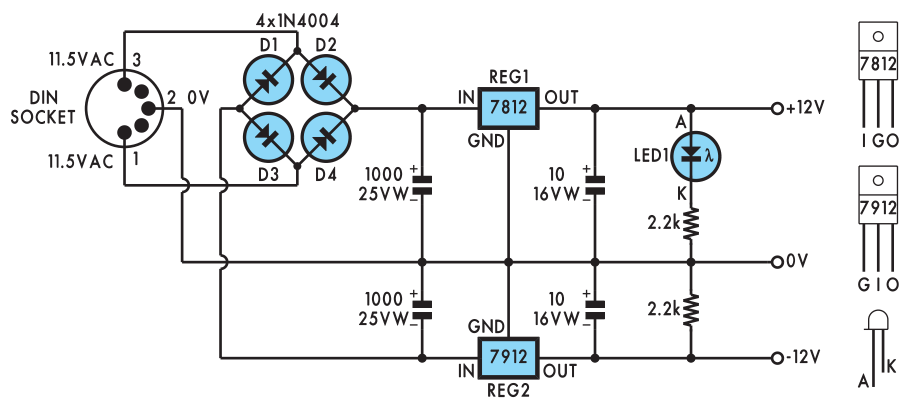
The best part, though, is that only six additional components are needed.

And just in case you were wondering if you could build a dual supply and only use the positive side for projects needing a single +12V/0V supply, the answer is yes, you can. For the cost of just two diodes, a regulator, two capacitors and a resistor, you will have a much more versatile supply, too!



You will need these additional parts

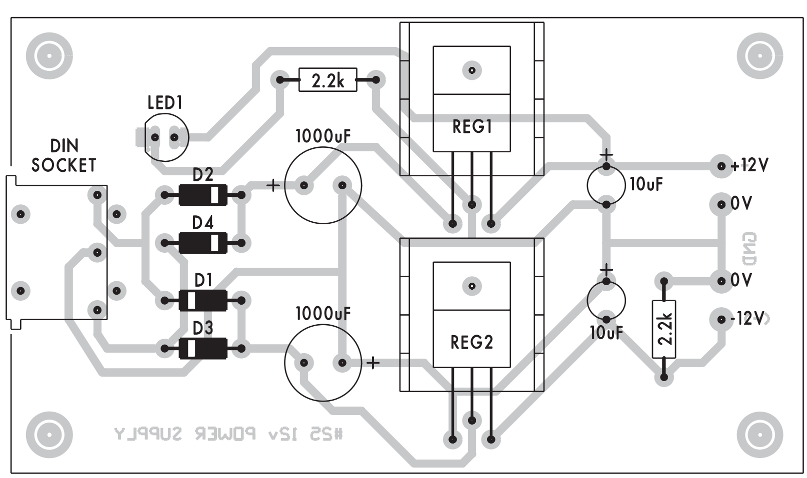
1 7912 negative 12V regulator (REG2)
2 1N4004 1A diodes (D1, D3)
1 1000µF 25VW PC electrolytic capacitor
1 10µF 16VW PC electrolytic capacitor
1 2.2kΩ 0.25W resistor



Construction

Follow the same order of construction as for the single regulator. Note the differences: D1 and D3 are included but their direction is reversed compared to D2 and D4 and there are two additional electrolytic capacitors, an additional resistor and an additional regulator.

Mount the regulator the same way as previously but ensure the two heatsinks do not touch each other, or anything else.



Testing

Follow a similar testing procedure as for the single rail version. You should get a reading very close to 12 volts when you measure between +12V and 0V, and 0V and -12V. Across the +12V and -12V outputs, ignoring 0V, your multimeter should read very close to 24V.

TECH TALK

The same transformer powers the dual supply as for the single supply. Diodes D2 & D3 conduct on one half cycle of the mains waveform and charge their respective 1000µF capacitors, while D1 & D4 conduct on the other half cycle to charge the same two capacitors. Therefore, both halves of the cycle are rectified, hence the term "full wave" rectifier.

Both capacitors are charged to around 16V so that we end up with +16V, 0V and -16V rails. The +16V rail goes to the input of 3-terminal regulator REG1, while the -16V rail is applied to REG2.

The negative regulator works in exactly the same way as the positive regulator described previously – except, of course, its output is -12V with respect to ground.

As before, the output of each regulator is bypassed with a 10µF capacitor. REG1 still has the "power on" LED and resistor across its output but REG2 just has a 2.2kΩ resistor to provide a minimum load.

WHERE DO THE EXTRA VOLTS COME FROM?

Have you ever wondered why you get a higher DC voltage output than the AC voltage supplied from the transformer?

It can be very confusing to anyone new to electronics to find that a circuit requiring, say, 15V DC to operate only needs a transformer with a 12V AC secondary. Can you really get something for nothing? It all happens because of the way voltages are measured.

When talking about a constant DC (direct current) voltage, there can be no confusion. That's because the voltage is just that – constant.

But the only constant thing about an AC voltage is that it is constantly changing. It starts off at zero, builds to a maximum or peak, returns to zero, then goes below zero, builds to a minus peak, returns to zero . . . and starts all over again.

So what does your multimeter measure? The vast majority of multimeters are calibrated to display what is called the "root mean square" (RMS) voltage. It's a type of average, taking into account the positive and negative voltage swings.

If we connected a heating element across a 100V RMS AC source we would find that it heated to exactly the same temperature as if we connected the element across a 100V DC source. That's handy to remember – they both represent the same amount of energy or work value.

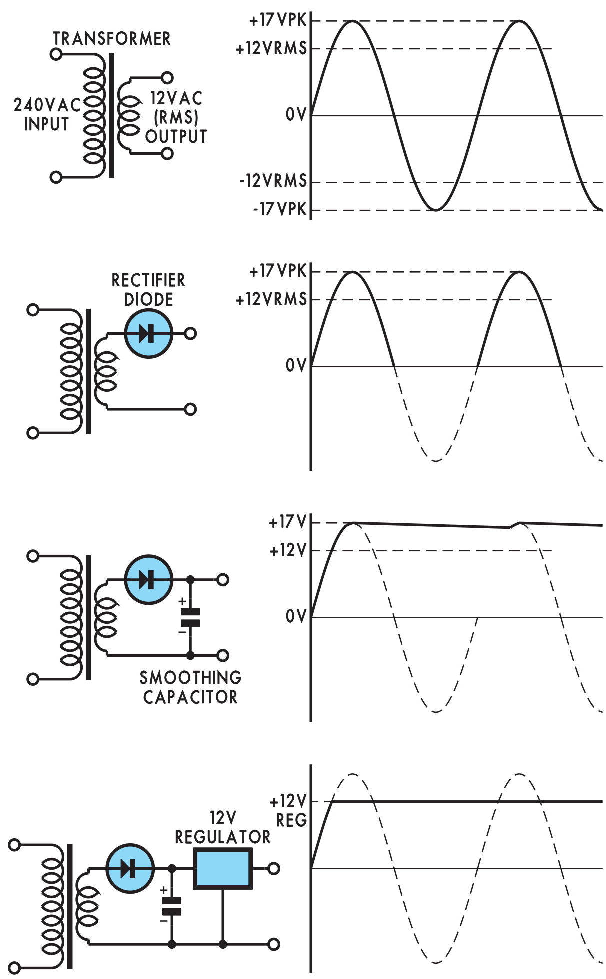
But we still haven't answered the question about something for nothing, have we?

Remember that we said a moment ago that the RMS voltage was a type of average? It stands to reason then that the actual voltage must be higher at some instants and lower at others. That's how we get an average.

Mathematically, it can be shown that the RMS voltage is 0.7071 times the peak voltage. Everyone knows that in Australia we have a domestic electricity supply of 240V AC, right? That's 240V RMS. It may surprise you to know that the peak voltage from our power points is 1.414 times that – or around 340V!

Now we don't want to play around with mains power – let's get back to that 12V transformer. That's 12V RMS, of course, so what's that in peak volts? If you answered 17V, well done!

Let's add a rectifier diode and a smoothing capacitor: if you allow for about 0.6V drop across the rectifier diode, you have a little over 16V DC output.



Each waveform above shows the output of the circuit at left. The transformer provides positive- and negative-going (AC) voltage. The half-wave rectifier diode simply lops off the negative-going cycles, while the smoothing capacitor charges up and fills in most of the gaps. The regulator clips off the top of the waveform, leaving behind a steady voltage. If the current drawn from the supply is too great, though, the capacitor isn't able to fill in the gaps properly and the regulator may not be able to provide a steady output.

Project 29

Universal Timer

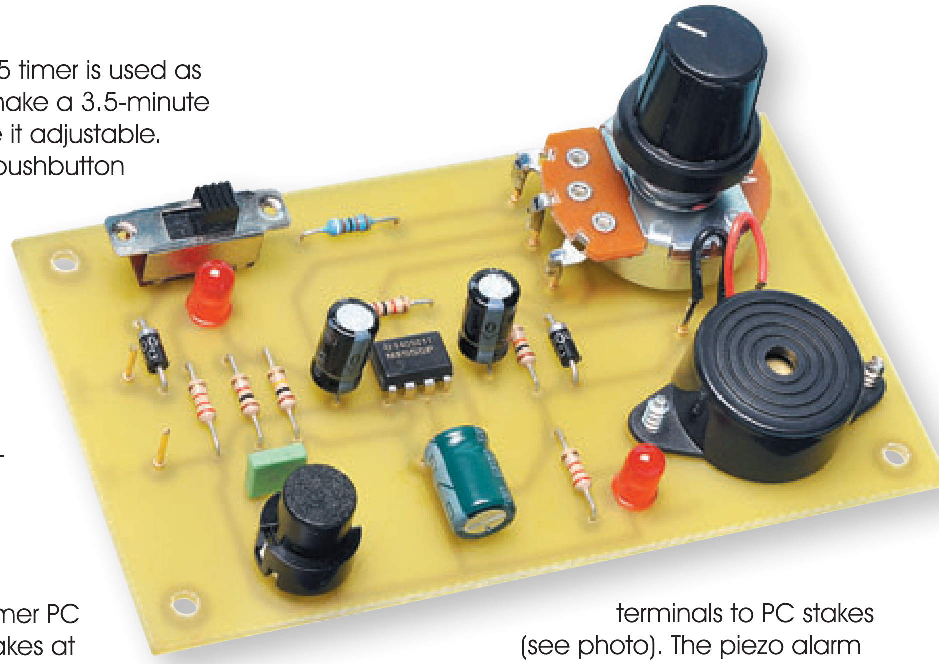
Ever wanted a timer – something that will let you know a certain period has elapsed? Here's one that can do just that – anywhere from one second to 3.5 minutes. Hey! That's how long it takes to boil an egg!

What does it do?

In this circuit, our old friend the 555 timer is used as a . . . timer! Originally we set out to make a 3.5-minute egg timer but then decided to make it adjustable.

The timer is started by pressing a pushbutton switch. During the timing period a LED glows to show you that something is happening. Once the preset time has expired, the LED goes off and a piezo alarm sounds for about one second. The timing period is set using a potentiometer.

The shortest period is produced when the pot is wound fully anticlockwise, while the longest is when it is wound fully clockwise.



Construction

All parts mount on the Universal Timer PC board. Start by soldering in the PC stakes at the external wiring points: +12V and 0V input, the piezo alarm and the three pot terminals.

Next come the resistors and 0.1µF capacitor, followed by the polarised components – ie, IC1, D1 the two LEDs and the electrolytic capacitors. The main timing capacitor (Ct) can be either a single 220µF unit or you can connect two 100µF capacitors in parallel (ie "+" to "+" and "-" to "-") and solder these to the PC board.

Switch S1 is installed by inserting its pins into the PC board and soldering them, while pushbutton switch S2 must go in with its flat side towards the 0.1µF capacitor.

Potentiometer VR1 is mounted by soldering its terminals to PC stakes (see photo). The piezo alarm unit is secured to the PC board with small self-tapping screws, with the wires soldered to the PC stakes as shown. Make sure the positive wire (red) goes to the PC stake labelled +.

Checking it out

Apply power to the circuit and check that LED1 lights. If it doesn't, you either have the supply back to front or the LED mounted back to front. Or perhaps you forgot to turn S1 on?

The piezo alarm should sound for about one second as the 47µF capacitor in series with it charges. Wind VR1 fully anticlockwise and press the start switch.

You will need these parts

Resistors (0.25W, 1%)
1 100kΩ 1 10kΩ 1 9.1kΩ
2 2.2kΩ 2 1kΩ
1 1MΩ linear pot. (VR1)

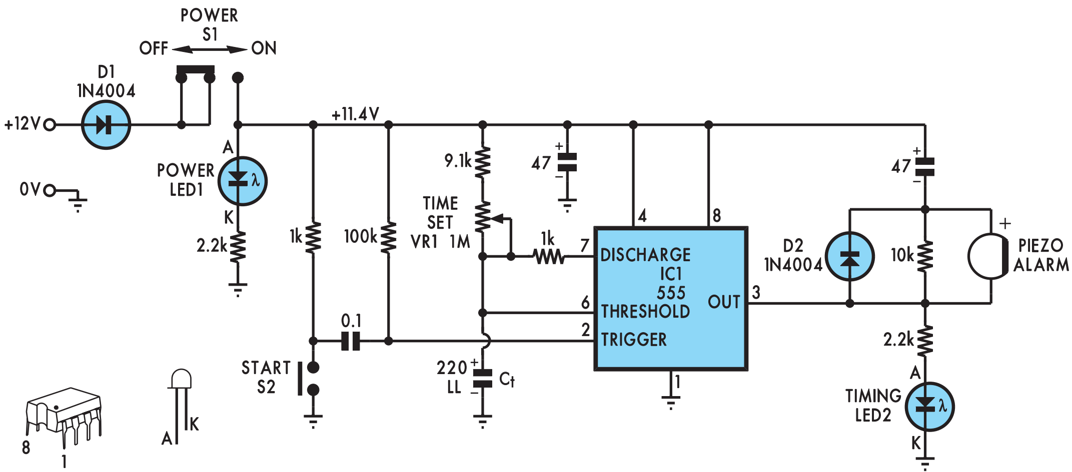
Capacitors
1 220µF or 2 x 100µF 25VW LL electrolytic
2 47µF 16VW electrolytic
1 0.1µF MKT polyester

Semiconductors
1 555 timer (IC1)
2 1N4004 1A diodes (D1, D2)
2 5mm red LEDs (LED1, LED2)

Miscellaneous
1 Universal Timer PC board
1 SPDT slider switch (S1)
1 momentary PC-mount pushbutton switch (S2)
1 piezo alarm
1 knob
7 PC stakes

LED 2 should light and after about one second, the piezo alarm should sound again and LED 2 should go out.

Check that you can obtain longer time periods by rotating VR1 clockwise.

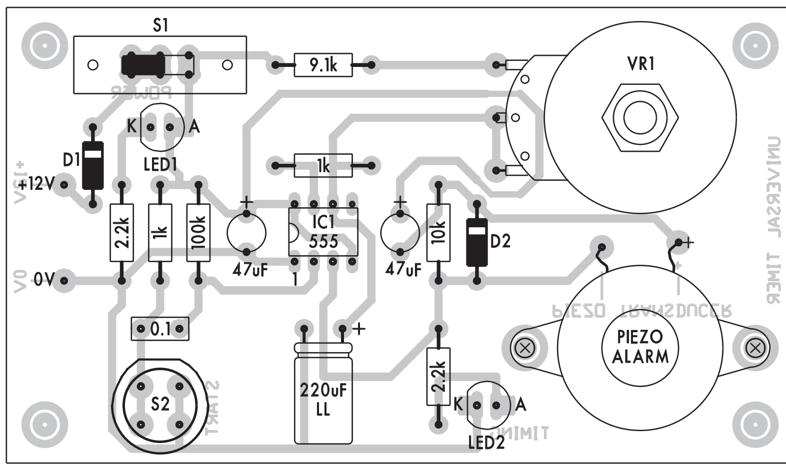


What to do next

A timer isn't much use without knowing how long it's taking! The first step would be to mount the timer in a suitable case, place a knob on VR1 and draw up a scale. Unfortunately, due to component tolerances, each timer built is likely to be slightly different so there's no point in printing a scale.

We suggest you mark various points around the arc of travel of the knob with a pencil, set the knob pointer to those marks and then accurately measure the time it takes from push button to beep at each point. It won't take too long to draw up a scale marked say in 5 second increments from 0 to 1 minute and 15 or 30 second increments from 1 minute to 3.5 minutes.

Note: Ct can be either a single 220µF capacitor or two 100µF capacitors connected in parallel– see text.



TECH TALK

The Universal Timer is again based on a 555 timer IC.

When power is applied, the pin 3 output of the 555 is low, as is pin 7. The 220µF low leakage (LL) capacitor (or two 100µF capacitors in parallel) is discharged via the 1kΩ resistor and the low pin 7.

A low leakage capacitor is required because a standard capacitor would not give the accuracy required for timing purposes. A perfect capacitor would have no leakage but there is no such thing. Next best is a capacitor specially made to have the lowest leakage possible.

Initially, pin 2 is triggered by pressing switch S2. This pulls pin 2 to ground (low) via the 0.1µF capacitor. The pin 3 output goes high, lighting the timing LED (LED2) via its 2.2kΩ resistor. At the same time, the 220µF capacitor at pin 6 begins to charge towards the supply rail via potentiometer VR1 and the 9.1kΩ resistor. The rate at which the capacitor charges is set by VR1.

The 0.1µF capacitor at pin 2 also charges via the 100kΩ resistor to the 11.4V supply. When S2 is released, the 0.1µF capacitor discharges via the 1kΩ resistor.

All this time, the 220µF capacitor has continued to charge. Pin 6 detects when this capacitor has charged to 2/3 the supply voltage, at which time pin 3 and pin 7 go low. The capacitor now discharges via the 1kΩ resistor and pin 7.

The low pin 3 output turns off LED2 and the piezo alarm sounds. The 47µF capacitor in series with the piezo alarm now charges via the current through the piezo alarm and once charged, the piezo alarm turns off.

When the circuit is next triggered and the pin 3 output of the 555 timer goes high, diode D2 becomes forward biased, allowing the 47µF capacitor to discharge.

The circuit is powered from 12V with diode D1 included to provide reverse polarity protection. If operated from a 12V plugpack, S1 could be replaced by a link on the PC board as the untriggered current drain is only about 10-12mA. The 47µF capacitor decouples or smooths the supply rails to provide reliable operation of IC1.

Project 30

Waveform Generator

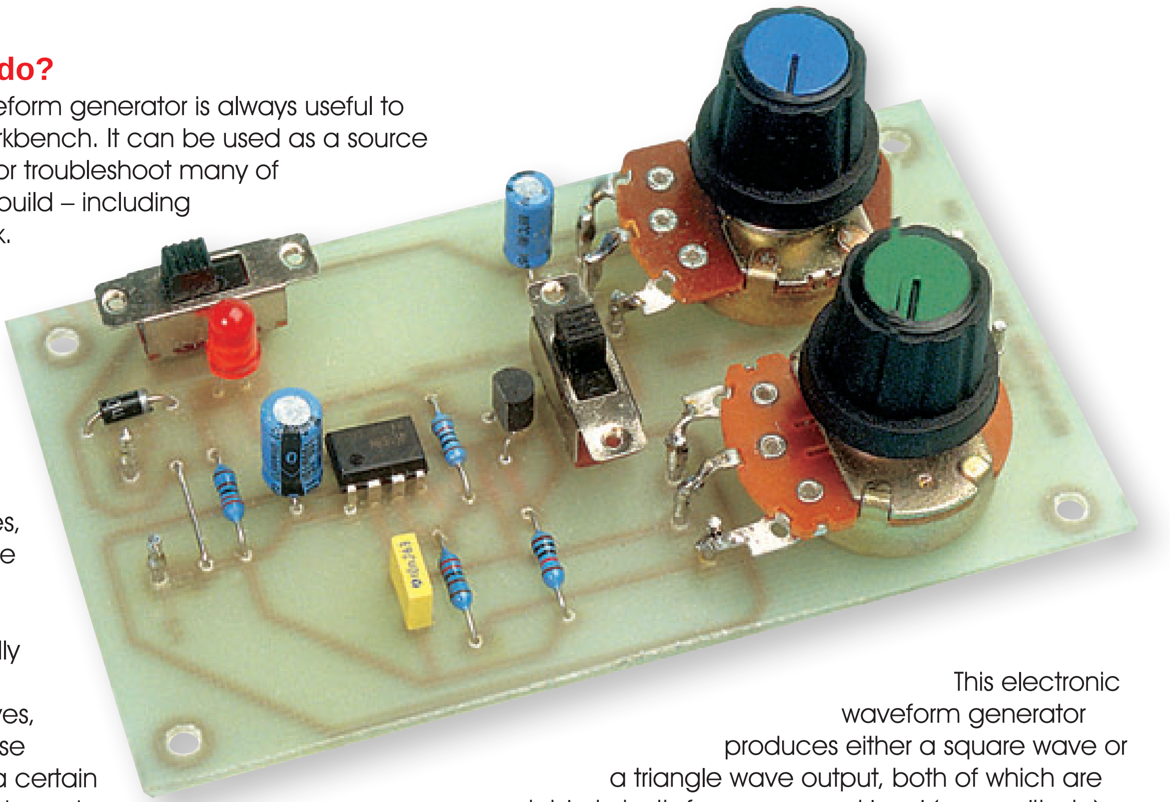
As a hobbyist and experimenter, you'll often need a source of audio signals for testing, troubleshooting and developing circuits. Here's one that produces both square waves and triangle waves and is very low in cost.

What does it do?

A simple waveform generator is always useful to have on your workbench. It can be used as a source of signals to test or troubleshoot many of the projects you build – including many in this book.

Apart from simply sounding different, circuits react differently to different types of waveforms. One reason for this is that square waves, for example, have a very short "rise time" – basically, they are either fully on or fully off.

Triangular waves, though, are all "rise time": they take a certain time to reach their maximum level and when they do, they immediately start to fall away, or decay, again until they reach their minimum. The cycle then starts all over again.



This electronic waveform generator produces either a square wave or a triangle wave output, both of which are variable in both frequency and level (or amplitude).

The frequency can be adjusted from about 100Hz to about 20kHz. The square wave amplitude is variable from 0-10.5V peak-to-peak and the triangle wave output is variable from 0-4V peak-to-peak.

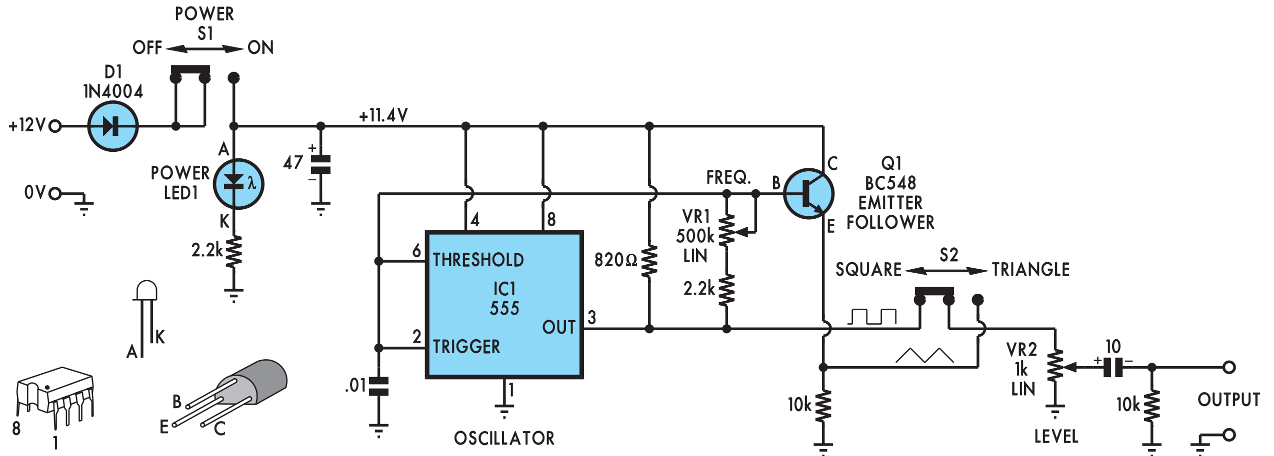
You will need these parts

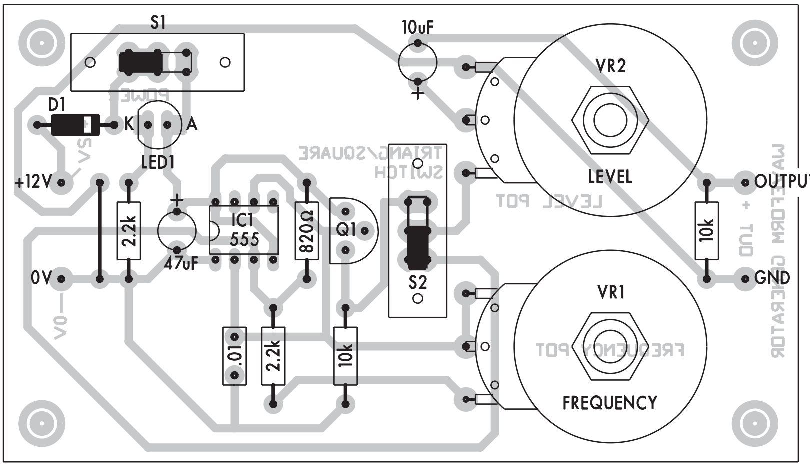
Resistors (0.25W, 1%)
2 10kΩ
2 2.2kΩ
1 820Ω
1 500kΩ linear pot. (VR1)
1 1kΩ linear pot. (VR2)

Capacitors
1 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
1 0.01µF MKT polyester

Semiconductors
1 555 timer (IC1)
1 BC548 NPN transistor (Q1)
1 1N4004 1A diode (D1)
1 5mm red LED (LED1)

Miscellaneous
1 Waveform Generator PC board
2 knobs
2 SPDT slider switches (S1, S2)
10 PC stakes





Construction

All parts are assembled onto the Waveform Generator PC board. Start by installing the PC stakes at the external wiring points and at the connection points for the pots. Once these are in, fit the resistors and the link, then the capacitors, diode D1, the LED, the IC and the transistor. The semiconductors and the two electrolytic capacitors are polarised and must be mounted the right way around.

The switches and pots are mounted directly onto the board. Cut the pot shafts to length before installing them – this is easiest if you grip the shaft (not the body) in a vyce and cut the shaft to the appropriate length with a hacksaw.

The pots are held in place by soldering their terminals to the PC stakes. If you wish to make them even more secure, a drop of super glue between the back of the pots and the PC board will help.

Testing

This circuit is so simple it should work first time if everything is correct. Apply power and switch on. First check that the LED lights – if so, you're halfway there.

Normally, a generator such as this would be checked by connecting the output to an oscilloscope so that you can observe the waveforms. But not many people new to electronics have access to an oscilloscope. However, most schools and colleges have one or more and might let you use them if you ask. Even so, you will probably need some oscilloscope "driving lessons".

You can check the voltage readings with a multimeter set to AC. With VR1 wound fully anticlockwise and VR2 wound fully clockwise, measure the voltage at the output. You should obtain a reading of about 5V AC for square waves and about 1V AC on triangle waves. Note that some multimeters are not particularly accurate when measuring AC voltages at high frequencies so your readings may differ from these figures.

Any reading on the AC range of your multimeter implies that the circuit is functioning correctly.

Of course, the other way to check it is with an audio amplifier. If you connect the generator to an amplifier input (it doesn't matter which one but keep VR2 wound down) you should be able to hear the output vary in frequency as you adjust VR1 and in level as you adjust VR2.

Switch to the square wave and the output should sound quite pleasant – almost like a musical instrument. The triangle wave will sound quite a lot harsher. If you can hear a difference between the two, chances are your Waveform Generator is working as it should!

TECH TALK

The heart of this circuit is, once again, a 555 timer (IC1) which is connected as an oscillator. The .01µF capacitor at pins 2 and 6 is charged and discharged via the 2.2kΩ resistor and VR1. The time taken to charge and discharge, and hence the frequency of oscillation, is set by VR1.

The waveform at pin 3 is a nominal square wave as seen in Figs. 1 and 2. These show the waveform at about 19kHz and 120Hz respectively. The duty cycle (or high time to low time ratio) is not exactly 50% because the pin 3 output does not go fully high. But it is close enough for our purposes.

The wiggly waveform along the tops and bottoms is noise picked up by the very sensitive digital oscilloscope used to capture these waveforms. In normal use, this can be ignored (viewed on an analog oscilloscope the noise probably would not even show up).

The waveform at pins 2 and 6 is nominally triangle-shaped since it is the capacitor charging and discharging voltage. In fact, because of the slight curves in the waveform, it is better described as sawtooth (perhaps even shark's tooth!) – a true triangle wave would have completely straight lines.

The reason for the curvature is that the voltage across the capacitor does not increase and decrease at a constant rate – it rises quickly when the capacitor is discharged then increases more slowly as the capacitor charges. Therefore the waveform is steeper at the start and flatter at the top when looked at on an oscilloscope.

However, we are using only a small section of the charging period to generate our waveform – the period of charge and discharge between 1/3 and 2/3 supply voltage. Fortunately, this is the area where the waveform is closest to a straight line – hence for most purposes it can be regarded as a triangle wave.

To minimise any interaction between any following device and the capacitor charge/discharge cycle, transistor Q1 is used to buffer the waveform. No buffering is necessary on the square wave output because devices connected to the output of the 555 will have little, or no, effect on its operation.

Q1 is connected as an emitter follower; ie, the voltage at its emitter follows that at the base but is about 0.6-0.7V lower. This difference in voltage is due to the voltage drop across the base/emitter junction. Fig.3 shows the output triangle wave at about 11kHz.

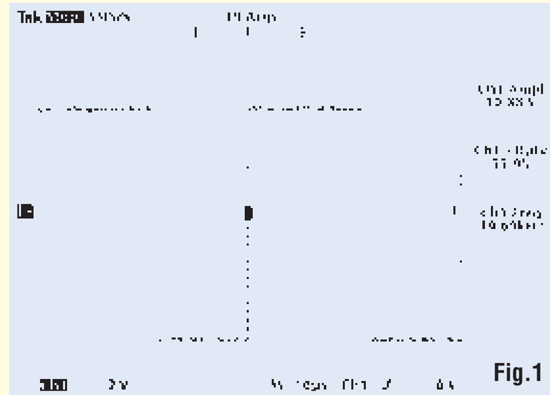


Fig.1

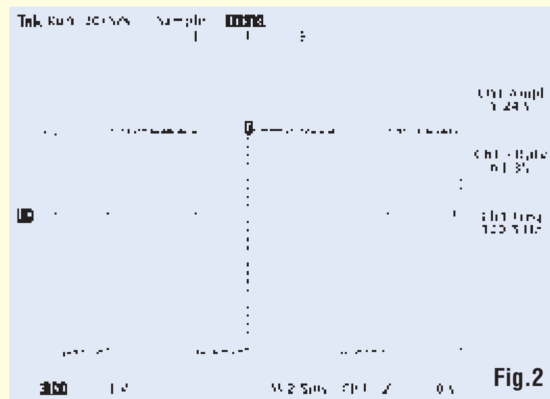


Fig.2

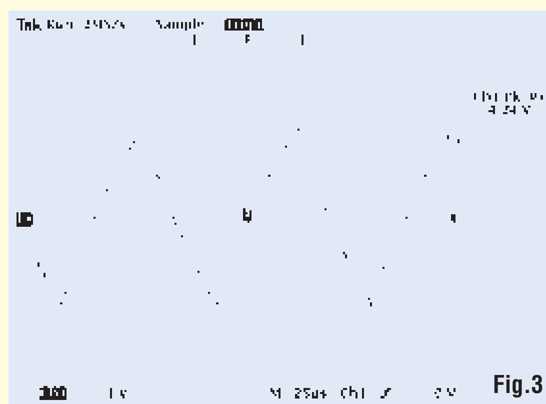


Fig.3

Switch S2 selects either the square wave output from pin 3 or the triangle wave output from the emitter of Q1. VR2 sets the output level. The 10µF capacitor and 10kΩ resistor at the output provide an AC-coupled signal which swings above and below earth.

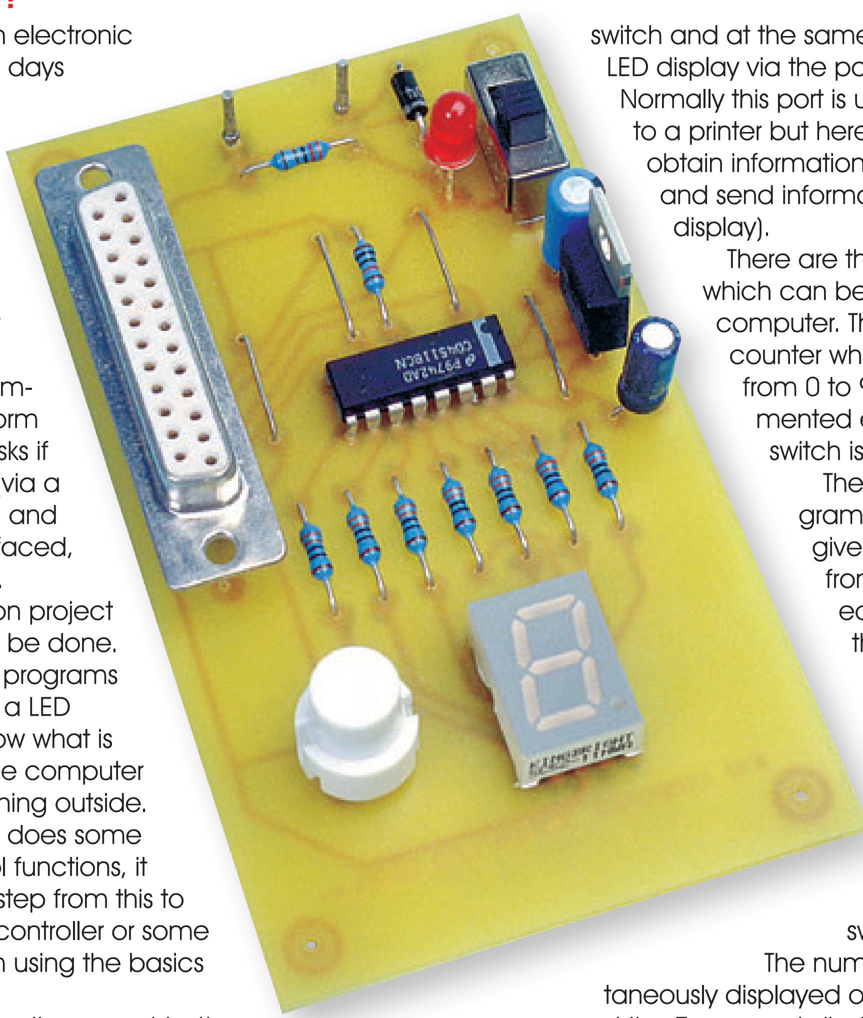
Power for the circuit can be from virtually any 5-15V DC supply capable of about 20mA. Naturally, with a low supply voltage you won't obtain the output levels of a higher supply voltage. Diode D1 provides reverse polarity connection protection. It only conducts when the polarity of the supply is correct. Switch S1 applies power and this is indicated by the power LED (LED1). A 47µF capacitor decouples, or smooths, the supply.

Project 31

Computer Driven Display

Ever wanted to make a computer work? No, not just play games but actually "talk" to the real world? This simple demonstration project could start you on a whole new career path!

What does it do?



There is hardly an electronic device made these days which doesn't have some type of computer built into it. Most computers, though, are designed to perform just a few tasks specific to their host device.

Your personal computer (PC) can perform a huge variety of tasks if it is told what to do (via a computer program) and connected, or interfaced, to the outside world.

This demonstration project shows how that can be done. It uses some simple programs and an interface to a LED display board to show what is happening inside the computer can also be happening outside.

While this project does some rather simple control functions, it really is not a huge step from this to make up a robotic controller or some process control item using the basics learnt here.

The computer monitors a pushbutton switch and at the same time drives a LED display via the parallel port. Normally this port is used to connect to a printer but here it is used to obtain information (from the switch) and send information (to the LED display).

There are three programs which can be run on the computer. The first is a simple counter which counts up from 0 to 9 and is incremented every time the switch is pressed.

The second program is a dice which gives out a number from 1 to 6 at each pressing of the switch. The third program is a random number generator producing a number from 0-9 for each switch pressing.

The numbers are simultaneously displayed on the computer screen and the 7-segment display.

You will need these parts

Resistors (0.25W, 1%)
1 10kΩ 1 2.2kΩ
7 330Ω

Capacitors
1 47µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic

Semiconductors
1 4511 binary to 7-sement decoder (IC1)
1 common cathode 7-segment LED display (LTS543R)
1 7805 5V regulator (REG1)
1 1N4004 1A diode (D1)
1 5mm red LED (LED1)

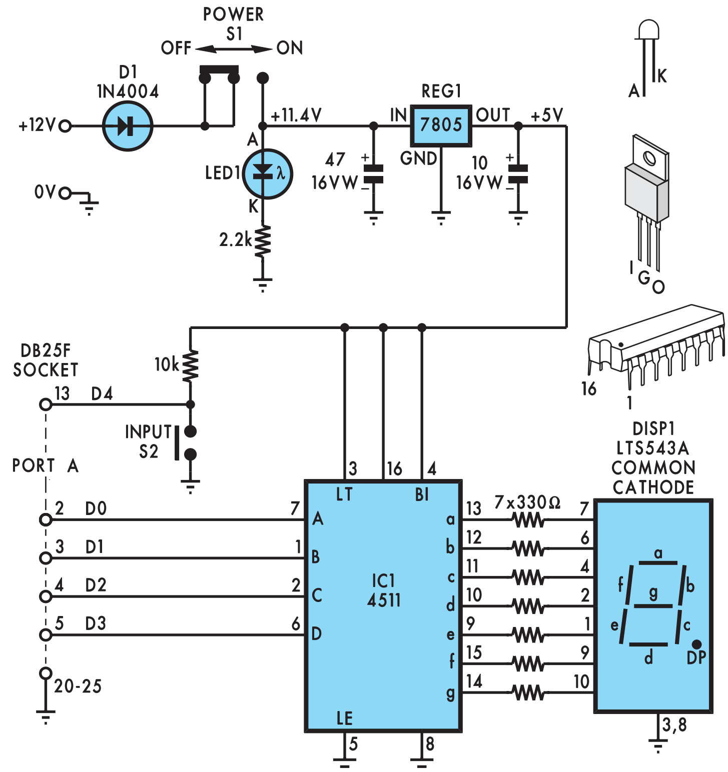
Miscellaneous
1 Computer Driven Display PC board
1 SPDT slider switch (S1)
1 momentary PC-mount pushbutton switch (S2)
1 DB25F PC-mount socket
1 DB25 male-to-male lead
2 PC stakes

Construction

All components are mounted on the Computer Driven Display PC board. Begin by installing the two PC stakes, followed by the three links and the resistors and capacitors, taking care to orient the electrolytic types correctly.

Next are the semiconductors – D1, the LED, regulator and IC1, again noting their polarities. Install switch S1 by crimping the mounting pins with pliers first. S2 must be mounted with its "flat" side oriented as shown.

Finally, the LED display and the DB25 socket can be soldered in place. On the display, the decimal point should be towards the edge of the PC board. When soldering these components, take extra care with their close lead spacing.



The software

You will need to install the software on your computer before testing the circuit. The software has been designed to run with a standard (IBM-compatible) personal computer which has its parallel printer port located at address hex 0378 to hex 037F. This is normally called LPT1 on your computer.

There are two versions of the software. One is a Quick Basic program (*ledccts.bas*) which must itself be run under the BASIC program. The listing for this is included for those who wish to type it in themselves. However, it is a fairly long and tedious process.

To use this software, run your BASIC program and load *ledccts.bas* in the normal way.

If you do not have BASIC, then a self-running or "executable" file, *ledccts.exe*, can be used. It works in much the same way as the BASIC file. First, though, you'll need to get a copy of this file (it is too long to type in!).

Ledccts.exe (and also *ledccts.bas*) are available for downloading free of charge from the Jaycar Electronics website: **www.jaycar.com.au**

If using *ledccts.exe*, simply copy this file onto a

TECH TALK

The circuit for the Computer Driven LED Display comprises just a few components. We'll start with the display first. If you look at the display, you'll see it has seven segments which make up the figure "8". Each of these segments is a LED and lighting various combinations of segments make up the numbers 0-9.

For example, if you wanted to read "3", you would light segments a, b, c, d & g. Just for the sake of it, which segments do you light to read "6"? If you answered all segments except b, well done!

Fortunately, we don't have to remember which segments to light because IC1 does that for us. It is a "binary" to 7-segment decoder. It takes an input in binary form (the language of the computer), decodes it and then lights the appropriate segments of the LED display.

Current overload is prevented by the 330Ω resistors between IC1 and the 7-segment display.

IC1 has five data inputs, four of which (D0, D1, D2 & D3) are used to read the binary number from the computer. If the computer outputs a 0 on each of the D0-D3 lines, the LED display will decode this and show a "0". If the computer outputs a 0001, then the display will show a 1.

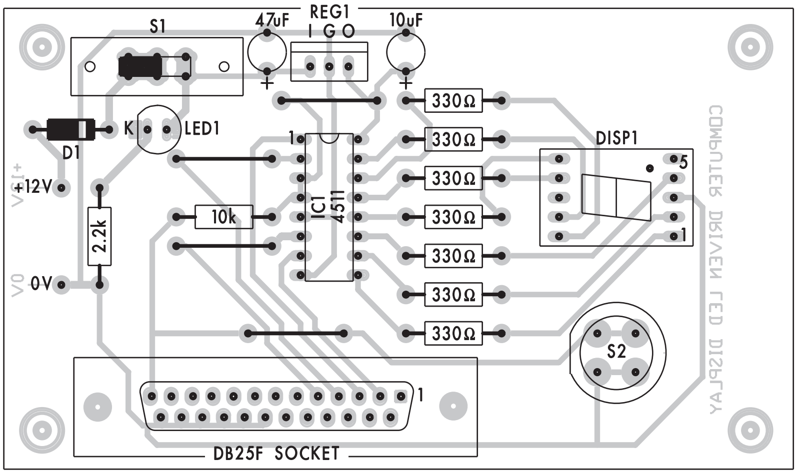
The fifth data input, D4, monitors pushbutton switch S2. When this switch is open, the 10kΩ resistor pulls this input high to 5V. When the switch is closed, the computer input is pulled low and the computer recognises a switch closure.

All five data inputs connect to the appropriate pins of a DB25 socket which in turn is connected to the parallel printer port on the computer.

Power for the circuit is from a 12V source with diode D1 providing reverse polarity protection. A 47µF capacitor across the supply provides a reservoir for transient loads. The regulator (REG1) reduces the 12V to the 5V supply required by the computer input.

memory stick or into a directory on your hard disk and run the file in the normal way, either from a DOS prompt (eg, *d:\ledccts.exe*) or by using the Run command in Windows. The program will remind you to connect power to the PC board and to select which program you wish to run.

Connect the DB25F socket to the printer output on your computer using a standard 25-pin male to 25-pin male connecting lead. Apply power to the circuit, select the program and press switch S2 to select the next number.



ledccts.bas listing

```
DIM D(10500) '(210 x 50)  "1-50 line screen information"
CLS 'clear the screen
COLOR 15, 1
FOR A = 0 TO 50
PRINT ' fill screen with colour first
NEXT A
PORT.B = &H379 'inputs
PORT.A = &H378 'data outputs
OUT PORT.A, &HFF 'load all highs into data lines
LOCATE 5, 1
PRINT "              ****************************************"
PRINT "                   Short Circuits 3 "
PRINT "                 —LED Display Driver— "
PRINT "              ****************************************"
PRINT
COLOR 12, 1
PRINT "          MAKE SURE THAT THE COMPUTER DRIVEN LED"
PRINT "        DISPLAY BOARD IS CONNECTED TO THE PARALLEL"
PRINT "        COMPUTER PORT AND APPLY POWER TO THE CIRCUIT"
COLOR 29, 1
PRINT
PRINT
PRINT "  PRESS THE D KEY TO BEGIN THE DICE PROGRAM"
PRINT
PRINT "  PRESS THE C KEY TO BEGIN THE COUNTER PROGRAM"
PRINT
PRINT " PRESS THE R KEY TO BEGIN THE RANDOM NUMBER SELECTOR"
PRINT
COLOR 12, 1
1 A$ = INPUT$(1)' get keyboard input
PRINT A$
IF A$ = CHR$(67) THEN GOTO 5' C pressed then counter program
IF A$ = CHR$(68) THEN GOTO 2000' D pressed then dice program
IF A$ = CHR$(99) THEN GOTO 5' c pressed then counter program
IF A$ = CHR$(100) THEN GOTO 2000' d pressed then dice program
IF A$ = CHR$(82) THEN GOTO 3000' R pressed then dice program
IF A$ = CHR$(114) THEN GOTO 3000' r pressed then dice program
GOTO 1
5 CLS
COLOR 12, 1
PRINT "                  COUNTER PROGRAM"
PRINT
PRINT
PRINT "             PRESS THE SWITCH (S2) TO COUNT"
PRINT "          PRESS ESCAPE (Esc) KEY TO EXIT PROGRAM"
GOSUB 100
200 OUT PORT.A, &H0 'ZERO
PRINT "0 ";
GOSUB 1000
GOSUB 100
OUT PORT.A, &H1 'ONE
PRINT "1 ";
GOSUB 1000
GOSUB 100
OUT PORT.A, &H2 'TWO
PRINT "2 ";
```

continued next page

ledccts.bas listing – continued from previous page

```
GOSUB 1000
GOSUB 100
OUT PORT.A, &H3 'THREE
PRINT "3 ";
GOSUB 1000
GOSUB 100
OUT PORT.A, &H4 'FOUR
PRINT "4 ";
GOSUB 1000
GOSUB 100
OUT PORT.A, &H5 'FIVE
PRINT "5 ";
GOSUB 1000
GOSUB 100
OUT PORT.A, &H6 'SIX
PRINT "6 ";
GOSUB 1000
GOSUB 100
OUT PORT.A, &H7 'SEVEN
PRINT "7 ";
GOSUB 1000
GOSUB 100
OUT PORT.A, &H8 'EIGHT
PRINT "8 ";
GOSUB 1000
GOSUB 100
OUT PORT.A, &H9 'NINE
PRINT "9 "
GOSUB 1000
GOSUB 100
GOTO 200
'****************************************************
'SUBROUTINES FOR TIMING AND READING S2.

1000 Z = TIMER
12 Y = TIMER
IF Y > Z + 1 THEN GOTO 13 'ONE SECOND
GOTO 12
13 RETURN

100 IF INKEY$ = CHR$(27) THEN GOTO 50'END OF PROGRAM
E = INP(PORT.B) 'check if S2 closed
F = &HEF OR E 'single out D4
IF F = &HFF GOTO 100 'switch open
RETURN
'***********************************************************
2000 CLS
PRINT "                    DICE PROGRAM"
PRINT
PRINT
PRINT "              PRESS SWITCH (S2) TO SELECT A NUMBER"
PRINT "              PRESS ESCAPE (Esc) KEY TO EXIT PROGRAM"
RANDOMIZE TIMER 'initialise random number using timer
3 GOSUB 1000
GOSUB 100
4 A = RND
A = A * 10 'process random number from .xxx to x.xx
C = FIX(A)' get number before decimal point
IF C = 0 THEN GOTO 4' zero not on dice
IF C > 6 THEN GOTO 4' numbers greater than 6 not allowed
PRINT C;
OUT PORT.A, C' number to display
GOTO 3
'***********************************************************
3000 CLS
PRINT "                    RANDOM NUMBER PROGRAM"
PRINT
PRINT
PRINT "              PRESS SWITCH (S2) TO SELECT A NUMBER"
PRINT "              PRESS ESCAPE (Esc) KEY TO EXIT PROGRAM"
RANDOMIZE TIMER 'initialise random number using timer
7 GOSUB 1000
GOSUB 100
A = RND
A = A * 10 'process random number from .xxx to x.xx
C = FIX(A)' get number before decimal point
PRINT C;
OUT PORT.A, C' number to display
GOTO 7

'***********************************************************
50 END
```

Transistors And Integrated Circuits

Like virtually all electronic equipment nowadays, the projects described in this book rely on tiny amplifying and switching devices called ***transistors***. Often, quite a lot of transistors are combined with miniaturised resistors, diodes and other components, to form completely ***integrated circuits*** or "ICs". Transistors and ICs have taken over completely from the amplifying devices that were used for most of the first radios, amplifiers, TV sets and even computers: ***thermionic valves***, or "tubes" as they were called in America.

Valves were a development from the light bulb we all know so well (more properly called an "incandescent" bulb). Like light bulbs, valves have a glass container from which the air is pumped out, to leave a vacuum. They also have a filament (called a "cathode") which is heated by an electrical current until it glows red hot. Electrons are "boiled off" the cathode and head towards the other main electrode, called the anode or "plate". Other electrodes (eg, a grid) are placed in the electrons' path to control their flow.

Transistors and ICs work in a different way. In this case, the electrons move around inside a solid piece of crystal.

The first transistor was developed in 1947 at Bell Laboratories in the USA, by physicists John Bardeen, William Shockley and Walter Brattain. It had two tiny pointed gold electrodes touching a sliver of germanium crystal – very crude, but it had quite a useful amplification and could be made to oscillate. The era of "solid state" electronics had begun and in 1956 the transistor's three inventors were awarded the Nobel Prize for this important achievement.

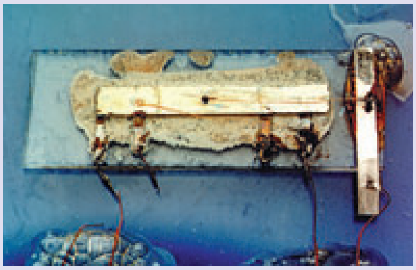
The first crude transistor, developed in 1947 by Bell Lab researchers Bardeen, Shockley and Brattain.

Solid state, by the way, is simply a reference to the solid material used to make transistors, etc – as distinct from the electron flow through the vacuum of a valve.

Soon it was discovered that transistors had much better performance if they were made using silicon instead of germanium and from that point on silicon has been used for most solid-state devices. Fortunately, silicon is the most abundant mineral on Earth: every time you go to the beach, you're walking over millions of tonnes of silicon in the form of sand.

A very pure silicon is used for solid-state devices, in which different regions are "doped" with microscopic amounts of other elements (like phosphorus or boron) to vary their electrical behaviour.

As more became known about making transistors, it was realised that they could be made very much smaller than the first models. Not only that, but engineers soon found that other components like diodes, resistors and even capacitors could be miniaturised in the same way – raising the possibility that many components could be "integrated", or placed together, making "integrated circuits" (ICs) much smaller than ever before.



This is the first working IC, developed in 1958 by Texas Instruments engineer Jack Kilby.

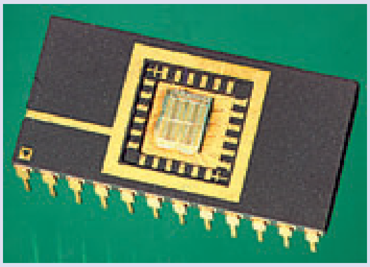
In September 1958 in the USA, Texas Instruments engineer Jack Kilby produced the first working IC on a tiny sliver of germanium. It was a crude phase-shift audio oscillator but it worked. The following year Dr Robert Noyce of Fairchild Semiconductor worked out how to make much better ICs out of silicon.

The age of the integrated circuit had begun and ICs have become more and more complex, much more powerful and yet lower in cost ever since. And this has been happening at a faster and faster rate, which still shows no sign of slowing down.

Nowadays the latest microprocessor, memory and signal processing ICs can contain many ***millions*** of transistors and other components, on a tiny "chip" of silicon which is usually less than 8-10mm square and only 1mm or so thick. For physical protection this chip is then usually mounted inside a larger ceramic or plastic package, with one, two or four rows of metal pins or pads to allow it to be connected to the "outside world".

The projects in this book generally use relatively simple and very low cost ICs containing only a few dozen transistors, like the 555 timer chip which forms the heart of our first three projects. This comes in a small plastic package with two parallel rows of four pins, known as the "8-pin DIP". Others like the 4049 logic inverter used in Project 4 come in a larger version of the same package known as the "14-pin DIP", with two rows of seven pins.

Individual "discrete" transistors are still made, in a variety of different 3-pin packages. These provide a convenient way to experiment with new circuits and you'll find this type of transistor used in many of the projects in this book.



Today's ICs can contain millions of transistors, all in a tiny chip mounted (and usually sealed) inside a ceramic or plastic package with rows of pins or pads for the connections.

Technical Terms Explained

AC: Abbreviation for Alternating Current. The voltage we get from a power point or from an unrectified transformer is AC. The term is applied to any voltage or current which continually changes direction rather than remaining in one direction (as for DC).

AC 240V: Nominal voltage available from a domestic power outlet in Australia and New Zealand (also called "mains" voltage). Other countries have different voltages –110, 115, 220 and 230VAC are common overseas. Mains voltages are lethal!

AC-Coupled: Method of connecting two sections of a circuit together so that DC is blocked but AC signals can pass. The usual method of doing this is via a capacitor.

AM : Abbreviation for Amplitude Modulation (see modulation).

Amp: Abbreviation for Ampere.

Ampere: Basic unit of current flow. 1 amp flows through a resistance of 1 ohm when 1 volt is applied to it – equivalent to a flow of 6×10^{18} electrons per second. Can be further defined with metric prefixes (eg, milli-, kilo-). A typical transistor radio might draw a few tens of milliamps from its batteries; a typical lightning strike might have a current flow of hundreds of thousands of amperes. The normal "shorthand" for Ampere is "A" but in equations and on circuits, current may be denoted by the letter "I".

Amplifier: Any active device or circuit (eg, using transistors or op amps) where there is an increase in level between the input and the output. The amount of increase is the amplifier's gain.

Anode: The positive terminal of any component. (Applies particularly to diodes as far as this book is concerned).

AND Gate: A logic gate which will have a high level output only if all of its inputs are high.

Antenna: A wire or coil attached to a circuit to pick up radio and TV signals (also known as an aerial).

Astable: Refers to a type of multivibrator circuit (or an IC connected as one) which has two states, high or low, and constantly swaps back and forth between them of its own accord.

Attenuation: A decrease in signal level, measured as a change in voltage, current or power level, achieved through the use of an attenuator.

Attenuator: Any device which decreases the level of a signal; typically a potentiometer.

Audio Frequency: Normally regarded as the frequency range between 20Hz and 20kHz. However, high quality audio circuits are usually made to operate over a significantly wider range than this – from less than 20Hz up to 50kHz or more.

Bandpass: A range, or band, of frequencies which a filter will allow through. See filter.

Base: The input or control connection to a transistor. A small current into the base of a transistor causes a much larger current to flow through the collector.

Battery: A number of chemical cells connected together in series to provide a DC voltage. A typical single "dry cell" produces 1.5V (see "cell").

Bias: A small DC current or voltage applied to a diode, the base of a transistor or the gate of a FET to turn it on. In the case of an op amp, the bias sets the reference voltage above and below which the output will swing.

Bipolar: Literally means "two poles". Common use is in referring to transistors – bipolar transistors are the most common type used in electronics.

Bistable: An electronic circuit (or device) which has two stable output states, high and low, but requires some form of external control input to make it swap from one to the other. See flipflop.

Block Diagram: A simplified diagram of a circuit which demonstrates its operation without showing individual components. Each operational section of the circuit is shown as a functional block.

Bridge Rectifier: A set of four silicon diodes (either individual or encapsulated in one package) which provides full-wave rectification of AC to DC.

Buffer: A circuit or component which acts to prevent one section of a circuit from interfering with the operation of another section.

Capacitive Load: Any load on a circuit involving capacitors or the effect of capacitance (for example, a long run of screened or coax cable has capacitance). Such a load is said to exhibit capacitive reactance.

Capacitor: A component which stores electric charge. It consists of two plates separated by an insulator. The amount of capacitance is measured in Farads but this is much too large a unit for everyday use. Instead, we use microfarads (μF) – 1/1,000,000 of a Farad and smaller. Capacitors let AC signals pass through them but block DC voltages. Capacitors come in many types including electrolytic, polyester, polypropylene, ceramic, paper and mica (the last two are not common these days).

Cathode: The negative terminal of any electrical or electronic component, particularly diodes. (Converse "anode").

Cell: A container of chemicals which react together to produce electricity. A number of cells connected together form a battery.

Circuit: An arrangement of electronic components designed to perform some function or task. The simplest circuits may have only two components (eg, a battery and a torch bulb); the most complex have many millions.

Circuit Diagram: The graphical representation or drawing, usually on paper, of all the elements of an electronic circuit using commonly understood symbols for components (eg, resistors, diodes, ICs and so on) with lines joining the components together showing their interconnection. Also known as a "schematic" or "schematic diagram". See also Block Diagram and Component Overlay.

Charge: The quantity of electrons stored in a capacitor or battery. When a capacitor is connected to a battery via a resistor, it will charge to the same voltage as the battery, the time taken depending on the resistance in the circuit. The opposite is discharged or "flat".

Chip: Abbreviation for "silicon chip", a common name for an integrated circuit or IC.

Choke: Another name for an inductor or coil. In most cases (though certainly not all), chokes are wound on a core of ferrite or iron to increase their inductance for the size of the coil.

Clip: Where the top and/or bottom of the signal waveform is flattened, either deliberately or accidentally, due to circuit overload.

Clock: A section of a circuit which generates pulses at a preset rate which are used by other sections of the circuit. All computers have a clock which can typically run at anywhere between 1MHz and 400MHz. The pulse rate can itself be variable in some circuits. Can also be used to mean the action which occurs when a pulse is detected by a circuit or component.

Coil: Another name for an inductor – wire wound around a former to hold a certain shape, size and number of turns.

Collector: One of the three terminals of a transistor. On an NPN transistor, the collector connects to the positive side of the circuit; on a PNP transistor, the negative side.

COM: Abbreviation for "common". For example, the common contacts in a relay connect to either the normally closed (NC) or normally open (NO) contacts, depending on whether or not the relay coil is energised.

Comparator: An op amp circuit which compares two voltages. For example, if one voltage is higher than the other, the comparator's output might be high. But if the two inputs are the same, or reversed in levels, then the comparator's output might be low.

Component Overlay: See PC Board Overlay.

Conductor: Any material which will allow electric current to flow along or through it. Most metals – for example, copper, gold, silver, mercury and aluminium are good conductors. (Converse: "insulator").

Continuity: The ability of a circuit to pass current with no, or virtually no, resistance.

Coupling: The method of connecting components together in a circuit. "Cross coupling" is used in multivibrators when the base of one transistor is connected to the collector of another via a capacitor.

Crystal: A tiny pellet of quartz which oscillates at a very precise frequency when stimulated by an electric current. Crystals are often part of clock circuits or pulse generators when high accuracy is required. Every digital watch contains a crystal, usually oscillating at precisely 32,768Hz.

Current Flow: The movement of electrons from one part of a circuit to another. Electrons are caused to flow when there is a difference of potential, or voltage, between the two points. In this book, wherever we talk about current, we mean "conventional current flow" where current flows from the positive supply through the circuit and back to the negative supply.

dB: Abbreviation for "decibel" – the basic unit for expressing sound level.

DC: Abbreviation for Direct Current – the current available from a battery or from a rectifier. Unlike AC, direct current does not change its direction.

DC-Coupled: Also known as "direct coupled" – sections of a circuit connected so that both AC and DC can pass between them.

DC Offset: In a direct-coupled amplifier, the output should generally be purely AC. However in most amplifiers, due to component tolerances, faults or poor design, there is always a small DC voltage, positive or negative with respect to earth, across the output. This is called the DC Offset. It is often just a few millivolts and can be ignored but if it is more than several hundred millivolts it may cause distortion and other problems in the circuit.

Decoupler: Usually refers to a capacitor used in a circuit to either smooth a supply line or to help remove any noise on that supply line. Basically, it holds a DC level constant but allows any AC to flow to earth.

Detector: In a radio receiver (including a crystal set) the component or circuit responsible for recovering the audio signal modulation from the RF signal. For an AM (amplitude modulated) signal, a germanium diode is often used because of the low voltage drop across it (0.2V).

DIN: Abbreviation of Deutches Industrie Normales – a German standard. In this book, it refers to a type of connector.

Diode: A semiconductor which allows DC to pass in one direction, from anode to cathode but not in the other. Diodes are typically made from two types of semiconductor: germanium (now usually only used for detectors in radio circuits) and silicon (most modern diodes are made from silicon).

Discharged: The state where a component (eg, a capacitor or battery) has no (or little) charge stored in it. In many cases, the component is said to be discharged long before the voltage level has dropped to zero but is too low to be of any use.

Distortion: A process, usually unwanted or unintended, by which the shape of a signal is altered. Distortion results in harmonics which can make the sound less pleasant.

DPDT: Abbreviation for "double pole, double throw". A switch (or relay) with six contacts which comprise two individual switches, switched at the same time by the same actuator. Each switch has one terminal (the "common") which connects to either of the other terminals, depending on the switch position or coil energisation. Also known as a changeover switch or relay. If a circuit calls for a "SPDT" switch it is usually OK to use a DPDT switch, either ignoring one set of contacts or connecting the two sets together in parallel. Most of the circuits in this book require a SPDT switch action but a DPDT switch will normally be supplied and used in the above manner.

DPST: Abbreviation for "double pole, single throw". A switch (or relay) with four contacts which comprise two individual switches, moved at the same time by the same actuator. The terminals will either be connected together (switch "on") or not (switch "off") depending on the switch position or coil energisation. DPST switches are relatively uncommon.

Duty Cycle: In a bistable circuit, the ratio of the "high" output to the "low" output (or on to off). If the duty cycle is 50%, the high and low times are equal. Used to be referred to as "mark/space" ratio.

Dynamic Microphone: A microphone based on a coil suspended in a permanent magnetic field. Sound waves entering the microphone move the coil, generating tiny electrical currents which can be amplified.

Earth: A reference point for measurements in a circuit having, or assumed to have, a potential of zero volts. Also known as ground. The voltage can go positive (+ or +ve) with respect to earth or negative (- or -ve) with respect to earth. In homes and other buildings, one side of the power circuit is physically connected to a water pipe buried underground and this becomes a "real" earth connection. If a circuit is operating entirely from batteries there is obviously no electrical connection with earth but the negative battery connection is often assumed to be at earth potential or 0V to provide a reference level for that circuit.

Earthed: The action of physically or electronically connecting a point of a circuit to the circuit earth (eg, to discharge a capacitor). Also known as "grounded".

Equalisation: A method of reducing distortion in recordings by applying certain characteristics to various bands of frequencies.

Electret Microphone: A microphone based on a charged capacitor. Sound waves entering the microphone vibrate the "plates" of the capacitor, thus altering its capacitance and varying the voltage across it. An electret microphone requires a permanent supply or "bias" voltage to operate.

Electrolytic: Usually an abbreviation for electrolytic capacitor. It actually refers to the conducting liquid or paste inside the capacitor. The vast majority of electrolytic capacitors are polarised, which means they can only be installed in a circuit one way.

Electronic Eye: A component or circuit which operates when a beam of light is cut; eg, by an intruder. See Electronic Eye, Project 3.

Emitter: One of the three terminals of a transistor. In an NPN transistor, the emitter connects to the more negative side of the circuit. PNP transistors are opposite.

Feedback: The action of returning some of the output signal from a circuit back to its input. Feedback can be negative or positive. Positive feedback can cause a circuit's output to increase and if pushed too far, it will break into oscillation. The howl you hear when a microphone is placed too close to speakers in a public address system is an example of positive audio feedback and oscillation. Negative feedback reduces the output of a circuit and is generally applied to improve the performance in some way.

Ferrite: A group of ferromagnetic materials which are compounds of iron oxides and elements such as cobalt, nickel and zinc. Ferrites can be used in the powerful magnets in speakers and also as the cores of inductors and high frequency transformers.

Ferrite Bead: A tiny cylinder-shaped component which helps reduce interference from RF radiation. It is usually slipped over a component lead at the input to a circuit.

FET: Abbreviation for field effect transistor, a special type of transistor which has a very high input impedance.

Figure-8 Cable: A very popular form of insulated 2-conductor cable so called because its cross-section (ie, viewed end-on) looks like an "8". It is available in various voltage and current ratings.

Filter: Any circuit (or component) which allows some signals to pass through but not others. Filters can be "high pass" (allowing signals above a certain frequency to pass); "low pass" (allowing signals below a certain frequency to pass); or "bandpass" which are in effect a combination of high and low pass – signals within a certain frequency band can pass. The pass frequencies of filters are determined by the values of the components (particularly capacitors and inductors) in them.

Flat Response: An amplifier will ideally apply the same amount of amplification across all frequencies. In this case, when the output voltage level is plotted against frequency on a graph or looked at on an oscilloscope, the line will be completely flat. This seldom, if at all, happens in real life.

Flipflop: A logic device which has two states and usually, two outputs. One output is always high and the other is always low and they can swap over. In the most common types, a clock or trigger pulse will cause the two outputs to flip from one state to the other, then the next pulse will cause them to flop back again – and so on. Hence the name, flipflop! See also multivibrator.

FM: Abbreviation for Frequency Modulation (see modulation).

Former: A tube or cylinder on which a coil of wire can be wound. The former may or may not stay inside the coil (also known as a mandrel).

Frequency: the number of times an event occurs in a given period of time. For example, if a wheel revolves 6000 times a minute, that would give rise to a frequency of 6000 cycles a minute or 10 cycles per second which is the same as 10 Hertz.

Frequency Response: The way in which gain or amplification varies across the full frequency range of operation of an amplifier. Ideally, the gain should be constant but this is seldom achieved in practice.

Full-Wave Rectifier: A rectifier using two or four diodes to convert both halves of the AC waveform to fluctuating DC; gives a better result than a half-wave rectifier which usually uses a single diode.

Gain: The factor by which a signal is increased by a circuit. If an input signal to an amplifier circuit is 100mV and the output signal from that amplifier is 1V, the circuit has a gain of 10. If the gain is shown as a minus figure (eg, -10) then the circuit still has a gain of 10 but the signal at the output is inverted with respect to the input.

Gate: A logic device which, like a gate in a fence, can be either open or closed. Whether it is open or closed depends on what type of gate it is and what the logic levels are at its inputs. Common gate types include AND, OR, NAND, NOR and NOT.

Germanium: A semiconductor element from which the first transistors were made; now mostly limited to germanium detector diodes. The advantage of a germanium semiconductor junction is that it has a much lower voltage drop across it than does a silicon junction (0.2V compared to 0.6V).

Grommet: A plastic or rubber sleeve which protects a cable from chafing where it passes through a hole in a metal chassis or box. Cordgrip grommets also anchor the cable firmly to prevent it from being pulled out of the chassis/box.

Ground: Another name for "earth" or zero volts.

Half-Wave Rectifier: A diode. When fed with a sinewave (ie, an AC signal) it lets only one half of the waveform (either the positive-going half or the negative-going half, depending on which way around the rectifier is connected) pass through to convert the AC to pulsating DC. The other half of the waveform is lost. Usually results in poorer quality DC than from a full-wave rectifier but less parts are required.

Hardware: Components such as potentiometers, switches, indicator lamps, dials or other parts which often mount separately from the PC board.

Harmonic: A multiple of a particular frequency. For example, a complex audio signal with a frequency of 1000Hz could have a "second harmonic" occurring at 2000Hz, a "third harmonic" at 3000Hz and so on. A pure sinewave contains no harmonics.

Heatsink: A metal object which conducts heat away from things that get hot such as power transistors. Usually the transistor is screwed or clamped to the heatsink but may be electrically insulated from it.

Hertz: The term for "cycles per second" – the number of times each second that an AC signal goes from zero to a positive peak, back to zero, to a negative peak and back to zero again. Abbreviation Hz; can be further modified with metric multipliers (eg, kilohertz or kHz; megahertz or MHz, etc).

High: When referring to logic circuits, the state which is the higher voltage of the two.

High Frequency Rolloff: Attenuation or reduction of high frequencies passing through a circuit. Many amplifiers are capable of working with frequencies far in excess of the required frequencies but this can lead to instability and interference problems. For this reason, a high frequency rolloff is applied.

Hum: Unwanted low-frequency signal or sound, often due to power supply ripple finding its way into wanted signal.

Hysteresis: The difference between the positive and negative voltages in a comparator or switching circuit. Hysteresis ensures that switching takes place cleanly without any tendency for the circuit to oscillate between the high and low condition.

Hz: Abbreviation for Hertz.

IEC: Abbreviation for International Electrotechnical Commission, a body which sets standards so that electronic devices around the world are compatible.

IC: Abbreviation for Integrated Circuit.

Impedance: The resistance of a circuit or component to AC signals. For example, an inductor or coil may have a high impedance (ie, high resistance to AC) but a low resistance to DC.

Inductance: A coil of wire which produces a magnetic field when a current passes through it and which thereby stores electrical energy. Inductance is measured in Henrys (H).

Induction: A process which occurs when the current flowing through an inductor is suddenly interrupted or changes. The resulting change in the associated magnetic field produces (or "induces") a voltage into any nearby inductor (eg, the secondary of a car ignition coil). This voltage will be proportional to the rate of change of current and to the number of turns in the secondary.

Inductive Load: Any load on a circuit involving inductance or the effect of inductance (eg, a transformer is an inductive load).

Inductor/Inductance: A component based on a coil of wire.

Insulator: A material which theoretically will not allow current to pass through it. Most plastics, rubbers, glass, fibreglass, mica and even dry air are insulators. No insulator is perfect – all will allow extremely tiny currents to pass but in most cases they are so small they can be ignored.

Integrated Circuit: A number, often a vast number, of circuit elements all constructed on a wafer, usually of silicon. Integrated circuits have replaced huge numbers of discrete components in modern electronics. Generally abbreviated to "IC".

Inverter: Any circuit or device which changes the polarity of the signal or the logic level between its input and output. Positive-going signal excursions become negative-going and vice versa; logic highs become logic lows and vice versa. Another type of inverter is a type of power supply which converts DC into AC to run power tools, appliances, etc away from the mains supply.

Junction: A point where circuit components or wires join. Also, within a semiconductor, the region where the p-type and n-type materials join together.

"k" & "K": Both abbreviations of the metric multiplier "kilo". However k = 1000 times while K = 1024 times (2^{10}). "K" is often used in reference to memory or data bits in computers while "k" is more common in electronics. (Another use for "K" is the abbreviation for "cathode" – it comes from the German word for cathode).

kHz: Abbreviation for kilohertz.

Kilohertz: One thousand Hertz (abbreviation kHz). (See Hertz).

LC: Abbreviation for inductance and capacitance. Usually refers to a circuit (often a tuned circuit) consisting of both inductance and capacitance.

LDR: Abbreviation for light dependent resistor; a component which changes its resistance in response to changes in the amount of light striking it.

Linear: Describes any circuit which has an output directly proportional to its input. Also applies to a potentiometer which changes its resist-ance in direct proportion to the rotation of its shaft.

Link: A short length of wire used to connect two points on a PC board where there is no room for a copper track underneath. Cut-off resistor leads can be used for short wire links.

Load: The resistance or impedance into which the output of another circuit operates. For example, a speaker is a load for an amplifier.

Logarithmic: A type of potentiometer which varies its resistance in logarithmic proportion to the shaft rotation. In practice, the resistance increases rapidly at first then more slowly.

Logic Circuit: Any circuit which operates following the rules of logic using high and low states. Also referred to as a digital circuit. (Converse linear).

Low: In digital circuits, the state which has a lower voltage than the alternate (high) state. It is quite rare for low states to be at 0V potential; however there is a usually a significant voltage difference between low and high logic levels.

Low Frequency Rolloff: Attenuation or reduction of low frequencies passing through a circuit. Can be used to stop hum or other low-frequency noise from being amplified by a circuit.

Low Leakage Electrolytic: Most electrolytic capacitors have a certain amount of leakage current between their plates due to the way they are made. Some types are specially constructed to offer very low leakage (but still not zero) for circuits where this is important; eg, in timing circuits.

mA: Abbreviation for milliamp; 1/1000 Amp.

Magnetic Flux: Refers to the imaginary lines of force of a magnetic field.

Mains: See 240V AC.

Mandrel: See former.

Megahertz: One million Hertz.

Metric Multipliers: Commonly used in electronics to signify smaller or greater values than the basic metric units. μ = micro (one millionth); m= milli (one thousandth); c= centi (one hundredth); k = kilo (one thousand times); M = Mega (one million times).

Microamp: (μA) 1 millionth of an Ampere.

Microfarad: (μF) 1 millionth of a Farad – the usual range of capacitance of electrolytic capacitors.

Microvolt: (μV) 1 millionth of a Volt.

Milliamp: (mA) 1 thousandth (1/1000) Amp.

Millisecond: (ms) 1 thousandth (1/1000) of a second.

Millivolt: (mV) 1 thousandth (1/1000) Volt.

MKT Polyester: An encapsulated metallised polyester capacitor that's used extensively in electronic circuits.

Modulation: The process of applying information or intelligence carried in one signal to another signal – for example, where audio frequency signals are applied to a radio frequency signal, or carrier, so they can be transmitted over long distances. The two most common types of modulation are amplitude modulation (AM) where the level, or amplitude, of the carrier varies in sympathy with the information in the audio waveform but the frequency remains constant; and frequency modulation (FM) where the frequency of the carrier varies in sympathy with the information in the audio waveform but the amplitude, or level, remains constant.

Monitor: Any circuit or device which continually examines another circuit or component. Usually has the ability to react if certain circumstances occur (either give a warning or change something).

Mono: Abbreviation for monaural, meaning one channel.

MOSFET: Abbreviation for Metal-Oxide-Semiconductor Field Effect Transistor – a special type of transistor offering extremely high gate impedance.

Multiplexing: A technique whereby signals are alternately switched or selected, so that different signals can be sent down the same circuit path.

Multivibrator: A circuit which produces high and low output states either continually by itself (called astable) or under the influence of an external trigger (called monostable or bistable). A flipflop is a bistable multivibrator.

Mute: To prevent a signal (usually audio) passing, either partially or completely.

mV: Abbreviation for millivolt (1/1000 volt).

NAND Gate: A logic gate which will have a low level output only if all of its inputs are high.

NC: Abbreviation for "normally closed" – the relay contact which is connected to the "common" (COM) contact when the relay coil is not energised.

Negative: Refers to any point in a circuit which has a voltage of less than zero volts; also means the "-" terminal of a battery or power supply.

nF: Abbreviation of nanoFarad, 1/1,000,000,000 Farad (10^{-9}F). As a unit, it is midway between µF and pF.

NO: Abbreviation for "normally open" – the relay contact which is not normally connected to the "common" (COM) contact. The NO contact only connects to the COM contact when the relay coil is energised.

Noise: Unwanted signals, often "random" in nature and generated within a circuit's components, which interfere with the wanted signals. Also refers to unwanted radio signals which might hide or mask distant or weak radio signals one is trying to receive. Some radio noise is man-made (eg, motors) and some occurs naturally (eg static from thunderstorms).

NOR Gate: A logic gate which will have a low level output if any of its inputs are high.

NOT Gate: A logic gate which has only one input and output – if the input is high, the output is low and vice versa. Also known as an inverter.

Nominal Value: Where a value is specified loosely. For example, a nominal 12V supply might be somewhere between 11V and 14V.

Non-Inverting Amplifier: An amplifier circuit where the phase of the output signal is the same as the input signal (positive-going signal excursions stay positive-going, etc).

NPO (Capacitor): An abbreviation for "negative-positive-zero". Refers to the temperature coefficient of a ceramic capacitor.

Ohm: The unit of electrical resistance (abbreviation Ω).

Ohm's Law: The most basic rule in electronics. The applied voltage (V) equals the current (I) times the resistance (R); or V = I x R. Therefore, if you know two out of the three values, you can work out the other. For example, consider a 1.5V battery connected to a 100W resistor; ie, V = 1.5; R = 100. Turning the above formula around, I = V/R; so I = 1.5/100 or .015A (15mA). Note that the letter E is sometimes used for voltage, so E = I x R is the same as V = I x R.

Op Amp: Abbreviation for Operational Amplifier

Operational Amplifier: A very high gain amplifier (usually an IC or part of an IC) which can have positive or negative feedback applied to define the circuit gain and other performance factors.

OR Gate: A logic gate which will have a high level output if any of its inputs are high (or low if none of its inputs are high).

Oscillate: To change polarity or logic level continuously.

Oscillator: A circuit which is designed to produce continuous oscillation without needing an input signal (only DC power).

Oscilloscope: A device which enables you to observe signal waveforms on a cathode ray tube, similar to a small TV screen; very handy for circuit development and service work.

Overload: The situation which occurs when any component or circuit is driven beyond its normal capabilities. Sometimes, overload can damage a component or circuit. Occasionally, circuits are deliberately overloaded under control to produce special characteristics.

Parallel: A method of connecting components, so that each lead of one component connects to the respective lead of the other – see diagram page 67. When capacitors are connected in parallel, their capacitances add; when resistors are connected in parallel, the total resistance is always less than the smallest resistor.

PC Board: Abbreviation for Printed Circuit Board.

PC Board Overlay: A drawing showing how components are laid out on a printed circuit board, viewed from above the board as if it was x-rayed to show the copper pattern underneath.

PC Stake: A small metal post, designed for mounting on a PC board, to which leads, terminals, etc can be soldered much more easily than soldering through the hole in the PC board.

Peak-to-Peak: The absolute maximum value of a waveform in the positive and negative directions (with respect to earth). If a signal goes 12V positive (peak) then 12V negative (peak) it is said to be 24V peak-to-peak.

pF: Abbreviation of picofarad (1/1,000,000,000,000 Farad), a tiny amount of capacitance. Capacitors from 1pF up are commonly available.

Phase: A particular stage in a waveform, such as the crest, trough, or zero-crossing point. If two waveforms of the same frequency are locked together, they are said to be "in phase".

Pilot Tone: In stereo FM, an inaudible tone at 19kHz which is transmitted along with the signal to tell the FM receiver that it is a stereo signal. This turns on the receiver's stereo decoder and lights the "stereo" indicator.

Pitch: The frequency of an audible sound or musical note.

Pk-Pk: Abbreviation for peak-to-peak.

Polyester: A plastic material commonly used for manufacturing capacitors.

Positive: Refers to any point in a circuit which has a voltage higher than zero volts; also means the "+" terminal of a battery or power supply.

Pot: Abbreviation for potentiometer.

Potentiometer: Typically a 3-terminal resistance device whose resistance can be varied or adjusted. The resistance element is usually connected between a pair of terminals while the third terminal is a wiper contact which can make contact anywhere along the resistance element. A potentiometer is typically used to control the signal or voltage being fed to a circuit.

Polarity (1): When referring to voltage, whether it is positive or negative with respect to earth, or 0V.

Polarity (2): When referring to components, the way they are connected in circuit. The positive terminal of an electrolytic capacitor, for example, must be positive with respect to its negative terminal (usually marked with a negative sign). If the polarity is reversed, the capacitor and/or circuit may be damaged.

Primary: The input winding of a transformer. In the case of a power transformer, the winding to which the 240V AC mains is connected.

Printed Circuit Board: A thin piece of (usually) fibreglass onto which is laminated an even thinner layer of pure copper. A pattern is etched into the copper which then forms the circuit connections for the various components. Components are mounted through holes in the PC board from the fibreglass side and soldered to the copper on the underside.

Probe: A metal prod, usually insulated, used to make electrical connection in, or to, a circuit.

Pullup Resistor: Some components, especially ICs, have pins which must not remain unconnected or instability or damage may result. Some need to be connected to a logical "high" voltage but not directly to the positive supply. A resistor is used to connect, or "pull up", these pins to the positive supply voltage. (Converse: a "pull down" resistor connects to the 0V or negative supply rail).

Pulse Generator: A circuit designed to continuously oscillate or produce clock pulses which will trigger another section of the circuit.

Quiescent Current: A (usually) small current which flows through a circuit in its "at rest" state. Normally used to minimise distortion.

Radio Frequency: Frequencies above about 200kHz are said to be radio frequencies. Often abbreviated as RF.

RC: Abbreviation for Resistor/Capacitor. Usually refers to a circuit (often a timing circuit) consisting of resistance and capacitance. (Sometimes also used as an abbreviation for radio control).

Rectifier: A device (usually a silicon diode) which rectifies, or converts, AC to a fluctuating DC. A large smoothing capacitor is normally required after the rectifier. A single diode will provide half-wave rectification; two or four diodes are required for full-wave rectification. See also bridge.

Regulator: A circuit or semiconductor component which maintains a constant voltage or current. In this book, the term usually refers to a voltage regulator, a small 3-terminal device.

Relay: A type of switch which is operated by a lever or plunger, moved by the electromagnetic force generated by a current through a coil. Often used to isolate two sections of a circuit from each other, for example a low voltage circuit switching a high voltage circuit.

Resistance: The property of any material which opposes electrical current when voltage is applied to it. Any resistance produces heat when current is passed through it and the amount of heat can be calculated by multiplying the resistance in Ohms by the current in Amps squared, to obtain power expressed in Watts.

Resistive Load: Any load for a circuit or component composed entirely of resistance.

Resistor: A component with a defined value of resistance. Resistors are available in values from zero ohms (0Ω) through to many, many millions of ohms (megohms, or MΩ) and in power ratings from 1/8 watt (or less) through to thousands of watts.

Resonance: The set of input conditions in a circuit which results in the optimum response; usually applies to a narrow band of frequencies at which tuned "resonant" circuits give their peak performance.

Reverse Polarity: For our purposes, the incorrect connection of a battery or power supply. Instead of + to + and 0V to 0V, reverse connection is + to 0V and 0V to +. Unless the circuit is designed to cater for this possibility, damage will often occur. Most of the circuits in this book feature a reverse polarity protection diode.

Reverse Polarity Protection: A diode will only allow current to flow one way. By placing a suitably-connected diode in series with the supply or battery it won't matter if the supply is connected with reverse polarity – the diode will not conduct and the circuit simply will not work. The down side is that there is a small voltage loss (about 0.6V) across a normal silicon diode so a circuit being supplied with 12V will actually only receive about 11.4V.

RIAA: Abbreviation for "Recording Industry Association of America" – in this context, a standard set up to ensure vinyl records are all made with the same characteristics.

Ripple: Unwanted AC present on a DC power supply, generally due to insufficient filtering from a rectifier.

RF: See Radio Frequency.

RMS: Abbreviation for Root-Mean-Square.

Rolloff: The reduction or attenuation of signal frequencies above or below a nominal figure.

Root-Mean-Square: A method of measuring the "work" value of an alternating current. 12V RMS will heat a certain value of resistor to exactly the same temperature as 12V DC. The mains voltage in Australia is nominally 240V RMS.

Saturation: A transistor is controlled by the current flowing into its base. If no current is flowing, the transistor is off and no current flows between collector and emitter. As the base current is increased the collector/emitter current also increases. At some point, no matter how much the base current is increased, there is no further increase in collector/emitter current. At this point the transistor is said to be saturated, or fully turned on.

Schematic Diagram: See circuit diagram.

Schmitt Trigger: A semiconductor gate or circuit (usually an IC but not necessarily) which has a very sharply defined on/off point.

Screened Cable: A type of cable which is intended to minimise hum and noise pickup. There is an inner conductor (sometimes solid, sometimes multi-wire) surrounded by a layer of insulation, surrounded by a braided wire sleeve, surrounded by an outer insulation. In virtually all cases, the braided sleeve connects to the earth or 0V side of the circuit. Also known as shielded cable, coax or coaxial cable.

Secondary: The output winding of a transformer, normally (but not always) with a lower voltage than the input, or primary.

Semiconductor: Refers to those elements which are intermediate between conductors (metals) and insulators (most non-metals). Commonly includes the elements germanium, silicon and selenium but there are many others. Semiconductors are used to manufacture the millions of semiconductor devices we now use – diodes, transistors, integrated circuits, etc.

Series: Where one end of a component is connected to one end of another, so that the components are effectively in-line – see diagram p67. When resistors are connected in series, their resistances add.

Short Circuit: A mistaken or accidental connection of two wires or components which allows current to flow where it shouldn't. Short circuits often cause irreparable damage to components or circuits.

Shielded Cable: See screened cable

Silicon Chip: See Integrated Circuit

Solenoid: A type of actuator which uses an electromagnet to pull or push a plunger linked to either a switch (this type of solenoid is usually called a relay) or some other mechanical device, such as a water valve in a washing machine.

SPDT: Abbreviation for "single pole, double throw" – a switch or relay with one set of three terminals, with one terminal (the "common") being connected to one of the other two terminals depending on the switch position or coil energisation. Also known as a "changeover" switch or relay.

SPST: Abbreviation for "single pole, single throw" – a switch or relay with two terminals which are either connected together or not, depending on the switch position or coil energisation.

Stereo: Two channels of information (usually audio).

Subsonic: Below the normal human hearing range, usually means below about 15Hz.

Supersonic: Above the normal human hearing range, usually means above about 20,000Hz.

Supply Rail: The voltage made available to a circuit for it to work; eg, from a battery or power supply. Generally there is one supply rail, consisting of two connections – a positive voltage and 0V or earth. However, there can often be a third rail; a minus or negative voltage which is lower than 0V.

Temperature Coefficient: All components change in value as temperature changes. The amount of change is known as the temperature coefficient. Most commonly used for ceramic capacitors, where positive temperature coefficient (PTC) means the capacitance increases as temperature increases. Negative Temperature Coefficient (NTC) means capacitance decreases as temperature increases. NPO (negative-positive-zero) capacitors remain close to their original value regardless of changes in temperature.

Threshold: A specific level (eg, a certain voltage) at which an action or event will occur.

Time Constant: The nominal time it takes a certain capacitance to charge through a certain series resistance. Formula is $T = RC$, where T is in seconds, R is in Ohms and C is in Farads.

Tinned: Where copper wire (or some other type of wire) has been given a thin plating of tin. This prevent tarnishing, thus making soldering easier and more reliable. Virtually all component leads are tinned. Can also mean "soldered".

Transformer: A type of inductor with two or more windings, usually one on top of the other (but insulated from each other). An AC voltage applied across one winding induces a voltage into the other windings, in proportion to the ratio between the number of turns of wire on each coil. The most common type of transformer is a power transformer which has a large number of turns on the primary coil (the coil which connects to mains power) and one or more secondary coils.

Transient: A short-term signal surge, usually unintended and unwanted, impressed upon another signal or supply rail.

Transistor: a very common semiconductor component. It has three terminals designated base, collector and emitter. These terms are defined elsewhere in this glossary. Transistors are used as switches or amplifiers and are used in large numbers in op amps and other ICs and in exceedingly large number in microprocessors. Normally come in two types: NPN and PNP.

Trimmer: Generally used as an abbreviation for trimmer capacitor, a small variable capacitor used to make circuit adjustments (especially in RF circuits). Usually adjusted with a small non-metallic screwdriver.

Trimpot: A small potentiometer used to make small and infrequent circuit adjustments. Usually adjusted with a small non-metallic screwdriver.

Tuned Circuit: A circuit, usually consisting of capacitor(s) and inductor(s) which is resonant at a particular frequency. Varying either the capacitor or inductor will vary the resonant frequency.

µA: Abbreviation for microamp (1/1,000,000 amp).

µV: Abbreviation for microvolt (1/1,000,000 volt).

Volt: The basic unit of electrical pressure or potential difference. When there is a difference in potential between two points in a circuit, electrons flow from one to the other in an effort to equalise the potential difference. This electron flow forms an electric current.

Voltage Controlled Amplifier (VCA): An op amp circuit in which the gain is controlled by varying a DC voltage on one of its pins rather than by rotating a feedback potentiometer knob.

Voltage Divider: Voltage Divider: Usually two or more resistors connected in series across a power supply. The junction of the resistors provide a voltage division in proportion to the ratio of their resistances. For example, if two 10kΩ resistors in series are connected across a 10V supply, the voltage at their junction would be 5V. If both resistors were increased to 100kΩ, the voltage would still be 5V because the ratio hasn't changed.

Wiring Diagram: A pictorial diagram of the way a circuit is assembled. It will normally include connections to any PC board used but may not necessarily include the PC board pattern or component overlay.

Zener Diode: A special type of diode which is used as a voltage reference. Reverse biased, it breaks down and the voltage across it remains quite stable.

Zobel Network: A small R/C (resistor/capacitor) circuit attached to the output of an amplifier to help prevent supersonic oscillation or instability.

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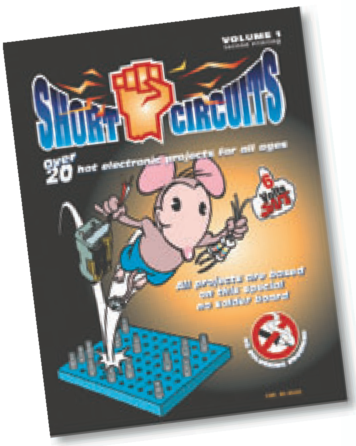

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