# INTEGRATED CIRCUITS

Michael D’Argenio – mjdargen@ncsu.edu
Electrical Engineering – SS 2019 – Duke TIP

# Intro to Integrated Circuits (ICs)

- A set of electronic circuits on one small flat piece (or "chip") of semiconductor material.
- Instead of having many discrete components, an IC provides the same functionality in a single package.
- Contain many transistors and other passive components.

# ICs

- Some of the ICs we will discuss are:
  - Op-Amps
  - Flip-Flops
  - Comparators
  - 555 Timers
  - Digital Logic Gates
- Many ICs use either TTL or CMOS technology.

# CMOS vs. TTL

# CMOS vs. TTL Logic

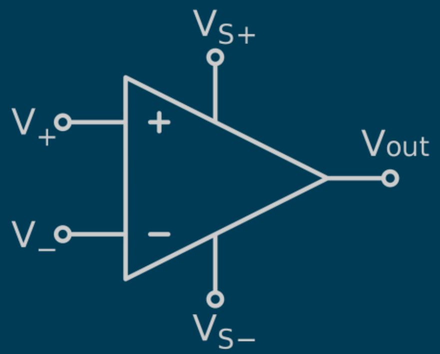
- CMOS – Complementary Metal-Oxide Semiconductor
  - MOSFETs
  - CMOS – uses complementary pairs of n&p MOS
  - Fewer parts, lower power consumption
- TTL – Transistor-Transistor Logic
  - BJTs
  - Stronger against ESD
- Made to implement logic, stay tuned for next week!!

# OP-AMPS

# Intro to Op-Amps

- Operational amplifiers -  a DC-coupled, high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output.
- An op-amp produces an output voltage that is typically hundreds of thousands of times larger than the potential difference between its input terminals.

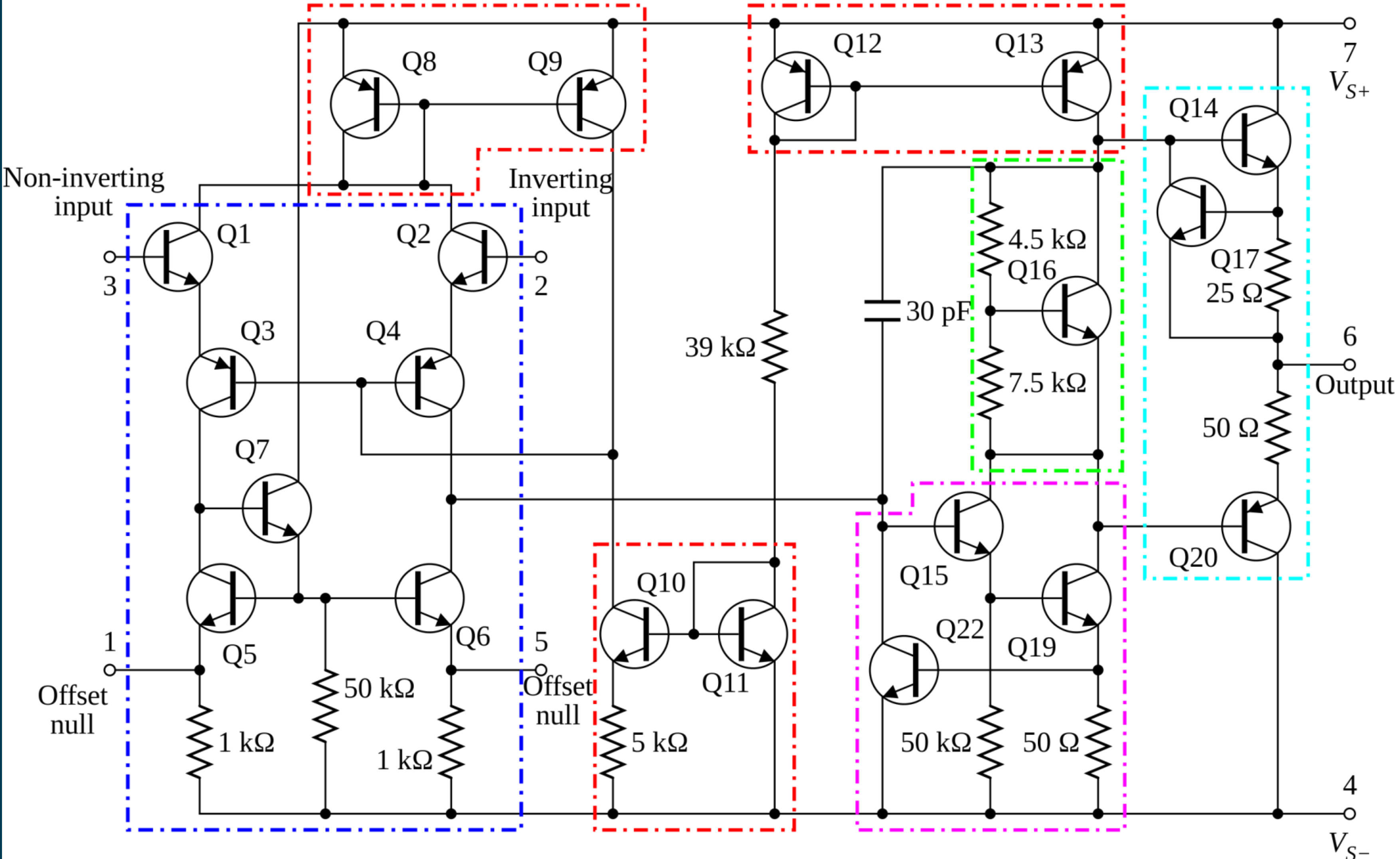
V+: non-inverting input
V−: inverting input
Vout: output
VS+: positive power supply
VS−: negative power supply



# Op Amp Characteristics

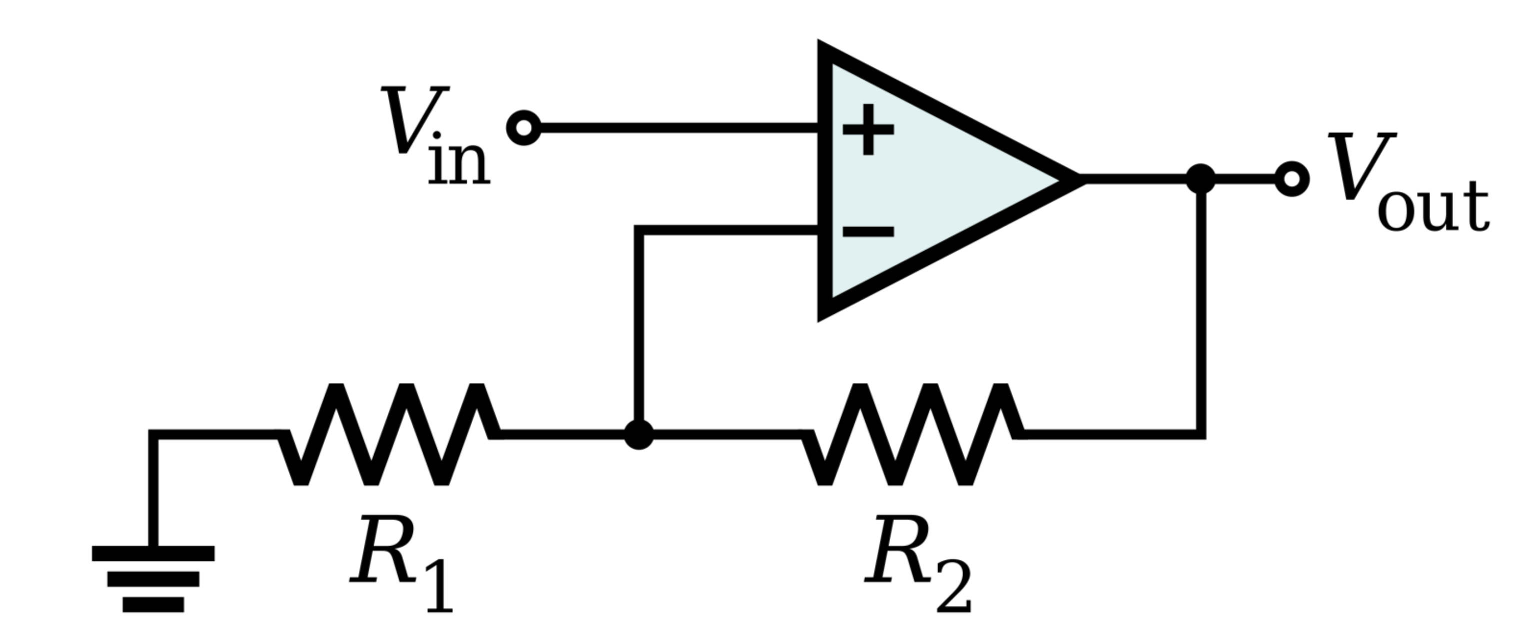
- In a closed loop, the output attempts to do whatever is necessary to make the voltage difference between the inputs zero.
- The inputs draw no current.
- Voltage Gain, $A = \frac{V_{out}}{V_{in}}$: $V_{in} = V_+ - V_-$

# 741 Op Amp

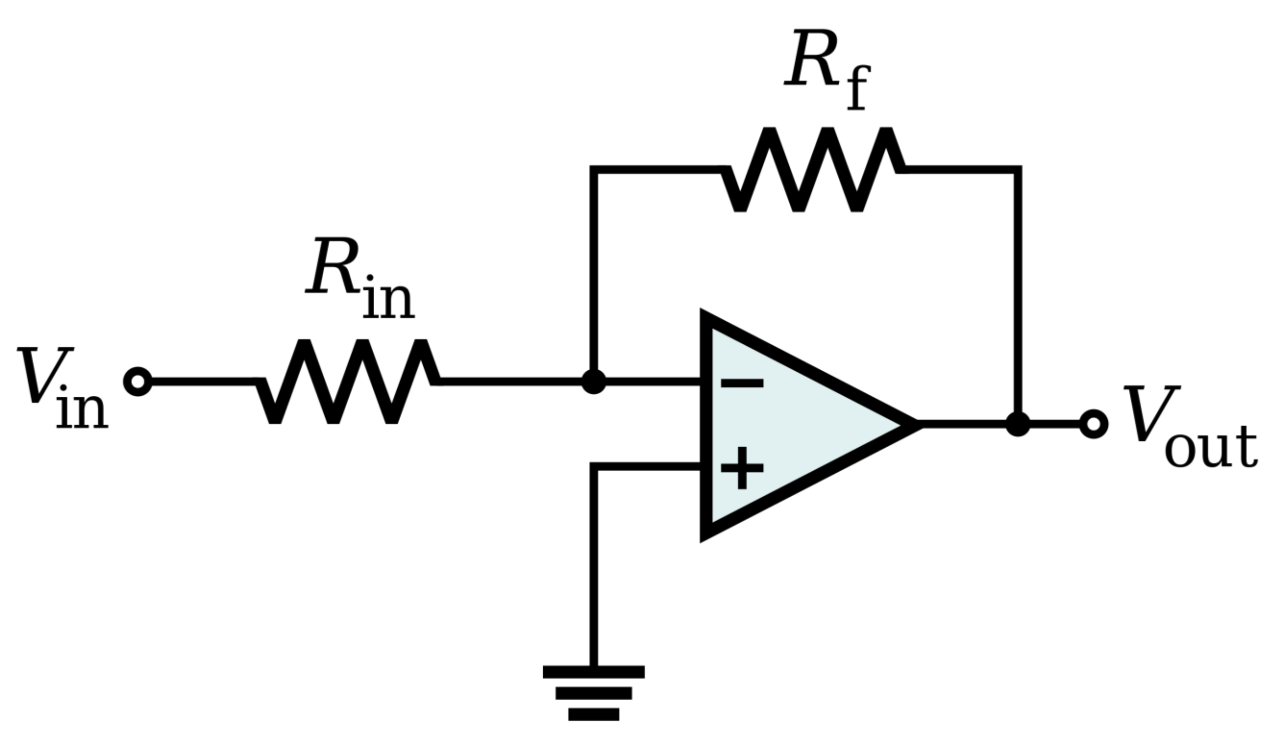


Q8
Q9
Q12
Q13
7
$V_{S+}$
Q14
Non-inverting input
Inverting input
Q1
Q2
3
2
Q3
Q4
4.5 kΩ
Q16
Q17
25 Ω
30 pF
39 kΩ
6
7.5 kΩ
Output
50 Ω
Q7
Q20
Q10
Q15
Q22
Q19
1
Q5
Q6
5
Offset null
50 kΩ
Offset null
Q11
1 kΩ
1 kΩ
5 kΩ
50 kΩ
50 Ω
4
$V_{S-}$

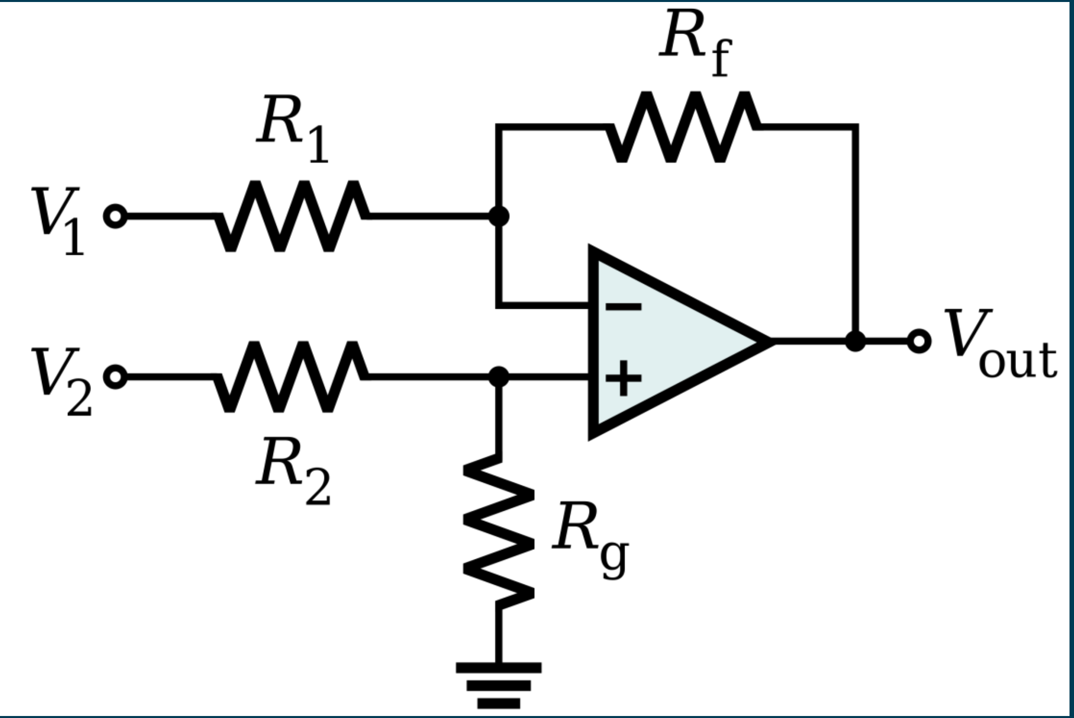
# Non-inverting Amplifier



# Inverting Amplifier

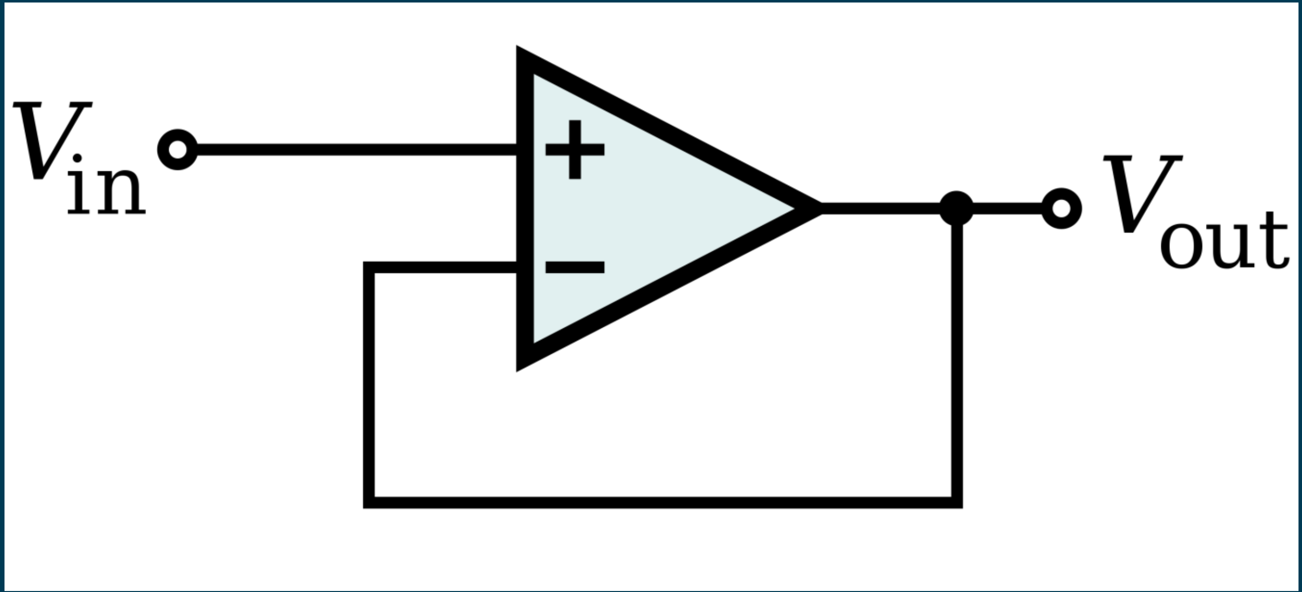


# Differential Amplifier



# Voltage Follower (Unity Buffer)

- Vout = Vin



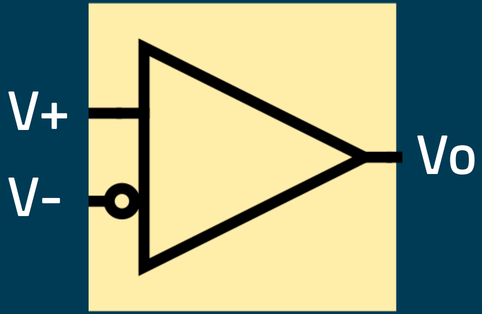
# Uses

- Audio video amplifiers and buffers
- Analog math using differentiators and integrators
- Rectifiers and regulators
- Analog-to-digital and digital-to-analog converters
- Oscillators and waveform generators
- Voltage clamping and clipping

# COMPARATOR

# Comparator

- A device that compares two voltages and outputs a digital signal indicating which is larger. It has two analog input terminals V+ and V-, and one binary digital output Vo.
- Vo = 1; if V+ > V-
- Vo = 0; if V+ < V-

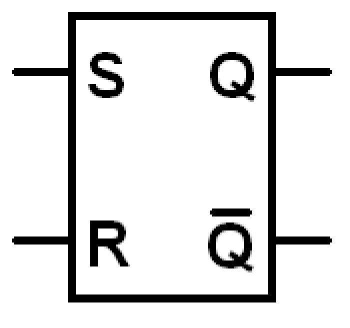


# S-R FLIP FLOP

# S-R Flip Flop

- A latch circuit that has two stable states and can be used to store information.
- S – Set, drives output Q high
- R – Reset, drives output Q low
- Q' – an inversion of output Q

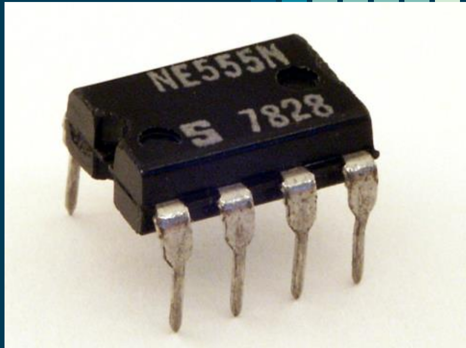
| S | R | Q |
|---|---|---|
| 0 | 0 | hold |
| 0 | 1 | 0 (reset) |
| 1 | 0 | 1 (set) |
| 1 | 1 | Forbidden |



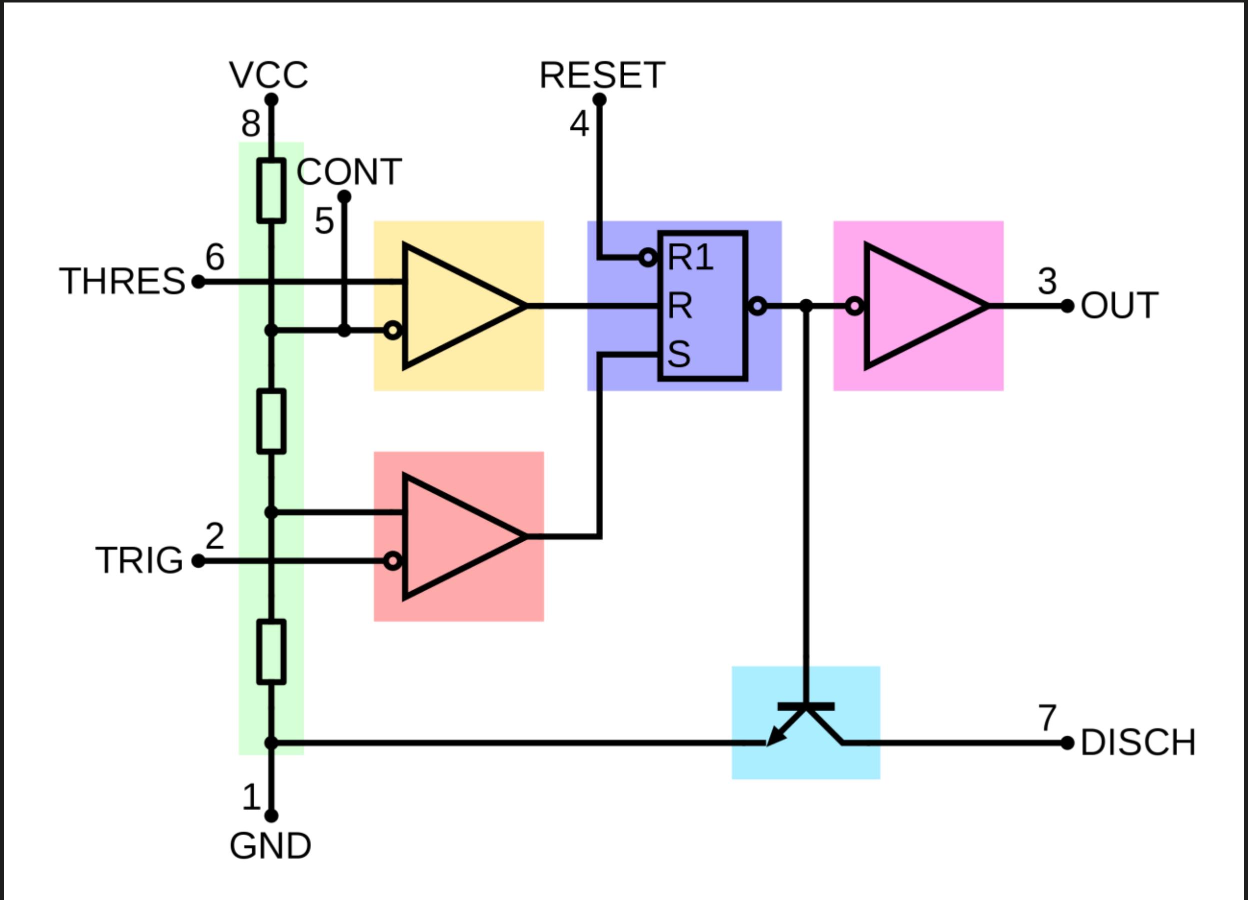
# 555 TIMER

# Intro to the 555 Timer

- An integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications.
- Can be used to provide time delays, as an oscillator, and as a flip-flop element.



# 555 Timer Block Diagram



# 555 Timer Explained

- Green: Between the positive supply voltage VCC and the ground GND is a voltage divider consisting of three identical resistors, which create two reference voltages at 1/3 VCC and 2/3 VCC. The latter is connected to the "Control Voltage" pin. All three resistors are 5 kΩ.
- Yellow: The comparator negative input is connected to higher-reference voltage divider of 2/3 VCC (and "Control" pin), and comparator positive input is connected to the "Threshold" pin.
- Red: The comparator positive input is connected to the lower-reference voltage divider of 1/3 VCC, and comparator negative input is connected to the "Trigger" pin.

# 555 Timer Explained Continued

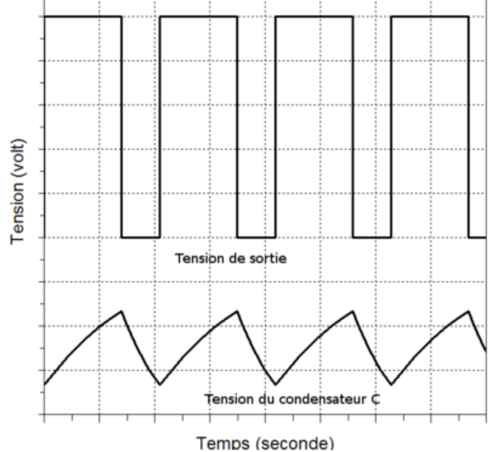
- Purple: An SR flip-flop stores the state of the timer and is controlled by the two comparators. The "Reset" pin overrides the other two inputs, thus the flip-flop (and therefore the entire timer) can be reset at any time.
- Pink: The output of the flip-flop is followed by an output stage with push-pull (P.P.) output drivers that can load the "Output" pin with up to 200 mA (varies by device).
- Cyan: Also, the output of the flip-flop turns on a transistor that connects the "Discharge" pin to ground.

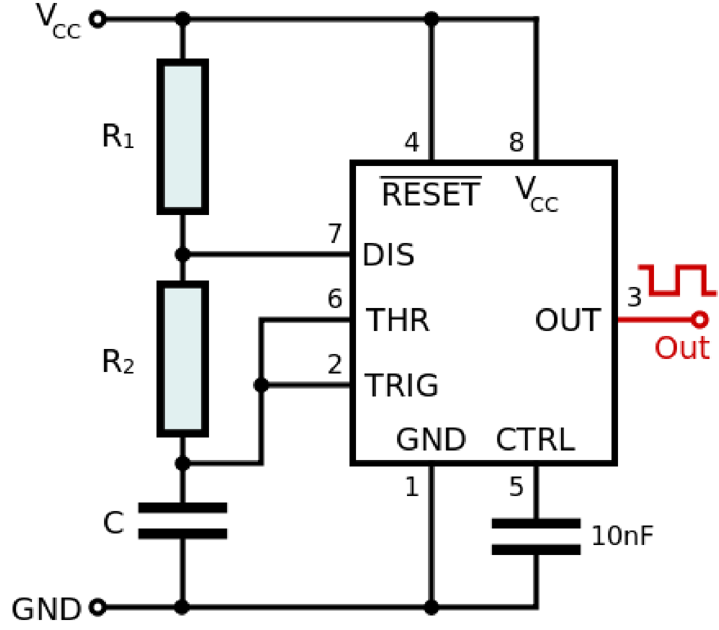
# 555 Timer Operating Modes

- We will focus on two of the possible 555 timer modes.
- Astable (free-running) mode – the 555 can operate as an electronic oscillator. Uses include LED and lamp flashers, pulse generation, logic clocks, tone generation, security alarms, pulse position modulation and so on.
- Monostable mode – in this mode, the 555 functions as a "one-shot" pulse generator. Applications include timers, missing pulse detection, bounce-free switches, touch switches, frequency divider, capacitance measurement, pulse-width modulation (PWM) and so on.

# Astable Mode (free-running)

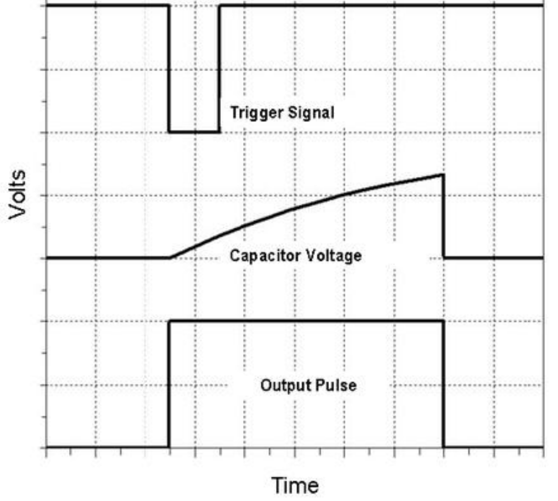
- Puts out a continuous stream of rectangular pulses having a specific frequency determined by R1, R2, C.
- Output high when trigger less than 1/3 Vcc, low when threshold greater than 2/3 Vcc.
- $f = \frac{1}{0.693 \times C \times (R_1 + 2R_2)}$
- $t_{high} = 0.693 \times C(R_1 + R_2)$
- $t_{low} = 0.693 \times C \times R_2$

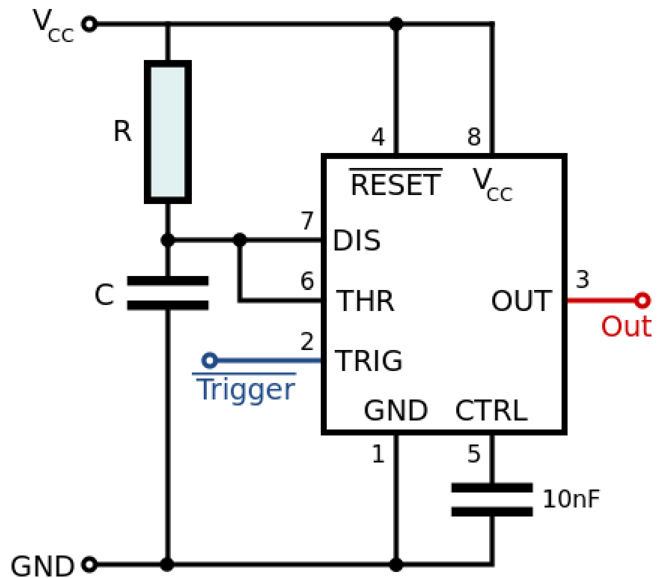


# Monostable

- Similar to astable but requires external trigger (driven by another source).
- Output driven high when trigger drops below 1/3 Vcc, and driven low when the threshold charges to 2/3 Vcc.
- $t_{pulse} = 1.099 \times RC$



# LOGIC ICs

# Logic ICs

- Uses multiple transistor to implement digital logic.
- What’s digital?
- More next week!