Electronic Lab

500 in ONE

⚠ CAUTION

Make Sure you read the section on "Cautions" in "Hardware Entry Course" before starting projects with the "500 in ONE-Electronic Lab." Proceeding without following the directions in "Cautions" can cause injurles and material damage.

1 Hardware

Entry Course

The User's manual for the "500 ine ONE Electronic Lab" Consista of the following 3volumes.

Hardware, Entry Course (Project Nos.: 1-254)

You can learn about analog and digital circuits while having fun.
This volume also includes the following contents.
•Cautions •Names of each part and accessories •Introduction
•Preparations •Terms

Hardware, Adovanced Course (Project Nos.: 255-400)

Your understanding of analog and digital circuits will be enhanced further while having fun.

Software, Programming Course (Ploject Nos.: 401-500)

You will learn about programming from its fundamentals.
Programming has never been so enjoyablel.

Cautions:

1. **Make sure you read the sections on "Introduction" and "Preparations" in "Hardware-Entry Course" before starting projects with the "500 in ONE Electronic Lab."**
2. **Start with project numbers 1 through 5 since details on how to operate this kit are described in project numbers 1 through 5.**

CONTENTS

7) Electronic Decision-Makers

8) Operational Amplifier IC Can Do Many Things

9) Introducing the Power Amplifier IC

10) A Trip to Digital Land

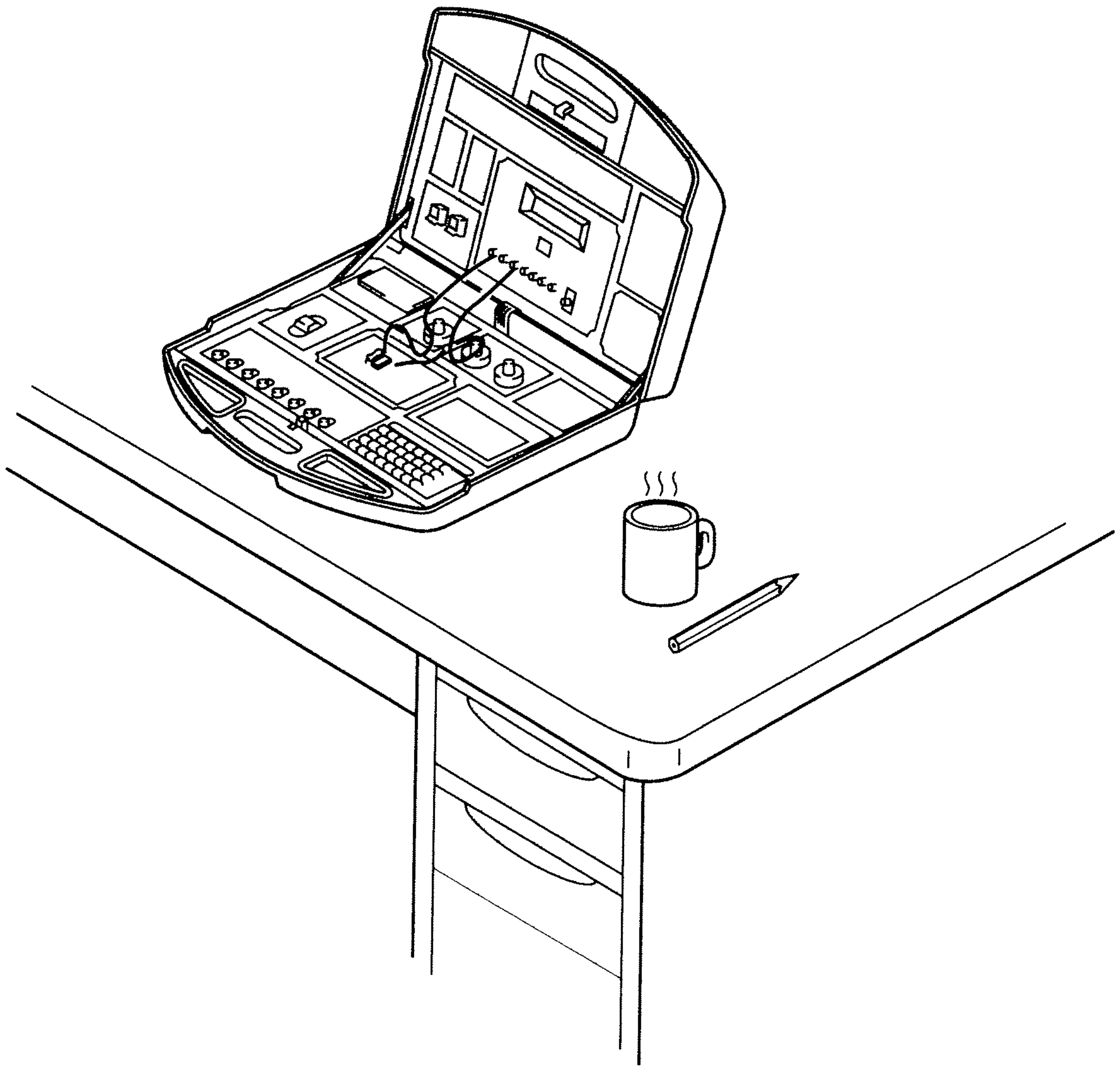
11) More Adventures in Digital Land

12) Circuits That Counts

13) Amusement in Digital Land

14) Surprise and Fun Revisited

15) Testing and Measuring Circuits



CAUTIONS

CAUTIONS FOR SAFETY

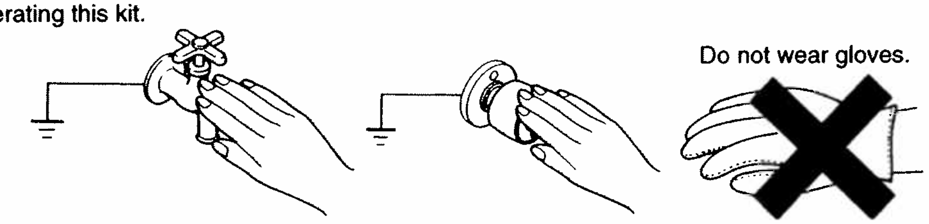
Read the following safety cautions thoroughly before using the "500 in ONE Electronic Lab," and operate this kit properly.

⚠ **CAUTION** ... Ignoring this sign when handling this kit can lead to injuries and material damages.

⚠ CAUTION
• Make sure you read the user's manual before operating this product. **• Do not swallow a battery or a small part by error. In the event that you do swallow such an object, immediately consult a physician.** **• Do not stick a component (electronic part) into your body. Doing so is hazardous, and may cause injuries and/or other ailments.** **• Use specified batteries only, and make sure their polarity (positive/negative poles) are set correctly.** **• Do not use old and new batteries, or different types of batteries, together.** **• Do not dispose a used battery into a flame. Doing so can cause injuries and other undesirable results.** **• Do not step on, or place heavy objects on top of the main body, and do not drop it. Doing so can crack the product and cause injuries. It can also cause failures in this kit.** **• Do not get your hand stuck when closing the attache case. Doing so can cause injuries.** **• Remove all wiring and batteries before closing the attache case. Closing the attache case without removing these objects can cause short circuits, and generation of heat and/or fire.** **• Use this product only as directed in the user's manual. Using them in other ways can cause short circuits, and generation of heat and/or fire.** **• Do not use this product for purposes other than those intended for it.** **• Do not connect ground or antenna wire to the power socket.**

GENERAL CAUTIONS

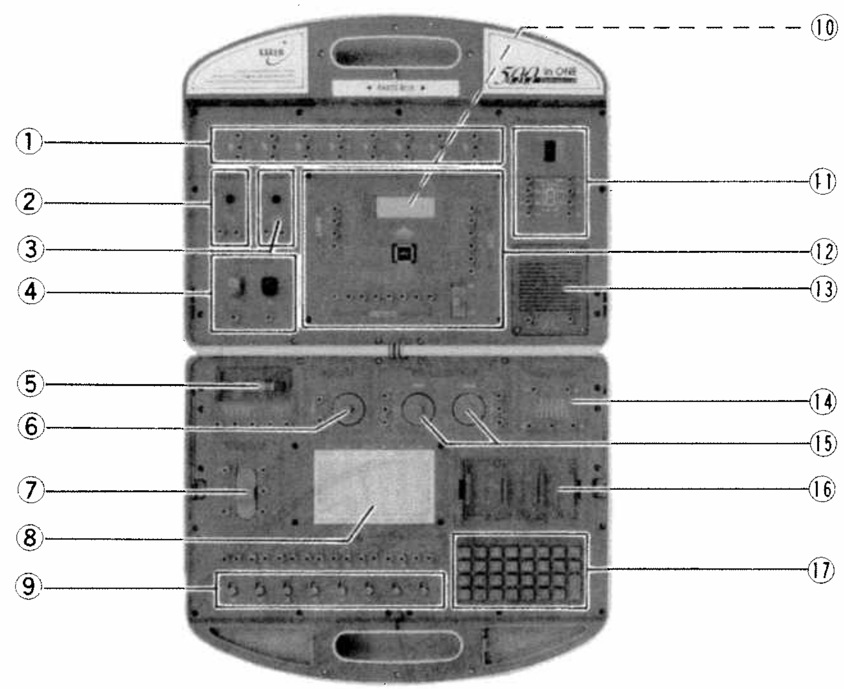
1. The absolute maximum voltage that can be applied to the CMOS IC (74HC series), that is used for this product, is 7.0 V. Do not apply a voltage that exceeds 7.0 V, for doing so can cause damage to the CMOS IC. Specifically, do not connect CMOS ICs between the breadboard's [-] and V5 (7.5V) or V6 (9V).
2. Do not open the battery compartment cover while assembling an experiment circuit. Objects such as components might get inside the battery compartment, and cause the battery to short, if the cover is open.
3. Make sure there is no inappropriate object, such as a component, inside the battery compartment when inserting batteries. After inserting the batteries, do not forget to close the battery compartment cover.
4. This kit uses a CMOS type IC. While CMOS ICs are ideal for this kit as they operate under a wide range of power voltages, their "substantially sensitive nature towards static" is a shortcoming. For this reason, each CMOS IC is inserted into a static resisting sponge. Make sure they are inserted back into this sponge for storage after using them. Use the kit at a location where static electricity is not likely to be generated, and touch a nearby grounded metal (such as a water faucet or door knob) to release your body's static energy. Additionally, do not wear gloves when operating this kit.



5. Remove the batteries when you do not plan to use the kit for a week or more. Never leave weak or dead batteries in the kit, since even "leak-proof" type batteries can leak hazardous chemicals if they are weak or dead.
6. Do not apply strong force to the glass surface of the LCD (liquid crystal display). Doing so will damage the glass.
7. Do not disassemble the kit.
8. Do not modify or alter the kit.
9. Do not place the kit under direct sunlight.
10. Do not spill water on the kit.
11. Make sure all wiring and batteries are removed, and the attache case is closed when you are not using the kit.

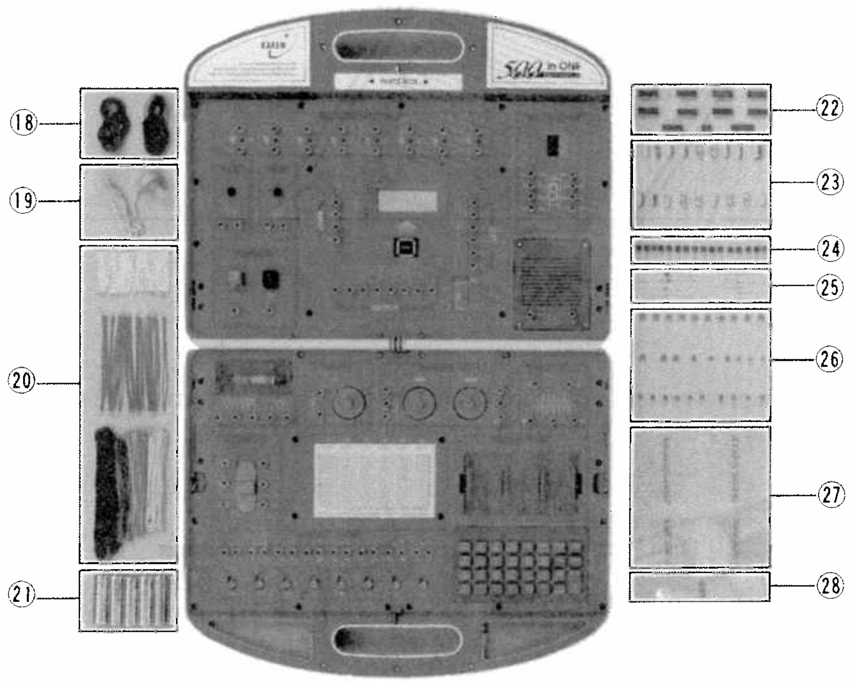
NAMES OF EACH PART AND ACCESSORIES

NAMES OF EACH PART



① LEDs
② Photo-transistor
③ CdS
④ Terminals
⑤ Antenna Coil
⑥ Tuning Control
⑦ Switch
⑧ Breadboard
⑨ Keys
⑩ LCD
⑪ LED Digital Display
⑫ Microcomputer
⑬ Speaker
⑭ Transformer
⑮ Control Volumes
⑯ Battery Compartment
⑰ Keyboard

NAMES OF ACCESSORIES



⑱ Wires
⑲ Earphone
⑳ Wires
㉑ Batteries
(Actual batteries may be different from the ones shown in the photo.)
㉒ ICs
㉓ Electrolytic Capacitors
㉔ Transistors
㉕ Diodes
㉖ Ceramic Capacitors
㉗ Resistors
㉘ LEDs

LIST OF ACCESSORIES

Name	Description	Q'ty
High-speed CMOS IC	74HC00	2
	74HC02	2
	74HC76	1
	74HC191	1
	74HC4511	1
	74HC4028	1
Operational Amplifier IC	324	1
Power Amplifier IC	546	1
Timer IC	555	1
Transistor (PNP)	2SA933A (R,S) or equivalent	8
Transistor (NPN)	2SC1740 (R,S) or equivalent	8
Diode	Germanium	1
	Rectifier (1N4001 or equivalent)	1
	Silicon (1S2473 or equivalent)	8
	Zener (RD4.7JSB1,B2 or equivalent)	1
Resistor	3.3 ohms, ±5%, 1/4W	1
	4.7 ohms, ±5%,1/4W	1
	33 ohms, ±5%, 1/4W	1
	68 ohms, ±5%, 1/4W	1
	100 ohms, ±5%, 1/4W	4
	270 ohms, ±5%, 1/4W	2
	470 ohms, ±5%, 1/4W	8
	680 ohms, ±5%, 1/4W	2
	1K ohms, ±5%, 1/4W	6
	1.8K ohms, ±5%, 1/4W	1
	2.2K ohms, ±5%, 1/4W	3
	2.7K ohms, ±5%, 1/4W	4
	3.3K ohms, ±5%, 1/4W	2
	4.7K ohms, ±5%, 1/4W	8
	5.6K ohms, ±5%, 1/4W	1
	6.8K ohms, ±5%, 1/4W	2
	8.2K ohms, ±5%, 1/4W	3
	10K ohms, ±5%, 1/4W	10
	12K ohms, ±5%, 1/4W	1
	22K ohms, ±5%, 1/4W	8
	27K ohms, ±5%, 1/4W	1
	33K ohms, ±5%, 1/4W	6
	47K ohms, ±5%, 1/4W	4
	100K ohms, ±5%, 1/4W	4

Name	Description	Q'ty
Resistor	150K ohms, ±5%, 1/4W	2
	220K ohms, ±5%, 1/4W	3
	330K ohms, ±5%, 1/4W	2
	470K ohms, ±5%, 1/4W	2
	1M ohms, ±5%, 1/4W	3
	1.5M ohms, ±5%, 1/4W	3
	1K ohms, ±2%, 1/4W	1
	1.5K ohms, ±2%, 1/4W	1
	2.18K ohms, ±2%, 1/4W	1
	2.45K ohms, ±2%, 1/4W	1
	2.74K ohms, ±2%, 1/4W	1
	3.27K ohms, ±2%, 1/4W	1
	3.67K ohms, ±2%, 1/4W	1
Ceramic Capacitor	10pF, ±5%, SL, CH	1
	33pF, ±5%, SL, CH	1
	100pF, ±5%, SL, CH	1
	470pF, ±5%, SL, CH	1
	0.001μF, ±10%, B	3
	0.0047μF, ±20% B	3
	0.01μF, ±20%	6
	0.022μF, +80/-20%	1
	0.047μF, +80/-20%	2
	0.1μF, +80/-20%	10
Electrolytic Capacitor	0.47μF, 50V	2
	1μF, 50V	3
	3.3μF, 50V	1
	10μF, 16V/25V/35V/50V	8
	100μF, 10V/16V/25V	3
	470μF, 10V	1
Earphone	Ceramic Type	1
Wire	5cm (White)	50
	10cm (Red)	30
	20cm (Blue)	15
	30cm (Yellow)	10
	40cm (Orange)	10
	50cm (Black)	10
	300cm (Green)	2
Batteries	AA Type	6
User's Manual	Hardware Entry Course	1
	Hardware Advanced Course	1
	Software Programming Course	1

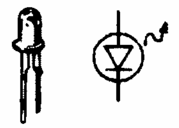
INTRODUCTION

Maxitronix® 500 in ONE Electronic Lab teaches you different electrical parts, how to read a schematic, how to make 500 projects without any soldering or tools, and how all 500 projects work. Of these, 100 projects teach you basic of programming.

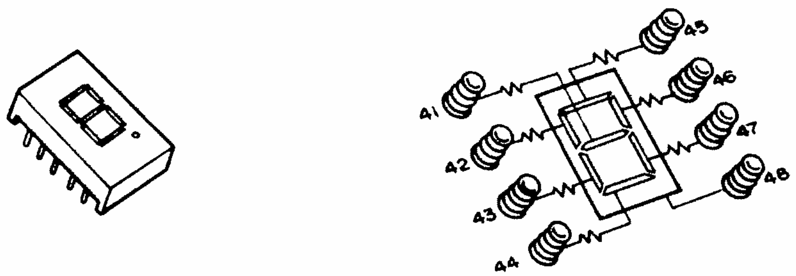
UNDERSTANDING PARTS ON THE KIT

You have probably noticed many different terminals, switches, and controls that are already on the kit and the many colored wires and pieces that you will use to build the projects. The following descriptions explain the purpose of each one of these parts so you can understand what each part does and why you can use it in the different projects.

LEDs — are Light Emitting Diodes and are located on the upper left of the upper case. These work just like other diodes (see next section for diodes), except that LEDs light when current flows through them. There are eight LEDs in your kit.



LED Digital Display — is an arrangement of seven tiny LEDs called segments. The seven segments form an outline that you can use to display numbers and some letters. The display's resistors are already connected inside the kit. The diagram between the spring terminals next to the display shows this connection.



Cadmium Sulfide Cell or CdS Cell — is a special semi-conductor device that is like a control volume, except that the resistance of this device changes with the amount of light that falls on its face. To vary the resistance of a control volume you rotate the knob; to vary the resistance of a CdS cell, you permit more or less light to fall on the front of the cell.

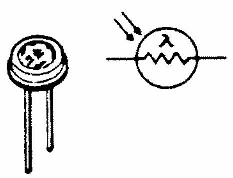
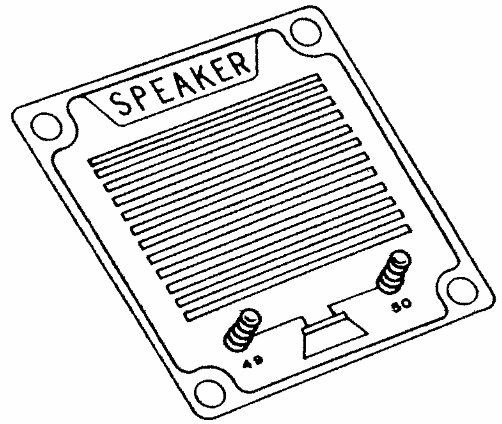


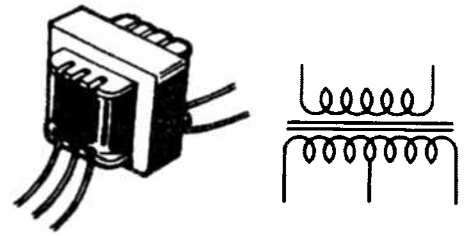
Photo-transistor — is a special semi-conductor device which receives light and converts into current. The amount of current flowing into the photo-transistor depends on the amount of light received.

Speaker — converts electrical energy to sound you can hear.

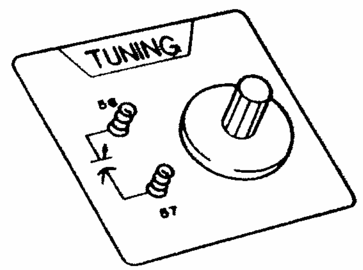


Antenna Coil — is a coil of wire wrapped around a dark colored rod made of ferrite, a special form of powered iron. It is used in radio circuits to pick up the signals. It is under the window marked ANTENNA.

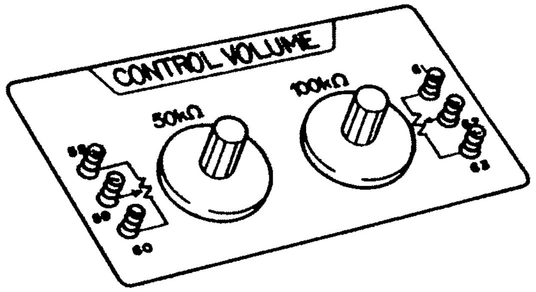
Transformer — constructed of plastic wound with hundreds of turns of very fine copper wire. Thin metal plates called lamination are in the center of the plastic form. It is used to match the output of the circuit to the output of the speaker or earphone.



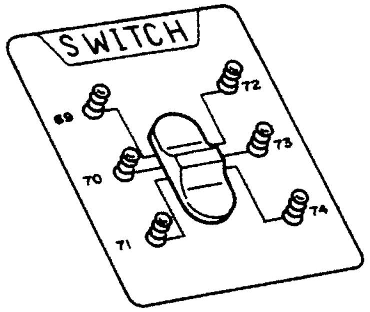
Tuning Control — is a capacitor with a value that changes when you turn its knob. This is called a variable capacitor. It is used in radio circuit to tune to a specific frequency.



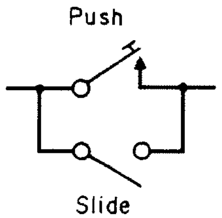
Control Volumes — let you change resistance values so you can adjust light, volume, movement, and much more.

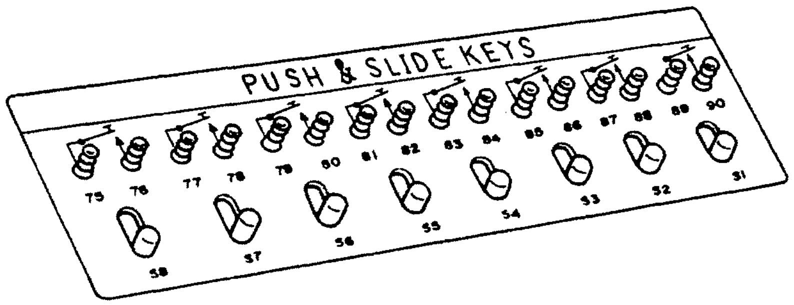


Switch — connects or disconnects electrical circuits. The one we are using is a double-pole, double-throw switch. It can control two different circuits and can switch them into two different modes of operation.

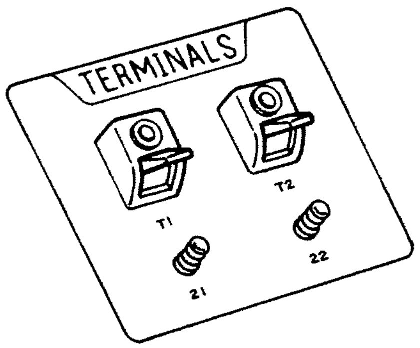


Push & Slide Keys — serve as push switches and slide switches. The push switches are another type of switch that let current flows when you press the key. When you release the key, the key stops the flow of current. This kit has eight keys. The slide switches connect or disconnect electrical circuits. The ones we are using are single pole, single through only when it is set to OFF position as shown below:

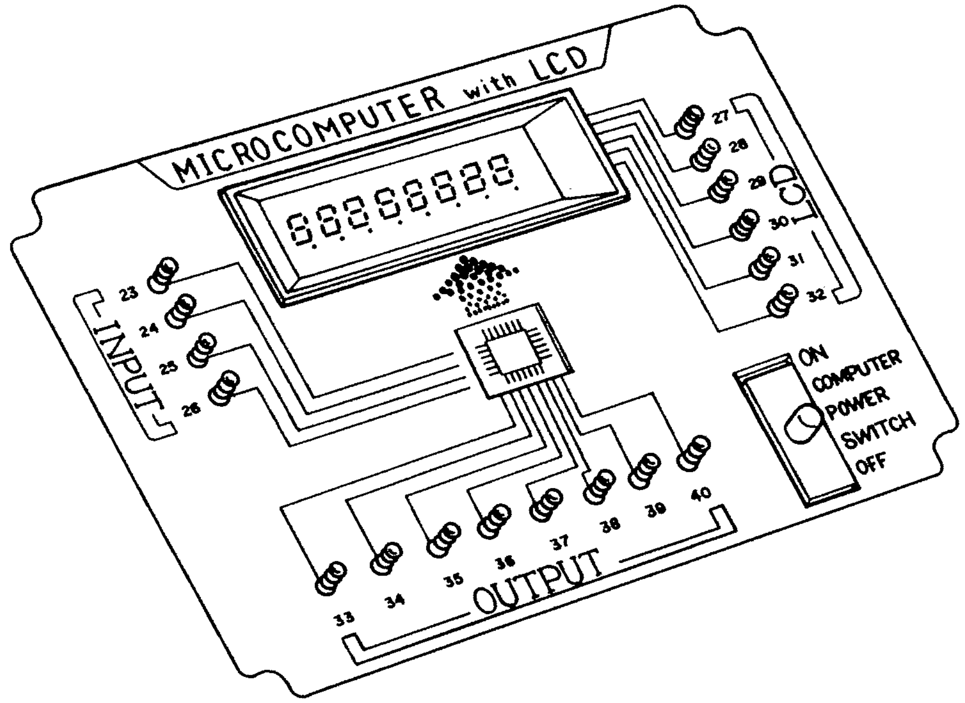




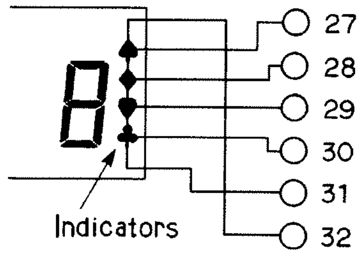
Terminals — connect external devices for this kit, such as an earphone, antenna, chassis ground, etc. The kit has two terminals labeled **T1** and **T2**.



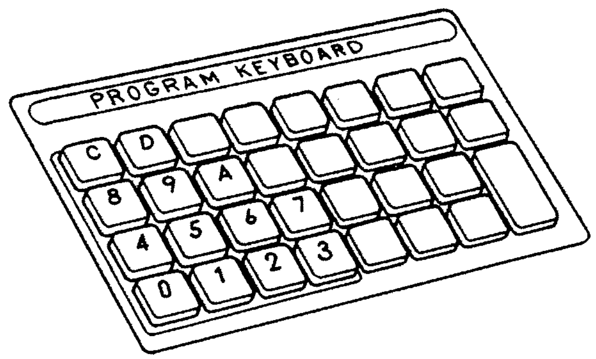
Microcomputer with LCD — consists of a 4-bit microcomputer with RAM (Random Access Memory) which can store the programming steps you enter, and LCD (Liquid Crystal Display). The LCD consists of 8-digit character display and four indicators. To enable the microcomputer section, the power switch must be set to ON (up) position.



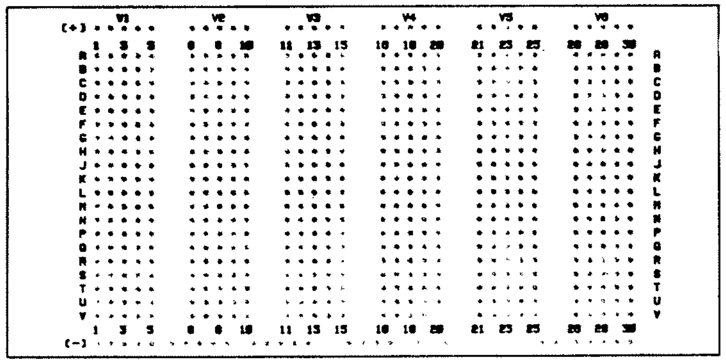
The four indicators are used for the projects other than the software projects, and work with the power switch set to OFF (down) position. The inter connection of each indicator is shown below:



Program Keyboard — is a input device used for programming, etc.



Breadboard — connects the parts you will use to make the 500 projects. You will wire a major portion of the projects on the breadboard. The board has 665 small holes. These are grouped by row and column as follows:



- The bottom row is connected to the negative (–) side of the batteries. The top row is connected to the positive (+) side of batteries. The remaining rows let you connect parts to each other and to the top and bottom rows for projects.
- Each of six columns (excluding the bottom negative (–) row) connect differently, but the five holes across one column provide the same connection point. That is, the first hole in the ROW **A** (first column) is electrically the same point as the second, third, fourth, and fifth holes. The sixth hole is a different, because it belongs to the next column. For example, if you want to connect a part to ROW **B**, first column, you can connect the part to any of the five holes.
- The markings for the middle section of rows are **A** through **V**, excluding I and O, and **1** through **30** for the hole number.
- The markings for the top row's columns are grouped as **V1 - V6**. Each column (group) connects to the positive (+) side of a battery: **V1** connects to the first battery; **V2** directly connects to the second battery, but also connects to the first battery through the second battery; **V3** directly connects to the third battery, but also connects to the first and second battery through the third battery, and so on. Each battery provides 1.5 volts, so **V1** provides 1.5 volts, **V2** provides 3 volts, and so on. As you go through projects, you will find some schematics show different voltage requirements for different parts of the schematic. Be sure you use the correct voltage supply groups.
- The marking for the bottom row's columns is a negative sign (–) and a straight line that indicates that all the holes are connected to the same point. It does not matter which hole you connect to.

Thus, the total number of connection points on the board are 30 holes of 6 groups for positive (+) power supply, 35 holes of 1 group for negative (–) power supply, and 600 holes of 100 groups for mounting parts.

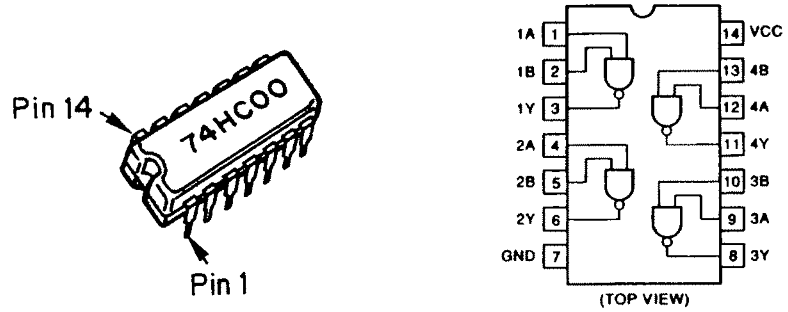
IDENTIFYING THE SEPARATE PARTS

The kit includes many small parts you will use to build projects. Use the following explanations and the chart in "Reading a Schematic" to identify the separate parts and their purpose.

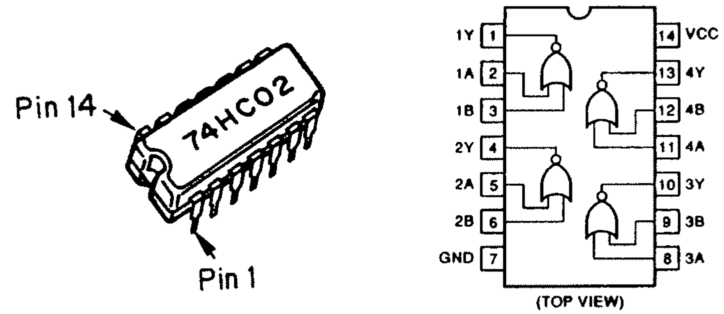
Integrated Circuit or IC — is a package of hundreds of other components, transistors, diodes, resistors, etc. This kit includes nine kinds of ICs. The ICs require electric power to operate. The notch on the IC shows the direction of the IC. The pin left to the notch is Pin 1 of the IC. Then count downward for the pin numbers. When you reach the end of the IC, move across to the right and count up. Try counting with the IC labeled 74HC00. If you count the pin right of the notch as Pin 14, you counted correctly. Remember this, because it is very important to correctly identify the IC pin numbers.

The various ICs are as follows:

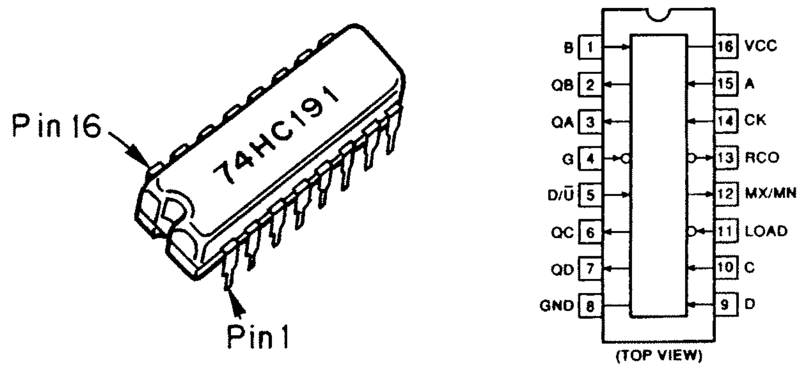
- **NAND IC** — has the number 74HC00. (Other letters or numbers might appear before and after this number, but these are codes for IC manufacturers and mean nothing for our work.) This and the NOR ICs are Gate ICs. These ICs change the output signal status depending on the level of input signals. The NAND IC's output is low (about 0 volts) when both inputs are high (about the power supply voltage VCC). The NAND IC has four NAND gates. See the following diagram.



- **NOR IC** — carries the number 74HC02. The output is low when either of the inputs (or both) are high. See the following diagram. This IC also has four gates.

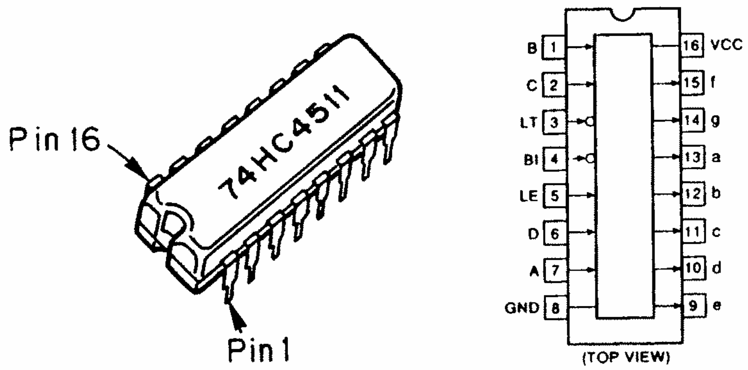


- **Counter IC** — carries the number 74HC191. This IC counts the number of pulses applied to the input pin and outputs the number of counts. The way it counts is binary. Also, the IC can count up or down.

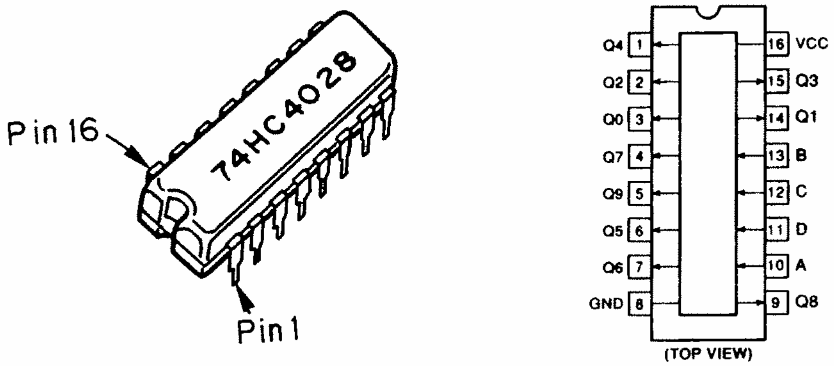


To count up (0-1-2-....), connect Pin 5 to logical 0 (ground). To count down (15-14-13-...), connect Pin 5 to logical 1 (high).

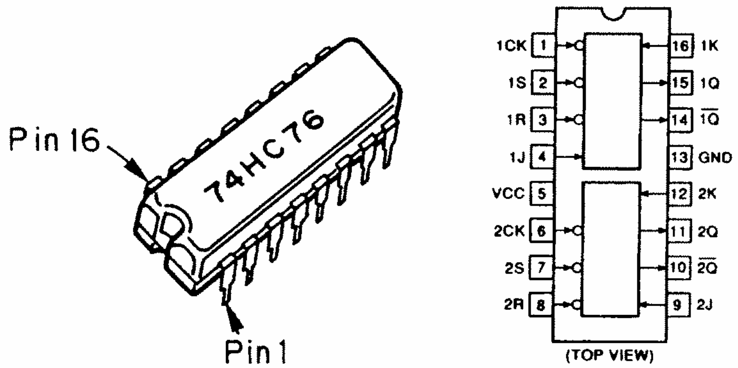
- **BCD to 7-Segment Decoder IC** — carries the number 74HC4511. This IC decodes the BCD input to a normal number and displays it on the LED display.



- **BCD to Decimal Decoder IC** — carries the number 74HC4028. This IC decodes the BCD input to a normal number.

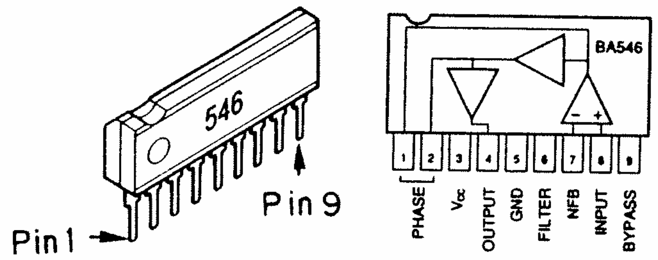


- **Flip-Flop IC** — carries the number 74HC76. When a pulse input occurs, the IC's output changes. Each time it receives a signal, the output "flips" and "flops." This IC has two independent flip-flop circuits.

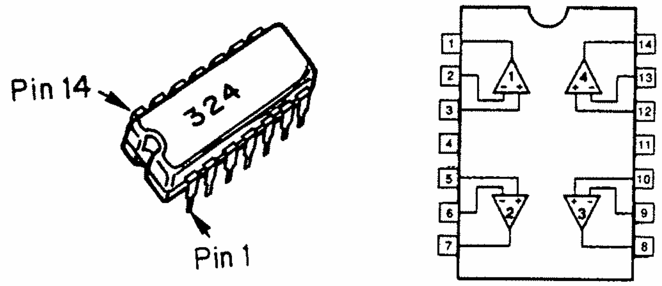


- **Timer IC** — carries the number 555. This IC is used to make a timer circuit.

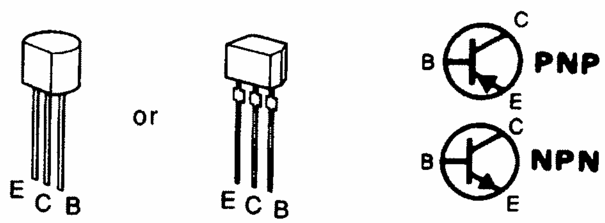
- **Audio Power Amplifier IC** — carries 546 marking. This IC increases (amplifies) the audio frequency signal level. Audio frequency signals have a frequency level that you can hear.



- **Operational Amplifier IC** — carries 324 marking. In this kit, you will mainly use this IC as a comparator. A comparator compares the level of the two input signals. When the level applied to the positive (+) terminal is higher than the level of the negative (–) terminal, the output becomes high.



Transistors — have three pins named emitter, collector, and base, from left to right with the flat side facing you. The transistor changes the current flow from its collector to emitter depending on how much current flows into the base. With this characteristic, you use transistors as switches, amplifiers, and oscillators.



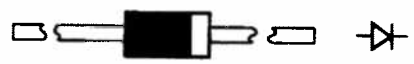
The PNP transistor may be labeled as 2SA or some other letters.

The NPN transistor may be labeled as 2SC or some other letters.

Diodes (except Zener Diode) — let current flow through them in one direction. The current flows only from anode to cathode. The diodes have a band on the cathode side. On schematics, diodes are shown as triangle arrow. The current flows in the same direction of the arrow. The kit includes four types of diodes:

- **Zener Diode** — has a set standard, or zener, voltage. When the voltage applied in reverse direction to the arrow exceeds the zener voltage, the diode lets current flow from cathode to anode and a stable zener voltage is obtained. The zener diode is the smallest. Glass-type diode. The kit contains only one.

- **Rectifier Diode** — is black. Plastic-type diode. The kit contains only one.

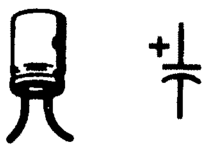


- **Germanium Diode** — is the longest. Glass-type diode. The kit contains only one.

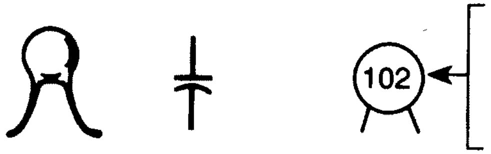
- **Silicon Diodes** — are other than above three types. Glass-type diode. The kit contains eight.

Capacitors — carries a three-digit number that tells you its value (electrostatic capacity). The first two digits indicate the value, and the last one indicates the number of zeros that follow. If a capacitor carries the number "104," it means that the value is 10 and is followed by four zeros. So, the capacitor is 100,000pF (this is the unit of electrostatic capacity). But in schematics you'll see in this manual, a larger unit, μF, is used to indicate the capacitor value. 1μF is equivalent to 1,000,000pF, so 100,000pF = 0.1μF. There are two types of capacitors:

- **Electrolytic Capacitors** — is tubular with a negative symbol (–) at one end. When building a project, you must correctly connect the negative (–) side of an electrolytic capacitor.

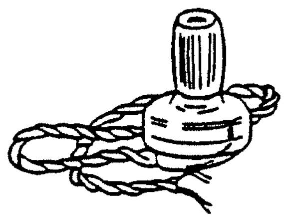


- **Ceramic Disc Capacitors** — are disc type and brown. You can connect them in any way.

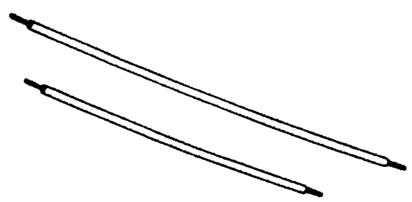


33: 33pF
101: 100pF
471: 470pF
102: 0.001μF
472: 0.0047μF
103: 0.01μF
223: 0.022μF
473: 0.047μF
104: 0.1μF

Earphone — lets you listen to sounds through it instead of the speaker. It also uses less current than the speaker.



Wires — connect one row to another row, a column to another column, or the breadboard to a switch or terminal. There are six different colors of wires in different lengths. All the wires work the same way, but are different lengths and colors so you can easily identify which wire you want to use.



Resistors — oppose the flow of current. They are brown tubular objects with color bands around them. The color bands show the resistor's value. The value determines how strongly the resistor opposes to the current flow. We measure the value in a unit called ohms. See "Using Resistors" for more information.

USING RESISTORS

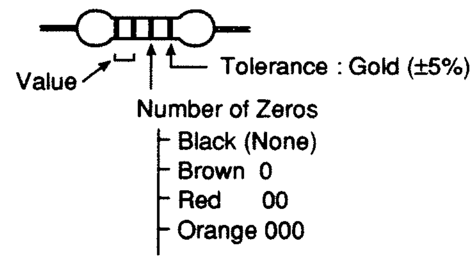
Use the following chart and explanation to learn a color band's value and how to use it.

Black	= 0	Green	= 5
Brown	= 1	Blue	= 6
Red	= 2	Violet	= 7
Orange	= 3	Gray	= 8
Yellow	= 4	White	= 9

There are two types of resistors — a four-band and a five-band.

Find one of the four-band resistors. Hold the resistor with gold band to the right. The first two bands from the left show the value. If they are red and red, the value is 22. The third band shows the number of zeros after the value. If it is yellow, then the number of zeros is 4. So the resistor is 220,000 ohms. To shorten the value name, we use the k symbol to- equal 1,000; so, 220,000 ohms equals 220k ohms. Try figure out the value of the resistors with following color bands:

1. orange-orange-red
2. yellow-violet-yellow
3. red-violet-brown
4. brown-black-green

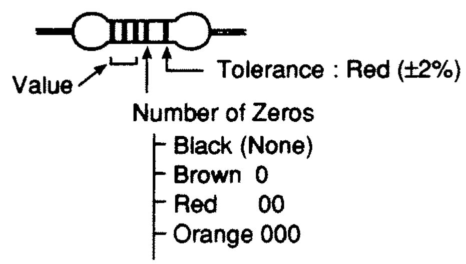


The answer is:

1. 3,300 ohm or 3.3k ohm
2. 470,000 ohm or 470k ohm
3. 270 ohm
4. 1,000,000 ohm (we use another unit for million - capital letter M for Mega. So this is 1M ohm.)

The gold band indicates that the resistors are of 5% tolerance. The resistors might have slightly different resistance from the value shown, within 5%.

Now find the resistors with five bands. They have a red band at an end and more space separates this band from the other four bands than there is between the four bands. This red band means these resistors are of 2% tolerance.



Hold one of these resistors with red band for tolerance to the right. With these resistors, the three bands from left show the value and the fourth band (the closest one to the tolerance band) shows the number of zeros.

For example, one of the resistors is red-brown-grey-brown.
The first three bands represent the value, so it is 218. We need to add one zero (brown is 1), so the actual value is 2,180 ohm, or 2.18k ohm. To easily remember where to place the decimal point, you simply replace the comma with the decimal point.

READING SCHEMATICS

At first, schematic diagrams might look difficult -- but they are actually quite simple once you get some practice with them. Don't get discouraged if you get confused at first. That's normal. Before long, you can build a circuit just by looking at its schematic diagram.

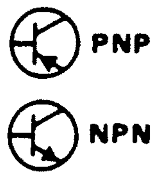
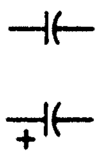
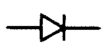
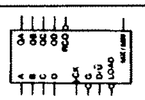
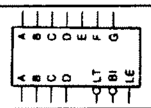
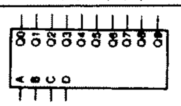
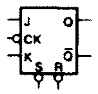
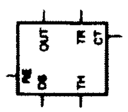
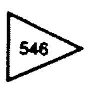
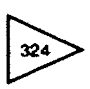
Schematics let you quickly see what happens during connection and how the current flows in the circuit. A schematic diagram is a road map for electronic circuits. Electronics technicians and engineers can build entire circuits with nothing more than a schematic diagram to guide them. While using this kit, you can learn how to build circuits from just the schematic.

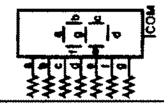
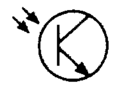
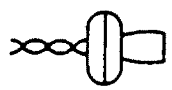
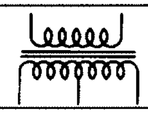
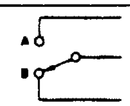
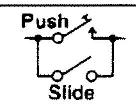
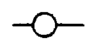
Notice on the following schematic that some lines cross each other and there is a dot at the point where they cross. This means that the two wires represented by the lines are connected together at the point indicated by the dot. If two lines cross without a dot, that's your clue that the wires aren't connected.

Lines Are Connected ─•─ / ─┼─ Lines Not Connected

Often a schematic diagram does not indicate the power supply (+ and –) for ICs so the diagram is easier to read. This is how the kit's schematics are made. Yet, the ICs must always connect to power. To show you how to connect to power, we provided the power connections in a separate diagram. The other parts are already mounted on the board. See the spring terminal number shown next to the part. Don't confuse this number with the IC pin numbers.

Use the following chart to read the schematic.

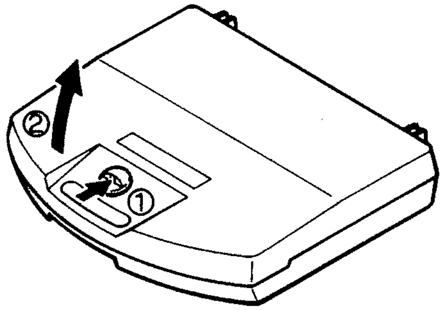
Symbol	Name	Physical	Description
	R	Resistor	Opposes current flow.
	Q	PNP Transistor NPN Transistor	Changes the current flow from its collector to emitter depending on how much current flows into the base and vice versa (PNP).
	C	Ceramic Capacitor Electrolytic Capacitor	Stores electric energy.
	D	Rectifier Diode Germanium Diode Silicon Diode	Lets current flow through them only in one direction.
	ZD	Zener Diode	Passes current only when the applied voltage is over a certain level.Stable veference voltage can be obtained.
	U	IC 74HC00 (NAND Gate)	Outputs low voltage when both inputs are high.
	U	IC 74HC02 (NOR Gate)	Outputs low voltage when either or both inputs are high.
	U	IC 74HC191 (Counter)	Counts the number of pulses applied to the input and outputs the number of counts .
	U	IC 74HC4511 (BCD to 7-Segment Decoder)	Decodes the BCD input and display it on the LED display.
	U	IC 74HC4028 (BCD to Decimal Decoder)	Decodes the BCD input to a normal number.
	U	IC 74HC76 (Flip Flop)	Changes ouptut when a pulse input occurs.
	U	IC 555(Timer)	Takes a certain time upon receipt a trigger input.
	U	IC 546 (Audio Amplifier)	Amplifies the audio frequency signal.
	U	IC 324 (Operational Amplifier)	Compares two input signals and outputs its result.

Symbol	Name	Physical	Description
	LED1	LED	Emits light when current flows through it.
		LED Digital Display	Displays numbers or some letters.
	CdS	CdS Cell	Changes resistance value with amount of light that falls on it.
	PHOTO-TRANSISTOR	Photo-transistor	Flows current with amount of light that falls on it.
	SPEAKER	Speaker	Converts electrical energy to sound you can hear.
	EARPHONE	Earphone	Lets you listen to sounds through it.
		Antenna Coil	Picks up the radio signals.
	OPT	Transformer	Matches the output of the circuit to the speaker.
	VC	Tuning Control	Lets you tune to a specific frequency.
	VR	Control Volume	Lets you change resistance values.
	SW	Switch	Connects or disconnects electrical circuits.
	S1	Key	Lets current flow when you press it.
	T1, T2	Terminal	Connect external devices.

PREPARATION

OPENING THE ATTACHE CASE

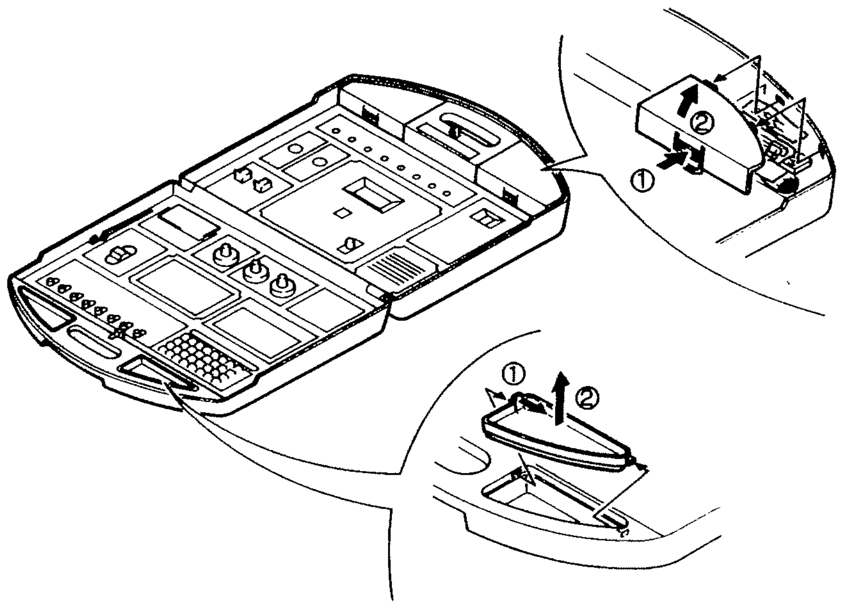
Push the knob and open the upper case in the direction of the arrow.



TAKING OUT THE PARTS

The parts for building the projects are stored in the upper case. Push the claw of the parts cover and remove it in the direction of the arrow. Remove two parts covers on both sides to take out all parts.

In the lower case, two parts trays are provided. You can put parts on them. Under the parts tray, there is space for saving parts. To remove the parts tray, push the knob of the parts tray innerward a little and detach the parts tray upward.



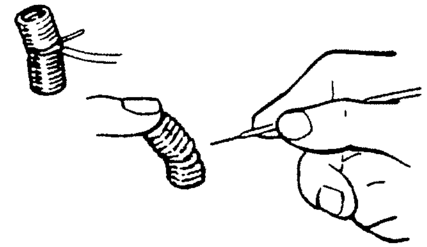
SORTING THE PARTS

To help you easily build the projects, sort the separate parts by part name, value, etc. Use several small boxes, or one box with divided sections (such as an ornament box or a shelf of a hardware box) for each group of parts. Label the box or section of box so you can easily find the part you want. For example, label a box or section "6.8k Resistors."

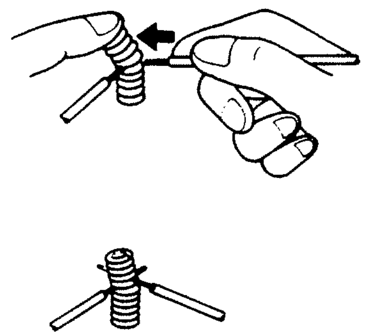
TIPS FOR CONNECTIONS

The kit has specially designed spring terminals and easy-to-use breadboard to make connections easy. Use th following tips when connecting terminals. You might want to practice connections before you begin a project.

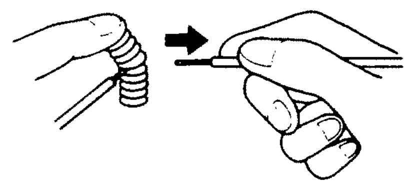
- To connect a wire to spring terminals, bend the spring to one side and insert the wires into the opening.



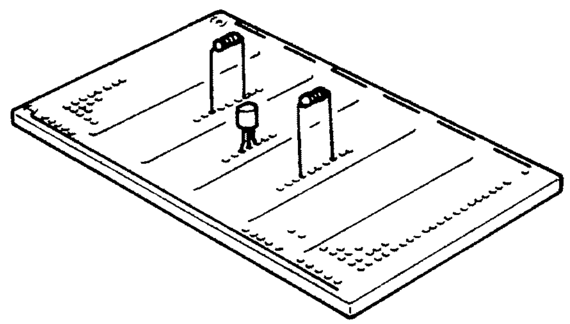
- To insert more than one wire into a spring terminal without disconnecting the first wire, bend the spring toward th side with the first wire.



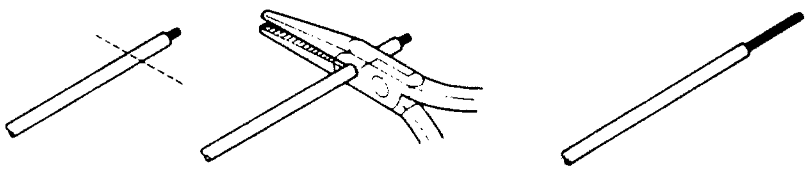
- To ensure proper connection, insert only the exposed part of the wire (lead) in the spring terminal. If you insert the wire's plastic insulation into the terminal, electrical contact won't occur and the circuit won't work.



- To remove wires from a spring terminal, bend the terminal and pull the wires from the terminal.
- To properly insert resistors, capacitors, and diodes into the breadboard, keep the pins from touching each other. Also, you might have to bend the pins or pull them apart to reach the contact points you need.



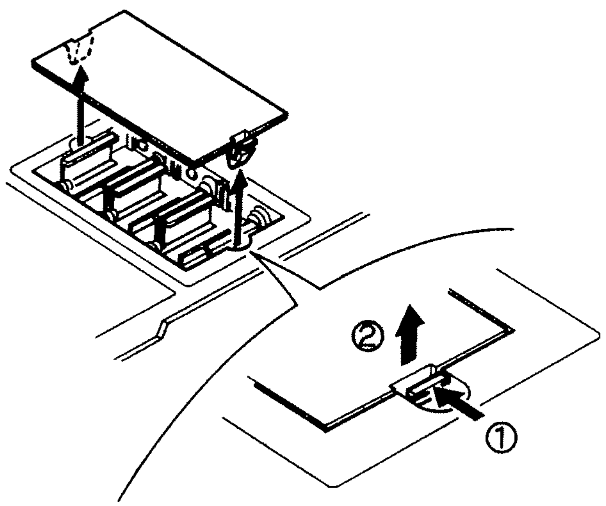
After using your kit for a while, some of the exposed wire ends might break off. If this happens, just remove 3/8 inch of insulation from the broken end and twist the strand together. You can remove the insulation with a penknife or wire stripper cutter.



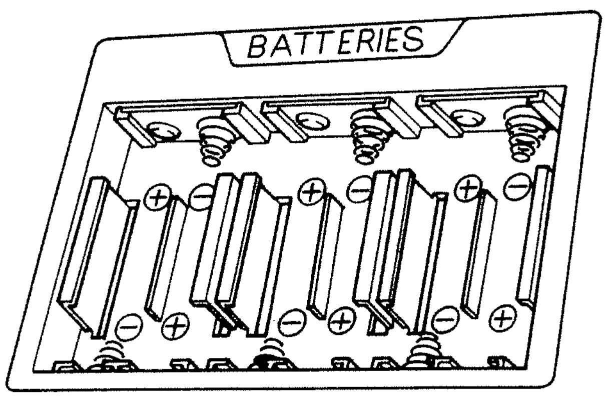
INSTALLING BATTERIES

The kit requires six AA batteries. We recommend alkaline batleries for longest life.
Follow these steps to install batteries.

1. Push the claw ends on both sides of the battery compartment cover and detach the cover upward.



2. Install the batteries observing the polarity symbols (+ and -) marked inside the compartment. The + end of a battery is the one with the small metal cap.

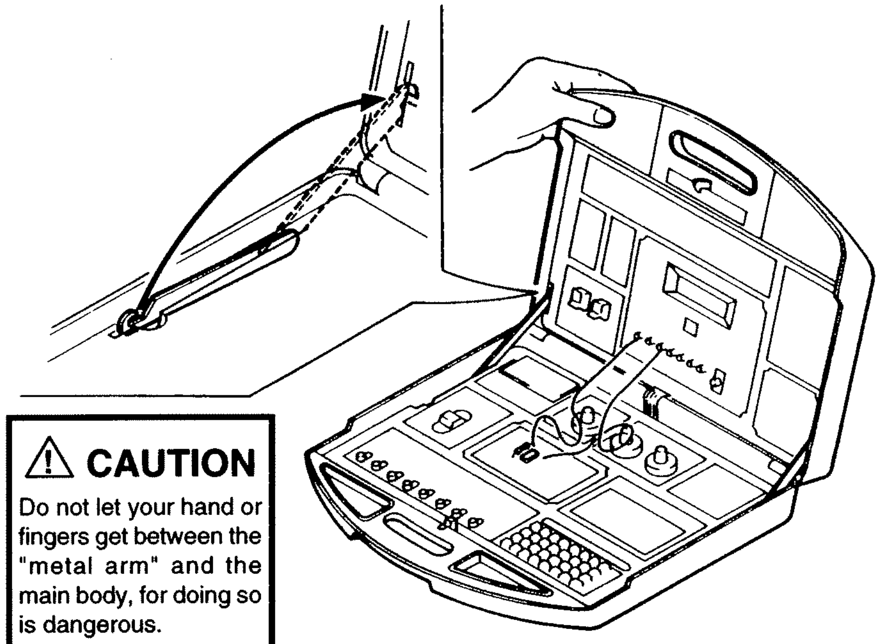


3. Replace the battery compartment cover.

SETTING UP THE ATTACHE CASE

Have the attache case completely open when assembling a project. After the assembly, lift the upper case and, while holding the upper case with your hand, secure its position by hooking the lower case's metal arm to the upper case's shaft, as shown in the diagram (do this at both sides). It becomes easier to view the display under this condition.

Cautions:
1. **Always secure the metal arms to the upper case while holding the upper case with your hand.** The upper case will drop if you release your hand, which may hit your hand or cause failures in the kit.
2. Pressing the upper case backwards will flip the kit. Be careful not to flip the kit.



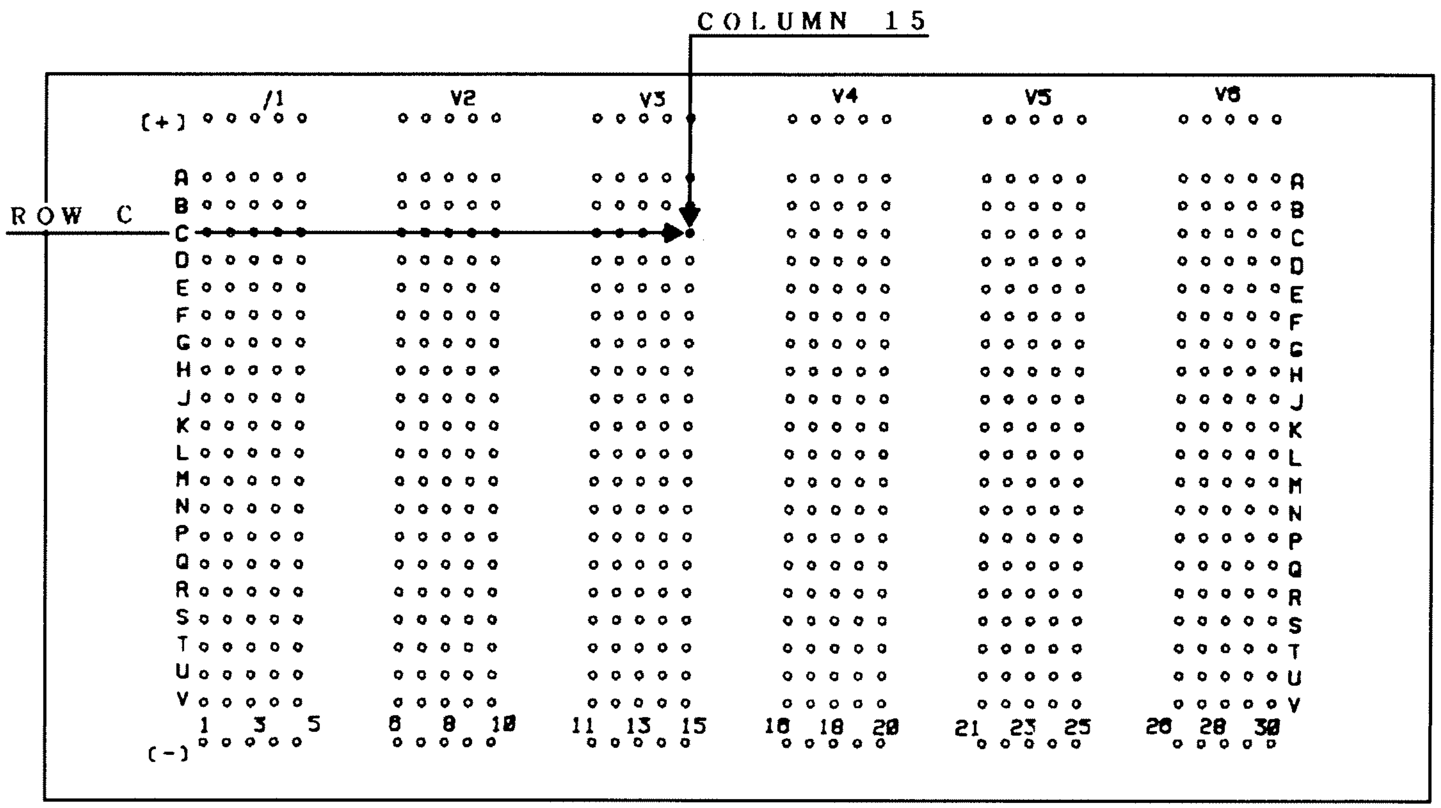
⚠ CAUTION

Do not let your hand or fingers get between the "metal arm" and the main body, for doing so is dangerous.

GETTING STARTED

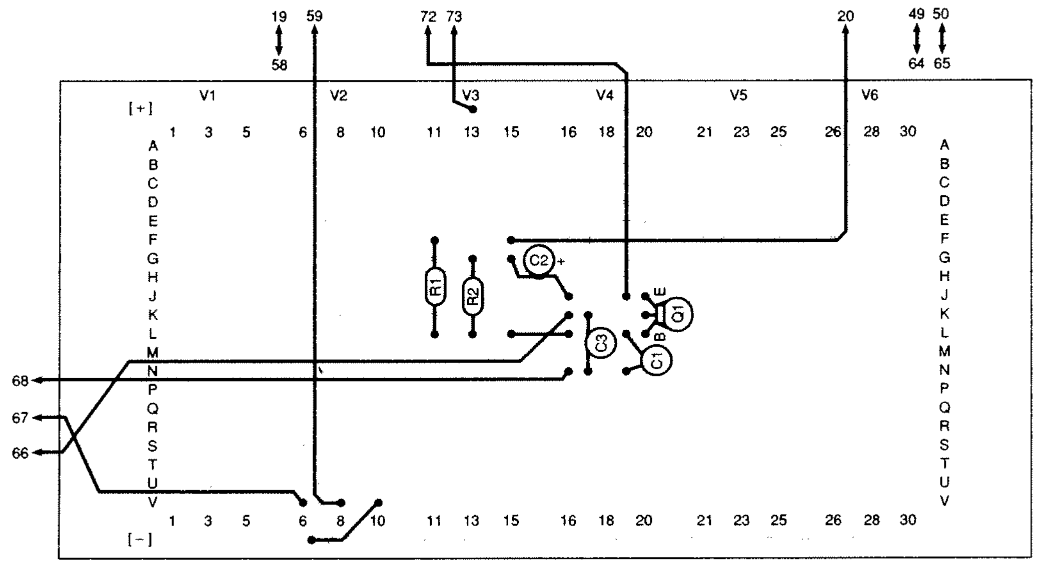
In the following projects, we will take you step-by-step through the first few projects. Then, we will gradually let you discover how to build the projects using the schematic. We recommend that you start at Project 1 and follow each project in numerical order. Otherwise, if you skip projects, you might miss valuable information. If you do choose to skip projects, be sure you complete Project 1 and 5.

For easy reading, the row and column number are used to indicate each hold location in the breadboard. For example, if the project requires a connection at Row **C**, column **15**, the instructions will say **C15**.



1) Surprise and Fun

PROJECT 1. LIGHT-CONTROLLED BIRD



Q1	PNP	C1	0.047µF
R1	10KΩ	C2	100µF
R2	1KΩ	C3	0.1µF

Here's an electronic bird that will sing for you from morning till night ... but his singing changes as it gets near sundown.

Follow the sections one at a time and step-by-step.

Parts You Need

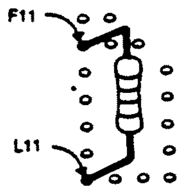
For this project, you need the following:

One 10K Resistor
One 1K Resistor
One PNP Transistor
One 0.047µF Ceramic Capacitor
One 100µF Electrolytic Capacitor
One 0.1µF Ceramic Capacitor
12 Wires

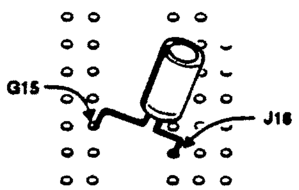
Connecting Components

Follow these steps or the schematic to make this project.

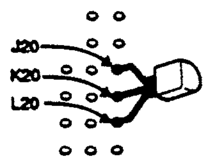
1. Insert the 10K Resistor in **F11** and **L11**.



2. Insert the 1K Resistor in **G13** and **L13**.
3. Insert the negative side of the electrolytic capacitor in **G15** and the positive side in **J16**.

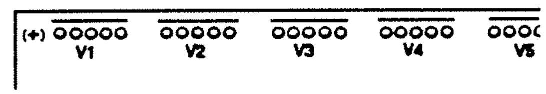


4. Insert the 0.1µF ceramic capacitor in **K17** and **N17**.
5. Insert the 0.047µF ceramic capacitor in **L19** and **N19**.
6. Insert the PNP transistor's emitter pin in **J20**, the collector pin in **K20**, and the base pin in **L20**. (The flat side of the transistor faces left).



Connecting Wires

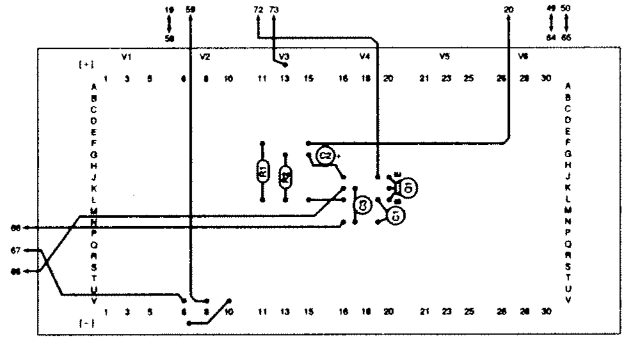
Connect the wires between the holes as indicated or between the hole and terminal. For example, **+V3 - 73** means that you connect a wire to the third section of the positive row of holes and to spring terminal **73**. Connect this wire as instructed.



V10 - (-) means that you connect a wire between Row **V/** Column **10** and any hole in the last row of holes, which is marked with the negative sign. (**V10** does not have a + sign in front of it so you know it is the Row **V**, Column **10**, and not the top row of holes). Connect this wire as instructed.

Make the rest of the connections as follows.
V6 - 67, V8 - 59, L15 - L16, F15 - 20, K16 - 66, N16 - 68, J19 - 72, 19 - 58, 49 - 64, 50 - 65.

The project should look like the following diagram.



Turning on the Project

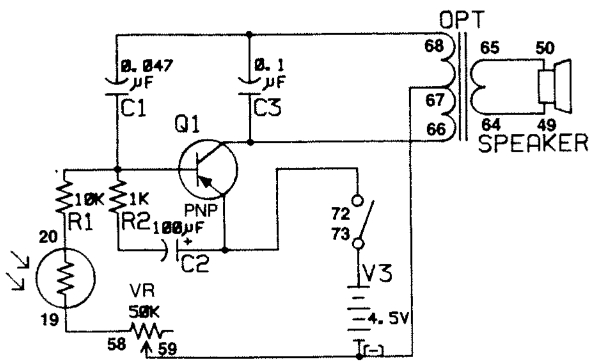
Now that you have finished all connections, press the switch toward the word **SWITCH**. This turns on the power. The sound of a chirping bird comes from the **speaker.**

Try varying the amount of light that falls on the **CdS cell** — cover it with your hand or shine a flashlight on it. Notice the chirping becomes faster in bright light. You can also alter the chirping rate by turning **control volume**.

If the project does not work as it should, check all connections and see "Tips for Connections."

How It Works 3/27/07

First compare your connections to the wiring diagram. Then, compare your connections to the schematic. Notice the different shapes for each component. (See "Reading Schematics").



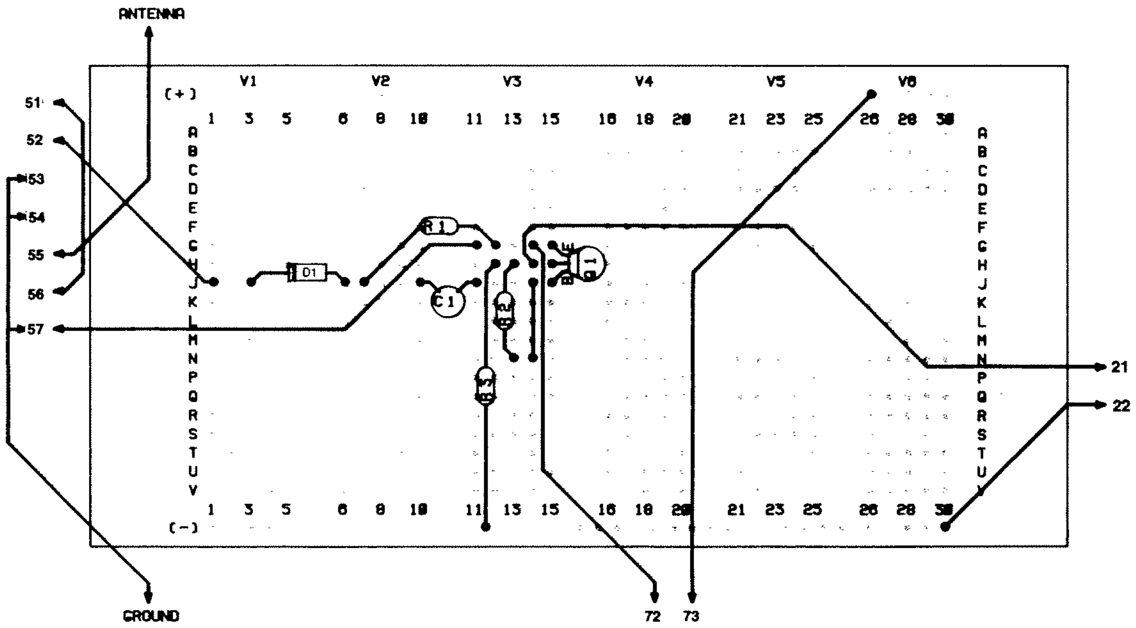
You see that on the schematic all the parts seem to be connected to each other. So, if you used the schematic to make connections, you would connect the parts so they would connect to each other through the breadboard. For example, find the 0.047µF ceramic capacitor on the schematic by its symbol and C1. Follow the line coming from the top of the capacitor's symbol. You see that C1 connects to the C3 capacitor, terminals **68**, **67**, and **66**, the transistor, all of the resistors, the electrolytic capacitor, terminal **72** and so on.

How can it be connected to all these parts when you only connect it in one place? Remember that all five holes on the same row and same group connect to the same point. For example, if you connect one pin of a resistor to the same row as a capacitor's pin, you are connecting the resistor to the capacitor. Furthermore, if the resistor's other pin connects to a row with a wire that connects to a terminal, you automatically connected the terminal to the resistor and the capacitor.

Now look at the kit. Terminal **19** is a terminal for the **CdS cell** and Terminal **58** is a terminal for **control volume**. You connected the **Cds cell** to the **control volume**. When you turn the **control volume**, it sends a signal to the **Cds cell** which alters the chirping sound.

Now look at the other parts on the schematic and look at the project you built to see how the parts are connected to each other. This way, you can see how the signals travel from one part to another.

PROJECT 2. A TRANSISTOR RADIO



Q1	PNP	R3	2.2KΩ
R1	22KΩ	C1	0.01µF
R2	470KΩ	D1	Ge

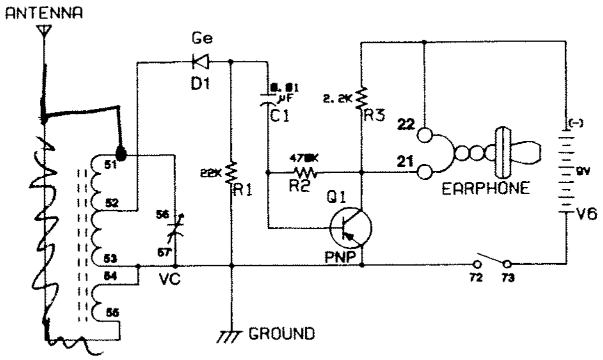
This project shows you how to make electronic devices from simple basic circuits. This circuit catches the radio frequency, converts it to the sound you can hear, and feeds it to a transistor amplifier.

Parts You Need

One 22K Resistor
One 470K Resistor
One 2.2K Resistor
One PNP Transistor
One 0.01µF Ceramic Capacitor
One Germanium Diode
12 Wires

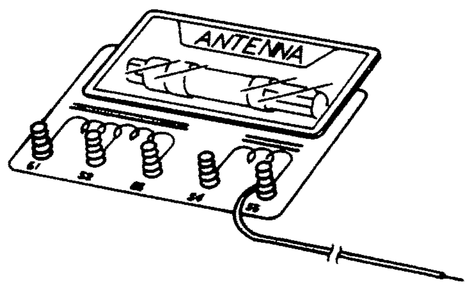
3/30/07

Connecting Conponents

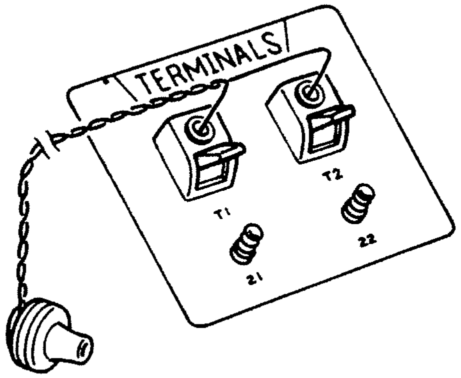


Follow these steps or the schematic to make this project.

1. Insert the 22K Resistor in **J7** and **G12**.
2. Insert the 470K Resistor in **H13** and **N13**.
3. Insert the 2.2K Resistor in **H12** and (–).
4. Insert the 0.01µF ceramic capacitor in **J10** and **J11**.
5. Insert the PNP transistor's emitter pin in **G15**, the collector pin in **H15**, and the base pin in **J15**. (The flat side of the transistor faces left).
6. Insert the cathode pin of the Germanium Diode in **J3**, anode pin in **J6**.
7. Connect the green antenna wire to terminal **55**.



8. Connect the one wire of earphone to the terminal marked **T1** and the other wire to the terminal marked **T2**.
9. Connect the other long green wire between terminal **57** and an earth ground such as a cold water pipe.



Connecting Wires

J14 - N14, J1 - 52, G11 - 57 - 54 - 53 - ground, 51 - 56, G14 - 72, H14 - 21, (–) - 22, +V6 - 73.

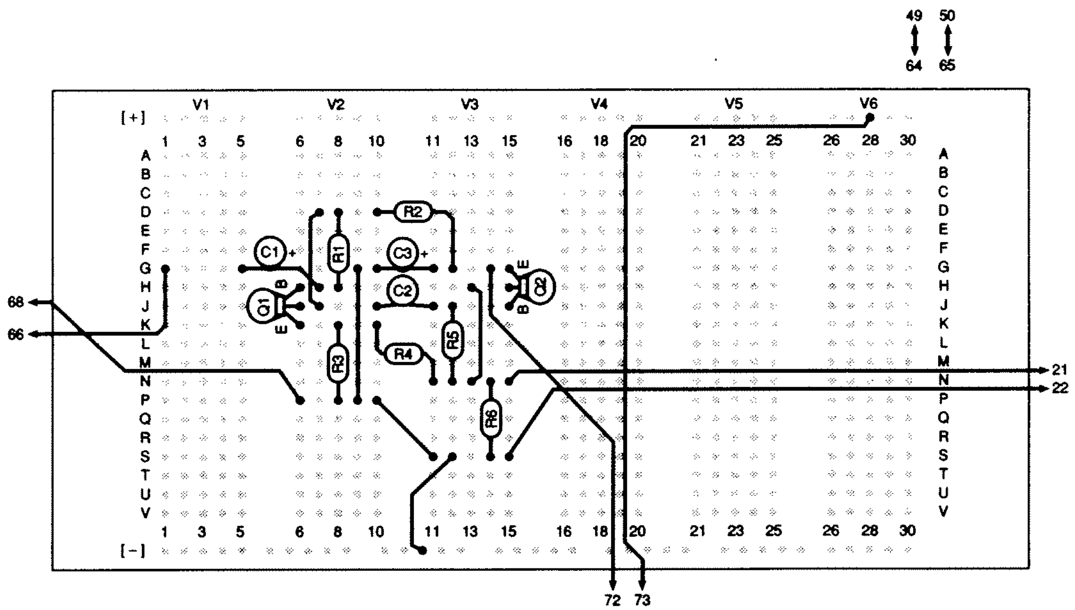
Turning On the Project

Press the switch toward the word **SWITCH**. This turns on the power. Put the earphone to your ear and slowly rotate the **tuning control**. You will be able to hear some of the AM broadcast stations in your area.

How It Works

The amplifier in this project amplifies the sound you hear in the earphone. It does not make the radio more sensitive (able to pick up weaker station). More complex radios have circuits which amplify the radio signals before they're changed to the sound.

PROJECT 3. SOUND SCOOPER



Q1	NPN	R2	1KΩ	R5	470KΩ	C2	0.1µF
Q2	PNP	R3	100Ω	R6	2.2KΩ	C3	100µF
R1	220KΩ	R4	22KΩ	C1	3.3µF		

Here's a different sort of amplifier. This one lets you listen through the earphone to sounds you send through the **speaker**. Therefore, the **speaker** acts as a microphone.

Parts You Need

One 220K Resistor ✓
One 1K Resistor ✓
One 100 ohm Resistor ✓
One 22K Resistor ✓
One 470K Resistor ✓
One 2.2K Resistor /
One NPN Transistor ✓
One PNP Transistor ✓
One 3.3µF Electrolytic Capacitor ✓
One 0.1µF Ceramic Capacitor ✓
One 100µF Electrolytic Capacitor ✓
13 Wires

Connecting Components

Follow these steps or the schematic to make this project.

1. Insert 220K Resistor in **D8** and **H8**.
2. Insert 1K Resistor in **D10** and **G12**.
3. Insert 100 ohm Resistor in **K8** and **P8**.
4. Insert 22k Resistor in **K10** and **N11**.
5. Insert 470k Resistor in **J12** and **N12**.
6. Insert 2.2k Resistor in **N14** and **S14**.
7. Insert the negative side of the 3.3µF electrolytic capacitor in **G5** and the positive side in **H7**.
8. Insert the 0.1µF ceramic capacitor in **J10** and **J11**.
9. Insert the negative side of the 100µF electrolytic capacitor in **G10** and the positive side in **G11**.
10. Insert the NPN transistor's emitter pin in **K6**, the collector pin in **J6**, and the base pin in **H6**. (The flatside of the transistor faces right.)
11. Insert the PNP transistor's emitter pin in **G15**, the collector pin in **H15**, and the base pin in **J15**. (The flast side of the transistor faces left.)
12. Insert one wire of earphone to the terminal marked **T1** and the other wire to the terminal marked **T2**.

Connecting Wires

G1 - 66, P6 - 68, P10 - S11, S12 - (–), G14 - 72, N15 - 21, S15 - 22, +V6 - 73, G9 - P9, D7 - J7, H13 - N13, 49 - 64, 50 - 65.

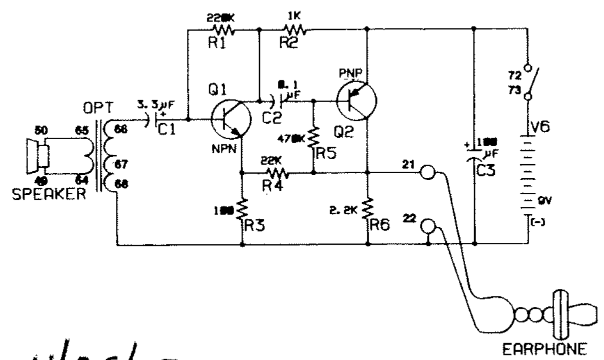
Turning On the Project

Slide the switch toward the word **SWITCH**. Put the earphone to your ear. Now rub your fingers across the **speaker** and tap the front of the **speaker**. What do you hear?

How It Works

We know a speaker gives off sounds, but did you know that it can also work as a microphone? It can because the magnet in the speaker gives off weak electric currents whenever sound waves strike it.

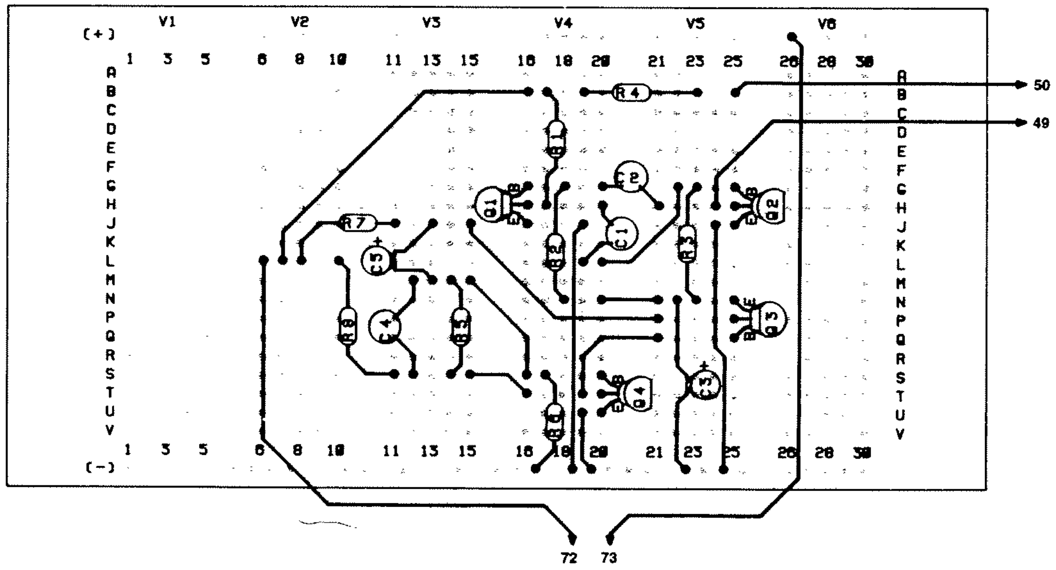
Normally a speaker doesn't make a good microphone. But in this circuit we have enough amplification to make a microphone. Notice that we use two transistors in this project for increased amplification.



4/05/07

1st try!

PROJECT 4. AMERICAN PATROL CAR SIREN



Q1	NPN	R1	1KΩ	R5	47KΩ	C1	0.047µF	C5	10µF
Q2	NPN	R2	22KΩ	R6	27KΩ	C2	0.047µF		
Q3	NPN	R3	22KΩ	R7	470Ω	C3	100µF		
Q4	NPN	R4	270Ω	R8	1KΩ	C4	0.01µF		

Wouldn't you like to make a siren of your own that sounds just like the patrol car siren? This project lets you use your creative mind to produce the sound of a real police car siren.

Parts You Need

Two 1K Resistors
Two 22K Resistors
One 270 ohm Resistor
One 47K Resistor
One 27K Resistor
One 470 ohm Resistor
Four NPN Transistors
Two 0.047µF Ceramic Capacitors
One 0.01µF Ceramic Capacitor
One 10µF Electrolytic Capacitor
One 100µF Electrolytic Capacitor
14 Wires

Connecting Components

Follow these steps or the schematic to make this project.

1. Insert 1K Resistor in **B17** and **H17**.
2. Insert 1K Resistor in **L10** and **S11**.
3. Insert 22K Resistor in **G18** and **N18**.
4. Insert 22K Resistor in **G23** and **N23**.
5. Insert 270 ohm Resistor in **B19** and **B23**.
6. Insert 47K Resistor in **M14** and **S14**.
7. Insert 27K Resistor in **S17** and (–).
8. Insert 470 ohm Resistor in **J11** and **L8**.
9. Insert the 0.047µF ceramic capacitor in **H20** and **L19**.
10. Insert the 0.047µF ceramic capacitor in **G20** and **H21**.
11. Insert the 0.01µF ceramic capacitor in **M12** and **S12**.
12. Insert the negative side of the 100µF electrolytic capacitor in (–) and the positive side in **N22**.
13. Insert the negative side of the 10µF electrolytic capacitor in **M13** and the positive side in **J13**.
14. Insert the NPN transistor's emitter pin in **J16**, the collector pin in **H16**, and the base pin in **G16**. (The flatside of the transistor faces right.)
15. Insert the NPN transistor's emitter pin in **J25**, the collector pin in **H25**, and the base pin in **G25**. (The flatside of the transistor faces right.)
16. Insert the NPN transistor's emitter pin in **N25**, the collector pin in **P25**, and the base pin in **Q25**. (The flatside of the transistor faces left.)
17. Insert the NPN transistor's emitter pin in **U20**, the collector pin in **T20**, and the base pin in **S20**. (The flatside of the transistor faces right.)

Connecting Wires

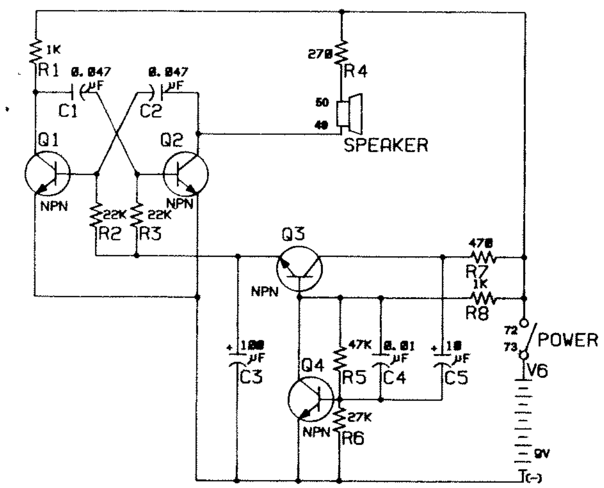
(+)V6 - 73, J19 - (-), J24 - (–), U19 - (–), B16 - L7, B25 - 50, G22 - L20, H24 - 49, J15 - P21, L6 - 72, M15 - S16, N20 - N21, Q21 - T19, S15 - T16.

Turning On the Project

Slide the switch toward the word **SWITCH**. Then you can hear the siren sound.

How it Works

The siren sound is produced by a circuit called astable multivibrator. You will learn more on this circuit in the later section of this manual.



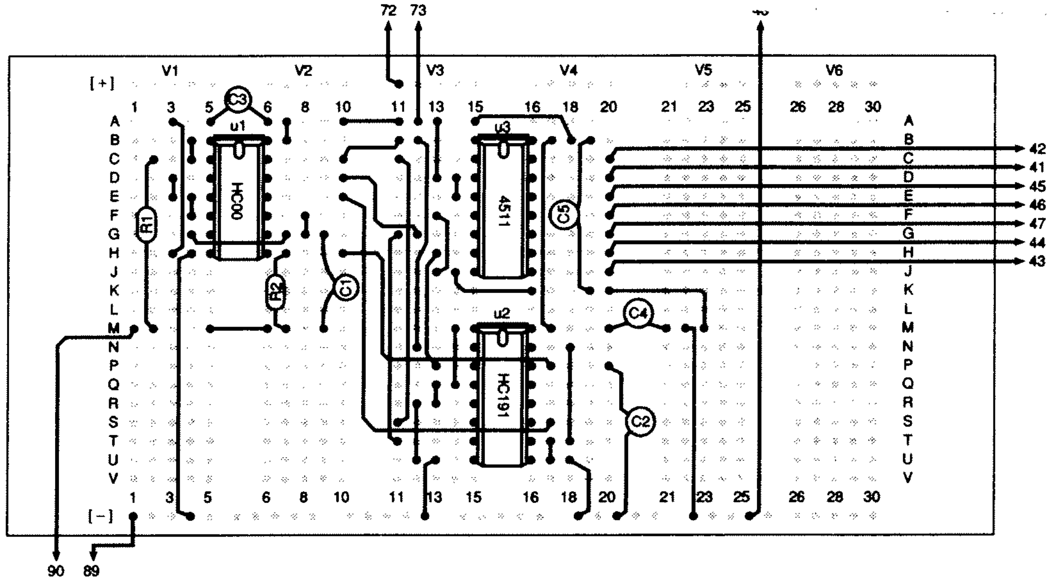
.047000 = 473

.010000 = 103

4/5/07
1st time!

27K - Rd Vi Or

PROJECT 5. DIGITAL ROULETTE



U1	74HC00	R1	22KΩ	C1	0.1µF	C3	0.1µF	C5	0.1µF
U2	74HC191	R2	100KΩ	C2	0.001µF	C4	0.1µF		
U3	74HC4511								

Let's make an electronic roulette wheel that can display one of the numbers 0 - 9, using a counter IC and a 7-segment **LED display**.

Parts You Need

One 22K Resistor
One 100K Resistor
Four 0.1µF Ceramic Capacitor
One 1000pF (0.001µF) Ceramic Capacitor
One C-MOS IC 74HC00
One C-MOS IC 74HC191
One C-MOS IC 74HC4511
45 Wires

Connecting Components

1. Insert the 22K resistor in **C2** and **M2**.
2. Insert the 100K resistor in **H7** and **M7**.
3. Insert the 0.1µF ceramic capacitor in **G9** and **M9**.
4. Insert the 1000pF (0.001µF) ceramic capacitor in **P20** and (–).
5. Insert the 0.1µF ceramic capacitor in **A5** and **A6**.
6. Insert the 0.1µF ceramic capacitor in **M20** and **M21**.
7. Insert the 0.1µF ceramic capacitor in **B19** and **K19**.
8. Insert the C-MOS 74HC00's pin 1 in **B5** and pin 8 in **H6**.
9. Insert the C-MOS 74HC191's pin 1 in **M15** and pin 9 in **U16**.
10. Insert the C-MOS 74HC4511's pin 1 in **B15** and pin 9 in **J16**.

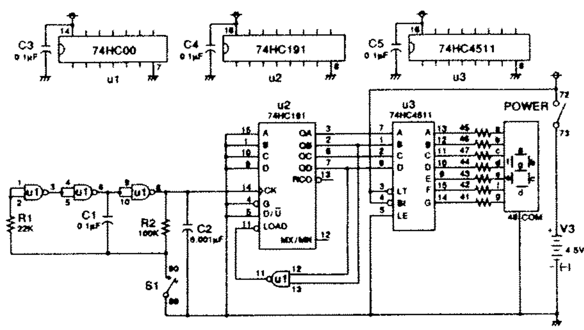
Turning On the Project

Press the switch toward the word **SWITCH**. This turns on the power. You can see to start moving the 7-segment **LED display**.

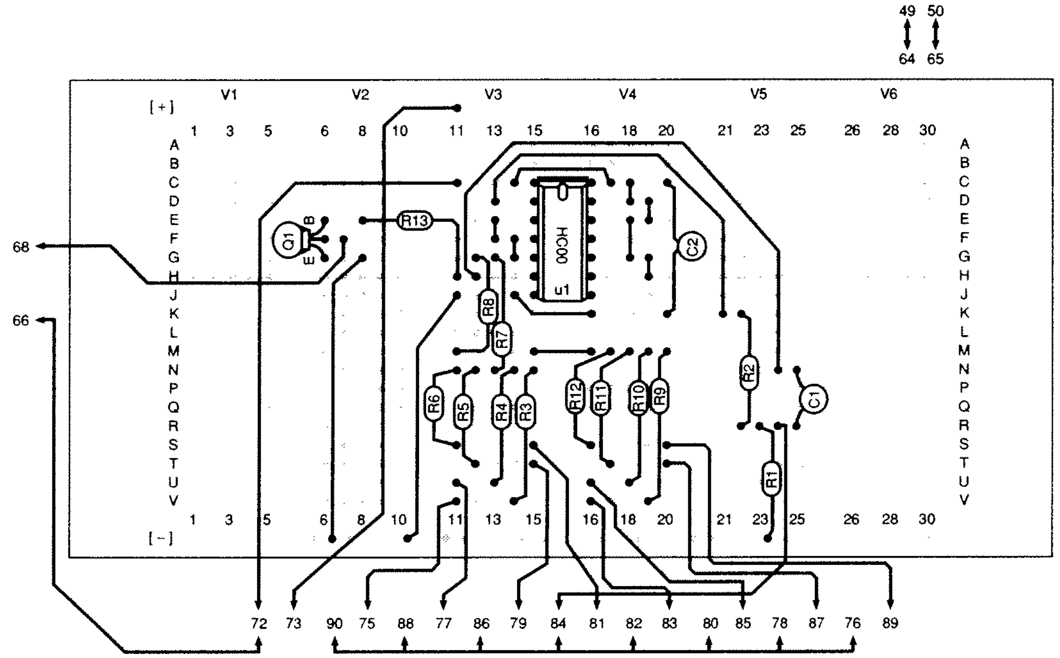
How It Works

The roulette wheel starts turning at a very high speed. What is the number on the display? It looks like "8", doesn't it? Actually, the numbers 0 - 9 appear in order, very rapidly. Press **S1**, and display stops at one number.

You can enjoy playing this electronic roulette as many times as you want. Release **S1** and press it again.



PROJECT 6. IC ORGAN



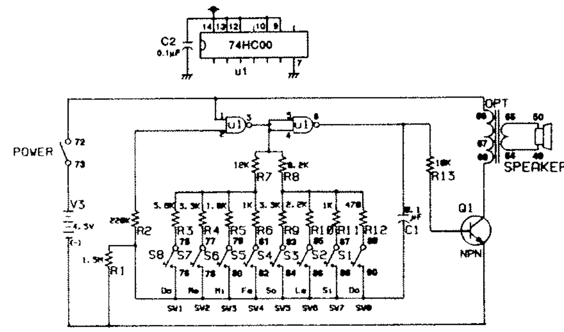
U1	74HC00	R3	5.6KΩ	R6	1KΩ	R9	3.3KΩ	R12	470Ω		
Q1	NPN	R4	3.3KΩ	R7	12KΩ	R10	2.2KΩ	R13	10KΩ		
R1	1.5MΩ	R5	1.8KΩ	R8	8.2KΩ	R11	1KΩ	C1	0.1µF		
R2	220KΩ							C2	0.1µF		

From this project on, we will show you only the schematic diagram and the wiring diagram. If you feel uncertain, refer back to previous projects and get the knack on how to do the wiring.

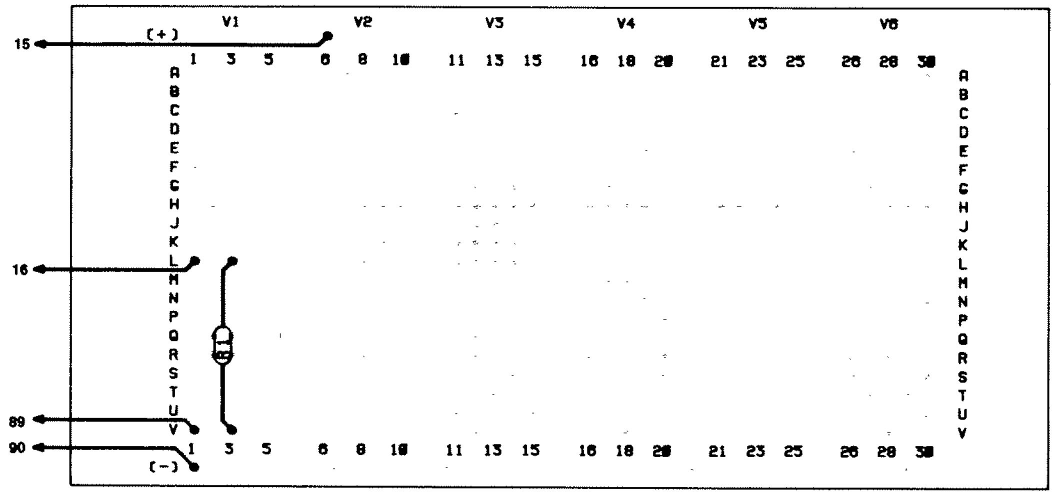
We'll now make an electronic organ that can produce a sound over a full octave, using three ICs. The sound is amplified by transistor Q1 so you can hear.

The diagrams might seem a little complex, but try building it anyway -- you will find it is not so difficult as you expected. Yes, the electronics are not too difficult as you would have imagined: even the sophisticated computer is the combination of many simple basic circuits.

When you finish wiring up the project, switch power ON and press the keys in turn from **S8** to **S7**, **S6** ..... and the organ plays the scale from do, re, mi, fa, and so on. Don't press **two** switches at a time; the organ makes an entirely different sound.

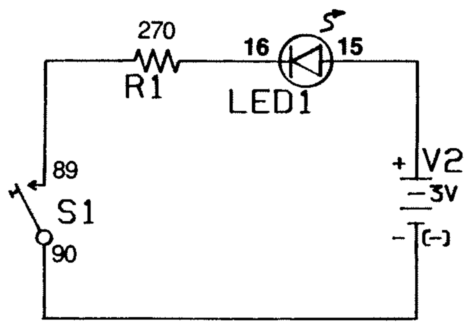


PROJECT 7. LIGHT TELEGRxAPH

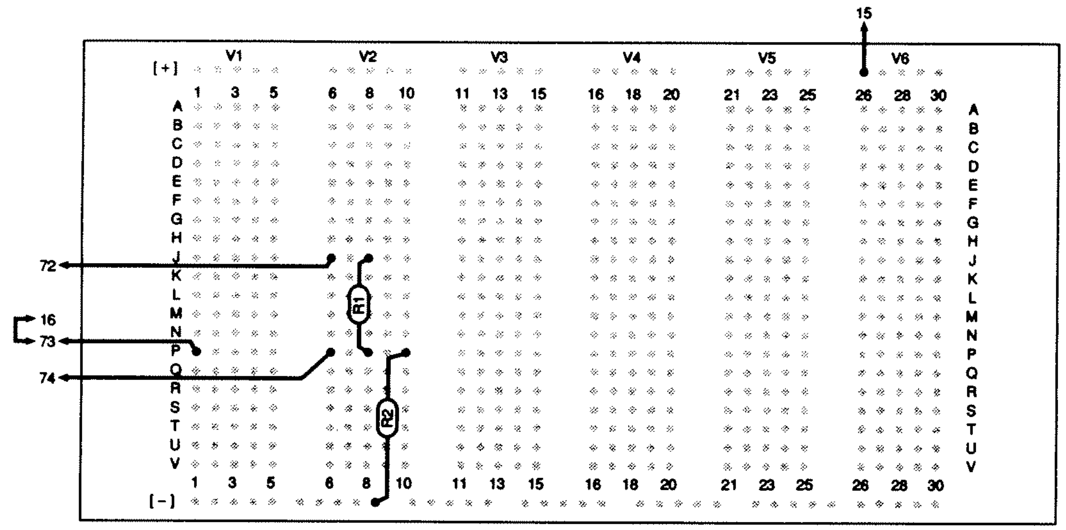


R1 270Ω

When you finish the wiring, press **S1**. The **LED 1** lights. It is simple enough, but it points out a couple of interesting things. When the key is open (upright position) the electrons cannot flow. This is called an open circuit. When the key is pressed down, the gap is closed and current can flow through the project. This is called a closed circuit. You can trace the flow of current in a circuit by looking at the schematic. In this project, you can see current flows from the positive side of the batteries through the **LED**. They then go through the resistor, key and back to the batteries at the negative side.



PROJECT 8. INTRODUCING THE RESISTOR



R1 470Ω
R2 470Ω

We've been using resistors in almost all of the projects up to this point. But we've never mentioned exactly what resistors do in a circuit. Here's an experiment to let us find out.

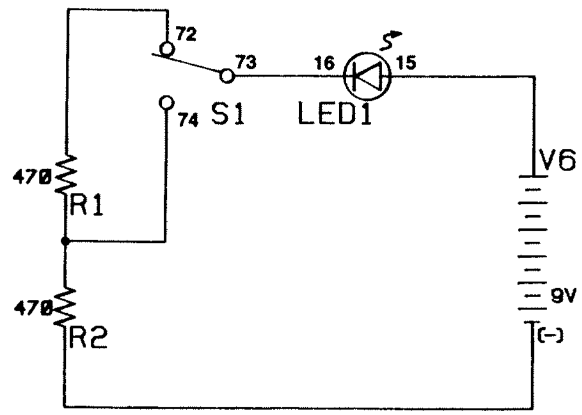
One clue to what resistors do is found in their name - they resist (oppose) the flow of electrons. This makes them handy for reducing voltages down to a desired value, for example.

Very often you'll see two or more resistors connected together in different ways in circuits. Notice in the schematic for this project that the resistors are connected one after another. You can see that the current flows from one resistor to the other. This is called a series connection.

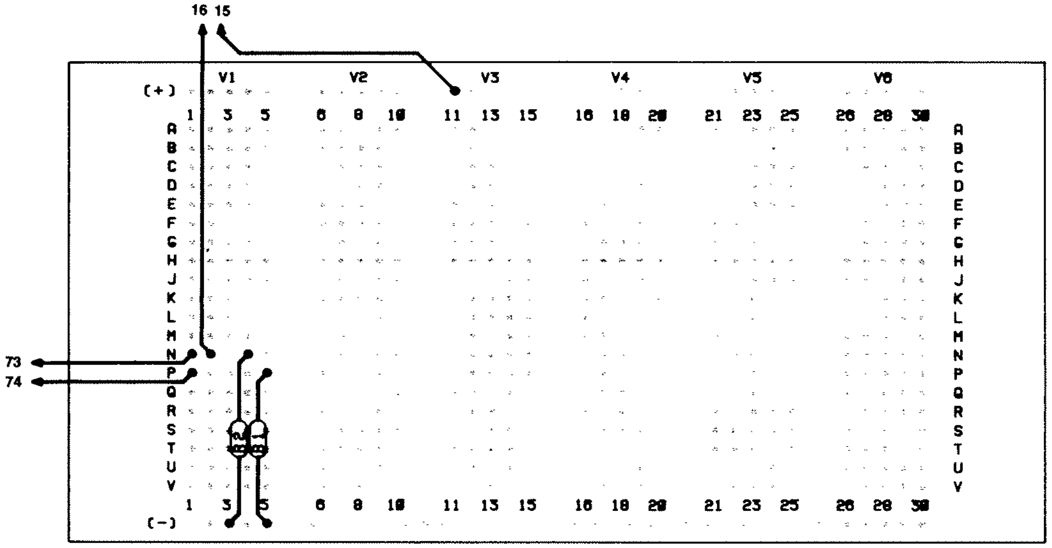
Set the **select switch** to down position (toward terminal **74**) and note the brightness of **LED**. Now look carefully at the schematic. What do you think would happen if the **select switch** is set to up position (toward terminal **72**)? Are you sure of your answer? Then set the **select switch** to up position (toward terminal **72**) and let's find out!

The **LED** becomes darker than you saw when the **select switch** is down (toward terminal **74**). This is because when resistors are connected in series, the total resistance increases. To find the total resistance, all you have to do is add the value of each resistor.

Resistors, by the way, are measured in a unit called the ohm. Larger resistors are measured in kilohms, which is often abbreviated simply as k. A kilohm is 1000 ohms. In our schematic, the two resistors are both 470 ohms. In series, they add up to 940 ohms.



PROJECT 9. PARALLEL RESISTOR



R1 470Ω
R2 470Ω

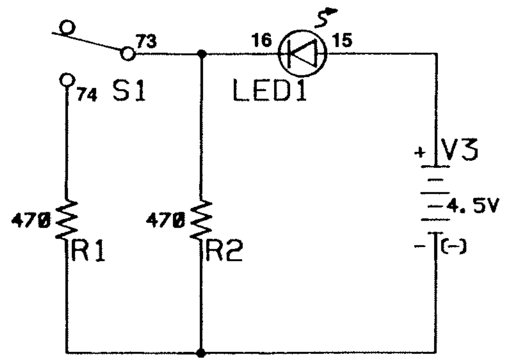
You might think from our last project that you always increase the resistance in a circuit whenever you add another resistor. Not so - in fact, you can even decrease the resistance in a circuit by adding another resistor.

Let's take a look at this project and see it we can figure out how this happens. In the schematic, note that the two resistors are side by side, not one after the other. This side by side arrangement is called as parallel connection. When you set the **select switch** to up position, only 470 ohm resistor is in the circuit. Setting the **select switch** to down position adds the another 470 ohm resistor.

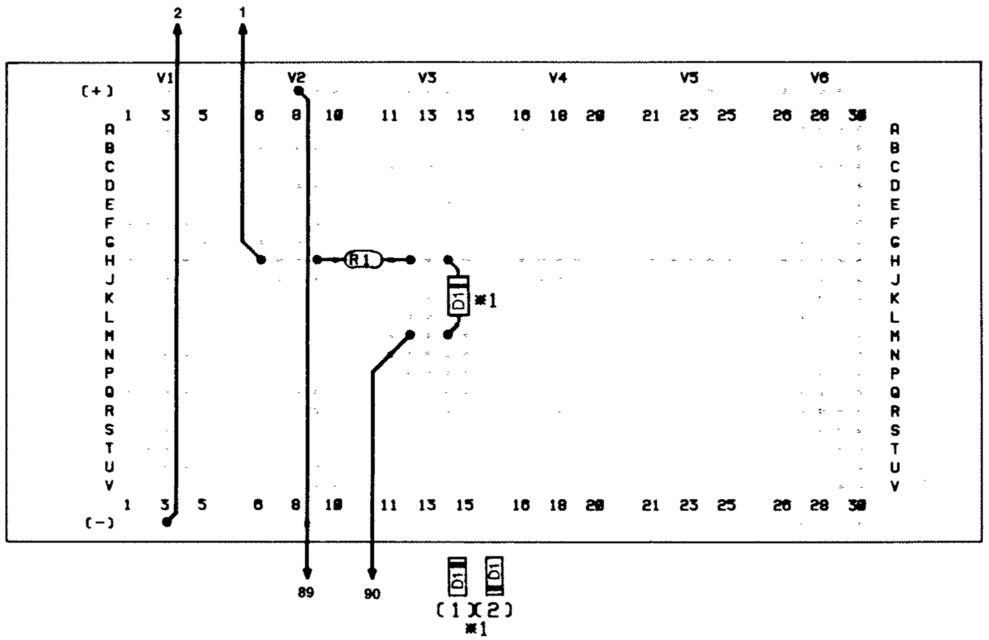
Set the **select switch** down and note the brightness of **LED**. Then change the **select switch** to up position and compare the **LED** brightness.

More current flowed in the circuit with the extra resistor. Seems impossible, but look at the schematic for this project. In a parallel arrangement, only a part of the total electric current flows to each resistor. In fact, the total resistance in a parallel circuit is always less than the lowest value resistor connected in parallel.

Curious to know how to calculate total resistance? Well, it's not too simple as was in series connection. Multiply the each value of resistors and divide the product by the sum of the values. In this project, the total resistance is (470 x 470)/(470+470)= 235 ohms.



PROJECT 10. MEET THE DIODE



R1 100Ω
D1 Si

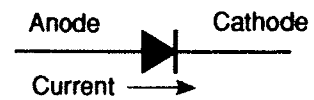
One electronic device we use in many circuits is the diode. A diode has a special advantage over other electronic parts. Let's see it in this project.

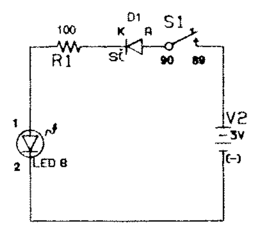
Wire this project as shown in the first schematic. When you press the key, **LED 8** lights. That means that current is flowing through the diode. Now reverse the wiring connections to the diode as shown in the second schematic. Press the key and see what happens.

A diode only conducts in one direction. This means it can change alternating current (AC) into a pulsing direct current (DC) by conducting only one of the direction AC flows. Diodes can also be used to change radio signals into electrical energy you can hear with an earphone. This is called rectification and we'll see how this works later.

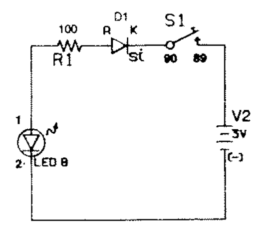
You're probably wondering when we're going to get around to telling you what AC and DC are... we'll do it sometime, but not now. But why not try to figure it out yourself? Be sure to keep a note of your guess so you can see how close you came...

Each diode has two parts inside: an anode and a cathode. In the schematic, the anode is the "arrow" and the cathode is the straight line within the diode symbol. Current flows from the anode to cathode. This is called forward bias by electronics engineers. When electrons are applied in the opposite direction (and the diode won't work), this is called reverse bias.



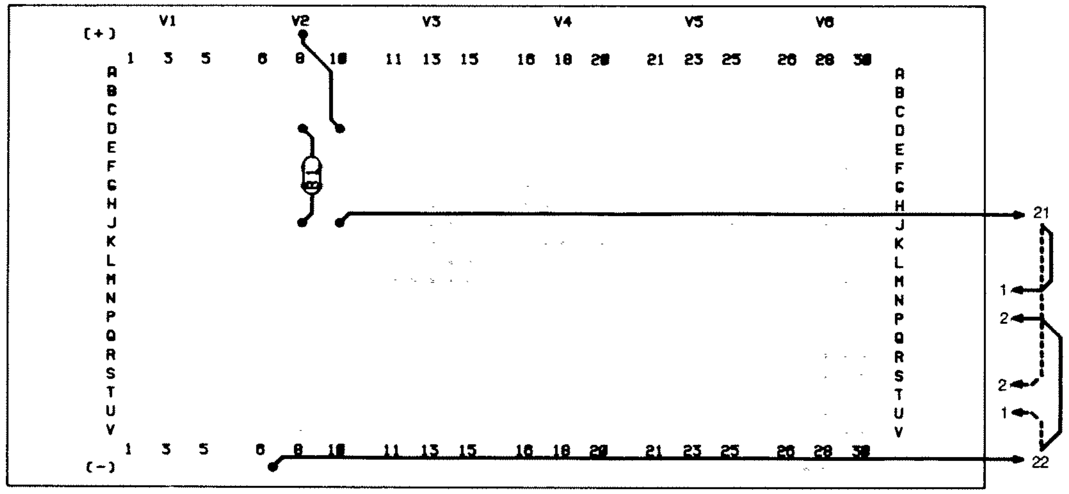


[1]



[2]

PROJECT 11. THE LED - A SPECIAL DIODE



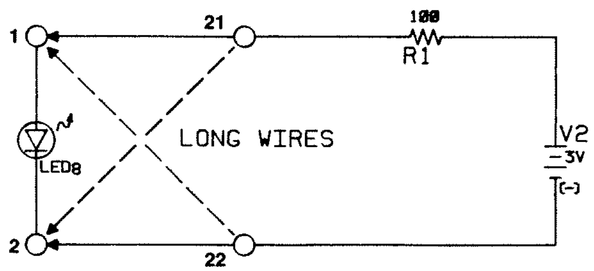
R1 100Ω

We've used **LEDs** in a number of earlier circuits. But just what is an **LED** anyway? "**LED**" stands for "light emitting diode." It is indeed a diode, but a very special one.

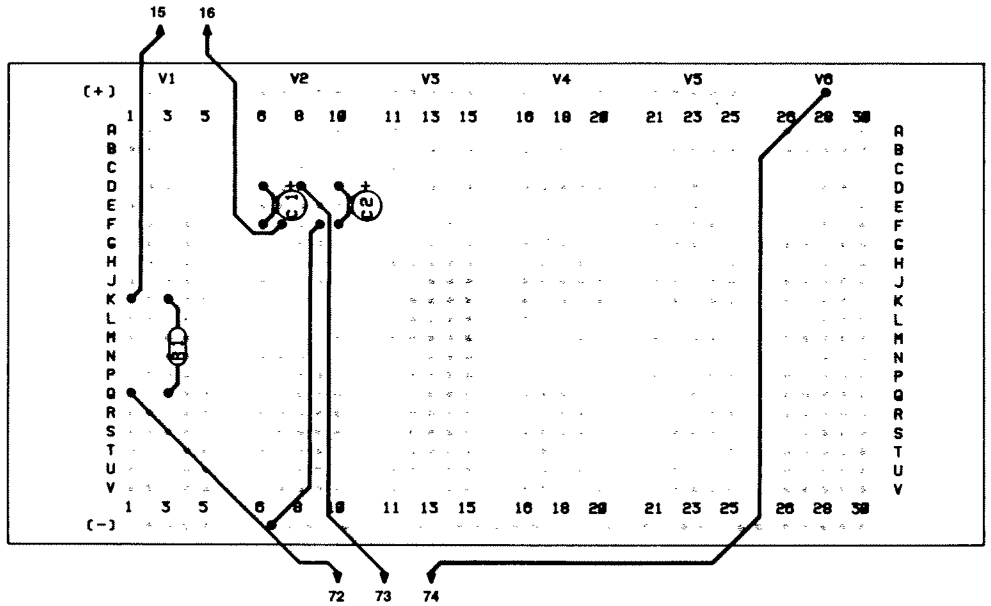
This project shows just how a **LED** works. Take the two long wires from terminals **21** and **22,** and touch terminals **2** and **1** with them. When do you make **LED 8** light?

When one long wire from terminal **21** touches **1** and the other from **22** touches **2**, **LED 8** lights up. Remember when we said that a diode can conduct only in one direction? When an **LED** is conducting, it gives off light. When current is applied from the opposite direction, it won't conduct, nor does it give off light.

Be careful and don't apply too much reverse bias to a diode - it could be damaged. That's why you notice we always add a resistor in series with an **LED. LEDs** are widely used in electronic circuits in place of lamps because they use little current and don't burn out like lamps do.



PROJECT 12. THE ELECTRONIC GAS TANK



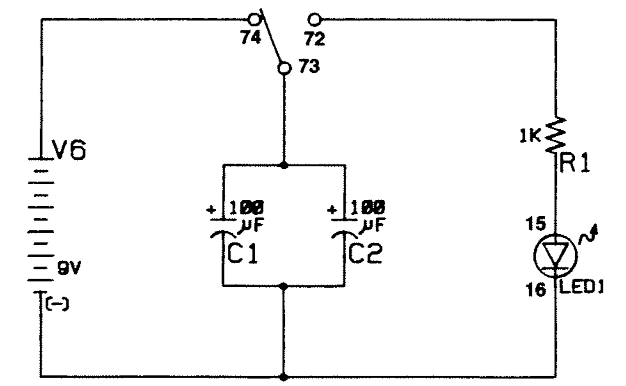
R1 1KΩ C1 100µF
C2 100µF

This project lets you see how these "electronic gas tanks" work. Before you make the final wiring connection, be sure the **select switch** is set to down position. Look at the schematic and you can see that in this position current flows from the batteries through two 100µF capacitors connected in parallel. Now set the **select switch** up. What does **LED 1** do?

As you saw, **LED 1** glows for a few seconds and then goes out. This happens because **LED 1** draws current from the capacitors until all the charge stored in them is exhausted. To recharge the capacitors, set the **select switch** down for a few seconds. When you again set the **select switch** up, **LED 1** again lights.

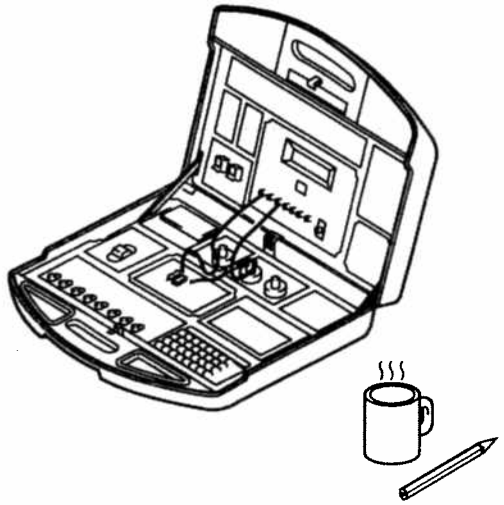
Do you think **LED 1** stays on longer if you let the capacitors charge longer? Try different charging times and find out. Do you think there is a limit to how much current a capacitor can hold?

We've used "µF" to describe capacitors. That's short fo microfarads. Farads are the units we use to measure capacitors (like we use ohms for resistors). Farads indicated how much electricity a capacitor can store. Bu farads are too big for use with electronic circuits, so mos capacitors are measured in microfarads (µF), which is one-millionth of a farad, or picofarads (pF), which is a millionth of a microfarad (now that's what you call a small charge!).



Coffee Break

Discovery of Static Electricity

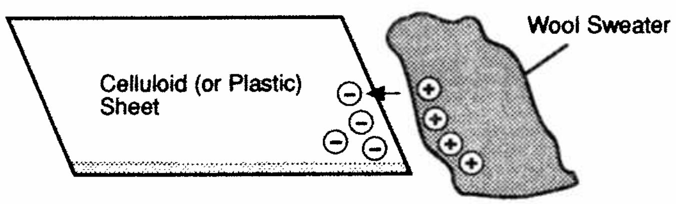


Did you know that you are surrounded by static electricity? Even though you cannot see them, because they are not creatures crawling around wiggling their tails, you know they are all around you all the time.
Static electricity was discovered by an ancient Greek called Thales more than 600 years Before Christ, or about 2600 years ago. He found out that light objects are attracted to amber (Yes, that's the stone you saw in "Jurassic Park") when the stone is rubbed. You probably conducted a similar experience before. First, you prepared small pieces of paper, and rubbed a celluloid, or plastic, sheet on a wool sweater or on a similar kind of fabric. Then, you noticed the pieces of paper jumped towards the plastic sheet and stuck to it. You probably noticed that your hair could be pulled toward the plastic sheet, too.
You can apply this phenomenon to tap water running out of a faucet as well (make sure only a small amount of water is running, though). Show your folks, and they will be surprised to see how much the water's direction can be bent when you bring the rubbed plastic sheet close by. It would also make a fun trick to show to your younger friends.

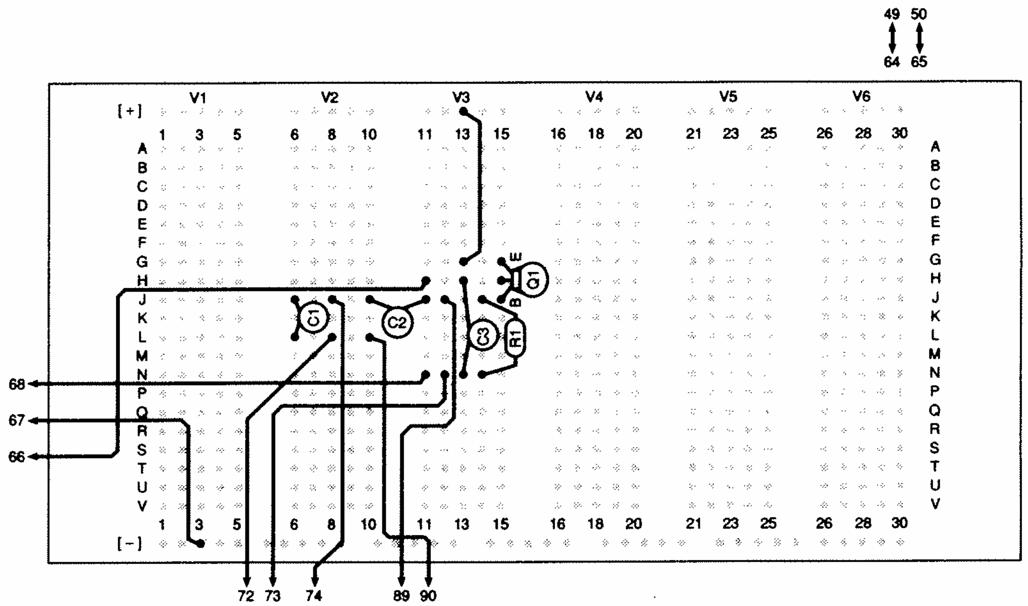
Now, the phenomenon of static electricity generation is called "charge." (It means an object becomes charged with electricity.) In the 16th century, an English physician called William Gilbert investigated which set of objects can be charged, and those that cannot be charged. Gilbert was the first to call the phenomenon of being charged "electrical." He coined the phrase from the Greek word, "Elektron," which means amber.

When else do you experience static electricity? Perhaps you guessed there are seasons when static electricity is more easily produced? You probably noticed a cracking kind of sound, during the winter, when you took off the sweater you were wearing over a shirt made of synthetic fiber. If you did this in the dark, you would have seen sparks produced between your sweater and shirt. Also, if you get off a car on a dry winter day, and insert a key held in your hand into a keyhole, you will see a light blue flash generate from the keyhole.
While it is harder to produce static electricity when the atmosphere is humid, static electricity tends to accumulate in objects when it is dry, because it has fewer places to escape to.

Well, let's look at that celluloid sheet once again thinking electrically. When they are not charged, both celluloid and wool are electrically neutral. However, when they are rubbed against each other, electrons migrate from the wool to the celluloid, and the celluloid becomes negatively (-) charged while the wool becomes positively (+) charged. (Yet, their combined charge is still neutral, isn't it?) In other words, whether an object becomes positively or negatively ("+" or "-") charged is determined by the material it is made of.



PROJECT 13. CAPACITORS IN SERIES AND PARALLEL



R1	220KΩ	C1	0.047µF	C3	0.1µF
Q1	PNP	C2	0.01µF		

Capacitors might be the handiest items in your kit. They can store electricity, smooth out pulsing electricity into a steady flow and let AC flow while blocking DC. This project lets you hear the effect of capacitors in series and parallel.

When you finish the wiring this project, set the **select switch** down. You hear a sound from the **speaker**. In this case current is flowing through 0.01µF capacitor (refer to the schematic diagram while we talk about this). Now press the key. What happens?

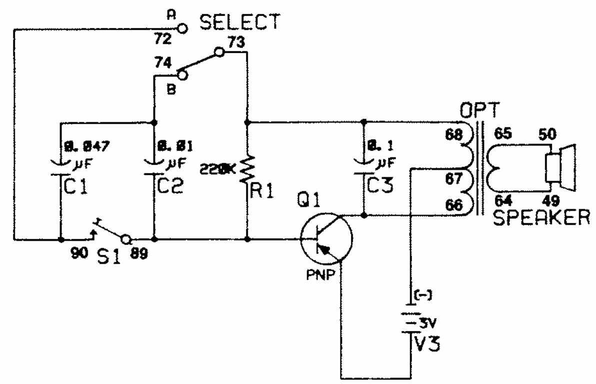
You hear a lower-pitched sound from the **speaker**. This is because the 0.047µF capacitor has been added in parallel to the first. What do you think happens to the total capacitance when you connect two capacitors in parallel?

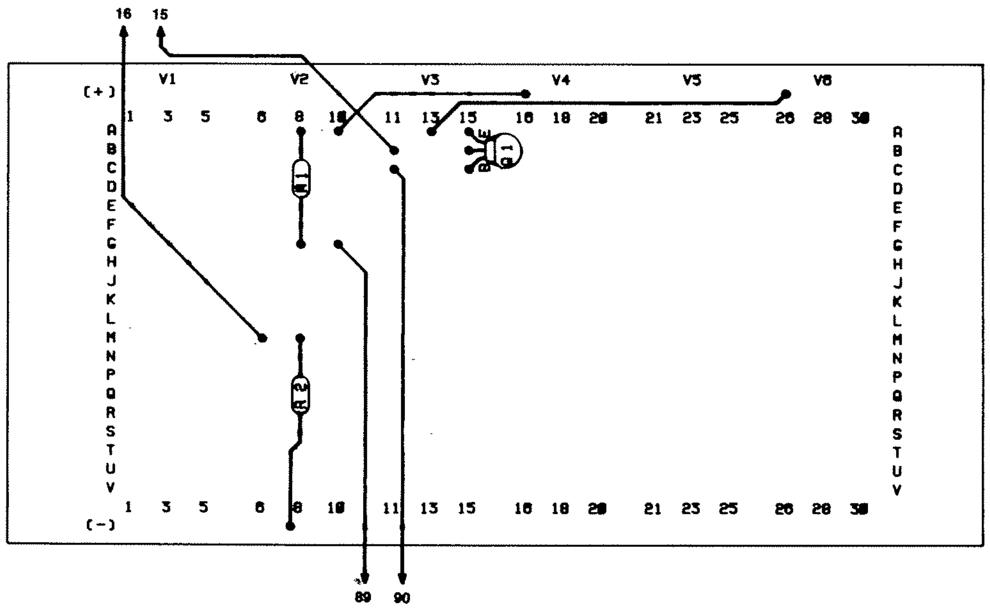
You might have guessed wrong. When two capacitors are connected in parallel, the total capacitance increases!

Now release the key and set the **select switch** from down to up... What do you hear? Do not press the key while **select switch** is set to up position. The transistor can be damaged. You hear a high-pitched sound from the **speaker**. This is because 0.047µF and 0.01µF capacitors are now connected in series. This means the total capacitance in the circuit is now less than the smallest capacitor making up the series connection.

You can see now that the connecting capacitors in series and parallel has the opposite effect of connecting resistors in the same way. Be careful - it's easy to get confused about which one increases or decreases.

You might be wondering how the circuit on the right side of the schematic works. It is called an oscillator, and you will learn how it works in later section.





Q1 PNP R1 12KΩ
R2 470Ω

You've heard about transistors for a long time - but what are they and how do they work? This project lets you find out!

Look at the schematic symbol for a transistor. You notice that there are three parts: an emitter (the line with the arrow), the base (the heavy vertical line) and the collector (the other line). Notice that some transistors have the emitter's arrow pointing toward the base - these are PNP transistors. Other have the arrow pointing away from the base, and these are NPN transistors. We've included two circuits here using both types.

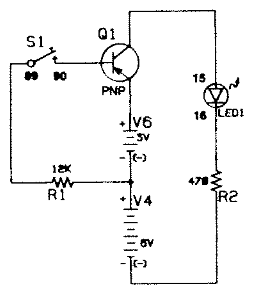
Look carefully at schematic-1. You see there are two paths for the current: one from emitter to base and another from the emitter to collector. The transistor is a PNP type. Notice the emitter-to-base path is open until you press the key.

When you finish wiring the circuit shown in schematic-1 the **LED** does not light. Press the key, and see what happens. Can you explain what you saw?

The secret to a PNP transistor is that a small change in the current from emitter to base causes a big change in the current flowing from emitter to collector. Here a large current flowed from emitter to collector once you let current flow from emitter to base by pressing the key.

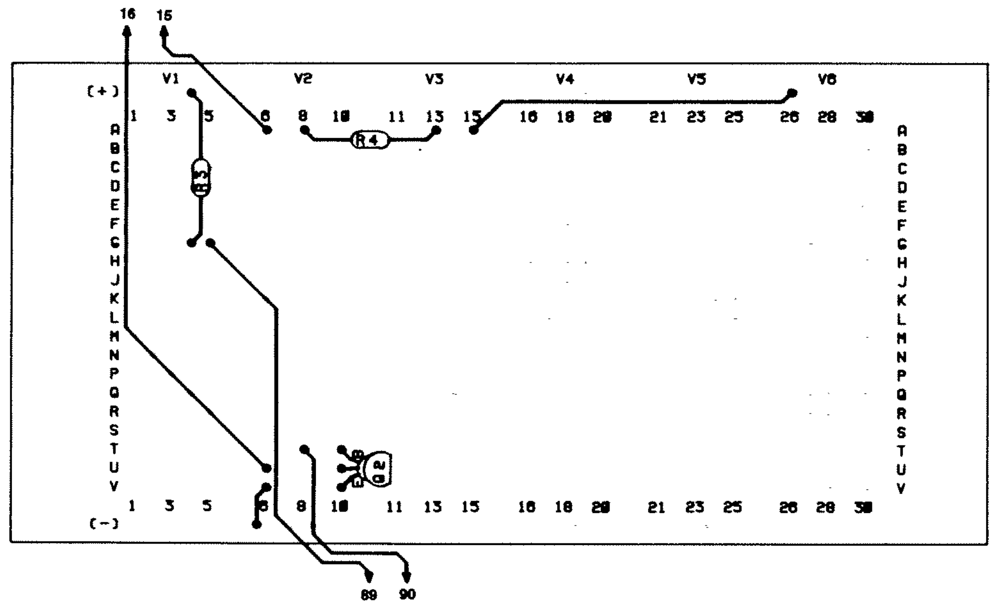
Schematic-2 shows a similar arrangement using a NPN transistor. However, with the NPN transistor a small change in the current flowing from the base to emitter can make a big change in the current flowing from collector to emitter (notice the different current flow directions in PNP and NPN transistors?)

The ability of the emitter/base current to control the collector/emitter current is called amplification. It's just like we took a weak current and made it bigger. Amplification is something transistors do very well indeed!

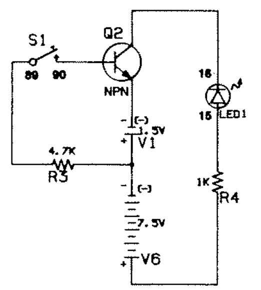


Schematic-1

PROJECT 14. MEET THE TRANSISTOR

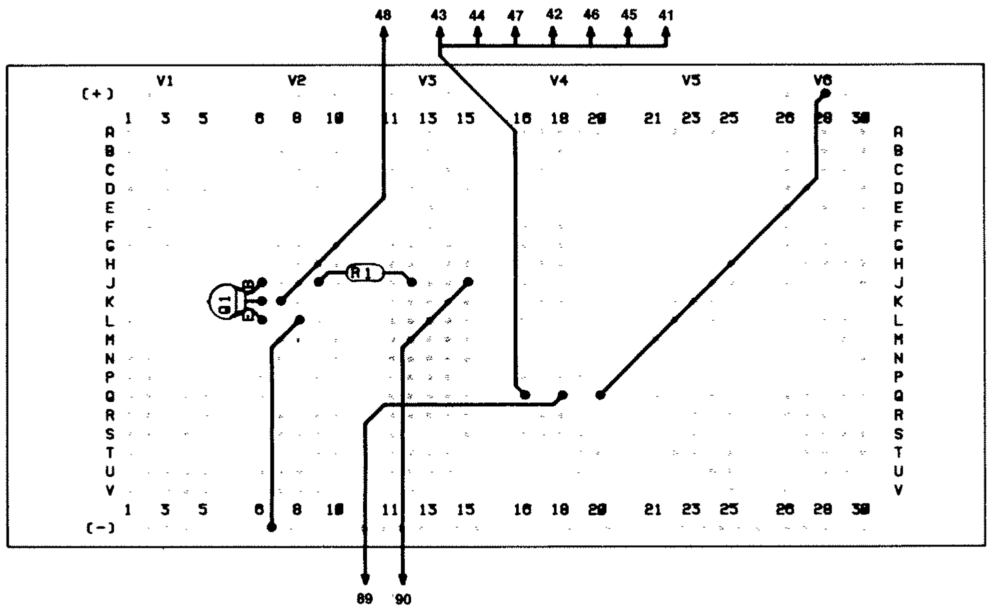


Q2 NPN R3 4.7KΩ
R4 1KΩ



Schematic-2

PROJECT 15. TRANSISTORS AS SWITCHES



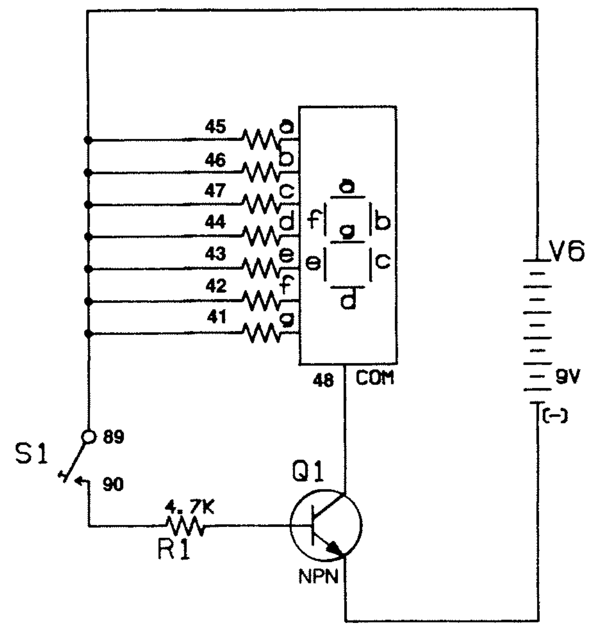
Q1	NPN
R1	4.7KΩ

Transistors do more than just amplify - they can also be used as switches. Can you think of how they could be used this way? (No fair peeking at the answer below!)

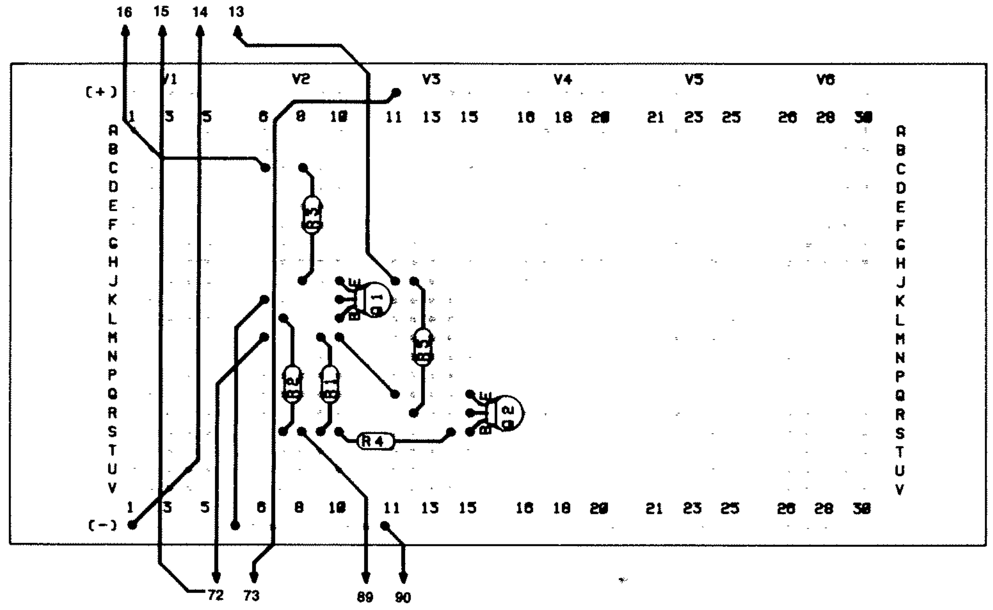
As you press the key, you see the **LED digital display** shows an **8**. Release the key and the display becomes dark again. Look at the schematic for this project - do you see what is going on?

In our project 14, "Meet The Transistor", we saw how a small change in the base-to-emitter current can cause a big change in the collector-to-emitter current. But did you realize that in most NPN transistor circuits there can't be any collector-to-emitter current flow unless the base-to-emitter current is at a certain level? The collector-to-emitter current can be shut off in the NPN transistor circuit just by lowering the base-to-emitter current. (Or turn it on by increasing the base-to-emitter current.)

In future projects, watch for transistors being used as switches. And when you build circuits on your own, think of ways you can make use of a transistor's switching ability.



PROJECT 16. PNP TRANSISTOR SWITCH



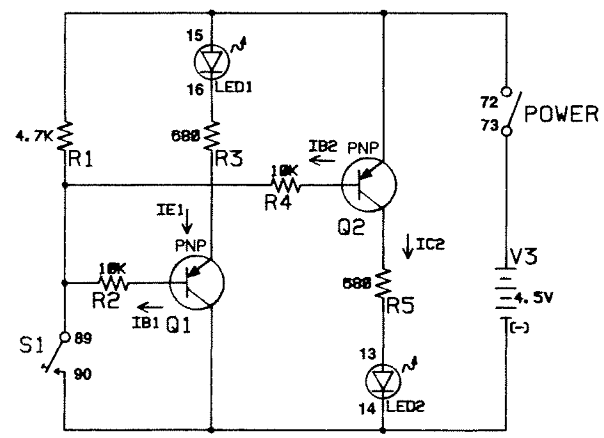
Q1	PNP	R1	4.7KΩ	R3	680Ω	R5	680Ω
Q2	PNP	R2	10KΩ	R4	10KΩ		

We're all familiar with mechanical switches like the power switch; the transistor can do the same as we saw in last projects. These are called electronic switches.

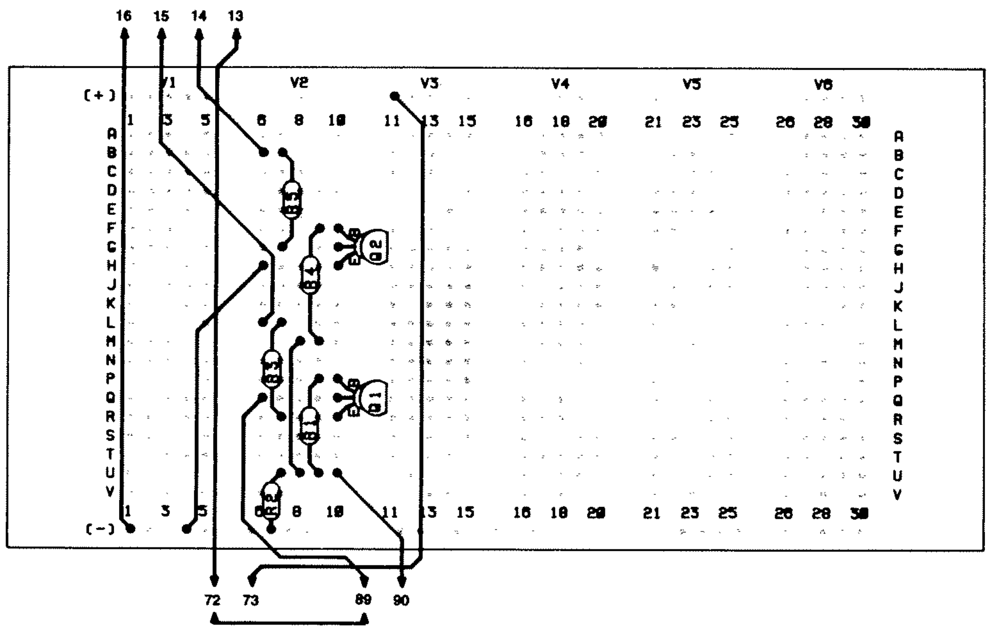
First let's try an electronic switch using two PNP transistors. The schematic shows you that the **LEDs** are connected to the emitter of Q1 and to the collector of Q2. Let's see how these transistors work as switches.

When you finish wiring up the circuit, switch power ON. Do any of the **LEDs** light up? They don't, do they? Now press **S1**, and both **LEDs** light up. Ib1 and Ib2 flowing at this time to **S1** are very small, but can switch the large currents Ie1 and Ie2 that flow to light the **LEDs**.

Oh, by the way, we expressed the emitter-to-base current for each transistor as Ib1 and Ib2, and the emitter-to-collector current as Ie1 and Ie2. The I's are the conventional symbol for current, and we added suffix b for current flowing into the base, e for current flowing into the emitter. We will use more of such expressions in this manual, so get used to it. Anyway, Ib1 is far better than "emitter-to-base current for Q1," isn't it?



PROJECT 17. NPN TRANSISTOR SWITCH

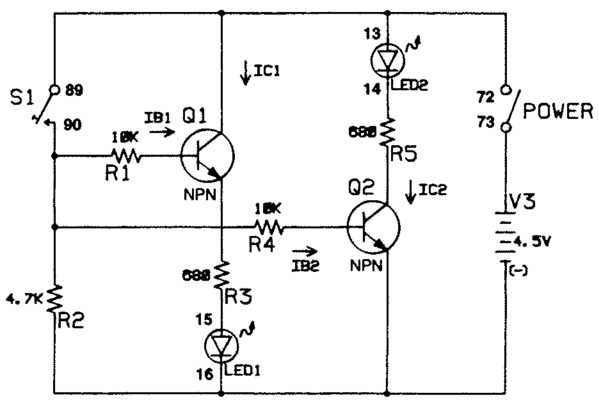


Q1	NPN	R1	10KΩ	R3	680Ω	R5	680Ω
Q2	NPN	R2	4.7KΩ	R4	10KΩ		

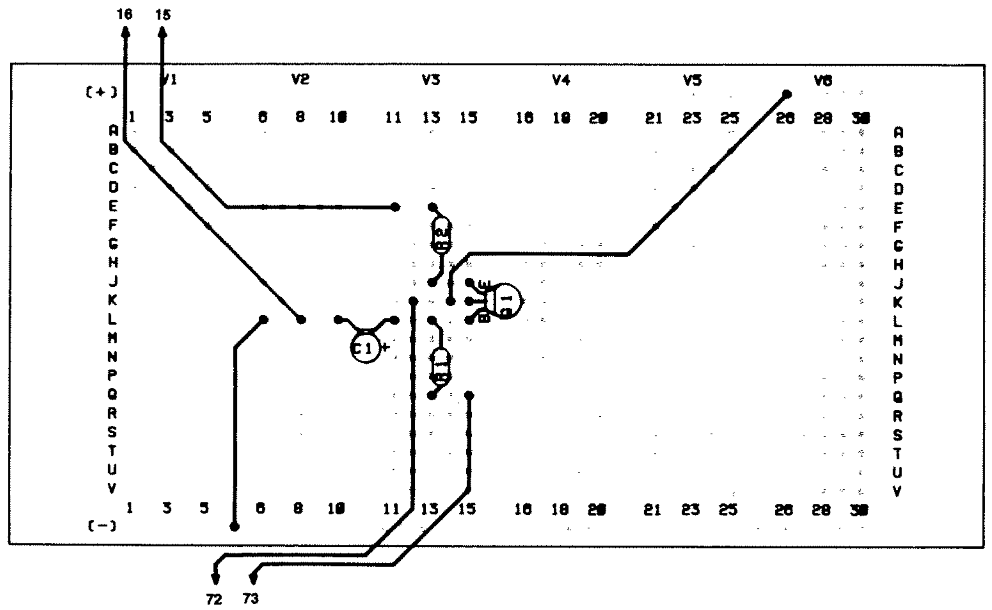
The experiment in this project shows you how an electronic switch using two NPN transistors works. Note that this circuit is very much alike to previous one, but the direction of current flow is opposite.

As you can see in the schematic, the **LEDs** are connected to the emitter of Q1 and to the collector of Q2. We'll see how these transistors work as switches.

When you finish wiring up the connections, switch power ON and see if any of the **LEDs** lights up. None of them light up, do they? Turn **S1** ON and you see that both **LEDs** light up. This means that Ib1 and Ib2 flowing from **S1** are very small, but they can switch the flow of the large currents Ie1 and Ie2 to turn the **LEDs** ON.



PROJECT 18. DELAY LIGHT



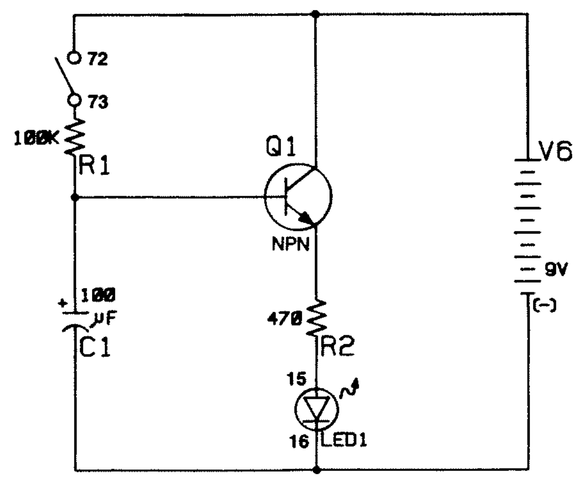
Q1	NPN	R1	100KΩ	C1	100μF
		R2	470Ω		

When you finish the wiring connections, set the **select switch** down. Then quickly set it to up position. You then see **LED 1** slowly begins to light up. After a few moment **LED 1** reaches maximum brightness and glows with a steady light. When that happens, set the **select switch** down. **LED 1** starts to gradually fade out, and finally goes out.

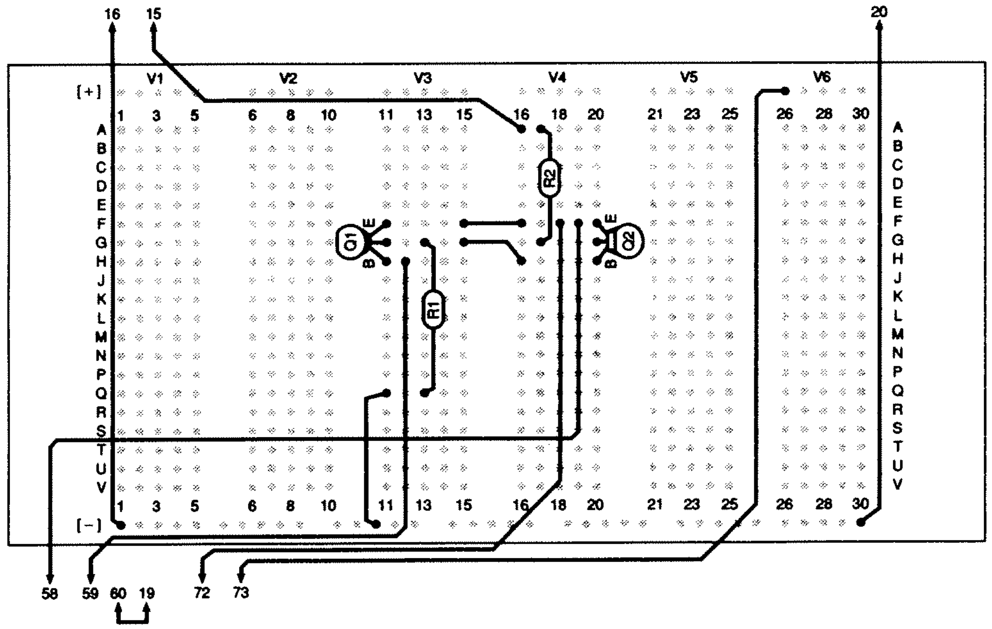
Take a look at the schematic. Can you figure out how this project works? Give it your best shot and then turn this manual upside-down for the answer.

With the **select switch** up, current flows from the batteries to charge the 100μF capacitor. As this capacitor builds its charge, it enables the transistor to operate and lights the **LED**. When the **select switch** is set to down position, current does not flow through the capacitor. It begins to discharge, and the current for the transistor gradually becomes weak. Finally, the capacitor can no longer provide enough current for the transistor and the **LED** goes out.

See- there was nothing hard about that. (Unless, of course, you tried to read it without turning the manual upside-down!)

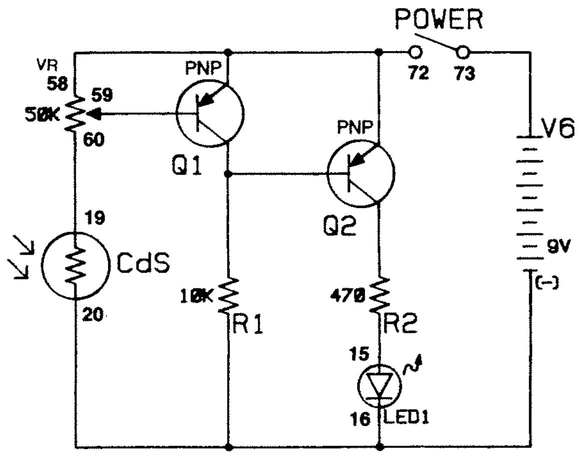


PROJECT 19. NIGHT LIGHT



Q1	PNP	R1	10KΩ
Q2	PNP	R2	470Ω

The **CdS cell** has a characteristic that its resistance increases as the light falling on it becomes darker. One very practical use for a **CdS cell** is to turn lights or other devices on or off at sunset or sunrise. Here's a circuit that lights up the **LED** at night.

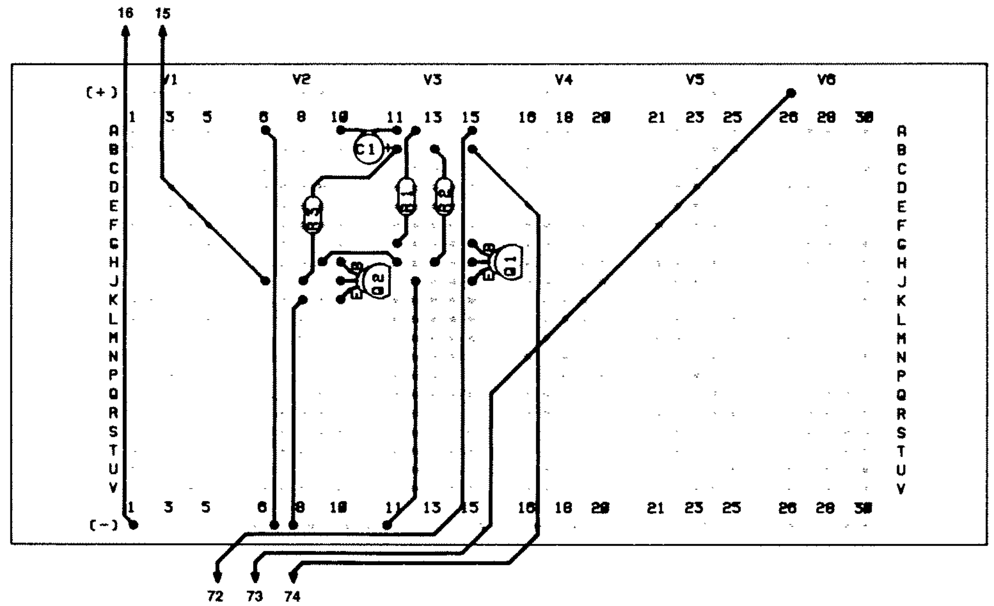


While you build this project, take a good look at where the **CdS cell** is placed in the circuit. Do you have any idea why it is placed there instead of at some other point? (If you do, make a note ... because we'll soon find out.)

Now switch power ON and carefully adjust the 50K **control volume** until you reach the point where the **LED** lights. Once you reach this point, reduce the **control volume** setting until the **LED** goes out.

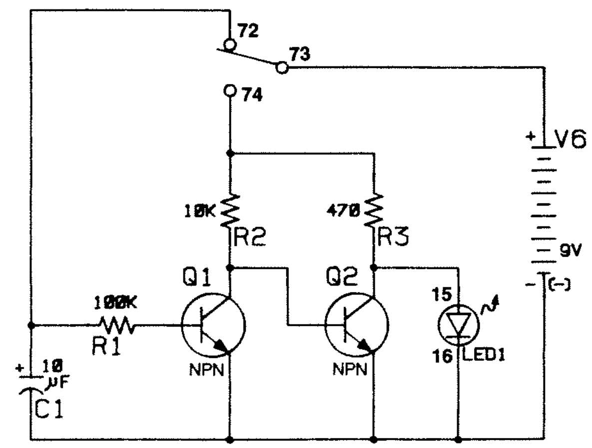
Once you get this project "set" to the right **control volume** setting, it lights the **LED** once the light surrounding your kit dims. You can find a more complex version of this circuit in some street light.

PROJECT 20. ELECTRONIC TIMER



Q1	NPN	R1	100KΩ	R3	470Ω
Q2	NPN	R2	10KΩ	C1	10μF

You saw in project 18 how a capacitor can store and discharge electricity. You probably noticed that capacitors take a certain amount of time to charge and discharge. Some of you were probably thinking that this fact could be put to some good use in a timer circuit of some sort--and it happens you are right.

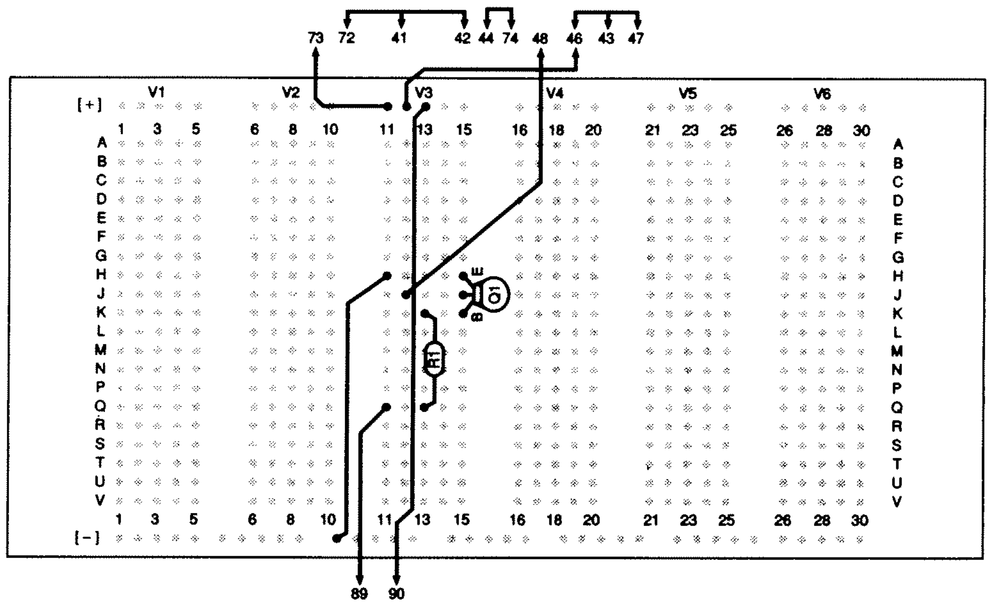


Before you finish the wiring, set the **select switch** up. When you finish the wiring, let the **select switch** remain at the up position for a few seconds. Then slide it down. The **LED** comes on for a few seconds and then goes off. Does it stay on longer if you let the **select switch** remain at the up position for more than a few seconds?

You should have no difficulty in figuring out how this circuit works. Actually this is a combination of projects 17 and 18. You might want to try replacing the 10μF capacitor with a 100μF one and see what happens (be sure to get the + connection right!).

What do you think happens now? You might try adding other capacitors in series and parallel and seeing what effect they have on circuit performance. Be sure to keep notes of what happens do you see any patterns in the results?

PROJECT 21. CAPITAL LETTER DISPLAY



Q1 NPN R1 4.7KΩ

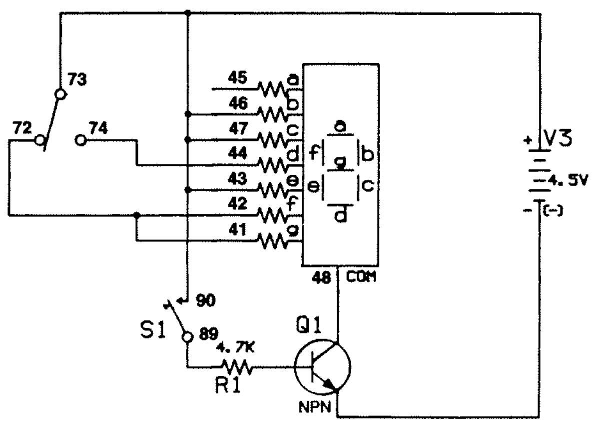
Let's see how the display in your kit can be used in different circuits - and how it works.

The **LED digital display** is actually seven small **LEDs** in the same package. You notice in the schematic that there are resistor symbols connected to the display symbol. These resistances are actually "built in" the display to protect the segments from damage from too much current.

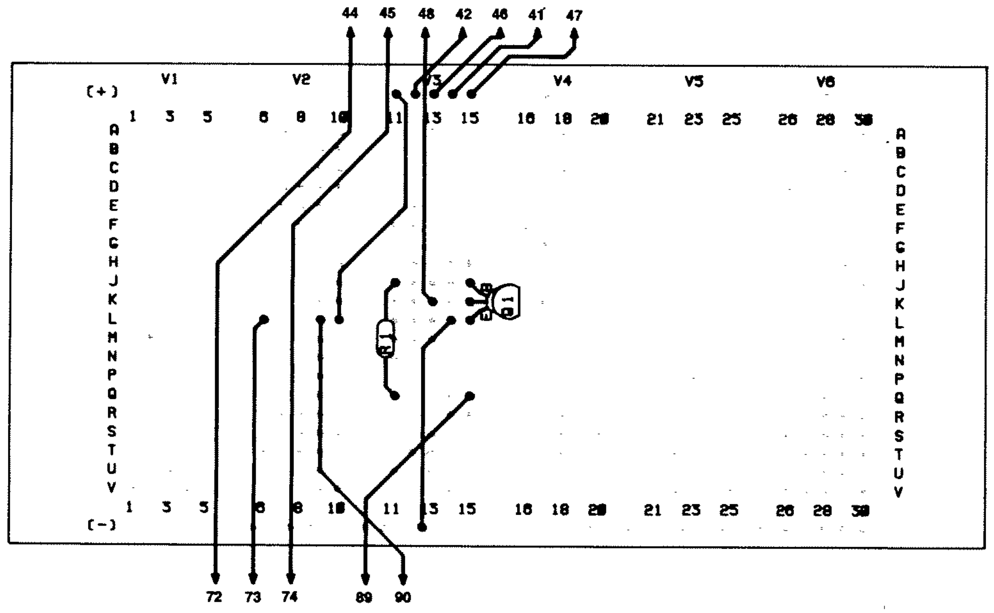
You can form different letters by wiring the segments together in various ways. In this project, the display shows either "J" or "H" depending on the setting of the **select switch**.

But those aren't the only capital letters that your kit can display. By simply changing the wiring connections at the display, you can get it to show **A, E, C, F, G, I, S** or **U**. But we're not going to tell you how to display these letters... just play around with this project a while and you'll soon find out how for yourself.

Once you do discover how to make these letters, be sure to make notes about how you did it - include the wiring sequences too. You'll find this information handy when you start cooking up your own circuits!



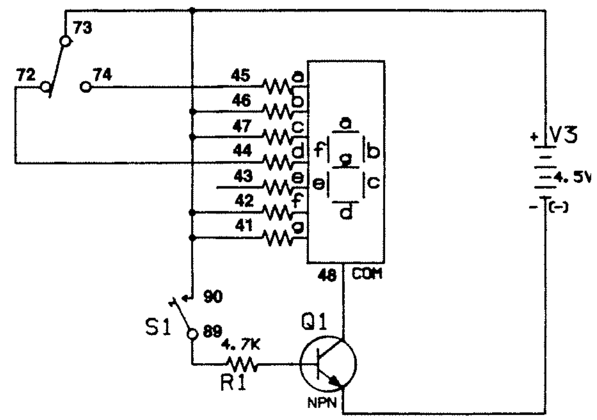
PROJECT 22. SMALL LETTER DISPLAY



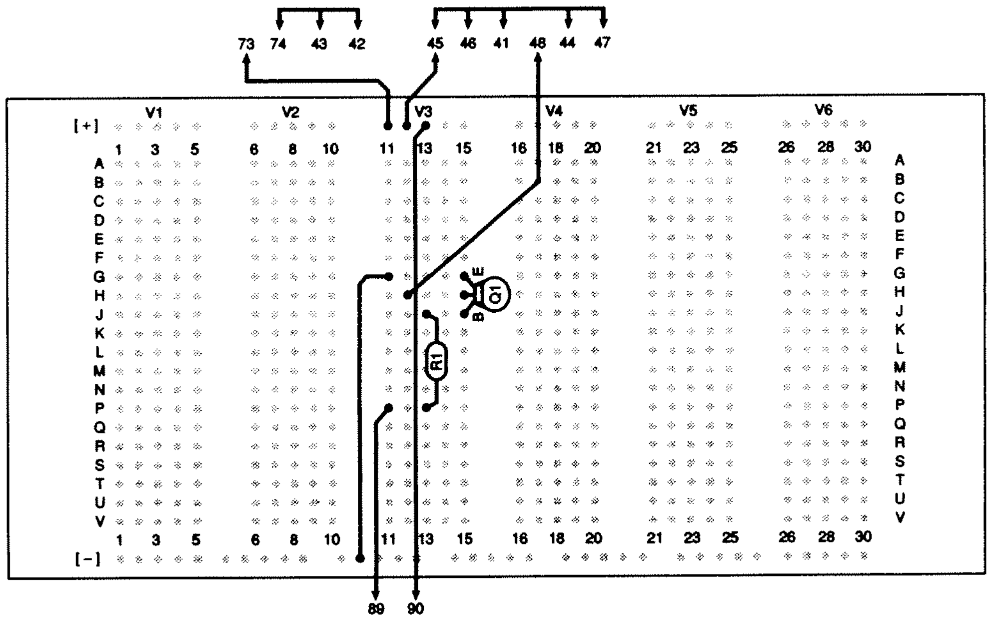
Q1 NPN R1 4.7KΩ

The digital display can also be used to show small letters, as this project demonstrates. As you change the setting of the **select switch**, either "**q**" or "**y**" is shown on the display.

By changing the wiring connections to the display, you can display **a, c, b, d, e, g, h** or **o**. Be sure to keep notes for use in your own circuits.



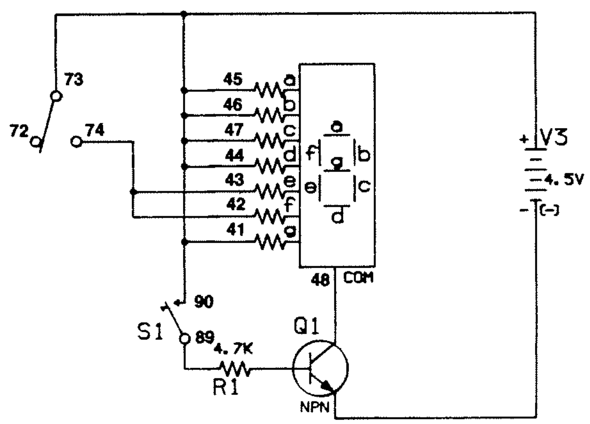
PROJECT 23. NUMBER DISPLAY



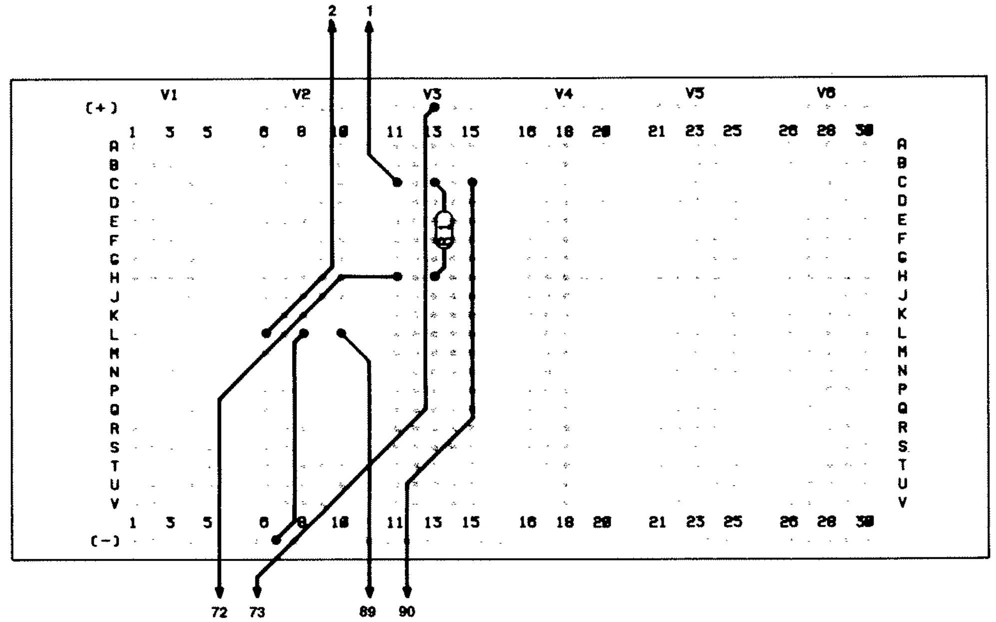
Q1 NPN R1 4.7KΩ

You might suppose, the **LED digital display** also can display numbers. You're right! This project displays either **3** or **8** when you press the key depending on the setting of the **select switch**.

By changing the wiring connections on the display, you can also display all the numbers from **0** to **9**. Be sure to keep notes of what you discover.



PROJECT 24. AN INVERTER CIRCUIT



R1 680Ω

We are now going to enter for digital electronic circuit, but what does the term mean? Digital circuits are also known as logic circuits. They are "logical" because they can make decisions.

When we talk about digital circuits, we sometimes use the numbers 0 and 1. Number zero means the circuit is off. All digital circuits are based on the simple fact that a circuit can be on or off.

Let's start out by exploring an inverter circuit. An inverter is a circuit that takes an input (an input is something that goes "into" a digital circuit) and "reverses" it.

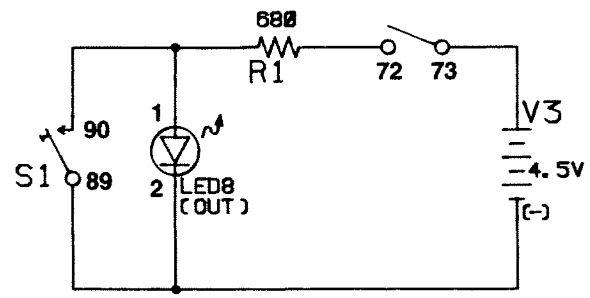
When you finish the wiring, switch power ON. **LED 8** lights. This can be called 1. When you press the key, **LED 8** goes out. This is 0.

But notice how the inverter "reverses" the input. When there is no input (you don't press the key), there is an output (**LED 8** is lit). But if there is an input (you press the key) there is no output (**LED 8** goes out).

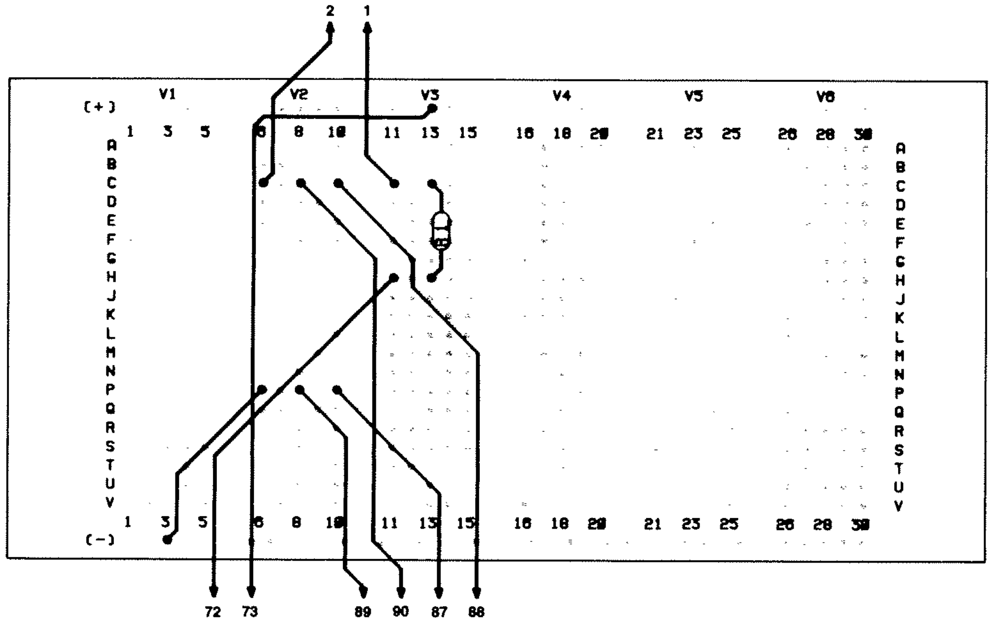
By the way, an output is something that "comes out of" a digital circuit,

Since an inverter reverses an input, what do you think the appropriate number would be if the key is not pressed? If the key is pressed? (No fair peeking at the answer!).

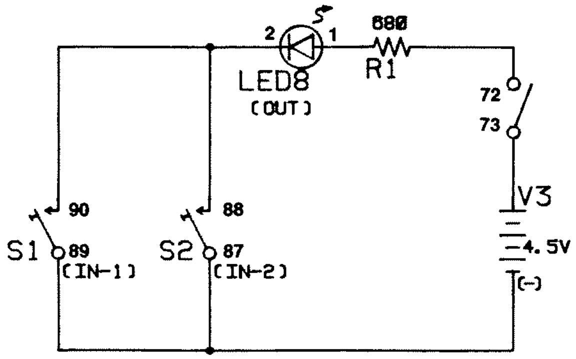
If the key is not pressed, that's 0 since the output (**LED 8** being lit) is 1. And if the key is pressed, that's 1 since the output is 0. Remember that the inverter reverses an input! (Or you might say it turns night into day!)



PROJECT 25. MEET THE OR GATE



R1 680Ω



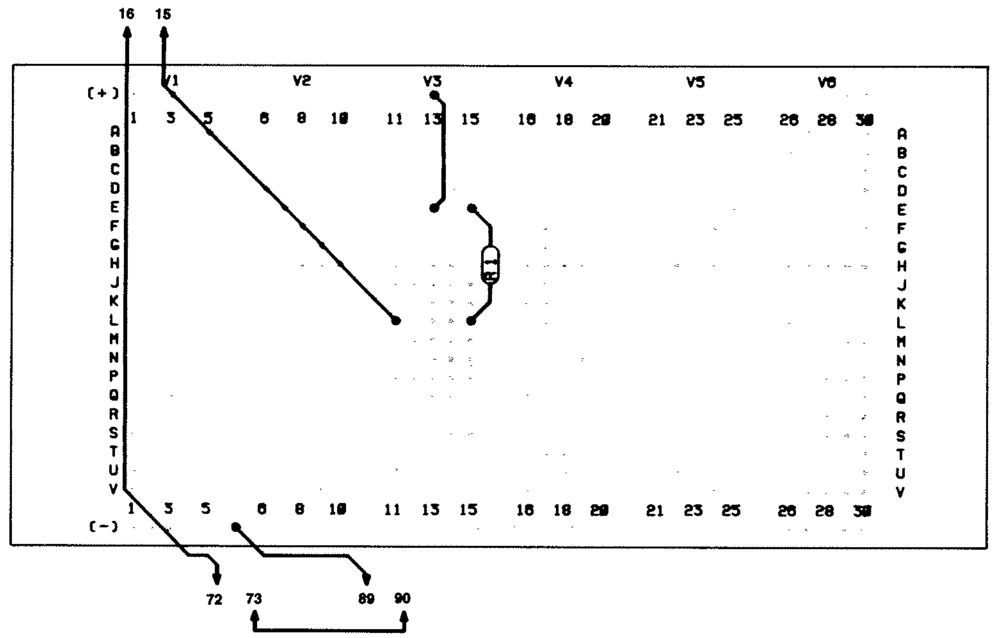
This project is a very simple OR circuit. Set the **select switch** up. This turns power ON. You notice that **LED 8** is out. Now press **S1**. What happens? Release **S1** and press **S2**. What happens now? Leave **S2**, now press **S1** again. Any change?

You see that as long as you set one of the inputs as 1, **LED 8** lit (also becomes 1). It stays on even when you had both inputs at 1 (**S1** key and **S2** key pressed). This is how an OR circuit works - it produces an output whenever at least one of its input is on (or 1, as digital electronics people like to say).

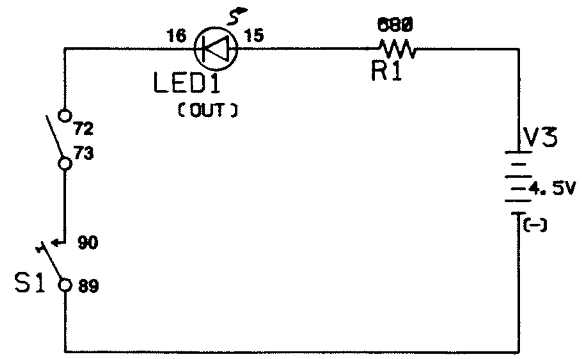
Circuits like this are sometimes called gates. It's not too hard to see where the name came from - the circuit "lets in" inputs and gives an output based upon those inputs.

The OR circuit is very handy! For example, a more complicated OR circuit could be used to turn on the lights if it got too dark in a room or if it is 7:00 p.m. Can you think of other good uses for an OR circuits? (Be sure to record what you think ...)

PROJECT 26. INTRODUCING THE AND GATE



R1 680Ω



Before we go any further, what do you suppose an AND gate does? Think about it a second ... since you know what an OR circuit does, what would it be logical (pardon the pun!) for an AND circuit to do?

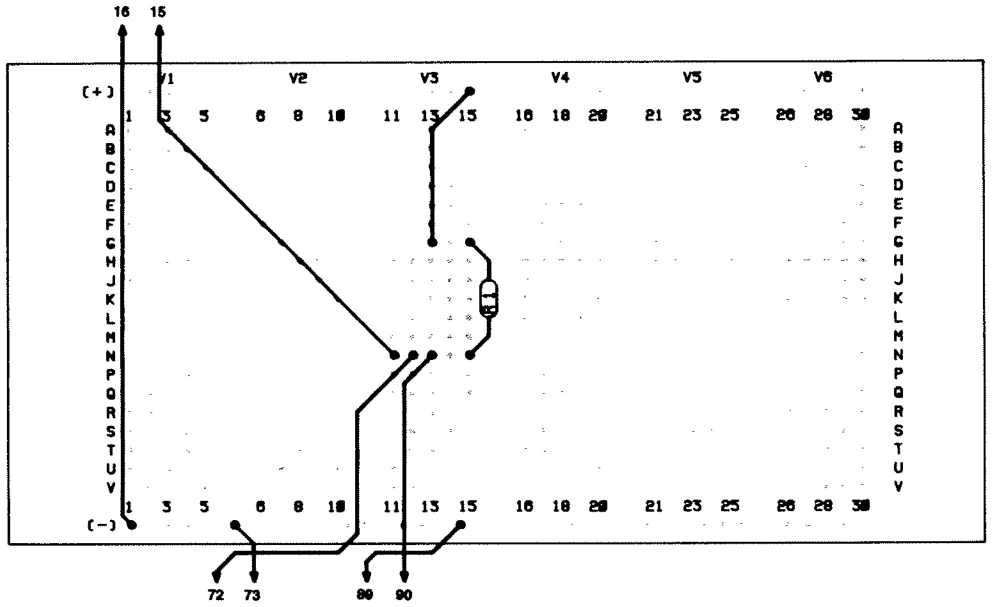
As you build this project, make sure the **select switch** is set to the down position and press **S1**. What happens? Now release **S1** and set the **select switch** up. What happens now? Finally, leave the **select switch** at the up position and press the key. Anything different happens?

You saw that nothing happened until you had the **select switch** at the up position and the key pressed. When you set both input as 1, **LED 1** comes on: an AND gate is a circuit whose output doesn't come on until all the inputs are also on.

Say, do you suppose an AND gate could be used in computers or calculators?

You bet your sweet bippy they're used in computers and calculators!

PROJECT 27. USING THE NOR GATE



R1 680Ω

Here's another circuit that gives you a clue to how it works by its name. Think you can figure it out? Try and see how close you come!

As you build this project, make sure the **select switch** is set to the down position. What does **LED 1** do? Now press the key. Is there any change in **LED 1**? Release the key and set the **select switch** up. What happens now? Now press the key again while the **select switch** is at the up position. Is there any change in **LED 1**?

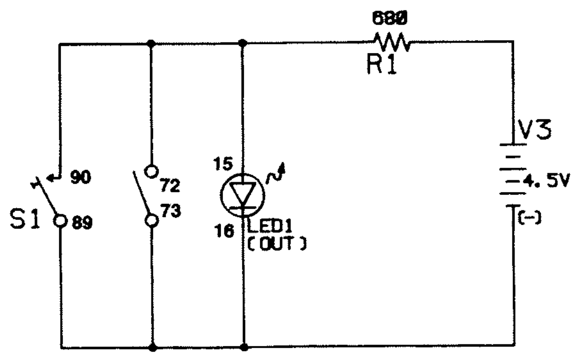
As you can see, a NOR gate does the opposite of what an OR gate does. A NOR gate normally has an output (or, as electronics engineers like to say, it's at 1). But whenever one or both inputs are activated, the output goes off (or becomes 0).

Now think a second... what does this NOR gate remind you do?

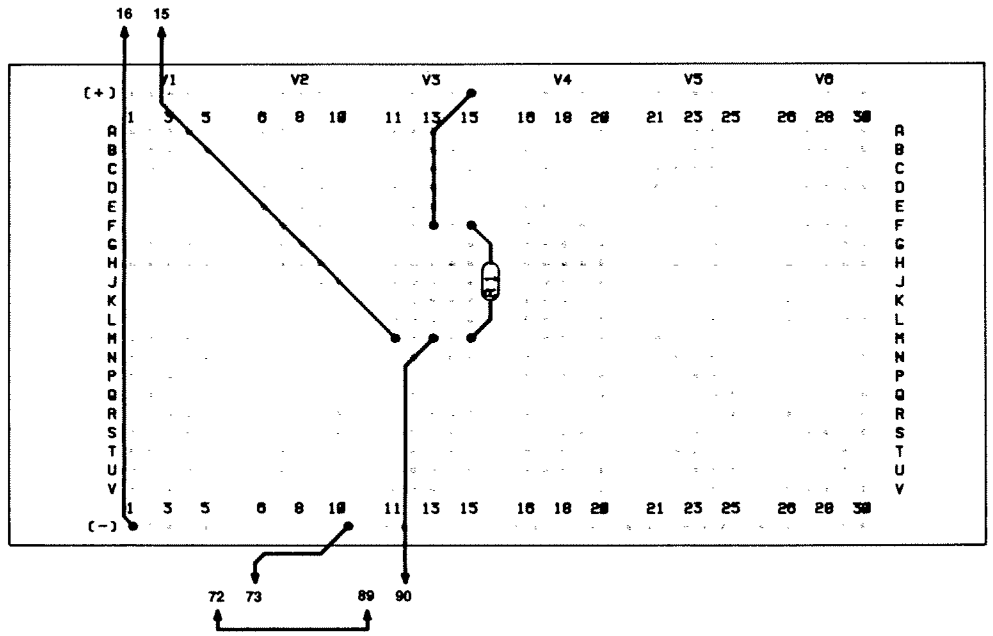
We hope you said project 24, where we met the inverter circuit. You can see that a NOR gate is really an inverter circuit with more than one input. If all of the inputs are 1, then the output becomes 0!

Where would you suppose they came up with this name from? How about "not" "or" (or in other words an inverted OR).

Can you think of how NOR circuits could be used in electronic devices?



PROJECT 28. MEET THE NAND GATE



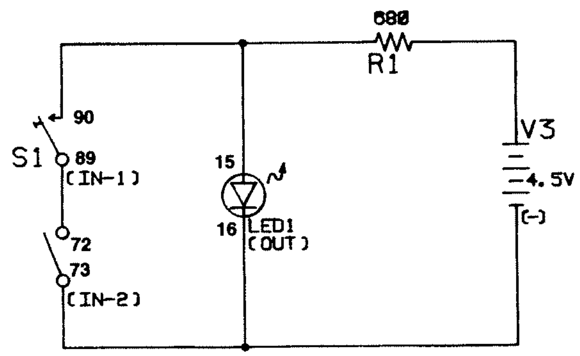
R1 680Ω

Were you able to figure out what a NOR gate did by its name? If so, it ought to be a cinch to guess how a NAND gate works. Make a mental note of how you think it works before building this project.

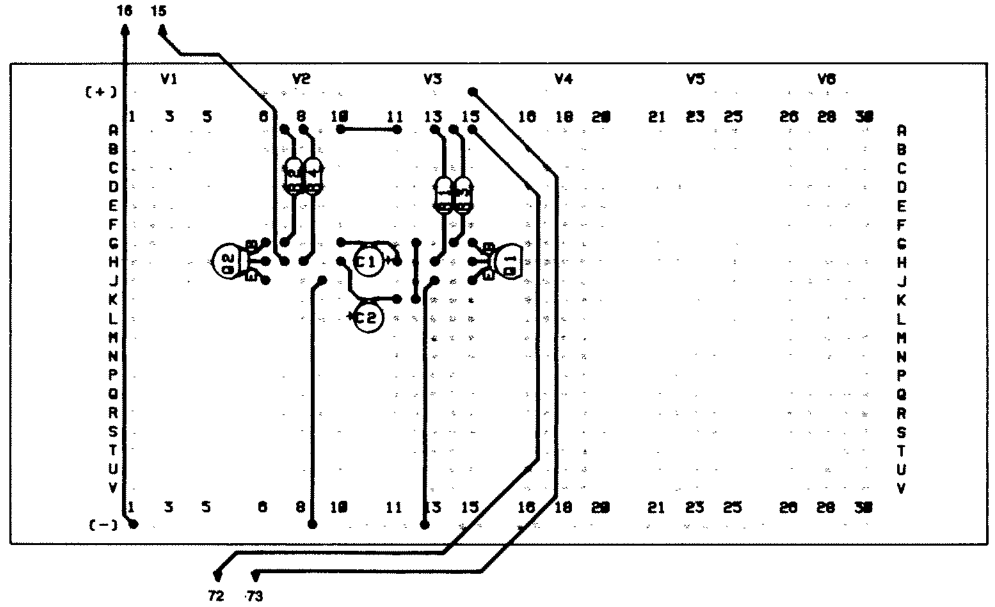
While you're making the wiring connections, set the **select switch** down. What does **LED 1** do? Now set the **select switch** up. Any change in **LED 1**? Now press the key while the **select switch** is at the up position. Anything different now?

As you probably suspected, a NAND gate turns off its output when all of its inputs are on. Or - to use some fancy electronic engineer's talk - the output of a NAND gate to 0 when all inputs are at 1. And you can also see that this is another type of inverter circuit.

Now look for the Integrated Circuit in the parts box of your kit. Two of them are labeled 74HC00: these are the ICs called "Quad 2-Input NAND IC." What do you think there's a NAND gate (or maybe several NAND gates) inside that tiny little part? Make notes of what you think ... you'll have fun looking back on them after some future projects!



PROJECT 29. HOW A MULTIVIBRATOR WORKS



Q1	NPN	R1	1KΩ	R3	4.7KΩ	C1	100µF
Q2	NPN	R2	4.7KΩ	R4	1KΩ	C2	100µF

After you finish the wiring connections, set the **select switch** up. This turns power ON. Look at the **LED 1** - what's happening?

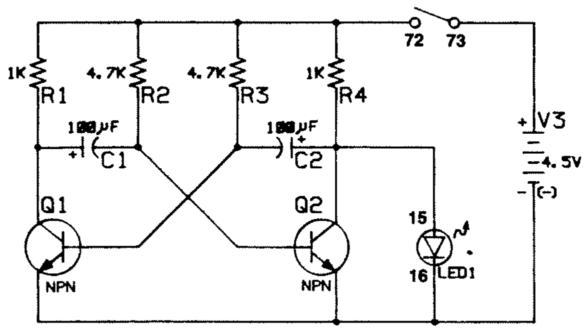
You see the **LED 1** lights up and then turns off immediately. The **LED** stays off a few moments, and then the cycle repeats itself.

This type of output is called a square wave. Can you imagine how it got this name? (Hint: think of how a square looks ... straight sides, a flat top... and now think of how the **LED 1** works.)

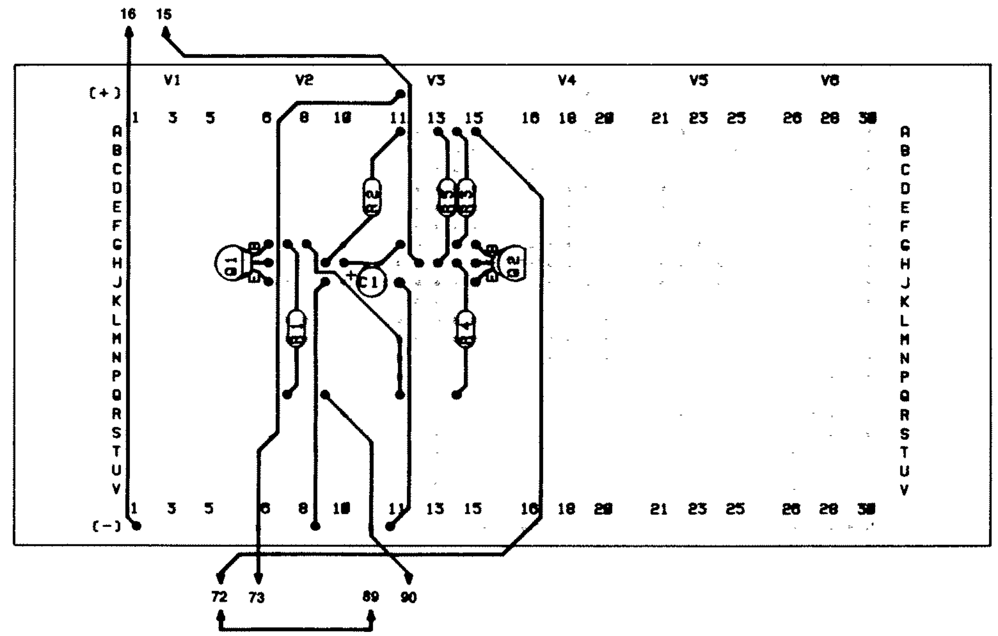
Yes the output is in the form of wave. But notice that the output is either on or it's off... there's no "in between!"

This means that a multivibrator is a digital circuit. 0 is when the circuit has no output while 1 is when there is an output.

You can see that it's possible to control the operation of OR, AND, NOR and NAND gates using a multivibrator circuit. You can also make a multivibrator operate at a different rate... try substituting 2.2K or 10K resistors in place of the 4.7K resistors used and see what happens.



PROJECT 30. A "ONE SHOT" MULTIVIBRATOR



Q1	NPN	R1	4.7KΩ	R3	33KΩ	R5	1KΩ
Q2	NPN	R2	1KΩ	R4	10KΩ	C1	100µF

Does the name of this circuit give you any hint as to how it operates? Make a mental note of how you think it works so you can compare with the results of this project.

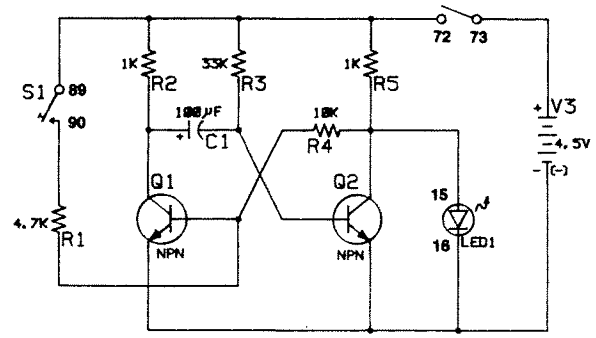
After making all the wiring connections, slide the **select switch** to up position. This turns power ON. Now press and release **S1**. Watch the **LED 1**... and continue to watch it for a few seconds. What happens?

Did you guess that the multivibrator would work just once ("fire one shot")? As you just saw, you were close... the multivibrator operates for a few moments and then stops. We might say this circuit makes "one shot" of pulses and then shuts off.

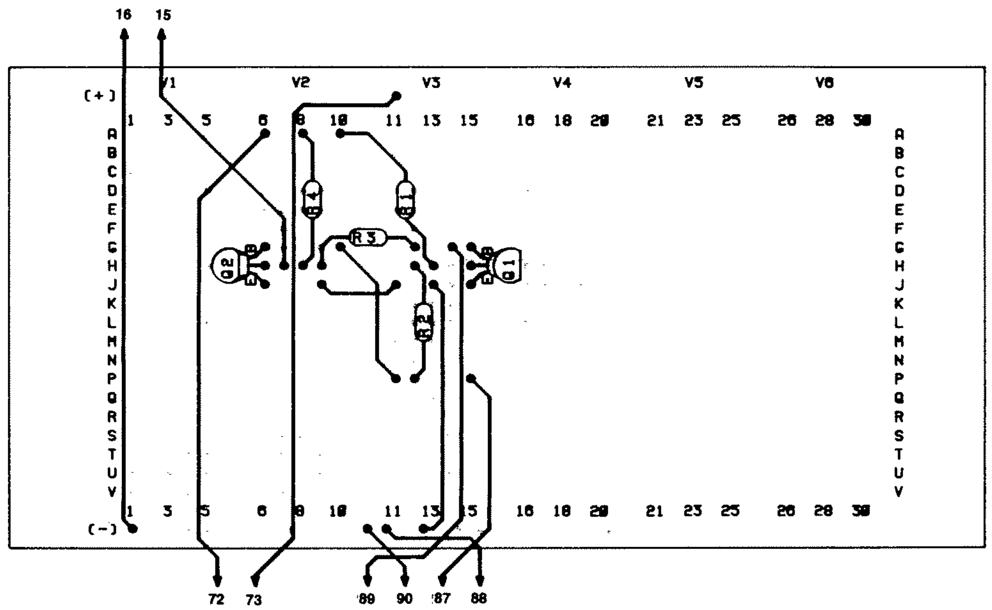
Try holding **S1** down for different lengths of time and compare it to how long the circuit operates .... can you make the circuit work longer by holding **S1** down for longer periods?

You found that you couldn't change how long the circuit operated. Do you have any idea why this is so by looking at the schematic? (No fair peeking at the answer.)

The difference in this multivibrator is the action of the 100µF capacitor. As you now know, this capacitor discharges to keep the circuit operating. Once it is completely discharged, circuit operation stops. And there's only so much current the capacitor can store, no matter how long you hold the key down!



PROJECT 31. AN R-S FLIP-FLOP

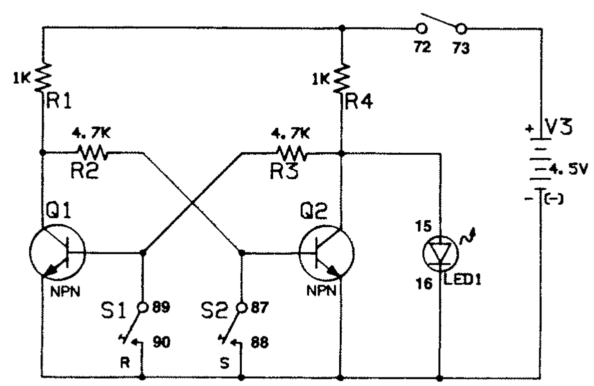


Q1	NPN	R1	1KΩ	R3	4.7KΩ
Q2	NPN	R2	4.7KΩ	R4	1KΩ

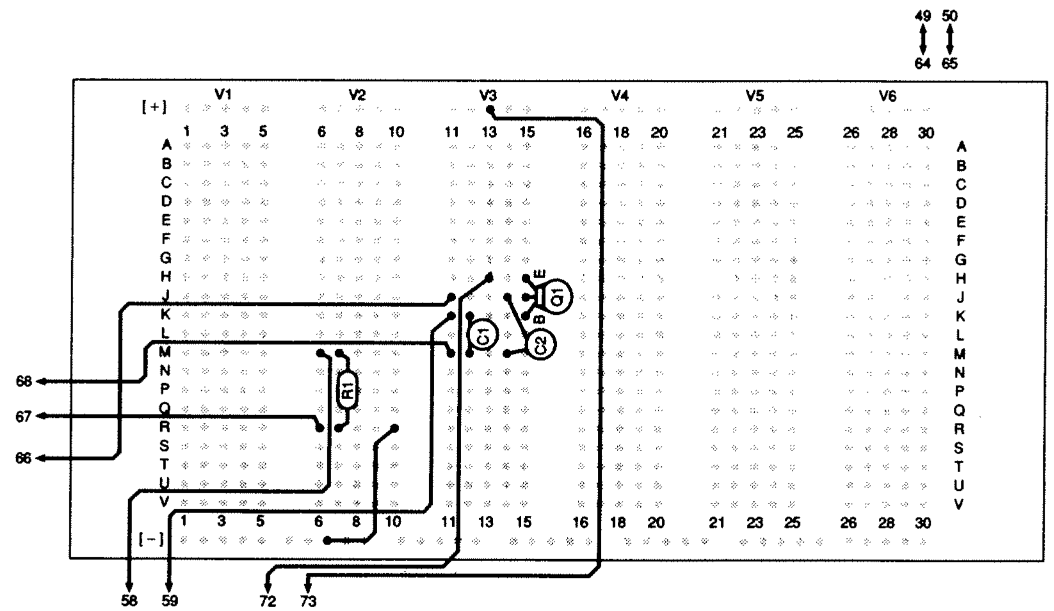
This project shows how a "flip-flop" circuit gets its name. It has two stages: off and on (or 0 and 1) and keeps that state until you change it. If the circuit is on (or 1), the circuit is said to be set. If the circuit is off (or 0), the circuit is said to be reset. (And that's where we get the R-S part of this project's name.)

After you wire this project, set the **select switch** to up position. This turns power ON. Look at the **LED 1** ... is anything happening? Now press **S1**. Is there any change? Now press **S2**, and see what happen to the **LED 1** again. Press **S1** once again.

Your kit has a part called a "Dual J-K Flip-Flop" (the Integrated Circuit marked "74HC76"). What do you think is different about this part and this circuit? Be sure to make a note about your guess.



PROJECT 32. MEET THE OSCILLATOR

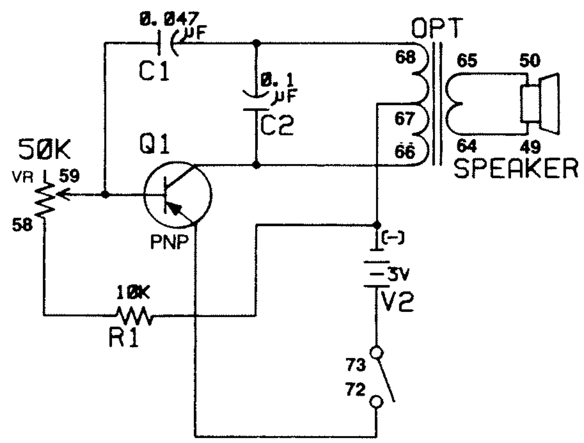


Q1	PNP	R1	10KΩ	C1	0.047µF
				C2	0.1µF

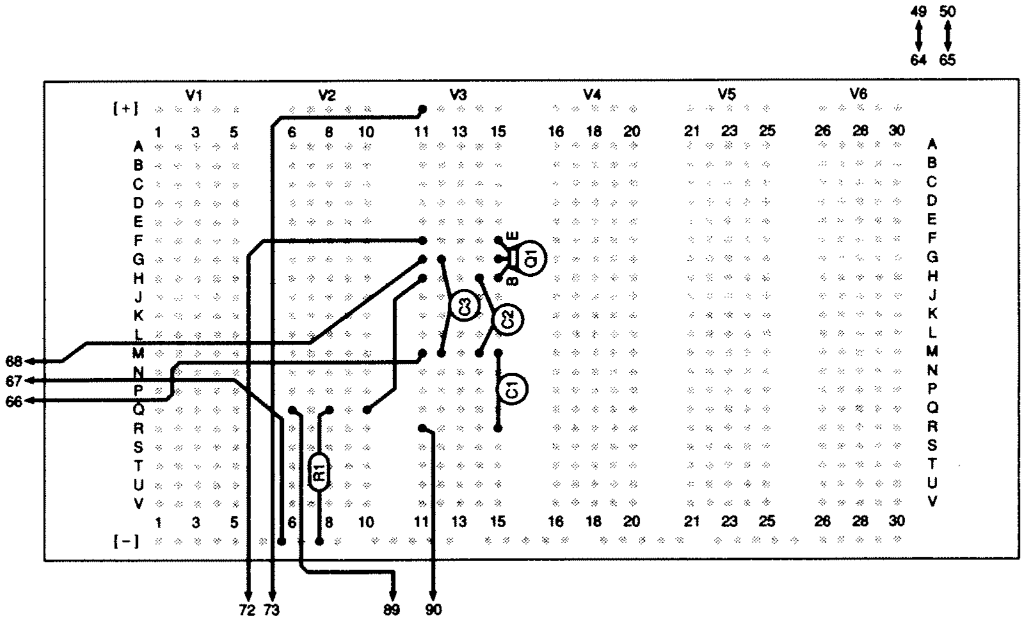
This project is an oscillator with adjustable frequency. You can change the notes by rotating the 50K **control volume**. With practice, you can play tunes on it, like an electronic organ. Adjust the **control volume** and set the **select switch** up then back down. Readjust the **control volume** for the next note and again set the **switch** up. After some practice you can play some simple tunes. You can even slur between notes, like a trombone.

This circuit is a typical pulse-tone oscillator. Oscillators require two conditions: a gain greater than the input and the feedback. The feedback control circuit is the key.

You'll find the more detailed explanations in later project. For now, note that the 0.047µF capacitor is rapidly charged and discharged: this results in oscillation. The 50K **control volume** adjusts the capacitor discharge time, thus the frequency of the sound you hear from **speaker** is changed.



PROJECT 33. CHANGING OSCILLATION WITH CAPACITOR

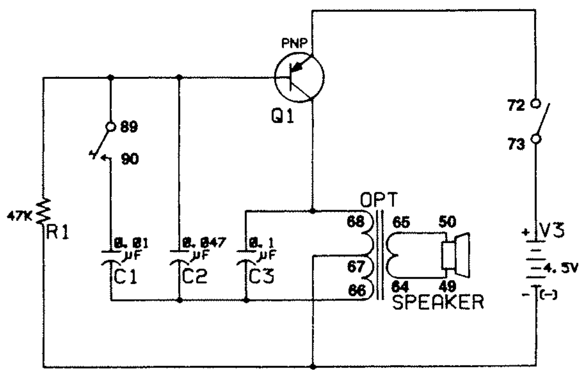


Q1 PNP R1 47KΩ C1 0.01μF C3 0.1μF
C2 0.047μF

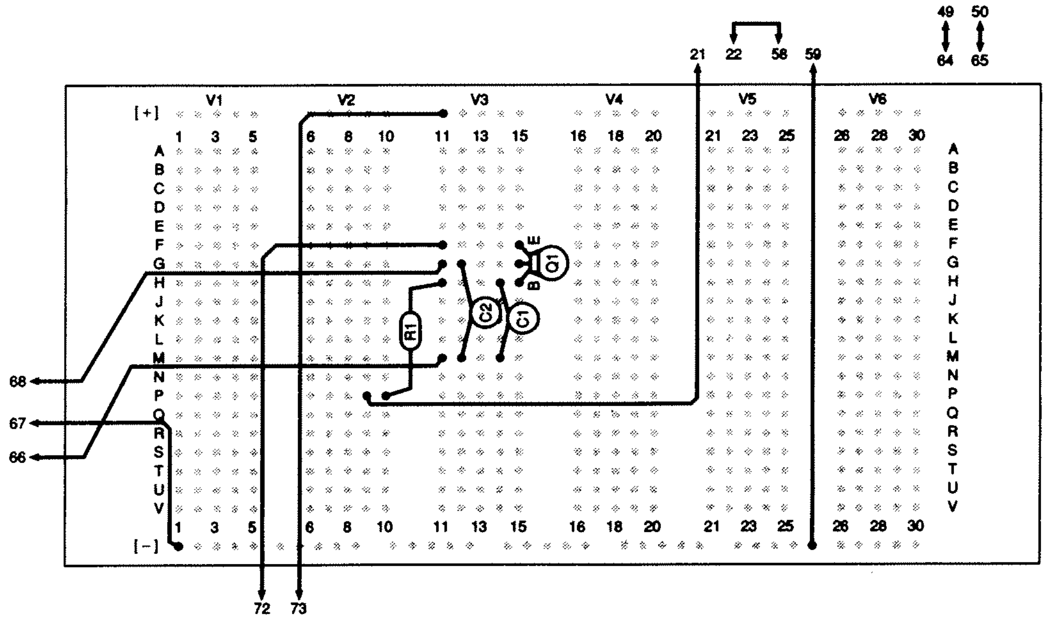
If things are too quiet around your house, this project fixes that in a hurry !

When you finish wiring this project, slide **select switch** up. This turns power ON. You immediately hear a loud, piercing tone (as does everyone else in the house!). When you press **S1**, you notice that the sound from the **speaker** becomes lower in tone - but still loud as ever. By pressing **S1** in the right rhythm you can create sounds like a police siren or ambulance.

The project also uses an oscillator circuit. Can you guess why does the circuit change tone when the key is pressed? See what part is added to the circuit when you press the key. You will soon learn why the addition of that part changes the tone—wait two projects...



PROJECT 34. CHANGING OSCILLATION WITH FOREIGN SUBSTANCE

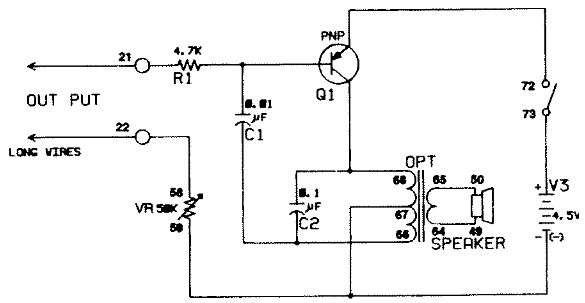


Q1 PNP R1 4.7KΩ C1 0.01μF
C2 0.1μF

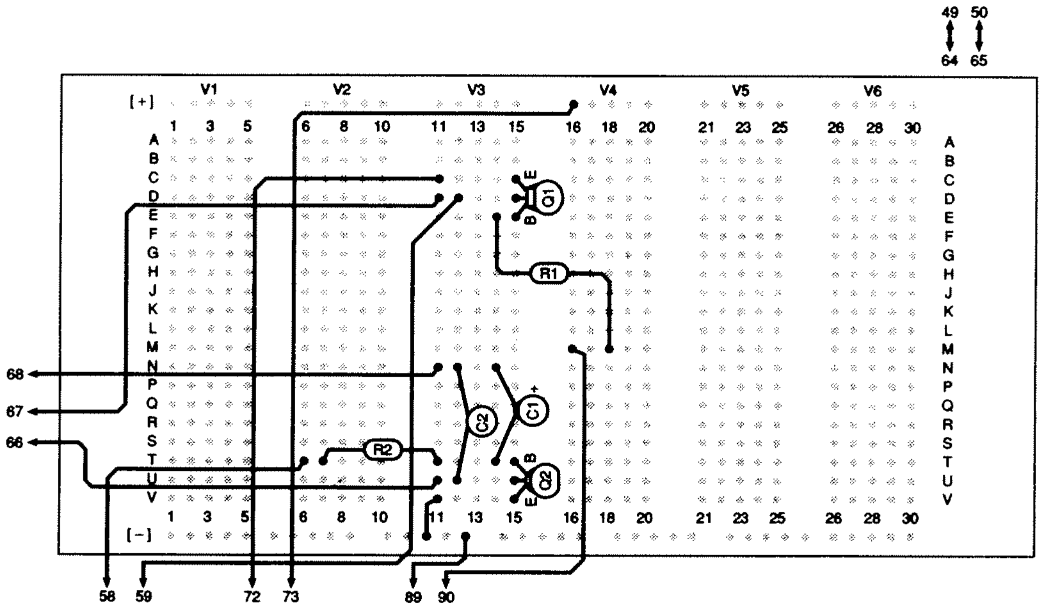
When you finish the wiring connection, set the **select switch** up. This turns power ON. Now grip the exposed ends of the long wires (from **21** and **22** terminals) and squeeze them tightly. The sound you hear from the **speaker** changes as the amount of current flowing through your body changes.

You can use this type of circuit as a lie detector by changes the tone of the sound from the **speaker**.

You can also use this circuit to see how well other things let current flow through them. Try such things as spoons, coins, different packages, furniture, etc. Make notes of things that let current flow well and those that don't.



PROJECT 35. MORE ABOUT OSCILLATOR



Q1	PNP	R1	10KΩ	C1	3.3µF
Q2	NPN	R2	22KΩ	C2	0.1µF

When you finish wiring this project, switch power ON and press **S1**. You'll hear a sound from the **speaker**. Now rotate the **control volume** back and forth. What do you now hear from the **speaker**?

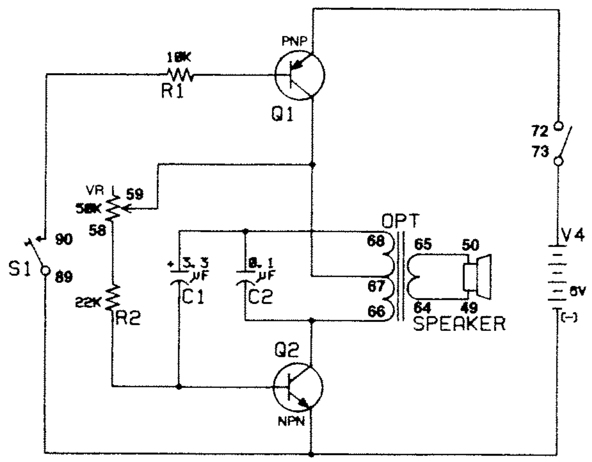
Oscillators make use of feedback. That means part of the output of the circuit is sent back into the input. Look carefully at the schematic for this project--can you see where some of the output goes back into the input?

Let's look how the current flows. When you press the key, current flows from the (+) terminals of the batteries through the transistor's emitter, then to its base. Also current flows through the collector of Q1 and enters the base of Q2 through the 22K and 50K resistances, then it returns to the batteries.

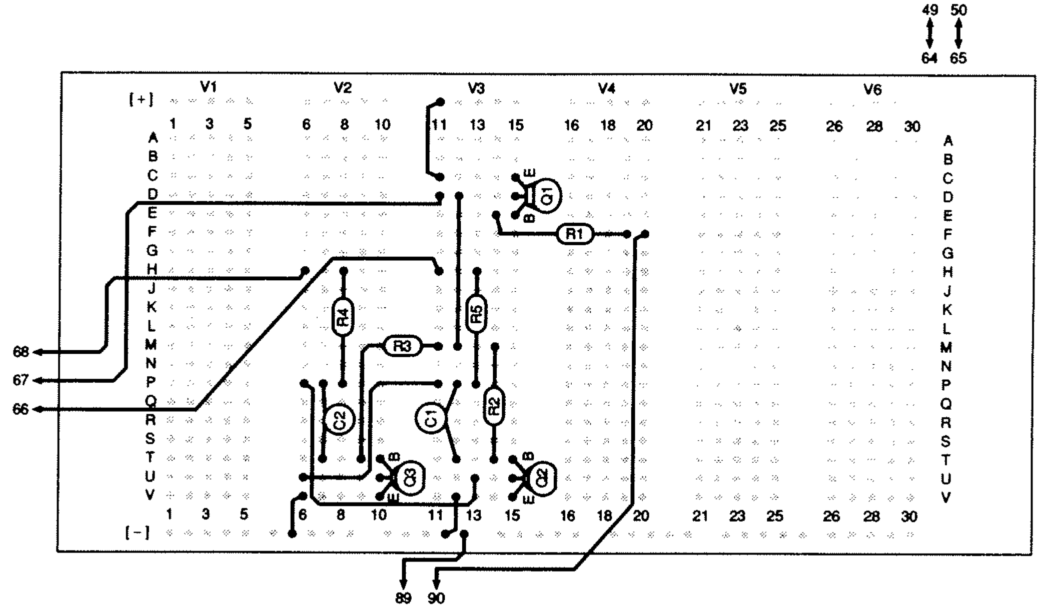
Current also flows in the OPT transformer the speaker is connected to. Think that electromagnetism might come into play here? You're right – an electric current is set up from the top of the transformer coil through the 3.3µF capacitor, the transistor's base and emitter, the key, batteries and back to the transformer by the connection at the middle of the its coil (that's called a tap).

As you might expect, charging and discharging of the 3.3µF capacitor is the key to this project's operation. When the 3.3µF capacitor discharges, it does so into the base of the transistor Q2. It just happens that this current is opposite from the emitter to base current (it's + instead of –). You guessed it - it shuts off the emitter to base current. But when the capacitor discharges low enough, emitter-to-base current again flows, the 3.3µF capacitor recharges, and the whole cycle starts again.

That's how feedback works. And feedback is necessary to make an oscillator go!.



PROJECT 36. A PUSH-PULL OSCILLATOR



Q1	PNP	R1	10KΩ	R4	1KΩ	C1	0.047µF
Q2	NPN	R2	47KΩ	R5	1KΩ	C2	0.1µF
Q3	NPN	R3	22KΩ				

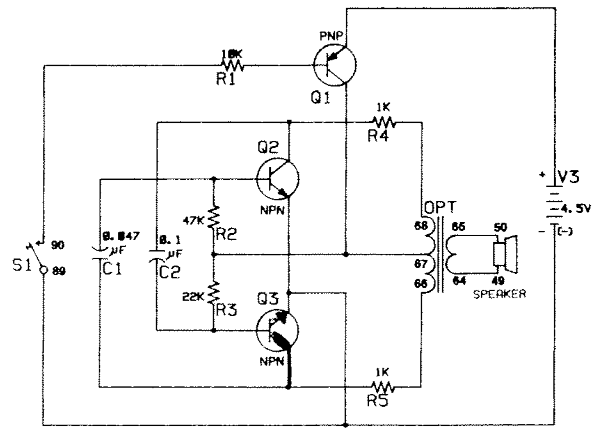
Once you finish the wiring connections, hold **S1** down and listen to the sound from the **speaker**.

Notice how feedback comes through the 0.047µF and 0.1µF capacitors connected to the transformer's coil. But see how each capacitor is connected at the ends of the transformer's coil. This means that when one capacitor is charging, the other is discharging. And this means...

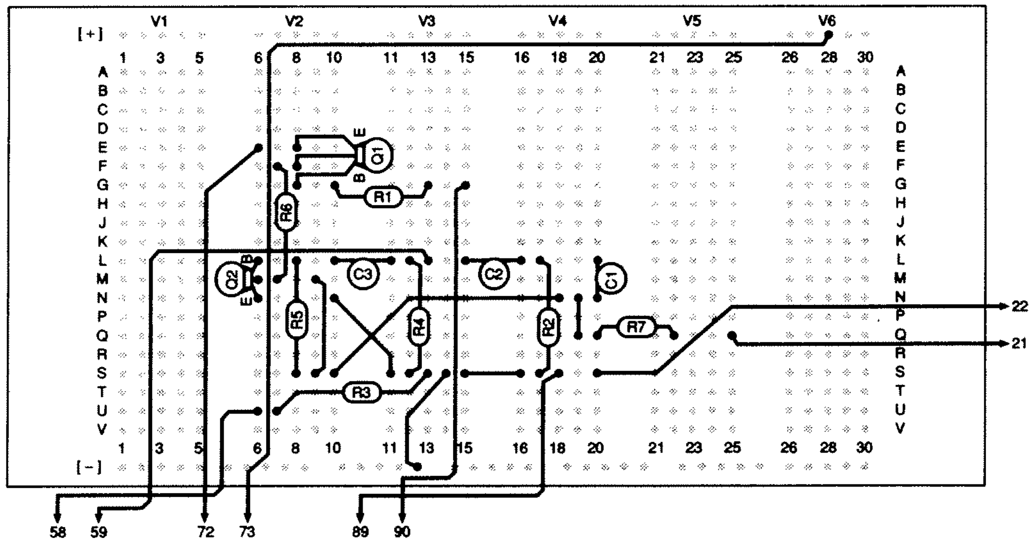
...that when one transistor is off the other is operating. There's always one transistor operating.

Since the 0.047µF and 0.1µF capacitors control circuit operation, try using different values of capacitors in their place. Since the 47K and 22K resistors control the base-to-emitter current, try using different values in their place and see what happens.

Be sure to keep notes of what you discover. What effects do higher and lower values have upon operation? You'll find this information handy when you start designing your own oscillator circuits.



PROJECT 37. LOW DISTORTION SINEWAVE OSCILLATOR



Q1	PNP	R1	10KΩ	R4	4.7KΩ	R7	100KΩ	C1	0.01μF
Q2	NPN	R2	2.7KΩ	R5	470KΩ			C2	0.01μF
		R3	1KΩ	R6	2.7KΩ			C3	0.01μF

Distortion? Sinewave? Hold on, we are going to explain you...

You know the sound you hear is waves of the air. The audio devices produce an AC signals that corresponds to the waves of the sound. The speakers convert this voltage change into the sound you hear.

The sinewave is a wave of pure single-frequency tone. For example, a 300 hertz sinewave alternates 300 cycles per second, and contains no other frequencies.

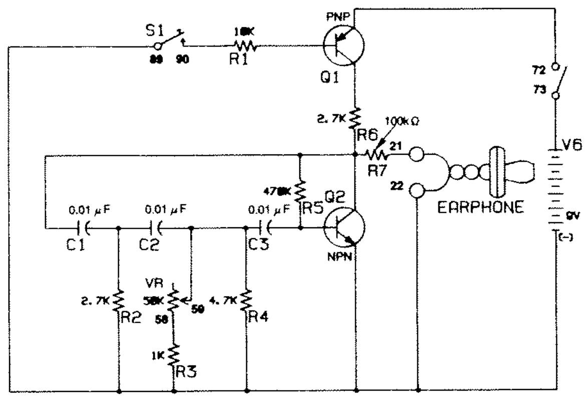
However, almost all sounds are mixture of various frequencies... normally the multiples of the main frequency. In case of 300 hertz tone, the sound contains a tone of 600 hertz, 900 hertz, and so on. These extra frequencies (engineers call them as harmonics) cause the distortion.

When wiring is complete, press **S1** key and adjust the **control volume** so you get the clearest sound. At this point you get the sinewave with lowest distortion.

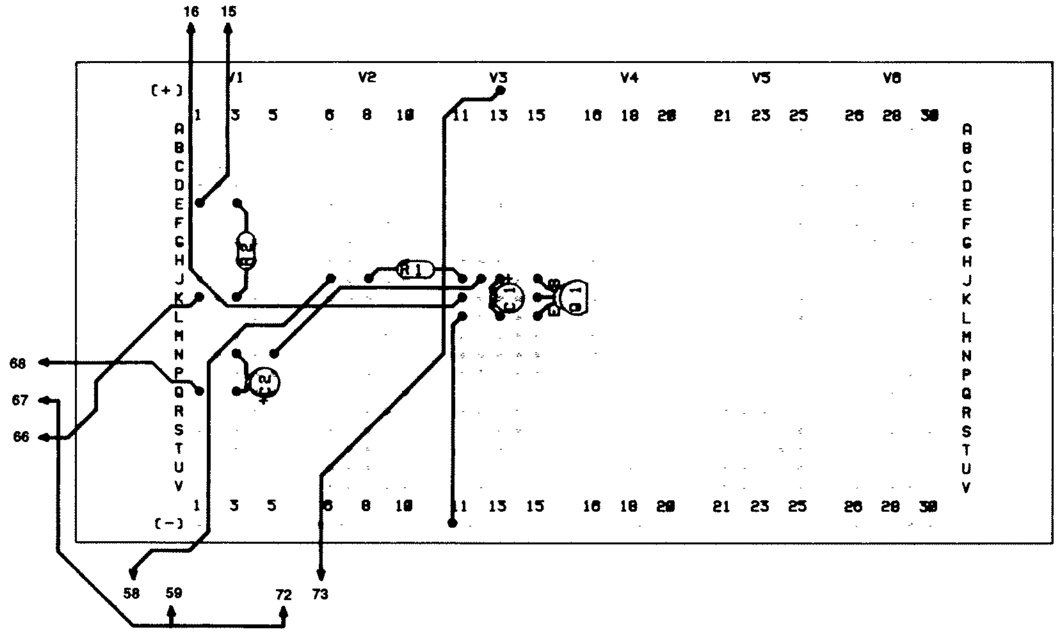
This circuit is a popular basic oscillator called an "RC phase shift" oscillator. (RC stands for resistor/capacitor -- did you guess correctly?) You will find this circuit described in many theory texts. Oscillation frequency is the one which the RC circuit shifts the wave half of its cycle, or as engineers would call it, shifts the phase 180 degrees.

This is necessary to get feedback, because the collector voltage of the transistor shifts 180 degrees from the base voltage. We must return this voltage back into original to get feedback.

The capacitors shift the phase 90 degrees if used alone. That is, the output waves are 1/4 cycle ahead of the input waves. With resistors added, the amount of phase shift decreases. When we add proper resistance we can make the phase shift to be 60 degrees. You see on schematic three RC combinations are used: namely, 60 degree phase shift is done three times to obtain 180 degree phase shift.



PROJECT 38. STROBE LIGHT

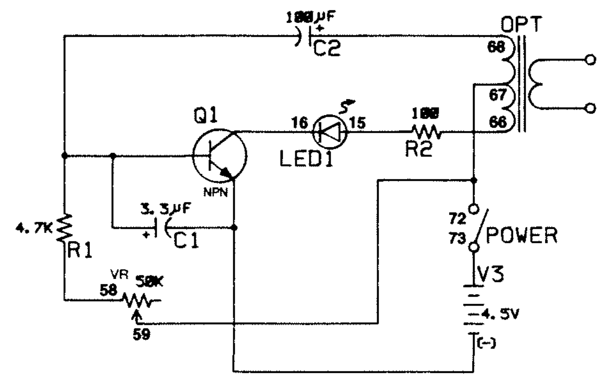


Q1	NPN	R1	4.7KΩ	C1	3.3μF
		R2	100Ω	C2	100μF

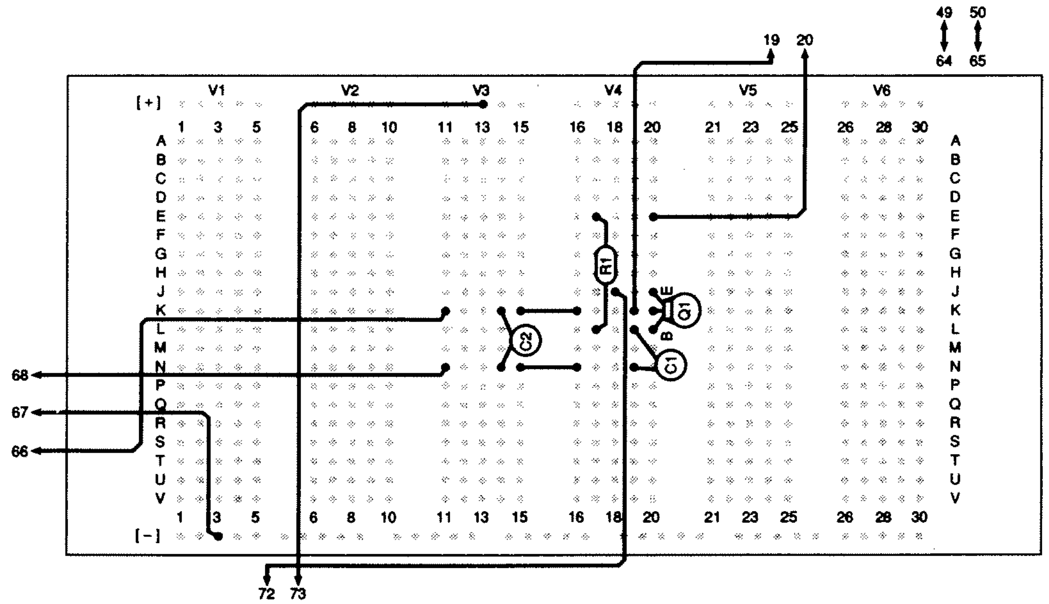
Here's an oscillator circuit that doesn't use the speaker or earphone - you don't hear its output. Instead, you see the output on an **LED**.

This project gives you an idea of how large strobe lights work. Turn power ON and watch **LED 1**: it turns on and off at a certain interval. You can control the blinking rate with the 50K **control volume**.

This project lets you get a "bird's eye view" of how an oscillator works. The charging and discharging of the 100μF capacitor controls the **LED** blinking rate. Try substituting a lower value capacitor and see what happens to the blinking rate.



PROJECT 39. CdS-CONTROLLED OSCILLATOR

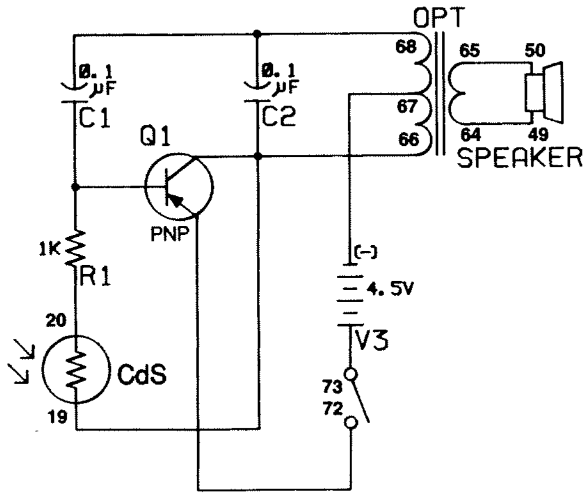


Q1	PNP	R1	1KΩ	C1	0.1µF
				C2	0.1µF

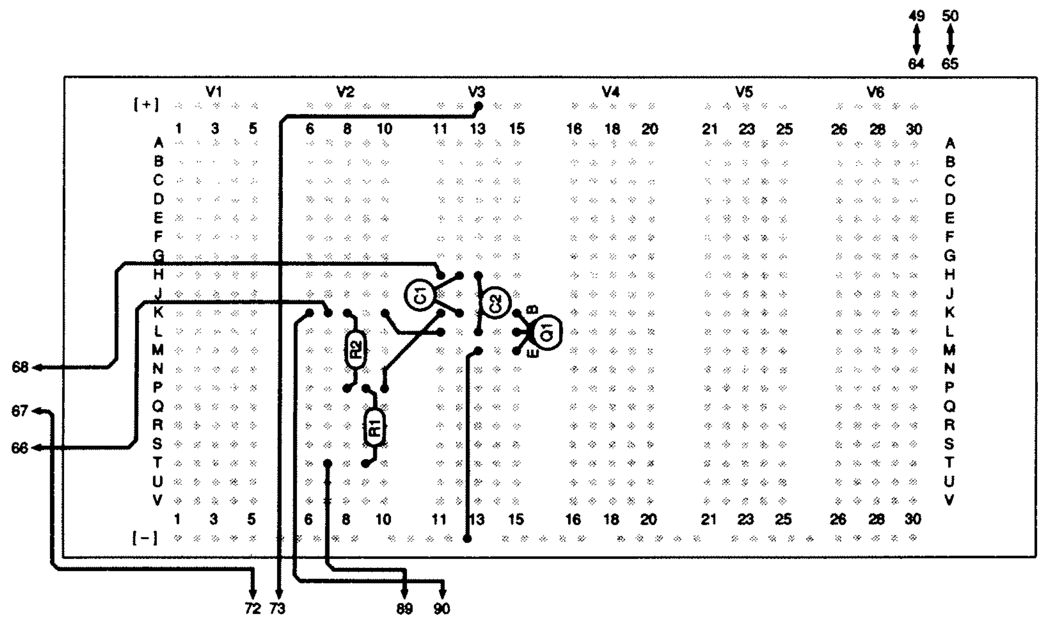
This project lets you control an oscillator's operation by the amount of light that falls on the **CdS cell**.

Wire this project and place your kit in a well-lit room and switch power ON. You hear a tone from the **speaker**. Now place your hand over the **CdS cell**... What happens to the tone? Try using this project in a darker room and see if you get the same results. You might also want to try a different value resistor in place of the 1 K in series with the **CdS cell**.

You can also use this circuit as a game. Place your kit in a dark room and try to "shoot" the **CdS cell** with a flashlight.



PROJECT 40. FREQUENCY SHIFT OSCILLATOR



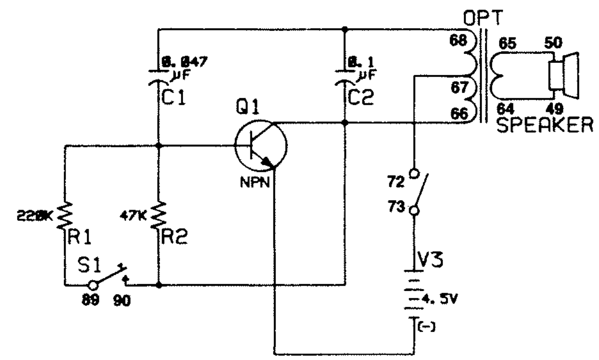
Q1	NPN	R1	220KΩ	C1	0.047µF
		R2	47KΩ	C2	0.1µF

Many of the oscillators we've played with so far have used **S1** to turn them on or off. This one is different ... can you tell what it does just by looking at the schematic?

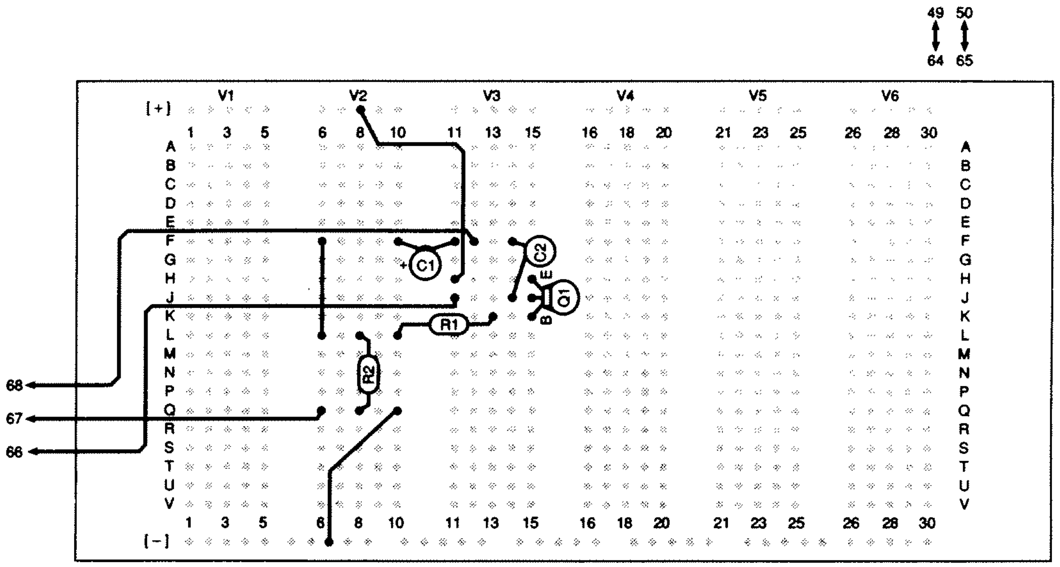
When you slide the **select switch** up to turn ON, you hear a tone from the **speaker**. Now press **S1**. What happens to the tone? Can you explain why this happens? (C'mon! By now this should be duck soup for you!)

When you press **S1**, you add the 220K resistor in parallel to the 47K resistor. When this happens, the tone become higher - just like you heard.

Try adding different resistors in place of the 220K. What effects do higher and lower values have on the tone when **S1** is pressed? Be sure to make notes of your results.



PROJECT 41. ELECTRONIC GRANDFATHER CLOCK



Q1	PNP	R1	100Ω	C1	100μF
		R2	100KΩ	C2	0.022μF

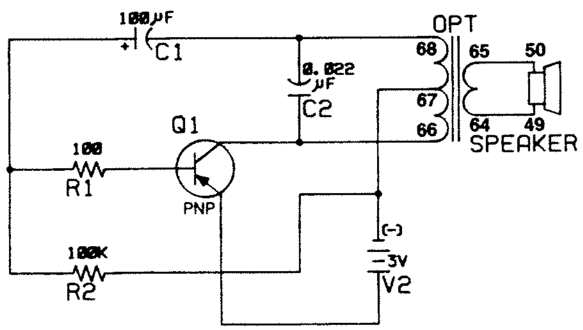
Do you want to perk up the ears of some of your elders? Anyone who has lived in a house with a grandfather clock will think you have one when they hear this project.

The circuit gives off clicks at one second interval. Change the 100K resistor to obtain faster or slower pulse rate. The timing and sound together remind the listener of the old grandfather clock.

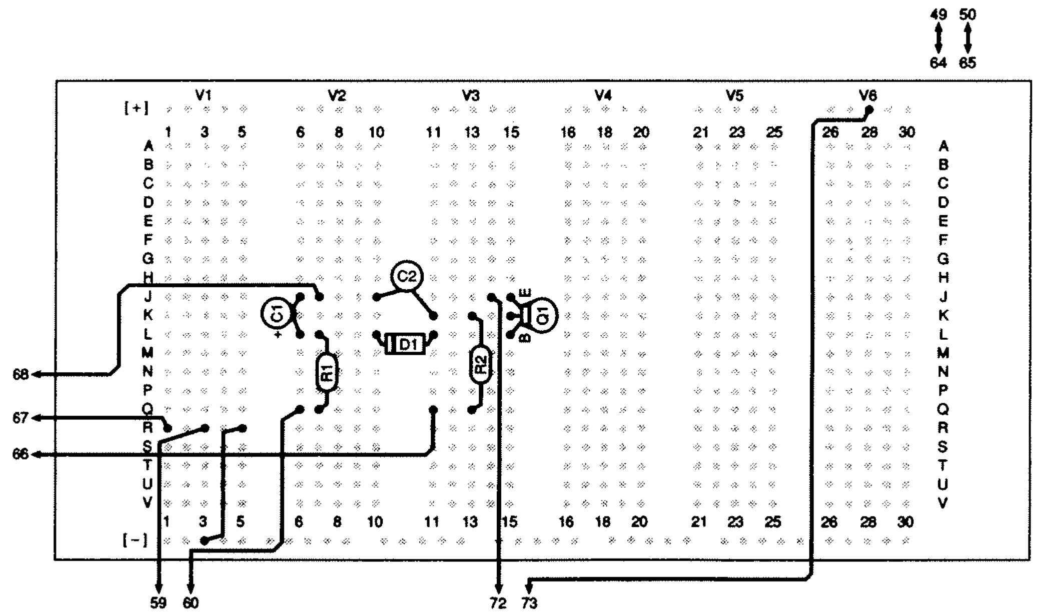
The steady monotonous ticking also gives animals (and people also!) a restful state of mind. If you have traveled on the train you know how you got sleepy as you heard the click, click, click of the tracks. Hypnotists have long been using this hypnotizing effect to gain control over the mind of his subject.

We've described circuit operation elsewhere in this book so we won't go into great detail. The transistor turns on as you apply power. The 100μF capacitor quickly charges up to a voltage greater than the 3V batteries. The capacitor charge quickly cuts off the transistor. Then the capacitor slowly discharges. When it discharges down to the battery voltage, the transistor turns on again, thereby giving off the click.

Now, want to scare this "clock" to stop? Yell into the **speaker**. How about that? You can momentarily stop this clock. Can you explain why?



PROJECT 42. ELECTRONIC METRONOME



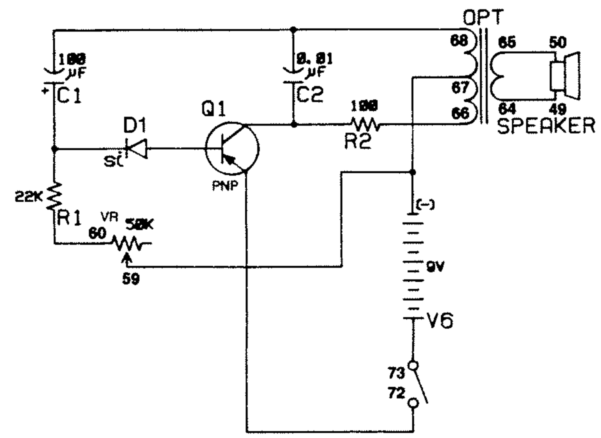
Q1	PNP	R1	22KΩ	C1	100μF
D1	Si	R2	100Ω	C2	0.01μF

Here's a project you might find useful if you're learning to play a musical instrument. This is an electronic version of the metronome used by music students everywhere.

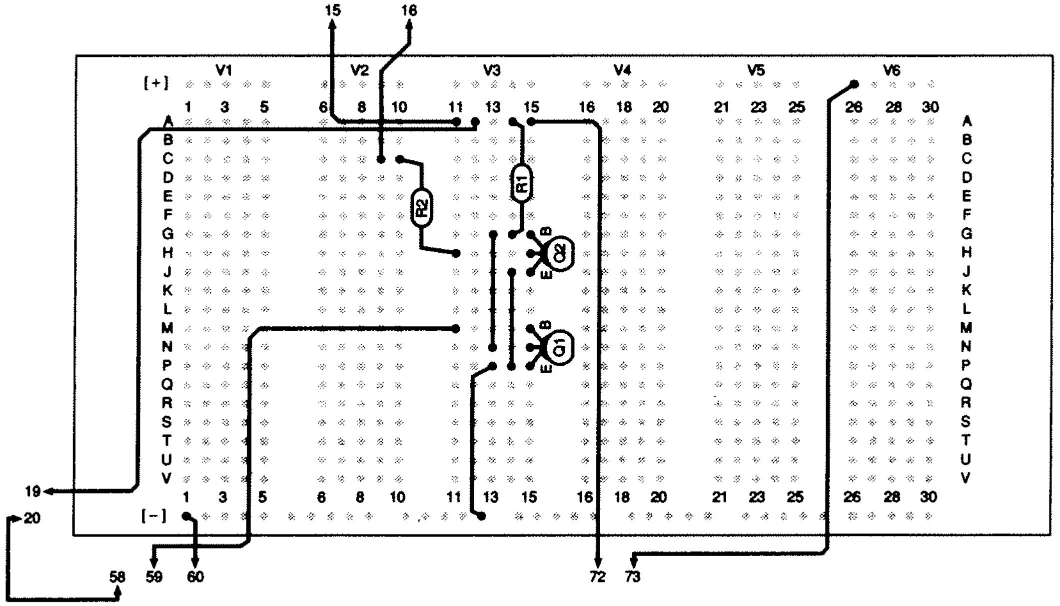
Slide the **select switch** up to turn power ON. You hear a sound from the **speaker** at a fixed interval. Now turn the **control volume** to the right (clockwise) and you hear the sounds "speed up" as the interval between sounds shortens.

The operation of this oscillator is like other we've played with. The circuit operates as the 100μF capacitor charges and discharges, and the 50K **control volume** controls its rate. This is why you can change the "speed" of the sounds by adjusting the **control volume**.

Try a different resistor in place of the 22K in series with the **control volume**. Also try a different capacitor in place of the 100μF electrolytic and see what effect this has on circuit operation. Remember to keep track of the results in your notes.



PROJECT 43. MOTION DETECTOR

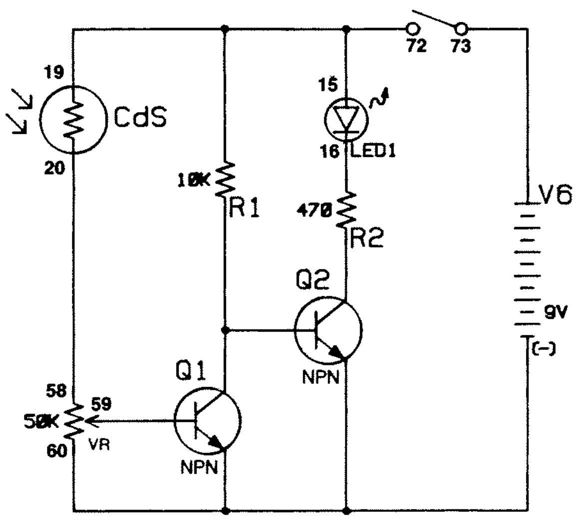


Q1	NPN	R1	10KΩ
Q2	NPN	R2	470Ω

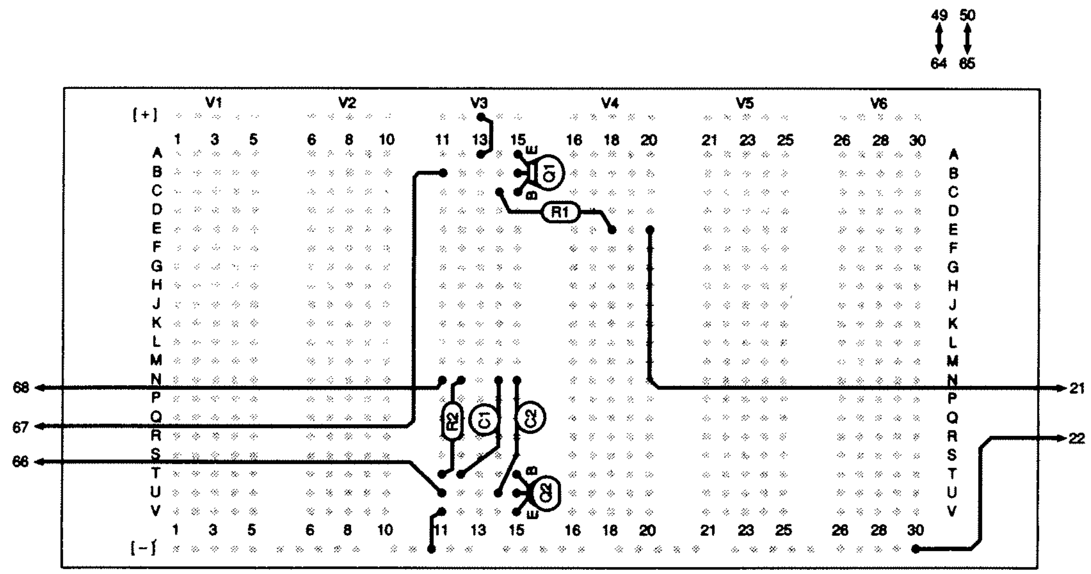
You need a flashlight and a dark room for this project. Now take your kit to a dark room along with a flashlight. Turn power ON and shine the flashlight directly at the **CdS cell**. Now move your hand in front of the flashlight beam and see what happens to the **LED**. Try adjusting the **control volume** for different results.

This is an example of a motion detector. These are often used in banks, defense plants, military bases and other areas where only certain people are admitted. This lets us detect intruders without the intruders being aware of it. The beam of light is usually located so that the intruder can't easily see it (for example, it can be only a few inches off the floor). Sometimes we use light invisible to the human eye, such as infrared, to make sure the intruder doesn't know about the motion detector.

Try using this detector in a normal room. Does it work?



PROJECT 44. DOOR ALARM



Q1	PNP	R1	10KΩ	C1	0.047μF
Q2	NPN	R2	220KΩ	C2	0.1μF

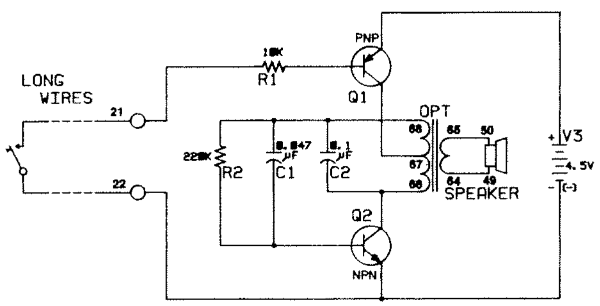
Here's a nifty buzzer circuit that makes a super alarm. This is known as a contact alarm for reasons you'll soon see.

As you build this project, you'll notice that there's no switch to turn it off or on, nor is the key used. When you finish, touch the two exposed metal ends of the long wires together. You'll hear a buzzer sound from the **speaker**.

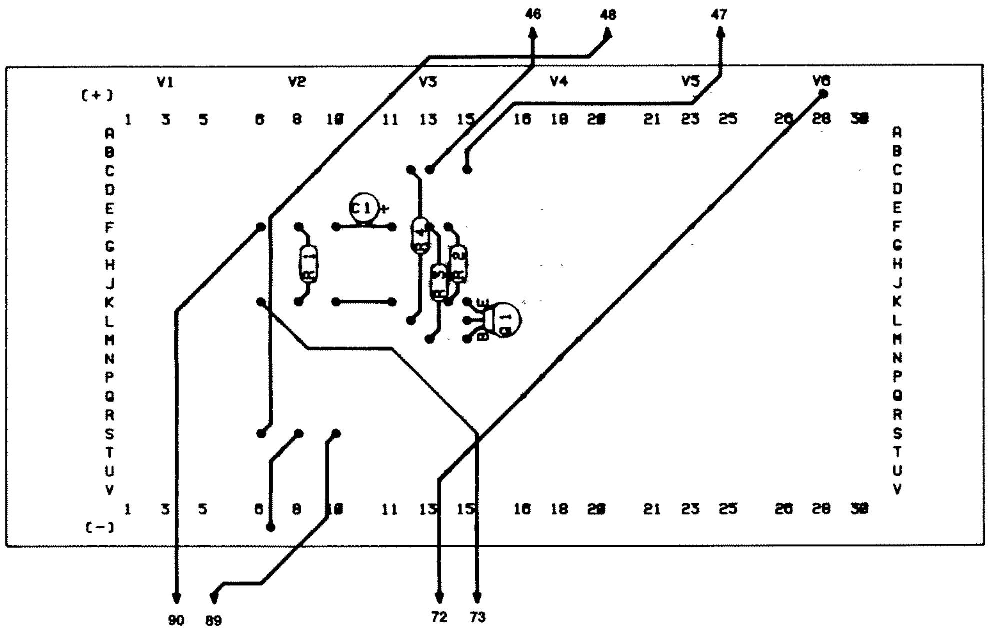
You can use this project to let you know if something moves and causes the two long wires to make contact with each other. For best results, place the wires so that one is horizontal while the other is vertical. This way they're more likely to make contact with each other.

You can place the long wires on a door and its frame so that they make contact when the door is closed. You can use this same arrangement for desk drawers, storage chest covers, cabinets, etc.

You can also use this circuit as a Morse code practice unit by attaching the two long wires to the key.



PROJECT 45. RAPID LED DISPLAY SWITCHING



Q1	PNP	R1	10KΩ	R3	470Ω	C1	3.3μF
		R2	10KΩ	R4	470Ω		

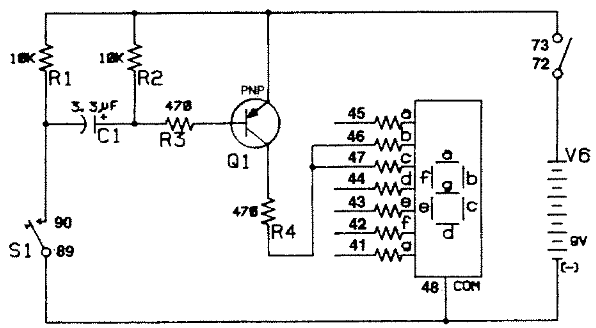
This project is a control circuit to produce pulses. When you turn power ON and press **S1**, the **LED display** lights for short period then goes off, even if you keep pressing the key.

You can make up a game. Have a number or letter displayed on the **LED**, and let the players see what's on display.

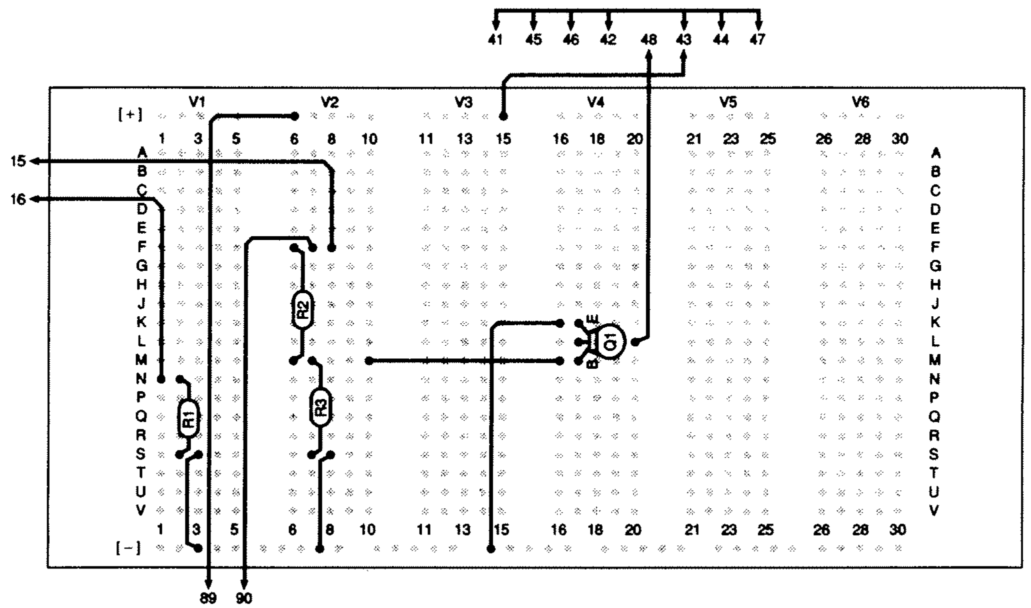
The circuit uses the capacitor charging current to turn the transistor ON. The transistor then completes the circuit to the **LED** anodes.

When the key is open the capacitor is discharged by the two 10K resistors. When you press **S1** key, the capacitor is quickly charged up to 9V through the transistor. The charging current through the B-E junction turns the transistor fully on to turn the **LED** on, but this last only up to the capacitor becomes fully charged. After the capacitor is charged to the 9V, no more current can flow to the transistor so the transistor is turned off.

You might want to try different values of capacitors and see their effect. However, don't use capacitor values higher than 10μF or the transistor can be burnt out by excessive current! Of course you can have many different numbers and letters on the **LED**, especially if you play the persistence-of-vision game, by changing the wiring on the **LED**. Now you can use the memo you made at projects 21-23!



PROJECT 46. CODE PRACTICE UNIT



Q1	NPN	R2	4.7KΩ
R1	470Ω	R3	22KΩ

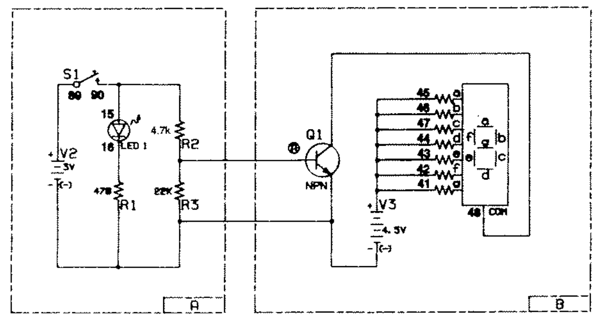
The ability to send and receive Morse code is a very useful skill to have. It is widely used in radio communications, and being able to send and receive Morse code is one of the requirements for some classes of "ham" radio licenses. Here is a neat project that lets you practice Morse code.

Press **S1**. The **LED 1** and the **LED display** turn on. This project is a wired type: the block A in the schematic diagram is the "sender" and block B is the "receiver". The two circuits are connected by the two wires.

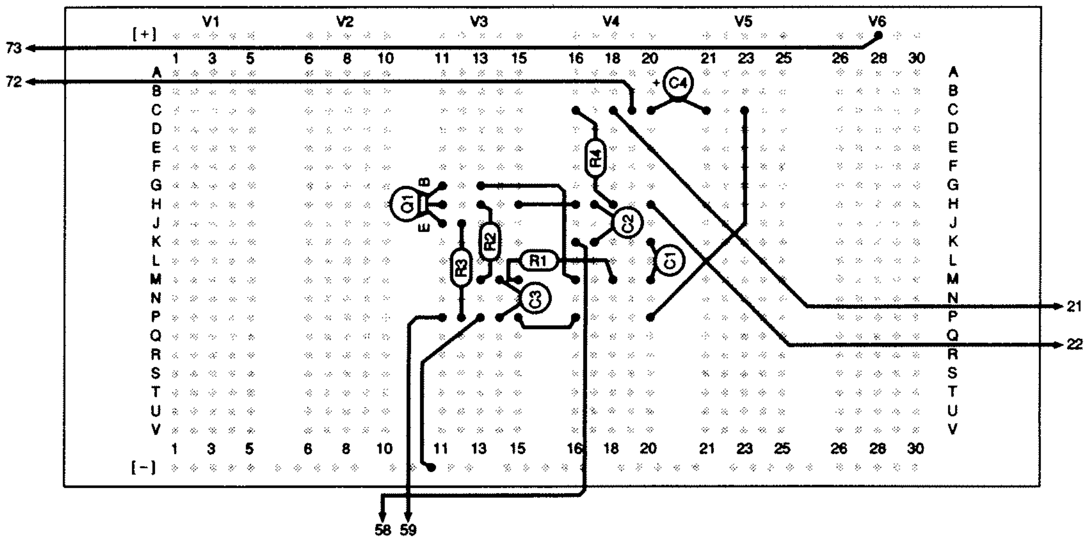
When the voltage of over 0.6V is applied to the base, Q1 turns on and the **LED display** turns on. What if the voltage is less than 0.6V? Try changing the value of R2 to 100 kohm. This reduces the Q1 base voltage to less than 0.6V. Now the **LED display** does not turn on even when you press **S1**.

You will build a wireless type of the Morse code transmitter later. Meanwhile, try practicing the Morse code with this project. We provided you the chart for Morse code for this purpose. (See Project 55 for Morse code.)

If you are interested in getting a "ham" radio license find books about "ham" radio in your school or public library (they might be listed under "amateur radio").



PROJECT 47. TWIN-T AUDIO OSCILLATOR



Q1	NPN	R1	47KΩ	R3	100Ω	C1	0.022µF	C3	0.047µF
		R2	22KΩ	R4	10KΩ	C2	0.01µF	C4	100µF

The purpose of this project is to study a twin-T type audio oscillator. Since this kind of oscillator is very stable in operation, it is often used for electronic organs, electronic test equipment, etc.

See schematic diagram: the resistors/capacitors are arranged in the form of the letter T, and there are two T's in parallel (or bridged across each other). That's where the name of this circuit comes from.

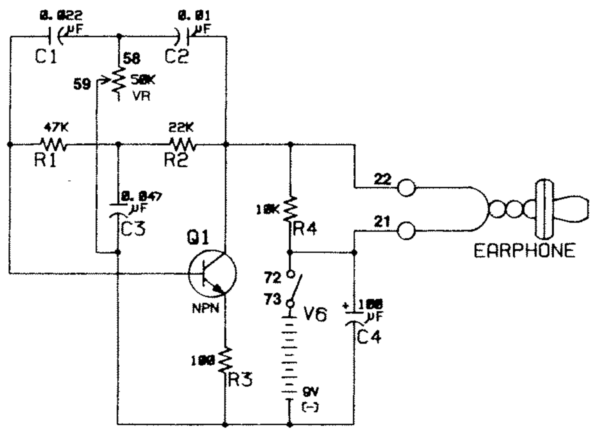
The values of the resistors and capacitors in the twin-T circuit decide the oscillation frequency: it gives off only the signal that can get through this network with the proper phase to keep oscillation.

If you set the **select switch** to up position, the transistor amplifies the oscillator output. The collector voltage is supplied through the 10K resistor. The 22K and 47K resistors supply the base bias current as well as functioning as part of the twin-T circuit. The 100 ohm resistor helps obtain a high input resistance at the base of the transistor and to reduce distortion.

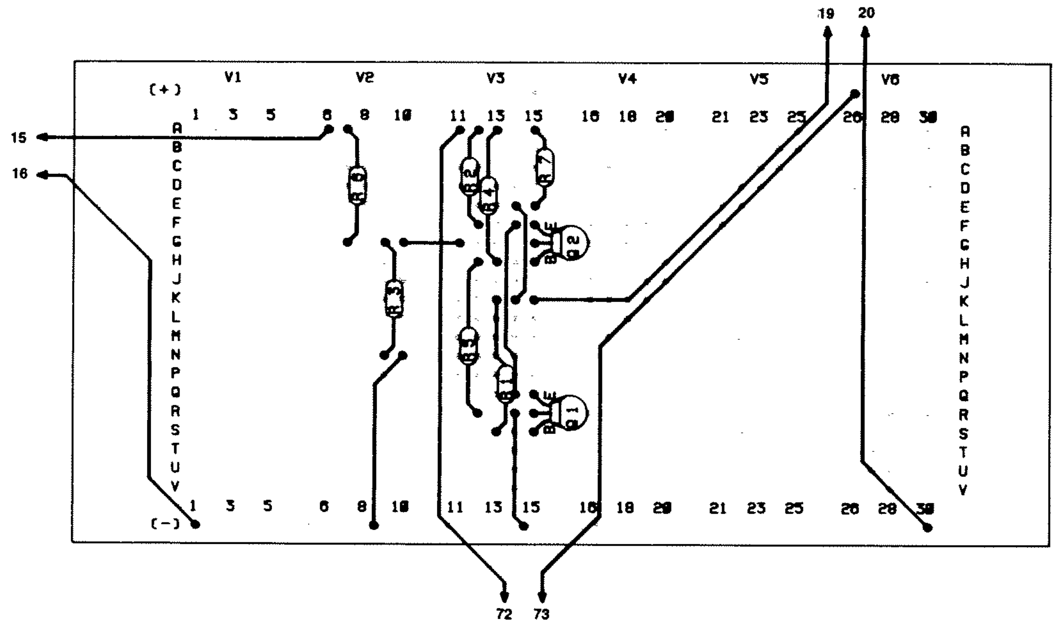
You need to adjust the circuit carefully to obtain pure sinewave output. Adjust the **control volume** clockwise very slowly over its entire range until you hear a tone in the earphone. The tone is very low and sounds like a lowest note of a large pipe organ. This control setting is the right end.

Once oscillation has started, adjust the **control volume** carefully so you can hear the purest sounding low note: it should be near the high end of the dial.

You can experiment with this circuit in many ways. Try different values for the 10K and 100 ohm resistors, and try higher and lower battery voltages. Also, if you have a VOM (volt-ohm meter), try measuring circuit voltages.



PROJECT 48. CURRENT SWITCH



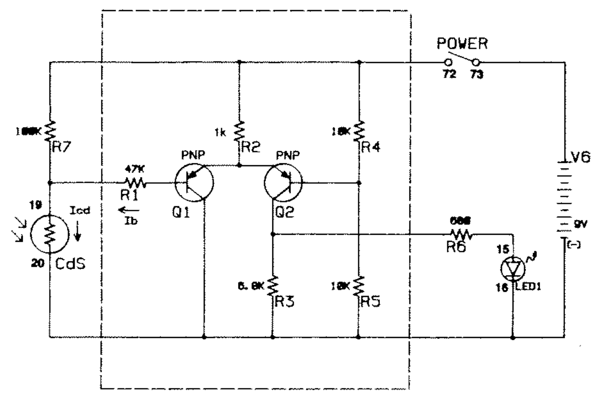
Q1	PNP	R1	47KΩ	R4	10KΩ	R7	100KΩ
Q2	PNP	R2	1KΩ	R5	10KΩ		
		R3	6.8KΩ	R6	680Ω		

A current switch is an electronic switch to turn the output voltage ON or OFF according to the input current. We're going the use this switch to build a circuit that turns **LED** on when it becomes dark and off when it becomes bright. As you might have imagined, we use the **CdS cell**.

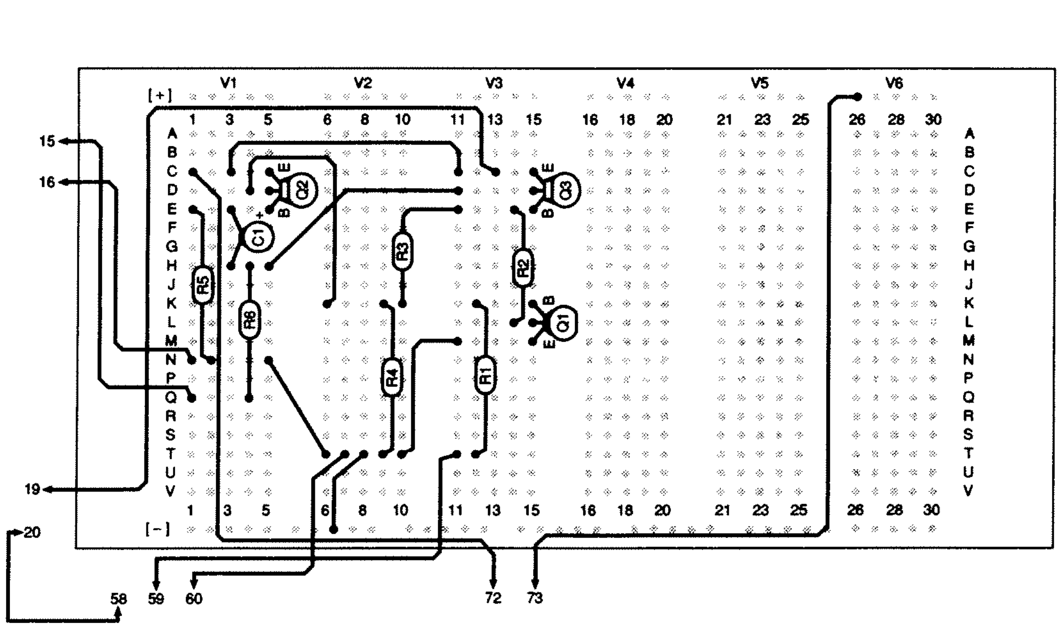
We use two transistors to make up the current switch. When it becomes bright and the resistance of the **CdS cell** decreases, Q1's basic current Ib flows to turn Q1 on and Q2 off, then **LED** goes out.

When the surroundings become dark, the current switch works in exactly the opposite way.

After switching the power ON, see how the **LED** lights up and goes out as you change the surrounding brightness by cupping your hand around the **CdS cell** and removing it.



PROJECT 49. SHOT IN THE DARK



Q1	NPN	R1	220KΩ	R4	1KΩ	C1	100μF
Q2	PNP	R2	10KΩ	R5	4.7KΩ		
Q3	PNP	R3	4.7KΩ	R6	470Ω		

Think you have good night vision? This project lets you find out for sure. It tests your aim-in a totally dark room!

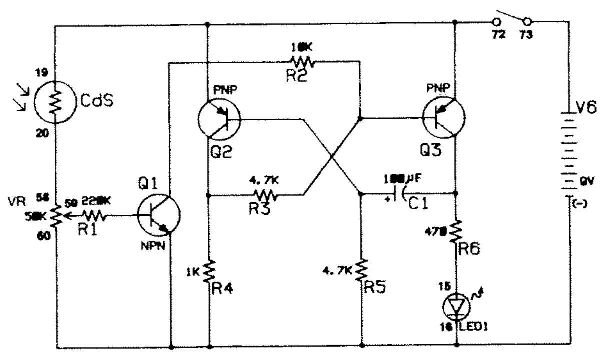
Your "gun" for this game is any ordinary flashlight. Just place your kit with this project wired up in a completely dark room. Use your flashlight to "shoot" the kit with a beam of light. If you aim correctly, you'll light the **LED 1**.

After you finish the wiring connections, put this project in as dark a room as possible. Turn power ON. Use a flashlight and shine a beam of light on the **CdS cell**. Carefully adjust the **control volume** until the **LED 1** lights. You're now ready to test your skill!

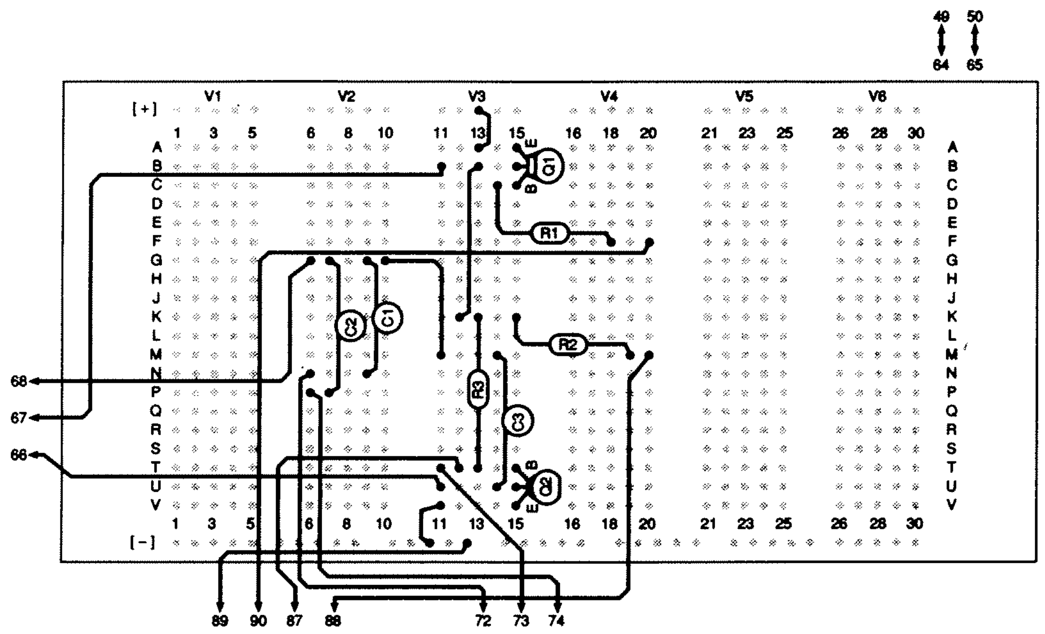
First try hitting the **CdS cell** from about five feet or so. As your aim improves try increasing the distance. For the most fun, try hitting the **CdS cell** just by quickly switching your flashlight on and off instead of using a steady beam of light.

Don't be surprised if you have to very carefully adjust the **control volume** to get the **LED** to come on when light strikes the **CdS cell**. For the best adjustment, be sure you have the kit in a completely dark room and use a sharply focused flashlight (not a fluorescent lamp or other light). Once you've found the best setting, don't change it.

Good luck. May you become "the fastest flashlight in the West!"



PROJECT 50. VARIABLE R-C OSCILLATOR



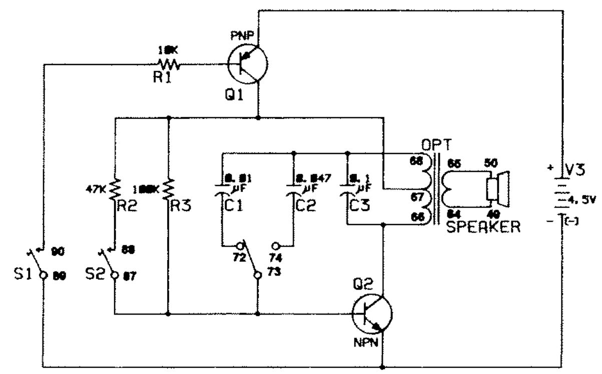
Q1	PNP	R1	10KΩ	C1	0.01μF
Q2	NPN	R2	47KΩ	C2	0.047μF
		R3	100KΩ	C3	0.1μF

We've seen how just varying resistance or capacitance can affect oscillator operation ... this project lets us see the effects when we change both.

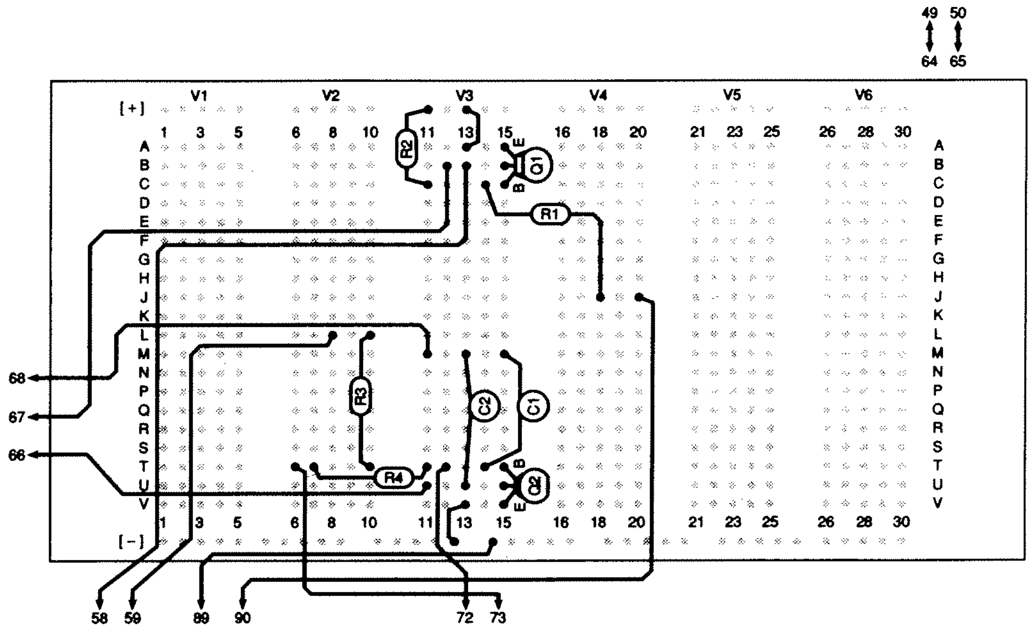
Look at the schematic for this project. You'll see that the **select switch** chooses between two different capacitors.

Now press **S1**. Then press **S2** and slide the **select switch** up. What kind of sound do you hear from the **speaker**? There are 4 different kinds of sound at the combination of **select switch** and **S2** key selection.

Which combination gives you the highest tone? The lowest? What does this tell you about how capacitors and resistors affect each other?

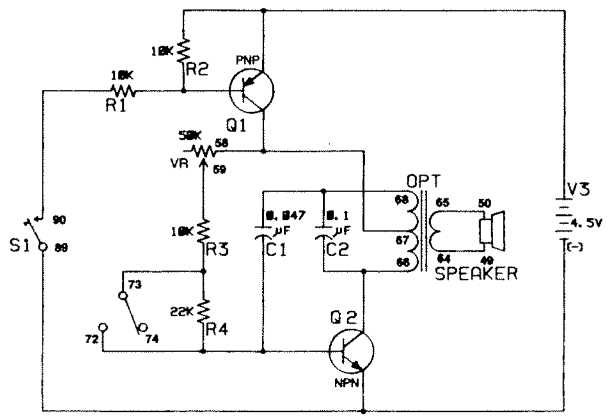


PROJECT 51. TWO-TONE BUZZER



Q1	PNP	R1	10KΩ	R4	22KΩ
Q2	NPN	R2	10KΩ	C1	0.047μF
		R3	10KΩ	C2	0.1μF

As you wire this project, set the **select switch** up and press **S1**. You'll hear a tone from the **speaker**. Now set the **select switch** down - what does the tone sound like now? Look at the schematic - can you see why this happens? (Don't peek at the answer before you figure it out!)

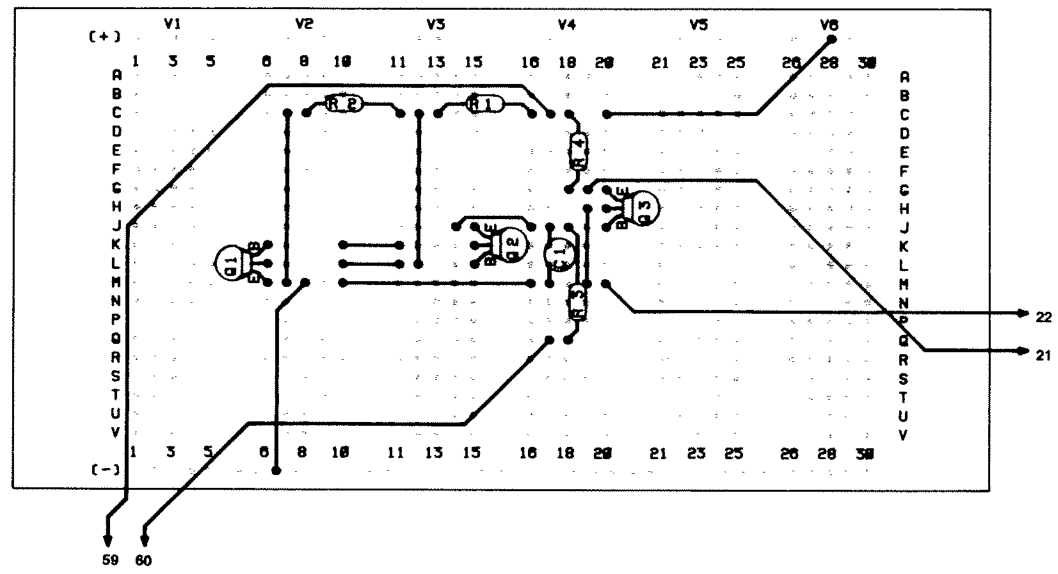


Yes - the answer involves the emitter-to-base current of Q1! With the **select switch** at the up position, the 22K resistor isn't in the emitter-to-base circuit. At the down position, it's added in series to the 10K resistor and the 50K **control volume**. You can see the effects of a different resistance on the emitter-to-base circuit by adjusting the 50K **control volume**.

So what effect do you think increasing the resistance in the emitter-to-base circuit has on an oscillator circuit like this?

(Be sure to keep a record of your answer.)

PROJECT 52. SAWTOOTH WAVE OSCILLATOR



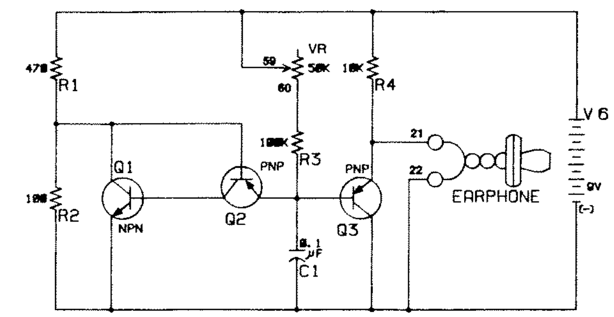
Q1	NPN	R1	470Ω	R4	10KΩ
Q2	PNP	R2	100Ω	C1	0.1μF
Q3	PNP	R3	100KΩ		

If you have oscilloscope and connect the output of this circuit to it, you would see something like following on the screen.

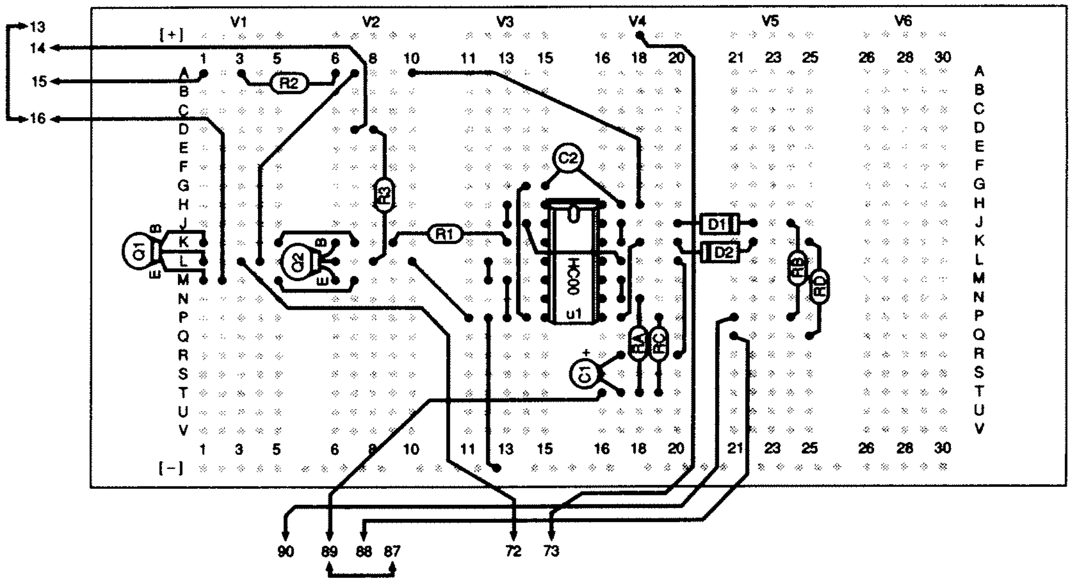
It does look like sawtooth, isn't it. The shape of the wave you see above is obtained like this. The 0.1μF capacitor is charged slowly through the **control volume** and 100K resistor and quickly discharged through the PNP and NPN transistors. The slow charge causes the slow rise of wave, and quick discharge causes the quick fall.

The 470 ohm and 100 ohm resistors provide a voltage of about 1.6 volts to the Q1 and Q2 transistors. The current flowing into the 0.1μF capacitor from the batteries through the **control volume** and 100K resistor slowly charges the capacitor. When the charge of the capacitor exceeds the voltage to the transistors (1.6V), the Q1 and Q2 turn on and provide a path for the 0.01μF to discharge quickly. Now the Q1 and Q2 turn off again, and the capacitor begins to slowly charge to repeat the cycle.

You can change the oscillator frequency by changing the values of the components in the "timer circuit" (**control volume**, 100K resistor and 0.1μF capacitor). Try a 47K or 220K in place of the 100K, and try several different capacitors. If you connect one of the electrolytic capacitors, make sure to use the proper polarity (+ and –).



PROJECT 53. ASTABLE MULTIVIBRATOR



U1	74HC00	RA	1.5MΩ	RD	470KΩ	R3	680Ω	D1	Si
Q1	NPN	RB	470KΩ	R1	1KΩ	C1	0.47μF	D2	Si
Q2	PNP	RC	1MΩ	R2	680Ω	C2	0.1μF		

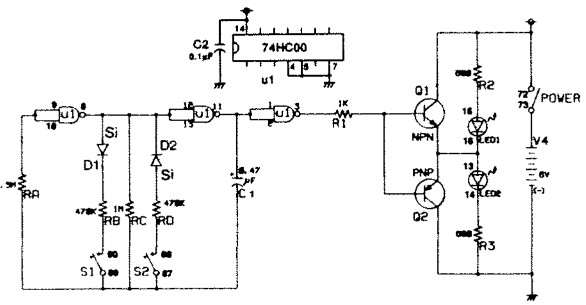
An astable multivibrator is an oscillator that generates a square wave output. In this project, we're going to experiment with a way of changing the duty ratio of the waveform. The duty ratio is the ratio of on time (T1) against the one entire cycle of the wave (T). See Figure 1.

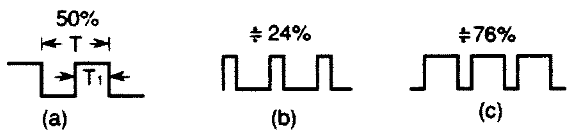
See the schematic: the astable multivibrator we're going to make uses a NAND gate. The frequency of this oscillator circuit is determined by C1 and Rc. When you press **S1** or **S2**, the duty ratio changes. We can see this change by watching **LEDs**. Transistors Q1 and Q2 are for switching **LEDs** on and off.

When you finish wiring up the circuit, turn power ON and see what happens to the **LEDs**: they take turns lighting at regular intervals. The circuit must be in the state shown in Figure 1 -(a).

Now press **S1**, and you'll notice that **LED 2** stays on for a shorter period, corresponding to the state shown in Figure 1-(b). Now release **S1** and press **S2**, and you'll see **LED 2** stays on for a longer period this time, corresponding to the state shown in Figure 1-(c).

Now you understand what this project is telling us ....we can change the duty ratio freely with an astable multivibrator.

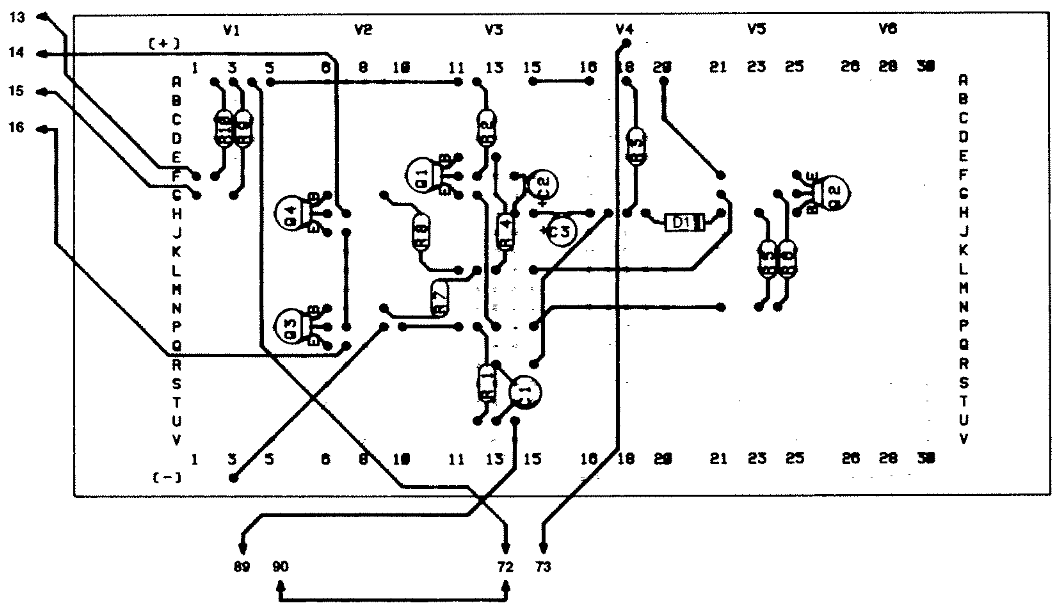




T1/T=Duty Ratio (%)

Figure 1-(a) **Figure 1-(b)** **Figure 1-(c)**

PROJECT 54. MONOSTABLE MULTIVIBRATOR



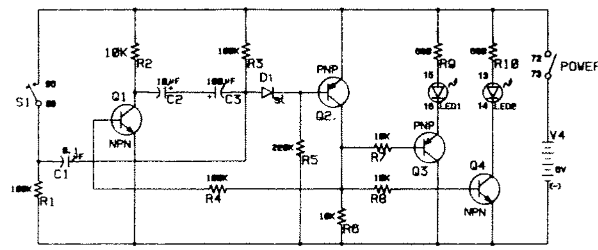
Q1	NPN	R1	100KΩ	R5	220KΩ	R9	680Ω	C1	0.1μF
Q2	PNP	R2	10KΩ	R6	10KΩ	R10	680Ω	C2	10μF
Q3	PNP	R3	100KΩ	R7	10KΩ	D1	Si	C3	100μF
Q4	NPN	R4	100KΩ	R8	10KΩ				

Let's make a monostable multivibrator using one PNP transistor and one NPN transistor. The monostable multivibrator produces an output for a fixed time after receiving a trigger pulse. In this project, we're going to check this function using **LEDs**.

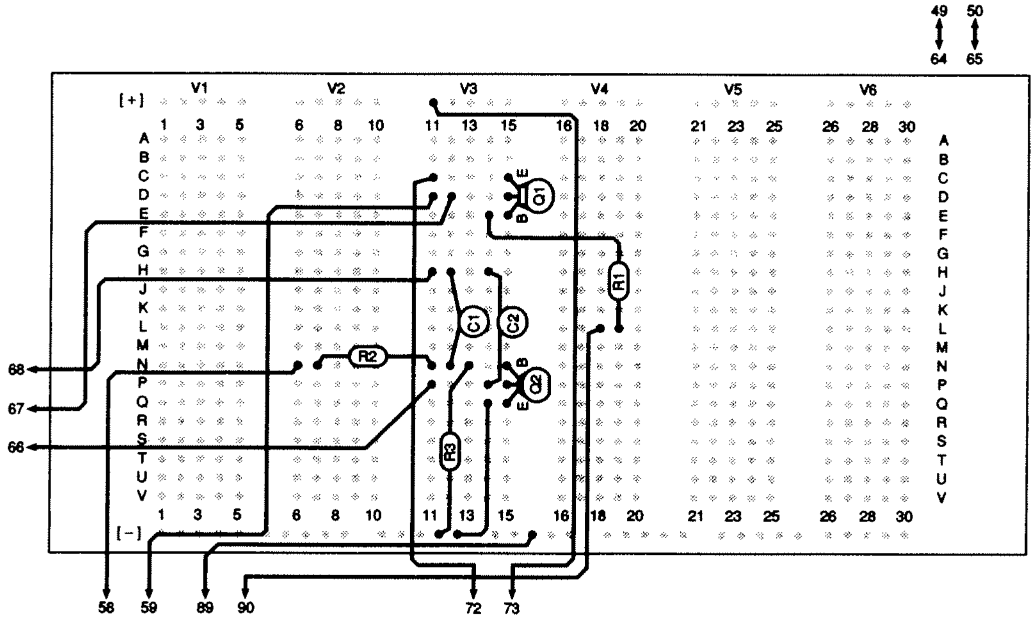
When you finish making the connection, turn power ON. You'll see **LED 1** goes out and **LED 2** lights up.

Now, press **S1** just for a moment and see what happens. This time **LED 1** lights up and **LED 2** goes out, but both return to the former state in about one second. This is the function of the monostable multivibrator.

Because of this function, the monostable multivibrator is used to sound alarms for a predetermined time or to shape pulse waveforms. It is also used in many delay circuits.



PROJECT 55. CODE PRACTICE UNIT



Q1	PNP	R1	10KΩ	C1	0.047µF
Q2	NPN	R2	47KΩ	C2	0.1µF
		R3	220KΩ		

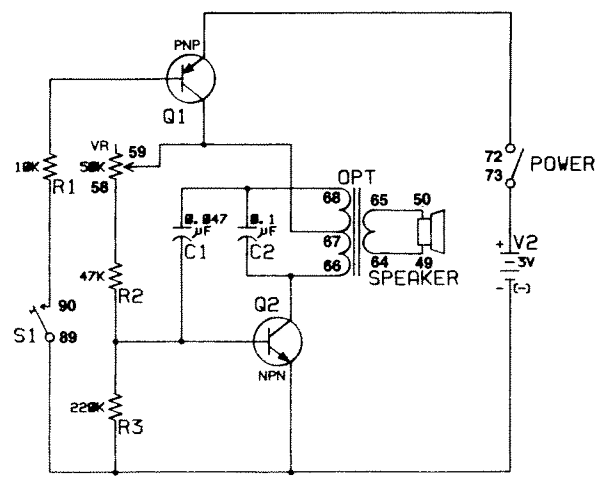
The ability to send and receive Morse code is a very useful skill. It's widely used in radio communications, and being able to send and receive Morse code is one of the requirements for a "ham" radio license. Here's a neat project that lets you practice Morse code.

MORSE CODE

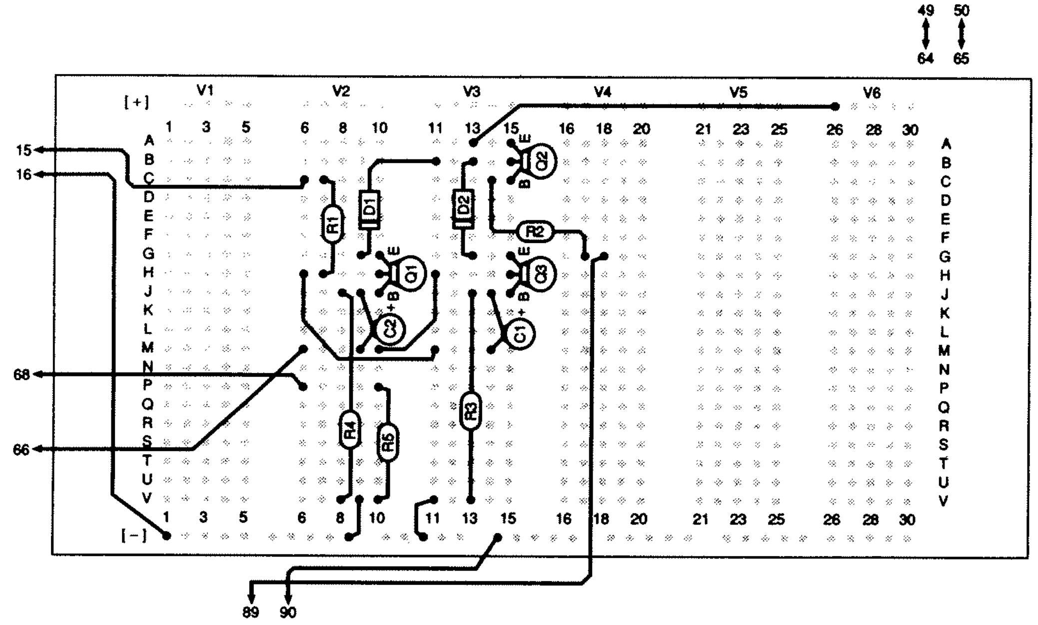
A	·—	U	··—
B	—···	V	···—
C	—·—·	W	·——
D	—··	X	—··—
E	·	Y	—·——
F	··—·	Z	——··
G	——·		
H	····	.	·—·—·—
I	··	,	——··——
J	·———	?	··——··
K	—·—	1	·————
L	·—··	2	··———
M	——	3	···——
N	—·	4	····—
O	———	5	·····
P	·——·	6	—····
Q	——·—	7	——···
R	·—·	8	———··
S	···	9	————·
T	—	0	—————

This circuit is a basic oscillator circuit that you've used in other projects. When you press **S1** and turn power ON, you'll hear a sound from the **speaker**. You can adjust the tone with the **control volume**.

If you're interested in getting a "ham" radio license, find books about "ham" radio in your school or public library (they might be listed under "amateur radio").



PROJECT 56. THE NOISY LIGHT



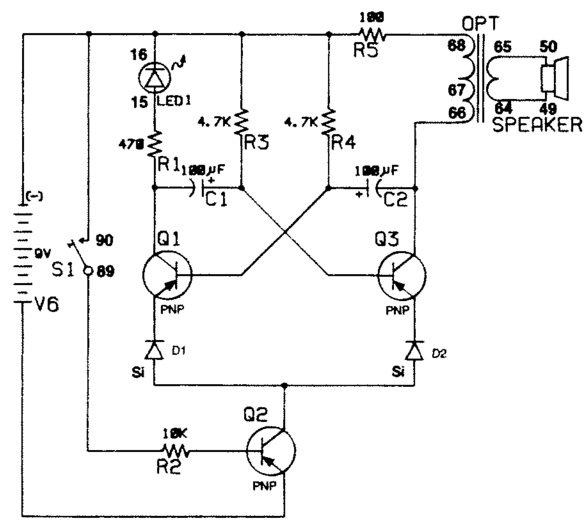
Q1	PNP	R1	470Ω	R4	4.7KΩ	C1	100µF	D1	Si		
Q2	PNP	R2	10KΩ	R5	100Ω	C2	100µF	D2	Si		
Q3	PNP	R3	4.7KΩ								

Some things go out with a bang ... others with a whimper... but this project just goes pop!

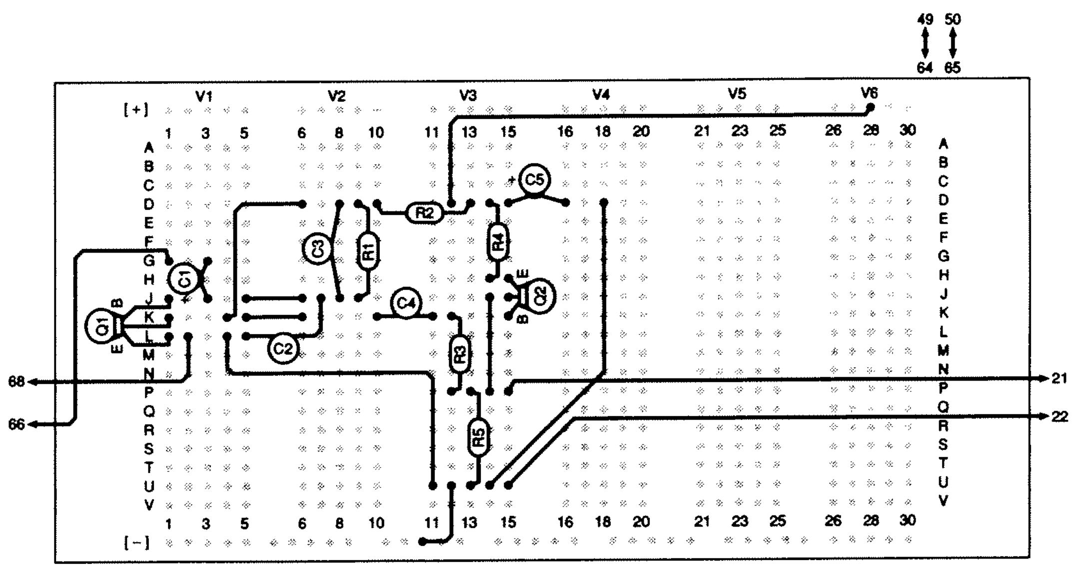
When you finish wiring this project, press and hold down **S1**. **LED 1** lights up. Keep holding down **S1**, and **LED 1** goes out. You hear a "popping" sound from the **speaker** when this happens.

Keep holding **S1** down and something interesting happens... the **LED** lights back up! It briefly stays on and goes out again, making another "pop" as it goes out. This continues over and over as long as you hold **S1** down.

The project uses a multivibrator circuit. You now know that the multivibrator circuits let us switch things (like the **LED** in this project) on and off electronically. They're also used in many of the digital electronics circuits in your kit.



PROJECT 57. HEARING AID AMPLIFIER



Q1	NPN	R1	220KΩ	R4	100Ω	C1	3.3μF	C4	0.1μF
Q2	PNP	R2	1KΩ	R5	2.2KΩ	C2	0.01μF	C5	100μF
		R3	470KΩ			C3	0.001μF		

This is a high gain two transistor amplifier like some of the early transistor hearing aid amplifiers. We use the **speaker** as a microphone.

This circuit is suitable for you to use a VOM (volt-ohm meter) to help learn how transistors work. Try measuring voltages with the VOM: it can help to determine currents and operating characteristics of the circuit.

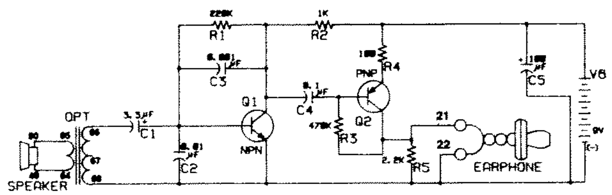
The **speaker** changes the sound pressure into weak voltage. It is then increased by the transformer. This voltage is applied to the B-E input junction of the Q1. The 0.01μF capacitor shuts off the ultrasonic oscillations because of the high gain and the long leads.

The output of the Q1 appears across the C-E leads, and is applied to the B-E input junction of the Q2. The Q2 further amplifies and outputs across the C-E terminals. The output voltage is then applied to the earphone.

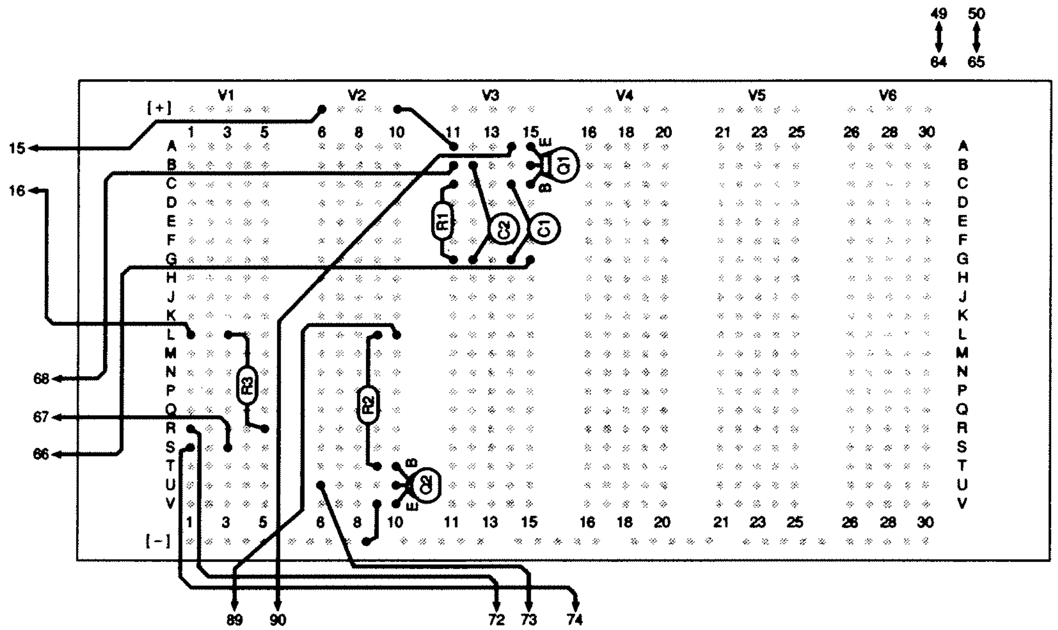
The resistors in the circuit supply the DC voltages and currents to the transistors. The 1K and 2.2K resistors supply the voltages and current to the collectors of the transistors. The 220K and 470K supply base current and voltage.

The type of bias current is same for both stages. It is called "self-current" bias, as the collector DC voltage provides the source of current through the base resistor with some self stabilizing feedback. The high value of the base resistance (220K and 470K) determines the base-bias current.

Measure the DC voltage across transistor C-E leads to see if the transistors are turned on by the right amount to act as amplifiers. The voltage (called VCE) should have a value between the OFF value (9V from the batteries) and full ON (0.5V). An electronics technician uses this voltage to verify that the bias is correct for the transistor to work as amplifier.



PROJECT 58. LIGHT/SOUND CODE PRACTICE UNIT

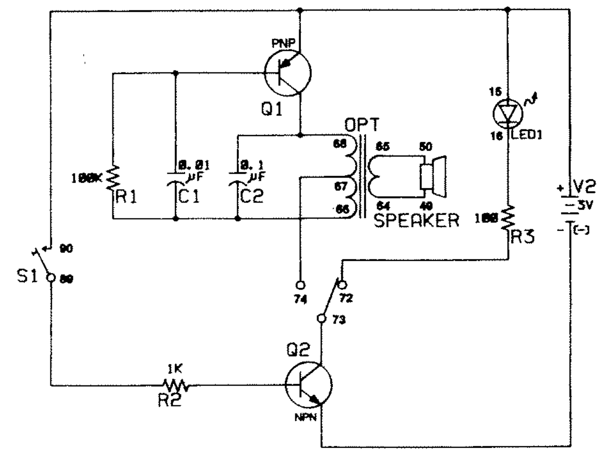


Q1	PNP	R1	100KΩ	C1	0.01μF
Q2	NPN	R2	1KΩ	C2	0.1μF
		R3	100Ω		

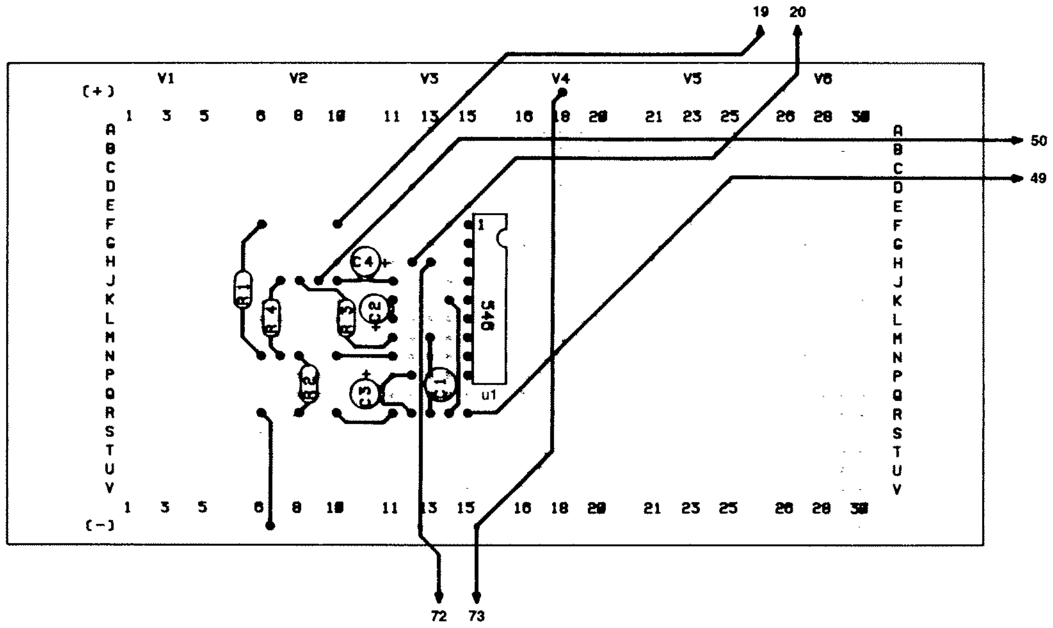
Morse code is also used for communicating with a flashing light. This circuit lets you practice Morse code using both sound and light. It's also great if the sound of the oscillator bothers others in your family.

Set the **select switch** down and push **S1**. You'll hear a sound from the **speaker**. Now set the **select switch** up and press **S1** again. This time the **LED** lights up.

If you examine the schematic for this project carefully, you'll notice that it seems like the circuit for projects 7 and 55 joined together. Like we've told you all along, complex electronic devices are just simple circuits connected to each other.



PROJECT 59. LIGHT CONTROLLED BURGLAR ALARM

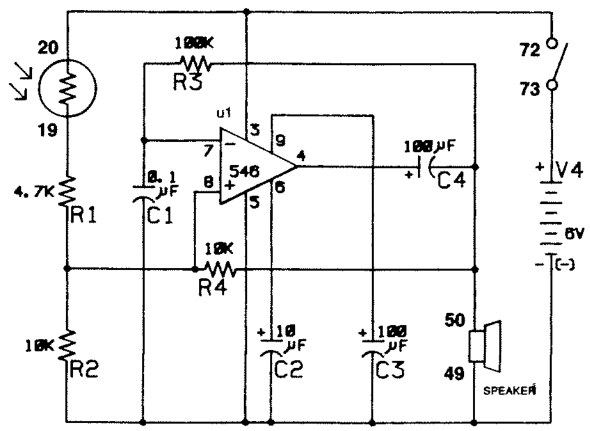


U1	546	R1	4.7KΩ	R3	100KΩ	C1	0.1µF	C3	100µF
		R2	10KΩ	R4	10KΩ	C2	10µF	C4	100µF

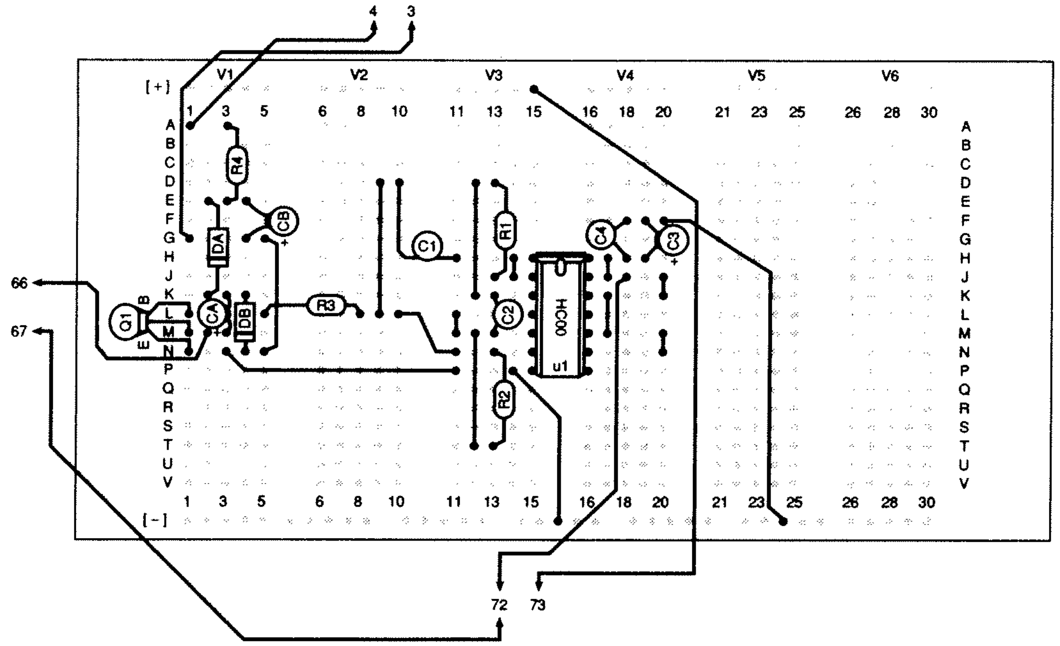
This project is a light controlled oscillator. In total darkness it just sits there nice and quiet, but a little light causes the **speaker** to give out a howl.

The **CdS cell** acts like an open circuit in total darkness, but when some light strikes the cell its resistance decreases enough to allow the feedback of output signal to get through and cause oscillations.

Do you want to see if someone is curious? Hide this circuit in a dresser drawer and then casually mention in someone's hearing that you have hidden something special in your dresser. Now find something to do away from the dresser but within range to hear the alarm. It usually isn't long before the alarm goes off!



PROJECT 60. DC-DC CONVERTER



U1	74HC00	R2	1KΩ	CA	100µF	C2	0.1µF	DA	Si
Q1	NPN	R3	10KΩ	CB	100µF	C3	10µF	DB	Si
R1	1KΩ	R4	680Ω	C1	0.1µF	C4	0.1µF		

A DC-DC converter is a device to convert DC voltages. In this project, we're going to make a DC-DC converter that first converts a DC voltage to AC and rectifies it back to DC.

As you see in the schematic, IC 74HC00 is an oscillator for converting a DC voltage to AC. It has a frequency of about 5 kHz. Output from this oscillator is amplified by Q1 and rectified by the voltage doubler rectifier made up of diodes DA and DB and capacitors CA and CB. The **LED** lights by the resulting DC voltage. This circuit also produces a minus voltage (below 0V).

When you finish wiring the project, turn power ON. The **LED** lights up, showing the presence of DC voltage.