Science Fair®

Catalog Number : 28-248

150 in 1 ELECTRONIC PROJECT KIT

CUSTOM MANUFACTURED FOR

RADIO SHACK TC A DIVISION OF TANDY CORPORATION

LIST OF EXPERIMENTS

I. ENTERTAINMENT CIRCUITS

Light Circuits and Games

1. Electronic Candle
2. "The Big Ear"
3. Electronic Reflex Tester
4. Machine Gun Pulse Oscillator
5. Rapid LED Display Switching, Persistence of Vision Test
6. Light Oriented Direction Finder

Special Sound Effects

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This **SCIENCE FAIR 150-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 list 150 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 23-583 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 hookup wires between the terminals listed in the wiring chart. Plenty of pre-cut, insulated hookup 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).

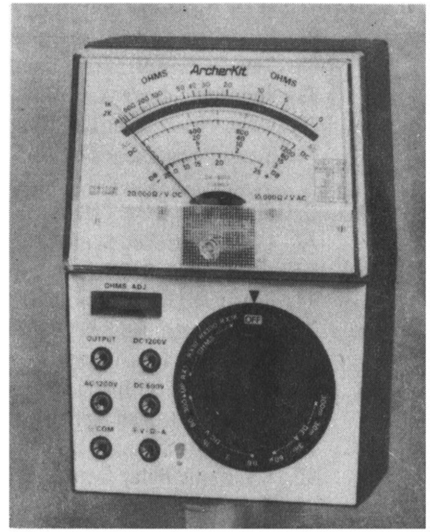
The 150 different projects in your Electronic Project Kit are divided into different categories. Take a look at the List of Experiments and you'll see what you can make. You can build game circuits, special sound effect experiments, IC circuits, LED display circuits, radios, sun powered radios, protection 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 (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 – and 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 scarcely, 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 one as long as you stay interested in electricity and electronics.

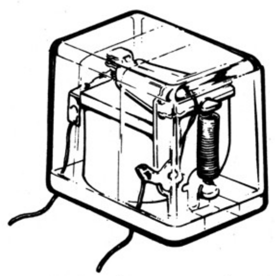
If you don't know how to use a VOM, we recommend that you obtain a copy of Radio Shack's book *BASIC DC CIRCUITS.*

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

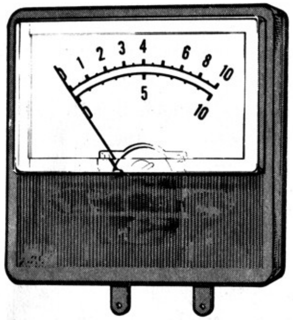
Your Kit has 48 separate components. The purpose of each component is explained below. The explanations will help you understand what each component does, and you will understand more about each component after building some of the projects.

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.

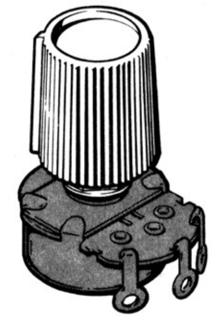
LAMP – Your lab kit has a 3-volt incandescent Lamp similar to those used in flashlights. The Lamp is used to send code signals or as an indicator or signal Lamp. **Be sure to connect the Lamp only to the 3-volt Battery. The 9-volt Battery will burn out the Lamp.**



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.

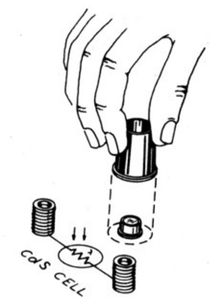
RESISTORS – There are twelve Resistors in your lab kit. Each Resistor is made from carbon particles mixed with a binder material. Resistors resist the flow of electricity. They are very useful in supplying any desired voltage to transistors. The resistance of a Resistor is given in **ohms**. A resistance 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.



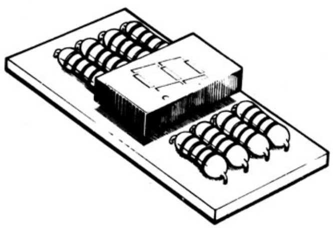
SOLAR CELL – The Solar Cell is the dark colored rectangular object just below the CdS Cell. In bright sunlight, the cell produces 0.6 volts. It is most sensitive to blue to red regions of the light spectrum. Properly cared for, the Solar Cell will produce electricity from sunlight virtually forever.

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. The Transistors are used to amplify weak signals. They are also used as switches and oscillators.

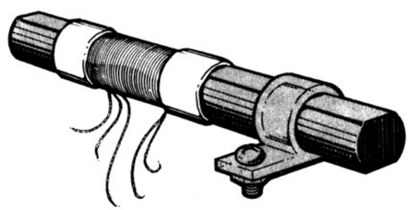
INTEGRATED CIRCUIT – As you probably already know, after the Transistor was invented in the middle '40s, the next big breakthrough was with the Integrated Circuit in the early '60s. The great advantage of IC's (as we call them) is that the equivalent of 100's or even 1000's of transistors, diodes and 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.

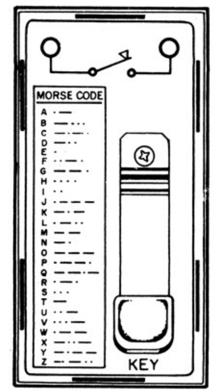
THE BATTERY HOLDERS are designed to hold two (2) type AA batteries and one 9-volt battery. **Batteries**, of course, supply the power for all the various experiments that you will be doing with your project kit. When connecting wires to the Batteries, be sure you connect only to the terminals noted. 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 23-582 or 23-552 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.

External Contacts – These terminals will be used for some experiments where you'll want to make connections to external contacts or circuits. There is no connection underneath the panel, so just use these spring terminals when you need some extra connection points.

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.



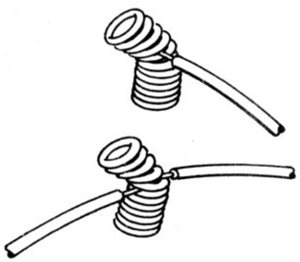
EARPHONE – An efficient, lightweight crystal Earphone is supplied with your lab kit. This Earphone is the high-impedance type. This means it can be connected to a circuit without causing very much of an electrical load. In most cases, the circuit doesn't even know the Earphone is there.

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 hookup wires supplied with your lab kit make it a snap to wire together the various projects. To connect a hookup 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" (0.95 cm) 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 of the platform showing how the wires should be connected for that experiment. We've also given you the Schematic Diagram.

MAKING 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, 6-2, 4-33-121, 122-3, 5-87, 34-73, 74-17, 16-86, 15-88-120

You should connect a wire between 123 and 7.
Another between 6 and 2.
Another between 4 and 33, then another from 33 to 121.
Another between 122 and 3.

And so you continue till 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

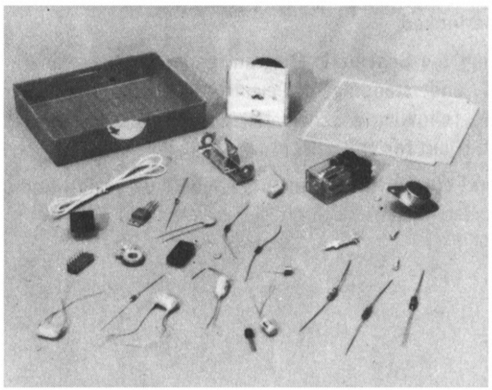
After you have built all the projects in your Lab Kit, you might want to experiment with some of the projects. The easiest experiments involve the broadcast band radios and the special sound effects oscillator projects. Try using different capacitors in place of the capacitor used in each of these projects.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

SOME FINAL THOUGHTS - For Teachers, Students and Hobbiests

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 – are 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

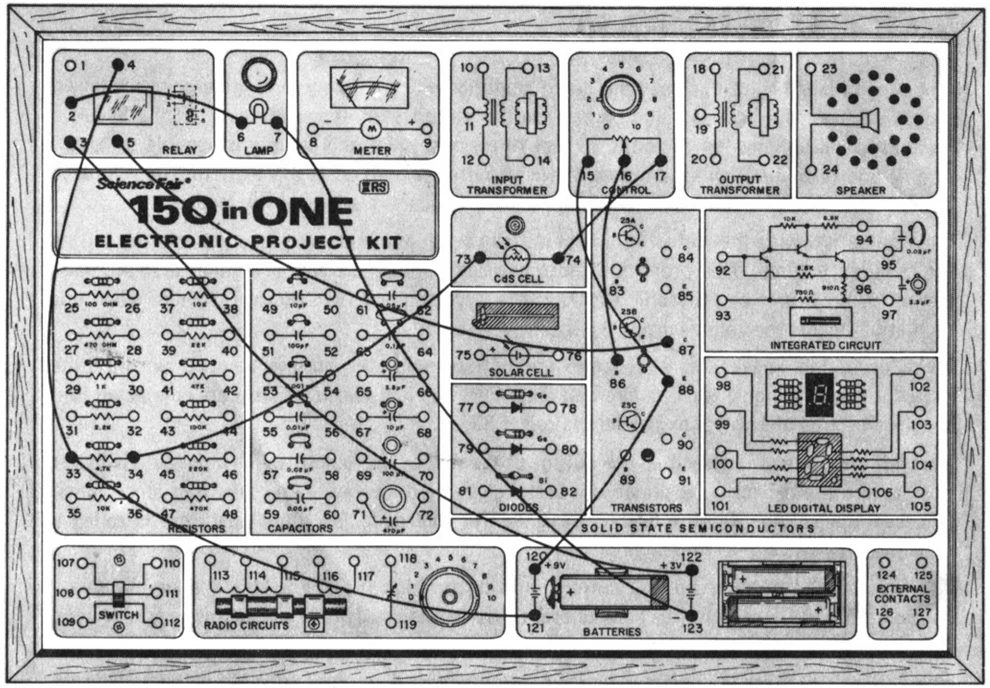
We'll start with an easy and fun project. Amaze your friends with this bit of electronic magic. You can "blow out the Lamp." The "candle" (Lamp) will come on when you let light shine on the CdS Cell; when the light is removed from the CdS Cell, the "candle" (Lamp) goes out. It is most effective when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

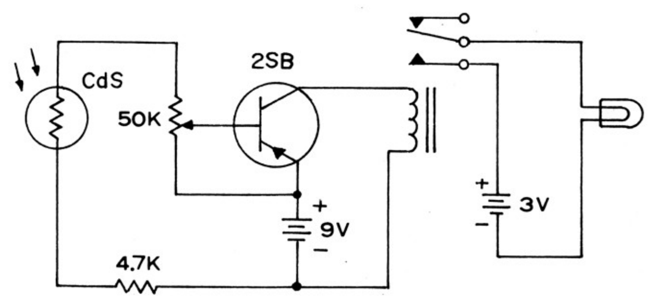
Now go to it, but remember, its our secret.



NOTES

WIRING SEQUENCE:

123-7, 6-2, 4-33-121, 122-3, 5-87, 34-73, 74-17, 16-86, 15-88-120



2. "THE BIG EAR"

This project is a high-gain, three-stage audio-amplifier which 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" as explained in Project 63.

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 which preceeds the volume Control and is designed for high-gain, low-noise operation is called a "pre-amplifier."

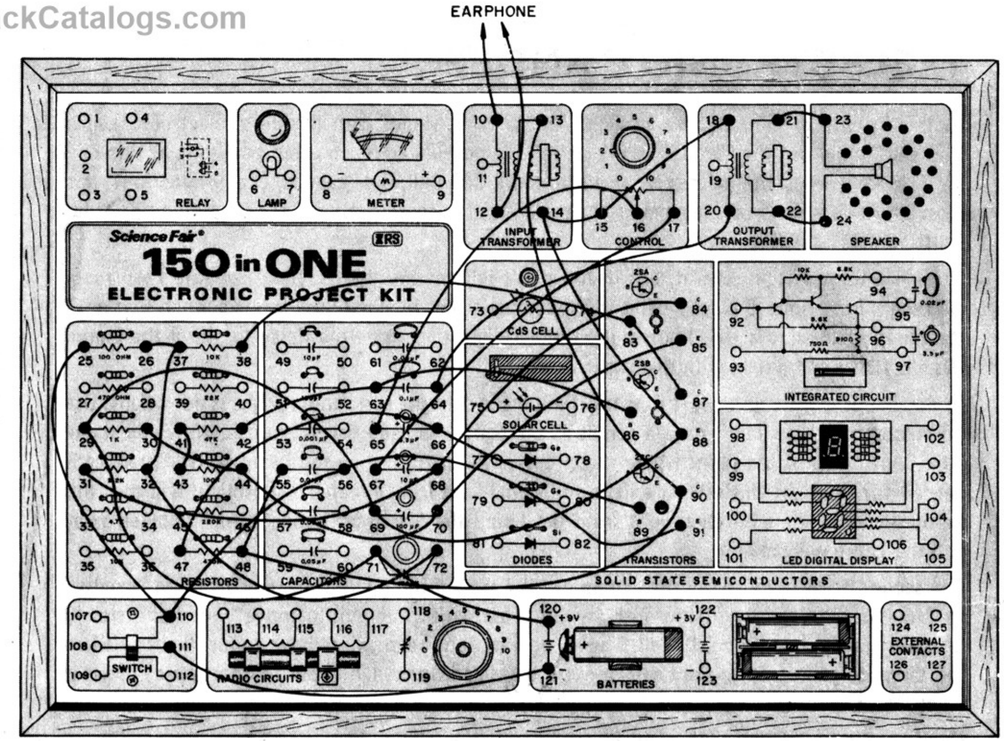
The volume Control has no DC current flowing through it. This is also a desirable design consideration as DC current in a control eventually causes the control to become very noisy and erratic.

The 2SC output stage is a common-emitter amplifier with fixed base current bias and a 0.01 µF 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 470 µF capacitor form what is called a decoupling filter. This is required in multiple-stage amplifiers such as this to keep oscillations from occurring 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 to measure and record voltages.

NOTES



WIRING SEQUENCE:

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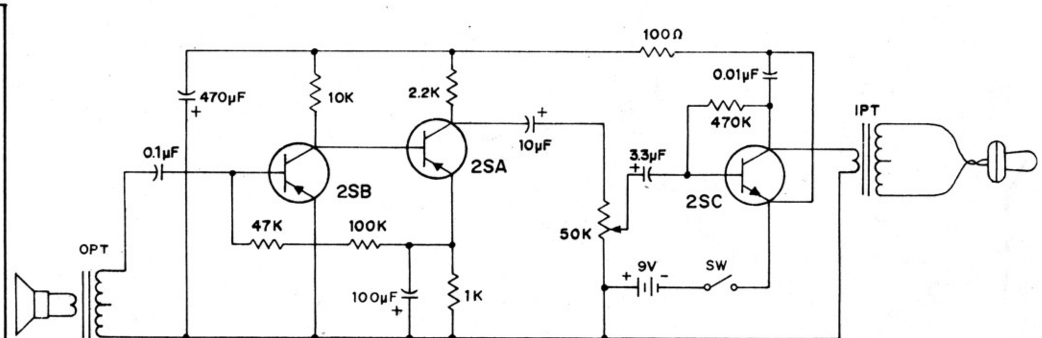


3. ELECTRONIC REFLEX TESTER

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 81.

The game takes two people and is played as follows:

1. Have one person place his finger on the slide Switch and prepare to push it down (OFF) at the signal.
2. Have a second person place his 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 2SB 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. 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.

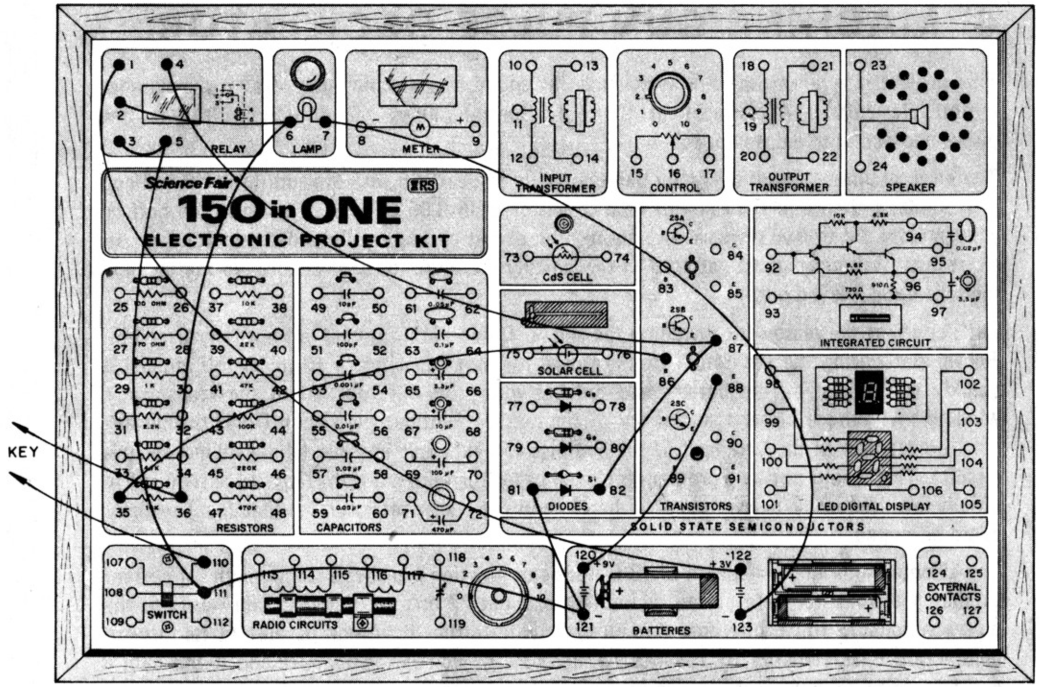
Additional keys may be placed in parallel with the Key supplied, and additional normally-closed switches added in series with the switch in order to have teams. This type of circuitry has been used with quiz teams where the side to "jump" first gets to try to answer a question.

The circuit used is the electronic version of the 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.

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

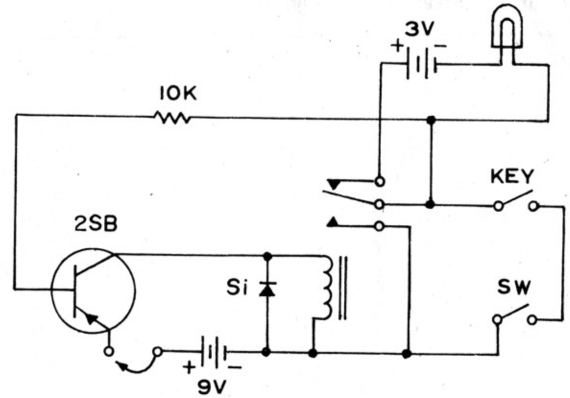
The silicon (Si) Diode across the relay keeps the turn-OFF surge of energy from the Relay from damaging the Transistor (by circulating the current from this surge back into the Relay). It is not required in this circuit but is included as a reminder that all high-reliability circuits must include some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

NOTES



WIRING SEQUENCE:

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



4. MACHINE GUN PULSE OSCILLATOR

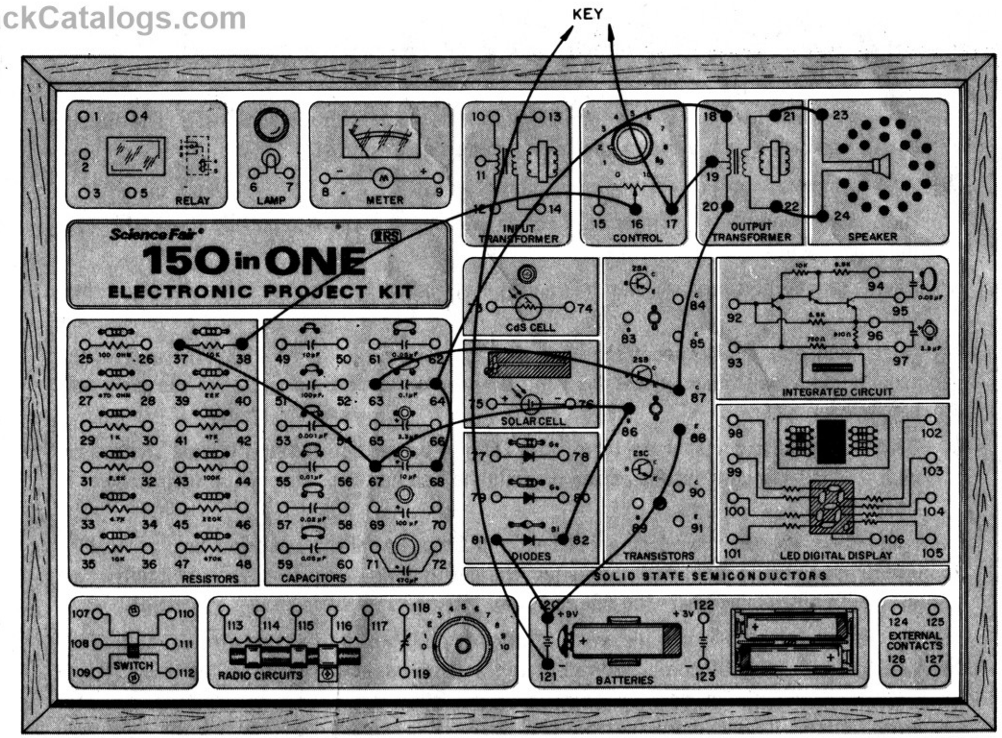
This project is a pulse oscillator which has the sound of a machine gun or of a one-cylinder motorcycle engine. Adjustment of the 50K Control allows you to obtain from a few pulses-per-second to a dozen or so.

The basic oscillator circuit is exactly like the one of Project 145 with the addition of the silicon (Si) Diode, a change in the value of base capacitor from 0.05 μF and a change in the battery voltage from 3V to 9V. We have also turned the circuit around on the schematic drawing. An electronics technician must get used to recognizing the basic types of circuits no matter how the schematic is layed out.

Let's consider the reason for including the silicon Diode in this project but not in Project 145. Recall that during the generation of the pulse, the base capacitor (a 10 μF in this circuit) is **quickly** charged up by the Battery and induces voltage on the top half of the Transformer winding to a voltage higher than the 9V of the battery. Without the silicon Diode the current which must flow in the base lead of the Transistor is excessive in value (about 80 mA for this circuit). This would not be a problem for small capacitor values, but the large value required to obtain low frequency pulses (a 10 μF here) causes so much total current that the Transistor could be ruined.

The silicon Diode in parallel with the B-E transistor junction provides a second path for current so that the transistor base current is limited to about 20 mA maximum (a safe value for the pulses supplied). The Diode does not interfere with normal operation because of its forward conduction characteristics. It requires about 0.3V of voltage across a silicon diode before current **begins** to flow, but once it begins to flow the current may be increased many times without the voltage across the diode increasing much at all. The B-E junction of the Transistor meanwhile begins to conduct at about 0.1V, but increases in voltage somewhat faster than the silicon Diode does. The result is that by the time the maximum current of the Transistor B-E junction is flowing, the silicon Diode has begun to conduct. The excessive current then is conducted by the Diode which is capable of conducting it without damage.

For experimentation try different values of capacitors in place of the 10 μF. Be sure to observe polarity on capacitors that are marked with a + sign.



WIRING SEQUENCE:

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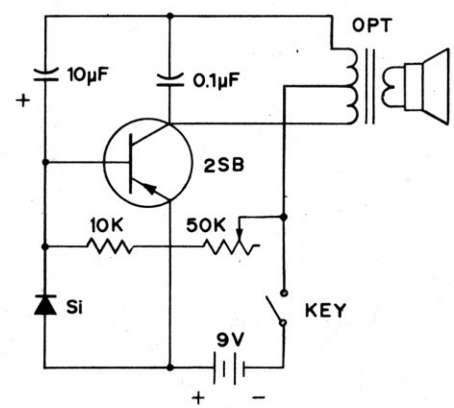


5. RAPID LED DISPLAY SWITCHING, PERSISTENCE OF VISION TEST

This project demonstrates a control circuit which is used to produce short pulses. When the Key is closed the LED display lights only momentarily even though the Key may be closed continuously.

This circuit may be used to make up a game where 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 a lot of other possibilities.

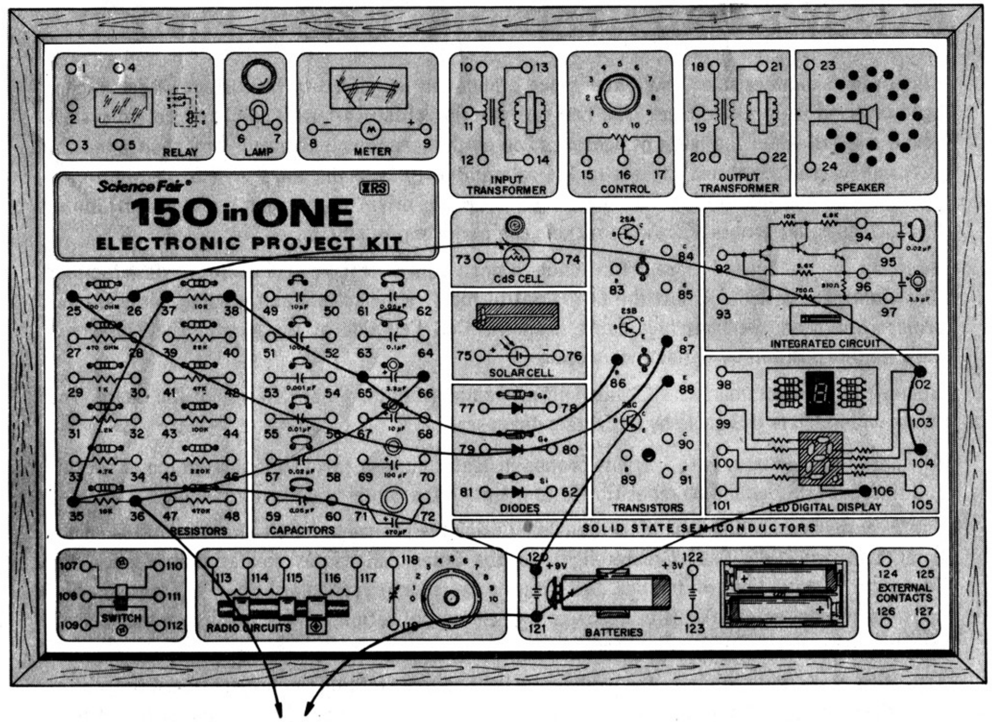
The transistor switching circuit uses capacitor charging current to turn the Transistor "ON". The Transistor then completes the circuit to the LED anode pins.

When the Key is open the capacitor is discharged by the two 10K resistors. Then when the Key is closed the 3.3 μF capacitor is quickly charged up to 9V through the B-E junction of the Transistor. The charging current which flows through the B-E junction turns the Transistor full "ON" only during the time this current flows. The ON transistor looks like a short circuit from C to E to allow LED current to flow simultaneously with the capacitor charging current. After the capacitor is charged up 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 too descriptive of circuit action because of the short time over which circuit parameters (currents and voltages) change. 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 10 μF 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, especially if you play the persistance-of-vision game.

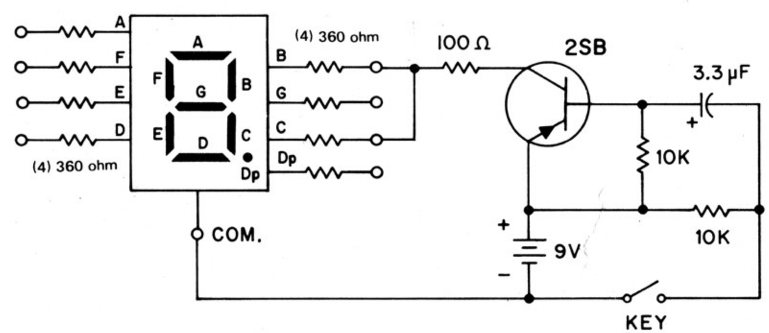
NOTES



KEY

WIRING SEQUENCE:

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



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 which can tell when the angle of light received by the telescope is 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 from 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.

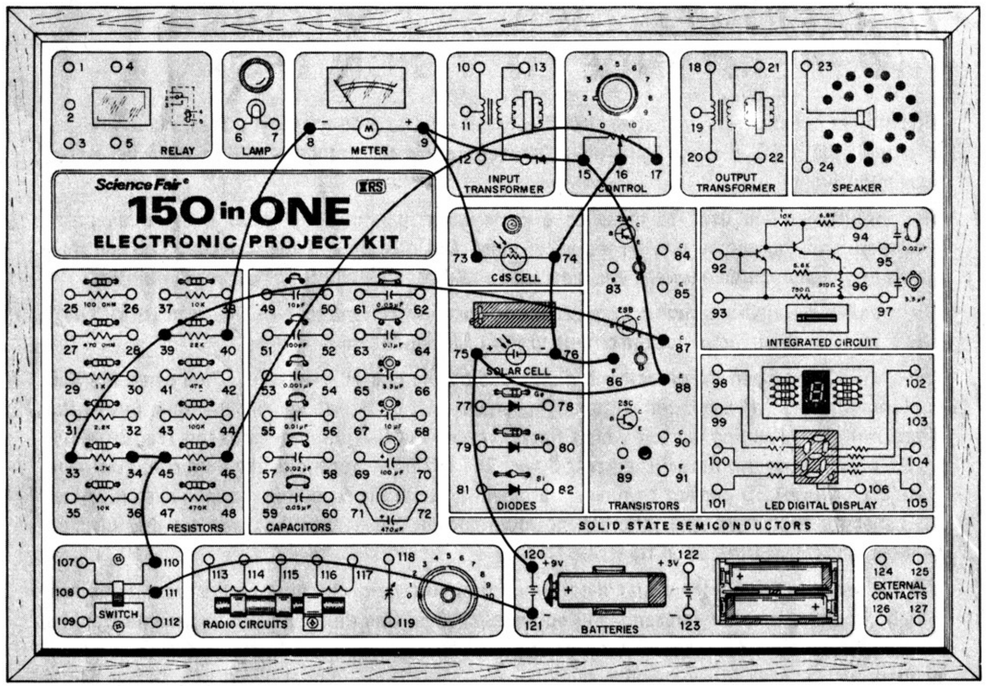
Now tilt the project board so that the light rays come from the Solar Cell side of the board. The Meter will indicate this angle by deflecting **down**-scale.

All that is needed now is to use this change in Meter current to control positioning of 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 till you find the one which 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 by use of sunlight. Look out for shadows though, they can lead you astray!



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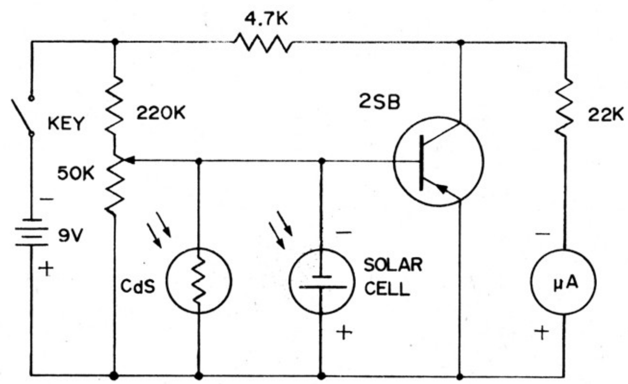
NOTES



7. ELECTRONIC BIRD

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. Simply 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.

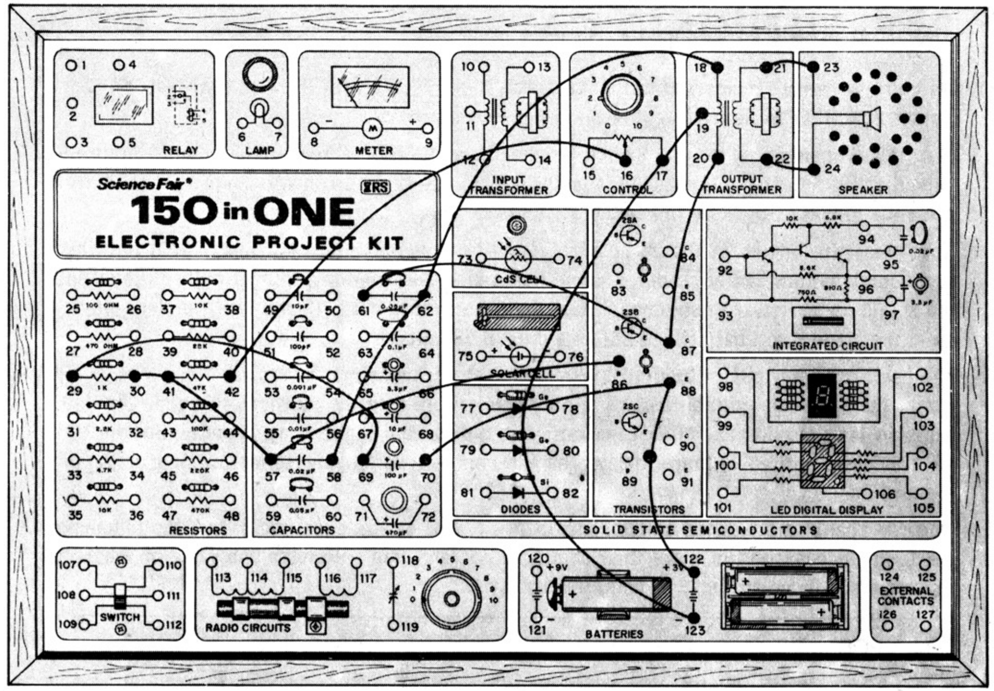
You may also want to try the 9V Battery. The output is louder and resembles even more the scolding chirps of the red-headed woodpecker. The chirps of the 3V supply circuit resemble more the English sparrow.

The oscillator circuit used is only slightly modified from the one described in Project 145. The important difference is the addition of the 1K and 100 μF 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 100 μF capacitor in this circuit accumulates a positive charge from the 0.02 μF 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 100 μF from shunting 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. Of course 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 100 μF will result in some interesting sounds from crickets to bears! Don't forget to record your results like a good scientist does.



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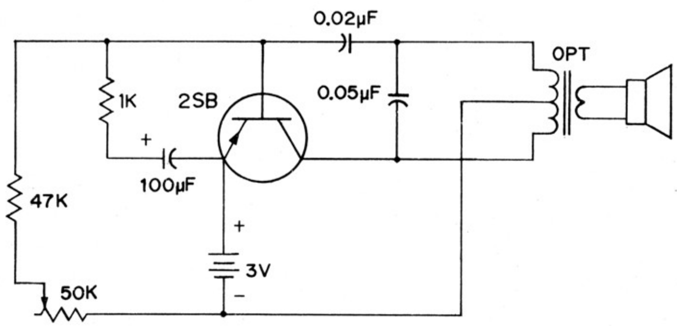


NOTES

8. 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!

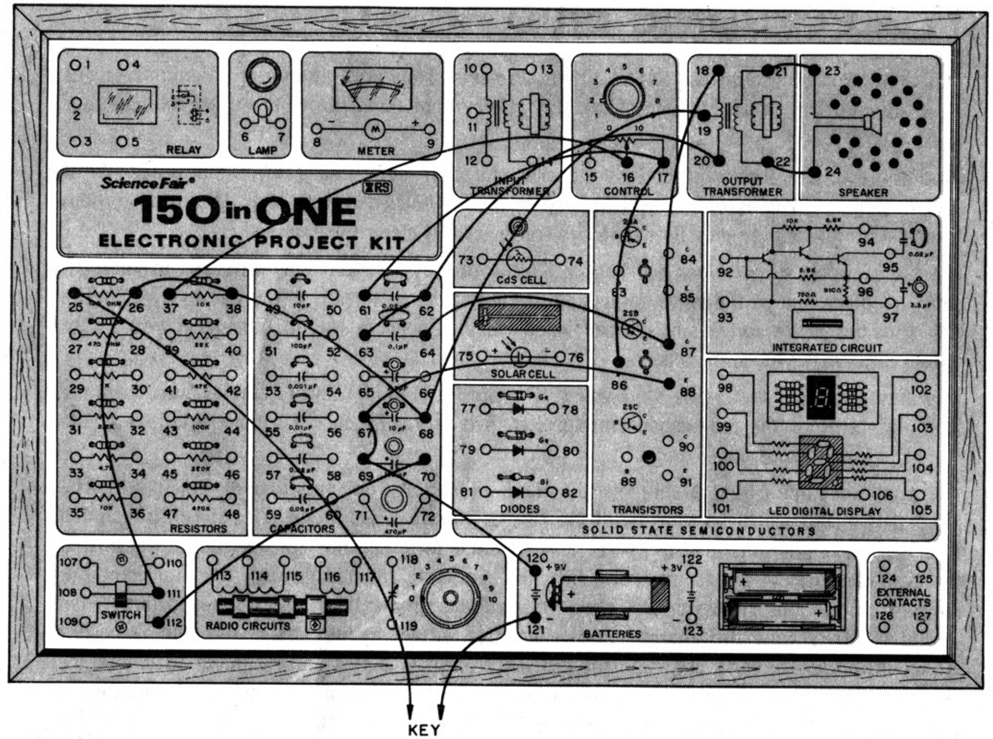
Start experimenting with the Switch in the down position. Press the Key and let it up immediately. Adjust the Control for the desired cat sound. You can try changing the Control while the tone is dying away to make the sound even more realistic.

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. If you want the sound to be lower in volume, change the Battery to 3 volts. If you want louder volume, series the 3 and 9 volt batteries to obtain a total of 12 volts.

The basic oscillator circuit used in this project is the same as that in Project 145 so we won't repeat the circuit description here. The only changes are actually additions to obtain the slow decay in tone output. The 10μF capacitor gives only a very slight delay in decay, but the 100 μF provides a noticeably 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 0.05 μF capacitor to more than about 10 μF, and don't decrease the value of the 10K resistor or the Transistor may be damaged. Have fun!

NOTES



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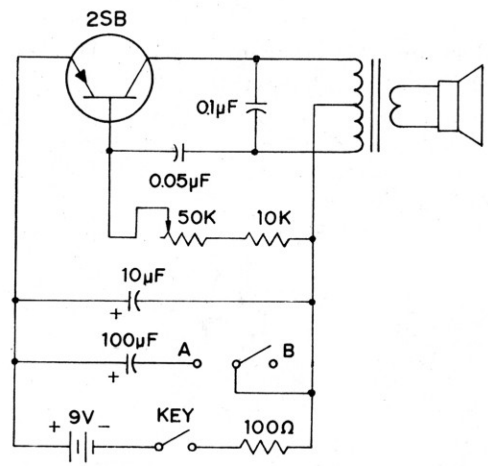


9. ELECTRONIC MOTORCYCLE

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 photo 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 hands, and also by making the shadow of your hands fall across the photo 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.

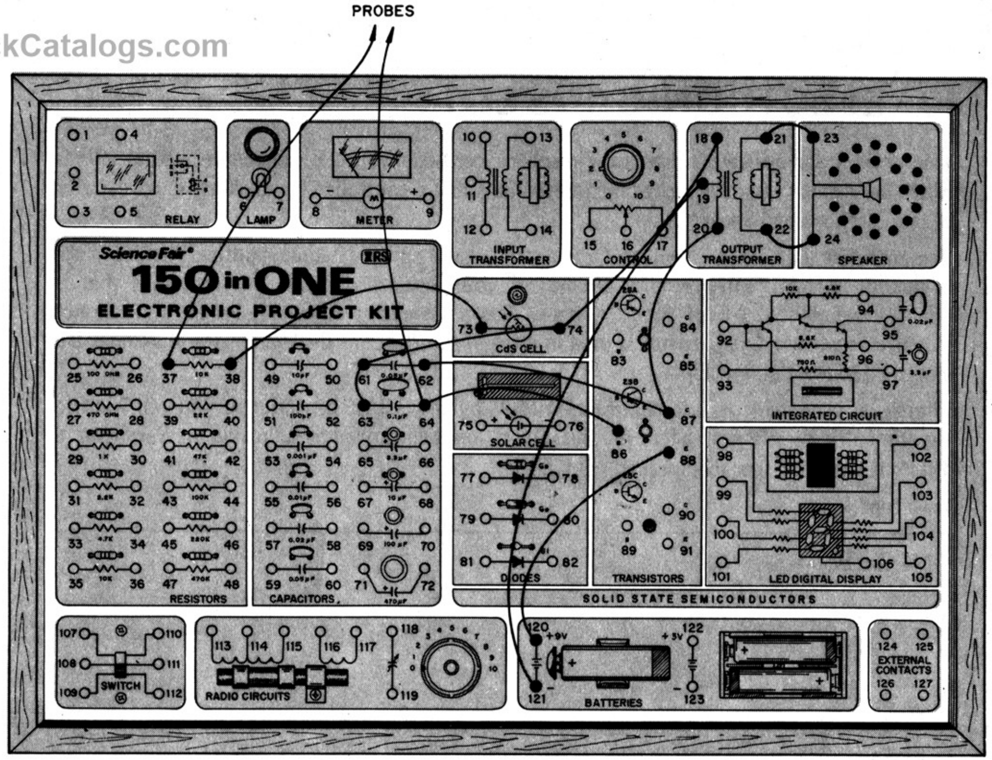
You can experiment with different values for the 0.1 and 0.05 μF capacitors but don't use values above about 10 μF or the transistor may be damaged. You can also try 3V in place of the 9V.

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, as 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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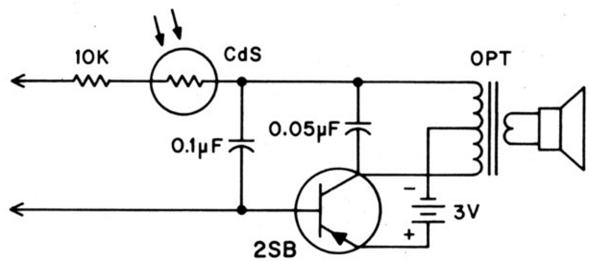


10. ELECTRONIC INSECT

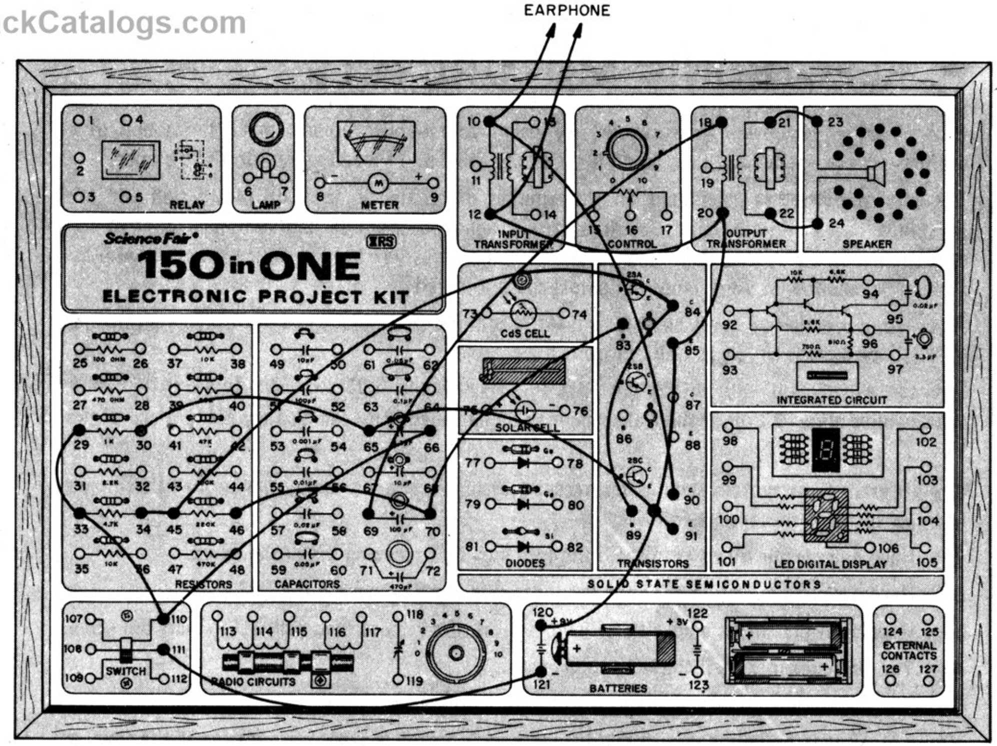
This project demonstrates an acoustic-feedback oscillator which is capable of making sounds which very much resemble night-time insects. Sounds are controlled by adjusting the proximity of the Earphone and Speaker.

The amplifier used for this project is a two-stage, direct-coupled audio amplifier. The 2SC stage is biased by the "universal bias circuit" if you consider the base-bias resistance that is effectively between C-E of the 2SA stage. This arrangement does not give as much circuit stability as when a fixed resistor is used in place of the 2SA, but this demonstrates another DC amplifier connection method.

The signal characteristics are controlled mostly by the 3.3 μF capacitor so you will want to experiment with different values for this. Operation is controlled by adjusting the Earphone to different positions near the Speaker.

Have fun!

NOTES



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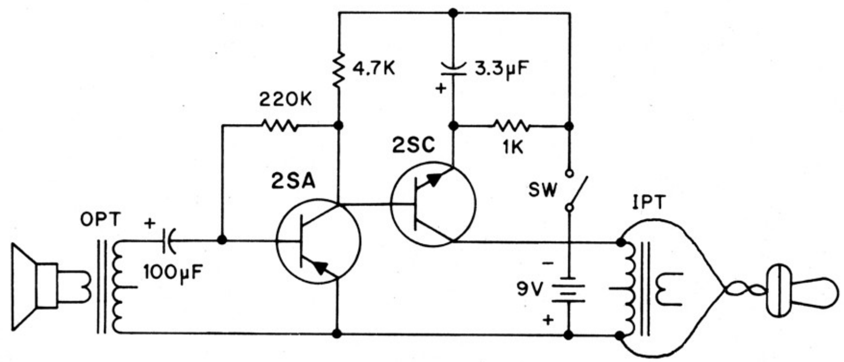


11. TWO-TONE PATROL CAR SIREN

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: gain greater than one, and feedback from output to input in such a manner (regenerative) that oscillations are sustained.

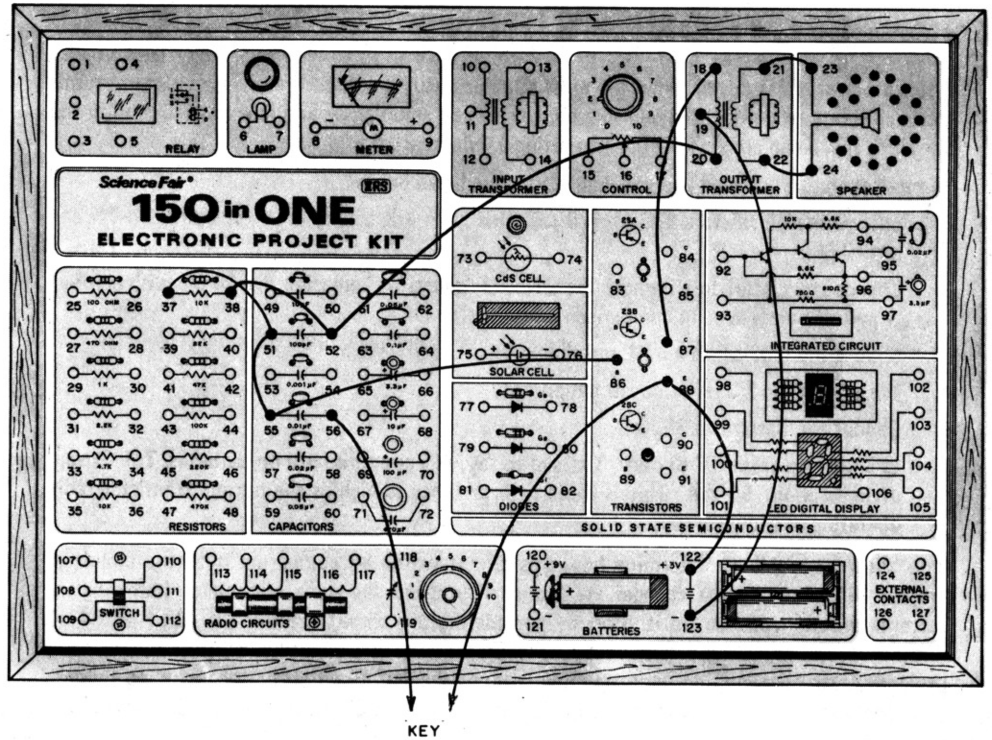
In this circuit the base-bias resistor is low in value (10K) and included in the feedback path. This helps to produce very strong oscillations, but also causes high battery current. The battery current drain from this circuit is one of the highest of all the projects. This is the price you must pay to get a loud output. After all, the power has to come from some place.

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 10K 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 0.01 µF capacitor slows down the switching action as its charge tends to both hold the Transistor ON and then hold it OFF.

You may experiment with different values of capacitors and resistors, but **do not** reduce the 10K value and **do not** allow voltage to be applied when the oscillations are not occurring or the Transistor will be ruined.

NOTES



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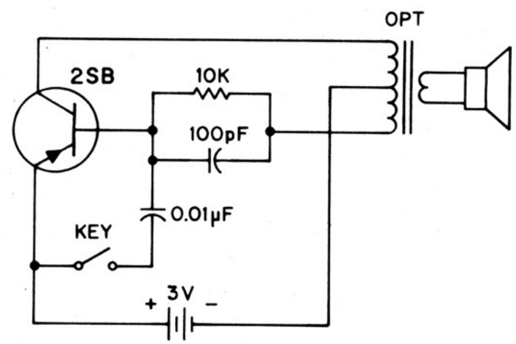


12. ELECTRONIC SIREN

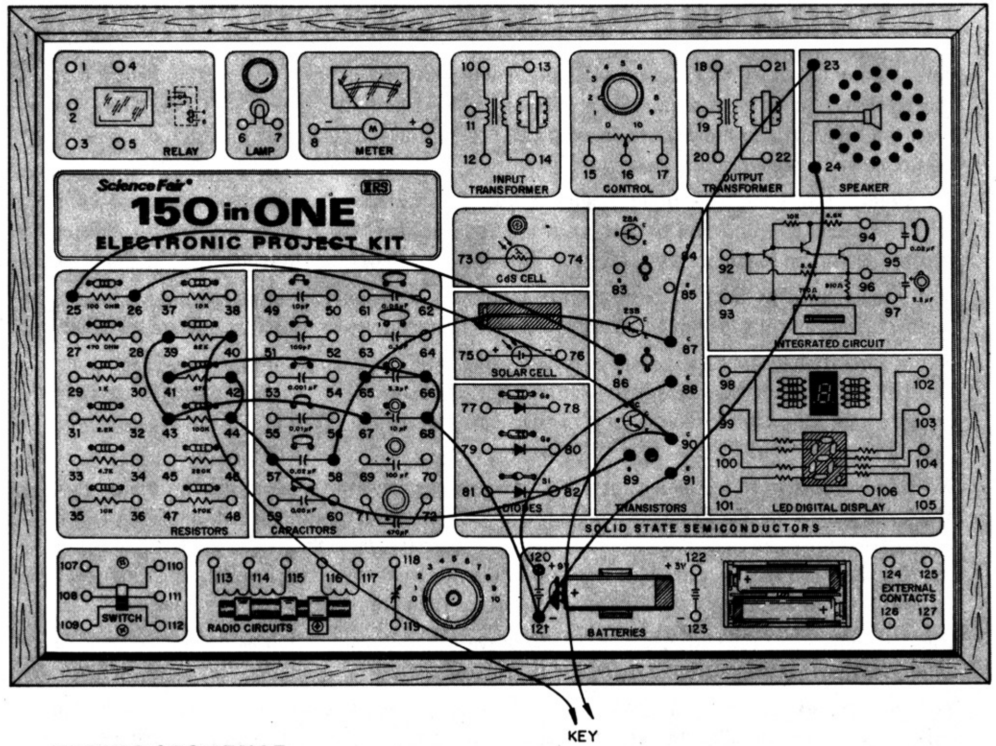
Don't be surprised if this becomes the most popular circuit in this entire kit! This circuit sounds so much like a real siren used on some police cars and ambulances you may **have** to modify the circuit or risk being arrested for impersonating a police car!

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

1. Change the 10 μF to a 100 or 470 μF. 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 10 μF with an open circuit. (Sounds dead in comparison doesn't it!)
3. Change the 0.02 μF to a 0.01 and then a 0.05.
4. Try it with the 3.3 μF removed temporarily.
5. Change the Battery to 3V.
6. Change to a fresh 9V Battery. Yes, sad to say, this circuit is hard on batteries. The current drain is about 50 mA. This is three or four times as high as the normal transistor radio operating at a low volume.

You should be able to determine how this circuit works by comparing it to the circuit of Project 144. 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 10 μF and 47K. Without these components the operating characteristics are virtually identical to the other project. After obtaining an understanding without the 10 μF and 47K, try including these in your analysis. Remember, with these in the circuit the turn-ON is delayed and the turn-OFF is delayed.

NOTES



WIRING SEQUENCE:

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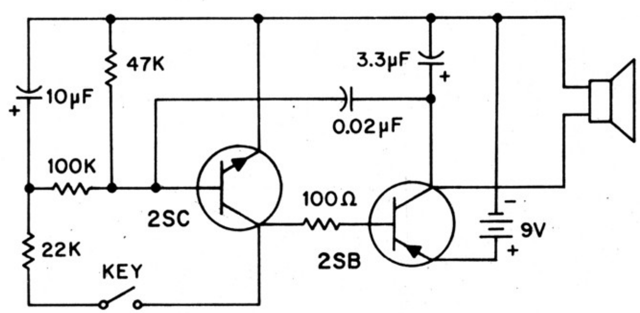


13. ELECTRONIC METRONOME

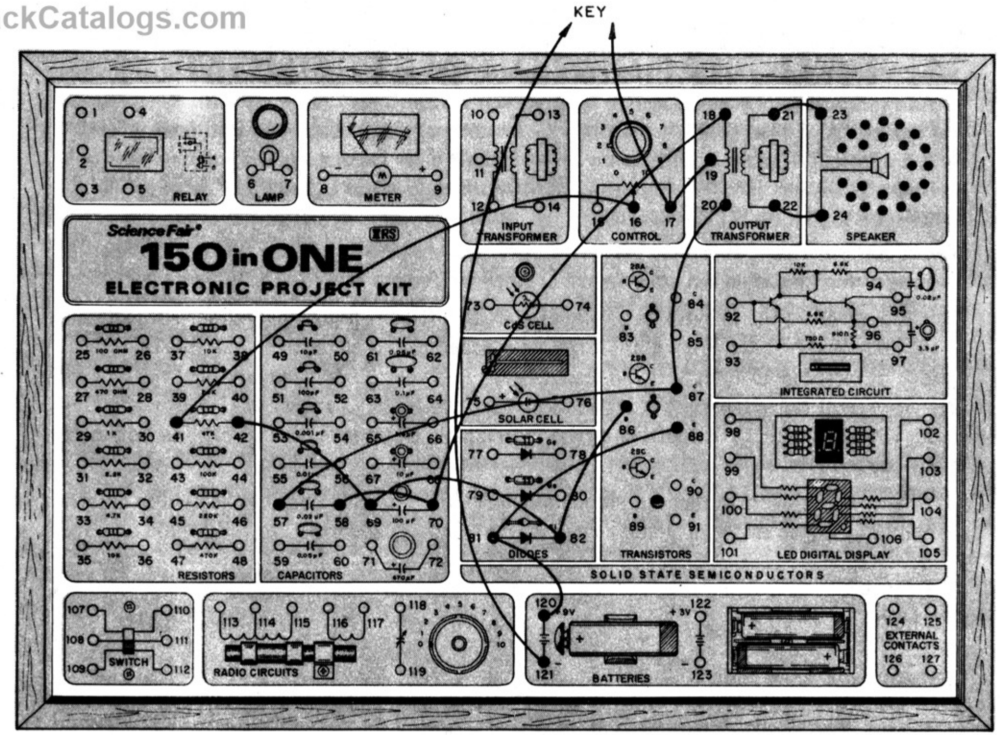
Anyone who is familiar with music has seen or used a Metronome. It is used to aid in setting the tempo of music and keeping that tempo. You can adjust the tempo (or rate) by rotating the Control. Years ago Metronomes were all mechanical – like a pendulum clock. But now many Metronomes are electronic, 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 (100 μF) is used along with a higher total resistance (47K and 50K) to obtain the pulse repetition rate required for a metronome.

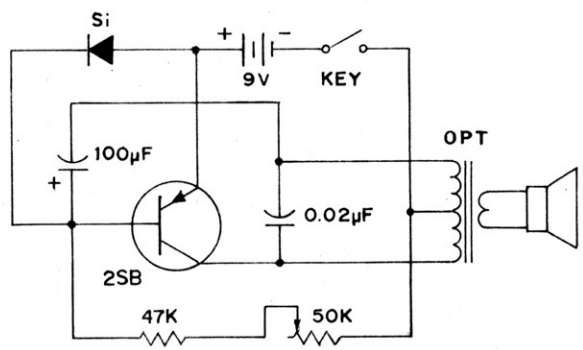
Circuit operation is described in detail in Projects 4 and 145 so we won't repeat it here. You may be interested to know that the base current pulse is limited by the silicon Diode to about 23 mA, and that the collector pulse is up to about 160 mA (depending on the freshness of the battery). This, and all other pulse oscillator circuits like it, are capable of higher current pulses if the Battery is paralleled (bypassed) with a large capacitance. You may want to try connecting the 470 μF capacitor across the battery to hear the difference. **Be sure to observe proper polarity, plus to plus, etc.** You most likely 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, 16-41, 20-87-57, 42-69-82-86, 88-81-120, 19-17-Key, 121-Key



14. TWO-TRANSISTOR METRONOME

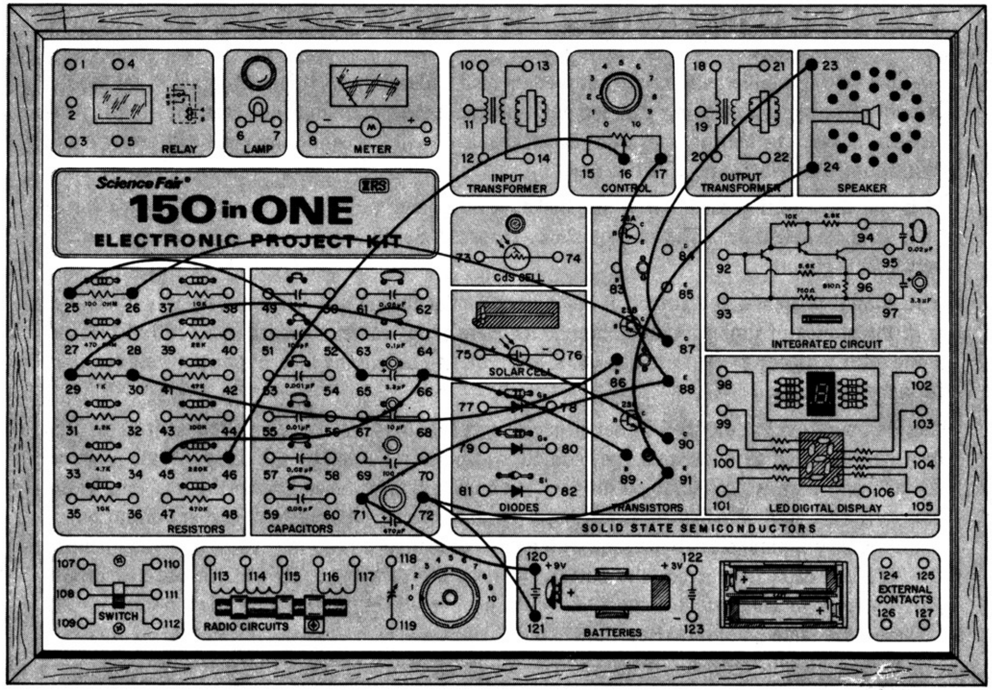
This project is a two-transistor metronome. The two Transistors are arranged in an oscillator circuit which is capable of driving the Speaker directly without a Transformer. A Control is provided to change the click rate. The 220K resistor may also be changed to 470K to obtain slower rates, or to 100K for faster rates.

The circuit is the same as Project 144 but with necessary changes to obtain clicks in the Speaker in place of the tone. You can use a Switch or Key as in Project 144.

This is a good project to check your circuit analyzing (circuit psyching) abilities also. Use the procedure described for Project 144. The only added circuit components are the 1K resistor (which is included to limit the 2SB base current to about 7 mA maximum) and the 470 μF Battery bypass capacitor which is included to make current pulse amplitudes less dependent on Battery characteristics. Of course a different schematic arrangement is used to give you some additional exercise.

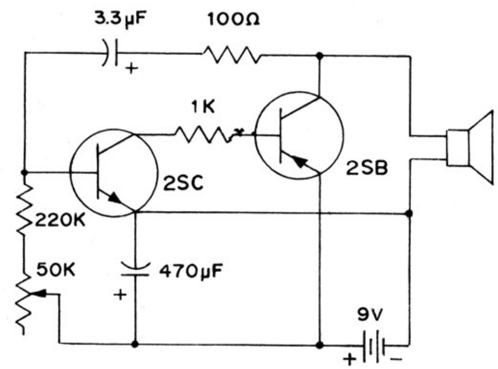
Use the space below to outline circuit operation. A VOM or oscilloscope can be used to observe polarity of voltages across all circuit components to verify your current flow directions.

NOTES



WIRING SEQUENCE:

23-87-26, 25-65, 24-91-72-121, 86-30, 29-90, 89-66-45, 46-16, 17-88-71-120



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 to obtain faster or slower pulse rate.) Both 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 both 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.

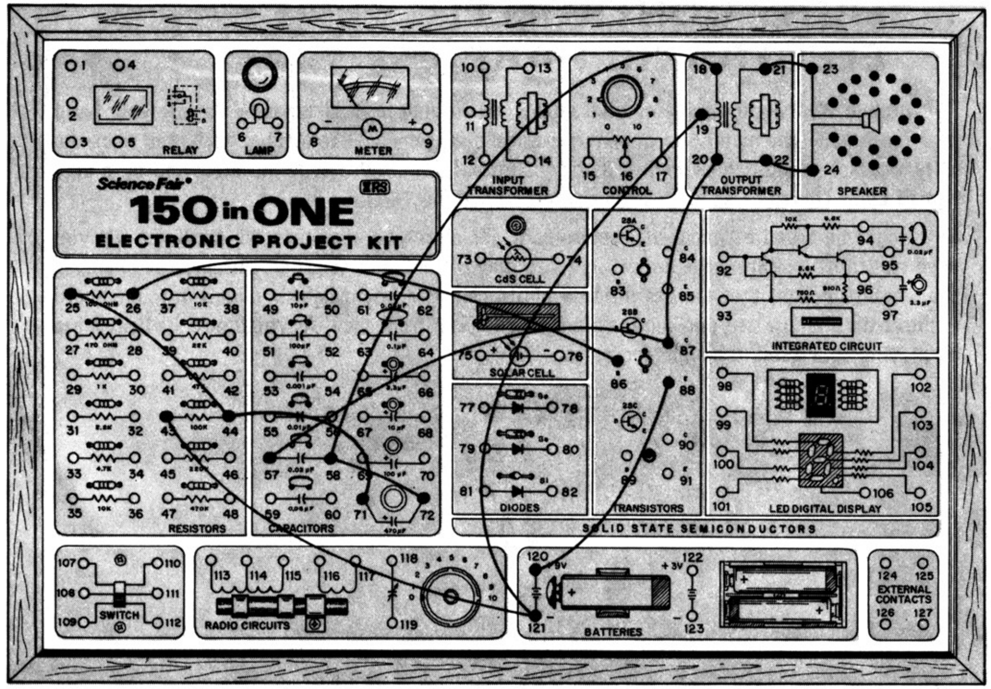
The hypnotists have long used this hypnotizing characteristic to gain control of their subject's mind.

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 470 μF quickly charges up to a voltage greater than the 9V Battery, due to induced voltage in the Transformer windings.
3. When the Transformer core reaches magnetic saturation, the induced voltage decreases, allowing the 470 μF charge to quickly cut off the Transistor (due to reverse base-bias).
4. The 470 μF must now slowly leak its charge off through the 100K and Battery until its voltage about equals that of the Battery.
5. When the 470 μF voltage about equals that of the Battery, the Transistor can conduct again for an instant of 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?

NOTES



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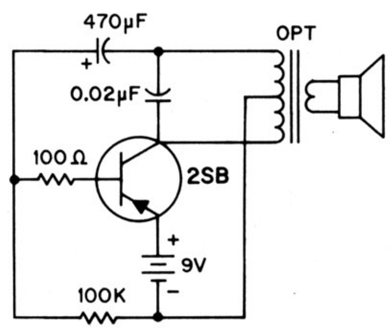


16. LIGHT CONTROLLED ELECTRONIC HARP

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 Terermin in his honor.

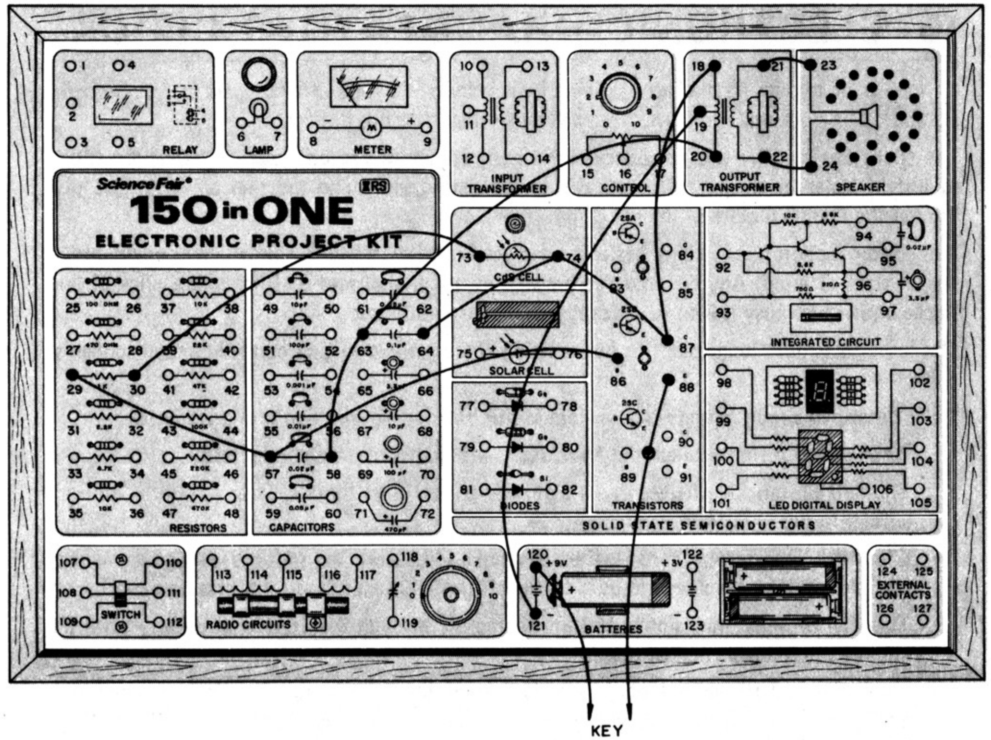
This might be called a "hands-off" instrument, for after you once turn the oscillator ON you need not touch it during the entire time you play a tune. The tones are obtained by changing the amount of light that reaches the CdS photo cell. If a bright light is placed over the board without the shadow 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 again). The only change in this circuit is the addition of the CdS photo cell in the base-bias circuit. A fixed 1K is also included in series with the photo cell to provide a protective limit on base bias.

Have fun!

NOTES



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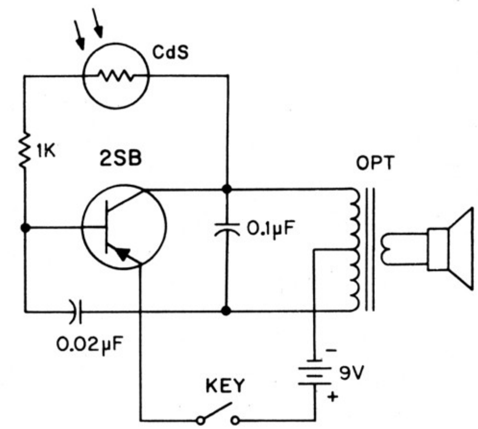
21-23, 22-24, 18-87-74-64, 19-121, 20-63-58, 73-30, 29-57-86, 88-Key, Key-120



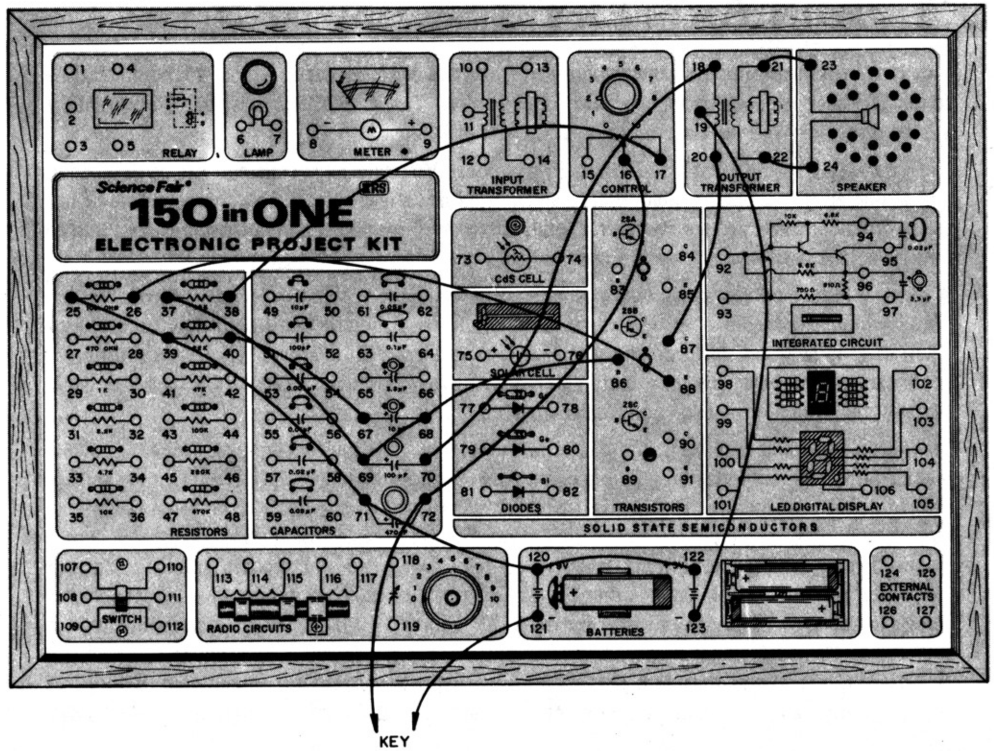
17. SLEEP MACHINE

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. I suppose 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 7. The added circuitry is the 9V Battery, Key and 470 μF capacitor. The change is in the source of base-bias. Instead of obtaining the bias from the 3V Battery through the 10K and 50K resistances, it is obtained from the 9V Battery or 470 μF capacitor charge. Base-bias current requirements are so low that it takes a long time for the charge on the 470 μF to leak down to near zero. Also the leakage of the 100 μF and Transistor keep the circuit going slowly ...... indefinitely.

Pleasant dreams.

NOTES



WIRING SEQUENCE:

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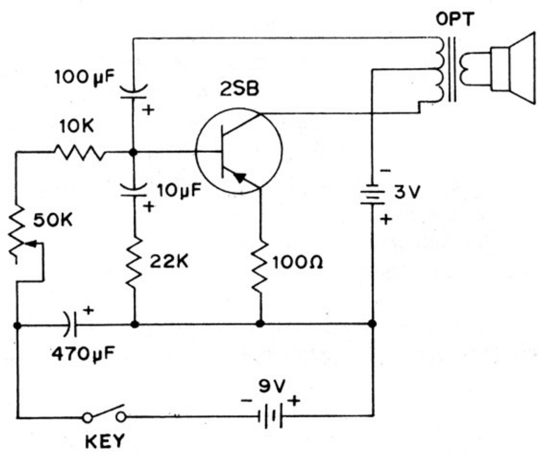
16-72-Key, Key-121, 17-38, 37-69-68-86, 25-39-71-120-122



18. 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 this world abounds in batteries? Virtually all metals can act as electrodes, and about anything but distilled water can be used as an electrolyte. This characteristic of our world is evident everywhere we look. Metals eaten away from rust and corrosion can be said to have given 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.

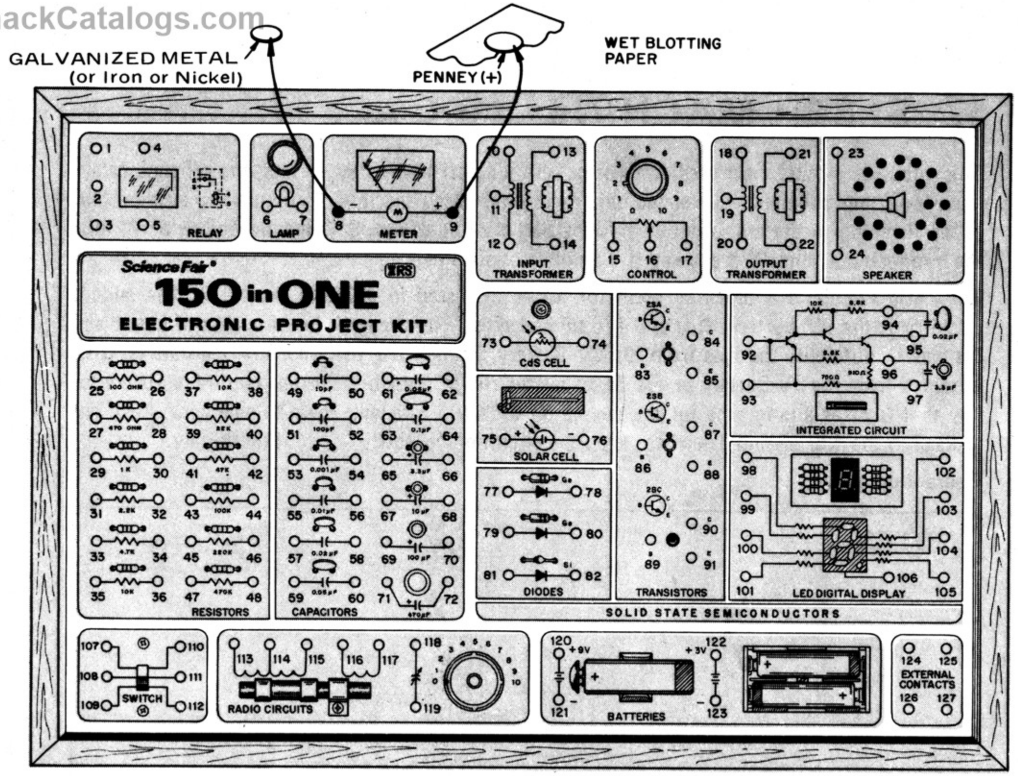
The voltage produced between the dissimilar metals depends on the chemical properties of the metals. Someone has tested all possible combinations of metals to determine the relative voltage between any two metals. The listing (in order of voltage amplitude and polarity relative to hydrogen as a 0V reference) 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 highest currents. 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 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.

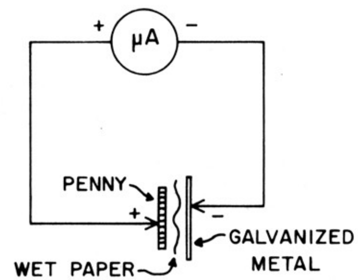
To compare the current delivering properties of different "coin batteries," use a 100 ohm resistor in shunt with the Meter. This increases the full-scale meter current from 0.25 mA to about 2 mA. It is an unusual penny battery that can pin this Meter circuit.

For circuits to operate with this Coin Battery, see Projects 64, 82, 116 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



19. ELECTRONIC THERMOMETER

The purpose of this project is to study the basic bridge circuit which is used in virtually every electronic thermometer. The temperature sensitive element is a common germanium (Ge) Transistor, 2SB. You may have seen or used an electronic thermometer in the hospital or in a doctor's office. If so, you have seen this concept developed to its practical end – an accurate, quick reading thermometer.

This circuit doesn't have all the refinements of the hospital type thermometer, but it can demonstrate some basic principles. The basic circuit type is the Wheatstone bridge (see also Project 129). This bridge is composed of four resistances connected in a continuously closed ring or circle. In this project the resistance between collector and emitter of the 2SB is used as one of the four resistances. The source of voltage (Battery) is connected across two opposite corners of the bridge, and the detector is placed across the remaining two corners of the bridge.

The bridge is said to be "balanced" when the ratio of resistances in adjacent arms of the bridge is equal. For this project the adjacent 10K resistors are two arms of the bridge and the 50K and 2SB are the other adjacent arms. Because the 10K resistors are equal in value (a ratio of one to one), the resistances of the 50K and 2SB must also be equal in value (a ratio of one to one) in order for this bridge to be balanced.

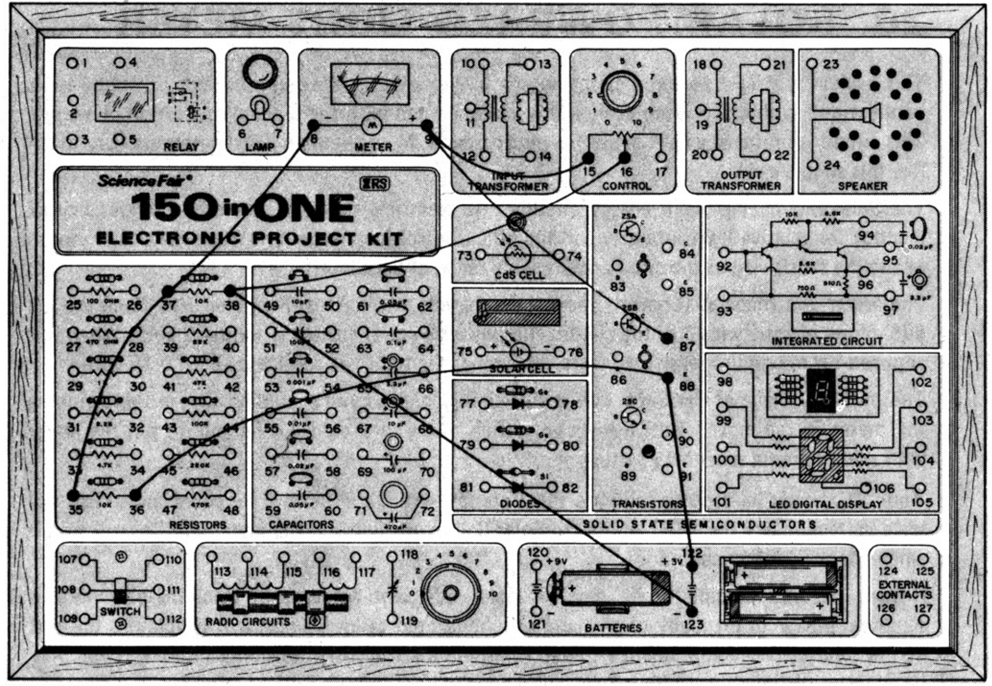
When the bridge is balanced, no current will flow through the meter. This is the starting condition for comparing temperature changes with this circuit. The procedure is as follows:

1. Keep the 2SB in the **lower** of the two temperatures to be measured for a few minutes – to stabilize this condition as the balanced-bridge reference condition. Keep the Meter on zero during this time by adjusting the 50K Control as required. When you no longer need to make adjustments of the Control to maintain a zero reading, the circuit is stabilized. Leave the control at this setting for the following.
2. Place the 2SB in the **higher** of the two temperatures and allow the Meter to come to rest at some up-scale reading. The amount of meter deflection above zero is an indication of the increase in temperature (temperature differences between the high and low temperatures).

Try measuring such temperature differences as room-temperature to outside-temperature, room-temperature to body-temperature (fingers gripping the 2SB), and shade-temperature to sunshine-temperature.

Battery current drain is very low for this circuit so hours of use make little change in battery life.

The characteristic of the Transistor which provides the resistance change is basic to all semiconductor devices, especially germanium. The resistance used in this project is that caused by the leakage between collector and emitter of the Transistor when it is in the OFF state. This leakage is usually measured in terms of the current which will flow with 2V applied. This current is called the I_{CEO} leakage current. Below about 10°C this leakage is very small and may be neglected, but as temperature increases (especially above 50°C) this leakage doubles for each 10°C or so increase in temperature and makes the device usable in circuits which are unable to cope with the excessive leakage current.



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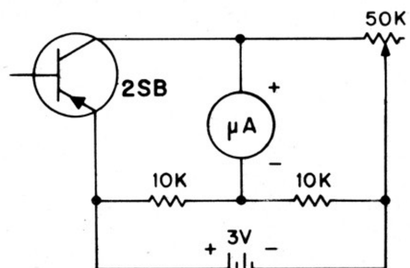
123-38-16, 15-9-87, 8-37-35, 36-88-122



20. 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 volt meter 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.

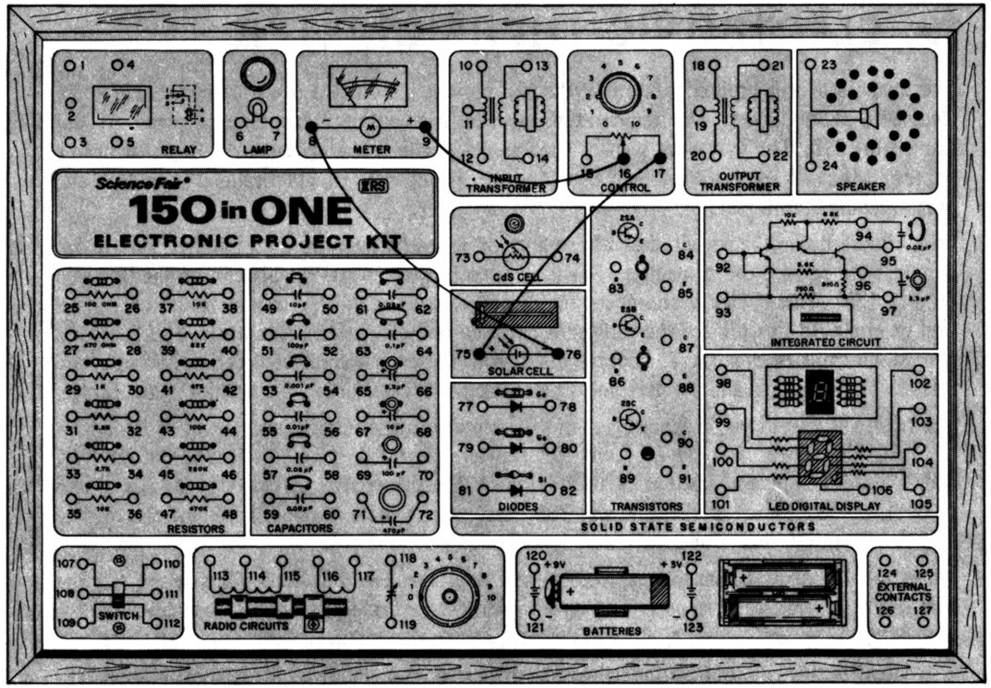
The output voltage of the Solar Cell is sufficiently high so you should have no trouble pinning the meter in the most sensitive rheostat setting, but you should not be able to pin the meter with the minimum sensitivity setting.

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.

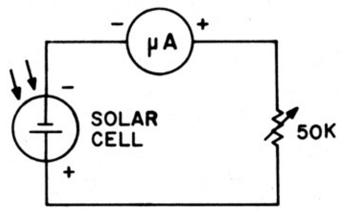
The photovolatic cell used in this kit is a selenium type which responds best to the blue to red region of light. Other solar cells are available which are made of silicon. These are far more efficient then selenium solar cells but are also much more expensive. If you are interested in this aspect of science we suggest 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 out doors in sunlight and in shade.



WIRING SEQUENCE:

76-8, 9-16, 17-75



NOTES

21. CdS PHOTO 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) photo cell which controls the amount of deflection obtained on the Meter. A Control is included to allow measurements of relative light intensity from near darkness to full sunlight.

The CdS Cell is effectively a resistor (as its schematic symbol implies) which 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 a function of base-bias; increased base-bias causes increased collector current. The collector current is caused to flow through the Meter t obtain a readout.

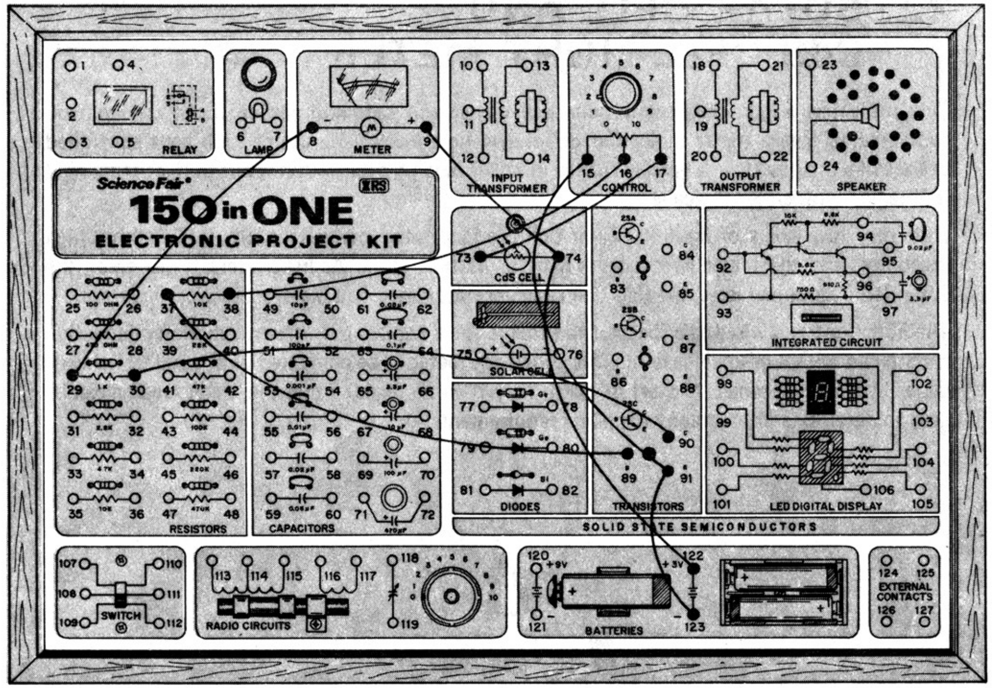
The 10K base resistor protects the Transistor from excessive base current in bright light when the 50K Control is set at maximum. The 1K resistor is included to protect the Meter from excessive current should the Control be set too high, or the light too bright – for the Control should be kept low (near zero on the dial) unless the high setting is definitely needed for 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 ohmmeter 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 which are accurate enough for most light meter requirements. You may want to use the space below for this purpose.

NOTES



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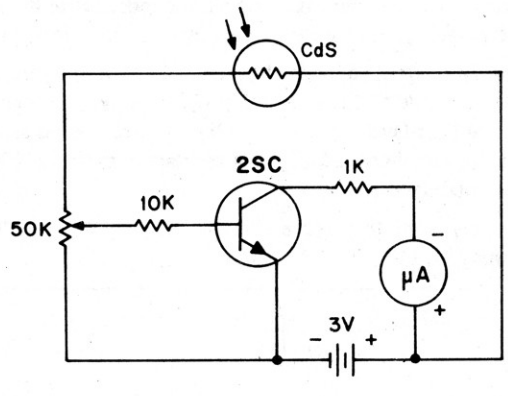
122-74-9, 90-30, 29-8, 73-17, 16-38, 37-89, 15-91-123

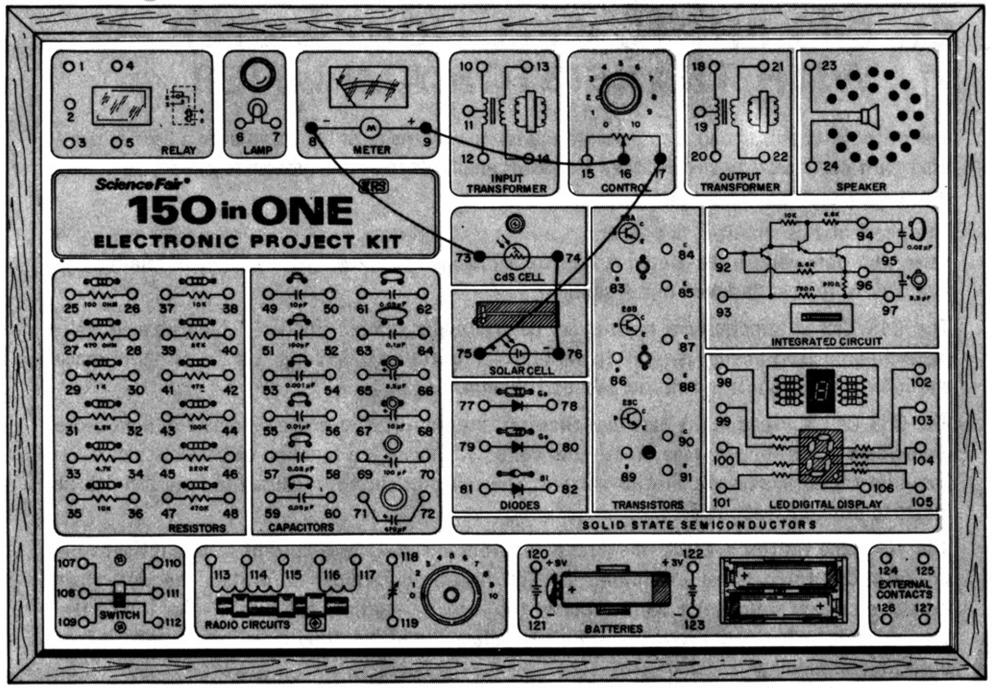


22. SOLAR CELL AND CdS CELL LIGHT METER

This project is a light meter with solar cell power and cadmium sulfide (CdS) cell control, combined to give a meter indication of relative light levels. The use of both light controlled devices like this results in a greater change in meter reading over certain levels of light than what is 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.



WIRING SEQUENCE:

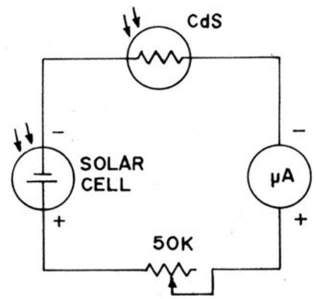
8-73, 74-76, 75-17, 16-9

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 photo cell but not the Solar Cell. The meter 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) photo cell is a resistance device which 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 photo 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 light meter sensitivities as compared with a photography light meter.



NOTES

23. 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 which has a high-gain transistor as one arm of the bridge. This transistor then is controlled by a CdS Cell in its base circuit.

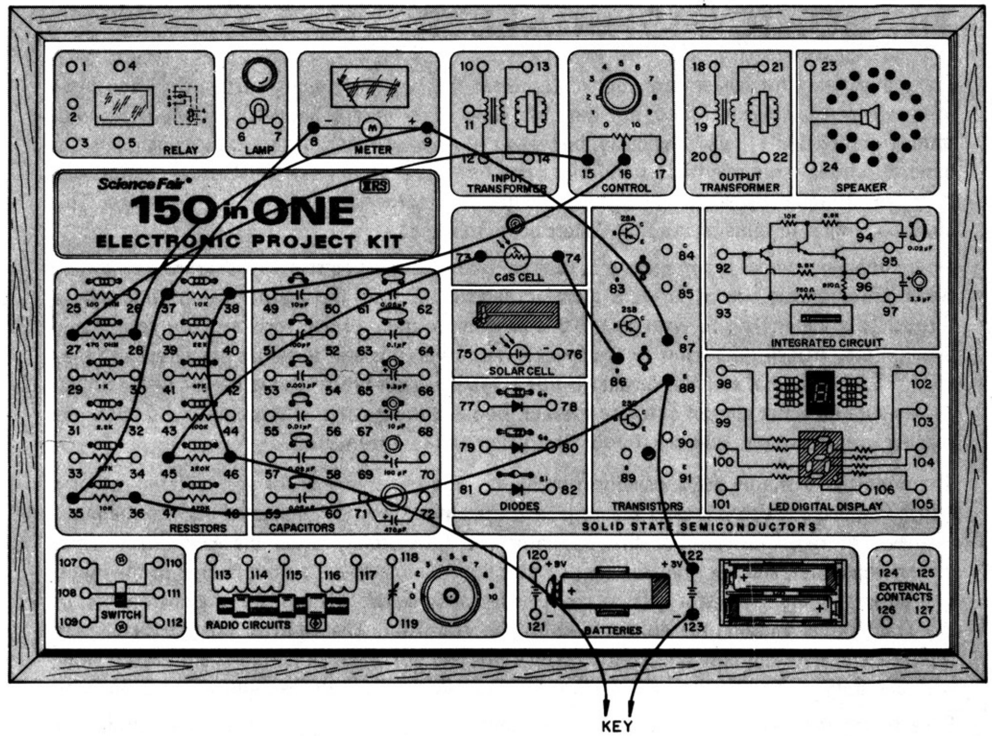
The bridge circuit is composed of four resistances arranged in a continuous ring or enclosed loop. This project uses 10K resistors as two arms, the series combination of a 470 ohm resistor and the 50K Control as the third arm, and the resistance between C-E of the 2SB Transistor as the fourth arm of 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 photo 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 then 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 changes in light.

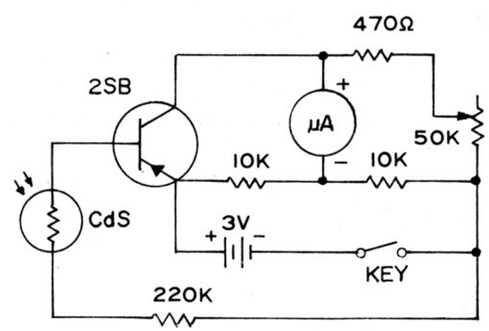
If you want to make this circuit very sensitive at low light levels (such as moon or star light) short-circuit the 220K resistor.

NOTES



WIRING SEQUENCE:

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



24. 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.

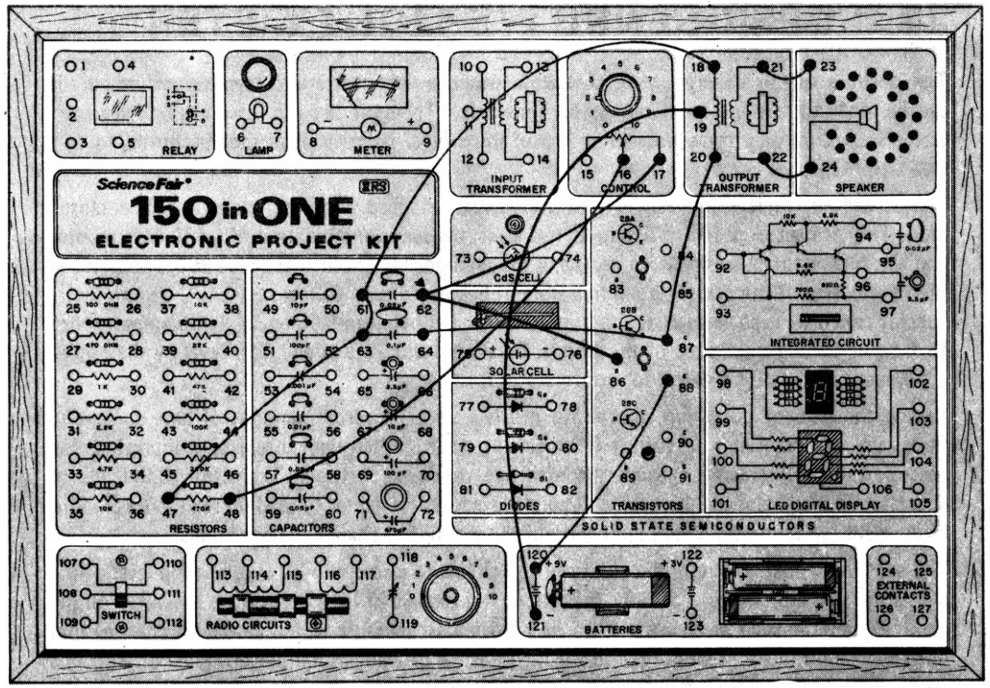
The circuit is a simple pulse waveform oscillator. The requirements for an oscillator is that a gain be available which is greater than one, and the output must be connected back to the input in-phase (or regenerative). For this oscillator the Transistor provides the gain (many times greater than one), and the Transformer provides the coupling of the output back into the input. The output of the Transistor is from across collector to emitter. This makes the bottom half of the Transformer winding the output load for the Transistor. The input to the Transistor is to the base and between base and emitter. The 470K and 50K Control (wired as a rheostat) along with the 0.05 μF 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 0.05 μF 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 0.1 μF capacitor helps determine the magnitude and frequency of the pulses. You may want to experiment with different values for this, as well as the 0.05 μF capacitor. Who knows, you may find the type of signal that will attract a whale!

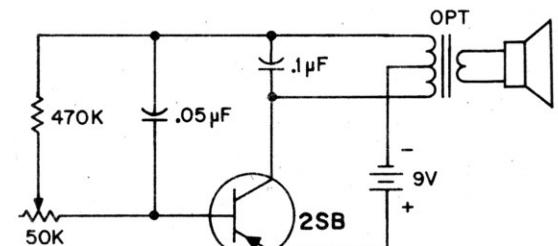
This might be a good experiment to build up on your own, using parts available from your electronic parts scrap box (you'll soon have such a box if you take up electronics as a hobby) or from Radio Shack. Build the circuit inside or on a convenient chassis, box or container; Radio Shack's P-Boxes are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

NOTES



WIRING SEQUENCE:

121-19, 21-23, 22-24, 18-61-63-47, 20-87-64, 16-48, 17-62-86, 88-120



25. HYGROMETER

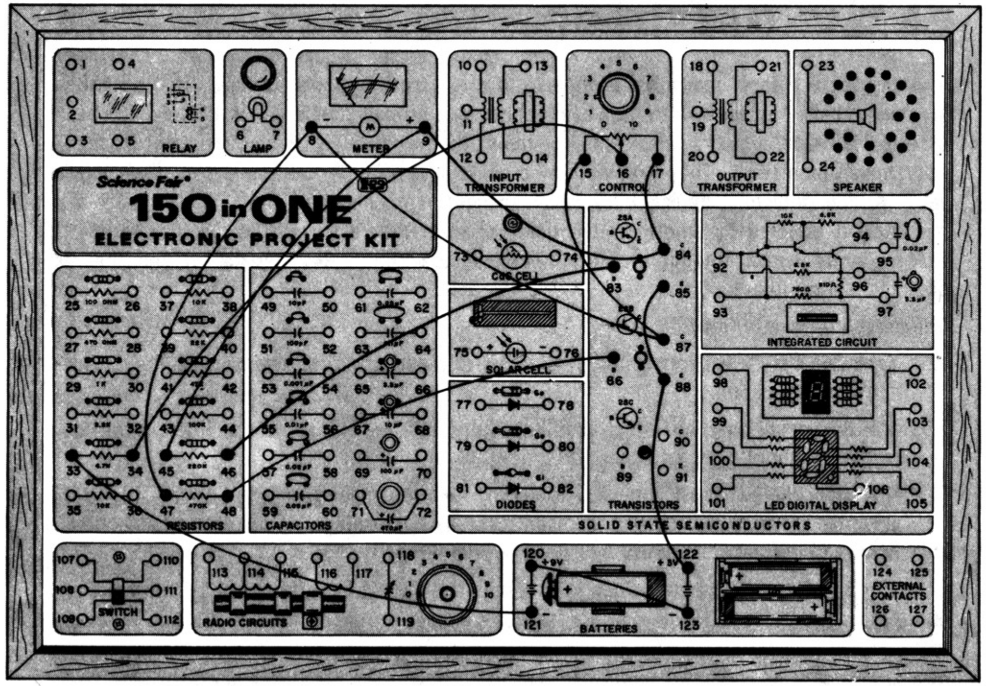
The purpose of this project is to construct and study the hygrometer. A hygrometer is an instrument used to measure the relative humidity in the air. This is generally accomplished with two identical thermometers by keeping the bulb on one dry and the second one dampened with water. As the water evaporates it cools the dampened thermometer. The percent of relative humidity is then determined from the two temperature readings by means of a chart.

This project demonstrates how two transistors arranged as two of the arms of a Wheatstone bridge circuit can be used to indicate relative humidity. Basic operation is as follows:

1. Connect the circuit and allow it to be on for a couple of minutes without any difference in the treatment of the Transistors (both dry). Keep the bridge circuit in balance during this time with the 50K Control. Recall that balance is indicated by a zero meter reading.
2. After the above stabilization do **not** adjust the 50K Control any more. Place a dampened cloth all around the 2SB Transistor. A small rubber band is helpful in holding the small cloth all around the transistor without taking away excessive exposed damp cloth surface. Do not allow the moisture to get on the terminals or mounting surface.
3. Place a small electric fan near the Transistors so that an air speed of about 9 miles (14 km) an hour or so is directed onto both Transistors.
4. Watch the Meter and record the highest level obtained. The higher the Meter reading the LOWER the relative humidity. A commercial calibrated hygrometer may be used to calibrate this Meter deflection in terms of relative humidity.

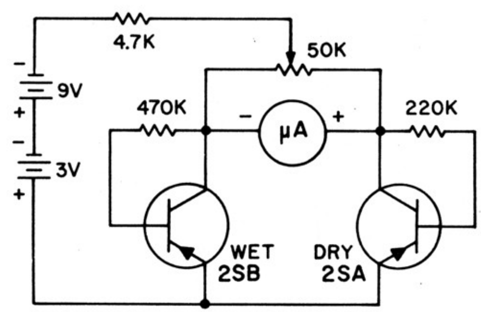
The reason this circuit works as it does is because transistor leakage currents are very sensitive to temperature changes. As a rule of thumb the leakage current doubles for each 10°C rise in transistor temperature. With the transistors arranged as the bottom arms of the bridge, any change in leakage between the two transistors is indicated by an unbalance of the bridge circuit and therefore an upscale meter reading.

If trouble is experienced in obtaining an initial balance without the 50K Control being near one end of its range, try reversing the 220K and 470K resistors or removing one from the circuit entirely. This trouble would not be present if two identical transistors and resistors were available for this experiment. Ideally the transistors would be mounted clear of surrounding objects and have the moisture supplied to the wet transistor from a gauze wick fed from a small container of water a couple of inches (about 5cm) below the transistor.



WIRING SEQUENCE:

17-84-9-45, 46-83, 15-87-8-47, 48-86, 16-34, 33-121, 85-88-122, 120-123



NOTES

26. LIE DETECTOR

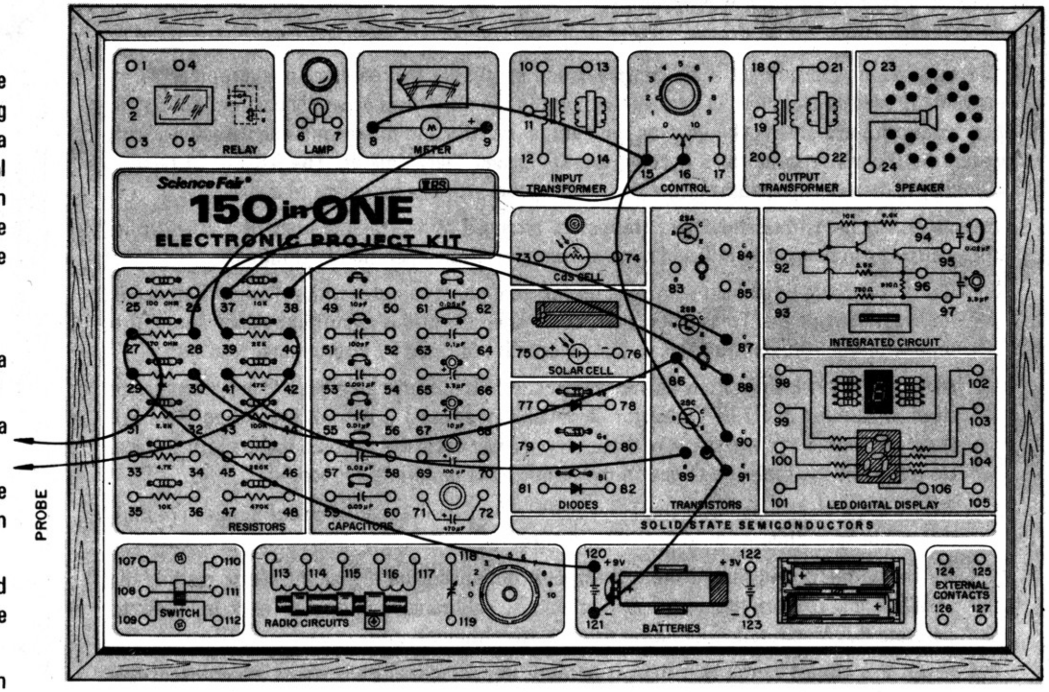
This project is a good one to use at a party to play "truth or consequences." It is a sensitive resistance-change detector. You have heard about, and probably seen on TV, lie detectors being used to help determine if a person is telling the truth. Technically such an instrument is called a "psychogalvanometer". 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 which require an honest answer and adjust the 50K Control for a reading of about 5 on the Meter.
3. Now play the game; ask other questions to which he 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 him lying.

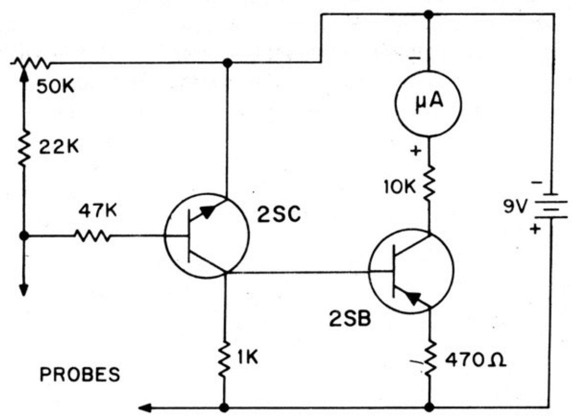
Commercial lie detectors also include measurements of breathing rate and heart pulse rate and are still not considered 100% accurate, so don't expect too much from just a skin resistance test.

The circuit is a two-stage DC amplifier. The current which is amplified is the current which flows over the surface of the person's skin from the 9V Battery. The Control functions by shunting excessive 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 from excessive current.



WIRING SEQUENCE:

87-38, 37-9, 90-86-30, 88-28, 89-41, 39-16, 120-29-27-Probe, 40-42-Probe, 8-15-91-121



NOTES

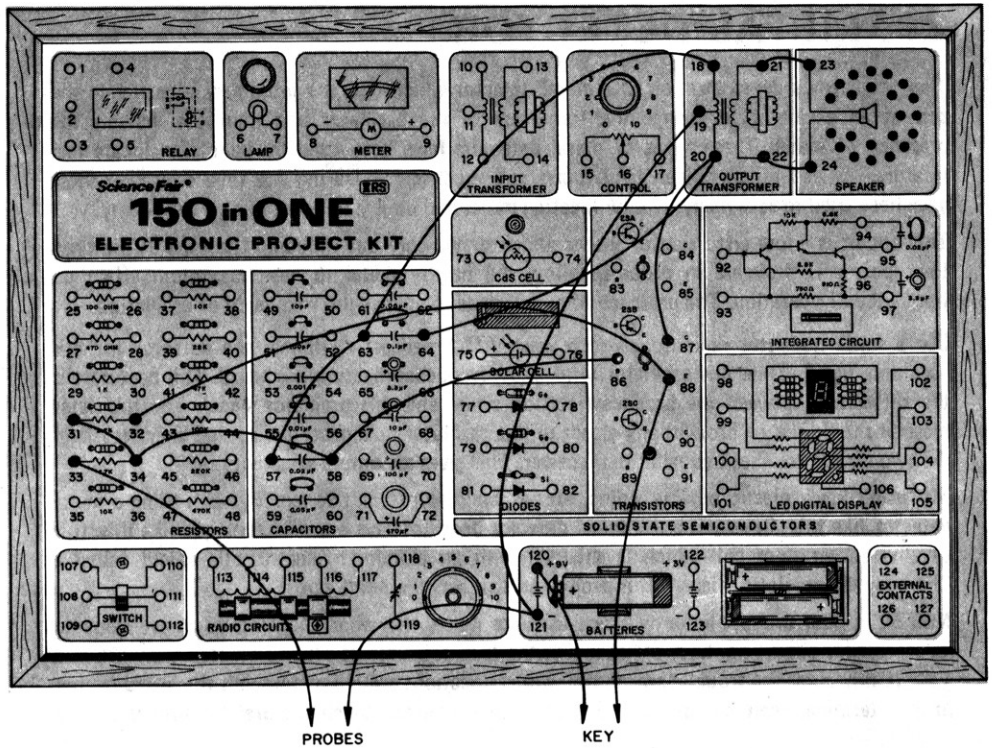
27. RAIN DETECTOR

This project can be used as a rain or water level detector. When the probes have above about 250K resistance between them (such as an open circuit), no current is drawn from the circuit even with the Key closed. When the Key is closed and moisture or water (or anything else which has a resistance below about 250K) 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 of the basic pulse-type which we've run into time and time again in this book. The 4.7K resistor is protection against excessive base current if the probes are shorted together. The 2.2K resistor keeps the transistor leakage current from turning on the oscillator during what should be the open-probes OFF time.

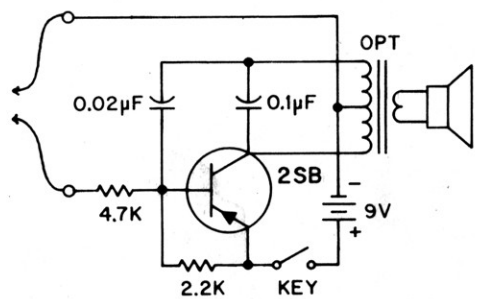
Have fun!



WIRING SEQUENCE:

21-23, 22-24, 18-63-57, 19-121-Probe, 87-20-64, 86-58-34-31, 32-88-Key, Key-120, 33-Probe

NOTES



28. METAL DETECTOR

This project is a demonstration of a metal detector which 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 especially these have been used to save many lives by locating mines and booby traps set out by the enemy.

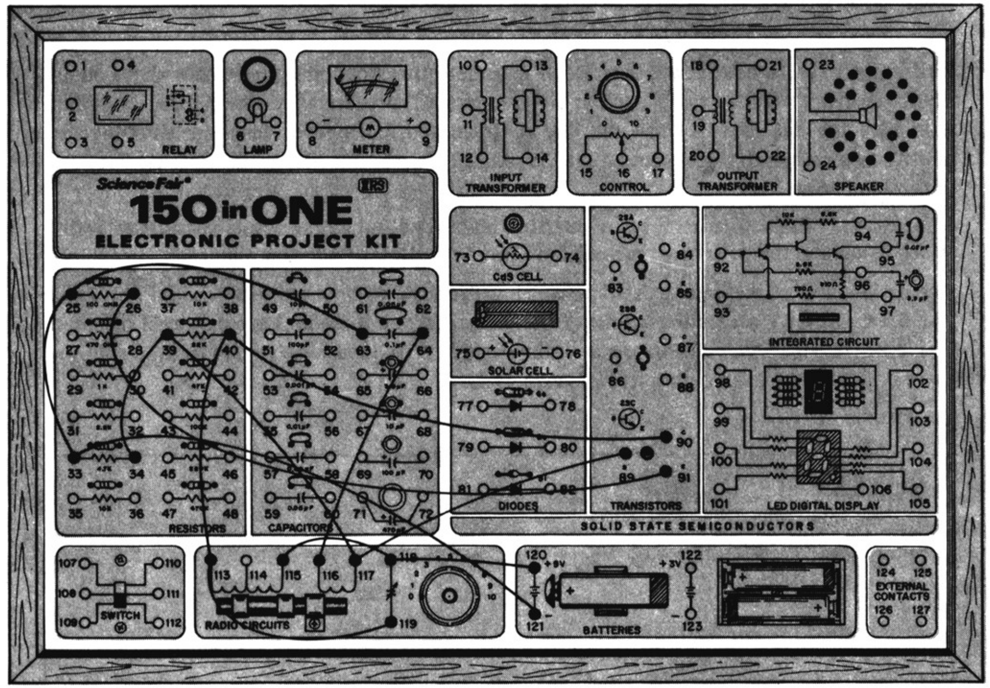
This circuit is a low distortion oscillator which draws only one milliamp from the 9V Battery. Low power is desirable in order to allow the nearby metal to have maximum affect on frequency of operation. The presence of metal tends to change the frequency of oscillation.

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 transistor receiver should not be brought any closer to this oscillator than necessary so that signal levels of the two signals are about equal in the receiver. 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.

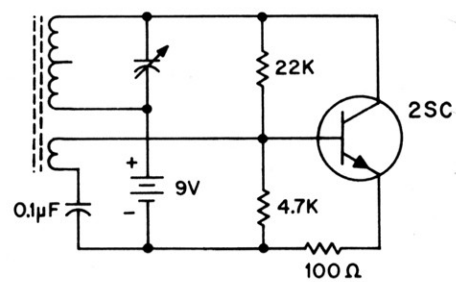
NOTE: In case this oscillator will not oscillate no matter what checking you have done to insure proper circuit hookup, try changing.the lead connections around on terminals 116 and 117. If this cures the trouble, switch the wire connections around underneath the board so that proper terminals can be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

NOTES



WIRING SEQUENCE:

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



29. 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 this accelerometer lamp.

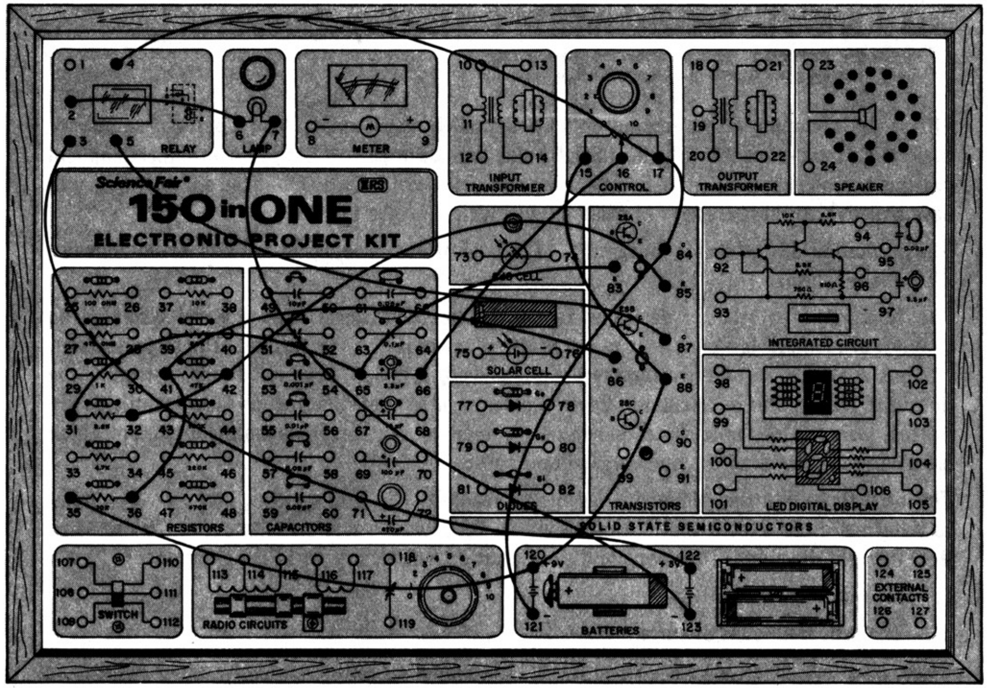
Start with the control on minimum (CCW) and try rotating the knob CW at different rates. You will notice that rotation must be above a certain rate or no results are shown on the Lamp.

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

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

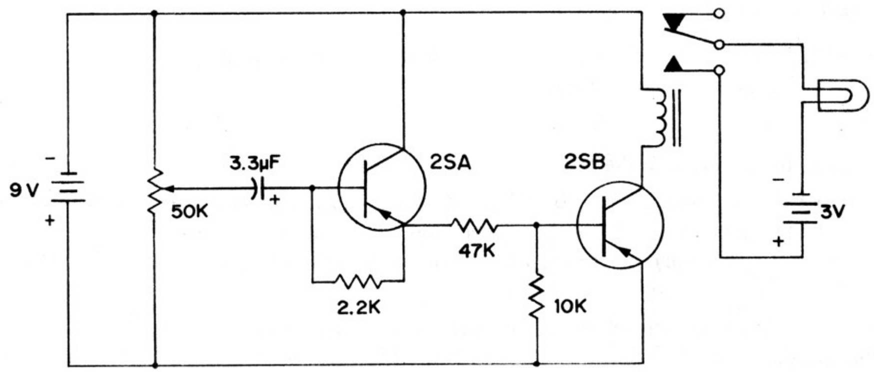
The 10K and 47K connected to the 2SA are used to limit circuit current in the 2SA C-E and 2SB B-E. The 2.2K helps minimize leakage effects from the 2SA and controls the rate of Control change required to turn the lamp ON.

The 3.3 μF capacitor discharges through the 2.2K, 47K 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.



WIRING SEQUENCE:

123-7, 6-2, 3-122, 32-42-85, 31-65-83, 36-41-86, 66-16, 5-87, 15-88-120-35, 4-17-84-121



NOTES

30. 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 this exciting component. You'll be using the LED Display throughout the entire Kit (as you have already), so there are lot's of other circuits which involve the LED.

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 numerals 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 upon for displaying these numbers, because these are the minimum which are able to display all of the numbers 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 then will determine how much current will flow, as it drops the voltage of the supply down to the LED voltage.

Use the 3V battery and leads as shown to light various segments and decimal point D_p. What numbers and letters can you display?

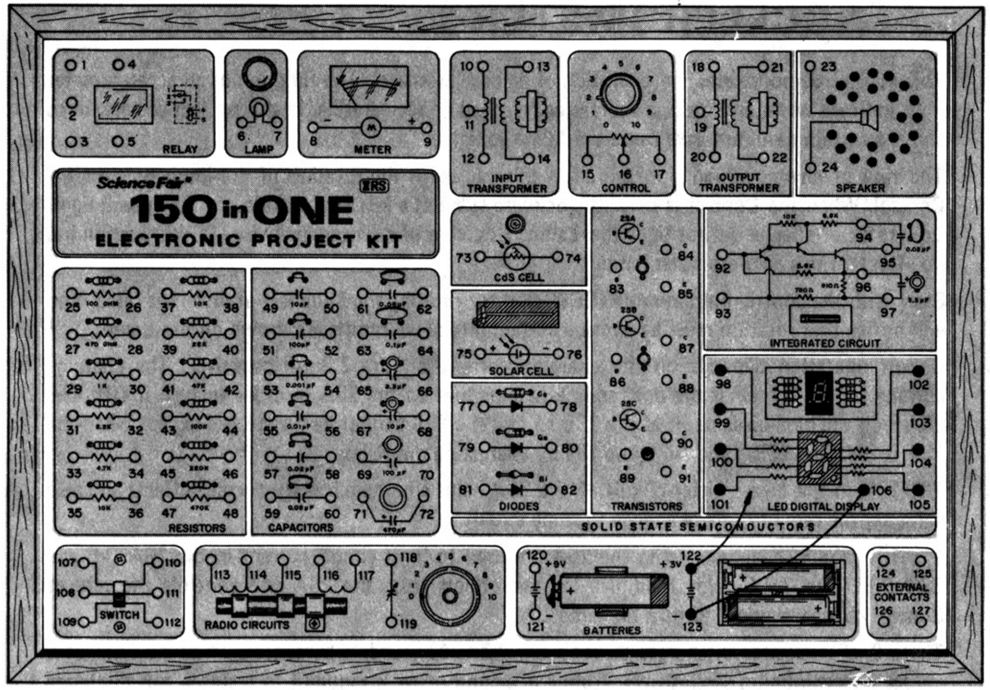
With this low battery voltage you may try reverse polarity operation by reversing the leads to the battery. Record your results below.

Reconnect 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)

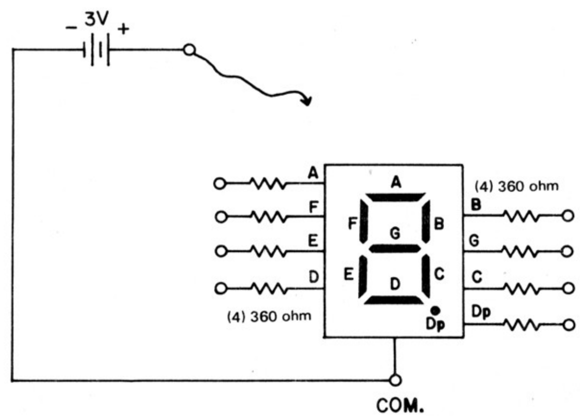
Use your VOM across each 1K resistor and determine the 1K resistor voltages. LED currents in milliamps equals the 1K resistor voltages in volts. LED segment currents are then all about mA (1.1 mA is typical) with the 3V battery and mA with the 9V battery.

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



31. BASIC (LED) DISPLAY

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

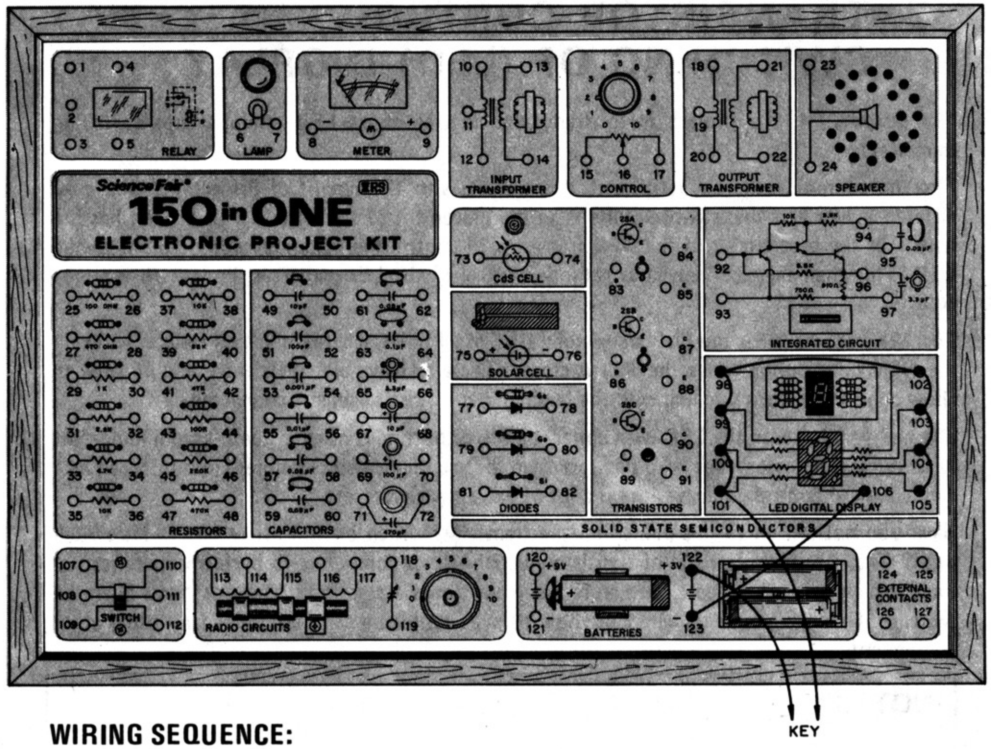
The LED manufacturer could construct the seven-segment readout with each segment having its cathode and anode leads brought out to separate pins, but this would require an excessive number of pins. Instead, seven-segment readouts are commonly made with either anodes or cathodes common to one pin. Common cathode types require a common for the negative supply and common anode types require a common 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 (No. 106) must be negative, and all anode segment pins are supplied with a positive polarity.

Light emitting diodes are very small. Therefore, to obtain a line of light, a number of diodes must be lined up next to each other to give the appearance of a continuous line. Some models of seven-segment readouts have a frosted lens so the individual diodes can not be distinguished. Can you see the individual diodes 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.

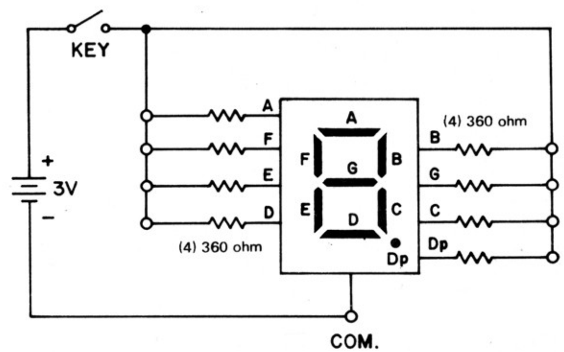
Demonstrate the fast LED action to yourself as follows. Hook up the circuit but do not close the Key. Decrease the surrounding ambient light to a very low level so that any LED light emission can be easily seen. Now close the Key for only a fraction of a second. Notice that the display goes quickly on 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 that of the LED light, 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



32. TRANSISTOR CONTROL SWITCHING OF (LED) DISPLAY

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

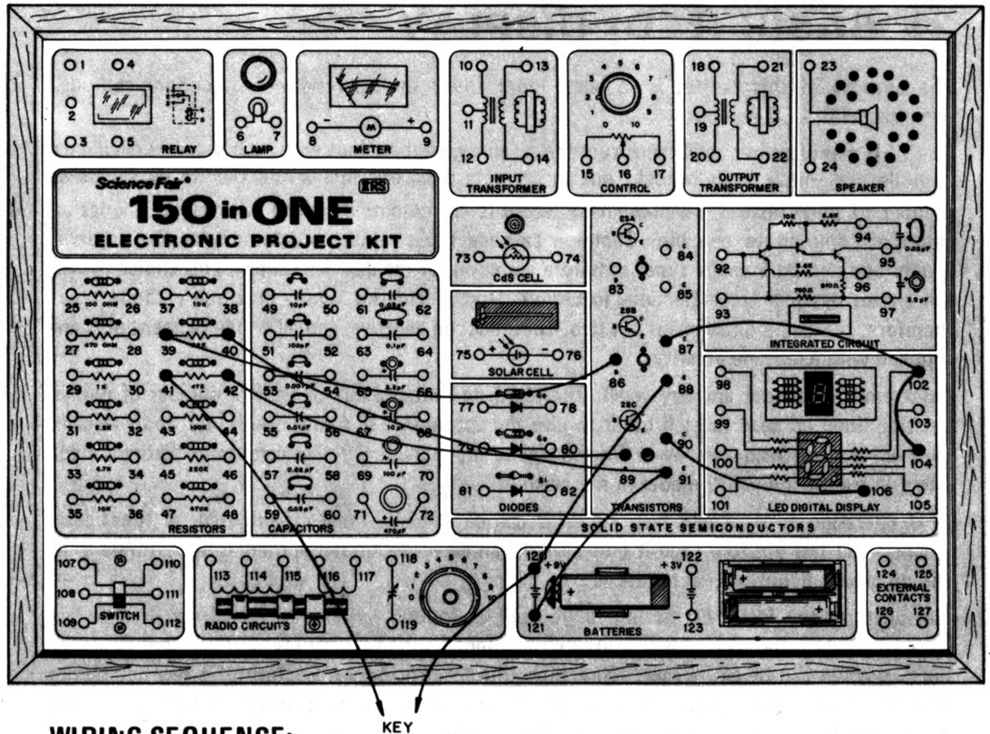
First of all notice the similarities of this circuit with the circuit of Project 79. The only difference between these two circuits is in the placement of the switch. This project has the switch in the base circuit of the NPN transistor to control the common cathode input to the LED. This then may be viewed as cathode control of the LED, whereas, Project 79 is anode control.

The 22K resistor turns the PNP transistor "ON" at all times, whereas the 47K 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.

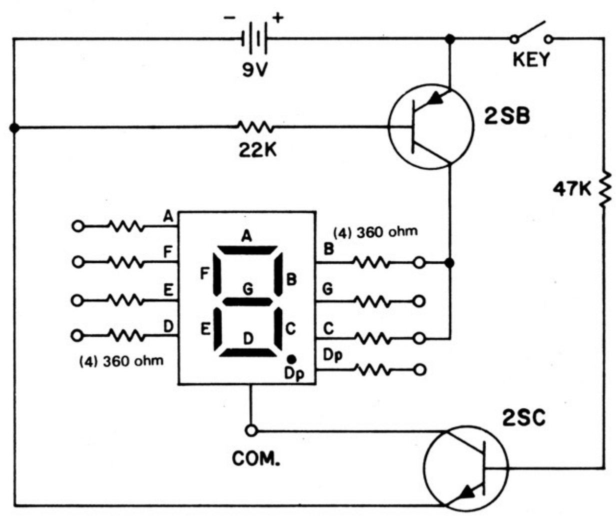
Have you noticed up to this point that the transistors switch on and off as fast as the switch itself? This is a characteristic of transistors which allows computers to perform operations at such a high rate of speed. Transistors are many times faster than relays or hand operated switches. Other experiments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

NOTES



WIRING SEQUENCE:

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



33. TRANSISTOR, PHOTOCELL AND LED DISPLAY CIRCUIT

The purpose of this project is to learn how a bipolar transistor and photo cell can be used to turn on a readout device.

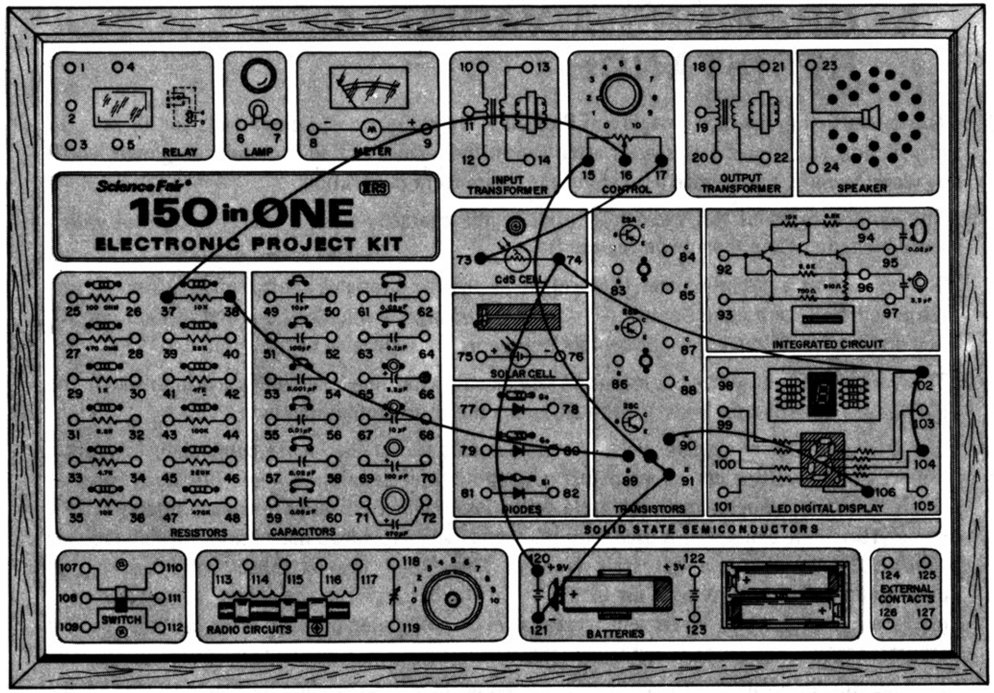
The cadmium sulfide (abbreviated CdS) photo cell may be thought of as a resistor which changes its resistance due to a change in light. Its resistance in darkness is very high, usually in the range of 5 megohms; in bright sunlight the resistance decreases to 1000 ohms or less. Intermediate amounts of light cause intermediate values of photo cell resistance. You can verify this by setting your VOM to the ohmmeter function and connecting it across the photo cell before wiring the photo cell into the circuit. Different amounts of light will show 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 when full "on" only drops a few tenths of a volt. 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 photo cell, which depends on the amount of light striking the photo 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.

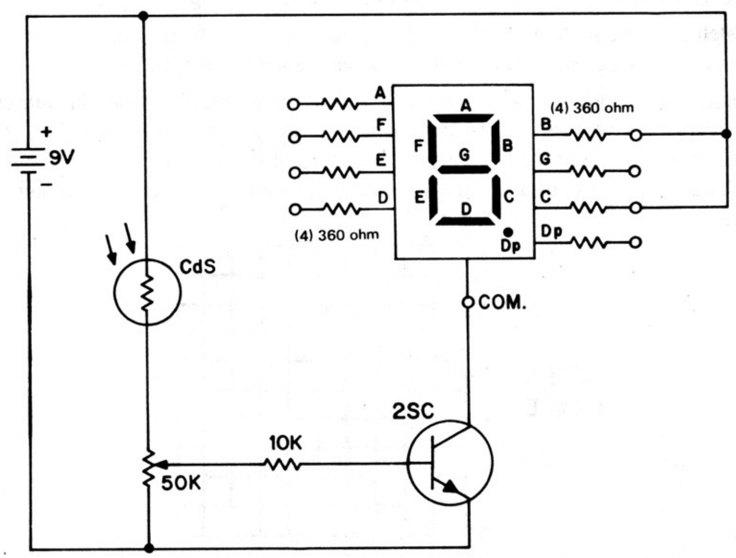
The seven-segment LED readout is shown wired to display the numeral 1 in the presence of bright light. Obviously it can be wired to display any desired character. At this time we might consider the 1 a binary digit which stands for a logic "high" to indicate the presence of a high level of light on the photo 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



34. 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.

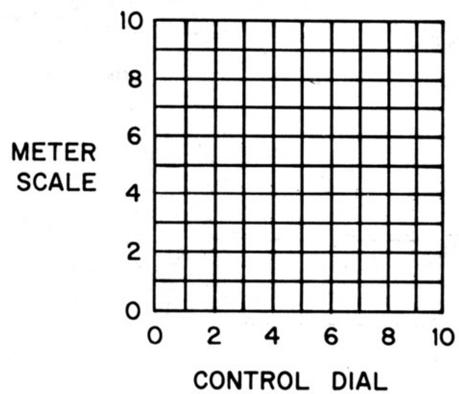
The purpose of a potentiometer (Control) is to provide a variable control of an output voltage (obtained from across the Control – between the adjustable wiper and one end of the Control). The arrow head on the schematic symbol represents the adjustable wiper.

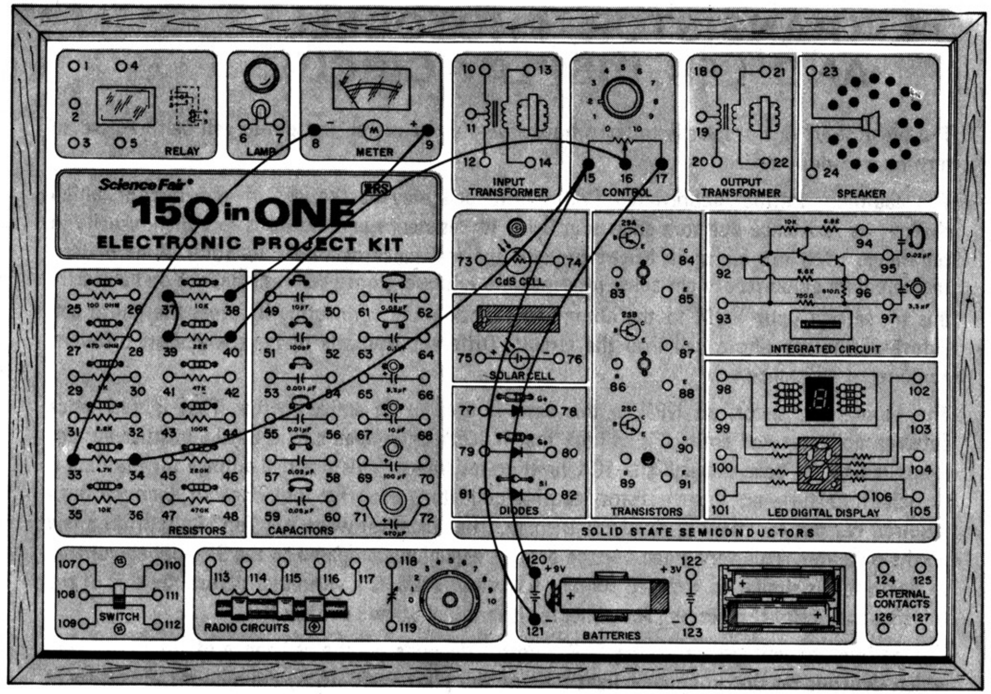
This variable output voltage is measured with a voltmeter (made up with parts in this kit). The 9V Battery is used as the constant voltage across the entire potentiometer.

The DC voltmeter as 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 top (blue) Meter calibration marks are used for this Meter when used as a DC voltmeter because these calibrations give accurate results in terms of actual DC voltage.

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.

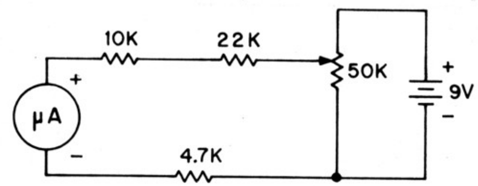
The potentiometer included with this kit typically has a smooth change in output between about 1 and 9 on the dial. The change in output is nearly a straight line. This straight line output is characteristic of a LINEAR potentiometer. Other potentiometers are available with other than a straight line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



35. RESISTORS IN SERIES AND PARALLEL

The purposes of this project are to study basic series and parallel connected resistors and to consider a shunted 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 250 μA (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 meter when shunted (or "paralleled") with the 50K as shown in the schematic diagram.

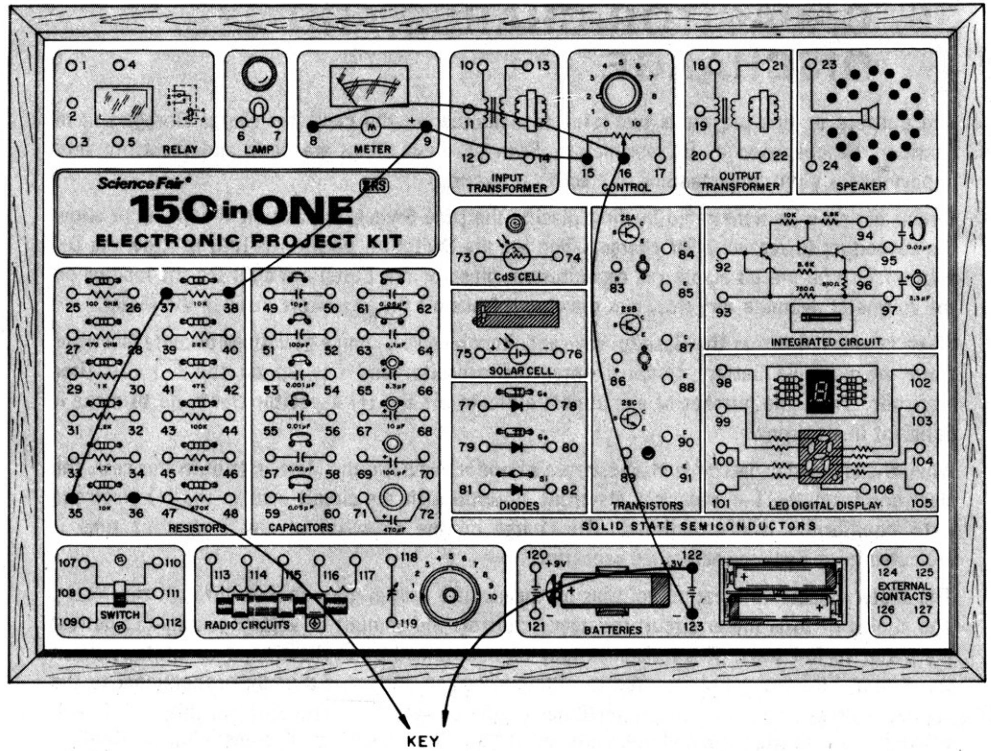
1. If the Control is adjusted for zero ohms across the Meter, it would act as a short circuit allowing almost unlimited current to flow before the Meter needle could reach full scale.
2. If the Control is adjusted for 650 ohms (equal to the meter resistance), it would pass the same amount of current as the Meter. A 250 μA meter current and 250 μA shunt current would result in a total of 500 μA. Full scale meter readings at this time then represent a total current flow of 500 μA.
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 250 μA 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 lets 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 $R_T=R1+R2$ 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   on the blue meter scale (4 is typical and expected).
3. Parallel the 10K resistors and measure the current. Current is   on the blue meter scale (8 is typical and expected).

Now lets consider the implications of the above tests. Series connecting resistors increases the resistance and decreases 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 above (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 R_{eq} when two resistors are connected in parallel is:

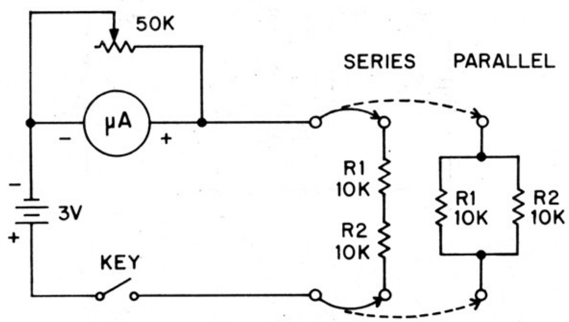
$$R_{eq} = \frac{R_1 X R_2}{R_1 + R_2}$$

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



36. 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.

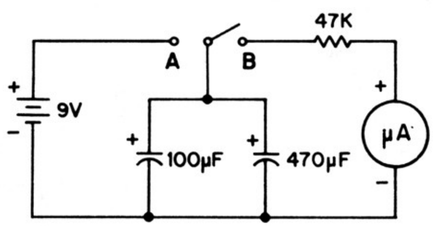
When connected across the Battery, the capacitors receive a charge of voltage because electrons from the negative Battery terminal enter the capacitor and pile up on the (–) capacitor electrode. The same number of electrons are drawn off the (+) capacitor electrode to make it deficient in electrons.

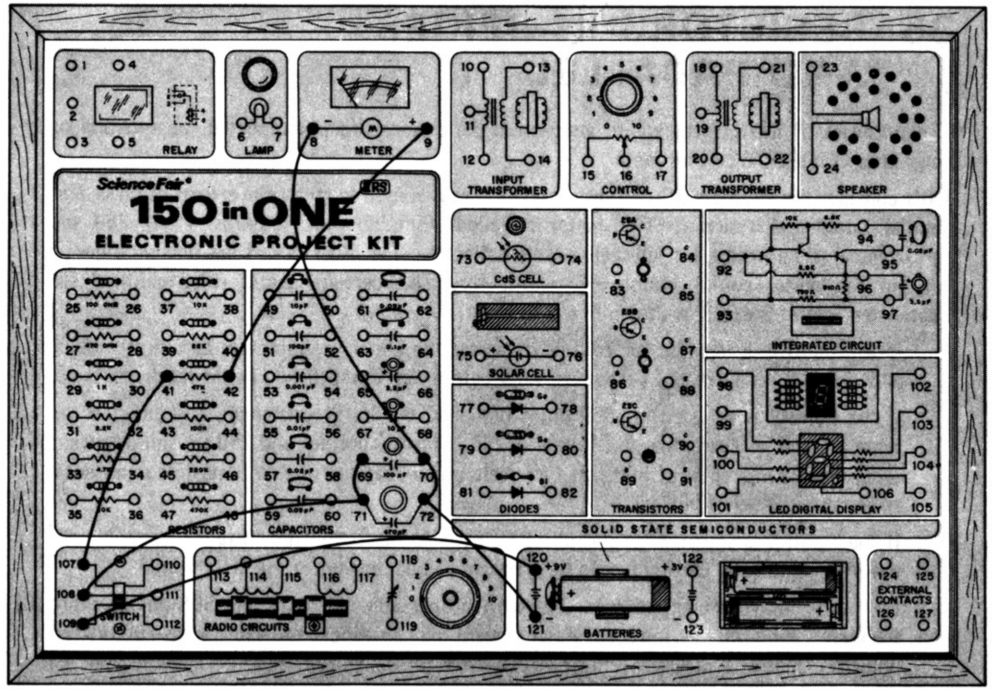
When the charged capacitor is placed across a conductive path, the Meter circuit in this case, the electrons from the (–) capacitor electrode flow through the circuit over to the (+) electrode until equilibrium is re-established. The charge on the capacitor at any instant of time is indicated by the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

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 that, "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 $R=E \div I$, where if we use volts for E and mA (milliamps) for I, the answer is in K ohms (ohms X 1000).

If we want a 10V Meter – the Meter in this kit requires a current of about 0.25 mA for full scale, the resistance is $10V \div 0.25\ mA = 40K$. There doesn't happen to be a resistor of this value in the 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.

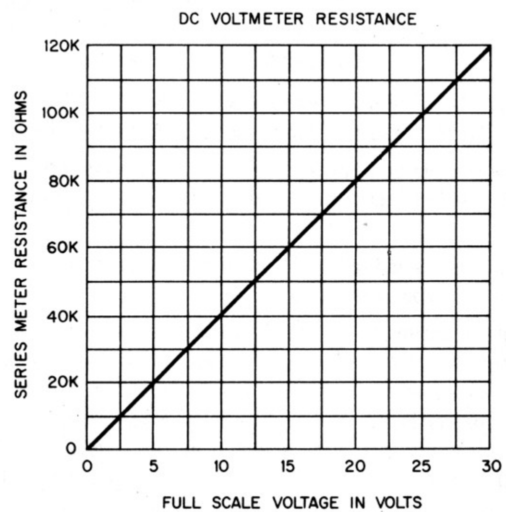
You can use the graph to construct other voltmeter ranges by using the series resistances indicated. You can use separate series resistors to obtain resistance values other than those incorporated in this kit. Remember, series resistor values are added together to determine the total resistance.





WIRING SEQUENCE:

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



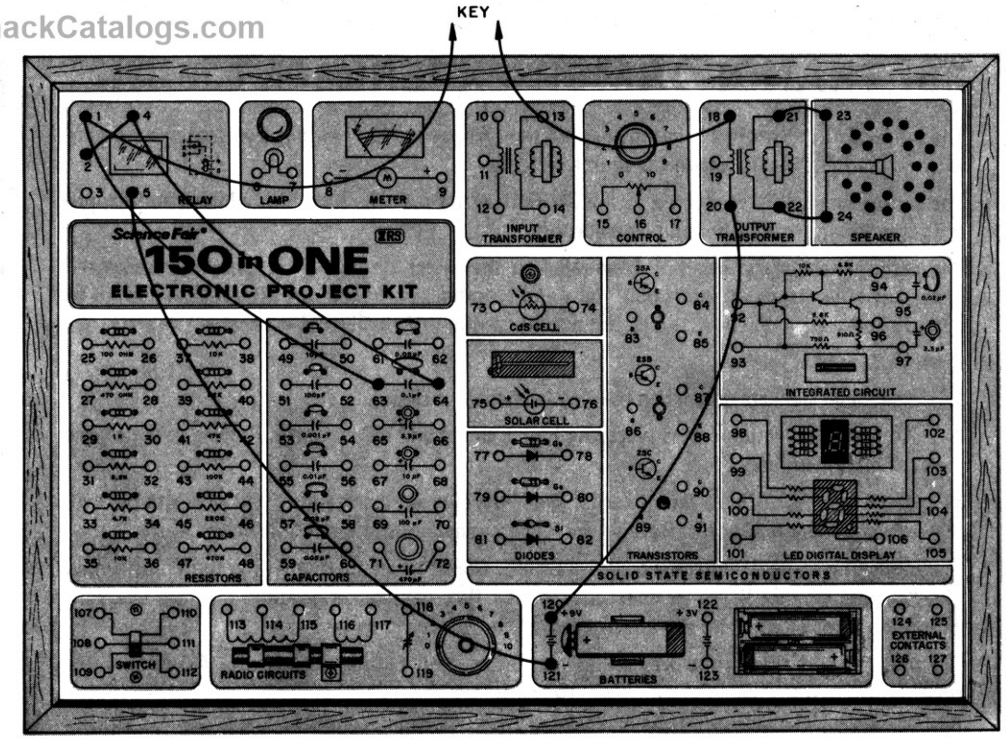
37. CAPACITOR AS A SPARK SUPPRESSOR

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 number 118, 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 which could be heard in 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 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.

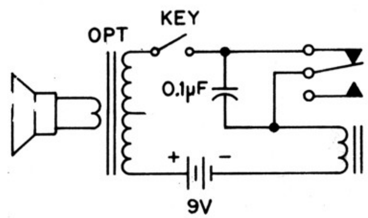
Connect up the circuit and close the Key a few times to listen to the sound. Now disconnect the lead from terminal 64 and close the Key a few times. The sounds you hear should be distinctly different. The original sound, with the capacitor, should be low in pitch and mellow. Without the capacitor it is raspy and higher in pitch. The difference in tone is a direct result of the change in waveform of 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, Key-1-63, 20-120, 64-4-2, 5-121

NOTES



38. 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 0.25 mA (250 μA) of current to obtain a full-scale deflection, this circuit acts like a 400 mV (millivolts) voltmeter.

Circuit action is as follows:

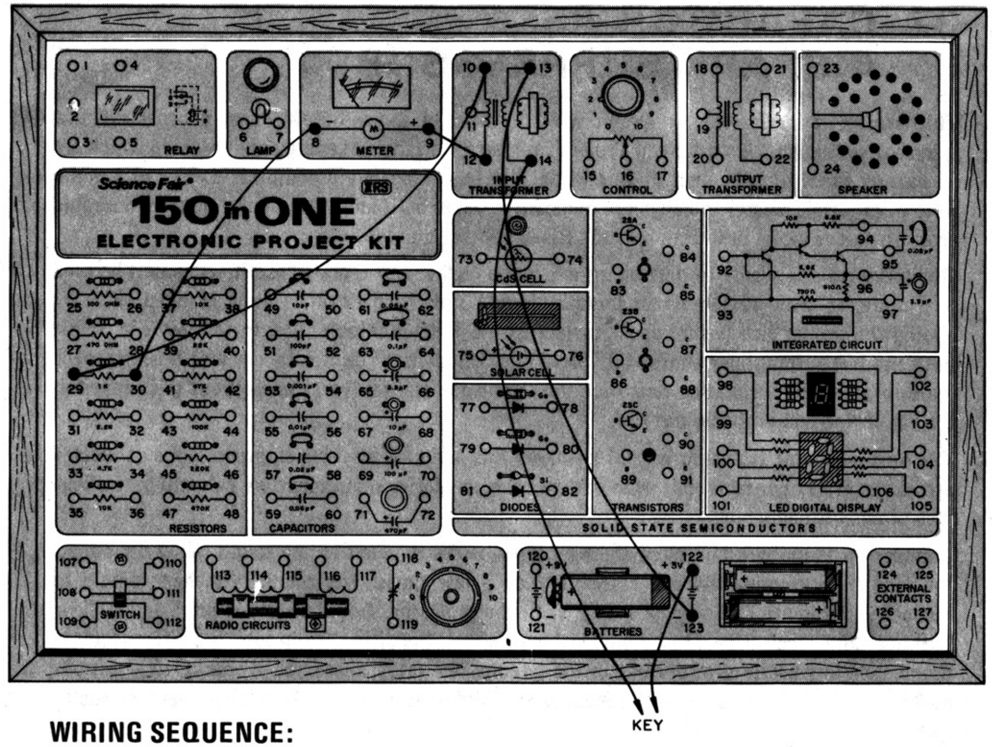
1. The Meter deflects only when the Key is opened or closed.
2. No Meter deflection occurs when the Key is closed and DC current is flowing in the source (primary) winding.
3. Meter deflection is in one polarity when the Key is closed and in the opposite polarity when the key is opened. (Reverse the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

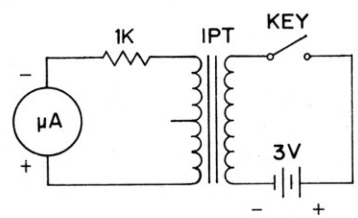
Can you think of a component that DC can pass through efficiently while AC is virtually stopped or choked off?

NOTES



WIRING SEQUENCE:

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



39. 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.

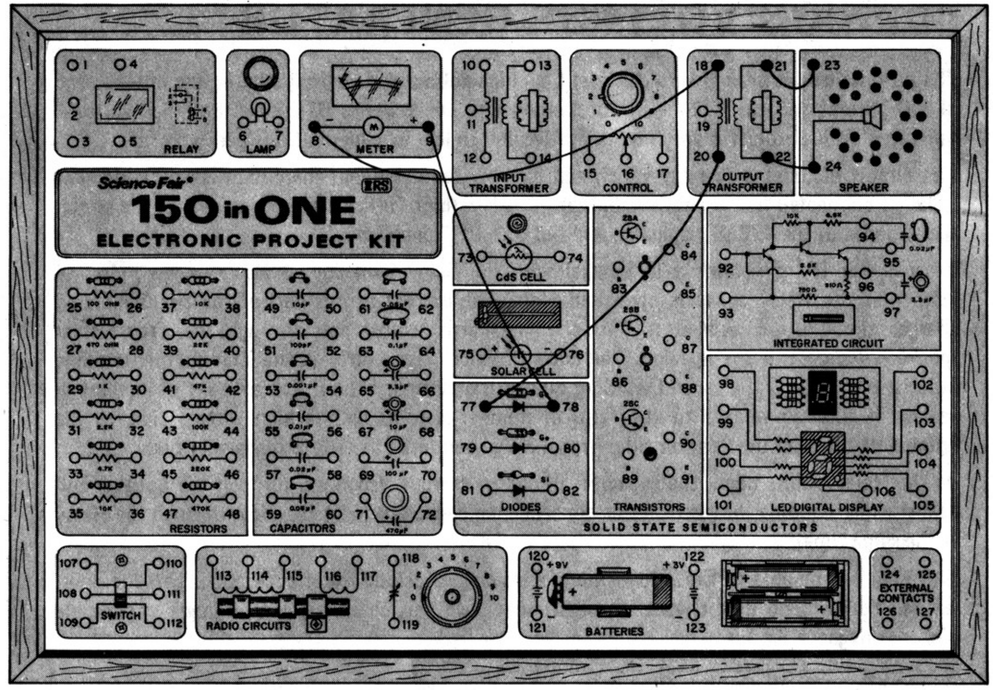
Generation of electric current: The Speaker may be used for the generation of electric current because it has the required parts, a magnetic field and turns of wire which can be made to move within the magnetic field. The turns of wire which are connected to the speaker cone are made to move back and 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 which is not connected to it except through the 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).

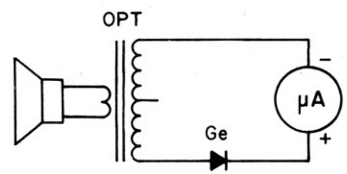
d'Arsonval meter operation: The Meter is similar to the speaker in basic theory of operation. The Speaker has a paper cone which is connected to a coil which moves in a permanent magnet field – whereas the Meter has a pointer which is connected to a coil which moves in a permanent magnet field. As current 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



40. HIGH VOLTAGE GENERATOR

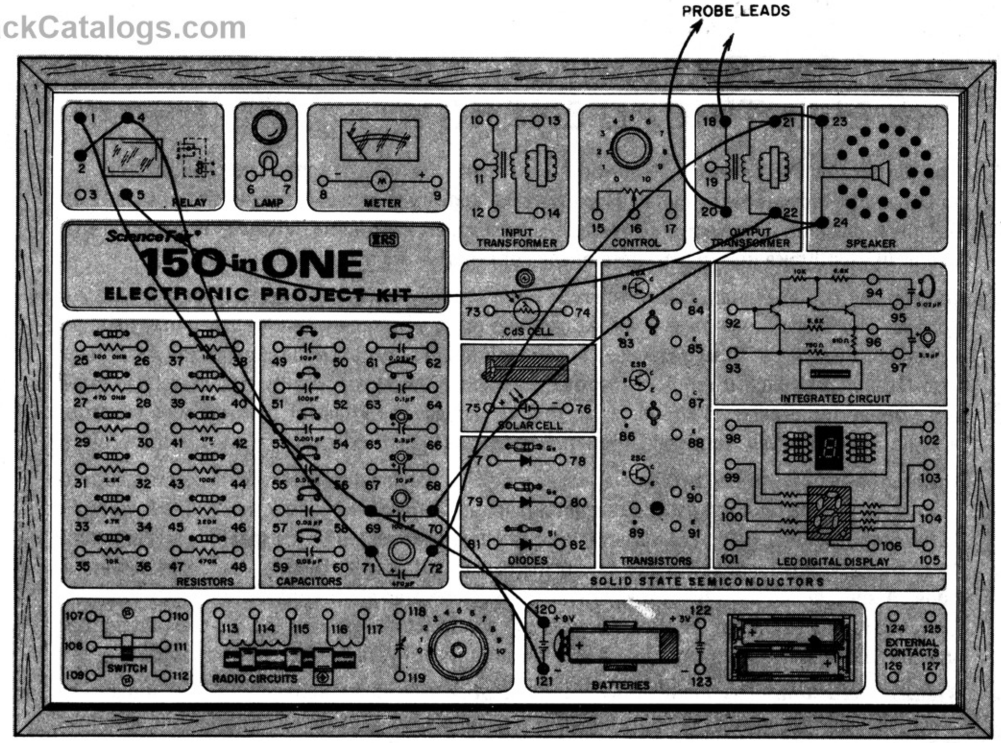
The purpose of this project is to consider how high voltage can be generated by the interruption of DC current such as is done in automobile ignition systems. Of course the "high voltage" generated in this project is only representative and so low in value that it is perfectly safe.

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 470 μF 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 470 μF capacitor. This charging current must pass through the Transformer speaker-winding and the Speaker. The current which passes through the Transformer winding induces a voltage in the second winding due to 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 also flow through the Relay at the same time.

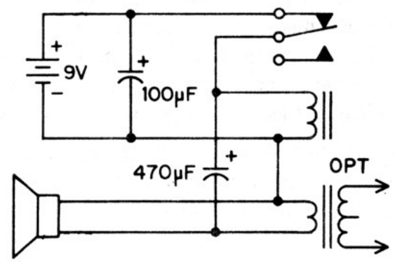
This may not be able to fire a spark plug or cause a shocking experience but it gets the point across. You will no doubt want to experiment with this circuit. It can be made to generate higher voltages. Have fun!



NOTES

WIRING SEQUENCE:

23-21-72, 5-22-24-70-121, 2-4-71, 1-69-120, 18-Probe, 20-Probe



41. HIGH DC VOLTAGE GENERATOR

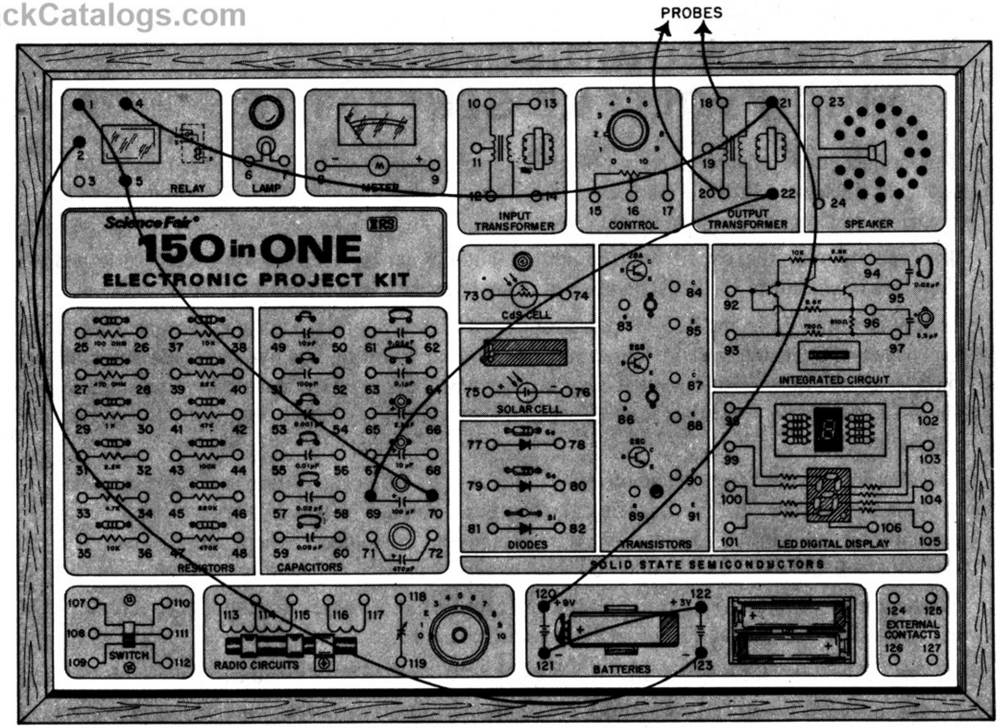
This project is to demonstrate how high voltage can be made from a 12V battery. This is done in your automobile to fire the spark plugs. It is done on the farm to electrify fences so that cattle and hogs will stay within bounds.

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.

For this circuit both Batteries are connected in series to obtain a total voltage of 12 volts. The Relay is connected like a doorbell buzzer to obtain square-wave pulses of DC voltage across the series connection of the 100 μF 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.

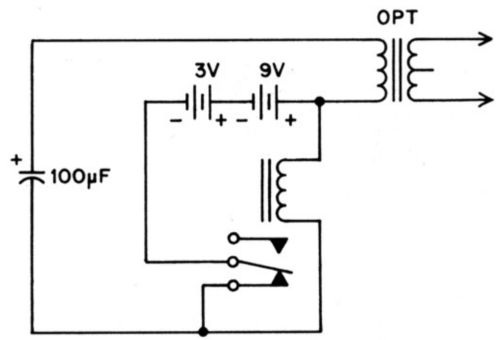
Because of transformer action the change of primary current generates a voltage in the secondary winding of the Transformer. The secondary winding has more turns than the primary winding (as used here) so the induced voltage is higher than the primary voltage of 12 volts.

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!



WIRING SEQUENCE:

120-21-4, 1-5-70, 69-22, 2-123, 121-122, 20-Probe, 18-Probe



NOTES

42. CAPACITOR DISCHARGE HIGH VOLTAGE GENERATOR

This project shows how single pulses of high voltage are generated when a charged capacitor is suddenly discharged through the low-voltage windings of a Transformer. This action is used in capacitor-discharge automobile 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 470 μF 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).

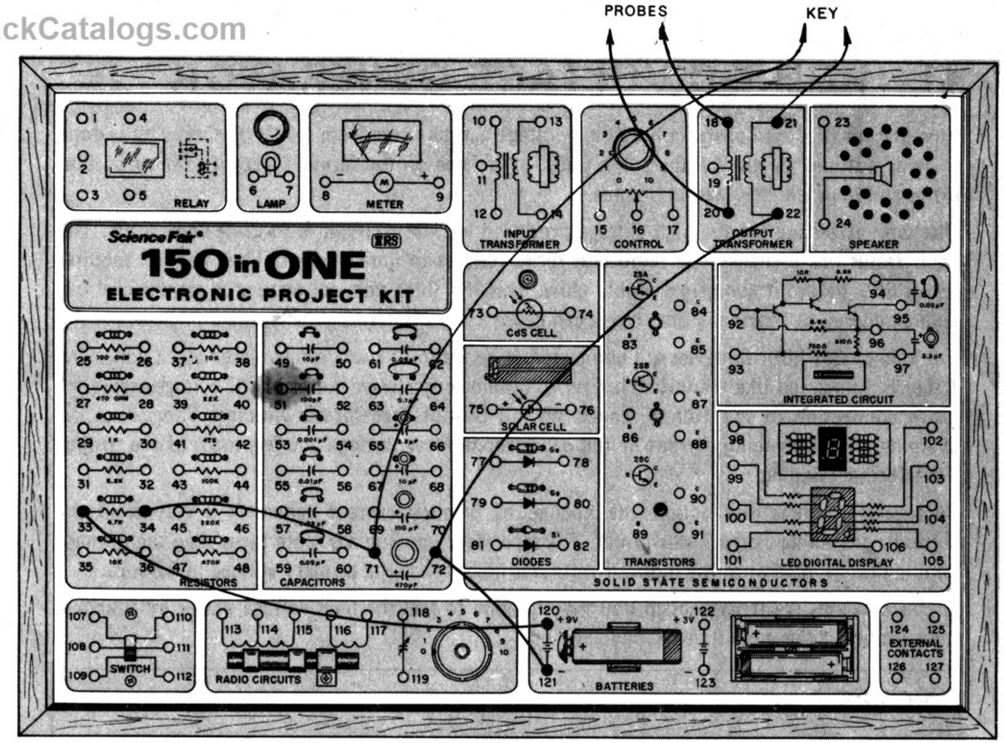
To determine the charge, Q, you multiply the capacitance, C, times the voltage, E, across the capacitor. Q = CE. For the 470 μF at 9V this is calculated as:

$$Q = CE = 470 \times 10^{-6} \times 9 = 4230 \times 10^{-6} = 4.23 \times 10^{-3} \text{ coulombs}$$

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 greater. This is possible because the neon lamp requires at least this voltage before it will ionize and give off light.

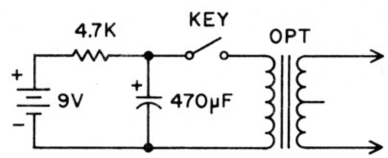
NOTES



WIRING SEQUENCE:

Key-21, Key-71-34, 22-72-121, 33-120

18-Probe, 20-Probe,



43. 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 review the operation of a DPDT switch hooked up as a three-way switch.

Basic circuit operation is as follows. A 3V Battery is connected through a 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 a 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.

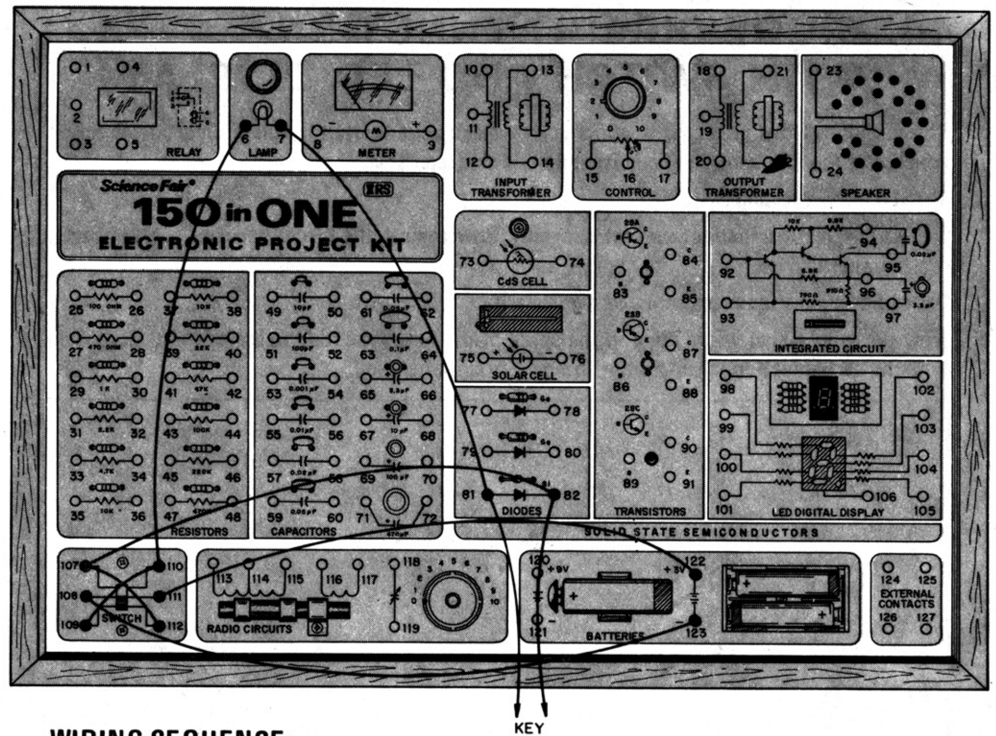
This basic property of a Diode has been known longer than what electric current is actually composed of. Because of this condition the diode symbol was originally drawn with the arrow pointing in the direction of the **supposed** direction of unexplained current flow. We now know that electric current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

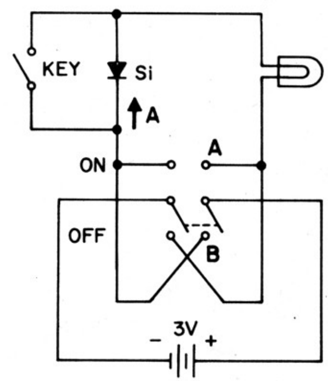
The polarity-reversing connections as used with the DPDT (double pole, double throw) switch are the same as used in 3-way switches used in electrical wiring around the house.

NOTES



WIRING SEQUENCE:

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



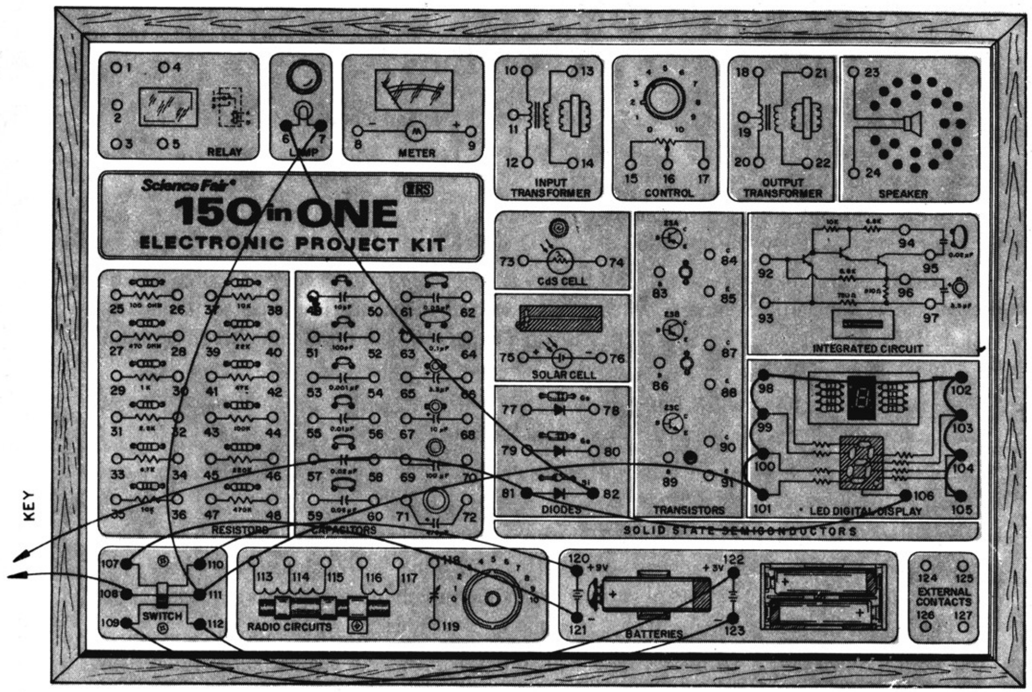
44. DIODE CIRCUIT FUNCTION WITH SWITCH AND LED DISPLAY

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

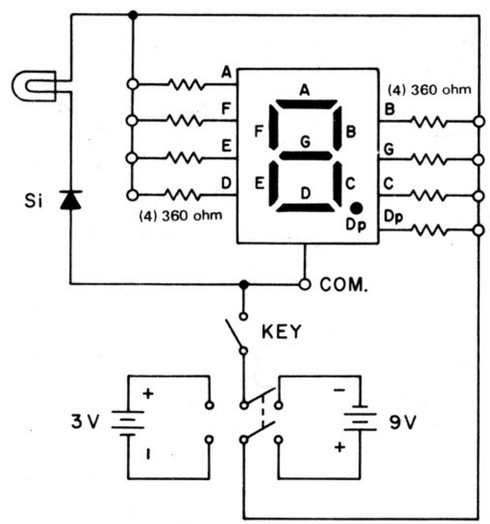
Now use your pencil and outline in the space below how the circuit operates and then explain how the parts function to obtain the observed circuit operation.

NOTES



WIRING SEQUENCE:

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



45. 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 control or produce a large signal.

This project demonstrates two methods of transistor control. One method involves removing the bias by shunting. 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).

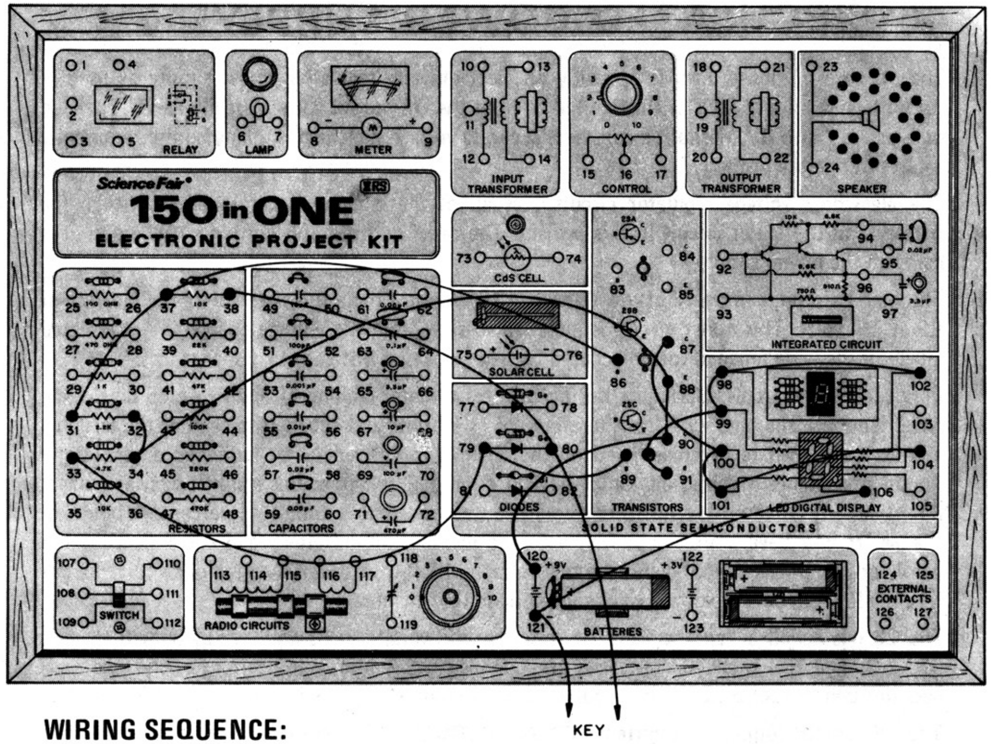
Circuit operation is as follows. With the Key open, the 2SC is full On because of base-bias current which flows through the 4.7K current limiting resistor. This turns the LED top segments (A, F and B) ON. At this time the 2SB is OFF because no base-bias current can flow. Recall that a negative base current source is required for a 2SB because current must always flow against the arrow head symbol in a transistor. Any current which would 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 2SB is turned ON at this time because of the base-bias current which can flow through the 10K to the base. This lights LED segments E, D and C.

The 2.2K resistor is needed to completely cut off the 2SB when the Key is up. Without this resistor the transistor leakage (I_{CEO}) which flows is sufficient to dimly light the LED segments driven by this transistor. You may remove one connection to this resistor to verify this action.

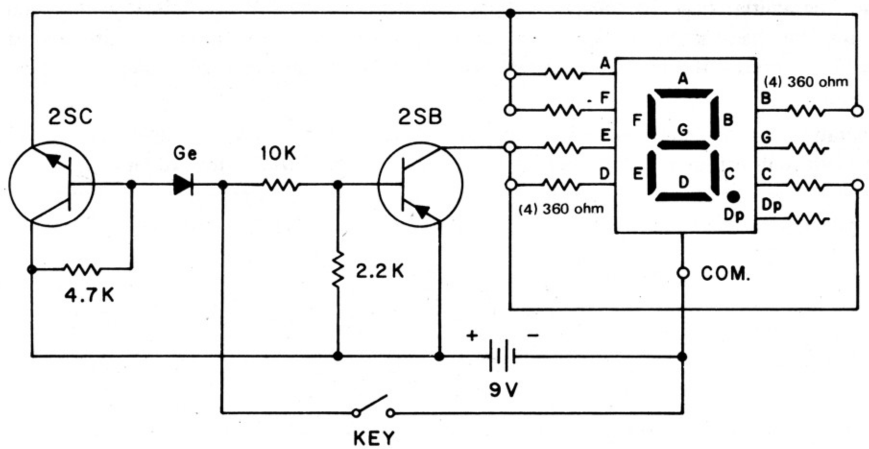
To verify the action requirements of the diode, try circuit operation with the diode replaced with a short circuit and then with an open circuit. Describe the results in the space below.

NOTES



WIRING SEQUENCE:

104-101-100-87, 102-98-99-91, 89-79-33, 86-37-31, 106-121-Key, Key-80-38, 32-34-88-90-120



46. 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 output 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 the wide range of loading caused by using the four different load resistances.

Connect up 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.

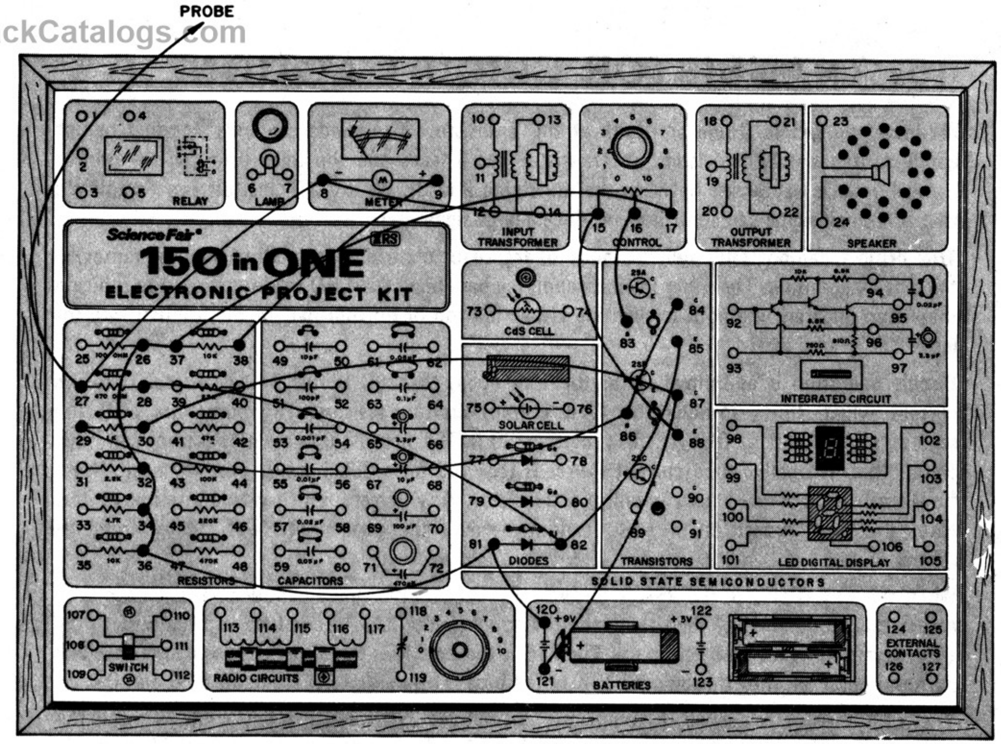
The 2SA is called a "comparator." It compares the voltage at its emitter (E) with that at its base (B). The 2SB is called the "series pass" Transistor because all the current of the load must pass through this series device from collector (C) to base (B).

The 1K resistor supplies the current to bias the 2SB. More current flows than what is required so that the 2SA 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.

Operation is as follows for a condition of heavy loading which would tend to pull the output voltage **down**. The 2SA base would tend to go **down**, but because the stage is operating as a common emitter stage, its collector voltage, and therefore the 2SB base voltage, would tend to go **up**. Now because the 2SB 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 output remains about constant.

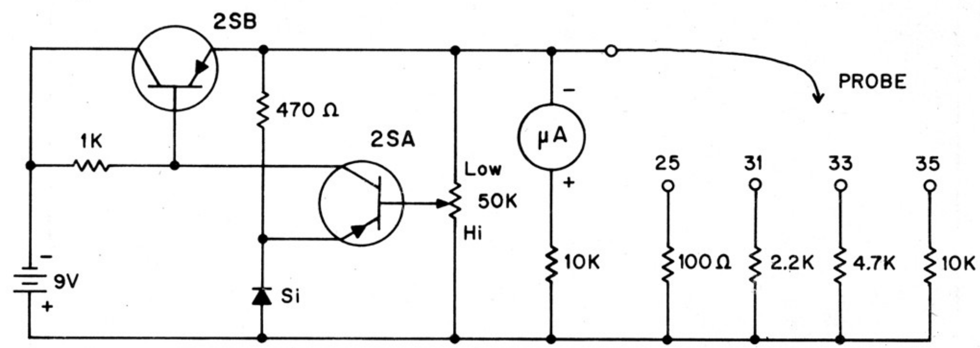
Operation for the condition where the output tends to go **up** due to light loading, is the opposite in direction of change, but the same in effect – stabilized output voltage.

NOTES



WIRING SEQUENCE:

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



47. 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 10 μF capacitor, a Transistor and a 50K potentiometer. 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. These are:

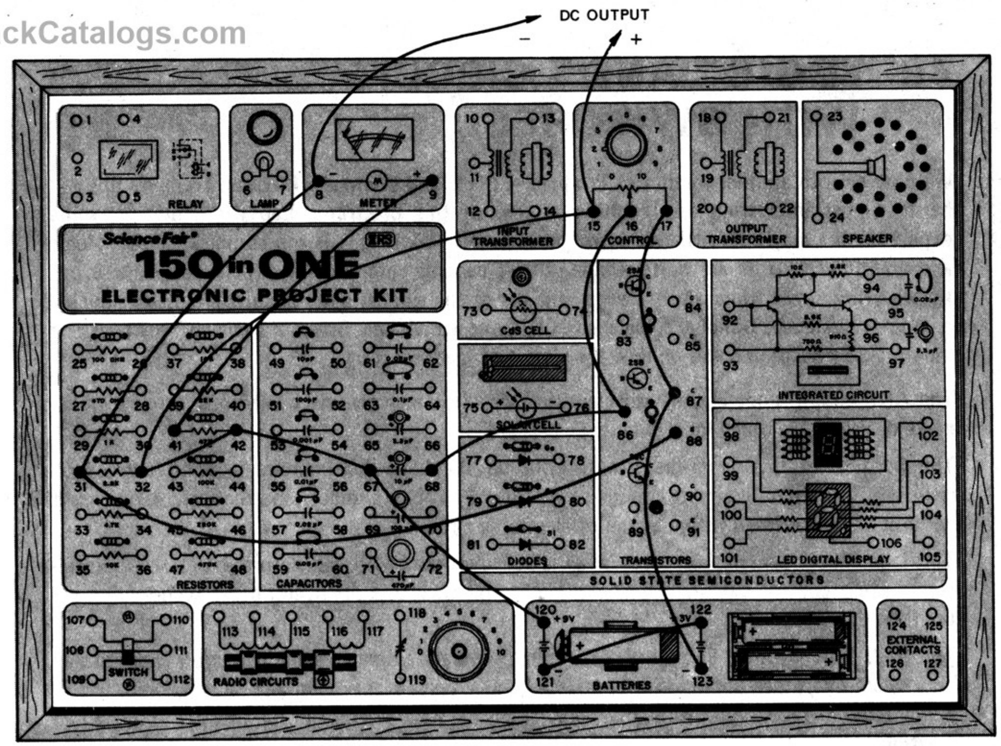
1. Base current is always much less then collector or emitter current, and is the controlling factor over how much collector current can flow. Recall the gain factor **beta** is the ratio of collector current I_C to base current I_B and is typically greater than 20.
2. Base-emitter (B-E) voltage is relatively constant and low in value. This is typically about 0.2V for germanium and 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 then, 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 this circuit is limited to about 50 mA, so be careful what you try to power with this circuit. The normal supplies like this use power transistors in order to handle higher load currents and power.

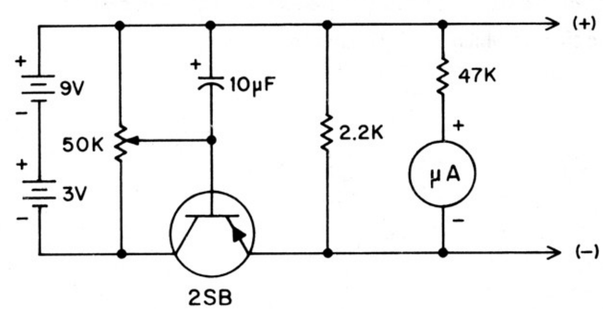
NOTES



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



48. LOGIC "AND" CIRCUIT WITH SWITCHES

We now go into another section of Projects – **Logic and Computer Circuits.** To many 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 which 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 which can make decisions. Circuits which 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 with a bunch of 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.

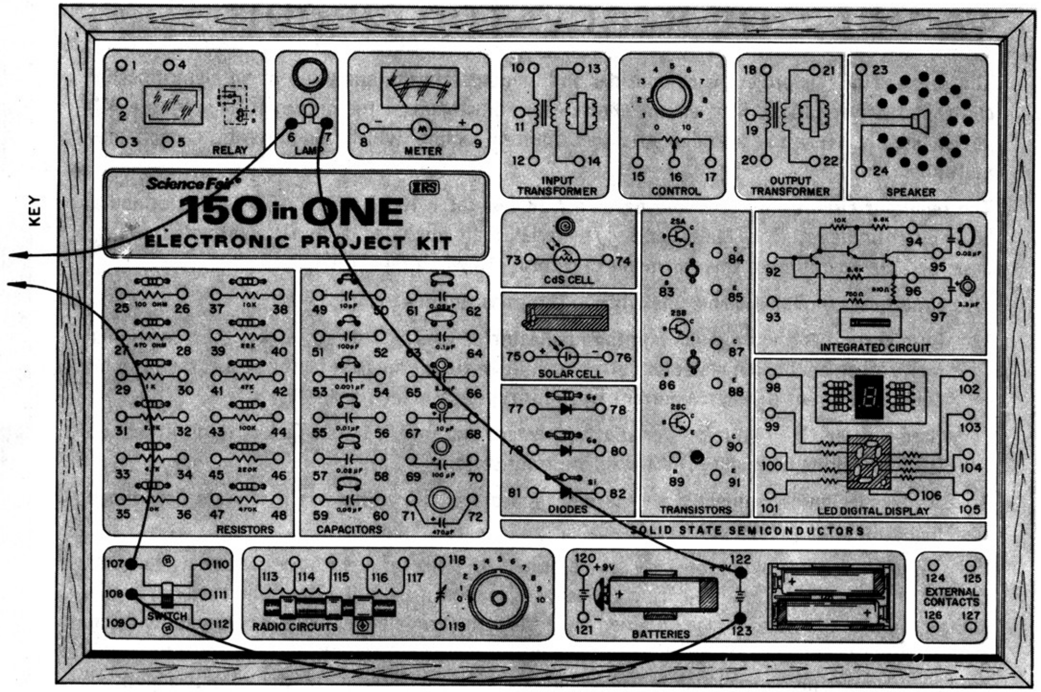
The AND function may be defined as a control system where a certain function is performed only when one other operation is completed **and** a second operation also is completed. In this demonstration the Lamp is turned ON only when the slide Switch **and** the Key are in the closed position.

The basic definition of the AND function does not have to be limited to two operations. We could have a large number of additional switches in series. The circuit would still be an AND circuit.

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, or in the case of more than two switches, **all** must be closed.

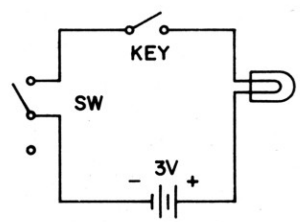
In electric AND circuits like this you should remember that the AND circuit is a **series** circuit. This is in contrast to the logic OR circuit where all switches are in **parallel.**

Can you list some circuits which are AND circuits?



WIRING SEQUENCE:

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



Now refer to Project 52 for additional material on the logic AND function.

49. LOGIC "OR" CIRCUIT WITH SWITCHES

The purpose of this experiment is to consider the logic OR circuit – constructed 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.

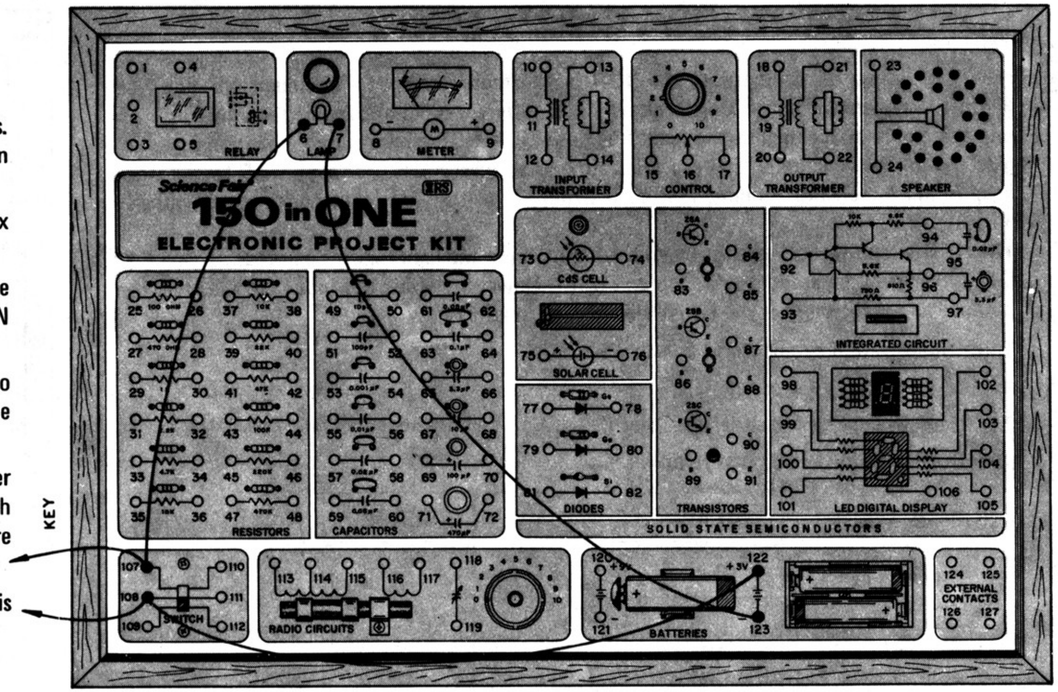
Notice that we could parallel any number of switches for the logic OR function. It is also important to notice that the OR circuit uses **parallel-connected** switches as contrasted with the AND circuit which uses **series-connected** switches.

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 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.

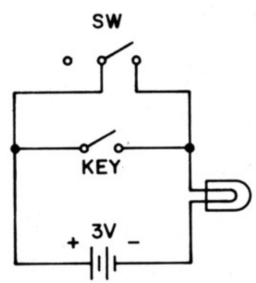
A	B	LAMP
L	L	L
L	H	H
H	L	H
H	H	H

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



WIRING SEQUENCE:

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



Now see Project 53 for additional material on the logic OR.

50. LOGIC "NOR" CIRCUIT

Here is a Project to demonstrate the NOR logic circuit (the next experiment will give you another – remember our comments about many different types of circuit configurations, each one being able to accomplish the same function ...). A NOR circuit is a combination of an OR gate 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).

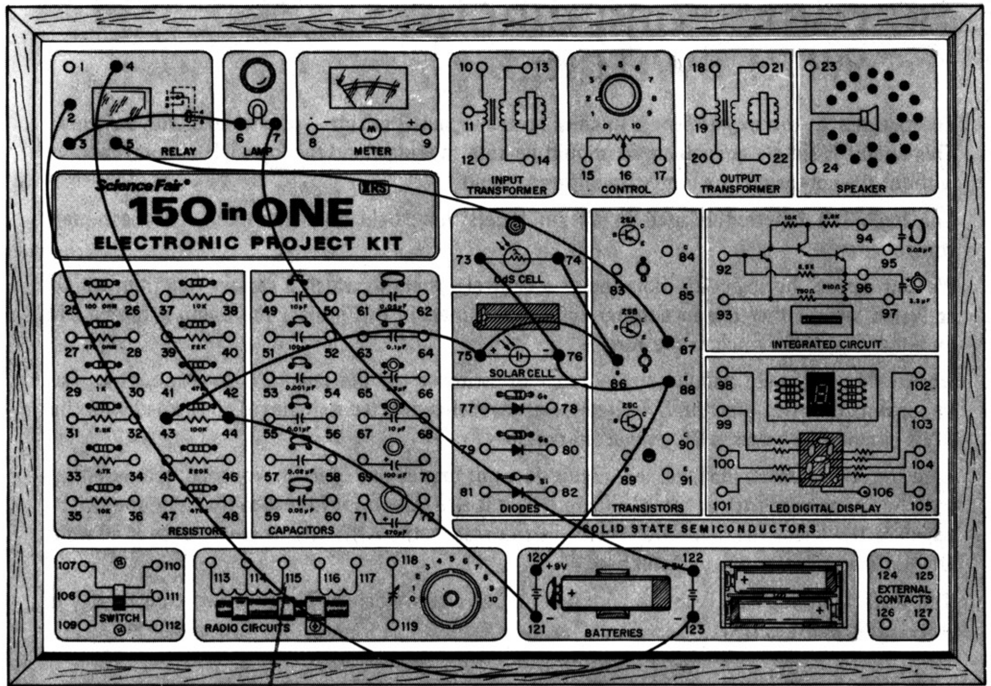
The NOR circuit works like this: When there is no input (no light falling on both Solar and CdS Cells), there will be an output (Lamp will light). However, neither one input **nor** the other can produce an output (neither can both inputs). Confusing? Try it.

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

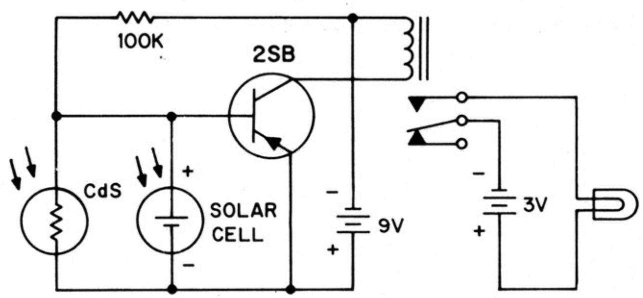


WIRING SEQUENCE:

122-7, 6-3, 2-123, 87-5, 74-86-75-43, 73-76-88-120, 4-44-121

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

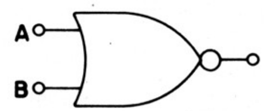
A	B	OUTPUT
L	L	H
L	H	L
H	L	L
H	H	L



The Solar Cell turns 2SB OFF when light hits it because it generates voltage which opposes the normal ON base-bias obtained from the 9V Battery through the 100K. The CdS Cell presents a shunting resistance to this bias when light is present.

Now you will want to compare this circuit with the NAND circuit of Project 54.

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).



SYMBOL

51. LOGIC "NOR" CIRCUIT

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 negated).

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.

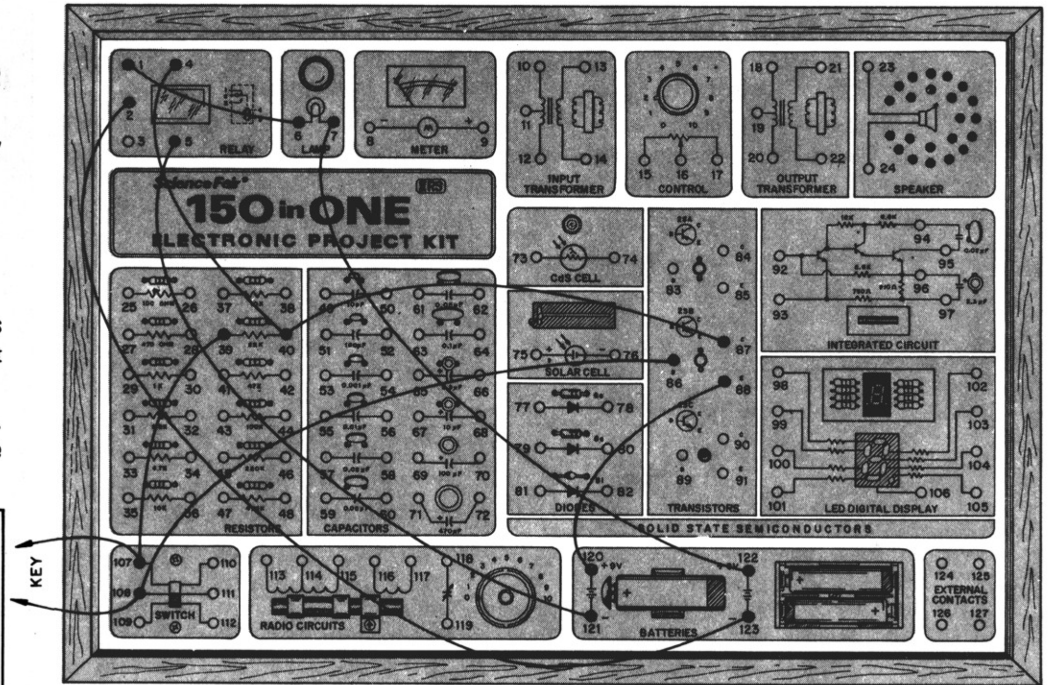
The circuit operates as follows:

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 accomplishes 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.

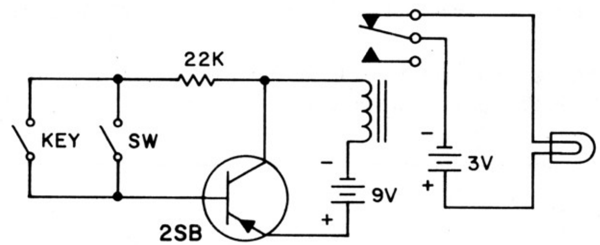
The NOR truth table and additional discussion on the NOR function are included in Project 55. Before you refer to that Project, can you reproduce the truth table for the NOR function in the space below all by your self?

NOTES



WIRING SEQUENCE:

122-7, 2-123, 87-40-4, 5-121, 39-107-Key, Key-108-86, 88-120, 1-6



52. 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. These letters all have logic significance; where, A and B are the logic inputs, H is a logic high, and L is a logic low. 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 AB, or as A • B, or as A X B.

Circuit operation is as follows. Whenever either one or both inputs are on L, 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.

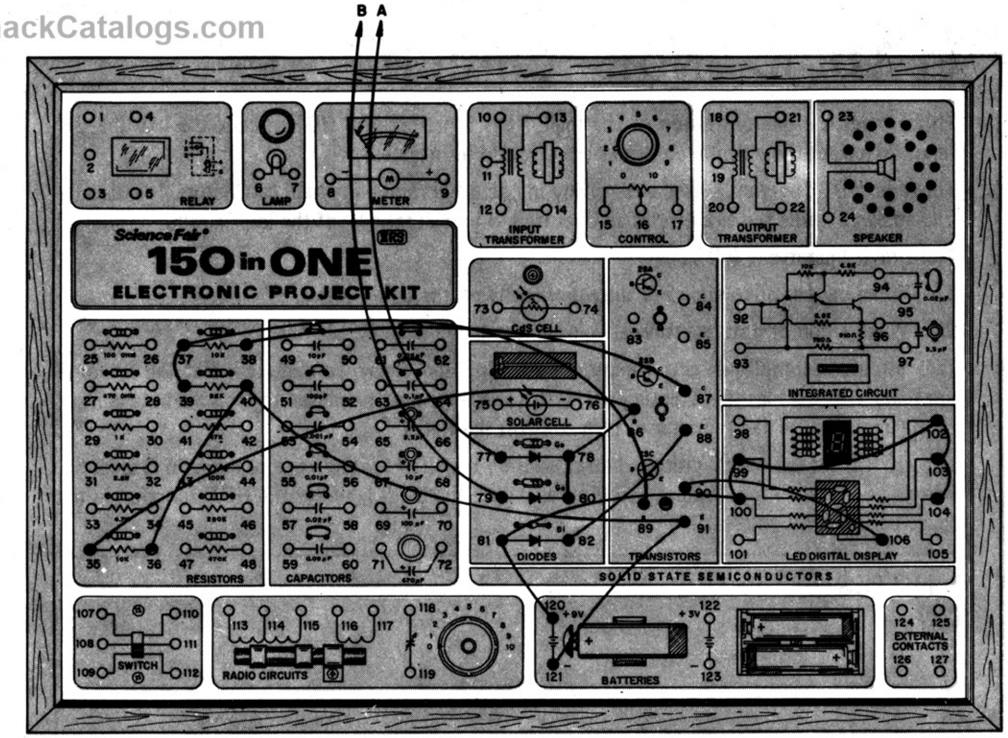
Now if both inputs are on H, both diodes are reverse-biased across the 10K resistor and perform no function. This 10K resistor provides bias to the base of the PNP to turn it full on. The NPN is also biased full on at this time with the current flowing through the 10K in its base circuit, the PNP and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

The silicon diode helps to insure that the PNP is off whenever either diode forward voltage is present at the base. The 22K resistor insures that any small amount of leakage current from the PNP in the off state is kept from turning on the NPN.

Your VOM voltmeter may be used across C and E to verify the on and off characteristics of the transistors.

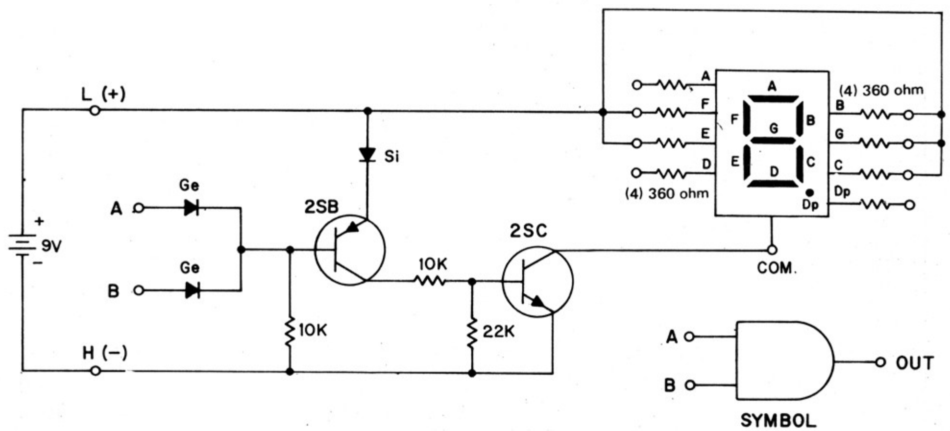
Because the two logic states are H and L, the input terminals should always be connected to one of these terminals. For this particular circuit open input terminals are the same as a high input.

NOTES



WIRING SEQUENCE:

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



53. 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. These letters all mean something in logic work; A and B are the logic input terminals, H is a logic high, and L is a logic low. 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 A + B, where the + sign is used in place of the word OR and is read as "OR".

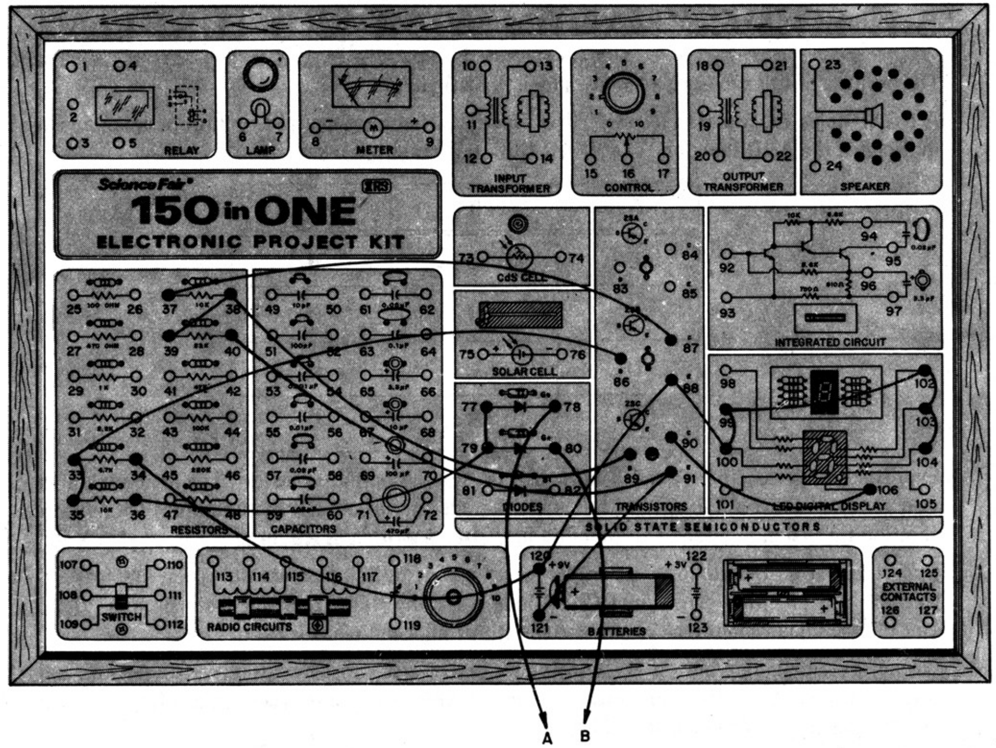
Circuit operation is as follows. Whenever both A and B are on L there is no source of base current for 2SB so it is in the OFF state. The 4.7K resistor insures that it is completely OFF by allowing C-B leakage current to flow outside the B-E junction. The 2SB when OFF presents what looks like a virtual open circuit between 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 2SB leakage current from turning 2SC ON by shunting the current around the B-E junction. The LED had 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 2SB, turning ON this Transistor. The 2SB 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 C-E 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 Diodes are in parallel. Parallel diodes act the same as a single diode.

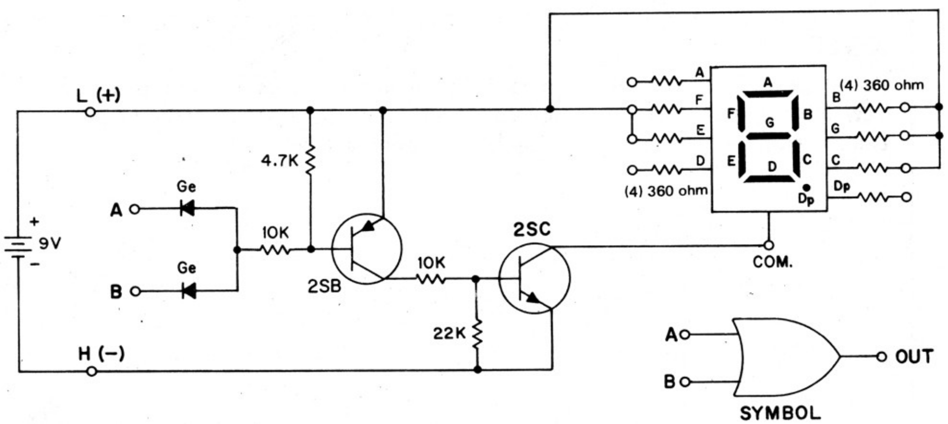
For this particular circuit an open input terminal functions the same as a logic low. This condition is not true for all logic circuits; see the AND circuit of Project 52.

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:

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



54. LOGIC "NAND" WITH LED DISPLAY

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

A NAND logic function is a negated 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

Expressed in words, both A and B must be high for the output to be low. The logic symbol is seen to be like the AND symbol but with the addition of a circle at the output to indicate negation (inversion of level). This function may also be written as $\overline{AB}$, or as $\overline{A \bullet B}$, or as $\overline{A \text{ X } B}$.

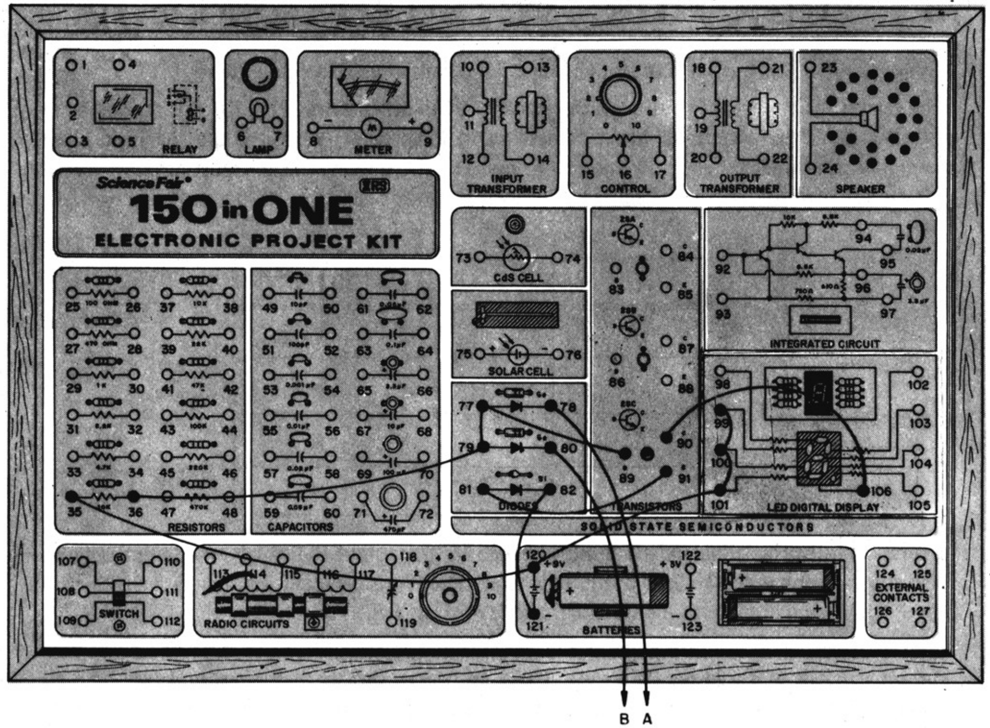
Circuit operation is as follows. Whenever either one or both inputs are on L, the low forward voltage drop of either germanium (Ge) Diode keeps the NPN Transistor from turning "ON". The LED Display cannot receive any current at this time and remains dark.

Whenever both inputs are on H, both diodes are reverse-biased across the 10K resistor and perform no function. This 10K resistor biases the NPN "ON" so that current can flow between emitter and collector to light the LED's.

As with Project 52, 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 52 this circuit has a (+) for a high (Project 52 used a (–) for a high). Either method 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".

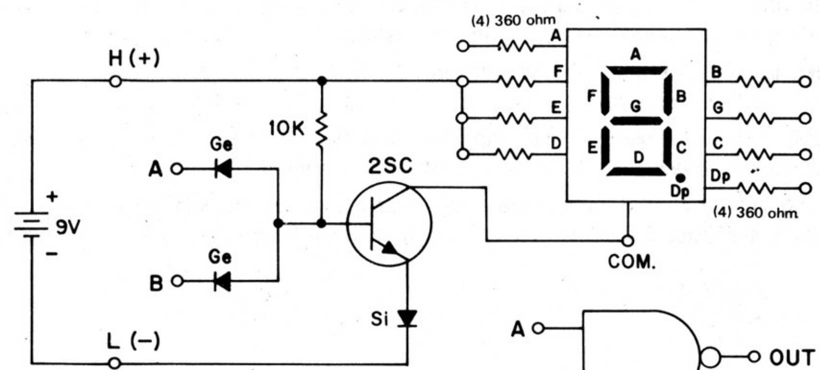
NOTES

Catch that nasty trick we played on you? High output in this case is no LED display; but Low output gives 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).



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

55. 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. 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. This output condition is the opposite of the OR circuit, so this is referred to as the "negated 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 – whenever either A or B are high the output is low. The logic symbol is also 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 negation.

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 2SC collector and emitter terminals. The LED is wired to display the letter L for low. Having both 10K resistors on H doubles the base-bias current and simply turns the transistor ON harder.

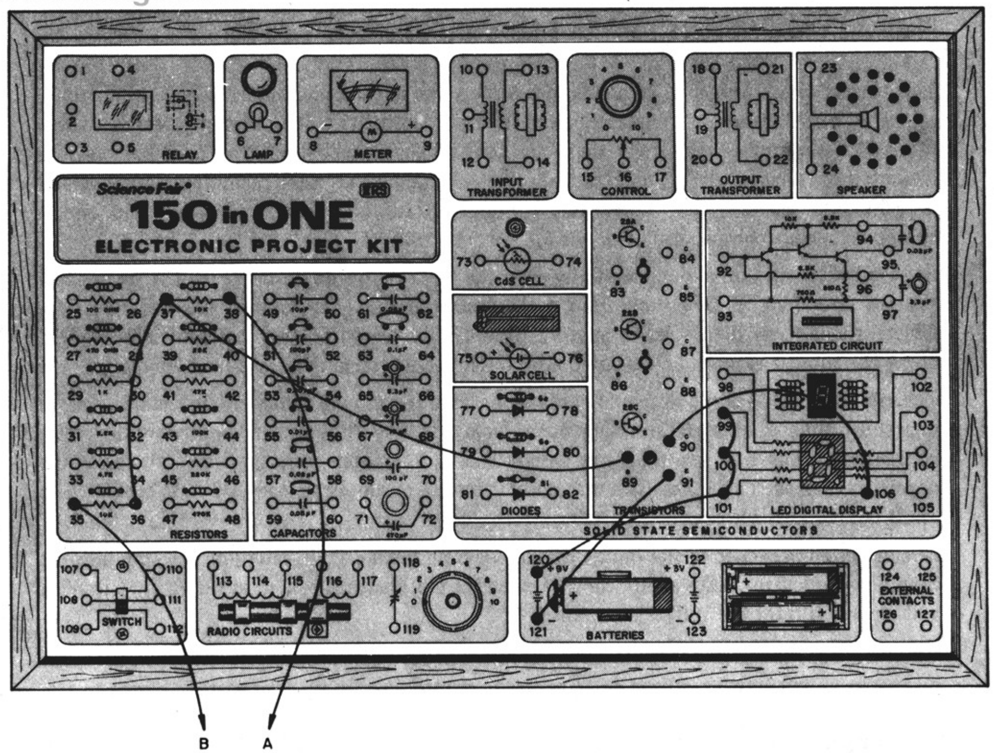
When both A and B terminals are on the negative low terminal L, the Transistor can receive no base-bias and is in the OFF state. This state causes the transistor to act as an open circuit between collector (C) and emitter (E). This virtual open circuit blocks current from flowing to the LED. The LED 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 diode 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, though that normal operation of a logic circuit is with the input always connected to either a high or a low.

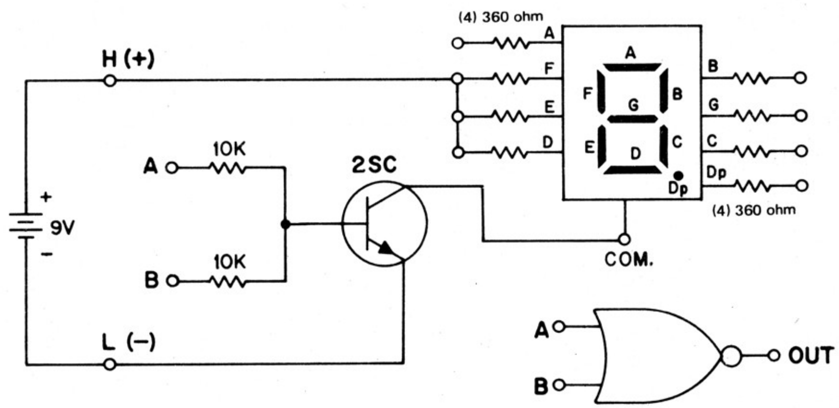
NOTES

Catch that output indication switch again? A High output is blank and a Low output is "L" 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



SYMBOL

56. ONE-SHOT MULTIVIBRATOR

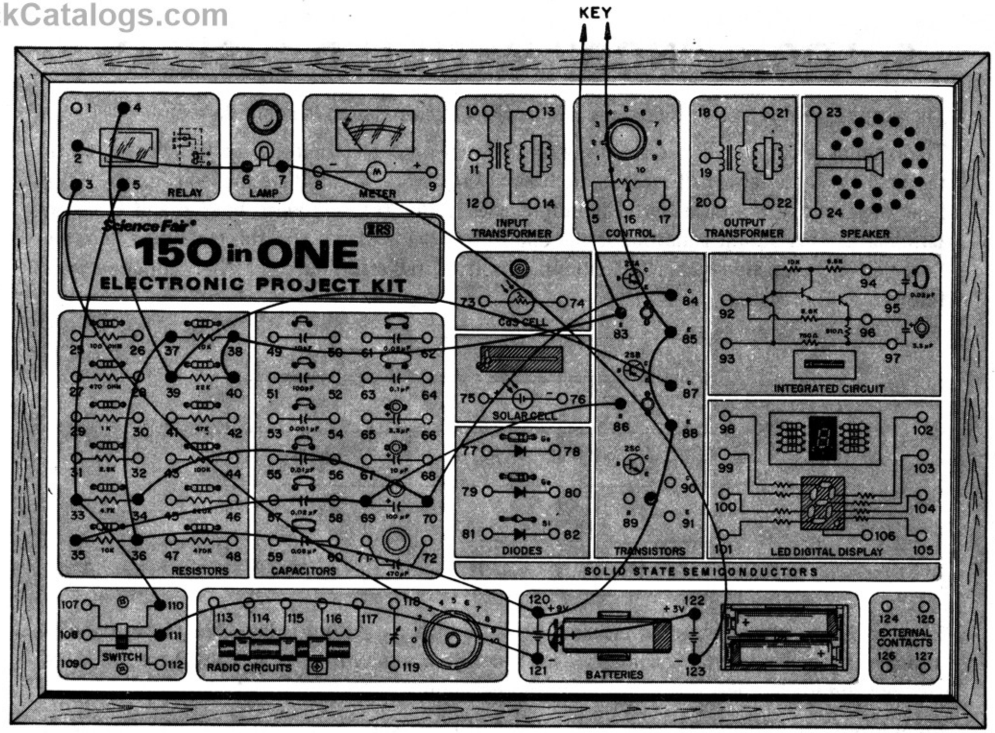
This project allows you to build and demonstrate a one-shot multivibrator, or as it is sometimes called a "pulse stretcher." These are used in logic control circuits and computers to obtain required timing pulses. Generally these are used on pulses which occur so fast that they are measured in small 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. It uses the multivibrator circuit configuration but with one transistor base-bias circuit component a capacitor, in place of the normal resistance. This makes this bias current unable to supply a steady DC base current. The result is a mono-stable circuit (one stable state).

Circuit action is similar to the multivibrators we'll be talking about later on. The 10K resistors have been added to insure a definite OFF state for the Transistors, and (at the 2SB) to provide a discharge path for the 100 µF capacitor.

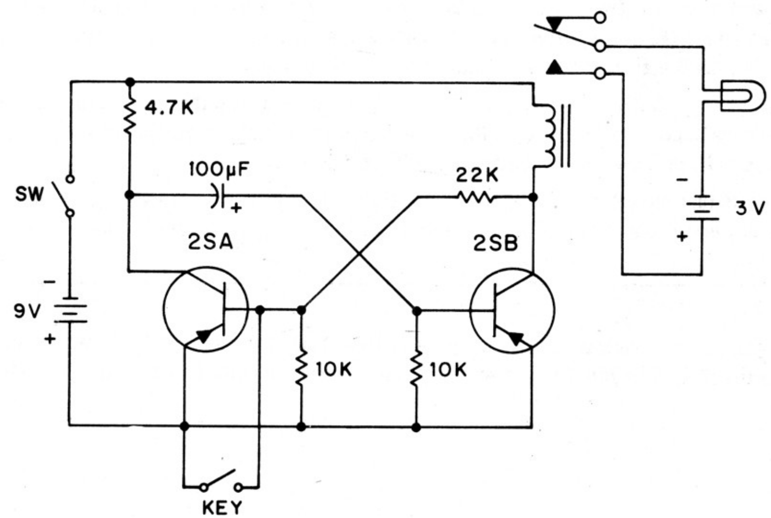
You may want to experiment with different values of capacitance to see the effect on ON time. Be sure to observe proper voltage polarity on the electrolytic types (those marked with a +).



NOTES

WIRING SEQUENCE:

2-6, 3-122, 4-39-87, 5-33-110, 7-123, 34-70-84, 35-69-86, 40-38-83-Key, Key-85-88-120-36-37, 111-121



57. 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."

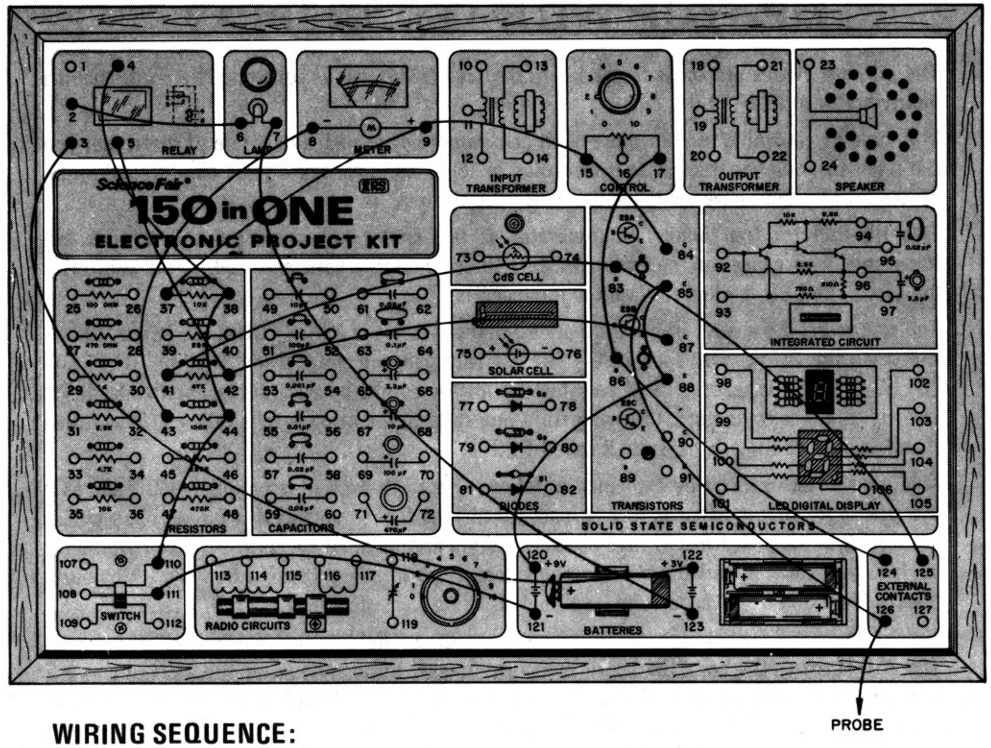
The circuit functions as follows. When the Lamp is ON it indicates the SET state or condition. When the Meter deflects to near mid scale it indicates the RESET state. It is impossible to have both states at the same time.

Use the lead wire from terminal 126 to apply an intermittent input to terminal 124 for the RESET state; and terminal 125 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 2SB is ON. C-E voltage then on the 2SB is less than 0.5V. This voltage is too low to be able to bias the 2SA base through the 47K so the 2SA is OFF. With this OFF the C-E of this transistor appears as an open circuit. This allows the 50K and 10K to pass bias current on to the 2SB to turn it full ON and hold it ON. Meter deflection 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 2SB, it comes out of conduction (OFF). Collector current decreases so the Relay drops out (OFF), but now the 2SA is fed base-bias current throughout the Relay coil and 47K so that it is turned ON. Its C-E voltage drops to less than 0.5V, preventing the 2SB from getting bias through the 50K.

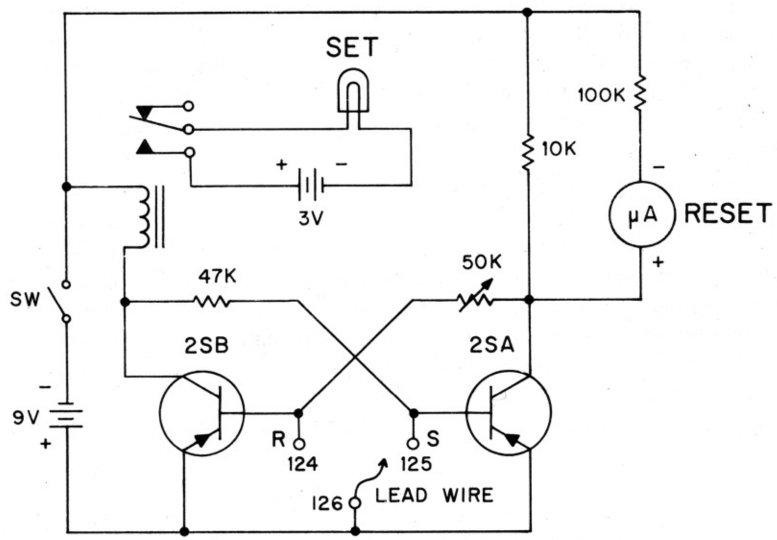
Shorting the B-E junction of the 2SA will now exchange the ON, OFF functions again by a similar process. These switching actions occur very fast because of the regenerative feedback between the stages.



WIRING SEQUENCE:

2-6, 3-122, 4-38-44-110, 5-42-87, 7-123, 8-43, 37-9-15-84, 41-83-125, 17-86-124, 120-88-85-126-Probe, 111-121

NOTES



58. FLIP-FLOP WITH LED DISPLAY

The purpose of this project is to see how a display readout can be controlled by a free-running 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; that is, when the 2SA is "ON", the 2SB is "OFF" and when the 2SB is "ON", the 2SA is "OFF". The change 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.

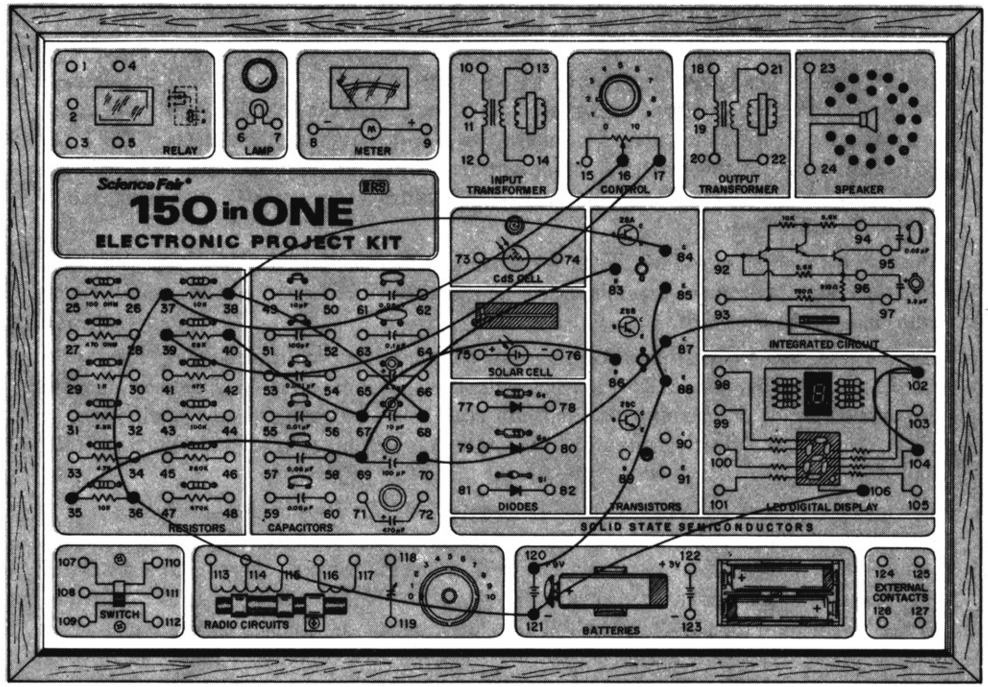
This flip-flop action may be explained as follows. Recall that a transistor which is ON acts as if it has a short circuit between C-E – and, when it is OFF it acts as if it has an open circuit between C-E. Also notice that base-biasing resistors are provided for both transistors so that if no feedback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

Let's start an assumed circuit operation with the 100 μF holding the 2SA in the "OFF" state. The 2SB is then "ON" and the 10 μF is charged quickly through its series 10K resistor and B-E junction of the 2SB by the Battery. The 22K and 50K Control keep the 2SB in the ON state after the 10 μF is charged up. At this time the charge which is on the 100 μF is slowly discharging through the 10K resistor, Battery and C-E elements of the 2SB. Remember, the 2SB is ON and its C-E elements look like a short circuit. The voltage on this capacitor maintains a reverse-bias on the 2SA as long as the charge is sufficiently high.

Before the 100 μF is completely discharged, the low C-E voltage of the 2SB allows the negative voltage from the (left) 10K to turn the 2SA "ON". The instant the 2SA is turned ON, the 10 μF quickly turns the 2SB "OFF". With the 2SB "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 100 μF, the 2SA is turned full ON. This change in state of FLIP occurs very quickly (microseconds).

After a while the charge on the 10 μF is decreased to where it can no longer hold the 2SB "OFF", and the circuit FLOPS back to the original state to begin the above action all over 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 operation. Can you now explain circuit operation to someone else without referring to any helps? If you can you have come a long way. This circuit seems very complicated till you study it for a while.

You can verify the circuit operation by temporarily short circuiting the B-E junctions of first the 2SA and then the 2SB. This holds the shorted transistor into the OFF state in place of the charged capacitor.



WIRING SEQUENCE:

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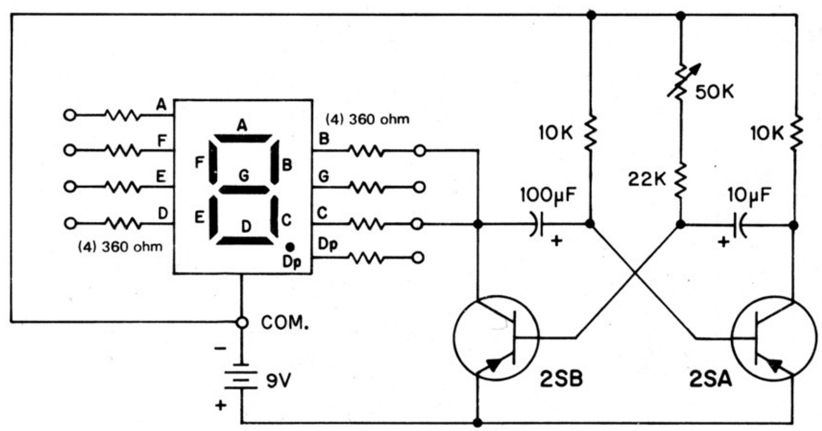
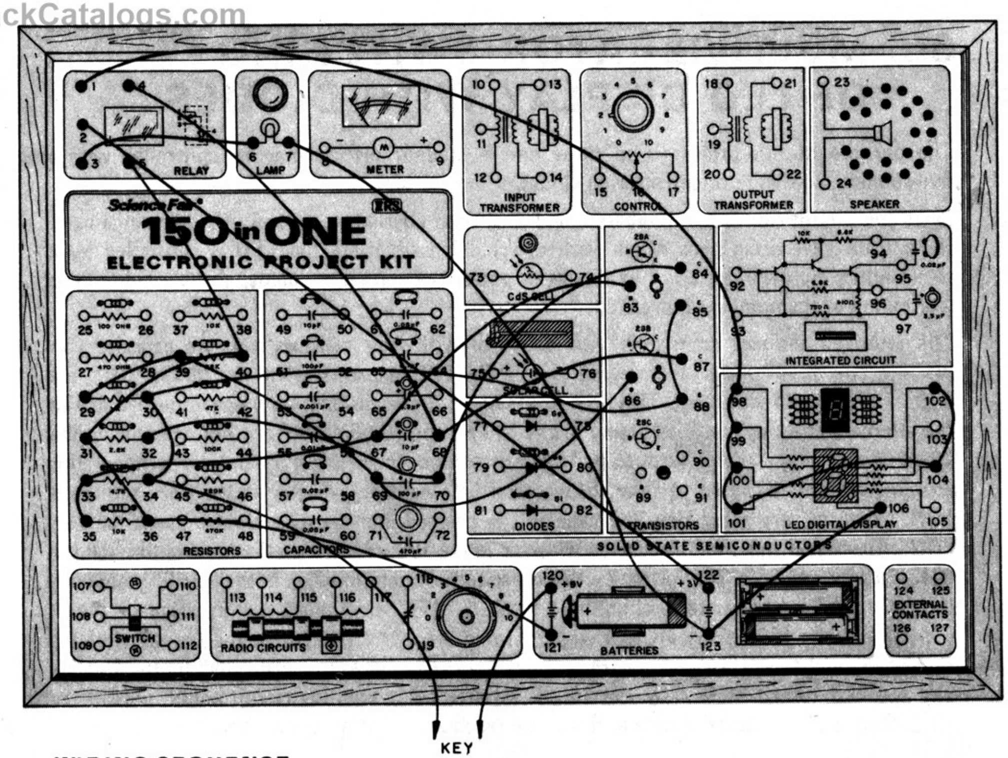


59. FLIP FLOP LED/LAMP DISPLAY

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

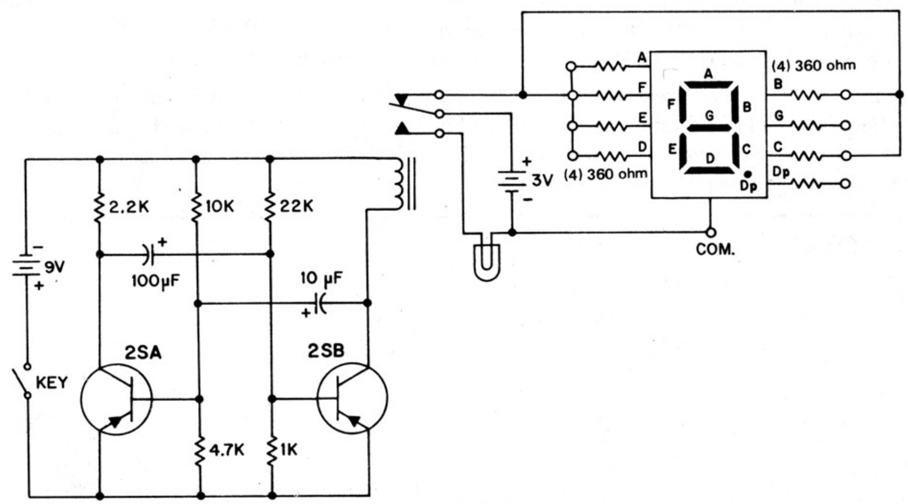
How about a little research on your own? Either from memory or by reference to other project writeups in this kit describe the operation of the multivibrator flip-flop. Try to use such terms as "transistor OFF and ON" states, "charging current" and "discharge current". Use the space provided below for your writeup. Use 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:

122-2, 1-98-99-100-101-104-102, 106-123-7, 6-3, 4-68-87, 5-40-31-36-121, 84-70-32, 83-67-33-35, 86-69-39-29, 85-88-30-34-Key, Key-120



60. MULTIVIBRATOR SWITCHING OF LED DISPLAY WITH DIODES

The purpose of this project is to show how a readout display may be controlled with a free-running multivibrator and steering diodes.

Since this circuit causes the numbers 1 and 2 to flash alternately on and off, it reminds us of some neon advertising signs which flash eye-catching ads. Here the LED is controlled by a free-running multivibrator and two diodes to power the correct segments, giving a continuous alternation of the numbers 1 and 2.

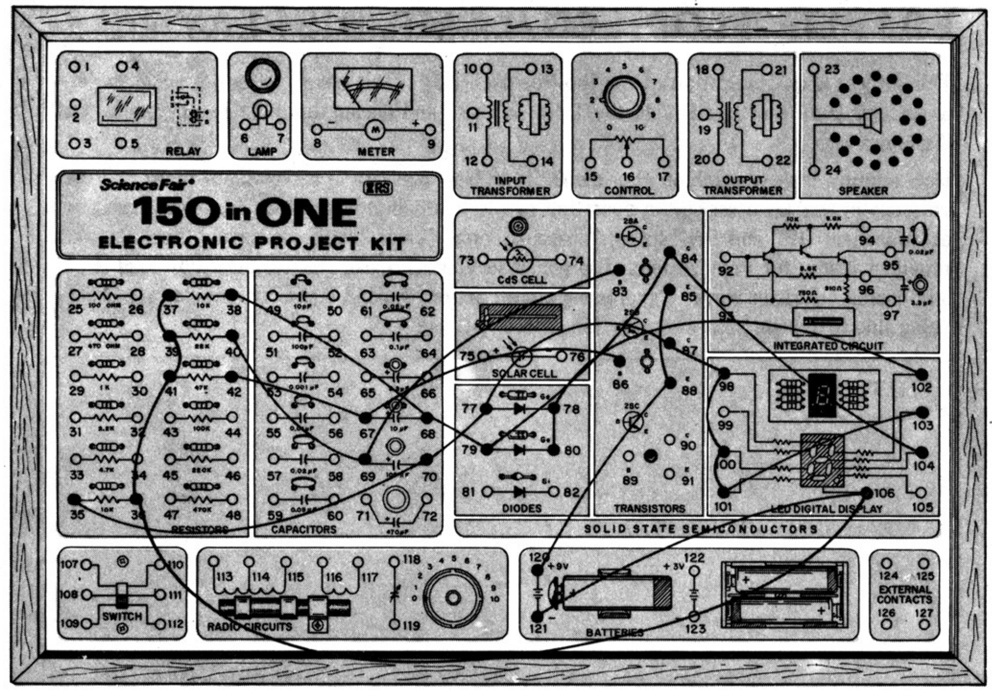
The multivibrator uses transistors 2SA and 2SB with four resistors and two capacitors to produce two out-of-phase square waves to drive the LED segments. When the 2SA is "ON", the 2SB is "OFF" and vice versa. This on and off operation is automatically accomplished due to the alternate charging and discharging of the 100 μF and 10 μF capacitors. For example, as the 10 μF 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 2SB, turning it "ON". After a very short time the capacitor is charged, but the 47K resistor keeps the 2SB "ON". During all this time the charge which is in the 100 μF is slowly discharging through the 22K, Battery and 2SB. The voltage on this capacitor will hold the 2SA in the "OFF" state until it discharges down to where it cannot hold the 2SA "OFF" any longer. At this point the circuit FLIPS, and the 100 μF begins to charge, turning the 2SA "ON". Now the functions of the capacitors (and transistors) are reversed so that the 2SA is quickly turned "ON" by the 100 μF, and the 2SB turned "OFF" by the 10 μF. After a short time the circuit action switches or FLOPS back to the opposite state as the 10 μF reaches the end of its discharge.

When the 2SB is "ON", the A, E, D, B and G segments light to form the number 2, and when the 2SA is "ON" the B and C segments light to form the number one. Notice that in both instances the B segment lights due to current flowing through one of the diodes. The unused diode in each case is reverse-biased and acts as an open circuit. This unique action of diodes has earned them the name "steering diodes."

You can measure voltages across about 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.

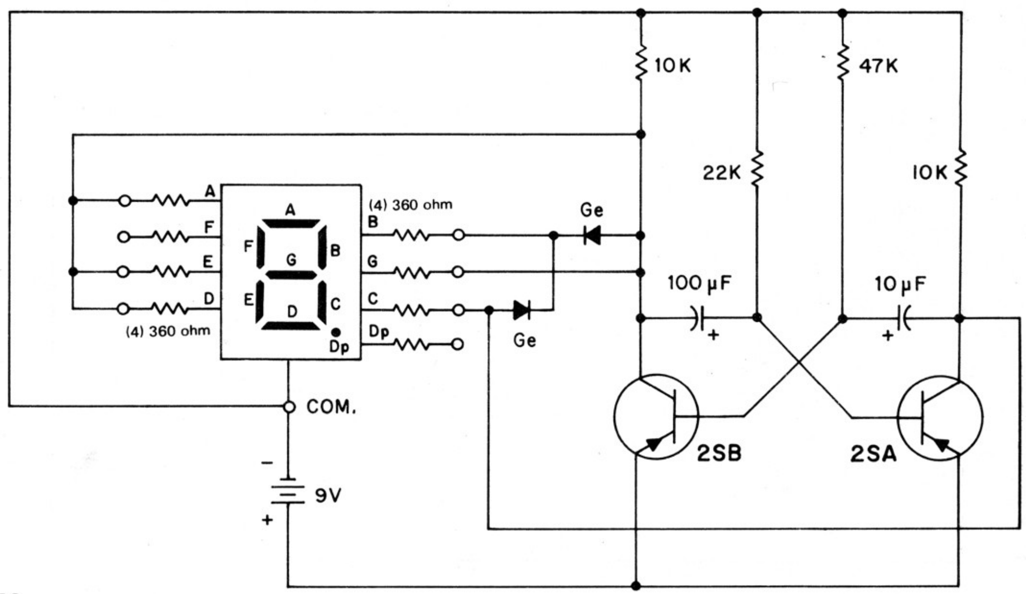
Some of the different experiments you might want to try – different size capacitors to see their effect on speed of operation; rewire the LED to display numbers other than 1 and 2. You may try different **higher** values in place of the 22K and 47K. **Do not use lower values for any of the resistors or you may damage the transistors.**

NOTES



WIRING SEQUENCE:

80-78-102, 103-101-100-98-87-77-70-35, 104-84-79-68-38, 120-88-85, 83-69-40, 86-67-42, 37-39-41-36-106-121



61. SPEAKER-MICROPHONE TRANSISTOR AMPLIFIER

This category of experiments deals with **Amplifiers.** As you know by now (or should know), many of the Projects you have already worked with are amplifiers. So you probably already understand much of the circuitry involved.

This project demonstrates how a speaker can be used as a microphone and how a transistor amplifies voltages hundreds of times. The amplifier circuit is similar to those used in radios, telephones, hearing aids and public address amplifiers.

In brief, the Speaker changes sound energy into electrical energy, which is then amplified by the transistor stage before being delivered to the Earphone, which changes the electrical energy back to sound energy.

The Speaker can produce electrical energy because it contains all the essentials of a dynamic microphone. That is, the coil of wire which is attached to the paper cone is suspended in the magnetic field of a strong permanent magnet. As the sound waves move the cone and coil, the coil movement within the magnetic field generates an electrical voltage. This electrical voltage contains all the required characteristics of the acoustical (sound) waves.

The Output Transformer is used in reverse to obtain a step-up of voltage. A transformer can be used in either direction and in this case the step-up of voltage is desirable as it helps contribute to the overall voltage amplification of the circuit.

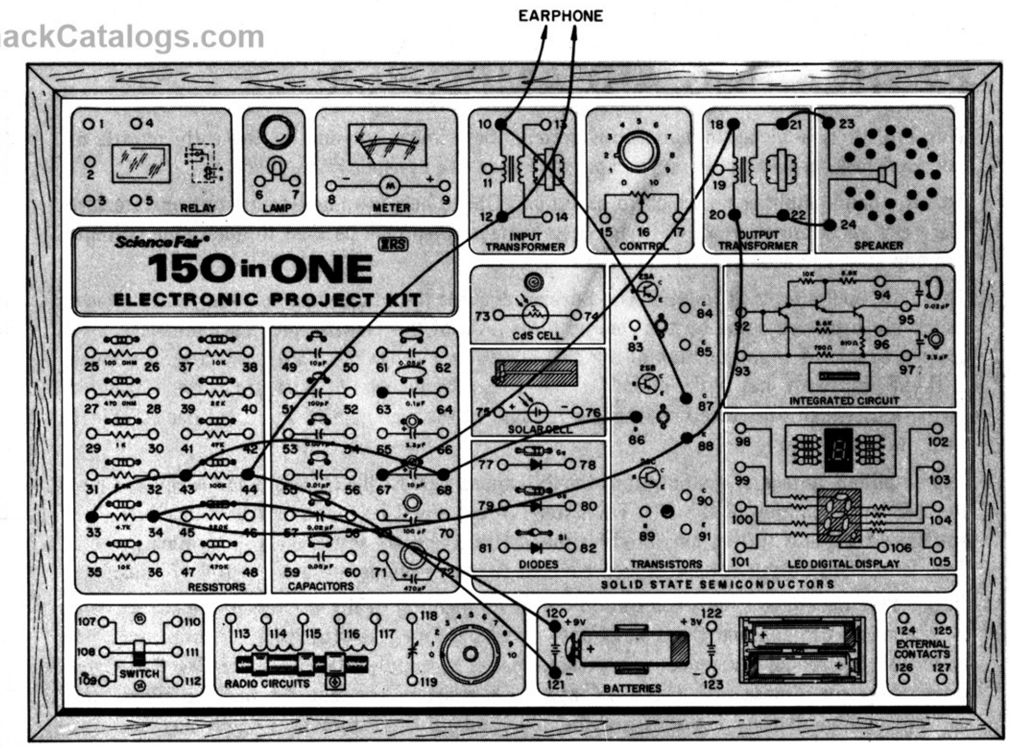
The Transistor is in what is called a common-emitter (CE) amplifier circuit. This term comes from the fact that the emitter (E) of the transistor is connected directly to both the input and output circuits; that is, its connection is common to both input and output.

The 2SB Transistor is a PNP germanium type so it requires a base voltage which is negative about 0.15 volt with respect to the emitter. You can remember this by looking at the schematic symbol of the transistor. The B-E junction is like a diode and must have some forward bias current to turn the transistor ON. Recall that forward bias current must always flow **against** the arrow head in the diode (and transistor) symbol. The 100K and 4.7K resistors form a voltage divider across the 9V Battery to supply the required polarity and magnitude of B-E forward bias voltage. This type base bias is called **fixed voltage bias.**

The Transformer is used in the collector circuit to obtain a high impedance at the audio frequencies without dropping much DC voltage. This and the Earphone then allow the circuit to have very high voltage amplification because neither one loads down the output.

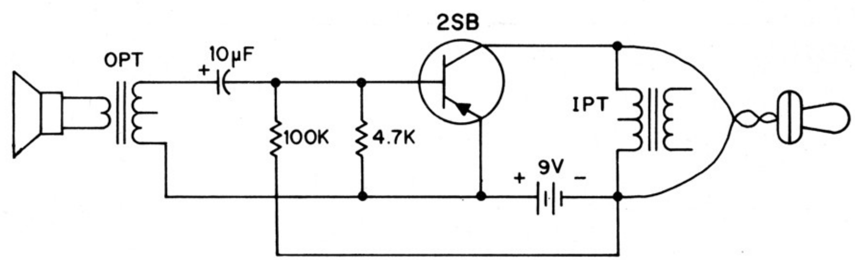
To demonstrate the tremendous voltage amplification of this circuit try temporarily changing the Earphone to across the B-E input. The advantage of this Earphone is that it may be connected anywhere in a low voltage circuit like this without hurting anything and without loading the circuit. So don't be afraid to listen around with it.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 120-34-88-20, 18-67, 86-68-43-33, 87-10-Earphone, Earphone-12-44-121



62. HEARING AID AMPLIFIER

This project 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 operate. Use the VOM to measure circuit voltages. These voltages then may be used to determine currents and operating characteristics of the circuit.

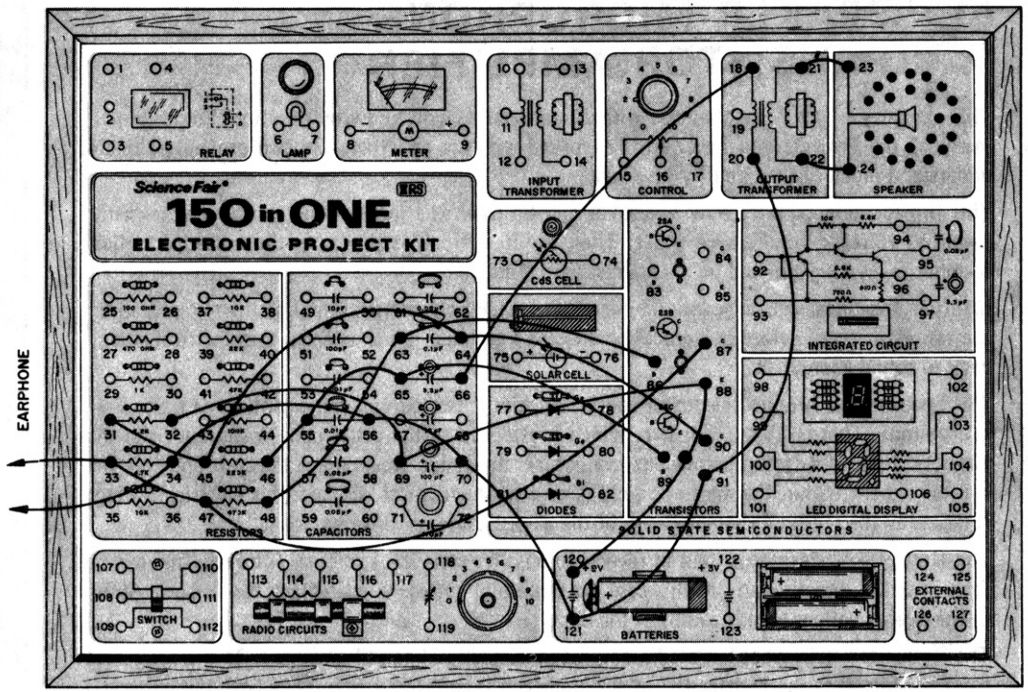
The basic operation is as follows. The Speaker changes the sound pressure into weak voltages which are increased some by the step-up turns ratio of the Transformer. This voltage is then applied to the B-E input junction of the 2SC Transistor through the 3.3 μF capacitor. The small 0.01 μF capacitor has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

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

Notice that the above circuit description makes no mention of the resistors in the circuit. This is because we can consider them all as open circuits as far as the audio signal is concerned. The basic purpose for all resistances in this amplifier is to supply the required DC voltages and currents to the Transistors. The 2.2K and 4.7K resistors are required only to supply the collectors with voltage and current; and the 220K and 470K resistors for the base currents.

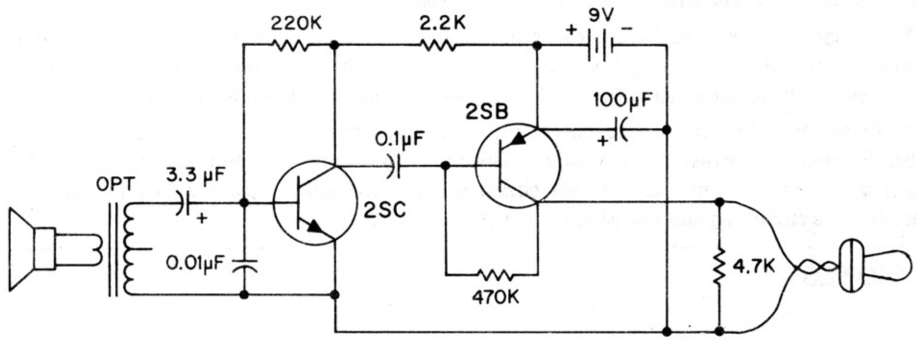
The type of bias circuit is the same for both stages and is called **self-current bias.** This is because the collector DC voltage is used to provide the source of current through the base resistor to the stage with some **self** stabilizing feedback. The high value of base resistance (220K or 470K) 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 to act as amplifiers. This voltage (called V_{CE}) should have a value between the OFF value (9V of the Battery) and the full ON voltage (0.5V). An electronics technician uses this voltage to verify that bias is correct for the amplifier to work as an amplifier.



WIRING SEQUENCE:

21-23, 22-24, 18-66, 20-91-121-70-56-34-Earphone, Earphone-33-47-87, 86-63-48, 90-64-45-31, 89-65-55-46, 32-69-88-120



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63. DIRECT-COUPLED TWO-TRANSISTOR AMPLIFIER

This project is a direct-coupled 2-transistor amplifier which has very high gain. It is used in this project with the Speaker connected as a dynamic microphone and with an Earphone output. This arrangement and circuit is very much like modern transistor hearing aids. Sensitivity is so good that you'll have to keep the Earphone away from the Speaker or oscillations will occur due to the acoustic feedback.

This two-transistor circuit is popularly called the "ring of two". It gets this name from the fact that the two transistors are coupled together in a DC feedback ring or loop. That is, the bias for one Transistor (2SA) is obtained from the second Transistor, while the bias for the second Transistor (2SB) is controlled by the first Transistor. The advantages of this circuit are many and include: few parts, high gain and good bias stability.

Signal operation is as follows. The signal on the base of the 2SA is amplified and appears at the collector. This amplified signal is directly coupled to the base of the 2SB. The 2SB further amplifies the signal and applies it to the Earphone. The transformer winding is used to obtain a low resistance to DC, while presenting a very high impedance to the AC signal.

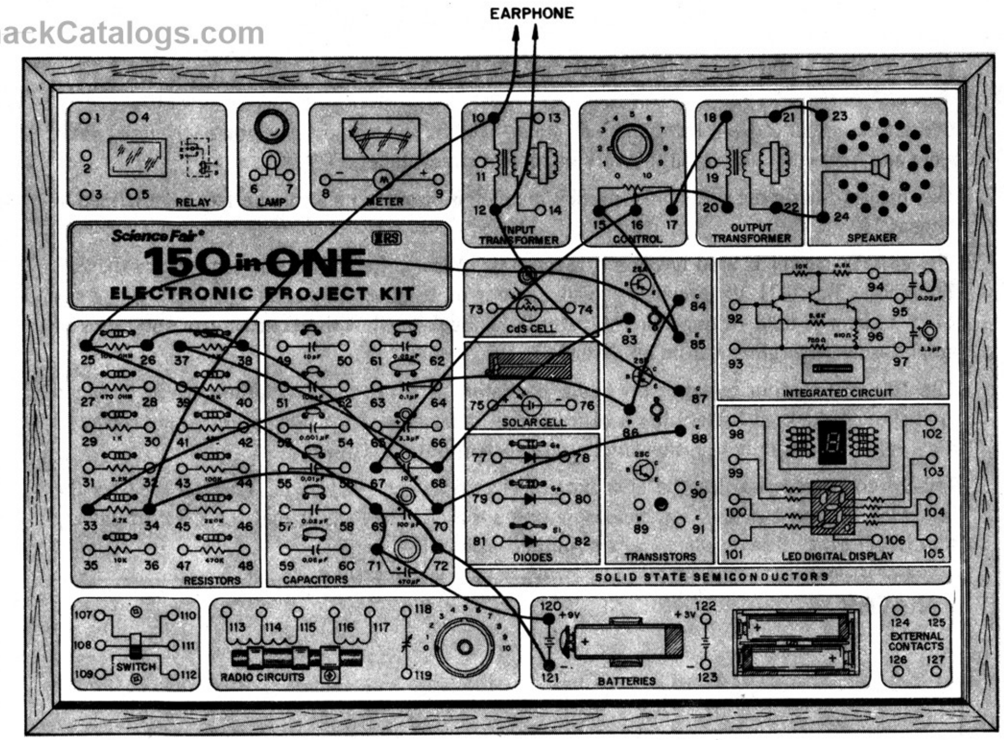
You can use a VOM to check out the DC vias voltages (which are obtained as follows). The 9V battery voltage is divided down by the 4.7K and effective resistance between C-E of the 2SA, to a low value at the base of the 2SB. The 2SB emitter current which flows through the 100 ohm resistor causes a small voltage to be developed across this resistor. This voltage is fed to the base of the 2SA through the 10K as base-bias. This bias controls the effective resistance between C-E of the 2SA.

Stabilizing effects may be described as follows. If the 2SB current were to tend to increase (possibly due to increased temperature), the voltage fed to the base of the 2SA would tend to increase also. This increased base-bias on the 2SA would cause its effective C-E resistance to decrease. This would cause the 2SA collector voltage to decrease (and 2SB base voltage). The decrease of 2SB base voltage is a decrease in bias which tends to reduce the current back to near normal.

The 100 μF capacitor prevents the above-explained negative feedback from reducing the signal gain along with the DC voltage change reduction.

This circuit is very similar to the "ring of three" circuit of the integrated circuit (IC) included in this kit. In fact, the voltage gain of this circuit is greater than that of the IC.

NOTES



WIRING SEQUENCE:

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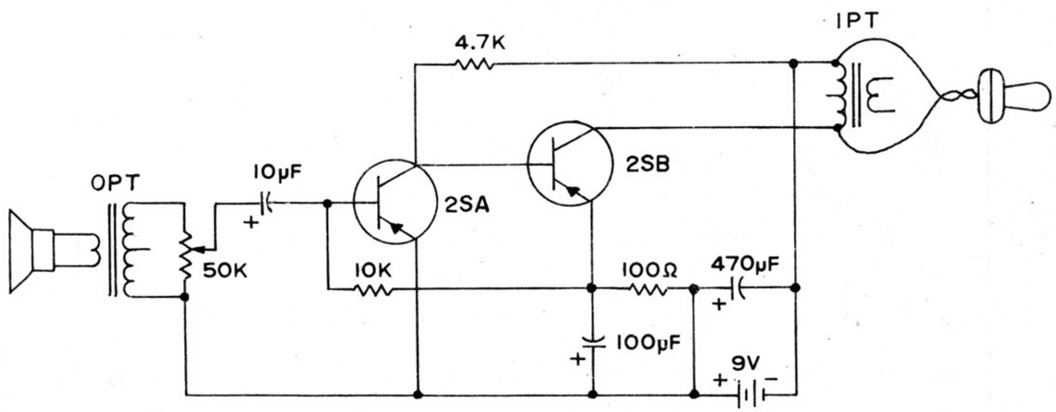


64. COIN BATTERY AUDIO OSCILLATOR

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

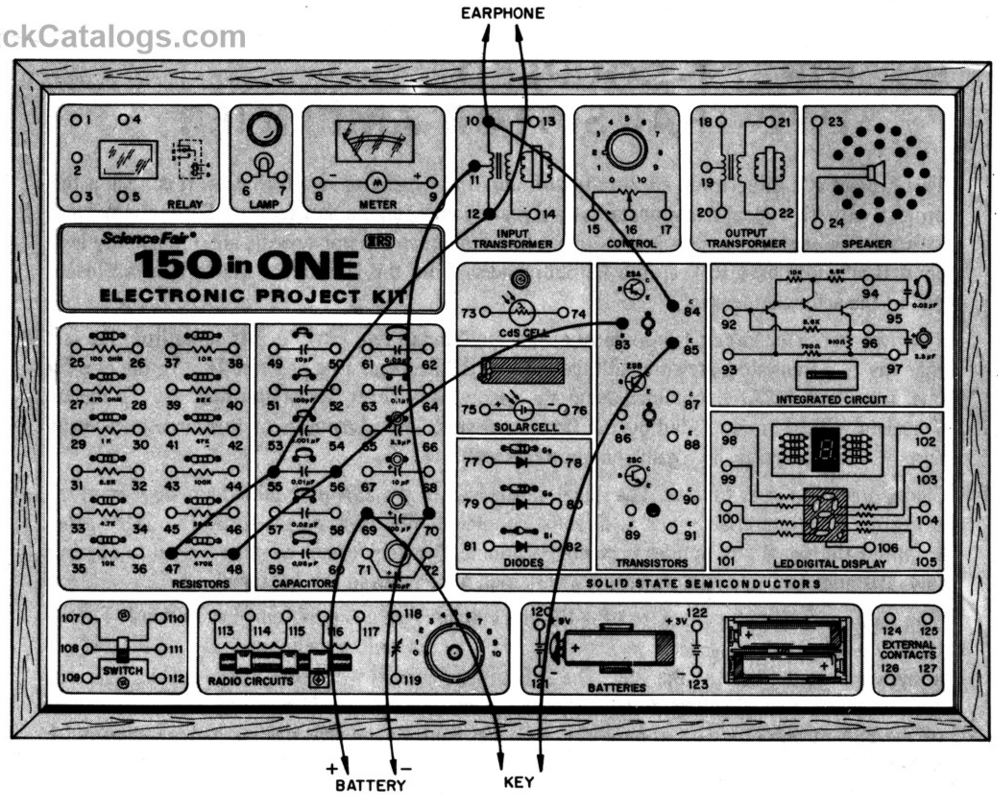
This project is a simple audio pulse oscillator which is powered by a coin battery as described in Project 18.

The 2SA Transistor is used because it is sensitive to low voltages, but you can also try the 2SB Transistor. The 0.01 μF 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 100 μF 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.

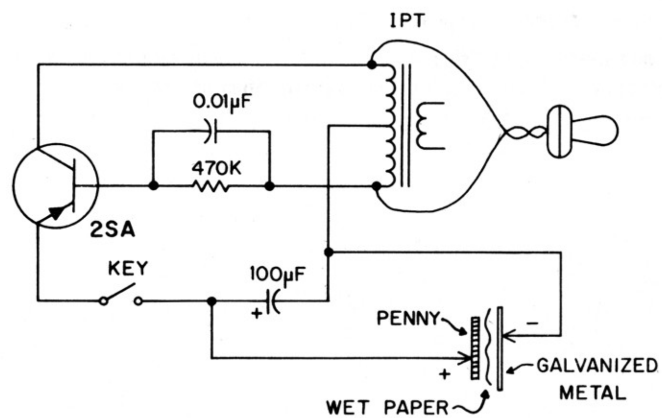
Try different materials for the coin battery electrodes and electrolyte. You can even try the following – with a penny, spit-wet paper and a nickel!! How about that for a 6 cent battery that is still worth 6 cents when you are finished with it?!

NOTES



WIRING SEQUENCE:

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



65. OSCILLATOR WITH TURN-OFF DELAY

The purpose of this project is to demonstrate how a turn-off delay can be obtained for a circuit. The oscillator used for this demonstration is a common type described elsewhere in this book. The delay is accomplished with one component, a 470 μF capacitor.

During normal operation of the oscillator the closed Key is in parallel with the capacitor so it 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.

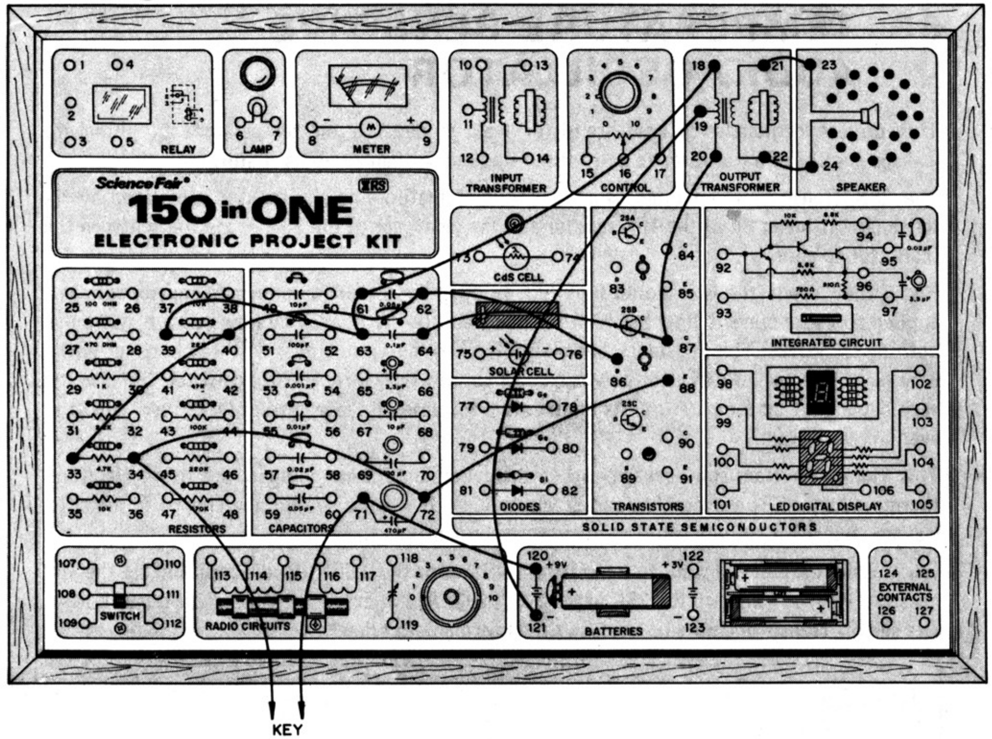
This unique characteristic of a capacitor is called **storage action** and is responsible for many functions the capacitor can perform. A discharged capacitor has an equal number of electrons on the (+) and (–) electrodes, but a charge is stored in a capacitor by drawing electrons off the (+) electrode 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."

No capacitor is a perfect insulator when charged up, so a small (microamperes) current flows whenever the voltage is applied. To keep this leakage current and the leakage current of the Transistor from sustaining a low level of oscillation after the capacitor is charged, the 4.7K resistor is included across the B-E junction of the Transistor.

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:

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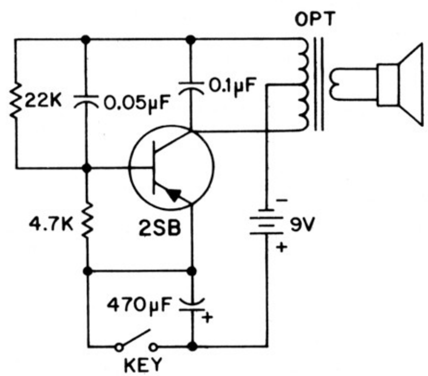


66. TEMPERATURE SENSITIVE AUDIO OSCILLATOR

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

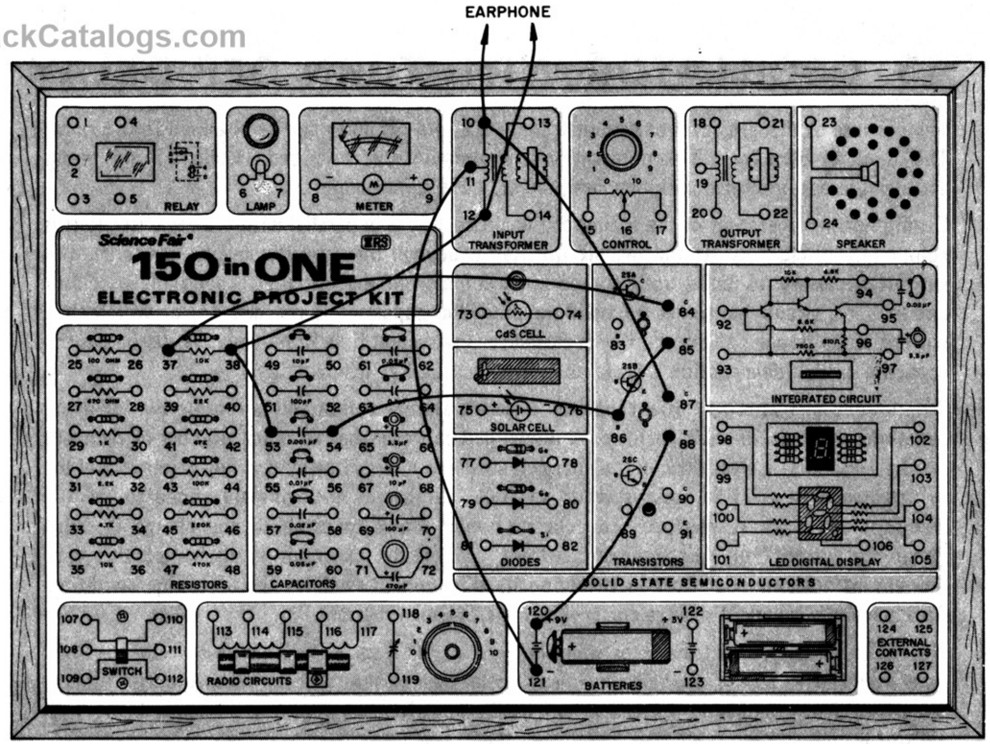
The 2SB Transistor is operated as a pulse-type oscillator. The bias resistor is replaced by the series circuit made up of the 10K resistor and the resistance of the 2SA Transistor between C-E (collector-to-emitter).

Recall that ideally the C-E should look like an open circuit unless some base-emitter voltage is applied to cause current flow between base and emitter leads. Well by now you are aware that nothing is "ideal." This resistance between C-E when the Transistor is OFF (no base current) is very high, but not infinity. Not only can some current flow through the transistor, but also it is very dependent on temperature. As temperature increases, leakage current increases – but at an ever increasing rate.

This change in transistor leakage makes them usable to sense temperature in an electronic thermometer. All is not peaches and cream though. If it were not for the change in transistor leakage, transistor circuits could be made even simpler than they are.

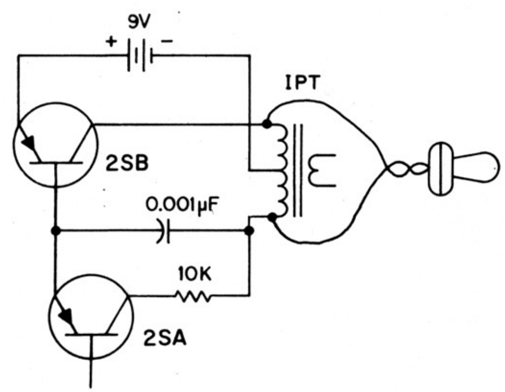
For this circuit you will want to try different values for the 0.001 µF capacitor and for the 10K resistor. You may also try the 2SC in place of the 2SA, but exchange places with C and E leads. Are silicon Transistors more or less leaky than germanium types?

NOTES



WIRING SEQUENCE:

Earphone-10-87, Earphone-12-38-53, 11-121, 37-84, 85-86-54, 88-120



67. 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.

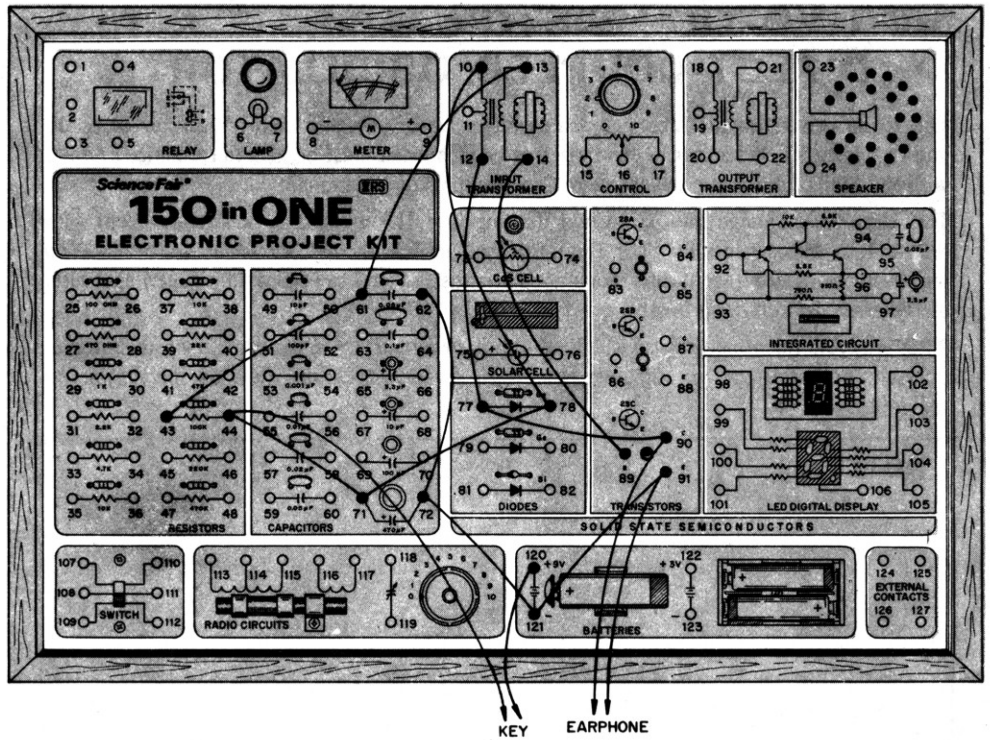
After the Switch is opened, the circuit continues to oscillate for about a minute. One reason for such a long time is that the oscillator has a very short "duty cycle". The duty cycle is a measure of comparison between the time a circuit is conducting and the total time to complete one cycle. This circuit, like most pulse and blocking type oscillators, 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 one, and regenerative feedback to sustain oscillations. The Transistor provides a gain much greater than one. 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 0.05 μF capacitor during the transistor OFF-times. During the ON-times the capacitor is charged up and the Transistor held ON by the induced voltage from the Transformer base winding.

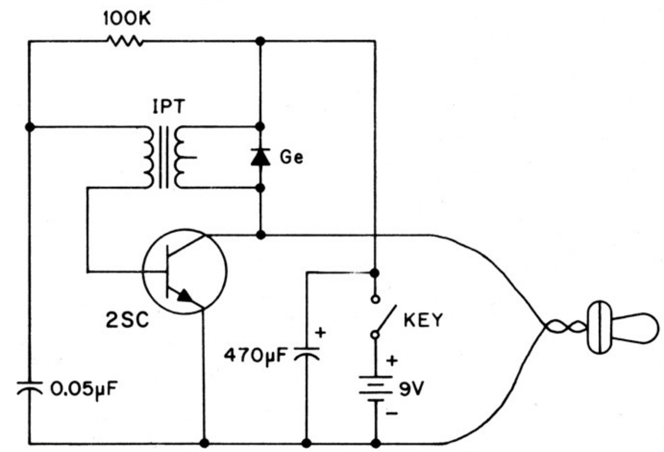
The germanium (Ge) Diode shorts out the Transformer at the instant the current stops flowing through the Transformer as the Transistor is turned OFF. This protects the Transistor from this potentially destructive spike of energy – for the Diode circulates the current back around the Transformer winding 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



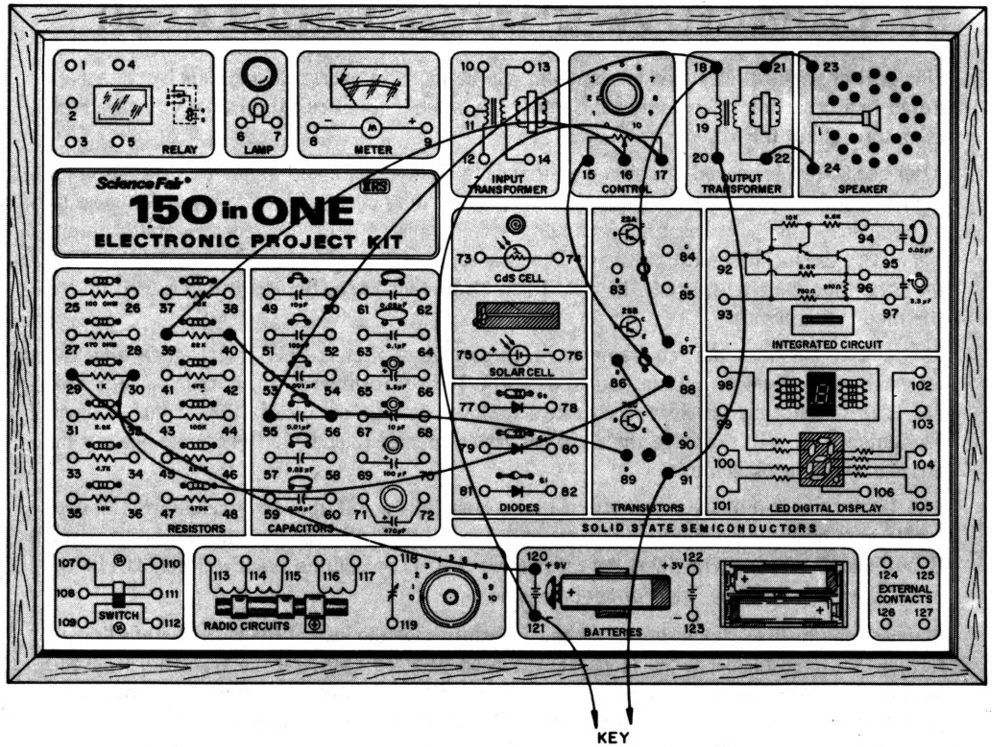
68. TWO-TRANSISTOR, DIRECT-COUPLED OSCILLATOR

This is the two-transistor, direct-coupled oscillator which you have seen in other projects. Do you recognize it? Remember, a good electronics 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 0.01 μF in the circuit. You may want to record your results like a good scientist, so you can repeat the experiment later on. Polarize electrolytics 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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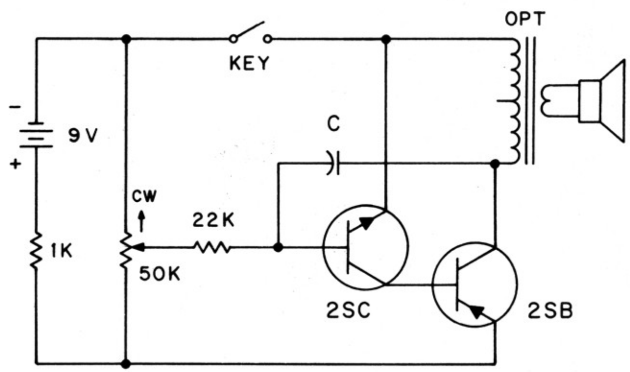


69. PUSH-PULL SQUARE WAVE OSCILLATOR

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 operation, converting DC to AC with high efficiency, testing frequency and phase response of circuits, etc.

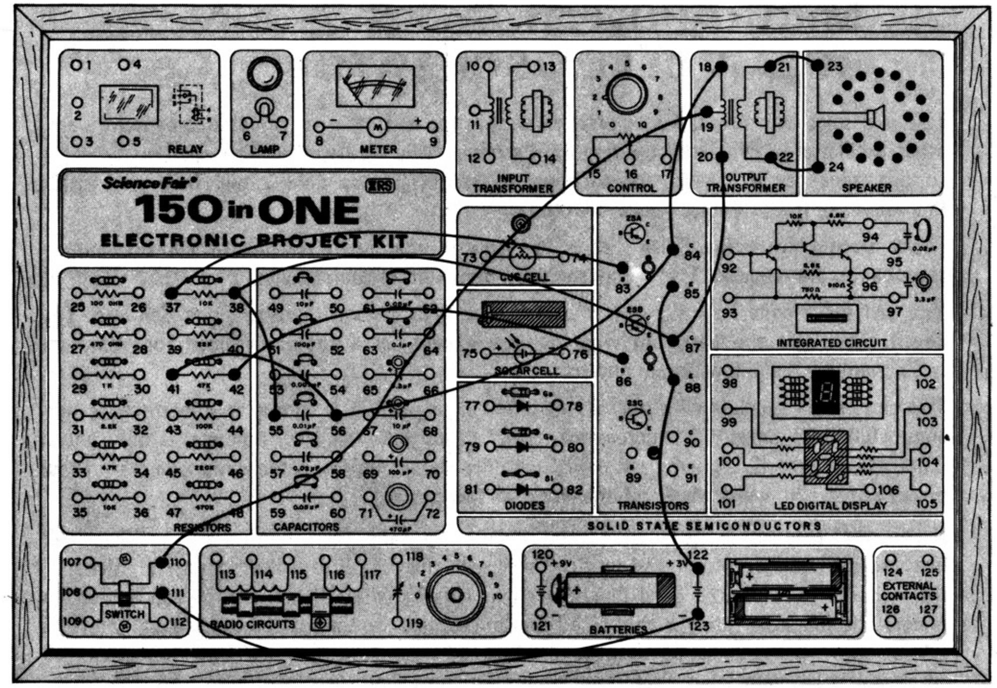
A square wave is rich in odd harmonic frequencies. That is, a 100 hertz square wave contains also frequencies of 300, 500, 700, 900, etc., all of which are equal to the fundamental frequency of 100 times the odd counting numbers. The strength of the harmonic frequencies decreases as the frequency increases,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

This circuit is very similar in operation to the single transistor circuit of Project 96 but with a second transistor which has its collector and base connections reversed. The 0.01 μF 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 will 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, 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 capability. That is, maximum output power is obtained for the particular size transformer used.

NOTES



WIRING SEQUENCE:

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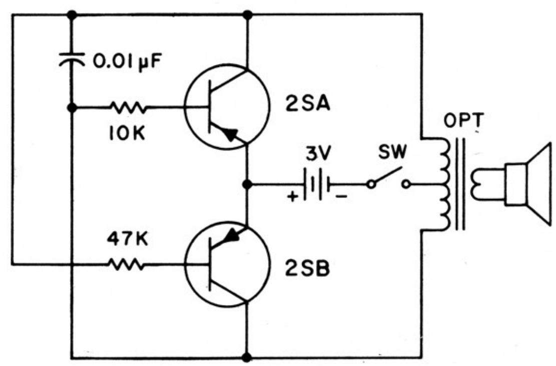


70. MICRO-POWER SOLAR CELL OSCILLATOR

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.

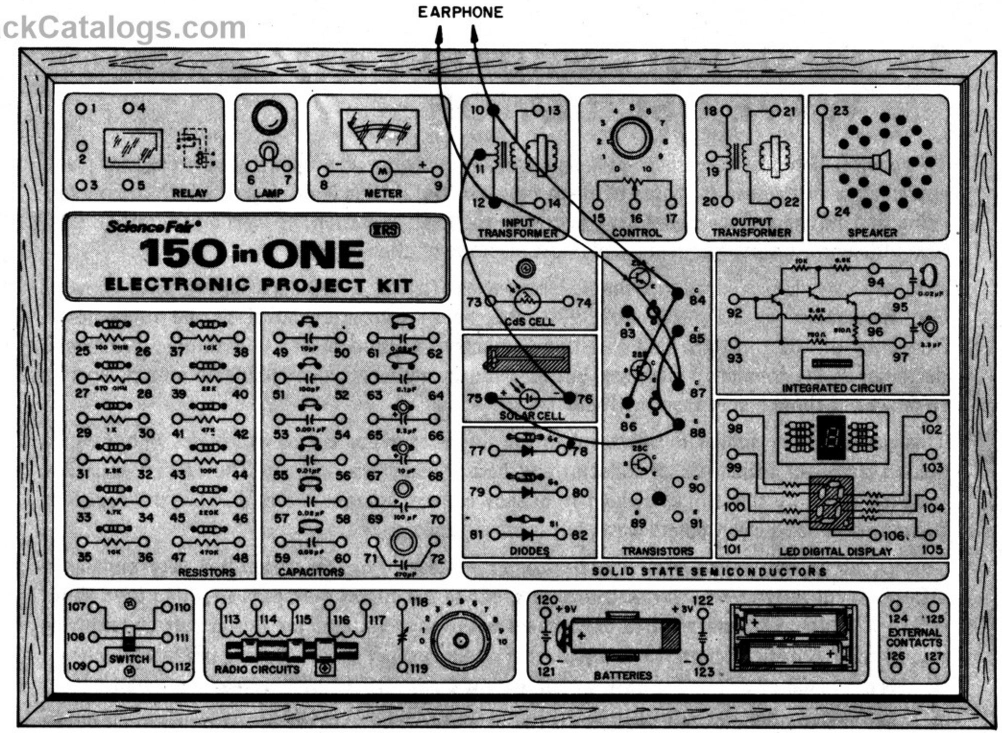
You can use a code Key if you like by inserting it in series with either Solar Cell lead. The keyed tone isn't the best, but what do you expect for a circuit designed for minimum component parts and low supply power!

This circuit will oscillate with only about 0.07 volt applied. The current at this voltage is only about 0.000,03 amps (30 microamps). This means that the circuit power is only about 0.000,002,1 watt (2.1 microwatt). 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 3.3 μF 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 250 μA (microamps), so the top (blue) scale represents 25 μA for each whole numbered calibration. **CAUTION**: Temporarily short circuit across the 3.3 μF capacitor before placing it across the meter to remove any stored charge.

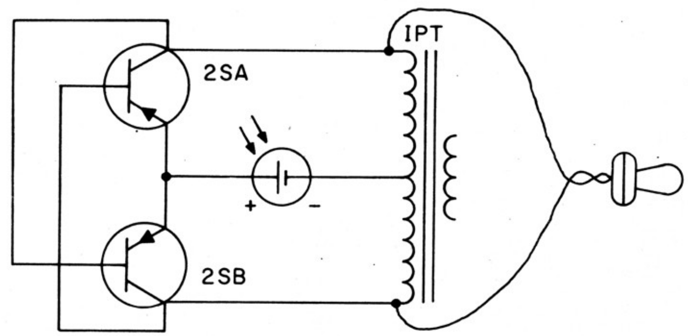
One of the biggest advantages to a circuit like this is — NO BATTERIES ARE REQUIRED!

NOTES



WIRING SEQUENCE:

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



71. MICRO-POWER SOLAR CELL OSCILLATOR WITH SPEAKER

PROJECT 71: MICRO-POWER SOLAR CELL OSCILLATOR WITH SPEAKER

This project is the same circuit as Project 70, modified to power a speaker for the output. The characteristics are very similar so we'll 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 sound more pleasant.

You will want to try operation with either and both capacitors. Notice how the 470 μF removes most of the raspyness and then the 0.01 improves it further and lowers the operating frequency so that output at low light intensities provides audible tones.

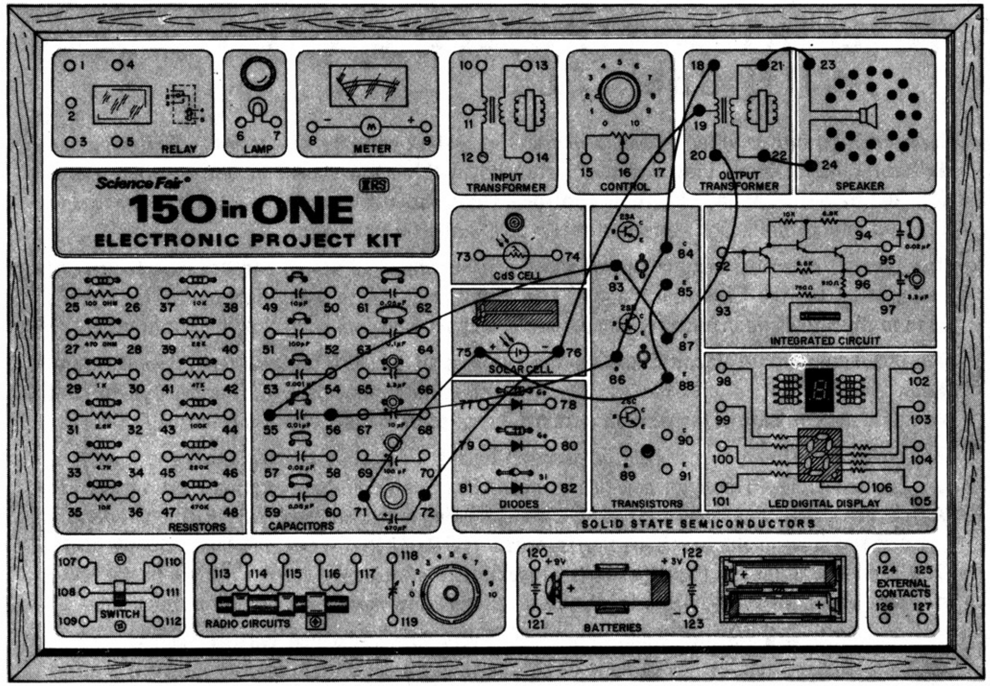
As with the Earphone circuit, you can connect the meter in series with the Solar Cell to measure total current. Connect it in so that the 470μF bypasses both Solar Cell and Meter. In order to measure the currents at high light intensities, parallel the Meter with a 470 ohm resistor. This makes the full-scale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

This same meter-shunting concept can be used with other resistors in this kit, or which you may have in your "junk box." The highest full-scale current you can obtain with any single resistor in this kit is about 2 mA when using the 100 ohm resistor. The formulas to use for other resistors or currents are as follows:

$$R_S = \frac{162}{I_T - 0.25} \text{ ohms, or } I_T = \frac{162}{R_S} + 0.25 \text{ milliamps,}$$

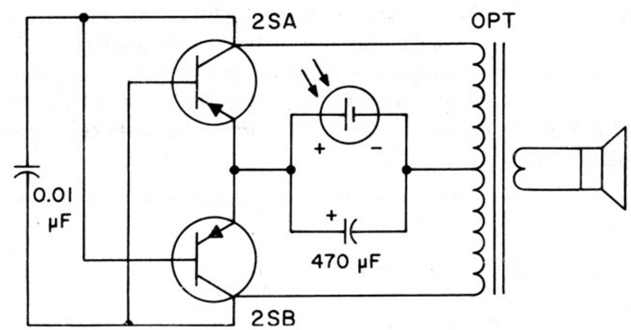
where R_S is the meter shunting resistance in ohms and I_T is the new full scale current calibration in milliamperes (mA).

NOTES



WIRING SEQUENCE:

21-23, 22-24, 18-84-86-56, 19-76-72, 20-87-83-55, 85-88-75-71



72. LIGHT CONTROLLED SWITCH WITH CdS CELL

Now we'll go into 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 it 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 circuit is similar to many light-controlled circuits used in the home and in industry. Many yard and street lights are controlled by photo 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 photo 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 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 one tenth of the collector current to turn the Transistor full ON. The Relay current is about 17 mA, so to be full ON the transistor only needs about 1.7 mA of base current. To obtain this current the photo cell resistance only needs to decrease to about 4300 ohms.

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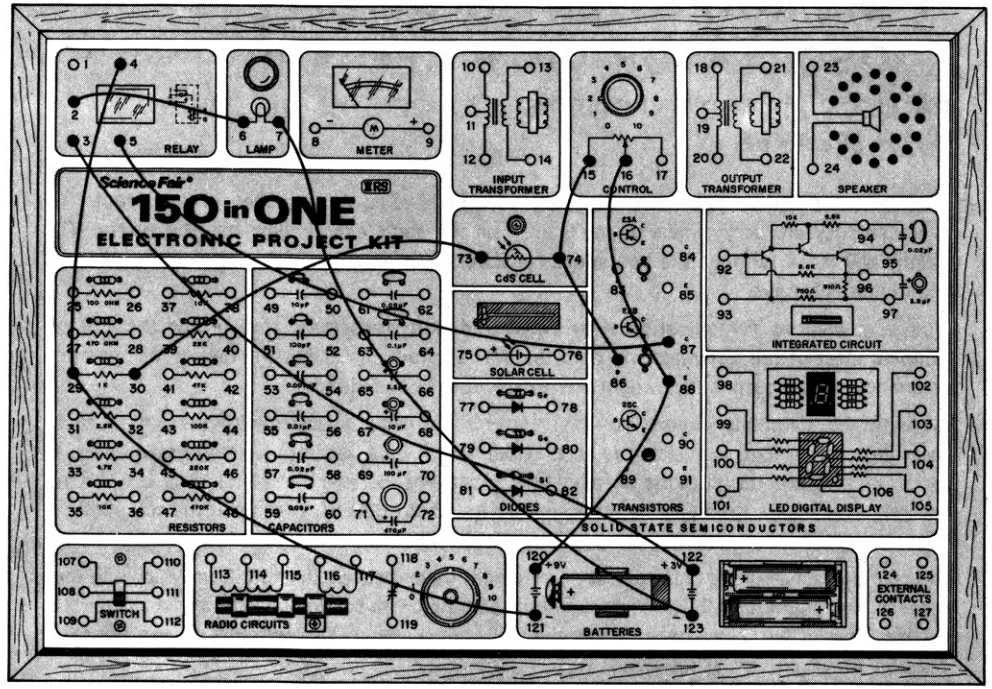
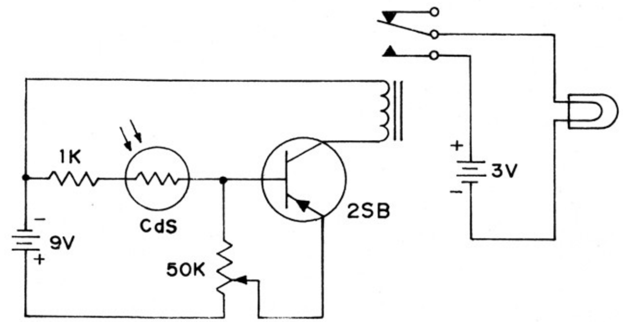


WIRING SEQUENCE:

123-7, 6-2, 3-122, 120-88-16, 15-74-86, 87-5, 73-30, 4-29-121

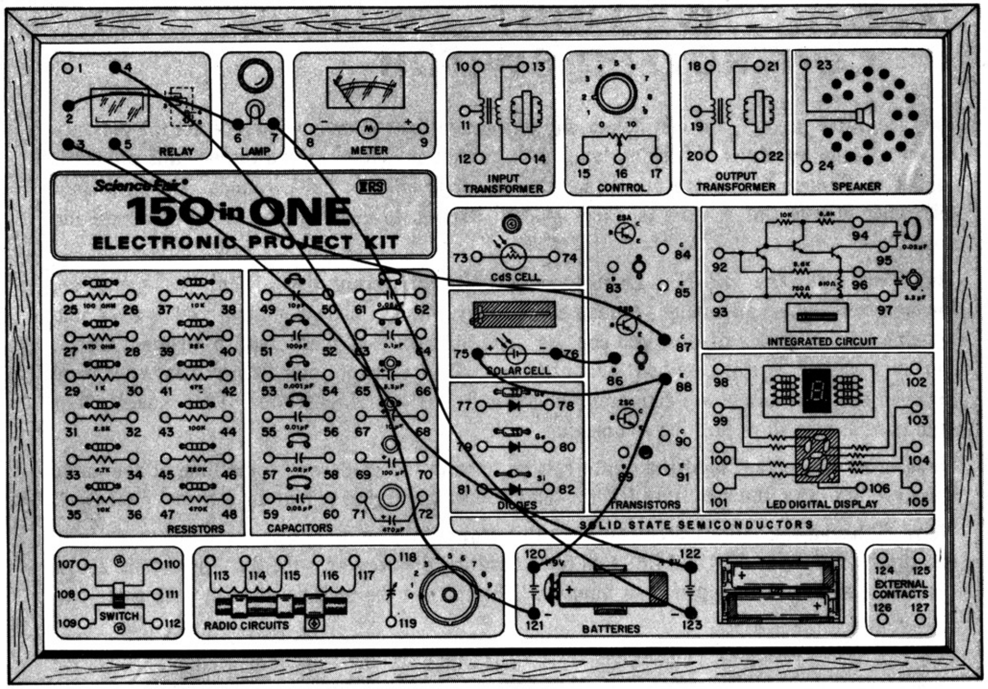


73. LIGHT CONTROLLED SWITCH WITH SOLAR CELL

This project is another in the series of light-controlled circuits. This circuit is unique in that 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 make the Lamp to be ON in the presence of darkness on the Solar Cell.

Study Project 72 to determine the operation of the transistor when controlled by a photo cell. The difference of this circuit compared with Project 72 is that here the Solar Cell produces the required base current directly from light striking the Solar Cell surface. This circuit generally requires more light than that required when using the photo cell, but could the circuit be much simpler than this? 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!



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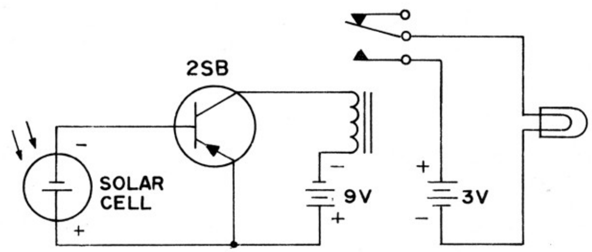
WIRING SEQUENCE:

123-7, 6-2, 3-122, 87-5, 4-121, 76-86, 75-88-120



74. SENSITIVE LIGHT CONTROLLED SWITCH

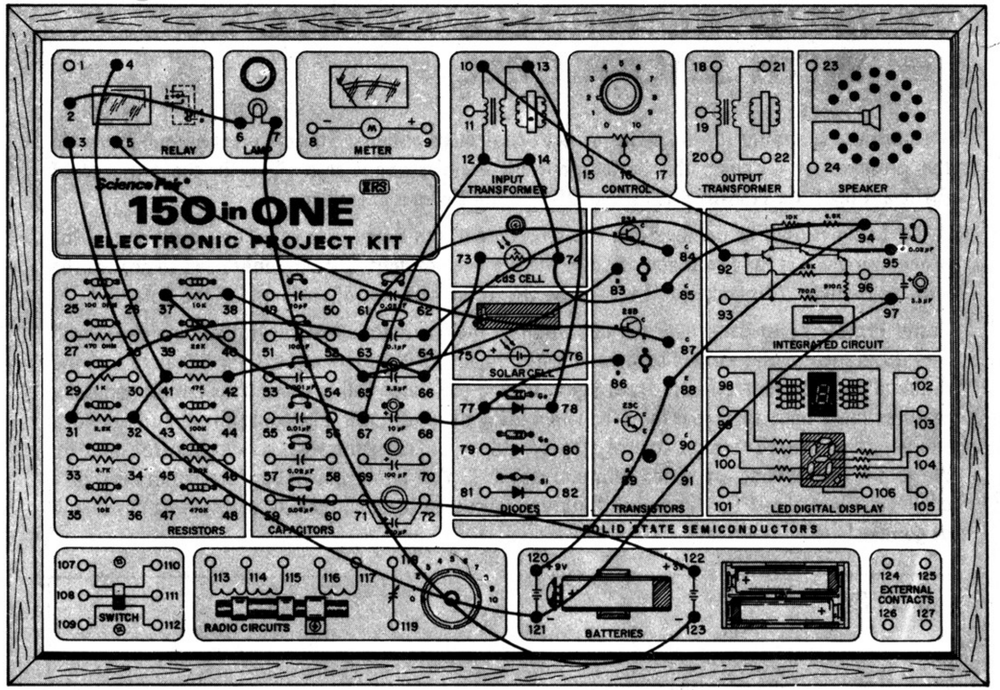
Here is a nifty project that will detect any changes in light intensity and indicate the presence of the change by either a flashing lamp or a continuous glow. In one respect this project is similar to Project 147 where you heard the hum and noise in the Earphone. The significant difference is that this is more sensitive and can respond to a wide range of light changes and noises.

The hum from the ON-OFF characteristics of a fluorescent light keeps the Lamp on. Incandescent lights and sunlight require some interruption or change in light level or the Lamp remains OFF. Because of this, you can use these light sources to accomplish different things. For example, while using sunlight or incandescent light you can momentarily pass your hand between the light and photo cell, and the light will go ON for a short time. If the movement of your hand is very slow, nothing will happen.

While using fluorescent light the photo cell must be in the shadow of something or the Lamp stays on. With this you can "turn ON the light" by simply laying something over the photo cell.

We've discussed the various circuits used in this project in other places, so we'll only give a brief description here. The 47K and CdS Cell form a voltage divider across the 3V. The voltage across the CdS Cell therefore depends on how the light changes the division of voltage to these two resistances.

The 2SA is in a zero-biased class C amplifier stage which amplifies the voltage charges appearing across the CdS Cell. The IC is a straight-forward audio amplifier with transformer-coupled output. The germanium (Ge) Diode changes the AC signal into DC, which is filtered by the 10 μF and applied as base-bias to the 2SB to turn it ON. The Relay is wired to light the Lamp whenever a signal is present.



WIRING SEQUENCE:

123-7, 6-2, 3-122, 4-41-32-121-97, 5-87, 10-95, 13-78, 86-77-68, 92-64, 84-63-31, 83-65-38, 73-66-42, 37-67-12-14-74-85-94-88-120

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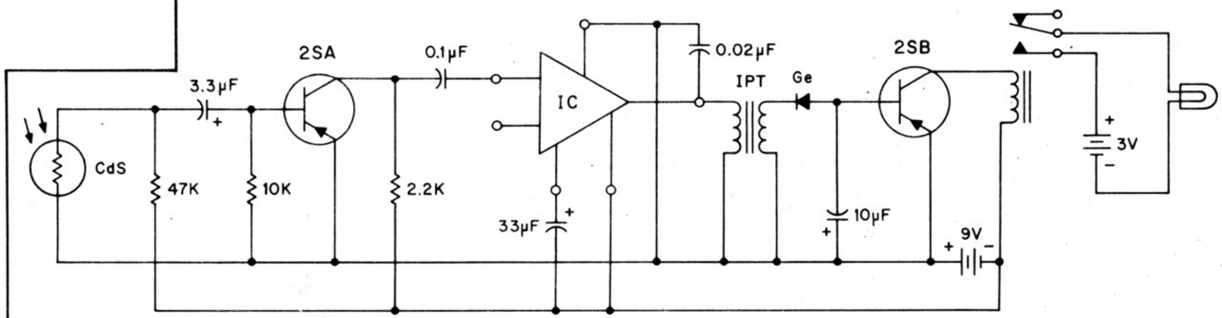


75. LIGHT CONTROLLED SWITCHER

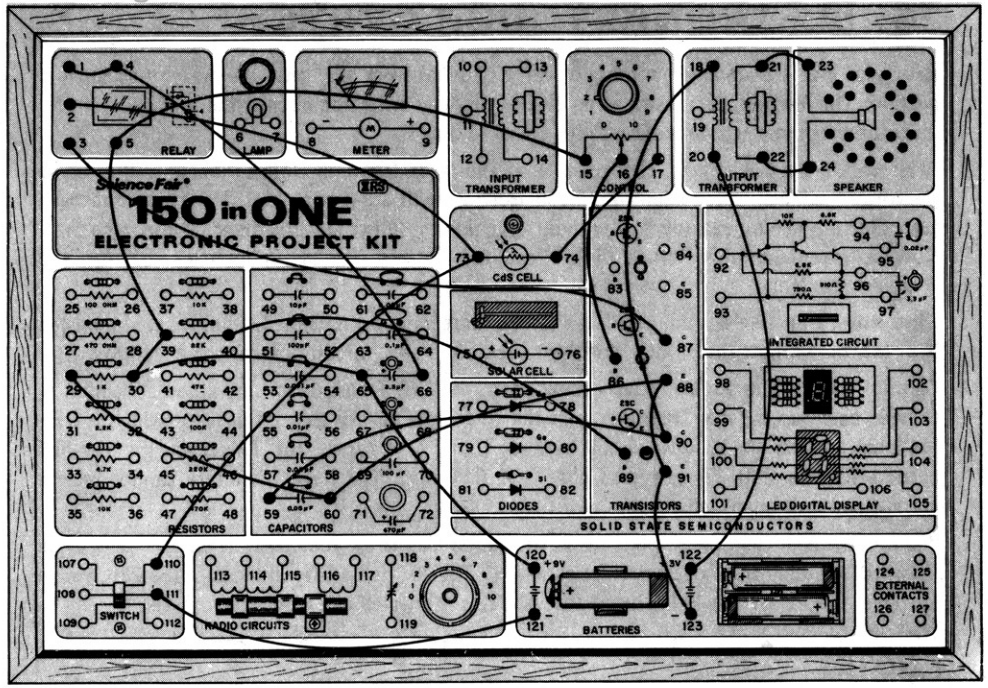
Here is a novel study in switching possibilities. The Relay is hooked up as a door-bell buzzer which operates continuously. The 2SB Transistor stage is operated like no other transistor stage you have ever seen before. We'll call it a light-controlled switcher. The output of this stage is then used to supply the B-E bias for the 2SC stage. The ON and OFF speed is controlled by the Relay and is at an audio rate so that output is heard from the Speaker when light strikes the CdS cell.

Circuit operation is controlled by the Switch which turns ON the Relay so that it will buzz. The 50K Control may then be adjusted so that the 2SB switcher will operate in whatever level of light is desired. Maybe you can think of a use for this kind of circuit, but it is included here for its unique switching actions.

Notice that as the Switch is closed and Control adjusted for the desired operation, the 2SB receives base voltage continuously. However, the collector only receives periodic pulses of voltage as the Relay armature (movable contact) swings toward the coil and makes momentary contact with the N.O. (normally open) contact. Emitter current then can only flow during these same brief periods of time.

The 2SB emitter current is made available as emitter current for the 2SC stage so that it can also conduct during the brief pulse current times. This part of the 2SC emitter current is only that which causes B-E bias for the stage. This bias current (between E-B) turns the 2SC ON so that current from the 3V Battery can flow around the circuit, and thus energize the Speaker momentarily.

The 0.05 μF capacitor keeps the transient spike from the Transformer from ruining the 2SC Transistor. This spike is generated by the sudden turn-OFF of current in the Transformer.



WIRING SEQUENCE:

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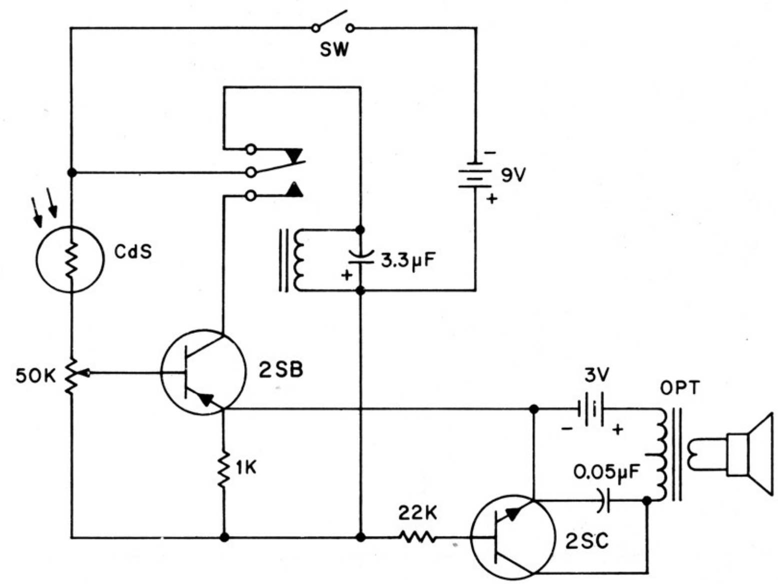


NOTES

76. ELETRONIC TOUCH SWITCH

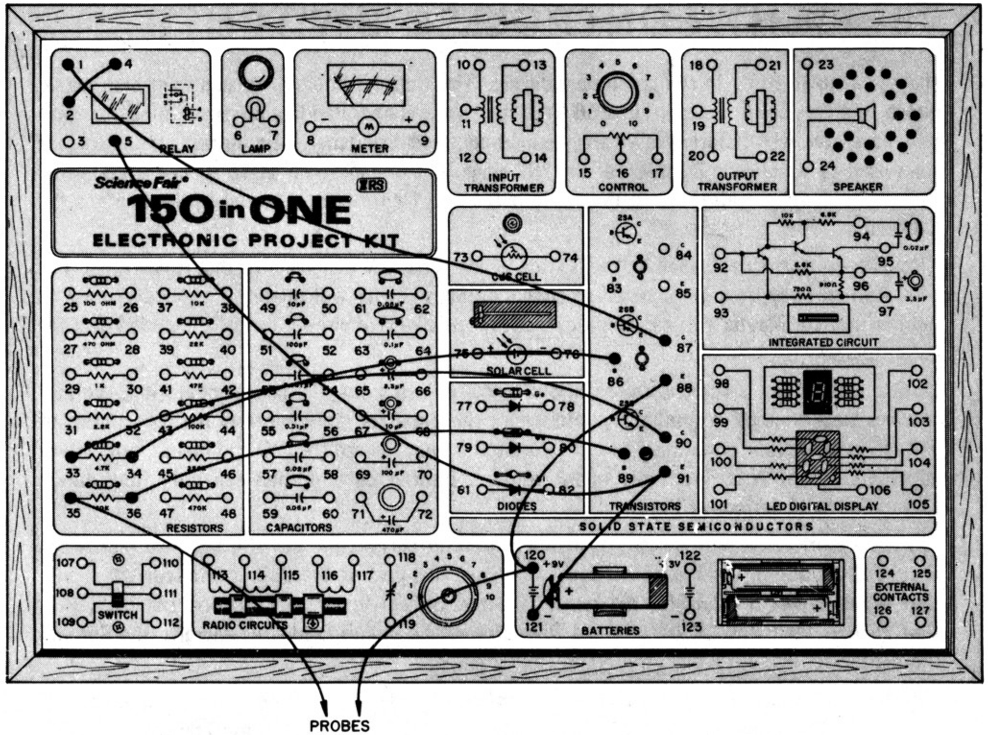
Have you ever wondered how those elevator switches work that only require you to touch a button? This project demonstrates an electronic relay switching circuit that will do it. Just a touch of a terminal or wire will cause the Relay to operate.

After wiring up this 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 appears like an open circuit between C to E of the transistor. This opens the base-bias current for the 2SB 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, and in turn the 2SB, which energizes the Relay. The Relay buzzes because it is connected like a door-bell buzzer.



WIRING SEQUENCE:

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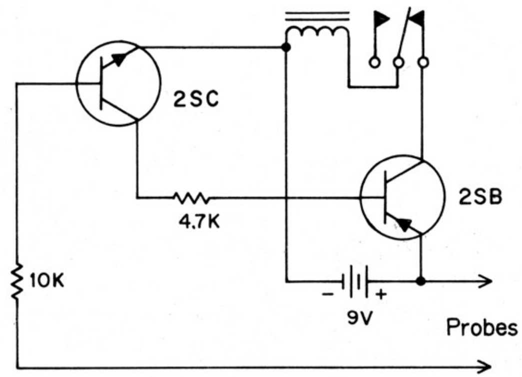


77. VOX– VOICE OPERATED (TRANSMIT) RELAY

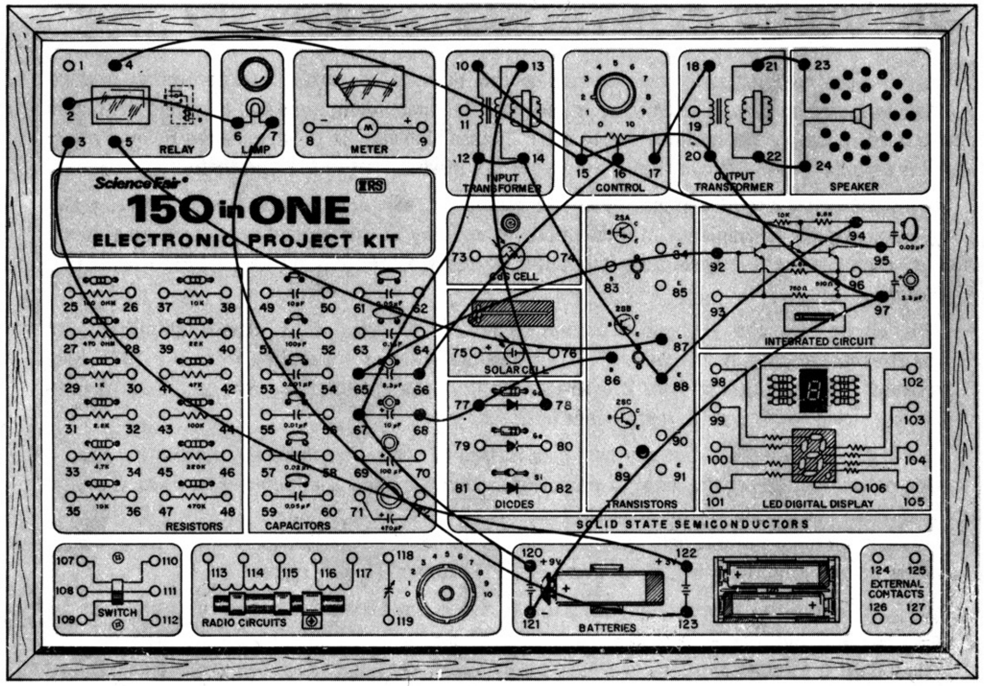
Have you ever wondered how a transmitter can go on automatically when an operator speaks in the microphone, and then turns off automatically when he is finished talking? This project shows you how it can be done.

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; in an actual transmitter it would turn on the transmitter.

This circuit is commonly called a VOX circuit. This comes from Voice Operated Xmtr (transmitter). It is generally used along with an "anti-trip" circuit. The anti-trip circuit samples the receiver speaker signal and feeds this into the VOX circuit out-of-phase (anti) with the microphone signal to keep the received signal from turning the transmitter ON (trip) as the microphone picks up the speaker sounds.

For demonstration 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 this can be used with it to record only when there is something to record. Most cassette recorders have this remote control feature available.

If longer or shorter delay times are desired, the 10 μF 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.



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WIRING SEQUENCE:

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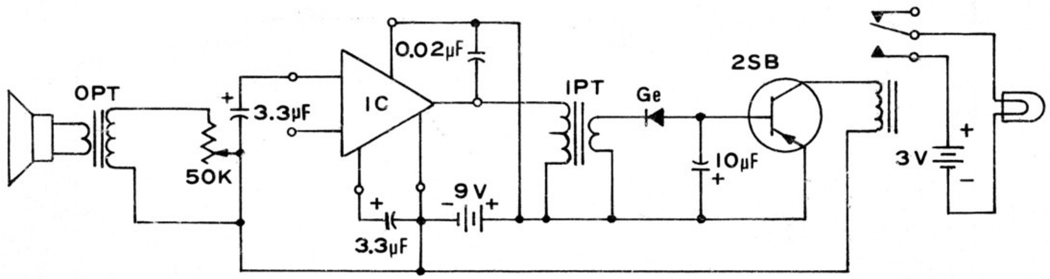


78. VOICE CONTROLLED SWITCH

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 77 is a similar type of circuit, but it uses the IC to provide most of the gain there.

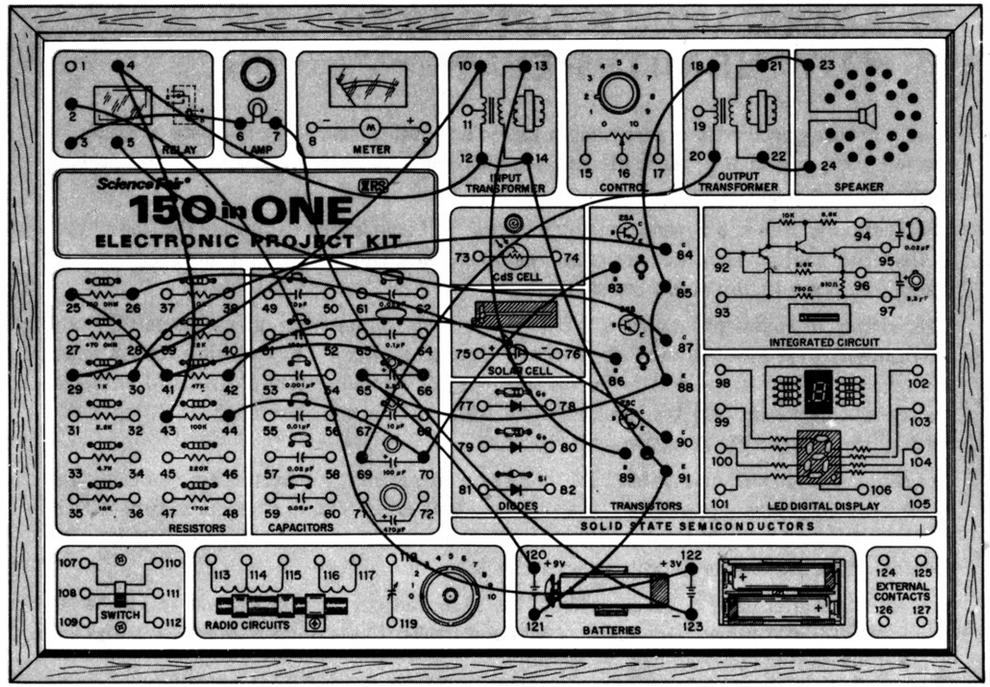
The VOX (voice operated transmit) circuit is used by radio amateurs on transmitters as a way of obtaining the convenience of a telephone. The Relay in this project only turns on a Lamp, but when used with transmitters it is wired to replace the function of the SEND-RECEIVE switch.

This circuit has the following features. The 2SA 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 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 then does not have to be rectified by a diode. The 100 ohm resistor functions to limit peak collector current for the 2SC Transistor. The 3.3 μF capacitor filters the signal so that the 2SB receives relatively smooth DC base current.

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

NOTES



WIRING SEQUENCE:

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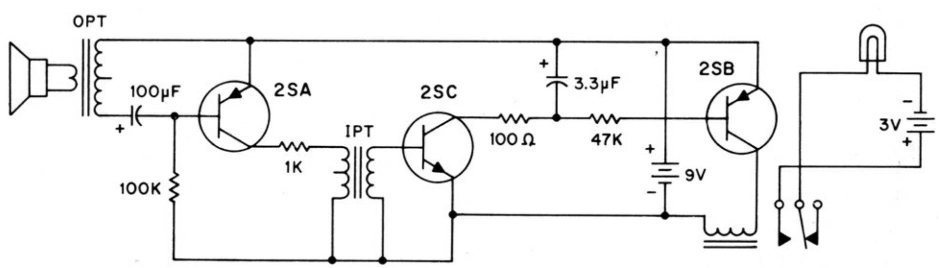


79. TRANSISTOR SWITCHER

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

The NPN transistor at the bottom of the circuit is continually turned on by a positive base voltage supplied through the 47K current 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 is across the 47K resistor. The base current may then be calculated by Ohm's law as:

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

If this NPN transistor has a current gain capability 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 PNP transistor at the top of the diagram is turned on through both a 22K current limiting resistor and an on-off switch. Because this resistance is about half that of the 47K, the current supplied as bias to this transistor is twice that supplied to the NPN. The PNP transistor is therefore said to be more on or "harder on" than the NPN.

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 voltage across the transistor collector-to-emitter, insufficient voltage available for the readout to give adequate illumination and possible over heating of the transistor.

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

Now attempt to parallel more segments in order to display different numerals such as 7, 4, 5, 6 and 8. You should notice that as more segments are added, the light output decreases. The reason for this is that the "on" transistors are not fully on.

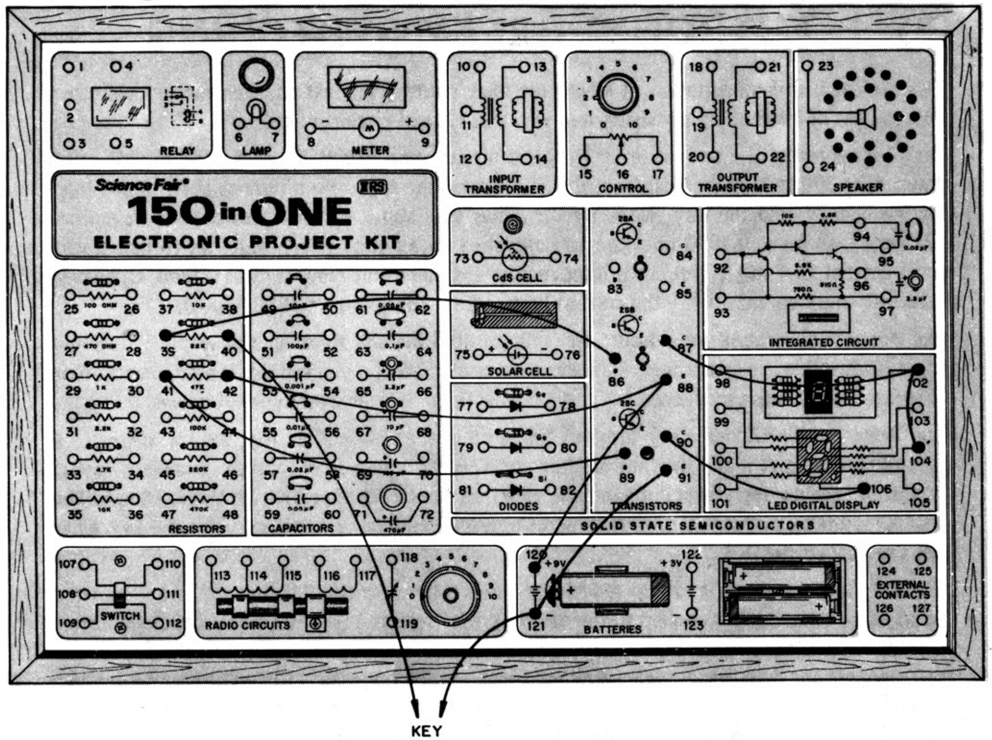
Transistors may be turned on harder by increasing the base-bias current. This is accomplished by decreasing the limiting resistance in the base circuit. **Don't decrease this resistance too far though or the transistor will be burned out!**

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.

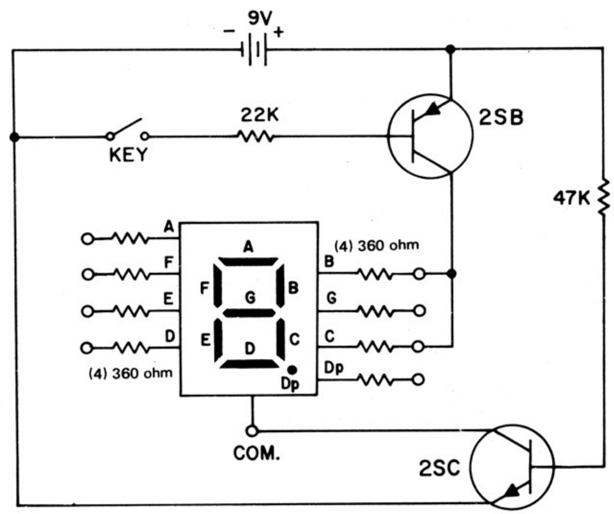
From this project we can see that whenever the base-bias is present the transistor is ON, but that full-on is indicated by the low voltage across collector to emitter. A transistor which has maximum collector-to-emitter voltage present is in the off state.

NOTES



WIRING SEQUENCE:

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



80. 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 300 mA (milliamps) from the 3V Battery, the Relay circuit draws about 9 mA from the 9V battery, and the Key switch circuit draws only about 0.4 mA. Notice that a circuit of relatively high current (300 mA) can be controlled by a switch which only has to pass a very small current (0.4 mA). 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).

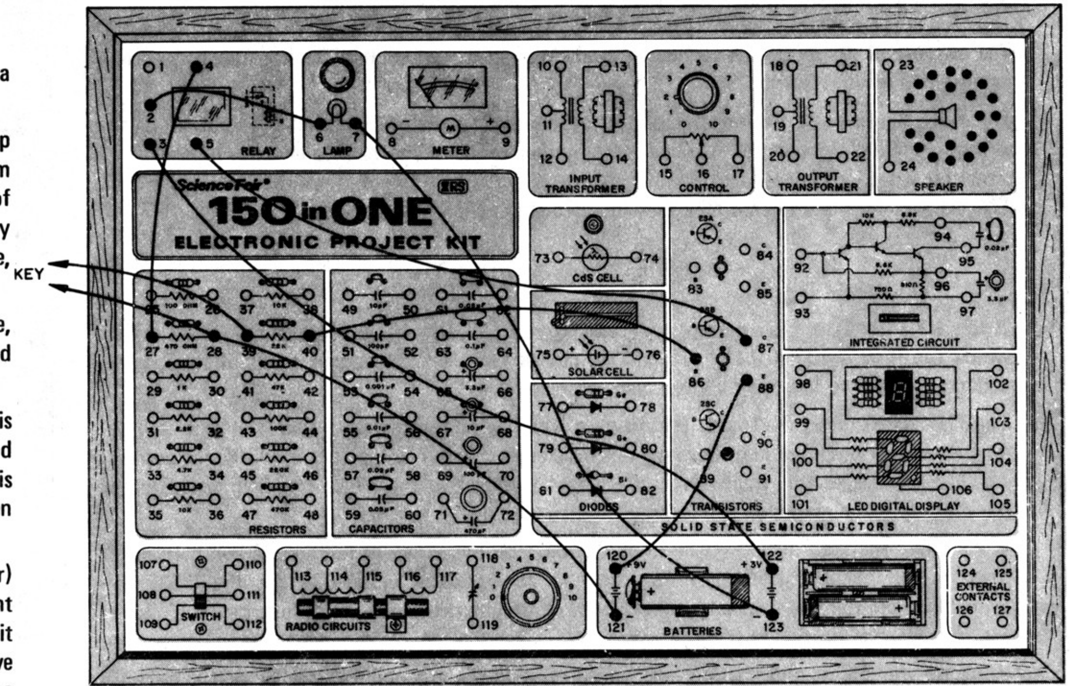
The relays used around your house for this purpose include those in the washing machine, dryer, dishwasher, electric range, furnace, automobile, etc. So you see this is a popular method of switching. It allows small switches and controls to control large amounts of power.

The Relay in this kit has many turns of fine wire in the field coil so that only 6 mA 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 18 mA. This circuit includes a series 470 ohm resistor in order to reduce the current to about 9 mA when using the 9V source.

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 2SB has (typically) a **beta** of 80 or so. This means that the base current must be at least one eightieth of the collector current.

To insure adequate ON characteristics it is best to assume a beta no greater than about 25 in this circuit. Required base current is then 9 mA ÷ 25 = 0.36 mA. The 22K resistor in series with the 9V battery is able to supply about 0.4 mA of current so operation is assured.

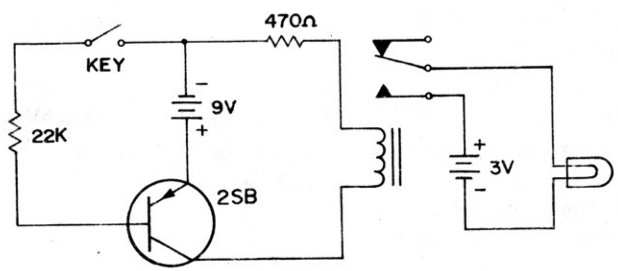
If you have a VOM you can check these currents directly in this circuit.



WIRING SEQUENCE:

123-7, 6-2, 3-122, 5-87, 4-27, 86-40, 121-28-Key, Key-39, 88-120

NOTES



81. 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 slide 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.

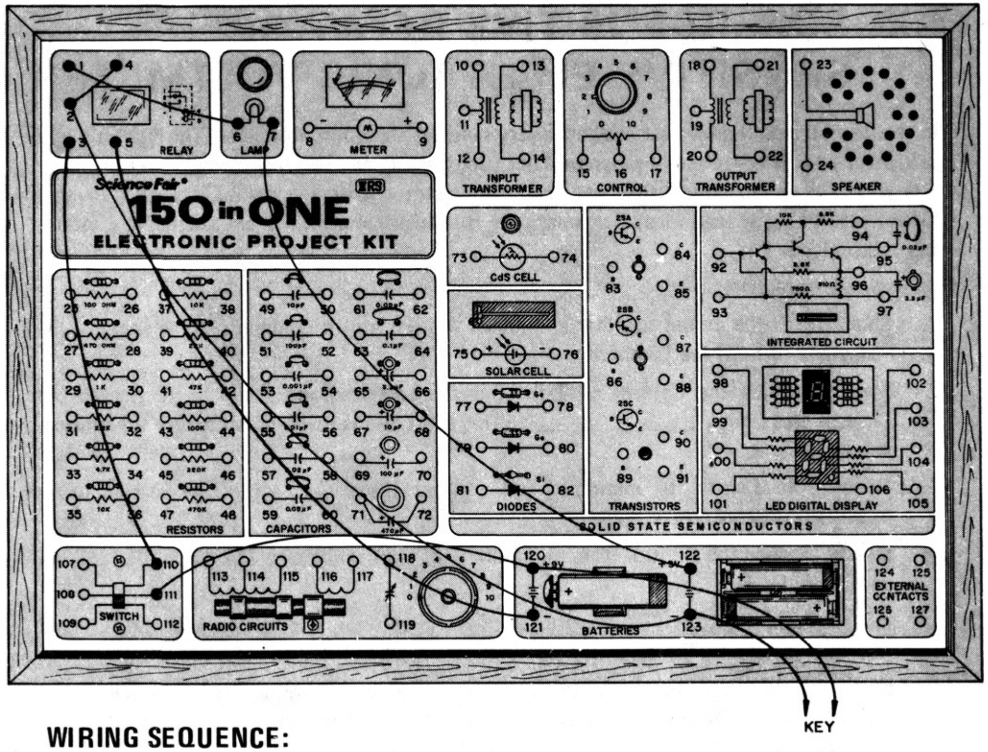
Connect the circuit and check operation by momentarily actuating the switches in sequence. You should find the following: The Lamp is always turned OFF by the N.O. switch (Key) and ON by the N.C. switch (slide Switch).

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 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" contacts) need only be momentarily opened, and the Relay drops out (de-energizes).

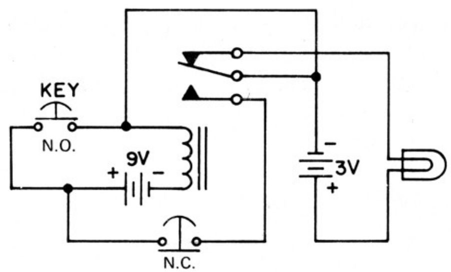
A separate set of contacts is generally used with this type of relay circuit so the circuit to be controlled can be turned ON and OFF along with the Relay. With only one set of contacts, like this Relay, the circuit is ON when the Relay is OFF and vice versa.

NOTES



WIRING SEQUENCE:

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



82. 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 in 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 and much more.

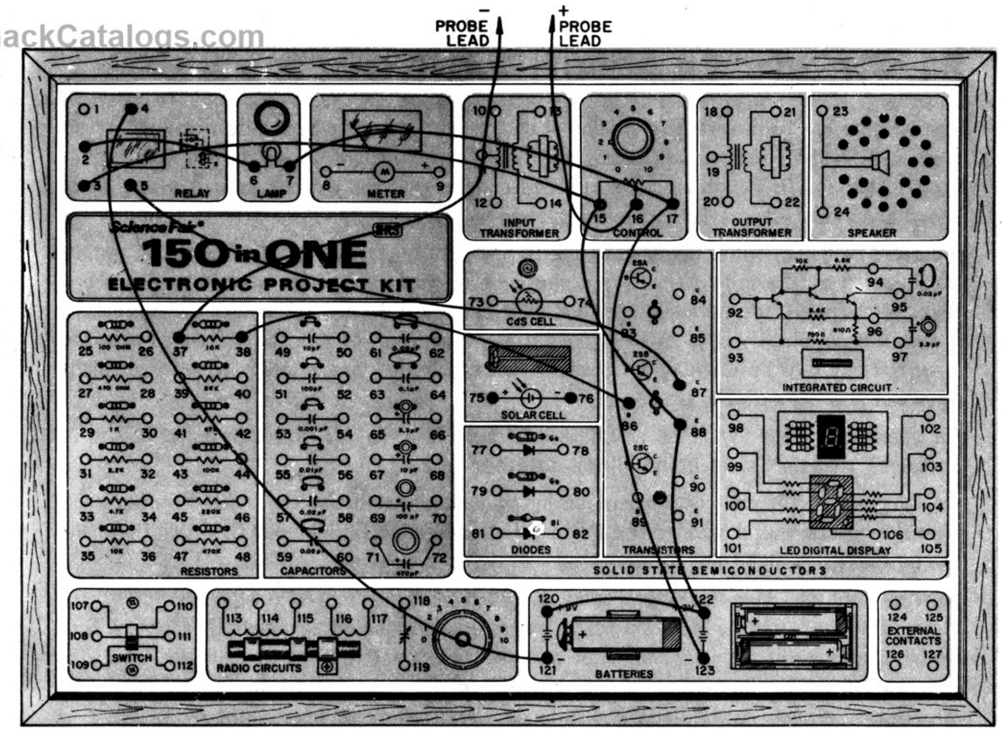
Operation is as follows:

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 Lamp lights at "0" or very low Control settings, the voltage is quite high and typically above 0.7 volt.
   b. If Lamp lights near but below the setting of Step 2 above, 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 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, penny battery (see Project 18) 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

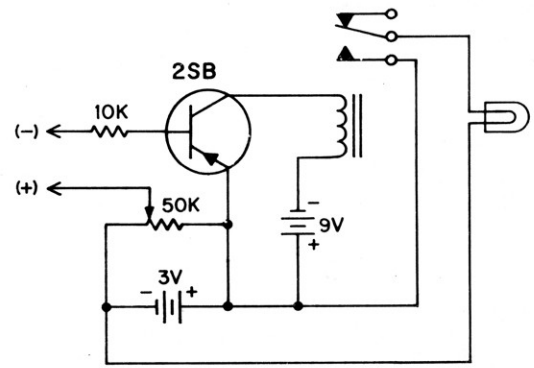


WIRING SEQUENCE:

123-17-7, 6-2, 121-4, 5-87, 86-38, 37-Negative Probe,

16-Postive Probe, 3-15-88-122-120

To Test with Solar Cell: (–) Probe to 76, (+) Probe to 75



83. RELAY LIGHT FLASHER

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

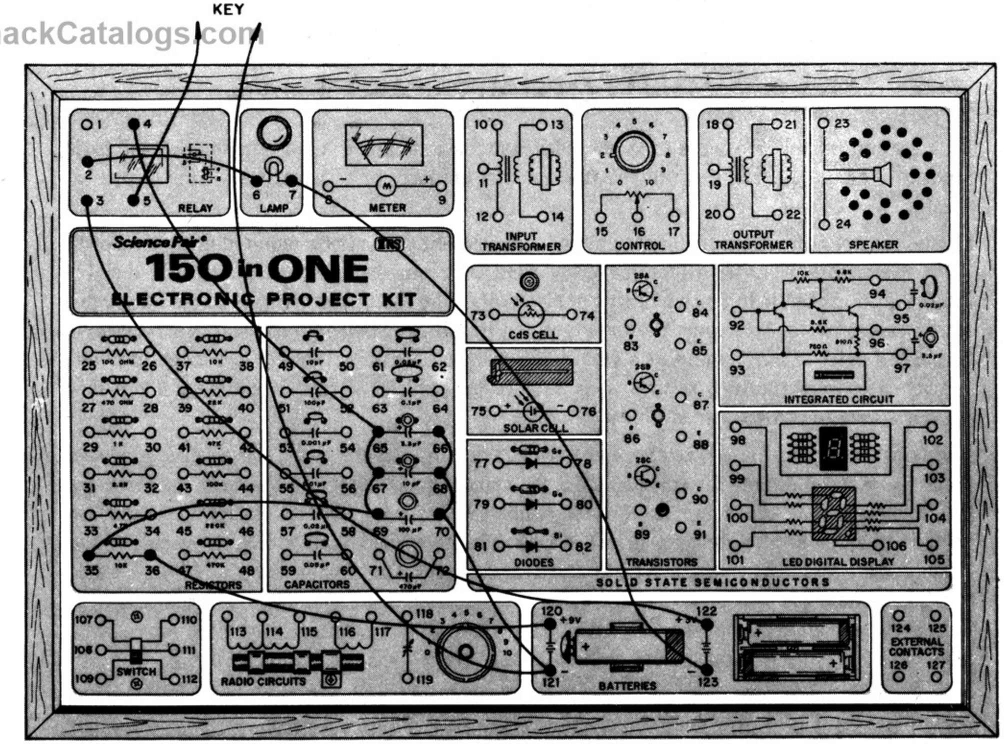
How about warning lights on barricades at highway danger or construction sites. Also flashing lights at a school crossing or a dangerous street intersection. And the turn signals on a vehicle. All of these use a circuit very similar to this one.

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 9V Battery but through a series 10K resistor and from across a total capacitance of $3.3 + 10 + 100 = 113.3\ \mu F$. 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 1.0 mA) to energize the Relay or to keep the Relay energized. This is because the Relay requires about 6 mA (or more) to be initially energized and as little as 1.0 mA 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 up 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 500 ohms) so that the Relay is only momentarily energized.

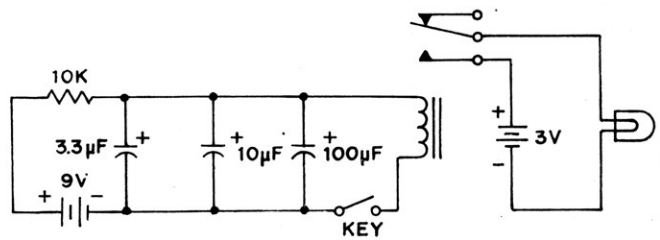
This type of circuit finds application in such equipment as spot welders and strobe lighting as used in photography.



NOTES

WIRING SEQUENCE:

123-7, 6-2, 3-122, 4-65-67-69-35, 66-68-70-121-Key, Key-5, 36-120



84. 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.

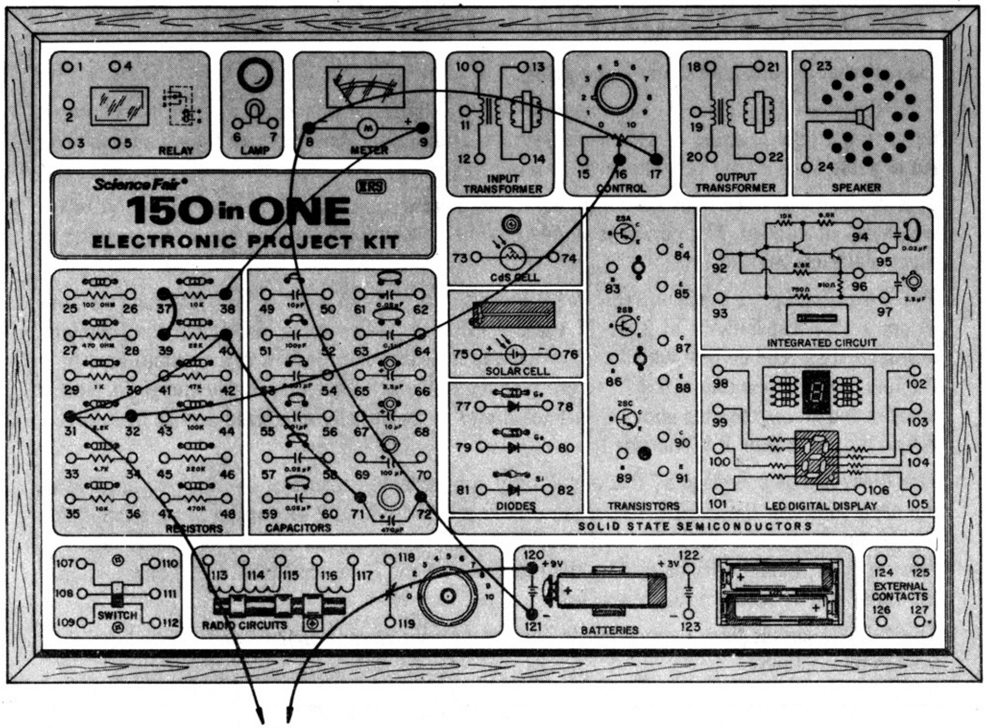
Many control circuits are required to either turn a circuit OFF after a required delay time or to turn the circuit ON after a required delay time. The most basic and simple control uses the ability of a capacitor to store a charge of electricity. The charge can be made to pass through a series resistance 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 is allowed to slowly be removed by a shunting resistance, a delay in the removal of capacitor voltage is obtained which 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 scale 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), that is, 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.

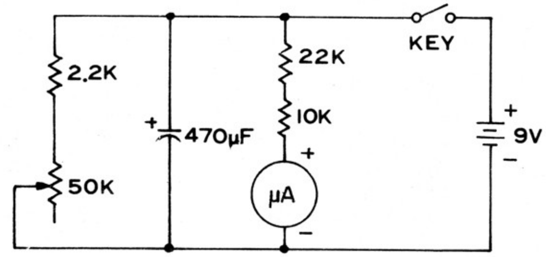
NOTES

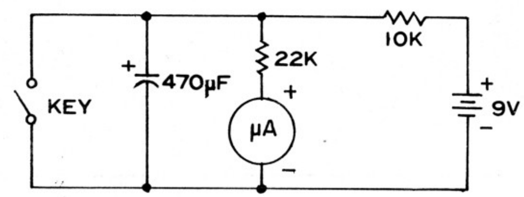


WIRING SEQUENCE:

FAST ON, SLOW OFF: 121-72-8-17, 9-38, 37-39, 16-32, 71-40-31-Key, 120-Key

SLOW ON, FAST OFF: 37-39-71-Key, 9-40, 38-120, 8-72-121-Key





85. 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, 100 μF or 470 μF. 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 2SB. The Relay is therefore energized.

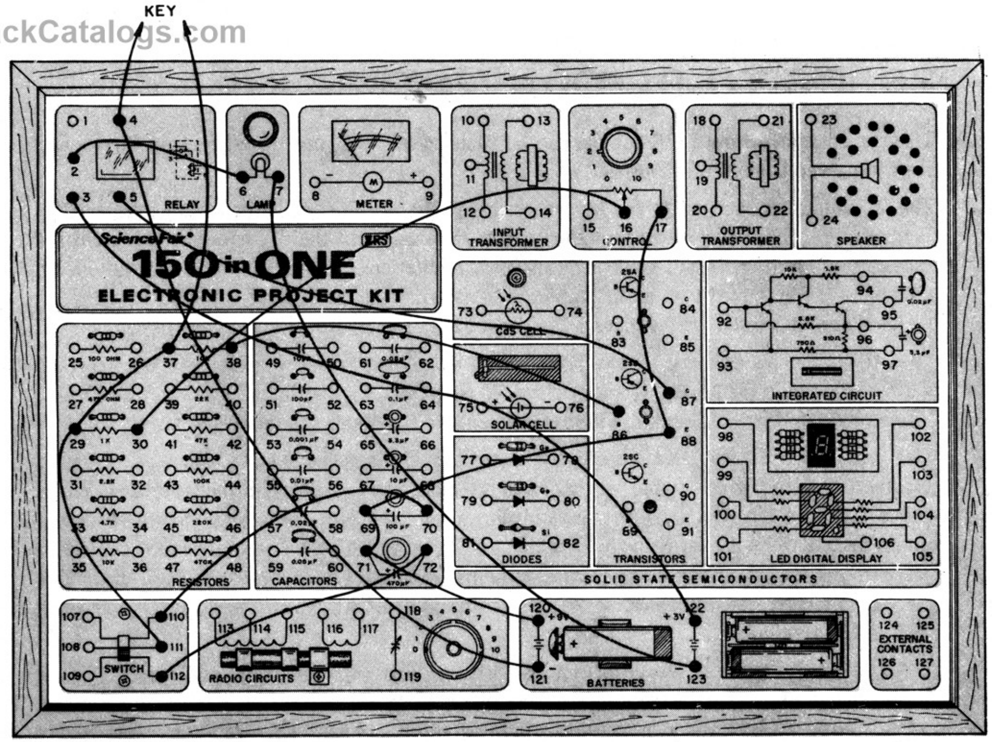
The above turn-off delay is dependent upon the product of R and C in the base circuit. The higher the product, the longer the delay. The smaller the product, the shorter the delay.

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

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

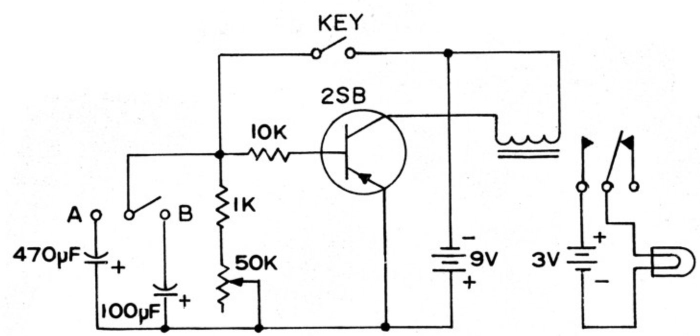
Now a measurement of the above extremes on the actual circuit may show differences in the actual times obtained, because of component tolerances, but the relative values will be very close. Use a watch or clock with a second hand and check these results for yourself.

NOTES



WIRING SEQUENCE:

123-7, 6-2, 3-122, 87-5, 86-38, 16-30, 17-88-69-71-120, 70-110, 72-112, 111-29-37-Key, Key-4-121



86. 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 2SB Transistor to obtain the necessary gain greater than one 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 0.05 μF and 0.1 μF capacitors are used to obtain a desired amount of feedback and a more useful waveshape of AC voltage.

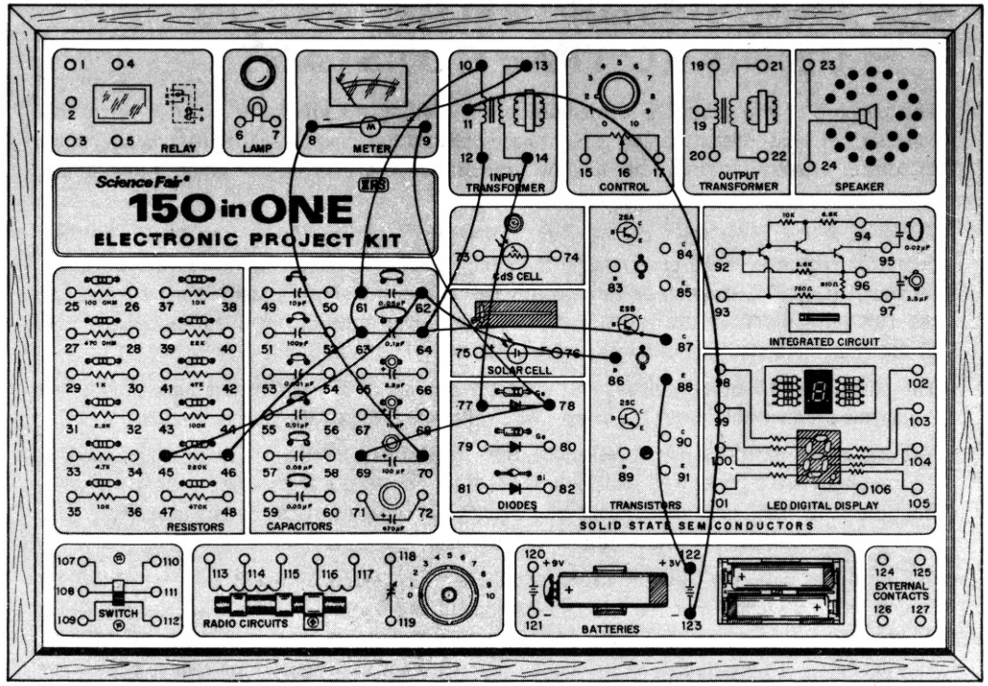
The AC across the primary of the Transformer is coupled to the secondary by the magnetic field within the Transformer. The secondary AC is rectified by the Ge half-wave rectifier Diode, filtered by the 100 μF capacitor, and then delivered to the Meter as a relatively pure DC.

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 through wires. If the DC were sent out over the transmission wires the losses would be high and efficiency would be low. This is over come by stepping the DC up to a high-voltage AC which can be sent out over the long transmission lines with little loss and high efficiency. At the end of the line the AC voltage is transformed down to the desired lever of AC which may then be converted back to DC as required.

This is a good project to experiment with different values for capacitors and resistors in the oscillator circuit. Be a good experimenter and record your results like the scientists do. You can try any value of capacitor in place of the 0.05 μF and 0.1 μF units, but don't go below 10K in value for the 220K resistor or the Transistor and Meter may be damaged. You can hear what the oscillator sounds like if you connect the crystal Earphone across the Transformer (either winding).

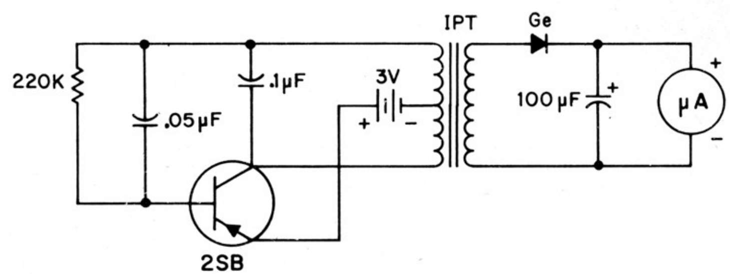
If you are able (and careful) the Meter may be replaced by the Relay, the 0.05 replaced with a 0.01, the 220K replaced with the 47K and the 3V Battery with the 9V Battery. This circuit is able to deliver enough power from the oscillator to energize the Relay. Also if this circuit is used the Relay may be replaced with the LED wired to display various letters and numbers. In the space below you might want to include a Schematic diagram and hookup chart for these alternate circuits.

NOTES



WIRING SEQUENCE:

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



87. LAMP BLINKER CIRCUIT

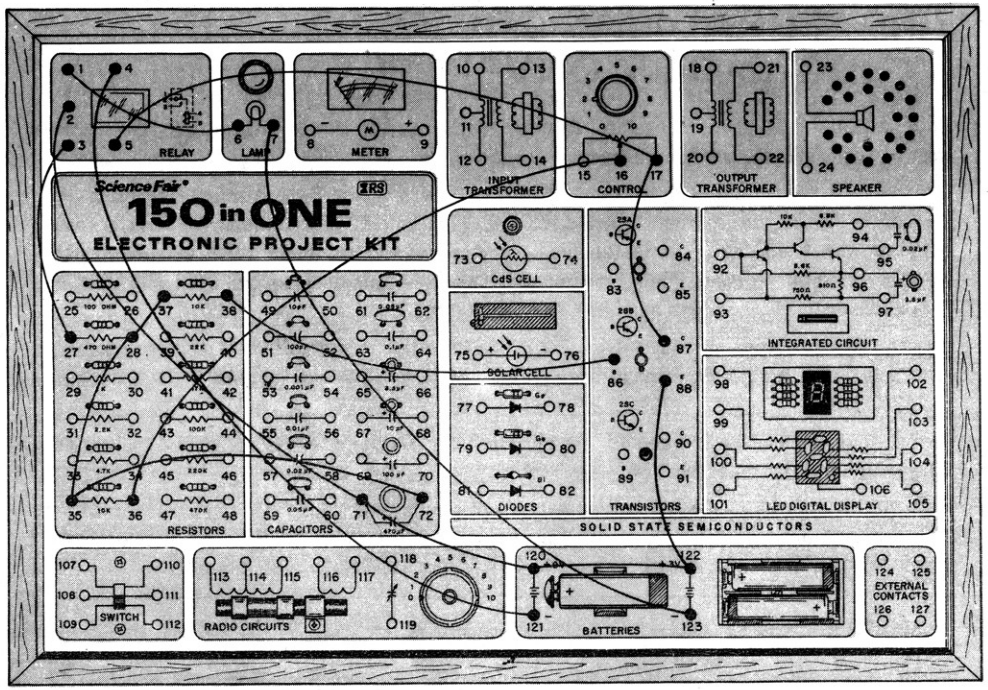
This project demonstrates the operation of a lamp blinker circuit like those you have seen blinking on the top of tall buildings and radio antenna towers. The actual switching of the lamp current is with reliable relay contacts, but the timing and control functions are provided by a switching transistor.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

This exact circuit could be used as emergency warning lights 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 not OFF, which would provide no protection).

When the 9V Battery is first connected, the Transistor remains OFF while the capacitor begins to receive a charge through the 10K and 50K Control resistances. 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 a discharging resistor across the timing capacitor. This discharges the capacitor down to where the Transistor loses base-bias and is turned OFF, setting conditions back to the start of the cycle.

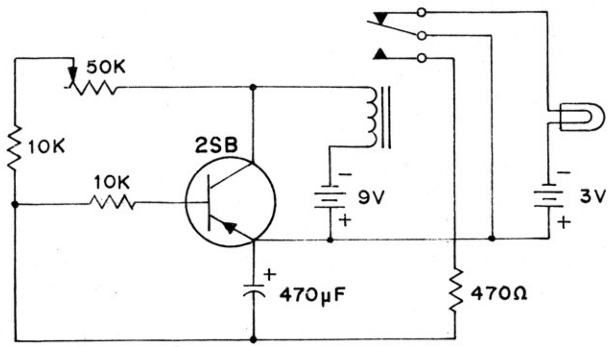
A characteristic of the Relay which helps give a delay in the OFF part of the cycle is that the Relay coil-current must be reduced to about 1.0 mA before the contacts will drop out. This is much lower than the 6 mA or more which is required to energize the Relay. The 470 ohm resistor is also included to slow down the OFF time. A secondary advantage of this resistor is to save the Relay points from the destructive surge of current from the capacitor.



WIRING SEQUENCE:

123-7, 6-1, 121-4, 87-17-5, 16-36, 3-27, 37-28-35-72, 38-86, 2-71-120-122-88

NOTES



88. MECHANICAL CHOPPER (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.

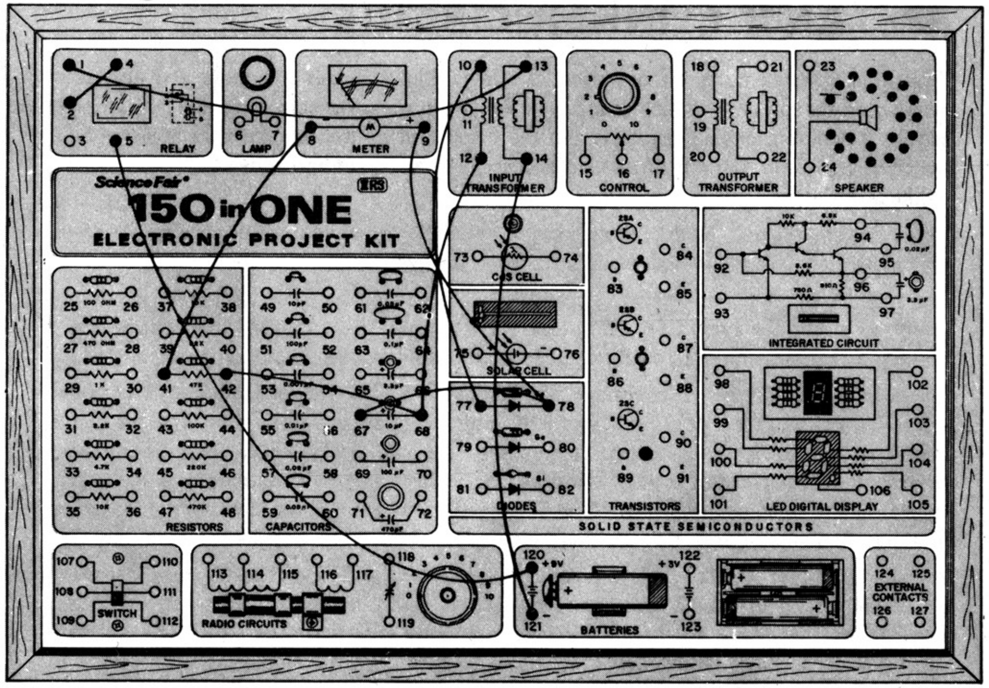
The Relay is wired similar to a door-bell buzzer. The vibrating Relay contact interrupts the current in the circuit so that square-wave pulses of current pass through the Transformer winding. The Transformer passes the square-wave waveform on to the other winding due to transformer action. Because more 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 10 μF capacitor, and then the resulting DC voltage is measured by the DC voltmeter, composed of the Meter and the 47K resistor.

For a more detailed description of the DC voltmeter see Project 36. For a more advanced DC-to-DC converter see Project 86.

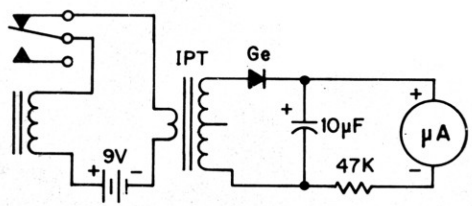
This mechanical chopper was very popular before the days of transistors, but now transistors have replaced these in all new designs. Your parents will remember the days of the automobile radio "vibrator". The vibrator performed the function of the Relay in this circuit.

NOTES



WIRING SEQUENCE:

10-77, 9-78-67, 12-68-42, 8-41, 120-5, 2-4, 1-13, 14-121



89. MOMEMTARY-ON CALL SWITCH

The purpose of this experiment is to demonstrate a momentary-ON circuit which is very easy to make. This type 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 36. The difference is that here the energy is put to work energizing the Relay.

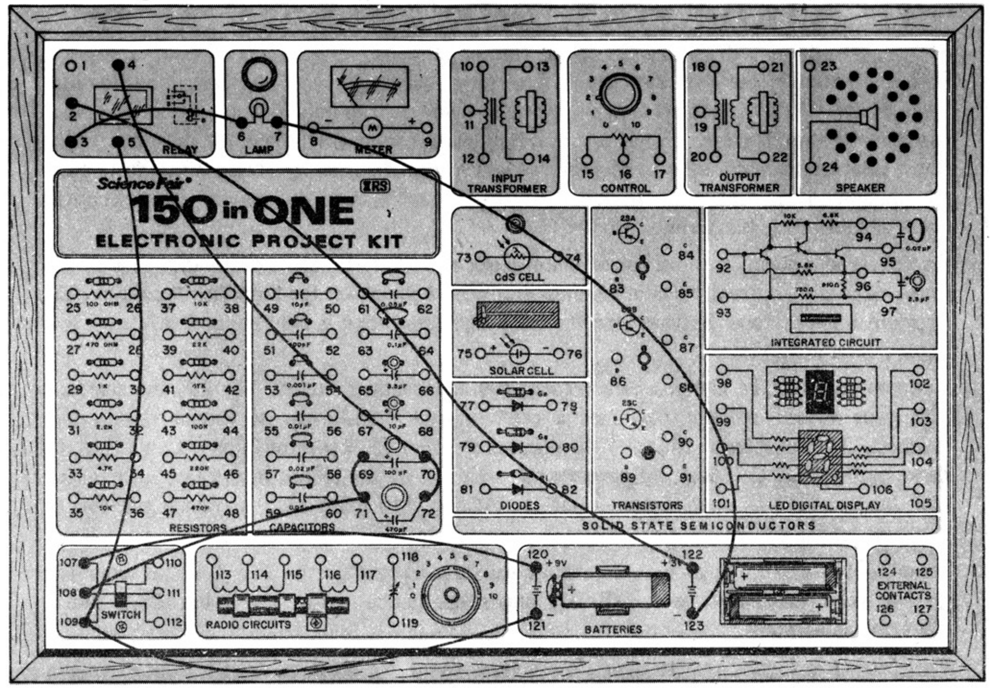
In one position of the switch the capacitors are charged by current which must flow through the Relay, and in the other position they are discharged by having the current flow through the Relay. The capacitance used is high enough to keep the Relay energized for about a second.

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

$$C = \frac{C_1 \times C_2}{C_1 + C_2}$$

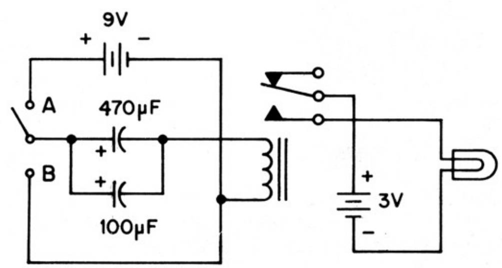
Therefore if the 470 and 100 are rewired for a series connection, the resulting capacitance is about

$$C = \frac{470 \times 100}{470 + 100} = \frac{4700}{570} = 82\,\mu F$$



WIRING SEQUENCE:

123-7, 6-3, 2-122, 4-70-72, 5-109-121, 108-71-69, 107-120



NOTES

90. "CRACK-OF-DAWN" ALARM CLOCK

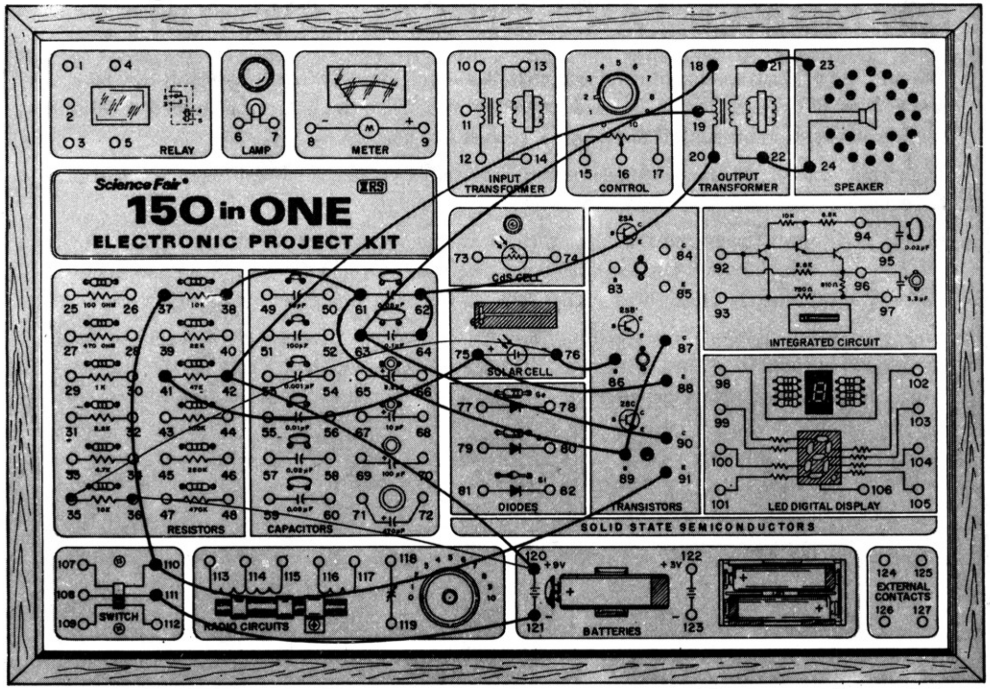
This is the first in the next category of projects — **Alarm, Warning and Protection Circuits.** Many of these experiments are very practical; you may want to build one or more of these in a permanent form. Try each circuit and think of ways you might be able to use them. Your Radio Shack store has a 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 with a steady tone. Battery current during alarm operation is only about 6 mA, so it is a battery saver at all times.

You can consider the 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 2SB is controlled by the Solar Cell. In darkness the Solar Cell does not generate any base-bias for the 2SB 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 2SB, the 2SB 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 OFF in the dark drawer, but if anyone opens your drawer you'll know it.



WIRING SEQUENCE:

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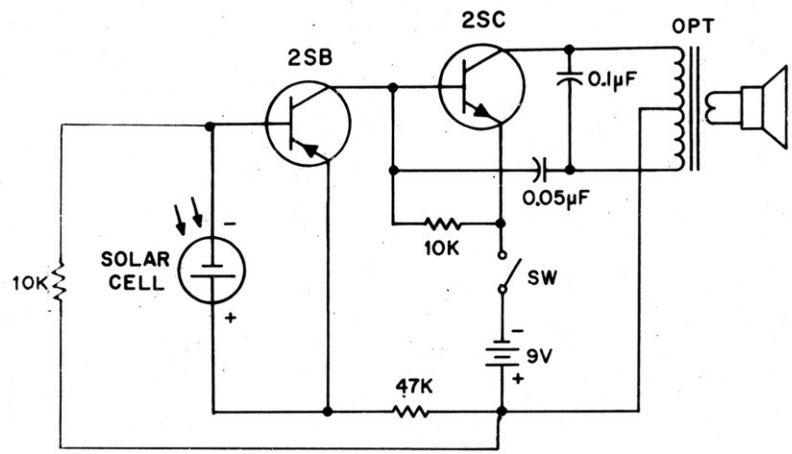


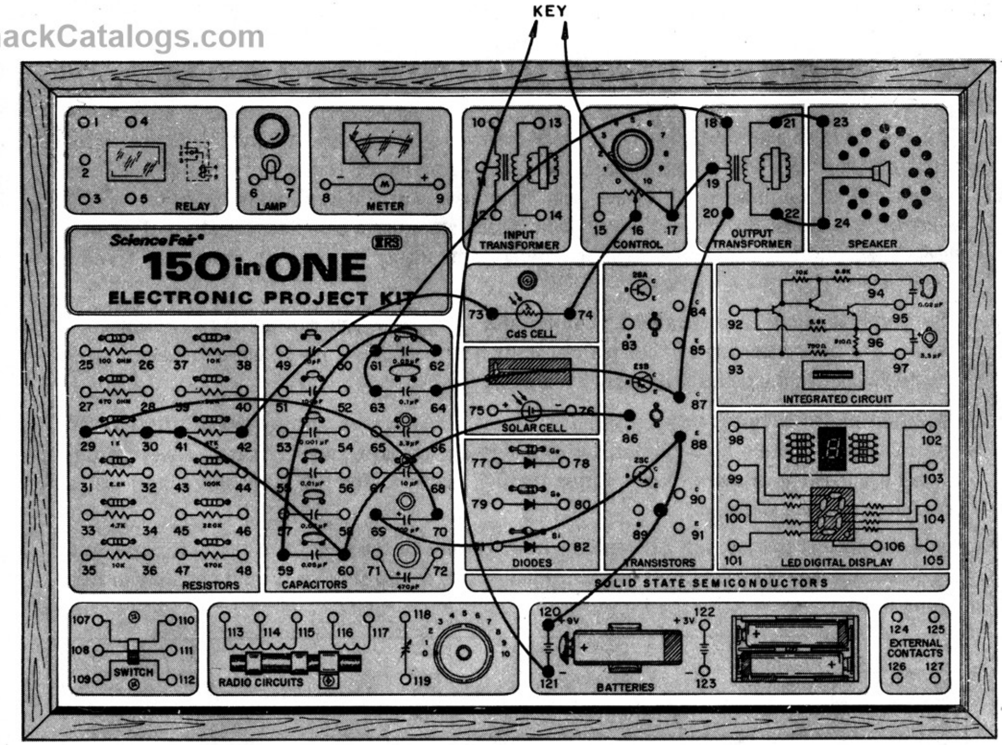
NOTES

91. DAY-LIGHT BIRD OR "EARLY BIRD"

This is the electronic bird circuit of Project 7, with photo-electric control of the transistor bias. The operation of the CdS photo cell is described in many other projects in this kit. We might call this circuit the day-light 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 7.

NOTES



WIRING SEQUENCE:

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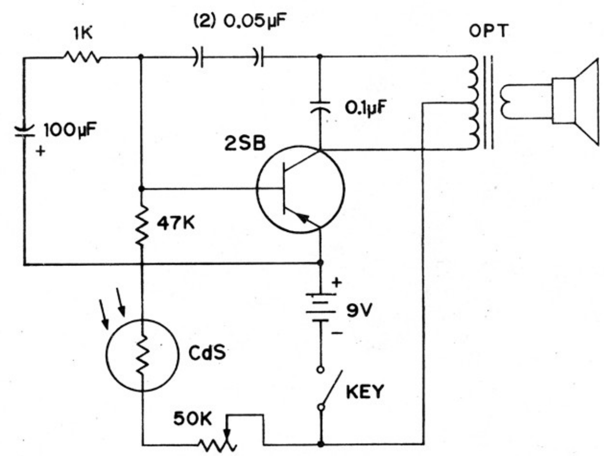


92. CLOSED LOOP BURGLAR ALARM

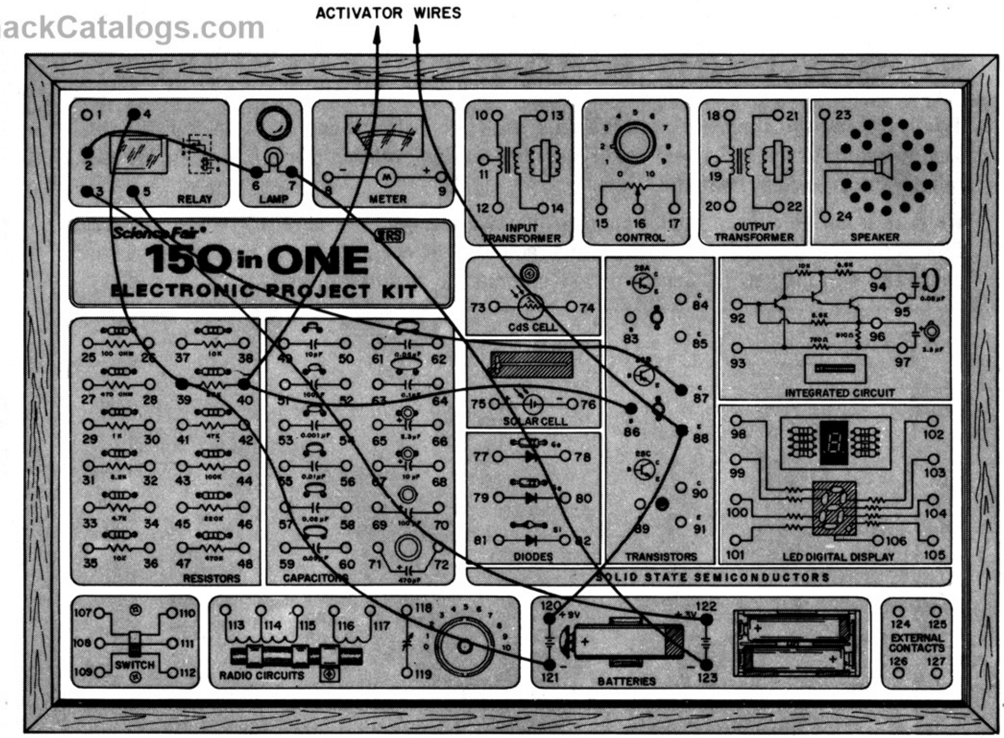
This project is an alarm which may be used wherever a closed loop of wire can be used as the activator. When the wire is opened or broken, the Lamp lights. This action is like that used by commercial establishments you have seen that have metallic conductive tape around the windows and doors. By the 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 activator 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 junction. The C-E leads appear to have an open circuit during this state.

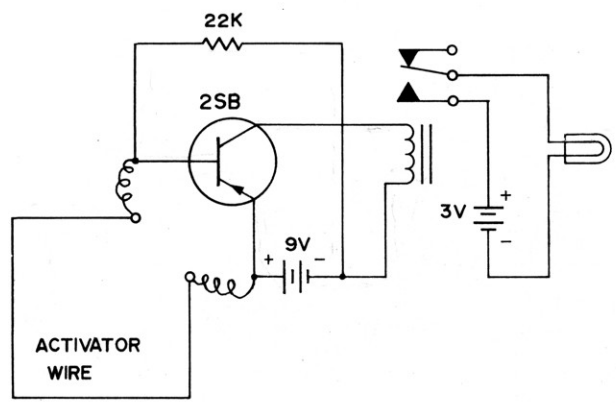
When the wire is opened, the 22K resistor feeds current to the base from the Battery to turn the Transistor ON. The C-E leads appear to be shorted in this state so current can flow to turn on the Relay.

NOTES



WIRING SEQUENCE:

123-7, 6-2, 87-5, 3-122, 4-39-121, 86-40-Activator Wire, Activator Wire-88-120



93. WATER LEVEL ALARM

This electronic circuit is an example of those used to monitor rising water levels such as on rivers, dams, spillways, etc. To prevent unexpected overflow, you can use it 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 constantly watch it.

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, RF output is weak but usable, to insure that the circuit is operating. When the contact probes both touch the water, RF output increases in strength and frequency changes some, 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 10 μF capacitor which acts as a short circuit at these frequencies. Feedback to the base is through the 0.05 μF capacitor. The 47K resistor supplies the base-bias current to turn the Transistor ON.

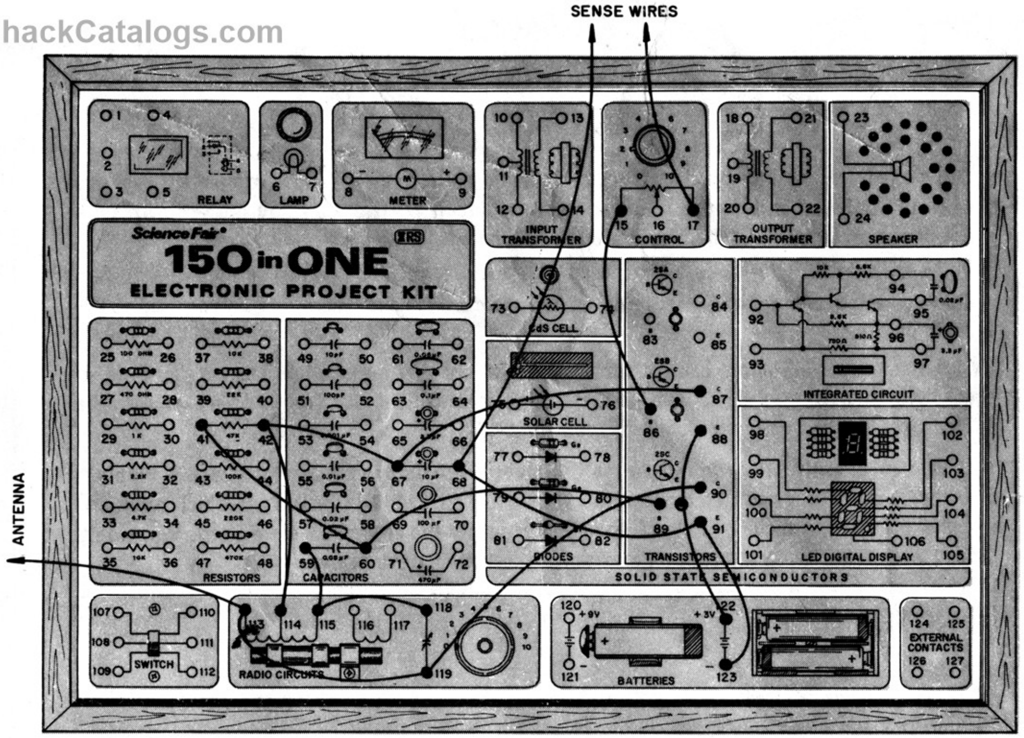
Notice that Battery current must flow through the 2SB Transistor to get to the oscillator circuit and back. With the probes insulated from each other, the only current that can flow is the leakage current I_{CEO} (current from **C**ollector to **E**mitter with the base **O**pen). This current is generally only a few hundred microamps. This low current only allows very weak oscillator operation. These oscillations are tuned with the tuning capacitor to obtain a beat note (whistle) in a nearby receiver which is tuned to a weak station.

When the probes both contact the water, some current can flow through the water to supply some base current to the 2SB. This base-current turns the 2SB ON so that oscillator current can flow between C-E of the 2SB with little resistance. We're using the full resistance of the 50K Control as a current limiting resistance. Without this resistance the 2SB could be burned out by excessive current, especially if the probes are accidently shorted.

With the 2SB ON, the RF oscillator produces a much stronger 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.

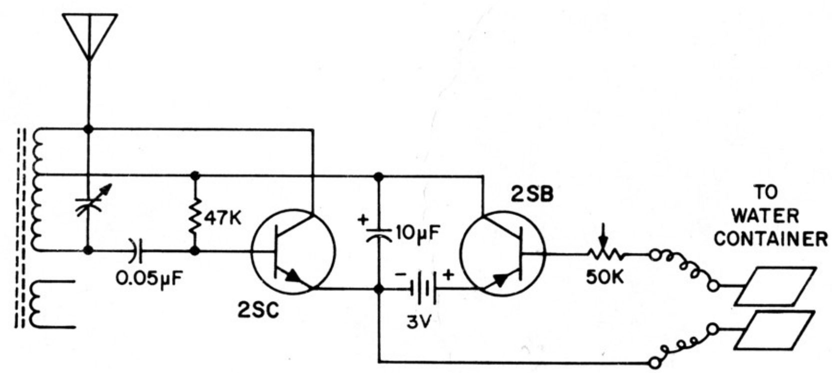
If you don't want the oscillator to operate when the probes are dry, shunt the 2SB B-E junction with a 22K resistor. This will reduce the I_{CEO} leakage current sufficiently to turn the oscillator off; but with this resistance present the contact probe area must be larger than without it.

NOTES



WIRING SEQUENCE:

15-86, 87-67-42-114, 88-122, 90-119-113-Antenna (green wire supplied), 118-115-59, 89-60-41, 17-Sense Wire, Sense Wire-68-91-123



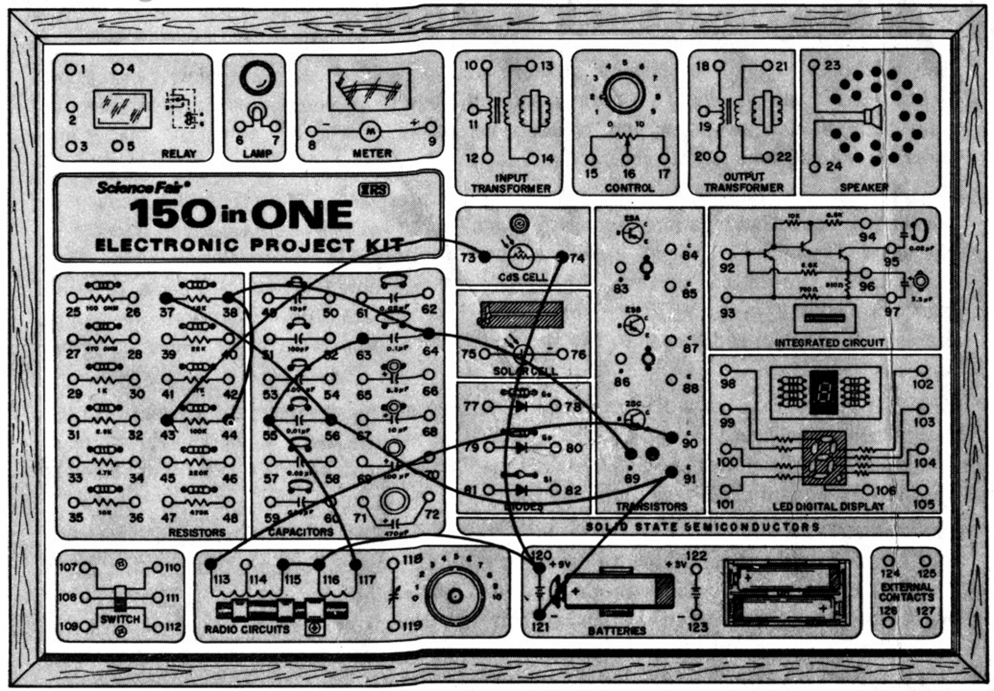
94. LIGHT OPERATED WIRELESS BURGLAR ALARM

This project is a wireless burglar alarm. It draws no Battery current and is completely dormant when the CdS Cell is in darkness; but in light the circuit sends out a raspy tone all across the AM broadcast band. Put a radio nearby and you'll hear what we mean.

One application of this circuit is for security. A circuit such as this can be used in a dresser drawer, locked room, etc. A nearby radio, not necessarily in the same room, can be used as the alarm monitor.

In darkness the CdS photo cell has such high resistance that no base-bias current can flow, so the 2SC Transistor is OFF. The 10K resistor across B-E of the Transistor makes sure the Transistor is OFF during this condition.

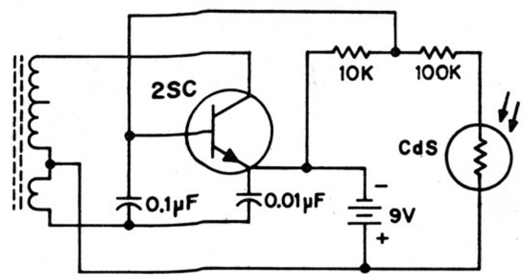
In light sufficiently bright to reduce the CdS photo Cell resistance adequately, bias is supplied to the base of the Transistor through the 100K and CdS Cell. The oscilations which result are spikes of energy which have signal components across the entire AM radio band. You won't need an antenna if you keep the radio within 20 feet (6 m) or so of this circuit.



NOTES

WIRING SEQUENCE:

90-113, 115-116-120-74, 73-43, 44-38-64-89, 63-55-117, 37-56-91-121



95. LIGHT CONTROLLED BURGLAR ALARM

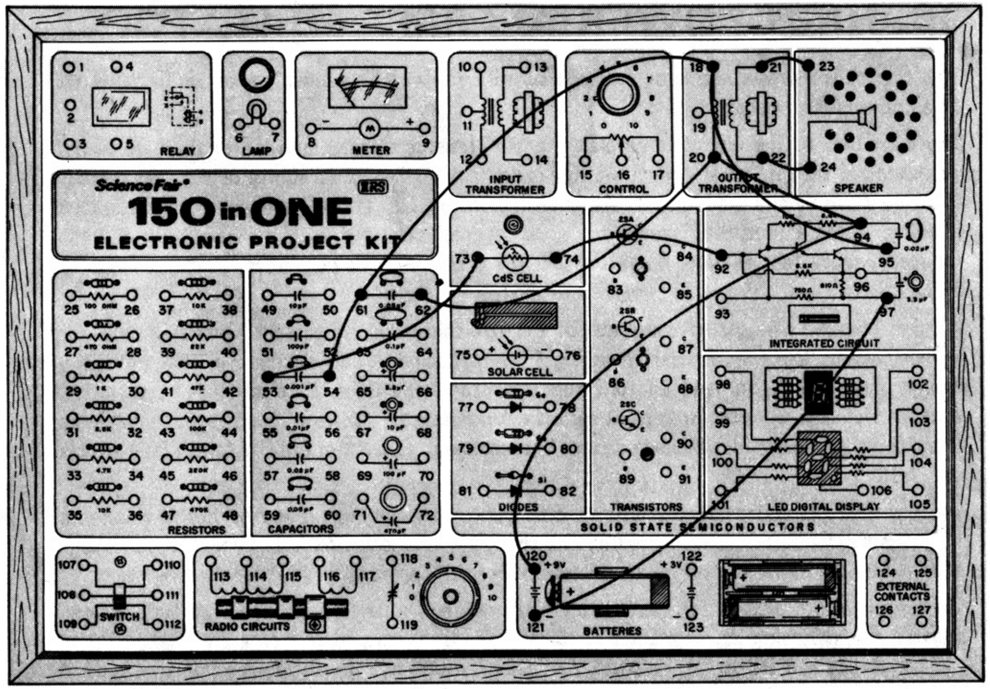
This project is a light-controlled oscillator which uses the integrated circuit (IC). In total darkness it just sits there nice and quiet, but a little light causes the Speaker to give out with a 1500 hertz howl.

The circuit is quick and easy to hook up because of the few components required outside of the IC. A 0.05 μF capacitor is used to obtain a strong output tone, a 0.001 μF 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 photo cell acts like an open circuit in total darkness, but when some light strikes the photo 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 oscillations. It usually isn't long before the alarm goes off!

NOTES



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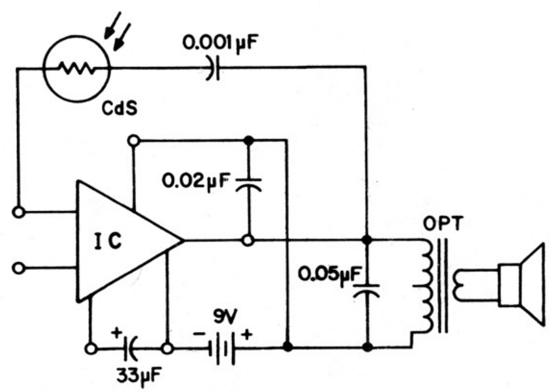


96. HIGH POWER ALARM OSCILLATOR

This project is a power oscillator that will surprise you with how much power can be delivered by a one-transistor circuit.

The operation of the circuit is simple. The 10K resistor supplies current to the base of the Transistor to turn it full ON when the Key is first closed. The initial source of this base current is the 12V supply and the induced voltage on the bottom half of the Transformer center-tapped winding. After a time the Transformer core becomes saturated with magnetic flux and the induced voltage falls to zero. As this occurs the Transistor base current is reduced enough to allow the transistor to **begin** to come out of the full ON state.

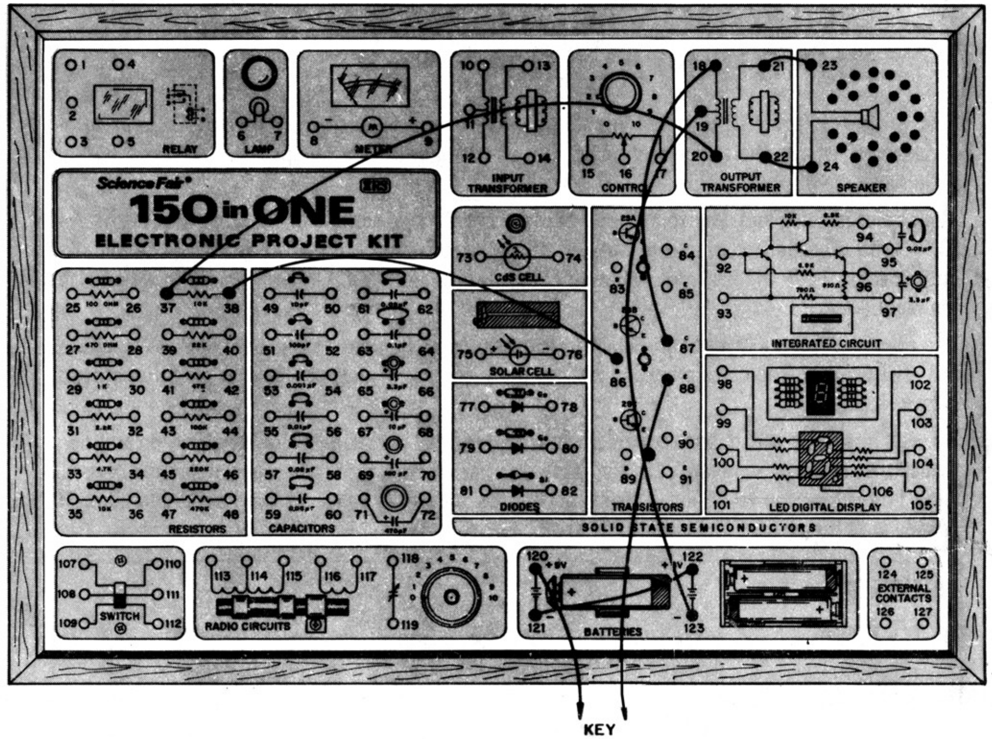
As the Transistor begins to come out of the ON state, the decrease in Transistor collector current causes the Transformer magnetic field to decrease. This decrease in flux induces a reverse base voltage to tend to turn the transistor more OFF. This action is regenerative, because a change in collector current causes the induced base voltage polarity which enhances this change (decrease) in collector current. This change of state from full ON to full OFF occurs very fast.

After a time the collapsing magnetic field begins to slow down as it approaches its minimum magnetism. The base voltage caused by the change in magnetic flux is exceeded by the voltage supplied by the batteries, and the transistor is turned ON again to begin the cycle over again.

No capacitors are used in this circuit, so the saturation characteristics of the Transformer alone provide the switching characteristics of this circuit. Oscillators of this type are used in DC to AC converters and DC to DC inverters but generally with two transistors in a full-wave type of operation.

This project draws about 100 mA from the batteries so if you use this circuit much, the batteries will have to be replaced often. Notice that the 12V supply is equal to the automobile battery voltage. Thus you could use this type of oscillator as a burglar alarm in a car without any modification.

NOTES



WIRING SEQUENCE:

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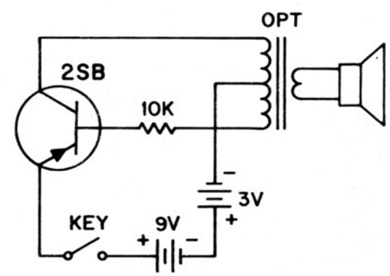


97. RELAY AND SPEAKER BUZZER

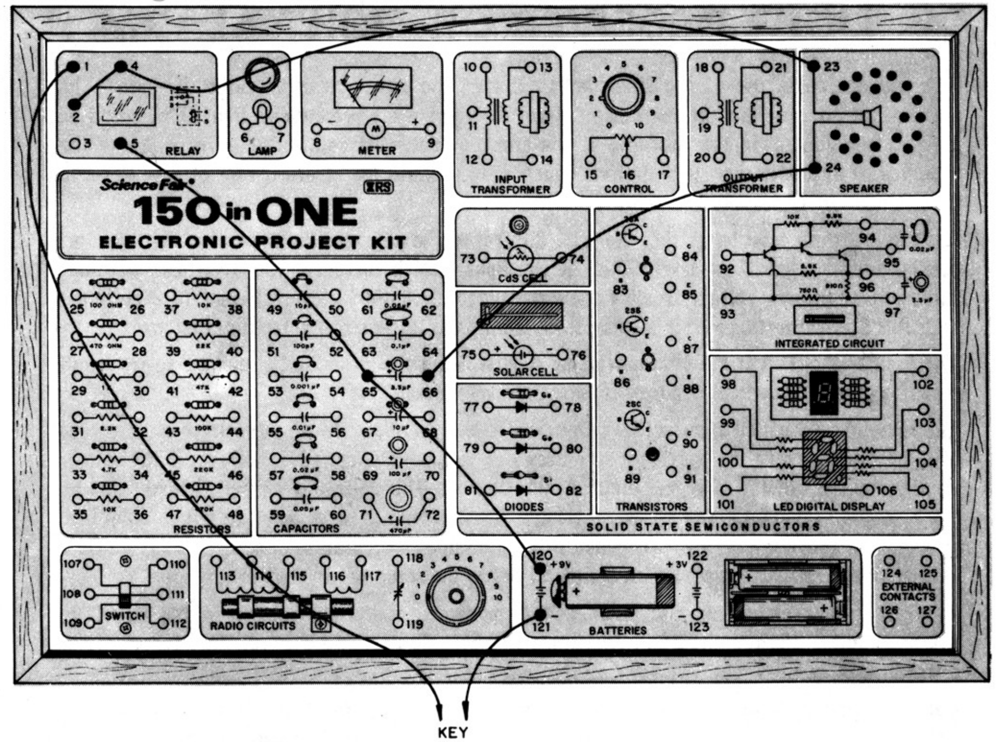
Here is a simple project which shows how a buzzer works and how the interrupted current can power a speaker.

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 in the 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 3.3 μF 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?

NOTES



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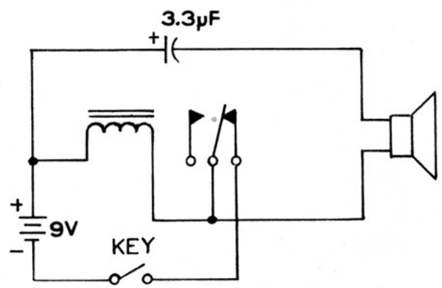
23-4-2, 24-66, 120-65-5, 1-Key, Key-121



98. 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 where the presence of excessive light is undesirable such as in a photo lab where it can form an alarm to alert you to the undesired light level.

The circuit is adjusted by setting the 50K Control to the point just below that which will start oscillations at a low-light level. 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 this Control setting as it is the key to obtaining the turn-on characteristics you want.

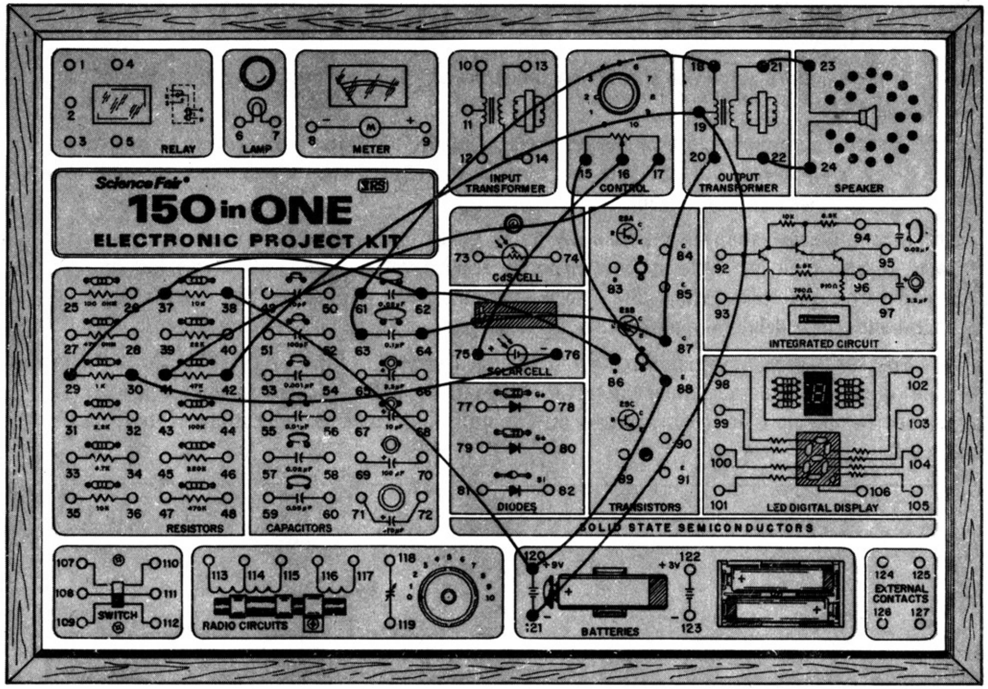
The oscillator circuit is the common pulse type which we've described elsewhere so we won't repeat it here. The control circuitry is unique, so we'll describe it.

The selenium Solar Cell appears like a common resistor of about 2K ohms without the presence of light. During this time 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 down by the Solar Cell resistance, the 1K and the 10K. The Control can be adjusted to obtain from zero volts bias to above the 0.1V or so needed to begin oscillations. Normal Control settings are for a voltage at the Transistor base which is slightly below that required to start oscillations.

Now as light is played on 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.

The 10K in the Transistor B-E circuit is required to keep Transistor leakage current from powering the oscillator without a source of base-bias voltage. The value of this resistor is determined by disconnecting the 1K resistor from the circuit. The required B-E resistance is then that which is the highest value usable without the circuit oscillating. Try it.

NOTES



WIRING SEQUENCE:

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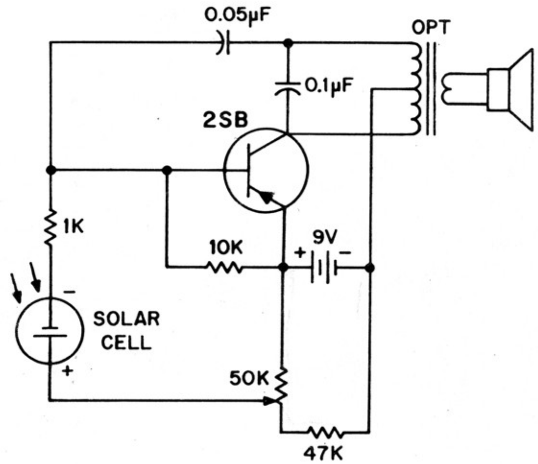


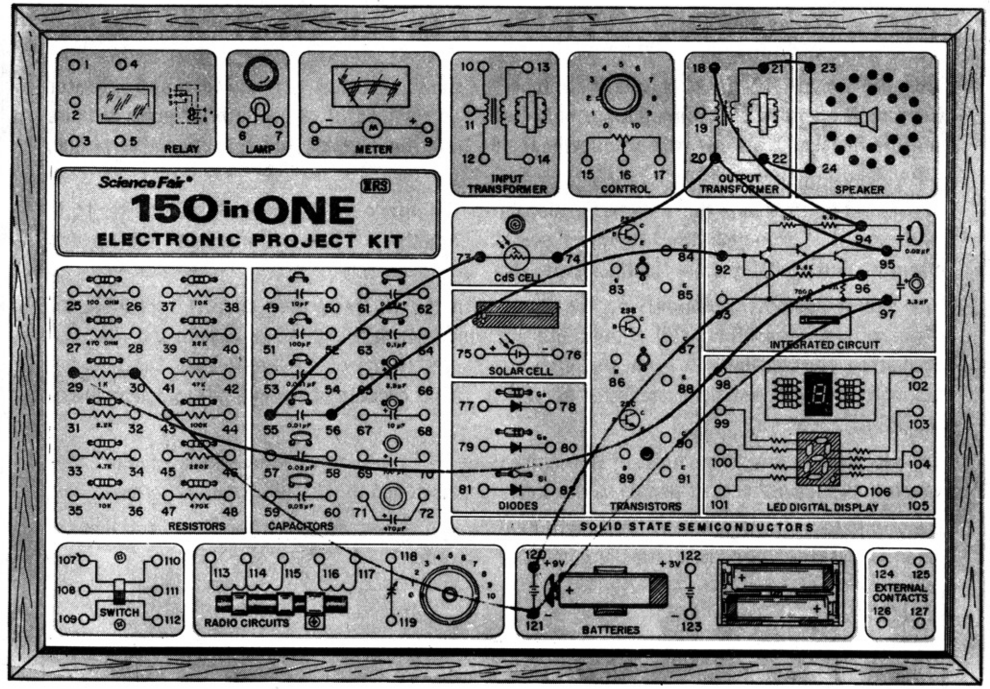
99. ACOUSTIC LIGHT ALARM

This project is an acoustic light alarm which uses the IC (integrated circuit) as an oscillator. Its operation is virtually the same as that of Project 95. 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 the 1K in this circuit across terminals 96 and 97, or the IC may be damaged. You may try every capacitor on the board without fear of trouble! Have fun!

Record any interesting results in the space below so you can repeat them later on.

NOTES



WIRING SEQUENCE:

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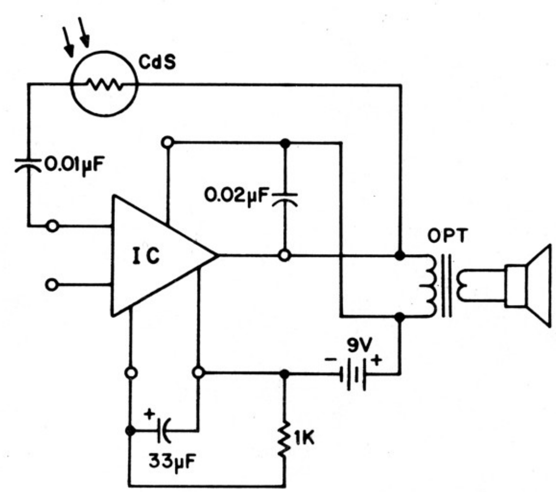


100. SOUND ACTIVATED ALARM

This project can be called a sound stretcher or sound actuated alarm. The sound detector (Earphone operated as a microphone) only has to be bumped or receive a brief pulse of noise and the Speaker gives out with a squawk. If you bring the Speaker too close to the earphone, sustained oscillations will result.

This could be used as a theft alarm by placing the Earphone (as the microphone) where it will be bumped if someone tries to move or take something. The resulting howl will attract attention and probably scare the thief away also.

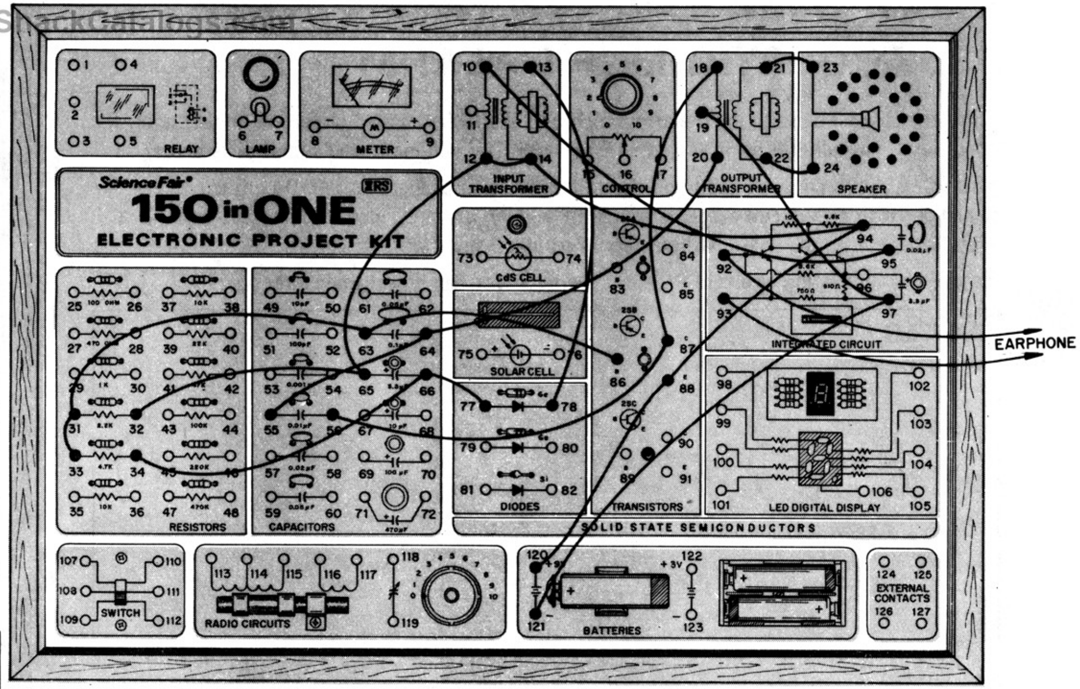
The circuit operates by amplifying the signal with the IC (integrated circuit), rectifying the signal with a germanium (Ge) Diode, and applying the resultant DC as base-bias to the 2SB oscillator. The oscillations from the 2SB are always stronger and longer than the noise or talking required to start the oscillator operating. This is because of the charge storage action of the 3.3 μF capacitor.

Try placing this near some noise or music maker or HI FI speaker without telling anyone. Then watch the looks on faces of people as this new signal is added to what they expect to hear.

Do you have a dog that barks? This might confuse him enough to be a little more careful about when he barks for fear of this mocking machine. Have fun!

NOTES

If temperature is high, try the 2SA in place of 2SB.



WIRING SEQUENCE:

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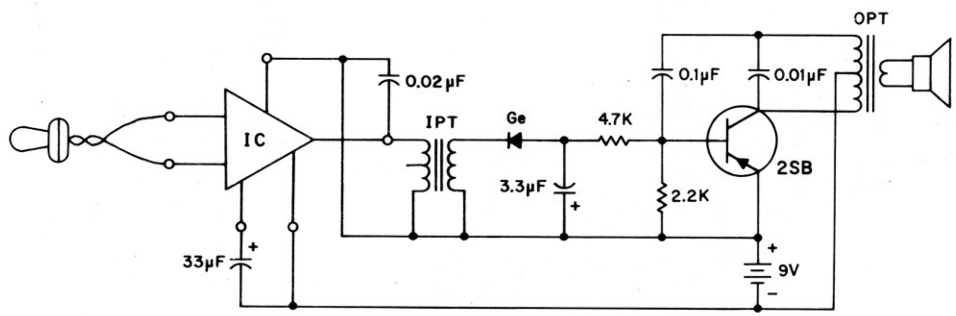


101. RADIO SIGNAL INDICATOR

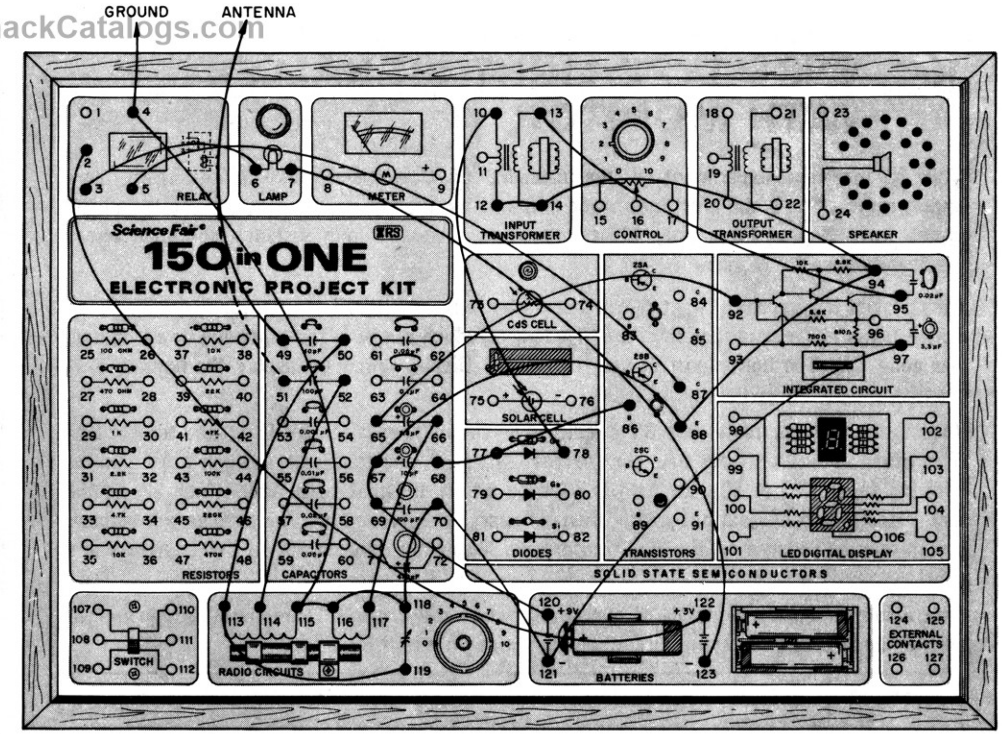
The purpose of this project is to demonstrate what may be called a radio signal indicator or alarm. When tuned to a frequency which has a strong radio signal, the Lamp lights. In the absence of a signal the Lamp goes out. This may be used as an alarm at a radio station to signal trouble at the transmitter which has shut down the station. Or it may be used to monitor the frequency of a radio station which comes on in the morning at the time you want to awaken out of sleep.

The receiver section of this project is similar to others we've described elsewhere.

The Transistor relay driver and Relay circuit are also described elsewhere.

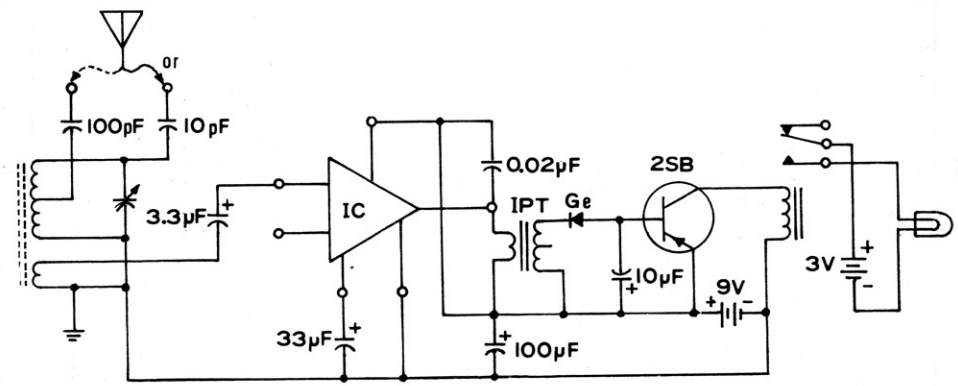
To check on proper operation you can connect the Earphone across either winding of the transformer. You will hear the radio stations and can then use this aural response to optimize tuning, antenna connection and ground connections. We have included some suggestions about antenna connections in various projects about radios and receivers.

NOTES



WIRING SEQUENCE:

123-7, 6-3, 2-122, 97-121-70-118-116-115-4-Earth Ground, 119-113-50, 114-52, 117-66, 65-92, 68-77-86, 78-10, 5-87, 13-95, 12-14-94-88-67-69-120, Antenna-49 or 51



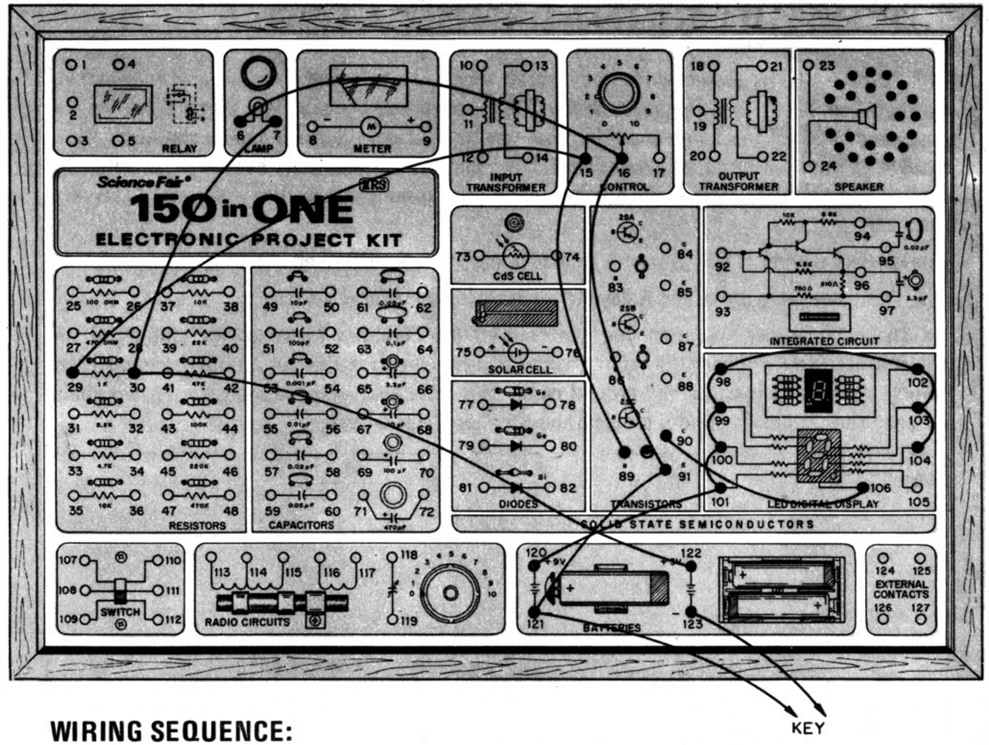
102. WIRE-TYPE LIGHT SIGNALLER WITH MONITOR

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 see a little about how Radio, Telephone, Light and other forms of long distance communications 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 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 would not be used in an actual circuit which has long transmission lines.



WIRING SEQUENCE:

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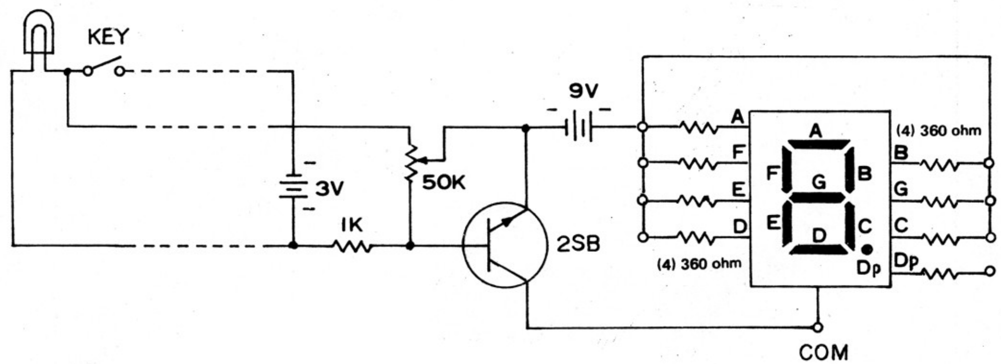


NOTES

103. 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 been mostly replaced by the telephone and teletype systems today.

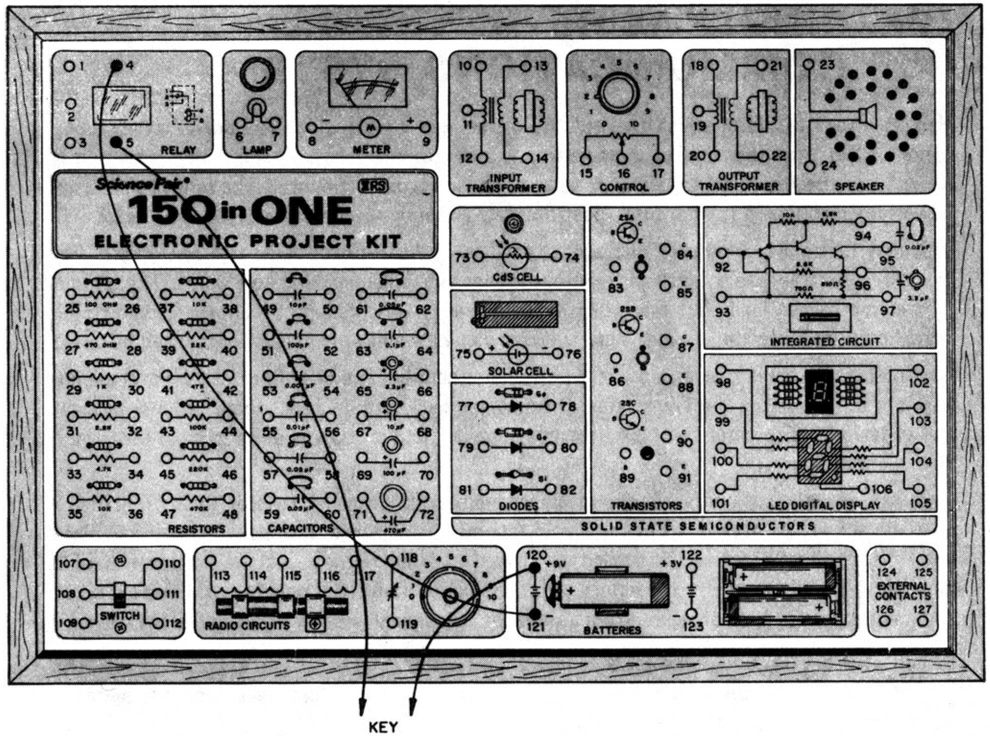
The Relay used here has a resistance of about 500 ohms and requires a minimum of about 6 mA (milliamps) to initially pull the armature (movable part) in. This means that the voltage required (minimum) is 0.5 X 6 = 3 volts. A fresh set of 3V batteries (two 1.5V cells) should just barely be able to pull the Relay in (energize it). Try it. It is not unusual 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 across 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 definitely or it (or a Battery) is defective. Try a 100 ohm resistor in series with the Relay. It ____________(can? cannot?) pull in. Usually it can.

Now try the 9V Battery. A series 470 ohm resistor should still allow Relay operation, but a 1K will not.

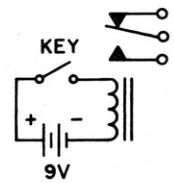
Insert a 1K resistor in series with the Relay and then momentarily short circuit across the 1K with a piece of wire. The Relay should operate and stay energized with the 1K in the circuit. The reason for this is that it takes more current to energize (typically 6 to 9 mA), but less current to stay in (typically 1 to 3 mA). The reason for this is that the magnetic air gap is much smaller when the Relay is energized.

NOTES



WIRING SEQUENCE:

121-4, 5-Key, Key-120



104. 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 earth 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 groundroots experimenting can be done!

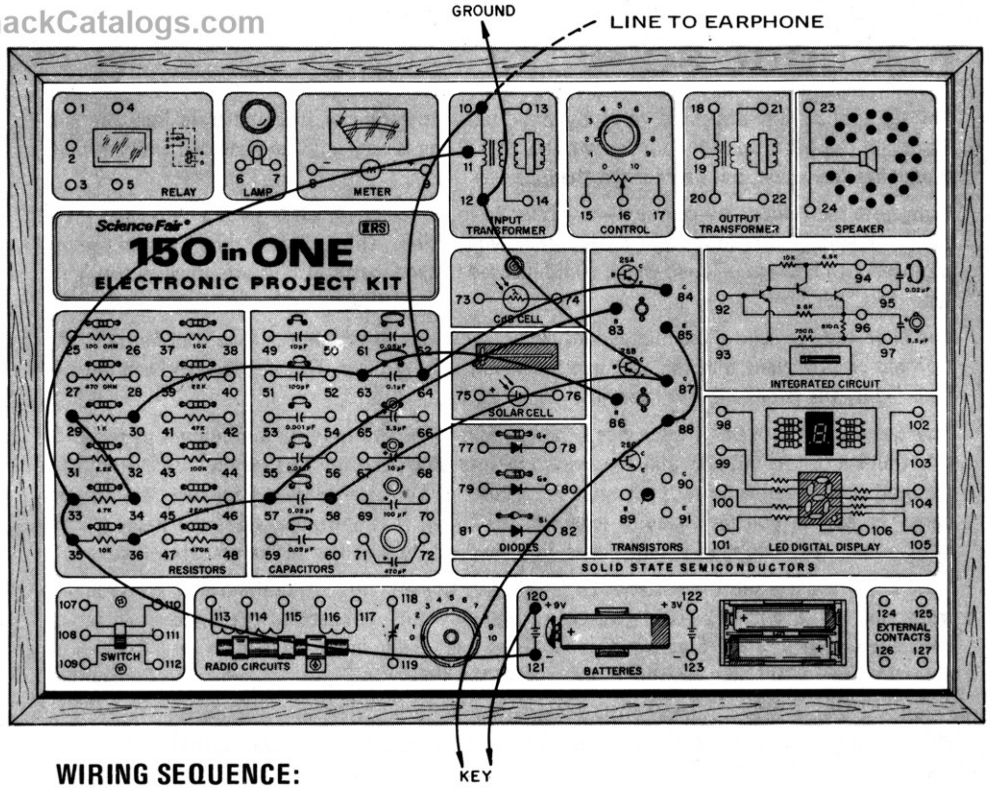
This oscillator circuit is arranged like a push-pull amplifier. The difference of course is mainly that the output across the Transformer is connected back into the input (base circuits) through the capacitors. The amount of bias current supplied to the bases is quite high to obtain the strong oscillations.

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. It is possible with this circuit to obtain about 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 15 mA, and then insert the meter in **series** with the Key.

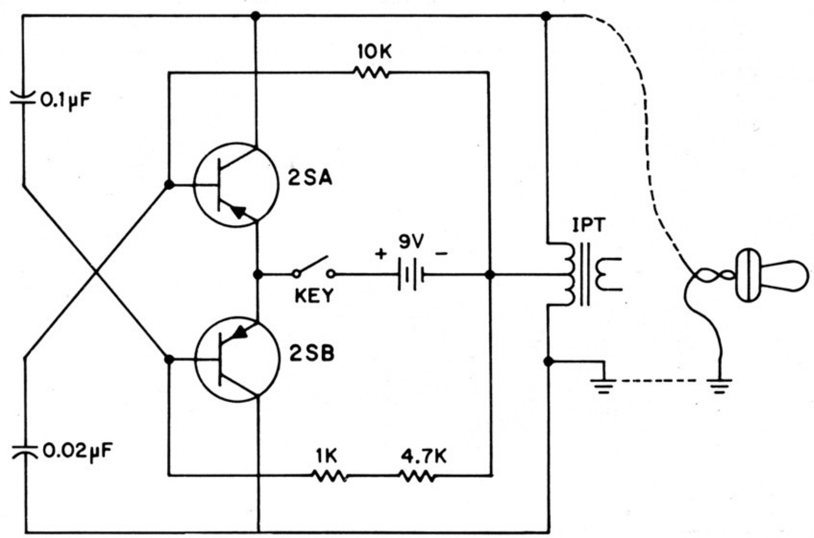
Will this circuit work on 3 volts? Try it. You are generally safe when trying lower voltages for transistor circuits. About the only time when a lower voltage may not be safe is when a motor is involved.

NOTES



WIRING SEQUENCE:

121-35-33-11, 10-64-84, 83-57-36, 34-29, 30-63-86, 12-87-58, 85-88-Key, Key-120, 12-Ground, 10-Line to Earphone, Earphone-Ground



105. CODE PRACTICE OSCILLATOR WITH TONE CONTROL

Would you like to become an amateur radio "ham"? Many of us started out with a code practice oscillator with tone control very similar to this. The tone control is handy when you tend to become fatigued listening to the same tone all the time.

The best way to learn the Morse code is to find someone else who is also interested in learning the code. Set up a regular schedule of a half hour or so a day and stick to it. Make up a progress chart so you can see the progress. Take turns sending and receiving. It won't be long at all and you will find the code will become like a spoken language. You won't have to think about the operation of the Key. It will be as automatic as peddling a bicycle or driving a car. The hardest part is disciplining yourself to stick with it. Any one who has stuck it out never regretted it.

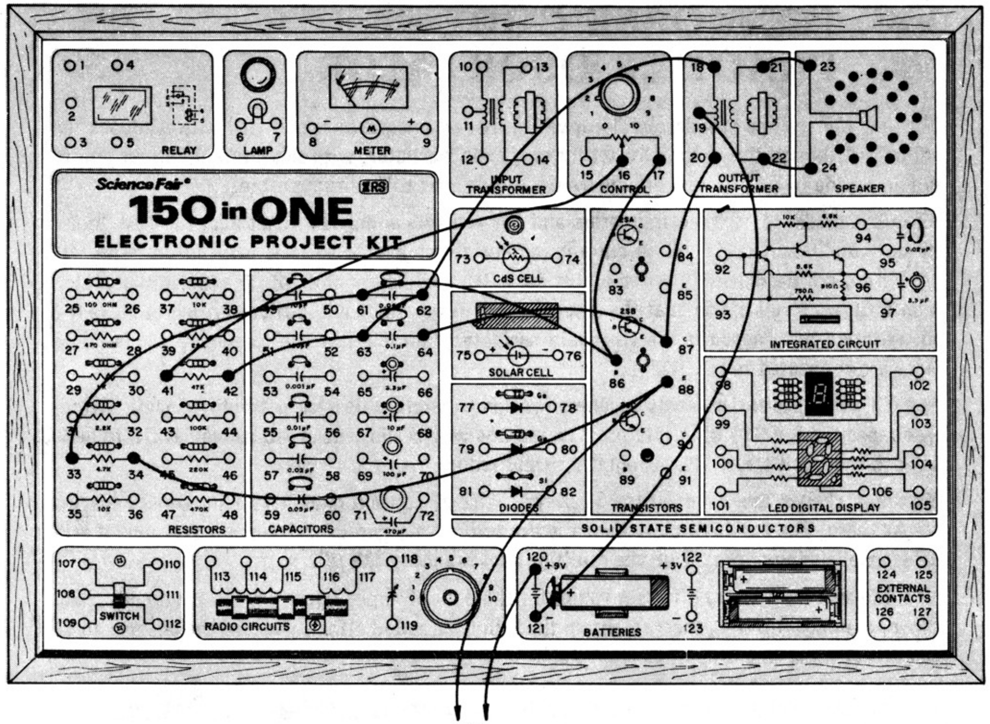
If you want to practice alone with the Earphone in place of the Speaker we suggest you disconnect the Speaker and connect the 50K Control across the primary windings, and then connect the Earphone from the center Control terminal (wiper) to one end of the Control. This way you have a volume control as well as a tone control. Replace the 50K tone control in the circuit with fixed resistance as desired.

The tone from this oscillator is not meant to be a pure sinewave, because it has been determined that a pure sinewave signal is more fatiguing than a tone which is full of harmonics.

The theory of this type of oscillator opperation is given in other projects so we won't repeat it here. The tone control though is worthy of mention. When the 50K Control is adjusted for less resistance in the circuit, less resistance is present across the 0.05 μF capacitor so it discharges faster between pulses. This causes the pulses to be closer together and therefore (because of having more pulses for each second of time) the frequency is increased. The opposite condition occurs to obtain the lower frequencies of operation.

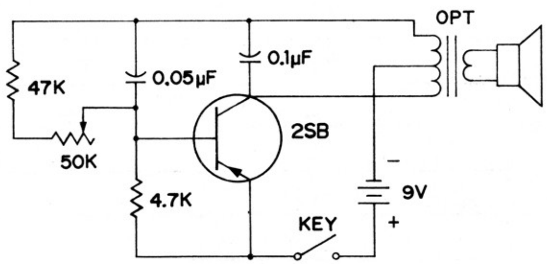
If you become proficient at Morse code, the next step is to contact your nearest Radio Shack store and see what study materials are available to prepare for the written part of the FCC exam. Good luck!

NOTES



WIRING SEQUENCE:

21-23, 22-24, 121-19, 20-87-64, 18-62-63-42, 41-16, 17-86-61-33, 34-88-Key, Key-120



106. I.C. MORSE CODE PRACTICE OSCILLATOR

This is a Morse code practice oscillator which uses an integrated circuit (IC) with feedback tone control. Although this is initially set up as a code oscillator, with slight modifications you can obtain a wide range of sound effects from a motor boat to a chirping robin.

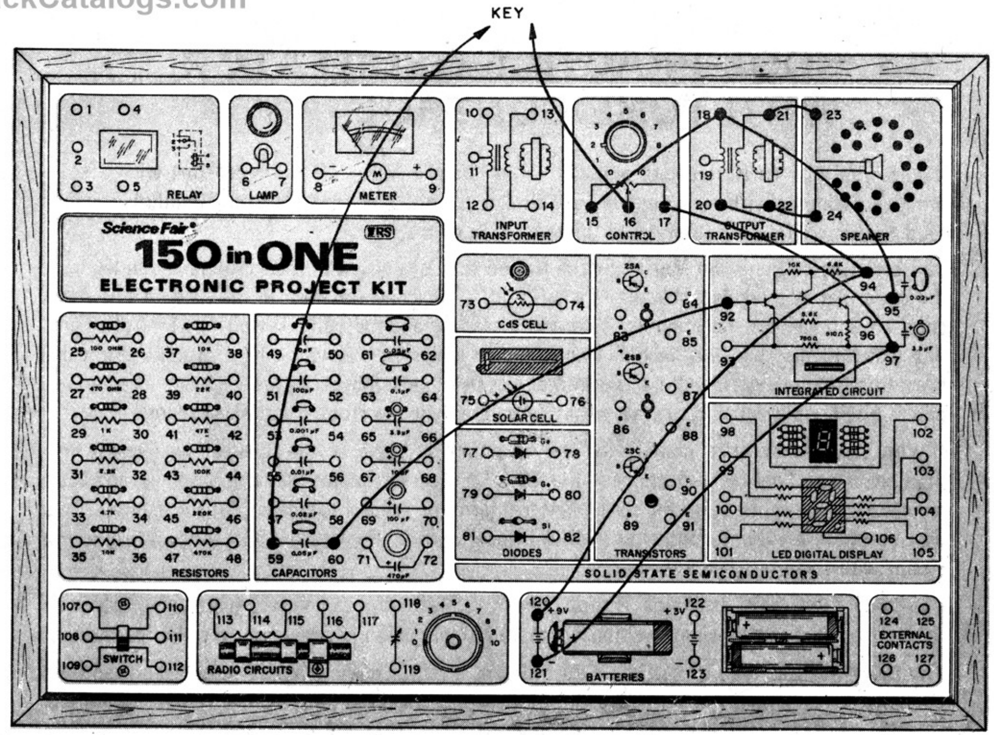
The IC is made up of three transistors and five resistors arranged into a direct coupled "ring of three" amplifier. Normal idling current is only about 2 mA, so it is easy on batteries. Two capacitors are permanently wired across some IC terminals. The 0.02 μF capacitor provides a high frequency roll off so that the amplifier will not oscillate without you trying to make it do so. Without this capacitor the IC would oscillate at some ultrasonic frequency whenever any leads are connected to it.

The 33 μF capacitor prevents degenération (and therefore decreased amplifier gain). Without this capacitor the 910 ohm internal bias resistor would allow both AC as well as DC to be fed back to the input stage. This would drastically reduce the total IC gain.

You may change the values of the 33 μF and 0.02 μF capacitors by paralleling other capacitors across these. The resulting capacitance is the sum of the two capacities. For example, if a 100 μF is paralleled with the 33 μF the resulting capacitance is 133 μF.

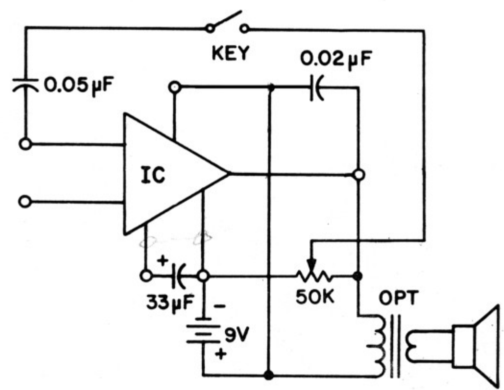
You will also want to try different values for the 0.05 μF input capacitor. See if you can change this one along with the others to obtain the following sound effects. Record the changes so you can repeat these later when you want them.

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



107. SOLAR POWERED CODE PRACTICE OSCILLATOR

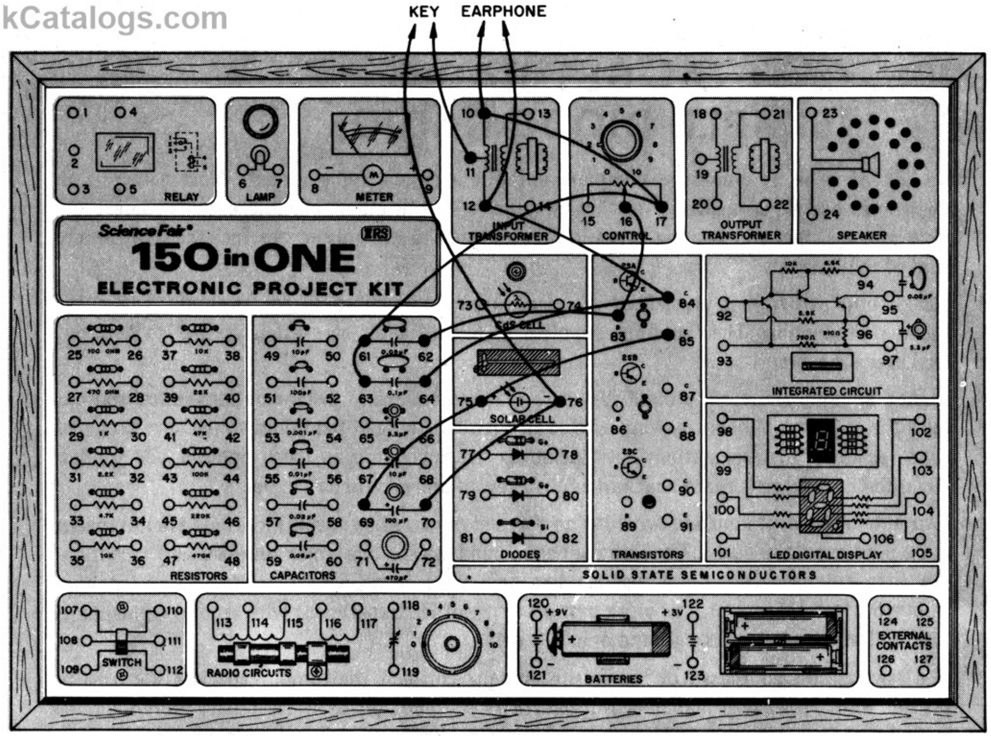
Here is one of the most efficient Morse code practice oscillators you will ever find. No batteries and no power line connections are needed. All you need is enough light and you're in business.

The Solar Cell provides all the required power. 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 cells available today, the selenium cell and the silicon cell. The silicon solar cell is very efficient in changing light energy into electrical energy but is very expensive. The selenium solar cell is not nearly as efficient in converting light energy, but it is much less costly. The selenium solar cell is able to demonstrate all the characteristics of a solar cell so it is the type used in this kit.

The oscillator circuit uses the 2SA Transistor which is most useful on low voltage, compared with the other transistors. You may try the other transistors in this circuit without any fear of damage. When using the 2SC Transistor though you must turn both the Solar Cell and 100 μF capacitor around to obtain correct polarity of voltage.

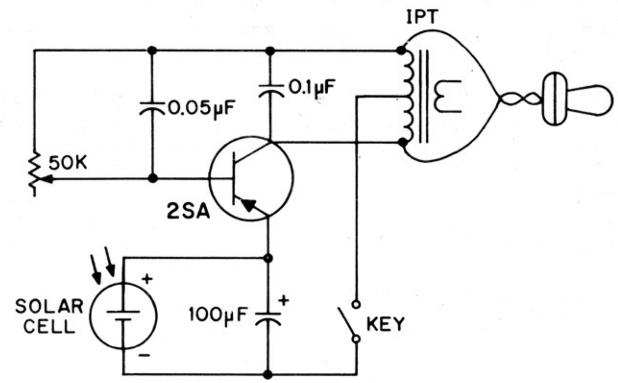
This circuit may have any component values changed without fear of damage because of the low power supplied by the Solar Cell. The 50K ohm Control provides a wide range of control over circuit operation besides giving a control over frequency of oscillation.

NOTES



WIRING SEQUENCE:

62-83-16, 85-75-69, 63-61-17-10-Earphone, Earphone-12-84-64, 70-76-Key, Key-11



108. CRYSTAL SET RADIO (SIMPLE DIODE RADIO)

No kit of projects would be complete without a crystal radio circuit. Most everyone in electronics has experimented sometime or other with this oldest of radio circuits. Before the days of transistors and vacuum tubes the crystal set was the only means for reception of any kind of radio signals.

Signals obtained from a crystal set are weak (no amplification) so an Earphone is used for sound reproduction. The Earphone supplied in this kit is of the crystal type which does not load down the circuit.

A good antenna and earth ground system is required to receive distant stations. Local stations can be heard with almost anything used as an antenna. Some of the things which have provided good reception of local stations have included: the finger stop on the telephone, bed springs, metal shelf brackets, furnace heat and cold air return pipes and many more.

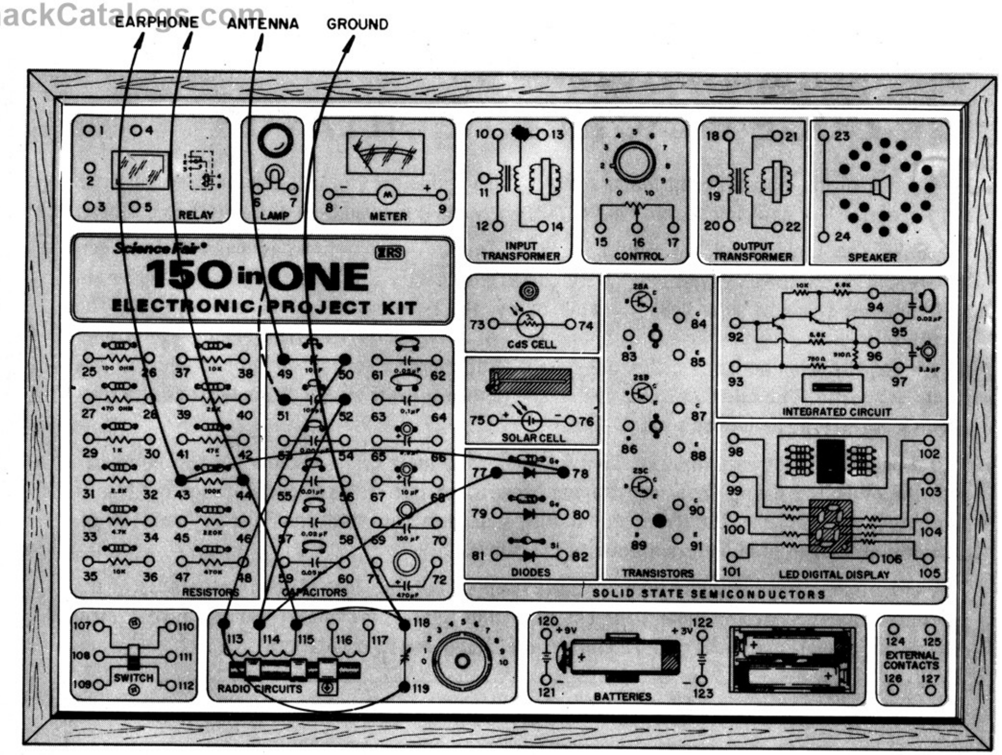
Two antenna connections are provided on this and other radios in this kit. These are not meant to be used simultaneously. Try each connection and use the one which provides best reception. The long antennas (and those that act like one) work best on terminal 51. Short antennas (about 50 feet [15 m] or less) work best on terminal 49. Experiment with ground connections because for some antennas a ground does not help.

The tank circuit composed of the ferrite antenna coil and the tuning capacitor are used to provide both impedance matching and selectivity. Without sufficient selectivity more than one station is heard at a time. This is one of the main problems with all simple radios like this. Impedance matching affects both selectivity and earphone volume. Connections which result in loud volume also cause poor selectivity so a compromise is always required (even in simple radios).

The diode rectifies the RF (radio frequency) signal sent out by the radio transmitter. The result of rectification is the recovery of the audio modulating signals which were placed on the RF signal at the transmitter in the form of amplitude variations. This overall modulation recovery process is called **detection.** The 100K resistor is included with this detector to provide a DC load for the Diode (especially for strong signals) because the Earphone is like an open circuit to the DC component of detection.

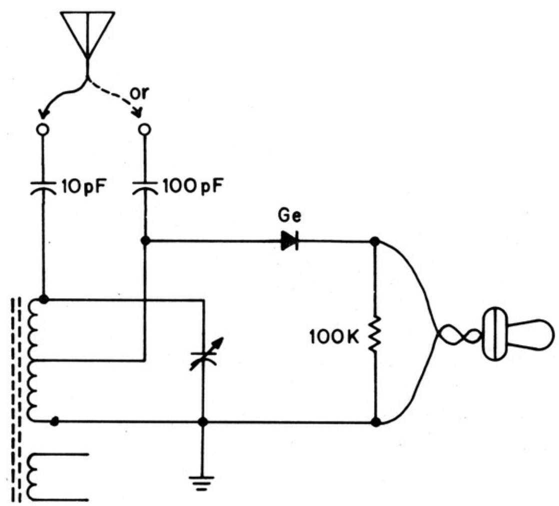
This is one circuit you can experiment with in about every way you can think of, except stay away from all voltages such as from batteries or the 120V AC power line. Have fun!

NOTES



WIRING SEQUENCE:

119-113-50, 118-115-44-Earphone, Earphone-43-78, 77-114-52, Antenna-49 or 51, Ground-118



109. TRANSISTOR DIODE-JUNCTION RADIO

This project is a one-transistor crystal set. Normally you think of a crystal set having a diode for the detector. The transistor is also a crystal but with two rectifying junctions instead of only one (as in the diode).

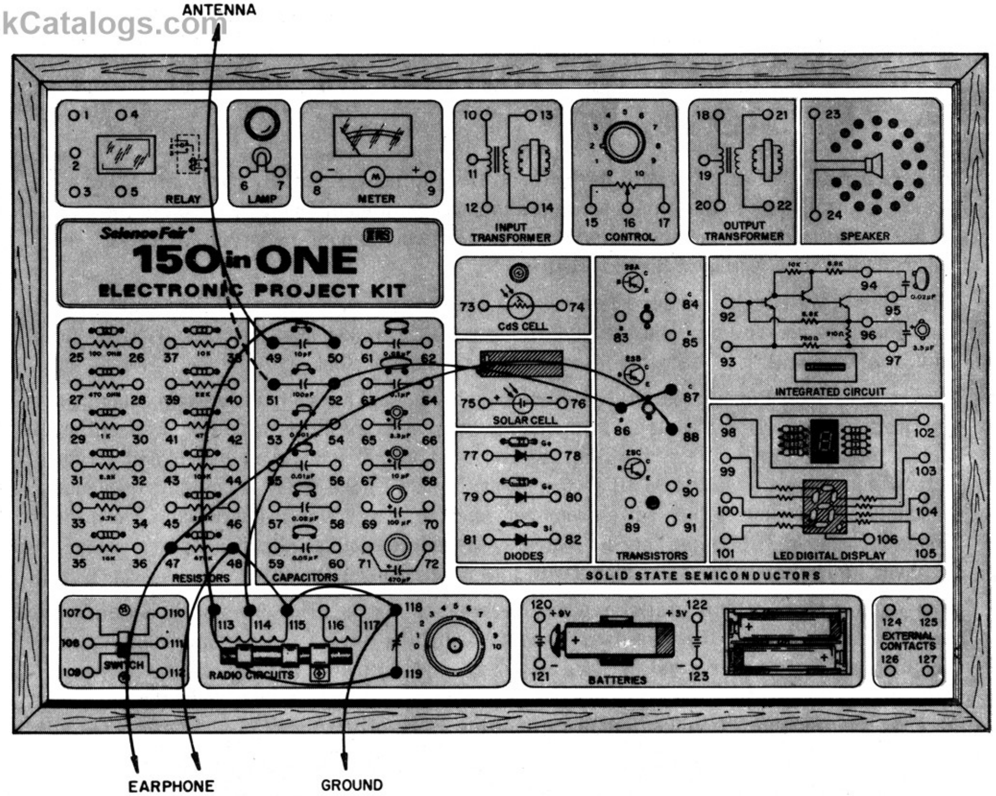
Refer to Project 108 for some suggestions about the antenna system as used with a simple radio such as this. Do you notice any similarity between the circuits?

You should try different resistors in place of the 470K, including the 100K used with the diode crystal set.

Also try different transistors and different elements of the transistor. You should find that the 2SA and 2SB Transistors both work well with either C-B or E-B junctions of the transistor used as the "crystal" detector. The 2SC is a silicon-type Transistor which is not as good for the very low signal levels obtained with a crystal set.

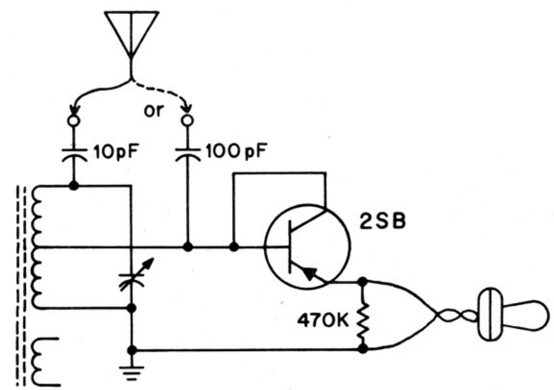
A transistor crystal set can give very good-sounding (high fidelity) results. Possibly for this reason (and also for cost) some transistor radio manufacturers have used transistors as detector diodes just as you have done here. An 8 transistor radio then may have one of the transistors operating as a diode.

NOTES



WIRING SEQUENCE:

119-113-50, 114-52-86-87, 88-47-Earphone, Earphone-48-115-118-Ground, Antenna-49 or 51



110. AUTOMATIC LIGHT ACTIVATED RADIO

Here is a radio that goes ON with daylight and OFF at night. A sensitive little two-transistor radio is controlled by a relay circuit which is photo cell controlled. The relay circuit draws most of the current drawn from the battery so if you just want a good radio you can replace the relay circuit with a section of the slide switch.

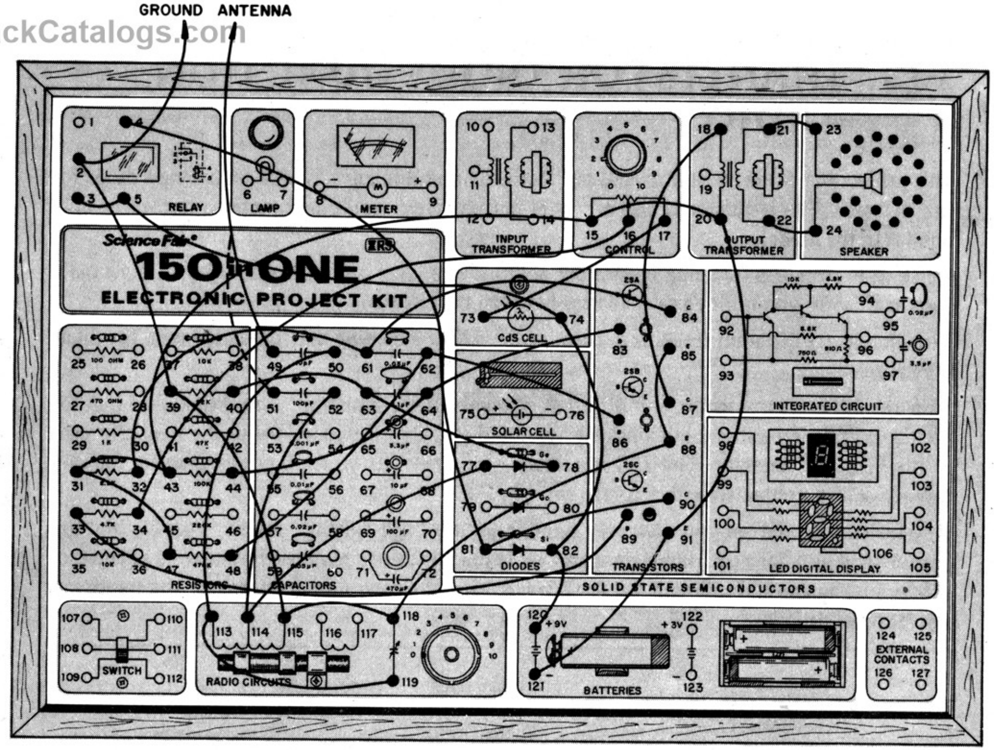
The relay driver circuit includes a sensitivity Control for the desired level of light required to turn the radio on. You can adjust the Control so you'll be awakened at the crack of dawn – or after the full warmth of the sun has turned on this radio alarm clock.

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 generate 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 for only having two transistors.

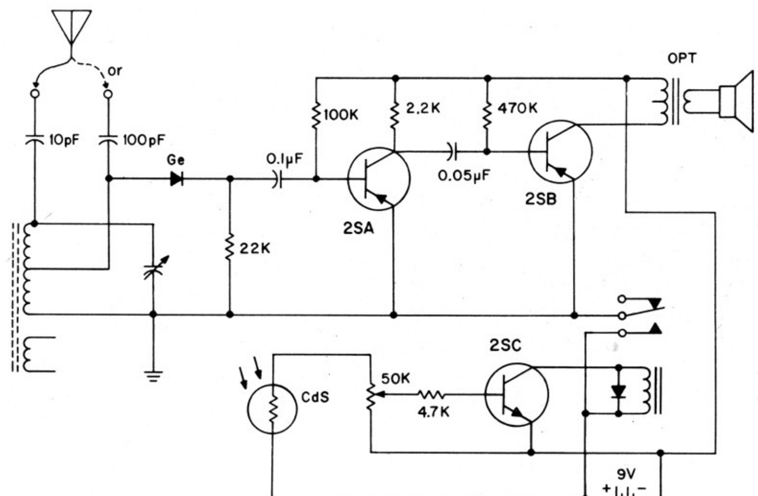
If you have a VOM, this is a good project on which to measure circuit voltages. The 2SA should have a voltage across C-E of between 1 and 4 volts. The 2SB collector current is between about 1 and 4 milliamps. The 2SC collector current is between about 6 and 18 milliamps when the Relay is energized.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 18-87, 85-88-118-115-39-2-Ground, 119-113-50, 52-114-77, 78-63-40, 4-81-90, 17-73, 16-34, 33-89, 32-61-84, 44-64-83, 48-62-86, 47-31-43-15-20-91-121, 3-5-74-82-120, Antenna-49 or 51



111. ONE TRANSISTOR RADIO WITH DIODE

The logical progression from the simple crystal radio of Project 108 is to this one transistor radio. The antenna and tuning circuitry is the same as for Project 108. The changes are described here. See Project 108 for a description 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 in selectivity. Stations which could not be separated on the crystal set are able to be separated with this receiver.

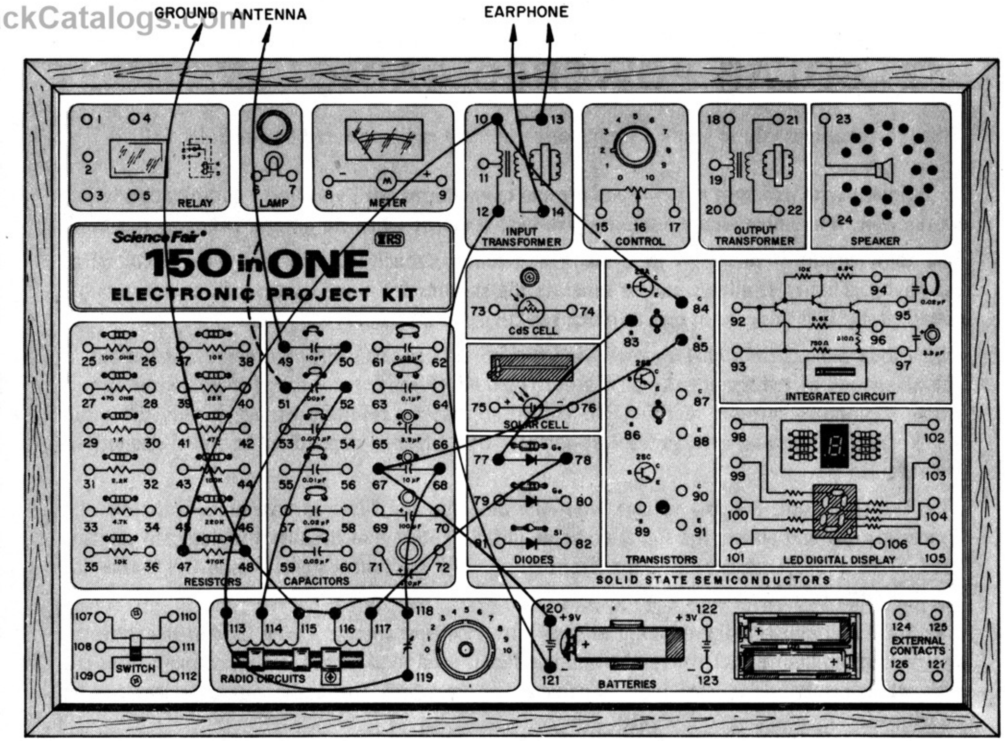
The Diode performs the same function of detection as in the crystal set except that now a very small Transistor base-bias current (about 20 μA) is also passed through the Diode. The effect of this small current is negligible as far as the function of the Diode is concerned. The 10 μF capacitor couples the ground side of the detector output to the Transistor without shunting out 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 1K ohms. Current flowing around the circuit from Battery negative to Transformer to collector and then from emitter back to Battery positive is about 9 mA (milliamperes). As the detected signal applied between B-E increases and decreases at an audio frequqnecy rate, the 9 mA of collector current also increases and decreases at this same audio frequency rate. This change in current through the primary of the Transformer causes a voltage to be developed at the secondary 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 some base-bias current so that collector current can flow is said to be ON.

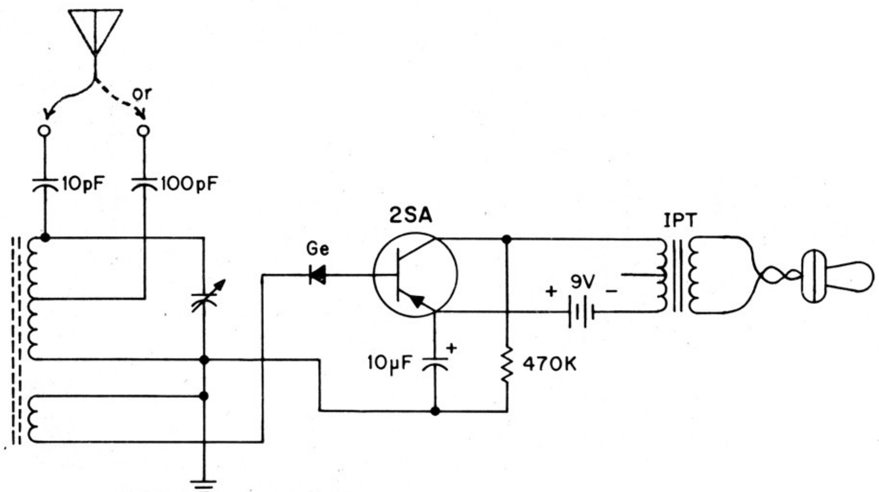
For experimentation you may want to try different antennas and grounds as before. Also you should try shunting the primary with different capacitors to see their effect on tone quality. Try the Earphone on the primary winding. If you want a pleasant surprise try replacing the diode with a short circuit. Who needs a diode when the transistor can perform double duty?!

NOTES



WIRING SEQUENCE:

119-113-50, 68-118-116-115-48, 114-52, 47-10-84, 12-121, 13-Earphone, Earphone-14, 83-77, 78-117, 85-67-120, Antenna-49 or 51, Ground-48



112. 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 coil and tuning capacitor in parallel. This circuit gives selectivity. That is, it allows you to separate the stations from one another. Of course, a single tuned circuit like this cannot give as much selectivity as we would really like.

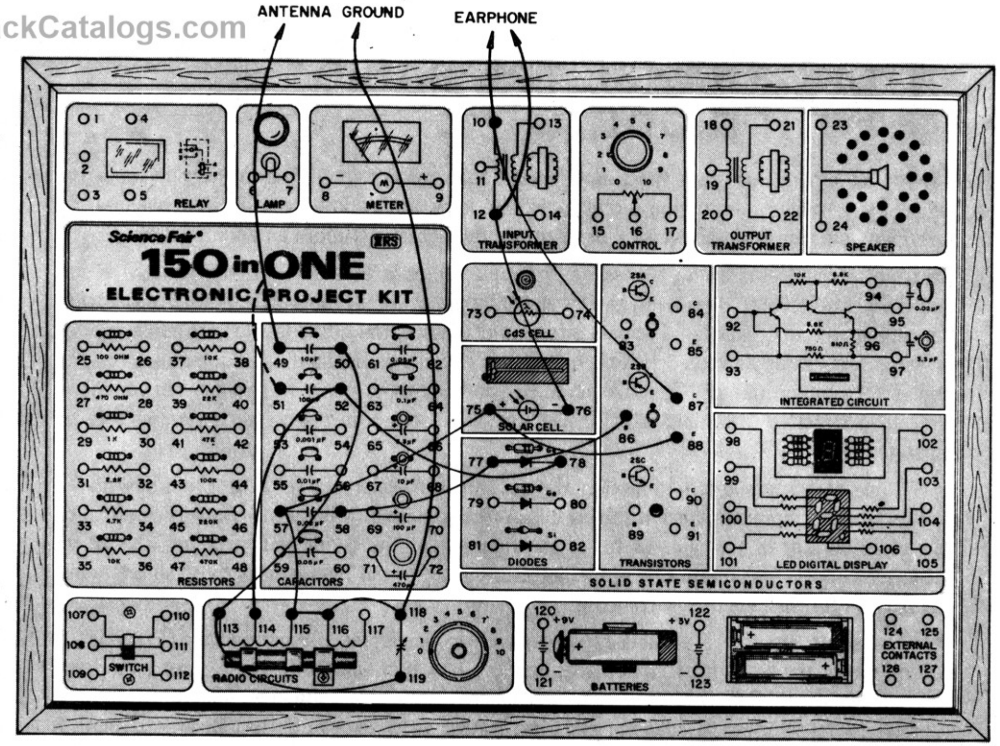
The Diode detects the signal by rectifying the RF voltage. This allows the audio variations in the amplitude of the signal to be recovered. The 0.02 μF capacitor is called the detector output filter. It smooths out the rectified RF voltage so that the resulting voltage is only the audio signal variations and an average level of voltage (DC) which is dependent on signal strength of the received RF.

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 amplifed. 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.

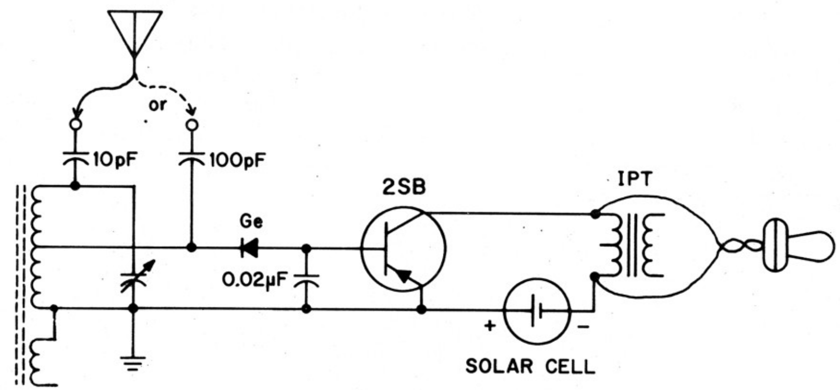
The Earphone changes the amplified (but weak) audio signal to an audible signal.

NOTES



WIRING SEQUENCE:

119-113-50, 118-116-115-57-75-88, 58-77-86, 114-52-78, 87-10-Earphone, 76-12-Earphone, Ground-118, Antenna-49 or 51



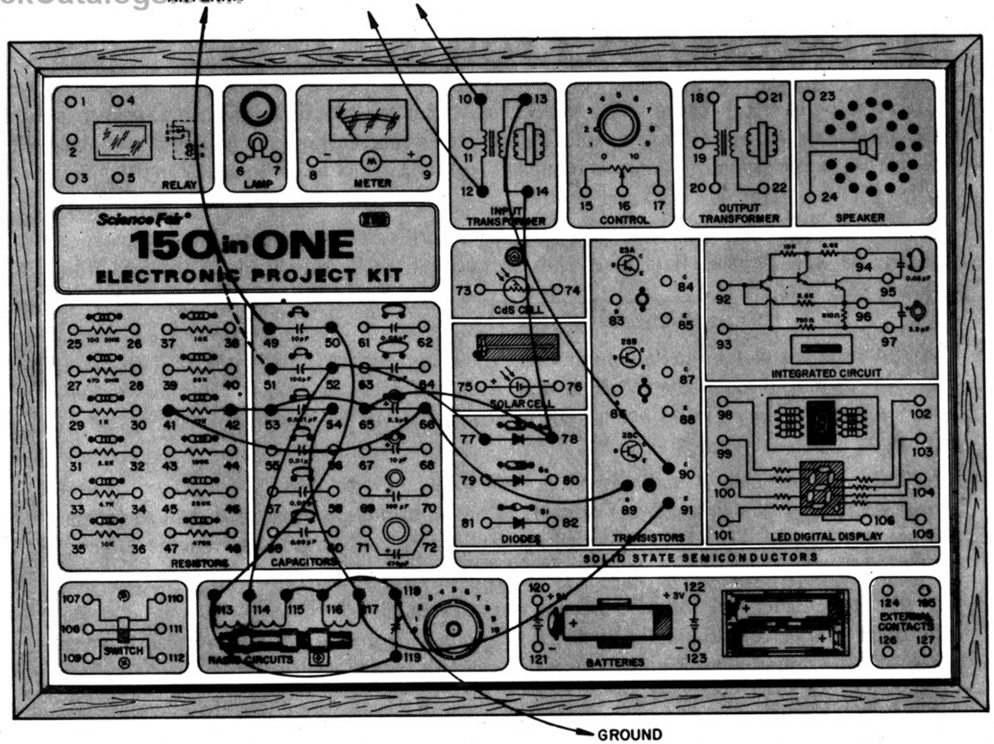
113. RF POWERED ONE-TRANSISTOR ONE-DIODE RADIO

This project is a one-transistor, one-diode radio which uses RF power received from the signal to power the transistor amplifier stage. The signal which is detected by the Diode is filtered by the 0.001 μF capacitor and then used to perform three jobs at once: provide the DC to the collector circuit and provide both DC bias and signal to the 2SC base.

You will want to experiment with different antenna connections and different antennas as we've explained in other Projects.

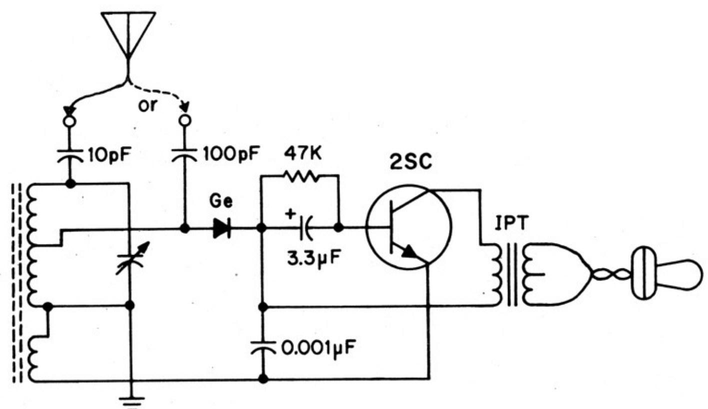
Try comparing this circuit with some of the simple crystal radios and one-transistor radios which use a battery to power the transistor amplifier. After this comparison you should be able to conclude that you can't get something for nothing.

NOTES



WIRING SEQUENCE:

119-113-50, 114-52-77, 41-66-89, 42-53-65-78-14, 115-116-118, 54-117-91, 90-13, 10-Earphone, Earphone-12. Ground-118, Antenna-49 or 51



114. TWO TRANSISTOR RADIO

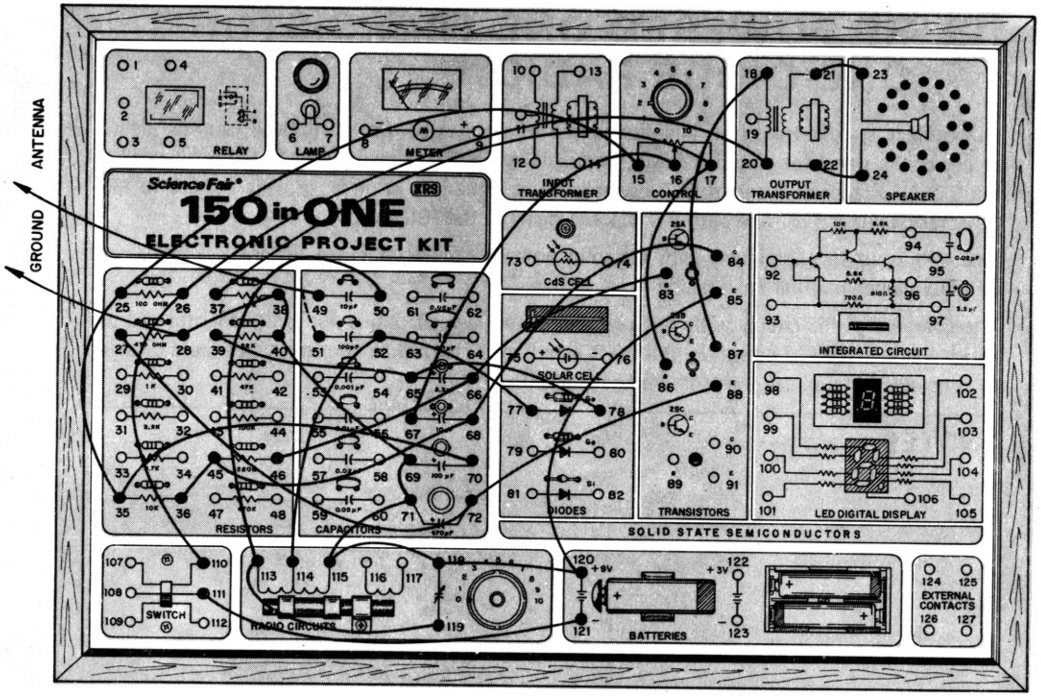
This is a two-transistor receiver which has sufficient gain and selectivity to drive a speaker to adequate volume. As with all simple radios like this, use a good antenna and ground system. Use terminal 28 as the ground terminal as required. Try the antenna on terminal 49 and then 51. Use the connection 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 2SA stage is a class A audio amplifier which uses self-current bias. That is, the base-bias is from the current through the 220K resistor from the collector voltage. This bias current provides some stability due to inverse DC feedback. The AC feedback also helps to reduce distortion.

The 2SB 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 470 μF 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.

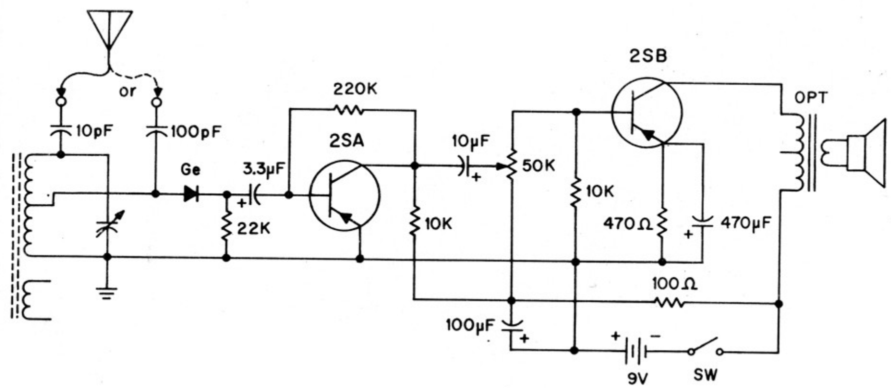
The 100 ohm resistor and 100 μF capacitor form a decoupling filter for the DC bias fed to the 2SA stage. This circuit eliminates tendency of oscillations due to battery impedance which might otherwise allow these high gain stages to oscillate (due to feedback from the AC voltage developed across this impedance).



NOTES

WIRING SEQUENCE:

21-23, 22-24, 18-87, 20-26-110, 86-17-37, 16-67, 15-25-35-70, 78-65-39, 28-38-40-69-71-115-118-120-85, 36-45-68-84, 77-52-114, 50-113-119, 46-66-83, 88-72-27, 111-121, 28-Ground, Antenna-49 or 51



115. TRANSISTOR RADIO WITH RF AMPLIFIER

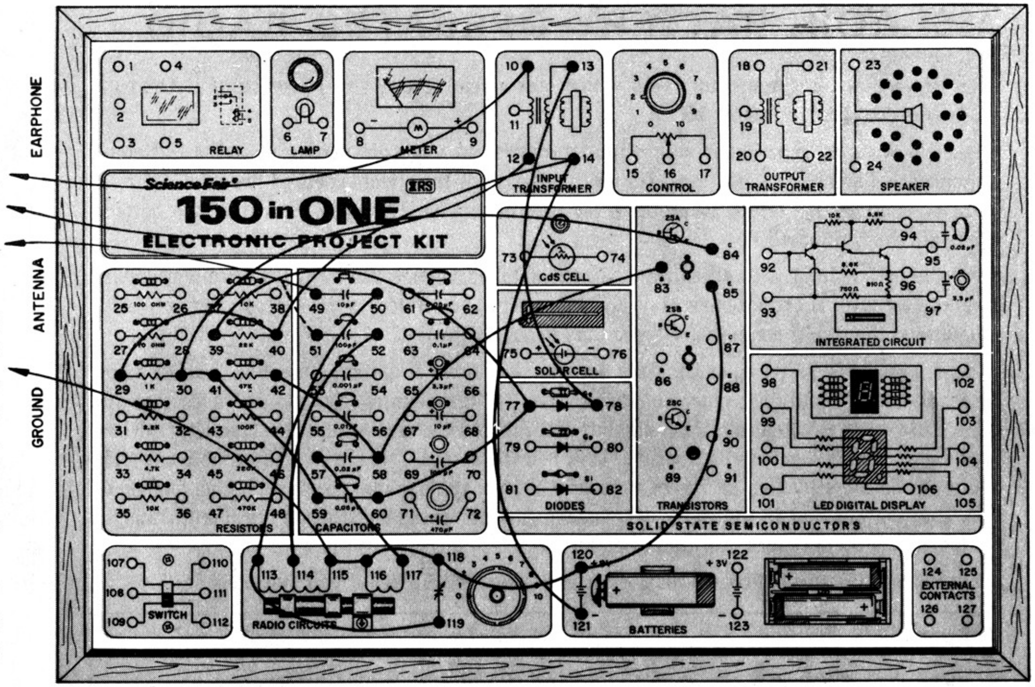
With this project you'll construct and test a simple radio which has an RF (radio frequency) amplifier ahead of the Diode detector. The 2SA Transistor is fed the very low level RF voltage from the antenna tank. It then amplifies this voltage to a high enough level to be detected by the Diode and appear 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 note on all the stations. Actually, when positioned near to any or all of these terminals, so that oscillation 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.

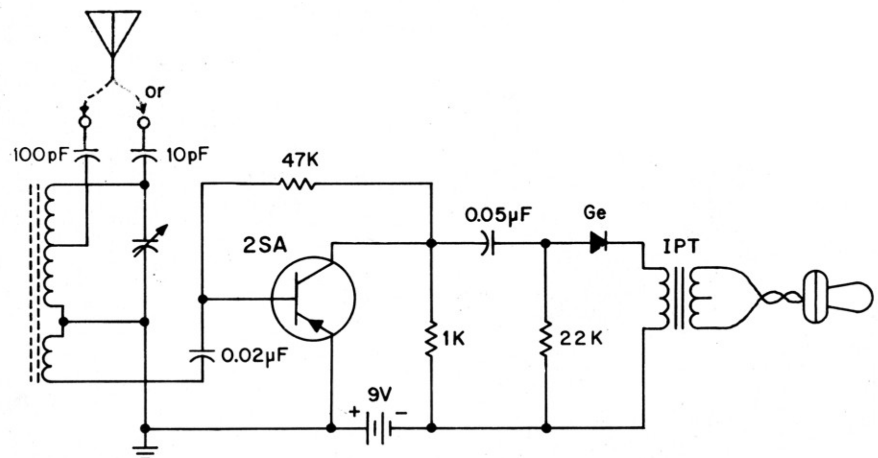
You will want to experiment with this circuit to determine if you can get operation on any station at the optimum sensitivity arrangement of the lead wires. When this is done you will be able to receive all local stations with good selectivity and sensitivity. Low frequency stations require the greatest 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 oscillations. Amplifiers like the one in this project have been used as intermediate frequency (IF) amplifiers in communication receivers. These often include a regeneration control to allow the operator to adjust for maximum selectivity or for oscillations so that CW code signals can be heard properly.



WIRING SEQUENCE:

13-78, 84-30-41-59, 83-58-42, 85-120-118-116-115, 117-57, 60-77-39, 52-114, 50-113-119, 29-40-14-121, 10-Earphone, Earphone-12, Ground-115, Antenna-49 or 51



NOTES

116. COIN BATTERY OPERATED RADIO

This project is a one transistor radio which uses a coin battery as a power supply! The coin battery is described in Project 18.

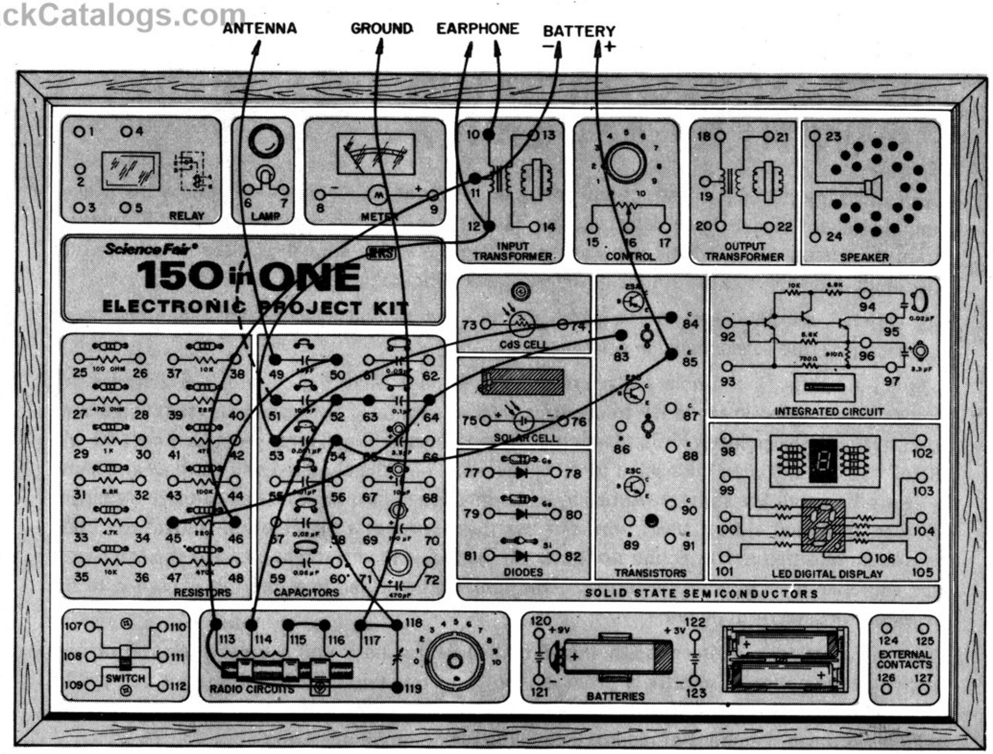
You will want to experiment with different metals for your coin battery as well as different antennas and antenna connections. The test to determine the effectiveness of the coin battery is simple: compare the results when using the coin battery to the results when the coin battery leads are shorted together.

When experimenting with antennas, try both antenna connections. The 10 pF 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 of the B-E (base-emitter) junction of the transistor. 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 coin battery. Strong stations may cause such high loading of 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.

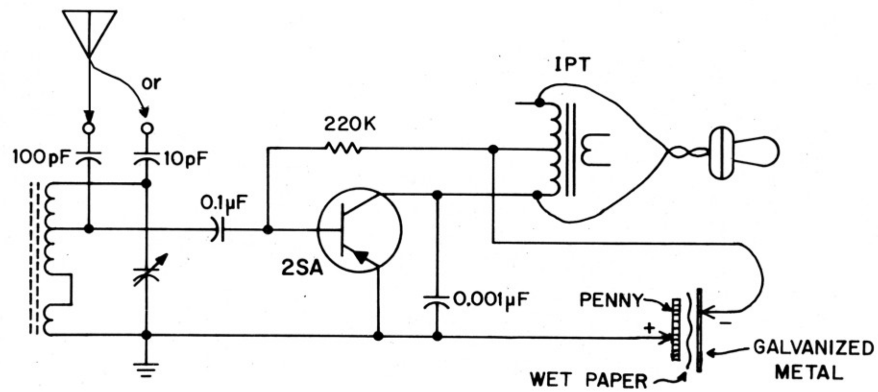
You can also use this radio with the 3V battery or even a 1.5V cell if you like. Have fun!

NOTES



WIRING SEQUENCE:

84-53-12-Earphone, Earphone-10, 83-64-45, 46-11-Battery (−), Battery (+)-85-54-118-117-Ground, 115-116, 119-113-50, 114-52-63, Antenna-49 or 51



117. TWO-TRANSISTOR RADIO WITH TRANSFORMERS

The next logical progression from the one transistor radio of Project 111 is to this two transistor reciever. The antenna and tuning circuitry is the same as Project 108, and the 2SA Transistor amplifier is virtually the same as the one in Project 111. 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 volume Control. This is necessary to keep from over-driving the 2SB Transistor stage and allows an adjustment of Speaker volume. The 10 μF capacitor couples the audio signal into the base of the 2SB without upsetting the DC voltages required on this stage for proper operation.

The 470 μF 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.

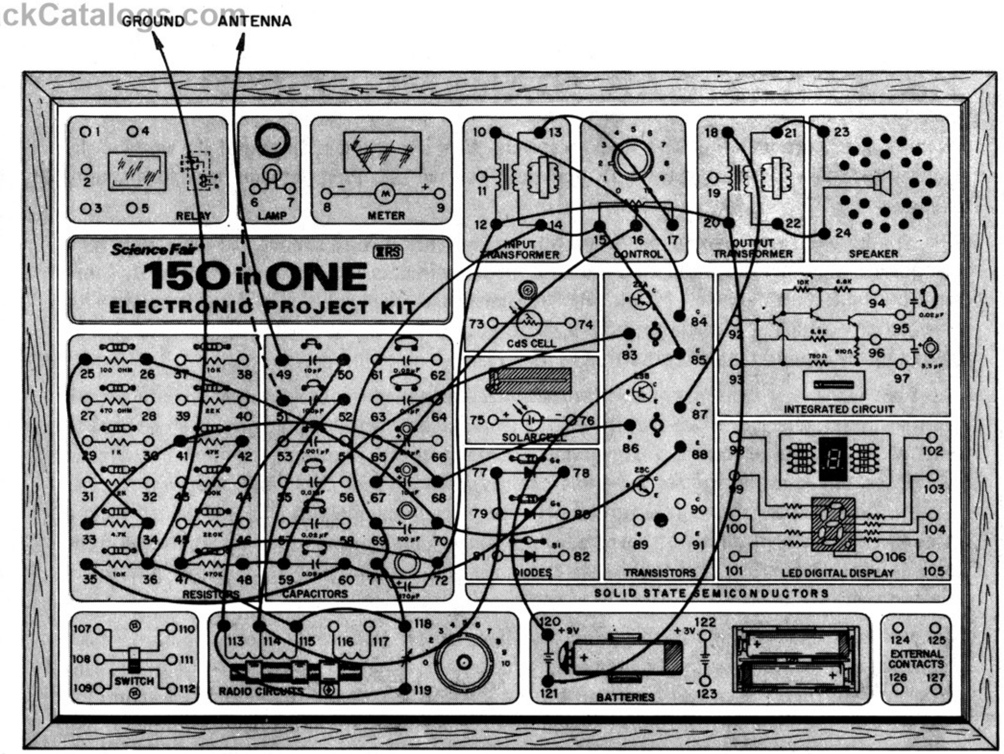
The 2SB stage is a very common type amplifier. The DC voltages (bias) on this stage is obtained from what has come to be called a "universal bias circuit" because of its universal acceptance in the industry as a very stable circuit. Collector voltage is supplied through the primary winding of the output Transformer. Base-bias voltage is supplied from a voltage divider made up of the 47K and 4.7K resistors. These provide a quite stiff voltage of about 0.6V on the base of the 2SB. The higher resistance of these two resistors is called the "base-bias resistor" and the lower value one 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 within the range of about 2 to 6 mA for all possible transistor characteristics. Your VOM can be used to measure the voltage drop across this resistor and then Ohm's law used to determine actual emitter current. Recall I=E/R. If emitter voltage is between 0.2V and 0.6V, the current is within the desired range. A value of about 0.4V is obtained when the transistor has average expected characteristics.

The 100 μF 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.

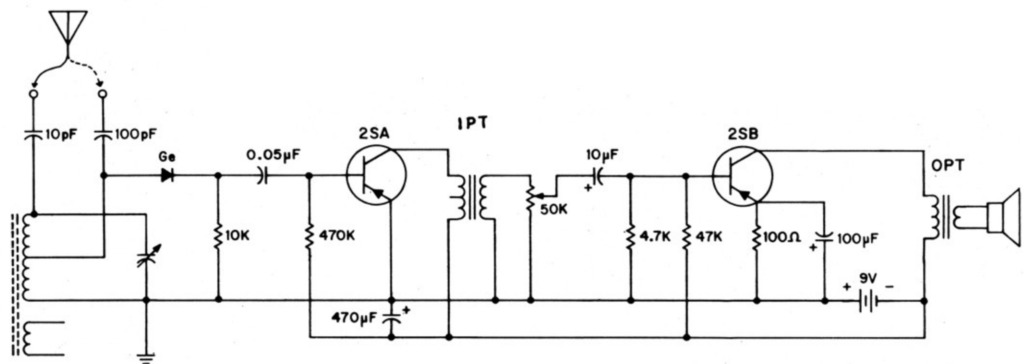
Until you know exactly what to expect, we suggest you don't try changing any resistor values in the 2SB stage or the Transistor may be damaged. Other projects provide an opportunity for experimentation on this type of circuit.

NOTES



WIRING SEQUENCE:

120-85-15-14-69-71-118-115-36-34-25, 21-23, 22-24, 18-87, 10-84, 13-17, 16-67, 83-59-48, 86-68-41-33, 88-70-26, 50-113-119, 52-114-77, 78-60-35, 42-47-72-12-20-121, Antenna-49 or 51, Ground-36



118. 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.

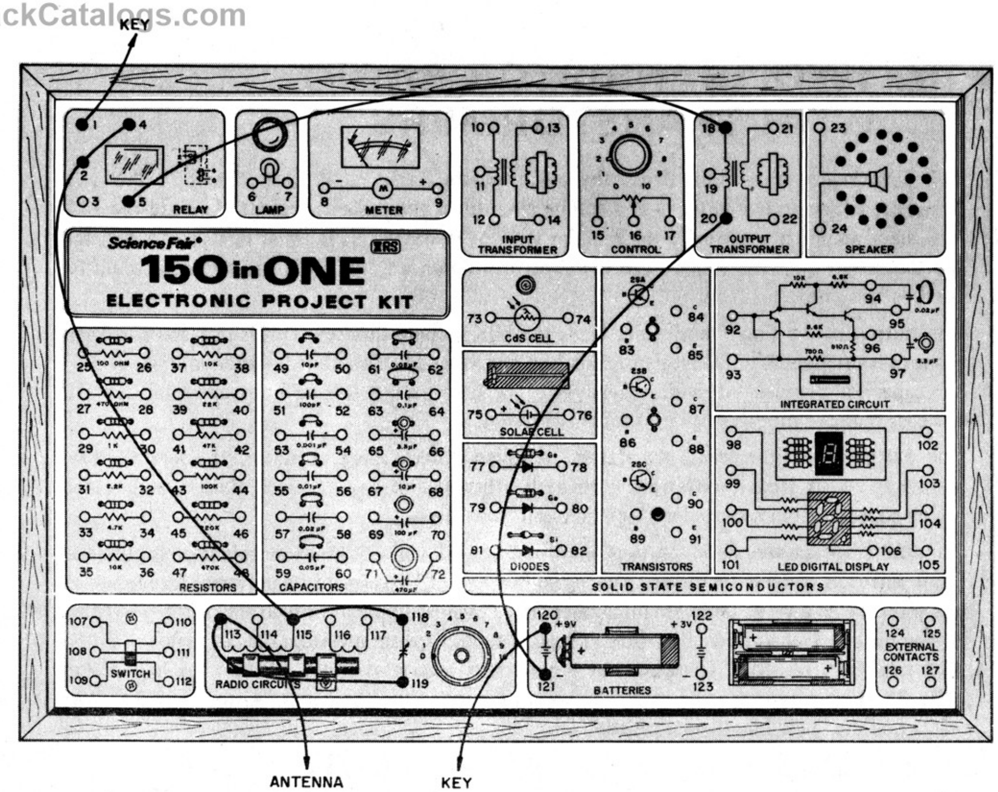
When Radio was first invented, there was no way to transmit voice sounds. All they could send was noise – and then they used a Key to send the noise in dots and dashes (Morse Code). Those early transmitters were called "spark gap" transmitters. Actually all they did was generate a lot of electricity 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 when a nearly 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 circuit here uses the Output Transformer and Relay field coil to provide a 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.

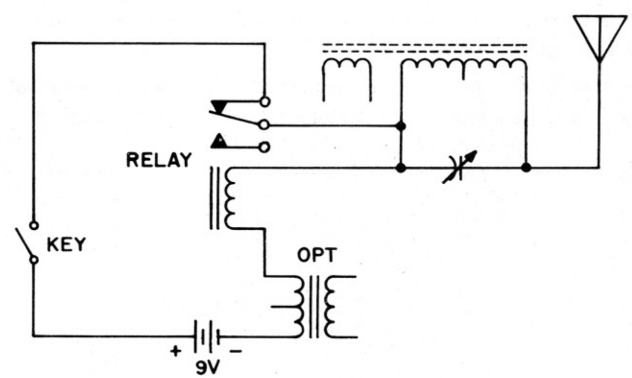
The main problem with this circuit is that the arcing and sparking at the contacts of the Relay tend to destroy the contacts after only a short time.



WIRING SEQUENCE:

121-20, 18-5, 4-2-115-118, 119-113-Antenna (green wire supplied), 1-Key, Key-120

NOTES



119. 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.

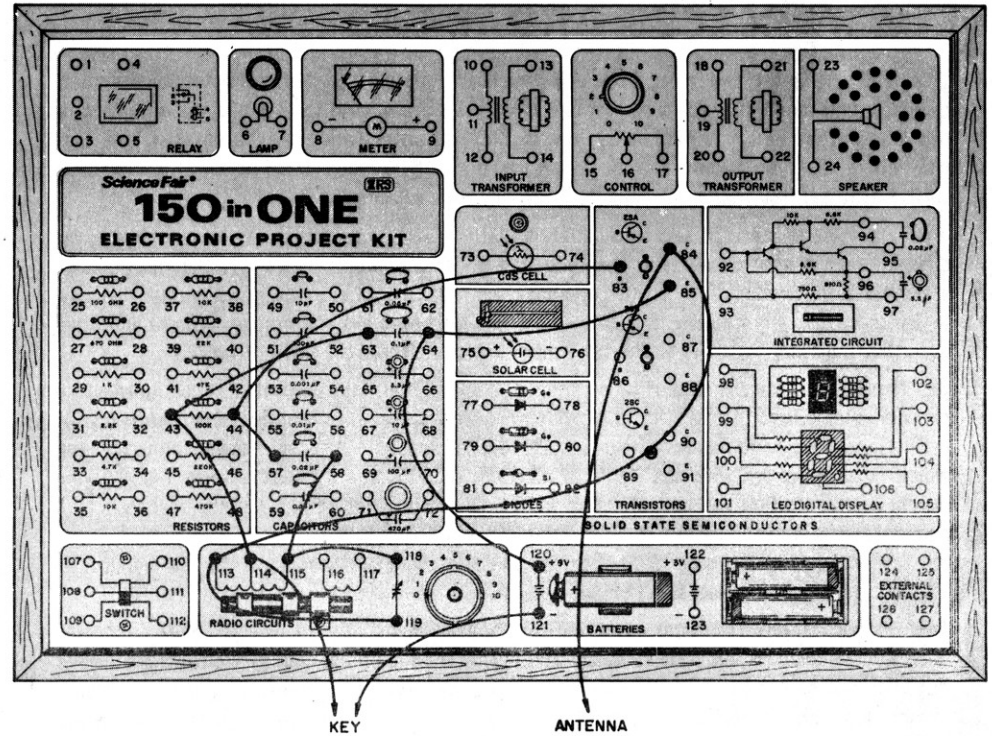
A common AM radio may be used to receive the code sent out by this transmitter, if the radio is first tuned to a weak station. This transmitter signal then mixes with the station's signal to produce an audio tone which is called a "beat note." It is this beat note which is then heard as the code signal. Tune this transmitter until a desired and strong beat-note is heard in the receiver.

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 receiver has a beat frequency oscillator (BFO). This BFO beats with the CW signal from this transmitter and produces the tone.

The two requirements for an oscillator, gain greater than one and regenerative feedback, are provided by the transistor (gain) and tank circuit connections. The emitter is connected by the 0.1 μF 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).

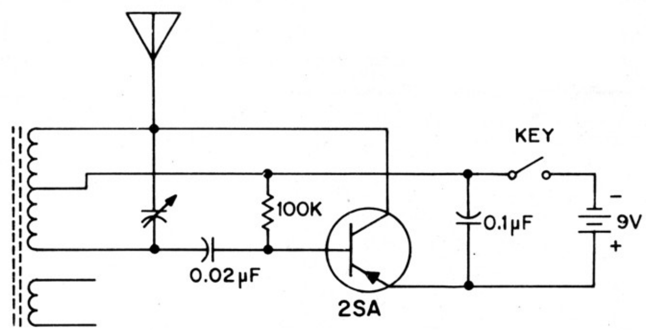
The 100K resistor provides some base-bias current to turn the Transistor ON as required for operation as an amplifier or oscillator.

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 a couple or three feet (about 60~90 cm) of wire will do. Have fun!



WIRING SEQUENCE:

120-64-85, 84-113-119, 83-44-57, 58-115-118, 63-43-114-Key, Key-121, Antenna (green wire supplied)-84



NOTES

120. WIRELESS BROADCASTER

This is the simplest and most basic AM transmitter possible, a one transistor combination oscillator and modulator all in one. A common AM radio is used to listen to the output from this transmitter. Power is necessarily low to limit distances which can be covered with this transmitter, but you should be able to get up to about 50 feet (15 m) or so. This should be sufficient to get from one side of the house to the other or outside.

The Transistor is operated as a modulated oscillator. Recall that there are two requirements for a circuit to oscillate: gain greater than one, and the output coupled back into the input in such a manner as to produce regenerative feedback. The Transistor has a gain much greater than one so it meets this requirement. Signal voltages between base (B) and emitter (E) are amplified over 100 times and appear as an output voltage across collector (C) and emitter (E).

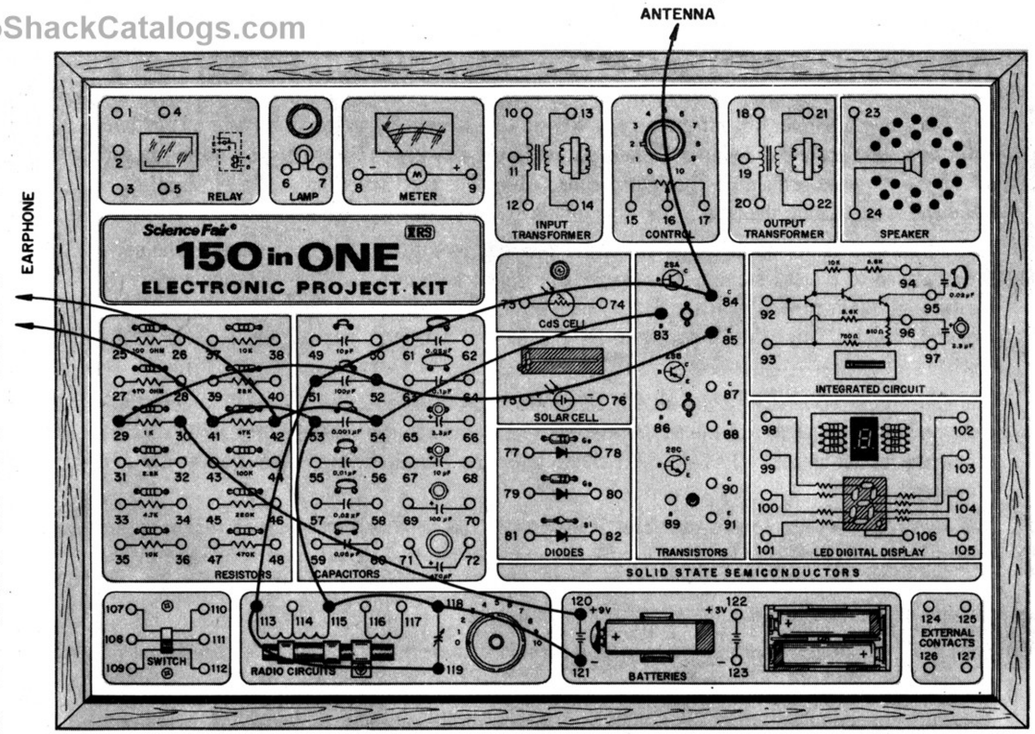
The requirement for the output to be coupled back to the input properly is accomplished by proper connections across the tank circuit which is used to control the frequency of oscillations. To have a regenerative feedback, the Transistor must have a signal fed to its base, which is out-of-phase with the signal at its collector. This out-of-phase condition is obtained simply by connecting the collector and base to opposite ends of the parallel resonant tank circuit formed by the ferrite coil and tuning capacitor. The 0.001 μF capacitor in this circuit effectively connects the base to the bottom of the tank circuit because at the RF frequencies involved it appears as a near short circuit.

The emitter of the Transistor must at least appear electrically (if not actually) connected between the collector and base voltages. Quite often the tap on the coil is used for this purpose, but in this circuit the emitter is made to only appear electrically connected due to the 100μF capacitor working in conjunction with the 1K emitter resistor and internal transistor impedance between base and emitter.

The 47K resistor provides some base-bias current to turn the transistor ON for proper operation as an amplifier or oscillator.

The Earphone is used to modulate the base voltage of the Transistor to obtain modulation of the RF frequency of oscillation. The crystal Earphone is very inefficient in this circuit as a generator of voltage so don't expect strong modulation.

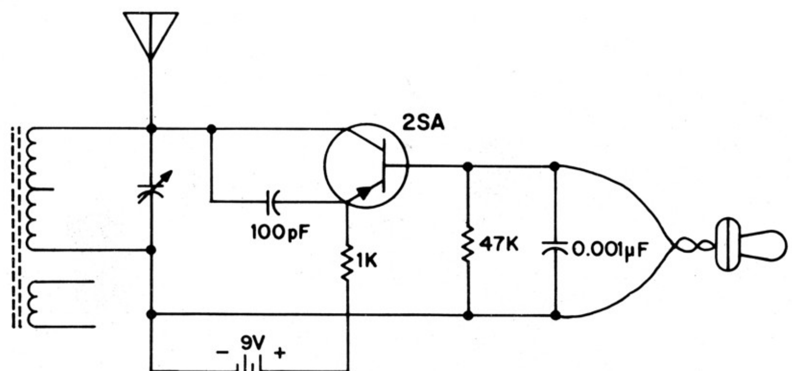
Best results are obtained by tuning a receiver near the high frequency end of the dial where no stations are present. Now slowly tune this transmitter until it can be heard in the receiver. The green wire supplied with this kit should be used as the antenna for this transmitter. Have fun.



WIRING SEQUENCE:

121-118-115-53-41-Earphone, Earphone-42-54-83,

85-52-29, 119-113-51-84-Antenna (green wire supplied), 30-120



NOTES

121. MODULATED CW TRANSMITTER

The purpose of this project is to build and operate a complete MCW 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.

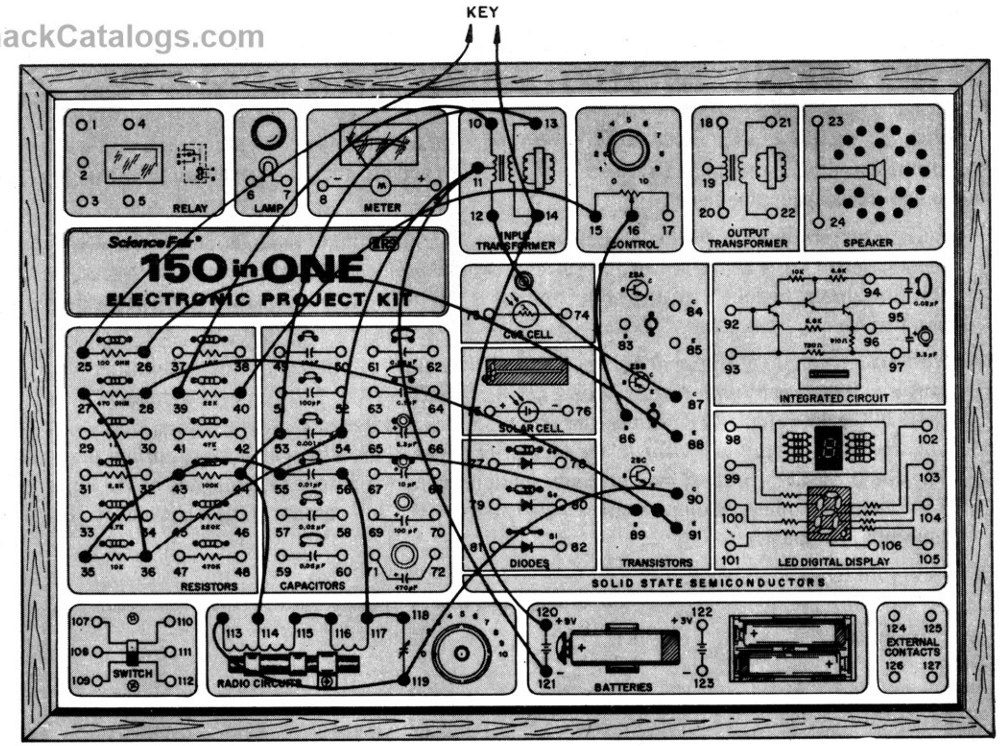
The RF oscillator part of this transmitter is ON whenever the battery is connected. The audio oscillator which modulates the RF is keved ON and OFF with the Kev.

You may want to use the length of wire that came with this kit 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 to find this transmitter signal.

The 50K Control allows you to change the audio tone to obtain the pitch you like. Usually the high pitch is desired by amateur and commercial code operators.

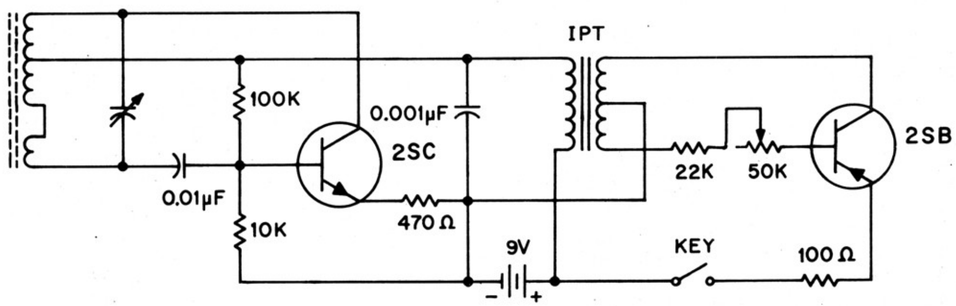
The Morse code is printed on the base of the key for your convenience. All you need now is a neighbor friend who also has a 150-in-1 Kit and you are in business. Have fun!



NOTES

WIRING SEQUENCE:

87-12, 10-39, 40-15, 16-86, 88-26, 90-119-113, 114-44-53-13, 115-116, 56-117-118, 35-43-55-89, 91-28, 27-36-54-11-121, 25-Key, Key-14-120



122. TONE MODULATED TRANSMITTER

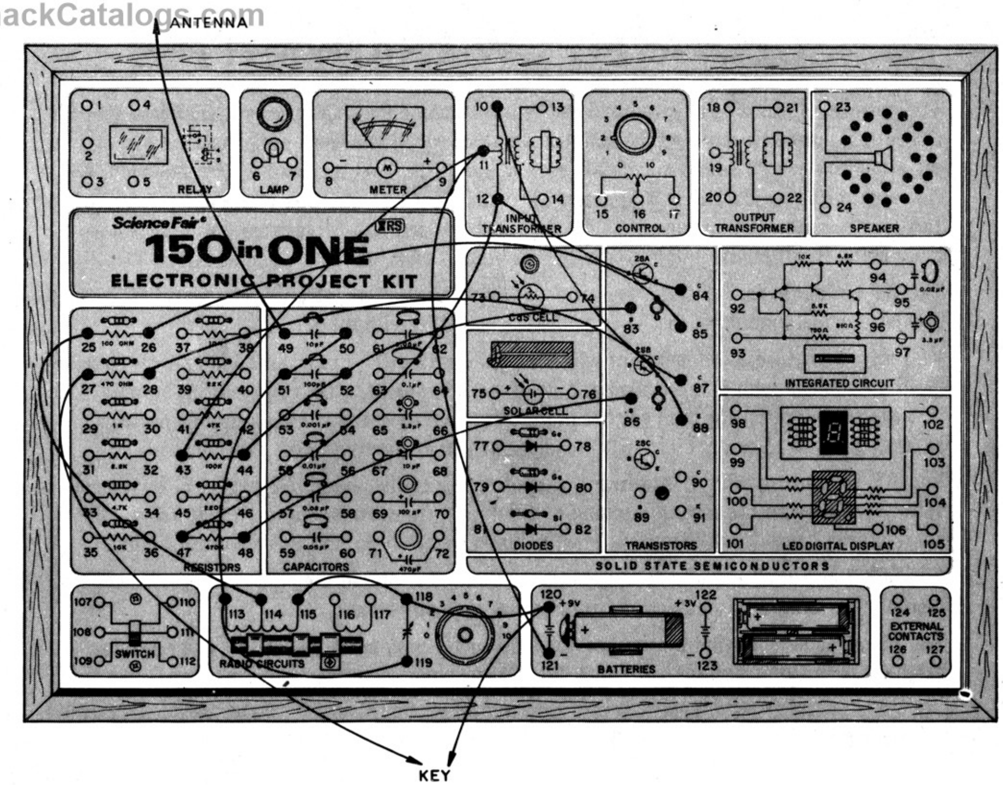
This is a second and improved MCW transmitter. The one in Project 121 produces a strong but distorted audio signal in the receiver while this Project provides the same results but with a much cleaner sounding signal.

Battery current drain with this transmitter is only 0.5 mA without modulation and 3 mA with modulation. This is about 1/4 of the current required by the circuit of Project 121. Because of this low current requirement the power output is also lower so you may want to use your kit antenna 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 about 22K, or the 470K below about 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!

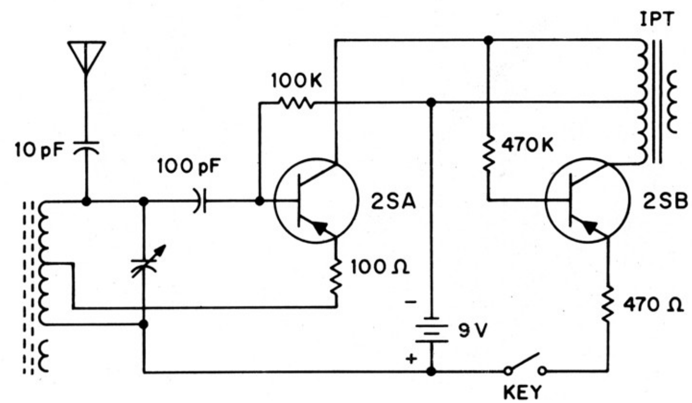
NOTES



WIRING SEQUENCE:

10-87, 43-11-121, 47-12-84, 26-85, 25-114, 28-88, 50-51-113-119, 44-52-83, 48-86, 115-118-120-Key, Key-27

49 - Antenna



123. SOLAR TELEMETRY

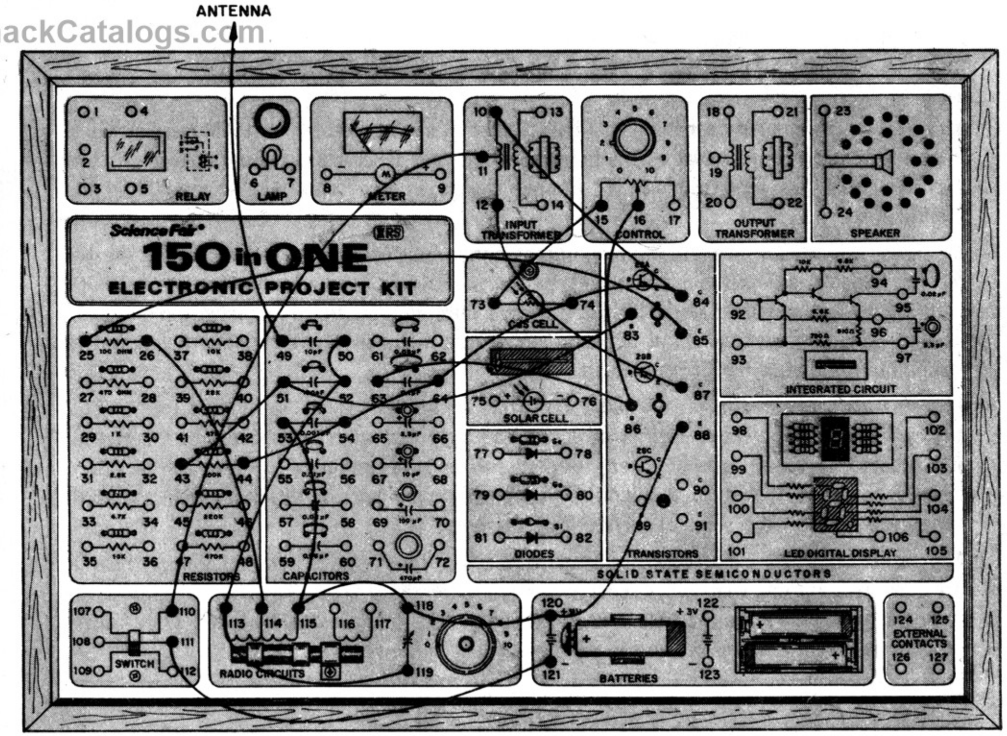
This project demonstrates how the amount of light intensity at a far distant point, such as on a space probe or satellite, can be transmitted back to earth by telemetry. A telemeter is a special transmitter which is used to transmit some measurable phenomenon from a distance above the earth. These are 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 photo 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 0.1 μF 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 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 included with the kit may be used to obtain a greater transmitter range.

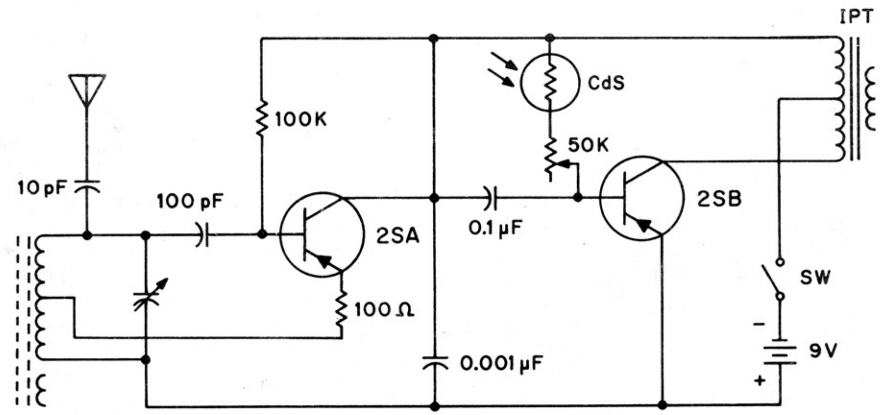
Place the slide Switch in the ON (up) position when the transmitter is ready to use. To measure total Battery current you may use a VOM across the switch terminals when the switch is OFF. This method of measuring battery current is a standard troubleshooting technique.



NOTES

WIRING SEQUENCE:

119-113-52-50, 114-26, 25-85, 10-84-74-64-54-44, 83-51-43, 11-110, 12-87, 73-15, 16-86-63, 88-120-118-115-53, 111-121, 49-Antenna (green wire supplied)



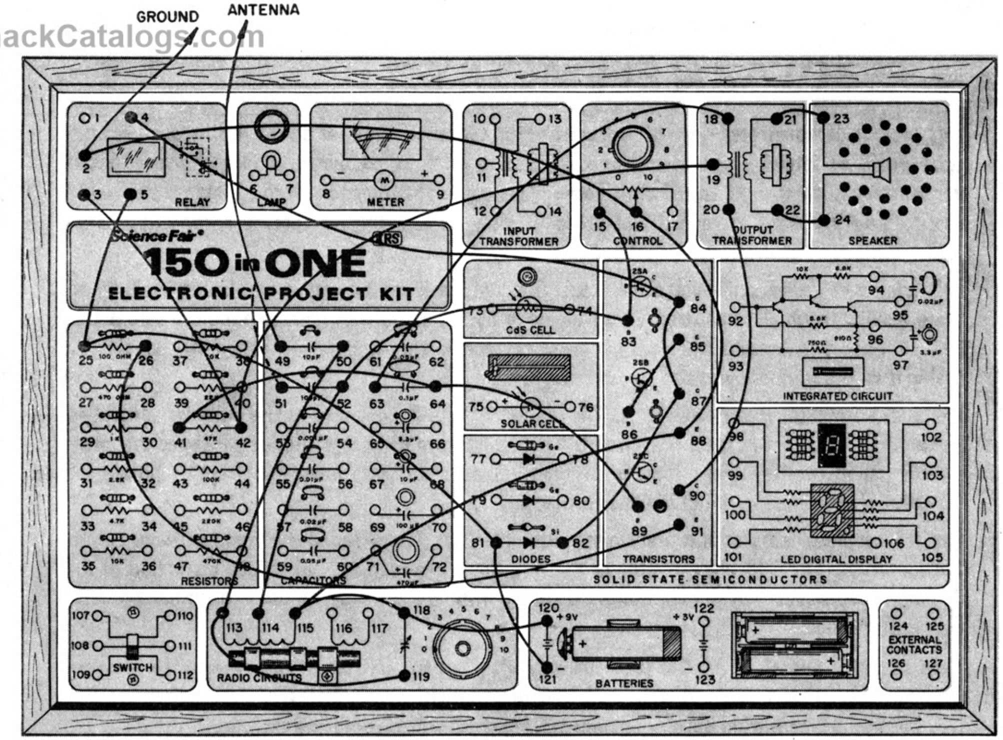
124. RADIO SIGNAL MONITOR

This project is a modified version of the OFF THE AIR alarms used by most AM radio stations. The modification is to provide a tone to indicate when the RF signal is present instead of when the RF signal has been removed. A simple change in one relay wire accomplished the modification.

Circuit operation is simple. Hook up a good antenna. Tune across the band and notice the dial settings which cause the tone to be generated in the speaker. These are the settings at which radio signals are present. Use the 50K Control as a sensitivity control. If adjusted too low some stations will not cause the alarm to sound – and, too high a setting may allow the circuit to respond to noise or to transistor leakages.

The circuit uses the 2SA and 2SB Transistors connected as a "Darlington pair". This arrangement gives extremely high current gain and high base input resistance. For this reason, and because no base-bias is provided, no detector diode is needed. The Relay can be driven directly by these Transistors. A silicon (Si) Diode is provided across the Relay field to absorb and direct the turn-OFF surge of current from the Relay.

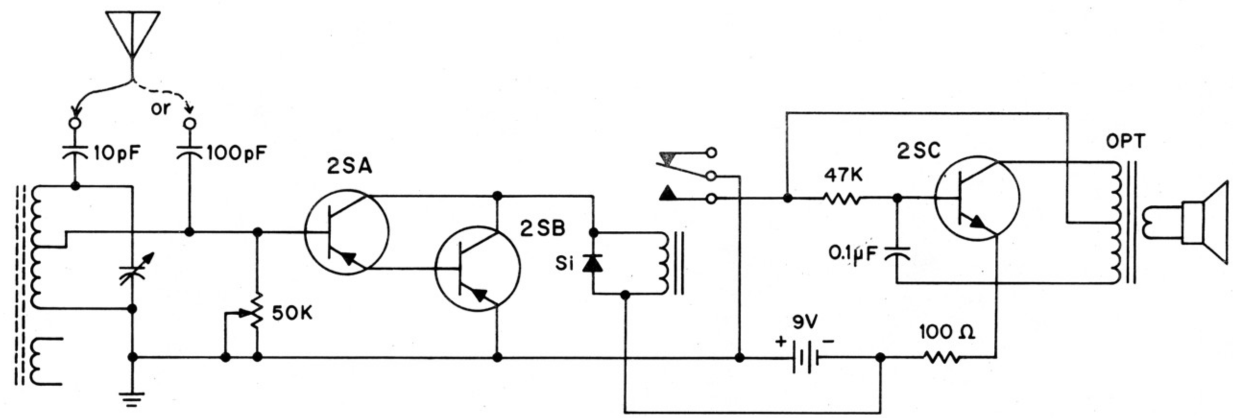
The oscillator circuit is a standard center-tapped transformer type of pulse oscillator. The 47K provides base starting bias and discharge resistance for the 0.1 μF. The 0.1 μF couples the regenerative feedback to the base and provides the OFF-time charge. The 100 ohm resistor provides some current limiting for the 2SC base and collector currents.



WIRING SEQUENCE:

21-23, 22-24, 20-90, 18-63, 19-42-3, 41-64-89, 91-26, 50-113-119, 114-52-83-15, 4-84-87-82, 85-86, 2-16-88-115-118-120, 5-25-81-121, Ground-2, Antenna-49 or 51

NOTES



125. 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 testing circuit methods. The following circuit 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 be simple, which it is, but it is very reliable.

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.

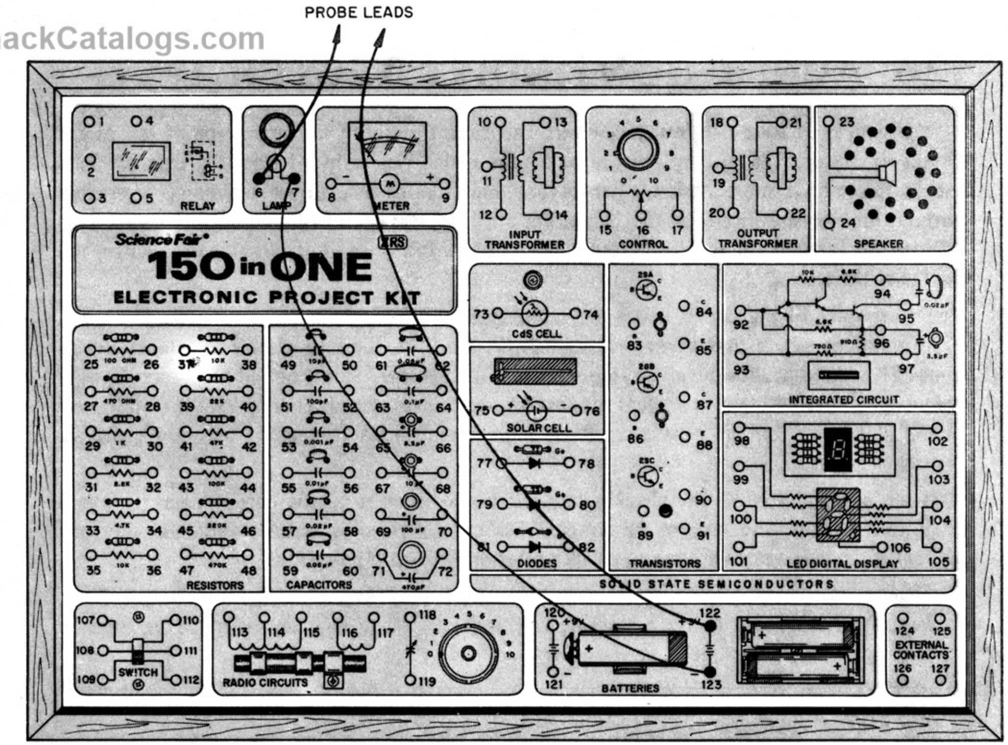
This tester (like all ohmmeters) must not be used on circuits where other sources of power are present or the Lamp will be burned out. It also should not be used on delicate solid-state circuits where the current for the Lamp (about 300 mA or more) may cause damage.

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 at all). This is caused by the fact that some equipment has relatively high resistance so that this simple tester cannot be used successfully.

By observing the glow on the Lamp, you can check circuits with up to about 10 ohms.

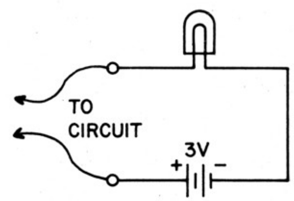
Now your next logical circuit area to study is that of ohmmeters, but first you may want to familiarize yourself with Project 126.

NOTES



WIRING SEQUENCE:

123-7, 6-long lead for Probe, 122-long lead for Probe



126. AURAL CONTINUITY TESTER

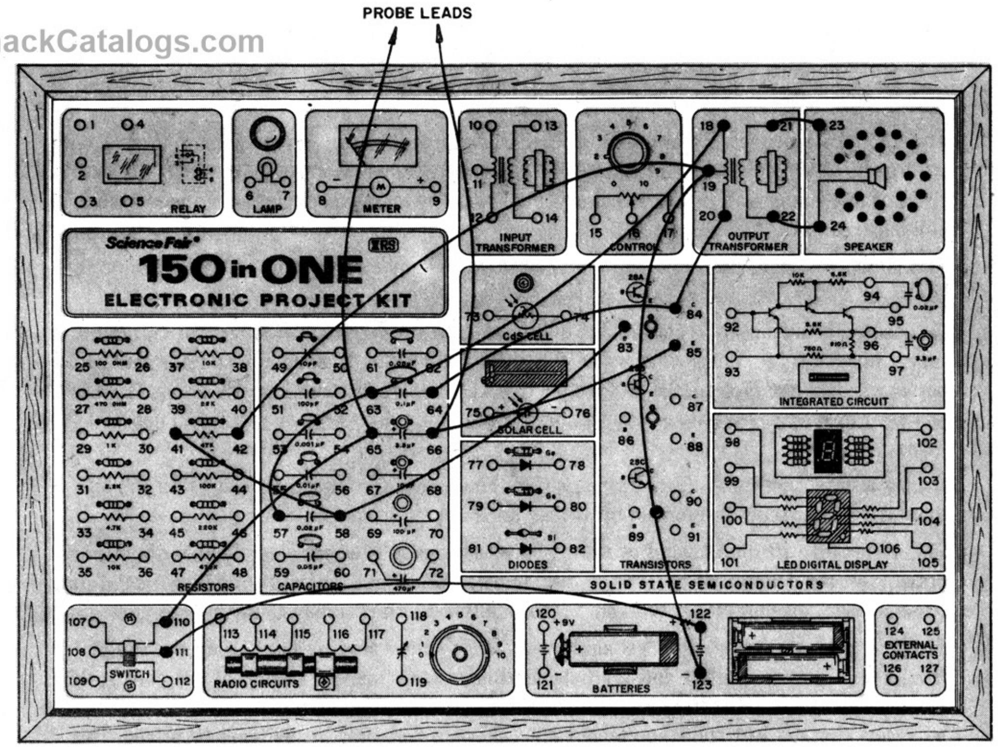
This project is an aural continuity checker. This circuit performs the same type of test as the circuit of Project 125 but by the use of a tone which can be heard from the Speaker. This makes this circuit more desirable where you may not be able to see the Lamp each time without looking specifically at the Lamp. For example, this circuit allows you to use your eyes entirely for locating the wires and terminals to be checked while your ears alone can 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, resistances up to about 2K ohms will allow an audio response from the Speaker. This is not all bad though, as the frequency of oscillation is somewhat proportional to this resistance. That is, a short circuit gives about 500 hertz, but all resistances cause higher frequencies (frequency becomes higher as resistance increases).

You can check this circuit by checking almost any component on the board **except the Meter** (it is too sensitive and may be damaged). When checking Diodes and transistor junctions try switching the probe leads around to check operation with both polarities.

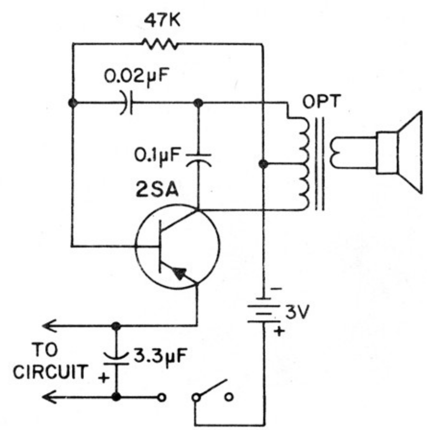
You can check almost anything with this continuity checker because of the low current (2 mA or less). You will want to try measuring continuity of pencil lines on paper, water, metallic surfaces and many other things.

NOTES



WIRING SEQUENCE:

21-23, 22-24, 123-19-42, 41-58-83, 18-63-57, 20-84-64, 85-66-Probe, 122-111, 110-65-Probe, (use long leads for Probes)



127 . 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 resistances. 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 (voltage) E is not changed, the (current) I is inversely proportional to (resistance) R.

A graph is included below to change the Meter 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 to eliminate 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 erroneous. Also make sure no voltage is present across the resistance or this Meter may be damaged.
3. Locate the above meter reading along the bottom of the graph. Go vertically up from here 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.

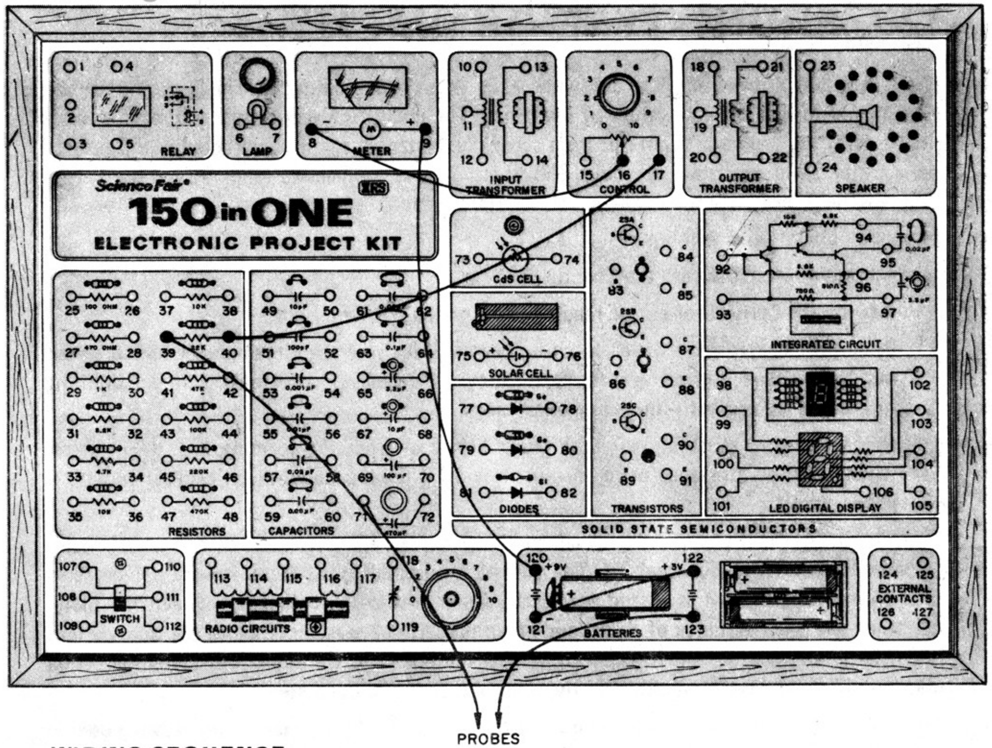
An ohmmeter such as this is one of the most valuable tools a repairman has to check for defective parts. Use the ohmmeter you have just made and measure some of the following parts.

1. Resistors: They should be relatively close to their marked value.
2. Diodes: With one ohmmeter connection polarity you should obtain a low resistance; but with the opposite polarity, a high resistance.
3. Transistors: Between C-B and E-B junctions 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 a high resistance with both polarities.
4. CdS photo Cells: Resistance depending on light level.
5. Capacitors: Values above about 0.01 μF 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.

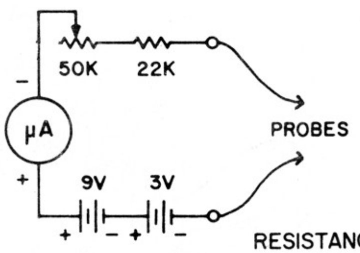
$$R = \frac{480}{I} - 48$$ K ohms, where I is the blue meter scale reading.

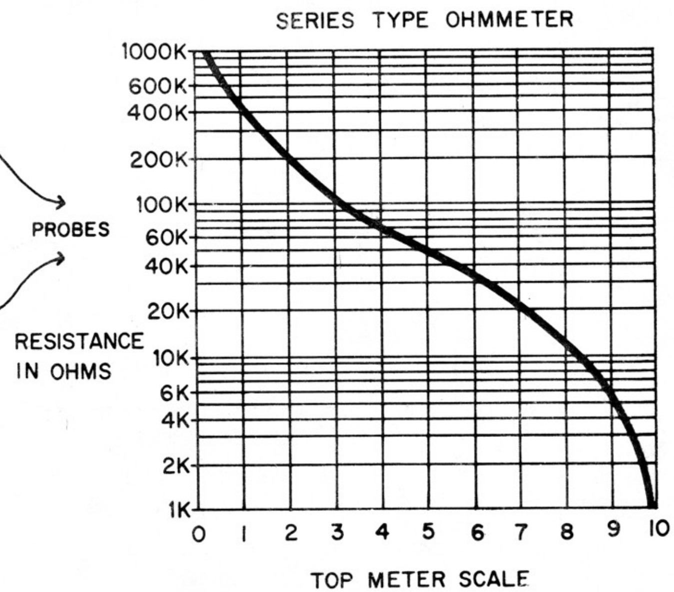
Notice that the most accurate range of resistances measured with this meter is between 2K and 900K ohms. The shunt-type ohmmeter project is next and is suitable for lower ranges of resistance.



WIRING SEQUENCE:

40-17, 16-8, 9-120, 121-122, 123-long lead as Probe, 39-long lead as Probe





128. SHUNT-TYPE OHMMETER

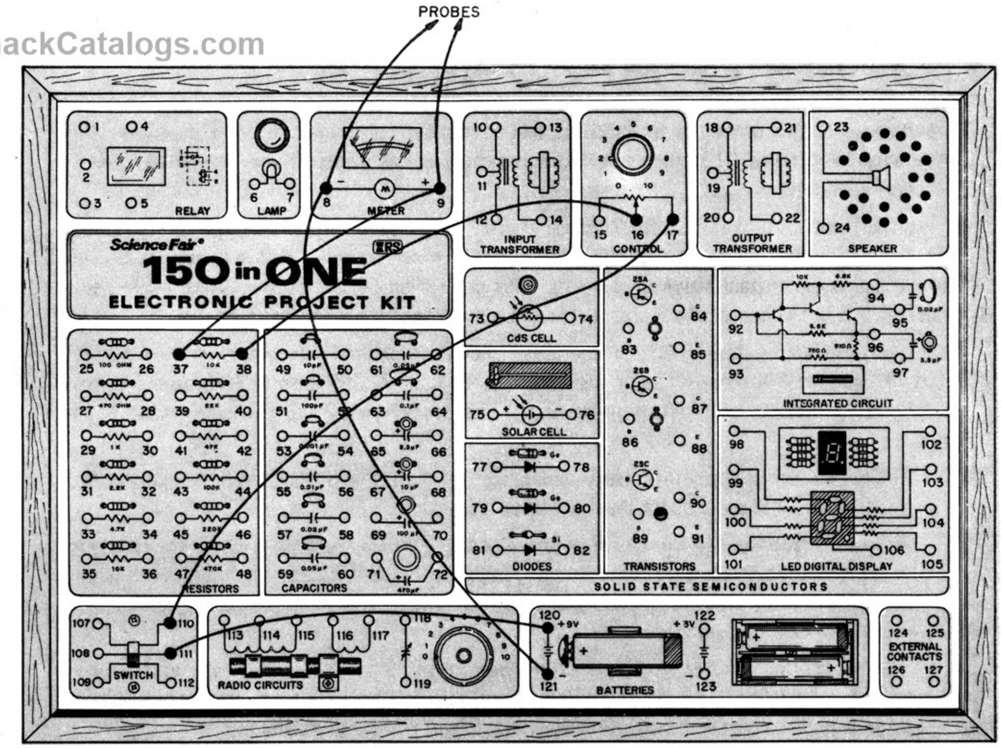
The purpose of this project is to study the basic shunt type ohmmeter. These ohmmeters are used mainly to measure low values of resistance. The circuit is a very simple and reliable series circuit, with the probes brought out from across the Meter. The unit constructed in this project has a center-scale 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 probes across resistance to be measured. **Make sure the circuit under measurement has NO voltage present or this Meter may be damaged.** Also make sure no shunting resistances are present – including your hands.
4. Determine the resistance from the graph below or from the formula $R = \frac{650\ I}{10-I}$ ohms, where R is the resistance being measured, and I is the top (blue) meter calibration with R in the circuit.

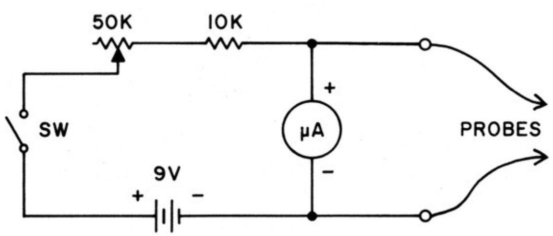
This circuit works by supplying a constant current to the meter from the series circuit composed of the 10K, 50K and 9V. The current is adjusted to the Meter full-scale value. Now as shunting resistance R is placed across the Meter, the current divides between the Meter resistance and the resistance 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 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.

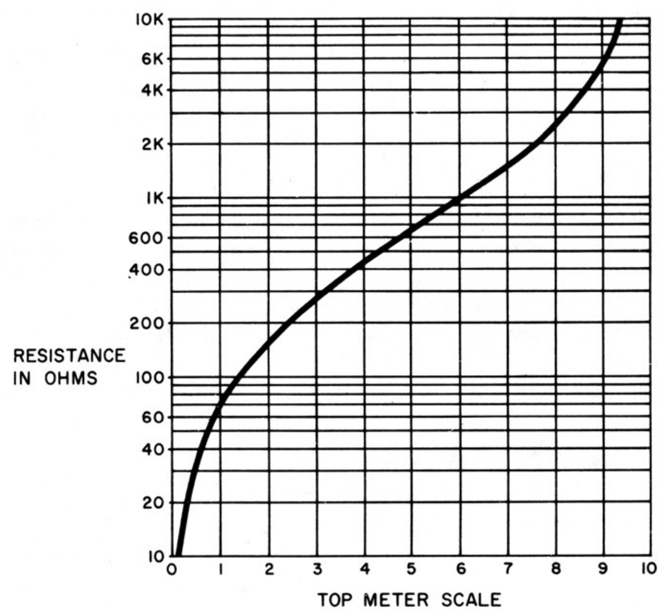


WIRING SEQUENCE:

16-38, 17-110, 111-120, 121-8-Probe, 37-9-Probe



SHUNT TYPE OHMMETER



129. WHEATSTONE BRIDGE

The purpose of this project is to consider the Wheatstone bridge circuit. This circuit has been around for over 100 years for measuring resistances, so it must be a good circuit to have survived this long. Virtually all instruments available 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 an enclosed ring as shown in the Schematic diagram. The generator (a Battery) is connected across two opposite corners of the bridge. The detector (a 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 indicate this by the unbalance 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:

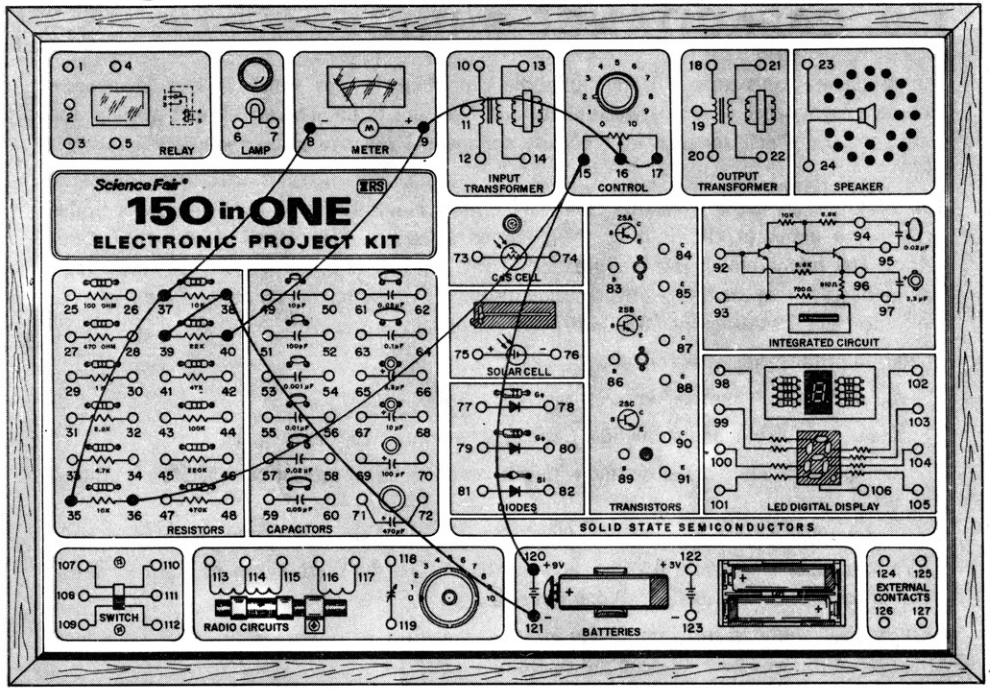
$$R4 = R3 \times \frac{R2}{R1}$$

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 up 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.

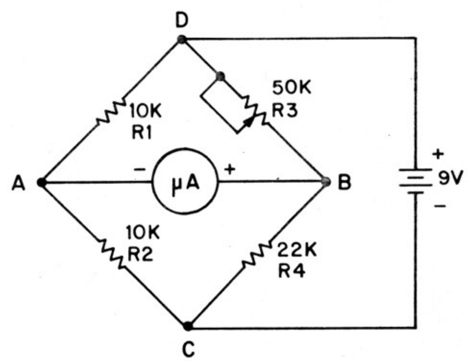
If the Control is calibrated by using a large number of known resistances for R4, you could use this as an ohmmeter like the circuit was intended. You may want to try measuring other devices such as the CdS Cell, other resistors or even between various leads of transistors. The resistances will have 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.

NOTES



WIRING SEQUENCE:

120-15-36, 17-16-9-40, 8-37-35, 39-38-121 (Plus Text Instructions)



130. CAPACITANCE BRIDGE

The purpose of this project is to study the capacitance bridge which is used to measure unknown capacitance values between about 0.001 μF and 10 μF. 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 you've run into before. 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.

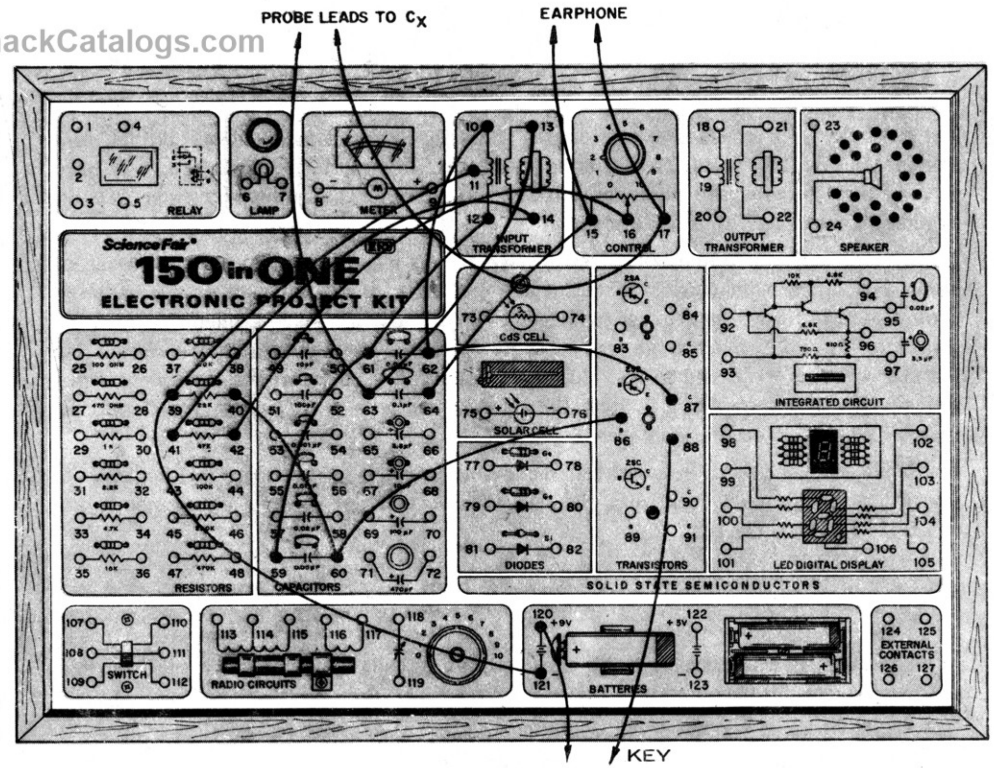
Operation of the bridge is as follows:

1. Connect unknown capacitance C_X 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 10 μF. Use the space below to make a chart or graph of capacitance versus Control dial settings.

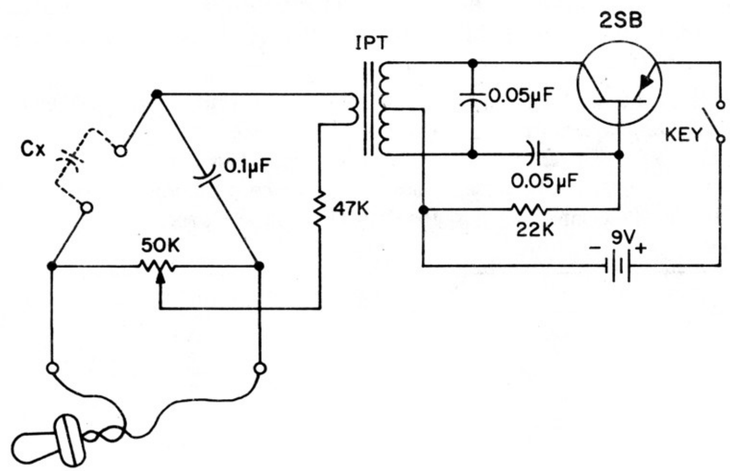
Once you've calibrated this capacitance bridge you can use it to check those mysterious color coded capacitors you have salvaged out of old radios and TVs.

NOTES



WIRING SEQUENCE:

87-62-10, 11-39-121, 12-61-59, 86-60-40, 41-14, 42-16.
88-Key, Key-120, 13-63-Probe for C_X, 64-15-Earphone,
Earphone-17-Probe for C_X



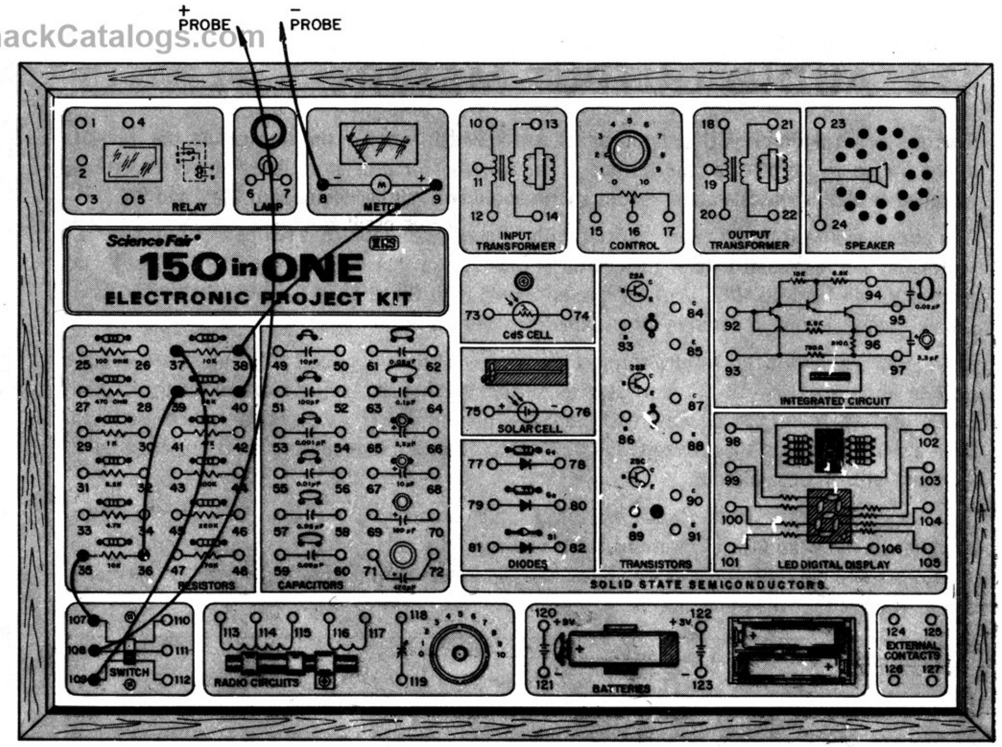
131. BATTERY VOLTMETER TESTER

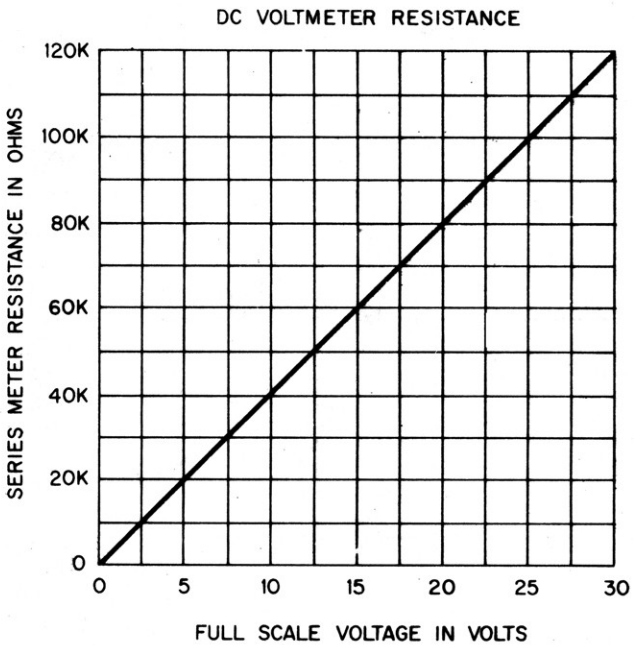
The purpose of this project is to construct a quick and simple circuit to test the batteries used in this kit. The circuit amounts to a two-range DC voltmeter.

The detailed description of the DC voltmeter circuit is included in other projects such as No. 36 where a graph is included. The full-scale voltages of this Meter are actually lower than the batteries to be tested, therefore, any time the batteries are not able to pin the Meter on full scale 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.

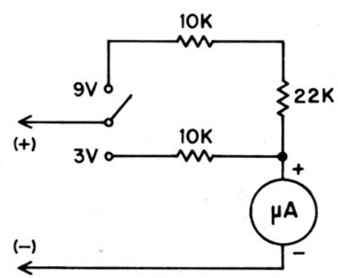
With the switch DOWN you have a low voltage range (3V) – and with the switch UP, the higher voltage (9V).





WIRING SEQUENCE:

9-38-40, 37-109, 39-36, 35-107, 108-Postive Probe, 8-Negative Probe



132. AUDIO OUTPUT METER

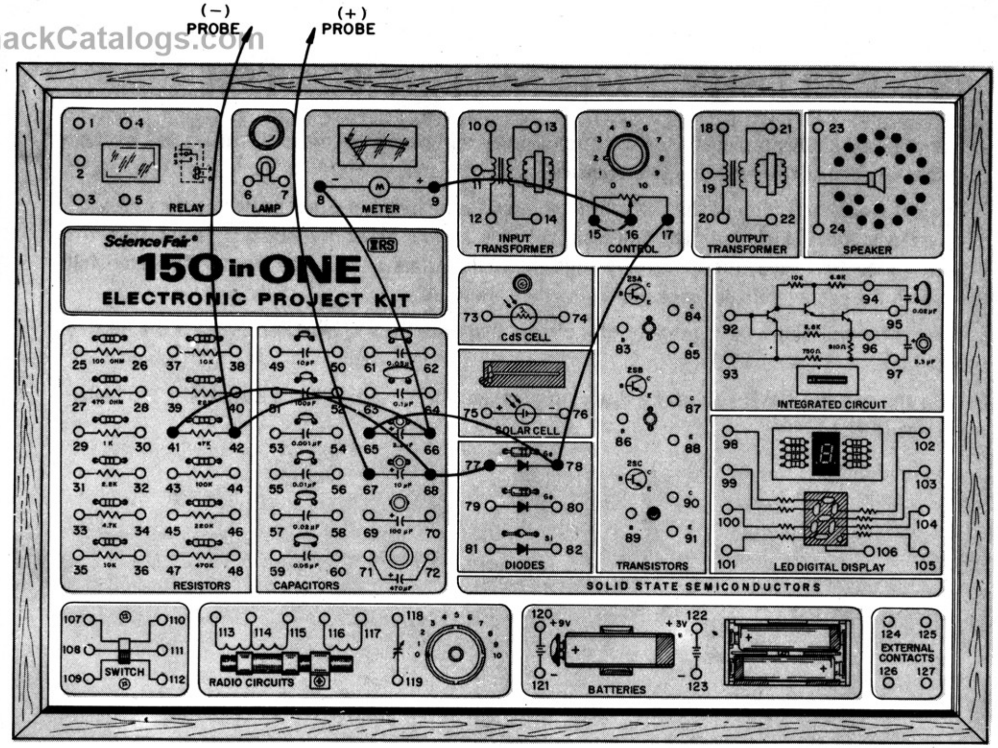
This project is a simple VU (volume unit) meter which you can use to measure the level of audio frequency voltages at the output of an amplifier or oscillator. A sensitivity control is included to allow full-scale meter readings with audio voltages between about 0.2V and 9V.

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 on the circuit. Adjust the 50K Control for the desired meter reading. In circuits where no DC voltage is present, the 10 μF capacitor may be replaced with a short circuit. In these circuits the 47K resistor may also be removed from this circuit and replaced with an open circuit.

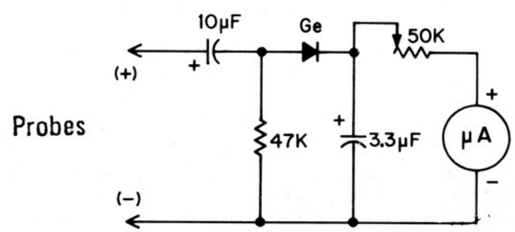
The applications for meters such as this include monitoring the level of audio for tape recorders, radio-stations, TV stations, etc. You may use this circuit to measure some of the oscillators and amplifiers in this kit. The only requirement is that the parts used in this meter not be required for the other circuit.

NOTES



WIRING SEQUENCE:

9-16-15, 17-78-65, 8-66-42-Negative Probe, 77-68-41, 67-Postive Probe



133. LOW FREQUENCY RESPONSE AUDIO LEVEL METER

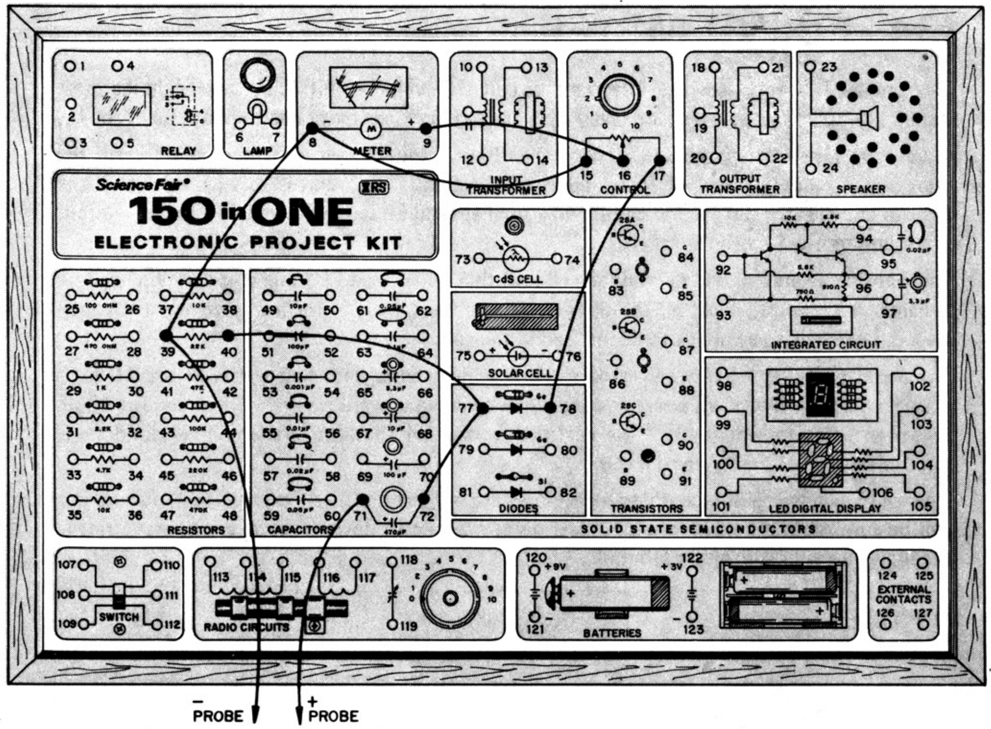
This project is an output level meter which is similar to the one in Project 132. Can you explain the differences?

This circuit has the same basic characteristics of the other circuit. 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.

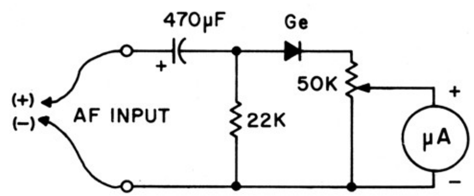
Another important change is that this circuit responds to the average signal level – the other circuit tends to respond to the peak of the signal. This is due to the action of the filter capacitor in the other circuit.

NOTES



WIRING SEQUENCE:

17-78, 16-9, 40-77-72, 15-8-39-Negative Probe, 71-Postive Probe



134. I.C. VU METER

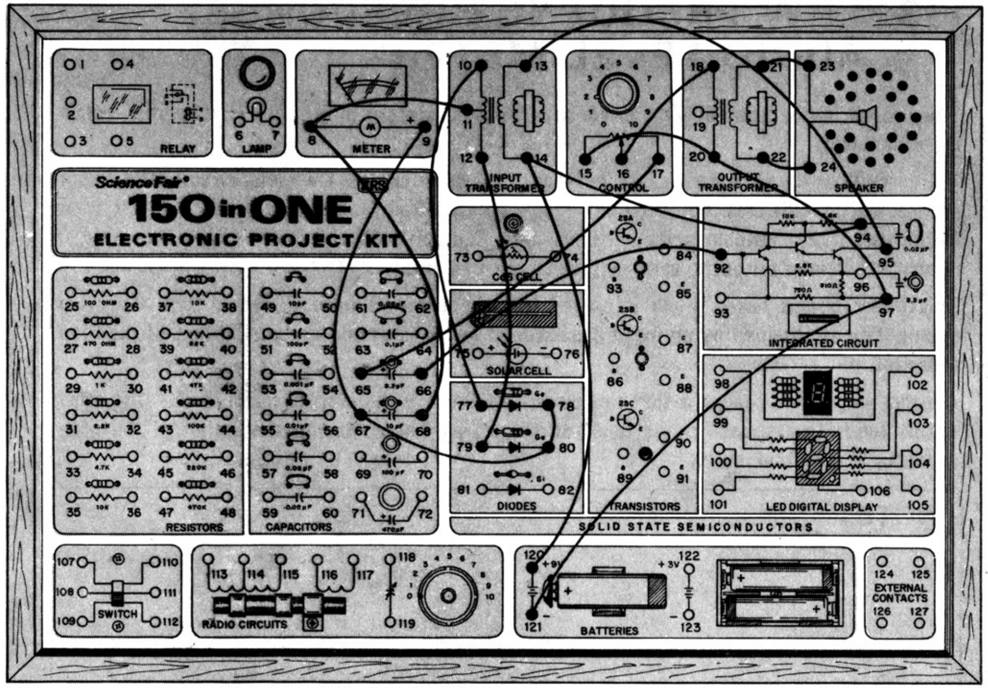
This project is a very sensitive integrated circuit (IC) volume unit (VU) meter. Unlike most meters like this to measure sound levels, this one has high sensitivity obtained by use of the IC.

Always start measuring the sound with the Control initially 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 it 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 which causes both half cycles of the AC to be passed on to the Meter with proper polarity to cause an upward pointer deflection. The 10 μF capacitor helps to smooth out the rectified voltage so that the meter will respond more smoothly to the changing signal levels.

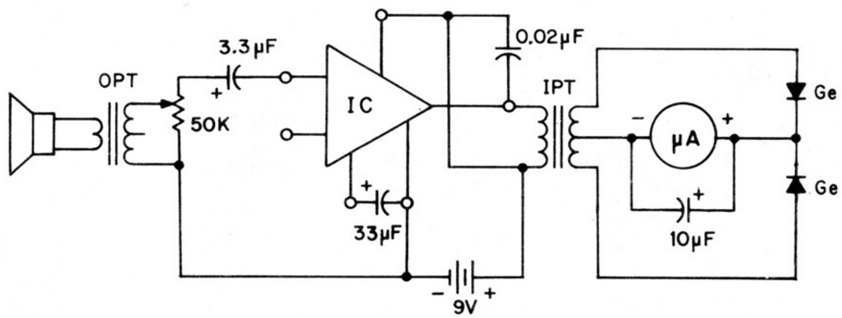
You will want to measure and compare noises around the house. Also when used outside you will be surprised how much the Meter action causes you to notice sounds which are normally tuned out by your subconscious mind.



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



135. METER AMPLIFIER

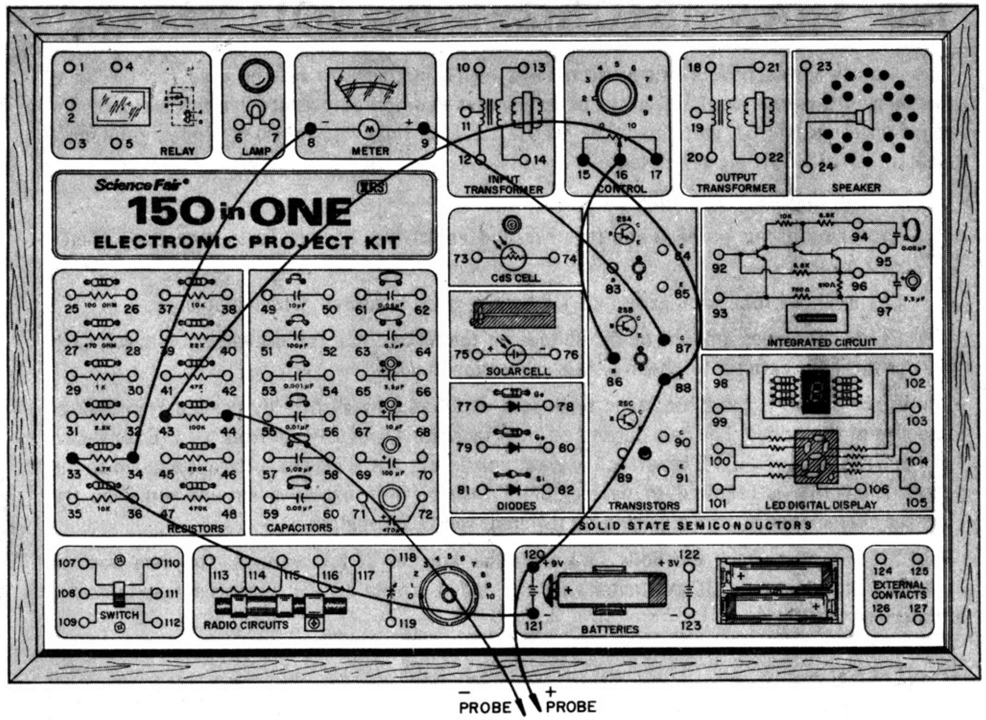
This project is a sensitive DC amplifier-voltmeter combination that allows you to measure both the leakage current of the 2SB and the amount of voltage connected between the probes. This circuit may be called a meter amplifier.

Notice that with the probes not connected to anything the Meter reads around 3 to 5 on the top meter scale when the 50K Control is on maximum, and with the probes shorted together it reads up to 2 or so with the same Control setting. Both readings decrease to less than 1.0 on the Meter when the Control is set on minimum.

The above readings point up the problem with this simple circuit. It is excessively dependent on transistor leakage for any calibrated voltage readings. In fact, if you will warm up the transistor by grasping it with your fingers you will see that it is very dependent on temperature also. We conclude from these findings that a sensitive electronic voltmeter must contain more circuitry than this to be reliable as a measuring instrument that can be calibrated.

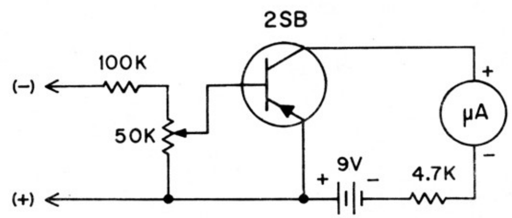
Some of the difficulties of this circuit are dealt with by the bridge circuit of Project 136. In that project the bridge is used to balance out the transistor leakage effects before each reading.

NOTES



WIRING SEQUENCE:

34-8, 9-87, 86-16, 17-43, 44-Probe(–), 15-88-120-Probe(+), 33-121



136. TRANSISTORIZED DC VOLTMETER

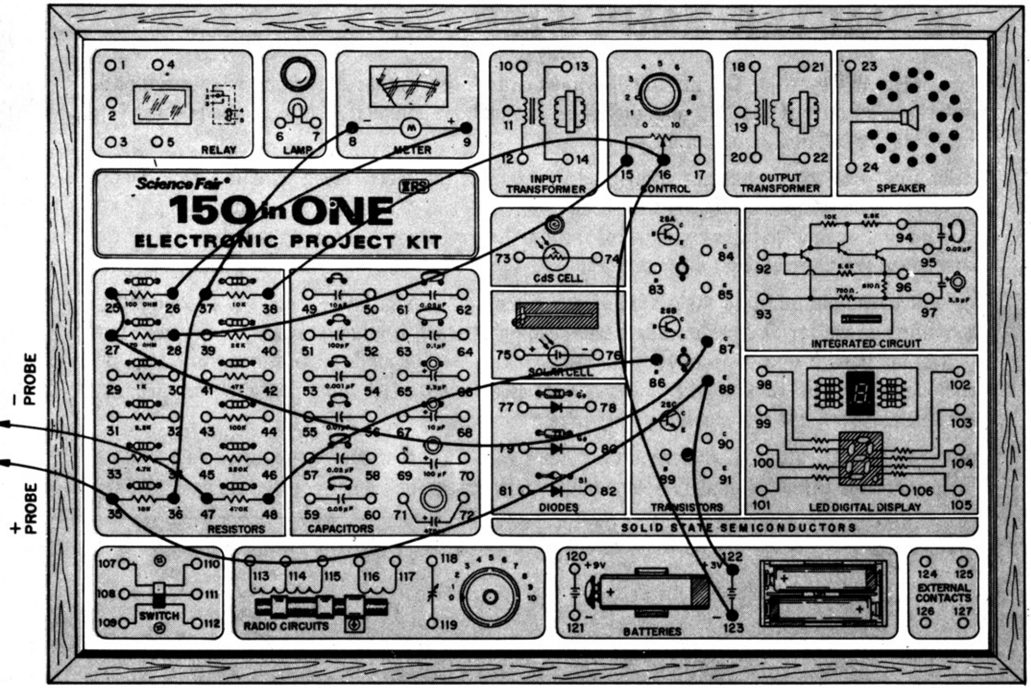
This project shows how a bridge circuit and high-gain transistor can be used together as a low-range DC voltmeter. A DC voltmeter which uses an amplifying device like this is commonly called an electronic DC voltmeter. The VTVM (vacuum tube volt meter) is probably the most well known of electronic voltmeters.

Operation of the circuit is as follows:

1. Short-circuit the probe wires together and adjust the Control for a zero ("0") meter reading.
2. Connect the probe wires across the DC voltage to be measured. Observe polarity.
3. Read the relative amount of DC voltage on the Meter. You can use known voltages, such as the 1.5V battery, to obtain a scale calibration in volts.

The bridge circuit is the Wheatstone type. It is modified only slightly by using a Transistor as one arm of the bridge. The base current on the Transistor effectively controls the C-E resistance of the Transistor. This C-E resistance is what unbalances the bridge as voltage is applied to the base. The 470K is required to protect the Transistor from excessive current and keep the leakage characteristics from changing for different source resistances.

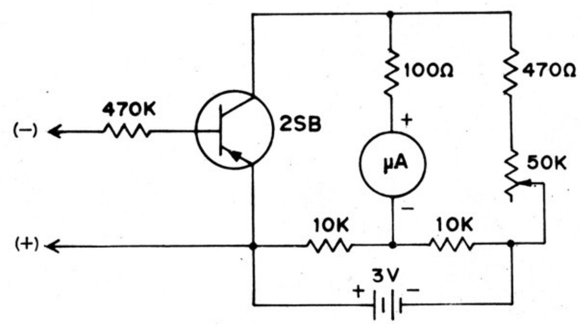
Use this meter to check the Solar Cell and other sources of low voltage. You may want to compare this electronic DC voltmeter with the one of Project 82 which drives a lamp indicator in place of the Meter.



NOTES

WIRING SEQUENCE:

87-27-25, 26-9, 28-15, 8-37-36, 38-16-123, 86-48,
47-Negative Probe, 122-88-35-Postive Probe



137. 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 in on the AC voltage function.

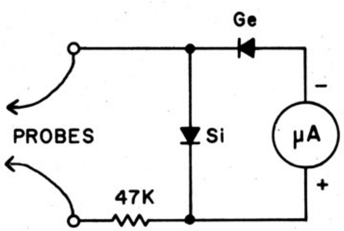
The way this project is originally wired with the 47K multiplier resistor, the full-scale RMS (root-mean-square) AC voltage is about 26 volts. By changing this resistor value it is possible to obtain full-scale AC voltages from about 0.6V to as high as you would ever need (thousands of volts). You can use the graph below to choose this series multiplier resistance for whatever full-scale voltage rating you want.

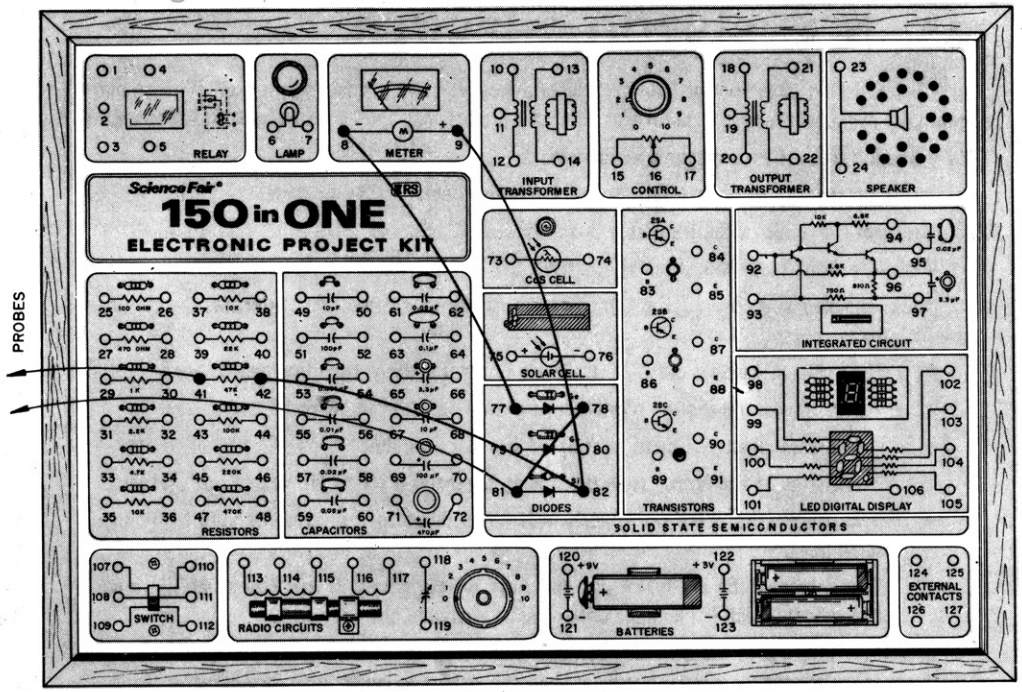
Calibration accuracy of this type meter is generally very good for full-scale voltages of about 10V and higher, but as you will notice on commercial VOM's, separate AC voltage scales are generally used for lower ranges. This problem is due to the fact that the germanium (Ge) Diode resistance changes over the current range of the meter from about 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 better 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, to 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 proper value for the full-scale meter voltage calibration desired. 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 of AC and shunts the current across the Meter and Ge Diode branch. Only the voltage drop of this Diode (about 0.6V or less) then is applied to the series Meter circuit. This voltage reverse-biases the germanium (Ge) Diode so it looks like 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.

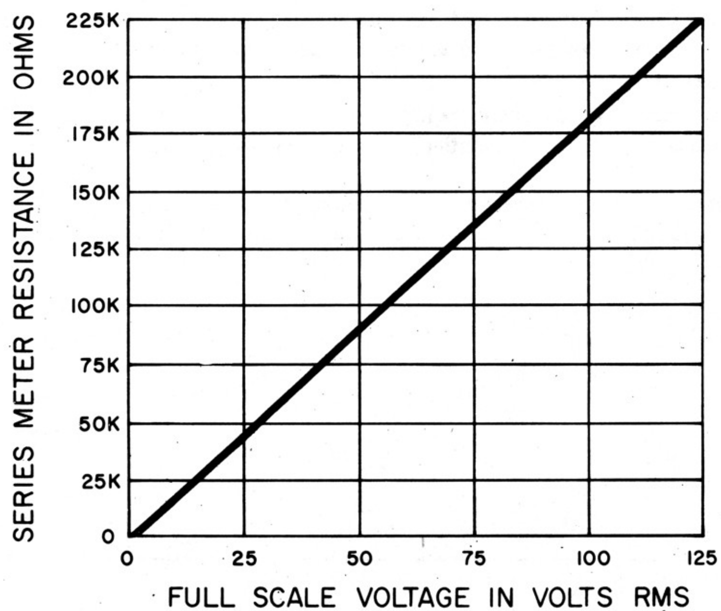




WIRING SEQUENCE:

8-77, 9-82-42, 78-81-Probe, 41-Probe, (Text describes other changes)

AC VOLTMETER RESISTANCE



138. 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.

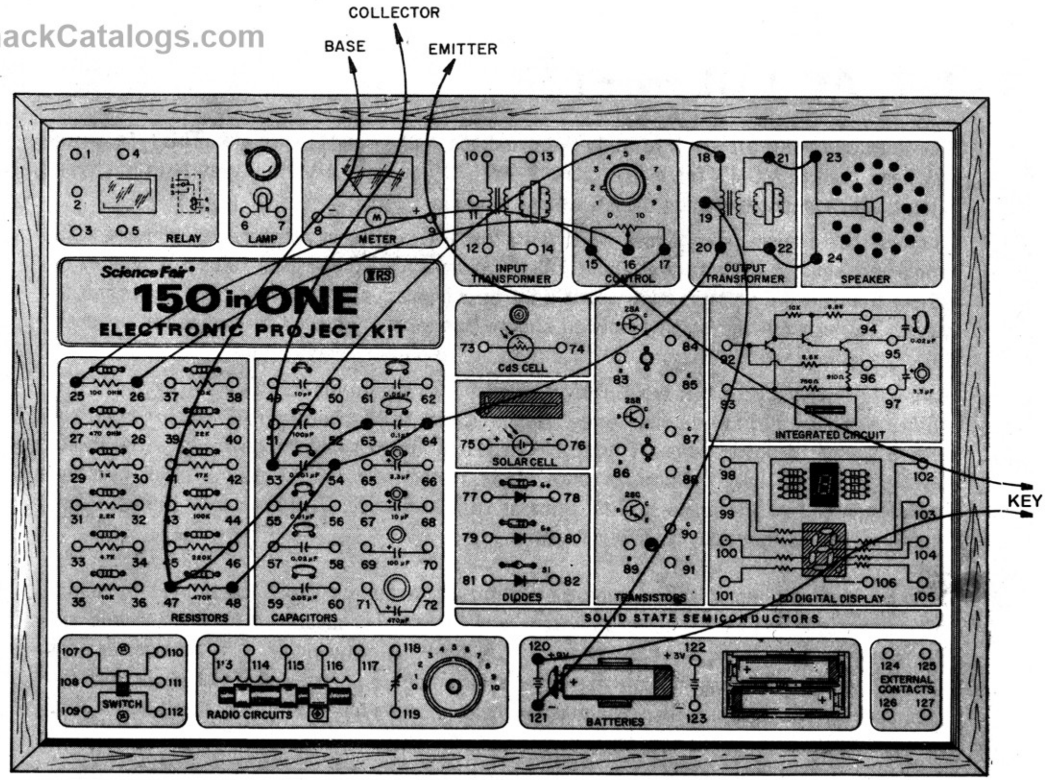
The circuit is a straight-forward audio oscillator but with a feedback control in the emitter lead. The feedback operates by inserting resistance in the circuit to cause both degenerative feedback and decreased transistor electrode voltages.

The only change between PNP and NPN checks is the reversal of the battery. This is required because transistor bias voltage must always cause current flow against 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 dial on ________, 2SB dial on________, 2SC dial on ________.

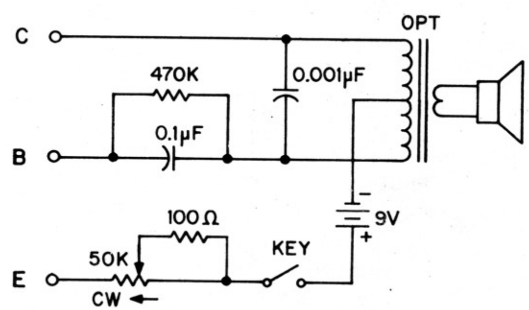
NOTES



WIRING SEQUENCE:

PNP Hookup: 21-23, 22-24, 20-64-54-48, 16-26, 19-121, 120-Key, Key-15-25, 18-53-Collector, 63-47-Base, 17-Emitter

NPN Hookup: (Reverse Battery Lead Connections)



139. SEMICONDUCTOR TESTER

This project is a series-type ohmmeter designed specifically to check diodes and transistor junctions for rectifier action. This is th same type circuit used in many VOM's (volt-ohm-milliamp meters) to measure resistance, but this project includes this particular circuit and test procedure specifically to test rectifying junctions.

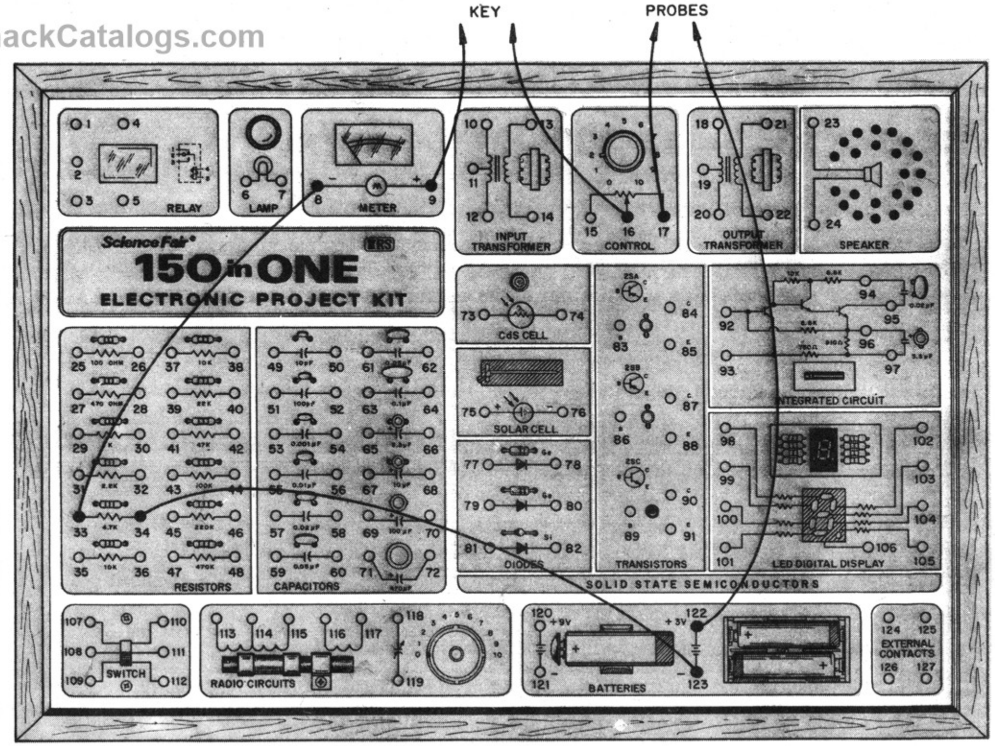
The test procedure is as follows:

1. Connect the test probes to the device (diode or 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 then leave the Control at this 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. Meter readings 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 the diodes and transistor junctions in this kit and record the results below. This way, later on you can check and compare when some one of these devices is suspected of being defective.

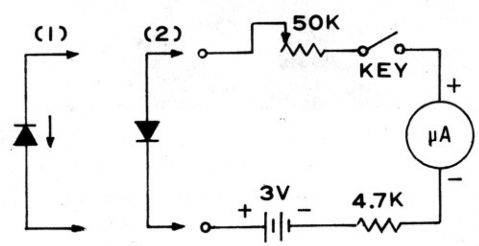
You may want to use your knowledge gained from Project 43 to include a polarity-reversing switch with this circuit. If you can do this you are progressing wonderfully in your training in electronics. Good luck!

NOTES



WIRING SEQUENCE:

123-34, 33-8, 9-Key, Key-16, 17-Probe, 122-Probe



140. SINEWAVE AUDIO OSCILLATOR

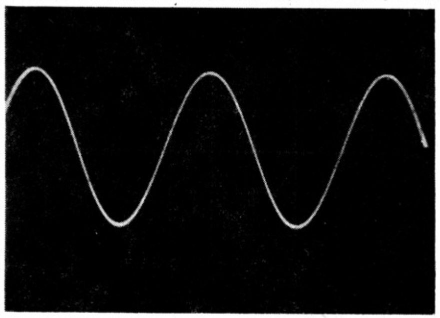
The purpose of this project is to consider sinewaves and a generator capable of producing sinewave output signals. A sinewave signal is used when testing HI FI amplifiers for distortion.

First let's consider what a sine wave 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 voltage which alternates throughout 400 cycles in each second of time and contains no other frequency components. A 400 hertz wave which is not a sine wave 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 then you may be able to test amplifiers and circuits by injecting a sinewave and then 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:

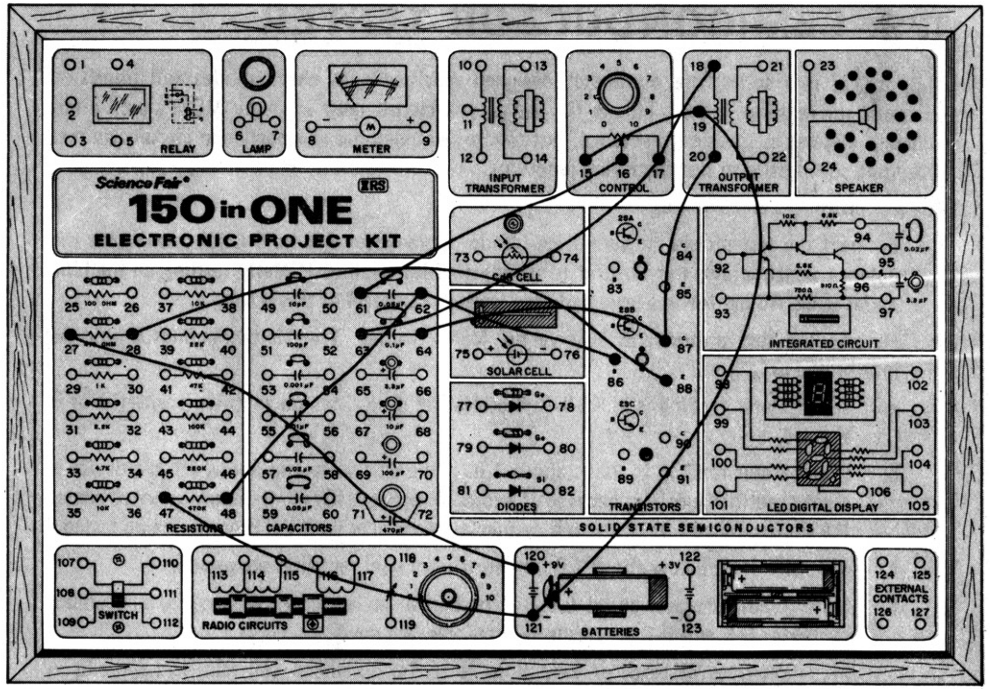
1. A 0.1 μF capacitor across the Transformer to form a tank circuit resonant at about 600 hertz.
2. A 470K base-bias resistor to turn the Transistor ON only a small amount.
3. An adjustable feedback circuit composed of the 50K Control and 0.05 μF capacitor.
4. A 470 ohm emitter-swamping-resistor to help 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 sine wave. Repeat this Control adjustment until you have no trouble distinguishing between a sine wave and a distorted wave.

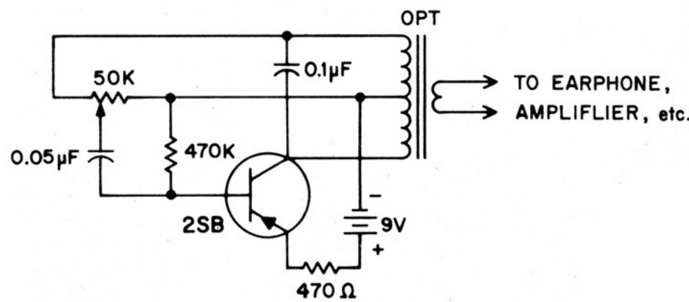
The most stable sine wave oscillator adjustment is to the point where the signal level is as strong as possible before the first trace of distortion can be heard.

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, 16-61, 18-17-63, 20-87-64, 48-62-86, 88-28, 27-120



141. LOW DISTORTION SINEWAVE OSCILLATOR

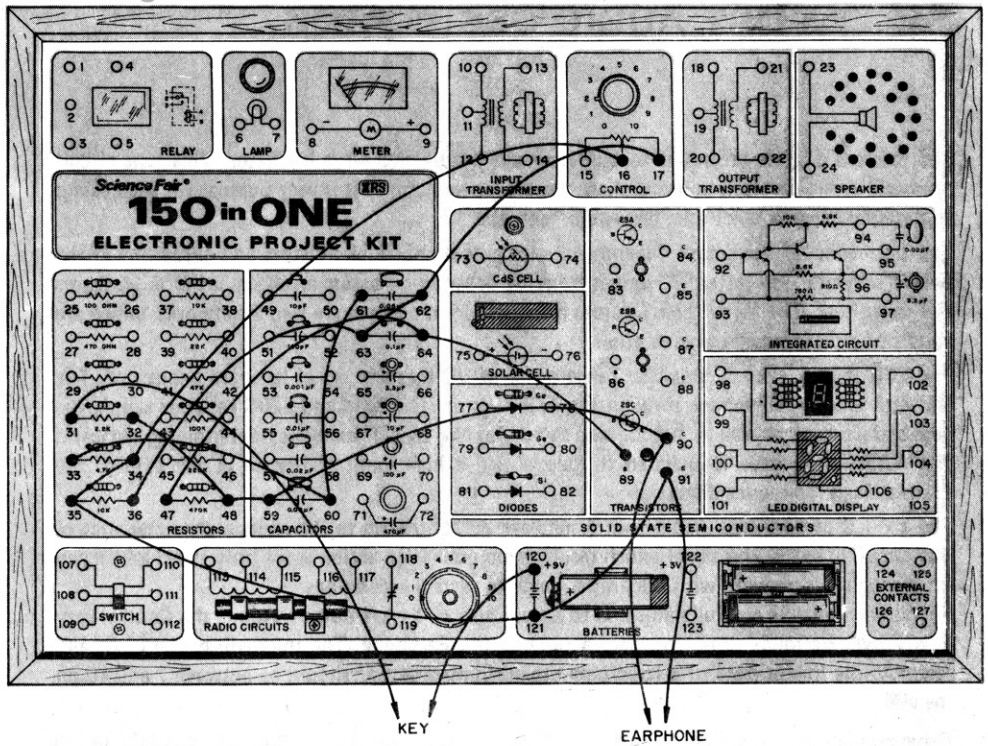
The purpose of this project is to build and study a low-distortion sinewave oscillator. This project should be built and used after you have built and studied Project No. 140. This oscillator is better than No. 140 because there is no Transformer with its inherent nonlinear characteristics to cause distortion.

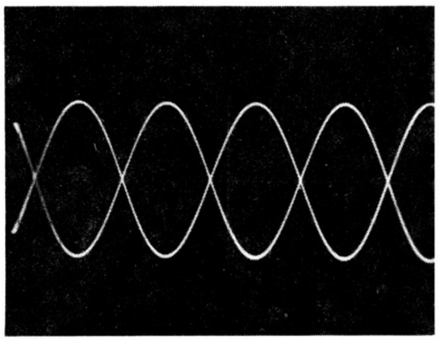
The adjustment for low distortion is similar in that you listen to the tone and adjust the Control for the clearest-sounding single tone. Start with the Control near maximum.

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 may be connected in series to obtain greater required gain so oscillations are sustained.

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° phase shift in voltage.

The 180° 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 input voltage by 180°. 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° is required.





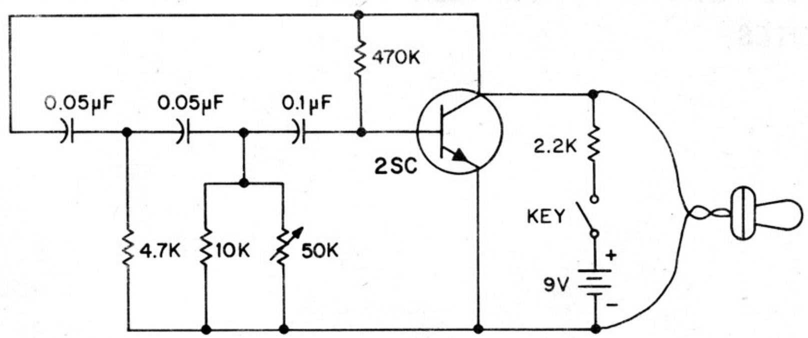
WIRING SEQUENCE:

89-64-47, 32-48-59-90-Earphone, Earphone-91-121-35-34-16, 17-62-63-36, 61-60-33, 31-Key, Key-120

The RC (resistor-capacitor) network composed of the three capacitors, the 4.7K, 10K and 50K resistors, and the B-E input resistance of the transistor cause exactly 180° of phase change at only one frequency. This is the frequency of the sinewave oscillation.

An RC network can shift the phase of a voltage due to the action of the capacitor on the current which flows in the circuit. A capacitor operating alone can cause the current to be 90° leading the voltage. That is, the current maximum (and minimum) occurs 90° ahead of the voltage maximum (and minimum). Any resistance in the circuit causes this phase difference to be less than 90°. With a certain resistance the phase shift can be made to be 60° 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 obtain oscillation.

This circuit is easy on batteries (only 1 mA) 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.



142. TWIN-T AUDIO OSCILLATOR

The purpose of this project is to study a twin-T type sine wave oscillator. This type circuit produces a very stable frequency. And because of its stability it is very popular for such things as electronic organs, electronic test equipment, etc..

The frequency of oscillation 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 in a class A amplifier range as far as DC bias and signal level are concerned. The collector is supplied voltage through the 47K resistor. The 100K and 220K resistors supply the base-bias current as well as functioning as part of the twin-T frequency-determining network. The 470 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 which results from oscillation action is the only signal which can get through this network with the proper phase to sustain oscillations.

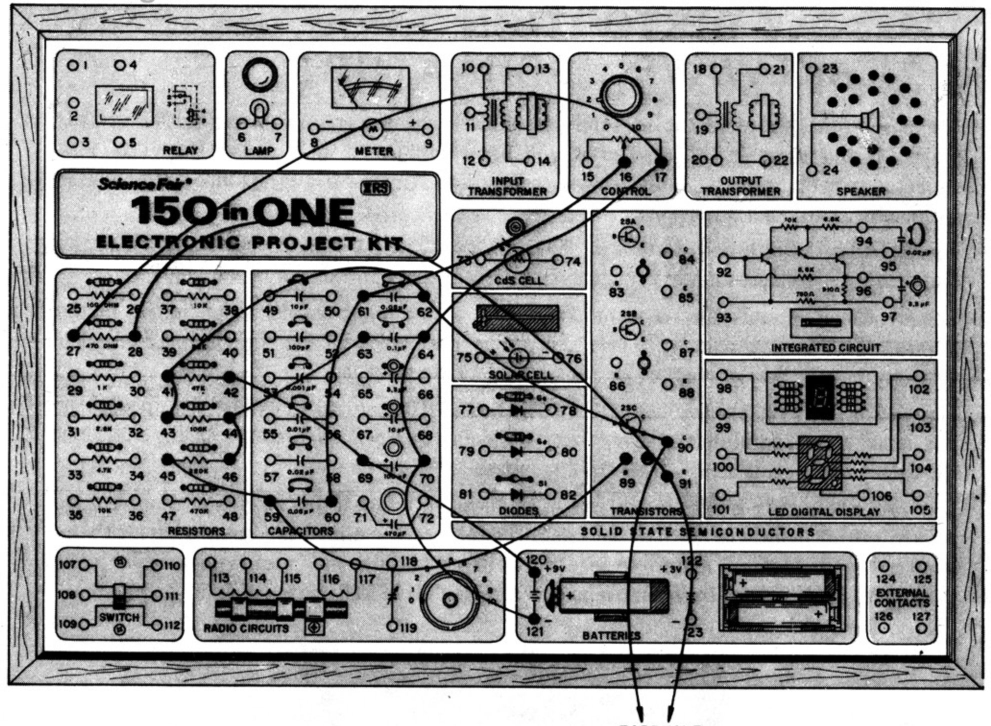
The circuit must be carefully adjusted to obtain pure sine wave output. Adjust the Control very slowly over its range until you hear a tone in the Earphone. The tone will be very low and resemble the lowest note of a large pipe organ. Control setting should be between 7 and 10 on the dial.

Once oscillations are started, adjust the Control carefully for the setting which gives the purest sounding low note near the high end of the dial.

This 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 47K and for the 470 ohm resistors and try using higher and lower battery voltages. Also if you have a VOM try measuring circuit voltages.

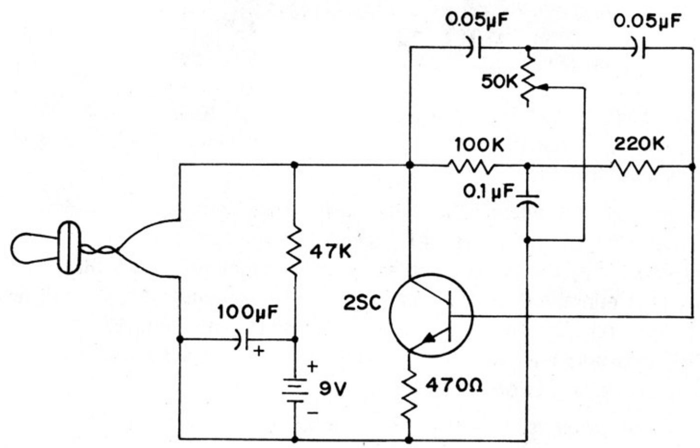
NOTES



EARPHONE

WIRING SEQUENCE:

16-61-60, 27-17-64-70-121, 63-44-46, 45-59-89, 43-41-62-90-Earphone, Earphone-91-28, 42-69-120

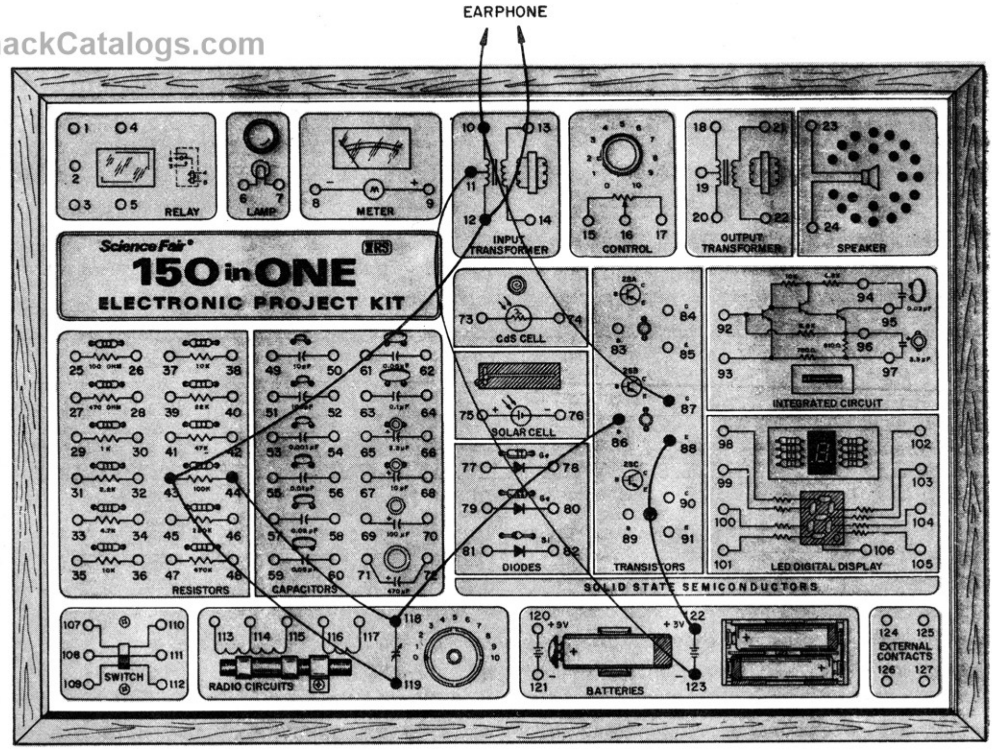


143. VARIABLE AUDIO OSCILLATOR

This project is a pulse-type audio-oscillator which can be changed slightly in frequency as the tuning capacitance is changed. A low tone is produced when the capacitance is at its maximum value, and a high tone is obtained with minimum capacitance.

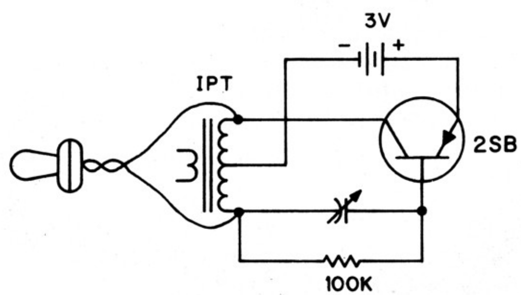
The reason for this change is that the capacitance charges up to a voltage greater than the 3V of the battery due to the induced voltage of the bottom half of the center-tapped transformer winding. This voltage then must be discharged through the 100K resistance to about 3V, before the transistor can 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 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.



WIRING SEQUENCE:

87-10-Earphone Earphone-12-43-119, 11-123, 44-118-86, 88-122



NOTES

144. POWERFUL AUDIO OSCILLATOR

This project is a loud two-transistor audio pulse oscillator. It could be used as an alarm or warning signal in high noise areas, or as a signal source for troubleshooting.

This is a good circuit on which to exercise your "circuit psyching" powers. The method we suggest you use is a good one for most circuits. It involves establishing current paths on the Schematic, and thinking these through till you understand the circuit. Of course you can (and should) verify your thinking by testing the meters, part value changes and an oscilloscope.

Use different colored pens or pencils and draw arrows directly on the Schematic to indicate the following loops of current. The direction of current flow should be indicated with arrow heads along the colored lines. We list the components through which the current flows in the order of start-to-finish as follows: (Number your colors to agree with this listing.)

1. Battery (–), 2SC E to B, 22K, 50K, Key, Battery (+)
2. Battery (–), 2SC E to C, 2SB B to E, Key, Battery (+)
3. Battery (–), Speaker, 2SB C to E, Key, Battery (+)
4. Battery (–), 2SC E to B, 0.1 µF, 100 ohm, 2SB C to E, Key, Battery (+)
5. 0.1 µF left side, 22K, 50K, Key, Battery (+) to (–), Speaker, 100 ohm, 0.1 µF right side

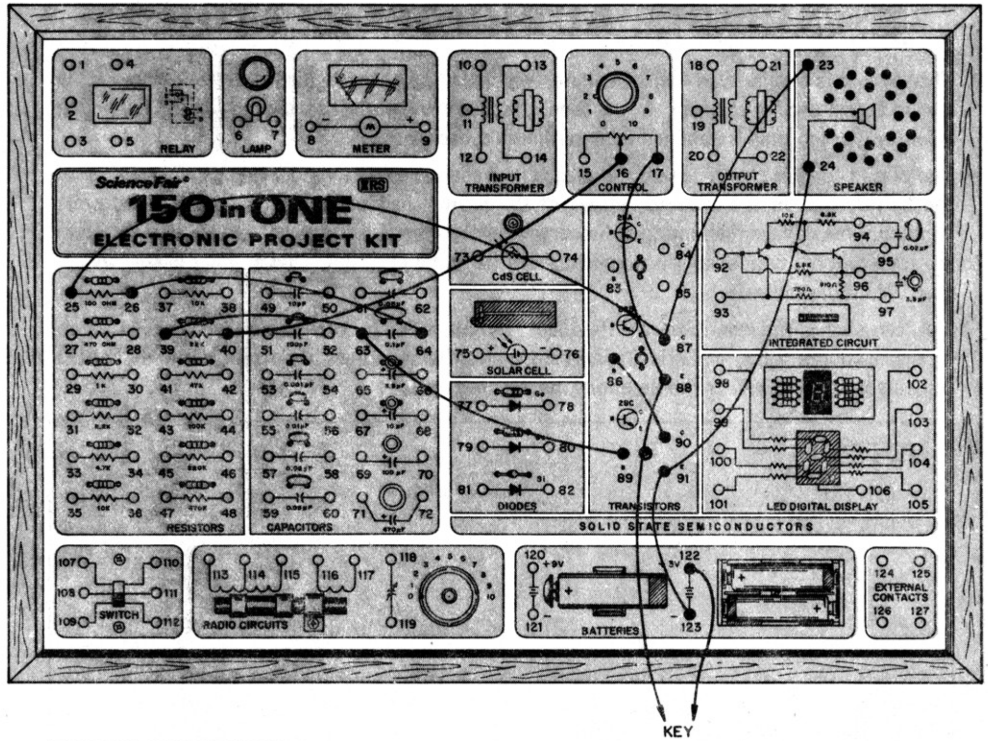
The first four currents flow immediately as you close the Key and are related as follows. Current 1 initially turns on the 2SC which then allows 2 to follow. Current 2 turns on the 2SB which then allows 3 and 4 to flow. Current 3 causes the Speaker coil and cone to move. Current 4 begins to charge up the 0.1 µF capacitor (negative on left) while with this same charging current the 2SC is turned ON harder. All this action occurs in a very short time (microsecond or less).

The above currents all flow for only about 100 microseconds because after this time the 0.1 µF charging current (4) decreases to where it allows the 2SC and therfore the 2SB to come out of saturation a little. When this occurs, the 2SB C-E voltage increases. This voltage increase (negative on C of the 2SB) coupled through the 100 ohm and 0.1 µF quickly reverse-biases the 2SC, turning it OFF. This action takes a very short time (microsecond or less) because as the 2SC is turned OFF it turns the 2SB OFF also, causing the C-E voltage to increase even more until the Speaker voltage is zero, while the 2SB voltage equals the Battery voltage.

As soon as the transistors become OFF, the currents 1, 2, 3 and 4 cease to flow and current 5 begins to flow. This is the discharge current for the 0.1 µF capacitor. Since this current must flow through the high resistances of the 22K and 50K, it takes between about 1.4 and 4.2 milliseconds before this action ends. These long OFF times depend on the 50K Control settings.

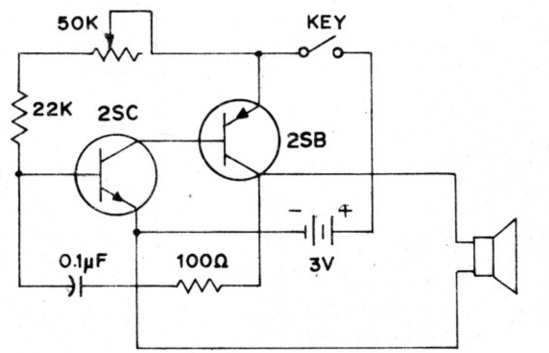
As soon as the 0.1 µF discharges, it can no longer hold the 2SC OFF, and the cycle begins again.

NOTES



WIRING SEQUENCE:

23-87-25, 26-64, 39-63-89, 40-16, 86-90, 17-88-Key, Key-122, 24-91-123



145. 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 momentarily press the Key. After some practice you should be able to play simple tunes. You will also be able to slur some 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 of an oscillator, gain greater than one and regenerative feedback. It is the feedback control circuit we will look at specifically.

First a review of basic transistor characteristics. Any current flowing through the transistor must pass through the emitter against the direction of the arrow head. 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 0.05 μF capacitor is quickly charged up to about 4V, and then 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 colored pencils or pens and 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 3V Battery, 10K, 50K, Transistor B-E, and Key. (Current always flows from negative to positive).

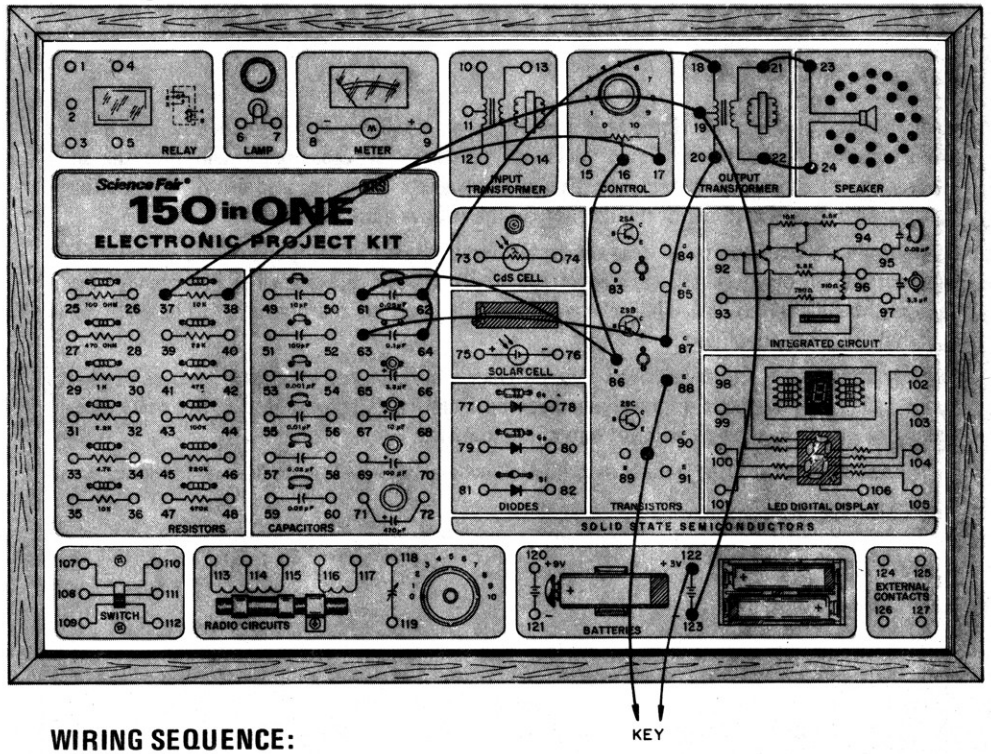
The above base-bias current causes collector current to flow around the loop formed by the 3V Battery, lower half of Transformer winding, Transistor C-E and Key.

The current flowing in the Transformer induces (by transformer action) a current around the loop formed by the top Transformer winding, the 0.05 μF, Transistor B-E, Key, Battery and back to the Transformer center tap. This current quickly (less than 0.0001 second) charges up the 0.05 μF 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 0.05 μF stops because the induced voltage from the top half of the Transformer winding stops, due to transformer core saturation. As soon as this charging current stops, the capacitor begins to discharge. 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 windings, the 10K and the 50K. When less of the 50K Control resistance is in the circuit the discharge is faster, so the process is repeated at a faster rate (higher frequency).

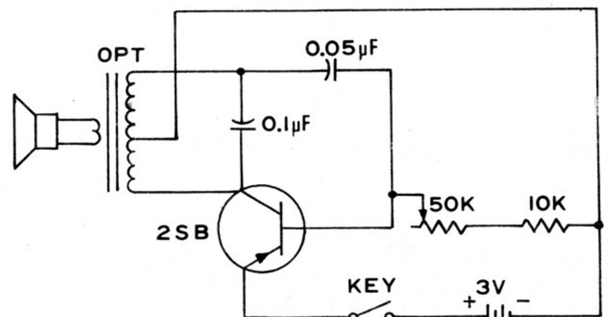
As soon as the 0.05 μF capacitor discharges to slightly below the 3V of the Battery, the above cycle of events is repeated.

The best way of observing the above circuit action is by the use of an oscilloscope. Eventually in your acquiring of test equipment you will want to get an oscilloscope, because no other instrument can show you as much about circuits as the oscilloscope.



WIRING SEQUENCE:

21-23, 22-24, 18-62-64, 61-86-16, 63-87-20, 17-37, 38-19-123, 88-Key, Key-122



146. I.C. OSCILLATOR/COMPONENT TESTER

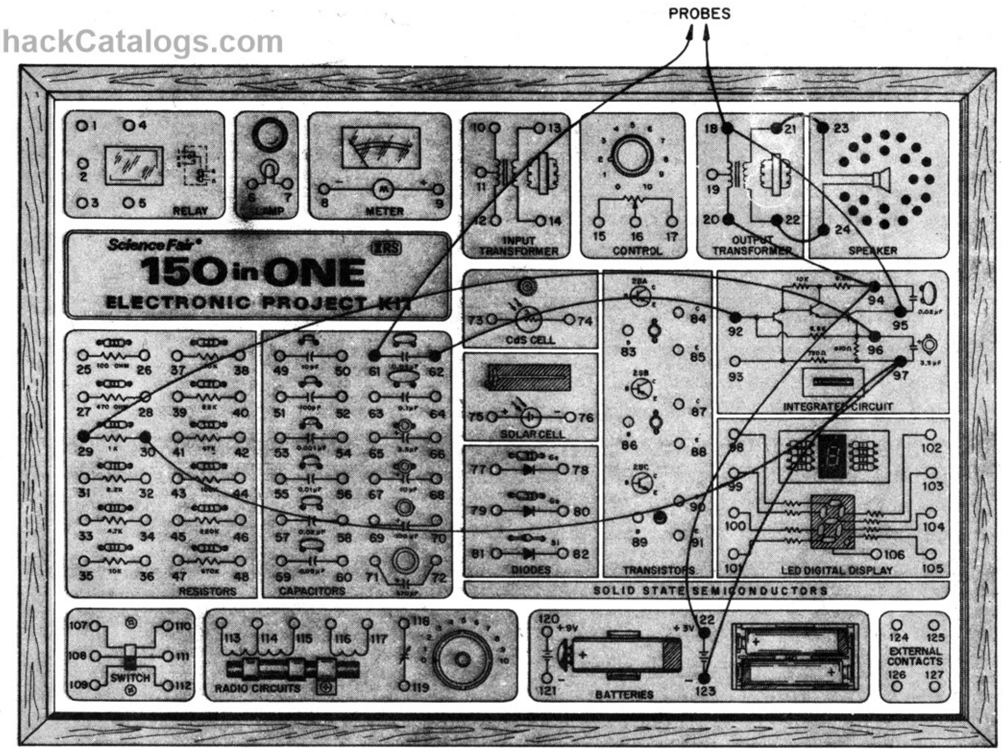
This project uses the IC (integrated circuit) as an oscillator with which you can test for resistance and capacitance. Equal values of resistance or capacitance will give the same frequency of oscillation (pitch) heard from the speaker. You can also use it to measure the resistance between your hands (by listening to the relative pitch of the tone).

Hook up the circuit and try placing the probes across all unused components. Do you recognize any correlation between resistance and frequency? Between capacitance and frequency? Try it across the CdS photo Cell while changing the light level on the photo cell. There are many possibilities with this circuit.

By connecting the probes between a metal chair and table you may play tunes as you wave your hands over the table or move your body back and forth. It becomes a funny party game if someone's chair is wired up without him or her knowing.

The basic IC hookup used here is described elsewhere (such as Project 37 and 95) so we won't repeat it here.

NOTES



WIRING SEQUENCE:

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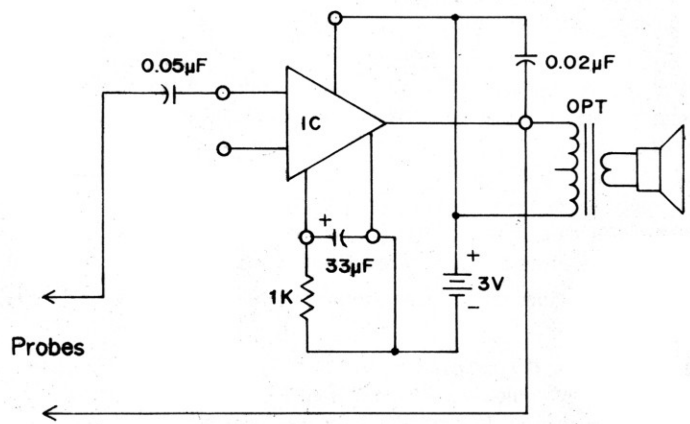


147. LIGHT HUM AND NOISE DETECTOR

Did you realize that the light you may be using is not a constant light. Fluorescent lights actually go ON and OFF 120 times each second. Even the incandescent lights have some change in light level at this same rate. What causes this and why don't we see this with our eyes?

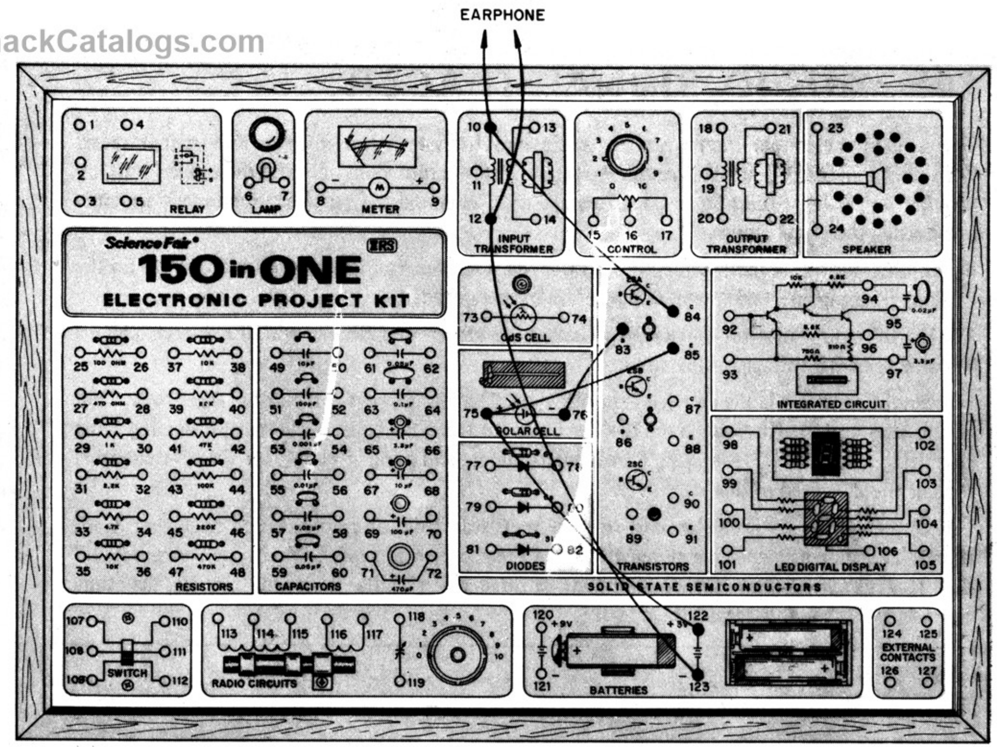
The Creator gifted us with what we call "persistance of vision." That is, what we see tends to stay with us for a fraction of a second. Therefore, if the light is turned completely OFF for a very short length of time, we can't even tell the difference. To us the light would appear dimmer but not to be going on and off.

Persistance of vision then allows us to use alternating current (AC) directly on our fluorescent and incandescent lights without trouble. There are some places where this can not be tolerated. One is for the exciter lamp which illuminates the sound track on a movie projector. This lamp must be driven by either DC or an AC with a frequency above the audio frequency range (ultrasonic). An ultrasonic AC is generally used for powering this lamp.

Hook up the circuit and listen to the lights around the house.

Can you think of a way in which a flash light can be used with a strobe disk to obtain musical tones?

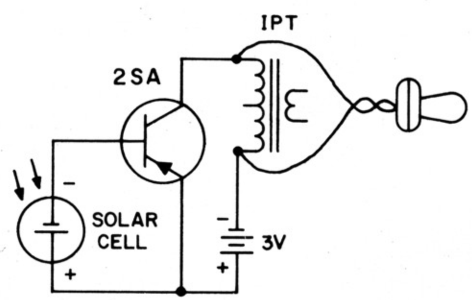
You may want to compare this circuit with Project 2 by replacing the Speaker (used as a microphone) with the Solar Cell. To do this, disconnect at least one Speaker lead, and then connect the Solar Cell to terminals 18 and 20. Can you hear the noise from the sun?



NOTES

WIRING SEQUENCE:

84-10-Earphone, Earphone-12-123, 83-76, 85-75-122



148. AUDIO SIGNAL TRACER

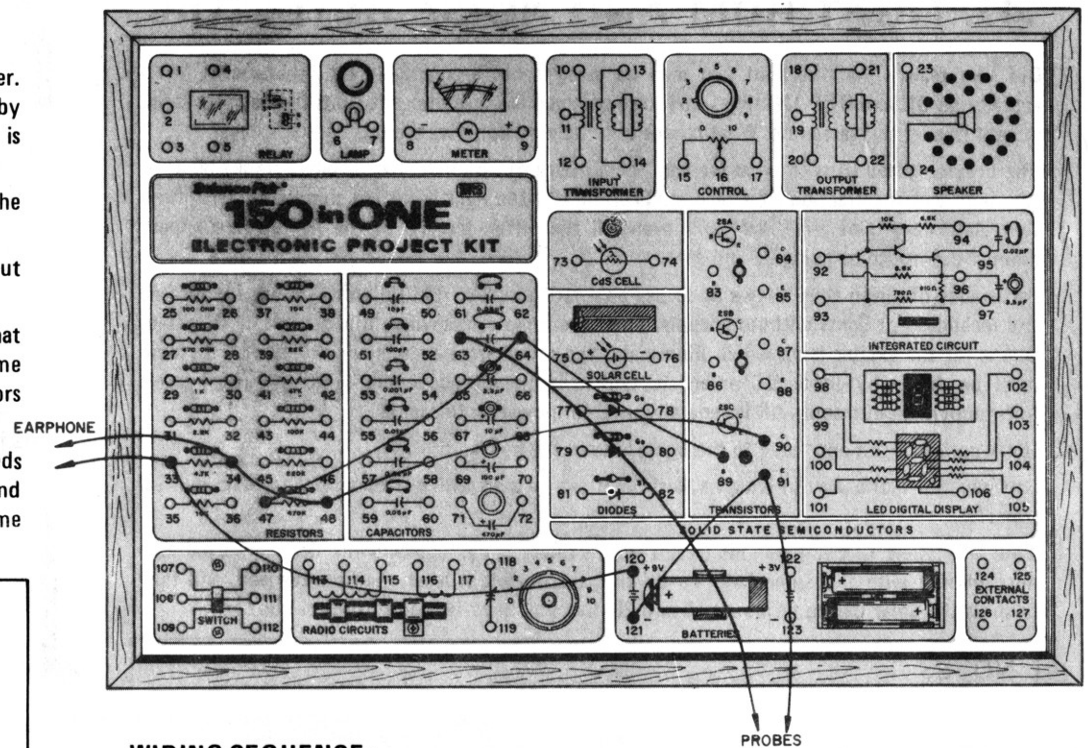
This project is a simple one-transmitter audio-amplifier which is used as an audio-signal tracer. With this amplifier you can troubleshoot transistor audio equipment. You can do this by probing across the circuit from stage to stage until you find the stage or component which is not passing the signal 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 where needed.

The 0.1 μF input capacitor blocks DC so you can probe around circuits without worrying about the effects of DC voltage on the circuit.

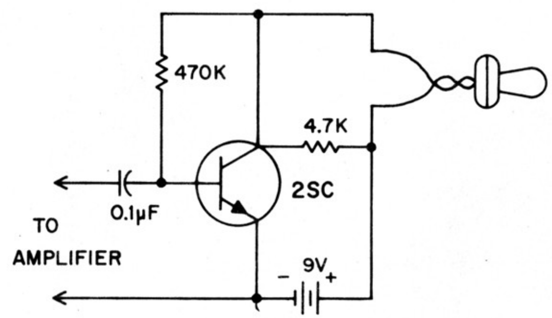
The amplifier circuit is the common-emitter type. The bias current is the self-current type. That is, the base current (through the 470K) is obtained from the collector voltage, providing some stabilizing negative DC feedback. This is a very simple and popular circuit for silicon transistors such as the 2SC used in this kit.

Use this amplifier to probe around on any transistor radio or amplifier you have that needs fixing. You may also try this along with some other projects in this Lab Kit, such as radios and oscillator circuits. The only requirement is that the circuits must not require the same components for **both** circuits. Have fun!



WIRING SEQUENCE:

90-48-34-Earphone, Earphone-33-120, 89-64-47, 121-91-Probe, 63-Probe



NOTES

149. RADIO FREQUENCY SIGNAL GENERATOR

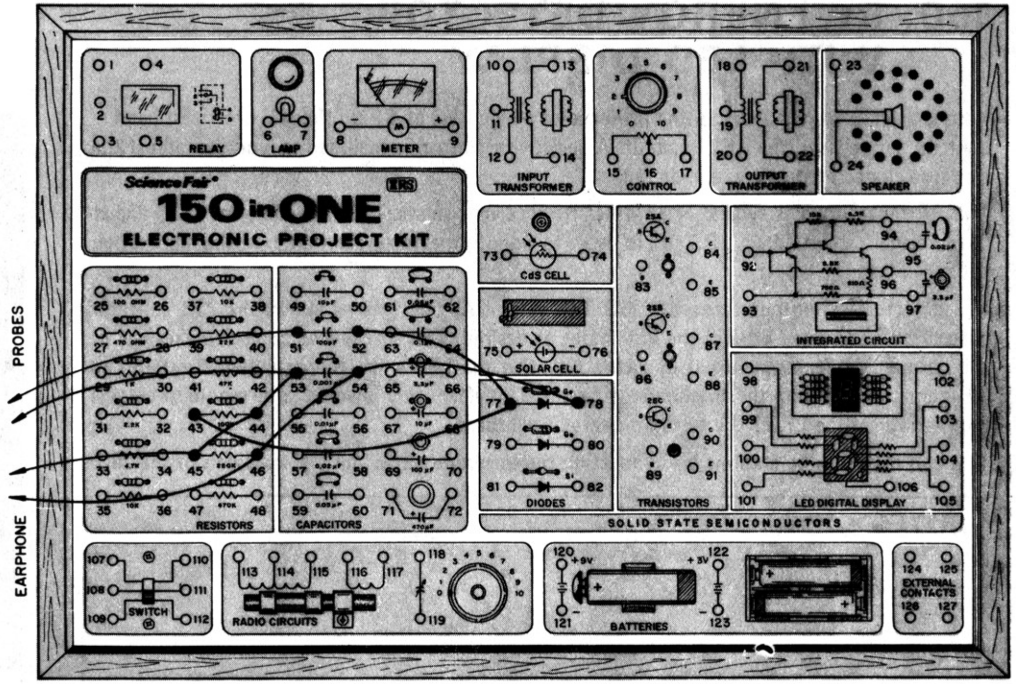
This project is a wide-band, untuned RF signal tracer. You can use it to find sources of RF noise and interference and check for antenna signals. This reminds us of an untuned crystal set.

The 100 pF capacitor is chosen for the input because it blocks DC and the 60 hertz power line frequency so that the probes can be touched on about anything without fear of electrical shock. Of course, you never want to probe around high voltages on purpose or you will be asking for trouble. Never fool with electrical energy. There is a famous saying, "There are old technicians, and there are 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 as long as they are close enough to your RF signal tracer.

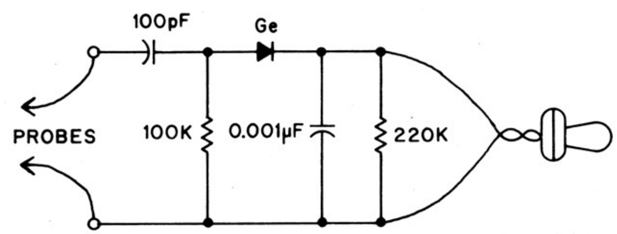
Some of the kinds of noise you may hear and identify originate from auto ignition systems, light dimmers, fluorescent lights, switches opening and closing, etc.

NOTES



WIRING SEQUENCE:

51-Probe, 52-77-43, 78-54-46-Earphone, Earphone-45-44-53-Probe



150. RF ENERGY DETECTOR WITH LED DISPLAY

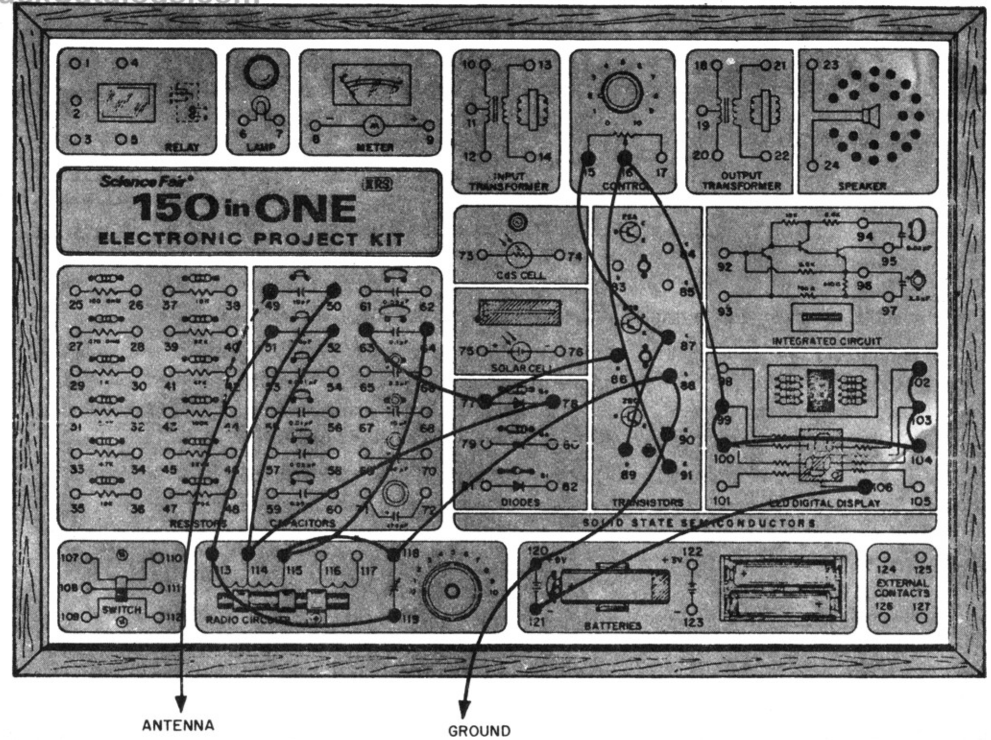
Here is a nifty way to indicate the presence of a high level of RF on the AM broadcast band – light the letter H on the LED readout. A sensitivity control is included so you can adjust the response characteristics over a wide range.

The RF tank circuit is typical of all other RF receiver circuits. The diode detector has a higher than normal output filter, a 0.1 μF, in order to smooth the output so that even the modulation is filtered into the DC.

The detector DC output turns the 2SB Transistor ON. This in turn allows the 2SB collector current to be shunted around the 2SC input as desired. This method of control makes use of the normal 2SB leakage current in such a way that the LED's may be partially ON without an RF signal present from the antenna tank circuit. This effectively lowers the threshold of voltage required to get the LED's ON to some desired brightness.

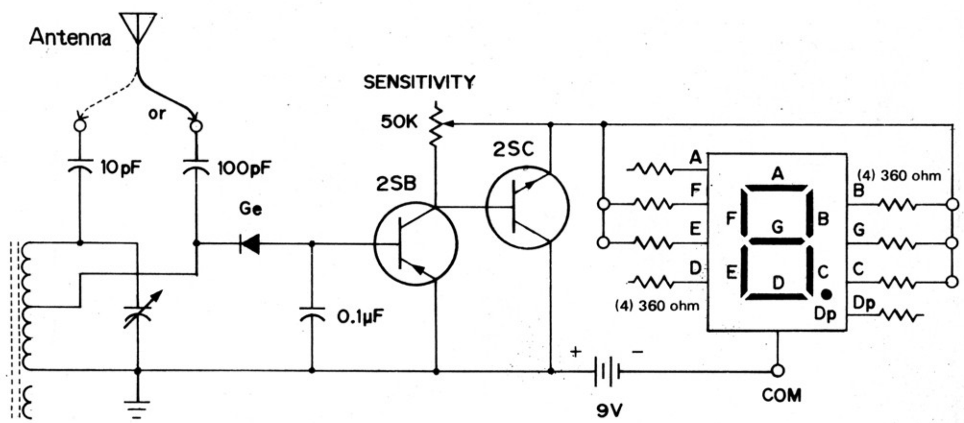
You can monitor the stations by connecting the earphone across the C-E terminals of the 2SC.

NOTES



WIRING SEQUENCE:

102-103-104-100-99-16-91, 15-87-89, 86-77-63, 78-114-52, 50-113-119, 64-115-118-88-90-120, 106-121, Ground-120, Antenna-49 or 51



NOTES, IDEAS AND APPLICATIONS

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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.

NOTES, IDEAS AND APPLICATIONS

PARTS LIST

NOTE: Most of these parts are already mounted on the Platform inside the Box. This Parts List will just 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	Z-2773
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	
10 µF, 10-volt electrolytic type	
33 µF, 10-volt electrolytic type	
100 µF, 16-volt electrolytic type	
470 µF, 16-volt electrolytic type	
Cadmium Sulfide Photo Cell, similar to KC-2S, CdS-1502 or CL-702L type	CS-0027
Diode, germanium, 1S188AM (2)	
Diode, silicon, KB-162C, 300 mA, 350-volt type	
Earphone, high Z crystal type (no DC path)	E-0007
Holder for Antenna	H-1535
Integrated Circuit, BA-302 (Vcc (max) = 15V, Pd(max) = 150 mW, Icc (max) = 2.5 mA)	
Key Lever with Knob	K-1225
Knob for Variable Capacitor (Tuning)	K-0669
Knob for Variable Resistor (Control)	K-2174
Lamp, red, 2.5 volt, 300 mA	L-0541
Light Emitting Diode (Digital Display) (1.6V min. per segment, 25 mA max. DC current per segment, 6V max. reverse voltage)	
Meter, 0-250 µA, 650 ohm movement (Blue scale is proportional to meter current, Black is logging/reference)	M-0294

Description	Part No.
Nut, 3 mm (5)	HD-7003
Printed Circuit Board for LED Display	X-7159
Relay (500 ohm coil, typical pull in @ 8 mA, drop out @ 5 mA)	R-8078
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	
Screw, 3 x 6 mm (8)	HD-2055
Screw, 2.6 x 4 mm (3)	HD-2042
Shield for CdS Cell	CS-0028
Socket for Lamp, with leads	HB-0535
Solar Cell, K-2 DA-40154 type	CS-0016
Speaker, 57 mm	S-4565
Spring Terminal (129)	HB-4804
Switch, DPDT	S-2241
Transformer, Input (yellow)	TD-0097
Transformer, Output (red)	TD-0136
Transistors	
2SA52 PNP germanium, RF converter type	
2SB56 PNP germanium, Audio type	
2SC711 NPN silicon, general purpose amplifier and switching type, similar to 2N3904	
Variable Capacitor (Tuning)	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.(3m).

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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