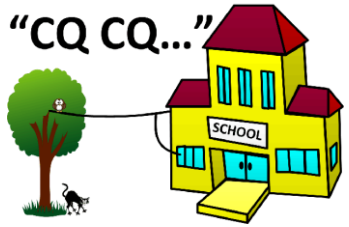


SCHOOL AMATEUR RADIO CLUB NETWORK®

STEM WORKSHOP - ELECTRONICS PROTOTYPING

- BUILD A WORKING ELECTRONIC CIRCUIT – FASCINATING TO WATCH!
- READ ELECTRONIC COMPONENT SYMBOLS AND CIRCUIT DIAGRAMS
- UNDERSTAND DIFFERENT COMPONENT FUNCTIONS AND MARKINGS
- VISUALISE HOW ELECTRIC CURRENT FLOWS THROUGH THE CIRCUIT
- INCLUDES A REUSABLE PROTOTYING BOARD AND ALL COMPONENTS
- INCLUDES A PRINTED CIRCUIT BOARD FOR HOME CONSTRUCTORS
- DOWNLOAD ADDITIONAL WORKSHOP NOTES FOR MORE PROJECTS
- DOWNLOAD THE PCB ASSEMBLY BOOK AT www.sarcnet.org

PROTOTYPING BOARD

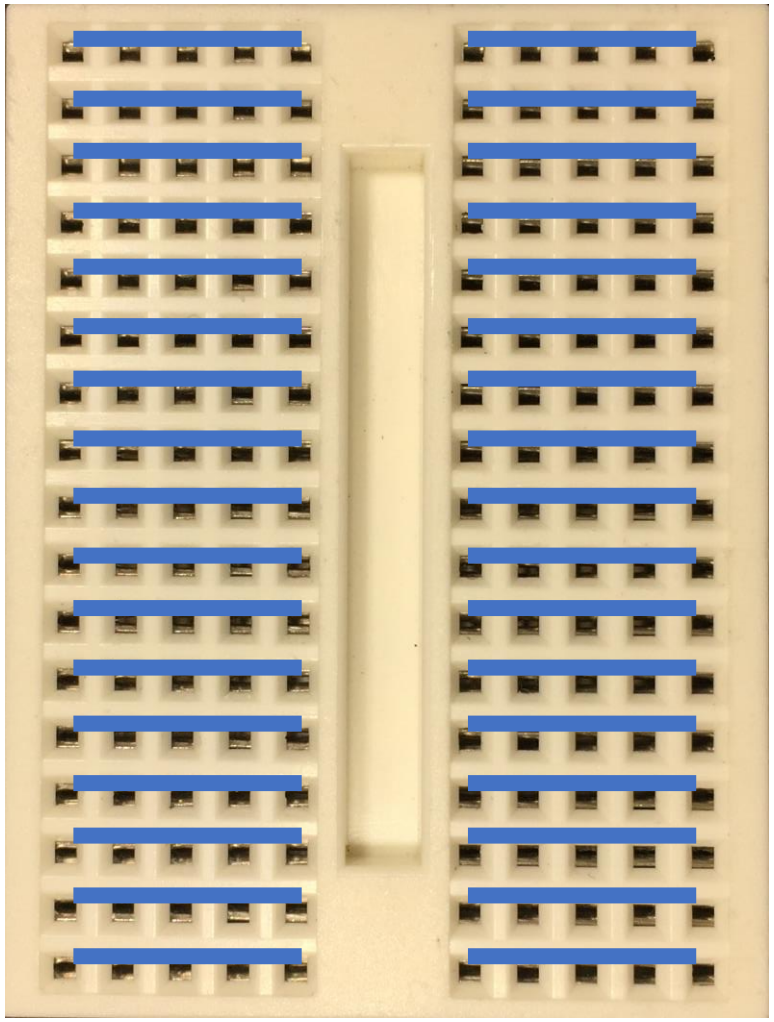
DESCRIPTION

PROTOTYPING BOARDS ARE USED TO CREATE CIRCUITS OF ELECTRONIC COMPONENTS WITHOUT HAVING TO SOLDER THEM

THE COMPONENTS CAN BE REMOVED AND RESUSED MANY TIMES

HOLES ARE SPACED 0.1 INCHES APART TO SUIT MANY TYPES OF ELECTRONIC COMPONENTS, EVEN INTEGRATED CIRCUITS

PHOTOGRAPH



NOTES

17 ROWS BY 10 COLUMNS

170 TIE POINTS IN TOTAL

THE TIE POINTS ON EACH ROW ARE CONNECTED TOGETHER AS SHOWN IN BLUE

THE LEFT AND RIGHT ROWS ARE NOT CONNECTED TOGETHER

PLEASE INSERT COMPONENT LEADS GENTLY

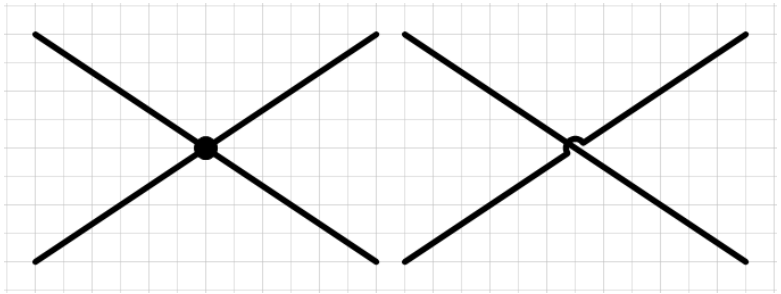
WIGGLE COMPONENTS SO AS NOT TO BEND THE LEADS

THE PROTOTYPING BOARD HAS DOUBLE-SIDED ADHESIVE TAPE

DO NOT REMOVE THE BACKING

WIRE LINKS

SYMBOL AND FUNCTION



WIRES CAN BE CONNECTED OR NOT-CONNECTED AS SHOWN

WIRE LINKS CONNECT SEPARATE ROWS OF THE PROTOTYPING BOARD TO FORM A CIRCUIT

TALL LINKS CAN CROSS OVER OTHER LINKS

PHOTOGRAPH

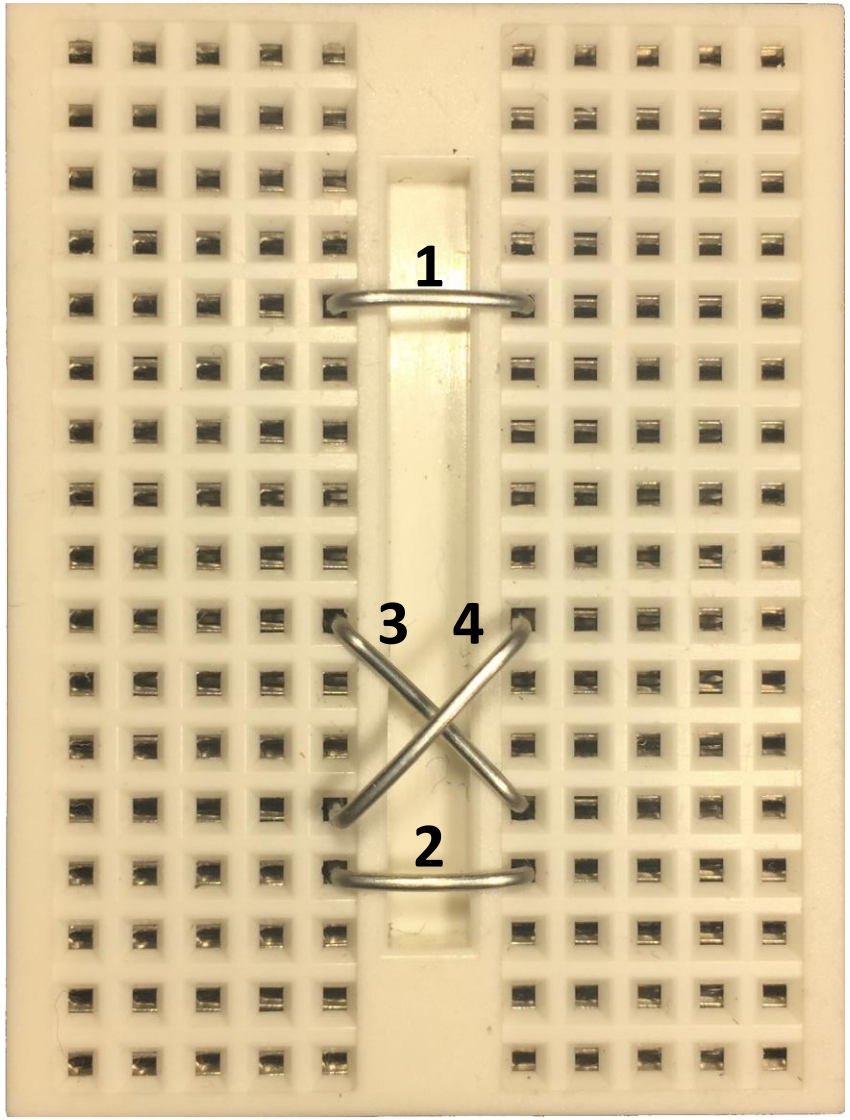
NOTES

1 x TALL LINK

1 x WIDE LINK

2 x SHORT LINKS

STEP 1: INSERT WIRE LINKS



WIGGLE THE COMPONENT UNTIL THE LEADS GO INTO THE HOLE EASILY

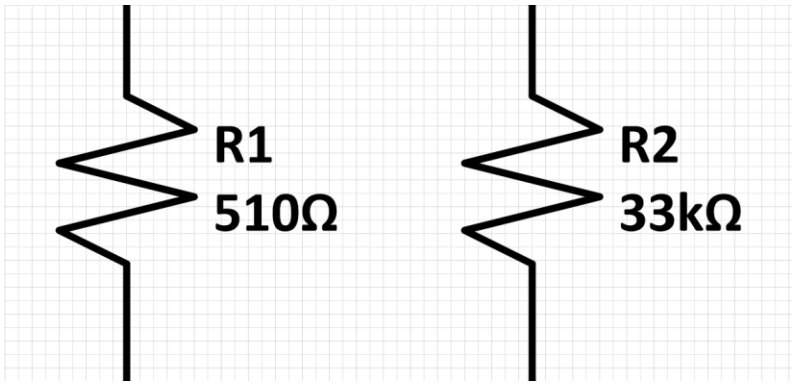
DO NOT PRESS HARD OR BEND THE LEADS

PRESS BOTH SIDES DOWN TOGETHER

1. **INSERT A SHORT WIRE LINK ACROSS THE CENTRE COLUMN ON ROW 5**
2. **INSERT A SHORT WIRE LINK ACROSS THE CENTRE COLUMN ON ROW 14**
3. **INSERT A WIDE WIRE LINK ACROSS THE CENTRE COLUMN ON THE DIAGONAL FROM ROW 10 TO THE ROW 13**
4. **INSERT A TALL WIRE LINK ACROSS THE CENTRE COLUMN ON THE DIAGONAL FROM ROW 10 TO THE ROW 13. IT SHOULD NOT TOUCH THE LINK UNDERNEATH.**

RESISTORS

SYMBOL AND FUNCTION



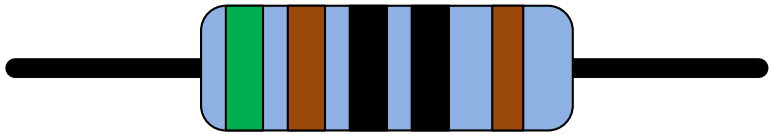
RESISTORS LIMIT THE FLOW OF ELECTRIC CURRENT IN A CIRCUIT TO A SAFE LEVEL BY CONVERTING THE EXCESS ENERGY INTO HEAT

RESISTANCE IS MEASURED IN OHMS (Ω)

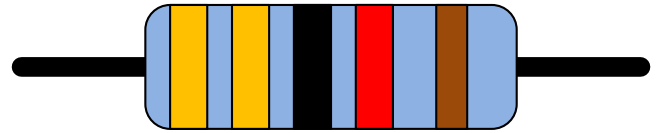
PHOTOGRAPH

NOTES

2 x 510 Ω RESISTORS

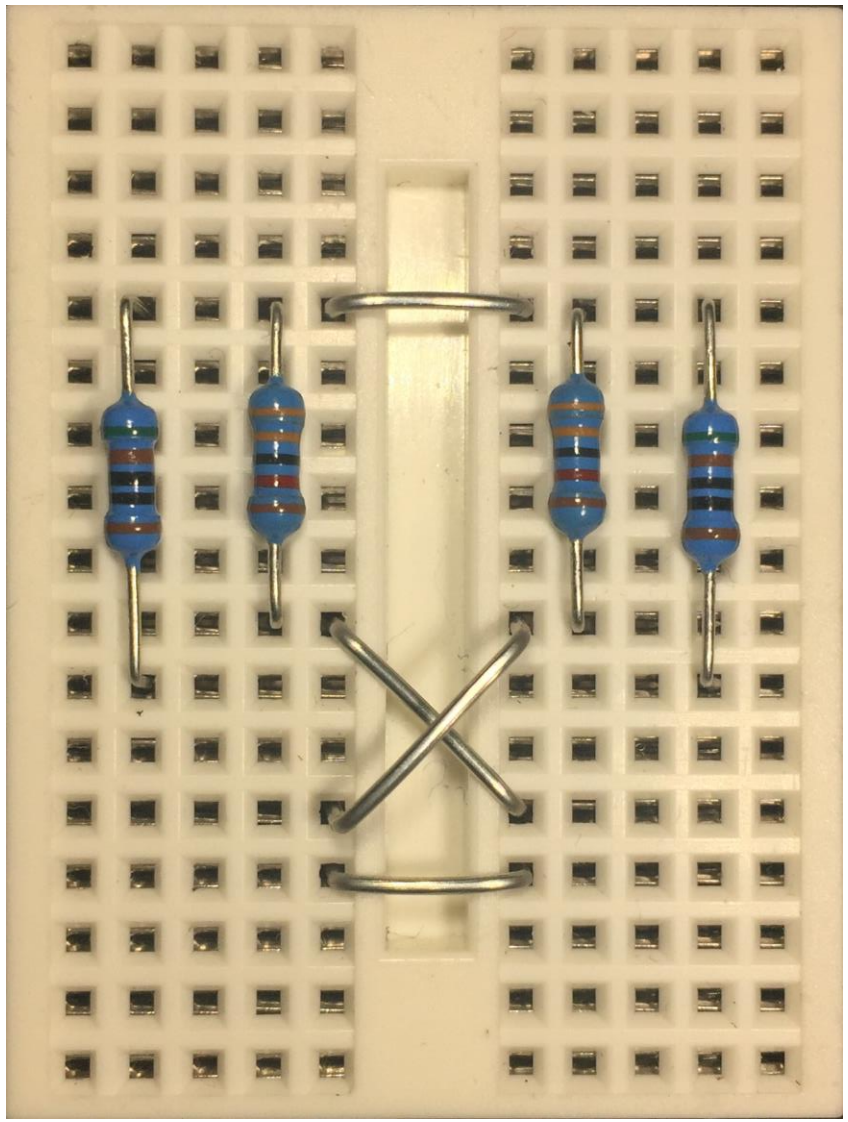


2 x 33 kΩ RESISTORS

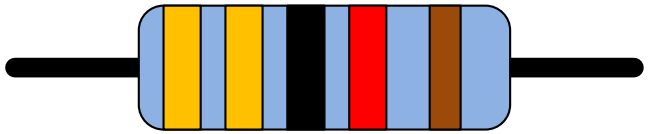


RESISTOR COLOUR CODE									
0	1	2	3	4	5	6	7	8	9
BAND 1	BAND 2	BAND 3	BAND 4	BAND 5	VALUE				
DIGIT 1	DIGIT 2	DIGIT 3	# ZEROS	TOL %					
5	1	0	0	1	510 OHM 1%				
3	3	0	2	1	33000 OHM 1%				

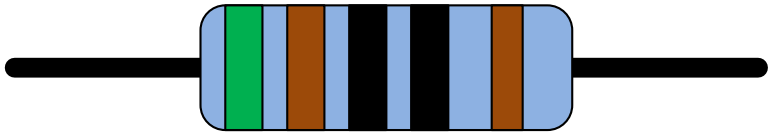
STEP 2: INSERT THE RESISTORS



1. **INSERT THE SHORT 33 kΩ RESISTORS FROM ROW 5 TO ROW 10 ON EITHER SIDE OF THE TOP LINK. PLACE THE ORANGE BAND AT THE TOP.**

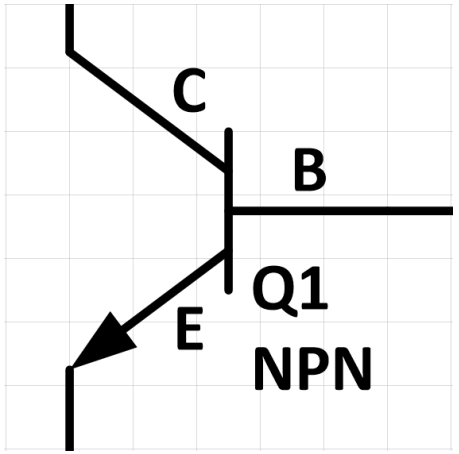


2. **INSERT THE LONGER 510 Ω RESISTORS FROM ROW 5 TO ROW 11, SEPARATED BY ONE SPACE ON EITHER SIDE OF THE 33 kΩ RESISTORS. PLACE THE GREEN BAND AT THE TOP.**



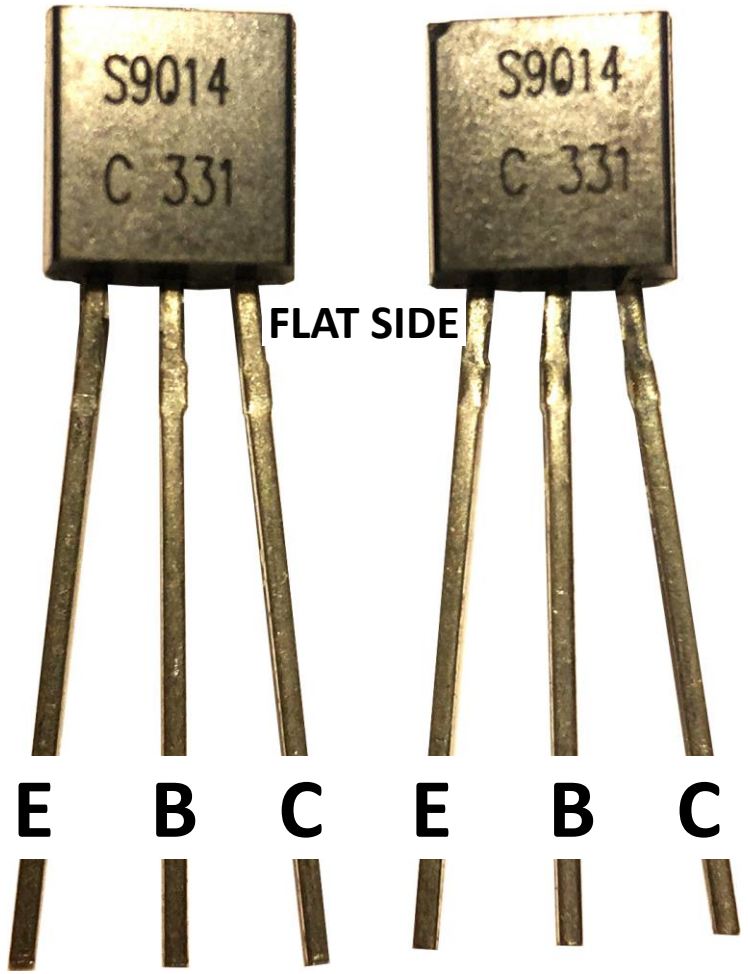
TRANSISTORS

SYMBOL AND FUNCTION



WHEN A VERY SMALL ELECTRIC CURRENT FLOWS INTO THE BASE (B) IT SWITCHES ON A MUCH LARGER CURRENT FLOWING FROM THE COLLECTOR (C) TO THE EMITTER (E) IN THE DIRECTION OF THE ARROW

PHOTOGRAPH

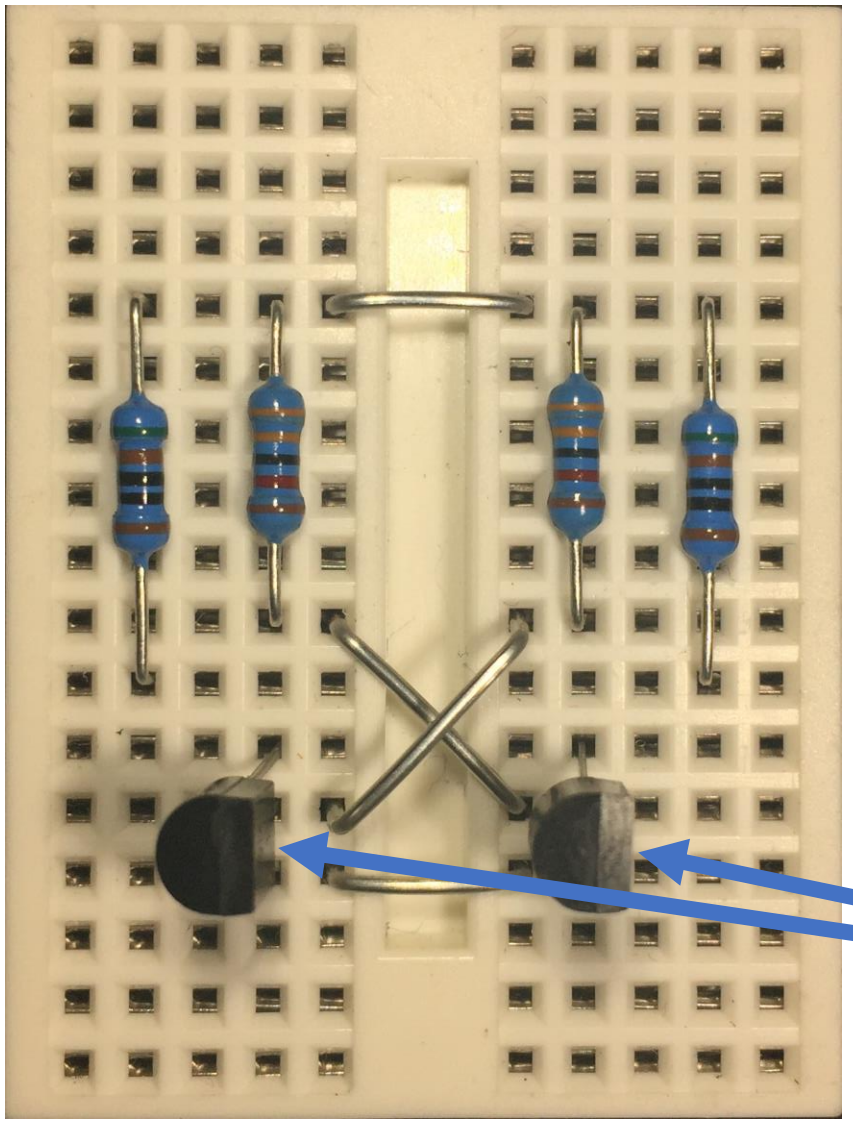


NOTES

2 x NPN TRANSISTORS

SPREAD THE TRANSISTOR LEADS SLIGHTLY APART AS SHOWN

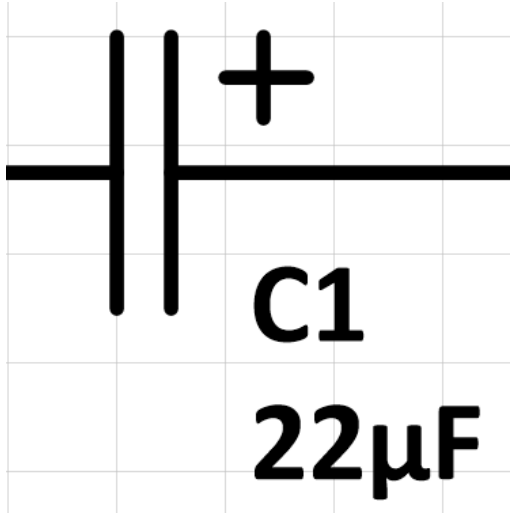
STEP 3: INSERT THE TRANSISTORS



1. INSERT A TRANSISTOR ON ETHER SIDE OF THE LINKS IN ROWS 12, 13 AND 14
2. REMEMBER TO SPREAD THE LEADS AND WIGGLE THE COMPONENT
3. THE FLAT SIDE OF THE TRANSISTORS SHOULD FACE THE RIGHT

CAPACITORS

SYMBOL AND FUNCTION



CAPACITORS CAN BE CHARGED UP AND DISCHARGED LIKE A TINY BATTERY

CAPACITANCE IS MEASURED IN MICRO FARADS (µF)

PHOTOGRAPH

NOTES

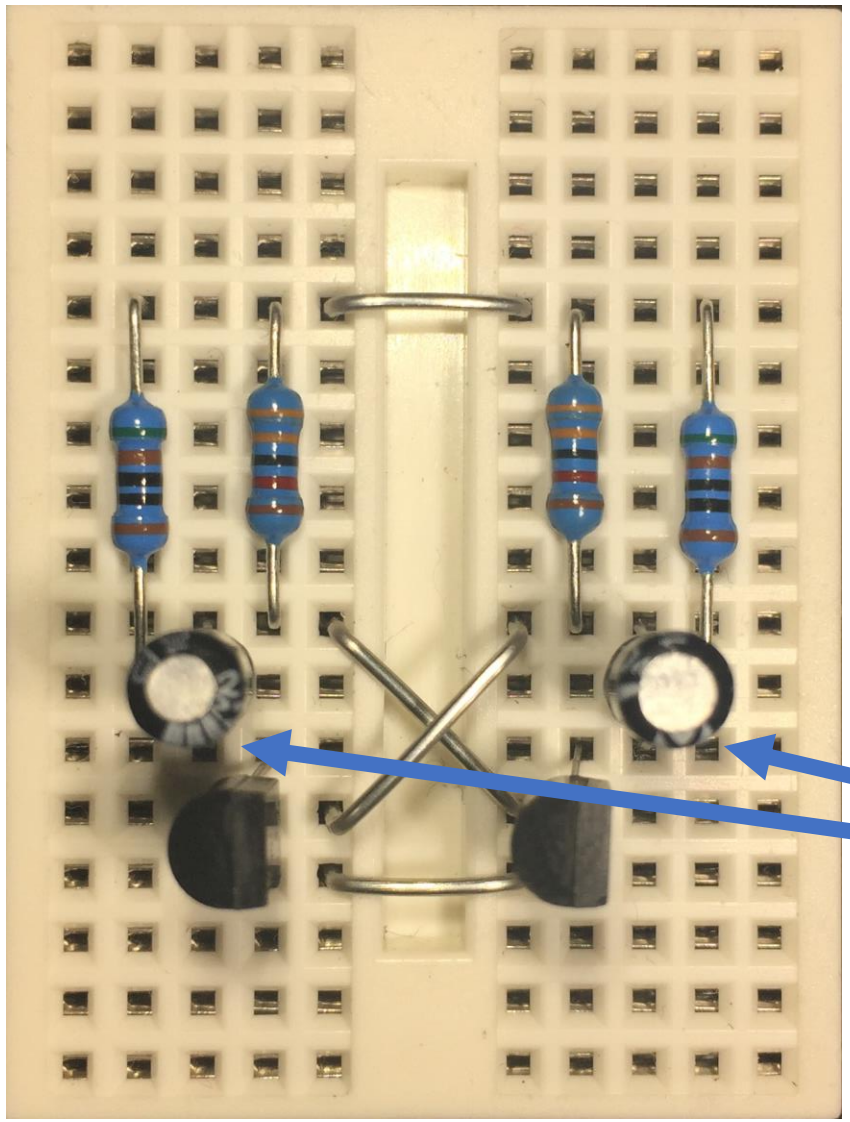
2 x 22µF CAPACITORS

SPREAD THE CAPACITOR LEADS SLIGHTLY APART AS SHOWN

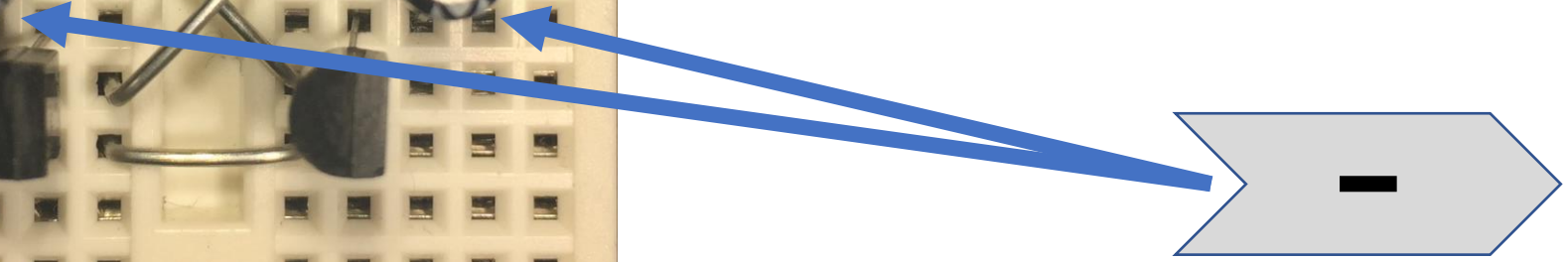
THIS MARK INDICATES THE NEGATIVE LEAD:

STEP 4: INSERT THE CAPACITORS

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

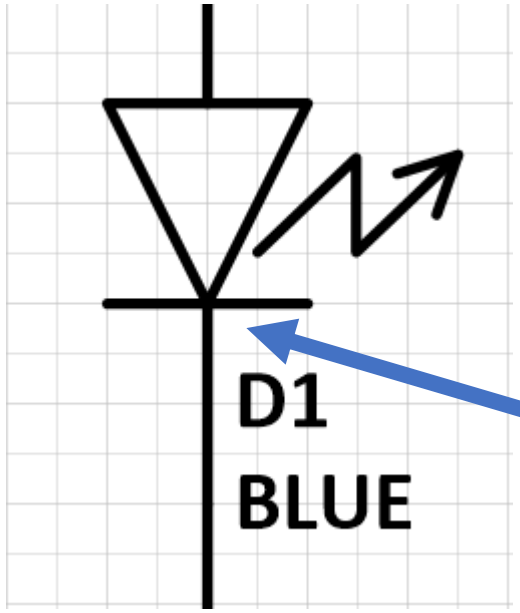


1. INSERT THE CAPACITORS ON EITHER SIDE OF THE CENTRE IN THE COLUMN BETWEEN THE RESISTORS
2. THE CAPACITOR LEADS GO INTO ROW 10 AND 12. THERE SHOULD BE ONE ROW SPACE BETWEEN THEM.
3. REMEMBER TO SPREAD THE LEADS AND WIGGLE THE COMPONENT
4. THE NEGATIVE LEAD OF THE CAPACITOR SHOULD BE CONNETED TO ROW 12



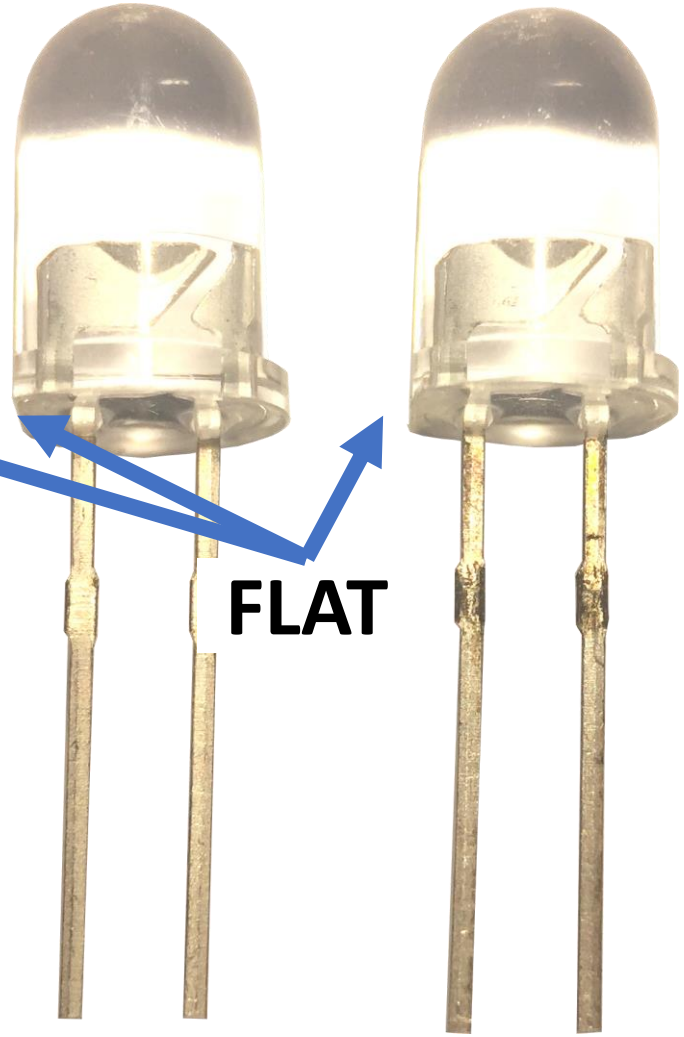
LIGHT EMITTING DIODES (LEDs)

SYMBOL AND FUNCTION



LIGHT EMITTING DIODES CONVERT ELECTRIC CURRENT DIRECTLY INTO LIGHT

PHOTOGRAPH



NOTES

2 x BLUE LEDs

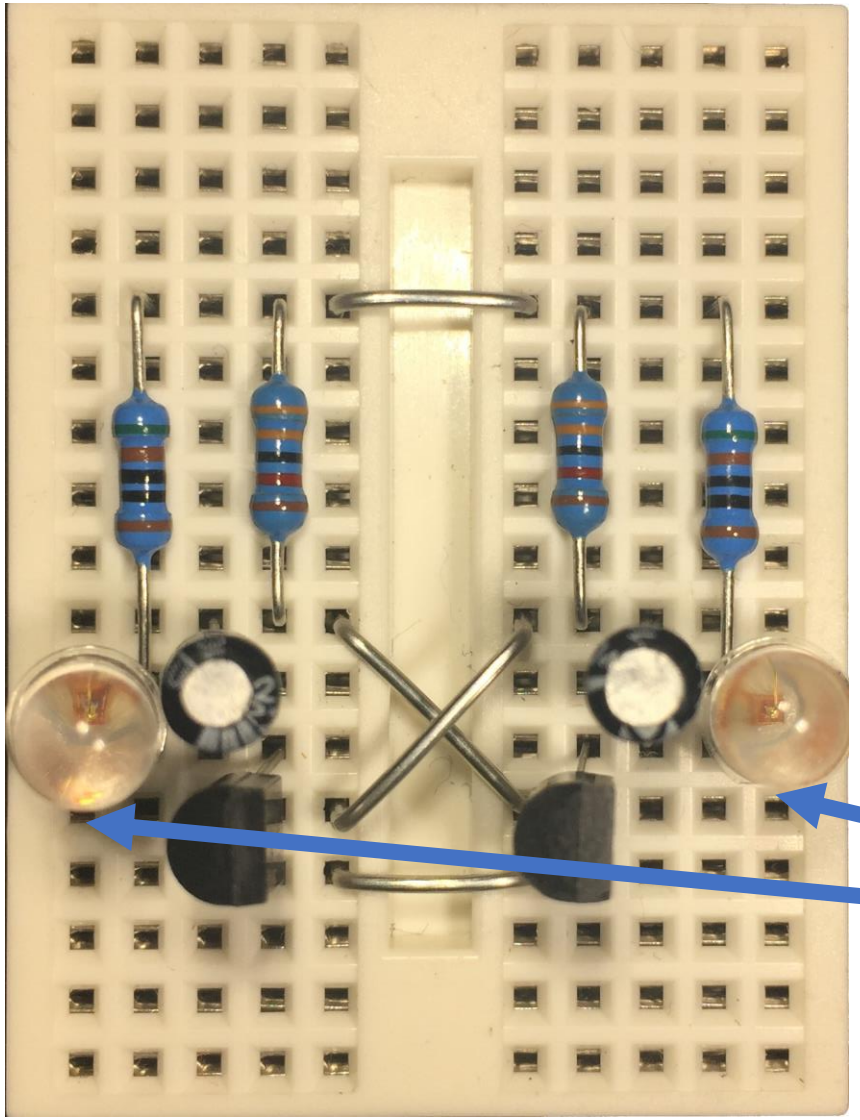
THE FLAT SIDE OF THE LED INDICATES THE NEGATIVE LEAD

SEE INTERNAL “POST” AND “ANVIL” STRUCTURE

THE “POST” IS THE POSITIVE LEAD

STEP 5: INSERT THE LEDs

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

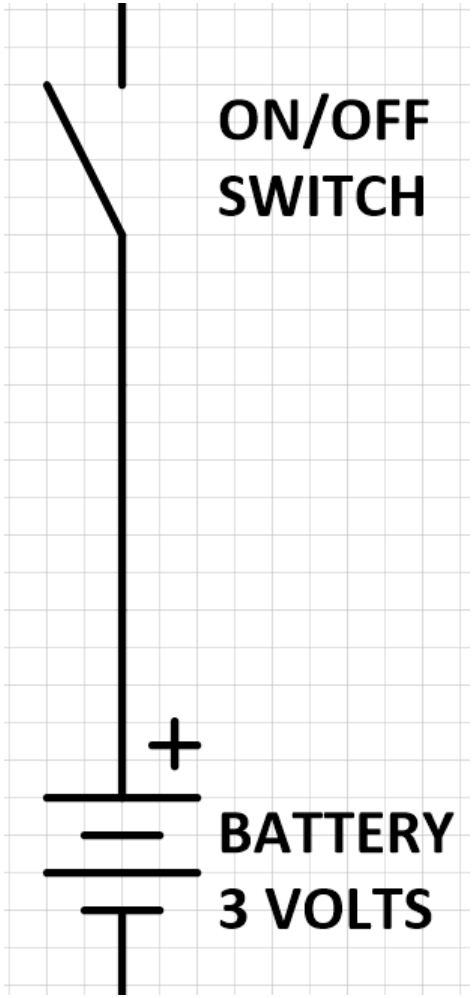


1. INSERT THE LEDs ON THE OUTSIDE OF THE 510 Ω RESISTORS IN ROWS 11 AND 12.
2. THE FLAT SIDE OF THE LED SHOULD BE AT THE BOTTOM

FLAT SIDE

BATTERY AND SWITCH

SYMBOL AND FUNCTION



THE BATTERY POWERS THE CIRCUIT

TWO 1.5 VOLT AA CELLS ARE CONNECTED IN SERIES TO PRODUCE 3 VOLTS

THE SWITCH CONTROLS THE FLOW OF ELECTRIC CURRENT INTO THE CIRCUIT.

PHOTOGRAPH

NOTES

THE BATTERY WILL BE PROVIDED FOR TESTING YOUR CIRCUIT AT THE END OF THE WORKSHOP

ENSURE THE SWITCH IS OFF AND REMOVE BATTERIES WHEN NOT IN USE.

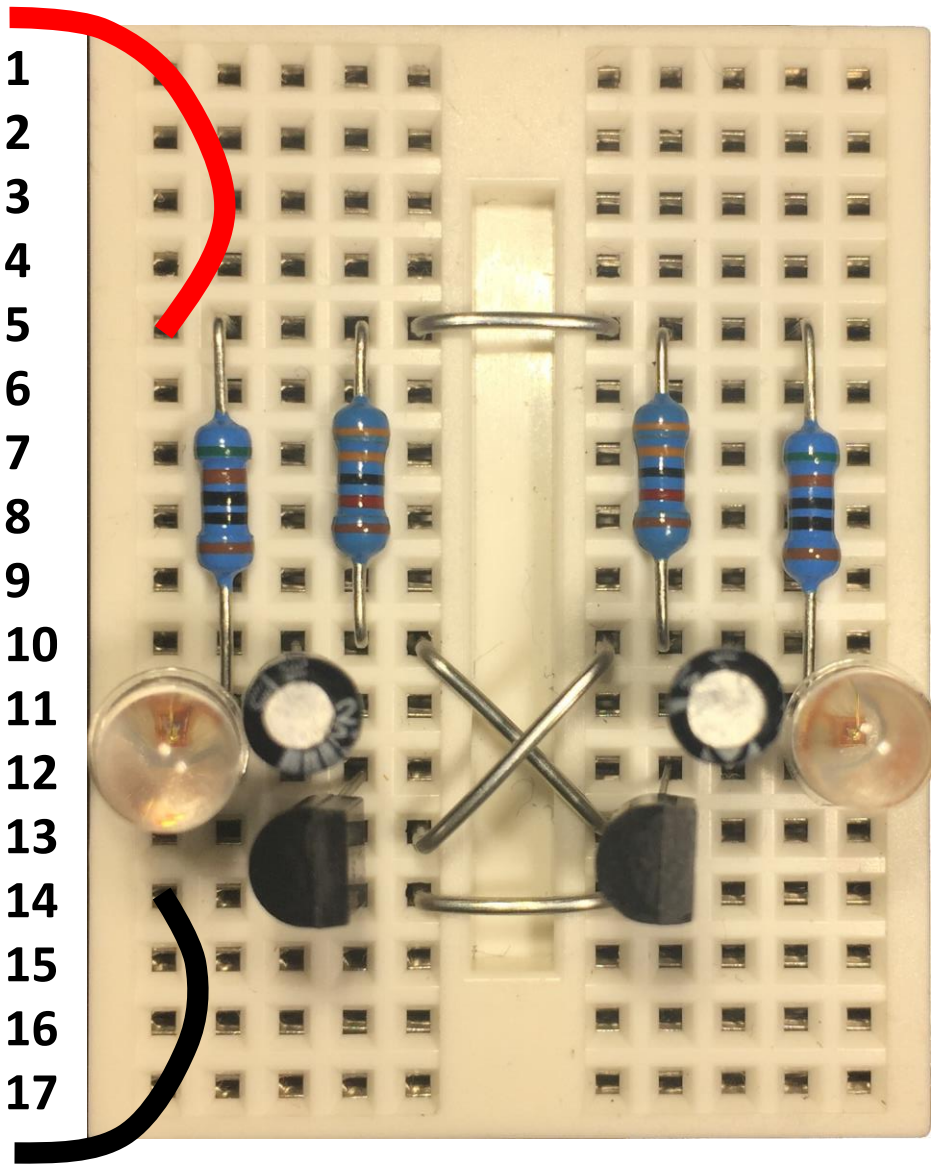
NEVER CONNECT THE WIRES TOGTHER

THE RED WIRE IS POSITIVE

THE BLACK WIRE IS NEGATIVE

AA CELLS ARE NOT INCLUDED

STEP 6: CONNECT THE BATTERY



1. CHECK THE ASSEMBLY ONE MORE TIME. ENSURE ALL COMPONENTS ARE IN THE RIGHT PLACE AND ORIENTED CORRECTLY.
2. MAKE SURE THE BATTERY SWITCH IS OFF

WARNING: IF YOU CONNECT THE BATTERY LEADS TOGETHER AND TURN THE SWITCH ON, THE BATTERY COULD GET HOT AND MAY START A FIRE. ALWAYS REMOVE THE AA CELLS FROM THE BATTERY HOLDER WHEN NOT IN USE.

4. CONNECT THE RED LEAD OF THE BATTERY TO ROW 5.
5. CONNECT THE BACK LEAD OF THE BATTERY TO ROW 14
6. TURN THE SWITCH ON AND YOUR LEDs SHOULD FLASH

PRINTED CIRCUIT BOARD

DESCRIPTION

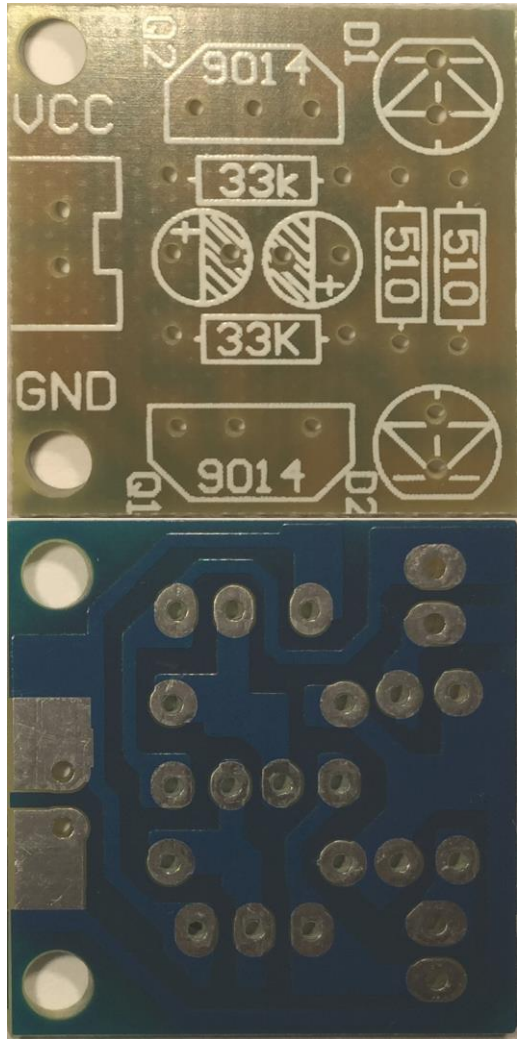
PRINTED CIRCUIT BOARDS (PCBs) ARE USED TO CREATE CIRCUITS OF ELECTRONIC COMPONENTS BY SOLDERING THE COMPONENT LEADS TO SOLDER PADS

COPPER PCB TRACKS CONNECT THE COMPONENT LEADS TO FORM A CIRCUIT

COMPONENTS CANNOT BE REMOVED VERY EASILY

THE PCB ASSEMBLY IS MORE STABLE AND PERMAMENT

PHOTOGRAPH



NOTES

HOLES IN THE PCB PERMIT COMPONENT LEADS TO FIT THROUGH THE BOARD

THE FRONT OF THE PCB HAS A WHITE, SILK-SCREENED PATTERN SHOWING WHERE EACH COMPONENT IS MOUNTED AND ITS CORRECT ORIENTATION

THE BACK OF THE PCB HAS A BLUE SOLDER MASK TO ENSURE THAT SOLDER ONLY FLOWS ON THE SOLDER PADS

SARCNET WORKSHOP NOTES
WWW.SARCNET.ORG

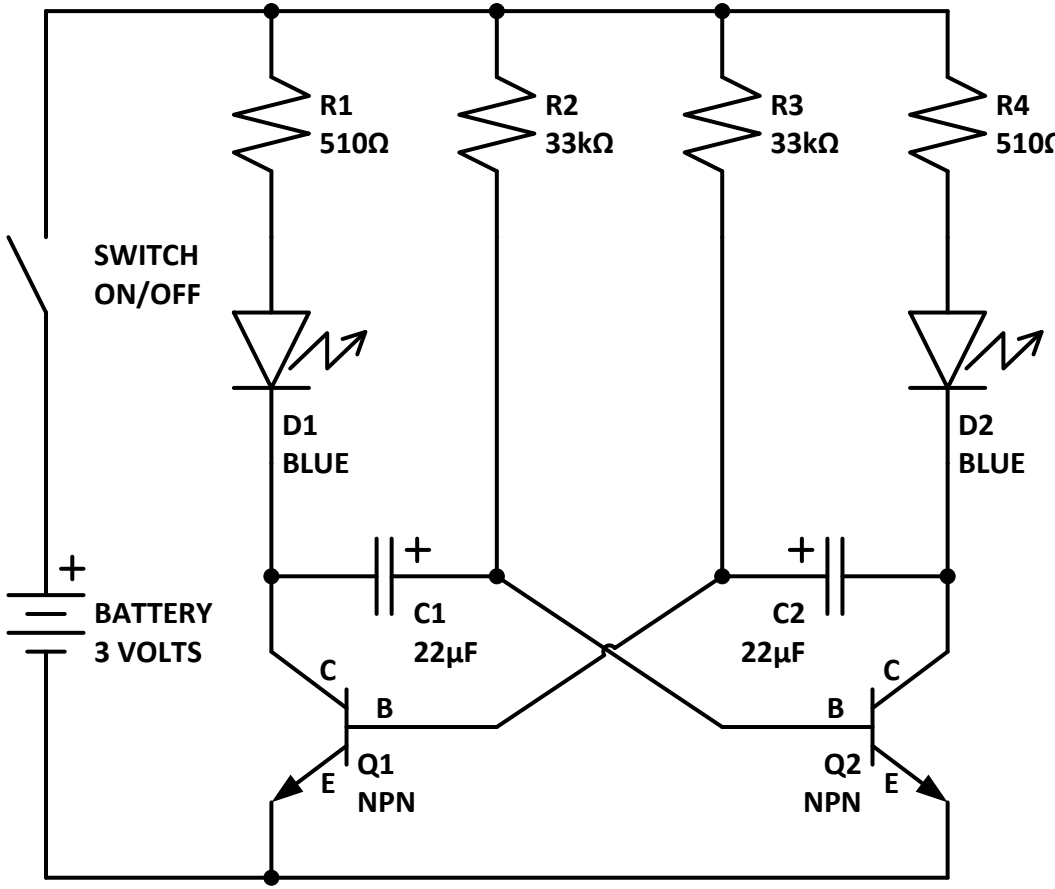
FLASHER

HOW IT WORKS

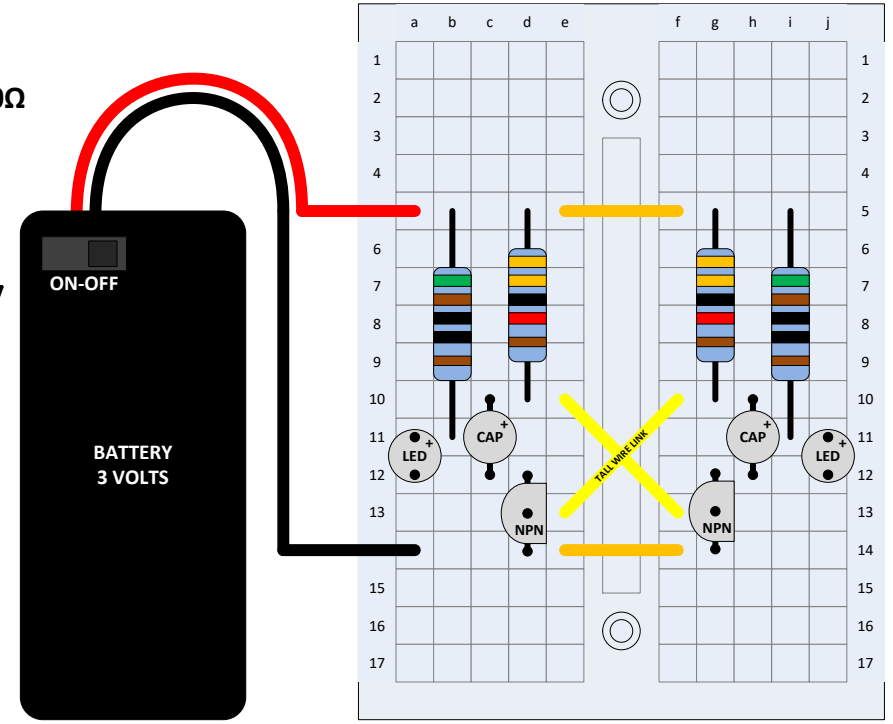
THE ELECTRONIC COMPONENTS ARE REPRESENTED BY SYMBOLS IN THE CIRCUIT DIAGRAM SHOWN BELOW. EACH COMPONENT HAS A DESIGNATOR AND A VALUE. THEY ARE CONNECTED BY BLACK LINES REPRESENTING WIRES. DOTS SHOW WHERE TWO WIRES ARE CONNECTED. EACH COMPONENT HAS A SPECIAL FUNCTION: TWO 1.5 VOLT AA CELLS CONNECTED IN SERIES PRODUCE 3 VOLTS TO POWER THE CIRCUIT. AN ON/OFF SWITCH 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. LIGHT EMITING DIODES (LEDS) CONVERT CURRENT DIRECTLY INTO LIGHT. TRANSISTORS WORK LIKE AN ON/OFF SWITCH, CONTROLLED BY A SMALL CURRENT FLOWING INTO THEIR BASE (B) CONNECTIONS. 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 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 (C) OF Q1 AND THEN OUT OF ITS EMMITER (E) 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. THIS FAMOUS CIRCUIT IS CALLED AN "ASTABLE MULTIVIBRATOR". DOWNLOAD MORE WORKSHOP NOTES AT WWW.SARCNET.ORG/WORKSHOPS.HTML.

PARTS LIST

1 - 3V BATTERY HOLDER WITH SWITCH
1 - PROTOTYPING BOARD - 170 TIE POINTS
2 - GENERAL PURPOSE NPN TRANSISTOR
2 - LIGHT EMITTING DIODE (BLUE)
2 - 22µF ELECTROLYTIC CAPACITOR
2 - 510Ω 1/4W RESISTOR
2 - 33kΩ 1/4W RESISTOR
2 - 0.3" WIRE LINK
1 - 0.4" WIRE LINK
1 - 0.4" WIRE LINK (TALL)



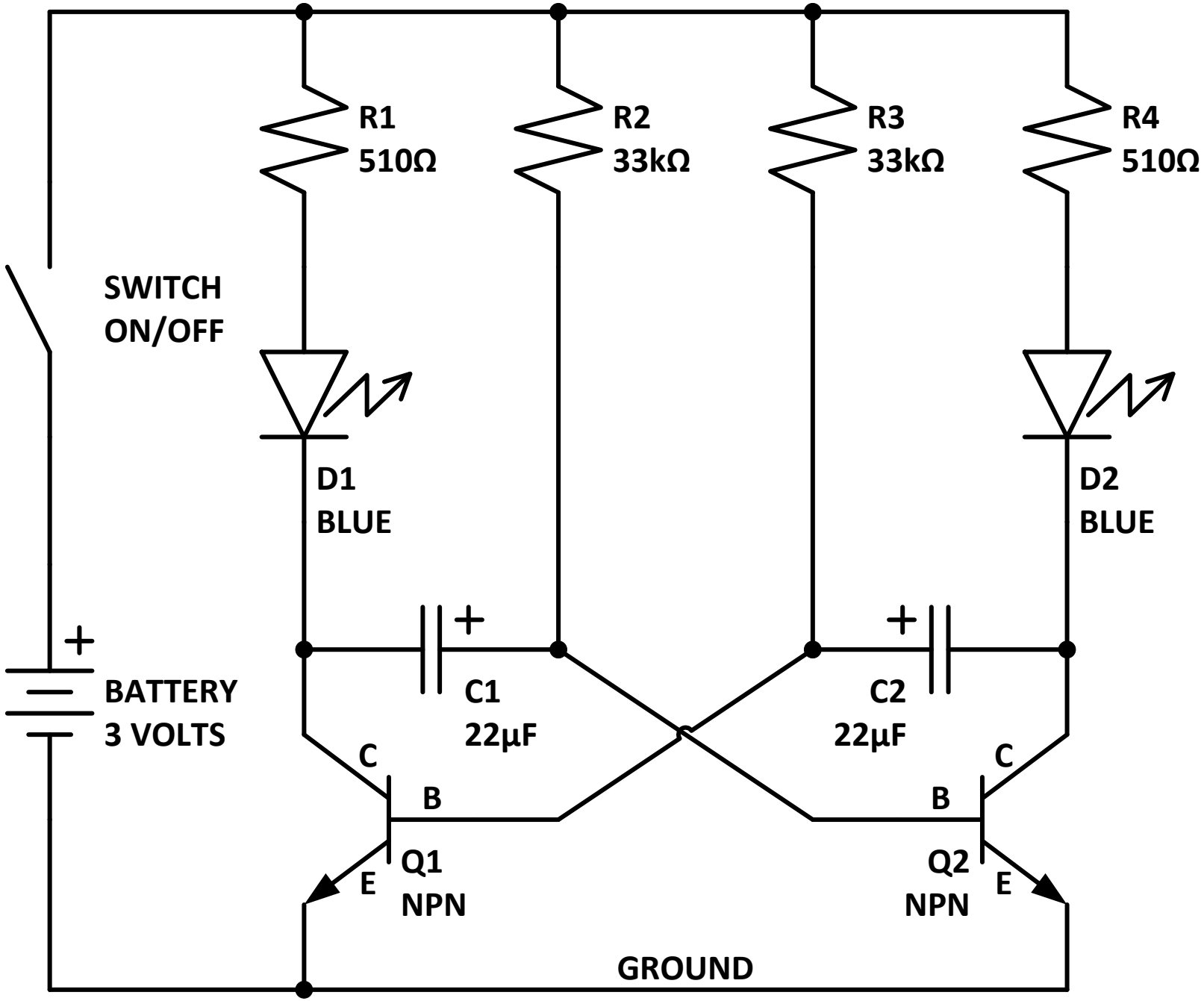
CIRCUIT SCHEMATIC DIAGRAM



RESISTOR COLOUR CODE									
0	1	2	3	4	5	6	7	8	9
BAND 1	BAND 2	BAND 3	BAND 4	BAND 5	VALUE				
DIGIT 1	DIGIT 2	DIGIT 3	# ZEROS	TOL %					
5	1	0	0	1	510 OHM 1%				
3	3	0	2	1	33000 OHM 1%				

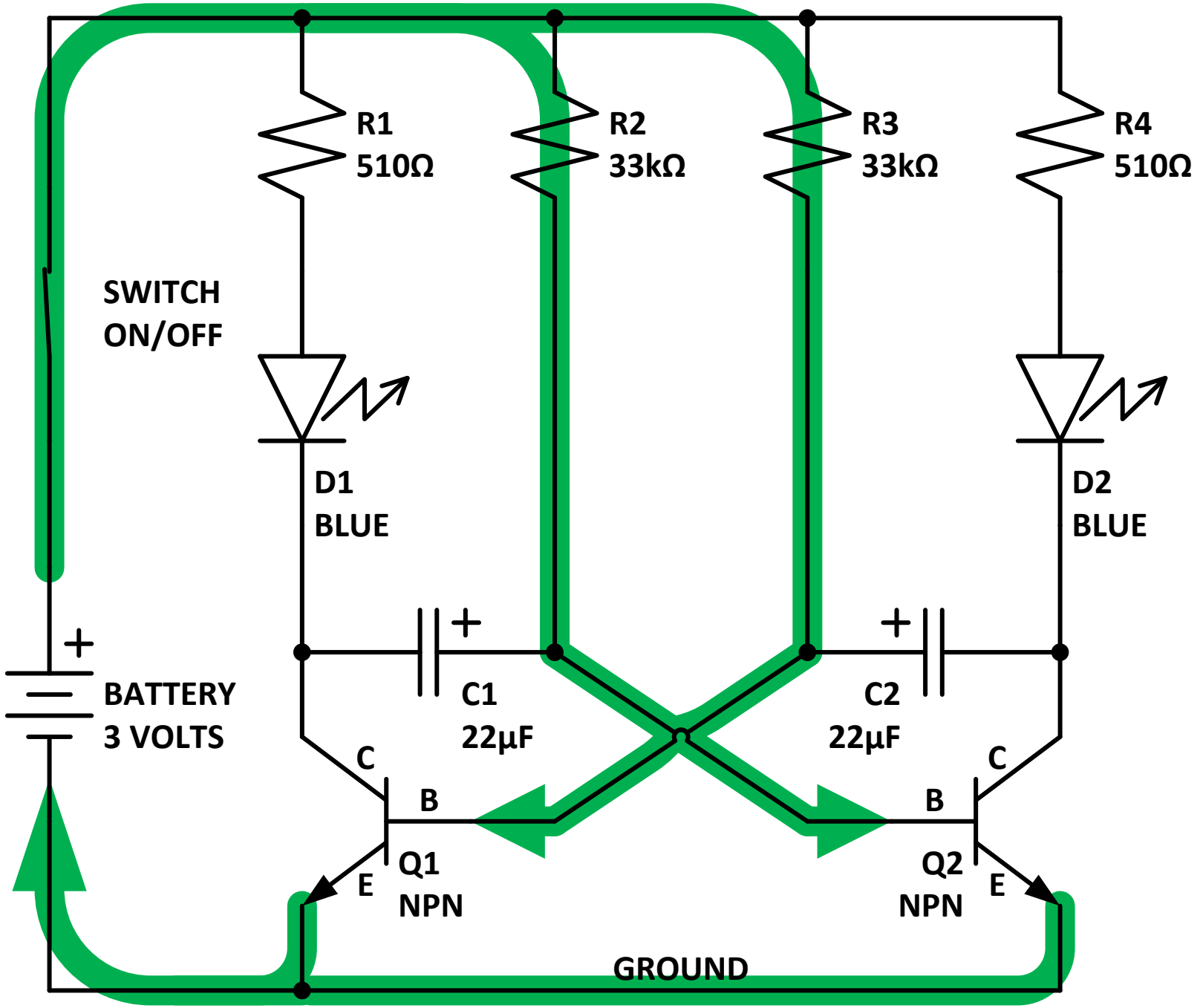
PROTOTYPE BOARD LAYOUT

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.

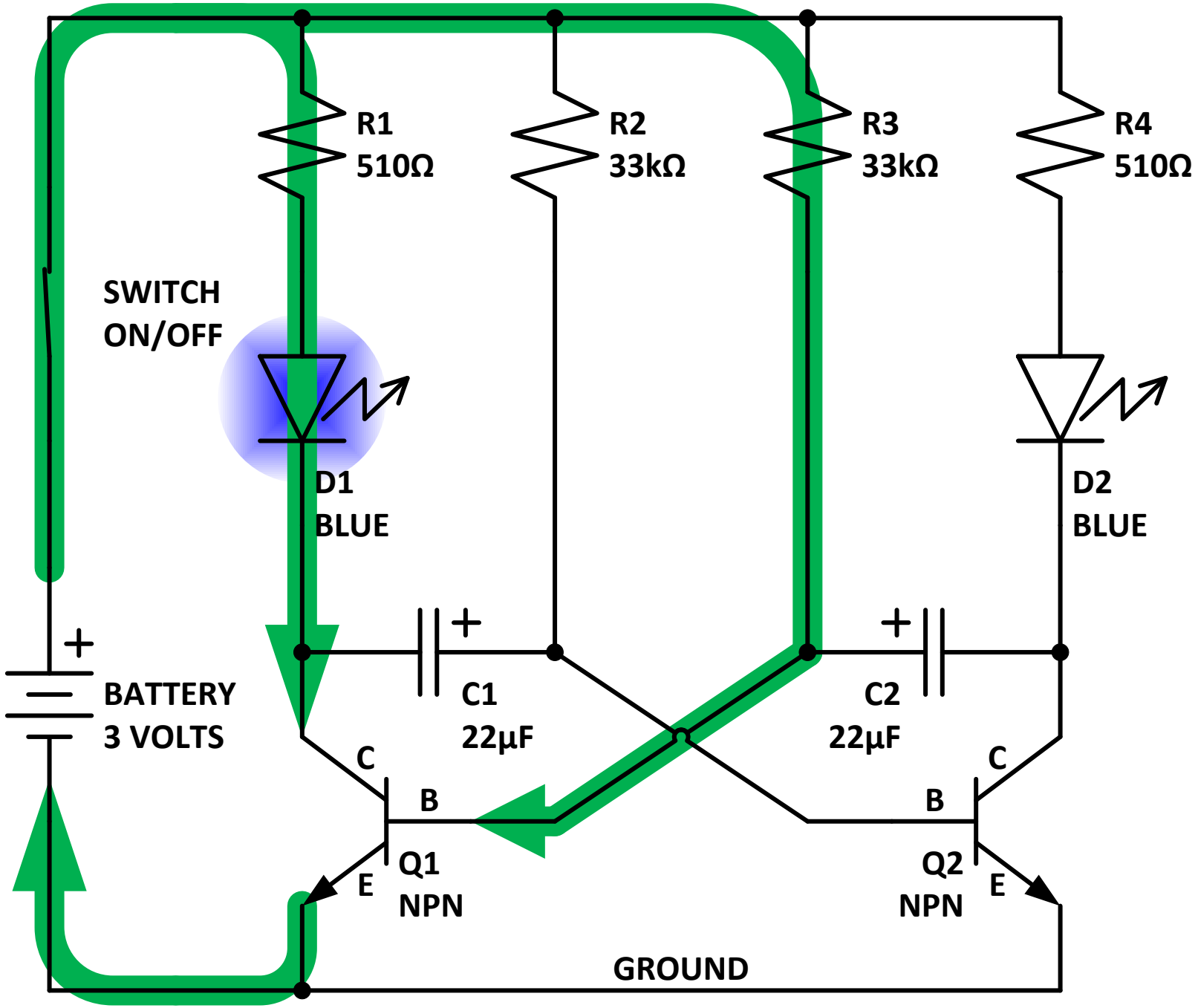


The wire at the bottom of this circuit is called GROUND for reference.

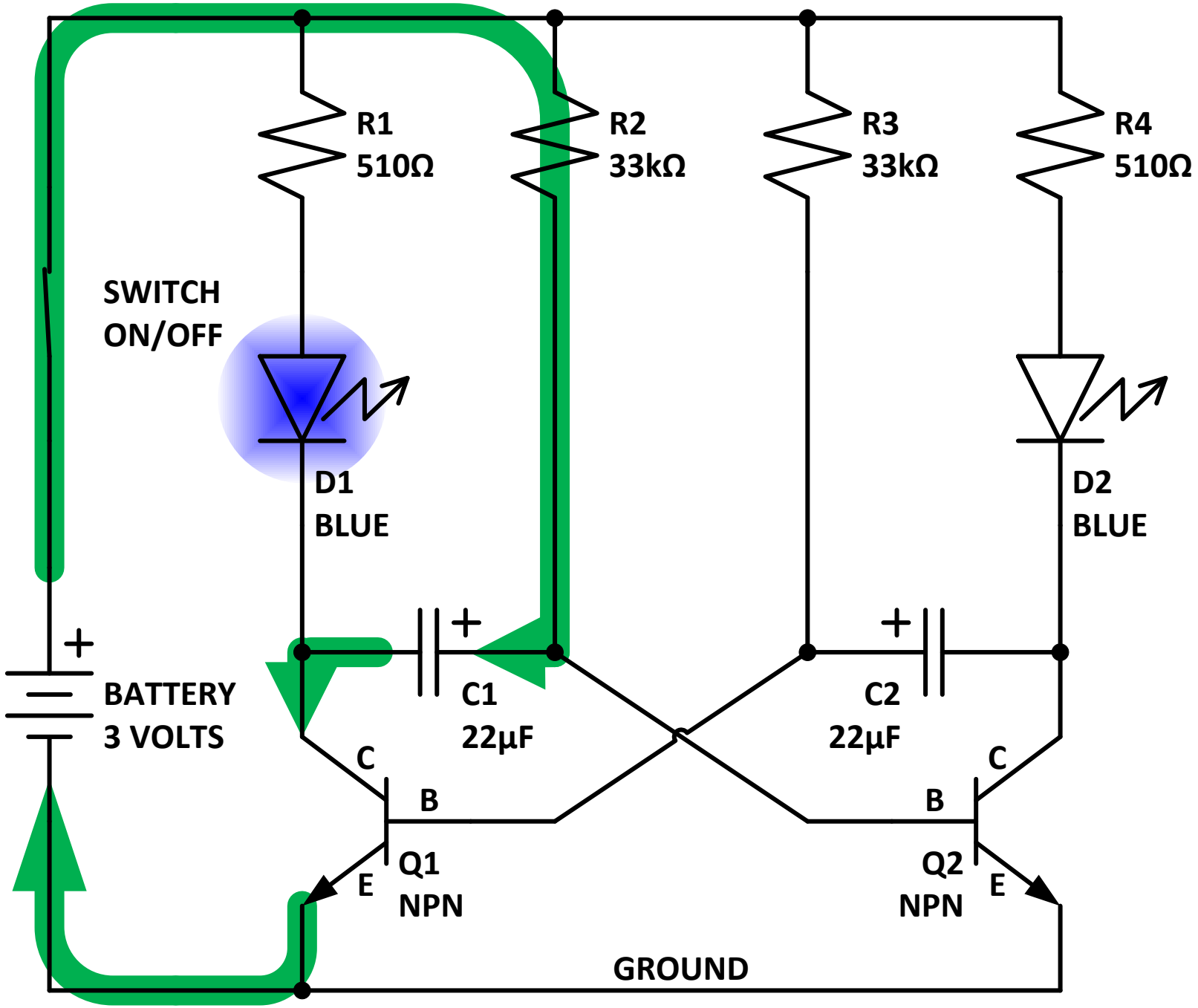
The switch is on. Current flows through resistors R2 and R3 into the Base of Q1 and Q2, down to GROUND and back to the battery. One of the transistors will turn on first. Which one? The fastest depends on minor variations in component parameters. It will be a race…



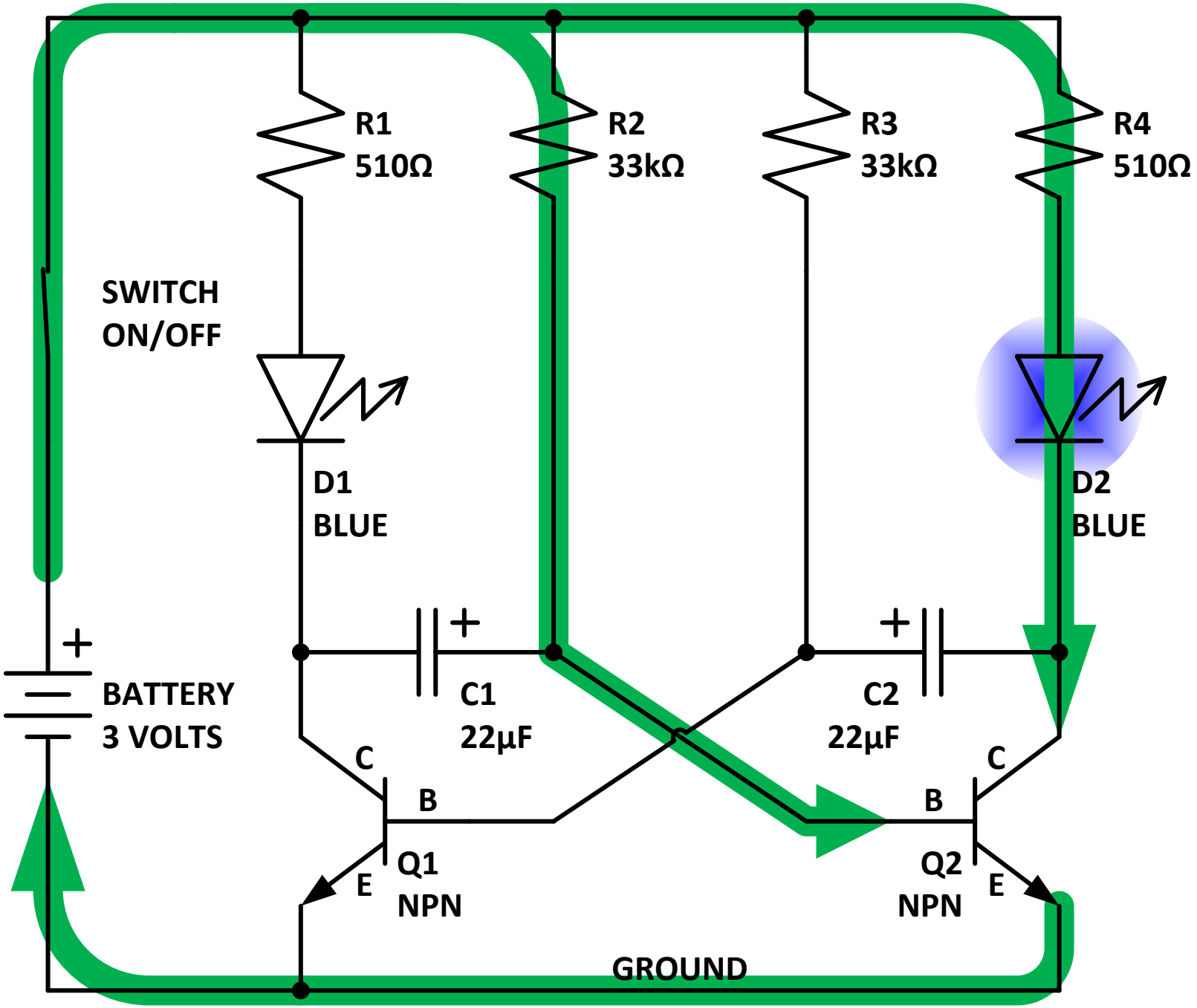
Q1 was the fastest and has turned on first! Current now flows through R1 and LED D1 into the Collector and out of the Emitter of Q1. D1 now emits light. But why doesn't Q2 also turn on as well? Wait and see…



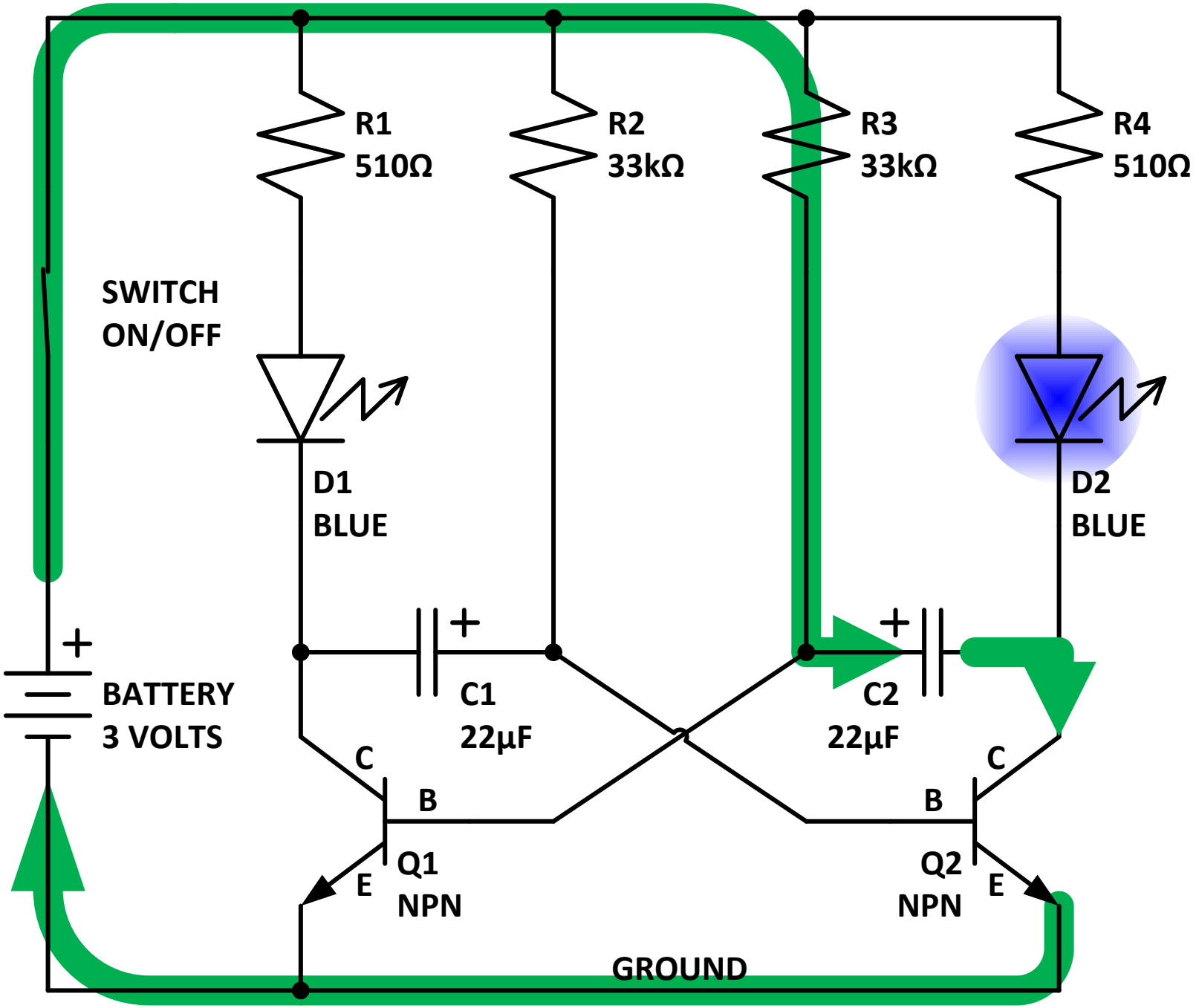
When Q1 turned on it also connected D1 and Capacitor C1 to GROUND. C1 was initially discharged. Since the voltage across a discharged capacitor must be zero, the Positive (+) side of C1 and the Base of Q2 were also pulled down to GROUND. Q2 was therefore switched off when Q1 turned on. However, C1 is 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?…



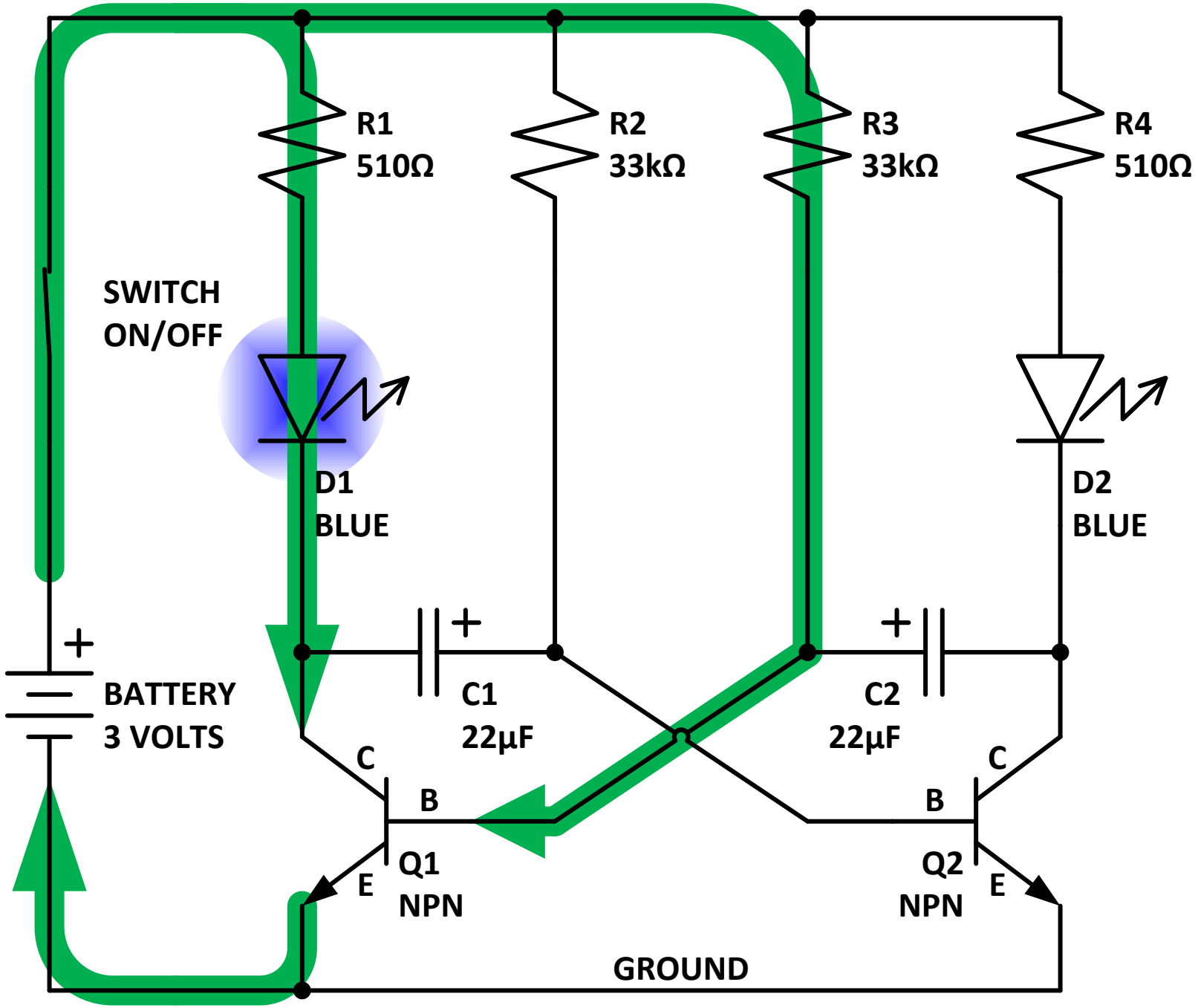
C1 has now been charged through R2. So current flows into the Base of Q2 and it turns on. D2 now emits light. But what makes Q1 turn off?...

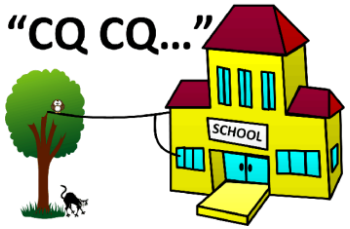


C2 was initially discharged when Q2 turned on. Since the voltage across a discharged capacitor must be zero, the Positive (+) side of C2 and the Base of Q1 were also pulled down to GROUND. So Q1 switches off. D1 stops emitting light. C1 discharges into the Base of Q2 and C2 is now charging through R3.



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 circuits is in fact oscillating like children on a seesaw or teeter-totter. The frequency of oscillation depends mainly in the values of R2(R3) and C1(C2).





SCHOOL AMATEUR RADIO CLUB NETWORK®

STEM WORKSHOP - ELECTRONICS PROTOTYPING

- WE HOPE YOU HAD FUN CREATING YOUR OWN ELECTRONIC CIRCUIT
- IMAGINE BUILDING YOUR OWN ELECTRONICS KITS AT HOME!
- IF YOU HAVE ANY QUESTIONS PLEASE ASK NOW
- DON'T FORGET TO VISIT www.sarcnet.org/workshops.html
- DOWNLOAD THESE SLIDES AND ALL WORKSHOP NOTES THERE
- HOME CONSTRUCTORS CAN DOWNLOAD THE PCB ASSEMBLY BOOK