

Operational Amplifiers

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- Frequency

- Terminology: ω_0 is the fundamental frequency, T is the period, $n\omega_0$ are harmonics of ω_0 or harmonic frequencies of $f(t)$

$$a_0 = \frac{1}{T} \int_{t_0}^{t_0+T} f(t) dt \quad (\text{This is the average of the signal over a period})$$

$$a_n = \frac{2}{T} \int_{t_0}^{t_0+T} f(t) \cos(n\omega_0 t) dt \quad (\text{This is how much the signal “looks” like a cos at } k\omega_0)$$

$$b_n = \frac{2}{T} \int_{t_0}^{t_0+T} f(t) \sin(n\omega_0 t) dt \quad (\text{This is how much the signal “looks” like a sin at } k\omega_0)$$

- Amplifiers

- Denoted as a triangle pointed in direction of current in circuit diagrams
- A signal is usually represented as current (i) or voltage (v)
- The purpose of amplifier is to increase the magnitude of incoming signal for meaningful use
- For example, a loud-speaker increases the amount of sound waves to make it audible to a public gathering
- You can increase or decrease the brightness of your computer screen by controlling the amount of amplification of the LED display
- The input signal can be (v or i) and the output signal can also be amplified version of (v or i).
- This gives us 4 combinations:
 1. A Voltage Amplifier amplifies voltage Input (v) to provide a voltage output (Av).

2. A Current Amplifier amplifies current Input (i) to provide a current output (Ai).
 3. A Transconductance Amplifier amplifies voltage Input (v) to provide a current output (Ai).
 4. A Transresistance Amplifier amplifies current Input (i) to provide a voltage output (Av).
- * A is called the gain of the amplifier.
 - * A can be dimensionless or can have the dimension of resistance or conductance.

- Operational Amplifiers

- Built out of diodes and transistors
- A complex circuit, but we will not study its internal details
- It has a very simplified terminal characteristics.
- Equivalent model is essentially a circuit with dependent source.
- Op-Amps are very common place in electronics systems.
- We are only interested in OP-Amp terminal characteristics and not its internal circuitry.

- In 1968, Fairchild made a popular Op-Amp which was an 8-pin micro-chip

- Out of 8 terminals, terminals NC and two offset terminals will not be discussed in this class
- Essentially, our Op-Amp will be a 5-terminal device
- Two input terminals:
 - * The $+ve$ terminal is called the non-inverting input
 - * The $-ve$ terminal is called the inverting input
- One output terminal
- Two power supplies, a $+ve$ voltage and a $-ve$ voltage

- The Op-Amp Operating Region

- The input voltage to the Op-Amp is $v_i = (v_p - v_n)$
- The output voltage of the Op-Amp is $Av_i = A(v_p - v_n)$
- The Op-Amp output has two regions: linear and saturation, as defined below

$$v_o = \begin{cases} -V_{CC} & A(v_p - v_n) < -V_{CC}, \\ A(v_p - v_n) & -V_{CC} \leq A(v_p - v_n) \leq +V_{CC}, \\ +V_{CC} & A(v_p - v_n) > +V_{CC} \end{cases}$$