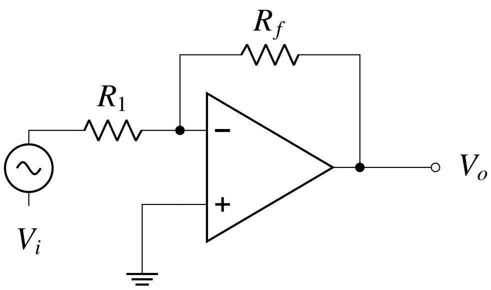
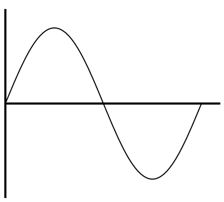
Operational Amplifier (Op-Amp)

Op-Amp: Single Ended Mode

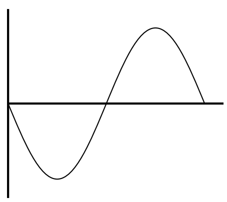


Inverting Amplifier

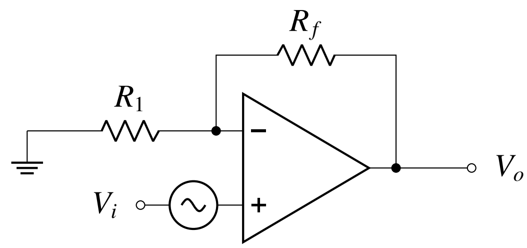
$$Av = -\frac{R_f}{R_1}$$



Analog Input

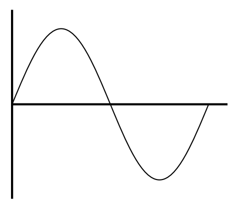


Analog Output

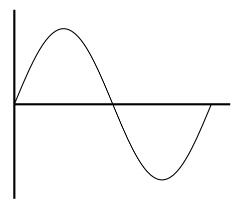


Non-Inverting Amplifier

$$Av = 1 + \frac{R_f}{R_1}$$

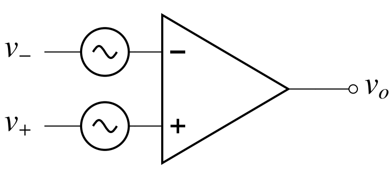


Analog Input



Analog Output

Op-Amp: Differential Mode



$$v_o = A_v v_d$$

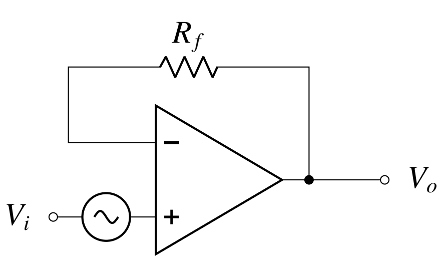
When $v_+ > v_-$, $\quad \therefore v_d = v_+ - v_-$

$\Rightarrow$ (Non-inverting amplifier)

When $v_- > v_+$, $\quad \therefore v_d = v_- - v_+$

$\Rightarrow$ (Inverting amplifier)

Op-Amp: Voltage Follower

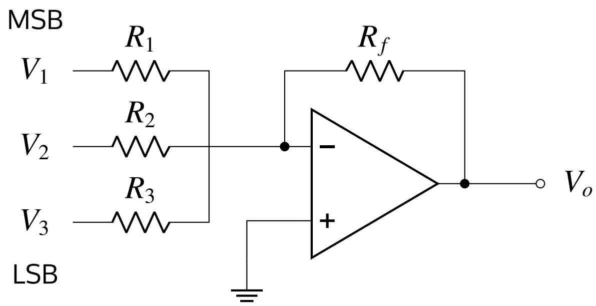


For voltage follower, Gain, $Av = 1$

$\therefore v_o = Av.v_i = 1.v_i = v_i$

$\therefore v_o = v_i$

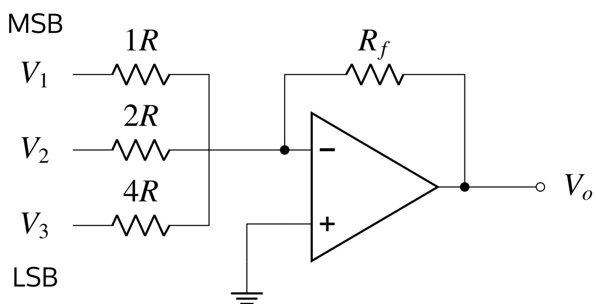
Op-Amp: Adder/Summer



$$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$$

$$= -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$$

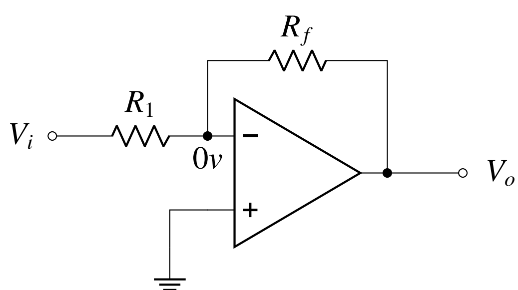
Op-Amp: Binary Weighted DAC



$$V_o = -\left(\frac{R_f}{1R}V_1 + \frac{R_f}{2R}V_2 + \frac{R_f}{4R}V_3\right)$$

$$= -\frac{R_f}{R}\left(\frac{V_1}{1} + \frac{V_2}{2} + \frac{V_3}{4}\right)$$

Virtual Ground



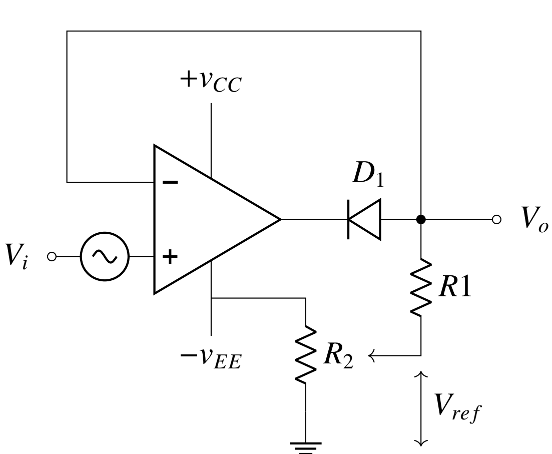
Let $A_v = \infty$, then $(v_1 - v_2) = \dfrac{V_{out}}{A} = \dfrac{V_{out}}{\infty} = 0 \;\therefore\; v_1 = v_2$

If any one is connected to the ground, another one is also $0V$

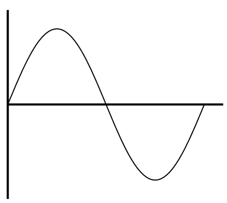
An ideal op-amp characteristics

voltage gain	∞
input impedance	∞
CMRR	∞
slew rate	∞
Bandwidth	∞
output impedance	0
input offset voltage	0
input offset current	0

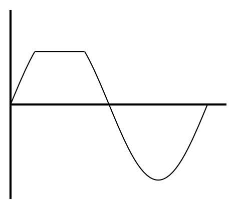
Op-Amp: Clipper Circuit



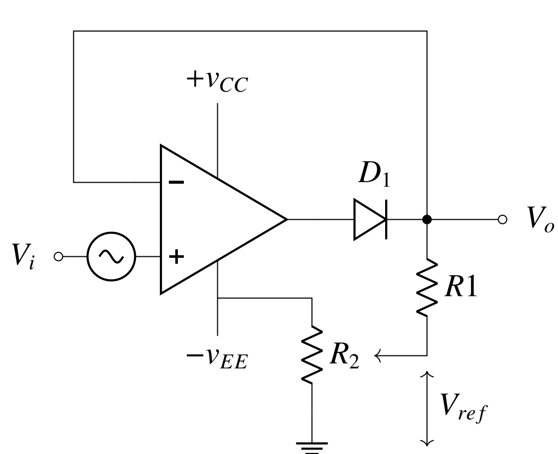
Positive Clipper



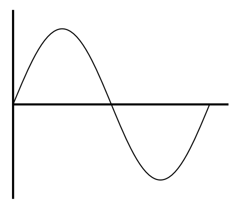
Analog Input



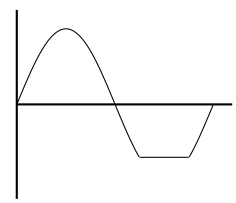
Analog Output



Negative Clipper

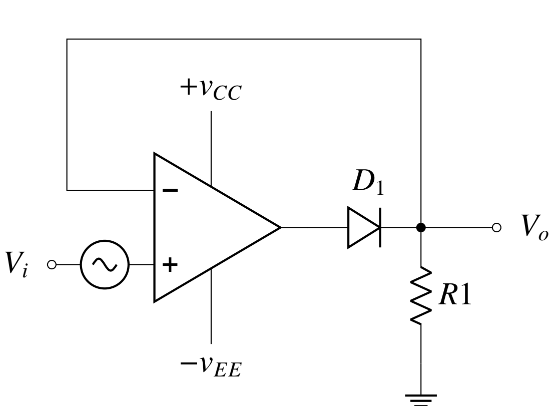


Analog Input

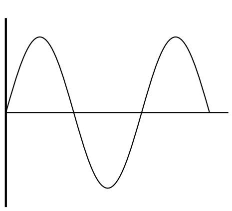


Analog Output

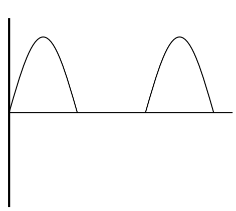
Op-Amp: Half Wave Rectifier



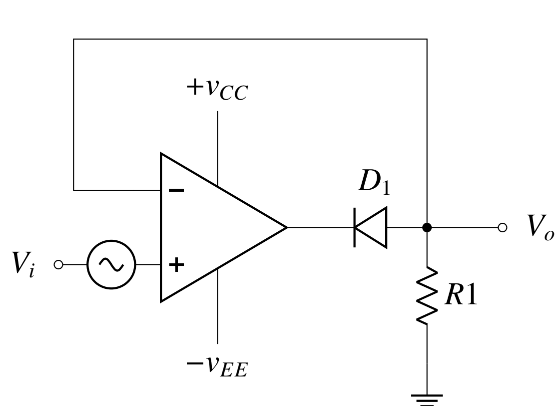
Positive Half Wave Rectifier



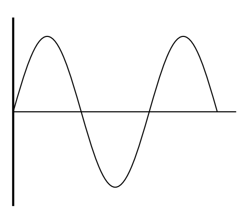
Analog Input



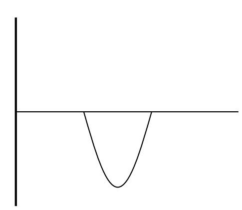
Analog Output



Negative Half Wave Rectifier

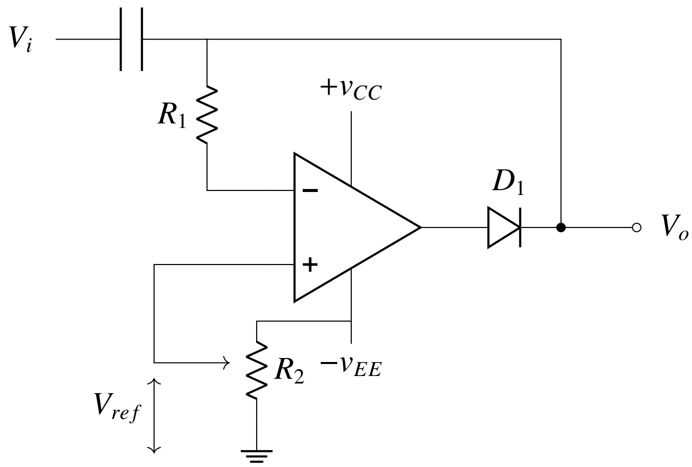


Analog Input

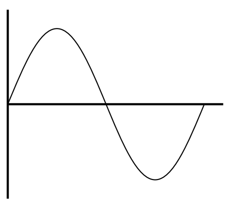


Analog Output

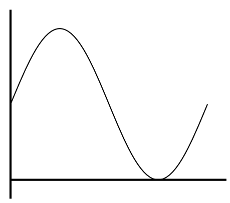
Op-Amp: Clamper Circuit



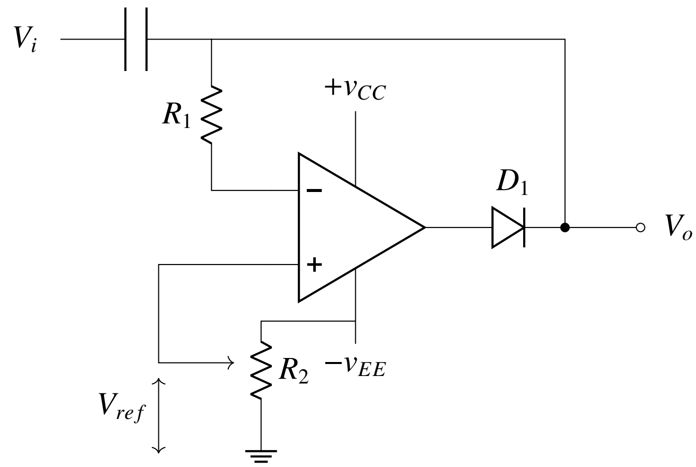
Positive Clamper



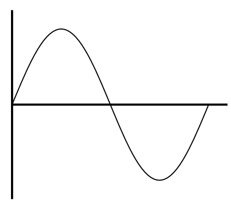
Analog Input



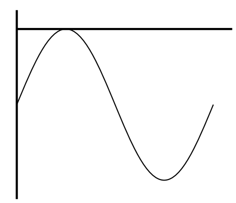
Analog Output



Negative Clamper



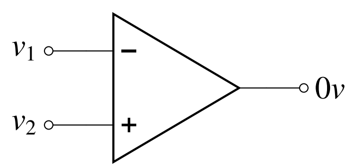
Analog Input



Analog Output

Op-Amp: Common Mode

When two input signals voltages of same phase, frequency and magnitude are applied are applied to both inputs, they tend to cancel each other resulting in a zero-output voltage. This action is called common mode rejection.



Common Mode Rejection Ratio (CMRR)

Unwanted signals or noise appearing with same polarity on both lines of input are common mode signals and are cancelled by the op-amp. The measure of the op-amp's ability to reject common mode signals is expressed in terms of common mode rejection ratio (CMRR). It is defined as

$$CMRR = \frac{A_d}{A_c}$$

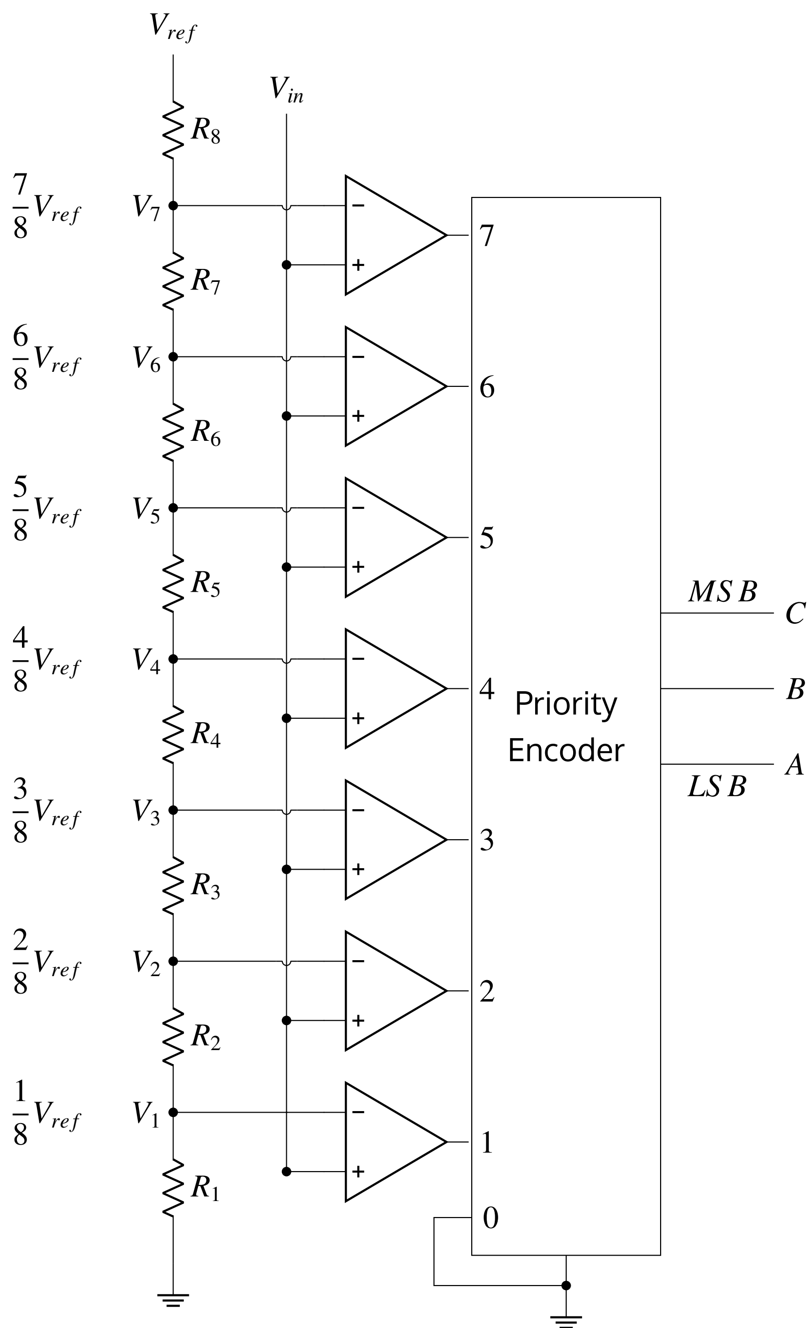
Maximum Output Voltage Swing

The output voltage never excess the DC voltage supply $(-v \text{ to } +v)$ of the Op-Amp.

Flash ADC: 3 bit

Components of Flash ADC: Structure of Flash ADC consist three major components –

1. High Speed Comparator $[2^n - 1]$
2. Resistive voltage divider Network $[2^n]$
3. Priority Encoder $[1]$



Op-Amp: Extra Terms

Input Offset Voltage: The input offset voltage (V_{iO}) is defined as the voltage that must be applied between the two input terminals of the op amp to obtain zero volts at the output.

Input Bias Current: Ideally no current flows into the input terminals of op-amp. But in practice, a small amount of current flows into the input terminals. These currents are called bias current.

Input Offset Current: The difference between these two input bias currents are called input offset current.

Input Impedance: The input impedance in the differential mode is the total resistance between inverting and noninverting inputs.

Output Impedance: The output impedance is the resistance viewed from the output terminal of the op-amp.

Slew rate: The slew rate is defined as the maximum rate of output voltage change per unit time.

$$\text{Slew rate} = \frac{\Delta V_{out}}{\Delta t}$$