Science Fair®

Cat. No. 28-258

160 in ONE ELECTRONIC PROJECT KIT

For Ages 10 and Up

LIST OF EXPERIMENTS

This **SCIENCE FAIR 160-in-1 Electronic Project Kit** may be your first experience with the very exciting field of electricity and electronics. We hope it won't be your last. As a matter of fact, we hope it stimulates your interest in Electronics as a hobby — and that it may eventually lead you into a job with this fascinating subject.

This manual lists 160 different experiments you can perform with this Kit. We have included all that you need for all of these experiments — except for the batteries:

You will need two type AA Penlight batteries. We recommend Radio Shack's Catalog Number 23-582 or 23-552.

Also, you'll need a 9-volt battery, such as our 23-151 or 23-553.

As you read this manual and wire up these experiments, you will see that we have carefully organized the sequence to aid you in learning. We'll help you understand how the circuits work and give you some ideas for additional experiments and fun.

We hope this Electronic Project Kit will just be the start of something that will excite and stimulate you. As you know, Electronics plays an important part in today's society. It offers you many chances for experimenting, fun, practical ideas and meaningful jobs and careers.

Even if you have never built an electronic circuit or project, you can build all of the projects in your Kit with ease. Assembly of the projects is simplified by the "breadboard" construction of your lab kit. Each of the different electronic components in the kit is mounted and clearly marked on the breadboard.

All of the projects can be assembled without soldering, since each component is connected to individual spring terminals. A wiring chart is included with each project, and all you have to do to build a working project is connect wires between the terminals listed in the wiring chart. Plenty of pre-cut, insulated wire is included with your lab kit.

Simple, clearly written instructions will help you operate and experiment with each project. A diagram called a Schematic is included with each project. The Schematic is an electronic blueprint which shows how the various components are wired together. Each component is represented by a Schematic symbol. The symbols for the various components in your lab kit are printed next to each component on the breadboard.

All of the projects in your lab kit are powered by low voltage batteries or a Solar Cell, so there are none of the hazards associated with using standard AC voltages (120 volts AC from an outlet in your house).

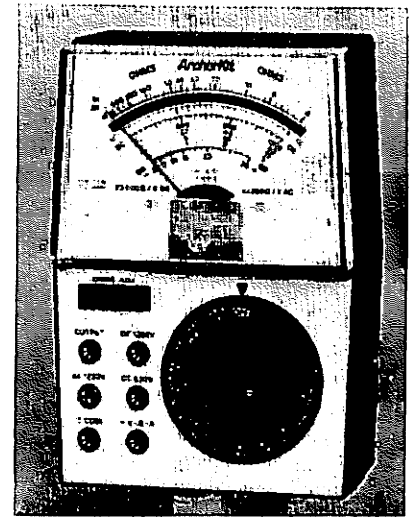
The 160 different projects in your Electronic Project Kit are divided into different categories. Take a look at the List of Experiments and you'll see what you can make. You can build game circuits, special sound effect experiments, IC circuits, LED display circuits, radios, sun powered radios, protection circuits, computer circuits and lots of others. No previous electronics experience is required to build any of the projects, but you will gain much valuable experience and learn a lot about electronics by building and experimenting with them.

As you go through the experiments — and you need not go through them in any special sequence — you'll see a great deal of similarity between circuits. This is natural, for all of electronic circuitry is made up of a limited number of fairly standard (and even common) circuits. Note at the back of this manual we've made up an index of experiments — a number of experiments are listed in more than one category (making it easier to find what you're looking for).

You'll notice we often refer to a Volt Ohm Meter, VOM for short, for making measurements. If you are going to understand electronic circuitry, it is important that you learn to measure circuit values — voltage, current and resistance — for only then can you really begin to understand the circuitry.

"When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind: it may be the beginning of knowledge, but you have scarceiy, in your own thoughts, advanced to the state of science."

LORD KELVIN, 1883



So we recommend that you take another trip to your Radio Shack store and invest in a VOM — a 20,000 ohms-per-volt model (or better). You don't have to use a VOM with the experiments, but you'll find it will help you greatly. A VOM is the most 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.

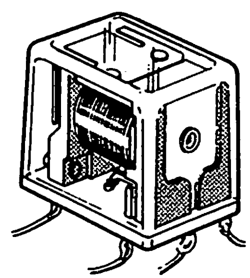
If you don't know how to use a VOM, we recommend that you obtain a copy of Radio Shack's book *BASIC DC CIRCUITS*.

We're excited with this kit — it really is a laboratory of electronics goodies. You'll have a lot of fun with it (and may not even realize how much you are learning as you "play" with it).

COMPONENTS

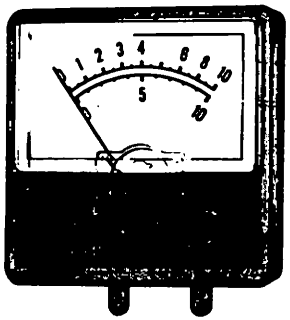
Your Kit has 55 separate components. The purpose of each component is explained below. The explanations will help you understand what each component does, and you will understand more about each component after building some of the projects.

There is a Parts List at the back of this Manual which lists all the parts in your kit. You might want to look at that list for additional notes and as a reference for the parts.



RELAY — A Relay is an electro-mechanical switch. It uses an electromagnet made from an iron rod wound with hundreds of turns of fine copper wire. When electricity is applied to the wire, the rod becomes magnetic. A movable contact arm above the rod is then pulled toward the rod until it closes a switch contact. When the electricity is removed, a small spring pulls the contact arm away from the rod until it closes a second switch contact. The entire Relay is protected by a plastic dust cover. You can see how a Relay works by watching the operation of the Relay in your lab kit.

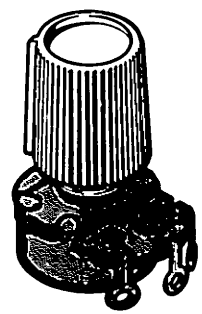
LAMP—Your lab kit has a 3-volt incandescent Lamp similar to those used in flashlights. The Lamp is used to send code signals or as an indicator or signal Lamp. Be sure to connect the Lamp only to the 3-volt Battery. The 9-volt Battery will burn out the Lamp.



THE METER is a very important electrical indicating and measuring device. You will use it to measure the amount of current flowing in a **circuit**. The pointer moves to indicate the amount of current; the higher the reading, the greater the current. The Meter is used in a number of experiments in your project kit. **Whenever you connect the Meter, be sure to observe proper polarity of the spring terminal connectors: minus (−) and plus (+).**

TRANSFORMER—There are two Transformers in your lab kit. They are made from a plastic form, wound with hundreds of turns of very fine copper wire. Thin metal plates called laminations are inserted inside the center of the hollow plastic form. A Transformer uses electromagnetic induction to transfer electrical energy flowing in one part of the Transformer to another part of the Transformer. A Transformer has an important job in the circuit—to help circuits "get along" with each other; they help to "match" circuits together so they all function efficiently. More on that as we get into the circuits.

CONTROL — Often for electronic circuits you need a variable Resistor, and that is what the Control is. You can use it as a light dimmer, a volume control and many other circuit applications where you'd like to be able to change resistance easily and quickly.



SPEAKER—For Radio circuits and special sound effect circuits, you will connect the Speaker (or the Earphone) to the circuit to hear the sounds and/or signals. For very weak sounds, the Earphone is best; for stronger sounds, use the Speaker.

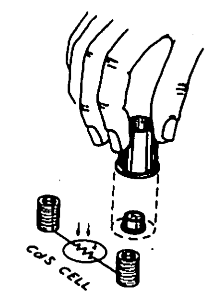
RESISTORS—There are 20 Resistors in your lab kit (8 are permanently connected to the LED). Each Resistor is made from carbon particles mixed with a binder material. Resistors resist the flow of electricity. They are very useful in supplying any desired voltage to transistors. The resistance of a Resistor is given in ohms. A resistance of just a few ohms means the Resistor offers little resistance to the flow of electricity. Often very high resistances are used in electronic circuits. The values of these Resistors are usually abbreviated by using the letter K to symbolize 1,000 ohms and the letter M (or Meg) to symbolize 1,000,000 ohms. A 470K Resistor therefore has a resistance of 470,000 ohms.

CAPACITORS — Your lab kit has fourteen fixed Capacitors (two of them are permanently connected to the Integrated Circuit—where they must always be). Unlike the Tuning Capacitor, their value is fixed and cannot be changed. Capacitors are very useful in electronic circuits. They can be used to pass an alternating current (AC) signal while blocking a direct current (DC) signal. They can also be used to store electricity or act as a filter to smooth out pulsating signals. Very small Capacitors are usually used in high frequency applications such as radios, transmitters and oscillators. Very large Capacitors are normally used as filters and for electrical storage. The capacitance of a Capacitor is expressed in a unit of electrical measure called the **farad**. The farad is to the Capacitor what the gallon is to an empty pail. They both tell how much of something each item can hold. The farad is a pretty big amount of electricity, so the value for most Capacitors is given in millionths-of-a-farad (**microfarads**).

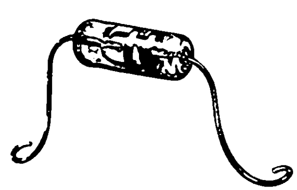
> An important note at this point; the 4 largest capacitors are a special type—**they must be connected into the circuit only one way** (the + lead must always go to the correct terminal). We'll remind you of this later too. The remaining capacitors can be connected either way (same is true for **all** the resistors).

CADMIUM SULFIDE CELL — A special semiconductor device that can be very handy is the **CdS Cell** (we use this abbreviation for this device). Simply, it is like the Control we mentioned earlier—except that the resistance of this device changes with the amount of light which falls on the face. 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 fall on the front of the cell.

NOTE: We've provided a special light shield to use with the CdS Cell. When you place this down over the top of the Cell it will block out all light from around the sides of the Cell and let in light only from directly in front. With many Projects you'll want to use this shield on the CdS Cell.



SOLAR CELL—The Solar Cell is the dark colored rectangular object just below the CdS Cell. In bright sunlight, the cell produces 0.6 volts. It is most sensitive to blue to red regions of the light spectrum. Properly cared for, the Solar Cell will produce electricity from sunlight virtually forever.

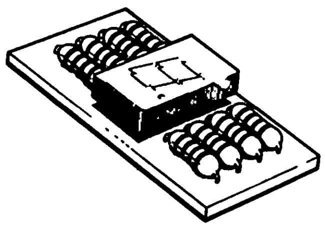


DIODES — There are three Diodes in your Kit. Diodes have many uses in Electronics. They have one simple characteristic — they will allow current to flow through them — **only in one direction** (not in the other direction). Diodes are used in various types of circuits — Radios, switching and other applications. There is one silicon type (marked Si) and two germanium types (marked Ge); they each have their own uses. More on that later.

By the way, the LED Digital Display is also made up of diodes—Light Emitting Diodes—they will allow current to pass only in one direction, and when they do, they emit (produce) light.

TRANSISTORS — Your lab kit has two PNP Transistors and one NPN Transistor. The working part of each Transistor is a tiny chip of a semiconductor material, either germanium or silicon. Each Transistor has 3 connection points: B (Base), C (Collector) and E (Emitter). The Transistors are used to amplify weak signals. They are also used as switches and oscillators.

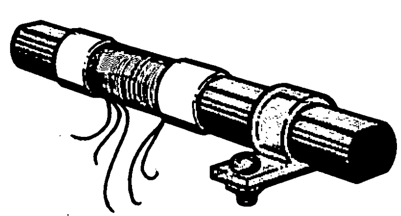
INTEGRATED CIRCUIT — As you probably already know, after the Transistor was invented in the middle '40s, the next big breakthrough was with the Integrated Circuit in the early '60s. The great advantage of IC's (as we call them) is that the equivalent of 100's or even 1000's of transistors, diodes and resistors can be put into a small package. As a matter of fact, often the IC is a tiny chip, not much bigger than this letter "o" — and it has hundreds or thousands of these electronic "components." The IC in your kit has the equivalent of only 3 transistors and 5 resistors and has only 6 leads. So it is hardly a complex example of today's IC technology, but you get the point.



LED DIGITAL DISPLAY — This is probably the most interesting component in the Kit. Let's mention what an LED is — it is a Light Emitting Diode. Yes, it is a diode; a diode which emits light when current passes through it (it can pass through only in one direction — just like "regular" diodes). In the case of a display, 7 LEDs are arranged to form the sides of an outline which can show all the numbers and most of the letters in our alphabet. An 8th LED is added for the decimal point. Now, if we connect external circuits to the correct terminals, we can display any desired number (or appropriate letters). The LED Display is mounted on a little board with resistors permanently wired to it (the resistors are there to be sure you don't burn out the Display with excess current). You'll have lot's of opportunity to experiment with this part later on.

SWITCH — You know what a switch is — you use it to connect or disconnect electrical circuits. The one we're using is a Double Pole Double Throw switch — this means it can control two different circuits (both independent) and can switch them into two different states or conditions. You'll see how it works later on.

RADIO CIRCUITS ANTENNA COIL — The Antenna Coil is the round (like a rod) component around which a coil of fine wire is wrapped. The dark colored rod the wire is wrapped around is made from a mixture of powdered iron. It is called a **ferrite core.** Ferrite cores are used to make antenna coils for almost all transistor radios.



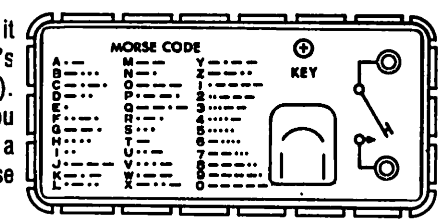
RADIO CIRCUITS TUNING CAPACITOR — The Tuning Capacitor is used with the Antenna Coil to select radio stations. The Capacitor is made from two metal plates separated by an insulator. The Tuning Capacitor in your lab kit is adjustable and its capacitance can be changed by turning the knob attached to its shaft. The shaft has several thin metal plates. When the knob is turned, these plates move between a similar set of fixed plates and the capacitance of the capacitor is changed.

THE BATTERY HOLDERS are designed to hold two (2) type AA batteries and one 9-volt battery. **Batteries,** of course, supply the power for all the various experiments that you will be doing with your project kit. When connecting wires to the Batteries, be sure you connect only to the terminals noted. Connection between terminals 122 and 123 will provide 3 volts. But, connections from terminals 120 and 121 will provide 9 volts — for some experiments, 9 volts can be too much (parts can be burned out). So be sure to make the right connections.

Batteries are available from any Radio Shack store. We recommend Radio Shack's Catalog Number 23-553 or 23-583 for the 9-volt battery and 23-552 or 23-582 for the penlight cells.

> *CAUTION:* When you connect wires to the Batteries, you must be sure to use the correct polarity: + and –. With some parts and circuits, components can be permanently damaged if you connect wires backwards.

KEY — We've put the Key on a separate base (so it won't take up a lot of space on the board and it's easy to use for Morse Code and other applications). It really is the same as a push-button switch. You can use the Key as an ordinary switch or as a telegraph key. For your convenience the Morse Code is printed on the base of the Key.



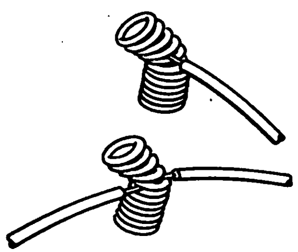
EARPHONE — An efficient, lightweight crystal Earphone is supplied with your lab kit. This Earphone is the high-impedance type. This means it can be connected to a circuit without causing very much of an electrical load. In most cases, the circuit doesn't even know the Earphone is there.

The Wires, of course, are used for making connections between terminals.

The Case has a platform on which the parts and spring terminals are mounted. Underneath the platform wires are used to connect between the terminals and the parts.

BUILDING THE PROJECTS

As explained above, your Electronic Project Kit requires two 1.5-volt AA penlight cells and a 9-volt battery for some of the projects. You can use any standard penlight cells for the 1.5-volt cells and a transistor radio battery for the 9-volt battery. Install the penlight cells in the holder next to terminals 122 and 123. **Be sure to install the cells according to the markings inside the holder.** The end of the cell with the small metal cap is plus (+) and the flat metal end of the cell is minus (–). Install the 9-volt battery by first snapping the battery clip to its terminals. Then press the battery into its plastic clip.



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, just bend the spring over to one side and insert the wire into the opening. Sometimes two or three hookup wires are connected to a single spring terminal so make sure the first wire doesn't come loose when the second and third wires are installed. The easiest way to do this is to push the spring on the side opposite where the first wire has already been inserted.

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

After a lot of use, the exposed metal ends of some of the hookup wires might break off. If this happens, just 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.

Each Project has a description of its purpose and use. In most cases we've given you a fairly simple description of the technical operation of the circuit. Also, each experiment has a drawing showing how the wires should be connected for that experiment. We've also given you the Schematic Diagram.

MAKING THE CONNECTIONS

There is a simple wire sequence listing for each project. You should connect appropriate length wires (whatever color wire will reach) between the terminals listed in each grouping. When you come to a new grouping, start new connections.

Here's an example. Project #1 has the following wire sequence listing:

123-7, 4-6, 122-5, 2-87-84, 74-17, 16-47, 15-88-120-38, 37-85-86, 48-83, 1-73-121.

You should connect a wire between 127 and 7.
Another between 4 and 6.
Another between 122 and 5.
Another between 2 and 87 and then another between 87 and 84.
And so you continue until all connections are made.

CAUTION: In each case, we've deliberately left an important power lead connection till the last. It is important that you make the last connection last. With some circuits, if you complete one electronic circuit before another, a transistor or other part can be damaged. So, do remember this little piece of advice.

TROUBLESHOOTING

If you assemble each project according to its wire sequence listing, 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 very similar to those used by electronics technicians in troubleshooting electronic equipment.

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

2. If the experiment is powered by the Solar Cell, is it getting enough light? Some projects need just a little light, but others need more.

3. If the indicator Lamp does not work, make sure it is screwed all the way into its socket.

4. Have you assembled the project properly? If everything else checks out OK, check all the wiring connections to make sure you have wired all the terminals correctly. Sometimes it's a good idea to have someone else take a look at it too — a second pair of fresh eyes may see something you have overlooked.

5. 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 just by following a Schematic; and if some circuit details are provided, you should be able to figure it out for yourself.

6. Try some voltage and current measurements — you'll very soon find out how handy a VOM can be to an electronics technician!

STRIKING OUT ON YOUR OWN

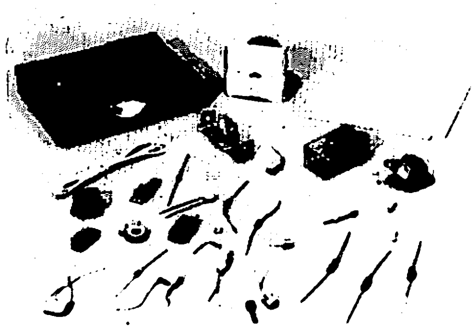
After you have built all the projects in your Lab Kit, you might want to experiment with some of the projects. The easiest experiments involve the broadcast band radios and the special sound effects oscillator projects. Try using different capacitors in place of the capacitor used in each of these projects. You may get some very unsual results.

All of the sun-powered projects can be powered by the 3-volt battery supply when it's dark, so you can use your lab kit at any time. Most of the "sun-powered" projects don't need bright sunlight and will work with a desklamp or even a flashlight.

Only some of the projects use the Key. You can easily add the Key to a project as a switch by simply connecting it between one of the battery terminals and the project. Do this by connecting a hookup wire between the plus battery terminal and one spring terminal on the Key platform base. Then move the hookup wire that was originally at the plus battery terminal to the other spring terminal for the Key. Now the circuit will receive battery power only when you press the Key.

Now that you know something about your Electronic Project Lab Kit, pick out a project, grab some hookup wires, and put it together. Good luck, and have fun experimenting with the marvels of modern Electronics.

If you particularly like one or more of the projects, you can always buy similar parts at your local Radio Shack store and wire up the project for permanent use.



The Radio Shack store has all kinds of Resistors and Capacitors, plus Antenna Coils, Wire, Relays, Transistors, Diodes, LED's, Displays, IC's, Solar Cells, Earphones (and small Speakers), Switches, Batteries and Battery Holders. You can wire up your own separate parts either on a small board, on a chassis, on one of our project boards, or even make the project on a Printed Circuit Board. We have all the materials for making your own Printed Circuit Boards. Then, install the project inside one of our boxes or cabinets and you have a nice, home-made electronic circuit in a permanent form.

While you're browsing around the Radio Shack store, take a look at some of the Electronics Project Books and Project Kits; you'll find lots of ideas there that you will like to do something with.

NOTES on Radio Circuits

For the very best reception with the Radio circuits, we suggest that you obtain a Radio Shack Shortwave Antenna Kit, Catalog Number 278-758. Have an adult help you put it up outside (don't do it yourself). Then, make a connection between this outdoor antenna and terminal **113** (or **114** or **116** — the spring terminal for connecting an Antenna). Then you can make another connection (with extra wire you can get from Radio Shack) between terminal **115** (or **117** — the spring terminal for Ground connections (and a cold water pipe — or a metal rod driven into the ground outside. A good Antenna and a good Ground connection are both very important for receiving radio signals.

SOME FINAL THOUGHTS
For Teachers, Students and Hobbyists

We have organized the Experiments into different categories and then within those categories, in progressive levels of circuit development. However, you need not feel you must stick with this sequence — although you might find it helpful to note the progression of complexity. And you'll also find a certain amount of circuit repetition or over-lapping. We often refer to previous experiments — or to experiments much farther on in the Manual.

All of this is done on purpose.

As you "play" with electronics, you will soon recognize (at least we hope you will) certain basic types of circuits are repeated over and over — often with only small differences between circuits. As you begin to recognize some of these basic circuits, you'll be able to see them even in complex circuit systems.

Both of these facts are important — basic circuits are used time and again, and often there are minor variations made to them.

There are many, many ways of making (and using) the same basic circuit. Many times the differences are very little and make very little change in circuit performance. However, sometimes a very little change can make a big improvement in performance. That is one reason why it is important to know and understand electronics very well. The more you know about electronics, the quicker you will see ways to change and improve circuits. Such little changes sometimes are all it takes to make the difference between a **poor** Radio, TV, Receiver (or other circuit) and a **good** one. A smart technician or engineer knows how to make little changes and improvements that really make a difference.

of course there are very, very complex electronic circuits too. But if you take time to carefully study such circuits, you'll find that when you take each section separately (break down the Schematic into its separate sections), it is easy to understand. Even the most complex electronics system — a multi-million dollar communications network for example — is made up of thousands (or even millions) of simple circuits, all combined to make one massive circuit system.

And so you see why you will run into the same type of circuit, with many variations (some only minor) throughout this Manual. Take a look at the Index of Projects at the back of the Manual and you'll see how many ways some of the circuits are used.

If you are interested in more theory and technical details, we suggest you talk with your school librarian or someone at your public library. There are many fine books which talk about Electricity and Electronics. There are books that are written especially for young people. Also, there are some good magazines which publish interesting articles with experimental circuits and schematics which may provide lots of extra ideas for using this Electronic Project Kit.

1. ELECTRONIC CANDLE

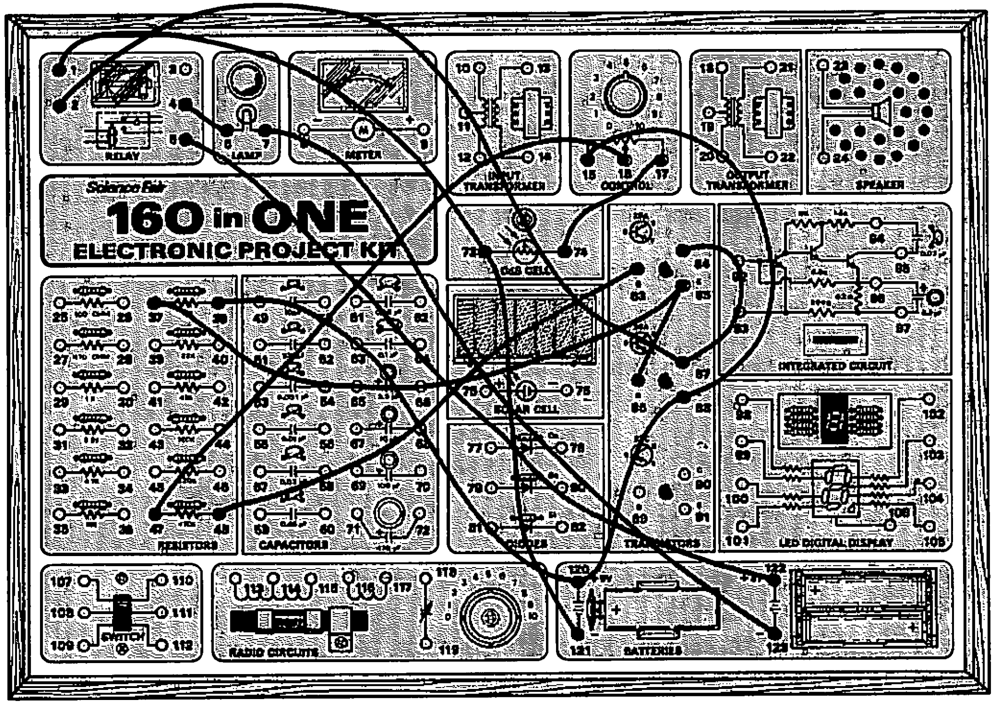
We'll start with an easy and fun project. Amaze your friends with this bit of electronic magic. You can "blow out the Lamp". The "candle"(Lamp) will come on when you let light shine on the CdS cell; when the light is removed from the CdS cell, the "candle"(Lamp) goes out. It is most effective when you use a match for the light, though you can also use a flashlight or other light source.

Of course there is a trick to it, but if you don't tell anyone the secret, it can sure keep them guessing a long time. Basically what is happening is that the light level is low enough that until the Lamp in this kit is ON, there is not enough light to turn on the Relay to power the Lamp. Use the CdS Light Shield with this experiment.

In detail this is how you get it to work. First make sure the surrounding light is not bright. Use the excuse that you don't need a candle if the light is already bright enough. Now adjust the 50K Control up to the point where the circuit is about to turn ON the Lamp (a little practice is needed for this). At this setting a little additional light from a match or flashlight will turn the Lamp ON. With the additional light from the Lamp the match or flashlight may be taken away and the Lamp will stay ON.

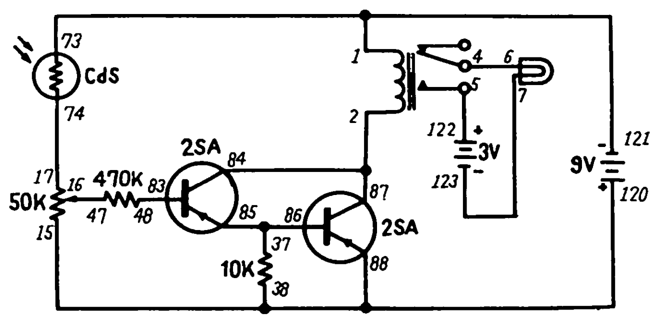
The second trick is to "blow the candle out". To do this, cup your hand around the "candle" to blow it out "gently". Now just as you blow with your mouth, move your hand slowly between the light and the CdS Cell. The shadow of your hand will remove enough light to allow the Lamp to go out. Once the Lamp is out it takes additional light from another source to get it on again.

Now go to it, but remember, it's our secret.



WIRING SEQUENCE:

123-7, 4-6, 122-5, 2-87-84, 74-17, 16-47, 15-88-120-38, 37-85-86, 48-83, 1-73-121



NOTES

2. "THE BIG EAR"

This project is a high-gain, three-stage audio-amplifier that allows you to increase sound levels just like a high-gain hearing aid. You can use this circuit with extension leads on the Speaker (used as a microphone) up to about 30 feet (9 m) or so. With this setup it is possible to "bug" an area and hear the slightest whisper. When you use the Speaker in this experiment, you must place the Earphone in your ear or the amplifier will oscillate due to acoustic feedback.

Start operation with the Volume Control initially set at minimum and then increase the setting for required volume. This procedure must be used because the gain is so high that the open circuit layout causes an ultrasonic oscillation to occur at very high Control settings. When this oscillation occurs the volume drops significantly.

We're using the Speaker as a dynamic microphone with the voltage stepped up with the Transformer to a higher level for the first amplifier. The first two Transistors are connected into a high-gain "ring-of-two" circuit. The volume Control is placed at the output of the ring-of-two amplifier. This position is better than at the input because it provides a better signal-to-noise ratio. Any amplifier stage that preceeds the volume Control is placed at the output of the ring-of-two amplifier. Any amplifier stage that preceeds the volume Control and is designed for high-gain, low-noise operation is called a "pre-amplifier".

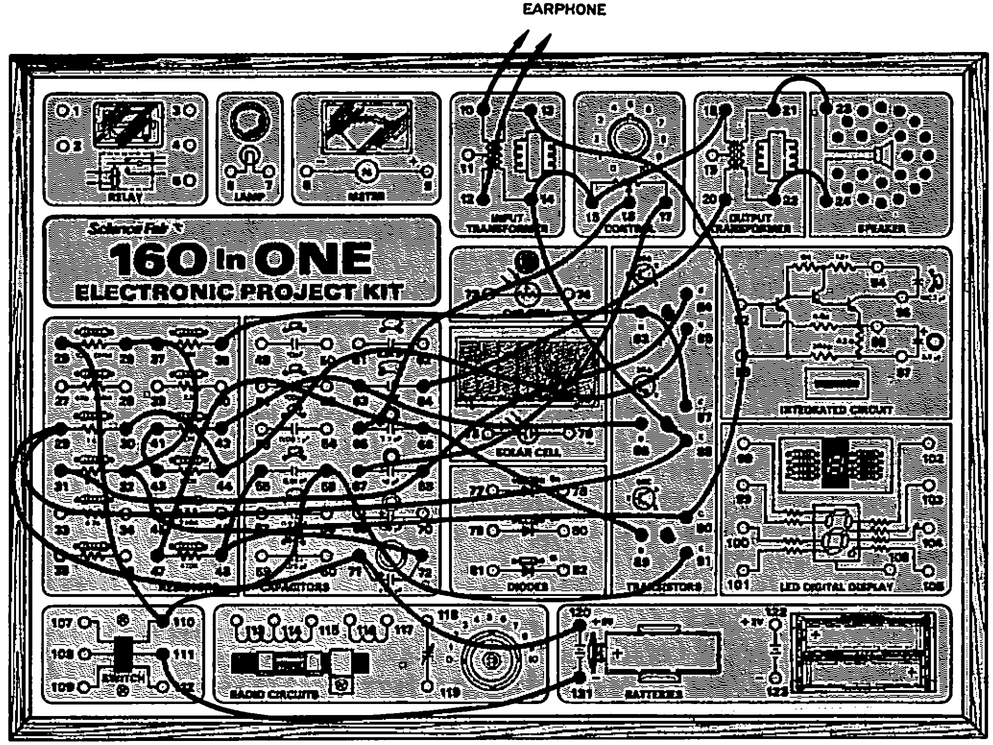
The volume Control has no DC current flowing through it. This is also a desirable design consideration as DC current in a control eventually causes the Control to become very noisy and erratic.

The 2SC output stage is a common-emitter amplifier with fixed base current bias and a 0.01uF high frequency bypass across the C-E output. This Capacitor cures the above mentioned ultrasonic oscillation on most hookups, but if your circuit should happen to be a little out of tolerance, be aware of this problem and recognize it for what it is.

The 100 ohm Resistor and 470uF Capacitor form what is called a decoupling filter. This is required in multiple-stage amplifiers such as this to keep oscillations from occuring due to Battery resistance. If batteries were perfect constant-voltage sources this decoupling would not be necessary, but as you will learn, there is no such thing as a "perfect" or "ideal" practical component.

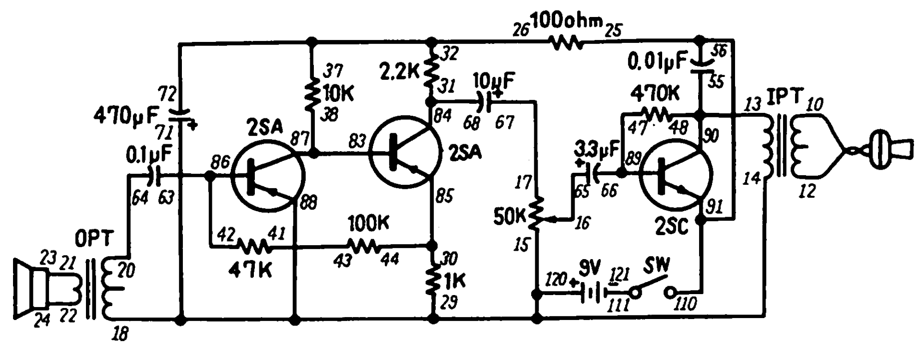
If you have a VOM, this is a good circuit for measuring and recording voltages.
By the way, if you don't understand all the technical explanations in this project, don't worry; we don't expect you to get everything at first. As the projects go by, we will gradually explain and define the new terms for you, and by the time you finish all the projects you'll understand everything (we hope).

NOTES



WIRING SEQUENCE:

21-23, 22-24, 26-37-32-72, 30-44-85, 41-43, 42-63-86, 64-20,
18-15-14-88-29-71-120, 87-83-38, 16-65, 17-67, 13-90-48-55, 84-68-31,
25-110-56-91, 47-66-89, 10-Earphone, 12-Earphone, 111-121.



3. ELECTRONIC REFLEX TESTER

This project was included so you can compare your reflex time with someone else's. The circuit is an adaptation of the push-button relay control circuit of project 86.

The game takes two people and is played as follows:

1. Have one person place their finger on the slide Switch and prepare to push it down (OFF) at the signal.
2. Have a second person place their finger on the Key and prepare to push it down (ON) at the signal.
3. First open and then connect the wire lead to the emitter of the 2SA Transistor. This accomplishes two things: places the Lamp ON, and completes the circuit so the game can be played.
4. Give the signal to press the Key. If the Lamp stays ON, the person controlling the slide Switch has won. If the Lamp goes out, the person pressing the Key has won. There is no such thing as a tie in this game.

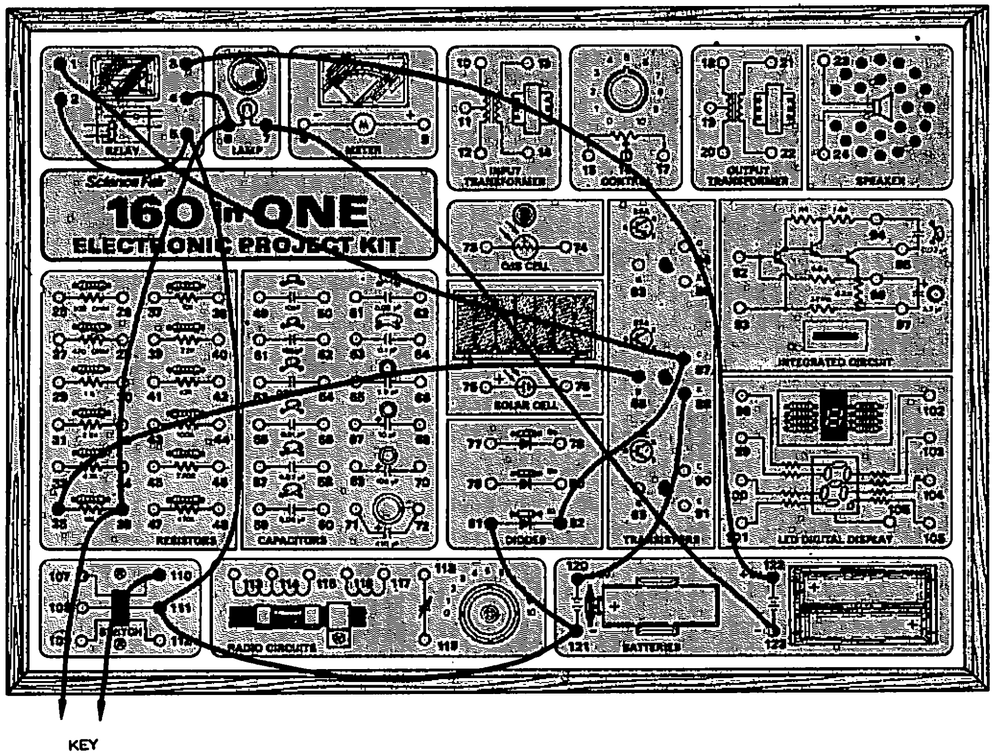
Additional keys may be placed in parallel with the Key supplied, and additional normally closed switches added in series with the switch in order to have teams. This type of circuitry has been used with quiz teams where the side to "jump" first gets to try to answer a question.

The circuit used is the electronic version of a push-button relay control circuit. The Key-Switch circuit must be completed to obtain Transistor base-bias to actuate the Relay. Once the Relay is energized, the closed contacts completes the Transistor base-bias circuit so the Key-Switch circuit has no more control. The Relay is de-energized by opening the field coil circuit at the Transistor emitter (disconnect the wire momentarily at 120).

Obviously if the Switch is opened before the Key is pressed the circuit cannot be completed and the Relay remains de-energized.

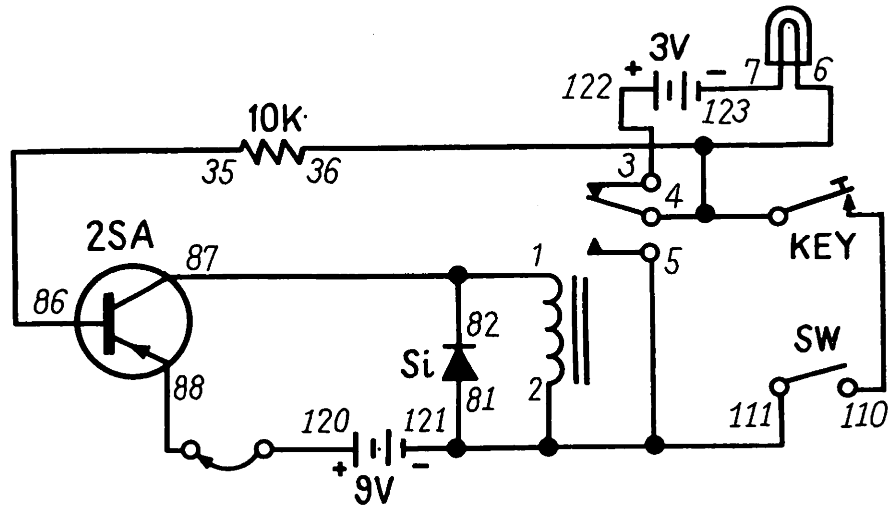
The silicon (Si) Diode across the Relay keeps the turn-OFF surge of energy from the Relay from damaging the Transistor (by circulating the current from this surge back into the Relay). It is not required in this circuit but is included as a reminder that all high-reliability circuits must include some means for handling such potentially destructive surges.

NOTES



WIRING SEQUENCE:

1-87-82, 4-6-36-Key, Key-110, 2-5-111-121-81, 35-86, 3-122, 88-120, 7-123



4. MACHINE GUN PULSE OSCILLATOR

This project is a pulse oscillator that has a sound like a machine gun or a one cylinder motorcycle engine. Adjustment of the Control (50K ohm variable resistor) allows you to change the sound from the Speaker from a few pulses per second to a dozen or so per second.

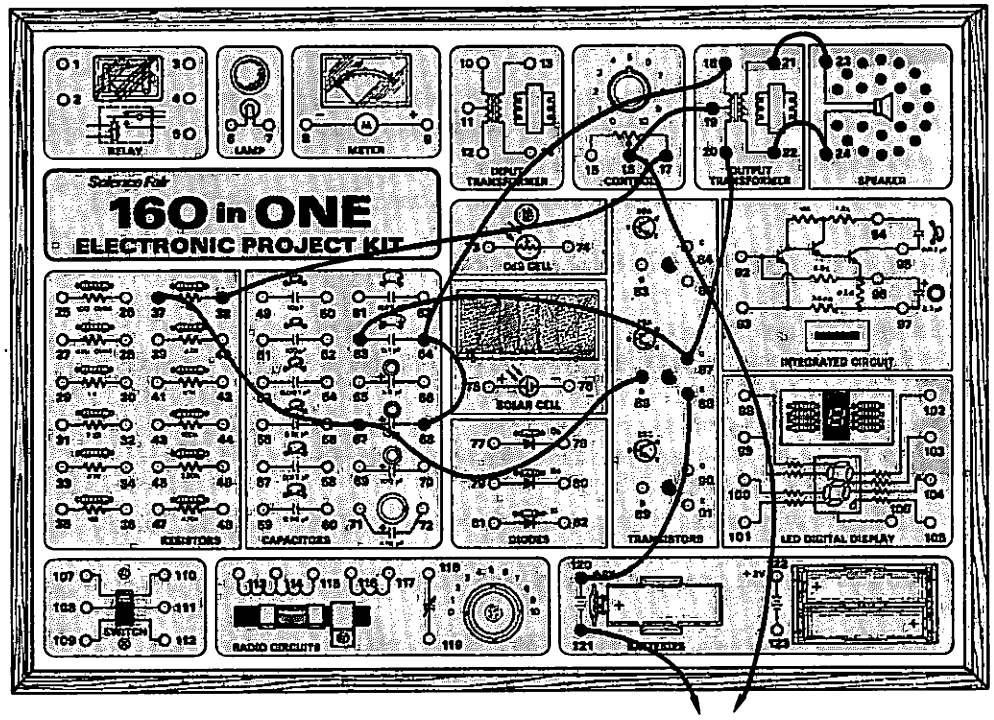
There are many different ways to make oscillators, and you will build several of them in this kit. Later on you will be told how they work. For now we'll simply tell you what an oscillator is.

An oscillator is any circuit that turns itself ON and OFF (or goes from high to low output). The oscillator in this project 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 blinker in your parents' car). Very fast oscillators are used to produce sounds. "Super" fast oscillators produce radio signals (RF signals). These RF signal oscillators can go from high to low (ON and OFF) millions of times per second.

The number of times an oscillator goes from high to low (ON and OFF) each second is called a Hertz (Hz). The Machine Gun Pulse Oscillator has a frequnecy (the number of ON/OFF "cycles" per second) of about 1 to 12 Hertz (Hz). The frequency of an RF signal oscillator would be measured in Mega-Hertz (Mega stands for millions).

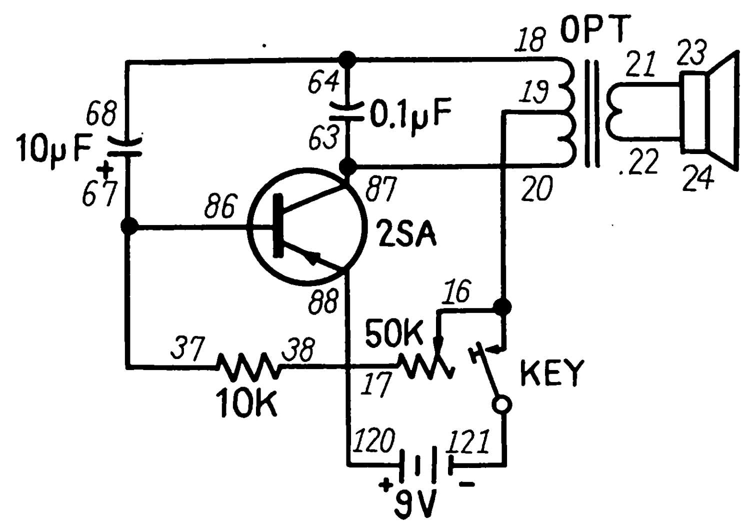
You can experiment and change the frequency of this oscillator by trying other Capacitors in place of the 10uf Capacitor. Be sure to observe the + and – connection (polarity) on the Capacitors marked with a + sign. Don't forget you can change the frequency by adjusting the Control (variable resistor), too!

NOTES



WIRING SEQUENCE:

21-23, 22-24, 18-64-68, 20-87-63, 17-38, 86-67-37, 88-120, 19-16-Key, Key-121



5. RAPID LED DISPLAY SWITCHING (PERSISTENCE OF VISION TEST)

This project demonstrates a control circuit that is used to produce short pulses. When the Key is closed the LED display lights only momentarily even if the Key remains closed continously.

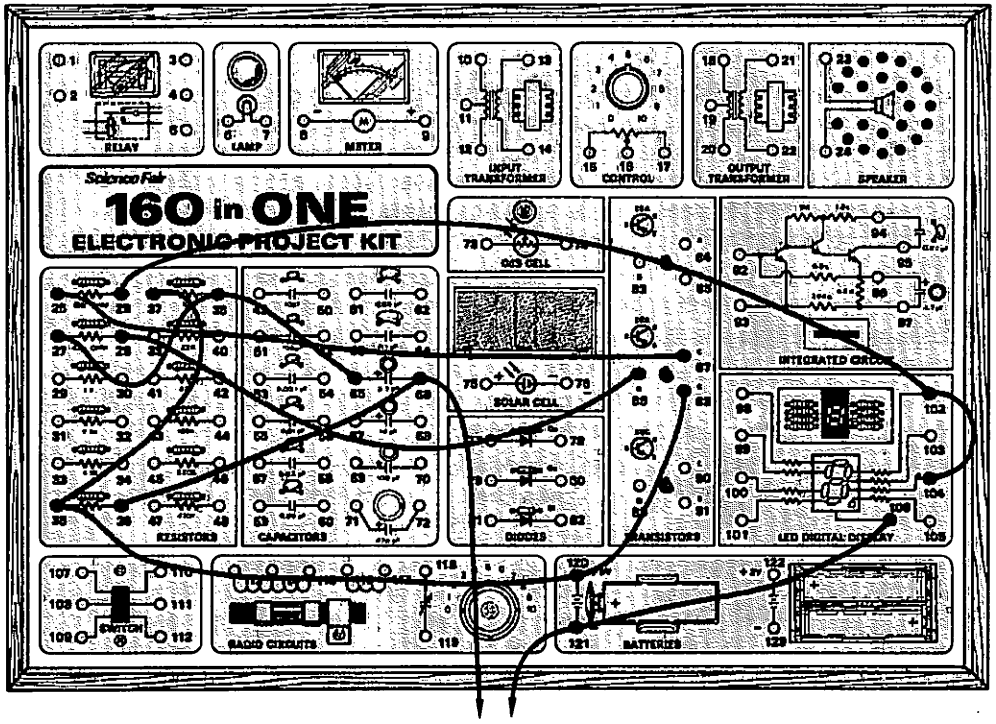
This circuit may be used to make up a game in which a number or letter is instantaneously displayed and the people playing the game must recognize the number or letter. You can spell words or give numbered answers, etc. You can probably think of many of other possibilities.

The Transistor switching circuit uses Capacitor charging current to turn the Transistor ON. The Transistor then completes the circuit to the LED anode pins (terminals 102 and 104).

When the Key is open the Capacitor is discharged by the two 10K Resistors. Then when the Key is closed the 3.3uF Capacitor is quickly charged up to 9V through the B-E junction of the Transistor. The charging current that flows through the B-E junction turns the Transistor full ON only during the time this current flows. The ON Transistor acts like a short circuit (a path for electricity with little or no resistance) from C to E to allow LED current to flow simultaneously with the Capacitor charging current. After the Capacitor is charged to the 9V, no more current can flow to the Transistor B-E junction so the Transistor is turned full OFF.

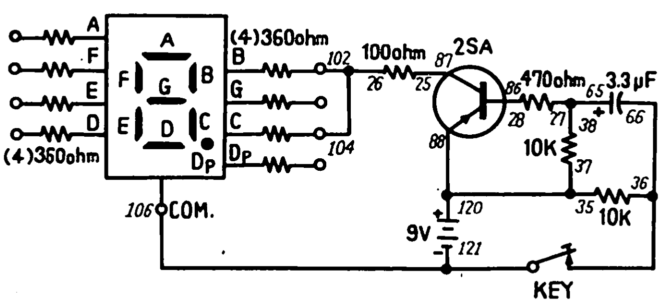
VOM voltmeter tests are not very descriptive of circuit action because the currents and voltages change so fast. One thing which is noticeable is that a measurable amount of time must be allowed for the Capacitor to discharge after the Key is opened.

You may want to try different values of Capacitors and see their effect. Don't use Capacitor values higher than 10uF or the Transistor may be burned out by excessive base current! Of course you will want to try many different numbers and letters on the LED, expecially if you play the persistance-of-vision game.



WIRING SEQUENCE:

104-102-26, 87-25, 27-38-65, 37-35-120-88, 36-66-Key, 28-86, 106-121-Key



NOTES

6. LIGHT ORIENTED DIRECTION FINDER

This project demonstrates how outer space probes can be guided to far distant places by star light received from a telescope. The heart of this navigation system is a light detection system that can tell when the angle of light received by the telescope has changed. Any change in light direction causes the thrust rockets to fire as required to keep the angle of light in the proper perspective. This action keeps the speeding space probe oriented always in the same position so that antennas, telescopes and thrust rockets can perform properly.

Hook up the circuit and place the kit under a single source of light such as a desk lamp or single-lamp room light. Adjust the 50K Control for a center-scale Meter reading. Now tilt the project board so the light rays come from the CdS Cell side of the board. The Meter will indicate this position by deflecting up-scale.

Now tilt the project board so that the light rays come from the Solar Cell side of the board. The Meter will indicate this angle by deflecting down-scale.

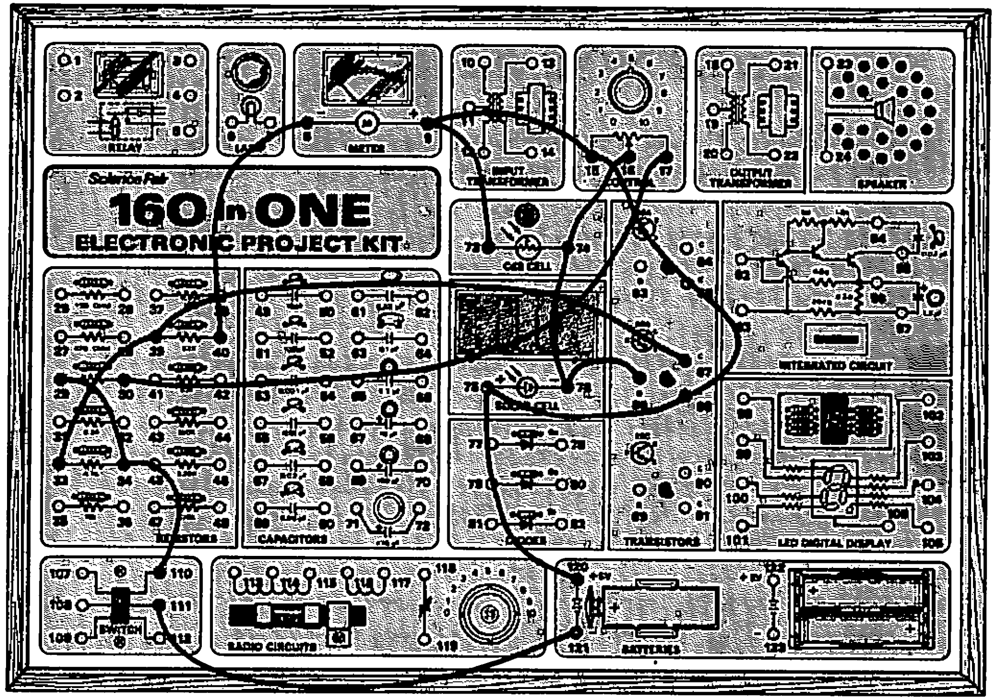
All that is needed now is to use this change in Meter current to activate the proper control rockets, and the space ship would be repositioned to maintain the center-scale Meter reading.

The circuit senses this change in light angle by using the change in relative light intensity on the Solar Cell and CdS Cell. Greater light on the Solar Cell causes greater base-bias on the Transistor. Greater light on the CdS Cell causes a decrease in Transistor bias. The Transistor bias controls the collector-to-emitter (C-E) voltage by amplification, so the small base-bias change results in a greater C-E voltage change.

Try using this circuit while walking toward a light source, holding the project board in front of you. Keep the board held against your stomach at a fixed position. Try holding different sides of the board against you until you find the one that gives the best sensitivity.

You may also want to try walking at angles which maintain Meter readings other than at the center. After some practice you should be able to navigate around the yard using this project and sunlight. Look out for shadows though; they can lead you astray!

NOTES



WIRING SEQUENCE:

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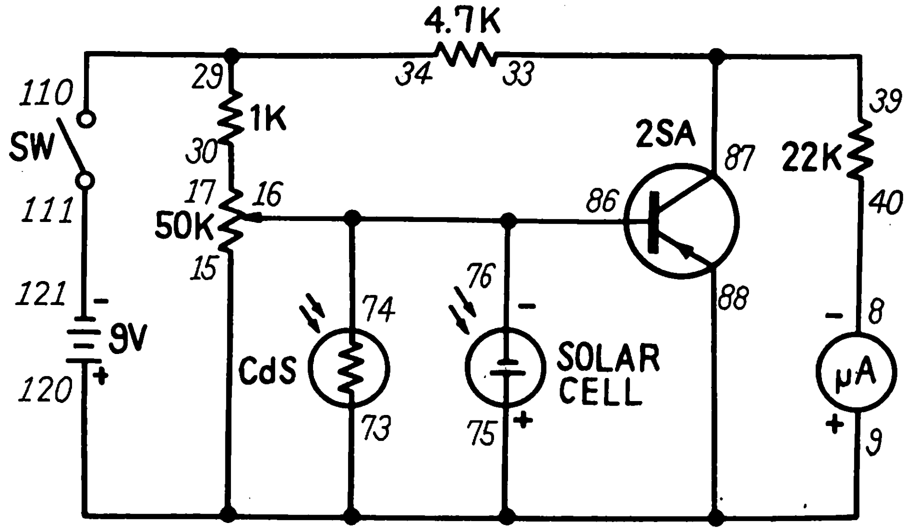


7. CdS CELL TARGET PRACTICE

This project lets you test your aim in the dark, using a flashlight for a "gun". If you hit the CdS Cell with a beam of light the Lamp will light.

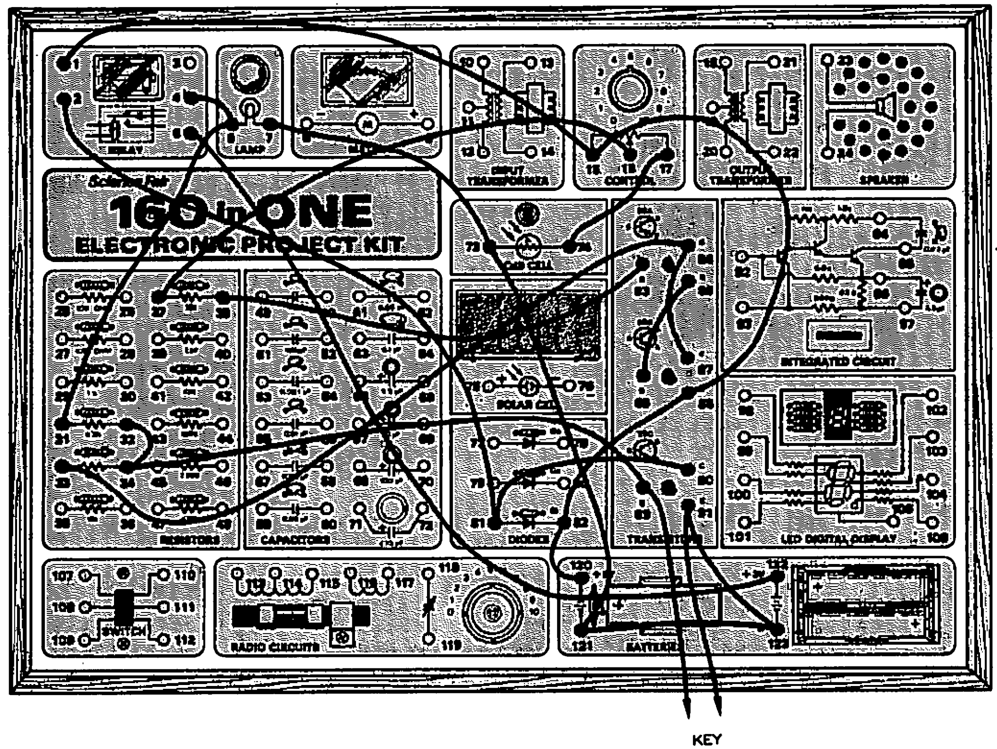
After you finish the wiring, put the project in as dark a room as possible. Then shine your flashlight on the CdS Cell and adjust the Control until you find the point where the light comes ON. Next, press the Key to turn the Lamp OFF, and you're ready to test your aim.

First try hitting the CdS "target" from about five feet. Then, gradually increase the distance as your skill increases. For the supreme test (and the most fun), try turning the flashlight ON and OFF quickly, and hitting the CdS Cell with a pulse of light.

Each time you hit the target you will have to reset the circuit by pressing the Key. The Lamp is controlled by a latching Relay circuit (like the one in project 106), and once it is turned ON it will stay ON until you press the Key.

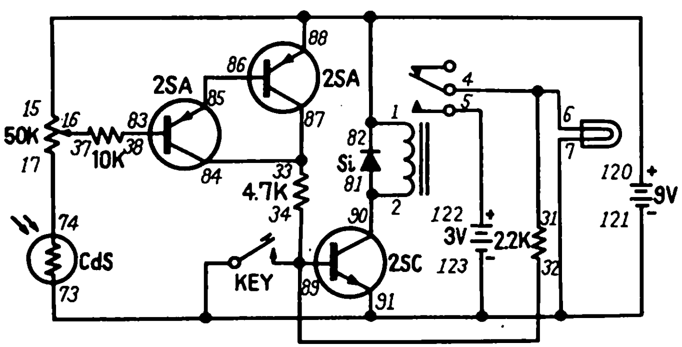
Don't be suprised if it takes several tries to get the Control adjusted to the point where the Lamp comes ON when you "hit" the CdS Cell. For best operation, have the room as dark as possible, and use a light with a sharply focused beam. Once you find the best setting make a note of it so it will be easier to find next time.

NOTES



WIRING SEQUENCE:

1-15-88-82-120, 2-81-90, 4-6-31, 5-122, 7-73-121-123-91-Key, 16-37, 17-74, 33-84-87, 32-34-89-Key, 38-83, 85-86



8. QUICK DRAW

This is another circuit to test your reflexes (like project 3). You will need two players and a referee to play this game.

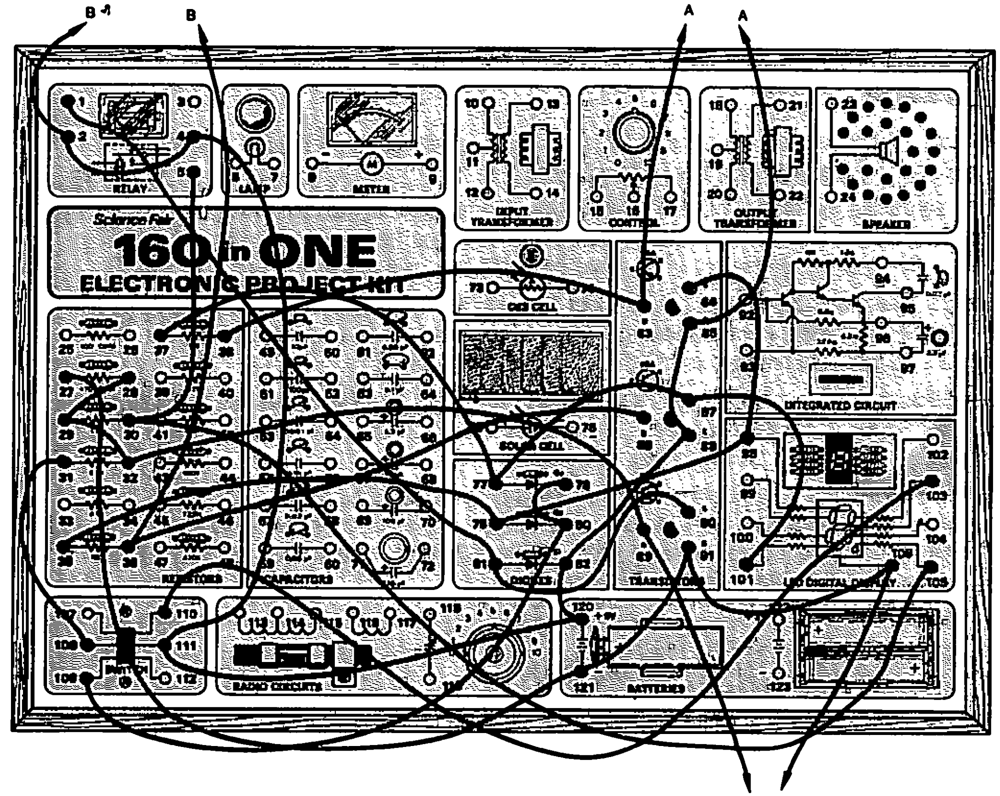
When the wiring is complete, player A holds the wires connected to terminals 83 and 85, and player B holds the wires connected to terminals 2 and 36. Both players should connect the tips of the wires until they are given the signal to separate them.

To prepare the circuit for the game the referee must set the Switch to the OFF (down) position, and press the Key momentarily. Then he must set the Switch to the ON (up) position. When this is done the center segment of the LED (segment G) will come ON. This is the "go" signal. Each player should try to be the first to separate their wires.

If player A separates his wires first, the upper segment (A) or the LED will light. If player B is first, the lower segment (D) will light. If either or both players separate their wires too soon (before the "go" signal), the decimal point of the LED will come ON. The latching Relay ciruit which turns ON the decimal point is very fast, and will catch you even if you are only a fraction of a second early.

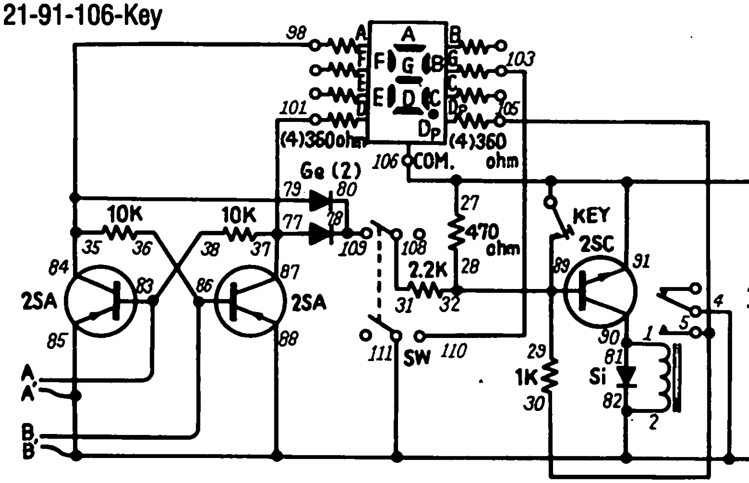
This circuit makes use of a flip-flop multivibrator circuit and a latching Relay circuit, plus the Diodes, Switch and Key. Study the more simple projects using these circuits, and then try your luck at explaining this one. If you can only explain part of it, that's OK. You'll get the rest the next time you go through the kit.

NOTES



WIRING SEQUENCE:

1-81-90, 2-4-111-120-82-88-85-Wire (for player A), 2-Wire (for player B), 5-30-105, 28-29-32-89-Key, 31-108, 35-79-98-84, 37-77-87-101, 38-83-Wire (for player A), 78-80- 109, 86-36-Wire (for player B), 103-110, 27-121-91-106-Key



9. ELECTRONIC WOODPECKER

This is the first of the Special Sound Effects Projects. They are fun and you'll enjoy hours of entertainment from each of them. They also offer lots of opportunity to experiment on your own.

Have you ever heard a red-headed woodpecker chirping? Here is an electronic bird capable of reproducing the sounds of some birds such as the red-headed woodpecker. If you have them around your house they may fly near by to try to see this electronic relative!

The basic circuit shown does not have a Switch or Key but you may wire one in yourself. Replace one of the wires connected to the Battery with leads to the Key or Switch. The Key provides more convenient control when carrying the kit around outside as you try to attract birds with your bird calls.

You may also want to try the 9V Battery. The output is louder and resembles even more the scolding chirps of the red-headed woodpecker. The chirps with the 3V supply circuit resemble more the English sparrow.

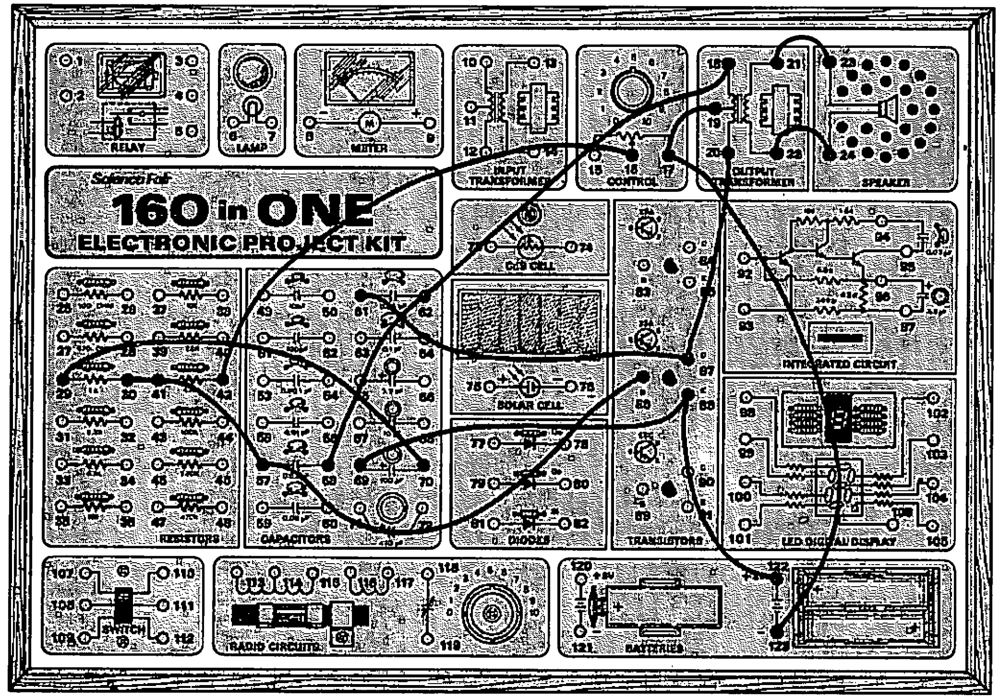
The oscillator circuit used is only slightly modified from the one described in project 145. The important difference is the addition of the 1K Resistor and 100uF Capacitor series circuit. This circuit is included to cause the oscillations to stop periodically in order to obtain the chirping sound. Recall that the base Capacitor in a pulse oscillator like this is quickly charged through the Transistor B-E junction during the Transistor ON time, to a voltage greater than that of the Battery. Then during the OFF time this charge causes a positive voltage at the base to turn the Transistor OFF, until the 47K and 50K Control resistances discharge this voltage down to where the Transistor can turn ON again. The 100uF Capacitor in this circuit accumulates a positive charge from the 0.02uF discharging current until finally this voltage is sufficient to turn the Transistor OFF for a period of time (the time between chirps).

The 1K Resistor is required to keep the 100uF from shunting (bypassing) the Transistor B-E signal voltage. Without this resistance the B-E junction voltage cannot change enough to allow oscillations and there would be no output.

When experimenting with this circuit you can change almost anything without causing damage. However, do not decrease the 47K Resistor to below about 10K or the Transistor may be damaged.

Some combinations of resistance and capacitance in place of the 1K and 100uF will result in some interesting sounds from crickets to bears! Don't forget to record your results for later use, like a good scientist does.

NOTES



WIRING SEQUENCE:

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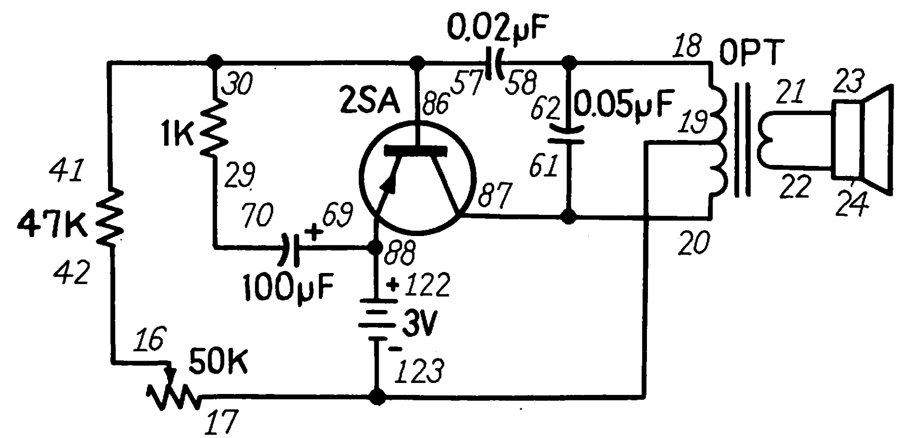


10. ELECTRONIC CAT

Do you have a cat? If not, you can make people think you do with this electronic cat. You can make meows that are so realistic that the mice will scatter!

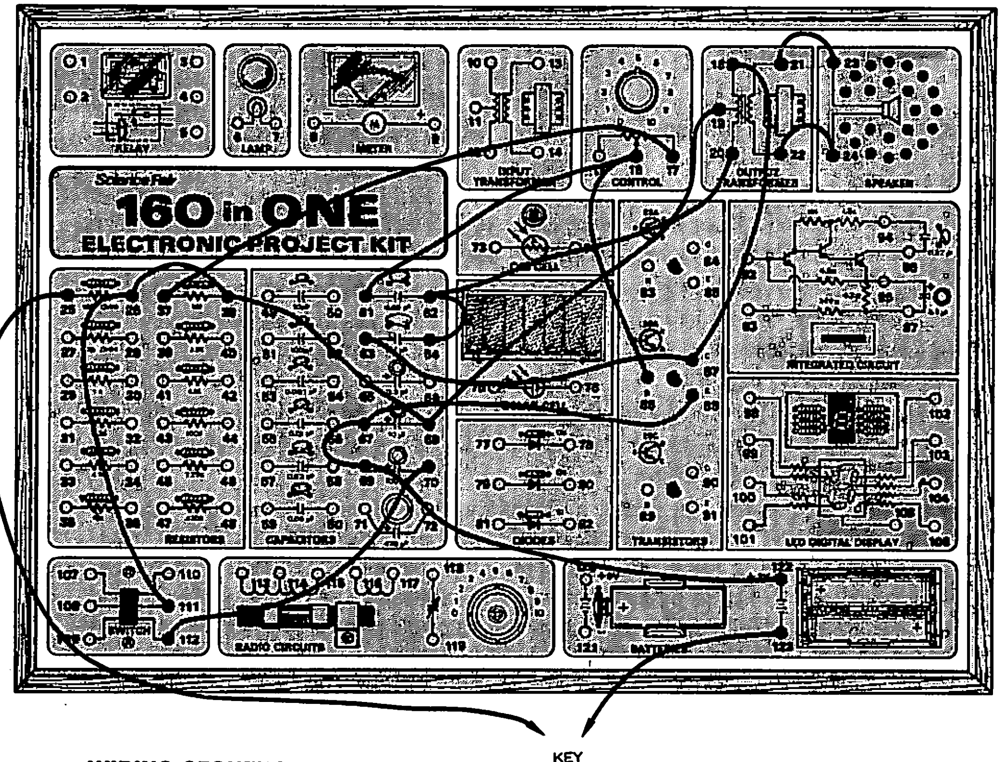
Start experimenting with the Switch in the DOWN position. Press the Key and let it up immediately. Adjust the Control for the desired cat sound. You can try changing the Control while the tone is dying away to make the sound even more realistic.

Now place the Switch in the UP position. Try all the combinations possible. You'll find that some combinations can be made to sound like a kitty begging for a dish of milk.

The basic oscillator circuit used in this project is the same as that in project 152 so we won't repeat the circuit description here. The only changes are actually additions to obtain the slow decay in tone output. The 10uF Capacitor gives only a very slight delay in decay, but the 100uF provides a noticebly longer delay. The 100 ohm Resistor provides some softening action on the turn-on.

You can change most of the components in this circuit as you experiment, but don't increase the 0.05uF Capacitor to more than about 10uF, and don't decrease the value of the 10K Resistor or the Transistor may be damaged. Have fun!

NOTES



WIRING SEQUENCE:

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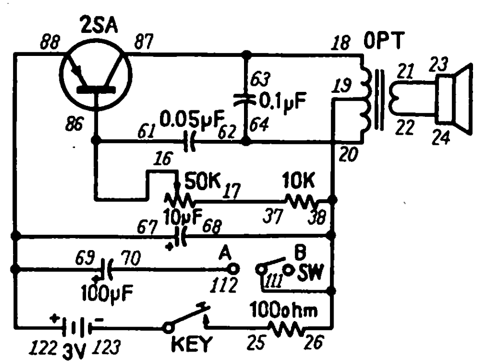


11. ELECTRONIC MOTORCYCLE

How about an electronic motorcycle? By using your hands, you can make the sound of a motorcycle starting up and then going through the gears as it speeds away into the distance.

The rate of pulsing is dependent on two sources of Resistance, the CdS Cell and the Resistance between your hands. With a strong light on the CdS Cell you can control the operation entirely by exerting more pressure on the wires you hold in your hand, and also by making the shadow of your hands fall across the CdS Cell.

After some practice you will be able to make it sound exactly like a real motorcycle on the go. You can even get it to idle as well as race.

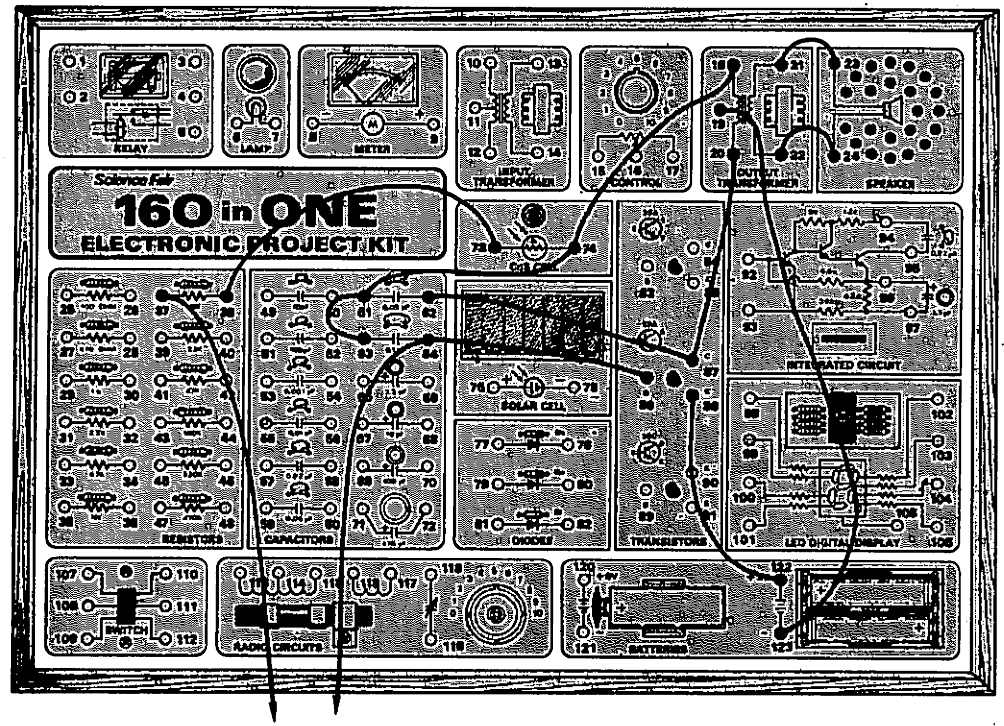
You can experiment with different values for the 0.1 and 0.05uF Capacitors, but don't use values above about 10uF or the Transistor may be damaged.

Try different light sources such as fluorescent, incandescent and sunlight. You might also try a game of speed-of-response as follows:

1. Have one person try to keep the pulse rate high by squeezing the probe wires.
2. Have a second person try to keep the pulse rate low by covering the CdS Cell.
3. Have each person be a specified distance from the kit and then yell GO to start the game.
4. The first person wins if the tone is increased.
5. The second person wins if the tone does not increase.

You will want to experiment with the distances each person is away from the kit at the start, because it takes longer to pick up the wires and squeeze them than to block the light from the CdS Cell.

NOTES



WIRING SEQUENCE:

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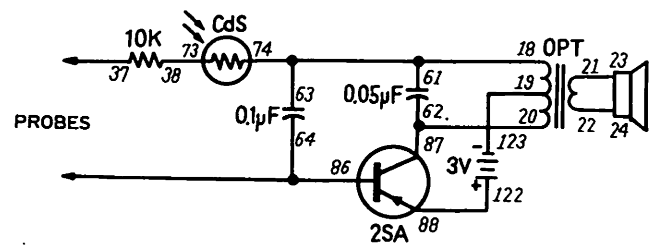


12. TWO-TONE PATROL CAR SIREN

Here is a loud siren which is so much like the real sirens on some police cars or ambulances that you will have to be careful you don't confuse people. The initial tone is at a high pitch, but when the Key is closed the pitch decreases. You can control the cycling of the pitch the same as the police and ambulance drivers do.

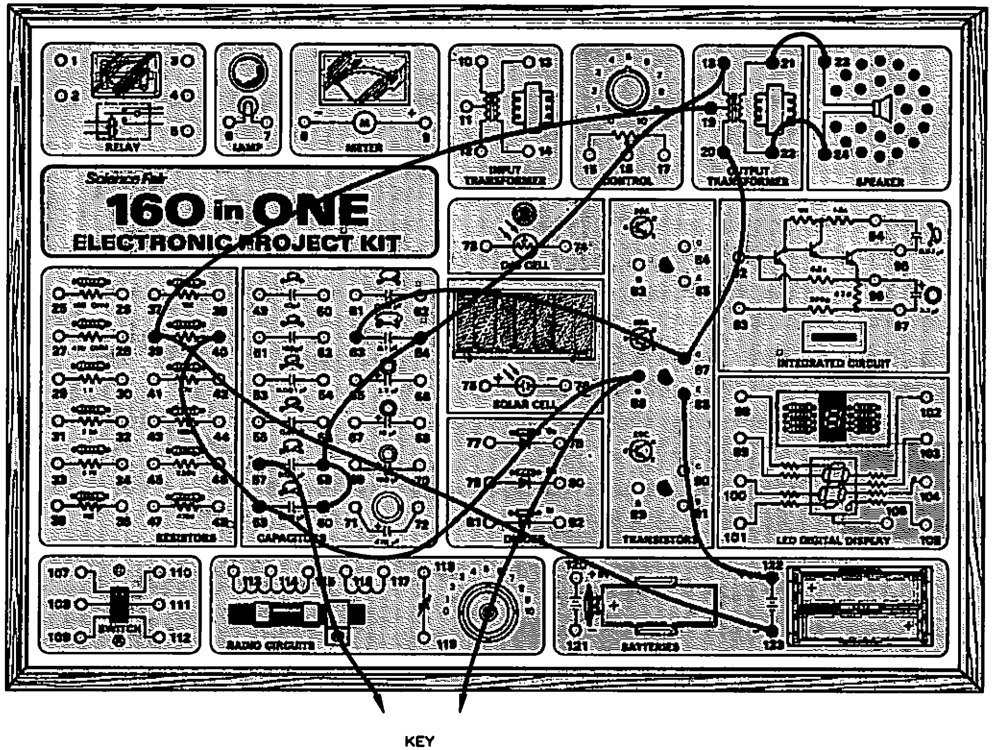
The circuit used is the basic pulse oscillator type. The Transistor is periodically turned ON and OFF to produce strong pulses of current in the Speaker. The Key is used to insert a Capacitor into the circuit to lengthen the pulse repetition rate and therefore lower the pitch of the tone.

This circuit contains the two basic requirements for an oscillator: output greater than the input, and feedback from output to input in such a manner (regenerative) that oscillations are sustained.

Switching occurs in this oscillator as the Transformer is driven into saturation by the current which flows through the Transistor when it is ON. When saturation is reached, the Transistor is turned OFF until the magnetic field collapses to such a low level that the bias current through the 22K Resistor can turn it ON again. Meanwhile the collapse and build up of magnetic flux induces a voltage across the secondary winding which produces the output power into the Speaker.

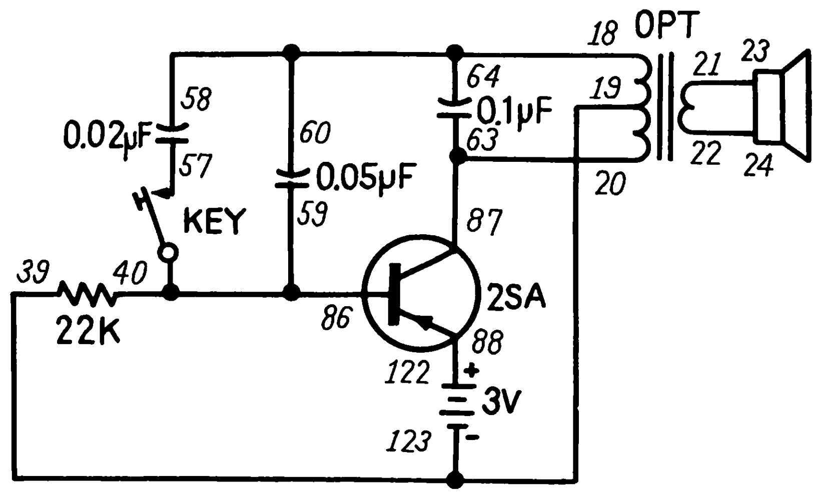
The addition of the 0.02uF Capacitor slows down the switching action as its charge tends to both hold the Transistor ON and then hold it OFF.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 19-39-123, 18-64-58-60, 20-87-63, 40-59-86-Key, 57-Key, 88-122



13. ELECTRONIC SIREN

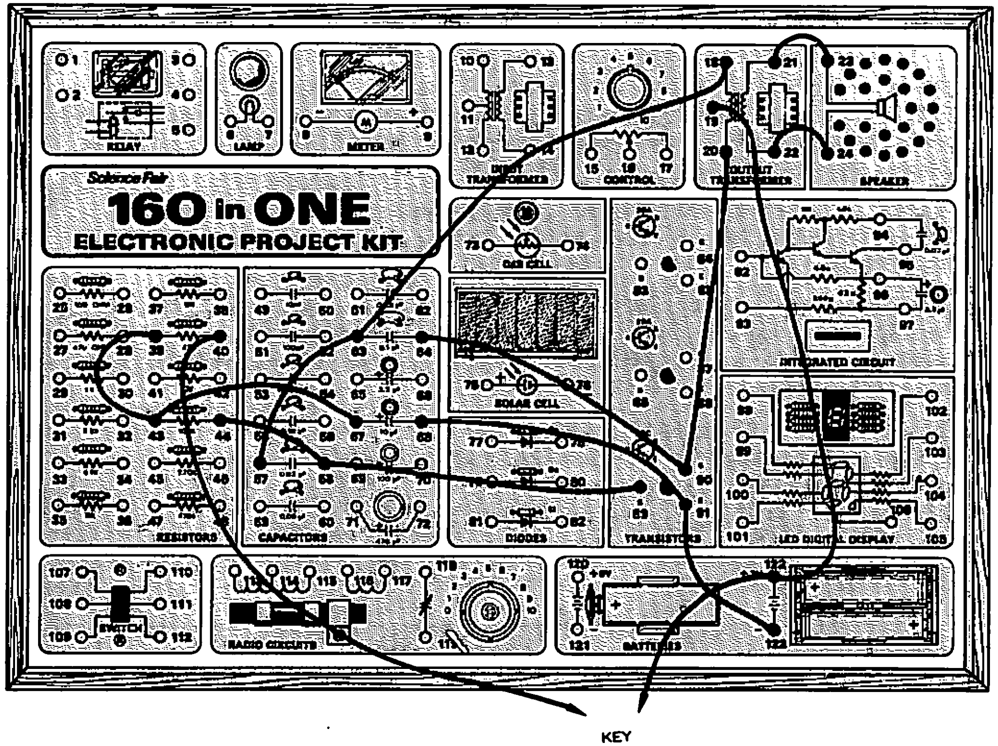
Don't be surprised if this becomes the most popular circuit in this entire kit! This circuit sounds so much like a real siren used on some police cars and ambulances you may have to modify the circuit or risk being arrested for impersonating a police car! (Don't worry...we're just kidding)

Some of the modifications you will want to try are listed below:

1. Change the 10uF to a 100 or 470uF. This gives a very long delay for both turn-ON and turn-OFF.
2. Change the circuit to eliminate the ON-OFF delays by replacing the 10uF with an open circuit. (Sounds dead in comparison doesn't it!)
3. Change the 0.02uF to a 0.01 and then a 0.05.

You should be able to determine how this circuit works by comparing it to the circuit of project 152. Actually the changes are few so if you use the same method of following the currents around you can do it. Start by considering this circuit without the 10uF Capacitor. Without this component the operating characteristics are virtually identical to the other project. After obtaining an understanding without the 10uF, try including it in your analysis. Remember, with the 10uF in the circuit the turn-ON and the turn-OFF are delayed.

NOTES



WIRING SEQUENCE:

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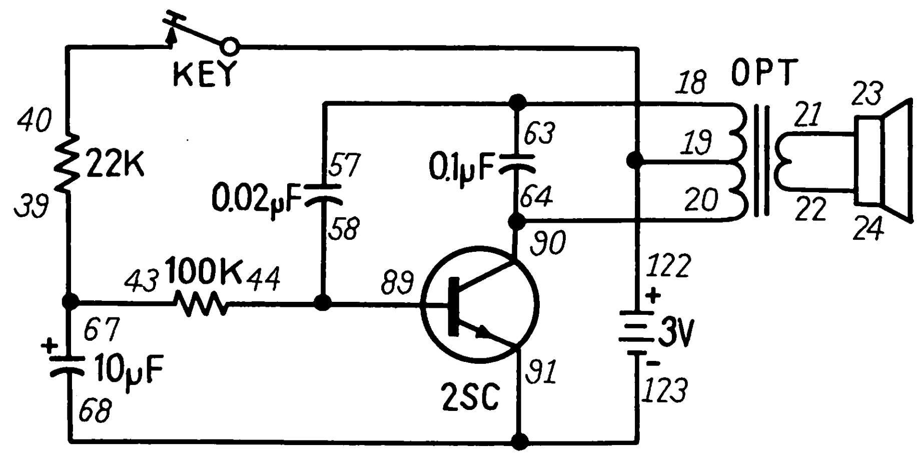


14. ELECTRONIC METRONOME

Anyone who is familiar with music has seen or used a Metronome. It is used to aid in setting the tempo of music and keeping that tempo. You can adjust the tempo (or rate) by rotating the Control. Years ago Metronomes were all mechanical — like a pendulum clock. But now many Metronomes are electronic, like this one.

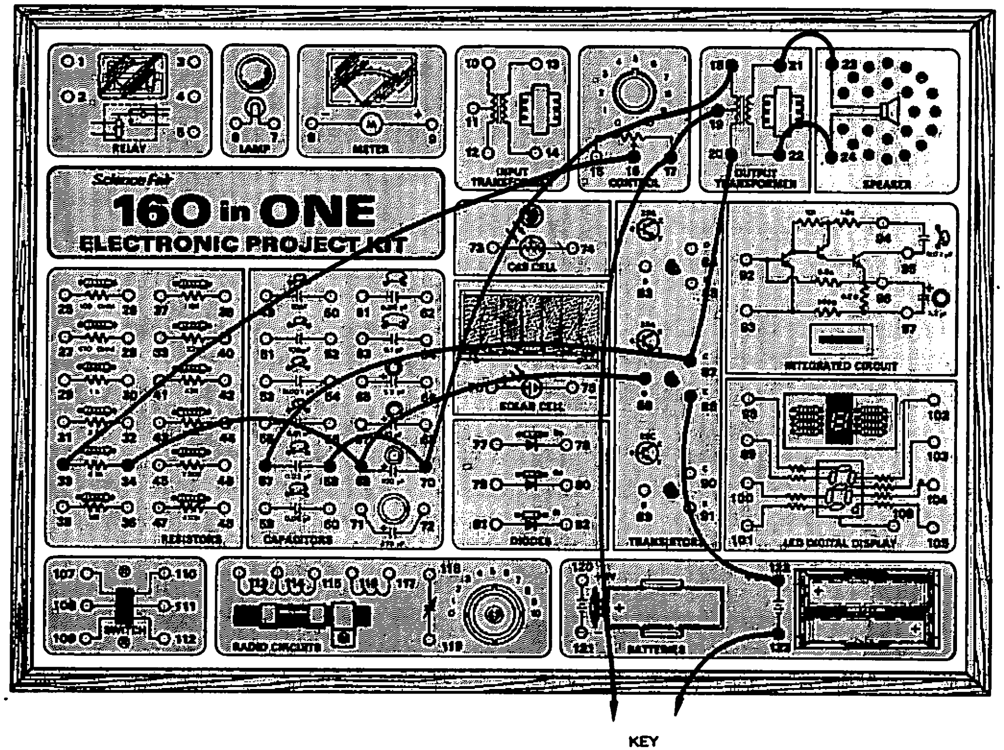
This is a slow pulsing oscillator which makes a very good Metronome to set the timing for all your musical selections. The output clicks from the Speaker are loud enough to make this a very usable circuit.

You should recognize the circuit as being very similar to that of project 4. The only difference is in the choice of timing circuit components. Here a high value of capacitance (100uF) is used along with a higher total resistance (4.7K and 50K) to obtain the pulse repetition rate required for a Metronome.

Circuit operation is described in detail in projects 4 and 152 so we won't repeat it here. This, and all other pulse oscillation circuits like it, are capable of higher pulses if the Battery is paralleled (bypassed) with a large capacitance.

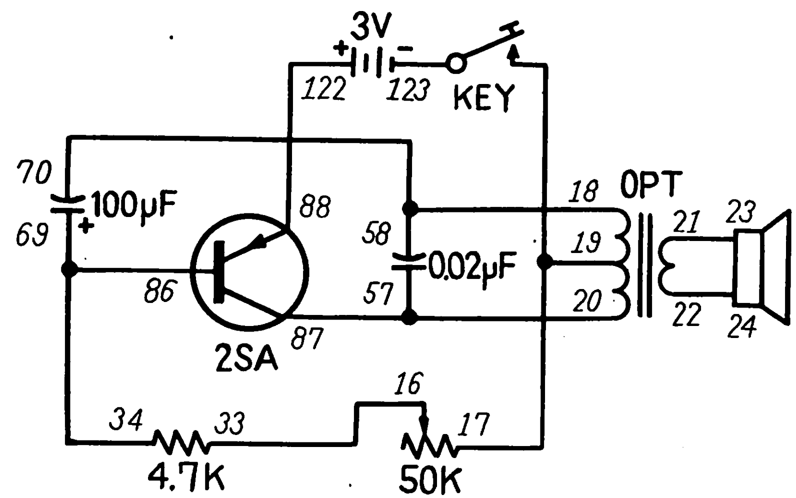
You may want to try connecting the 470uF Capacitor across the Battery to hear the difference. Be sure to observe proper polarity (plus to plus, etc). You will have to adjust the timing resistance some also to maintain the same pulse rate. Have fun!

NOTES



WIRING SEQUENCE:

21-23, 22-24, 18-70-58, 16-33, 20-87-57, 34-69-86, 88-122, 19-17-Key, 123-Key



15. 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 clicks obtained by this pulse-oscillator circuit are about a second apart. (Change the 100K Resistor to obtain faster or slower pulse rate.) The timing and sound together are what give the listener the mental picture of the old grandfather clock.

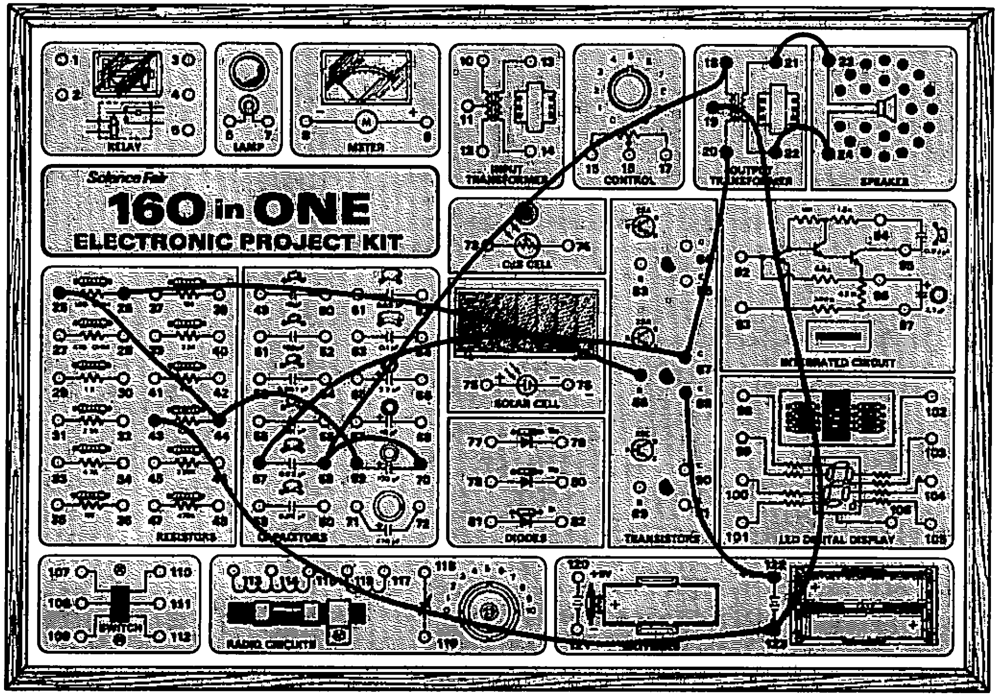
The steady monotonous ticking has also been used to stimulate animals and people into a restful state of mind. Anyone who has traveled by train and heard the click, click, click of the tracks knows how easy it is to fall asleep under these conditions.

Hypnotists have long used this hypnotizing characteristic to gain control of their subject's mind.

We've described circuit operation elsewhere in this book so we won't go into great detail.

1. When power is first applied, the 100K starts the Transistor into conduction.
2. The 100uF quickly charges up to a voltage greater than the 3V Batteries, due to induced voltage in theTransformer windings.
3. When the Transformer core reaches magnetic saturation, the induced voltage decreases, allowing the 100uF charge to quickly cut off the Transistor (due to reverse base-bias).
4. The 100uF must now slowly leak its charge off through the 100K and Battery until its voltage about equals that of the Battery.
5. When the 100uF voltage about equals that of the Battery, the Transistor can conduct again for a short time, and that's when you hear the click (as the Transistor conducts and the Capacitor receives a charge).

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



WIRING SEQUENCE:

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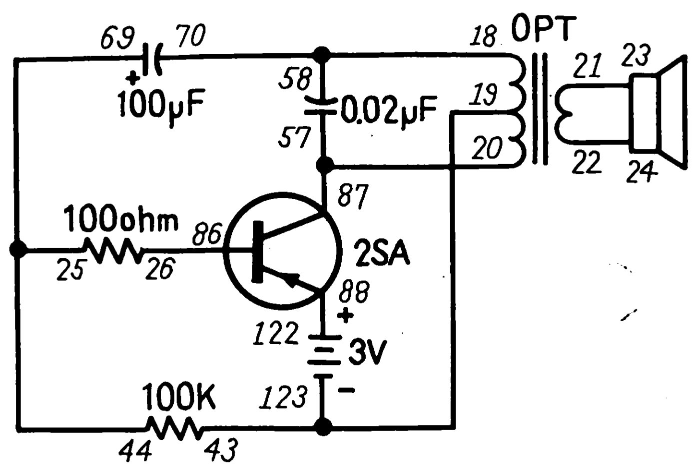
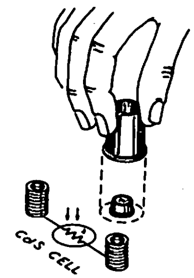


NOTES

16. LIGHT CONTROLLED ELECTRONIC HARP

This project is an audio oscillator that allows you to play musical tunes by waving your hand over the board. The method of obtaining musical arrangements like this has been used since the early days of vacuum tube radios. The first instrument of this type was invented by a man named Leon Theremin, so the instrument was named the Theremin in his honor.

This might be called a "hands-off" instrument, for once you turn the oscillator ON you need not touch it to play a tune. The tones are obtained by changing the amount of light that reaches the CdS Cell. If a bright light is placed over the board without the shadow of your hand, the pitch is high in frequency. As you block the light more by moving your hand, the pitch decreases.

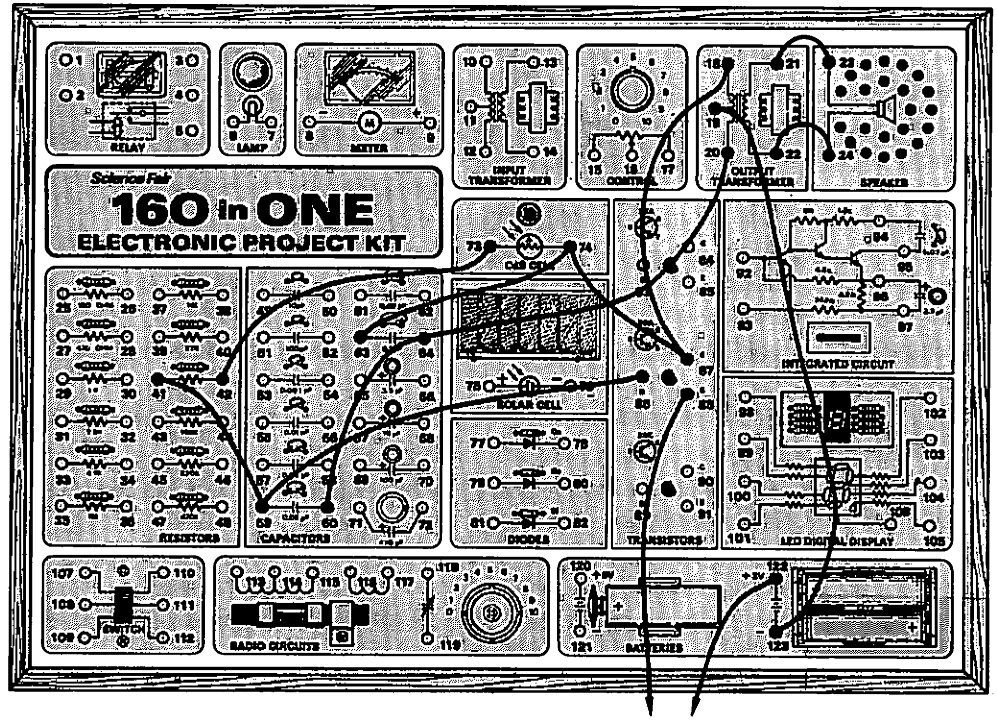


After a little practice you will be able to play many tunes with this musical instrument.

The oscillator circuit used for this project is the basic pulse type (which is used time and gain). The only change in this circuit is the addition of the CdS Cell in the base-bias circuit. A fixed 47K Resistor is also included in series with the Cell to provide a protective limit on base-bias.

Have fun!

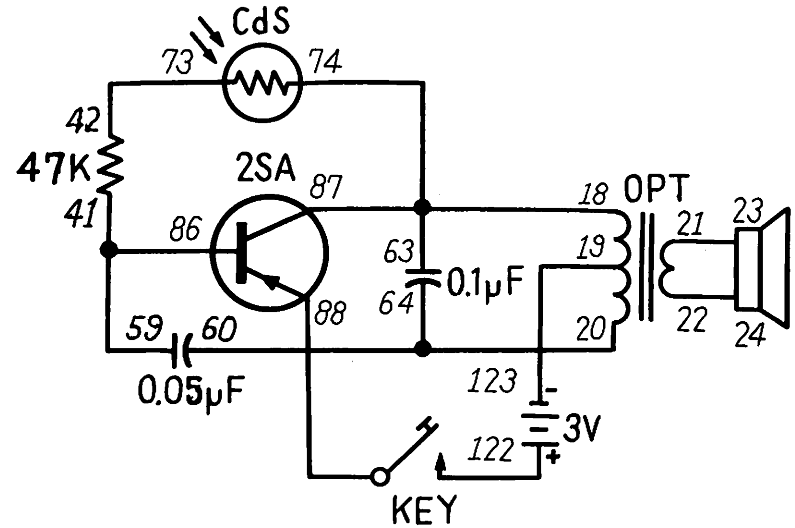
NOTES



KEY

WIRING SEQUENCE:

21-23, 22-24, 18-87-74-63, 19-123, 20-64-60, 73-42, 41-59-86, 88-Key, Key-122



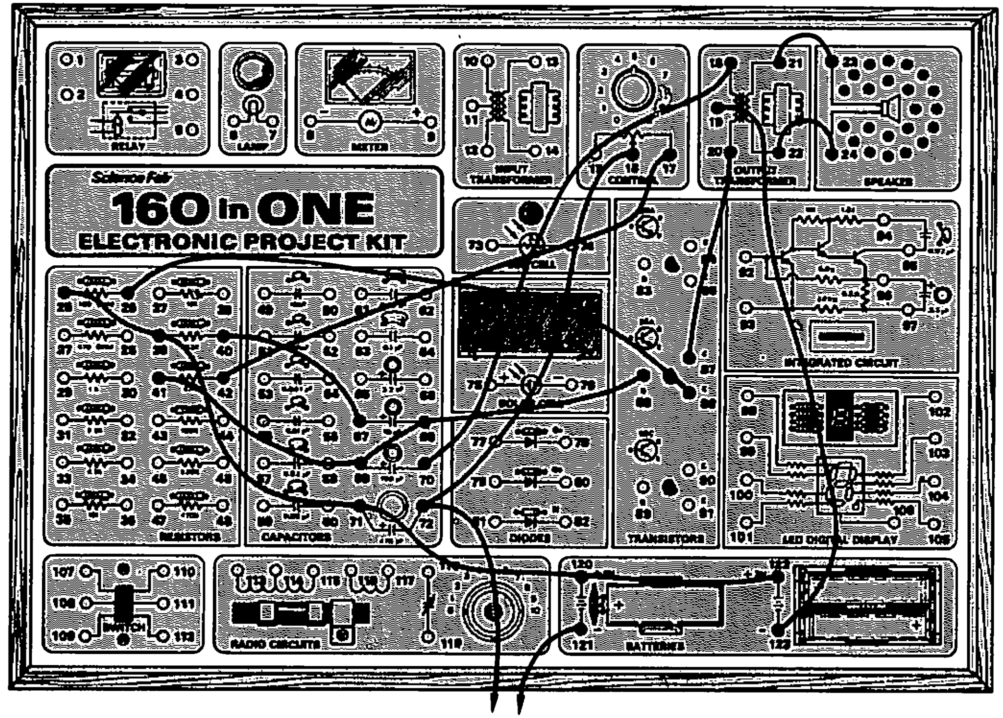
17. SLEEP MACHINE

This circuit is a pulse type oscillator with a very long OFF-time delay. In fact, the OFF-time delay is so long that someone has named this circuit the sleep machine. Probably because he fell asleep listening to the monotonous, hypnotizing, clicking sound. Say, maybe we could call this the hypnosis machine. Well anyway; it is an interesting circuit.

The basic circuit is a blocking oscillator as we discussed in detail in project 9. The added circuitry is the 9V Battery, Key and 470uF Capacitor. The change is in the source of base-bias. Instead of obtaining the bias from the 3V Battery through the 47K and 50K resistances, it is obtained from the 9V Battery or 470uF Capacitor charge. Base-bias current requirements are so low that it takes a long time for the charge on the 470uF to leak down to near zero. Also the leakage of the 100uF and Transistor keep the circuit going slowly .... indefinitely.

Pleasant dreams.

NOTES



WIRING SEQUENCE:

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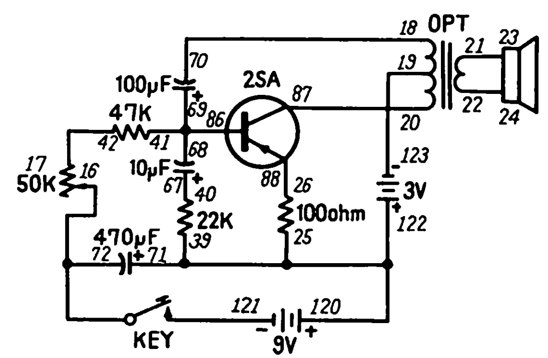


18. THE CHIRPING BIRD

This project is an oscillator that imitates the sound of bird (but not a woodpecker, as in project 9). When you set the Switch to the ON (up) position you won't hear any sound from the speaker, but when you also press the Key you will hear the sound of a chirping bird. When you release the Key the chirping will continue for a short time and then stop. You've built several circuits similar to this, so take a look at the Schematic and see if you can figure out what's happening in this one.

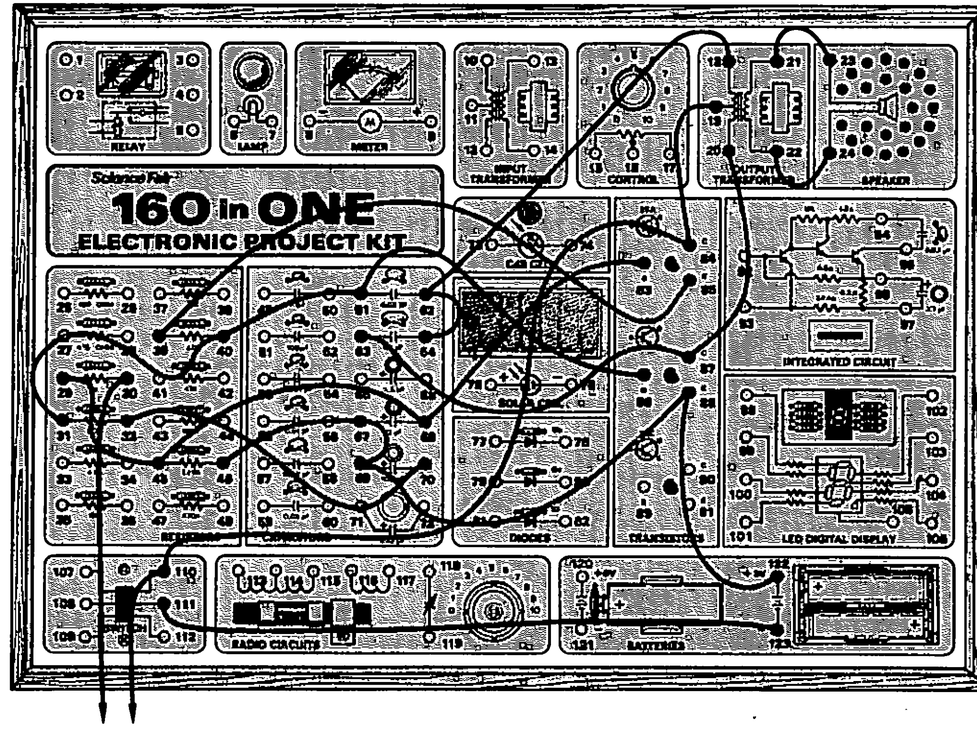
You should see that when you press the Key, current is supplied to the 2SA(1) Transistor. This allows the C-E circuit of the Transistor to conduct, and supply current to the base of the 2SA(2) Transistor which turns ON the oscillator (through the C-E circuit of the 2SA(2) Transistor). The 10uF Capacitor is charged when the Key is pressed, also. When you release the Key the current from the Capacitor keeps the circuit operating until it discharges.

Try a different value Capacitor for the 10uF and 100uF ones and see what happens. By changing the value of the 10uF, you should be able to vary the delay in the OFF time when you release the Key, but what will happen when you change the 100uF?

Can you think of uses for this circuit? It could replace the oscillator in many of the other circuits you have built, or it might make a very unusual door chime.

Can you think how the CdS could be used to control this circuit? If you can, make notes of the changes.

NOTES



WIRING SEQUENCE:

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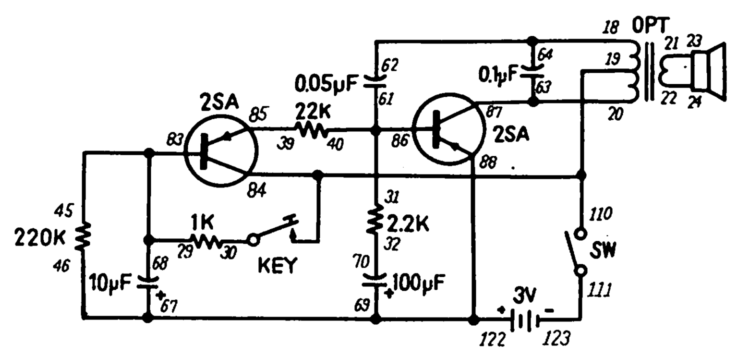


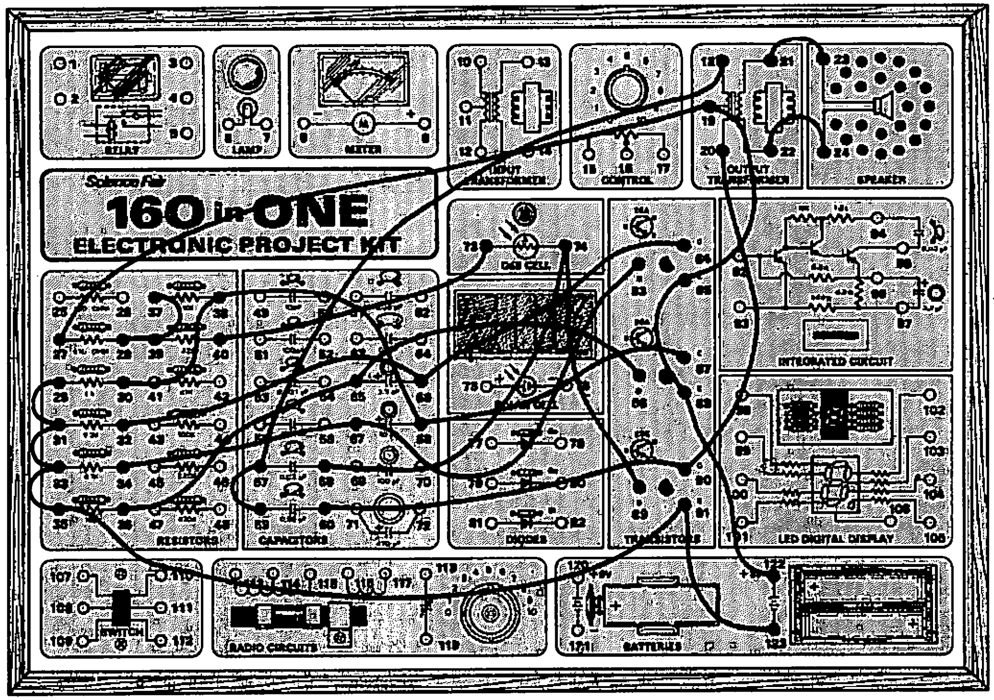
19. "HORROR MOVIE" SOUND EFFECT

This project is similar to project 77, except that it uses the CdS Cell to control the oscillation frequency instead of the 50K variable resistor (Control). The sound that it produces will remind you of the "scary" music you hear in horror movies.

The pulse type oscillator on the right side of the Schematic produces the basic sound. The base bias of its 2SC Transistor is supplied through two sources: the multivibrator circuit on the left side of the Schematic and the CdS Cell. The multivibrator provides a pulsating current flow, which causes the tremelo (wavering tone) effect, and the resistance of the CdS Cell controls how much of that current reaches the 2SC base. This determines the charge/discharge rate of the Capacitor and therefore the frequency of the pulse oscillator.

When the frequency of an oscillator is controlled by another circuit, it is called "FM" or frequency modulation. An FM radio signal is something like this, except at much higher frequencies.

NOTES



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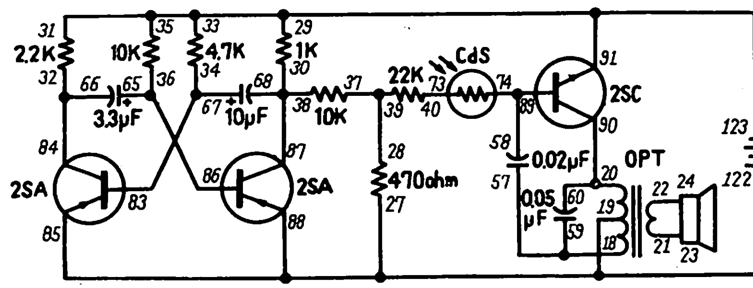


20. COIN BATTERY

This is the first experiment in the category of Natural Science Projects — most of them combine some Physical Science principle with electronics. These will show you what practical applications there are for electronics in all aspects of Science.

Did you know that the world abounds in batteries? Virtually all metals can act as electrodes, and almost anything but distilled water can be used as an electrolyte. This characteristic of our world is evident everywhere we look. Metals eaten away by rust and corrosion can be said to have sacraficed themselves as the electrode of nature's big battery.

A battery is formed whenever two dissimilar (not the same type) metals are in contact with a liquid which is capable of acting chemically on the two metals. The liquid may be acidic or alkali as long as it can react on the metal to extract electrons or atoms. There is an optimum chemical for use with any two metals, but many other chemicals will work acceptably as an electrolyte as long as they can conduct electricity.

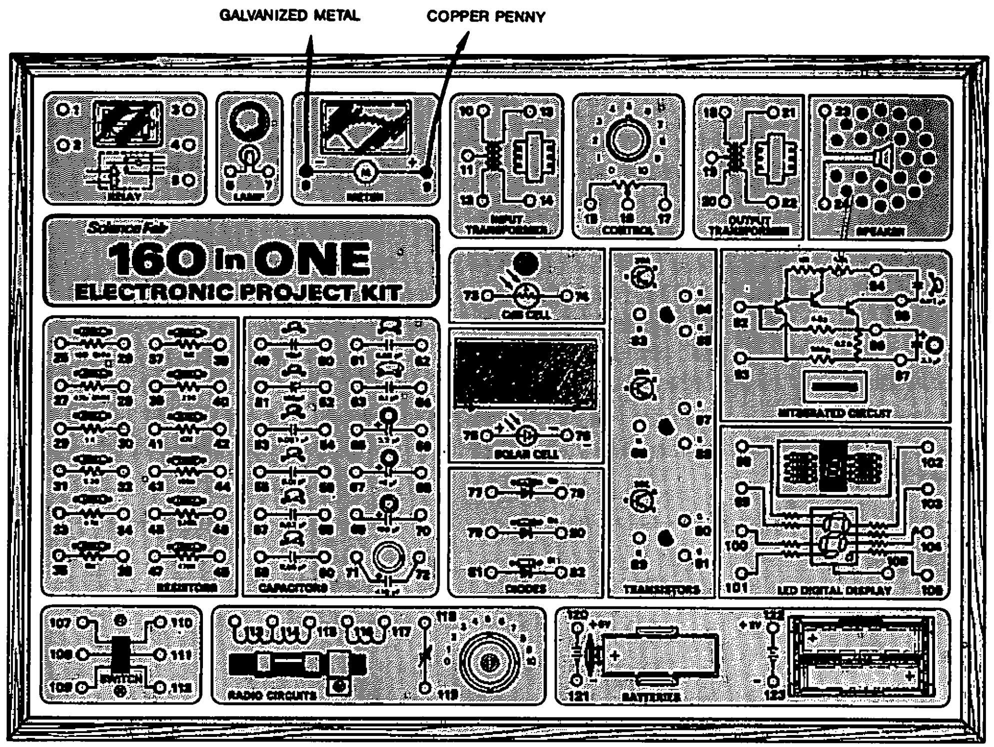
The voltage produced between the dissimilar metals depends on the chemical properties of the metals. Someone has tested all possible combinations of metals to determine the relative voltage between any two metals. The listing (in order of voltage amplitude and polarity relative to hydrogen as a 0V reference) is called the "electromotive series of the metals". Choosing metals in this listing which are farthest apart in the list will yield the highest voltages. Current delivering abilities are related to other chemical properties, so don't expect the highest voltages to also be able to supply the most current. An abbreviated listing is included below. Notice that copper is widely separated from iron, zinc (used for galvanizing) and aluminum, which are all relatively active and therefore able to produce the required current for your "coin battery". A copper penny can be used as the (+) electrode and many of the other metals as (–) electrodes.

MOST POSITIVE: Gold
Silver
Mercury
Copper
Bismuth
Antimony
Lead
Tin
Nickel
Cadmium
Iron
Chromium
Zinc
Manganese
Aluminum
MOST NEGATIVE: Magnesium.

Place a piece of paper or cloth moistened with vinegar (as an electrolyte) between a penny and some other metal. Connect the Meter across this "battery" you have just made. The amount of Meter deflection is an indication of "battery" output.

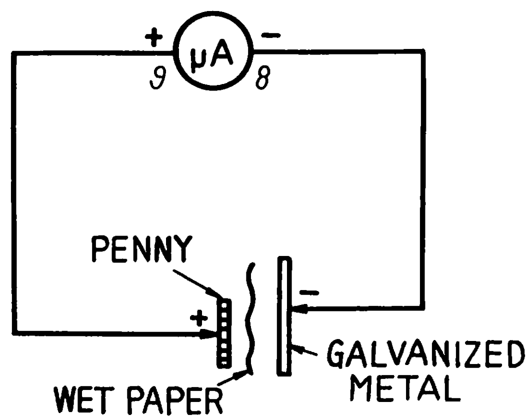
To compare the current delivering properties of different "coin batteries", use a 100 ohm Resistor in shunt (parallel) with the Meter. This increases the full-scale meter current from 0.25mA to about 2mA. It is an unusual penny battery that can pin this Meter circuit.

For circuits to operate with this Coin Battery, see projects 67, 87, 123 and other experiments which require very little power (for example, the circuits which are powered by the Solar Cell).



WIRING SEQUENCE:

9-Copper Penny, 8-Galvanized Metal



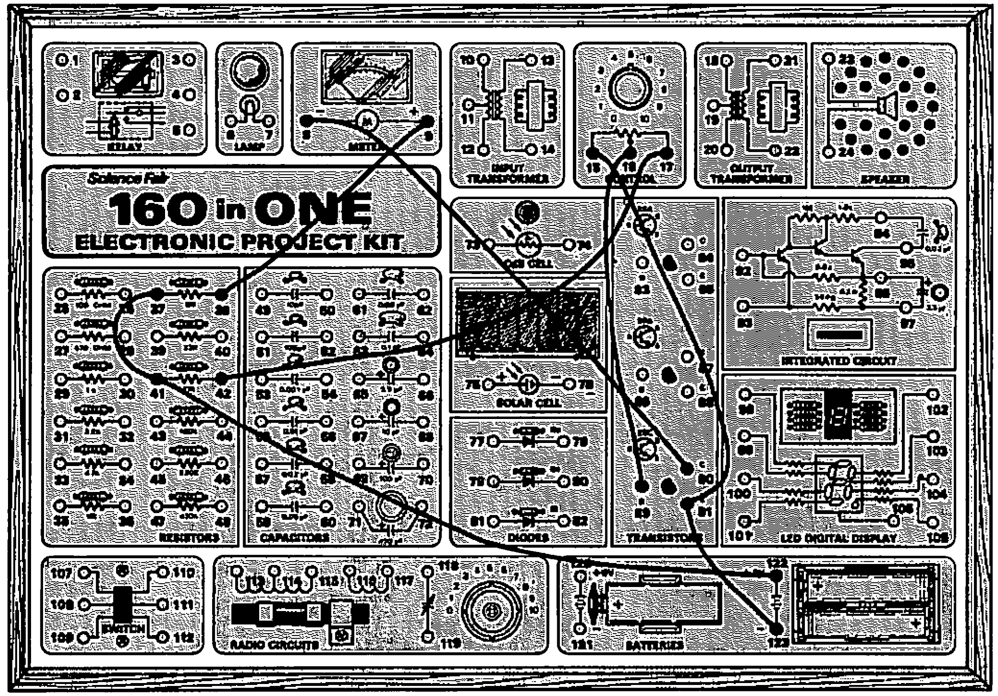
21. ELECTRONIC THERMOMETER

This experiment demonstrates the thermal sensitivity of semi-conductors and is the basic circuit used in most electronic thermometers. The temperature sensitive element is a common silcon Transistor (2SC).

Bias voltage is constantly applied to the base of the 2SC Transistor by the 47K Resistor and the 50K potentiometer (Control). Current is flowing into the base at the same time. As the temperature of the Transistor is raised, the base current increases even though the bias voltage is kept constant. The increasing base current causes the collector current to increase which increases the Meter reading.

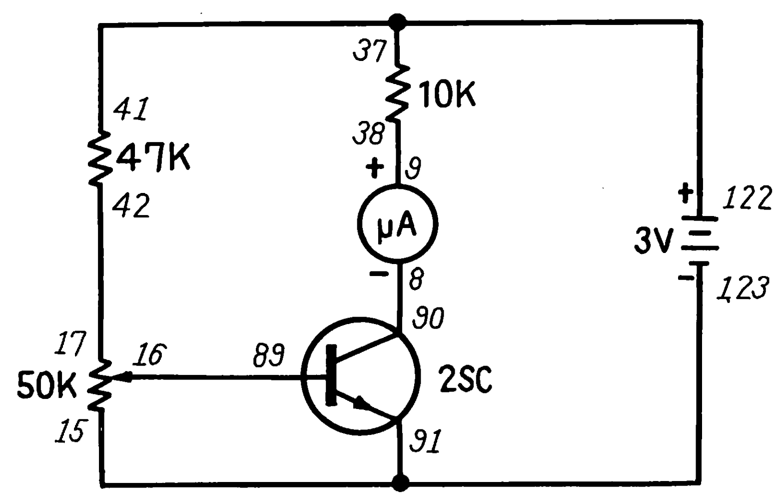
After wiring the circuit, use the Control to adjust the Meter pointer to the center of the scale. Gently hold the 2SC Transistor between your thumb and forefinger; the Meter pointer will move as the Transistor temperature changes. Try measuring such temperature differences as body-temperature to room-temperature, room-temperature to outside-temperature, and shade-temperature to sunshine-temperature. Battery current drain is very low for this circuit so hours of use will make little change in Battery life.

NOTES



WIRING SEQUENCE:

8-90, 9-38, 15-91-123, 16-89, 17-42, 37-41-122



22. SOLAR POWERED LIGHT METER

This project is a light powered circuit which is very easy to hook up but very profound in its implications in this day when everyone is so concerned with the use and generation of energy. This circuit is useful as a light meter for photography. Most common light meters are very much like this simple circuit.

The Solar Cell changes light energy directly into electrical energy. The Meter provides a visual readout for relative light intensity and the 50K Control (connected as a rheostat) allows you to adjust the sensitivity of the circuit over a wide range of light levels.

The Meter and rheostat (Control) form a simple voltmeter across the Solar Cell. When the full 50K ohms of resistance is in the circuit, the full scale meter voltage is about 12 volts. When it is adjusted for maximum sensitivity (zero resistance) the full scale voltage is about 0.16 volt.

The output voltage of the Solar Cell is sufficiently high so you should have no trouble pinning the Meter in the most sensitive rheostat setting (0), but you should not be able to pin the Meter with the minimum sensitivity setting (10).

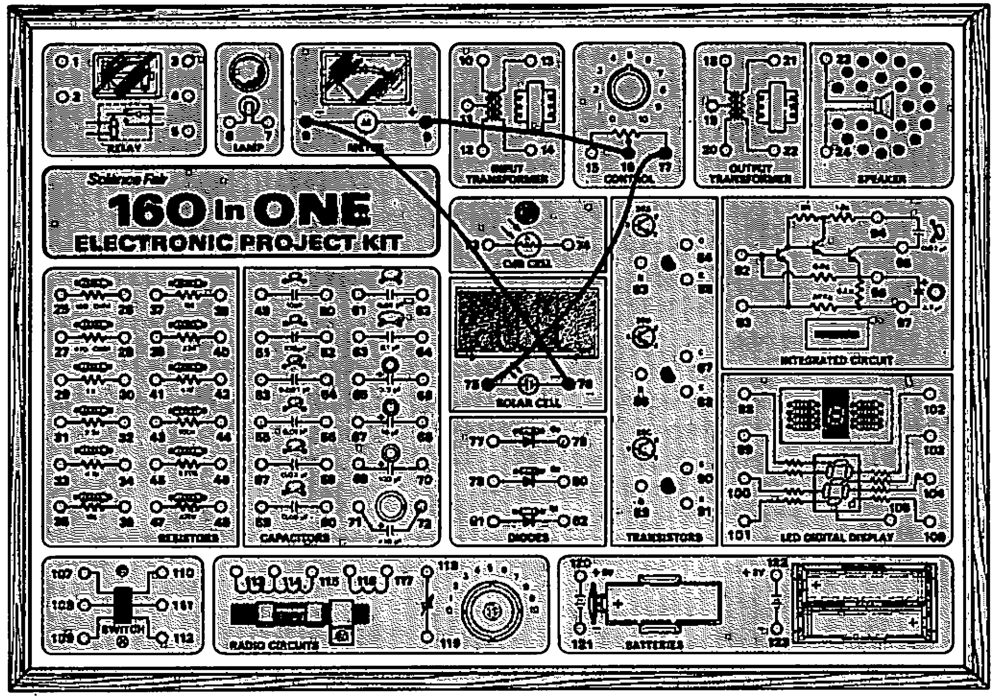
Your VOM may be used to calibrate the Meter by setting the Control for some convenient full scale voltage. Place the VOM across the Solar Cell in parallel with the Meter and Control circuit when checking Meter calibration.

It may become possible some day to make sufficient amounts of solar-energy-generated electrical power to do many of the common household tasks. The present problem is the cost of the solar cells and equipment required to obtain a sufficiently useful installation. It will only be a matter of time though before we will see many light powered things in common use.

The photovolatic cell used in this kit is a selenium type, which responds best to the blue to red region of light. Other solar cells are available that are made of silicon. These are far more efficient than selenium solar cells but are also much more expensive. If you are interested in this aspect of science we suggest that you take a look at the SOLAR POWER ELECTRONIC LAB KIT, which is available at your local Radio Shack store.

With this simple light meter you may want to check the relative light levels around the house and compare these with some obtained outdoors in sunlight and in shade.

NOTES



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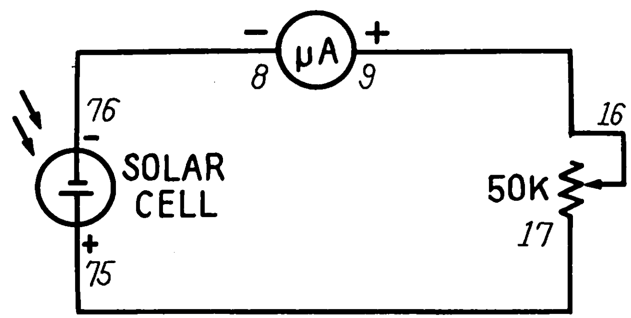
76-8, 9-16, 17-75



23. CdS CELL LIGHT METER WITH TRANSISTOR AMPLIFIER

The purpose of this circuit is to measure the relative intensity of light similar to a light meter as used with cameras. The circuit uses a Transistor amplifier to obtain greater sensitivity than what is obtained with many light meters.

The heart of this circuit is the cadmium sulfide (CdS) Cell which controls the amount of deflection obtained on the Meter. A Control is included to allow measurements of relative light intensity from near darkeness to full sunlight.

The CdS Cell is effectively a Resistor (as its schematic symbol implies) that changes value depending on light energy present. In darkness its resistance is very high (in the megohm range) and in bright sunlight it is very low (about 100 ohms or so).

The CdS Cell is placed in the base-bias circuit of the Transistor so that an increase in light causes an increase in base-bias voltage. Recall that collector current is determined by base-bias current; increased base-bias causes increased collector current. The collector current is caused to flow through the Meter to produce readout.

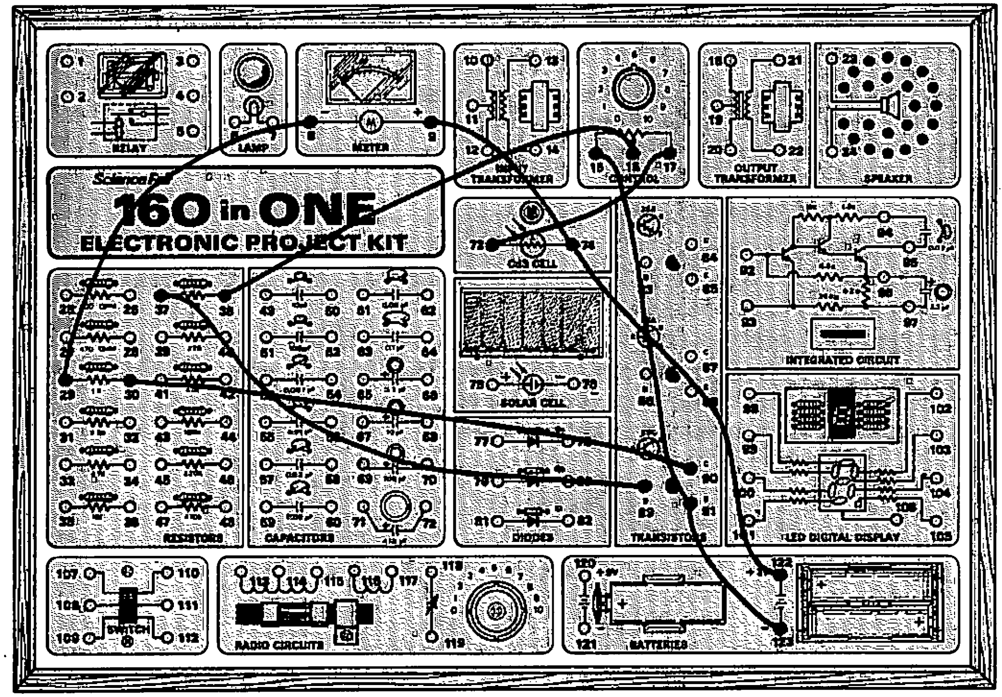
The 10K base Resistor protects the Transistor from excessive base current in bright light when the 50K Control is set at maximum. The 1K Resistor is included to protect the Meter from excessive current should the Control be set too high, or the light too bright. The Control should be kept low (near zero on the dial) unless a higher setting is definitely needed to get a usable Meter reading.

You can use your VOM to check the resistance of the CdS Cell (when not connected into the circuit); use the ohm meter function.

You can use your VOM to see the change in voltage across the 50K Control; use the voltmeter function. For best results set the Control at zero for this test.

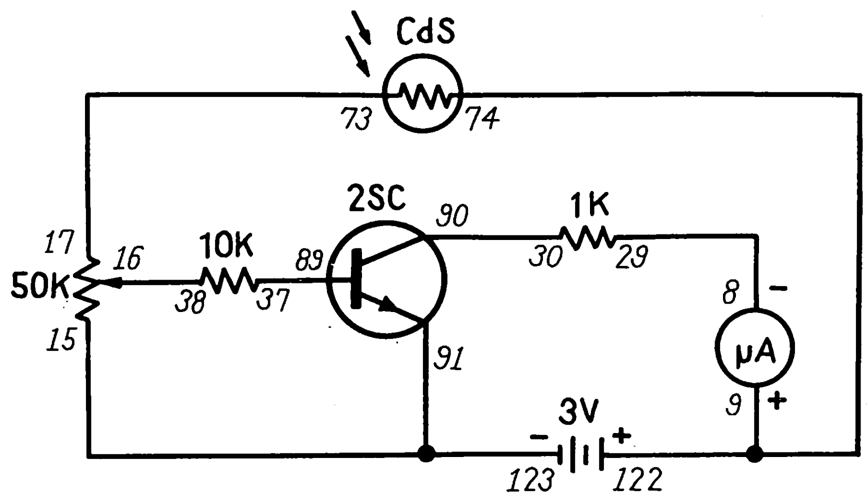
The Control settings and Meter readings may be recorded for comparison of light levels. If a calibrated light meter is available, you can make a chart of Control settings and Meter readings that is accurate enough for most light meter requirements. You may want to use the space below for this purpose.

NOTES



WIRING SEQUENCE:

122-74-9, 90-30, 29-8, 73-17, 16-38, 37-89, 15-91-123

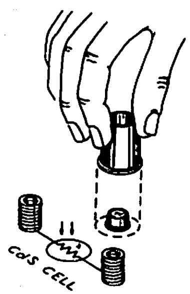


24. SOLAR CELL AND CdS CELL LIGHT METER

This project is a light meter with Solar Cell power and cadmium sulfide (CdS) Cell control, combined to give a Meter indication of relative lightlevels. The use of both light controlled devices like this results in a greater change in Meter readings over certain levels of light than that obtained with either device alone.

With very low levels of light the Solar Cell produces very low voltage, the CdS Cell has high resistance, and the Meter deflection is little or nothing at all. As light intensity increases, the Solar Cell output increases, the CdS Cell resistance decreases, and Meter deflection increases.

The 50K Control is wired as a rheostat to provide some control over how much Meter deflection is obtained with a given light level. This allows the Meter to be compared with a calibrated light meter over a large range. A chart or graph may then be made so that the Meter reading can be used to determine photography exposure requirements.

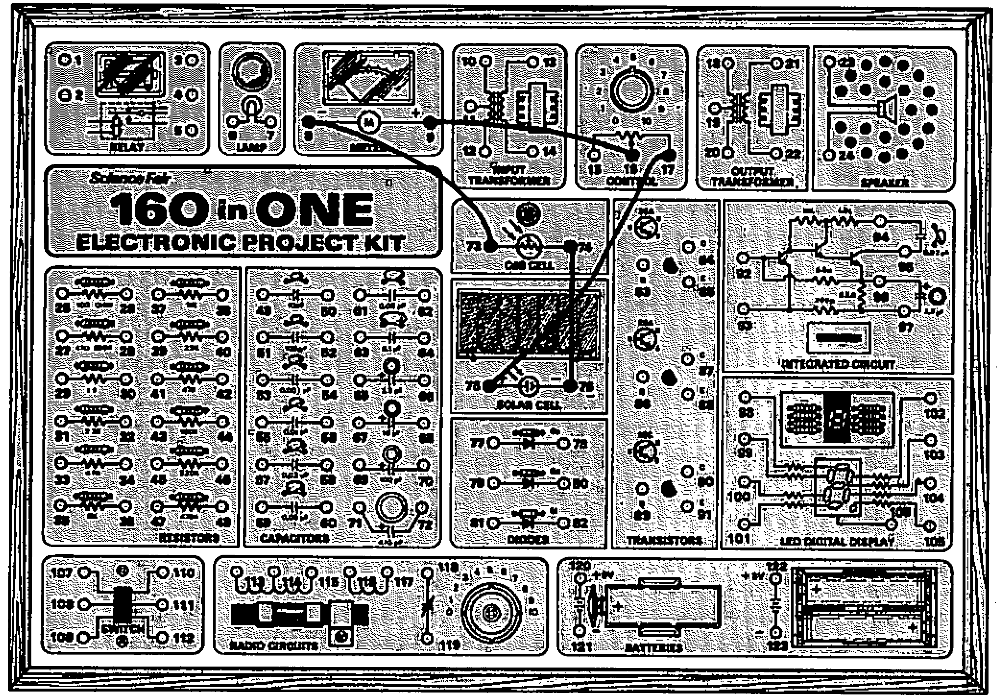


To demonstrate the effect of the Solar Cell and CdS Cell, begin with a bright light source and a Meter reading near maximum. Use a solid object large enough to block the light to the Solar Cell but not to the CdS Cell. The Meter reading should decrease to zero. Now cover the CdS Cell but not the Solar Cell. The Meter reading should again decrease. To obtain a zero Meter reading there can be no light allowed to leak through to the CdS Cell, as it is very sensitive.

The Solar Cell used in this kit is a selenium type which responds best to the blue to red region of light. The photons of light energy are converted directly to electric energy by this Solar Cell.

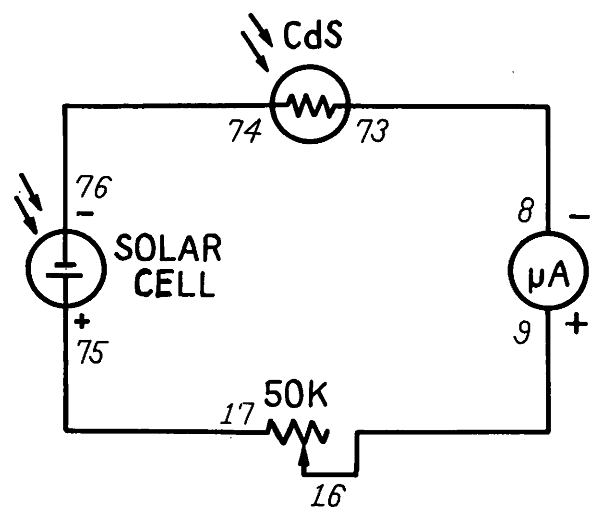
The cadmium sulfide (usually referred to by its chemical symbol CdS) Cell is a resitance device that changes resistance due to the presence of light energy. The change in resistance is inversely proportional to the light level. That is, high light causes low resistance and low light levels cause high resistance in the Cell. Typical resistances might be 100 ohms in bright sunlight and 5 megohms in total darkness.

In the space below you may want to make a chart or graph of this Meter's sensitivities as compared with a photography light meter.



WIRING SEQUENCE:

8-73, 74-76, 75-17, 16-9



25. SUPER-SENSITIVE LIGHT METER

The purpose of this experiment is to study a sensitive light meter and then determine how it can be made to respond to changes in light intensity. The basic circuitry used is a bridge circuit that has a high-gain Transistor as one arm of the bridge. This Transistor then is controlled by a CdS Cell in its base circuit.

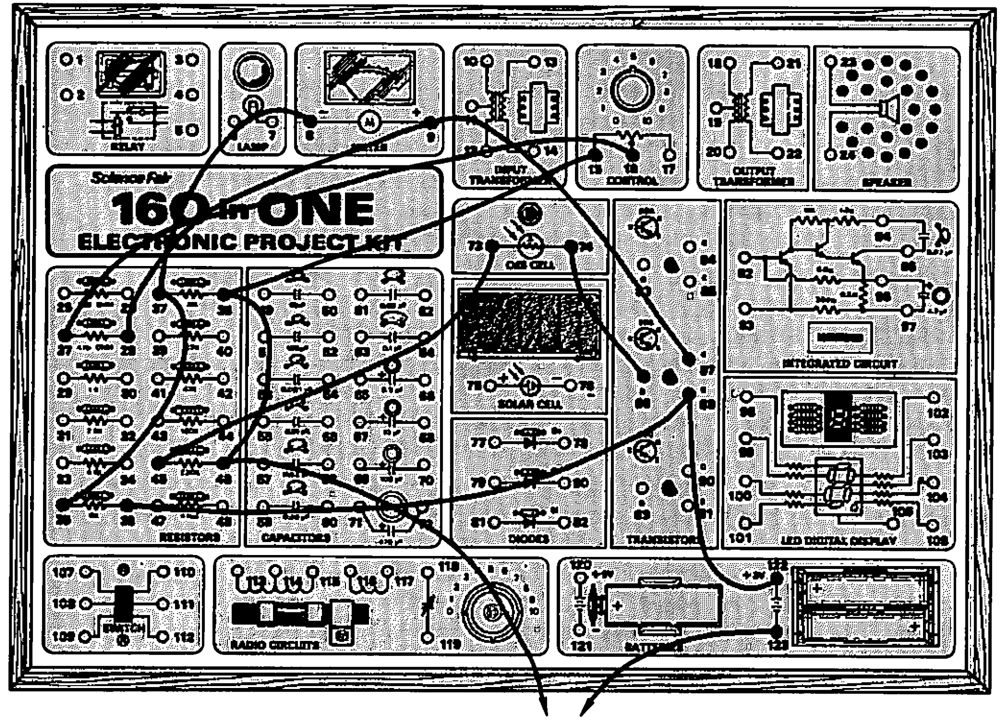
The bridge circuit is composed of four resistances arranged in a continous ring or enclosed loop. This project uses 10K Resistors as two arms, the series combination of a 470 ohm Resistor and the 50K Control as the third arm, and the resistance between C-E of the 2SA Transistor as the fourth arm of the bridge. When in a state of balance all arm voltages are equal and no Meter current can flow even though at this time a current of between 0.15 and 3.2 milliamperes may be flowing through the arms of the bridge. Balance is obtained at any light level by the proper adjustment of the 50K Control for a zero Meter reading.

During the balance condition, the CdS Cell is allowing a certain amount of base current to flow into the Transistor to turn it ON a small amount. When light intensity is increased, the base current is increased causing the effective resistance between Transistor C-E leads to decrease. This unbalances the bridge circuit and causes the Meter to read up scale. The amount of up-scale deflection is a direct indication of the amount of change in light intensity.

The sensitivity then is due to the ability of the circuit to effectively balance out the level of the light intensity initially so that only the amount of change in light intensity is indicated on the Meter. A circuit such as this can be adjusted to measure or indicate light changes that normally could not be sensed (due to the high normal or ambient light level). Most instruments respond only to total light rather than just to change in light.

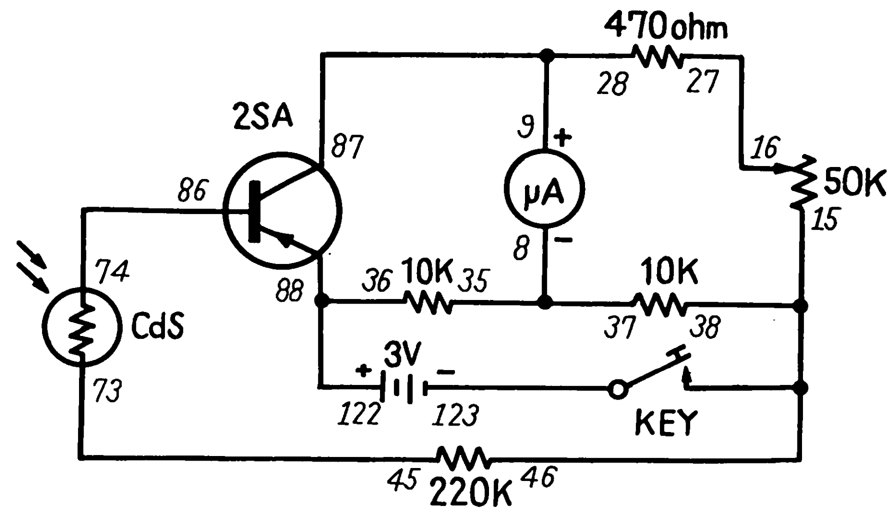
If you want to make this circuit very sensitive at low light levels (such a moon or starlight) short-circuit the 220K resistor.

NOTES



WIRING SEQUENCE:

87-9-28, 86-74, 73-45, 8-37-35, 16-27, 15-38-46-Key, Key-123, 36-88-122



26. SONIC FISH CALLER

For many years fishermen have looked for ideas that will help them catch fish. Then some scientists and biologists found out that fish (and other marine animals) communicate with sounds. They don't "talk" obviously, but they can make sounds that represent danger or other basic responses. Also, scientists found that some fish respond to certain sounds with curiosity; they are attracted by some sounds, and so the Fish Caller was invented for fishermen. This circuit is similar to some of the Fish Callers being sold today.

Unfortunately a water-proof speaker is very expensive, but if you seal a speaker inside a totally water-proof plastic bag or inside a glass jar, the sounds from the speaker can be transmitted through the water. If you want to try this in water, obtain a small speaker from your Radio Shack store. Attach long wires to the speaker terminals (it is best to solder the wires) and then VERY CAREFULLY seal the speaker inside a totally water-proof plastic bag or inside a glass jar. Be sure no water can get onto the speaker. Connect the speaker to this circuit and lower the speaker into the water. Now see if your Fish Caller works — try fishing.

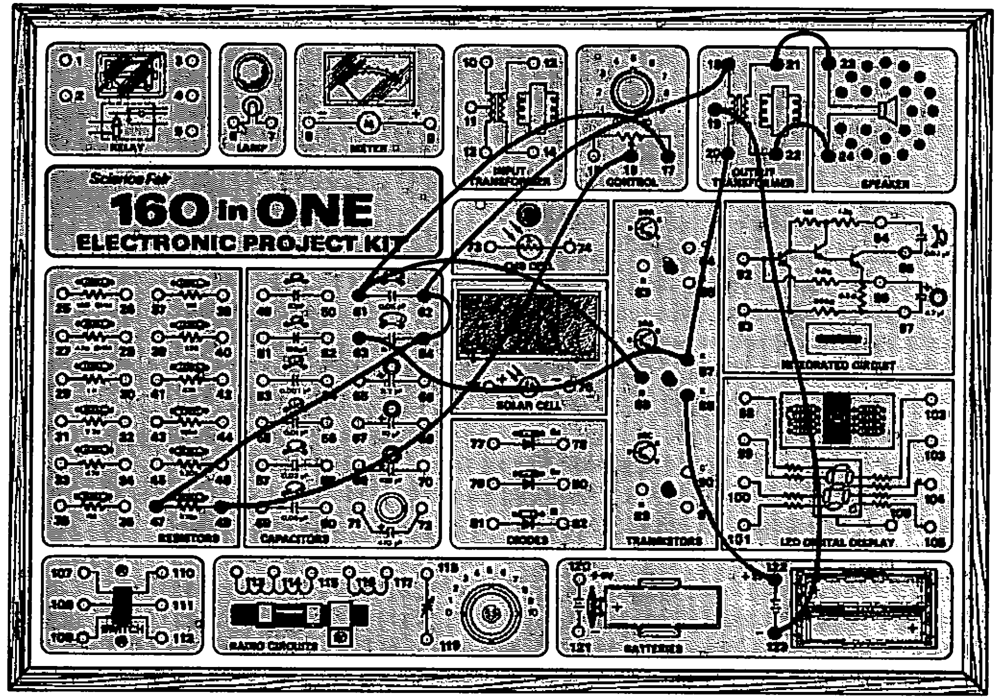
The circuit is a simple pulse waveform oscillator. The requirements for an oscillator are that the output be greater than the input, and the output must be connected back to the input in-phase (or regenerative). For this oscillator the Transistor provides a gain many times greater than 1 (1 stands for whatever the input or base current is), and the Transformer provides the coupling of the output back into the input. The output of the Transistor is through the collector to the emitter. This makes the bottom half of the Transformer winding the output load for the Transistor. The input to the Transistor is through the base to the emitter. The 470K and 50K Control (wired as a rheostat) along with the 0.05uF couple the output from the Transformer back to the input of the Transistor.

Because the emitter of the Transistor is common to both input and output of the Transistor (operating as an amplifier), the connections to opposite ends of the Transformer provide the proper in-phase or regenerative feedback. The 0.05uF Capacitor couples so much of the Transformer signal into the base that operation results in narrow pulses being developed and coupled to the Speaker. It is these narrow pulses which give this circuit its particular sound. Do the fish think it is a frog or other bait?

The 0.1uF Capacitor helps determine the strength (amplitude) and frequenc of the pulses. You may want to experiment with different values for this, as well as the 0.05uF Capacitor. Who knows, you may find the type of signal that will attract a whale!

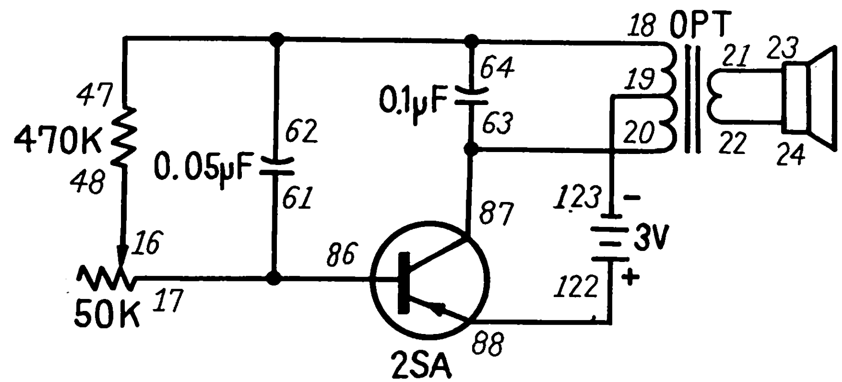
This might be a good experiment to build up on your own, using parts available from your electronic parts scrap box (you'll soon have such a box if you take up electronics as a hobby) or from Radio Shack. Build the circuit inside or on a convenient chassis, box, or container; Radio Shack's P-Boxes are ideal for such circuits.

NOTES



WIRING SEQUENCE:

123-19, 21-23, 22-24, 18-62-64-47, 20-87-63, 16-48, 17-61-86, 88-122



27. HYGROMETER (Relative Humidity Gauge)

The purpose of this project is to construct and study a Hygrometer. A Hygrometer is an instrument used to measure the relative humidity in the air. This is generally done by comparing the readings from two identical thermometers: one with a dry bulb, and one with the bulb dampened with water. As the water evaporates it cools the dampened thermometer. The relative humidity is indicated by the difference in the two temperature readings (using a chart). As you might suspect, the drier the air, the faster the water will evaporate. The faster the water evaporates, the more it cools the thermometer. Therefore, more difference in the two temperature readings indicates a lower relative humidity.

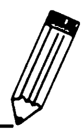
We use the two 2SA Transistors as thermometers in our hygrometer (look at project 21, if you've forgotten how this works). They are connected so that the difference in their outputs (C-E current) will control the base current of the 2SC Transistor, and therefore the Meter reading (the current flow in the C-E circuit of the 2SC).

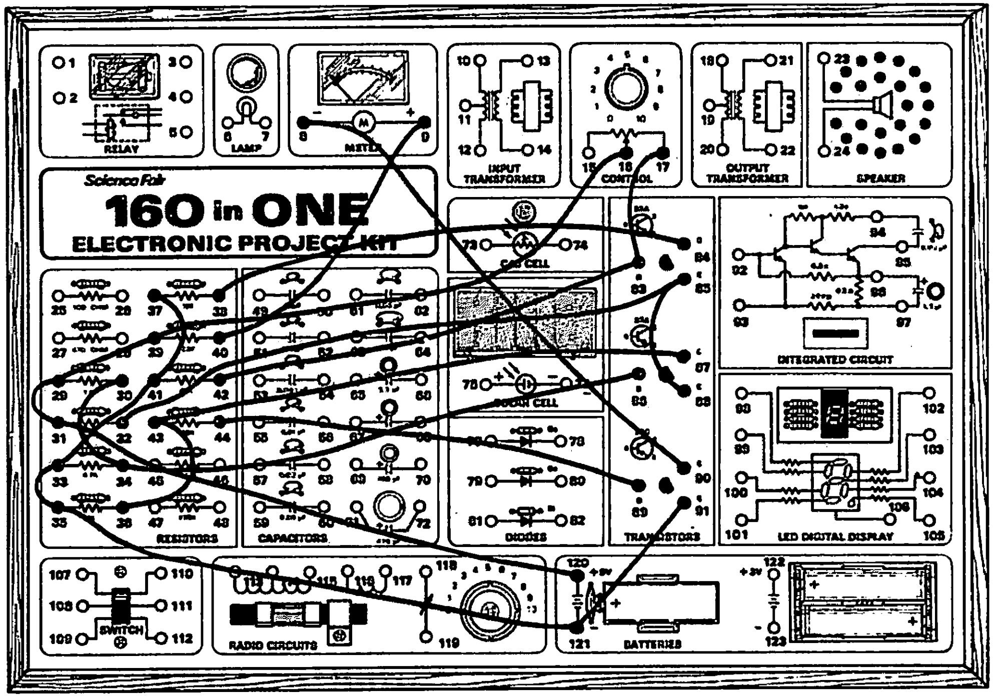
The steps for operating this Hygrometer are as follows:

1) After the wiring is complete, adjust the Control so that the Meter has a reading of exactly 10.
2) Without touching a terminal or the 'bread board', wrap a damp piece of cloth around the lower 2SA Transistor.
3) The Meter pointer will move to a lower reading to indicate the relative humidity.

Note: If the temperature around the kit is low, the Meter change will be slight. If the temperature is high, the Meter change will be greater.

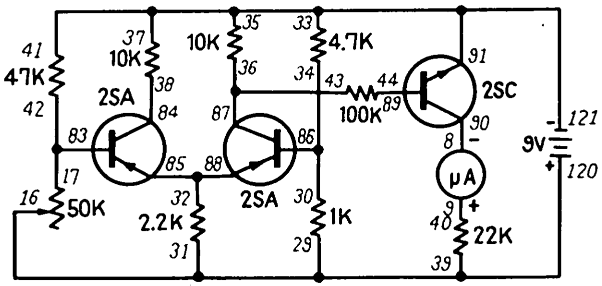
NOTES





WIRING SEQUENCE:

8-90, 9-40, 17-83-42, 30-34-86, 36-43-87, 37-41-33-35-121-91, 32-85-88, 38-84, 44-89, 16-39-29-31-120



28. LIE DETECTOR

This project is a good one to use at a party to play "truth or consequences". It is a sensitive resistance-change detector. You have heard about (and probably seen on TV) lie detectors being used to help determine if a person is telling the truth. Technically such an instrument is called a "psychogalvanometer". They are used in criminology, security work and for psychological tests. A "lie detector" detects very small changes in resistance of the skin. Normally skin resistance is affected by emotional reactions, so that when a person lies his skin resistance drops slightly (small amount of body sweat reduces normal skin resistance) and the "lie detector" senses this.

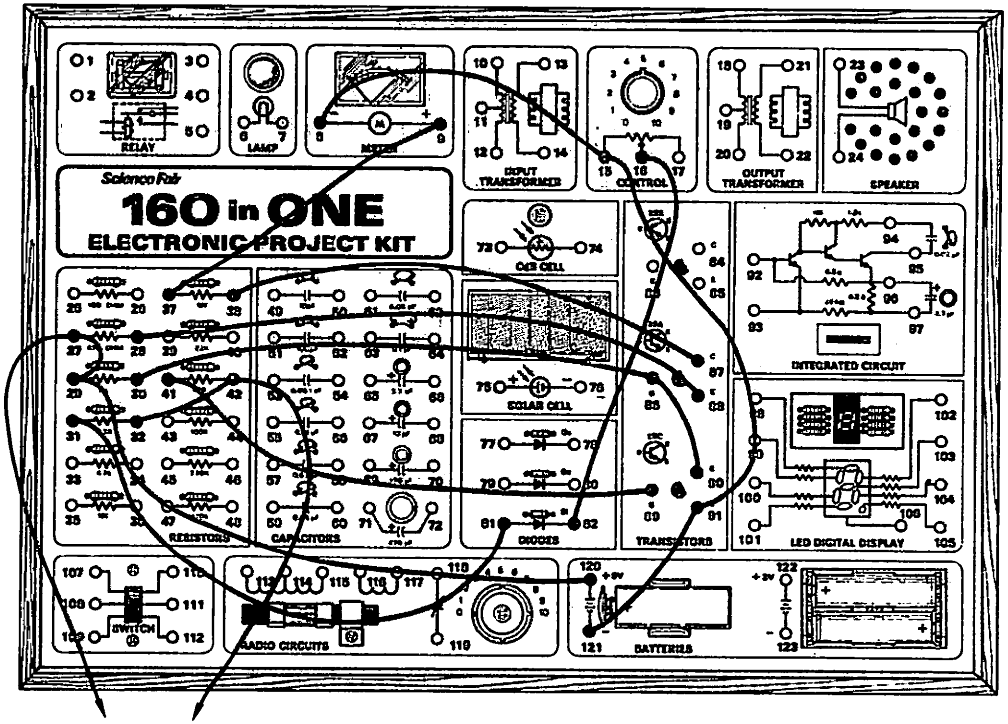
The procedure is as follows:

1. Tape two bare wires or metallic conductors to a person's skin. The back of the hand is a convenient location.
2. Ask the person questions that require an honest answer and adjust the 50K Control for a reading of about 5 on the Meter.
3. Now play the game. Ask each other questions to which you might give false answers. If you are able to get him "emotionally involved", the Meter reading will increase when the skin resistance decreases. This may be caused by his lying.

Commercial lie detectors also include measurements of breathing rate and heart pulse rate and are still not considered 100% accurate, so don't expect too much from just a skin resistance test.

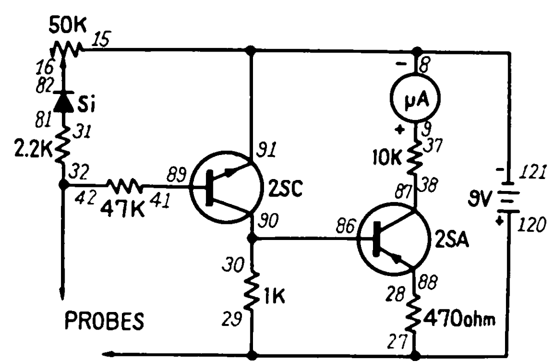
The circuit is a two-stage DC amplifier. The current that is amplified is the current that flows over the surface of the person's skin from the 9V Battery. The Control functions by shunting (bypassing) excess current around the input to the amplifier. The 1K prevents Transistor leakages from having an adverse effect on circuit operation. The 470 ohm Resistor also helps to stabilize the circuit from changes due to Transistor leakages, temperature changes, etc. The 10K provides protection against burn-out of the Meter due to excessive current.

NOTES



WIRING SEQUENCE:

87-38, 37-9, 90-86-30, 88-28, 89-41, 82-16, 120-29-27-Probe, 32-42-Probe, 81-31, 8-15-91-121



29. RAIN DETECTOR

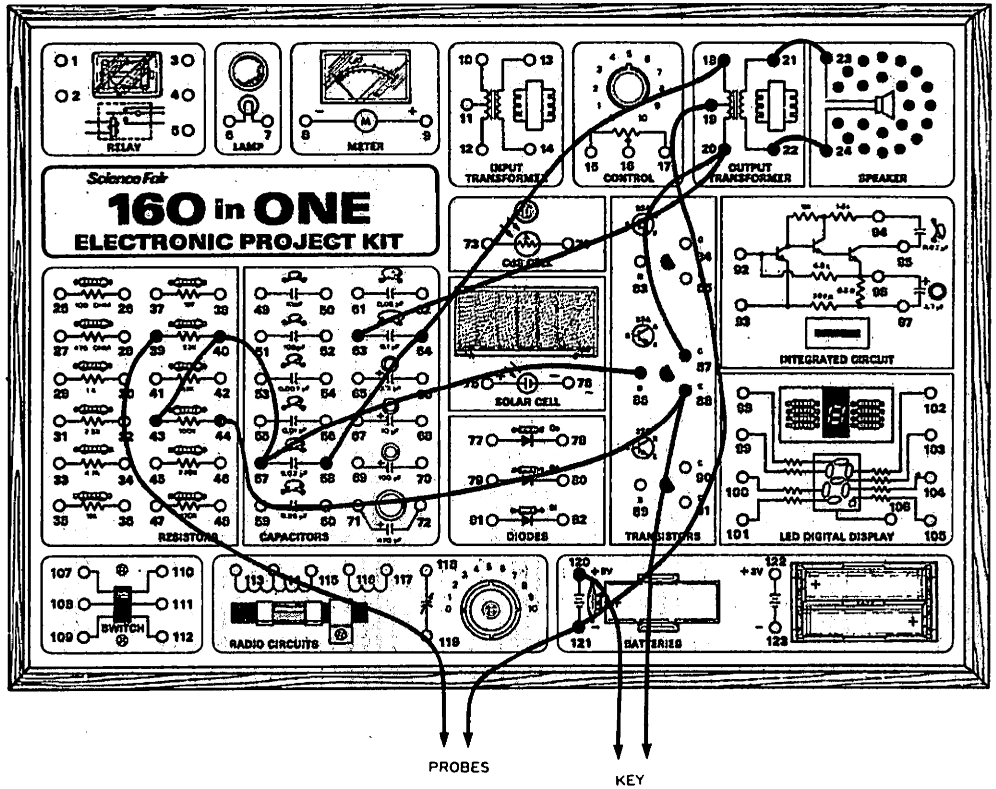
This project can be used as a rain or water level detector. When the probes have above about 250K resistance between them (almost like an open circuit), no current is drawn from the circuit even with the Key closed. When the Key is closed and water (or anything else which has a resistance below about 400K) is connected across the probes, the Speaker gives out with a loud howl.

Connect the probes to bare wires or metallic plates laid out on an insulated surface. Water which completes the circuit by touching both wires or plates will turn the alarm ON.

The oscillator is the basic pulse-type which we've used several times in this book. The 22K Resistor is protection against excess base current, if the probes are shorted together. The 100K Resistor keeps the Transistor leakage current from turning on the oscillator during what should be the OFF (open probes) time.

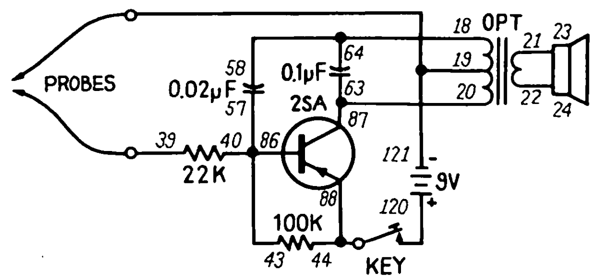
Have fun!

NOTES



WIRING SEQUENCE:

21-23, 22-24, 18-64-58, 19-121-Probe, 87-20-63, 86-57-40-43, 44-88-Key, Key-120, 39-Probe



30. METAL DETECTOR

This project is a demonstration of a metal detector that uses the proximity of metal to the coil of an oscillator to change the frequency of the oscillator and therefore indicate the presence of metal. These types of metal detectors have been used by people to locate lost treasures, buried pipes, hidden land mines and much more. During war time expecially these have been used to save many lives by locating mines and booby traps set out by the enemy.

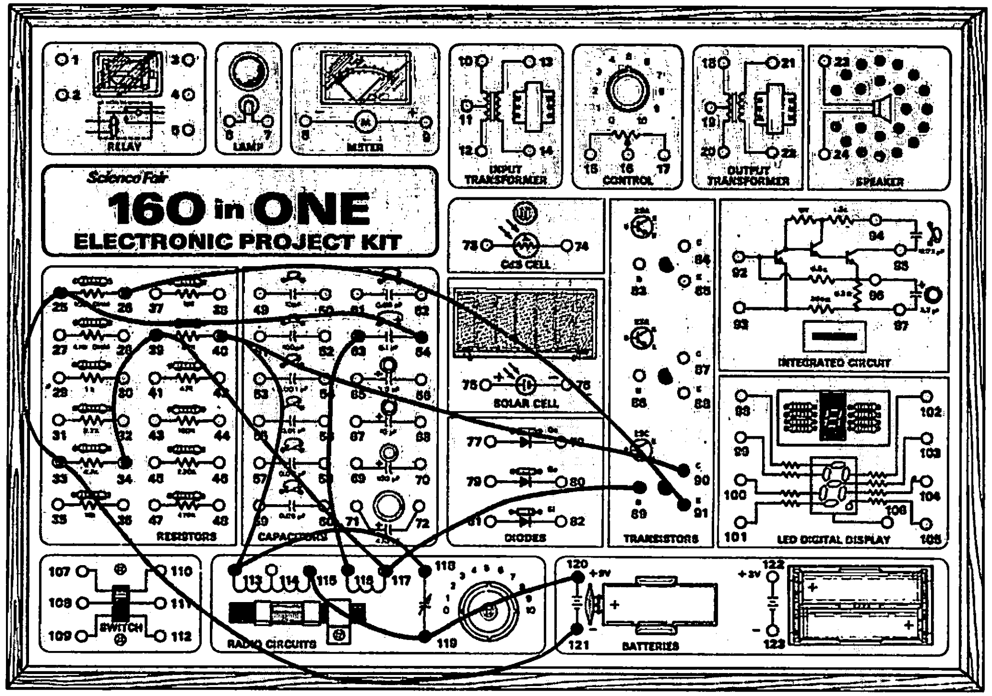
This circuit is a low distortion oscillator that draws only one milliamp from the 9V Battery. Low power is desirable in order to allow the nearby metal to have maximum affect on oscillation frequency.

Use a small transistor radio tuned to a weak AM broadcast station as the detector for this oscillator signal. Tune this oscillator until a low-frequency beat-note is heard. This beat-note is the difference between the broadcast station signal and this oscillator signal. The radio should not be brought any closer to this oscillator than necessary so that the levels of the two signals (the radio station and this oscillator) are about equal at the radio. This gives maximum sensitivity.

Try using keys, plastic objects, coins, etc. as samples of what to expect when using a metal detector like this. Of course a real metal detector does not have a small ferrite coil like this. It is usually an air core coil which is shielded with an aluminum electrostatic shield called a "Faraday electrostatic shield". This project at least gets the point across.

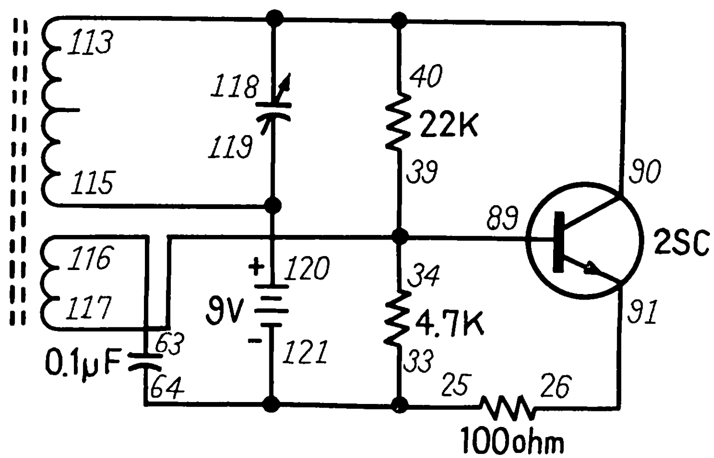
Note: In case this oscillator will not oscillate no matter what checking you have done to insure proper circuit hookup, try reversing the lead connections on terminals 116 and 117. If this cures the troublé, reverse the wire connections underneath the board so that proper terminals can be used for this and other projects which require this "phased" connection.

NOTES



WIRING SEQUENCE:

90-40-113-118, 89-117-39-34, 91-26, 63-116, 115-119-120, 64-25-33-121



31. ACCELEROMETER

This project demonstrates the operation of an accelerometer. The function of an accelerometer is to indicate when an object is increasing in speed or accelerating. In this project accelerations above a certain minimum rate cause the Lamp to light.

The rate of change which is measured in this project is the rotation of the knob on the 50K Control. When the Control is rotated clockwise (CW) at a fast enough rate, the Lamp will light. Low rates of change do not light the Lamp. Any rate of counterclockwise (CCW) rotation has no effect on the Lamp.

Start with the Control on minimum (CCW) and try rotating the knob CW at different rates. You will notice that rotation must be above a certain rate or the Lamp doesn't light.

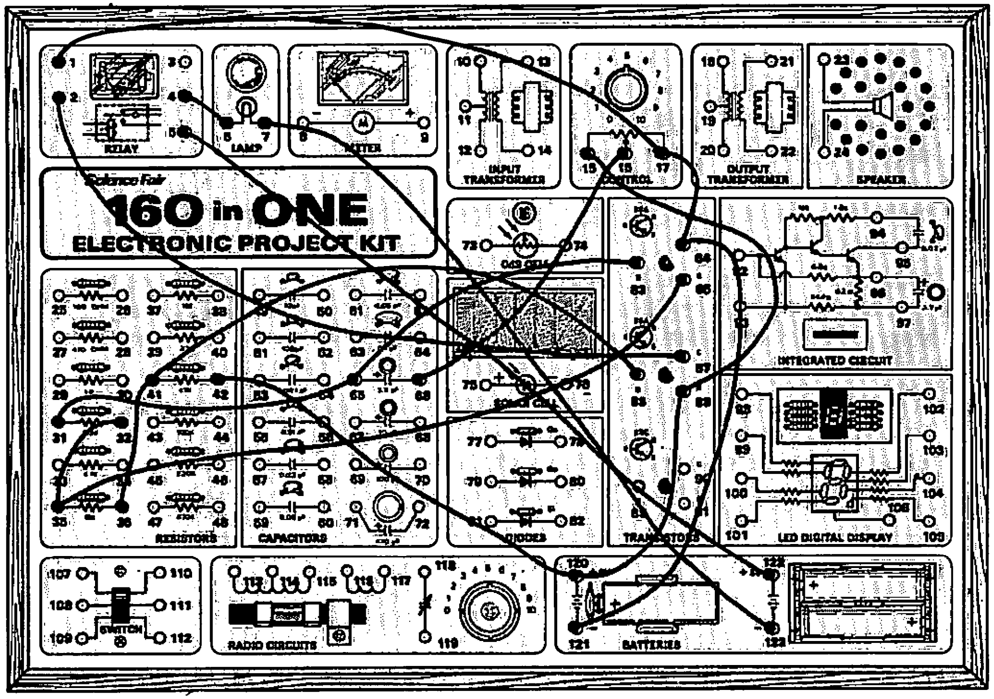
Circuit operation depends on the charging current on the 3.3uF Capacitor. The charging current of the 3.3uF is the only source of base-bias on the 2SA(1) in order to turn it ON. The 2SA(1) is in the base-bias circuit of the 2SA(2) so that the 2SA(2) cannot be turned ON except when the 2SA(1) is ON. The 2SA(2) turns the Lamp ON by energizing the Relay.

The 10K in the base-emitter circuit of the 2SA(2) helps eliminate leakage current effects and also helps set the rate of Control change to some extent.

The 10K and 47K connected to the 2SA(1) are used to limit circuit current in the 2SA(1) C-E and 2SA(2) B-E. The 22K helps minimize leakage effects from the 2SA(1) and controls the rate of Control change required to turn the Lamp ON.

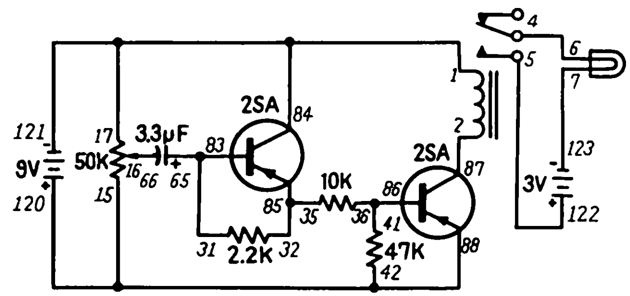
The 3.3uF Capacitor discharges through the 2.2K, 22K and 10K Resistors when the Control is reduced to minimum (full CCW). About a second or so is required to insure a full discharge before using the accelerometer.

NOTES



WIRING SEQUENCE:

123-7, 6-4, 5-122, 32-35-85, 31-65-83, 36-41-86, 66-16, 2-87, 15-88-120-42, 1-17-84-121



32. WATER QUALITY CHECKER

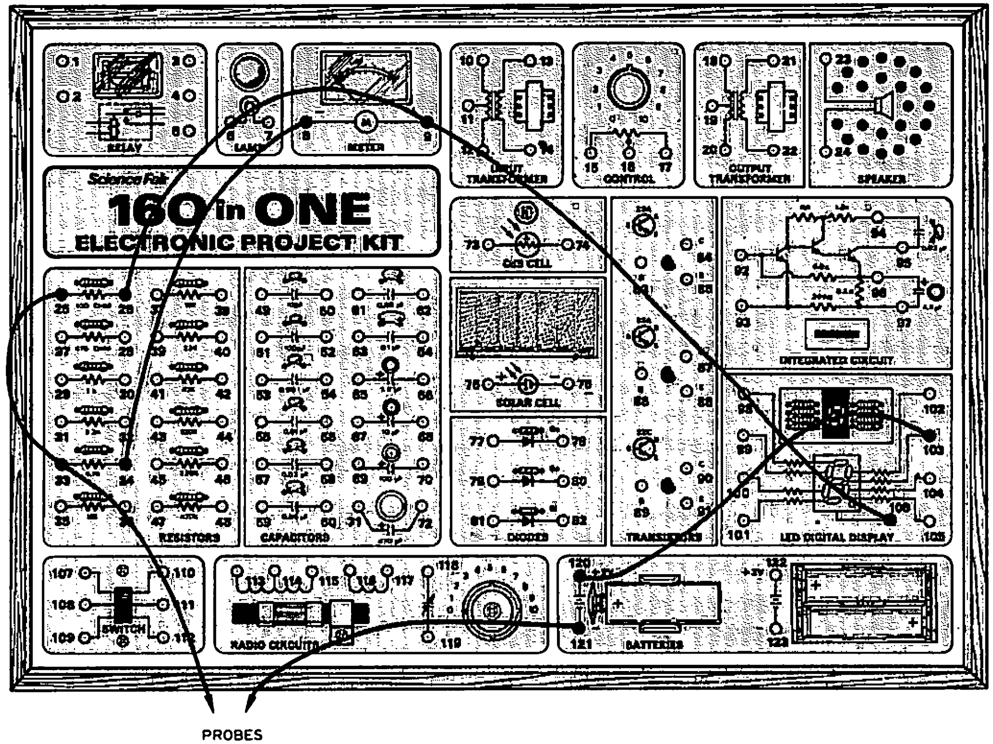
In this project you will see that water conducts electricity, and that it conducts better when impurities (salt in this case) are added to it.

After the wiring is complete, put the two Probe wires in a glass of pure water. For accurate results you will want to keep the Probe wires the same distance apart during your experiments. This can be done by taping or tying the wires to a piece of plastic or wood (maybe a popsicle stick).

With the pure water the Meter reading should be relatively low, and the LED segment will be dim. Now start to add salt to the water (it might be a good idea to remove the wires from the glass while you are stirring it up). As the salt concentration increases, the Meter needle should begin to move to the right and the LED segment should get brighter.

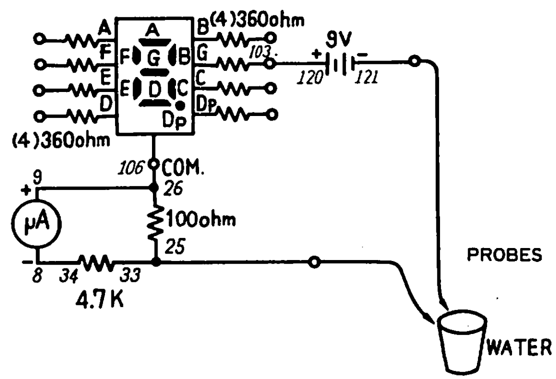
Salt is a compound of sodium and chlorine and it changes into sodium and chlorine 'ions' when it is dissolved in water. The sodium ion has a positive charge and the chlorine ion has a negative charge. Because these ions are are attracted by the charge of the Probe wires, they cause the electricity (electrons) to flow through the water.

NOTES



WIRING SEQUENCE:

8-34, 25-33-Probe, 26-9-106, 103-120, 121-Probe



33. SEVEN-SEGMENT (LED) DIGITAL DISPLAY CIRCUIT

This is the beginning of the section on LED Digital Display Circuits. You'll perform some very basic circuit experiments with the LED Display and we hope you learn how to understand and use the exciting component. You'll be using the LED Display throughout the Kit.

The purpose of this project is to learn the basic operation of a common-cathode, seven-segment, LED Digital Display.

The function of a readout device is to change electrical signals into a visual display. The simplest of readouts is a pilot light to tell us when power is ON in a circuit. The seven-segment readout was made in order to display the numberals 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 for reading the output of a computer or calculator. Seven segments (or separate lines which may be individually lighted) were decided on for displaying these numbers because this is the minimum number which are able to display all of the digits without confusion.

The LED (light emitting diode) is used in this readout. The light emitting Diode is very similar to a normal Diode except that it emits a visible light when a forward bias current is caused to flow through the Diode. Thus two conditions must be met for proper LED operation:

1. Proper polarity of voltage.
2. The proper amount of current flow.

Reverse voltage polarity can burn out the LED unless the voltage is below about 4 volts, or unless the current is limited to a safe value. No light is emitted with reverse polarity voltage.

Proper limiting of current flow is obtained when proper resistance is included in series with the LED. The LED forward voltage remains relatively constant (around 1.7 volts) therefore, applied voltages above this value are required to obtain current flow. A series resistance will determine how much current will flow, and lower the voltage of the supply to the LED voltage.

Use the 3V Battery and leads as shown to light various segments and decimal point (Dp). What numbers and letters can you display?

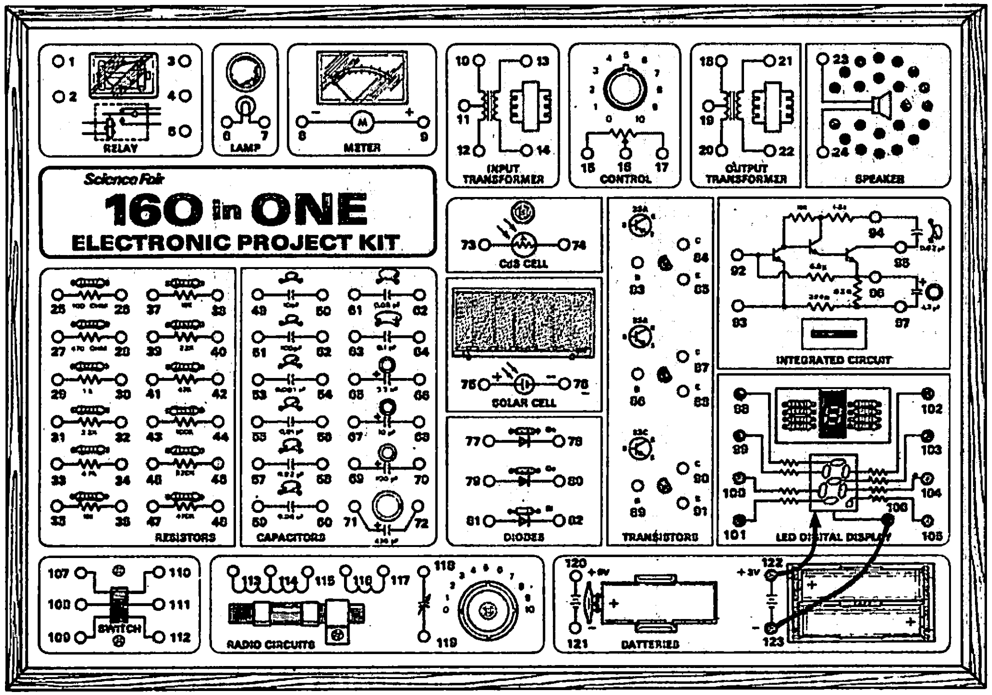
With this low Battery voltage you may try reverse polarity operation by reversing the leads to the Battery. Record your results below.

Reconnect to the Battery with the correct polarity.

Use your VOM to measure the LED voltages (terminal 106 to each separate terminal [98 thru 105]). Temporarily change to the 9V Battery and make these same measurements. With this 3-times increase in supply voltage the LED voltage only increased by what amount? (0.25V is typical.)

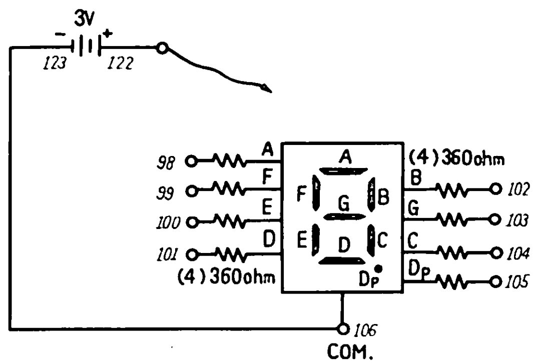
Use your VOM across each 360 ohm Resistor and determine the 360 ohm Resistor voltages. LED current in milliamps is calculated by dividing the voltages by 360 ohms LED segment currents are then all about ________ mA (3 mA is typical) with the 3V Battery and____ mA with the 9V Battery.

In the space below make a chart of connections required to display each numeral from 0 to 9 on the readout.



WIRING SEQUENCE:

123-106, 122-leads as required to terminals: 98, 99, 100, 101, 102, 103, 104, 105



34. BASIC (LED) DISPLAY

The purpose of this project is to learn more about the operation of a common-cathode, seven-segment, LED readout.

The LED manufacturer could construct the seven-segment readout with each segment having its cathode and anode leads brought out to separate pins, but this would require an excessive number of pins. Instead, seven-segment readouts are usually made with either the anodes or cathodes connected to one common pin. Common cathode types require a common connection for the negative supply and common anode types require a common connection for the positive supply. This choice allows the circuit designer some freedom in circuit designs. This kit uses a common cathode type; therefore, the common segment pin (terminal 106) must be negative, and all anode segment pins are suplied with a positive polarity.

LED display segments are very small. Therefore, to obtain a line of light, a number of segment Diodes must be lined up next to each other to give the appearance of a continous line. Some models of seven-segment readouts have a frosted lens so the individual segments can not be distinguished. Can you see the segments in this readout?

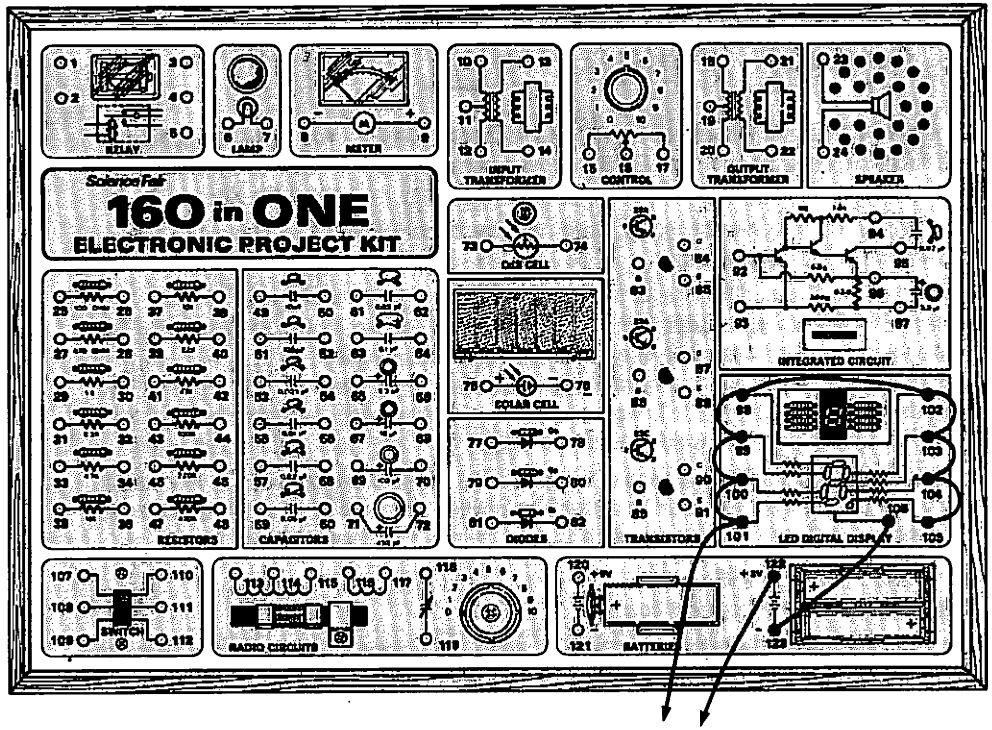
LED operation is extremely fast. An LED can be turned ON and OFF hundreds of times each second; so fast you can't see it blink. Unlike an incandescent lamp, there is no warm up time and no great amount of heat produced by LED's.

Demonstrate the fast LED action to yourself as follows.

1. Hook up the circuit but do not close the Key.
2. Decrease the surrounding ambient light to a very low level so that any LED light emission can be easily seen.
3. Close the Key for only a fraction of a second.

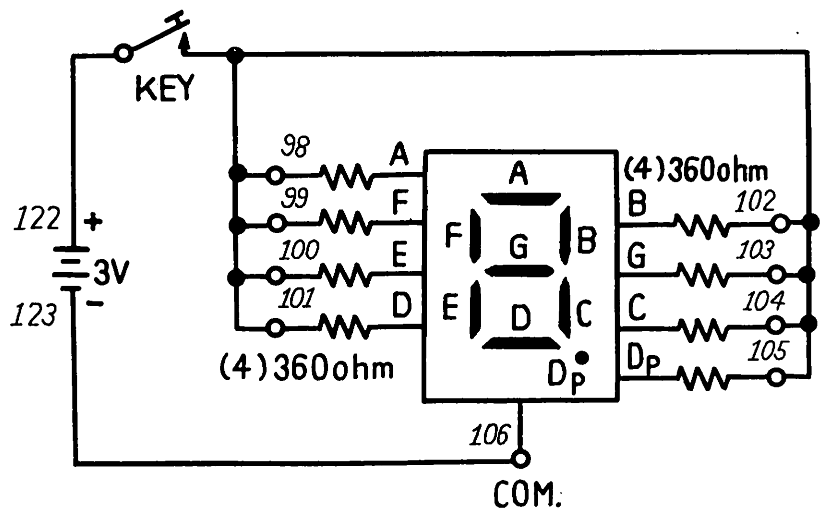
Notice that the display goes quickly ON and OFF. Now hold the platform steady but glance quickly across the LED display as you very briefly tap the Key. The display should appear to go abruptly ON and OFF. Actually, the persistence of the human eye is much longer than the LED's ON time, but without special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

NOTES



WIRING SEQUENCE:

123-106, 105-104-103-102-98-99-100-101-Key, 122-Key



35. TRANSISTOR CONTROL SWITCHING OF THE LED DISPLAY

The purpose of this project is to study the control of an LED readout with switching Transistors.

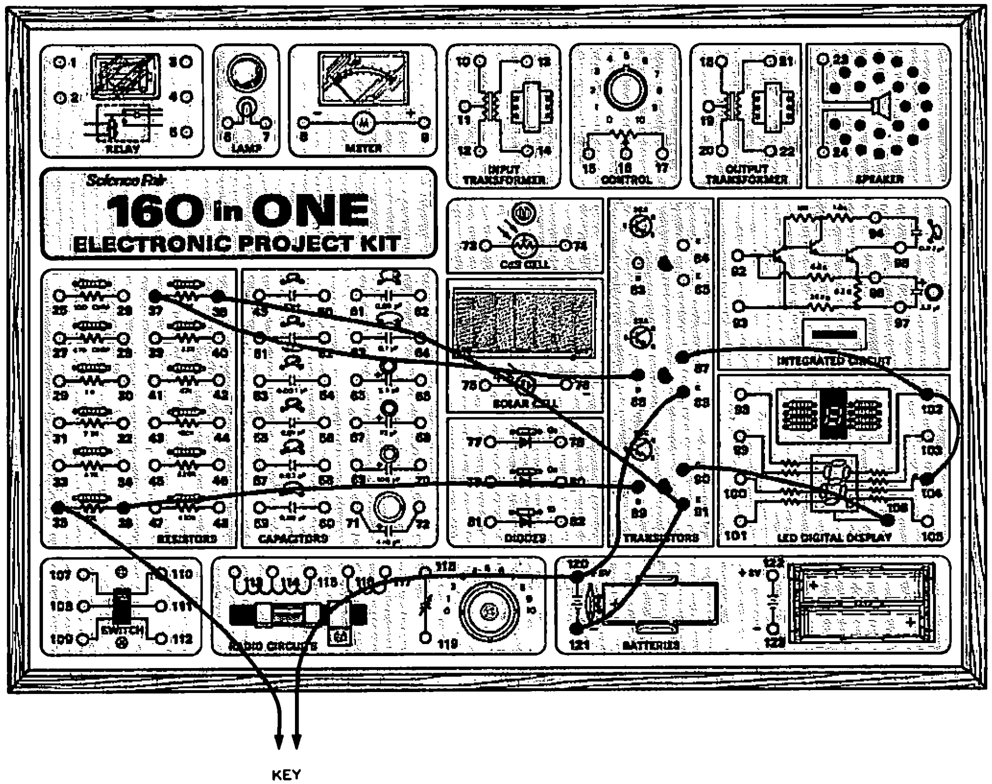
First of all notice the similarities of this circuit with the circuit of project 84. The only difference between these two circuits is in the placement of the switch and the value of the Resistor. This project has the switch in the base circuit of the NPN Transistor to control the common cathode input to the LED. This may be viewed as cathode control of the LED, and project 84 is anode control.

One of the 10K Resistors turns the PNP Transistor ON at all times, and another 10K Resistor turns on the NPN only during times the Key is closed. These Resistors are sufficiently low in value to allow good Transistor switching with the few number of LED segments connected.

The ability to turn on the LED with either the top or bottom Transistor doesn't seem important to us now. But to someone who has to design those complicated computer circuits, it can be a handy way to control circuits without a lot of extra Transistors, etc.

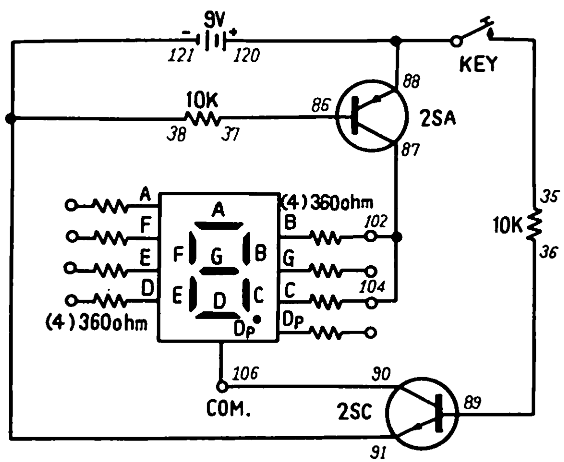
Have you noticed up to this point that the Transistors switch ON and OFF as fast as the switch itself? This is a characteristic of Transistors that allows computers to perform operations at such a high rate of speed. Transistors are many times faster than Relays or hand operated switches. Other experiments will show how delayed switching can be obtained by using other components.

NOTES



WIRING SEQUENCE:

104-102-87, 106-90, 86-37, 38-91-121, 35-Key, 36-89, 88-120-Key



36. TRANSISTOR, CdS CELL AND LED DISPLAY CIRCUIT

The purpose of this project is to learn how a bipolar Transistor and CdS Cell can be used to turn on a readout device.

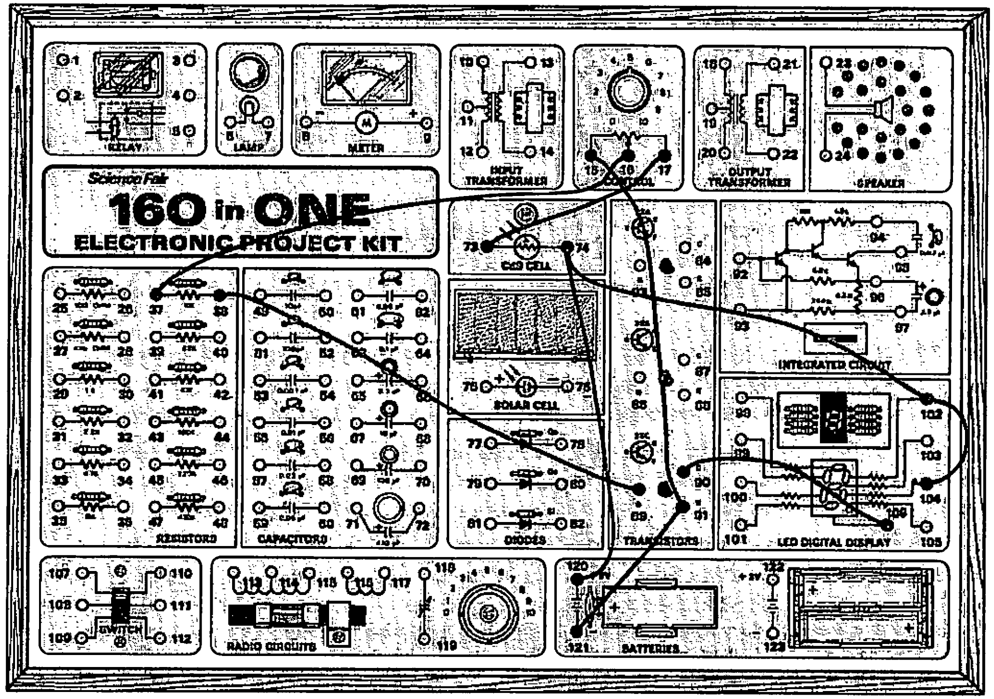
The cadmium sulfide (abbreviated CdS) cell may be thought of as a Resistor which changes its resistance due to a change in light. Its resistance in darkness is very high, usually in the range of 5 megohms; in bright sunlight the resistance decreases to about 100 ohms, or less. Intermediate amounts of light cause intermediate values of Resistance. You can verify this by setting your VOM to the ohmmeter function and connecting it across the CdS Cell before wiring the Cell into the circuit. Different amounts of light will cause different amounts of resistance.

The bipolar Transistor (an NPN in this case) is used as an active switch. That is, resistance between collector and emitter is so high that it acts like an open circuit until a positive voltage is applied to the base through the 10K limiting resistance. This positive voltage on the base is sufficient to turn ON the Transistor, causing collector-to-emitter resistance to decrease until required current can flow to the LED Display. The Transistor only drops a few tenths of a volt, when full ON. This very small voltage drop is negligible compared to the 9V applied voltage, so operation is similar to a closed switch. Use your VOM as a voltmeter across the C-E of the Transistor to verify this action. The collector is terminal 90 and emitter 91.

The amount of voltage across the 50K Control depends on the resistance of the CdS Cell, which depends on the amount of light striking the Cell. Thus, the amount of voltage at the output of the Control depends on both the setting of the adjustable contact inside the Control and the amount of light. Use your voltmeter across the output of the Control to verify this voltage change. The Control is adjusted to obtain ON-OFF operation over the desired range of light.

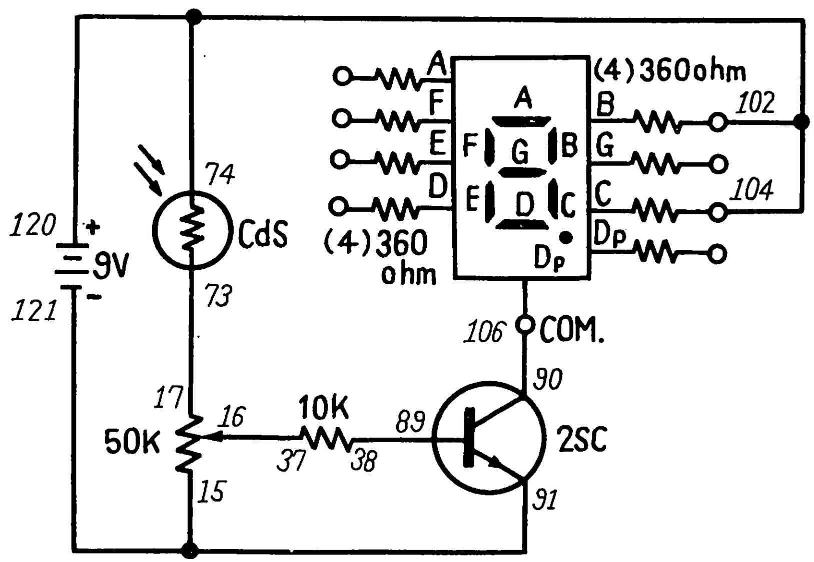
The seven-segment LED readout is shown wired to display the numeral "1" in the presence of bright light. Obviously it can be wired to display any desired character. At this time we might consider the "1" to be a binary digit, which stands for a logic "high" (H or ON), to indicate the presence of a high level of light on the CdS Cell. Can you rewire the readout to display another convenient character to indicate this condition?

NOTES



WIRING SEQUENCE:

104-102-74-120, 106-90, 73-17, 16-37, 38-89, 15-91-121



37. GRAPHING A VARIABLE RESISTANCE

This is the first in the next category of Projects: Basic Electronic Components and Circuits. In this section you should pay special attention to the Schematics and to each component you'll be working with. You'll learn a lot about the basics from this section.

The main purpose of this project is to study the characteristics of the 50K Control with a voltmeter circuit and then graph the results.

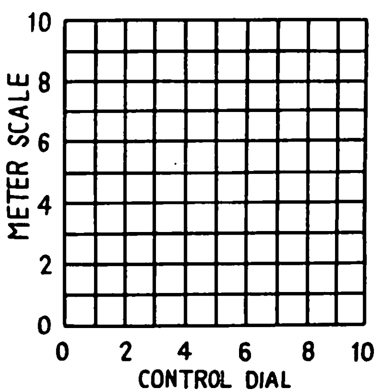
The purpose of a potentiometer (Control) is to provide a variable control of an output voltage (between the center connection and one end of the Control). The arrow head on the Schematic symbol of the Control tells you it is adjustable.

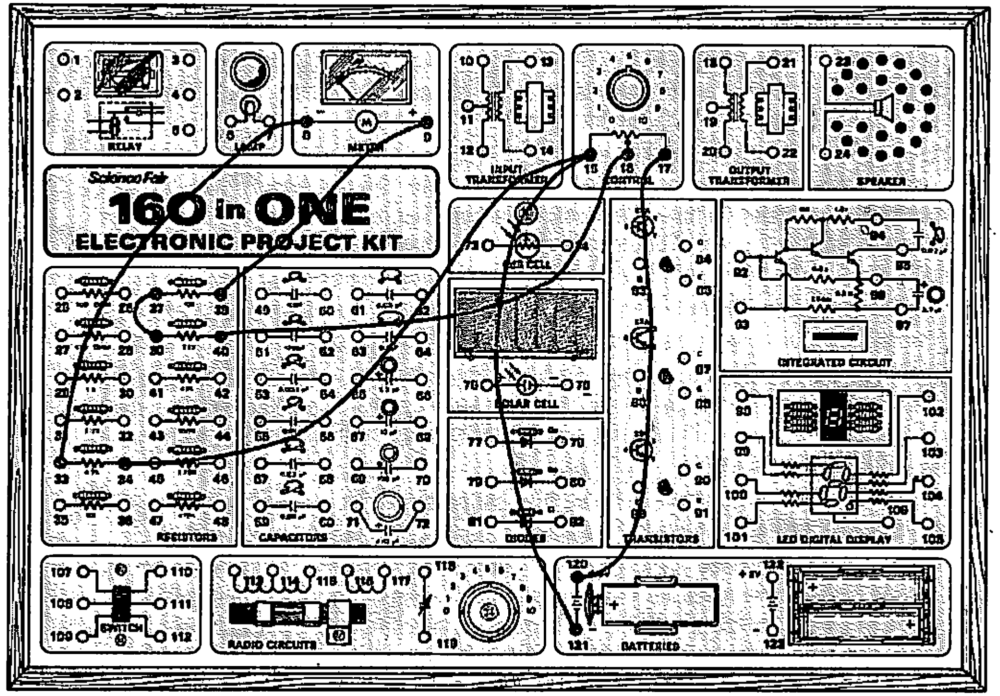
This variable output voltage is measured with a voltmeter (made up with parts in this kit). The 9V Battery is used as the constant voltage across the entire potentiometer.

The DC voltmeter used for voltage measurements is described more completely in another project on DC voltmeters, so we'll just give you a brief description here. The Meter requires about 250 microamperes for a full scale deflection. Therefore, a series resistance totaling 36.7K ohms (10K, 22K and 4.7K) is used with the Meter. This provides a Meter circuit which requires about 9.3V to obtain a full scale reading. This Meter then is capable of measuring all potentiometer output voltages up to the (9V of the Battery). The blue scale on the Meter is used for this circuit because these calibrations give accurate results in terms of actual DC voltages.

1. Set the Control at zero and record the Meter blue scale reading by placing a dot on the graph provided below.
2. Set the Control at 1 and record the Meter's blue scale reading with a second dot on the graph.
3. Repeat the above procedure for each Control number setting.
4. Sketch in a smooth line connecting all the dots together. The result is the graph of relative potentiometer output voltage when loaded with a load of about 37K ohms.

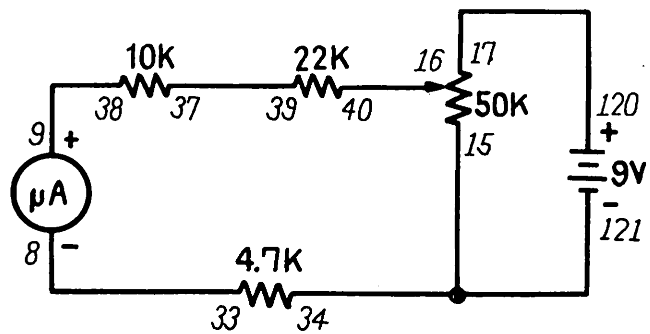
The potentiometer included with this kit typically has a smooth change in output between about 1 and 9 on the dial. The change in output is nearly a straight line. This straight line output is characteristic of a LINEAR potentiometer. Other potentiometers are available with other than a straight line output. Some common types are the LOG, SEMI-LOG and REVERSE LOG tapers.





WIRING SEQUENCE:

121-15-34, 33-8, 9-38, 37-39, 40-16, 17-120



38. RESISTORS IN SERIES AND PARALLEL

The purposes of this project are to study basic series and parallel connected Resistors and to consider a shunted (bypassed) DC current meter.

Let's consider the shunted DC current meter first, as it is used to study the effects of series and parallel connected Resistors. The Meter supplied with this kit requires about 250uA (microamperes) to produce a full-scale needle deflection. The resistance of the fine windings of wire in the Meter coil is about 650 ohms. Now consider this resistance when the Meter is shunted ("paralleled") with the 50K as shown in the Schematic diagram.

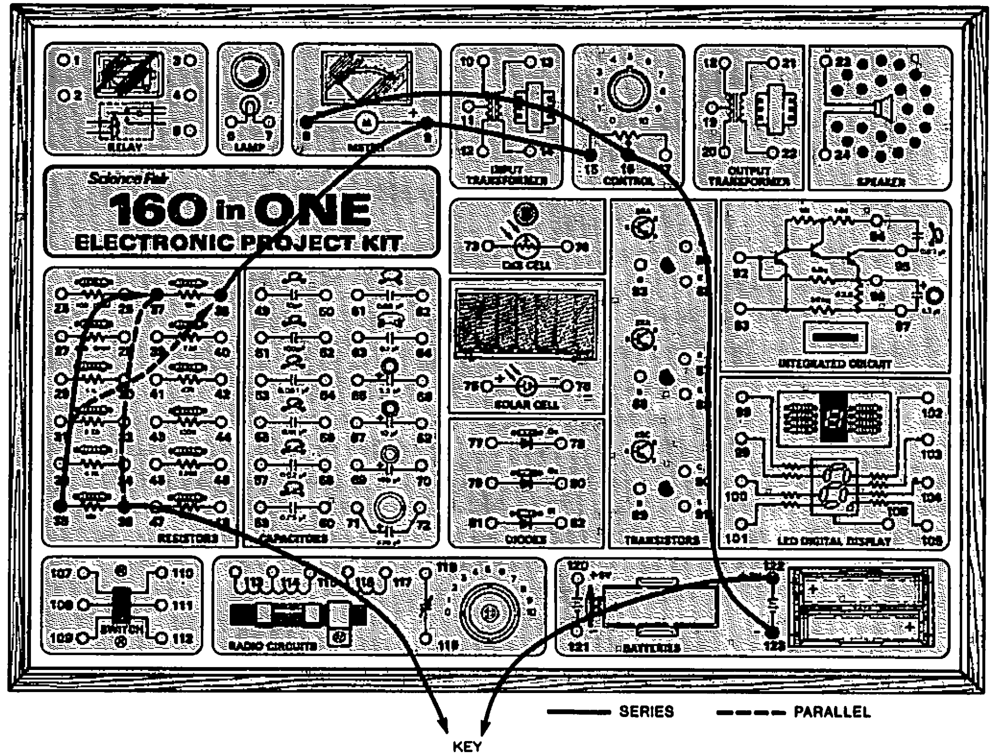
1. If the Control is adjusted for zero ohms across the Meter, it would act as a short circuit allowing almost unlimited current to flow before the Meter scale could reach full scale.
2. If the Control is adjusted for 650 ohms (equal to the meter resistance), it would pass the same amount of current as the Meter. A 250uA Meter current and 250uA shunt current would result in a total of 500uA. Full scale Meter readings at this time then represent a total current flow of 500uA.
3. If the Control is adjusted for its full 50K, it would pass such little current compared with the Meter that total current would be practically equal to that of the Meter alone.
4. From the above it can be seen that with proper adjustment of the 50K Meter shunt (Control), the effective full scale Meter current may be almost any value from 250uA and upward. There is a practical limit though because of the current handling capability of the Control. Therefore the maximum current shouldn't be allowed to exceed about one milliamp through the Control.

Now let's consider series and parallel connected Resistors. It seems logical (and is) that when resistances are connected in series their resistance values add together to obtain the total resistance. Expressed in formula form this is RT = R1 + R2 for the circuit shown.

Parallel connected resistors present quite a different result. As with the shunted Meter discussed above, parallel (or shunted) Resistors cause more current to flow and therefore the resistance to current flow to decrease. This may be nicely demonstrated as follows:

1. Connect the circuit for series 10K Resistors. Adjust the 50K for a Meter reading of 2 on the blue meter scale. Do not move this Control setting for the following tests.
2. Now temporarily remove one 10K Resistor from the circuit and replace it with a wire so that only one 10K is in the circuit. Current is now higher on the blue scale (4 is typical and expected).
3. Parallel the 10K Resistors and measure the current. Current is higher on the blue scale (8 is typical and expected).

Now let's consider the implications of the above tests. Series connecting Resistors increase the resistance and decrease the current. For our test we showed that series connecting equal value Resistors caused the current to be half of what it is with one Resistor (2 is half of 4). Parallel connecting Resistors causes the resulting resistance to decrease and the current to increase. Our test verified the fact that paralleling equal value resistors causes the current to double (from 4 to 8), and if the current is doubled, the resistance must have decreased to half of the single Resistor value.



The formula for finding the equivalent resistance Req when two resistors are connected in parallel is:

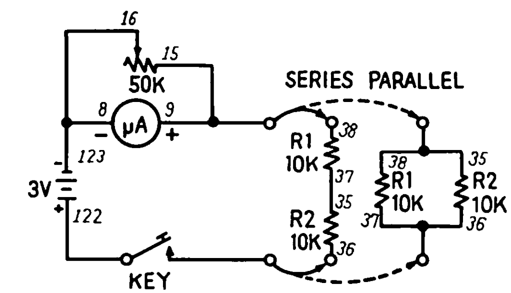
$$Req = 6\ \frac{R1XR2}{R1+R2}$$

If you want to check series and parallel connections of other Resistors in this kit, be careful not to allow the resultant resistance to go below about 2.2K or the Control may be damaged.

WIRING SEQUENCE:

SERIES 123-16-8, 15-9-38, 37-35, 36-Key, 122-Key

PARALLEL Remove 37-35 Wire, Connect 35-38 and 36-37



39. CAPACITOR CHARGE AND DISCHARGE

The purpose of this project is two-fold: to demonstrate the Capacitor charge storage and to consider the operation of DC voltmeters. Both of these things are basic and therefore very important for your understanding of electronic circuits.

Circuit action is demonstrated by first placing the slide Switch in position A (down) to allow the Capacitors to receive a 9V charge. Then set the Switch to position B (up) to allow the DC voltmeter to be placed across the Capacitors in place of the Battery. You'll see the reading on the voltmeter decrease very slowly as the charge leaks off the Capacitors through the Meter.

When connected across the Battery, the Capacitors receive a charge of voltage because electrons from the negative Battery terminal enter the Capacitor and pile up on the (-) Capacitor electrode. The same number of electrons are drawn off the (+) Capacitor electrode to make it deficient in electrons.

When the charged Capacitor is placed across a conductive path, the Meter circuit in this case, the electrons from the (-) capacitor electrode flow through the circuit over to the (+) electrode until equilibrium is re-established. The charge on the Capacitor at any instant of time is indicated by the reading shown on the Meter.

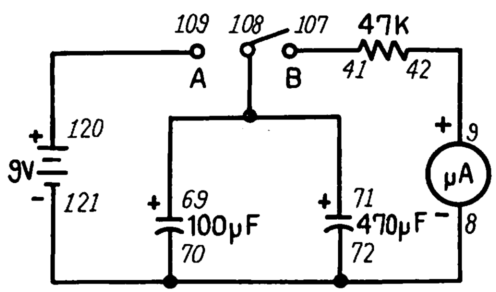
The Meter is able to measure voltages by means of a proper current flow through the Meter. The choice of total Meter circuit resistance controls the amount of voltage required to deflect the Meter to full scale. This resistance may be determined by application of Ohm's law, which states, "the resistance required to obtain a desired current is directly proportional to the applied voltage and inversely proportional to the current". In formula form this is $R=E/I$

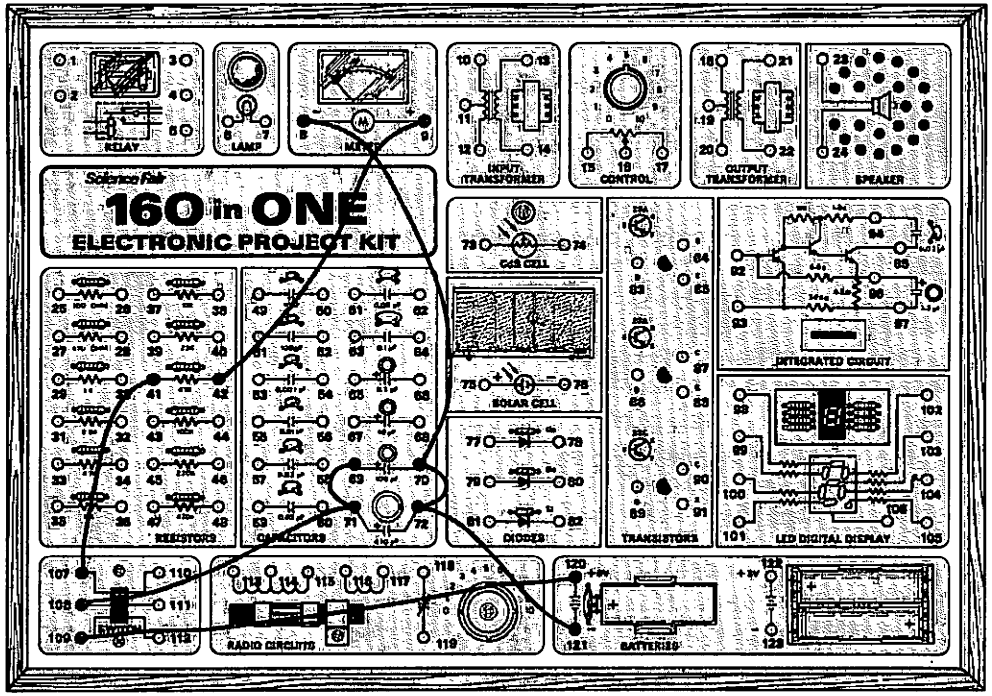
$R=$ Resistance (ohms), $E=$ Voltage, $I=$ Current (amps)

In this formula, if we use volts and mA (milliamps or thousandths of an amp), the answer will be in K ohms (ohms x 1000).

The Meter in this kit requires a current of about 0.25mA for a full scale reading. If you want a 10 volt Meter, the required resistance will be 10V divided by 0.25mA = 40K. There doesn't happen to be a Resistor of this value in this kit, so we will use the next closest value of 47K. Now by using the graph included here we determine the actual full-scale voltage to be just a little under 12V.

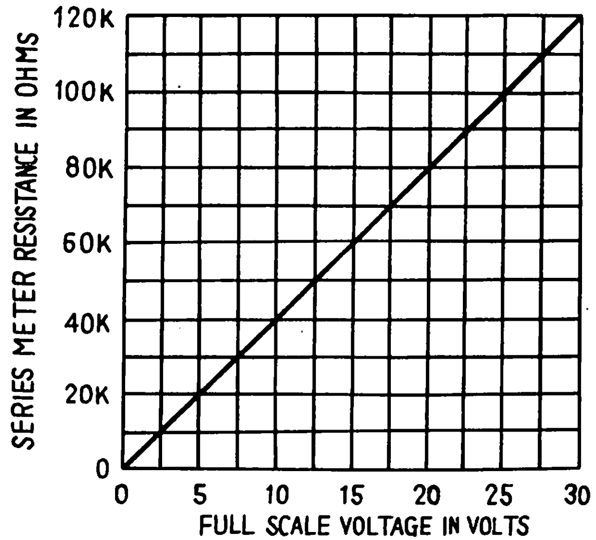
You can use the graph to construct other voltmeter ranges by using the series resistances indicated. You can use separate series Resistors to obtain resistance values other than those incorporated in this kit. Remember, series Resistor values are added together to determine the total resistance.





WIRING SEQUENCE:

120-109, 108-71-69, 107-41, 42-9, 8-70-72-121



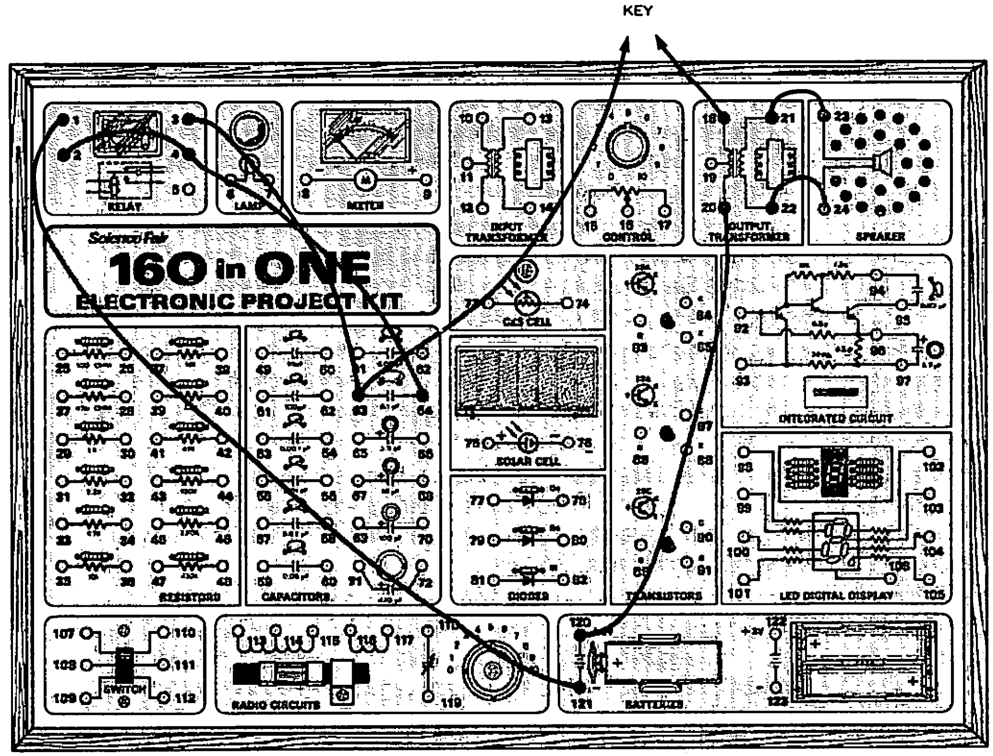
40. CAPACITOR AS A SPARK SUPPRESSOR

This project is a Relay buzzer circuit which is used to show the effects of a Capacitor as a transient suppressor. Note that in project 125, spikes of energy are obtained which are so narrow in width and high in amplitude that two things are accomplished. The first is the generation of RF energy that can be heard through a nearby radio. The second is the undesirable errosion and eventual destruction of the Relay contact points.

Obviously no one wants to destroy an expensive Relay, and spark transmitters cannot be used any more, so why not eliminate this destructive spike? This can be done in most cases by adding the proper size (value) Capacitor across the Relay contacts. This is no new idea. It has been used in automobiles for almost 50 years. The "condenser" (as it is called) which is across the ignition points performs this very function. Your dad can tell you that without this Capacitor, the car engine will probably not run.

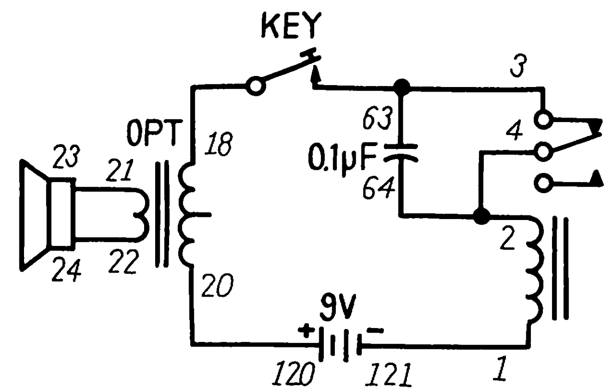
The best and most scientific way of checking this action is by using an oscilloscope connected across the Relay contacts, but even without this expensive instrument we can still get a rough idea of what is happening.

Connect the circuit and close the Key a few times to listen to the sound. Now disconnect the lead from terminal 64 and close the Key a few times. The sounds you hear should be distinctly different. The original sound (with the Capacitor) should be low in pitch and mellow. Without the Capacitor it is raspy and higher in pitch. The difference in tone is a direct result of the change in waveform of the current in the circuit. The raspy high-pitched sound is a result of a narrow high spike of current. The mellow low pitched sound is a result of the lack of such a spike.



WIRING SEQUENCE:

21-23, 22-24, 18-Key, 3-63-Key, 20-120, 64-4-2, 1-121



NOTES

41. TRANSFORMER EXPERIMENT

The purpose of this project is to prove that a Transformer can only induce a voltage in a winding when the current is changing in the source winding.

The source winding is connected to the 3V Battery through the Key. This allows you to apply and remove Battery current easily and abruptly.

The second (secondary) winding is coupled to the Meter through a 1K Resistor. Because the Meter has a resistance of about 650 ohms and requires about 0.25mA (250uA) of current to obtain a full-scale deflection, this circuit acts like a 400mV (millivolts) voltmeter.

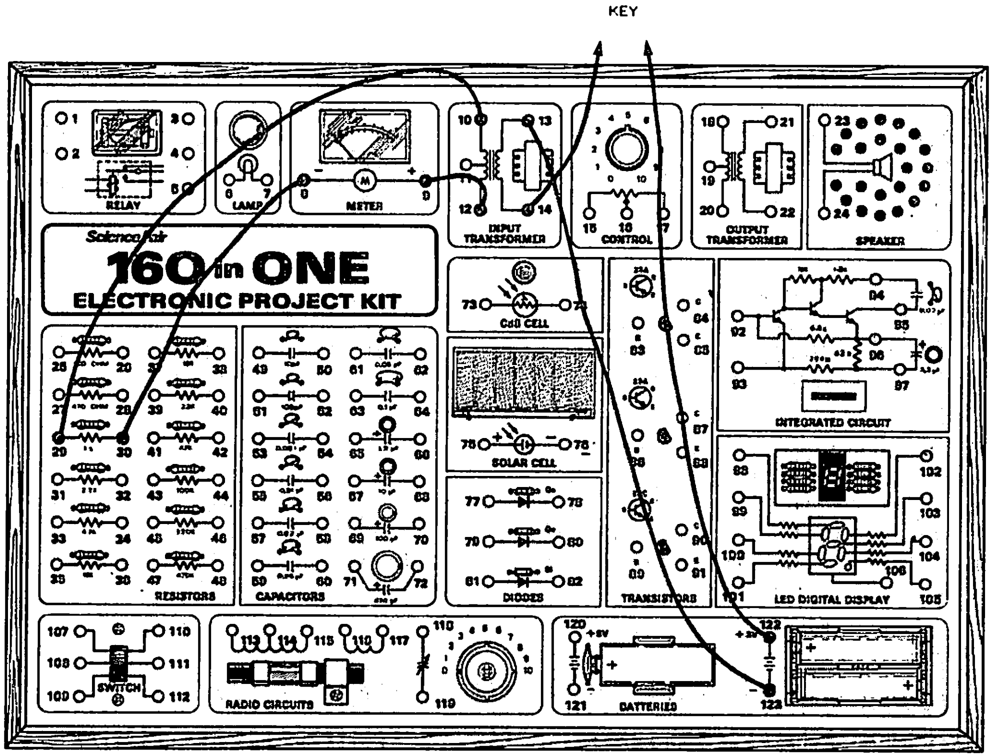
Circuit action is as follows:

1. The Meter deflects only when the Key is opened or closed.
2. No Meter deflection occurs when the Key is closed and DC current is flowing in the source (primary) winding.
3. Meter deflection is in one polarity when the Key is closed and in the opposite polarity when the Key is opened. (Reverse the meter connections to verify this more clearly.)

The induced secondary voltage is caused by the changing magnetic flux within the Transformer. The "cutting of flux lines" or the "changing of flux density" is required to move electrons within the turns of wire and therefore generate the "induced" voltage.

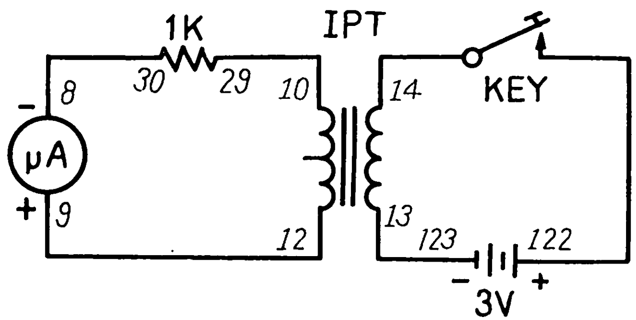
Try opening and closing the Key faster and faster. You can see by this why AC (alternating current) can pass through a Transformer efficiently.

Can you think of a component that DC can pass through efficiently while AC is virtually stopped or choked off?



WIRING SEQUENCE:

122-Key, Key-14, 13-123, 10-29, 30-8, 9-12



NOTES

42. GENERATION OF ELECTRICAL ENERGY

The purpose of this project is to consider how electricity may be generated, changed from AC to DC and be indicated on a Meter. This uses what appears to be a very simple circuit (and it is), but the important basic electronic operations used are very profound. Virtually every electronic circuit in your house uses one or more of the concepts we are about to consider.

In brief the circuit operation is as follows. Loud sounds received by the Speaker generate AC voltage. The Transformer steps these AC voltages up to a higher level so that they may be more effective in causing a Meter reading. The Germanium(Ge) crystal Diode changes the AC voltage into DC voltage which is required to drive the Meter. The Meter uses the DC current to move the pointer (or needle) of the Meter so that we can see the effect of the generated electrical energy. There are four basic (and therefore important) electrical concepts used in this project.

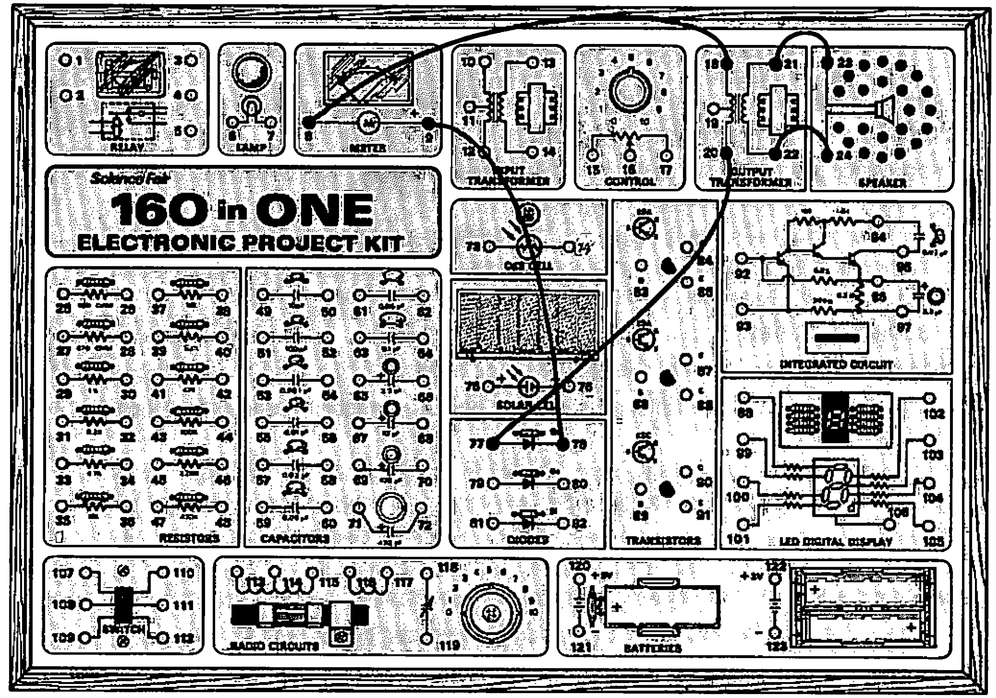
Generation of electric current: The Speaker may be used for the generation of electric current because it has the required parts: a magnetic field and turns of wire which can be made to move within the magnetic field. The turns of wire which are connected to the speaker cone are made to move back and forth across the gap in the permanent magnet field as the sound moves the cone. A Speaker has very few turns of wire so the generated alternating current (AC) voltage is very small, and operation requires a very loud sound into the speaker. A dynamic microphone uses this exact same principle but with many more turns of wire to obtain higher output.

Transformer action: The Transformer is capable of causing an AC voltage on one winding to be made available on another winding that is not connected to it except through a magnetic field. The Transformer used here has only a few number of turns connected to the Speaker but many turns of wire on the Diode and Meter side. This causes the voltage to be increased in proportion to the ratio of turns used for the windings. A turns ratio of 10 to 1 causes a voltage change ratio of 10 to 1 also.

Diode rectification: The Diode allows electric current to flow in only one direction. The result is that no matter which polarity of voltage is applied through the Diode, current will always flow in only one direction like direct current (DC) from a battery. Because the symbol for a Diode was decided on before electric current was understood, the arrow head points against the direction of actual electron current flow. (This was a case of a guess which happened to be wrong, but these results have stuck with us ever since).

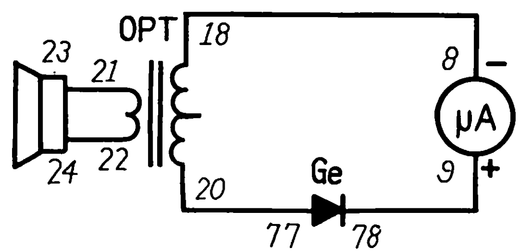
d'Arsonval meter operation: The Meter is similar to the Speaker in basic theory of operation. The Speaker has a paper cone that is connected to a coil that moves in the permanent magnet field, whereas the Meter has a pointer that is connected to a coil that moves in a permanent magnet field. As current flows in the coil, it reacts with the magnetic field of the permanent magnet and causes the coil (with attached pointer) to move.

To obtain measurable outputs from this circuit you may have to close your hands around your mouth and Speaker and speak out with a loud voice. Remember, the Speaker was not designed to perform as an efficient generator but as a Speaker.



WIRING SEQUENCE:

21-23, 22-24, 18-8, 20-77, 78-9



43. HIGH VOLTAGE GENERATOR

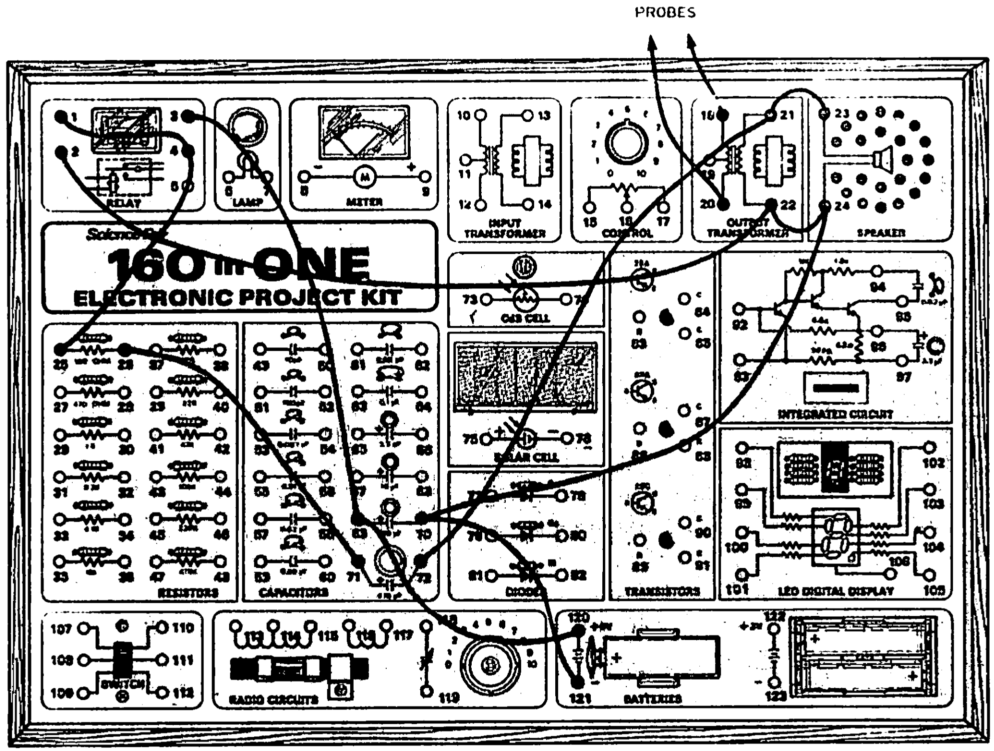
The purpose of this project is to consider how high voltage can be generated by the interruption of DC current such as is done in automobile ignition systems. Of course the "high voltage" generated in this project is only representative and so low in value that is it perfectly safe.

The circuit includes a Speaker which will be your reminder that the circuit is operating. The Relay is connected like a doorbell buzzer. The HV (high voltage) generating part of the circuit is composed of the 470uF Capacitor and the Output Transformer.

Because the HV generator is in parallel with the Relay field coil, it also receives pulses of voltage as the Relay contacts open and close. The current to this part of the circuit quickly charges the 470uF Capacitor. This charging current must pass through the Transformer speaker-winding and the Speaker. The current that passes through the Transformer winding induces a voltage in the second winding due to a transformer action. The amount of increase in voltage is directly related to the ratio of number-of-turns on the high voltage side, to the number-of-turns on the Speaker side. In real HV generators this ratio is made very high.

As the Relay points open, the Capacitor discharge current also flows through the Speaker and Transformer winding, but is of lesser consequence because it must flow through the Relay at the same time.

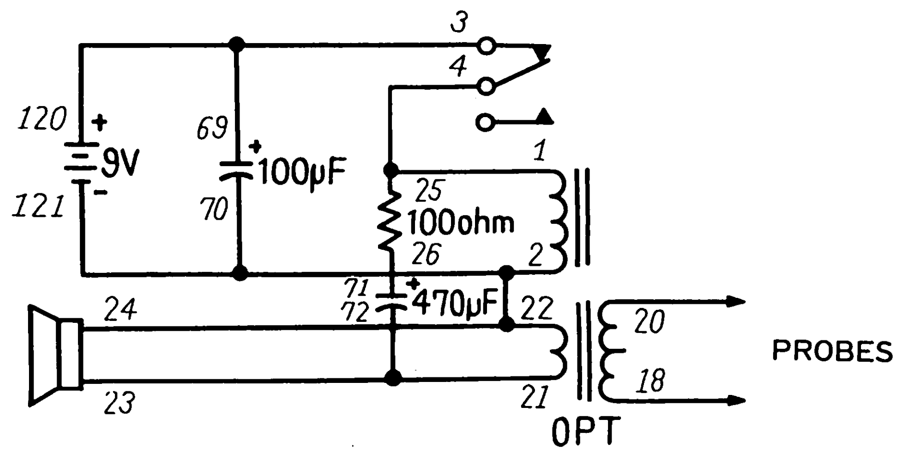
This may not be able to fire a spark plug or cause a shocking experience, but it gets the point across. You will no doubt want to experiment with this circuit. It can be made to generate higher voltages. Have fun!



WIRING SEQUENCE:

23-21-72, 2-22-24-70-121, 1-4-25, 18-Probe, 20-Probe, 26-71, 3-69-120

NOTES



44. HIGH VOLTAGE GENERATOR II

This project is to demonstrate how high voltage can be made from the 9V Battery. This is done in your automobile to fire the spark plugs. It is done on the farm to electrify fences so that cattle and hogs will stay within bounds.

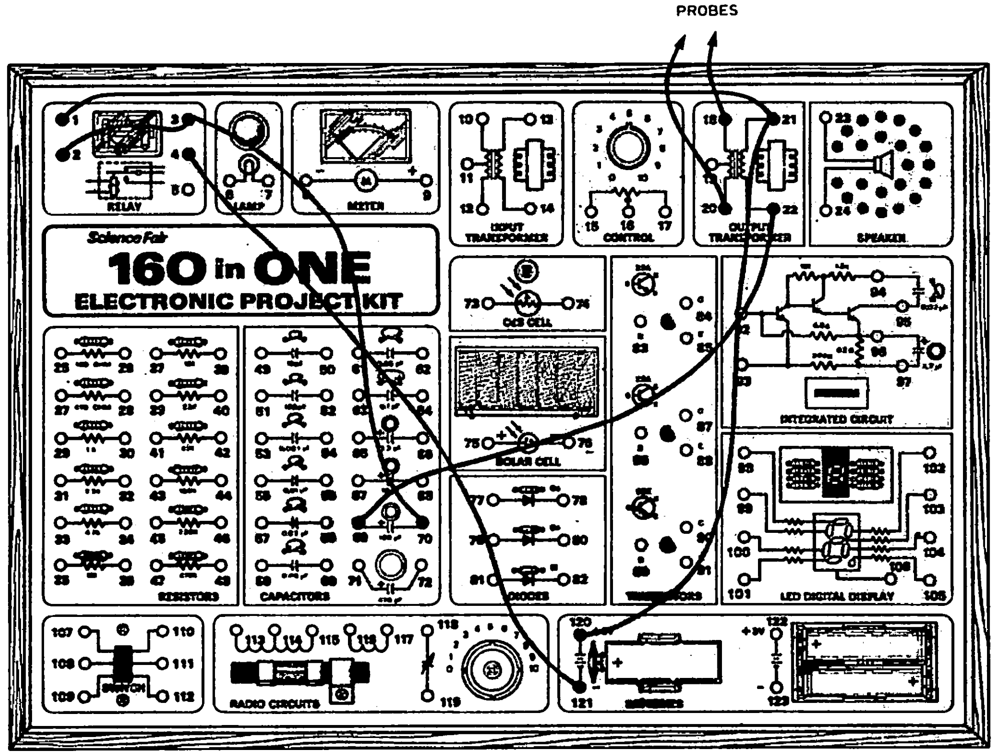
One way of testing for the high voltage produced with this circuit is to use a neon tester. The neon tester has a small neon lamp and series resistor to limit current. The neon gas requires about 90V before it can give a visible glow. This HV (high voltage) generator cannot give out enough energy to shock any one, but it can cause a neon tester to glow with a dim glow.

The Relay is connected like a doorbell buzzer to obtain square-wave pulses of DC voltage across the series connection of the 100uF Capacitor and Output Transformer winding. This causes the charging and discharging current of the Capacitor to flow through the few turns of the Output Transformer winding.

Because of transformer action the change of primary current generates a voltage in the secondary winding of the Transformer. The secondary winding has more turns than the primary winding (as used here) so the induced voltage is higher than the primary voltage of 9 volts.

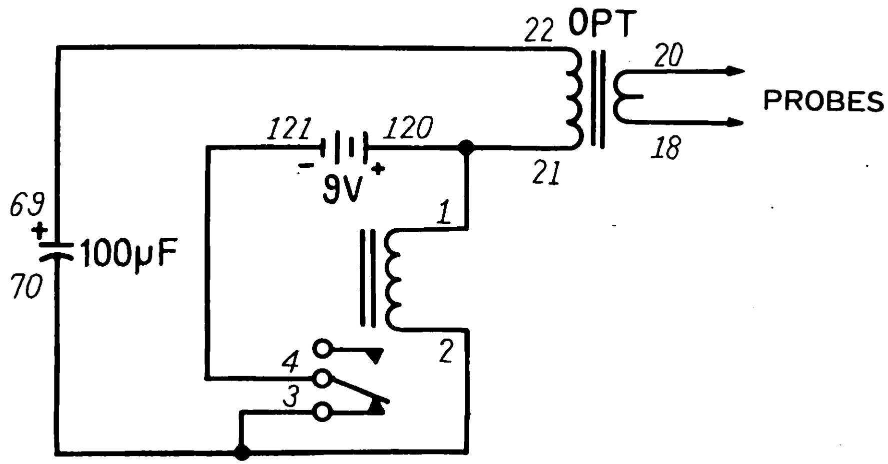
If the Batteries are fresh enough you may be able to feel the high voltage pulses by touching both probes at the same time. Happy zapping!

NOTES



WIRING SEQUENCE:

120-21-1, 2-3-70, 69-22, 20-Probe, 18-Probe, 4-121



45. CAPACITOR DISCHARGE HIGH VOLTAGE GENERATOR

This project shows how single pulses of high voltage are generated when the charged Capacitor is suddenly discharged through the low-voltage windings of the Transformer. This action is used in capacitor-discharge automotible ignition systems.

The operation of the circuit may be simple, but the concepts involved are very basic and therefore important to the understanding of many other more complicated circuits.

Energy is stored up in the 470uF Capacitor by the battery supplying many excess electrons to the negative electrode, and at the same time drawing from the positive electrode the same number of electrons so that it is deficient in electrons. Because of the current limiting action of the 4.7K Resistor, it requires at least 12 seconds for the Capacitor to receive the 9V charge from the Battery.

The amount of charge in a Capacitor can be indicated by either the voltage across the capacitor or (more accurately) by the quantity of electrons displaced in one of the electrodes of the capacitor. The quantity of electrons is measured in "coulombs", where one coulomb is a quantity of 6,280,000,000,000,000,000 electrons (6.28×10^{18} in scientific notation).

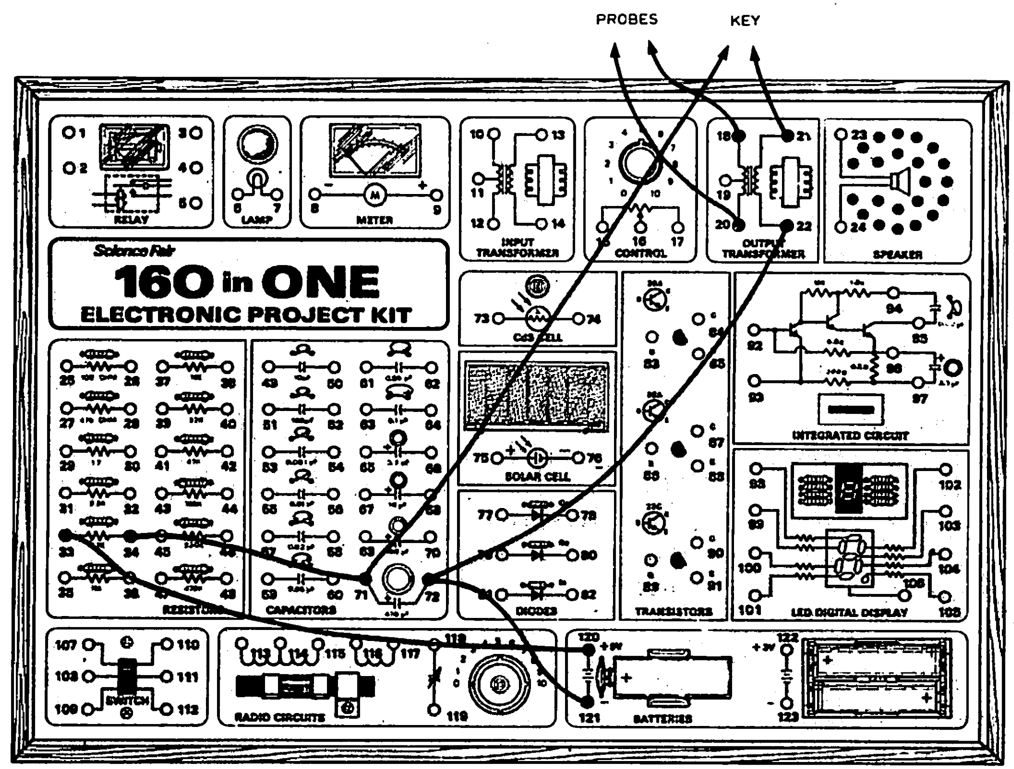
To determine the charge (Q) you multiply the capacitance (C) times the voltage (E) across the capacitor (Q = C X E). For the 470 uF at 9V this is calculated as:

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

When the above amount of electrons is passed through the Transformer winding in a very short time, it induces a high voltage in the second (secondary) winding.

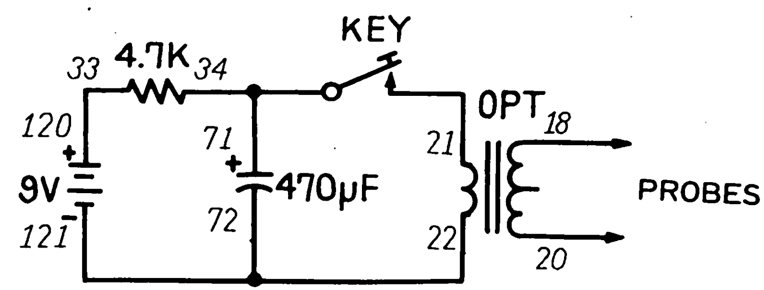
If you have a neon voltage tester you can connect it across the output to indicate the presence of 90V or more. This is possible because the neon lamp requires at least this voltage before it will ionize and give off light.

NOTES



WIRING SEQUENCE:

Key-21, Key-71-34, 22-72-121, 18-Probe, 20-Probe, 33-120



46. DIODE ACTION OR DIODE SWITCHING

This is the first of the next category of experiments: Basic Semiconductor Circuits. You'll get a chance to look at some of the most simple and basic types of semiconductor circuitry. This section is very important, so follow along closely.

The purpose of this project is to demonstrate and study the switching capabilities of a Diode, and in the process show the operation of a DPDT (double pole-double throw) switch hooked up as a three-way switch.

Basic circuit description is as follows: A 3V Battery is connected through the DPDT switch, which is connected as a polarity reversing switch. The output of the switch is connected through the silicon (Si) Diode to the 3V Lamp. A Key is wired in parallel with the Diode.

Circuit operation is as follows:

1. Place the Switch in the ON (up) position. The Lamp lights with or without the Key closed. This verifies that the Diode can act like a closed switch.
2. Place the switch in the OFF (down) position. The Lamp will not light unless the Key is closed. This verifies that a Diode can act like an open switch.

What makes the Diode operate this way? The only change which we made to the circuit was to reverse the polarity of the 3V applied-voltage. Therefore it may be concluded that a Diode may conduct current or block the flow of current depending entirely upon the polarity of the circuit current. This is the fundamental and unique property of a Diode.

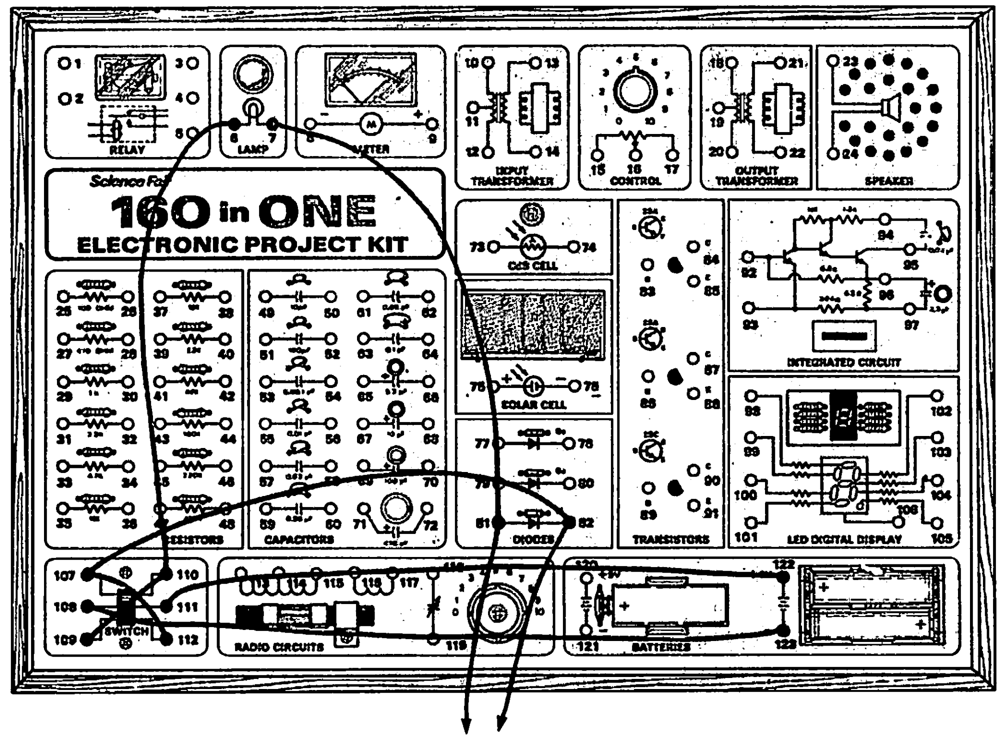
This basic property of a Diode has been known longer than what electric current is actually composed of. Because of this condition the diode symbol was originally drawn with the arrow pointing in the direction of the supposed direction of unexplained current flow. We now know that electric current is composed of electrons which are moving in the opposite direction of the originally assumed current, called "conventional current". Actual current (composed of moving electrons) can only flow through a Diode against the arrow head.

Diodes are never ideal components so a small amount of voltage is always dropped across the Diode when current is flowing in the forward (conducting) direction. Also, when reverse-biased (reverse or non-conducting polarity), the Diode allows a small amount of leakage current to flow (microamperes).

Silicon Diodes are referred to by the chemical symbol for silicon (Si); Germanium (Ge) Diodes may also be used for switching but are generally not able to handle as much current as Si types can.

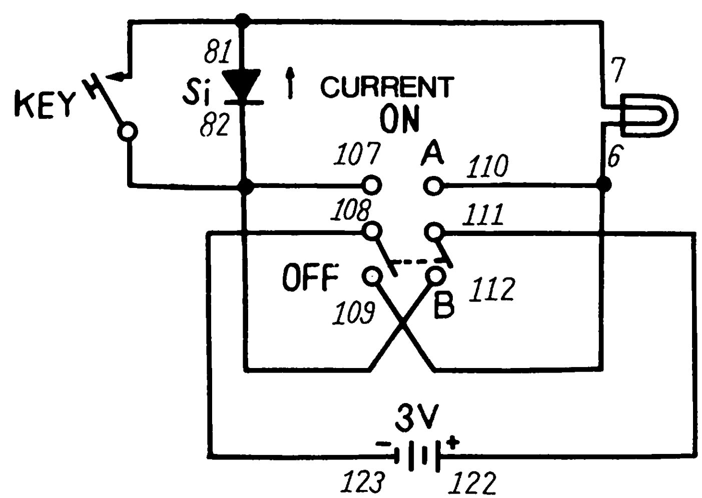
The polarity-reversing connections used with the DPDT (double pole-double throw) switch are the same as those in 3-way switches used in electrical wiring around the house.

NOTES



WIRING SEQUENCE:

122-111, 109-110-6, 7-81-Key, Key-82-107-112, 108-123



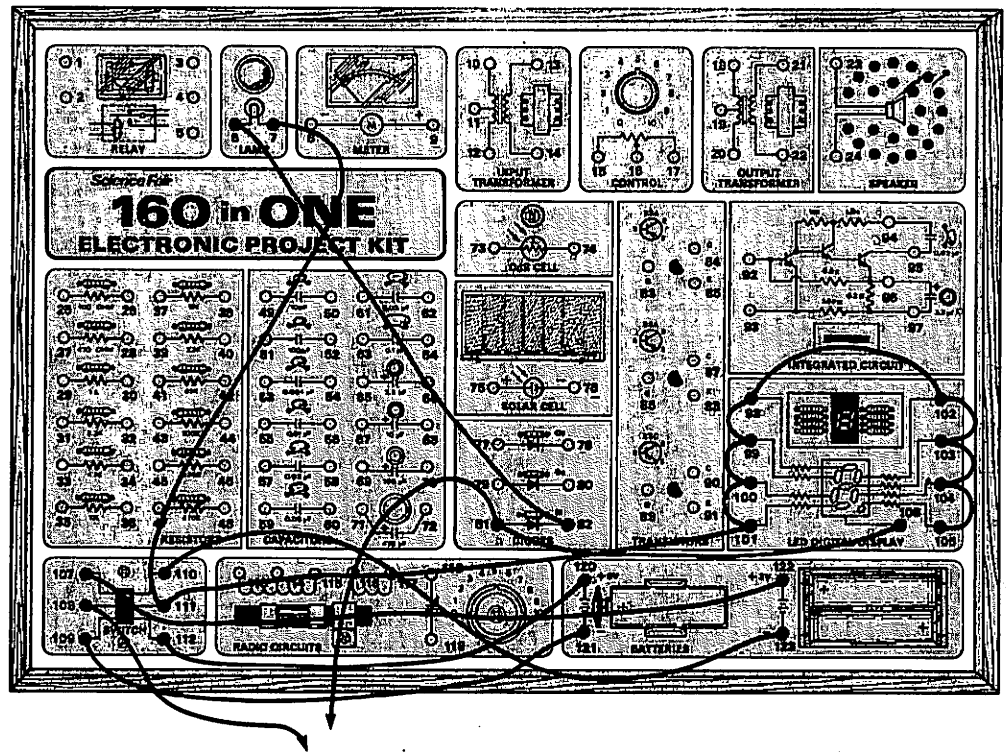
47. DIODE CIRCUIT FUNCTION WITH SWITCH AND LED DISPLAY

The purpose of this project is to allow you to check your ability to explain some circuit action which uses the following components and basic characteristics.

1. Polarity reversing switch.
2. Diode rectifier action: current can only flow against the arrow head on the Schematic symbol.
3. LED's glow requires proper voltage polarity.

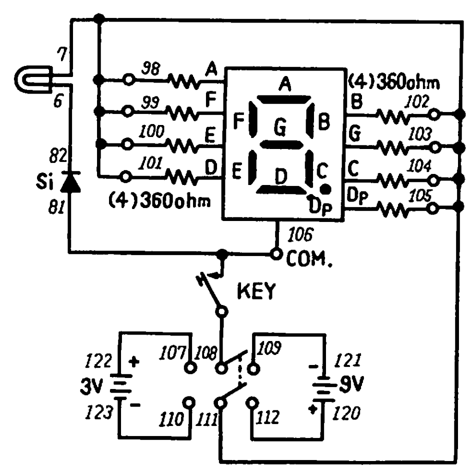
Now use your pencil and outline in the space below how the circuit operates and then explain how the parts function to obtain the observed circuit operation.

NOTES



WIRING SEQUENCE:

105-104-103-102-98-99-100-101-111-7, 6-82, 106-81-Key, Key-108, 107-122, 109-121, 110-123, 112-120



48. TRANSISTOR CIRCUIT ACTION

We leave the simple Diode and look at the Transistor. The Diode can only conduct or not conduct; it has only two leads. A Transistor has 3 leads and the third lead can be used to control what is happening between the remaining 2 leads. We say a Transistor can "amplify"; that is, a small signal can contol or produce a large signal.

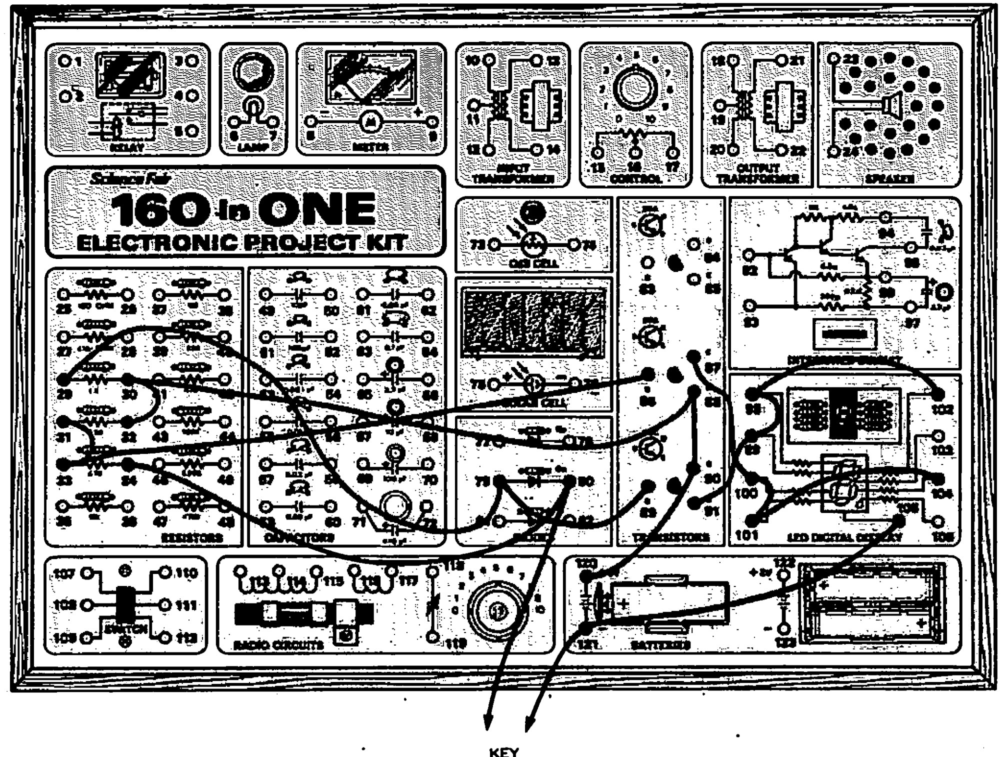
This project demonstrates two methods of transistor control. One method involves removing the base-bias by shunting (bypassing); the other involves applying base-bias. The LED readout is used to indicate these two different methods by lighting either the top or bottom half of the number zero (or letter "O" if you like).

Circuit operation is as follows: With the Key open, the 2SC is full ON because of base-bias current that flows through the 1K current limiting Resistor. This turns the LED top segments (A, F and B) ON. At this time, the 2SA is OFF because no base-bias current can flow. A negative base current source is required for a 2SA because current must always flow against the arrow head symbol in a Transistor (just like in a Diode). Any current that might attempt to flow from the base circuit of the 2SC cannot, because the germanium (Ge) Diode would be reverse-biased.

When the Key is closed, the 2SC is turned OFF because the Diode conducts. The voltage drop across the Diode is lower than that required to allow the 2SC to conduct, especially with the LED segments in the emitter circuit. The 2SA is turned ON at this time because of the base-bias current, which can flow though the 4.7K to the base. This lights LED segments E, D and C.

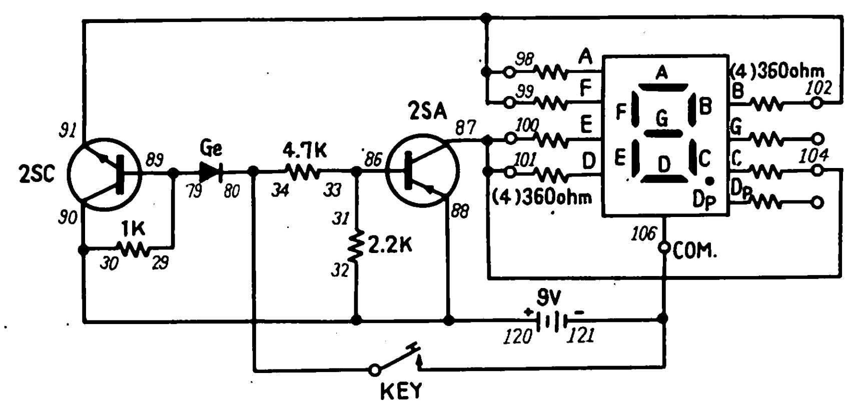
The 2.2K Resistor is needed to completely cut OFF the 2SA when the Key is up. Without this Resistor the Transistor leakage (ICEO) might be sufficient to dimly light the LED segments driven by this Transistor.

NOTES



WIRING SEQUENCE:

104-101-100-87, 102-98-99-91, 89-79-29, 86-33-31, 106-121-Key, Key-80-34, 32-30-88-90-120



49. HEARING AID AMPLIFIER

This is a high gain two Transistor amplifier similar to some of the early models of Transistor hearing aid amplifiers. The Speaker is used as a dynamic microphone.

This is a good amplifier on which to use your VOM to help learn how Transistors work. Use the VOM to measure circuit voltages. These voltages may then be used to determine currents and operating characteristics of the circuit.

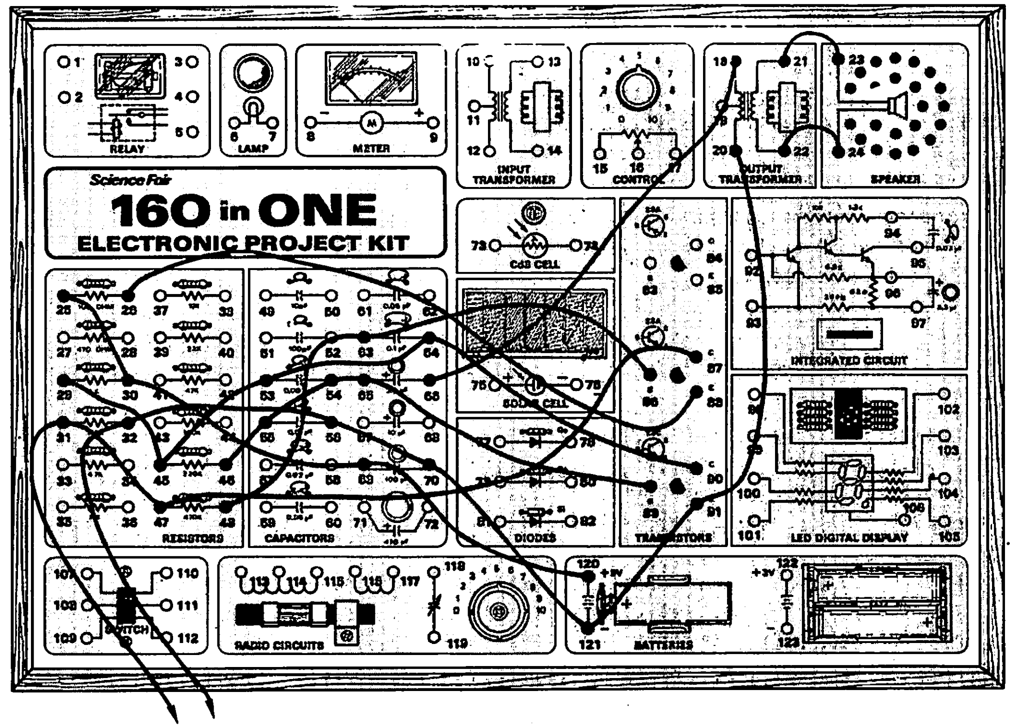
The basic opertion is as follows: The Speaker changes the sound pressure into weak voltages which are increased some by the step-up turns ratio of the Transformer. This voltage is then applied to the B-E input junction of the 2SC Transistor through the 3.3uF Capacitor. The small 0.01uF Capacitor has little effect at the audio frequencies, but it stops the ultrasonic oscillations which would otherwise occur because of the high gain of this combined with the long circuit leads.

The amplified voltage at the output of the 2SC Transistor appears across the C-E leads and is coupled into the B-E input junction of te 2SA Transistor through the 0.1uF Capacitor. This amplified voltage is further amplified by the 2SA and appears across the C-E terminals of this Transistor. The output voltage is then coupled to the Earphone through the 100uF Capacitor.

Notice that the above circuit description makes no mention of the Resistors in the circuit. This is because we consider them all as open circuits as far as the audio signal is concerned. The basic purpose of all the resistance in this amplifier is to supply the required DC voltages and currents to the Transistors. The 1K and 2.2K Resistors are required only to supply the collectors with voltage and current. The 220K and 470K supply base current and voltage.

The type of bias current is the same for both stages and is called "self-current" bias. This is because the collector DC voltage is used to provide the source of current through the base Resistor to the stage with some self stabilizing feedback. The high value of the base resistance (220K and 470K) determines the base-bias current which will flow.

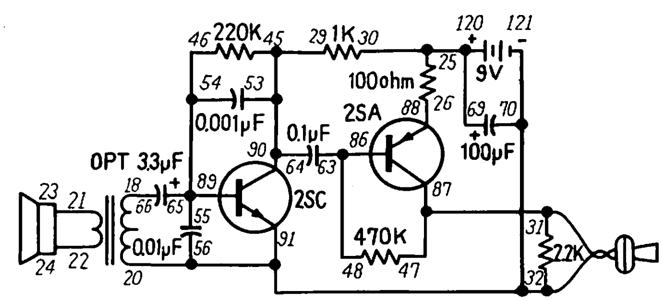
Measure the DC voltage across Transistor C-E leads to determine if the Transistors are turned ON by the right amount act as amplifiers. The voltage (called V CE) should have a value between the OFF value(9V of the Battery) and full ON (0.5V). An electronics technician uses this voltage to verify that the bias is correct for the Transistor to work as amplifier.



EARPHONE

WIRING SEQUENCE:

21-23, 22-24, 18-66, 20-91-121-70-56-32-Earphone, Earphone-31-47-87, 86-63-48, 90-64-53-45-29, 89-65-54-55-46, 26-88, 25-30-69-120



NOTES

50. REGULATED POWER SUPPLY

The purpose of this project is to study an electronically regulated power supply as used in computers. A supply such as this is used to hold the DC ouput voltage steady at a fixed value such as 3.6V or 5.0V. Without a constant, accurate voltage such as this, many computer circuits could not operate properly.

The electronic voltage regulator circuit uses all of the Schematic components between the Battery and the Meter circuit in this project. The Resistors from 100 ohms to 10K are used as loads on the power supply.

The Meter circuit, composed of the Meter and 10K Resistor has a full-scale voltage calibration of about 2.7 volts. This Meter circuit is included to show that the voltage change is not affected much by this wide range of loading caused by using the four different load resistances.

Connect the circuit and adjust the Control for a Meter reading of about 5 or 6 on the top scale. Now use the lead wire from terminal 27 as a Probe and touch it to each of the terminal numbers and load Resistors as listed on the Schematic. The voltage as indicated on the Meter should not change much at all. Only the 100 ohm load, which causes a much heavier current flow than any of the other Resistors, should cause more than a couple of percentage points of change. If you have a VOM you can use it to measure the different load currents. Take our word for it, a power supply delivering this voltage without the use of a regulator circuit like this would allow the output voltage to change at least 10% or more.

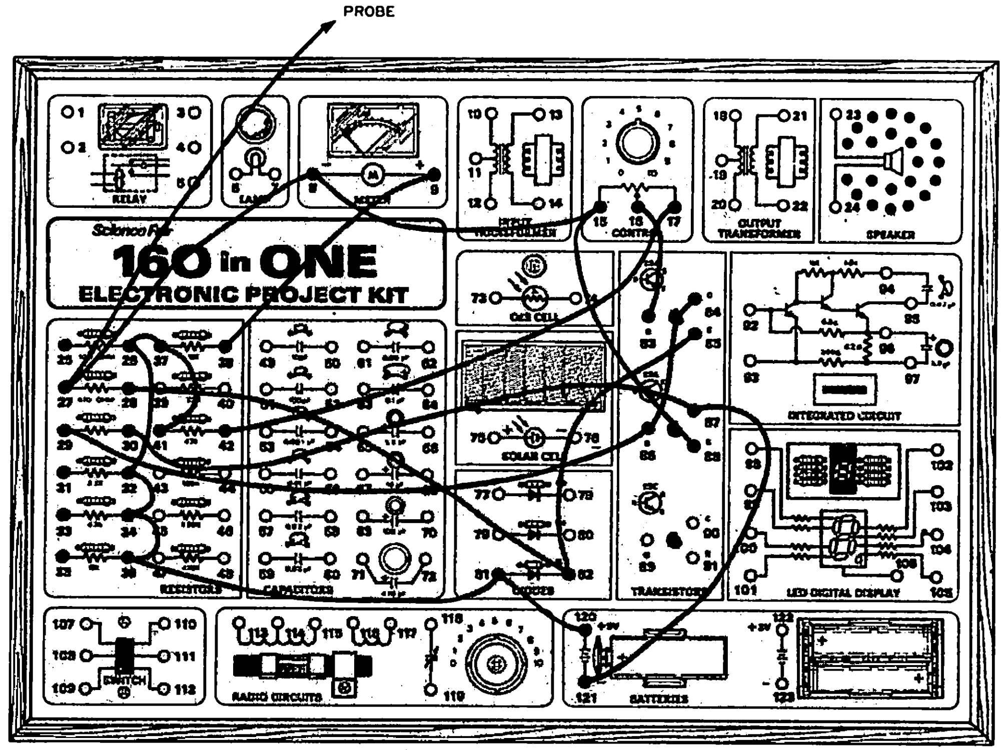
The 2SA(1) is called a "comparator". It compares the voltage at its emitter (E) with that at its base (B). The 2SA(2) is called the "series pass" Transistor because all the current of the load must pass through this series device from collector (C) to base (B).

The 1K Resistor supplies the current to bias the 2SA(2). More current flows than what is required so that the 2SA(1) can also pass some current during normal operation. The 470 ohm Resistor and (Si) silicon Diode provide a constant voltage of about 0.7V for the emitter of the 2SA(1).

Operation is as follows, for a condition of heavy loading that would tend to pull the output voltage down. The 2SA(1) base would tend to go down, but because the stage is operating as a common emitter stage, its collector voltage (and therefore the 2SA(2) base voltage) would tend to go up. Now because the 2SA(2) acts as an emitter follower stage, the output would also tend to go up. This opposes the original tendency for the output to go down so the output remains about constant.

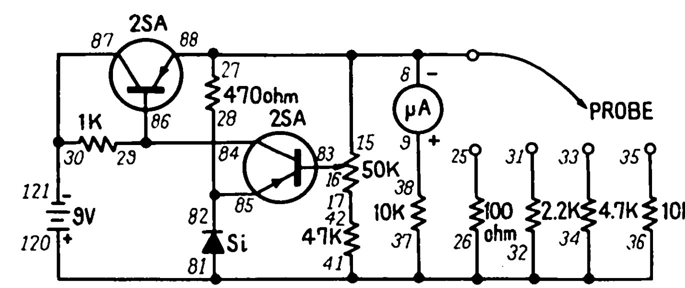
Operation for the condition where the output tends to go up due to light loading, is the opposite in direction of change, but the same in effect — stabilized output voltage.

NOTES



WIRING SEQUENCE:

120-81-36-34-32-26-37-41, 16-83, 17-42, 84-86-29, 85-82-28, 38-9, 88-15-8-27-Probe (long lead), 30-87-121



51. VOLTAGE REGULATOR CIRCUIT

The purpose of this project is to consider and demonstrate the operation of an electronically controlled power supply. This circuit allows easy adjustment of the output voltage from a DC power supply. It also provides effective filtering action which amounts to capacitance multiplication.

The regulator circuit only uses four parts: a 2.2K Resistor, a 10uF Capacitor, a Transistor and a 50K potentiomenter (the Control). The Meter and 47K Resistor are included as a DC voltmeter. We've described the operation of this voltmeter previously, so won't repeat it.

This circuit uses three basic characteristics of the Transistor. They are:

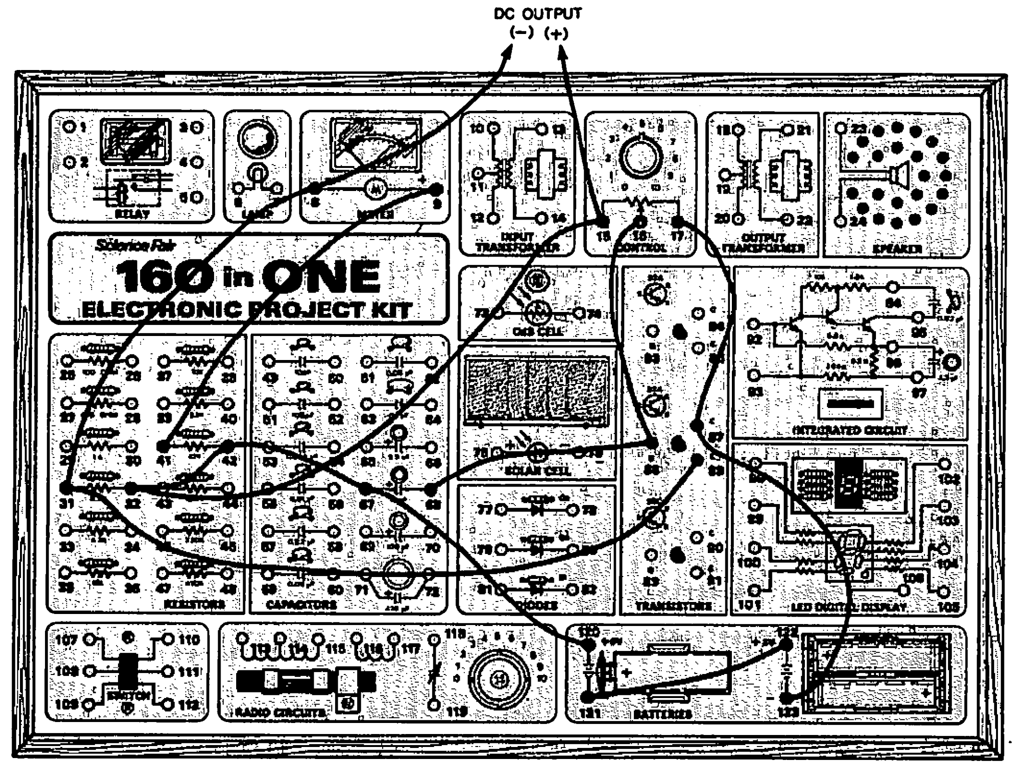
1. Base current is always much less than collector or emitter current, and is the controlling factor over how much collector current can flow. The gain factor (Beta) is the ratio of collector current IC to base current IB and is typically greater than 80. (See project 160 for more about the Beta factor.)
2. Base-emitter (B-E) voltage is relatively constant and low in value. This is typically about 0.7V for silicon Transistors.
3. Any capacitance connected to the base appears at the emitter as if it were Beta-times higher in value.

For this circuit, operation may be described in terms of the above factors as follows. Output voltage may be adjusted from almost zero to almost the full 12V of the batteries as the emitter follows the base voltage obtained from the potentiometer (2). This is obtained by using a low-powered control because the base current requirements are low (1). The output at the emitter is not only controlled in value but also is well filtered by the effective emitter capacitance (3).

The Meter registers about 12V full scale with this circuit. Use this Meter to observe the control of output voltage as the Control is adjusted throughout its range. Connect the output to one or more segments of the LED and check operation over the range of voltage available.

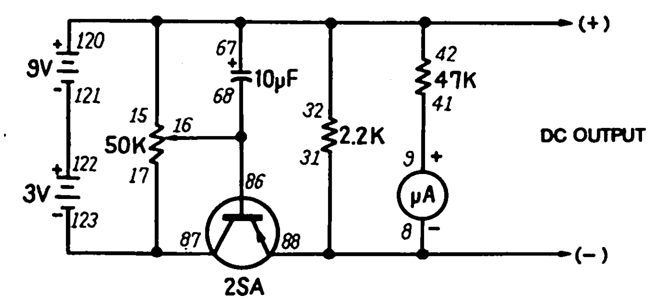
The current which may be drawn from the circuit is limited to about 50 mA, so be careful what you try to power with this circuit. Actual voltage regulators, similar to this, use power transistors in order to handle higher load currents and power.

NOTES



WIRING SEQUENCE:

8-31-88, 9-41, 15-32-42-67-120, 16-86-68, 17-87-123, 121-122, 15 "+" DC OUTPUT, 8 "–" DC OUTPUT



52. LOGIC "AND" CIRCUIT WITH SWITCHES

We now go into another section of Projects: Logic and Computer Circuits. To many people, this will be the most interesting and exciting section of this Electronic Lab Kit. However, some experimenters may be a little afraid to get into this (thinking it is too complex). Really, logic and computer circuits are quite simple; they become complex only when everything is put together (hundreds, thousands or even millions of the simple, basic circuits are used in the big computer systems). Simply, a logic circuit is one that can "make a decision" (of course it only makes a decision based on how the circuit designer set it up).

The AND circuit is one of the basic electronic circuits that can make decisions. Circuits that make decisions are called logic circuits.

The purpose of this experiment is to consider the logic AND circuit (constructed with switches). This circuit is simple enough so we should be able to understand the logic AND circuit without being confused by too much electronic circuitry.

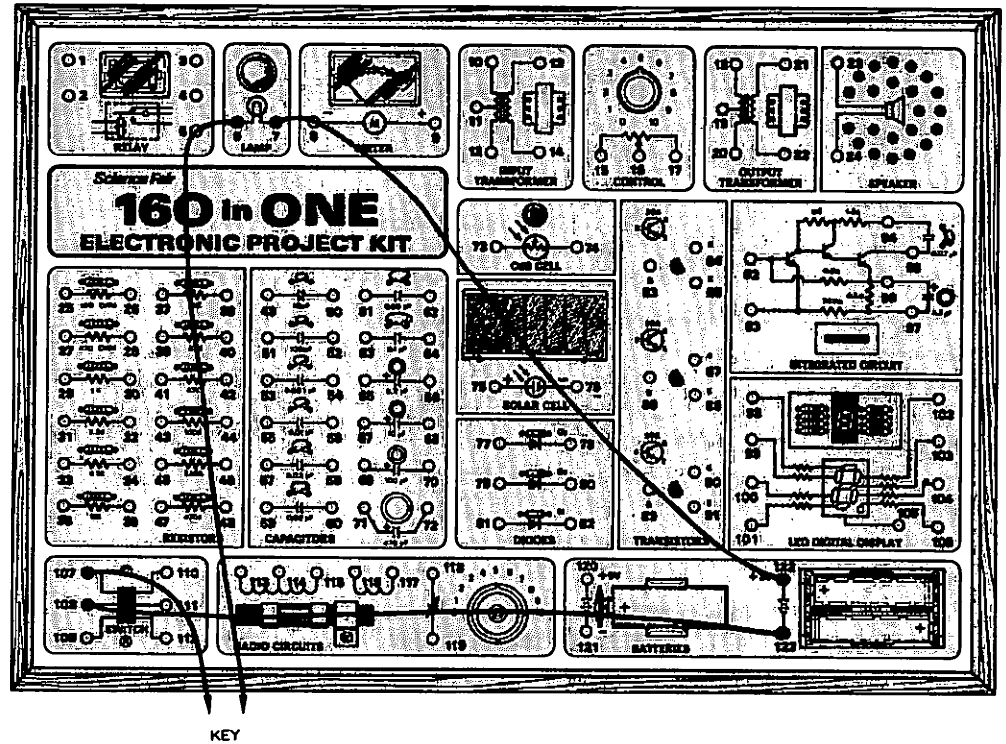
The logic AND function is used in all electronic hand-held calculators, computers and all complicated control circuits. Your washing machine, clothes dryer and other such equipment use this type of circuitry.

The AND function may be defined as a control system where a certain function is performed only when one other operation is completed and a second operation is completed, also. In this demonstration the Lamp is turned ON only when the slide Switch AND the Key are in the closed position.

Notice that the AND circuit does not require any specific sequence; that is, either switch may be operated first (or last). The important feature is that both switches must be closed for the output to be ON. In an AND circuit with more than two switches, all must be closed.

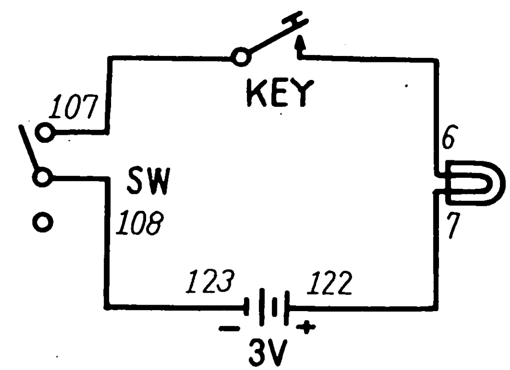
In electric AND circuits like this you should remember that the AND circuit is a series circuit. This is in contrast to the logic OR circuit where all switches are in parallel. You'll see an example of this in the next project.

Can you list some circuits which are AND circuits?



WIRING SEQUENCE:

122-7, 6-Key, 107-Key, 108-123



Now refer to project 56 for additional material on the logic AND function.

53. LOGIC "OR" CIRCUIT WITH SWITCHES

The purpose of this experiment is to consider the logic OR circuit (contructed with switches). This circuit is simple enough so we should be able to understand the logic OR circuit function without the confusion of a more complicated circuit.

The logic OR function is used in all computers, hand-held calculators and many complex control circuits.

We can define the logic OR function as a control system in which a certain function will be activated when either one OR another condition is met. In this project the Lamp is turned ON by either the slide Switch OR the Key.

Notice that we could parallel any number of switches for the logic OR function. It is also important to notice that the OR circuit uses parallel-connected switches as contrasted with the AND circuit which uses series-connected switches.

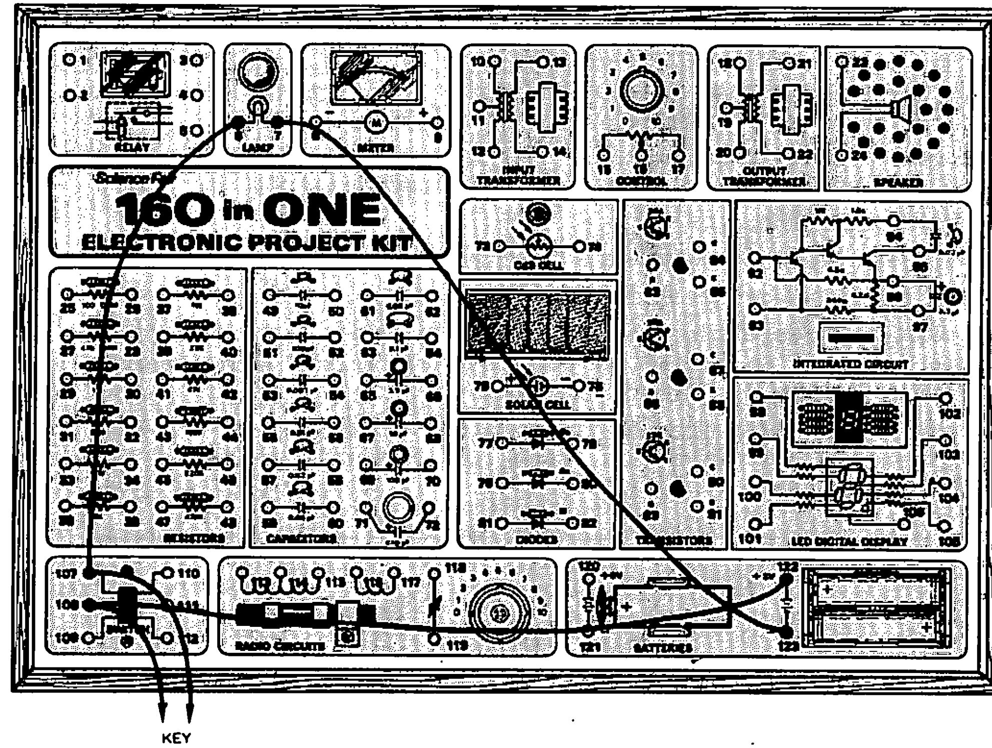
Like the AND circuit, the logic OR circuit does not require any specific sequence; that is, either switch may be used first to turn the Lamp ON. It is also important to realize that any one switch, which is ON, keeps the light ON. This is in contrast to the AND circuit where even if all inputs were ON but one, the Lamp would still be OFF.

The Truth Table for an OR circuit with two inputs is shown below. The slide Switch is A; Key is B; H is ON, and L is OFF.

A	B	Lamp
L	L	L
L	H	H
H	L	H
H	H	H

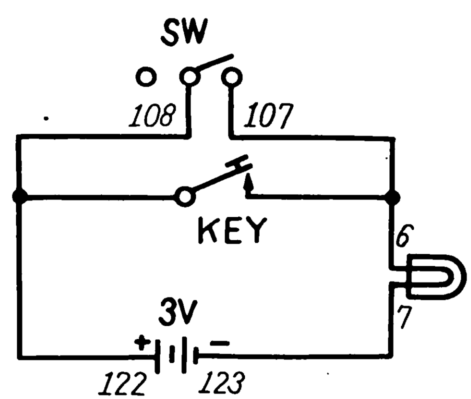
Can you think of some circuits which use the logic OR function?

Now see project 57 for additional material on the logic OR.



WIRING SEQUENCE:

123-7, 6-107-Key, Key-108-122



54. LOGIC "NOR" CIRCUIT (Part 1)

This project is a demonstration of the logic NOR function. The NOR function is like the OR function except the output conditions are reversed (or inverted).

The logic NOR function is used extensively in computers and hand-held calculators. It is usually tucked away inside the circuitry as an obscure but important part of the logic circuit.

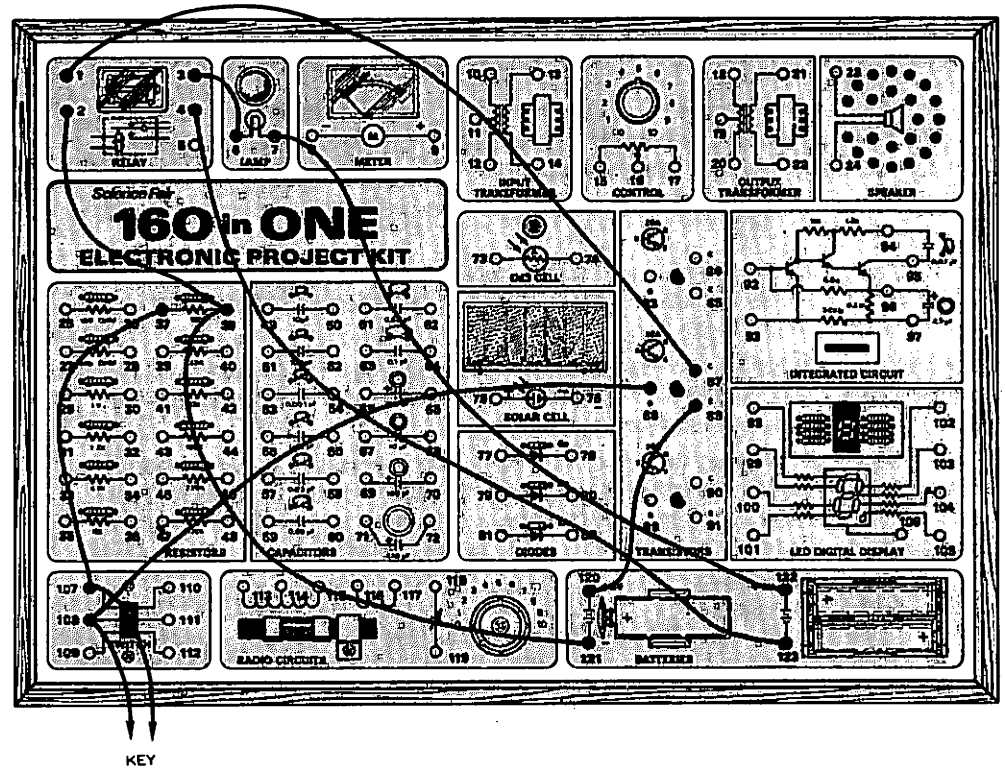
The circuit operates as follows:

1. When neither one switch nor the other is closed, the Lamp is ON.
2. When either or both switches are closed, the Lamp is OFF.

This circuit accomplises this function by wiring the Relay contacts so that the Lamp is normally ON. To bias the Transistor ON, the switches must be closed to feed the base current to the Transistor. The Transistor in turn controls the Relay.

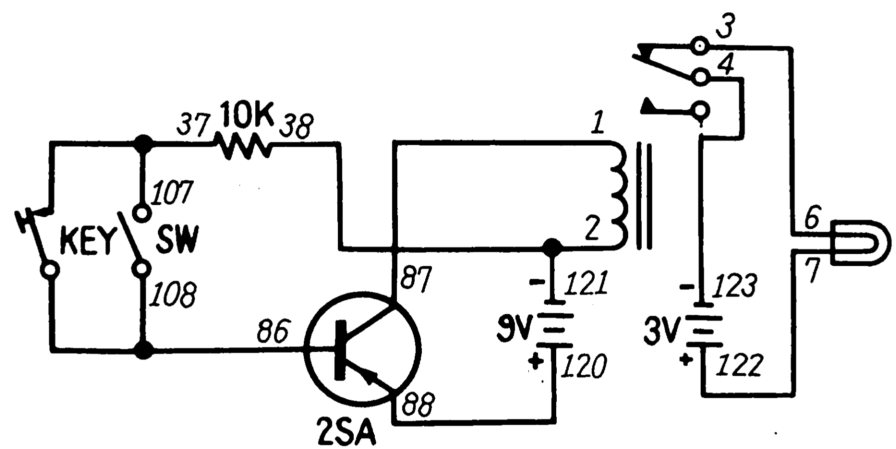
The NOR Truth Table and additional discussion on the NOR function are included in projects 55 and 59. Before you refer to them, try to make a Truth Table for the NOR all by yourself in the space provided below.

NOTES



WIRING SEQUENCE:

122-7, 4-123, 87-1, 2-38-121, 37-107-Key, Key-108-86, 3-6, 88-120



55. LOGIC "NOR" CIRCUIT (Part 2)

Here is another project to demonstrate the NOR logic circuit (many different types of circuit configurations, can accomplish the same function). A NOR circuit is a combination of an OR gate ("gate" is another word used for a logic circuit) and an inversion gate. You can think of it as an inverse OR or as a NOT OR (or even just keep in mind the word combination "neither/nor" — neither one input nor the other will give an output).

This NOR circuit works as follows: When there is no input (no light falling on the Solar or CdS Cell), there will be an output (the Lamp will light). However, neither one input NOR the other can produce an output (neither can both inputs). Confusing? Try it.

This demonstration circuit works as follows:

1. In darkness the Lamp goes ON.
2. If bright light strikes either the Solar Cell or CdS Cell or both, the Lamp goes OUT.

A Truth Table of this action is as follows:

SOLAR	CdS	LAMP
OFF	OFF	ON
OFF	ON	OFF
ON	OFF	OFF
ON	ON	OFF

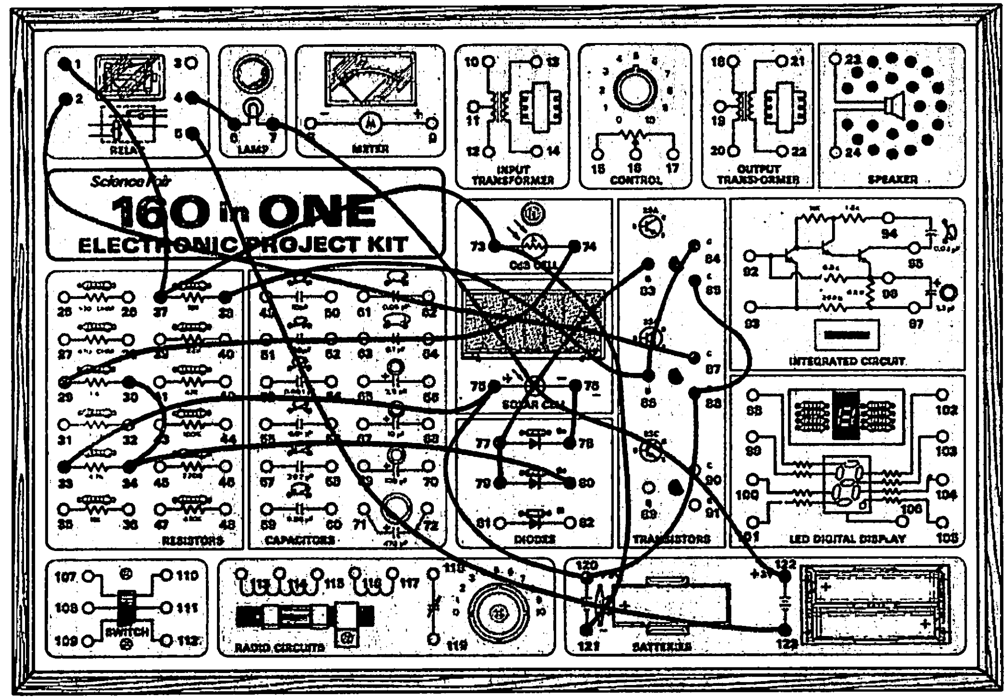
Expressing it as : A=Solar Cell; B=CdS Cell; H=ON; L=OFF; OUTPUT=Lamp.

A	B	OUTPUT
L	L	H
L	H	L
H	L	L
H	H	L

Either the CdS or the Solar Cell turns ON the 2SA(1) and turn OFF the 2SA(2), when the light hits it.

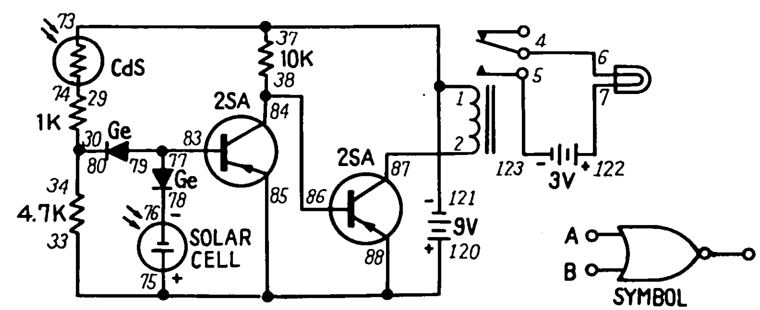
Now you will want to compare this circuit with the NAND circuit of project 58.

The symbol for the NOR circuit is shown next to the Schematic. It is the same as an OR symbol, with a small circle added at the output (this means the main symbol function is inverted).



WIRING SEQUENCE:

2-87, 4-6, 5-123, 7-122, 29-74, 30-34-80, 33-75-120-88-85, 38-86-84, 76-78, 79-77-83, 1-37-73-121



56. LOGIC "AND" WITH LED DISPLAY

The purpose of this project is to study a logic AND circuit as used in computers.

The readout is connected to display the letter H when terminals A and B are both connected to terminal H (121). These letters all have logic significance; where, A and B are the logic inputs, H is a logic high (ON), and L is a logic low (OFF). The Truth Table for the logic AND function is as follows:

A	B	OUTPUT
L	L	L
L	H	L
H	L	L
H	H	H

Expressed in words, both A and B must be high for the output to be high. The logic symbol is also shown along with the Schematic. This function may also be written as $\overline{AB}$, or as $\overline{A\ B}$, or as $\overline{A \times B}$.

Circuit operation is as follows: Whenever either one or both inputs are on L (terminal 120), the low forward voltage drop of either germanium (Ge) Diode keeps the PNP Transistor from turning ON. With this Transistor OFF, no bias is supplied to the base of the NPN so that it is OFF, also. This causes the readout to remain dark.

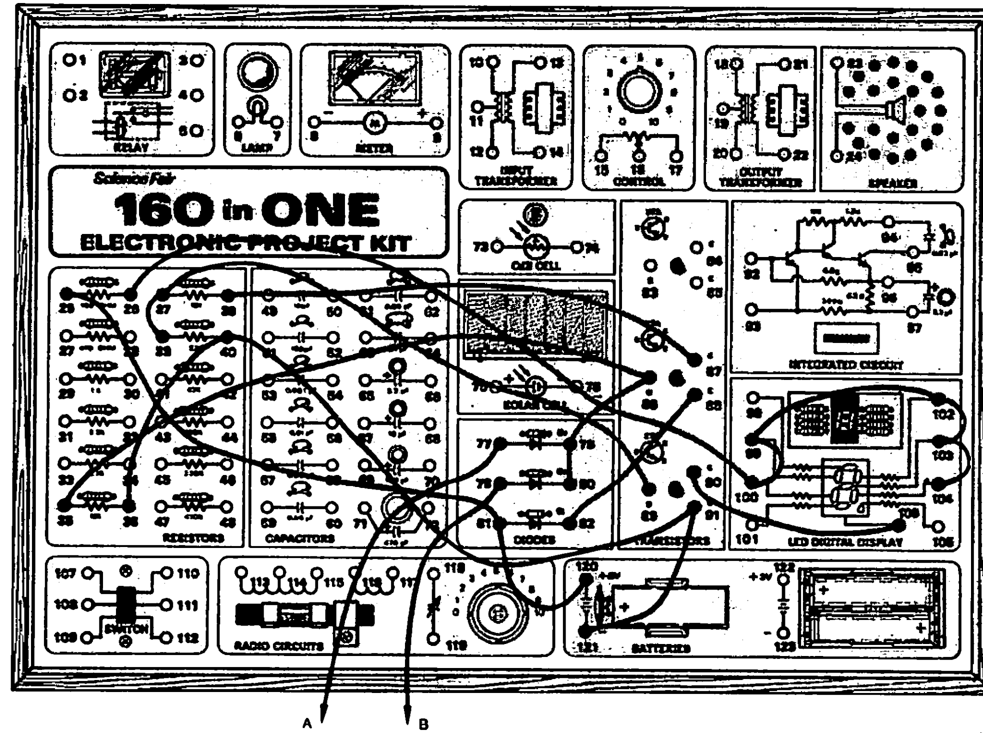
Now if both inputs are on H (terminal 121), both Diodes are reverse-biased across the 10K Resistor and perform no function. This 10K Resistor provides bias to the base of the PNP to turn it full ON. The NPN is also biased full ON at this time with the current flowing through the 10K in its base circuit, the PNP and the silicon (Si) Diode. With the NPN on, current can flow to the readout to light the LED (forming the letter H).

The silicon Diode helps to insure that the PNP is off whenever either Diode's (Ge) forward voltage is present at the base. The 22K Resistor insures than any small amount of leakage current from the PNP in the OFF state, doesn't turn ON the NPN.

Your VOM voltmeter may be used across C and E to verify the ON and OFF characteristics of the Transistors.

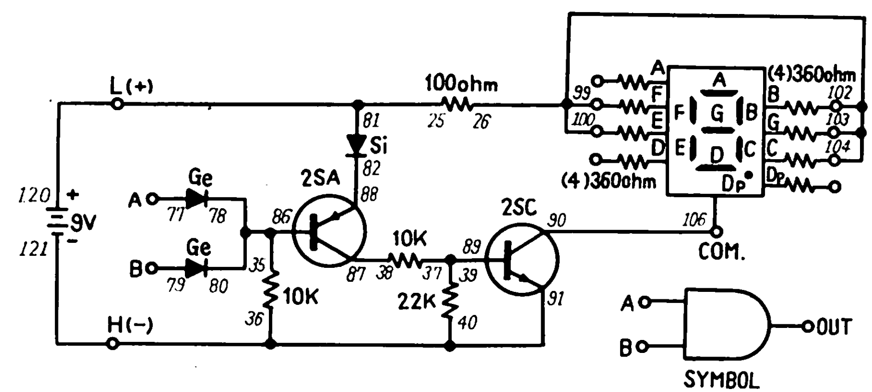
Because the two logic states are H and L, the input terminals should always be connected to one of these terminals (120 or 121). For this particular circuit open (not connected) input teminals are the same as a high input.

NOTES



WIRING SEQUENCE:

90-106, 104-103-102-99-100-26, 89-37-39, 82-88, 87-38, 25-81-120, 80-78-86-35, 77-Long Lead for A, 79-Long Lead for B, 36-40-91-121



57. LOGIC "OR" WITH LED DISPLAY

The purpose of this project is to study a logic OR circuit as used in computers.

The readout is connected to display the letter H when either terminal A OR B is connected to terminal H (121). These letters all mean something in logic work; A and B are the logic input terminals, H is a logic high (ON), and L is a logic low (OFF). The H terminal is on the most negative part of the circuit therefore this is called "negative logic". A Truth Table for the logic OR function is as follows:

A	B	OUTPUT
L	L	L
L	H	H
H	L	H
H	H	H

Expressed in words, either A OR B must be high for the output to be high. The logic symbol is also shown along with the Schematic. This logic function is generally written as $\overline{A + B}$, where the + sign is used in place of the word OR and is read as "OR".

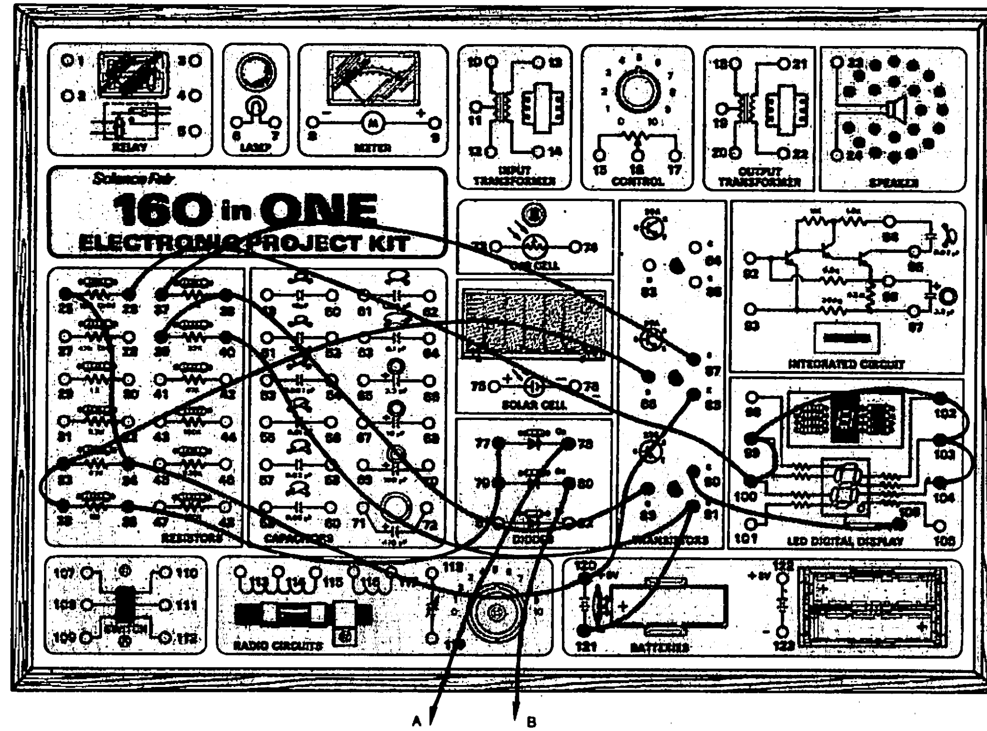
Circuit operation is as follows: Whenever both A and B are on L there is no source of base current for the 2SA, so it is in the OFF state. The 4.7K Resistor insures that it is completely OFF by allowing C-B leakage current to flow outside the B-E junction. When OFF, the 2SA acts like a virtual open circuit between the collector (C) and emitter (E). This removes the source of base current from 2SC to keep it OFF as well. The 22K removes the possibility of any remaining 2SA leakage current from turning 2SC ON by shunting the current around the B-E junction. The LED has no current and is therefore dark.

When either A or B is connected to H it completes the base-bias circuit through the 10K to the 2SA, turning ON this Transistor. The 2SA Transistor completes the base-bias circuit through the second 10K to the 2SC, turning this Transistor ON. Current can now flow to the LED through the virtual short circuit between the C-E circuit of the 2SC Transistor.

Connecting both A and B to H gives the same results as for either terminal alone as the only difference is that the Diodes are in parallel. Parallel Diodes act the same as a single Diode.

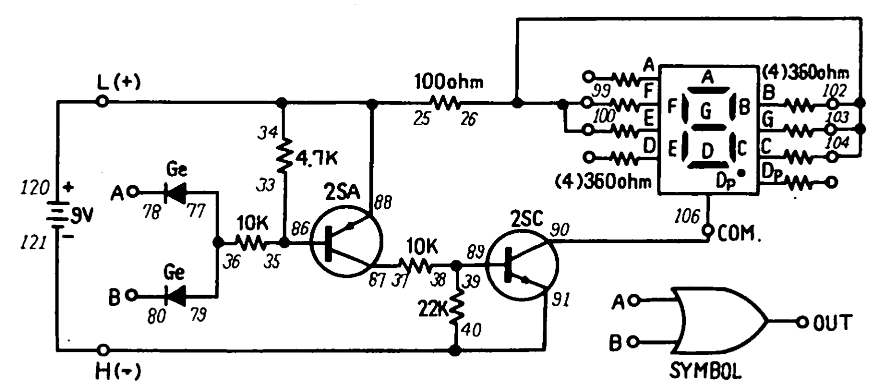
For this particular circuit an open (not connected) input terminal functions the same as a logic low. This condition is not true for all logic circuits; see the AND circuit of project 56.

You can use your VOM to measure circuit voltages during the two conditions of circuit operation. Transistor C-E voltage should be high when the Transistor is OFF and low when it is ON.



WIRING SEQUENCE:

104-103-102-99-100-26, 87-37, 86-33-35, 106-90, 89-38-39, 36-79-77, 78-Long Lead for A, 80-Long Lead for B, 88-120-34-25, 40-91-121



58. LOGIC "NAND" WITH LED DISPLAY

The purpose of this project is to study a logic NAND circuit.

A NAND logic function is an inverted AND function. That is, the output conditions are opposite to those of the AND function. The NAND Truth Table is as follows:

A	B	OUTPUT
L	L	H
L	H	H
H	L	H
H	H	L

Expressd in words, both A and B must be high for the output to be low. The logic symbol is like the AND symbol, but with the addition of a circle at the output to indicate inversion. This function may also be written $\overline{AB}$, $\overline{A\ B}$ $\overline{A \times B}$.

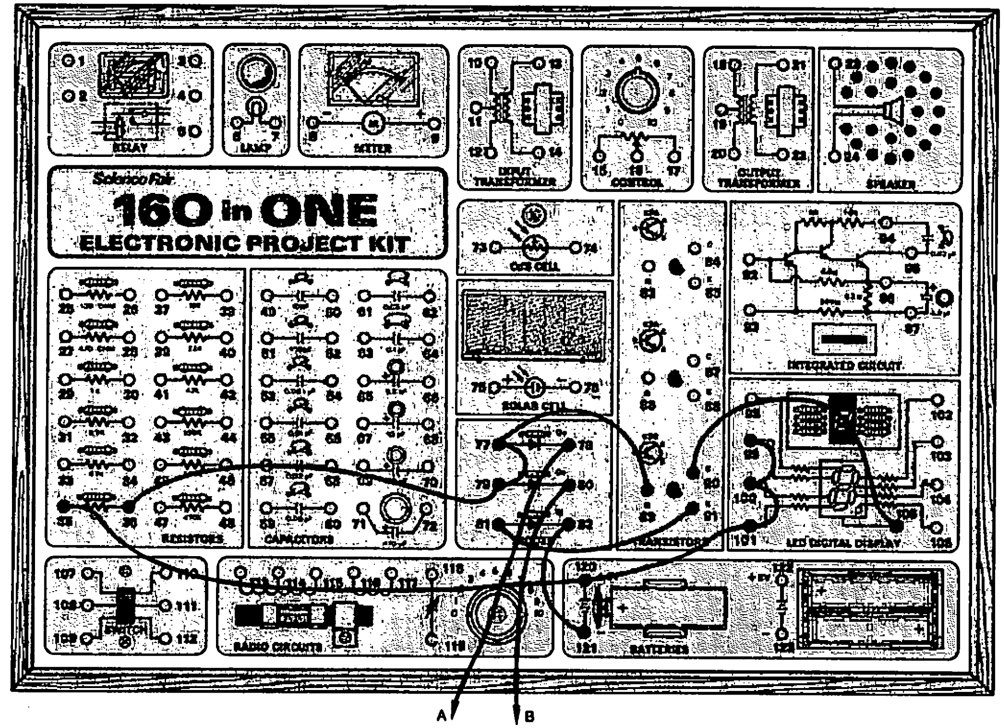
Circuit operation is as follows: Whenever either one or both of the inputs are conected to L (terminal 121), the forward voltage drop of either germanium (Ge) Diode keeps the NPN Transistor from turning ON. The LED cannot receive any current at this time, and remains dark.

Whenever both inputs are connected to H (terminal 120), both Diodes are reversed-biased across the 10K Resistor and perform no function. The 10K biases the NPN Transistor ON, so that current can flow between emitter and collector to light the LED segments.

As with project 56, this circuit also provides a high (H) input to the input terminals when they are not connected to the low (L) terminal. In contrast to project 56, this circuit has a (+) for high (project 56 used (-) for a high). Either metnod can be used. When the more positive voltage is used as the high, the logic is called "positive logic"; when the more negative is used as the high, it is called "negative logic".

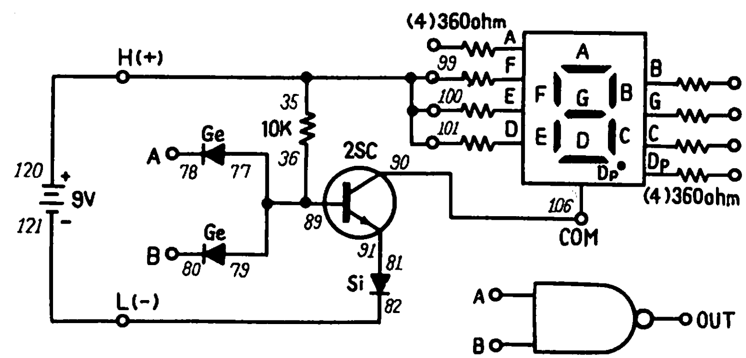
Note: Did you catch the trick we played on you? High output in this case is no LED display, and low output causes a letter L display on the LED. There are different forms of output; don't let electronic circuitry trip you up (check it over carefully).

NOTES



WIRING SEQUENCE:

99-100-101-120-35, 106-90, 89-77-79-36, 91-81, 78-Long Lead for A, 80-Long Lead for B, 82-121



SYMBOL

59. LOGIC "NOR" WITH LED DISPLAY

The purpose of this project is to study a logic NOR circuit as used in computers.

The readout is connected to display the letter L when either terminal A or B is connected to terminal H (120). These letters all mean something in logic work; A and B are the logic inputs, H is a logic high, and L is a logic low. The output goes to low (L) only when both A and B are on terminal L (121). This output condition is the opposite of the OR circuit, so this is referred to as the "inverted OR" or simply a NOR circuit. The Truth Table for the logic NOR function is as follows:

A	B	OUTPUT
L	L	H
L	H	L
H	L	L
H	H	L

Expressed in words the NOR function is: Whenever either A or B are high the output is low. The logic symbol is shown along with the Schematic. This function is also written as $\overline{A + B}$, where " + " is the OR sign and the bar over the symbol indicates inversion.

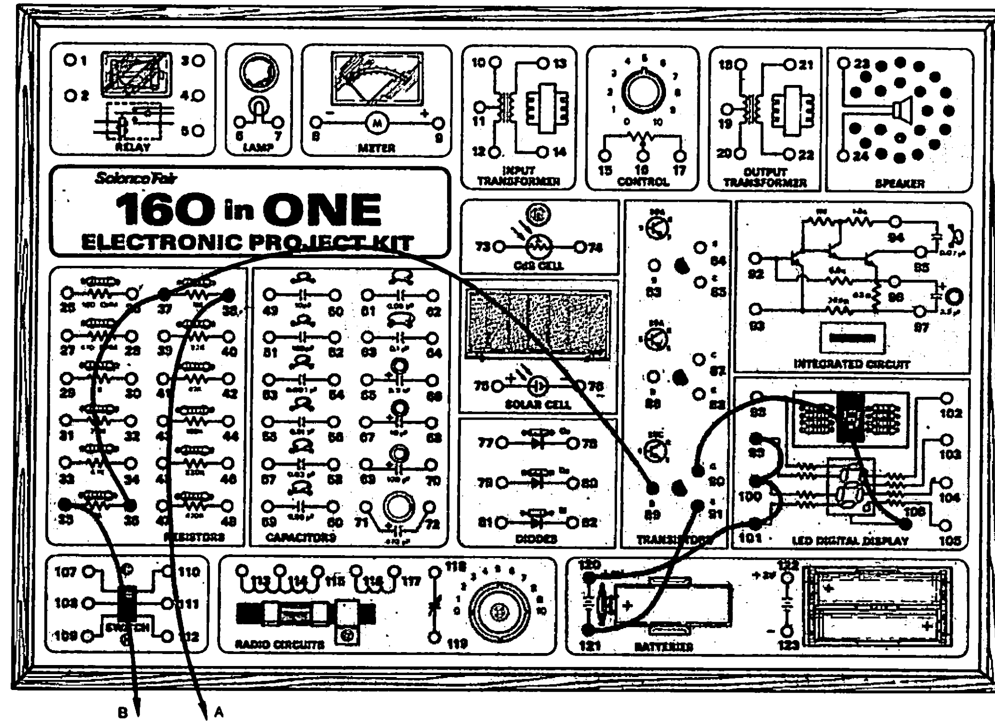
Circuit operation is as follows: When either 10K Resistor is connected to the positive H terminal, sufficient base-bias is supplied to the 2SC to turn it ON. Anytime the 2SC is ON the LED receives current through the virtual short circuit between the 2SC's collector and emitter terminals. The LED is wired to display the letter L for low. Having both 10K Resistors connected to H doubles the base-bias current and simply turns the Transistor ON harder.

When both A and B terminals are on the negative low terminal L, the Transistor can receive no base-bias and is in the OFF state. This state causes the Transistor to act as an open circuit between the collector (C) and emitter (E). This virtual open circuit blocks current from flowing to the LED. The LED is therefore dark (indicating an output high state).

You can use your VOM to verify circuit operation. When OFF, the Transistor C-E voltage approaches the supply voltage (7V at this time due to LED threshold voltage), and when ON this C-E voltage is only a few tenths of a volt (at the most).

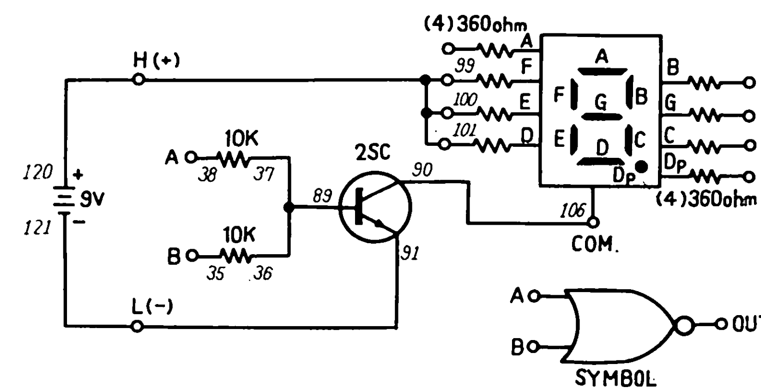
For this particular circuit an open input terminal functions just like a low input. Remember, normal operation of a logic circuit is with the input always connected to either a high or a low.

NOTE: Catch that output indication switch again? A high output is blank and a low output is "I" on the LED. Can you think of some ways in which such reverse logic output is useful?



WIRING SEQUENCE:

99-100-101-120, 106-90, 89-37-36, 38-Long Lead for A, 35-Long Lead for B, 91-121



60. ONE-SHOT MULTIVIBRATOR

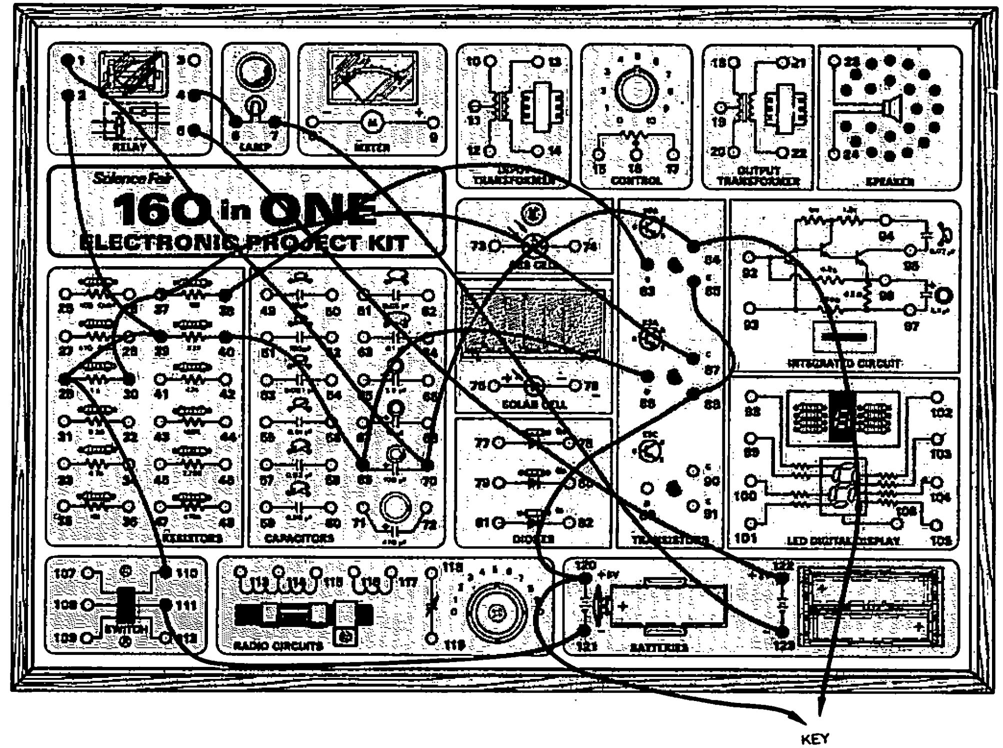
This project allows you to build and demonstrate a one-shot multivibrator, or as it is sometimes called a "pulse stretcher". These are used in logic control circuits and computers to obtain required timing pulses. Generally these are used on pulses which occur so fast that they are measured in small units of time such as the millisecond (1/1000 second) or microsecond (1/1,000,000 second), but to be able to demonstrate this circuit we have used circuit components which give about 2 seconds for the pulse time.

Set the Switch ON (up) and momentarily close the Key. The Lamp should come ON for about 2 seconds and then go OFF until you again press the Key. Try holding the Key down for different lengths of time (up to about 2 seconds). The length of time the Lamp is ON should always be about 2 seconds unless you hold the Key closed too long (2 seconds or longer).

The circuit is called a one-shot multivibrator because it can only remain in its second state for one short time after each initiating pulse from the Key.

This circuit is quite similar to two types of multivibrators (Reset/Set and Free-Running) you will learn later. The base-bias circuit of one Transistor is identical to the Reset/Set type while the other base-bias circuit is similar to the Free-Running type. The operation of this multivibrator is somewhere between the other two.

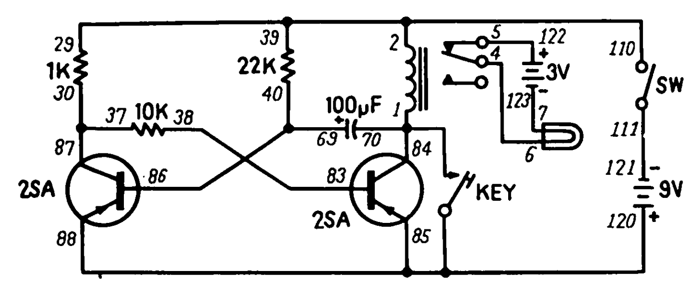
You may want to experiment with different values of capacitance to see how it affects ON time. Be sure to observe proper voltage polarity on the electrolytic Capacitors (those marked with a +).



NOTES

WIRING SEQUENCE:

1-70-84-Key, 2-39-29-110, 4-6, 5-122, 30-37-87, 38-83, 40-69-86, 85-88-120-Key, 111-121, 7-123



61. RESET/SET FLIP-FLOP

The purpose of this project is to study an RS (reset-set) flip flop as used in computer logic circuitry. The electronic circuit used to accomplish the desired circuit action is called a bistable multivibrator. That is, the circuit is a multivibrator which has two stable states, RESET and SET. Once either of these states or conditions exist, it will remain in this state as long as the supply voltage is applied. This ability to remain in either state long after the initial state is obtained is called "memory".

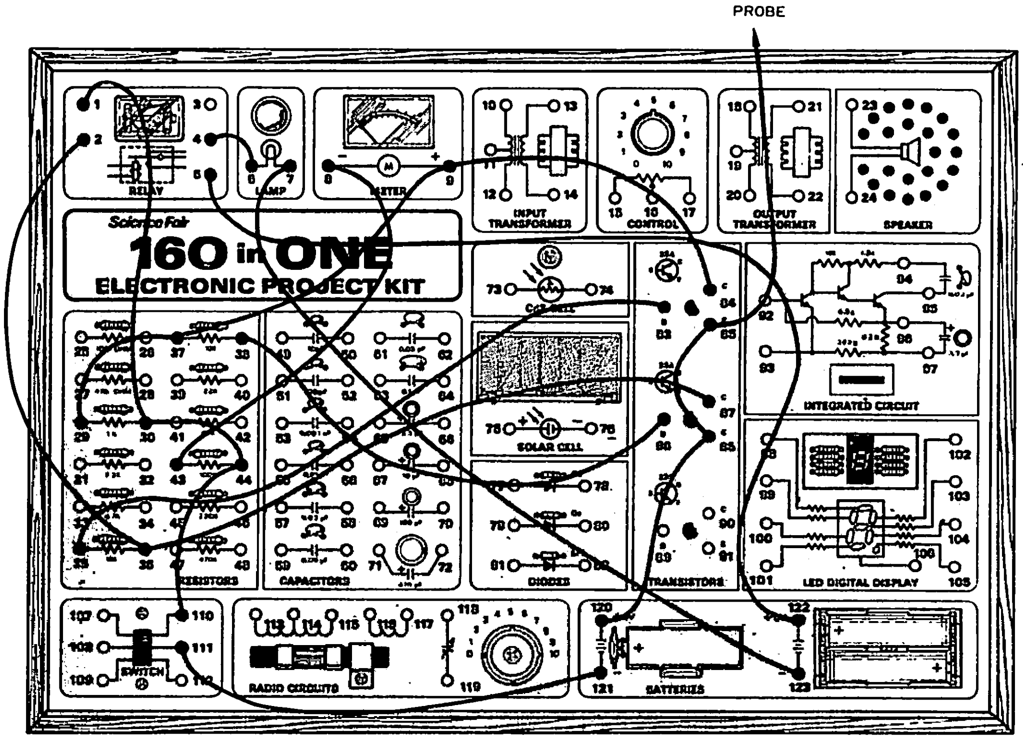
The circuit functions as follows: When the Lamp is ON it indicates the SET state or condition. When the Meter deflects to near mid-scale it indicates the RESET state. It is impossible to have both states at the same time.

Use the lead wire from terminal 85 to apply an intermittent input to terminal 86 for the RESET state, and terminal 83 for the SET state. Notice that once a terminal has been touched with the lead wire, the circuit locks itself into one of the states and repeated touches have no effect. Also, if left alone the state will remain as long as the battery is good and the Switch ON (up).

To understand circuit operation, assume the Lamp is ON. The Relay must be receiving field coil current, so the 2SA (2) is ON. C-E voltage on the 2SA(2) is less than 0.5V. This voltage is too low to be able to bias the 2SA(1) base through the 10K, so the 2SA(1) is OFF. With the 2SA(1) OFF its C-E circuit acts as an open circuit. This allows the 1K and 10K to pass bias current on to the 2SA(2) to turn it full ON and hold it ON. Meter deflections is only a small amount at this time.

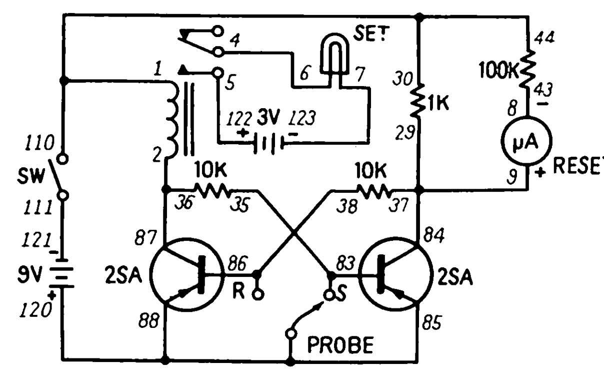
Now if the lead probe is used to short circuit across the B-E junction of the 2SA(2), it turns OFF. Collector current decreases so the Relay drops out (OFF), but now the 2SA(1) is fed base-bias current throughout the Relay coil and 10K so that it is turned ON. Its C-E voltage drops to less than 0.5V, preventing the 2SA(2) from getting bias through the 10K.

Shorting the B-E junction of the 2SA(1) will exchange the ON, OFF functions again by a similar process. These switching actions occur very fast because of the regenerative feedback between the stages.



WIRING SEQUENCE:

4-6, 5-122, 1-30-44-110, 2-36-87, 7-123, 8-43, 29-37-9-84, 35-83, 38-86, 120-88-85-Probe, 111-121



NOTES

62. FLIP-FLOP WITH LED DISPLAY

The purpose of this project is to see how a display readout can be controlled by a free-runing multivibrator or "flip-flop".

This type of control is used in most hand calculators but at such a high rate of speed that you can't see the numbers flicker. It is also used in some equipment as a logic circuit clock pulse generator. Flip-flops have many applications in electronics.

This flip-flop (or free-running multivibrator, as this circuit is more often called) uses two Transistors, two Capacitors and four Resistors to accomplish a variable-speed ON-OFF control of the LED. The LED is wired to flash the number "1".

The Transistors are always in opposite states; when the 2SA(1) is ON, the 2SA(2) is OFF and when the 2SA(2) is ON, the 2SA(1) is OFF. The changes of states from ON to OFF and OFF to ON is accomplished very fast (in microseconds) because of regenerative feedback between the two Transistors. Changing from one state to the other is called the "flip", and then changing back to the original state is called "flop".

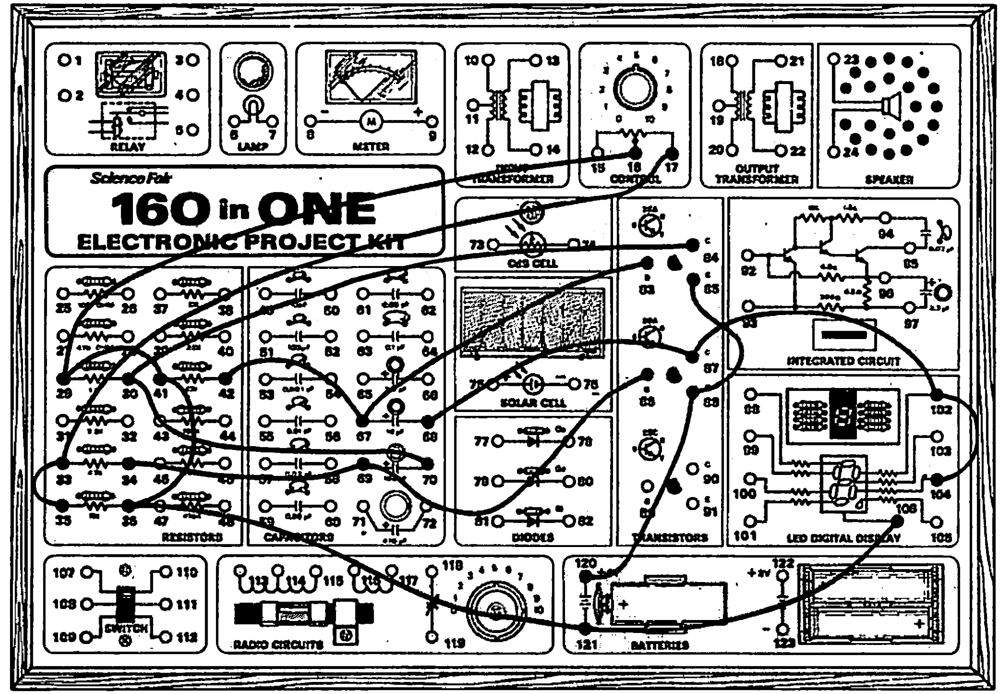
This flip-flop action may be explained as follows: Recall that a Transistor which is ON acts as if it has a short circuit between C-E, and when it is OFF it acts as if it has an open circuit between C-E. Also, notice that base-biasing Resistors are provided for both Transistors so that if no feedback were provided from the Capacitors, both Transistors would be ON. Obviously, the function of the Capacitors is to hold alternate Transistors in the OFF state.

Let's start an assumed circuit operation with the 10uF holding the 2SA(1) in the OFF state. The 2SA(2) is then ON and the 100uF is charged quickly through its series 10K Resistor and B-E junction of the 2SA(2), by the Battery. The 4.7K and 50K Control keep the 2SA(2) in the ON state after the 100uF is charged up. At this time the charge which is on the 10uF is slowly discharging through the 47K Resistor, Battery and C-E elements of the 2SA(2). Remember, the 2SA(2) is ON, and its C-E elements act like a short circuit. The voltage on this Capacitor maintains a reverse-bias on the 2SA(1) as long as the charge is sufficiently high.

Before the 10uF is completely discharged, the low C-E voltage of the 2SA(2) allows the negative voltage from the 47K to turn the 2SA(1) ON. The instant the 2SA(1) is turned ON, the 100uF quickly turns the 2SA(2) OFF. With the 2SA(2) OFF, its collector voltage is allowed to rise toward the 9V of the Battery. As this occurs, the LED is turned OFF, and through the fast charging of the 10uF, the 2SA(1) is turned full ON. This change in state of "flip" occurs very quickly (microseconds).

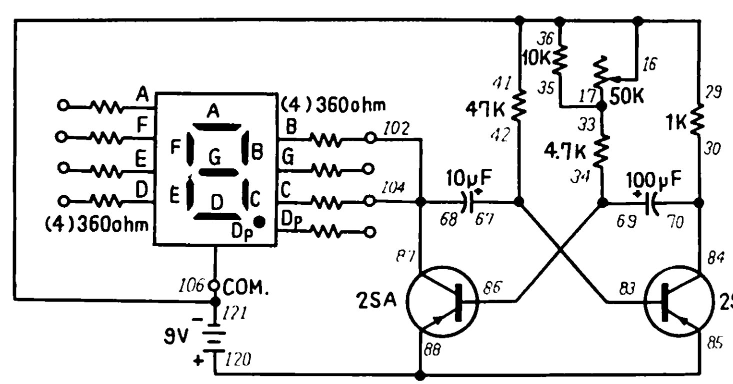
After a while the charge on the 100uF is decreased to where it can no longer hold the 2SA(2) OFF, and the circuit "flops" back to the original state to begin the above action, again. Adjust the 50K Control throughout its range and notice the effect on LED flashing rate. Use your VOM to measure Capacitor voltages, Transistor voltages and LED voltage while the circuit is operating. The slow rate of flashing should allow you to correlate the VOM readings with circuit opeation. Can you now explain circuit operation to someone else without referring to any notes? If you can, you have come a long way. This circuit seems very complicated until you study it for a while.

You can verify the circuit operation by temporarily short circuiting the B-E junctions of first the 2SA(1) and then the 2SA(2). This holds the shorted Transistor in the OFF state in place of the charged Capacitor.



WIRING SEQUENCE:

104-102-87-68, 106-121-36-41-29-16, 17-33-35, 84-30-70, 83-67-42, 86-69-34, 85-88-120

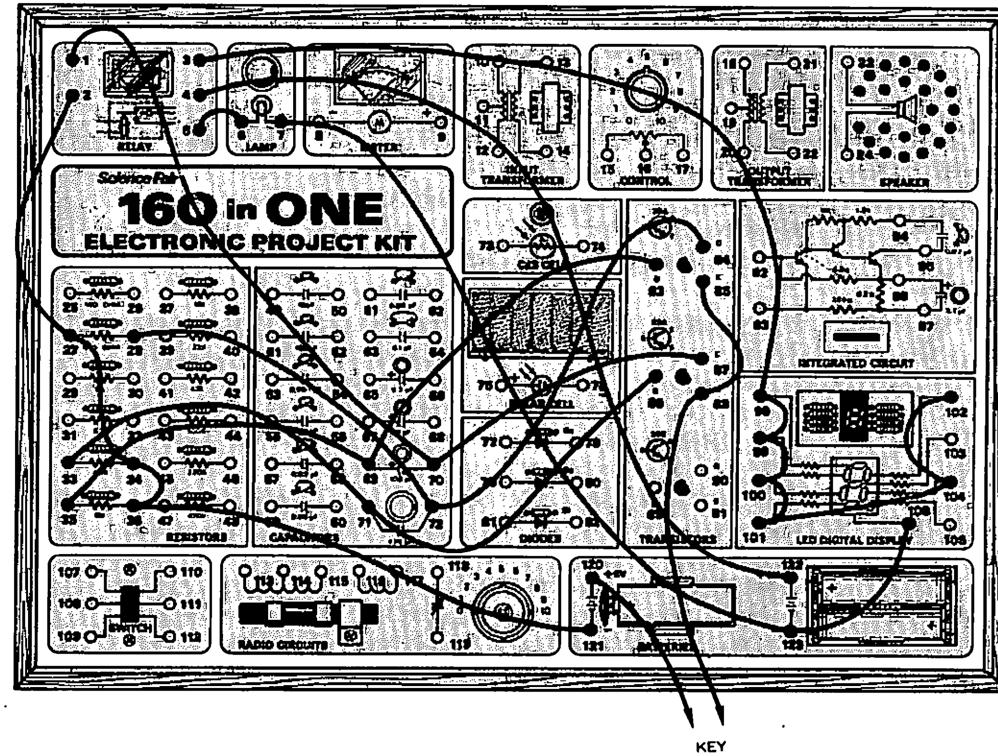


63. FLIP-FLOP LED/LAMP DISPLAY

This project is an application of the flip-flop oscillator circuit, which we've decribed in detail elsewhere. During one half-cycle the Lamp is ON, and during the other half-cycle the LED displays a zero.

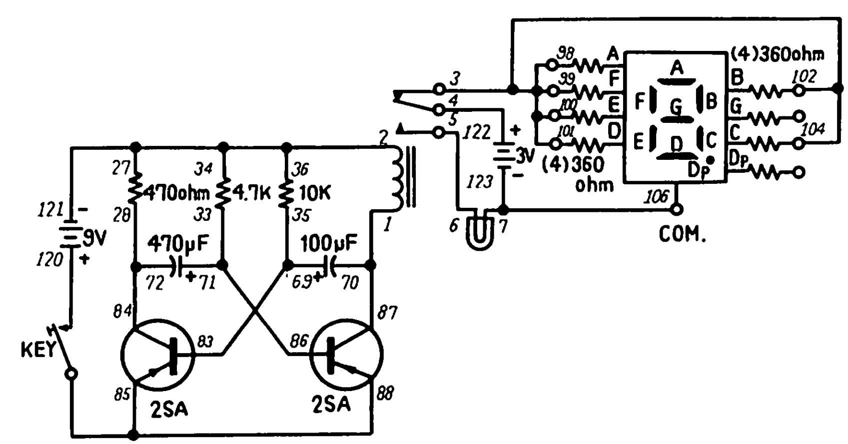
How about a little research on your own? Either from memory or by reference to other project write-ups in this kit, decribe the operation of the multivibrator flip-flop. Try to use such terms as "Transistor OFF and ON" states, "charging current" and "discharge current". Use the space provided below for your writeup. Use a pencil so you can make changes after you read it over and decide on better ways of expressing circuit action. A good technician should take pride in being able to explain basic circuit actions. Have fun!

NOTES



WIRING SEQUENCE:

3-98-99-100-101-104-102, 106-123-7, 6-5, 1-70-87, 2-27-34-36-121, 84-72-28, 83-69-35, 122-4, 86-71-33, 85-88-Key, Key-120



64. MULTIVIBRATOR SWITCHING OF LED DISPLAY WITH DIODES

The purpose of this project is to show how an LED display may be controlled with a free-running multivibrator.

Since this circuit causes the numbers 1 and 2 to flash alternately ON and OFF, it reminds us of some neon advertising signs with flashing, eye-catching ads. Here the LED is controlled by a free-running multivibrator to power the correct segments, giving a continous alternation of the numbers 1 and 2.

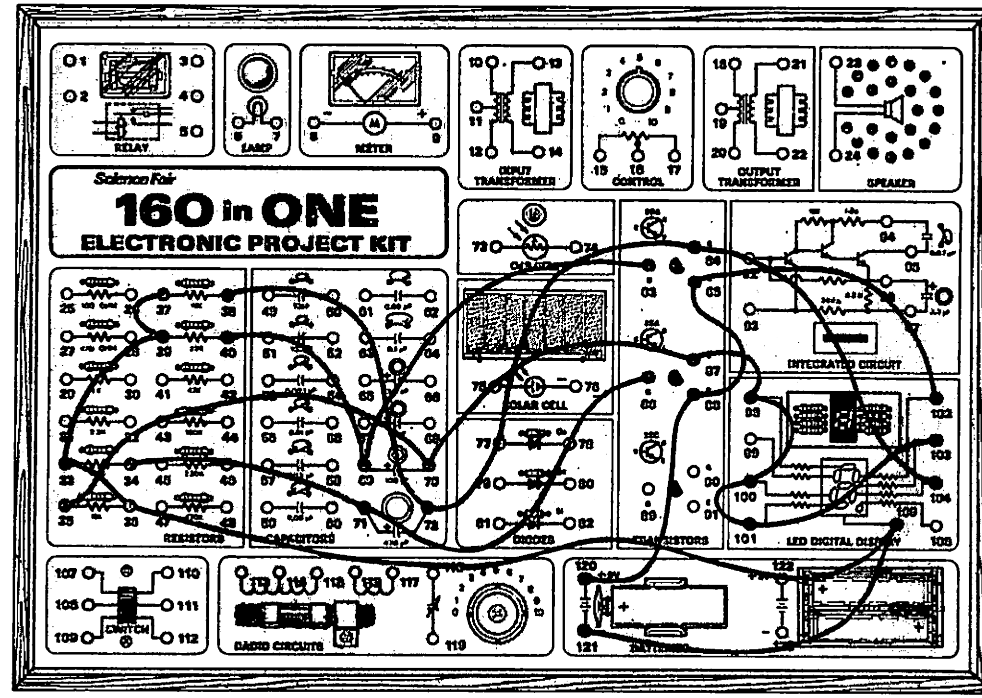
The multivibrator uses Transistors 2SA(1) and 2SA(2) with four Resistors and two Capacitors to produce two out-of-phase square waves to drive the LED segments. When the 2SA(1) is ON, the 2SA(2) is OFF, and vice versa. This ON and OFF operation is accomplished automatically, due to the alternate charging and discharging of the 100uF and 470uF Capacitors. For example, as the 470uF is receiving a charge through its 10K Resistor from the negative 9V Battery terminal, this charging current is caused to flow through the base emitter junction of the 2A(2), turning it ON. After a very short time, the Capacitor is charged, but the 47K Resistor keeps the 2SA(2) ON. During all this time the charge which is in the 100uF is slowly discharging through the 22K, Battery and 2SA(2). The voltage on this Capacitor will hold the 2SA(1) in the OFF state until it discharges to a point where it cannot hold the 2SA(1) OFF any longer. At this point the circuit "flips", and the 100uF begins to charge, turning the 2SA(1) ON. Now the functions of the Capacitors (and Transistors) are reversed so that the 2SA(1) is quickly turned ON by the 100uF, and the 2SA(2) is turned OFF by the 470uF. After a short time the circuit action switches or "flops" back to the opposite state as the 100 uF reaches the end of its discharge.

When the 2SA(2) is ON, the A, E, D, B and G segments of the LED light to form the number 2, and when the 2SA(1) is ON the B and C segments light to form the number 1. Notice that is both instances the B segment lights, due to its direct connection to the (+) terminal of the Battery.

You can measure voltages across any component in this circuit with your VOM while watching the LED operation. Thus you can verify the circuit explanation and you can learn how it works. This is a popular circuit so you will see it often in days to come.

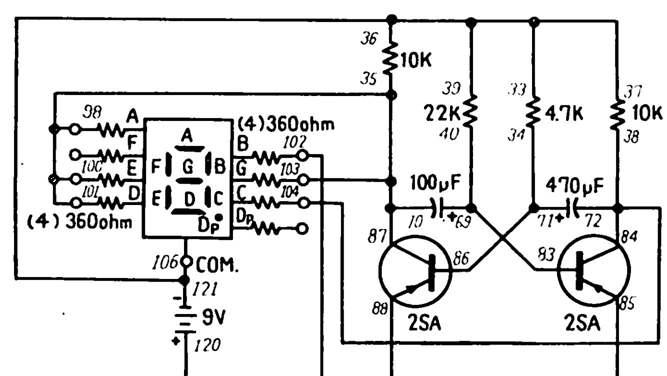
Some of the different experiments you might want to try are: different size Capacitors to see their effect on the speed of operation; rewire the LED to display numbers other than 1 and 2. You may try different, higher values in place of the 22K and 4.7K. Do not use lower values for any of the Resistors or you may damage the Transistors.

NOTES



WIRING SEQUENCE:

103-101-100-98-87-70-35, 104-84-72-38, 120-88-85-102, 83-69-40, 86-71-34, 37-39-33-36-106-121



65. TOGGLE FLIP-FLOP

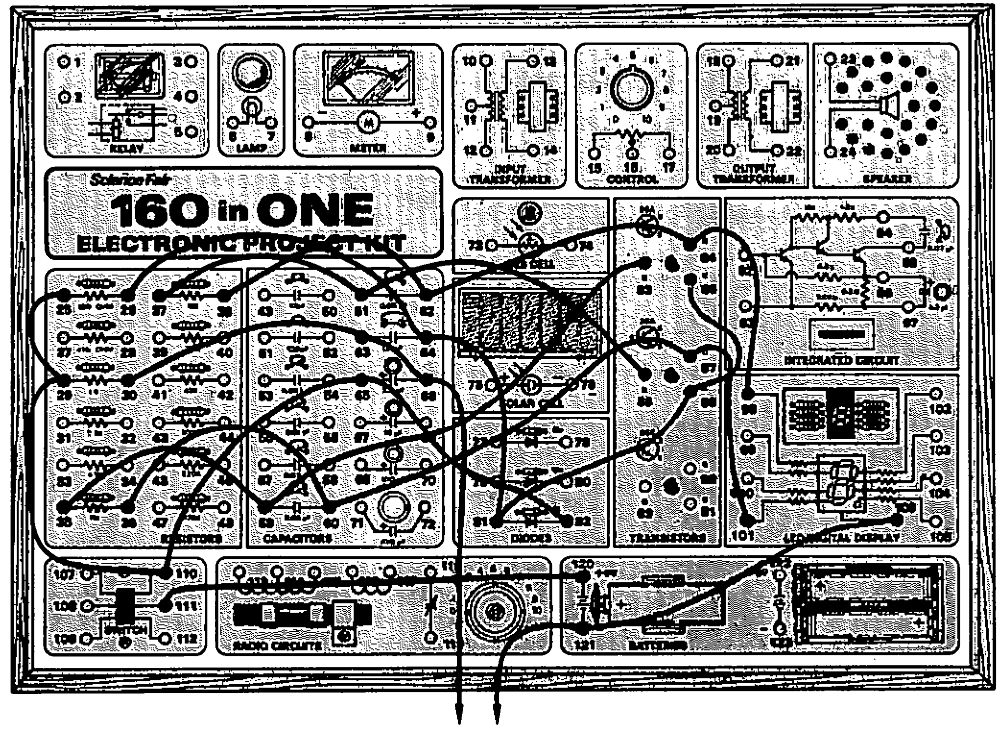
A toggle switch is used in electronics to turn circuits ON and OFF, and that is what this flip-flop (multivibrator) circuit does.

After the wiring is complete, set the Switch to the ON (up) position. The lower segment of the LED (D) should light. Now press the Key. The lower segment will go OFF and the upper segment (A) will light. Each time the Key is pressed the ON segment will change (flip-flop), and it will not change again until you tell it to by pressing the Key.

This circuit works very much like project 61 in that it sets and resets; when one Transistor is ON the other is OFF, and it stays ON (or OFF) until it is told to change. The difference is that the switching is done by the repetition of a single input, rather than by changing from one input to another.

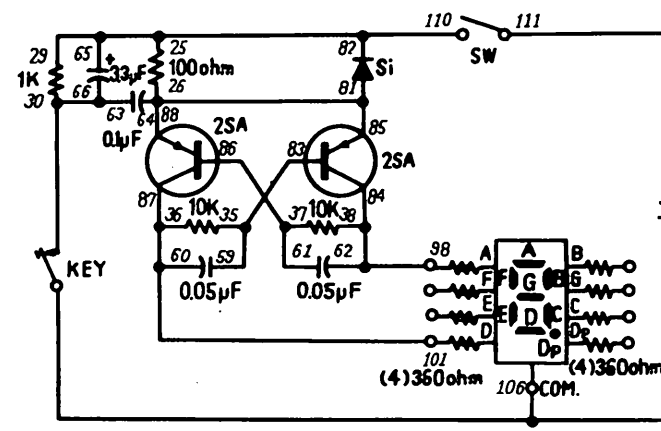
We have already said that flip-flop circuits can 'remember' things because of their set/reset ability. That means that several flip-flops controlled by a single toggle signal can remember several things. That's how computers remember so many things.

NOTES



WIRING SEQUENCE:

25-29-110-65-82, 26-64-81-88-85, 30-63-66-Key, 35-59-83, 36-60-87-101, 37-61-86, 38-62-84-98, 111-120, 106-121-Key



66. EXCLUSIVE " OR " LOGIC CIRCUIT

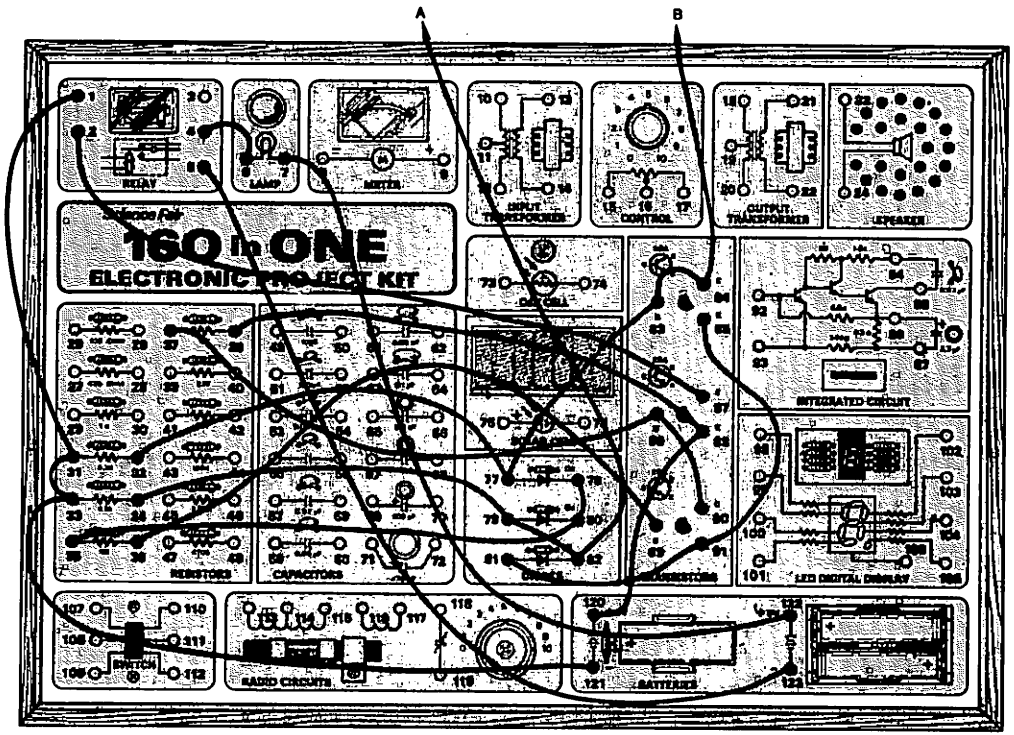
The best way to understand what an exclusive OR circuit is, is to compare its Truth Table with the one for the OR circuit.

A	B	OUTPUT
L	L	L
L	H	H
H	L	H
H	H	L

When both inputs are L (OFF) or if one input is L while the other is H (ON), the Truth Table is the same. The difference is that if both inputs are H, the output is L. In other words, the input must be H from only one source OR the other EXCLUSIVELY for the output to be H. This type of circuit is abbreviated XOR.

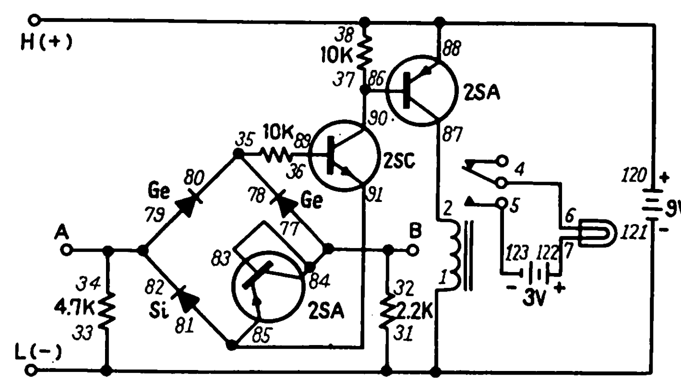
There can also be Exclusive NOR circuits (XNOR). We won't build one here, but maybe you can figure out how since it's similar to a NOR circuit. If you do figure it out, be sure to make notes.

NOTES



WIRING SEQUENCE:

1-31-33-121, 2-87, 4-6, 5-123, 7-122, 32-77-83-84-Long Wire (B), 34-79-82-Long Wire (A), 37-86-90, 78-80-35, 81-91-85, 36-89, 38-88-120



67. COIN BATTERY AUDIO OSCILLATOR

Oscillators — you've been using them all along. This section will give you a lot more circuit ideas and help you understand this very important circuit function.

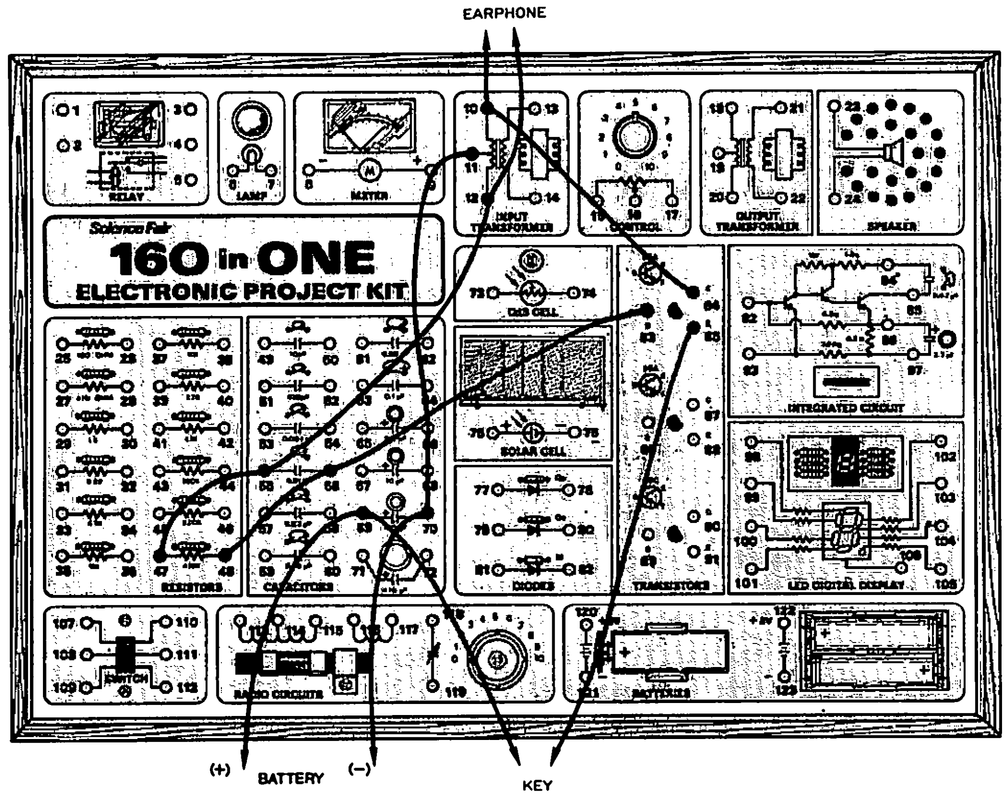
This project is a simple audio pulse oscillator which is powered by a coin battery as described in project 20.

The 0.01uF provides a high amount of feedback to sustain oscillations, and the 470K Resistor is used to turn the Transistor ON enough to allow the Transistor to operate as an amplifier (and therefore also an oscillator).

The 100uF Capacitor bypasses the audio oscillator current so that oscillations can be obtained even though the coin battery has a high internal resistance. If the oscillations sound chirpy or die out as you close the Key, the coin battery current output is weak.

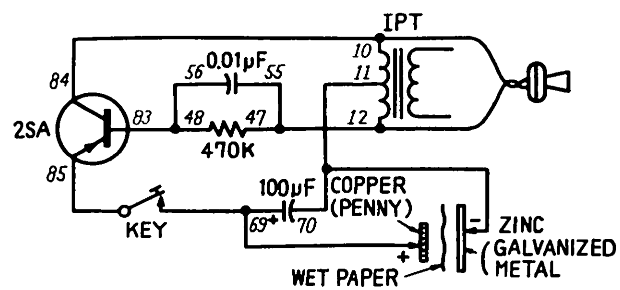
Try different materials for the coin battery and electrolyte. You can even try the following with a penny, damp paper and a nickel!!! How about that for a 6-cent battery that is still worth 6 cents when you are finished with it?!

NOTES



WIRING SEQUENCE:

Earphone-10-84, Earphone-12-55-47, 83-56-48, 11-70-Battery (–), 85-Key, Key-69-Battery (+)



68. OSCILLATOR WITH TURN-OFF DELAY

The purpose of this project is to demonstrate how an OFF delay can be obtained for a circuit. The oscillator used for this demonstration is a common type described elsewhere in this manual. The delay is accomplished with one component; a 470uF Capacitor.

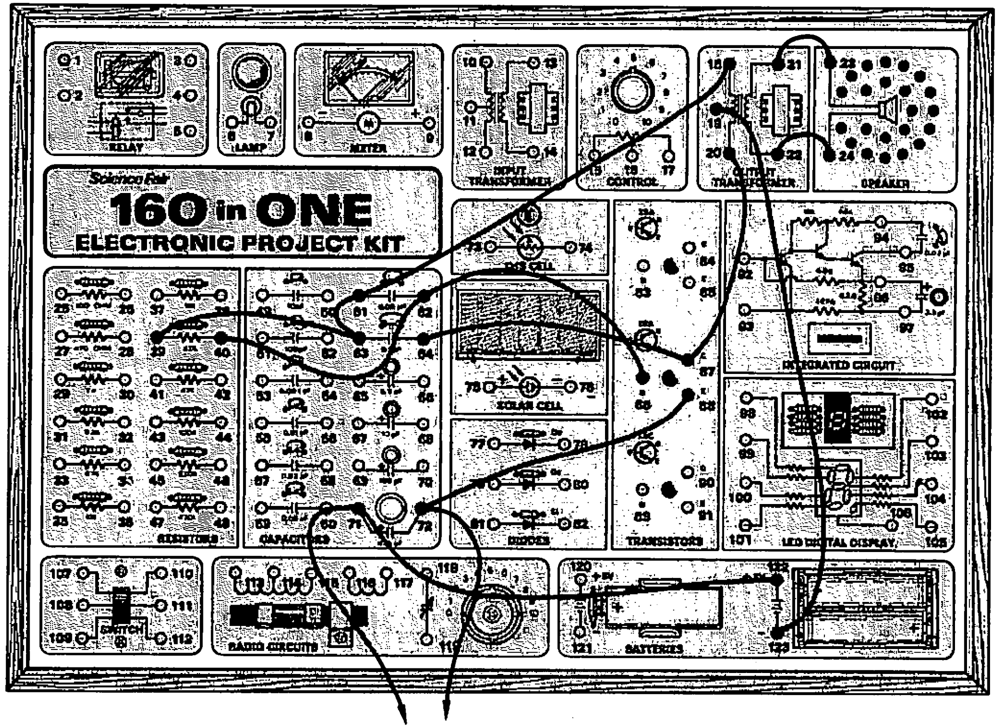
During normal operation of the oscillator the closed Key is in parallel with the Capacitor, so the Capacitor is completely discharged. At the instant the Key is opened the Capacitor begins to charge. The current necessary to build up a charge must come from the Battery, through the oscillator circuit. The circuit continues to oscillate until the Capacitor is charged up, at which time current stops flowing. When the Key is closed for the second time it immediately discharges the Capacitor so that delay action is again possible when the Key is opened.

This unique characteristic of a Capacitor is called storage-action, and is responsible for many functions the Capacitor can perform. A discharged Capacitor has an equal number of electrons on the (+) and (-) electrodes, but a charge is stored in a Capacitor by drawing electrons off the (+) electrode to make it positive while an equal number of electrons are added to the (-) electrode to make it negative. The current which flows to establish the charge is called "charging current" or "displacement current". When the Capacitor is discharged this same amount of current must flow in the opposite direction to establish the no-charge condition. 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 may be measured with the current function.

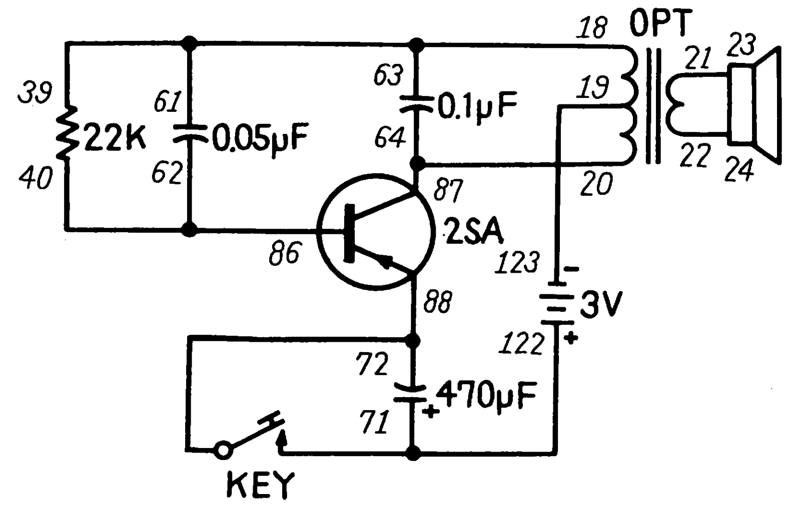
It is this storage action of Capacitors which makes Capacitors in high voltage circuits a source of possible shock or electrocution. Play safe! Discharge Capacitors before touching them if voltages above 50V or so have been applied.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 18-61-63-39, 19-123, 20-87-64, 86-62-40, 88-72-Key, Key-71-122



69. TEMPERATURE SENSITIVE AUDIO OSCILLATOR

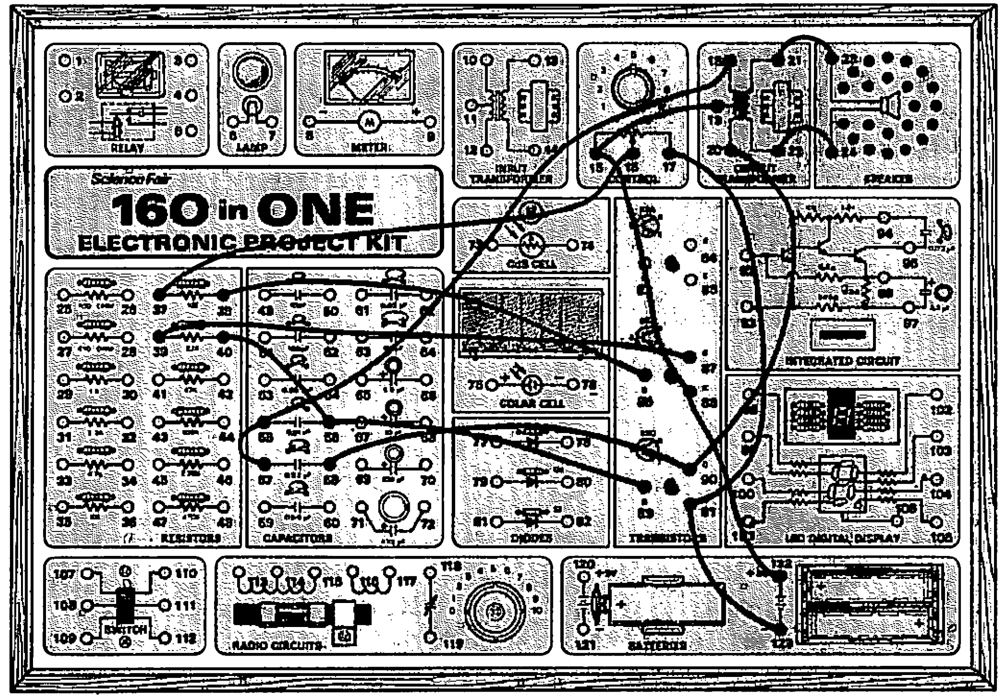
This project demonstrates how Transistor collector current depends on temperature, by using the leakage current of a Transistor to control the frequency of an audio oscillator.

The 2SC Transistor is operated as a pulse-type oscillator. The bias voltage is controlled by the series circuit made up of the 22K Resistor and the resistance of the 2SA Transistor between C-E (collector-to-emitter).

This circuit is similiar to the Electronic Thermometer in project 21. The base current and collector current of a Transistor vary with the temperature when you apply a specified base bias voltage to the Transistor.

Adjust the 50K Control so that the Speaker output is a low sound or pulses. Now warm up the 2SA Transistor by holding it between your fingers. You should hear the tone become higher as the Transistor temperature is increased.

NOTES



WIRING SEQUENCE:

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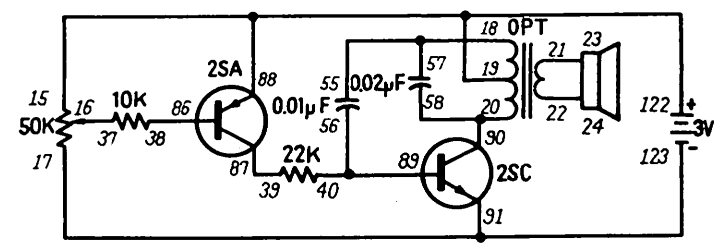


70. CAPACITIVE CHARGE OSCILLATOR

This project demonstrates how an oscillator can be made to operate a long time by the energy stored in a Capacitor. It also uses a different type of oscillator circuit from what you have been using throughout this kit.

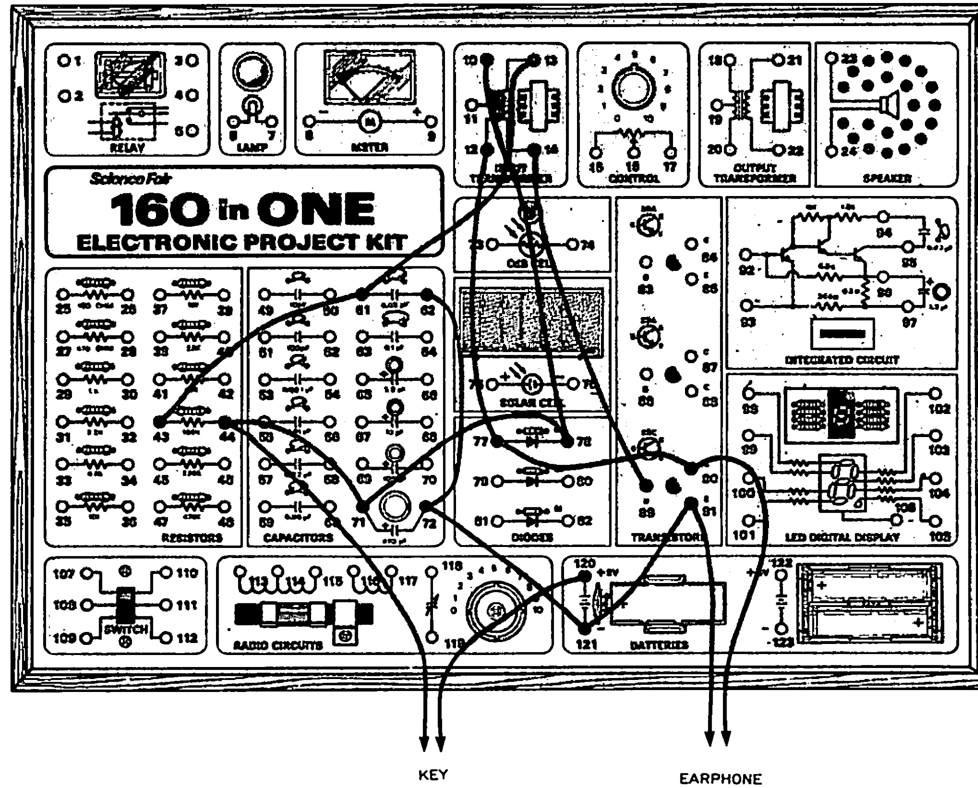
After the switch is opened, the circuit continues to oscillate for about a minute. One reason for such a long time is that the oscillator has a very short "duty cycle". The duty cycle is a measure of comparison between the time a circuit is conducting and the total time to complete one cycle. This circuit, like most pulse and blocking ocillators, conducts for less than half of the total time the circuit is ON. In fact, 10 to 15 percent of the time is all that is used for the ON time in this circuit.

This circuit has both the requirements of an oscillator. That is, gain greater than 1 (the output is greater than the input), and regenerative feedback to sustain oscillations. The Transistor provides a gain much greater than 1 (1 stands for the value of the input). The Transformer provides regenerative feedback with proper polarization of the windings. To demonstrate this, exchange the wires between terminals 13 and 14. The correct phase is the one that gives the oscillations.

The 100K Resistor initially supplies base-bias current to the 2SC to begin oscillations, but once oscillations begin it provides a discharge path for the 0.05uF Capacitor during the Transistor OFF times. During the ON times the Capacitor is charged and the Transistor held on by the induced voltage from the Transformer base winding.

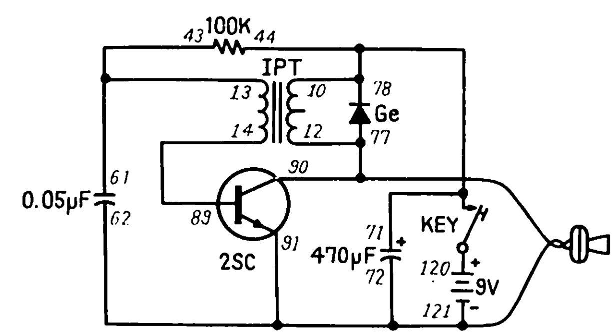
The germanium (Ge) Diode shorts out the Transformer at the instant the current stops flowing through the Transformer as the Transistor is turned OFF. This protects the Transistor from this potentially destructive spike of energy(the Diode circulates the current back around the Transformer winding so that no harm is done. During all other parts of the oscillation cycle, the Diode receives either reverse bias voltage or zero voltage so that it acts like an open circuit. Remember, in all semiconductor devices current can only flow against the arrow head symbol.

NOTES



WIRING SEQUENCE:

13-61-43, 14-89, 10-78-71-44-Key, 12-77-90-Earphone, Earphone-91-121-72-62, Key-120



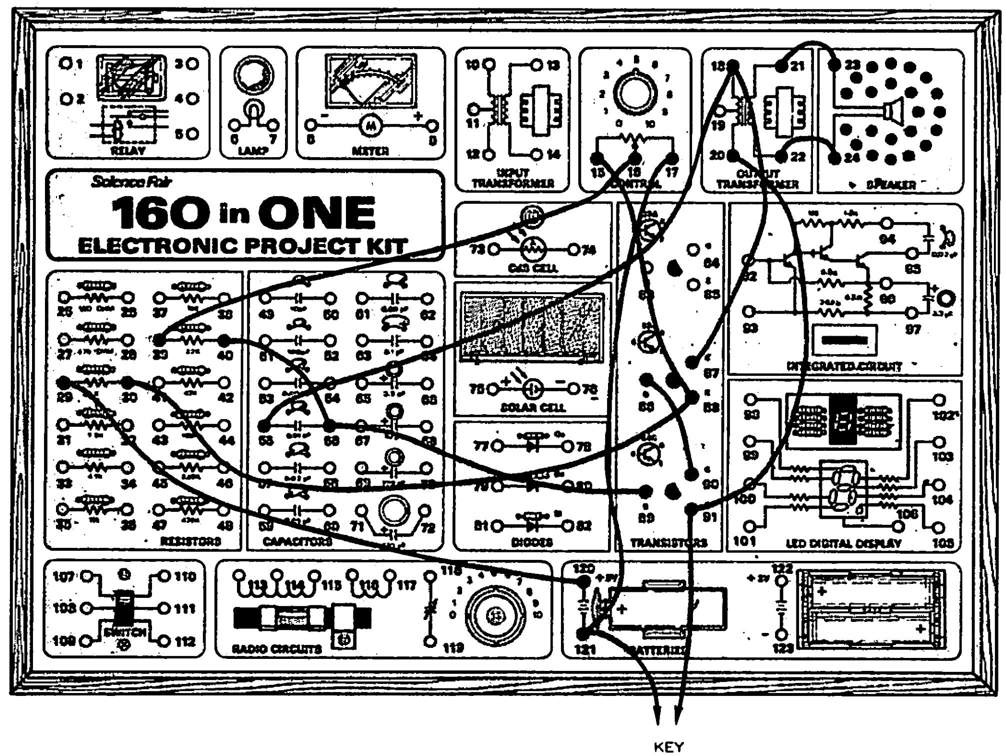
71. TWO-TRANSISTOR, DIRECT-COUPLED OSCILLATOR

This is the two-transistor, direct-coupled oscillator which you have seen in other projects. Do you recognize it? Remember, a good electronic technician must be able to recognize a circuit with any kind of Schematic arrangement. Can you spot the variations?

This circuit has enough built-in current limiting (the 1K) so that you can experiment with different Capacitor values for "C". The initial hookup is with the 0.01uF in the circuit. You may want to record your results like a good scientist, so you can repeat the experiment later on. Polarize electrolytic capacitors properly.

After studying the other projects which use this basic circuit, try to explain circuit operation to yourself, or better yet, to someone else. Draw arrows of current flow on the diagram as required.

NOTES



WIRING SEQUENCE:

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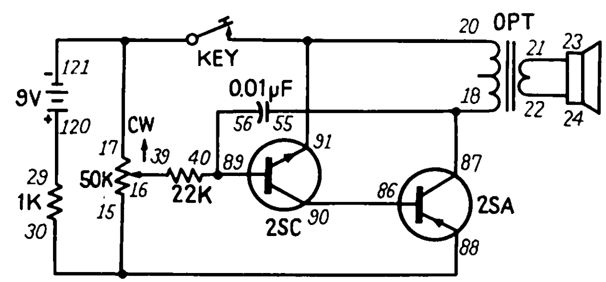


72. PUSH/PULL SQUARE WAVE OSCILLATOR

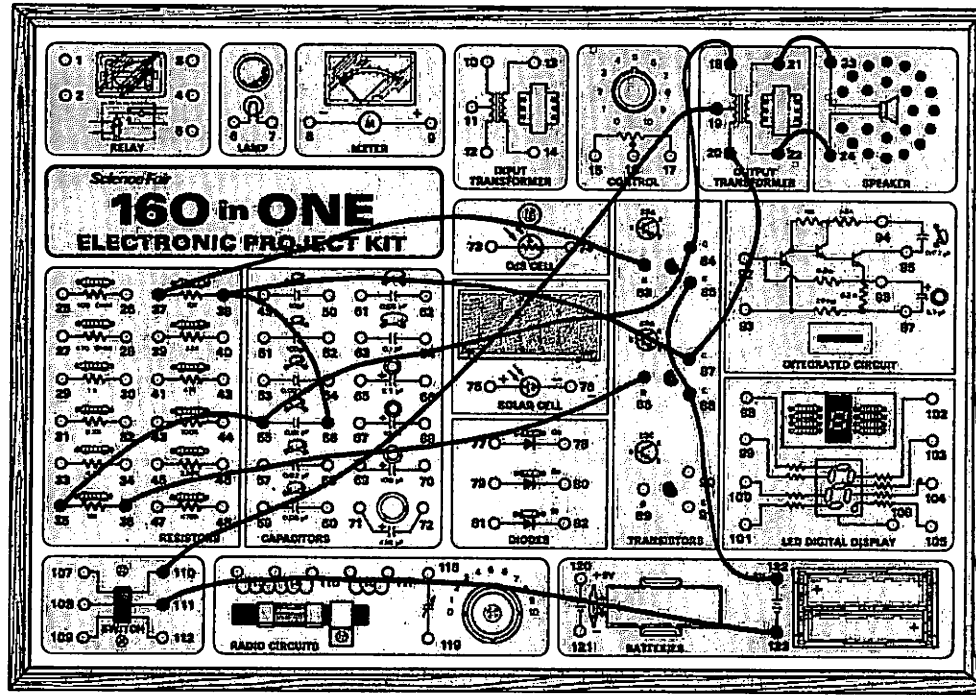
This project demonstrates a push/pull, square wave oscillator. The square wave is used for many applications in electronics. Some of these uses include: driving logic circuits, which require fast rising and falling voltage waveforms to trigger the logic circuits' operation, converting DC to AC with high efficiency, testing frequency and phase response of circuits, etc.

A square wave is rich in odd harmonic frequencies. That is, a 100 hertz square wave also contains frequencies of 300, 500, 700, 900Hz, etc., all of which are equal to the fundamental frequency of 100 times the odd counting numbers. The strength of the harmonic frequencies decreases as the frequency increases, but for good square waves measurable harmonics exist up to dozens of times higher than the fundamental.

The 0.01uF Capacitor is added to insure that spikes of high frequency content are minimized. Without this Capacitor the output is not a clean square wave, but is mainly spikes.

This circuit is very reliable for low DC supply voltages. For this reason, it is very popular in DC to AC converters and DC to DC inverters, where the supply voltage is anything from about 0.5 to 12 volts. You may want to experiment with lower voltages for this circuit by removing one of the AA penlight Batteries and replacing it with a short circuit. Do not use higher voltages on this particular circuit or the 2SA(A) (which is a low-power RF Transistor) may be ruined.

Another characteristic of this oscillator is that it makes maximum use of the Transformer power handling capabilty. That is, maximum output power is obtained for the particular size Transformer used.



WIRING SEQUENCE:

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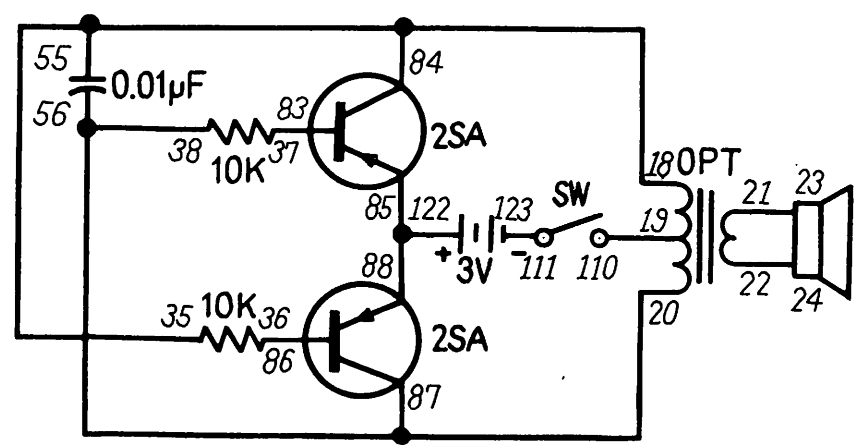


NOTES

73. MICRO-POWER SOLAR CELL OSCILLATOR

This is a Solar Cell powered oscillator which uses the least number of parts compared to any other oscillator — five parts counting the Earphone. The oscillator configuration is push/pull. Output frequency is inversely proportional to light brightness. That is, high brightness yields low tones and low brightness yields high tones.

Power output from the Solar Cell is low enough that no protection or current limiting components are required. This is why there is a minimum of components.

You can use a code Key if you like by inserting it in series with either Solar Cell lead. The keyed tone isn't the best, but what do you expect for a circuit designed for minimum component parts and low supply power!

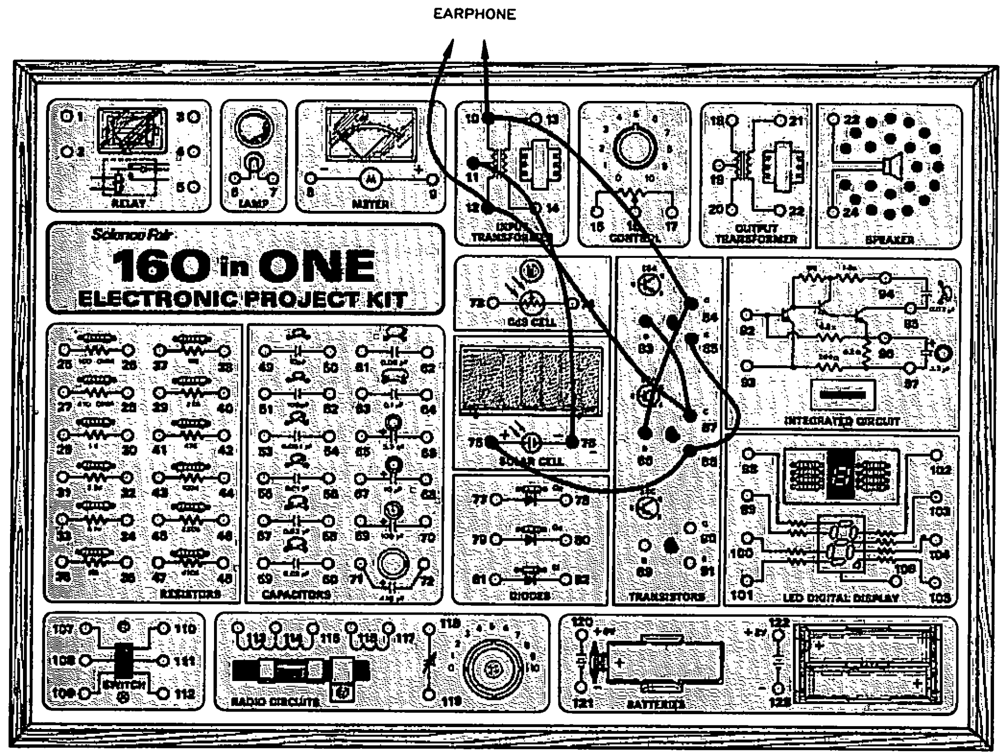
This circuit will oscillate with only about 0.05 volts applied. The current at this voltage is only about 0.000,005 amps (5 microamps). This not only shows how well the circuit works on low power, but also how well the Earphone works on low power.

If you want to measure the circuit current you can insert the Meter in series with the Solar Cell like you did the Key. If you bypass the Meter with the 3.3uF Capacitor (properly polarized) the circuit will retain the good low light characteristics which it had before you added the Meter. The full scale rating is about 250uA (microamps), so the top (blue) scale represents 25uA for each whole numbered calibration.

CAUTION: To remove possibly damaging stored current, temporarily short circuit across the 3.3uF Capacitor before placing it across the Meter.

One of the biggest advantages to a circuit like this is: NO BATTERIES ARE REQUIRED!!

NOTES



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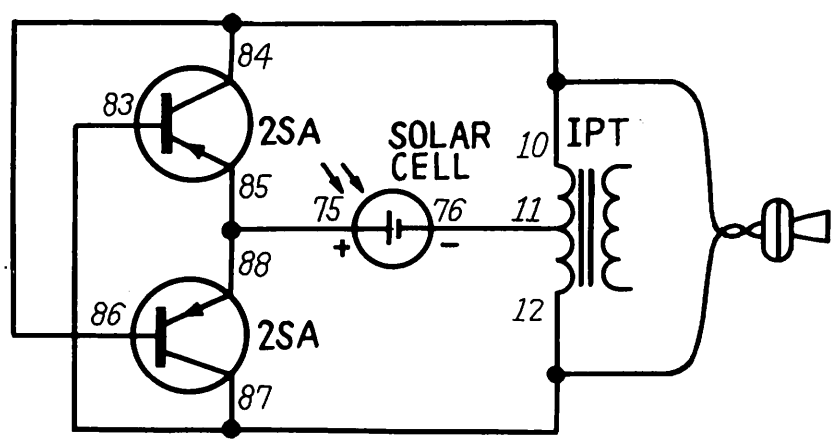
86-84-10-Earphone, 83-87-12-Earphone, 11-76, 75-88-85



74. MICRO-POWERED SOLAR CELL OSCILLATOR WITH SPEAKER

This project is the same as 73, modified to power a Speaker at the output. The characteristics are very similar, so we will only suggest some experiments for you to try. The circuit will work without the two added Capacitors, but these are included to make the tone more pleasant.

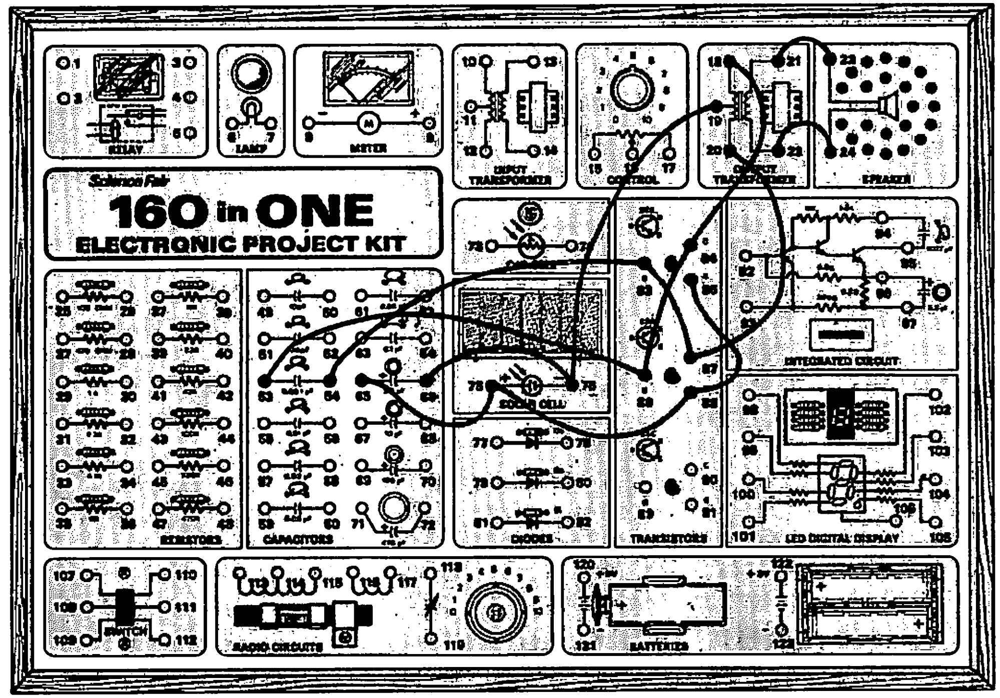
As with the Earphone circuit, you can connect the Meter in series with the Solar Cell to measure total current. Connect it so that the 3.3uF bypasses the Solar Cell and Meter. In order to measure the current at high light intensities, parallel the Meter with a 470 ohm Resistor. This makes the full-scale Meter calibration about 600uA, because at full-scale 250uA goes through the Meter and 350uA goes through the 470 ohm Resistor.

The same Meter-shunting concept can be used with other Resistors in the kit, or that you have in your "junk box". The highest full-scale current reading you can get using the Resistors in the kit is about 2mA when using the 100 ohm Resistor. The formulas to use for other Resistors or currents are as follows:

$$RS = \frac{162}{IT-0.25}\text{ohms,} \qquad \text{or} \qquad IT = \frac{162}{RS} + 0.25\text{mA}$$

RS is the Meter shunting resistance in ohms and IT is the new full-scale current calibration in milliamperes (mA).

NOTES



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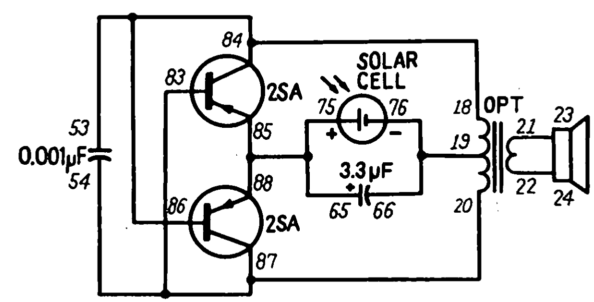
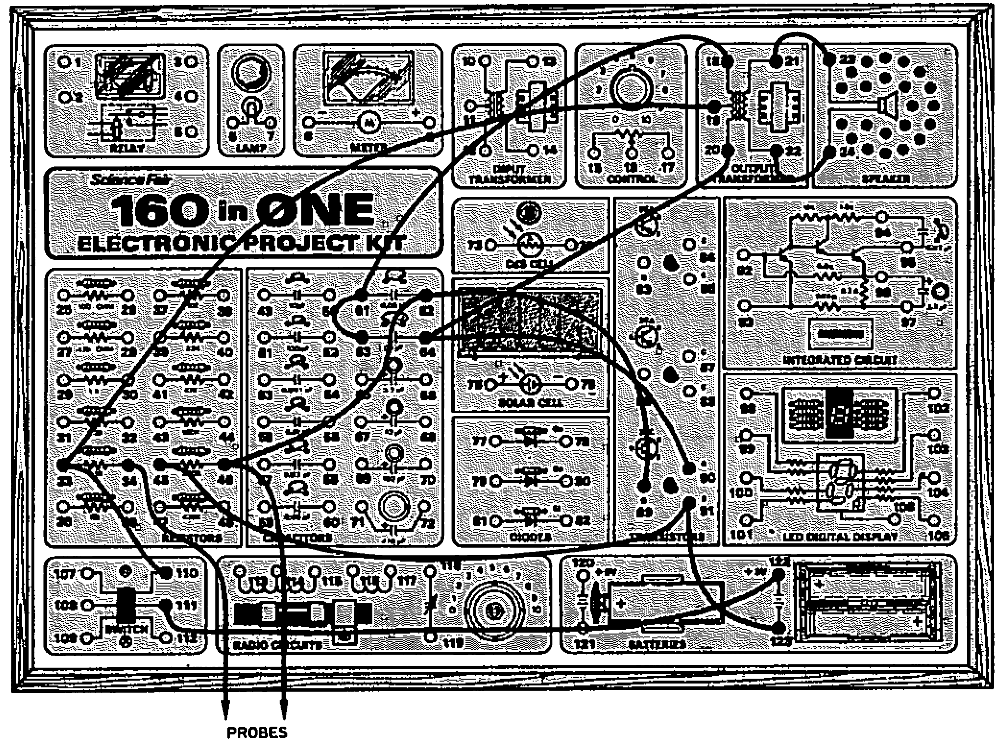


75. PENCIL LEAD ORGAN

This project is an oscillator, like some of the others you have built, but it is controlled in an unusual way: with a pencil mark! You have seen, in other oscillator projects, how changing the resistance can change the sound. 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.

After you finish the wiring, you will need to make a very heavy pencil mark on a sheet of paper (a soft lead pencil will work best). The mark will need to be about 1 inch (2.54 cm) wide and 5 to 6 inches (14 cm) long. Now hold one of the Probes to one end of the mark (or attach it with tape) and move the other Probe back and forth along the mark. You will 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



WIRING SEQUENCE:

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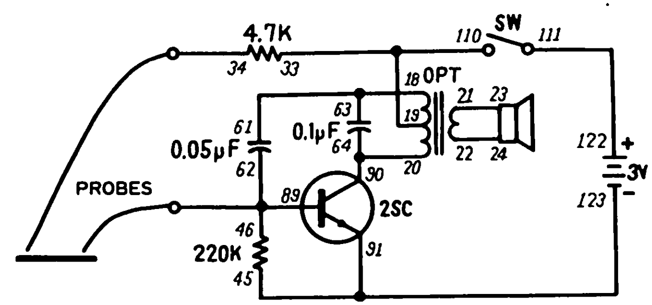


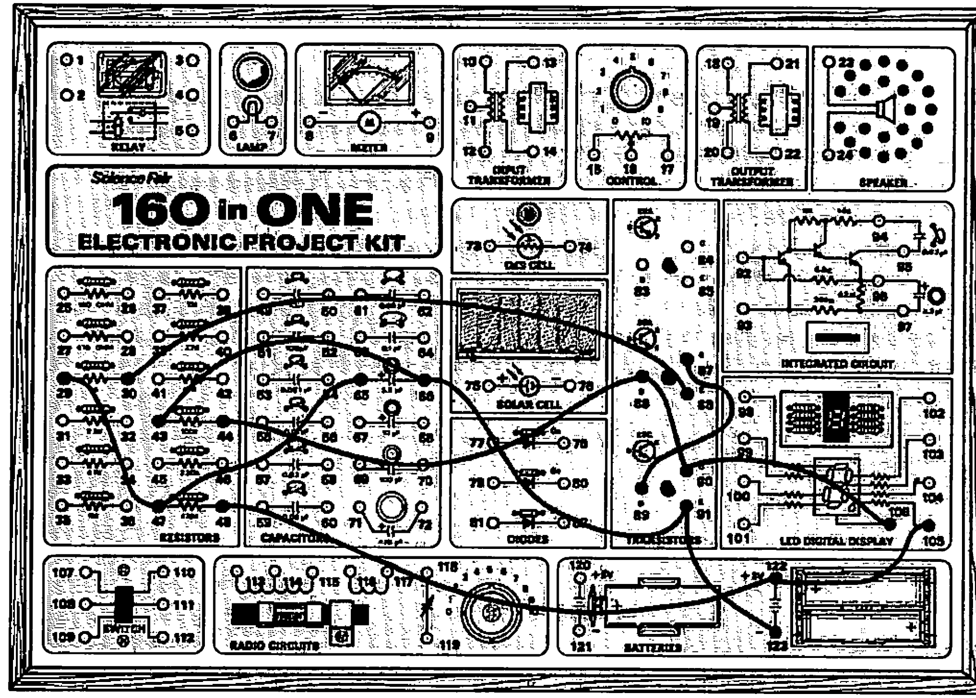
76. LED STROBE LIGHT

This circuit is an oscillator with a low frequency (so you will be able to see the LED going ON and OFF), and a longer OFF time than ON time. Because of this, you get short pulses of light with relatively long periods of OFF time between them.

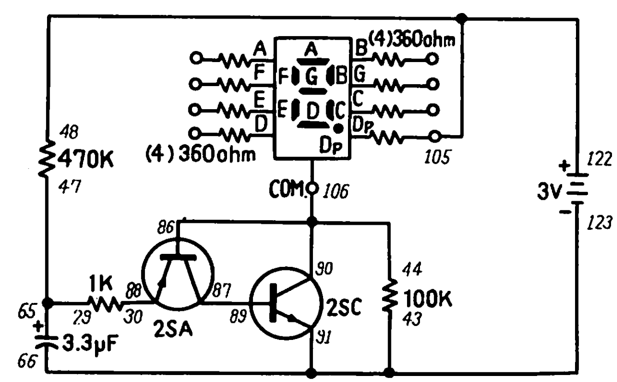
This circuit can also be used as a 'sawtooth wave' oscillator if you take the output from the emitter of the 2SA Transistor. If this output is used to supply base current to the 2SC Transistor (as in this circuit), shorter pulses are generated.

Try experimenting by changing the value of the 3.3uF capacitor to 10uF. You may also vary the 1K Resistor and change the 470K to 220K. The frequency of this oscillator is controlled by the rate of charge and discharge of the Capacitor. For that reason, you shouldn't be surprised that changing its value, or the values of the Resistors that supply current to the Capacitor, alter the frequency.

NOTES



WIRING SEQUENCE:
29-47-65, 30-88, 43-66-91-123, 44-86-90-106, 87-89, 48-122-105



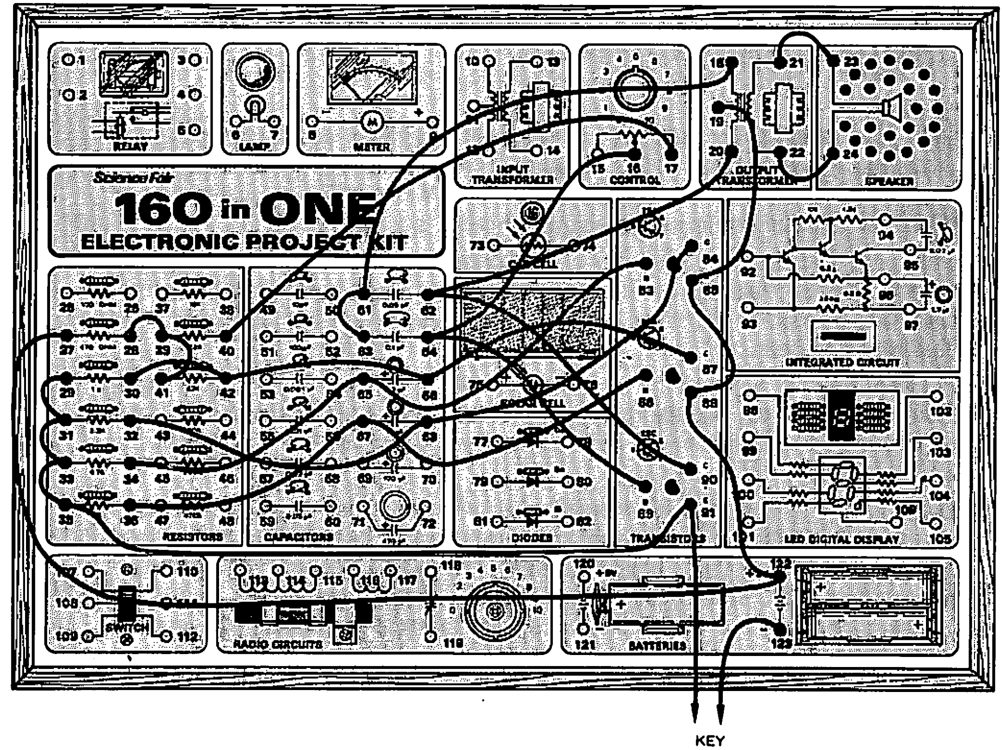
77. ELECTRONIC ORGAN

This circuit is similar to the one in project 108 because it has a multivibrator connected to a pulse type oscillator. It is different because the multivibrator is used to make a 'tremelo' effect (wavering tone) in the pulse oscillator's signal, rather than turn it completely ON and OFF. You've probably heard this tremelo effect on other electronic organs.

The Control is used to vary the base current to the 2SC Transistor. This changes the charge/discharge rate of the 0.1uF and 0.05uF Capacitors, and therefore the frequency of the pulse oscillator.

The Key is used to turn the entire circuit ON and OFF. You may want to try replacing it with the slide Switch in your experimentation. You can change the tonal range by changing the 10uF and 3.3uF to other values. Also, try using the Switch or Key to add extra components to the circuit (like an extra Capacitor in parallel with the 10uF or 3.3uF), so you can change from one tonal range to another, quickly. Be sure to keep notes on what you do.

NOTES



WIRING SEQUENCE:

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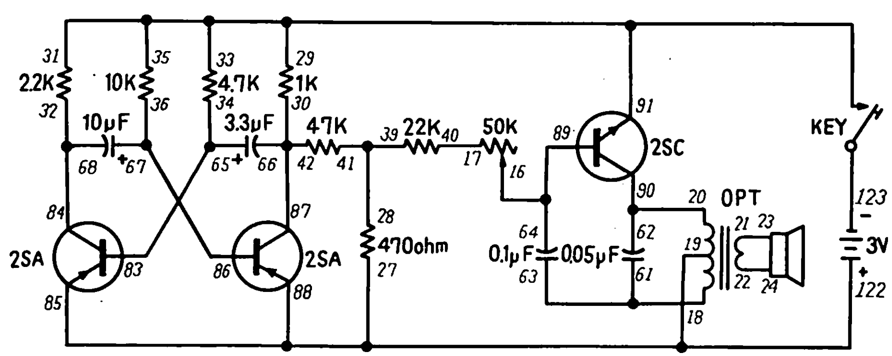


78. LIGHT CONTROLLED SWITCH WITH CdS CELL

Now we'll go to another very common, and important category of circuits: Switching and Control Circuits. Have you ever really stopped to think how much of our everyday life is affected by electrical and electronic controls? Think about if for a while — you'll be amazed to find out how common and important this type of circuit is to all of us.

This project demonstrates the operation of a light controlled switch and provides the circuit explanation for the Electronic Candle (the first project). The circuit is similar to many light controlled circuits used in the home and in industry. Many yard and street lights are controlled by similar cells.

The 3V Lamp circuit is controlled by the contacts of the SPDT (signal-pole, double-throw) Relay. We have started out with the Relay contacts wired so that the light is normally OFF, but you only need to change the wire on terminal 3 over to terminal 1 to make it normally ON.

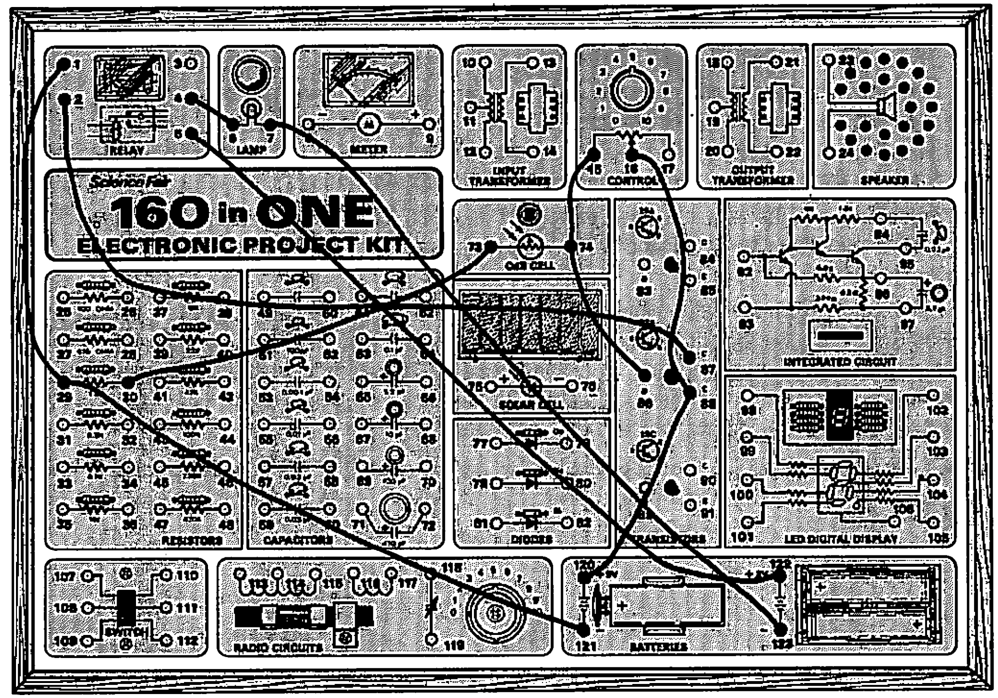
The Relay coil (field) is energized or powered by the 9V Battery through the C and E leads of the Transistor. The Transistor acts like an open circuit between these terminals when it is OFF. A Transistor is OFF whenever it has no current flowing in its base lead. When sufficient current is caused to flow in the base lead, the Transistor is ON. When it is ON, the C and E leads of the Transistor act as though they are shorted together. This allows the current to flow to the Relay coil to energize the Relay. All Transistor currents must flow against the emitter arrow head.

The CdS Cell is a Resistor which appears as a very high resistance (virtual open circuit) in darkness, but in the presence of light its resistance decreases until in bright sunlight it is about 100 ohms, or so. This low resistance looks like a virtual short circuit or closed switch in circuits with normal resistance above a few thousand ohms or so.

Now, coupling the Transistor and CdS Cell together as shown in the Schematic diagram, we have effectively a CdS Cell "switch" controlling a Transistor "switch" which controls a Relay. With insufficient light, not enough current can flow into the base to turn the Transistor ON, or you can adjust the control to shunt (bypass) most of the current, keeping the Transistor OFF.

When sufficient light is present, the CdS Cell allows enough current to flow into the base of the Transistor so it can turn on. The 1K Resistor provides a little protection against excessive base current which could burn out the Transistor when bright light produces a very low CdS Cell resistance. Also the base current only has to be about 1/100 of the collector current to turn the Transistor full ON. The Relay current is about 40mA, so to be full ON the Transistor only needs about 0.04mA of base current. To obtain this current the CdS Cell resistance only needs to decrease to about 2200 ohms.

NOTES



WIRING SEQUENCE:

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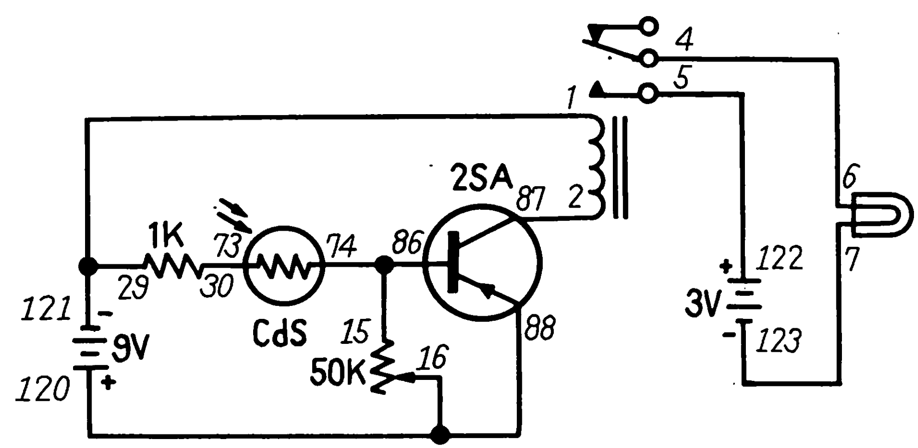


79. LIGHT CONTROLLED SWITCH WITH SOLAR CELL

This project is another in the series of light controlled circuits. This circuit is special because in the presence of darkness the Battery current drain is about zero. Then in the presence of sufficient light the Transistor is turned on and the Relay is energized.

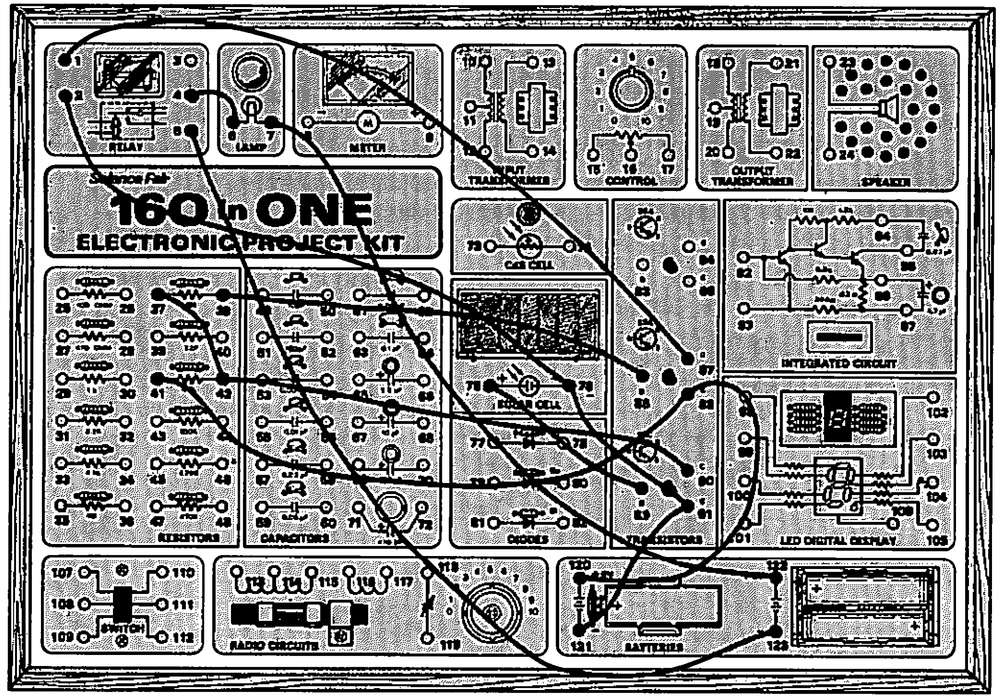
A 3V Lamp is used to demonstrate the switching of the Relay contacts. The circuit and wiring procedure given is for Lamp operation in the presence of light, but you only need to change the wire on terminal 1 to turn the lamp on when there is no light on the Solar Cell.

Study project 78 to determine the operation of the Transistor when controlled by a CDS Cell. The difference in this circuit compared with project 78, is that here the Solar Cell produces the required base current directly from light striking the Sôlar Cell surface.

The Relay coil cannot be fully energized by a single Transistor, as the current generated by the Solar Cell is weak. We therefore use a 2SA and a 2SC Transistor in this test circuit.

The next logical step would be a Transistor with a light control built in. We've got them!! They are called "photo transistors". You know, this is why electronics is such a challenge; just about the time you think you have seen it all, somebody developes a new batch of goodies!

NOTES



WIRING SEQUENCE:

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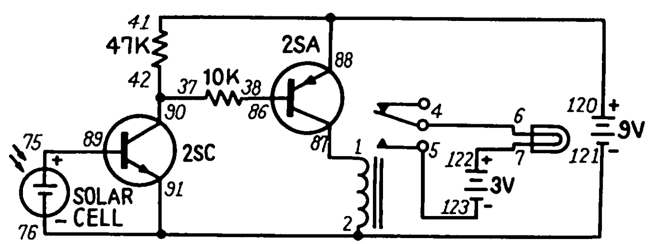


80. SENSITIVE LIGHT CONTROLLED SWITCH

This project is a switch that responds to even a slight change in the intensity of light hitting the CdS.

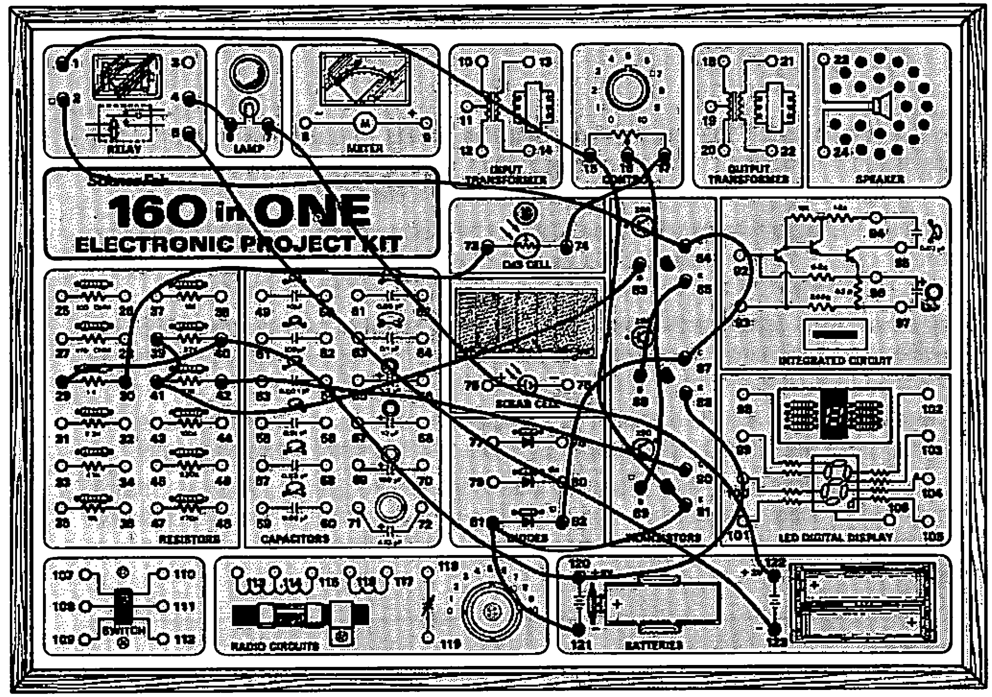
By nature, the CdS is not a very "fast" component. It does not react (change resistance) quickly to changes in light intensity. However, by using all three Transistors to amplify the changes, we can make a very sensitive light controlled switch.

After you have finished the wiring, adjust the Control to the point where the Lamp comes ON (but no higher). This adjustment is very important to the sensitivity of the switch. Now when you move your hand over the CdS cell the light should go OFF.

Note: You will find that this circuit works best if you use the CdS shield.

You can see from the schematic that the three Transistor amplifier energizes the Relay coil, which in turn closes the Lamp/3 volt Battery circuit. The Diode in the circuit protects the 2SA Transitors from damage by a "spike" of electricity caused by the collapse of the magnetic field in the Relay coil, when it is de-energized.

NOTES



WIRING SEQUENCE:

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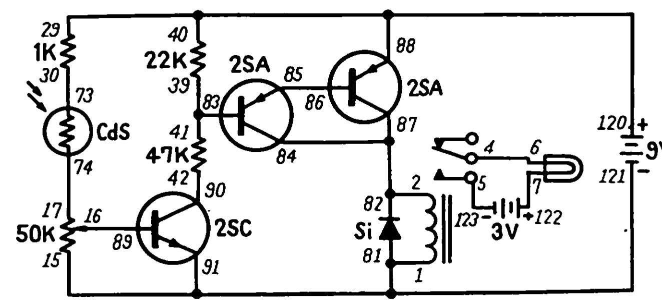


81. ELECTRONIC TOUCH SWITCH

Have you ever wondered how those elevator switches work that only require you to touch a button? This project demonstrates an electronic relay switching circuit that will do it. Just a touch of a terminal or wire will cause the Relay to operate.

After wiring the circuit, connect one of the leads (the one from terminal 120), to some electrical appliance which is not grounded (such as with a 3-prong plug). Make the other lead available so that you can touch it without touching any other metallic object at the same time. Now, as you touch this "touch plate" lead, the Relay will buzz, indicating it has received energizing current.

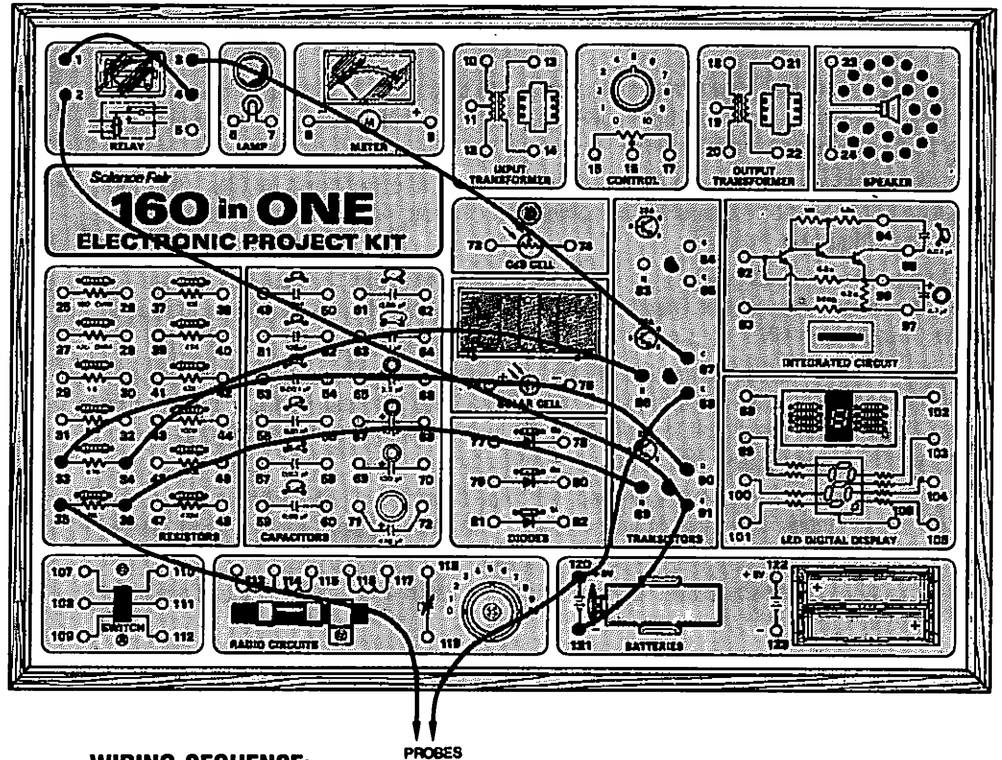
Obviously, to operate anything with the Relay, more circuitry is needed. What we are interested in at this time is how the "touch sensitive" circuit operates.

Circuit operation is as follows:

Without connections to the "touch plate" lead, the 2SC Transistor has no complete circuit to provide base-bias, so this Transistor is in the OFF state. Recall that a Transistor which is OFF has what acts like an open circuit between C and E of the Transistor. This opens the base-bias current for the 2SA Transistor so that it is OFF, also. The Relay therefore cannot receive current, and is de-energized.

When you touch the "touch plate" lead, the static charge on your body is enough to provide the small required base-bias current to the 2SC. The 2SC turns ON, as does the 2SA which energizes the Relay. The Relay buzzes because it is connected like a doorbell buzzer.

NOTES



WIRING SEQUENCE:

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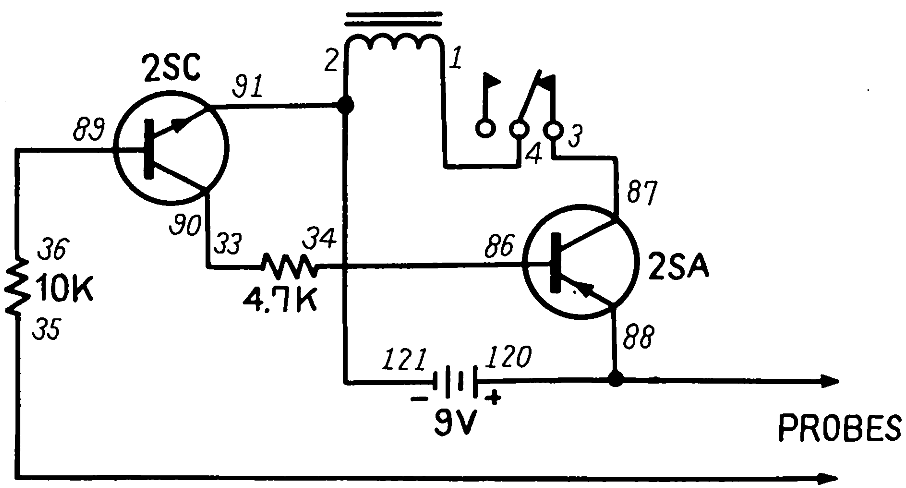


82. VOX-VOICE OPERATED (TRANSMIT) RELAY

Have you ever wondered how a transmitter can go ON automatically when an operator speaks into the microphone, and then turns OFF automatically when he is finished talking? This project shows you how it can be done.

When you finish wiring, turn the Control fully clock-wise (the Lamp will be ON). Then turn the Control counter clock-wise until the Lamp goes OFF (but no further) and speak into the microphone (Speaker).

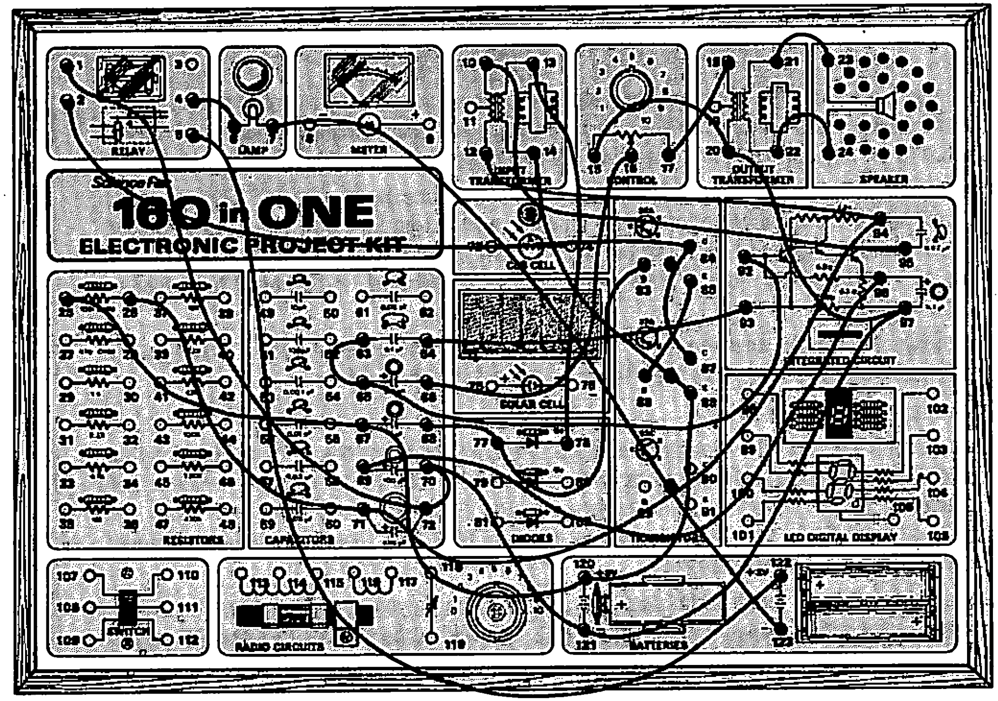
The Speaker is used as a dynamic microphone and the Lamp is used to indicate the transmitter is ON. The control Transistor turns ON the Relay which turns ON the Lamp. Of course, it could turn ON a transimitter (or just about anything else) if you wanted it to.

For demostration purposes we have used the Lamp only as an ON indicator, but you could use it for other functions. For example, if you have a tape recorder with a remote control feature, you can use this circuit to make it come on only when there is something to record. Most cassette recorders have this remote control feature.

If longer or shorter delay times are desired, the 10uF Capacitor may be changed to a higher or lower value. Higher values cause longer delays, and smaller values cause shorter delays. Use the Control to adjust the sensitivity of the circuit.

Note: Too much sensitivity causes the circuit to malfunction with a clicking sound when the Relay is turned OFF.

NOTES



WIRING SEQUENCE:

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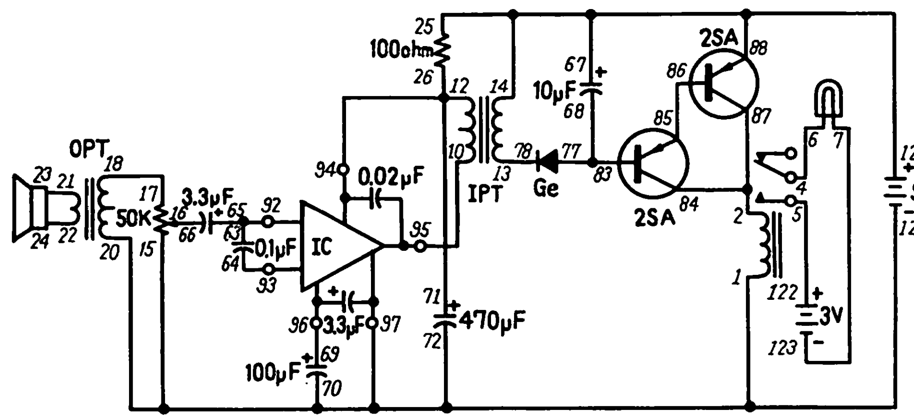


83. VOICE CONTROLLED SWITCH

This project demonstrates how your voice can be used to turn on a transmitter or tape recorder automatically. The speaker is used as a dynamic microphone and all three Transistors are used to change the audio signal to a DC voltage high enough to energize the Relay. Project 82 is a similar type of circuit, but it uses the IC to provide most of its amplification.

The VOX (voice operated transmit) circuit is used by radio amateurs on transmitters as a way of obtaining the convenience of a telephone. The Relay in this project only turns on a Lamp, but when used with transmitters it is wired to replace the function of the SEND/RECEIVE switch.

This circuit has the following features: The 2SA(1) is used as a class A amplifier with Transformer-coupling in the output. Fixed base-bias current is supplied from the 100K base Resistor. A 1K collector Resistor is used to both limit the maximum current to the 2SA(1) and to prevent unwanted (parasitic) oscillations in this stage.

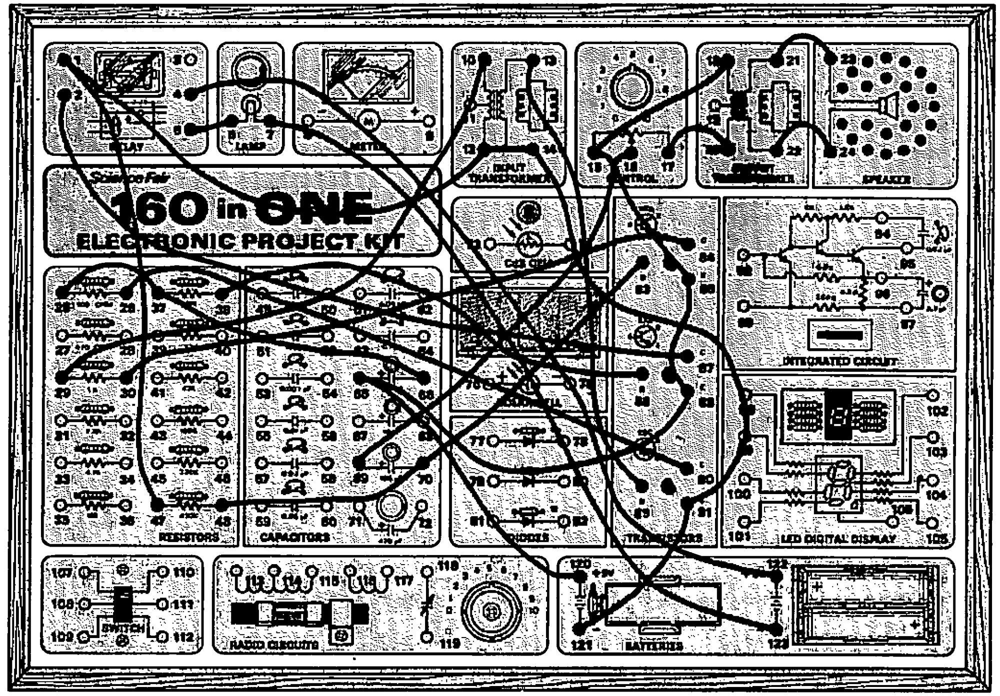
The 2SC is operated without any base-bias voltage or current so this stage is operating class C. One desired feature of this class of operation is that the signal is effectively rectified as well as amplified. The output of this stage does not have to be rectified by a Diode. The 100 ohm Resistor functions to limit peak collector current for the 2SC Transistor. The 3.3uF Capacitor filters the signal so that the 2SA(2) receives relatively smooth DC base current.

The 2SA(2) is the Relay switching Transistor. It also is not biased ON and relies entirely on the presence of a signal that has been converted to DC across the 3.3uF. The ON and OFF delay of this circuit is affected most by the value of the 3.3uF Capacitor. You may want to experiment with the value of the Capacitor to see the results. To try the 100uF (which is already in the circuit), replace it with the 10uF for the input to the 2SA.

Turn the Control to obtain an adequate sensitivity.

WARNING: Too much sensitivity causes the circuit to malfunction with a click sound when the Relay is turned OFF (acoustic feedback).

NOTES



WIRING SEQUENCE:

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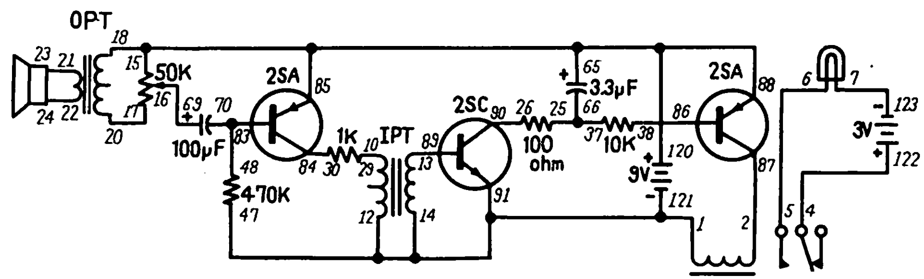


84. TRANSISTOR SWITCHER

The purpose of this project is to further study the switching action of bipolar Transistors used to turn ON a readout device.

The 2SC Transistor at the bottom of the circuit is continually turned ON by the positive base voltage supplied through the 47K limiting Resistor. The base-to-emitter voltage of a Transistor which is biased ON is only a few tenths of a volt, so almost all the 9V of the Battery goes through the 47K Resistor. The base current may then be calculated by Ohm's Law:

$$I = \frac{E}{R} = \frac{9}{47K} = 0.19 \text{ mA}$$

If the 2SC Transistor has a current gain of 100, then the amount of collector current which can flow is 100 X 0.19 = 19 mA. Of course, a higher current gain would allow a larger collector current to flow; and a lower gain, a lower current.

The 2SA Transistor at the top of the Schematic is turned ON through the 22K limiting Resistor and the ON-OFF Switch. Because this resistance is about half of the 47K, the current supplied to the base of the Transistor is about twice as much as that supplied to the 2SC. The 2SA Transistor is therefore said to be more ON or "harder ON" than the 2SC.

A switching Transistor which is not ON hard enough cannot allow the required circuit current to flow in its collector circuit. The result is an excessive current across the Transistor collector-to-emitter, insufficient voltage available for the readout to give adequate illumination and possible overheating of the Transistor.

Hook up the circuit and check operation to see that the numeral "1" can be displayed with adequate brilliance.

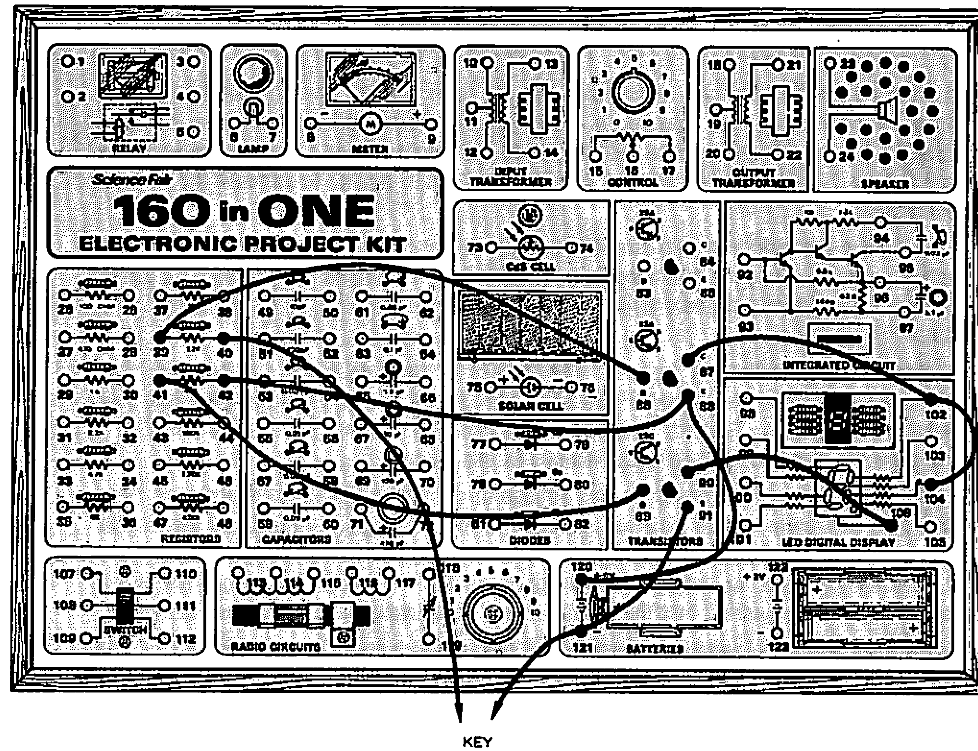
Transistors may be turned ON harder by increasing the base current. This is accomplished by decreasing the limiting resistance in the base circuit. Don't decrease the resistance too far, or the Transistor will be burned out!

Now change both Resistors to 10K and repeat the above experiment. The illumination should not drop off much with the Transistors ON this hard. If much change does occur, check the 9V Battery. It's probably weak.

With your VOM you can check the voltage drop across collector-to-emitter on each Transistor to determine when it is not turned ON hard enough to keep its voltage below 0.5V or so.

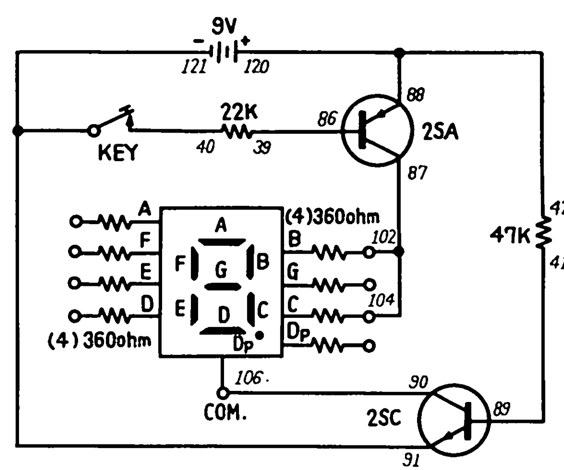
From this project we can see that whenever the base-bias is present the Transistor is ON, but full ON is indicated by the low voltage across the collector-to-emitter. A Transistor which has maximum collector-to-emitter voltage is in the OFF state.

NOTES



WIRING SEQUENCE:

104-102-87, 106-90, 86-39, 40-Key, 91-121-Key, 41-89, 42-88-120



85. ELECTRONIC RELAY SWITCHING

This project is a demonstration of electronic relay control. We will consider how to energize a Relay by use of a switching Transistor, and why this type of circuit is used.

Let's first consider the current levels in this demonstration circuit. To start with, the 3V Lamp draws over 300mA (milliamps) from the 3V Battery, the Relay circuit draws about 40mA from the 9V Battery, and the Key circuit draws only about 1mA. Notice that a circuit of relatively high current (300mA) can be controlled by a switch that only has to pass a very small current (1mA). This is the basic reason why electronic relay control is used. Of course, in industrial power machinery the current levels are in amps (amps = 1000 X mA).

The relays used around your house for this purpose include those in the washing machine, dryer, dishwasher, electric range, furnace, automobile, etc. So you see this is a popular method of switching. It allows small switches and controls to control large amounts of power.

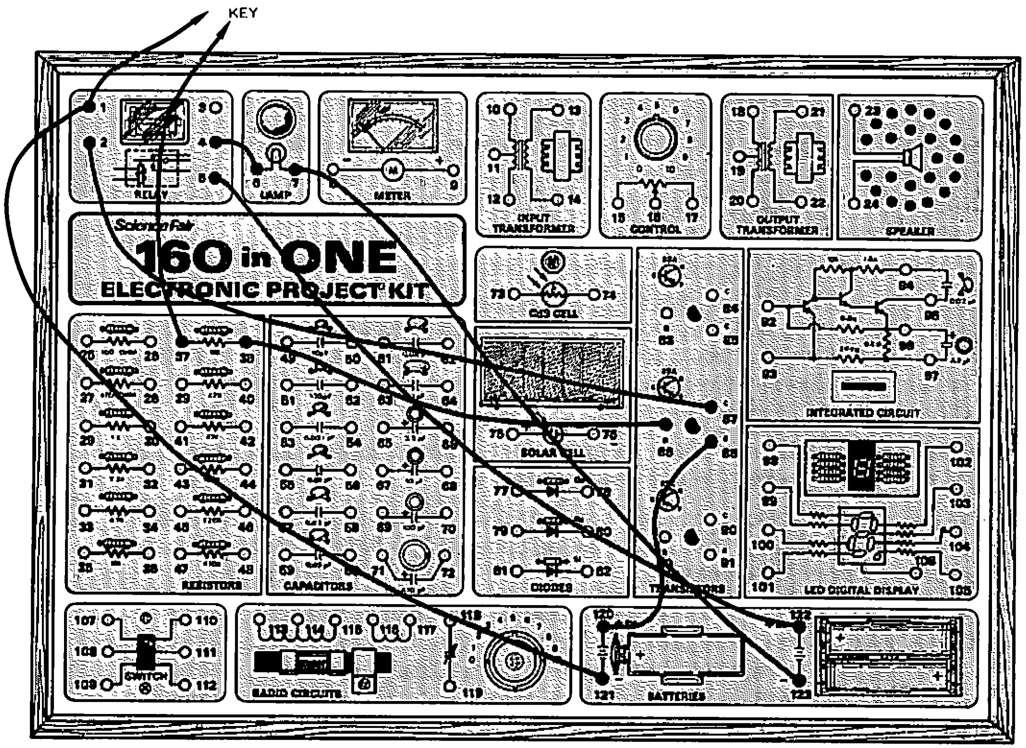
The Relay in this kit has many turns of fine wire in the field coil so that only 30mA or so is required to energize it and thus activate the contacts. Current greater than this is always applied to obtain reliable operation. For example, when used with 9V the current is about 40mA.

The Transistor can operate so that it acts like a switch between the C (collector) and E (emitter) leads. When no current is applied to the base (B), the Transistor is OFF. When sufficient current is supplied to the base, the Transistor is ON. The amount of current required in the base circuit is dependent on the current gain (called Beta) of the Transistor. Different Transistors have different gains or current ratios. The 2SA has (typically) a Beta of 200 or so. This means that the base current must be at least 1/200 of the collector current.

To insure that circuit will consistently turn ON, it is best to assume a Beta (gain of Transistor) of no more than 40. The required base current then is 40mA divided by 40 = 1mA. The 10K Resistor in series with the 9V Battery is able to supply about 1mA of current, so operation is assured.

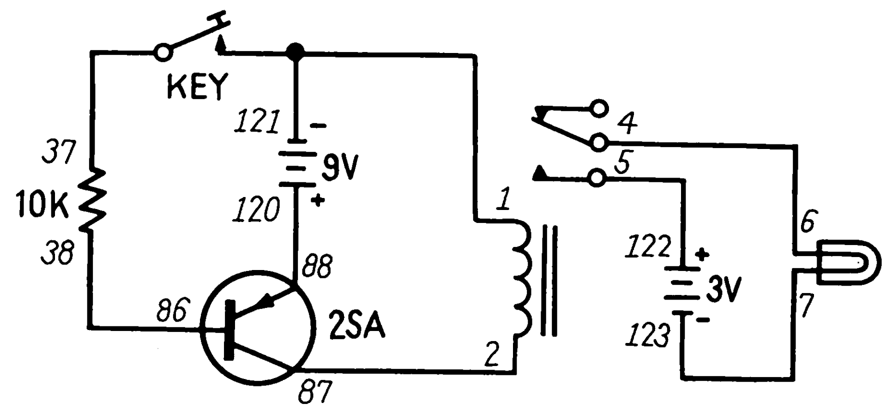
If you have a VOM you can check these currents directly in this circuit.

NOTES



WIRING SEQUENCE:

123-7, 6-4, 5-122, 2-87, 86-38, 121-1-Key, Key-37, 88-120



86. RELAY LATCHING CIRCUIT

The purpose of this project is to study and demonstrate the basic push button control circuit used with relays. This circuit allows any kind of equipment to be turned ON by one push button and OFF with a second push button. You will find this circuit used on most large power equipment where Relays are normally used for switching.

We don't have push button switches to use for this circuit so we will use the Key as one and the side switch as the other. The Key is the same (in function) as the push button switch it represents. That is, it is normally open and must be pressed to be ON. The slide Switch replaces a push button which would be a normally closed type; this one must be pressed to open the circuit. These two different types of switches are indicated by the letters N.O. for normally open and N.C. for normally closed.

To operate the slide Switch as a N.C. switch, keep it in the up position unless it is to be pressed, then only momentarily slide it down and back up.

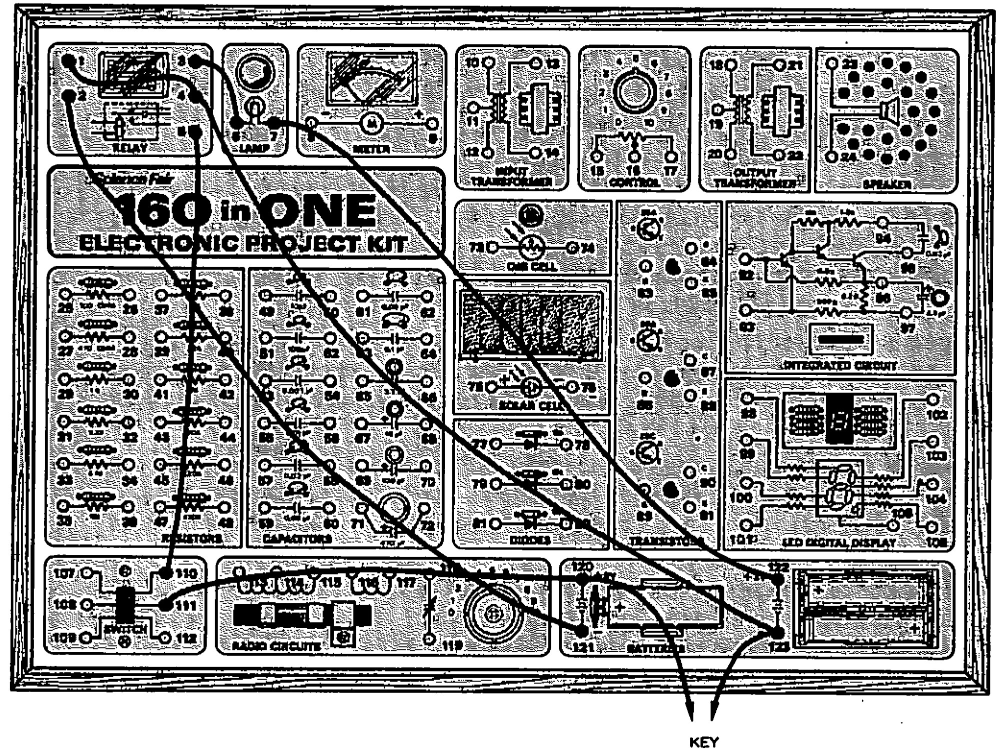
Connect the circuit and check operation by momentarily actuating the switches in sequence. You should find the following: the Lamp is always turned OFF by the N.O. switch (Key) and ON by the N.C. switch (slide Switch).

Now let's consider how this circuit operates. Use the Schematic to follow the description. The Relay is shown in the de-energized condition (as usually done on Schematics). When the N.O. switch is closed, the circuit is completed between the Battery and Relay, energizing the Relay. The N.O. contacts of the Relay are closed, and the N.C. contacts are opened (turning the Lamp OFF). The closed contacts on the Relay complete the Relay coil circuit because these contacts are in parallel with the N.O. switch (Key). This N.O. switch may be left open now as the Relay has locked itself into the ON or energized state.

To de-energize the Relay the N.C. switch (in series with the Relay's lock in contracts) need only be momentarily opened, and the Relay drops out (de-energizes).

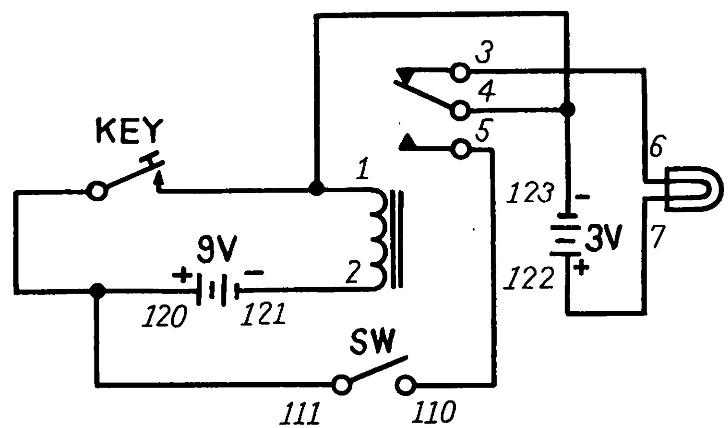
A separate set of contacts is generally used with this type of relay circuit so the circuit to be contolled can be turned ON and OFF along with the Relay. With only one set of contacts, like this Relay, the circuit is ON when the Relay is OFF and vice versa.

NOTES



WIRING SEQUENCE:

111-120-Key, Key-123-4-1, 5-110, 2-121, 3-6, 7-122



87. SUPERSENSITIVE RELAY OR SENSITIVE ELECTRONIC VOLTMETER

In this project you'll construct and test a very sensitive electronic voltmeter. The high gain of a Transistor and the output of a potentiometer (Control) are coupled together is such a way that very low voltages (much less than one volt) can be sensed with this circuit. This will allow you to test such things as thermocouples, solar cells, dissimilar metals which are generating a voltage (like the Coin Battery in project 20), and much more.

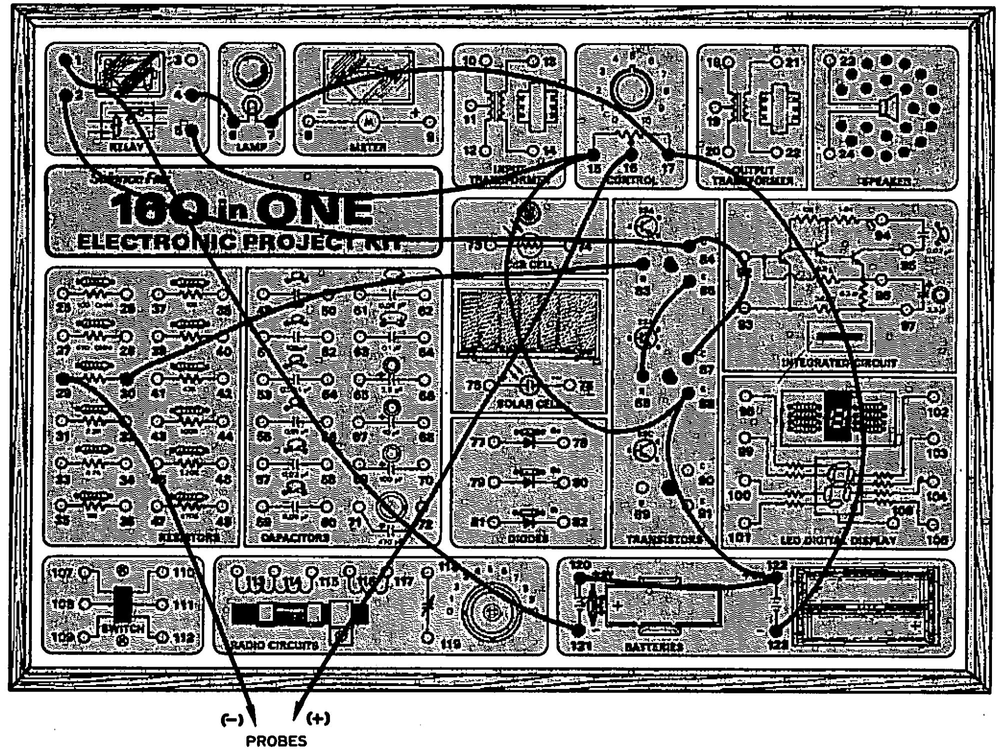
Operation is as follows:

1. Short-circuit the Probes together and adjust the Control to minimum (to de-energize the relay and turn OFF the Lamp).
2. Slowly increase the Control until the Relay is energized and Lamp is ON. Record the Control dial setting ______. This point on the dial represents zero (0) external voltage.
3. Reduce the Control to minimum and connect the probes across the voltage to be measured. Observe proper polarity.
4. Slowly increase the Control from minimum until the Lamp lights. The dial setting will tell you the following:
   a. If the Lamp lights at "0" or very low Control settings, the voltage is quite high (typically about .3 volt).
   b. If the Lamp lights near but below the setting of Step 2, the voltage value is very low. The closer this setting is to the number you recorded in Step 2, the lower the voltage.
   c. If the Lamp lights on a setting of Step 2, the voltage is zero.
   d. If the Control setting must be higher than Step 2 to get the lamp to light, the polarity is probably reversed. Change positions of the leads.

Now try measuring such things as the Solar Cell, Coin Battery (see project 20) and a thermocouple, if you have one.

Operating theory for this circuit is included in many other projects, so we won't repeat it here. Have fun!

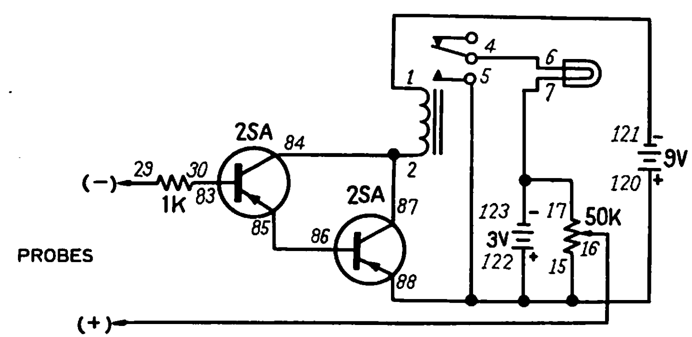
NOTES



WIRING SEQUENCE:

123-17-7, 6-4, 121-1, 2-84-87, 83-30, 85-86, 29-Negative Probe, 16-Positive Probe, 5-15-88-122-120,

To test the Solar Cell, connect the (–) probe to 76, and the (+) Probe to 75.



88. RELAY LIGHT FLASHER

Light flasher circuits are used in many places. Can you think of some?

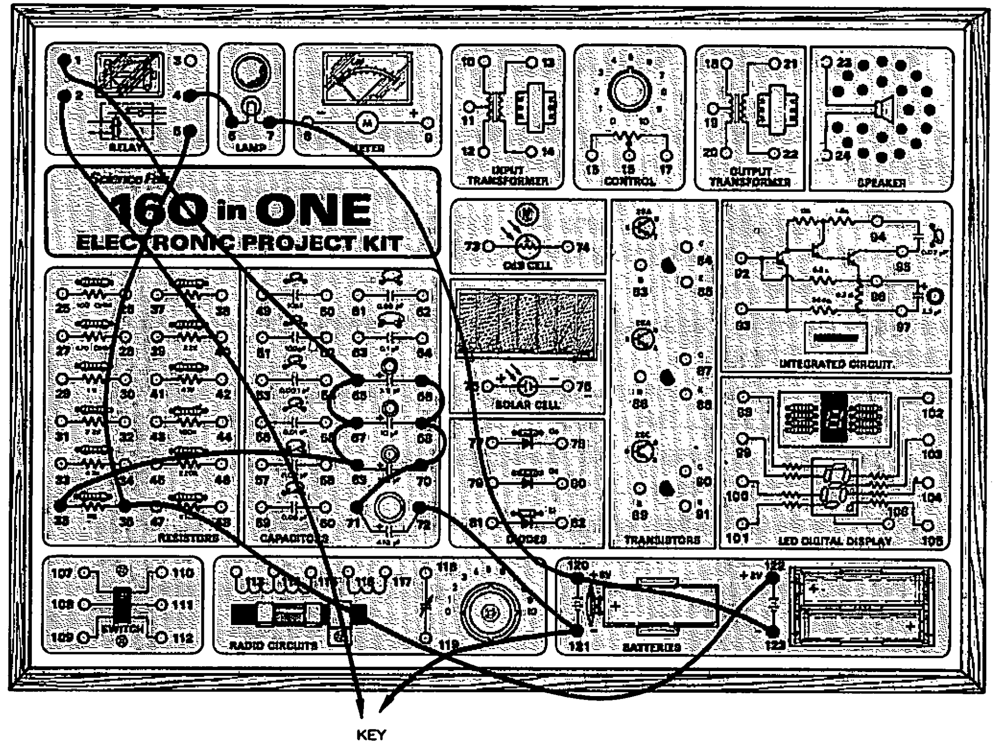
How about warning lights on barricades at highway danger or construction sites, flashing lights at a school crossing or a dangerous street intersection, and the turn signals on a vehicle. All of these use a circuit very similar to this one.

This project is a Relay light flasher which demonstrates some aspects of Capacitors and Relays which are of interest. The circuit is simple but the concepts are basic to the understanding of many electrical circuits.

The Relay voltage is supplied from a 12V Battery but through a series 10K Resistor and across a total capacitance of 91.3uF. This supply circuit has the following characteristics: The current which can be made to flow through the 10K as a constant current is too low in value (less than 1.0mA) to energize the Relay or to keep the Relay energized. This is because the Relay requires about 30mA (or more) to initially energize and as little as 1.0mA to hold it in after it is energized.

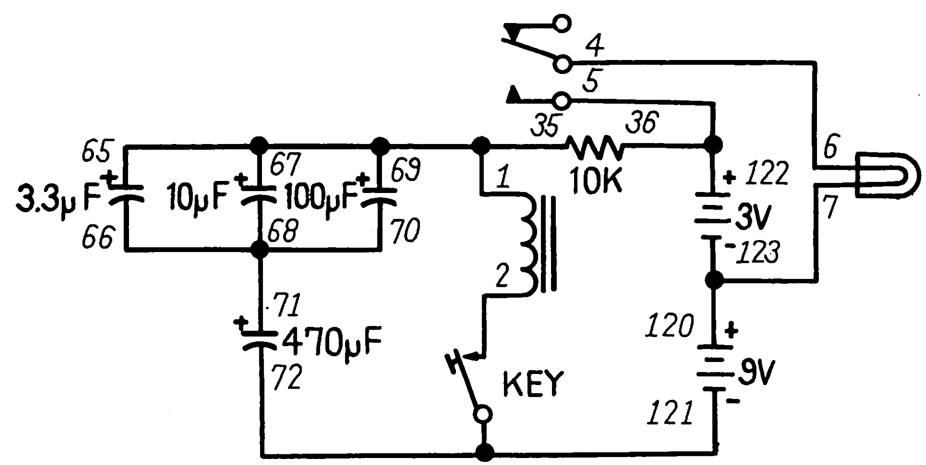
The Relay can be energized by this circuit only momentarily because of the charging abilities of the capacitance in the circuit. If enough time is allowed (about 2 seconds or so) the Capacitors charge enough to be able to deliver the required energizing current to the Relay. The Capacitors are quickly discharged by the resistance of the Relay coil (about 225 ohms) so that the Relay is only momentarily energized.

This type of circuit finds application in such equipment as spot welders and strobe lighting (used in photography).



WIRING SEQUENCE:

123-120-7, 6-4, 5-36-122, 1-65-67-69-35, 66-68-70-71, Key-2, 72-121-Key



NOTES

89. DELAY SWITCHING CIRCUITS

The purpose of this project is to study delay switching circuits as used in computer and logic control. The circuits make use of the fundamental property of all Capacitors — the storage of charge.

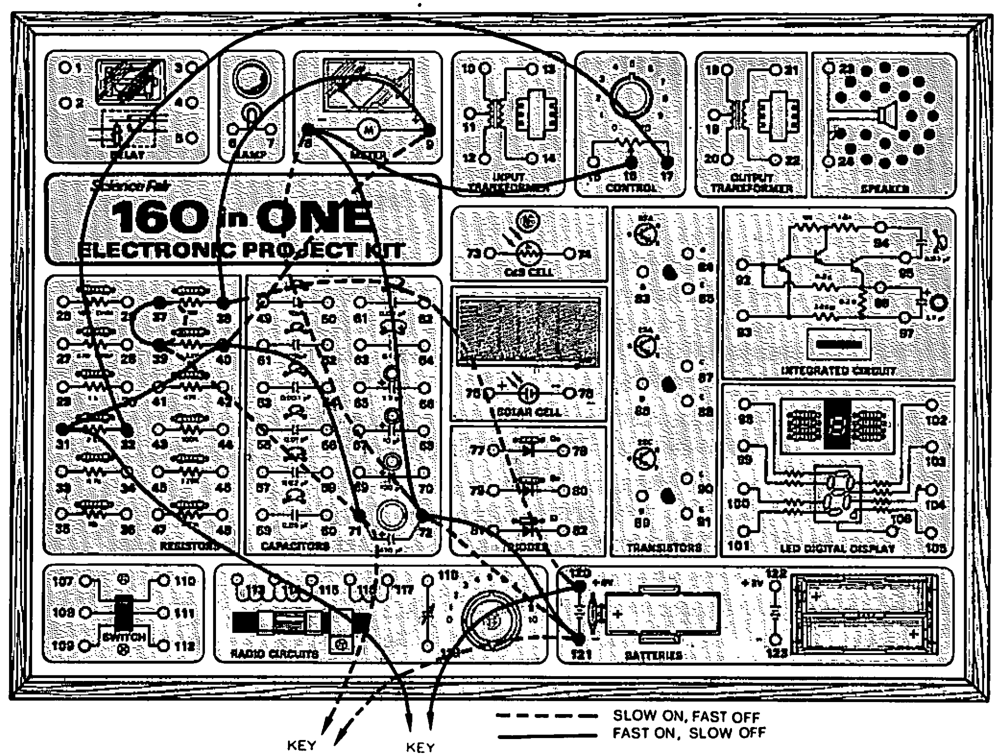
Many contol circuits are required to either turn a circuit OFF after a required delay time or to turn the circuit ON after a required delay time. The most basic and simple control uses the ability of a Capacitor to store a charge of electricity. The charge can be made to pass though a series resistance to slow down the time required to initially charge a Capacitor. This is used to provide a delay in the turn ON of a circuit. When the charge on a Capacitor voltage is allowed to slowly be removed by a parallel resistance, a delay in the removal of Capacitor voltage is obtained that is used to control the turn OFF of a circuit.

Hook up the first circuit (1) to check operation. Try both high and low control settings. Notice that the Meter indicates the voltage across the Capacitor. The series resistance to the Meter has been chosen to obtain a full scale Meter reading with the 9V Battery. Let's assume that the circuit to be controlled requires at least a half-scale Meter reading to be ON, all voltages below this indicate an OFF condition. This circuit provides a fast on but a delayed OFF. Use a watch or clock which has a second hand and record the time delay this circuit can provide. Use the 5 Meter reading as the switching level from ON to OFF. ______ seconds maximum and ______ seconds minimum. From about 14 to 2 seconds is typical.

Hook up the second circuit (2) and check operation. This provides the opposite action of circuit 1 (e.g., it provides a slow ON and a fast OFF). Measured delay is _____ seconds. About two seconds is typical.

Now let's consider what causes this delay in the charge or discharge of a Capacitor. Notice that the fast ON circuit has no resistance between the Battery and Capacitor, and that the fast OFF circuit places a zero resistance (short circuit) across the Capacitor to obtain a fast discharge. When these conditions are compared with the slow OFF and slow ON circuit conditions we see resistances through which the Capacitor charging or discharging current must pass. It is the combination of resistance (R) and capacitance (C) then which is seen as the controlling factor. The product of RC in the circuit is called the "time constant". The higher the product of RC, the longer the time delay to either charge or discharge the Capacitor.

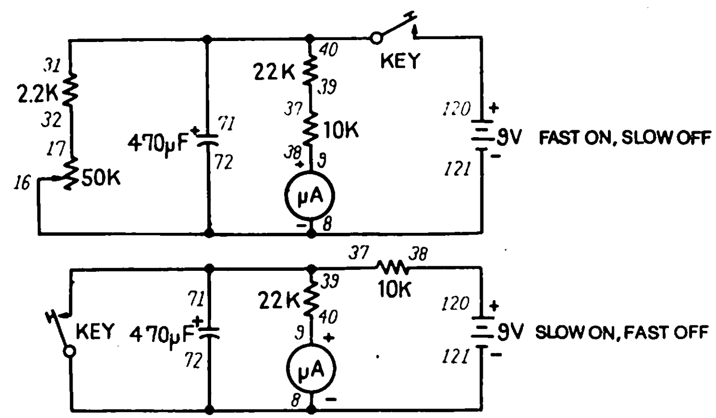
NOTES



WIRING SEQUENCE:

Fast on, Slow off: 121-72-8-16, 9-38, 37-39, 17-32, 71-40-31-Key, 120-Key

Slow on, Fast off: 37-39-71-Key 9-40, 38-120, 8-72-121-Key



90. TRANSISTOR DELAY CIRCUIT USING RC TIME CONSTANT

The purpose of this project is to demonstrate and study the effects of our RC (resistance, capacitance) time constant circuit. This is accomplished by using the RC time constant circuit to control a switching Transistor which in turn controls the Relay which finally turns OFF the Lamp.

The slide switch gives you a choice of two different Capacitors: 100uF or 470uF. Consider operation with one of the Capacitors in the circuit and with the 50K Control set on maximum resistance (full CCW rotation or zero on the dial). When the Key is closed the current through the 10K turns the Transistor full ON. This causes a virtual short circuit to appear between C-E of the 2SA, thereby energizing the Relay.

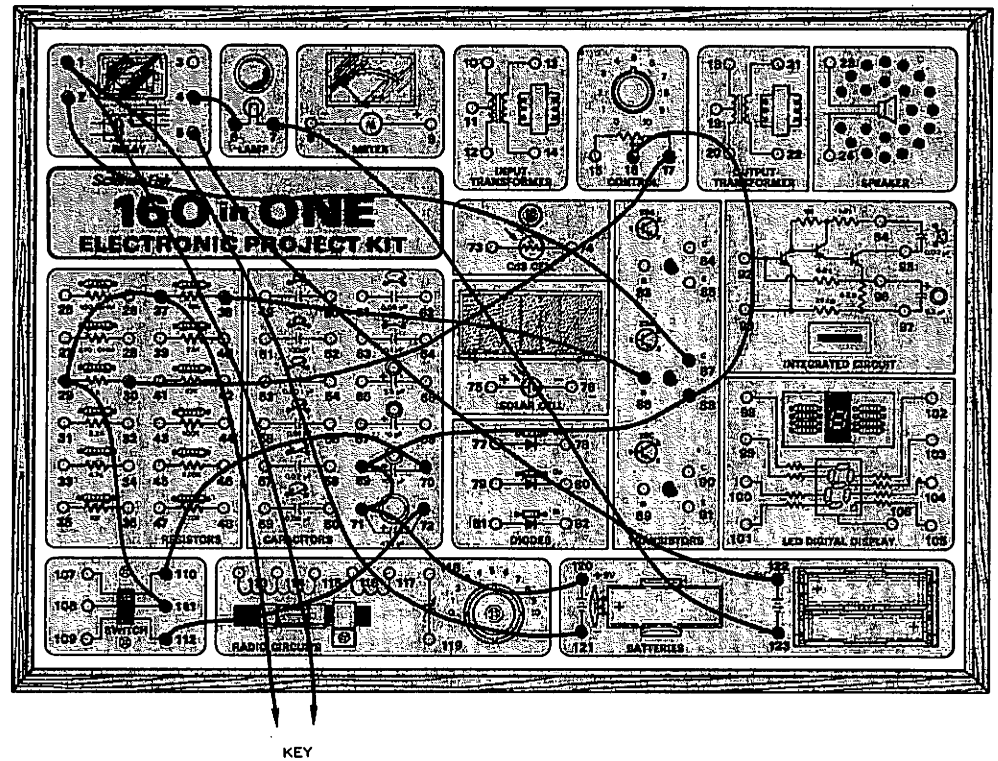
The above turn OFF delay is dependent upon the product of R and C in the base circuit. The higher the product, the longer the delay. The smaller the product, the shorter the delay.

Because of the parallel paths of resistance, the effective base circuit resistance is calculated as adjustable between about 910 ohms and 8.4K ohm. It is this effective resistance that, when multiplied by the circuit capacitance, yields the time contant of the circuit in seconds. This time gives us a relative indication of how long the delay will take.

For example, with the 100uF Capacitor the time constants at the R extremes are: 0.09 second and 0.8 second; for the 470uF: 0.4 second and 4 seconds. Now if we consider that it takes about five times the constants for the voltage to reduce to near zero volts, the delay times are approximately 5 times the above time constant extremes. These calculate to be from about 0.45 second to 4 seconds for the 100uF Capacitor, and from about 2 seconds to 20 seconds for the 470uF Capacitor.

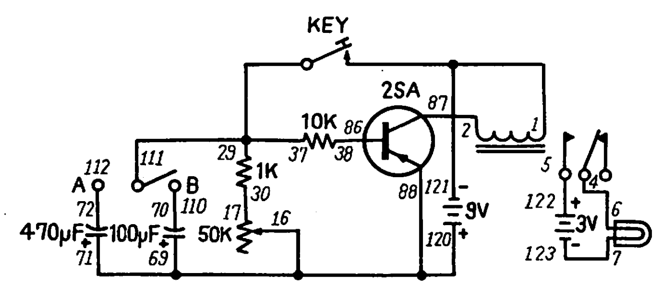
Now a measurement of the above extremes on the actual circuit may show differences in the times obtained because of component tolerances, but the relative values will be very close. Use a watch or clock with a second hand and check the results for yourself.

NOTES



WIRING SEQUENCE:

123-7, 6-4, 5-122, 87-2, 86-38, 17-30, 16-88-69-71-120, 70-110, 72-112, 111-29-37-Key, Key-1-121



91. DC-TO-DC CONVERTER

This project shows how a DC voltage can be changed into AC, put through a Transformer and then converted back to a DC voltage.

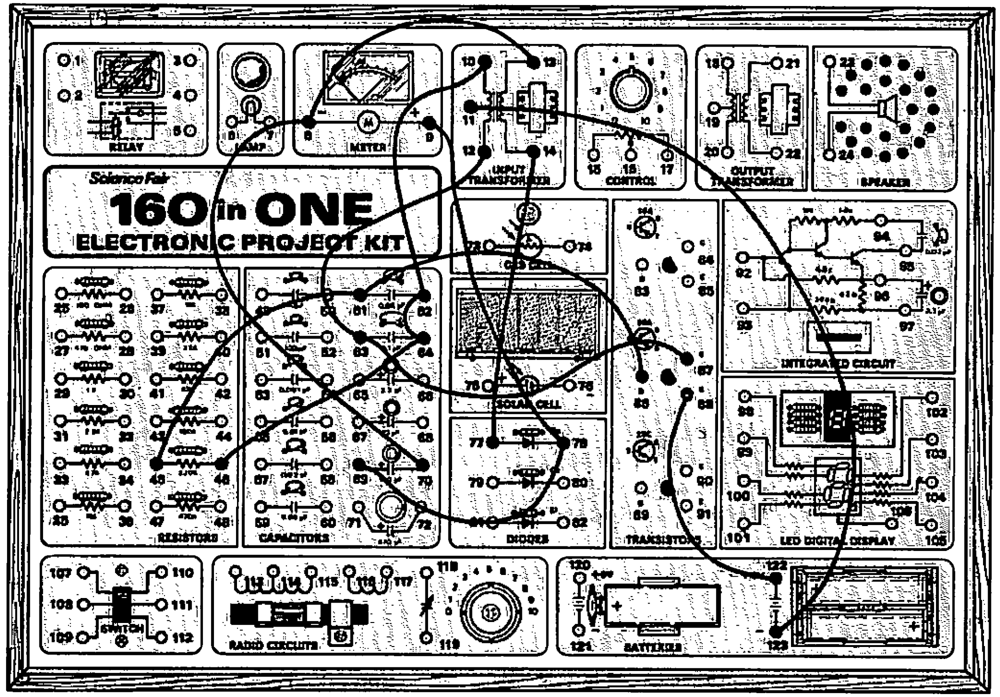
The DC voltage is changed to AC by the oscillator circuit. This oscillator circuit uses the 2SA Transistor to obtain the necessary gain greater than 1, and the Transformer to obtain the necessary phase reversal and feedback to sustain oscillations. The 220K Resistor provides a DC current to the base of the Transistor to bias it on. The 0.05uF and 0.1uF Capacitors are used to obtain a desired amount of feedback and a more useful waveshape of AC voltage.

The AC across the primary winding of the Transformer is coupled to the secondary by the magnetic field within the Transformer. The secondary AC is rectified by the Ge half-wave rectifier Diode, filtered by the 100uF Capacitor, and then delivered to the meter as a relatively pure DC.

This type circuit finds application where a low voltage DC is available but a higher DC voltage is needed. It is also usable where a voltage must be transported over long distances though wires. If the DC were sent out over the transmission wires the losses would be high and efficiency would be low. At the end of the line the AC votage is transformed down to the desired level of AC which may then be converted back to DC as required.

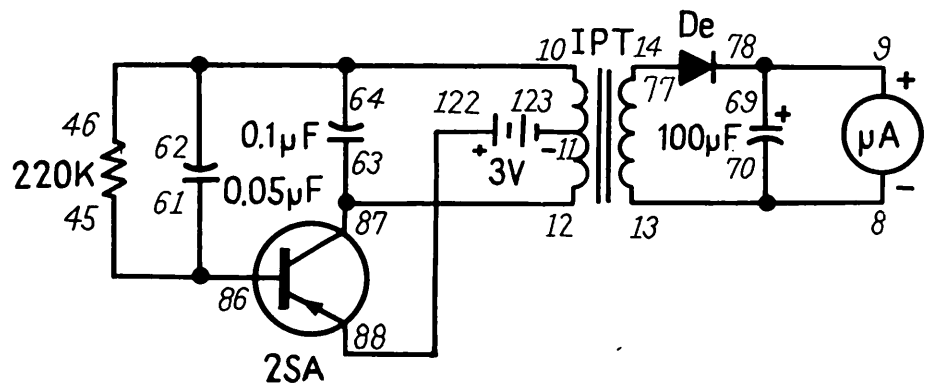
This is a good project for experimenting with different values for Capacitors and Resistors in the oscillator circuit. Be a good experimenter and record all your results. You can try any value of Capacitor in place of the 0.05uF and 0.1uF, but don't go below 100K in value for the 220K Resistor or the Transistor and Meter may be damaged. You can hear what the oscillater sounds like if you connect the crystal Earphone across the Transformer (either winding).

NOTES



WIRING SEQUENCE:

13-8-70, 14-77, 9-78-69, 10-62-64-46, 45-61-86, 12-63-87, 88-122, 11-123



92. LAMP BLINKER CIRCUIT

This project demonstrates the operation of a lamp blinker circuit like those you have seen blinking on the tops of tall buildings and radio antenna towers. The actual switching of the Lamp current is done with reliable Relay contacts, but the timing and control functions are provided by a switching Transistor. The rate of flashing is adjustable from about one or two per second, using the 50K Control.

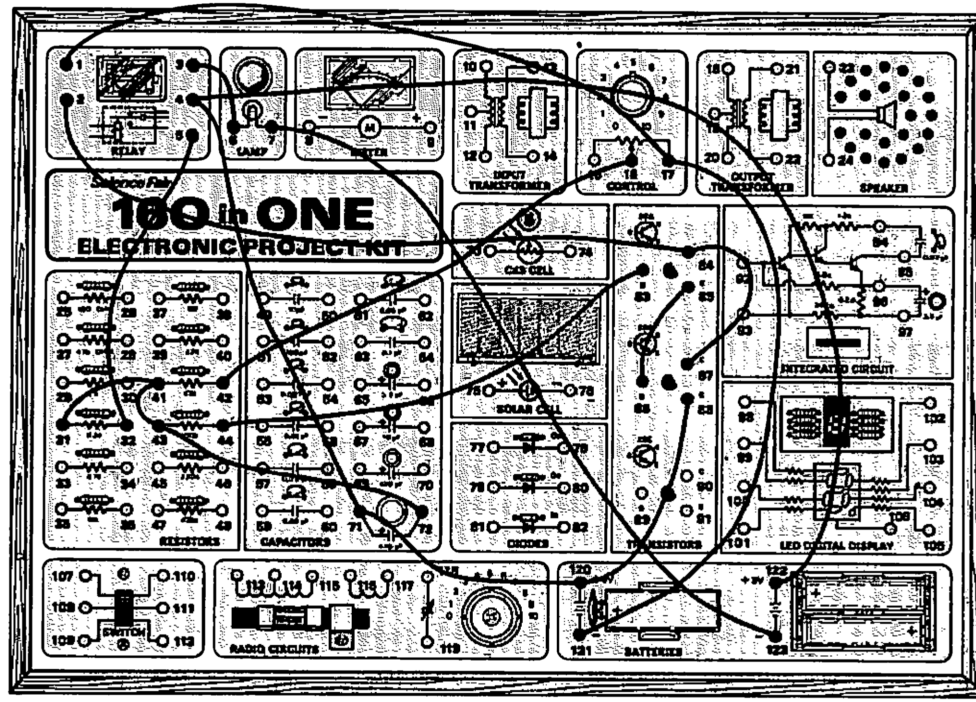
This exact circuit could be used as an emergency warning light on your car or bicycle. A flashing red tail light on a bicycle is more easily seen than a steady light.

The Lamp is wired to the normally closed (N. C.) contacts of the Relay, so the Relay must be energized to turn the Lamp OFF. This provides fail-safe operation. That is, if the control circuit doesn't work, the Lamp is ON and will provide some protection even though it won't be flashing.

When the 9V Battery is first connected, the Transistor remains OFF while the Capacitor begins to receive a charge through the 47K Resistor and 50K Control. After a short time the charge is high enough to allow the voltage to turn the Transistor ON. When the Relay is energized through the ON Transistor, it does two things: turns the Lamp OFF, and places the a discharging Resistor across the timing Capacitor. This discharges the Capacitor to a point where the Transistor loses base-bias and is turned OFF, setting conditions back to the beginning of the cycle.

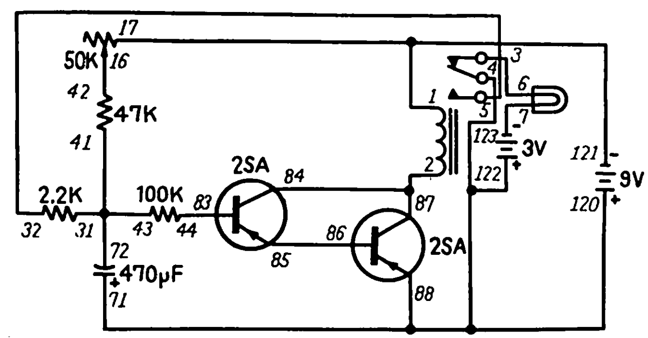
A characteristic of the Relay which helps give a delay in the OFF part of the cycle is that the current required to energize the Relay coil (and move the contacts) is higher than the current required to keep the Relay energized (and hold the contacts in position). The 2.2K Resistor is also included to delay the OFF time. A secondary advantage of the 2.2K Resistor is that it saves the contacts of the Relay from a destructive surge of current from the Capacitor.

NOTES



WIRING SEQUENCE:

1-17-121, 2-84-87, 3-6, 5-32, 7-123, 16-42, 31-41-43-72, 44-83, 85-86, 88-120-71-4-122



93. MECHANICAL COPPER (DC-TO-DC CONVERTER)

This project shows how a mechanical chopper can be used to change DC into AC, which can then be changed back to DC as desired.

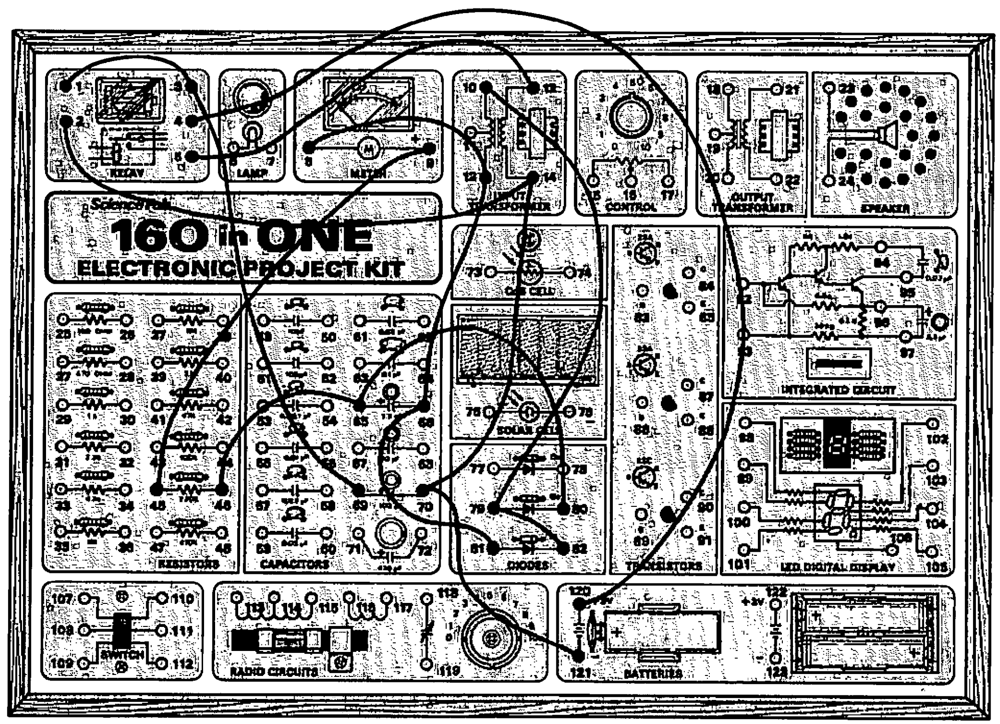
The Relay is wired similar to a doorbell buzzer. The vibrating Relay contact interrupts the current in the circuit so that square-wave pulses of current pass through the Transformer winding. The Transformer passes the square-wave on to the other winding due to transformer action. Because more Transformer turns are wound on the winding which feeds the Diode circuit, the voltage is stepped up to a higher voltage.

The square-wave secondary voltage is rectified by the Diode, filtered by the 3.3uF Capacitor, and then the resulting DC voltage is measured by the DC voltmeter, composed of the meter and the 220K Resistor.

For a more detailed description of the DC voltmeter see Project 39. For a more advanced DC-to-DC converter see Project 91.

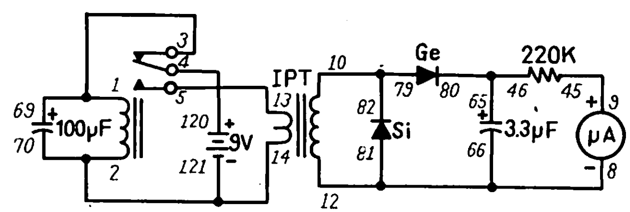
This mechanical chopper was very popular before the days of Transistors, but now Transistors have replaced these in all new designs. Your parents will remember the days of the automobile radio "vibrator". The vibrator performed the function of the Relay in this circuit.

NOTES



WIRING SEQUENCE:

1-3-69, 2-14-70-121, 5-13, 8-12-66-81, 9-45, 10-79-82, 46-65-80, 4-120



94. MOMENTARY ON CALL SWITCH

The purpose of this experiment is to demonstrate a momentary ON circuit which is very easy to make. This type of circuit could be used where we would like to alert or call someone without causing an excessive amount of disturbance, such as in a hospital.

The circuit uses the capacitor storage theory discussed in project 39. The difference is that here the energy is put to work energizing the Relay.

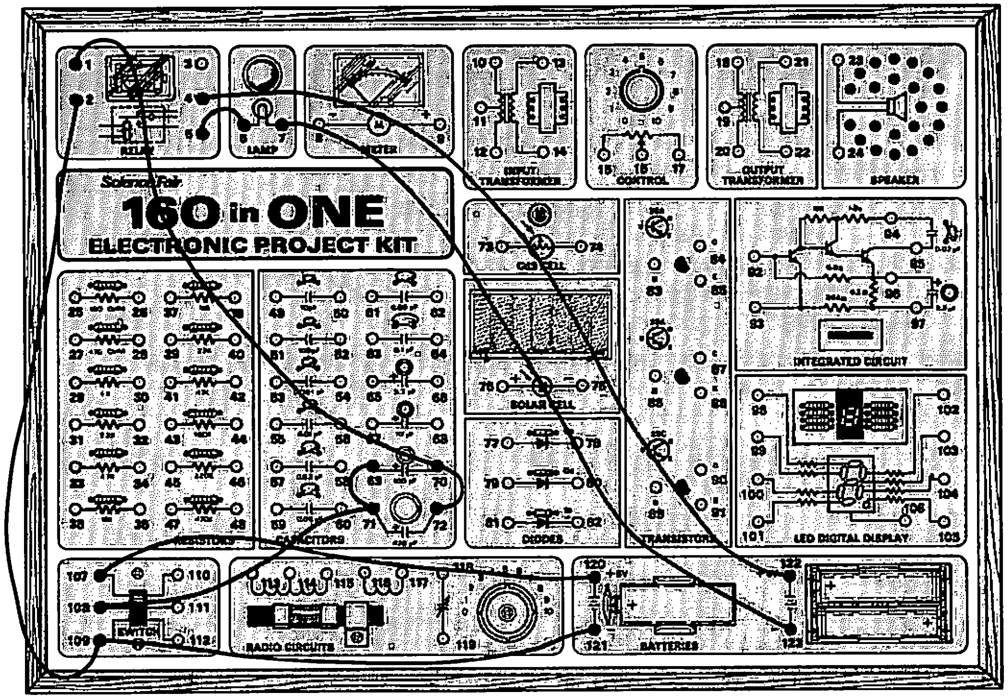
In one position of the switch the Capacitors are charged by current which must flow through the Relay, and in the other position they are discharged by having the current flow through the Relay. The capacitance used is high enough to keep the Relay energized for about a second.

You may want to experiment with different amounts of capacitance. Remember, when connecting Capacitors in parallel, the resultant capacitance equals the sum of the individual capacitances. When connected in series capacitance must be calculated with the formula given below:

$$C = \frac{C1 \times C2}{C1 + C2}$$

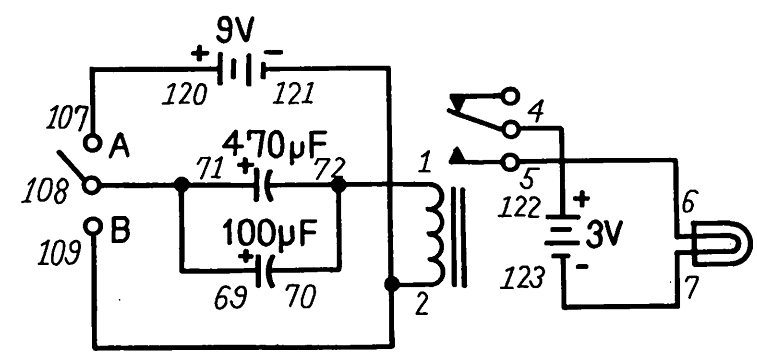
Therefore if the 470 and 100 are rewired for a series connection, the resulting capacitance is about

$$C = \frac{470 \times 100}{470 + 100} = \frac{47{,}000}{570} = 82\text{uF(approx)}$$



WIRING SEQUENCE:

123-7, 6-5, 4-122, 1-70-72, 2-109-121, 108-71-69, 107-120



NOTES

95. LIGHT DIMMER

This project shows you how a Capacitor's charging and discharging can be used to dim a light (an LED in this case).

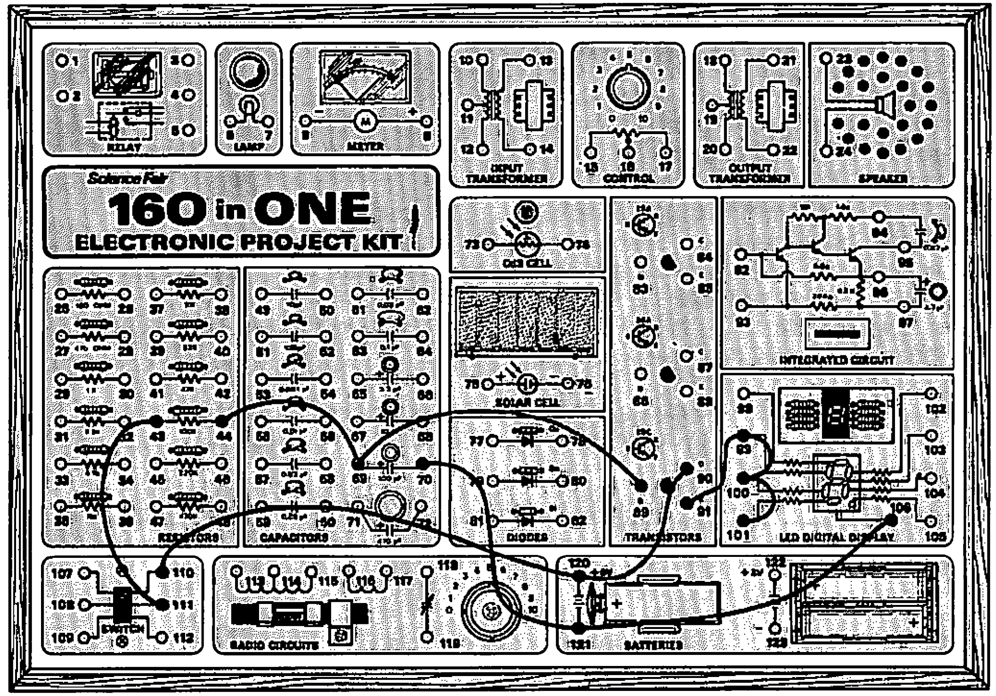
When you finish the wiring, set the Switch to the ON (up) position and the LED segments will slowly light up, displaying an "L". In a few seconds the LED will reach its brightest point and will continue to give off a steady light. Now move the Switch to the OFF (down) position, and the "L" will gradually fade and go dark.

Take a look at the Schematic and see if you can figure out why this happens. Then look at the answer below.

With the Switch ON, current flows from the Battery to charge the 100uF Capacitor. As the Capacitor approaches full charge, more and more electricity flows to the base of the Transistor, gradually turning it ON (and therefore the LED segments). When the Capacitor is completely charged, the current continues to flow to the Transistor base, and the LED stays ON.

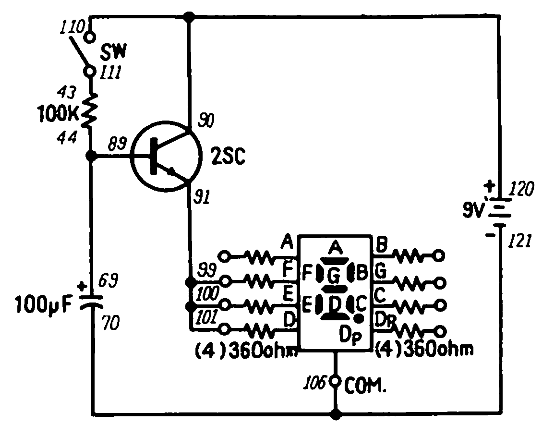
When the Switch is turned OFF, the Battery is taken out of the circuit and the Capacitor begins to discharge through the LED. The "L" gradually dims and goes dark when the 100uF is fully discharged.

If you want a really "slow" dimmer circuit, replace the 100uF with the 470uF. You'll have to be patient, but the LED will come ON, eventually.



WIRING SEQUENCE:

43-111, 44-69-89, 110-120-90, 91-99-100-101, 70-121-106



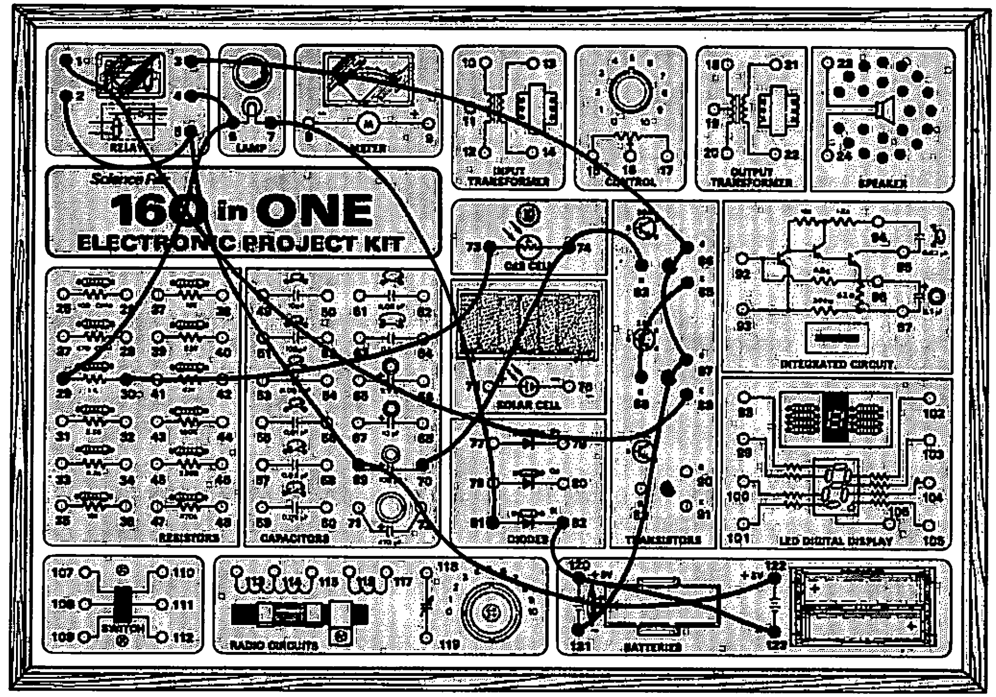
NOTES

96. LIGHT CONTROLLED BLINKER

This project is a very slow blinker (oscillator) with a frequency of one cycle every few seconds (depending on the amount of light present). The CdS cell controls the charge and discharge rate of the 100uF Capacitor and this controls the ON/OFF time of the 2SA(1) Transistor. This, in turn, controls the ON/OFF time of the 2SA(2) Transistor. When it is ON, the 2SA(2) supplies current to energizes the Relay coil. This completes a path for electricity from the 3V Battery to flow to the Lamp and turn it ON. When the 2SA(2) is OFF, the Relay coil is de-energized and the Relay contacts return to their other position. At first you may think the Lamp should be ON all the time, because of the current from the 9V Battery. However, if you look closely you will see that the Diode is biased against the the current from the 9V Battery and will not let it flow to the Lamp.

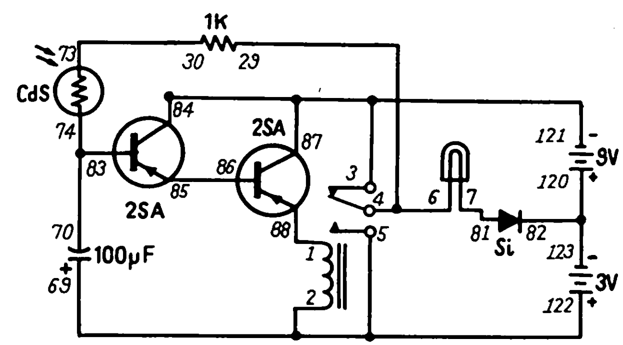
You will find that this project works best without the CdS sheild, unless you are in extremely bright light. You may want to try replacing the 100uF Capacitor with the 10uF, for a faster rate of blinking.

NOTES



WIRING SEQUENCE:

1-88, 2-5-69-122, 4-6-29, 30-73, 70-74-83, 85-86, 7-81, 3-84-87-121, 82-120-123



97. "CRACK-OF-DAWN" ALARM CLOCK

This is the first in the next category of projects: Alarm, Warning and Protection Circuits. Many of these experiments are very practical; you may want to build one or more of them in a permanent form. Try each circuit and think of ways you might be able to use them. Your Radio Shack store has a number of products which you might be interested in; some of them are simple and some of them are quite complex, but all of them can provide useful security, alarm and switching functions.

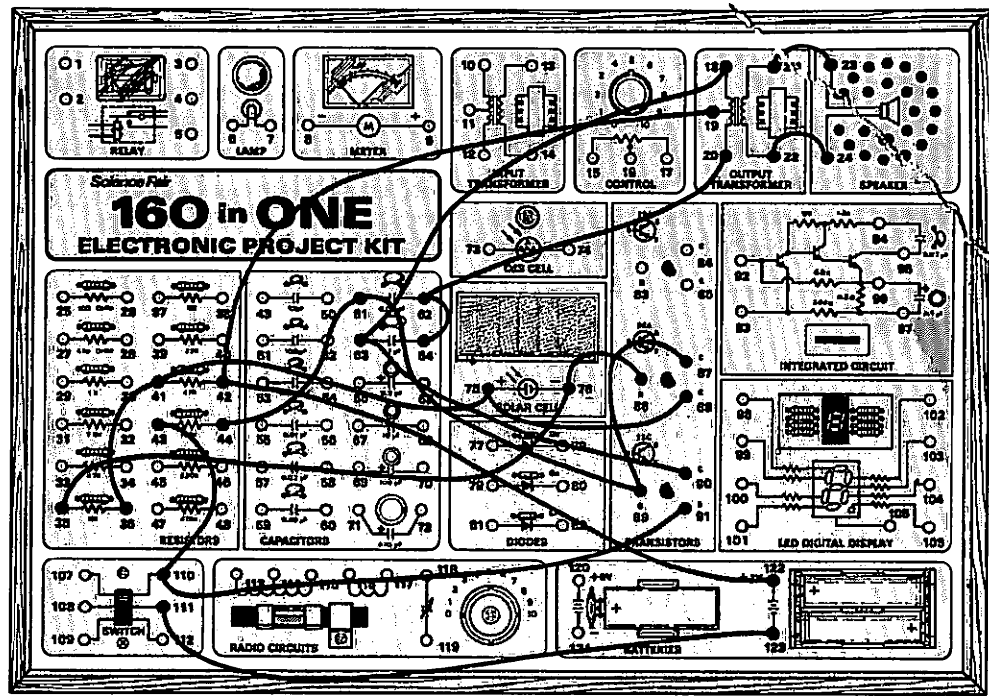
Do you need a good "crack-of-dawn" alarm clock or a good light alarm? Here it is. This circuit draws no battery current when in darkness, but when light strikes the Solar Cell the alarm gives out a steady tone. Battery current during alarm operation is only about 2 mA, so it is a Battery saver at all times.

You can consider this circuit as two separate or independent circuits. The 2SC is a standard pulse-type audio oscillator that uses a center tapped Transformer to obtain regenerative feedback. The collector-to-emitter (C-E) resistance of the 2SA is controlled by the Solar Cell. In darkness the Solar Cell does not generate any base-bias for the 2SA so its C-E resistance is very high (approaching an open circuit in effect). At this time insufficient current is available as base-bias for the 2SC so it is also OFF.

When light causes the Solar Cell to generate base-bias current for the 2SA, the 2SA turns ON, causing a low resistance between C-E. This allows base-bias current to flow to the 2SC to turn it ON so it can oscillate.

This project is a good one to build up and leave connected when you put this kit away in a drawer. There is no need to worry about Battery drain while it is in the dark drawer, but if anyone opens your drawer you'll know it.

NOTES



WIRING SEQUENCE:

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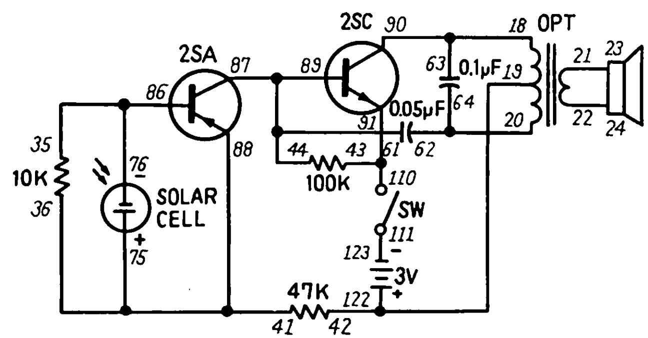
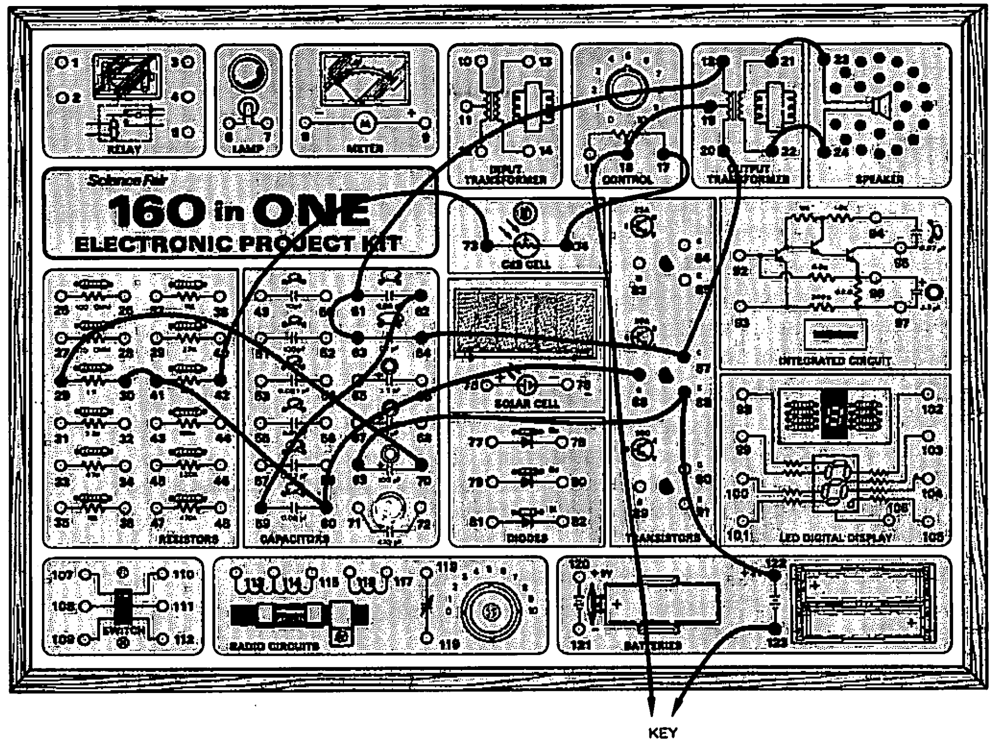


98. DAYLIGHT BIRD OR "EARLY BIRD"

This is the electronic bird circuit of Project 9, with photo-electric control of the Transistor bias. The operation of the CdS Cell is described in many other projects in this kit. We might call this circuit the daylight bird.

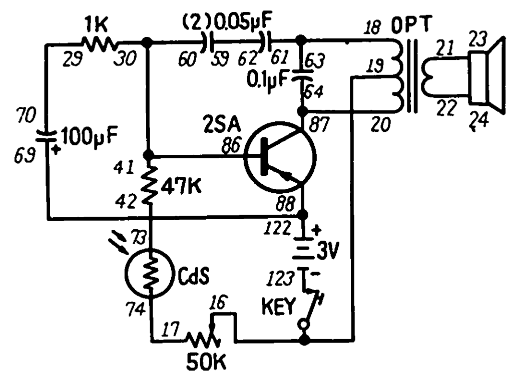
We have made only slight circuit component value changes, and have rearranged the circuit Schematic. Can you spot the changes and rearrange the circuits to look alike? Use the space below and try to redraw the Schematic to look more like that of project 9.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 18-61-63, 62-59, 64-87-20, 19-16-Key, Key-123, 17-74, 73-42, 30-41-60-86, 29-70, 69-88-122



99. CLOSED LOOP BURGLAR ALARM

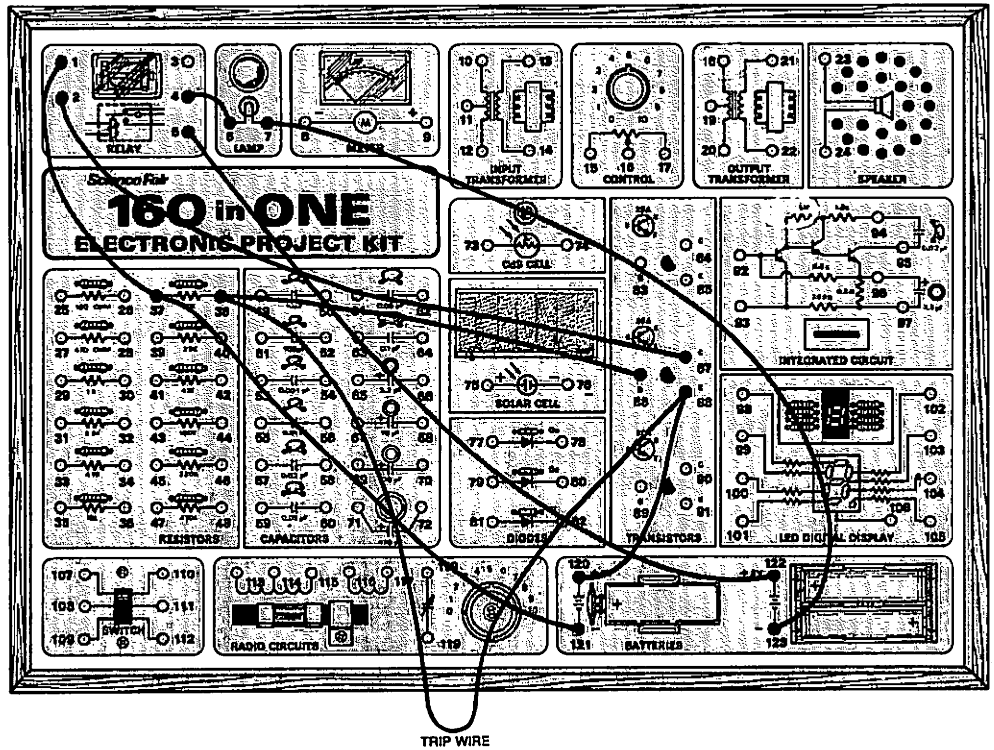
This project is an alarm that may be used wherever a closed loop of wire can be used as the activator. When the wire is opened or broken, the Lamp lights. This action is like that used by commercial establishments you have seen that have metallic conductive tape around the windows and doors. By the way, your Radio Shack store has a complete selection of security devices, accessories, conductive tape and other components to make up your own "professional" alarm circuits and systems.

The circuit is wired as illustrated to control the Lamp, but you can use it to control other circuits and devices as desired. Commercial units like this control lights, alarms and automatic telephone calls to the police station (to name just a few).

Operation of the circuit is very simple. The trip or "trip" wire places a normal short circuit across the B-E junction of the Transistor so that it is in the OFF state. This state always results when no current is allowed to pass across the B-E juction. The C-E leads appear to have an open circuit during this state.

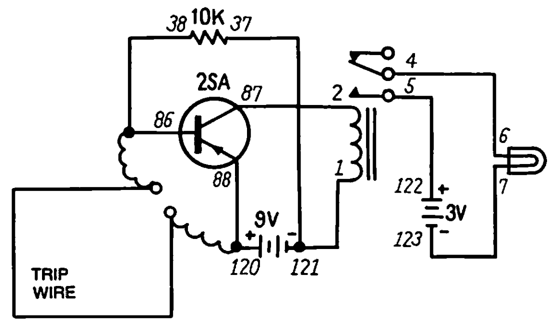
When the wire is opened, the 10K Resistor feeds current to the base from the Battery to turn the Transistor ON. The C-E leads appear to be shorted in this state so current can flow to turn ON the Relay.

NOTES



WIRING SEQUENCE:

123-7, 6-4, 87-2, 5-122, 1-37-121, 86-38-Trip Wire, Trip Wire-88-120



100. WATER LEVEL ALARM

This electronic circuit is an example of those used to monitor rising water levels such as on rivers, dams, spillways, etc. You can use it to prevent overflow when filling up your bathtub, sink, swimming pool or any other container when it's important that it not overflow and you are unable to watch it constantly.

This project is a radio/transmitter water level warning device. An RF (radio frequency) oscillator is controlled by a second Transistor which is controlled by contact probes placed over the water. The transmitted signal is received on an ordinary AM receiver placed nearby. When the water contact plates or probes are out of the water, no RF output is sent out. When the contact probes both touch the water, RF output is sent out indicating that the water level is up to the probes.

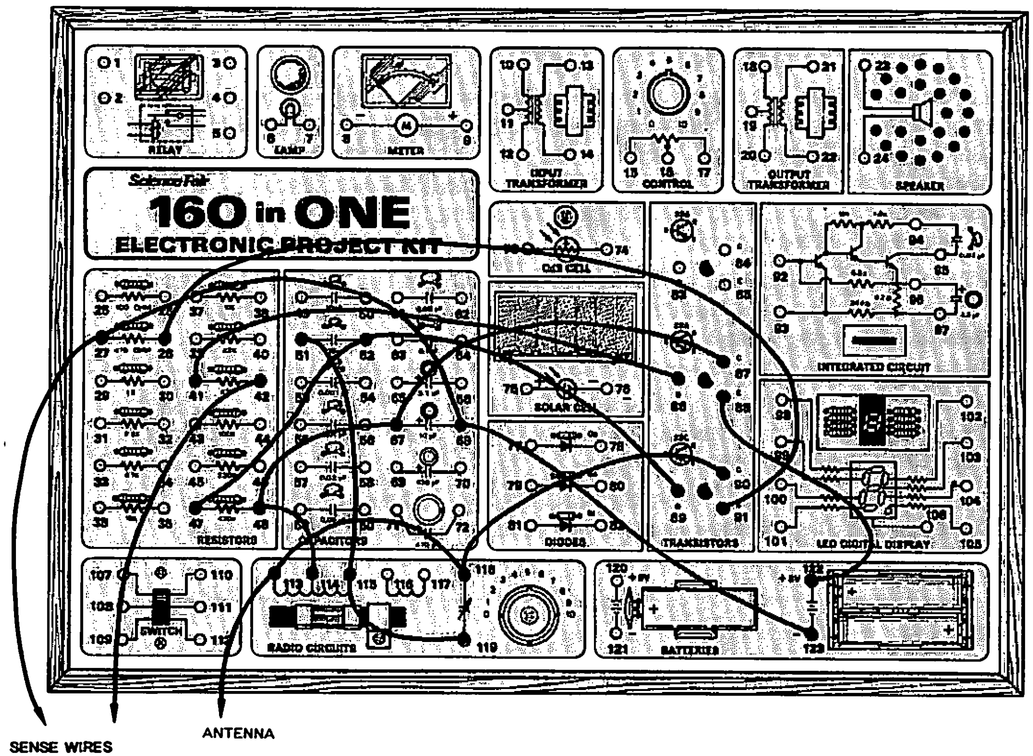
The 2SC Transistor is in the RF oscillator circuit. The emitter is effectively connected to the ferrite coil center tap through the 10uF Capacitor, which acts as a short circuit at these frequencies. Feedback to the base is through the 100pF Capacitor. The 470K Resistor supplies the base-bias current to turn the Transistor ON.

Notice that Battery current must flow through the 2SA Transistor to get to the oscillator circuit and back. With the probes insulated from each other, the only current that can flow is the leakage current 1 CEO (current from the collector to emitter with the base open). This weak current cannot drive the RF oscillator.

When the probes both contact the water, some current can flow through the water to supply base current to the 2SA. This base current turns the 2SA ON so that oscillator current can flow between C-E of the 2SA with little resistance. We're using the 47K Resistor as a current limiting resistance. Without this resistance the 2SA could be burned out by excessive current, expecially if the probes are accidently shorted.

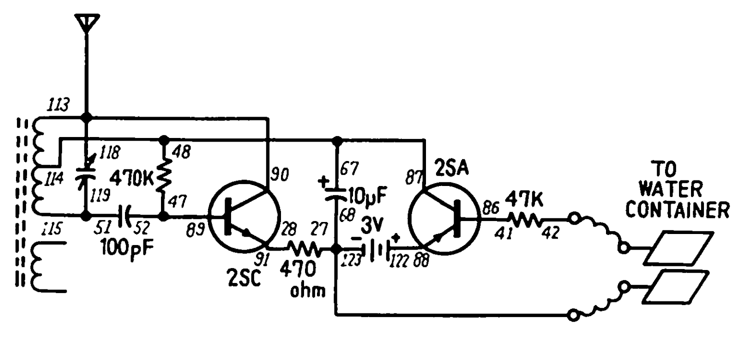
With the 2SA ON, the RF oscillator produces an RF signal — indicating the water level has reached the probes. These probes may be made of almost any insulated conductors, but large surface areas provide the most abrupt turn ON characteristic.

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 the signal is heard through the radio.



WIRING SEQUENCE:

41-86, 87-67-48-114, 88-122, 90-118-113-Antenna (green wire supplied), 119-115-51, 89-52-47, 42-Contact Probe, 28-91, Contact Probe-27-68-123



NOTES

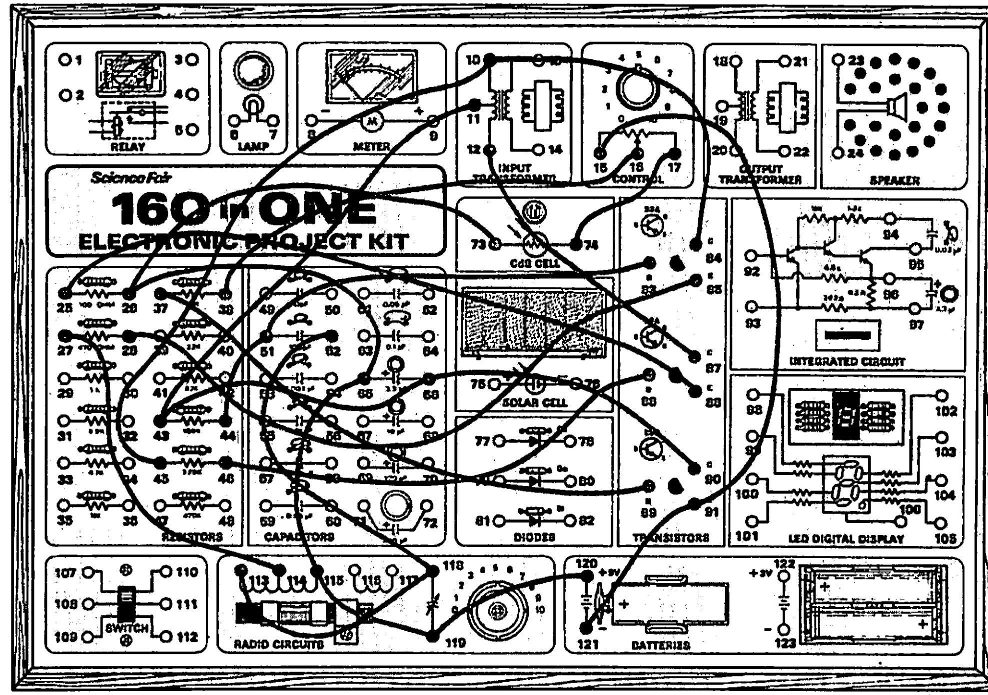
101. LIGHT ACTIVATED WIRELESS BURGLAR ALARM

This circuit is actualy an AM radio transmitter which is turned on when the necessary amount of light strikes the CdS. You will need an AM radio tuned to a weak station to receive the alarm signal from this project.

When the wiring is complete, you will need to adjust the Control to the desired sensitivity for the switch section of the circuit (the CdS, 50K Control, 10K Resistor and 2SC Transistor). You will probably want the transmitter to be activated by low light levels. Then if you place the alarm in a dark place (like a desk drawer or closet) it will send a signal to the nearby radio receiver whenever light hits the CdS.

The transmitter section of this circuit consists of two oscillators. One produces the RF (radio frequency) signal and the other produces the audio frequency signal. The signal from the audio oscillator controls the amplitude (strength) of the RF signal. These changes in RF signal amplitude (controlled by the audio oscillator) are called modulation. The amplitude modulations are turned into sound by the AM radio. By the way, that's where AM radio gets its name . . . Amplitude Modulation.

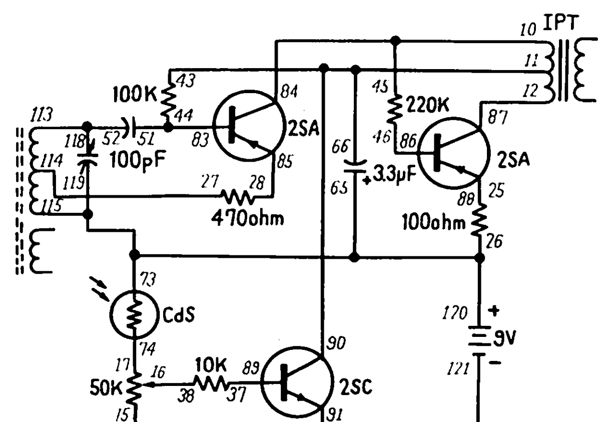
Have fun with this circuit, and see whom you can catch!



NOTES

WIRING SEQUENCE:

11-43-66-90, 12-87, 15-91-121, 16-38, 17-74, 25-88, 27-114, 28-85, 37-89, 44-51-83, 45-10-84, 46-86, 52-118-113, 73-26-65-115-119-120



102. LIGHT CONTROLLED BURGLAR ALARM

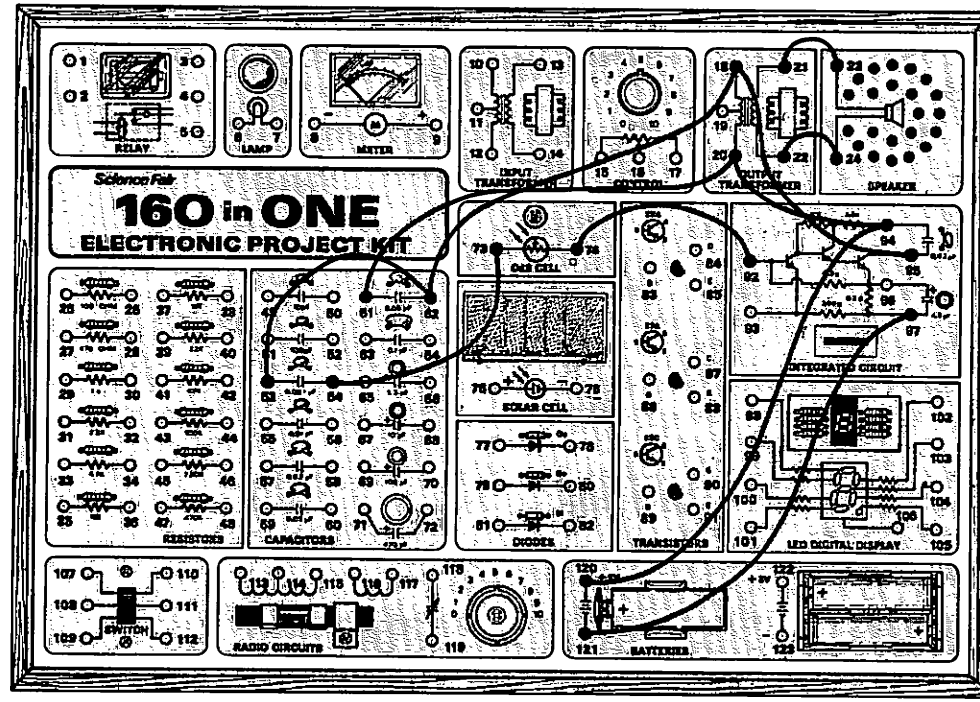
This project is a light controlled oscillator which uses the integrated circuit (IC). In total darkness it just sits there nice and quiet, but a little light causes the speaker to give out a 1500 hertz howl.

The circuit is quick and easy to hook up because of the few components required outside of the IC. A 0.05uF Capacitor is used to obtain a strong output tone, a 0.001uF is used to couple the output signal back to the input while blocking the DC and the CdS Cell is placed in series with the feedback.

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

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

NOTES



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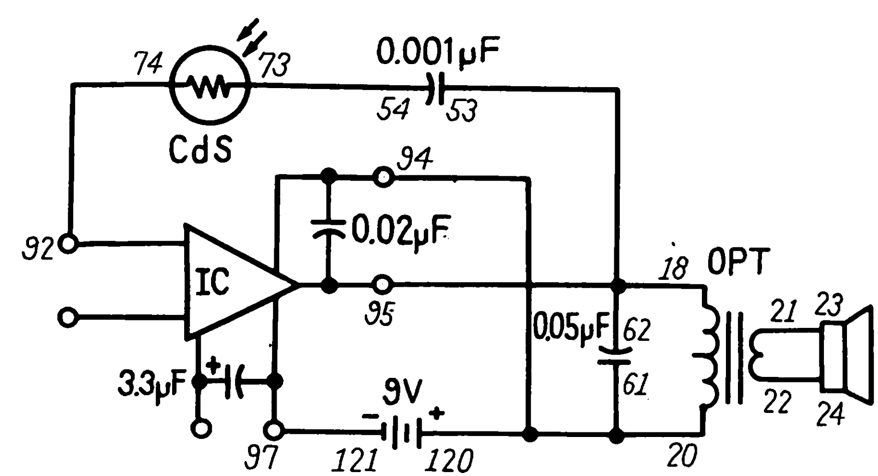


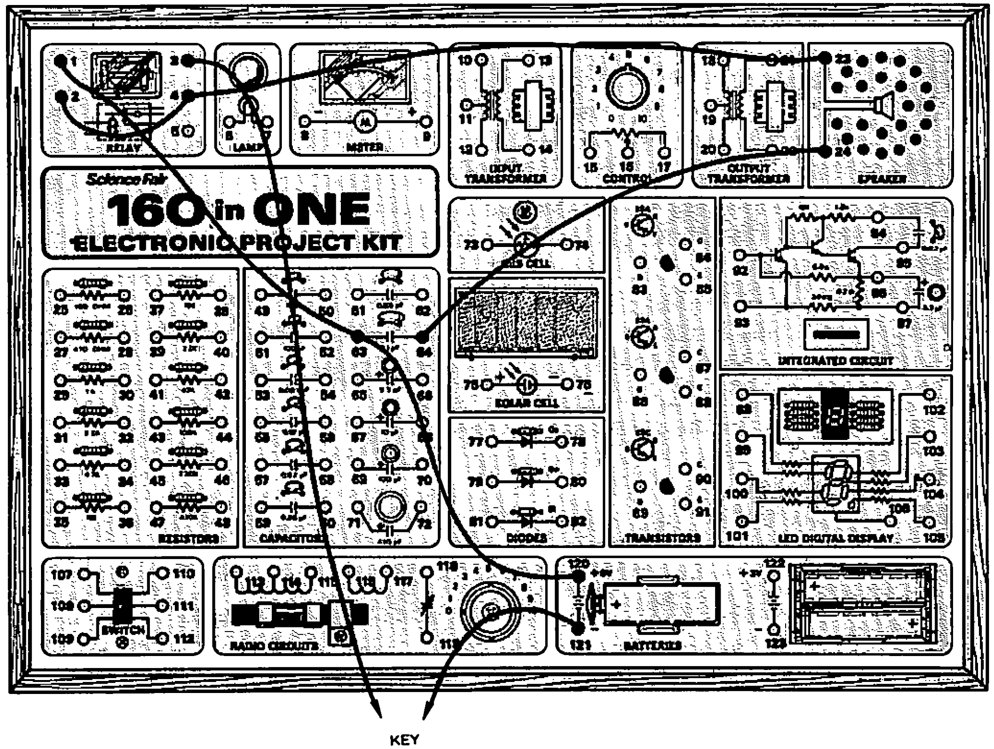
103. RELAY AND SPEAKER BUZZER

Here is a simple project which shows how a buzzer works and how the interrupted current can power a speaker.

Notice that the normally closed Relay contacts are used. This causes the circuit to be opened as the Relay is energized, but obviously an open circuit de-energizes the Relay and the contacts close again to begin a repeat of the cycle.

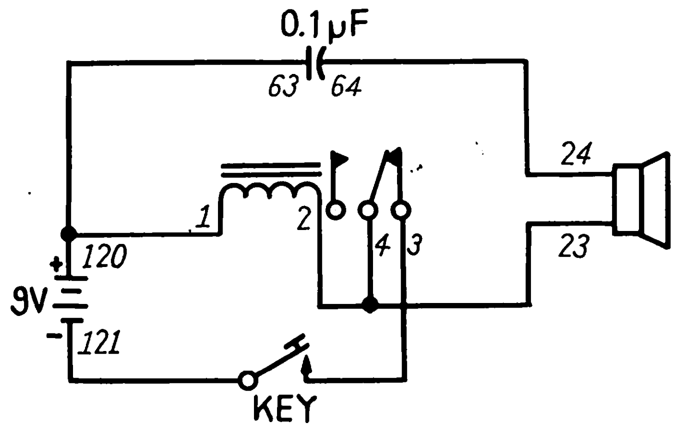
Many factors affect the rate at which the Relay points open and close — mass of the moving parts, magnetic air gap, type of core material, applied voltage, etc. This circuit has another circuit across the Relay which also affects operating speed. This speaker and series Capacitor circuit adds some delay to operation due to Capacitor charging and discharging current.

The Speaker is driven by the charging and discharging current of the 0.1uF Capacitor. Volume is not great, but it demonstrates the fact that the interrupted Relay current and voltage can also be used to operate other electrical devices. Can you think up some applications of this type of circuit?



WIRING SEQUENCE:

23-4-2, 24-64, 120-63-1, 3-Key, Key-121



NOTES

104. LIGHT RECEIVER OR LIGHT ALARM

This project makes use of the Solar Cell to control the operation of an audio oscillator. The audible output may then be used as an alarm to indicate the presence of light. This could be used to get you up in the morning at the crack of dawn. It could also be used as an alarm where the presence of excessive light is undesirable, such as in a photo lab.

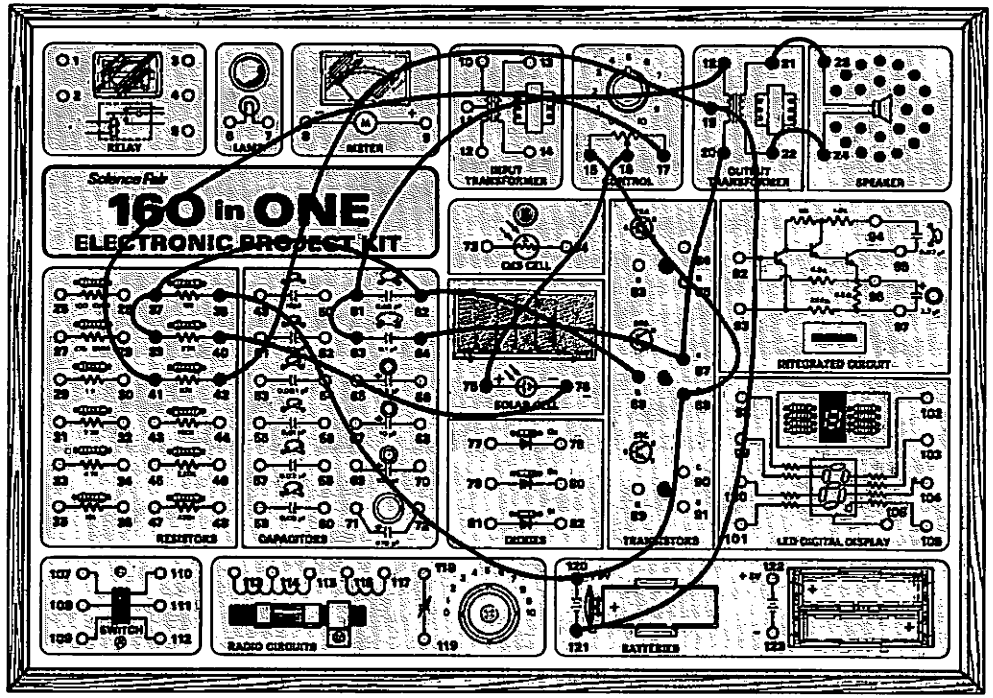
The circuit is adjusted by setting the 50K Control to the point just below that which will start low level oscillations. Then as the light level is increased the Solar Cell develops sufficient additional voltage to start the circuit into oscillation. You will want to experiment with the Control setting as it is the key to obtaining the turn ON characteristics you want.

The oscillator circuit is the common pulse type, which we've described elsewhere so we won't repeat it here. However, the control circuitry is unique, so we will describe it.

With light not applied to the Solar Cell, the Transistor base-bias voltage is obtained entirely from the voltage divider (made up of the 47K Resistor and 50K Control). This voltage is further divided by the Solar Cell resistance, the 22K and the 10K. The Control can be adjusted to obtain from zero volts bias to above the 0.6 volts or so needed to begin oscillations. Normal Control settings should be for a base voltage to the Transistor, which is slightly below that required to start oscillations.

Now as light hits the Solar Cell it generates additional voltage in the circuit to overcome the difference between that from the 50K Control and that required for oscillator operation.

NOTES



WIRING SEQUENCE:

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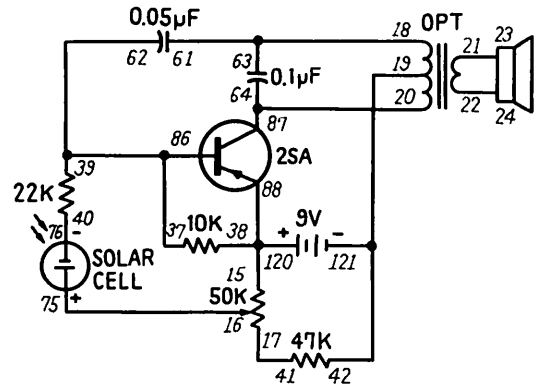


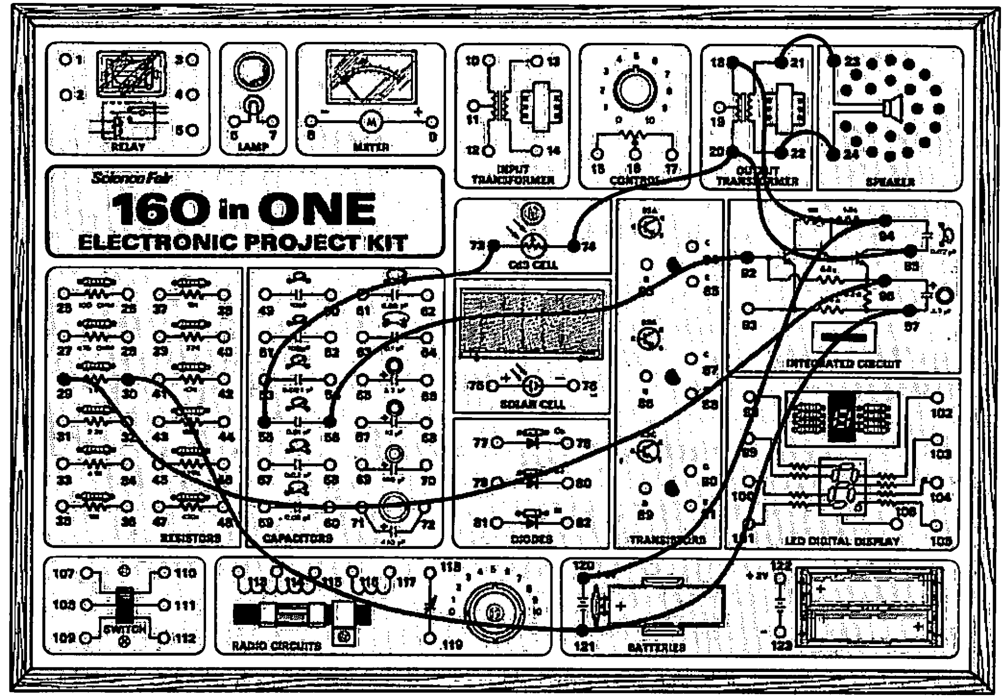
105. CdS CONTROLLED I. C. OSCILLATOR

This project is a circuit which uses the IC (integrated circuit) as an oscillator. The tone of this oscillator varies with the amount of light hitting the CdS. Try changing the tone by moving your hand over the CdS (with and without the CdS shield). Operation is virtually the same as that of project 102. Can you locate the circuit differences?

You will want to compare the two circuits and try other changes as well. Do not use values less than 1K between terminals 96 and 97 in this circuit, or you may damage the IC. You may try every Capacitor on the board without fear of damage. Have fun!

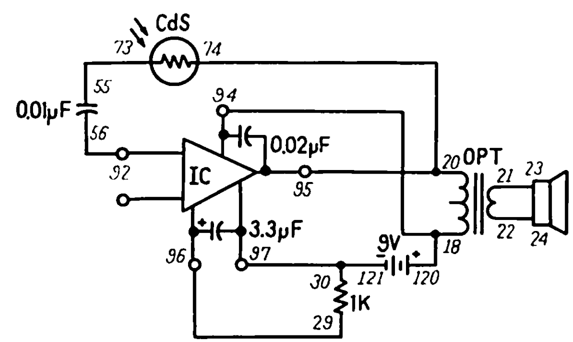
Record any interesting results in the space below, so you can repeat them later for your friends.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 95-20-74, 73-55, 56-92, 96-29, 30-121-97, 18-94-120



106. BURGLAR ALARM WITH A LATCHING RELAY

This project shows you how disconnecting a wire can turn ON a circuit.

After you've finished the wiring, set the Switch to the ON position (up). Now disconnect the "trip wire" between terminals 48 and 120. The alarm oscillator will be activated, and will continue to sound even if you reconnect the trip wire. To turn the alarm OFF, you must move the Switch to the OFF position.

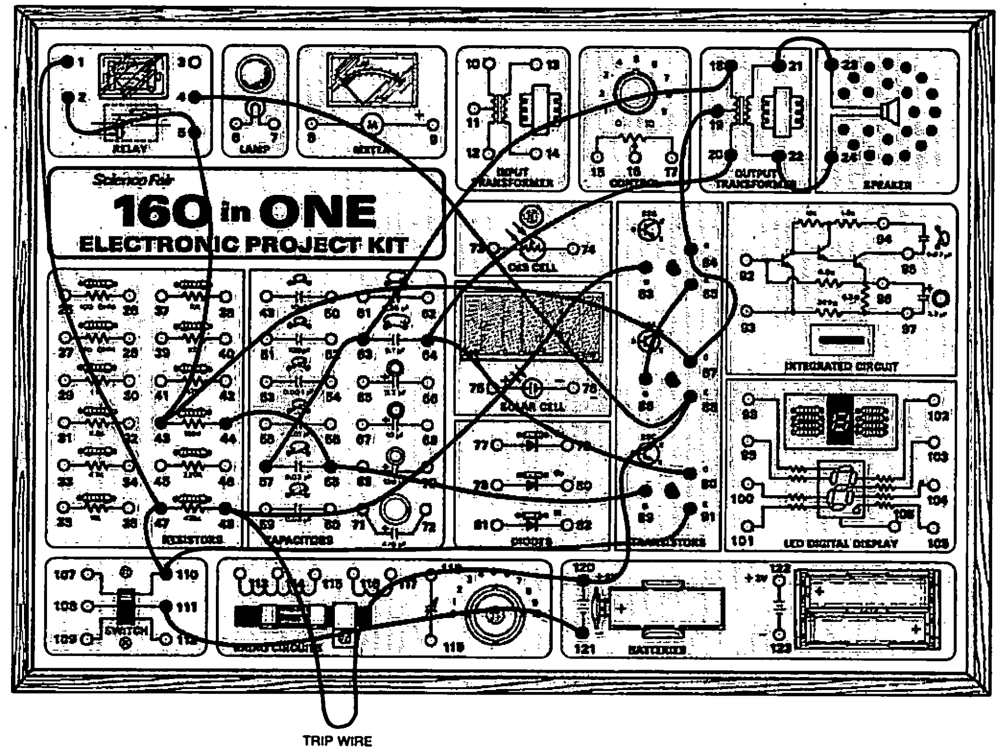
Electricity will always follow the path with the least amount of resistance, and that is why this circuit works as it does. The trip wire makes a short circuit (almost no resistance) that bypasses the base of the 2SA(1) Transistor. With the 2SA(1) Transistor OFF, there is no current flowing in its C-E circuit or the C-E circuit of the 2SA(2). Without this current flow, the Relay coil is not energized and the oscillator is OFF.

When the trip wire is disconnected, base current is applied to the 2SA(1), turning it and the 2SA(2) ON. The current flow in the 2SA(2) C-E circuit energizes the Relay coil which closes the Relay contacts and activates the the oscillator. When the Relay contacts close, they also complete a direct path (without going through the 2SA(2) C-E circuit) for current from the 9V Battery to continue supplying power to the Relay coil. That's why the alarm continues to sound even if you reconnect the trip wire.

To use this circuit as a real burglar alarm, position the trip wire so that it will be disconnected by someone opening a door or drawer. If you really want to get fancy, you could use magnetic switches like professional alarm systems do. These types of switches are available at Radio Shack.

This circuit has a very limited current drain, so the alarm will sound a long time before the Battery gives out.

NOTES



WIRING SEQUENCE:

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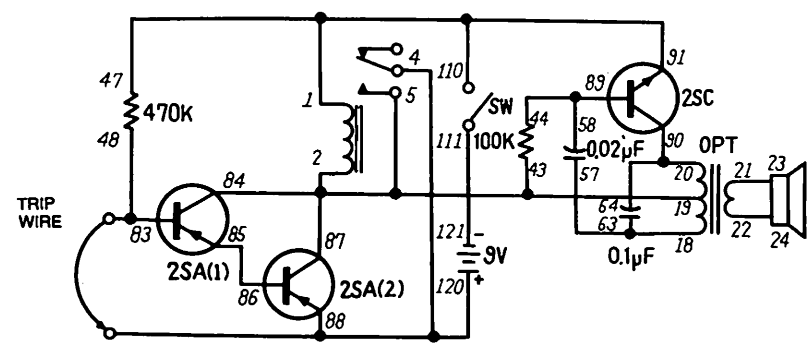


107. ONE TOUCH ALARM

This project is an alarm that is activated when someone's hand touches the two Probe wires. Both the Lamp and an audio oscillator are triggered by this circuit.

Follow the steps below to operate the alarm:

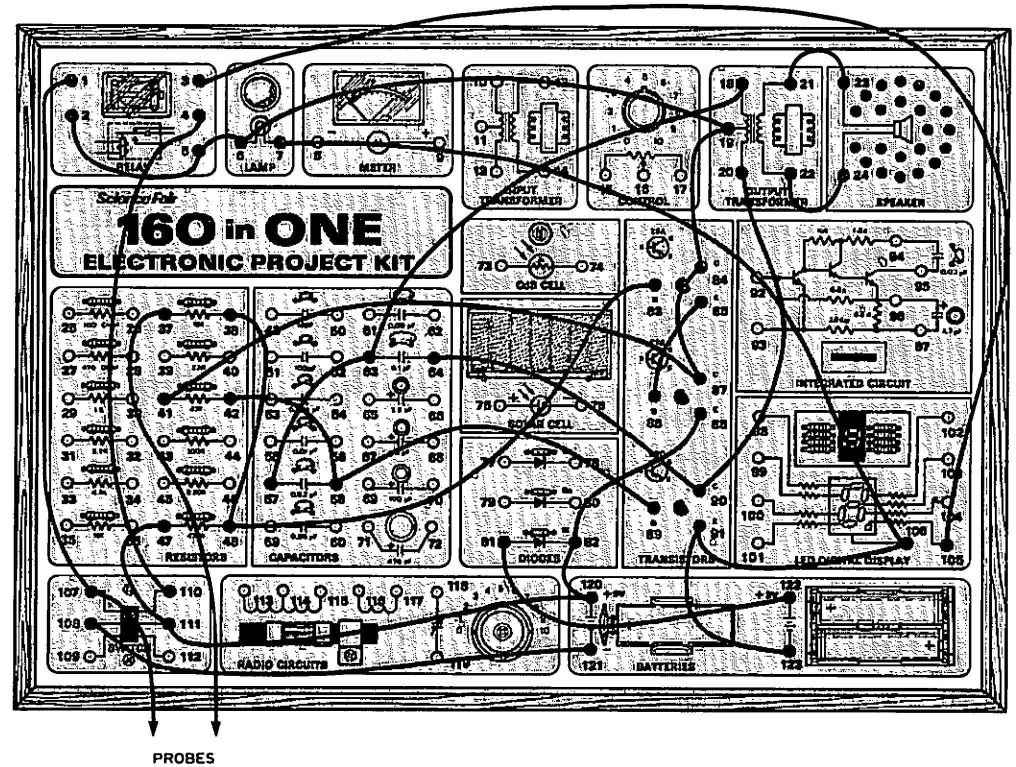
1) Set the slide Switch to the OFF (down) position, and complete the wiring.
2) Set the Switch to the ON (up) position. The decimal point of the LED should light to indicate the alarm is 'standing by'.
3) Touch the two Probe wires with your hand.

This will supply base current to the 2SA(1) Transistor, which is connected to the 2SA(2) Transistor in a way (called 'Darlington') that produces a high gain amplification. This energizes the Relay coil and causes the Relay to switch power from the LED circuit to the Lamp/oscillator circuit. The Relay is now locked in that position and the alarm will continue to sound even if the Probe wires are no longer connected (by being touched).

To turn the alarm OFF, set the Switch to the OFF (down) position. Then return it to the ON (up) position and the LED will indicate 'stand by', again.

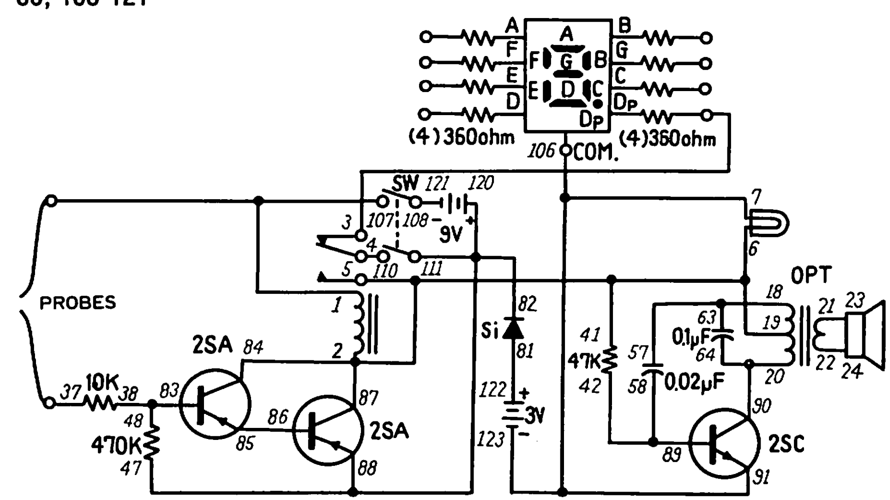
Try wiring the ONE TOUCH ALARM to safeguard one of your desk drawers or a cash box.

NOTES



WIRING SEQUENCE:

1-107-Probe, 2-5-6-19-84-87-41, 3-105, 4-110, 7-106-91-123, 18-63-57, 20-90-64, 21-23, 22-24, 37-Probe, 38-48-83, 42-58-89, 47-111-120-82-88, 81-122, 85-86, 108-121



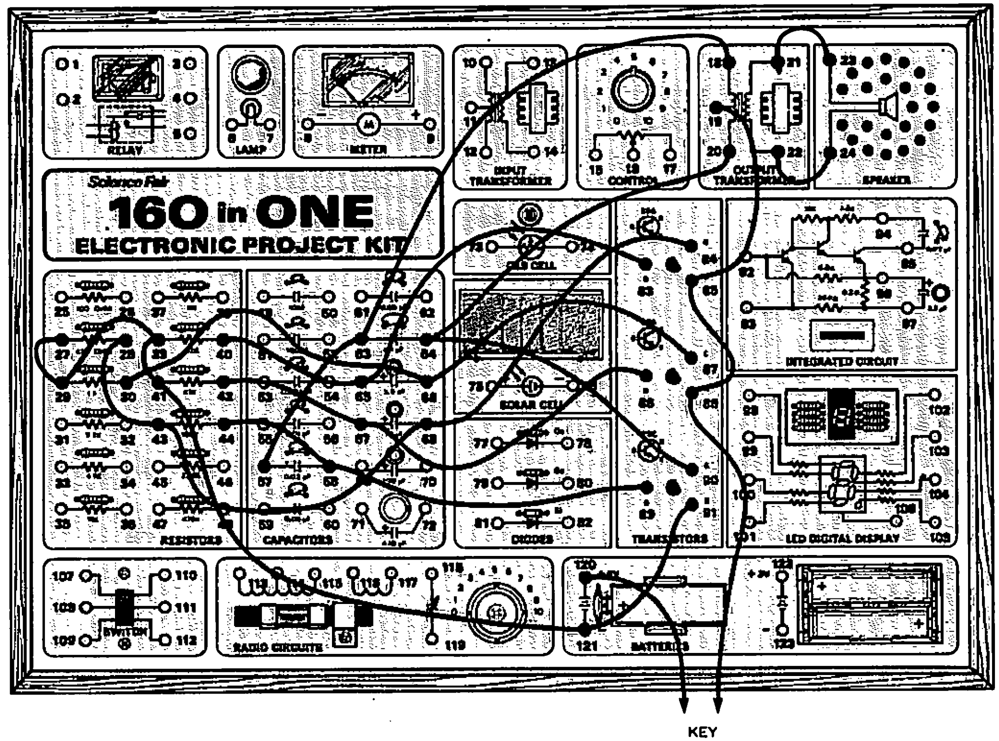
108. ALARM SOUND GENERATOR

The purpose of this project is to show how one oscillator can control another. In this case we have a multivibrator (oscillator) controlling a pulse oscillator. By now you should recognize the multivibrator circuit on the left side of the Schematic (made up of the two 2SA Transistors and the controlling Resistors and Capacitors). Its relatively slow oscillation frequency (only a few cycles per second) turns the pulse oscillator ON and OFF. The pulse oscillator's frequency is in the audible range (20 to 20K Hertz). The multivibrator controls the pulse oscillator by controlling its base current, but you probably already knew that.

This intermittent sounding alarm would be more effective than a continuous tone, because it is more noticeable

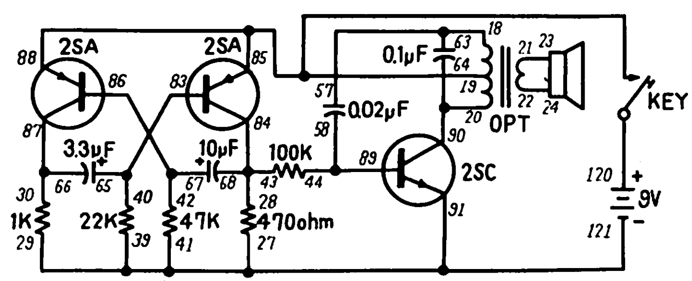
You can experiment with this project by varying the values of the 22K, 47K, and 100K Resistors, and the 0.02uF Capacitor.

NOTES



WIRING SEQUENCE:

18-63-57, 19-85-88-Key, 20-64-90, 21-23, 22-24, 27-29-39-41-121-91, 28-43-68-84, 30-66-87, 40-65-83, 42-67-86, 44-58-89, 120-Key



109. 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 which show the water level.

When the water is below all three of the Probe wires, only the bottom segment (D) of the LED will be on (indicating a low water level).

When the water rises to a level that touches the two long Probe wires (but is below the short Probe wire) base current is supplied to the 2SA(2) Transistor and the middle segment of the LED (G) is activated through the Transistor's C-E circuit (indicating a moderate water level).

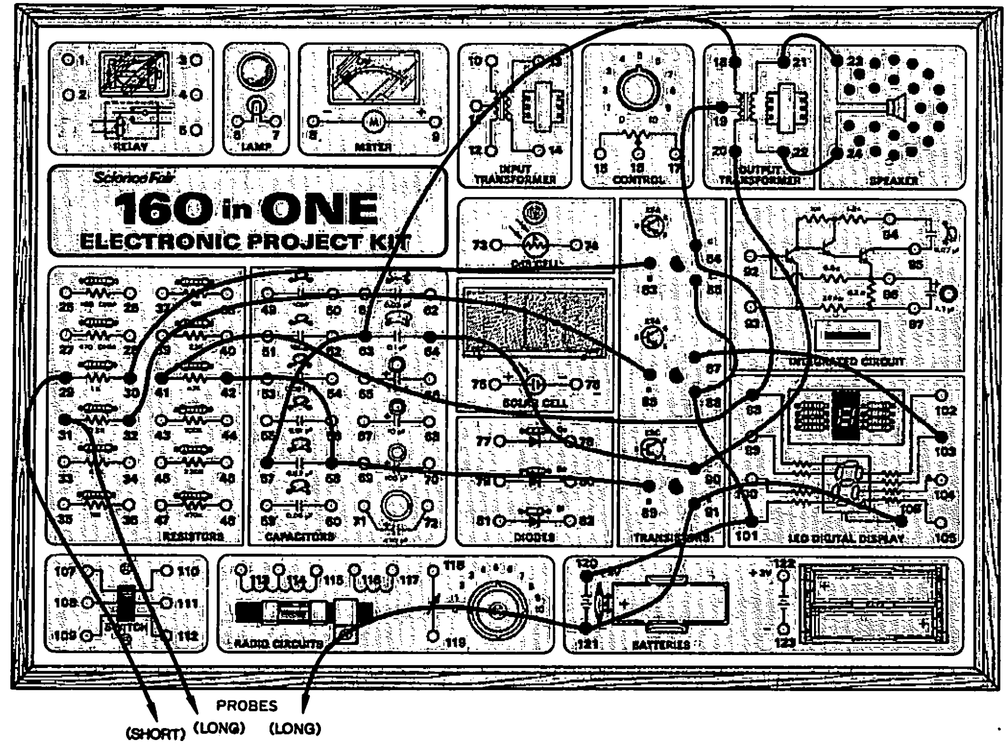
If the water reaches a level high enough to touch all three Probe wires, base current is supplied to the 2SA(1) Transistor also, and the top segment of the LED (A) lights. In addition, the audio oscillator is activated (as a warning of a high water level).

A circuit like this could be used to show water levels and help prevent an overflow in anything from a home aquarium to a city's water resevoir.

Try adding the wiring below to get a different display from the LED.

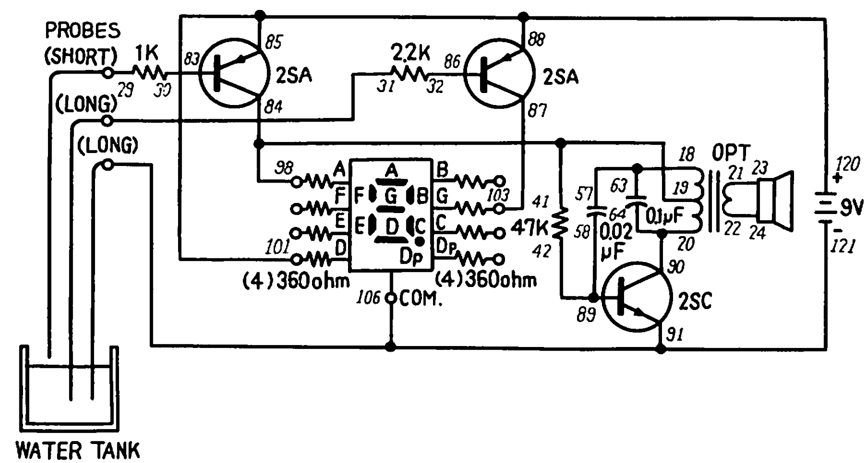
85-99-100-102-104, 84-86

NOTES



WIRING SEQUENCE:

18-63-57, 19-84-98-41, 20-90-64, 21-23, 22-24, 29-Probe (short), 30-83, 31-Probe (long), 32-86, 42-58-89, 85-88-101-120, 87-103, 106-91-121-Probe (long)



110. NIGHT LIGHT

One very practical use for the CdS Cell is to turn lights ON or OFF at sunrise or sunset. This circuit will automatically turn ON the Lamp at night.

Try studying the Schematic before you look at the explanation below, and see if you can figure out what's going on in this circuit. Then see if your notes match our's. If they do . . . GREAT! If they don't, at least you'll be sure to remember it next time.

Circuit operation is as follows:

1. Adjust the Control until you reach the point where the light comes ON.
2. Reduce the Control setting just enough to turn the light OFF, again.

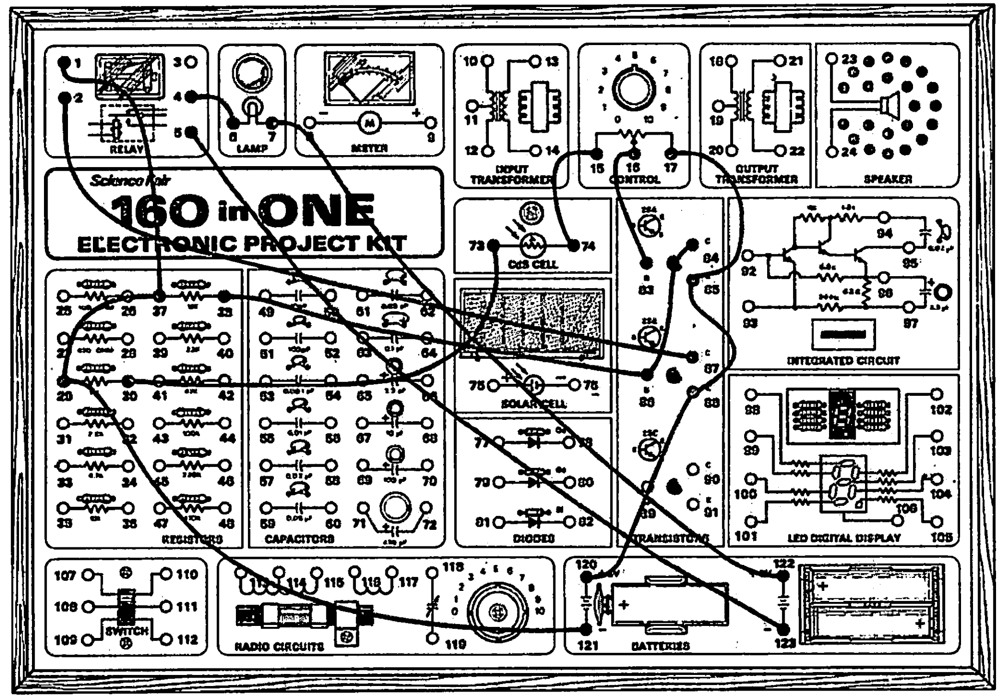
Once the project is set, it will light the Lamp whenever the level of light around the CdS dims.

As you probably guessed, the CdS in this circuit controls the base current to the 2SA(1) Transistor. When the light on the CdS is relatively high, the resistance through the CdS is low, and enough base current flows to turn ON the 2SA(1). When the 2SA(1) is ON, its C-E circuit conducts and short circuits the current past the base of the 2SA(2) Transistor (the 2SA(2) is therefore OFF). With the 2SA(2) OFF, no current flows through its C-E junction and the Relay coil is de-energized. The Relay is in the normally open position, so the Lamp is OFF.

When the light around the CdS dims, the resistance increases and turns OFF the 2SA(1). Now the current can flow to the base of the 2SA(2) which turns it ON and energizes the Relay coil. This pulls the contact points of the Relay to the closed position and turns on the Lamp.

The Control in this circuit allows you to set the Lamp to come ON with different amount of light (or should we say darkness).

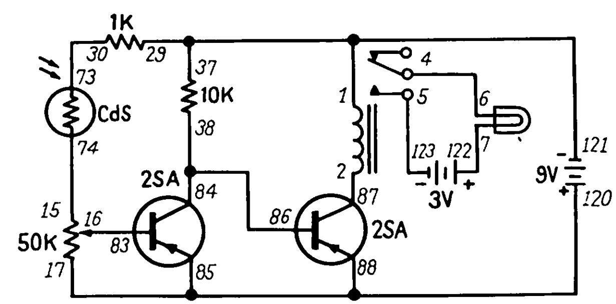
CAUTION: To avoid damage to the Transistor, be sure to set the Control to 0 before wiring this circuit.



WIRING SEQUENCE:

1-37-29-121, 2-87, 4-6, 5-123, 7-122, 15-74, 16-83, 30-73, 38-86-84, 17-85-88-120

NOTES



111. WIRE TYPE LIGHT SIGNALER WITH MONITOR

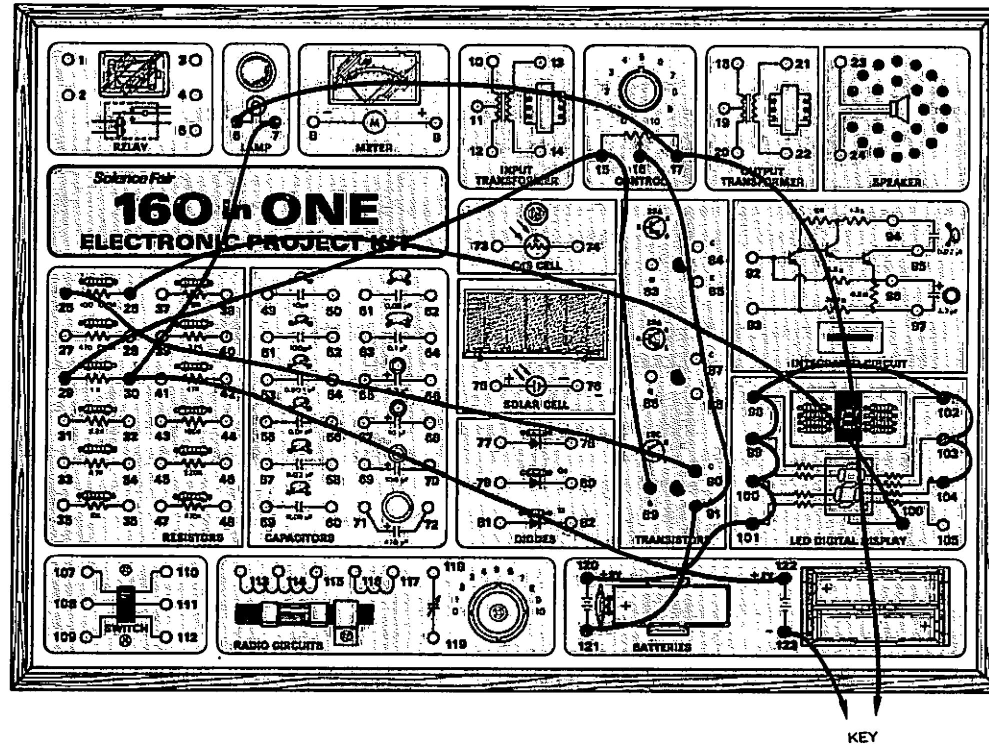
This is the first experiment in the category of Communications Circuits. For many experimenters this is the most interesting and exciting type of circuit, because you learn a little about how radios, telephones, light and other forms of long distance communication electronics circuitry works.

This project is a wire type, light signal transmitter with monitor. The monitor is the 3V Lamp which lights to indicate that the other light signal, which can be at the other end of a long line, has gone ON. The light signal device is the LED display wired to display the number 8. A Transistor is used to switch the LED ON.

Closing the key completes two 3V circuits. One circuit powers the 3V Lamp and turns it ON. The other circuit provides base-bias to the 2SC switching Transistor through a 1K current limiting Resistor. The 50K Control is used to adjust the base-bias to a level which allows the Transistor to turn ON but not greater than necessary. The reason for this is to keep any voltages, which may be induced on the long transmission lines, from also turning ON the Transistor and LED.

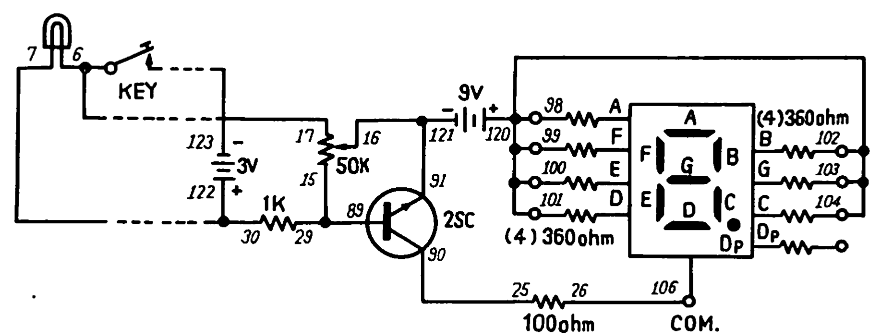
This demonstrates the principle of operation, but of course the 3V Lamp, with its high current drain, would not be used in an actual circuit that has long transmission lines.

NOTES



WIRING SEQUENCE:

122-30-7, 6-17-Key, 29-15-89, 90-25, 26-106, 104-103-102-98-99-100-101-120, 123-Key, 16-91-121



112. CODE SOUNDER

The purpose of this project is to study basic Relay operation, and demonstrate how the old fashioned clapper type code sounder worked. This Relay is very small and covered with a sound deadening dust cover, but you can get the idea.

Using just two wires you can apply a voltage to make the Relay close with a click, and then when the voltage is removed the Relay opens with a click. This "click", "click" sound can be arranged into a telegraph code which could be used to send messages. Can you imagine trying to learn this "language"?

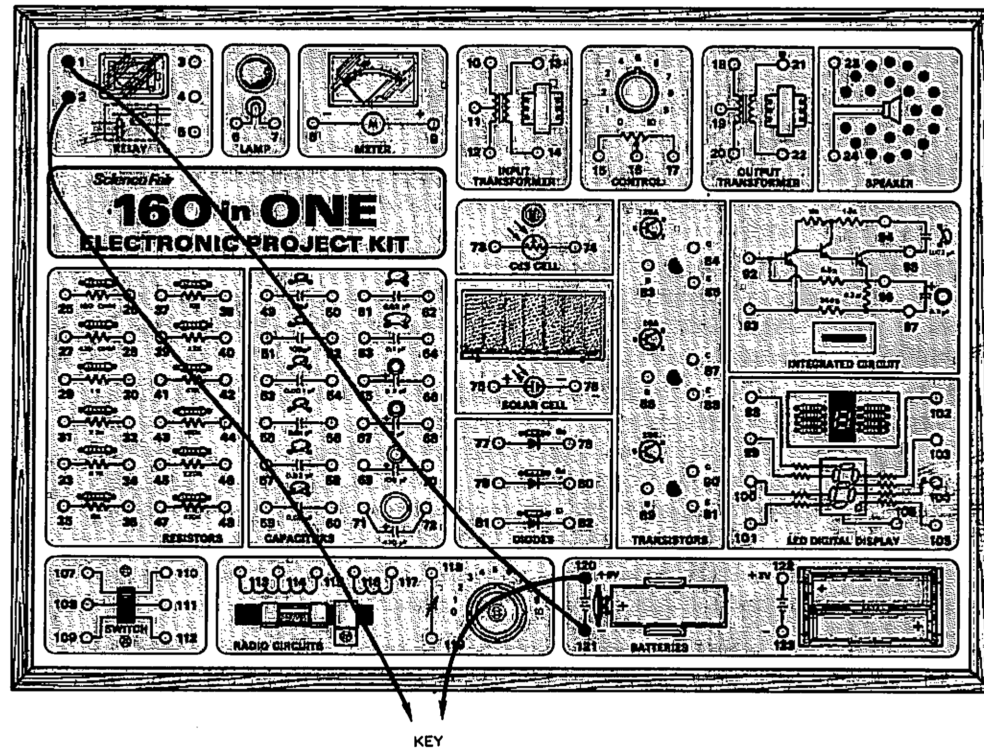
The code used to send these messages of clicks and clacks was called the American Morse Code. Men got so proficient that this was like a new language to them. This method has mostly been replaced by the telephone and teletype systems today.

The Relay used here has a resistance of about 500 ohms and requires a minimum of about 6mA (milliamps) to initially pull the armature (movable part) in. This means that the voltage required (minimum) is 0.5 X 6 = 3 volts. A fresh set of 3V batteries (two 1.5V cells) should just barely be able to pull the Relay in (energize it). Try it. It is usual for the Relay to not quite pull in at this voltage. If yours does, you are lucky to have one of the more sensitive units.

Now series the 3V and 9V Batteries to obtain 6V. Connect 121 to 123 and then 6V is taken from 120 and 122. (Did you figure that one out? Connecting the Batteries in series opposing results in 9-3 = 6 volts.) This should pull the Relay in easily. If it doesn't, you may need to replace the Batteries. Try a 100 ohm Resistor in series with the Relay. It ______ (does or does not?) pull in. Usually it does.

Now try the 9V Battery, alone. A series 470 ohm Resistor should still allow Relay operation, but a 1K will not.

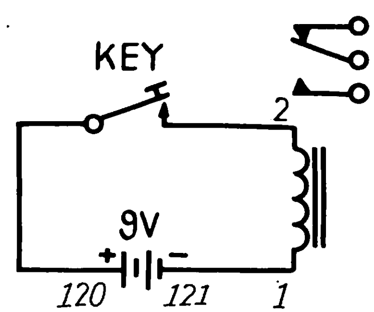
Insert a 1K Resistor in series with the Relay and then momentarily short circuit across the 1K with a piece of wire. The Relay should operate and stay energized with the 1K in the circuit. The reason for this is that it takes more current to energize the Relay (typically 6 to 9mA), than to hold the contacts in place (typically 1 to 3mA). The is because the magnetic air gap is much smaller when the Relay is energized.



WIRING SEQUENCE:

121-1, 2-Key, Key-120

NOTES



113. SINGLE WIRE COMMUNICATIONS SYSTEM

Here is a tone oscillator which uses two Transistors in a circuit which can power an Earphone connected at the other end of a single line a long distance away. A single line is all that is needed because the ground may be used as the second conductor. The tone is composed of pulses which have a fundamental repetition rate of about 1600 cycles per second (hertz).

This may be used to send code messages to a friend who is at the opposite end of the yard. For the wire, you can use a fence or a clothes line, or any other metallic conductor. The ground connection can be made by connecting to some already grounded metallic object or something metallic pushed into the ground. Here is where some 'grassroots' experimenting can be done!

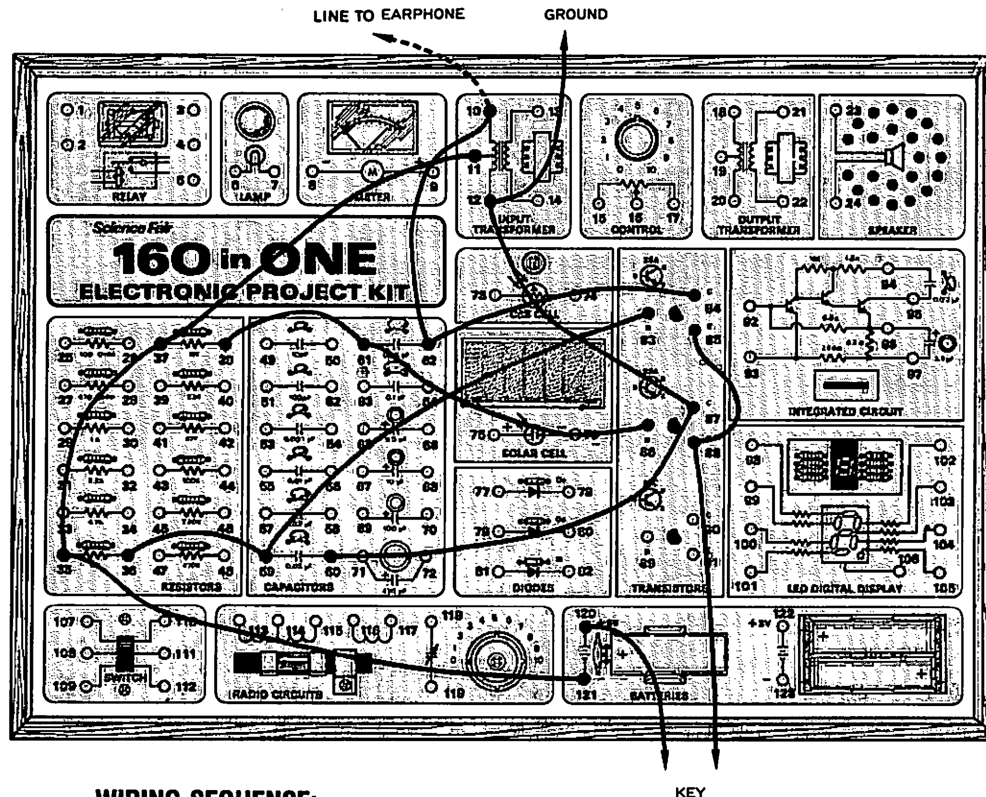
The oscillator circuit is arranged like a push/pull amplifier. The difference, of course, is mainly that the output across the Transformer is connected back into the input (base circuits) through the Capacitors. The amount of bias current supplied to the bases is quite high to obtain the strong oscillations.

You can experiment with this circuit by changing Capacitor and Resistor values, but don't decrease the values of Resistors or the Transistors may be damaged. It is also interesting to place the Resistor directly across the Capacitors instead of from Battery negative to one end of a Capacitor. Try different size Capacitors with these connections. With this circuit it is possible to obtain nearly every type of signal, from a sinewave to a square wave to a narrow pulse wave.

If you have a VOM you will want to measure total Battery current as you experiment with this circuit. Place the Meter on a current range above about 15mA, and then insert the Meter in series with the Key.

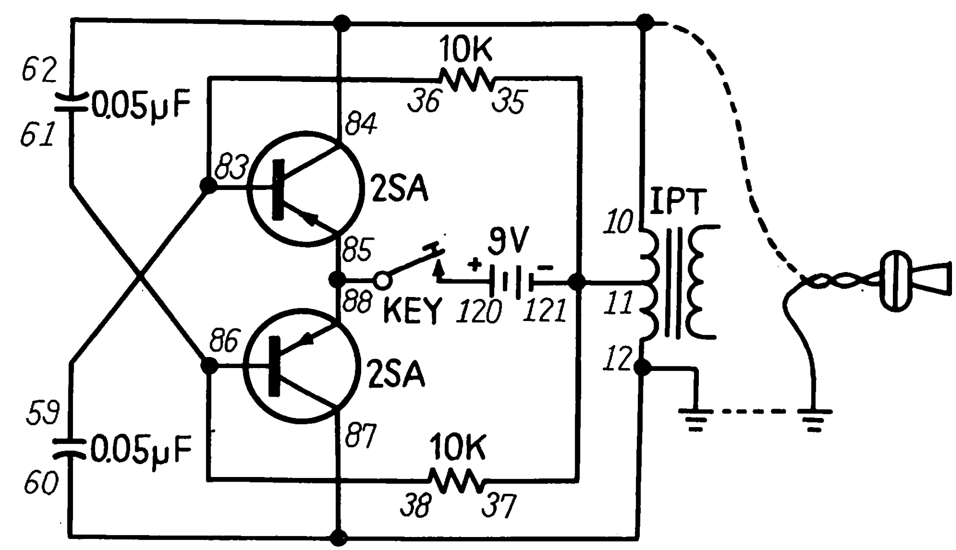
Will this circuit work on 3 volts? Try it. You are generally safe when trying lower voltages for Transistor circuits. About the only time a lower voltage may not be safe is when a motor is involved.

NOTES



WIRING SEQUENCE:

121-35-37-11, 10-62-84, 83-59-36, 38-61-86, 12-87-60, 85-88-Key, Key-120, 12-Ground, 10-Line to Earphone, Earphone-Ground



114. CODE PRACTICE OSCILLATOR WITH TONE CONTROL

Would you like to become an ameteur radio "ham"? Many radio operators started out with a code practice oscillator with tone control like this one. The tone control is handy when you tend to become fatigued listening to the same tone all the time. You can also use the differences in tone for your own special code, in addition to the Morse Code shown on the Key.

The best way to learn the Morse Code is to find someone else who is interested in learning 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. The operation of the Key will become automatic, like riding a bike or driving a car. It will take hard work to get to this point, but you'll be proud when you do.

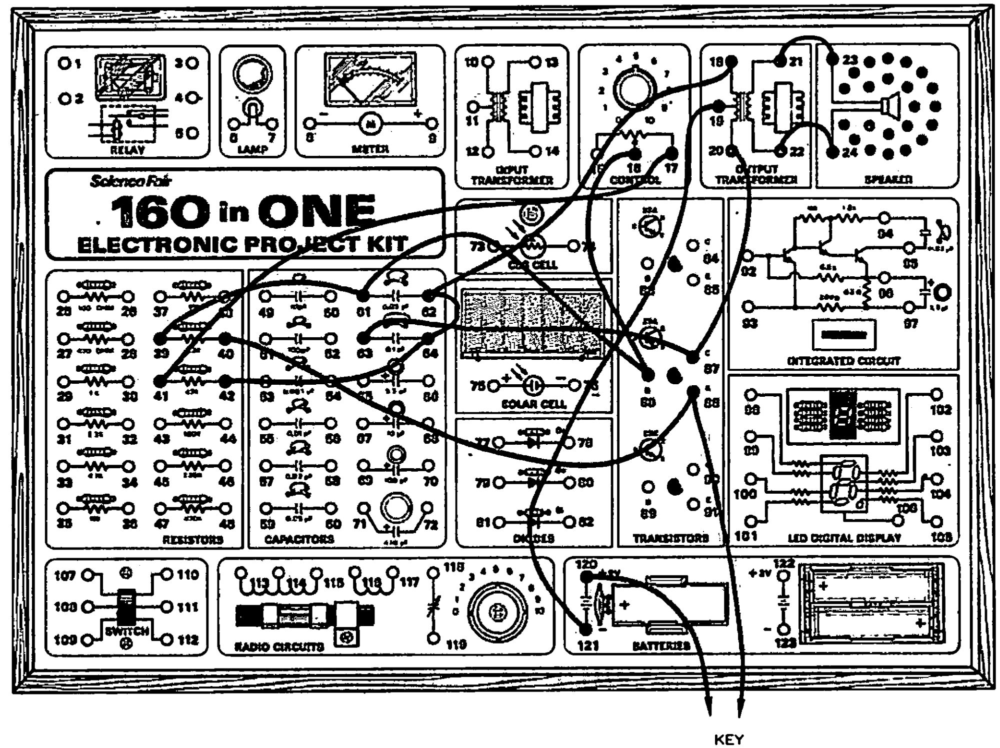
If you want to practice privately (with the Earphone), disconnect the Speaker and connect the 50K Control across the primary Transformer windings, and then connect the Earphone from the center Control terminal (wiper) to one end of the Control. With these connections the Control will act as a volume control as well as a tone control. You may replace the 50K Control with a fixed resistance if you want a fixed tone and volume.

The tone from the oscillator is not designed to be a pure sinewave, because it has been learned that a pure sinewave signal is more tiring than a tone full of harmonics.

The theory of this oscillator is given in other projects, so we won't repeat it here. However, we will discuss how the tone control works. When the 50K Control is adjusted for less resistance in the circuit, less resistance is present across the 0.05uF Capacitor so that it charges faster between pulses. This causes the pulses to be closer together and therefore the frequency (and tone) is higher. The opposite condition occurs when the Control is adjusted for more resistance.

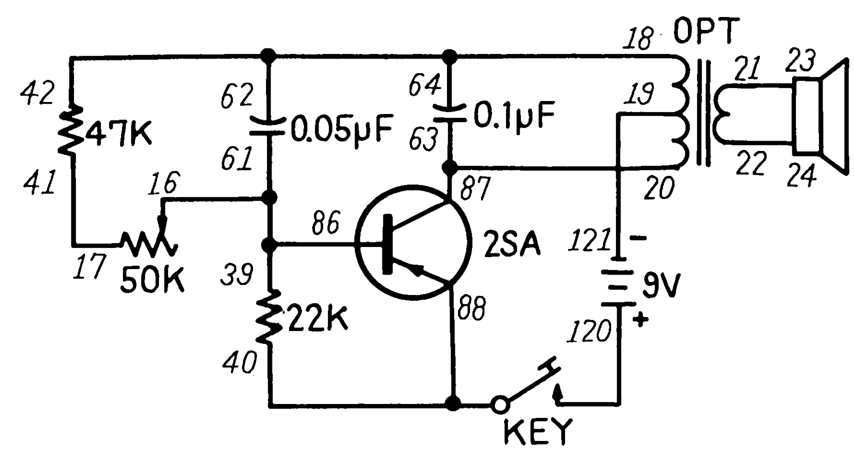
If you become proficient at Morse Code, the next step is to contact your nearest Radio Shack store and see what study materials are available for the written part of the FCC exam. Good luck!

NOTES



WIRING SEQUENCE:

21-23, 22-24, 121-19, 20-87-63, 18-62-64-42, 41-17, 16-86-61-39, 40-88-Key, Key-120



115. I. C. MORSE CODE PRACTICE OSCILLATOR

This is a Morse Code practice oscillator which uses the IC (integrated circuit) with feedback control. Although this project is originally set up as a code oscillator, with slight variations you can obtain a wide range of sounds effects (from a motor boat to a chirping bird).

The IC in your kit can take the place of three Transistors and five Resistors. Normal current usage is about 2mA, so it is easy on your Batteries. Capacitors are permanently wired across two IC terminals. The 0.02uF Capacitor provides a high frequency roll off so that the amplifier will not oscillate when you don't want it to. Without this Capacitor the IC would oscillate at some ultrasonic frequency whenever any lead is connected to it.

The 3.3uF Capacitor prevents degeneration (which would cause decreased amplifier gain). Without this Capacitor the 910 ohm internal bias Resistor would allow both AC and DC current to be fed back into the input stage. This would dramatically reduce the total IC gain.

You may change the values of the 3.3uF and 0.02uF Capacitors by paralleling other Capacitors across them. The resulting capacitance is the sum of the two Capacitors. For example, if a 100uF is paralleled with the 3.3uF, the resulting capacitance is 103.3uF.

You will also want to try different values for the 0.05uF input Capacitor. See if you can change this one along with the others to obtain the following sound effects. Record the changes so you can repeat them, later.

1. Phone ringing at the other end of the line ____________________

2. Clucking chicken ____________________

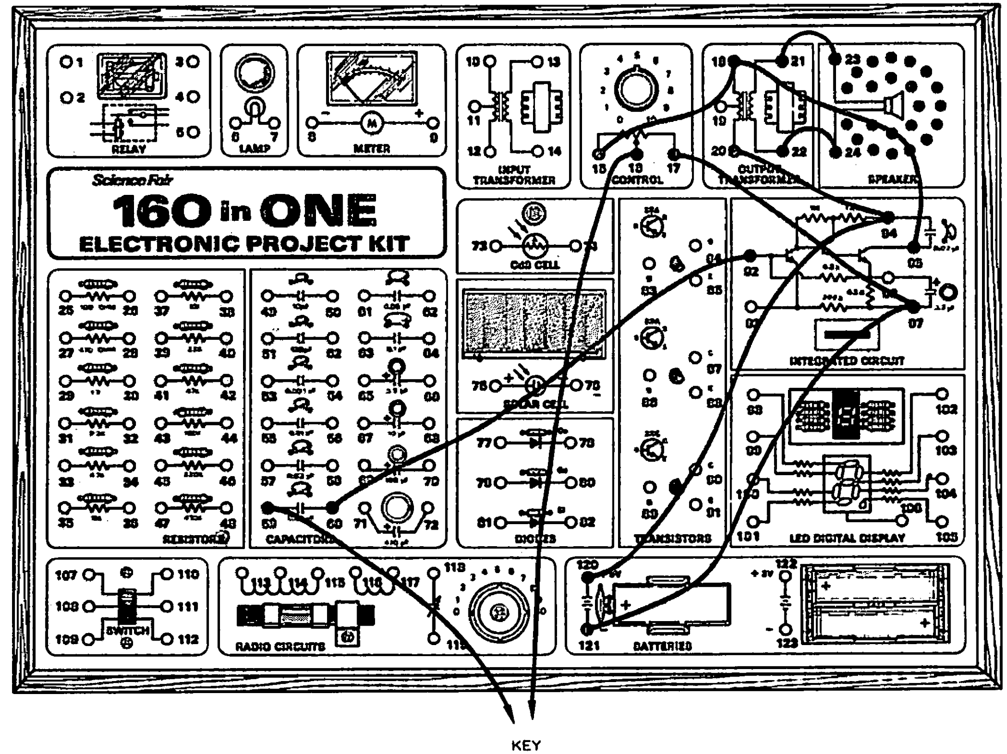
3. Police siren ____________________

4. Chirping robin ____________________

5. Scolding squirrel ____________________

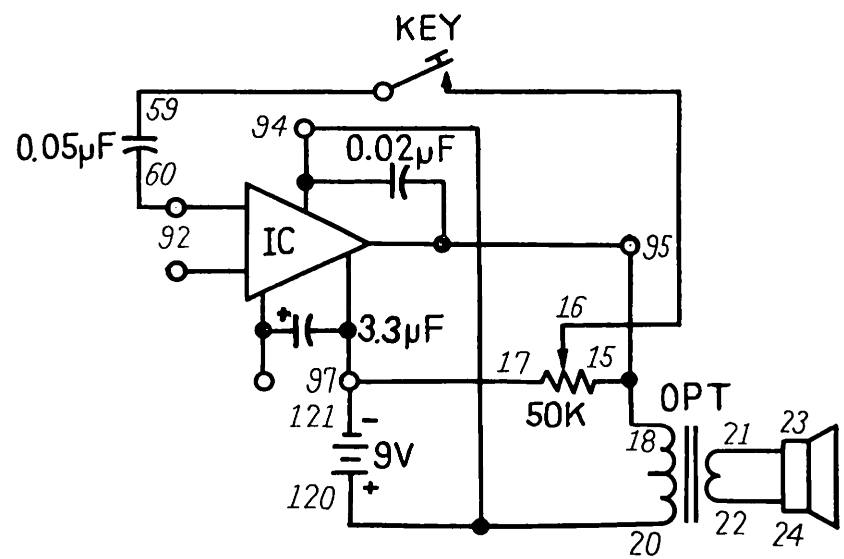
6. Motor boat ____________________

7. Grandfather clock ____________________



WIRING SEQUENCE:

21-23, 22-24, 20-94-120, 92-60, 95-18-15, 59-Key, Key-16, 17-97-121

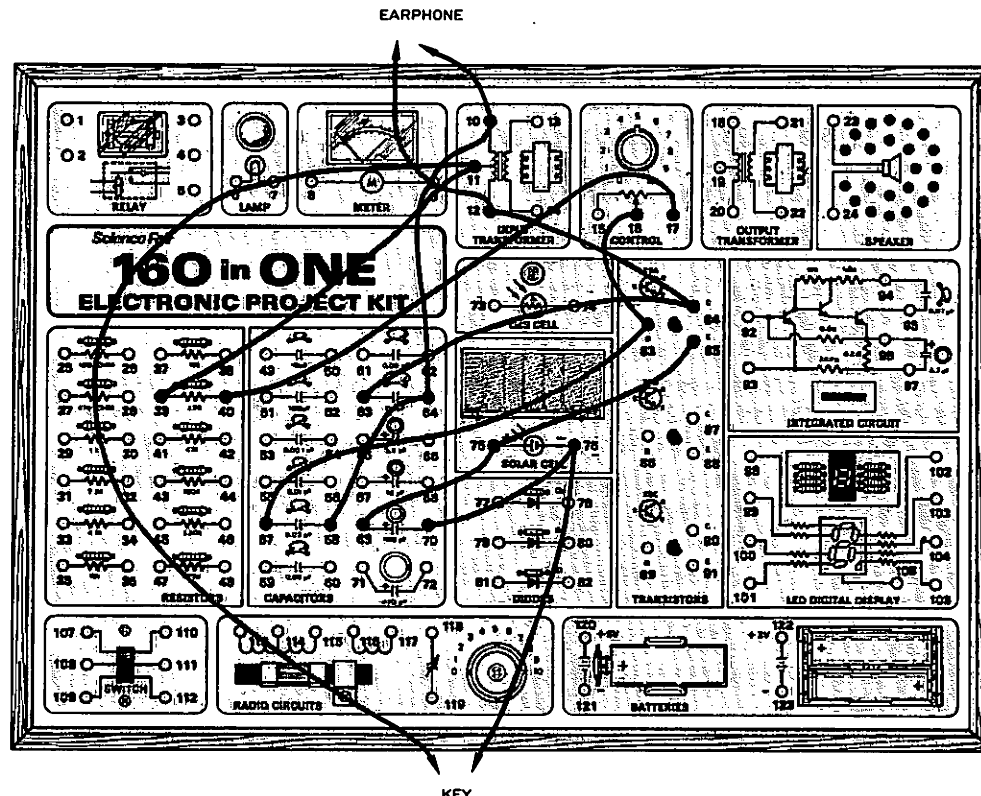


116. SOLAR POWERED CODE PRACTICE OSCILLATOR

Here is one of the most effective Morse Code practice oscillators you will ever find. No batteries and no power line connections are needed. All you need is enough light, and you're in business. The Solar Cell provides all the power required. This Cell is sometimes referred to as a "sun battery". The photons of light energy are converted directly into electrical energy. There are two common types of Solar Cell available today: the selenium cell and the silicon cell. The silicon cell is very efficient in changing light energy into electrical energy, but it is very expensive. The selenium solar cell is not nearly as efficient in converting light energy, but it is much cheaper. The selenium cell demonstrates all the characteristics of a solar cell, and the Solar Cell in your kit is of that type.

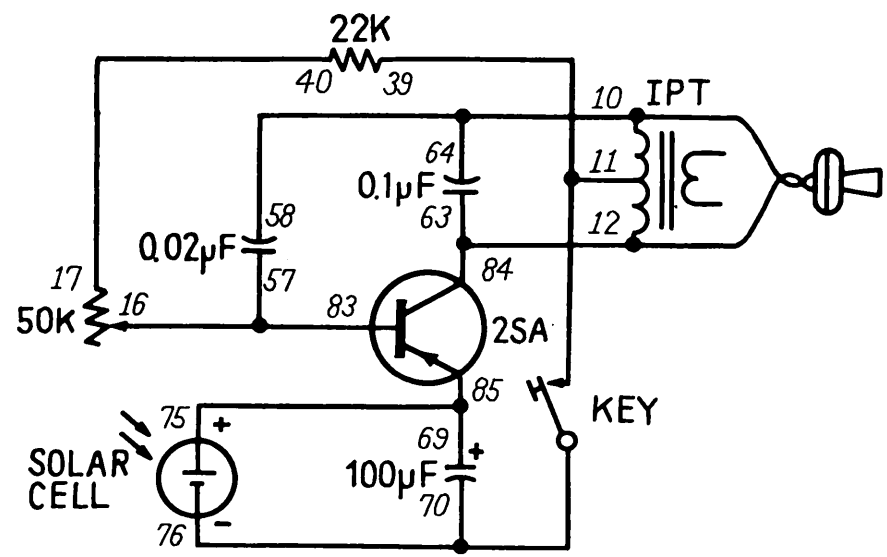
This circuit may have any component values changed without fear of damage, because of the low power supplied by the Solar Cell.

NOTES



WIRING SEQUENCE:

57-83-16, 85-75-69, 58-64-10-Earphone, Earphone-12-84-63, 70-76-Key, Key-11-39, 17-40



117. CRYSTAL SET RADIO (SIMPLE DIODE RADIO)

No kit of projects would be complete without a crystal radio circuit. Most everyone in electronics has experimented with this 'oldest of all' radio circuits. Before the days of vacuum tubes or transistors, the crystal set was the only way to receive radio signals.

The signals produced by a crystal radio are weak (no amplification) so an earphone is used for sound reproduction. The Earphone supplied with this kit is a crystal type, and requires very little current for operation.

A good Antenna and earth Ground connection are required to receive distant stations. Local stations can be heard with almost anything used as an antenna. A long piece of wire (like the green wire in your kit) will probably make 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 this is not possible, you will need to drive a metal stake into the ground and connect the wire to that.

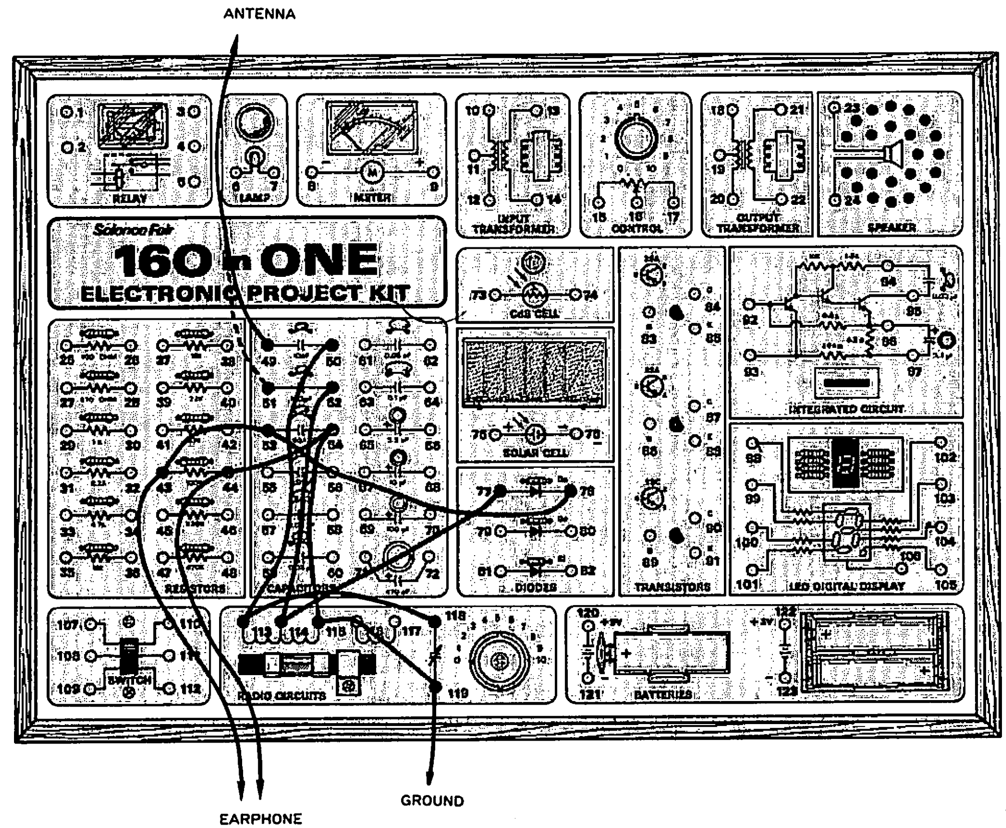
Two Antenna connections are provided on this and other radio circuits in your kit. They are not meant to be used at the same time. Try each connection and use the one that gives the best reception. Long Antennas (and those that act like one) work best on terminal 51. Short Antennas (50 ft./15 m or less) work best on terminal 49.

The part of the radio circuit made up of the Antenna Coil and the Tuning Capacitor is called the 'tank circuit'. A tank circuit is the part of any radio that selects the station (frequency) that you will listen to. Without this 'selectivity' you might hear all the stations mixed together.

The Diode 'rectifies' the RF signal sent out by the radio transmitter. The result of rectification is the recovery of the audio signal (modulation) which was placed on the RF signal at the transmitter in the form of amplitude variations. (Review the explanation of this in project 94, if you've forgotten.) This modulation recovery is called 'detection'. The 100K Resistor is included in the detection circuit to provide a DC load for the Diode (especially for strong signal) because the Earphone is like an open circuit to the DC component of detection.

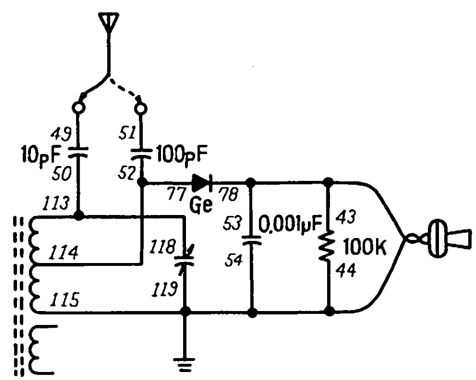
You can experiment with this circuit in just about any way (except for using batteries or AC current), so have fun!

NOTES



WIRING SEQUENCE:

118-113-50, 119-115-54-44-Earphone, Earphone-43-53-78, 77-114-52, Antenna-49 (or 51), Ground-119



118. AUTOMATIC LIGHT ACTIVATED RADIO

Here is a radio that goes ON at daylight and OFF at night. This sensitive little two Transistor radio is controlled by a Relay circuit which is CdS Cell controlled. The Relay circuit draws most of the current used by this project, so if you just want a good radio you can replace the Relay circuit with a section of the slide Switch.

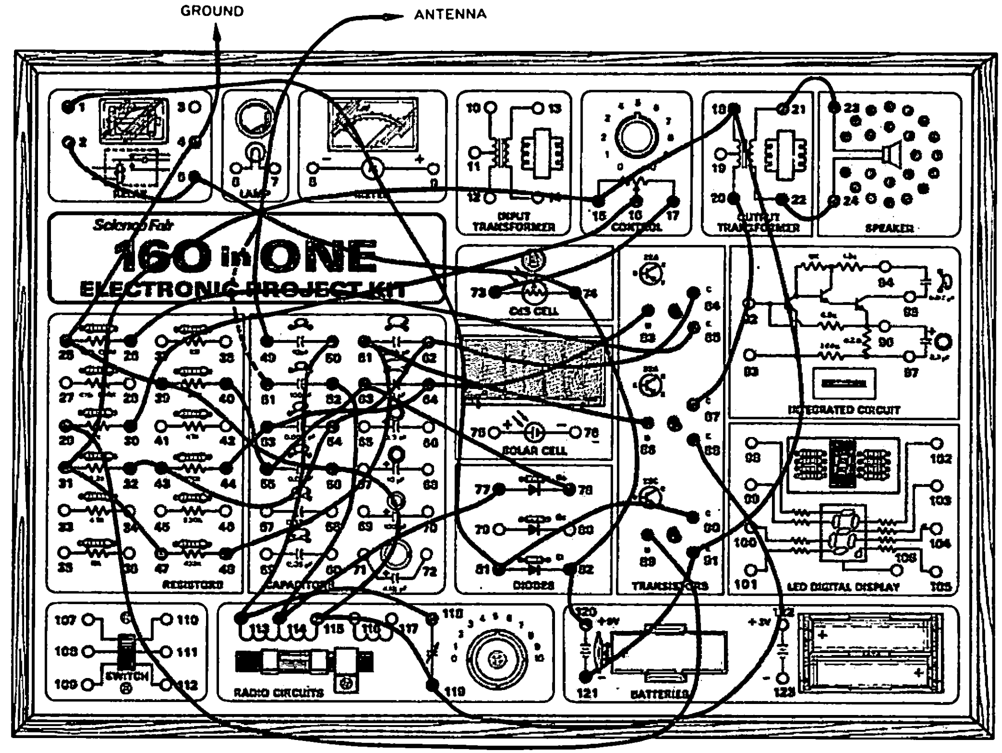
The Relay driver circuit includes a sensitivity control for the desired level of light required to turn the radio ON. You can adjust the Control so you'll be awakened at the crack of dawn, or after the full warmth of the sun is hitting the CdS Cell.

Notice the silicon Diode across the Relay field. Such a Diode is normally included in equipment designed for high reliability. It performs its function when the Relay is de-energized. During normal operation of the Relay the Diode is reverse-biased so it acts like an open circuit. At the instant the Transistor is turned OFF, the magnetic field of the Relay attempts to decrease suddenly and generates a high spike of voltage which appears across the Transistor. When the Diode is included, it becomes forward-biased by the induced voltage of the collapsing magnetic field and limits the voltage to less than a volt, thus protecting the Transistor.

The radio section of this project requires an antenna system. The detector is a standard Diode-detector circuit. The two-stage Transistor amplifier uses RC (resistance-capacitance) coupling and fixed base current bias. No volume control is provided so you will have to change volume by changing the Antenna connection or tuning slightly to one side of the station. This receiver is a good one considering it has only two Transistors.

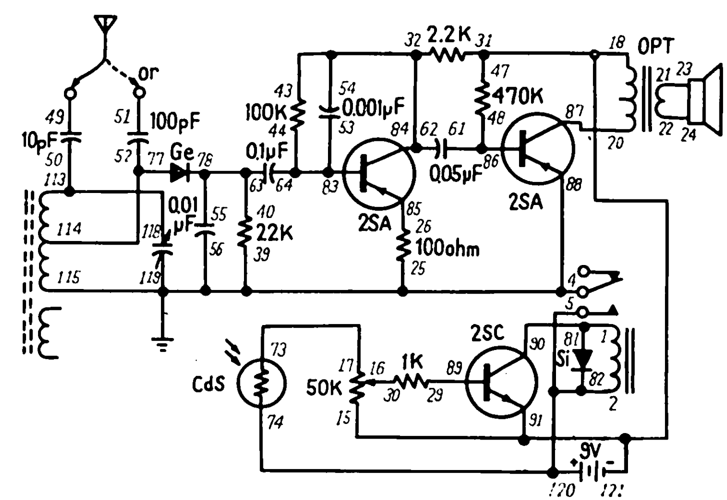
If you have a VOM, this is a good project for measuring circuit voltages. The 2SA(1) should have a voltage across C-E of between 1 to 4 volts. The 2SA(2)collector current is between 2 an 6 milliamps. The 2SC collector current is between 30 and 40 milliamps when the Relay is energized.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 20-87, 88-119-115-56-39-25-4-Ground, 118-113-50, 52-114-77, 78-63-55-40, 1-81-90, 17-73, 16-30, 29-89, 32-43-54-62-84, 44-53-64-83, 48-61-86, 47-31-15-18-
91-121, 2-5-74-82-120, 26-85, Antenna-49 or 51



119. ONE TRANSISTOR RADIO WITH DIODE

The logical progression from the simple crystal radio on project 117 is to this one Transistor radio. The Antenna and tuning circuitry is the same as for project 117. The changes are described here. (See project 117 for a decription and suggestions about antenna systems.

Recall that one compromise necessary in simple radios is that between the selectivity and sensitivity (or volume). Because of the Transistor amplifier we may now take the RF signal from the tuning coil link. This link has only a few turns of wire around the ferrite core so transfer of power is low, giving decreased sensitivity, but this also causes less loading on the tank circuit so that selectivity is improved. For this reason we can't expect as much improvement in volume as we can selectivity. Stations which could not be separated on the crystal set are easier to separate with this receiver.

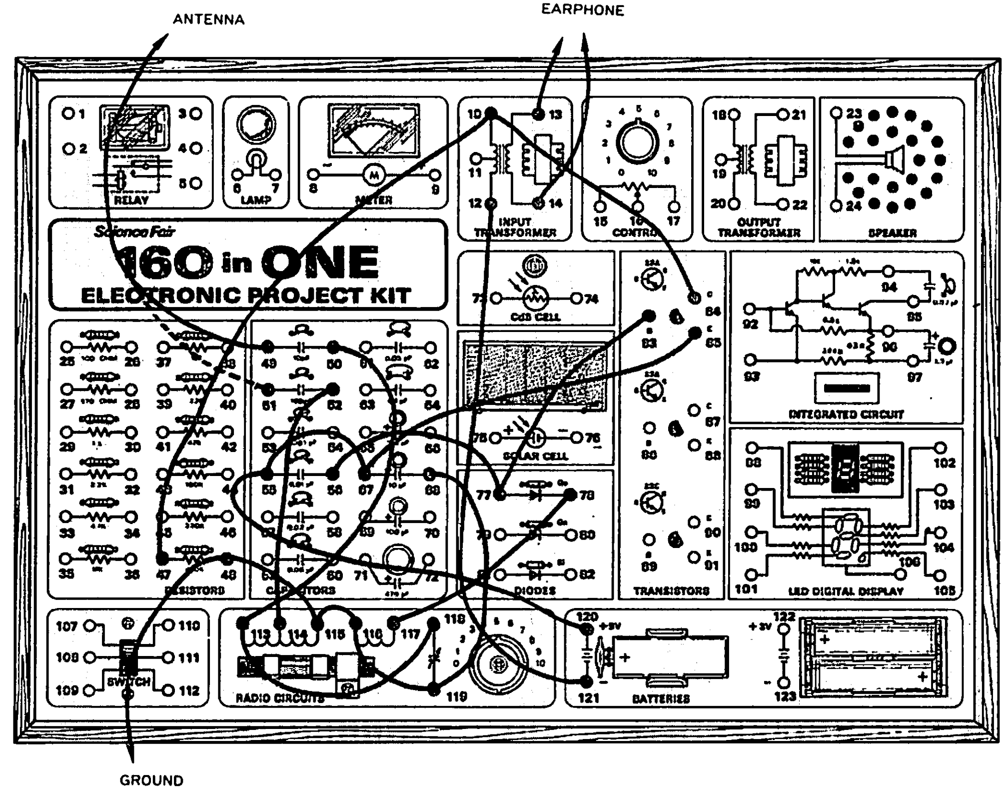
The Diode performs the same function of detection as in the crystal set except that now a very small Transistor base-bias current (about 20uA) is also passed through the Diode. The effect of this small current is negligible as far as the function of the Diode is concerned. The 10uF Capacitor couples the ground side of the detector output to the Transistor without shunting (bypassing) the DC bias for the base of the Transistor.

The Transistor acts like a variable resistance between collector (C) and emitter (E), which is controlled by the amount of input signal between base and emitter (B-E). Assume an average resistance between C-E of about 22K ohms. Current flowing around the circuit from Battery negative, to the Transformer, to collector and then from emitter back to the Battery positive is about 4mA (milliamperes). As the detected signal applied between B-E increases and decreases at an audio frequency rate, the 4mA of collector current also increases and decreases at this same audio frequency rate. This change in current through the primary winding of the Transformer causes a voltage to be developed at the secondary winding for use by the Earphone.

The 470K Resistor supplies a very small current to the base of the Transistor to turn it ON a small amount. A Transistor is said to be OFF when voltage is applied between C-E but no current is supplied to the base-emitter junction, so no collector current is flowing. A Transistor which has base-bias current so that collector current can flow, is said to be ON.

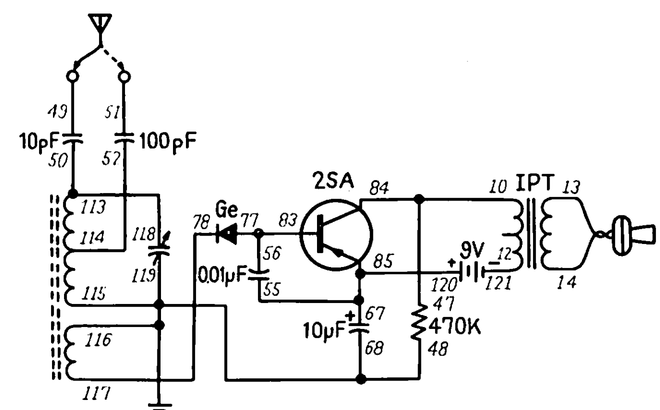
For experimentation you may want to try different Antennas and Grounds, as before. Also, you should try shunting the primary winding with different Capacitors to see their effect on tone quality. Try the Earphone on the primary winding. If you want a pleasant surprise try replacing the Diode with a short circuit. Who needs a Diode when the Transistor can perform double duty?!

NOTES



WIRING SEQUENCE:

118-113-50, 68-119-116-115-48, 114-52, 47-10-84, 12-121, 13-Earphone, Earphone-14, 83-77-56, 78-117, 85-67-55-120, Antenna-49 or 51, Ground-48



120. SOLAR POWERED RADIO

This project allows you to study a simple one Transistor radio powered by the Solar Cell.

Experiment with different Antenna and Ground connections until you find a combination which works well. Remember, some Antennas give best response when no Ground connection is used.

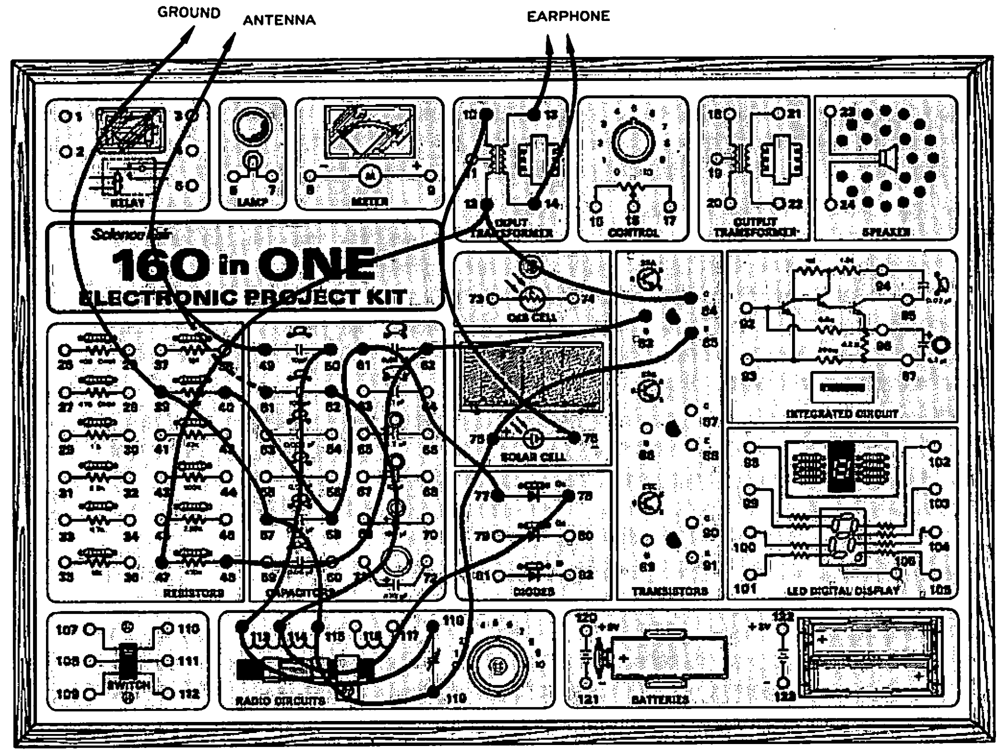
The tank circuit is made up of the Antenna coil and Tuning Capacitor in parallel. This circuit gives selectivity. That is, it allows you to separate the stations from each another. Of course, a single tuned circuit like this cannot give as much selectivity as we would really like.

The Diode detects the signal by rectifying the RF voltage. This allows the audio variations in the amplitude of the signal to be recovered. The 0.02uF Capacitor is called the detector output filter. It smooths out the rectified RF voltage so that the resulting voltage is only the audio signal variations and an average level of voltage (DC) which is dependent on RF signal strength.

The Transistor uses the DC voltage from the detector and filter as base-bias. This turns the Transistor ON and allows the signal to be amplified. Notice that because the detected signal is used to turn the Transistor ON, the Transistor is OFF without a signal, and ON harder for strong signals than for weak signals.

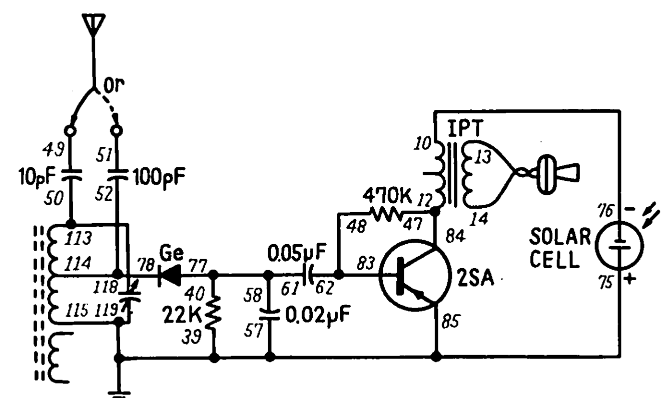
The Solar Cell converts light energy directly into electrical energy. This is used as the collector bias voltage and current. The Transformer winding is used to present a low resistance to this DC bias while presenting a very high impedance across which the audio output signal can be developed.

The Earphone changes the amplified (but weak) audio signal into sound.



WIRING SEQUENCE:

10-76, 84-12-47, 13-Earphone, Earphone-14, 39-57-115-119-75-85, 40-58-61-77, 48-62-83, 50-113-118, 52-114-78, Ground-39, Antenna-49 or 51



NOTES

121. TWO TRANSISTOR RADIO

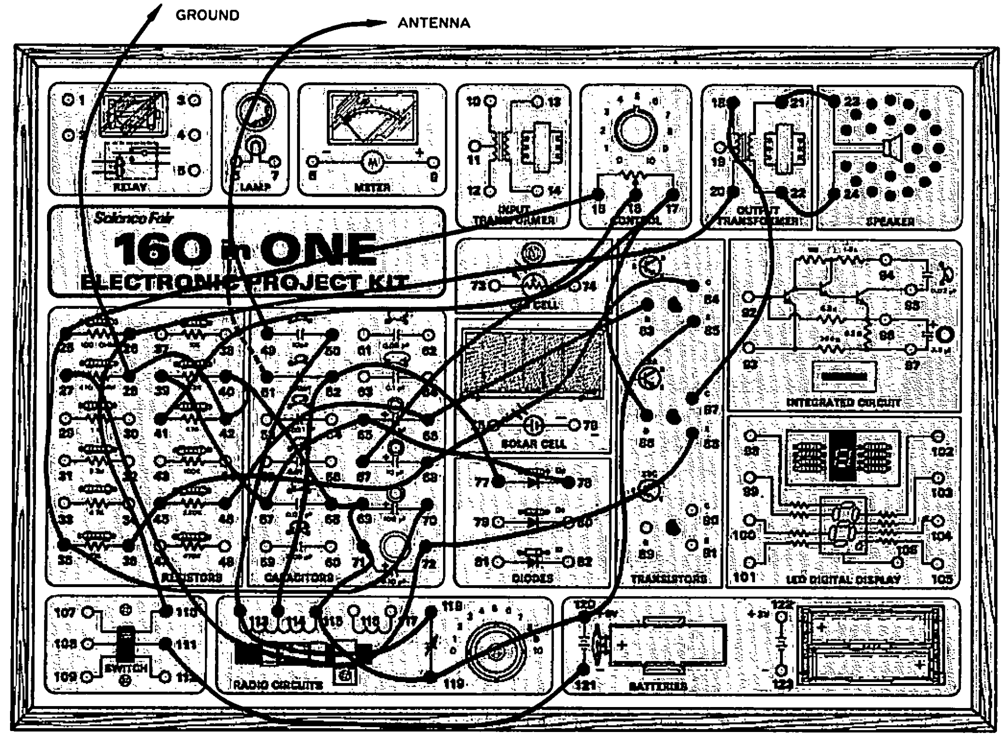
This is a two Transistor receiver which has sufficient gain and selectivity to drive a Speaker to adequate volume. As with all simple radios like this, use a good Antenna and Ground system. Use terminal 28 as the Ground terminal, as required. Try the Antenna on terminal 49 and then 51. Use the connection that gives the best results.

The detector stage uses a germanium (Ge) Diode and 22K detector load Resistor. Try operation without the 22K Resistor. Replace it with an open circuit by simply lifting the lead from terminal 39. Results are ________ (worse, improved) for weak stations and ________ (worse, improved) for strong stations.

The first 2SA(1) stage is a class A audio amplifier which uses universal bias. The bias arrangement always uses a voltage divider of two Resistors to obtain base-bias voltage, and then an emitter swamping Resistor. A 470uF Capacitor is used to eliminate the AC feedback from the 470 ohm Resistor while allowing it to provide DC feedback to obtain good stability for the stage.

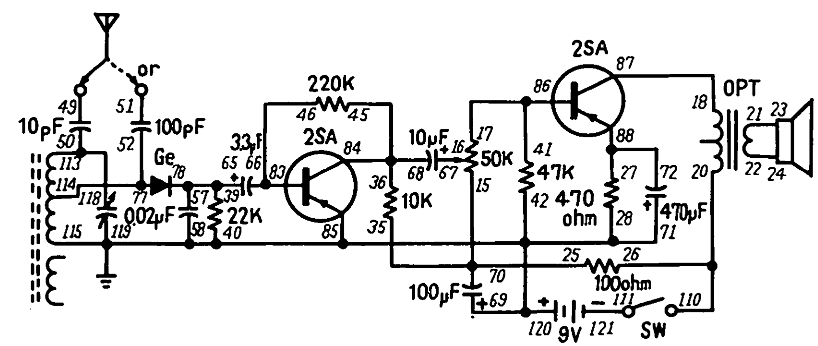
The 100 ohm Resistor and 100uF Capacitor form a decoupling filter for the DC bias, fed to the first stage. This circuit eliminates the tendency for oscillations, due to Battery impedance, that might otherwise allow these high gain stages to oscillate (due to feedback from the AC voltage developed across this impedance).

NOTES



WIRING SEQUENCE:

21-23, 22-24, 18-87, 20-26-110, 86-17-41, 16-67, 15-25-35-70, 78-65-57-39, 28-42-40-58-69-71-115-119-120-85, 36-45-68-84, 77-52-114, 50-113-118, 46-66-83, 88-72-27, 111-121, 28-Ground, Antenna-49 or 51



122. TRANSISTOR RADIO WITH RF AMPLIFIER

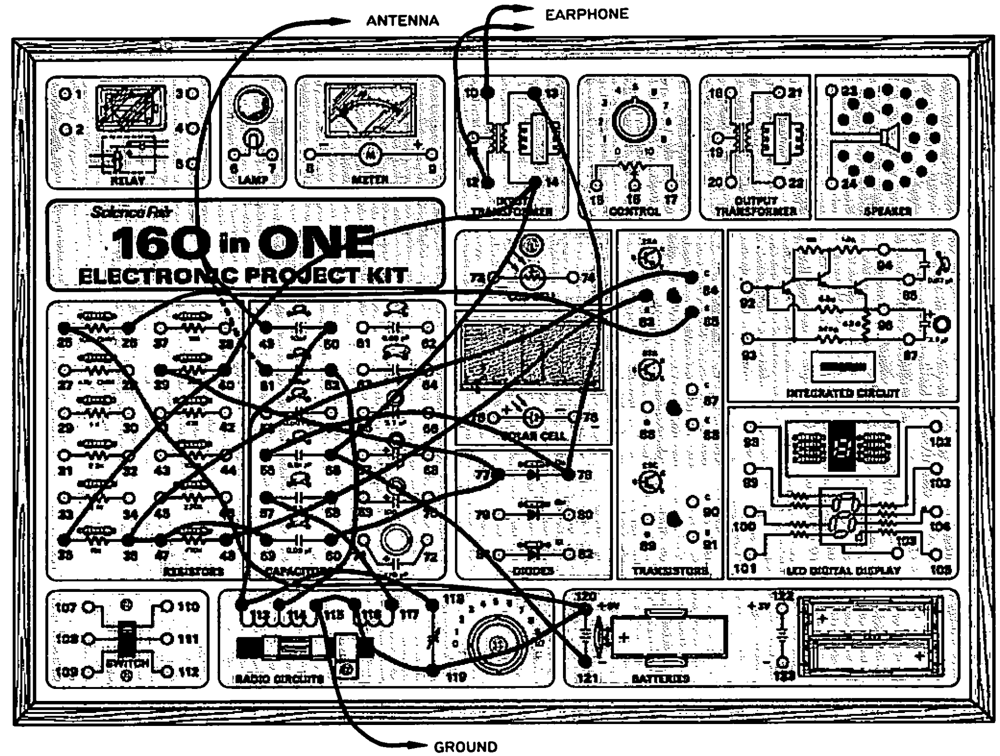
With this project you'll construct and test a simple radio which has an RF (radio frequency) amplifier ahead of the Diode detector. The 2SA Transistor is fed the very low level RF voltage from the Antenna link. It then amplifies this voltage to a high enough level to be detected by the Diode and appear at the output to the Earphone with usable volume.

As with all simple radios, use a good Antenna and Ground system and experiment with connections as we've explained in other projects.

The RF amplifier is a simple RC coupled, class A stage using self-current bias. Because this Transistor has high gain at the RF frequencies, and because the circuit uses long leads and a large circuit layout, the collector circuit leads may have to be positioned away from Terminals 49, 50, 51 and 52 and any wires connected to these terminals (or the amplifier) will oscillate and cause a "beat" tone on all the stations. Actually, when positioned near to any or all of these terminals, so that oscillations almost starts, you can use these wires as a regeneration control to obtain maximum sensitivity. This action occurs as the feedback to the Antenna end of the coil causes the amplifier to overcome the losses in the tank circuit. Operation like this is used with the regenerative detector type radio.

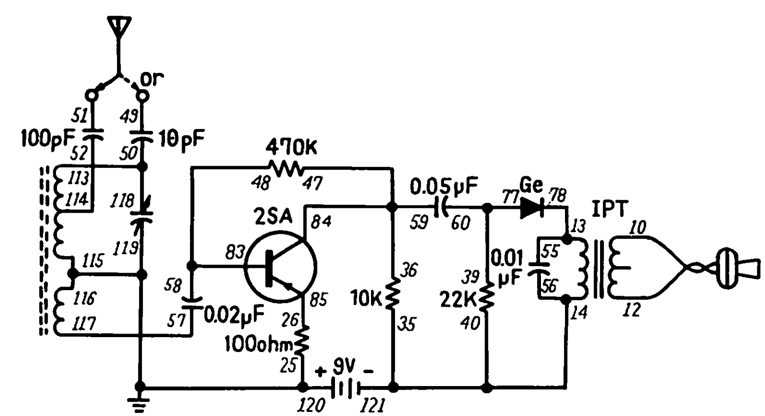
You will want to experiment with this circuit to determine if you can get operation on any station at the optimum sensitivity arrangement of the lead wires. When this is done you will be able to receive all local stations with good selectivity and sensitivity. Low frequency stations require the greatest amount of feedback coupling for optimum operation.

RF amplifiers are usually built on a PC (printed circuit) board with proper layout to eliminate the possibility of unwanted oscillations. Amplifiers like the one in this project have been used as intermediate frequency (IF) amplifiers in communication receivers.



WIRING SEQUENCE:

13-78-55, 84-36-47-59, 83-58-48, 25-120-119-116-115, 117-57, 26-85, 60-77-39, 52-114, 50-113-118, 35-40-14-56-121, 10-Earphone, Earphone-12, Ground-115, Antenna-49 or 51



NOTES

123. COIN BATTERY OPERATED RADIO

This project is a one Transitor radio which uses a coin battery as a power supply! The coin battery is described in project 20.

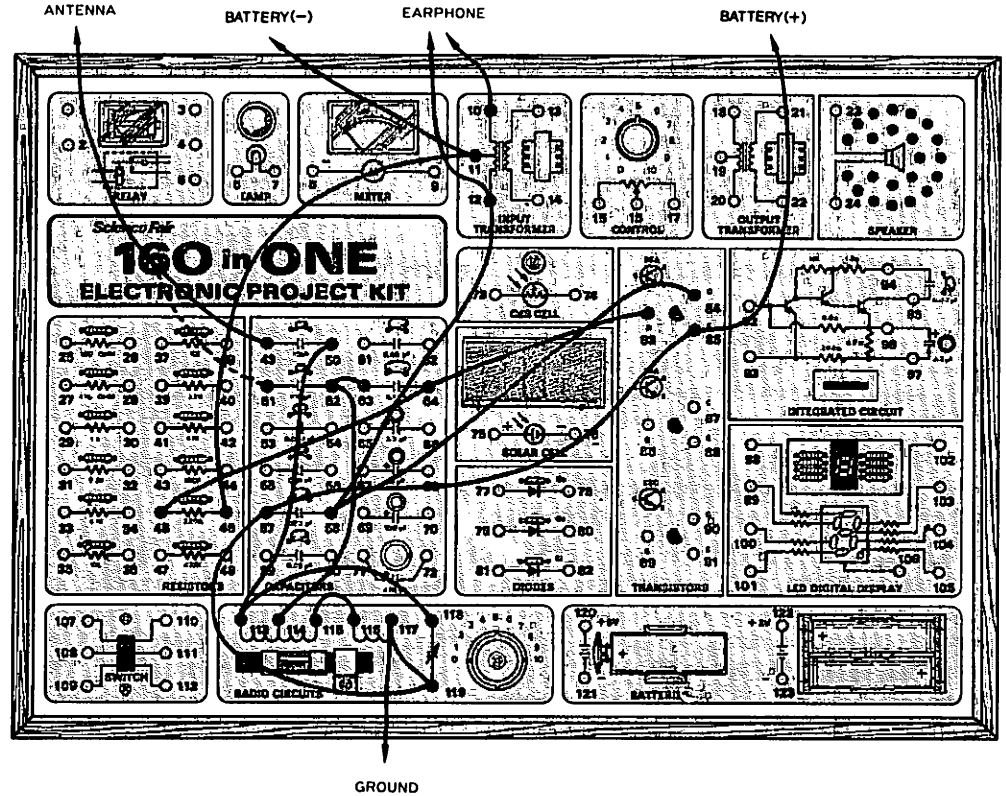
You will want to experiment with different metals for your coin battery as well as different antennas and Antenna connections. The test to determine the effectiveness of the coin battery is simple: compare the results when using the coin battery to the results when the coin battery leads are shorted together.

When experimenting with antennas, try both Antenna connections. The 10pF one generally works best with short Antennas. Try operation with and without a Ground connection, also. Sometimes the results are better without the Ground connection.

The Transistor is operating as both the detector and audio amplifier. Detection is obtained by the non-linear (rectifying) characteristics or the B-E junction (base-emitter). The 220K Resistor supplies a small amount of initial base current to turn the Transistor ON. As radio signals are detected, the Transistor is turned ON harder. This in turn causes more collector current and more loading on the battery. Strong stations may cause such a high loading on the coin battery that its voltage is decreased to the point where distortion is evident. Decrease antenna pick up to reduce this kind of distortion.

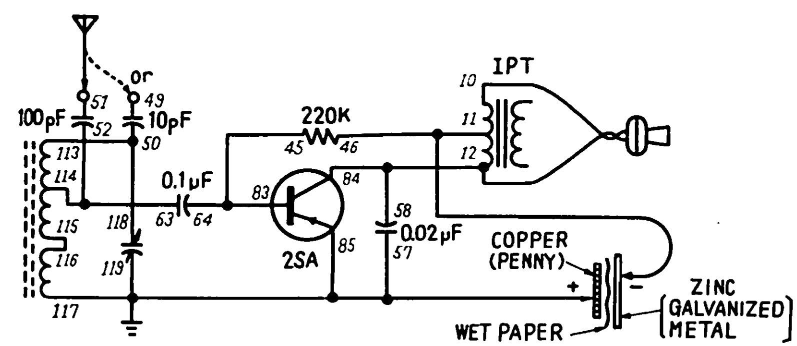
You can also use this radio with the 3V Battery or even a 1.5V cell if you like. Have fun!

NOTES



WIRING SEQUENCE:

84-58-12-Earphone, Earphone-10, 83-64-45, 46-11-Battery (−), Battery (+)-85-57-119-117-Ground, 115-116, 118-113-50, 114-52-63, Antenna-49 or 51



124. TWO-TRANSISTOR RADIO WITH TRANSFORMERS

The next logical progression from the one Transistor radio of project 119 is to this two Transistor receiver. The antenna and tuning circuitry is the same as project 117, and the 2SA(1) Transistor amplifier is virtually the same as the one in project 119. Refer to these projects for the discussion on these items. Also, the experimentation you did on those projects should be tried on this one.

The output of the first Transformer feeds the 50K Control. This is necessary to keep from over-driving the final stage and allows a Speaker volume adjustment. The 10 uF Capacitor couples the audio signal into the base of the 2SA(2) without upsetting the DC voltages required on this stage for proper operation.

The 470uF Capacitor across the Battery is called a "decoupling capacitor". It keeps the two Transistor stages from interferring with each other due to any common Battery impedance which could otherwise cause feedback between these stages.

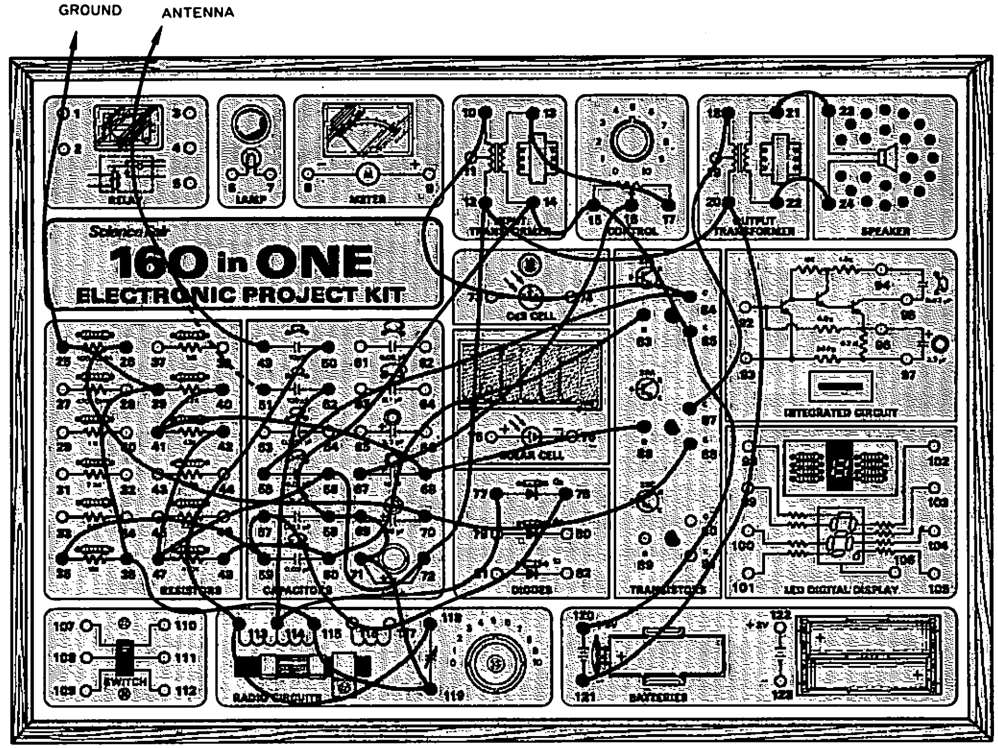
The final stage is a very common type amplifier. The DC voltage (bias) on this stage is obtained from what has come to be called a "universal bias circuit" because of its universal acceptance in the industry as a very stable circuit. Collector voltage is supplied through the primary winding of the output Transformer. Base-bias voltage is supplied from a voltage divider made up of the 47K and 22K Resistors. These provide quite a stiff voltage (about 1.6V) on the base of the 2SA(2). The higher resistance of these two Resistors is called the "base-bias resistor" and the lower value is called the "base-bias divider resistor".

The 100 ohm emitter Resistor, called the "emitter swamping resistor", is used to stabilize the DC bias currents in the circuit by swamping out any tendency of the Transistor to change characteristics. In this circuit design it was chosen to keep the emitter current near 10mA for all possible Transistor characteristics. Your VOM can be used to measure the voltage drop across this Resistor and then Ohm's law will let you figure the actual emitter current. Recall I = E/R. If emitter voltage is between 0.8V and 1.2V, the current is within the desired range. A value of about 1V is obtained when the Transistor has operated within the expected characteristics.

The 100uF emitter-bypass Capacitor is used to prevent decreased signal amplification due to degeneration feedback from the voltage across the 100 ohm Resistor. This Capacitor may be disconnected to demonstrate its action.

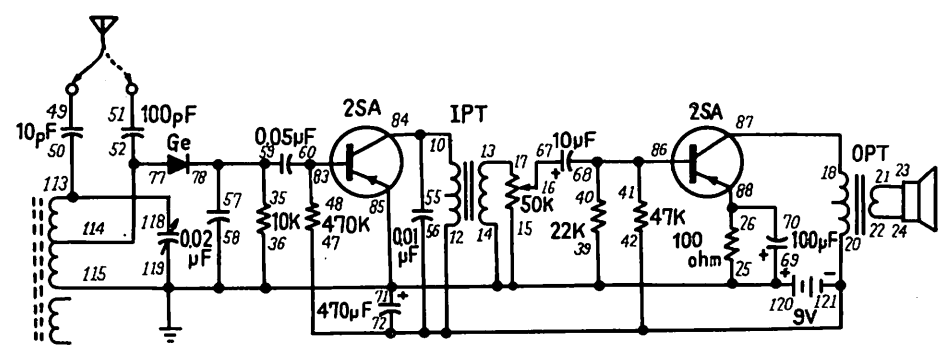
Until you know exactly what to expect, we suggest you don't try changing any Resistor values in the final stage or the Transistor may be damaged. Other projects provide an opportunity for experimentation on this type of circuit.

NOTES



WIRING SEQUENCE:

120-85-15-14-58-69-71-119-115-36-39-25, 21-23, 22-24, 18-87, 10-84-55, 13-17, 16-67, 83-60-48, 86-68-41-40, 88-70-26, 50-113-118, 52-114-77, 78-57-59-35, 42-47-56-72-12-20-121, Antenna-49 or 51, Ground-25



125. SPARK GAP TRANSMITTER

We have been experimenting with radio receivers. What about the other end of the signal — the transmitter? Can we experiment with that, too? Yes, we can! First, let's go back to the early circuits.

When radio was first invented, there was no way to transmit voice sounds. All they could send was noise — and then they used a key to send the noise in dots and dashes (Morse Code). Those early transmitters were called "spark gap" transmitters. Actually all they did was generate a lot of electricity which was made to jump a gap (between two metal objects, like two large iron balls) and they found that this produced radio signals.

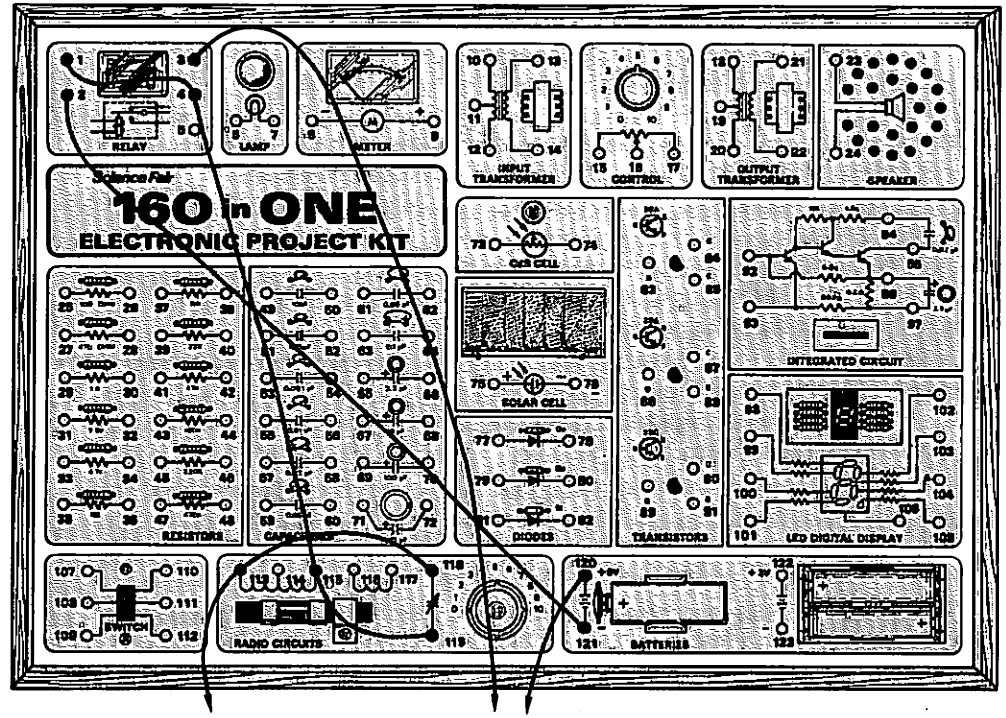
There are two major concepts of electronics which are applied to obtain operation with a spark gap transmitter. One is the fact that the energy stored in an electromagnetic field can be used to generate a spike of electrical energy which contains many frequency components. We all experience this characteristic of inductive circuits, when we hear clicks and pops in a receiver as a nearby electrical circuit is turned OFF. The primary example of this is obtained from a gasoline engine which does not have radio resistance ignition wire or noise suppressing type spark plugs. The energy radiated from these ignition systems will even cause "snow" on a television screen.

The second major concept is that a high-Q tank circuit will accept energy at its resonant frequency and reject energy far removed from its resonant frequency. At the resonant frequency the energy is passed back and forth between the coil and Capacitor. This action has been explained by some with the pendulum analogy. That is, if you bump a pendulum it will begin to swing back and forth at its own resonant rate as determined by the physical mass. Likewise, if you shock an electrical circuit with a sudden pulse of current it will resonate at its own resonant point as determined by the size of the coil and Capacitor in the circuit.

The ciruit here uses the Relay field coil to provide.high inductance which then causes a surge of energy as the Relay contacts open and form a gap; this surge jumps across this gap in the form of a spark. The radio tank circuit uses part of the inductive circuit which is common to both circuits to pick up some of the energy. This energy then causes a few cycles of oscillation to occur in the tank circuit. This action is repeated as the Relay contacts continue to vibrate back and forth like a door bell buzzer. The radiated signal as picked up on a nearby radio sounds like a raspy buzz. The telegraph key allows you to send Morse Code with this transmitted signal.

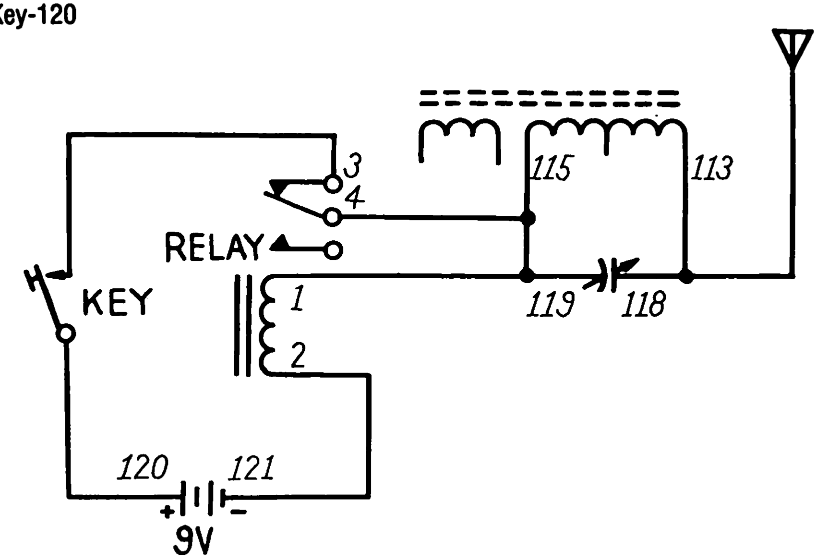
The main problem with this circuit is that the arcing and sparking at the contacts of the Relay tend to destroy the contacts after only a short time.

NOTES



WIRING SEQUENCE:

121-2, 1-4-115-119, 118-113-Antenna (green wire supplied with kit), 3-Key, Key-120



126. WIRELESS CODE TRANSMITTER

This project is a simple but effective code transmitter as used by the military and by amateur radio operators around the world. Code is sent with the key which turns the transmitter ON and OFF in the required sequence. The Morse Code (which has been accepted as the universal code language) is printed on the base of the key included in this kit.

A common AM radio may be used to receive the code sent out by this transmitter, if the radio is first tuned to a weak station. This transmitter signal then mixes with the station's signal to produce an audio tone which is called a "beat note". It is this beat note which is then heard as the code signal. Tune this transmitter (using the Tuning Capacitor) until a desired and strong beat note is heard in the receiver when the key is pressed.

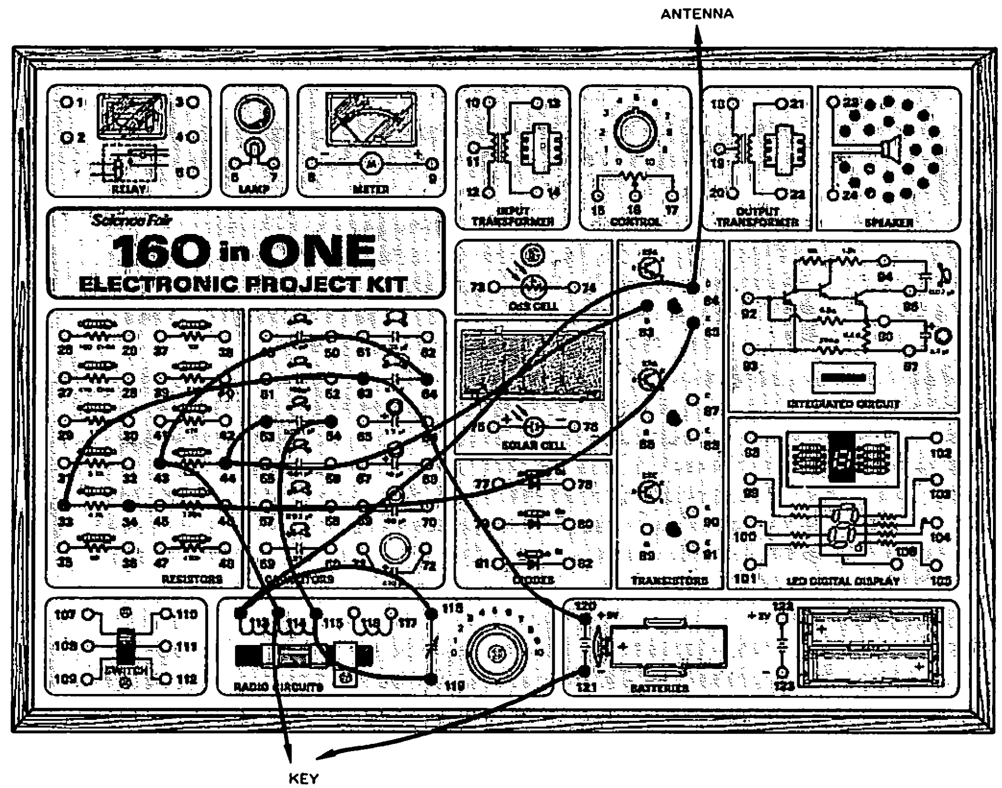
The continuous wave (CW) signal of this transmitter may also be received on a communications receiver without having to tune to another station, if the communications received has a "beat frequency oscillator" (BFO). The BFO beats with the CW signal from this transmitter and produces the tone.

The two requirements for an oscillator (gain greater than 1, and regenerative feedback) are provided by the Transistor (gain) and tank circuit connections. The emitter is connected by the 0.1uF Capacitor to the center-tap of the ferrite coil. The collector is directly connected to the top end of the tank circuit (out-of-phase connection).

The 100K Resistor provides some base-bias current to turn the Transistor OFF as required for operation as an amplifier or oscillator.

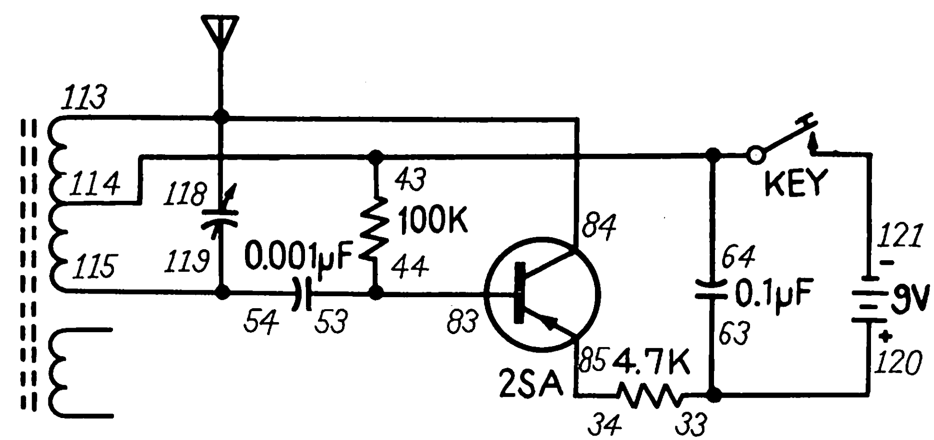
Transmission and reception of CW signals is very efficient (much more so than voice modulation of any kind) so that during times of emergency this is the most reliable type of transmission. You may find that because of this high efficiency, no antenna is required, or if one is needed, only two or three feet (about 60 - 90 cm) of wire will do. Have fun!

NOTES



WIRING SEQUENCE:

120-63-33, 84-113-118, 83-44-53, 54-115-119, 34-85, 64-43-114-Key, Key-121, Antenna (green wire supplied with kit)-84



127. AM RADIO STATION

You have built AM radio transmitters in earlier projects (100, 101, 125 and 126), but they have been used to send only a single tone or series of dots and dashes. With the AM RADIO STATION you will actually send your voice through the air.

The Speaker acts as a dynamic microphone in this circuit, and you will notice that the Transformer marked OPT (output) on the Schematic and 'bread board' is actually being used as an input transformer (this has been done in many of the projects).

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'.

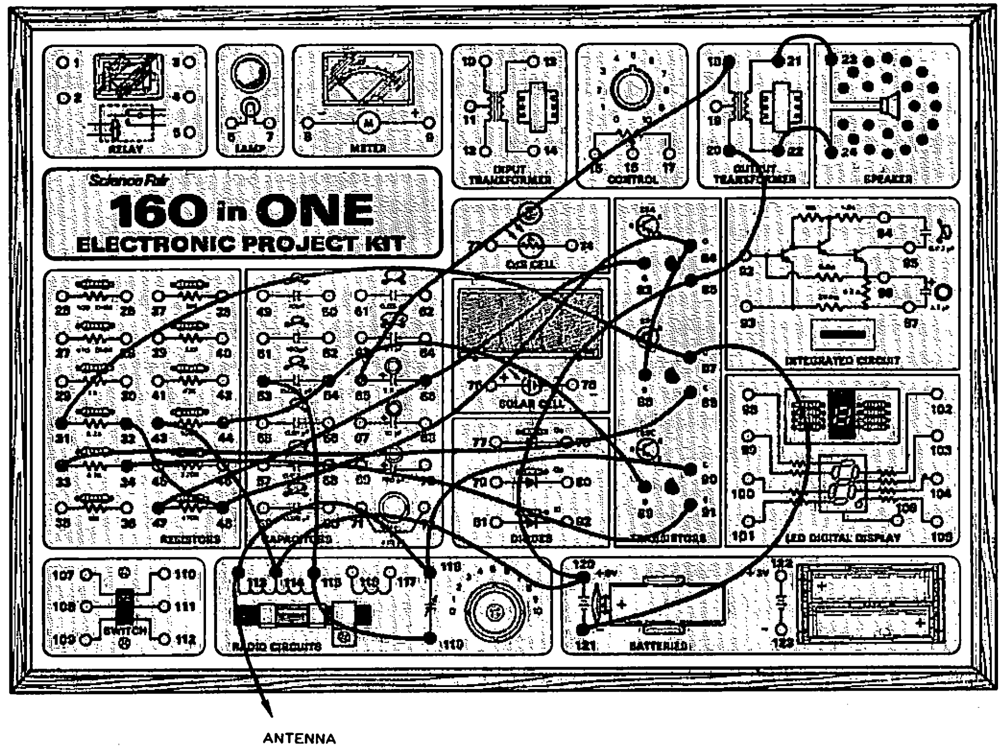
Note: This transmitter may only send signals a few feet, so the AM radio will have to be close by.

This transmitter works very much like the one in the Light Operated Wireless Burglar Alarm (project 101) except that the audio frequnecy (AF) oscillations provided electronically in project 101, are created by your voice and the Speaker (microphone) in this circuit. The 2SA(1) Transistor amplifies the AF signal and this signal modulates the amplitude (strength) of the signal being produced by the RF (radio frequency) oscillator. The RF is tuned to the setting on your AM radio dial by the Tuning Capacitor and Antenna Coil (remember this is called a 'tank circuit') and sent out through the Antenna.

The 2SA(2) Transistor helps in controlling the amplitude of the RF signal, also. The 2SC Transistor is a part of the RF oscillator and provides the primary amplification of the RF signal (before the AF signal modulates it).

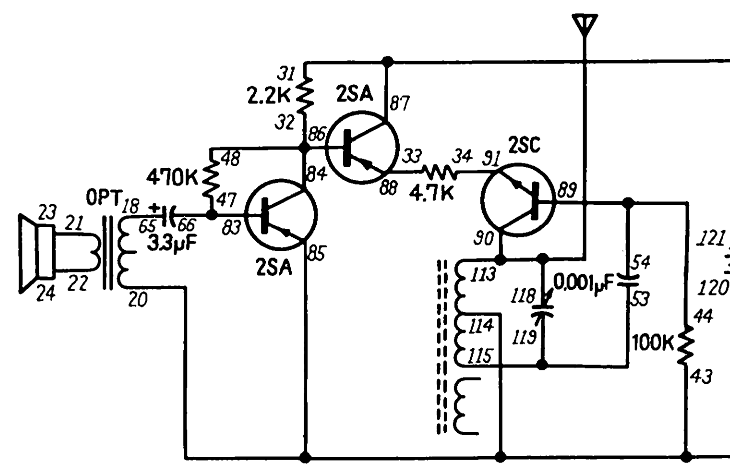
If you ever wanted to be a 'DJ', now is your chance.

NOTES



WIRING SEQUENCE:

18-65, 21-23, 22-24, 20-85-120-114-43, 32-48-84-86, 33-88, 34-91, 44-54-89, 47-66-83, 53-115-119, 90-118-113-Antenna, 31-87-121



128. MODULATED CW TRANSMITTER

The purpose of this project is to build and operate a complete MCW (modulated continuous wave) transmitter. Recall that the CW code transmitters required the AM receiver to be tuned to a weak radio station to be able to get a beat note, or a communications receiver had to be used that had a BFO included. Well, this transmitter sends out a modulated CW code signal. This allows you and your friends to carry on communications anywhere on the AM broadcast band free from any interference by radio stations. Of course the power is low, so your friends will have to be just a few feet away.

The RF oscillator part of this transmitter is ON whenever the Battery is connected. The audio oscillator which modulates the RF is turned ON and OFF with the key.

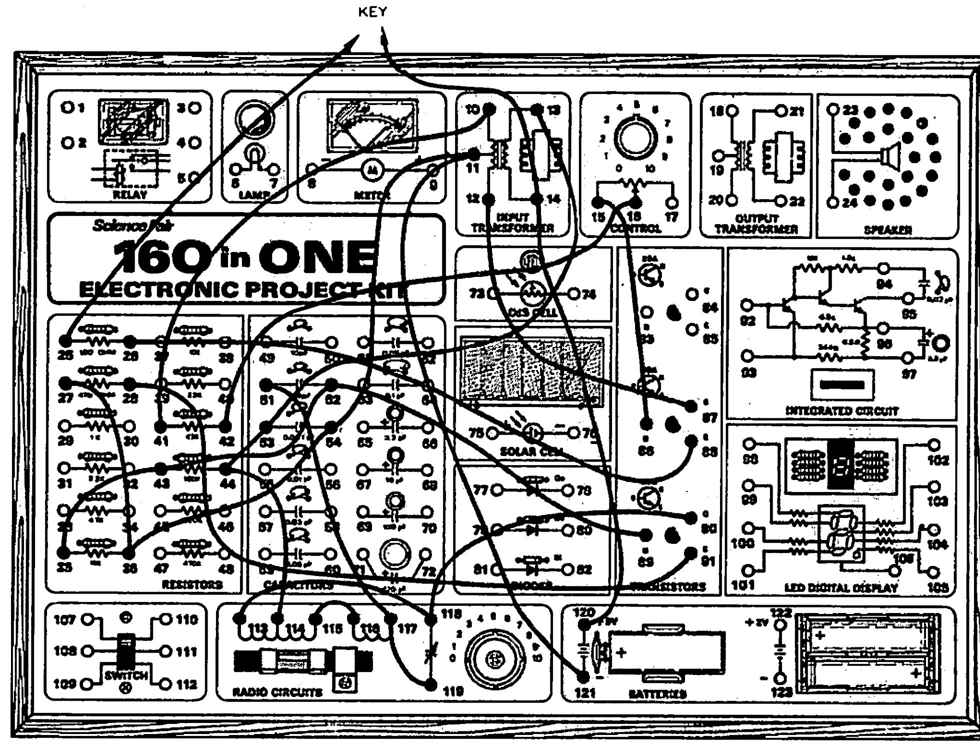
You may want to use the length of wire that came with this kit (green) as an Antenna to increase signal levels to a friend who is more than about 20 feet (6m) away. If so, connect it to terminal 113. To keep from interferring with anyone in your (or your neighbor's) house, use the Antenna only as required. Also, to comply with FCC regulations you are limited to the short Antenna.

The RF oscillator of this transmitter is modulated (actually turned ON and OFF) by the audio voltage induced on the output winding of the Input Transformer. Both RF and AF oscillators are relatively "clean", so the receiver must be tuned carefully (with the Tuning Capacitor) to find this transmitter signal.

The 50K Control allows you to change the audio tone to obtain the pitch you like. Usually a high pitch is desired by amateur and commercial code operators.

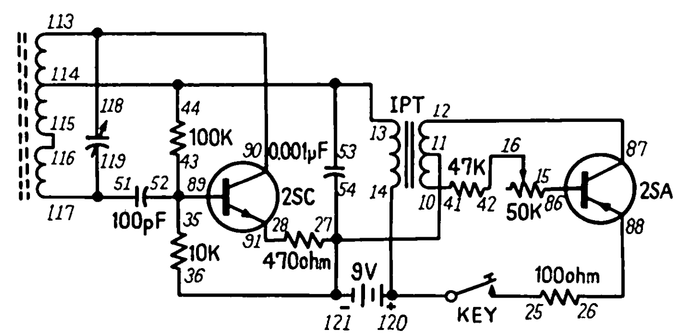
The Morse Code is printed on the base of the Key for your convenience. All you need now is a neighborhood friend who also has a 160-in-1 Kit and you are in business. Have fun!

NOTES



WIRING SEQUENCE:

87-12, 10-41, 42-16, 15-86, 88-26, 90-118-113, 114-44-53-13, 115-116, 51-117-119, 35-43-52-89, 91-28, 27-36-54-11-121, 25-Key, Key-14-120



129. TONE MODULATED TRANSMITTER

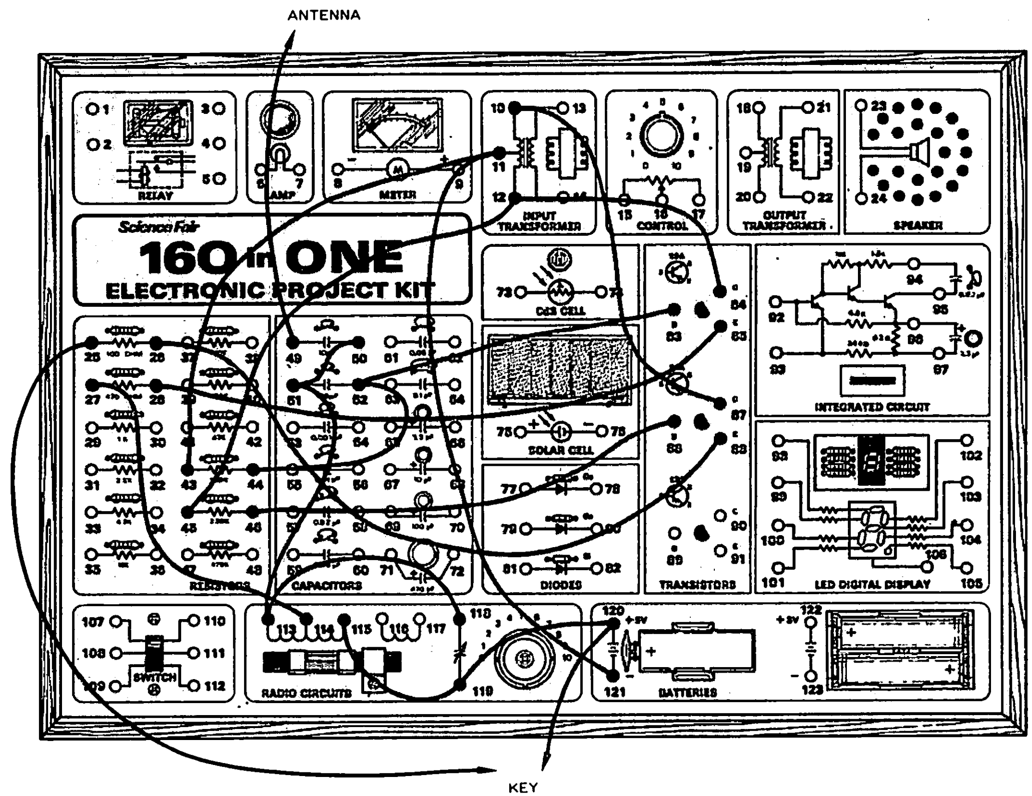
This is a second and improved MCW transmitter. The one in project 128 produces a strong but distorted audio signal in the receiver while this project provides the same results but with a much cleaner sounding signal.

Battery current drain with this transmitter is only 0.5mA without modulation and 5mA with modulation. This is about 1/4 of the current required by the circuit of project 128. Because of this low current requirement the power output is also lower, so you may want to use your kit Antenna (green wire) for this transmitter.

You may want to try different Battery voltages (from 3 to 12 volts) with this transmitter. You may also experiment with Resistor values, but don't decrease the 100K to below 22K, or the 220K below 47K. Notice the effect on tone and frequency when making changes. If you have a VOM you will want to see what effect these changes have on Battery current drain. The audio oscillator output may be heard by connecting the Earphone across one of the Input Transformer windings. Compare this with that from the AM receiver which is tuned to the transmitter frequency.

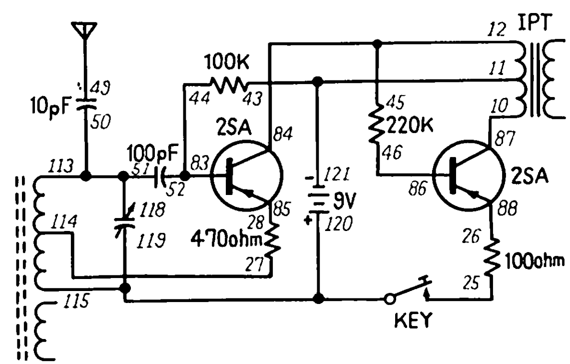
Have fun!

NOTES



WIRING SEQUENCE:

10-87, 43-11-121, 45-12-84, 28-85, 27-114, 26-88, 50-51-113-118, 44-52-83, 46-86, 115-119-120-Key, Key-25, 49-Antenna



130. SOLAR TELEMETRY

This project demonstrates how the amount of light intensity at a far distant point (such as on a space probe or satellite) can be transmitted back to earth by telemetry. A telemeter is a special transmitter which is used to transmit some measurable phenomenon from a distance above the earth. These are used to record and transmit data on pressure, temperature, radiation of all kinds, etc.

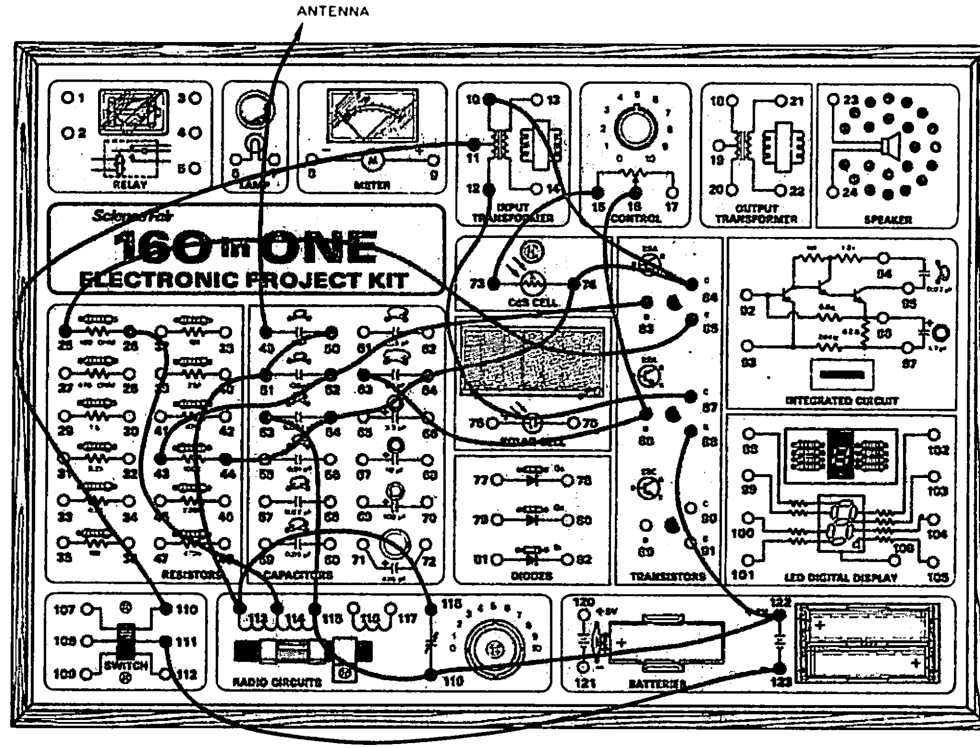
This telemeter uses a single-stage RF transmitter which is modulated in amplitude (AM) by an audio oscillator which is controlled in frequency by the amount of light striking the CdS Cell. A nearby AM transistor radio is used to receive the modulation (telemetry signal) by tuning it to the frequency of the transmitter.

The audio-oscillator is the pulse type. The repetition rate (frequency) of the pulses is controlled by the resistance in the feedback circuit. Low resistances discharge the 0.1uF Capacitor faster, so that frequency is higher than with high resistances. Basic operation of this pulse-type oscillator is explained in detail in other projects.

The RF oscillator part of this transmitter uses the 2SA(1) Transistor in a straight forward circuit configuration. The 100 ohm Resistor in the emitter is included to help reduce distortion of the RF sine wave signal. The short antenna (green wire) included with the kit may be used to obtain a greater transmitter range.

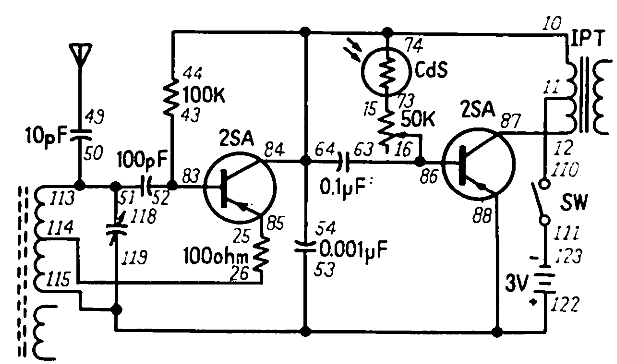
Place the slide switch in the ON (up) position when the transmitter is ready to use. To measure total Battery current you may use a VOM across the Switch terminals when the Switch is OFF. This method of measuring Battery current is a standard troubleshooting technique.

NOTES



WIRING SEQUENCE:

118-113-51-50, 114-26, 25-85, 10-84-74-64-54-44, 83-52-43, 11-110, 12-87, 73-15, 16-86-63, 88-122-119-115-53, 111-123, 49-Antenna (green wire supplied with kit)



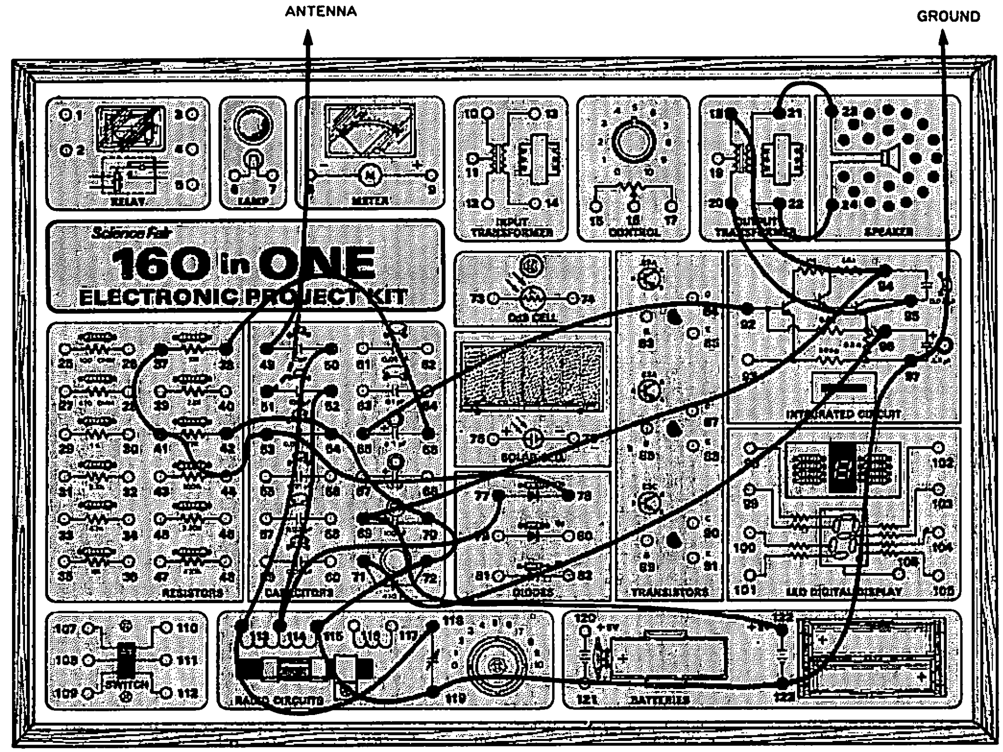
131. IC RADIO

This circuit is similar to the other radios you have built, except that it uses the IC (Integrated Circuit). ICs are widely used in radios, TVs, digital clocks, calculators, etc, and make it possible to build more compact units with better performance. You can see from the Schematic on the Kit's 'breadboard', that this small IC can take the place of 8 other components (3 Transistors and 5 Resistors). In this project the IC is used as an amplifier, but ICs can be built and used for almost any function in electronics.

Follow the same instructions for the Antenna and Ground connections, as you did in the other radio circuits.

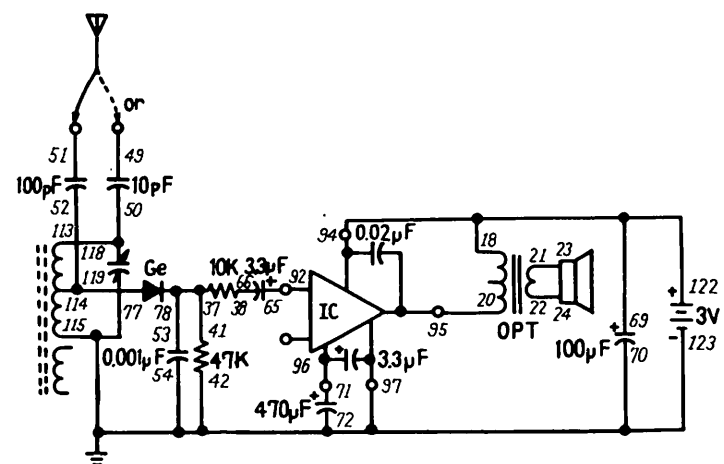
By the way, can you identify the 'tank circuit' and 'detector' in this radio circuit?

NOTES



WIRING SEQUENCE:

20-95, 21-23, 22-24, 37-41-53-78, 38-66, 42-54-70-72-115-119-123-97-Ground, 50-113-118, 52-114-77, 65-92, 71-96, 18-94-69-122, Antenna-49 or 51,



132. CONTINUITY TESTER

This next category of experiments is Test Equipment Circuits. If you intend to stay with electronics either as a hobby or eventually as a career, you will want to know about the various types of test equipment and circuit testing methods. The following experiments will help you begin to learn these things.

This simple circuit is used as a continuity checker by people making up cables and connectors. It may look simple, which it is, but it is very reliable and useful.

By continuity we mean "a continuous unbroken path for current". This test for continuity is very important for those who have the responsibility of making up complicated wiring harnesses. The test probes may be touched to each completed circuit in quick order. The Lamp will light as long as the wire or connection has continuity, but an open circuit will not light the Lamp.

It may also be used to indicate a short circuit between two conductors. The Lamp will light if there is a short circuit, but remain OFF if they are insulated from each other.

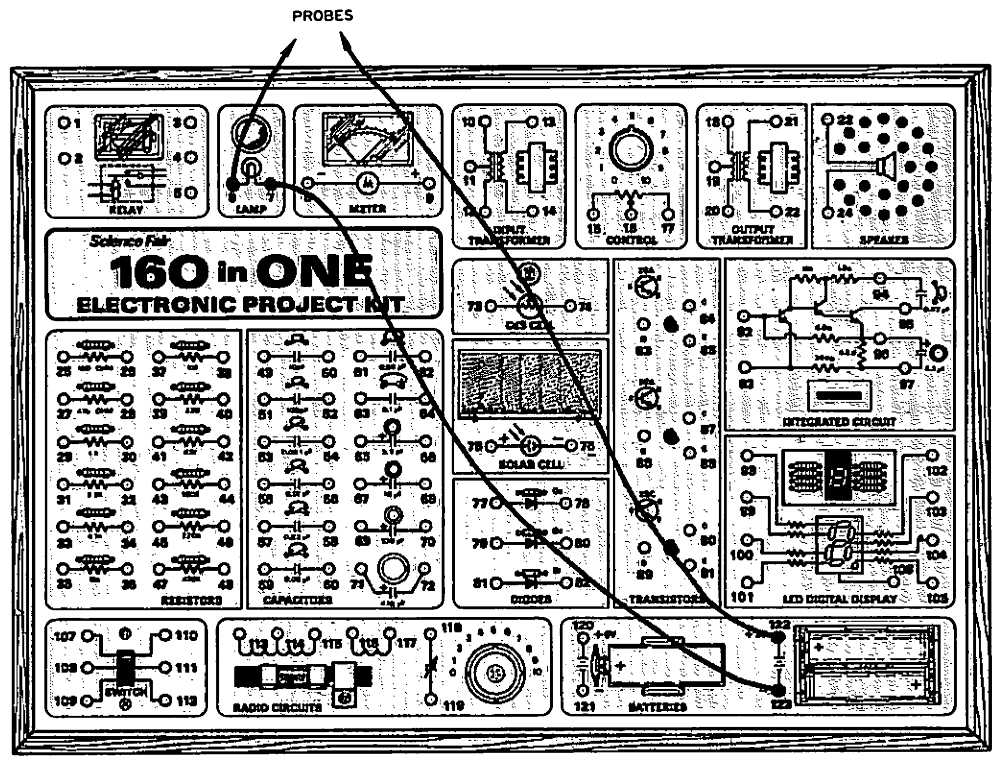
This tester (like all ohmmeters) must not be used on circuits where other sources of power are present, or the Lamp will be burned out. It also should not be used on delicate solid-state circuits where the current for the Lamp (about 300mA or more) may cause damage.

Try this tester on some electrical equipment around the house by unplugging the equipment from the 120V wall outlet and then placing this tester across the prongs of the plug — NOT CONNECTED TO THE OUTLET. Notice that motors and transformer-operated equipment can be easily checked but some equipment only allows a dull glow in the Lamp (if any at all). This is caused by the fact that some equipment has relatively high resistance which this simple tester cannot handle.

By observing the glow of the lamp, you can check circuits with up to about 10 ohms resistance.

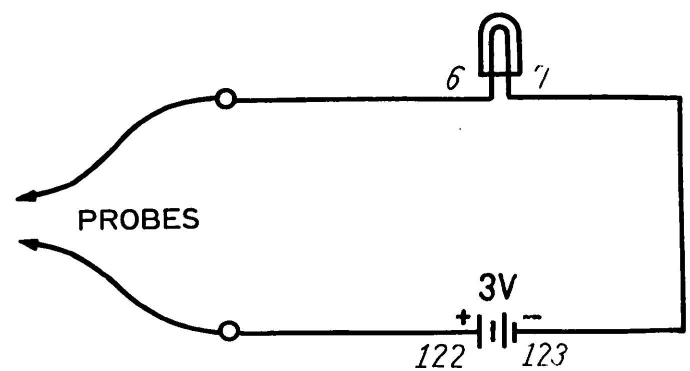
Now your next logical circuit area to study is that of ohmmeters, but first you may want to familiarize yourself with project 133.

NOTES



WIRING SEQUENCE:

123-7, 6-Long Wire (Probe); 122-Long Wire (Probe)



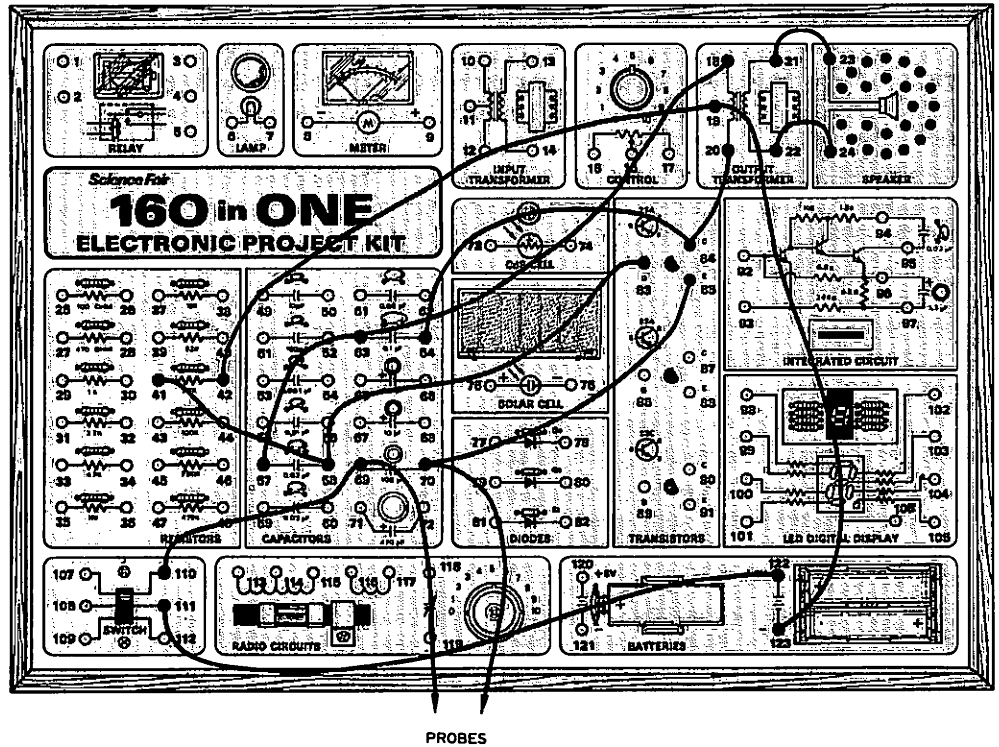
133. AURAL CONTINUITY TESTER

This project is an aural continuity checker. It performs the same types of tests as the circuit in project 132, but use a tone from the Speaker instead of the Lamp to indicate continuity. That makes this circuit more desirable when you aren't able to look at the Lamp each time you make a test. For example, this circuit allows you to use your eyes entirely for locating the wires and terminals to be checked, while your ears detect the results of the test.

The continuity of the circuit under test completes the supply connection to a standard pulse type oscillator which uses a sensitive Transistor (the 2SA). Because of this, you can check the tester by checking almost any component on the board except the Meter (it is too sensitive and may be damaged). When checking Diode and Transistor junctions, try switching the probe leads around to check operation with both polarities.

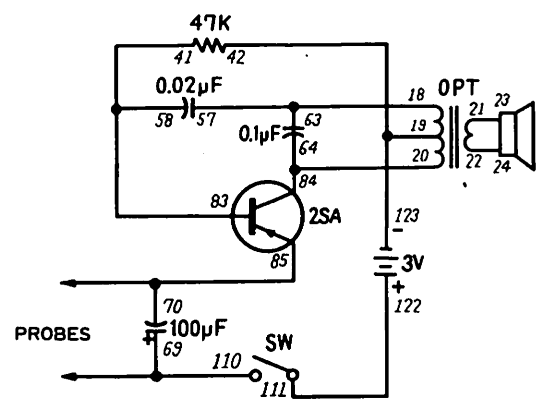
You can check almost anything with this continuity checker because of the lower current (15mA or less). You will want to try measuring the continuity of pencil lines on paper, water, metallic surfaces and many other things.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 123-19-42, 41-58-83, 18-63-57, 20-84-64, 85-70-Probe, 122-111, 110-69-Probe



134. SERIES TYPE OHMMETER

The purpose of this project is to build and test a series type ohmmeter and in the process learn more about resistance. If you own a VOM it probably has a circuit very much like this to measure resistances.

This circuit uses both 3 and 9 volt Batteries in order to obtain measurement of high resistance. The Meter may be considered a current detector which can be calibrated in resistance because the voltage is a constant value of 12 volts. This is justified by Ohm's law where I = E/R, so if E (voltage) is not changed, I (current) is inversely proportional to R (resistance).

A graph is included below to change the Meter's blue scale calibrations directly to K ohms. The letter K means "thousands" so a resistance of 22K is 22,000 ohms. This amounts to a shorthand method that eliminates writing zeros. The procedure for using this ohmmeter is as follows:

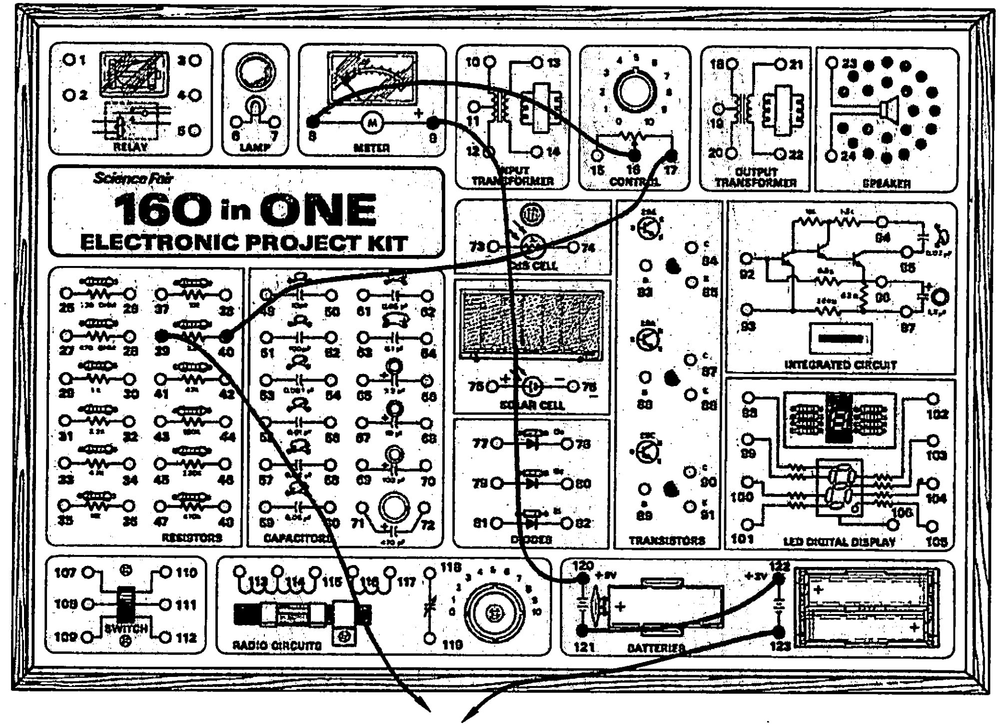
1. Touch the Probes together (zero resistance between the probes) and adjust the 50K Control for a full scale Meter reading (10 on the scale).
2. Without disturbing the Control as adjusted above, connect the Probes across the resistance to be measured. Make sure there are no parallel paths of resistance (including your hands) or results will be incorrect. Also, make sure no voltage is present across the resistance or the Meter may be damaged.
3. Locate the Meter reading along the bottom of the graph. Go vertically up from there to the curved line. This point on the curve indicates the resistance. Read the resistance value from the resistance scale directly to the left of this point on the curve.

An ohmmeter such as this is one of the most valuable tools a repairman has to check for defective parts. Use the ohmmeter you have just made, and measure some of the following parts.

1. Resistors: They should be relatively close to their market value.
2. Diodes: With one ohmmeter connection polarity you should obtain a low resistance; with the opposite polarity, a high resistance.
3. Transistors: Between C-B and E-B junctions you will get the same results as with Diodes. (An exception to this is the E-B junction of silicon Transistors which gives intermediate resistance in the high resistance polarity. This does not indicate a fault.) Between C-E terminals you will see a high resistance with both polarities.
4. CdS photo cells: Resistance depending on light level.
5. Capacitors: Values above 0.01uF indicate charging (displacement) current before showing a very high resistance (virtually infinity on this meter). Electrolytic Capacitors which are marked with voltage polarity will show near infinity resistance (after charging) when correctly polarized and intermediate resistance when improperly polarized. Always discharge Capacitors completely with a short circuit before attempting to measure their resistance.

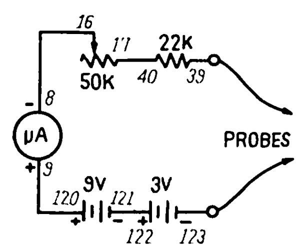
In case you are interested in the formula which is used to determine the resistance from the Meter, here it is: $R = \frac{480}{I} - 48K$ ohms, where I is the blue meter scale reading.

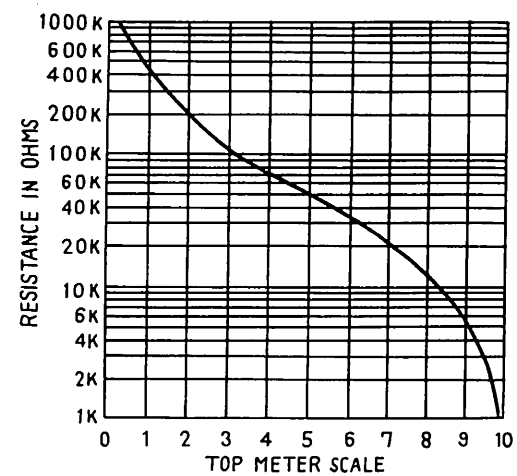
Notice that the most accurate range of resistances measured with this meter is between 2K and 900K ohms. The Shunt-Type Ohmmeter project is next and is suitable for lower ranges of resistance.



WIRING SEQUENCE:

40-17, 16-8, 9-120, 121-122, 123-Long Wire (Probe), 39-Long Wire (Probe)





135. SHUNT TYPE OHMMETER

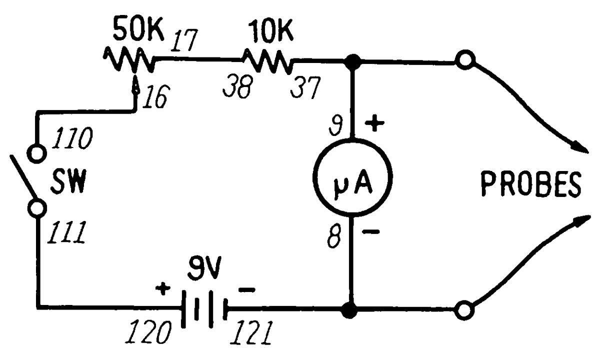
The purpose of this project is to study the basic shunt type ohmmeter. These ohmmeters are used mainly to measure low values of resistance. The circuit is a very simple and reliable series circuit with the Probes brought out from across the Meter. The unit constructed in this project has a center scale resistance of about 650 ohms. The recommended range for measurements with reasonable accuracy is from about 30 to 10,000 ohms.

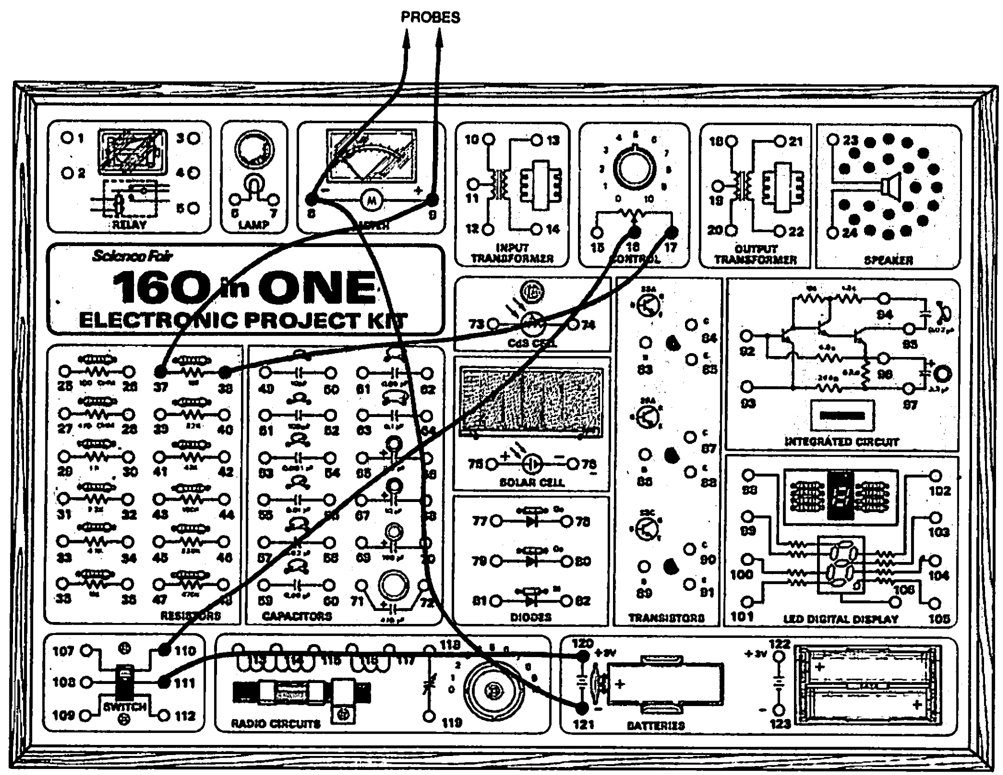
Ohmmeter operation is as follows:

1. Turn ohmmeter ON with the slide Switch.
2. Adjust 50K Control for a scale reading of 10 on the top (blue) scale.
3. Place the Probes across the resistance to be measured. Make sure the circuit under measurement has NO voltage present or this Meter may be damaged. Also make sure no parallel resistances are present (including your hands).
4. Determine the resistance from the graph below or from the formula R = 650 I over 10-I ohms, where R is the resistance being measured, and I is the top (blue) Meter calibration with R in the circuit.

This circuit works by supplying a constant current to the Meter from the series circuit composed of the 10K, 50K and 9V. The current is adjusted to the Meter full scale value. Now as shunting resistance R is placed across the Meter, the current divides between the Meter resistance and the resistance of R, depending on the ratio of resistances. Since the total current is constant and equal to the 10 calibration mark on the Meter, the amount of Meter deflection may be calibrated directly in ohms for the resistance shunting (paralleling) the Meter.

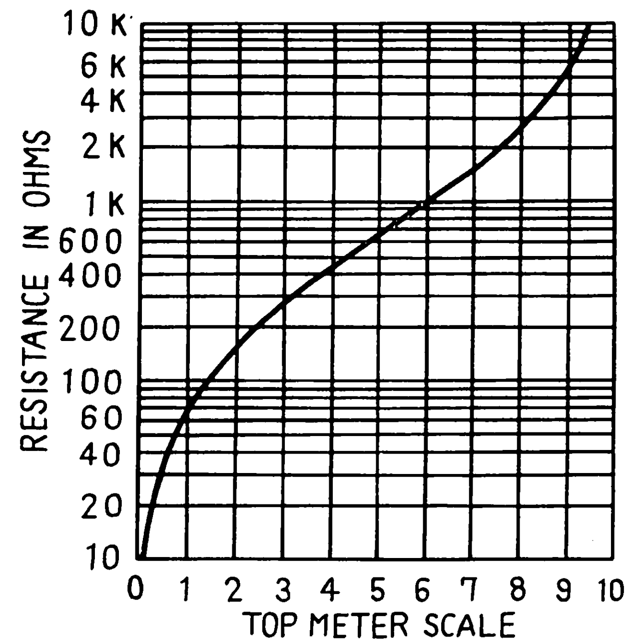
You can use this Meter to measure about anything in the kit (except components being used in this circuit) without problem. The main thing to always remember is to NEVER place the ohmmeter Probes across voltage (including charged Capacitors). Measure such things as the Relay winding, Transformer windings and low-value resistors.





WIRING SEQUENCE:

17-38, 16-110, 111-120, 121-8-Probe, 37-9-Probe



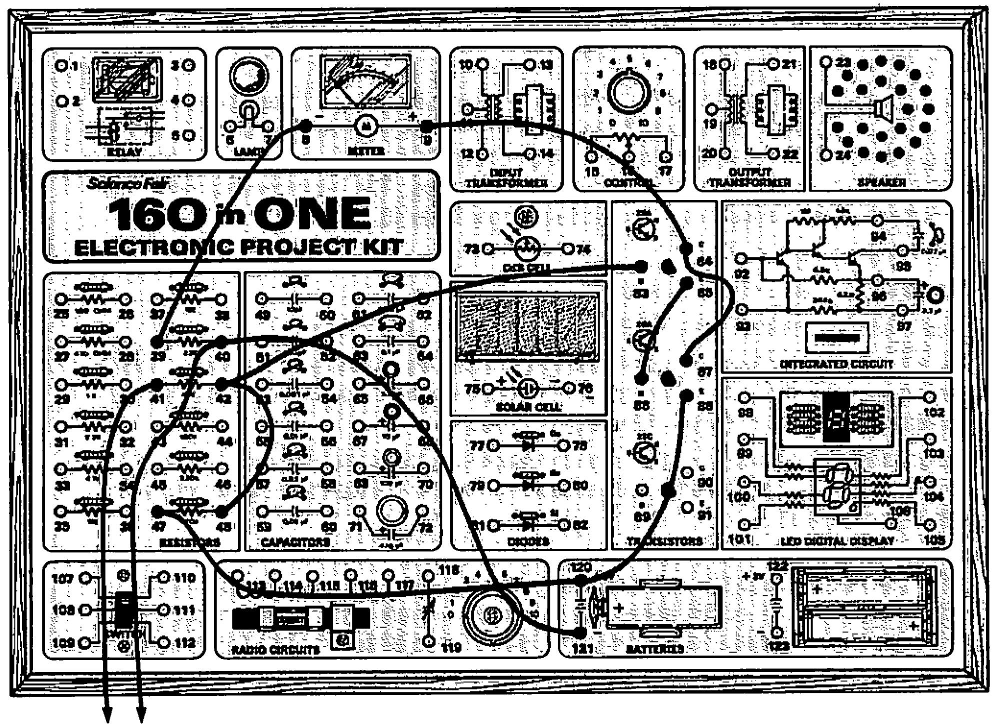
136. ISOLATION CHECKER

Have you ever gotten a mild shock from an electrical appliance in you house. It could have been caused by poor isolation or current "leakage". This project is a Meter for measuring high resistances (up to about 3,000,000 ohms). Most cases of poor isolation you will encounter will involve high resistances.

To test for leakage in an appliance you must first unplug it. DO NOT TEST AN APPLIANCE THAT IS CONNECTED TO ANY POWER SOURCE. Then connect one of the Probes to the plug of the appliance and touch the other Probe to the metal parts of the appliance. If you get a high reading, you may have poor isolation and a shock hazard.

This circuit can be used to measure any large value resistance.

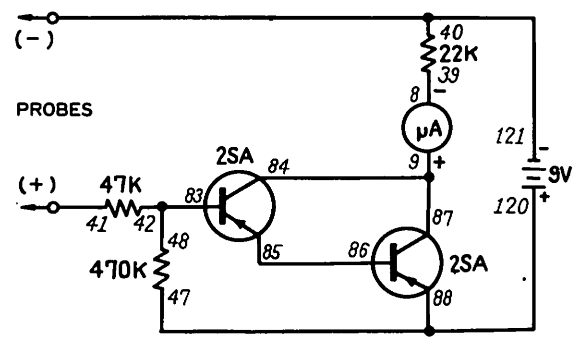
NOTES



PROBES

WIRING SEQUENCE:

8-39, 9-84-87, 83-42-48, 85-86, 88-120-47, 41-Probe, 121-40-Probe



137. WHEATSTONE BRIDGE

The purpose of this project is to consider the Wheatstone bridge circuit. This circuit for measuring resistances has been around for over 100 years. It must be a good circuit, to have survived so long. Virtually all instruments availble today, for measuring DC resistances with extreme accuracy, are Wheatstone bridges.

The circuit is made up of four resistances: R1, R2, R3 and R4, connected in a ring as shown in the Schematic diagram. The generator (a Battery) is connected across two opposite corners of the bridge. The detector (the Meter) is connected across the remaining two opposite corners of the bridge. When proper resistances are used in the bridge, no current will flow in the Meter and the bridge is said to be "balanced". For all other combinations of resistances the Meter will receive current and thus indicate the inbalance of the bridge. The Control is usually calibrated directly in resistance.

The intelligent use of this bridge circuit requires some simple mathematical relationships. In words, the relationship is: "balance is obtained when the ratios of adjacent arm resistances are equal". In a formula this is:

$$\frac{R4}{R3} = \frac{R2}{R1}$$

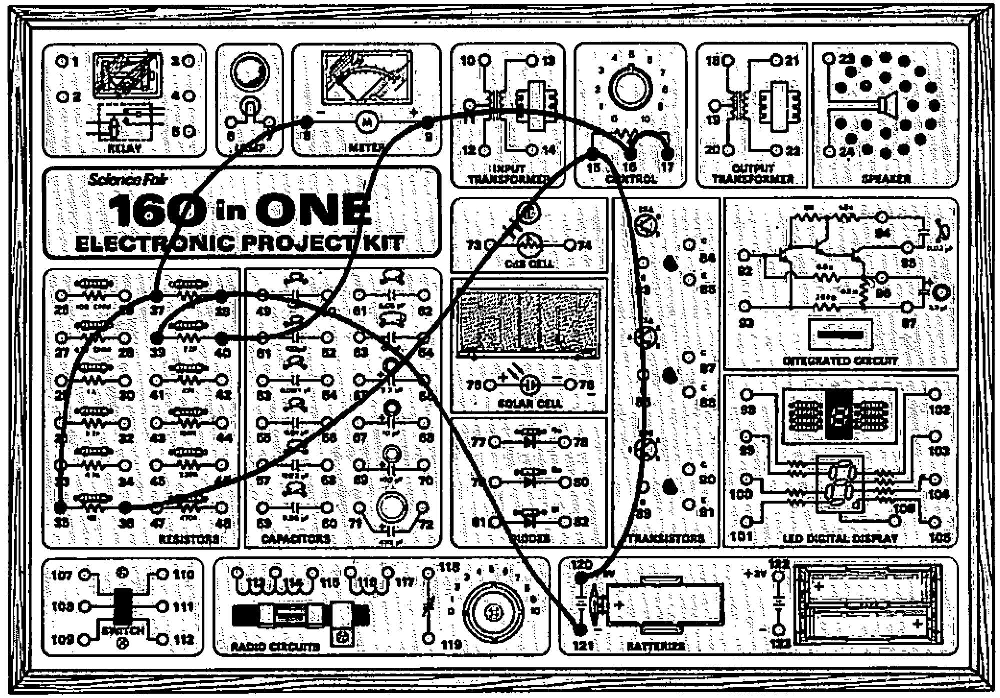
If R4 is an unknown resistance to be measured, the formula is rearranged to solve for this resistance in terms of the other three known resistances. The formula is then as follows:

$$R4 = R3 \times \frac{R2}{R1}$$

Notice that resistors R1 and R2 are in the form of a ratio in this final formula. For this reason these resistances are called the "ratio arms" of the bridge. In the bridge here R1 and R2 are equal in value so that R4 and R3 must also be equal for the bridge to be in balance. When the bridge is in balance the Meter will be exactly on zero.

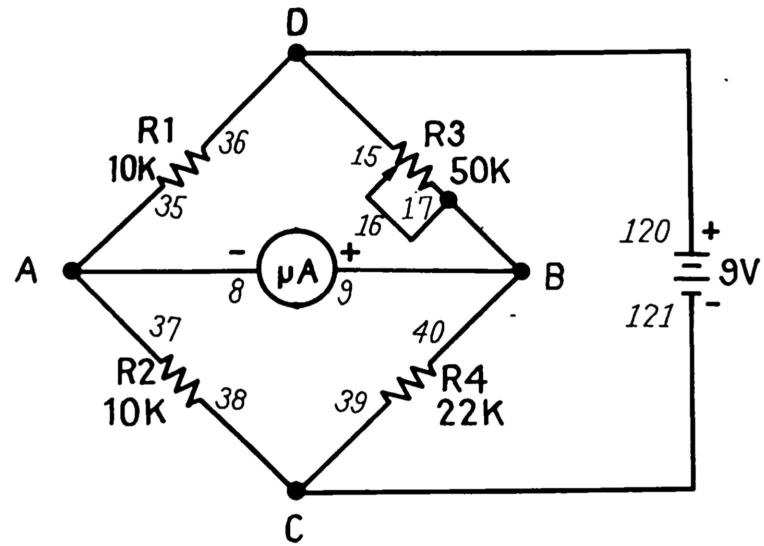
Connect the circuit and notice that the Control must be set near center to obtain a zero Meter reading with the R4 value of 22K as shown. At this balance setting the control resistance is equal to the resistance of the 22K Resistor.

If the Control is calibrated by using a large number of known resistances for R4, you could use this as an ohmmeter like the circuit was intended. You may want to try measuring other devices such as the CdS Cell, other Resistors or even between different leads of the Transistors. The resistances will have to be estimated, of course, unless you make up a calibration chart using known resistances for R4. Remember to adjust the Control for an exact zero meter reading to obtain circuit balance.



WIRING SEQUENCE:

120-15-36, 17-16-9-40, 8-37-35, 39-38-121 (Plus Text Instructions)



138. CAPACITANCE BRIDGE

The purpose of this project is to study the capacitance bridge which is used to measure unknown capacitance values between about 0.001uF and 10uF. This circuit uses many of the same concepts which are used in expensive commercial capacity bridges which sell for over $100.

The circuit is an audio oscillator combined with a modification of the Wheatstone Bridge circuit. The oscillator circuit is of the common pulse tone type which we've talked about before. The bridge circuit is a modification of the Wheatstone Bridge in project 137. The modification to the bridge involves substituting Capacitors for the two top adjacent arms of the bridge, and then using the 50K Control for the remaining two arms.

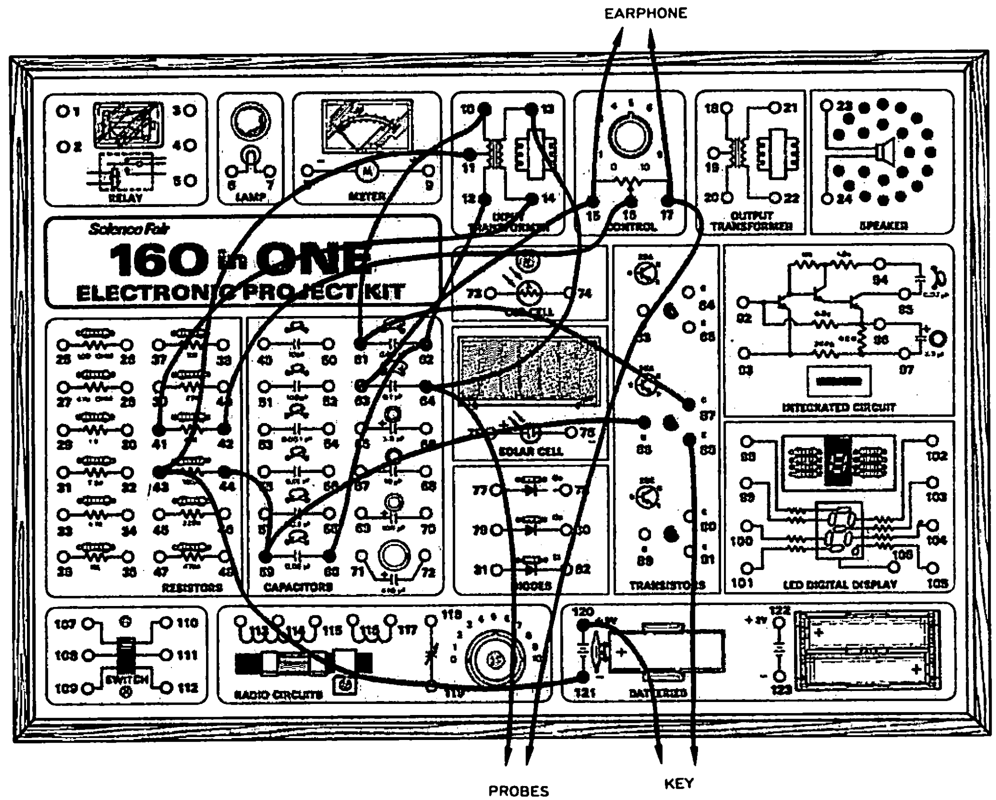
Operation of the bridge is as follows:

1. Connect unknown capacitance Cx across the Probes.
2. Close the key and adjust the 50K Control for minimum earphone signal.
3. Compare the Control dial setting with settings obtained by measuring Capacitors of known value.

You can use some of the Capacitors on the board, such as the 0.001, 0.01, 0.02, 0.05, both 0.05's in parallel to obtain a 0.1, 3.3 and the 10uF. Use the space below to make a chart or graph of capacitance versus Control dial settings.

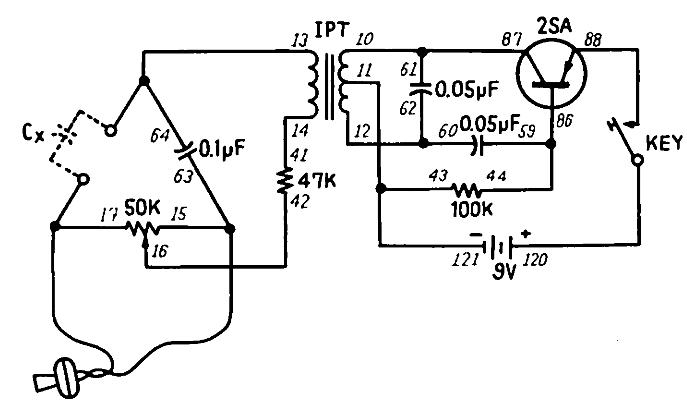
Once you've calibrated this capacitance bridge you can use it to check those mysterious color coded Capacitors you have salvaged out of old radios and TV's.

NOTES



WIRING SEQUENCE:

87-61-10, 11-43-121, 12-62-60, 86-59-44, 41-14, 42-16, 88-Key, Key-120, 13-64-Probe (for Cx), 63-15-Earphone, Earphone-17-Probe (for Cx)



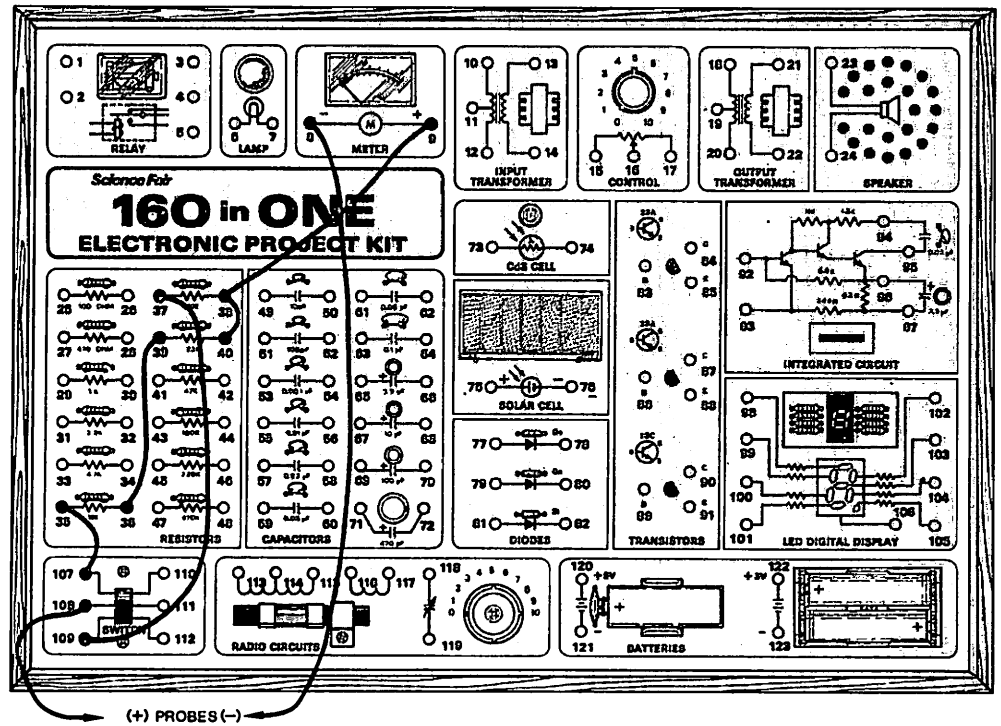
139. BATTERY VOLTMETER TESTER

The purpose of this project is to construct a quick and simple circuit to test the Batteries used in this kit. The circuit amounts to a two-range DC voltmeter.

The detailed description of the DC voltmeter circuit is included in other projects (such as project 39) where a graph is included. The full-scale voltages of this Meter are actually lower than the Batteries to be tested. Therefore, anytime the Batteries are not able to pin the Meter (when set on the proper voltage range), you know they are weak.

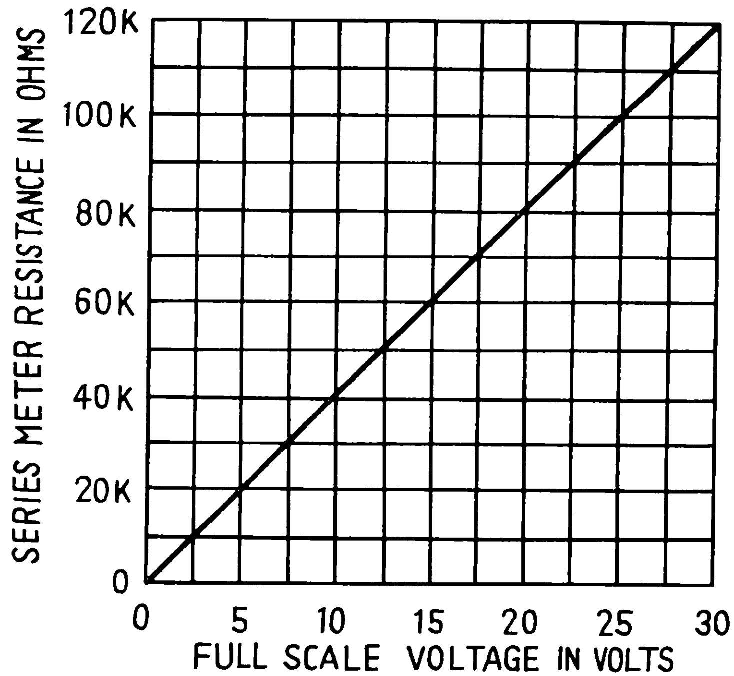
This Meter will help you troubleshoot a circuit that won't work, by determining if the Battery is at fault.

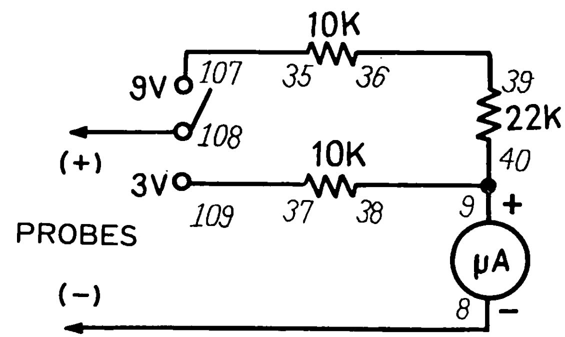
With the Switch DOWN you have a low voltage range (3V), and with the Switch UP, the higher voltage range (9V).



WIRING SEQUENCE:

9-38-40, 37-109, 39-36, 35-107, 108-Probe (+), 8-Probe (−)





140. AUDIO OUTPUT METER

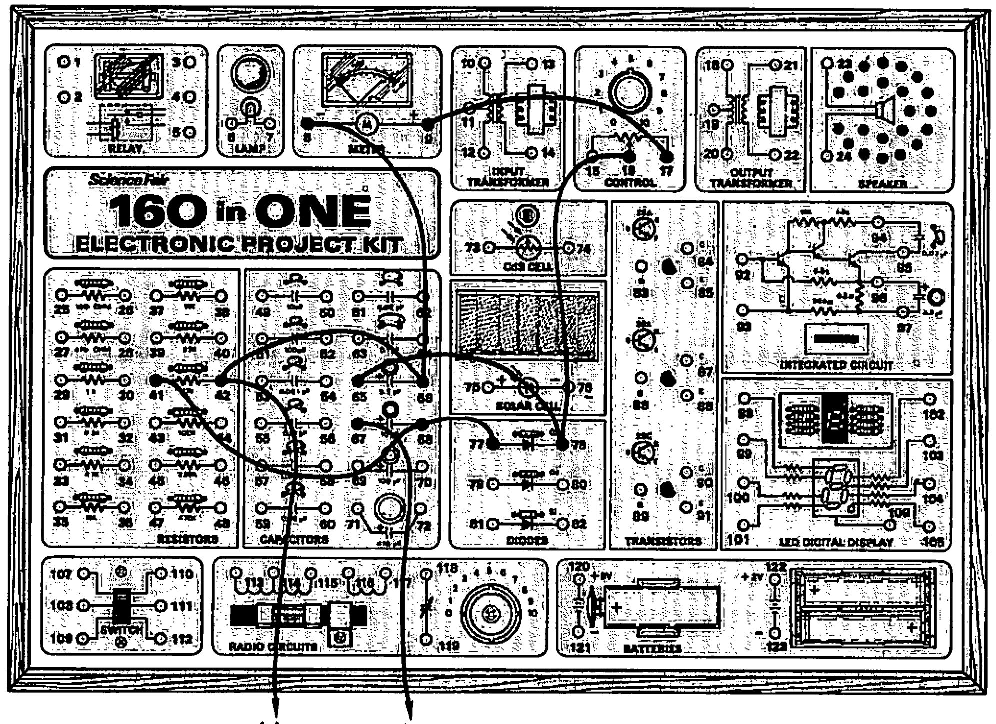
This project is a simple VU (volume unit) Meter which you can use to measure the level of audio frequency voltages at the output of an amplifier or oscillator. A sensitivity control is included to allow full-scale Meter readings with audio voltages betwen about 0.2V and 9V.

The circuit is a simple half-wave rectifier with filtered output which is fed to an adjustable DC voltmeter. An input DC blocking Capacitor is included so that measurements can be made on circuits which have up to 25V of DC present along with the audio AC signal. We've discussed DC voltmeter circuits in detail in other experiments in this kit.

To operate the VU Meter simply connect the Probes across the circuit to be measured, taking care to observe polarity if DC is present in the circuit. Adjust the 50K Control for the desired Meter reading. In circuits where no DC voltage is present, the 10uF Capacitor may be replaced with a short circuit. In these circuits the 47K Resistor may also be removed, and replaced with an open circuit.

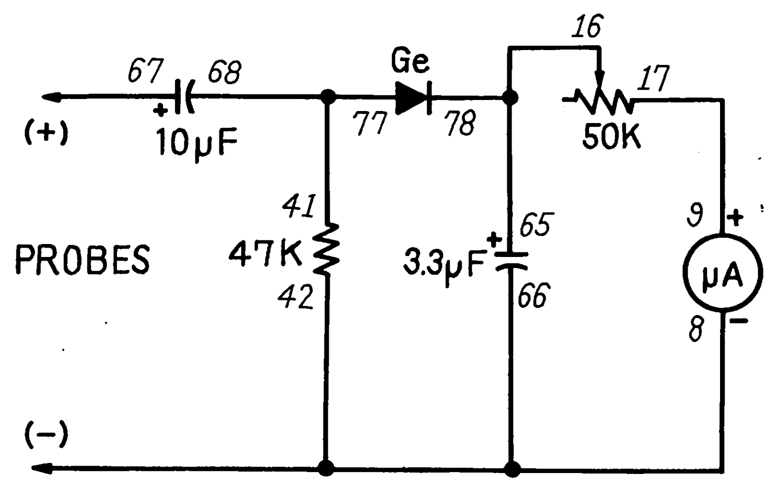
The applications for Meters such as this include monitoring the level of audio for tape recorders, radio-stations, TV stations, etc. You may use this circuit to measure some of the oscillators and amplifiers in this kit. The only requirement is that the parts used in this Meter not be required for the other circuit.

NOTES



WIRING SEQUENCE:

9-17, 16-78-65, 8-66-42-Probe (-), 77-68-41, 67-Probe (+)



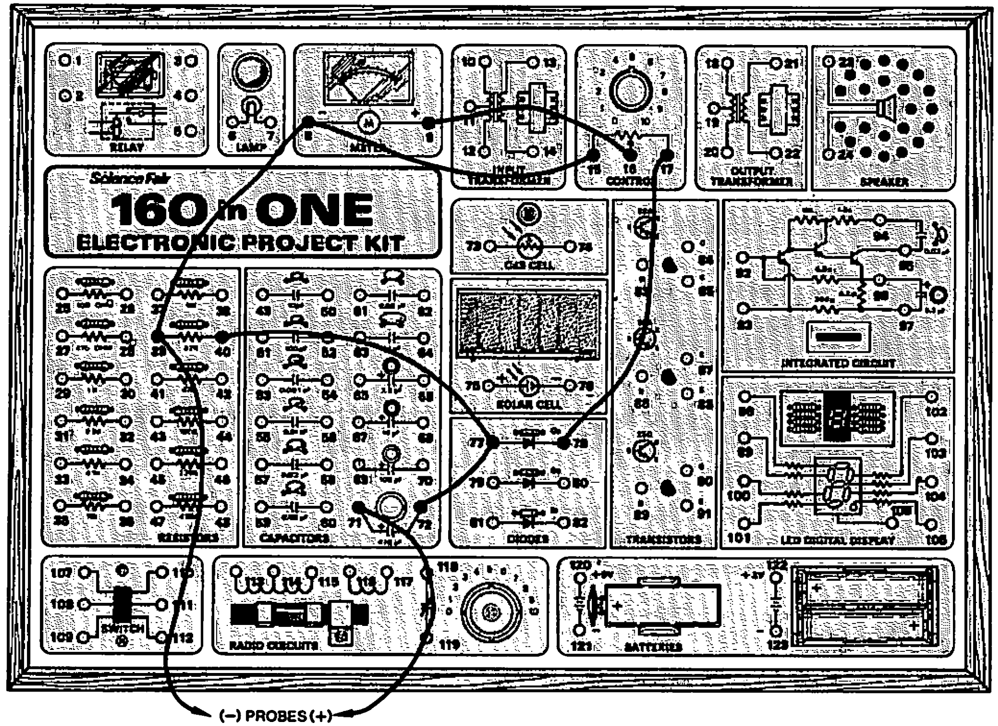
141. LOW REQUENCY RESPONSE AUDIO LEVEL METER

This project is an output level meter which is similar to the one in project 140. Can you explain the differences?

This project has the same basic characteristics of the other project. The Meter circuit is the major change. This circuit uses the 50K Control as a combination shunt-series resistance — the other circuit uses it as a variable series resistance only. Can you determine which circuit is capable of reducing the Meter output to zero, and which circuit is not?

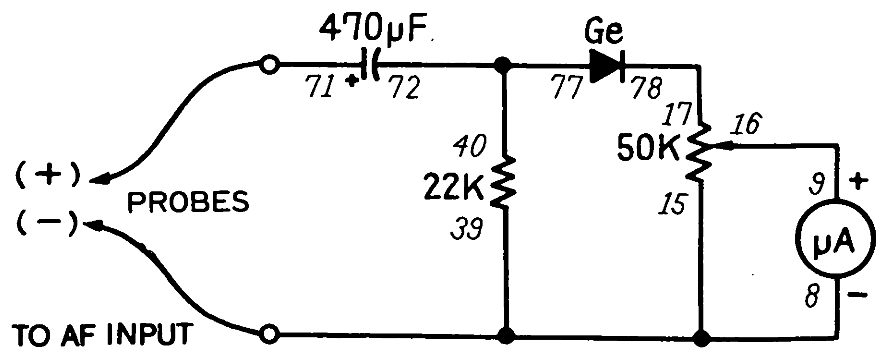
This Meter circuit has a much improved low frequency response compared with the other circuit. This is obtained by an input Capacitor of larger value and the elimination of the filter Capacitor.

Another important change is that this circuit responds to the average signal level — the other circuit tends to respond to the peak of the signal. This is due to the action of the filter Capacitor in the other circuit.



WIRING SEQUENCE:

17-78, 16-9, 40-77-72, 15-8-39-Probe (−), 71-Probe (+)



NOTES

142. I.C. VU METER

This project is a very sensitive integrated circuit (IC) volume unit (VU) meter. Unlike most VU meters used to measure sound levels, this one has high sensitivity obtained by use of the IC.

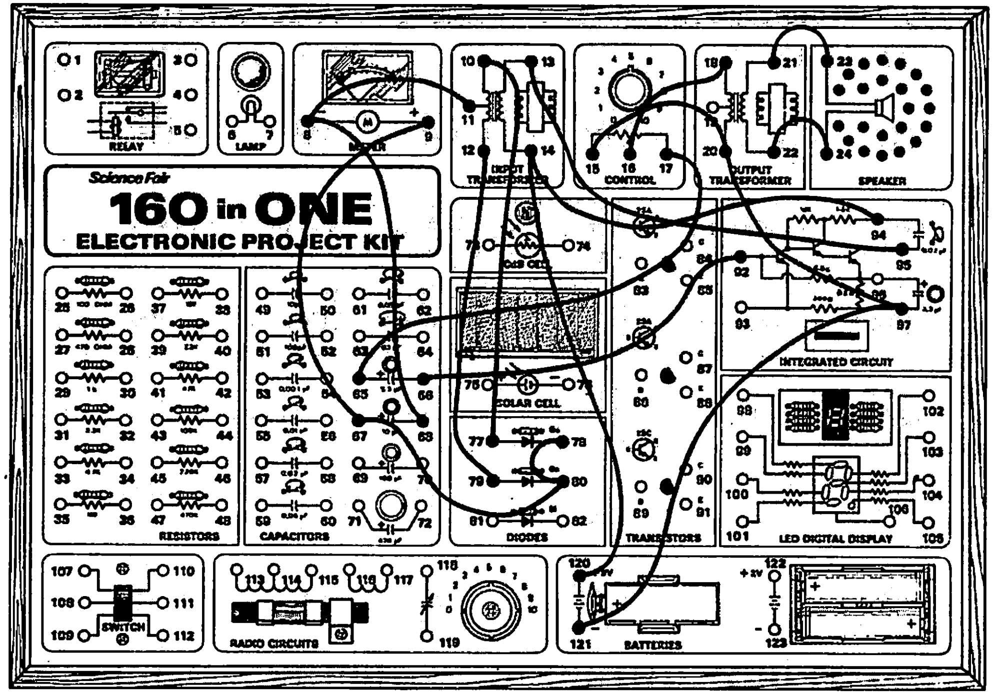
Always start measuring the sound with the Control set at minimum. Increase the Control for a desired level of Meter pointer deflection. This circuit is so sensitive that, if the control is increased too far, the circuit may oscillate and cause the Meter to be pinned without any sound received by the Speaker.

The Speaker is used as the microphone. Recall that when used like this, the Speaker is very similar to a dynamic microphone. That is, the Speaker coil moves back and forth in a strong permanent magnet field, causing a voltage to be induced in the coil.

The Meter circuit is a full-wave rectifier circuit that causes both half cycles of the AC to be passed on to the Meter with proper polarity to cause an upward pointer deflection. The 10uF Capacitor helps to smooth out the rectified voltage so that the Meter will respond more smoothly to the changing signal levels.

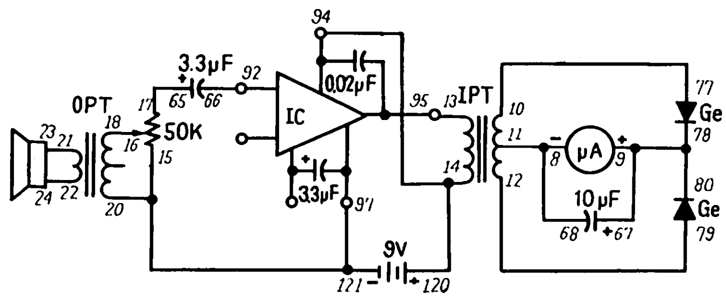
You will want to measure and compare noises around the house. Also, when used outside, you will be surprised how much the Meter action causes you to notice sounds that are normally tuned out by your subconscious mind.

NOTES



WIRING SEQUENCE:

11-8-68, 9-67-80-78, 10-77, 12-79, 13-95, 94-14-120, 21-23, 22-24, 18-16, 17-65, 66-92, 15-20-97-121



143. METER AMPLIFIER

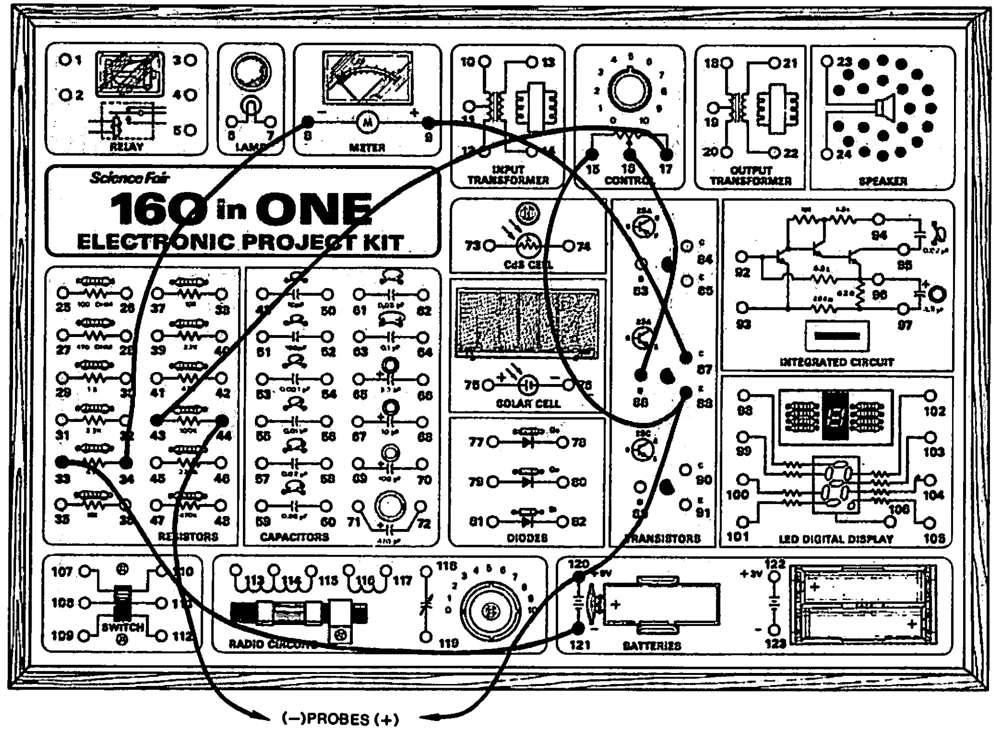
You will see the combination of a DC amplifier and the Meter, in this project.

This combination of the Meter with a DC amplifier is frequently used to improve the Meter sensitivity, and it is also required to prevent other circuits from being affected by the low resistance of the Meter, when it is connected solely to the other circuits.

The DC amplifier we use in our test is one of the simplest type, but it makes us remember a fact that can be overlooked. Set the Control knob to the "0" position, and connect the Probes to the 3V Battery (observe correct polarities). Then slowly turn the Control knob clockwise. How does the Meter pointer move? It almost stays still until the Control knob reaches "5" (approx.). The Meter pointer starts to swing when the Control knob is turned beyond that point. Change the Probe connections to a 1.5V battery. At this moment the Meter pointer stays still no matter where the Control knob is positioned, or maybe it moves a bit when the Control knob is turned fully clockwise.

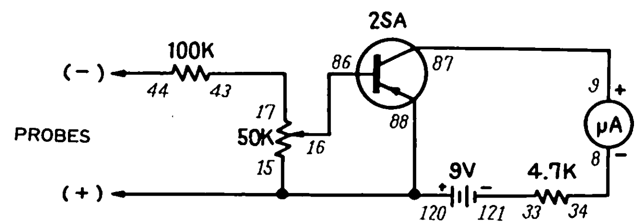
No current is allowed to flow into the B-E junction of the Transistor unless certain bias voltage (about 0.6V for a silicon Transistor) is applied. In our test the Meter does not respond against any voltage lower than about 1.8V, as the base circuit of Transistor has both the 100K and 50K Control resistance. The next project will show a way to solve this problem.

NOTES



WIRING SEQUENCE:

34-8, 9-87, 86-16, 17-43, 44-Probe (−), 15-88-120-Probe (+), 33-121



144. TRANSISTORIZED DC VOLTMETER

This project shows how a bridge circuit and a high-gain amplifier can be used together as a low-range DC voltmeter. A DC voltmeter which uses an amplifying device like this is called an electronic voltmeter. The VTVM (vacuum tube volt meter) is probably the best known electronic voltmeter.

Operation of this circuit is as follows:

1) After the wiring is complete, adjust the Control so the Meter gives a reading of 1 on the blue scale. The reading of 1 will indicate 0 volts on this Meter. This setting is necessary to keep a small amount of current flowing to the Transistor at all times. This will improve the linearity of the Meter (make each segment of the scale represent the same amount of voltage).

   Note: Each segemnt of the blue scale will represent about 0.25 volts with this Meter. A 1.5 volt battery should register about 7 (6x0.25, plus 1 for the begining Meter setting).

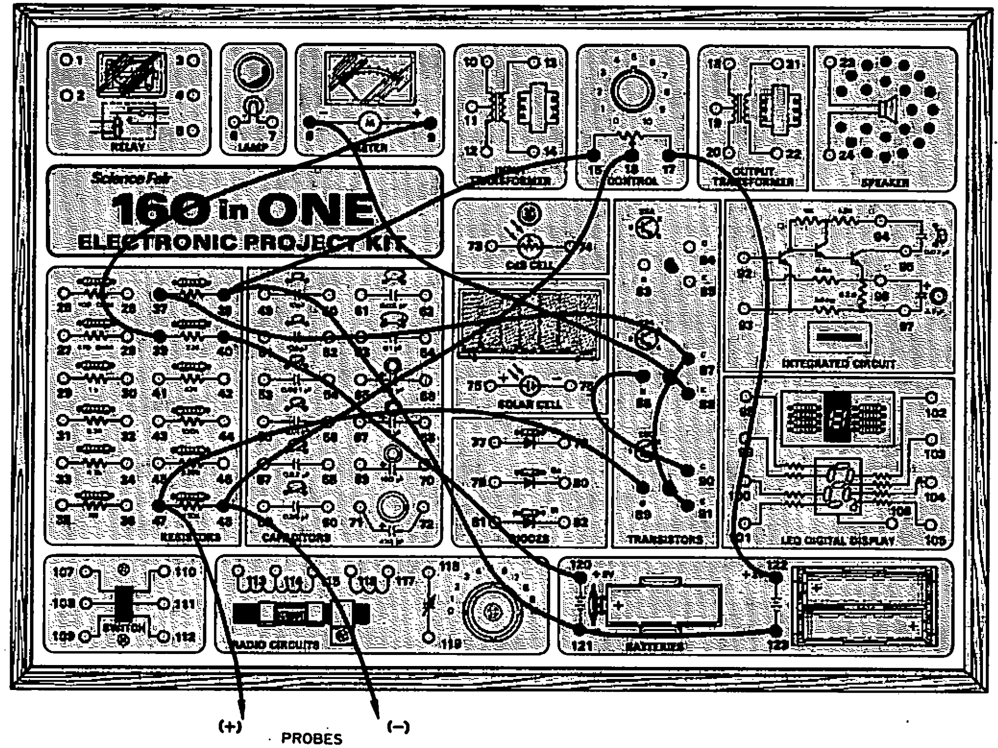
2) Connect the Probe wires to the DC voltage to be measured (it must be less than 2 1/4 volts for this circuit). Make sure you observe the correct polarity (+ and -).

To change the Meter for measuring lower voltages, replace the 10K resistor with a lower value (4.7 K or 1K). The amount of voltage for each unit on the scale will decrease in proportion with the resistance. For example, if you decrease the 10K Resistor to a 4.7K (about half the resistance), each unit on the scale will represent about half of the original 0.25 volts (0.125).

CAUTION: A very sensitive Meter can be damaged by even a small voltage. Use the information above to calculate the voltage limit of the Meter before you use it.

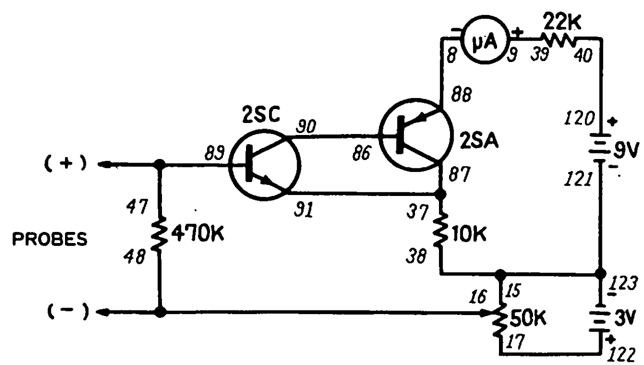
The 2SC and 2SA Transistors are connected in a way that produces a very high gain (amplification). This special way of connecting transistors is called 'Inverted Darlington'.

NOTES



WIRING SEQUENCE:

8-88, 9-39, 15-38-121-123, 16-48-Probe (−), 17-122, 37-87-91, 86-90, 89-47-Probe (+), 40-120



145. AC VOLTMETER

The purpose of this project is to study the two Diode, half-wave AC voltmeter. This type Meter has been used in VOM's for many years. In fact, if you have a VOM it may have this type circuit, which is switched ON in the AC voltage function.

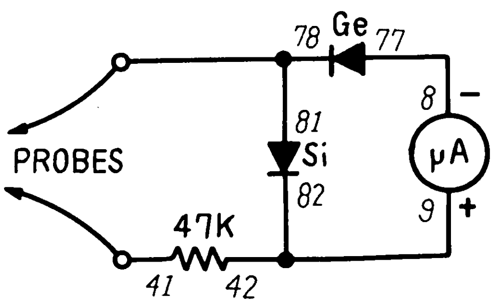
The way this project is originally wired with the 47K multiplier Resistor, the full-scale RMS (root-mean-square) AC voltage is about 26 volts. By changing this Resistor value it is possible to obtain full-scale AC voltages from about 0.6V to as high a you would ever need (thousands of volts). You can use the graph below to choose this series multiplier resistance for whatever full-scale voltage rating you want.

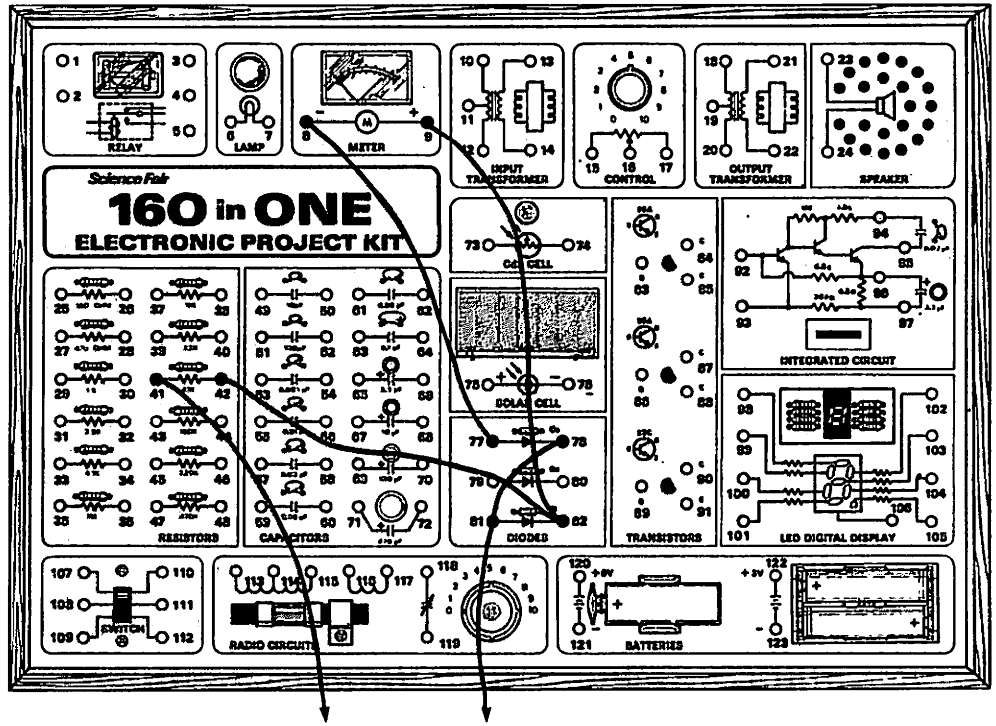
Calibration accuracy of this type Meter is generally very good for full-scale voltages of about 10V and higher, but as you will notice on commercial VOM's, separate AC voltage scales are generally used for lower ranges. This problem is due to the fact that the germanium (Ge) Diode resistance changes over the current range of the Meter from a few K ohms near the low-voltage end of the range to 100 ohms or so at full scale. This resistance change causes non-linear scale calibrations for low voltages.

You can use this Meter to measure the output of oscillators which operate in the audio frequency range and all AC power line frequency voltage. Try measuring between Ground and the metal parts on equipment plugged into the 120V AC power line. Any voltage readings above about 60 volts may indicate excessive leakage that you should tell someone about, so the appliance may be repaired. Also, try plugging the appliance's line cord into the wall outlet with the plug turned around; then check leakage with this polarity.

Circuit operation is as follows: On one half-cycle of the AC, the germanium (Ge) Diode conducts and passes the current through the Meter. The series multiplier Resistor limits the current to the desired value for a full-scale Meter reading. At this time the silicon (Si) Diode is reverse-biased and acts as an open circuit. The Meter is deflected up scale due to the current flowing on this half-cycle.

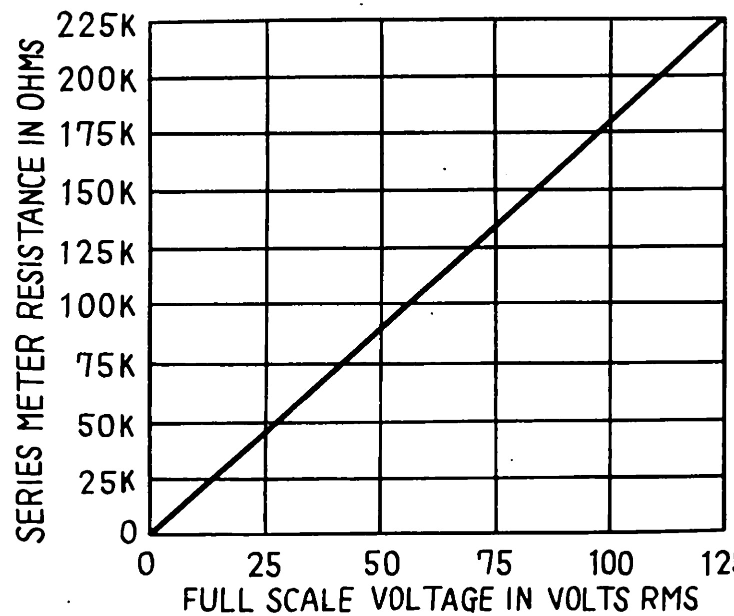
The silicon (Si) Diode conducts on the other half-cycle and parallels the current with the Meter and Ge Diode branch. Only the voltage drop of this Diode (about 0.6V or less) is applied to the series Meter circuit. This voltage reverse biases the germanium (Ge) Diode so it acts as an open circuit. The silicon Diode then functions only to keep the reverse voltage across the germanium Diode to a low value (about 0.6V) no matter what voltage is applied to the circuit.





WIRING SEQUENCE:

8-77, 9-82-42, 78-81-Probe, 41-Probe, (Text describes other changes)



146. TRANSISTOR CHECKER

This project is the construction and testing of a very practical Transistor checker. With an aural signal you can check any Transistor for (1) short circuits, (2) open circuits and (3) relative gain.

The procedure to test a Transistor is as follows:

1. Hook up the circuit for the type Transistor to be checked (PNP or NPN).
2. Connect the leads to the Transistor properly.
3. Place the Control on minimum (full CCW).
4. Close the Key and advance the Control until oscillations begin. You interpret the results as follows:
   a. High-gain Transistors oscillate on lower Control settings than low-gain types.
   b. Power Transistors require higher Control settings than small-signal Transistors.
   c. Transistors which are open or shorted will not oscillate.
   d. Transistors of the wrong type for the circuit setup (PNP or NPN) will not oscillate.
   e. Transistors connected improperly will not oscillate or may require very high Control settings.
   f. Transistors which are leaky but still have proper gain will oscillate much like a good Transistor. Check for leakage with a high-resistance ohmmeter.

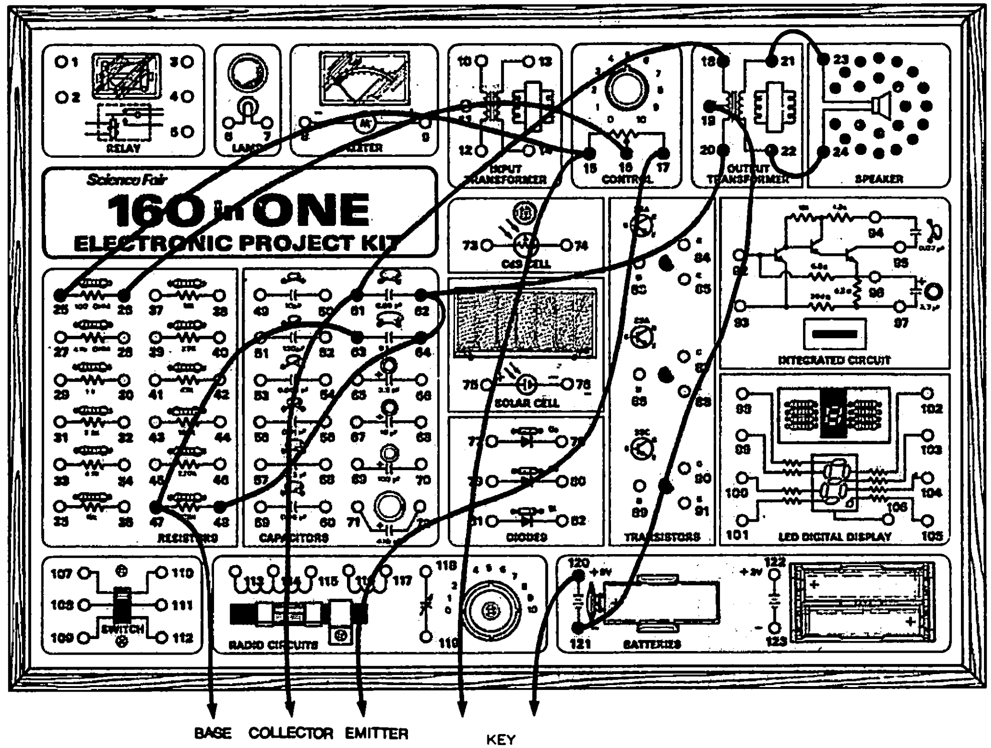
The circuit is a straight-forward audio oscillator, but with a feedback control in the emitter lead. The feedback operates by inserting resistance into the circuit to cause both degenerative feedback and decreased Transistor electrode voltages.

The only change between PNP and NPN checks is the reversal of the Battery connections. This is required because Transistor bias voltage must always cause current flow gainst the arrow head symbol in the emitter of the Schematic symbol. The PNP Transistor symbol has the arrow head pointing away from the emitter lead, therefore, both base and collector currents must flow toward the emitter inside the Transistor. The NPN Transistor symbol has the arrow head pointing toward the emitter lead, therefore, both base and collector currents must flow from the emitter to the base and collector inside the Transistor.

Use this tester to check each Transistor in this kit and record the control dial setting below for comparison later on when troubleshooting for a suspected bad Transistor.

2SA (upper)____________ , 2SA (lower) ____________ , 2SC ____________ .

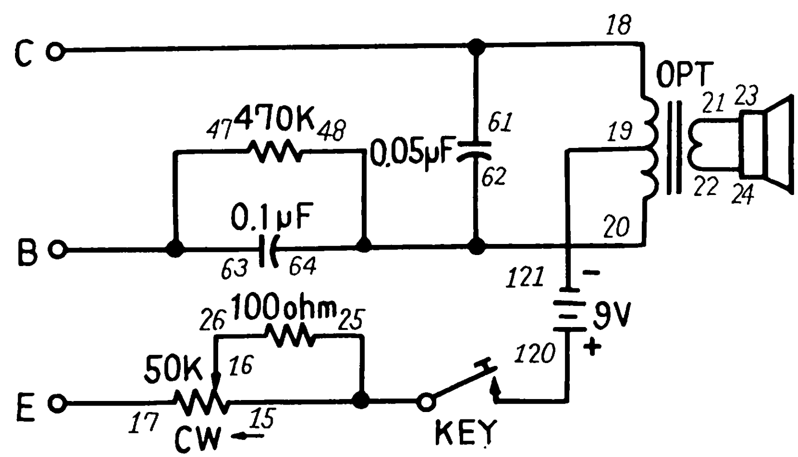
NOTES



WIRING SEQUENCE:

PNP Hookup: 21-23, 22-24, 20-62-64-48, 16-26, 19-121, 120-Key, Key-15-25, 18-61-Collector, 63-47-Base, 17-Emitter

NPN Hookup: (Reverse the Battery Lead Connections)



147. SEMICONDUCTOR TESTER

This project is a series-type ohmmeter designed specifically to check Diode and Transistor junctions for rectifier action. This is the same type circuit used in many VOM's (volt-ohm-milliamp meters) to measure resistance, but this project includes this particular circuit and test procedures specifically to test rectifying junctions.

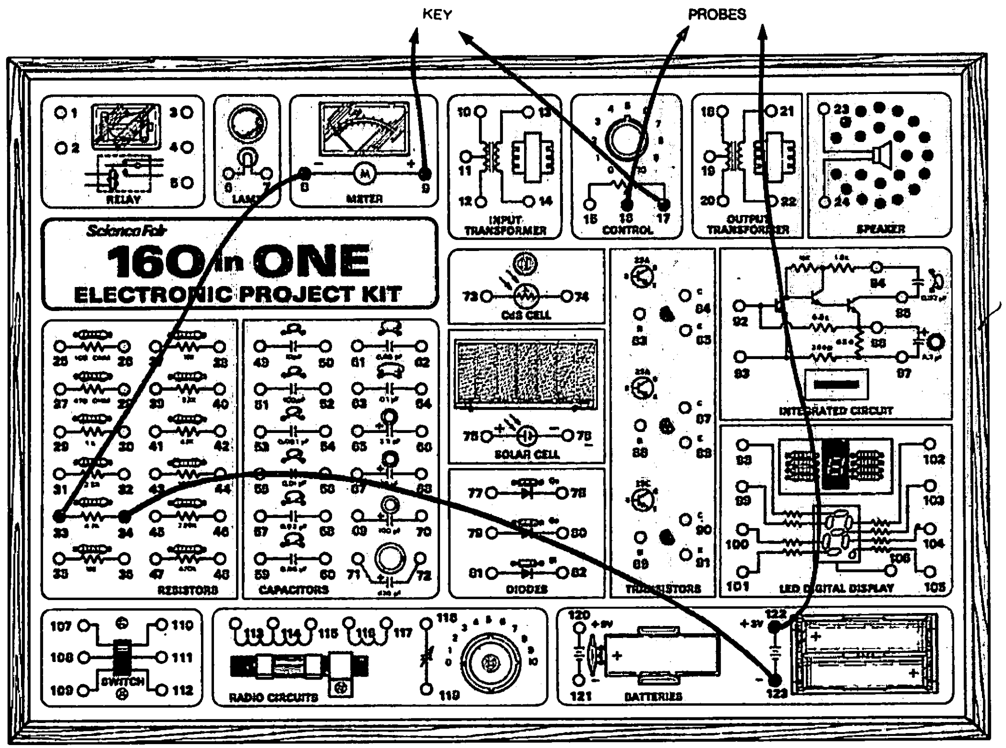
The test procedure is as follows:

1. Connect the test Probes to the device (Diode, Transistor B-E or B-C junction) with the polarity which allows the Control to be adjusted for a full-scale Meter reading on the blue Meter scale. Adjust for this level and leave the Control at that setting.
2. Reverse the test Probes and observe the Meter reading. The Meter readings should be interpreted as follows:
   a. If the Meter reading is still 10 (full scale) the device has no rectifier properties or is shorted.
   b. If the Meter reading is above about 1.0 on the blue scale (but below 10) the device is a poor rectifier junction because of excessive leakage. (Or something is shunted across the device. Make sure nothing is connected in parallel with the junction being tested.)
   c. With a Meter reading below about 1.0 for germanium (Ge), rectifiers are good.
   d. Meter readings below about 0.5 (the first small Meter scale marking) for germanium Transistor B-E and B-C junctions, indicate they are good.
   e. Meter readings of zero (or very close to it), for all silicon (Si) rectifiers and silicon Transistor B-E and B-C junctions, indicate they are good.

It would be a good idea to check all Diodes and Transistor junctions in this kit and record the results below. This way, later on you can check and compare when one of these devices is suspected of being defective.

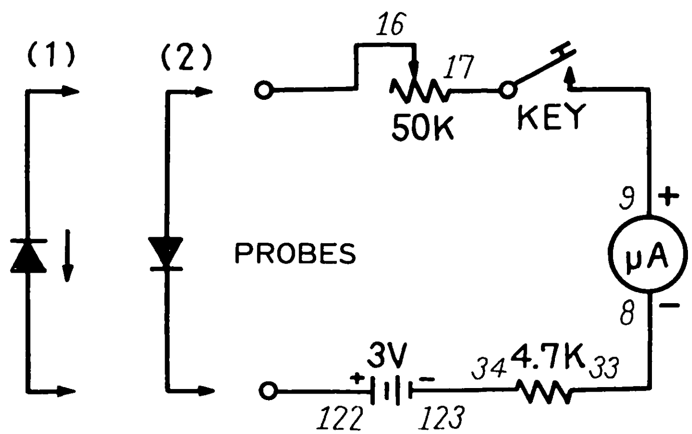
You may want to use your knowledge gained from project 46 to include a polarity-reversing switch with this circuit. If you can do this you are progressing wonderfully in your training in electronics. Good luck!

NOTES



WIRING SEQUENCE:

123-34, 33-8, 9-Key, Key-17, 16-Probe, 122-Probe



148. SINEWAVE AUDIO OSCILLATOR

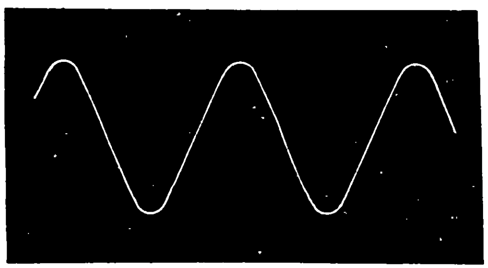
The purpose of this project is to consider sinewaves and a generator capable of producing sinewave outut signals. A sinewave signal is used when testing HI FI amplifiers for distortion.

First let's consider what a sinewave is. In one simple sentence it may be defined as "a wave of pure single-frequency tone". For example, a 400 hertz sinewave is an AC volume which alternates throughout 400 cycles in each second of time, and contains no other frequency components. A 400 hertz wave which is not a sinewave is actually composed of the 400 hertz wave (fundamental), a 800 hertz wave (2nd harmonic), 1200 hertz wave (3rd harmonic), etc., depending on the actual waveform as viewed on an oscilloscope.

With a little training anyone can be taught to distinguish between a sinewave and one which is not. With this ability you may be able to test amplifiers and circuits by injecting a sinewave and listening to the output. The results of amplitude nonlinear distortion is the generation of undesired harmonic frequencies. These newly-generated frequencies are easily detected by the trained ear.

The circuit used here to generate a sinewave of about 400 hertz has the following features:

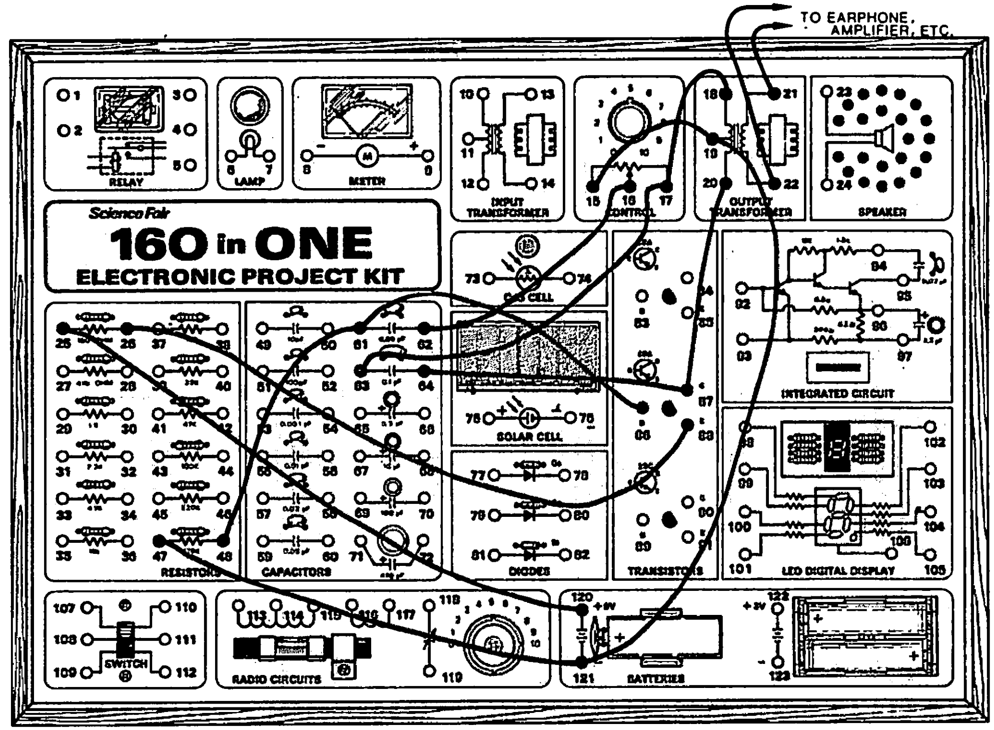
1. A 0.1uF Capacitor across the Transformer to form a tank circuit resonant at about 600 hertz.
2. A 470K base-bias Resistor to turn the Transistor ON only a small amount.
3. An adjustable feedback circuit, composed of the 50K Control and 0.05uF Capacitor.
4. A 100 ohm emitter-swamping-resistor to help minimize the nonlinear B-E Transistor resistance.
5. The output should be connected to an amplifier input or Earphone.



The procedure for getting this oscillator to produce a sinewave output is also a good one for training you to distinguish a sinewave from a distorted wave. Connect the Earphone across the output of the Transformer. Start operating with the Control on maximum (10 on dial). Slowly decrease the Control while listening to the tone quality of the output. You will reach a point, before oscillations stop, where one tone is heard. This last clear-sounding tone is the sinewave. Repeat this Control adjustment until you have no trouble distinguishing between a sinewave and a distorted wave.

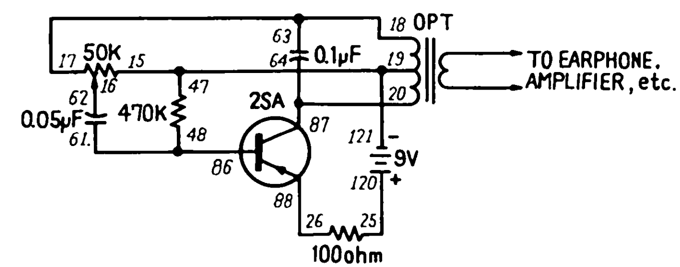
The most stable sinewave oscillator adjustment is the point where the signal level is as strong as possible before the first trace of distortion can be heard.

If you own a HI FI or STEREO amplifier, this tone may be coupled into the AUX, or auxillary input or into the HI Z or high impedance input.



WIRING SEQUENCE:

47-121-19-15, 16-62, 18-17-63, 20-87-64, 48-61-86, 88-26, 25-120, 21-Earphone (or amplifier), Earphone (or amplifier)-22



149. LOW DISTORTION SINEWAVE OSCILLATOR

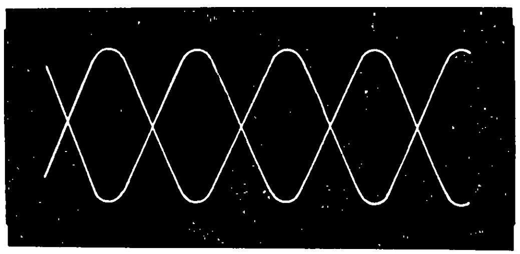
The purpose of this project is to build and study a low-distortion sinewave oscillator. This project should be built and used after you have built and studied project 148. This oscillator is better than project 148 because there is no Transformer, with its inherent nonlinear characteristics, to cause distortion.

The adjustment for low distortion is similar in that you listen to the tone and adjust the Control for the clearest-sounding single tone. Start with the Control near maximum.

The frequency of operation is about 300 hertz, at the minimum distortion setting of the Control. If oscillations cannot be made to continue, the 3V and 9V Batteries can be connected in series to obtain the higher required gain, and therefore sustain oscillations.

This circuit is a popular basic oscillator known as an "RC phase shift" oscillator. You will find this circuit described in many theory texts. Oscillations occur at the one frequency where the RC circuit values cause a 180 degree phase shift in voltage.

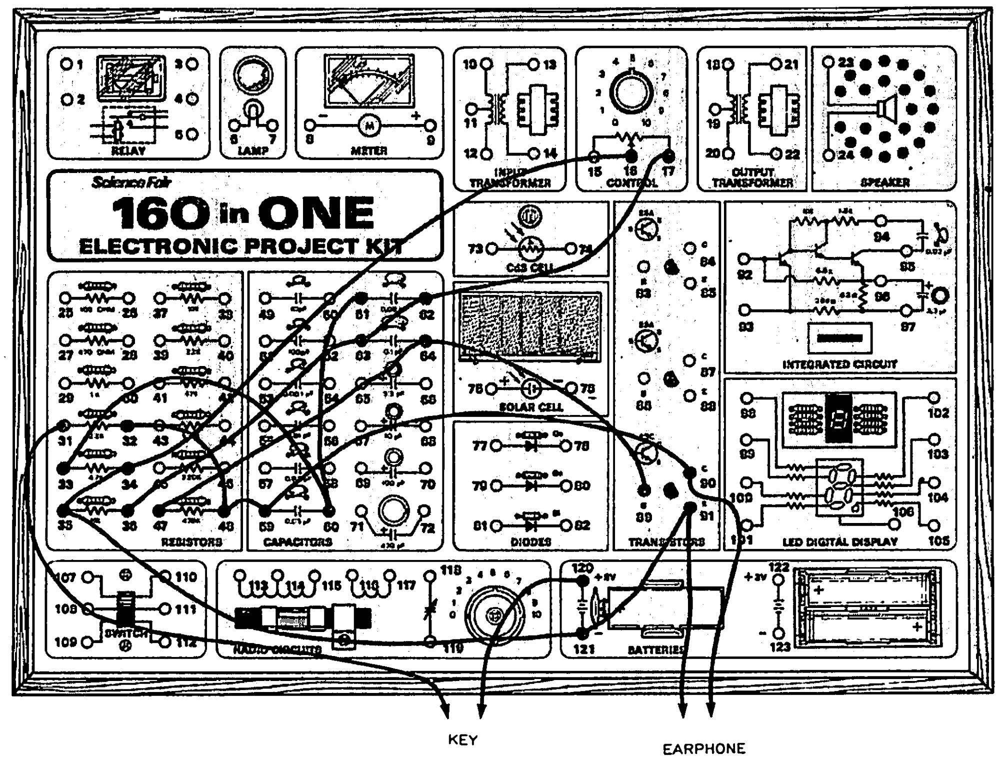
The 180 degree phase shift is required to obtain regenerative feedback for a common-emitter stage such as this. A voltage at the base appears at the collector, amplified and out of phase with the output voltage by 180 degrees. Therefore, to feed this voltage back into the input in the same phase as the original input voltage (regenerative phase) a phase shift of 180 degrees is required.



The RC (Resistor-Capacitor) network composed of the three Capacitors, the 4.7K, 10K and 50K Control, and the B-E input resistances of the Transistor causes exactly 180 degrees of phase change at only one frequency. This is the frequency of sinewave oscillation.

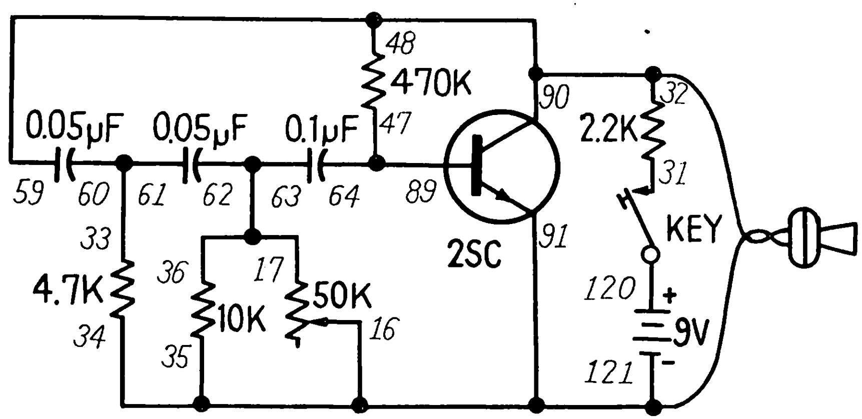
An RC network can shift the phase of a voltage due to the action of the Capacitor on the current that flows in the circuit. A Capacitor operating alone can cause the current to be 90 degrees leading the voltage. That is, the current maximum (and minimum) occurs 90 degrees ahead of the voltage maximum (and minimum). Any resistance in the circuit causes the phase difference to be less than 90 degrees. With a certain resistance the phase shift can be set to 60 degrees, exactly. Then if three of these RC networks are connected in series we can obtain 60+60+60=180 and (presto!) the proper phase shift to produce oscillation.

This circuit is easy on batteries (it only draws 2mA) but must not be loaded much or oscillations cannot be sustained. The crystal Earphone does not present much loading to the circuit, so it is ideal.



WIRING SEQUENCE:

89-64-47, 32-48-59-90-Earphone, Earphone-19-121-35-34-16, 17-62-63-36, 61-60-33, 31-Key, Key-120



150. TWIN-T AUDIO OSCILLATOR

The purpose of this project is to study a twin-T type audio oscillator. Because of its stability, it is very popular for such things as electronic organs, electronic test equipment, etc.

The frequency of the oscillations depends on an accurate choice of Resistors and Capacitors in the twin-T network. The letter "T" comes from the Schematic diagram arrangement of the Resistors and Capacitors. The term "twin" comes from the fact that there are two T networks, which are paralleled or bridged across each other.

The 2SC is a class A amplifier as far as DC bias and signal level are concerned. The collector is supplied voltage through the 10K Resistor. The 22K and 47K Resistors supply the base bias current as well as functioning as part of the twin-T frequency determining network. The 100 ohm Resistor is included to help obtain a high input resistance at the base of the Transistor and to reduce distortion.

The six RC components in the twin-T network all contribute to the unique characteristics of this circuit. That is, the signal that results from oscillation action is the only signal that can get through this network with the proper phase to sustain oscillations.

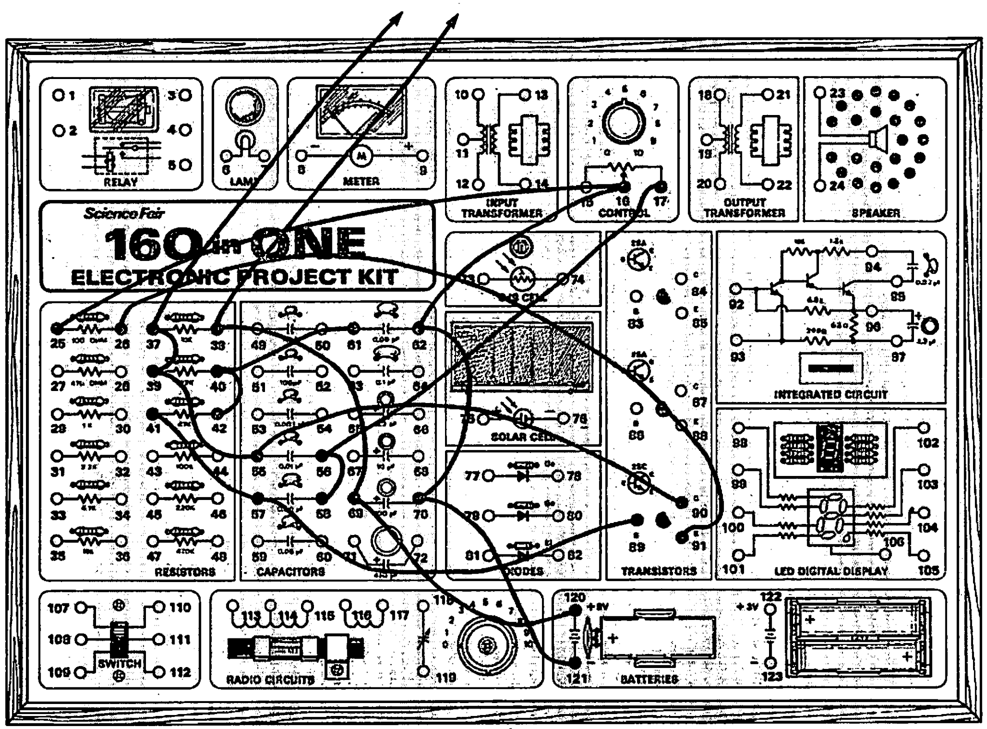
The circuit must be carefully adjusted to obtain pure sinewave output. Adjust the Control very slowly over its entire range until you hear a tone in the Earphone. The tone will be very low and resemble the lowest note of a large pipe organ. This Control setting should be between 7 and 10 on the dial.

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

The circuit cannot tolerate much of a load, therefore the crystal Earphone is ideal (as it does not present much of a load to the circuit).

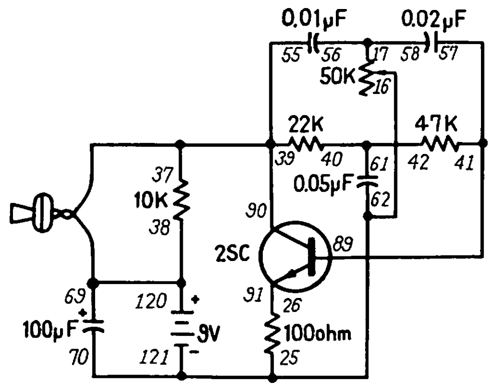
You can experiment with this circuit in many ways. We suggest you try different values for the 10K and 470 ohm Resistors, and try using higher and lower Battery voltages. Also, if you have a VOM, try measuring circuit voltages.

NOTES



WIRING SEQUENCE:

17-56-58, 25-16-62-70-121, 61-40-42, 41-57-89, 90-55-39-37-Earphone, 91-26, Earphone-38-69-120



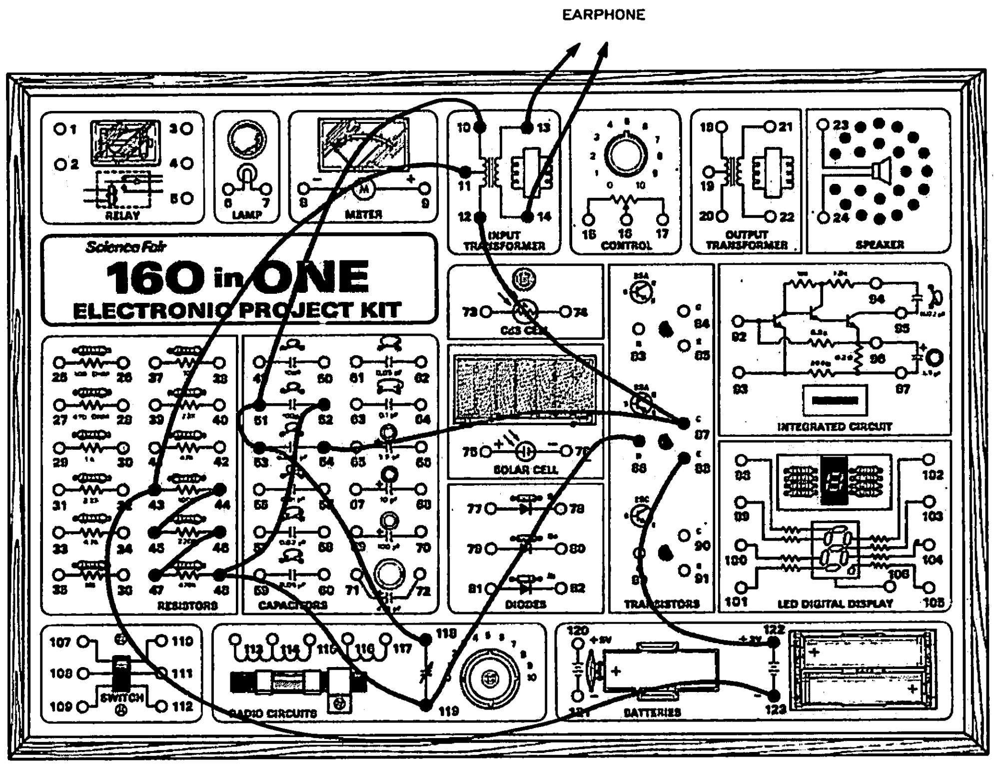
151. VARIABLE AUDIO OSCILLATOR

This project is a pulse-type audio oscillator that can be changed in frequency as the tuning capacitance is changed. A low tone is produced when the capacitance is at its maximum and a high tone is obtained with minimum capacitance.

The reason for this change is that the capacitance charges to a voltage greater that the 3V of the Battery, due to the induced voltage of the bottom half of the center-tapped Transformer winding. This voltage must then be discharged through the total resistance of 790K ohms (100K + 220K + 470K) to about 3V, before the Transistor can conduct again to produce another pulse of output (and another charge greater than 3V on the Capacitor).

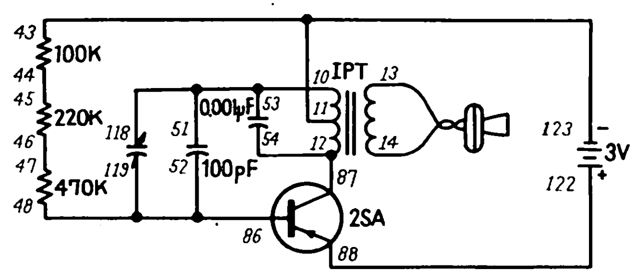
You can change the repetition rate (frequency) of the operation by changing either the capacitance or the resistance value, or both. Experiment with different values of resistance, but do not use resistors less than 100K or the Earphone may be damaged.

NOTES



WIRING SEQUENCE:

10-51-53-118, 11-43-123, 12-87-54, 13-Earphone, Earphone-14, 44-45, 46-47, 52-48-119-86, 88-122



152. PULSE OSCILLATOR TONE GENERATOR

This project is a pulse-tone oscillator which is adjustable in frequency to obtain a wide range of notes. With practice you should be able to play tunes on it, similar to an electronic organ.

To play a tune, adjust the Control to the proper note and press the Key momentarily. Readjust the Control for the next note and again press the Key. After some practice you should be able to play some simple tunes. You will also be able to slur between notes, like a trombone.

This circuit is such a typical pulse-tone oscillator, we will explain the circuit in some detail. Like all oscillators, it meets the two basic requirements for oscillations: a gain greater than 1 (1 being the input) and regenerative feedback. It is the feedback control circuit we will look at specifically.

First, review of basic Transistor characteristics: Any current flowing through the Transistor must pass through the emitter against the direction of the arrowhead. Collector current cannot flow unless there is also base current (unless resistance is in series with the collector to limit the collector current).

Now we will try to show how the 0.05uF Capacitor is quickly charged to about 4V, and how this charge must leak off some before it will allow the Transistor to turn ON and repeat the cycle. It will help you if you use different color pencils or pens to draw arrows around the Schematic diagram to identify the following currents.

When the Key is first closed the base bias current flows around the loop formed by the Battery, 10K, 50K, Transistor B-E and Key. (Current always flows from negative to positive.)

The above base bias current causes collector current to flow around the loop formed by the 3V Battery, lower half of the Transformer winding, Transistor C-E and the Key.

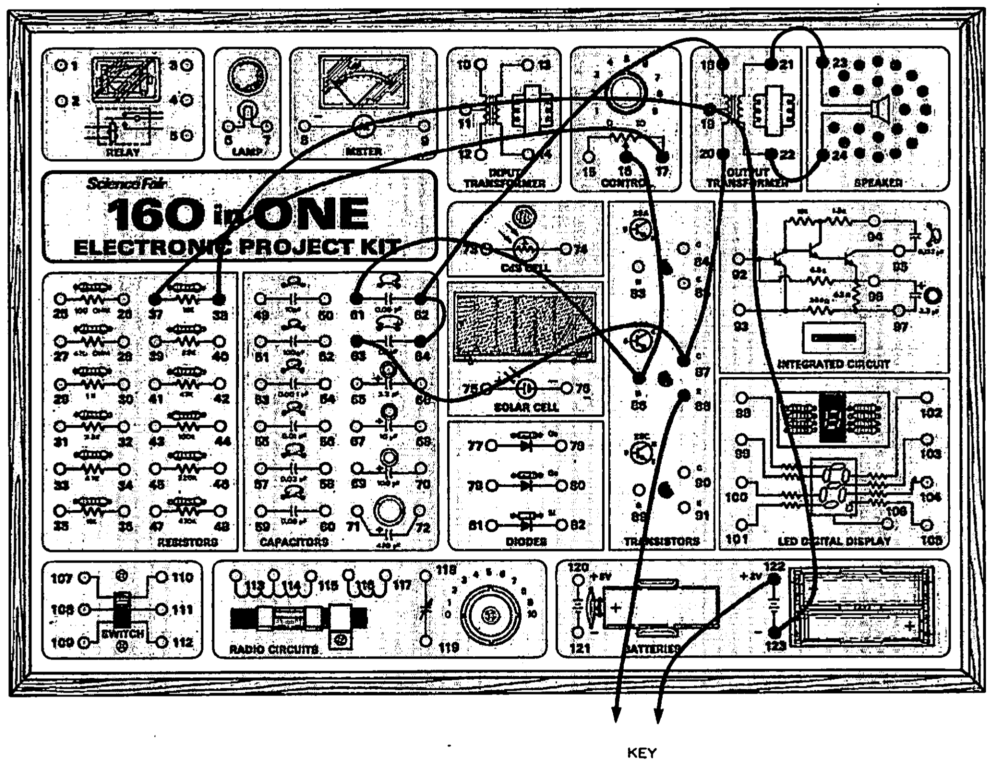
The current flowing in the Transformer induces (by transformer action) a current around the loop formed by the top Transformer winding, the 0.05uF, Transistor B-E, Key, Battery and back to the Transformer center tap. This current quickly (in less than 0.0001 seconds) charges the 0.05uF to about 4V or so with a polarity which is negative on the Transformer side and positive on the Transistor base lead side. The Speaker output pulse is obtained only during the time current flows in the Transformer.

The charging of the 0.05uF stops because the induced voltage from the top half of the Transformer winding stops, due to Transformer core saturation. As soon as this current stops, the Capacitor begins to charge. As soon as the discharge begins, it turns the Transistor OFF because the Capacitor voltage is higher than the Battery voltage and has reverse polarity voltage applied to the base of the Transistor. All Transistor junctions act like open circuits at this time. The Capacitor discharges around the loop formed by the top Transformer winding and the 10K and 50K.

When less of the 50K resistance is in the circuit, the discharge is faster, so the process is repeated at a faster rate (higher frequency).

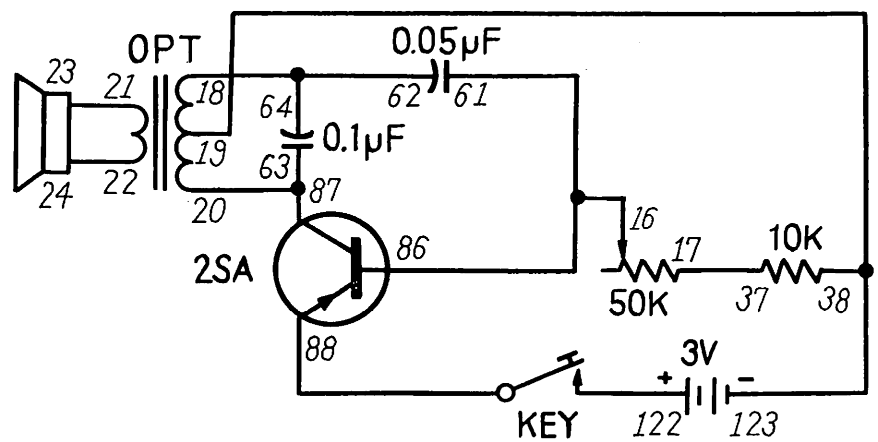
As soon as the 0.05uF Capacitor discharges to slightly below the 3V of the Battery, the above cycle of events is repeated.

The best way of obtaining the above circuit action is with the use of an oscilloscope. Eventually you will want to add an oscilloscope to your test equipment, because no other instrument can show you as much about circuits as it can.



WIRING SEQUENCE:

21-23, 22-24, 18-62-64, 61-86-16, 63-87-20, 17-37, 38-19-123, 88-Key, Key-122



153. I. C. OSCILLATOR/COMPONENT TESTER

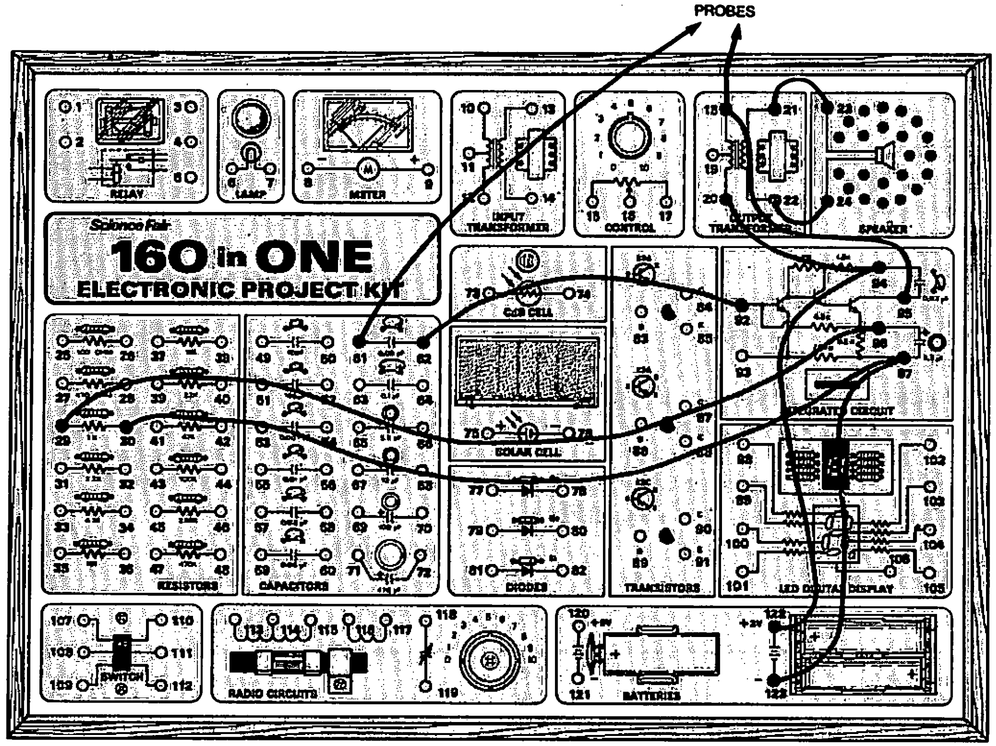
This project uses the IC (integrated circuit) as an oscillator, and allows you to test for resistance and capacitance. Equal values of resistance or capacitance will produce the same pitch from the Speaker.

Hook up the circuit and try placing the Probes across all unused components. Do you see any correlation between resistance and frequency? Between capacitance and frequency? Try testing the CdS Cell while changing the light level on the Cell. There are many possibilities with this circuit.

By connecting the Probes between a metal chair and table, you may play tunes as you move your hands over the table or move your body back and forth. This would make a fun party game!

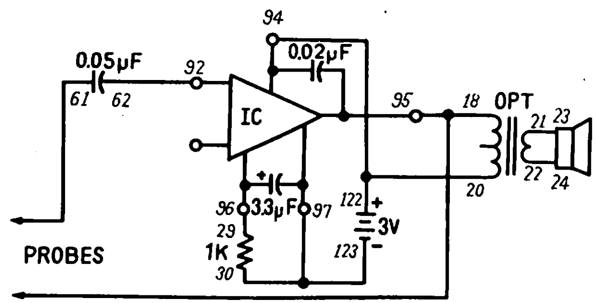
The basic IC hookup used is described elsewhere (projects 40 and 102), so we won't repeat it here.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 95-18-Probe, Probe-61, 62-92, 96-29, 30-97-123, 20-94-122



154. LIGHT HUM AND NOISE DETECTOR

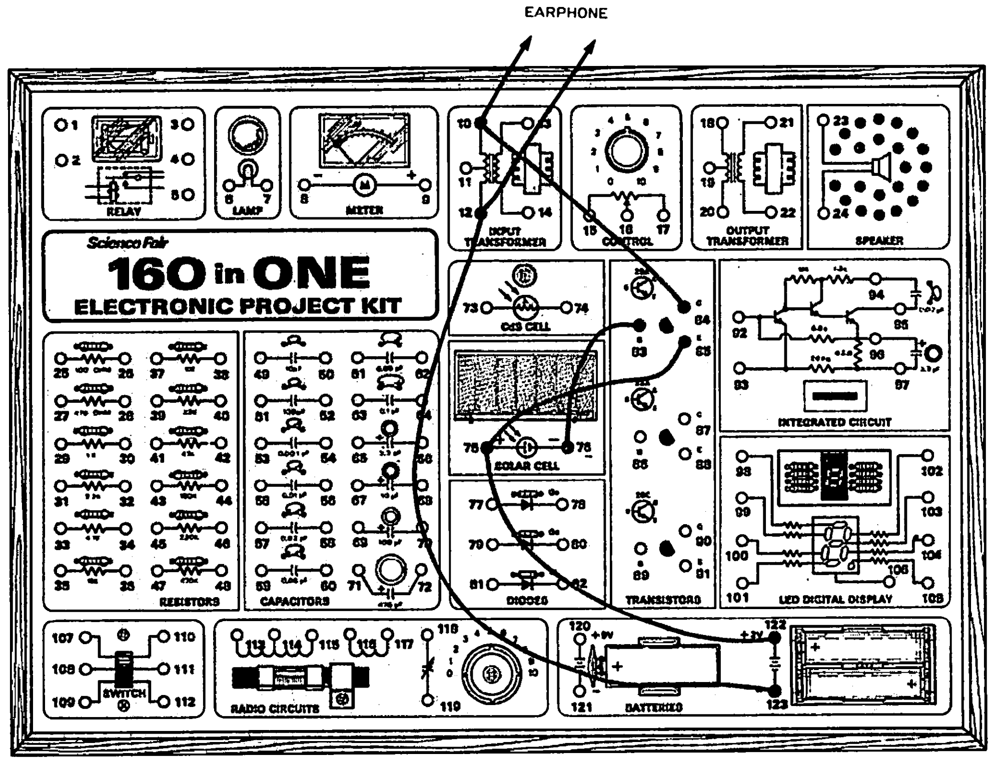
Did you know that the light you are using might not be a constant light. Fluorescent lights actually go ON an OFF 120 times per second. Even incandescent lights have some variation in light level at this same rate. Do you know what causes this, or why we don't see it with our eyes?

We all have something called "persistence of vision". That is, what we see tends to stay with us for a fraction of a second. Therefore, if a light is turned completely OFF for a fraction of a second, we can't see the difference. To us, the light would appear to be dimmer, but not to be going ON and OFF.

Persistance of vision allows us to use alternating current (AC) directly on our fluorescent and incandescent lights without trouble. There are some places where this cannot be tolerated. One such place is in the exciter lamp of a movie projector. This lamp must be powered by either DC or an AC current with a frequency above the audio range (ultrasonic). An ultrasonic AC current is usually used in movie projectors.

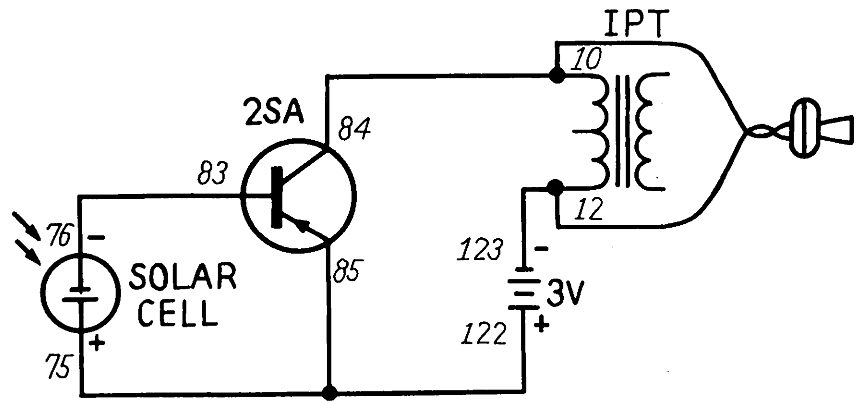
You may want to compare this circuit with project 2 by replacing the Speaker (used as a dynamic microphone) with the Solar Cell. To do this, disconnect at least one Speaker lead, and connect the Solar Cell to terminals 18 and 20. Can you hear the noise from the sun?

NOTES



WIRING SEQUENCE:

84-10-Earphone, Earphone-12-123, 83-76, 85-75-122



155. AUDIO SIGNAL TRACER

This project is a simple one Transistor audio amplifier which is used as an audio signal tracer. With this amplifier you can troubleshoot transistor audio equipment. You do this by connecting the Probes across the circuit from stage to stage until you find the stage or component which is not passing the signal along.

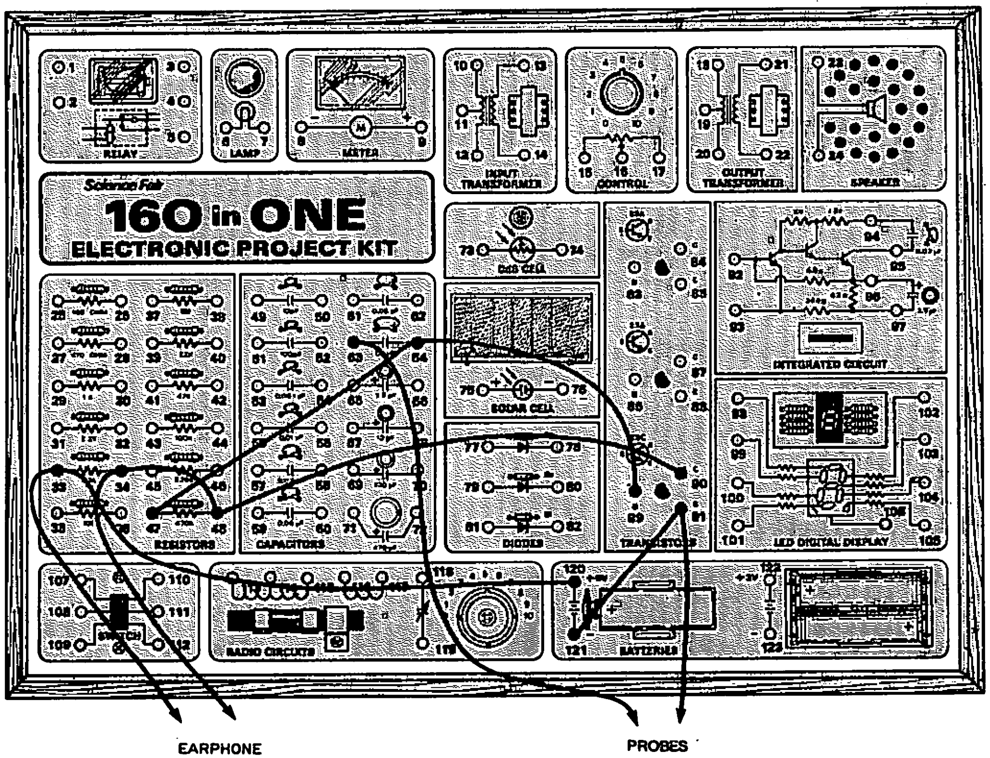
No volume control is used with this amplifier because you can use the volume control on the equipment being checked to adjust signal levels when necessary.

The 0.1uF input Capacitor blocks DC so you can probe around circuits without worrying about the effects of DC voltage on the circuit.

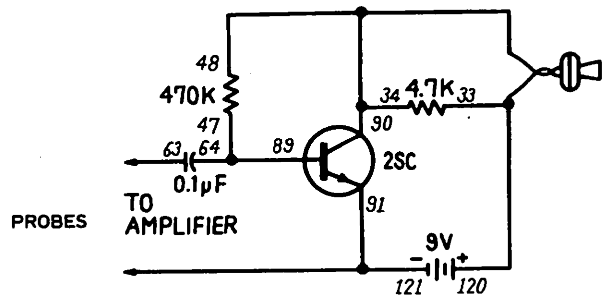
The amplifier circuit is the common-emitter type. The bias current is the self current type. That is, the base current (through the 470K) is obtained from the collector voltage, providing some stabilizing negative DC feedback. This is a very simple and popular circuit for silicon Transistors such as the 2SC in your kit.

Use this amplifier to probe around on any Transistor radio or amplifier you have, that needs fixing. You may also use this circuit to test some of the other projects in this kit. The only requirement is that they do not have any common components. Have fun!

NOTES



WIRING SEQUENCE:
90-48-34-Earphone, Earphone-33-120, 89-64-47, 121-91-Probe, 63-Probe



156. RADIO FREQUENCY SIGNAL TRACER

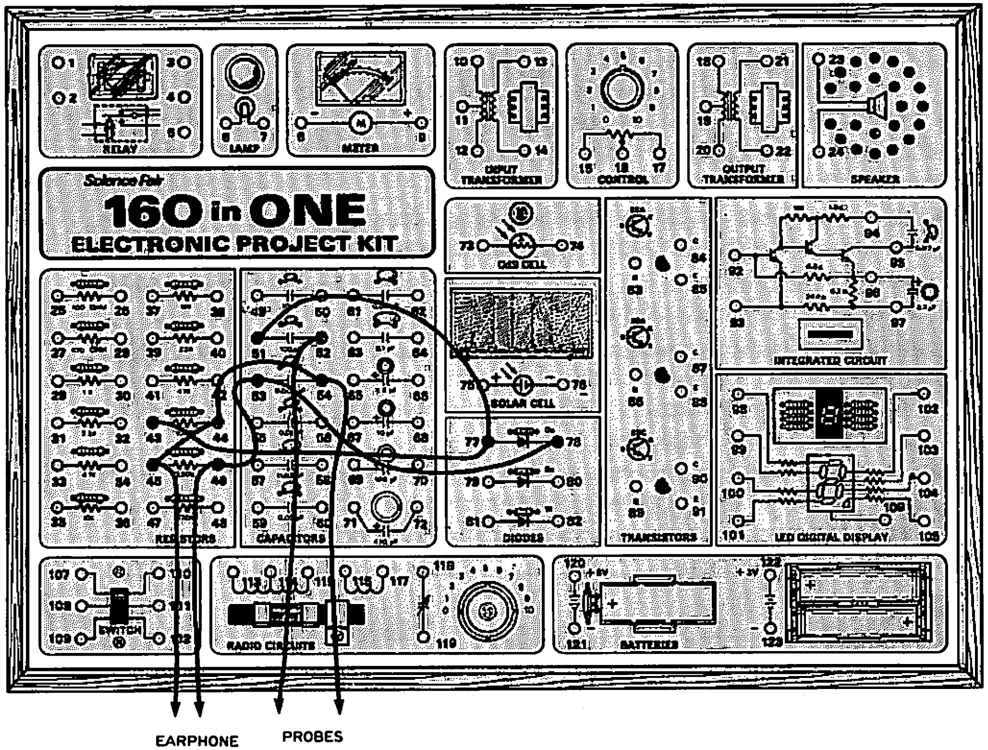
This project is a wide band, untuned, RF signal tracer. You can use it to find sources of RF noise and interference, and to check for antenna signals. This circuit is like an untuned crystal set.

The 100pF Capacitor is chosen for the input because it blocks DC and the 60 hertz power line frequency so that the Probes can be touched almost anywhere without fear of electrical shock. Of course, if you probe around high voltage on purpose, you are asking for trouble. There is an old saying, "There are OLD technicians and BOLD technicians, but there are no OLD BOLD technicians.'

Try connecting the Probes between grounded objects and other metallic objects which 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 or your neighbors have CB (citizen's band) transmitters, you will be able to hear these signals as long as the transmitter is close enough to the RF Signal Tracer.

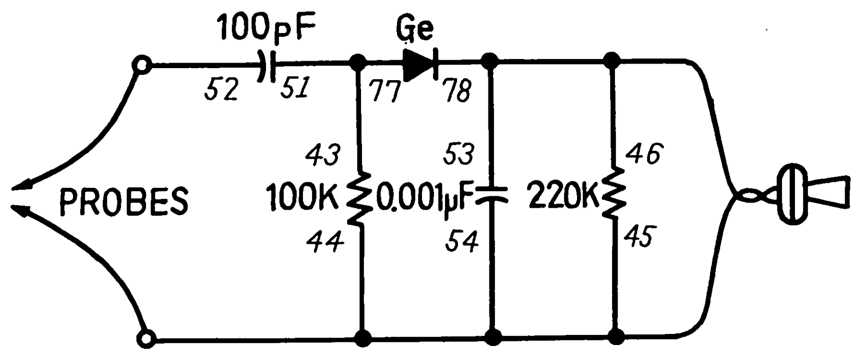
Some of the kinds of noise you may hear and identify originate from auto ignition systems, light dimmers, fluorescent lights, switches opening and closing, etc.

NOTES



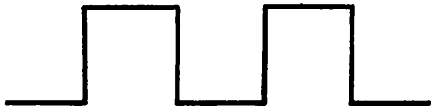
WIRING SEQUENCE:

52-Probe, 51-77-43, 78-53-46-Earphone, Earphone-45-44-54-Probe



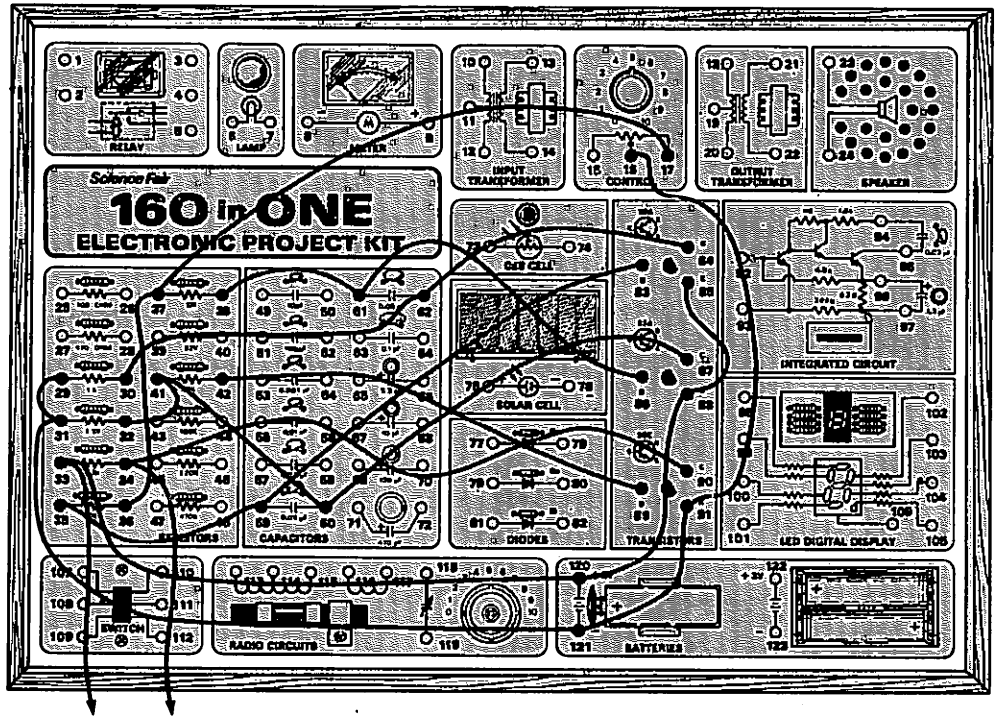
157. SQUARE WAVE AUDIO OSCILLATOR

Square waves are used as test signals, too. They are produced by a special kind of oscillator called a multivibrator. Remember, you used this type of circuit in project 64. The name square wave comes from the pattern the signal produces on an oscilloscope (shown below).



You can vary the pitch (frequency) of the square wave by adjusting the Control, which varies the current supplied to the base circuits of the 2SA Transitors. The high/low (ON OFF) times for this oscillator are equal at all frequències, because the Resistors and Capacitors controlling the Transistors' base currents are equal (10K and 0.05uf).

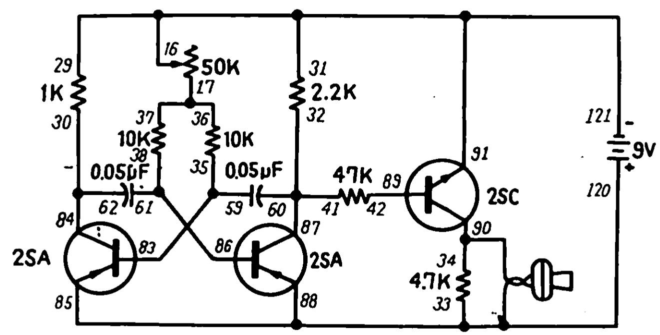
NOTES



EARPHONE

WIRING SEQUENCE:

16-91-121-31-29, 17-37-36, 30-62-84, 32-41-60-87, 35-59-83, 38-61-86, 42-89, 90-34-Earphone, 85-88-120-33-Earphone



158. RF SIGNAL METER

The purpose of this project is to measure the intensity of RF signals. The circuit is very much like a radio circuit you have already built (project 121), except that the output is connected to the Meter instead of the Speaker or Earphone.

Operation is as follows:

1) Complete all wiring except for the Antenna and Ground connection.
2) Adjust the Control so that the Meter is just beginning to move. Make this adjustment carefully; too much current could damage the Meter.
3) Connect the Antenna and Ground and adjust the Tuning Capacitor until you get a reading on the Meter.

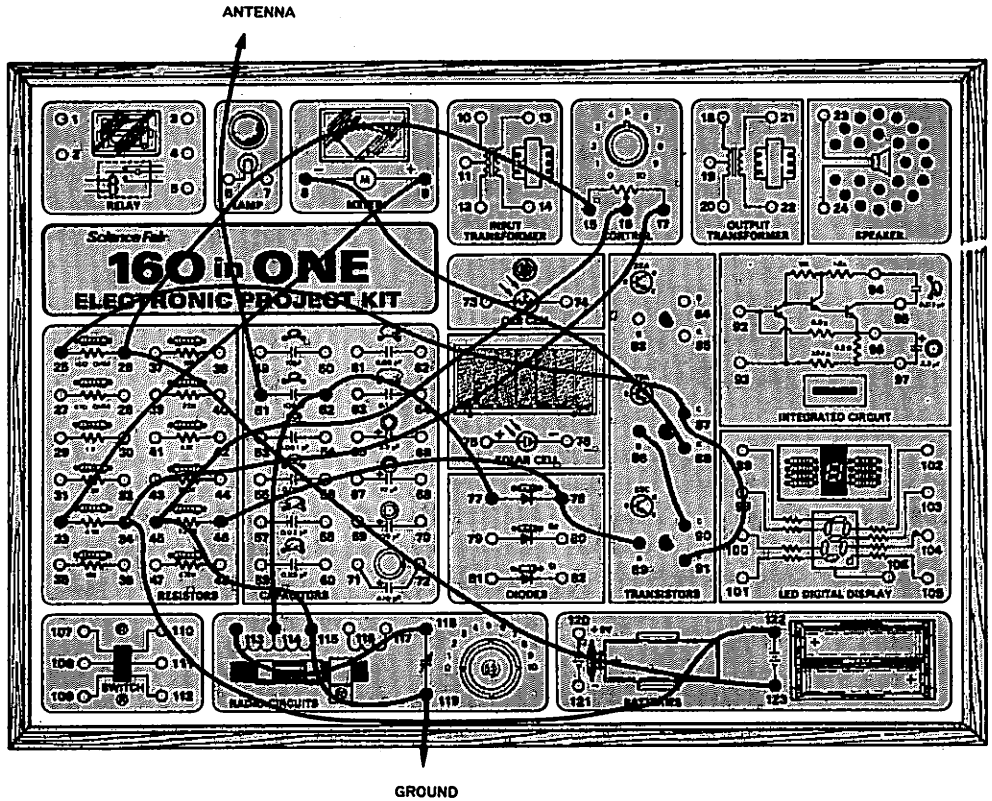
Note: It may take a strong radio station to cause more the a slight change in the Meter reading.

This circuit works by amplifying the modulated DC signal which is created when the RF signal is 'detected' by the Diode. This signal causes changes in the base current supplied to the 2SC Transistor (which we have set to a 'threshold' level by adjusting the Control in step 2). The 2SC Transistor (C-E circuit) supplies base current to the 2SA Transistor, and its C-E circuit controls the Meter.

By connecting the Earphone to terminals 33 and 34, you can listen to the RF signals you are measuring.

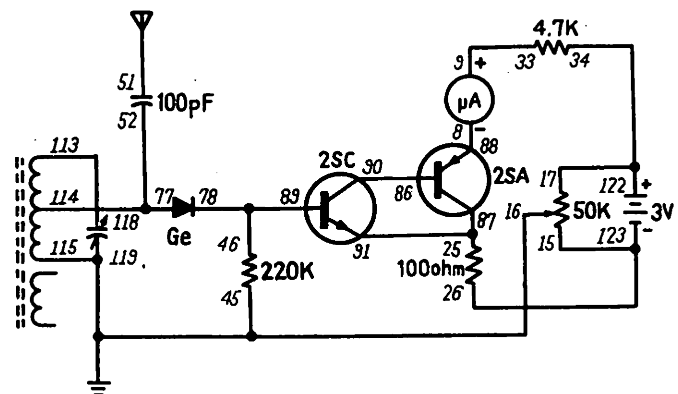
CAUTION: To avoid damage to the Meter, set the Control to 0 before making the wiring connections.

NOTES



WIRING SEQUENCE:

8-88, 9-33, 15-26-123, 16-45-115-119-Ground, 25-87-91, 46-78-89, 77-52-114, 86-90, 113-118, Antenna-51, 17-34-122



159. SAWTOOTH WAVE OSCILLATOR

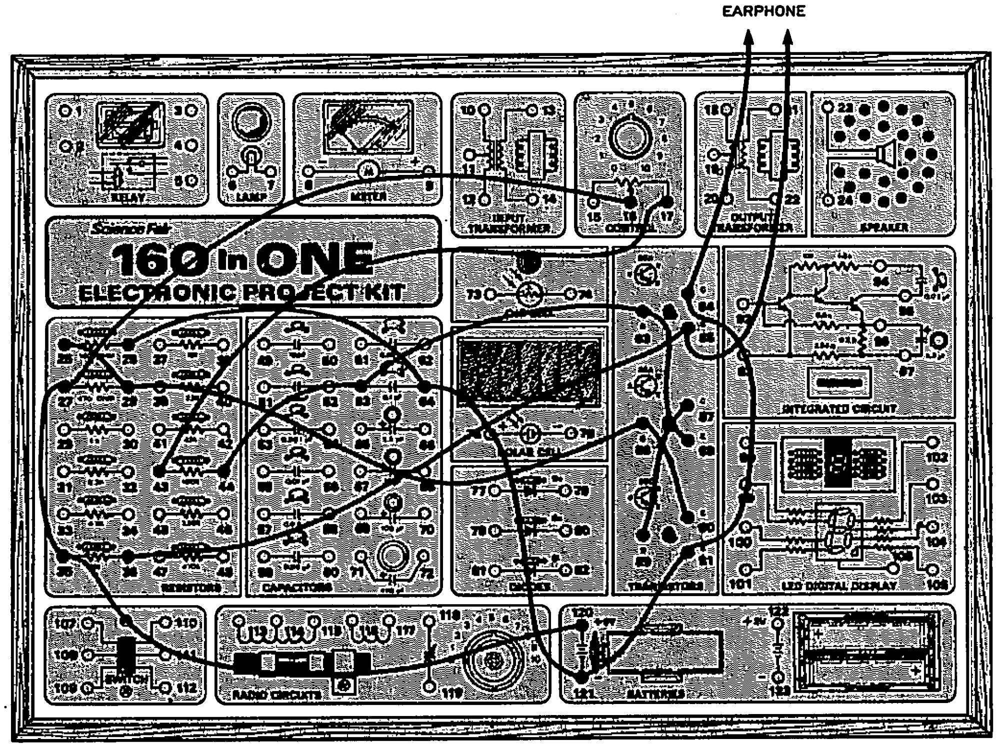
When the type of signal generated by this oscillator is connected to an oscilloscope, it makes a pattern that looks like the teeth of a saw (as shown below).

The shape of the wave you see above is caused by the slow charging of the 0.1uF Capacitor through the Control and 100K Resistor and its quick discharge through the 2SA(1) and 2SC Transistors. Circuit operation is as follows:

The voltage divider (470 ohm and 100 ohm Resistors) provides a voltage of about 1.6 volts to the 2SA(1) and 2SC Transistors. The current flowing into the 0.1uF Capacitor from the 9V battery (through the Control and 100K 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 2SA(1) and 2SC turn ON and provide a path for the 0.1uF to discharge quickly. Now the 2SA(1) and 2SC turn OFF again, and the Capacitor begins to slowly charge for a repeat of the cycle.

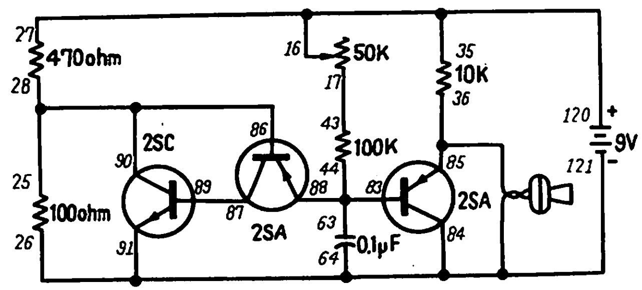
The oscillator frequency can be altered by changing the values of the components in the 'timer circuit' (Control, 100K Resistor and 0.1uF Capacitor). Try a 47K or 220K in place of the 100K, and try several different Capacitors. If you connect one of the electrolytic Capacitors, make sure to use the proper polarity (+ and −).

NOTES



WIRING SEQUENCE:

17-43, 25-28-86-90, 26-64-121-91-84-Earphone, 36-85-Earphone, 44-63-83-88, 87-89, 16-27-35-120



160. TRANSISTOR BETA CHECKER

One of the most important specifications of a transistor is the current amplification or Beta factor (hFE). This value is the ratio of the collector current to the base current. The higher the Beta factor, the more amplification the transistor can provide.

After completing the Wiring Sequence, including connections to one of the 2SA Transistors (or any other PNP transistor), you can determine the Beta factor as follows:

1) Set the slide Switch to the OFF (down) positon.
2) Adjust the Control for a reading of 5 on the blue scale of the Meter. With this setting the Meter is measuring a base current of approximately 0.125mA.
3) Set the Switch to the ON (up) position and read the meter. Do not change the Control setting!

When the Switch is moved the Meter changes from measuring the base current to measuring the collector current. The 100, 2.2K and 22K Resistors set the Meter sensitivity to about 62.5mA for a full scale reading of the collector current.

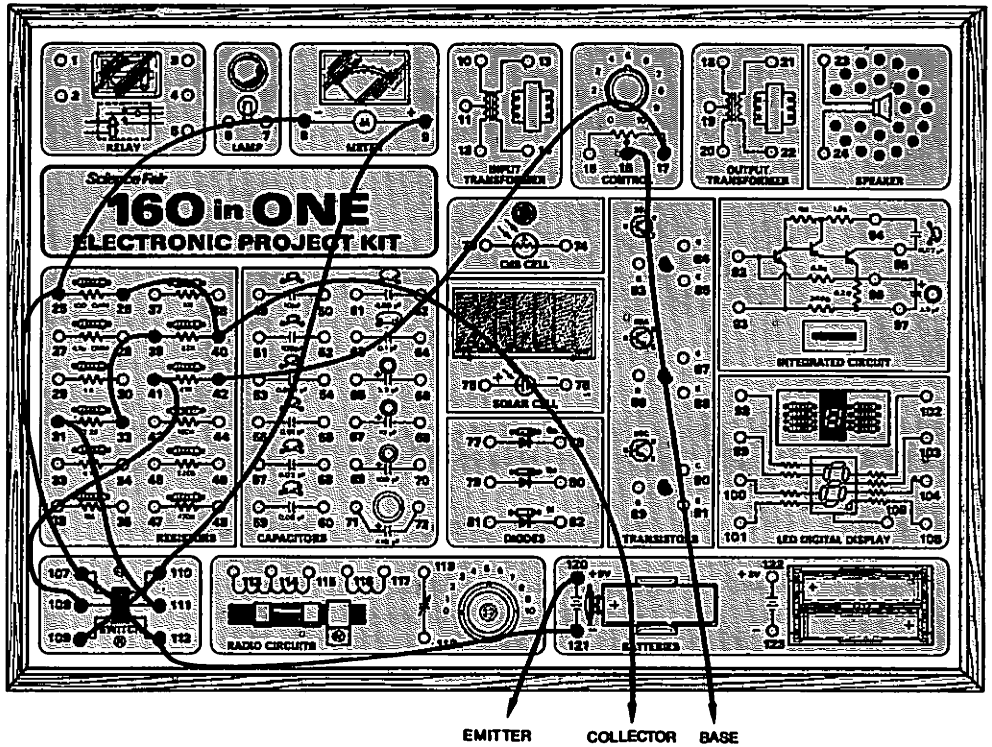
Therefore, if the Meter indicates full scale, the Beta factor of the Transistor can be calculated as follows:

62.5(collector)/0.125(base) = 500(Beta)

From this you can see that each segment on the blue scale is equal to a Beta factor of 50.

Try measuring the Beta factor of both 2SA Transistors in your kit. Then reverse the connections to the Battery and Meter if you want to measure the 2SC Transistor.

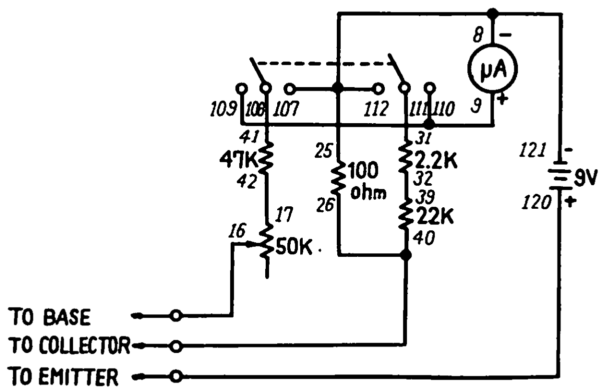
NOTES



WIRING SEQUENCE:

PNP Hookup: 8-25-107-112-121, 9-110-109, 16-Base, 17-42, 26-40-Collector, 31-111, 32-39, 41-108, 120-Emitter

NPN Hookup: Reverse Battery and Meter connections.



INDEX

We've added this listing to aid you in finding experiments and circuits which you might be especially interested in. Many of the Experiments are listed 2 or 3 or 4 times — since they can be used in many ways. You'll find some listed as "Entertainment" type circuits, even though 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.

Want to learn more about a specific type of circuit? Just 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.

PARTS LIST

Note: Most of these parts are already mounted on the Platform inside the Box. This Parts List will serve to remind you what parts make up your Lab Kit.

Description	Part No.
Antenna Coil (with 5 leads)	CA–0619
Base Assembly for Key	HC–1709
Battery Clip for 9–volt Battery	B–0172
Battery Connector for 9–volt Battery	B–0209
Battery Holder for 2 AA Penlight Cells	B–0166
Capacitors	
10 pF, ceramic disc type	
100 pF, ceramic disc type	
0.001 μF, ceramic disc type	
0.01 μF, ceramic disc type	
0.02 μF, ceramic disc type (2)	
0.05 μF, ceramic disc type (2)	
0.1 μF, ceramic disc type	
3.3 μF, 25–volt electrolytic type (2)	
10 μF, 16–volt electrolytic type	
100 μF, 10–volt electrolytic type	
470 μF, 10–volt electrolytic type	
Cadmium Sulfide Cell, KC–4S	CS–0100
Diodes, germanium, 1N60 (2)	
Diode, silicon, 1N4001, 50 volt, 800mA	
Earphone, high Z crystal type (no DC path)	E–0007
Holder for Antenna	H–1535
Integrated Circuit, BA–306 (Vcc max = 12V)	
Key Lever	HC–1710
Knob for Key Lever	K–5074
Knob for Variable Capacitor (Tuning)	K–0669
Knob for Variable Resistor (Control)	K–5073
Lamp, red, 2.5 volt, 300 mA	L–0541
Light Emitting Diode Display (1.6V min. per segment, 25mA max. DC current per segment. 3V max. reverse voltage)	
Meter, 0–250 μA, 650 ohm movement (Blue scale is proportional to meter current, Black is logging/reference)	M–0294
Nuts, 3 mm (5)	HD–7003
Printed Circuit Board for LED Display	X–7159
Relay 9V, 225 ohm Coil	R–8158
Resistors	
100 ohm	
360 ohm (8)	
470 ohm	
1 k	
2.2 k	
4.7 k	
10 k (2)	
22 k	
47 k	
100 k	
220 k	
470 k	
Screws, 3 x 8 mm (7)	
Screws, 2.6 x 4 mm (3)	HD–2042
Shield for CdS Cell	CS–0028
Soket for Lamp, with leads	HB–0535
Solar Cell, open voltage 2.5V typical, short circuit current 29 μA typical at 300 lux	CS–0099
Speaker, 57mm	S–4565
Spring Terminals (125)	HB–4804
Switch DPDT	S–2241
Transformer, Input (yellow)	TD–0097
Transformer, Output (red)	TD–0136
Transistors	
2SA733, PNP, silicon (2)	
2SC945, NPN, silicon, general purpose amplifier and switching type	
Variable Capacitor (Tuning) 265pF	C–4242
Variable Resistor (Control), 50k ohms	P–1656
Wires	
White, 7.5 cm (11)	
Red, 15 cm (14)	
Blue, 25 cm (8)	
Yellow, 35 cm (7)	
Black, 38 cm (2)	
Green, 3 m (2)	W–1587

Certification of Compliance with Federal Communications Commission Regulations, Part 15:

Radio Shack certifies that the low power communications circuit experiments incorporated in this Lab Kit will comply with the requirements of Paragraph 15.204 of FCC Rules and Regulations — under the following conditions:

1. When assembled in strict accordance with the instructions in this manual, using only those components and materials supplied with the kit.

2. When operated on a frequency between 510 and 1600 kilohertz, using a combined antenna and lead in length no greater than 10 feet.

3. When powered by the batteries as instructed.

Radio Shack
Engineering Group

I hereby certify that I have constructed and adjusted this device in complete accordance with the instruction manual.

______________________________ __________
(signature of builder) (date)

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