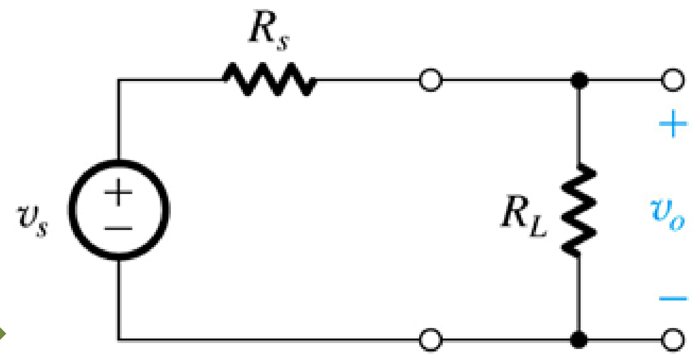
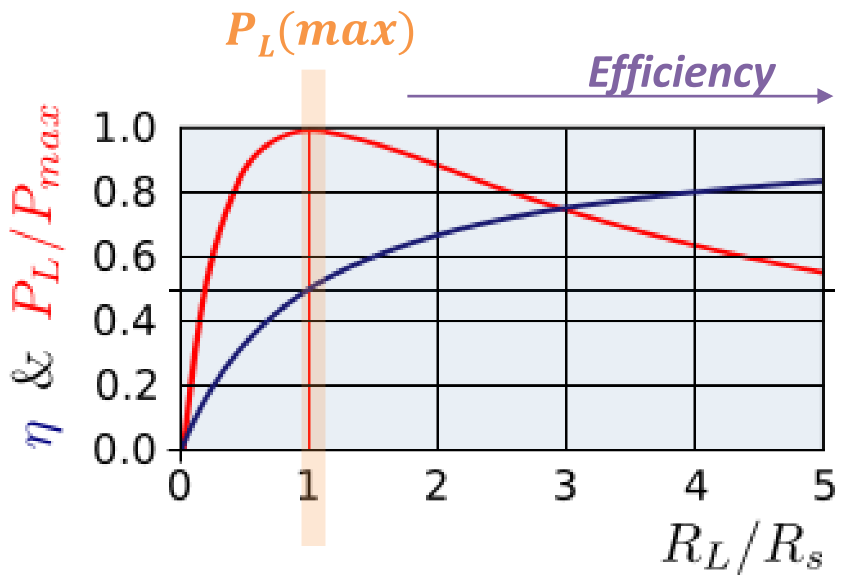
Last Lecture → Chapter 1.1

Concepts revisited…

- *electronics*
- *signal representation*
- *basic circuit analysis*
- *maximum power transfer*





- **Power** $P_L = V_0 \cdot I_L = \frac{R_L}{(R_L + R_S)^2} {V_s}^2$
- **Efficiency** $\eta = \frac{P_L}{P_{supply}} = \frac{R_L}{R_L + R_S}$
- **Maximum Power**

$$\frac{\partial P_L}{\partial R_L} = 0 \Rightarrow @\, R_L = R_S$$

Frequency Spectrum → Chapter 1.2

... defines a time-domain signal in terms of the strength of harmonic components

Fourier Series → an expression of a periodic function as the *sum of an infinite number of sinusoids* whose *frequencies are harmonically related*

Fourier Series Representation of **f**(x)

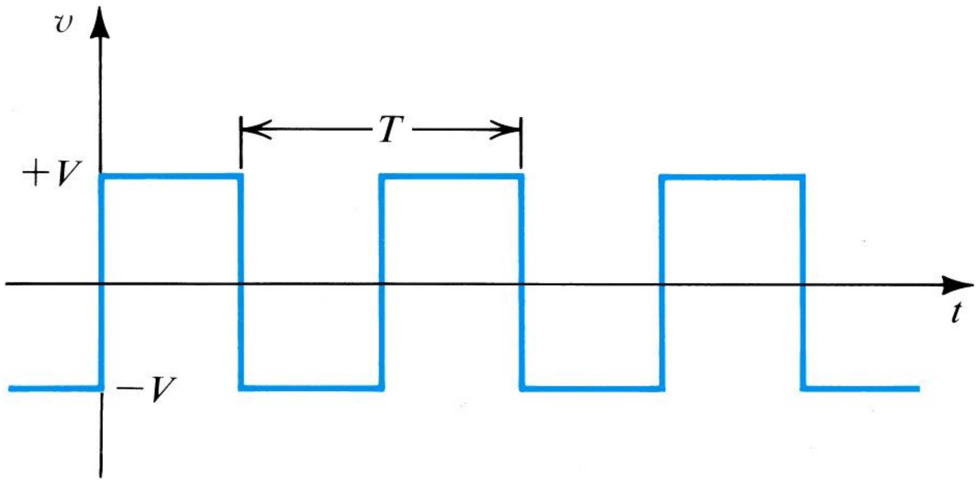
$$\mathbf{f}(x) = \frac{a_0}{2} + \sum_{k=1}^{\infty}\left[a_k \cos(kx) + b_k \sin(kx)\right]$$

$$a_k = \frac{1}{\pi}\int_{-\pi}^{\pi} \mathbf{f}(x)\cos(kx)\,dx,\ n \geq 0$$

$$b_k = \frac{1}{\pi}\int_{-\pi}^{\pi} \mathbf{f}(x)\sin(kx)\,dx,\ n \geq 1$$

Frequency Spectrum

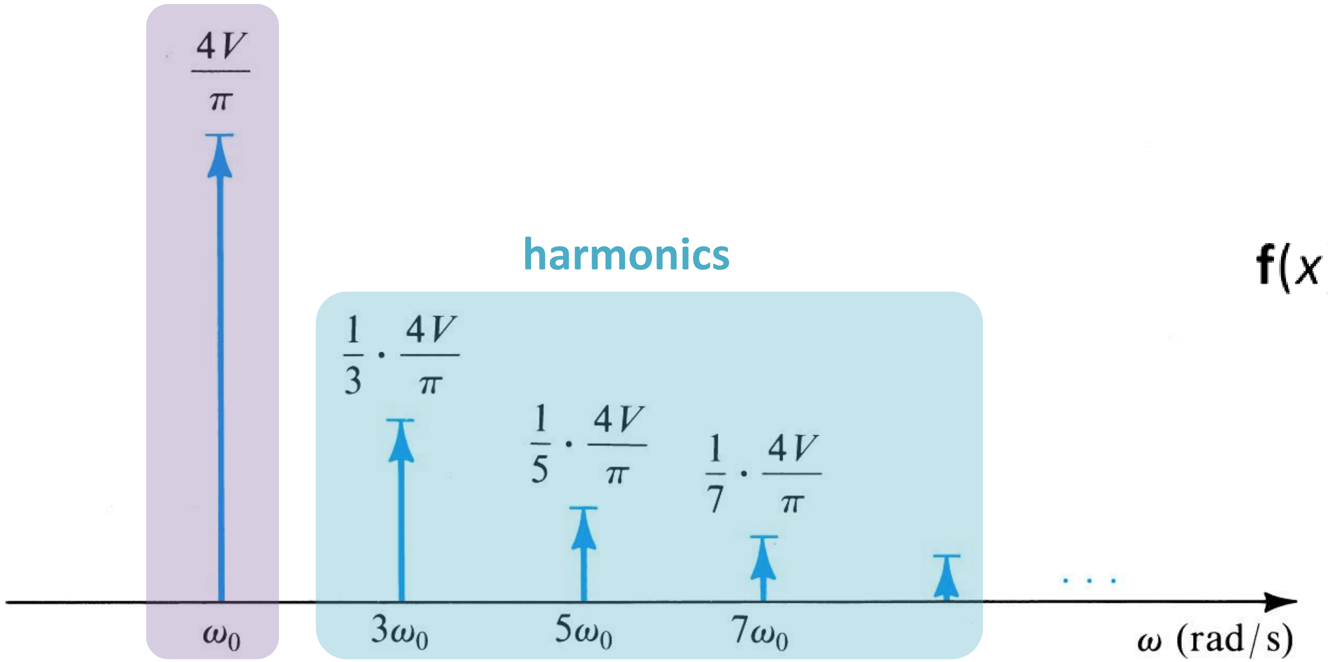
... of a square wave?



$$f(x) = \frac{4V_a}{\pi}\left[\sin(\omega_0 t) + \frac{1}{3}\sin(3\omega_0 t) + \frac{1}{5}\sin(5\omega_0 t) + \ldots\right]$$

fundamental — harmonics

fundamental



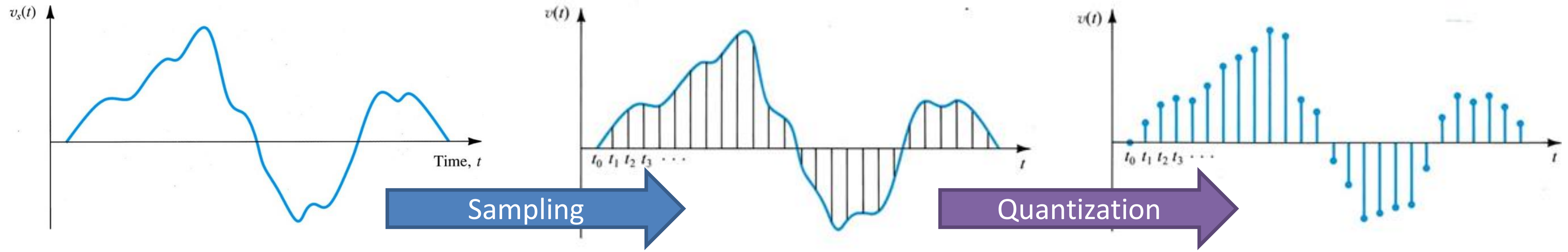
Analog & Digital Signals → Chapter 1.3

- **analog signal** – is continuous with respect to both value and time
- **discrete-time signal** – is continuous with respect to value but *sampled* at discrete points in time
- **digital signal** – is *quantized* (applied to values) as well as *sampled* at discrete points in time

analog signal

discrete-time signal

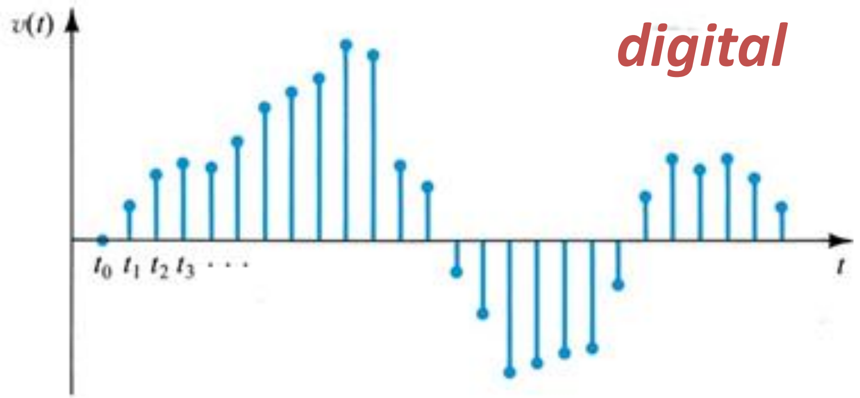
digital signal



Analog & Digital Signals

Are digital and binary synonymous?

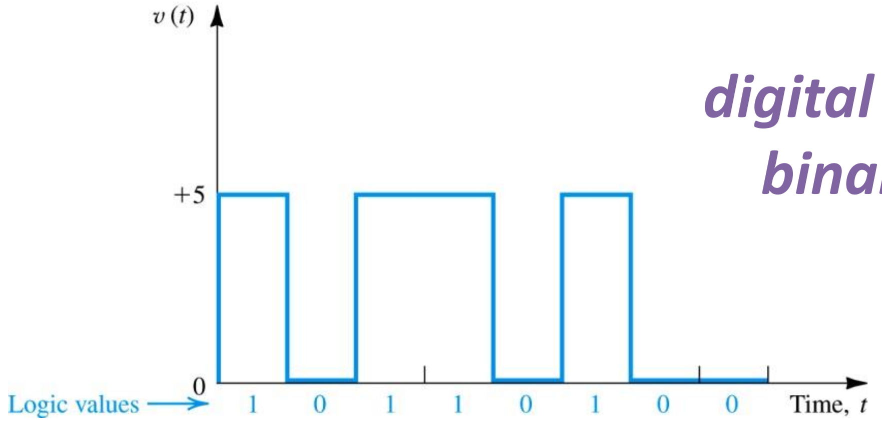
No. The binary number system ($base_2$) is one way to represent digital signals.



base 10 ← base 2

$$y = \underbrace{b_0}_{LSB} 2^0 + b_1 2^1 + b_2 2^2 + \ldots$$

$$\ldots + b_3 2^3 + \ldots \underbrace{b_{n-1}}_{MSB} 2^{n-1}$$



***Binary Signal:* a digital signal with only 2 distinguishable levels!**

Amplifiers → Chapter 1.4

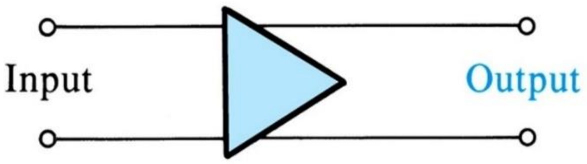
Why is signal amplification needed?

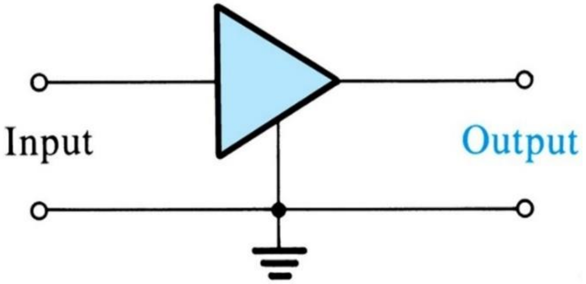
Because many transducers yield output at low power levels (mW)

- **Voltage Amplifier** – is used to boost voltage levels for increased resolution
- **Power Amplifier** – is used to boost current levels for increased “intensity”

  - **Linearity** – is property of an amplifier which ensures a signal is not “altered” from amplification
  - **Distortion** – is any unintended change in output

Amplifier Circuit Symbol





Differential Input / Differential Output

Single-Ended Input / Single-Ended Output

Voltage Gain

$$V_{out}(t) = A_V \cdot V_{in}(t)$$

$$\boldsymbol{V_{out}(t) = A_V \cdot [V_1(t) - V_2(t)]}$$

$$\boldsymbol{V_{out}(t) = A_V \cdot V_1(t)}$$

- **Gain in decibels…**

$$\text{voltage gain in decibels} = 20\ \mathbf{log}|A_v|\,dB$$

$$\text{current gain in decibels} = 20\ \mathbf{log}|A_i|\,dB$$

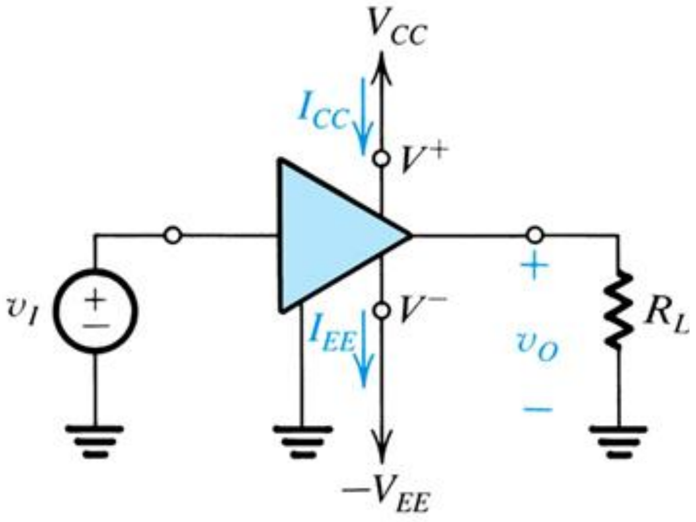
$$\text{power gain in decibels} = 10\ \mathbf{log}(A_p)\,dB$$

What is one main difference between an amplifier and a transformer?

An amplifier may be used to boost power delivery!

$$\textit{power gain } (A_p) = \frac{\textit{load power } (P_L)}{\textit{input power } (P_I)} = \frac{v_o i_o}{v_i i_i}$$

Amplifiers Power & Saturation

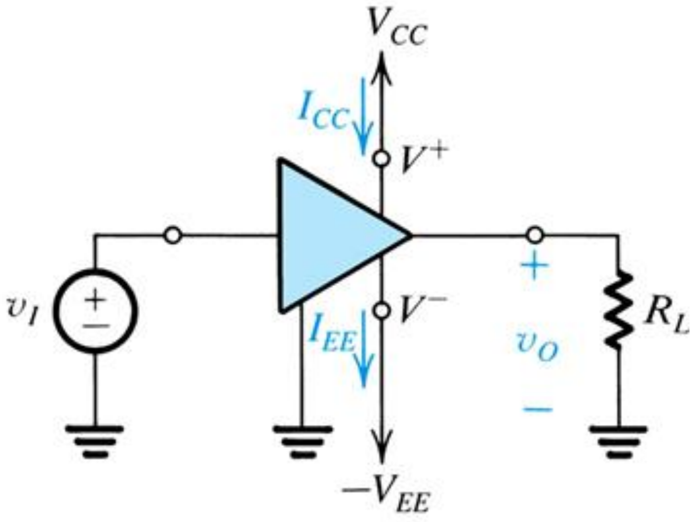


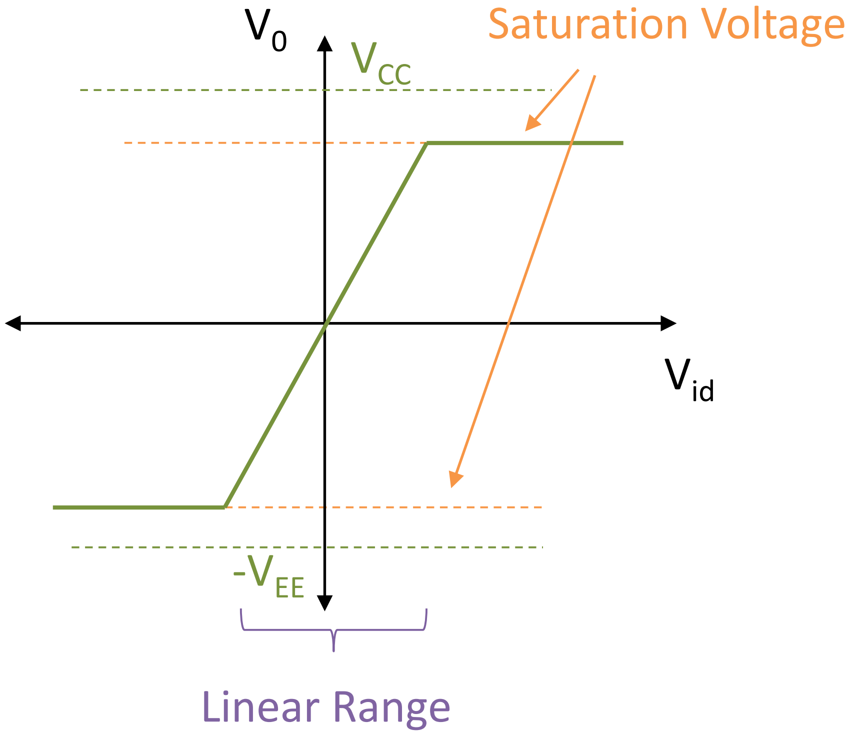
Exercise 1.11

An amplifier operating from a single 15-V supply provides a 12-V peak-to-peak sine wave signal t a 1-kΩ load and draws negligible input current from the signal source. The dc current drawn from the 15-V supply is 8 mA. What is the power dissipated in the amplifier, and what is the amplifier efficiency?

- **Conservation of power** – the input power plus the power drawn from the supplies is equal to the output power
- **Efficiency** – the ratio of the output power to the total power
- **Limited Linear Range** – input voltage range over which the amplifier is linear
- **Saturation Voltage** – maximum output voltage

Amplifiers Power & Saturation





- **Conservation of power** → $P_{V_I}+P_{V_{CC}}+P_{V_{EE}} = P_L + P_{amp}$
- **Efficiency** → $$\eta = \frac{P_L}{P_{in}} = \frac{P_L}{P_{V_I}+P_{V_{CC}}+P_{V_{EE}}}$$
- **Limited Linear Range**
- **Saturation Voltage**

Amplifier Circuit Model → Chapter 1.5

… is the description of the amplifier's terminal behavior, neglecting internal operation / transistor design

model of amplifier input terminals

input voltage $= v_i = (v_s)\dfrac{R_i}{R_i + R_s}$

(v_s: source volt.; $R_i + R_s$: source and input resistances)

model of amplifier output terminals

output voltage $= v_o = (A_{vo} v_i)\dfrac{R_L}{R_L + R_o}$

($A_{vo} v_i$: open-ckt output voltage; $R_L + R_o$: output and load resistances)

Voltage Gain Expression

$$\frac{V_0}{V_s} = \frac{R_i}{R_i + R_s} A_{oc} \frac{R_L}{R_L + R_0}$$

magnification (A_{oc}), attenuation ($\frac{R_i}{R_i + R_s}$), loading ($\frac{R_L}{R_L + R_0}$)

Amplifier Circuit Model