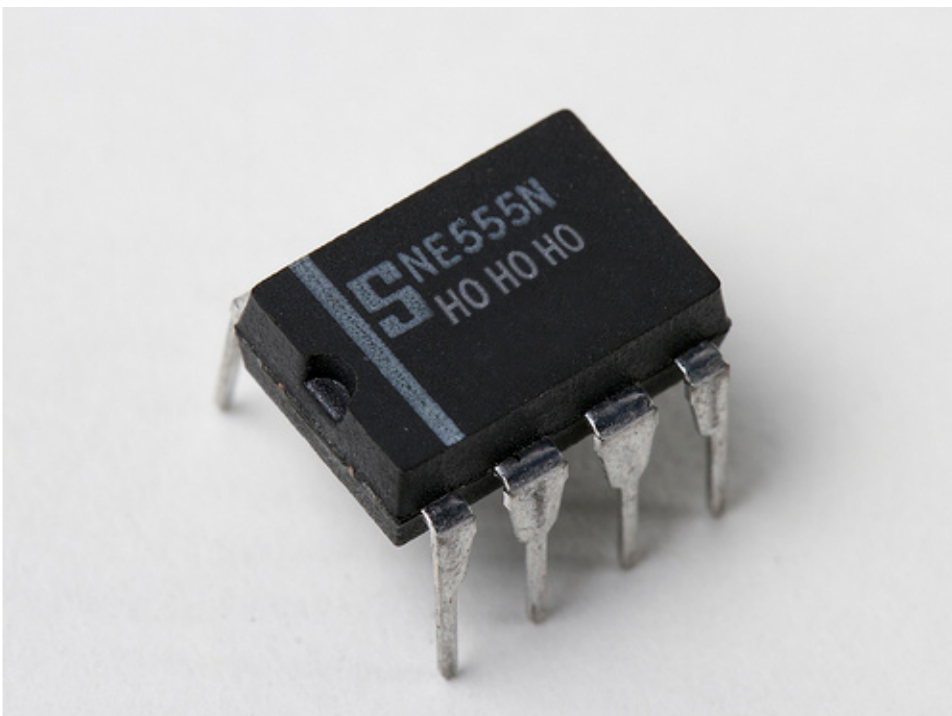
Fabian Winkler
555 Holiday Fun – workshop
Purdue Electronic and Time-Based Art Program
Purdue Makers Student Club



Overview:

1. Start: Concepts, Conventions, Components

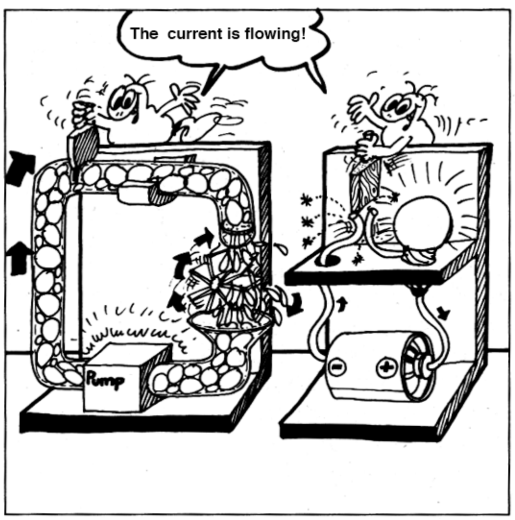
A. Concepts and conventions

- All our circuits use DC electricity (a battery or wall adapter), do not connect them to AC (i.e. outlet) electricity

- For all our circuits we assume that the flow of **electrons** is in one direction only from + (positive) to – (negative). The flow of electrons is called **current**.

- As a convention, positive power is marked with red, negative (or ground, "GND") is marked with black or blue.

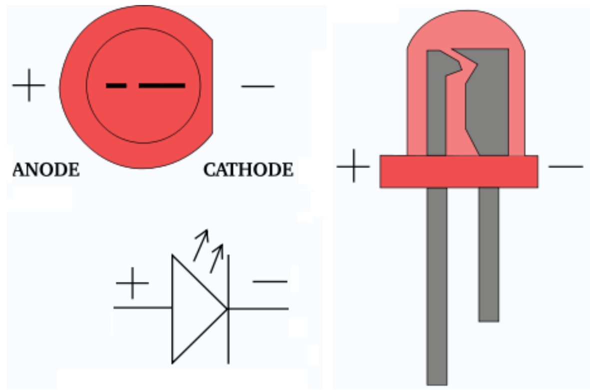
- We distinguish between **voltage (V or E)** (potential energy – "pressure" of electrons into the circuit) and **current (I)** (amount of electrons passing a point in the circuit) – look at water analogy.



- We distinguish between polarized and non-polarized parts/electric components. The orientation of a non-polarized part in a circuit does not matter, it does matter however for a polarized part.

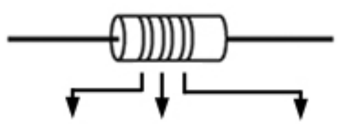
B. Components

- <u>LEDs</u> – polarized, light up when electrons pass through them



- <u>Resistors</u> – non-polarized, limit amount of electrons that pass through them

Resistor color chart: use this table to determine a resistor's value based on it's colored rings



BLACK	0	0	x	1
BROWN	1	1	x	10
RED	2	2	x	100
ORANGE	3	3	x	1,000
YELLOW	4	4	x	10,000
GREEN	5	5	x	100,000
BLUE	6	6	x	1,000,000
VIOLET	7	7	x	10,000,000
GRAY	8	8	x	100,000,000
WHITE	9	9		--

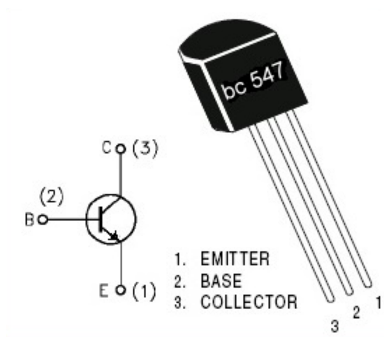
The fourth band indicates accuracy (GOLD = +/- 5%, SILVER = +/- 10%, NO FOURTH BAND = +/- 20%)

- Capacitors – polarized/non-polarized, store electrons after charging, release electrons when discharging, do not allow any more electrons to pass once charged

longer leg is **+**, band around cylinder specifies **–** or GND

non-polarized

- Transistors – polarized, amplify amount of electrons going through a circuit, a weak current (i.e. few electrons) controls a larger current (lots of electrons).



The presence/absence of a current at the transistor’s base determines the opening closing of the collector/emitter gate for amplification.

The following picture from my old electronics junior project book illustrates this:

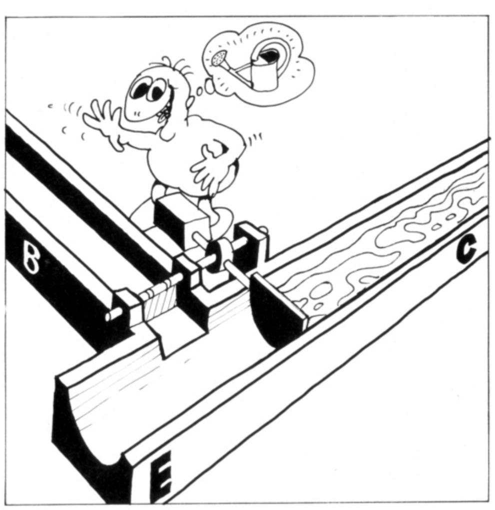


Bild 60. „Wasser-Transistor“ (gesperrter Zustand)

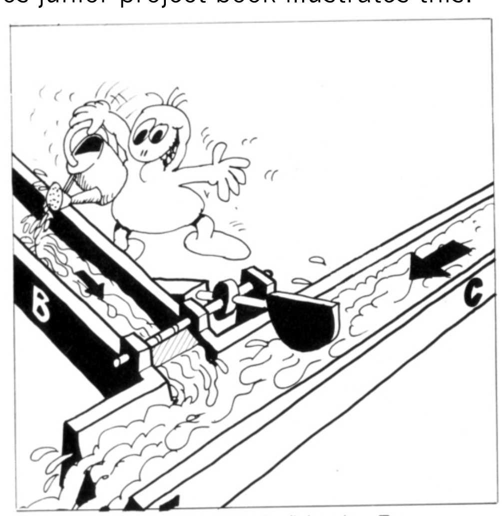
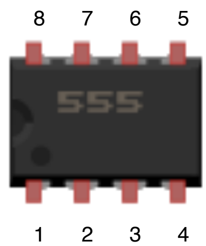


Bild 61. „Wasser-Transistor“ (leitender Zustand)

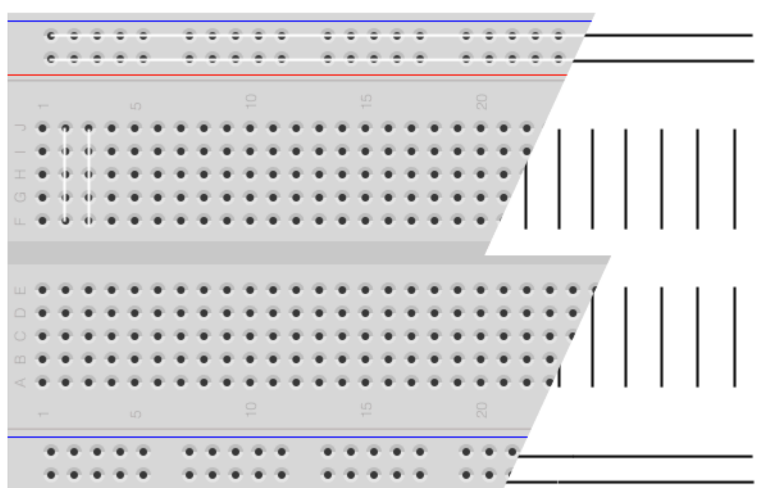
- ICs – integrated circuit (look up datasheet for polarity and pin-out), specialized components that do a variety of things, in case of the 555 timer IC creating a pulse or frequency.



Pins are counted counter-clockwise from left of notch (sometimes there's a little dot next to pin 1).

C. Building Tips

- How to use the breadboard: look at the picture below to see how rows and columns connect parts on the breadboard



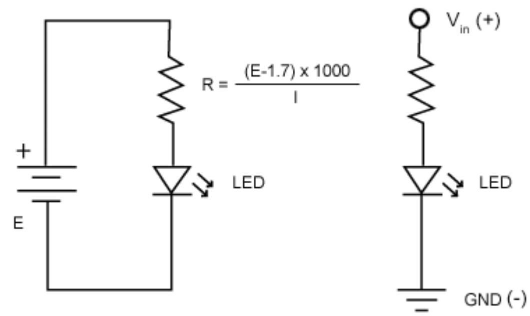
- Keep all your jumper cables, component legs, etc. short, straight and as close as possible to the surface of the breadboard.

- Use the hot foam cutter on a medium heat setting and use the special UHU glue to stick Styrofoam pieces together.

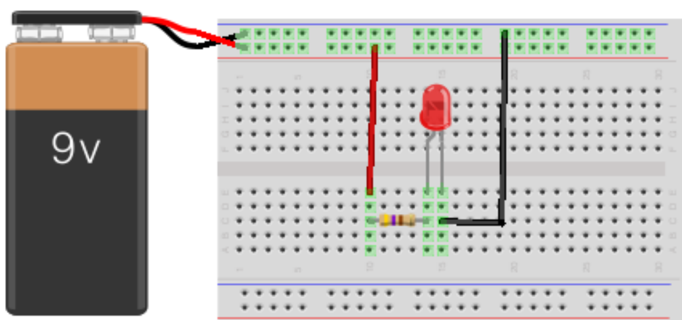
- We probably won't make it to this stage in today's workshop but when soldering parts together, use the IC sockets for soldering first and then place the IC into the socket after soldering all the connections to avoid overheating the IC.

2. Making Things Blink, part 1: lighting up an LED

Use this circuit to light up an LED. Observe the LEDs polarity and use the formula below to determine the resistance of R1 (resistor 1). Look at the colored bands around the resistor to specify its value (see resistor color codes in 1.B. components section.



The formula next to resistor R on the left helps you to determine the correct resistor value for R, so you don't burn the LED. As a rule of thumb you can use **1.7V @ 20mA** for standard LEDs (colored, i.e. non-clear plastic cap). Here is what this should look like on your breadboard, **use a 470Ω resistor** with a standard LED:



The red, green and yellow LEDs in the holiday kit are **1.7V@20mA**

The blue LED is **3.4V@20mA**

If you would like to connect more than just one LED you can connect multiple LEDs in **series** or **parallel**, and the value of the resistor changes like this:

<u>Series circuit:</u>

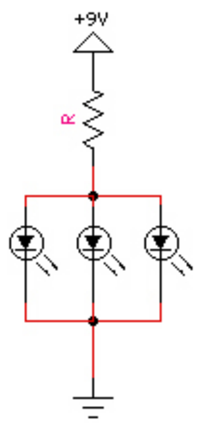
LED1 = LED2 = LED3 = 1.7V, 20mA

$$R = \frac{(E - (\text{number of LEDs} \times 1.7)) \times 1000}{20\ \text{mA}}$$

$$R = \frac{(9V - (3 \times 1.7)) \times 1000}{20\ \text{mA}} = 195\Omega$$

It is hard to find a 195Ω resistor, also the values of resistors tend to vary up to +/- 10-20% so a safe and easy to find value for R would be 220Ω or 270Ω.

Parallel circuit:



LED1 = LED2 = LED3 = 1.7V, 20mA

$$R = \frac{(E - 1.7) \times 1000}{\text{number of LEDs} \times 20\ \text{mA}}$$

$$R = \frac{(9V - 1.7)) \times 1000}{3 \times 20\ \text{mA}} = 121\Omega$$

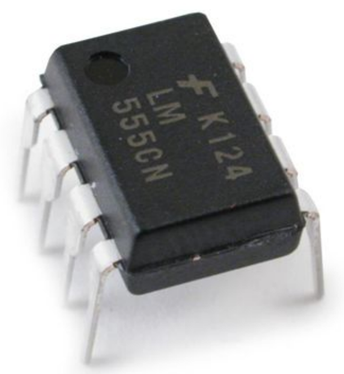
Again, 121 Ω is an odd value for a resistor. Also, including possible imprecision, R=150Ω would be a safe choice.

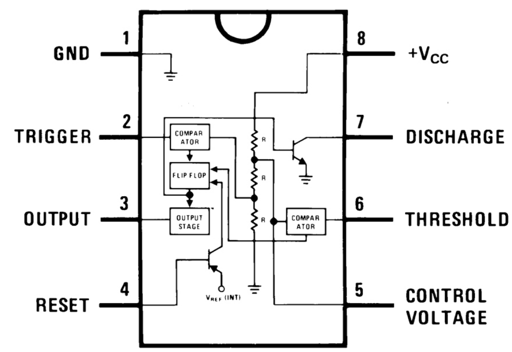
Things to think about: Why do you choose a specific LED color? And what ideas can the brightness of the LED convey?

If you open and close the circuit with a jumper wire the LED blinks – not much fun yet, so we continue...

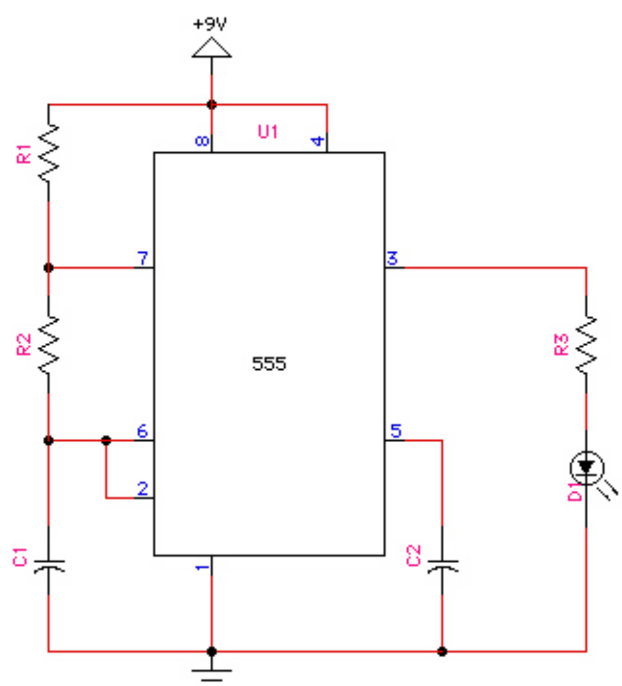
3. Making Things Blink, part 2: the 555 Timer IC

The first circuit for making an LED blink is based on an extremely popular integrated circuit (IC) called 555 timer IC. This IC is extremely useful and versatile and with only a handful of external components, it can be easily configured to perform many different timing task. The main two configurations, independent of the 555's final usage, are the monostable mode ("one shot" output) and astable mode (pulsed output). In the following example, we use the 555 timer IC in its astable mode, constantly turning an LED connected to its output pin ON and OFF – before we start building the circuit, let's take a look at the 555's pin configuration:





Here is a simple circuit for making an LED blink:

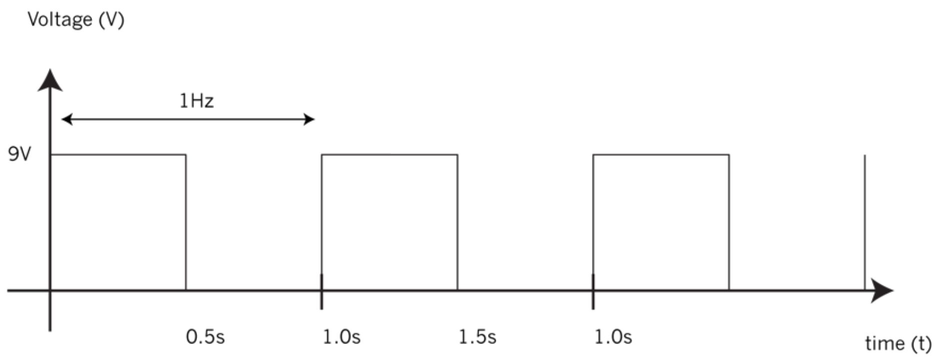


initial setup:

R1 = 1kΩ
R2 = 10kΩ
C1 = 22μF

C2 = 0.001μF
R3 = 470Ω/1kΩ

We measure the turning on and off of the 555 timer's IC output on pin 3 in a unit called Hertz (Hz) – this unit of frequency defines the number of cycles per second of a periodic phenomenon, like this:



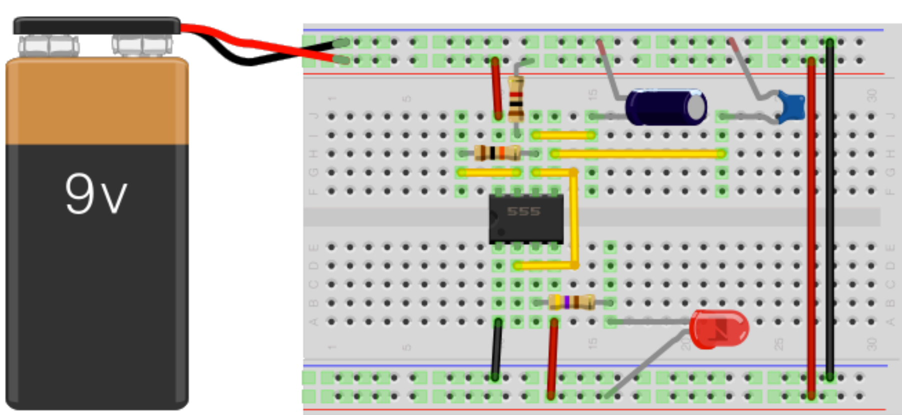
We can calculate the on/off times of a 555 timer's output very precisely using this formula:

$t1 = 0.693 \times (R1+R2) \times C1$
$t2 = 0.693 \times R2 \times C1$

the units are: F, Ω, s and Hz

$$f = \frac{1.44}{(R1 + 2R2) \times C1}$$

Here is what it looks like on the breadboard:



<u>Things to think about:</u> Which ideas can be expressed using different blinking frequencies (slow/fast), how do they relate to/reference things we know from the world around us, e.g. flashing lights on a police car, heartbeat/pulse monitor, the blinking of fireflies, etc.? What shapes could hold such a blinking light (Rudolph's nose, etc...).

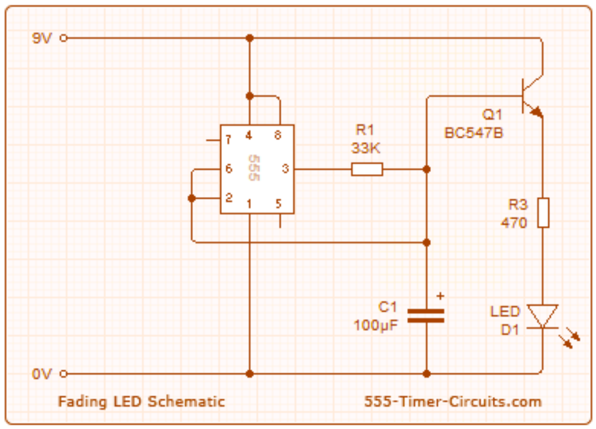
You can experiment further by connecting the output of one timer IC (pin 3) to the input of another (pin 4) for more (seemingly) randomized flickering behavior...

4. Making Things Pulse

This is a simple circuit I found online at: http://www.555-timer-circuits.com/up-down-fading-led.html

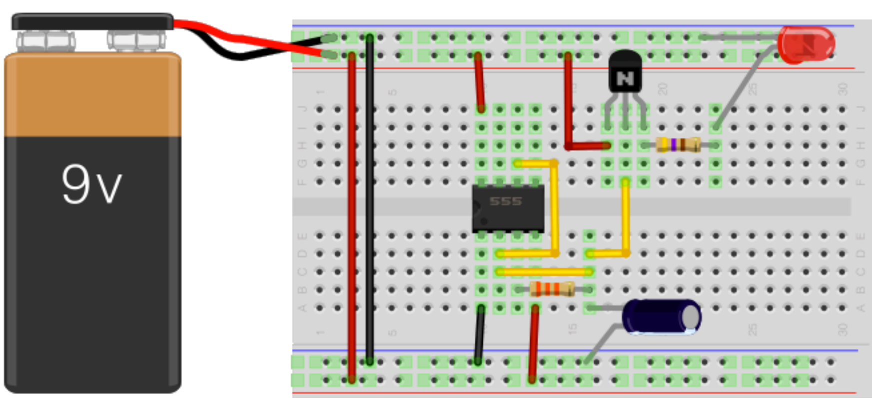
These two circuits make a LED fade on and off. The first circuit charges a 100u and the transistor amplifies the current entering the 100u and delivers 100 times this value to the LED via the collector-emitter pins. The circuit needs 9v for operation since pin 2 of the 555 detects 2/3 Vcc before changing the state of the output so we only have a maximum of 5.5v via a 470R resistor to illuminate the LED.

Schematic

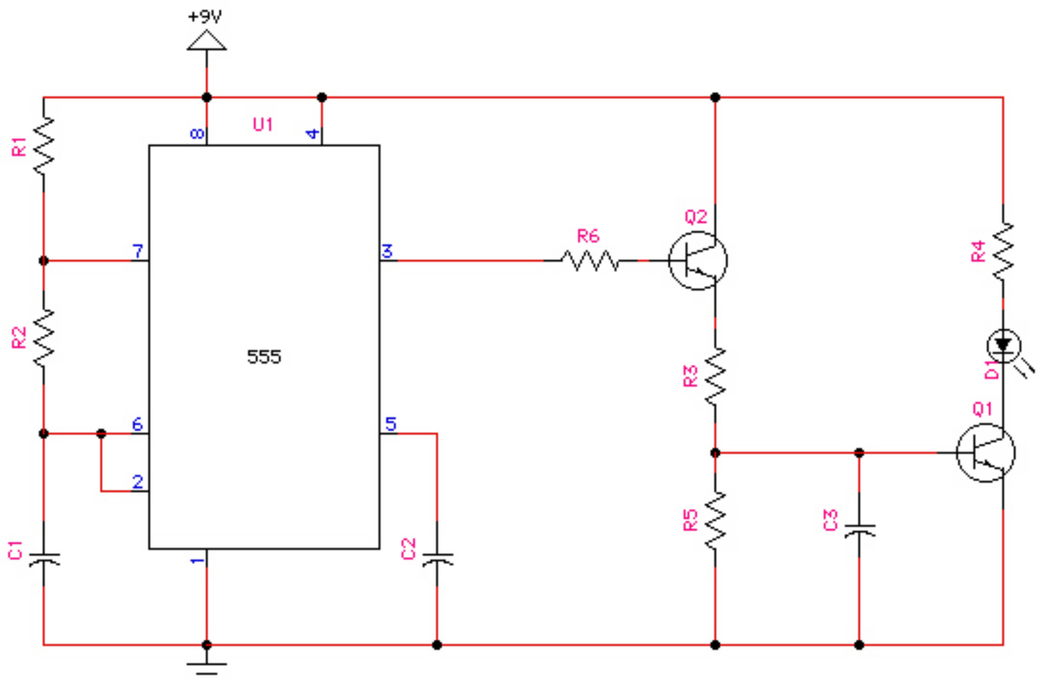


You might need to experiment with different values for R1 and C1 to get the desired pulse frequency. Look at section 1.B Components – Transistors (p.4) for a pinout of the BC547 NPN transistor.

Here is the breadboard view:



This is a more complicated circuit that also fades the LED, however, it uses the 555 timer IC more closely to how we had set it up in section 3:



initial setup:

R1 = 1kΩ	R3 = 100kΩ
R2 = 10kΩ	R5 = 47kΩ
C1 = 220μF	C3 = 220μF
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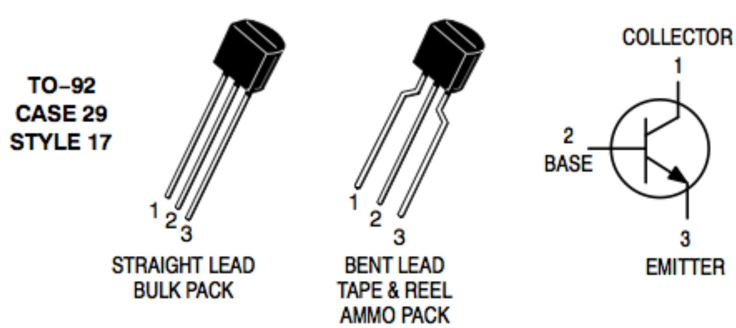
C2 = 0.001μF	R4 = 470Ω/1kΩ
R6 = 1-10kΩ	Q1 = Q2 = 2222 NPN

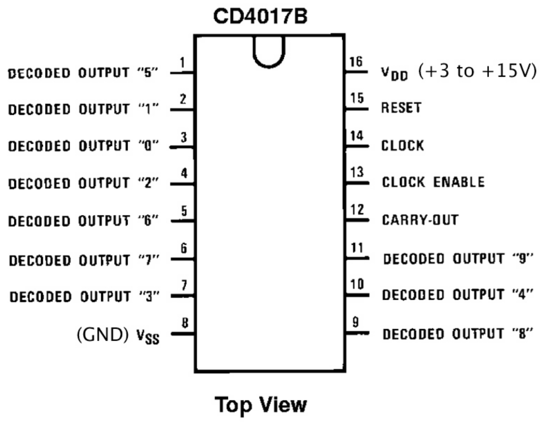
You might have to experiment with the initial values for R1, R2 and C1 a little to make the 555 frequency slow enough so that you can see the fading in and out of the LED (or, in turn fiddle with R3, R5 and C3 for the timing of the fading processes).

This is the pinout for the two 2N2222 NPN transistors in this circuit:



5. Making Things Blink, part3: counting with the CD4017B IC

The CD4017B is a decade (1 to 10) counter IC advances its count as the clock input becomes high (e.g. clock or timing input from the pulsed output of a 555 timer IC). Each "DECODED OUTPUT 0-9" goes high in turn as counting advances.

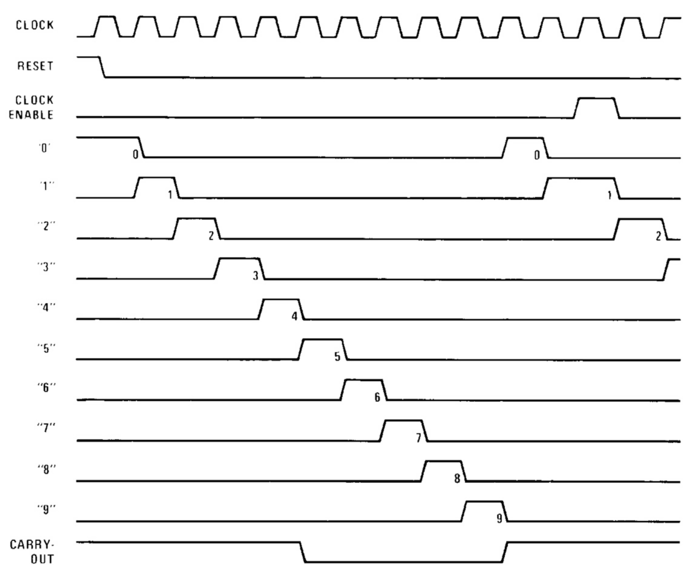


The reset input should be low (GND, 0V) for normal operation (counting 0-9). When high it resets the count to zero (DECODED OUTPUT 0 high). This can be done manually with a switch between reset and +Vs and a 10kΩ resistor between reset and 0V. Counting to less than 9 is achieved by connecting the relevant output (DECODED OUTPUT 0-9) to reset, for example to count 0,1,2,3 connect DECODED OUTPUT 4 to reset.

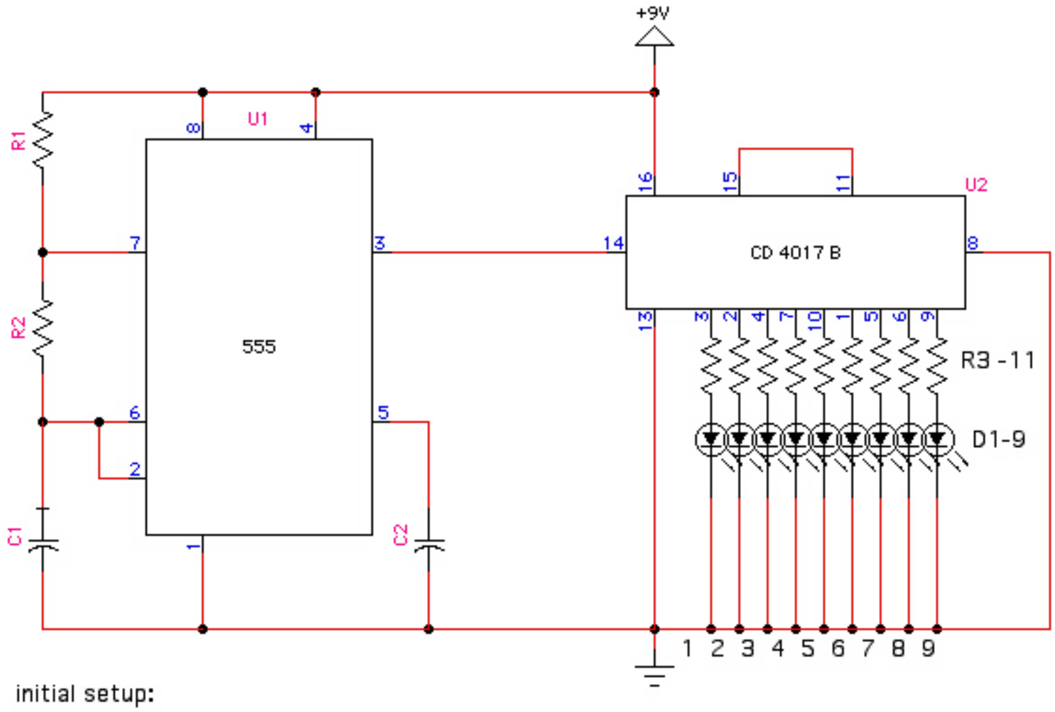
The CLOCK ENABLE input should be low (GND, 0V) for normal operation. When high it disables counting so that clock pulses are ignored and the count is kept constant.

The ÷10 output is high for counts 0-4 and low for 5-9, so it provides an output at 1/10 of the clock frequency. It can be used to drive the clock input of another 4017 (to count the tens) since the clock input is triggered on the rising edge of a signal becoming high.

This is what happens at each of the pins precisely:



The following circuit lights up 9 LEDs in sequence, the duration at which each LED is on and the speed at which they are changing can be set with R1, R2 and C1.



initial setup:

R1 = 2.2kΩ
R2 = 47kΩ
C1 = 1μF

R3 - R11 = 270/470Ω
D1 - D9 = LED

6. Further Reading and experimentation:

Purdue, Program in Electronic and Time-Based Art Website - more electronics workshops in the website's resources section:
http://www.cla.purdue.edu/vpa/etb/resources/tech_workshops.html

For more information on the 555 timer IC see:
Hewes, John. The Electronics Club. http://www.kpsec.freeuk.com/555timer.htm

For more counting fun with LEDs see the 4026 decade counter and 7-segment display see:
Hewes, John. The Electronics Club.
http://electronicsclub.info/cmos.htm#4026

Ideas: Evil Mad Scientist - LED Hanukkah Menorah Kit:
http://www.evilmadscientist.com/2009/new-led-hanukkah-menorah-kit/

Please e-mail any feedback, ideas for improvement or modifications to this document to:
fwinkler@purdue.edu

7. Appendix

Parts in the 555 Holiday Fun Kit:

Resistors:
1x 270Ω
1x 330Ω (for blue LEDs)
2x 470Ω (for green, red, yellow LEDs)
1x 1kΩ
1x 2.2kΩ
2x 10kΩ
1x 33kΩ
1x 47kΩ
1x 100kΩ

LEDs:
1x LED (blue, 3.4V @ 20mA)
1x LED (red, green and yellow, 1.7V@20mA)

Battery:
1x 9V battery clip
1x 9V battery

ICs:
2x 555 timer IC
1x decade counter CD4017
1x 16pin DIP socket

Capacitors:
1x 0.001µF
1x 1µF
1x 4.7µF
1x 22µF
1x 100µF
2x 220µF

Transistors:
2x 2N2222
1x BC547

Optional:
1x breadboard

Hookup wires (solid core and stranded), solder, soldering equipment, Styrofoam and a Styrofoam cutter and UHU Styrofoam glue are available in the ETB lab.

The website for a download of this document is:
http://www.cla.purdue.edu/vpa/etb/events/555_workshop_handout.pdf