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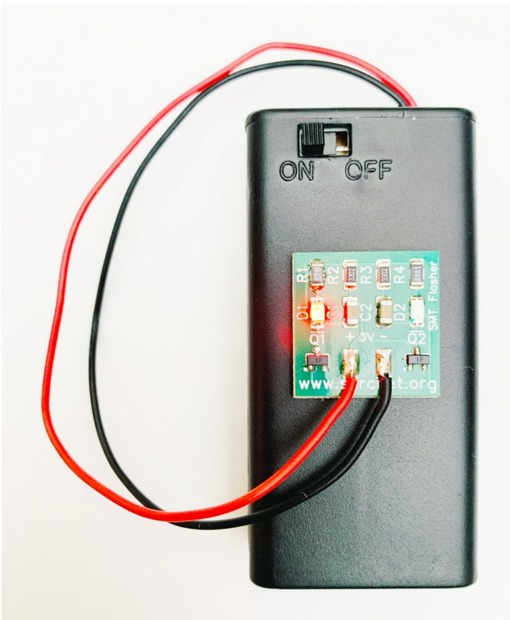
STEM Activity Sheet – Microelectronics Kit Construction



Microelectronics Kit - SMT Flasher

14 March 2024

Microelectronic Kit Construction – SMT Flasher

Learn how to construct inexpensive microelectronic kits for your own projects with this fun activity. Build your first microelectronics kit, using Surface Mount Technology (SMT), by soldering components to a Printed Circuit Board (PCB). In this activity sheet you will make an electronic flashing light circuit. It has two Light Emitting Diodes (LEDs) and all the components required to make them flash on and off.

Warning

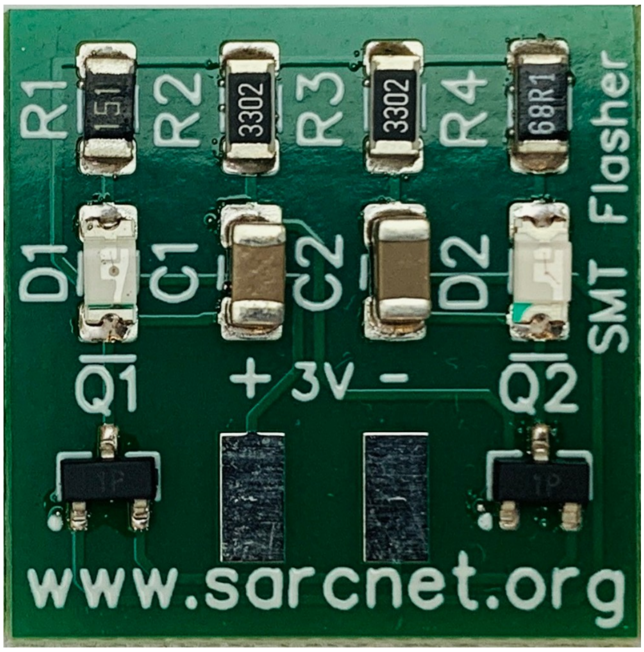
This kit requires the use of a very hot soldering iron and hotplate. Constant adult supervision is required and safety equipment like goggles and gloves must be used. Do not use any tools until instructed to do so. Observe all safety instructions in this document.

Description:

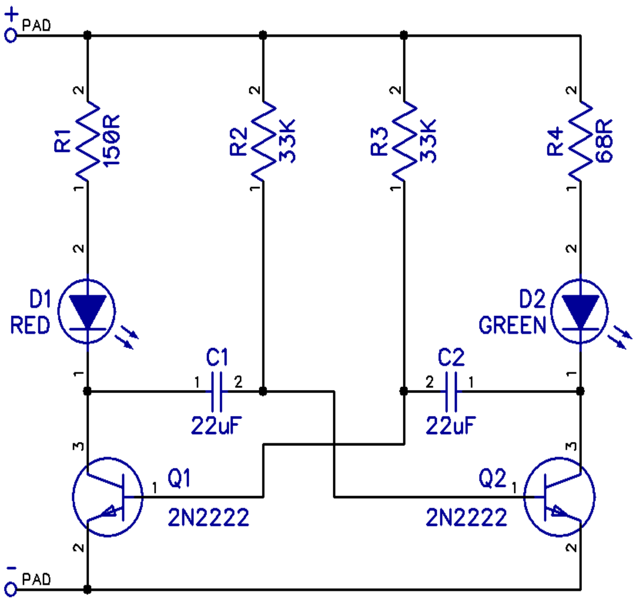
Connect a 3-volt battery to this simple circuit and its cross-connected transistors turn on and off, alternately, several times every second. This causes the red and green LEDs to flash. This famous circuit is called an “Astable Multivibrator”, since once it starts flashing it just can’t stop!

Circuit diagram:

Electronic components are represented by symbols in a circuit diagram as shown below. Compare the physical circuit on the left to the circuit diagram on the right. Each component has a symbol, a designation, pin numbers and a value. For example, the resistors are shown as zig-zag lines, designated R1, R2, R3 and R4 and have values, measured in Ohms, of 150Ω, 33kΩ and 68Ω. Capacitors are C1 and C2. LEDs are D1 and D2, Transistors are Q1 and Q2. There are ten electronic components in this circuit. In the physical circuit, electronic components are connected by thin copper tracks. In the circuit diagram, electronic components are shown connected by black lines. Dots show where overlapping lines are connected.



Physical Circuit



Circuit Diagram

Each component has a special function: The two 1.5 volt AA cells, connected in series in the battery holder, produce 3 volts to power the circuit. An on/off switch on the battery holder controls the current into the circuit. Resistors limit the current that can flow in various parts of the circuit. Capacitors can be charged and discharged, like tiny rechargeable batteries. Light Emitting Diodes (LEDs) convert electric current directly into light. They have two connections called Cathode (pin1) and Anode (pin 2). When electric current flows from the anode to the cathode the LEDs turn on. Transistors work like an on/off switch, controlled by a small current. They have three connections called Base (pin 1), Emitter (pin 2) and Collector (pin 3). A small electric current flowing into the Base causes a larger electric current to flow from the Collector to the Emitter in the direction of the arrow.

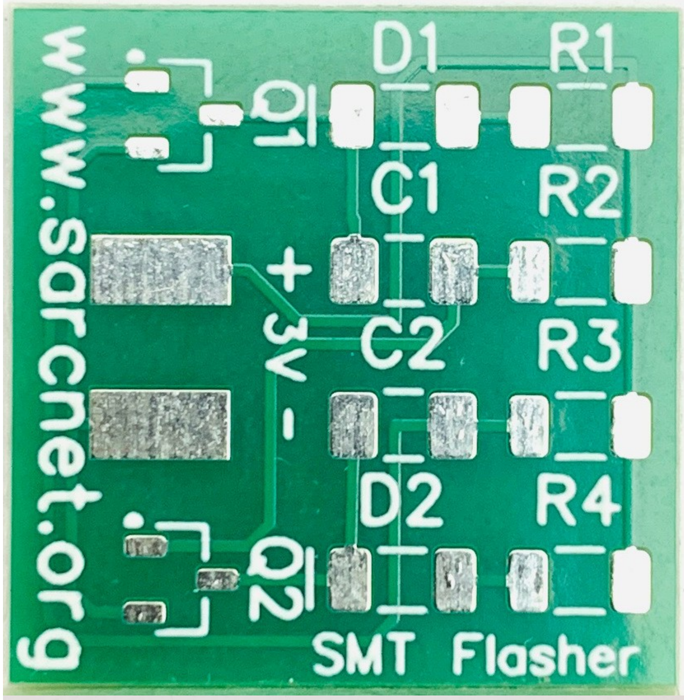
When the switch is off, no current flows in the circuit. The transistors and LEDs are turned off and the capacitors are discharged. When the switch is first turned on, current flows from the battery, down through R2 into Q2 and R3 into Q1. You can trace it with your finger. It is initially a race to see which transistor will turn on first. Suppose Q1 turns on first. Current will flow through R1 and D1 into the Collector of Q1 and then out of its Emitter in the direction of the arrow. R1 limits the current through D1 to a safe value. When Q1 turns on, C1 begins to charge up through R2. Q2 will not turn on until C1 is charged. This takes some time depending on the values of R2 and C1. When C1 is charged, Q2 turns on. Current flows through R4, D2 and Q2, turning on D2 for the first time. When Q2 turns on, it diverts the current flowing into the base of Q1 from R3 to charge up C2 instead. This causes Q1 and D1 to turn off immediately. The process continues with C1 and C2 being charged and discharged by Q1 and Q2 and the LEDs turning on and off alternately. The value of resistors R1 and R4 were chosen to limit the current flowing through the LEDs to about 6 milliamps. The value of resistors R2 and R3 and capacitors C1 and C2 were chosen to set the flashing rate. See the sequence diagram below to trace out the electric current flowing in the circuit.

What you will need:

1. Safety equipment: A heat resistant mat and, if it is your first time soldering, protective goggles and gloves
2. The SMT Flasher Printed Circuit Board (PCB)
3. A 3V switched battery holder for 2 x AA batteries
4. 2 x AA batteries
5. Lead-Free solder paste
6. Small tweezers
7. Side cutters
8. Isopropyl alcohol and a soft brush
9. Magnifying lamp (or you can use a magnifying camera app on your smart phone!)
10. SMD soldering hot plate (other possibilities exist – see below)
11. An 8W USB or 25W AC soldering iron
12. Resin-cored, lead-free, soldering wire

Step-By-Step Instructions:

1. Inspect the PCB.



One side has brightly tinned, solder pads surrounded by a green solder mask. This is where the Surface Mount Devices (SMDs) will be mounted. There is a white screen-printed component overlay indicating where each of the SMDs go. Through the green solder mask you can see copper tracks joining the solder pads. These tracks form the electric circuit through which electric current will flow, from the battery and via the two pads marked “+” and “-”.

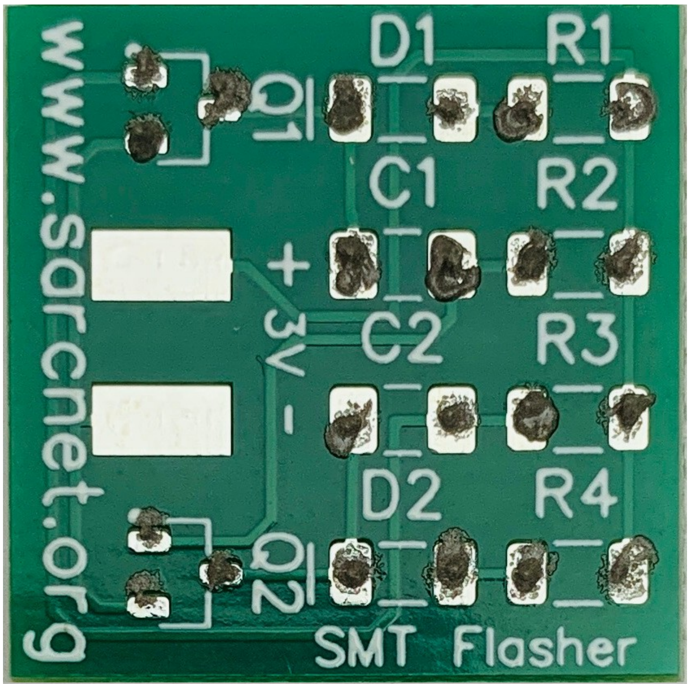
The other side of the PCB is blank so that it can sit flat on the hotplate for soldering. The PCB itself is made of fibre-glass, so be careful of any prickly bits sticking out of the edges.

2. For the next steps you will need a good, sharp pair of tweezers and a syringe of solder paste.

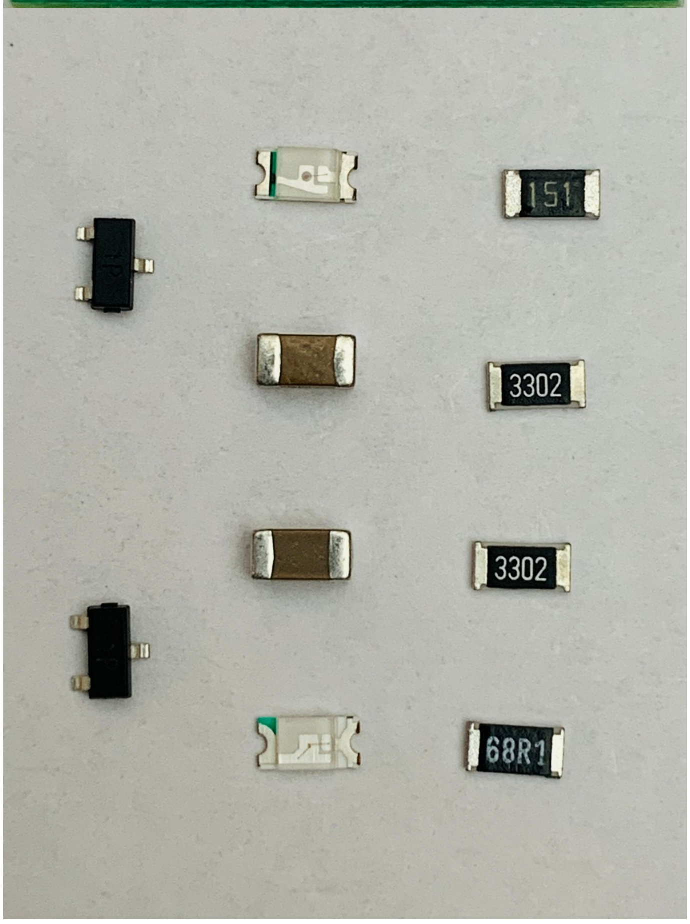
The tweezers are used to pick up the tiny SMDs. You need to be gentle picking up SMDs with tweezers. If you grab them too hard you might break them or they might all of a sudden go “twang” and fly across the room. Good luck finding the ones that do! The tweezers are also used to place the SMDs on to the solder pads. You will have to practice to place them accurately.

The solder paste is like the glue that sticks the SMDs onto the PCB, but unlike glue it is made of conductive metals, which only melt at a high temperature. You will see, on the side of the solder paste that we use, it is made of Sn (tin) 42%, Bi (bismuth) 57.6% and Ag (silver) 0.4%. There is no Pb (lead) in it so it is safe to use and safe for the environment. It is really just a metal powder that is suspended in a sticky gel of soldering flux (which is a heat-activated contact cleaner). Unlike solder wire you can squeeze it out of a syringe through the fine, blunt-ended, needle.

3. Use a magnifying lamp or magnifying app to clearly see the component side of the PCB. Place a very small blob of solder paste from the syringe onto each solder pad (except for the two large rectangular pads). Just enough to cover the pad is sufficient. If you make a mistake and get solder paste all over the place you can clean it off with a cotton bud or wipe it clean with a tissue and start again. When the solder paste melts, it forms into tiny silver balls, which eventually combine together and stick to the solder pad – not to the green solder mask. So even if it looks a bit messy now, it should clean up pretty well when soldered.



4. Next inspect the SMDs. They are tiny. They are generically a “1206” size, which means 0.12x0.06 inches (about 3.2x1.6 millimetres).



The resistors are the black flat rectangles shown on the right. The markings indicate the value of the resistor: “151” = 150Ω, “3302” = 33kΩ and 68R1 = 68.1Ω. It does not matter which way the resistors are mounted on the PCB, but it is convenient to have all their labels the same way up.

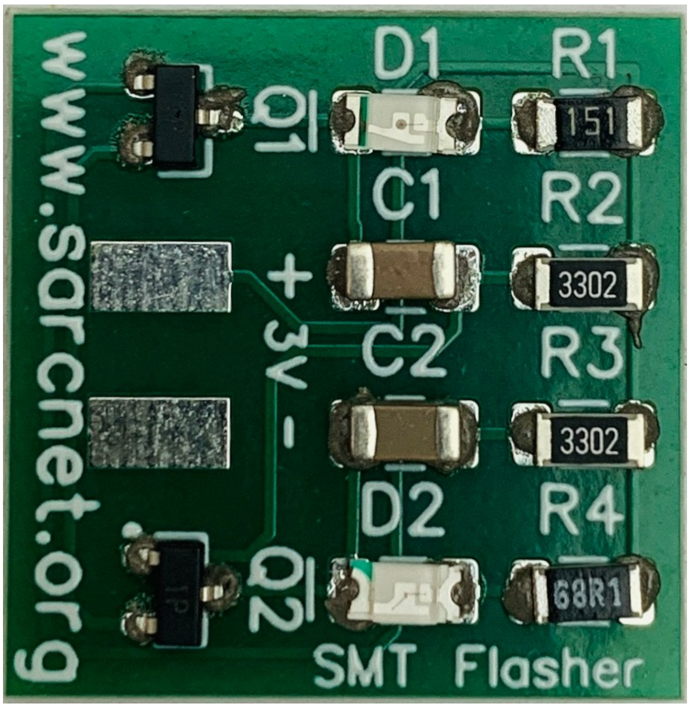
The capacitors are the brown cubes. They have no value markings and it does not matter which way around they are mounted.

The transistors have three metal contacts and only fit onto the PCB in one way.

The LEDs have a green stripe on one side indicating the cathode (negative terminal). It goes next to the solid white line on the silk-screen. The shape of the green stripe is the only way to identify the LEDs. The one with the solid green line is a red LED. The one with a green arc on one side is a green LED.

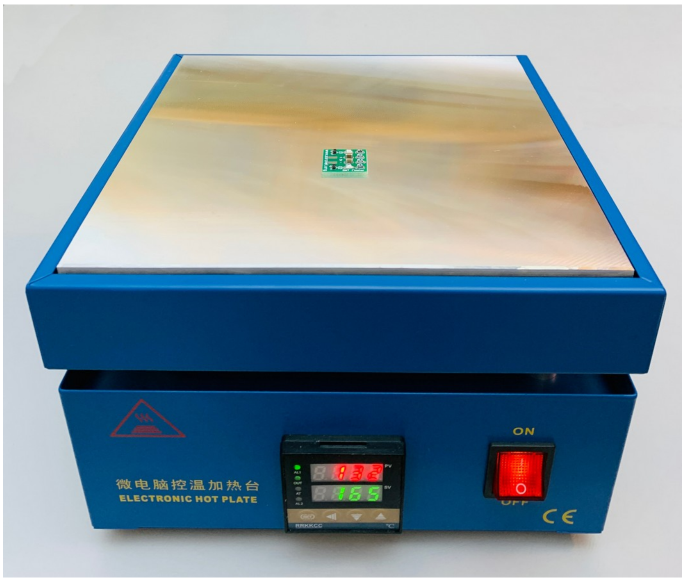
5. Use the tweezers to carefully place the SMDs, in the correct place and correct orientation, onto the sticky solder paste. Keep your wrist on the bench to steady your hand while doing this. It sometimes helps to drop the SMD onto the paste first and then to tap it down afterwards. It takes a little practice. You can always start again if it goes wrong or clean up a small area with a cotton bud. The SMDs should be straight and within the outlines shown on the white screen-printing.

A fun fact is that when the solder melts, in the next step, the SMDs often re-orient themselves more precisely onto the solder pads, due to capillary action.

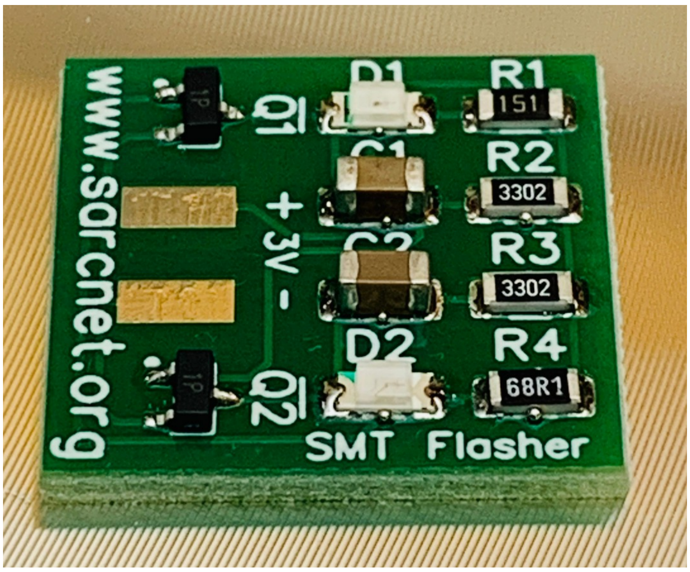


6. Place the PCB to be soldered onto the temperature controlled soldering hotplate. Turn it on and set the temperature to 165 Celsius (Note: The temperature may vary due to the type of solder paste used – Check the instructions).

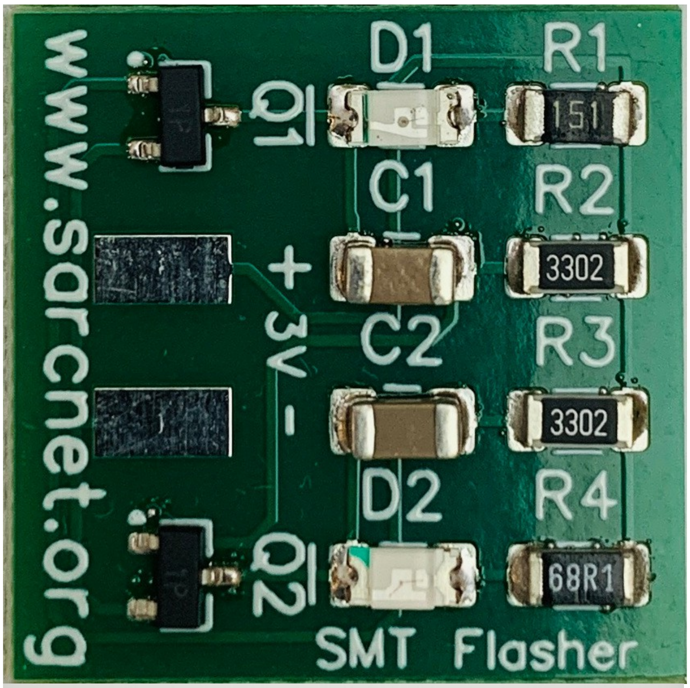
Now, if you don't have a temperature controlled soldering hotplate, you could theoretically use an electric fry pan, or a flat plate in a preheated conventional oven. The problem will be regulating the temperature and getting the right temperature profile. If you want to try it we suggest reading about it and watching videos, online.



7. Watch the PCB vary carefully. At some point, as the temperature rises to 165 Celsius, the flux will run and may even start to smoke a bit, the grey solder paste will then quickly melt and the solder will form into small balls before being sucked into the area between the solder pad and the SMD. Check that all SMDs are now sitting flat on the solder pads, in their correct positions, and that their contacts have a smooth fillet of solder connecting them to their pads. Leave the PCB for a minute or so and then carefully remove it from the hotplate to a heat-resistant surface. Turn off the hotplate after use. Warning: It will remain very hot for some time.

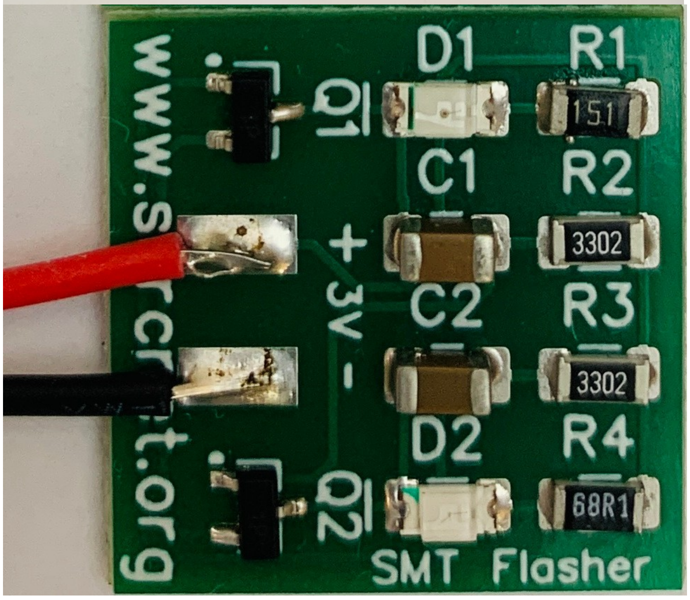


8. When the PCB is cool you can clean it up a bit: Remove any excess solder balls with the point of the tweezers. Use isopropyl alcohol and a brush to remove any excess solder flux.

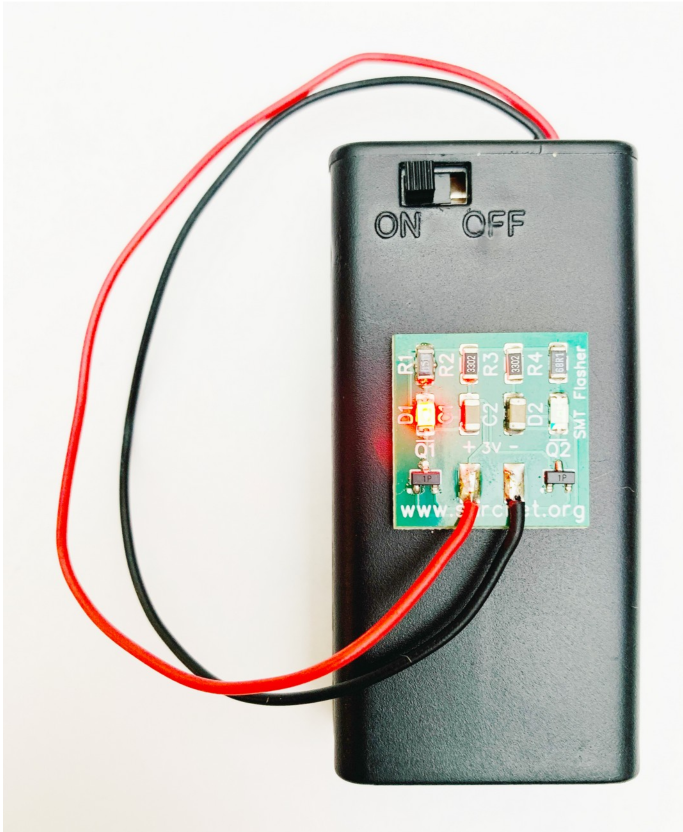


9. Next, get 2xAA cells and a 3V switched battery holder. Strip the leads of the battery holder with side-cutters and tin them with a conventional soldering iron and resin-cored solder wire , if necessary.

10. Solder the battery holder leads to the large rectangular solder pads on the PCB using a conventional soldering iron and resin-cored solder wire. The red wire goes to the one marked “+”. The black wire goes to the one marked “-”.

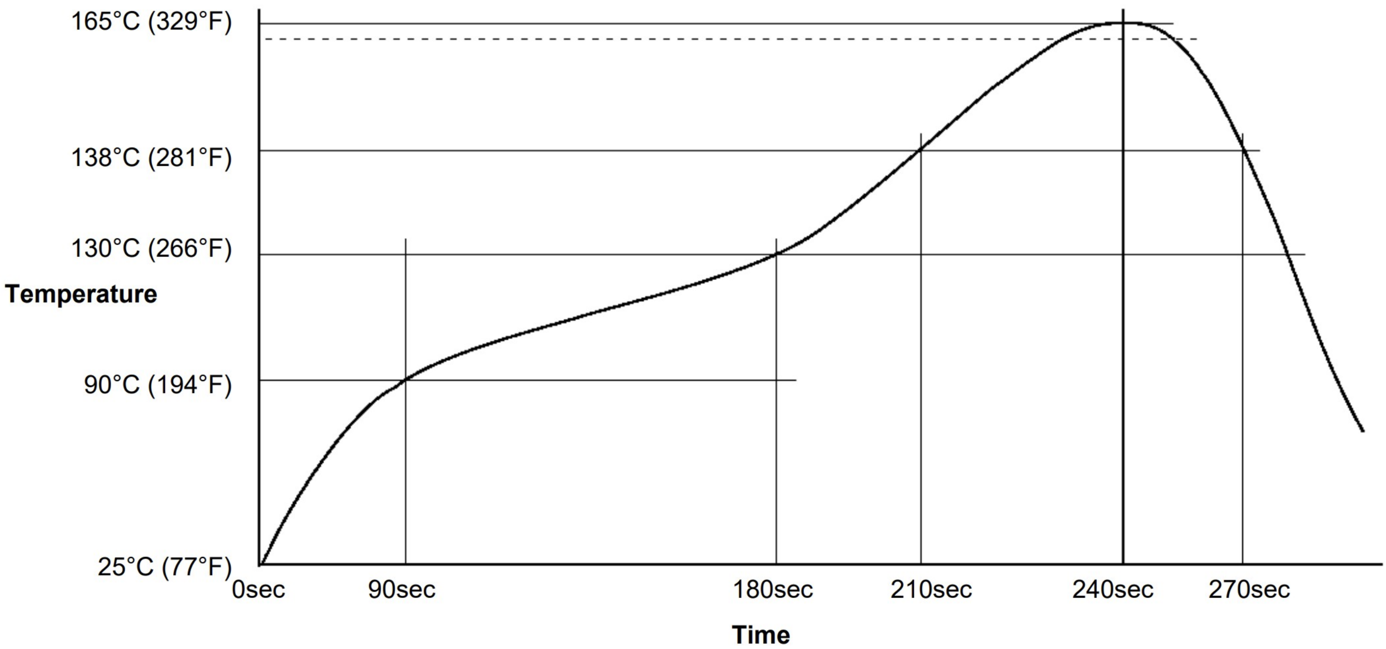


11. Switch on the power and watch the circuit work. When an LED is lit the transistor directly under the LED is switched on. You can use the assembled microelectronic kit to demonstrate the theory and techniques to others. You can mount the PCB on a model to brighten it up. It makes a great Christmas Tree ornament!

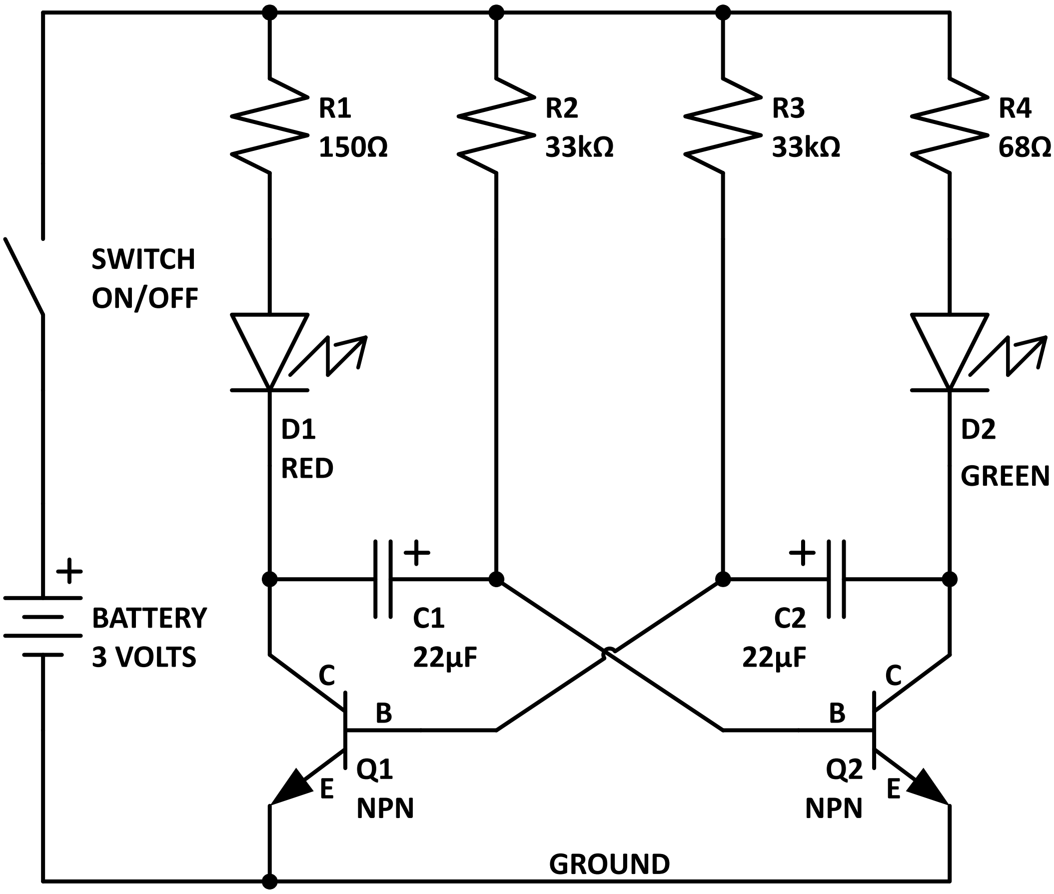
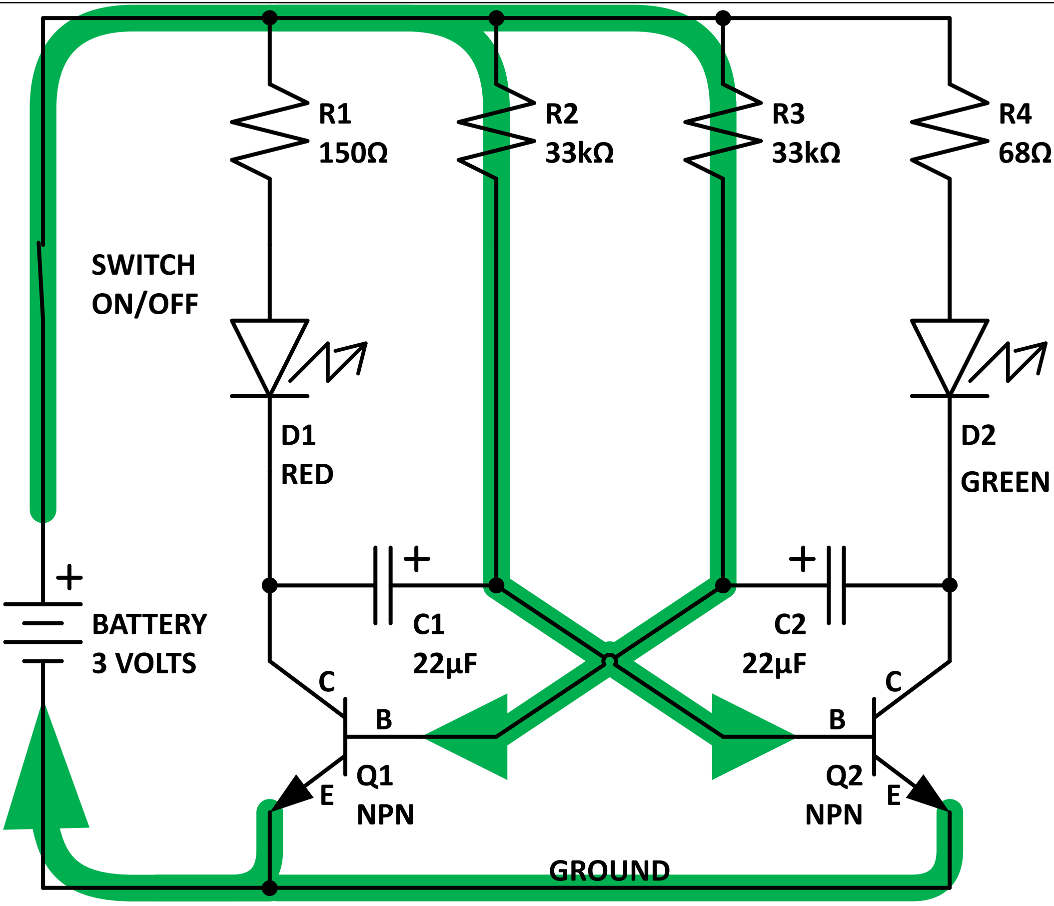


Reflow Soldering:

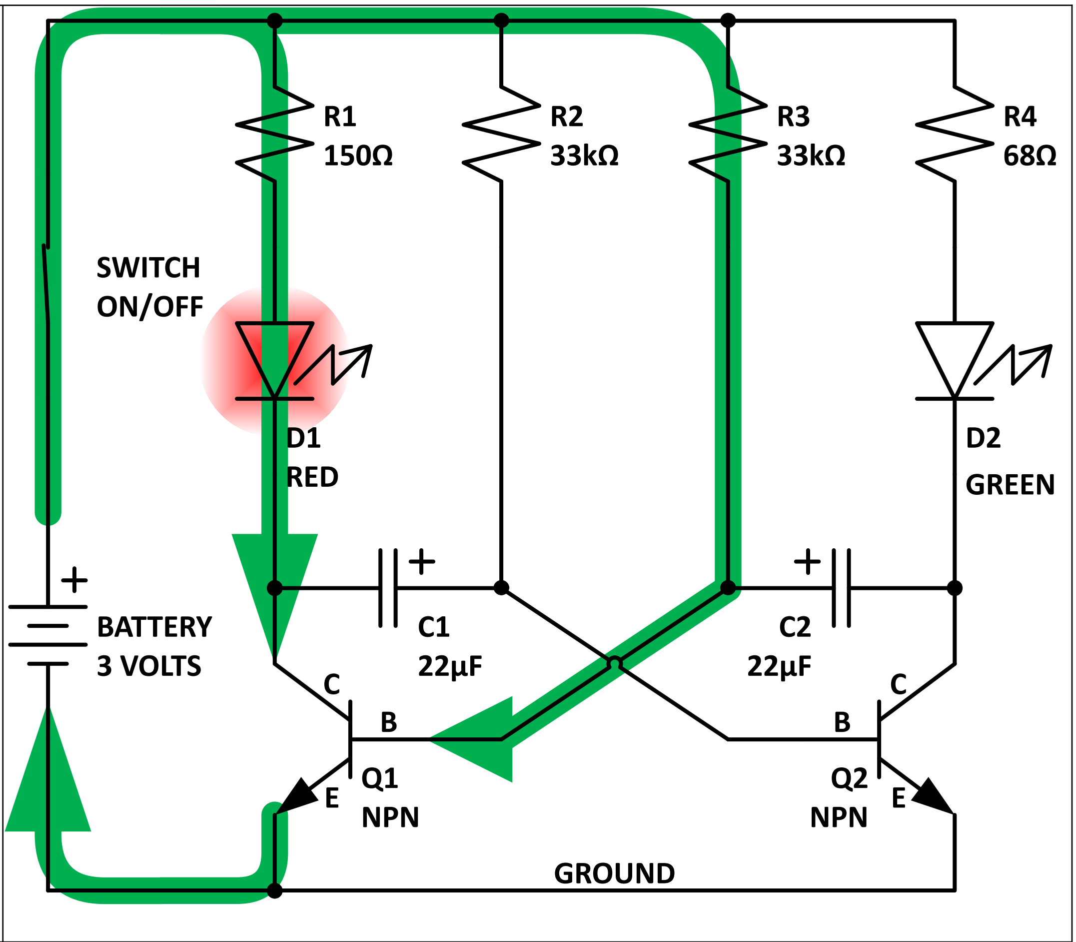
Reflow soldering is the name of a technique used to solder SMDs to PCBs using solder paste. When reflow soldering it is recommended to use a temperature-time profile for heating and cooling. The profile is characterised by zones called “preheat”, “soak”, “reflow” and “cooling”. The zones define periods for which the PCB and SMDs should be held at certain temperatures. The purpose of the profile is to minimise thermal shock on the components, promote uniform temperature distribution, activate the solder flux and create strong metallurgical bonds. However, for home construction projects, it is sufficient to adjust the heater power setting to approximate heat-up time, switch it on at 25 Celsius and then switch it off at the maximum reflow temperature. The reflow soldering profile for the solder paste we use is shown in the following diagram:



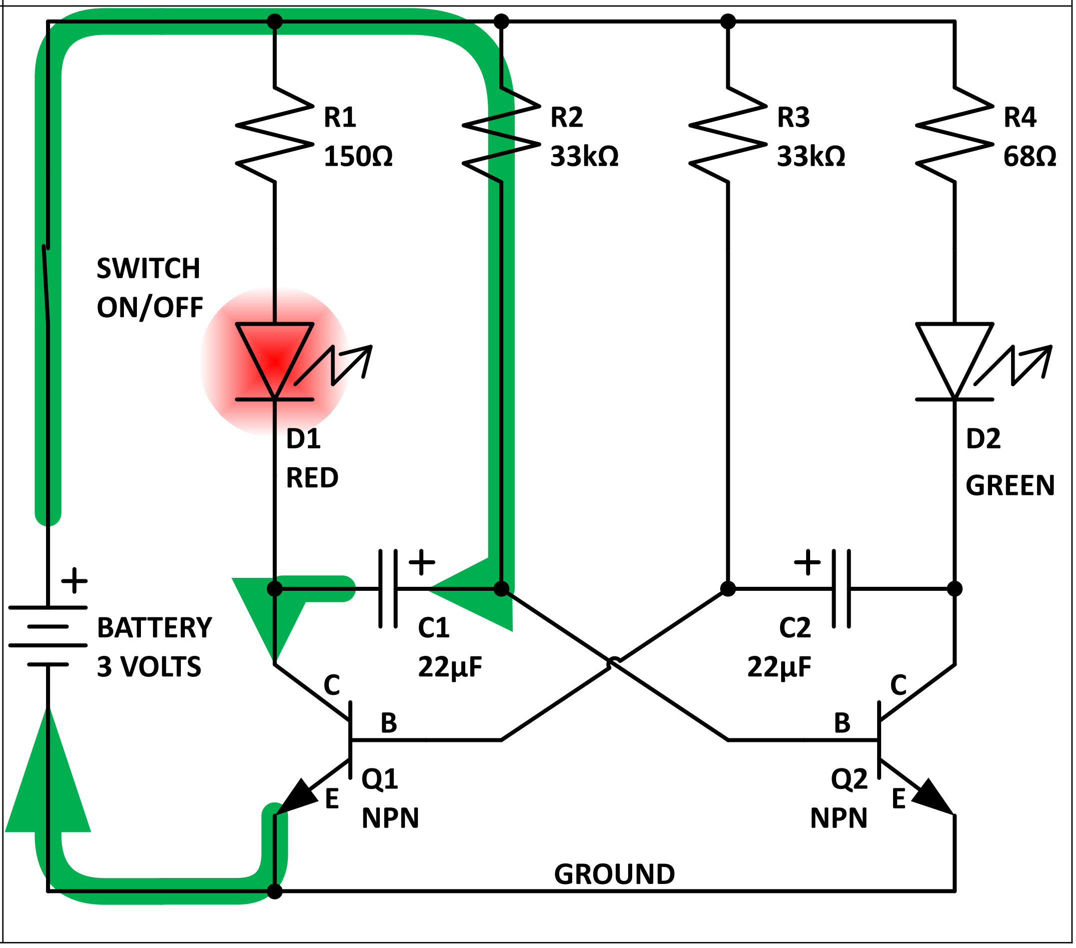
Sequence of operation:

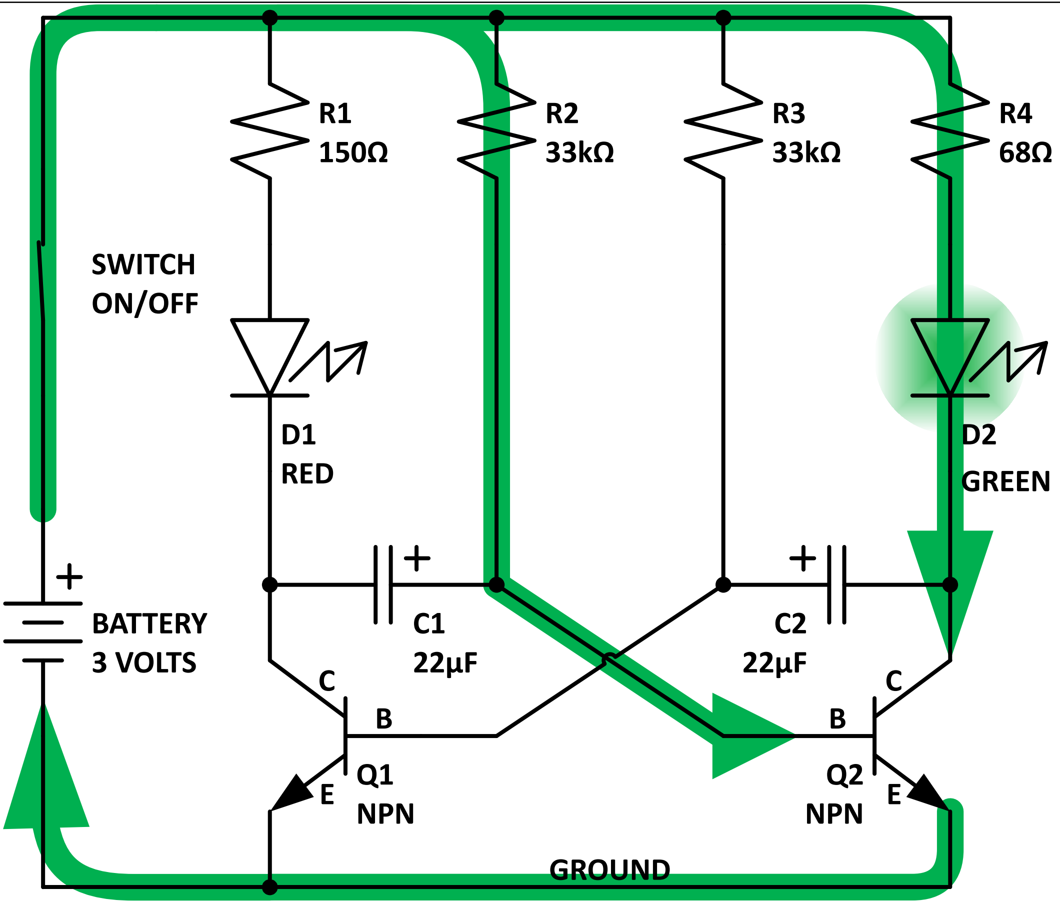
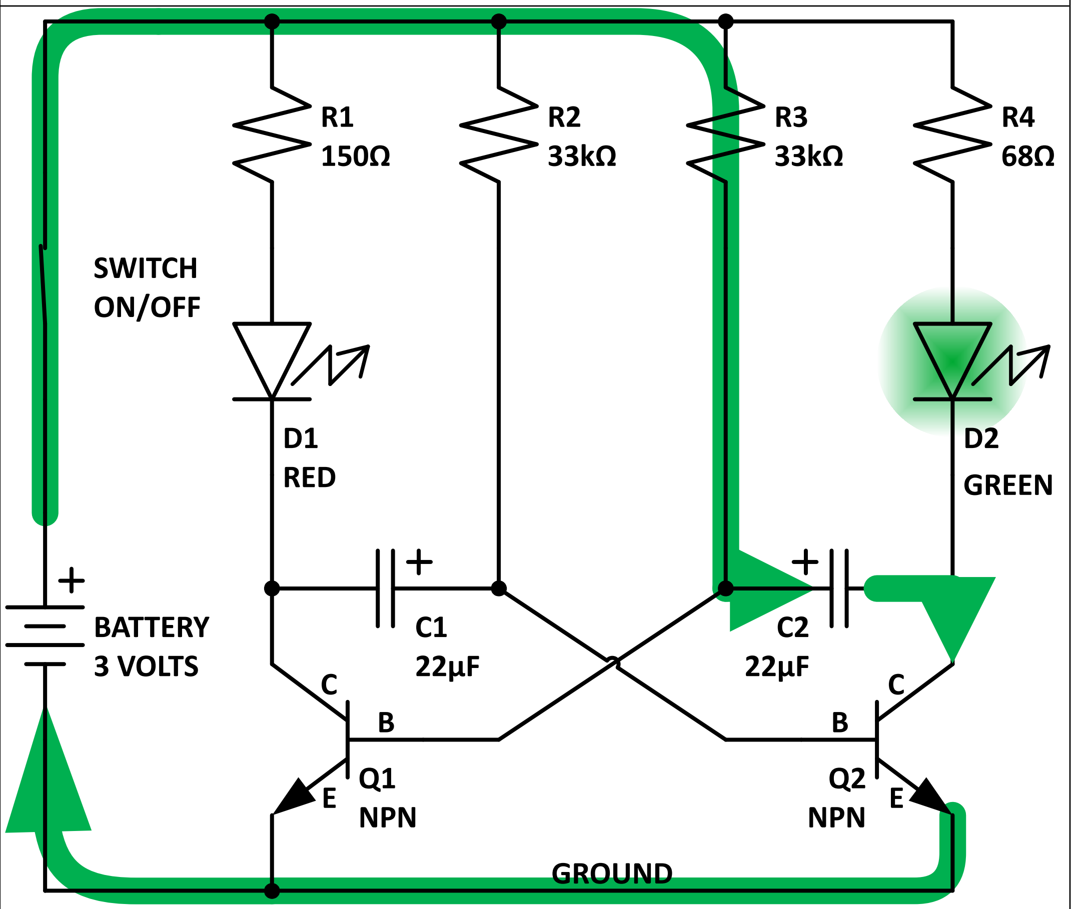
1. The switch is off, so no current flows from the battery into the circuit. The Transistors Q1 and Q2 are both off, so no current flows from their Collectors (C) to their Emitters (E). The Capacitors C1 and C2 are both discharged, so there is no voltage across them. The wire at the bottom of this circuit is called GROUND for reference.	
2. The switch is on. Current flows through resistors R2 and R3 into the Base of Q1 and Q2, down to GROUND and back to the battery. One of the transistors will turn on first. Which one? The fastest depends on minor variations in component parameters. It will be a race…	

3. Q1 was the fastest and has turned on first! Current now flows through R1 and LED D1 into the Collector and out of the Emitter of Q1. D1 now emits light. But why doesn’t Q2 also turn on as well? Wait and see...



4. When Q1 turned on it also connected D1 and Capacitor C1 to GROUND. C1 was initially discharged. Since the voltage across a discharged capacitor must be zero, the Positive (+) side of C1 and the Base of Q2 were also pulled down to GROUND. Q2 was therefore switched off when Q1 turned on. However, C1 is now charging through R2. The time it takes for C1 to charge depends on the values of R2 and C1. So, what happens when C1 is charged?...



5. C1 has now been charged through R2. So current flows into the Base of Q2 and it turns on. D2 now emits light. But what makes Q1 turn off?...	
6. C2 was initially discharged when Q2 turned on. Since the voltage across a discharged capacitor must be zero, the Positive (+) side of C2 and the Base of Q1 were also pulled down to GROUND. So Q1 switches off. D1 stops emitting light. C1 discharges into the Base of Q2 and C2 is now charging through R3. Does this all sound familiar?	

7. When C2 is charged, current flows through R1 and LED D1 into the Collector and out of the Emitter of Q1.

The process starts again. The circuit is in fact oscillating like two children on a see-saw (or teeter-totter). The frequency of oscillation depends mainly in the values of R2(R3) and C1(C2).