EC8453 LINEAR INTEGRATED CIRCUITS

Linear integrated circuits

A linear integrated circuit (linear IC) is a solid-state analog device characterized by a theoretically infinite number of possible operating states. It operates over a continuous range of input levels

APPLICATIONS

Linear ICs are employed in

audio amplifiers,

A/D (analog-to-digital) converters,

averaging amplifiers,

differentiators,

DC (direct-current) amplifiers,

integrators,

multivibrators,

oscillators,

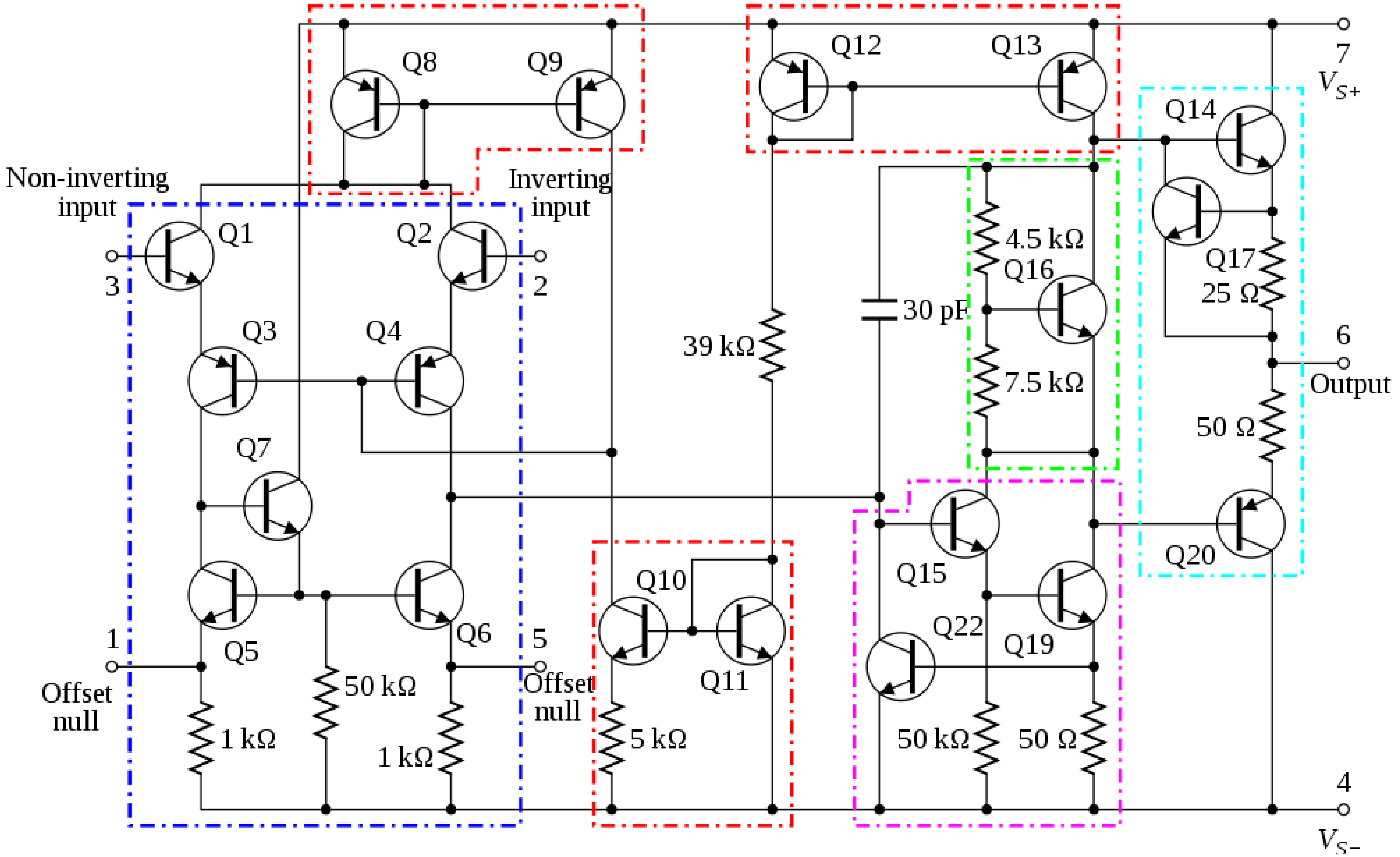
audio filters, and

sweep generators.

OPERATION AMPLIFIER

An operational amplifier is a direct coupled high gain amplifier consisting of one or more differential amplifiers, followed by a level translator and an output stage.

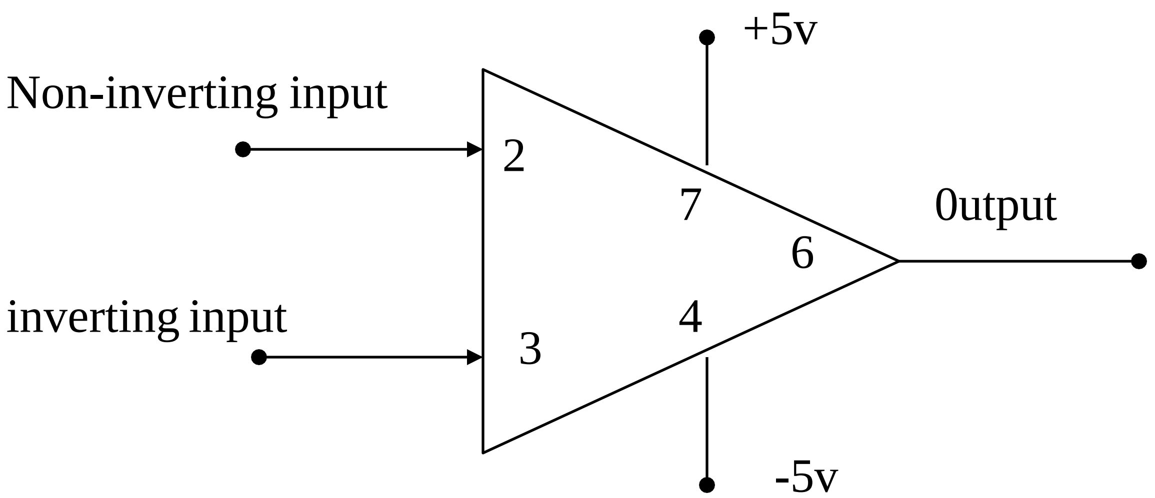
741 Op-Amp Schematic



Ideal characteristics of OPAMP

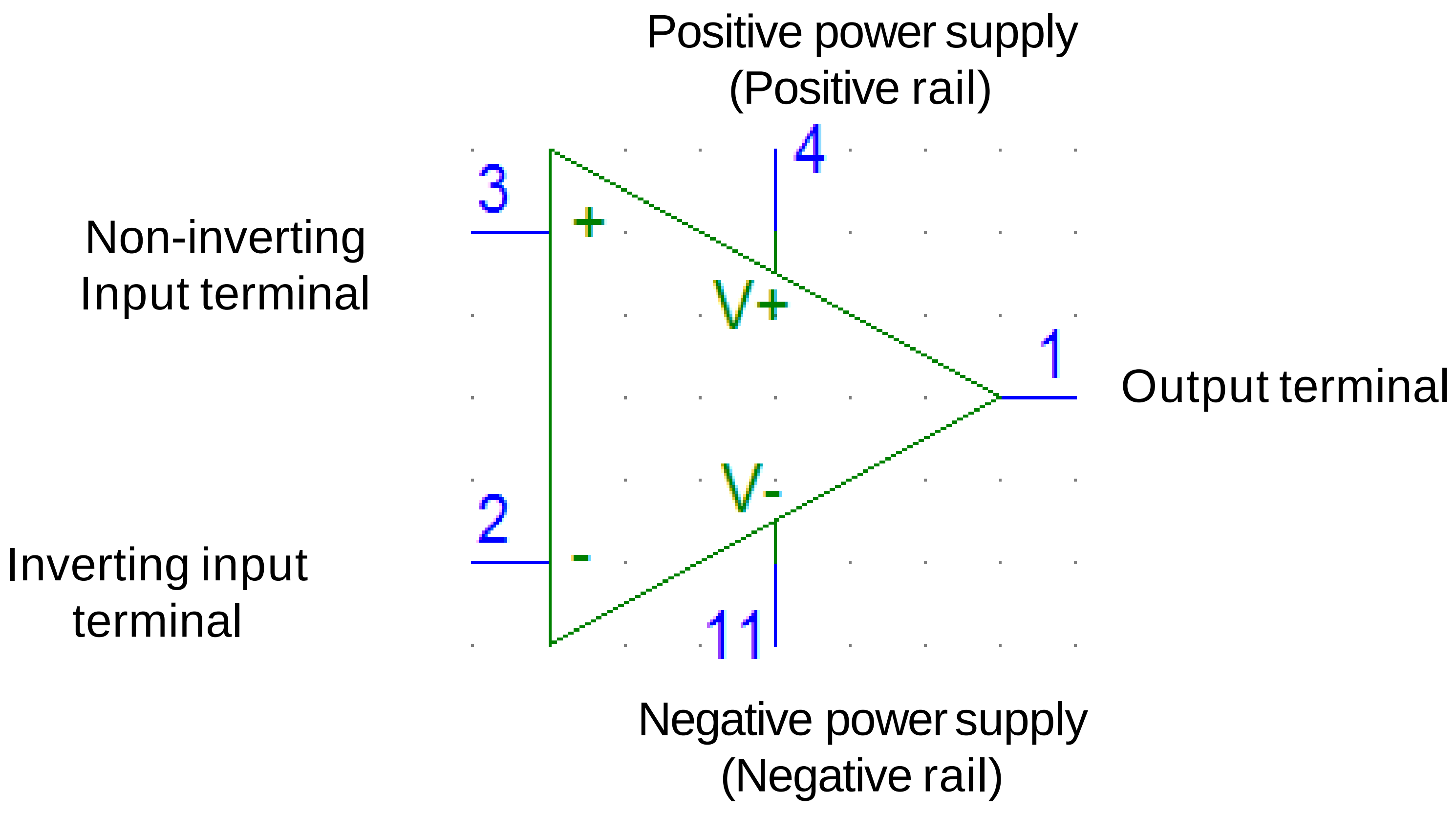
1. Open loop gain infinite
2. Input impedance infinite
3. Output impedance low
4. Bandwidth infinite
5. Zero offset, ie, Vo=0 when V1=V2=0

Op-amp symbol



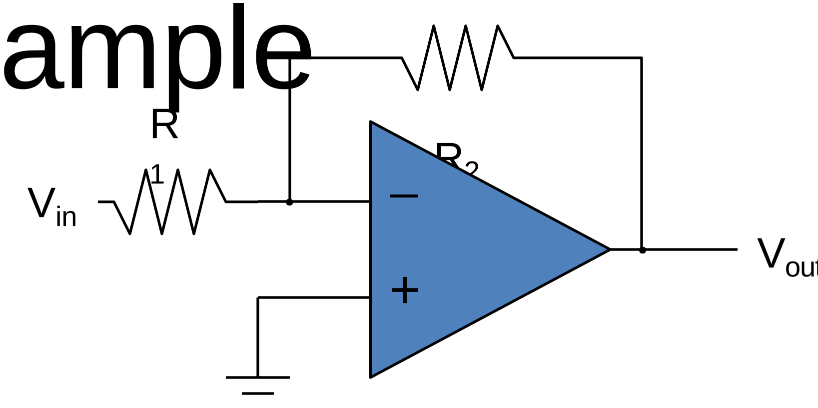
Linear Integrated Circuits − An analog IC is said to be Linear, if there exists a linear relation between its voltage and current. IC 741, an 8-pin Dual In-line Package (DIP)op-amp, is an example of Linear IC.

Op
Amp



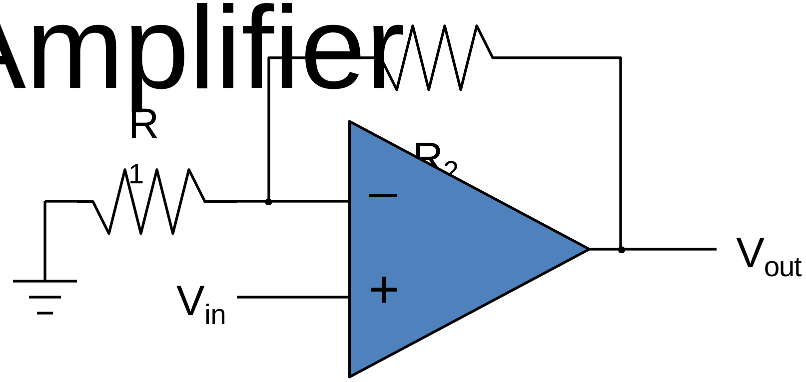
Positive power supply
(Positive rail)
4
3
+
Non-inverting
Input terminal
V+
1
Output terminal
V-
2
-
Inverting input
terminal
11
Negative power supply
(Negative rail)

Inverting amplifier example



- Applying the rules: – terminal at "virtual ground"
  - so current through R_1 is $I_f = V_{in}/R_1$
- Current does not flow into op-amp (one of our rules)
  - so the current through R_1 must go through R_2
  - voltage drop across R_2 is then $I_f R_2 = V_{in}\times(R_2/R_1)$
- So $V_{out} = 0 - V_{in}\times(R_2/R_1) = -V_{in}\times(R_2/R_1)$
- Thus we amplify V_{in} by factor $-R_2/R_1$
  - negative sign earns title "inverting" amplifier
- Current is *drawn into* op-amp output terminal

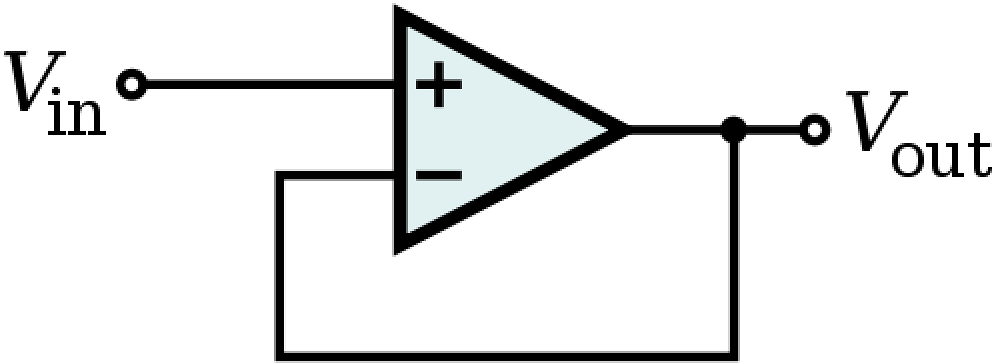
Non-inverting Amplifier



- Now neg. terminal held at V_{in}
  - so current through R_1 is $I_f = V_{in}/R_1$ (to left, into ground)
- This current cannot come from op-amp input
  - so comes through R_2 (delivered from op-amp output)
  - voltage drop across R_2 is $I_f R_2 = V_{in} \times (R_2/R_1)$
  - so that output is higher than neg. input terminal by $V_{in} \times (R_2/R_1)$
  - $V_{out} = V_{in} + V_{in} \times (R_2/R_1) = V_{in} \times (1 + R_2/R_1)$
  - thus gain is $(1 + R_2/R_1)$, and is positive

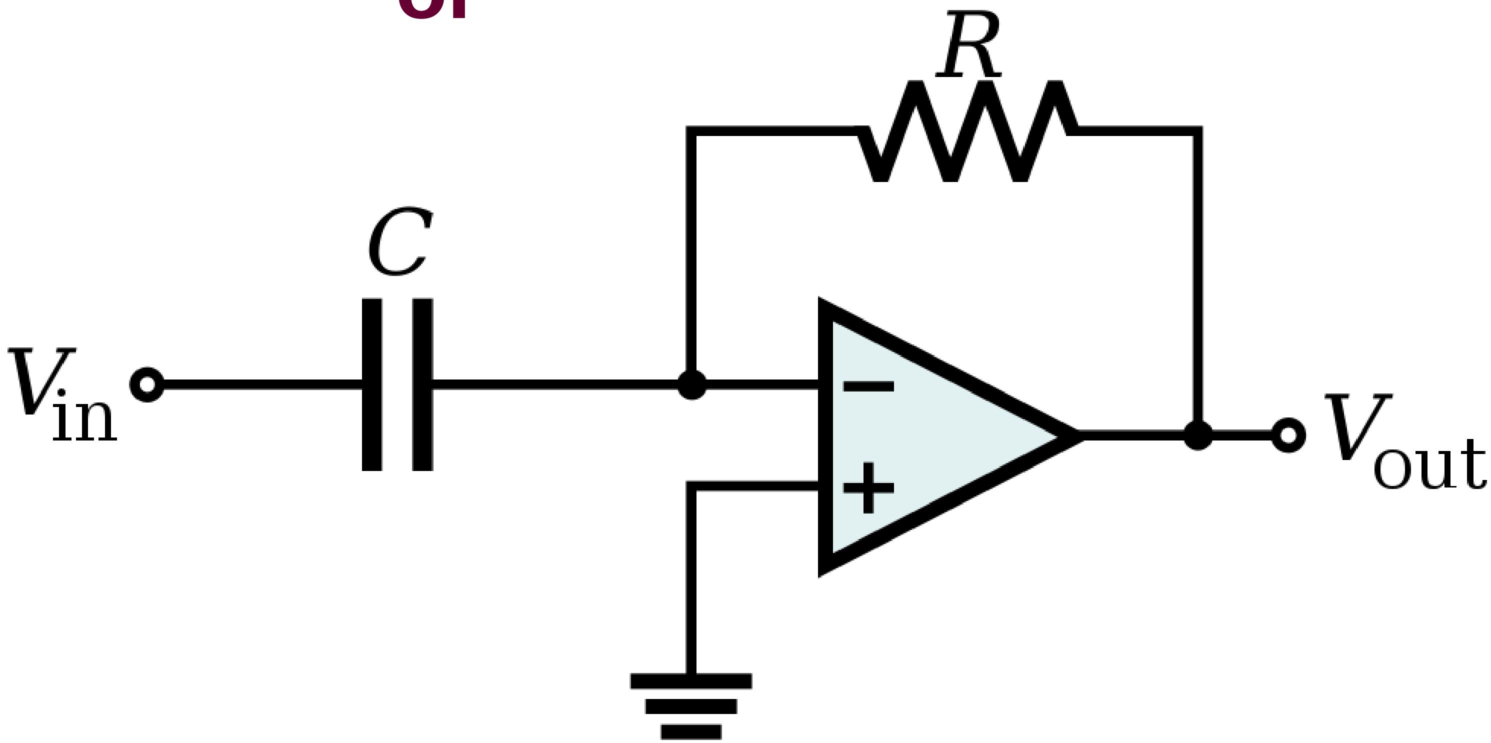
- Current is sourced from op-amp output in this example
- Current is sourced from op-amp output in this example

Voltage follower



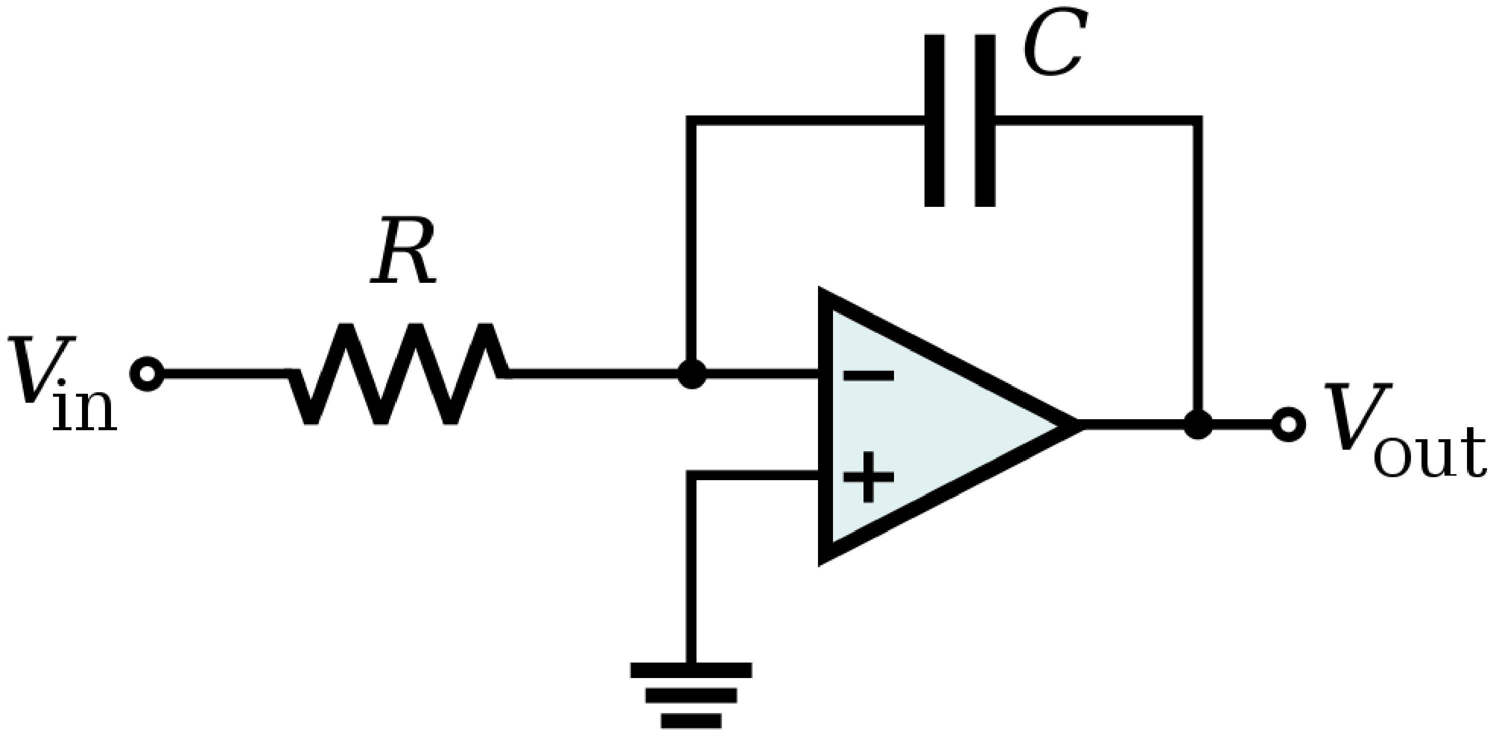
$$V_{OUT} = V_{IN}$$

Differentiat
or



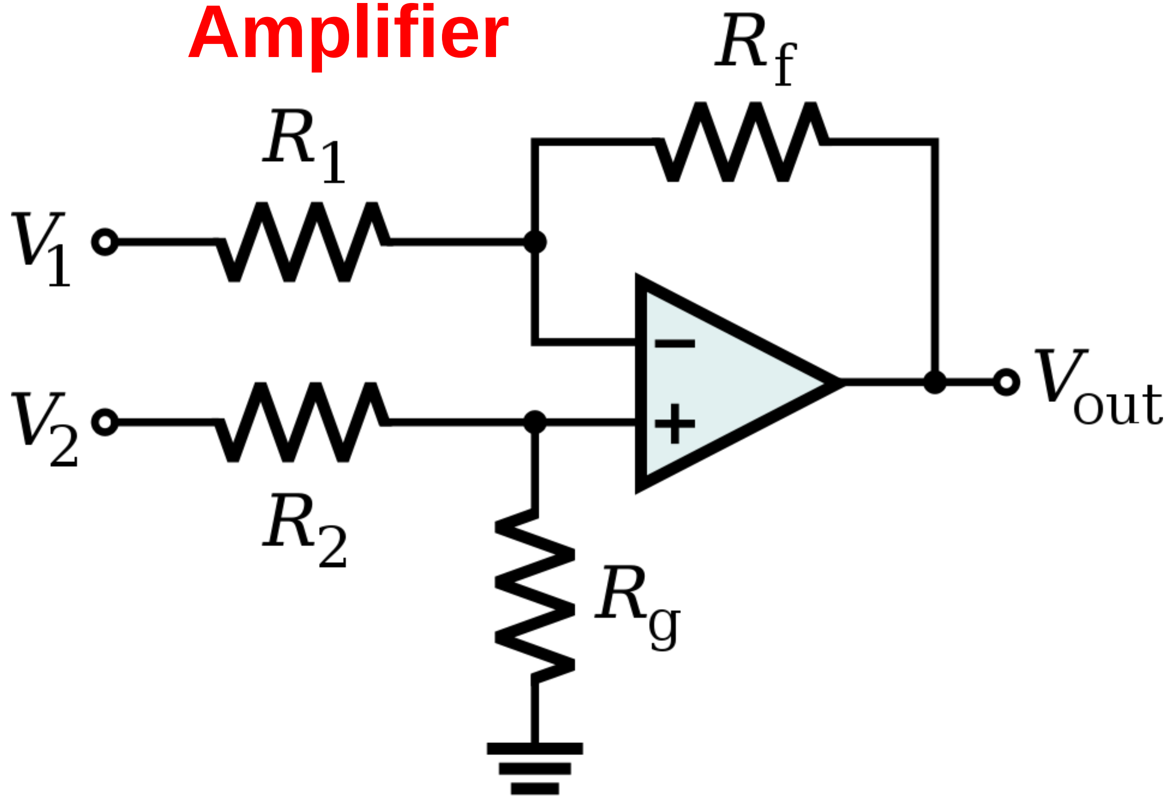
$$V_{out} = -RC \frac{dV_{in}}{dt}$$

Integrator



$$V_{out} = -\int_0^t \frac{V_{in}}{RC}\,dt + V_{initial}$$

Differential Amplifier

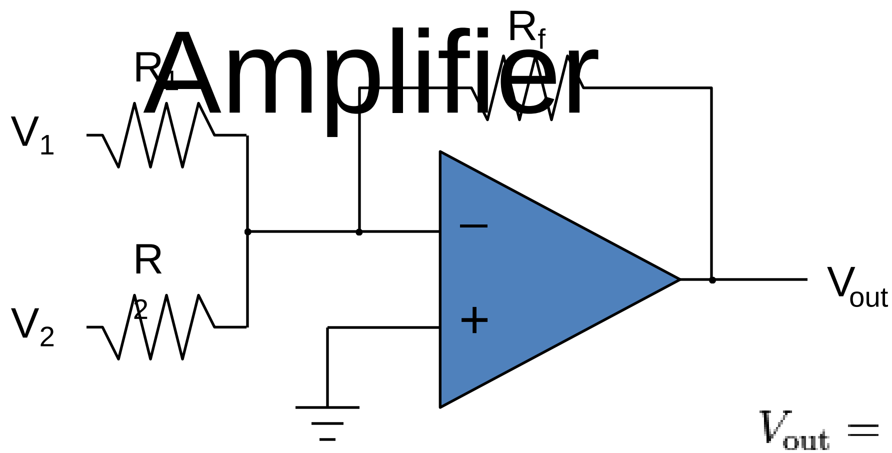


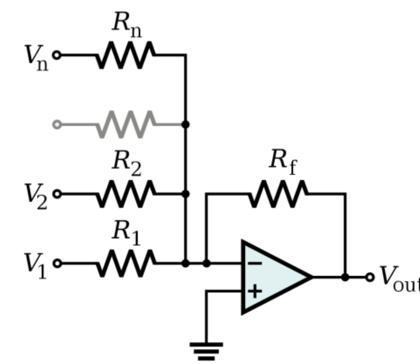
$$V_{out} = \frac{(R_f + R_1)\,R_g}{(R_g + R_2)\,R_1} V_2 - \frac{R_f}{R_1} V_1$$

If $R_1 = R_2$ and $R_f = R_g$:

$$V_{out} = \frac{R_f}{R_1}(V_2 - V_1)$$

Summing Amplifier

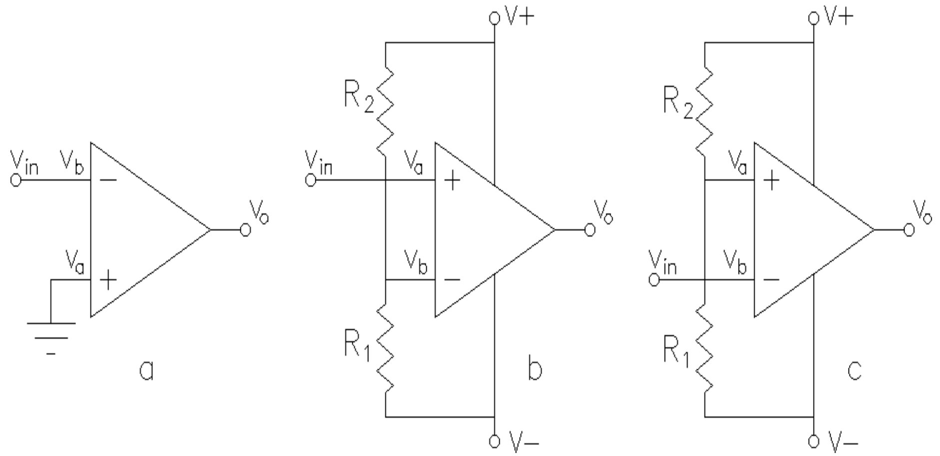




$$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \cdots + \frac{V_n}{R_n}\right)$$

- Much like the inverting amplifier, but with two input voltages
  - inverting input still held at virtual ground
  - I_1 and I_2 are added together to run through R_f
  - so we get the (inverted) sum: $V_{out} = -R_f \times (V_1/R_1 + V_2/R_2)$
    - if $R_2 = R_1$, we get a sum proportional to $(V_1 +$

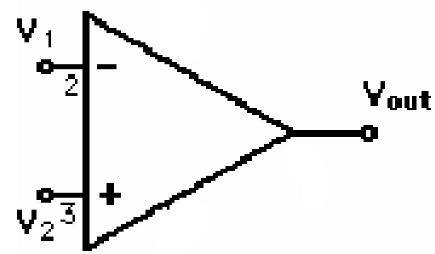
Comparator



V_1 is V_{ref}

V_2 is V_{in}

$$v_{out} = \begin{cases} +V_{max} & v_+ > v_- \\ -|V_{min}| & v_+ < v_- \end{cases}$$

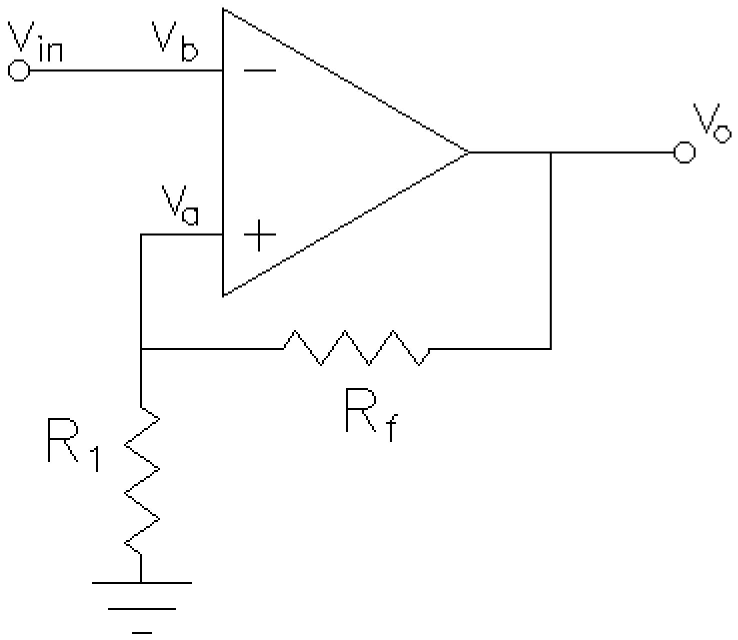


Determines if one signal is bigger than another

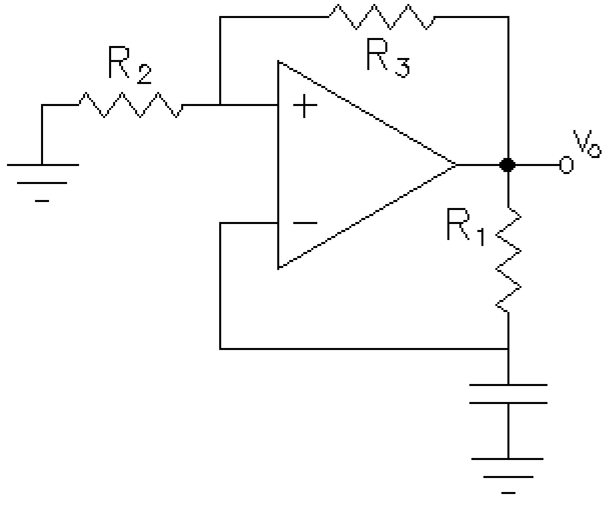
Applications of comparator

1. Zero crossing detector
2. Window detector
3. Time marker generator
4. Phase detector

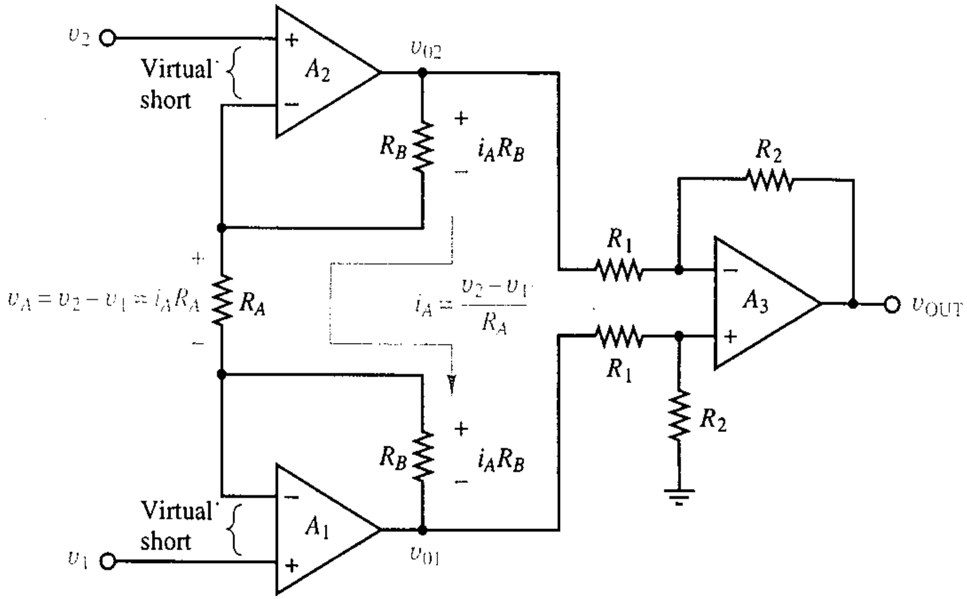
Schmitt trigger



square wave generator



Instrumentation Amplifier

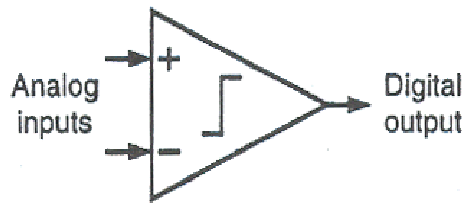


$v_{OUT} = (R2/R1)(1 + [2R_B/R_A])(v1 - v2)$

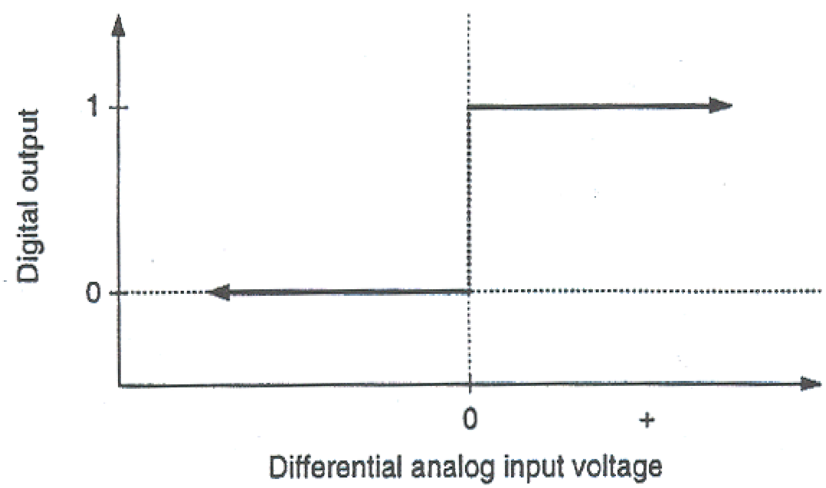
By adjusting the resistor R_A, we can adjust the gain of this instrumentation amplifier

Analog-to-digital converter (ADC)

- An **analog-to-digital converter (ADC)** converts real-world signals (usually voltages) into digital numbers so that a computer can:
  - acquire signals automatically,
  - store and retrieve information about the signals,
  - process and analyze the information,
  - display measurement results.



(a)



(b)

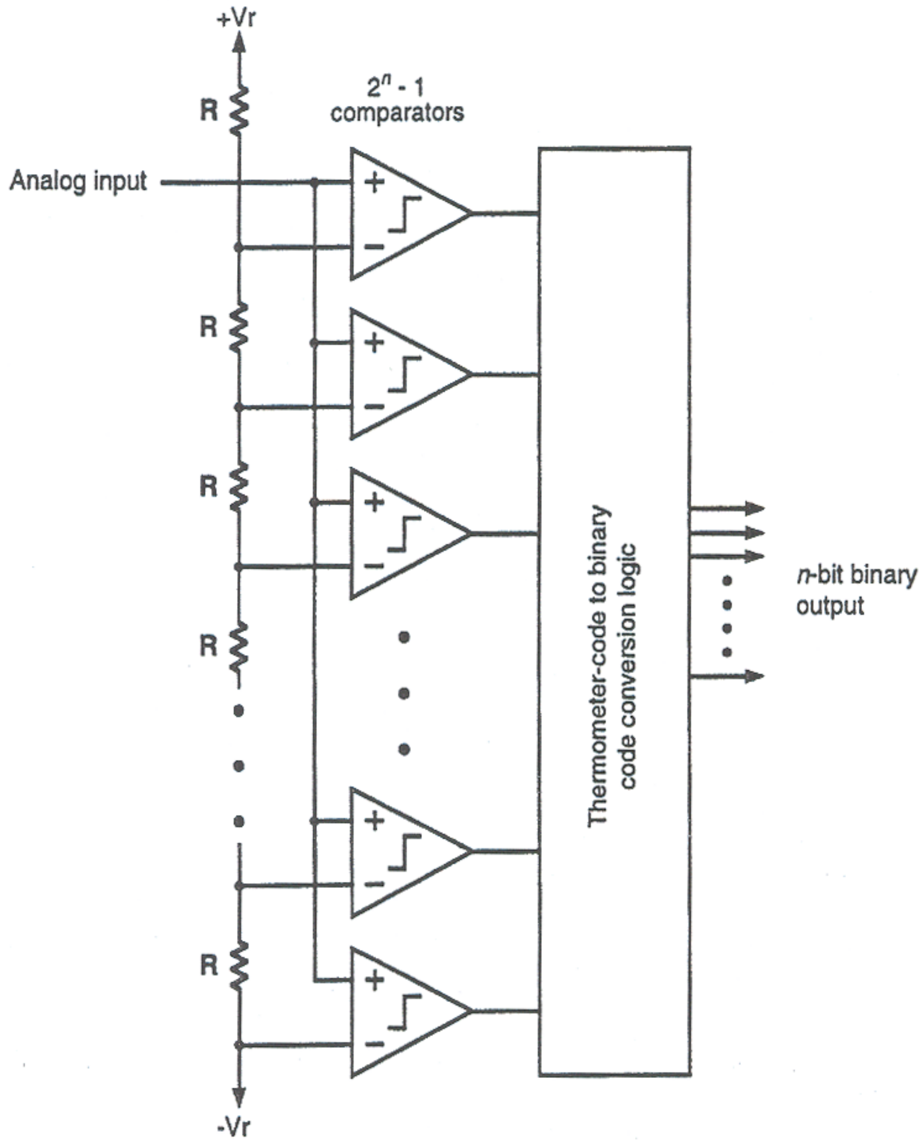
- **The comparator—the essential building block of all ADCs. (a) Comparator symbol. (b) Comparator I/O transfer function.**

Types of ADCs

- There are 5 major types of ADCs:
  - Flash (parallel) converters,
  - Dual-slope, integrating converters,
  - Successive-approximation converters,
  - Tracking (servo) types,
  - Dynamic range, floating point converters.
- The fastest ADCs are the flash converters. They can convert 8 bits with a sampling period of less than 1 ns. Such fast speed is useful for measuring transient phenomena. E.g. Transient events in particle physics and lasers.

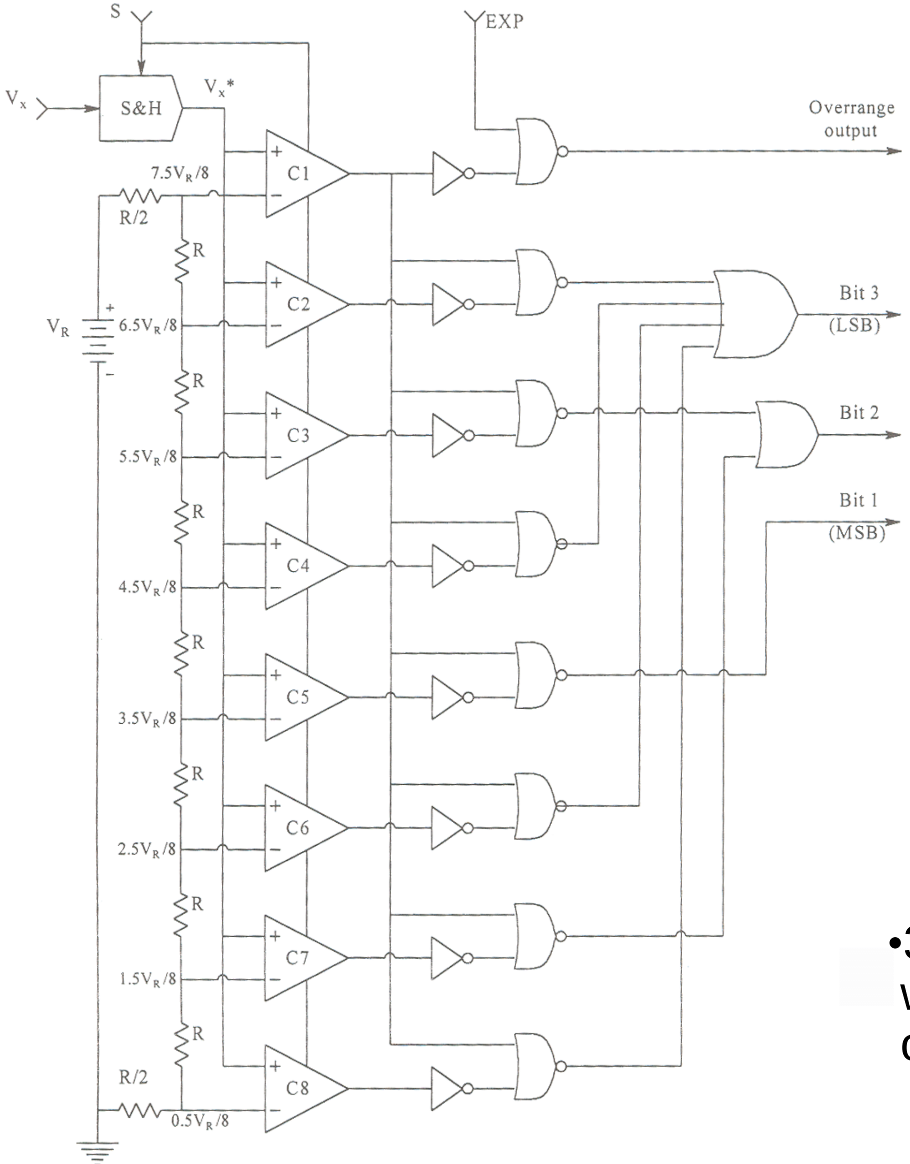
Flash (parallel) converter

- Since **Flash ADCs (FADCs)** is simple-structured, they are fast.
- A string of resistors between two voltage references supplies a set of uniformly spaced voltages that span the input range, one for each comparator. The input voltage is compared with all of these voltages simultaneously.
- Comparator outputs = 1 for all voltages below the input voltage
- Comparator outputs = 0 for all the voltages above the input voltage.
- The resulting collection of digital outputs is called a "thermometer code".



- A flash converter has 2^n-1 comparators operating in parallel.

Flash converter (More Complicated



- 3-bit flash ADC with binary output.

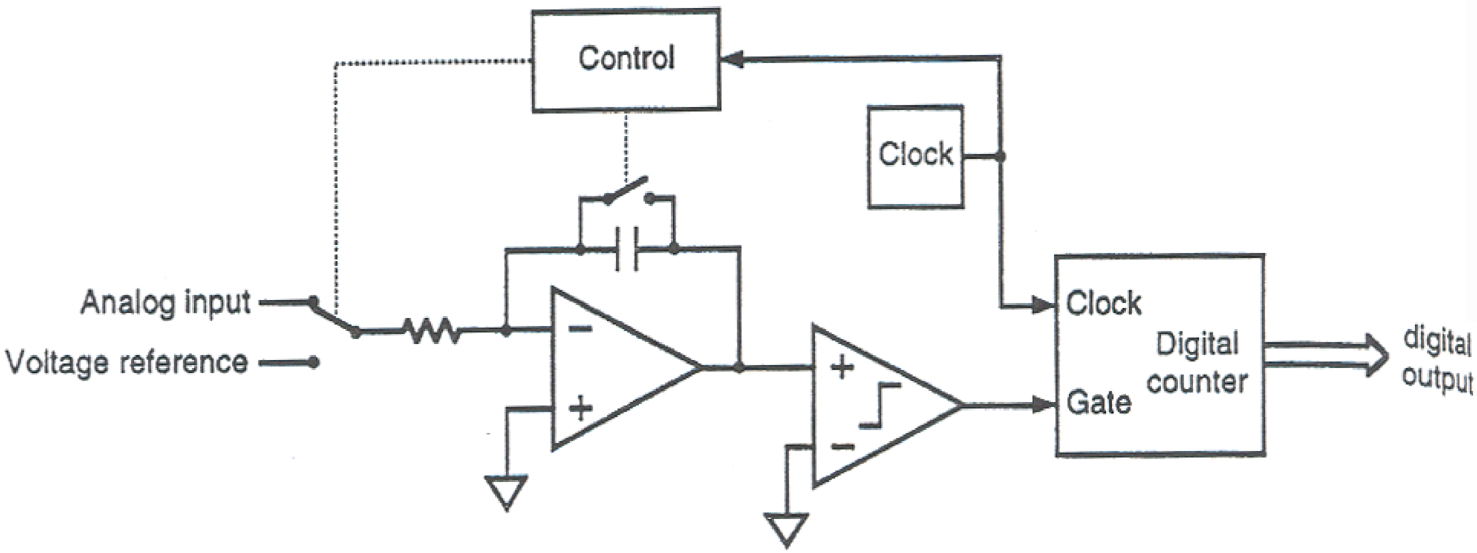
Integrating converter

- Integrating converters are used for low-speed, high-resolution applications such as voltmeters. They are conceptually simple, consisting of an integrating amplifier, a comparator, a digital counter, and a very stable capacitor for accumulating charge.

Integrating converter

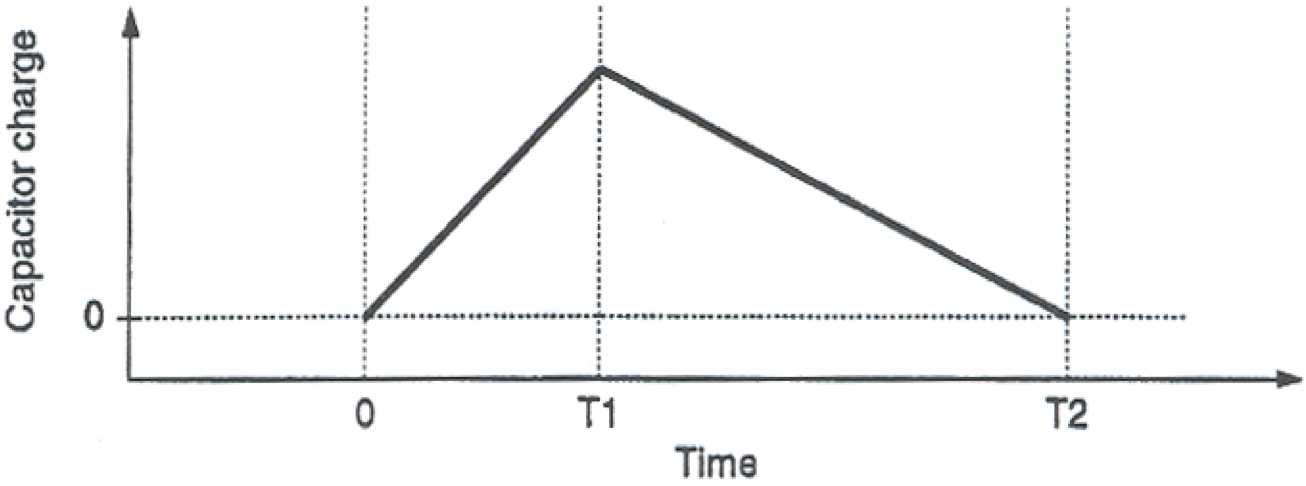
- The most common integrating ADC in use is the dual-slope ADC. Its action is illustrated in the next slide.

Integrating converter



- A dual-slope integrating converter uses a comparator to determine when the capacitor has fully discharged.

Integrating converter



- At time 0, the input is switched to analog input and the switch across the capacitor opens. After the capacitor is integrated, the input is switched to the voltage reference to discharge the capacitor, and the counter begins counting a known clock. The comparator turns off the counter at time T2.

Integrating converter

- Dual-slope integrating ADCs (DSI-ADCs) have the advantages of high inherent accuracy (up to 22 bits output), excellent high-frequency noise rejection. They are widely used in inexpensive DC digital instruments.

Digital-to-analog converter (DAC)

- A **digital-to-analog converter (DAC)** is an integrated circuit (IC) device which converts an N bit digital word to an equivalent analog voltage or current. It allows digital information which has been processed and/or stored by a digital computer to be realized in analog form.
- After digitalization, a staircase waveform can be smoothed by a low-pass filter. In this way, an analog output signal is reconstructed.

Digital-to-analog converter (DAC)

- At sampling instants, the difference between DAC output and the analog input signal is called a **quantization error**.
- The quantization error of an ADC is equivalent to $\pm$½ least significant bit (LSB).

Digital to Analog Conversion

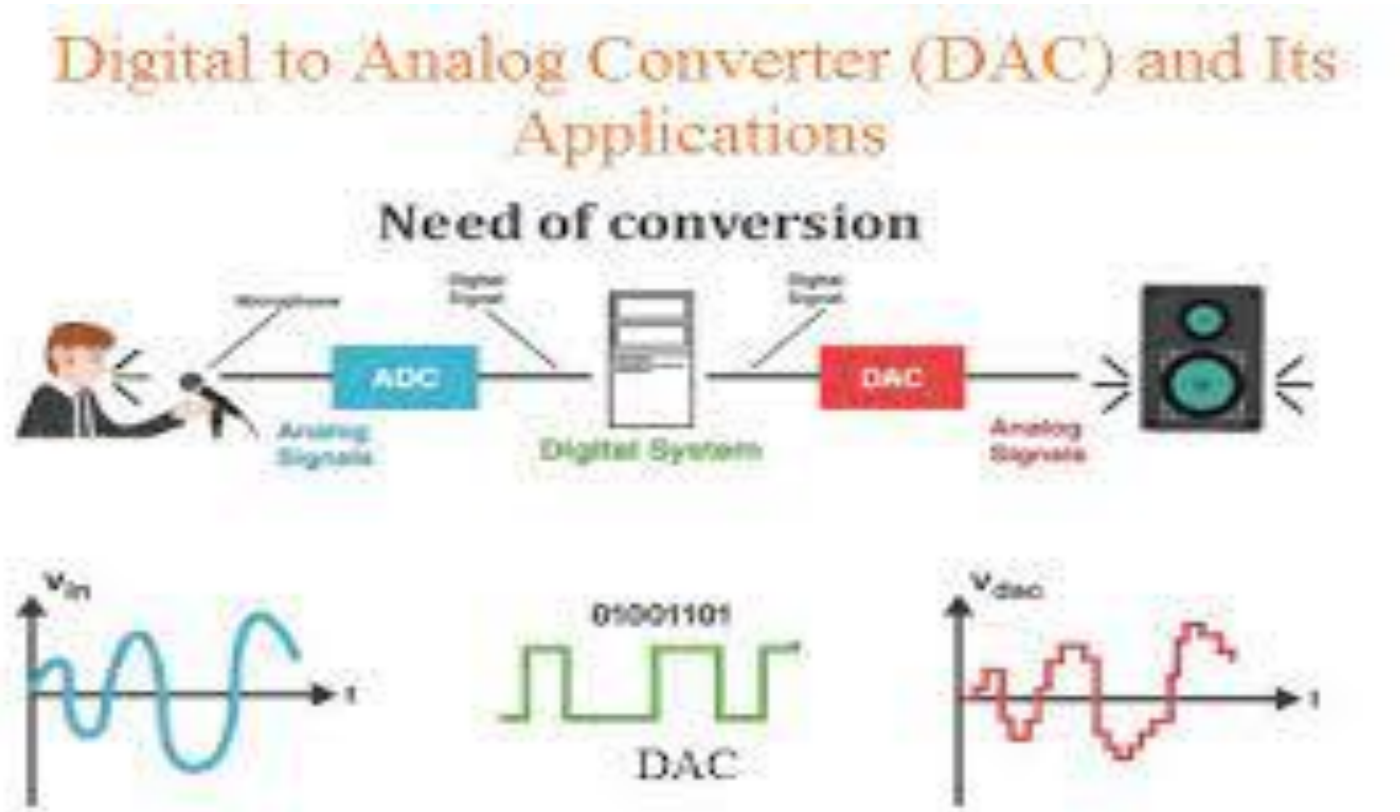
A D/A Converter produces an analog voltage proportional to the digital input.

Example:

D/A designed to output 0 to 10 volts.

- Input to D/A is an 8 bit digital value.
- Digital value 0 produces a 0 volt output.
- Digital value 1 produces a 1 x 10/256 volt ouput.
- Digital value 2 produces a 2 x 10/256 volt output.
- Digital value 255 produces a 255 x 10/256 volt output.

Typical 4-bit D/A Converter



Parameters Affecting D/A Converter Performance

Output Range

- The voltage difference between the max and min output voltages of the D/A.

Accuracy

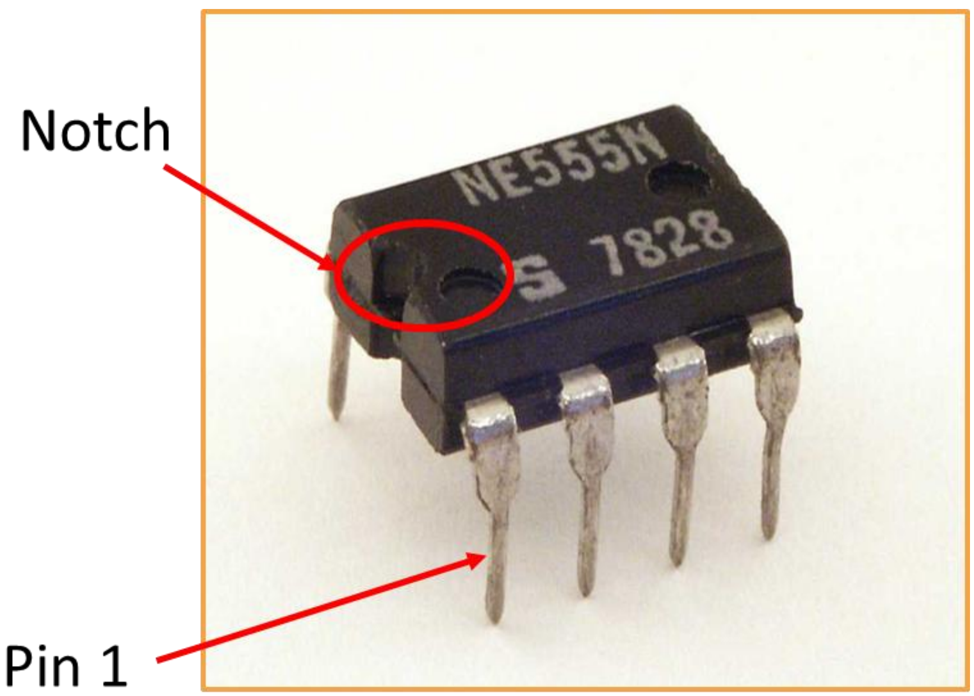
- Expressed as a percentage of the maximum output voltage
- Or as an error of the least significant bit (e.g.,+1/2 LSB).
- Expected amount of accuracy in actual output based on digital input.

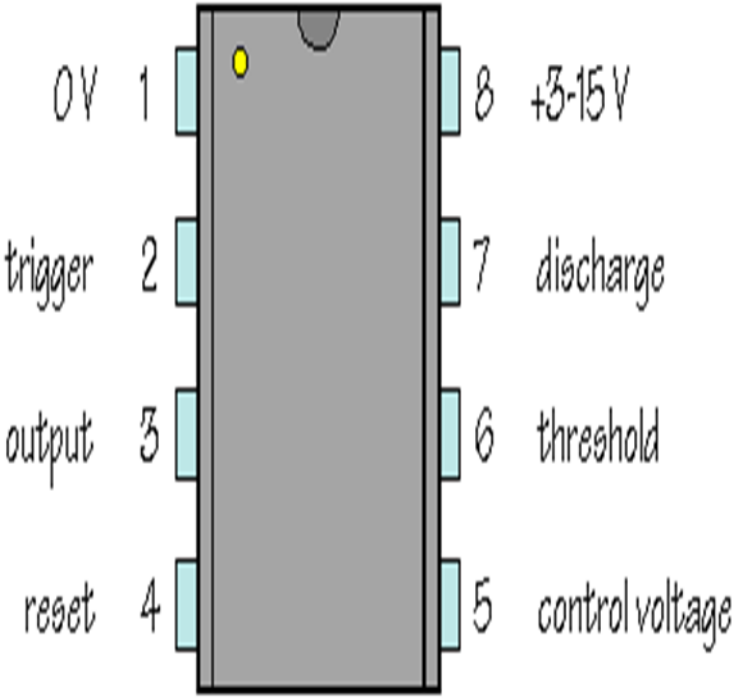
IC 555 TIMER

Introduction:

- The 555 Timer is one of the most popular and versatile integrated circuits ever produced!
- "Signetics" Corporation first introduced this device as the SE/NE 555 in early 1970.
- It is a combination of digital and analog circuits.
- It is known as the "time machine" as it performs a wide variety of timing tasks.
- Applications for the 555 Timer include:
  - Square wave generator
  - Frequency dividers
  - Voltage-controlled oscillators
  - Pulse generators and LED flashers

The 555 timer is an 8-Pin D.I.L. Integrated Circuit or ‘chip’

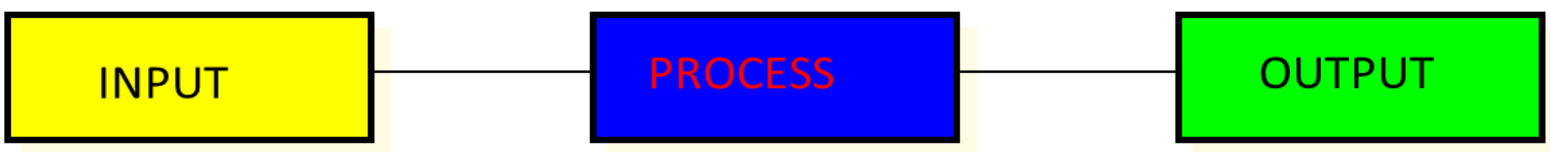




555 Timer

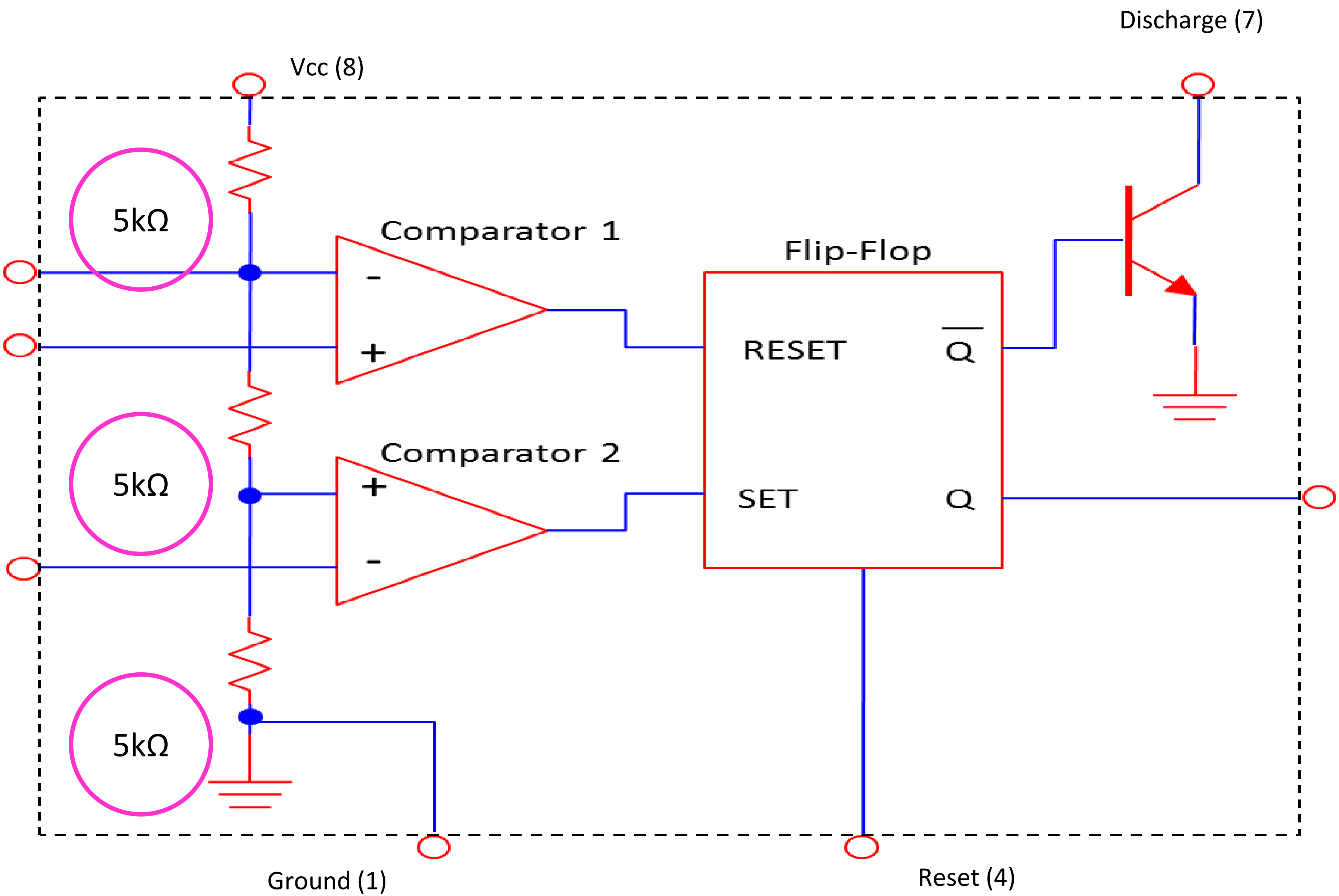
Description:

- Contains 25 transistors, 2 diodes and 16 resistors
- Maximum operating voltage 16V
- Maximum output current 200mA
- Best treated as a single component with required input and output



If you input certain signals they will be processed / controlled in a certain manner and will produce a known output.

IC 555



Discharge (7)
Vcc (8)
5kΩ
Comparator 1
Flip-Flop
-
+
RESET
Q
5kΩ
Comparator 2
+
SET
Q
-
5kΩ
Ground (1)
Reset (4)

555 timer Applications

- To switch on or off an output after a certain time delay i.e.
  Games timer, Exercise timer.
- To continually switch on and off an output i.e.
  warning lights, Bicycle indicators.
- As a pulse generator i.e.
  To provide a series of clock pulses for a counter.

- The 555 has three operating modes:
  1. Monostable Multivibrator
  2. Astable Multivibrator
  3. Bistable Multivibratior

Schematic Diagram of 555 Timer