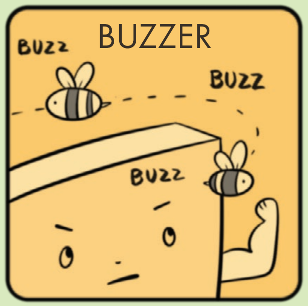
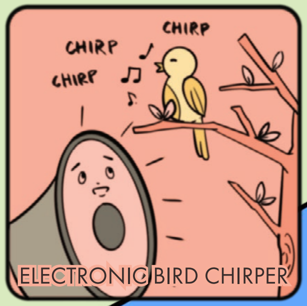
CIRCUIT SCHOLARS

INSTRUCTION BOOK | 31 FUN EXPERIMENTS!





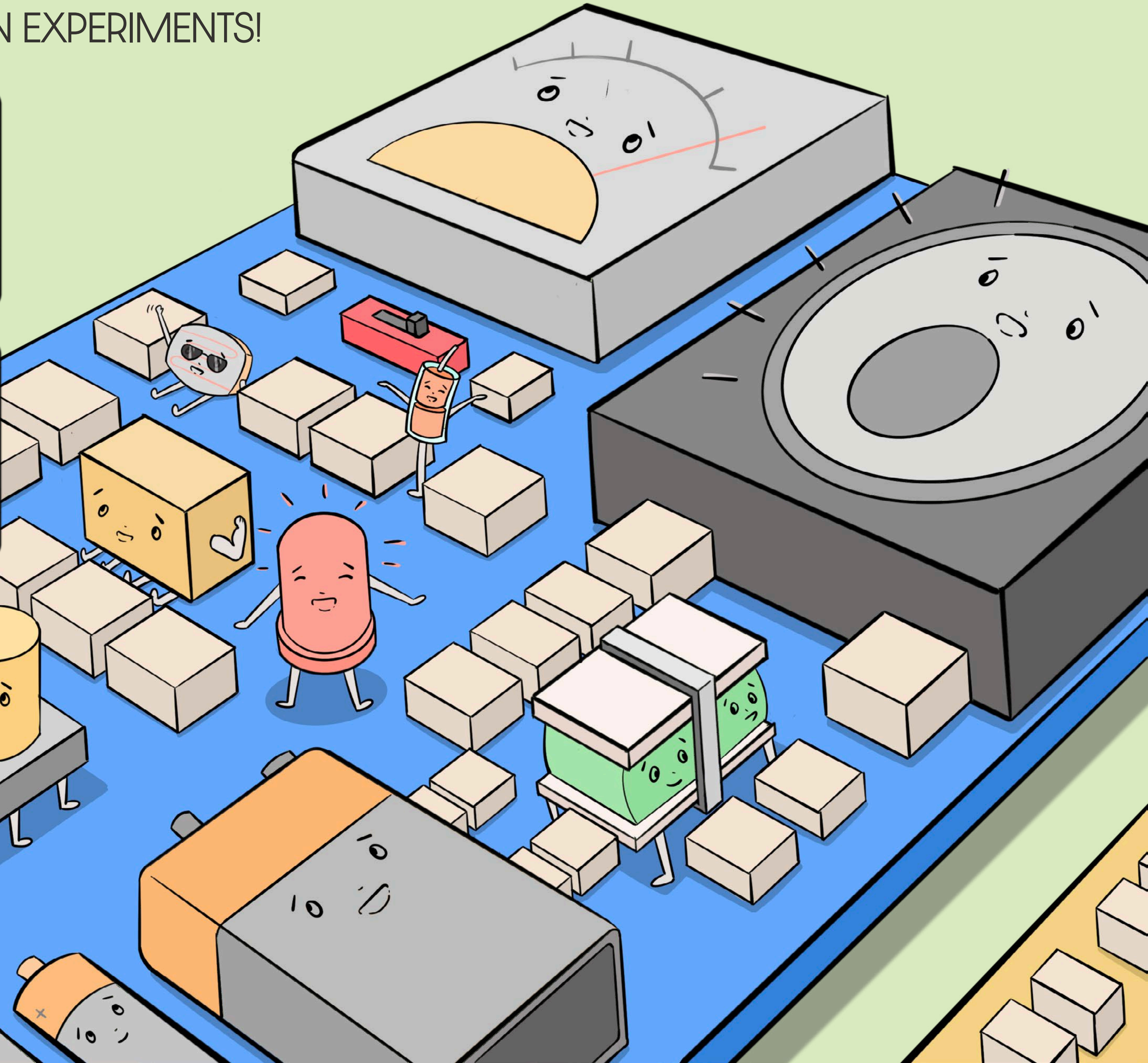


TABLE OF CONTENTS

GLOSSARY

Electron – a tiny particle that carries a negative charge

Circuit – the continuous pathway connecting electronic components. Basic circuits usually contain a power source (such as a battery), and an output, or "load"

Conductor – Usually a wire or circuit board trace that allows current to flow from one point to another in a circuit

Voltage – The Electro-motive force (EMF) that causes electrons to move through a conductor

Current – The "flow rate" of electrons through a conductor

Resistance – The opposition of current flow

Induction – The voltage that is created by a changing magnetic field in a conductor

Power Source – A device that can produce current, usually at a fixed voltage

Load – A device that uses current to produce an output

Series Circuit – A circuit where all components are connected end to end, such that there is only a single pathway for the current to flow.

Parallel Circuit – A circuit where components are connected "across" each other, such that there are multiple paths that the current can flow through

INTRODUCTION:

Welcome to the World of Electronics! You may not be aware of it, but anything that runs on a battery, plugs into the wall, lights up, makes sounds, has a screen, controls a motor, or sends signals is made of electronic components. When these components are connected together (with wires, or on a circuit board) to do something useful, it is called a circuit.

With this kit you will build a number of different circuits. You will learn the basics about each component and understand its purpose. Everything is contained in the box. You don't need to solder or buy anything else to do the projects, and no phone or laptop is required!

But can I do this?? I've never connected any circuits together!! Yes, you can! By following the instructions and simply plugging in the wires carefully, you can put together a number of very interesting and fun projects and experiments.

This project box is designed to be portable – it does not need to be plugged in, and the batteries will last a long time (don't forget to turn off the power when you are done!) This allows you to work on projects virtually anywhere, and the circuits are safe – there's no danger of working with high-voltage.

GOALS:

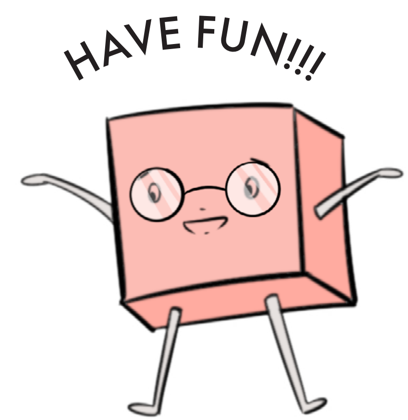
The goals of using this kit are:

- Introduce the concepts of electronics in simple language and diagrams
- Learn to identify components and understand their purpose
- Develop skills like following instructions and troubleshooting
- Learn to "read" basic electronic schematics
- Develop wiring skills
- Think outside the box by modifying the projects
- Learn how components can be connected together to create a practical project
- Have fun!!

CONTENTS:

Each page contains all the information for one project.

- **Introduction** – A short description of the project and how it works
- **Instructions** – The instructions describe all the steps needed to wire and test the circuit
- **Wiring Chart** – this chart shows the pin to pin connections for each wire
- **Illustration** – A fun way to visualize what the components are doing in the circuit
- **Wiring Diagram** – This diagram helps visualize how each of the color coded wires is connected
- **How it Works** – A simple explanation of what the components do in the circuit
- **Schematic** – The schematic is a diagram of the circuit using standard component symbols



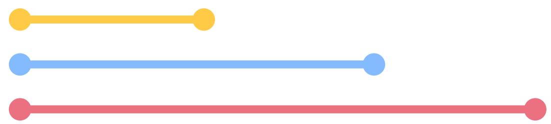
Many people have started on the road to a career path by building circuits just like these... or it may become a very fun hobby for you to pursue. Once you understand the basics you can also start to build your own projects; there are many kits and projects you can find online. As soon as you begin these projects, you will start down the path of becoming a Circuit Scholar!

How To Build The Project:

1. **Power off first!** Turn the Power switch OFF! You never want to wire a "live" circuit!

2. **Wiring the circuit:** Follow the wiring chart step by step and plug in the wire jumpers. There are numbers that show each component "pin." You can also reference the wiring diagram. To plug in the wire, carefully hold the rectangular end and push it down on the pin on the board. There are three colors of wire jumpers and each color is a different length as follows:

   Short: Yellow
   Medium: Blue
   Long: Red

   In the wiring chart, you start with the Yellow wires (short) first, then the Blue (medium) , and finally the Red (long).

3. **Check your work:** When you are finished connecting all the wires carefully look over the wiring and make sure everything looks correct. Are any wires connected to just one pin of a component? Is a wire in the wrong location?

4. **Power it up!** Next, turn on the power switch. Both LEDs should light up! If either LED does not light up, turn off the power switch and check the wiring – you might have a short circuit! Or, you might need to replace the battery (the batteries should last a long time).

5. **Operation:** Next, follow the instructions in the OPERATION section. Sometimes there will be ways to modify the circuit by changing the wiring or components.

6. **Finishing the project:** When you have finished the project, turn off the power and remove the wires one at a time, pulling them straight up from the connector pins.

Helpful Hints:

Do not rush! Take your time and double-check your work as you go! Engineers and Technicians spend time checking their work as they are building and testing, which takes a lot less time than trouble-shooting a circuit that is not wired correctly!

When removing wires, do not just pull a bunch of them out at the same time. This can damage the connectors or break the wires. Instead, carefully remove each one at a time. Pull out one end and then the other. Keeping the wires sorted by colors / sizes will make it easier to build the next project.

What if it doesn't work??

Often it's a very simple problem – a wire in the wrong location, or a missing wire. The temptation is to rip all the wires out and start all over again, but this is not very efficient! First, turn off the power. Then go through the wiring chart or diagram step by step and double check each connection. Having someone else look at your wiring is also a great way to check it!

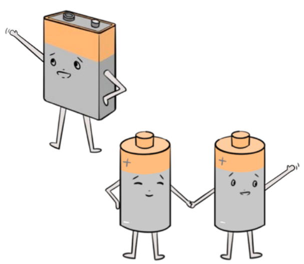
If the wires become very loose on the connector, it may need to be replaced. Your kit has extra lengths of each wire color.

ELECTRONIC CIRCUITS & COMPONENTS

Electronic Circuits:

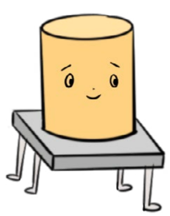
An electronic circuit is either a single component or a series of components that are connected with wires (or other conductive materials) to a power source. Electronic power sources are often batteries or AC wall adapters. For a simple circuit to work there needs to be a continuous path from the positive terminal of the battery, through the circuit, to the negative terminal of the battery.

Common Components:



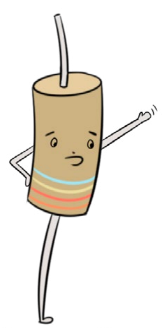
Battery:

A battery is an electro-chemical device that stores energy. In our circuits we use a series combination of two AA batteries (rated at 1.5 Volts each) to create a 3V energy source. We also use a larger 9V battery for circuits that need a higher voltage. Batteries do not last forever, so make sure to turn off the board when it is not being used!



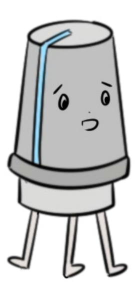
Switch:

A switch is used to disconnect power from a circuit, or re-direct signals in a circuit. In our case we have a power switch to turn the board on and off, and a pushbutton switch to activate some of the circuits.



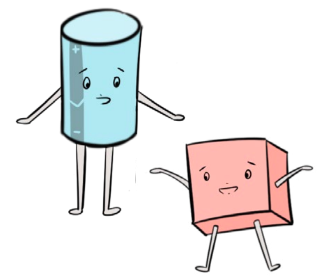
Resistors:

Resistors are used to limit current in electronic circuits. A simple example is limiting the current to an LED or speaker to prevent them from being damaged. Series combinations of resistors are also used to divide voltage between different points in a circuit. This is sometimes used to set a specific voltage or bias an input to a transistor.



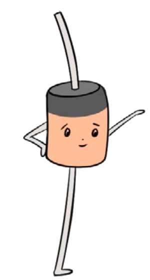
Variable Resistors:

Variable resistors are used to control the voltage or current in a circuit. They convert a rotary motion on the knob into a divided resistance on the output pins. When used to change the size of a signal or voltage by dividing, they are referred to as potentiometers. When controlling the current in a series circuit, they are called rheostats. Both of these names are not as common, but the variable resistors we use in the projects are used to control both voltage and current.



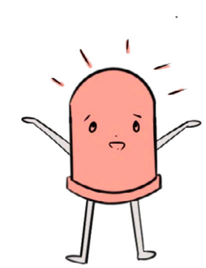
Capacitors:

Capacitors store small amounts of energy like a battery. Depending on their value (which is also related to their size), capacitors can charge and discharge at different rates. This is used to create circuits that can oscillate or create tones. They are also used to filter signals. Very large capacitors can be used to replace batteries – these are often called "Super Capacitors."



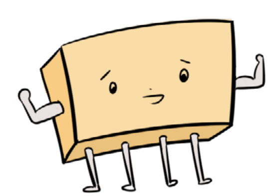
Diode:

A diode acts like a one-way valve, allowing current to flow in one direction but blocking it when the voltage is reversed. They are often used to convert AC signals into DC signals. Diodes have different maximum ratings based on how much voltage or current is applied to them in the circuit.



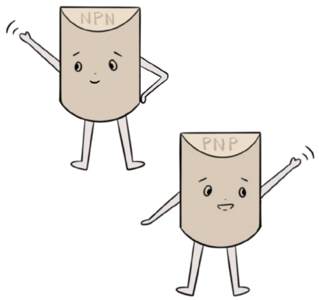
LEDs (Light Emitting Diodes):

LEDs are a special type of diode that produces light when current flows from the Anode (positive lead) to the Cathode (negative lead). LEDs produce many different colors of light and are very efficient as they do not produce as much heat as old lamps used to. However, because LEDs are a type of diode, they need to be connected to a circuit properly to work. Applying too much voltage across an LED in either direction can damage or destroy it!

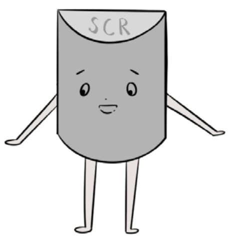


Relay:

A relay is a switch (think of a light switch) that is controlled by an electromagnet (coil). Usually, the coil input current and voltage are small, but the switching output can control higher voltages and currents. Relays are often used in power equipment, for example controlling motors and traffic lights.

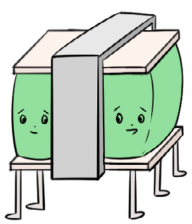


Transistors:
Transistors can be used to switch (turn on or off), or amplify voltages and currents. The base pin on the transistor is often used as the input and uses a very small amount of current to turn the transistor on. When the transistor is turned on, the collector (often used as an output), can control larger voltages and currents. Because transistors are not mechanical (like relays), they can turn on and off at very high speeds, and control very large voltages and currents without wearing out.

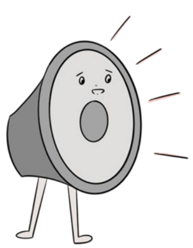


SCR:
An SCR (Silicon Controlled Rectifier) also called a Thyristor is a device often used to control power equipment, such as motors. SCRs are different than transistors in the fact that they can be used to "latch" or stay on after a control signal is removed.

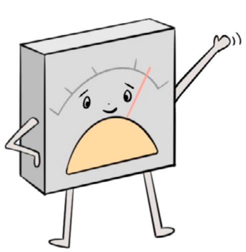
Output devices:



Transformer:
A transformer is used to couple (electrically connect) a small signal to an output device that requires more power. This is done using magnetic induction. In our projects we often use the transformer to connect the transistors to the speaker to produce more volume. Transformers can also be used to allow voltages that change direction over time (called AC or alternating current) to be increased or decreased.



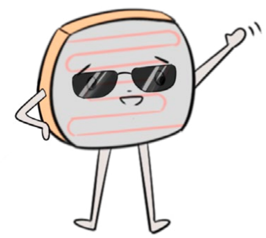
Speaker:
A speaker is a device that converts electronic signals into sound waves by moving a paper cone back and forth with an electromagnet. Depending on the size of the speaker very loud or soft sounds can be created.



Meter:
A meter uses a small magnetic coil to move an indicator back and forth. This allows the user to see varying voltages or currents in a circuit. Today meters are not used as often as digital meters are more common. However, meters are more useful at seeing slow changes of voltage or current in a circuit.

Sensors:

Sensors are used to convert physical changes in the world to electrical signals. Two sensors we use detect heat and light. These are actually specialized types of resistors:



LDR (Light Dependent Resistor):
This device can detect different amounts of light – in this case changing the resistance between the two pins depending on how much light is striking the surface of the part. The resistance ranges from 1,000 Ohms when it is very bright to 100,000 Ohms when it is dark. We can use this sensor to detect when the light in a room is turned on or off (like a night light), or to turn on streetlights at night.

Thermistor:
Thermistors change their resistance value depending on how hot or cool the temperature is. Thermistors are often used for heat controllers or thermostats.

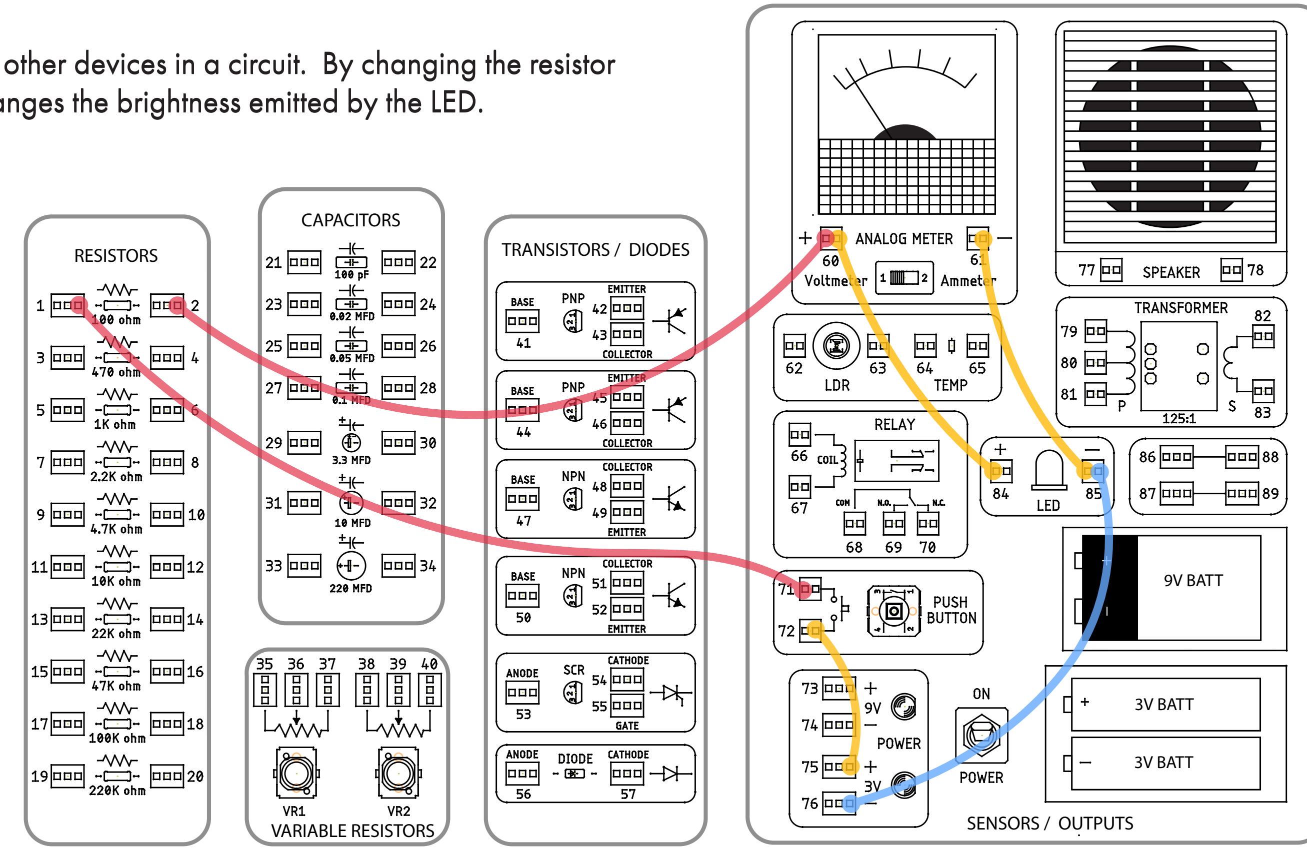
PROJECT #1:
LED BRIGHTNESS CONTROL

This circuit demonstrates how resistors can be used to limit current to other devices in a circuit. By changing the resistor value the amount of current flowing into the LED changes, which changes the brightness emitted by the LED.

INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Slide the Analog Meter switch to the Voltmeter position.
3. [ ] Press the Pushbutton and observe the meter reading and the brightness of the LED.
4. [ ] Next, change the 100 ohm resistor to a 1K resistor. Move the wire connected to pin 1 and plug it into pin 5. Do the same for the wire connected to pin 2 and move it to pin 6.
5. [ ] Press the Pushbutton again and observe the meter reading and brightness of the LED.
6. [ ] Finally, move the two resistor wires to the 4.7K resistor (pin 5 to 9 and 6 to 10).
7. [ ] Press the Pushbutton again and observe the meter and the LED.

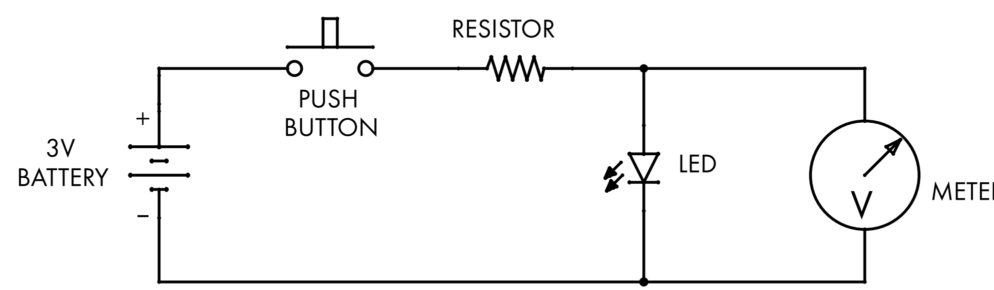
What conclusions can you draw based on the values of the resistor, the meter readings and the brightness of the LED?

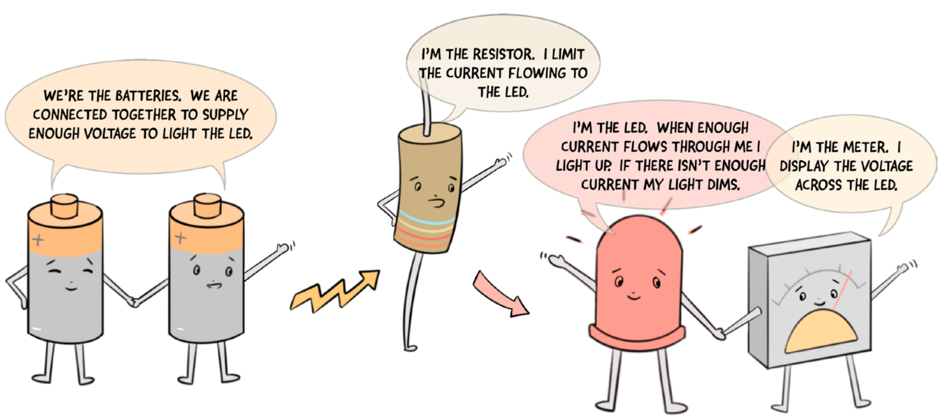


WIRING CHART		
LENGTH	**FROM**	**TO**
Short	60	84
	61	85
	72	75
Med	76	85
Long	1	71
	2	60

HOW IT WORKS

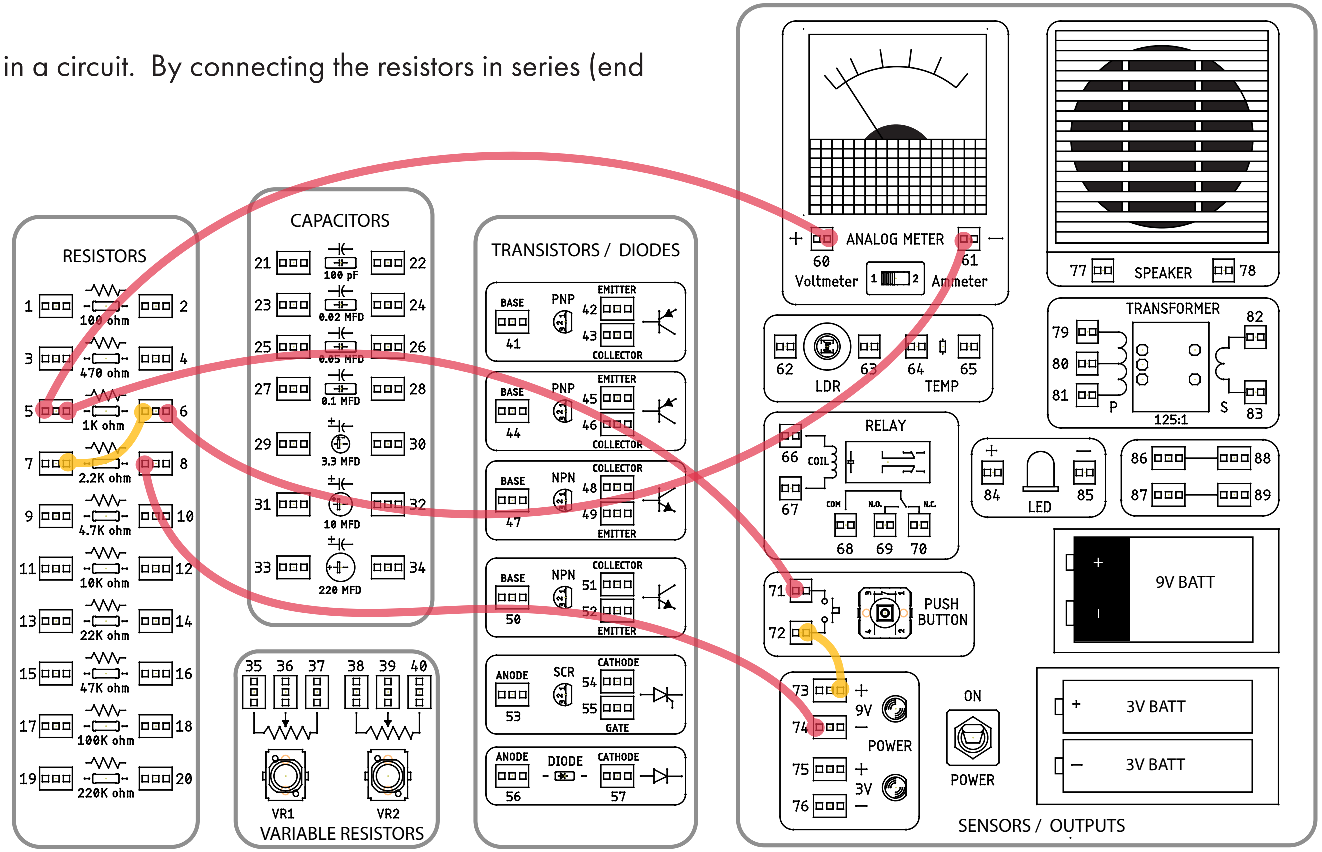
This circuit is called a "series circuit" where all the components are connected from end to end in a loop. The switch is used to turn the circuit on and off by connecting and disconnecting the power. The current flowing in the circuit depends on the value of the resistor. The larger the resistor value the less current, and therefore less light emitted by the LED.





PROJECT #2:
VOLTAGE DIVIDER

This circuit demonstrates how resistors can be used to divide voltage in a circuit. By connecting the resistors in series (end to end) the voltage will "drop" across each resistor.



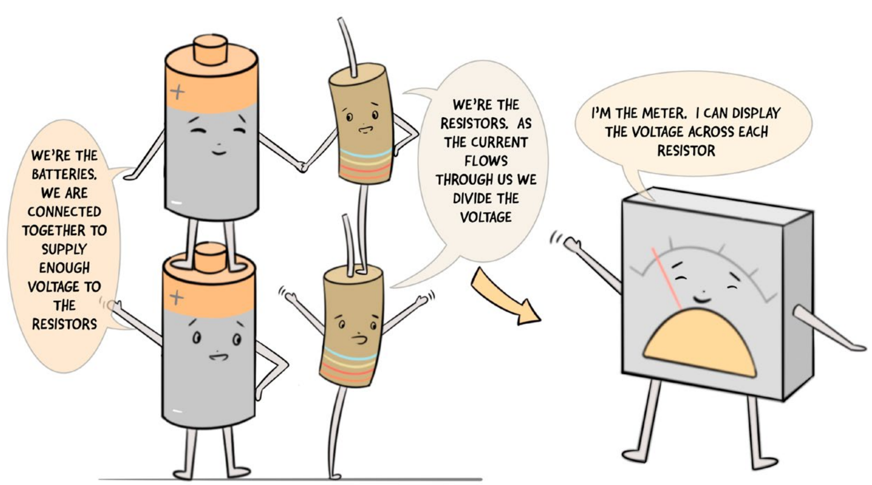
INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Slide the Analog Meter switch to the Voltmeter position. Note: to read the meter, multiply the value shown by 10 (for example, 0.4 = 4 Volts).
3. [ ] Press the Pushbutton and enter the voltage reading across the 1K resistor __________.
4. [ ] Next, switch the meter probes by moving the wires from 60 to 7 and 61 to 8 and press the button to measure the voltage across the 2.2K resistor. Write down this value: ________.

What conclusions can you draw based on the values of the resistor, the meter readings, and the total value of the two voltages?

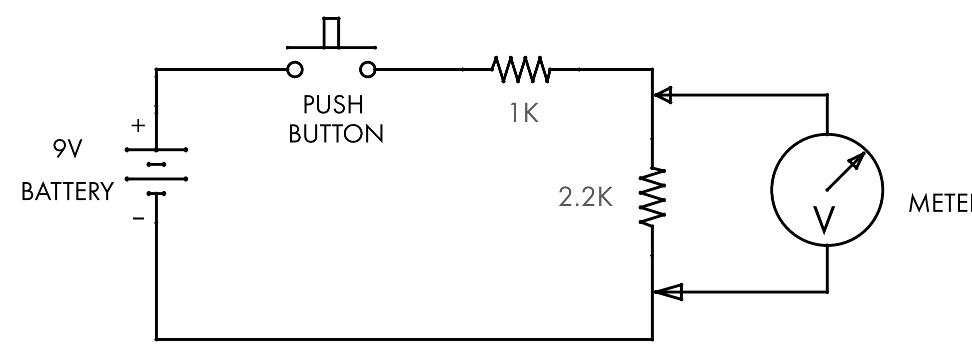
WIRING CHART

LENGTH	FROM	TO
Short	72	73
	6	7
Long	5	71
	8	74
	5	60
	6	61



HOW IT WORKS

This circuit is called a "voltage divider" where the resistors are connected from end to end in a loop. The current that flows through each resistor creates a voltage drop that is proportional to the value of each resistor. Note also that the two voltages add up to the total voltage from the battery. This result demonstrates the conservation of energy in the circuit.

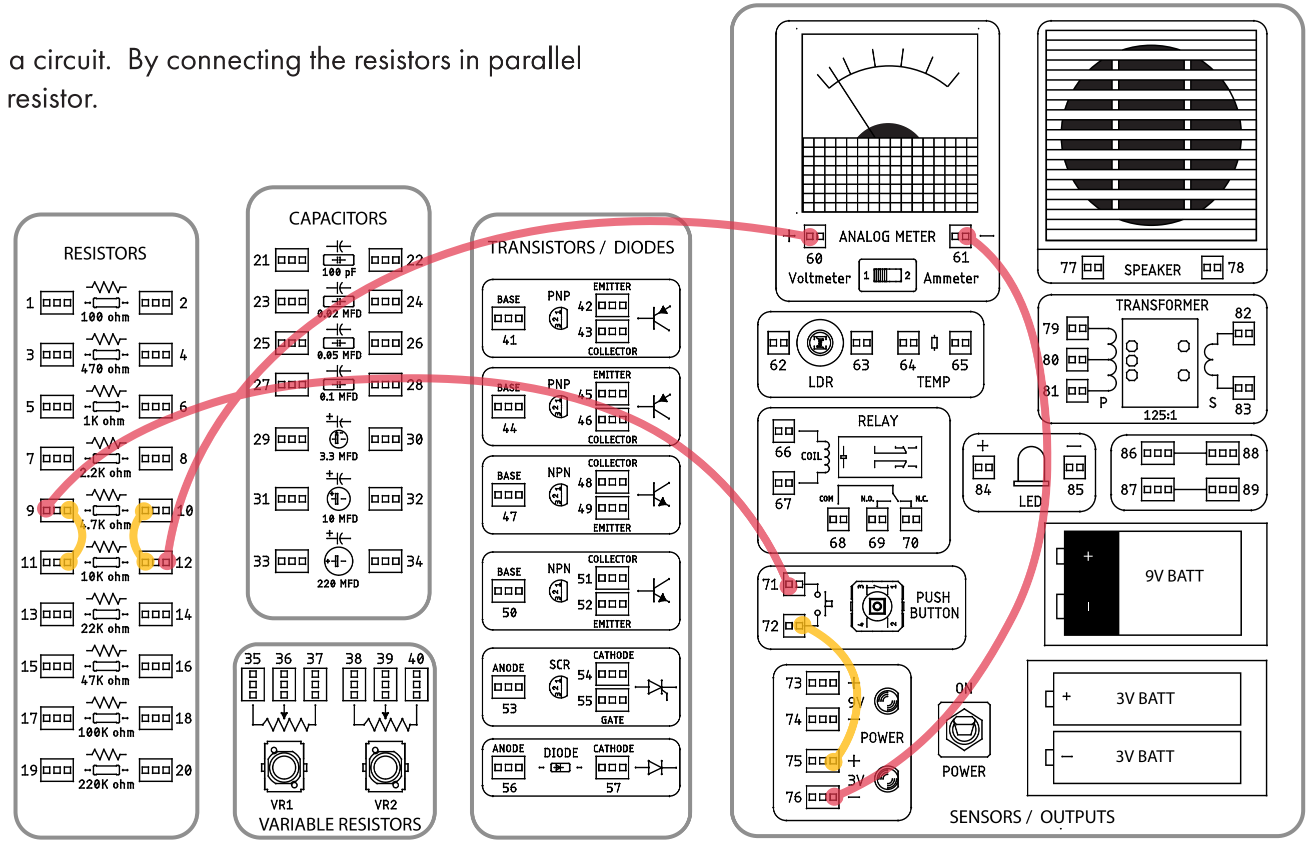


PROJECT #3:
CURRENT DIVIDER

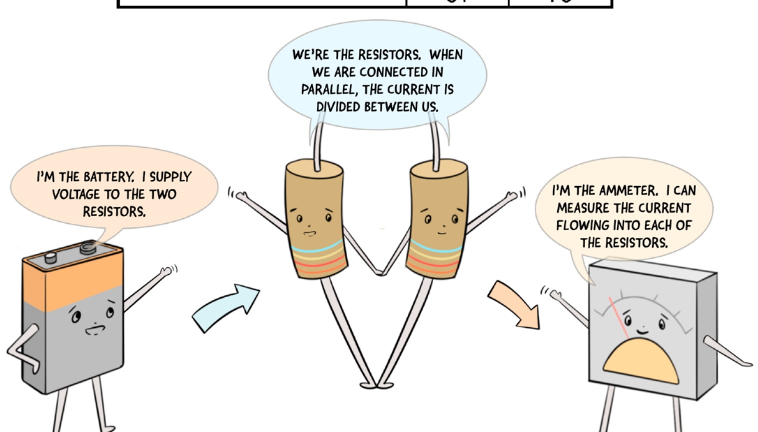
This circuit demonstrates how resistors can be used to divide current in a circuit. By connecting the resistors in parallel (both ends connected together) the current will "divide" through each resistor.

INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Slide the Analog Meter switch to the Ammeter position.
3. [ ] Press the Pushbutton and observe the meter reading. Write it down: __________. This number shows the total current flowing through the resistors.
4. [ ] Next, pull the wire out of pin 11 (leave the other wire connected).
5. [ ] Press the Pushbutton and observe the meter reading: Write it down: __________. This value is the current flowing through the 4.7K resistor.
6. [ ] Re-connect the wire to pin 11.
7. [ ] Next, remove the wire going to pin 10.
8. [ ] Press the Pushbutton and observe the meter reading: Write it down: __________. This value is the current flowing through the 10K resistor.
9. [ ] Press the Pushbutton again and observe the meter and the LED.
10. [ ] Add the values observed in step 5 and 8. How does this compare to the total current?

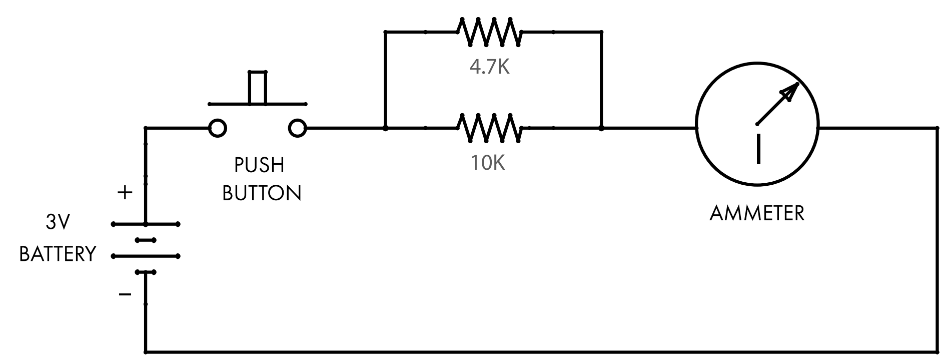


WIRING CHART		
LENGTH	FROM	TO
Short	9	11
	10	12
	72	75
Long	9	71
	12	60
	61	76



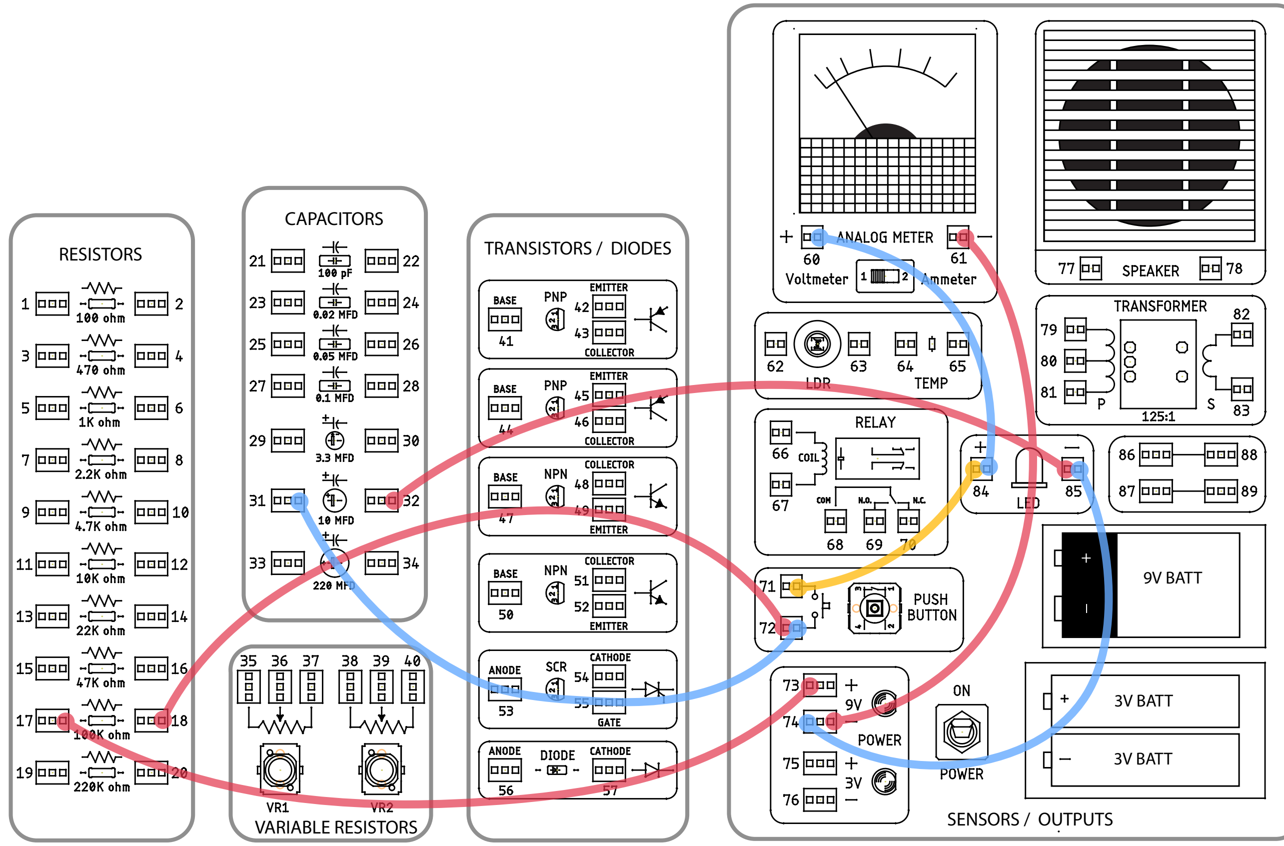
HOW IT WORKS

This circuit is called a "current divider" where the resistors are connected "across" or in parallel with each other. The voltage is the same across each resistor, but the current divides between the two. These two currents add up to the total current when they are both connected.



PROJECT #4:
CAPACITOR EXPERIMENT

In this experiment you will see how a capacitor can store energy.

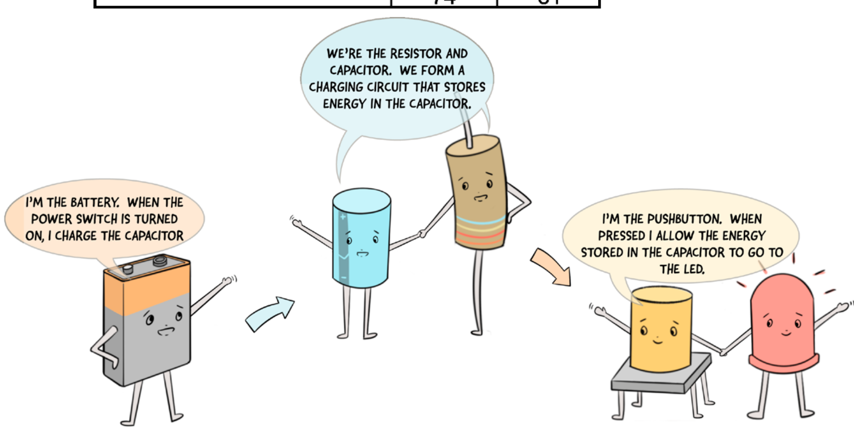


INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Slide the Analog Meter switch to the Voltmeter position. Note: to read the meter, multiply the value shown by 10 (for example, 0.4 = 4 Volts).
3. [ ] Turn on the Power switch and leave it on for at least one second.
4. [ ] Turn **off** the Power switch. This disconnects the battery from the circuit.
5. [ ] Press the Pushbutton and observe the meter reading and LED. Because we are using a small capacitor it will discharge very quickly, so you might need to do steps 3-5 again.
6. [ ] Next, move wires 31 to 33 and 32 to 34. This changes the capacitor to a larger value.
7. [ ] Repeat steps 3-5 EXCEPT turn on the power switch for at least 5 seconds before turning on again.

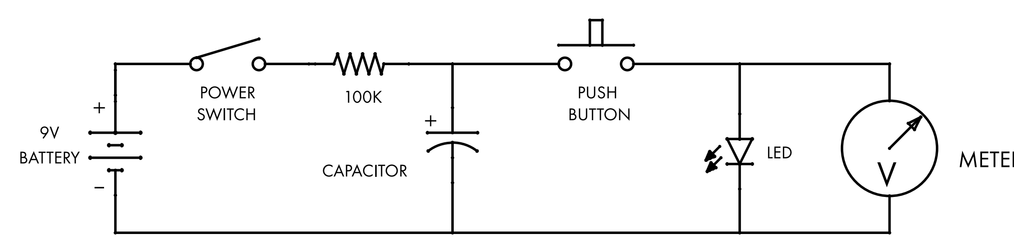
What differences do you notice between the two different capacitors?

WIRING CHART		
LENGTH	FROM	TO
Short	71	84
Med	31	72
	60	84
	74	85
Long	17	73
	18	72
	32	85
	74	61



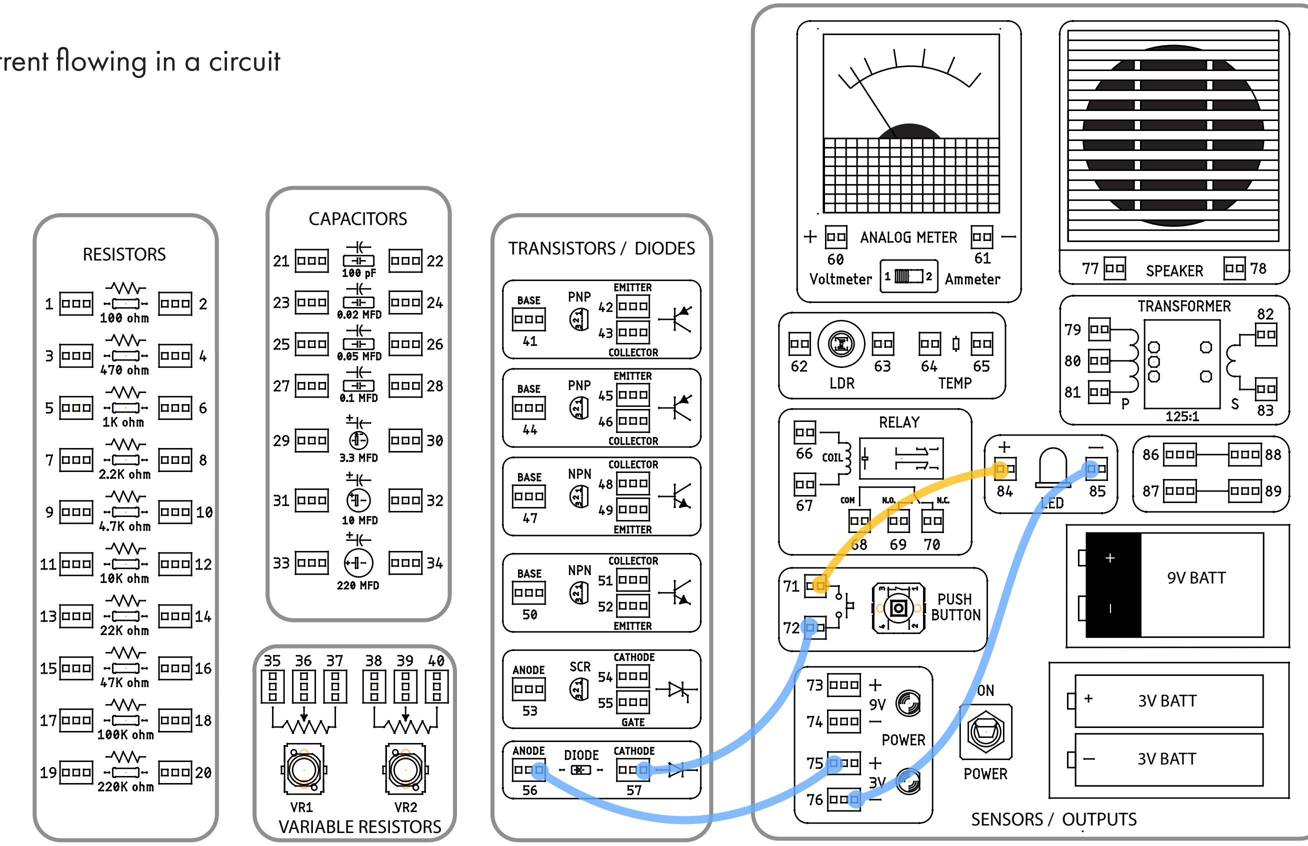
HOW IT WORKS

This circuit uses an RC (Resistor - Capacitor) network that charges a capacitor. The size of the capacitor determines how much charge can be stored. The pushbutton switch allows the stored charge to light the LED. Some large capacitors, called "Super Capacitors" can even replace batteries!



PROJECT #5:
DIODE CIRCUIT

This circuit demonstrates how a diode can be used to control the current flowing in a circuit



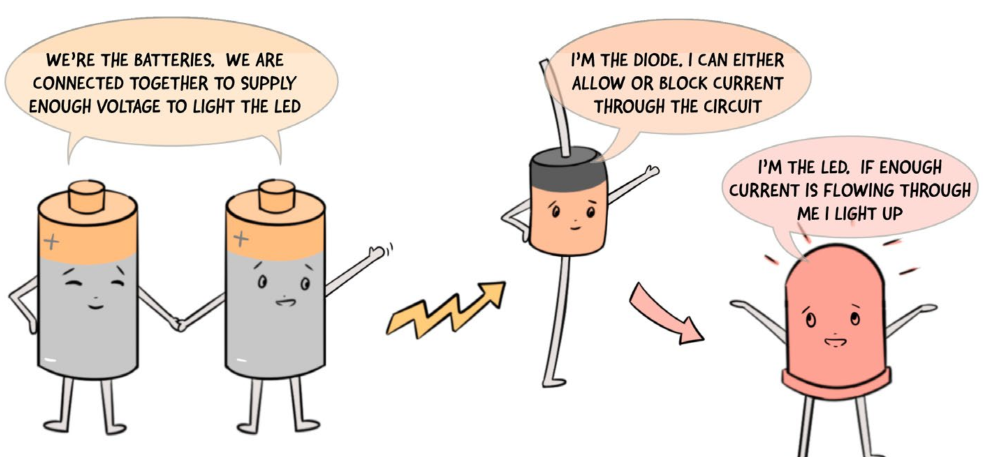
INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the Pushbutton and observe the LED.
3. [ ] Next, swap wires 56 and 57.
4. [ ] Press the Pushbutton and observe the LED.

When you switched the wires can you describe how the circuit was changed? What would the schematic look like at this point?

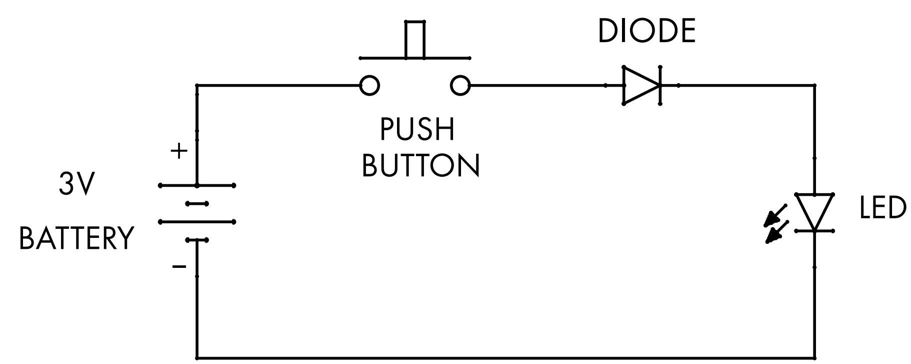
WIRING CHART

LENGTH	FROM	TO
Short	71	84
Medium	56	75
	57	72
	76	85



HOW IT WORKS

This circuit uses a diode to demonstrate how current can be controlled like a switch. When a larger voltage is present on the Anode compared to the Cathode, current flows through the diode to the rest of the circuit. This is called "Forward Biasing." When the diode is reversed in the circuit, the diode is "Reverse Biased" and no current flows to the LED.



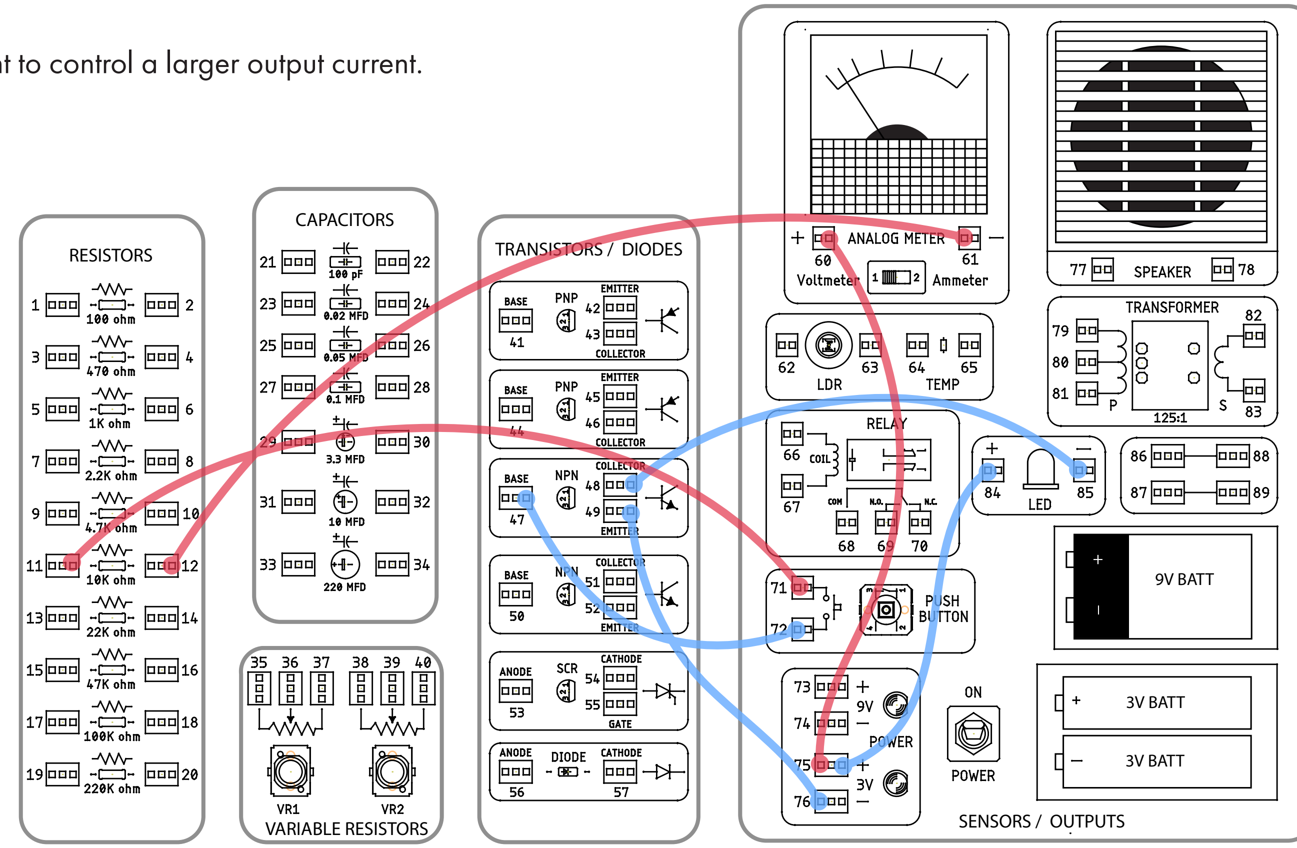
PROJECT #6:
TRANSISTOR EXPERIMENT

This circuit demonstrates how a transistor can use a small input current to control a larger output current.

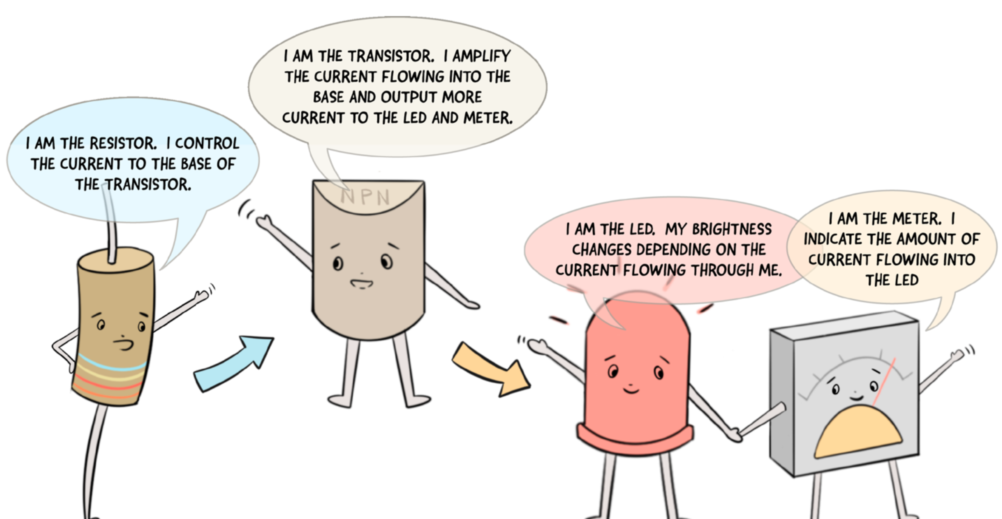
INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Move the Meter Switch to the Ammeter position (right)
3. [ ] Press the Pushbutton and observe the Meter reading and the LED. Note, the meter reading is displaying milli-Amps, or thousandths of an Amp of current.
4. [ ] Next, change the resistor from the 10K to the 100K resistor by moving wires 11 and 12 to17 and 18.
5. [ ] Press the Pushbutton and observe the meter and the LED.

When you changed the wires can you describe how the circuit was changed? What was the difference in the LED? What was the difference in the meter reading?

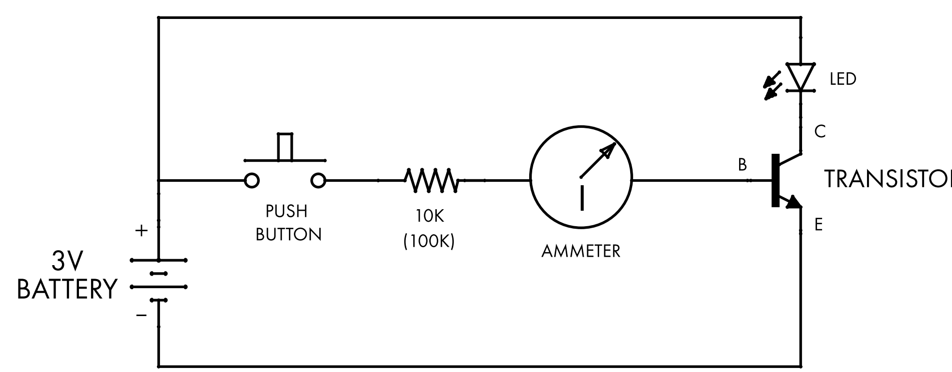


WIRING CHART		
LENGTH	FROM	TO
Medium	47	72
	48	85
	49	76
	75	84
Long	11	71
	12	61
	60	75



HOW IT WORKS

This circuit uses a transistor to increase the small current going into the Base (B on the schematic) to allow a larger current to flow into the Collector (C), which lights the LED. LEDs usually use about 10-20 milliAmps to light, and the current flowing into the Base is less than 0.1 milliAmps!



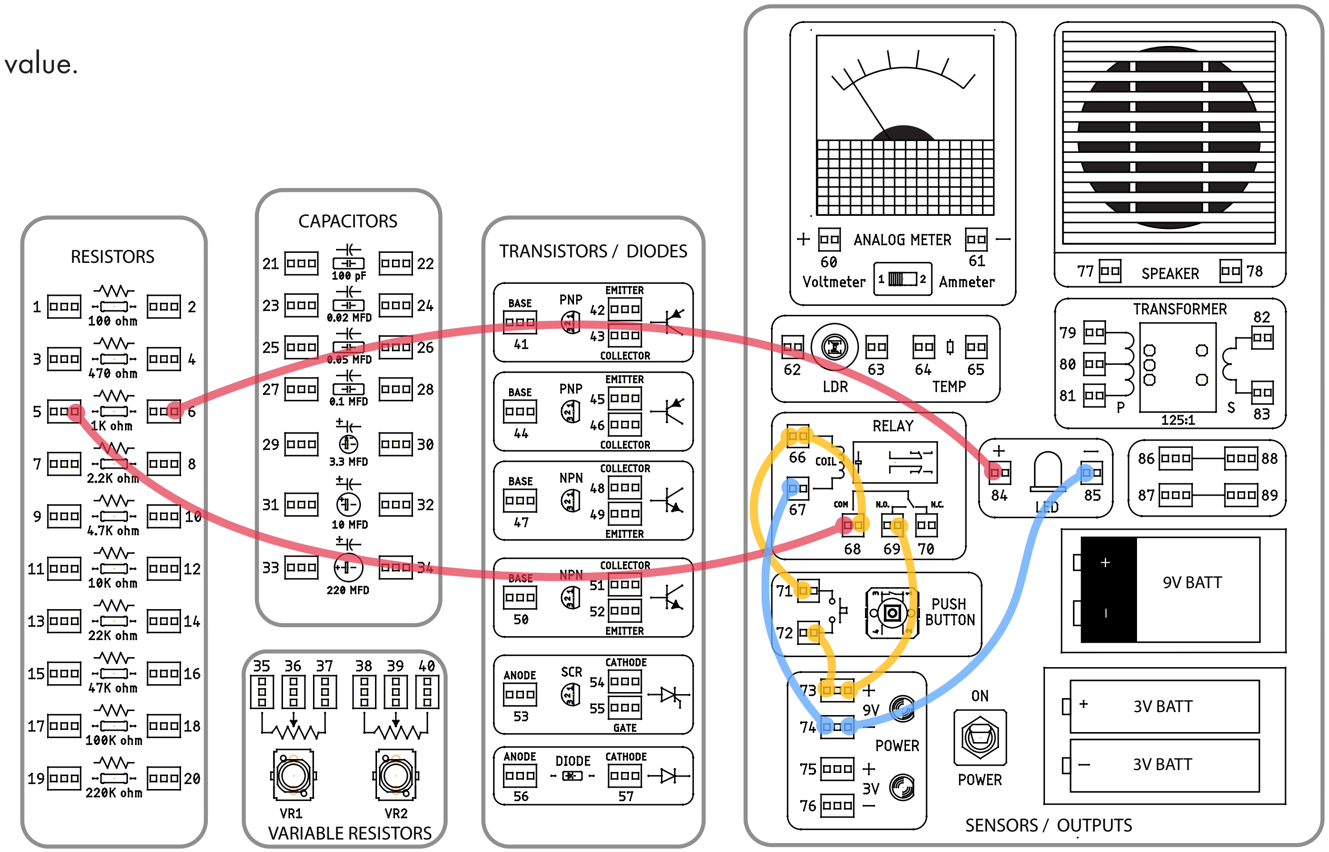
PROJECT #7:
LATCHING RELAY

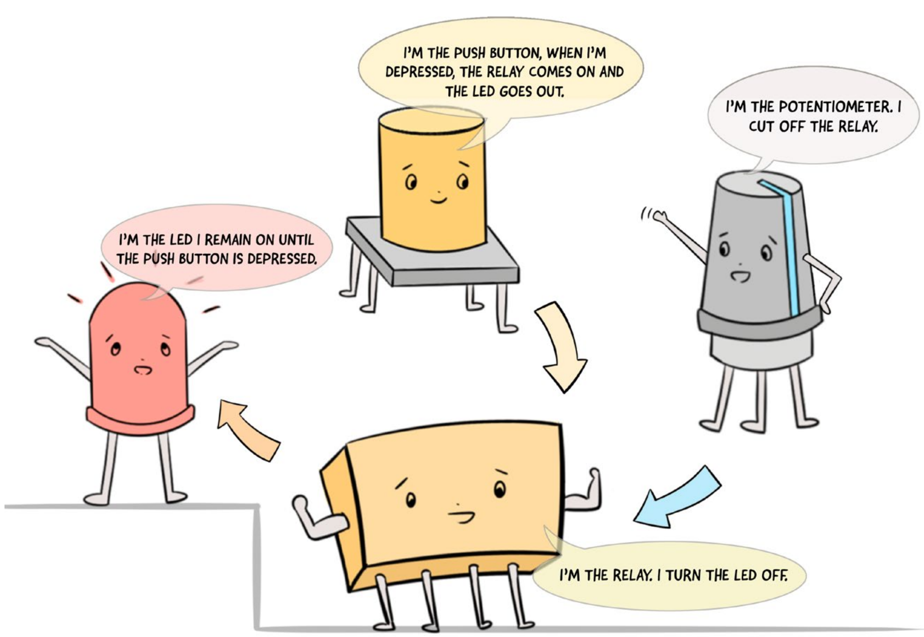
This circuit demonstrates how a relay can be used to latch or store a value.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the push button and observe the LED.
3. [ ] Press the push button again. Nothing should change!
4. [ ] Turn off the power switch, and then turn it back on.
5. [ ] Press the push button again.

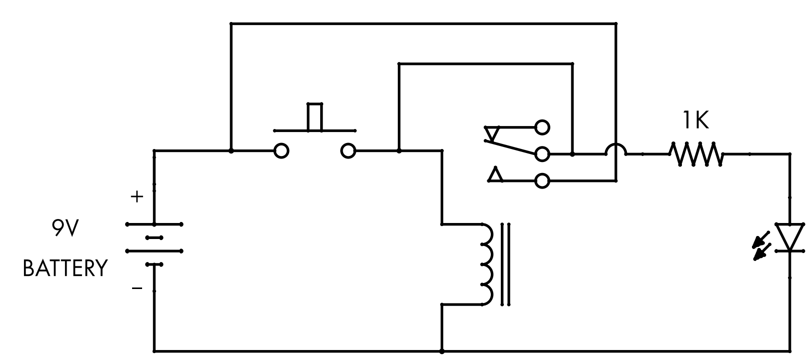
WIRING CHART		
LENGTH	FROM	TO
Short	66	71
	66	68
	69	73
	72	73
Medium	67	74
	74	85
Long	5	68
	6	84





HOW IT WORKS

When the Push button is pressed, current flows through the relay coil, closing the normally open and common contacts of the relay. Since these contacts are in parallel with the Push button connections, the circuit latches so that when the Push button is released, the power is still connected to the relay coil.
These types of circuits are often used in industrial circuits like elevators and traffic lights.



PROJECT #8:
BUZZER

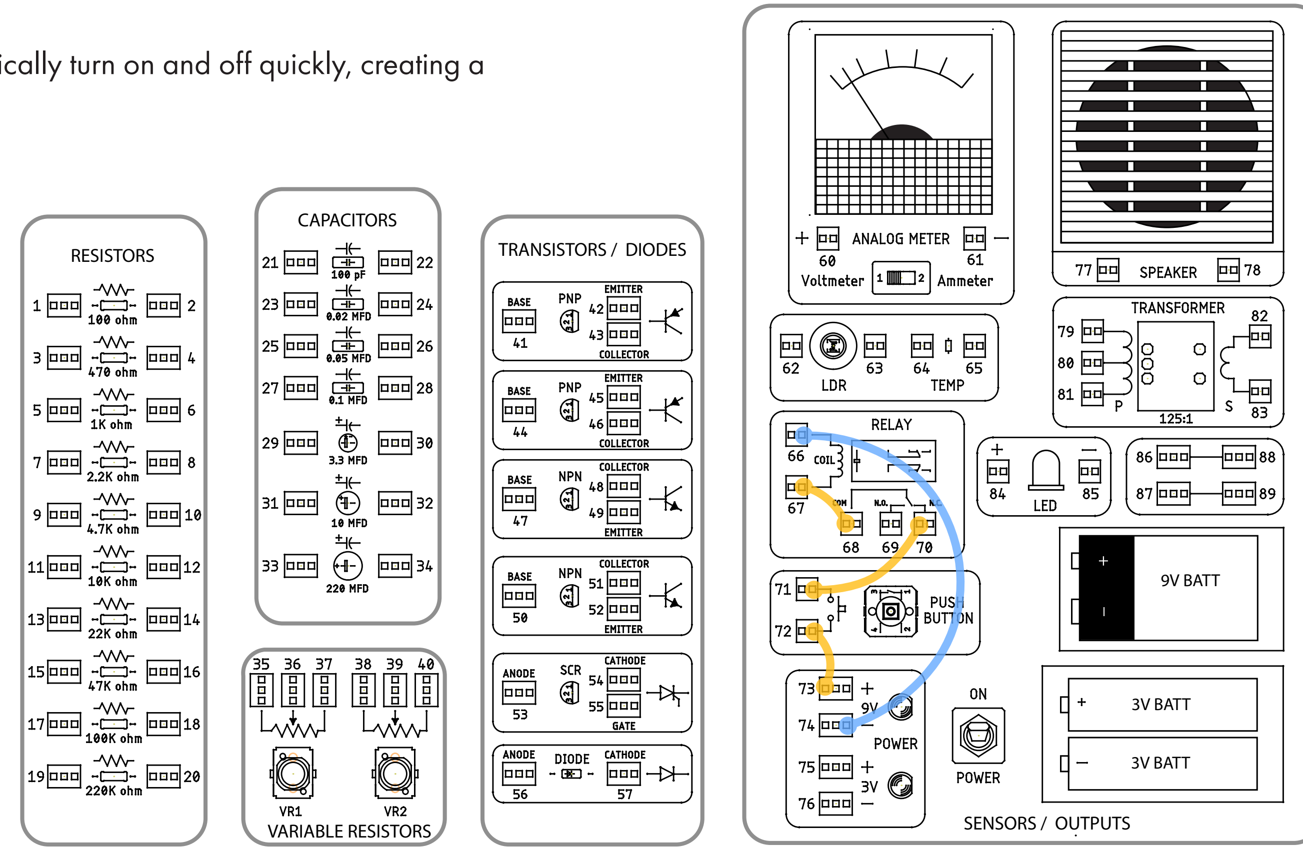
This simple circuit demonstrates how a relay can be used to automatically turn on and off quickly, creating a "buzzing" sound.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the Push button and listen to the relay.
3. [ ] Release the Push button and note what happens.

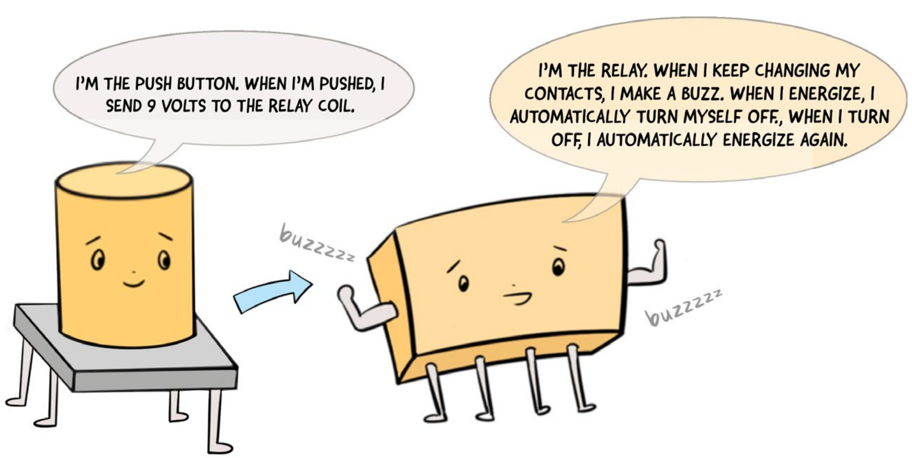
WIRING CHART

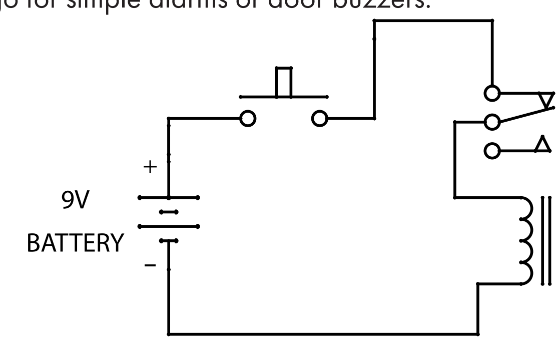
LENGTH	FROM	TO
Short	73	72
	71	70
	68	67
Medium	66	74



HOW IT WORKS

When the Push button is pressed, current flows through the relay coil, opening the **normally closed** and common contacts of the relay. However, since the coil is also wired in series with these contacts, current stops flowing through the coil. This causes the contacts to open very quickly, and the process starts over again. This opens the contacts, and the process starts all over again. The buzzing sound comes from the rapid closing and opening of the contacts on the relay. Buzzers like these were used a long time ago for simple alarms or door buzzers.





PROJECT #9:
ELECTRONIC SWITCH

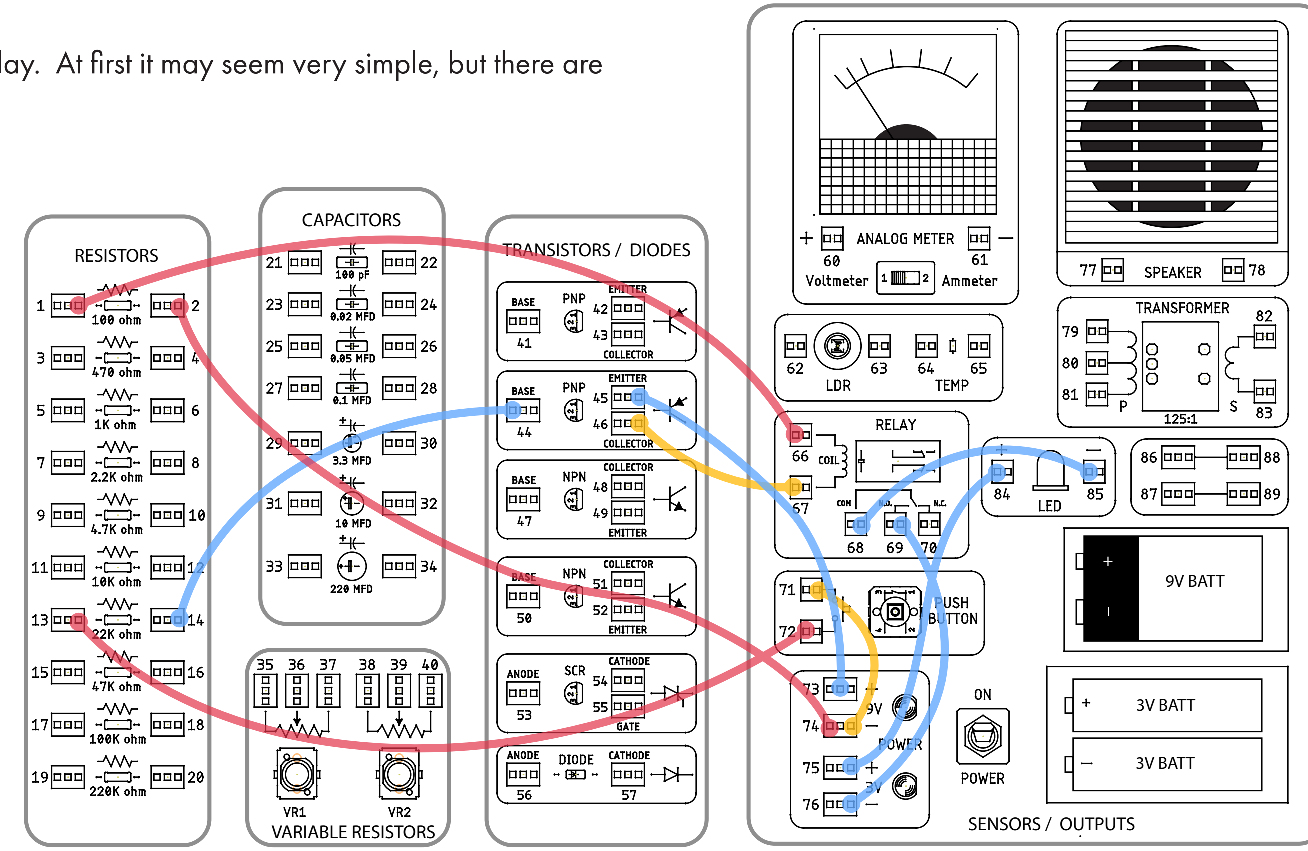
This circuit demonstrates how a transistor can be used to switch a relay. At first it may seem very simple, but there are many applications for this circuit.

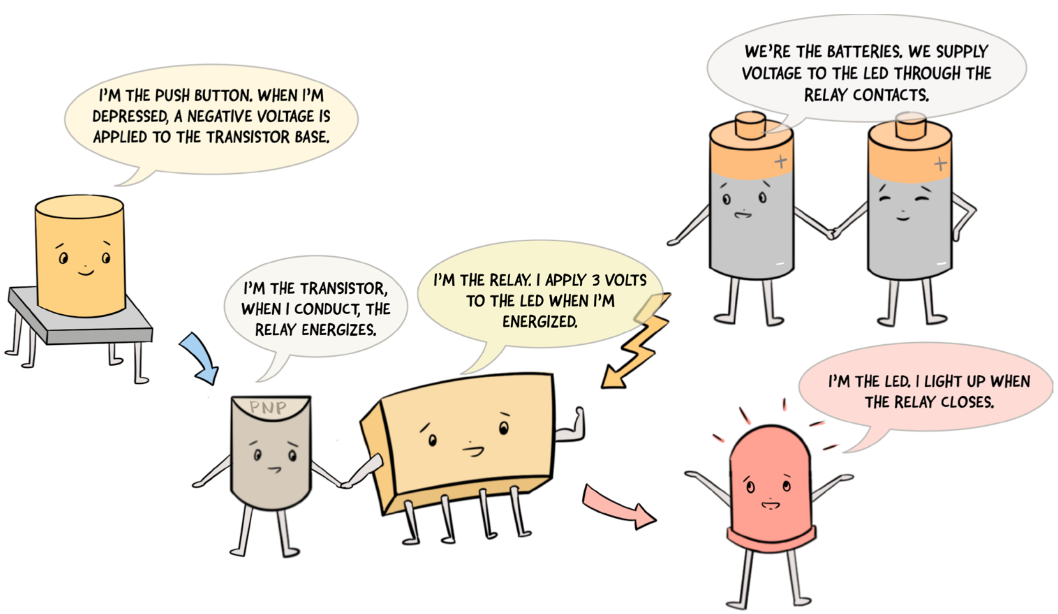
INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the Push button and observe the LED.
3. [ ] Release the Push button and note what happens.

WIRING CHART

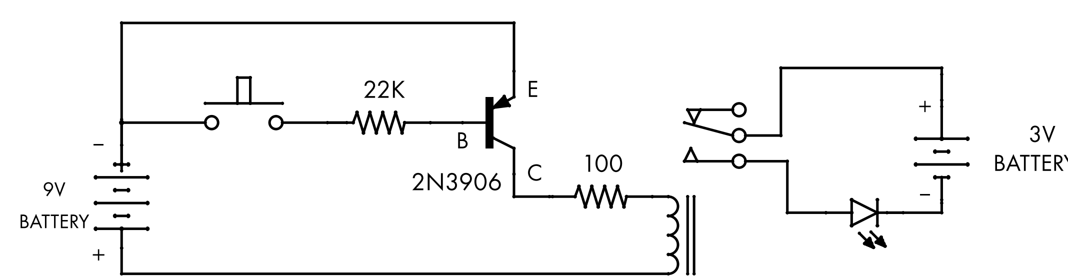
LENGTH	FROM	TO
Short	46	67
	71	74
Medium	14	44
	68	85
	69	76
	73	45
	75	84
Long	1	66
	2	74
	13	72





HOW IT WORKS

When the Push button is pressed, a small current flows into the base of the PNP transistor. This allows a larger current to flow out of the emitter, which turns on the relay coil. The contacts of the relay are wired to the 3V battery and LED, and the LED lights when the coil is energized. This demonstrates how a transistor can turn on a higher current device and allow a different output voltage to be controlled in a circuit.

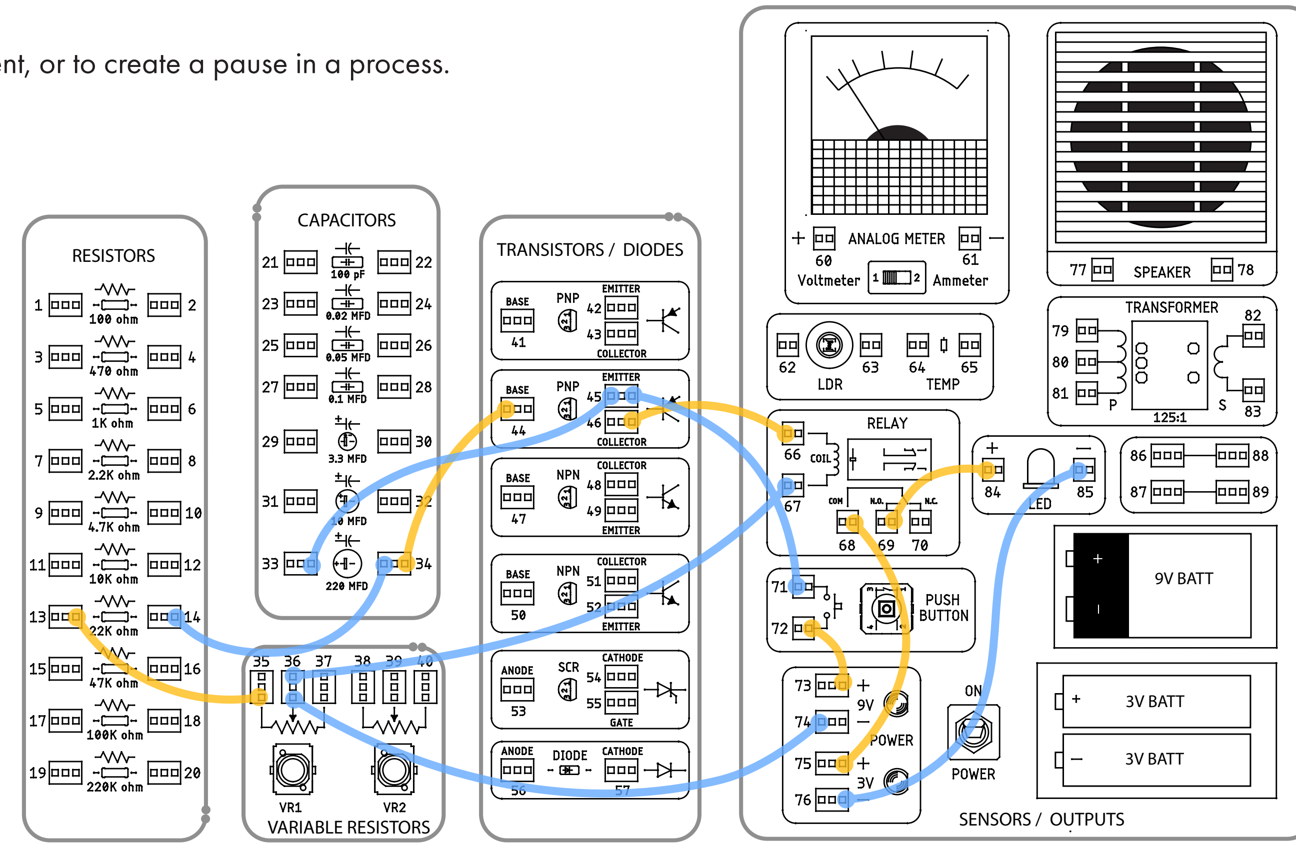


PROJECT #10:
TIME DELAY RELAY

Time Delay relays are used to delay the power on cycle for equipment, or to create a pause in a process.

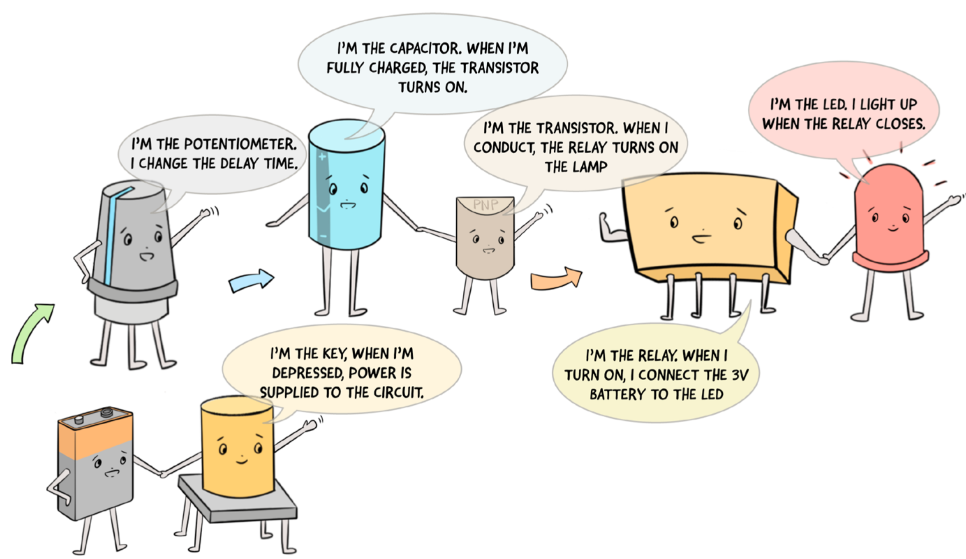
INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Turn VR1 all the way counter clockwise.
3. [ ] Press and hold the Push button and observe the LED.
4. [ ] Release the Push button and note what happens.
5. [ ] Rotate VR1 clockwise to increase the time delay and repeat steps 2-4.
6. [ ] Note that if you turn VR1 too far it may not turn the relay on at all!



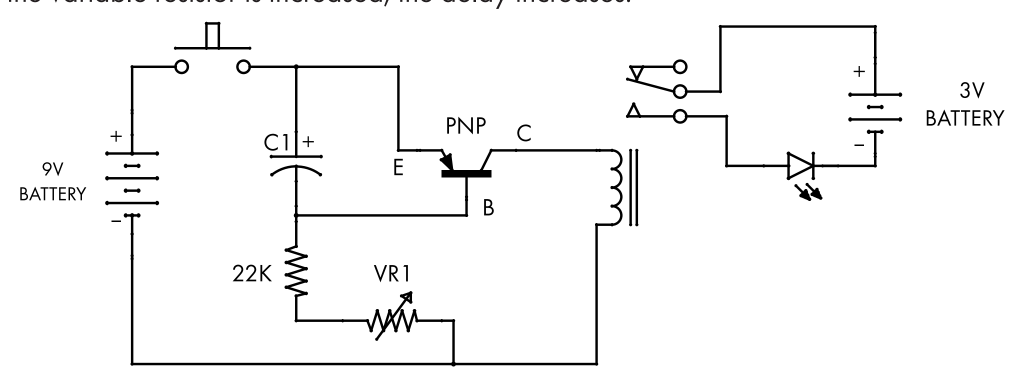
WIRING CHART

LENGTH	FROM	TO
Short	72	73
	13	35
	34	44
	46	66
	68	75
	69	84
Medium	14	34
	33	45
	36	67
	36	74
	45	71
	76	85



HOW IT WORKS

This circuit uses an RC (Resistor / Capacitor) network to create a delay. When the switch is pressed, the capacitor charges through the resistor and Variable resistor. When the voltage across the capacitor is above approximately 0.6V, the transistor turns on, which then activates the relay and turns on the LED. The time of the delay is dependent on both the value of the capacitor and the two resistors. As the value of the variable resistor is increased, the delay increases.



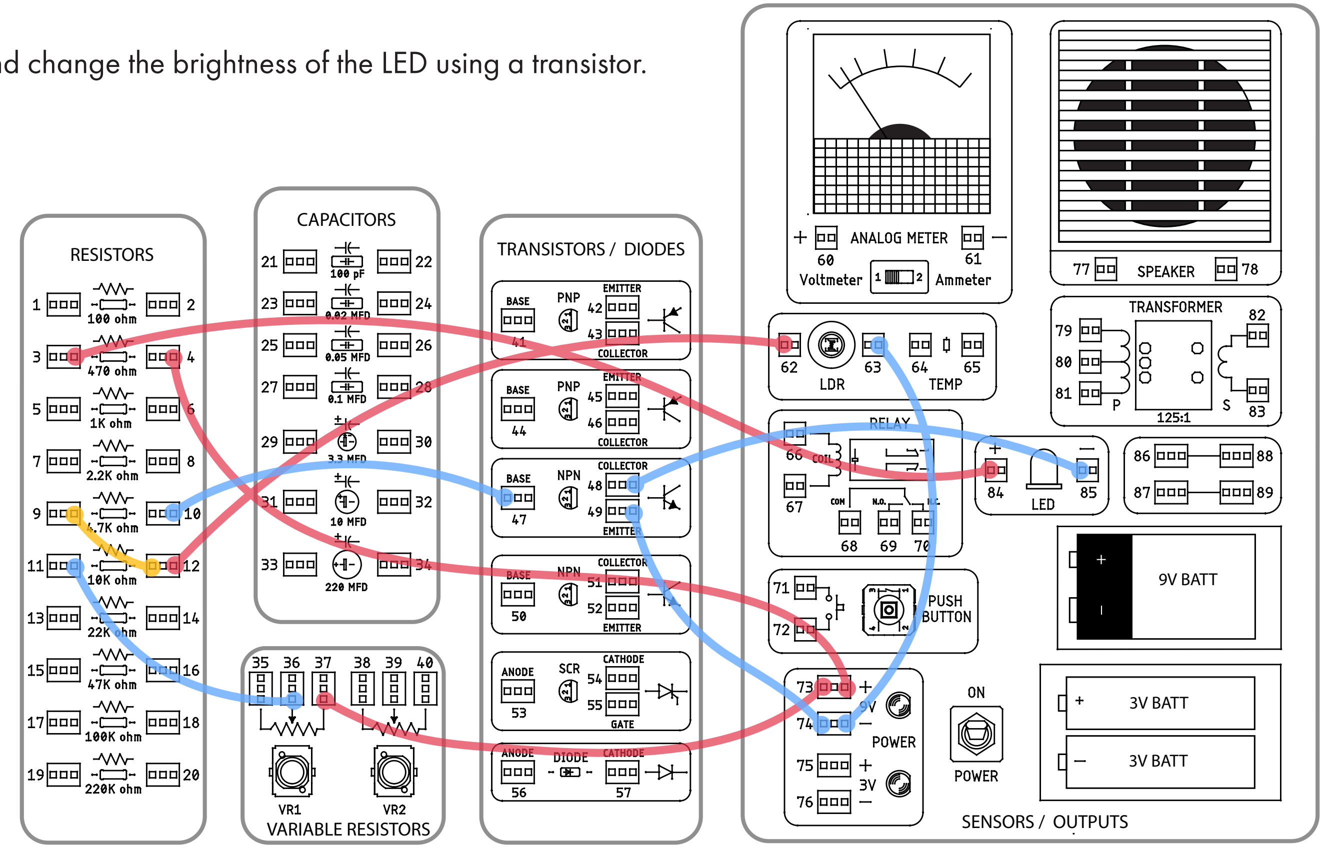
PROJECT #11:

DIMMABLE NIGHT LIGHT

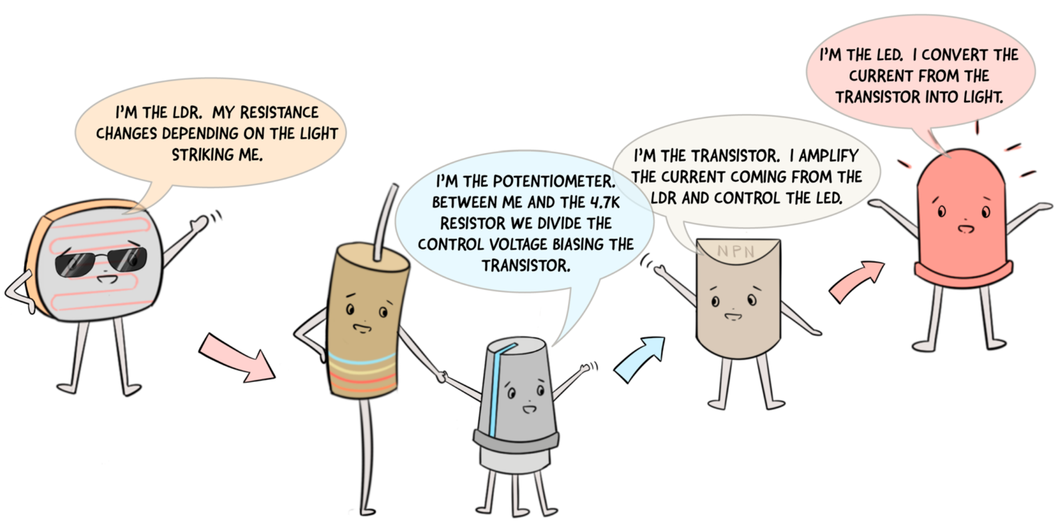
This circuit uses a Light Dependent Resistor (LDR) to sense the light and change the brightness of the LED using a transistor.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Turn VR1 completely counter-clockwise
3. [ ] Cover the LDR with your hand (but don't touch it) to prevent light from hitting it.
4. [ ] Turn VR1 clockwise until the LED turns bright.
5. [ ] Move your hand away and the LED should turn off.
6. [ ] You can adjust the threshold and brightness of the LED depending on the room you are in.

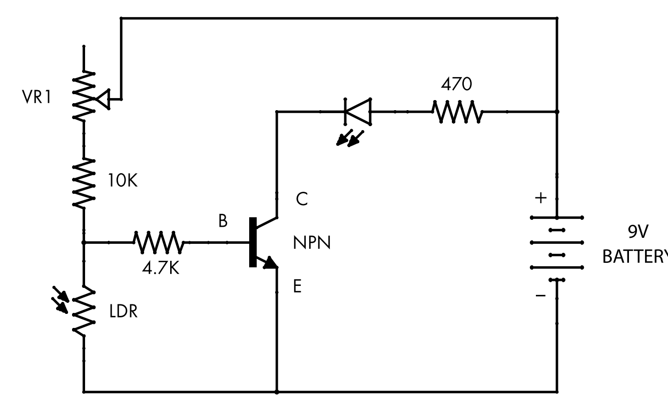


WIRING CHART		
LENGTH	FROM	TO
Short	9	12
Medium	10	47
	11	36
	48	85
	49	74
	63	74
Long	3	84
	4	73
	12	62
	37	73



HOW IT WORKS

This circuit uses an LDR voltage divider circuit. The voltage between the 10K resistor and LDR changes depending on the light striking the LDR. Additionally, the Variable Resistor is used to change the voltage so it allows an adjustment range. The current flowing into the base of the transistor through the 4.7K resistor is amplified to light the LED that is connected to the collector.



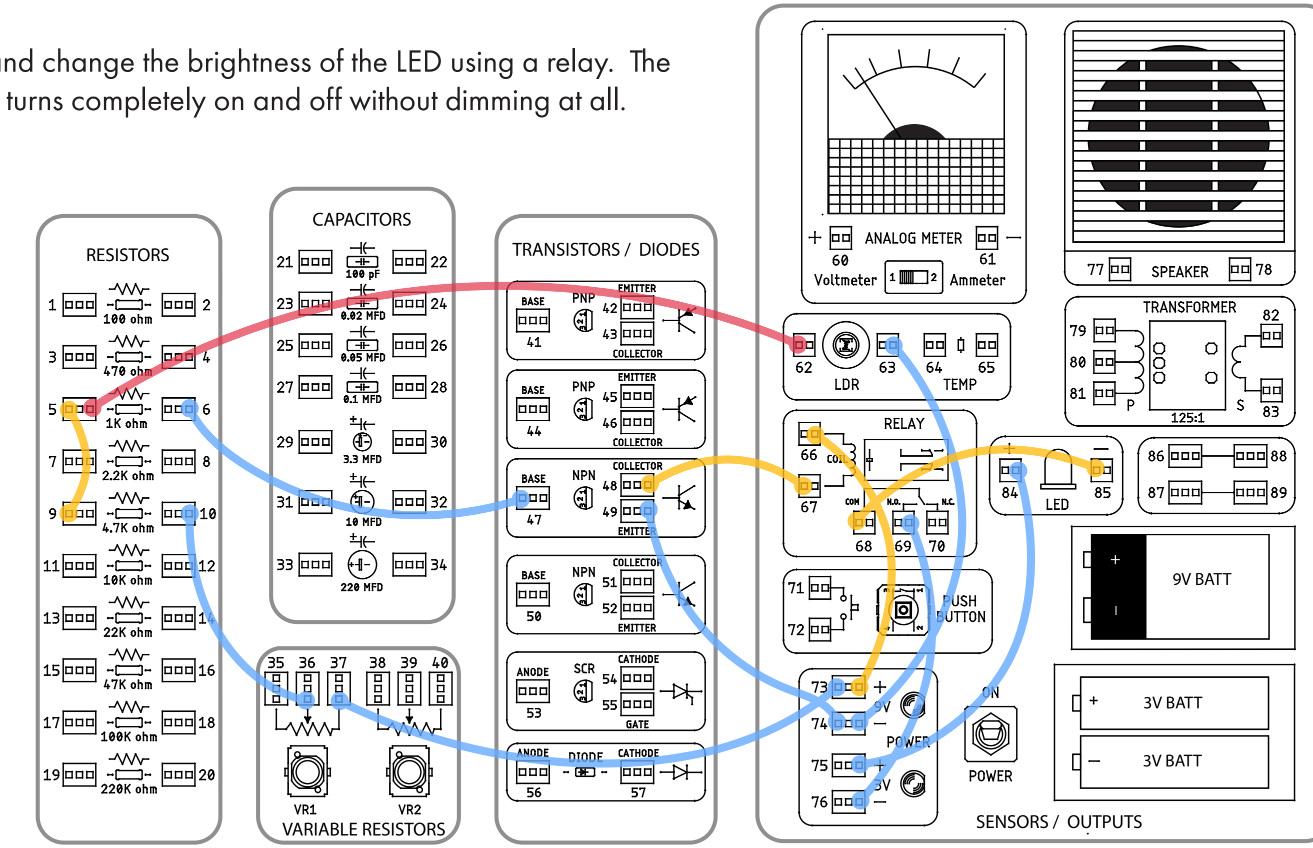
PROJECT #12:

RELAY NIGHT LIGHT

This circuit uses a Light Dependent Resistor (LDR) to sense the light and change the brightness of the LED using a relay. The difference between this project and the previous one is that the LED turns completely on and off without dimming at all.

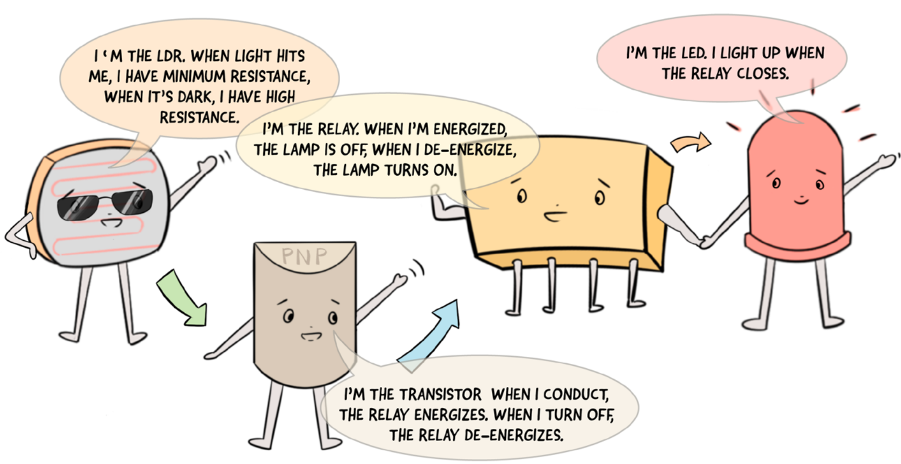
INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Turn VR1 completely counter-clockwise
3. [ ] Next, turn VR1 slowly clockwise until the LED turns on. Then, turn the knob counter-clockwise until the LED turns off.
4. [ ] Cover the LDR with your hand to block the light. The relay will click and the LED should turn on.
5. [ ] Move your hand away and the LED should turn off.
6. [ ] You can adjust the threshold and brightness of the LED depending on the room you are in.



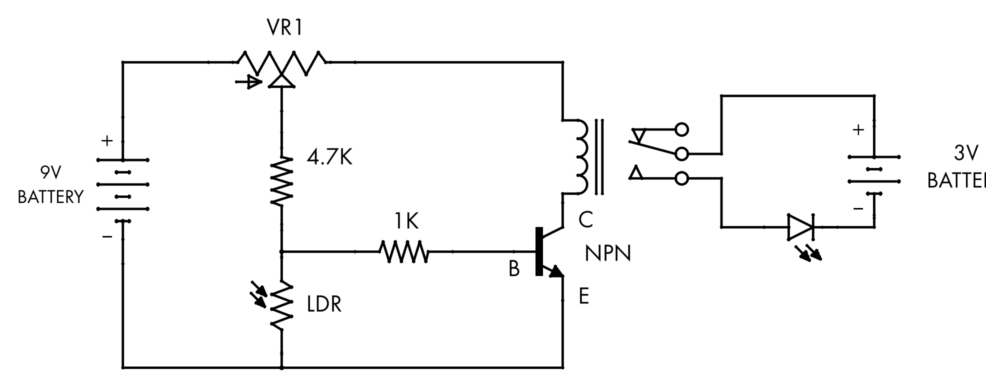
WIRING CHART

LENGTH	FROM	TO
Short	5	9
	48	67
	66	73
	68	85
Medium	6	47
	10	36
	37	73
	49	74
	63	74
	69	76
	75	84
Long	5	62



HOW IT WORKS

This circuit uses an LDR voltage divider circuit. The voltage between the 10K resistor and LDR changes depending on the light striking the LDR. Additionally, the Variable Resistor is used to change the voltage so it allows an adjustment range. The current flowing into the base of the transistor through the 4.7K resistor is amplified to turn on the relay, which in turn lights the LED.



PROJECT #13:
LED FLASHER

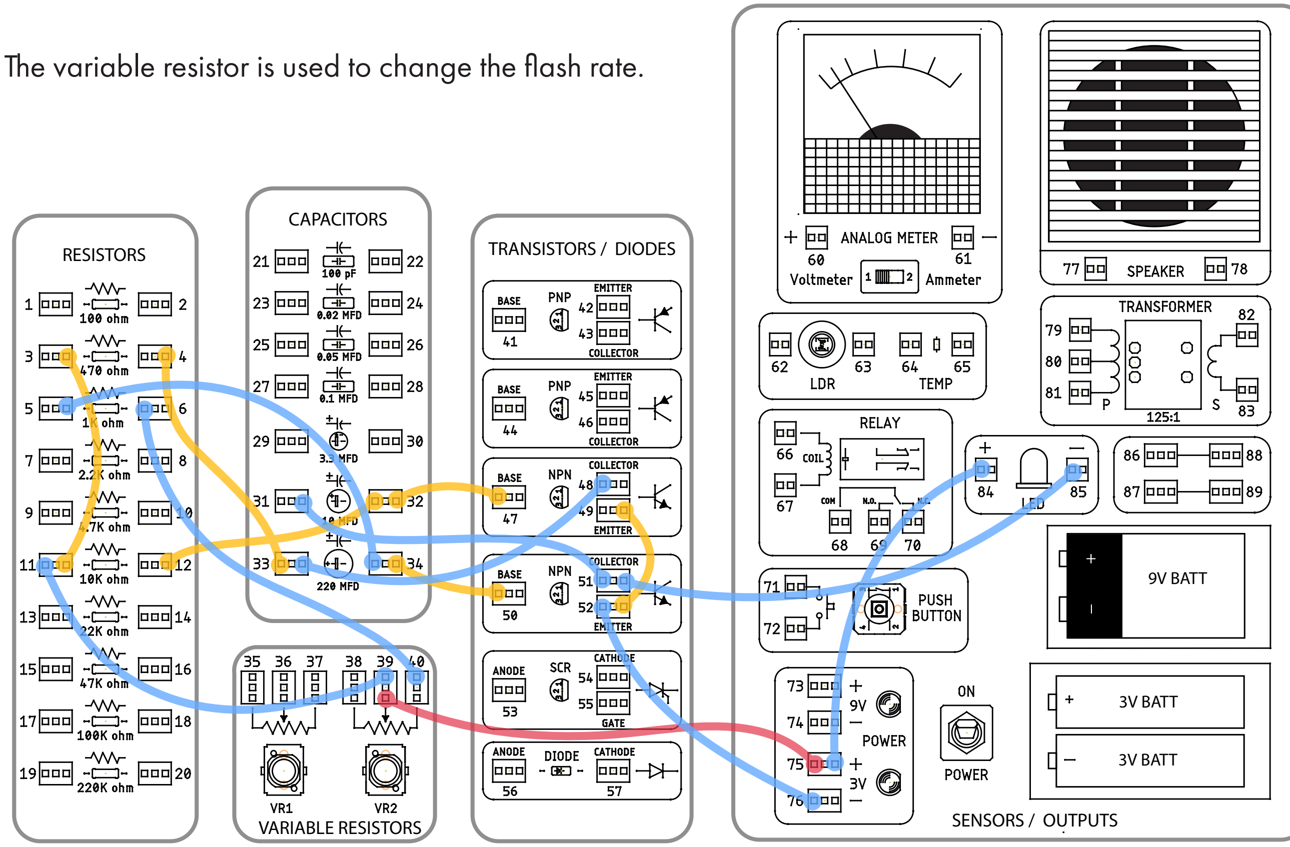
This circuit uses two transistors wired as an oscillator to flash an LED. The variable resistor is used to change the flash rate.

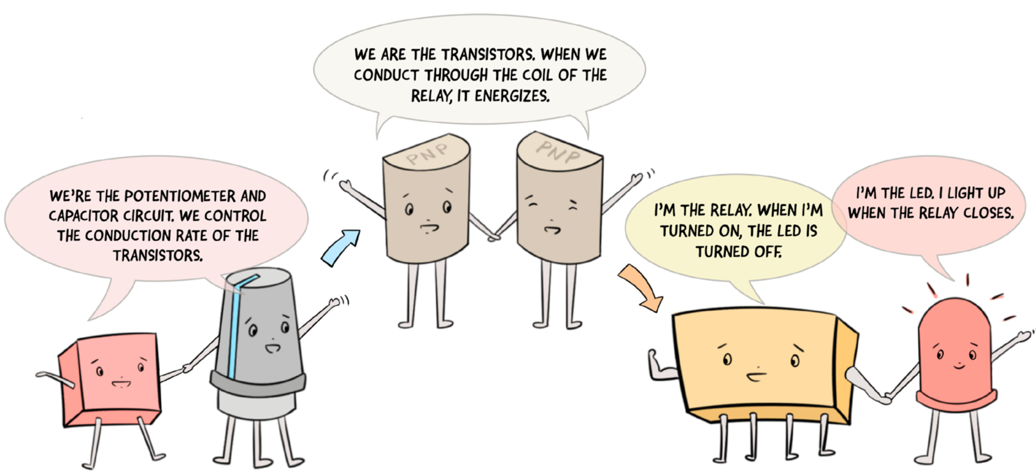
INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Turn VR1 completely counter-clockwise
3. [ ] Note the flash rate of the LED
4. [ ] Turn VR1 clockwise to adjust the flash rate.

WIRING CHART

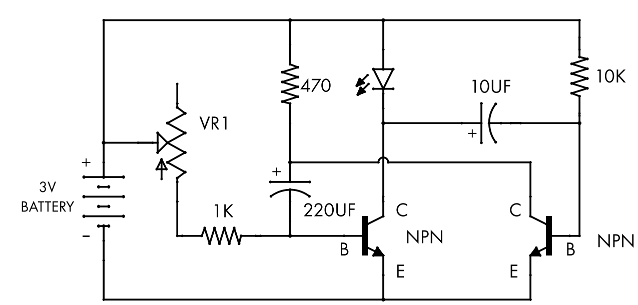
LENGTH	FROM	TO
Short	3	11
	4	33
	12	32
	32	47
	34	50
	49	52
Medium	5	34
	6	40
	11	39
	31	51
	33	48
	51	85
	52	76
	75	84
Long	39	75





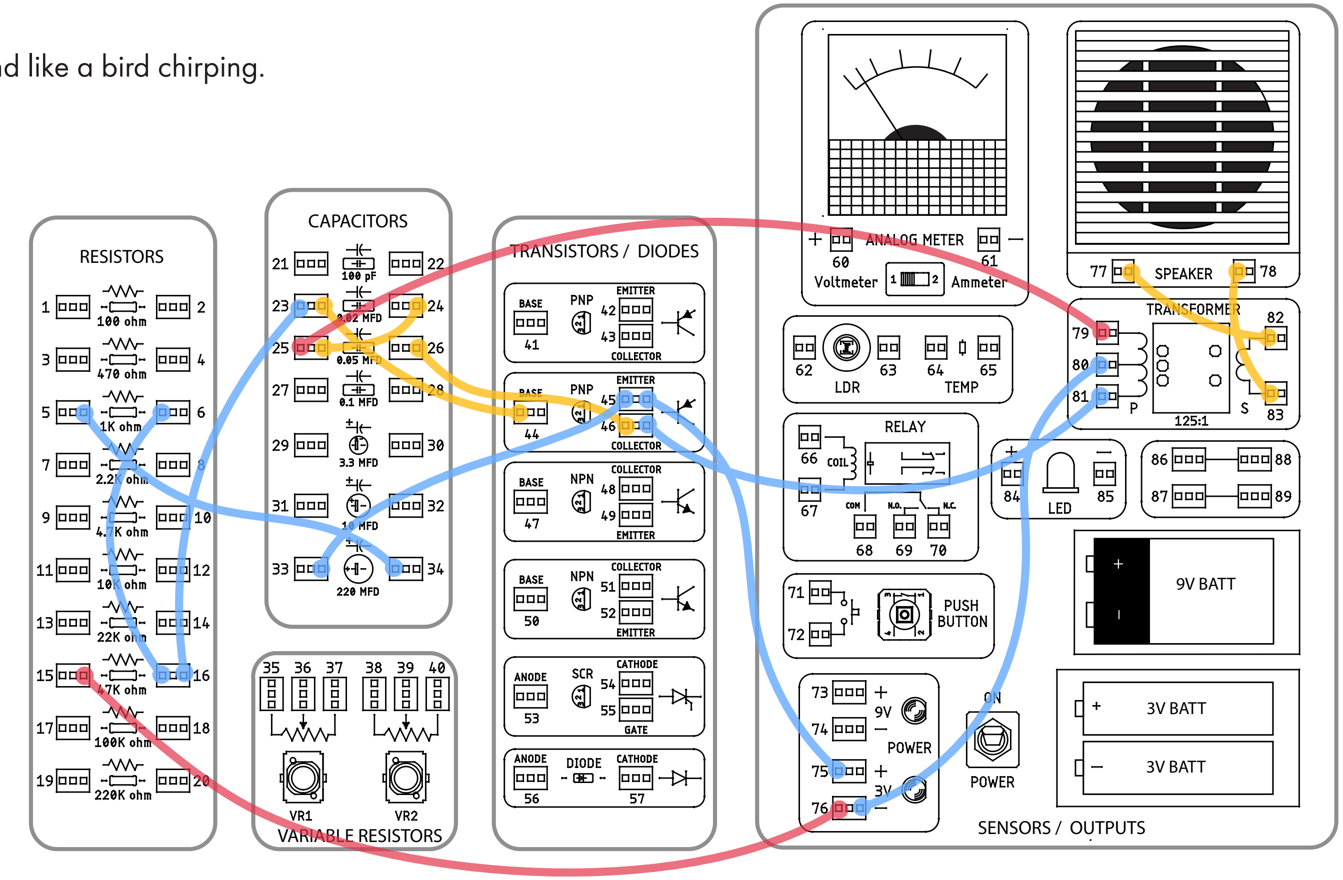
HOW IT WORKS

This circuit uses two NPN transistors wired together to create a continuously running on and off state. As the 220uF capacitor charges the voltage eventually becomes high enough to turn on the first transistor, which also turns on the LED. When that transistor turns on, the second transistor discharges the capacitor quickly. When the voltage becomes low enough, the cycle repeats. Using this method, each transistor switches the other transistor off, and the charge time of the capacitor determines the amount of time between flashes. The variable resistorallows the time constant to be adjusted. As the resistance increases, the charge time increases, which in turn increases the time between flashes.



PROJECT #14:
ELECTRONIC BIRD CHIRPER

This circuit creates a combination of two oscillators to create a sound like a bird chirping.

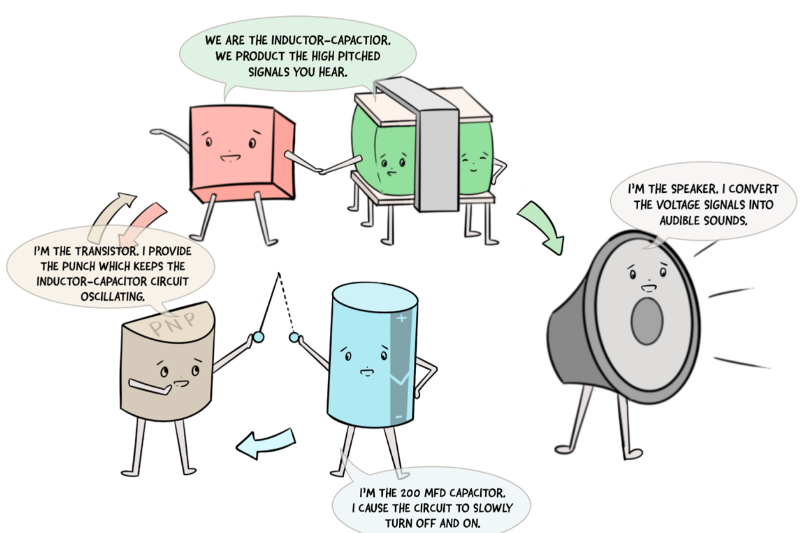


INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] When powered on the speaker will emit a bird-like chirp.
3. [ ] To create different sound effects, switch the 1K resistor to different values by movingVthe wires going to pins 5 and 6 to other resistors.
4. [ ] What do you notice when you use a smaller or larger resistor?
5. [ ] You can also change the 220uf capacitor to 10uF, although the sounds start to get a little strange!

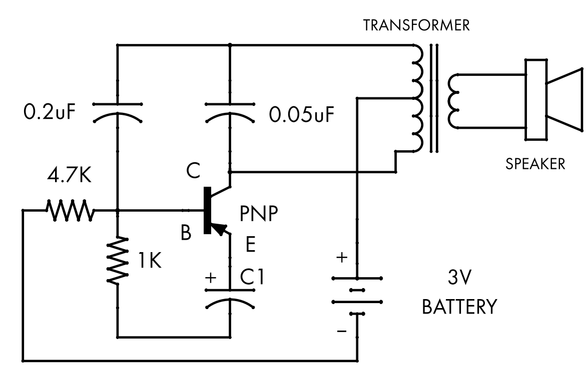
WIRING CHART

LENGTH	FROM	TO
Short	24	25
	23	44
	26	46
	77	82
	78	83
Medium	5	34
	6	16
	16	23
	33	45
	45	75
	46	81
	76	80
Long	15	76
	25	79



HOW IT WORKS

This circuit uses two types of oscillators. The first oscillator uses the transformer and the 0.02uF capacitor as a "tank" oscillator. The second oscillator (which is a much lower frequency) uses the 220uF capacitor and the 1K resistor in an RC network. The second oscillator "modulates" the higher frequency to create a bird-chirping sound. By changing the values of resistors and capacitor, various other sounds can be created. Additionally, you can add a variable resistor in series with the resistor to allow adjusting the sounds with a knob.

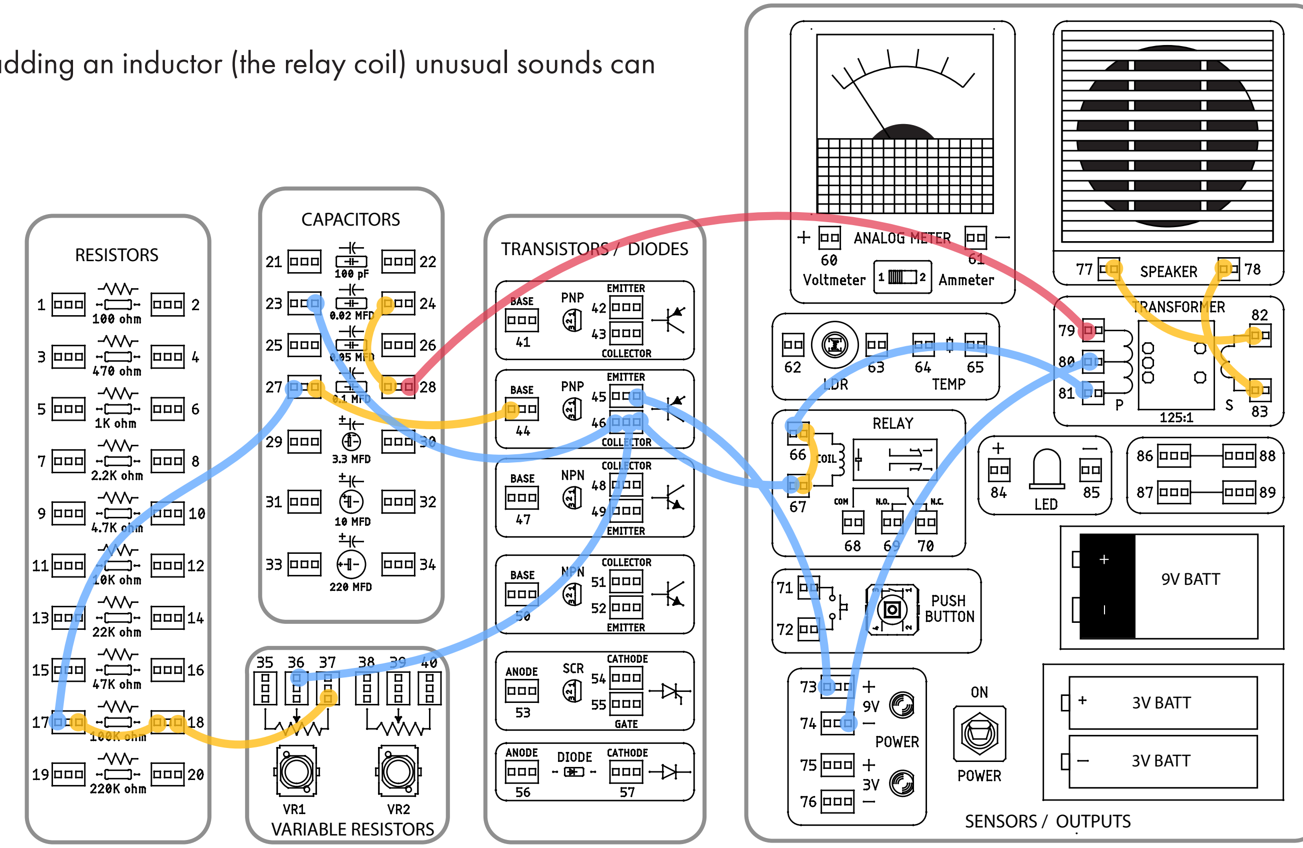


PROJECT #15:
ELECTRONIC SOUND EFFECTS

This circuit uses a transistor oscillator to create different sounds. By adding an inductor (the relay coil) unusual sounds can be produced.

INSTRUCTIONS:

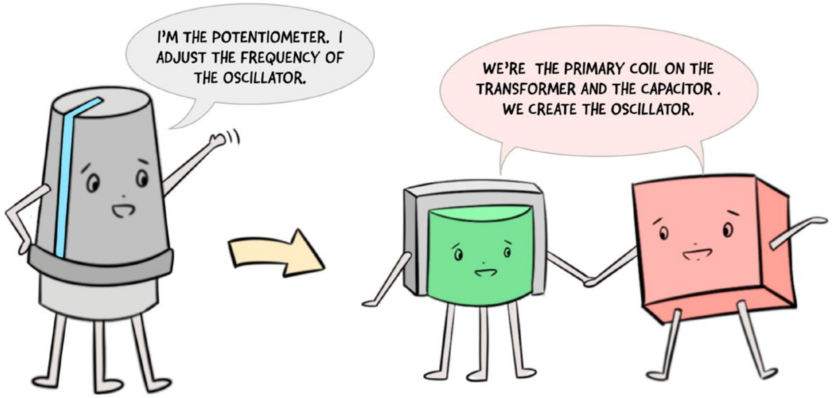
1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Adjust VR1 to change the frequency range.
3. [ ] Remove the jumper wire between pins 17 and 18 to adjust the frequency range, and adjust VR1to manually change the frequency.
4. [ ] Next remove the wire between pins 66 and 67. Adjust VR1 to see the different effects.
5. [ ] By changing the capacitor values and resistor values you can create a number of different effects!

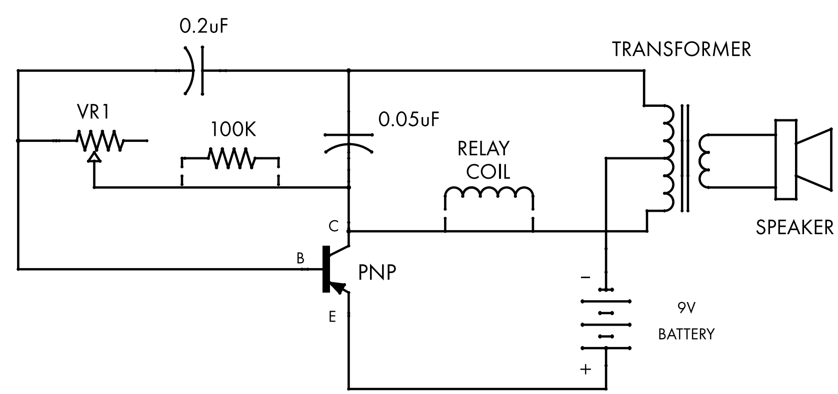


WIRING CHART		
LENGTH	FROM	TO
Short	17	18
	18	37
	24	28
	27	44
	66	67
	77	82
	78	83
Medium	17	27
	23	46
	36	46
	45	73
	46	67
	66	81
	74	80
Long	28	79

HOW IT WORKS

This circuit uses the NPN transistor to create a simple oscillator. By using a transformer the audio signal is matched from the low level, high impedance output of the transistor to the lower impedance of the speaker. By changing the values of capacitors and resistors different sound effects are created. Additionally, adding the coil of the relay as an inductor in the circuit allows even more dramatic effects.



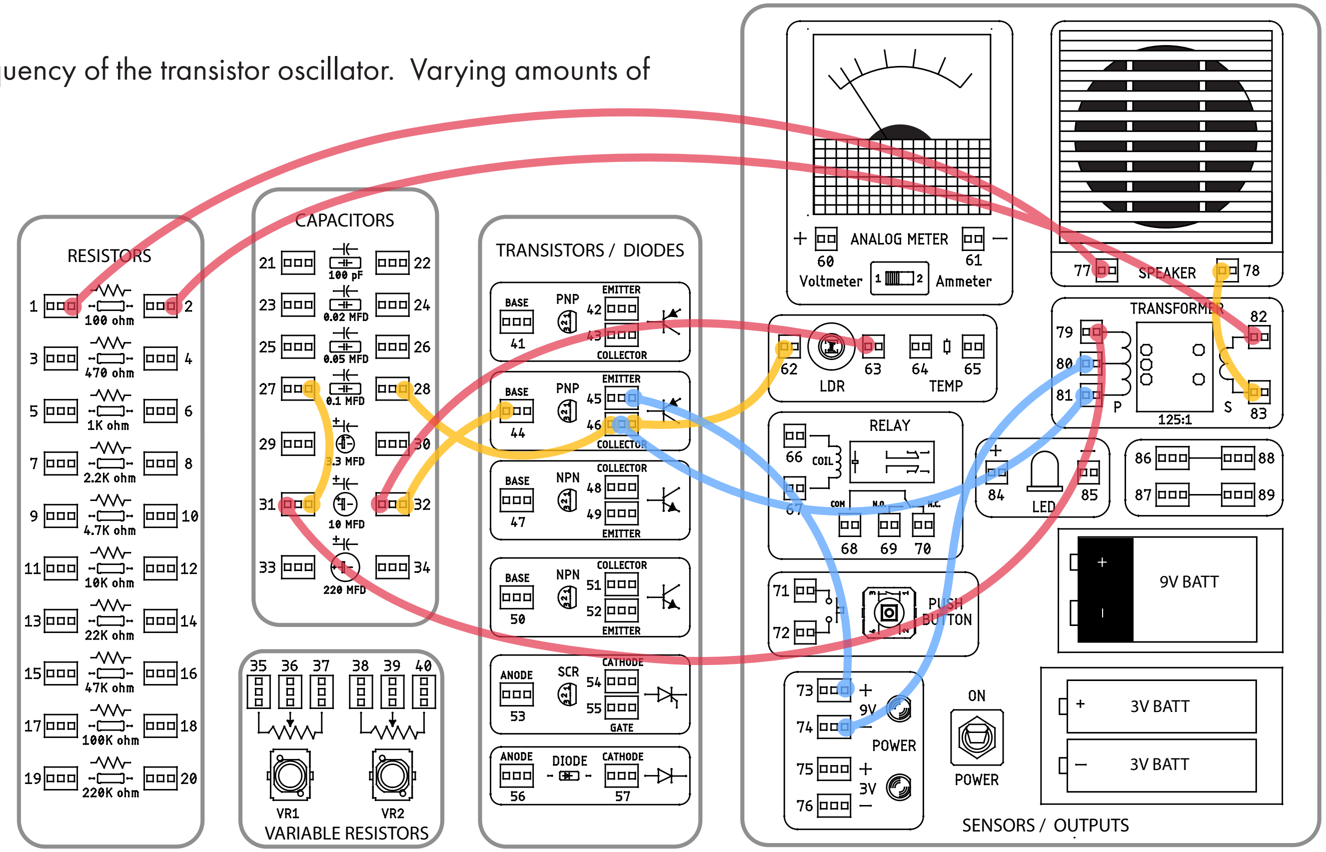


PROJECT #16:
LIGHT SENSING OSCILLATOR

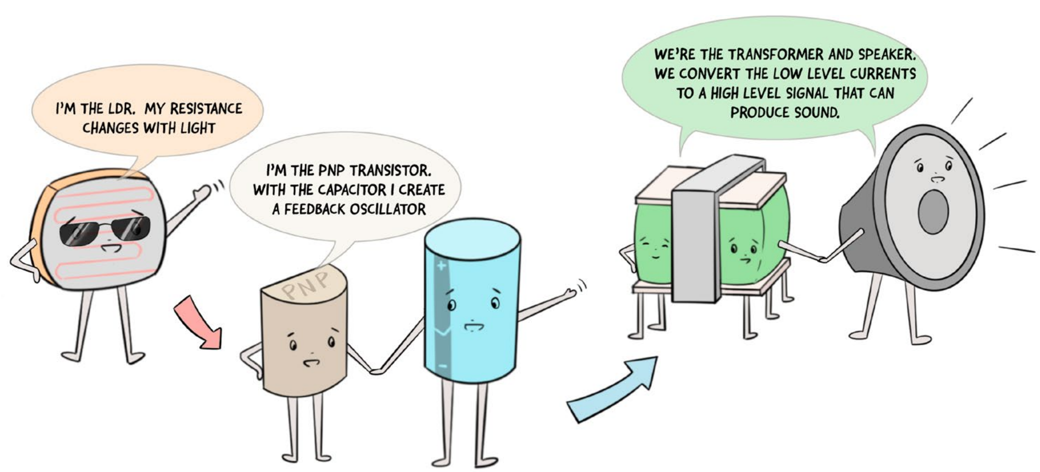
This circuit uses the LDR (Light Dependent Resistor) to change the frequency of the transistor oscillator. Varying amounts of light striking the LDR will change the pitch.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Move your hand over the LDR to change the frequency. You can also shine a bright light or turn the lights off to change the frequency.

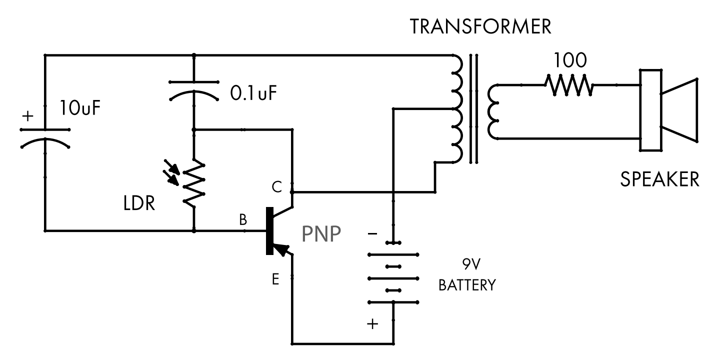


WIRING CHART		
LENGTH	FROM	TO
Short	27	31
	28	46
	32	44
	46	62
	78	83
Medium	45	73
	46	81
	74	80
Long	1	77
	2	82
	31	79
	32	63



HOW IT WORKS

The 0.1uF capacitor and transformer create the basic oscillator circuit, using the 10uF capacitor for feedback. The LDR changes the RC time constant with the 10uF capacitor to change the frequency of the oscillator. The LDR output is not linear (like a straight line), so the frequency changes more dramatically with small light level changes. The 100 Ohm resistor limits the current flowing to the speaker - if it is shorted out (connect a wire from pins 1 to 2), the sound is much louder.

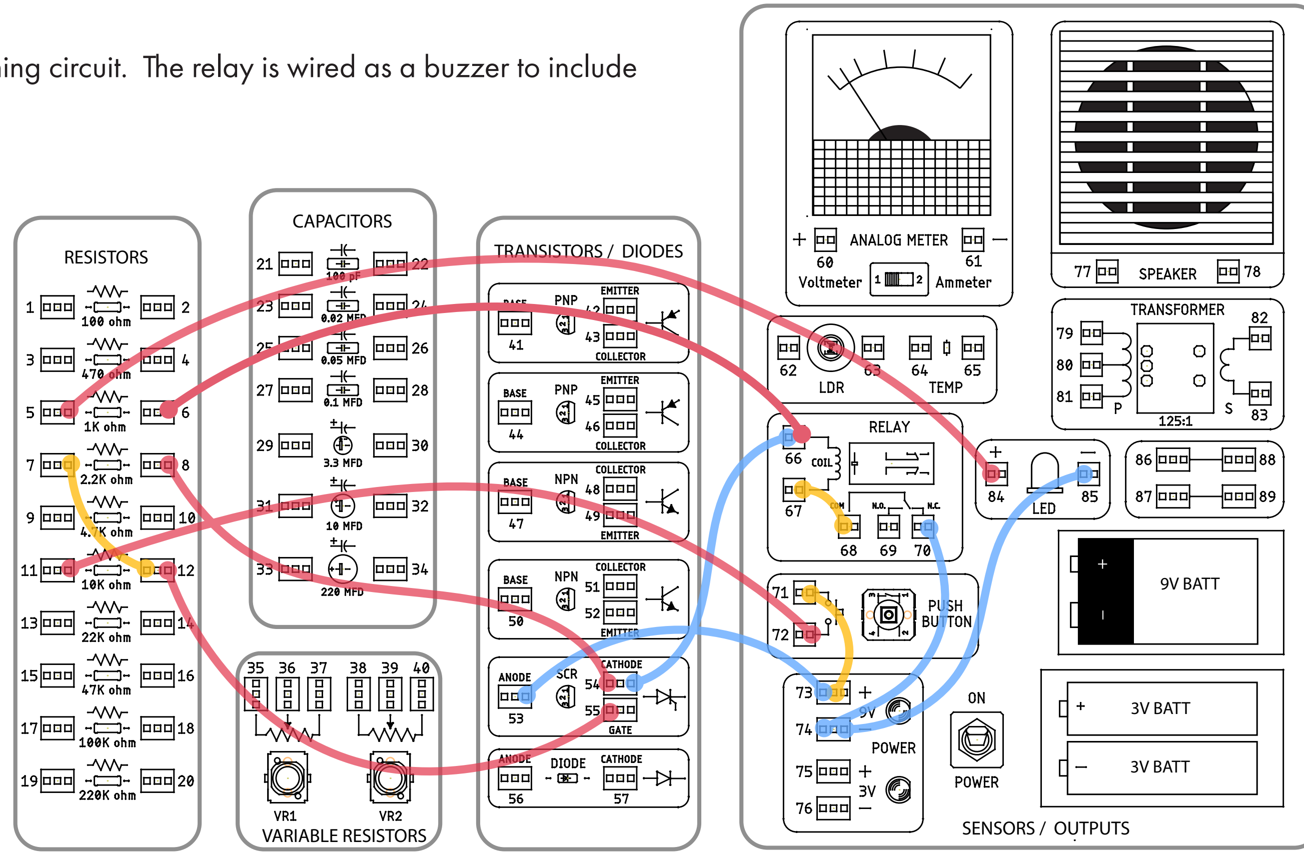


PROJECT #17:
LATCHING BURGLAR ALARM WITH BUZZER

This circuit uses an SCR (Silicon Controlled Rectifier) to create a latching circuit. The relay is wired as a buzzer to include an audible alert.

INSTRUCTIONS:

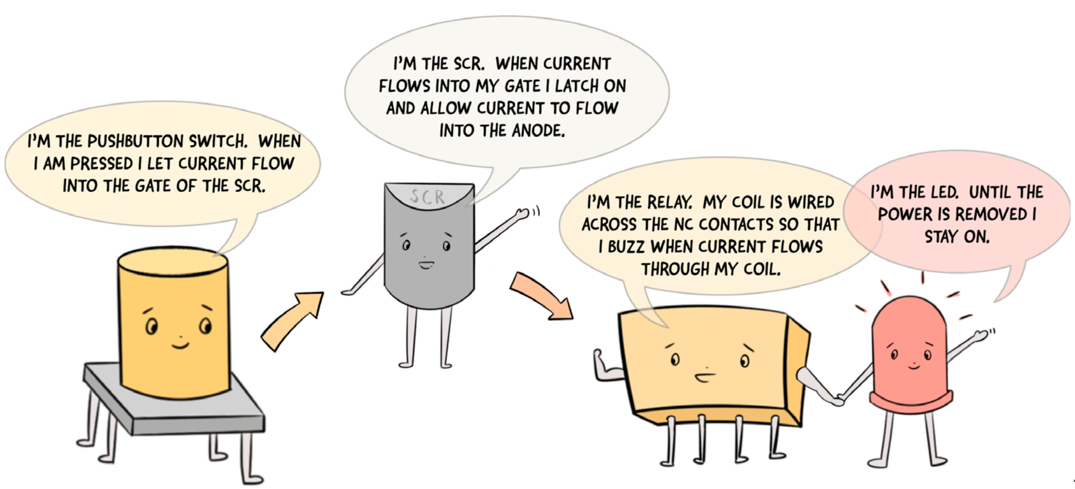
1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the puhbutton (this simulates an alarm condition). The LED will turn on and the relay will buzz. In order to stop the alarm you need to turn off the power. Turning the power back on will reset the circuit.

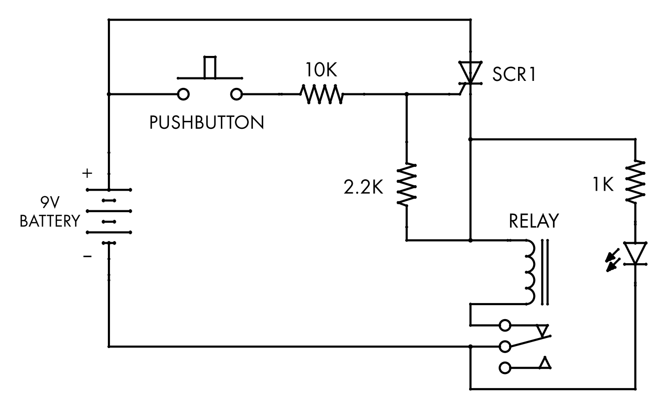


WIRING CHART		
LENGTH	FROM	TO
Short	7	12
	67	68
	71	73
Medium	53	73
	54	66
	70	74
	74	85
Long	5	84
	6	66
	8	54
	11	72
	12	55

HOW IT WORKS

When the pushbutton is pressed it provides current to the gate of the SCR, which causes it to "fire" and latch on. The output of the SCR is connected to both the LED and the relay. The relay is wired so that the normally closed contact cuts the power when the coil turns on, then re-energizes the coil very rapidly. This is what creates the buzzing sound. In order to reset the circuit the power needs to be turned off, which cuts the current going to the SCR.



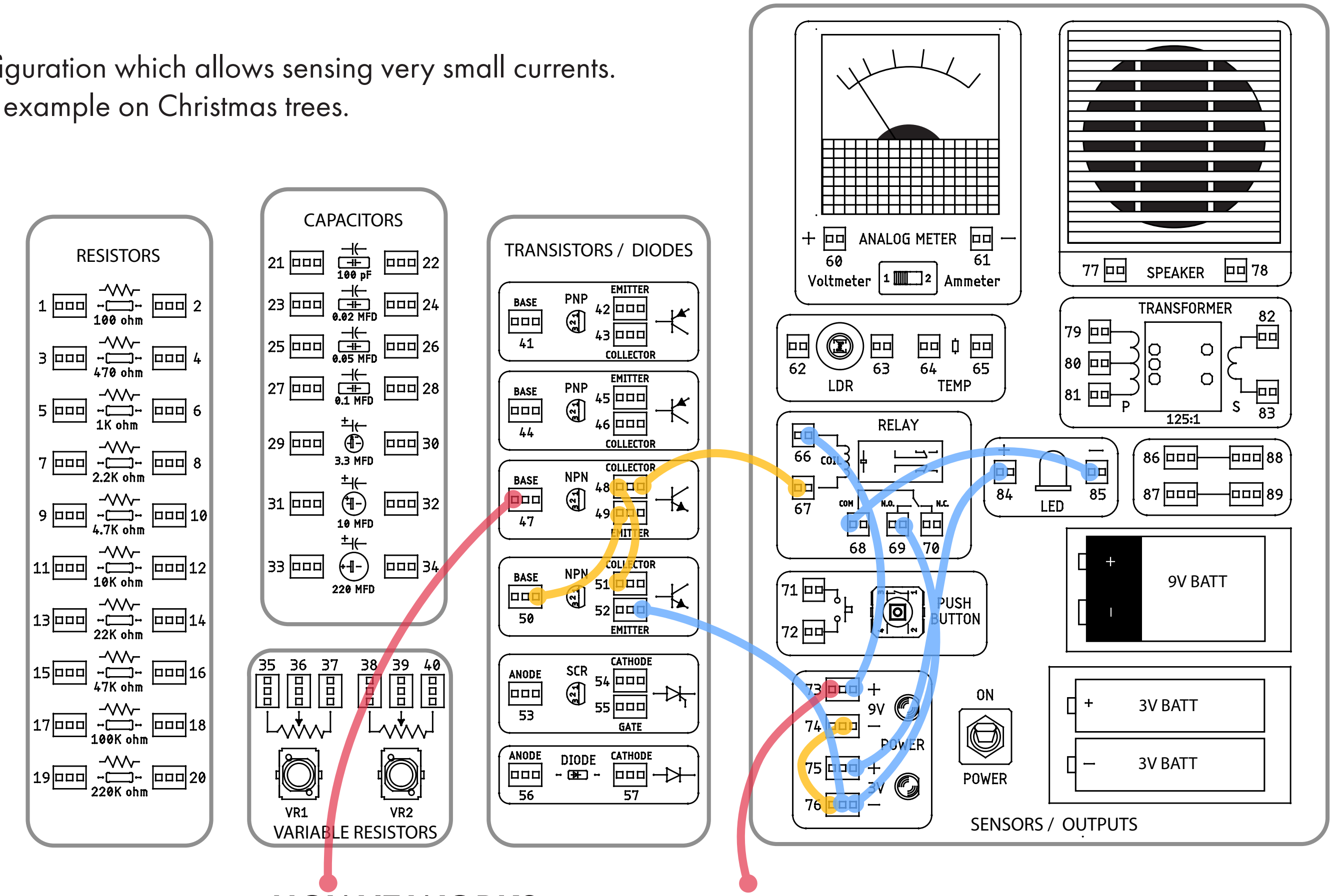


PROJECT #18:
TOUCH SWITCH / WATER LEVEL SENSOR

This circuit uses two transistors wired together in a "Darlington" configuration which allows sensing very small currents. These types of sensors were popular with touch controlled lights, for example on Christmas trees.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Connect the two wires with bare pins on the ends to pins 47 and 73.
3. [ ] Touch the exposed metal wires with your fingers. You should hear the relay click and the LED turn on. Releasing the wires should cause the LED to turn off. If the LED does not light up, try getting your fingers wet.

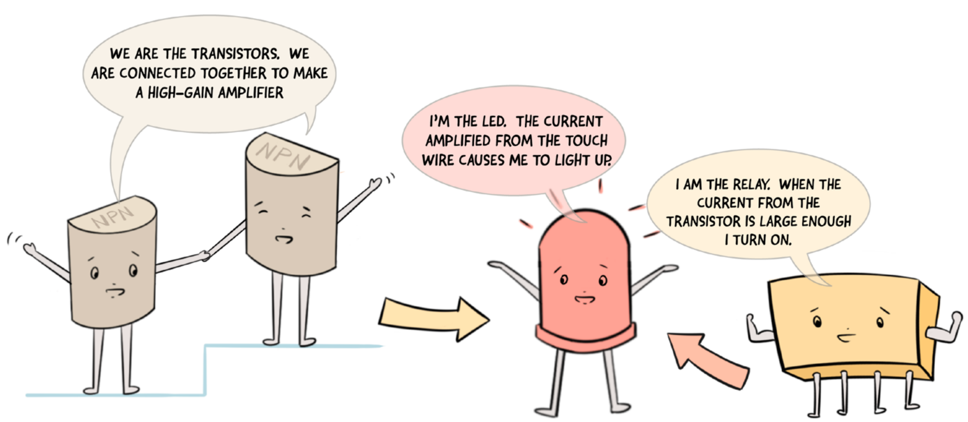


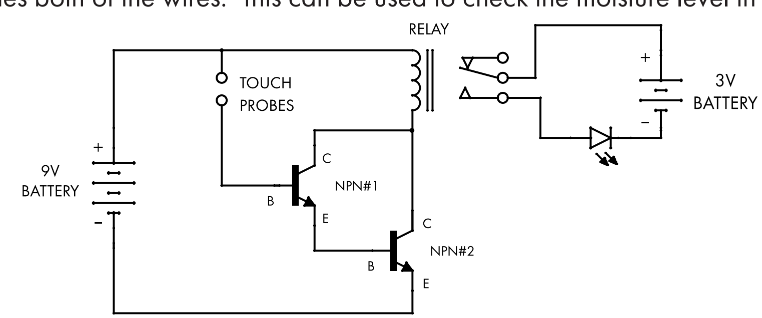
WIRING CHART

LENGTH	FROM	TO
Short	48	51
	48	67
	49	50
	74	76
Medium	52	76
	66	73
	68	85
	69	76
	75	84
Long (F-M Wires)	47	x
	73	x

HOW IT WORKS

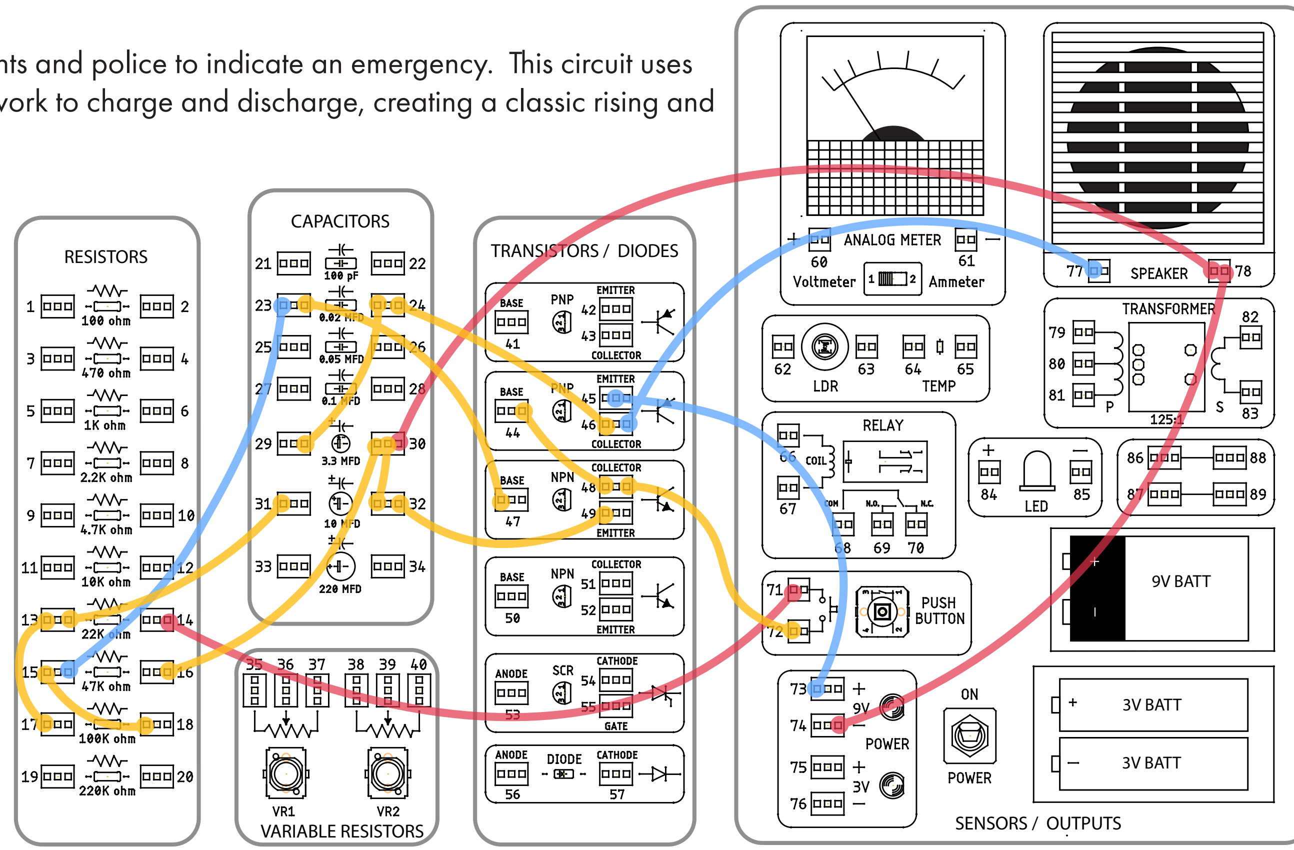
When you touch the wires, a very small amount of current goes to the base of one of the NPN transistors. This transistor is connected directly to the next transistor as a "Darlington Pair," which produces a high amount of gain. The second transistor turns on the relay, which in turns connects the 3V battery to the LED, causing it to light. You can try this experiment by holding hands with friends in a loop - see how many people can be in a chain and still allow the LED to light up! You can also use this as a water level or moisture alarm. By taping the wires into the top of a cup or cylinder and filling it with water it will turn on the LED when water touches both of the wires. This can be used to check the moisture level in a pot of soil.





PROJECT #19:
SIREN

Sirens were often used as alarms, and are still used by fire departments and police to indicate an emergency. This circuit uses an oscillator circuit with two transistors and a Resistor-Capacitor network to charge and discharge, creating a classic rising and falling siren sound when the pushbutton is pressed and released.

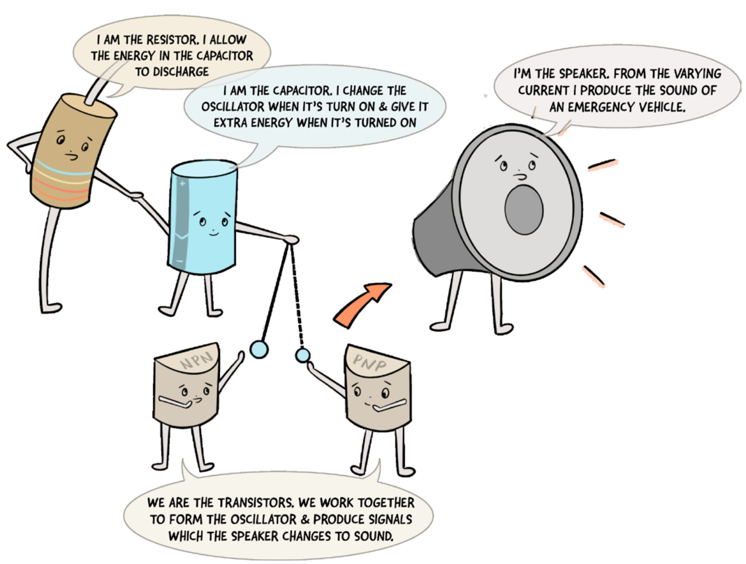


INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the Push Button - you will hear the rising pitch of the siren.
3. [ ] Releasing the Push Button will cause the pitch to lower and then stop.

WIRING CHART

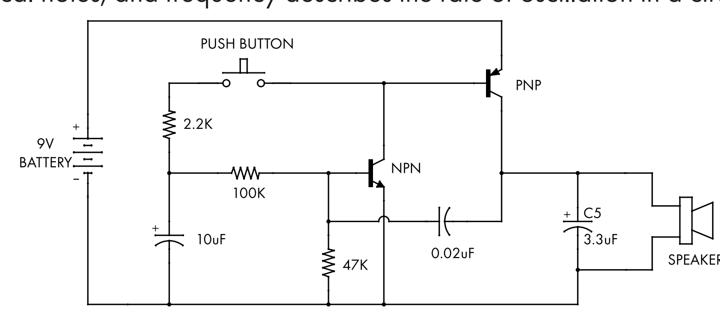
LENGTH	FROM	TO
Short	13	17
	13	31
	15	18
	16	30
	23	47
	24	29
	24	46
	30	32
	32	49
	44	48
	48	72
Medium	15	23
	45	73
	46	77
Long	14	71
	30	78
	74	78



HOW IT WORKS

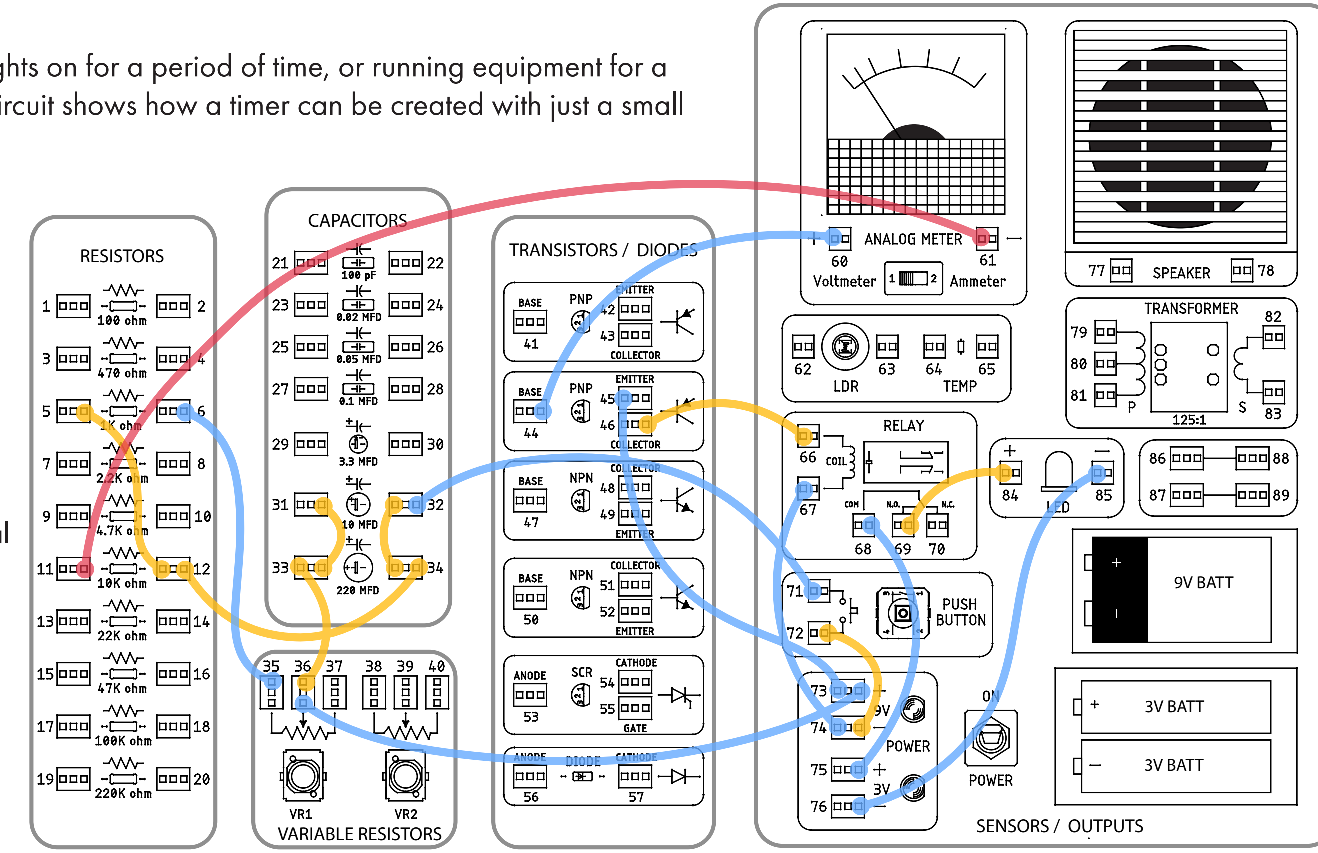
The NPN and PNP transistors are wired together to create a "regenerative" feedback circuit. The key component is the 0.02uF capacitor which feeds the output from the PNP transistor to the input of the NPN transistor.

When the pushbutton is pressed, the 10uF capacitor to charge, which changes the RC network with the 47K resistor and slowly increases the pitch. When the pushbutton is released, the capacitor discharges, which slowly decreases the frequency of the oscillator. The terms "pitch" and "frequency" essentially mean the same thing, however pitch is used to describe musical notes, and frequency describes the rate of oscillation in a circuit or system.



PROJECT #20:
ELECTRONIC TIMER WITH METER

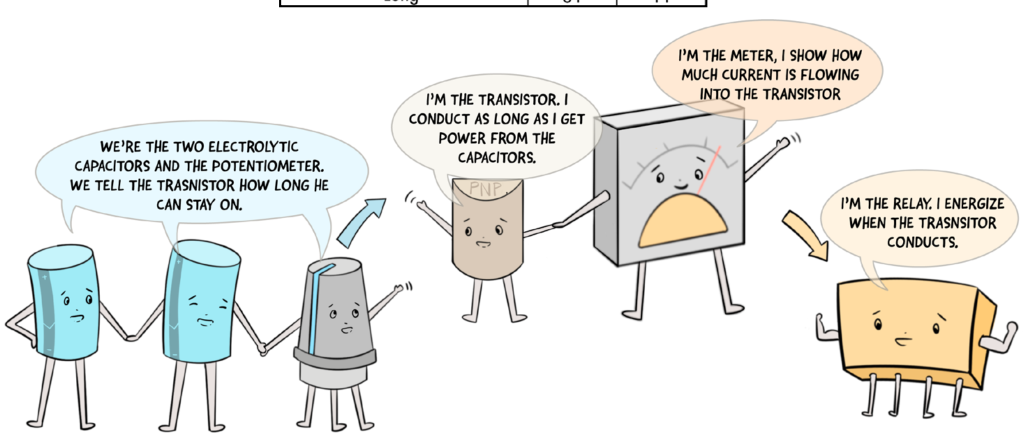
Electronic timers are used in a number of circuits, such as turning lights on for a period of time, or running equipment for a specific time interval. Most timers are now digital, but this simple circuit shows how a timer can be created with just a small number of basic components.



INSTRUCTIONS

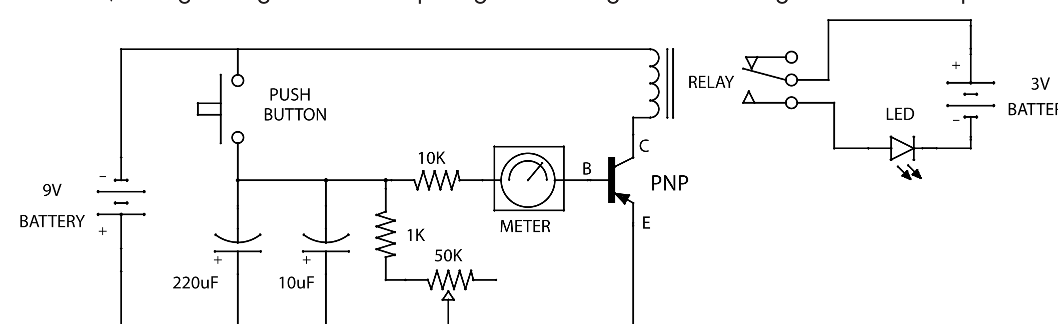
1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Move the Analog meter switch to the Ammeter setting (right).
3. [ ] Turn VR1 fully Counter-Clockwise.
4. [ ] Press the Push Button and note the LED and meter.
5. [ ] Turn VR1 to the 9 o'clock position. Use a stopwatch or timer to count the number of seconds the LED is on after you press and hold the switch.
6. [ ] By turning VR1 more in the Clockwise direction the time interval will increase.

WIRING CHART		
LENGTH	FROM	TO
Short	5	12
	12	34
	31	33
	32	34
	33	36
	46	66
	72	74
	69	84
Medium	6	35
	32	71
	36	73
	44	60
	45	73
	67	74
	68	75
	76	85
Long	61	11



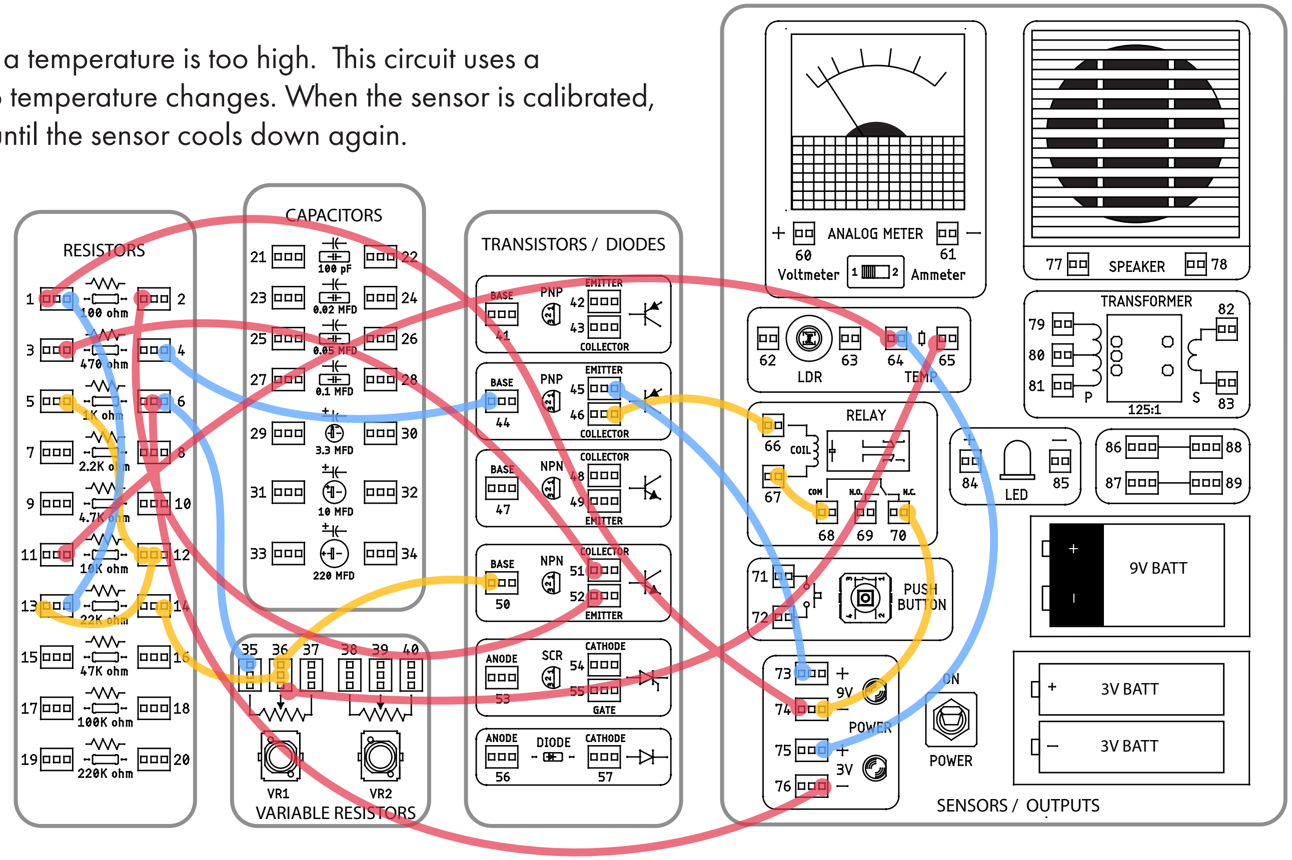
HOW IT WORKS

When the switch is pressed, the capacitors charge up very quickly. The capacitor is connected through the 10K resistor and Ammeter to the base of the transistor. The output of the transistor is connected to the relay coil, which in turn switches on the contacts and connects the 3V battery to the LED. When the button is released, the capacitor discharges through the 1K resistor and VR1. When the voltage at the base of the PNP transistor drops below a certain level it does not provide enough current to turn on the relay, and the relay turns off, extinguishing the LED. Adjusting VR1 changes the discharge rate of the capacitor.



PROJECT #21:
HEAT ALARM WITH BUZZER

Temperature alarms are used to regulate temperature or indicate when a temperature is too high. This circuit uses a thermistor, which is a special type of resistor designed to be sensitive to temperature changes. When the sensor is calibrated, it can sense a very small increase in temperature, turning on a buzzer until the sensor cools down again.

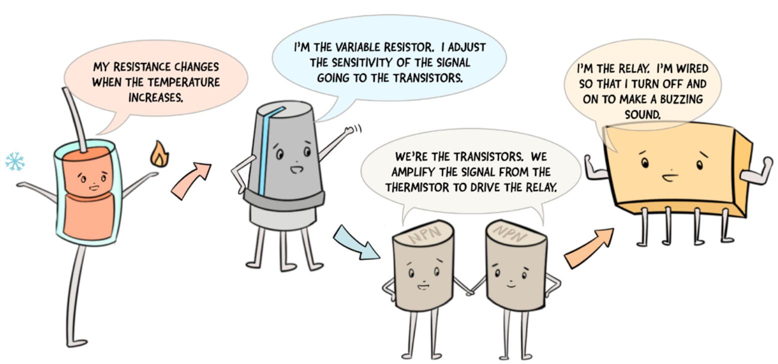


INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Touch the thermistor (TEMP sensor) with your finger for a few seconds.
3. [ ] While holding your finger on the sensor, turn VR1 Clockwise until the relay just starts to buzz.
4. [ ] Remove your finger. After a few seconds, the buzzing should stop.
5. [ ] Next, touch the thermistor on the sensor, and after a short period of time it will start buzzing again.
6. [ ] You can calibrate the sensor to detect hot or cooler temperatures, such as a hot cup of liquid.

WIRING CHART

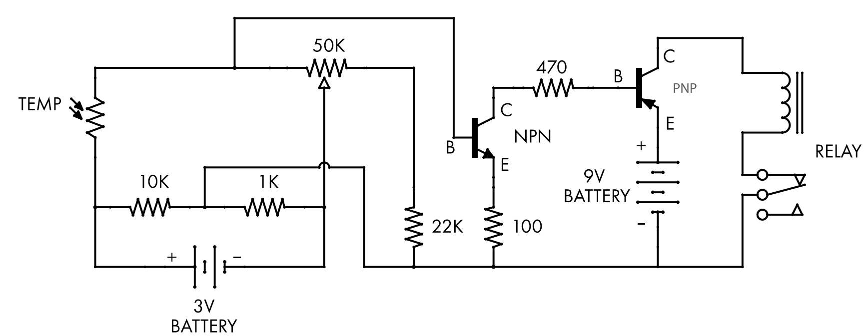
LENGTH	FROM	TO
Short	5	12
	12	13
	14	36
	36	50
	46	66
	67	68
	70	74
Medium	1	13
	4	44
	6	35
	45	73
	64	75
Long	1	74
	2	52
	3	51
	6	76
	11	64
	36	65



HOW IT WORKS

The thermistor (labeled TEMP) on the board is connected with a network of resistors called a Wheatstone bridge. This type of circuit is used to detect very small changes in resistance of a sensor. Once the resistance in the thermistor changes, the two-stage transistor network amplifies this value, and turns on the relay which is wired as a buzzer.

You may notice that the buzzing does not stop immediately when your finger is removed. This is because the body of the thermistor holds some heat for a short period of time, and takes some time to cool down.

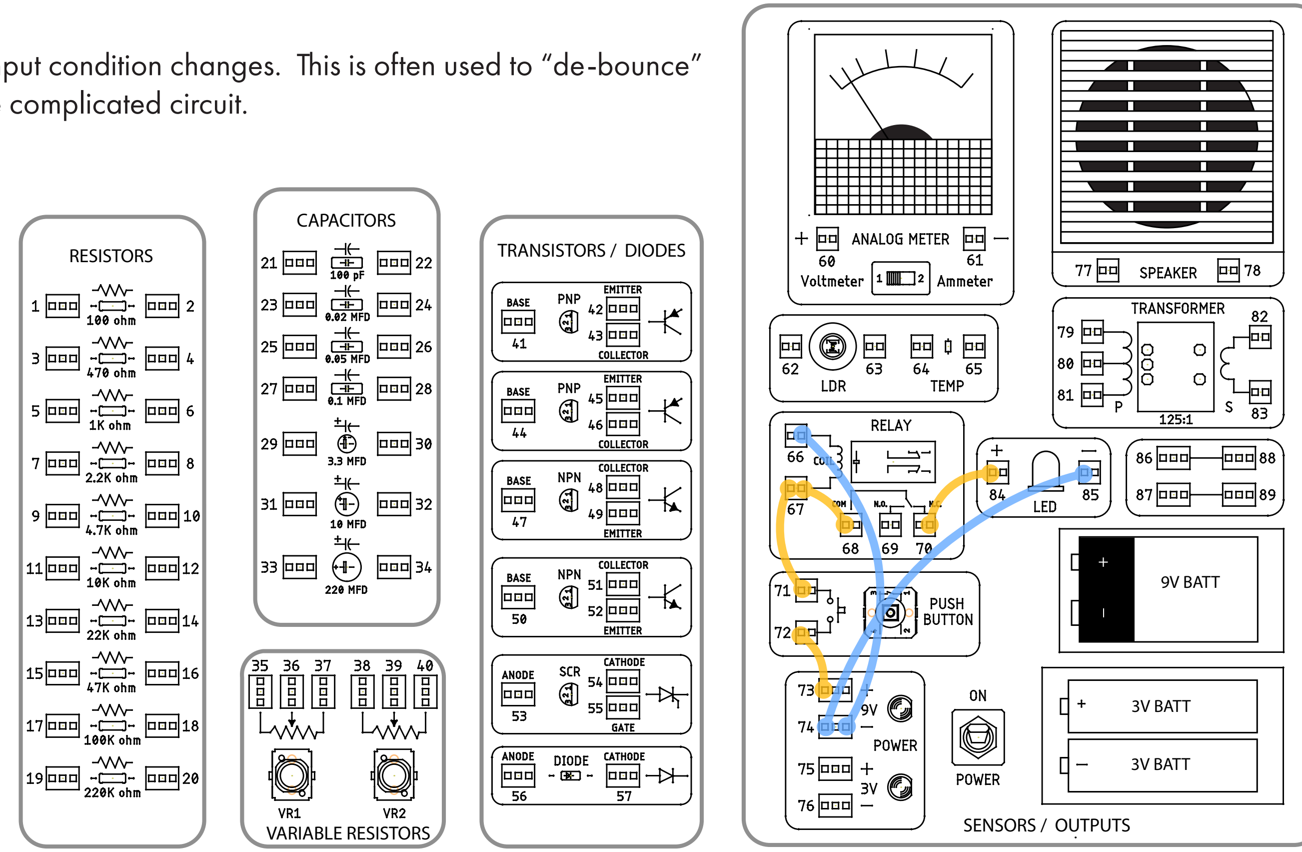


PROJECT #22:
ONE SHOT

"One Shots" are logic circuits that generate a short pulse when an input condition changes. This is often used to "de-bounce" switches (prevent multiple false pulses) or start a sequence in a more complicated circuit.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the button and observe the LED. Note that holding the push button does not change the state of the LED.
3. [ ] Release the button and then press it again.
4. [ ] Next, connect a wire between pins 69 and 72.
5. [ ] Press the button and the LED will light briefly. However, this time when you release and press the button it will not flash again.
6. [ ] Turn off the power and repeat step 3.

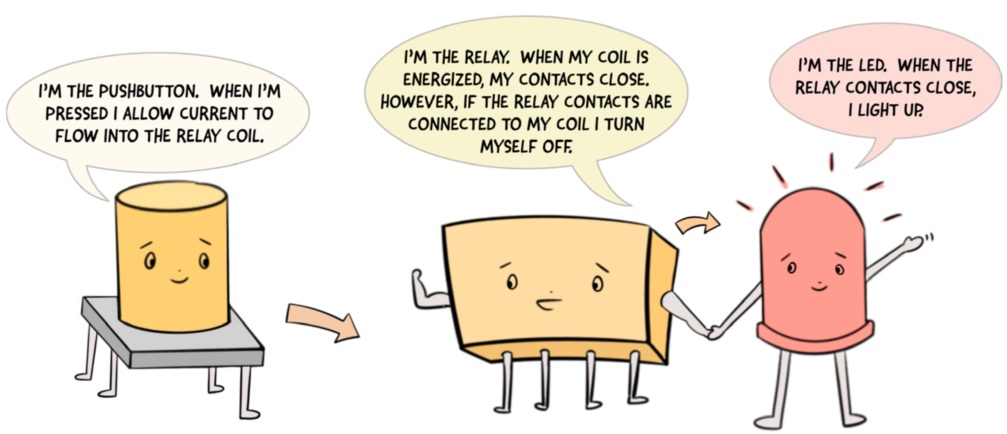


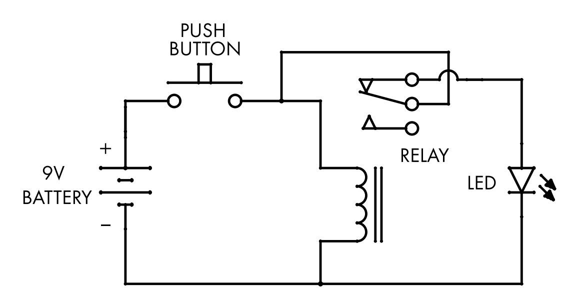
WIRING CHART		
LENGTH	FROM	TO
Short	67	71
	67	68
	70	84
	72	73
Medium	66	74
	74	85

HOW IT WORKS

This circuit uses the relay as a logic control device. When the button is pressed, the coil energizes through the normally closed (NC) contacts and the LED turns on. However, when the NC contacts open, it disconnects the switch from the LED, turning it off, even though the coil is still energized. This short pulse is due to the fact that the relay takes a short period of time to activate.

When the second wire in step 4 is connected, the relay is latched on when the pushbutton is pressed. However, because the LED is still connected to the NC contacts, it turns off.





PROJECT #23:
FSK CODER

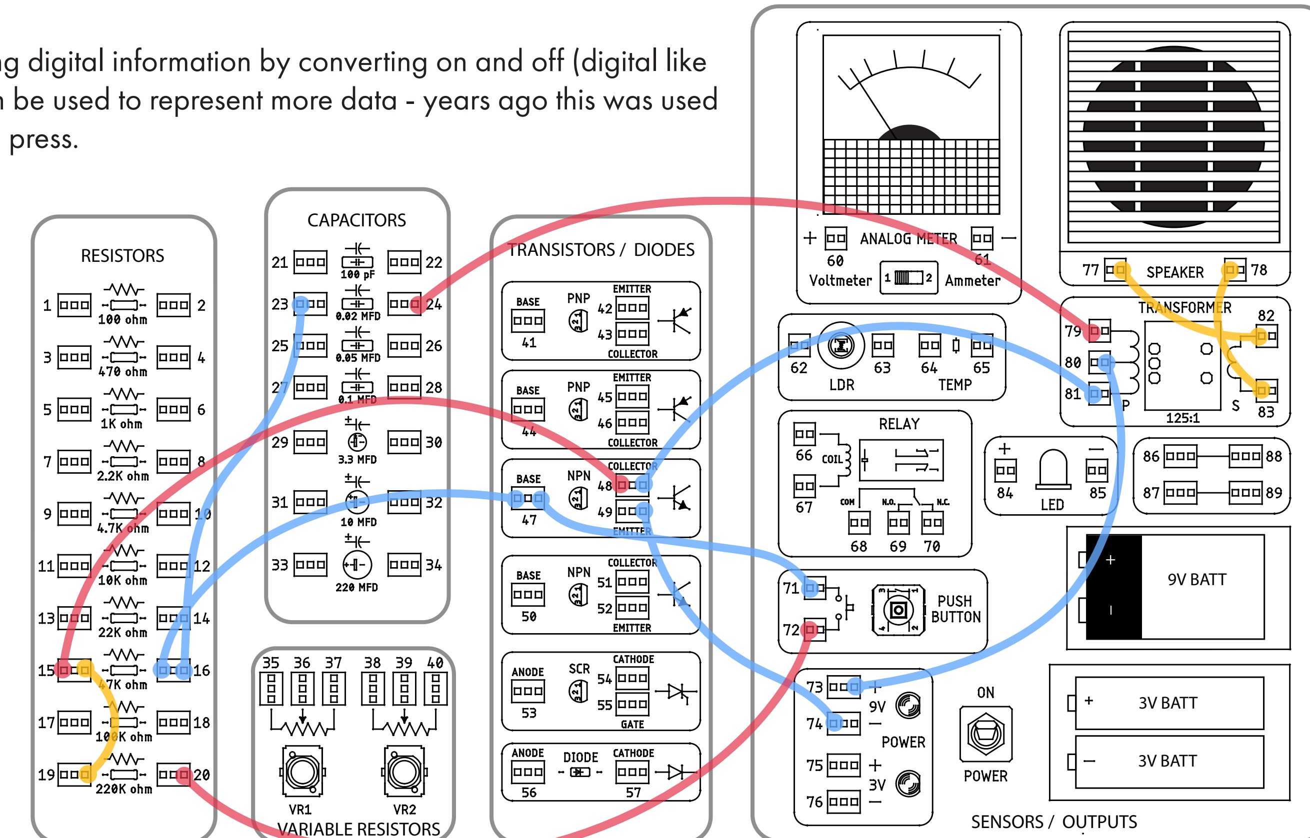
FSK stands for "Frequency Shift Keying." This is a way of transmitting digital information by converting on and off (digital like 0s and 1s) data into different frequencies. Multiple frequencies can be used to represent more data - years ago this was used with old phones that generated sets of frequencies with each button press.

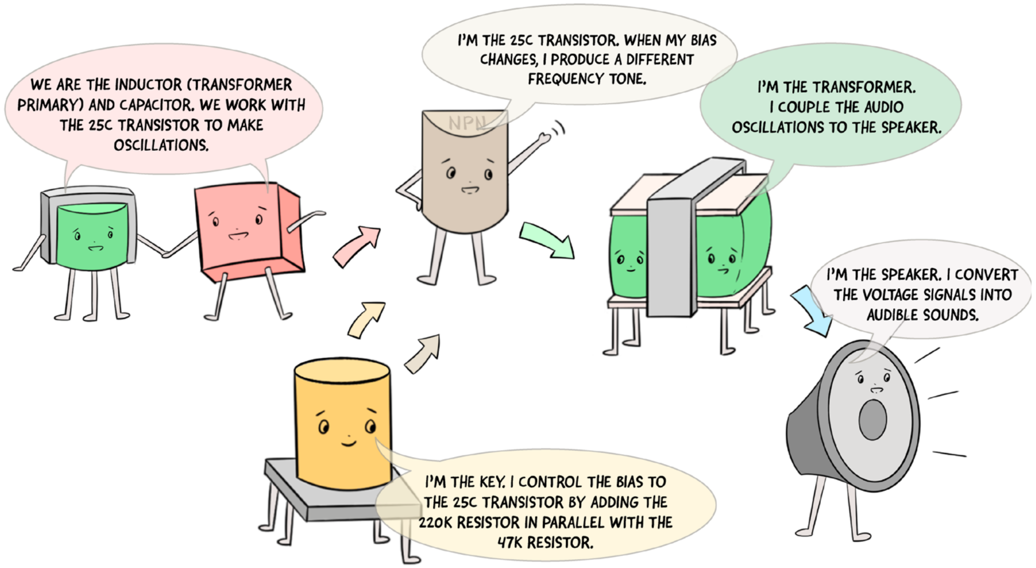
INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] A steady tone is generated by the oscillator.
3. [ ] Press the push button - what do you notice?

WIRING CHART

LENGTH	FROM	TO
Short	15	19
	77	82
	78	83
Medium	16	23
	16	47
	47	71
	48	81
	49	74
	73	80
Long	15	48
	20	72
	24	79

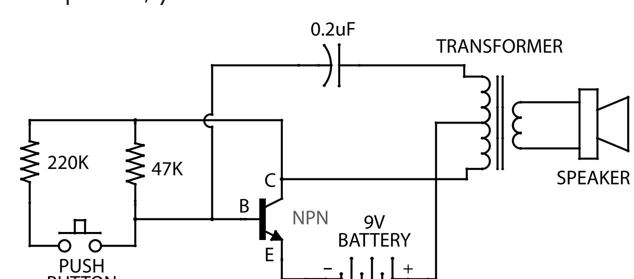




HOW IT WORKS

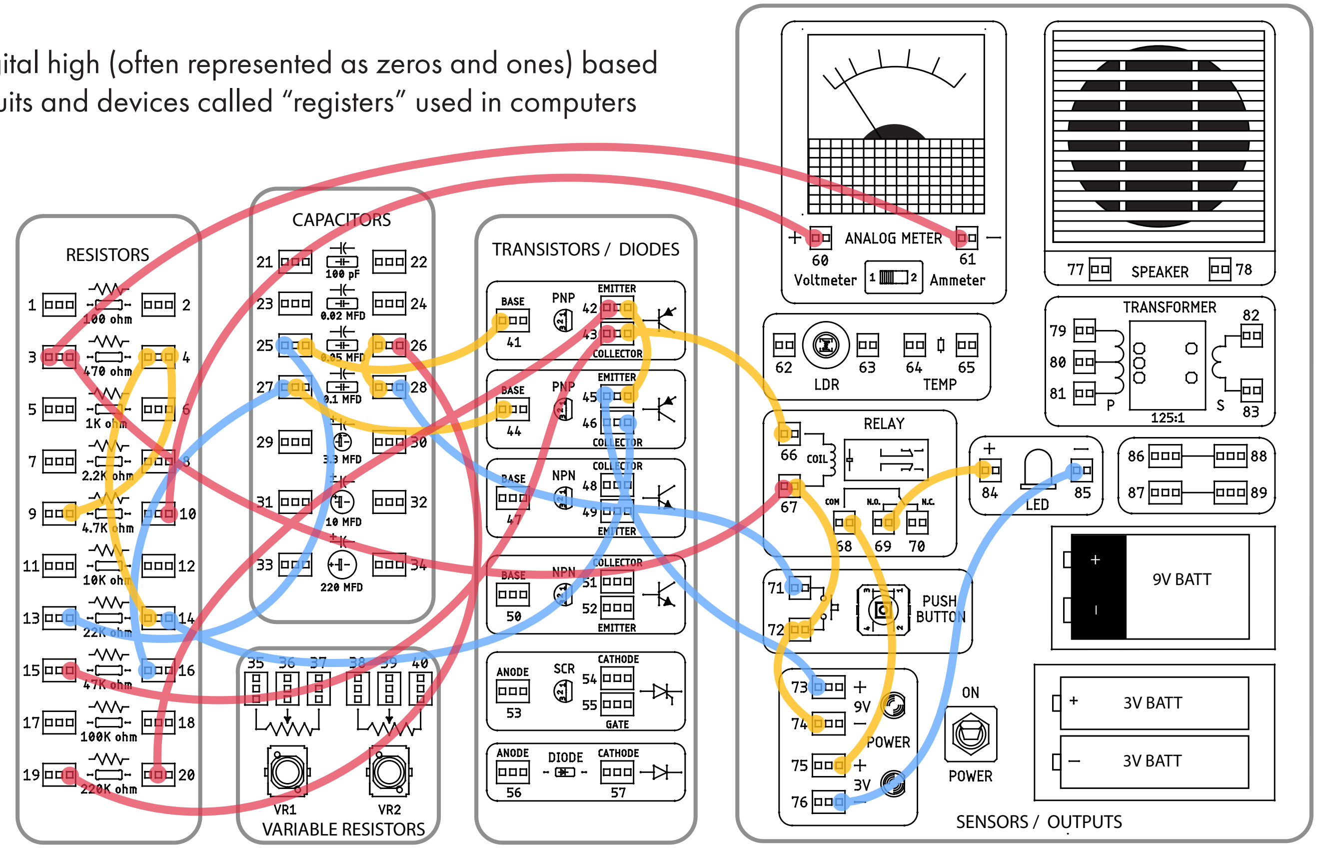
This circuit is a simple transistor oscillator that uses the 0.02uF capacitor to generate feedback, which generates a tone that we can hear. The frequency of the circuit is dependent on the RC constant of the capacitor and 47K resistor. When the button is pressed, the 220K resistor is connected in parallel with the 47K resistor, which lowers the R value. This in turn increases the frequency of the tone.

In order to "read" the data on the other end, you would need a circuit that can detect the frequencies and convert them back into on and off values. By changing the value of the resistors or the capacitor, you can create different sets of tones.



PROJECT #24:
FLIP - FLOP

A flip-flop is a digital circuit that alternates from a digital low to a digital high (often represented as zeros and ones) based on the input signal. Flip flops are the building blocks of memory circuits and devices called "registers" used in computers which "remember" data or the state a circuit is in.

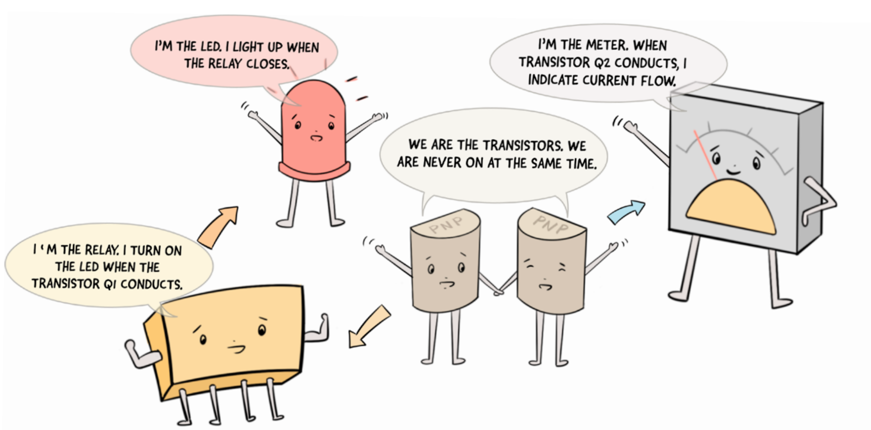


INSTRUCTIONS

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Slide the meter switch to the Voltmeter position.
3. [ ] Note the state of the LED and the meter (The meter represents an off (zero) state and the LED represents the on (one) state .
4. [ ] Press the push button - what do you notice?
5. [ ] Press the push button again - what do you notice?

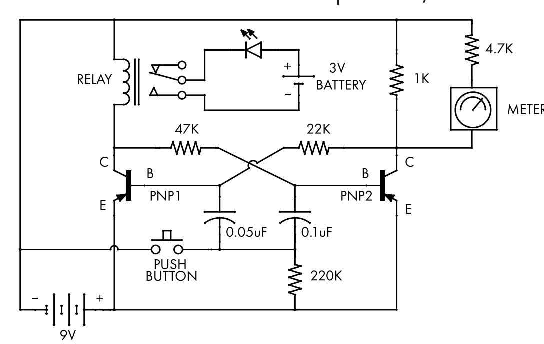
WIRING CHART

LENGTH	FROM	TO
Short	4	9
	4	14
	25	41
	26	28
	27	44
	42	45
	66	43
	67	72
	68	75
	69	84
	72	74
Medium	13	25
	14	46
	16	27
	28	71
	73	45
	76	85
Long	3	61
	3	67
	10	60
	15	43
	19	26
	20	42



HOW IT WORKS

If you look carefully at the schematic you will see that some of the wires connecting the transistors look like an "X." This indicates that the output of each transistor is affecting the input of the other transistor. This is very typical of all flip-flop circuits where the states of each side of the circuit are opposite each other. Before the button is pressed, the first PNP transistor (Q1) is on. The output of Q1 is connected to the base of Q2, and turns it off. When the button is pressed, a negative pulse is generated at the base of Q2, turning it on. This in turn turns on the meter, but also turns off Q1. Each time the button is pressed, the two states changed, hence the name "flip-flop"

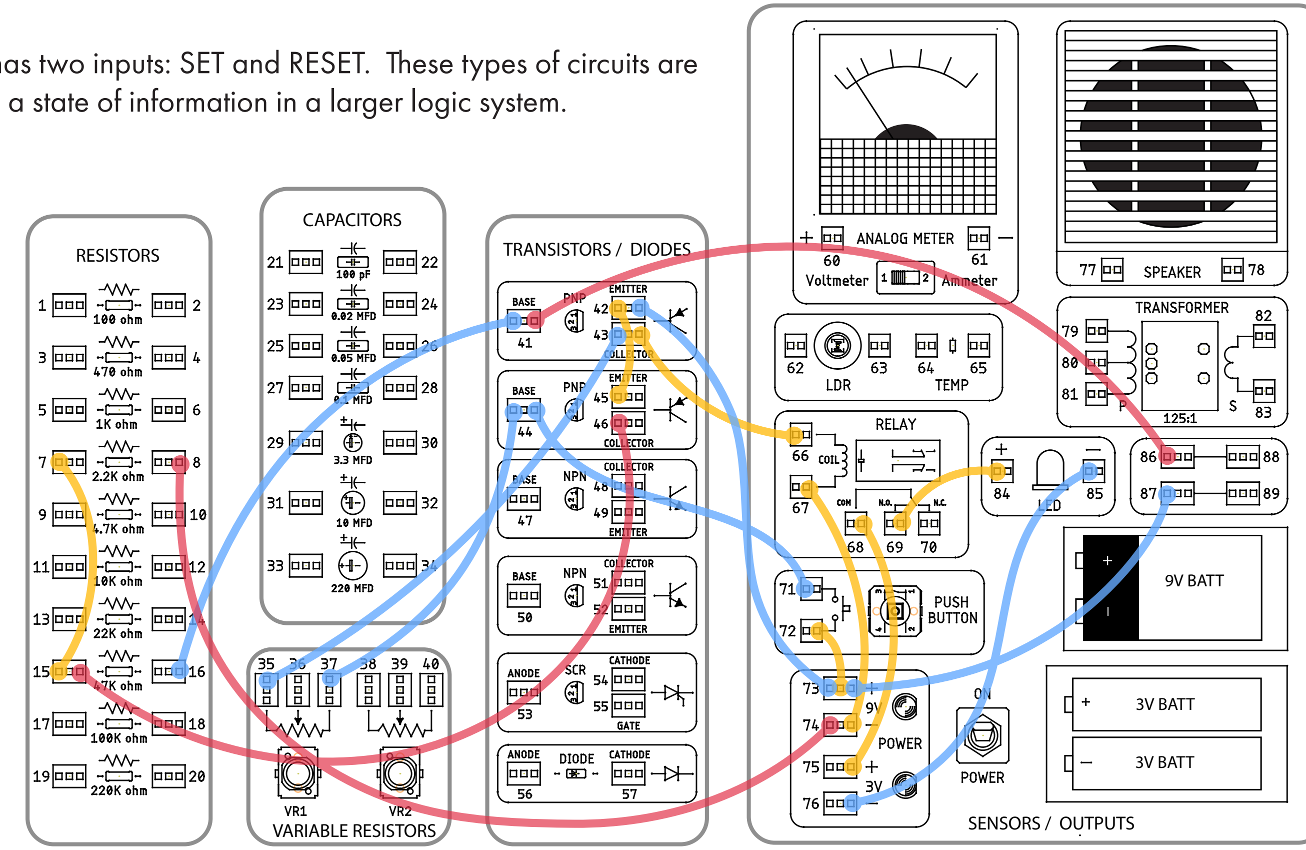


PROJECT #25:
SR LATCH

An SR (Set-Reset) latch is different compared to a flip flop in that it has two inputs: SET and RESET. These types of circuits are also used for memory (storing a bit of data) and as registers to hold a state of information in a larger logic system.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the pushbutton and notice the state of the LED.
3. [ ] In order to reset the LED, connect a jumper between pins 88 and 89.

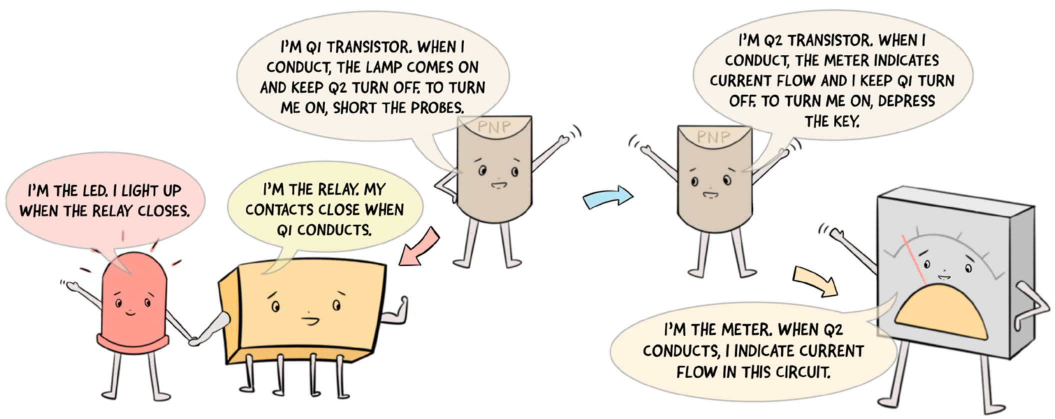


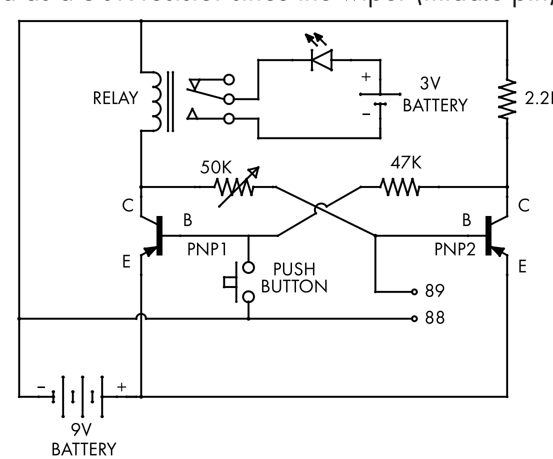
WIRING CHART

LENGTH	FROM	TO
Short	7	15
	42	45
	43	66
	67	74
	68	75
	69	84
	72	73
Medium	16	41
	35	43
	37	44
	42	73
	44	71
	73	87
	76	85
Long	8	74
	15	46
	41	86

HOW IT WORKS

The SR latch is similar to the flip-flop; however there are two inputs instead of one. However, since the changes move to a fixed no capacitors are required. The LED lights when the coil is energized. Note that although two wires are connected to VR1, it is only being used as a 50K resistor since the wiper (middle pin) is not connected.

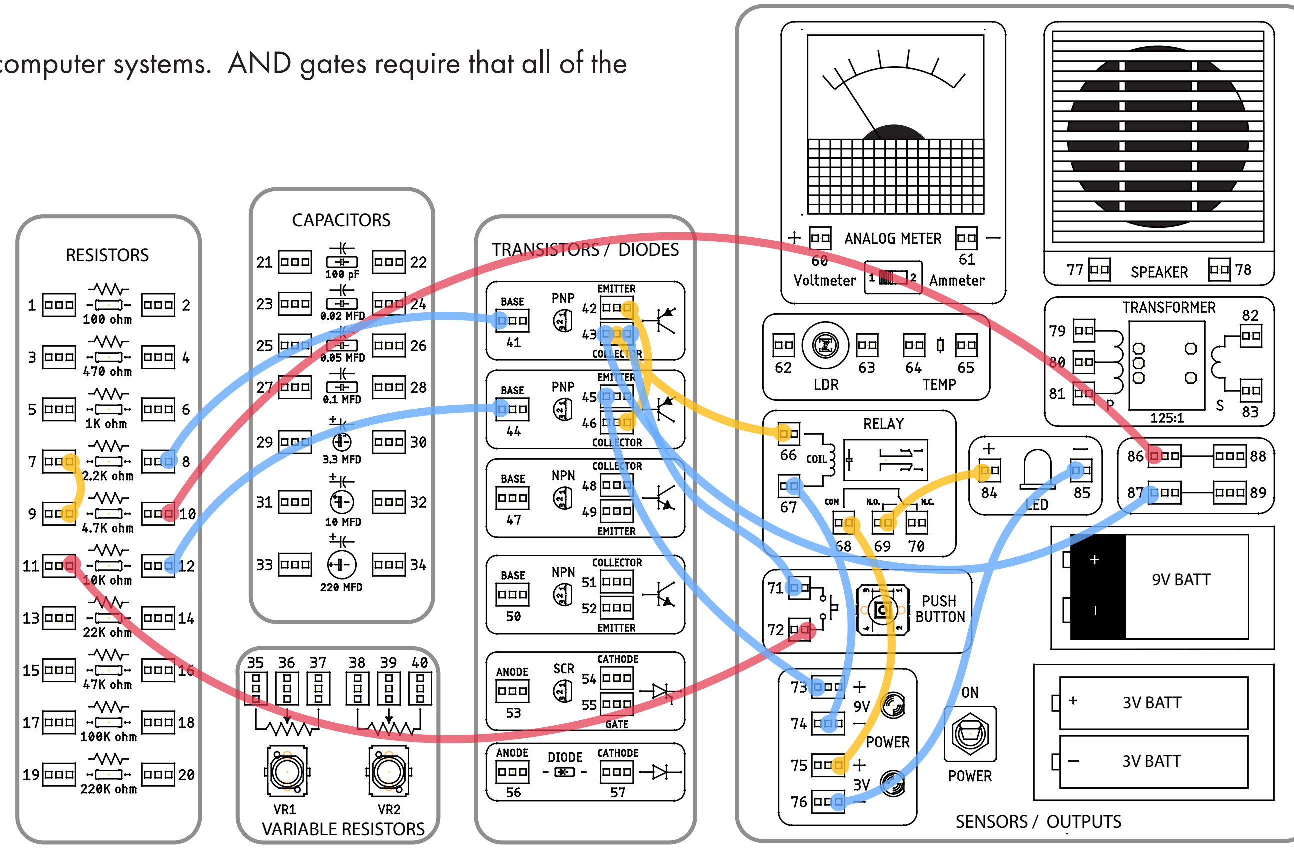




PROJECT #26:

AND GATE

A "gate" is one of the most basic logic devices used for digital and computer systems. AND gates require that all of the inputs are on in order for the output to be on.



INSTRUCTIONS:

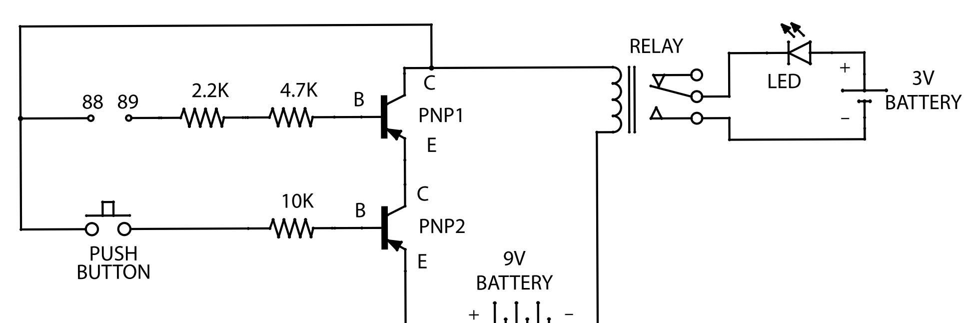
1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Press the pushbutton (this is input "A" on the AND gate. Notice the state of the LED.
3. [ ] Release the pushbutton
4. [ ] Connect a jumper between pins 88 and 89 (this is input B on the AND gate). Notice the state of the LED.
5. [ ] With the jumper still connected, press the push button. This represents both inputs A and input B on at the same time.

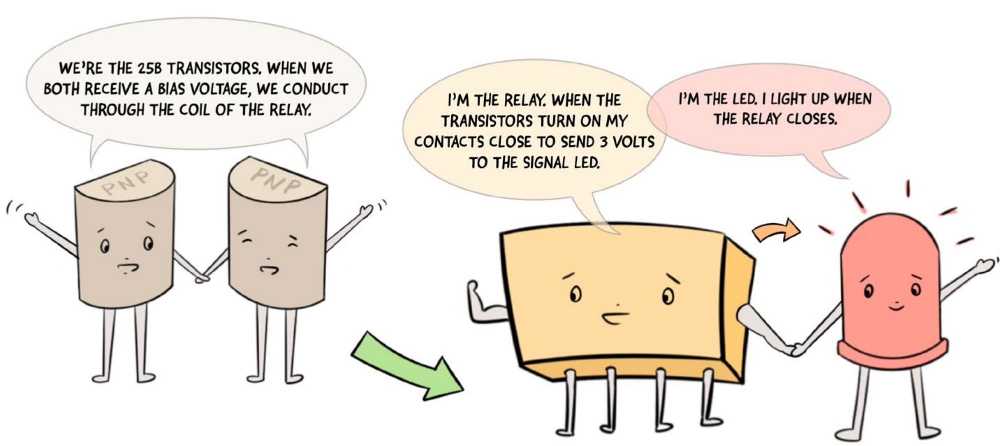
WIRING CHART

LENGTH	FROM	TO
Short	7	9
	42	46
	43	66
	75	68
	69	84
Medium	8	41
	12	44
	43	87
	43	71
	45	73
	67	74
	76	85
Long	10	86
	11	72

HOW IT WORKS

If you look carefully at the schematic you can see that the outputs of the two transistors are wired in series, creating a loop that can allow current to flow from the battery into the relay coil. In order for both transistors to be turned on, current must flow into the base (B) terminals of both transistors. If only one switch is on, current will not flow through both outputs, so the coil will not energize.



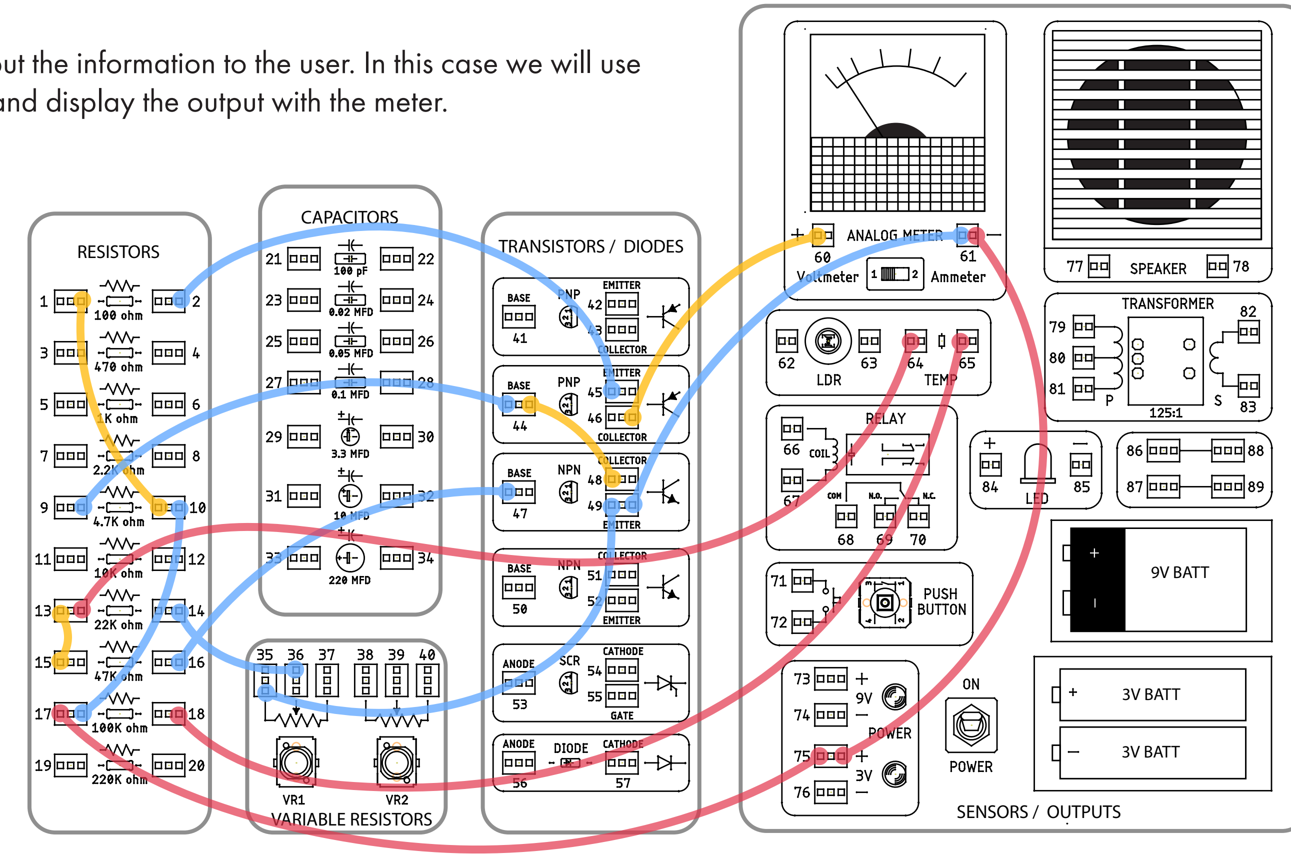


PROJECT #27:
ANALOG THERMOMETER

A thermometer can measure the temperature using a sensor and output the information to the user. In this case we will use a thermistor (temperature sensitive resistor) to sense the temperature and display the output with the meter.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Slide the meter switch to the Ammeter position (to the right).
3. [ ] Before turning on the circuit, turn VR1 completely counterclockwise.
4. [ ] Turn on the power, and slowly turn up VR1 until it displays a reading (less than 0.2mA).
5. [ ] Rub your fingers together until they get warm and touch the TEMP sensor (thermistor).
6. [ ] The meter will display a change of temperature. After you move your fingers, blow on the sensor to cool it off.
7. [ ] You can also use a hot cup of water or ice cubes to see the different measurements - note that you may have to adjust VR1 to adjust the meter reading.

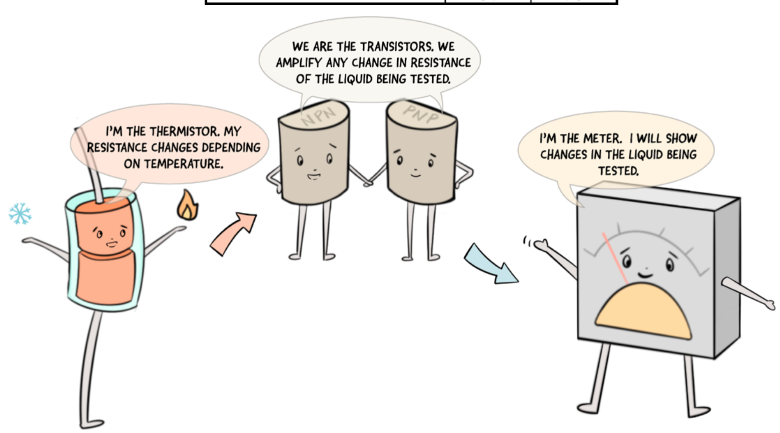


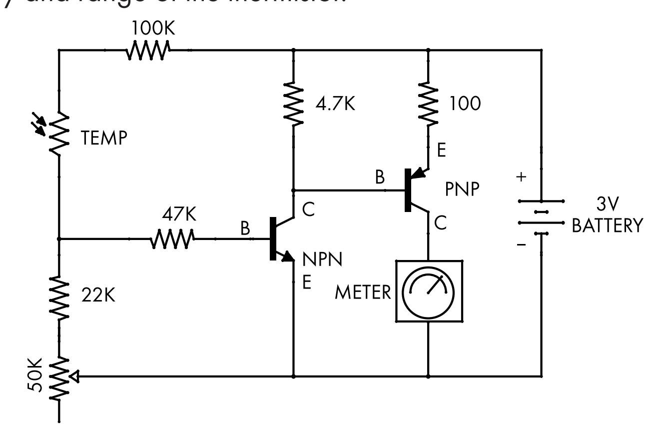
WIRING CHART

LENGTH	FROM	TO
Short	1	10
	13	15
	44	48
	46	60
Medium	2	45
	9	44
	10	17
	14	36
	16	47
	35	49
	49	61
Long	13	64
	17	75
	18	65
	61	76

HOW IT WORKS

In this circuit the thermistor is connected as a voltage divider with VR1, the 22K and 100K resistors. As the temperature changes, the thermistor resistance changes, changing the voltage present at the left side of the 47K resistor. This voltage change is amplified by the NPN transistor and fed to the PNP transistor to drive the meter. VR1 is used to adjust the voltage sensitivity and range of the thermistor.



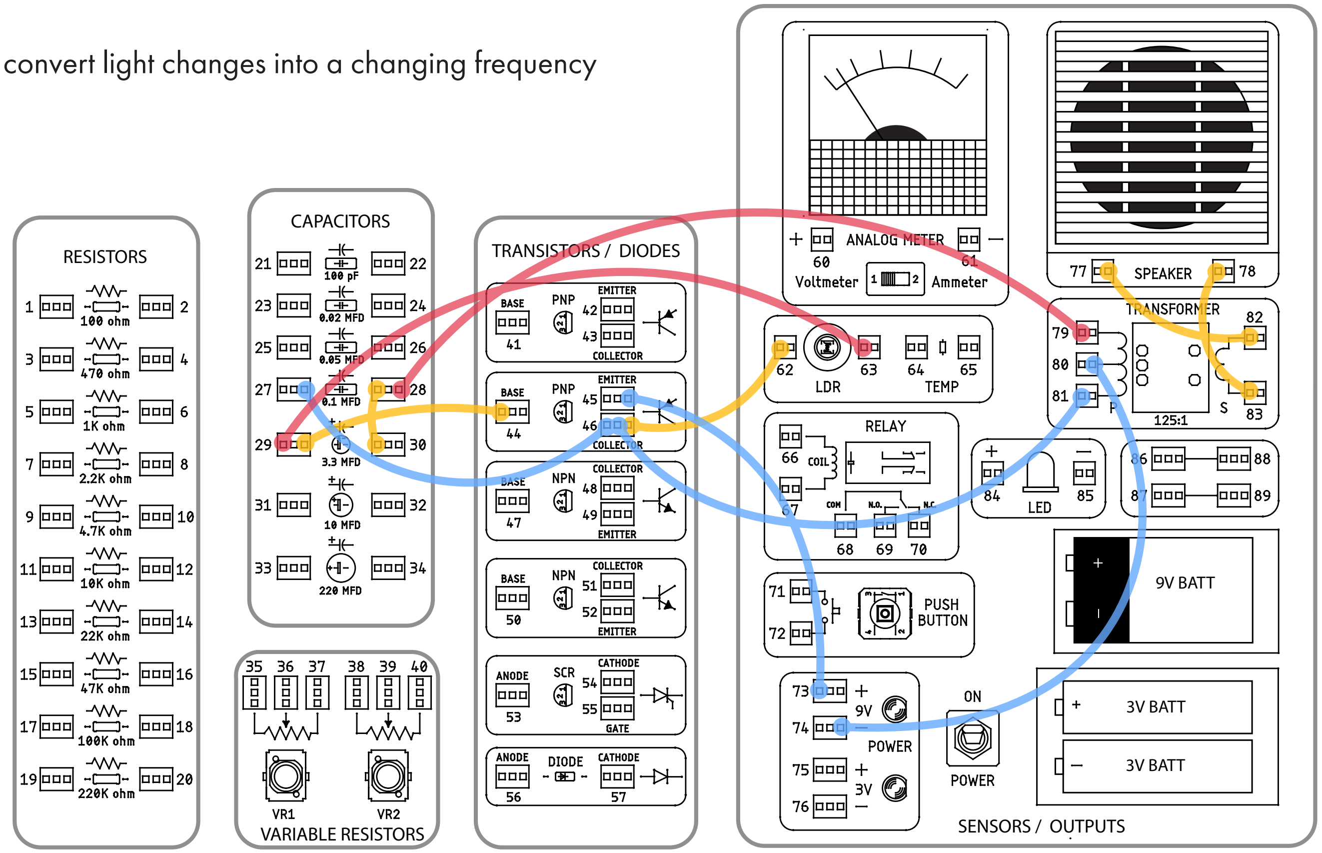


PROJECT #28:
AMPLIFIED LIGHT OSCILLATOR

This simple circuit uses a single NPN transistor and the transformer to convert light changes into a changing frequency or tone.

INSTRUCTIONS:

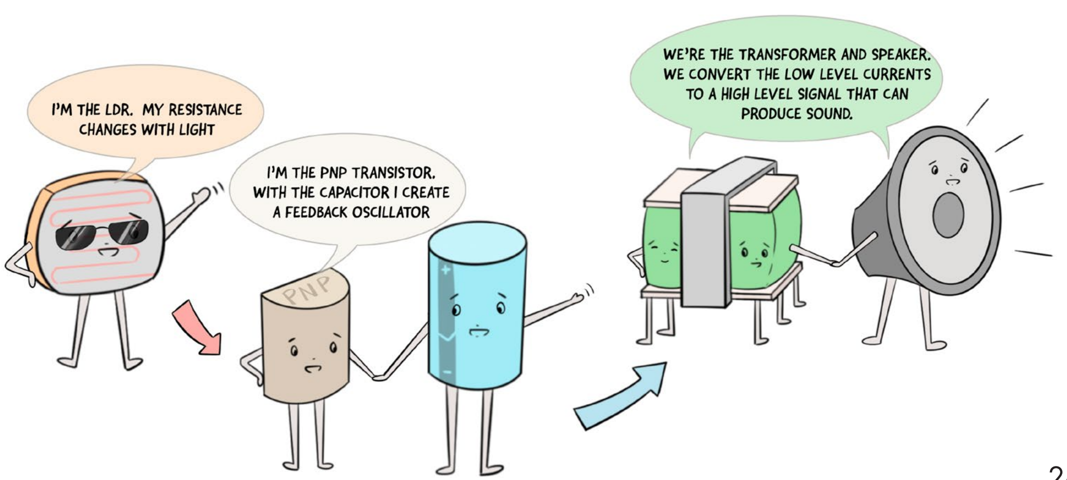
1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Use your hand to block the light of the LDR, or shine light on it to change the pitch of the tone coming from the speaker.
3. [ ] If the volume is too loud you can connect the 100 ohm resistor between pins 82 and 77.
4. [ ] By changing the wires going to the 3.3uF capacitor to the 10uF or 220uF capacitor you can lower the frequency considerably.

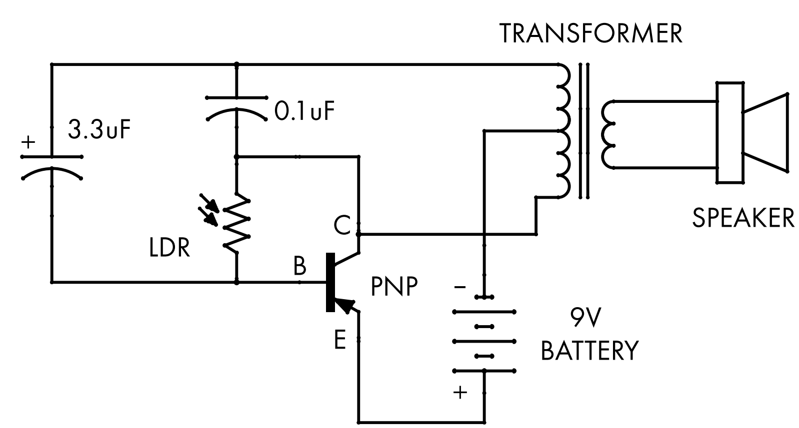


WIRING CHART		
LENGTH	FROM	TO
Short	28	30
	29	44
	46	62
	77	82
	78	83
Medium	27	46
	45	73
	46	81
	74	80
Long	28	79
	29	63

HOW IT WORKS

The transistor is wired as an amplifier with the 0.02uF capacitor as a feedback device which causes the signal to oscillate. The LDR changes the voltage across the base, and combined with the larger capacitor changes the frequency of the signal.





PROJECT #29:
LIGHT METER

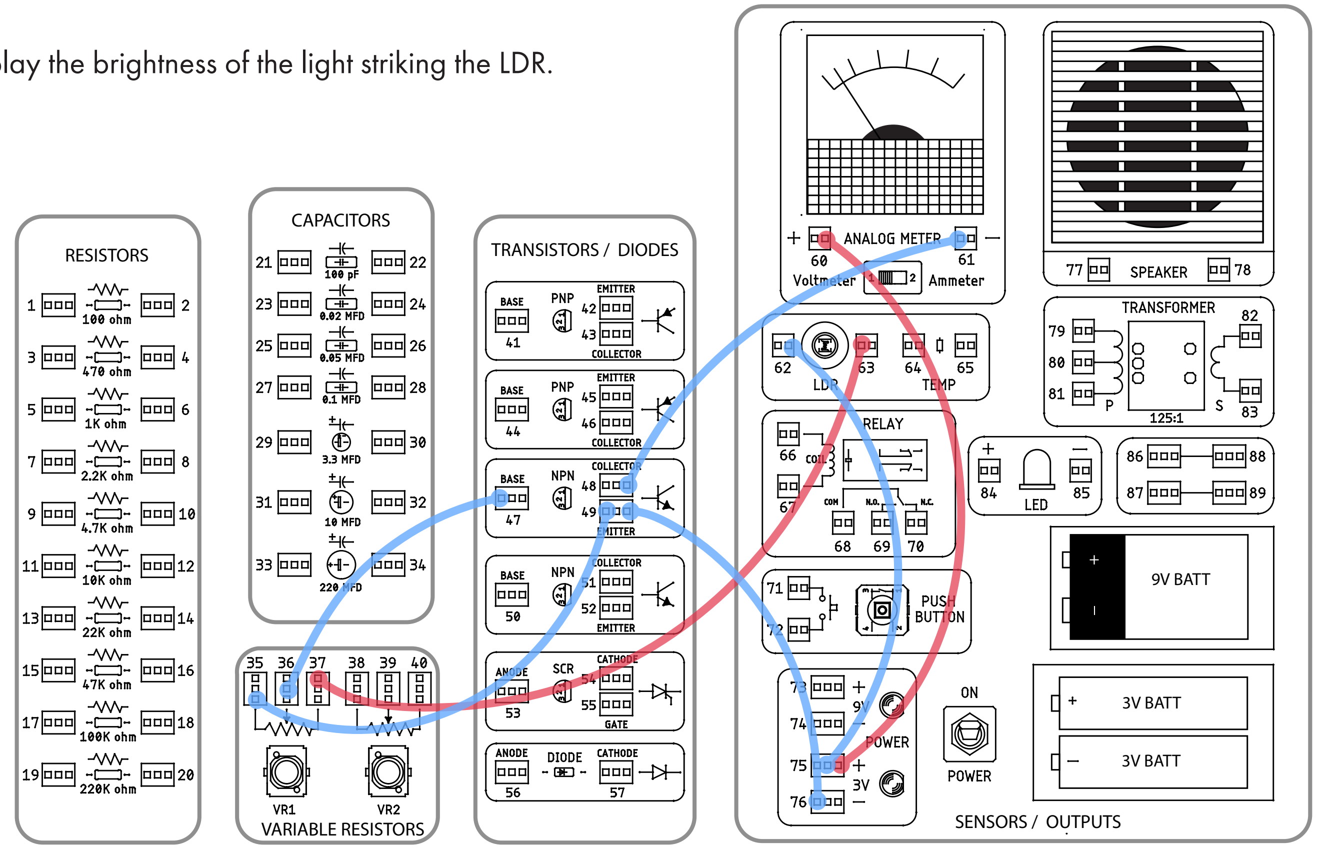
This simple circuit uses a single NPN transistor, LDR and meter to display the brightness of the light striking the LDR.

INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Turn VR1 completely counter clockwise.
3. [ ] Adjust the project box or a light to shine down on the LDR tube.
4. [ ] Slowly turn VR1 clockwise until the meter starts moving. Keep turning VR1 it so that the meter is on the 1.0 value.
5. [ ] Block the LDR tube to see the change on the meter.
6. [ ] You can adjust VR1 to change the sensitivity for different light levels.

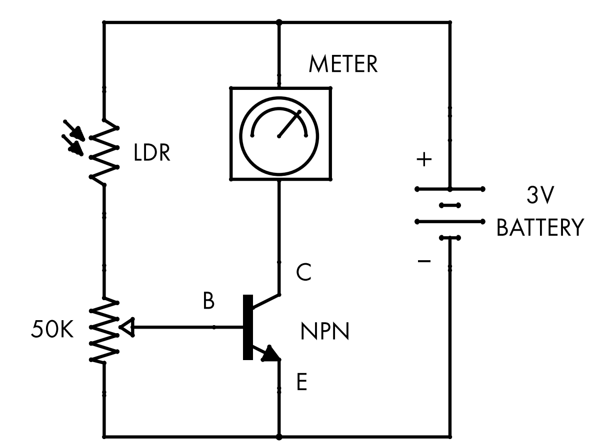
WIRING CHART

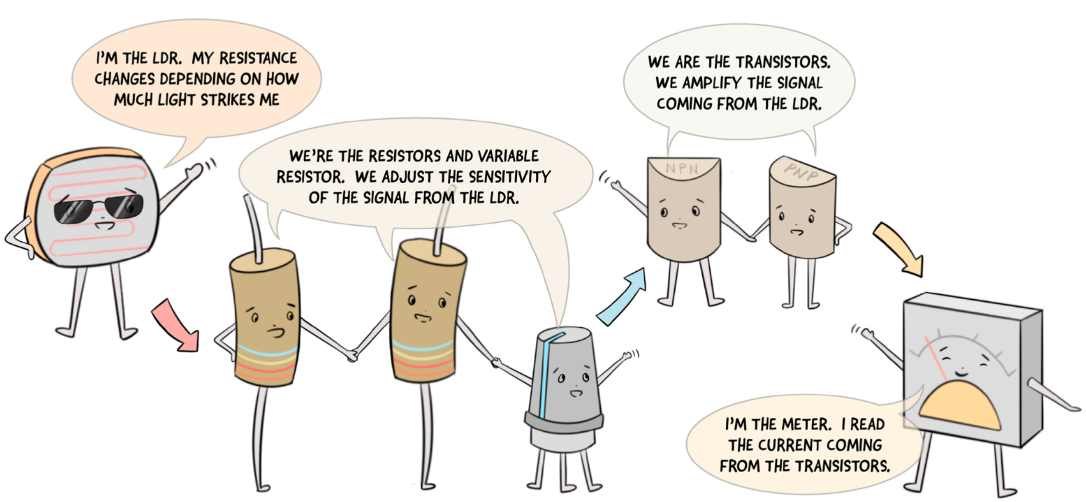
LENGTH	FROM	TO
Medium	35	49
	36	47
	48	61
	49	76
	62	75
Long	37	63
	60	75



HOW IT WORKS

The transistor is wired as a simple current amplifier to drive the meter. The LDR and VR1 are wired as a voltage divider so that the voltage level at the base of the NPN transistor can be adjusted.



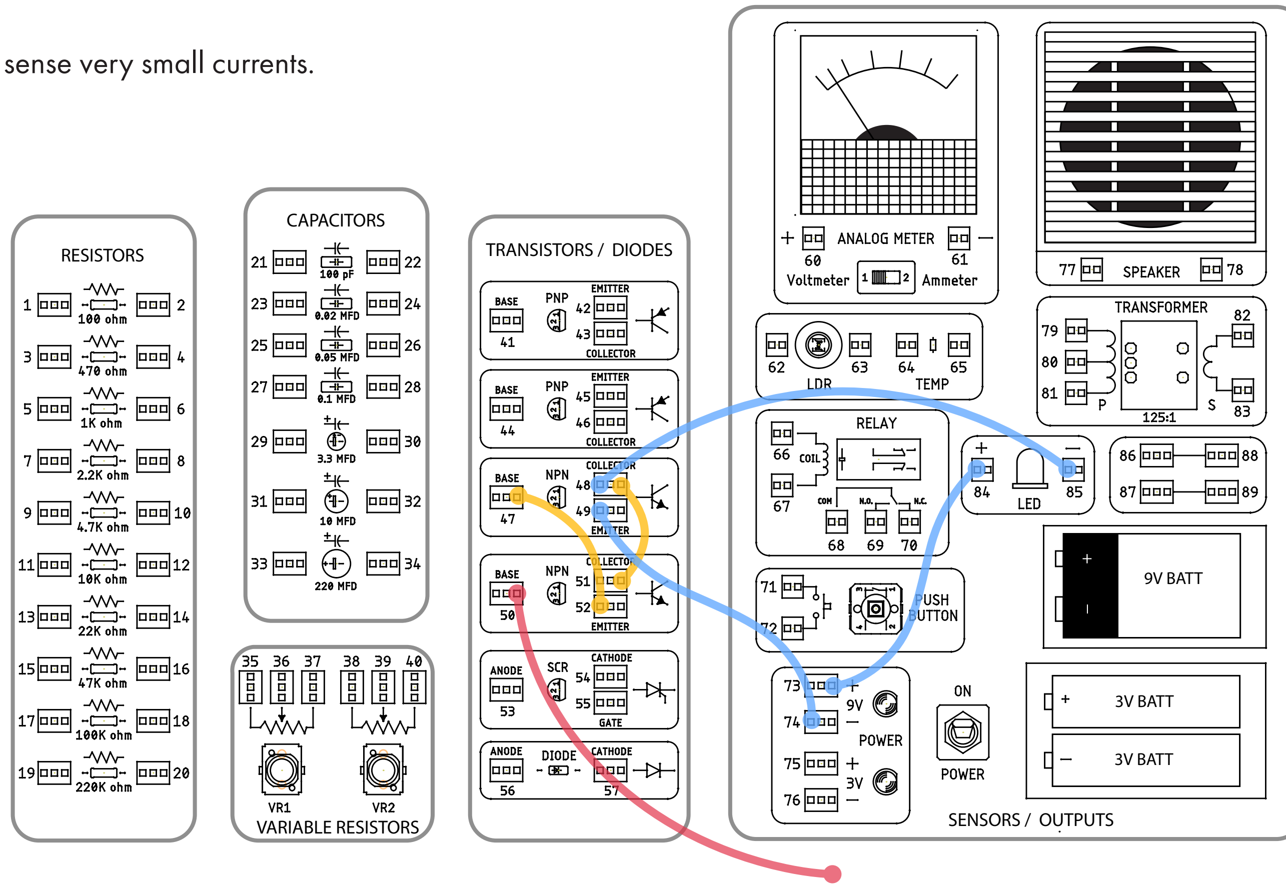


PROJECT #30:
TRANSISTOR STATIC ELECTRICITY SENSOR

This circuit demonstrates how two transistors can be wired together to sense very small currents.

INSTRUCTIONS:

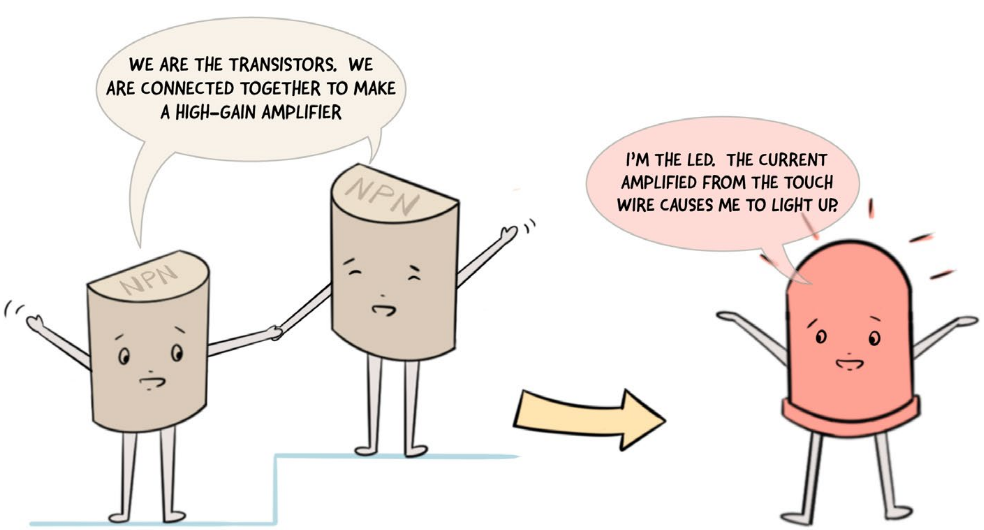
1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Connect a wire with one end to pin 50. The other end does not need to be plugged in.
3. [ ] Move your hand close to the wire - the LED should light up, but may be dim.
4. [ ] Touching the outside of the wire should make the LED glow brighter. You can also rub your feet on the ground or have someone else stand close to you to light the LED!

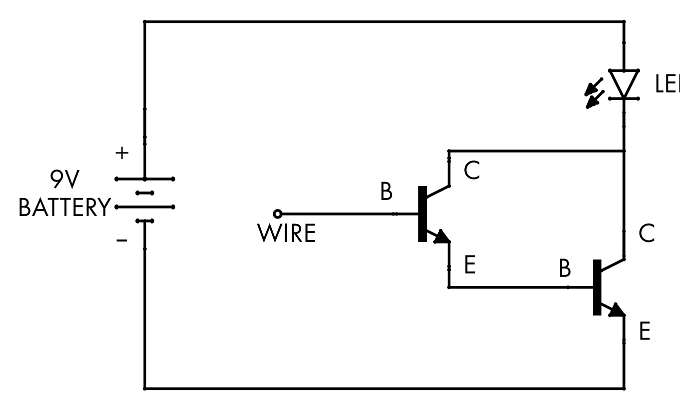


WIRING CHART		
LENGTH	FROM	TO
Short	47	52
	48	51
Medium	48	85
	49	74
	73	84
Long	50	xx

HOW IT WORKS

This circuit uses two transistors wired into a “Darlington” configuration. This type of circuit allows the gain, or amplification of the transistors to be multiplied together. The current flowing through your body is very small, but the two transistors work together to turn these tiny currents into larger currents that light the LED.



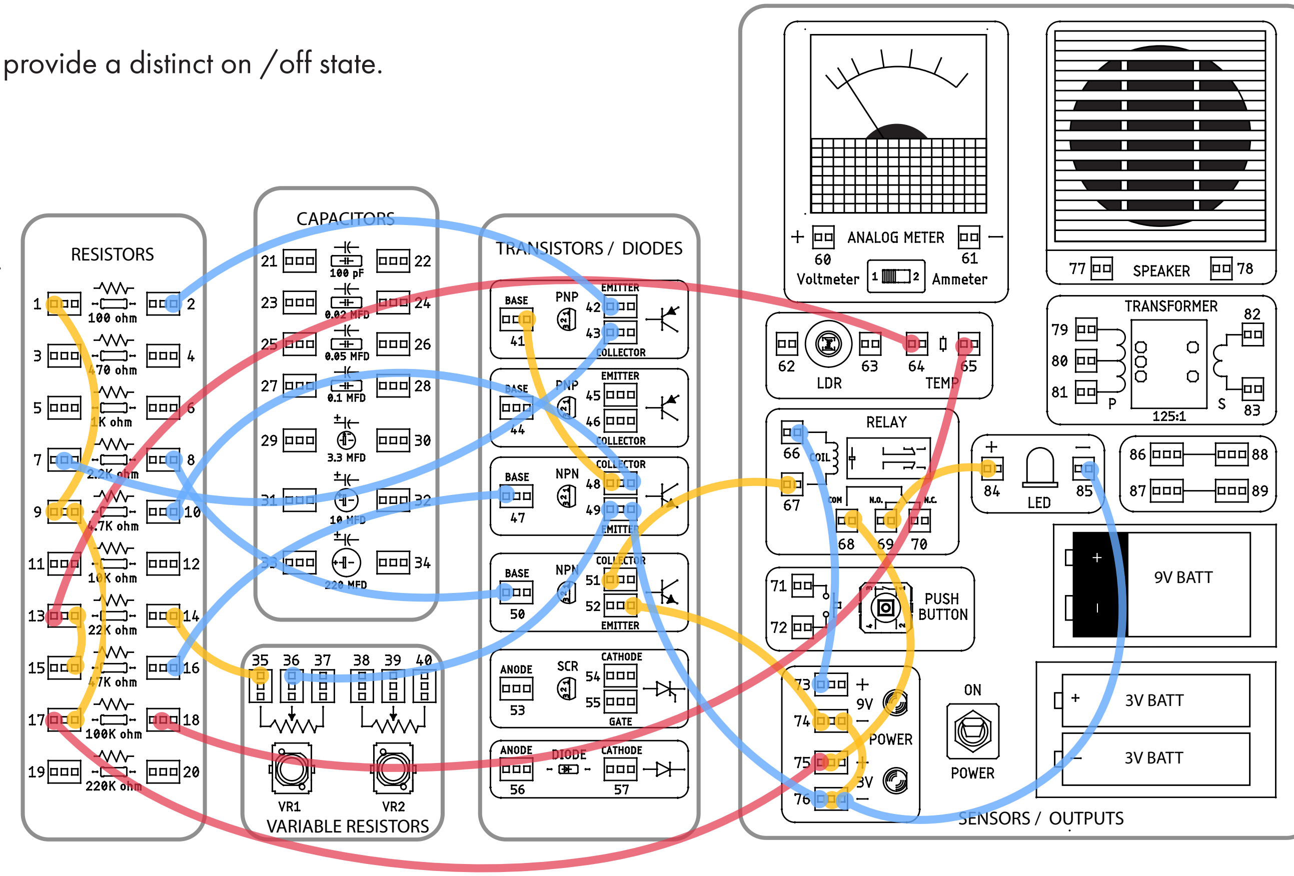


PROJECT #31:
RELAY SWITCHED THERMOMETER

Although similar to project 27, this temperature sensor uses a relay to provide a distinct on / off state.

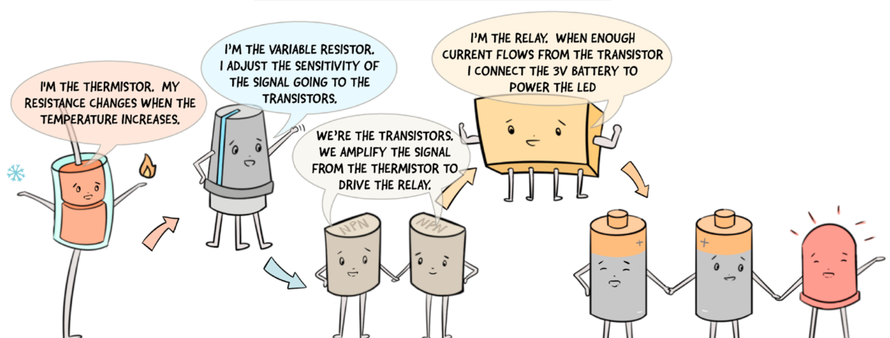
INSTRUCTIONS:

1. [ ] Complete the wiring as seen in the wiring chart.
2. [ ] Before turning on the circuit, turn VR1 completely counterclockwise.
3. [ ] Turn on the power, and slowly turn up VR1 until the LED turns on.
4. [ ] Back off VR1 until the LED just turns off.
5. [ ] Rub your fingers together until they get warm and touch the TEMP sensor (thermistor).
6. [ ] The LED should turn on. After you move your fingers, blow on the sensor to cool it off. The LED should turn off.
7. [ ] You can also use a hot cup of water or ice cubes to see the different measurements - note that you may have to adjust VR1 to adjust the meter reading.



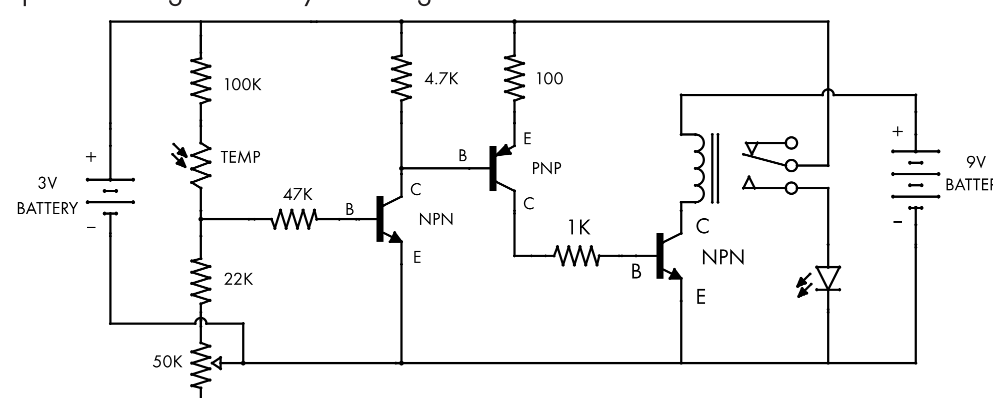
WIRING CHART

LENGTH	FROM	TO
Short	1	9
	9	17
	13	15
	14	35
	41	48
	51	67
	52	74
	68	75
	69	84
	74	76
Medium	2	42
	7	43
	8	50
	10	48
	16	47
	36	49
	49	76
	66	73
	76	85
Long	13	64
	17	75
	18	65



HOW IT WORKS

In this circuit the thermistor is connected as a voltage divider with VR1, the 22K and 100K resistors. As the temperature changes, the thermistor resistance changes, changing the voltage present at the left side of the 47K resistor. This voltage change is amplified by the NPN transistor and fed to the PNP transistor to drive the relay coil. VR1 is used to adjust the voltage sensitivity and range of the thermistor.



CREDITS

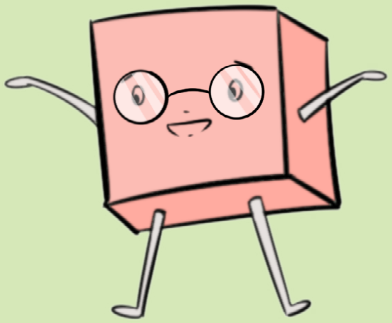
CREATOR
Tom Thoen

CONCEPT ARTIST / GRAPHIC DESIGNER / PACKAGING DESIGN
Tiffany Tong

LASER CUTTING / TECHNICAL INPUT
Kino Davita

3D CAD DESIGN / 3D PRINTINNG
Roman Sanchez

SPECIAL THANKS TO SUPPLY FRAME DESIGN LAB
Majenta Strongheart
Giovanni Salinas



Created by Tom Thoen and Tiffany Tong