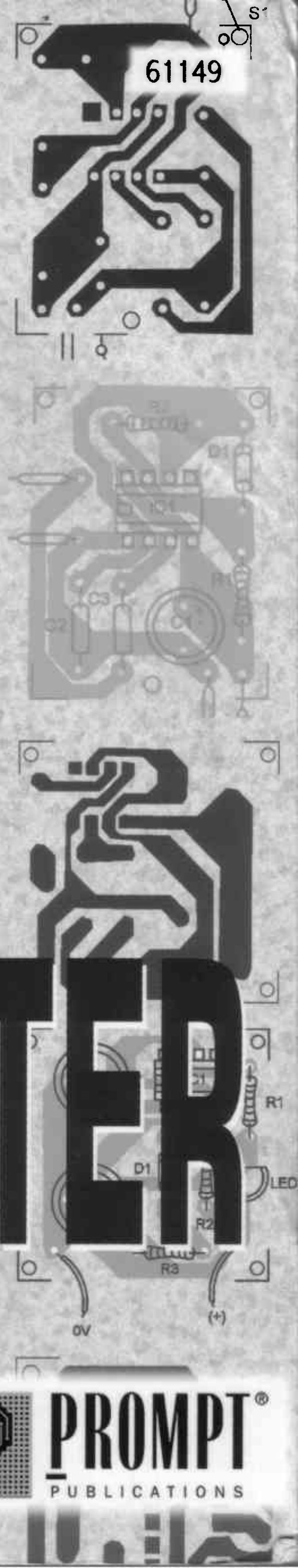
FUN PROJECTS *for the* EXPERIMENTER



Newton C. Braga

PROMPT® PUBLICATIONS

During more than 20 years, the author, as a collaborator with American, European and Latin American electronics magazines*, has published a large assortment of practical circuits using common parts.

Now many of those projects are included in this volume, most of which you can build in one evening. The projects range from fun types through practical types to amusement types. Of course, there are other devices that can be used to teach you something about circuits or components.

An important feature of theses projects are the Ideas to Explore, intended for students looking for projects in science or to use in practical research.

We can consider this book as a source book of the easiest and fun-to-make of the hundreds of projects created and published by the author during these last years.

But, as the projects are in a wide range of types, we should separate the electronics experimenters into two groups: the ones who want to improve or expand some other area of their electronics interest, such as computers, radio, instrumentation, audio, security and even games; and the ones who want to learn something about electronic circuits and devices or want new ideas to use in science projects.

Most of the projects described herein can be stand-alone as individual accessories; wherever possible the circuits have been designed so that they can be ganged with one or more other projects. For example, many projects of audio effects or generators can be ganged with audio amplifiers or high-power output stages.

All the projects are simple, with few low-cost components that can be made in one evening of work.

To make it easy for the reader to choose the projects we added codes after each title to indicate the kind of experimenter for whom they are intended: the code "P" (Practical) indicates a project built for practical use. The code "E" (Experimental) indicates that the project is intended for the experimenter to teach something about circuits or devices.

Of course, you can also find projects with both codes (E and P)which can either be mounted to teach something or/and be used for a practical end.

The presentations of the projects are practical. Electronics components are listed with each circuit diagram. But secondary parts such as sockets, chassis, enclosures, miscellaneous hardware and so on, are not specified, since the reader is free to choose these non-critical items according to his preferences and demands.

The manner in which the circuits work and can be modified is explained in practical terms so the reader can acquire some knowledge of practical electronics as he progresses through the book.

Although many of the projects we enjoyed constructing as they are described here, you may think of possible modifications. We just recommend that you go ahead and modify the circuits to your personal ends. There is a wide latitude in circuit modifications and most of them will be of value to the experimenter who wants to see how things work, even though each project's primary intent is for the builder who desires a functional item of equipment as the result of his work.

As the book includes easy-to-build projects, the author hopes it will help you to learn many of the fundamentals of electronics in an easy and fun way, and, if you're a student, provide a source for school projects.

Newton C. Braga

* Mini-Projects is the title of a column published by the author during several years in a Brazilian Electronics Magazine named Eletrônica Total (Total Electronics).

MICRO-POWER LED FLASHER (E/P)

A simple LED flasher can be built with a TLC7555 Timer used as a low-frequency oscillator and drive to an LED. IC1 runs in a low frequency determined by R2/R3 and C1. Frequency is in the range between 0.1 and 5 Hz but you can alter it by changing C1. This capacitor can range from 1 to 10 uF.

Duty cycle is determined by R2/R3 ratio and is important in applications where you need reduction of energy consumed. Though Figure 1 shows fixed resistors for R2 and R3, you can use trimmer potentiometers if you prefer. The potentiometers, of course, are handy for altering the frequency and duty cycle of the oscillator.

R1 values depend upon the power supply voltage. With power supplies between 5 and 6 volts, R1 is 470 ohms. With power supplies between 6 and 9 volts, R1 is 560 or 680 ohms. With power supplies in the range between 9 and 12 volts, R1 must be 1,000 ohms. The circuit drains only 250 uA from a 6-volt power supply.

Figure 1 shows the schematic diagram for the Micro-Power LED Flasher. At the heart of the circuit is IC1, a 555 timer.

Use the parts placement diagram as a guide when assembling the Micro-Power LED Flasher. Components placement, using a terminal strip as chassis, is shown in ***Figure 2***.

Take special care with positions of polarized components, such as the LED and electrolytic capacitor.

After you are sure that you have wired all the components correctly, put the batteries in the battery holder. The LED should flash.

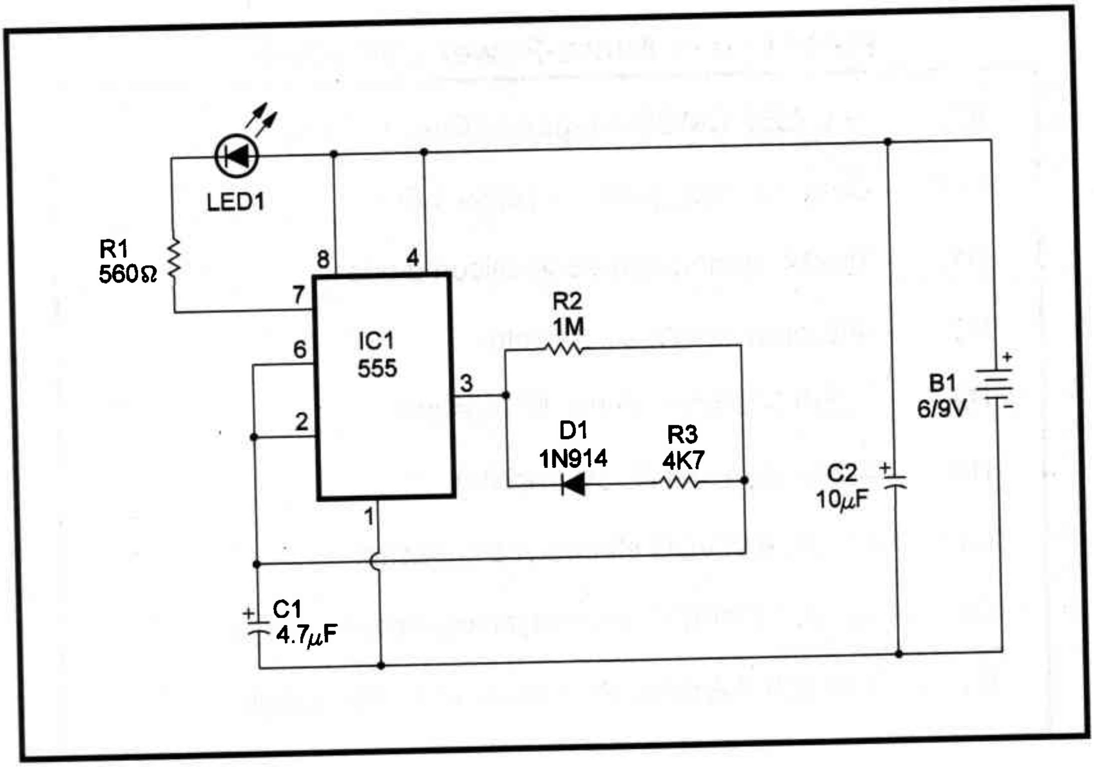


Figure 1

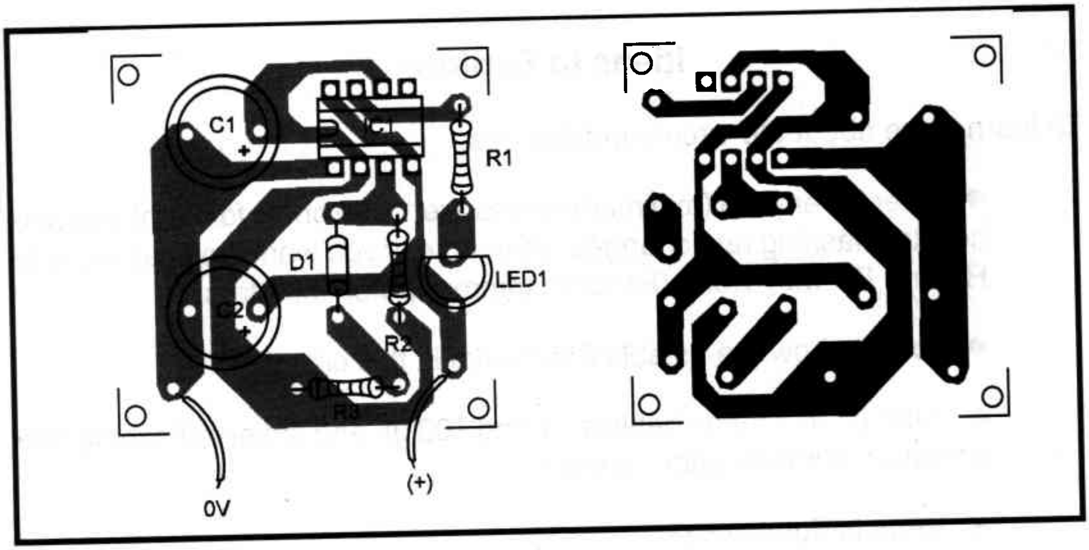


Figure 2

Parts List — Micro-Power LED Flasher

IC1	- TLC7555 CMOS Integrated Circuit - Timer
LED1	- Common red, green or yellow LED
D1	- 1N914 general purpose silicon diode
R1	- 560 ohm, 1/4W, 5% resistor
R2	- 1,000,000 ohm, 1/4W, 5% resistor
R3	- 4,700 ohm, 1/4W, 5% resistor
C1	- 4,7 uF, 6 WVDC electrolytic capacitor
C2	- 10 uF, 12 WVDC electrolytic capacitor
B1	- 6 to 12V AA cells, 9V battery or power supply

Ideas to Explore

To learn more about the circuit and devices:

- Alter R2 and R3 (minimum values are 1,000 ohms for both) and see how the flashing rate changes. Of course, if you want, you can replace R2 and R3 with 1,000,000-ohm trimmer potentiometers.
- Explain how the astable 555 works in this circuit.
- Alter C1 in a range between 1 and 100 uF and observe flashing rate alteration. Explain what happens.
- What is duty-cycle?

Science experiments with the circuit:

- LED is a monochromatic light source. You can perform some experiments in optics using this kind of light source. Chromatic filters can be used in some experiments involving LEDs. Try to use LEDs of different colors (red, yellow, green and, if possible, blue).

- Light flashes, as the ones produced by this circuit, can be used in hypnotic experiments.

- The circuit can be used to indicate operation of other electronic devices. Wired to the power supply of a monitored device, the blinker LED will indicate its operation.

Remember that the theory in this book is specifically related to the associated experiments and projects. This book is designed as an introduction, not as an in-depth treatment of electronics. If you are interested in finding out more about the subjects touched on in this book, several texts can be found for further reading.

SET-RESET FLIP-FLOP (E)

With this project we can show how two NAND gates of a 7400 IC (TTL Integrated Circuit) can be wired to perform as an R-S flip-flop.

This circuit is a pulse-triggered flip-flop that needs negative-going pulses to be triggered. This circuit operates as follows: as we see, it has two outputs; a normal output called Q (LED1) and an inverted output called $\overline{Q}$ (LED2). When one output is 1 the other necessarily will be 0 and vice-versa because they are complementary.

The circuit has also two inputs named S (SET) and R (RESET) as shown in the schematic diagram, where the trigger signals are applied.

R input is wired to Q output and S input is wired to $\overline{Q}$ output, forming a closed-loop for the digital signals.

When a negative-going trigger pulse is applied to S input the output Q swings to the 1 state. As this output is wired to R input, the 1 state causes output $\overline{Q}$ to fall to a 0 level. But $\overline{Q}$ output is also wired to S input causing a feedback that makes its output remain at 1 also after the trigger pulse has disappeared. To trigger the flip-flop again, changing the output states, we should apply a negative-going pulse to R input. This pulse causes the output to go to 1, and as this output is wired to R input, the trigger pulse also causes the output Q to go to 0 level.

A zero in this output goes to R input, and also after the trigger pulse disappears the outputs remain in their states.

See that the circuit has two stable states, and we only can change these states with set or reset (S or R) negative-going pulses applied to its inputs.

Our project is a manually-triggered flip-flop and can be constructed wiring a switch to the R-S inputs as shown in ***Figure 1***.

Logic states are indicated by two LEDs. LED1 glows with a 1 at Q output and LED2 glows with a 1 at $\overline{Q}$ output.

The circuit must be powered by a 5-volt regulated power supply as it uses a TTL IC. Current requirements range typically from 5 to 15 mA.

Components placement on a small printed-circuit board is shown in ***Figure 2***.

Experiments like this can also be performed on what electronics experimenters call "breadboards". These are boards on which the parts of experiments can be temporarily assembled. By using breadboards it is not necessary to

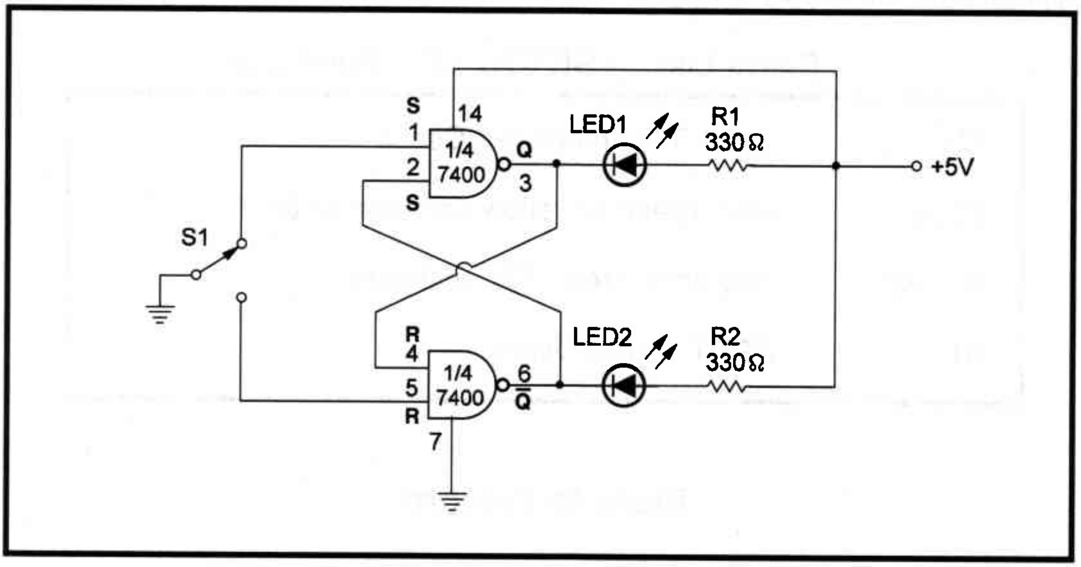


Figure 1

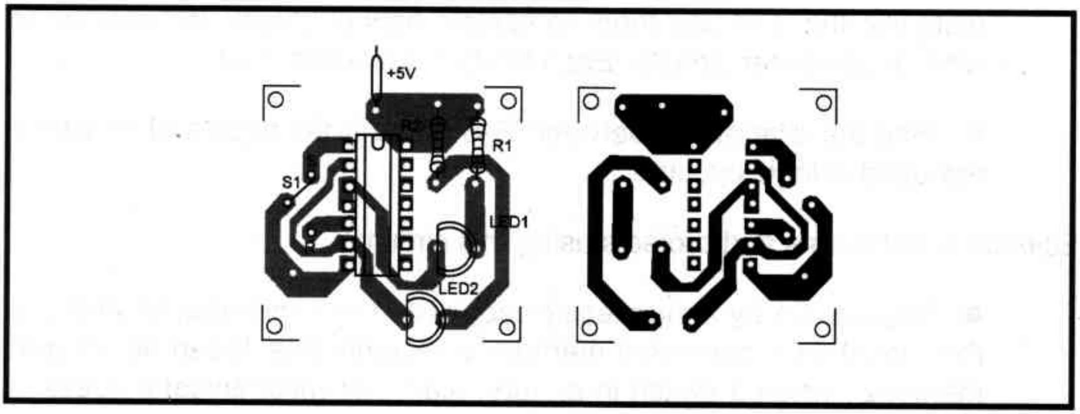


Figure 2

solder the components. This is why they are also called "solderless boards"

The circuit can be used to teach much about flip-flops, used in computers as counters and in memories and many other applications.

Observation: In digital electronics an electrical signal is either high or low. These two states are used to represent binary bits 1 and 0. Since digital logic ICs operate from a single-ended power supply, a high state represents a voltage near the supply voltage and a low state represents a voltage near 0V.

PARTS LIST — SET-RESET FLIP-FLOP

IC1	- 7400 TTL Integrated Circuit
LEDs	- Red, green or yellow common LEDs
R1, R2	- 330 ohm, 1/4W, 5% resistors
S1	- SPDT toggle switch

Ideas to Explore

To learn more about the circuit and devices:

- The common flip-flop is a fundamental counter circuit. Mount other units like this and use them to explain how counters and memories work in computer circuits. Each flip-flop can store a bit.

- Find the differences between R-S and J-K flip-flops and how they are used in logic circuits.

Science experiments and projects using this circuit:

- Replace S1 by a magnetic (reed) switch or a microswitch and use this circuit as a one-event memory in experiments. It can detect and memorize when a switch in an lure, alarm, or mechanical process is closed for a moment.

MINI-METRONOME (P)

Here is a dandy two-transistor metronome which you can build into a small plastic case. You can use an old nonworking transistor radio to house this gadget. In most case you can merely remove the main circuitry but retain some parts, such as the on-off volume control potentiometer, speaker and battery holder. If you have done this, you have just eliminated the following items: SPKR, S1, and B1.

The circuit can be powered with two or four AA cells and drains about 10 mA.

As soon as S1 is closed, the metronome starts clacking. By adjusting potentiometer P1 you find the "beat" or frequency of clacking you wish to set.

To calibrate, you have only to synchronize your metronome with a commercial type or any known source.

Figure 1 shows the schematic diagram for the Mini-Metronome. At the heart of the circuit are Q1 and Q2, as a two-stage direct-coupled amplifier, which allows the circuit to generate intervalled pulses.

Figure 2 shows a mechanical view of the metronome, using a terminal strip as "chassis" for the small components.

Position of the polarized components, such as C1, C2 and the transistor, should be observed in the mounting.

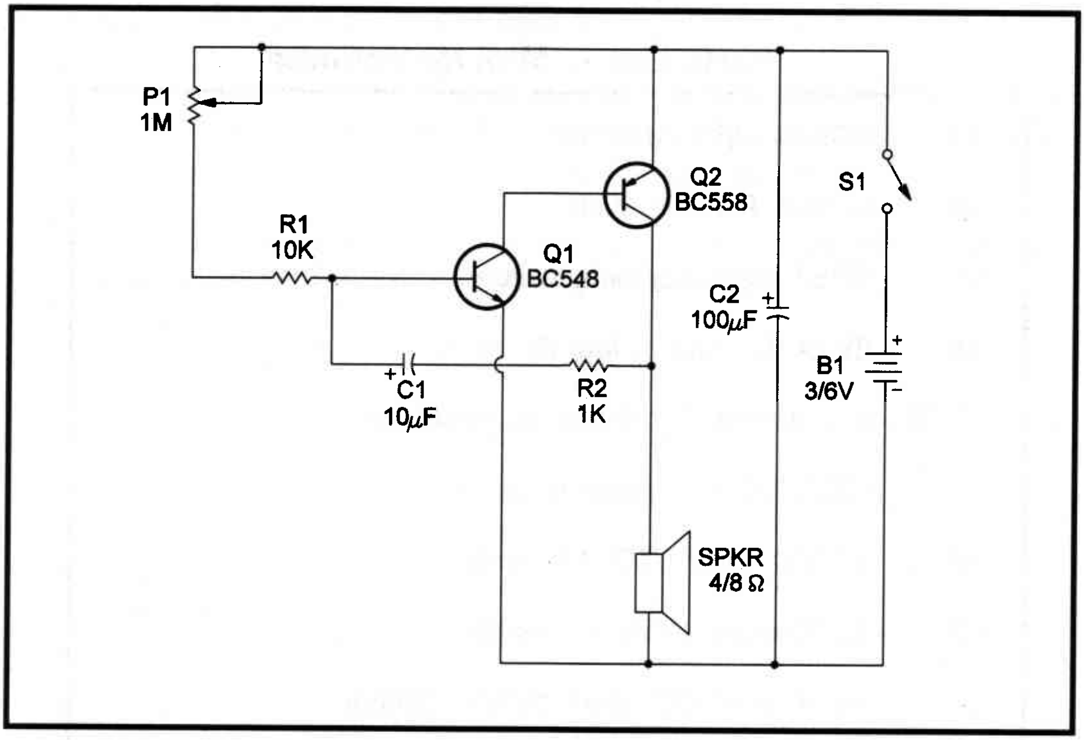


Figure 1

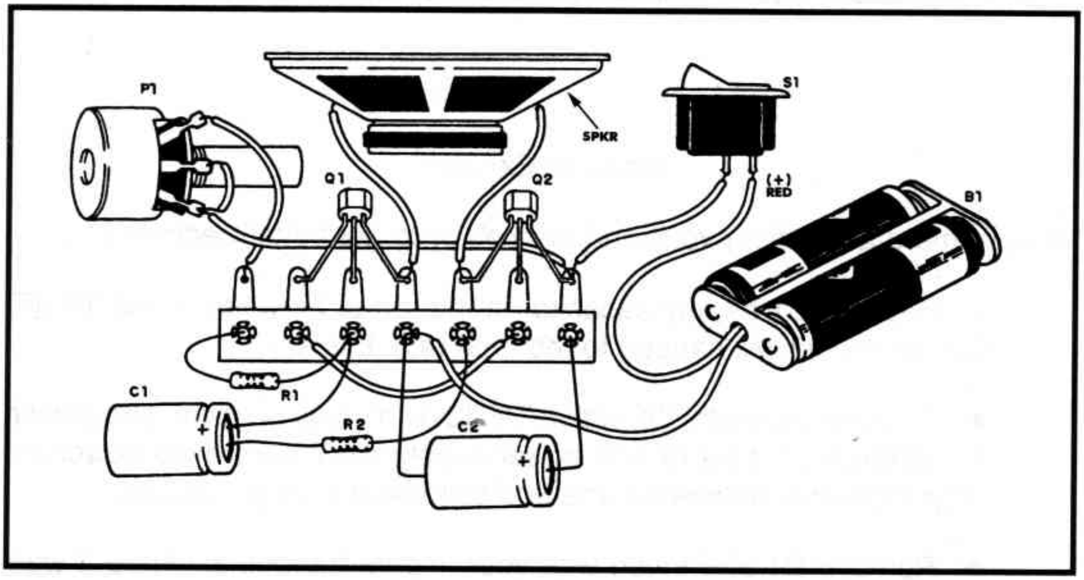


Figure 2

Parts List — Mini Metronome

Q1	- BC548 NPN transistor
Q2	- BC558 PNP transistor
S1	- SPST toggle or slide switch
B1	- 3V or 6V - two or four AA cells
SPKR	- 4 or 8 ohm, 2 to 4-inch loudspeaker
P1 -	1,000,000 ohm potentiometer
R1	- 10,000 ohm, 1/4W, 5% resistor
R2	- 1,000 ohm, 1/4W, 5% resistor
C1	- 10 µF, 6 WVDC electrolytic capacitor
C2	- 10 µF, 6 WVDC electrolytic capacitor

Ideas to Explore

To learn more about the circuit and devices or to get better performance:

- Replace C1 by any capacitor in the range between 1 and 10 µF. Observe what will happen to the beat rate. Explain it.

- Replace transistor Q2 with a TIP32 on a small heatsink and power the circuit from a 9V or 12V power supply. You'll have extra power for your experimental metronome and can use it in larger places.

- Remove P1 and touch with your fingers the points where it was wired. Will the circuit operate? Can you explain what is going on?

Science experiments and different uses for the circuit:

- The metronome can be used in gymnastic exercises or in running to find the correct rhythm. The metronome can be housed in a small plastic box, powered by cells and easily carried with the runner.

- Biological experiments with sounds can be made with this device; experiments in animal conditioning, for example.

PENDULUM ALARM (E/P)

Any movement that swings the pendulum sensor triggers this alarm, enabling a relay.

The circuit can be used to protect cars, large objects, homes and other places as the sensor can be used to detect any movement. This device can also be used for scientific experiments, as suggested at the end of the section.

The relay can drive powerful sound systems, such as sirens, horns, lamps, etc. The circuit can be powered by a 12-volt battery (when used in cars, for instance) or a power supply. Current drain is very low (about 100 uA) when the relay is deenergized, extending battery life.

The schematic circuit of the Pendulum Alarm is shown in ***Figure 1***. The circuit has as its heart an SCR (Silicon Controlled Rectifier), which energizes the relay when the sensor detects any movement.

A mechanical view of the circuit mounting, using a terminal strip as chassis, is shown in ***Figure 2***.

Relay coil voltage is chosen according to the power supply voltage. You can use a mini DPDT 1A Mini Relay (Radio Shack 275-249) or, for heavy loads, a 10A mini SPDT relay (Radio Shack 275-248). These relays are rated to 12 VDC and drain only 38 mA (their coil resistance is about 320 ohms). As equivalent types can be used, you should take care with terminal layout.

Reset can be made with a momentary-type switch (Push-On) wired between the SCR anode and catode, or by using the on-off switch.

Positions of polarized components, such as the SCR and diode, should be observed.

Sensor details are also given in ***Figure 2***. Notice that operation occurs when the vertical (or horizontal) bare wire touches the ring during any movement.

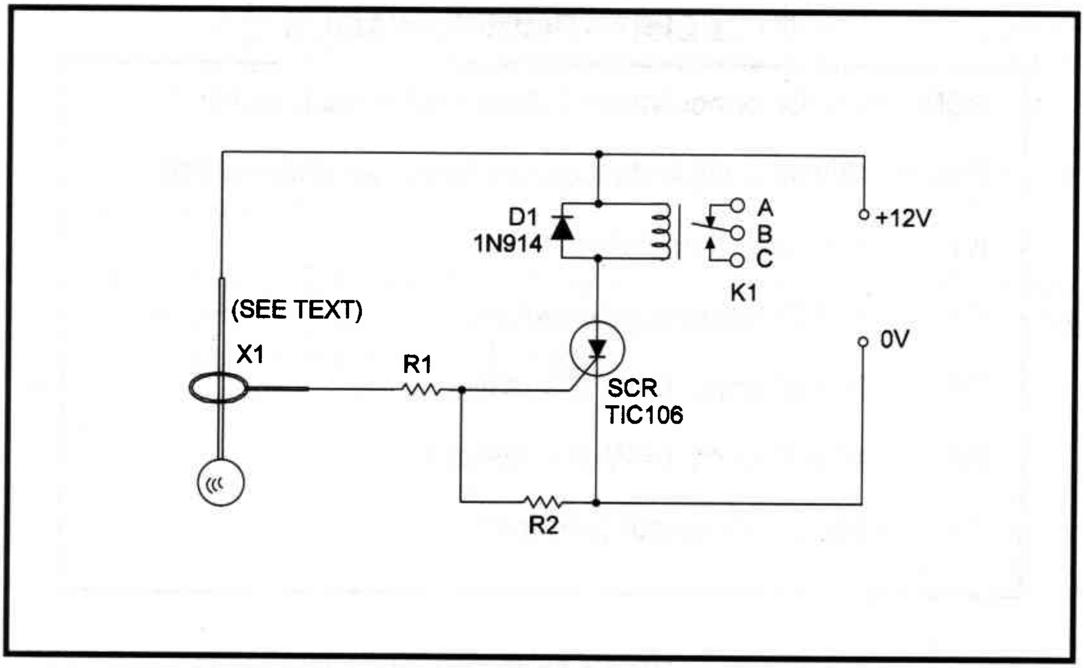


Figure 1

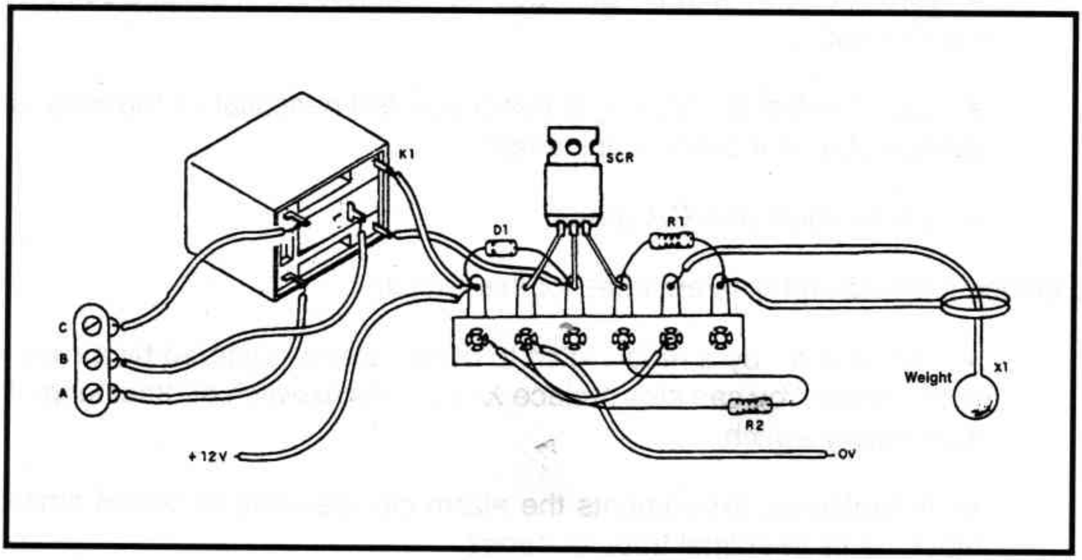


Figure 2

Parts List — Pendulum Alarm

SCR	- TIC106 or equivalent Silicon Controlled Rectifier
D1	- 1N914 or equivalent general-purpose silicon diode
K1	- 12V relay (see text)
S1	- SPST slide or toggle switch
R1	- 22,000 ohm, 1/4W, 5% resistor
R2	- 10,000 ohm, 1/4W, 5% resistor
X1	- Pendulum sensor (see text)

Ideas to Explore

To learn more about circuit and devices:

- Replace relay with a 12V x 200 mA incandescent lamp. Does the circuit work?
- Explain what D1 is doing in this circuit. Is it necessary if the relay is replaced by an incandescent lamp?
- Explain how an SCR works.

Science projects and different uses for this circuit:

- Replace X1 by a reed switch to get an alarm triggered by a magnetic sensor. You can also replace X1 by a microswitch or other kind of momentary switch.
- In biological experiments the alarm can be used to detect small movements in animal traps or cages.

- Replacing X1 by two metal wires enables the circuit to be triggered by water. Water level detectors can be made using this kind of sensor, and it can be used in many experiments and practical applications.

- Installed in your car, this circuit can be used as an alarm, driving the horn or a siren.

- By replacing X1 with a large metal plate, the circuit can be used to detect wind. Air flow can move the plate so that the bare wire touching the loop causes the alarm to trigger.

MEDIUM-WAVE RF PRESELECTOR (P)

The sensivity of most moderately-priced AM receivers is poor in the medium-wave band. Worse yet, selectivity also drops off sharply within the upper part of the band, making the receiver highly susceptible to images, noise and annoying heterodynes.

Even the best antenna and a good booster amplifier can't make up for these deficiencies in a common receiver's front end. But, using an RF preselector between the antenna and the receiver's antenna input terminals will give you real increase in the reception quality.

This circuit matches the antenna impedance with the receiver's antenna input according the frequency of the tuned station.

Figure 1 shows schematic diagram of the Medium-Wave Preselector.

Figure 2 shows an exploded view of the circuit, which can be housed in a small plastic box.

L1 is formed by turns of No. 28 enameled wire, wound on a 5/16-inch ferrite form. Taps are made each 15 or 20 turns and its number is not critical. The number of taps can be altered.

Attach your antenna and ground to the input terminals of the preselector. Tune to the desired station on your receiver, and, by choosing the best position of the alligator clip on the strip and by adjusting CV, find the best signal.

The required antenna will depend upon the station you want to tune. A random length of wire will give fairly good performance through the AM band. Antennas with lengths between 15 and 150 feet are recommended for best performance.

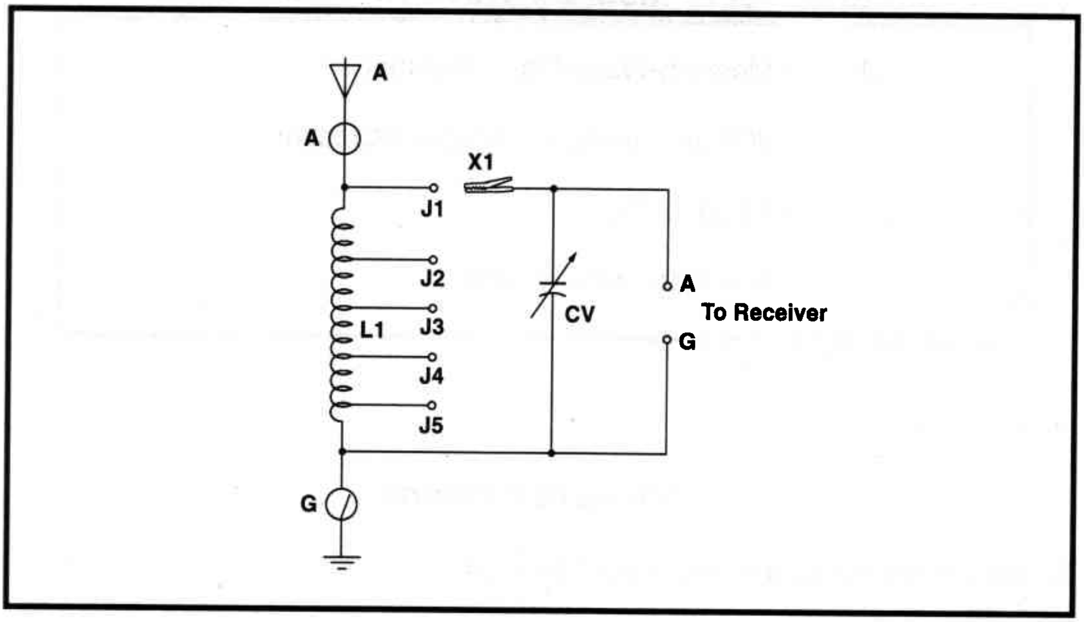


Figure 1

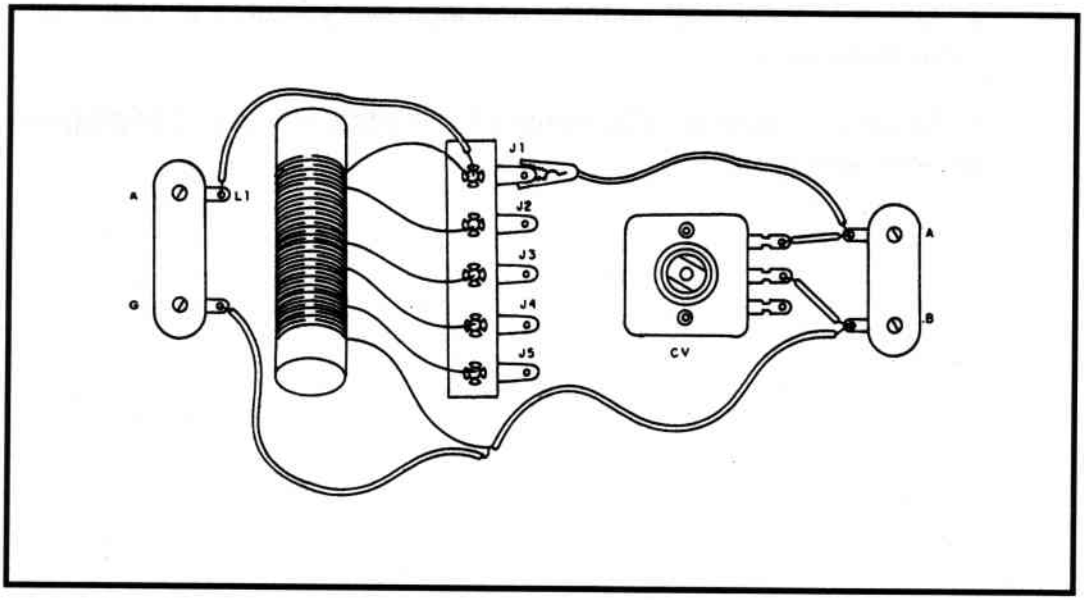


Figure 2

Parts List — Medium-Wave RF Preselector

L1	- Medium-Wave Coil - see text
CV	- 365 pF miniature variable capacitor
X1	- Alligator clip
	- 2-position barrier strip

Ideas to Explore

To learn more about the circuit and devices:

- Explain the importance of a good ground connection in this circuit. What is the meaning of “impedance”?

- Use a new coil with 20 turns and taps every 3 turns to tune short-wave stations.

- Make a second coil (20 turns) on the same ferrite rod to plug the antenna and ground.

ELECTRONIC FISHING LURE (P)

This circuit imitates the sound of wet bugs milling about the surface to attract curious fish.

The circuit is basically a Hartley audio oscillator operating in a frequency between 200 and 2,000 Hertz. Powered by an AA cell, it can housed in a clean empty peanut butter jar with the buzzer circuitry mounted upside-down on the cover. You must be carefull not to drill in such a way as to allow water to leak through the cap. Silicon rubber can be used to close any water leak.

Capacitor C1 would give a resonant frequency of approximately 1,000 Hz, but P1 would give a wide variation in signal tone generated in the audio range.

You can also use a low-impedance earphone as a transducer, connecting it to the second coil (output) of the transformer.

To operate, unscrew the cap, throw S1 ON, put the cover back on, and drop the fish lure into the water in the vicinity of where you will be fishing. Allow 20 minutes before reeling them in. If necessary, adjust P1 to a new signal tone.

Figure 1 shows the schematic diagram for the Fish Lure. Observe that the secondary coil of the small audio transformer is not used in this circuit.

Construction details of the Electronic Fishing Lure, using a terminal strip as chassis, is shown in ***Figure 2***. The exact locations of components is not critical.

T1 is also not critical. Any 500:8 or 1,000:8 transistor transformer with center-tapped primary can be used. We can also suggest that any small transistor transformer can be experimented with.

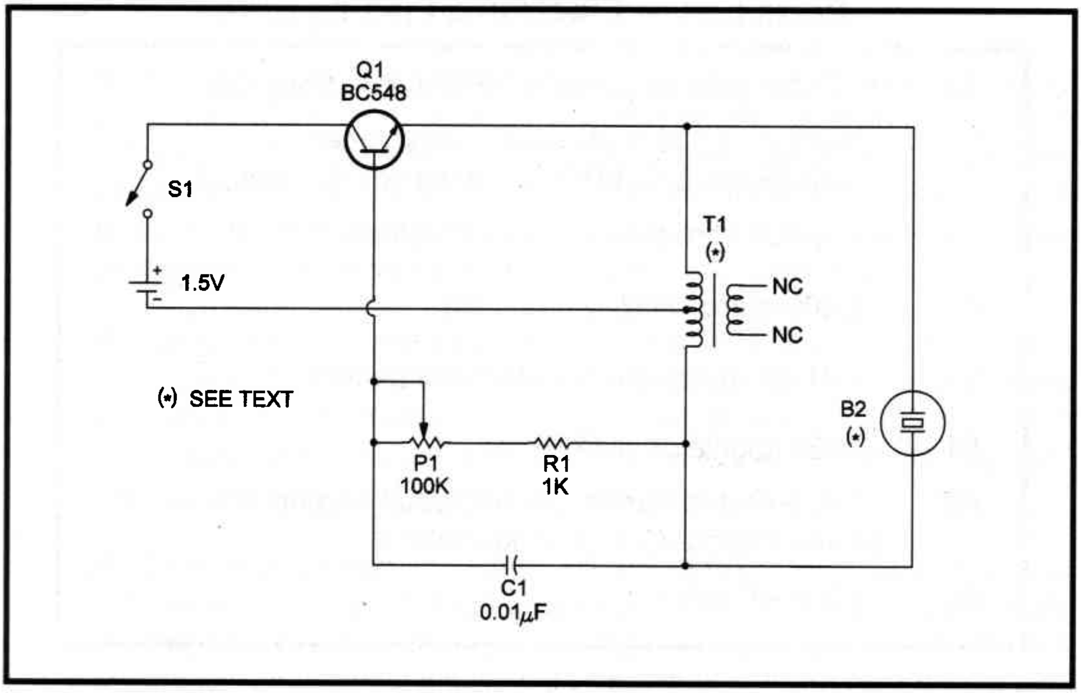


Figure 1

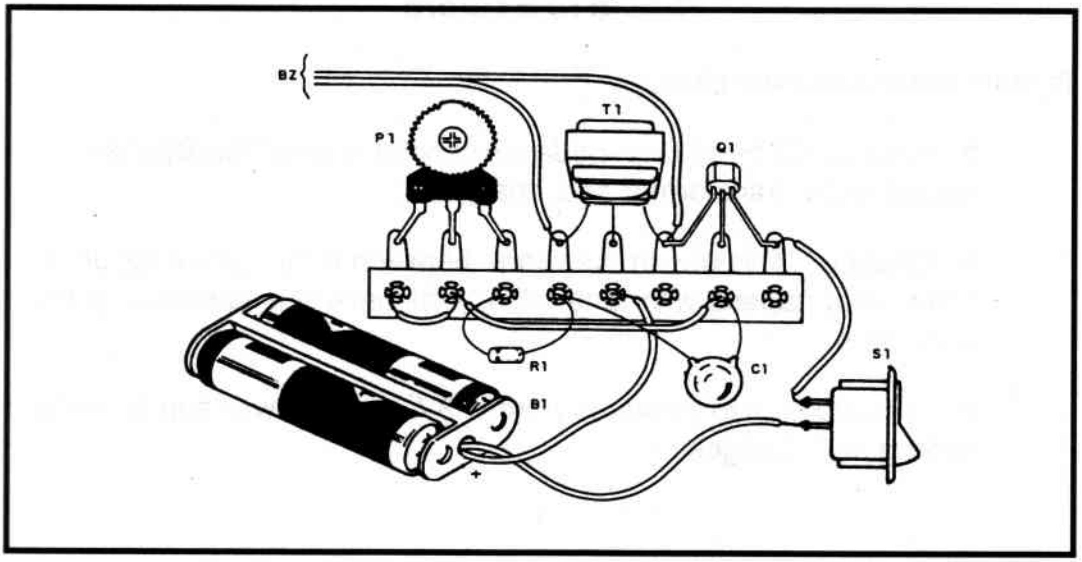


Figure 2

Parts List — Electronic Fishing Lure

Q1	- BC548 general-purpose NPN silicon transistor
T1	- 500:8 or 1,000:8 transistor transformer (RadioShack 273-1380 is suitable for this task)
P1	- 100,000 ohm trimmer potentiometer
R1	- 1,000 ohm, 1/4W, 5% resistor
C1	- 0.01 uF metal film or ceramic capacitor
S1	- SPST toggle or slide switch
BZ	- Piezoelectric transducer or crystal earphone (Radio Shack273-073 or equivalent)
B1	- 1.5 V AA cell

Ideas to Explore

To learn more about the circuit:

- Replace BZ by a low-impedance tweeter or small loudspeaker connected to the transformer secondary coil.

- Change C1 values in the range between 0.001 and 0.22 uF. Observe what hapens with tone pitch. A higher-value capacitor gives a lower tone.

- The circuit also operates from a 3V or 6V power supply without making any changes.

Science and different uses for the device:

- You can make several experiments in animal conditioning, including the ones that live in the water. Try to alter the RC network (P1, R1 and C1) to get tones of different pitch. Try to use diodes, small transformer coils and other passive components in this experiment. Sounds like those produced by songbirds can be generated with a few components arranged in the correct way. Can you discover how to do it?

- Remove the piezoelectric transducer and wire electrodes in its place. The device can be use as a nerv stimulator. Experiments with animals and plants can be made. What physiological functions are affected? Can circadian rhytms or internal biological clocks be affected by continuous exposure to sounds?

- Electrodes placed into water and wired in place of the transducer will produce a current field. You can perform interesting scientific work relating how fish and other water beings react to the current field. Can the current fields affect physiological functions? If you experiment with plants, select a fast growing house plant.

FREE-POWER AM RECEIVER (P,E)

This project uses a strange way to get its power. It uses power "extracted" from the tuned station to give to the amplifier transistor. With a reasonably strong applied modulation envelope, this type of detector produces a strong demodulated output.

Naturally, the closer you are to a strong station, the more current your radio will be able to supply.

For best results, you must do everything possible to deliver a strong signal to the transistor detector. We recommend a good antenna and ground, the latter preferably being made to a water pipe or solid external ground composed of a pipe driven at least 5 feet into moist earth. This is important for ensuring maximum signal pickup.

If you have plenty of space available, the longer the antenna (up to about 100 feet), the better the results.

Figure 1 shows the schematic diagram of the Free-Power AM receiver. Observe that the heart of the circuit is a germanium transistor that works as a detector and audio amplifier.

Components placement on a terminal strip used as a chassis is shown in ***Figure 2***. The terminal strip can be fixed on an experiment board that can be constructed using some common tools and materials.

Q1 is any germanium transistor, such as GE-2 or 2N107. You can find germanium transistors in old nonworking AM transistor radio receivers. Nonworking AM radios can also supply the variable capacitor and the loopstick (ferrite rod).

Earphone must be a high-impedance crystal type. Low-impedance earphones don't function in this circuit.

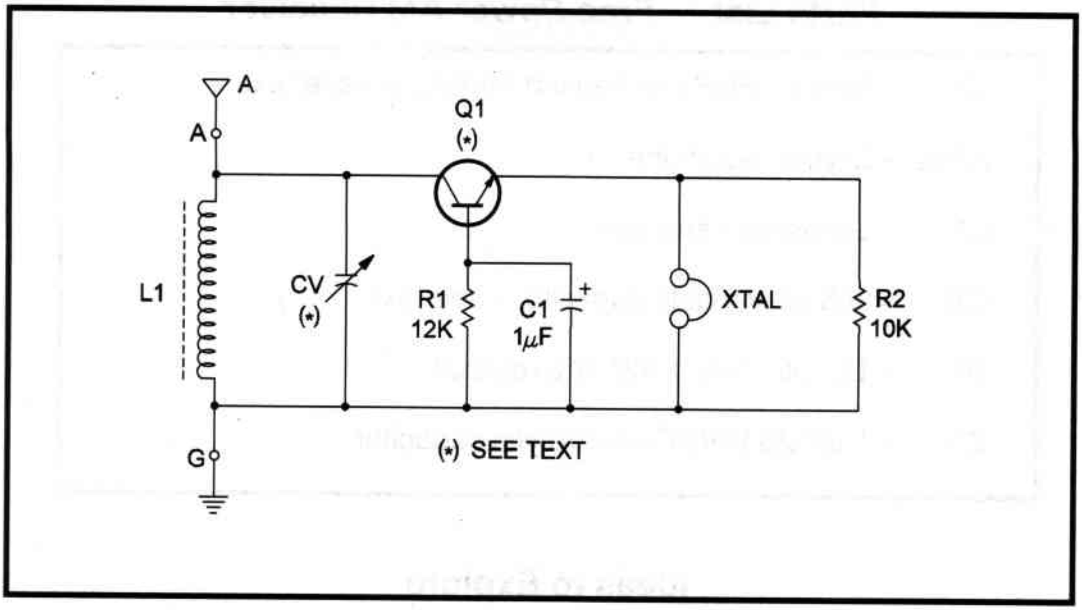


Figure 1

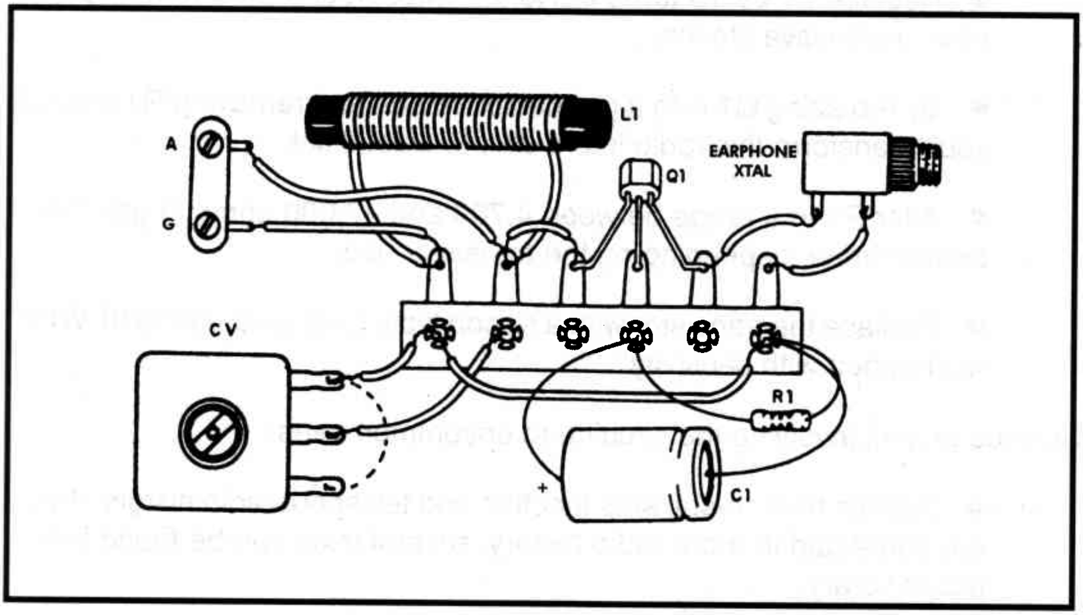


Figure 2

Parts List — Free-Power AM Receiver

Q1	- NPN or PNP germanium transistor - see text
XTAL	- Crystal earphone
L1	- Loopstick - see text
CV	- 365 pF variable capacitor - see text
R1	- 12,000 ohm, 1/4W, 5% resistor
C1	- 1 uF, 25 WVDC electrolytic capacitor

Ideas to Explore

To learn more about the circuit:

- Replace L1 by 15 turns of No. 28 wire, wound on a ferrite rod, to tune short-wave stations.
- By replacing Q1 with a germanium diode and removing R1 and C1 you'll transform this radio into a simple crystal set.
- Alter R1 in a range between 4,700 and 47,000 ohms to get better performance, depending on the transistor used.
- Replace the transistor with a silicon type, such as the BC548. What will happen with sensivity?

Science project involving the circuit and uncommon uses:

- Explain how crystal sets function and tell about radio history. If you are interested in more radio history, several texts can be found in the public library.
- If you want to learn more about radio receivers, try to find information about heterodyne and super-hereterodyne types.

DUAL-LED FLASHER (E,P)

This circuit uses a one-gate oscillator, with a 4093 CMOS IC, to produce a 50% duty-cycle flasher in two LEDs or a bi-color LED. The circuit can be powered by a 3 to 12-volt power supply and is useful in several experiments and practical applications. You can use it as part of alarms, warning systems, games, toys, and some scientific experiments, as we will describe here.

R2 and R3 values depend upon the power supply voltage, according to the following table:

Power Supply	R2, R3
3 Volts	220 ohms
5 Volts	330 ohms
6 Volts	470 ohms
9 Volts	820 ohms
12 Volts	1,000 ohms

For more output you can use a transistorized output stage driving incandescent lamps. Experiments to observe light effects on animals and plants can be conducted with this circuit.

P1 and C1 determine flash rate. Flash rate can be adjusted by P1, but C1 also can be altered in a large range of values, according to the application you intend for the device.

Schematic diagram for the Dual-Led Flasher is shown in ***Figure 1***. One gate of a 4093 IC is used as oscillator and the other two are used as inverters.

Components placement on a PC board is shown in ***Figure 2***. You can also use a breadboard or solderless board to mount it as an experimental circuit.

Position of the polarized pieces, such as LEDs, eletrolytics and IC, should be observed.

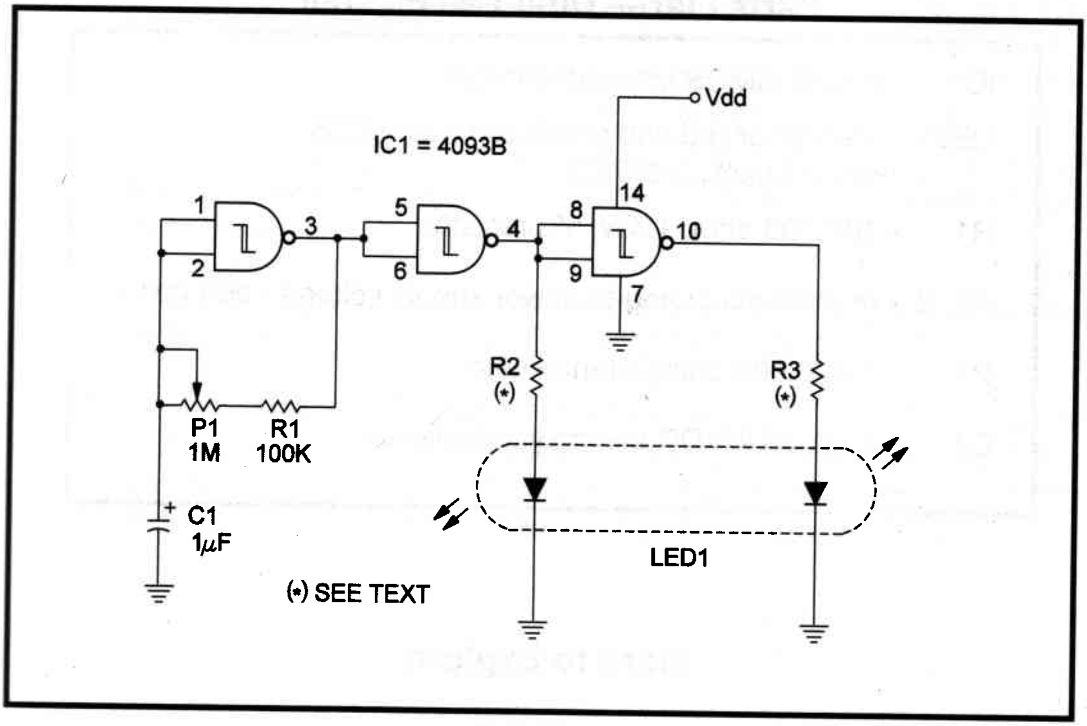


Figure 1

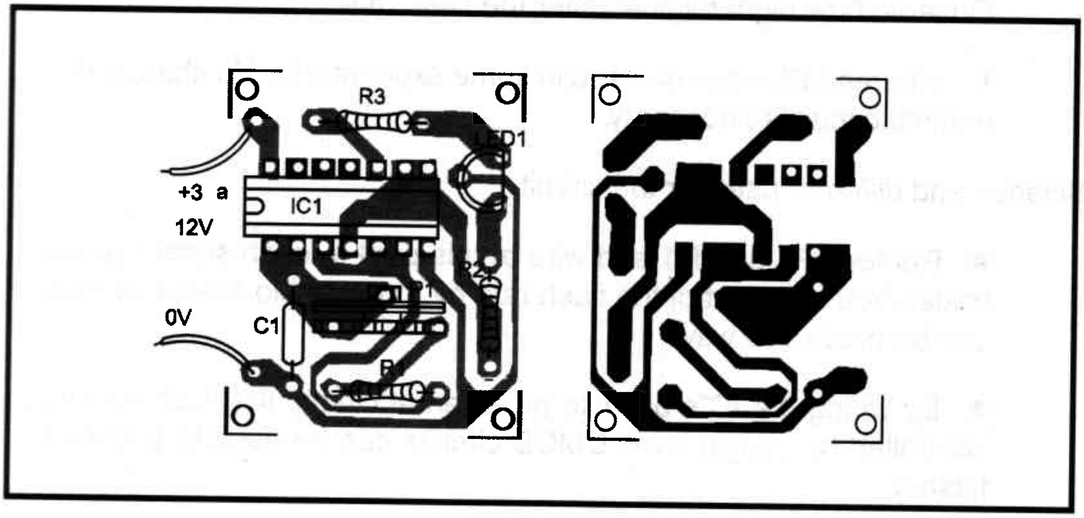


Figure 2

Parts List — Dual-Led Flasher

IC1	- 4093B CMOS integrated circuit
LED1	- bi-color or red and green common LEDs (Radio Shack 276-012)
R1	- 100,000 ohm, 1/4W, 5% resistor
R2, 3	- resistor according to power supply voltage - see text
P1	- 1,000,000 ohm potentiometer
C1	- 1 uF, 25 WVDC electrolytic capacitor

Ideas to Explore

To learn more about the circuit and devices:

- Replace C1 with capacitors in the range between 1 and 47 uF. Observe how higher values alter the flash rate.

- Infrared LEDs can be used in some experiments. No change in the original circuit is necessary.

Science and different uses for the circuit:

- Remove P1 and R1 and wire at this pont a touch sensor or electrodes. You can control the flash rate by touch. A bio-feedback device can be made this way.

- By wiring the IC"s pin 1 to an external circuit, the flasher can be controlled by a logic level. CMOS circuits can be used to control the flasher.

- Mount the LEDs in place of the lenses of a set of eyeglasses. The flash rate can be adjusted to make an hypnotic or relaxing effect. Combine this with a touch sensor and you have an uncommon bio-feedback device. You can also use this circuit to make experiments in circadian rhythms or internal biological clocks, determining how they can be altered by light pulses. Various theories have been proposed about this subject.

- Psychiatrists are using phototherapy to help some patients. Can you find some application for the circuit in this field?

- P1 also can be replaced by resistive transducers, such as LDRs or NTCs, to give a light- or temperature-dependent flash-rate circuit. Experiments can be made with conductivity of materials by connecting probes in series with R1. Replace P1 with the probes in this case.

6V X 1A POWER SUPPLY (P)

In order to perform experiments and projects involving electricity you will need a source of voltage. Voltage requirements for common projects, such as the ones in this book, depend upon their applications, and typically range from a few milliamperes to one or two amperes.

Instead of using a battery you can use a circuit called a *power supply*.

The power supply we show here can be used to provide 6V x 1A regulated output to the experimental and practical circuits described in this book. The output voltage is fixed by the IC.

Figure 1 shows the schematic diagram for this power supply. IC1 is a voltage regulator, #7806. The "06" indicates that it is a 6-volt regulator.

Figure 2 shows the components layout, using a terminal strip as chassis.

The complete project can be assembled in a small plastic box. The integrated circuit should be mounted on a heatsink. You can also add an LED in series with a 470 ohm resistor, wired in the output of the circuit to indicate that it is on.

External circuits can be connected to the power supply with alligator clips.

Position of the polarized pieces, such as diodes, the IC, and electrolytic capacitors, must be observed.

The transformer isn't a critical part of this project. Types with a secondary coil ranging from 7.5 to 12 volts and currents between 500 mA and 1A can be used.

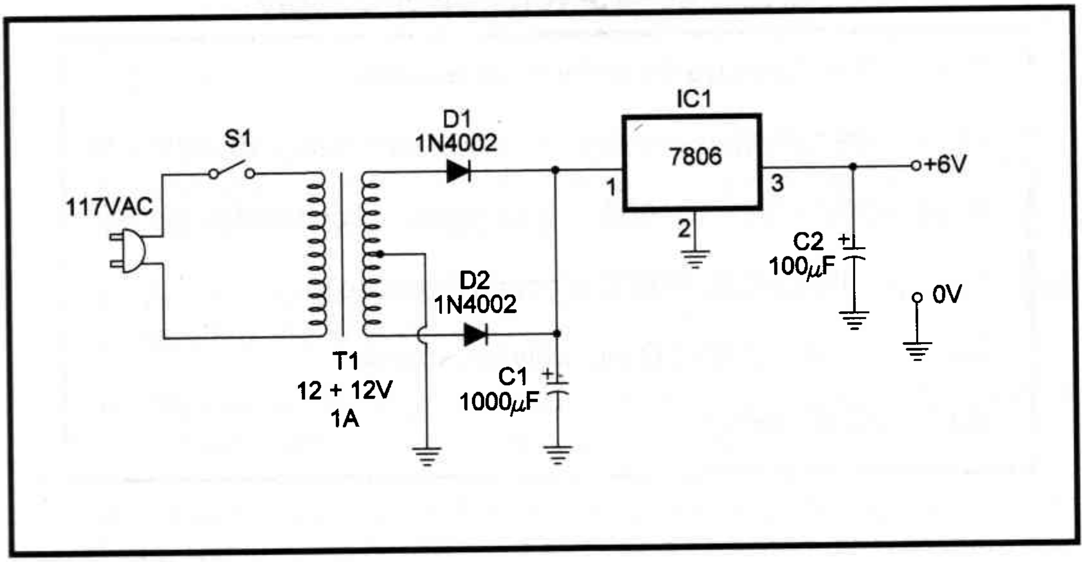


Figure 1

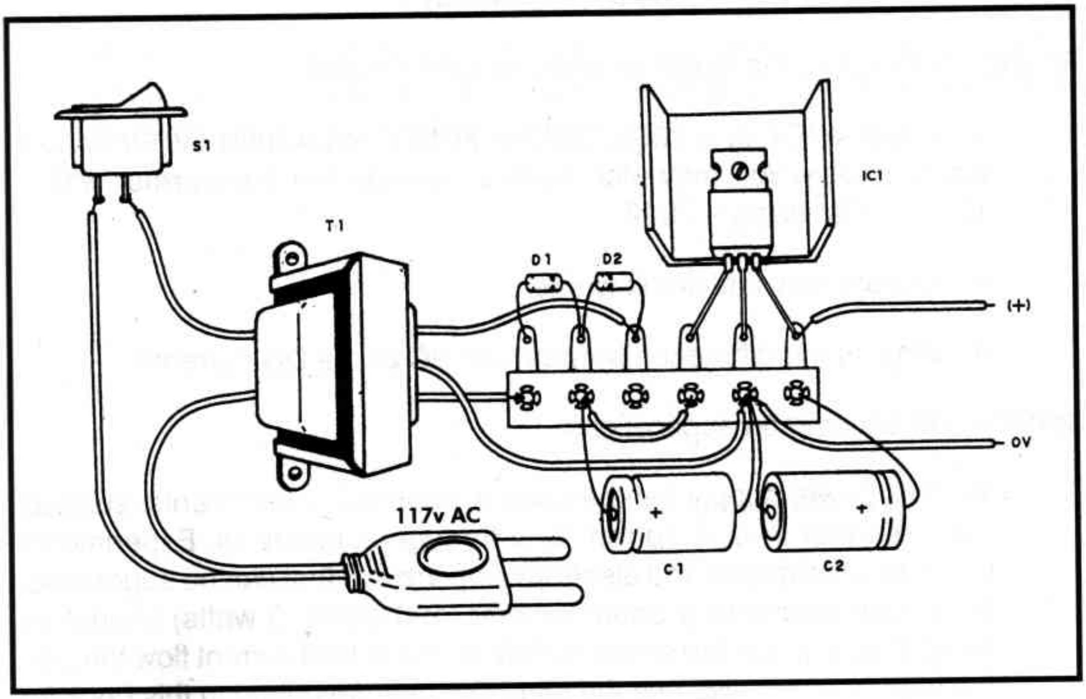


Figure 2

Parts List — 6-Volt Power Supply

IC1	- 7806 positive three-terminal regulator
T1	- Transformer: primary 117 VAC ; secondary 12+12V x 1A
D1, 2	- 50V x 1A - 1N4002 or equivalent silicon rectifier diodes
C1	- 1,000 uF, 25 WVDC electrolytic capacitor
C2	- 10 uF, 12 WVDC electrolytic capacitor
S1	- SPST switch

Ideas to Explore

To learn more about the circuit or alter the performance:

- Replace IC1 by a 7805, 7809 or 7812 if you want a 5V, 9V or 12V power supply. You may also have to change the transformer with a 117:15+15V using a 7812.
- Explain how the circuit works.
- What is the difference between an AC and a DC current?

Science and uncommon applications:

- This power supply can be used in chemical experiments, such as the ones that involve current flow through substances. Experiments involving electrolysis and electroplating are two that can be suggested. A variable wound-wire potentiometer (100 ohms, 5 watts) should be wired in series with the power supply output to limit current flow through the load. You can also use the Light Dimmer described in this book for this task.

- 6V, 200 mA small incandescent lamps can be supported by this power supply. These lamps are excellent light sources to work with microscopes.

- Small motors and lamps in experiments involving physics, mechanics and robotics can be powered from this power supply with advantages. You don't have to spend a lot of money on cells or batteries.

- All circuits described in this book which require a 6V supply can be powered by this power supply.

- The circuit can be used as an excellent power adapter for your 6V equipment, such as small radios, calculators, etc.

- 6V lamps can be used in experiments involving plant growth. Select a fast growing house plant and use a darkroom or cardboard box to cover them. Lamps with colored filters can be used in an experiment involving growth and development.

- Circadian rhythms can also be studied using animals or plants. Lamps can be powered on at night and off at day. What physiological functions could be affected?

INSECT REPELLENT (P)

Some continuous sounds can repel insects (and also attract). The frequency and intensity depends upon the application and type of insect and can be found through experimentation.

The circuit shown here generates a continuous sound that can be used to repel (or attract) some types of insects, or in scientific experiments involving animals.

Our insect repellent can be powered by 9V batteries, two AA cells or four AA cells, and its low current requirements will extend the life of those cells or batteries.

Figure 1 shows the schematic diagram of the Insect Repellent. The heart of the circuit is a 7555 IC, a CMOS timer wired as an audio oscillator and driving a piezoelectric transducer.

The components placement on a homemade printed-circuit board is shown in ***Figure 2***. Exact placement is not that critical.

All the components and the power supply can be housed in a small plastic box. Transducer BZ is a crystal earpiece or a piezoelectric transducer, such as the Radio Shack 273-073.

Position of the polarized pieces, such as C2 and the power supply, must be carefully observed.

Using the insect repellent is very easy. You only need to adjust the trimmer potentiometer P1 to produce a sound with the same pitch as the insect you intend to repel. Experimentation should be made until you find the best sound to repel a specific insect.

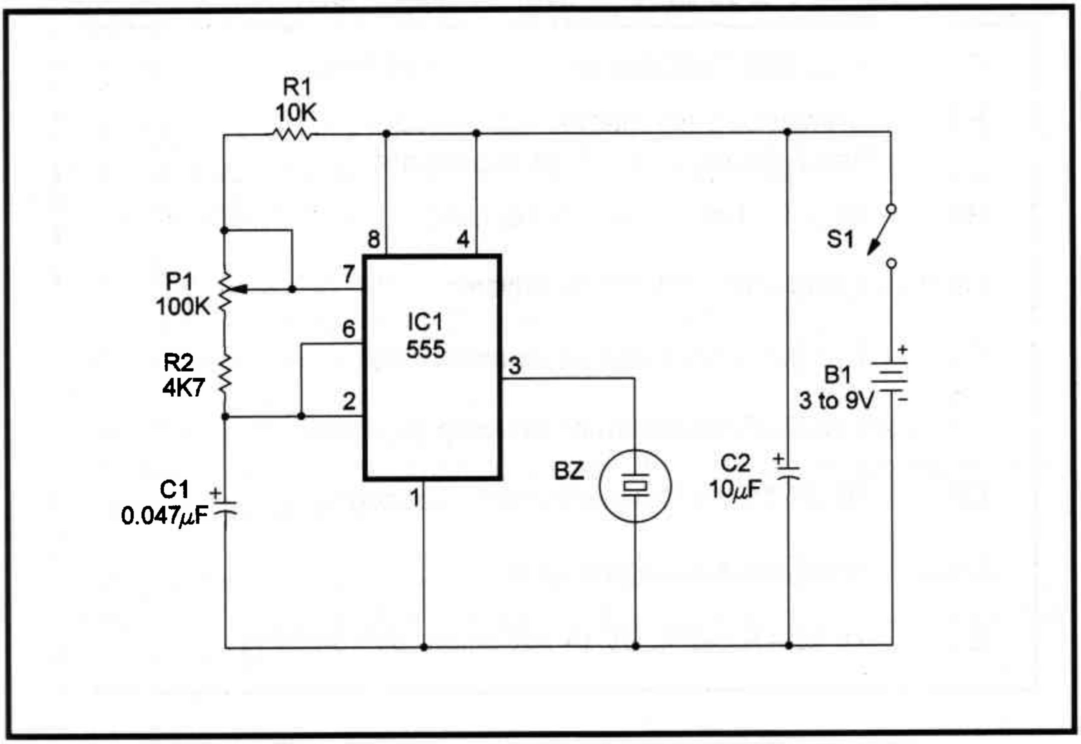


Figure 1

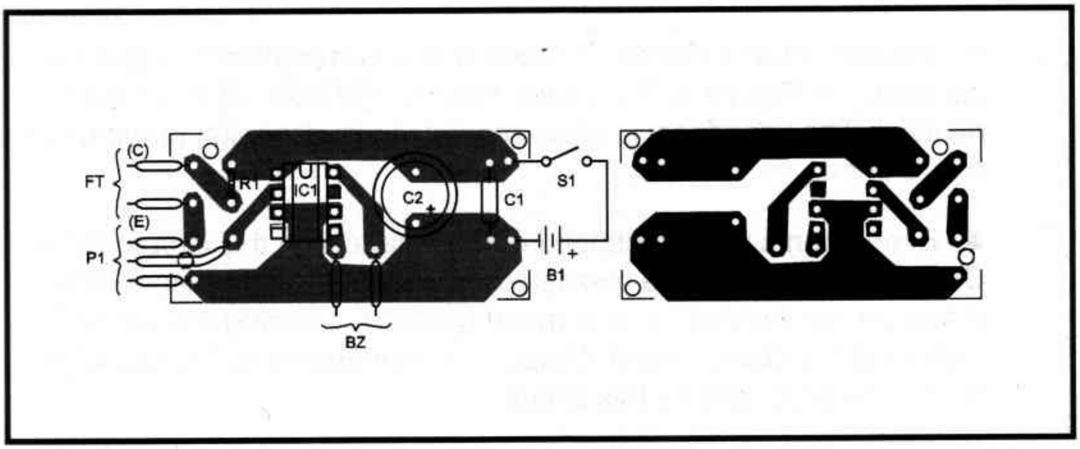


Figure 2

Parts List — Insect Repellent

C1	- TLC7555 CMOS integrated-circuit timer
BZ	- Crystal or piezoelectric transducer Radio Shack 273-073 or equivalent
R1	- 10,000 ohm, 1/4W, 5% resistor
R2	- 4,700 ohm, 1/4W, 5% resistor
P1	- 100,000 ohm trimmer potentiometer
C1	- 0.047 uF metal film or ceramic capacitor
C2	- 10 uF, 12 WVDC electrolytic capacitor
S1	- SPST slide or toggle switch
B1	- 3V (2 AA cells), 6V (4 AA cells), 9V (battery)

Ideas to Explore

To learn more about the circuit or get better performance:

- Powerful output can be obtained with a transistorized output stage as shown in ***Figure 3***. The power transistor should be mounted on a heatsink. The transducer is a low-impedance loudspeaker ranging from 4 to 8 ohms.

- Experiments with ultrasound can be made with this circuit: reduce C1 to 1200 pF and use a piezoelectric tweeter as transducer. Remove the small transformer used in these tweeters and plug the transducer directly to the circuit output. Outputs in frequencies as high as 40,000 Hz can be produced by this circuit.

- Explain how sounds can be produced by electronic transducers such as the one used in this project.

- What are ultrasounds?

Science and different applications:

- Of course, you can test the real effects of this device on several kinds of insects. An attractive biological experiment can be conducted based on this circuit.

- Effects of sounds on plant growth or development can be conducted using this circuit. Can sounds (or ultrasounds) alter the circadian rhythms of plants and insects?

- The continuous tone produced by this circuit can be used in alarms or warning systems. Mice and other small animals are repelled by powerful ultrasounds.

- Replace R2 by an LDR. The circuit now becomes a light-dependent oscillator. Experiments with light and sounds can now be conducted using the device.

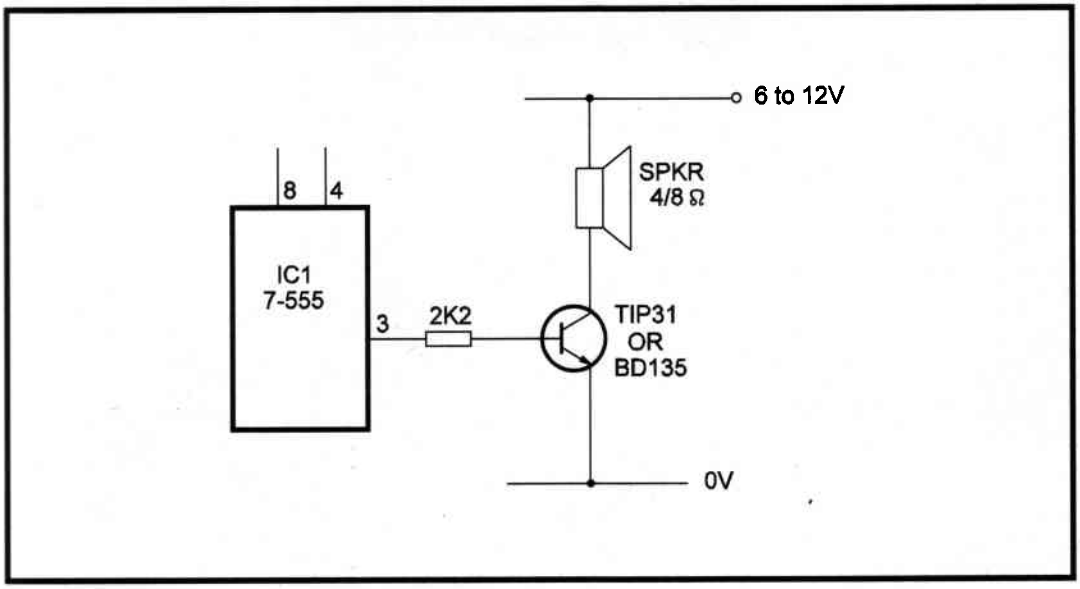


Figure 3

ULTRASONIC GENERATOR (E/P)

Dogs, mice, bats and other animals can hear sounds with frequencies up to 40,000 Hz. There are several kinds of insects that can also hear or react to these sounds. The circuit we propose here produces a continuous sound emission in frequencies above the human limit, or a range between 18,000 and 40,000 Hz. These sounds are called ultrasounds and can be used in several experimental and practical applications.

The device we describe here can be used to scare dogs and other animals, in biological experiments, and many other interesting applications.

The recommended piezoelectric transducer has its maximum output power between 700 and 3,000 Hz, but it also will operate at higher frequencies emitting less power.

The recommended power supply is four AA cells or a 9-volt battery.

Our project runs between approximately 18,000 and 40,000 Hz, but you can easily alter this range by changing C1, in a range between 470 pF and 0.001 uF. Frequency can be set by P1 in the range determined by C1.

Remember that the 4093B IC will oscillate in frequencies up to 500 kHz.

The complete circuit of the Ultrasonic Generator, using the four gates of a 4093B integrated circuit, is shown in ***Figure 1***.

Components placement on a printed-circuit board is shown in ***Figure 2***.

The circuit can be housed in a small plastic box and the transducer will be fixed in the front panel.

Take care with the position of the polarized parts, such as the transistor, electrolytic capacitor and power supply.

For continuous operation, Q1 should be mounted on a heatsink.

The transformer is not a critical part. Any transformer with a secondary coil ranging from 100 to 500 mA can be used in this project.

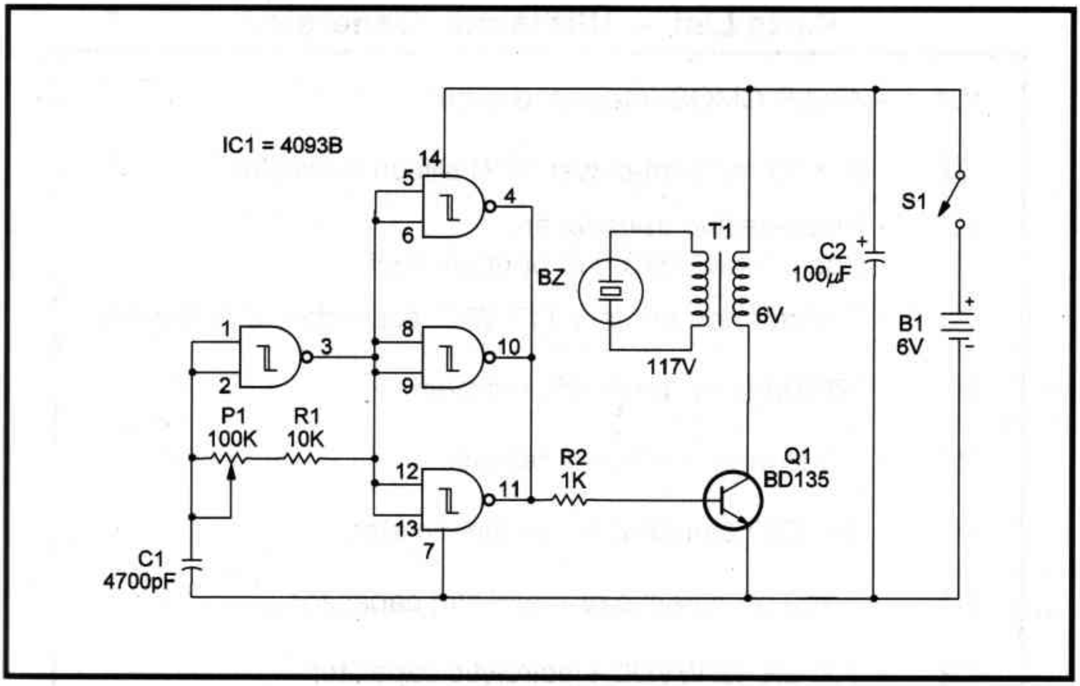


Figure 1

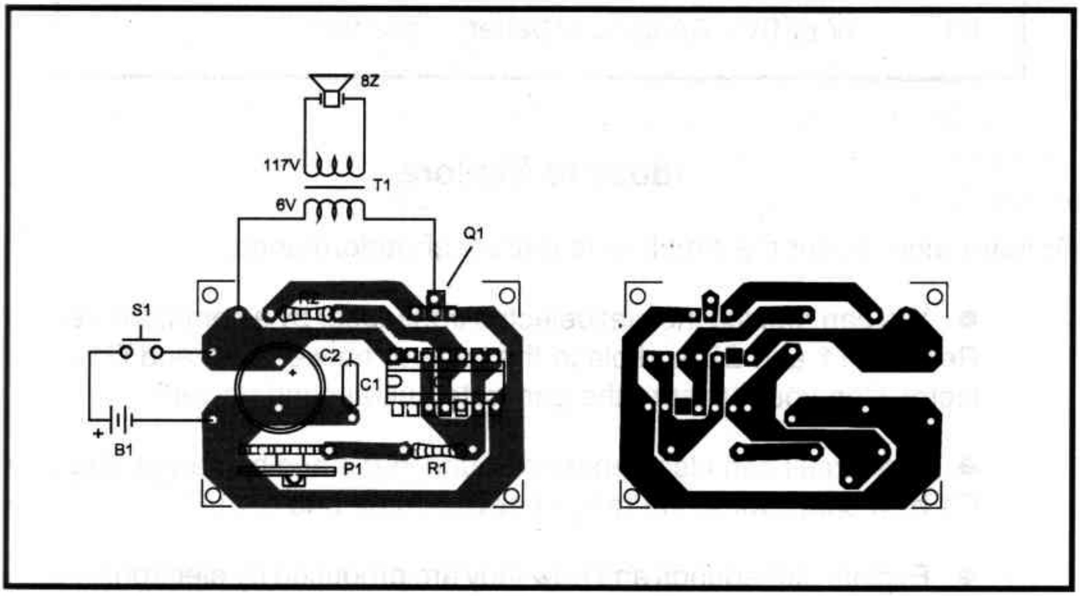


Figure 2

Parts List — Ultrasonic Generator

IC1	- 4093B CMOS Integrated circuit
Q1	- BD135 medium-power NPN silicon transistor
BZ	- Piezoelectric transducer Radio Shack 273-090 or equivalent
T1	- Transformer: primary 117 VAC; secondary 6Vx100 mA
R1	- 10,000 ohm, 1/4W, 5% resistor
R2	- 1,000 ohm, 1/4W, 5% resistor
P1	- 100,000 ohm trimmer potentiometer
C1	- 4,700 pF ceramic or metal film capacitor
C2	- 100 uF, 12 WVDC electrolytic capacitor
S1	- SPST toggle or slide switch
B1	- 6V or 9V - AA cells or battery - see text

Ideas to Explore

To learn more about the circuit or to get better performance:

- You can replace the piezoelectric transducer by a common tweeter. Remove T1 and BZ and place the tweeter between S1 and Q1's collector. Can you measure the generated ultrasound power?

- The circuit can also generate sound in the audible range. Replace C1 by a capacitor in the range between 0.02 and 0.1 uF.

- Explain ultrasounds and how they are produced by electronic transducers.

- What is a piezoelectric material?

Science and different applications:

- Several experiments can be made using ultrasounds. You can experiment with dog conditioning. Using this oscillator you can call a dog using an inaudible sound! (inaudible to humans)

- Choose a capacitor between 0.01 and 0.047 uF to produce sounds both in the audio range and ultrasound range. You can now conduct experiments to determine the exact upper-limit frequency heard by humans. You also can conduct experiments with animals. It will be important to have a frequency counter on hand to do this work.

- Replace BZ by electrodes. The circuit will generate a high-voltage output that can be used in nerve stimulation. Use a 10,000 ohm potentiometer to adjust output voltage at this point. Pulses can reach peaks as high as 400 volts.

- To get pulses (for nerve stimulation and other experiments) you only have to replace C1 with a 1 uF capacitor and P1 with a 1,000,000 ohm potentiometer. Pulses in the rate range between 0.1 per second to 10 per second can be generated with this change.

- This circuit can also be used as a fluorescent lamp inverter. A common fluorescent lamp (4 to 20 watts) in place of the transducer will glow, even one that is weak enough to not function on the AC power line.

DC LAMP DIMMER (E,P)

This circuit can be used to control the amount of current in an incandescent lamp and also a DC motor. If you change the amount of current through a lamp you change its brightness. And if you change the amount of current through a DC motor you change its speed. Input voltage can range from 6 to 12 volts and current drain in the output is up to 2A. You can also use this circuit in the output of a 6V or 12V fixed power supply, converting it into a variable 0 to 6 volt or 0 to 12 volt supply.

The power transistor should be mounted on a heatsink. The circuit can be housed in a small plastic box and the heatsink with the transistor fixed on the outside.

The circuit can be used to control brightness of a car's panel lamps and in robotics to control DC motor speed along a wide range of values. Also, several experiments involving current flow control can be performed using this circuit.

The circuit acts as a variable resistor or rheostat with the principal current flowing through the transistor and the control current flowing through the potentiometer. Current through the potentiometer is only a few milliamperes.

The schematic diagram of the DC dimmer is shown in ***Figure 1***. Q1 is an NPN power transistor and the principal component used in this project.

Components layout is shown in ***Figure 2***. The transistor does not show on the heatsink, however.

Equivalent transistors can be used, but take care with the maximum current they can control. Types such as TIP31 and TIP41 can be used to control lamps up to 2 amperes. Also, a further modification in R1 value must be made to ensure that, when P1 is set near its minimum value, that current is flowing through the lamp.

If equivalent transistors are used, take care with their terminal positions, as they can be different.

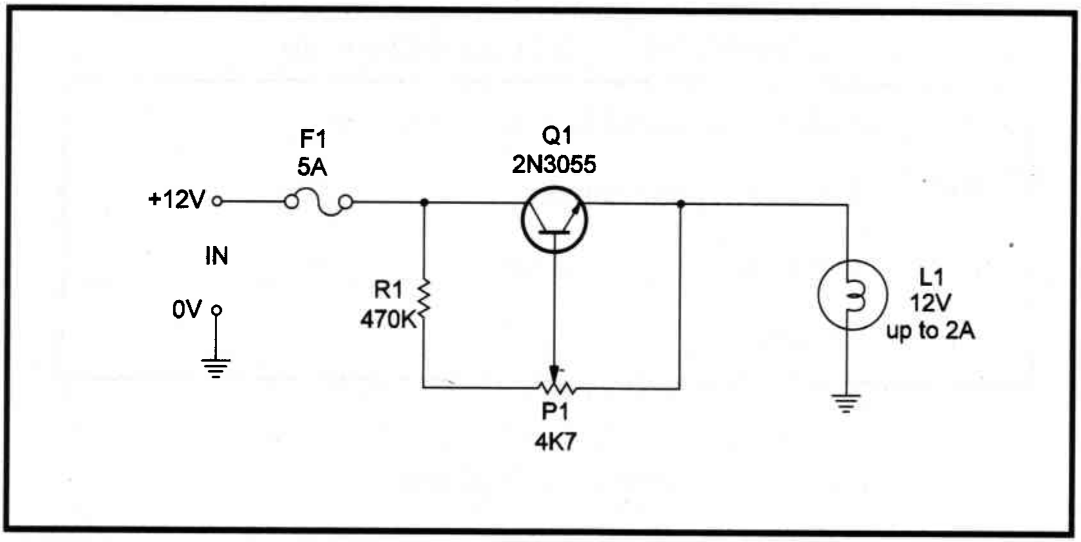


Figure 1

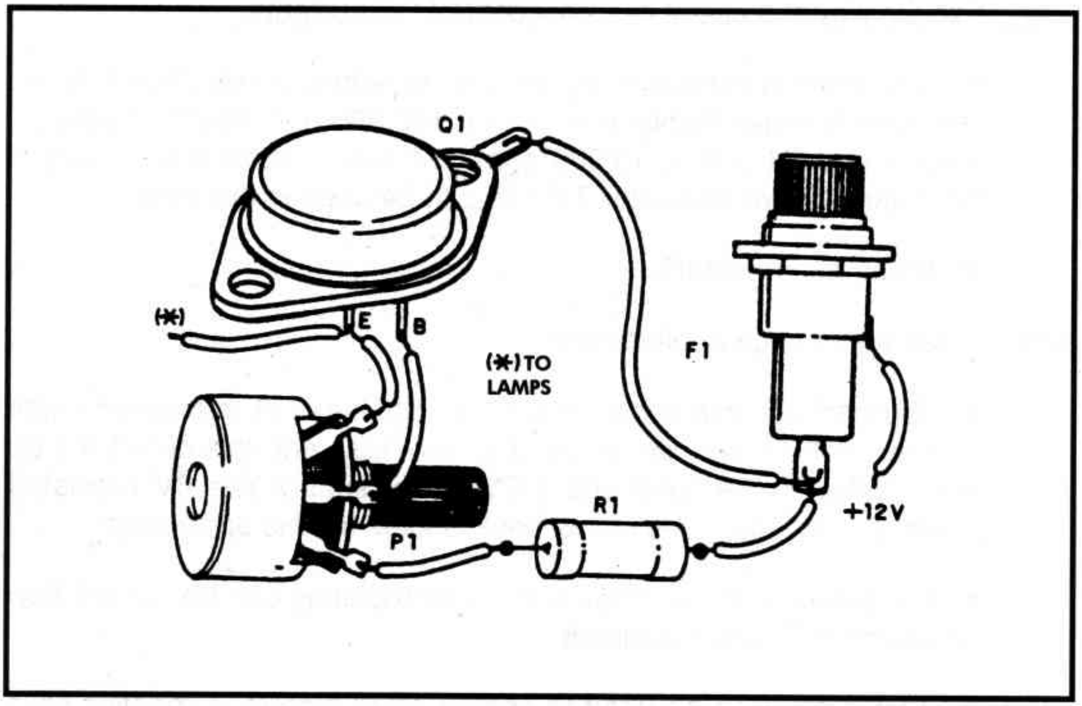


Figure 2

Parts List — DC Lamp Dimmer

Q1	- 2N3055 Silicon NPN power transistor
P1	- 4,700 ohm potentiometer
R1	- 470 ohm, 2W, 5% resistor
F1	- 5A fuse

Ideas to Explore

To learn more about the circuit or to get better performance:

- You can use a PNP power transistor, inverting input polarization. Explain why this circuit can only control DC currents.

- A Darlington transistor can be used to reduce current flow through the potentiometer. Replace P1 with a 100,000 ohm common potentiometer and R1 with a 10,000 ohm, 1/4 watt resistor when using a Darlington power transistor. TIP110 can be used in this case.

- What is a rheostat?

Science and uncommon applications:

- You can use this circuit to control brightness of microscope light sources. A 6V lamp can be used for that task and this circuit will be wired between the lamp and a 6V power supply. The 6V regulated power supply described in this book is ideal for this application.

- Experiments in electrolysis and electroplating can be current-flow controlled by using this circuit.

- This circuit can be used to control small motors in robotics or in physics experiments.

- The amount of current in current fields can be controlled by using this circuit and a DC power supply. Experiments involving electrotropism can be attempted. Try to put plants within a coil to observe the influence of the magnetic field on their growth and development. Remember that there is a magnetic field around a coil of wire that is carrying a current.

Figure 3 shows how this experiment can be arranged.

The coil is formed by 10 to 50 turns of common No.18 to 22 wire around a cardboard box or wood form. An ammeter in series with the coil circuit can be used to control the amount of current used in the experiment.

Remember that too much current will cause the coil and the transistor to overheat. It is a good idea to add a lamp in series with the coil circuit. The lamp will add resistance to the coil circuit, reducing current flow to a safe level.

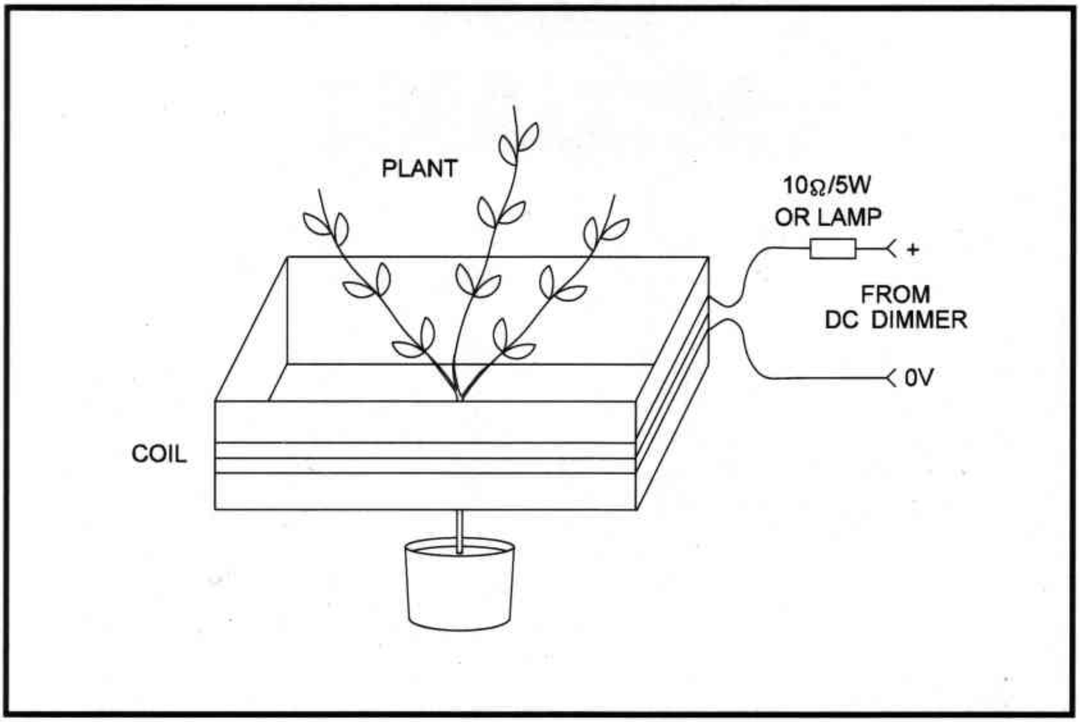


Figure 3

AUDIO OSCILLATOR (E)

This low-power experimental oscillator can generate audible signals in the range between 100 and 2,000 Hz, driving a small loudspeaker or a low-impedance earphone. The circuit can be powered by 2 two or four AA cells or a fixed 6 volt power supply. Current requirements for this circuit depend upon the power supply voltage and the loudspeaker impedance and range typically from 10 to 300 mA.

Potentiometer P1 adjusts the operating frequency and can be set within a large range of values. Potentiometers up to 1,000,000 ohms can be used, changing the frequency range lower limit to about 10 Hz.

C1 can also be altered, and values between 0.01 and 0.22 uF are suitable for experimentation. Large C1 values will produce frequencies in the lower part of the range.

The circuit can be used as part of alarms, games, toys and to learn more about transistorized oscillators.

Figure 1 shows the schematic diagram of the Audio-Oscillator. Q1 and Q2 form a directed-coupled amplifier and R1/C1 is the closed loop that takes the signal back from the output to the input.

Figure 2 shows the layout of the components, using a terminal strip as chassis. All the components and power supply can be housed in a small plastic box.

The key is a telegraph homemade-type switch, but you can also use an SPST toggle or slide switch for continuous operation. A key is recommended if you want to use the oscillator as a Morse Code sender in demonstrations or practice. You can wire the points A and B to the contacts of a relay to use the circuit as part of an alarm.

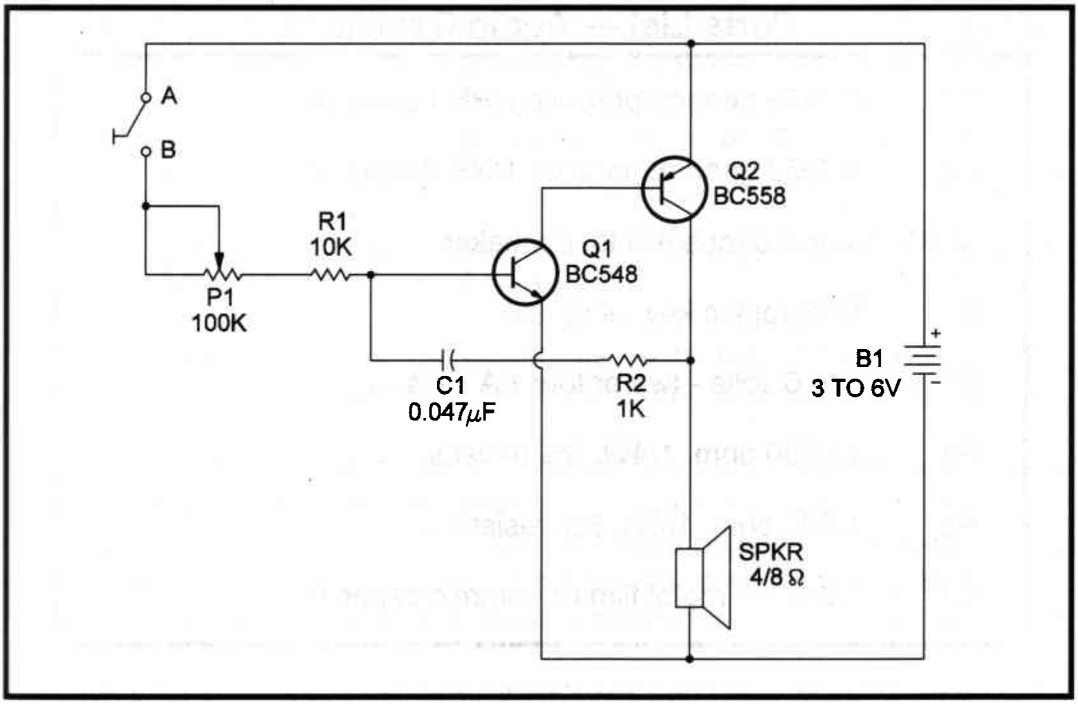


Figure 1

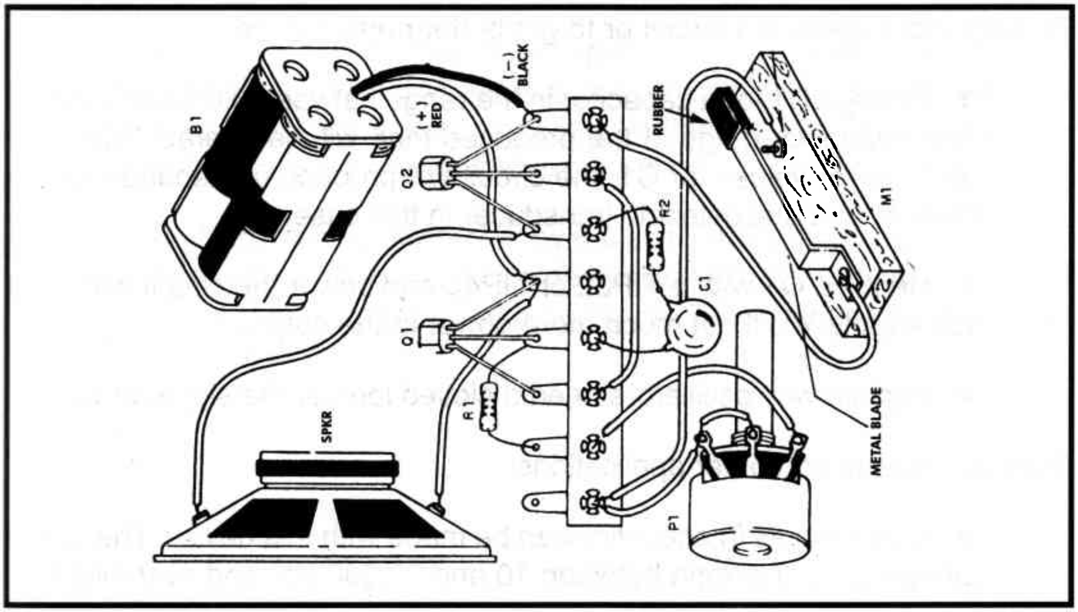


Figure 2

Parts List — Audio Oscillator

Q1	- BC548 general purpose NPN transistor
Q2	- BC558 general purpose PNP transistor
SPKR	- 4 or 8 ohm small loudspeaker
K	- Telegraphic key - see text
B1	- 3 to 6 volts - two or four AA cells
R1	- 10,000 ohm, 1/4W, 5% resistor
R2	- 1,000 ohm, 1/4W, 5% resistor
C1	- 0.047 uF metal film or ceramic capacitor

Ideas to Explore

To learn more about the circuit or to get better performance:

- Change C1 for a capacitor in the range between 0.01 and 0.22 uF. The frequency range of the produced tone will be altered. With 0.01 uF or lower values for C1, the circuit will produce ultrasounds. Use a tweeter or a piezoelectric transducer in this case.

- Replace Q1 with a TIP32 or TIP42 and power the circuit with a 12 volt supply. You'll get much more power in the output.

- Explain why oscillators need a closed loop to the signal to work.

Science projects and other applications:

- Experiments in acoustics can be made with this device. The circuit can produce any tone between 10 and 20,000 Hz, and even higher.

- A telegraph station can be simulated with this circuit. You can find Morse Code in any book about telegraphy.

- By replacing K with a reed swich wired to points A and B, the circuit will operate as an alarm.

- Experiments involving conductivity of materials can be made with probes plugged to points A and B.

- Connect resistive transducers as LDRs and NTCs at points A and B to get a light-dependent or temperature-dependent oscillator.

- Using two metal rods as sensors, the circuit can be use as a lie detector or bio-feedback device. Replace C1 with a 0.22 or 0.47 uF capacitor and adjust P1 to get separated pulses at the speaker. The pulse rate will be altered when the skin conductivity of the interrogated person changes while in a state of strain due to a lie or stress.

- A 117V—6V x 250 mA transformer can replace SPKR to produce high-voltage pulses in nerve stimulation experiments. The generated pulses can reach voltages as high as 400Vpp.

- Experiments in animal physiology can be conducted using sounds or high voltage as described in other projects. Growth of plants submitted to high-power sounds or high-voltage fields can be observed using this circuit with practical experiments.

- AC fields can be generated by replacing the speaker with a 20-turn coil. The plants or animals can be positioned within the coil's electric field. See the same experiment using the DC Dimmer for coil and experiment details.

AUDIO SWITCH (E/P)

This audio controlled relay has a large number of applications and is interesting to the experimenter who wishes to explore the working universe of relays and audio or sound controlled circuits.

An audio signal in the amplitude range between 1 Vpp and 5 Vpp triggers the relay, powering on the device, wired between points A and B.

Relay value is determined by power supply voltage. For a 12 volt power supply you must use a 12 volt relay. Current drain depends upon the power supply voltage and also the relay used. Using a 12V x 38 mA (Radio Shack 275-248) relay, the current drain is low enough to allow the use of common cells in the power supply.

C1 can range between 0.01 and 1.0 uF, and determines the sensitivity of the circuit in the audio range. Large values give more sensitivity at low frequencies.

This circuit has a high-impedance input and needs a strong audio signal to operate.

Figure 1 shows the schematic diagram of the Audio Switch. Observe that the heart of the circuit is a common general-purpose NPN transistor that acts as a DC amplifier.

In ***Figure 2*** we show layout of components for this project. The components can be soldered on a terminal strip used as chassis. The terminal strip can be fixed on a wooden board.

Position of the polarized components, such as the diodes, power supply and capacitor C2, must be observed.

To use this audio relay you have to wire ponts A and B to the output of an audio amplifier (minimum power required is 5 watts) and adjust the volume control for best operation.

A small transistor output transformer should be used to operate the relay with low-impedance signals, such as the ones from the output of audio amplifiers.

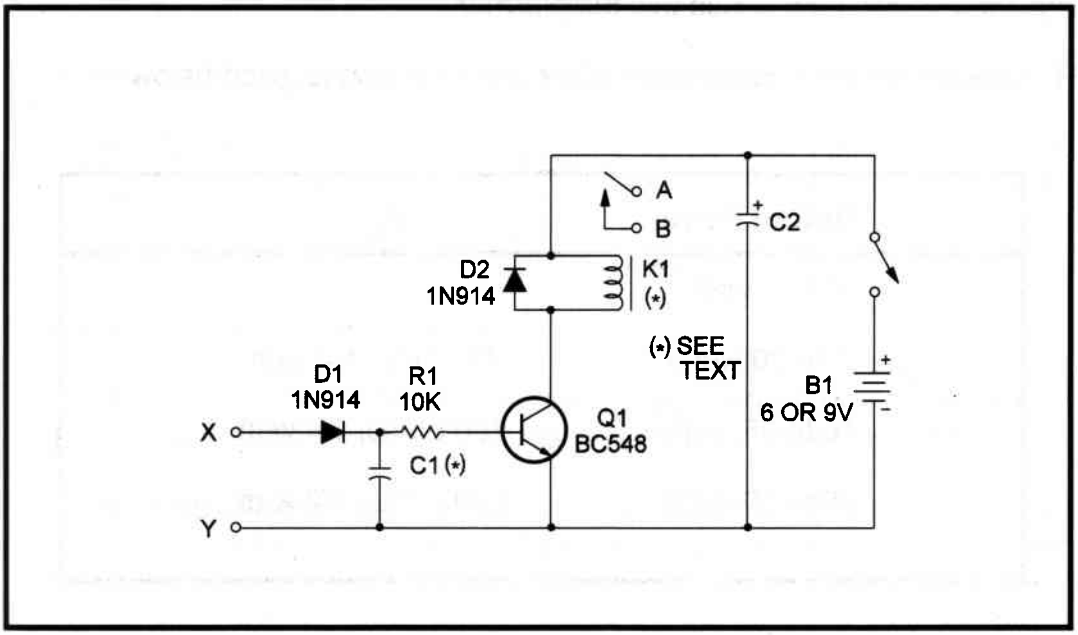


Figure 1

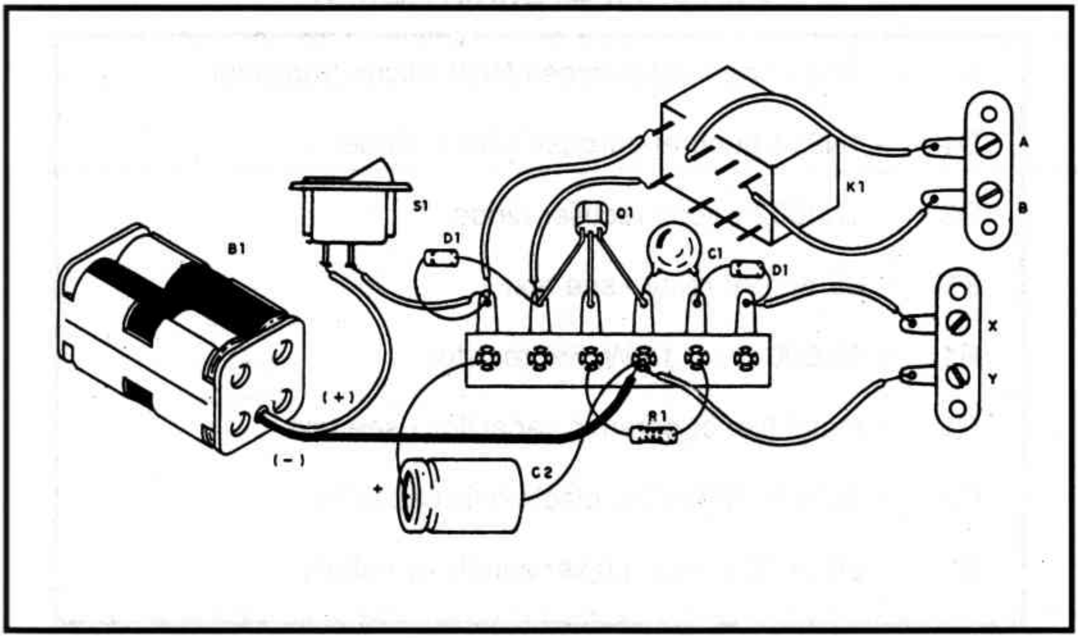


Figure 2

Figure 3 shows how to use this transformer.

R_x depends on the output power of the amplifier and is given below:

Output Power	R_x
0 to 1 watt	-
1 to 10 watts	47 ohms, 1/4 watt
10 to 25 watts	100 ohms, 1/4 watt
25 to 50 watts	220 ohms, 1/2 watt

Parts List — Audio Switch

Q1	- BC548 general-purpose NPN silicon transistor
D1	- 1N914 general-purpose silicon diode
D2	- 1N4002 silicon rectifier diode
K1	- 6V or 12V relay - see text
R1	- 10,000 ohm, 1/4W, 5% resistor
C1	- metal film or ceramic capacitor - see text
C2	- 100 uF, 12 WVDC electrolytic capacitor
B1	- 6V or 12V cells, power supply or battery

Ideas to Explore

To learn more about the circuit and devices or to get better performance:

- Replace Q1 with a Darlington transistor (such as a BC517) and resistor R1 with 100,000 ohms. The circuit will increase in sensitivity.

- Explain how C1 functions in this circuit.

Science and different applications:

- Connect the circuit to an audio amplifier output, with a microphone plugged to the amplifier input. You'll have a sound-operated switch.

- This circuit with a microphone and an audio amplifier can be used to close a trap with sound activation or to activate a recording with sounds.

  You can also use it to photograph an explosion or the crash of an object by triggering a flash with the produced sound.

- The audio output of a multimedia system in a computer can be used to control external devices with this circuit.

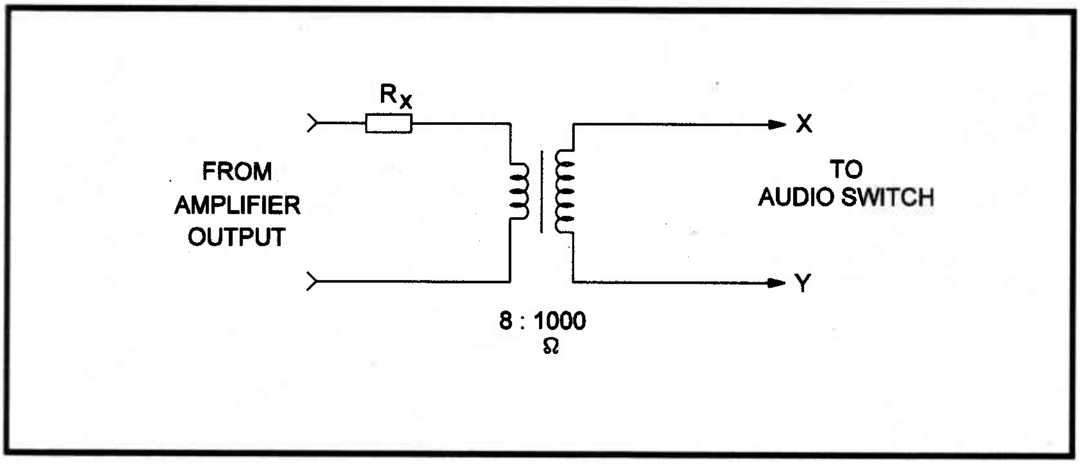


Figure 3

6 VOLTS FROM 12V BATTERIES (P)

With this adapter you can power 6 volt (up to 1A) devices, such as recorders, CD players, calculators, radios, battery chargers, etc., from your car battery. The current adapter is plugged into the vehicle lighter socket and is small enough to be housed in a very compact plastic box.

Only four components are used. The IC determines the output voltage and should be mounted on a heatsink. Capacitors are polarized components, so you must observe their position when mounting. The fuse is very important in order to protect the device and car wiring against shorts.

Output varies according to the device you are applying power to. DC extension cables with plugs to fit the device to be powered should be used. Take care with the output poles. Check if your device has a positive or negative pole in the central terminal.

The schematic diagram of the 12V to 6V x 1A converter is shown in ***Figure 1***. The principal component is IC1, a 6V voltage regulator that operates with input voltages ranging from 8 to 35 volts.

Components layout is shown in ***Figure 2***. All the components can easily be housed in a plastic box.

The integrated circuit can be changed to alter the output voltage. You can use a 7809 for 9V x 1A output or a 7805 for 5V x 1A output.

It is very important that no parts of the components used in this circuit touch one another. The IC has short-circuit and thermal protection.

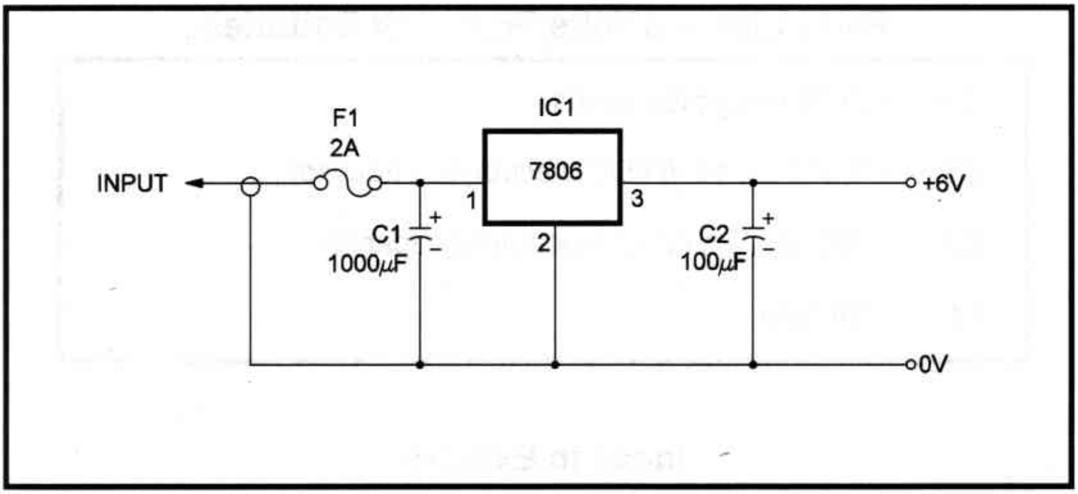


Figure 1

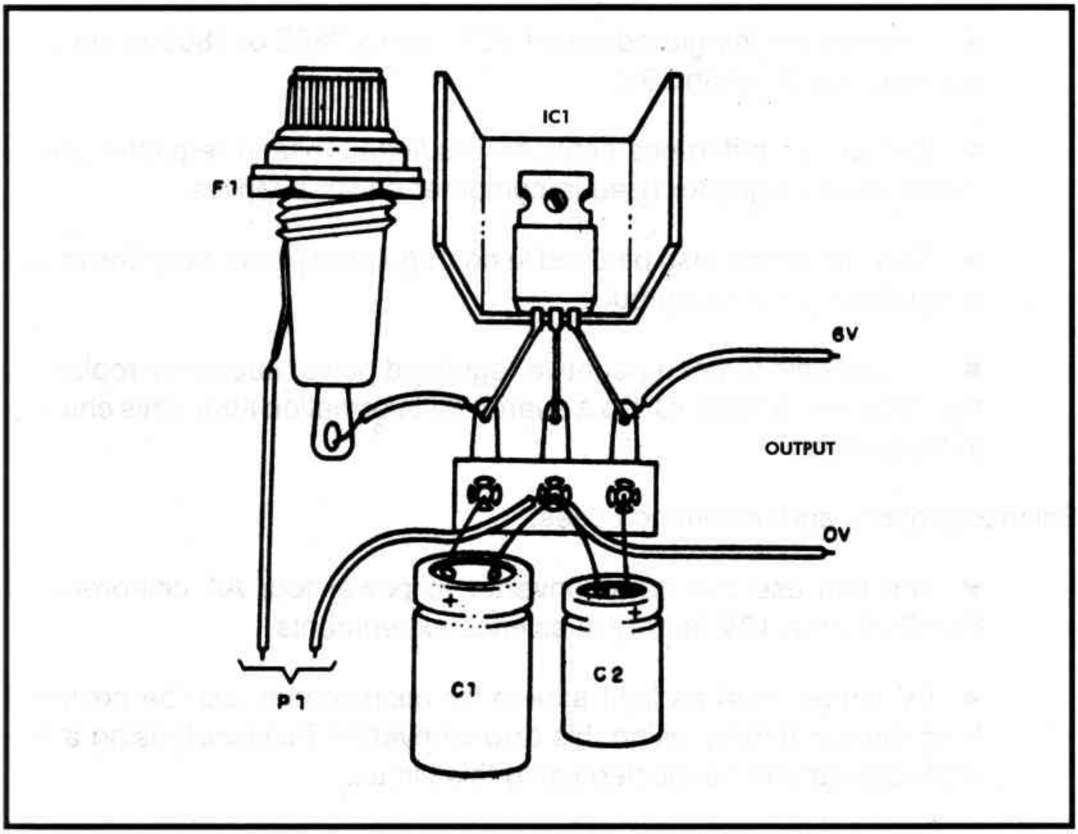


Figure 2

Parts List — 6 Volts From 12V Batteries

IC1	- 7806 Integrated circuit
C1	- 1,000 uF, 16 WVDC electrolytic capacitor
C2	- 100 uF, 12 WVDC electrolytic capacitor
F1	- 2A fuse

Ideas to Explore

To learn more about the device or to get better performance:

- Replace the integrated circuit (IC1) with a 7805 or 7809 to get output voltages of 5V and 9V.
- Explain the difference between this linear voltage regulator and a switch-mode regulator used in computer power supplies.
- This circuit can also be used in nonregulated power supplies to get a regulated 6V x 1A output.
- It's possible to get a negative regulated power supply by replacing the 7806 with a 7906 IC. Do a search for information about this change in the project.

Science projects and uncommon uses:

- You can use this downconverter to power four AA cell-powered circuits from a 12V battery in science experiments.
- 6V lamps used as light source for microscopes can be powered from the car battery using this downconverter. Fieldwork using a microscope can be conducted using this circuit.

ONE-COMPONENT TRANSMITTER (E)

Here is a project that should be constructed by those with no patience for electronics building. Only one component is used to build a complete wireless transmitter!

Of course, this is the simplest way to generate radio signals. It is a CW (continuous wave) transmitter and is powerful enough to plunk down a signal anywhere on the 550 kHz to 7 MHz band.

The fundamental frequency depends upon power supply voltage and is in the range between 100 kHz and 1 MHz, but there are strong harmonics reaching up to 7 MHz.

Figure 1 shows the schematic diagram of this simple tramsmitter. As you can see, we have only one component: a 4049 CMOS IC that is formed by six inverters. In this project only five inverters are used.

The circuit is powered from AA cells or battery, and current drain is very low.

As an experimental project you can place the IC on a universal solderless board. The antenna is a single wire 2 to 5 feet long.

A common AM (medium wave or short wave) receiver is placed near the transmitter. A signal can be tuned in from distances up to some feet away.

There are two ways to tune the transmitter, shown in ***Figure 2***.

In the first case, as the frequency is voltage-dependent, we change the power supply voltage. Use a 12 volt power supply and adjust the voltage in the IC with P1. In the second case, we include a variable capacitor in the feedback loop to alter the frequency.

Parts List — One-Component Transmitter

IC	- 4069 or 4049 CMOS integrated circuit (only this!)
	(And a power supply, of course)

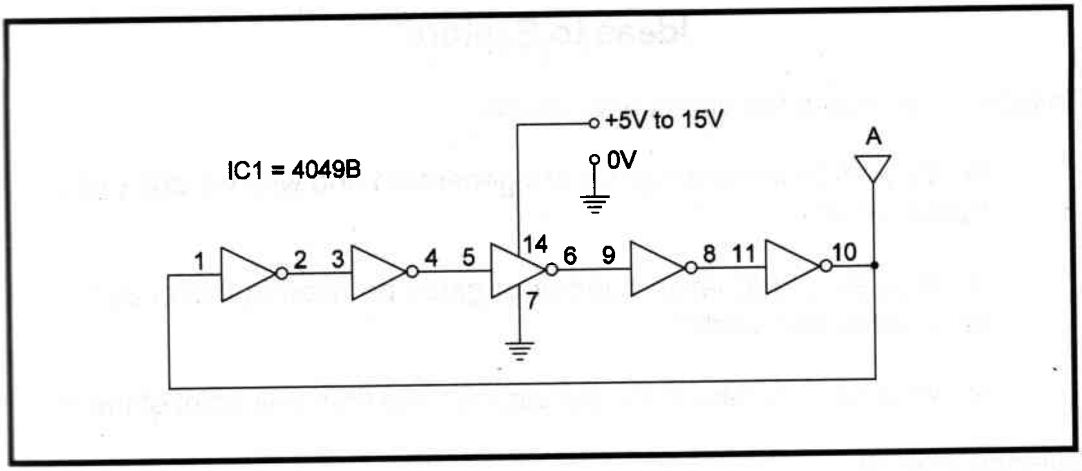


Figure 1

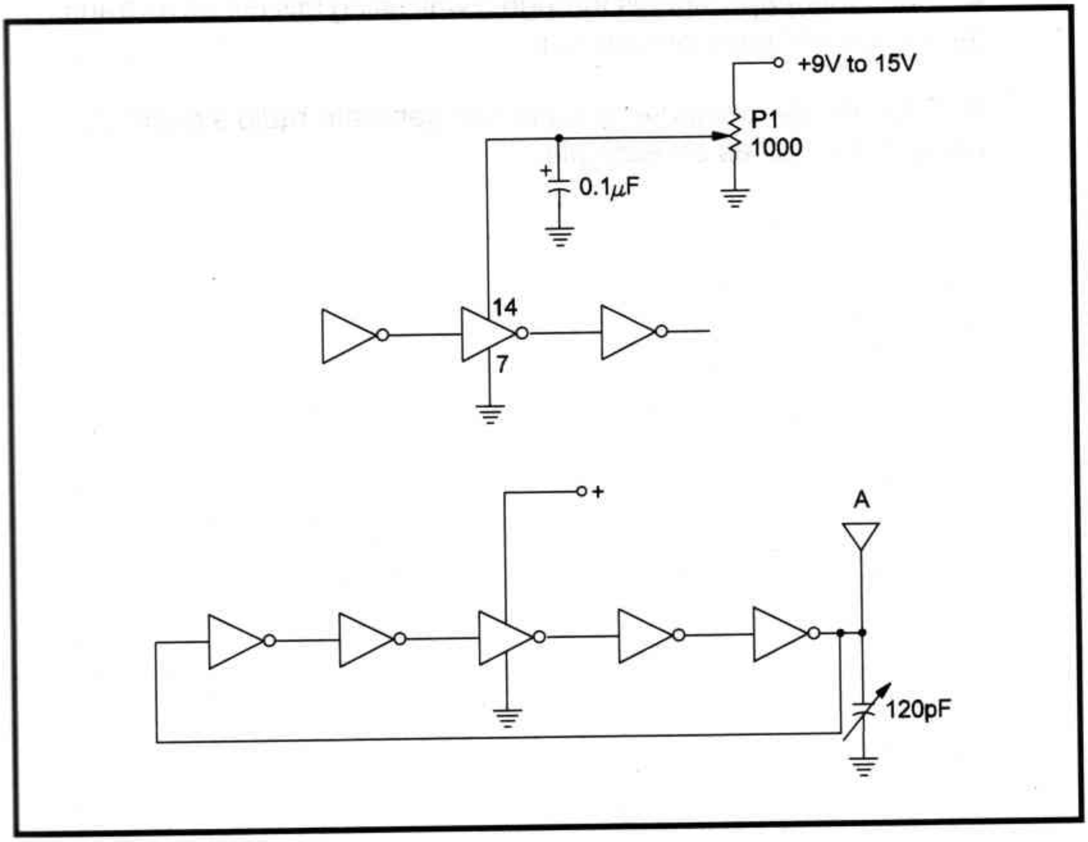


Figure 2

Ideas to Explore

To learn more about the circuit and device:

- Explain how radio signals are generated and why we don't need a tuned circuit.

- Why should an even number of gates be used in this circuit? Will an odd number work?

- Why can you tune in the signals on more than one point of the dial?

Science projects:

- Send telegraph signals through a wall using this circuit as transmitter and an AM radio as receiver.

- Explain how computer circuits can generate radio signals (noise), using this circuit as an example.

WIRELESS FM TRANSMITTER (E/P)

These circuits have always been popular for both utility and entertainment purposes.

The FM transmitter described here is built with few components to save space and cost. The circuit has only one transistor and is powered by two or four AA cells.

The broadcasting frequency of the unit, in the range between 88 and 108 MHz (FM band), is determined by L1 and the variable capacitor CV (a 20 or 30 pF trimmer capacitor). L1 consists of four turns of No. 22 wire, wound in a single close-spaced layer on a 1/2-inch form. The coil is center tapped where it is wired to the antenna terminal.

Any piece of stiff wire will serve as the antenna and will give good coverage. For better operation, antenna length should be between 5 and 15 inches.

Try out your unit at any convenient dead spot on the the FM band. Adjust CV to the best signal. The signals can be tuned in distances up to 150 feet.

A schematic diagram of the FM transmitter is shown in ***Figure 1***. Only one transistor as used as a high-frequency oscillator. Any small RF NPN transistor can be used for the task.

Components placement on a printed-circuit board is shown in ***Figure 2***. Capacitors are critical components and should be the types indicated in the parts list. Don't use metal film capacitors instead of the ceramic capacitors which are called for in the parts list.

You can also use a terminal strip as chassis as shown in ***Figure 3***, but keep all the component terminals and wiring short to avoid instability.

The circuit can be housed in a small plastic box along with the power supply. Avoid the use of metal boxes to house the circuit.

Take care with position of the polarized pieces, such as the electret microphone, electrolytic capacitor and power supply.

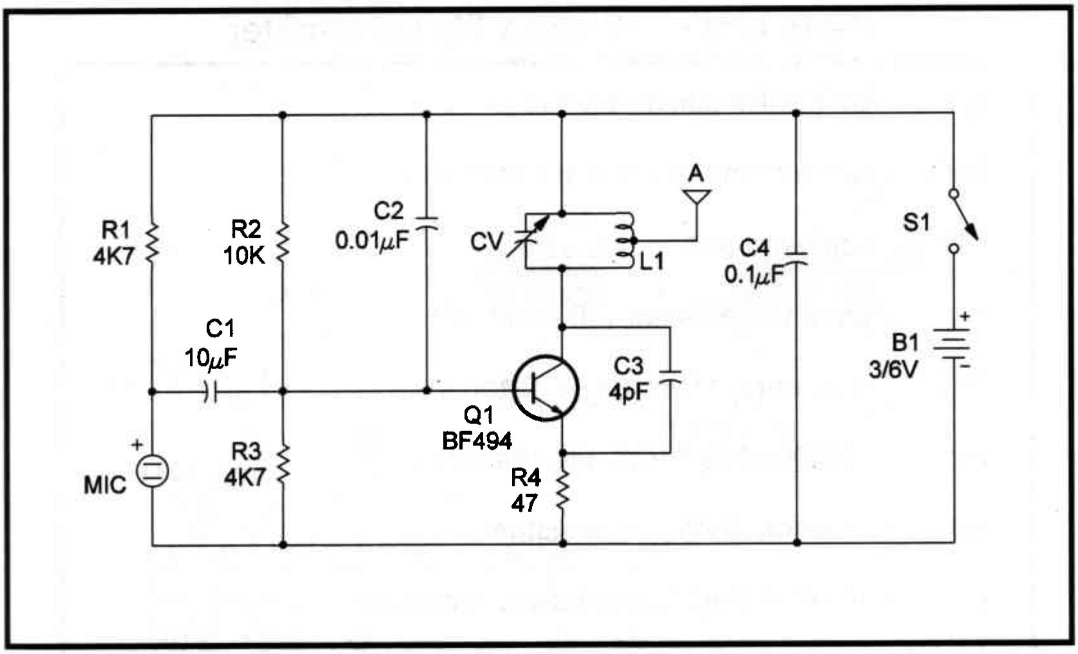


Figure 1

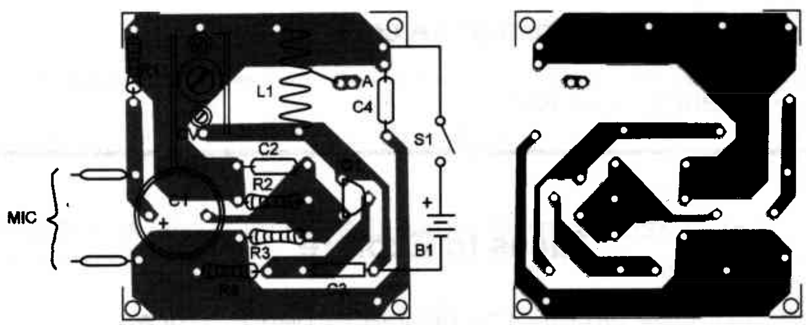


Figure 2

Parts List — Wireless FM Transmitter

Q1	- BF494 RF silicon transistor
MIC	- two-terminal electret microphone
L1	- coil - see text
CV	- trimmer capacitor (20 to 50 pF)
R1, 3	- 4,00 ohm, 1/4W, 5% resistor
R2	- 10,000 ohm, 1/4W, 5% resistor
R4	- 47 ohm, 1/4W, 5% resistor
C1	- 10 uF, 6 WVDC electrolytic capacitor
C2	- 0.01 uF ceramic capacitor
C3	- 4.7 pF ceramic capacitor
C4	- 0.1 uF ceramic capacitor
S1	- SPST slide or toggle switch
B1	- 3V or 6V - two or four AA cells
A	- antenna - see text

Ideas to Explore

To learn more about the circuit or to get better performance:

- Replace transistor Q1 with a 2N2218 and power the circuit from a 9V battery. The signals will be tuned in from distances up to 1,500 feet.
- The circuit can be used as a "bug" to hear secret conversations.

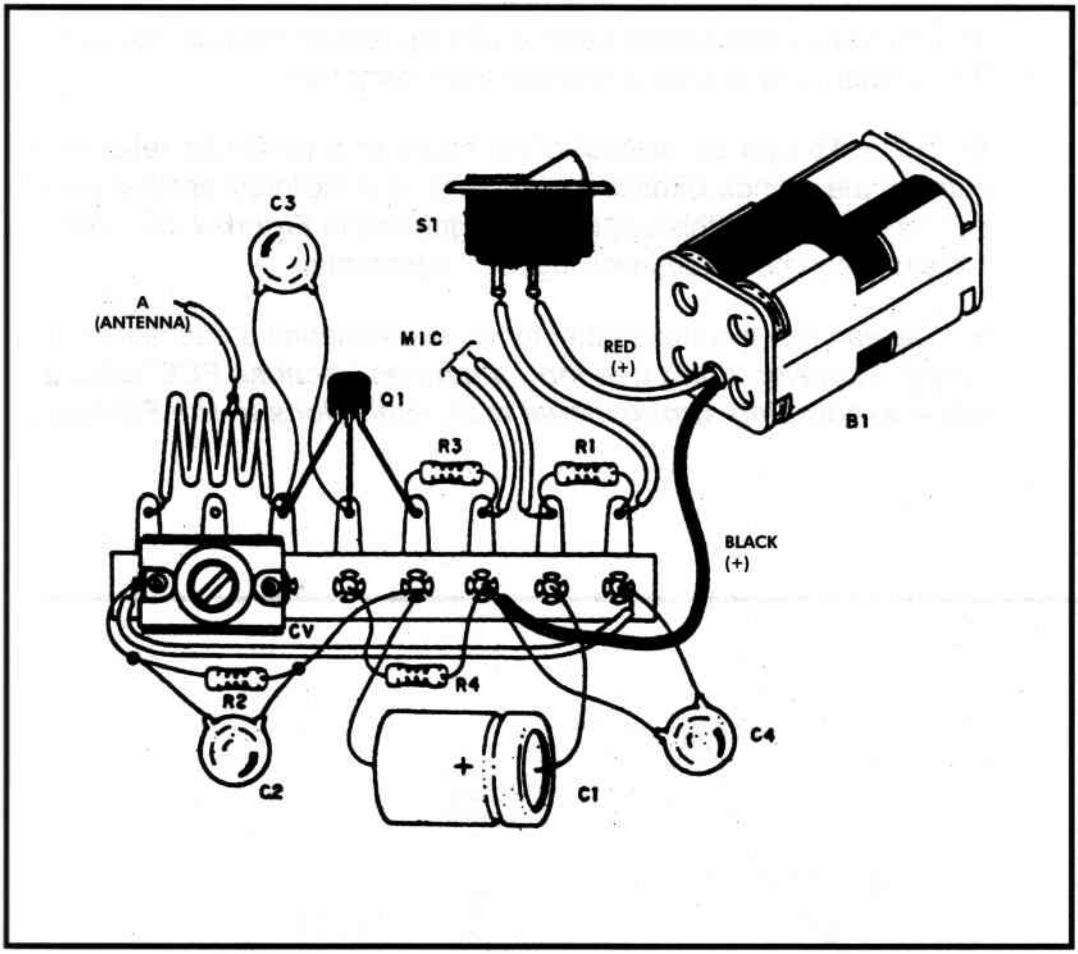


Figure 3.

Place the circuit inside a false book on a desk to pick up conversations.

- Explain how the transmitter works.
- What are radio waves or electromagnetic waves?
- What is Frequency Modulation (FM) and Amplitude Modulation (AM)? Explain the differences.

Science projects using this transmitter:

- The transmitter can be used to pick up remote sounds. You can fix it in animal pens or jails to monitor them remotely.

- The mike can be placed in the focus of a parabolic reflector to concentrate sounds. Birds and other animals in the forest or other places can be heard using this system, as suggested in ***Figure 4***. An interesting study can be made involving local songbirds.

- You can use this transmitter for an experimental broadcast in your school. However, ***don't use long antennas because FCC rules are severe regarding strong illegal radio emissions in the FM band.***

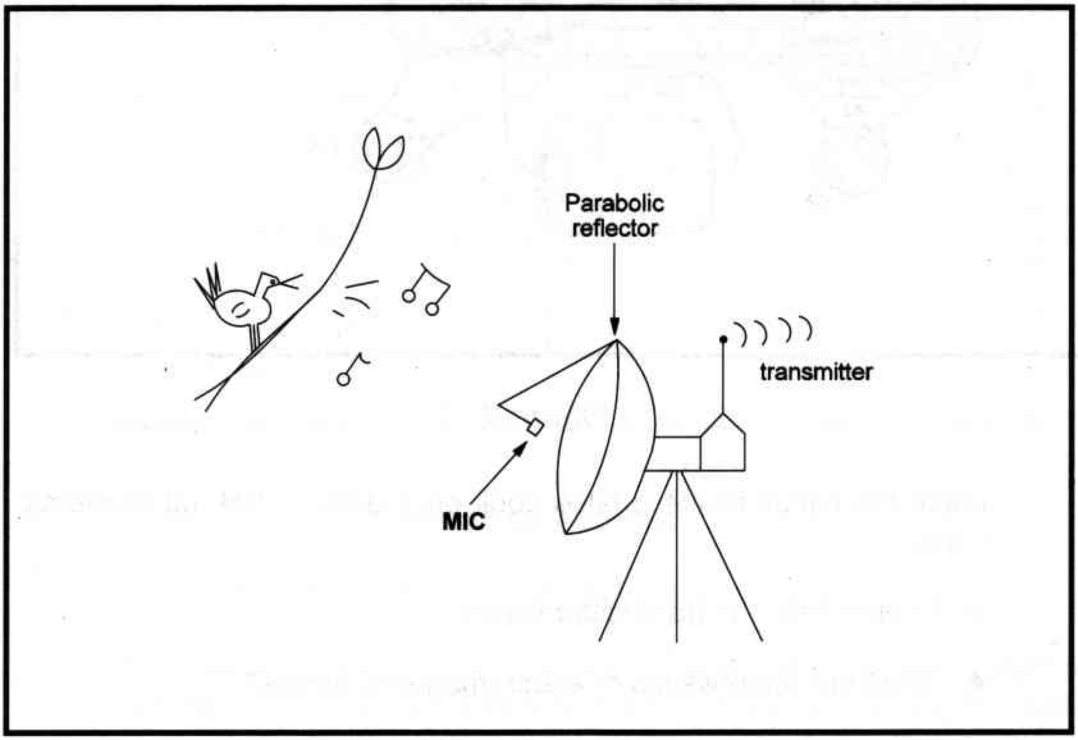


Figure 4

HIGH-POWER AUDIO OSCILLATOR (E)

This high-power version of an audio oscillator produces a strong audible tone using a piezoelectric transducer. All four gates existing in the 4093 IC are used in this project to drive the transducer with a good audio signal.

The circuit can be used in alarms, toys, as a standalone project to teach about oscillators specifically, or in experiments using continuous sounds in the frequency range between 100 and 10,000 Hz.

The recommended piezoelectric transducer emits maximum output power between 700 and 3,000 Hz, but it will also operate in other frequencies with less power.

Power supply voltage range is between 5 and 12 volts. Current requirements depend upon the power supply voltage, ranging from 10 to 50 mA typically.

P1 adjusts the tone frequency. C1 can be altered within a large range of values as indicated in the schematic diagram, shown in ***Figure 1***.

Components placement on a printed-circuit board is shown in ***Figure 2.*** You can also mount the circuit using a solderless board for experimental applications.

All the components and the batteries (if used as power supply) can be housed in a small plastic box.

BZ can be replaced with a common piezoelectric tweeter. But, in this case, you should open the tweeter and remove the small transformer from inside it. Then the output of the circuit should be connected directly to the small piezoelectric transducer.

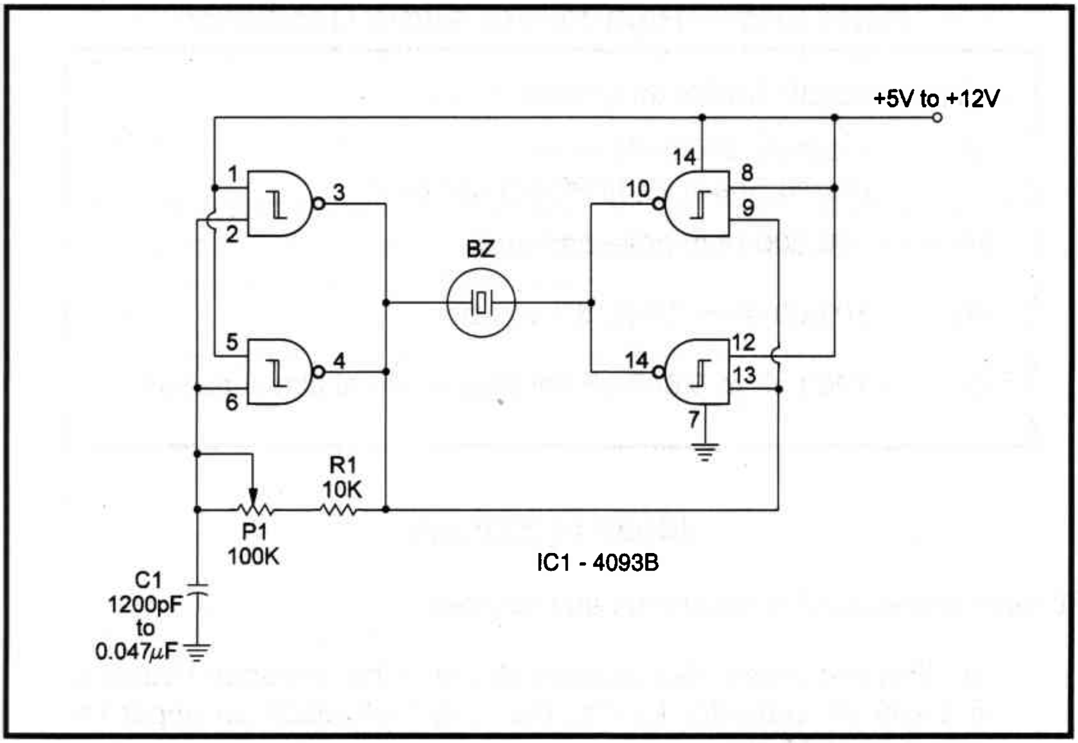


Figure 1

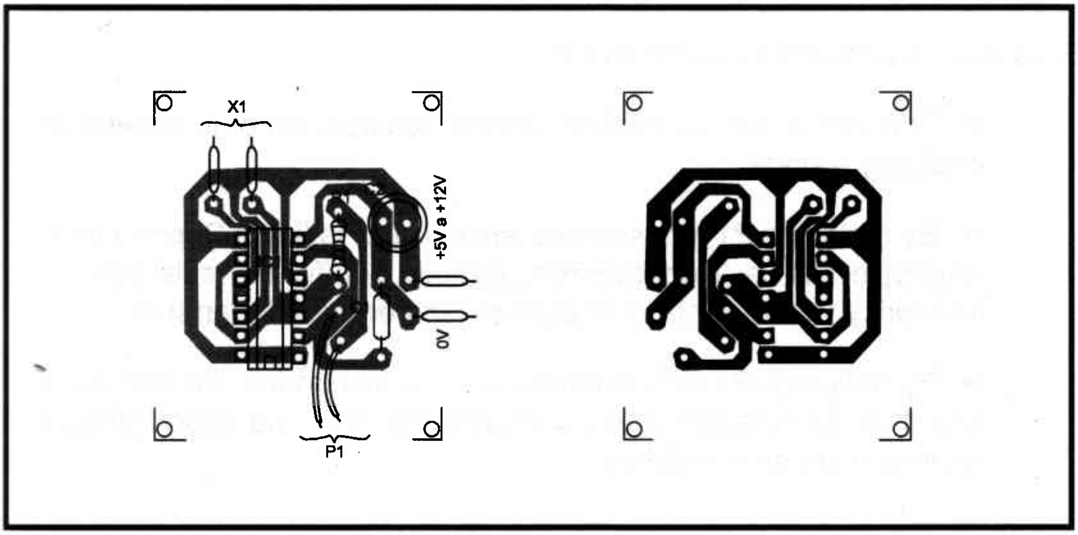


Figure 2

Parts List — High-Power Audio Oscillator

IC1	- 4093B CMOS integrated circuit
BZ	- Piezoelectric transducer (Radio Shack 273-090 or equivalent)
P1	- 100,000 ohm potentiometer
R1	- 10,000 ohm, 1/4W, 5% resistor
C1	- 1200 pF to 0.047 uF ceramic or metal film capacitor

Ideas to Explore

To learn more about components and devices:

- This circuit can also produce sound in the ultrasound band. Using a 1,200 pF capacitor for C1, the range will reach an upper limit of about 100,000 Hz.

- Explain how a push-pull output stage operates.

Science and uncommon applications:

- This circuit can be used for animal conditioning or in experiments involving sounds.

- By replacing P1 with sensors, such as LDRs (Light Dependent Resistors) or NTCs (Negative-Temperature Coefficient resistors), tone frequency will be light-dependent or temperature-dependent.

- By replacing P1 with touch sensors or electrodes, we can use the circuit as lie detector or bio-feedback devices. The sound pitch will depend upon skin resistance.

- The circuit can also be used as a fish attractor or in experiments involving water animals and sounds. Replacing BZ with wires immersed into water will generate electric current fields for experimental works involving the influence of these fields on fish or other beings.

- Some animals, such as mice and rats, are scared off by ultrasounds. The circuit can be used in experiments to determine the frequencies that are more effective for this task.

See other projects involving sounds for new ideas to explore.

TIMER (E/P)

Small home appliances and circuits can be turned on after a time delay ranging from seconds to minutes using this simple timer. School and hobbyist experiments can be time-controlled by using this circuit.

The unit has a constant-current source to charge C1. C1 and P1 adjust the time range. You can alter C1 within a range of 100 and 1000 uF to change the time range.

Using a 1 ampere relay you can control AC loads up to 100 watts wired to the 117 VAC power line.

To operate the unit, connect the load to the relay contacts (points A and B, used as a switch) and adjust P1 to the desired time delay. Press S2 do discharge C1 completely . Then close S1 to start. After the adjusted time delay, the relay will close, and the load will be powered ON.

Conversely, by using the NC (Normally Closed) contacts of the relay you can turn a device OFF after the adjusted time.

To use the unit again you must press S2 to discharge C1 before starting.

Figure 1 shows the schematic diagram of the timer. Observe the different components used in this project: a unijunction transistor (UJT) and an SCR (Silicon Controlled Rectifier).

An mechanical view is shown in ***Figure 2,*** using a terminal strip as chassis. All the components and power supply can be housed in a small plastic box. Take care with positions of critical components, such as the UJT, SCR, diodes and electrolytic capacitors.

The relay depends upon the power supply voltage and voltage drop through the SCR. This drop is about 2 volts, so you need to use 6 to 7.5-volt relays with a 9-volt power supply.

The SCR needn't be mounted on a heatsink, as the current drain is low.

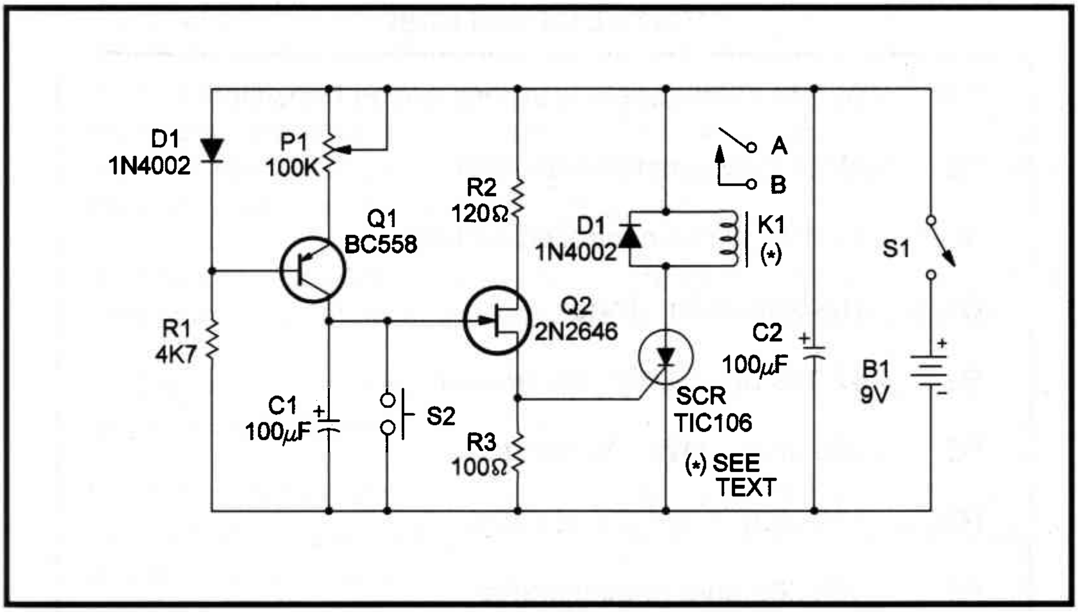


Figure 1

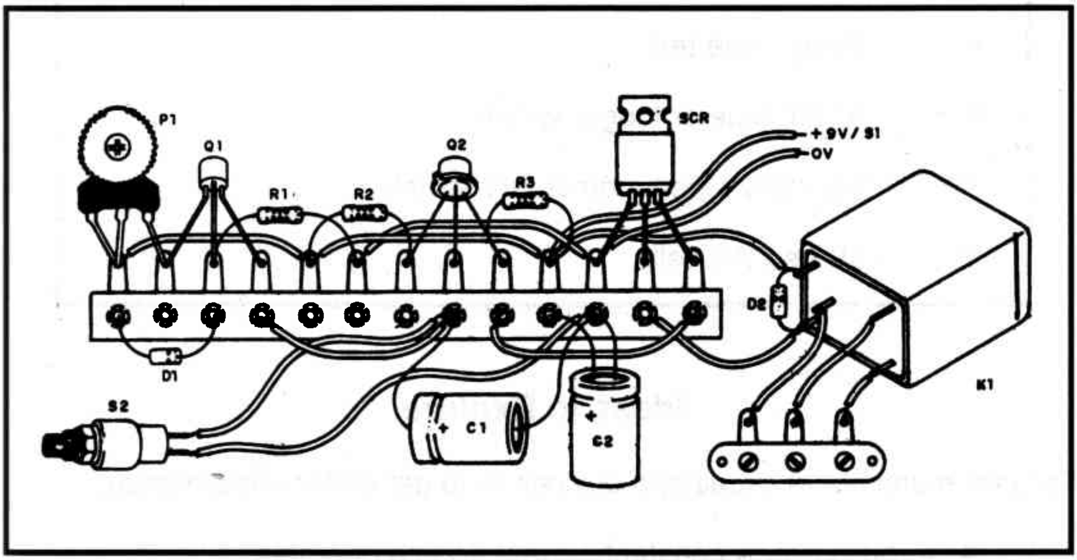


Figure 2

Use AA cells or a transformer to power this timer. Remember that current drain is low only when the relay is not energized.

Parts List — Timer

Q1	- BC548 NPN general-purpose silicon transistor
Q2	- 2N2646 unijunction transistor
SCR	- TIC106 silicon controlled rectifier
D1, 2	- 1N4002 silicon diodes
R1	- 47,000 ohm, 1/4W, 5% resistor
R2	- 120 ohm, 1/4W, 5% resistor
R3	- 100 ohm, 1/4W, 5% resistor
P1	- 100,000 ohm potentiometer
C1, 2	- 100 uF, 12 WVDC electrolytic capacitors
K1	- Relay - see text
S1	- SPST slide or toggle switch
S2	- Normally Open momentary switch
B1	- 9V - six AA cells

Ideas to Explore

To learn much about circuit and devices or to get better performance:

- Explain how a constant-current source operates.
- Explain how a UJT and SCR operate.
- Alter C1 to get higher time delays. Try values up to 1,000 uF.

Science projects and uncommon uses for this device:

- All experiments that need time-delay control can use this device, as long as the time delay needed falls in the range of this timer (between a few seconds and minutes). Use a common watch as reference to make a scale for the potentiometer.

- The circuit can be used to activate dangerous experiments with a safe time-delay allowing the experimenter to reach safe distance.

- Traps can be armed after a time-delay, so the experimenter can avoid the trap himself.

- Chemical processes can be controlled using this timer. Any audio oscillator described in this book can be use as warning circuit when wired to the relay output.

MICRO AM RADIO (E/P)

This micro AM radio will tune strong stations in the frequency range between 530 and 1,600 kHz.

The circuit uses only one transistor as the amplifier and with a transformer drives a small loudspeaker. As the circuit is very poor in amplification, it needs a long wire antenna. The antenna should be from 15 to 50 feet long for best results. A good ground connection is also important.

Of course, this is a small inexpensive transistor radio with low listening volume, particularly on a weak station. If the station is too weak, replace the SPKR by a low-impedance earphone.

The power supply is formed by two or four AA cells and current drain is very low, extending their life. The circuit drains only few microamperes.

L1 is a tapped loopstick, connected to variable capacitor CV. These items can often be found in non-working transistor radios, as well as the speaker and transformer.

Figure 1 shows the schematic diagram for this project. Diode D1 acts as a detector and Q1 as an audio amplifier. T1 is a common transistor output transformer.

In ***Figure 2*** we show the components layout. All the components can be housed in a small plastic box. A terminal strip is used as chassis in an experimental version.

T1 is a transistor transformer (1,000:8) and the SPKR is a miniature type. But, if you have an unworking AM radio you can get these parts without spending any money.

To use, close S1 and tune to the desired station by adjusting CV. You can adjust R1 for the best results according to your transistor gain.

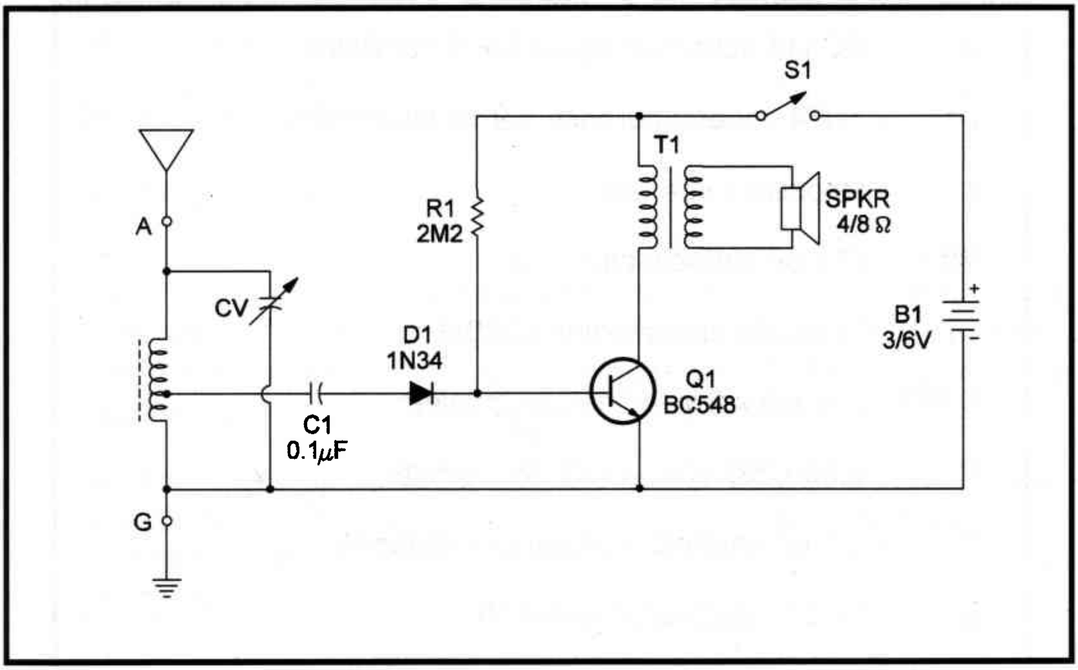


Figure 1

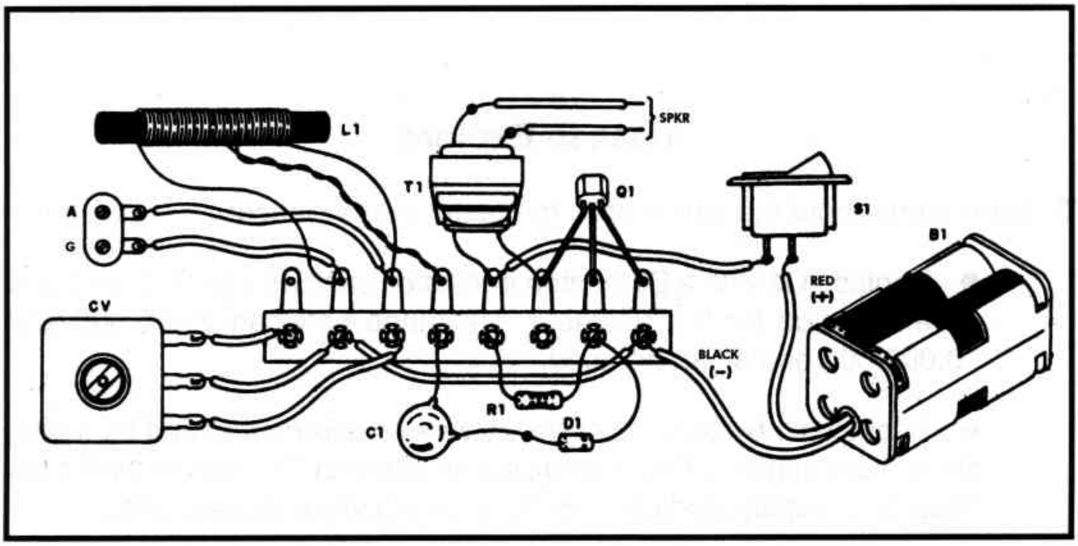


Figure 2

Parts List — Micro AM Radio

Q1	- BC548 general-purpose NPN transistor
D1	- 1N34 general-purpose germanium diode
L1	- loopstick - see text
CV	- 365 pF variable capacitor
T1	- Transistor transformer 1,000:8
SPKR	- 8 ohms x 2 in. miniature speaker
R1	- 2,200,000 ohm, 1/4W, 5% resistor
C1	- 0.1 uF ceramic or metal film capacitor
S1	- SPST toggle or slide switch
B1	- 3 or 6V - two or four AA cells

Ideas to Explore

To learn more about the circuit or to get better performance:

- Replace Q1 with a Darlington transistor, such as a BC517, and find a better value for R1. Values in the range between 2,200,000 and 10,000,000 ohms can be used.

- Replace L1 by 20 turns of No. 28 wire on a ferrite rod and try tuning short-wave stations. Use a long wire as antenna. Position of the L1 tap must be carefully studied to get best selectivity and sensibility.

- Experiment with a crystal earpiece in the place of T1 and SPKR. A 10,000 ohm resistor should be wired in parallel with the earpiece.

- Explain how crystal sets or direct-detection receivers operate.
- Define the term “selectivity”.
- What is a galena-crystal?

Science projects:

- This receiver can be used to demonstrate how antique radio receivers operated when radio was first invented. It can be presented as a “modern version” of a crystal or galena receiver in a demonstration. An interesting exhibit can be made with this set, the free-power AM receiver (described in this book), and a crystal set.

- The circuit can also be used as an RF “sniffer”, detecting radio signals produced by experimental circuits in the AM or short-wave band. Replace L1 with a 1,000 uH choke and remove C1 to get a sensitive RF sniffer.

TOUCH SWITCH (E)

Small appliances, lamps and motors can be controlled by a simple touch with this experimental circuit. Loads are ON during the time adjusted by P1 for a few seconds to more than 10 minutes. Conversely, by using the NC (normally closed) contacts you can also turn off an appliance after the adjusted time.

The sensor is formed by two small metal plates, and shouldn't be placed far from the circuit. The metal plates are finger-touched at the same moment.

The circuit can be powered from a 6- or 12-volt power supply, depending on the relay used. Do not use transformeless power supplies with this project, to avoid shocks or dangerous shorts. Transformerless power supplies are not isolated from the AC power line and represent a dangerous shock hazard.

K1 is a relay with 6- or 12-volt coil and is energized by current up to 50 mA. With relays in this range you can power the touch switch from AA cells (6 volts) or small power supplies.

A schematic of the Touch Switch is shown in ***Figure 1***. The circuit uses a 555 IC timer as its heart, and time delay is determined by adjusting P1.

Circuit mounting, using a small homemade printed-circuit board, is shown in ***Figure 2***. If you'd like to etch your own board use this parts placement diagram as guide.

In ***Figure 3*** we show the sensor that can be made with two small metal plates on a plastic or wood base. Wires to the sensor shouldn't be long. A maximum lenght of 10 feet is recommended to avoid erratic operation.

Position of the polarized components, such as the electrolytic capacitors and diodes, should be observed. Load is connected to terminals A and B. Remember that the relay acts as a switch.

Don't power this circuit from transformerless power supplies to avoid dangerous shocks and shorts.

A sensitivity control can be added to this circuit in a simple manner. Use a 1,000,000 ohm potentiometer for this task.

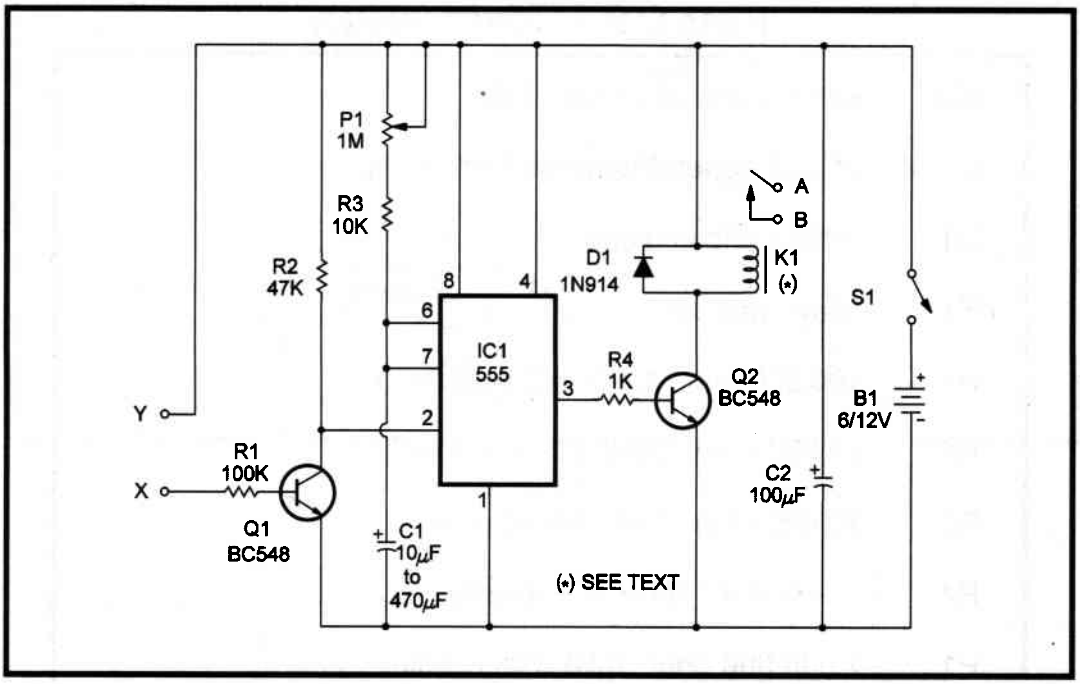


Figure 1

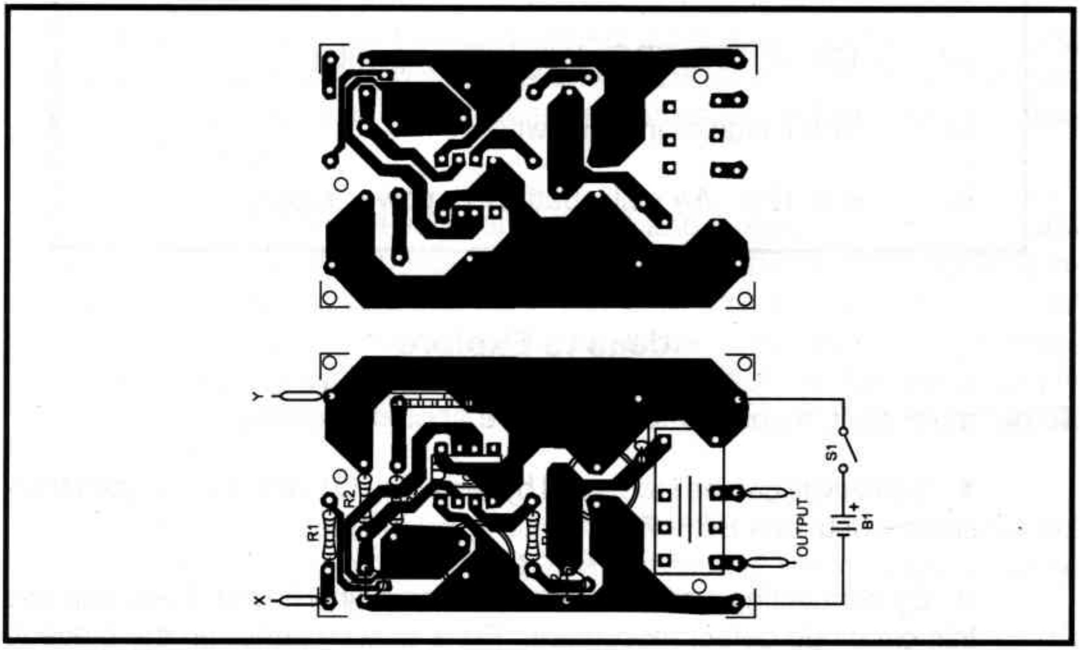


Figure 2

Parts List — Touch Switch

IC1	- 555 integrated circuit, timer
Q1, 2	- BC548 general-purpose NPN transistors
D1	- 1N914 silicon diode
K1	- relay - see text
R1	- 100,000 ohm, 1/4W, 5% resistor
R2	- 47,000 ohm, 1/4W, 5% resistor
R3	- 10,000 ohm, 1/4W, 5% resistor
R4	- 1,000 ohm, 1/4W, 5% resistor
P1	- 1,000,000 ohm, 1/4W, 5% resistor
C1	- 10 to 470 uF, 12 WVDC electrolytic capacitor - see text
C2	- 100 uF, 16 WVDC electrolytic capacitor
S1	- SPST toggle or slide switch
B1	- 6 or 12V - AA cells, battery or power supply

Ideas to Explore

To get more performance or to learn more about the circuit:

- Sensitivity can be increased by replacing Q1 with a Darlington transistor, such as a BC517.
- By connecting a reed switch between points Y and X you can use this circuit do detect movement. Fix a small magnet on the piece to act on the reed switch.

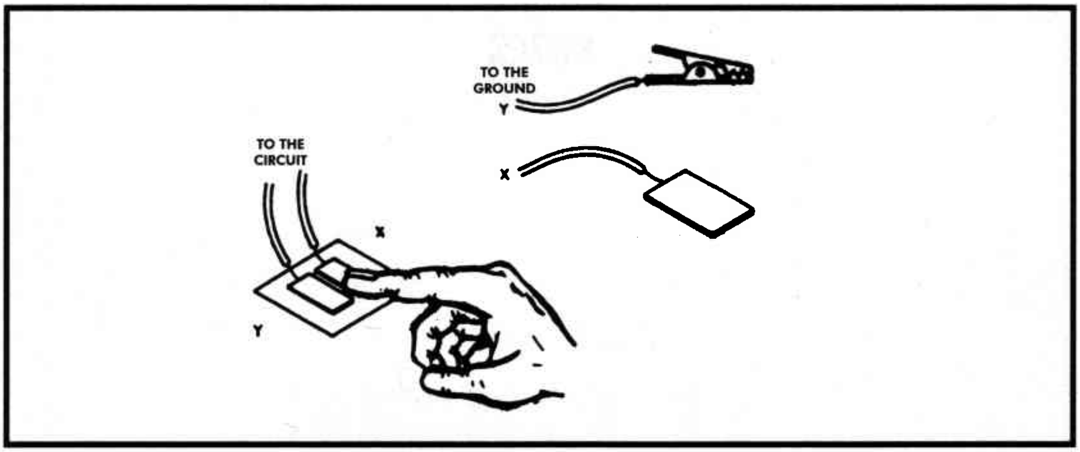


Figure 3

Science and uncommon applications:

- This circuit can be used to close a trap. The touch sensor will detect when the animal enters the trap.

- Projects that need a way to detect movements, switching any load, can be made with this circuit. Several kind of sensors, like microswitches, pendulum sensors or any other momentary-type switch can be used in this circuit.

- Connect an LDR between points A and B. Also connect a 100,000 ohm potentiometer between X and the negative pole of the power supply. You'll have a light-operated relay or remote control. A flash of light produced by a lantern or even a cigarette lighter can close the relay, powering the load. The circuit can be used to detect flashes of light in science experiments. Fix the LDR into a telescope and you can detect meteor fallings.

- Experiments involving thunderstorms at night can be conducted automatically using this circuit. The first flash of lightning can be used to power ON the equipment.

SIMPLE FLUORESCENT LAMP INVERTER (E/P)

This circuit will light a common fluorescent tube (from 7 to 40 watts) from a 6- or 12-volt power supply, such as ni-cad cells, D cells, car battery or other source, without need of a choke or starter. Even the old tubes which no longer function at all on AC power lines will light when used for this purpose. (Some of them, though, may be too weak to light when the circuit is powered from 6 or 12 volts. You should experiment beforehand.)

You can use the device as an emergency light, in trailers, signaling, etc.

By powering the fluorescent lamp with a transformer power supply you increase safety factor of an experiment, avoiding dangerous shocks or shorts.

Current drain, typically ranging from 100 to 800 mA, depends on the characteristics of the lamp used, the power supply voltage, and the transformer.

The lamp will brighten according to the drained current. Experiments should be done with some different transformers and oscillator frequencies to get better performance out of the circuit.

Basicaly, the circuit is a low-frequency oscillator driving a transformer. High voltage is obtained from the transformer to light a fluorescent light.

The trimmer potentiometer allows frequency adjustment to get better performance.

Schematic diagram of the Fluorescent Lamp Inverter is displayed in ***Figure 1***. As you see, the circuit consists of a low-frequency oscillator with a pair of complementary transistors.

Components layout, using a terminal strip as chassis, is shown in ***Figure 2***. Components placement is not critical.

Transistor Q2 should be mounted on a large heatsink. T1 is a 6V x 450 mA or 12V x 450 mA transformer. If a CT (center-tapped secondary coil) transformer is you should use only two of the three secondary's wires.

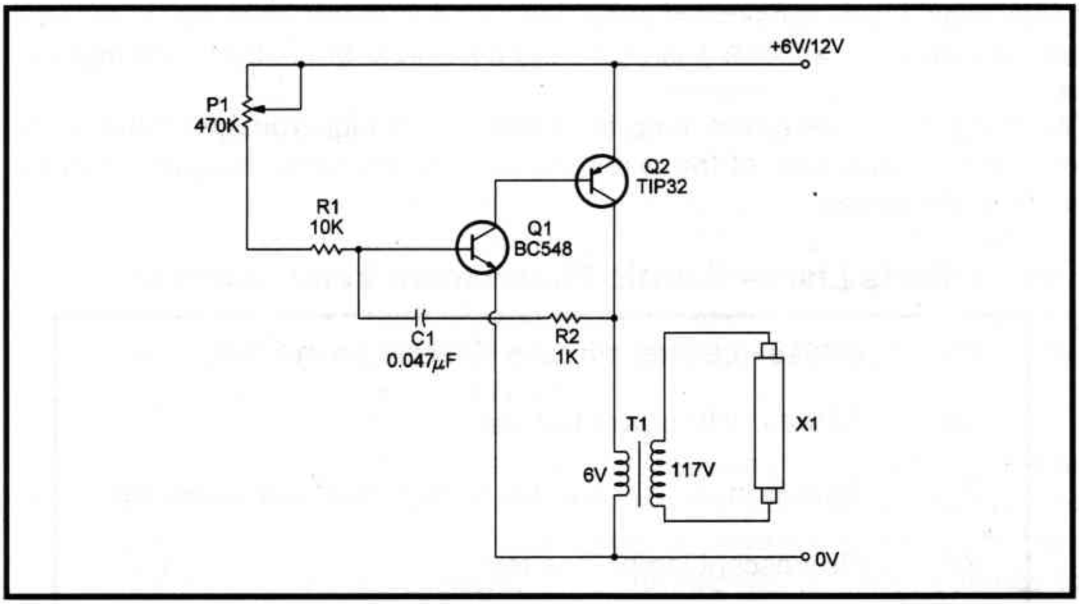


Figure 1

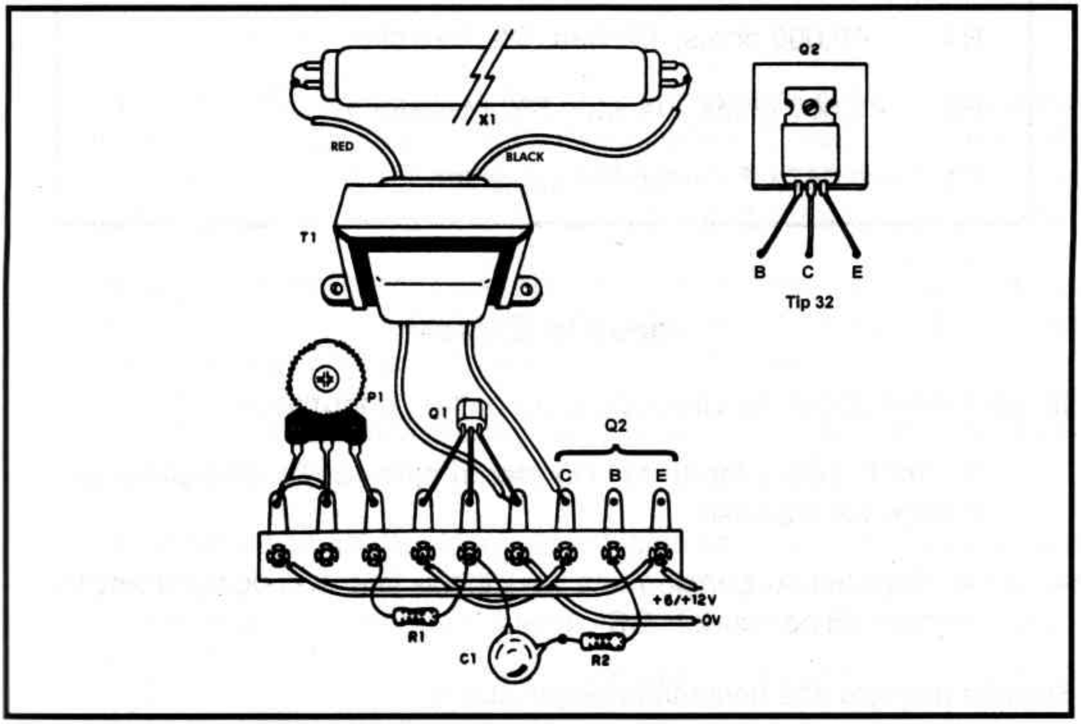


Figure 2

Experiments with transformers with secondary currents from 300 to 800 mA and voltages betweeen 9 and 15V can be made to get better performance.

Warning: The fluorescent lamp is powered with high voltages that can be dangerous. Take care of the wires' insulations and when handling connections to the device.

Parts List — Simple Fluorescent Lamp Inverter

Q1	- BC548 - general purpose NPN silicon transistor
Q2	- TIP42 - PNP power transistor
T1	- Transformer: 117 VAC; 6V x 450 mA or 12V x 450 mA
X1	- Fluorescent lamp - see text
P1	- 470,000 ohms - trimmer potentiometer
R1	- 10,000 ohms, 1/4-watt, 5% - resistor
R2	- 1,000 ohms, 1/4-watt, 5% - resistor
C1	- 0.047 uF - metal film capacitor

Ideas to Explore

To learn more about the circuit or to get better performance:

- Try to use a ferrite transformer in place of T1. The circuit performance will increase.

- Explain how transformers work in this kind of circuit and why transformers do not work in DC circuits.

Science projects and uncommon applications:

- Replace X1 by an small ultraviolet fluorescent lamp and you'll have a mineral or fluorescent materials searcher. Many materials, including the ones with a high percentage of calcium, will glow when illuminated by ultraviolet. Many experiments and demonstrations can be made involving minerals, plants and fluorescent materials .

- An interesting experiment with plants is to study the effect of ultraviolet radiation on different plants' growth or germination. Irradiate several batches of various seeds, such as tomato, been, squash, etc., with UV, and then plant. Because of increasing UV radiation reaching the earth due to depletion of the ozone layer, the effect of this radiation on plant life is of concern to us all.

- Compare effects of different light wavelengths to seed germination. The wavelenghts of incoming solar radiation range from 200 to 3,000 nanometers (nm). UV radiation is between 380 and 400 nm. Select seeds from common plants and expose differrent batches to UV and/or common light (red to blue). What happens with the diferent seeds during germination? You also can conduct the experiment not only with seeds, but plants and insects.

- High voltage present in the 117V transformer coil can be used in nerve stimulation experiments. *Please add a 10,000 ohm potentiometer to control the applied voltage if the circuit is intended to be used on humans! The voltage in the transformer has peaks as high as 400V!*

- Fluorescent light can also be use in experiments with insects. Some kinds of insects are attracted by light (visible and ultraviolet!). Insect traps can be constructed using this circuit as base.

- Fish and other animals can be attracted by fluorescent light. A circuit powered by cells or battery is important for fieldwork.

- Alternate methods of farm pest control can use light, visible as well as radiation in the ultraviolet part of the spectrum. Insect traps can be constructed with fluorescent lamp inverters. For further information:

The International Alliance for Sustainable Agriculture
1701 University Avenue SE
Minneapolis, MN 55414 (612) 331-1099

TOUCH ON/TOUCH OFF RELAY (P)

AC-powered appliances, such as lamps, small home appliances, tools and other items, can be controlled by your fingertips using this circuit. Also, test equipment and experiments can be controlled by this circuit. You can turn on any load by first touching time sensor X1, then turn it off by touching X1 again. There is no shock hazard, as the control circuit is completely isolated from the AC power line.

The control circuit is powered from four or eight AA cells, or, if you prefer, a power supply ranging from 6 to 12 volts according to the relay coil.

Don't use transformerless power supplies because they are not isolated from the AC power line and can cause severe shocks and shorts.

The schematic diagram of the Touch On/Touch Off Relay is given in ***Figure 1***. The circuit uses two ICs. The 555 timer works as a monostable, producing one control pulse when the sensor is touched. The 4013 is a flip-flop that controls the relay by a transistor.

Components placement on a homemade printed-circuit board is as shown in ***Figure 2***. Component layout should be altered if the relay used in the project is an equivalent of the type indicated in parts list.

Relay coil voltage is determined by the power supply voltage and the load current requirement. You can use a mini 1A DPDT (Radio Shack 275-249) 12V, 280 ohm, 43 mA, and wire it as shown in the figure, or use another type of relay, depending on the load requirements.

A 10A SPDT mini-relay (Radio Shack 275-278) is suitable for heavy duty appliances.

As a simple rule, you can use a 6- or 12-volt relay with coil currents ranging from 10 to 100 mA and contacts up to 10A, according to the task you have in mind.

Positions of the polarized components, such as the diode, electrolytic capacitors and transistor, should be observed.

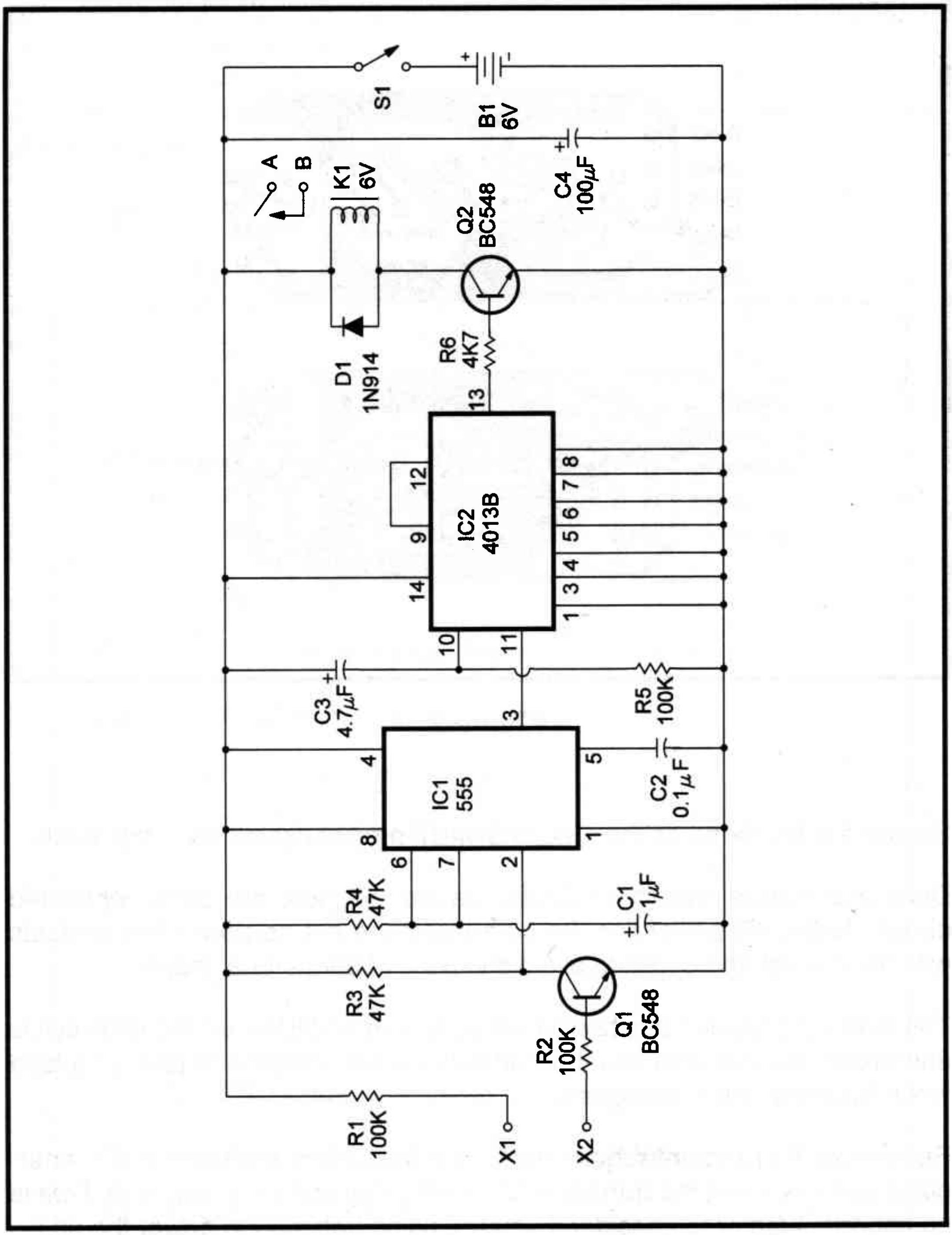

S1
B1
6V
A
B
K1
6V
C4
100µF
Q2
BC548
D1
1N914
R6
4K7
IC2
4013B
C3
4.7µF
R5
100K
IC1
555
C2
0.1µF
R4
47K
C1
1µF
R3
47K
R2
100K
Q1
BC548
R1
100K
X1
X2

Figure 1

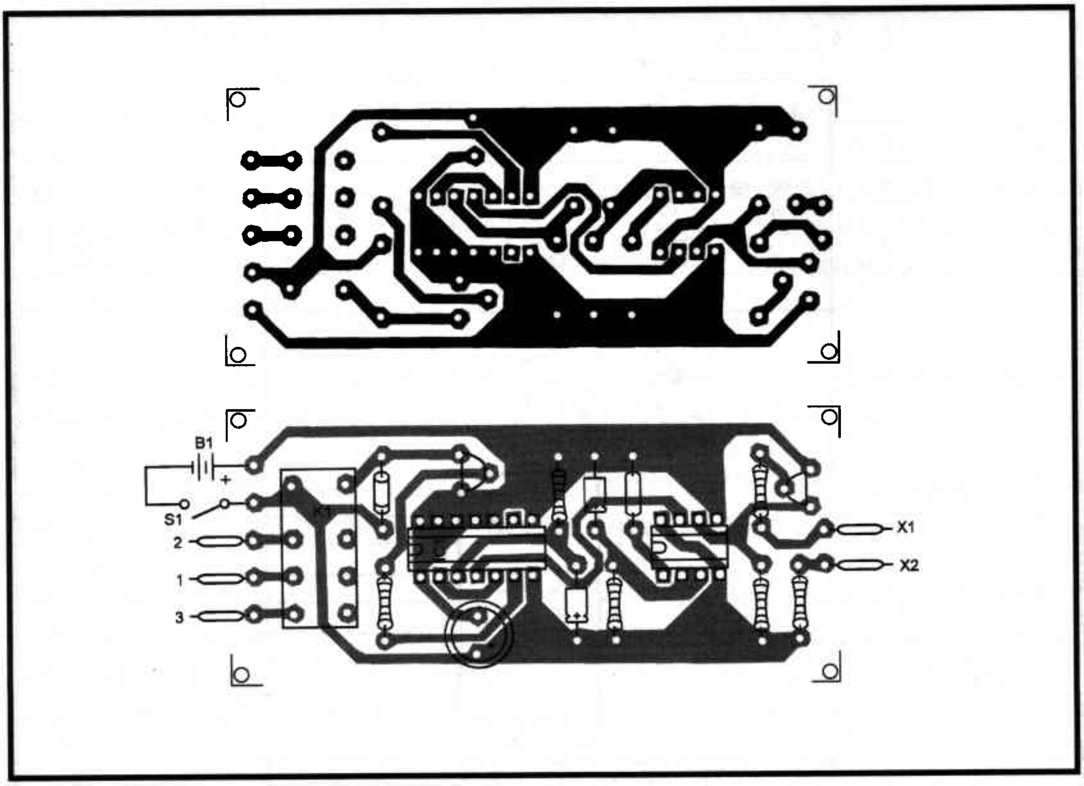


Figure 2

Sensor are the same as the "Touch Switch" project described in this book.

Don't use metallic box to house the device, as there are parts connected directly to the AC power line. Be sure that there are no power line contacts with the low voltage circuit to avoid shocks and dangerous shorts.

The load is connected as shown in ***Figure 3,*** to be ON when the relay coil is energized. You can also use the normally closed contacts to turn off a load when the relay coil is energized.

Remember that current requirements are high when the relay coil is energized and low when the transistor Q2 is off (relay coil nonenergized). That is an important factor to consider if you are using batteries to power the unit.

After you are sure that you have wired all parts of the circuit correctly, plug the power cord into the wall socket. You can now test the circuit.

Connect a load to the output (relay contacts) and touch the sensor. The load should be powered ON if all is OK.

Parts List — Touch On/Touch Off Relay

IC1	- 555 Integrated circuit - timer
IC2	- 4013B CMOS integrated circuit - dual flip-flop
Q1, 2	- BC548 General-purpose NPN silicon transistors
D1	- 1N914 General-purpose silicon diode
K1	- Relay - see text
R1, 2, 5	- 100,000 ohm, 1/4W, 5% resistors
R3, 4	- 47,000 ohm, 1/4W, 5% resistors
R6	- 1,000 ohm, 1/4W, 5% resistor
C1	- 1 uF, 25 WVDC electrolytic capacitor
C2	- 0.1 uF ceramic or metal film capacitor
C3	- 4.7 uF, 12 WVDC electrolytic capacitor
C4	- 100 uF, 16 WVDC electrolytic capacitor
S1	- SPST toggle or slide switch
B1	- 6 or 12V (according to relay) - see text
X1, 2	- sensor - see text

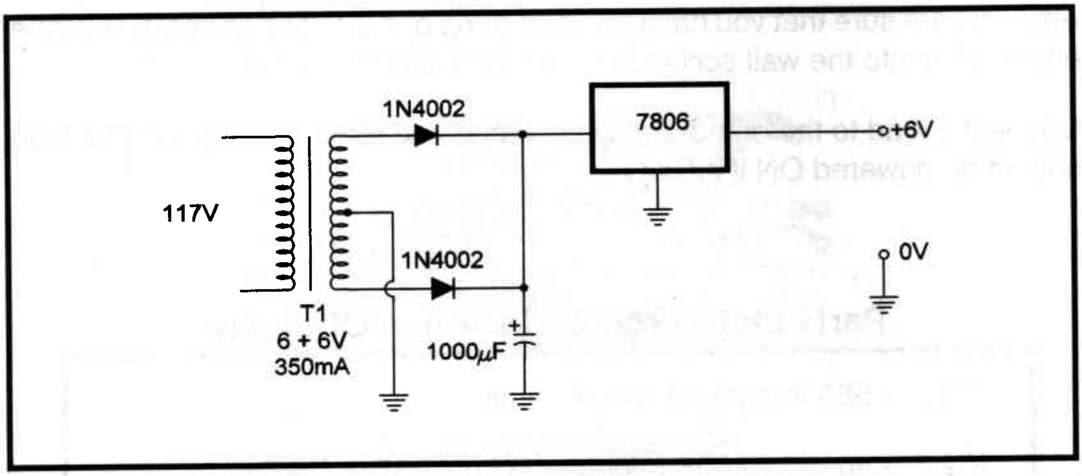


Figure 3

Ideas to Explore

To learn more about the circuit or to get better performance:

- Better performance can be obtained by replacing Q1 with a Darlington transistor, such as a BC517.

- A 100,000 ohm potentiometer placed between the base of Q1 and the negative pole of the power supply will give a sensitivity adjustment for the circuit.

- Explain how a flip-flop, as used in this circuit, works, and the function of the C3/R5 network in this project. Explain why the current flowing through the fingers when the sensor is touched doesn't cause any shock hazard.

- Depending upon the application, you can power ON the load when relay is not energized (to reduce power consumption). That is possible using the normally closed contacts of the relay.

Science projects and uncommon uses:

- By connecting a reed switch between points X1 and X2 you can use the circuit to detect movement of mechanical items in experiments or projects. Just affix a magnet on the moving item to act on the switch.

- Experiments with animals can be conducted with this circuit by using appropriate transducers connected between X1 and X2.

- An LDR can be used to control the circuit with a flash of light. A lantern, cigarette lighter, etc., can be used to turn appliances on or off.

EXPERIMENTAL GALVANOMETER (E)

The experimental galvanometer described here can detect currents as low as few microamperes and uses unusual parts. This galvanometer operates as common commercial galvanometers found in multimeters and several other analog instruments.

One purpose of this experiment can be to demonstrate that there is a magnetic field around a coil that that is carrying electricity (Oersted Experiment).

The operating principle is very simple to understand: an electric current flowing across a coil (or a wire) produces a magnetic field. The field can act on a mobile magnetic metal piece, such as a compass pointer or a blade, as shown in the figures herein. The compass or blade movement indicates the presence of a current.

Figure 1 shows the two basic versions of the experimental galvanometer, using a common compass and using a blade. Is very important to observe the correct path for the current flow in the coil. The coil should be wired exactly as shown in the figure.

In ***Figure 2*** we have a circuit to operate the galvanometer. The resistor can range from 100 to 100,000 ohms. The higher the resistor, the more sensitive is the galvanometer. Experiment to find the highest resistor value that can cause the pointer to move.

The coil is made with 50 to 200 turns of No. 28 to 32 wire on a paper form. Number of turns determines sensitivity. The higher the number of turns, the more sensitive is the galvanometer.

Currents as low as a few microamperes can be detected with a carefully made prototype.

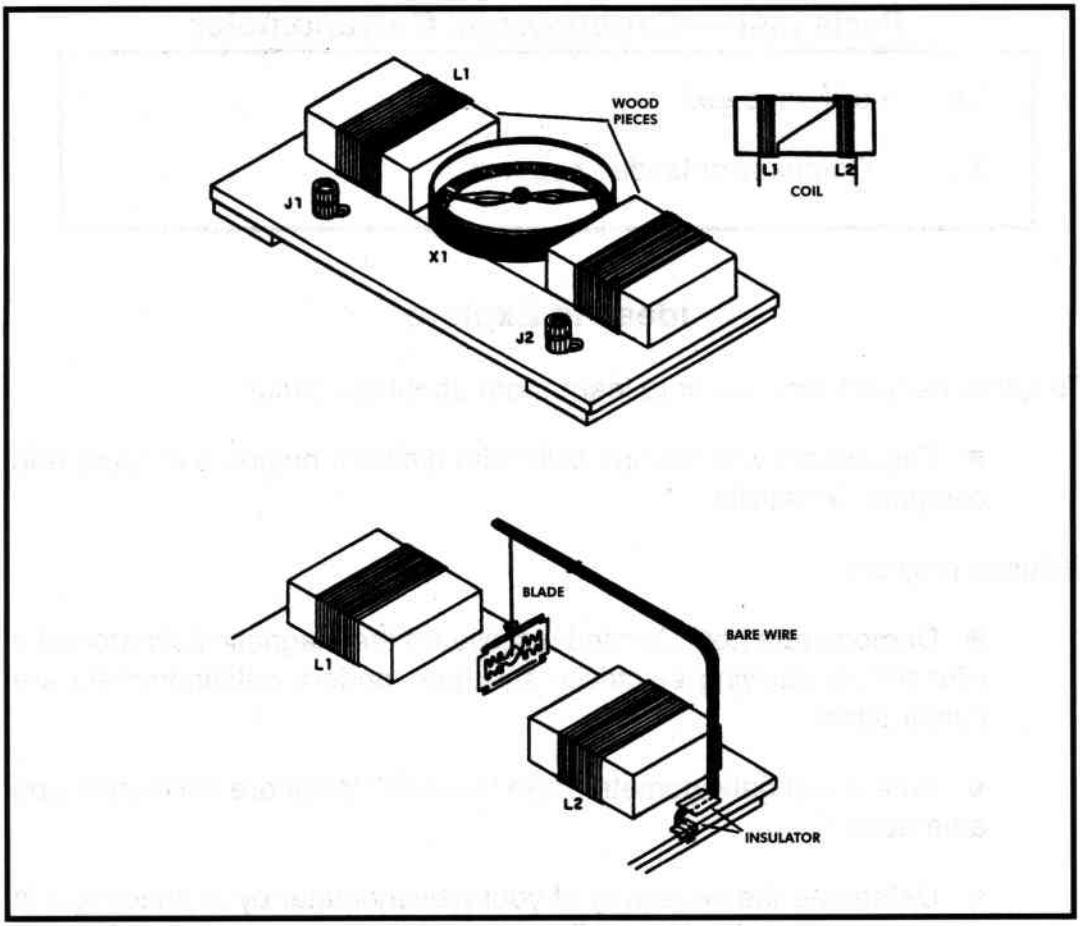


Figure 1

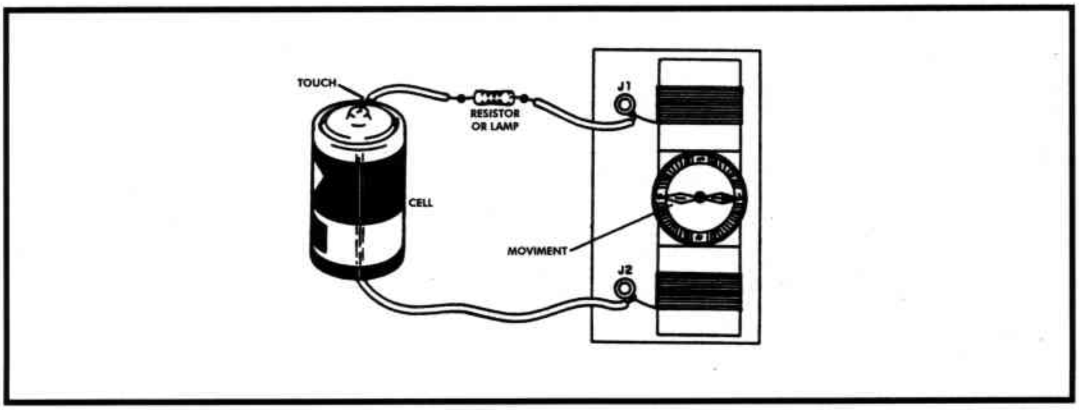


Figure 2

Parts List — Experimental Galvanometer

L1	- coil - see text
X1	- Compass or blade - see text

Ideas to Explore

To get better performance or to learn more about the circuit:

- Experiment with several coils with different numbers of turns and compare sensitivity.

Science projects:

- Demonstrate how Oersted discovered the magnetic field around a wire that is carrying electricity and how modern galvanometers are constructed.
- Where can galvanometers can be used? What are voltmeters and ammeters?
- Determine the sensitivity of your galvanometer by connecting it in series with a multimeter (DC mA or uA scale) and a 100,000 ohm potentiometer.

OVER-TEMPERATURE ALARM (E/P)

This circuit will produce intermittent beeps by a piezoelectric transducer when the temperature rises over a preadjusted value. You can use this circuit in greenhouses, heaters, etc. The sensor is a common silicon diode but an NTC can also be used if you change some components' values.

Exchanging positions of R1 and P1 with D1 will cause the device to operate as an under-temperature alarm.

The intermittent signal is generated by two oscillators. IC1a (pins 1,2 and 3) is an inverter that controls IC1b and IC1c (oscillators). IC1c (pins 8, 9 and 10) is a very-low-frequency oscillator that provides the modulation rate for the second oscillator. The second oscillator (pins 5,6 and 4) has its frequency determined by R2 and C1. The produced audio tone can be altered by adjusting both C1 and R2 within a large range of values.

Power comes from a 3- to 15-volt power supply. For portable use a small 9-volt battery is recommended. Current drain is very low, about 0.5 mA when the tone is off. When the tone is on, current drain rises to about 5 mA.

A schematic of the Over-Temperature Alarm is shown in ***Figure 1***. IC1, a 4093B, has two gates operating as oscillators and two as buffer-inverters.

Components placement on a homemade printed-circuit board is shown in ***Figure 2***. You can made your prototype using a single-sided PC board.

Position of the polarized components, especially diode D1 (used as sensor), should be observed. This sensor can be placed far from the device by using common wiring. You must take some care to avoid humidity or water falling onto the sensor, which will cause adversely affect the alarm operation.

BZ is a piezoelectric transducer (Radio Shack 273-073 or equivalent) or a crystal earpiece.

Operation is adjusted by P1. Set this potentiometer to get sound at the desired temperature. To get a more precise adjustment you can replace the common trimmer potentiometer by a multi-turn potentiometer.

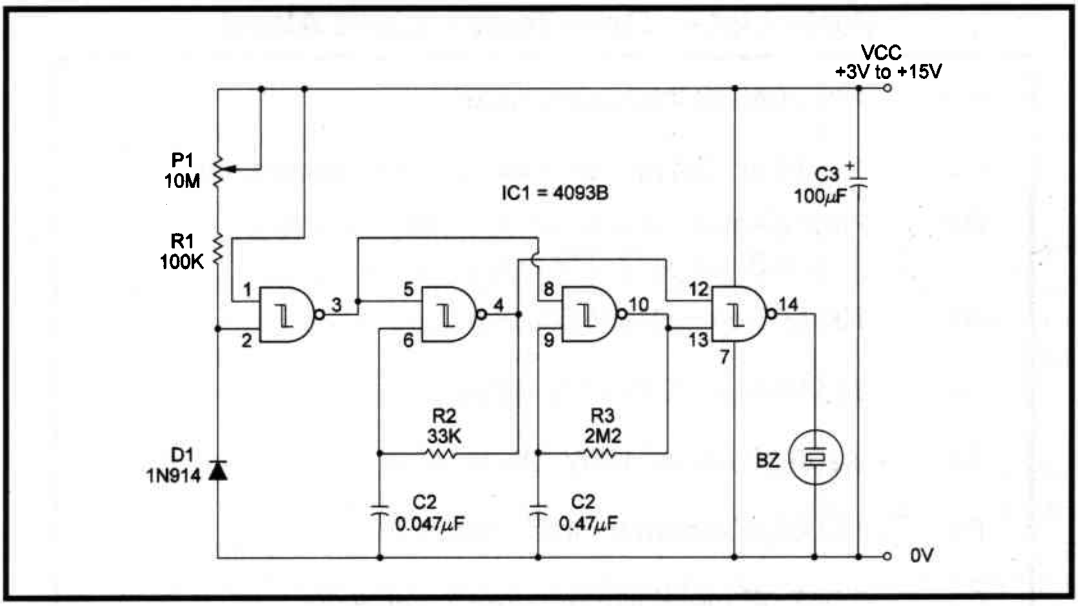


Figure 1

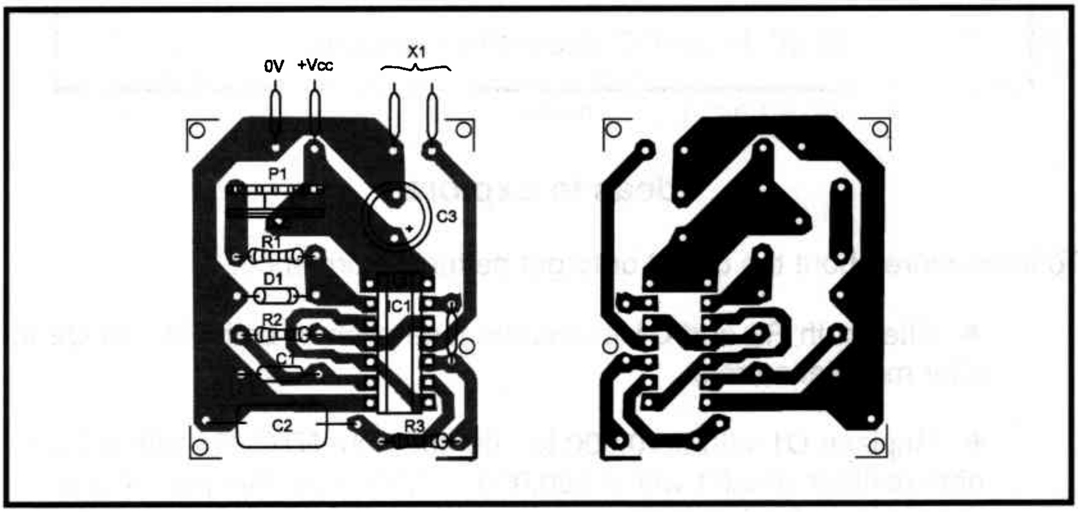


Figure 2

Get the sensor between your fingers to see how it works: when the temperature rises some degrees the circuit will produce a serie of beeps. Isolate the sensor, and after some seconds sound emission will stop.

Parts List — Over-Temperature Alarm

IC1	- 4093 CMOS integrated circuit
D1	- 1N914 or 1N4148 general purpose silicon diode
BZ	- Piezoelectric transducer or crystal earphone (Radio Shack 273-073 or equivalent)
R1	- 100,000 ohm, 1/4W, 5% resistor
R2	- 33,000 ohm, 1/4W, 5% resistor
R3	- 2,200,000 ohm, 1/4W, 5% resistor
P1	- 10,000,000 ohm trimmer potentiomer
C1	- 0.047 uF metal film or ceramic capacitor
C2	- 0.47 uF metal film or ceramic capacitor
C3	- 100 uF, 16 WVDC electrolytic capacitor

Ideas to Explore

To learn more about the circuit or to get better performance:

- Alter both R2 and C1 to change tone pitch or both R3 and C2 to alter modulation rate.

- Replace D1 with a 10,000 to 100,000 ohm NTC, R1 with a 2,200 ohm resistor, and P1 with a 100,000 to 1,000,000 ohm potentiometer, to get a new kind of sensor.

- Try to add a powerful output audio stage using a transistor, such as a BD135 and a small loudspeaker. See other projects in this book for suggestions about the configuration.

Science projects and other applications:

- Chemical processes that involve heat changes can be controlled using this alarm. The sensor should be protected against moisture and water in experiments involving liquids.

- Replace D1 by an LDR or photodiode. The circuit will operate as a light alarm or dark alarm, depending upon sensor position. With an LDR it would be better to replace P1 with a 1,000,000 ohm potentiometer and R1 with a 10,000 ohm resistor. Lenses placed in front of the LDR or phototransistor can be used to increase sensitivity.

- The circuit can also operate as a water-level alarm by using a two-wire sensor to replace D1. The sensor is made with two bare wires. The wires are separated by a distance of about 2 or 3 inches. The water completes the circuit while the wires are immersed. When the water level falls below the wires, the circuit is opened and the alarm is triggered.

- Temperature in greenhouses, animal pens, incubators and aquariums can be monitored using this device. And if working with an LDR as the sensor, experiments involving light can be conducted.

CAPACITOR TESTER (P)

This circuit can be used to test metal film ceramic capacitors and other types of capacitors in a range of values between 470 pF to 10 uF.

The device is formed by an audio-oscillator that produces a tone determined by the capacitor under test. Probes connect the capacitor to the circuit. The frequency of the produced tone is higher for lower-value capacitors. A falling tone indicates a bad capacitor.

Testing capacitors in the range between 1 and 10 uF, the oscillator will produce separated audio pulses, working like a metronome.

The circuit is powered by two or four AA cells, and current drain is very low. P1 is adjusted to set an audible tone at the speaker, according the value of the capacitor being tested.

You can also use this device to compare capacitor values. Two capacitors with the same value will give the same tone.

The schematic diagram of the Capacitor Tester is shown in ***Figure 1***. The circuit has as its heart two complementary transistors working as a direct-coupled amplifier. Feedback is provided by resistor R1 and the capacitor under test.

Components placement on a terminal strip is shown in ***Figure 2***. Use this parts placement as a guide when assembling the terminal strip and when housing the circuit into a box.

Termination components should be short as possible to avoid instability.

Position of the polarized components, such as the electrolytic capacitor and power supply, should be observed when mounting. The capacitor under test is placed in the circuit by two alligator clips as shown in Figure 2.

The circuit can be housed in a small plastic box.

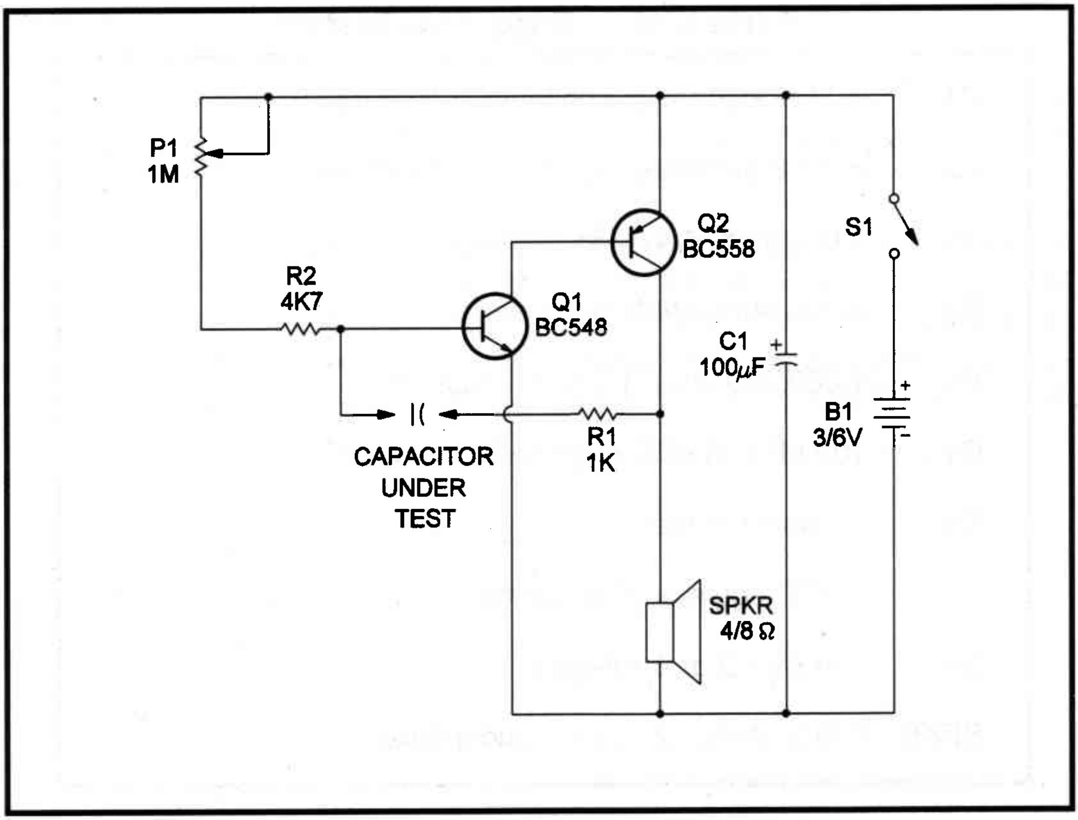


Figure 1

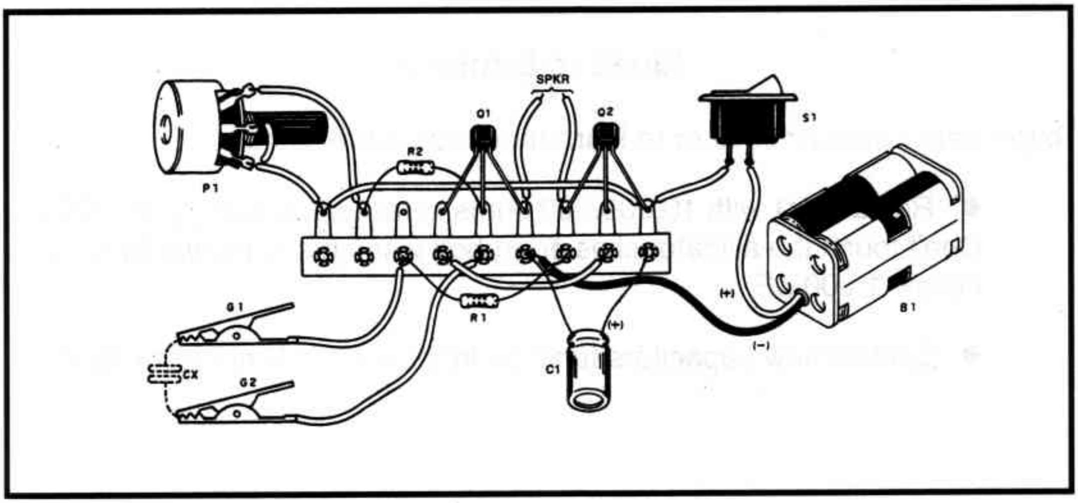


Figure 2

Parts List — Capacitor Tester

Q1	- BC548 general-purpose NPN transistor
Q2	- BC558 general-purpose PNP transistor
R1	- 1,000 ohm, 1/4W, 5% resistor
R2	- 4,700 ohm, 1/4W, 5% resistor
P1	- 1,000,000 ohm, 1/4W, 5% resistor
C1	- 100 uF, 6 WVDC electrolytic capacitor
Cx	- capacitor in test
S1	- SPST toggle or slide switch
B1	- 3 or 6V - 2 or 4 AA-cells
SPKR	- 4 to 8 ohms - 2 to 4 in. loudspeaker

Ideas to Explore

To get better performance or to learn more about the circuit:

- Replace P1 with 10,000,000 ohms to test capacitors under 470 pF. Don't touch the alligator clips or probes when testing small capacitors bellow 1,000 pF.
- Explain how capacitors function in this circuit. What is feedback?

Science projects and uncommon uses:

- Mount an experimental capacitor using aluminum foil and paper as dielectric. Test the capacitor using this device and compare the value with known capacitors.

- Experiments involving capacitive transducers can be conducted with this circuit. The circuit can be used as an analog-to-digital (A/D) converter. These circuits can convert capacitances (an analog quantity) into frequencies (a digital quantity). With an appropriate conversion scale it will be possible to use a frequency counter to measure capacitances.

CONTINUITY TESTER (E/P)

This circuit can be used to test electronic components such as diodes, resistors, coils, transformers, lamps, fuses, switches, loudspeakers and many others. The state of the component under test is indicated by an LED.

When the probes are separated or when the resistance between them is very high (more than 1,000,000 ohms) the LED is off. When the resistance is low (the transistor is in a conduction state) the LED is on.

The circuit is powered from a 6- or 9-volt supply (AA cells or battery). Current drain is less than 10 mA with the LED on. R2 value depends on the power supply voltage. For a 9V supply we recommend 820 or 1,000 ohms for R2.

A schematic diagram of the Continuity Tester is given in ***Figure 1.*** Two transistor are wired as a Darlington pair. The configuration reduces the current flow between probes to microampere values.

Components placement on a terminal strip, used as chassis, is shown in ***Figure 2.*** It is very important to observe positions of the transistors and LED.

House the device in a small plastic box and use probes or alligator clips to connect the components under test.

Parts List — Continuity Tester

Q1, 2	- BC558 general-purpose PNP silicon transistors
LED	- Common red, green or yellow LED
R1	- 100,000 ohm, 1/4W, 5% resistor
R2	- 470 ohm, 1/4W, 5% resistor - see text
S1	- SPST slide or toggle switch
B1	- 6V or 9V (four AA cells or battery)
PP1, 2	- Red and black probes

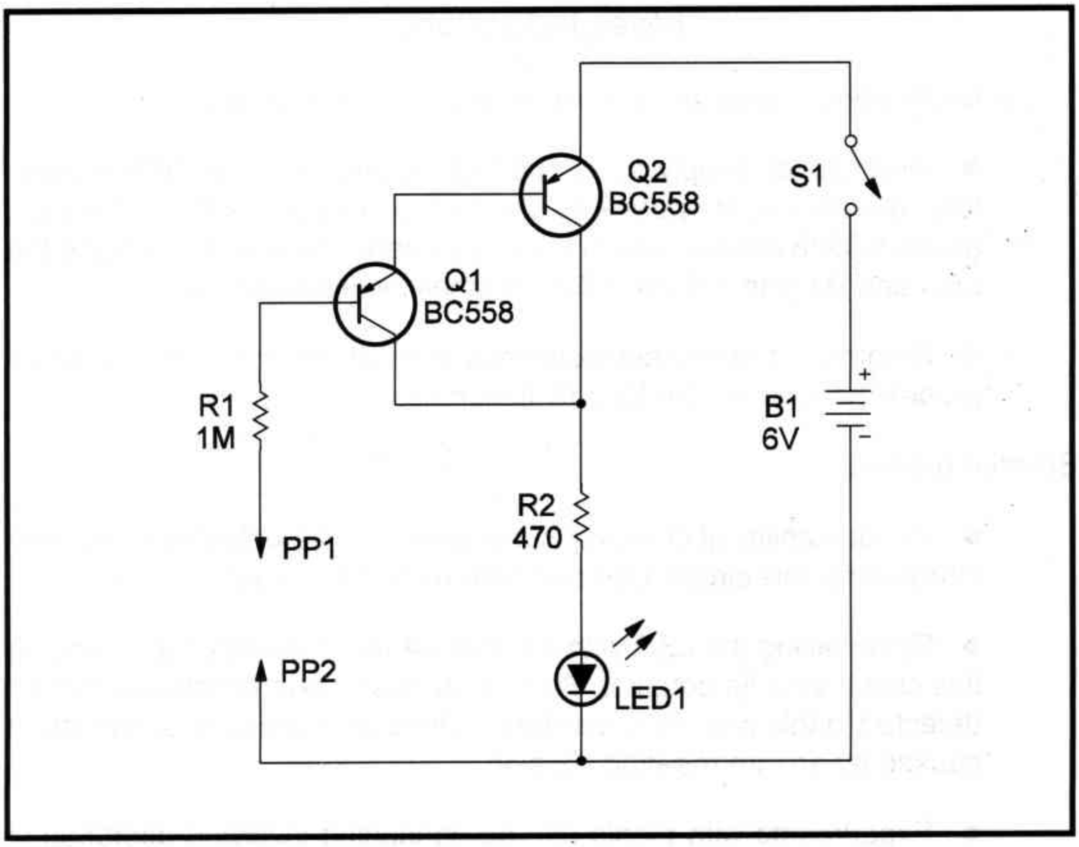


Figure 1

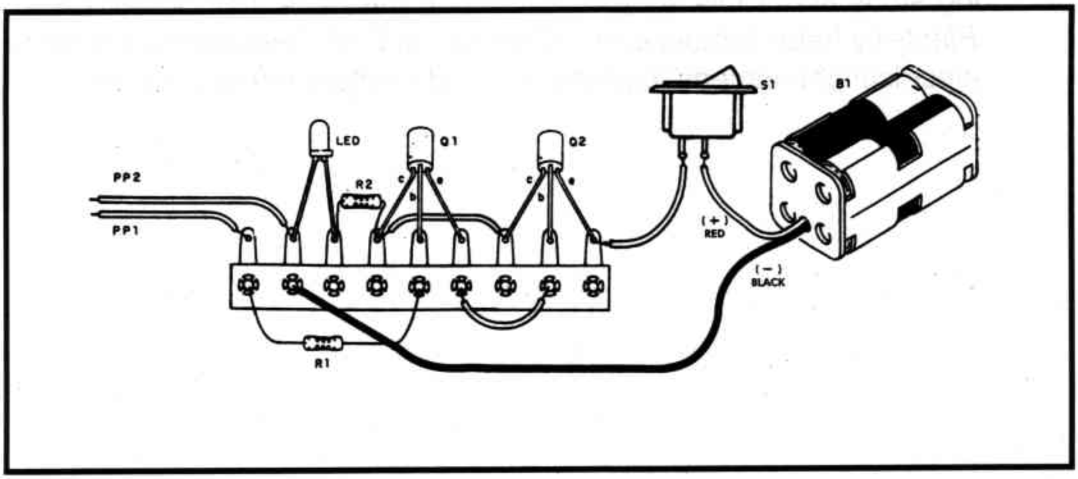


Figure 2

Ideas to Explore

To get better performance or to learn more about circuit and devices:

- Invert power supply poles and LED position and use NPN transistors. Will the circuit operate as the original version? A transistor such as the BC548 can be used in this experiment. You can also replace the LED and R1 with a 6-volt x 50 mA small incandescent lamp.

- Determine the highest resistance that can be connected between probes that causes the LED to illuminate.

Science projects:

- Conductability of chemical substances can be detected or demonstrated with this circuit. Use two bare wires as probes.

- By replacing the LED with a 0-200 uA microammeter you can use this circuit as a lie detector. Small changes in skin resistance can be detected in this way. Skin resistance alters with stress or by the strain caused by an interrogation session.

- Experiments with plants can be conducted involving alteration in the resistance between electrodes placed on their leafs . An interesting study about this subject is found in the book *The Secret Life of Plants* by Peter Tompkins and Christopher Bird. The authors associate electrical phenomena in plants to a rudimentary nervous system.

LED BARGRAPH (E/P)

This circuit drives ten LEDs in response to an analog voltage applied to its input and can be used to provide a visual indication of the instantaneous power being developed by an audio amplifier. It can also be used to provide visual indication of variable events in science experiments.

You can extend the project by using two chips and you'll be able to continuously monitor the audio output power of both channels of your stereo system.

The circuit can be used with amplifiers ranging from 0.1 to 100 watts.

In some cases you should use a small transformer, wired as in ***Figure 1***, to isolate the input and match impedances. This is necessary when the amplifier has a low-output impedance. Resistor R_x is chosen according to the output power of the amplifier. Values are given in Table 1.

Table 1

Amplifier Output Power	Rx
0.1 to 1 watt	-
1 to 5 watts	10 ohms, 1/2 watt
5 to 20 watts	22 ohms, 1 watt
20 to 50 watts	47 ohms, 1 watt
50 to 100 watts	100 ohms, 2 watts

A schematic diagram of the LED bargraph is shown in ***Figure 2***. The circuit uses an LM3914 IC to drive the LEDs, converting voltages into one of ten outputs.

The components are placed on a printed-circuit board as shown in ***Figure 3***. If you'd like to build your circuit the same way, you can etch your own board using the solder and component-side templates shown in this figure.

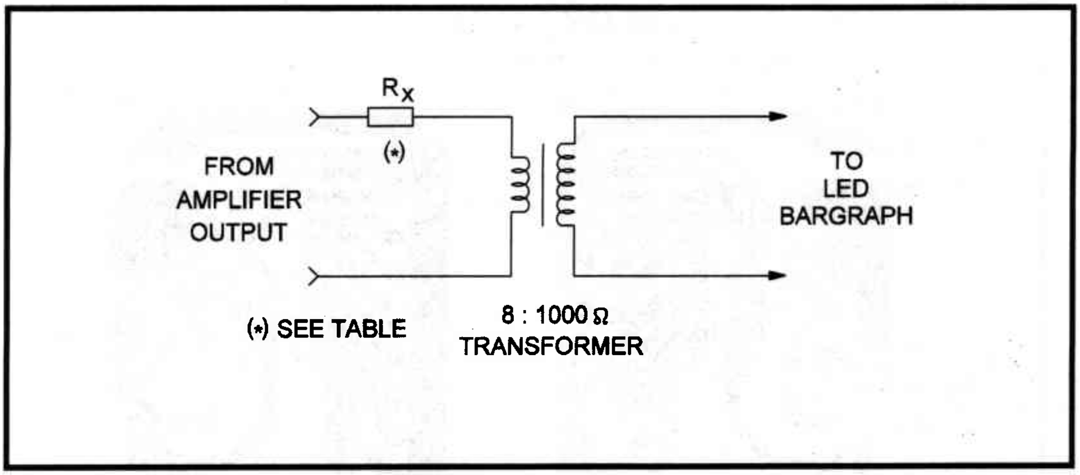


Figure 1

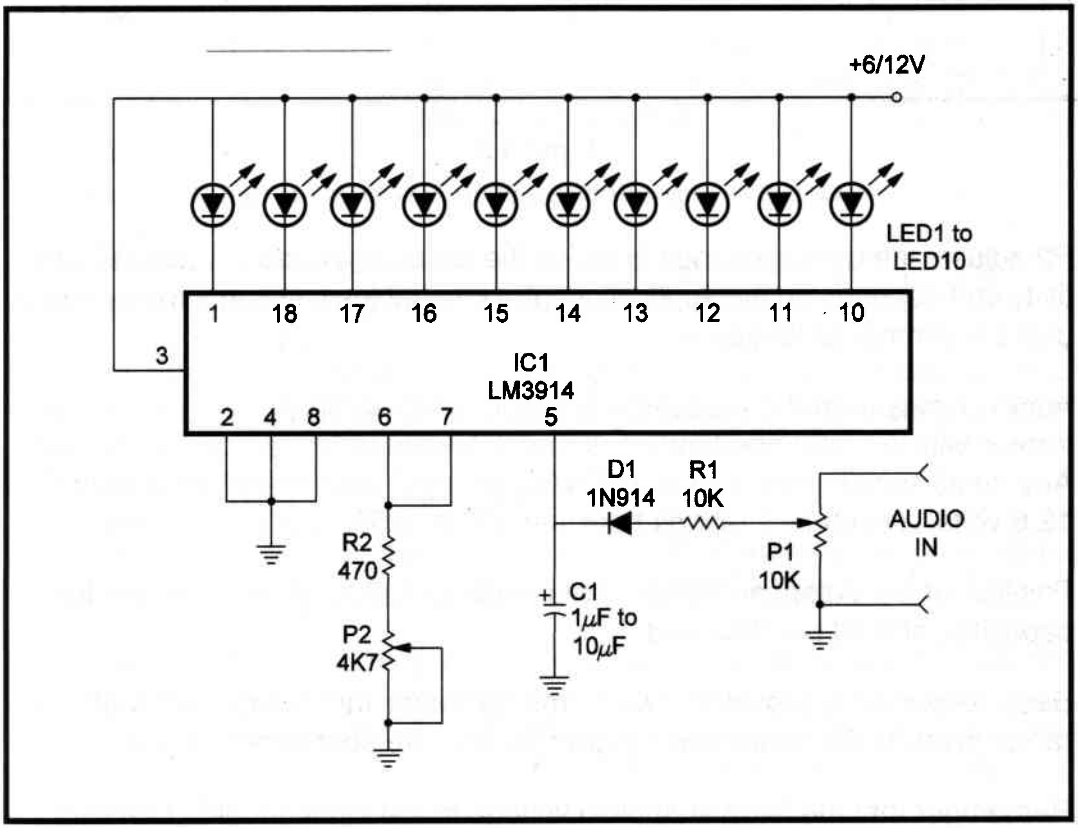


Figure 2

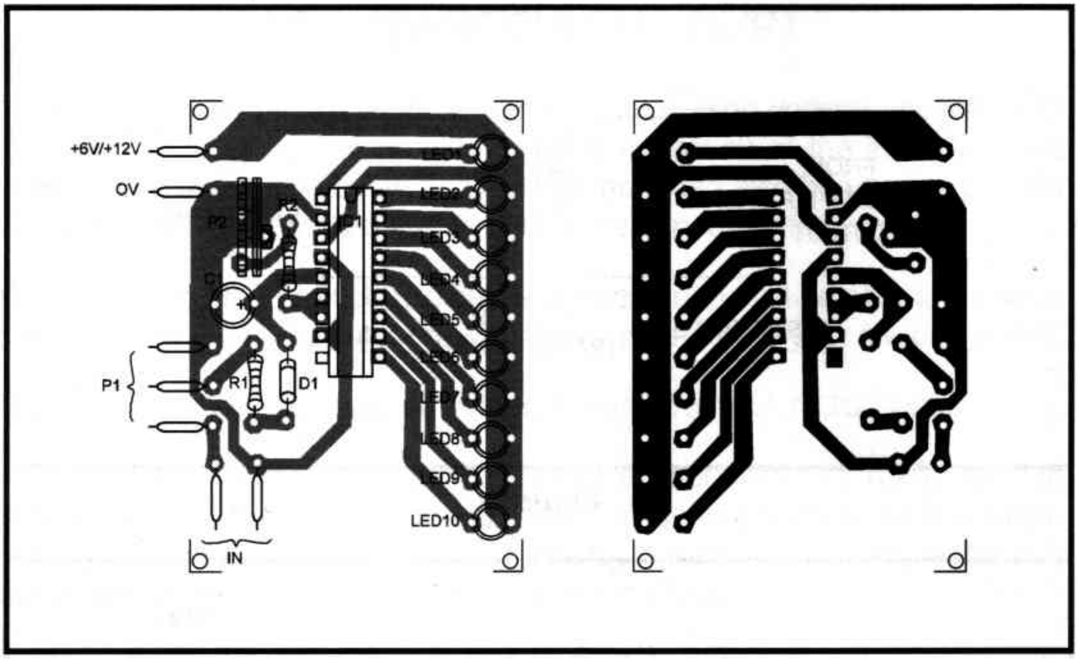


Figure 3

P2 adjusts the dynamic range in which the circuit operates. P1 adjusts sensitivity and depends on the application. You can set the value to a fixed point by using a trimmer potentiometer.

Audio comes from the loudspeaker output of the amplifier. Any small transformer with a high-impedance coil and a low-impedance coil can be used. Any small transformer with a 117 VAC primary, secondary rated from 5 to 12.6 volts, and current ratings between 100 and 500 mA can be used.

Position of the polarized components, such as LEDs, diode, and electrolytic capacitor, should be observed.

Bass response is provided by C1. You can alter this component within the range given in the schematic diagram to achieve best performance.

Remember that the highest applied voltage to the input shouldn't exceed the power supply voltage.

Parts List — LED Bargraph

IC1	- LM3914 Integrated circuit (National)
LEDs	- Common red, yellow or green
D1	- 1N914 or 1N4148 general purpose silicon diode
R1	- 10,000 ohm, 1/4W, 5% resistor
R2	- 470 ohm, 1/4W, 5% resistor
P1	- 10,000 ohm potentiometer
P2	- 4,700 ohm trimmer potentiometer
C1	- 1 to 10 uF, 12 WVDC electrolytic capacitor - see text

Ideas to Explore

To learn more about the circuit or to get better performance:

- Determine the voltage level that turns on each LED using a DC power supply plugged to the input of the device.

- By wiring probes at the positive power supply line and the input you can use this circuit as a digital resistance or conductance meter.

Science projects:

- This circuit can replace the common multimeter to indicate voltage variations in experiments. The visual effect is better.

- It can also be used in the output of a lie detector or bio-feedback.

- Conect an LDR between the input and (+) for a digital photometer. For a digital thermometer wire an NTC between (+) and the input.

- This circuit can also replace the LED and resistor in the Continuity Tester and the same experiments, with advantages, can be performed.

LIQUIDS SHAKER (P/E)

A toy's small DC motor can be used to mount a liquids shaker. The shaker can be used in chemical experiments to mix substances quickly and efficiently.

The circuit is powered from the power supply line (to avoid the expense of batteries), but there is no shock hazard because an isolation transformer is used. Of course, for fieldwork you can also power your mixer from common AA cells.

The transformer is chosen according to the motor voltage. A four-AA-cell DC motor requires a 6+6 volt x 500 mA transformer (a 6-volt center tapped transformer). A two-AA-cell DC motor requires a 3V x 500 mA transformer.

Secure the motor into a small cylindrical plastic box. Use a long shaft to attach a small plastic screw propeller.

Figure 1 shows the schematic diagram of the electronic part of the circuit: a power supply. The diodes are common 50V x 1A silicon rectifiers, and C1 is not critical. C1 should be in the range between 100 and 1,000 uF.

Figure 2 shows a mechanical view, using a small terminal strip as chassis. The fuse is important to avoid severe troubles if shorts occur.

R1 is a current-limiting resistor and can be altered according to the motor. Values between 4.7 and 100 ohms can be experimented with for better performance.

Position of the polarized parts, such as the diodes and electrolytic capacitor, should be observed. Remember that the motor rotates clockwise or not according to the voltage polarization.

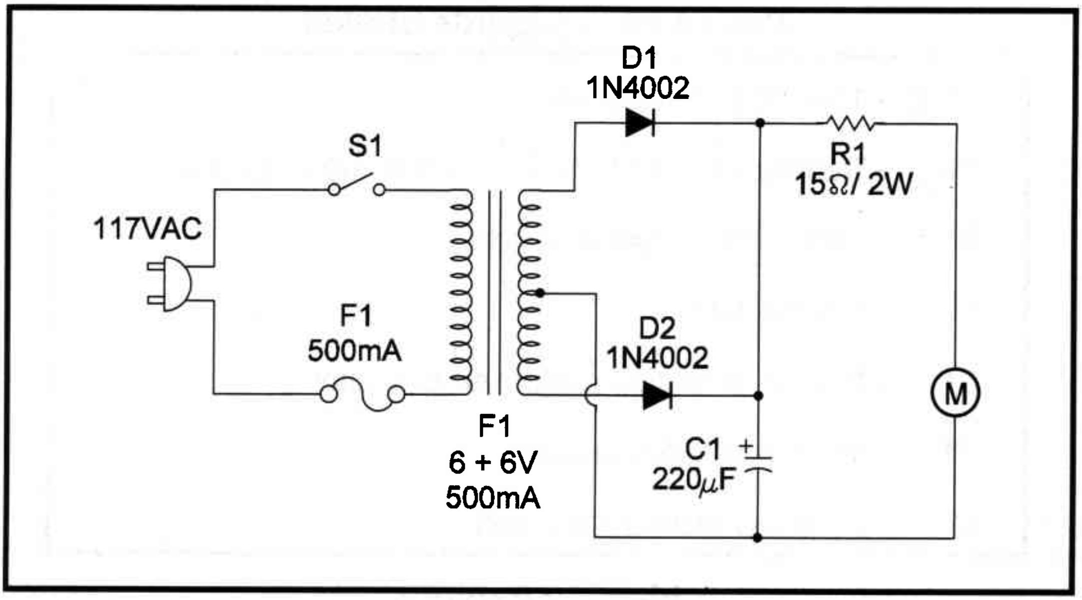


Figure 1

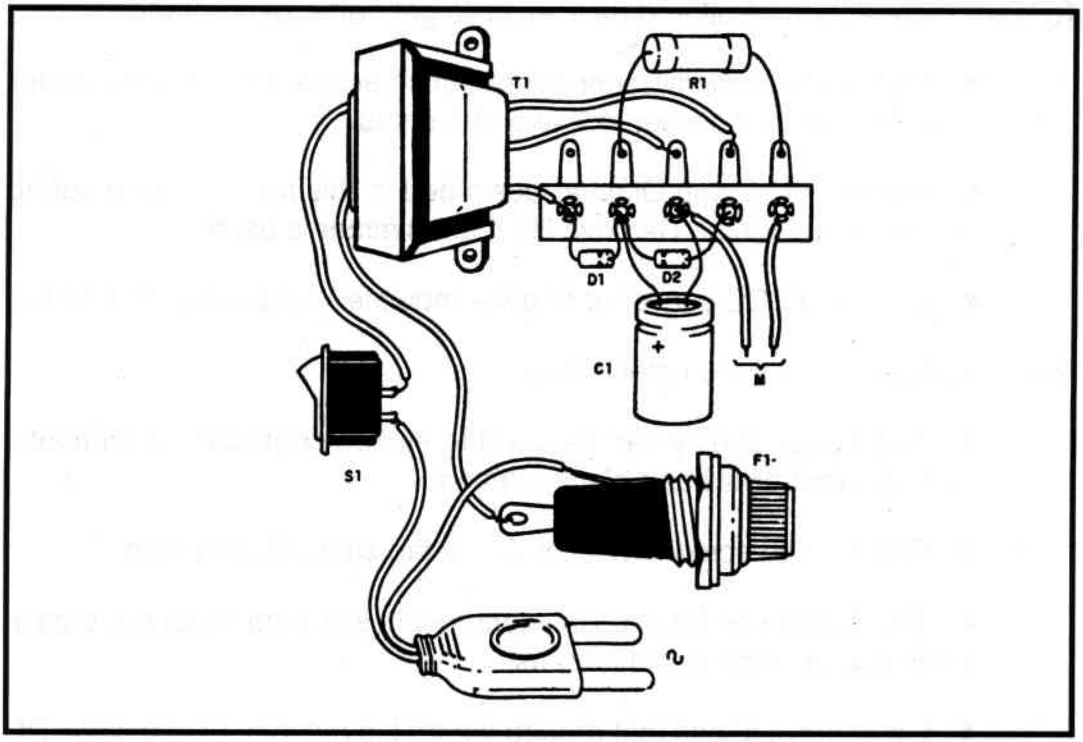


Figure 2

Parts List — Liquids Shaker

D1, 2	- 1N4002 silicon diodes
T1	- Transformer: 117 VAC: 6+6V x 500 mA - see text
S1	- SPST slide or toggle switch
F1	- 500 mA fuse
C1	- 220 uF, 16 WVDC electrolytic capacitor
R1	- 15 ohm, 2W, 5% resistor
M	- small DC motor (3 to 6 volt)

Ideas to Explore

To learn more about circuit and devices or to get better performance:

- Alter R1 to achieve better performance according to the DC motor used. Try values between 4.7 and 100 ohms.
- Use the DC Lamp Dimmer described in this book to get a speed control for the motor. Remove R1 if the dimmer is used.
- Use the 6V DC converter to get a regulated output from the circuit.

Science projects and uncommon uses:

- This power supply can be used in electro-chemical experiments, such as electrolysis and electroplating.
- Replace the screw propeller with a fan blade. Experiment.
- The device can be used in experiments involving water currents in small places, such as aquariums.
- Other applications that require controlled movement of a small DC motor can use this circuit.

SIGNAL TRACER (P)

Signal tracing by means of a signal tracer offers a valuable method for servicing a variety of electronic equipment. This method is often employed when a circuit is not completely dead, but rather malfunctioning. AM and FM receivers, CD players, multimedia amplifiers, TV sets, etc., can be serviced using this simple signal tracer.

The circuit we show here consists of a two-stage direct-coupled transistor amplifier. The circuit has two inputs. When the probe is used in the RF mode the detector diode is inserted into the circuit. When the probe is used in the audio mode the signal is applied directly to the base of the first transistor (Q1).

As the circuit has a low-power output, a gain control is not used.

The circuit is powered from two AA cells, and current drain is only few milliamperes. Since the circuit draws such low current, long battery life can be expected.

Figure 1 shows the schematic diagram of the signal tracer. R1 determines the gain of the amplifier stage and can be altered to get better performance depending on the transistors used.

Figure 2 shows the signal tracer mounted on a terminal strip, which is used as a chassis. Take care with the transistors; one is an NPN and the other is a PNP. If you switch one with the other the circuit will not work.

This project can be housed in a small plastic box. The size of the plastic box is determined by the speaker size. Position of the polarized pieces should be observed.

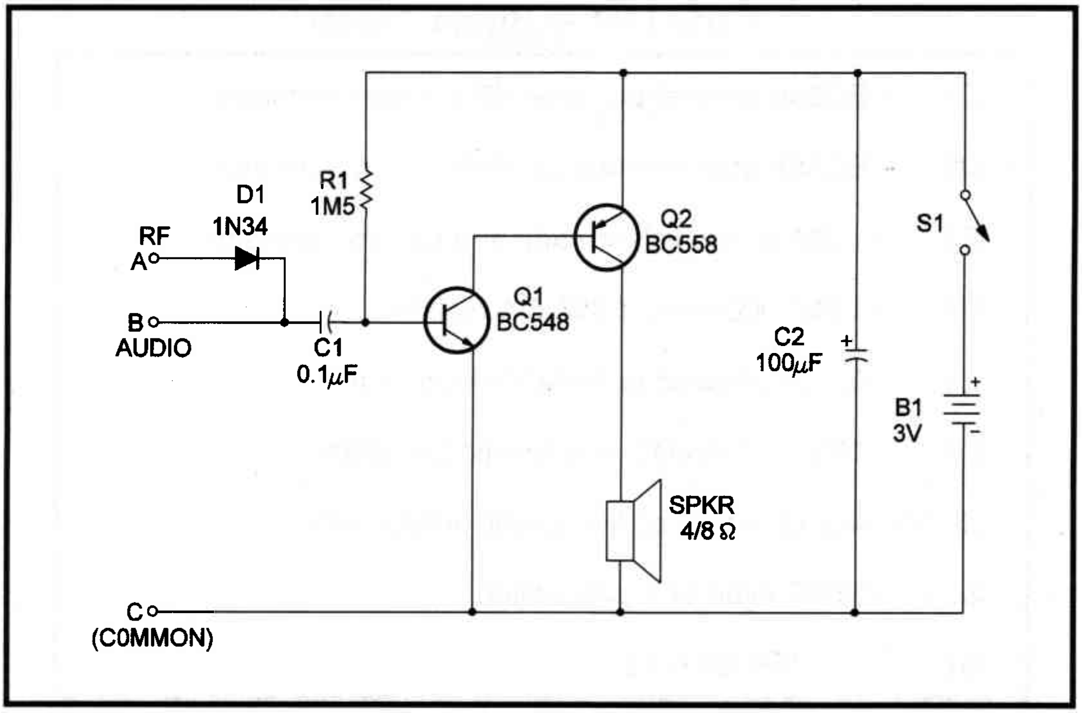


Figure 1

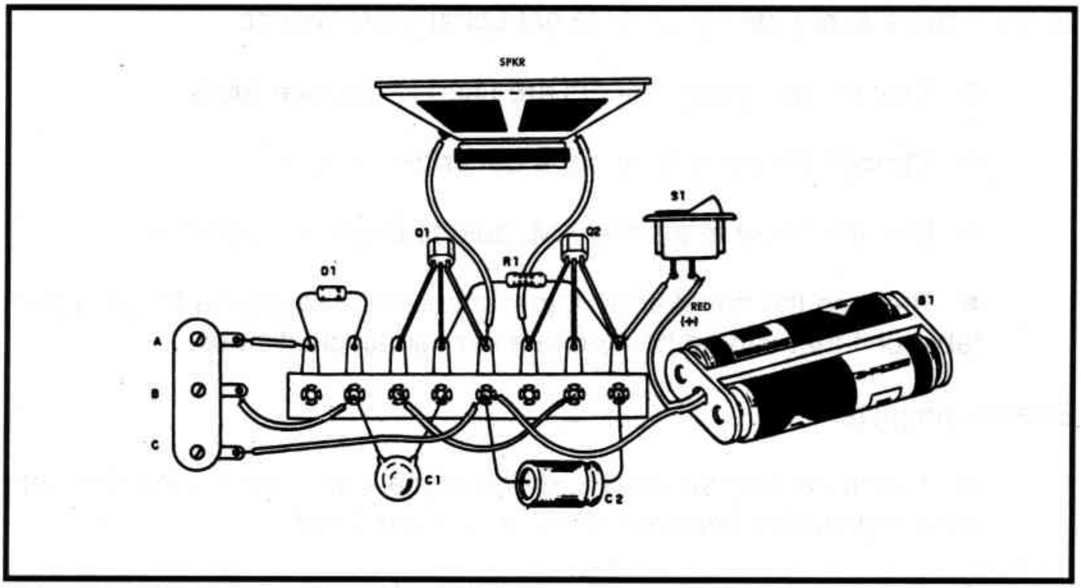


Figure 2

Parts List — Signal Tracer

Q1	- BC548 general-purpose NPN silicon transistor
Q2	- BC558 general-purpose PNP silicon transistor
D1	- 1N34 or equivalent - any germanium transistor
R1	- 1,500,000 ohm, 1/4W, 5% resistor
C1	- 0.1 uF ceramic or metal film capacitor
C2	- 100 uF, 6 WVDC electrolytic capacitor
SPKR	- 4/8 ohms - 2 or 4 in. small loudspeaker
S1	- SPST slide or toggle switch
B1	- 3V - two AA cells

Ideas to Explore

To learn more about the circuit or to get better performance:

- Explain how signal tracers are used for service work.
- Change R1 value to achieve better performance.
- Use the tracer in a small AM radio to study its operation.
- Replace the speaker by a low-impedance earphone to get a portable unit that can be housed in a very small plastic box.

Science projects:

- The tracer can be used to detect signals produced in experiments involving current fields, as described in this book.
- The tracer can be used as an experimental audio amplifier with transducers such as piezoelectric pickups or microphones.

ONE-EVENT REGISTER (P/E)

This is a one-bit memory that can be used to store a simple bit of information, such as a remote power-failure or closed-trap detector, or a touch sensor.

The circuit operates as follows: When the resistance between the alligator clips falls, the SCR is triggered, powering ON the LED.

The SCR and LED stay in the ON state even after the applied pulse to the input is gone. So the device "memorizes" the event.

The sensor can be a magnetic switch (reed switch), a microswitch, or a touch switch. A simple touch switch is a metal plate wired to G2. To get best sensitivity, G1 needs a good ground. You can also use as sensor two metal plates that are touched at the same time to trigger the circuit ON.

The circuit is powered by four AA cells and current drain is very low when the LED is off. When the LED is on, current drain is less than 10 mA.

To reset the device you only have to toggle S1. Another way to reset the circuit is to wire a momentary switch between the anode and cathode of the SCR. Sensors can be wired to the device with long unshielded wires.

The schematic of the One-Event is shown in ***Figure 1.*** Though R2 and R3 are shown as fixed, you can use a 1,000,000 ohm potentiometer if you prefer. A sensitivity adjustment will get better performance from the register.

Figure 2 shows the One-event Register, on terminal strip mounting. As it is an experimental circuit you can also use a solderless board to install the components.

The circuit can easily be housed into a small plastic box. Observe the positions of all the polarized components, such as the LED, SCR and power supply.

Resistor R3 is only necessary if TIC106 is used. Other SCRs, such as the MCR106 and C106, don't require R3.

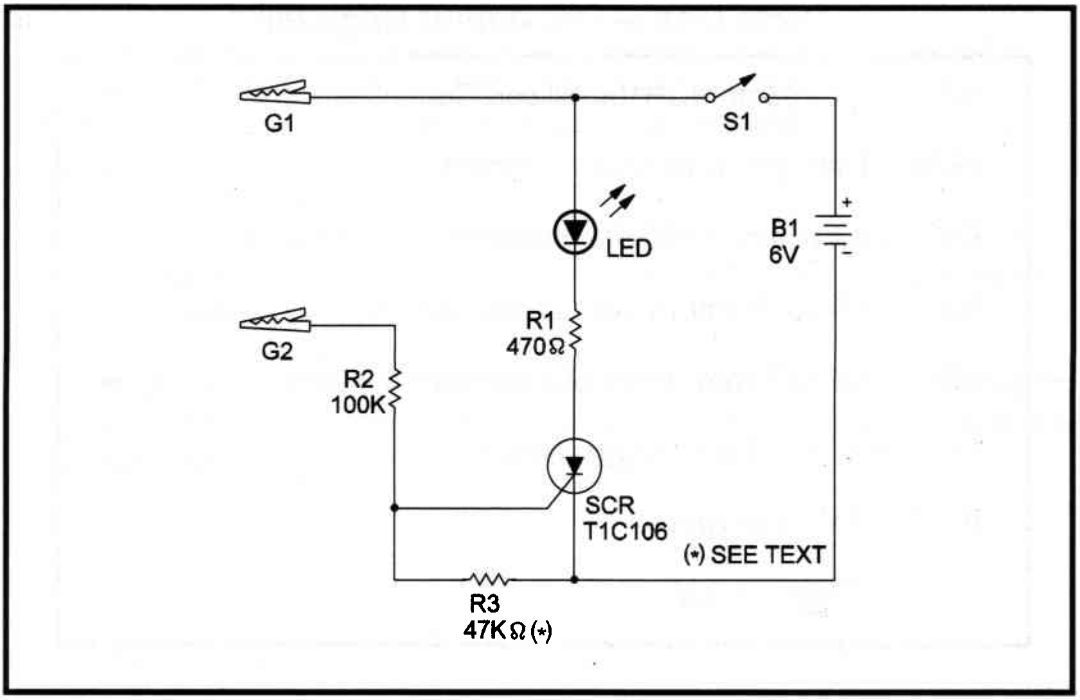


Figure 1

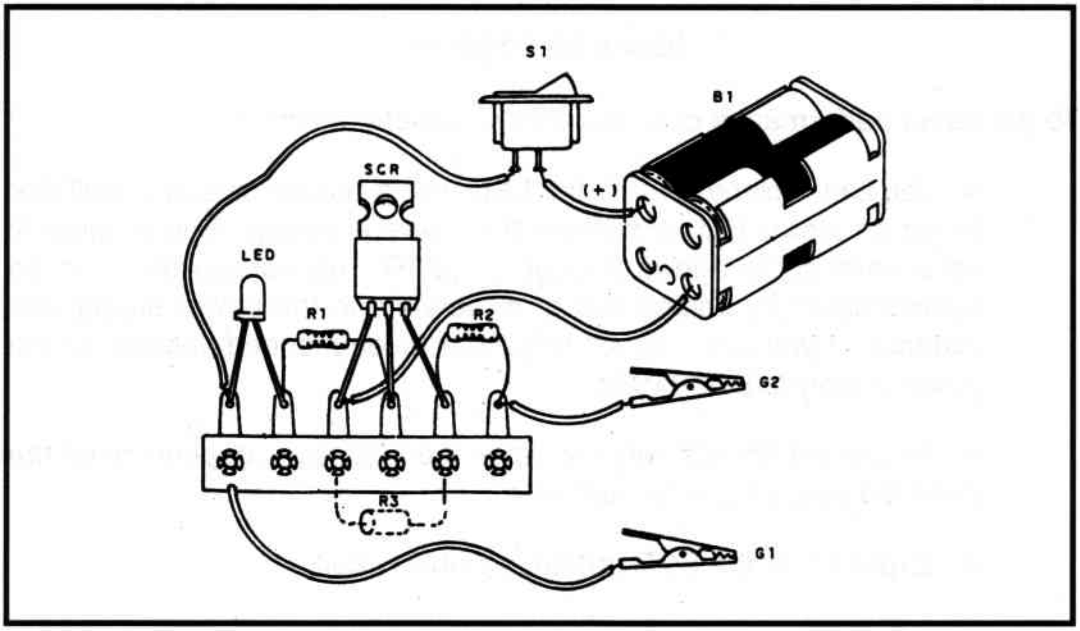


Figure 2

Parts List — One-Event Register

SCR	- TIC106 or MCR106 Silicon Controlled Rectifier
LEDs	- Red, yellow or green common
R1	- 470 ohm, 1/4W, 5% resistor
R2	- 100,000 ohm, 1/4W, 5% resistor
R3	- 47,000 ohm, 1/4W, 5% resistor - see text
S1	- SPST slide or toggle switch
B1	- 6 V - four AA cells
G1, 2	- Alligator clips

Ideas to Explore

To get better performance or to learn more about the circuit:

- You can replace R1 and the LED with a buzzer or audio oscillator to get an alarm. But, remember that there a voltage drop of about 2 volts when current flows through the SCR. This voltage drop can be compensated by adding two or three volts to the power supply. For instance, if you use a 6-volt relay, the recommended voltage for the power supply is 8 or 9 volts.

- As current drain is very low when the LED is off, depending on the intended use, S1 can be removed.

- Explain how the SCR operates in this circuit.

Science and uncommon applications:

- You can connect an LDR between G1 and G2 for a light-operated one-event memory or alarm. A single short pulse of light can trigger the circuit.

- Use this circuit to know when someone touches an object when you leave it unattended. You can also know if someone entered your room when you were out.

- By using two bare wire as sensors, you have a water-level alarm. The LED will glow when the water touches the two bare wires at the same time.

NOISE GENERATOR (E)

The purpose of this simple experiment is to produce noise in the AM radio band. The circuit can be used to show how brush motors and general appliances with motors can generate noise in the radio band, interfering in radio, TV, and radio communication services.

The circuit is very simple and the produced noise is too weak to cause any problem to radio receivers. (FCC rules about noise and radio interference are severe.) The noise produced by this experiment will interfere only in receivers just a few feet away.

The schematic diagram of the device is shown in ***Figure 1***. The heart of the circuit is a small DC motor that works as a automatic key, producing rapid variation in the current flow.

A mechanical view of the circuit, using a terminal strip as chassis, is shown in ***Figure 2***. All the components, including the power supply, can be fixed on a plastic board.

Any small DC motor obtained from a nonworking toy can be used in this project. The power supply depends upon the motor used.

CV and L1 can be obtained from any nonworking AM radio.

You can get more power for the RF noise by wiring a piece of wire to the antenna (A) terminal, but limit this wire to no longer than 6 feet. L1 is formed by 100 turns of No. 28 wire wound on a ferrite rod (diameter and length are not critical).

By adjusting CV, you can try to tune the signal to be stronger on a dead point of the AM radio band.

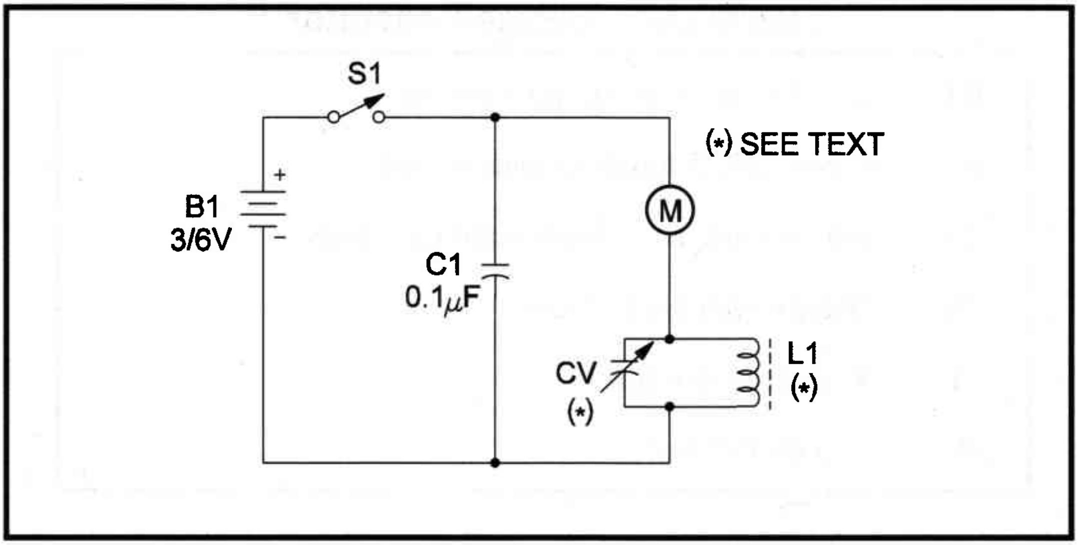


Figure 1

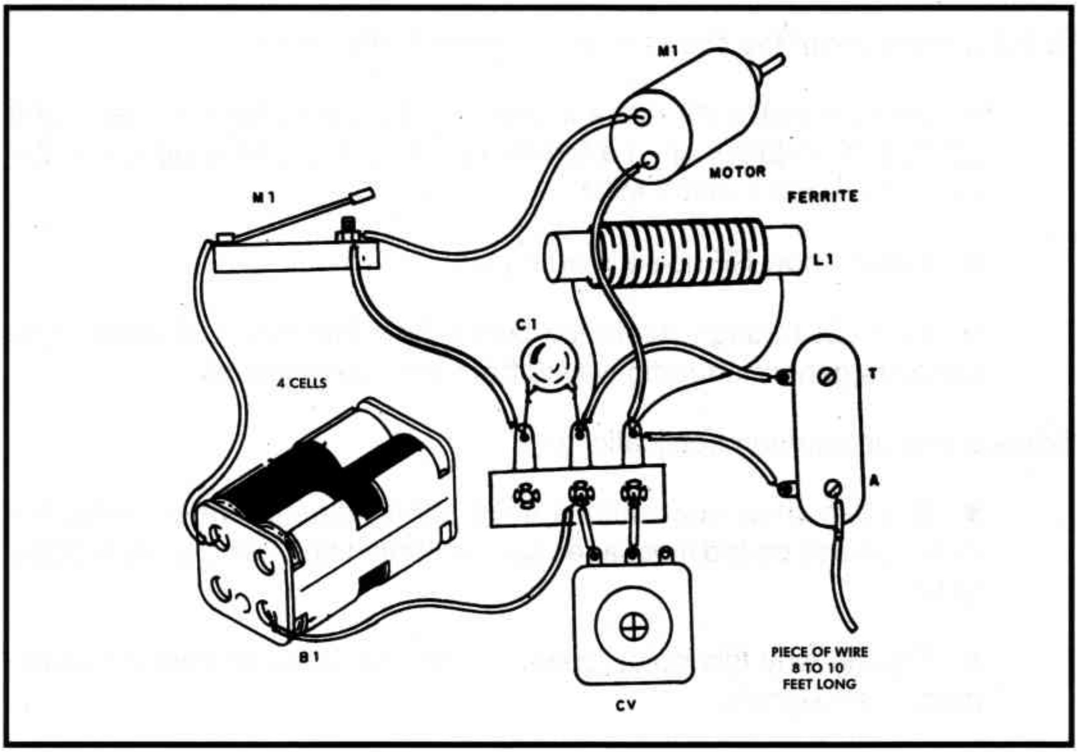


Figure 2

Parts List — Noise Generator

B1	- 3 to 6V - cells or battery - see text
T	- Key or SPST toggle or slide switch
C1	- 0.1 uF ceramic or metal plate capacitor
CV	- 365 pF variable capacitor
L1	- loopstick - see text
M	- 3 to 6V DC motor

Ideas to Explore

To learn more about the circuit or to get more performance:

- Try to produce RF noise in the high-frequency band by replacing L1. With a 30-turn coil on a ferrite rod you can produce signals in the range between 2 and 7 MHz.
- Explain how RF noise is produced.
- Find out through reference books how Marconi and other radio pioneers generated radio waves from their transmitters.

Science and uncommon applications:

- You can show how antique radio transmitters operated using this circuit. Morse coded messages can be transmitted using a key in place of S1.
- Explain why this noise generator can be used to transmit voice-modulated signals.

EXPERIMENTAL OHMMETER (E)

As commercial ohmmeters are cheap and easy to find, anyone who wants a good instrument for his own use will not build one. But you can build a simple ohmmeter to demonstrate how it works or study how the big ones are made.

The simple ohmmeter described here can easily be made from a milliammeter or microammeter, and can be used in experiments, demonstrations and many other applications.

Our ohmmeter is also a voltmeter. And since this ohmmeter can measure a large range of voltages and resistances we can say that it is, in practice, a multimeter. Voltages can be measured in the range between 0 and 12 volts (the range used to power almost all circuits in this book), and resistances between 0 and infinite.

If using a 200 uA microammeter, the sensitivity will be 5,000 ohms per volt. This value is typical of several commercial types of common multimeters.

But you can use any other ammeter with a full-scale value ranging from 100 uA to 1 mA. Simply change R1 to achieve best performance.

The schematic of the experimental ohmmeter is shown in ***Figure 1***. Note that we use only four components that can easily be housed in a small plastic box.

Layout is shown in ***Figure 2***. Components mounting is not critical, and you can replace the banana jacks by probes or any other method to make external connections.

Probes are connected to the external banana jacks depending on the measurement you intend to make. To measure voltage, the red probe is connected to J1 and the black probe is connected to J2. To measure resistance, connect the red probe to J1 and the black probe to J3. Put the probes together and adjust P1 to get an indication of zero at the instrument scale.

By using a series of known resistors, it is possible to calibrate the meter scale to read ohms directly. Start from 0 (with J1 and J2 shorted), and note the meter readings when 1k, 2k, etc, resistors are connected across J1 and J3.

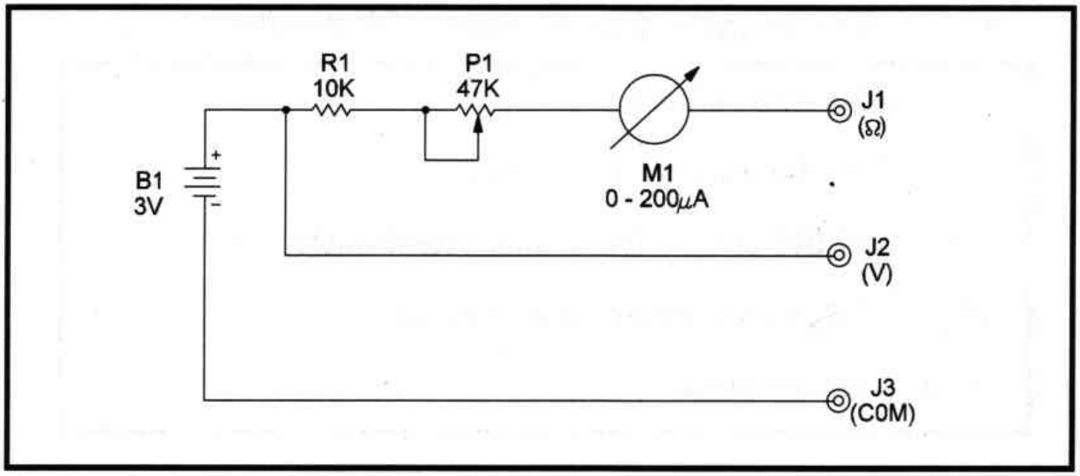


Figure 1

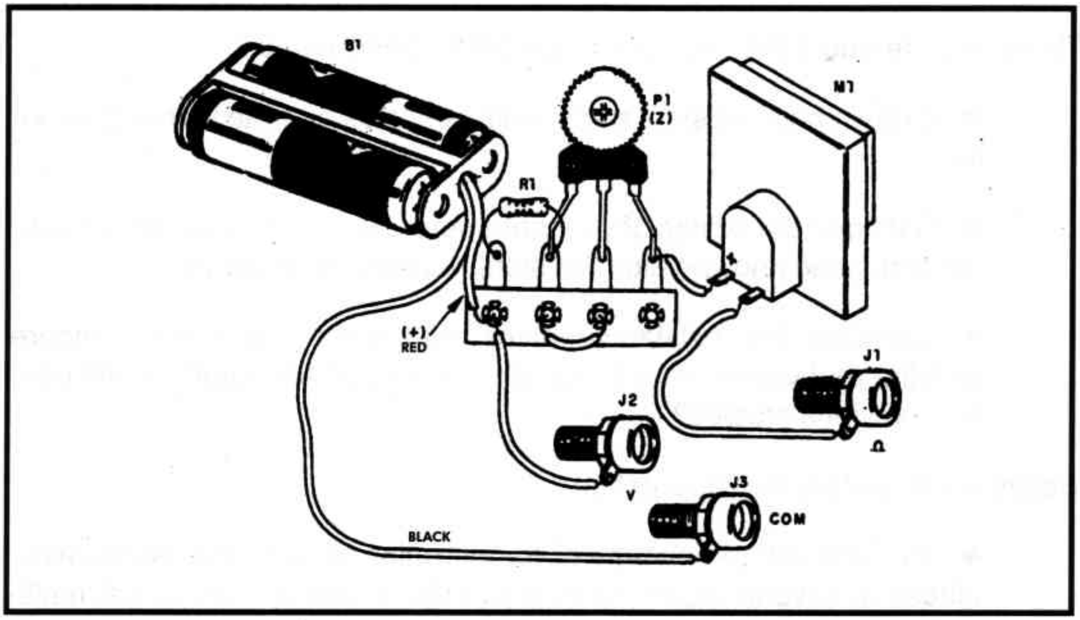


Figure 2

After calibrating the device to read ohms, use a variable power supply to calibrate the voltage scale.

Position of the polarized components, such as the ammeter and power supply (cells), must be observed.

Parts List — Experimental Ohmmeter

B1	- 3V - two AA cells
R1	- 10,000 ohm, 1/4W, 5% resistor
P1	- 47,000 ohm, 1/4W trimmer potentiometer
M1	- 0-200 uA microammeter - see text
J1-3	- banana jacks

Ideas to Explore

To learn more about the circuit or to get better performance:

- Explain how resistance and voltage scales operate in this ohmmeter.

- Calibrate the scales of your ohmmeter using a variable power supply and some known-value resistors, as described above.

- Calculate the resistance values read in the meter and compare with the real values of used resistors. Do your calculated results confirm previous studies?

Science and uncommon applications:

- You can use the ohmmeter to determine sensor and media resistances in several experiments if you don't have a commercial multimeter.

- By wiring a 47,000 ohm potentiometer between J1 and J3 you can use this device as a position indicator. Cursor positions can be directly converted into current as indicated by the meter. A scale of angles can be arranged to read degrees directly.

TEST YOUR NERVES (P/E)

This circuit puts your manual skills to a lively test. As shown in the schematic diagram, the circuit has a small loop that you must navigate around a wire. The object of the game is to guide the loop over the weaving course without touching the wire.

A slight misdjudgement or quiver of the hand and the ring will contact the weaving wire, enabling the circuit that will produce a noticeable (but inoffensive) shock!

The skill required to play the game depends largely on the size of the loop and the degree of twist and turn in the wire.

Scoring is a matter of counting the number of times the player is affected by a shock! The person with the lowest total (or no touch) wins.

The circuit is powered from a D cell, as the current drain is high when the loop touches the wire. When not in use, don't leave the ring and wire together. This will cause the battery to run down in a short time.

A circuit diagram of the device is shown in ***Figure 1***. The heart of the project is the transformer that converts 1.5 VDC into high-voltage pulses up to 400 volts.

A mechanical view of the mounting is shown in ***Figure 2***.

All the components can be housed in a small plastic box. Wires to the loop and weaving wire should be 2 or 3 feet long to prevent pull-outs when the player is struck.

Observe the isolation between the points where the player touches and the weaving wire. The two wires that connect X2 should be twisted.

T1 is any small transformer with a 117 VAC primary, and secondary coil ranging between 3 and 9V. Current drain can range from 100 to 500 mA when the wire touches the loop.

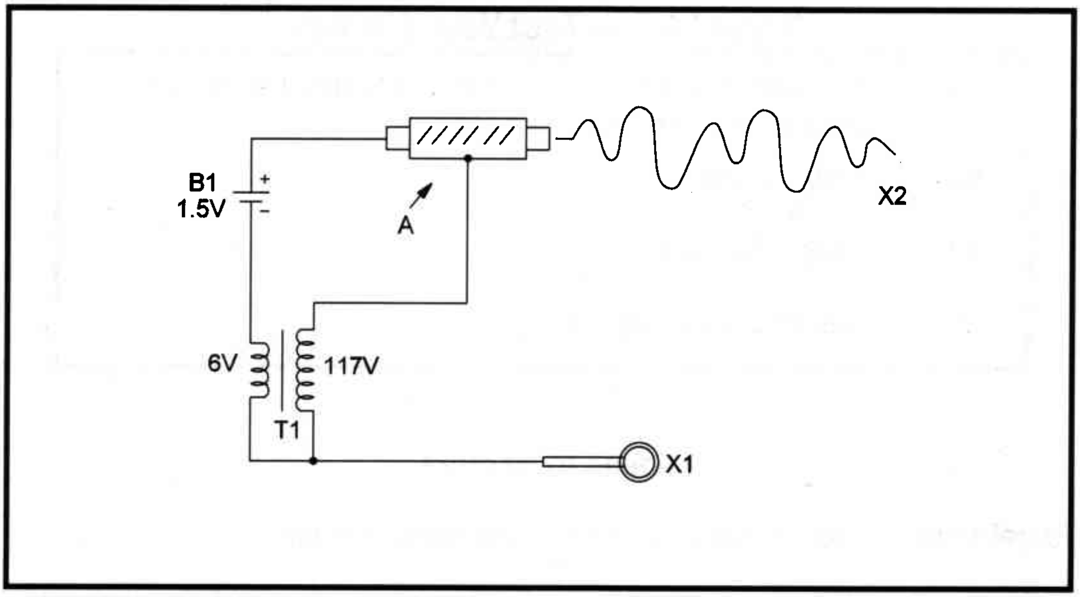


Figure 1

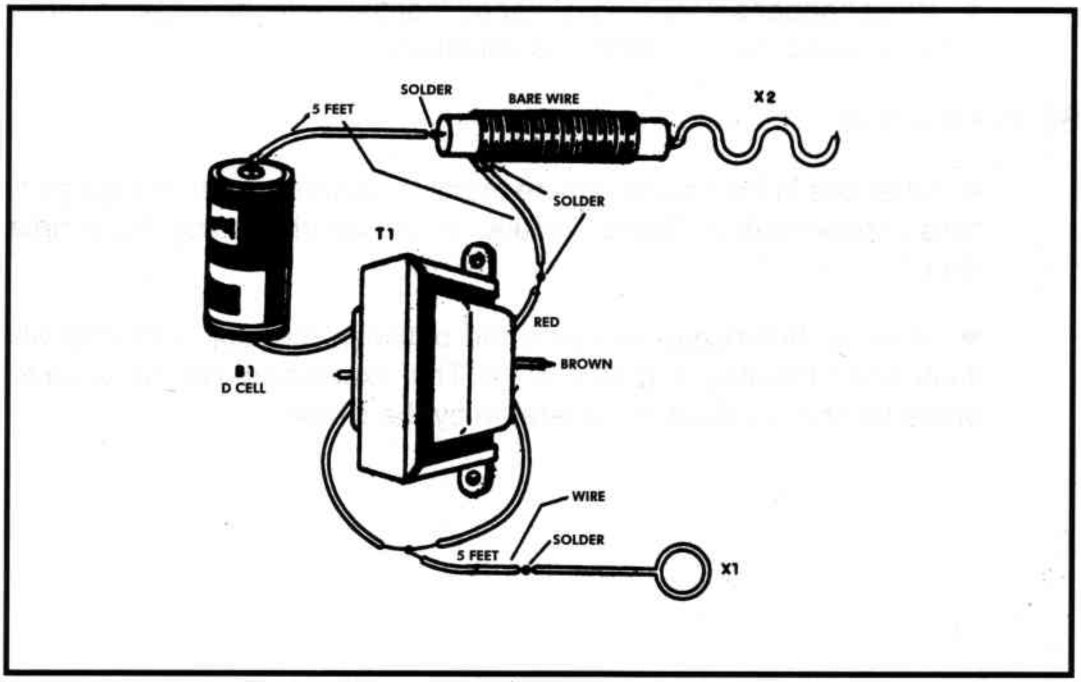


Figure 2

Parts List — Test Your Nerves

T1	- Any transformer with a 117 VAC coil and low-voltage secondary - see text
B1	- 1.5V - D cell
X1	- Loop - see text
X2	- Weaving wire - see text

Ideas to Explore

To get better performance or to learn more about the circuit:

- Explain why the transformer does not operate with DC but that this project is able to generate high voltage using that device.

- What happens if the loop is placed together with the weaving wire? Why it is necessary to avoid this condition?

Science projects:

- Changes in the project can be made to generate high voltage from cells in experiments. Nerve stimulation can be tried using this simple circuit.

- Neon or fluorescent lamps wired between the loop and wire will flash when the loop and wire touch. This experiment can be used to prove that high voltage is generated by the circuit.

WIRELESS BEEPER (E)

This FM wireless transmitter produces a beep that can be tuned on any dead point of the FM broadcast band. The circuit can be used as a localizer when attached to objects or persons. You also can use it as a wireless alarm.

The signal can be tuned on common FM radios in a range up to 150 feet. Alterations for a far-reaching version are given below.

The circuit produces an intermittent beep of about 1 Hz. An audio tone is generated by IC1b (pins 5, 6 and 4) and its frequency is determined by R2 and C2. You can easily alter this frequency by adjusting R2. Resistor values between 22,000 and 100,000 ohms can be experimented with or, if you prefer, 100,000 ohms in series with 10,000 ohms can replace R1.

Repetition rate is per R1 and C1. Values are variable. For C1, values between 0.15 and 1 uF can be tried. It is important to test for the ideal value of this component, depending on the intended application.

The schematic diagram of the wireless beeper is shown in ***Figure 1.*** Three gates of a 4093 IC are used to generate the low-frequency signals, and one RF transistor is used to generated the high-frequency signal.

Components placement on a homemade printed-circuit board is shown in ***Figure 2***. Placement is critical for the high-frequency stage. Capacitors in this stage should be ceramic.

L1 consists of four turns of No. 18 or 20 wire on a 1/2 in. form without a ferrite core.

The antenna is formed by a piece of bare wire between 5 and 10 inches long. It can be connected to any tap on the coil. Experiment to get better performance.

The power supply current drain is about 10 mA. You can use four AA-cells or a 9V battery to power the transmitter.

For a wireless alarm, S1 can be replaced by the contacts of a relay. The relay is used to interface the alarm with the transmitter in this application.

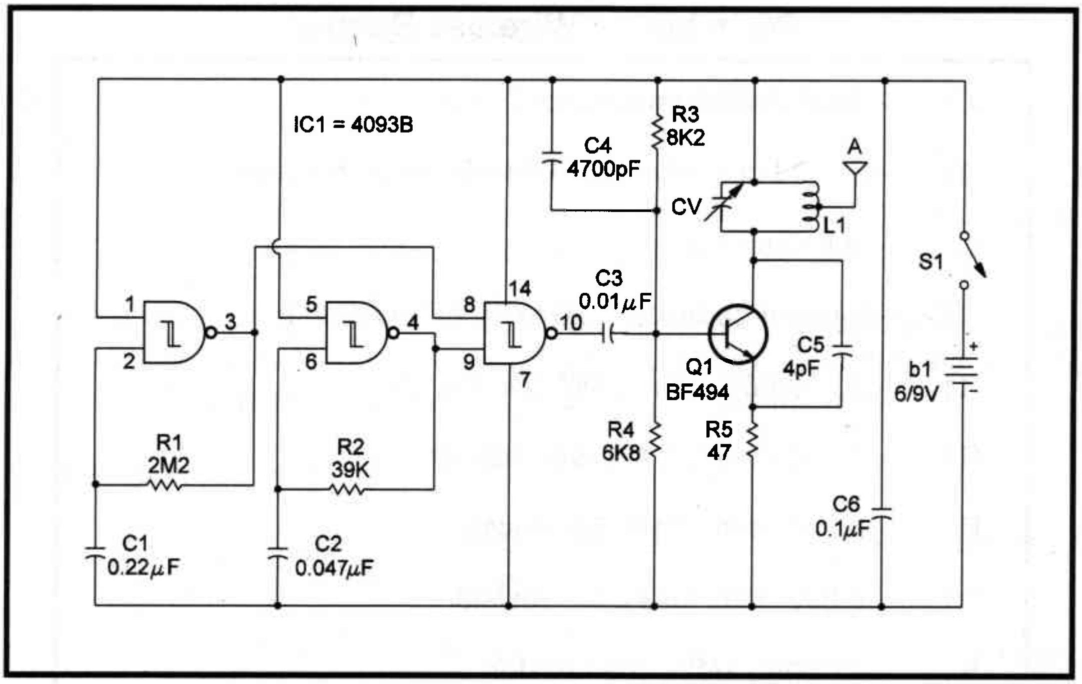


Figure 1

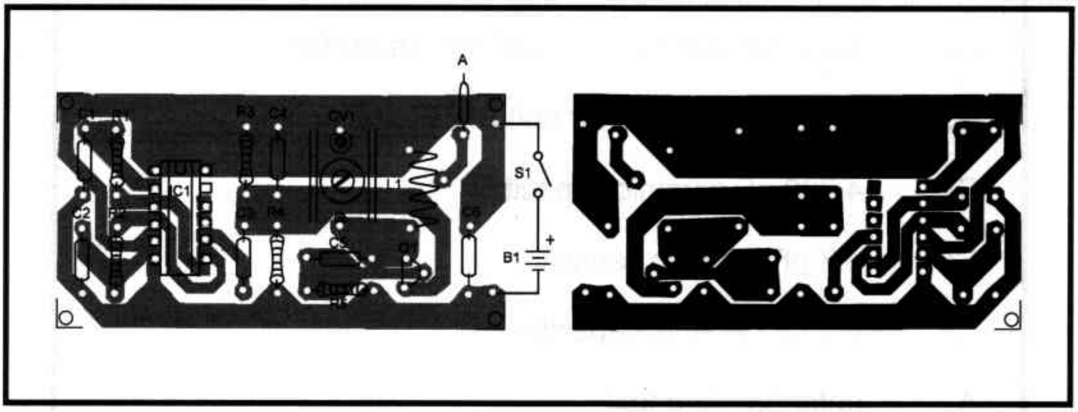


Figure 2

Another way to interface an alarm with the transmitter is to connect relay contacts in series with C3 or between points A and B in the schematic. See more detals in Ideas to Explore.

Parts List — Wireless Beeper

IC1	- 4093 CMOS Integrated Circuit
Q1	- BF494 or equivalent NPN RF silicon transistor
L1	- coil - see text
CV	- trimmer capacitor - 20 to 40 pF maximum
R1	- 2,200,000 ohm, 1/4W, 5% resistor
R2	- 39,000 ohm, 1/4W, 5% resistor
R3	- 8,200 ohm, 1/4W, 5% resistor
R4	- 6,800 ohm, 1/4W, 5% resistor
R5	- 47 ohm, 1/4W, 5% resistor
C1	- 0.22 uF ceramic or metal film capacitor
C2	- 0.047 uF ceramic or metal film capacitor
C3	- 0.01 uF ceramic or metal film capacitor
C4	- 4,700 pF ceramic capacitor
C5	- 4.7 pF ceramic capacitor
C6	- 0.1 uF ceramic capacitor
A	- antenna - see text
S1	- SPST slide or toggle switch
B1	- 6 to 9V - four AA cells or 9V battery

Ideas to Explore

To get better performance or to learn more about the circuit:

- You can control the beeper oscillator by IC1, pins 1 and 5. Put these pins together. When in a high logic level the circuit produces intervalled beeps. When in a low logic level the circuit stops.

- Replace Q1 by a 2N2218. Power the circuit with a 12V power supply. Signals can now be tuned from distances up to 1,500 feet. A 5- to 6-foot antenna will increase the range of the transmitter.

Science projects or uncommon applications:

- House this circuit in a box and tell someone to hide it. You'll find it by using a small FM receiver.

- The transmitter can be used to track animals by fixing it on a collar.

- You also can use the transmitter to monitor remote sensors in experiments. The circuits can power ON the transmiter or trigger the oscillator as indicated above.

ELECTROSCOPE (E/P)

An electroscope is an instrument that can be used for detecting the presence of an electric static charge. We describe here an electronic version of the traditional electroscope—one that is made with gold foils placed into a glass jar. This circuit can also be used for "sniffing" high voltage without actually making contact with dangerous circuitry.

A metal ring, which constitutes the sensor, is simply poked into the electric field. This operation must be done with caution to avoid contact with the conductors carrying the high voltage.

You can use the device in experiments with high voltage generators (Van de Graaff accelerator) and in many other applications at home or school.

The circuit is portable, powered from four AA cells or a 9V battery.

Presence of a static charge or a strong field created by high-voltage lines is indicated by an LED.

The schematic diagram of the Electroscope is shown in ***Figure 1***. The circuit uses four gates of a 4093 IC that work as buffers and inverters, driving the LED. The high-impedance input of the CMOS integrated circuits results in high sensivity to detect static charges.

All the components are mounted on a homemade printed-circuit board as shown in ***Figure 2***.

Sensor X1 is a small bare wire lop. The completedcircuit can be housed into a small plastic box with the batteries. The LED should be placed in a visible point of the box.

To use:

Bring a charged source close to the sensor. A piece of paper or plastic stroked with a rod of insulating material will do. Adjust P1 to get better sensitivity. The LED will glow according to the electric charge movement.

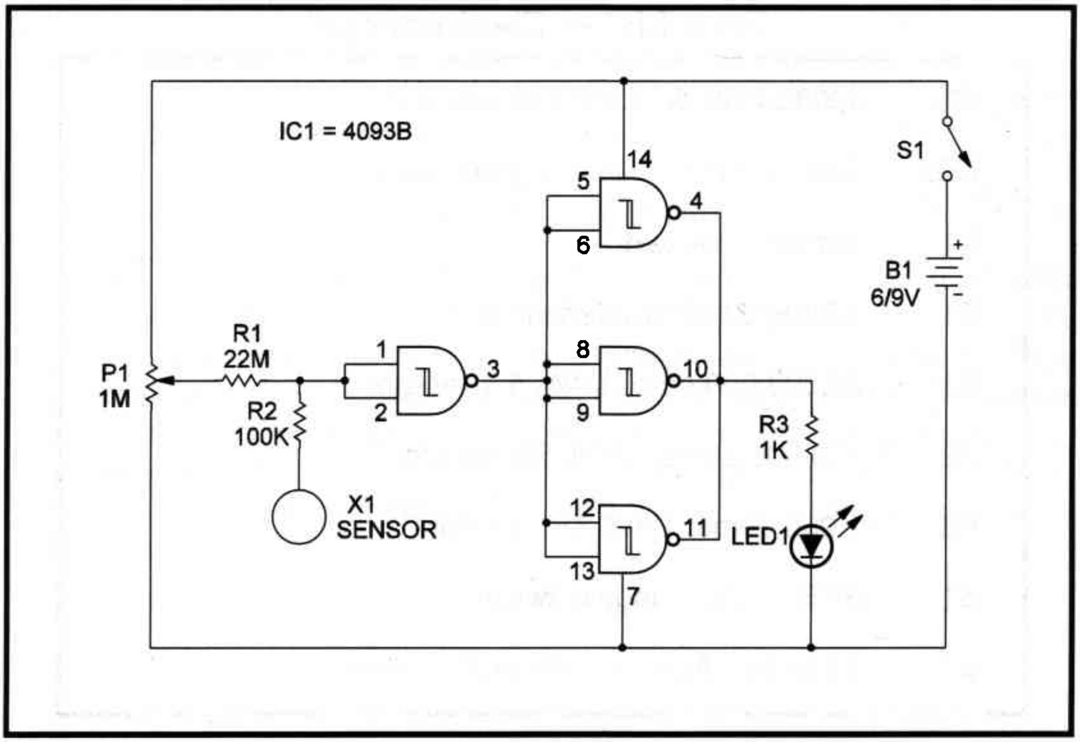


Figure 1

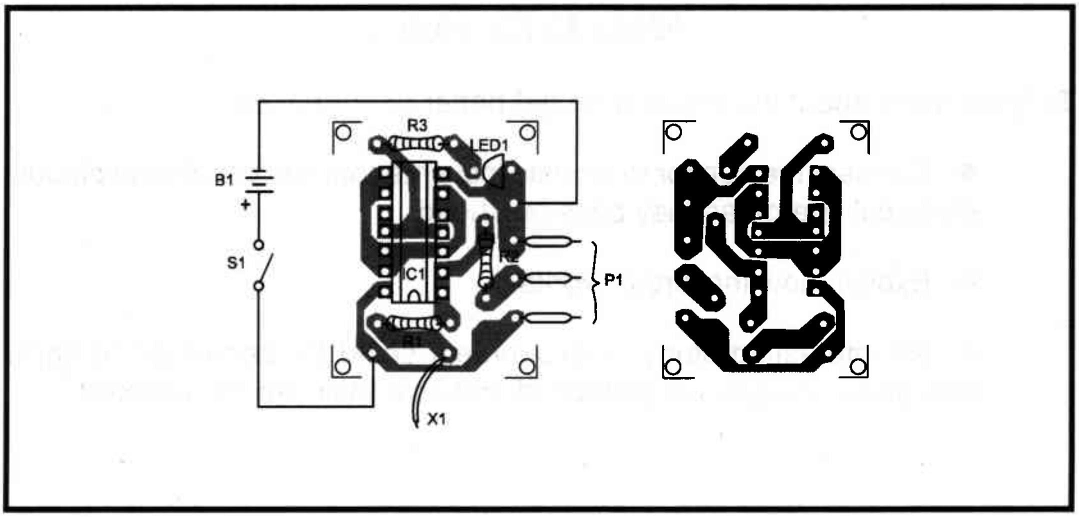


Figure 2

Parts List — Electroscope

IC1	- 4093B CMOS Integrated Circuit
LED	- Common red, yellow or green LED
X1	- Sensor - see text
P1	- 1,000,000 ohm potentiometer
R1	- 22,000,000 ohm, 1/4W, 5% resistor
R2	- 100,000 ohms, 1/4W, 5% resistor
R3	- 1,000 ohms, 1/4W, 5% resistor
S1	- SPST slide or toggle switch
B1	- 6V or 9V - four AA cells or 9V battery

Ideas to Explore

To learn more about the circuit or to get better performance:

- Connect the sensor to an external antenna. You can detect clouds' electrical charge as they pass overhead.
- Explain how the circuit works.
- An interesting study or experiment could be performed to show how static charges are produced and how they can be detected.

Science and uncommon applications:

- In all the experiments that can be conducted with a common electroscope, the electronic version can replace it.

- Determine the polarity of the charge that makes the LED to glow.

- Static charges could have some influence on animals and plants. An experiment to support this affirmation can be conducted. This project, of course, will involve some special equipment such as a high-voltage generator (Van de Graaff or other) and an electroscope. Select seeds from common plants such as tomatoes and beans, and expose several batches of seeds to a static high-voltage field. What are the effects on seed germination? Is plant growth also affected by electric fields?

UNIVERSAL PROBE (P)

This ultra-simple probe can be used to test almost every electronic component. Capacitors, resistors, fuses, switches, coils, transformers, diodes, wires, etc., can be tested with this simple circuit.

Only three components are used and they can easily be housed in a small plastic box, performing as a portable unit.

The circuit consists basically of a continuity tester with a visual indication by an LED. If current can flow between the probes the LED glows; if not, the LED remains off.

Current flowing between probes is very low to avoid overloading the tested components.

A schematic diagram of the Universal Probe is shown in ***Figure 1***. As you can see, only three electronic components are used in this project.

A components layout view is shown in ***Figure 2***. The components can be housed in a small box and no ON-OFF switch is necessary.

When mounting, take care with position of the two polarized components, the LED and power supply.

The power supply consists of two AA cells.

An ON-OFF switch is not necessary, as the circuit is off when the probes are separated.

Current through the component under test is determined by the voltage drop across the LED (about 1.6V for red LEDs and 1.8V for yellow LEDs), and resistance of R1.

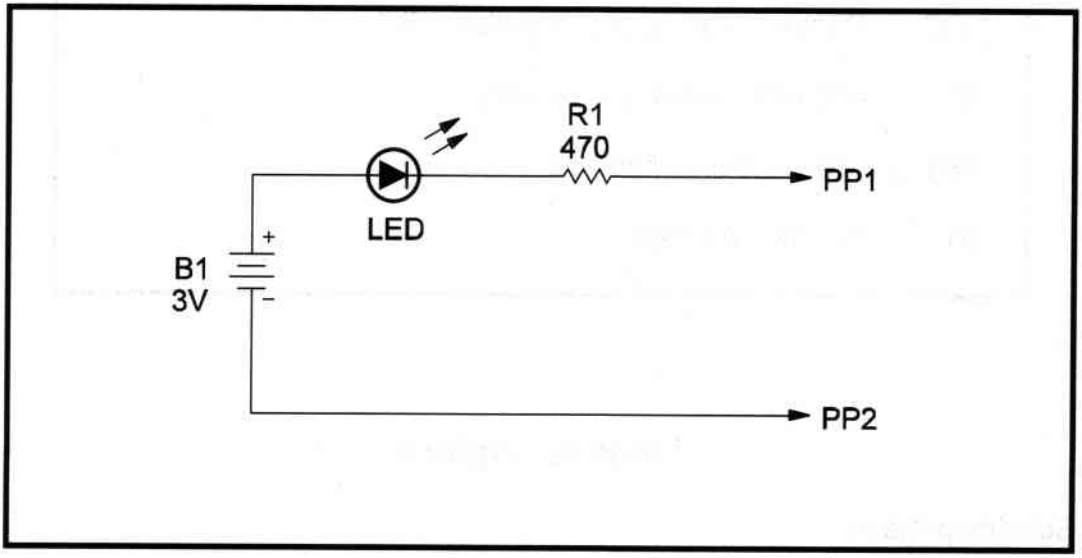


Figure 1

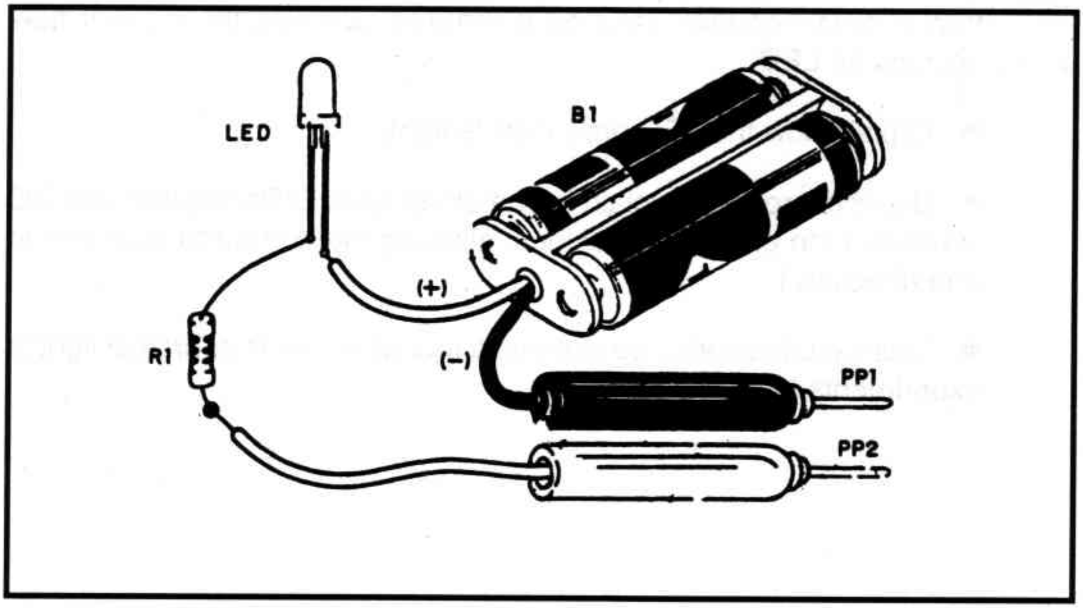


Figure 2

Parts List — Universal Probe

LED	- Common red, green or yellow LED
R1	- 470 ohm, 1/4W, 5% resistor
PP1, 2	- Red and black probes
B1	- 3V - two AA cells

Ideas to Explore

Science projects:

- Use this probe in to find materials that conduct or do not conduct electric current. Several other simple experiments in electricity can be conducted using this probe: for example, show how a switch works, or how a potentiometer used as a rheostat controls the current flow accross an LED.

- Explain how the LED produces its light.

- Use this probe to explain how a diode works. (Remember that DC is used in the probes and diodes, allowing the current to flow only in one direction.)

- This circuit can also be used as a monochromatic source of light in experiments involving optics.

TONE-ACTIVATED RELAY (E)

This circuit can be used to recognize a tone by its frequency. When this tone is present in a circuit the relay is energized, which could supply power to a selected appliance.

Wired to the output of a receiver, the circuit can be used as part of a tone-modulated wireless remote control. The receiver can be a common FM radio or an infrared receiver, depending on the intended application.

The circuit can be used with tones ranging up to 100,000 Hz. The circuit is tuned by P1.

Inputs of other units can be wired in parallel to get a multi-channel remote control system. Take care to avoid using harmonic frequencies.

The schematic diagram of the Tone Activated Relay is shown in ***Figure 1***. The heart of the circuit is the LM567 IC, a National Semiconductor PLL (Phase-Locked Loop) that drives the relay through transistor Q1.

Components placement on a homemade printed-circuit board is shown in ***Figure 2***. Placement is not critical, but when operating in frequencies above 50,000 Hz it is important to avoid long connections.

The relay is any type with a 6V coil and current rated for values between 10 and 100 mA.

Position of the polarized components, such as the diode and electrolytic capacitor, should be observed.

To use:

Wire the output of an audio generator or audio oscillator to points X and Y. The signal should have amplitude in a range between 100 mV and 1 V peak-to-peak for best results. Adjust P1 to trigger the relay. Reduce the signal amplitude and trim P1 for the best performance.

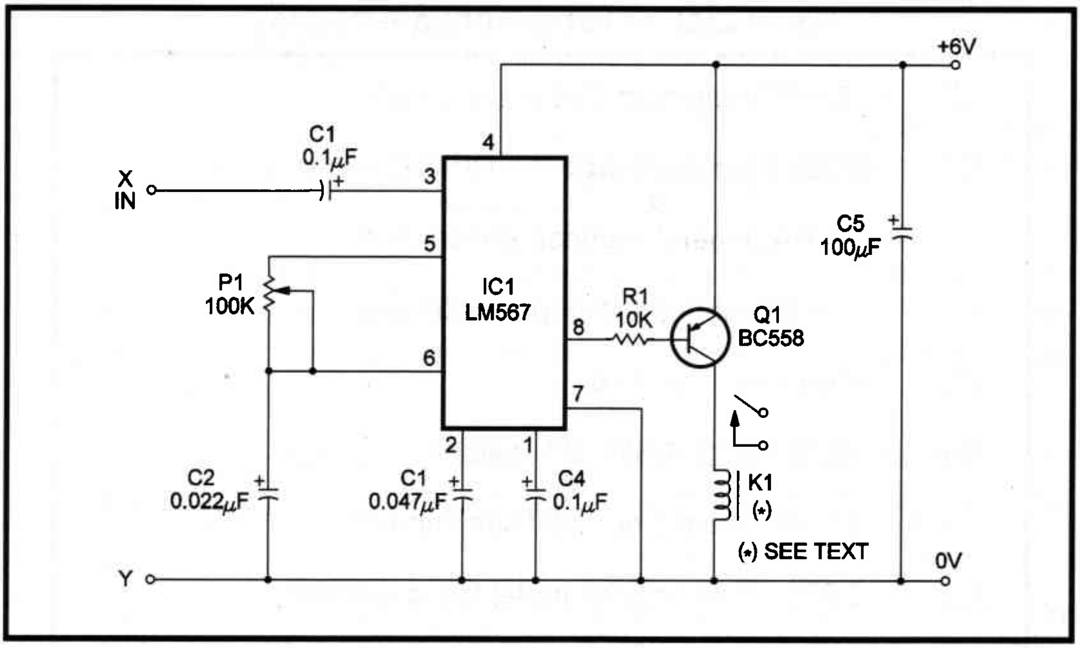


Figure 1

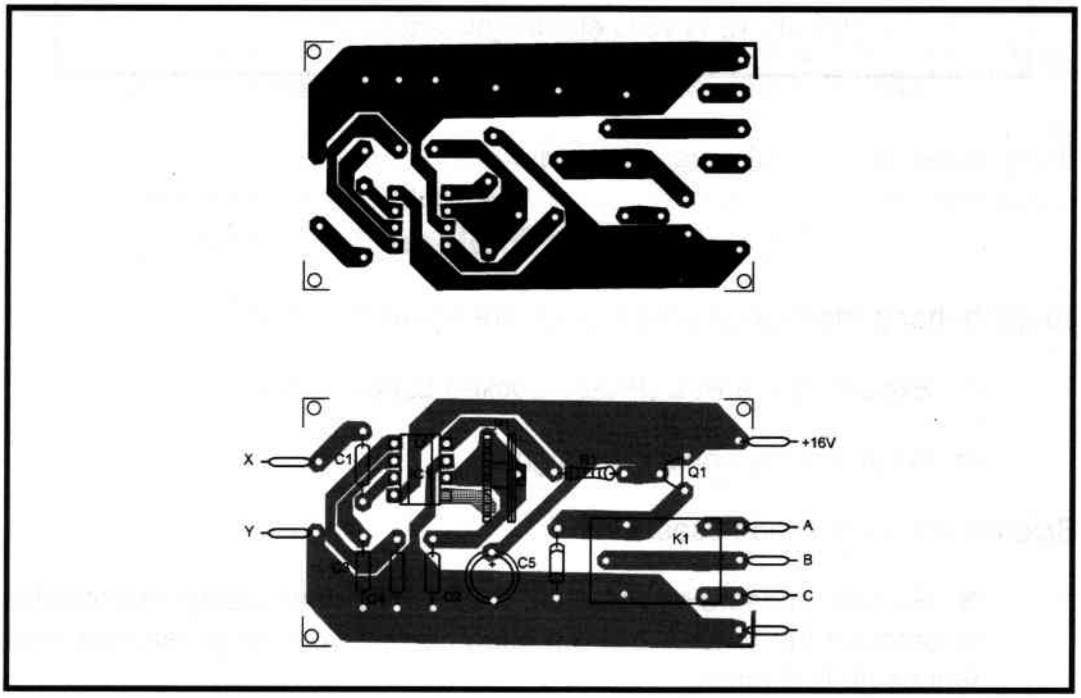


Figure 2

Parts List — Tone-Activated Relay

IC1	- LM567 Integrated Circuit (National)
Q1	- BC558 general-purpose PNP silicon transistor
D1	- 1N914 general-purpose silicon diode
P1	- 100,000 ohm trimmer potentiometer
K1	- relay - 6V - see text
R1	- 10,000 ohm, 1/4W, 5% resistor
C1, 4	- 0.1 uF ceramic or metal film capacitor
C2	- 0.022 uF ceramic or metal film capacitor
C3	- 0.047 ceramic or metal film capacitor
C5	- 100 uF, 12 WVDC electrolytic capacitor

Ideas to Explore

To get better performance or to learn more about the circuit:

- Explain how a PLL (Phase-Locked Loop) works.
- What are harmonics of a signal?

Science and uncommon uses:

- Remote sensors can be used to close the relay. Using an oscillator to produce the tone, the wires used can be very long, reaching distances up to 5 miles.

- You can use a small oscillator as transmitter and this circuit as part of a receiver to activate devices by telephone line.

- Connect the input of this circuit to the output of an audio amplifier. Plug a microphone to the input of the amplifier. With some practice you can control the relay by whistling.

- You can also use this tone-activated relay to control appliances from your computer, using the multimedia audio output. Write a program to produce a tone when an icon on your Windows screen is clicked with the mouse.

- The tone can be used to turn on the relay if the circuit is plugged to the audio output of your computer. Three modes of operation are possible:

a) By adjusting the length of the tone pulse you can turn on any appliance connected to the relay during this time interval. The appliance will turn off after the pulse ends.

b) Using a monostable with a 555 timer, for instance, a short pulse can turn on the appliance after a preadjusted time interval.

c) Using the turn-on-and-off circuit, described in this book, you'll have a bistable operation: a click on the icon turns on the appliance controlled by the relay, and the next click turns it off.

LIGHT COMPARATOR (E)

This device can be used to compare two light sources by their intensities. Several optical experiments can be conducted using this. You can compare colors of surfaces by reflected light or compare colors using special filters.

The sensors used are CdS photoresistors or LDRs (Light Dependent Resistors) that have peak sensitivity in the red part of the spectrum (7350 angstroms or 735 nm).

As the name suggests, the LDR has a resistance which varies as light falls on its sensitive surface. As the light intensity increases, resistance falls. In total darkness resistance can be high as 1,000,000 ohms or more. Illuminated by direct solar light, the resistance falls to 100 ohms or less.

Our circuit is a simple Wheatstone Bridge equilibrated by two LDRs and an adjustable potentiometer (P1).

When the two LDRs are receiving the same amount of light, P1 can be adjusted to get a null indication on the ammeter (M1).

If we use one LDR as reference, we can compare another source of light with this by using the other LDR as sensor. A new adjustment of P1 can reveal the difference between the two light sources.

The schematic diagram of the light comparator is shown in ***Figure 1***. No transistors are used in this project—only resistors.

Components layout, using a terminal strip as chassis, is shown in ***Figure 2***. The terminal strip can be fixed in the plastic box using screws. Wires to the sensor can be as long as 6 feet without instability problems.

The LDRs should be mounted into two small opaque tubes to receive light from different sources without outside interference. M1 should be a zero-center microammeter. A 50-0-50 uA microammeter would be suitable.

The circuit can be powered from two or four AA cells, and current drain is very low, extending battery life to many months.

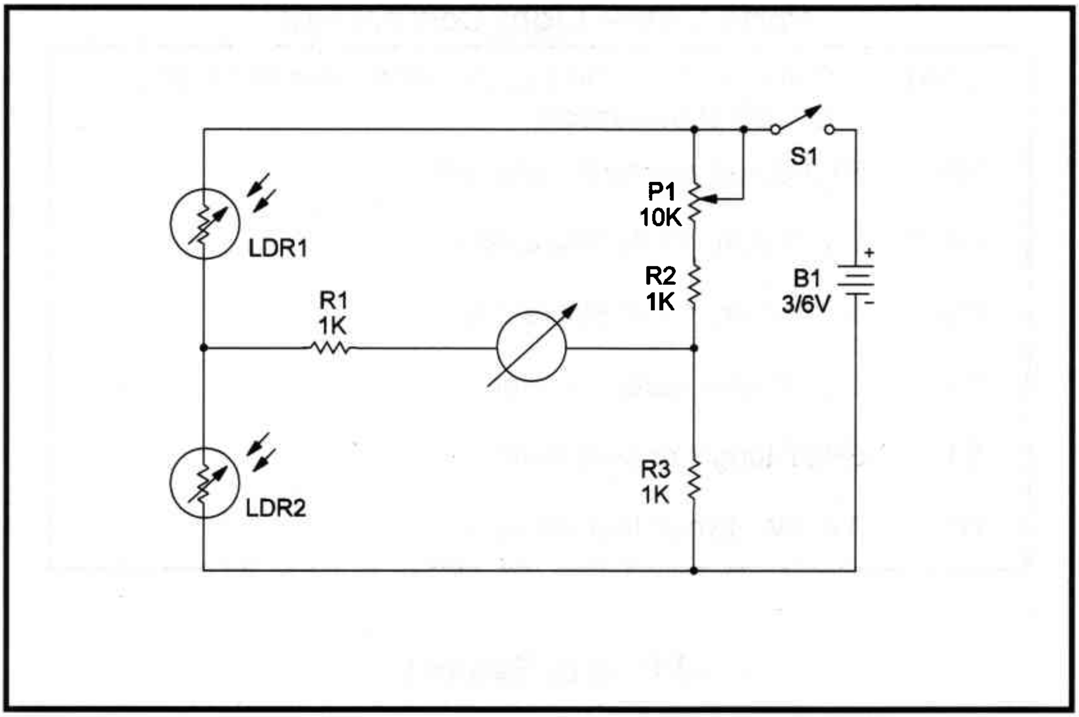


Figure 1

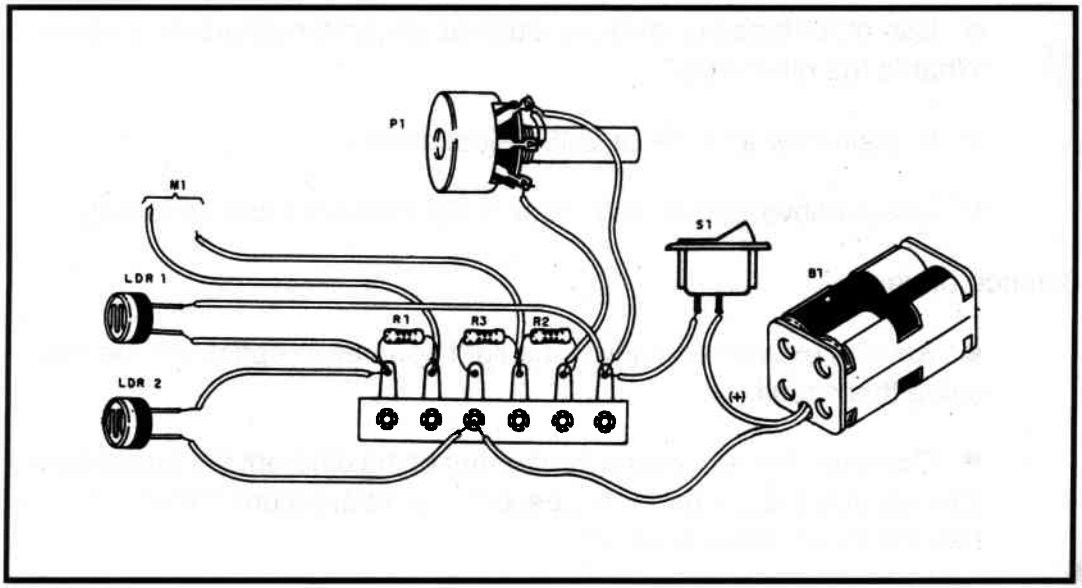


Figure 2

Parts List — Light Comparator

LDR1, 2	- Common 1cm LDRs (Light Dependent Resistors) or CdS photosensors
M1	- 50-0-50 uA ammeter - see text
R1, 2	- 1,000 ohm, 1/4W, 5% resistor
R3	- 4,700 ohm, 1/4W, 5% resistor
P1	- 10,000 ohm potentiometer
S1	- SPST toggle or slide switch
B1	- 3 to 6V - two or four AA cells

Ideas to Explore

To learn more about the circuit or to get better performance:

- Use other types of sensors, such as phototransistors in the circuit. What is the difference?
- Explain how an LDR or CdS cell operates.
- Use a convergent lens in front of the cells for more sensitivity.

Science projects:

- Several experiments involving light sources in optics can be made using this circuit.
- Compare the reflections from paper using different but equal-power light sources, such as incandescent and fluorescent. Which of them has the better performance?
- It is possible to change this circuit into a temperature comparator. Just replace the LDRs with NTCs.

ELECTRONIC ORGAN (E/P)

This is an interesting experiment in audio which would make a nice toy for children.

This circuit produces a musical note by pressing a key on a keyboard. The sound is produced by a small speaker.

The electronic organ will play only one note at a time, but the number of notes is unlimited.

Different tones can be selected by pressing different keys, as in a common electronic organ. Tonal range is determined by C1, which can be altered within a large range of values. Values between 0.022 uF (for higher notes) and 1 uF (for lower notes) can be experimented.

You can also use this circuit as a multi-tone bell in your home or to monitor several places at the same time. Replacing the keys with different sensors (reed switches, for instance) will produce different tones when closed.

A schematic diagram of the simple Electronic Organ is given in ***Figure 1***. The circuit consistis of a simple two-transistor oscillator. The transistors are direct- coupled and drive a small loudspeaker.

Components layout, using a terminal strip as chassis is, shown in ***Figure 2***. The circuit can be housed in the same box as the keyboard.

In ***Figure 3*** we show the layout of the keyboard. Each trimmer potentiometer is used to adjust individual notes.

The circuit can be powered from AA cells or a power supply ranging from 3 to 6 volts.

The keyboard can also be made from a printed-circuit board or with small metal plates. When each metal plate is touched by a probe the corresponding circuit closes and a musical tone is produced.

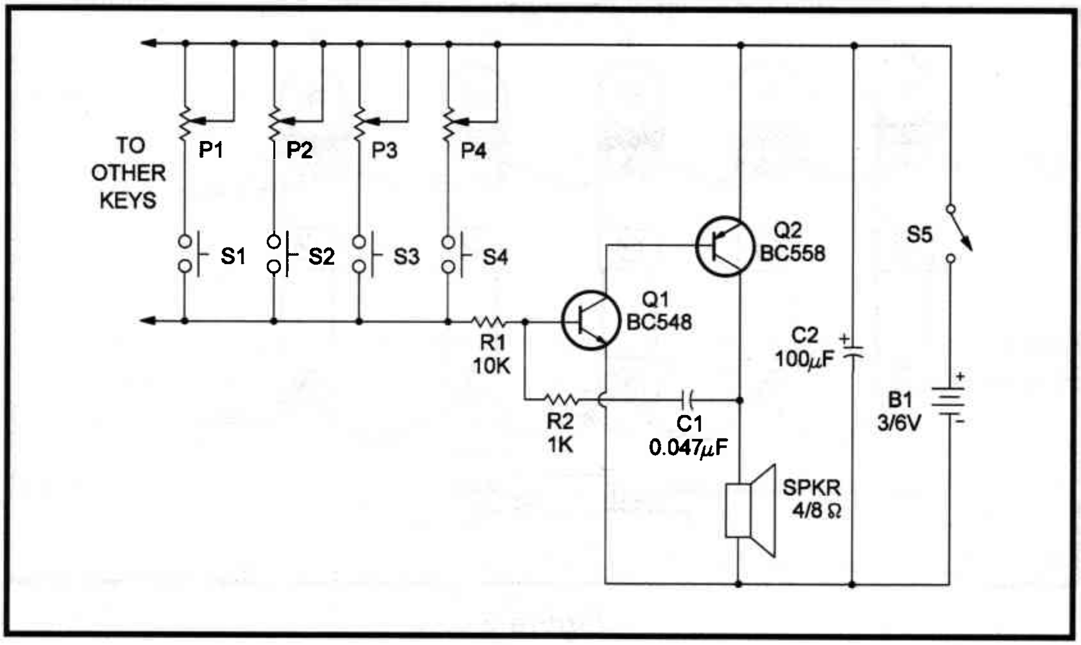


Figure 1

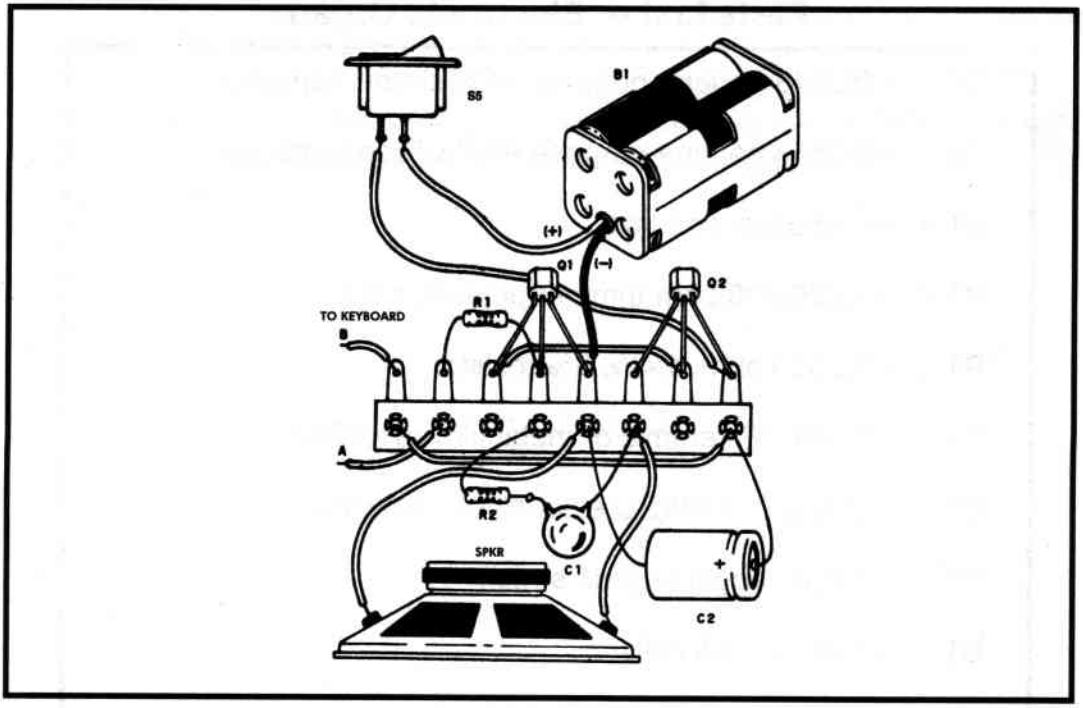


Figure 2

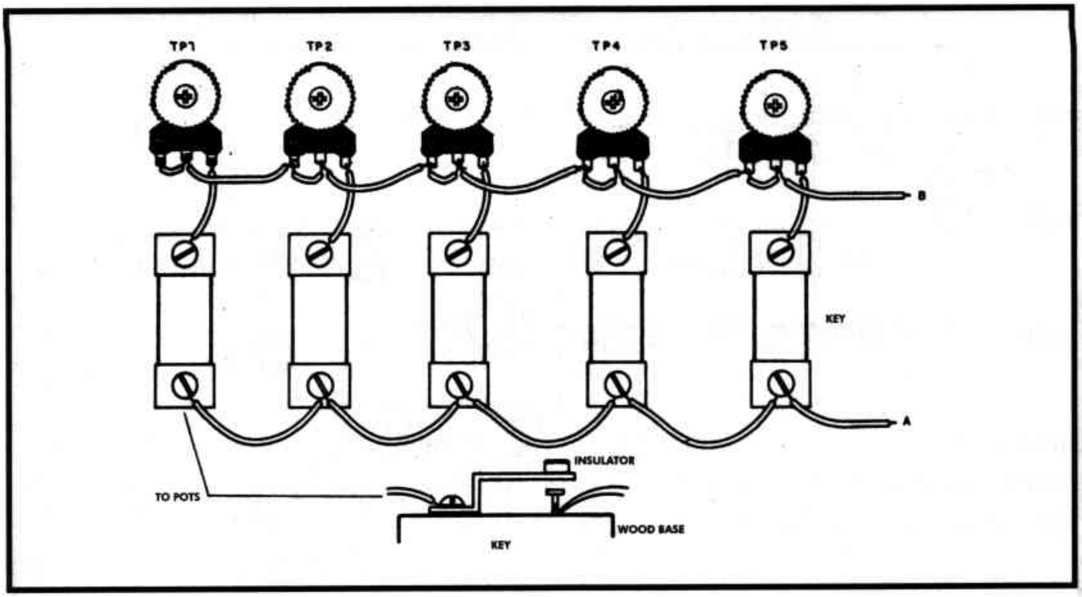


Figure 3

Parts List — Electronic Organ

Q1	- BC548 general-purpose NPN silicon transistor
Q2	- BC558 general-purpose PNP silicon transistor
S1-4	- keyboard- see text
P1-4	- 1,000,000 ohm trimmer potentiometer
R1	- 10,000 ohm, 1/4W, 5% resistor
C1	- 0.047 uF ceramic or metal film capacitor
C2	- 100 uF, 12 WVDC electrolytic capacitor
S5	- SPST toggle or slide switch
B1	- 3 or 6V - AA cells
SPKR	- 4/8 ohm, 2 to 4 in. - small loudspeaker

Ideas to Explore

To learn more about the circuit or to get better performance:

- Alter C1 in the range given in the text to produce a different range of sounds.

- Explain how the circuit works.

- Try to replace R1 with a network formed by small transformers, diodes, resistors, capacitors and other components. Modifications in the tone pitch could be found this way.

Science and uncommon applications:

- Replace S1, S2, etc., with different kinds of switches. You can identify the closed switch by the tone.

- Use only one potentiometer coupled to a cursor. You can produce music by rapidly changing cursor position and pressing the series switch.

- The same keyboard can be used in other audio oscillators, resulting in different configurations of electronic organ.

EXPERIMENTAL LIGHT-ALARM (E)

This circuit consists of a simple but effective light-activated alarm which uses only a half dozen components. A light falling on the LDR turns on the SCR. The lamp will remain on until the power is off or S1 is used to reset the circuit.

P1 adjusts sensitivity according to the application. To get better performance the LDR can be housed in an opaque tube with a convergent lens.

A 6-volt lamp can be used without problems since there is a voltage drop of about 2 volts when in the ON state.

The schematic diagram is shown in ***Figure 1***. S1 is optional, as you can reset the circuit by turning off the power supply.

Components layout, using a terminal strip, is shown in ***Figure 2***. The lamp can be replaced by an LED in series with a 470 ohm resistor or a buzzer. You also can control an audio oscillator, replacing the lamp with it.

The lamp isn't a critical component. Any 6V lamp ranging from 50 to 250 mA can be used.

The LDR is a common CdS photoresistor. The SCR needn't be mounted on a heatsink as the current is very low.

Parts List — Experimental Light-Alarm

SCR	- TIC106 Silicon Controlled Rectifier
LDR	- Common LDR - see text
P1	- 1,000,000 ohm potentiometer
X1	- 6V incandescent lamp - see text
B1	- 6-9V - four AA cells, D cells, battery or power supply
S1	- SPST momentary switch

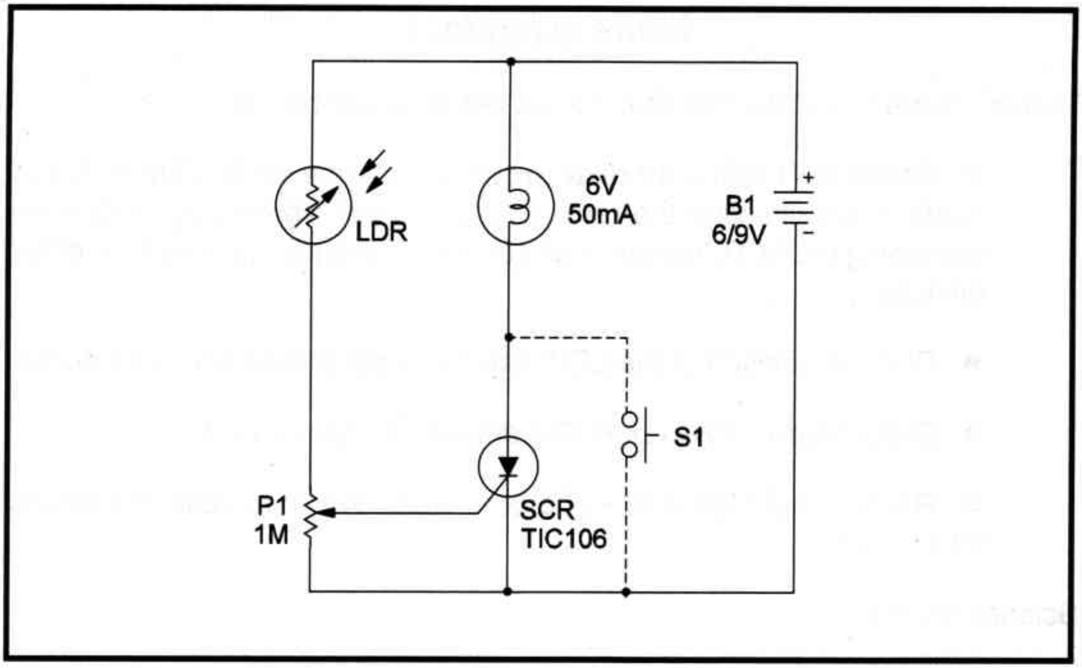


Figure 1

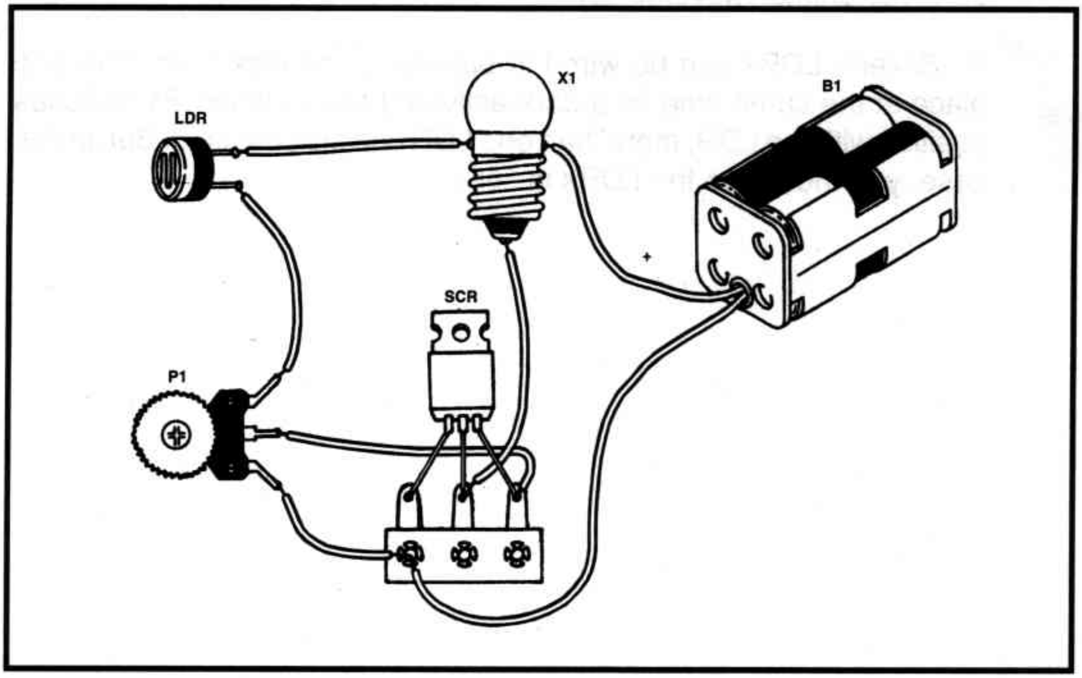


Figure 2

Ideas to Explore

To learn more about the circuit or to get better performance:

- Replace X1 with a 6V relay to control external loads. Wire a 1N914 diode in parallel with the relay coil to prevent high-voltage kick from damaging the SCR. You can also control small audio oscillators or other devices.

- Change position of the LDR with P1 to get a dark-activated alarm.

- Explain how LDRs (Light Dependent Resistors) work.

- Replace the LDR with a phototransistor. Will the circuit operate as you want?

Science projects:

- This circuit can be used to monitor traps or events that involve object or animal movements.

- Several LDRs can be wired in parallel to monitor more than one place at the same time. In a dark-activated alarm, when P1 switches position with the LDR, more than one LDR can also be used. But, in this case, you must wire the LDRs in series.

PHOTOMETER (E/P)

Some of the most common applications for LDRs are as sensing elements in alarms, photo-relays, counters, light meters for photography and also experiments in optics.

The project described here is a simple light meter made from an LDR (Light Dependent Resistor or Photoresistor), a 0-200 uA microammeter, and a 3V battery formed by two AA cells.

Use any general-purpose LDR with a high dark-to-light resistance ratio.

Since the circuit is operating for short durations you don't need an ON-OFF switch. Just put the cells in the battery holder when using the unit.

P1 adjusts sensitivity to the range of your working light intensity.

Figure 1 shows the schematic of the Photometer. The ammeter is not critical. Any type with full scale ranging from 100 uA to 1 mA can be used.

Figure 2 shows a mounting view, using a terminal strip as chassis. The device can be housed in a small plastic box. The meter and LDR are placed on the front panel.

If the ammeter used is out of specification, you need to adjust P1. Try values between 10,000 and 100,000 ohms. The LDR can be housed in a small opaque tube, depending on the application.

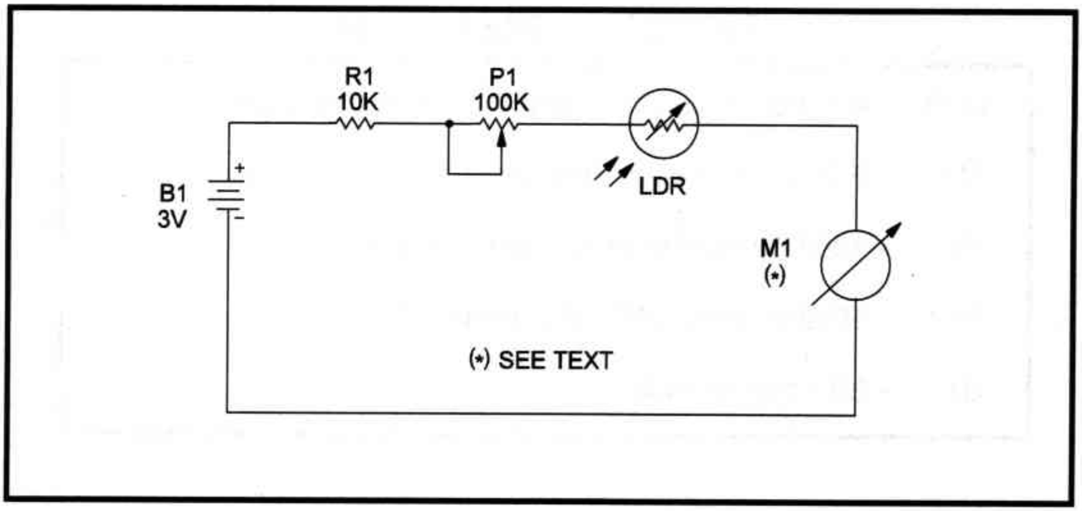


Figure 1

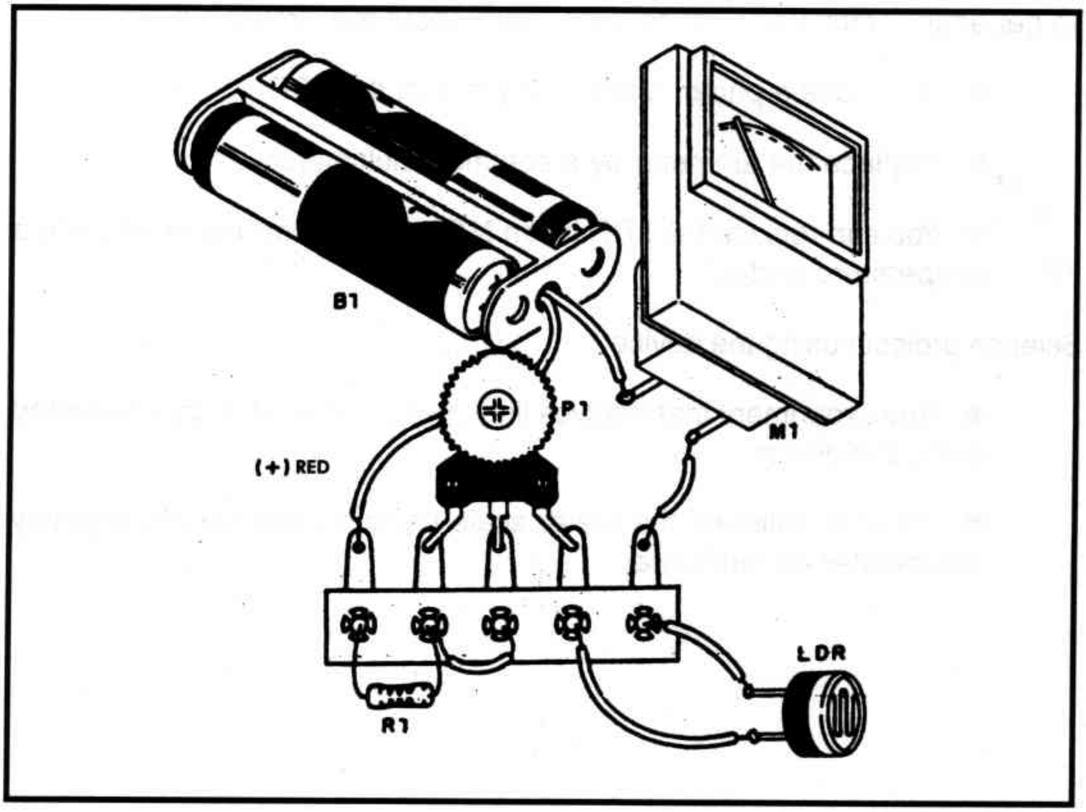


Figure 2

Parts List — Photometer

LDR	- Any common LDR (Light Dependent Resistor)
M1	- 0-200 uA - meter - see text
P1	- 100,000 ohm trimmer potentiometer
R1	- 10,000 ohm, 1/4W, 5% resistor
B1	- 3V - two AA cells

Ideas to Explore

To get better performance or to learn more about the circuit:

- Try to use a phototransistor in place of the LDR.
- Replace the ammeter by a common multimeter.
- You can replace the LDR by an NTC and convert the device into a temperature meter.

Science projects using the device:

- Any experiment that involves light measurement can be conducted using this device.
- You can calibrate the meter scale using a common photography photometer as reference.

SEQUENCE GENERATOR (E/P)

An astable multivibrator, put to work by using it as a source of clock pulses for a 4017 counter, is the basis for this circuit.

We can use it to generate random numbers in a range of one-of-ten or as a 0-to-9 counter in science projects or in other applications.

You can also adjust the clock so that it supplies one pulse each second for using the circuit as a timer in scientific experiments or at home. If you alter the clock pulse frequency, time range can be changed so that it supplies one pulse each minute or ten minutes. In this case, the time range will rise to 9 minutes or 90 minutes (in 1- or 10-minute steps)!

As a sequence generator in logic circuits demonstrations, you can change the astable operation of the 555 to monostable, connecting a momentary switch or any sensor that can be used to trigger it.

The circuit can be powered from 6 to 12V supplies, and R3 depends upon the voltage of the power supply. Use a 470 ohm resistor if the supply voltage is 6V. Use a 1,000 ohm resistor if the power supply used is 12V.

Capacitor C1 determines the pulse rate range and can be altered. Values between 1 and 1,000 uF can be used. Remember that higher values mean lower pulse rate.

P1 adjusts the pulse rate within 100:1, depending on the capacitor used.

Figure 1 shows the schematic diagram of the Sequence Generator. The circuit uses a 555 IC timer to generate the clock pulses and a 4017 CMOS IC, a counter and 1-of-10 decoder to drive ten LEDs as indicators.

Components placement on a homemade printed-circuit board is shown in ***Figure 2***. You can also use a solderless board or breadboard to mount it.

Positions of the polarized pieces, such as the LEDs and electrolytic capacitor, should be observed.

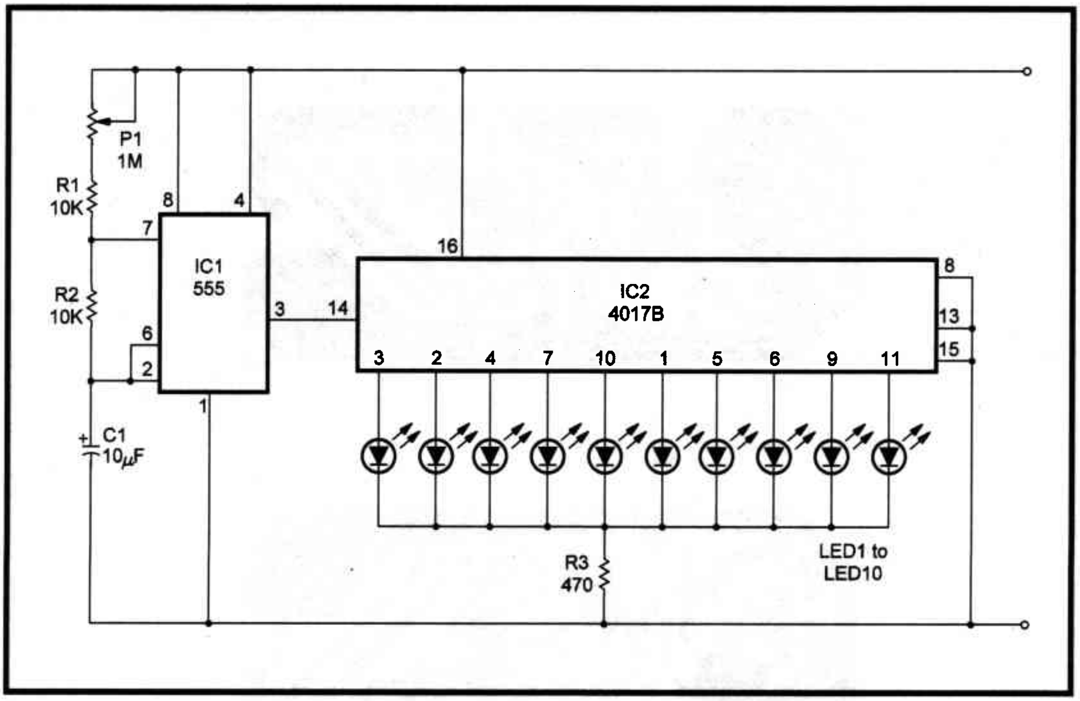


Figure 1

Parts List — Sequence Generator

IC1	- 555 - Integrated circuit, timer
IC2	- 4017 - CMOS Integrated circuit, counter
LEDs	- Common red, yellow or green
P1	- 1,000,000 ohm potentiometer
R1, 2	- 10,000 ohm, 1/4W, 5% resistors
R3	- 470 ohm, 1/4W, 5% resistor
C1	- 10 uF/16 WVDC electrolytic capacitor

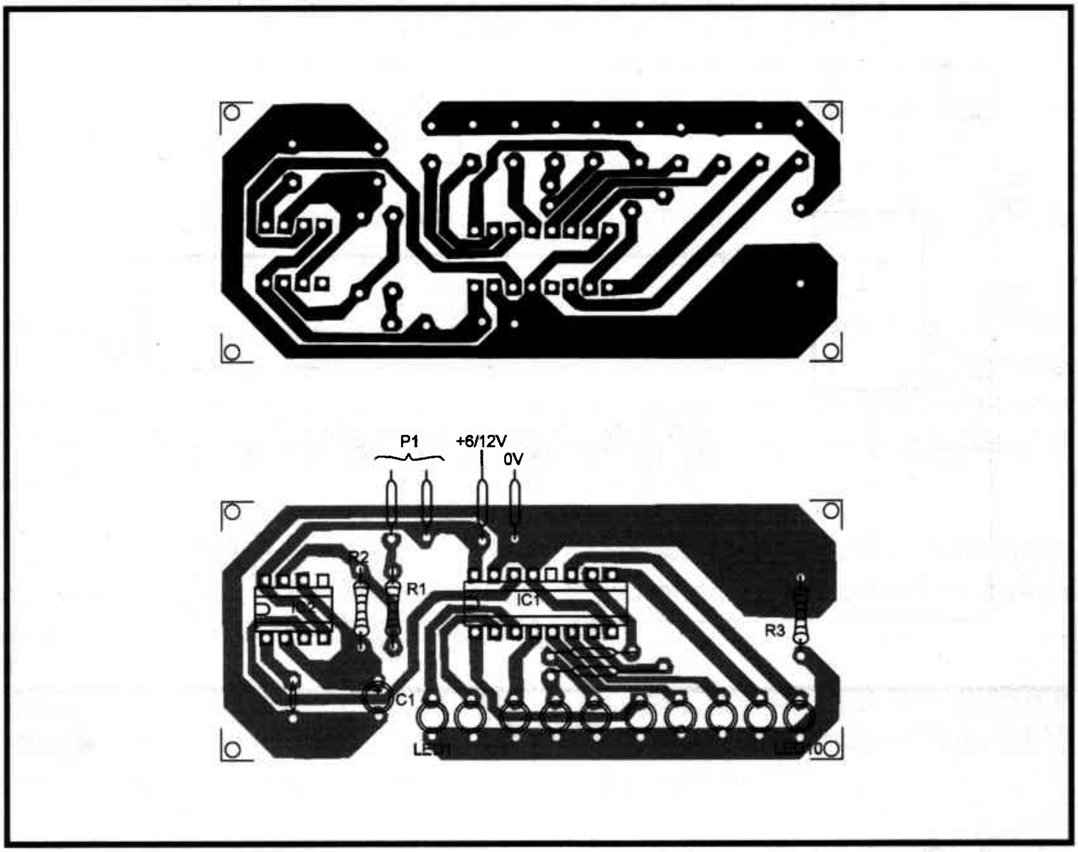


Figure 2

Ideas to Explore

To learn more about the circuit or to get better performance:

- Wire a momentary switch between IC1's pin 3 and IC2's pin 14 to control the counter. You can stop the counter any time with this switch.

- Explain how counters such as the 4017 work.

- Could you alter the circuit so that it counts to any value between 2 and 9?

Science and uncommon uses:

- Wire the 555 as a monostable multivibrator and use an LDR as sensor to trigger it. The circuit will operate as a pulse-of-light counter.

- Use this circuit in a project about computers. You can produce pulses to be counted using the experimental flip-flop described in this book.

- Experiments on ESP (Extra-Sensory Perception) can be conducted using this circuit. Random numbers in a scale of 1-to-10 can be generated using this circuit.

SIGNAL INJECTOR (E/P)

If you're interested in doing some servicing on your audio equipment (multimedia, for instance) you will undoubtedly find this square wave generator to be a handy tool. You can also use this circuit in RF stages in AM/FM receivers, since the oscillator harmonics are strong in frequencies as high as 100 MHz.

In this arrangment, frequency is determined by capacitor C2, resistors R1 and R2, and D1. The frequency can be altered by the values of resistors and/or capacitors selected. In our circuit the oscillator runs at about 1,000 Hz.

The output signal waveform is square and the output swings the full power supply voltage, which can be anything between 3 and 12 volts (we recommend a 3-volt power supply if you want a portable unit). Supply current is typicaly 10 uA, extending battery life.

Figure 1 shows the complete schematic diagram of the Signal Injector. IC1 is a 555 timer, wired as an audio oscillator. Frequency is determined by C2, R2 and R1. You can change C2 within a large range of values.

Figure 2 shows the homemade PC board where the components are mounted. A small 3V battery can also be used if you want a very compact mounting.

A signal injector is used from the "back" to the "front" of an audio (or RF) circuit. For instance, to use the signal injector with an AM receiver, apply the signal from the probe at the base of the output transistor. If that stage and everything after it operates correctly the signal will be heard in the speaker. If the output stage proves to be OK, move back to the base of the driver transistor. The output signal will be higher if everything is working. Then, apply the signal progressively towards the front of the circuit by injecting it at the volume control, detector stage, IF stages and the mixer.

The circuit can be housed in a small plastic box and connected to the external circuit through a probe and an alligator clip. ***Figure 3*** represents a possible housing arrangement.

To test the signal injector, apply the signal to the input of any audio amplifier.

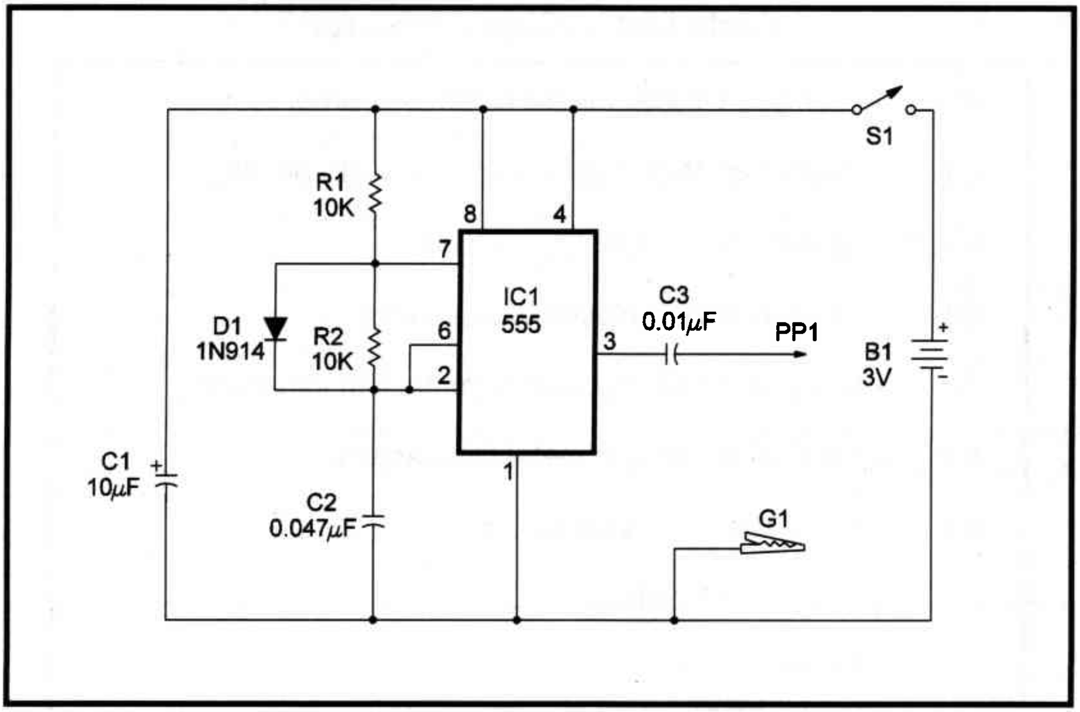


Figure 1

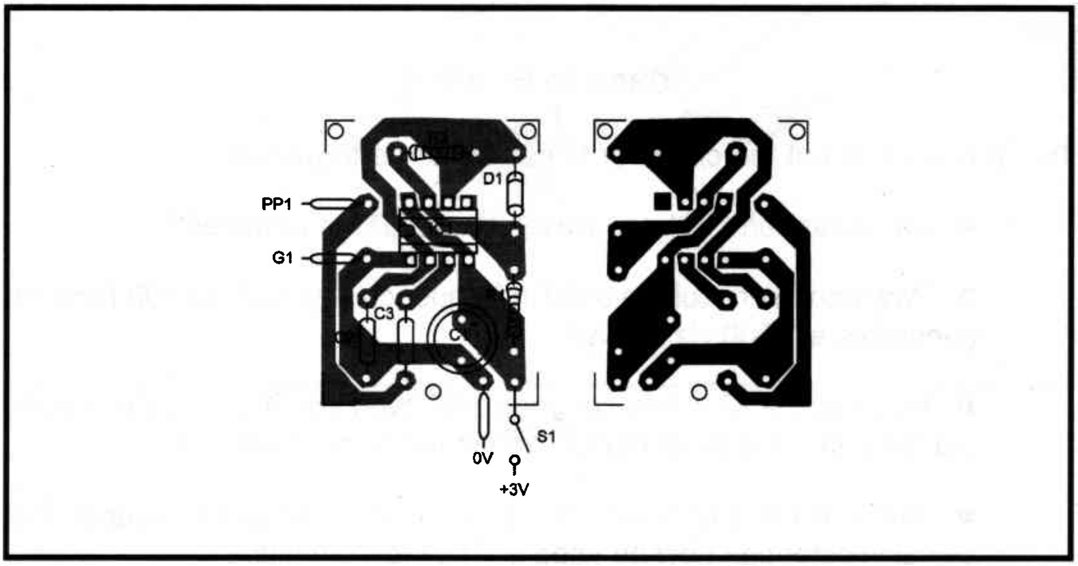


Figure 2

Parts List — Signal Injector

IC1	- TLC7555 CMOS integrated circuit - timer
D1	- 1N4148 or 1N914 general-purpose silicon diode
R1, 2	- 10,000 ohm, 1/4W, 5% resistor
C1	- 10 uF, 6 WVDC electrolytic capacitor
C2	- 0.047 to 0.1 uF ceramic or metal film capacitor
C3	- 0.01 uF ceramic or metal film capacitor
S1	- SPST toggle or slide switch
B1	- 3V - two AA cells
PP1	- Probe
G1	- Alligator clip

Ideas to Explore

To learn more about the circuit or to get better performance:

- What happens with the wave shape if D1 is removed?
- Why can the circuit be used in frequencies as high as 100 MHz if it generates a 1,000 Hz signal?
- Replace the IC with a common 555 (bipolar). The circuit will work, but the current drain is higher than in the original version.
- Remove C3 and power the circuit from a 5V power supply. The signal injector can now be used in TTL logic circuits.

- R1 and R2 are shown as fixed resistors in this project. You can change these resistors to a potentiometer (1,000,000 ohms, for instance) in series with a 1,000 ohm resistor to generate signals within a large range of frequencies and duty-cycles.

Science projects using the signal injector:

- The circuit can be used as a simple bio-stimulator in biological experiments. Stimulation levels as high as the power supply voltage can be achieved. These levels can be used in direct nerve stimulation.

- Wire a piezoelectric transducer or crystal earphone to the output of this signal injector. A tone of about 1,000 Hz will be produced and can be used in experiments.

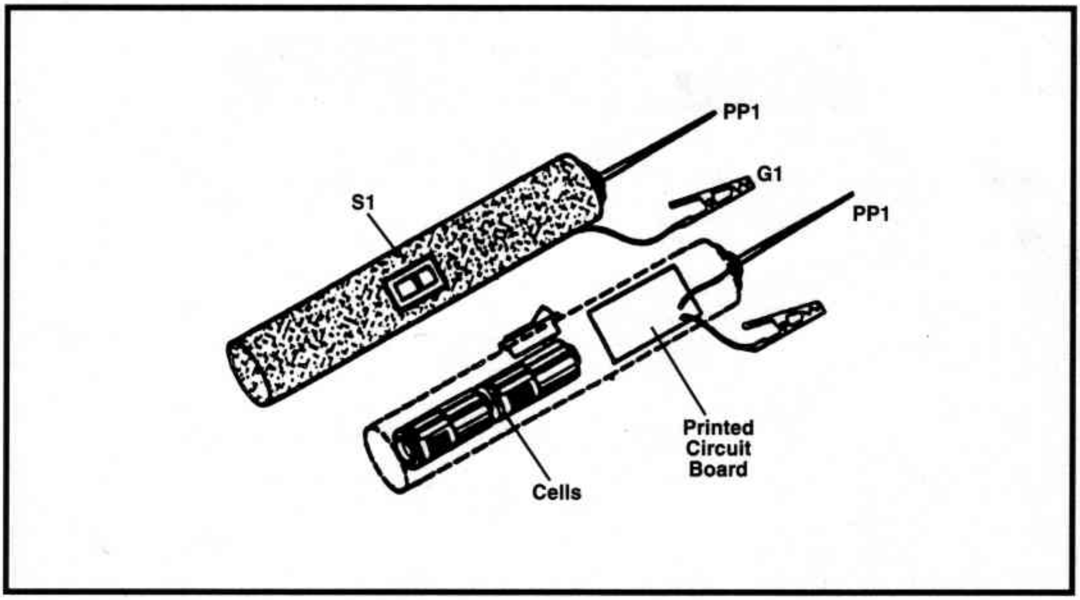


Figure 3

METAL DETECTOR (E)

You can use this simple metal detector to locate plumbing pipes, electrical wiring inside walls, find a lost watch or coin at the beach or even a treasure with gold coins buried years ago by pirates.

You can also use the circuit in experiments where you can show the magnetic properties of materials. The differences between paramagnetic, diamagnetic, and nonmagnetic materials can be shown. Interesting experiments can be conducted using the metal detector described here.

This circuit will detect the presence of metallic objects through any nonconductive material such as dirt, wood, stone, plaster or plastic.

With a little practice, you will be able to detect metallic objects to depths of over several inches and will give you a fairly good idea of their size.

Our circuit uses the beat-frequency method to detect an object.

The frequency of the search coil oscillator changes when the conductance in the field of the search coil changes. Therefore, when metals come within a short distance of the coil, the frequency is changed, which in turn changes the pitch of the audible sound.

The sound is produced by the speaker of a common AM receiver that tunes the coil oscillator.

A schematic diagram of the Metal Detector is shown in ***Figure 1***. Observe that the circuit is a very simple one-transistor oscillator. You can also use a general-purpose PNP silicon transistor, inverting the power supply polarity.

The physical arrangment of the electronic components, using a terminal strip as chassis, is shown in ***Figure 2***. The critical part of this project is the search coil.

The search coil is wound in a large 6-inch plastic Frisbee. Begin by securing one end of the enameled magnet wire form (18 to 22 AWG) with masking tape. On the tenth wrap (halfway) form a loop in the magnet wire for the center tap, then continue until you complete the 20 turns of wire.

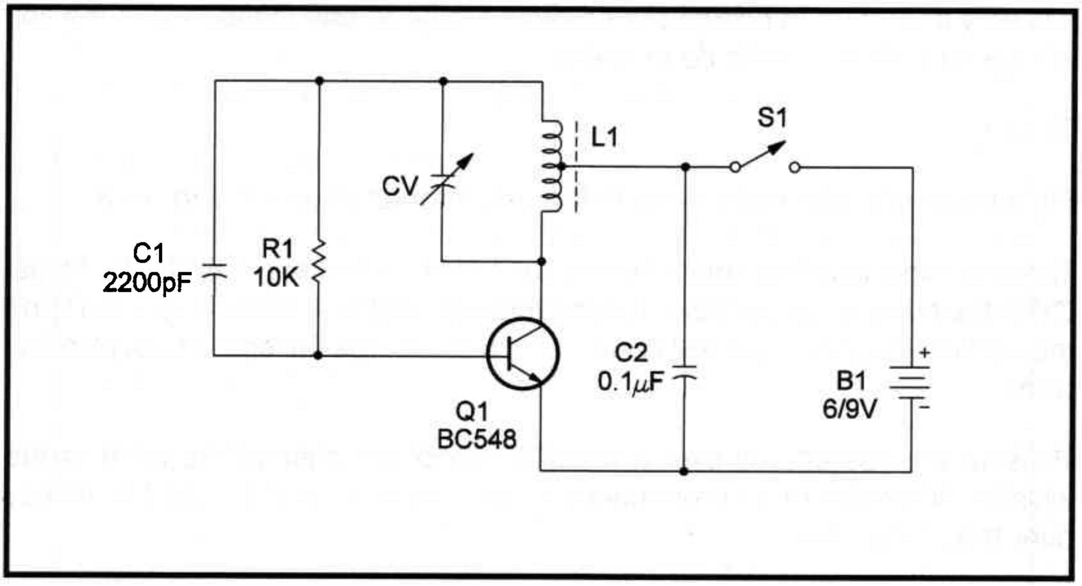


Figure 1

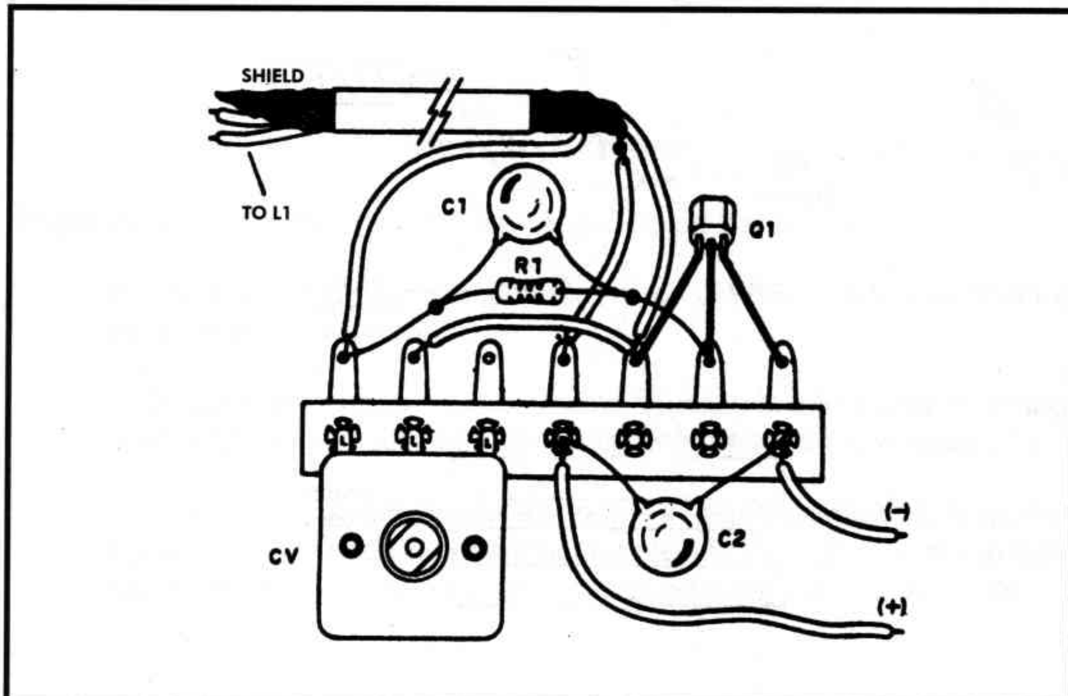


Figure 2

It is very important to secure the coil wire firmly, as one loose loop in the coil will cause the detector to be unstable.

To use:

Fix a small portable radio close to the oscillator as shown in ***Figure 3***.

Tune the radio to a free point of the range between 550 and 1,600 kHz. Adjust CV in the search coil oscillator to tune this signal as a whistle. If you can't find the oscillator signal in the AM band, reduce or enlarge the search coil by a few turns.

Passing the search coil over a metallic object will change the pitch of the whistle. When the most pronounced change occurs, you should be directly over the metal object.

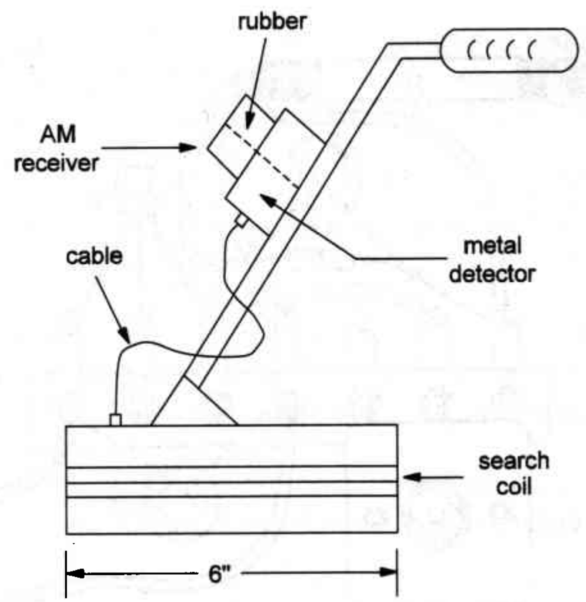


Figure 3

Parts List — Metal Detector

Q1 - BC548 general-purpose NPN silicon transistor

L1 - Search coil - see text

CV - 365 pF - any variable capacitor (from nonworking AM radio)

C1 - 2,200 pF ceramic capacitor

C2 - 0.1 uF ceramic capacitor

R1 - 10,000 ohm, 1/4W, 5% resistor

S1 - SPST slide or toggle switch

B1 - 6 or 9V - four AA cells or 9V battery

Ideas to Explore

To get better performance or to learn more about the circuit:

- Make experiments with different kinds of materials to see how the detector works with each one.

- Explain what happens when a metal object is introduced in a magnetic field. Is there any way to identify the metal being detected?

- The circuit can also be used as an RF signal generator. To get the signal from this oscillator, connect a probe to the collector of the transistor with a 1,000 pF capacitor and an alligator clip to the emitter.

Science projects and uncommon applications:

- Several experiments involving metal detection can be conducted using this simple metal detector. An example would be a work to show the differences between paramagnetic, diamagnetic and non-magnetic materials, as suggested earlier.

- The search coil can be modified to apply RF signals to plants or animals. Experiments to find the effects of RF (Radio Frequency) on seed germination or plant growth can be made with this circuit.

CRYSTAL SET (E)

A complete radio AM receiver which requires no battery power at all can be created with a few components. The classic circuit of the well-known crystal radio or crystal receiver can be based on a germanium diode as detector, or if you prefer, the original galena crystal.

Figure 1 shows the classic circuit. L1 is a proprietary antenna tuning coil wound on a paper tube and C1 is a matching variable capacitor (365 to 500 pF). A variable capacitor can be found in old non-working transistor radios. You can also find the diode in these sets and use it for this project.

Virtually any diode can be used, and the only other circuit component is capacitor C1, connected across the output. The earphones must be a high-impedance type (headphones).

An external aerial and good physical ground connection is essential for good reception.

The circuit will tune AM band radio stations not far from your home.

Component layout is shown in ***Figure 2***.

L1 is formed by 100 turns of No. 22 to 28 AWG enamelled wire on a 1-inch diameter paper tube.

Parts List — Crystal Radio

D1	- 1N34 or any germanium diode
L1	- Coil - see text
CV	- 365 to 500 pF variable capacitor
C1	- 470 pF ceramic capacitor
PHONE	- High-impedance (2,000 to 10,000 ohms) phone

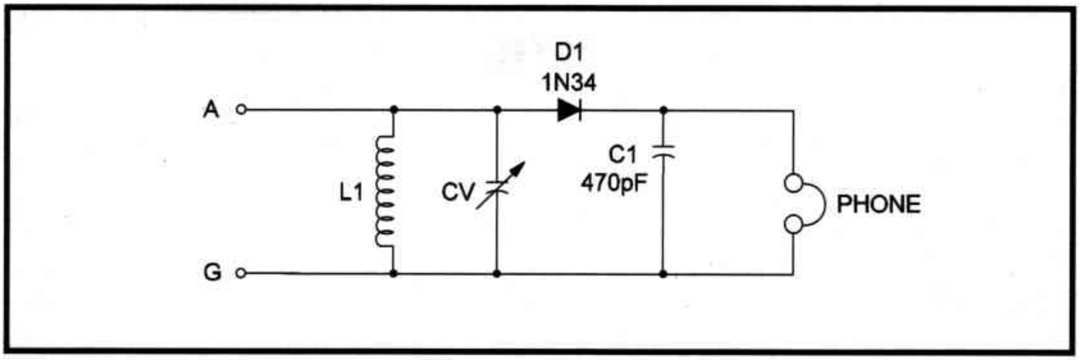


Figure 1

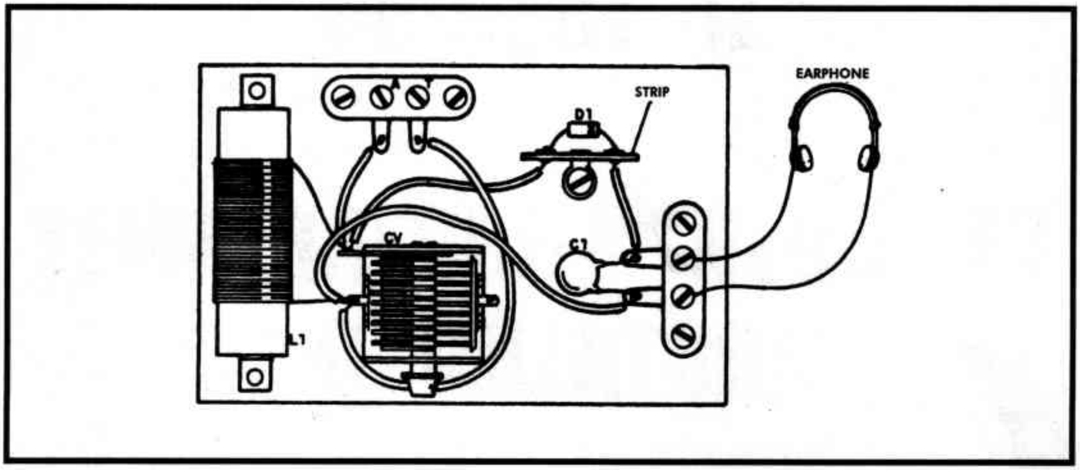


Figure 2

Ideas to Explore

To learn more about the circuit or to get better performance:

- Use an audio amplifier to get better reception.
- Replace the coil by 100 turns of No. 22 to 28 wire on a ferrite rod.

Science projects:

- This set can be used to demonstrate how old-time radio receivers operated. Explain how a galena detector works.

TEMPERATURE-CONTROLLED OSCILLATOR (E)

You can conduct interesting experiments with this temperature-dependent oscillator. Tone pitch depends upon the temperature of a sensor. The sensor is a common general-purpose silicon diode. The reverse resistance of this diode is slight, dependent on the junction temperature. The circuit can operate in a temperature range typically between -20 and +100 degrees Celsius.

Frequency range depends upon C1. This component can be altered in a large range of values. Values between 0.01 and 0.47 uF can be substituted to produce tones in the audio range.

If you want to produce "clicks" with a rate dependent upon the temperature of the sensor, try capacitors with values between 0.47 and 1 uF. Metal film or ceramic capacitors can be used in this circuit.

By adjusting P1 you can put the oscillator near the point where it begins to run. Then, any temperature rise will trigger the oscillator, making it operate as a temperature alarm.

The circuit can be powered from two or four AA cells, and current drain is low.

The sensor is any general-purpose silicon diode. The diode can be protected against moisture and water.

The schematic diagram of the Temperature-Controlled Oscillator is shown in ***Figure 1***. The sensor can be wired to the circuit by a long twisted-pair wire for remote operation.

Components layout, using a terminal strip as chassis, is shown in ***Figure 2***. As the circuit is intended for experimental purposes, you can also mount it on a solderless board.

Position of polarized components, such as the diode and power supply, should be observed.

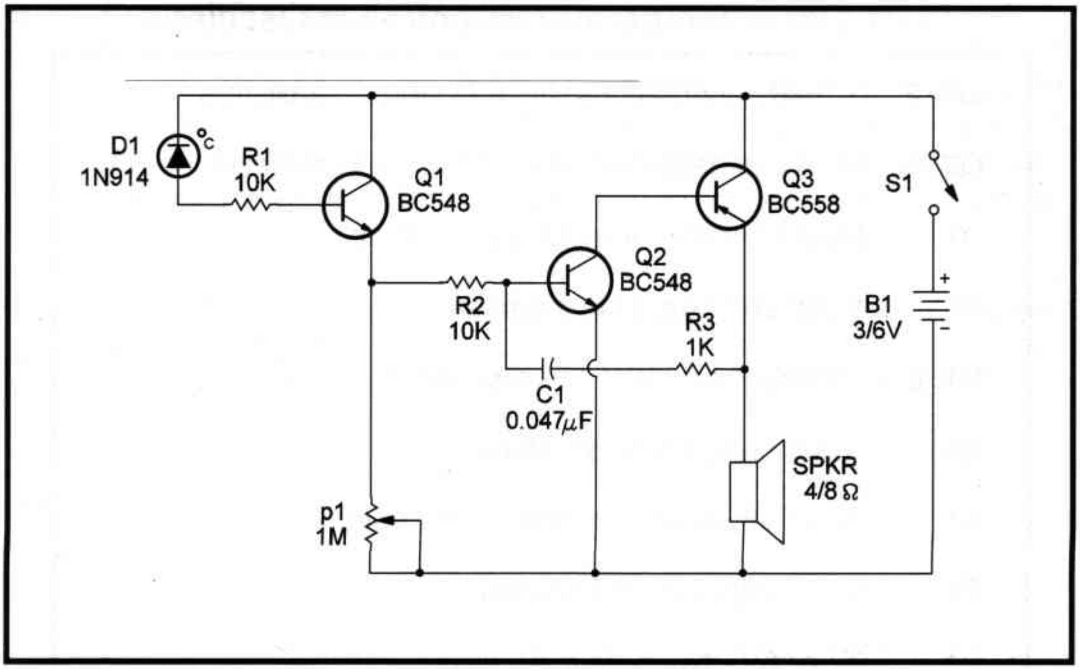


Figure 1

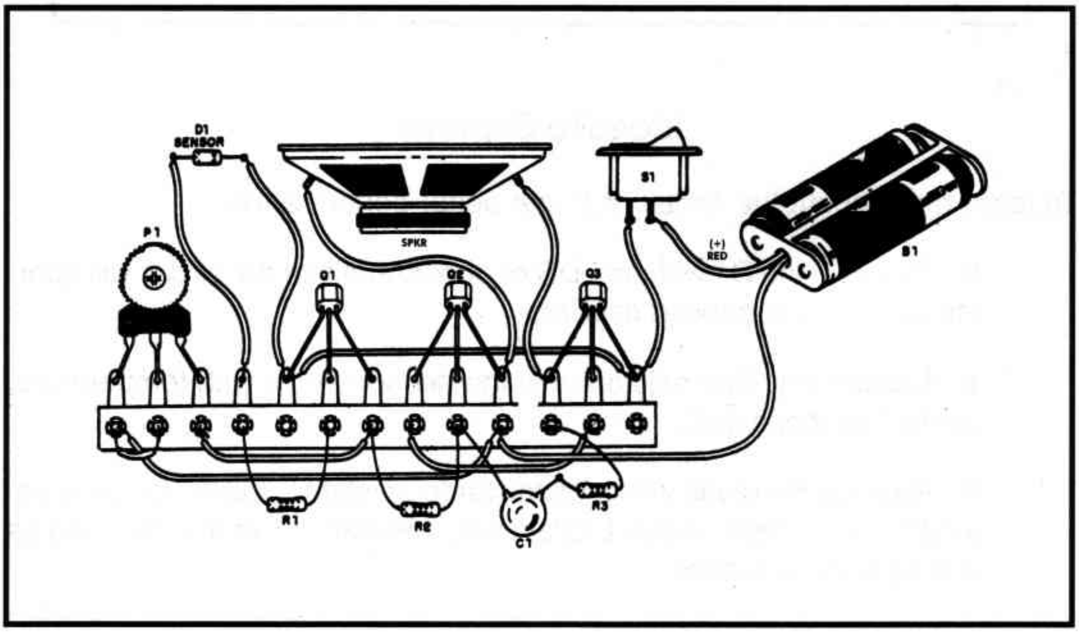


Figure 2

Parts List — Temperature-Controlled Oscillator

Q1, 2	- BC548 general-purpose NPN silicon transistors
Q3	- BC558 general-purpose PNP silicon transistor
D1	- 1N914 general-purpose silicon diode
P1	- 1,000,000 ohm potentiometer
R1, 2	- 10,000 ohm, 1/4W, 5% resistors
R3	- 1,000 ohm, 1/4W, 5% resistor
C1	- 0.047 uF ceramic or metal film capacitor
S1	- SPST toggle or slide switch
B1	- 3V or 6V - two or four AA cells
SPKR	- 4 or 8 ohms - 2 or 4 in. loudspeaker

Ideas to Explore

To learn more about the circuit or to get better performance:

- By replacing D1 with an LDR or phototransistor the circuit will operate as a light-controlled oscillator.

- Explain why the resistance of the sensor varies with temperature, controlling this circuit.

- Replace the diode with a transistor (conection is made using collector and emitter terminals). Explain why this device can also be used as a temperature sensor.

Science projects or uncommon uses:

- You can use this circuit as a biofeedback device by replacing the sensor with two electrodes. The subject, holding the sensor in hand, can learn how to control the tone through stress and breathing management. The circuit also operates as a lie detector using this configuration.

- Any experiment involving temperature variations can be conducted using this circuit.

FREQUENCY-MODULATION SIREN (E/P)

Acting on a capacitor charging, one oscillator (pins 1,2 and 3 of IC1) can modulate another oscillator in frequency, as described in this project. The produced tones thus run from high to low and vice-versa at a rate determined by the first oscillator frequency and also by P1 and P2 adjustments.

The circuit can be used as a siren, part of alarms, games and many other applications. With a 12V power supply the output power is up to a wattage representing an excellent audio level in a loudspeaker.

The basic circuit has tone, modulation rate and depth adjusted by trimmer potentiometer. There are also some components that can be changed to alter the performance of the siren. C1, for instance, determines modulation rate and can range from 1 to 47 uF. C2 determines modulation depth and rate and can also be altered within a large range of values. C3 determine tone frequency, ranging from 0.01 to 0.1 uF.

Power supply can range from 6 to 12V. With a 12V power supply current drain is as high as 2 or 3 amps. F1 is important to prevent problems with shorts.

Q1 is a power FET and equivalents can be used. You also can replace this transistor with a Darlington NPN power transistor such as TIP110, but you must also add a series resistor with base terminal. Use a 10,000 ohm resistor for this task.

The schematic for the Frequency-Modulation Siren is shown in ***Figure 1***. Observe that two gates are used as oscillators and the other two of a 4093B IC are used as buffer-inverters.

Components placement on a homemade printed-circuit board is shown in ***Figure 2***. For experimental purposes the circuit can also be mounted on a solderless board, and it is important to place the transistor on a large heatsink.

Position of the polarized components, such as electrolytic capacitors, should be observed.

The speaker should be a high-power type for better performance. Installing it in an enclosure will provide better sound level.

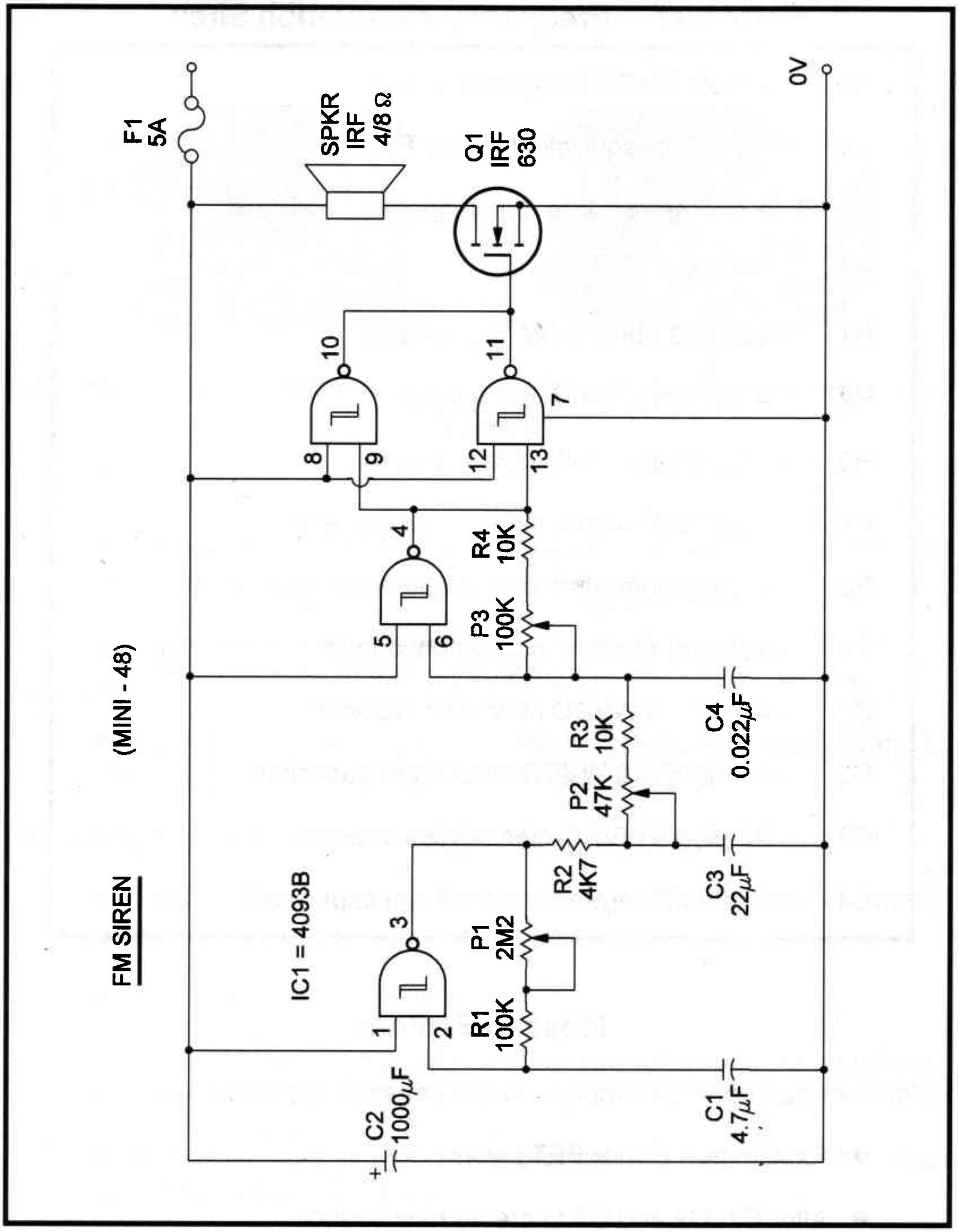

FM SIREN
(MINI - 48)
IC1 = 4093B
F1
5A
SPKR
IRF
4/8 Ω
Q1
IRF
630
0V
C2
1000μF
C1
4.7μF
R1
100K
P1
2M2
R2
4K7
C3
22μF
P2
47K
R3
10K
C4
0.022μF
P3
100K
R4
10K
1
2
3
4
5
6
7
8
9
10
11
12
13

Figure 1

Parts List — Frequency-Modulation Siren

IC1	- 4093B CMOS Integrated Circuit
Q1	- IRF630 or equivalent Power FET
SPKR	- 4 or 8 ohms, 4- to 8-inch speaker - see text
F1	- 5A fuse
R1	- 100,000 ohm, 1/4W, 5% resistor
R2	- 4,700 ohm, 1/4W, 5% resistor
R3, 4	- 10,000 ohm, 1/4W, 5% resistors
P1	- 2,200,000 ohm trimmer potentiometer
P2	- 47,000 ohm trimmer potentiometer
P3	- 100,000 ohm trimmer potentiometer
C1	- 4.7 uF, 16 WVDC eletrolytic capacitor
C2	- 1,000 uF, 16 WVDC electrolytic capacitor
C3	- 22 uF, 16 WVDC electrolytic capacitor
C4	- 0.022 uF ceramic or metal film capacitor

Ideas to Explore

To learn more about the circuit or to get better performance:

- Explain how Power FETs work.
- Alter C1, C2 and C3 to create new sounds.

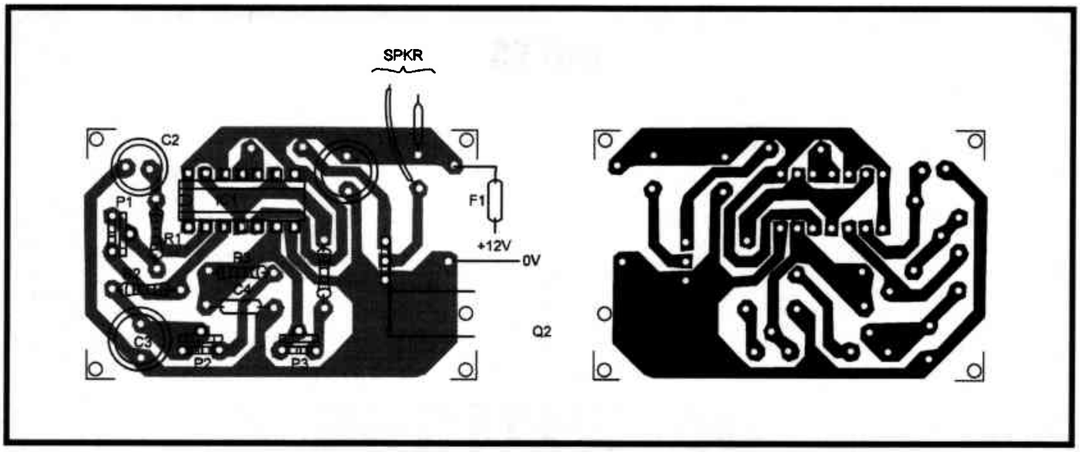


Figure 2

- Wire pins 1 and 5 together and to an external control circuit. The siren can be controlled by external logic circuits.

- Determine the logic level in pins 10 and 11 when pins 1 and 5 go low. What will happen with current drain in this case?

- Replace Q1 by a TIP31 or BD135 to operate with less power. The power supply should be reduced to 6 or 9V in this case.

Science projects and uncommon applications:

- Replace R1 with an LDR and experiment with a light-controlled siren.

- Use this siren as part of alarms.

- Using this siren you can generate special sounds to experiment with animal conditioning.

- Modulated ultrasounds can be produced by reducing C4 to values as low as 2,200 or 4,700 pF.

COIN TOSSER (E/P)

This circuit simulates the flipping of a coin by merely pressing S1. Of course, the electronic version, if used for important decisions (or experiments), can't be loaded or weighted and is 100% random.

The circuit has two LEDs that flick alternatingly, in a frequency rate determined by C1, when power is ON. When you press S1 the circuit stops immediately and only one LED remains ON.

Power supply can range from 5 to 12 volts, and this means that you can use AA cells in a portable version.

Some components can be altered according to the intended application: C1, for instance can be altered in a range from 0.01 to 0.47 uF. You can also use a touch sensor to stop the tosser or increase R1's value to up to 10,000,000 ohms.

The schematic diagram for the coin tosser is shown in ***Figure 1***. Only one gate a 4093 IC is used as oscillator to produce random pulses in this circuit.

Components placement on a homemade printed-circuit board is shown in ***Figure 2***. The circuit can easily be housed in a small plastic box.

Position of the polarized components, such as the LEDs and electrolytic capacitor, should be observed.

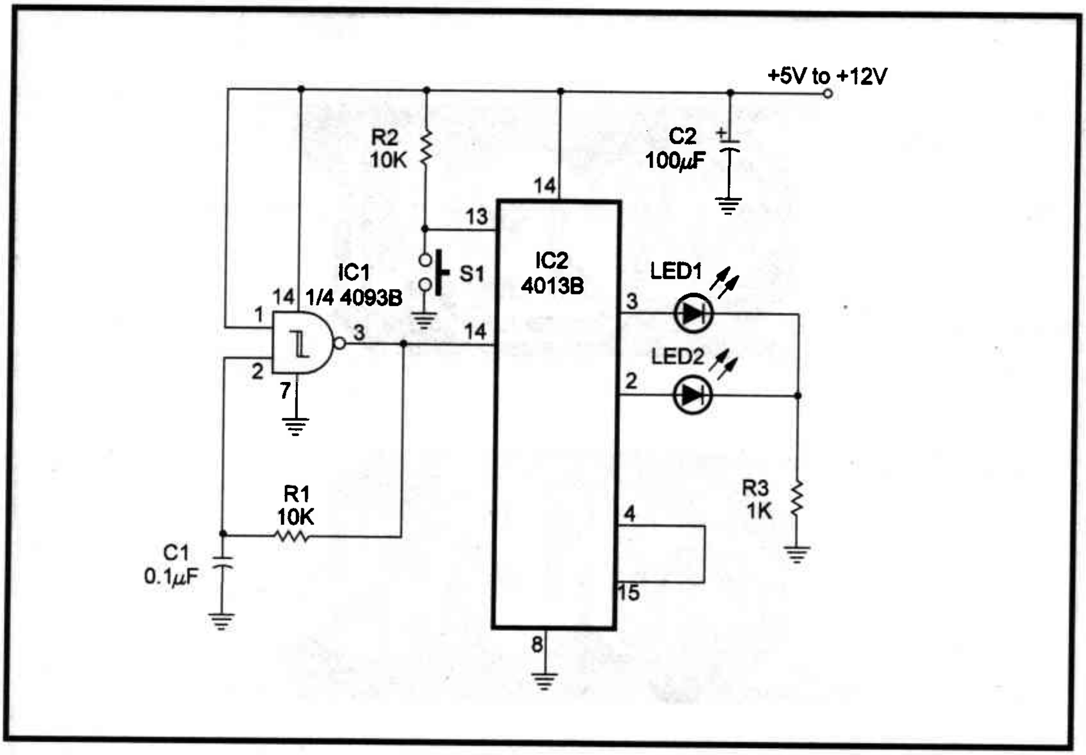


Figure 1

Parts List — Coin Tosser

IC1	- 4093B CMOS Integrated Circuit
LEDs	- Common red, yellow or green
S1	- SPST Momentary switch
R1, 2	- 10,000 ohm, 1/4W, 5% resistors
R3	- 1,000 ohm, 1/4W, 5% resistor
C1	- 0.1 uF ceramic or metal film capacitor
C2	- 100 uF, 16 WVDC electrolytic capacitor

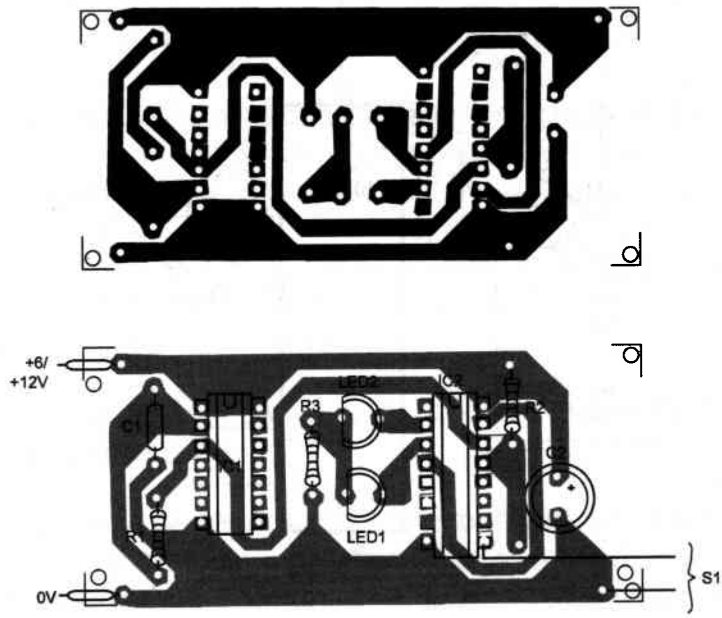


Figure 2

Ideas to Explore

To learn more about the circuit or to get better performance:

- Instead of using LEDs, transistors can be used to drive incandescent lamps.

- S1 can be placed as far as you want from the circuit. Common parallel wire can be used for this task.

- Explain how a flip-flop works and how you can guarantee that the circuit is 100% random.

Science and uncommon applications:

- You can conduct ESP (Extra-Sensory Perception) experiments using this circuit. S1 can be placed far from the LEDs for better results.
- Experiments with probability theory can be conducted using this circuit.
- Try to couple a sequence generator to the oscillator used in this circuit to get a 1-to-10 raffle circuit.

PLASMA OSCILLATOR (E)

A flame is a conductive medium that can be used in an uncommon feedback loop to control the frequency of an audio oscillator. This configuration can be used as a confirmation of the conductivity of a flame.

The audio oscillator described in this project is controlled by the "fourth" matter state, the "plasma" or an ionized gas, and can be used as part of an interesting experiment in physics.

The flame can be produced by a simple match or a candle and the flickering effect will modulate the generated sound.

The circuit runs in frequencies between 1 and 500 Hz, depending on the electrodes and flame positions.

A schematic diagram of the Plasma Oscillator is shown in ***Figure 1***. The high input impedance of a 4093B is fundamental in this project. A flame typically has a resistance in the range of tenths of megohms.

The printed circuit board for the components positioning is shown in ***Figure 2***.

Sensor details are also given in that figure. Two wires, one placed near the other, with about 1 inch of bared length as shown in the figure, form the "plasma sensor". The flame should involve the two bared wires at the same time to allow the feedback current to flow and the oscillator to operate.

An output stage using a piezoelectric transducer can replace the transistor and loudspeaker. With a lower current drain this configuration can be powered from four AA cells or a 9V battery.

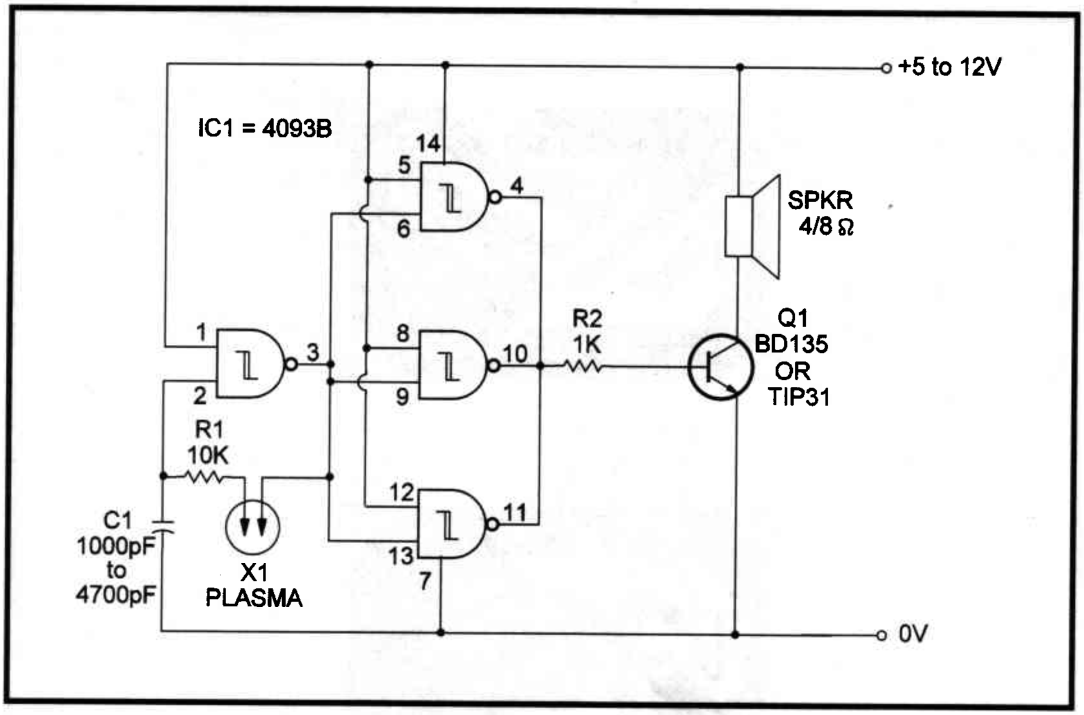


Figure 1

Parts List — Plasma Oscillator

IC1	- 4093B CMOS Integrated Circuit
SPKR	- 4/8 ohm 4-inch loudspeaker
Q1	- BD135 or TIP31 Power NPN silicon transistor
R1	- 10,000 ohm, 1/4W, 5% resistor
R2	- 1,000 ohm, 1/4W, 5% resistor
X1	- Plasma sensor - see text
C1	- 1,000 to 4,700 pF ceramic or metal film capacitor

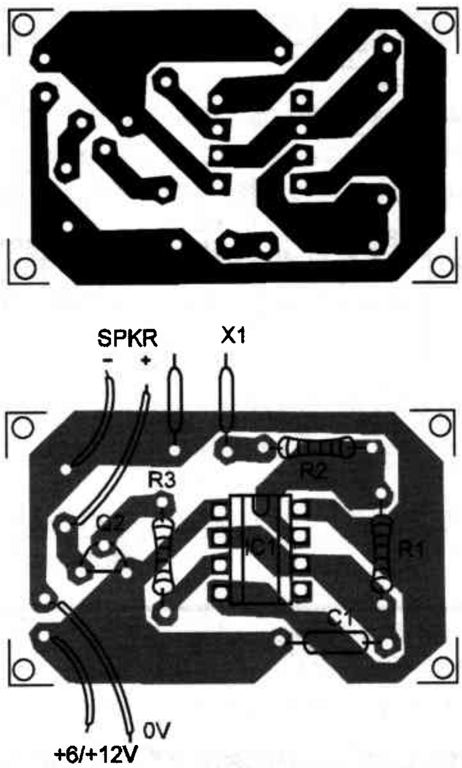


Figure 2

Ideas to Explore

To get better performance or to learn more about the circuit:

- Explain why the circuit doesn't operate using a neon or fluorescent lamp as a plasma medium.
- Explain what "plasma" is.
- You can alter this circuit to use it as a flame alarm.

Science applications:

- Off course, the basic idea of this project is to use it in an experiment involving plasma. Plasma is produced when an ionized gas loses electrons. The the gas converts in a “soup” of free electrons and ionized atoms.

- Use different kinds of flames, such as those produced by matches, gas, paper, etc., and compare their conductivity by the tone pitch.