Electronic Measurements

2- Signal Generators

2-1 Applications of Operational Amplifiers

2-2 Idea of Operation of Oscillators

2-3 Types of Signal Generators

- Low Frequency (LF) Gen.
- Function Gen.
- Radio Frequency (RF) Gen.
- Pulse Gen.
- Sweep Frequency Gen.

2-1 Applications of OP-Amp

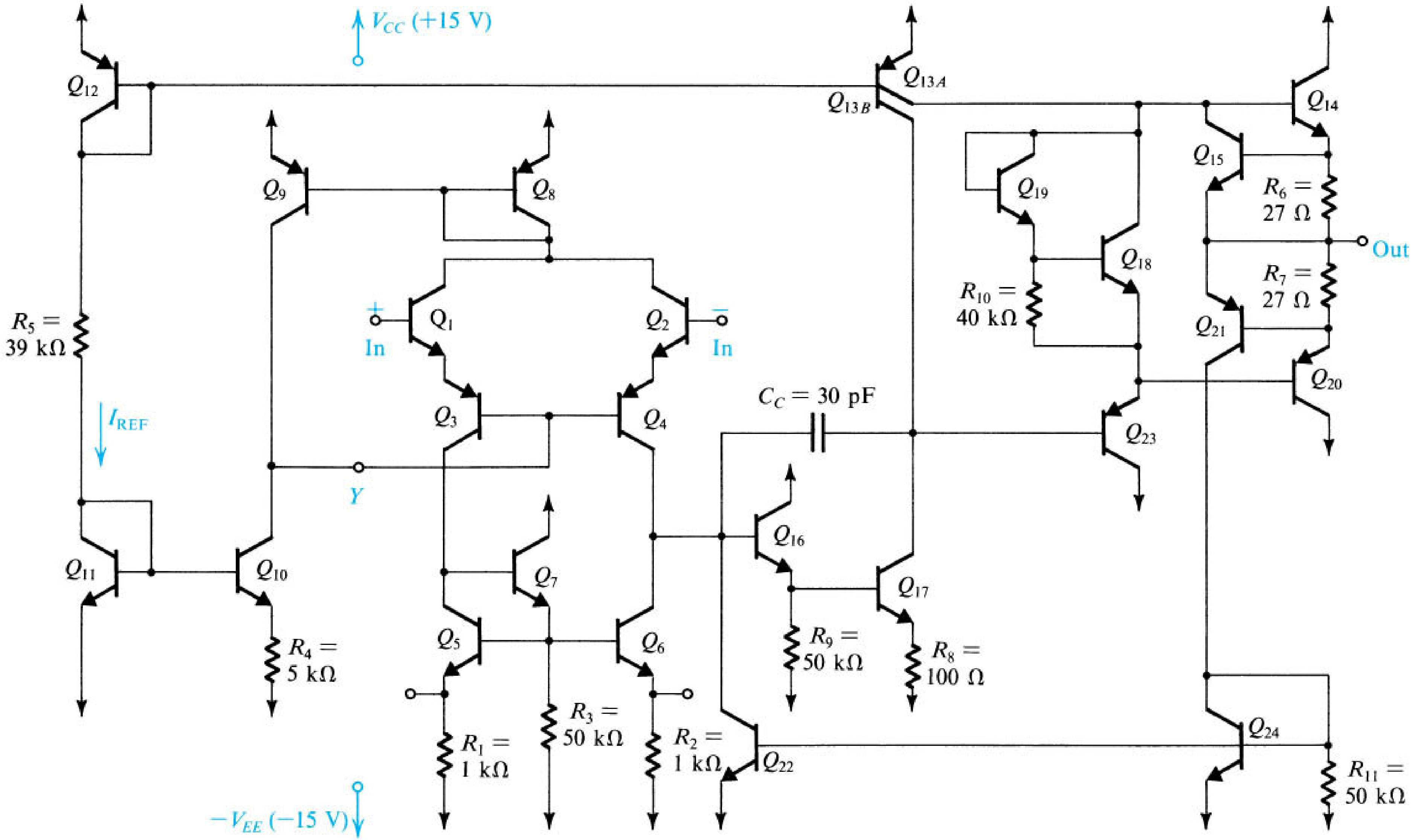
General Description:

The Op-Amp consists of transistors, resistors, capacitors, and power supplies. It has two inputs and **one output**.

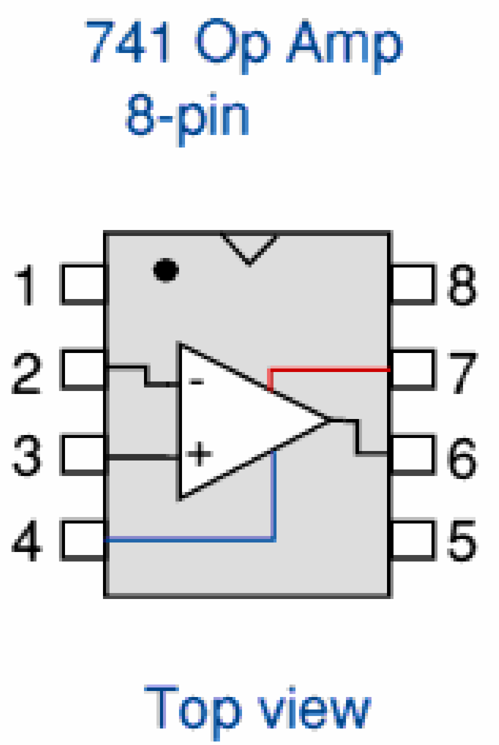
Characteristics:

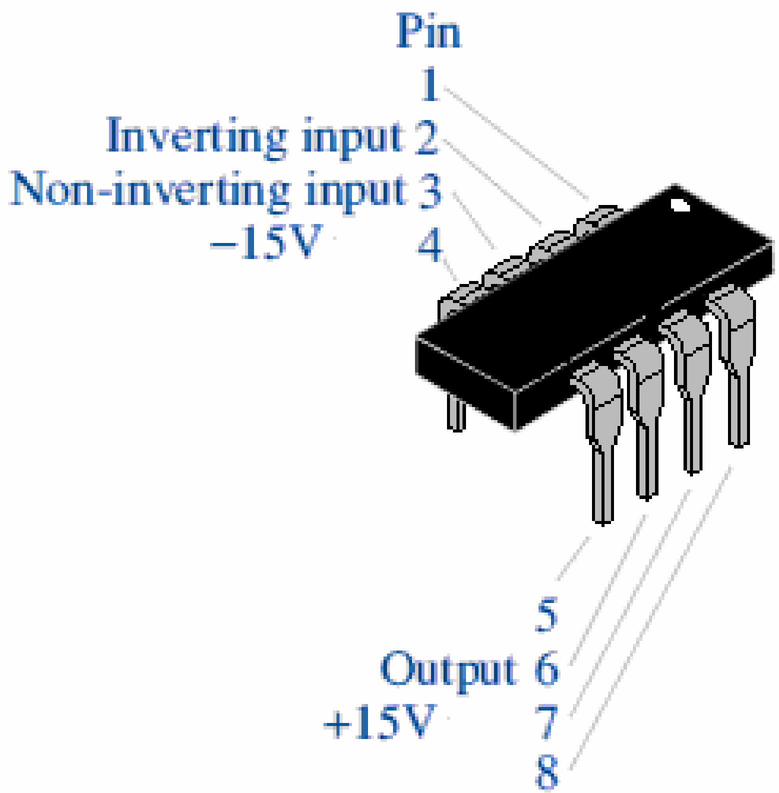
- Input resistance is very large (ideally: ∞)
- voltage gain is very large (ideally: ∞)
- Bandwidth is very large (ideally: ∞)
- Output resistance is very small (ideally: zero)

A Circuit Diagram of an Op-Amp



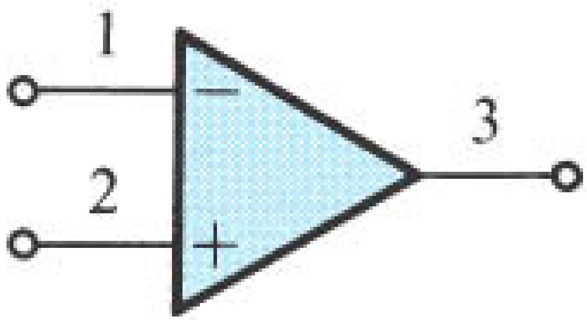
IC of an Op-Amp

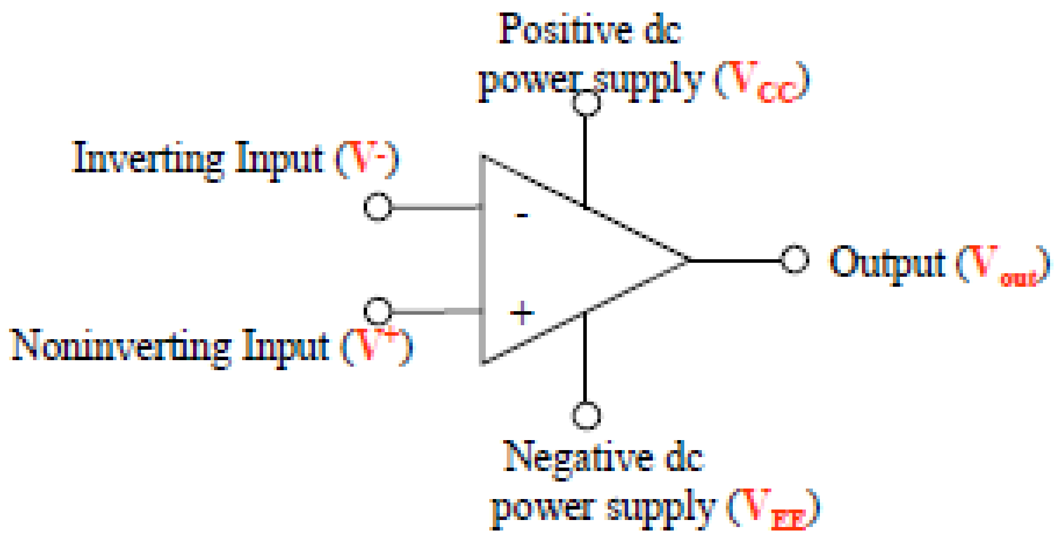




The most usual 741 package

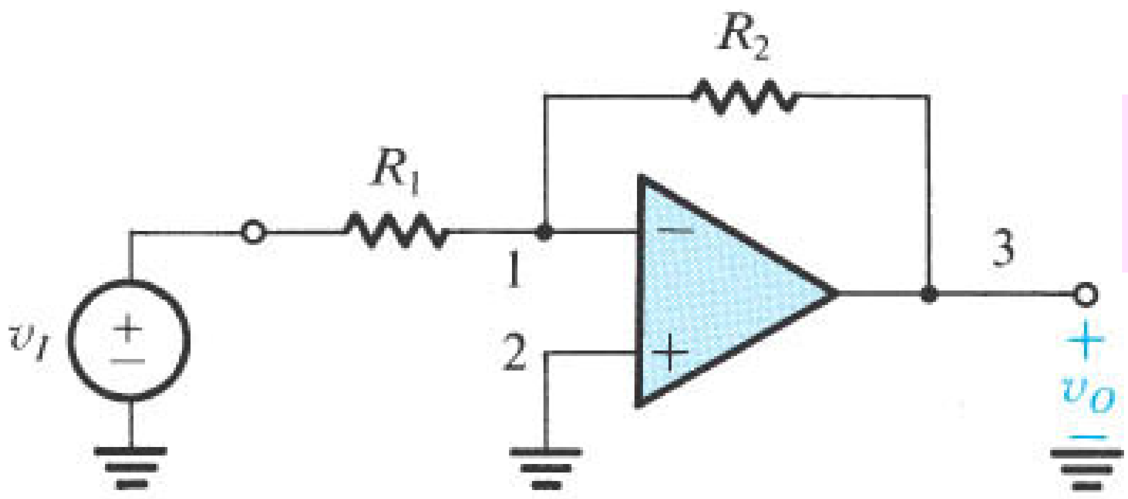
Symbol





- Terminal **1** is called inverting terminal (**input 1**)
- Terminal **2** is called non-inverting terminal (**input 2**)
- Terminal **3** is the output terminal
- **The output** depends on the configuration.
- The output does not exceed the saturation levels (V_{CC} and V_{EE}) i.e. $V_{EE} \leq V_{out} \leq V_{CC}$
- For example, if $V_{CC}=15$, $V_{EE}=-15$, → $-15 \leq V_{out} \leq 15$

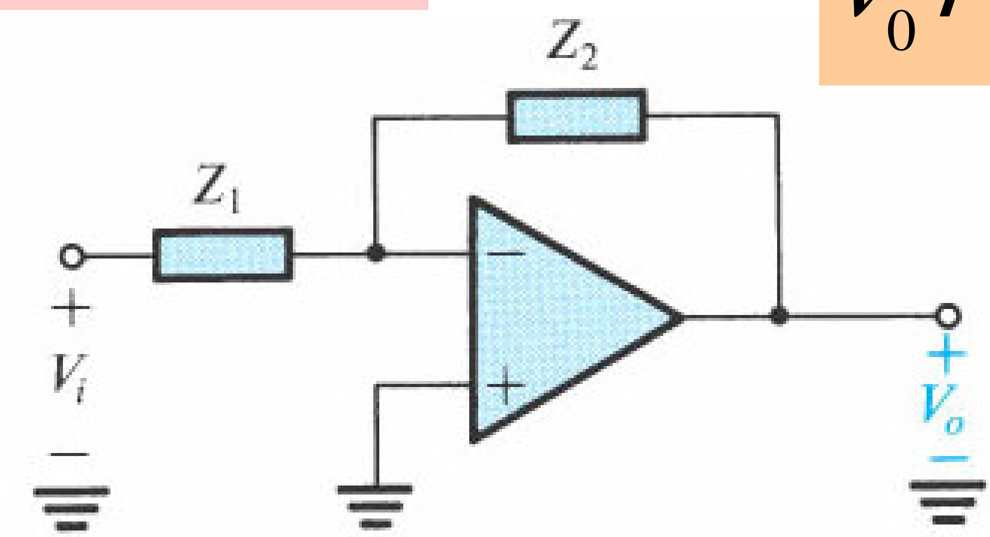
Inverting Op –Amp.



$$v_0 / v_i = -R_2 / R_1$$

In general

$$v_0 / v_i = -z_2 / z_1$$

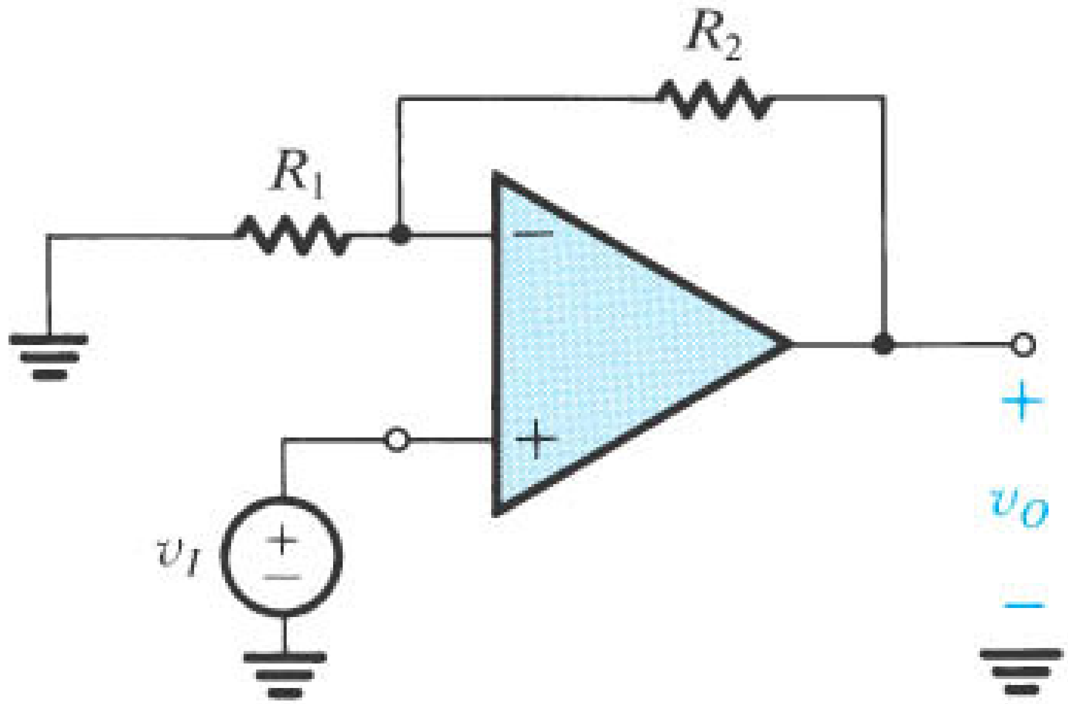


$Z_R = R$ (resistance)

$Z_L = J\omega L$ (inductor)

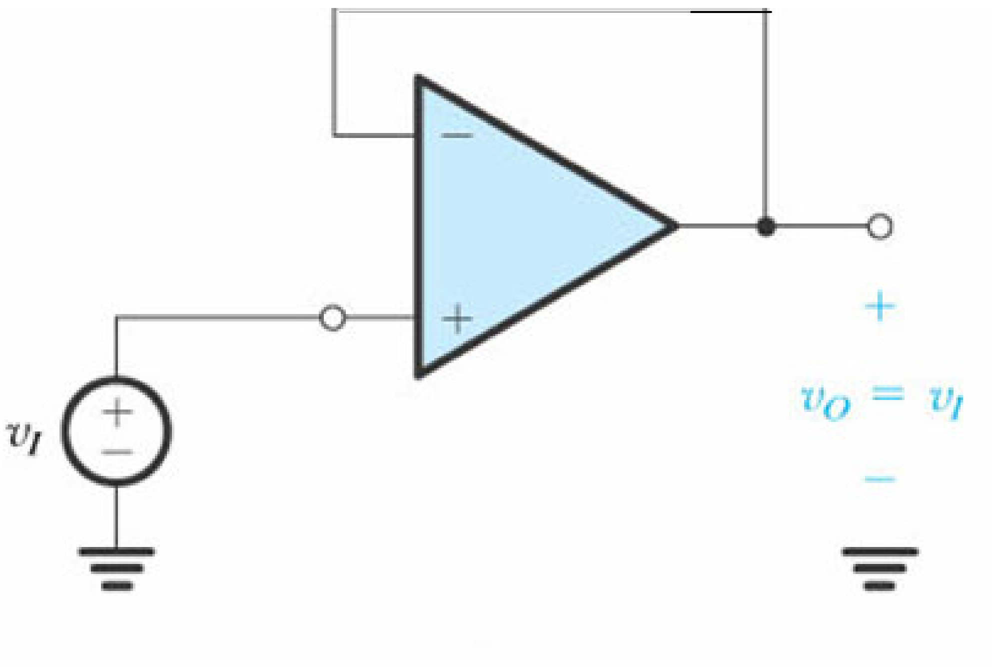
$Z_C = 1 / J\omega C$ (capacitor)

Non-Inverting Op-Amp



$$\frac{v_0}{v_i} = \left(1 + \frac{R_2}{R_1}\right)$$

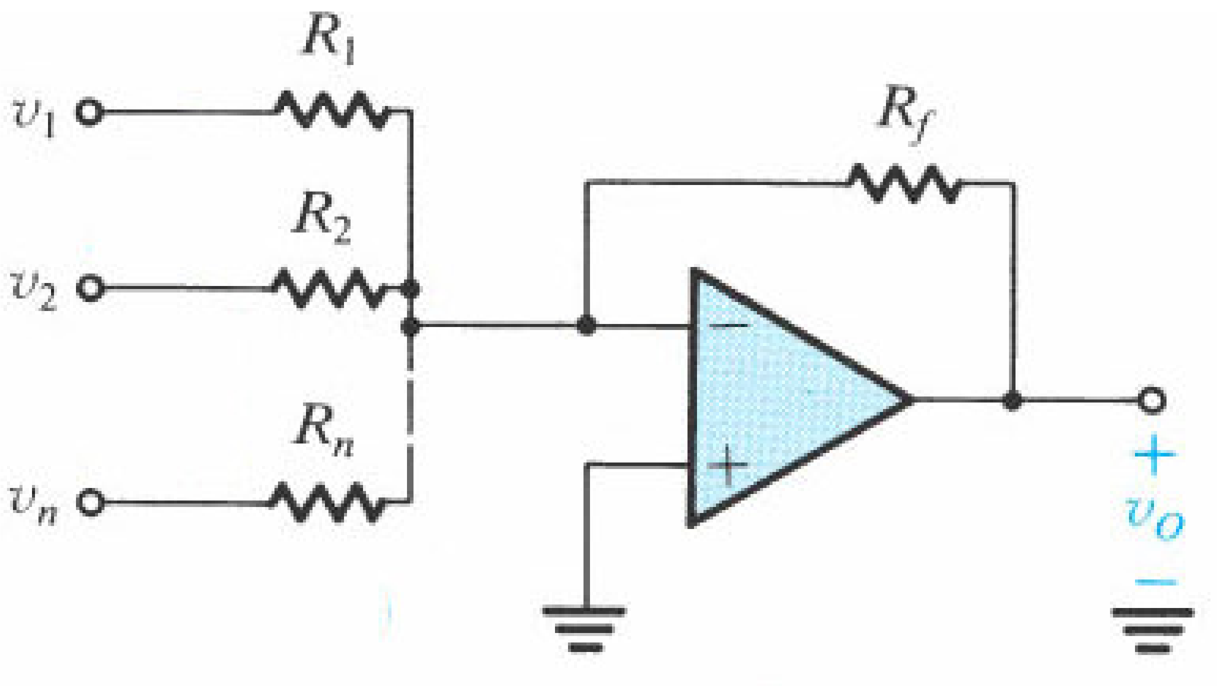
Voltage Follower (Buffer)



$$\frac{v_0}{v_i} = 1$$

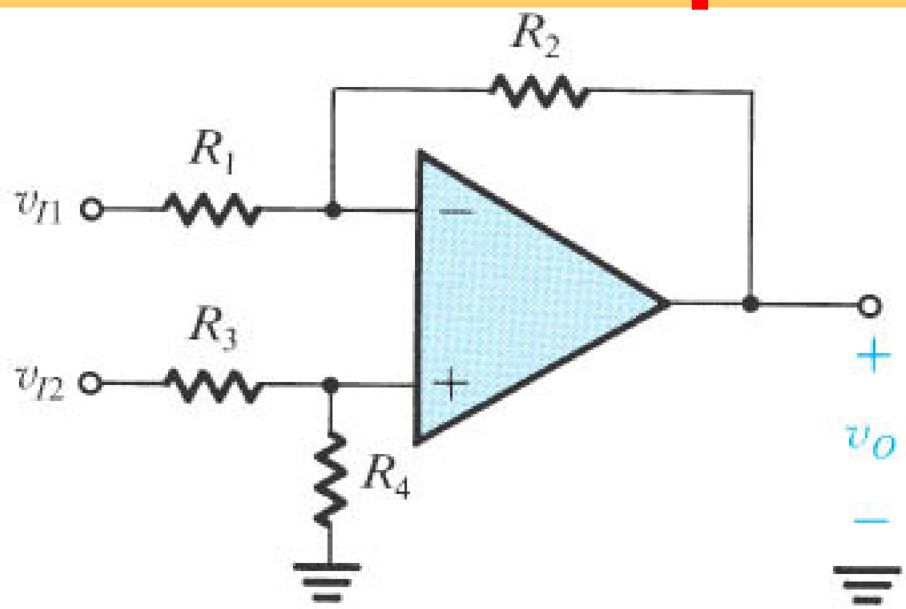
The gain is unity. The output is the same as the input but with very low output impedance (to prevent a high source resistance from being loaded by down by a low resistance load) .

Summing Amplifier



$$v_0 = -\left(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \ldots\ldots\ldots \frac{R_f}{R_n}v_n\right)$$

Difference Amplifier

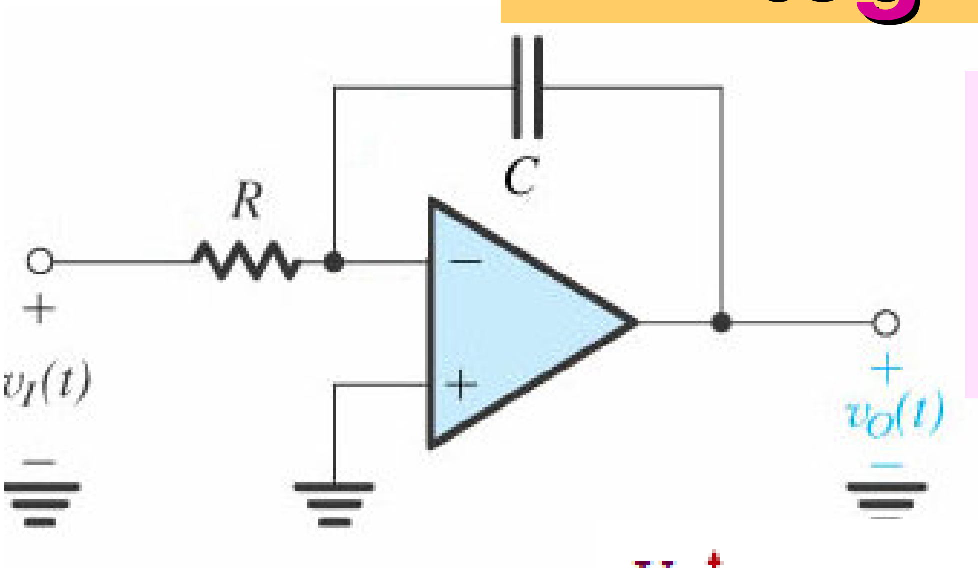


$$v_0 = -\left(\frac{R_2}{R_1}\right) v_{i1} + \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right) v_{i2}$$

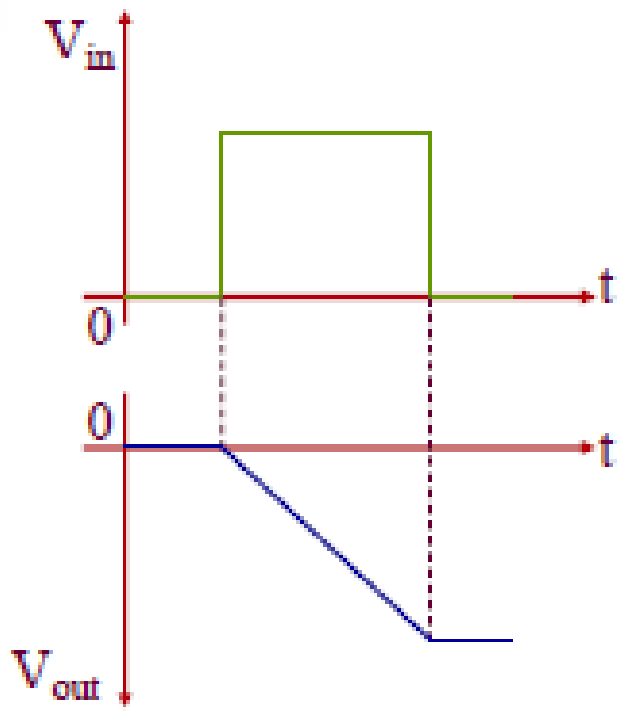
If $R_1 = R_3$, and $R_2 = R_4$ → $$v_0 = \left(\frac{R_2}{R_1}\right)(v_{i2} - v_{i1})$$

Hint: Apply superposition principle.

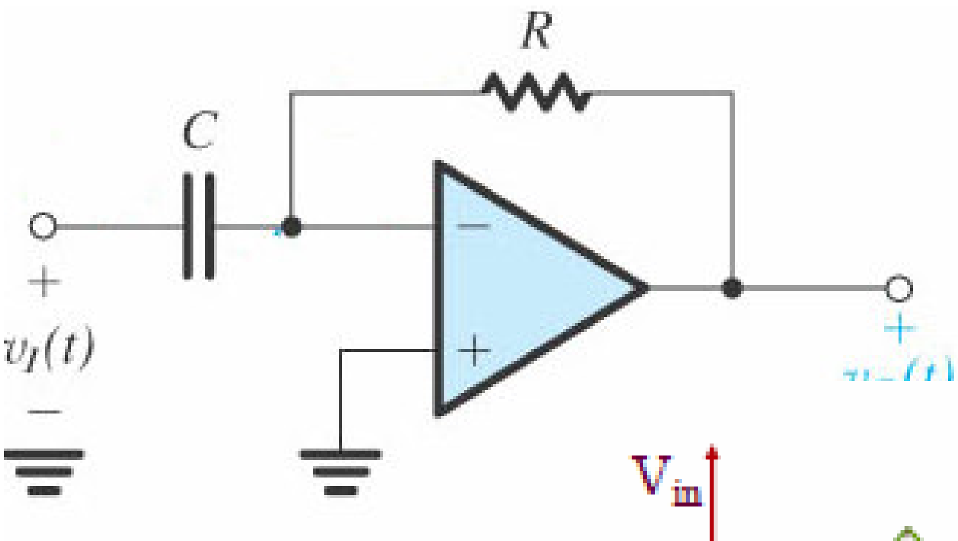
Integrator



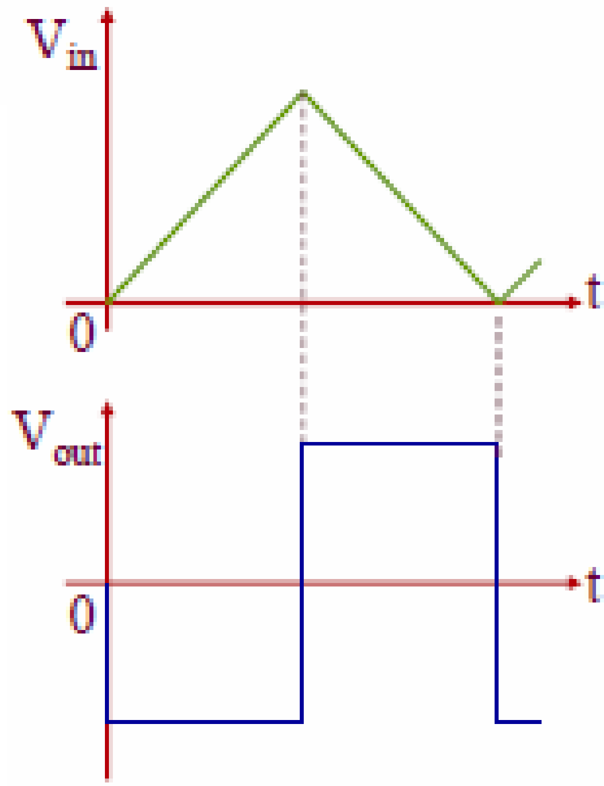
$$v_0 = -\frac{1}{RC}\int_0^t v_i(t)\,dt$$



Differentiator



$$v_0 = -RC\frac{dv_i(t)}{dt}$$

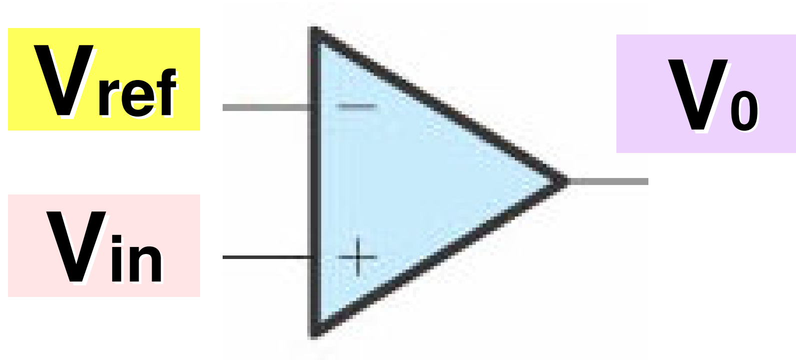


Comparator

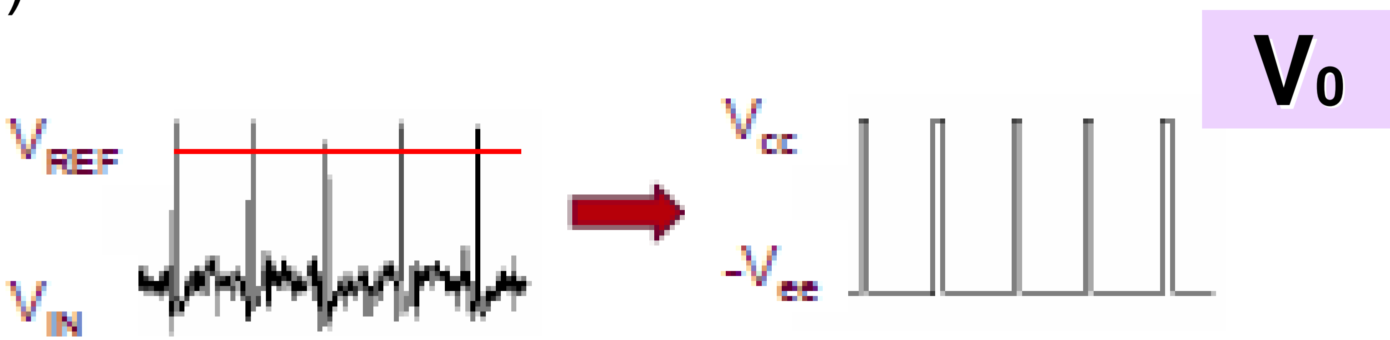
$$V_0 = A(V_{in} - V_{ref})$$

If $V_{in} > V_{ref}$, (A is very large)
V_o is very large in positive
(but <= V_{CC})

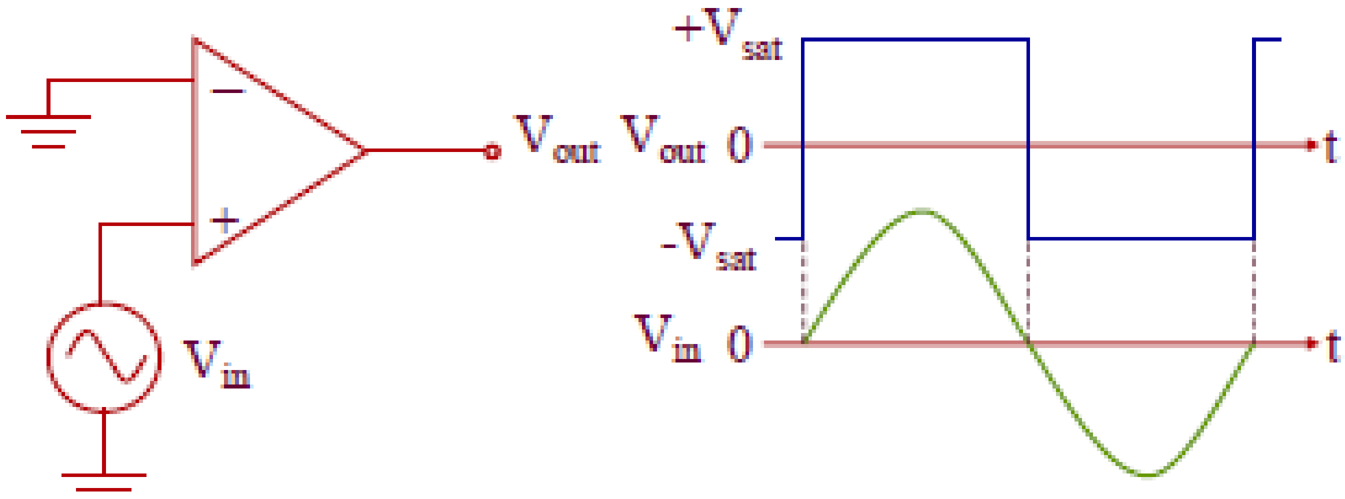
If $V_{in} < V_{ref}$, (A is very large)
V_o is very large in negative
(but >= V_{EE})



Example



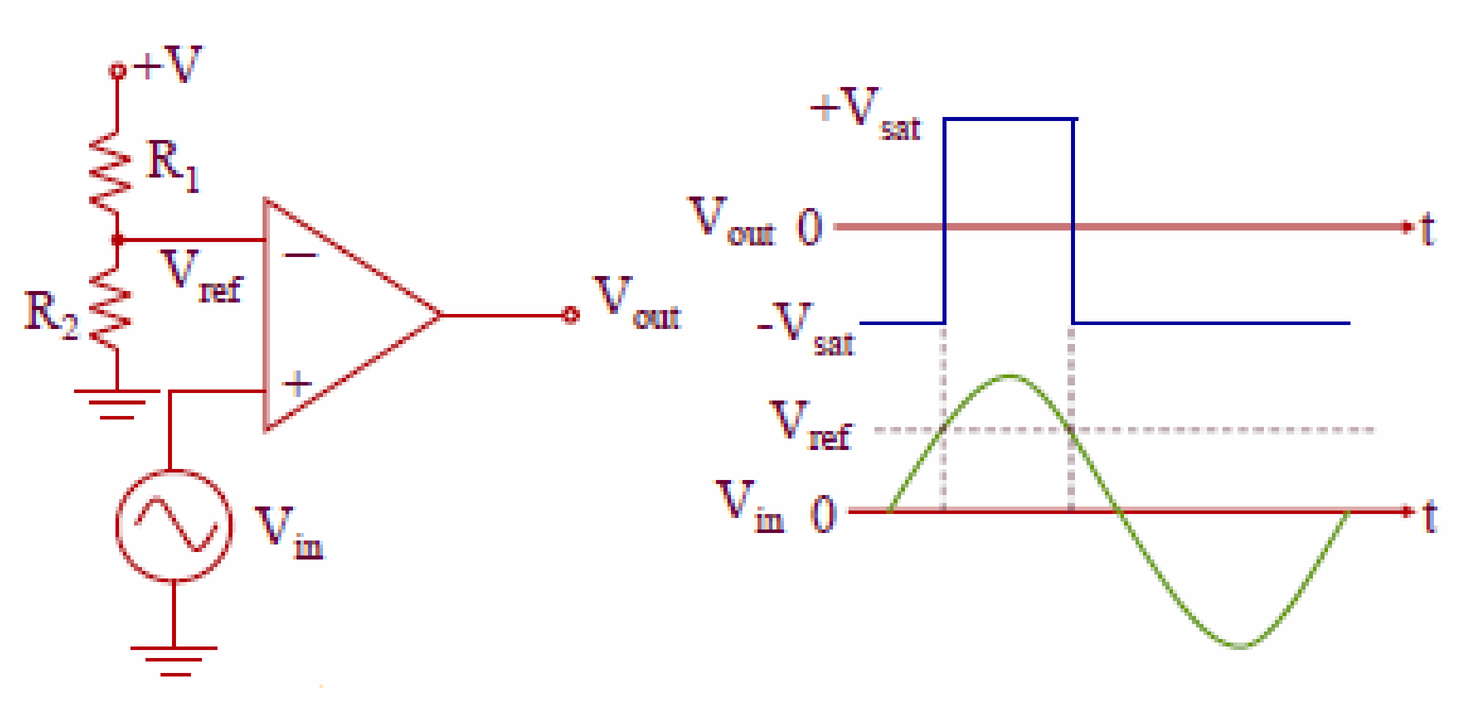
Zero Level Detector



In this case, $V_{ref} = 0$.

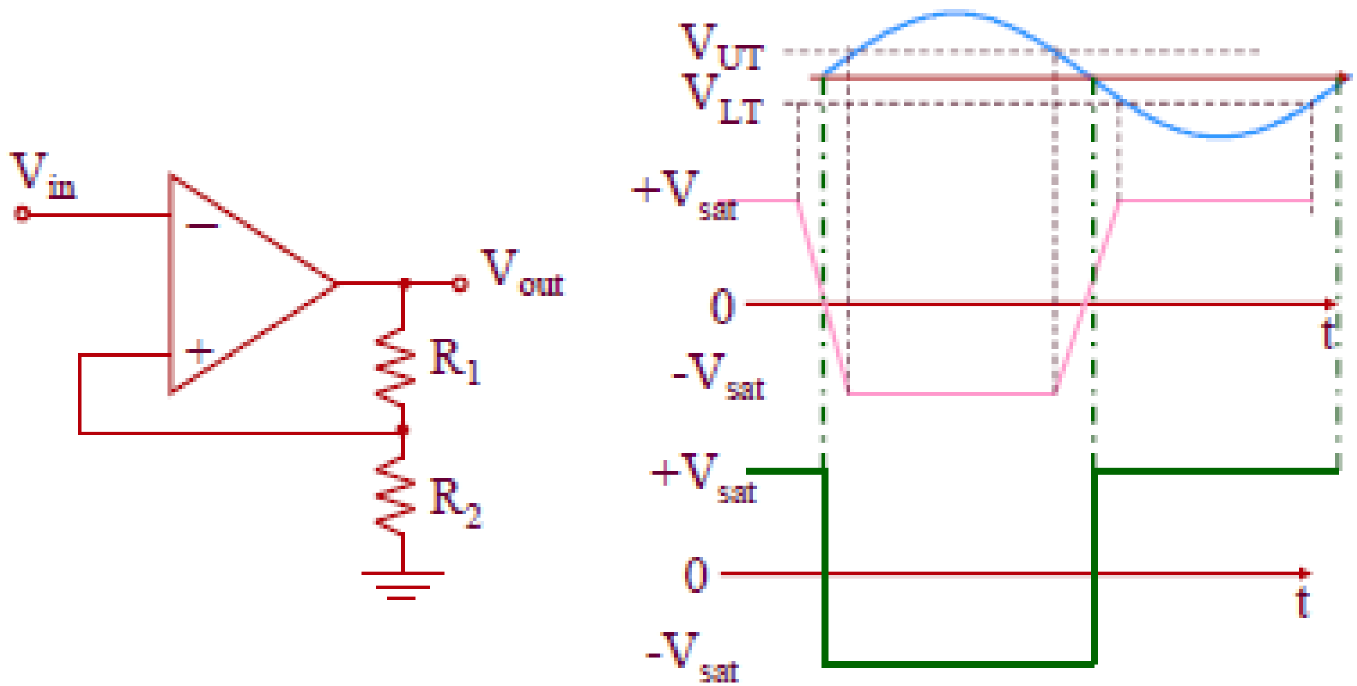
(<u>Note:</u> usually $V_{CC}=-V_{EE}$)

Non-Zero Level Detector



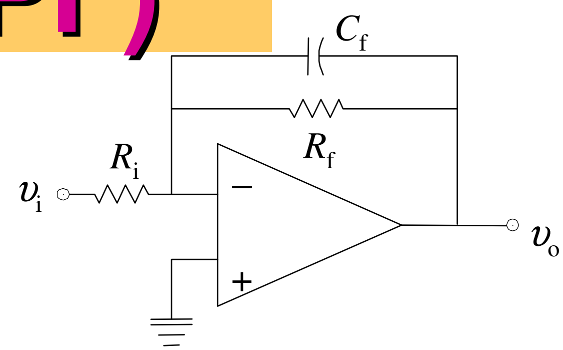
In this case, V_{ref} can be any value. (according to the values of V, R_1 and R_2)

Schmitt Trigger Circuit

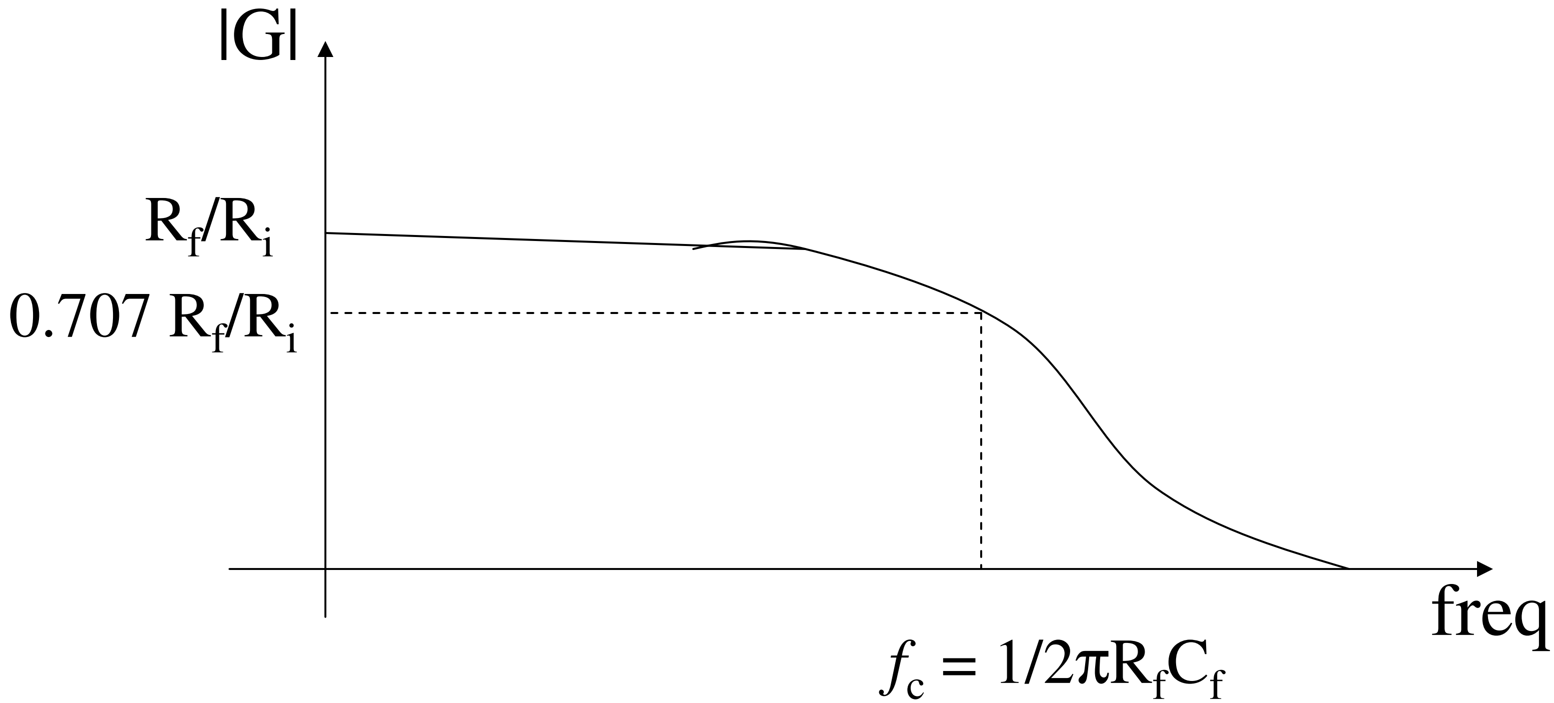


- It is used to generate a train of pulses.
- The input is applied to the negative terminal.
- R_1 and R_2 control the values of V_{UT} and V_{LT}.

Low-Pass Filter (LPF)

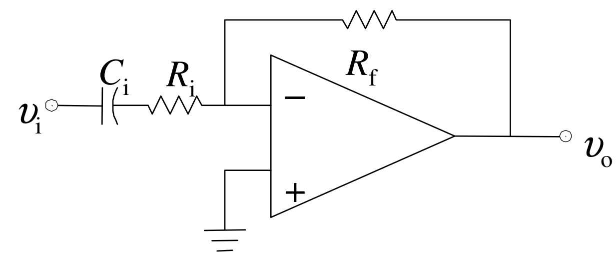


$$\text{Gain} = G = \frac{V_o(j\omega)}{V_i(j\omega)} = \frac{-R_f}{R_i}\,\frac{1}{1 + j\omega R_f C_f}$$

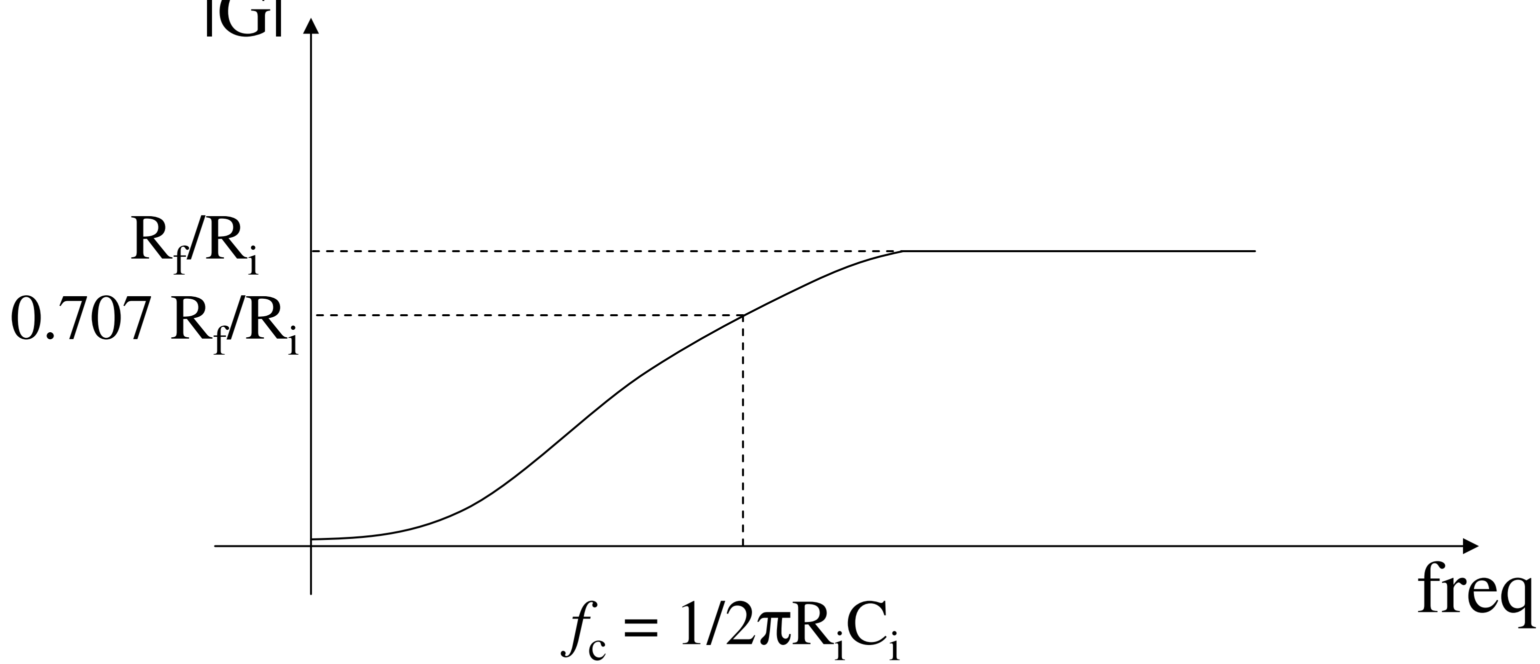


A low-pass filter attenuates high frequencies.

High-Pass Filter (HPF)



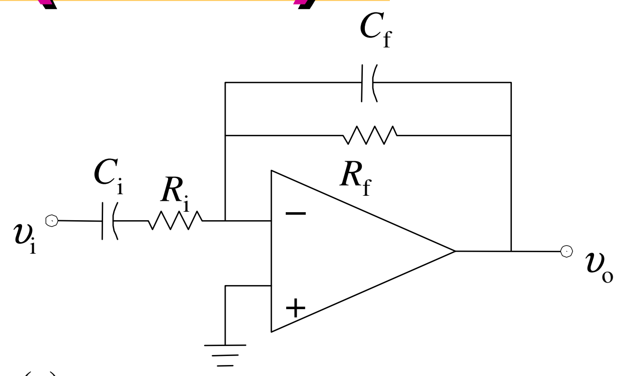
$$\text{Gain} = G = \frac{V_o(j\omega)}{V_i(j\omega)} = \frac{-R_f}{R_i}\frac{j\omega R_i C_i}{1 + j\omega R_i C_i}$$



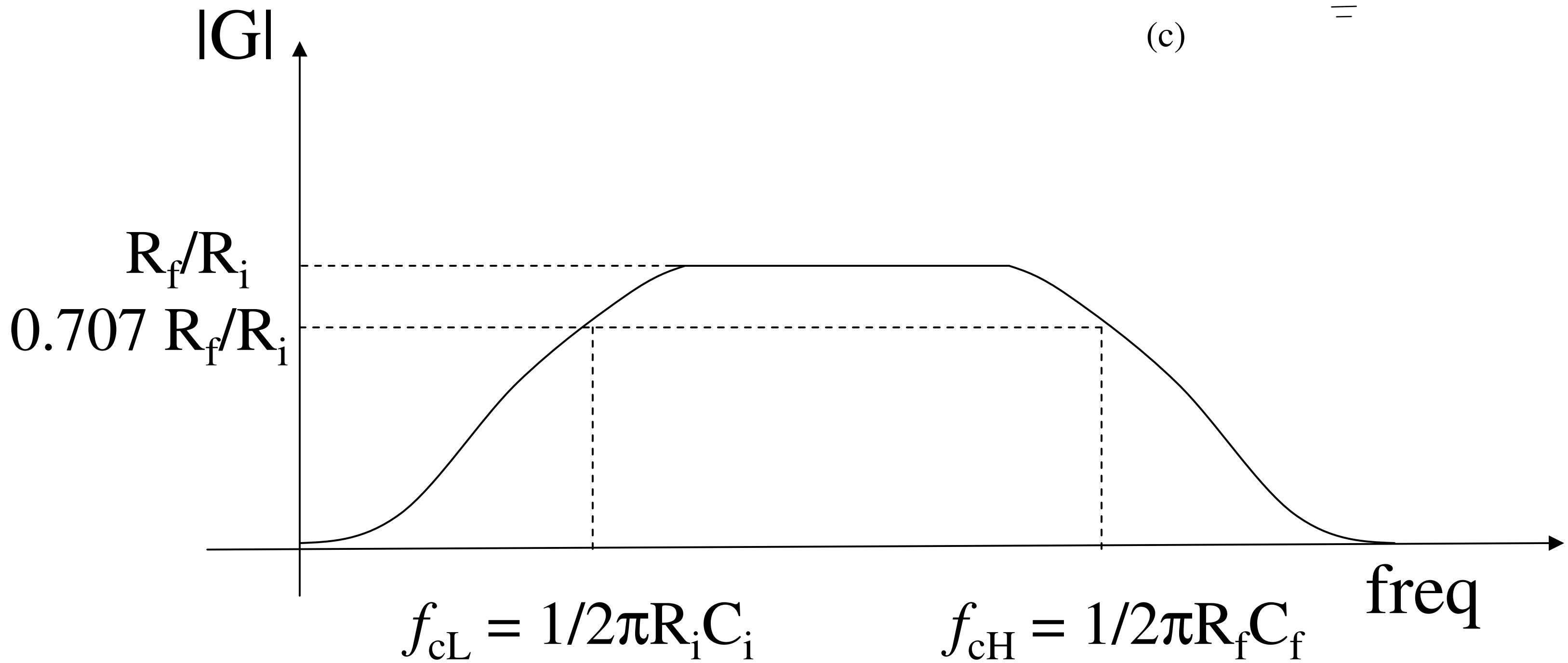
A high-pass filter attenuates low frequencies and blocks dc.

Band-Pass Filter (BPF)

$$\frac{V_o(j\omega)}{V_i(j\omega)} = \frac{-j\omega R_f C_i}{(1 + j\omega R_f C_f)(1 + j\omega R_i C_i)}$$



(c)



A band-pass filter attenuates both low and high frequencies.

Notes:

- The amplifier increases the input power by a factor of **A** **($P_0 / P_i = A$)**.
- The attenuator reduces the input power by a factor of **A** **($P_i / P_o = A$)**.
- It can be expressed In dB → A(dB)= 10 log (A)
- If the power in **watt**, its dB may be written as **dBw**
- If the power in **milli watt**, its dB is written as **dBm**
- **$P_{dBm} = P_{dB} + 30.$**
- Ex: if P=20 dB_w, it will be 50 dB_m

- If $P_0/P_i > 1$, then $P_0 > P_i$ →
  $10 \log (P_0/P_i)$ is +ve dB (**amplifier**)
- If $P_0/P_i < 1$, then $P_0 < P_i$ →
  $10 \log (P_i/P_0)$ is +ve dB (attenuator)
  $10 \log (P_0/P_i)$ is –ve dB (attenuator)

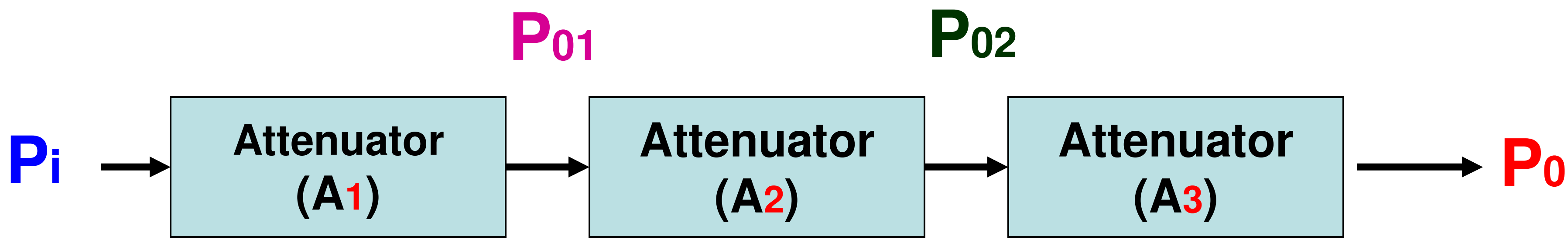
Attenuator
15 dB

→ $A(dB) = 10 \log(P_i / P_0) = 15$ dB

-15 dB

→ $A(dB) = 10 \log(P_i / P_0) = 15$ dB

Cascaded attenuators (or amplifiers)



- $A_t = A_1\ A_2\ A_3$ (absolute values)
- $A_t\,(dB) = 10 \log (A_1\ A_2\ A_3)$
- $A_t\,(dB) = A_1\,(dB) + A_2\,(dB) + A_3\,(dB)$

- **Hint:** $\log (XY) = \log (X) + \log (Y)$

  $\log (X/Y) = \log (X) - \log (Y)$

2-2 Idea of Operation of Oscillators

- **Oscillation:** means fluctuation about the mean value
- **Oscillator:** circuit that generates oscillation
- **Characteristics:**

1- wave-shape

2- frequency

3- amplitude

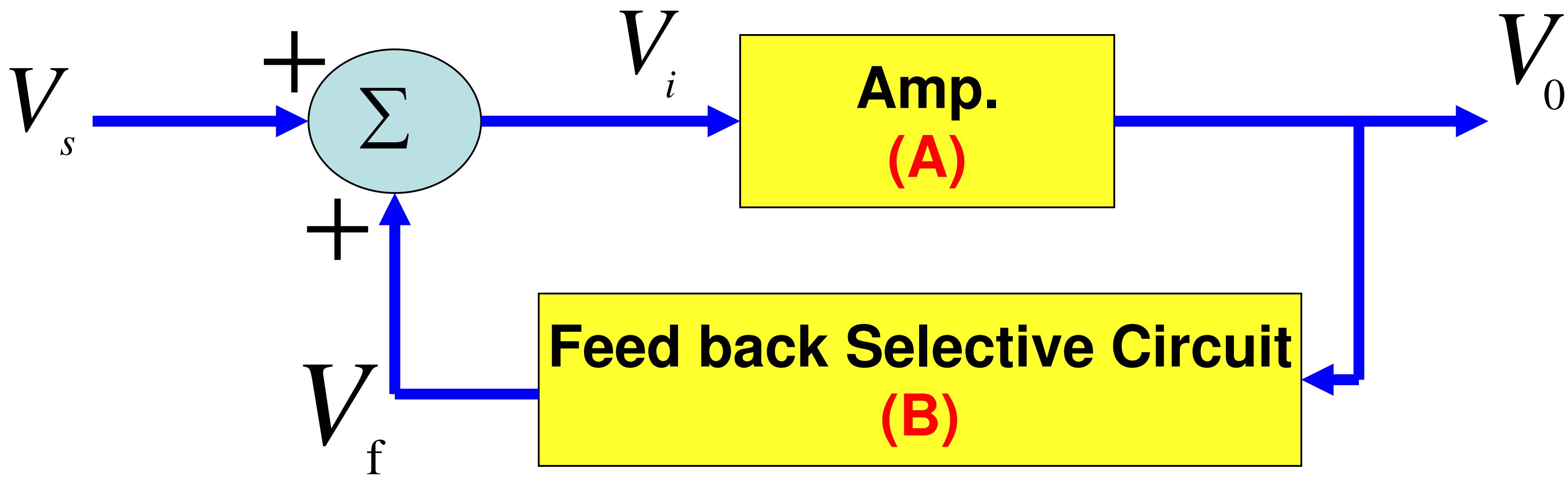
4- distortion

5- stability (w.r.t. amplitude and frequency)

6- Common mode rejection ratio (CMRR) (if $V_{in1}=V_{in2}$, then V_{out} should be zero (rejected)).

- The oscillator is used to generate signals.
- The oscillator is the **major block of signal generators**.
- It generates periodic signals without input signal, i.e. it is not necessary to supply an input signal to initiate oscillation.
- It converts DC power from the power supply into AC signal power spontaneously, without the need for an AC input source.

Oscillator Idea of operation



The feed back is +ve F. B.

A is the open loop gain

B is the feed back gain

AB is the loop gain

$A_f = V_0/V_s$ = closed loop gain

$$V_0 = A V_i$$

$$V_f = B V_0$$

$$V_i = V_s + V_f$$

Then we have

$$V_0 = A(V_s + V_f) = A(V_s + BV_0) \longrightarrow$$

$$A_f = \frac{V_0}{V_s} = \frac{A}{1 - AB}$$

If $V_s = 0$, the only way that V_o can be nonzero is that loop gain $AB=1$.

Since the amp. and the feed back selective circuit contain inductors and capacitors, then A and B are complex numbers, i.e. AB = **Real** + **Imaj**.

It means that: the magnitude of the loop gain must be unity and the phase must be zero, i.e.

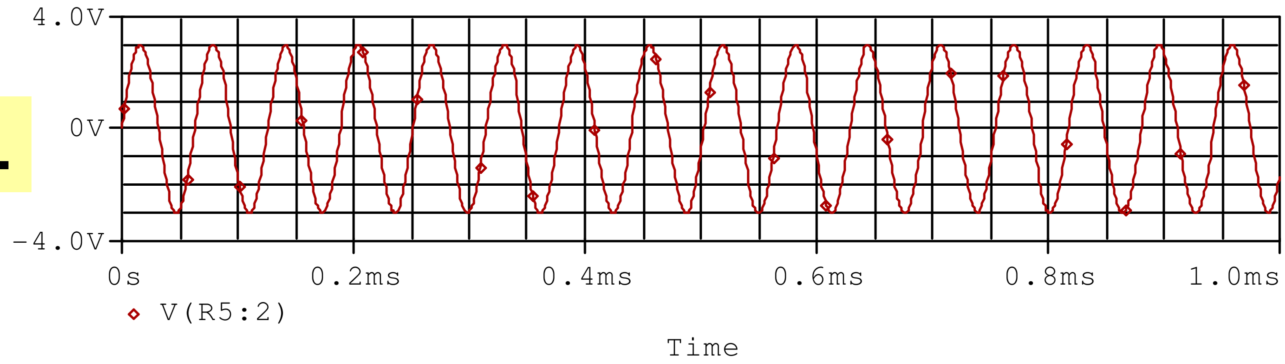
$$|AB| = 1$$

$$\angle AB = 0$$

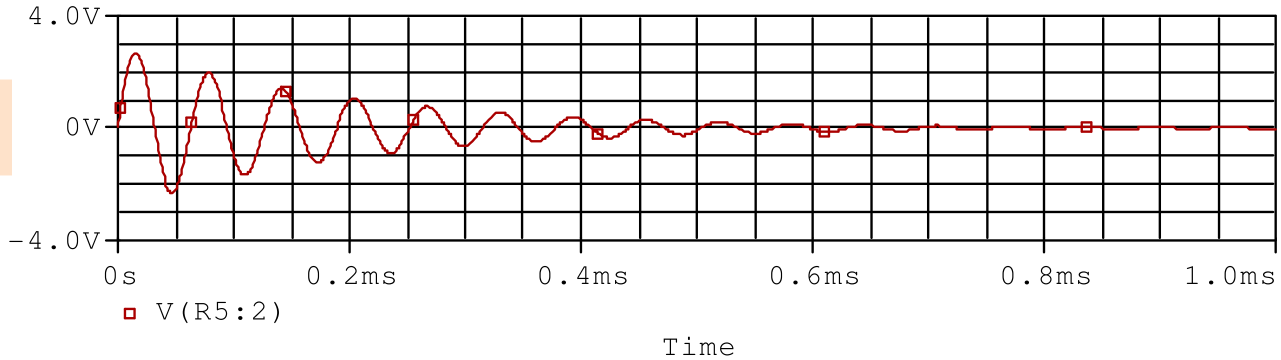
These two conditions are called Barkhausen Criterion (conditions of oscillation).

If at certain frequency we achieve the previous two conditions ($|AB| \approx 1$ is acceptable at the desired frequency to avoid saturation), the circuit will have a finite output for a zero input ($V_{s=0}$).

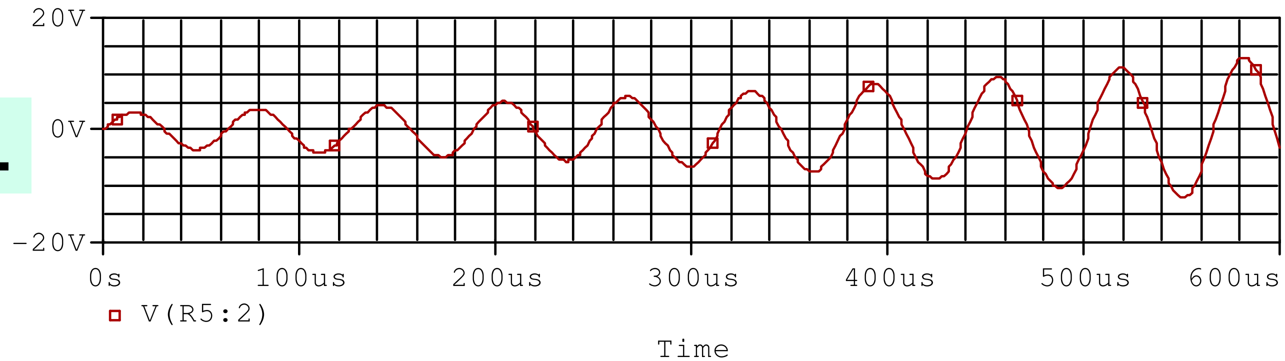
|AB| = 1


4.0V
0V
-4.0V
0s
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
V(R5:2)
Time

|AB| < 1


4.0V
0V
-4.0V
0s
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
V(R5:2)
Time

|AB| > 1


20V
0V
-20V
0s
100us
200us
300us
400us
500us
600us
V(R5:2)
Time