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EEE 331
Analog Electronics

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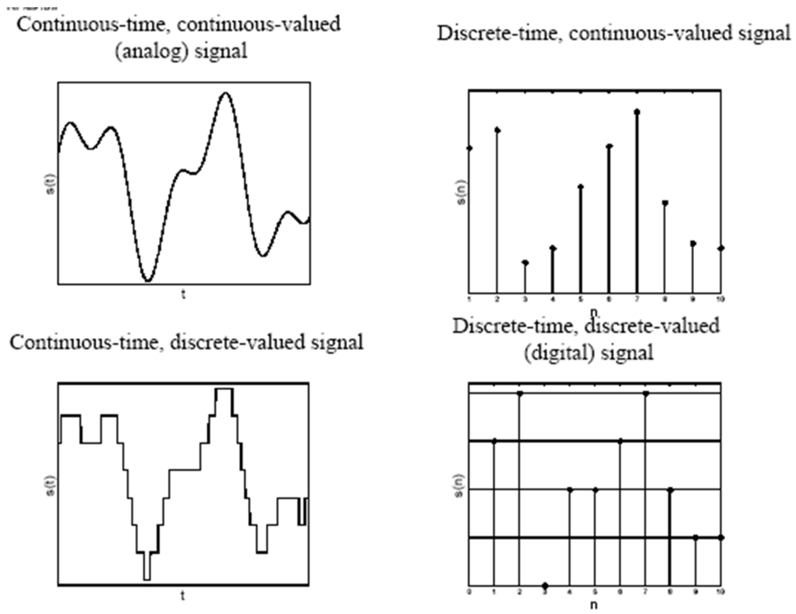
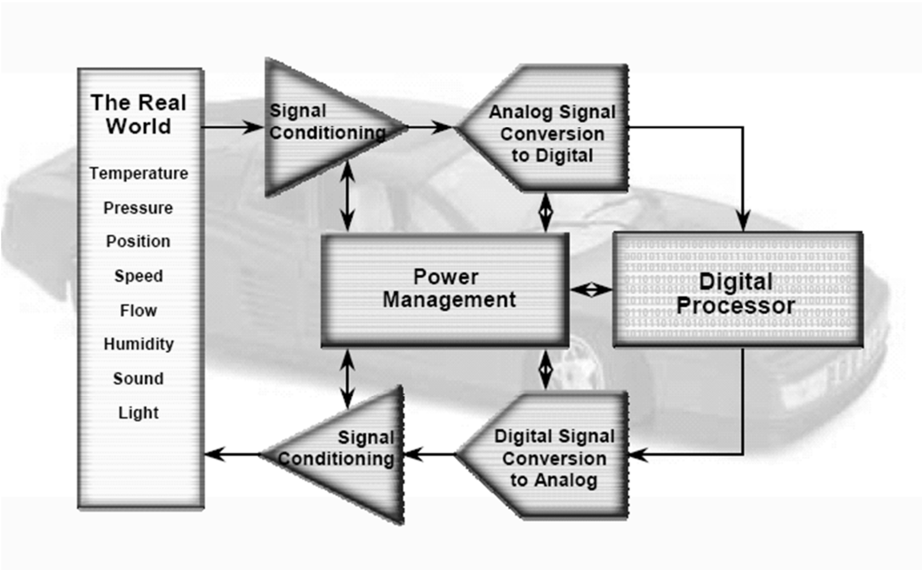
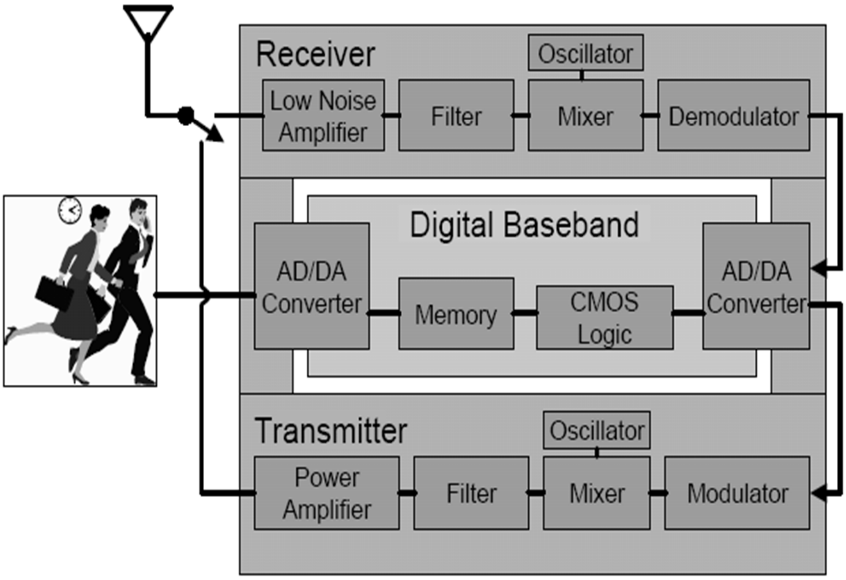
Analog and Digital Signals



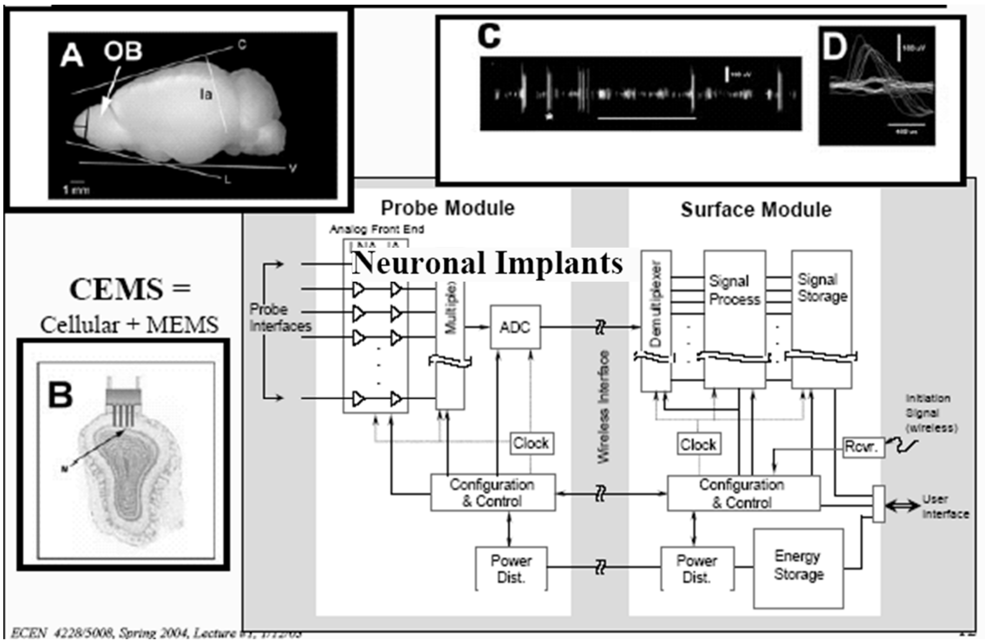
Analog Signals are links to the real world



Transreceiver



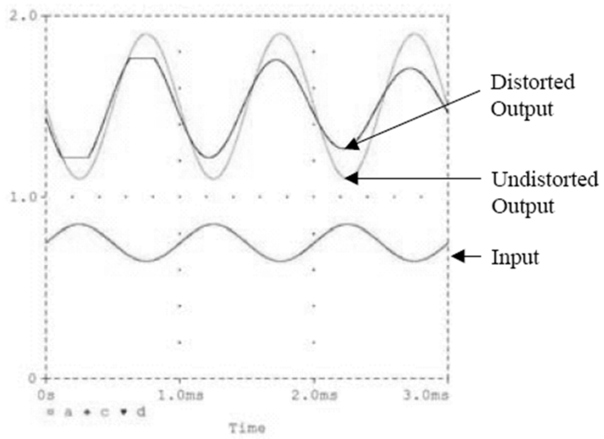
Bio-eng: Neuronal implants



Linear Amplifiers (1)

Multiply amplitude of a signal by a constant scalar quantity

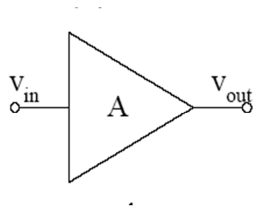
$$x_o(t) = A\, x_i(t)$$

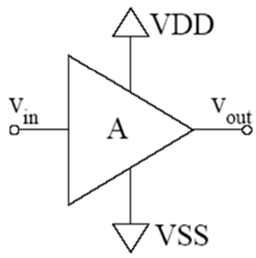


Non-scalar or non-uniform amplification is called **distortion**

Linear Amplifiers (2)

- Symbol for a single-ended input linear voltage amplifier.
- Ideally provides linear voltage gain regardless of the amplitude of the input signal
- Real amplifiers have power supplies that limit the amplitude of the output
- If input is too large, output clamps





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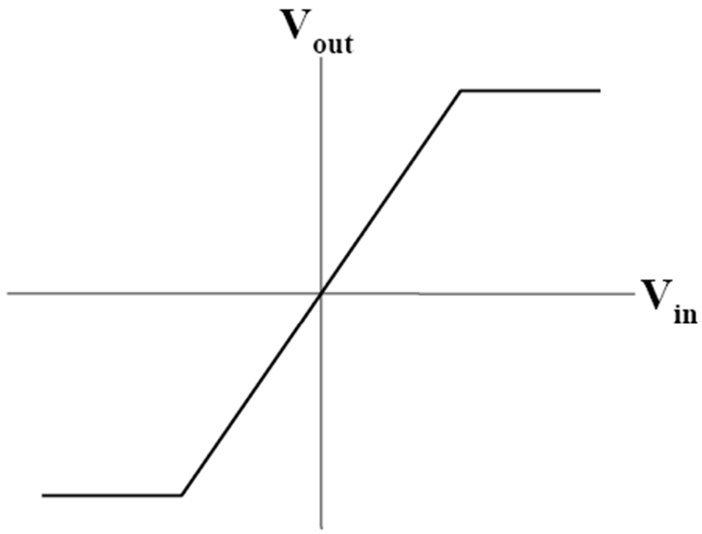
Transfer Characteristics (1)

Plot of amplifier output versus amplifier input



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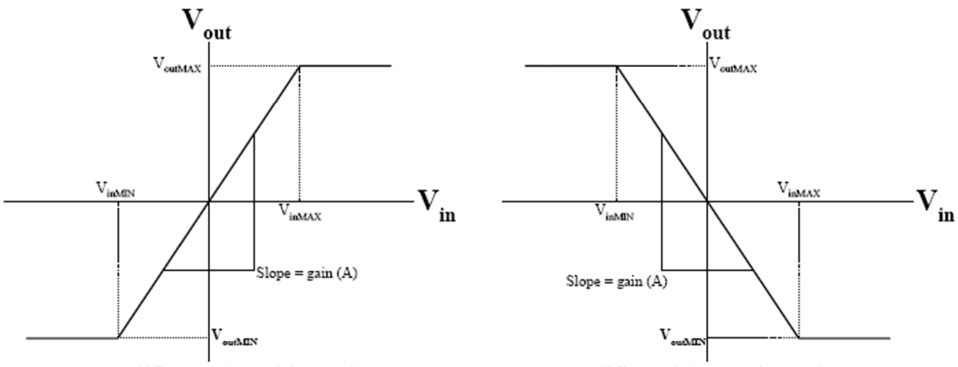
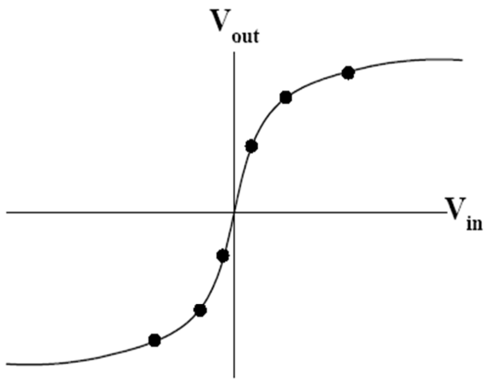
Transfer Characteristics (2)



Amplifier with positive gain   Amplifier with negative gain

- Gain = Slope
- To operate amplifier in its linear region, the input must be kept small enough

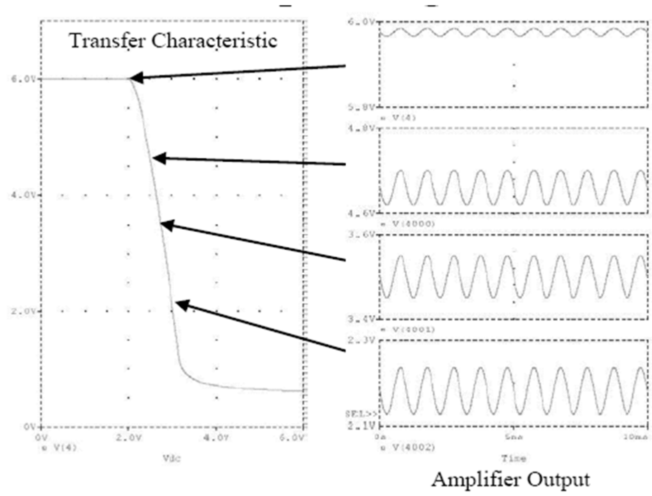
Real Transfer Characteristics



- Each circle represents a different DC component for the input and output signals – called an **operating point**
- Location of **operating point** has an effect on
  - input signal range
  - amplifier gain magnitude
  - amount of distortion

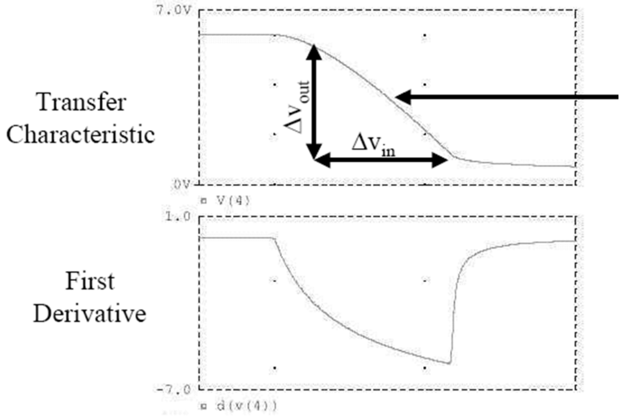
Operating Point (1)

Voltage gain, output DC voltage, allowable input magnitude range are affected



Operating Point (2)

Input and output signal amplitude ranges are maximized when operating point is near middle of linear region



Derivative of transfer characteristic gives measure of amplifier gain linearity (and distortion)

Signal Convention (1)

- ***DC*** magnitudes in uppercase symbol and subscript
  - Example: I_D, V_D
- ***Ac signal*** quantities in lowercase symbol & subscript
  - Example: $i_d(t)$, $v_d(t)$
- Total ***DC + ac signal*** quantities in lowercase symbol, uppercase subscript
  - Example: $i_D(t)$, v_D (t)

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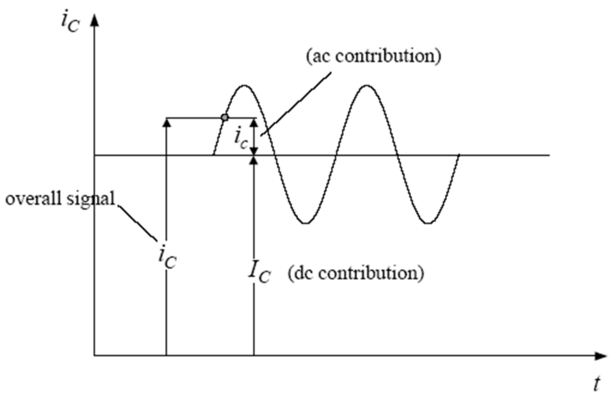
Signal Convention (2)

In general

$$v_D(t) = V_D + v_d(t)$$

$$i_C(t) = I_C + i_c(t)$$



Superposition

- If the amplifier is linear, **superposition** can be applied. Each component can be determined seperately.
- Determine the ***DC magnitude*** of the output using DC model (i.e capacitors are open circuited, inductors are short circuited)
  - Example: I_O, V_O
- Determine the ***ac signal component*** of the output using the ac model (i.e., DC sources are killed and capacitors are short circuited, inductors are open circuited) as
  - Example: $v_o(t) = A_v \, v_i(t)$

Amplifier Classification

Input	**Output**	**Type**
Voltage	Voltage	**Voltage**
Voltage	Current	**Transconductance**
Current	Voltage	**Transresistance**
Current	Current	**Current**

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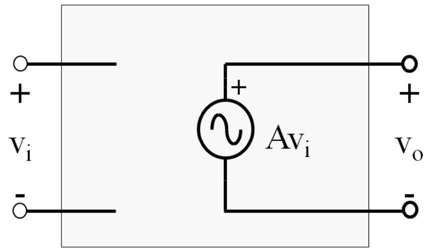
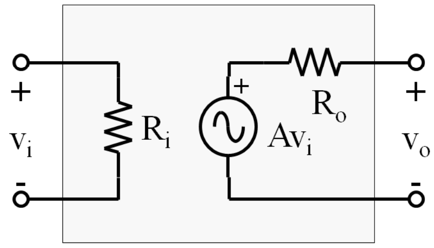
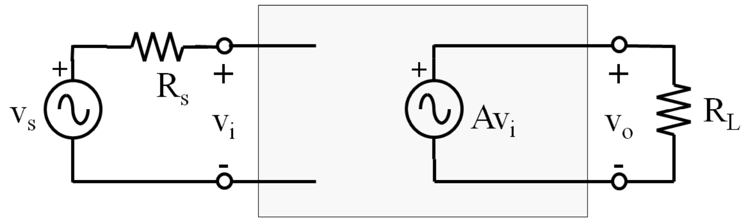
Ideal Voltage Amplifier



Real Voltage Amplifier

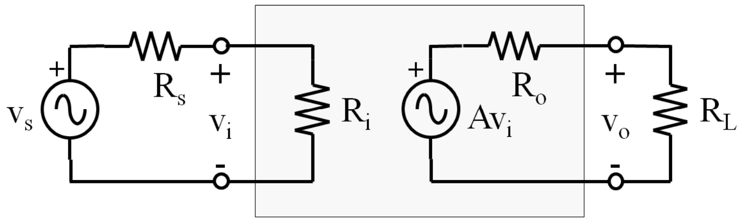


Loaded Ideal Voltage Amplifier



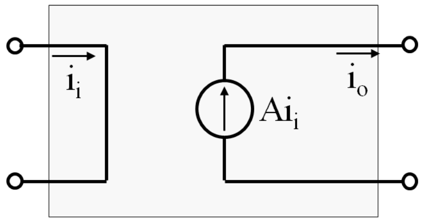
$$\frac{v_o}{v_s} = A$$

Loaded Voltage Amplifier

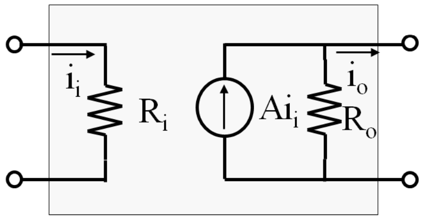


$$\frac{v_o}{v_s} = A \frac{R_i}{R_s + R_i} \frac{R_L}{R_o + R_L}$$

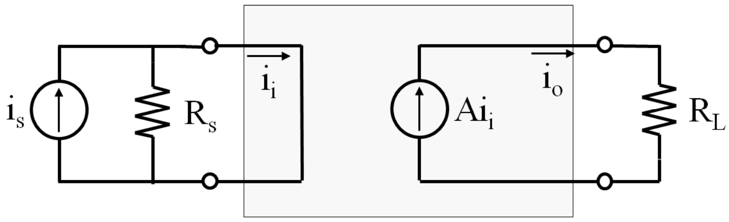
Ideal Current Amplifier



Real Current Amplifier

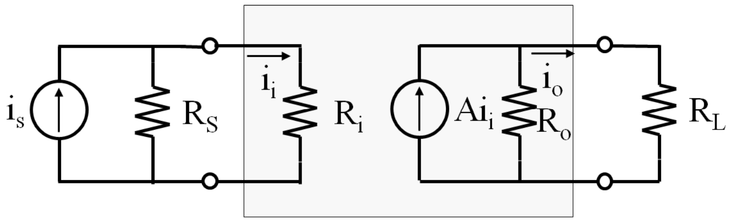


Loaded Ideal Current Amplifier



$$\frac{i_o}{i_s} = A$$

Loaded Current Amplifier



$$\frac{i_o}{i_s} = A \frac{R_s}{R_s + R_i} \frac{R_o}{R_o + R_L}$$

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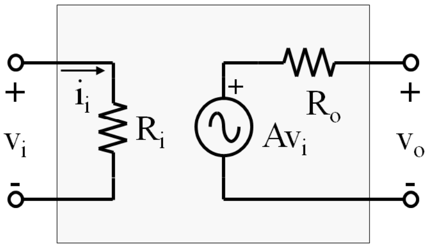
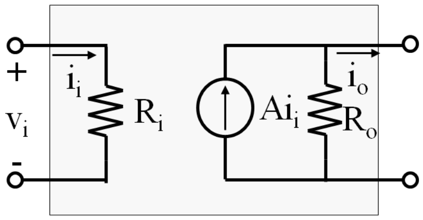
To determine Input Resistance R_i



Voltage Amplifier



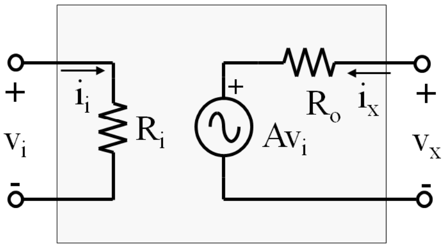
Current Amplifier

- Apply input voltage v_i (or input current i_i)
- Determine the input current i_i (or input voltage v_i)

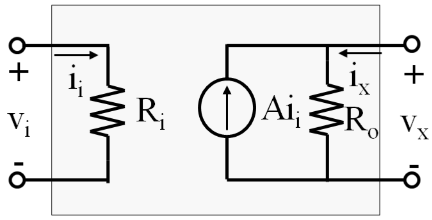
Then

$R_i = v_i / i_i$

To determine Output Resistance R_o



Voltage Amplifier



Current Amplifier

- Kill the input signal (set v_i or i_i to zero)
- Apply a test voltage v_x to the output node
- Determine the current i_x that the source delivers to the circuit

Then

$R_o = v_x / i_x$