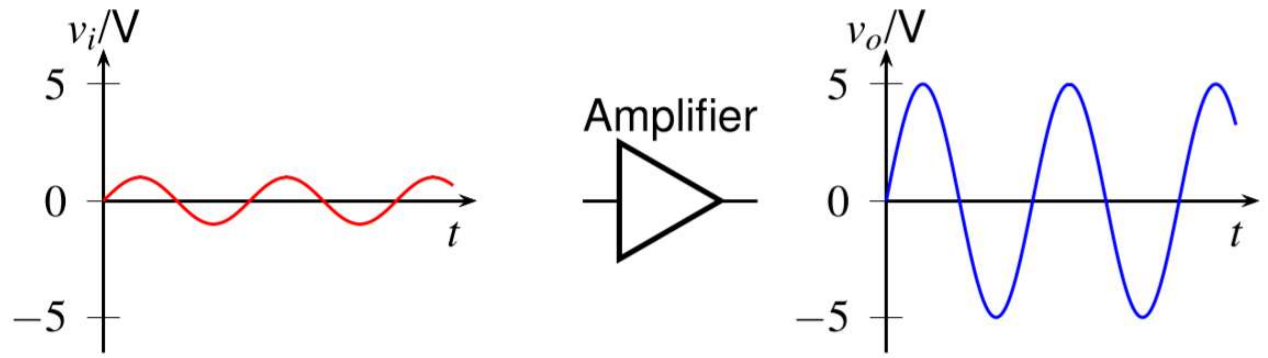
Chapter 1

1-1 Signal Amplification

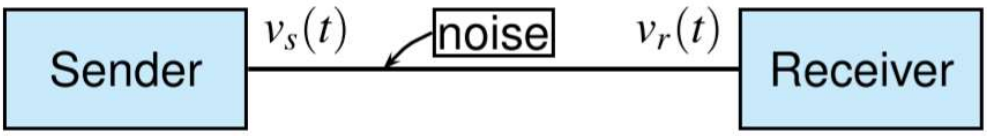


$$v_o(t) = C \cdot v_i(t)$$

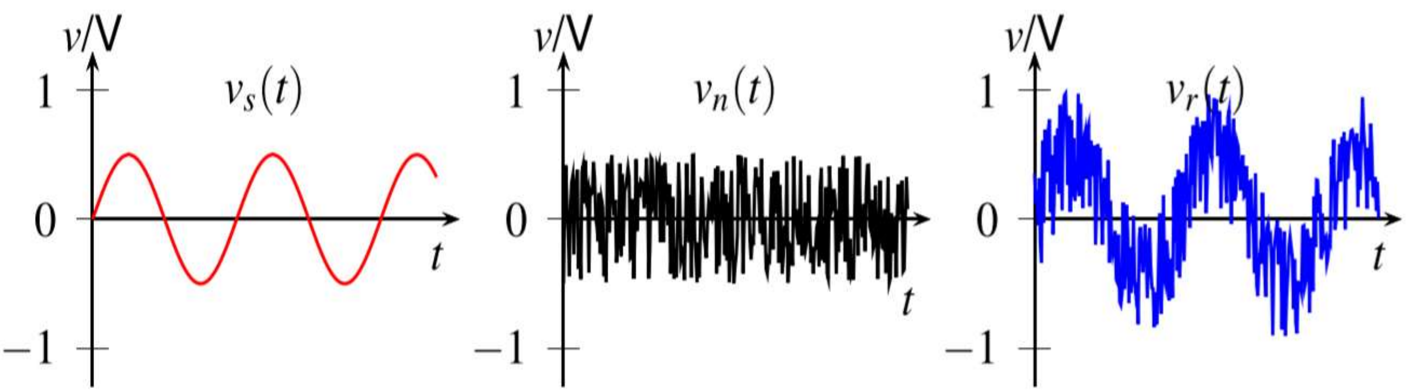
- $v_i(t)$: input signal
- $v_o(t)$: output signal
- A: **amplifier gain**

Case 1: Signal Transmission

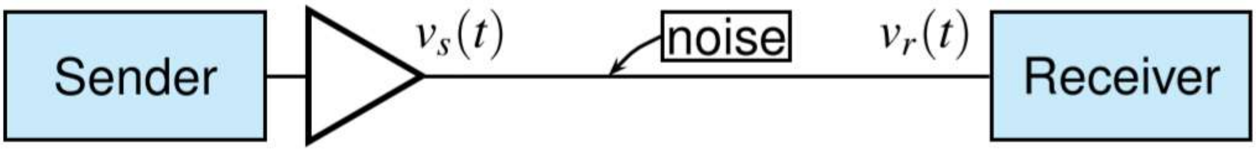
A small signal need to be transmitted from a sender to a receiver through a wired channel



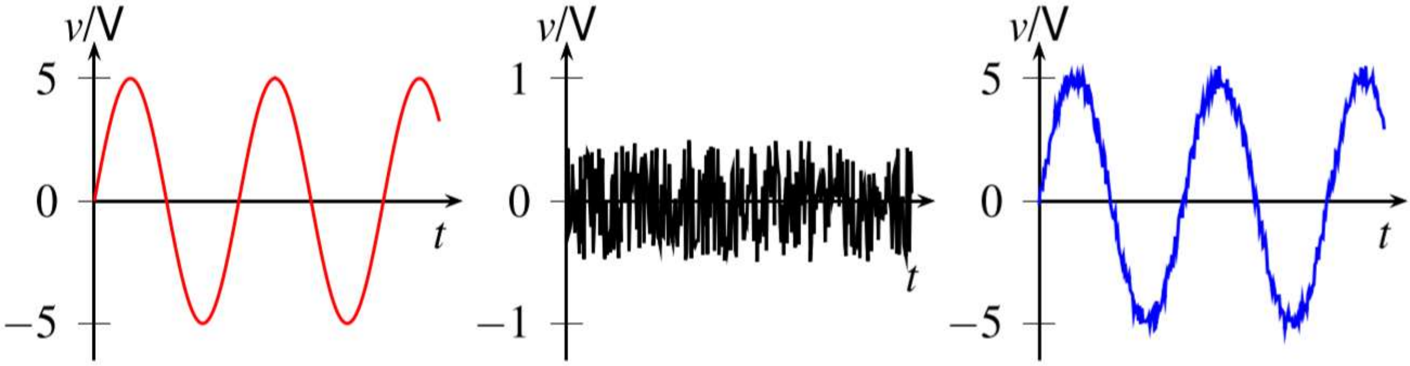
It could be hard to be finished because the transmitting channels are noisy. Let $v_n(t)$ denote the noise voltage, then $v_r(t) = v_s(t) + v_n(t)$



If the signal is amplified before transmission

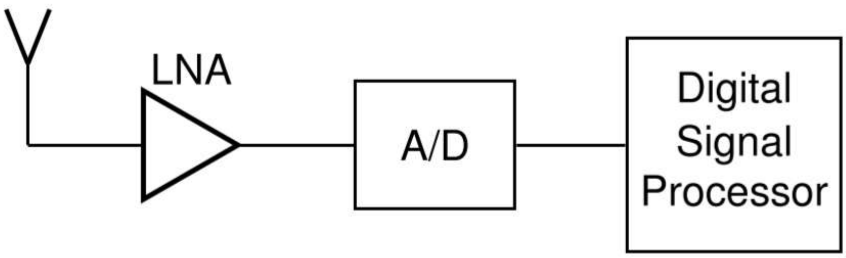


Then it could be easier to identify the receive voltage



Case 2: Digital Mobile Phone

The signal processing subsystem in a digital mobile phone

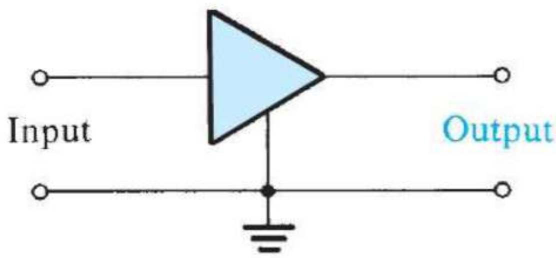


- LNA: low noise amplifier
- A/D: analog to digital converter

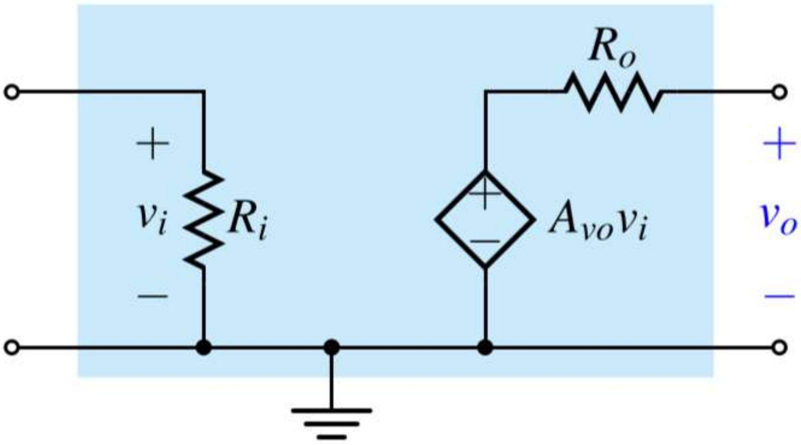
Since the signal received by antenna is too weak, which is usually in μV range, while the A/D converter required the input signal with the range from 0 to 3.3 V.

The processing could be much easier if the signal magnitude is larger.

1-2 Amplifiers



The signal amplifier is a two-port network and only **dependent sources** could be used to realize amplifiers

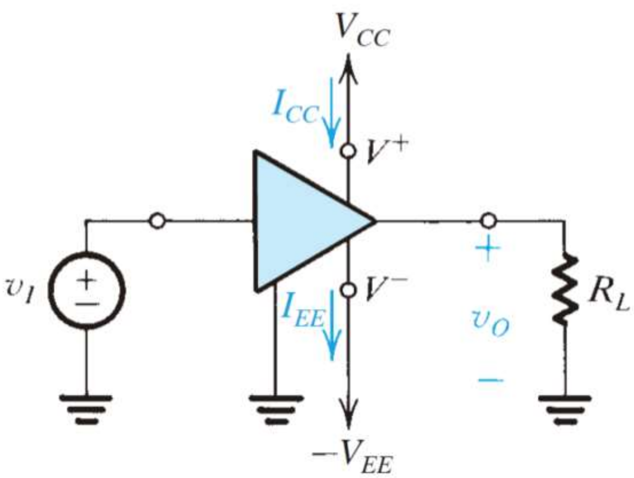


- R_i: input resistance
- R_o: output resistance
- A_{vo}: **open-circuit** voltage gain

Different Amplifiers

Type	Circuit Model	Gain Parameter	Ideal Characteristics
Voltage Amplifier		$A_{vo} = \frac{v_o}{v_i}$	$R_i = \infty, R_o = 0$
Current Amplifier		$A_{is} = \frac{i_o}{i_i}$	$R_i = 0, R_o = \infty$
Transconductance Amplifier		$G_m = \frac{i_o}{v_i}$	$R_i = \infty, R_o = \infty$
Transresistance Amplifier		$R_m = \frac{v_o}{i_i}$	$R_i = 0, R_o = 0$

Amplifier Power Efficiency



The DC power delivered to the amplifier is

$$P_{dc} = V_{CC} I_{CC} + V_{EE} I_{EE}$$

The power-balance equation over the circuit is

$$P_{dc} + P_I = P_L + P_{\text{dissipated}}$$

The amplifier power efficiency is

$$\eta = \frac{P_L}{P_{dc}} \times 100\%$$

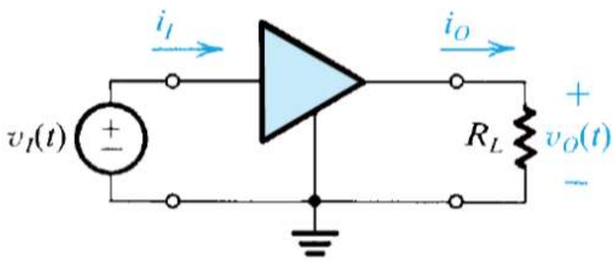
Characters of Amplifiers

There are several important parameter of amplifiers:

- A: Gain
- R_i: Input Resistance
- R_o: Output Resistance

Amplifier Gain

A voltage amplifier fed with a signal $v_i(t)$ and connected to a load resistance R_L



- Voltage Gain: $A_v = \frac{v_O}{v_i}$
- Current Gain: $A_i = \frac{i_O}{i_i}$
- Power Gain: $A_p = \frac{v_O i_O}{v_i i_i}$

And there is relationship between power gain, voltage gain and current gain is

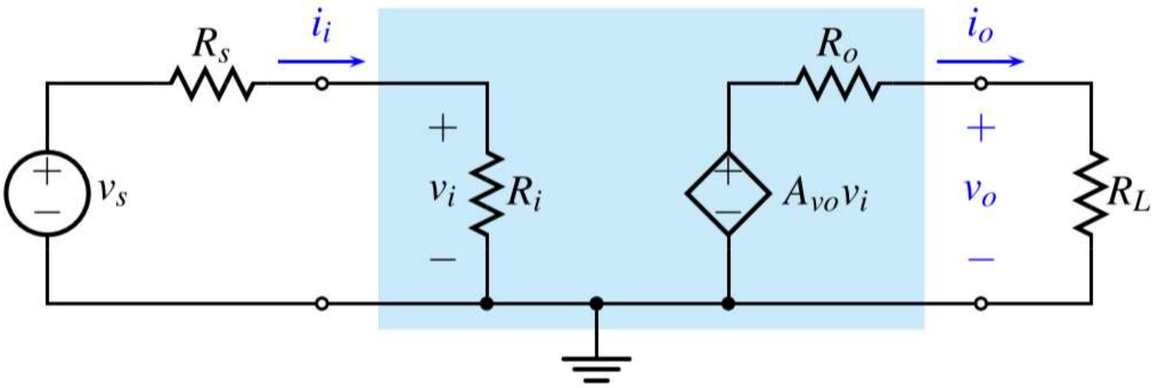
$$A_p = A_o A_i$$

And electronics engineers prefer to express amplifier gain with **logarithmic measure**

- Voltage Gain in decibels: $20 \log ||A_v|| \ dB$
- Current Gain in decibels: $20 \log ||A_i|| \ dB$
- Power Gain in decibels: $10 \log ||A_p|| \ dB$

Input and Output Resistance

The input resistance R_i is **an equivalent resistance** that accounts for the fact that the amplifier draws an input current from the signal source



$$v_i = v_s \frac{R_i}{R_i + R_s}$$

A **voltage amplifier** with ***larger input resistance*** draw less current from the signal source, and its v_i is closer to v_s

$$v_o = A_{vo} v_i \frac{R_L}{R_L + R_o}$$

A **voltage amplifier** with ***smaller output resistance*** has stronger ability to drive a heavy load

Determine Input and Output Resistance

- Determine R_i: by applying an **input voltage** v_i and calculating the **input current** i_i

$$R_i = \frac{v_i}{i_i}$$

- Determine R_o: by finding ratio of the **open-circuit output voltage** to the **short-circuit output current**

Overall Gain

- Voltage Gain

$$A_v = \frac{v_o}{v_i} = A_{vo} \cdot \frac{R_L}{R_L + R_o}$$

- Overall Gain

$$\frac{v_o}{v_s} = A_{vo} \cdot \frac{R_i}{R_i + R_s} \frac{R_L}{R_L + R_o}$$

Characterizing Amplifiers

A perfect **voltage amplifier** should have

- large input resistance
- small output resistance

- a gain that is controllable ina wide range