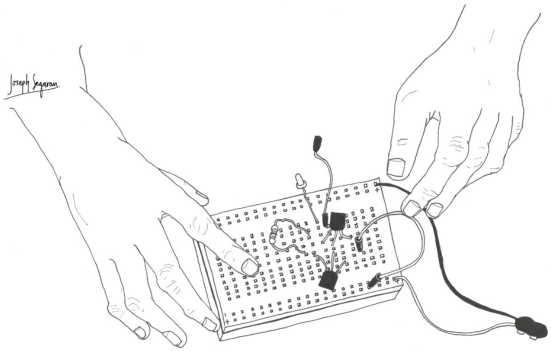
Ten Experiments in Electronics for Students



These are real experiments aimed at showing students of electronics how various devices behave. Resistors, Capacitors, Inductors, Diodes, Zeners, Transistors and Relays are covered. If you want flashing lights and sound effects then this kit is not for you. If you want to start on a path of learning about electronic devices then this kit is a very good place to start.

SF Innovations Ltd

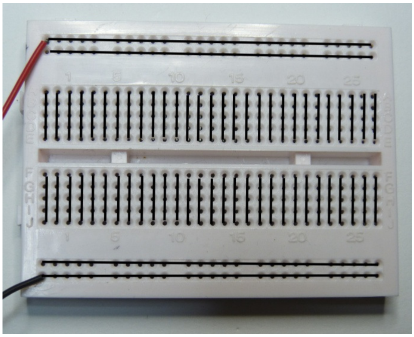
Kit contains:

Prototyping Board
Jumper leads
Assorted resistors
Light Emitting Diodes (LEDs)
Diode
Switch
Capacitors
Transistors
Relay
Zeners
PP3 (9V) battery clip (battery not supplied)
Book of experiments

Prototyping board

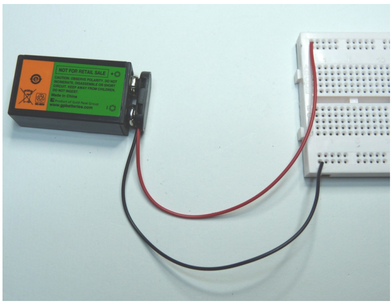
This is very useful for experimentation with electronics. Components can be quickly plugged in and circuits tried out. The electrical connections within the prototyping board are shown below.

In this image you can see that the top rail is being used for the +ve voltage connection and the bottom rail is being used for the 0V connection.



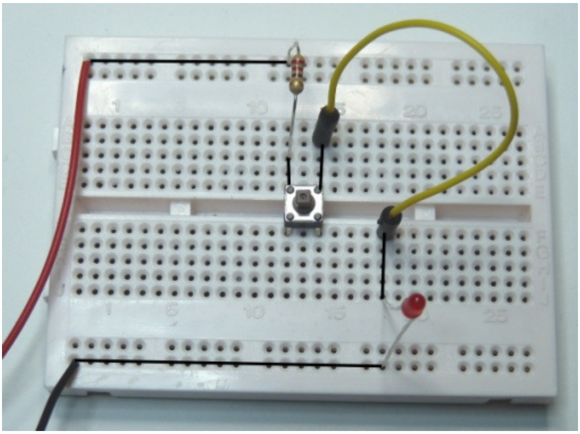
PP3 battery connector

This is used to connect a voltage to the prototyping board. (The battery is not supplied - it's best to use a rechargeable 9V PP3 battery here).

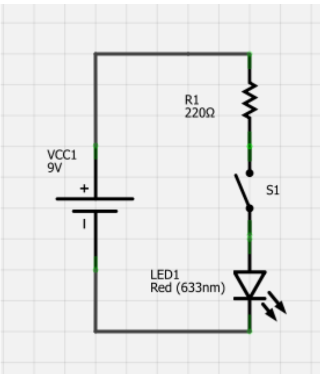


Experiment 1: Circuit with LED

Objective: Build a simple circuit with a switch and Light Emitting Diode (LED). This will help the beginner get familiar with the use of the prototyping board and simple circuits.



Circuit schematic:



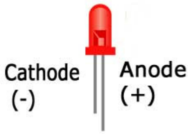
Parts needed:
Prototyping board
Battery connector and battery
220 ohm resistor
Switch
Red LED
One male to male jumper wire

Connecting up:
The 220 ohm resistor is colour coded red, red, brown. (In the Appendix there is a section dealing with resistor colour codes).

Resistors can be connected either way round. Note also how the switch is connected.

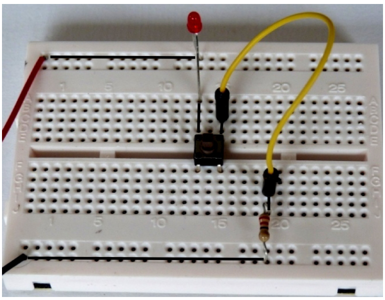
The LED must be connected the right way round to work. The long leg is the +ve side (known as the Anode) and the shorter leg is the -ve side (known as the

Cathode).



The shorter leg has to be connected to the -ve (0V) rail - ie to the black wire of the battery connector.

When the button is pressed, the LED light up.



Question: Does it matter if the LED and resistor are connected the other way round? (like in the set-up below).

Answer: No. In a simple series circuit like this it does not matter if the current first flows through the LED then the switch and then the resistor or the other way round.

Question: Why do we need a resistor? When using a bulb one just connects the bulb to the battery and it lights up.

Answer: A bulb is a metal filament that heats up when a current passes through it. An LED is a semiconductor and behaves differently. One needs a resistor to limit the current flowing when it is connected to a battery. If an LED is connected directly to a 9V battery without a series resistor it will be damaged.

Summary: This simple experiment shows how to build a series circuit using the prototyping board.

Experiment 2: Using resistors to control LED brightness

Objective: Use different resistors to understand how they control the current in a circuit.

Circuit schematic:
Same as experiment 1

Parts needed:
Same as experiment 1 +
10 k ohm resistor
100 k ohm resistor

Connecting up:
Same as experiment 1

Let's estimate the current with a 220 ohm resistor: One uses Ohms Law for this. (In the Appendix, there is a section dealing with this).

The typical voltage drop across an LED is about 2V. With a 9V battery this leaves 7V (9-2) across the 220 ohm resistor. Using Ohms Law this gives the current through the LED as

7V divided by 220 ohms = 32 milli amps.

Replace the 220 ohm resistor with a 10 k ohm resistor (brown, black, orange). Note that when the switch is pressed the LED comes on but is not very bright.

Using the same method as before the current is:
7V divided by 10 k ohm = 0.7 milli amps.

Now replace the 10 k ohm resistor with a 100 k ohm resistor (brown, black, yellow). Note that when the switch is pressed the LED does not light up at all.

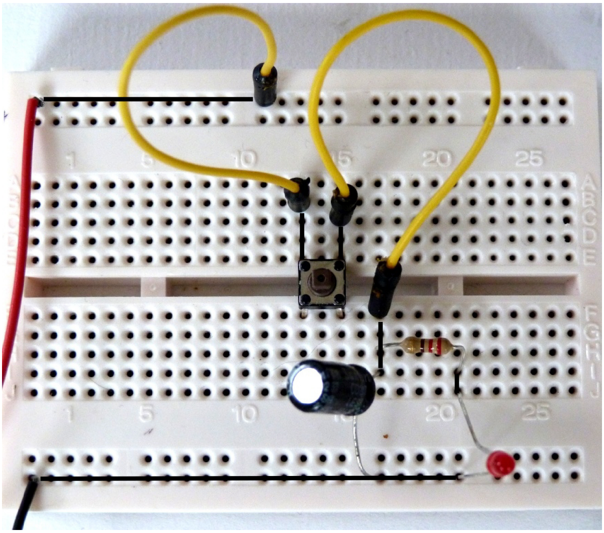
Using the same method as before the current is:
7V divided by 100 k ohm = 0.07 milli amps.

This current is too small to light up the LED.

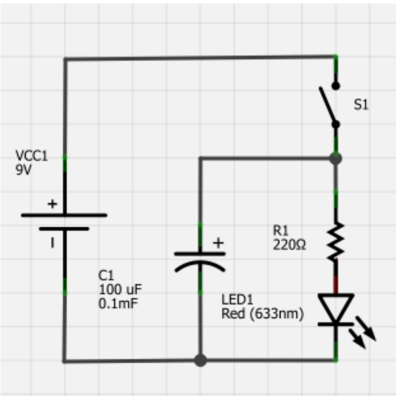
Summary: This experiment introduces the user to Ohms Law and demonstrates how resistors are used to control the current in a circuit.

Experiment 3: How a capacitor stores energy

Objective: This experiment introduces the user to capacitors and how they behave in a circuit.



Circuit Schematic:



Parts needed:
Prototyping board
Battery connector and battery
220 ohm resistor
1 k ohm resistor
10 k ohm resistor
100 uF capacitor
470 uF capacitor
Switch
Red LED
2 x male to male jumper wires

Connecting up:
The circuit is built up as shown with a 100uF capacitor and a 220 ohm resistor.

Note that the capacitor has a -ve marking on it against the shorter leg. This has to go to the more negative side of the circuit (ie the 0V rail on the prototyping board).

When the switch is pressed the LED comes ON. When the switch is released, the LED will stay on for slightly longer, compared to the capacitor not being there.

This is much more noticeable when the 220 ohm resistor is changed to a 1k ohm resistor. The LED stays on for about half a second after the switch is released.

Question: What is happening here?

Answer: When the switch is pressed, the capacitor is being charged up to the battery voltage of 9V. When the switch is released, it discharges the stored energy through the resistor and LED. The bigger the resistor, the smaller the current and the longer the capacitor takes to discharge.

Now change the capacitor to 470 uF and the resistor to 10 k ohm. When the switch is released, the LED stays on for nearly 10 seconds.

Question: Is it possible to calculate this time?

Answer: Yes. When a capacitor (C) and resistor (R) is used this way, the delay is called the 'RC time constant' and can be calculated by multiplying the 2 together. This is the time it takes the Capacitor to discharge to about a third of its initial value.

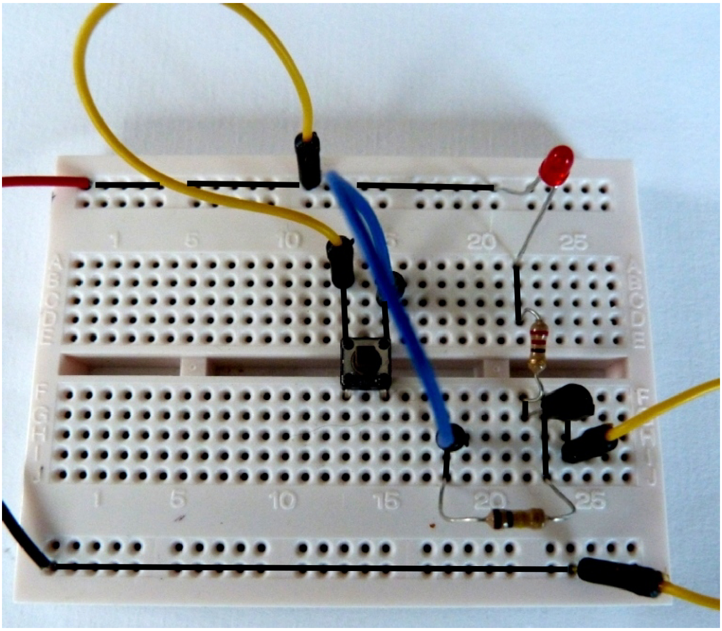
When C = 470 uF and R = 10k this gives 4.7 seconds. (The LED stays on for nearly twice this time as the Capacitor can still power the LED while it discharges even further).

When C = 100 uF and R = 1k the RC time constant is 0.1 second which is what was observed earlier.

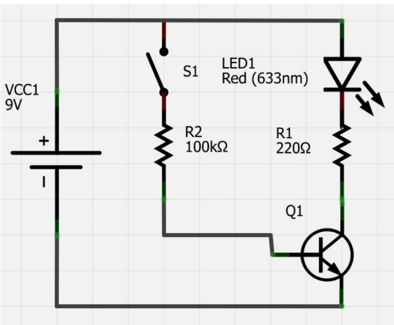
Summary: This experiment shows how capacitors store energy. The concept of 'RC time constant' is also introduced.

Experiment 4: Working with a transistor

Objective: This experiment shows how a transistor can be used to amplify current.

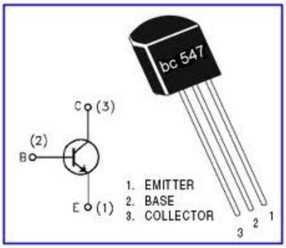


Circuit schematic:



Parts needed:
Prototyping board
Battery connector and battery
220 ohm resistor
100 k ohm resistor
BC546 transistor
Switch
Red LED
3 x male to male jumper wires

Connecting up:
The circuit is built up as shown.



The pin-out of the BC547 is as shown. It's an NPN transistor. The Emitter is connected to the 0V rail (the black wire from the battery connector). The Collector is connected to the 220 ohm resistor. The Base is connected to the 100 k resistor.

In experiment 2 we found that a 100k resistor resulted in a current of around 0.07 mA which was not enough to light an LED. In this experiment we are using the transistor as a 'current amplifier' to light an LED.

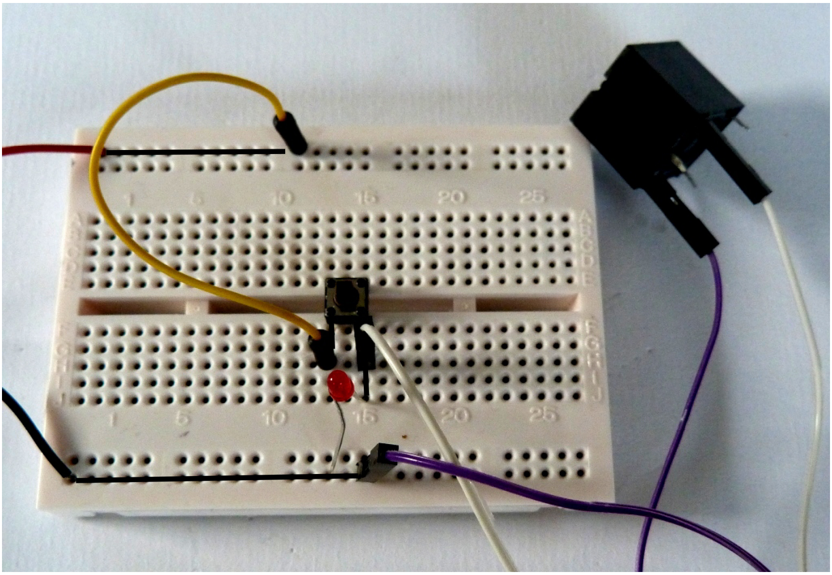
When the switch is pressed, the current into the Base of the transistor is around 0.07 mA. On the Collector of this transistor, we have an LED and a 220 ohm in series. In Experiment 2 we saw that the current when a 220 ohm resistor is used is about 32 mA.

In this experiment, the transistor is amplifying this current from 0.07 mA to 32 mA to light up the LED.

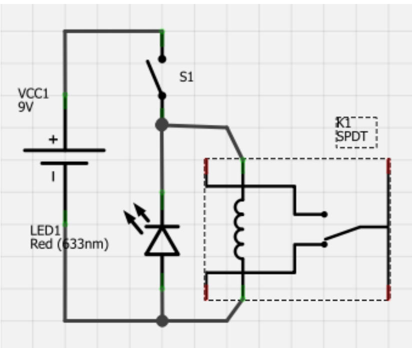
Summary: This experiment demonstrates how a transistor works.

Experiment 5: Working with inductors

Objective: Demonstrate the behavior of an Inductor by using a relay coil.



Circuit Schematic:

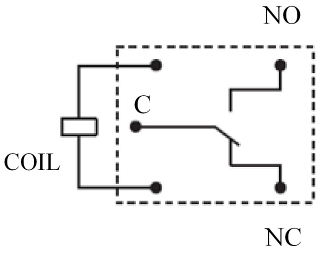


Parts needed:

Prototyping board
Battery connector and battery
Relay
Switch
Red LED
1 male to male jumper wire
2 x male to female jumper wires

Connecting up:
The relay pins don't easily plug into the prototyping board so we use jumper leads to connect to the pins.

The pinout of the relay is shown below. For this experiment we are just connecting to the coil.



Bottom View of pins

Note that in this experiment, the anode (+ve) of the LED is connected to the 0V rail.

When the switch is pressed the relay coil is energised and you will clear a click as the contacts make. When the switch is released there is another click. You will also notice that the LED flashes momentarily.

Question: Why does the LED flash?

Answer: The relay coil is an inductor. When the switch is pressed, the electric energy due to the current passing through the coil is saved in the magnetic fields of the relay. When the switch is released, this energy is discharged through the LED and causes it to flash.

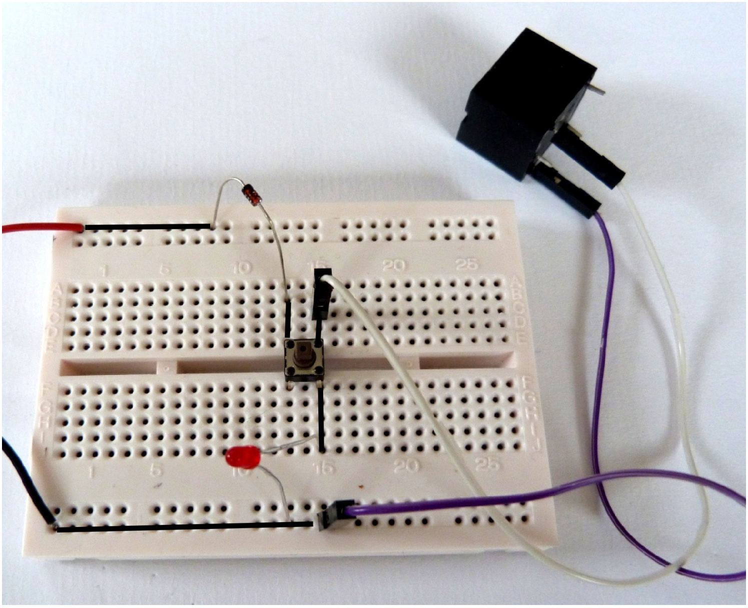
Question: How much energy is stored in the inductor?

Answer: The energy stored is given by the equation (LxIxI)/2 where L is the inductance of the coil and I is the current flowing through it.

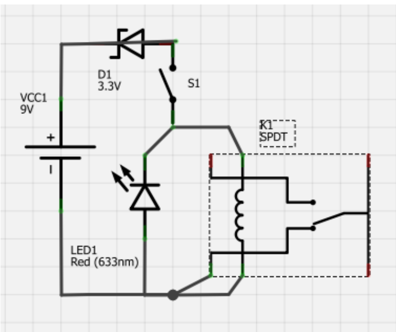
Summary: The coil of a relay behaves like an inductor and stores energy in its magnetic field.

Experiment 6: How to use zeners

Objective: Show how zeners can be used to adjust supply voltage



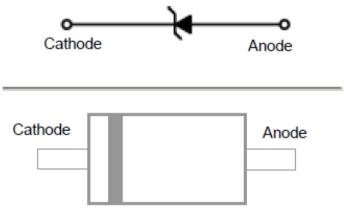
Circuit schematic:



Parts needed:
Prototyping board
Battery connector and battery
Relay
Switch
Red LED
2 x 3.3V zener
2 x male to female jumper wires

Connecting up:
The set-up is similar to the previous experiment except on this one we use a 3.3V zener in series with the relay coil.

The pins on the zener are shown below. We connect the Cathode to the more positive rail (red connector from battery).

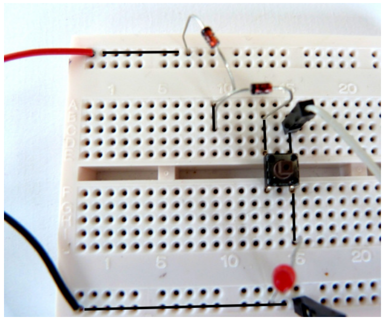


If we look closely at the previous experiment we would see a voltage mismatch. The PP3 battery is supplying 9V while the relay is rated at 6V. In practice the relay will work from about 4.5V to 7.5V.

It's not good practice to have this mismatch and to solve this we use a 3.3V zener. When a voltage greater than this is applied to the Cathode with respect to the Anode, the zener 'breaks down' and maintains the voltage drop to around 3.3V. This means that the nominal voltage supplied to the relay is 5.7V which is within the acceptable range.

When we operate the switch we hear the click as the relay is energised. When the switch is released, the LED flashes as before.

Question: What happens when we connect 2 x 3.3V zeners in series with the coil as shown below?

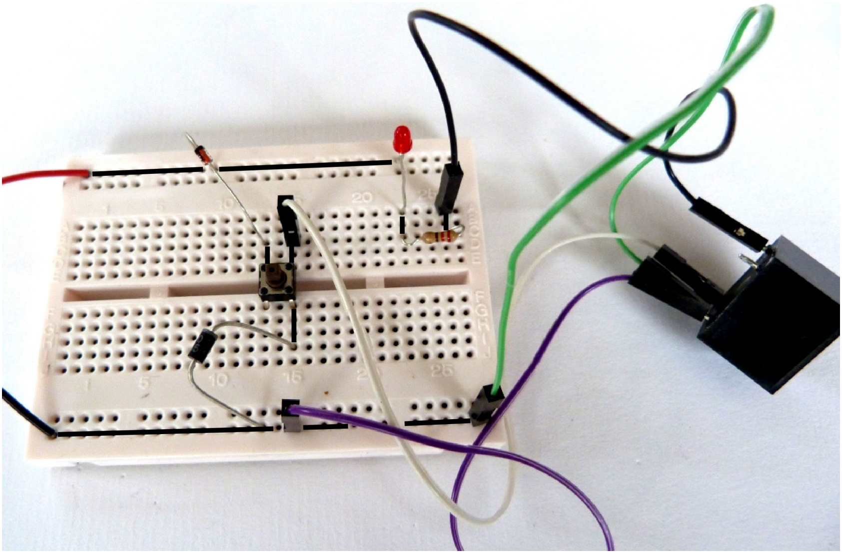


Answer: The voltage drop in this case is around 6.6V resulting in a voltage of 2.4V across the relay coil when the switch is operated. This is too low for the relay to operate and no click will be heard.

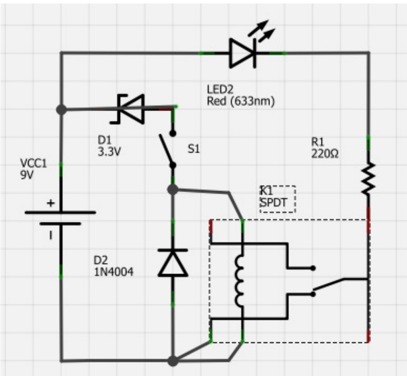
Summary: This experiment shows how zeners can be used to drop voltage in a circuit.

Experiment 7: Using a relay in a circuit

Objective: Show how to connect up and operate a relay

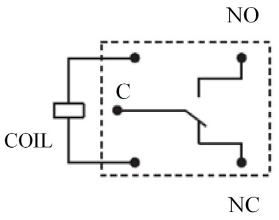


Circuit Schematic:



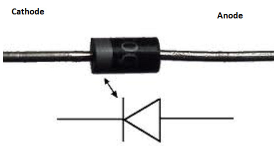
Parts needed:
Prototyping board
Battery connector and battery
Relay
Switch
Diode 1N4004
LED
3.3V Zener
4 x male to female jumper wires

Connecting up:
We connect the Common and Normally Open contacts of the Relay to turn an LED on when the relay is energised.



Bottom View of pins

In this set up, we replace the LED with a diode. This controls the 'back EMF' when the current to the relay coil is switched off.



The drawing above shows the pin out of the Diode. The Anode is connected to the 0V rail (black wire of battery connector).

Diodes conduct current one way (Anode to Cathode) but block current from flowing the other way (Cathode to Anode).

Question: Is the relay doing the work of a transistor here?

Answer: Yes. But there are some key differences.

1. The relay needs much more current to operate. e.g. the coil current for this relay is about 60 m Amps.

2. The relay can switch much higher loads. For example it can switch currents up to 10 Amps.

3. The relay provides isolation between the switching side and the switched side. For example it can switch mains voltages (with proper safety precautions).

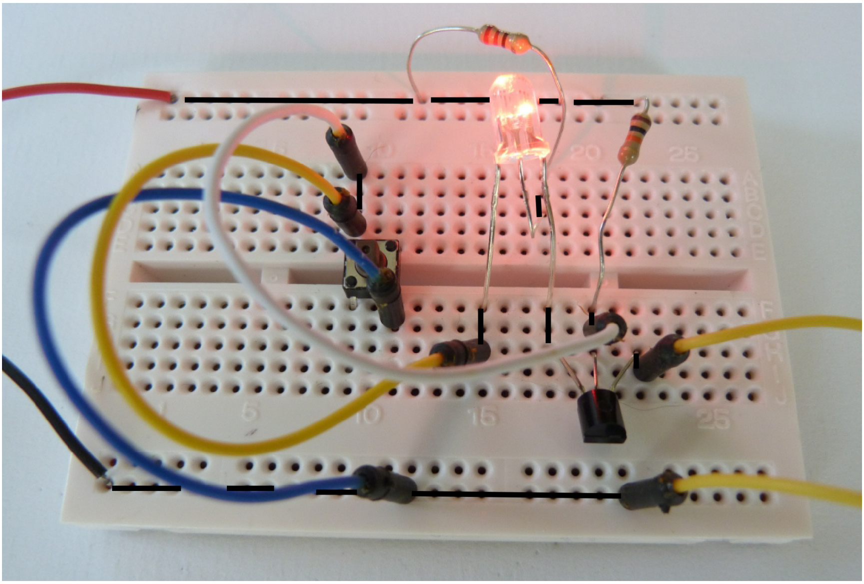
Question: What will happen if the diode is left out?

Answer: When the current through the coil is switched off and there is nowhere for the current to go there will be a huge voltage spike as the coil tries to 'dump' the energy stored in it. This spike can damage components in the circuit. The diode provides a path for this current and dissipates the energy.

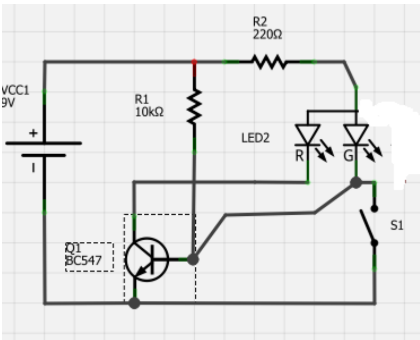
Summary: This experiment shows how to wire up a relay to switch things. It also shows why it's important to use a diode to limit voltage spikes.

Experiment 8: Using a bi-colour LED

Objective: Demonstrate how to light up a bi-colour LED using a transistor.

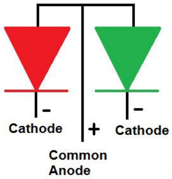


Circuit schematic:



Parts needed:
Prototyping board
Battery connector and battery
Switch
220 ohm resistor
10k resistor
Bi-colour LED
BC547 transistor
4 x male to male jumper wires

Connecting up:
The pinout of the bi-colour LED is shown here. The current limiting resistor can be connected to the Common Anode and then to the +ve supply.



In the circuit, the transistor is normally ON due to the 10k resistor on the base. This means that the red LED is ON. When the switch is pressed this turns ON the green LED at the same time as pulling the base of the BC547 to 0V and switching it OFF. This turns off the current to the red LED.

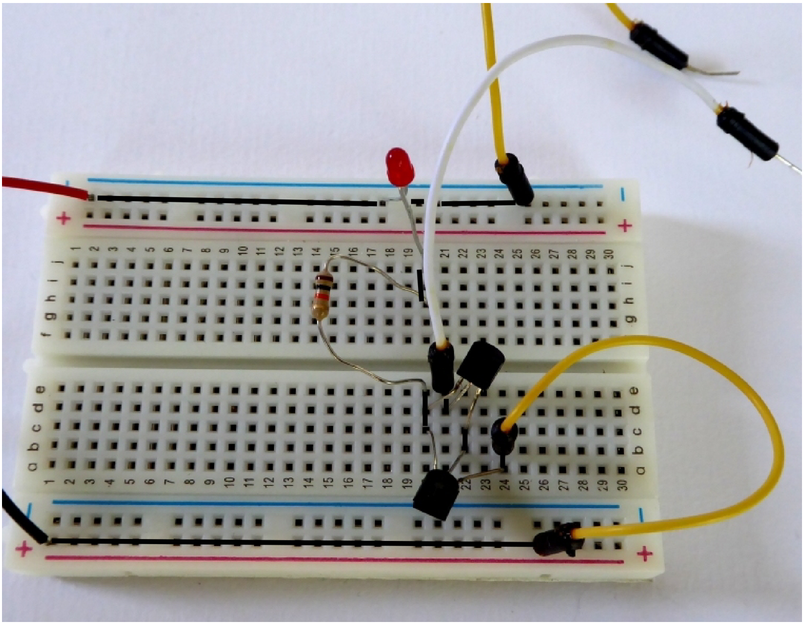
Question: Where would you use a bi-colour LED?

Answer: They could be used to indicate battery status for example. A steady green LED could be used to indicate a charged battery and a red one to indicate low battery.

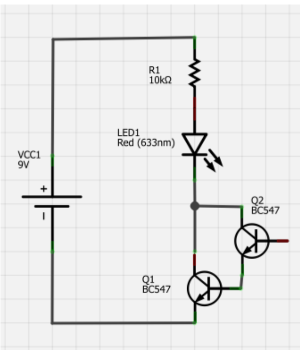
Summary: This circuit uses a transistor to interface to a bi-colour LED.

Experiment 9: A touch sensitive switch

Objective: Demonstrate how to use a Darlington Pair to build a touch sensitive switch.

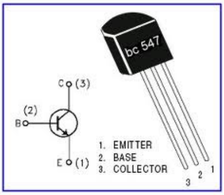


Circuit schematic:



Parts needed:
Prototyping board
Battery connector and battery
10k resistor
2 x BC547 transistor
Red LED
3 x male to male jumper wires

Connecting up:
The circuit is connected up as shown with a jumper wire to the base of the transistor instead of a switch.



The Darlington Pair consists of 2 NPN transistors connected up as shown. The emitter of one goes into the base of the second. This means that if the gain of the BC547 is 200, the gain of the Darlington Pair is 200 x 200 = 40,000.

When you touch the white wire connected to the base of the first transistor, the led should glow faintly. This is due to electrical noise picked up from your finger.
If you touch the white and yellow wires the LED should light up brighter. If you wet your fingers and touch the 2 wires then it should light up even brighter.

Question: Why does wetting the finger make a difference?

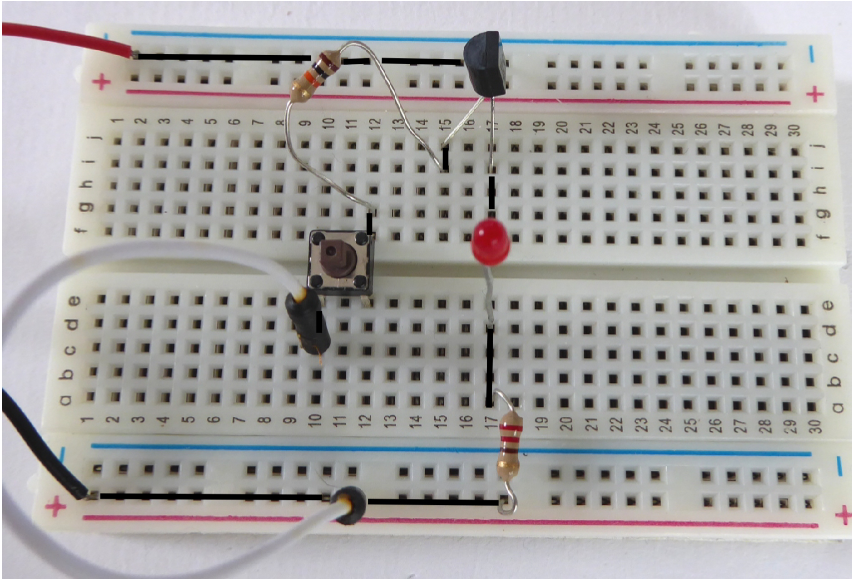
Answer: When one touches the 2 wires with a finger, a small current flows from the 9V supply into the base of the first transistor. This current is amplified by about 40,000 and flows through the LED.

Wetting the finger reduces the resistance and causes more current to flow into the base, resulting in a higher current through the LED.

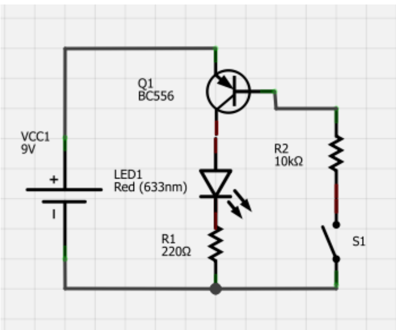
Summary: This experiment shows how a Darlington Pair works and how this can be used to build a touch sensitive switch.

Experiment 10: Working with a PNP transistor

Objective: Using a PNP transistor to switch a Relay

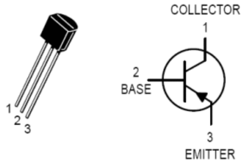


Circuit schematic:



Parts needed:
Prototyping board
Battery connector and battery
10kohm resistor
220 ohm resistor
BC556 transistor
Red LED
1 male to male jumper wire

Connecting up:
The BC556 PNP transistor is connected differently from the BC547 NPN transistor.



The Emitter is connected to the 9V supply voltage (instead of the 0V). To turn the PNP transistor ON, one pulls current out of the base. In the circuit, you can see this happens when the switch is pressed and the base current flows through the 10kohm resistor.

Question: Where would you use a PNP transistor instead of an NPN one?

Answer: PNP transistors are useful to source current into a load that needs one end connected to 0V or ground side of a circuit.

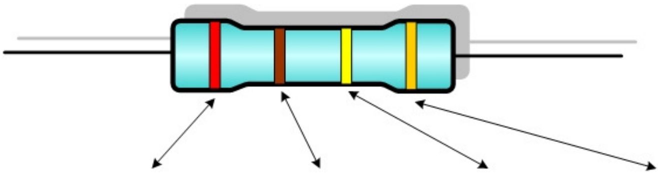
In the circuit here you can see that the LED and resistor are connected to 0V.

Summary: This experiment shows how a PNP transistor can be used to switch an LED on.

Appendix 1: Resistor colour codes

Leaded resistors are colour coded for identification. This is presented below.

4-band Resistor



Color	1st band value	2nd band value	Multiplier	Tolerances
Black	0	0	× 1	
Brown	1	1	× 10	± 1%
Red	2	2	× 100	± 2%
Orange	3	3	× 1000	± 3%
Yellow	4	4	× 10,000	± 4%
Green	5	5	× 100,000	± 0.5%
Blue	6	6	× 1,000,000	± 0.25%
Violet	7	7	× 10,000,000	± 0.10%
Grey	8	8	× 100,000,000	± 0.05%
White	9	9	× 1,000,000,000	

Examples:

#1: Red, red, brown = 22 x 10 = 220 ohms

#2: Brown, black, orange = 10 x 1000 = 10,000 = 10 k ohms

#3: Yellow, violet, red = 47 x 100 = 4700 = 4.7 k ohms

#4: Red, red, red = 22 x 100 = 2200 = 2.2 k ohms

Appendix 2: Ohms Law

This Law relates voltage, current and resistance.

It's easiest to describe these three parameters by using the behaviour of water as an analogy.

Voltage is like pressure. When it is high it can drive a lot of water through. Current is analogous to the flow of water. Water only flows when a tap is opened (Current only flows when the switch is closed and a circuit is made). The amount of water that flows in a given size of pipe depends on the water pressure. The larger the pressure the higher is the rate of flow of water. Given the same pressure, more water can flow through a bigger pipe than a smaller pipe.

In this analogy:

Pressure = Voltage (V)
Water flow = Current (I)
Size of pipe = Resistance (R) (smaller pipe has a higher resistance).

Ohms Law states that the current through a conductor is proportional to the voltage across it. It is expressed by the following equation.

$I = V/R$

One can derive these other equations from it.

$V = IR$ (the voltage across a conductor is proportional to the current flowing through it).

$R = V/I$ (The resistance of a conductor is the voltage across it divided by the current flowing through it).

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