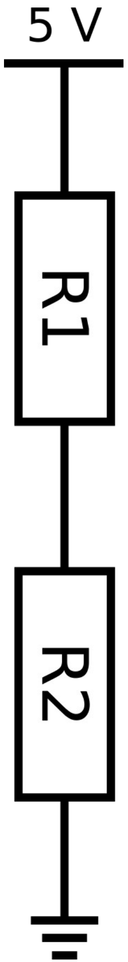
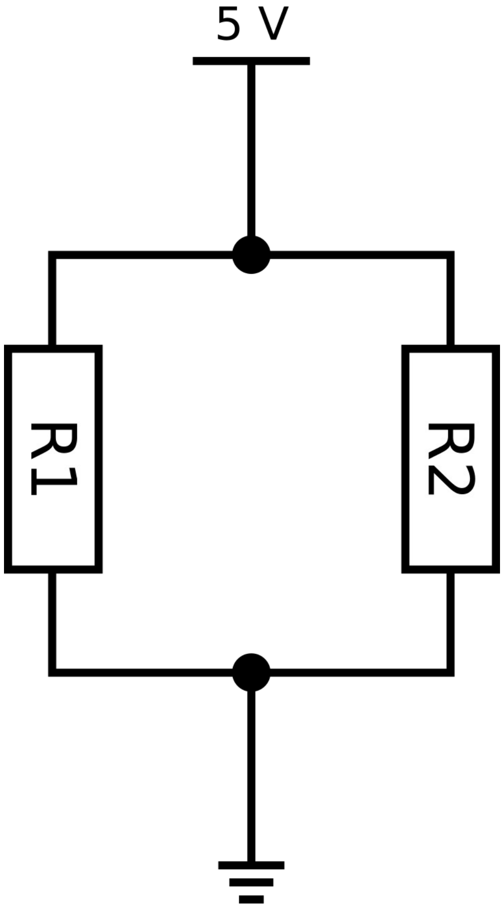
Sketching with Hardware

04: Electronics 02 + Digital Circuits

Parallel- and Series Connection

Series Connection





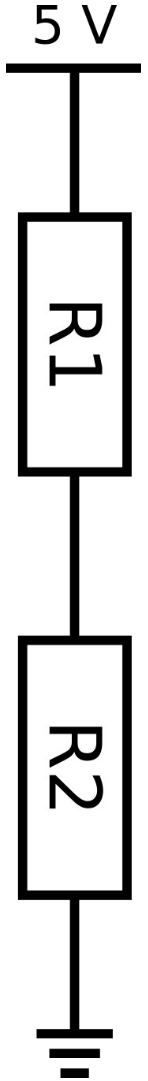
Parallel Connection

Series Connection

- The total resistance R_{total} is the sum of all partial resistances in the series connection

$$R_{total} = R_1 + R_2 + ... + R_n = \sum_{i=1}^{n} R_i$$

- The total voltage U_{total} is divided up into n partial voltages
- The current I is the same at every point in the series connection

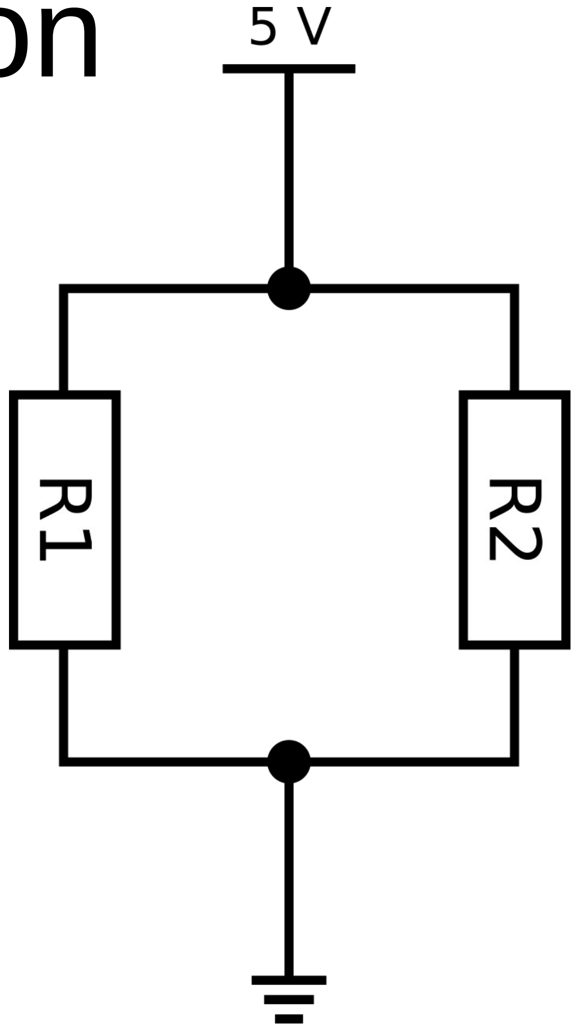


Parallel Connection

- The reciprocal of the total resistance R_{total} is the sum of the reciprocals of all partial resistances in the parallel connection

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n} = \sum_{i=1}^{n} \frac{1}{R_i}$$

- The total current I_{total} is divided up into n partial currents
- The voltage over every resistor connected in parallel is the same

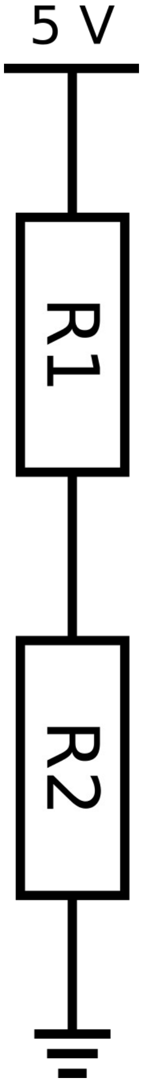


Voltage Divider

- Series connection of resistors
- Divides the total voltage into several smaller partial voltages
- The ratio of the partial voltage over any resistor to the total voltage is proportional to the ratio of the partial resistance to the total resistance

$$U_{total} = U_1 + U_2 + \ldots + U_n \qquad \frac{U_i}{R_i} = \frac{U_{total}}{R_{total}}$$

- Exercise: $R1$ = 100Ω, $R2$ = 400Ω → calculate $U1$



Any questions?

A red LED (~2 V) is supplied with power over a USB cable (5 V). In order to protect the LED from overvoltage, it is connected in series with a dropping resistor (220 Ω).

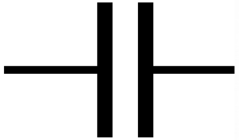
How can the circuit be changed to reduce the LED’s brightness?

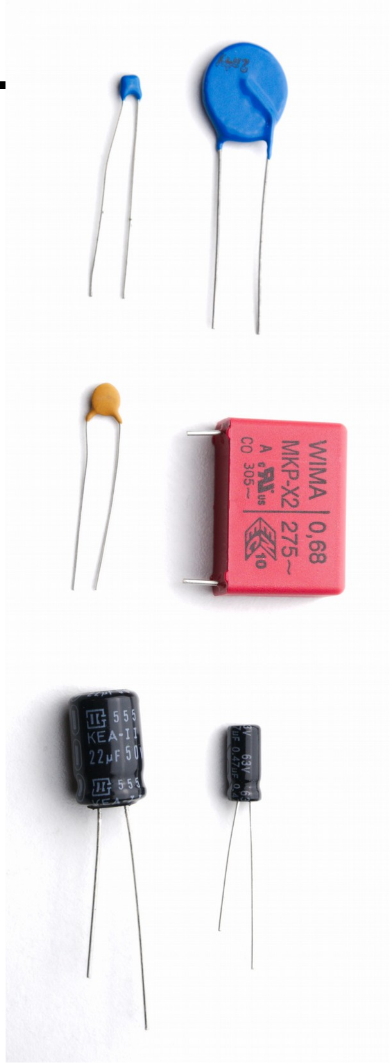
How can an electric motor (9 V) be supplied with power only using AA batteries (1.5 V)?

The motor from the last tasks works now but the batteries are draining too fast. What can be changed to fix this problem?

How can twelve red LEDs (~2 V) be supplied with power only using a power supply with 5 V?

The dropping resistor used in the last example gets very hot. How can the circuit be changed to avoid this?

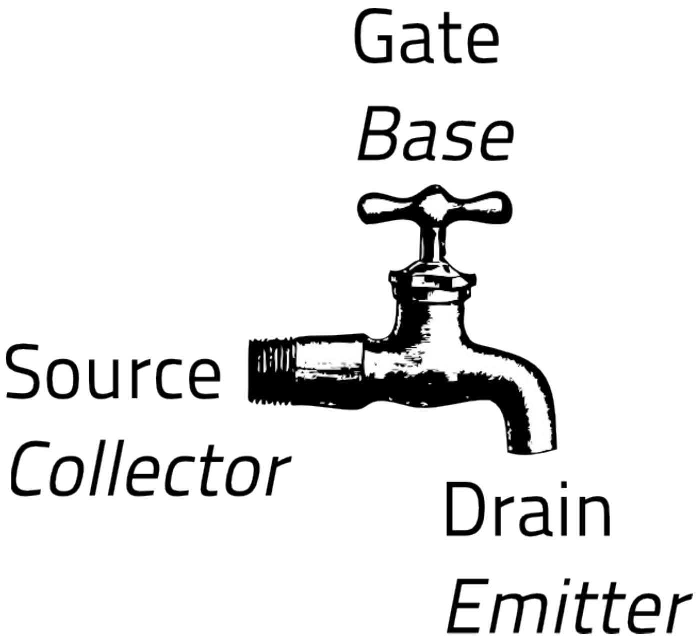
Capacitors 



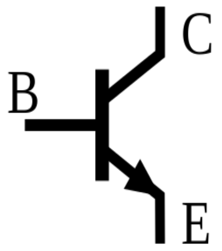
- Stores electrical charge (Q)
- Stored charge per Volt = Capacitance (C)
- Unit of capacitance: Farad (F)
  - C = Q / U
- Polarity is (sometimes) important!
- Usage:
  - Store charge
  - filter noise from signals
  - compensate peaks in voltage

Transistor

- Electronically controlled switch
- If there is a voltage on the **base**, current can flow from **collector** to **emitter**
- Application:
  - Switching large loads
  - Logic gates
  - Fundamental for digital circuits



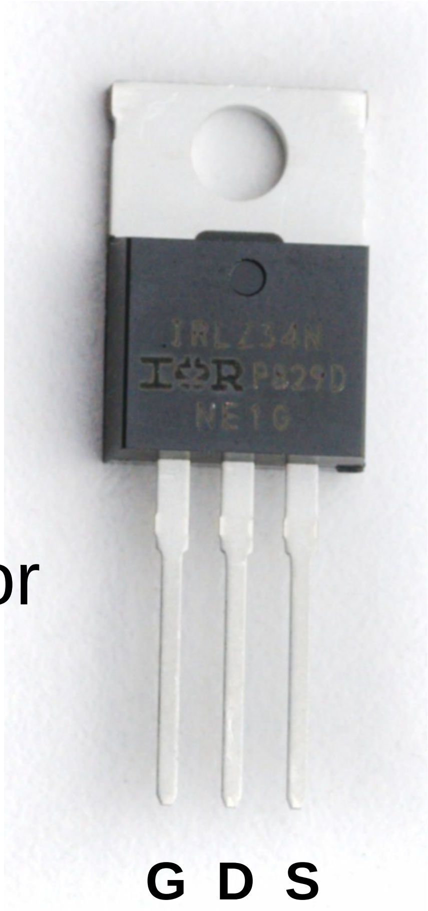
TODO: Source



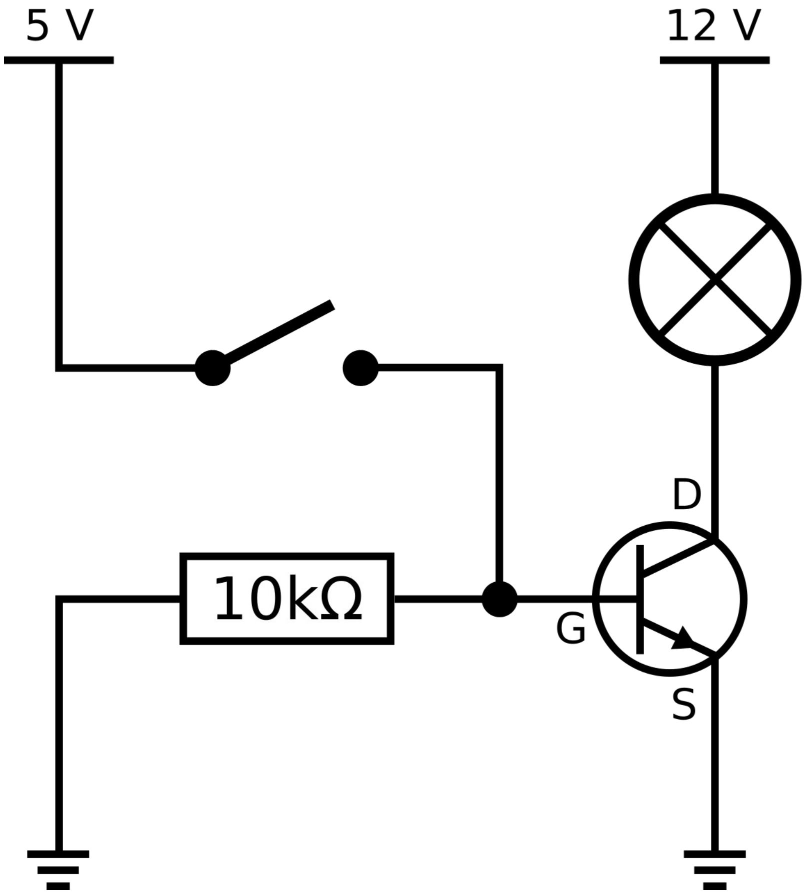
https://de.wikipedia.org/wiki/Datei:BJT_NPN_symbol-fr.svg

Transistor: MOSFET

- Two types:
  - Normally open
  - Normally closed
- Can be used like a voltage controlled resistor
- Can switch large loads with a low voltage



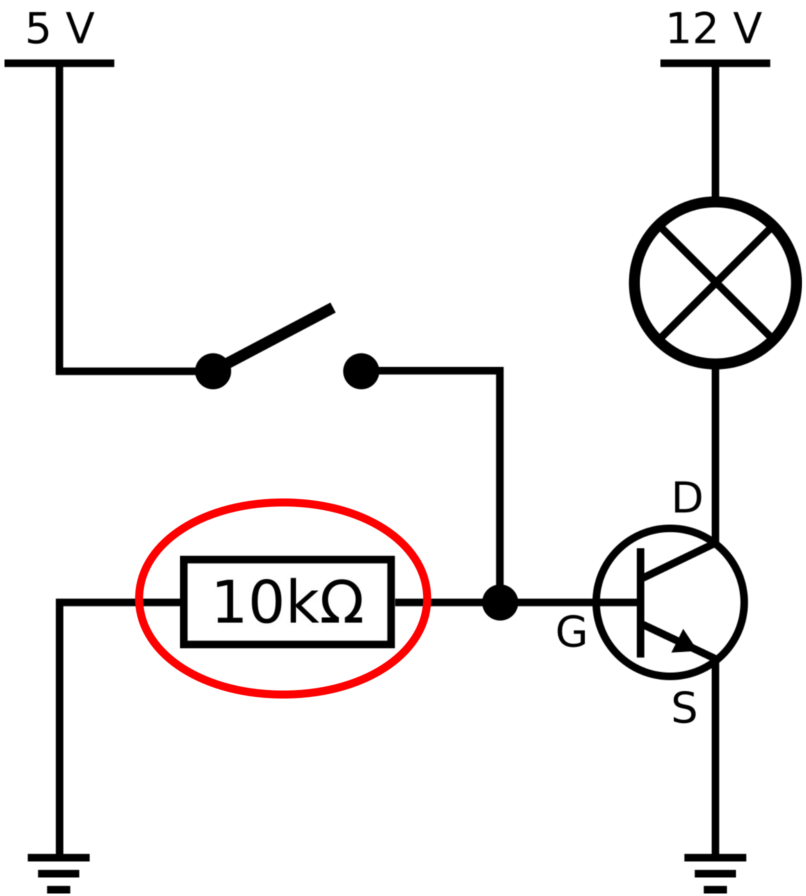
Switching a load with a MOSFET



Pull-Down Resistor

- When the switch is closed, voltage can flow from 5 V over *Gate* and *Source* to *GND*
- When the switch is opened again, there might still be potential between the switch and *GND*

→ Use a big resistor between *Gate* and *GND* so this voltage is **pulled down** to 0 V

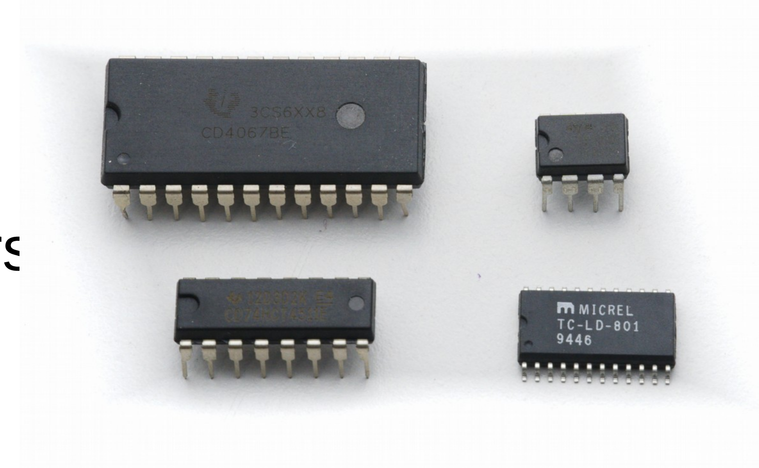


Integrated Circuits

- Dedicated component that contains a certain circuit manufactured at a very small scale
- May contain millions of transistors, capacitors and resistors
- Used as a “black box”
- Examples:

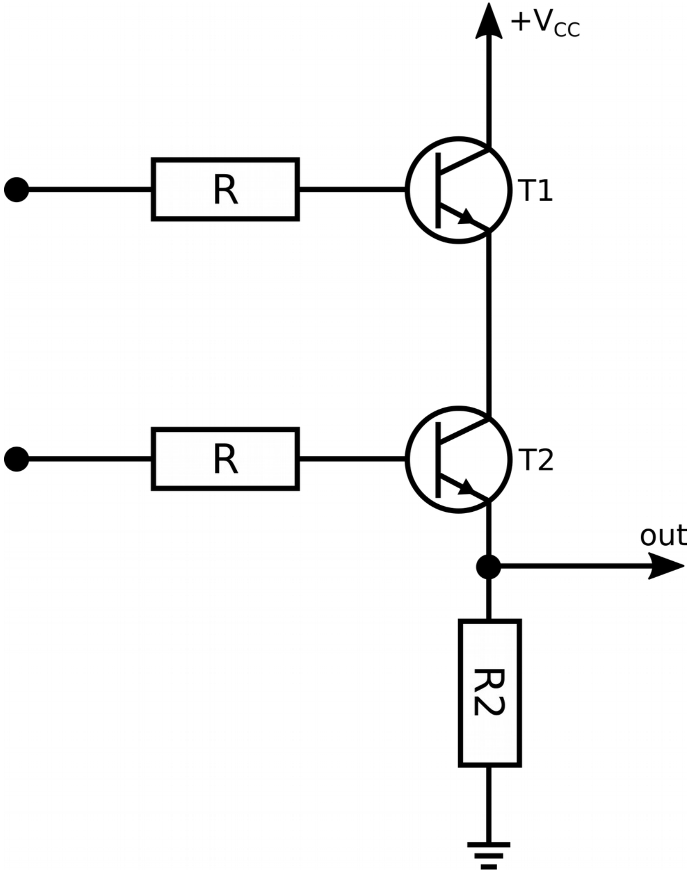
    Logic gates, amplifiers, timers, registers

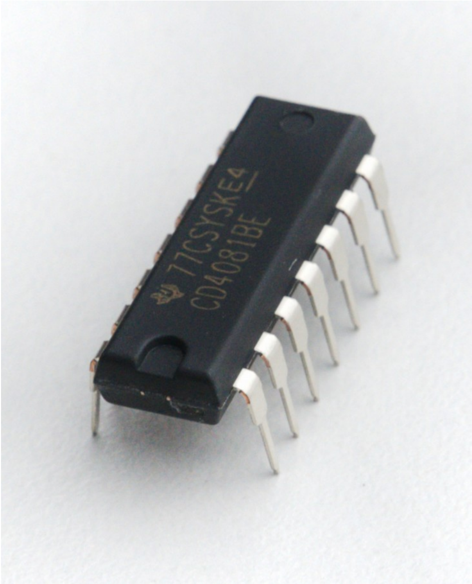
    memory, sensors, ...



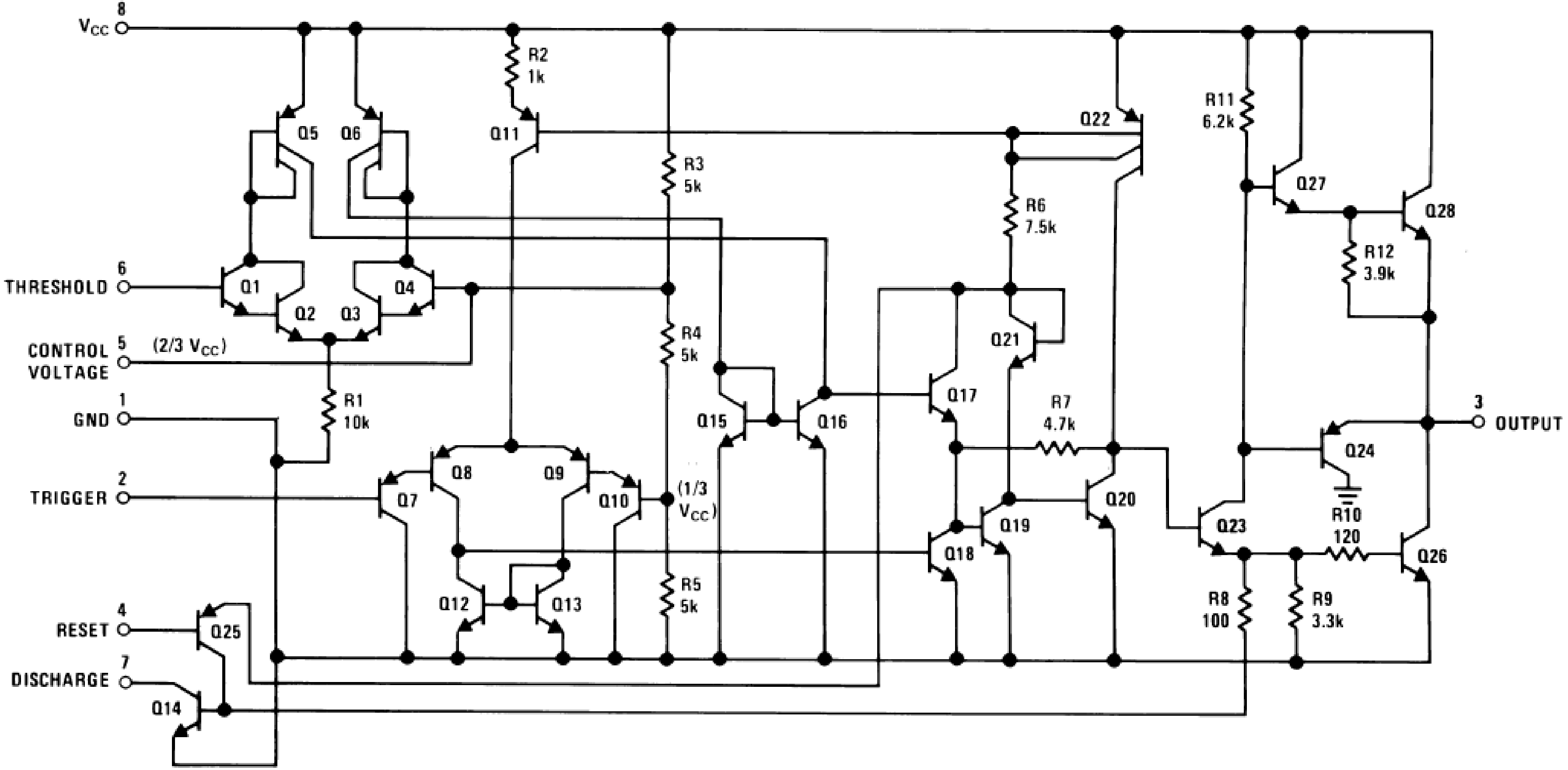
Example: The AND Gate

```
and(a, b){

    if  (a == 1)

    and (b == 1):

        return 1

    else:

        return 0

}
```





Example: LM555



Source: Texas Instruments LM555 Data Sheet

How does a 555 timer IC work?

- Different modes – depending on the circuit connection
- Basic principle: Charge a capacitor and do something when it's fully charged. Example: *astable multivibrator:*

1) C_1 is charged. *THRES* measures the voltage at C_1.

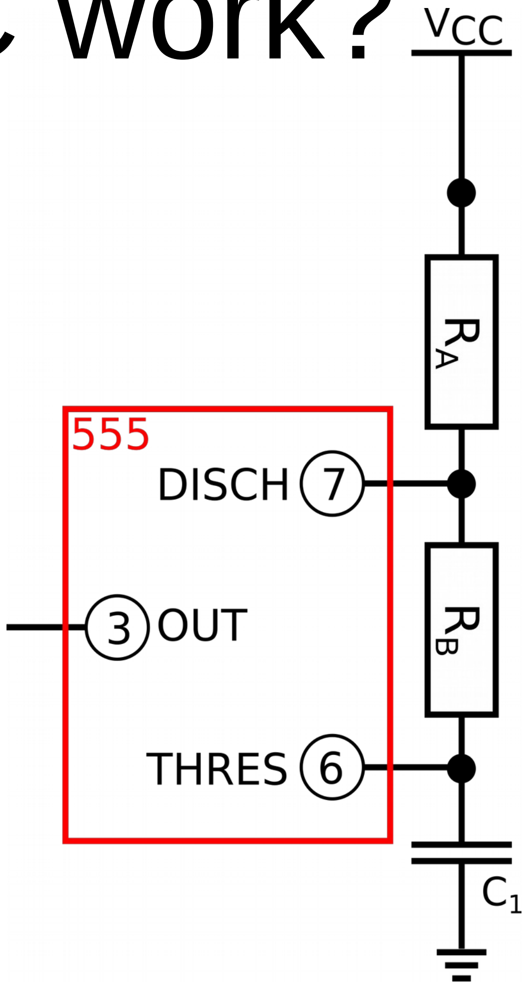
→ the voltage at *THRES* starts at 0 V as all of the voltage is used to charge C_1. As C_1 gets charged, the voltage at *THRES* approaches V_{CC}

2) When the voltage at *THRES* reaches 2/3 of V_{CC}, *DISCH* is connected to *GND*. *OUT* is set to *high* (V_{CC}).

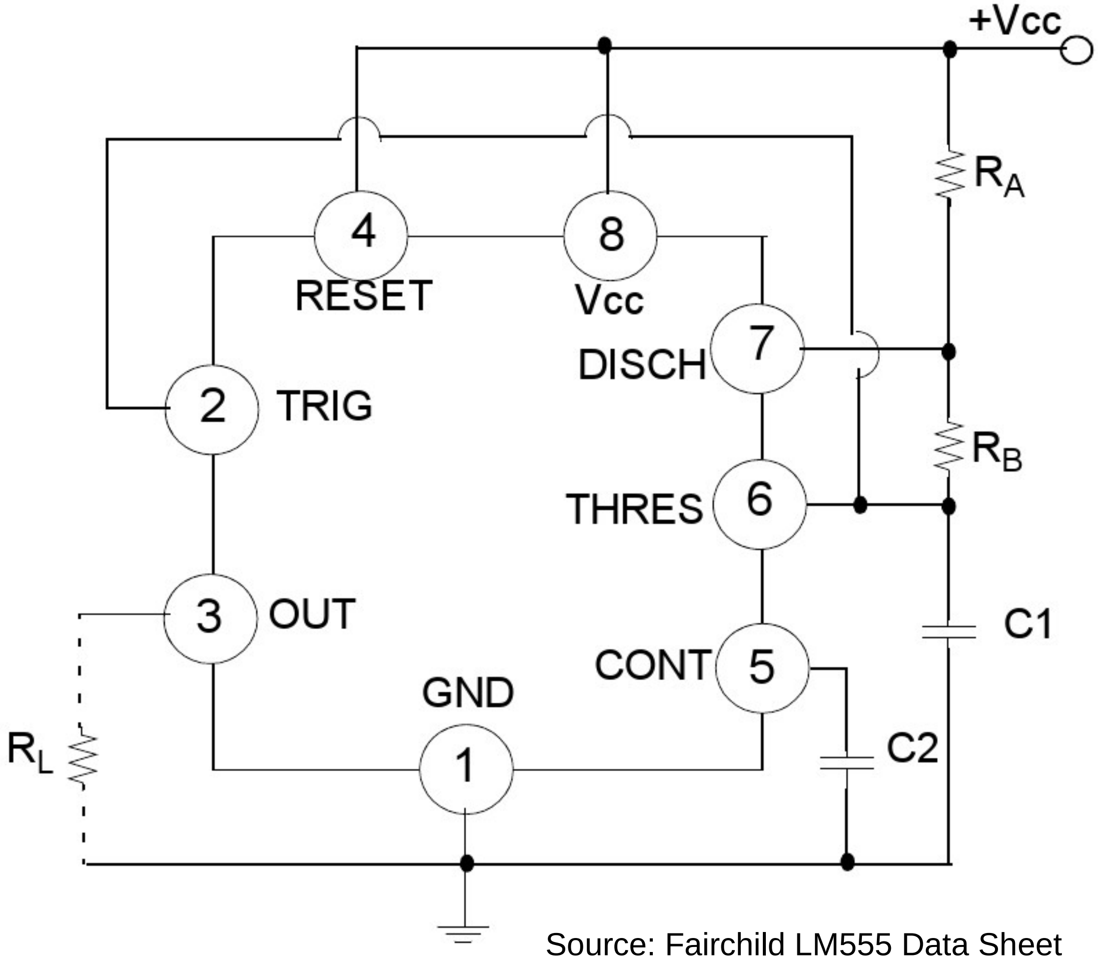
→ C_1 gets discharged

3) When the voltage at *THRES* reaches 1/3 of V_{CC}, *DISCH* is disconnected from *GND*. *OUT* is set to low (*GND*).

→ go to step 1



555: Astable Multivibrator



Source: Fairchild LM555 Data Sheet

Reading Data Sheets

FAIRCHILD SEMICONDUCTOR®

January 2013

LM555 — Single Timer

LM555
Single Timer

Features

- High-Current Drive Capability: 200 mA
- Adjustable Duty Cycle
- Temperature Stability of 0.005%/°C
- Timing From µs to Hours
- Turn off Time Less Than 2 µs

Applications

- Precision Timing
- Pulse Generation
- Delay Generation
- Sequential Timing

Description

The LM555 is a highly stable controller capable of producing accurate timing pulses. With a monostable operation, the delay is controlled by one external resistor and one capacitor. With astable operation, the frequency and duty cycle are accurately controlled by two external resistors and one capacitor.

8-DIP

8-SOIC

Ordering Information

Part Number	Operating Temperature Range	Top Mark	Package	Packing Method
LM555CN	0 ~ +70°C	LM555CN	DIP 8L	Rail
LM555CM		LM555CM	SOIC 8L	Rail
LM555CMX		LM555CM	SOIC 8L	Tape & Reel

LM555 — Single Timer

Block Diagram

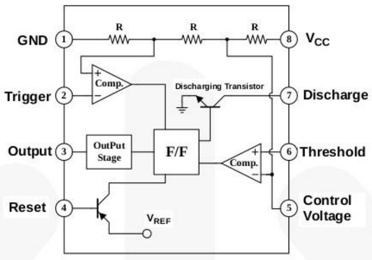


Figure 1. Block Diagram

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at T_A = 25°C unless otherwise noted.

Symbol	Parameter	Value	Unit
V_{CC}	Supply Voltage	16	V
T_{LEAD}	Lead Temperature (Soldering 10s)	300	°C
P_D	Power Dissipation	600	mW
T_{OPR}	Operating Temperature Range	0 ~ +70	°C
T_{STG}	Storage Temperature Range	-65 ~ +150	°C

LM555 — Single Timer

Electrical Characteristics

Values are at T_A = 25°C, V_{CC} = 5 ~ 15 V unless otherwise specified.

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Supply Voltage	V_{CC}			4.5		16.0	V
Supply Current (Low Stable) (1)	I_{CC}	V_{CC} = 5 V, R_L = ∞			3	6	mA
		V_{CC} = 15 V, R_L = ∞			7.5	15.0	mA
Timing Error (Monostable) Initial Accuracy (2)	ACCUR	R_A = 1 kΩ to100 kΩ C = 0.1 µF			1.0	3.0	%
Drift with Temperature (3)	Δt / ΔT				50		ppm / °C
Drift with Supply Voltage (3)	Δt / ΔV_{CC}				0.1	0.5	% / V
Timing Error (Astable) Initial Accuracy (2)	ACCUR	R_A = 1 kΩ to 100kΩ C = 0.1 µF			2.25		%
Drift with Temperature (3)	Δt / ΔT				150		ppm / °C
Drift with Supply Voltage (3)	Δt / ΔV_{CC}				0.3		% / V
Control Voltage	V_C	V_{CC} = 15 V		9.0	10.0	11.0	V
		V_{CC} = 5 V		2.60	3.33	4.00	V
Threshold Voltage	V_{TH}	V_{CC} = 15 V			10.0		V
		V_{CC} = 5V			3.33		V
Threshold Current (4)	I_{TH}				0.10	0.25	µA
Trigger Voltage	V_{TR}	V_{CC} = 5 V		1.10	1.67	2.20	V
		V_{CC} = 15 V		4.5	5.0	5.6	V
Trigger Current	I_{TR}	V_{TR} = 0 V			0.01	2.00	µA
Reset Voltage	V_{RST}			0.4	0.7	1.0	V
Reset Current	I_{RST}				0.1	0.4	mA
Low Output Voltage	V_{OL}	V_{CC} = 15 V	I_{SINK} = 10 mA		0.06	0.25	V
			I_{SINK} = 50 mA		0.30	0.75	V
		V_{CC} = 5 V, I_{SINK} = 5 mA			0.05	0.35	V
High Output Voltage	V_{OH}	V_{CC} = 15 V	I_{SOURCE} = 200 mA		12.5		V
			I_{SOURCE} = 100 mA	12.75	13.30		V
		V_{CC} = 5 V, I_{SOURCE} = 100 mA		2.75	3.30		V
Rise Time of Output(3)	t_R				100		ns
Fall Time of Output(3)	t_F				100		ns
Discharge Leakage Current	I_{LKG}				20	100	nA

Notes:
1. When the output is high, the supply current is typically 1 mA less than at V_{CC} = 5 V.
2. Tested at V_{CC} = 5.0 V and V_{CC} = 15 V.
3. These parameters, although guaranteed, are not 100% tested in production.
4. This determines the maximum value of $R_A + R_B$ for 15 V operation, the maximum total R = 20 MΩ, and for 5 V operation, the maximum total R = 6.7 MΩ.

Source: Fairchild LM555 Data Sheet

Tutorial 03 – Electronics 02