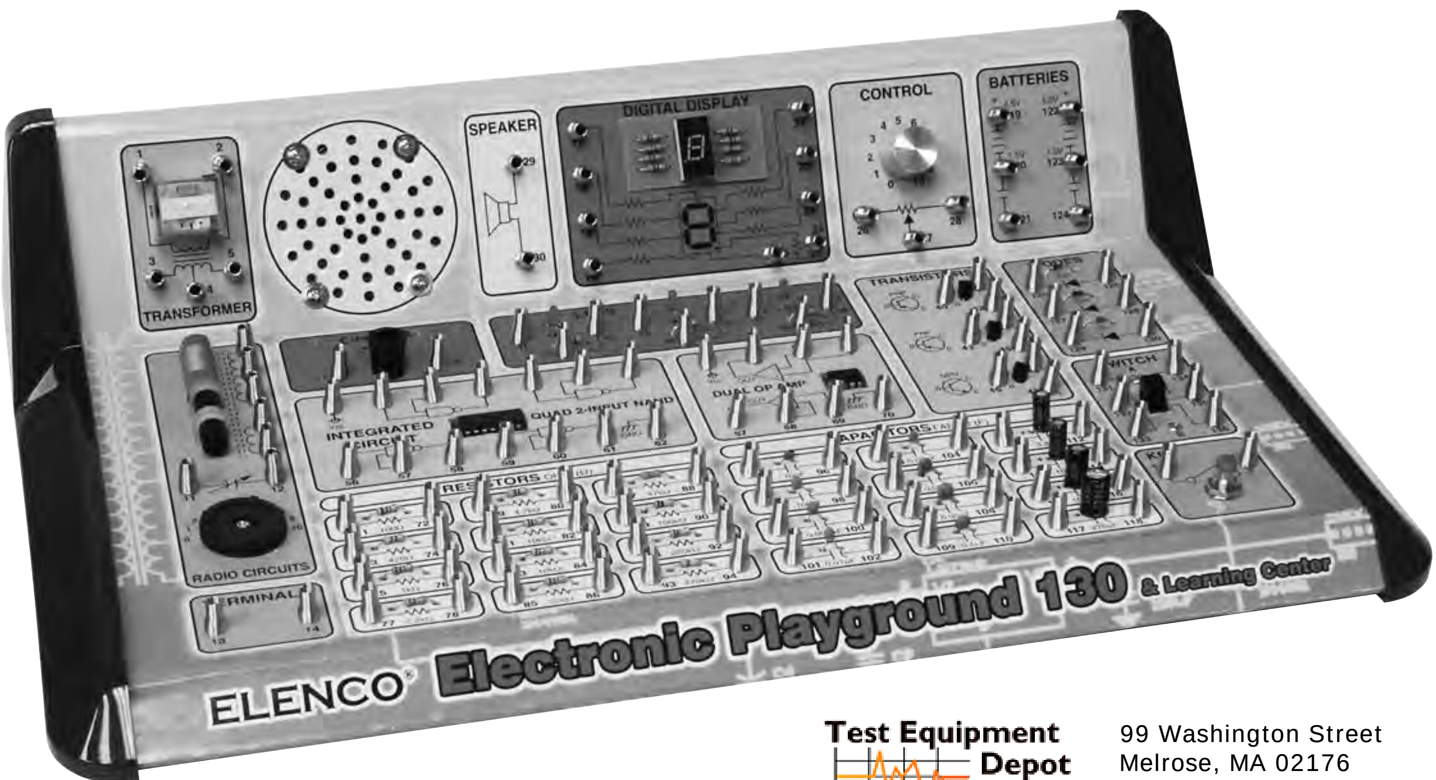
ELECTRONIC PLAYGROUND™ and LEARNING CENTER

MODEL EP-130



Elenco® Electronics, Inc.
Wheeling, IL, USA

753039

Important: If you encounter any problems with this kit, **DO NOT RETURN TO RETAILER**. Call toll-free (800) 533-2441 or e-mail us at: help@elenco.com. Customer Service • 150 Carpenter Ave. • Wheeling, IL 60090 U.S.A.

WARNING: Always check your wiring before turning on a circuit. Never leave a circuit unattended while the batteries are installed. Never connect additional batteries or any other power sources to your circuits.

WARNING:
CHOKING HAZARD - Small parts. Not for children under 3 years.

Conforms to all applicable U.S. government requirements.

Batteries:

- **Do not short circuit the battery terminals.**
- **Never throw batteries in a fire or attempt to open its outer casing.**
- **Use only 1.5V "AA" type, alkaline batteries (not included).**
- **Insert batteries with correct polarity.**
- **Do not mix alkaline, standard (carbon-zinc), or rechargeable (nickel-cadmium) batteries.**
- **Non-rechargeable batteries should not be recharged. Rechargeable batteries should only be charged under adult supervision, and should not be recharged while in the product.**
- **Do not mix old and new batteries.**
- **Remove batteries when they are used up.**
- **Batteries are harmful if swallowed, so keep away from small children.**

TABLE OF CONTENTS

BEFORE WE BEGIN

Welcome to the exciting world of electronics! The Elenco® EP-130 Electronic Playground Kit may be your first experience in electronics. This manual describes 130 different experiments you can perform with your kit. We have included everything that you need for all of the experiments (except the batteries).

As you read this manual and complete the experiments, you will notice that we've organized the projects and information in a logical sequence. We'll have you start with simple circuits and work toward more complex ones. Take your time and have fun.

You can assemble all of the projects without soldering because each component is connected to spring terminals. A wiring sequence is included with each project, so all you have to do to build a working project is connect wires between the terminals listed in the wiring sequence. We have provided plenty of pre-cut, insulated wire. All of the projects are powered by low voltage batteries, so there is none of the danger associated with using standard AC voltages.

Simple, clearly-written instructions help you operate and experiment with each project. A diagram called a *schematic* is included with later projects. A schematic is an electronics blueprint that shows how various components are wired together. Each component has its own schematic symbol. The symbols for the various components in your lab kit are printed next to each component.

You'll notice that we often refer to a *Volt / Ohm Meter* (VOM) for making measurements. A VOM, or multimeter, is a device that measures voltage, current (amperes or amps), and resistance (ohms - Ω). We will tell you more about these later. If you are going to understand electronic circuits, it is important that you learn to measure circuit values - for only then can you really begin to understand electronic circuitry.

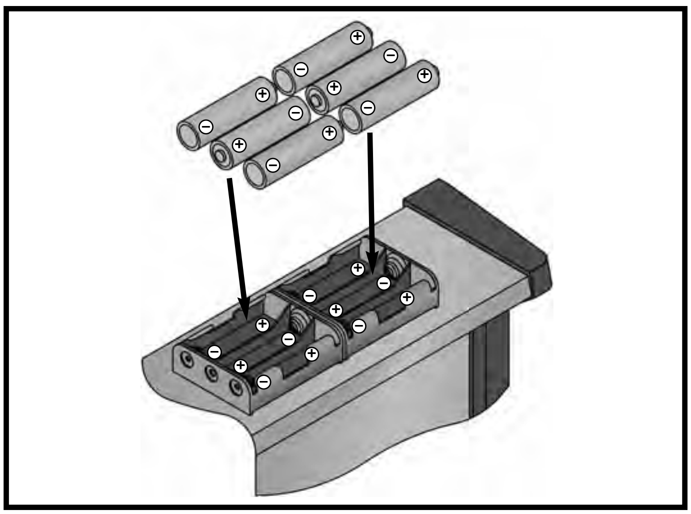
So, we recommend that you invest in a VOM with a sensitivity reading of 20,000 *ohms-per-volt* or more. Ohms-per-volt is a rating for the sensitivity of the device (the higher the rating, the more sensitive the meter).

You don't have to use a VOM to build the experiments, but you'll find it will help you to better understand how the circuits work. A VOM is a basic test instrument and it is an excellent investment - you'll always want and need one as long as you stay interested in electricity and electronics.

INSTALLING THE BATTERIES

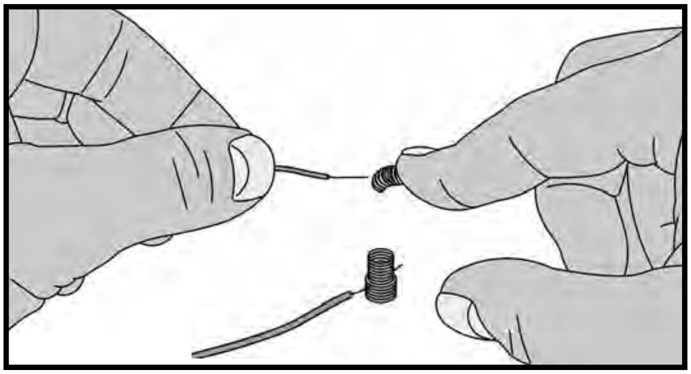
Your kit requires six (6) "AA" batteries. Install the batteries in the compartment at the back of your kit. Be sure to install them correctly according to the (+) and (–) markings inside the compartment. The (+) end of a battery is the one with the small metal cap.

Note: Whenever you are not using your kit, remove the batteries. Never leave weak or dead batteries in your kit - they can leak damaging chemicals, even if they are "leak-proof" type batteries. This is a good habit to get into for all battery-operated products.

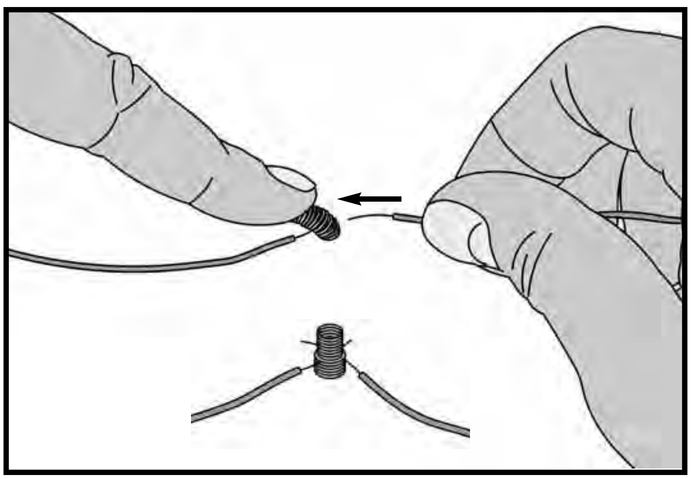


MAKING WIRING CONNECTIONS

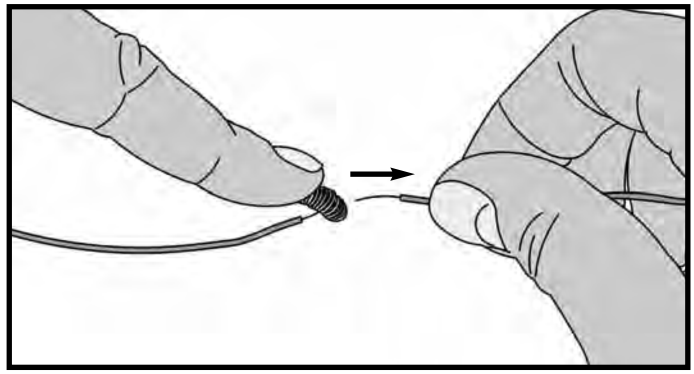
The spring terminals and the pre-cut wires supplied with your lab kit make it a snap to wire together the various projects. To connect a wire to a spring terminal, simply bend the spring over to one side and insert the wire into the opening.



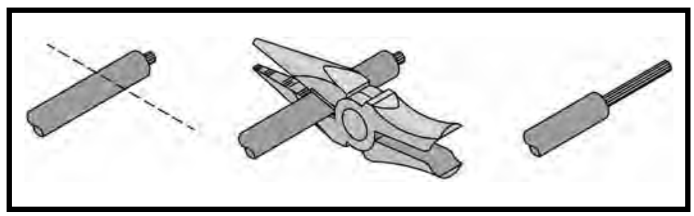
Sometimes you need to connect two or three wires to a single spring terminal, so be sure the first wire doesn't come loose when you add the second and third wires. The easiest way to do this is to push the spring on the side opposite side where you connected the first wire.



Be sure that you only insert the exposed, shiny part of the wire into the spring terminal. If the plastic insulation part of the wire is inserted into the terminal, electrical contact is not made. To remove the wire from the spring terminals, simply bend each terminal and pull the wires from it.



After a lot of use, the exposed metal ends of some of the wires might break off. If this happens, remove 3/8" of insulation from the broken end and twist the strands together. You can remove the insulation with a wire-stripper tool or a penknife. Be very careful doing this, as a penknife is very sharp.

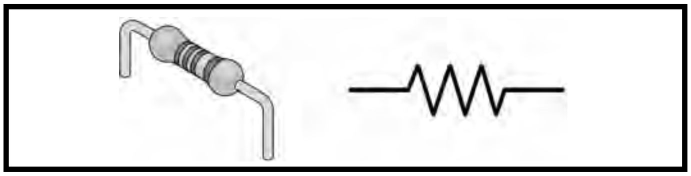


COMPONENTS

Your kit has more that 30 separate components. If this is your first experience with electronics, you probably don't know the difference between a resistor and a transistor. If so, don't worry - the general purpose fo each component will be explained. The explanations help you understand what each component does, and you will understand more about each component as you build the projects.

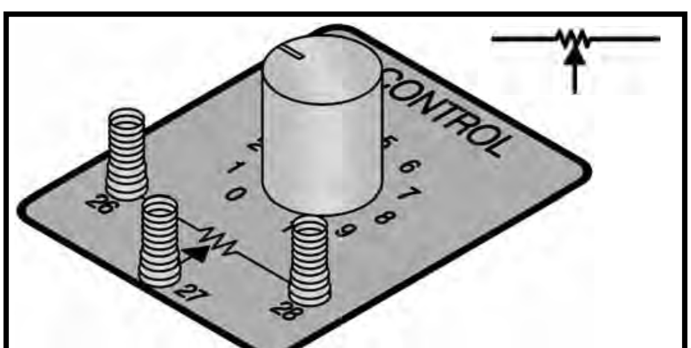
There is a parts list near the back of this manual. You might want to compare the parts in your kit with those in the list.

Resistors: Why is the water pipe that goes to your kitchen faucet smaller than the one that comes to your house from the water company? And why is it much smaller than the main water line that supplies water to your entire town? Because you don't need so much water. The pipe size limits the water flow to what you actually need. Electricity works in a similar manner, except that wires have so little resistance that they would have to be very, very thin to limit the flow of electricity. They would be hard to handle and break easily. But the water flow through a large pipe could also be limited by filling a section of the pipe with rocks (a thin screen would keep the rocks from falling over), which would slow the flow of water but not stop it. Resistors are like rocks for electricity, they control how much electric current flows. The **resistance**, expressed in **ohms** (Ω, named after George Ohm), kilohms (kΩ, 1,000 ohms), or megohms (MΩ, 1,000,000 ohms) is a measure of how much a resistor resists the flow of electricity. To increase the water flow through a pipe you can increase the water pressure or use less rocks. To increase the electric current in a circuit you can increase the voltage or use a lower value resistor (this will be demonstrated in a moment). The symbol for the resistor is shown below.

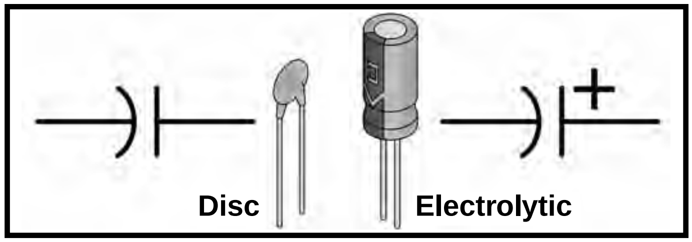


Resistor Color Code: The colored bands on the resistors are the method for marking the value of resistance on the part. The first ring represents the first digit of the resistor's value. The second ring represents the second digit of the resistor's value. The third ring tells you the power of ten to multiply by, (or the number of zeros to add). The final and fourth ring represents the construction tolerance. Most resistors have a gold band for a 5% tolerance. This means the value of the resistor is guaranteed to be within 5% of the value marked. See color code chart on page 159.

Control (variable resistor): Many electronic circuits require a variable resistor, and that is just what the control is. You can use it as a light dimmer, a volume control, and in many other circuits where you'd like to be able to change resistance easily and quickly.
This is a normal resistor with an additional arm contact that can move along the resistive material and tap off the desired resistance.



Capacitors: Capacitors can pass alternating current (AC) signals while blocking direct current (DC) signals. They can also store electricity or act as filters to smooth out pulsating signals. Very small capacitors are usually used in high-frequency applications such as radios, transmitters, and oscillators. Very large capacitors normally store electricity or act as filters.

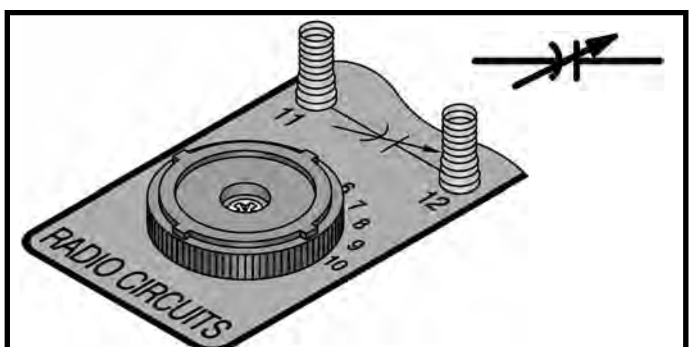


The *capacitance* (electricity storage capacity) of a capacitor is expressed in a unit called a *farad*. The farad is an extremely large amount of electricity, so the value for most capacitors is given in millionths-of-a-farad (microfarads).

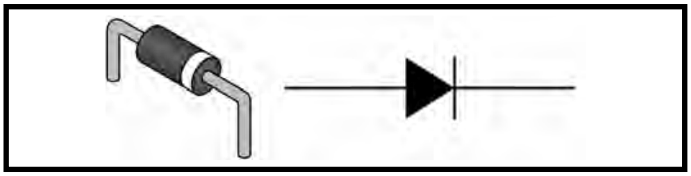
Electrolytic - The four largest capacitors are electrolytics. They are marked with a "–". You must connect them into the circuit only one way - the (+) and (–) wires must always go to the correct terminals.

Disc - These capacitors have no polarity and can be connected either way.

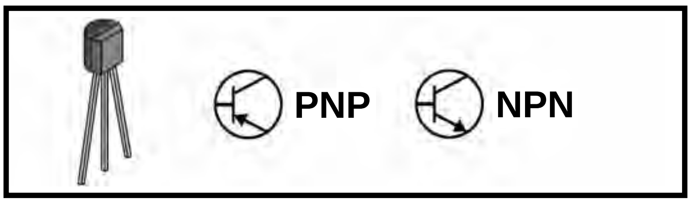
Tuning Capacitor: The tuning capacitor is used with the antenna to select radio frequencies. As you rotate the knob, you change the capacitance. This changes the frequency these circuits work best with. The tuning capacitor lets through only one frequency and blocks out the rest.



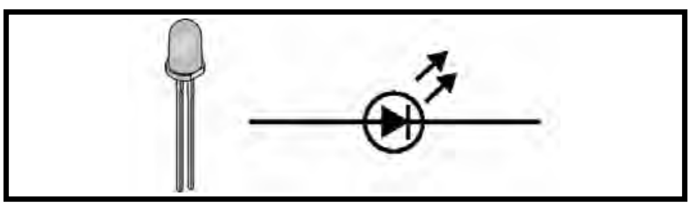
Diodes: There are three diodes in your kit. Diodes have many uses in electronics, but they have one simple characteristic - they allow electricity to flow through them in only one direction. Your kit has one silicon diode (marked Si) and two germanium diodes (marked Ge); they each have their own uses as we'll explain later.



Transistors: Your lab kit has three transistors. The working part of each transistor is a tiny chip (made of either germanium or silicon). Each transistor has three connection points: B (base), C (collector), and E (emitter). Transistors are used to amplify weak signals. They are also used as switches to connect or disconnect other components and as oscillators to allow signals to flow in pulses.

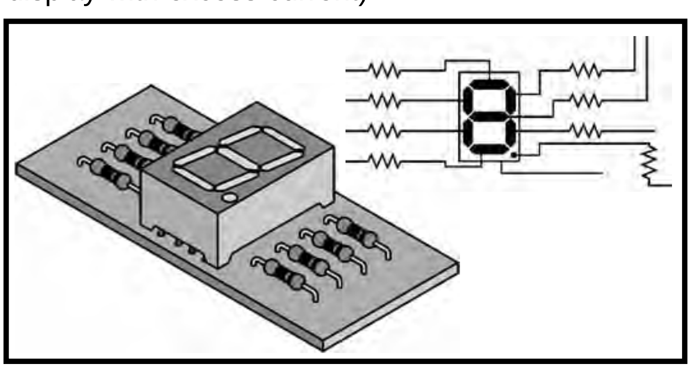


LEDs (Light Emitting Diodes): LED stands for Light Emitting Diode. These little parts are special diodes that give off light when electricity flows through them. (Current can pass through only in one direction - just like "regular" diodes).

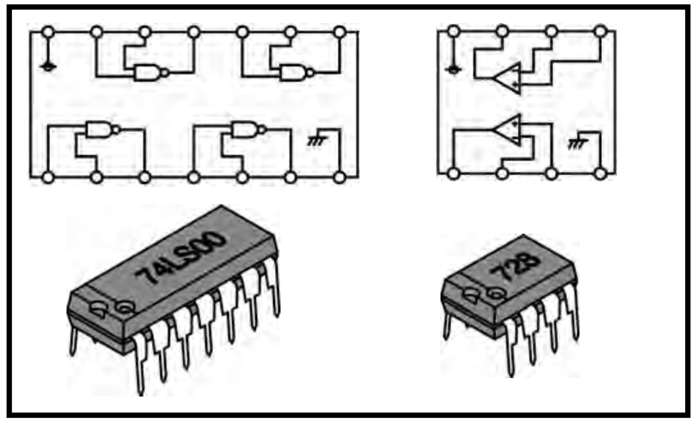


LED Digital Display: To make the display, seven LEDs are arranged to form an outline that can show all the numbers and most of the letters in our alphabet. An eighth LED is added for the decimal point.

The LED display is mounted on a little board with resistors permanently wired to it. (The resistors are there to help prevent you from burning out the display with excess current).



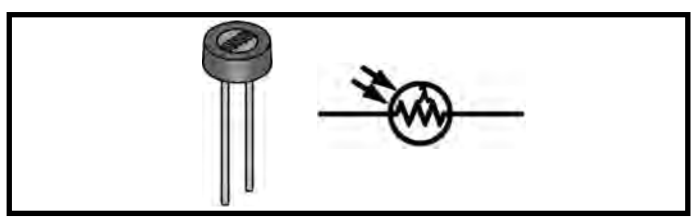
Integrated Circuit: As you might already know, after the transistor was invented in the middle 1940's, the next big breakthrough in electronics was the integrated circuit in the early 1960's. The great advantage of ICs (as we call them) is that the equivalent of hundreds or even thousands of transistors, diodes, and resistors can be put into a small package.



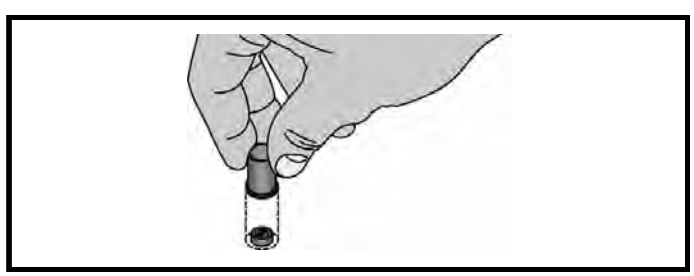
There are two types of ICs used in this kit - the quad two-input NAND and the dual-operational amplifier. You will learn more about these later.

Our simple ICs will help you learn enough to begin to understand the basic principles of the more advanced ICs.

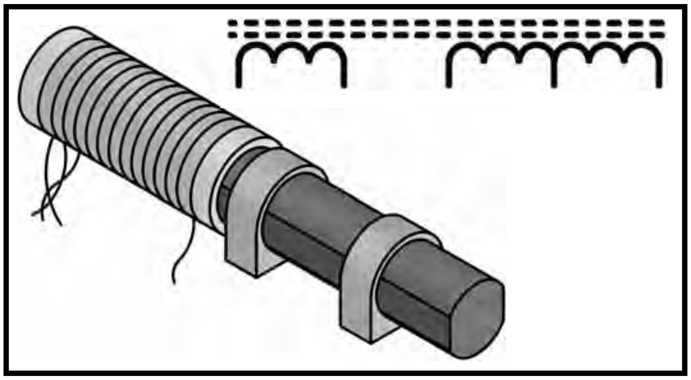
Cadmium Sulfide (CdS) Cell: This is a semiconductor - that is, it conducts electricity, but partially resists it. The resistance of this device changes with the amount of light that shines on it. (It is similar to your kit's control - to vary the resistance of the control, you rotate the knob; to vary the resistance of the CdS cell, you permit more or less light to shine on the front of the cell.)



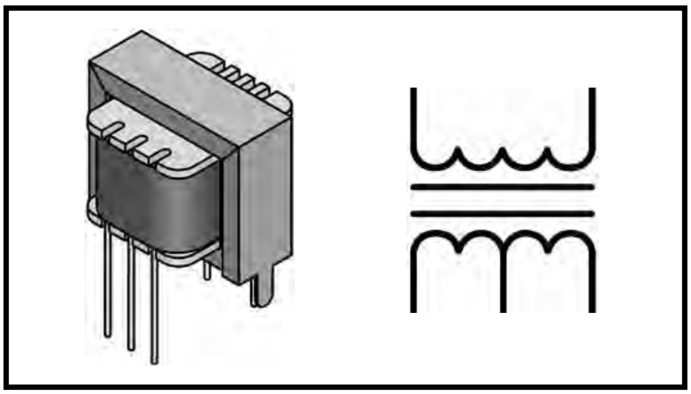
Note: We've provided a special light shield to use with the CdS cell. When you place this over the cell, it helps block light from the cell.



Antenna: The radio antenna is the cylindrical component with a coil of fine wire wrapped around it. The dark colored rod is made mostly of powdered iron. Ferrite cores (rods made from powdered iron and other oxides) make efficient antennas for almost all transistor radios.

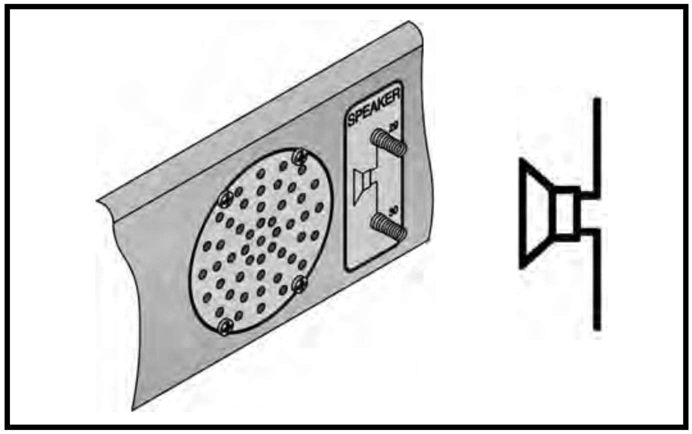


Transformer: If you wrap two wires from different circuits around different ends of an iron bar then a current flowing through the wire from the first circuit will magnetically create a current in the wire from the second circuit! If the second coil has twice as many turns (more magnetic linkage) as the first coil then the second coil will have twice the voltage but half the current as the first coil. A device like this is called a *transformer*.

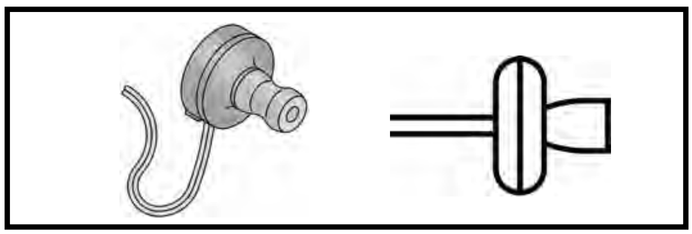


The magnetic field created in an iron bar by an electric current in the coil around it can be harnessed if the bar is allowed to rotate - it is a motor. It could be used to drive the wheels of a car, for example. The reverse is also true, if a magnet within a coil is rotating then an electric current is created in the coil - a generator. These two statements may not seem important to you at first but they are actually the foundation of our present society. Nearly all of the electricity used in our world is produced at enormous generators driven by steam or water pressure. Wires are used to efficiently transport this energy to homes and businesses where it is used. Motors convert the electricity back into mechanical form to drive machinery and appliances.

Speaker: A speaker converts electrical energy into sound. It does this by using the energy of an AC electrical signal to create mechanical vibrations. These vibrations create variations in air pressure, called sound waves, which travel across the room. You "hear" sound when your ears feel these air pressure variations. You need high current and low voltage to operate a speaker, so we will always use the transformer with the speaker. (Remember that a transformer converts high-voltage/low-current to low-voltage/high-current).

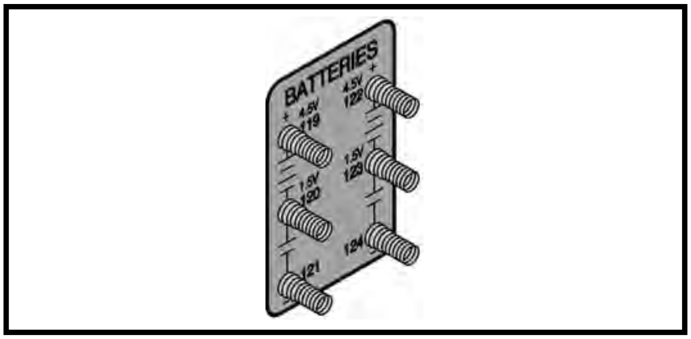


The earphone is similar to the speaker, except that it is more sensitive (and moveable). It is an efficient, lightweight earphone that can be connected without drawing too much electrical energy from the circuit. For very weak sounds, the earphone is best; for stronger sounds, you will use the speaker.

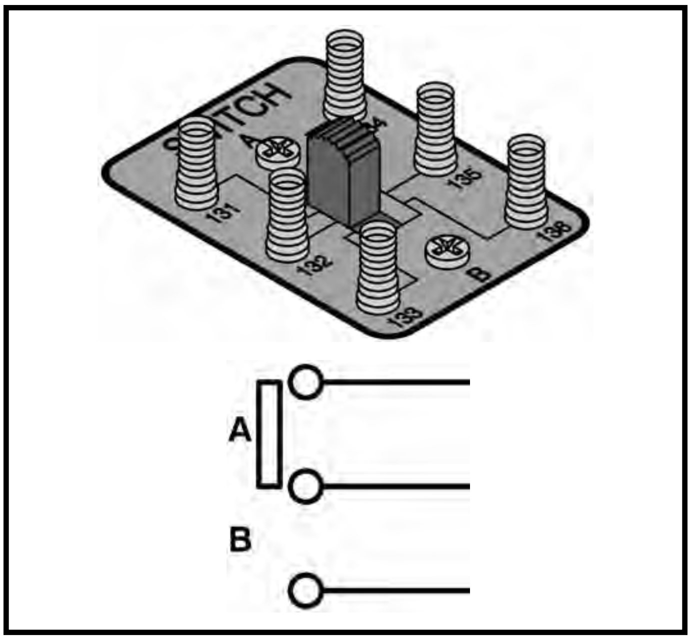


Batteries: The battery holders are designed to hold six (6) "AA" batteries. Batteries supply the power for all the experiments in your kit. When connecting wires to the batteries, be sure you connect only to the terminals noted. Terminals 119 and 120 provide 3 volts. Terminals 119 and 121 provide 4.5 volts. You need to be aware that connecting too much voltage (you can get up to 9 volts from these battery connections) can damage some parts (they can be burned out). So, be sure to make the right battery connections.

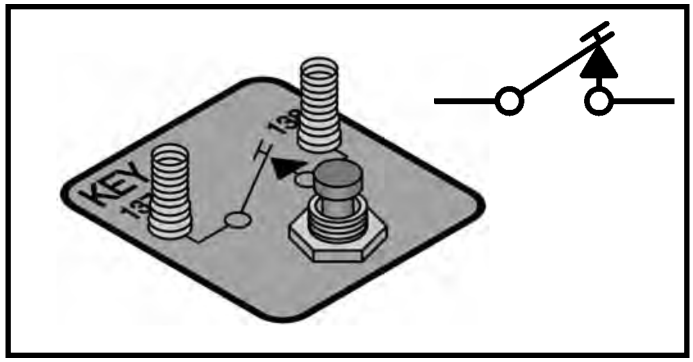
Caution: When you connect wires to the batteries, you must be sure to use the correct polarity: (+) and (–) sides of the battery. With some parts and circuits, components can be permanently damaged if you reverse the polarity.



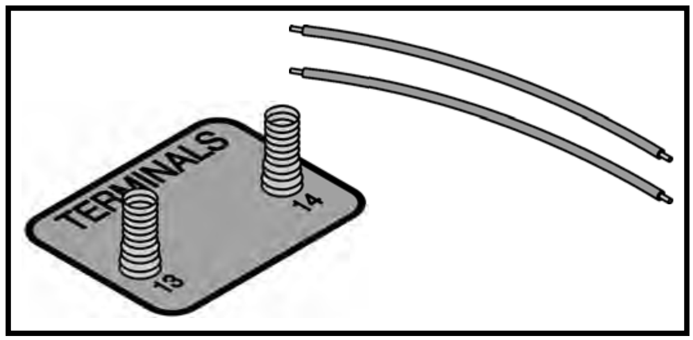
Switch: You know what a switch is - you use it to connect or disconnect electrical circuits. When you slide the switch to the correct position, the circuit is complete, allowing electricity to flow through it. In another position, the switch causes a break in the circuit's path, so that the circuit is not complete and electricity cannot flow through it. The switch we're using is a double-pole, double-throw switch; this means it can connect one pair of terminals to either of two other pair of terminals. You will learn how this works later on.



Key: The Key is a very simple switch - press it and the circuit allows electricity to flow through it. Release it and there is a break in the circuit's path, so the circuit is not complete. You will use the key in many circuits, most often in the signaling circuits (to send Morse code, and so on).



Terminals: You will use the two terminals (13 and 14) in some projects to make connections to external devices, such as the earphone, an antenna or earth ground connection, special sensor circuits, and so on.



Wires: You will use the wires to make connections between terminals.
The parts and spring terminals are mounted onto a platform. If you look underneath it you can see how wires are used to connect the parts and their terminals.

BUILDING YOUR FIRST PROJECT

There is a simple wiring sequence listing for each project. You should connect appropriate length wires between the terminals listed in each grouping. Always use the shortest wire that will do the job. When you come to a new grouping (separated by a comma), connect the terminals in that group.

Here's an example:

Project 1 has the following wire sequence listing:

1-29, 2-30, 3-104-106, 4-28-124, 5-41-105, 27-88, 75-87-103-40, 115-42-119, 76-116, 121-122.

You should connect a wire between 1 and 29, another between 2 and 30, another between 3 and 104, and then another between 104 and 106. So, you continue until all connections are made.

Caution: In each wiring sequence, we've deliberately left an important power wire connection as the last connection. It is important that you make this last connection LAST. With some circuits, if you complete one part of the electronic circuit before another, a transistor or another part can be damaged. So, follow the wiring sequence exactly.

TROUBLESHOOTING

If you assemble each project according to its wiring sequence, you should have no problem getting the projects to work properly. But if you do have a problem, you can usually find and correct it by using the following troubleshooting steps. These steps are similar to those used by electronics technicians who troubleshoot complex electronic equipment.

1. Are the batteries fresh? If not, they may be too weak to power the project.

2. Have you assembled the project properly? If everything else checks out okay, check all the wiring connections to be sure you have wired all the terminals correctly. Sometimes it's a good idea to have someone else take a look at it too.

3. How about following the schematic diagram and circuit explanation? As you progress in your knowledge and understanding of electronics, you should be able to do some troubleshooting only by following a schematic; and if you add the circuit description, you should be able to figure out problems for yourself.

4. If you have a VOM, try some voltage and current measurements - very soon you'll find out just how handy a VOM can be to an electronics technician!

HELPFUL SUGGESTIONS

Keeping a Notebook

You're going to find out a lot about electronics as you play around with this kit. Much of what you discover about electronics in early projects will be useful in later projects. We strongly suggest that you keep a notebook to help you collect and organize all of this information.

Your notebook doesn't have to be like the ones you keep at school. Think of it as your diary - you'll have fun looking at it after you finish connecting all 130 projects.

Marking the Wiring Sequence

As you wire up a project (especially the ones with lots of connections) you might find it helpful to mark through each terminal number as you connect a wire to that terminal. Mark lightly with a pencil so that you will be able to build a circuit many times and still be able to read all of the wiring sequence.

Collecting Components

It would be a good idea for you to start collecting different electronic parts and make your own electronic parts scrap box. You can build circuits inside or on a convenient chassis, box, or container. You might turn it in as a Science Fair project at school and make a major research project out of it.

I. ENTERTAINMENT CIRCUITS

EXPERIMENT #1: ELECTRONIC WOODPECKER

Have you ever heard a red-headed woodpecker chirping? Here is an electronic bird that sounds a little like a red-headed woodpecker. If you have one of these birds around your house, it might come to visit this electronic relative!

This is a fairly simple circuit. Follow the wiring sequence below and the drawings we've provided. Make all the connections and have some fun with this project.

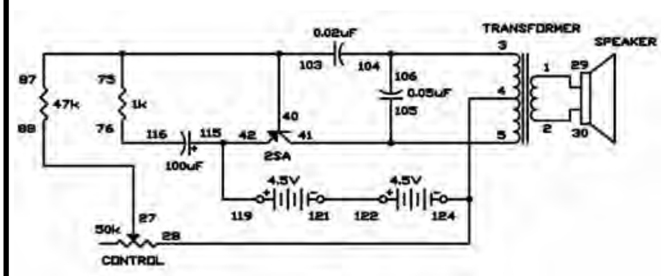
The basic circuit we've shown here does not have a switch or key, but you can add one very easily. Simply replace wire connection 124-28 with connections 124-137 and 138-28 in order to connect the key. To use the switch, replace connection 124-28 with connections 124-131 and 132-28. When you press the key or slide the switch, the circuit path for the electrical current is complete and you hear the woodpecker. The key provides a more convenient control for carrying the kit outside as you try to attract birds with your bird caller.

Try different combinations of resistance and capacitance in place of the 1kΩ resistor and the 100µF capacitor. To change the 100µF capacitance to 470µF, disconnect the wire at terminal 116 and reconnect it to terminal 118. Then, transfer the wire attached to terminal 115 to terminal 117. Now your "bird" might sound more like a cricket or a bear!

You can also try the 3V power supply (V is the abbreviation for volt or volts - the basic unit of measure of electric energy). Disconnect the wire from terminal 119 and connect it to terminal 123. Now the "bird" will sound more like an English sparrow.

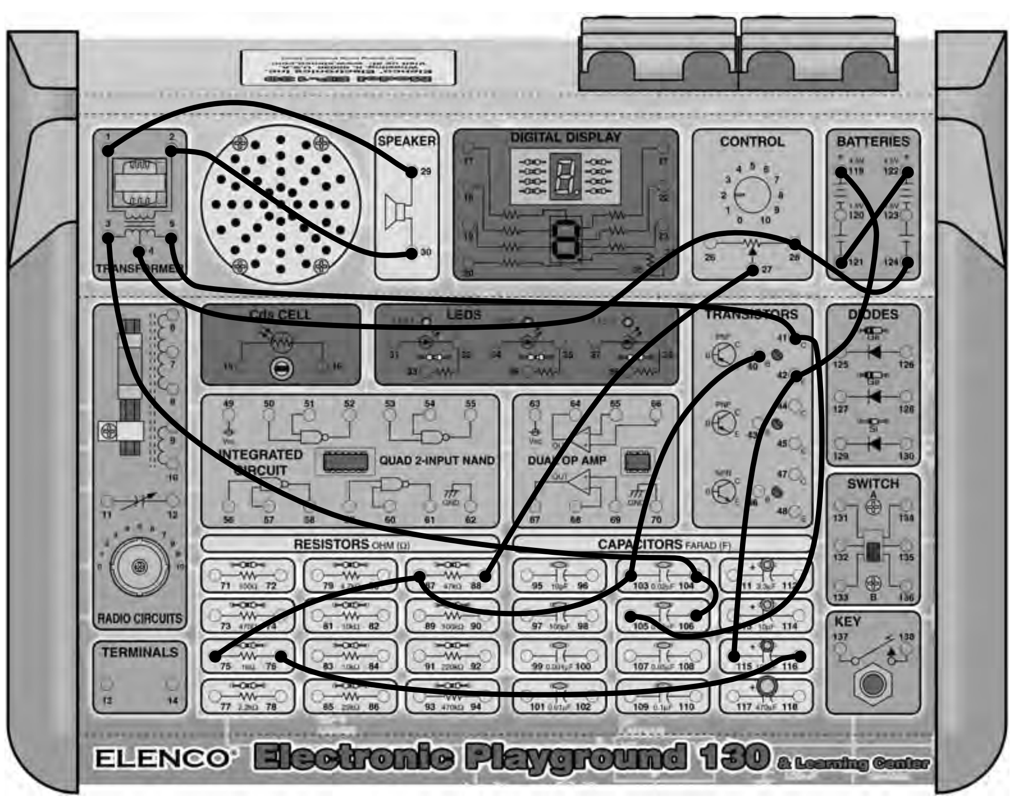
When experimenting with this circuit, you can change almost anything without causing damage. However, do not decrease the 47kΩ resistor to below 10kΩ or the transistor might be damaged.

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-104-106
- ☐ 4-28-124
- ☐ 5-41-105
- ☐ 27-88
- ☐ 75-87-103-40
- ☐ 115-42-119
- ☐ 76-116
- ☐ 121-122



EXPERIMENT #2: THE CHIRPING BIRD

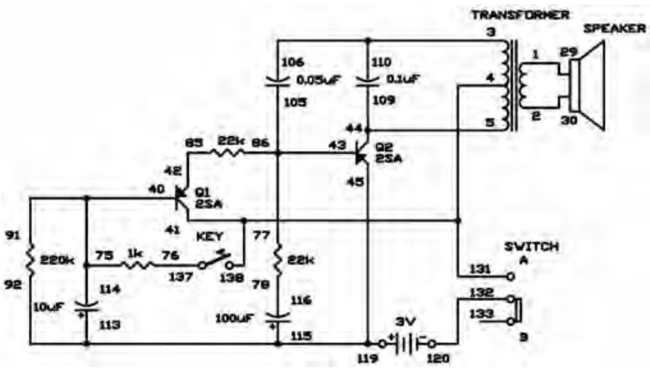
Here's a circuit that imitates more of our feathered friends - you could say it mocks the mockingbird!

Complete the circuit as shown below and slide the switch to position A to turn on the power. You won't hear any sound from the speaker yet. Press the key and you'll hear a chirping sound from the speaker. Release the key - you'll still hear the chirping sound, but then it will slow down and stop. You can see that when the key is released, the first transistor "Q1" is cut off from the battery. The second transistor "Q2" can still produce the chirping sound, until transistor "Q1" stops controlling it through its base.

Try a different value capacitor in place of the 10μF and the 100μF capacitors and hear what happens. These capacitors control the amount of electricity reaching the transistors through connections to the transistor bases. Remember to keep notes on your experimentation.

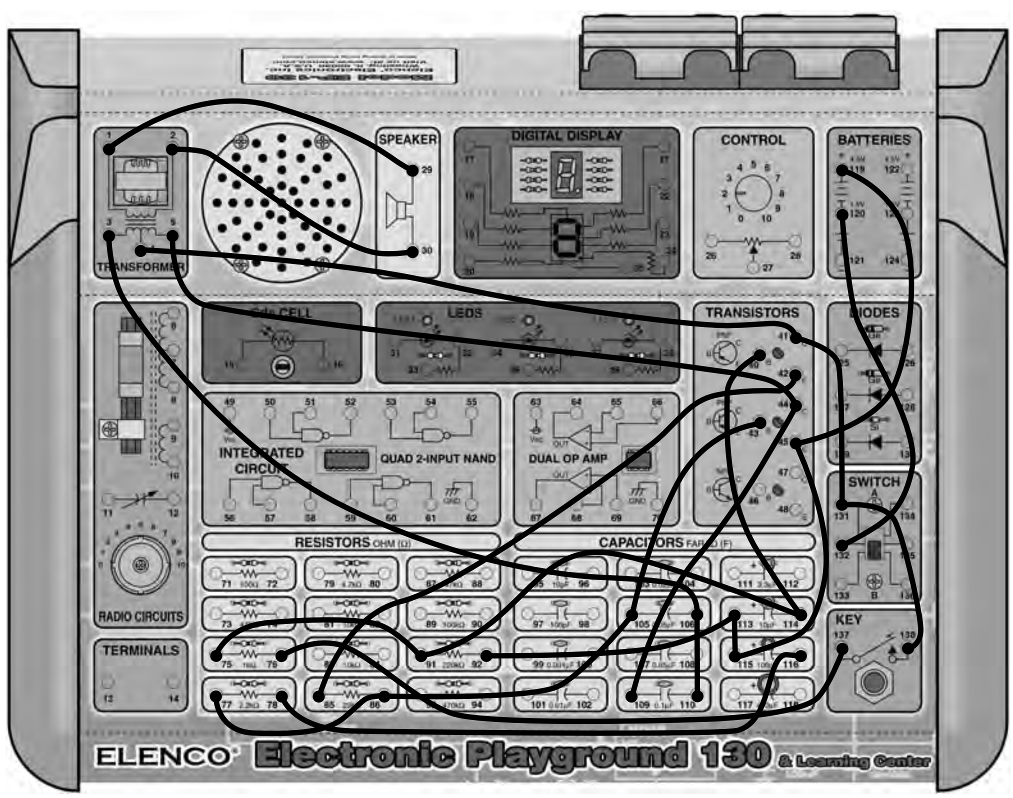
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-106-110
- ☐ 4-41-131-138
- ☐ 5-44-109
- ☐ 40-114-91-75
- ☐ 42-85
- ☐ 43-105-86-77
- ☐ 119-45-115-113-92
- ☐ 76-137
- ☐ 78-116
- ☐ 120-132



EXPERIMENT #3: ELECTRONIC CAT

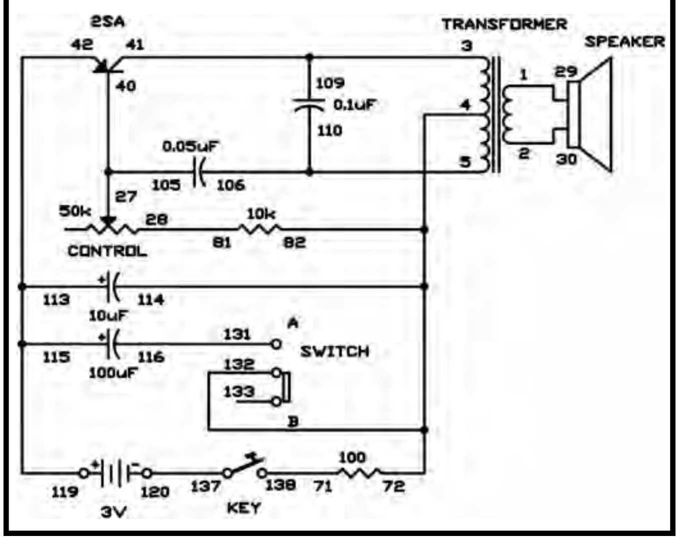
Bothered by mice? And you don't have a mousetrap? Try this instead - see if the sound of the electronic feline can keep those pests away.

Follow the wiring sequence and drawing, and start the experiment with the switch set to B. Press the key and release it immediately. You'll hear the "cat's meow" from the speaker. Adjust the control knob while the meow is dying away - what effect does it have on the circuit's operation? Set the switch to A and try again. Now the sound is lower and lasts longer as if the cat is begging for a dish of milk.

You can experiment with this circuit to produce a variety of other sounds. But don't change the value of the 0.05μF capacitor to more than 10μF or reduce the value of the 10kΩ resistor - otherwise, the transistor might be damaged.

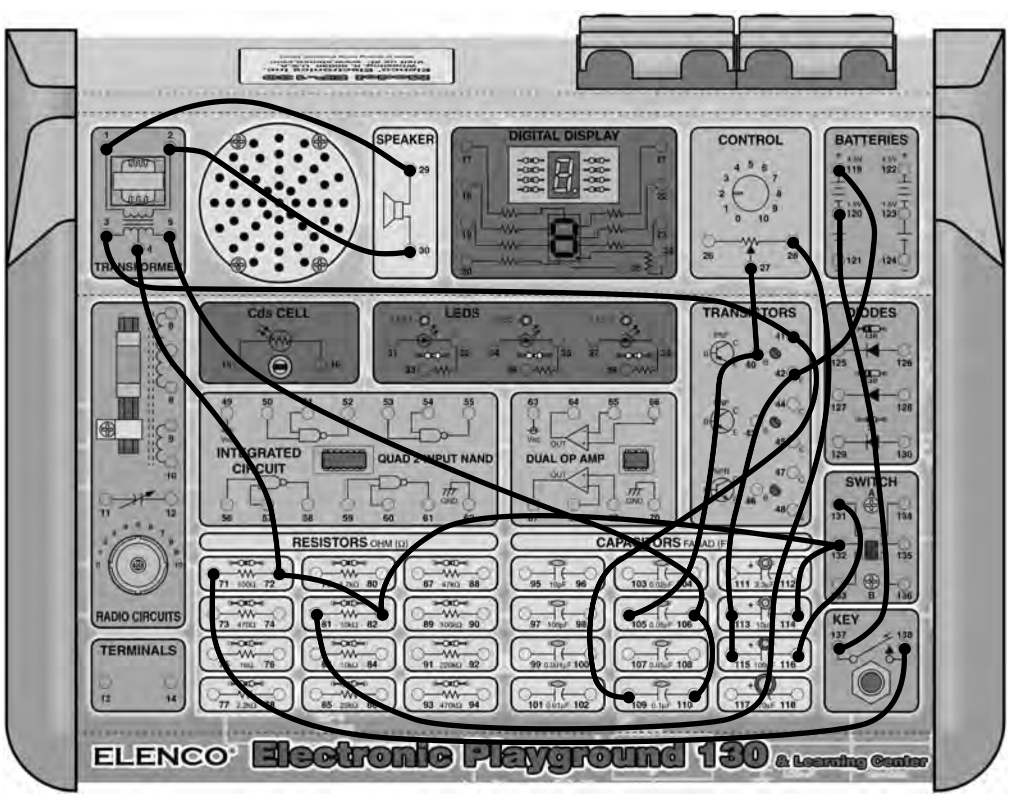
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-41-109
- ☐ 4-72-82-132-114
- ☐ 5-106-110
- ☐ 27-40-105
- ☐ 115-113-42-119
- ☐ 71-138
- ☐ 81-28
- ☐ 116-131
- ☐ 120-137



EXPERIMENT #4: SONIC FISH CALLER

Did you know that some marine animals communicate with each other by sound? You've probably heard that whales and porpoises communicate by sound, but they're not the only ones. Research indicates that some fish are attracted by certain sounds. This circuit will let you do some research of your own.

When you make the last connection, you're actually turning on the power. You should hear sound pulses from the speaker. Change the sound by turning the control. This circuit is a variation of the audio oscillator circuit. (You'll learn more about audio oscillators later on in this manual).

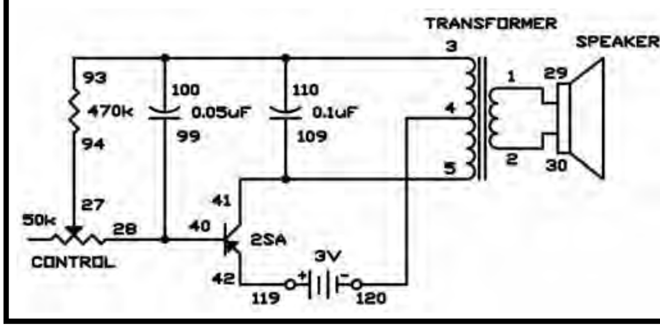
How well does this work in attracting fish? If you have an aquarium at home or at your school, place your kit near the aquarium glass and see if fish are attracted to the sound.

Or, you can actually try it out while fishing. Get another speaker and attach it to terminals 1 and 2 using long lengths of insulated wire. Carefully wrap the speaker in a waterproof plastic bag or seal it inside a jar. Be sure no water can reach the speaker. Now, lower it into the water. Then, cast a line into the water and wait for the results.

If you don't have much luck with this project, try altering a few parts values for a different pulse sound. Try a different value for the 0.1μF capacitor or the 0.05μF capacitor. Be sure to keep notes of your results - and good fishing! Who knows, you might find the type of signal that attracts a whale!

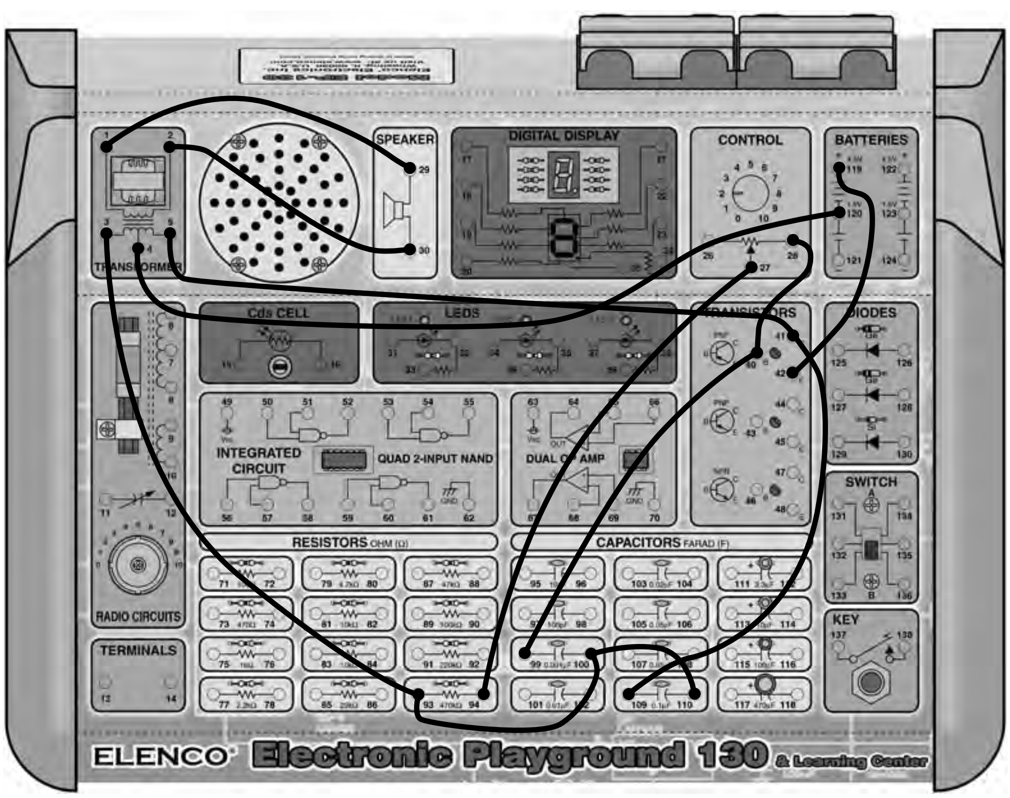
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-93-100-110
- ☐ 4-120
- ☐ 5-41-109
- ☐ 27-94
- ☐ 28-40-99
- ☐ 42-119



EXPERIMENT #5: MACHINE GUN PULSE OSCILLATOR

In this you'll build a circuit that engineers call a "pulse oscillator". It makes sounds like a machine gun. (Engineers have all kinds of technical words to describe their circuit and ideas - you might as well get used to them now and soon you'll be talking just like an electronics engineer.)

There are many ways to make oscillators. You will build several of them in this kit. Later on, you will be told how they work. For now, we'll simply tell you what an oscillator is.

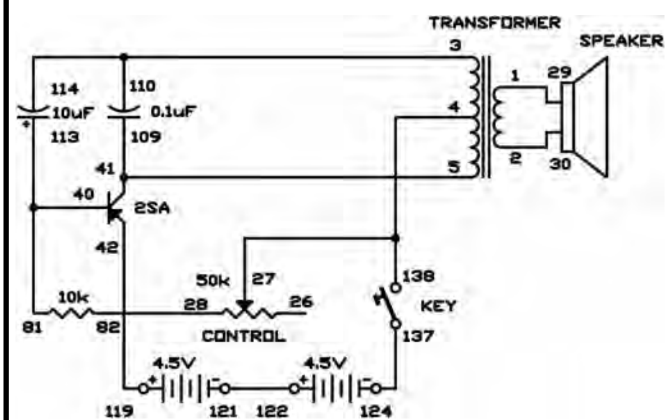
An oscillator is a circuit that turns itself on and off (or goes from high to low output). A pulse oscillator is controlled by pulses such as those made by a capacitor charging and discharging. This oscillator turns on and off slowly, but some oscillators turn on and off many thousands of times per second. "Slow" oscillators are often used to control blinking lights (like the turn signal in a car or truck). Faster oscillators are used to produce sounds. "Super" fast oscillators produce radio frequency signals (RF signals). These RF signal oscillators turn on and off millions of times per second.

The number of times an oscillator turns on and off each second is called the frequency of the oscillator and is measured in units called hertz (Hz). This oscillator has a frequency of about 1 to 12Hz. The frequency of a radio frequency signal oscillator would be measured in kHz, (kilohertz, meaning a thousand hertz) or MHz (megahertz, meaning a million hertz).

When you finish wiring, press the key to start the oscillator. Adjust the control (50kΩ variable resistor) to change the sound coming from the speaker from a few pulses per second to a dozen or so per second. You can also change the frequency of this oscillator by trying other capacitors in place of the 10µF capacitor. Be sure to observe the (+) and (–) connections (polarity) on the capacitors marked with a (+) sign.

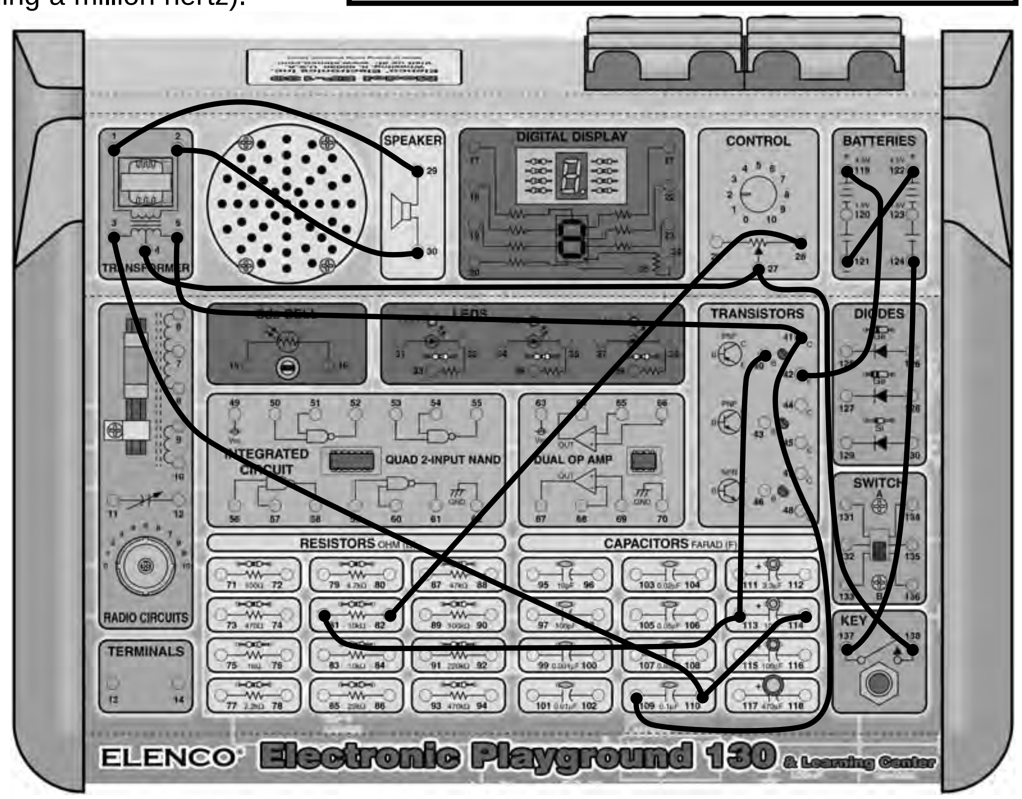
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-110-114
- ☐ 4-27-138
- ☐ 5-41-109
- ☐ 28-82
- ☐ 40-113-81
- ☐ 42-119
- ☐ 121-122
- ☐ 124-137



EXPERIMENT #6: ELECTRONIC MOTORCYCLE

Ever try steering a motorcycle (OK, maybe a bicycle) with just four fingers? That's dangerous on a real motorcycle, but it's a lot of fun in this electronic version.

To use this project, connect the components according to the wiring sequence. Then grasp the exposed metal ends of each of the two long wires (connected to terminals 110 and 81) between your thumb and the index finger of each hand. Now vary the pressure (your "grip") and listen to the sound from the speaker. The sound changes as you change your grip on each wire.

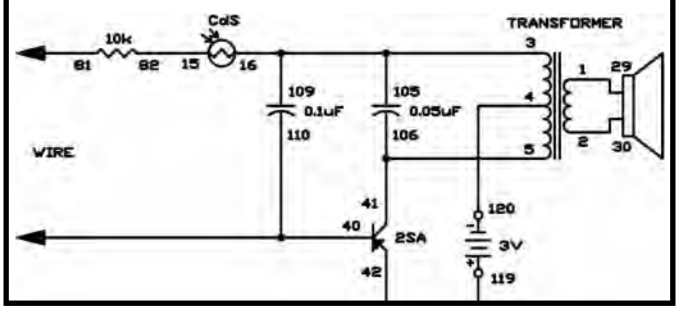
You can also get different sounds by controlling the amount of light that falls on the CdS cell. With a strong light on the CdS cell, you can control the operation entirely by exerting more pressure on the wires in your hand. Use your hand to make a shadow over the CdS cell and see what happens.

When you hold the ends of the wires, you make yourself another part of the circuit - a resistor. Changing your grip changes the resistance to the current in the project. With some practice you will be able to make this circuit sound like a real motorcycle on the go. You can make it idle as well as race.

You can experiment with different values for the 0.1µF and 0.05µF capacitors, but don't use values above 10µF or the transistor might be damaged.

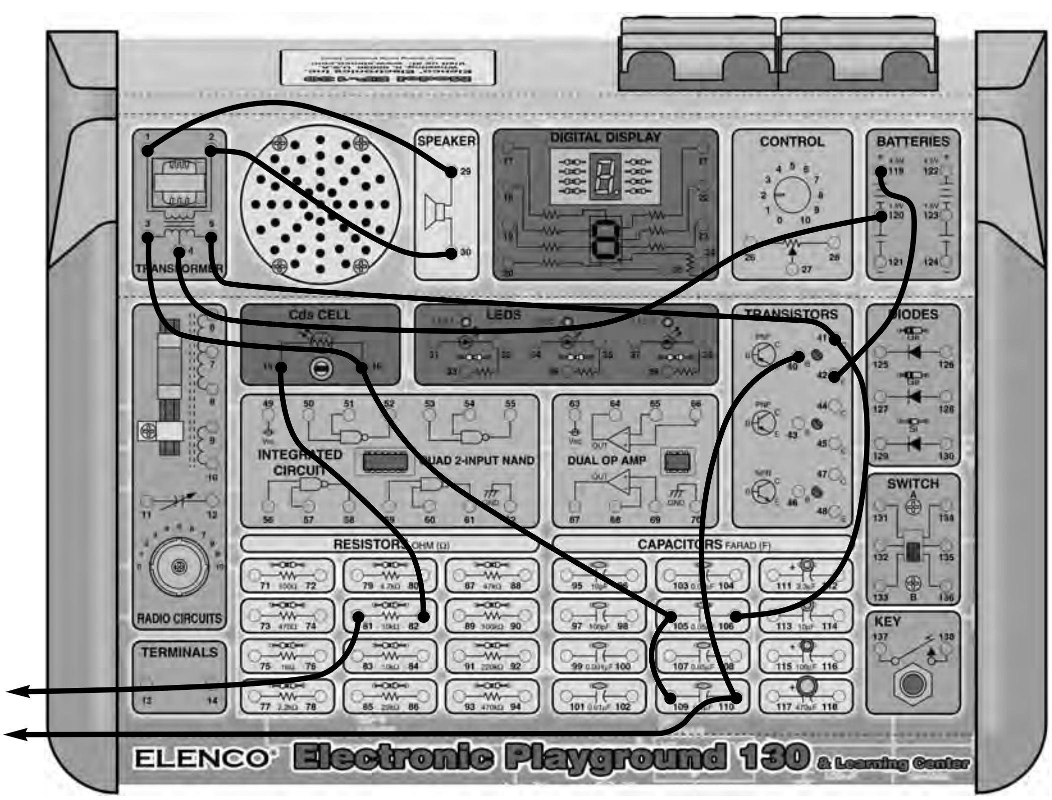
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-16-105-109
- ☐ 4-120
- ☐ 5-41-106
- ☐ 15-82
- ☐ 40-110-WIRE
- ☐ 42-119
- ☐ 81-WIRE



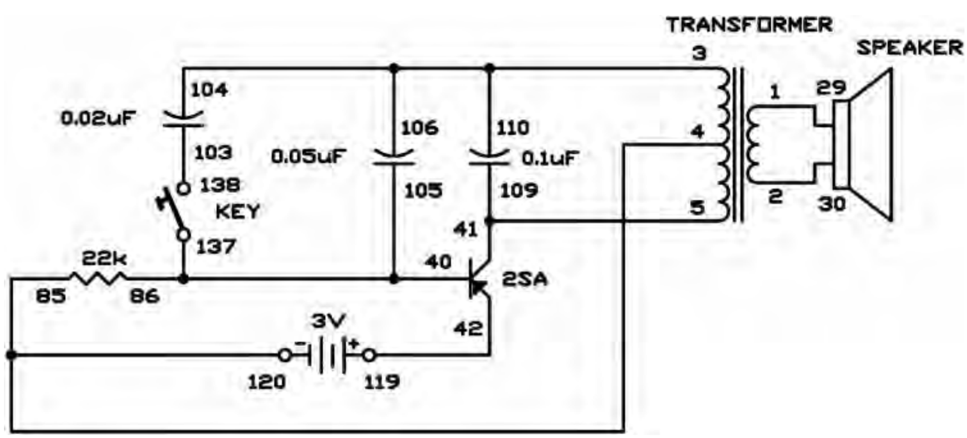
EXPERIMENT #7: TWO-TONE PATROL CAR SIREN

Here is a loud siren that is so much like the real sirens on some police cars and ambulances, that you may have to be careful not to confuse your neighbors. The initial tone is high, but when you close the key, the tone lowers. You can control the tone the same way police and ambulance drivers do.

This is the same type of oscillator circuit used in many other projects. When you press the key, another capacitor is added to the circuit to slow down the oscillator action.

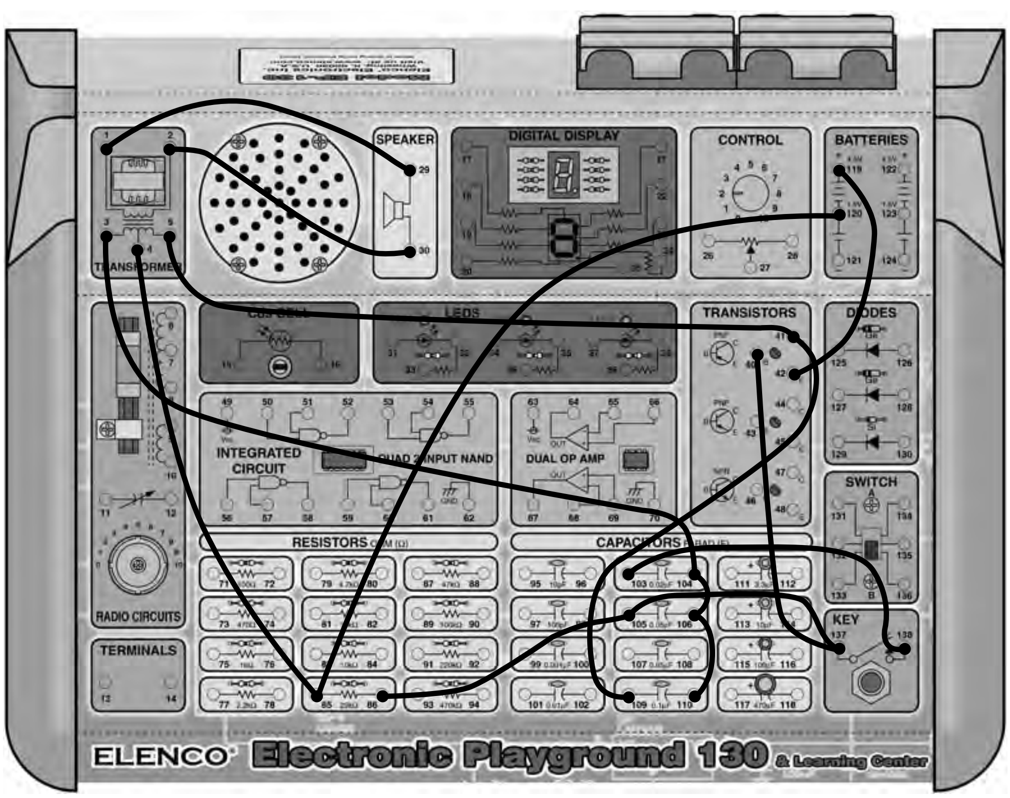
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-104-106-110
- ☐ 4-85-120
- ☐ 5-41-109
- ☐ 40-137-105-86
- ☐ 103-138
- ☐ 42-119



EXPERIMENT #8: ELECTRONIC SIREN

Here's another siren - don't be surprised if this becomes the most popular circuit in this entire kit.

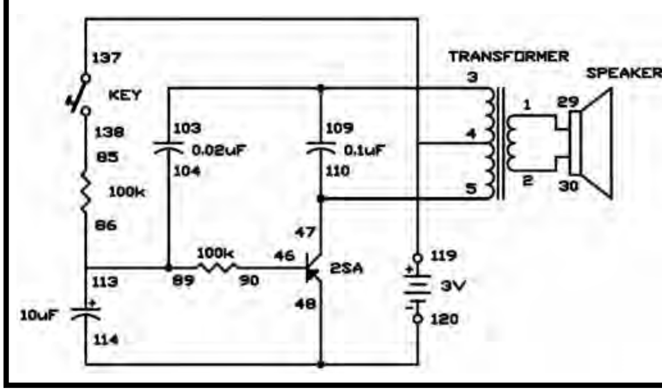
This circuit sounds even more like a real siren on a police car! After completing the wiring, press the key. You'll hear a tone gradually getting higher. Release the key, and the tone becomes lower and then fades out.

Here are some of the modifications you might want to try:

1. Change the 10μF capacitor to a 100μF or 470μF. This gives a very long delay for both turn on and turn off.
2. Change the circuit to eliminate the delays by temporarily disconnecting the 10μF capacitor. Simply disconnect one of the wires from terminal 113 or terminal 114. (Sounds dead in comparison doesn't it!)
3. Change the 0.02μF capacitor to a 0.01μF and then to a 0.05μF.

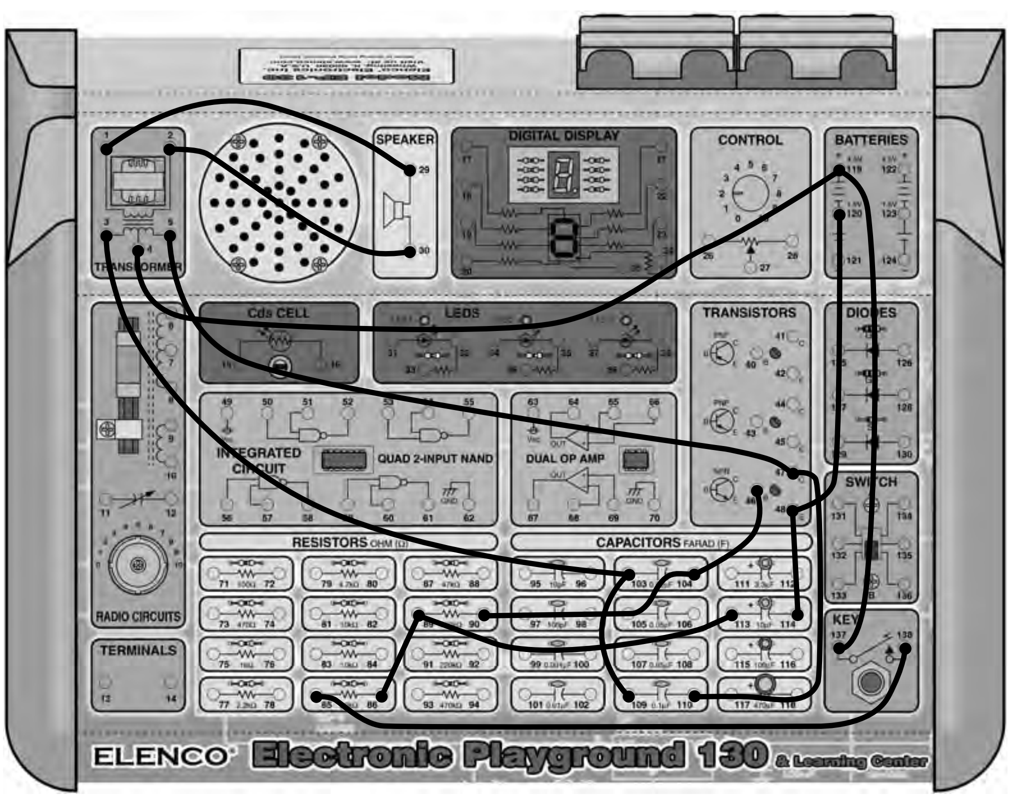
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-103-109
- ☐ 4-119-137
- ☐ 5-47-110
- ☐ 46-104-90
- ☐ 114-48-120
- ☐ 85-138
- ☐ 86-89-113



EXPERIMENT #9: ELECTRONIC METRONOME

Here's a circuit 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.

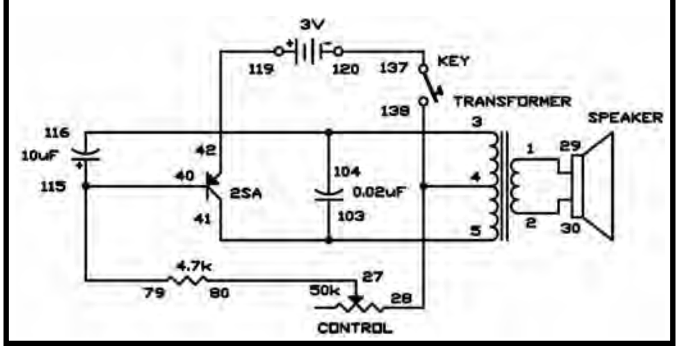
Press the key. You'll hear a sound from the speaker at fixed intervals. Now, turn the control knob to the right and you'll hear the sound "speed up" as the intervals between sounds shorten.

Try a different resistor in place of the 4.7kΩ resistor. (This resistor is in series with the control. That is, they are connected end to end so that the current runs through both components.) Also, try a different capacitor in place of the 100μF capacitor and see what effect this has on circuit operation. Remember to keep track of the results in your notes.

Try connecting the 470μF capacitor to the batteries to hear the difference a stronger capacitor makes. Connect terminal 117 to terminal 119 and terminal 118 to terminal 120. You might have to adjust the control also to maintain the same pulse rate.

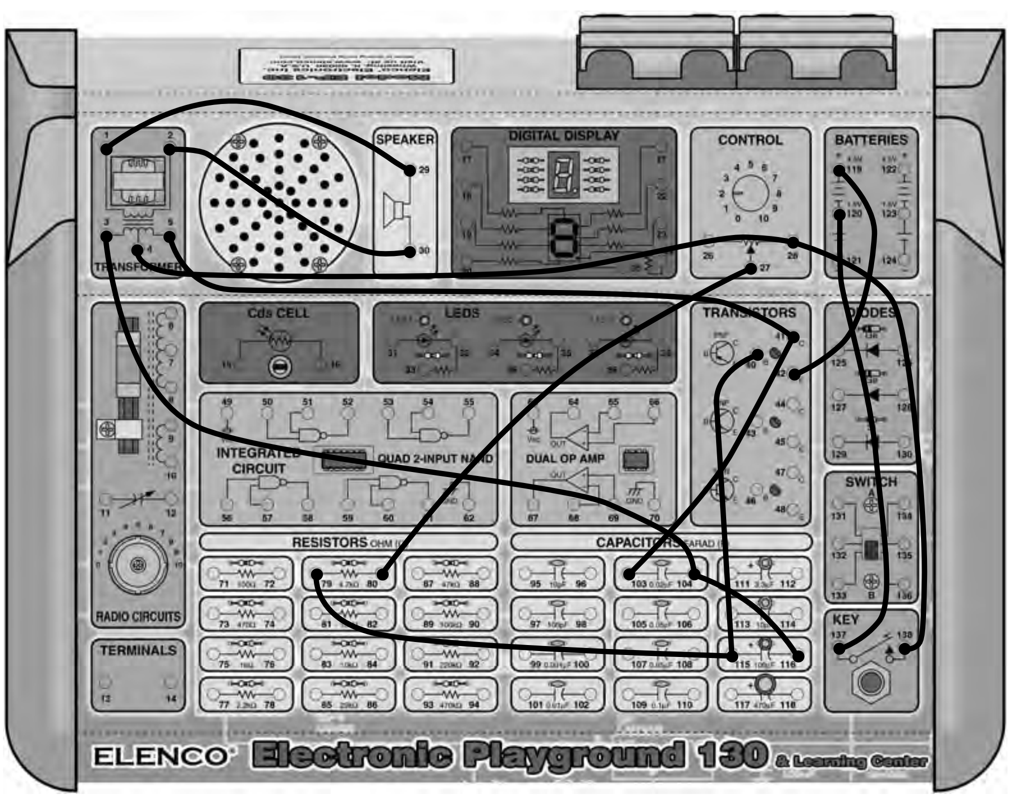
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-104-116
- ☐ 4-28-138
- ☐ 5-41-103
- ☐ 27-80
- ☐ 40-115-79
- ☐ 42-119
- ☐ 120-137



EXPERIMENT #10: ELECTRONIC GRANDFATHER CLOCK

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.

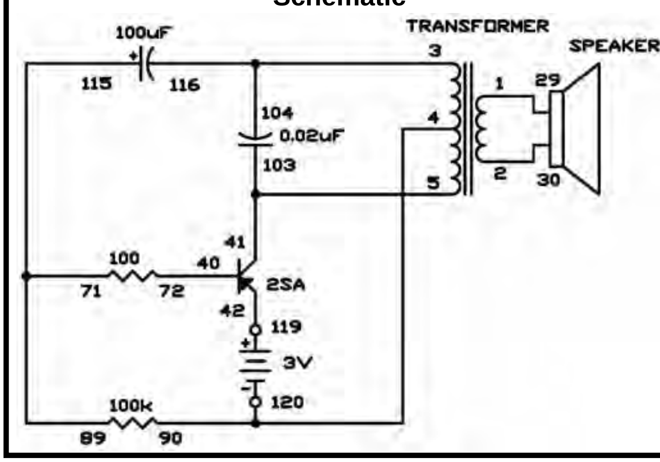
The circuit produces clicks at approximately one second intervals. The timing and sound together will remind you of an old grandfather clock. You can change the 100kΩ resistor to obtain faster or slower pulse rates.

The steady monotonous ticking can put animals (and people) into a restful state of mind. If you have traveled on a train, you know how sleepy you get as you hear the click, click, click of the wheels.

Now, want to scare this “clock” to stop? Yell into the speaker. How about that? You can momentarily stop the clock! The speaker acts as a microphone. The sound of your voice vibrates in the speaker and upsets the electrical balance of the circuit momentarily.

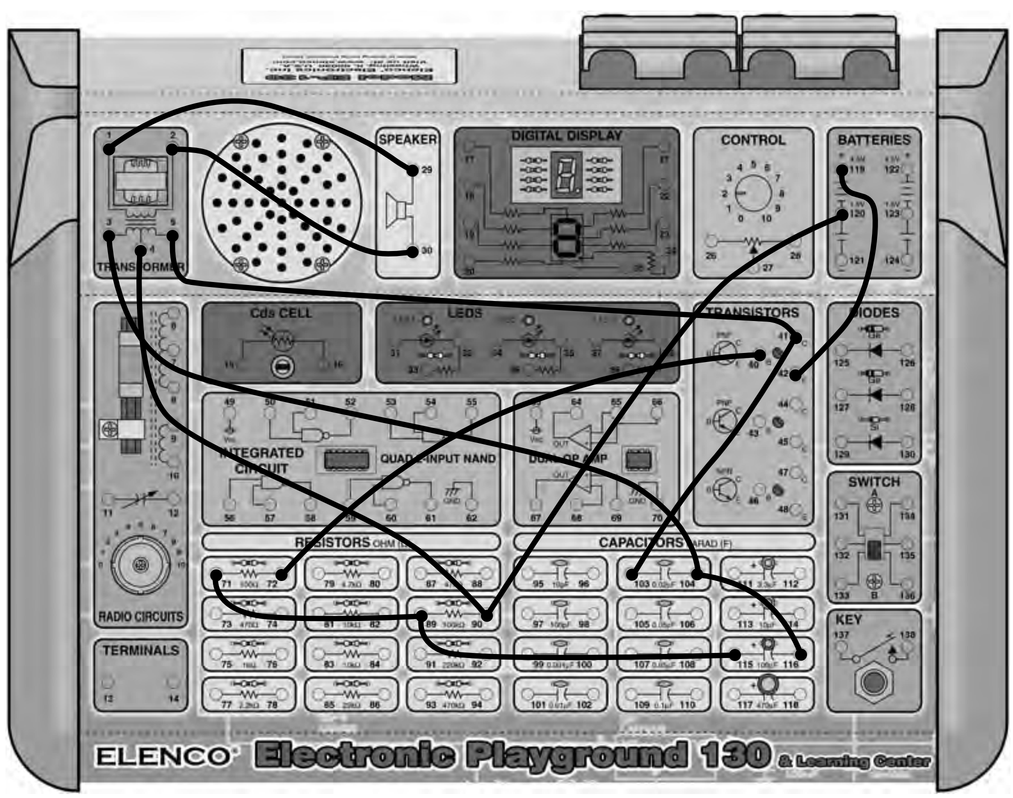
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-104-116
- ☐ 4-90-120
- ☐ 5-41-103
- ☐ 40-72
- ☐ 42-119
- ☐ 71-89-115



EXPERIMENT #11: LIGHT-CONTROLLED ELECTRONIC HARP

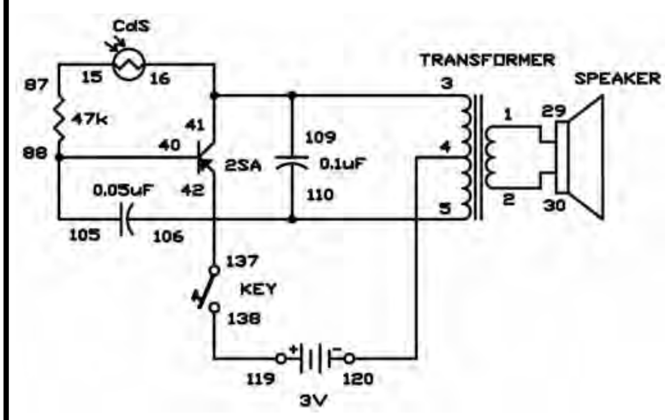
You are going to play musical tunes by waving your hand over the board without touching it! Magic? Incredible? The tones change with the amount of light that reaches the CdS cell. Under a bright light, the tone is high. As you block the light with your hand, the tone lowers.

This method of creating musical sound has been used since the early days of vacuum-tube circuitry. The first instrument of this type was invented by a man named Leon Theremin, so the instrument was named Theremin in his honor.

When you complete the wiring, press the key and wave your hand over the CdS cell. With a little practice, you will be able to play tunes with this magical electronic musical instrument. Experiment with the CdS cell light shield for more light control. Have fun!

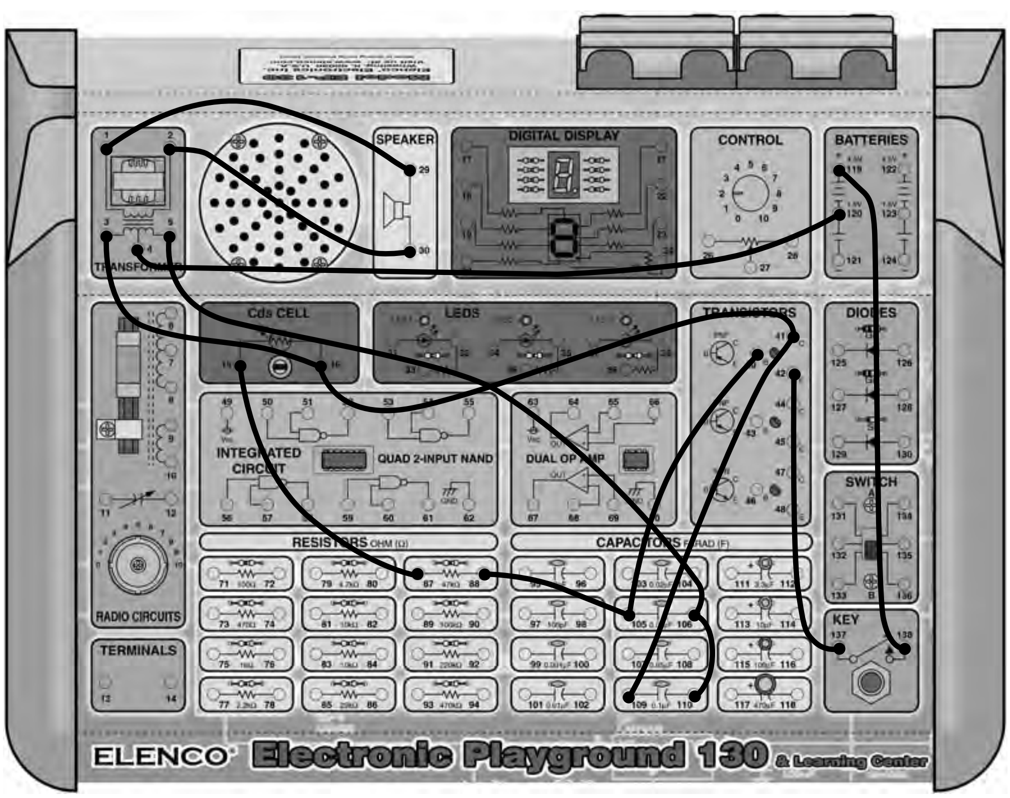
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-16-41-109
- ☐ 4-120
- ☐ 5-106-110
- ☐ 15-87
- ☐ 40-105-88
- ☐ 42-137
- ☐ 119-138



EXPERIMENT #12: HORROR MOVIE SOUND EFFECTS

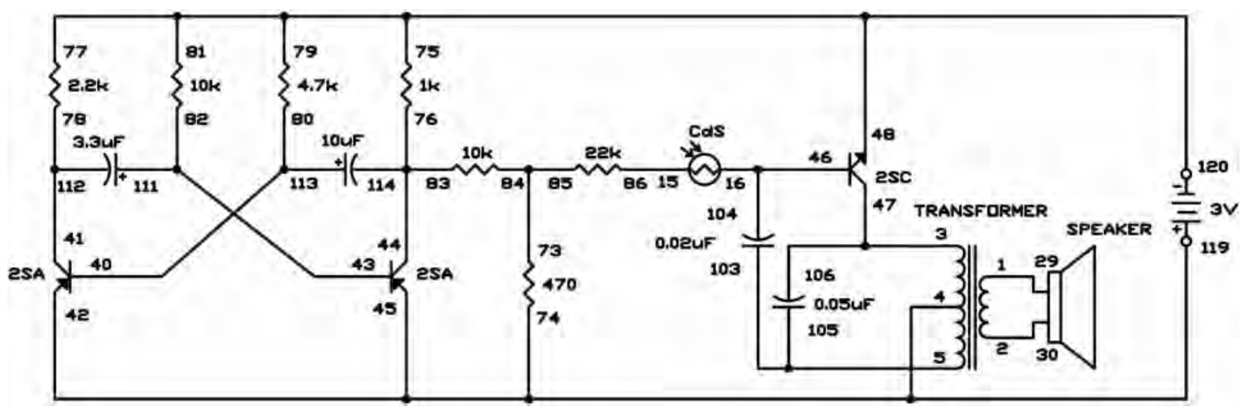
The sound that this circuit produces will remind you of the scary music you hear in horror movies. After wiring the project, use your special light shield and your hand to change the amount of light that falls on the CdS cell. The music changes in pitch.

The pitch of a sound is determined by the frequency of the sound wave - the number of cycles of electromagnetic energy per second. The amount of light of the CdS cell determines the resistance value of the cell. More resistance from the cell slows down the frequency of the music sound waves. The basic “music” is produced by the oscillator circuit.

When a circuit controls the frequency of an oscillator, we call it FM or frequency modulation. An FM radio signal is something like this, but at much higher frequencies.

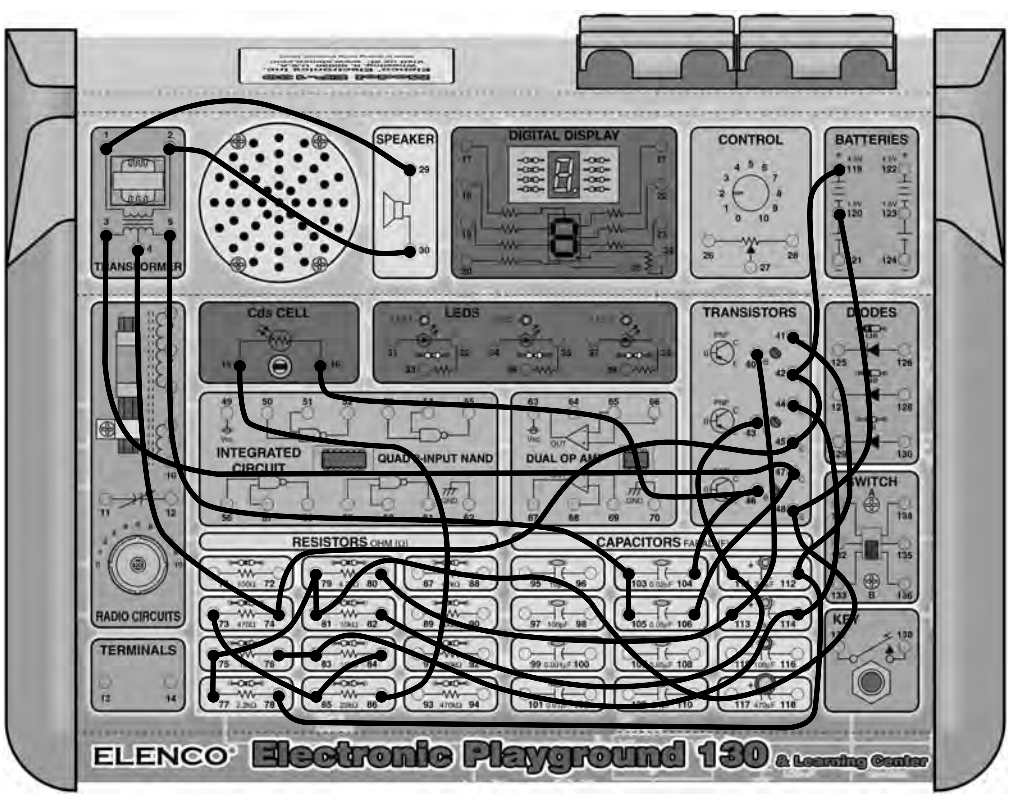
Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-47-106
- ☐ 4-74-45-42-119
- ☐ 5-103-105
- ☐ 15-86
- ☐ 16-46-104
- ☐ 40-113-80
- ☐ 41-112-78
- ☐ 44-114-83-76
- ☐ 120-48-81-79-75-77
- ☐ 73-85-84



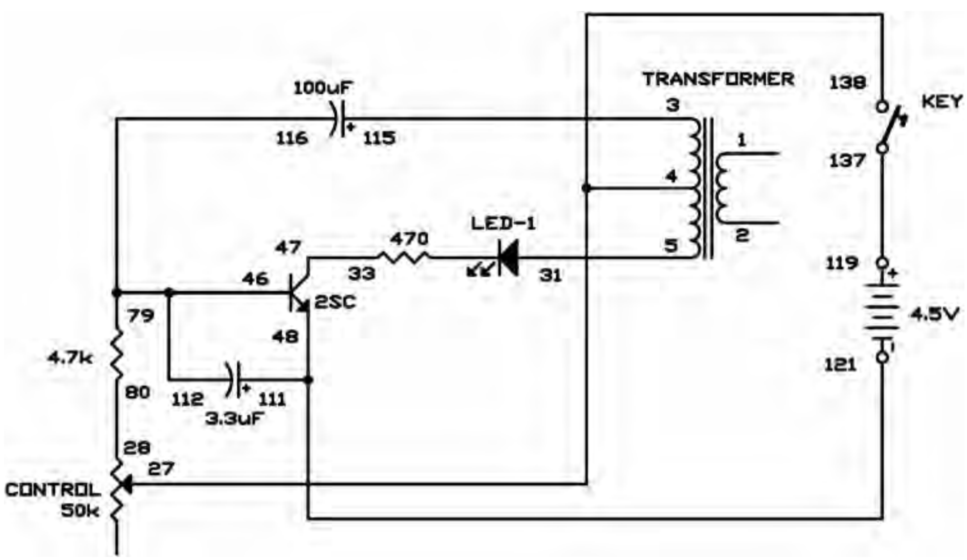
EXPERIMENT #13: STROBE LIGHT

Here's an oscillator circuit that doesn't use the speaker or earphone - you don't hear its output. Instead, you see the output from an LED. This gives you an idea of how large strobe lights work. Press the key and watch LED 1. It turns on and off at certain intervals. You can control the blinking rate with the 50kΩ control.

This lets you "see" how an oscillator works. Try substituting a lower value capacitor for the 100μF capacitor. What do you think will happen? Were you right?

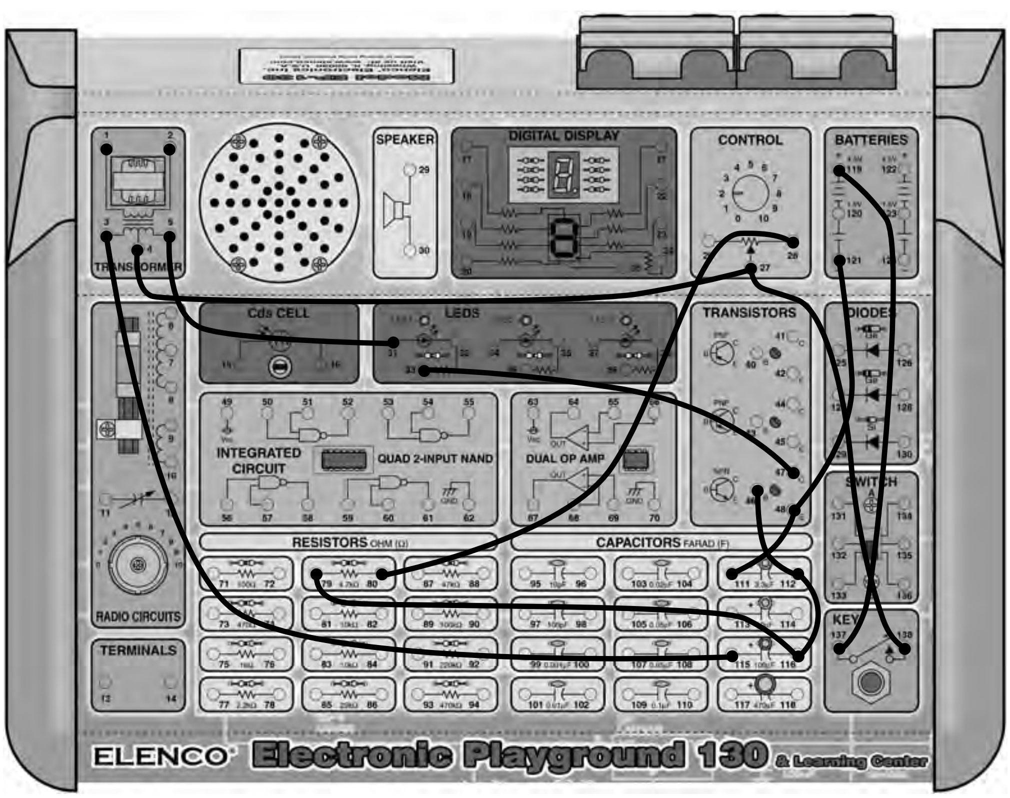
Notes:

Schematic



Wiring Sequence:

- ☐ 3-115
- ☐ 4-27-138
- ☐ 5-31
- ☐ 28-80
- ☐ 33-47
- ☐ 79-116-112-46
- ☐ 111-48-121
- ☐ 119-137



EXPERIMENT #14: RAPID LED DISPLAY SWITCHING (PERSISTENCE OF VISION TEST)

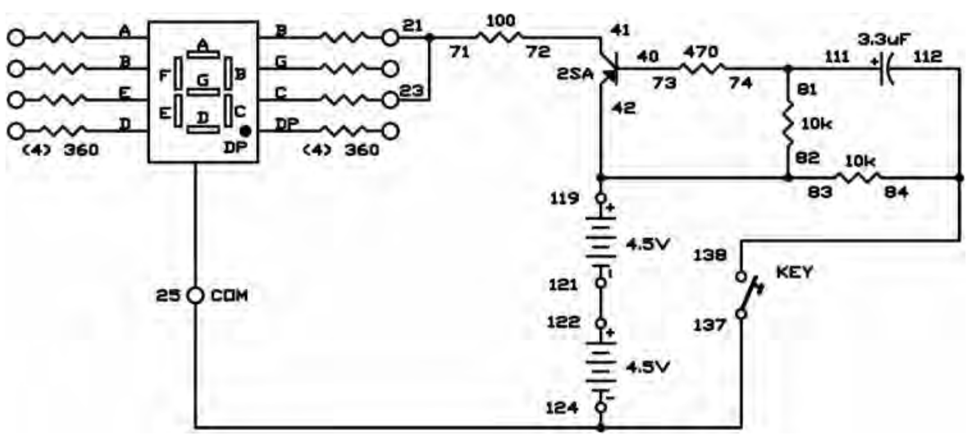
This is a control circuit that produces short pulses. When you close the key, the LED display shows 1 for an instant and then goes off, even if you keep pressing the key.

You can make up a game with this circuit. Display a number or letter on the LED, and have the players tell you what number is on the display. You can have different numbers or letters displayed by the LED by changing the wiring of the LED. Connect the appropriate terminals to form letters or numbers to terminal 71 (in place of terminals 21 and 23). The connections for the number 3 would be: 17-21-22-23-20-71.

You might want to try different values of capacitors and see their effects, but don't use a capacitor value higher than 10µF or the transistor might be damaged by excessive current.

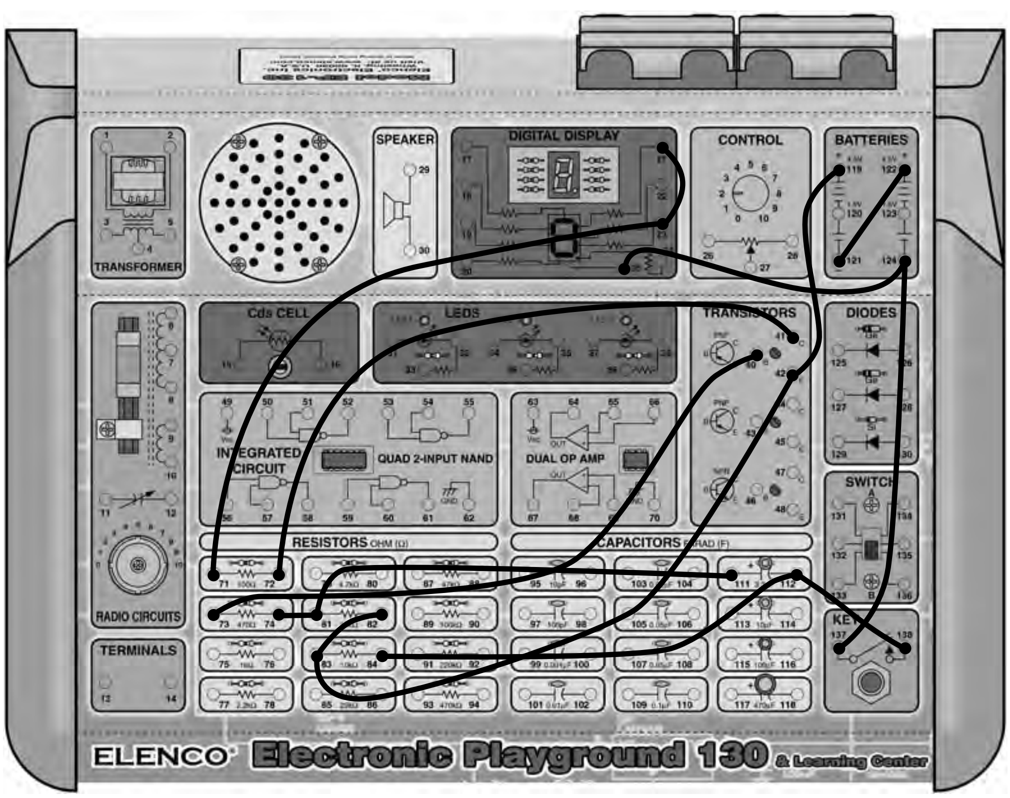
Notes:

Schematic



Wiring Sequence:

- ☐ 21-23-71
- ☐ 25-124-137
- ☐ 40-73
- ☐ 41-72
- ☐ 82-83-42-119
- ☐ 74-81-111
- ☐ 84-112-138
- ☐ 121-122



II. BASIC SEMICONDUCTOR AND COMPONENTS CIRCUITS

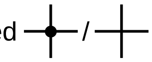
A BIG CHANGE

Until now, you have had drawings of your kit, in addition to the wiring sequences, to guide you in making wiring connections. The rest of the projects in this manual will have a schematic diagram in place of the kit drawing.

A schematic diagram is a road map for electronic circuits. It shows how different parts are connected together and lets you follow the flow of electricity through the circuit. Highly skilled electronics technicians and engineers can build entire circuits with nothing more than schematic diagrams to guide them.

We won't ask you to build circuits from schematic diagrams alone. To help you, we've added the number of the terminal where you will make each wiring connection on the schematics. A line between numbers 32 and 64 on the schematic means you should connect a wire between those two terminals on your kit. Each part in your kit has its own schematic symbol. You'll find a picture of each part, along with its schematic symbol and a brief description at the beginning of this manual.

You'll notice on the schematics that some lines cross each other and there's a dot at the point where they cross. This means that the two wires represented by the lines are connected at the point indicated by the dot. (You'll usually find a terminal number beside the dot.) If two lines cross without a dot, that means the wires aren't connected. (You also won't see a terminal number near the area where they cross.)

Lines Are Connected  Lines Not Connected

At first, schematic diagrams might look confusing, but they are actually quite simple once you get some practice using them. Don't be discouraged if you get confused by them at first. Before long, you will be building circuits just by looking at their schematic diagrams.

The ability to read schematic diagrams is important in electronics. Many electronics magazines and books give interesting circuits only in schematic form. A schematic is also a shorter and more accurate way to describe or show a circuit than a written description.

EXPERIMENT #15: CAPACITOR DISCHARGE / HIGH VOLTAGE GENERATOR

This circuit shows how single pulses of high voltage electric energy are generated when a charged capacitor is suddenly discharged through a transformer. (Capacitor-discharge automobile ignition systems use this same type of reaction.)

The operation of this circuit is simple, but the concepts involved are important to understanding more complicated circuits. If you have a Voltage/Ohm meter, you can scientifically measure the energy that is discharged through the transformer.

The 470μF capacitor stores up energy when the batteries supply millions of electrons to the capacitor's negative electrode. At the same time, the batteries draw the same number of electrons from the capacitor's positive electrode so that the positive electrode is deficient in electrons. Since the current must pass through the 4.7kΩ resistor, it requires at least 12 seconds for the capacitor to receive the 9V charge from the batteries.

The amount of charge in a capacitor can be indicated by the "voltage across" the capacitor (the voltage supplied by a battery or other power source) or, more accurately, by the quantity of electrons displaced in one of the capacitor's electrodes.

The quantity of electrons in an electrode of a capacitor is measured in coulombs. One coulomb is a quantity of 6,280,000,000,000,000,000 electrons (6.25×10^{18}).

To determine the charge in either electrode of the capacitor (Q), multiply the capacitance (C) by the voltage across the capacitor (E). (Q = C x E). For the 470μF (470×10^{-6}F) capacitor at 9V, this is calculated as follows:

$$Q = C \times E = 470 \times 10^{-6} \times 9 = 4.23 \times 10^{-3} \text{ coulombs}$$

or:

$$470 \times 0.000001 \times 9 = 4.23 \times 10^{-3} \text{ coulombs}$$

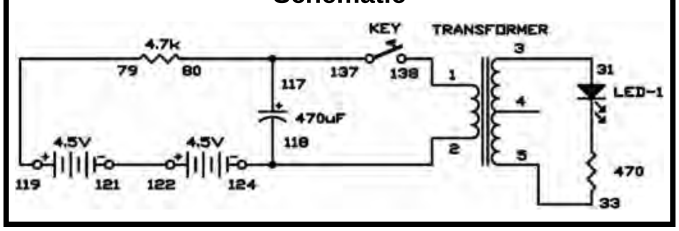
(265,564,400,000,000 electrons)

When you press the key, the above number of electrons pass through the transformer winding a very short time and induce a high voltage in the secondary winding. This causes the LED to flash.

If you have a VOM, connect it as directed to terminal 3 and terminal 5 of the transformer to indicate the presence of 90V or more. The indicated voltage is held by the capacitor and is released when the transformer is brought into the circuit.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-138
- ☐ 2-118-124
- ☐ 3-PROBES
- ☐ 5-PROBES
- ☐ 79-119
- ☐ 80-117-137
- ☐ 121-122

EXPERIMENT #16: CAPACITORS IN SERIES AND PARALLEL

The capacitors are some of the handiest items in your kit. They can store electricity, smooth out pulsing electricity into a steady flow and let some electric current flow while blocking other current. This lets you hear the effects of capacitors connected in series and parallel.

When you finish wiring this project, set the switch to B. Then, connect terminals 13 and 14. You'll hear a sound from the speaker. In this case, electricity is flowing through the 0.01μF capacitor (refer to the schematic while we talk about this). Now press the key. What happens?

You hear a lower-pitched sound from the speaker. This is because the 0.05μF capacitor has been added in parallel to the first capacitor. That is, the current flows through both capacitors at the same time, through two separate channels. What do you think happens to the total capacitance when you connect two capacitors in parallel?

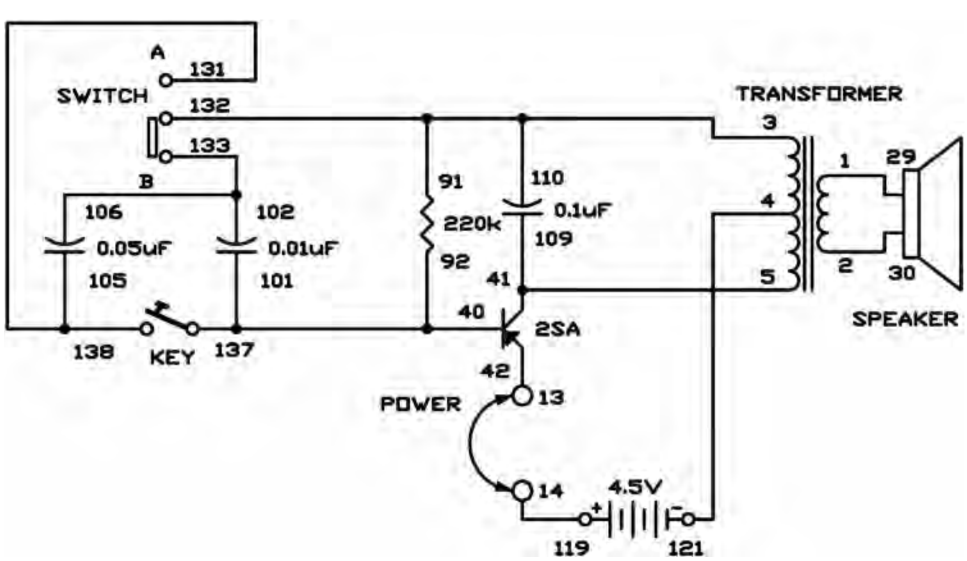
You might have guessed wrong. When two capacitors are connected in parallel, the total capacitance increases. The increased capacitance causes the tone to be lower.

Now release the key and move the switch from B to A, but do not press the key while the switch is set to A. (The transistor can be damaged.) What do you hear?

You hear a high-pitched sound from the speaker. This is because the 0.05μF and 0.01μF capacitors are not connected in series - current flows from one directly to another. The total capacitance in the circuit is now less than the smallest capacitor making up the series connection. This lower capacitance allows the more high-pitched sound.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-91-110-132
- ☐ 4-121
- ☐ 5-41-109
- ☐ 13-42
- ☐ 14-119
- ☐ 40-92-101-137
- ☐ 102-106-133
- ☐ 105-131-138
- ☐ 13-14 (POWER)

EXPERIMENT #17: RESISTORS IN SERIES AND PARALLEL

In this project, you will see what happens when you connect resistors in series and in parallel. When you finish wiring, you can see LED-1 on the panel flash on and off.

Slide the switch and see what happens to the LED on side A and then on side B. It shows no change at all. The schematic shows you that two 10kΩ resistors are connected in series to side A of the switch, and one 22kΩ resistor is connected to side B. The total resistance of the resistors connected in series on side A is equal to the sum of each resistor's value - 20kΩ. This is about the same as the 22kΩ resistance in side B. That's why the LED shows no change, even when you move the switch.

Press the key and you see the LED become brighter. Look at the schematic and you'll see that resistor 1 - R1 (470Ω) is connected to the LED in series. This resistor controls the flow of current to the LED. When you press the key, R1 and resistor 2 - R2 (100Ω) are connected in parallel, and the total resistance decreases. The LED becomes brighter because the current flowing to it increases when the amount of resistance decreases.

Calculating the total resistance in a parallel connection is not as easy as calculating resistance in a series connection. You must multiply the values together, then divide the product by the sum of the values. In this case, the total resistance is:

$$\frac{470 \times 100}{(470 + 100)} = 82\Omega$$

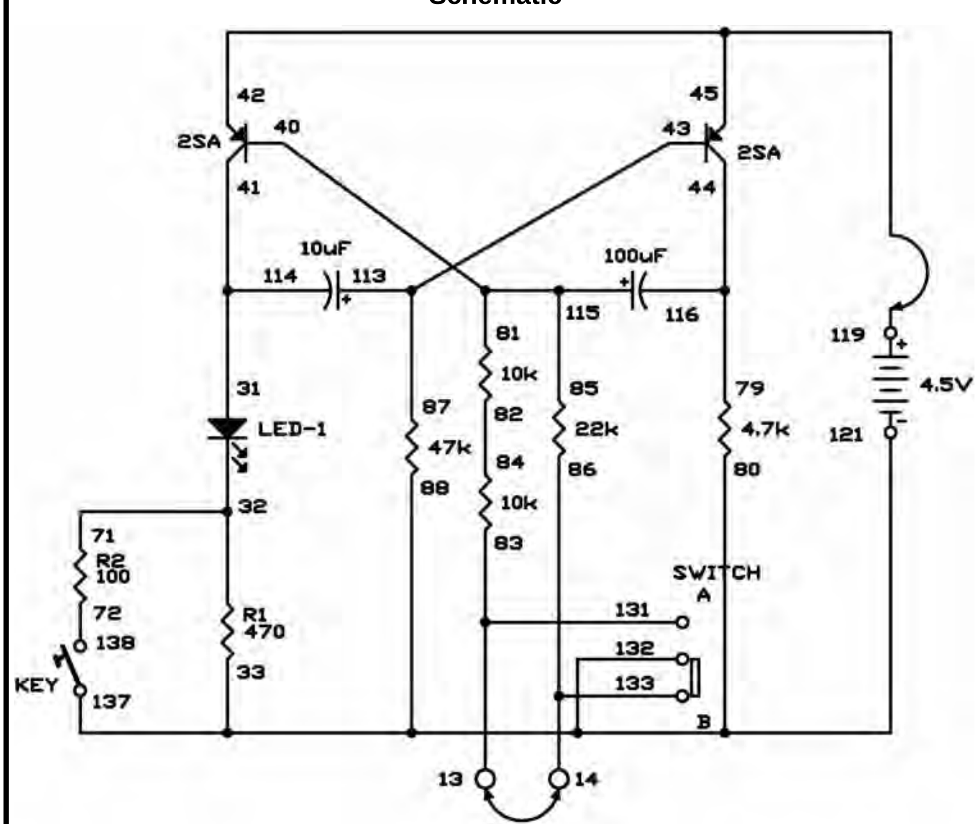
Now, connect terminals 13-14. As shown in the schematic, this connects the 22kΩ resistor in parallel with the two 10kΩ resistors. Any change in the LED? It flashes on and off at shorter intervals because the resistance connected to the slide switch decreases. Try calculating the new resistance value. It's about 10.5kΩ.

This circuit is called a multivibrator. A multivibrator is an oscillator that uses components that direct current back to each other. In the schematic you can see that the 10μF and the 100μF capacitors discharge through the transistors. This multivibrator circuit controls oscillations to make the LED flash at certain intervals.

You can see now that resistors and capacitors have opposite effects when connected in series or in parallel. Be careful - it's easy to get confused about which one increases or decreases in strength.

Notes:

Schematic



Wiring Sequence:

- ☐ 31-41-114
- ☐ 79-116-44
- ☐ 40-115-85-81
- ☐ 43-113-87
- ☐ 32-71
- ☐ 72-138
- ☐ 82-84
- ☐ 13-83-131
- ☐ 14-86-133
- ☐ 33-80-88-137-132-121
- ☐ 45-42-119

EXPERIMENT #18: LIGHT DIMMER

In this project, you use a capacitor's charging and discharging to dim a light (an LED in this case). When you finish the wiring, set the switch to A. The LED segments slowly light up, displaying an L. In a few seconds, the LED reaches its brightest point and stays on. Now move the switch to B, and the L gradually fades away.

Take a look at the schematic. With the switch on, current flows from the battery to charge the 100μF capacitor. As the capacitor approaches full charge, more and more electricity flows to the base of the transistor, gradually turning it on (and thereby turning the LED on). When the capacitor is completely charged, the current continues to flow to the transistor base, and the LED stays on.

When you turn the switch off, you remove the battery from the circuit and the capacitor begins the discharge through the transistor and the LED. The L gradually dims until the 100μF fully discharged.

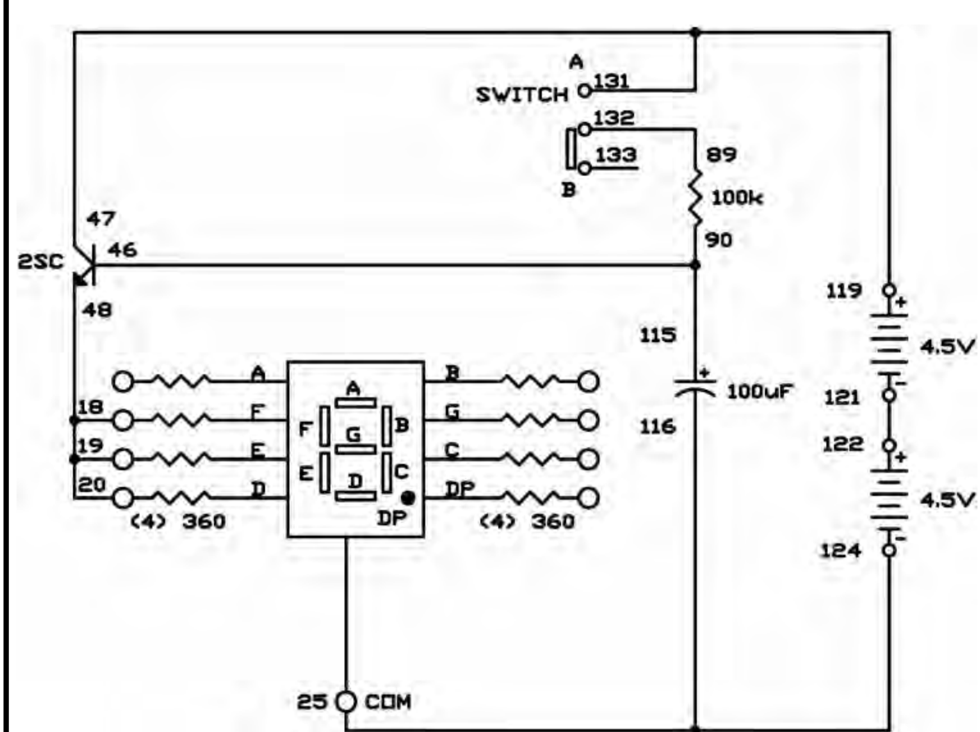
If you want a slower dimmer circuit, replace the 100μF capacitor with the 470μF capacitor. Simply replace connections 25-116-124 with connections 25-118-124, and replace connections 46-115-124, and replace connections 45-115-90 with 46-117-90. You'll have to be patient, but the LED comes on eventually.

Now go back to project 8 (Electronic Siren) and see if you can figure out why the siren sound goes from high to low as you press and release the key.

Hint: when you close the key the 10μF capacitor begins to charge.

Notes:

Schematic



Wiring Sequence:

- ☐ 18-19-20-48
- ☐ 25-116-124
- ☐ 46-115-90
- ☐ 119-47-131
- ☐ 89-132
- ☐ 121-122

EXPERIMENT #19: TRANSISTOR SWITCHER

This is designed to help you study the switching action of the transistors in turning on the LED. You will use two different transistors – the NPN type and one of two PNP types included in your kit. NPN and PNP refer to the arrangement of the semiconductor materials that make up the transistors.

The 47kΩ resistor supplies a base voltage so that the NPN transistor at the bottom of the schematic stays on. The PNP transistor at the top of the schematic turns on when you close the switch and make the connection through the 22kΩ resistor.

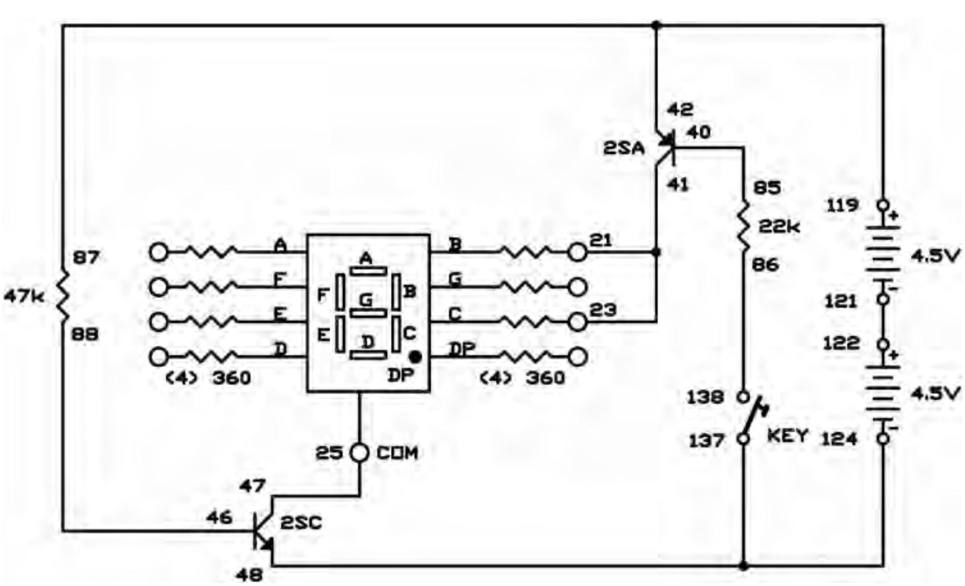
Because the 22kΩ resistance is about half that of the 47kΩ resistor, the current supplied to the base of the PNP transistor is about twice as much as that of the NPN. The PNP is therefore “more” on than the NPN.

Hook up the circuit and press the key: 1 is displayed. To increase the base current of the NPN transistor, decrease the value of the 47kΩ resistor connected to the base – terminal 46. Simply disconnect terminals 87 and 88, and replace them with connections to another resistor. For example, change connections 87-42 and 46-88, to 83-42 and 84-46 to change the 47kΩ resistor to a 10kΩ resistor. Each time you use a lower value resistor, more current is supplied to the base of the transistor, and the LED display lights a little brighter when you use the key. Don’t decrease the resistance below 1kΩ, or the transistor might burn out.

Now change the resistors to 10kΩ and press the key. Use terminals 81 and 82, and terminals 83 and 84. The brightness should not change much with transistors both fully on. If much change does occur, check the batteries. They might be weak.

Notes:

Schematic



Wiring Sequence:

- ☐ 21-23-41
- ☐ 25-47
- ☐ 40-85
- ☐ 87-42-119
- ☐ 46-88
- ☐ 124-48-137
- ☐ 86-138
- ☐ 121-122

EXPERIMENT #20: TRANSISTOR CIRCUIT ACTION

A transistor has three connections; one of these (the base) is used to control the current between the other two connections. Remember this important rule for transistors: a transistor turns on when a certain voltage is applied to its base. Positive voltage turns on an NPN type transistor. Negative voltage turns on a PNP type transistor.

In this project, the LED display shows which transistor is on by lighting either its top or its bottom half. This will demonstrate how positive voltage powers an NPN transistor and negative voltage powers a PNP transistor.

After you make the connections, the NPN transistor is on because positive voltage is applied to its base through the 1kΩ resistor. This turns on the upper half of the LED. At the same time, the PNP is off because no current can flow to its base. (Current flows from the PNP emitter to the base of the NPN transistor, but this flow is blocked from the PNP base by the diode.)

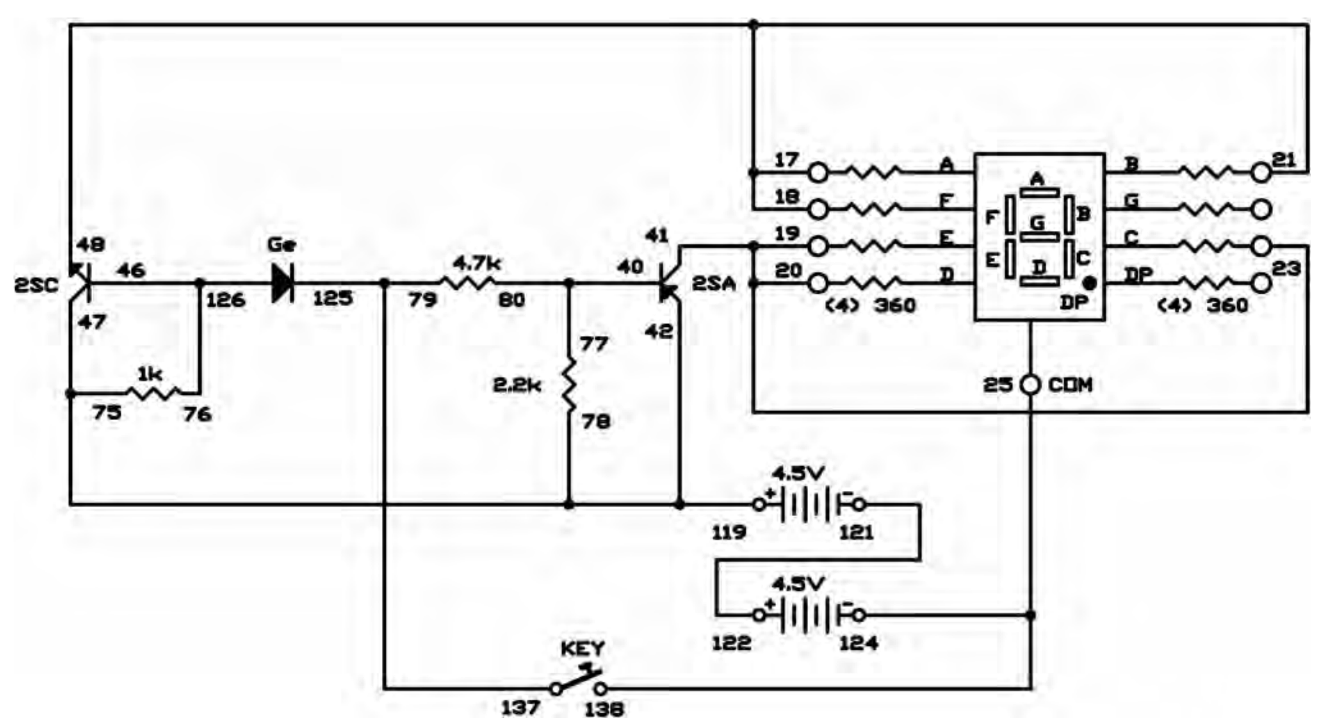
When you press the key, the NPN is turned off because negative voltage is applied to its base through the diode. The PNP is turned on at the same time because the current now flows through the 4.7kΩ resistor. This lights the lower segments of the LED.

Notes:

Wiring Sequence:

- ☐ 18-17-21-48
- ☐ 19-20-23-41
- ☐ 25-124-138
- ☐ 40-80-77
- ☐ 75-78-47-42-119
- ☐ 76-46-126
- ☐ 79-137-125
- ☐ 121-122

Schematic



EXPERIMENT #21: SOUND AMPLIFIER

This circuit is a strong two-transistor amplifier. An amplifier uses a small signal to control or produce a large signal. This amplifier is similar to an early model transistor hearing aid amplifier. The speaker acts as a dynamic microphone.

Using your VOM on this amplifier to measure circuit voltages will help you learn how transistors work. The measured voltages will help you determine current measurements and the way this circuit works.

Your kit's speaker can change sound pressure into weak voltages. The transformer increases the voltage somewhat. This voltage is then applied to the NPN transistor through the 3.3μF capacitor.

The amplifier voltage at the output of the NPN transistor is coupled into the PNP transistor through the 0.1μF capacitor. It is further amplified by the PNP, and is coupled to the earphone through the 100μF capacitor.

It's about time to talk about the transformer. The transformer has a copper wire wound hundreds of turns. We call it a coil. A transformer has two coils separated by a plate.

When electricity flows through a coil, it creates a magnetic field. The reverse is also true – if a coil is subjected to a change in its magnetic field strength, electricity flows through it. So, when electricity flows through the first (or primary as we often call it) coil of a transformer, the magnetic field created by the number of windings of each coil is different, so the voltage of the electricity for each coil is also different.

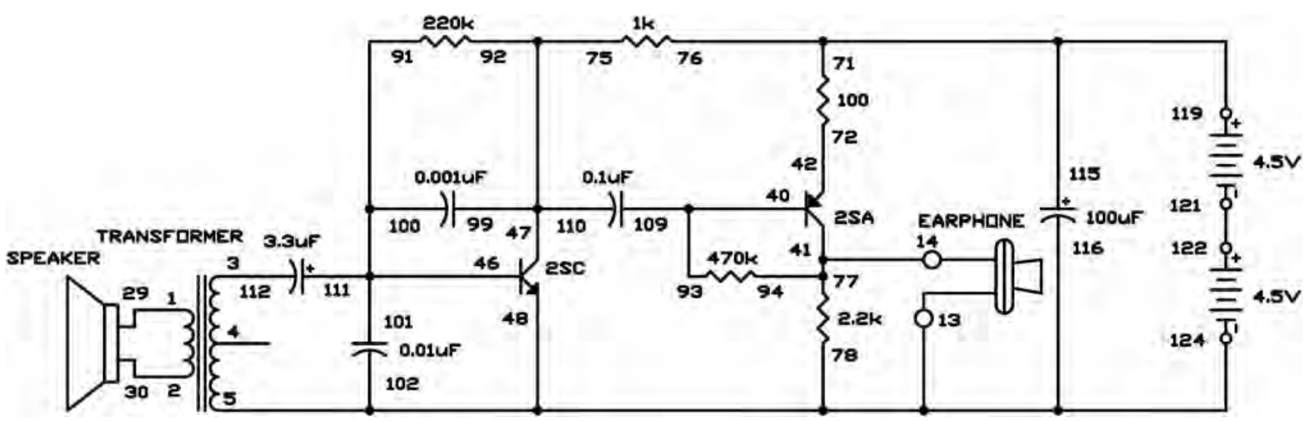
This establishment of an electric charge using a magnetic field is called induction. Go back to Project 15 (Capacitor Discharge / High Voltage Generator) and recall how large voltage is induced at the secondary side when 9V is applied by the primary side of the transformer.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-112
- ☐ 5-124-48-116-102-78-13-EARPHONE
- ☐ 93-109-40
- ☐ 41-94-77-14-EARPHONE
- ☐ 42-72
- ☐ 91-100-101-111-46
- ☐ 75-92-99-110-47
- ☐ 71-76-115-119
- ☐ 121-122

Schematic



EXPERIMENT #22: FLIP-FLOP MULTIVIBRATOR WITH LED DISPLAY

How about some rest? Here's another circuit for entertainment. This circuit flashes the numbers 1 and 2 on the display. You might be reminded of some neon signs with flashing, eye-catching advertisements on them.

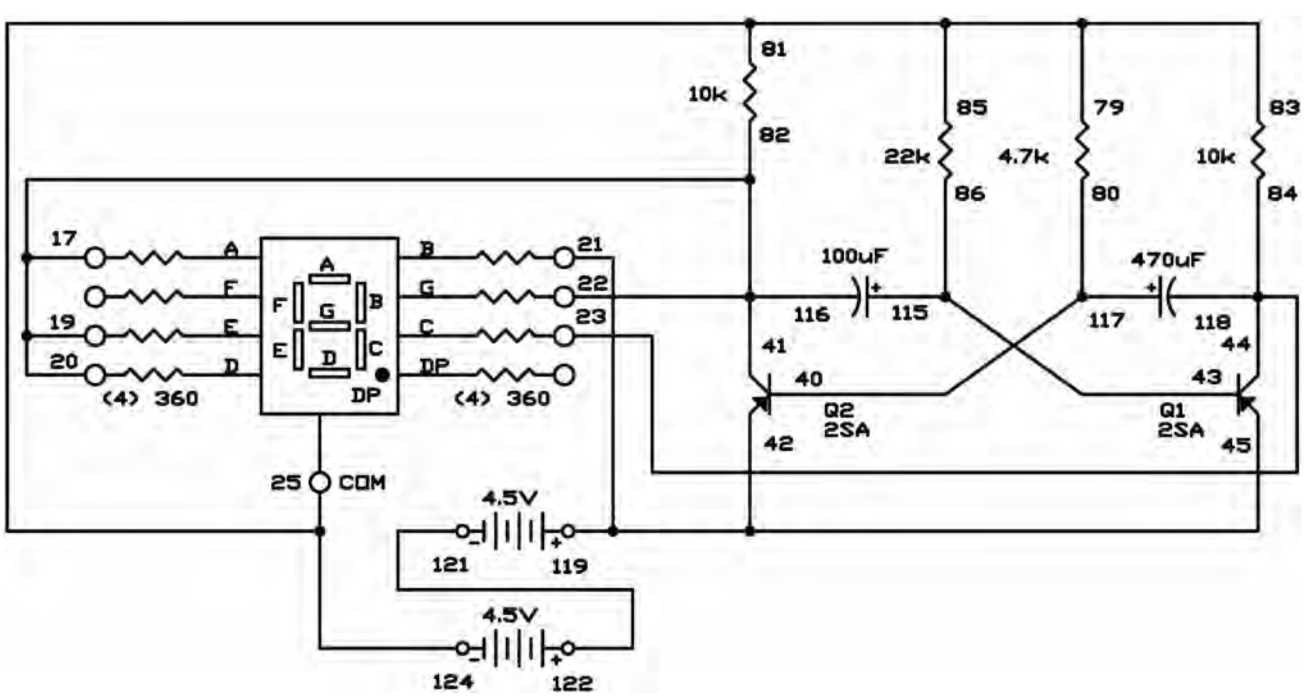
A circuit called a flip-flop controls the LED display in this project. You will learn more about flip-flop circuits in later projects. For the moment, try a different value for the capacitors to see their effects on the speed of operation. See if you can rewire the LED to display numbers other than 1 and 2. You can try different, higher values in place of the 2kΩ and 4.7kΩ resistors. Do not use lower values for any of the resistors or you might damage the transistors.

Notes:

Wiring Sequence:

- ☐ 17-19-20-22-41-116-82
- ☐ 21-42-45-119
- ☐ 23-44-118-84
- ☐ 79-81-83-85-25-124
- ☐ 80-117-40
- ☐ 86-115-43
- ☐ 121-122

Schematic



III. LED DIGITAL DISPLAY CIRCUITS

EXPERIMENT #23: SEVEN-SEGMENT LED DIGITAL DISPLAY CIRCUIT

In this section, we perform some basic circuit experiments with the LED display to learn how to better use this component. We'll be using the LED display in all four of these projects.

The LED display allows you to see the effect of electrical signals. It is similar to a normal diode but it emits light when current flows through it. One example of an LED display is a power indicator on your radio or DVD player that tells you the power is on.

Similar seven-segment LED displays show the numbers 0 through 9 for reading the output of a computer or a calculator. Seven is the minimum number of segments (separate lines that can be individually lighted) necessary to clearly display all ten digits. You must always observe two conditions for proper LED operation:

1. Correct polarity (+ and – LED connections)

2. Proper amount of current flow

Reverse polarity can burn out the LED unless the voltage is below about 4 volts, or the current is limited to a safe value. The LED will not light when the polarity is reversed.

To keep the current flow at a proper level, we use series resistors (permanently wired to your kit) with the LED. These resistors supply a relatively constant voltage (around 1.7 volts) to the LED through the terminal 25. We need voltages above this value to make current flow through the LED display. The series resistors determine how much current flows from the batteries to the diodes.

Complete the wiring as shown to connect the 3V supply with the LED segments and the decimal point (Dp). What numbers and letters can you display?

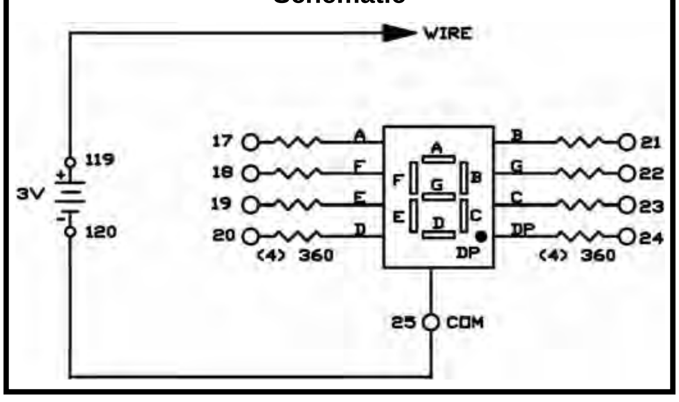
At this low battery voltage, you can reverse the polarity of the circuit by reversing the connections to the battery. (Change 25-120 and 119-WIRE, 25-119 and 120-WIRE.) Record your results on the right. After noting the results, reconnect the battery with the correct polarity. Use your VOM to measure the LED voltages between terminal 25 and each separate terminal (17 through 24). Temporarily change to the 9V supply by changing the battery connections to: 25-124, 121-122, and 119-WIRE. Then, make the same measurements. With this three-time increase in voltage supplied from the battery, the LED voltages only increased by what amount? (A typical increase is 0.25V.)

Now try measuring the voltage in each resistor attached to an LED segment. The resistors are all 360Ω. LED current in milliamps (one-thousandths of an ampere) is calculated by dividing the voltages by 360Ω. LED segment currents are about ____ milliamperes (mA) with the 3V supply (3mA typically), and ____ mA with the 9V supply.

In the space below make a chart of connections required to display 0 through 9 on the display.

Notes:

Schematic



Wiring Sequence:

- ☐ 25-120
- ☐ 119-WIRE

or

- ☐ 25-120
- ☐ 119-(17, 18, 19, 20, 21, 22, or 23)

EXPERIMENT #24: BASIC LED DISPLAY

Now you will learn about a common-cathode, seven-segment, LED digital display. Common-cathode means that the seven LED display segments use one contact point – terminal 25 – as a common negative electrode.

The LED must have (+) and (–) connections so that current can flow through it. The positive side is called the anode, and the negative side is called the cathode. Because the seven-segment display consists of seven LEDs (not counting the decimal point), there should be 14 connection points in total – seven anodes and seven cathodes.

However, we can make either anodes or cathodes common, making the number of terminals only eight – one whole anode terminal for each of the even segments and one terminals to act as a common cathode (or seven cathode terminals and one common anode).

The LED display in this kit is a common cathode type. You connect the common cathode segment terminal (terminal 25) to the negative side of the battery, and any anode segment terminals as required, to the positive side of the battery.

LEDs operate extremely fast. An LED can turn on and off hundreds of times each second; so fast you can't see it blink. Unlike an incandescent lamp, there is no warm up time, and no great amount of heat is produced.

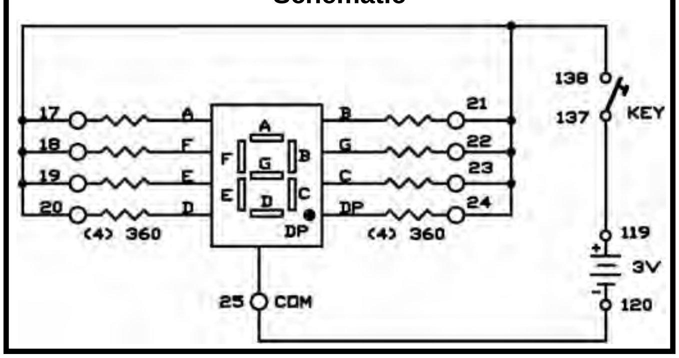
Perform the following experiment to see how fast the LED operates.

1. Hook up the circuit but do not close the key.
2. Decrease the surrounding the room light to a very low level so you can see any LED light emission easily.
3. Close the key for only a fraction of a second.

Notice that the display goes quickly on and off. Now hold the platform steady but glance quickly across the LED display as you briefly tap the key. The display should appear to go abruptly on and off. Actually, the persistence of the human eye is much longer than the LED's on time, but without special instruments this gets the point across.

Notes:

Schematic



Wiring Sequence:

- ☐ 17-18-19-20-21-22-23-24-138
- ☐ 25-120
- ☐ 119-137

EXPERIMENT #25: TRANSISTOR CONTROL SWITCHING OF THE LED DISPLAY

Now we're getting down into the field of electronics. The explanations from now on will become a bit more difficult, and more interesting! This project shows how to control the LED display with transistors.

This circuit is very much like the one in Project 20 (Transistor Circuit Action). The only differences are the position of the switch and the value of the resistor. This project uses the base circuit of the NPN transistor as a switch, to control the cathode of the LED. In project 20 we controlled the LED from the anode (positive side).

Both transistors in this project act as switches. The PNP transistor is always on, allowing current to flow from collector to emitter, because a sufficient amount of negative voltage is applied to its base through one of the 10kΩ resistors. The NPN transistor turns on when you close the key, thereby applying sufficient positive voltage to its base, through another 10kΩ resistor. So, the current can flow from emitter to collector only when you close the key.

The following basic principles are important for you to remember:

- A PNP transistor turns on when negative voltage is applied to its base; the current flows from collector to emitter.
- An NPN transistor turns on when positive voltage is applied to its base, the current flows from emitter to collector.

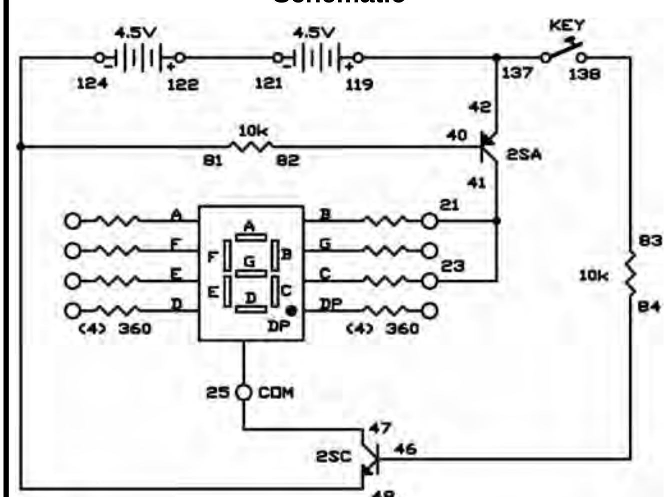
Now that the current can flow through the NPN transistor, it can travel a complete path – from the negative side of the batteries, to the NPN transistor, to the common cathode terminal of the display, to b and c anode terminals of the display, to the PNP transistor, to the positive side of the batteries – thus the display lights.

Turning on the LED with either transistor might not seem important now. But to people who design complicated computer circuits, it is a handy way to control circuits.

Have you noticed that the transistors switch on and off as fast as you press the key? This speedy switching allows computers to perform operations very quickly. Transistors are many times faster than relays or hand operated switches. Later we will show you how to delay this fast switching by using other components.

Notes:

Schematic



Wiring Sequence:

- ☐ 21-23-41
- ☐ 25-47
- ☐ 40-82
- ☐ 119-42-137
- ☐ 46-84
- ☐ 124-48-81
- ☐ 83-138
- ☐ 121-122

EXPERIMENT #26: TRANSISTOR, CdS CELL AND LED DISPLAY CIRCUIT

This project shows you how to turn on the LED using a transistor and a CdS cell.

Think of the CdS cell as a resistor that changes its resistance with the amount of light that falls on it. In darkness the resistance is very high, around 5 megohms (MΩ, 5 million ohms); in bright sunlight, it increases to about 100Ω, or less.

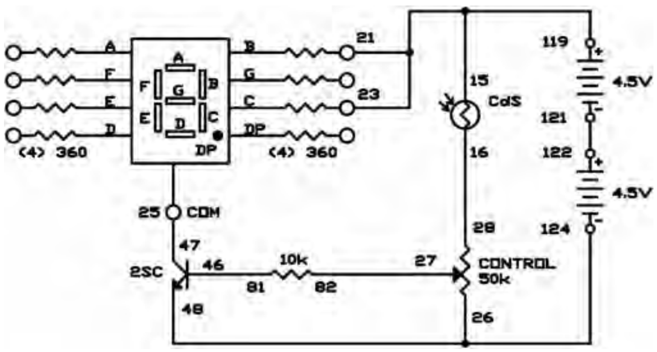
You can test this easily; set your VOM to the resistance function and connect it to the CdS cell. Hold your hand over the CdS cell and note the resistance. Now remove your hand, and read the resistance again.

You can use the NPN transistor as a switch. As we saw in the last project, it turns on when sufficient positive voltage is applied to its base. The positive voltage leads from the positive terminal of the battery, to the CdS cell, to the control, to the 10kΩ resistor.

The amount of voltage applied to the base is determined by the total resistance value of the CdS, the control, and the 10kΩ resistor. The amount of light striking the cell and the setting of the control change the base voltage – making it low or making it high enough to turn on the transistor. Use your voltmeter on the control and try changing the control position while casting a shadow over the CdS to verify this voltage change. Adjust the control so that the transistor turns on and off when the light changes over the CdS.

This circuit displays 1 under bright light. Of course, you can connect the wires to display any number you desire. We might consider 1 to be a binary digit, showing logic "high" (H or ON), to indicate the presence of a bright light on the CdS cell. Can you rewire the circuit to display another character to indicate this condition?

Schematic



Notes:

Wiring Sequence:

- ☐ 15-21-23-119
- ☐ 16-28
- ☐ 25-47
- ☐ 124-26-48
- ☐ 27-82
- ☐ 46-81
- ☐ 121-122

IV. A TOUR THROUGH DIGITAL CIRCUITS

EXPERIMENT #27: DIODE-TRANSISTOR LOGIC "AND" WITH LED DISPLAY

Now let's step into the world of digital circuits and learn some basics. First, a digital circuit is a circuit that acts as a switch to turn different components on and off. This section deals with diode-transistor logic (DTL) circuits – circuits that use diodes and transistors in switching power on and off.

It usually doesn't matter how much voltage is applied to a digital circuit; what matters is whether the circuit is on (voltage is present) or off (voltage is not present). When the circuit is on, we describe it as logic high, or use the number 1 to describe the circuit. When the circuit is off, we say logic low, or use a number 0.

First, you will learn about the AND circuit. The AND circuit produces output when all the connections to its terminals are logic high (receive voltage).

Connect this circuit according to the wiring sequence below. Then, connect terminals A (126) and B (128) to terminals 119 and 124 in different combination to complete the circuit and learn how an AND circuit works.

In this circuit, terminal 124 provides logic high (voltage) and terminal 119 provides logic low (no voltage). The LED shows H only when you connect terminal A and terminal B to terminal 124 (the high terminal). If you connect terminal A or B, or both, to terminal 119 (low terminal), the LED shows nothing. Both A and B must be high for their combined output (the LED) to read H (high).

When either or both inputs are low (that is, terminal 126 and/or terminal 128 is connected to terminal 119), positive voltage is applied to the PNP transistor base through the diode(s) and the PNP transistor stays off. Because the PNP transistor does not complete the circuit, no current is supplied to the base of the NPN transistor and it is also off. The common cathode terminal is not connected to the negative power supply and the LED remains off.

When both inputs are high, both diodes supply negative voltage to the base of the PNP transistor, so it turns on. The NPN transistor also turns on, and the current flows to the readout to light the LED.

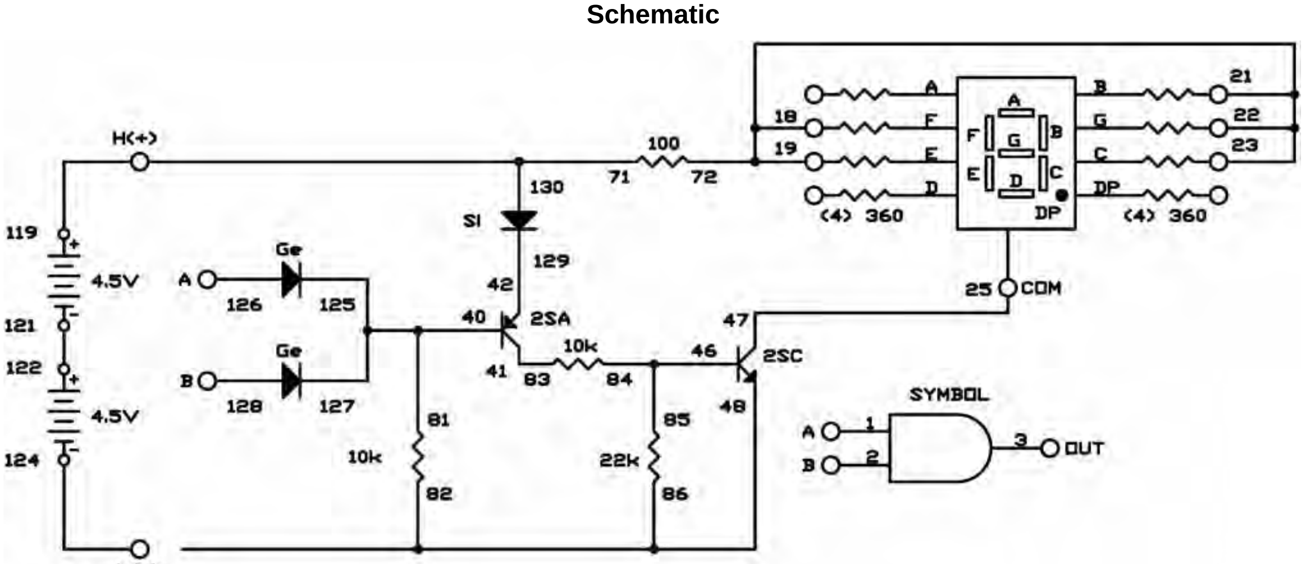
Mathematicians use the symbol AB to represent an AND function. On the bottom right of the schematic you can see the schematic symbol for the AND circuit.

Notes:

Wiring Sequence:

- ☐ 22-23-21-18-19-72
- ☐ 25-47
- ☐ 81-40-125-127
- ☐ 41-83
- ☐ 42-129
- ☐ 46-84-85
- ☐ 86-82-48-124
- ☐ 71-130-119
- ☐ 121-122
- ☐ 126-(to 119 "HIGH" or 124 "LOW")
- ☐ 128-(to 119 "HIGH" or 124 "LOW")

Schematic



EXPERIMENT #28: DTL "OR" CIRCUIT WITH LED DISPLAY

This next logic circuit is a logic OR circuit. Can you guess how this circuit works? Remember the AND circuit produces logic high when both A and B inputs are high. The OR circuit produces logic high when A or B receives a logic high input.

The display shows H when you connect either terminal A or B to terminal 119 (our logic high terminal). Try connecting both terminals to terminal 119; then, to terminal 124. What happens? The output is high when either A or B is connected to H. This logic function is symbolized as A + B.

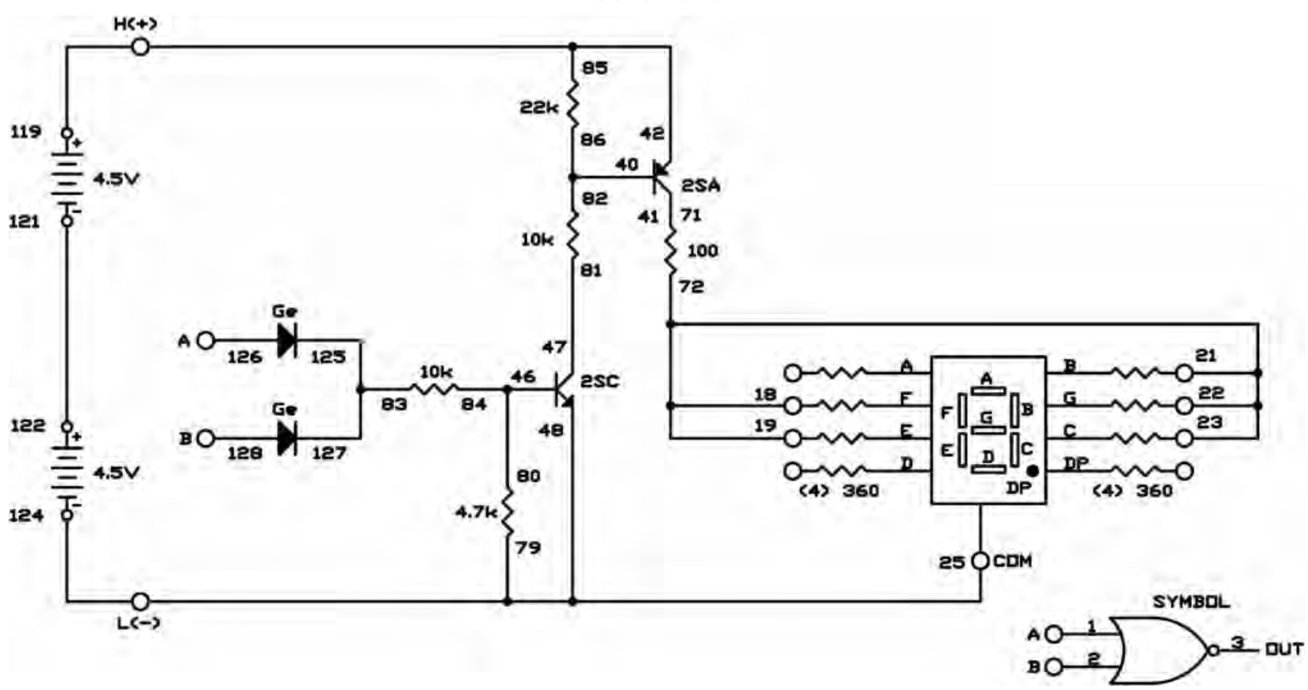
This circuit is similar to the previous project, so we won't explain the whole operation for you here. Compare the two projects and make notes of their similarities and differences. See if you follow the circuit on the schematics diagram.

Notes:

Wiring Sequence:

- ☐ 71-41
- ☐ 72-19-18-21-22-23
- ☐ 79-25-48-124
- ☐ 81-47
- ☐ 83-127-125
- ☐ 84-80-46
- ☐ 85-42-119
- ☐ 86-82-40
- ☐ 121-122
- ☐ 126-(to 119 "HIGH" or 124 "LOW")
- ☐ 128-(to 119 "HIGH" or 124 "LOW")

Schematic



EXPERIMENT #29: DTL "NAND" CIRCUIT WITH LED DISPLAY

No, you cannot find the word NAND in your dictionary (unless it is an electronics or computer dictionary). This is a newly coined term that means an inverted, or a Non-AND function. It produces output conditions that are the opposite of the AND circuit's output conditions. The NAND output is low when both inputs A and B are high. And the output is high if either or both of the inputs are low. The logic symbol looks like the AND symbol, but with a small circle at the output. The function is represented $\overline{AB}$.

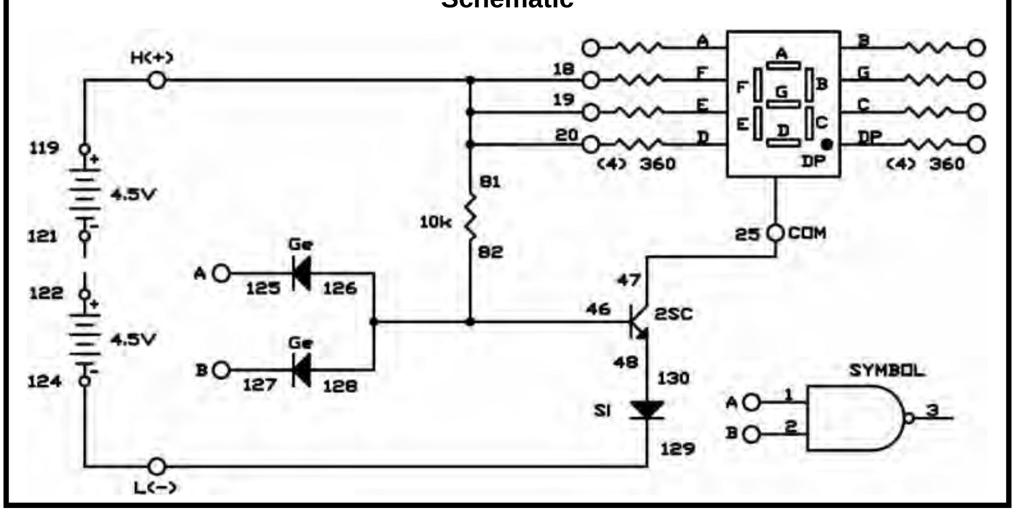
When either or both terminals, A and B are connected to terminal 124 (the logic low terminal), negative current flows through the diode(s) and the NPN transistor stays off. The LED remains off. When both inputs are connected to terminal 119 (the logic high terminal), both diodes allow positive voltage to flow through them. This positive voltage turns the NPN transistor on, so that current flows to light L on the LED.

Notes:

Wiring Sequence:

- ☐ 81-20-19-18-119
- ☐ 25-47
- ☐ 82-46-128-126
- ☐ 48-130
- ☐ 121-122
- ☐ 124-129
- ☐ 125-(to 124 "LOW" or 119 "HIGH")
- ☐ 127-(to 124 "LOW" or 119 "HIGH")

Schematic



EXPERIMENT #30: DTL "EXCLUSIVE OR" CIRCUIT

Don't worry if you don't know what exclusive OR means. An exclusive OR (abbreviated XOR) circuit provides a high output only when one or the other of its inputs is high.

So, you can see that an XOR circuit produces a low output if both inputs are the same (high or low). If the inputs are different (high and low, or low and high), then the output is high. This is a handy circuit to let us know if we have two inputs that are the same or that are different.

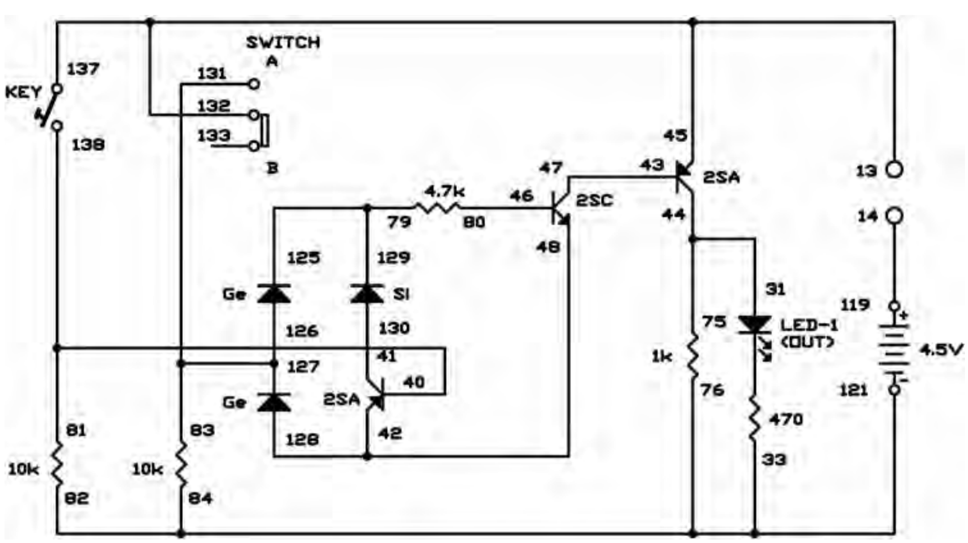
Before you complete this circuit, be sure the switch is set to B. When you finish the wiring, connect terminals 13 and 14 to turn on the power. Watch LED 1. Now press the key to produce a high input. Is there any change in LED 1? Release the key to make both inputs low. Now set the switch to A and make the input traveling through the switch high. What does LED 1 do now?

Leave the switch at A and press the key to make both inputs high. You can see that in an XOR circuit, two high inputs produce a low output.

You can also build an XNOR circuit (exclusive NOR). We won't build one here, but you might be able to figure out how to do it. Hint: It's the same thing as a NOR circuit followed by additional wiring to reverse the circuit. Be sure to keep track of your experiments in your notebook, especially if you make an XNOR circuit.

Notes:

Schematic



Wiring Sequence:

- ☐ 13-45-132-137
- ☐ 14-119
- ☐ 44-31-75
- ☐ 76-84-82-33-121
- ☐ 81-40-138
- ☐ 41-130
- ☐ 48-42-128
- ☐ 43-47
- ☐ 46-80
- ☐ 79-129-125
- ☐ 83-126-127-131

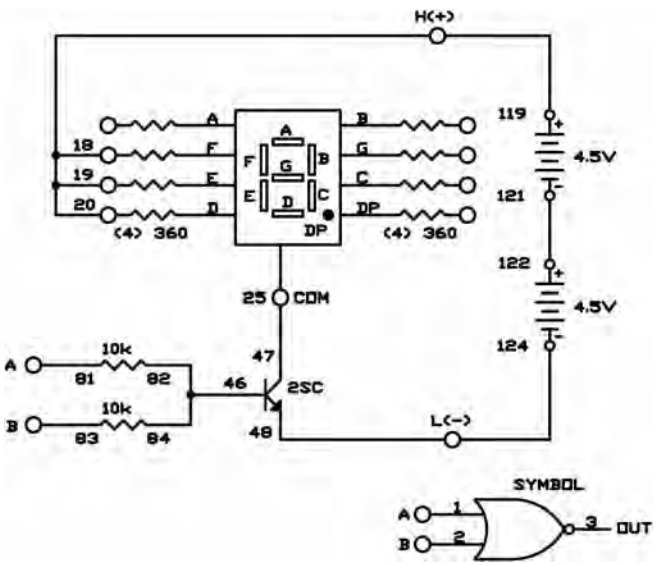
EXPERIMENT #31: TRANSISTOR "NOR" CIRCUIT WITH LED DISPLAY

Now that you've built and learned about the NAND (inverted AND) circuit, it's easy to determine what the NOR (inverted OR) circuit does. The display shows L when either terminal A or B is connected to terminal H (119). The circuit output is high only when both A and B receive low inputs. This is the opposite of the OR circuit. The logic symbol for the NOR circuit is shown with the schematic. The function is written as $\overline{A + B}$. The + symbolizes the OR circuit and the bar over the symbol indicates the circuit is inverted.

When you connect either A or B (or both) to terminal H, the NPN transistor turns on, completing the current path for the LED. When you connect both A and B to L, the transistor turns off and LED goes off.

Notes:

Schematic



Wiring Sequence:

- ☐ 18-19-20-119
- ☐ 25-47
- ☐ 46-82-84
- ☐ 48-124
- ☐ 81-(to 119 "HIGH" or 124 "LOW")
- ☐ 83-(to 119 "HIGH" or 124 "LOW")
- ☐ 121-122

EXPERIMENT #32: TRANSISTOR "FLIP-FLOP" CIRCUIT

What is a flip-flop? It is a kind of circuit that changes back and forth between two states (on and off) at certain intervals. It flips into one state, and then flops to another, and so on.

This flip-flop uses two transistors, two capacitors, and four resistors to turn the LED on and off. Each transistor is always in the opposite state of the other; when transistor Q1 is on, transistor Q2 is off; when Q2 is on, Q1 is off. This change from on to off (and off to on) happens very fast (in microseconds). Adjust the control and note its effect on the flashing rate of the LED.

Look at the schematic to see how this circuit works. Remember that a transistor turns on when voltage is applied to its base. The two PNP transistors' bases are connected to the negative side of the batteries through resistors. You might think that both transistors would always be on, but there are two capacitors connected to the bases that help cause the flip-flop action.

To explain the circuit, let's assume that transistor Q1 is off. Transistor Q2 is on because the 100µF capacitor is charging and discharging through its base. The 4.75kΩ resistor and the control keep transistor Q2 on after the 100µF capacitor has discharged. Now, the 10µF capacitor has received a charge and is discharging through the 47kΩ resistor, the battery, and the Q2. (Remember, when transistor Q2 is on, this means current can flow through its collector to its emitter.) Transistor Q1 remains off as long as the charge on the 10µF capacitor is high enough.

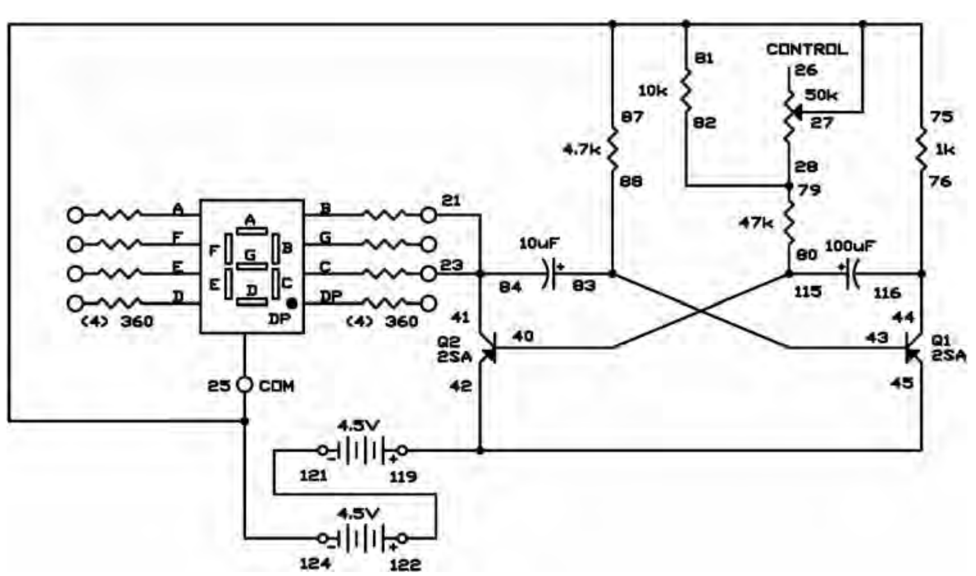
When the charge drops to a certain point, the negative voltage from the 47kΩ resistor turns on transistor Q1. And, when Q1 turns on, the 100µF quickly starts charging and lets transistor Q2 turn off. With Q2 off, its collector voltage rises toward the 9V of the battery supply and the LED turns off. Through the fast charging of the 10µF, the Q1 turns fully on. This flip occurs very quickly.

After a while the 100µF discharges through the Q2 transformer, and the circuit flops back to the original state to begin the above action again.

We have used this sort of circuit in several previous projects. Look back and try to locate them.

Notes:

Schematic



Wiring Sequence:

- ☐ 21-23-41-84
- ☐ 75-81-87-25-27-124
- ☐ 28-79-82
- ☐ 40-115-80
- ☐ 45-42-119
- ☐ 43-88-83
- ☐ 44-116-76
- ☐ 121-122

EXPERIMENT #33: TRANSISTOR "TOGGLE FLIP-FLOP"

A toggle switch is a switch that turns circuits on and off. Here we use the flip-flop circuit to work as a toggle switch. In the previous project, the circuit flipped and flopped automatically. In this project, the circuit does not change until you tell it to.

After you complete the wiring, set the switch to A. The lower segment of the LED lights. Now press the key. The lower segment goes off and the upper segment lights. Each time you press the key the LED segments change – flip and flop.

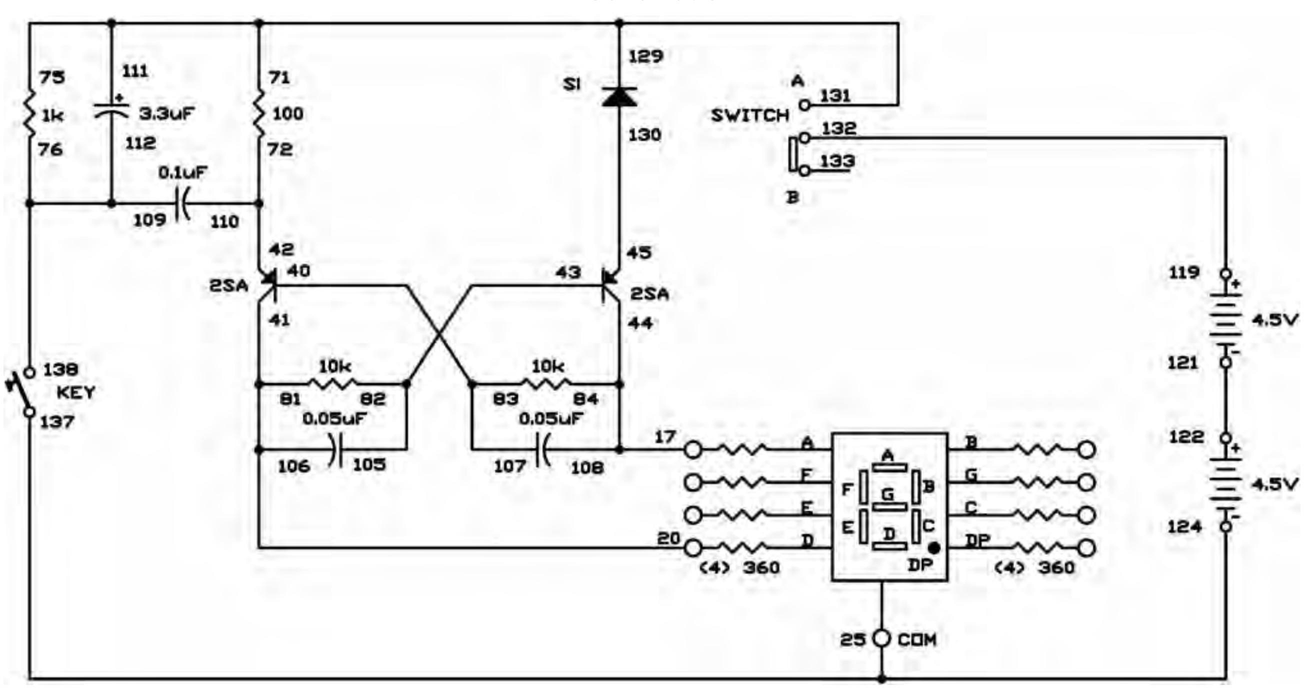
When one transistor is on, the other is off; it stays on (or off) until you tell it to change. So, we can say that flip-flop circuits can remember things. When you leave a circuit in a certain condition, it stays in that condition until you want to change it. Many flip-flops that are controlled by a single toggle signal can remember many things. That is how computers can remember so many things.

Notes:

Wiring Sequence:

- ☐ 84-108-44-17
- ☐ 81-106-41-20
- ☐ 25-124-137
- ☐ 40-107-83
- ☐ 42-110-72
- ☐ 45-130
- ☐ 43-105-82
- ☐ 71-75-111-131-129
- ☐ 76-109-112-138
- ☐ 119-132
- ☐ 121-122

Schematic



V. MORE ADVENTURES WITH DIGITAL CIRCUITS

EXPERIMENT #34: TRANSISTOR-TRANSISTOR LOGIC "BUFFER" GATE

Did you ever wonder what happens when you start adding digital circuits together, using the output of one as the input of another? When you build this project you'll find out.

One of the integrated circuits contained in your kit is a quad two-input NAND gate IC. You are probably not familiar with some of these words. IC is short for integrated circuit. An integrated circuit contains many transistors, diodes, and resistors in one small package.

Quad literally means four. In this IC there are four separate NAND gate circuits, each receiving two inputs. Each NAND gate has two input terminals. We have been using only two-input logic circuits so far, but some circuits have more than two inputs.

Finally, this circuit is called a gate, because this is your entrance to the digital world (just a joke). Seriously, a gate is a circuit that has more than one input and only one output. Its output is not energized until its inputs meet certain conditions. We will use this handy component with more digital circuits in other projects.

This gate circuit is called a buffer because it is used to keep two portions of a device isolated from each other.

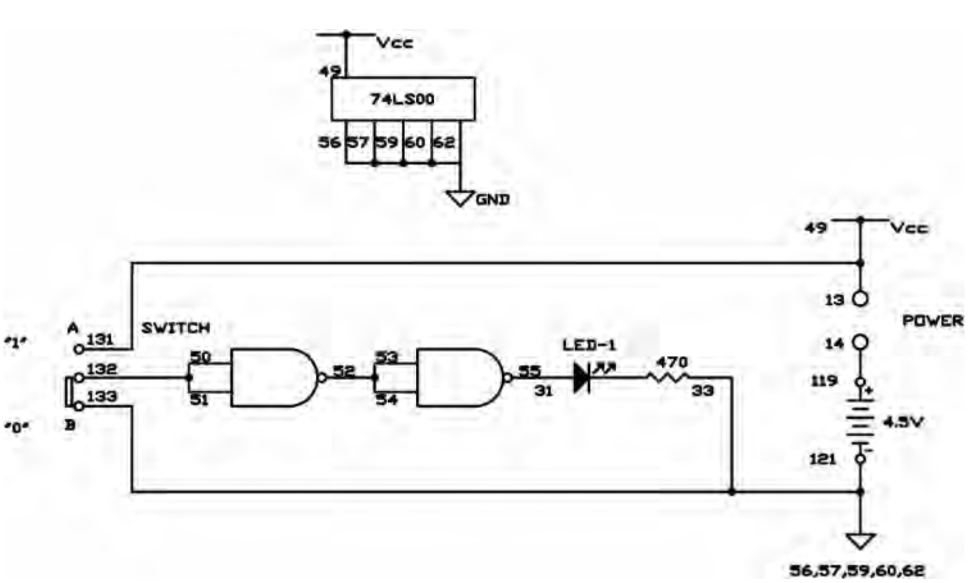
Refer to the schematic as you build this project. We take the output from one NAND gate, and use it for both inputs to the second (note the two inputs for the two NANDs are always the same). From what you know about NANDs, what do you think happens if the input to the first NAND is 1? If the first input is 0? Try to figure it out before building this project.

Before completing the wiring, set the switch to B. Connect terminals 13 and 14 to turn the power on. What happens to LED 1? Now set the switch to A. LED 1 lights up.

As you've probably figured out, 1 is the input when the switch is set to A, and 0 is the input when the switch is at B. When the input to the first NAND is 1, its output is 0. But the 0 output of the first NAND is the input to the second. The 0 input to the second makes its output become 1, lighting the LED.

Notes:

Schematic



Wiring Sequence:

- ☐ 13-49-131
- ☐ 14-119
- ☐ 31-55
- ☐ 33-56-57-59-60-62-133-121
- ☐ 50-51-132
- ☐ 52-53-54
- ☐ 13-14 (POWER)

EXPERIMENT #35: TTL "INVERTER" GATE

An inverter is a circuit that has an output that is the opposite of its input. If the input is 1 (high), the output is 0 (low). If the input is 0, then the output is 1.

Set the switch to A before you complete this project. Then, connect terminals 13 and 14. You'll notice that both LED 1 and LED 2 are off. Since the output is 0, the input must be 1. Now, set the switch to B and see both LEDs come on, indicating you're inputting 0.

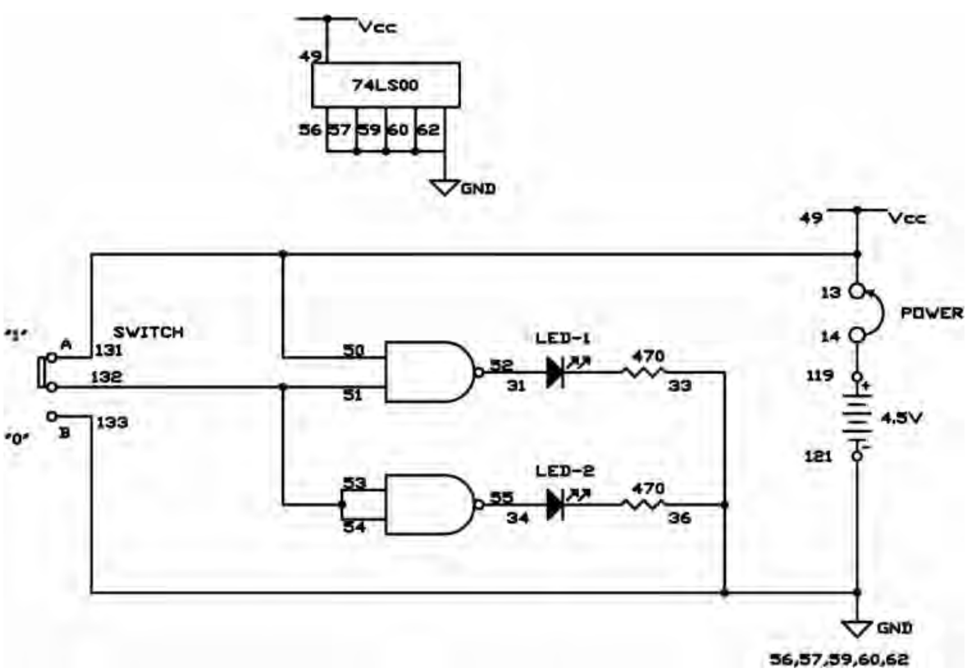
You can see from the schematic that we use two of the four NAND gates in the IC. With the switch at A, both inputs to the two NANDs are 1. This means the outputs of both NANDS are 0 (and the LEDs go out). When the switch is set to B, we no longer have all inputs at 1, and the LEDs come back on.

One amazing thing to think about is how large the RTL and DTL circuits were that we played with in earlier projects. Believe it or not, four of those circuits have been shrunk down to fit inside this tiny IC.

There's a special type of IC, a bit bigger than the ICs in your kit, which is actually a computer shrunk to miniature size. This mini-computer is called a microprocessor. The process of putting several circuits inside just one IC is called large-scale integration (LSI). You'll see this term often used to describe ICs.

Notes:

Schematic



Wiring Sequence:

- ☐ 13-49-50-131
- ☐ 14-119
- ☐ 31-52
- ☐ 36-33-56-57-59-60-62-133-121
- ☐ 34-55
- ☐ 51-53-54-132
- ☐ 13-14 (POWER)

EXPERIMENT #36: TTL "AND" GATE

Can you figure out how to make an AND gate using your kit's NAND gates? Let's experiment, to find out how.

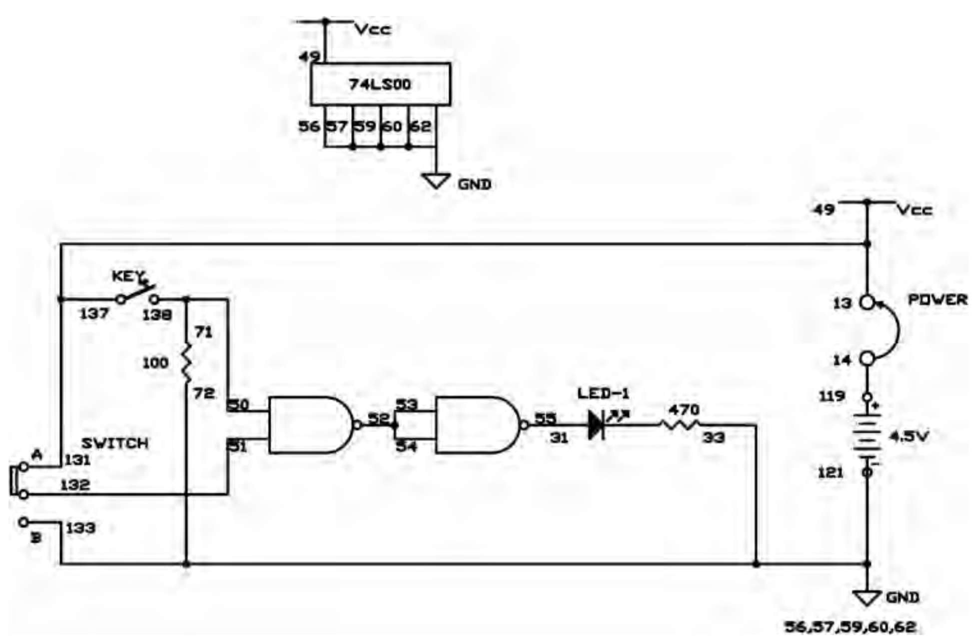
Leave the switch at B as you build this circuit. When you are finished, connect terminals 13 and 14 to turn the power on. Press the key. What does LED 1 do? Now set the switch to A while pressing the key. Is there any change in LED 1?

As you see, pressing the key and setting the switch to A make the inputs 1, causing the overall output to be 1. Can you flow the 1 input through the circuit until you reach a 1 output? Try it – and don't peek at the answer.

It works like this – each 1 input goes into the first NAND gate. This causes the output of the NAND to be 0. This 0 output is used for both inputs to the second NAND. The 0 inputs to the second NAND cause its output to be 1, and the LED lights. So, two NAND gates form an AND gate.

Notes:

Schematic



Wiring Sequence:

- ☐ 13-49-131-137
- ☐ 14-119
- ☐ 31-55
- ☐ 72-56-57-59-60-62-33-133-121
- ☐ 50-71-138
- ☐ 51-132
- ☐ 52-53-54
- ☐ 13-14 (POWER)

EXPERIMENT #37: TTL "OR" GATE

One of the nice things about the quad two-input NAND IC is that we can combine the four NAND gates to make up other logic circuits. Our last two projects have shown how we can use NANDs to make up some other logic circuits. This project will show how to make up an OR gate from the NAND gates.

Take a look at the schematic for this project – can you trace what happens from each input to the eventual output? (Sure you can, just give it a try.)

As you work on this project, keep the switch set to B. When you've finished, connect terminals 13 and 14. Now press the key. What happens to LED 1? Release the key and set the switch to A. When happens to LED 1 now? Keep the switch at A and press the key again. Is there are any change in LED 1?

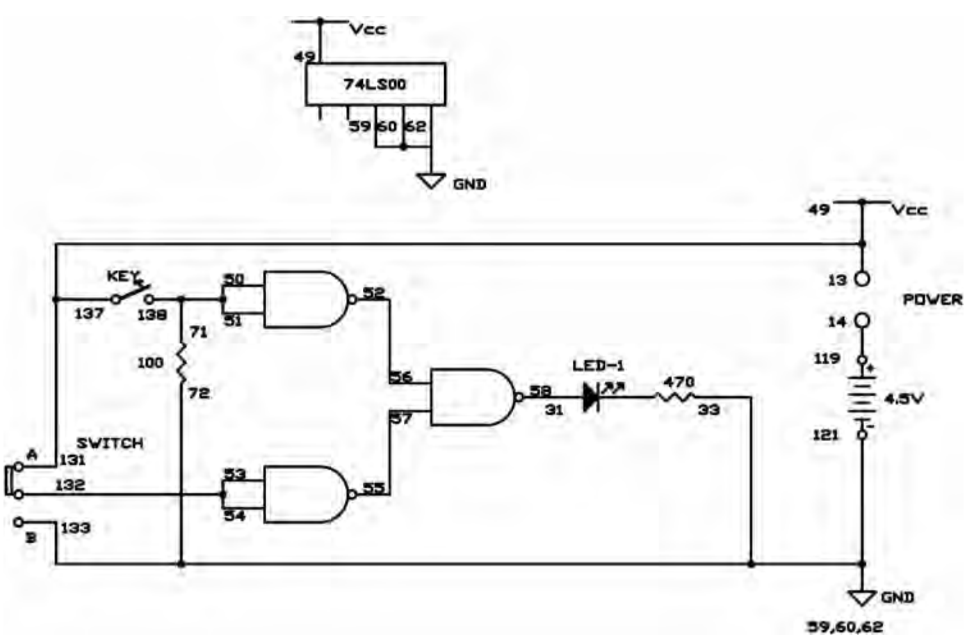
You see that this circuit indeed behaves like other OR gates you've played with. If at least one or the other of the inputs is 1, the output to the LED is 1. Have you traced what happens from input to output yet? The explanation is in the next paragraph, but no fair peeking.

Let's say you press the key with the switch set to B. This enters 1 as both inputs of the NAND, causing the NAND's output to become 0. This 0 output is one of the inputs to the NAND gate controlling the LED. Since a NAND's output is 0 only if all inputs are 1, the 0 input causes the NAND's output to go to 1, and LED 1 lights!

We can make up AND, NOR, XOR, and NAND gates using the quad two-input IC. Can you figure out how we would connect the NANDs in the IC to make these other logic circuits? Give your best try and take notes – because we're soon going to find out.

Notes:

Schematic



Wiring Sequence:

- ☐ 13-49-131-137
- ☐ 14-119
- ☐ 31-58
- ☐ 72-59-60-62-33-133-121
- ☐ 50-51-71-138
- ☐ 52-56
- ☐ 53-54-132
- ☐ 55-57
- ☐ 13-14 (POWER)

EXPERIMENT #38: TTL "EXCLUSIVE OR" GATE

Since we've made up other digital circuits by combining NAND gates, it makes sense that we can make XOR gates as well. We can, as this circuit will show you.

Set the switch to B before you complete this circuit. After you finish the wiring, connect terminals 13 and 14. Press the key – does anything happen to LED 1? Now release the key and set the switch to A. What does LED 1 do? Leave the switch at A and press the key. What happens to LED 1 now?

The output is 1 as long as the inputs are different. If both inputs are the same – either 0 or 1 – the output of the XOR gate is 0.

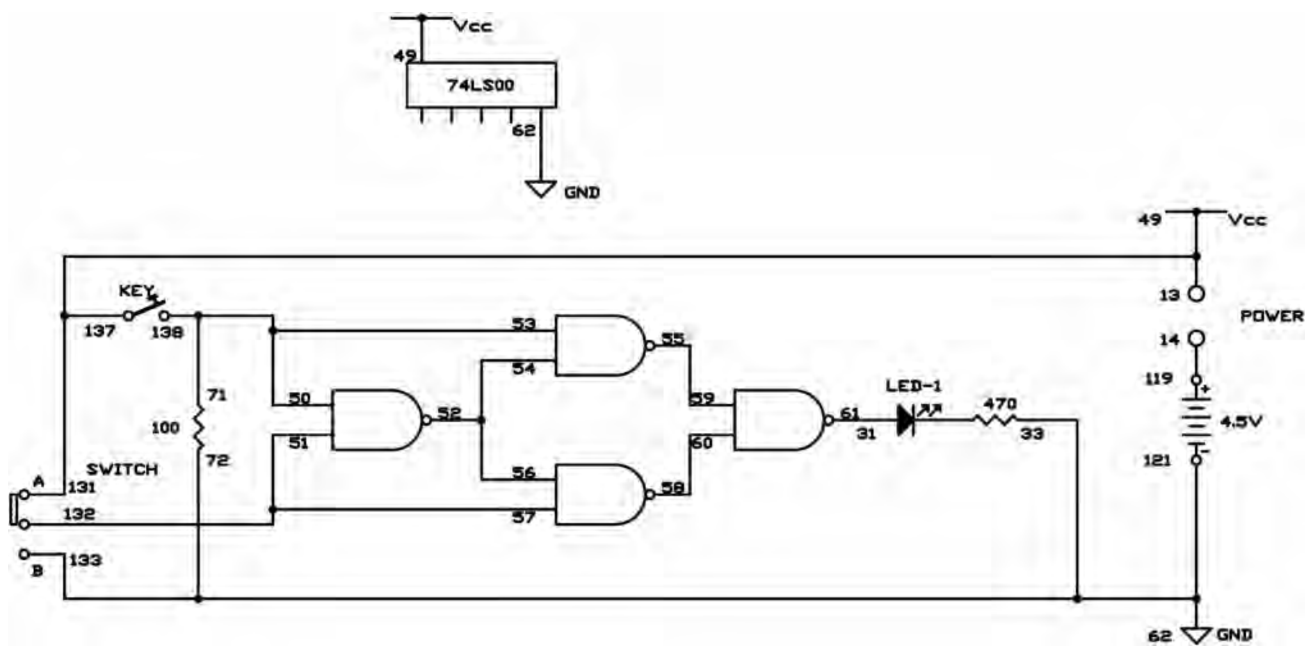
Put on your thinking cap and follow each 0 or 1 input through the circuit until you reach the output. It might help if you mark 0 or 1 on the schematic at the input and output of each NAND gate.

Notes:

Wiring Sequence:

- ☐ 13-49-131-137
- ☐ 14-119
- ☐ 31-61
- ☐ 72-62-33-133-121
- ☐ 71-50-53-138
- ☐ 57-51-132
- ☐ 54-52-56
- ☐ 55-59
- ☐ 58-60
- ☐ 13-14 (POWER)

Schematic



EXPERIMENT #39: TTL "NOR" GATE

Try marking 0 and 1 inputs on the schematic as you've been doing with the past few projects and see how this circuit arrives at a 0 or a 1 output. Give it a good try, and don't peek at the answer.

As you're building this circuit, keep the switch set to B. When you complete the wiring, connect terminals 13 and 14. Press the key. Is there any change in LED 1? Release the key and set the switch to A. What happens to LED 1 now? Leave the switch at A and press the key. Does anything different happen?

As you can see, this project behaves just like other NOR gates we've built. Both of the NANDs marked A and B have input of 1. So, they each have an output of 0 when the input is 1. Their outputs are used as inputs to the NAND marked C. NAND C has an output of 1 as long as one or both of its inputs are 0. This 1 output is used for the inputs of the next NAND causing an output of 0. Thus LED 1 does not light.

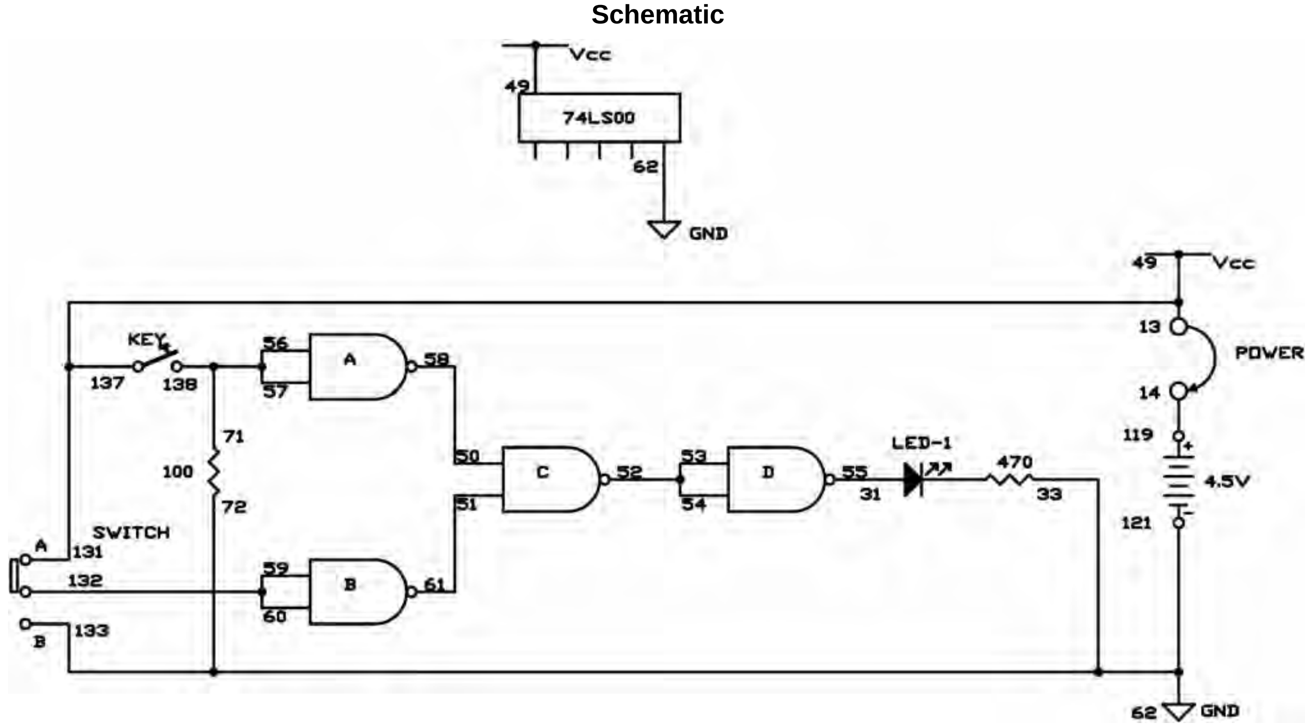
As you can see, a NOR gate has an output of 1 only when both inputs are 0 that is, when the switch is set to B and the key is not pressed.

Notes:

Wiring Sequence:

- ☐ 13-49-131-137
- ☐ 14-119
- ☐ 31-55
- ☐ 72-33-62-133-121
- ☐ 50-58
- ☐ 51-61
- ☐ 52-53-54
- ☐ 56-57-71-138
- ☐ 59-60-132
- ☐ 13-14 (POWER)

Schematic



EXPERIMENT #40: TTL "THREE-INPUT AND" GATE

Although we've been using digital circuits that have two inputs, that doesn't mean we can't have more than two inputs. Here's a TTL AND gate that has three inputs. Try to use the schematic to figure out how three inputs produce an output of 1.

You'll notice that we're doing things a bit differently this time – terminals 13 and 14 make P an input signal. Connecting the two terminals makes a 1 input and disconnecting them makes a 0. You "turn on" this project by connecting terminals 119 and 137.

You know how AND gates work, so we won't go into detail here. Can you look at the schematic and figure out the connections for the switch, the key, and terminals 13 and 14 that will give you a 1 output? Try to figure it out, and then read on to see if you were right.

Here's how this circuit works; the key and switch are both connected to one NAND. When they each provide an input of 1, that NAND has an output of 0. This 0 makes up the input of another NAND, causing its output to become 1.

This 1 output then goes to another NAND gate (see it on the schematic?). There it makes up one input, along with the input from terminals 13 and 14 making up the other. When these inputs are both 1, the NAND's output goes to 0. This output is used for both inputs of the last NAND, causing it to become 1, and the LED lights.

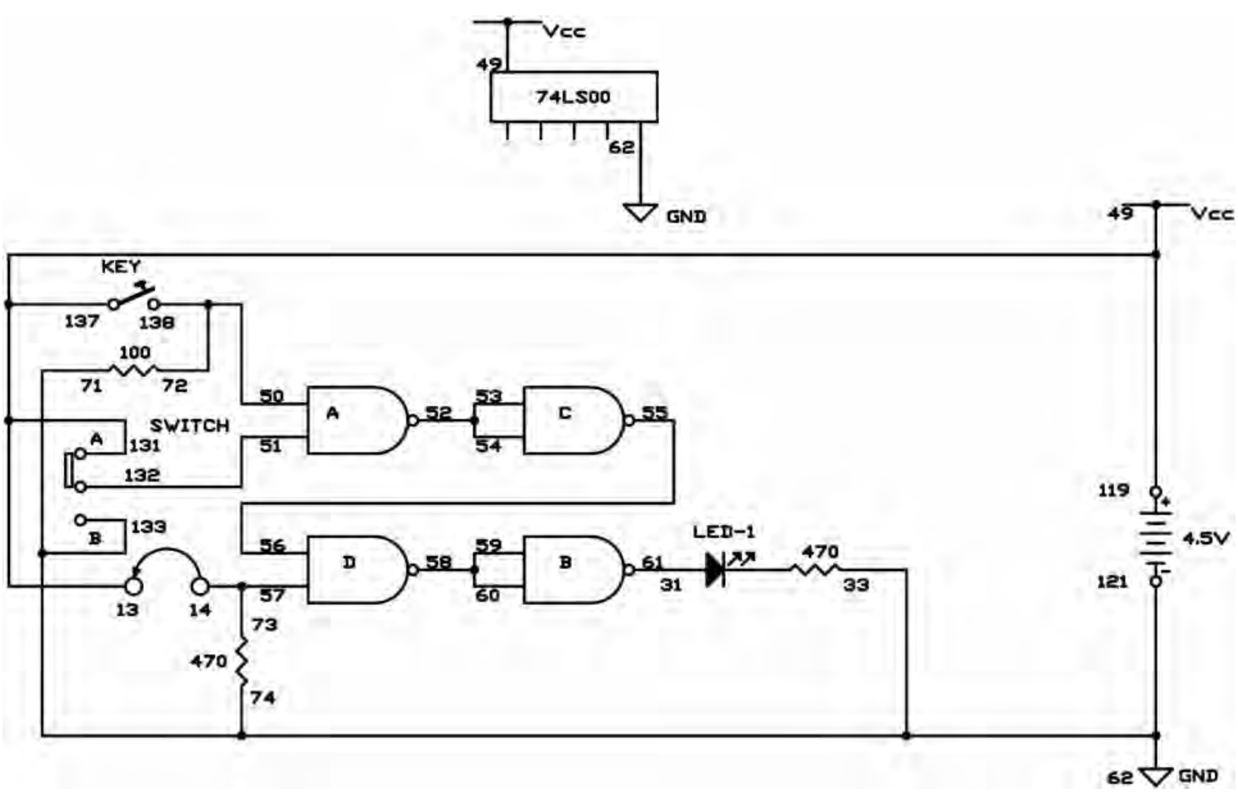
Seems simple, doesn't it? Believe it or not, even complex computers operate by using the same basic principles we're using with the digital circuits in this kit.

Notes:

Wiring Sequence:

- ☐ 13-49-131-137-119
- ☐ 14-73-57
- ☐ 31-61
- ☐ 74-71-62-33-121-133
- ☐ 50-72-138
- ☐ 51-132
- ☐ 52-53-54
- ☐ 55-56
- ☐ 58-59-60

Schematic



EXPERIMENT #41: TTL "AND" ENABLE CIRCUIT

Our last project had a characteristic that could be a problem in some situations. LEDs 1 and 2 take turns lighting and turning off. We might want both LEDs to light and turn off together. Did you figure out how to make the LEDs do this when you experimented with the last project? This circuit shows you how.

If you look carefully at the schematic for this project and the schematic for the last project, you will find they are almost identical. The only change is the addition of another NAND gate circuit.

As in our last project, setting the switch to B blocks the channel from LED 1 to LED 2. But when you set the switch to A, you'll see LED 2 light and turn off at the same time at LED 1. The two NAND gates make up an AND gate (remember this circuit from Project 36 ("TTL "AND" GATE')).

In this circuit, LED 1 is called the data input. LED 2 is called the output. These terms are often used with enable circuits. They will pop up from time to time when we talk about digital electronics.

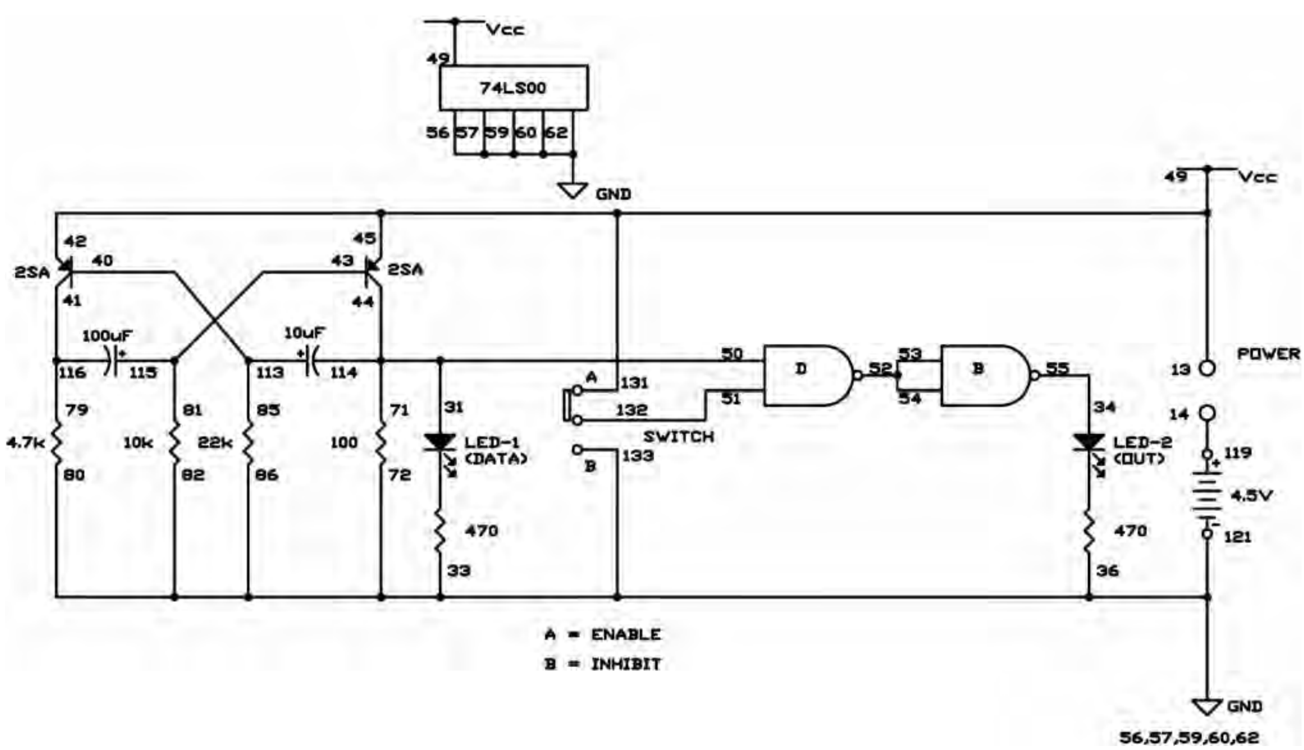
You might suspect by now that we can use other digital circuits to perform enable functions. Can you figure out how? Be sure to keep notes of our findings, especially if you figure out how to use an OR gate in an enable circuit. (You'll see why in the project.)

Notes:

Wiring Sequence:

- ☐ 13-49-42-45-131
- ☐ 14-119
- ☐ 71-50-31-44-114
- ☐ 86-82-80-72-56-57-59-60-62-33-36-121-133
- ☐ 34-55
- ☐ 40-113-85
- ☐ 41-116-79
- ☐ 43-115-81
- ☐ 51-132
- ☐ 52-53-54
- ☐ 13-14 (POWER)

Schematic



EXPERIMENT #42: TTL "OR" ENABLE CIRCUIT

Have you figured out how to make an enable circuit using an OR gate? If so, here's a chance to check your design against our OR enable circuit.

As in the last two projects, a multivibrator provides input to the OR gate in this circuit. You can see the output of the OR gate when you look at LED 1 – it flashes on and off according to the output of the multivibrator. Can you tell what happens once the multivibrator's input is applied to the OR gate by looking at the schematic? Give it a shot before building the project.

Before you complete this circuit, set the switch to A rather than B as we have done for the last two projects. After you finish the wiring, connect terminals 13 and 14 to turn the power on. What does LED 1 do? And what is LED 2 doing? Now set the switch to B. What happens to LED 1 and LED 2 now?

We simplify the circuit by saying that setting the switch to A blocks the flow of data from LED 1 to LED 2. (This is called the inhibit status.) But when the switch is at B, data can flow from LED 1 to LED 2. This is called the enable status.

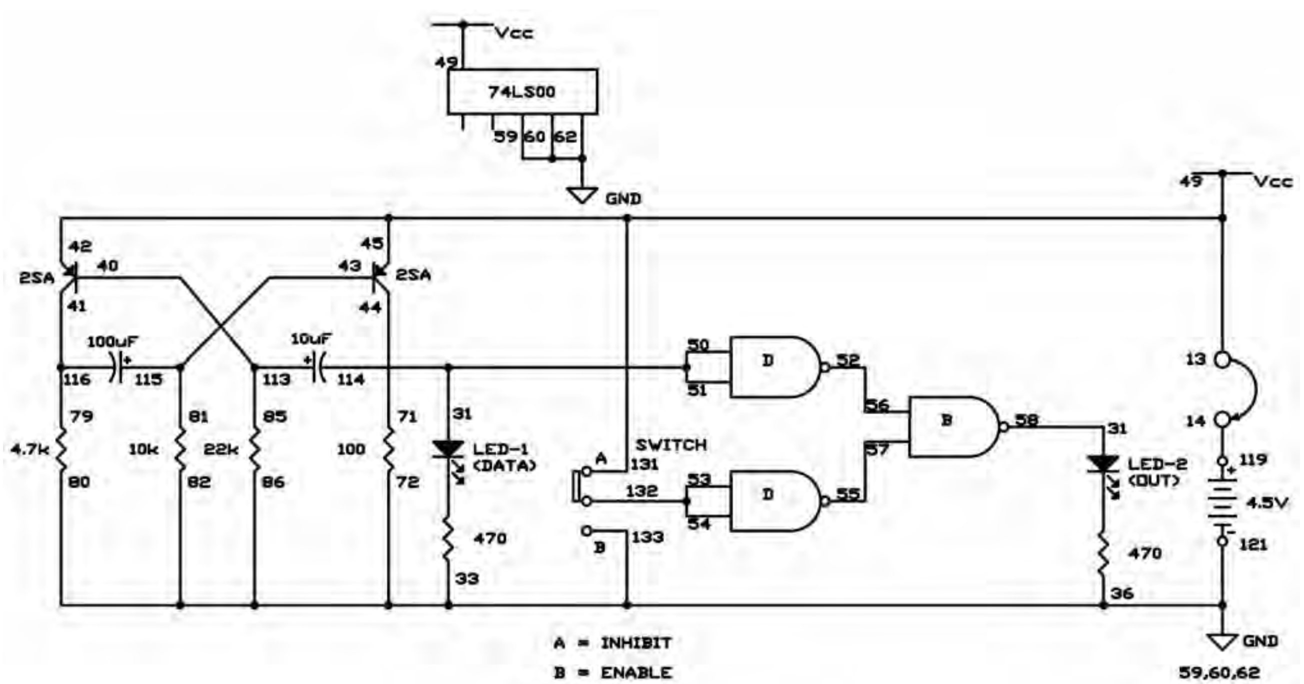
This is the third circuit in the family of enable circuits so we won't show you how it works. Try to follow the operational flow on the schematic.

Notes:

Wiring Sequence:

- ☐ 13-49-42-45-131
- ☐ 14-119
- ☐ 71-50-51-31-44-114
- ☐ 86-82-80-72-59-60-62-33-36-121-133
- ☐ 34-58
- ☐ 40-113-85
- ☐ 41-116-79
- ☐ 43-115-81
- ☐ 52-56
- ☐ 53-54-132
- ☐ 55-57
- ☐ 13-14 (POWER)

Schematic



EXPERIMENT #43: TTL “NAND” ENABLE CIRCUIT

NAND gates can act as electronic sentries. If you don’t want a signal to be input into a part of the circuit, a NAND gate can be sure it is not.

You probably recognized one circuit in the schematic right away – the multivibrator. You can see the output of the multivibrator by watching LED 1. You’ll also notice that the multivibrator provides one of the inputs to the NAND gate. Use the schematic to figure out what happens when the switch is set to A? To B? Can you figure out what LEDs 1 and 2 do with the switch set to A and set to B? Be sure to make some notes and compare them with what you learn.

Before you complete this circuit, set the switch to B. When you finish the wiring, connect terminals 13 and 14 and look at LEDs 1 and 2. You’ll see LED 1 “blink” to indicate the output of the multivibrator. But look at LED 2. You’ll see that it lights continuously, indicating that something is preventing the signal at LED 1 from reaching LED 2. Now set the switch to A and observe LED 1. What is happening? Is the same thing happening to both LED 1 and LED 2?

You can see that LED 1 and LED 2 take turns going on and off. This is because we make one of the two inputs to the NAND equal 1 when the switch is set to A. The multivibrator sends 0 and signals to the other NAND input. When the multivibrator’s output is 1, LED 1 lights, but because both input signals to the NAND are 1, the NAND’s output is 0, and LED 2 goes out. When the multivibrator’s output is 0, the NAND’s output becomes 1, and LED 2 lights. Try to figure out what happens when the switch is set to B – why LED 2 always lights. Hint: switch B supplies an input of 0.

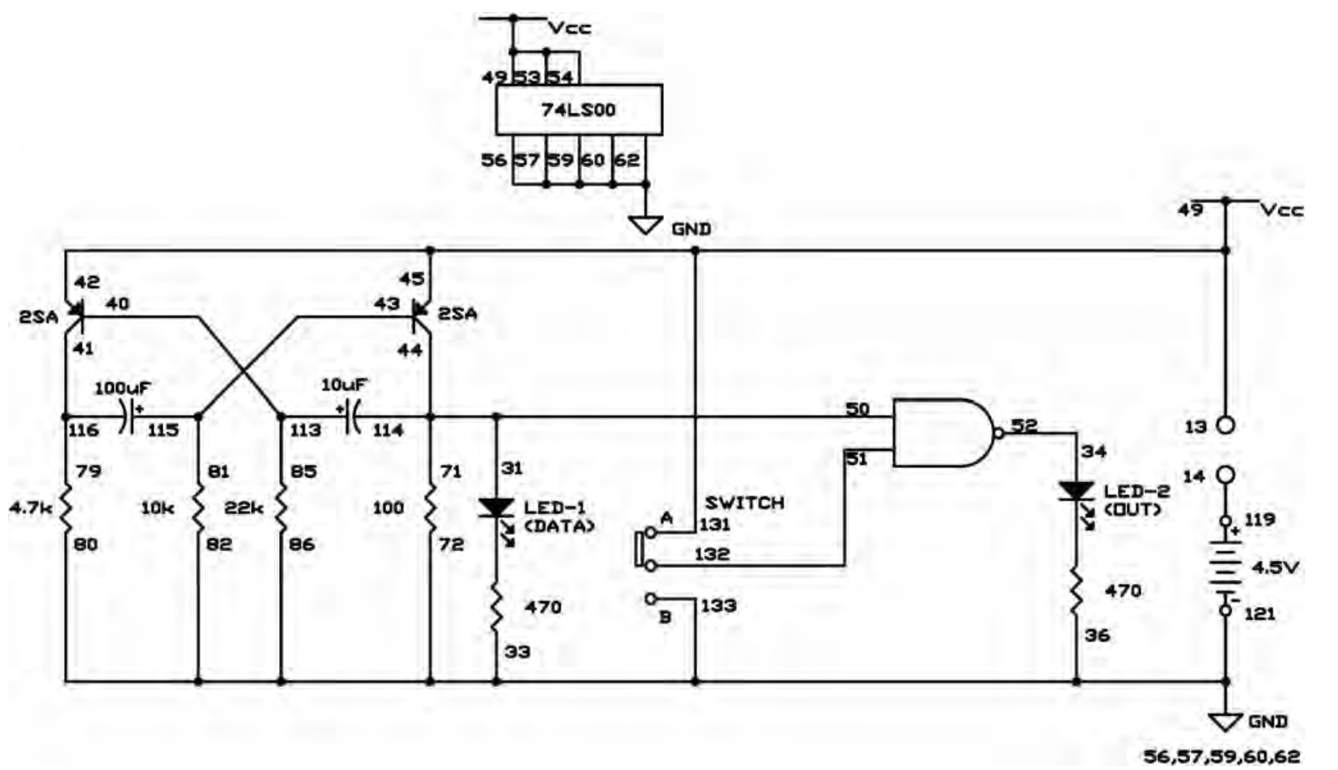
Now, did you figure all that out before building the circuit? We hope so.

Notes:

Wiring Sequence:

☐ 13-49-53-54-42-45-131
☐ 14-119
☐ 71-50-31-44-114
☐ 86-82-80-72-56-57-59-60-62-33-36-121-133
☐ 34-52
☐ 40-113-85
☐ 41-116-79
☐ 43-115-81
☐ 51-132
☐ 13-14 (POWER)

Schematic



EXPERIMENT #44: TTL "R-S FLIP-FLOP"

No, R-S does not mean Radio Shack® flip-flop. As we mentioned, earlier, flip-flop circuits are circuits that alternate between two states. Engineers often use flip-flop circuits to switch between high (1) and low (0) outputs. When the output is high, or on, we say the circuit is at set status (S). When it is off, we say it is at rest (R). This explains where the R-S flip-flop circuit got its name.

After you finish the wiring, turn the switch to A to turn on the power. Either LED 1 or LED 2 lights. Take the long wire connected to terminal 56 and touch terminals 13 and 14 in turn. What happens to LED 1 and LED 2?

When LED 2 lights, the R-S flip-flop is in the set state. When LED 1 lights, the R-S Flip-flop is reset. After you set or reset the flip-flop, remove the long wire from the circuit and see what happens.

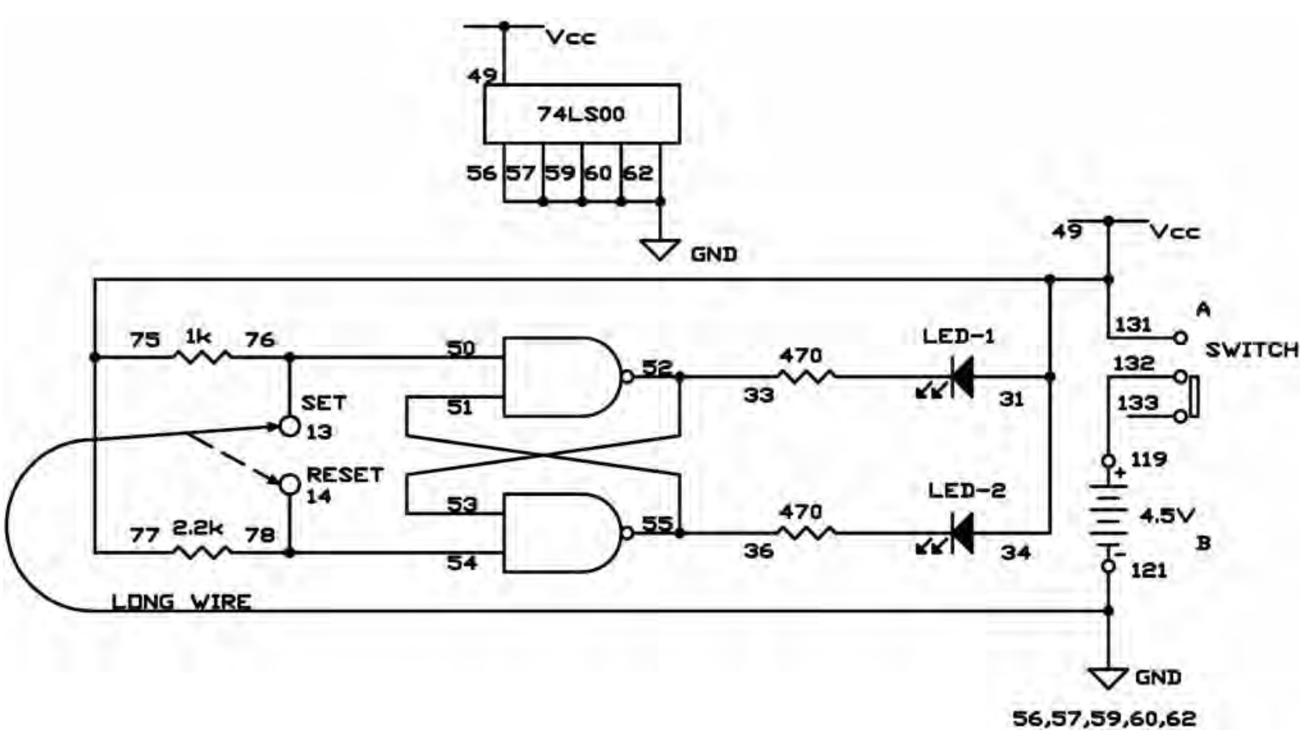
Now you can see one of the prime characteristics of the R-S flip-flop. Once the circuit is set or reset, the circuit keeps that state until an input signal causes it to change. This means the R-S flip-flop can remember things. Advanced computers use circuits similar to this one so they can remember things as well.

Notes:

Wiring Sequence:

- ☐ 77-75-49-31-34-131
- ☐ 33-53-52
- ☐ 36-55-51
- ☐ 50-76-13 (SET)
- ☐ 54-78-14 (RESET)
- ☐ 121-62-60-59-57-56-LONG WIRE
- ☐ 119-132

Schematic



EXPERIMENT #45: "TOGGLE FLIP-FLOP" CIRCUIT MADE FROM "NAND" GATE

If you think the NAND gate is a very versatile circuit, you're right! Here's a toggle flip-flop circuit made from four NAND gates.

Connect terminals 13 and 14 to turn the power on after you finish building this circuit. Press the key slowly several times. You'll see that LED 1 turns on or off each time the key is pressed. Put on your thinking cap and try to trace what happens from the key input to LED 1. Two of the four NANDs function as an R-S flip-flop. See if you can figure out what the remaining NANDs are doing.

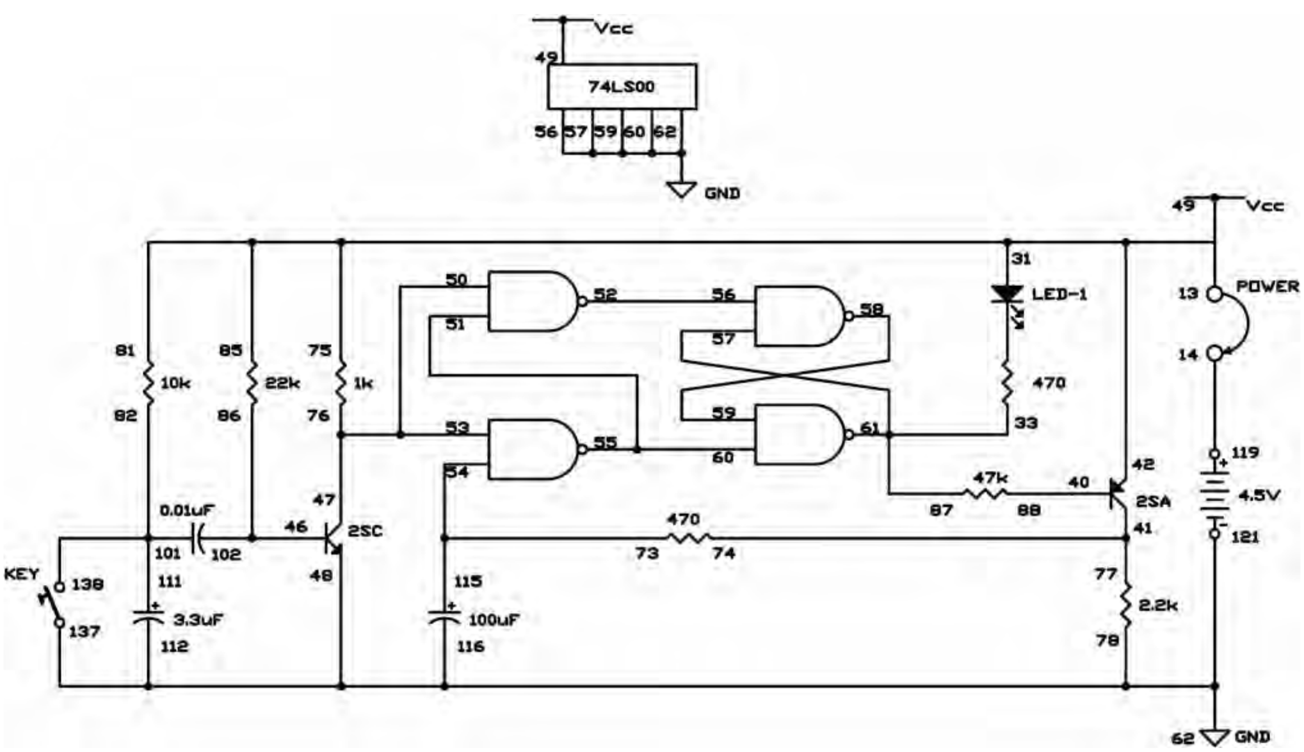
This circuit is an inverter, because it takes inputs and reverses them.

Wiring Sequence:

- ☐ 13-75-85-81-49-31-42
- ☐ 14-119
- ☐ 33-57-61-87
- ☐ 40-88
- ☐ 41-74-77
- ☐ 46-102-86
- ☐ 47-53-50-76
- ☐ 78-62-48-112-116-137-121
- ☐ 51-55-60
- ☐ 52-56
- ☐ 73-54-115
- ☐ 58-59
- ☐ 82-101-111-138
- ☐ 13-14 (POWER)

Notes:

Schematic



EXPERIMENT #46: TTL LINE SELECTOR

It isn't hard to think of situations where we might want to send input data to two or more different outputs. This project shows how we can use a network of NAND gates to help do just that.

You can see that we use a multivibrator and three NAND gates in this circuit. You can leave the switch at either A or B as you build this project. When you connect terminals 13 and 14, you'll see that LED 1 is blinking. If the switch is at A, LED 2 is blinking also. If the switch is at B, LED 3 blinks.

As you can see on the schematic, setting the switch to A or B controls the inputs to the two NANDs that light LED 2 and LED 3. With the switch at A, the NAND controlling LED 2 gets one steady input of 1. The output of the multivibrator supplies the other input. As the multivibrator's output switches from 0 to 1, the NAND controlling LED 2 switches its output from 1 to 0.

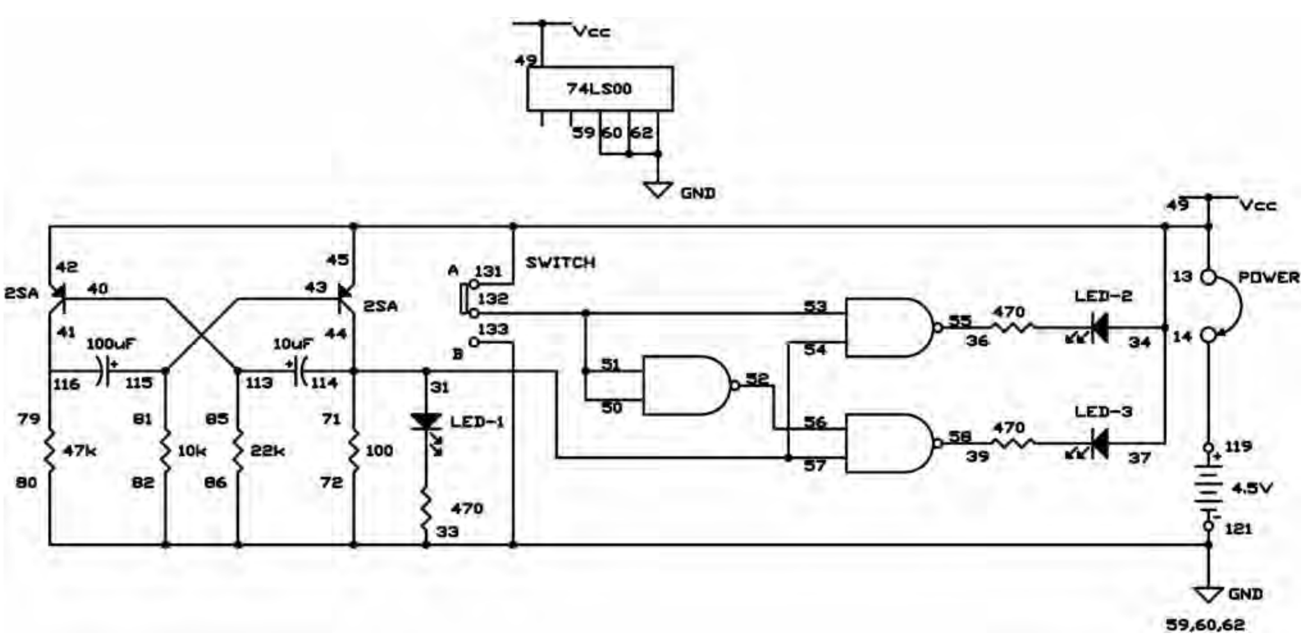
The opposite happens when you set the switch to B. Now the NAND controlling LED 3 gets a steady input of 1 so that LED 3 can go on and off according to the input from the multivibrator.

Notes:

Wiring Sequence:

- ☐ 13-49-34-37-42-45-131
- ☐ 14-119
- ☐ 71-57-54-31-44-114
- ☐ 86-82-80-72-59-60-62-33-121-133
- ☐ 36-55
- ☐ 39-58
- ☐ 40-113-85
- ☐ 41-116-79
- ☐ 43-115-81
- ☐ 50-51-53-132
- ☐ 52-56
- ☐ 13-14 (POWER)

Schematic



EXPERIMENT #47: TTL DATA SELECTOR

Our last projects let you see how data could be sent to two or more different outputs. You can probably think of some situations where we might want (or need) to do the opposite – send data from two or more different sources to output. The following circuit shows how to send data this way.

When you look at the schematic for this project, you'll notice two different input sources. The multivibrator circuit provides one input signal to control LED 2. The other signal is provided by – can you guess?

Yourself! You provide the input signal by pressing and relieving the key. The action of the key controls LED 1.

Set the switch to A before you complete this project. When you connect terminals 13 and 14 to switch on the power LED 2 blinks. Watch both LED 1 and LED 3. Is anything happening yet? Now press the key and see what happens to LED 1 and LED 3. LED 3 goes on and off at the same time as LED 1. Now set the switch to B. LED 3 turns on and according to the blinking of LED 2. You can use either of the two sources as the input to determine the output of LED 3.

Now put on your thinking cap and try to follow the inputs from the multivibrator, to the key, to the setting of the switch, to the LED. Mark a 1 or 0 by each terminal of the NANDs to see the different high and low inputs.

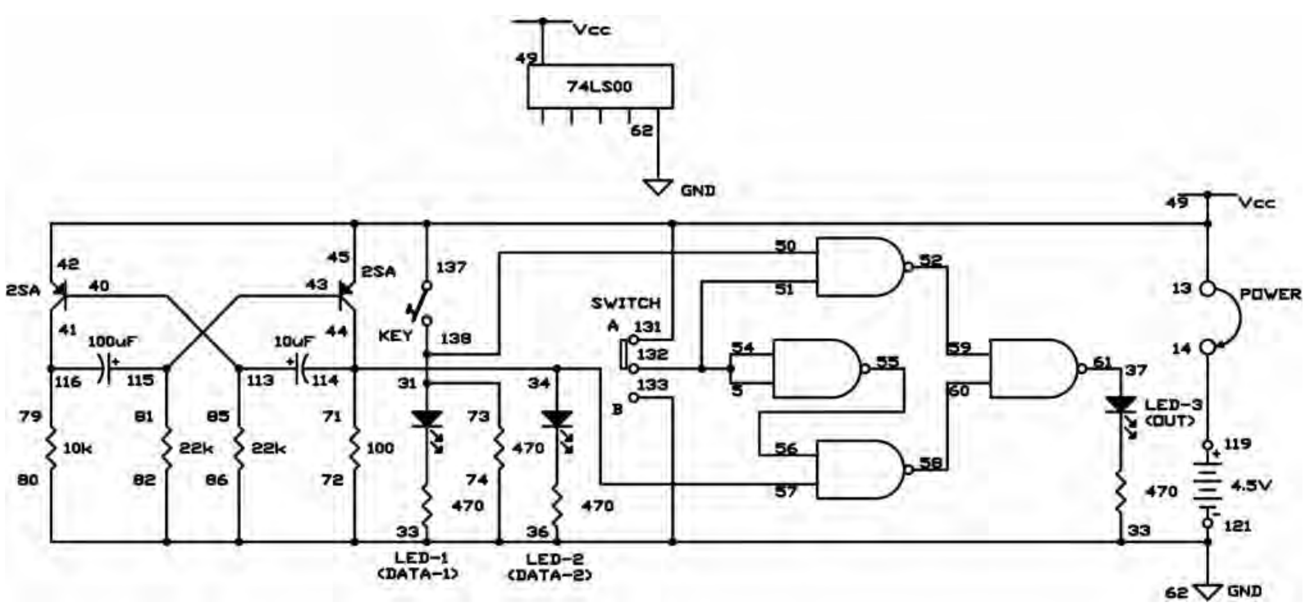
Computers and other highly advanced digital circuits use a more complex version of these circuits. As you probably suspect, switching from one input channel to another is done electronically in most cases.

Notes:

Wiring Sequence:

- ☐ 13-49-42-45-131-137
- ☐ 14-119
- ☐ 73-50-31-138
- ☐ 86-82-74-72-80-62-33-36-39-121-133
- ☐ 71-57-34-44-114
- ☐ 37-61
- ☐ 40-113-85
- ☐ 41-116-79
- ☐ 51-53-54-132
- ☐ 43-115-81
- ☐ 52-59
- ☐ 55-56
- ☐ 58-60
- ☐ 13-14 (POWER)

Schematic



VI. THE WORLD OF TRANSISTOR-TRANSISTOR LOGIC

EXPERIMENT #48: TTL ASTABLE MULTIVIBRATOR

Even multivibrator circuits can be made from NAND gates. This project is an example of an astable multivibrator – can you guess what astable means? Make a guess, and complete this project to see if you were right.

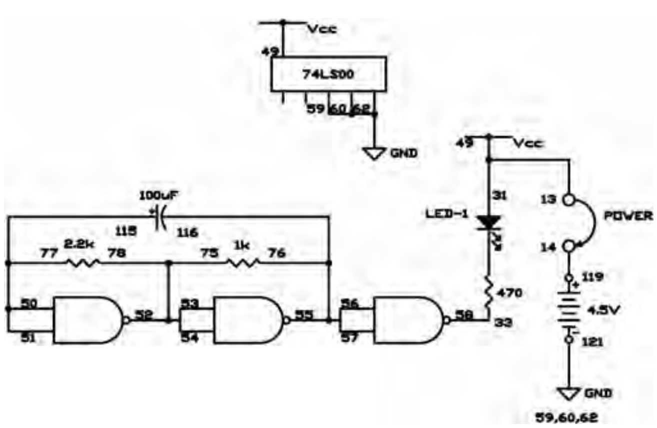
Connect terminals 13 and 14 to turn the circuit on. You'll see LED 1 begin to flash. Astable means the multivibrator's output keeps switching back and forth between 0 and 1. As you remember, most of the multivibrators you've built so far do the same thing.

You shouldn't have much trouble figuring out how this particular circuit works. The 100µF capacitor makes it all possible. Try using other electrolytic capacitors in place of the 100µF capacitors and see what effect they have on LED 1 (Be sure to use the correct polarity.)

By now you can see why NAND gate ICs are so useful. The quad two-input NAND IC in your kit is one of the most widely used electronic components in the world. It can be applied to many different circuits. (You can probably think of many more!)

Notes:

Schematic



Wiring Sequence:

- ☐ 13-49-31
- ☐ 14-119
- ☐ 33-58
- ☐ 50-51-77-115
- ☐ 54-53-52-75-78
- ☐ 55-56-57-76-116
- ☐ 59-60-62-121
- ☐ 13-14 (POWER)

EXPERIMENT #49: TTL TONE GENERATOR

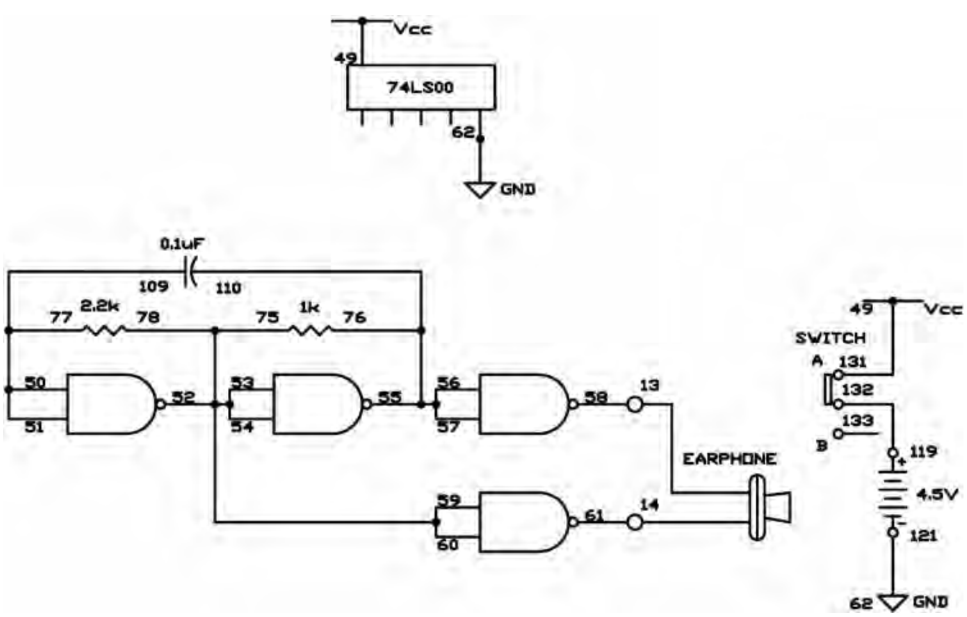
We've been producing tones with audio oscillators for so long that it might seem as if there's no other way to produce tones from electronic circuits. Not so – a multivibrator made from NAND gates does the job nicely.

When you finish wiring this circuit, connect the earphone to terminals 13 and 14 and set the switch to A to turn on the power. You'll hear a tone that is produced by the multivibrator. Try changing the value of the capacitors from 0.1μF to 0.5μF. What effect does this have on the sound you hear?

You might also want to try different capacitors in this project. Don't try using any of the electrolytic capacitors, however (terminals 111-118). Try to arrange the circuit so you can switch different value capacitors in and out of this circuit to vary the tone. Can you think of ways to use this circuit with any other digital circuits?

Notes:

Schematic



Wiring Sequence:

- ☐ 49-131
- ☐ 50-51-77-109
- ☐ 52-53-54-60-59-75-78
- ☐ 55-57-56-76-110
- ☐ 62-121
- ☐ 119-132
- ☐ 58-13-EARPHONE
- ☐ 61-14-EARPHONE

EXPERIMENT #50: WINKING LEDS

Complete the wiring sequence for this circuit and connect terminals 13 and 14 to turn on the power. You'll see both LED 1 and LED 2 take turns going on and off. You can change the speed of the blinking by substituting different values for the 100µF capacitor.

TTL multivibrators are becoming more widely used today in place of transistor multivibrators. Can you think of some reasons why? Write down any reasons you think TTL multivibrators would work better than regular transistor multivibrators.

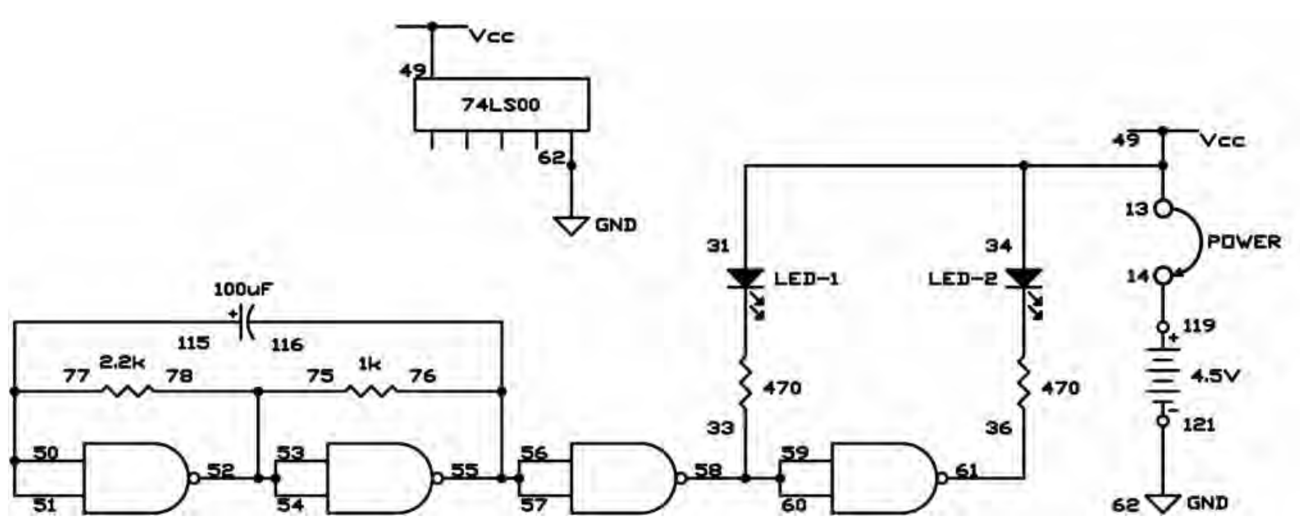
TTL multivibrators take up much less space than transistor multivibrators. TTL ICs also use less current than similar transistor arrangements.

Notes:

Wiring Sequence:

- ☐ 13-49-31-34
- ☐ 14-119
- ☐ 33-60-59-58
- ☐ 36-61
- ☐ 50-51-77-115
- ☐ 52-53-54-78-75
- ☐ 55-57-56-76-116
- ☐ 62-121
- ☐ 13-14 (POWER)

Schematic



EXPERIMENT #51: A ONE-SHOT TTL

Does the term one-shot mean anything to you? (No, it's not a nickname for a cowboy or a gun that holds just one bullet!)

After you complete the wiring for this circuit, turn the switch to A to turn on the power. Press the key once and see what happens to LED 1. Try holding the key down for different periods of time. Does LED 1 stay on the same length of time or does it vary?

You see that a one-shot multivibrator has an output for a certain length of time regardless of the length of the input. (It "fires one shot.") This means that it can be used in many circuits as a timer. You might also see this circuit called a monostable multivibrator.

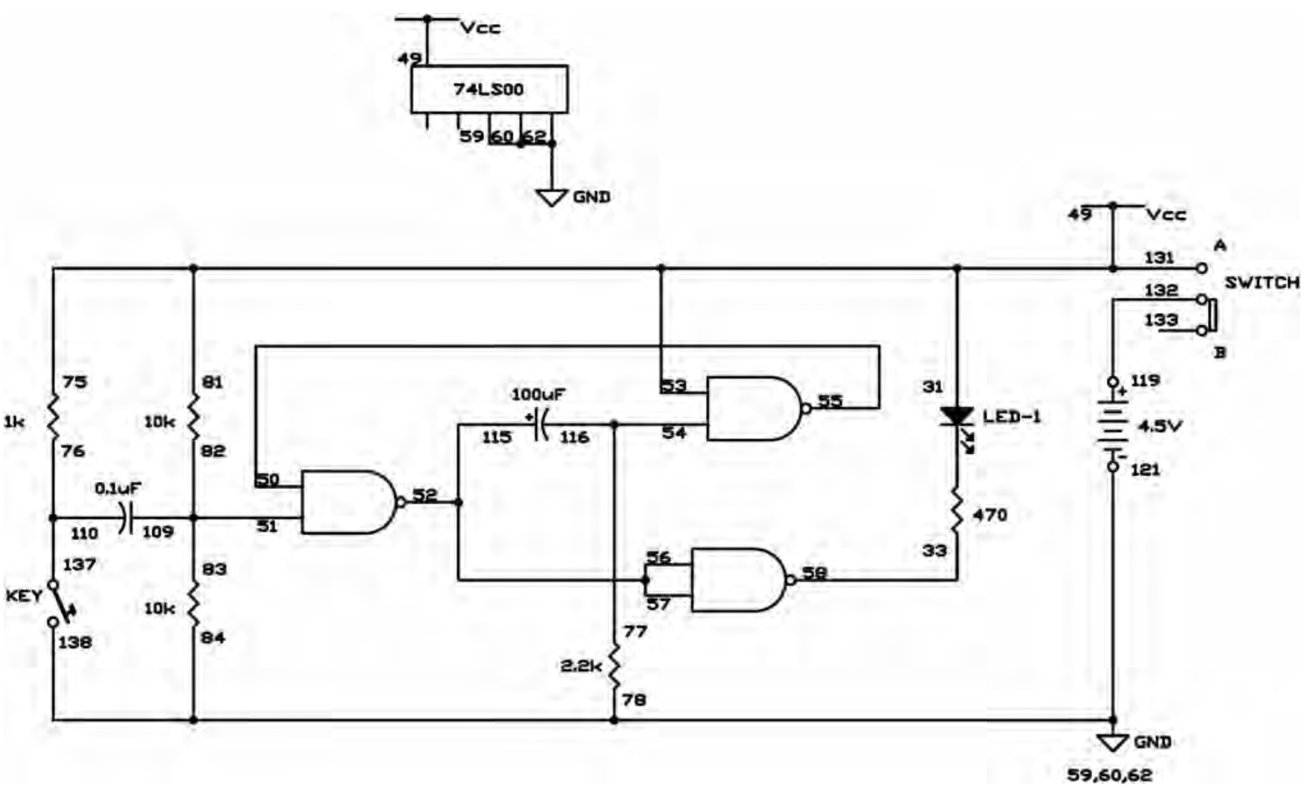
Since this is a multivibrator, you might suspect that there's some way to vary the time it produces an output. You're right – there is a way – and we'll let you try to figure out what it is. (Actually, you shouldn't have much trouble discovering which parts you need to change. Be sure to make notes about the effect of higher and lower component values on circuit operation.)

Notes:

Wiring Sequence:

- ☐ 81-75-49-53-31-131
- ☐ 33-58
- ☐ 50-55
- ☐ 51-82-83-109
- ☐ 52-56-57-115
- ☐ 54-77-116
- ☐ 59-60-62-78-84-138-121
- ☐ 76-110-137
- ☐ 119-132

Schematic



EXPERIMENT #52: TRANSISTOR TIMER WITH TTL

Here's another type of one-shot circuit, but in this project you hear the effects of the multivibrator. You can see from the schematic that this project uses a combination of simple components and digital electronics. When you press the key, the 100μF capacitor is charged and lets the NPN translator in the left corner of the schematic operate. You can see that the collector of this transistor serves as both inputs for the first NAND gate.

The digital portion of this circuit controls the operation of the PNP transistor on the right side of the schematic. Set the switch to A to turn the power on. When the output of the first NAND is 1, the multivibrator works, and you hear a sound from the speaker.

The sound will continue until the 100μF capacitor discharges, keeping the first transistor from operating. The output of the first NAND becomes 0, stopping the multivibrator. The sound will last about 10 seconds with the 22kΩ resistor. Try replacing the 22kΩ with the 47kΩ or the 100kΩ resistor and find out what happens.

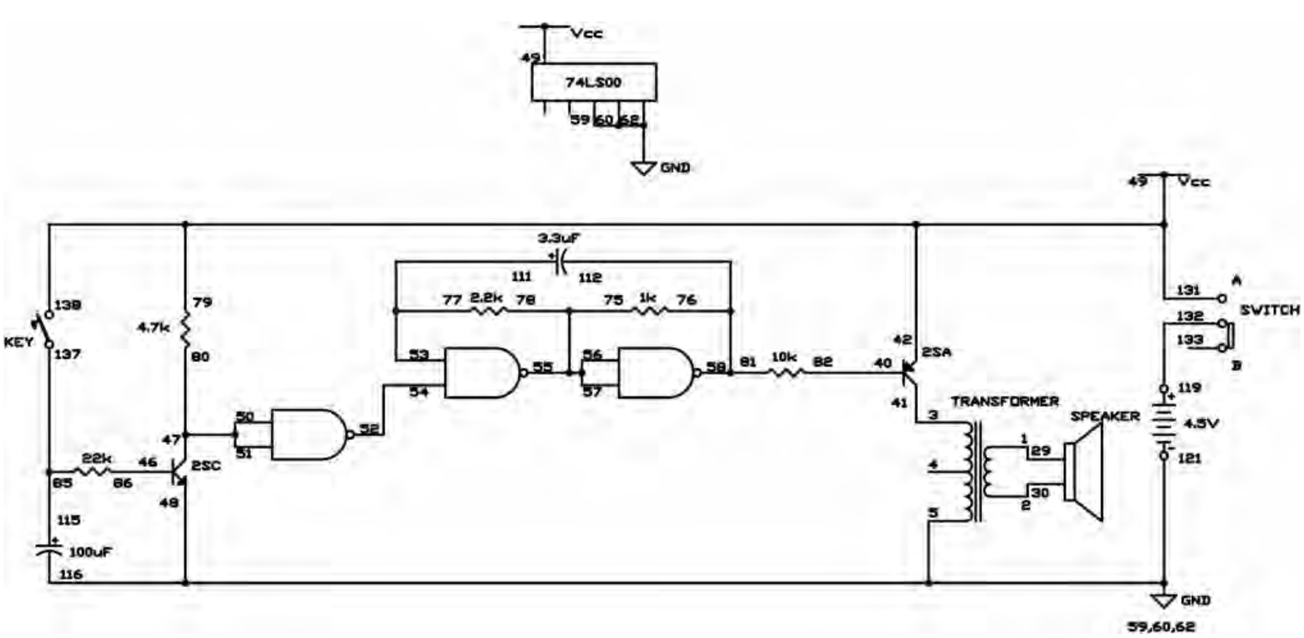
After you've experimented with this project a bit, try this: press the key and release it. When the sound stops, find the wire running between terminals 52 and 54. Disconnect the wire from terminal 52. Does anything happen? If something does happen, can you explain why?

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-41
- ☐ 5-59-60-62-48-116-121
- ☐ 40-82
- ☐ 79-49-42-131-138
- ☐ 46-86
- ☐ 47-50-51-80
- ☐ 52-54
- ☐ 53-77-111
- ☐ 55-57-56-75-78
- ☐ 58-76-81-112
- ☐ 85-115-137
- ☐ 119-132

Schematic



EXPERIMENT #53: BUZZIN' LED

Here's another circuit that uses both transistor and NAND type multivibrators. It allows you to see LED 1 light up at the same time you hear a sound through the earphone.

When you finish building this project, connect the earphone to terminals 13 and 14 and set the switch to position A. You'll hear a pulse in the earphone each time the LED lights up. Do you know why this happens?

Assume the output of the NAND multivibrator is 0, and trace that output from the NAND multivibrator to the transistor multivibrator. Do you think the operation of the transistor multivibrator is affected by the NAND multivibrator? If you say yes, how is it affected?

Try using other electrolytic capacitors in place of the 100µF capacitor in the NAND multivibrator to see what effects they have on the circuit. Try changing the transistor multivibrator and see how you can alter its operation.

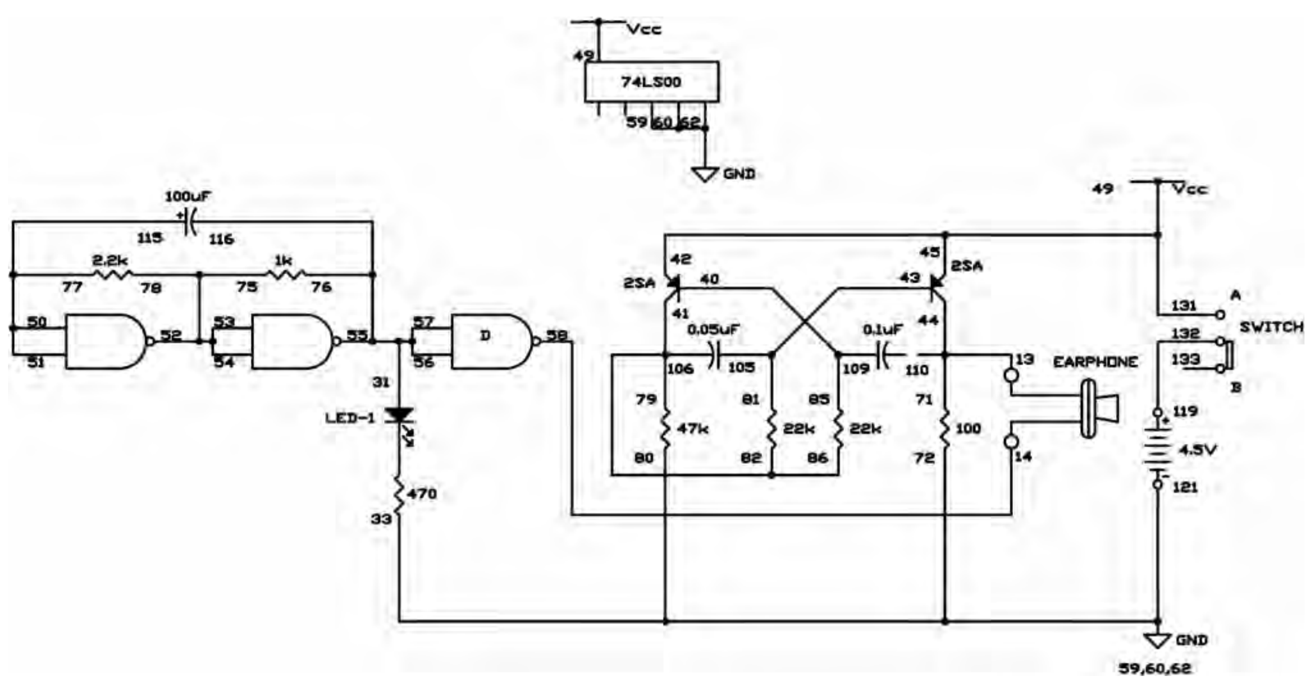
You can use the speaker instead of the earphone with this project by connecting the NPN transistor, the output transformer, and maybe a resistor or two. Try adding the speaker – but be sure to write down the new circuit you design.

Notes:

Wiring Sequence:

- ☐ 31-55-56-57-76-116
- ☐ 33-59-60-62-72-80-121
- ☐ 40-109-85
- ☐ 131-45-42-49
- ☐ 43-105-81
- ☐ 50-51-77-115
- ☐ 52-53-54-75-78
- ☐ 58-82-86
- ☐ 119-132
- ☐ 110-44-71-13-EARPHONE
- ☐ 106-41-79-14-EARPHONE

Schematic



EXPERIMENT #54: SON OF BUZZIN' LED

Carefully compare the schematic for this project with the schematic for the last project. They are similar in many ways, but there's an important difference.

Do you see what it is? Better still, can you tell what effect the difference has on the project's operation? Try to figure it out before you build this circuit.

Connect the earphone to Terminals 13 and 14 and set the switch to position A. You should find that LED 1 lights up, but you hear nothing in the earphone. When LED 1 turns off, then you hear a sound in the earphone.

Try to figure out why this happens. Study the schematic and when you think you have the answer, read on to check your guess.

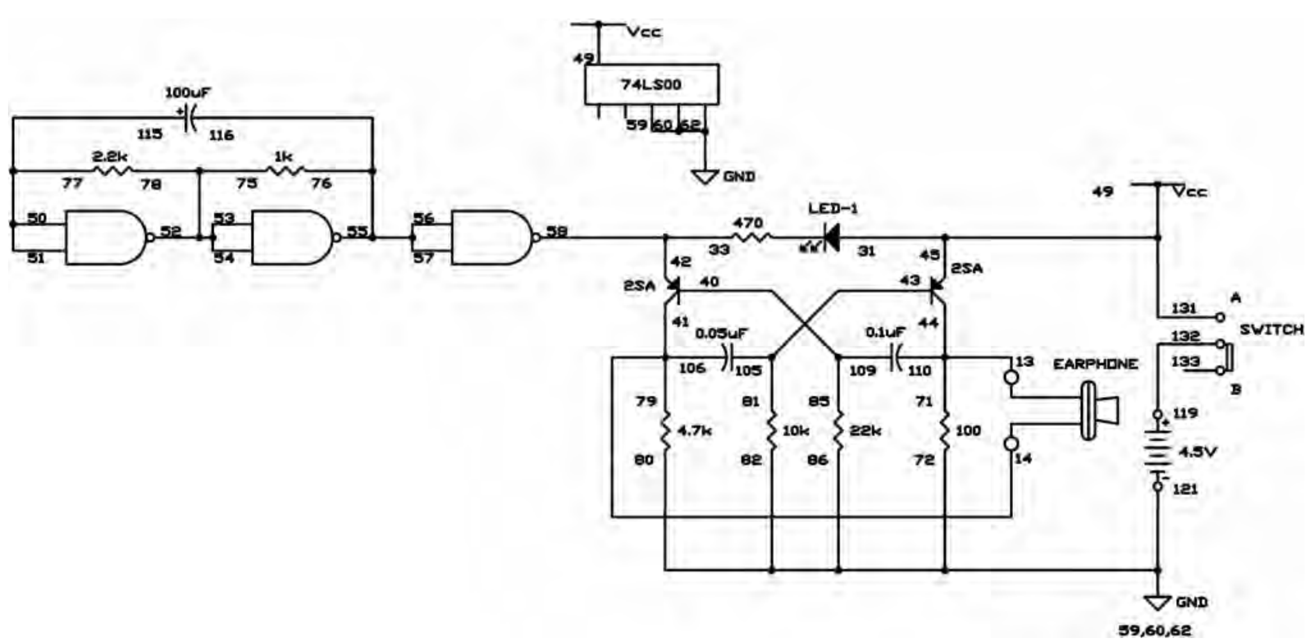
When the output of the NAND multivibrator is 0, current can flow through LED 1 to light it but the transistor multivibrator won't work because the left transistor has a 1 signal applied to its emitter. When the output of the NAND multivibrator is 1, LED 1 won't light but a 0 signal is applied to the emitter of the left transistor. The transistor multivibrator can then work, and you can hear the sound in your earphone.

Notes:

Wiring Sequence:

- ☐ 131-45-31-49
- ☐ 116-76-56-57-55
- ☐ 40-109-85
- ☐ 42-58-33
- ☐ 43-105-81
- ☐ 50-51-77-115
- ☐ 52-53-54-75-78
- ☐ 72-59-60-62-80-82-86-121
- ☐ 119-132
- ☐ 44-110-71-13-EARPHONE
- ☐ 41-106-79-14-EARPHONE

Schematic



EXPERIMENT #55: SET/RESET BUZZER 1

Anything look familiar about the schematic for this project? This circuit uses an R-S flip-flop circuit made from NAND gates, similar to the circuit in Project 44 ("TTL R-S Flip-Flop").

After you finish building this project, set the switch to position A and press the key. You should hear a sound through the earphone. Try pressing the key several times. This should not affect the sound in your earphone. Now move the switch to position B and press the key one more time. What happens now?

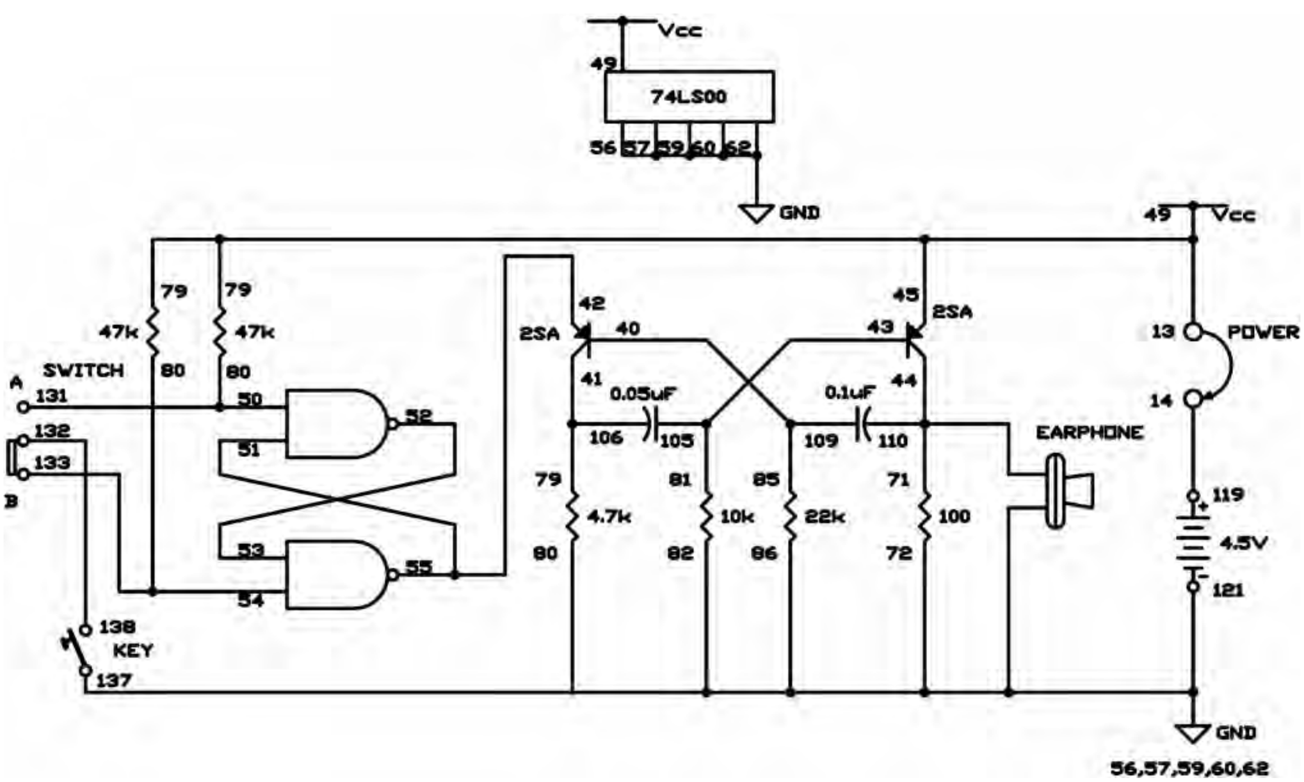
Circuits like this can be used in alarms. They are very useful since intruders often can't figure out how to make the sound stop. You might also want to experiment using light from LEDs instead of sound to tell you that the circuit has been set or reset.

Notes:

Wiring Sequence:

- ☐ 13-77-75-49-45
- ☐ 14-119
- ☐ 40-109-85
- ☐ 41-106-79
- ☐ 42-55-51
- ☐ 43-105-81
- ☐ 50-78-131
- ☐ 52-53
- ☐ 54-76-133
- ☐ 132-138
- ☐ 44-110-71-EARPHONE
- ☐ 121-137-62-60-59-57-56-80-82-86-72-EARPHONE
- ☐ 13-14 (POWER)

Schematic



EXPERIMENT #56: SET/RESET BUZZER 2

Here's another version of the last project. This time we use a NAND multivibrator and an R-S flip-flop made with transistors.

This circuit works like the last one. When you set the switch to B and press the key, you hear a sound in the earphone. You can still hear the sound no matter how many times you press the key again. Set the switch to A and press the key and the sound will stop.

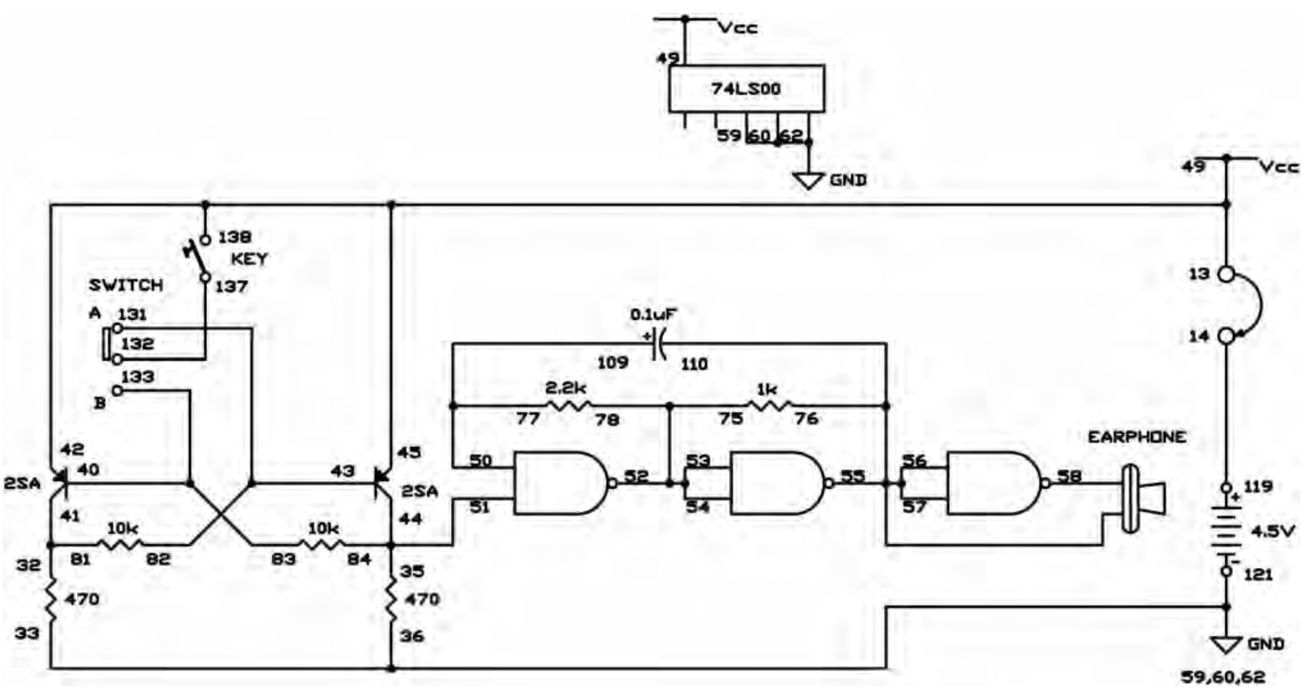
Compare the operation of this project with the previous one. What makes them different from each other? Can you think of some situations where one circuit might be better suited than the other? Be sure to make some notes about what you learn.

Notes:

Wiring Sequence:

- ☐ 13-49-42-45-138
- ☐ 14-119
- ☐ 81-32-41
- ☐ 33-59-60-62-36-121
- ☐ 44-35-51-84
- ☐ 40-133-83
- ☐ 82-43-131
- ☐ 50-77-109
- ☐ 54-53-52-75-78
- ☐ 132-137
- ☐ 110-76-57-56-55-EARPHONE
- ☐ 58-EARPHONE
- ☐ 13-14 (POWER)

Schematic



EXPERIMENT #57: SOUND MACHINE

This digital sound project makes use of a circuit we've used in some earlier projects. Try to tell which circuit we're talking about by looking at the schematic.

While you're looking for that certain circuit, why not listen to the sound this project makes? Because there are a lot of wiring steps, you need to take your time and check your work. When you've finished, set the switch to position A. What do you hear? Can you explain how looking at the schematic produces this sound?

The two PNP transistors are used to make up a multivibrator circuit. (Did you recognize this familiar circuit?) Notice that we're also using two NAND gates to make a multivibrator. The NAND gate multivibrator affects the operation of the transistor multivibrator, which sends its output through the NPN transistor to the audio amplifier. The result is the sound you hear from the speaker.

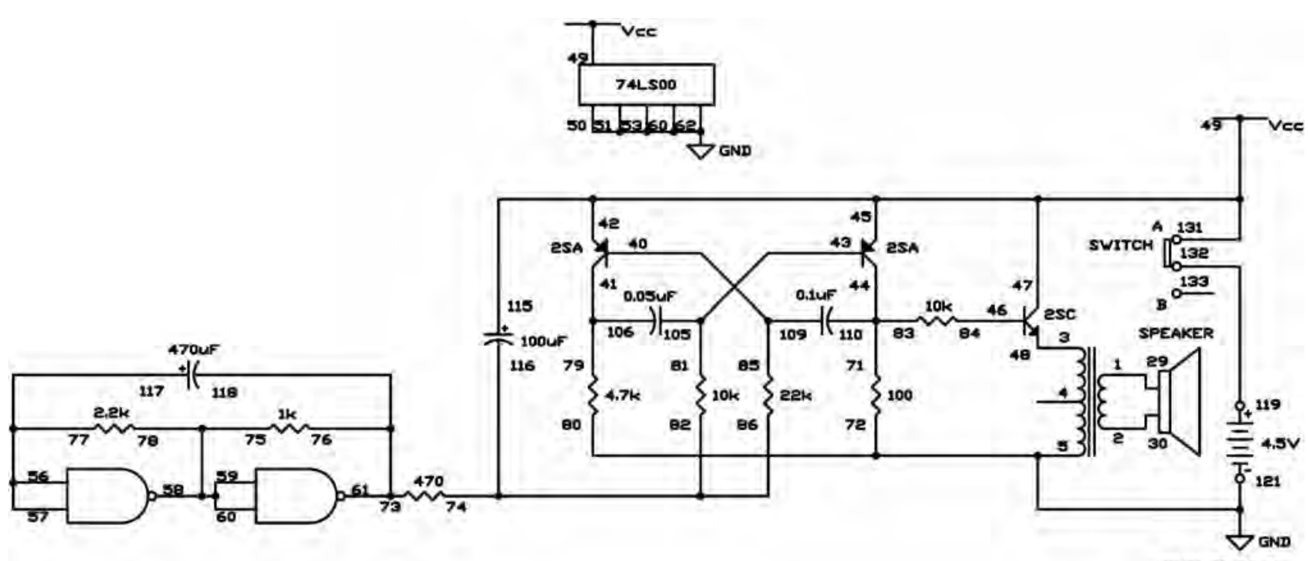
You can change the sound this circuit makes by substituting a different value for the 470μF capacitor. Try different values for the 10kΩ resistor and the 0.05μF capacitor and see what happens.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-48
- ☐ 5-50-51-53-54-72-80-62-121
- ☐ 40-109-85
- ☐ 41-106-79
- ☐ 42-45-47-131-115-49
- ☐ 43-105-81
- ☐ 44-110-83-71
- ☐ 46-84
- ☐ 57-56-77-117
- ☐ 58-59-60-75-78
- ☐ 61-73-76-118
- ☐ 74-82-86-116
- ☐ 119-132

Schematic



EXPERIMENT #58: BIG MOUTH

Do you know someone who is a big mouth? (Or, have you been accused of being one?) This project lets you and your friends see who's got the loudest voice.

You can see how this project works by looking at the schematic. When you yell into the earphone, your voice creates electrical energy through the process of piezoelectricity, the special characteristics of crystalline substances. The crystal in your kit's earphone produces voltage when it is subjected to mechanical stress – such as the sound pressure of your voice.

The two-transistor circuit amplifies the electrical energy from the earphone. You can use the control to change the amount of the signal from the earphone that is amplified. The two NAND gates in series control the lighting of LED 1. Trace 0's and 1's as they change from input to output.

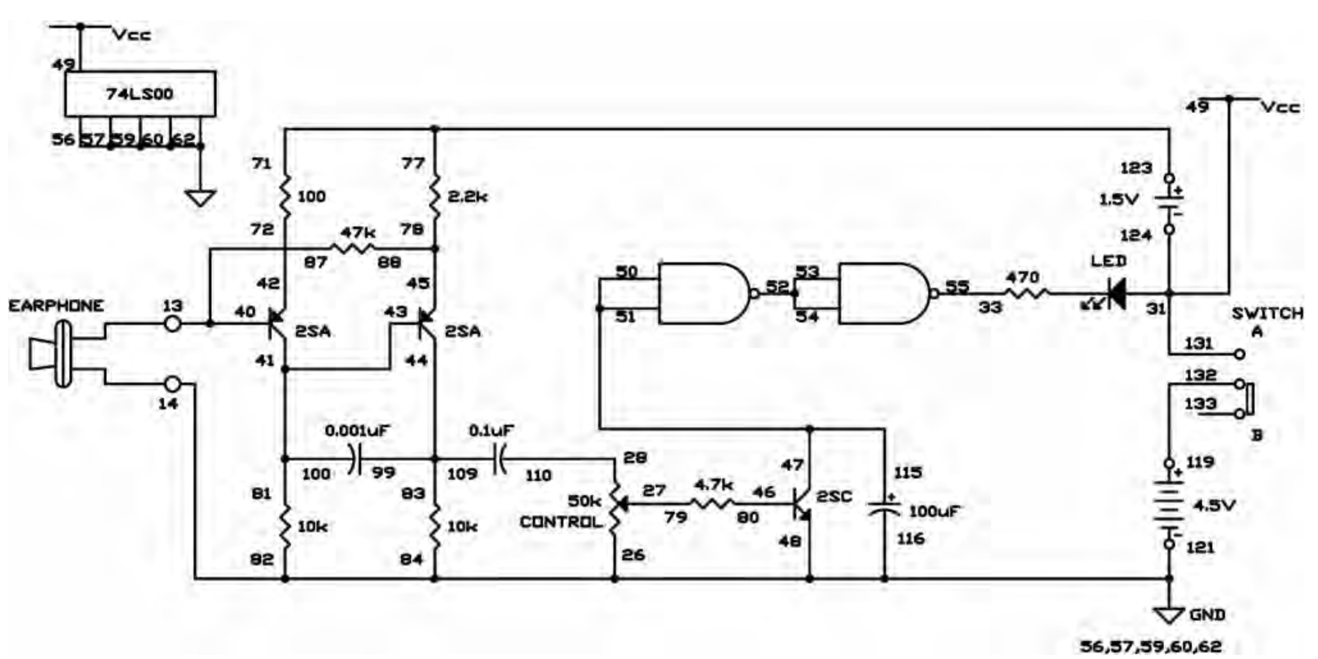
To use this circuit, set the switch position A and set the control to position 5. Yell into the earphone and watch LED 1. It probably lights. If so, try turning the control counter-clockwise to make it more difficult to light LED 1. (Try adjusting it just a tiny bit each time.) See how far you can lower the control to reduce the strength of the amplifier and still light the LED.

Notes:

Wiring Sequence:

- ☐ 27-79
- ☐ 28-110
- ☐ 124-131-31-49
- ☐ 33-55
- ☐ 41-43-100-81
- ☐ 42-72
- ☐ 44-109-99-83
- ☐ 45-88-78
- ☐ 46-80
- ☐ 47-115-51-50
- ☐ 52-53-54
- ☐ 77-71-123
- ☐ 119-132
- ☐ 40-87-13-EARPHONE
- ☐ 121-26-48-116-62-60-59-57-56-84-82-14-EARPHONE

Schematic



EXPERIMENT #59: SHOT IN THE DARK

Do you think you have good night vision? This last project in this section is a game that lets you find out how well you can see in the dark. It tests your aim – in a completely dark room!

After you finish building the project, put it in as dark a room as possible. Slide the switch position A and adjust the control in a counter-clockwise direction until LED 1 and LED 3 light. Now you're ready to test your skill.

Your "gun" for this game is any ordinary flashlight. You use your flashlight to "shoot" the kit with a beam of light. If you aim correctly, you'll hit the CdS cell to light LED 2 and turn off LED 1 and LED 3. Then turn off your flashlight and wait until LED 2 goes off before you try the next shot.

First try hitting the CdS cell from about five feet or so. As your aim improves try increasing the distance. When you are really good, you can try hitting the CdS cell simply by switching your flashlight on and off rather than using a continuous stream of light.

You might have to adjust the control knob very carefully to have LED 2 come on when light strikes the CdS cell. For the best results, 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, keep it there so you can use it again. Don't change it until you want to stop using the "shot in the dark" game.

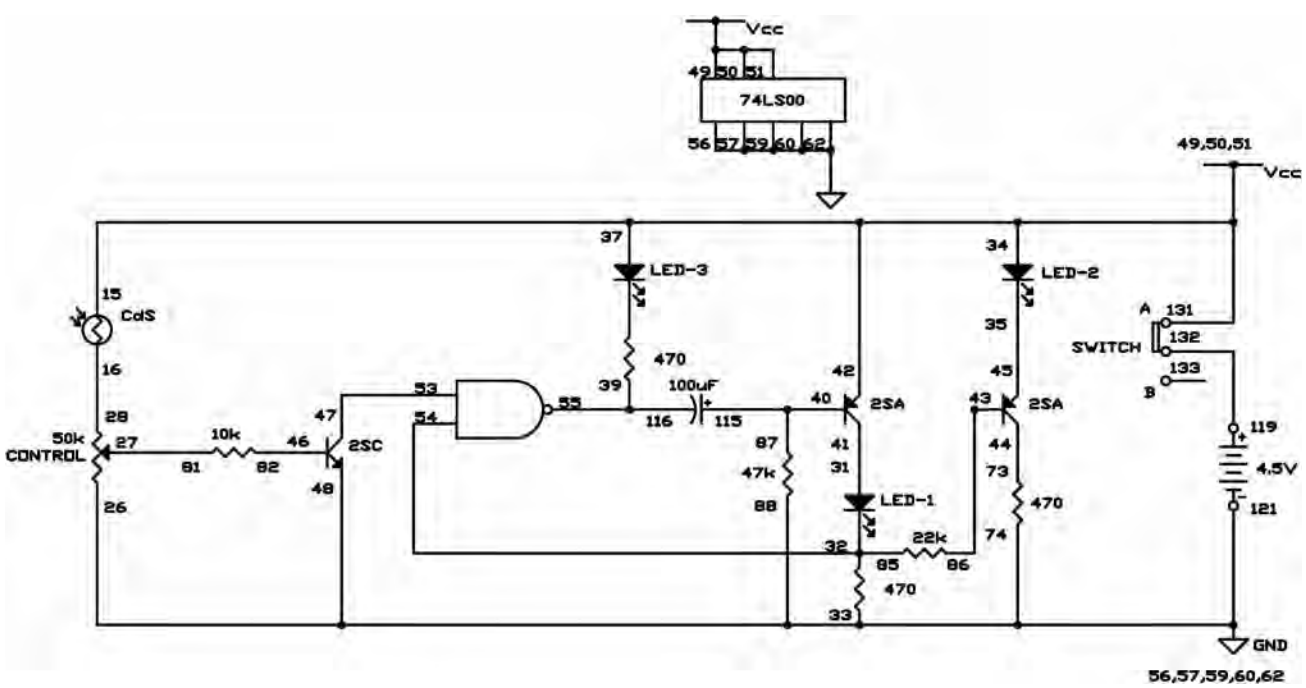
Good luck and may you become "the fastest flashlight in the West!"

Notes:

Wiring Sequence:

- ☐ 15-34-49-50-51-37-42-131
- ☐ 16-28
- ☐ 48-121-26-88-74-62-60-59-57-56-33
- ☐ 27-81
- ☐ 31-41
- ☐ 32-54-85
- ☐ 35-45
- ☐ 73-44
- ☐ 39-55-116
- ☐ 40-115-87
- ☐ 43-86
- ☐ 46-82
- ☐ 47-53
- ☐ 119-132

Schematic



VII. APPLICATION CIRCUITS BASED ON THE OSCILLATOR

EXPERIMENT #60: VARIABLE R-C OSCILLATOR

The "R-C" in this project's name stands for resistance-capacitance. We've seen how varying resistance and capacitance can affect the pulsing action of an oscillator. This project lets us see the effects when we change the strengths of both resistors and capacitors.

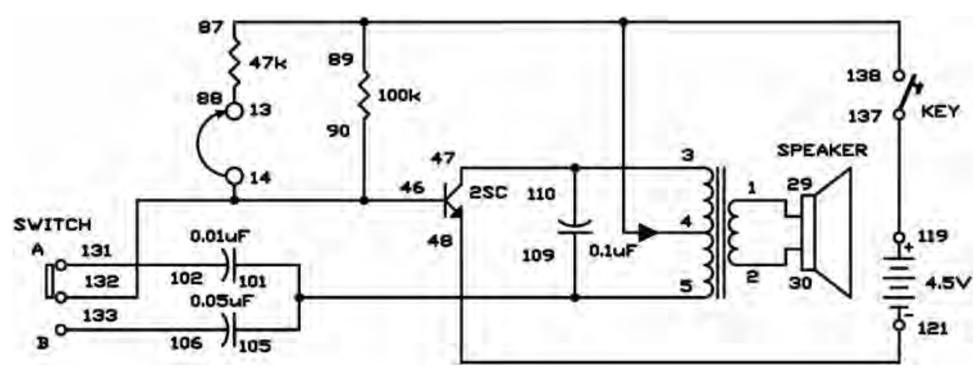
Look at the schematic. You can see the switch allows you to choose between two different capacitors. You can add a second resistor to the circuit by connecting terminals 13 and 14.

After you build the project, set the switch to position B. Leave terminals 13 and 14 and press the key. What kind of sound do you hear from the speaker? Now set the switch to A and press the key again. Is there any change in the sound? Now connect terminals 13 and 14 and press the key. Try both settings of the switch with terminals 13 and 14 connected and see what happens.

Which combination gives you the highest tone? The lowest? What does this tell you about how capacitors and resistors affect each other? Take careful notes about the effects of the different value capacitors and resistors.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-47-110
- ☐ 4-87-89-138
- ☐ 5-101-105-109
- ☐ 13-88
- ☐ 14-90-46-132
- ☐ 48-121
- ☐ 102-131
- ☐ 106-133
- ☐ 119-137

EXPERIMENT #61: OSCILLATOR WITH TURN-OFF DELAY

We've seen how a capacitor's charge/discharge cycle can be used to delay certain circuit operations. Now let's delay the oscillator action in this project with a 470μF capacitor.

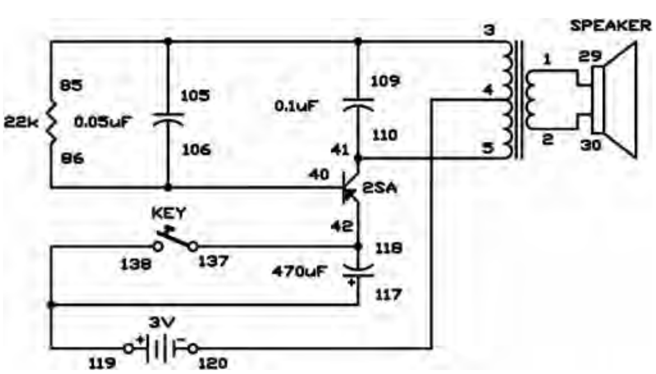
When you press the key, the capacitor discharges. When you release the key, the capacitor begins to charge. The circuit continues to oscillate until the capacitor is charged, then current stops flowing. When you close the key for the second time, it immediately discharges the capacitor.

A discharged capacitor has an equal number of electronics on its positive (+) and negative (–) electrodes. A charge is stored in a capacitor by drawing electrons from the positive electrode (to actually make it positive) and an equal number of electrons are added to the negative electrode (to make it negative). The current that flows to charge the capacitor is called charging current or displacement current. When the capacitor is discharging, the same amount of current must flow in the opposite direction. This current is called discharge current or displacement current.

If you have a VOM, use it to measure the charge on the capacitor with the voltmeter function. The displacement current can be measured with the current function.

Only the capacitor has this unique storage-action. We can use capacitors to perform many functions using this characteristic. However, this storage-action makes capacitors in very high voltage circuits dangerous sources of possible shock or electrocution. Play it safe? You should discharge capacitors before touching them if they use voltages above 50V.

Schematic



Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-85-105-109
- ☐ 4-120
- ☐ 5-41-110
- ☐ 40-106-86
- ☐ 42-118-137
- ☐ 117-138-119

EXPERIMENT #62: TEMPERATURE-SENSITIVE AUDIO OSCILLATOR

Did you know that a transistor changes its characteristics according to the temperature? This project will show you how temperature affects transistor action.

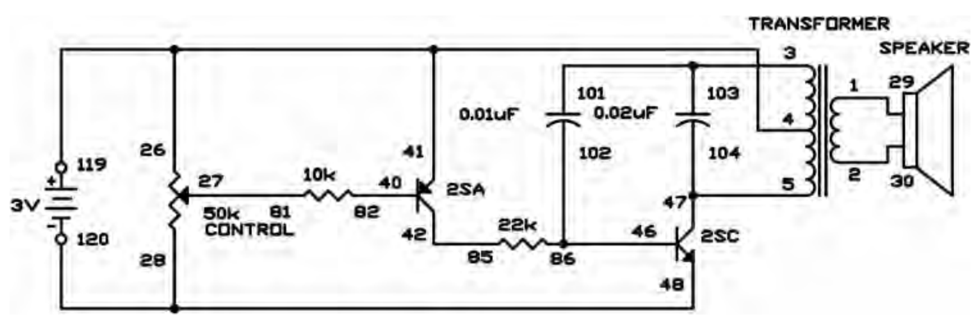
Look at the schematic. The NPN transistor acts as a pulse oscillator. The voltage applied to its base is controlled by the 22kΩ resistor and the PNP transistor. The base current and collector current of the PNP transistor vary with the temperature of the transistor.

Build this project and you will hear a sound from the speaker. Adjust the 50kΩ control so that the sound is low or a series of pulses.

Now warm up the PNP transistor by holding it between your fingers. You hear the tone become higher as the transistor temperature increases.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-101-103
- ☐ 4-26-41-119
- ☐ 5-47-104
- ☐ 27-81
- ☐ 120-28-48
- ☐ 40-82
- ☐ 42-85
- ☐ 46-102-86

EXPERIMENT #63: TWO-TRANSISTOR, DIRECTLY CONNECTED OSCILLATOR

Now we will build an oscillator using two transistors connected directly to each other. As you have seen, there are many ways to make an oscillator. This way is simple compared to some.

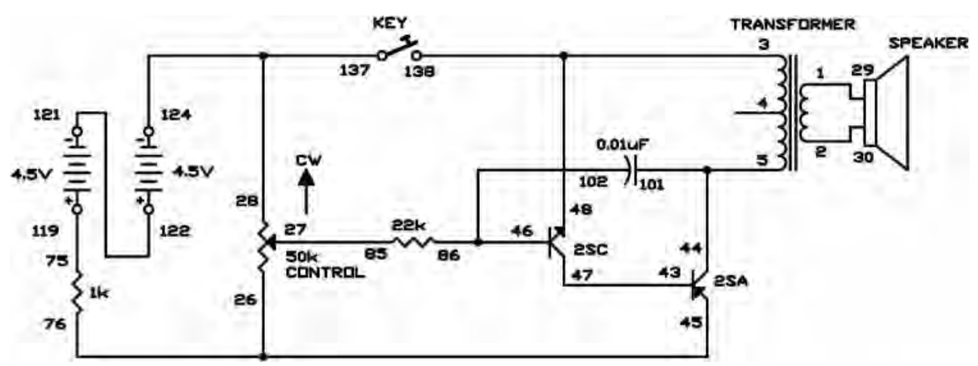
After completing the wiring, press the key. You hear a beep sound from the speaker. Now rotate the control. How does it affect sound?

The two transistors cooperate with each other and act as a single transistor. The NPN transistor amplifies the signal from the 22kΩ resistor and directs it to the PNP transistor, to obtain a greater output.

The capacitor determines the frequency of the oscillation. The project starts with the 0.01μF capacitor in the circuit but you can experiment with different value capacitors. The control adjusts the voltage leading to the base of the NPN transistors. It changes the tonal quality as well as the frequency. You should be sure to record your results like a professional scientist, so you can repeat the experiment later on. Be sure to observe the polarity (+ and –) of the electrolytic capacitors.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-48-138
- ☐ 5-101-44
- ☐ 26-45-76
- ☐ 27-85
- ☐ 28-124-137
- ☐ 46-102-86
- ☐ 47-43
- ☐ 75-119
- ☐ 121-122

EXPERIMENT #64: PUSH/PULL SQUARE WAVE OSCILLATOR

In this project we will make a push/pull, square wave oscillator. This oscillator is called a push/pull because it uses two transistors that are connected to each other. They take turns operating so that while one transistor is "pushing," the other is "pulling." Scientists study waveform patterns to help understand electronic signals – such as the signal produced by the current in this project. A square wave oscillator produces waves that look like squares.

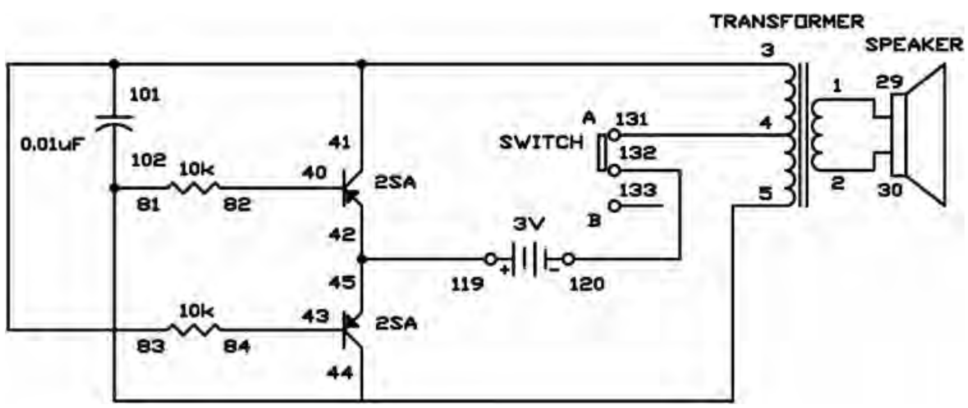
After wiring the circuit, slide the switch to position A to turn on the power. Note the sound from the speaker, because we will be using square wave signals in later projects.

This oscillator circuit works well with low DC voltage supplies. For this reason, scientist and technicians use DC to AC converters and DC to DC inverters with supply voltages of about 0.5 to 12 volts.

Another characteristic of this oscillator is that it makes a maximum use of the transformer. The circuit produces the maximum power for the particular size transformer that is used.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-83-101-41
- ☐ 4-131
- ☐ 5-81-102-44
- ☐ 40-82
- ☐ 45-42-119
- ☐ 43-84
- ☐ 120-132

EXPERIMENT #65: PENCIL LEAD ORGAN

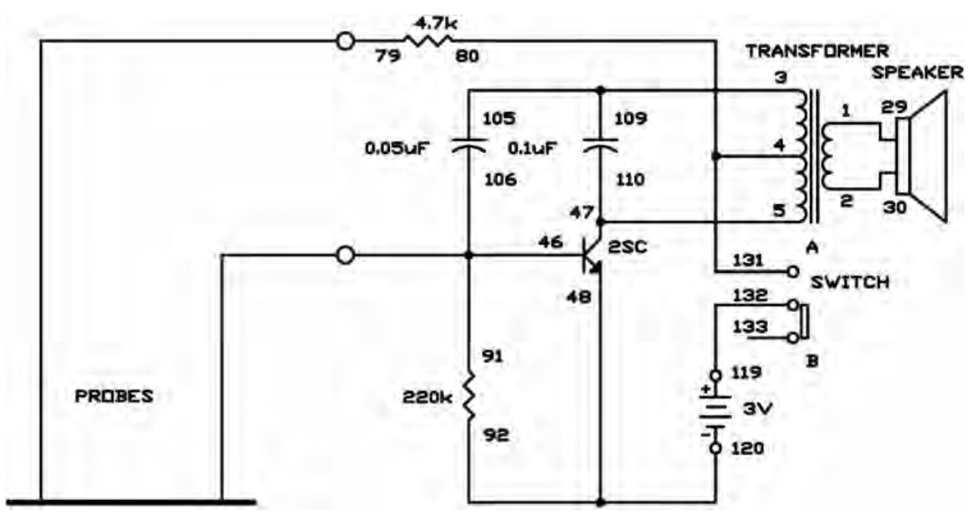
This project is an oscillator that is controlled in an unusual way: with a pencil mark! You have seen in other oscillator projects how changing the circuit's resistance can change the sound that is produced. The resistors, like the ones in your kit, are made of a form of carbon, and so is pencil lead. By causing the current to flow through different amounts of pencil lead, we can vary the resistance and therefore, the tone of the sound coming from the speaker.

After you complete the wiring, make a very heavy pencil mark on a sheet of paper (a soft lead pencil works best). The mark needs to be about an inch wide and 5 to 6 inches long.

Now slide the switch to position A to turn on the power and hold one of the probes to one end of the mark (or attach it with tape). Move the other probe back and forth along the mark. You hear the pitch rise and fall as you move the probe. With a little practice you should be able to play a tune with this organ.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-105-109
- ☐ 4-80-131
- ☐ 5-47-110
- ☐ 92-48-120
- ☐ 119-132
- ☐ 46-106-91-PROBES
- ☐ 79-PROBES

EXPERIMENT #66: LED STROBE LIGHT

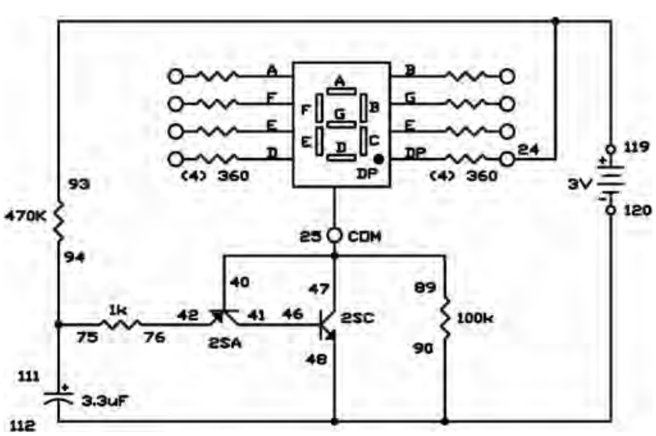
This circuit is an oscillator with a low frequency. So, you can see the LED lighting and turning off. The off time is longer than the on time, so you see short pulses of light with long periods between them. The wiring sequence below will make the decimal point light, but you can light any part of the LED display.

This type of circuit is called a sawtooth wave oscillator. The signal changes as the LED lights and turns off. The waveform of this signal's frequency shows a sawtooth pattern representing the two different voltage values. When the output from the emitter of the PNP transistor supplies the base current to the NPN transistor (as in this circuit), shorter pulses are generated.

Try experimenting by changing the value of the 3.3μF capacitor to 10μF. You can also vary the 1kΩ resistor and change the 470kΩ resistor to 220kΩ. The frequency of this oscillator is controlled by the rate of charge and discharge of the capacitor. So changing its value or the values of the resistors that supply current to the capacitor changes the frequency.

Notes:

Schematic



Wiring Sequence:

- ☐ 47-40-25-89
- ☐ 41-46
- ☐ 42-76
- ☐ 90-112-48-120
- ☐ 75-94-111
- ☐ 93-119-24

EXPERIMENT #67: ELECTRONIC ORGAN

This circuit has a multivibrator connected to a pulse type oscillator. The multivibrator provides a tremolo effect (a wavering tone), rather than turning the oscillator completely on and off.

After you build the project, you can use the control to vary the base current supplied to the NPN transistor. This changes the charge/discharge rate of the 0.1μF and 0.05μF capacitors, and the frequency of the pulse oscillator.

The key works to turn the entire circuit on and off. You can replace it with the slide switch. Also, you can change the tonal range by changing the 10μF and 3.3μF capacitor values.

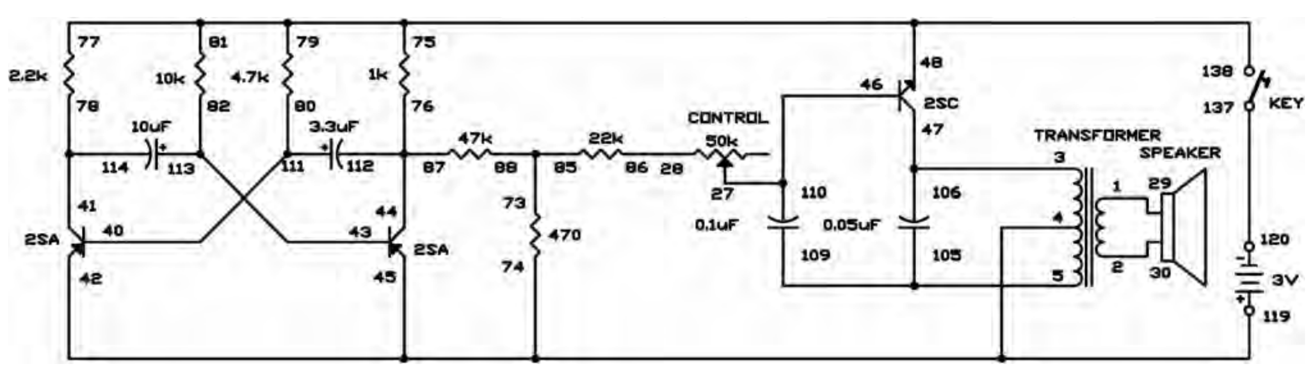
Try using the switch or the key to add extra components to the circuit (like an extra capacitor in parallel with the 10μF or 3.3μF), so you can change from one tonal range to another, quickly. These changes will make a more complete organ from this project. Be sure to keep notes on what you do.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-47-106
- ☐ 4-74-45-42-119
- ☐ 5-105-109
- ☐ 27-46-110
- ☐ 28-86
- ☐ 40-111-80
- ☐ 41-114-78
- ☐ 43-113-82
- ☐ 44-112-87-76
- ☐ 77-75-81-79-48-138
- ☐ 73-85-88
- ☐ 120-137

Schematic



EXPERIMENT #68: DAYLIGHT EARLY BIRD

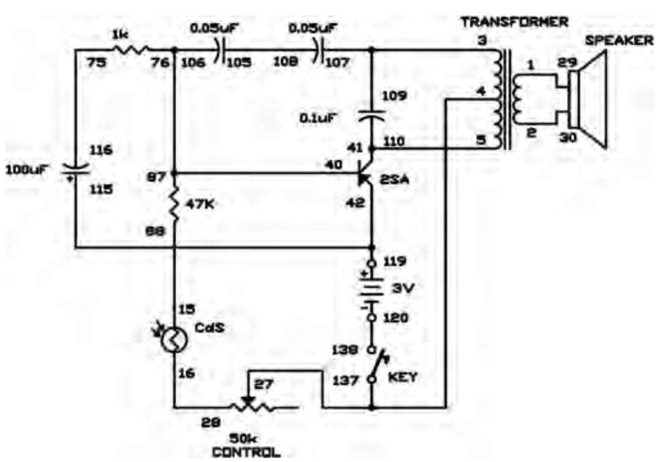
This is the electronic bird circuit that you built for Project 1 (Electronic Woodpecker), but now it has a photoelectric control of the transistor base. You know how the CdS cell works. Since this electronic component is activated by daylight, you can use it as an early bird wake up alarm.

Press the key to make the sound of the early bird. You can adjust the control so that the right amount of light will set off the bird and wake you up in the morning – not too early and not too late.

We have changed only a few component values, and rearranged the circuit schematic from the original electronic bird. See if you can spot the changes and rearrange the circuit so that it looks like Project 1. Use the space below to redraw the schematic.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-107-109
- ☐ 4-27-137
- ☐ 5-41-110
- ☐ 15-88
- ☐ 16-28
- ☐ 76-87-106-40
- ☐ 119-42-115
- ☐ 75-116
- ☐ 105-108
- ☐ 120-138

EXPERIMENT #69: INTERMITTENT ALARM GENERATOR

Now we'll let one oscillator control another to make an effective alarm. In this project we have a multivibrator-type oscillator controlling a pulse oscillator. You should recognize the multivibrator circuit on the left side of the schematic. The pulse oscillator's frequency is in the audible range (20 to 20K Hertz). The multivibrator controls the pulse oscillator by allowing current to flow to the transistor base.

Build the project and press the key to hear the alarm sound coming from the speaker. You hear the alarm sound turning on and off as the pulse oscillator turns on and off.

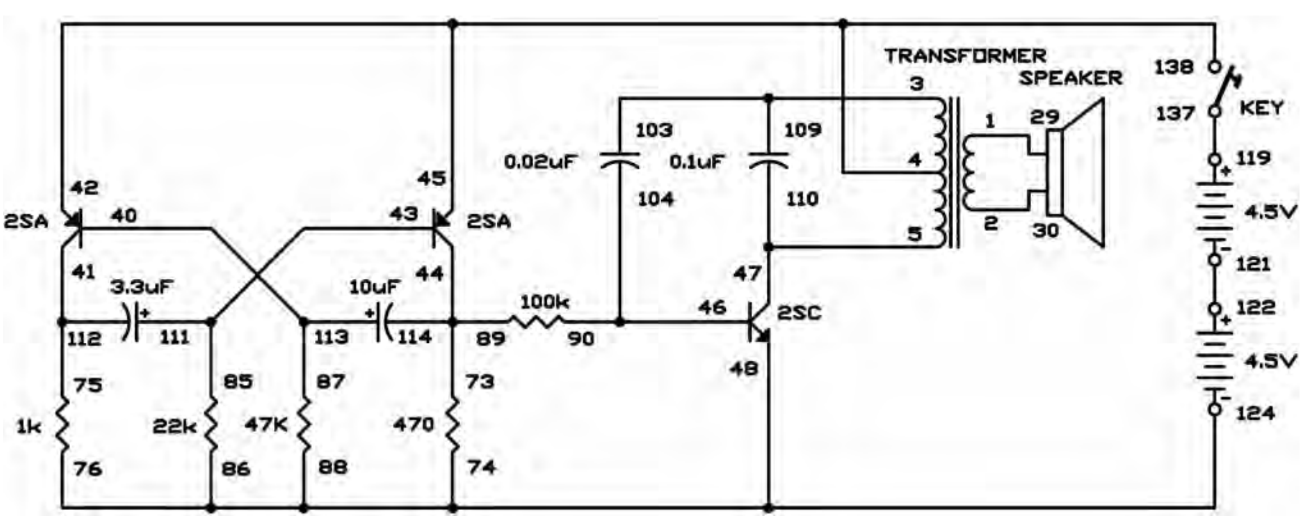
This intermittent sounding alarm is more effective than a continuous tone, because it is more noticeable. You can experiment with this project by varying the values of the 22kΩ, 47kΩ, and 100kΩ resistors, and the 0.02μF capacitor.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-103-109
- ☐ 4-42-45-138
- ☐ 5-47-110
- ☐ 40-113-87
- ☐ 41-112-75
- ☐ 43-111-85
- ☐ 44-114-73-89
- ☐ 46-104-90
- ☐ 76-86-88-74-48-124
- ☐ 119-137
- ☐ 121-122

Schematic



VIII. BASIC OPERATIONAL AMPLIFIER CIRCUITS

EXPERIMENT #70: COMPARATOR

For this section you will need some basic knowledge about the operational amplifier integrated circuit. First, we can use one power source for both the circuit and the IC, or we can use separate power sources.

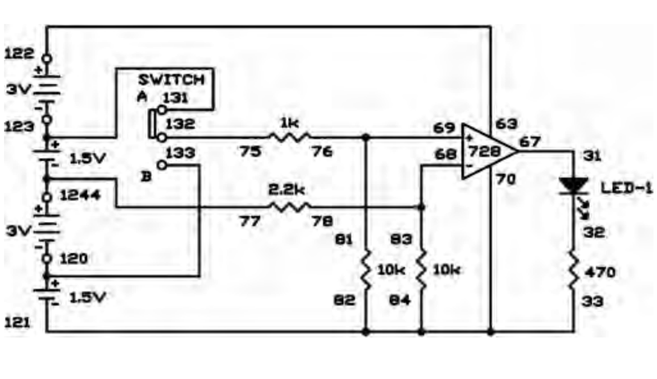
The operational amplifier can be used as a non-inverting amplifier, an inverting amplifier, or a differential amplifier. A non-inverting amplifier reproduces an input signal as an output signal without any change in polarity. An inverting amplifier does the opposite: its output has the reverse polarity of its input. The differential amplifier has an output that is the difference between the strengths of the two input signals.

A comparator compares two voltages and tells you which one is stronger than the other. We call the controlled voltage the reference voltage because we use it as a reference for measuring other voltages. The voltage that is compared is the input voltage.

The reference voltage in this project is about 3.7V. It is connected to terminal 68 of one of the integrated circuits. Input voltage flows to terminal 69 of the same IC. The LED lights if this voltage is higher than the reference voltage, and stays off if it is lower. In this circuit the operational amplifier acts as an inverting amplifier for the reference voltage to keep the LED turned off, or as a non-inverting amplifier to light the LED.

Build the project and then set the switch to position A. This provides an input of 6V. The LED lights because the input voltage is higher than the reference voltage. Now slide the switch to position B. This provides an input voltage of 1.5V. The comparator IC does not let the current pass because the input voltage is now lower than the reference voltage – the LED remains off.

Schematic



Notes:

Wiring Sequence:

- ☐ 31-67
- ☐ 84-82-33-70-121
- ☐ 63-122
- ☐ 68-83-78
- ☐ 69-81-76
- ☐ 75-132
- ☐ 77-119-124
- ☐ 120-133
- ☐ 123-131

EXPERIMENT #71: BASIC INCREASE IN DC VOLTAGE

Now we move along to the simplest experiment on amplifying DC voltage. After you complete the wiring, set the switch to position B.

LEDs 1 and 2 indicate the output voltage of the operational amplifier IC. An LED only lights when it is connected with about 1.5V. In this project, we connect the two LEDs in series, so they only light when connected with about 3V. Now they are off, so the output voltage of the operational amplifier must be less than 3V.

Look at the schematic diagram. With the switch at position B, a 10kΩ resistor is connected in series between each of the battery terminals and the positive (+) input terminal of the operational amplifier. These two 10kΩ resistors divide the 1.5V supply voltage in half. This means the positive input terminal receives an input voltage of only 0.75V.

To calculate the output voltage of the operational amplifier you multiply its input voltage by the amplification factor (R1/R2) + 1. So, the output voltage is 0.75V x ((220kΩ / 100kΩ) + 1) = 2.4V.

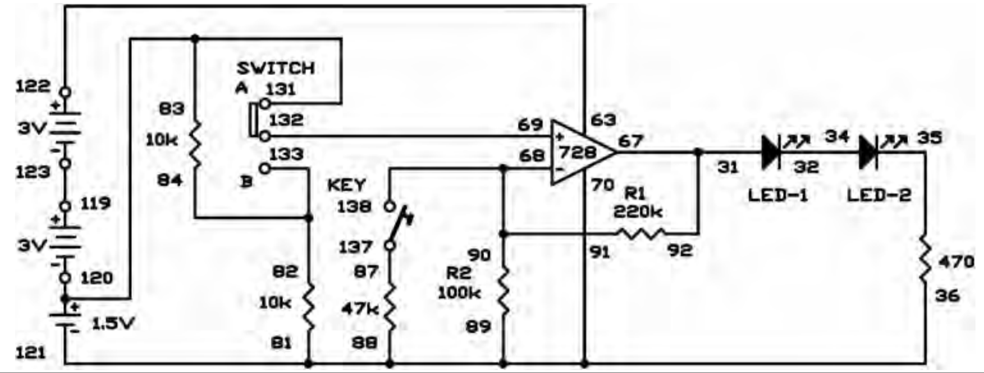
Now, slide the switch position A. This eliminates the 10kΩ resistors from the circuit, so the amplifier's positive input terminal receives the full 1.5V input voltage. Using the above equation, you can see that the output voltage of the operational amplifier is now 1.5V X ((220kΩ / 100kΩ) +1) = 4.8V. The LEDs light dimly because the voltage supplied to them is more than 3V.

Let's change the amplification factor. Slide the switch to position B again and press the key. This adds the 47kΩ resistor to the 100kΩ resistor in parallel, making total resistance of R2 about 32kΩ. (Do you remember how to calculate the total resistance for parallel connection from Project 17 ("Resistors in Series and Parallel")). Now the output voltage is 0.75V x ((220kΩ / 32kΩ) +1) = 5.9V, enough to light the LEDs.

If you slide the switch to position A again and press the key to connect 1.5V to the amplifier's positive (+) input terminal, the LEDs light brightly. Try to calculate the value of the output voltage with the switch at position A with the key pressed.

Notes:

Schematic



Wiring Sequence:

- ☐ 31-67-92
- ☐ 32-34
- ☐ 81-89-88-70-36-121
- ☐ 63-122
- ☐ 68-90-91-138
- ☐ 69-132
- ☐ 82-84-133
- ☐ 83-131-120
- ☐ 87-137
- ☐ 119-124

EXPERIMENT #72: CONSTANT-CURRENT SOURCE

In this project, we will make a constant current circuit, using an operational amplifier and a transistor. This circuit maintains a constant current even when the source voltage changes, because more energy is used up in the circuit.

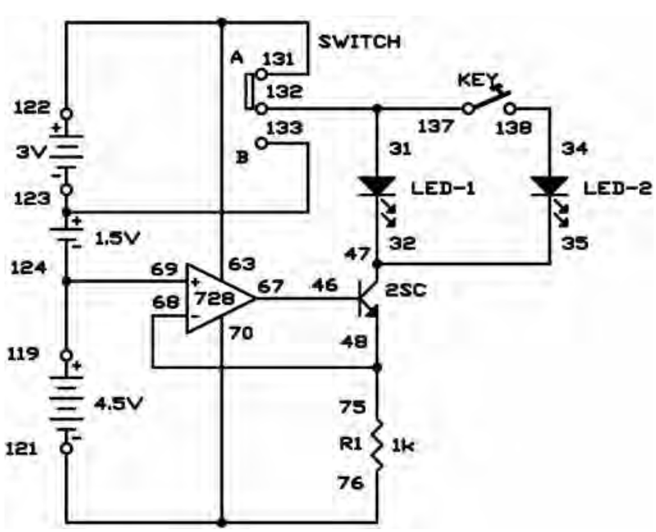
Look at the schematic. When the current changes, the voltage transmitted through R1 changes. The output of the operational amplifier changes according to the feedback signal from R1. This output from the amplifier controls the base voltage of transistor Q1 allowing it to maintain the constant current.

Let's get to the experiment. First set the switch to position A, and press the key while watching LED 1. It is dimmer when the key is closed. This is because both LED 1 and LED 2 are in the circuit when the key is closed. The load – the amount of energy used by the LEDs in this circuit – increases, but the current remains constant. So the LED becomes dimmer.

Now, set the switch to position B with the key off. Do you see any change in LED brightness from position A to position B? Setting the switch to B changes the supply voltage from 9V to 6V. But the current remains constant again, so the LED brightness does not change.

Notes:

Schematic



Wiring Sequence:

- ☐ 31-132-137
- ☐ 32-35-47
- ☐ 34-138
- ☐ 46-67
- ☐ 48-68-75
- ☐ 63-131-122
- ☐ 69-119-124
- ☐ 76-70-121
- ☐ 123-133

EXPERIMENT #73: INTEGRATING CIRCUIT

You know that an LED instantly lights when you turn it on. But you can also light it up gradually. In this project, you'll be able to watch the LEDs slowly get brighter while you hold down the key.

This circuit is called a Miller integrating circuit. The output of this IC increases as its input increases. The integrating circuit increases the value of capacitor CA past the stated 100μF. When you press the key, the capacitor charges slowly through resistor R and the LEDs become brighter. Setting the switch to position B discharges the capacitor and turns the LEDs off.

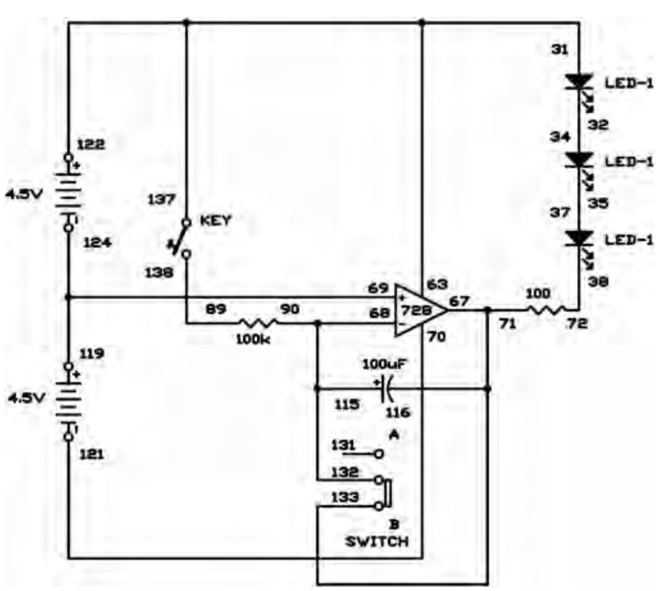
Set the switch to position B before completing the project to discharge the capacitor. Set the switch to position B and hold the key down to see LEDs 1, 2, and 3 become brighter. They reach maximum brightness in about 5 seconds. Set the switch to B to discharge the capacitor and then hold down the key to repeat the experiment.

Notes:

Wiring Sequence:

- ☐ 31-63-122-137
- ☐ 32-34
- ☐ 35-37
- ☐ 38-72
- ☐ 71-67-116-133
- ☐ 68-90-115-132
- ☐ 69-124-119
- ☐ 70-121
- ☐ 89-138

Schematic



EXPERIMENT #74: SCHMITT TRIGGER CIRCUIT

We're going to use the operational amplifier as a Schmitt trigger circuit and as a comparator. The operational amplifier produces a signal as long as its input voltage exceeds a certain value. Look at the schematic: can you see how it works? It shows that the voltage level that causes the output to turn on is higher then the voltage level that stops the output. It looks like the Schmitt trigger circuit resists changing the output state. We call such operation as "hysteresis loop."

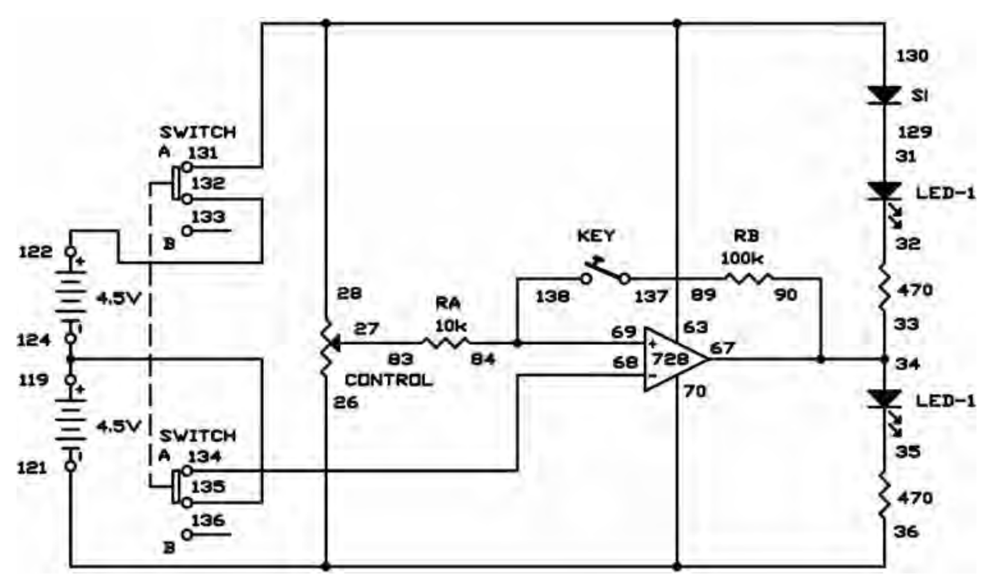
Now, let's get to the experiment. First leave the key off. The operational amplifier works as a comparator in this state. When you rotate the control, LEDs 1 and 2 take turns lighting at some point. Note that this point doesn't change whether you turn the control clockwise or counterclockwise.

Now, press the key on, and you'll have a Schmitt trigger circuit that produces hysteresis loops, as shown in Figure 1.

The width of hysteresis becomes narrower as the RB/RA increases. Notice how the width changes when using different values for RA and RB.

Notes:

Schematic



Wiring Sequence:

- ☐ 70-36-26-121
- ☐ 27-83
- ☐ 63-28-130-131
- ☐ 34-33-67-90
- ☐ 68-134
- ☐ 84-69-138
- ☐ 89-137
- ☐ 119-124-135
- ☐ 122-132
- ☐ 31-129

EXPERIMENT #75: NON-INVERTING TWO-POWER SUPPLY AMPLIFIER

In this project, we will make a microphone amplifier, using the operational amplifier as a non-inverting amplifier with two power sources. The earphone works as a microphone.

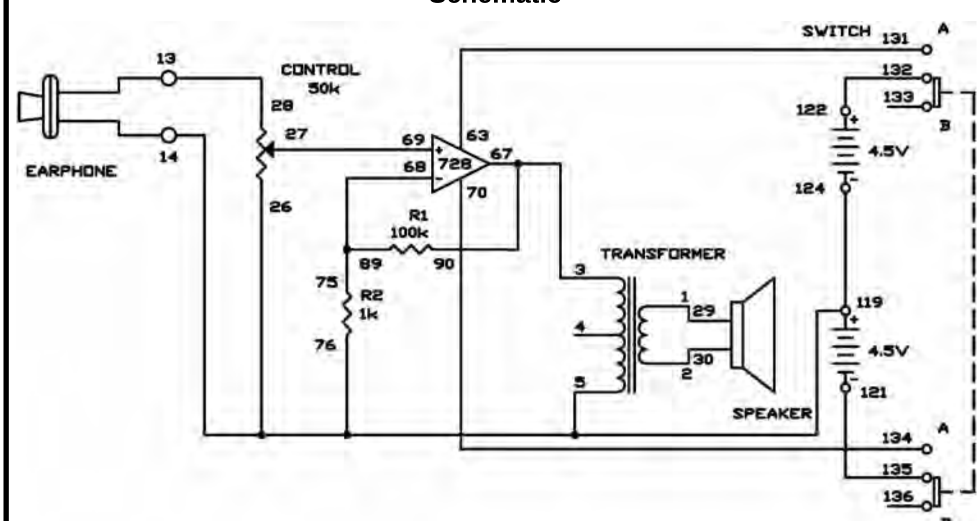
Start by sliding the switch to position B and completing the wiring for the circuit. When you finish connecting the wires, set the switch to position A to turn on the power, rotate the control fully clockwise, and lightly tap your microphone – the earphone. The tapping sound comes through the speaker.

When you use the earphone as a microphone, as in this project, it's better to remove the end that you put in your ear. You can unscrew it by turning it counter-clockwise. Turning the control adjusts the volume.

As you can see in the schematic, the dual operational amplifier uses two power sources: 4.5V for the circuit and 9V for the IC. Note that the dual operational amplifier has two input terminals, the positive (+) and negative (–) terminals 69 and 68. The non-inverting input is applied to the positive (+) terminal. The gain in strength of the signal through this amplifier is about 100 – determined with the formula R1/R2. Thus 100k/1k = a gain of 1.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-67-90
- ☐ 27-69
- ☐ 63-131
- ☐ 68-89-75
- ☐ 70-134
- ☐ 121-135
- ☐ 122-132
- ☐ 124-119-26-76-5-14-EARPHONE
- ☐ 28-13-EARPHONE

EXPERIMENT #76: INVERTING TWO-POWER SUPPLY AMPLIFIER

Here's another two-power source microphone amplifier, but this one is an inverting amplifier. We use the earphone as a microphone again.

Slide the switch to position B and assemble the circuit. When you finish the wiring, slide the switch to position A to turn the power on, rotate the control clockwise, and speak into the microphone – the earphone. You will find that the project works just like our last project.

IC 1 used as a buffer of gain 1, and IC 2 as an inverting amplifier. Input reaches this inverting amplifier through its negative (–) terminal, not the positive (+) one as in our last project. Its gain is about 100, as determined by: R1/R2 = 100k/1k.

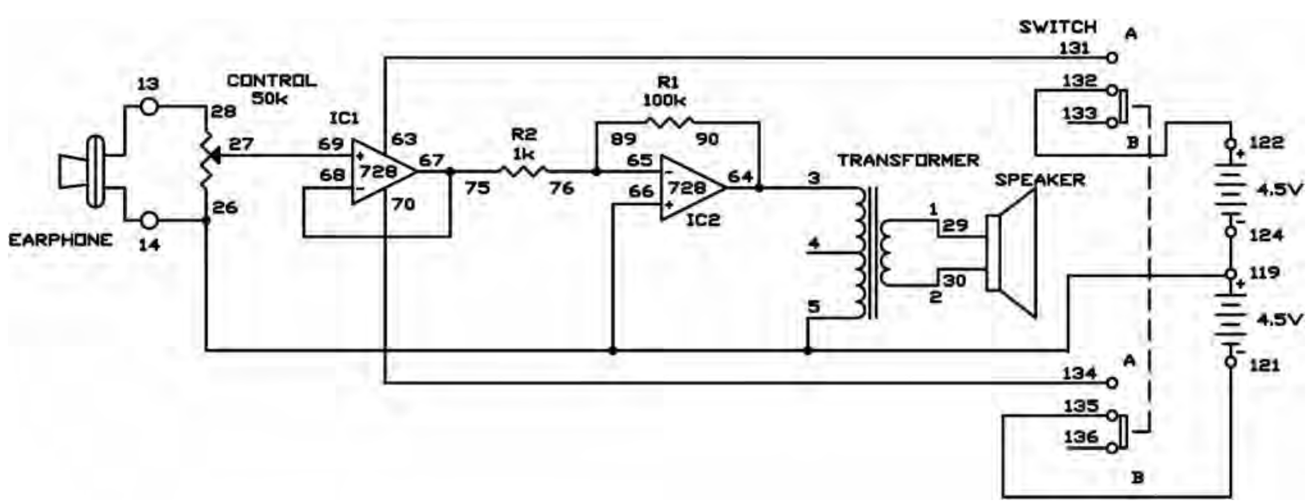
The gain becomes larger if you increase R1 or decrease R2. See what happens to the gain when you change the value of R2 to 470.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-64-90
- ☐ 27-69
- ☐ 63-131
- ☐ 65-89-76
- ☐ 68-67-75
- ☐ 70-134
- ☐ 121-135
- ☐ 122-132
- ☐ 124-119-26-66-5-14-EARPHONE
- ☐ 28-13-EARPHONE

Schematic



EXPERIMENT #77: NON-INVERTING SINGLE-POWER SUPPLY AMPLIFIER

In Projects 75 and 76 ("Non-inverting Two-Power Supply Amplifier," and "Inverting Two-Power Amplifier," respectively), we used the operational amplifier with two power sources. In this project, we will make a single-power source, non-inverting microphone amplifier. Again, the earphone works as a microphone.

Slide the switch to position B and assemble the circuit. When you finish the wiring, slide the switch to position A to turn on the power, rotate the control clockwise, and speak into the microphone. The project works just like Projects 75 and 76, but you'll notice something different.

The difference comes from the gain of this microphone amplifier. It is still determined by R1 and R2, but now it's much larger. Can you see why? Yes, we use the 100kΩ resistor in place of the 1kΩ resistor from the last two projects. Try changing R2 to 1kΩ, and the gain drops to the level of the last projects.

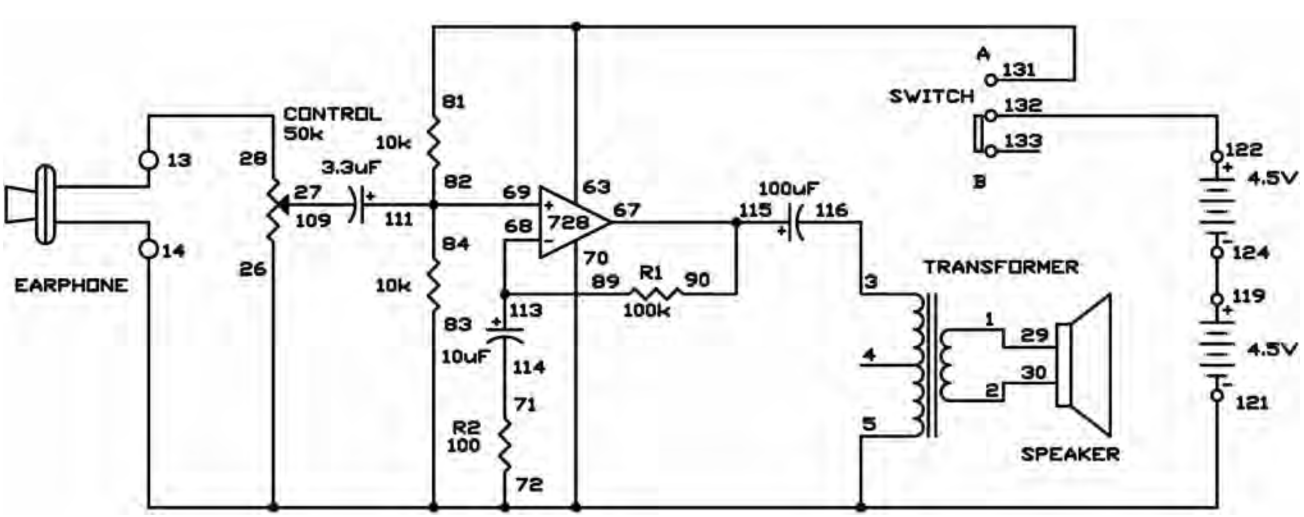
In this project, two power sources are connected in series to operate the dual operational amplifier at 9V. But the operational amplifier can work at half this voltage, at a 4.5V. See what happens when you disconnect the operational amplifier from battery terminal 122 and connect it to terminal 119.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-116
- ☐ 27-112
- ☐ 71-114
- ☐ 81-63-131
- ☐ 67-90-115
- ☐ 89-68-113
- ☐ 84-82-69-111
- ☐ 119-124
- ☐ 122-132
- ☐ 121-26-70-83-72-5-14-EARPHONE
- ☐ 28-13-EARPHONE

Schematic



EXPERIMENT #78: TWO-POWER SUPPLY DIFFERENTIAL AMPLIFIER

This is the last in the series of microphone amplifiers. Now we use the operational amplifier as a differential amplifier. It is a two-power source type amplifier, and this time we use the speaker as a microphone.

Slide the switch to position B and assemble the circuit. When you finish the wiring, apply the earphone to your ear, slide the switch to position A to turn on the power, and tap the speaker lightly with your finger. Can you hear the tapping sound from the earphone?

The dual operational amplifier works as a differential amplifier when two inputs are applied at the same time to its positive (+) and negative (–) terminals. The transformer plays an important role in this amplifier circuit. Its two different outputs from terminals 3 and 5 supply the opposite inputs for terminals 68 and 69.

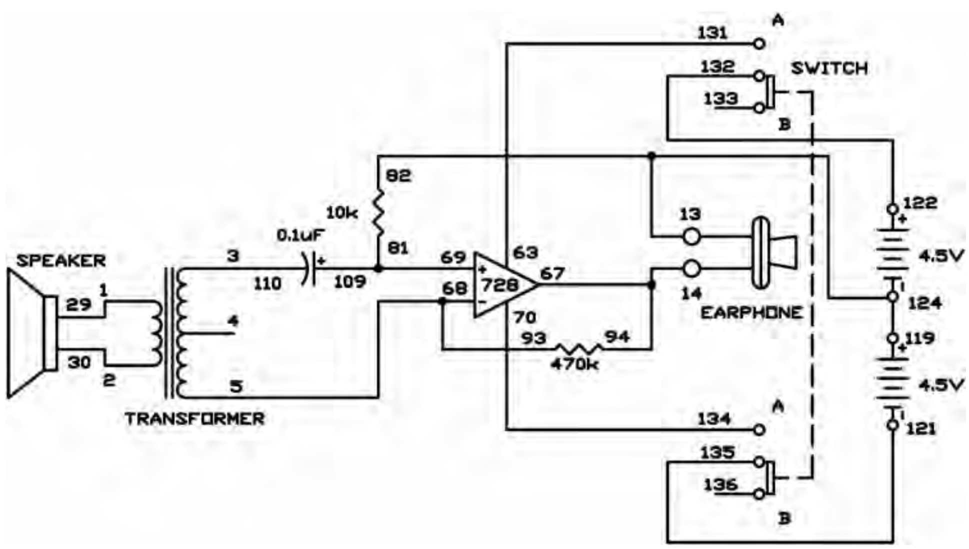
You should remember that the speaker has a coil and a magnet inside. When used as a normal speaker, electricity flows through the coil, and a magnetic field is created around the coil. The magnet attracts or repulses the coil depending on the magnetic field created by the coil. So the coil moves; this movement is transferred to the cone paper attached to it and this creates the sound you hear.

Here, the speaker is used as a microphone, so the opposite takes place. When sound makes the coil move, the distance from the magnet changes, and the strength of the magnetic field changes so that the voltage appears at both ends of the coil. This small voltage is applied to the primary of the transformer, which then results in larger voltage at the secondary side of the transformer.

So using the microphone simplifies the circuit. In order to use the earphone as in previous projects, we would need to make a far more complex circuit.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-110
- ☐ 5-68-93
- ☐ 63-131
- ☐ 69-81-109
- ☐ 70-134
- ☐ 121-135
- ☐ 122-132
- ☐ 124-119-82-13-EARPHONE
- ☐ 94-67-14-EARPHONE

EXPERIMENT #79: TONE MIXING AMPLIFIER

How about building a tone mixing amplifier that mixes two tones together? There are many different kinds of tone mixing circuits, but the operational amplifier is considered one of the best.

After completing the wiring, slide the switch to position A to turn on the power. Note the tone of the sound that is produced. Now press the key to mix this tone with another. You can change the two separate tones by changing the values for the two 10kΩ resistors.

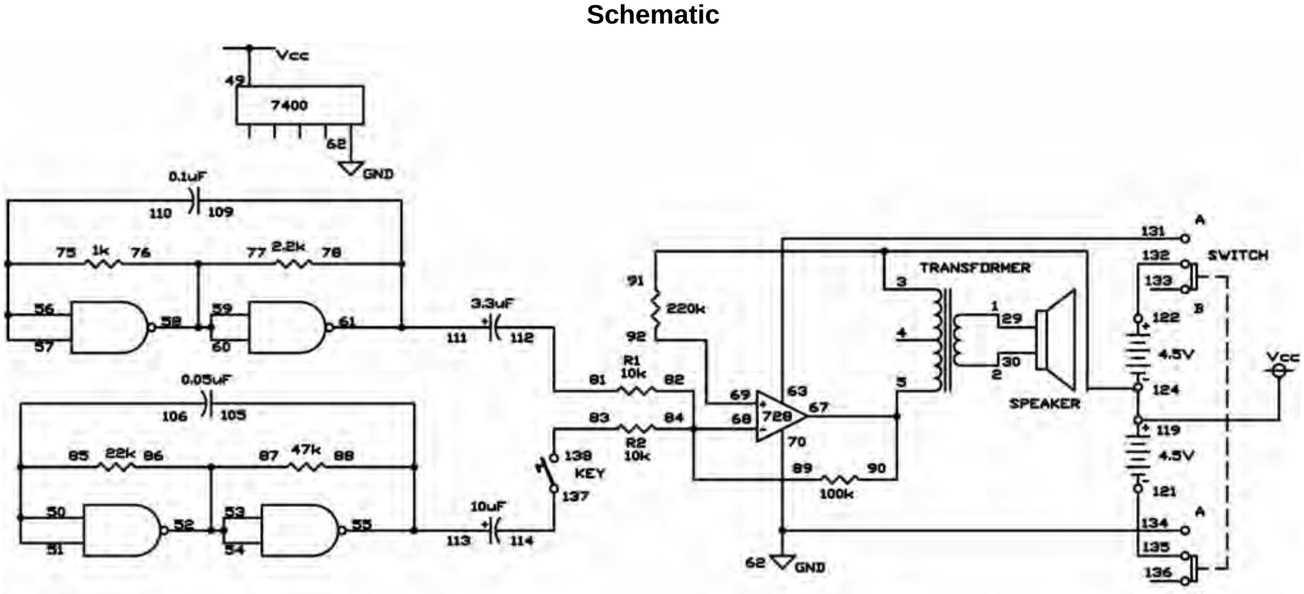
Thus, the tone mixing amplifier allows you to mix two tones together by changing resistances with no need to change the other circuits.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-49-91-119-124
- ☐ 5-67-90
- ☐ 50-51-85-106
- ☐ 52-53-54-87-86
- ☐ 55-88-105-113
- ☐ 56-57-75-110
- ☐ 58-59-60-76-77
- ☐ 78-61-109-111
- ☐ 62-70-134
- ☐ 63-131
- ☐ 68-82-84-89
- ☐ 69-92
- ☐ 81-112
- ☐ 83-138
- ☐ 114-137
- ☐ 121-135
- ☐ 122-132

Schematic



EXPERIMENT #80: POWER AMPLIFIER USING OPERATIONAL AMPLIFIER

Now we're going to produce a loud sound by combining the operational amplifier with two transistors. After you complete the wiring, set the switch to position A to turn on the power. When you press the key, you hear a loud sound from the speaker.

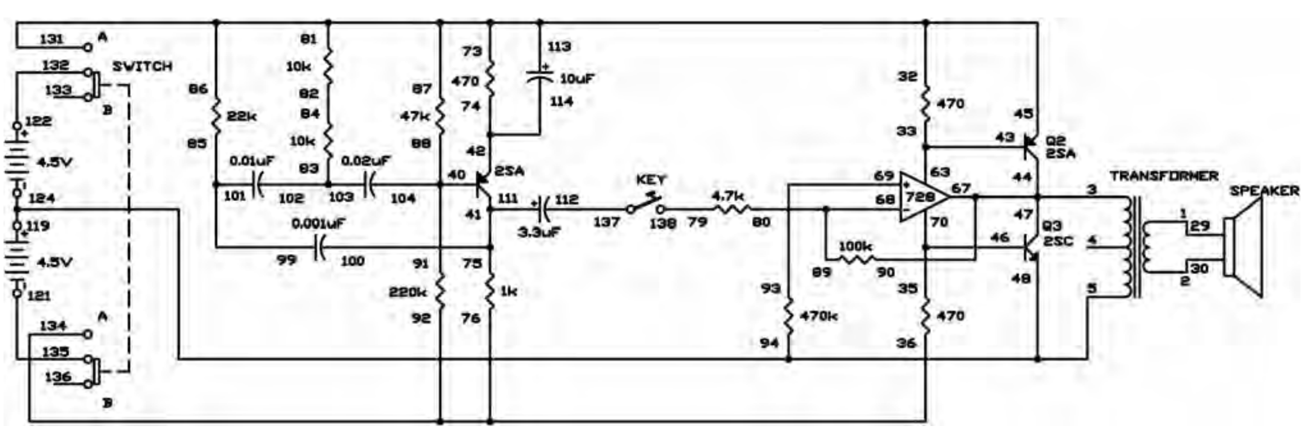
The signal source for this sound is a capacitor-resistor oscillator. The operational amplifier acts as an inverting amplifier, and transistors Q2 and Q3 cause the speaker to produce the sound. This circuit is called a single ended push-pull circuit (SEPP). You have learned about push-pull circuits. Single ended means the circuit has only one output. Most amplifiers have a second output that is connected to the negative (–) side of the battery.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-90-67-47-44
- ☐ 5-94-48-119-124
- ☐ 73-81-86-87-32-113-45-131
- ☐ 33-63-43
- ☐ 35-46-70
- ☐ 76-92-36-134
- ☐ 91-88-104-40
- ☐ 75-100-111-41
- ☐ 74-114-42
- ☐ 68-80-89
- ☐ 69-93
- ☐ 79-138
- ☐ 82-84
- ☐ 83-102-103
- ☐ 85-99-101
- ☐ 112-137
- ☐ 121-135
- ☐ 122-132

Schematic



EXPERIMENT #81: VOLTAGE CONTROLLED OSCILLATOR CIRCUIT

VCO? What's that? VCO stands for voltage controlled oscillator, and as the name implies, this oscillator changes its oscillation frequency according to the voltage applied to the circuit. The circuit produces two different output signals that have triangular and square waves.

When you complete the wiring sequence, slide the switch to position A to turn on the power. Turn the control slowly while you listen to the sound from the earphone. When you turn the control clockwise, the sound becomes lower.

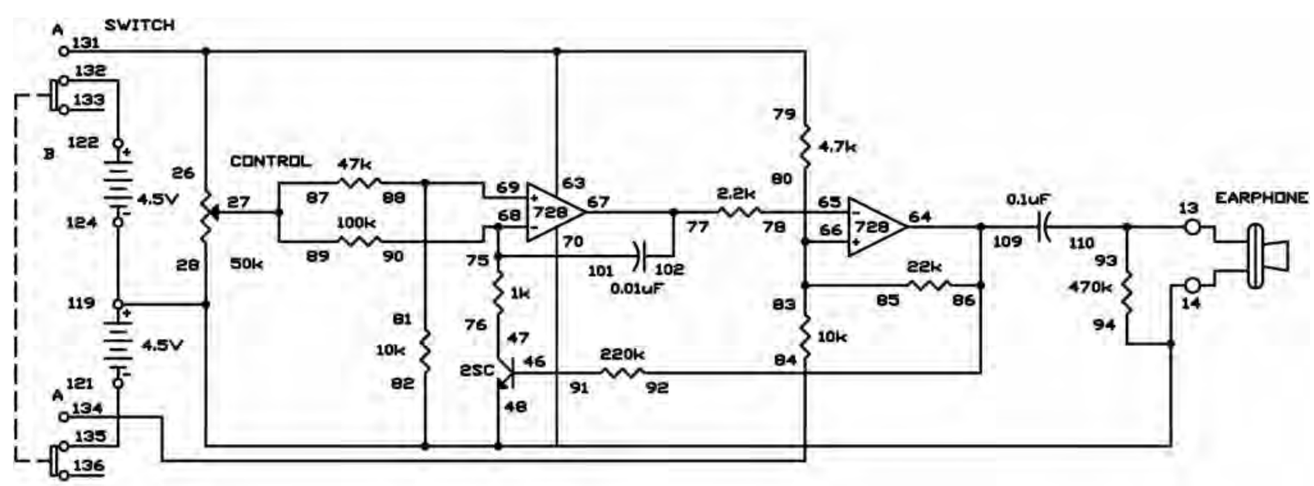
When the voltage through terminal 27 of the control changes, the 0.01μF capacitor's charging / discharging time also changes, causing a change in the frequency of the oscillator. Current that shows a triangular wave travels from terminal 67 of the first operational amplifier to terminal 65 of the second amplifier which acts as a comparator. The comparator releases output from terminal 64 - current that shows a square wave.

Notes:

Wiring Sequence:

- ☐ 79-63-26-131
- ☐ 27-87-89
- ☐ 46-91
- ☐ 47-76
- ☐ 86-92-109-64
- ☐ 65-78
- ☐ 66-80-83-85
- ☐ 67-102-77
- ☐ 68-90-101-75
- ☐ 69-88-81
- ☐ 84-70-134
- ☐ 121-135
- ☐ 122-132
- ☐ 124-119-28-48-94-82-14-EARPHONE
- ☐ 110-93-13-EARPHONE

Schematic



EXPERIMENT #82: OPERATIONAL AMPLIFIER BUZZER

The dual operational amplifier works well as an oscillator. In this project, we will build an electric buzzer that makes a continuous beep. You can change the tone of this buzzer by rotating the control.

When you complete the wiring, set the control to the 12 o'clock position and press the key. You hear a continuous beep from the speaker. Now turn the control while pressing the key. The tone of the buzzer changes.

The electronic buzzer only makes a beep, but it can be used for many different purposes as you'll see later.

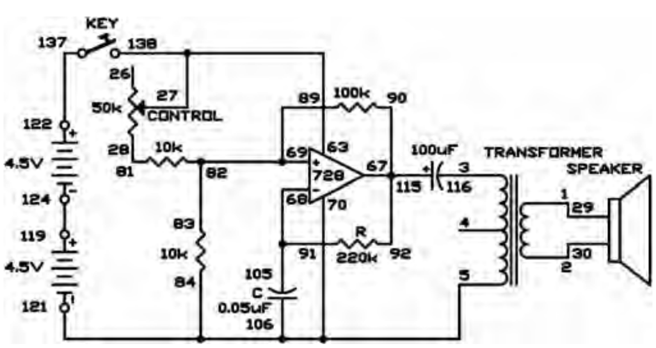
The oscillating circuit of this buzzer is an astable multivibrator and works as an oscillator producing current that shows a square wave. Changing the control changes the tone of the sound because it changes the frequency of the signal. The frequency is determined by the resistance from the battery input (+) and the resistance from the capacitor that is connected to the (–) battery terminal. Test to find out how the tone changes when you set the value of the capacitor to 0.02µF or 0.1µF.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-116
- ☐ 5-84-70-106-121
- ☐ 63-27-138
- ☐ 28-81
- ☐ 67-90-92-115
- ☐ 91-68-105
- ☐ 69-82-83-89
- ☐ 119-124
- ☐ 122-137

Schematic



EXPERIMENT #83: BURGLAR ALARM

This burglar alarm makes a buzzing sound when anyone sneaking into your house trips over a wire and breaks it off or disconnects it from a terminal. Instead of stretching out the wire, try to figure out how to connect a switch to the door of your house, so that the alarm sounds when a burglar opens the door.

Start by sliding the switch to position B and assembling the circuit. When you finish the wiring, connect the terminals 13 and 14 to the long wire, and slide the switch to position A to turn on the power. At this time, no sound comes from the speaker.

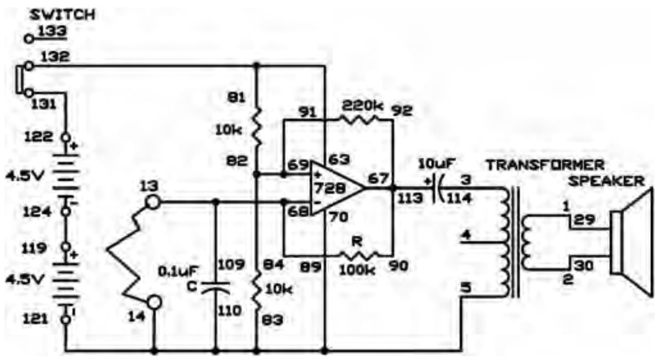
To test the alarm, detach the wire from terminal 13. The speaker gives out a beep. This beep is the alarm that tells you a burglar is about the break into your house.

As you can see in the schematic, this burglar alarm uses the dual operational amplifier as an astable multivibrator, as the electronic buzzer in the last project did. You can change its frequency by using different values for the 10kΩ resistor and the 0.1μF capacitor. Note how the tone of the buzzer changes when you set the 10kΩ resistor to 47kΩ or switch the 100kΩ and 220kΩ resistors with each other.

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-114
- ☐ 5-14-83-70-110-121
- ☐ 13-89-68109
- ☐ 81-63-132
- ☐ 67-90-92-113
- ☐ 69-82-84-91
- ☐ 119-124
- ☐ 122-131
- ☐ 13-14 (LONG WIRE)

Schematic



Notes:

EXPERIMENT #84: HAND OPERATED SWEEP OSCILLATOR

The electronic buzzer we built in project 82 can only make a continuous beep, but we can make a similar circuit that produces various siren sounds.

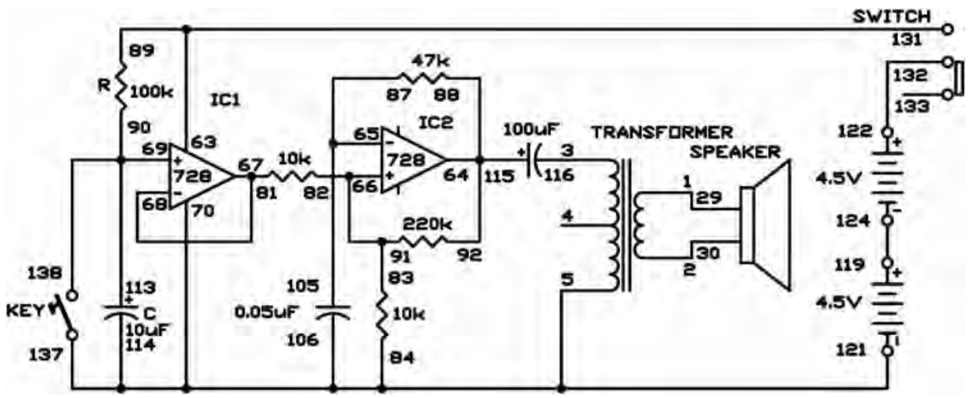
Now we're going to make a siren that gives out a sound with a variable pitch. When you move the switch, this siren wails and then makes a continuous high-pitched noise.

Slide the switch to position B and assemble the circuit. When you finish the wiring, turn the power on by sliding the switch to position A. You hear the speaker give out a sudden, roaring siren sound. The sound is low at first and becomes higher, then changes to a steady tone in about 3 to 4 seconds. When you press the key and release it, the capacitor discharges and starts the siren sound again.

Refer to the schematic. IC 1 works as a buffer and IC 2 as an astable multivibrator. The pitch changes when the 100kΩ resistor increases the voltage applied to the 10µF capacitor.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-116
- ☐ 5-84-70-106-114-137-121
- ☐ 89-63-131
- ☐ 64-88-92-115
- ☐ 65-87-105
- ☐ 66-82-83-91
- ☐ 68-67-81
- ☐ 90-69-113-138
- ☐ 119-124
- ☐ 122-132

EXPERIMENT #85: FALLING BOMB SOUND

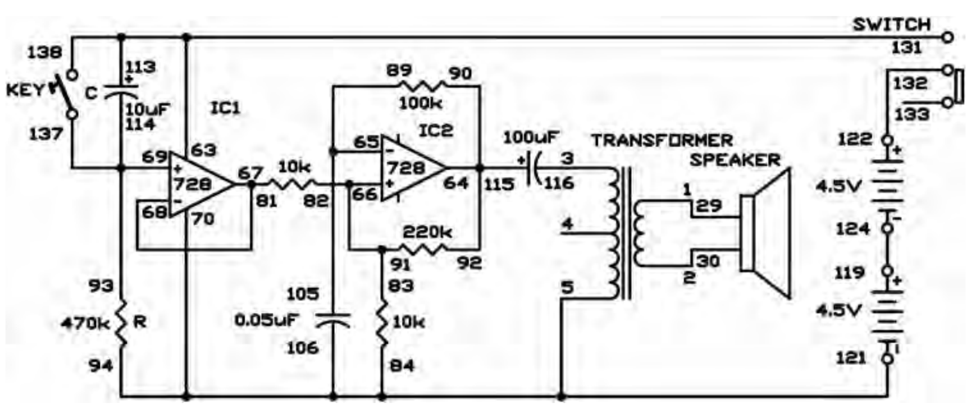
Here's another siren that changes its pitch. The siren we built in our last project changes pitch from low to high, but this one changes its pitch from high to low and finally stops making any sound. When it stops, press the key and the siren sound will start again.

Set the switch to position B and assemble the circuit. When you complete the wiring, slide the switch to position A to turn on the power. You hear a high-pitched siren sound that becomes progressively lower. Press the key to start the sound again.

Like the siren in our last project, this siren uses IC 1 as a buffer and IC 2 as an astable multivibrator. The capacitor C and the resistor R change the pitch of the siren sound. The pitch changes slowly when you increase the values of C and R, and it changes quickly when you decrease their values. Use the 3.3μF capacitor for C and notice how the pitch changes.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-116
- ☐ 5-84-94-106-70-121
- ☐ 63-113-131-138
- ☐ 64-90-92-115
- ☐ 65-105-89
- ☐ 66-82-83-91
- ☐ 68-67-81
- ☐ 93-69-114-137
- ☐ 119-124
- ☐ 122-132

EXPERIMENT #86: EMERGENCY SIREN

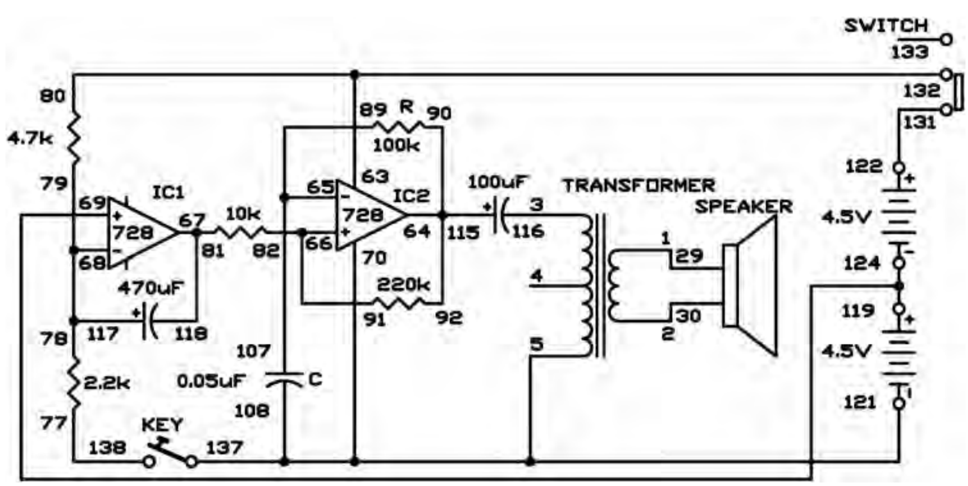
The sirens we built in Projects 84 and 85 (“Hand-Operated Sweep Oscillator” and “Falling Bomb Sound”, respectively) change pitch only in one direction, but this one makes a low sound that becomes higher, and goes back to its original low sound. The siren sounds only once when you press the key.

Assemble the circuit after setting the switch to position B. Turn on the siren by sliding the switch to position A. When you press the key, the siren starts over at the original low pitch. Do you hear the siren sound change pitch as you expected? IC 1 is an oscillator that produces current that forms a triangular wave, so when you press the key, it produces a triangular wave output. Then the output is sent to IC 2 which acts as an astable multivibrator.

In projects 84, 85, and 86, the astable multivibrator produces the siren sound and the pitch changes according to the values of R and C. Find out how the pitch changes when you set C to 0.02μF and then to 0.1μF.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-116
- ☐ 5-70-108-137-121
- ☐ 80-63-132
- ☐ 64-90-92-115
- ☐ 65-89-107
- ☐ 66-82-91
- ☐ 81-67-118
- ☐ 78-79-68-117
- ☐ 69-119-124
- ☐ 77-138
- ☐ 122-131

EXPERIMENT #87: FIRST AID SIREN

The sirens we built in Projects 84, 85, and 86 (Hand-Operated Sweep Oscillator", "Falling Bomb Sound", and "Emergency Siren", respectively) change the pitch of their sounds smoothly between low and high, but this siren is a little different. It gives off alternating high and low sounds.

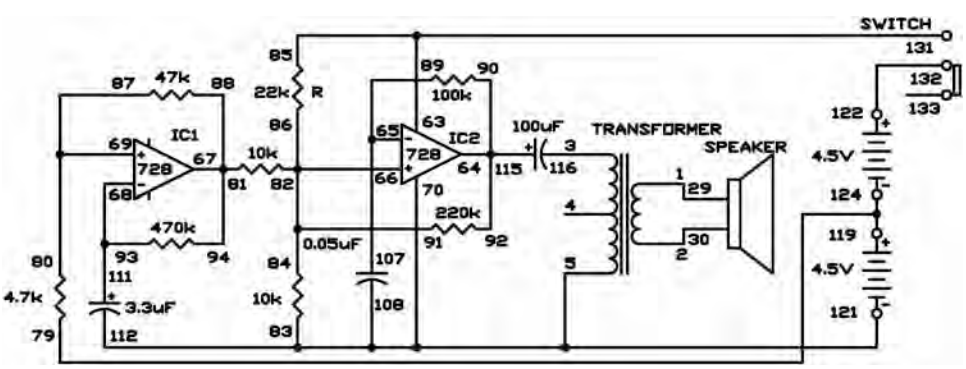
Slide the switch to position B and assemble the circuit. After you finish the wiring and slide the switch to position A, the power turns on and the speaker makes the sound of a two-pitch siren.

This siren is made up of two astable multivibrators. IC 2 provides the normal beep sound that we heard in Project 82 ("Operational Amplifier Buzzer"), and IC 1 produces the signal that changes the pitch of its sound at regular intervals.

Let's perform a small experiment now. Detach the 22kΩ resistor, and you find that the siren gives out an intermittent beep instead of the two-pitch sound. Can you figure out why? Yes, IC 1 interrupts the siren sound produced by IC 2.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-116
- ☐ 5-83-70-108-112-121
- ☐ 85-63-131
- ☐ 64-90-92-115
- ☐ 65-107-89
- ☐ 66-82-84-86-91
- ☐ 81-94-88-67
- ☐ 93-68-111
- ☐ 69-80-87
- ☐ 79-119-124
- ☐ 122-132

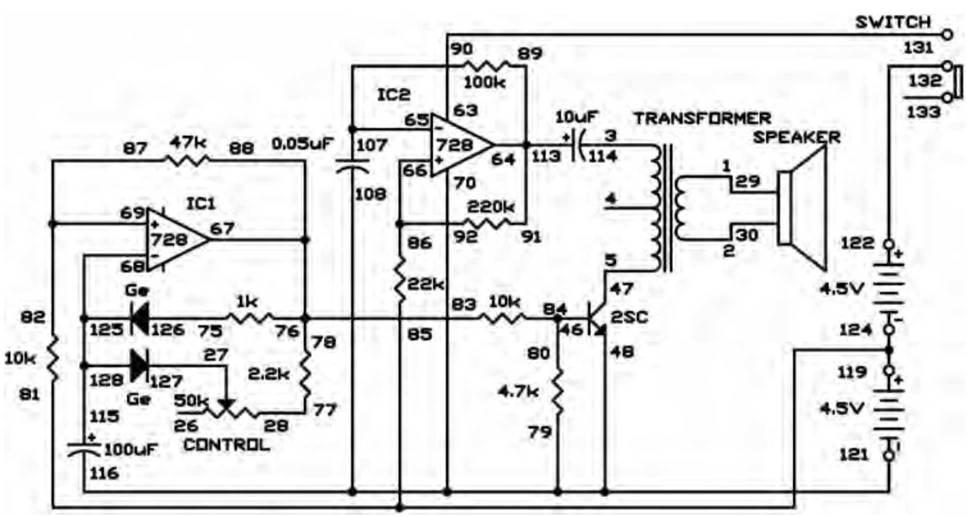
EXPERIMENT #88: MUSICAL TEMPO GENERATOR

Here's the operational amplifier version of the electronic metronome from Project 9 ("Electronic Metronome"). Slide the switch to position B, and connect the wires carefully - this project is much more complicated than most of the others. When you finish assembling the circuit, set the control to the 12 o'clock position and slide the switch to position A to turn on the power. You'll hear a pip sound from the speaker at fixed intervals. Now slowly rotate the control clockwise, and the beats come faster.

Now take a look at the schematic. IC 1 and IC 2 are used as astable multivibrators, as in our last project. But you'll notice that IC 1 uses diodes to generate short pulses and the control is used to adjust the speed of the pulses. The transistor turns on each time a pulse is generated, and produces a sound.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-114
- ☐ 5-47
- ☐ 27-127
- ☐ 28-77
- ☐ 46-80-84
- ☐ 79-70-108-116-48-121
- ☐ 63-131
- ☐ 89-91-113-64
- ☐ 65-90-107
- ☐ 86-92-66
- ☐ 78-76-83-88-67
- ☐ 68-115-125-128
- ☐ 82-87-69
- ☐ 75-126
- ☐ 85-81-119-124
- ☐ 122-132

EXPERIMENT #89: OPERATIONAL AMPLIFIER WINKING LED

Now we're going to make a winking LED circuit using a dual operational amplifier. In this circuit, an LED continues to light and turn off slowly.

Slide the switch to position B and connect the wires for this circuit. When you finish assembling the project, slide the switch to position A to turn on the power. After a few seconds, you'll see the LED start to blink. Watch carefully and you should be able to see that its on and off periods are about equal.

The dual operational amplifier works as an astable multivibrator of a low frequency. You can change the period of oscillation, that is, the LED blinking rate, by using different values for R and C. See what happens to the blinking rate when you change the value of R to 220kΩ.

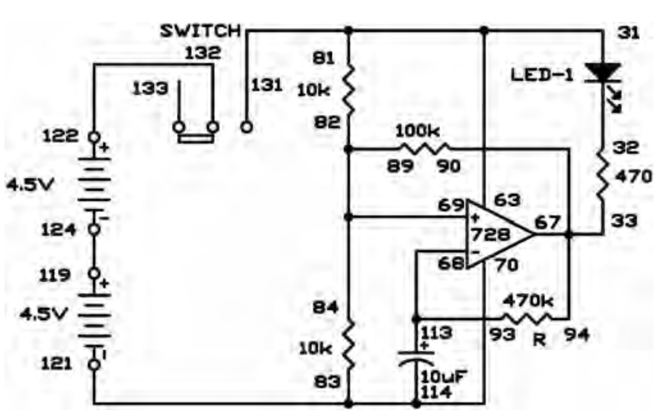
One last thing - the dual operational amplifier has a high input impedance - resistance to input - so it loses very little input current. This means you can use it to build accurate blinkers and timers with longer intervals.

Notes:

Wiring Sequence:

- ☐ 81-31-63-131
- ☐ 33-67-90-94
- ☐ 93-68-113
- ☐ 69-82-84-89
- ☐ 83-70-114-121
- ☐ 119-124
- ☐ 122-132

Schematic



EXPERIMENT #90: LED FLASHING LIGHT

The winking LED in the last project stays on and off for about the same amount of time, but we can make it flash on for a very short time.

Start out by sliding the switch to position B and wiring the circuit. This LED flasher uses two diodes. As you build this project, be sure to connect these diodes in the correct direction.

When you finish assembling the project, turn on the power by sliding the switch to position A, and lightly tap the key. The LED starts blinking immediately. Even if you don't press the key, this LED flasher starts flashing shortly after you turn on the power; if you press the key, it begins blinking immediately.

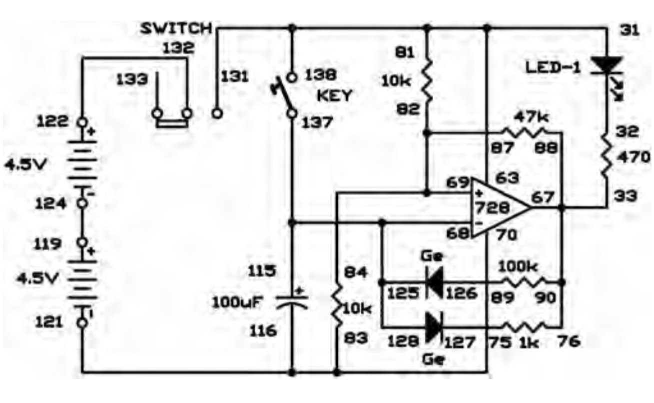
Just like the LED winker in the last project, this LED flasher uses a dual operational amplifier as an astable multivibrator, but its flashing time is much shorter because of the two diodes.

Notes:

Wiring Sequence:

- ☐ 81-31-63-131-138
- ☐ 33-67-88-90-76
- ☐ 68-115-137-128-125
- ☐ 69-87-82-84
- ☐ 83-70-116-121
- ☐ 75-127
- ☐ 89-126
- ☐ 119-124
- ☐ 122-132

Schematic



EXPERIMENT #91: TWO LED WINKER

The LED circuits in Projects 89 and 90 (“Operational Amplifier Winking LED” and “LED Flashing Light”, respectively) each use one LED, but the circuit in this project uses two LEDs that take turns lighting. Slide the switch to position B and assemble the circuit. Then, turn the power on by sliding the switch to position A and wait for a few seconds. The LEDs light and turn off alternately.

The dual operational amplifier works as an astable multivibrator as in previous projects. When the output is high, LED 1 lights; when it is low, LED 2 lights.

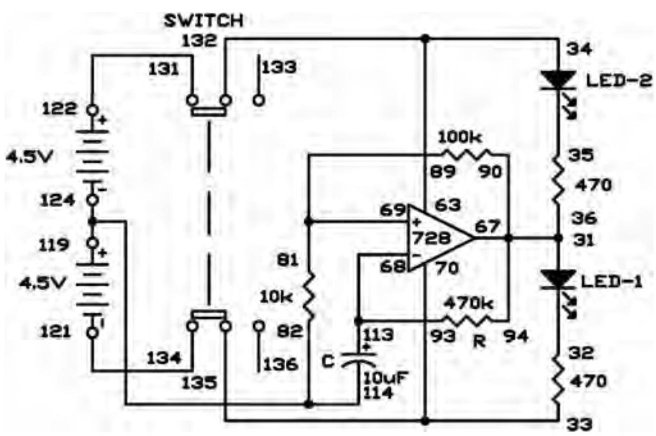
You can change the speed of the winking by using different values for R and C. See how the speed of the pulses change when you change the value of R to 220kΩ.

Notes:

Wiring Sequence:

- ☐ 31-36-67-90-94
- ☐ 33-70-135
- ☐ 34-63-132
- ☐ 93-68-113
- ☐ 81-89-69
- ☐ 82-114-124-119
- ☐ 121-134
- ☐ 122-131

Schematic



EXPERIMENT #92: ONE SHOT LIGHT

We've built many circuits using the dual operational amplifier, but there are many other ways to use this handy IC. The one shot multivibrator is one of them. With this multivibrator, we can make the LED stay on for a preset amount of time when the key is pressed - a one shot light.

Slide the switch to position B and build the circuit. Turn on the power by sliding the switch to position A. The LED lights, but quickly turns off. Now, press the key and see what happens. The LED lights and stays on for 2 to 3 seconds and then turns off.

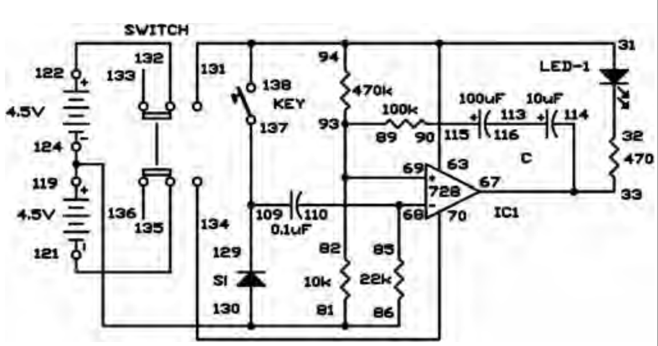
You can change the amount of time the LED is on by using different values for C. Change the value of C from 10µF to 100µF and see what happens to the LED. It stays on much longer.

Notes:

Wiring Sequence:

- ☐ 31-63-94-131-138
- ☐ 33-67-114
- ☐ 85-68-110
- ☐ 69-82-89-93
- ☐ 70-134
- ☐ 81-86-130-124-119
- ☐ 90-115
- ☐ 109-137-129
- ☐ 113-116
- ☐ 121-135
- ☐ 122-132

Schematic



EXPERIMENT #93: LED INITIALS

The digital LED display can't display all 26 letters of the alphabet, but it's possible to display many of them. Let's make an LED display that alternately shows the initials E and P of our ELECTRONIC PLAYGROUND. You can display other initials too. You can thrill your sweetheart by displaying his/her initials!

Slide the switch to position B and build the circuit. When you complete the wiring, slide the switch to position A to turn on the power, and you'll see the letters E and P lighting alternately on the LED display.

IC 1 works as an astable multivibrator and displays the letter E. IC 2 is used as an inverter, with an output that is opposite to that of IC 1; it displays the letter P.

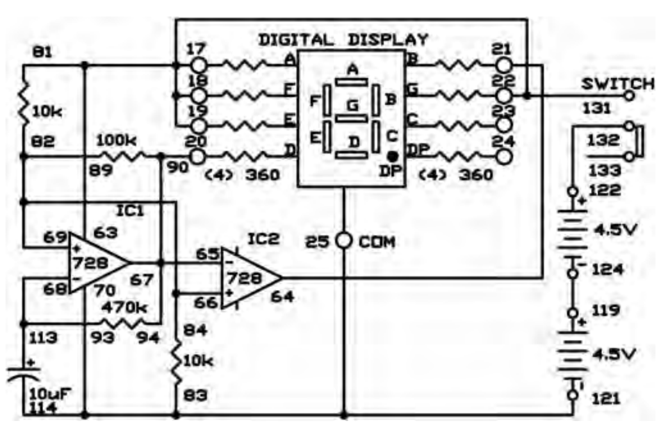
Now that you've successfully displayed the letters E and P, why not try displaying other letters? It should be a cinch if you take a close look at the schematic.

Notes:

Wiring Sequence:

- ☐ 22-17-18-19-63-131-81
- ☐ 20-65-67-90-94
- ☐ 21-64
- ☐ 83-114-70-25-121
- ☐ 66-69-82-84-89
- ☐ 93-68-113
- ☐ 119-124
- ☐ 122-132

Schematic



EXPERIMENT #94: WAKE UP SIREN

Are you a late sleeper? Even if you are, don't worry! Because you can make this alarm siren that wakes you up gradually as the day dawns.

First, set the switch to position B and complete the wiring. Then, set the switch to A to turn on the power. Can you hear the siren sound coming from the speaker?

The siren sounds when you expose the CdS cell to light. When you cast a shadow over the CdS, the siren sound stops.

Like the electronic buzzer in Project 82 ("Operational Amplifier Buzzer"), the alarm siren uses a multivibrator, and controls its operation with the CdS.

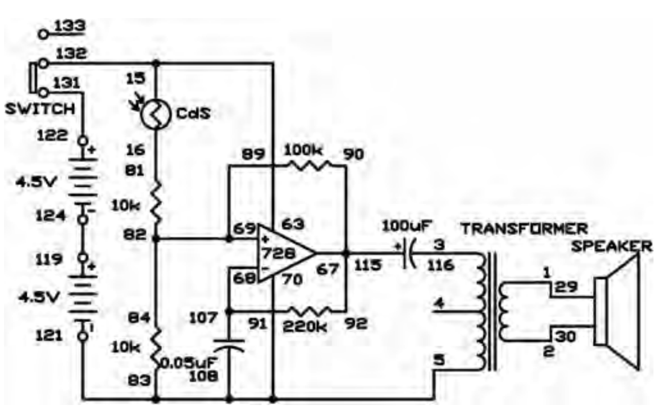
Turn on the power for this project when you go to bed at night, and sleep with your room dark. Then, the alarm siren will wake you up the next morning.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-116
- ☐ 5-83-108-70-121
- ☐ 15-63-132
- ☐ 16-81
- ☐ 67-90-92-115
- ☐ 91-68-107
- ☐ 69-82-84-89
- ☐ 119-124
- ☐ 122-131

Schematic



EXPERIMENT #95: VOICE ACTIVATED LED

You can use a microphone to detect sound. Here we will make a circuit that lights the LED when the microphone detects sound, using the speaker as a microphone.

Slide the switch to position B and assemble the circuit. When you finish the wiring, turn on the power by sliding the switch to position A. Then speak into the microphone - the speaker - or give it a light tap. The LED flashes in response.

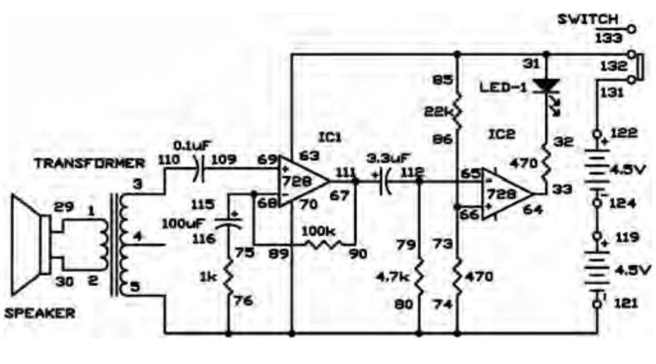
Look at the schematic. IC 1 acts as a microphone amplifier - a non-inverting amplifier with a gain of about 100. IC 2 works as a comparator. Its positive (+) input terminal receives a reference voltage from the battery. The output of the microphone amplifier goes to the comparator's negative (–) input terminal. When this input voltage is higher than the reference voltage, the comparator's output level becomes low and the LED lights.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-110
- ☐ 5-76-74-80-70-121
- ☐ 85-31-63-132
- ☐ 33-64
- ☐ 79-65-112
- ☐ 73-86-66
- ☐ 90-67-111
- ☐ 89-68-115
- ☐ 69-109
- ☐ 75-116
- ☐ 119-124
- ☐ 122-131

Schematic



EXPERIMENT #96: LOGIC TESTER

You know that digital circuits produce high or low (H or L) outputs (1 or 0). Now we're going to make a logic tester that shows 1 for high level (H) and 0 for low level (L) on the LED display.

Slide the switch to position B and assemble the circuit. When you finish the wiring, turn on the power by sliding the switch to position A. The number 0 is on the display because the test terminal (terminal 13) is at low level when no input is applied. Connect the test terminal to terminal 122 to apply +4.5V. The display changes to 1.

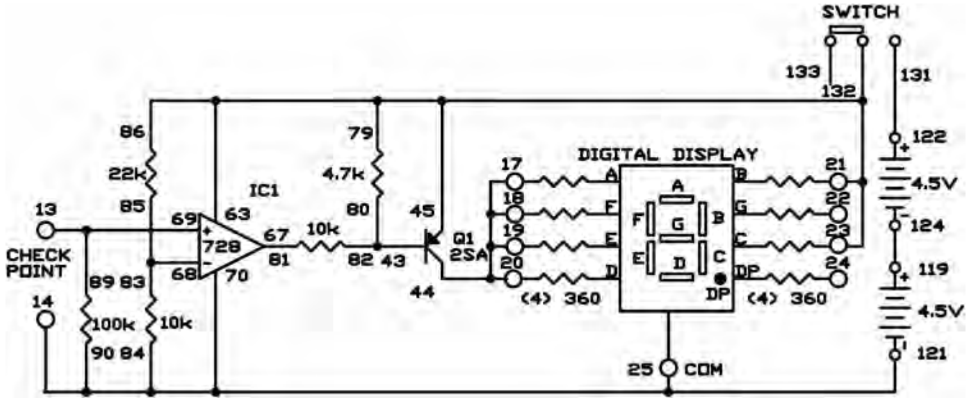
Look at the schematic. The dual operational amplifier works as a comparator. A reference voltage of about 3V is applied to its negative (–) input terminal. When the input applied to its positive (+) terminal is higher than this reference voltage, the comparator's output level becomes high, turning off the transistor Q1. Segments A, E, F, and D of the display turn off, leaving 1 on the display.

Notes:

Wiring Sequence:

- ☐ 17-18-19-20-44
- ☐ 86-79-63-21-23-45-132
- ☐ 43-80-82
- ☐ 67-81
- ☐ 68-83-85
- ☐ 119-124
- ☐ 122-131
- ☐ 69-89-13-CHECK POINT
- ☐ 121-25-70-90-84-14-CHECK POINT

Schematic



IX. MORE ADVENTURES WITH OPERATIONAL AMPLIFIERS

EXPERIMENT #97: ALTERNATING CURRENT SOUND

The circuit in this project allows you to hear alternating current. You probably know that the electric power running through your home is an alternating current. All your appliances that receive power from electric outlets operate on AC - including lamps. Lamps actually flicker at the rate of 60 times per second, but it looks constant because our eyes see after images. In this project you will hear sound converted from light.

Ready to start? After building this circuit, turn on the power to your kit by setting the switch to A. Place the CdS cell near an electric lamp. Can you hear a hissing sound coming from the earphone? This is the sound of the alternating current. Now place the CdS cell under a fluorescent lamp, and listen for a similar sound.

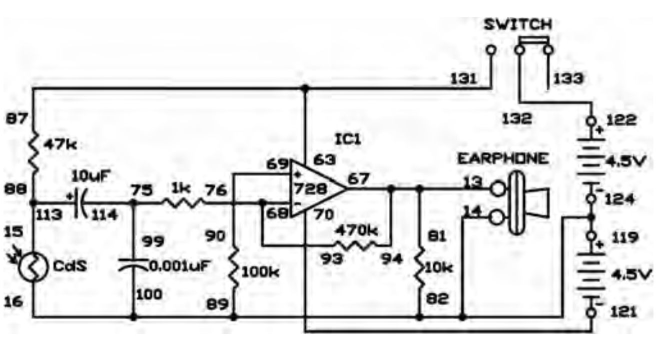
This circuit greatly amplifies the signals of light on the CdS cell through the operational amplifier. Adjust the quantity of light on the CdS cell with your hand. You can probably hear the volume of the hissing sound reduce and the quality of the sound improve. See what happens when you expose the CdS to sunlight.

Notes:

Wiring Sequence:

- ☐ 15-88-113
- ☐ 87-63-131
- ☐ 76-93-68
- ☐ 70-121
- ☐ 69-90
- ☐ 75-99-114
- ☐ 122-132
- ☐ 67-94-81-13-EARPHONE
- ☐ 124-119-16-100-89-82-14-EARPHONE

Schematic



EXPERIMENT #98: LIGHT CONTROL SOUND CIRCUIT

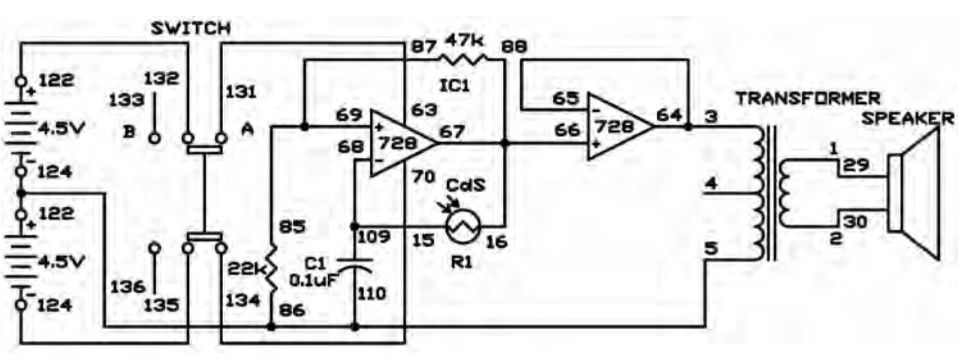
This circuit changes the intervals between each sound according to the amount of light falling on the CdS cell. The sound changes continuously as you adjust the light intensity.

Set the switch to position A to turn on the power after you complete the wiring. The speaker immediately makes a sound. Move your hand over the CdS to change the sound.

You can calculate the approximate value of the frequency of the signal by using the equation 1/2 x C1 x R1. However, R1, in this project, is the CdS and is not constant. You can change the value of the output frequency by changing C1. In this experiment, the speaker is equipped with a buffer so that the light control sound circuit is not affected when the speaker emits sounds.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-64-65
- ☐ 5-86-110-119-124
- ☐ 15-68-109
- ☐ 16-66-67-88
- ☐ 63-131
- ☐ 69-87-85
- ☐ 70-134
- ☐ 121-135
- ☐ 122-132

EXPERIMENT #99: SOUND ALARM CIRCUIT

This alarm gives out an alarm light and sound when it detects your voice or any other sound. The earphone acts as a microphone. Sounds picked up by the microphone are amplified by IC 1. Diodes Da and Db rectify the amplified signal - that is, they convert the sound signal from AC to DC. The signal travels through IC 2, the comparator, and activates the LED and the speaker.

When you finish building the circuit, rotate the control fully counter-clockwise, and set the switch to position A. Then, rotate the control clockwise while speaking into the microphone, and set the control in a position where the LED light only when you speak into the microphone. Stop speaking and you will see the LED turn off.

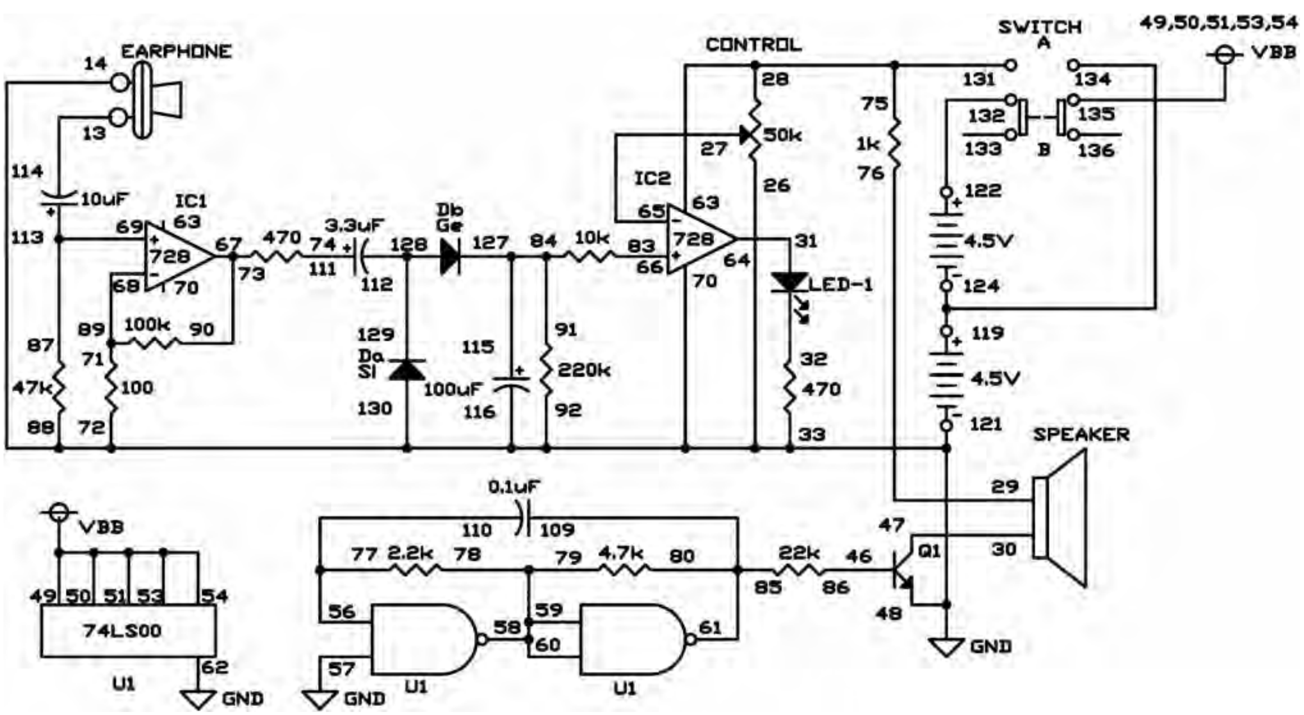
Now, see what happens when you disconnect the wire between 57 and 62, and reconnect it between 57 and 32. When you blow into the microphone (earphone), the LED and the speaker sounds.

Notes:

Wiring Sequence:

- ☐ 75-63-28-131
- ☐ 29-76
- ☐ 30-47
- ☐ 31-64
- ☐ 46-86
- ☐ 56-77-110
- ☐ 58-59-60-79-78
- ☐ 85-80-61-109
- ☐ 66-83
- ☐ 67-90-73
- ☐ 68-89-71
- ☐ 87-69-113
- ☐ 74-111
- ☐ 84-91-115-127
- ☐ 112-129-128
- ☐ 49-50-51-53-54-135
- ☐ 114-13-EARPHONE
- ☐ 122-132
- ☐ 27-65
- ☐ 57-26-121-130-48-116-70-92-88-62-33-72-14-EARPHONE
- ☐ 119-124-134

Schematic



EXPERIMENT #100: STUDY TIMER

Here's a timer you can use for taking timed tests or simply for knowing when an amount of time has passed. You can preset this timer for as much time as you like, up to about 15 minutes. When the time is up, it gives out a continuous buzzer sound until you turn off the power or press the key to reset the circuit.

After you build this project, set the control to position 2 on the dial and slide the switch to position A to turn on the power. Hold a stop-watch and start it when you press the key. The timer makes a buzzing sound in about 30 seconds or more.

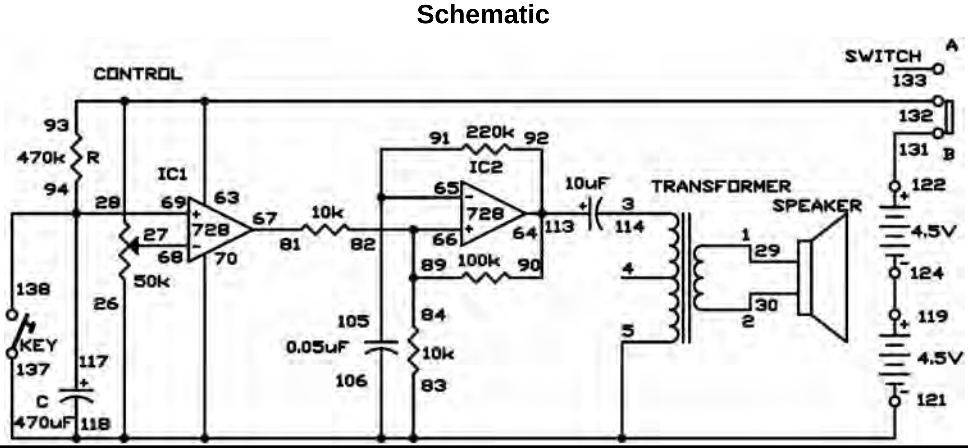
Now set the control to each division on the dial from 2 to 8, and note how long it takes the timer to produce a sound. Setting the timer's calibration - the time that passes at each setting of the dial - requires a lot of patience, but it is necessary for making sure your timer works accurately. After you set the calibration, make a graph showing each control position and the time it takes for the buzzer to sound. Now, your tester is ready for use.

Look at the schematic. The control changes the reference voltage of the comparator (IC 1). The timer setting is determined by the resistor R and the capacitor C. When the voltage applied to the positive (+) terminal of IC 1 exceeds the reference voltage, the alarm sounds.

Since the dual operational amplifier has a high input impedance (input resistance), its current loss is very small, so you can use it to make a timer with a very long setting. IC 2 works as an astable multivibrator that produces the buzzer sound.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-114
- ☐ 5-83-70-106-118-137-26-121
- ☐ 93-63-28-132
- ☐ 92-90-64-113
- ☐ 65-105-91
- ☐ 66-82-84-89
- ☐ 67-81
- ☐ 94-69-117-138
- ☐ 119-124
- ☐ 122-131
- ☐ 27-68

EXPERIMENT #101: KITCHEN TIMER

Wouldn't you like to make a kitchen timer that you can use for cooking meals? This timer is the same as the test timer in the last project, except for one point. It gives out a buzzer sound for 1 to 2 seconds and automatically stops.

Slide the switch to position B and build the circuit. When you finish assembling the project, turn on the power by sliding the switch to position A. Set the control to position 2 on the dial, and press the key to start the timer. After about 40 seconds, the timer sounds for 1 to 2 seconds and stops. Use the graph you made in project 100 to preset this timer.

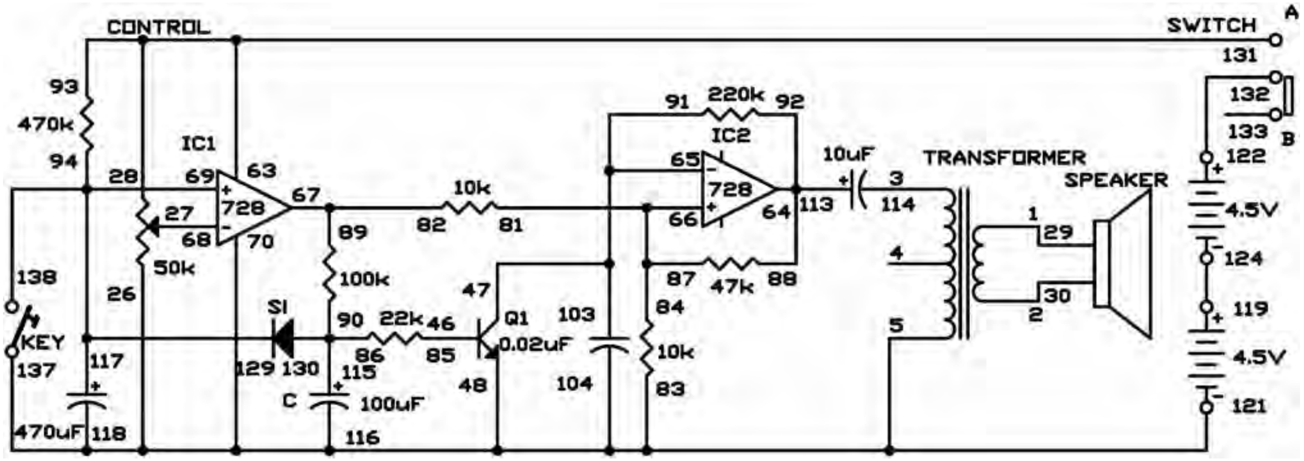
Look at the schematic. When the preset time is up, the comparator (IC 2) sends out an output. After a time lag of 1 to 2 seconds produced by R and C, the transistor Q1 turns on to stop the multivibrator. The silicon diode discharges C and restores the circuit to the original state when the timer is restarted.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-114
- ☐ 5-83-70-104-116-118-137-48-26-121
- ☐ 27-68
- ☐ 93-63-28-131
- ☐ 46-85
- ☐ 91-103-65-47
- ☐ 92-88-64-113
- ☐ 81-84-87-66
- ☐ 67-82-89
- ☐ 69-94-117-138-129
- ☐ 86-90-115-130
- ☐ 119-124
- ☐ 122-132

Schematic



EXPERIMENT #102: THREE-INPUT "AND" GATE USING OPERATIONAL AMPLIFIER

Who says the operational amplifier can't be used to make a digital circuit? Here, we use one to make an AND gate. The LED display is the output device. If it displays nothing, at least one of the output signals is logical 0 or low; if it displays H, they are all logical 1 or high.

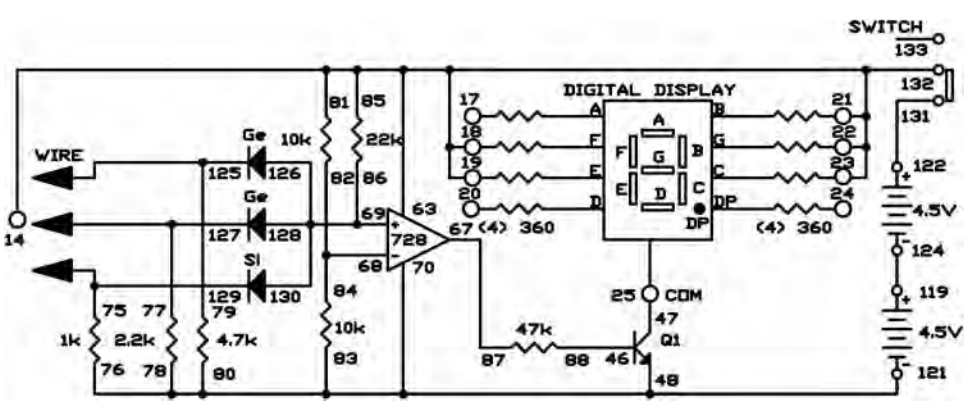
When you complete the wiring, turn on the power by setting the switch to position A. The LED remains dark. Terminals 125, 127, and 129 are the input terminals. These terminals are connected to the negative (–) terminal, so they do not cause the LED to light. Terminal 14 is connected to the positive (+) terminal, so it is the logic 1 terminal. When you connect terminals 125, 127, and 129 to terminal 14 in various combinations, you see that the LED lights and shows H only when terminals 125, 127, and 129 are all connected to terminal 14 - logic 1.

Notes:

Wiring Sequence:

- ☐ 14-85-81-63-19-18-21-22-23-132
- ☐ 25-47
- ☐ 46-88
- ☐ 78-76-83-80-70-48-121
- ☐ 67-87
- ☐ 68-82-84
- ☐ 86-69-126-128-130
- ☐ 129-75-WIRE
- ☐ 127-77-WIRE
- ☐ 125-79-WIRE
- ☐ 119-124
- ☐ 122-131

Schematic



EXPERIMENT #103: VOICE LEVEL METER

In this project, we will make a voice input level meter. The brightness of the LED in this circuit changes according to the level of voice input that comes from the microphone (the earphone). Since voice levels change very quickly, the brightness of the LED should also change very quickly. In order to show the highest voice input levels, we use a circuit called a peak-level hold circuit. This allows the LED to hold a certain brightness after it reaches peak strength, rather than turning off immediately.

Set the switch to position A after completing the wiring. You will use the earphone as a microphone. Speak loudly or blow strongly into the earphone. You can see the LED get brighter temporarily and then gradually grow dimmer.

Look at the schematic. You can see that the signal from the earphone travels through the PNP transistor and then becomes the positive (+) input for the first operational amplifier. The output of this operational amplifier is stored at the 100μF capacitor. The voltage of the capacitor lowers as it slowly discharges through the 47kΩ resistor. As the voltage decreases, the LED grows dim. At the same time, the voltage that lights the LED flows to the negative (–) input of the first operational amplifier. The first operational amplifier compares this voltage with the input signal from the earphone; when the input signal is larger, it charges the 100μF capacitor, when the input signal is smaller, no output is produced.

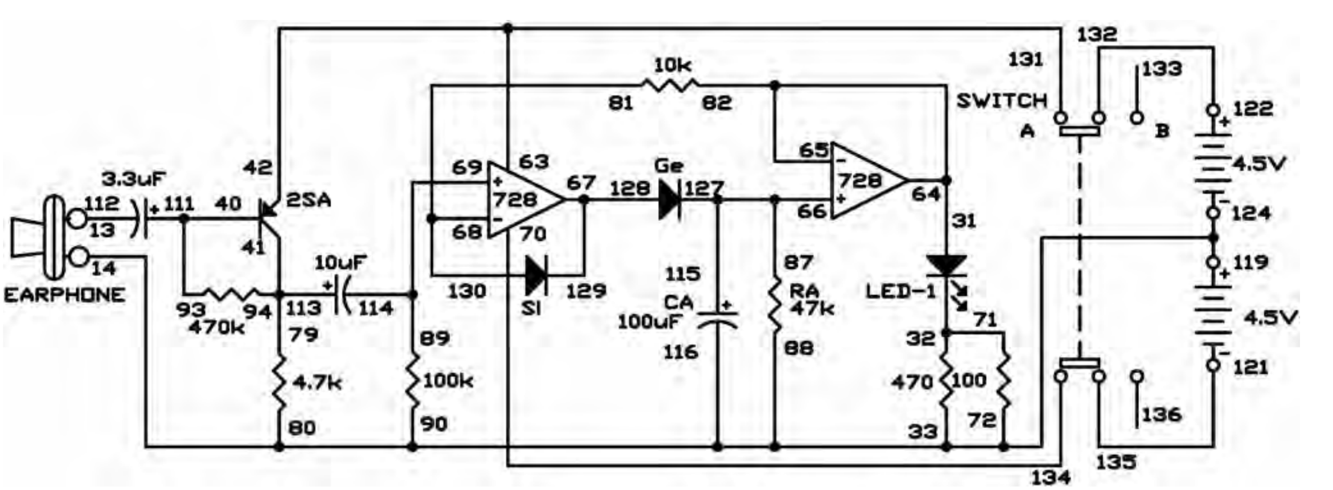
You can change the brightness of the LED by changing resistor RA (47kΩ) or the capacitor CA (100μF).

Notes:

Wiring Sequence:

- ☐ 112-13-EARPHONE
- ☐ 119-124-116-33-88-90-80-72-14-EARPHONE
- ☐ 31-65-64-82
- ☐ 32-71
- ☐ 93-111-40
- ☐ 79-94-113-41
- ☐ 63-42-131
- ☐ 87-66-127-115
- ☐ 67-129-128
- ☐ 81-68-130
- ☐ 89-69-114
- ☐ 70-134
- ☐ 121-135
- ☐ 122-132

Schematic



EXPERIMENT #104: POWER-ON RESET CIRCUIT

Do you know what a reset circuit does? It activates other circuits and detects any power fluctuations in order to prevent malfunctions. In this project, we change the supply voltage to the circuit with the switch. The power to the display portion of the circuit is on, or logic high, when the switch is set to position A; it is off when the switch is at position B. The LED display shows 1 when the circuit has been reset.

Let's start experimenting. First, complete the wiring and set the switch to position B. Now, with the switch set to B, the power reset circuit operates under 6V, and the three LEDs light dimly. The LED display is off, meaning that the display circuit is not activated.

Now, set the switch to position A. You can see the three LEDs light brightly because the supply voltage has been changed to 9V. For a moment, the LED display still shows no change, indicating that the circuit is being reset. After a short interval, the LED displays 1 to show that the circuit has finished resetting and now it is stabilized.

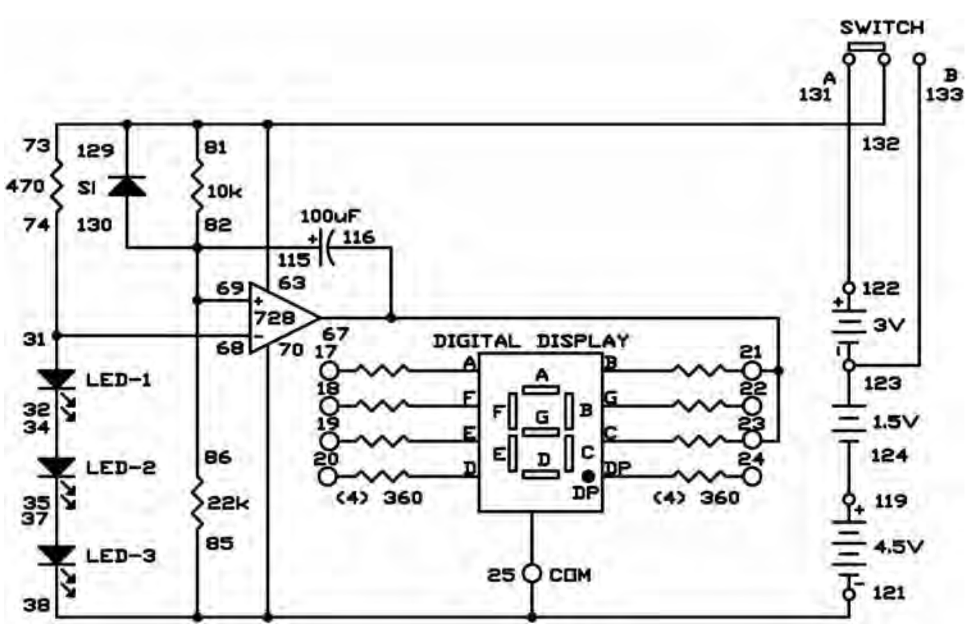
Set the switch to position B to switch the power back to 6V. You will see the 1 on the LED disappear, because now the display circuit is off.

Look at the schematic as you read the following. The operational amplifier acts as a comparator. The negative (–) terminal receives the reference voltage of about 5.4V. When the switch is at position B, the positive (+) terminal receives about 4.1V, so the comparator does not allow the display to light. When you use position A to switch to the 9V supply, the 100μF capacitor causes the comparator's positive (+) terminal voltage to gradually increase to about 6V. When this voltage exceeds the reference voltage of 5.4V, the LED display lights 1.
When you set the switch to B, the voltage at the amplifier's positive (+) terminal discharges through the diode, so the voltage is reduced immediately to 4.1V.

Although this circuit seems very simple (consisting of only one operational amplifier), it is very complex and important for later use.

Notes:

Schematic



Wiring Sequence:

- ☐ 21-23-67-116
- ☐ 85-70-38-25-121
- ☐ 31-68-74
- ☐ 32-34
- ☐ 35-37
- ☐ 73-81-63-129-132
- ☐ 86-82-69-115-130
- ☐ 119-124
- ☐ 122-131
- ☐ 123-133

EXPERIMENT #105: DELAYED TIMER

This circuit is a delayed timer that uses an operational amplifier and the CR time constant. You remember that CR stands for capacitor/resistor. A time constant is a circuit that delays an operation.

The negative (–) terminal of the operational amplifier receives a voltage of about 4.5V through resistors RA and RB. This is the comparator's reference voltage. The positive (+) terminal of the comparator is connected to capacitor C1. This capacitor receives its charge through the series resistance of R2 and the control. The charging speed is slower when the resistance is large, and faster when the resistance is small. This charging speed set the delay time for the timer circuit.

Now turn the control fully clockwise to position 10. Set the switch to position A to turn on the power. LED 1 lights first; LED 2 lights about 5 to 7 seconds later. This 5 to 7 second time difference is the delay time that is set by the CR time constant.

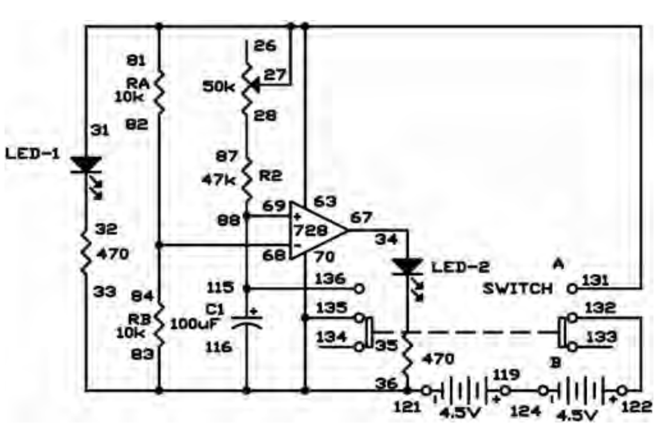
Now, turn off the power, set the control fully counter-clockwise to position 1, and see what happens when you turn on the power again. LED 2 lights later than LED 1 again, but how many seconds later?

Notes:

Wiring Sequence:

- ☐ 81-31-63-27-131
- ☐ 28-87
- ☐ 83-33-36-70-116-135-121
- ☐ 34-67
- ☐ 68-82-84
- ☐ 88-69-115-136
- ☐ 119-124
- ☐ 122-132

Schematic



EXPERIMENT #106: PULSE FREQUENCY DOUBLER

This is a pulse frequency multiplier with one transistor. It is called a pulse frequency doubler because it doubles the frequency of the input signal.

The operational amplifier IC 728 acts as a square-wave oscillator. The output from the oscillator is an AC signal of about 500Hz.

When you complete the wiring, set the switch to position A to turn on the power. Connect the earphone to terminals 93 and 134 and press the key to listen to the oscillating sound of 500Hz. Note the pitch of the tone.

Now, connect the earphone to terminals 13 and 14 and press the key. Listen through the earphone; this time you hear a sound that is an octave higher than the previous sound. This means the frequency is doubled to 1,000Hz.

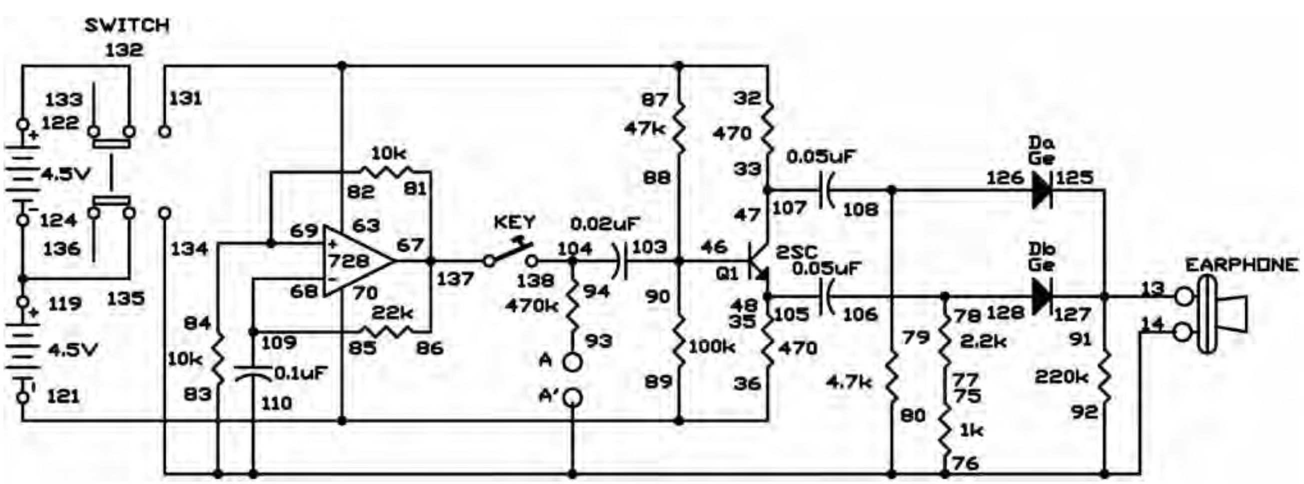
Now let's see how this frequency doubler works. Transistor Q1 receives signals from the operational amplifier through its transistor base. The base voltage changes with the oscillations. This results in the opposite phase signals appearing at the collector and emitter - when one signal is at a wave peak, the other is at the bottom. The two outputs from transistor Q1 are applied to diodes Da and Db. The diodes pass through only the positive portion of the waves. These two signals combine to give us the doubled frequency.

Notes:

Wiring Sequence:

- ☐ 125-127-91-13-EARPHONE
- ☐ 134-110-92-80-83-76-14-EARPHONE
- ☐ 32-63-87-131
- ☐ 33-47-107
- ☐ 35-48-105
- ☐ 89-36-70-121
- ☐ 88-90-103-46
- ☐ 81-86-67-137
- ☐ 85-68-109
- ☐ 69-82-84
- ☐ 75-77
- ☐ 78-106-128
- ☐ 79-108-126
- ☐ 94-104-138
- ☐ 119-124-135
- ☐ 122-132

Schematic



EXPERIMENT #107: WHITE NOISE GENERATOR

White noise is a noise that has a wide frequency range. The shower-like noise you hear when you tune your FM radio to an area with no station is one kind of white noise. It is a useless noise normally, but when you play electronic musical instruments, you can use white noise as a sound source.

When you finish building this circuit, set the switch to position A to turn on the power. Look at the schematic. We will use the noise that is generated when you apply a reverse voltage to the base and the emitter of transistor Q1.

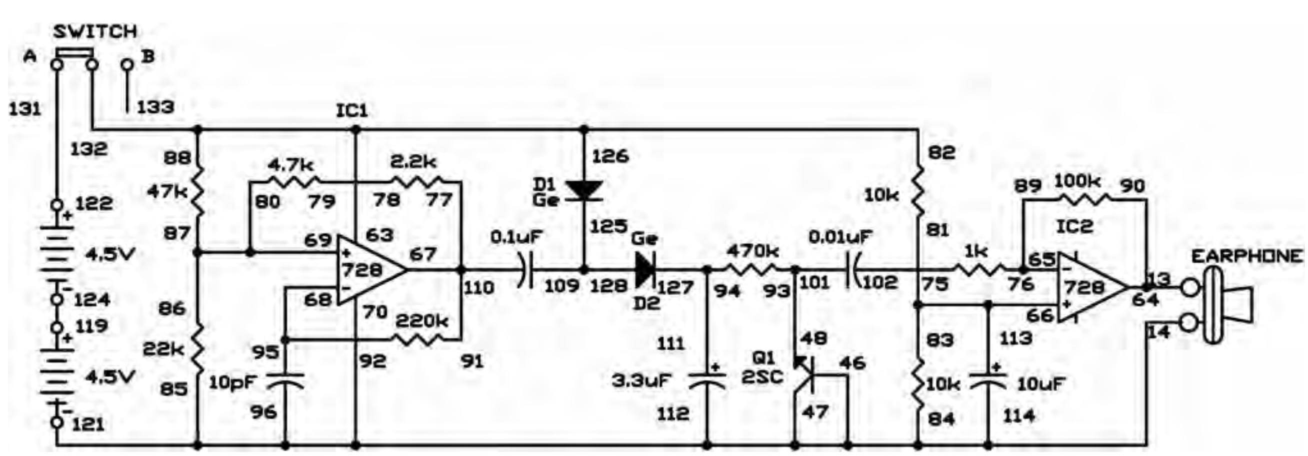
IC 1 acts as an oscillator. The output of this oscillator is rectified (remember this term from Project 99 ("Sound Alarm Circuit") by diodes D1 and D2 and flows to Q1. IC 2 amplifies the noise so that you can hear it through the earphone.

Notes:

Wiring Sequence:

- ☐ 64-90-13-EARPHONE
- ☐ 121-114-112-46-47-70-96-84-85-14-EARPHONE
- ☐ 93-48-101
- ☐ 94-111-127
- ☐ 82-88-63-132-126
- ☐ 76-89-65
- ☐ 113-66-81-83
- ☐ 77-91-67-110
- ☐ 68-95-92
- ☐ 69-80-87-86
- ☐ 78-79
- ☐ 109-128-125
- ☐ 119-124
- ☐ 122-131
- ☐ 102-75

Schematic



EXPERIMENT #108 DC-DC CONVERTER WITH OPERATIONAL AMPLIFIER

Here's a DC-DC converter circuit; it can gain 5VDC from 3VDC. Build the project, set the switch to position A, and see how this circuit works.

Look at the schematic. IC 1 acts as an oscillator. The output of IC 1 turns on transistor Q1. Self-induction of the transformer coil instantly generates a high voltage current. Diode D1 rectifies this voltage and passes on a high DC voltage current. IC 2 is a comparator that examines the voltage increase. When the input voltage to IC 2 is more than 5V, the LED lights.

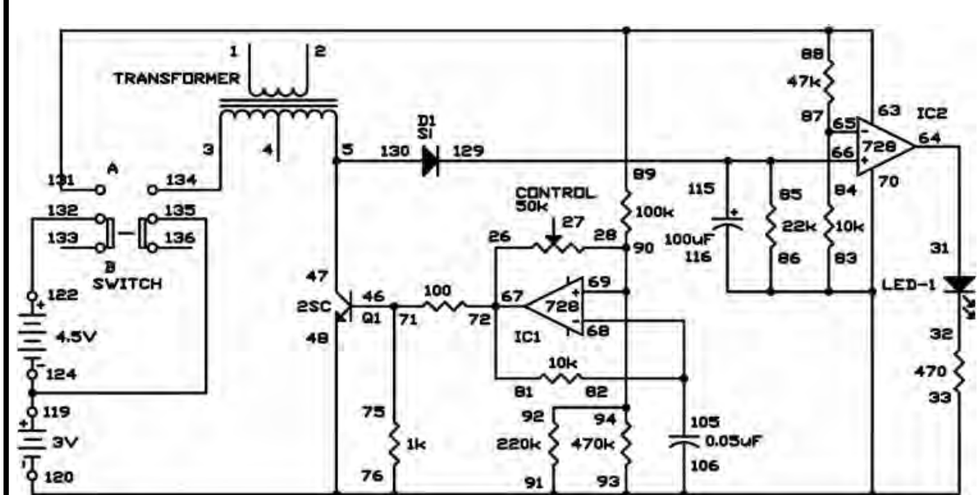
By the way, did you try rotating the control? How does it affect the circuit? In this circuit the control is used as a fixed resistor of 50kΩ. Rotating the control has no effect. (Sorry if we had you worried).

Notes:

Wiring Sequence:

- ☐ 3-134
- ☐ 5-47-130
- ☐ 26-67-72-81
- ☐ 28-69-90-92-94
- ☐ 31-64
- ☐ 33-76-83-86-93-91-70-106-116-48-120
- ☐ 46-71-75
- ☐ 89-88-63-131
- ☐ 84-87-65
- ☐ 85-66-115-129
- ☐ 82-68-105
- ☐ 119-124-135
- ☐ 122-132

Schematic



X. COMMUNICATION CIRCUITS

EXPERIMENT #109: CODE PRACTICE OSCILLATOR WITH TONE CONTROL

Would you like to become an amateur radio ham? Many radio operators started out using an oscillator with a tone control like this one. The tone control in this project can be very helpful because listening to the same tone for a long time can be very tiring. Simply connect the wires for this circuit and your code practice oscillator is ready for use.

You can use the different tones to make up your own special code, in addition to the Morse Code - the code system with dots and dashes invented by Samuel Morse. The best way to learn the Morse Code is to find someone else who is interested in learning the code. Set up a schedule and practice everyday. Make a progress chart so you can see your improvement. Take turns sending and receiving, and it won't be long until the code becomes almost like a spoken language. Operating the key becomes automatic, like riding a bike or driving a car. It takes hard work to get to this point, but you'll be proud when you do.

If you want to practice privately, you can use the earphone. Simply disconnect the speaker and connect the earphone to terminals 27 and 28. With these connections, the control acts as a volume control as well as a tone control. You can replace the control with a fixed resistance if you want a fixed tone and volume.

When you adjust the control for less resistance in the circuit, more electricity flows to the 0.05μF capacitor, so it charges faster between pulses. The pulses are closer together, making the frequency (and the tone) higher. The opposite situation occurs when the control is adjusted for more resistance.

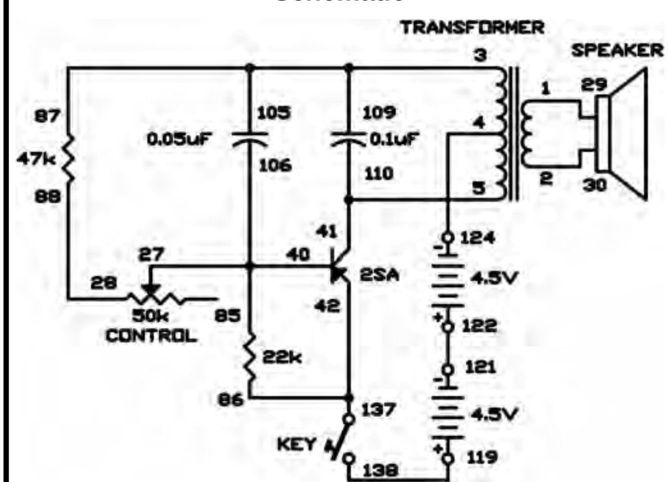
After you master Morse Code, the next step is to contact your nearest store and see what study materials are available for the written part of the FCC (Federal Communications Commission) exam. Good luck!

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-87-105-109
- ☐ 4-124
- ☐ 5-41-110
- ☐ 85-106-40-27
- ☐ 28-88
- ☐ 86-42-137
- ☐ 119-138
- ☐ 121-122

Notes:

Schematic



EXPERIMENT #110: CRYSTAL SET RADIO (SIMPLE-DIODE RADIO)

No project kit is complete without a crystal radio circuit. Most people in electronics have experimented with this oldest of all radio circuits. Before the days of vacuum tubes or transistors, people used crystal circuit sets to pick up radio signals.

The signals from a crystal radio are weak, so you must use an earphone to pick up the sounds. Your earphone will reproduce these sounds well because it is a ceramic type and requires very little current for operation.

A good antenna and earth ground connection are necessary for receiving distant stations, but you can hear local stations using almost anything as an antenna. A long piece of wire (like the green wire in your kit) makes an adequate antenna in most cases. Earth ground means just that; you connect the wire to the ground. One easy way to do this is to connect a wire to a metal cold water pipe. If you can't do that, you can drive a metal stake into the ground and connect the wire to the stake.

Build the circuit according to the wiring sequence to use your crystal diode radio. Two antenna connections are provided on the radio circuit in your kit, but don't use them both at the same time. Try each connection and use the one that results in the best reception. Short antennas, 50 feet or less, work best on terminal 95. Longer antennas work best on terminal 97.

The part of the radio circuit that includes the antenna coil and the tuning capacitor is called the tank circuit. When a coil and the tuning capacitor are connected in parallel, the circuit resonates only at one frequency. So the circuit picks up only the frequency that causes the tank circuit to resonate. The tuning capacitor changes its capacitance as you rotate it. When the capacitance changes, the resonating frequency for the circuit changes. Thus, you can tune in various stations by rotating the tuning capacitor. Without this selectivity, you might hear several stations mixed together (or only a lot of noise).

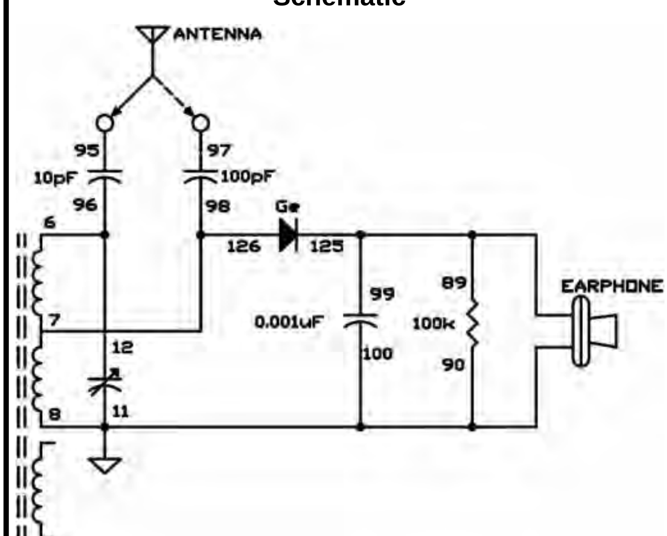
The signals received by the tank circuit are high-frequency RF (radio frequency) signals. At a broadcast station, sound signals are used to control the amplitude (strength) of the RF signals - that is, the height of the RF wave varies as the sound varies. The diode and the 0.001μF capacitor in this circuit detect the changes in the RF amplitude and convert it back to audio signals. This converting of amplitude modulation into audio signals is called detection or demodulation.

Notes:

Wiring Sequence:

- ☐ 6-12-96
- ☐ 7-98-126
- ☐ 8-11-90-100-EARPHONE
- ☐ 89-99-125-EARPHONE
- ☐ 95-ANT or (97-ANT)

Schematic



EXPERIMENT #111: TWO-TRANSISTOR RADIO

This is a two-transistor receiver with enough gain (amplification) to allow you to hear the signal through the speaker. Simple radios like this one require a good antenna and ground system. Connect the circuit and use terminal 74 as the ground terminal. Connect the antenna to terminal 95 or 97. Use the one that provides the best results.

The radio's detector circuit uses a diode and a 22kΩ resistor. Try to use the radio without the 22kΩ resistor. Simply disconnect the wire from terminal 85. The results are ________ (worse / improved) for weak stations and ________ (worse / improved) for strong stations.

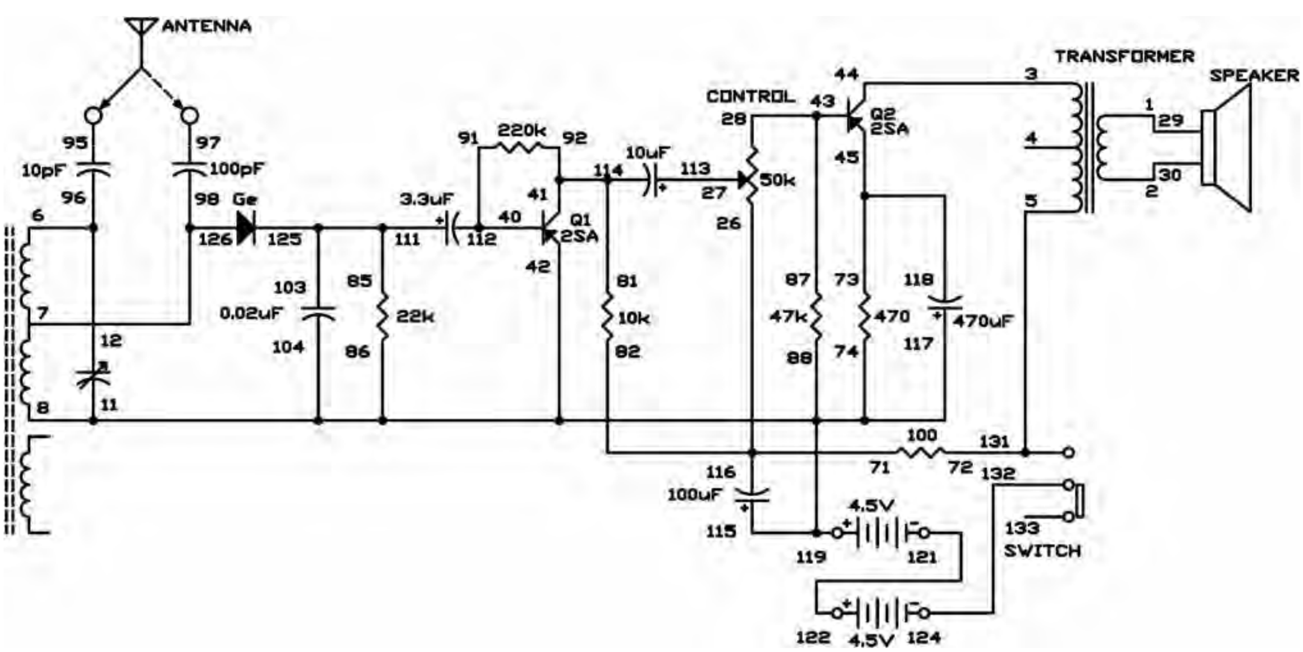
The basic rules of radio reception are the same as in Project 110 ("Crystal Set Radio (Simple-Diode Radio)"). The tuning capacitor selects the radio station frequency. The diode and 0.02μF capacitor rectify (detect) the audio signal, changing it from AC to DC. This signal is so weak that we must amplify it to be able to hear it through the speaker. Transistor Q1 amplifies the signal first, then the control adjusts the volume, and finally Q2 amplifies the signal again. Finally, the speaker produces the amplified sounds.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-44
- ☐ 5-72-131
- ☐ 6-12-96
- ☐ 7-98-126
- ☐ 8-11-74-86-88-104-115-117-42-119
- ☐ 71-82-116-26
- ☐ 27-113
- ☐ 28-43-87
- ☐ 40-112-91
- ☐ 81-92-114-41
- ☐ 45-118-73
- ☐ 85-103-111-125
- ☐ 121-122
- ☐ 124-132
- ☐ 95-ANT (or 97-ANT)

Schematic



EXPERIMENT #112: WIRELESS CODE TRANSMITTER

This project is a simple but effective code transmitter like the kind used by military and amateur radio operators around the world. When you press and release the key, the transmitter turns on and off in sequence.

You can use a common AM radio to receive the code sent out by this transmitter. Tune the radio to a weak station. The transmitter signal mixes with the station's signal to produce an audio tone called a beat note. This beat note is what you hear as the code signal. Use the tuning capacitor to tune this transmitter until you can hear the beat note in the receiver when you press the key.

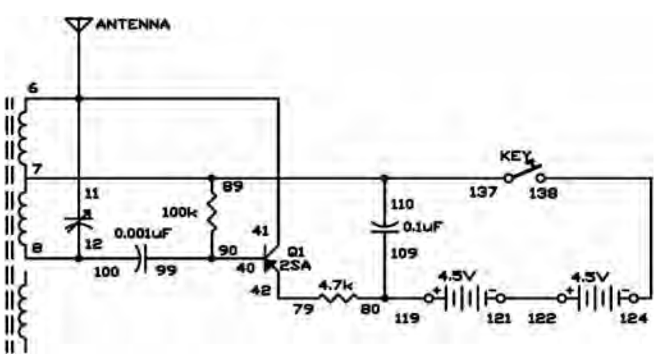
You can receive the carrier wave (CW) signal of this transmitter on a communications receiver, without tuning to another station, if the communications receiver has a beat frequency oscillator (BFO). The BFO beats with your transmitter's CW signal and produces the tone.

This oscillator sends out an RF signal because the frequency is very high (500,000Hz to 1,600,000Hz). When you tune to a weak AM station first and then send a signal slightly off from the station frequency, you can hear the beat note that you produced.

Transmission and reception of CW signals is very efficient. In fact, it is the most reliable type of transmission for some emergencies. You might find that you do not need an antenna, but if you do, 1, 2, or 3 feet (about 60-90 cm) of wire will probably be enough. Have fun!

Notes:

Schematic



Wiring Sequence:

- ☐ 41-6-11-ANT
- ☐ 7-89-110-137
- ☐ 8-12-100
- ☐ 40-90-99
- ☐ 42-79
- ☐ 80-109-119
- ☐ 121-122
- ☐ 124-138

EXPERIMENT #113: AM RADIO STATION

If you ever wanted to be a disc jockey, this is your chance. This AM radio station lets you actually send your voice through the air. You built an AM radio transmitter in the last project, but it could send only a single tone or a series of dots and dashes.

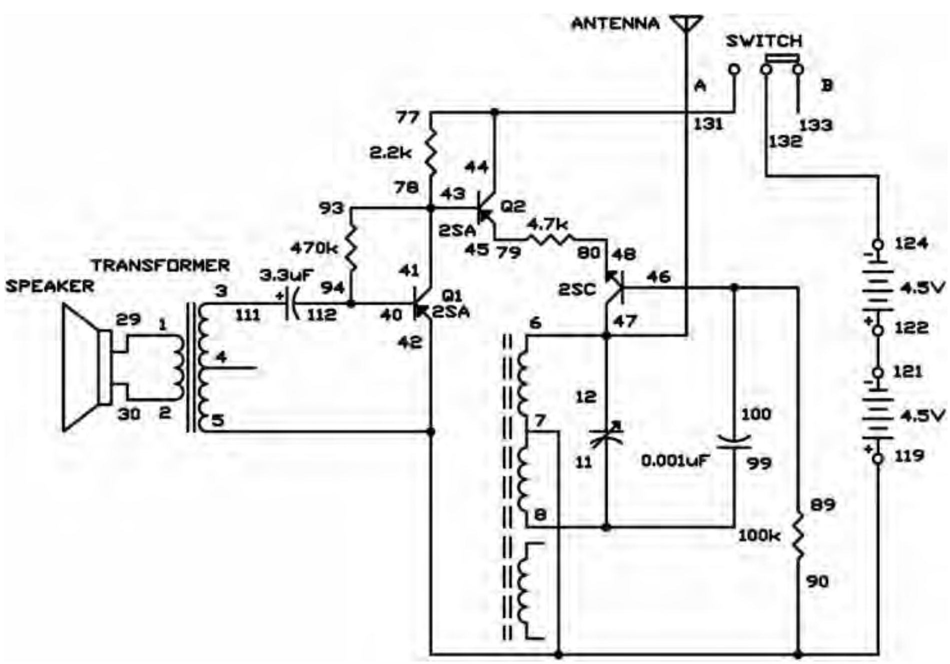
When you finish the wiring, turn on your AM radio receiver and tune it to a weak station or silent setting on the dial. Now, begin to talk into the speaker while adjusting the tuning capacitor, until you hear your voice on the air. This transmitter can only send signals a few feet, so place your AM radio close to the kit.

Transistor Q1 amplifies the audio frequency signal. The amplified signal controls the amplitude of the RF oscillator signal. The tuning capacitor and antenna coil tune the RF signal to the setting on your AM radio dial and send it through the antenna.

Transistor Q2 helps control the amplitude of the RF signal. The NPN transistor is a part of the RF oscillator and provides the primary amplification of the RF signal (before the AF (audio frequency) signal modulates it).

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-111
- ☐ 5-7-90-42-119
- ☐ 6-12-47-ANT
- ☐ 8-11-99
- ☐ 40-112-94
- ☐ 41-43-93-78
- ☐ 77-44-131
- ☐ 45-79
- ☐ 89-100-46
- ☐ 48-80
- ☐ 121-122
- ☐ 124-132

EXPERIMENT #114: OPERATIONAL AMPLIFIER RADIO

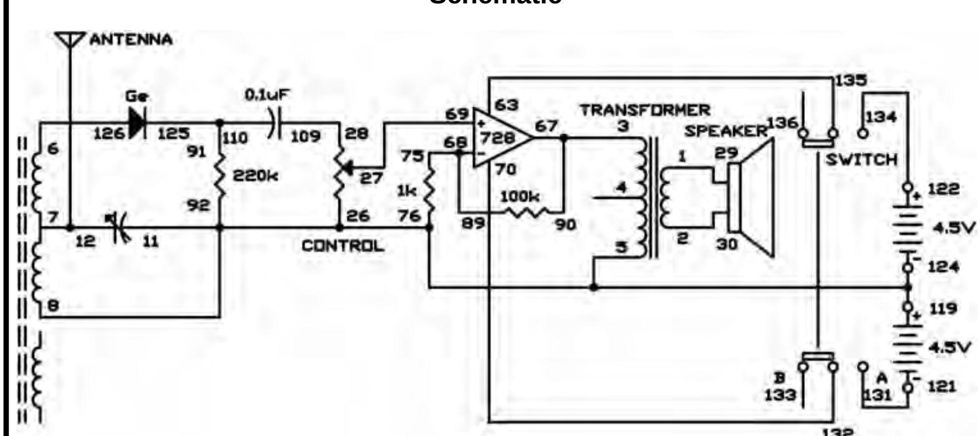
Germanium diode radios generally do not perform well, but they can be important for emergency communication because they need no power source.

Usually, you can listen to a germanium radio only through an earphone, but we have added an operational amplifier to this project so that you can hear it through the speaker. We are going to make an IC radio using the dual operational amplifier as a two-power source, non-inverting amplifier. This is the simplest way to use this IC.

Slide the switch to position B and assemble the project. When you complete the circuit, put up the antenna, connect it to the circuit, set the control to the 12 o'clock position, and slide the switch to position A to turn on the power. Turn the tuning capacitor until you hear a station. To pick up weaker stations, try using the earphone in place of the speaker in connections to terminals 1 and 2.

Notes:

Schematic



Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-67-90
- ☐ 5-8-11-76-92-26-119-124
- ☐ 6-126
- ☐ 7-12-ANT
- ☐ 27-69
- ☐ 28-109
- ☐ 63-135
- ☐ 68-89-75
- ☐ 70-132
- ☐ 91-110-125
- ☐ 121-131
- ☐ 122-134

XI. TESTING AND MEASURING CIRCUITS

EXPERIMENT #115: AURAL CONTINUITY TESTER

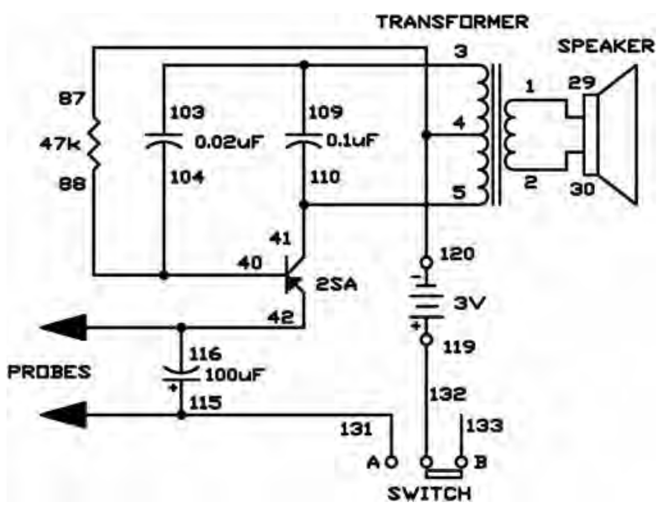
This circuit emits a sound if the material you are checking conducts electricity. This is convenient when you are looking at wires, terminals, or other things and cannot look at a signal lamp or LED. Your ears detect the results of the test while your eyes are busy.

If the circuit that you are testing conducts electricity, it will complete a voltage supply connection to a standard pulse-type oscillator that uses a sensitive PNP transistor. This tester can check almost any component on the board. When testing the diodes and transistors, remember that electricity only flows in one direction through them (unless they have been damaged).

If you look at the schematic, you will see that the output from the transistor goes through the transformer to the 0.02μF capacitor and then to the base of the transistor. The emitter of the transistor is connected to the TEST terminal. When something that allows electricity to flow is connected to the terminal, the transistor starts to oscillate.

You can safely check almost any component with this continuity checker because it carries a very low current of about 15mA or less. You may want to try measuring the continuity of pencil lines on paper, water, metallic surfaces, and many other things.

Schematic



Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-103-109
- ☐ 4-87-120
- ☐ 5-110-41
- ☐ 88-104-40
- ☐ 42-116-PROBES
- ☐ 115-131-PROBES
- ☐ 119-132

EXPERIMENT #116: CONDUCTIVITY TESTER

You can find the exact value of a resistance if you use a meter; but when you only want to know approximate resistance values, you can use this conductivity tester.

This circuit converts resistance to electric current and compares it with the comparator's reference current to tell you the approximate range of resistance. The comparator has a reference voltage of about 0.82V.

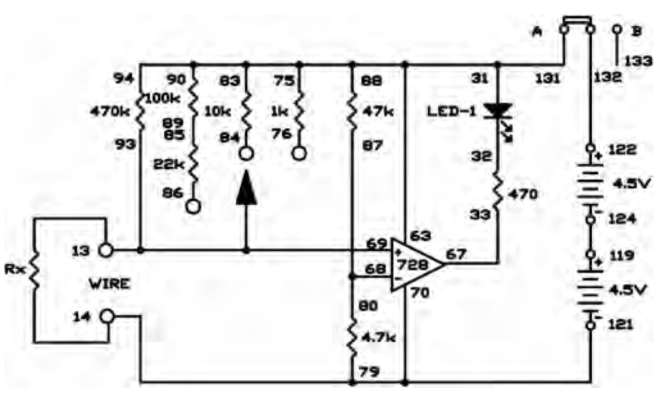
To use this project, build the circuit and set the switch to position A to turn on the power. Connect the material to be tested between terminals 13 and 14. If the LED lights, the resistance is less than 100kΩ. If the LED does not light, the resistance is greater than 100kΩ.

If the LED lights, connect terminals 93 and 86, and see if the LED stays on or turns off. If it turns off, the resistance is in the range of 10Ω to 100kΩ. If it stays on, remove the wire from terminal 86 and connect it to terminal 84. If the LED turns off, the resistance is in the range of 1 to 10kΩ. If the LED still doesn't turn off, remove the wire from terminal 84 and connect it to terminal 76. Does the LED turn off? If it does, it means that the resistance is in the range of 100Ω to 1kΩ. If it stays on, the resistance is less than 100Ω.

Wiring Sequence:

- ☐ 13-93-69-WIRE
- ☐ 14-79-70-121
- ☐ 75-83-94-90-88-31-63-131
- ☐ 33-67
- ☐ 68-80-87
- ☐ 85-89
- ☐ 119-124
- ☐ 122-132

Schematic



Notes:

EXPERIMENT #117: TRANSISTOR CHECKER

You will probably test transistors more than any other component. You can't tell if a transistor is working or not by looking at it, but this project lets you hear whether or not it is. You can also tell if a transistor is a PNP or an NPN with this circuit.

You'll notice that this project has three long wires - one for the emitter, one for the collector and one for the base. The schematic shows the terminals marked for checking PNP transistors.

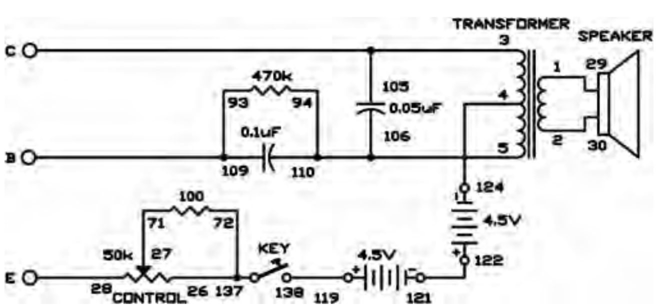
To use this project, connect the long wires to the base, collector, and emitter of the transistor you want to test. Turn the control fully counter-clockwise. Then, press the key and turn the control clockwise. If you hear a sound from the speaker, the transistor is a working PNP transistor. If you hear no sound at all, change connections 4-124 and 119-138 to 4-119 and 124-138, and repeat the test. If you get a sound from the speaker this time, the transistor is a working NPN type. If you get no sound from the speaker using either set of connections, the transistor is defective.

As you start to accumulate parts for other electronic circuits, you'll find this a handy circuit for testing unmarked transistors.

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-105-COLLECTOR
- ☐ 4-124
- ☐ 5-94-106-110
- ☐ 26-72-137
- ☐ 27-71
- ☐ 28-EMITTER
- ☐ 93-109-BASE
- ☐ 119-138
- ☐ 121-122

Schematic



Notes:

EXPERIMENT #118: SINEWAVE AUDIO OSCILLATOR

Now, you will learn about generating sinewave signals. We can define a sinewave as a wave of pure single-frequency tone. For example, a 400Hz sinewave is a wave that oscillates 400 cycles in one second and contains no other frequency components. Non-sinewaves have harmonics - waves with frequencies that are multiples of the single-frequency fundamental wave. A non-sine 400Hz wave can include the 400Hz wave (its fundamental wave) along with an 800Hz wave (its 2nd harmonic wave) and a 1200Hz wave (its third harmonic wave).

An experienced technician can test a circuit by using a sinewave and listening to its output. Soon, you will be able to do this too. If you put in a sinewave, and something else comes out, the undesired harmonic frequencies must have been generated somewhere in the circuit.

The part of this project that generates a 400Hz sinewave has:

- A 0.1μF capacitor connecting terminals 3 and 5 of the transformer to form a tank circuit that resonates at about 600Hz.
- A 470kΩ resistor to turn on the base of the transistor only a small amount.
- An adjustable feedback circuit that includes the control and the 0.05μF capacitor.
- A 100Ω resistor connected to the emitter to help stabilize the circuit and keep the sound from being distorted.

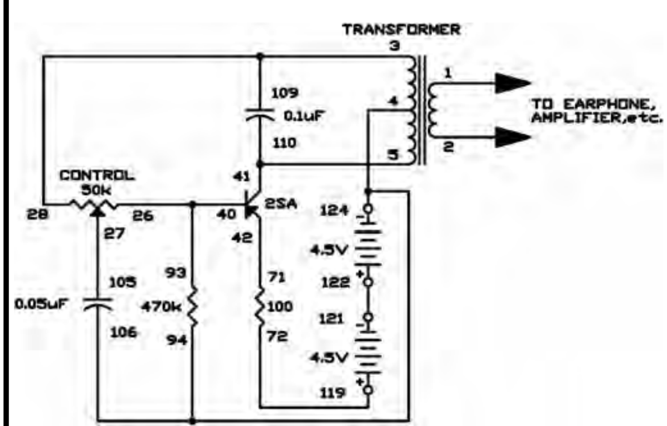
Connect the earphone to terminals 1 and 2 of the transformer. Start with the control on maximum - 10 on the dial - and slowly decrease the control setting while listening to the tone quality of the output. Before the oscillations stop, you will reach a point where you hear only one tone. This last clear-sounding tone is the sinewave. Repeat these control adjustments until you have no trouble distinguishing between a sinewave and a distorted wave.

Notes:

Wiring Sequence:

- ☐ 1-EARPHONE
- ☐ 2-EARPHONE
- ☐ 3-28-109
- ☐ 4-94-106-124
- ☐ 5-41-110
- ☐ 26-40-93
- ☐ 27-105
- ☐ 42-71
- ☐ 72-119
- ☐ 121-122

Schematic



EXPERIMENT #119: LOW DISTORTION SINEWAVE OSCILLATOR

In this project, you will build and study a low-distortion sinewave oscillator. Build this project after you have built and studied the previous project because this one has no transformer; transformers are likely to cause distortion because of their non-linear characteristics.

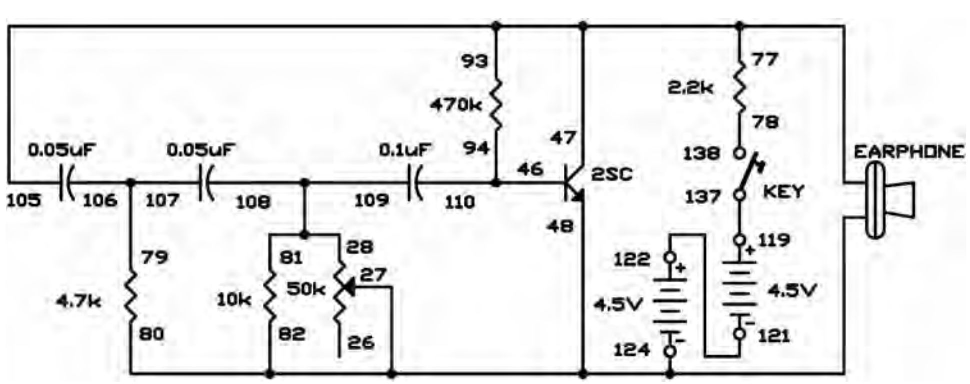
As in the previous project, you should listen to the tone of this oscillator and adjust the control for the clearest-sounding single tone (the one with the least distortion). Again, start with the control near maximum. The frequency of operation is about 300Hz, at the minimum distortion setting of the control.

This circuit is called an RC phase shift oscillator and is considered a basic sinewave oscillator. Oscillations occur because of the positive feedback of the signals. The resistors (R) and capacitors (C) make up the path for the circuits to the transistor base. Every time the signals pass the RC circuits, a slight time lag occurs. In other words, the rise and fall of the wave (the phase) shifts slightly. That's why we call it phase shift. After the signal has traveled through the circuit, the phase shifts 180 degrees. When the collector voltage rises, this rise is fed back to the collector with the phase shifted. When the base voltage rises, the collector voltage falls. This repeating cycle causes the transistor to oscillate.

When you change the control setting, the frequency changes. This is because the degree of phase shift changes. The tonal quality also changes. Set the control to the point where you can hear the purest tone. At this point, a clear sinewave is generated.

Notes:

Schematic



Wiring Sequence:

- ☐ 124-27-48-82-80-EARPHONE
- ☐ 47-105-93-77-EARPHONE
- ☐ 81-109-108-28
- ☐ 94-110-46
- ☐ 78-138
- ☐ 79-106-107
- ☐ 119-137
- ☐ 121-122

EXPERIMENT #120 TWIN-T AUDIO OSCILLATOR

Because it is very stable, the twin-T type audio oscillator is very popular for use with electronic organs and electronic test equipment.

The oscillation frequency depends on the resistors and capacitors in the twin-T network. The letter T is used because the schematic diagram for this circuit shows its resistors and capacitor arranged in the shape of the letter T. The term twin comes from the face that there are two T networks in parallel across from each other. The capacitors in series shift the phase of the wave; the resistors in series supply voltage to the transistor's base as well as shifting the phase of the wave.

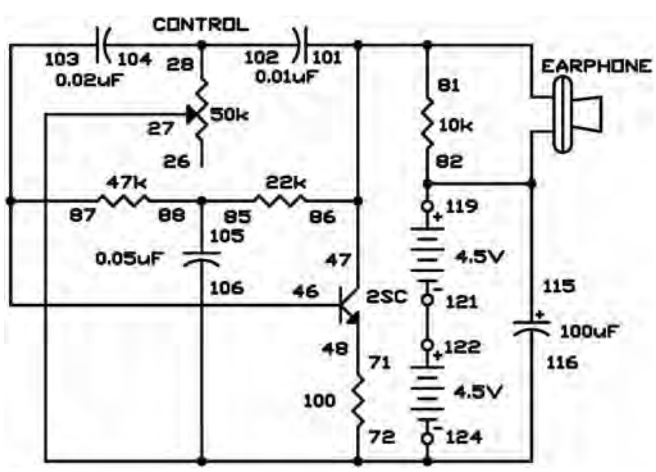
Carefully adjust the circuit to obtain pure sinewave output as in the previous two projects. Adjust the control very slowly over its entire range until you hear a tone in the earphone that is very low and resembles the lowest note of a large pipe organ. This control setting should be between 7 and 10 on your dial.

Once the oscillation has started, adjust the control carefully for the setting that gives the purest sounding low note near the high end of the dial.

You can experiment with this circuit in many ways. We suggest you try different values for the 10kΩ and 470Ω resistors, and try using higher and lower battery voltages. Also, if you have a VOM, try measuring circuit voltages.

Notes:

Schematic



Wiring Sequence:

- ☐ 72-106-116-27-124
- ☐ 28-104-102
- ☐ 46-103-87
- ☐ 47-101-86-81-EARPHONE
- ☐ 48-71
- ☐ 119-115-82-EARPHONE
- ☐ 85-88-105
- ☐ 121-122

EXPERIMENT #121: PULSE OSCILLATOR TONE GENERATOR

This project is a pulse-tone oscillator with an adjustable frequency that can obtain a wide range of notes. With practice, you can play tunes on it that sound like an electronic organ.

To play a tune, adjust the control to the proper note and press the key. Readjust the control for the next note and press the key again.

When you close the key the first time, the base current flows around the loop formed by the battery, the 10kΩ resistor, the 50kΩ resistor, the transistor base and emitter, and the key.

The base current causes the collector current to flow around the loop formed by the 3V supply, the lower half of the transformer winding, the transistor collector and emitter, and the key.

The current flowing in the transformer causes a current to flow around the loop formed by the top transformer winding, the 0.05μF capacitor, the transistor base and emitter, the key, the battery and back to the transformer's center terminal (terminal 2). This current quickly (in less than 0.0001 seconds) charges the 0.05μF to about 4V or so with a polarity negative on the transformer side and positive on the transistor base lead side. Output activates the speaker only while the current flows in the transformer.

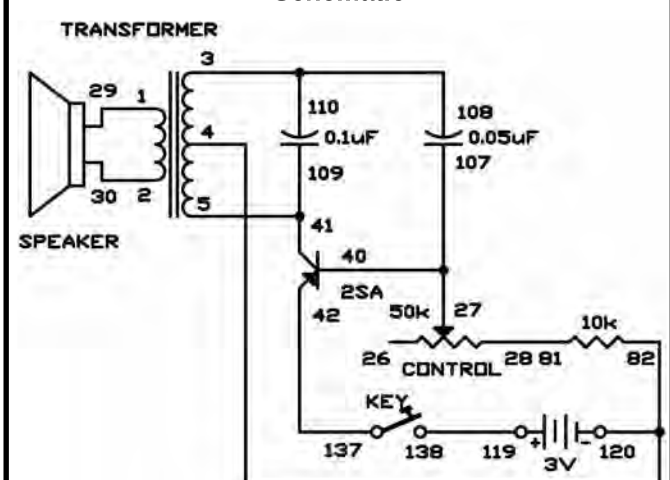
The charging of the 0.05μF capacitor stops when the induced voltage from the top half of the transformer winding stops. Then, the capacitor begins to charge again. As soon as the discharge begins, the capacitor voltage becomes higher than the battery voltage. The reverse polarity voltage is applied to the base and the transistor turns off. Now, all transistor junctions act as open circuits. The capacitor discharges around the loop formed by the top transformer winding, the 10kΩ resistor, and the 50kΩ resistor. When you reduce the control setting, the discharge is faster, so the process is repeated at a faster rate causing a higher frequency. As soon as the 0.05μF capacitor discharges to slightly below the 3V of the battery, this cycle repeats.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-108-110
- ☐ 4-82-120
- ☐ 27-40-107
- ☐ 28-81
- ☐ 5-41-109
- ☐ 42-137
- ☐ 119-138

Schematic



EXPERIMENT #122: AUDIO SIGNAL TRACER

This project is a simple transistor audio amplifier used as an audio signal tracer. You can use this amplifier to troubleshoot transistor audio equipment. When a circuit does not work correctly, you can connect the wires to different terminals in the circuit until you find the stage or component that does not pass the signal along.

The 0.1μF input capacitor blocks DC so you can probe around circuits without worrying about damaging the circuit.

The amplifier circuit is a common-emitter type. That is, the transistor's emitter is connected directly to the input and the output of the earphone. Its base current is the self current type. The current from the transistor collector provides current to the base (through the 470kΩ resistor). This provides some stabilizing negative DC feedback.

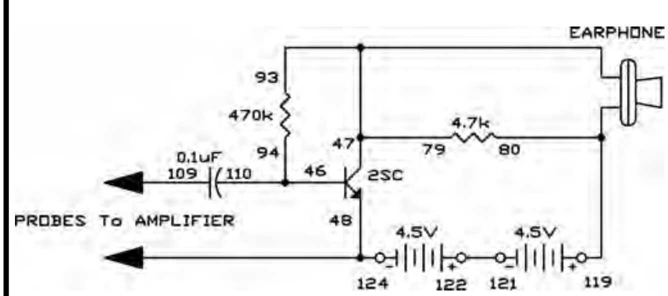
You can use this amplifier to check any transistor radio or amplifier you have that needs fixing.

Notes:

Wiring Sequence:

- ☐ 46-110-94
- ☐ 47-79-93-EARPHONE
- ☐ 124-48-PROBES
- ☐ 119-80-EARPHONE
- ☐ 109-PROBES
- ☐ 121-122

Schematic



EXPERIMENT #123: RADIO FREQUENCY SIGNAL TRACER

This project is a wide band, untuned RF signal tracer. You can use it to find sources of RF noise and interference, and to check for antenna signals. This circuit is like an untuned crystal set.

We use the 100pF capacitor for the input in this circuit because it blocks DC and the 60Hz power line frequency so that the wires can touch almost anywhere without fear of electrical shock. Of course, you should never probe around high voltage on purpose. There is an old saying, “There are OLD technicians and BOLD technicians, but there are no OLD BOLD technicians.”

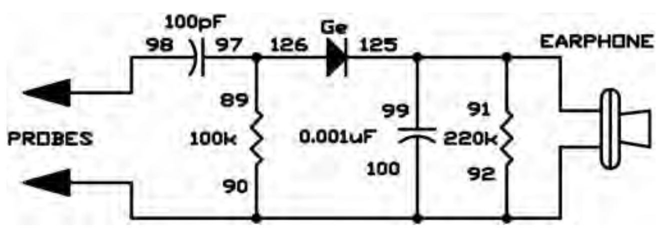
Connect the probes between grounded objects and other metallic objects that can act as antennas. You will find that this circuit allows you to receive all kinds of AM signals as well as noise. For example, if you have citizens’ band transmitters, you can hear these signals if the transmitter is close enough to the signal tracer.

Some of the noise you might hear and identify originates from auto ignition systems, light dimmers, fluorescent lights, or switches opening and closing.

Wiring Sequence:

- ☐ 89-97-126
- ☐ 90-92-100-EARPHONE-PROBES
- ☐ 125-99-91-EARPHONE
- ☐ 98-PROBES

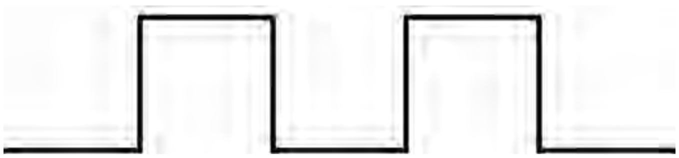
Schematic



Notes:

EXPERIMENT #124: SQUARE WAVE AUDIO OSCILLATOR

You can use square waves as test signals, too. Square waves are produced by multivibrator oscillators. Remember, you used this type of circuit in previous projects. The name square wave comes from the pattern produced by the signal on an oscilloscope (shown below).



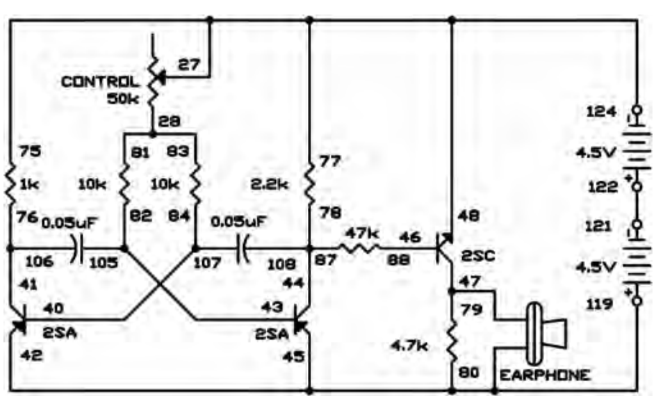
Build this circuit and you will hear the sound produced by a square wave signal. You can vary the pitch and the frequency of the signal by adjusting the control. This varies the current supplied to the PNP transistor bases.

Notes:

Wiring Sequence:

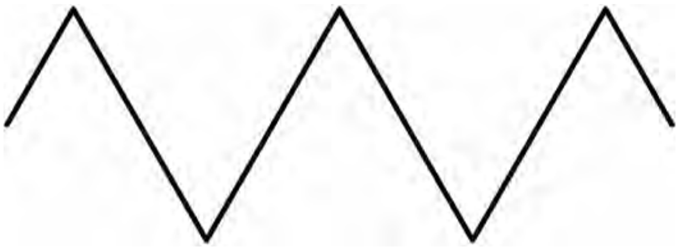
- ☐ 77-75-48-27-124
- ☐ 28-81-83
- ☐ 40-107-84
- ☐ 41-106-76
- ☐ 119-42-45-80-EARPHONE
- ☐ 43-105-82
- ☐ 78-87-108-44
- ☐ 46-88
- ☐ 47-79-EARPHONE
- ☐ 121-122

Schematic



EXPERIMENT #125: SAWTOOTH WAVE OSCILLATOR

When you connect the signal from this oscillator to an oscilloscope, it makes a pattern that looks like the teeth of a saw (as shown below).

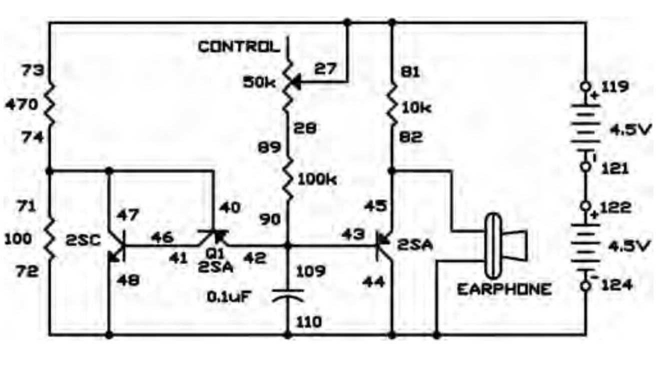


The shape of this wave comes from the slow charging of the 0.1μF capacitor through the control and the 100kΩ resistor, and the capacitor's quick discharge through the PNP and NPN transistors.

The voltage divider - the 470Ω and 100Ω resistors - provides about 1.6 volts to the transistors. The current flowing into the 0.1μF capacitor from the 9V supply (through the control and the 100kΩ resistor) causes the charge of the capacitor to slowly increase. When the charge of the capacitor exceeds the voltage of the voltage divider (1.6V), the transistors turn on and provide a path for the 0.1μF capacitor to discharge quickly. Now, the transistors 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 - the control, the 100kΩ resistor and the 0.1μF capacitor. Try a 47kΩ resistor or a 220kΩ resistor in place of the 100kΩ resistor, and try several different capacitors. If you connect one of the electrolytic capacitors, be sure that you use the proper polarity (+ and –).

Schematic



Notes:

Wiring Sequence:

- ☐ 73-81-27-119
- ☐ 28-89
- ☐ 71-74-47-40
- ☐ 41-46
- ☐ 42-43-90-109
- ☐ 124-44-48-110-72-EARPHONE
- ☐ 45-82-EARPHONE
- ☐ 121-122

EXPERIMENT #126: RAIN DETECTOR

This circuit works as a rain detector. When the resistance between the long wires is more than about 250kΩ, no current is drawn from the circuit - whether the key is open or closed. When the key is closed and water (or anything else that has a resistance of less than about 400kΩ) is connected to both of the test wires, the speaker produces a tone.

Connect the wires to other wires or metallic plates laid out on an insulated surface. When water completes the circuit by spanning the two wires or plates, the alarm turns on.

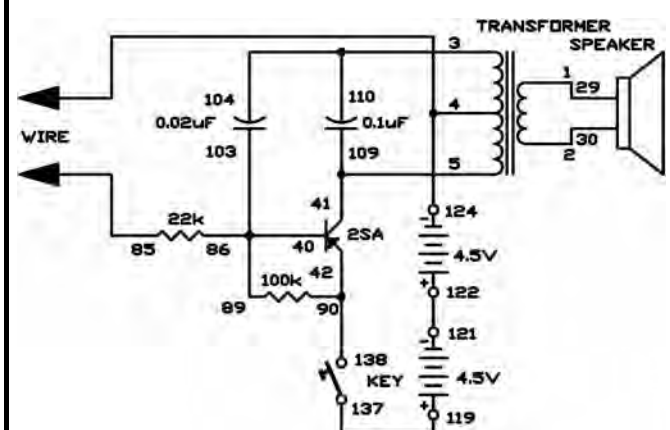
This oscillator is the basic pulse-type that we've used several times in this kit. The 22kΩ resistor protects the circuit against excess base current, in case the wires are shorted together. The 100kΩ resistor keeps any transistor leakage current from turning on the oscillator.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-104-110
- ☐ 124-4-WIRE
- ☐ 5-41-109
- ☐ 86-89-103-40
- ☐ 42-90-138
- ☐ 85-WIRE
- ☐ 119-137
- ☐ 121-122

Schematic



EXPERIMENT #127: WATER LEVEL BUZZER WITH OPERATIONAL AMPLIFIER

You can use the dual operational amplifier as a comparator for detecting changes in voltage. In this project, we're going to use this comparator function to make a water buzzer that sounds when the wire ends come into contact with water.

Slide the switch to position B and assemble the circuit. When you finish connecting the wiring, slide the switch to position A to turn on the power. You should hear no sound from the speaker. Now, connect the two output terminals with a wire. You will hear a sound from the speaker.

Next, touch the two output terminals with your fingers. If the speaker makes a sound again, the electricity is flowing through your body because the wire lead is in contact with sweat.

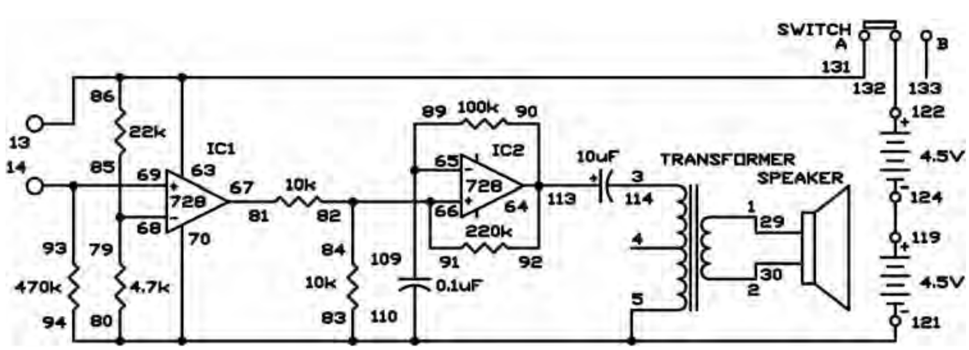
This project uses two dual operational amplifiers. IC 1 works as a comparator. The IC's negative (–) input terminal has a reference voltage of about 1.6V. When a voltage exceeding 1.6V is applied to the positive (+) input terminal, the output of the comparator allows IC 2 to work as an astable multivibrator.

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-114
- ☐ 5-83-80-94-70-110-121
- ☐ 13-86-63-131
- ☐ 14-93-69
- ☐ 65-89-109
- ☐ 66-82-84-91
- ☐ 64-90-92-113
- ☐ 67-81
- ☐ 68-79-85
- ☐ 119-124
- ☐ 122-132

Schematic



EXPERIMENT #128: METAL DETECTOR

This project demonstrates how a metal detector works. When the coil comes close to the metal, the oscillator changes the frequency; then, you know there is something close by that is made of metal. This type of metal detector has been used to locate lost treasures, buried pipes, hidden land mines, and so on. During war time, these have been used to save many lives by locating mines and booby traps set out by the enemy.

This circuit is a low distortion oscillator that draws only one milliamp from the 9V supply. Using low power allows the nearby metal to have maximum effect on oscillation frequency.

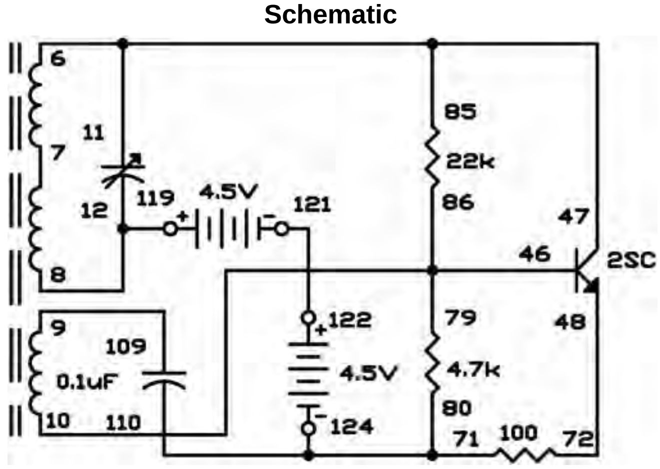
Use a small transistor radio tuned to a weak AM broadcast station as the detector. Tune the oscillator until you hear a low-frequency beat note. This beat note is the difference between the signal of a broadcast station and this oscillator. Do not bring the radio any closer than necessary. The best position is where the levels of the two signals are about equal. This gives maximum sensitivity.

Try using keys, plastic objects, coins, and so on, as sample objects. Of course, a real metal detector does not have a small ferrite coil like this. It usually uses an air-core coil shielded with an aluminum electrostatic shield called a Faraday electrostatic shield.

If the oscillator does not oscillate no matter what you do, try reversing the wire connections on terminals 9 and 10. If this fixes the problem, reverse the wire connections underneath the board so you can use the proper terminals for this and other similar projects.

Notes:

Schematic



Wiring Sequence:

- ☐ 6-11-85-47
- ☐ 8-12-119
- ☐ 9-109
- ☐ 10-79-86-46
- ☐ 48-72
- ☐ 71-80-110-124
- ☐ 121-122

EXPERIMENT #129: WATER LEVEL ALARM

This electronic circuit is a radio transmitter/alarm device used to monitor rising water levels such as on rivers, dams, and spillways. Its alarm signals are received by a standard AM radio. When the water-contact plates or wires are out of the water, the circuit is not complete and there is no RF output. When the contacts are connected by water, an RF output received by the radio indicates that the water level has reached the height of the contacts.

The emitter of the NPN transistor in the RF oscillator circuit is connected to the ferrite coil center terminal through the 10μF capacitor. The capacitor acts as a short circuit at these frequencies. Feedback to the base is through the 100pF capacitor. The 470kΩ resistor supplies the base current that turns on the transistor.

Notice that the battery current must flow through the PNP transistor to get to the oscillator circuit and back. With the wires insulated from each other, the only current that can flow is the leakage current from the collector to the emitter with the base open. This weak current cannot drive the RF oscillator.

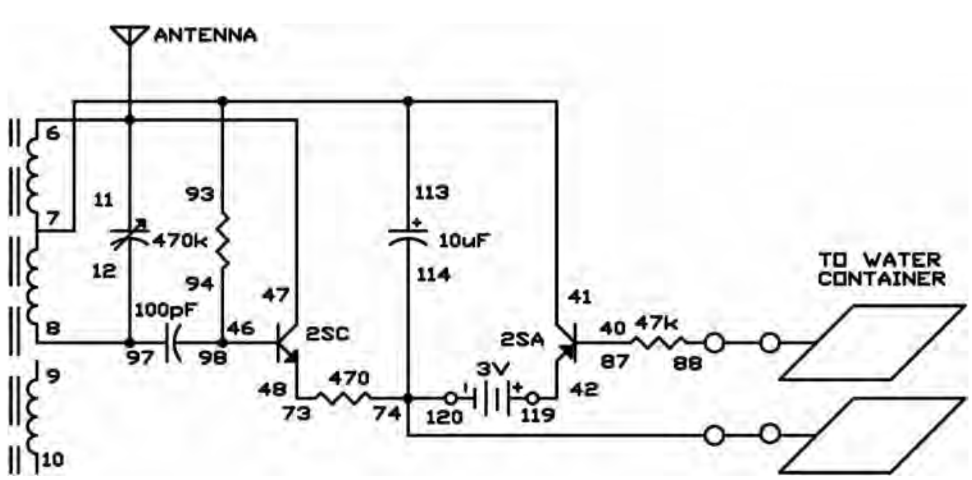
When the wires are connected by the water, some current can flow through the water to supply base current to the PNP transistor. This base current turns on the PNP transistor so that oscillator current can flow between the collector and the emitter of the PNP transistor with little resistance. Without this resistance, the PNP transistor could be burned out by excessive current, especially if the probes were accidentally touched directly together.

When the transistor is on, the RF oscillator produces an RF signal. These probes can be made of almost any insulated conductor, but large surface areas provide the quickest results.

Place an AM radio receiver nearby and tune it to a weak station. Then, adjust the oscillation frequency with the tuning capacitor to a point where you can hear through the radio.

Notes:

Schematic



Wiring Sequence:

- ☐ 47-11-6-ANT
- ☐ 7-93-113-41
- ☐ 8-12-97
- ☐ 40-87
- ☐ 42-119
- ☐ 46-98-94
- ☐ 48-73
- ☐ 74-114-120-WATER
- ☐ 88-WATER

EXPERIMENT #130: THREE-STEP WATER LEVEL INDICATOR

This project uses the LED and an audio oscillator alarm to indicate three different levels of water in a container. The water is used as a conductor to complete the circuits and show the water level.

When the water is below all three of the wire connections, only the bottom segment (D) of the LED is on (indicating a low water level).

When the water rises to a level that touches the two long wires connected to terminals 77 and 124 (but is below the shorter wire), the base current turns on transistor Q2 and the middle segment of the LED (G) turns on (indicating a moderate water level).

If the water reaches a level high enough to touch all three wires, the base current is supplied to transistor Q1, and the top segment of the LED (A) lights. The audio oscillator is also activated as a warning of a high water level.

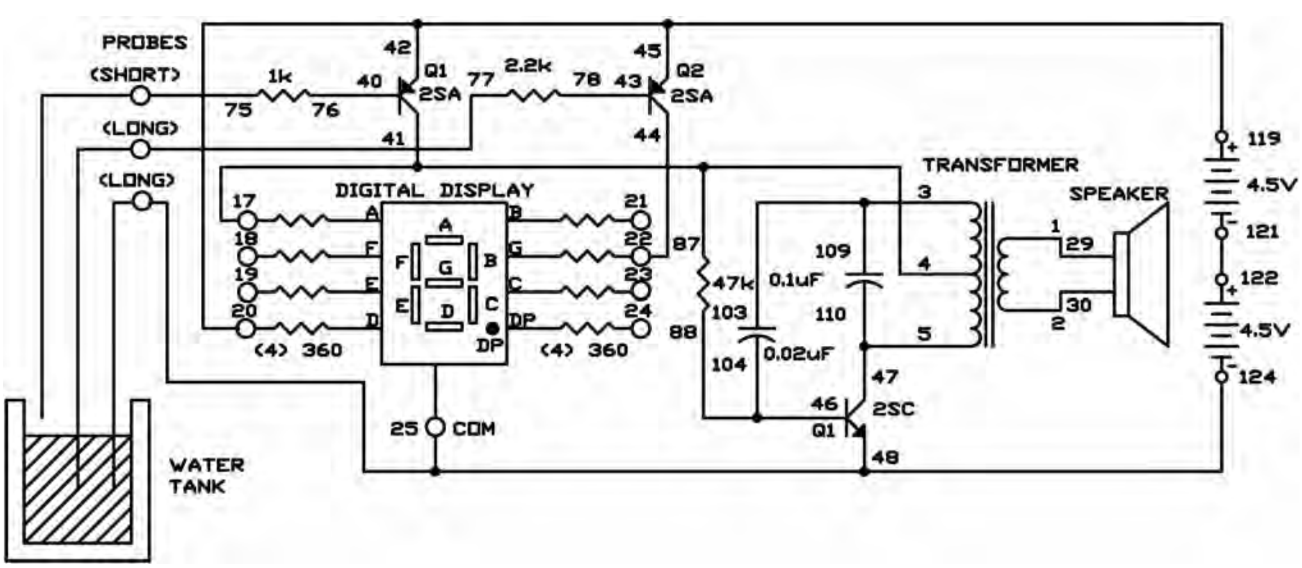
Of course, you can modify this wiring to make the LED display show other letters of symbols to indicate the different water levels. Can you think of any good symbols? (How about L = low, C = center, and H = high?)

Notes:

Wiring Sequence:

- ☐ 1-29
- ☐ 2-30
- ☐ 3-103-109
- ☐ 4-17-41-87
- ☐ 5-47-110
- ☐ 20-42-45-119
- ☐ 22-44
- ☐ 25-48-124-WIRE
- ☐ 40-76
- ☐ 43-78
- ☐ 46-104-88
- ☐ 75-WIRE
- ☐ 77-WIRE
- ☐ 121-122

Schematic



INDEX

We've added this listing to aid you in finding experiments and circuits that you might be especially interested in. Many of the experiments are listed two, three, or four times - since they can be used in many ways. You'll find some listed as entertainment-type circuits, even through they were not organized that way in the sequence of projects. However, you may find some of these same circuits to be good for other uses too.

Do you want to learn more about a specific type of circuit? Use this Index to look up all the other uses and applications of any specific circuit - then turn to those and read what we've told you in each one. You'll find by jumping back and forth and around, you often will pick up a lot more circuit details than just by going from one project to the next in sequence.

Use this Index and your own creative ability and we know you will have a lot of extra fun with your Lab Kit.

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INTEGRATED CIRCUIT PROJECTS

LED DISPLAY

LOGIC AND COMPUTER CIRCUITS

NATURAL SCIENCE PROJECTS

OSCILLATORS

SWITCHING AND CONTROL CIRCUITS

TEST EQUIPMENT

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  - 0.001μF, ceramic disc type
  - 0.01μF, ceramic disc type
  - 0.02μF, ceramic disc type
  - 0.05μF, ceramic disc type (2)
  - 0.1μF, ceramic disc type
  - 3.3μF, 25V electrolytic type
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DEFINITION OF TERMS

AC Common abbreviation for alternating current.

Alternating Current A current that is constantly changing.

AM Amplitude modulation. The amplitude of the radio signal is varied depending on the information being sent.

Amp Shortened name for ampere.

Ampere (A) The unit of measure for electric current. Commonly shortened to amp.

Amplitude Strength or level of something.

Analogy A similarity in some ways.

AND Gate A type of digital circuit which gives a HIGH output only if all of its inputs are HIGH.

Antenna Inductors used for sending or receiving radio signals.

Astable Multivibrator A type of transistor configuration in which only one transistor is on at a time.

Atom The smallest particle of a chemical element, made up of electrons, protons, etc.

Audio Electrical energy represent-ing voice or music.

Base The controlling input of an NPN bipolar junction transistor.

Battery A device which uses a chemical reaction to create an electric charge across a material.

Bias The state of the DC voltages across a diode or transistor.

Bipolar Junction Transistor (BJT) A widely used type of transistor.

Bistable Switch A type of transistor configuration, also known as the flip-flop.

Capacitance The ability to store electric charge.

Capacitor An electrical component that can store electrical pressure (voltage) for periods of time.

Carbon A chemical element used to make resistors.

Clockwise In the direction in which the hands of a clock rotate.

Coil When something is wound in a spiral. In electronics this describes inductors, which are coiled wires.

Collector The controlled input of an NPN bipolar junction transistor.

Color Code A method for marking resistors using colored bands.

Conductor A material that has low electrical resistance.

Counter-Clockwise Opposite the direction in which the hands of a clock rotate.

Current A measure of how fast electrons are flowing in a wire or how fast water is flowing in a pipe.

Darlington A transistor configuration which has high current gain and input resistance.

DC Common abbreviation for direct current.

Decode To recover a message.

Detector A device or circuit which finds something.

Diaphragm A flexible wall.

Differential Pair A type of transistor configuration.

Digital Circuit A wide range of circuits in which all inputs and outputs have only two states, such as high/low.

Diode An electronic device that allows current to flow in only one direction.

Direct Current A current that is constant and not changing.

Disc Capacitor A type of capacitor that has low capacitance and is used mostly in high frequency circuits.

Electric Field	The region of electric attraction or repulsion around a constant voltage. This is usually associated with the dielectric in a capacitor.
Electricity	A flow of electrons between atoms due to an electrical charge across the material.
Electrolytic Capacitor	A type of capacitor that has high capacitance and is used mostly in low frequency circuits. It has polarity markings.
Electron	A sub-atomic particle that has an electrical charge.
Electronics	The science of electricity and its applications.
Emitter	The output of an NPN bipolar junction transistor.
Encode	To put a message into a format which is easier to transmit.
Farad, (F)	The unit of measure for capacitance.
Feedback	To adjust the input to something based on what its output is doing.
Flip-Flop	A type of transistor configuration is which the output changes every time it receives an input pulse.
FM	Frequency modulation. The frequency of the radio signal is varied depending on the information being sent.
Forward-Biased	The state of a diode when current is flowing through it.
Frequency	The rate at which something repeats.
Generator	A device which uses steam or water pressure to move a magnet near a wire, creating an electric current in the wire.
Germanium	A chemical element that is used as a semiconductor.
Ground	A common term for the 0V or "–" side of a battery or generator.
Henry (H)	The unit of measure for Inductance.
Inductance	The ability of a wire to create an induced voltage when the current varies, due to magnetic effects.
Inductor	A component that opposes changes in electrical current.
Integrated Circuit	A type of circuit in which transistors, diodes, resistors, and capacitors are all constructed on a semiconductor base.
Kilo- (K)	A prefix used in the metric system. It means a thousand of something.
Light Emitting Diode (LED)	A diode made from gallium arsenide that has a turn-on energy so high that light is generated when current flows through it.
Magnetic Field	The region of magnetic attraction or repulsion around a magnet or an AC current. This is usually associated with an inductor or transformer.
Magnetism	A force of attraction between certain metals. Electric currents also have magnetic properties.
Meg- (M)	A prefix used in the metric system. It means a million of something.
Micro- (μ)	A prefix used in the metric system. It means a millionth (0.000,001) of something.
Microphone	A device which converts sound waves into electrical energy.
Milli- (m)	A prefix used in the metric system. It means a thousandth (0.001) of something.
Modulation	Methods used for encoding radio signals with information.
Morse Code	A code used to send messages with long or short transmit bursts.
NAND Gate	A type of digital circuit which gives a HIGH output if some of its inputs are LOW.
NPN	Negative-Positive-Negative, a type of transistor construction.

Ohm's Law The relationship between voltage, current, and resistance.

Ohm, (Ω) The unit of measure for resistance.

Oscillator A circuit that uses feedback to generate an AC output.

Parallel When several electrical components are connected between the same points in the circuit.

Pico- (p) A prefix used in the metric system. It means a millionth of a millionth (0.000,000,000,001) of something.

Pitch The musical term for frequency.

Printed Circuit Board A board used for mounting electrical components. Components are connected using metal traces "printed" on the board instead of wires.

Receiver The device which is receiving a message (usually with radio).

Resistance The electrical friction between an electric current and the material it is flowing through; the loss of energy from electrons as they move between atoms of the material.

Resistor Components used to control the flow of electricity in a circuit. They are made of carbon.

Resistor-Transistor-Logic (RTL) A type of circuit arrangement used to construct digital gates.

Reverse-Biased When there is a voltage in the direction of high-resistance across a diode.

Saturation The state of a transistor when the circuit resistances, not the transistor itself, are limiting the current.

Schematic A drawing of an electrical circuit that uses symbols for all the components.

Semiconductor A material that has more resistance than conductors but less than insulators. It is used to construct diodes, transistors, and integrated circuits.

Series When electrical components are connected one after the other.

Short Circuit When wires from different parts of a circuit (or different circuits) connect accidentally.

Silicon The chemical element most commonly used as a semiconductor.

Speaker A device which converts electrical energy into sound.

Switch A device to connect ("closed" or "on") or disconnect ("open" or "off") wires in an electric circuit.

Transformer A device which uses two coils to change the AC voltage and current (increasing one while decreasing the other).

Transient Temporary. Used to describe DC changes to circuits.

Transistor An electronic device that uses a small amount of current to control a large amount of current.

Transmitter The device which is sending a message (usually with radio).

Tuning Capacitor A capacitor whose value is varied by rotating conductive plates over a dielectric.

Variable Resistor A resistor with an additional arm contact that can move along the resistive material and tap off the desired resistance.

Voltage A measure of how strong an electric charge across a material is.

Voltage Divider A resistor configuration to create a lower voltage.

Volts (V) The unit of measure for voltage.

IDENTIFYING RESISTOR VALUES

Use the following information as a guide in properly identifying the value of resistors.

BAND 1
1st Digit

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

BAND 2
2nd Digit

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

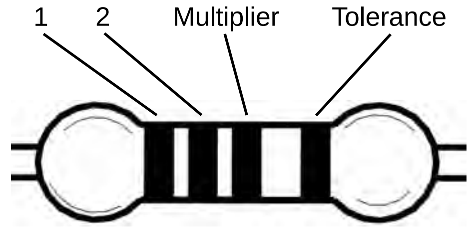
Multiplier

Color	Multiplier
Black	1
Brown	10
Red	100
Orange	1,000
Yellow	10,000
Green	100,000
Blue	1,000,000
Silver	0.01
Gold	0.1

Resistance Tolerance

Color	Tolerance
Silver	±10%
Gold	±5%
Brown	±1%
Red	±2%
Orange	±3%
Green	±0.5%
Blue	±0.25%
Violet	±0.1%

BANDS



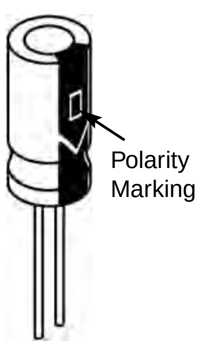
IDENTIFYING CAPACITOR VALUES

Capacitors will be identified by their capacitance value in pF (picofarads), nF (nanofarads), or μF (microfarads). Most capacitors will have their actual value printed on them. Some capacitors may have their value printed in the following manner. The maximum operating voltage may also be printed on the capacitor.

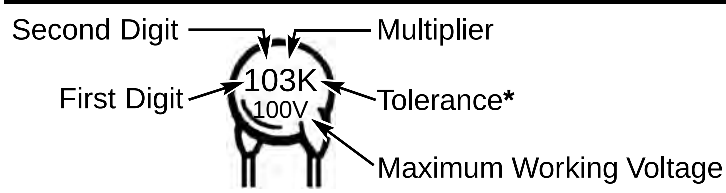
Electrolytic capacitors have a positive and a negative electrode. The negative lead is indicated on the packaging by a stripe with minus signs and possibly arrowheads.

Warning:

If the capacitor is connected with incorrect polarity, it may heat up and either leak, or cause the capacitor to explode.



Multiplier	For the No.	0	1	2	3	4	5	8	9
	Multiply By	1	10	100	1k	10k	100k	.01	0.1



The value is 10 x 1,000 =
10,000pF or .01μF 100V

*The letter M indicates a tolerance of $\pm$20%
The letter K indicates a tolerance of $\pm$10%
The letter J indicates a tolerance of $\pm$5%

Note: The letter "R" may be used at times to signify a decimal point; as in 3R3 = 3.3

METRIC UNITS AND CONVERSIONS

Abbreviation	Means	Multiply Unit By	Or
p	pico	.000000000001	10^{-12}
n	nano	.000000001	10^{-9}
μ	micro	.000001	10^{-6}
m	milli	.001	10^{-3}
–	unit	1	10^{0}
k	kilo	1,000	10^{3}
M	mega	1,000,000	10^{6}

1. 1,000 pico units	= 1 nano unit
2. 1,000 nano units	= 1 micro unit
3. 1,000 micro units	= 1 milli unit
4. 1,000 milli units	= 1 unit
5. 1,000 units	= 1 kilo unit
6. 1,000 kilo units	= 1 mega unit