Design IV

E232 Fall 07

Class 3

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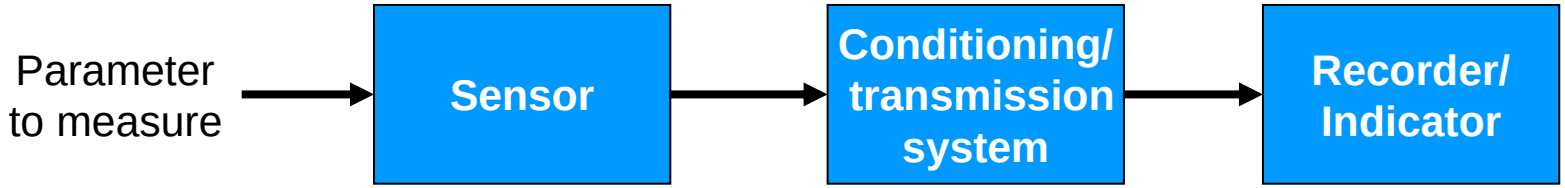
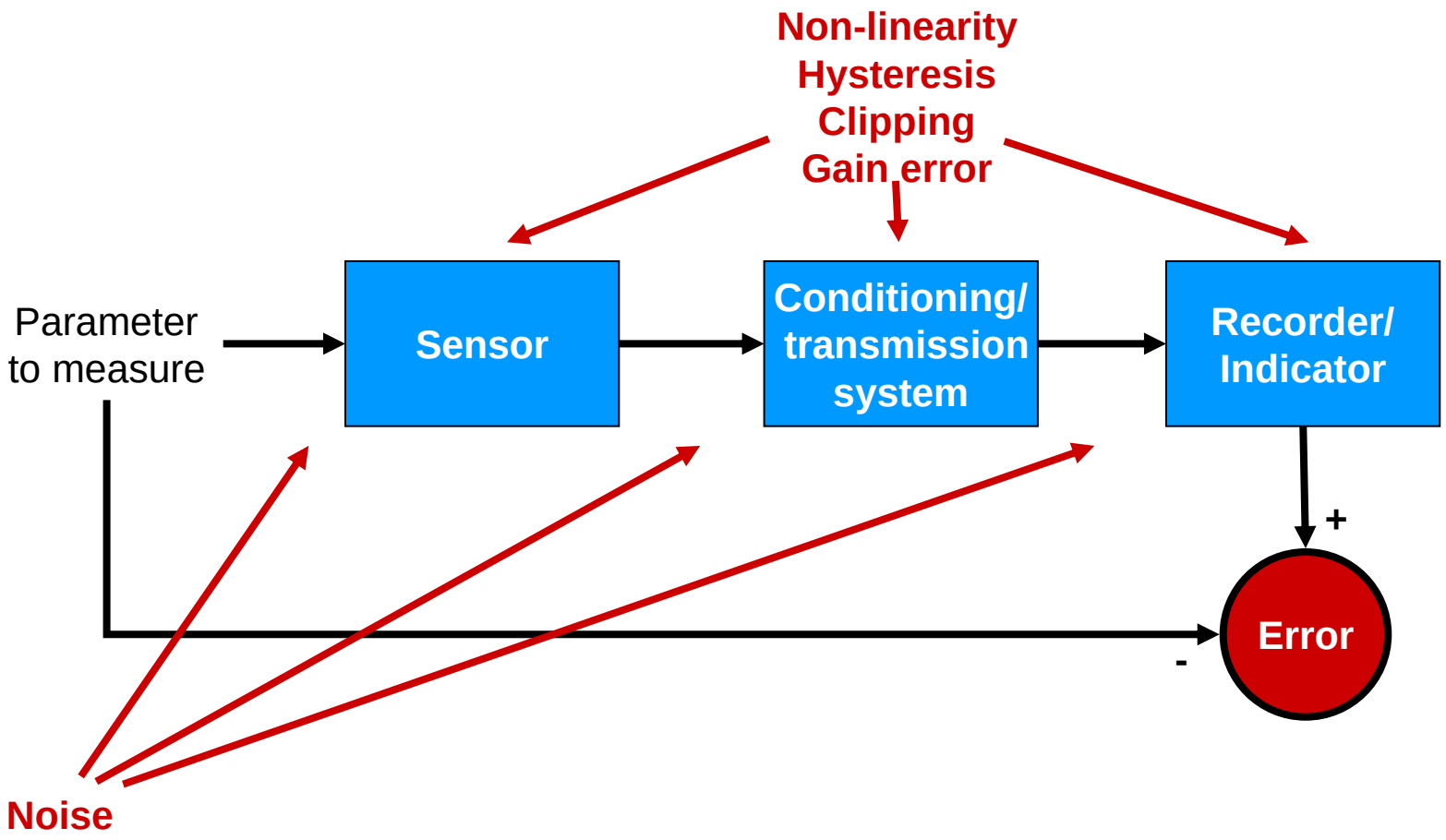
Measurement Systems



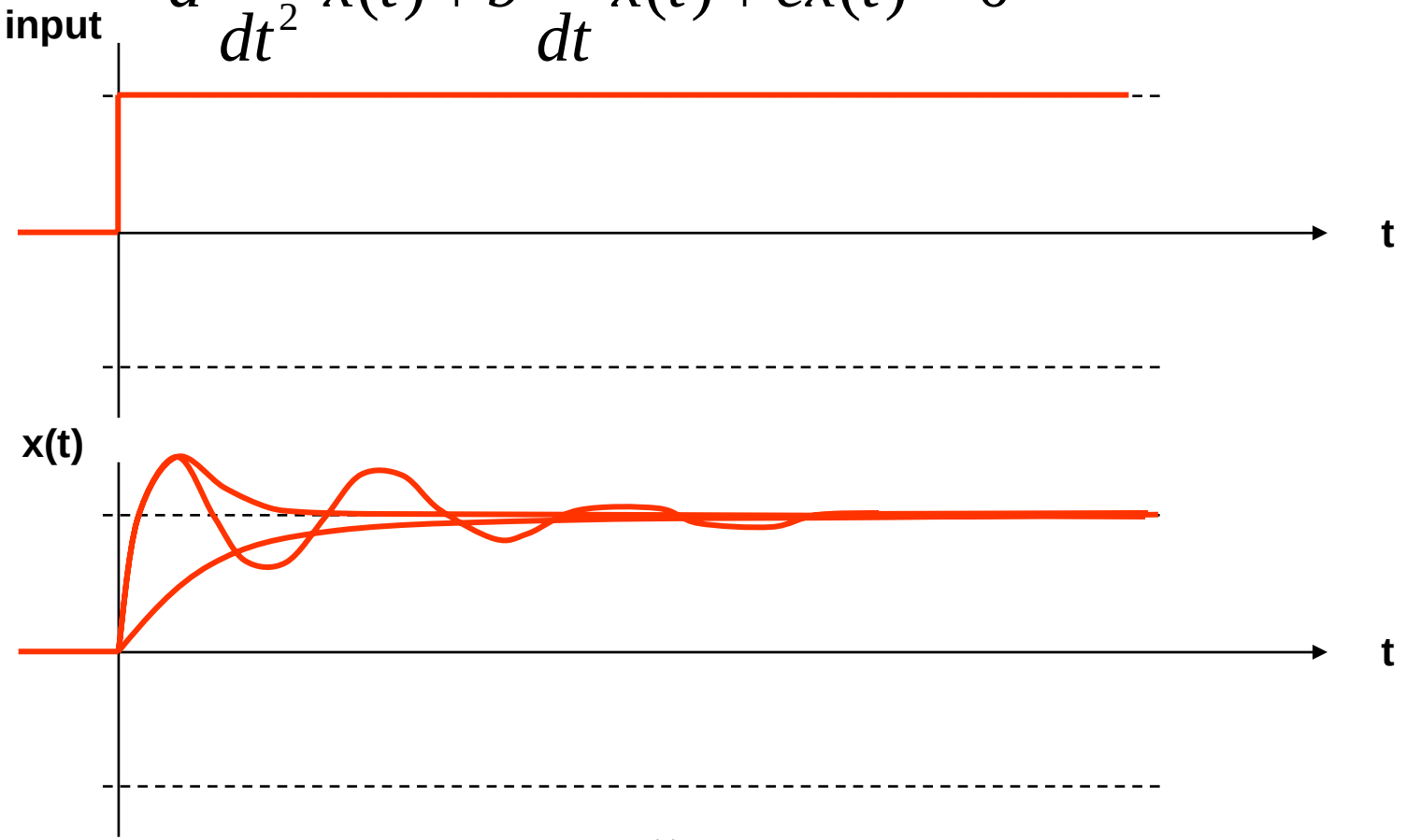
Measurement Systems



Dynamic Systems

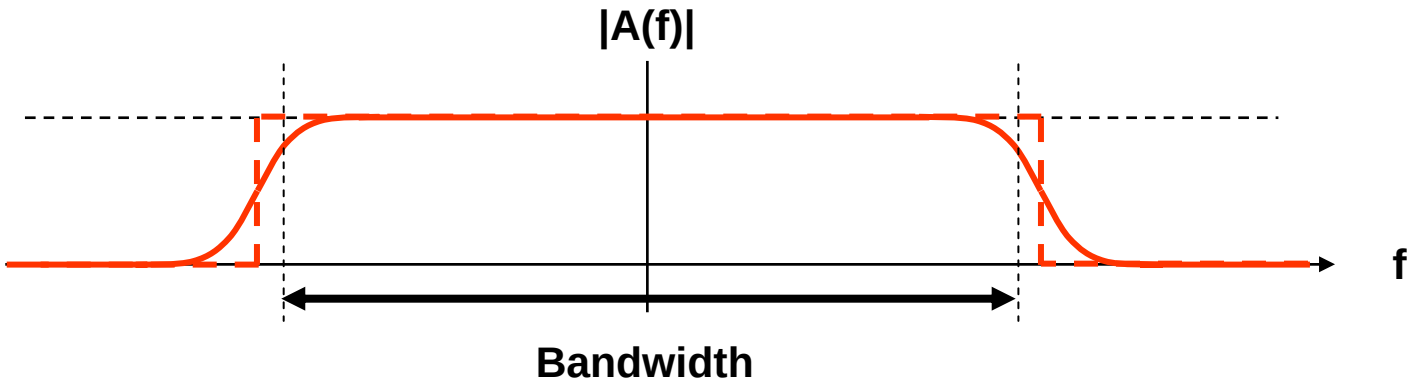
- Second-order system performance measures

$$a\frac{d^2}{dt^2}x(t)+b\frac{d}{dt}x(t)+cx(t)=0$$



Frequency Response

- Practical low-pass response

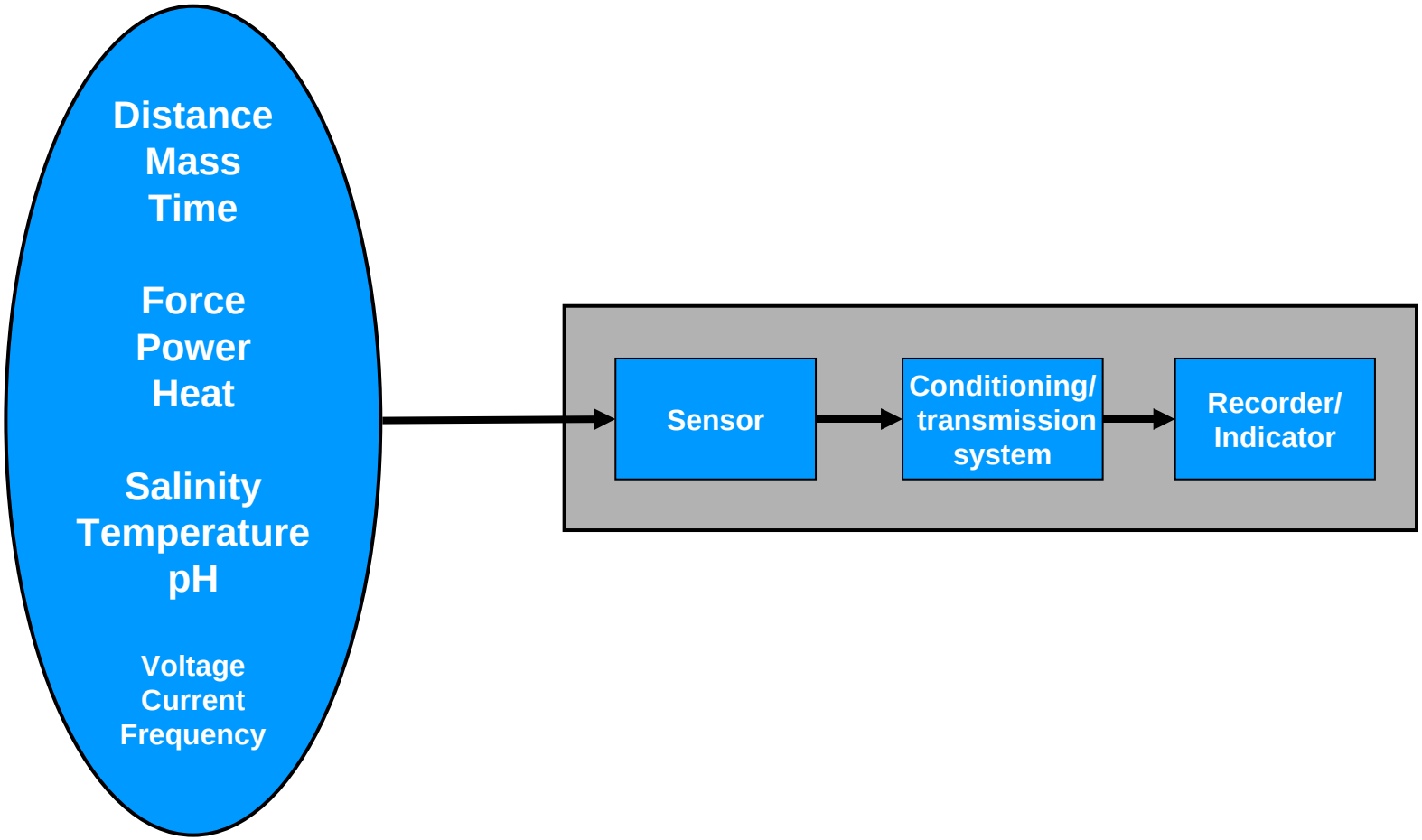


Today's topics

- Why deal with electrical signals?
- Signal conditioning, transformation
  - Amplifiers
    - Gain
    - Bandwidth
    - Phase shift
    - Common mode rejection

Electrical Signals In a Physical World

- Most parameters we want to sense and record have physical values



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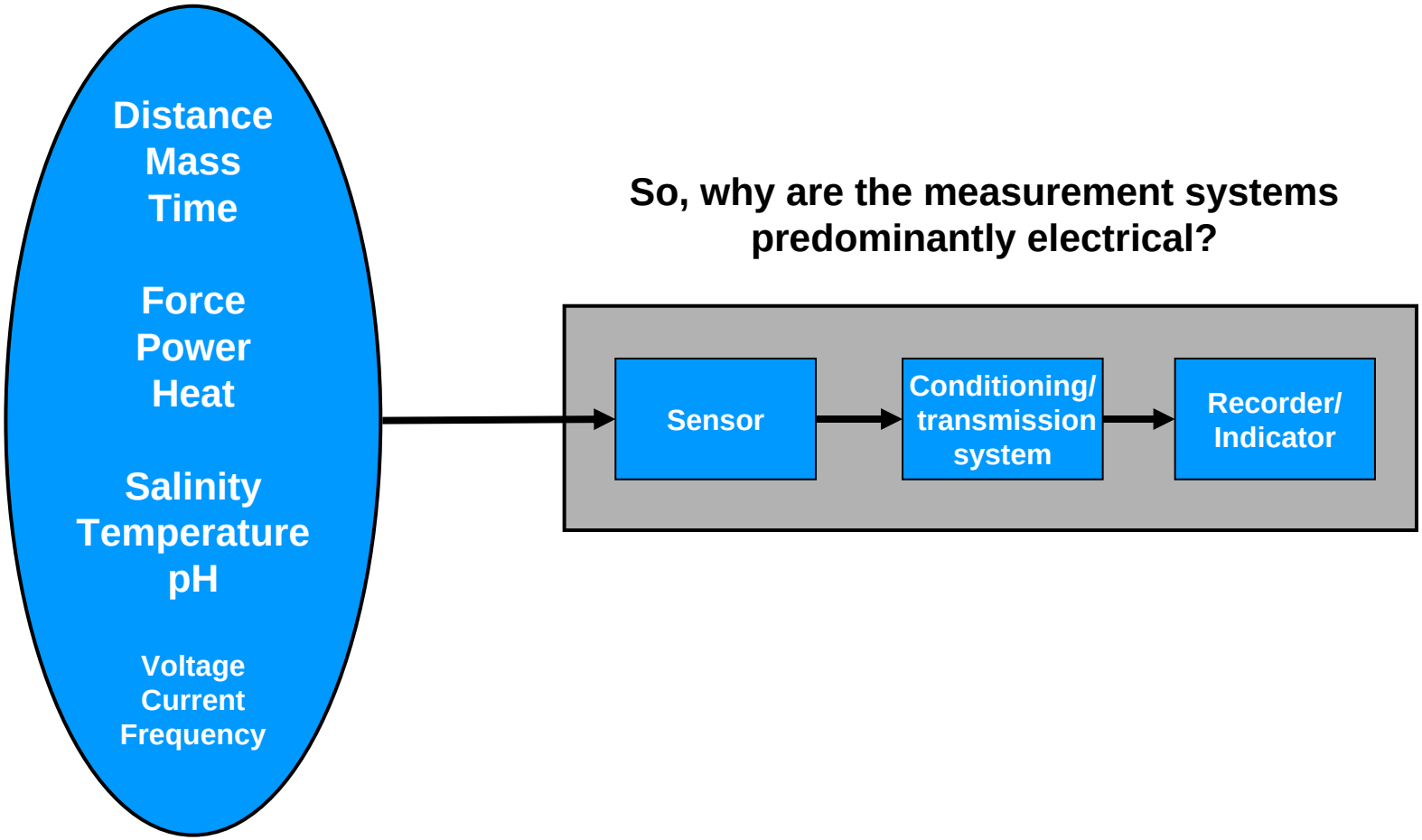

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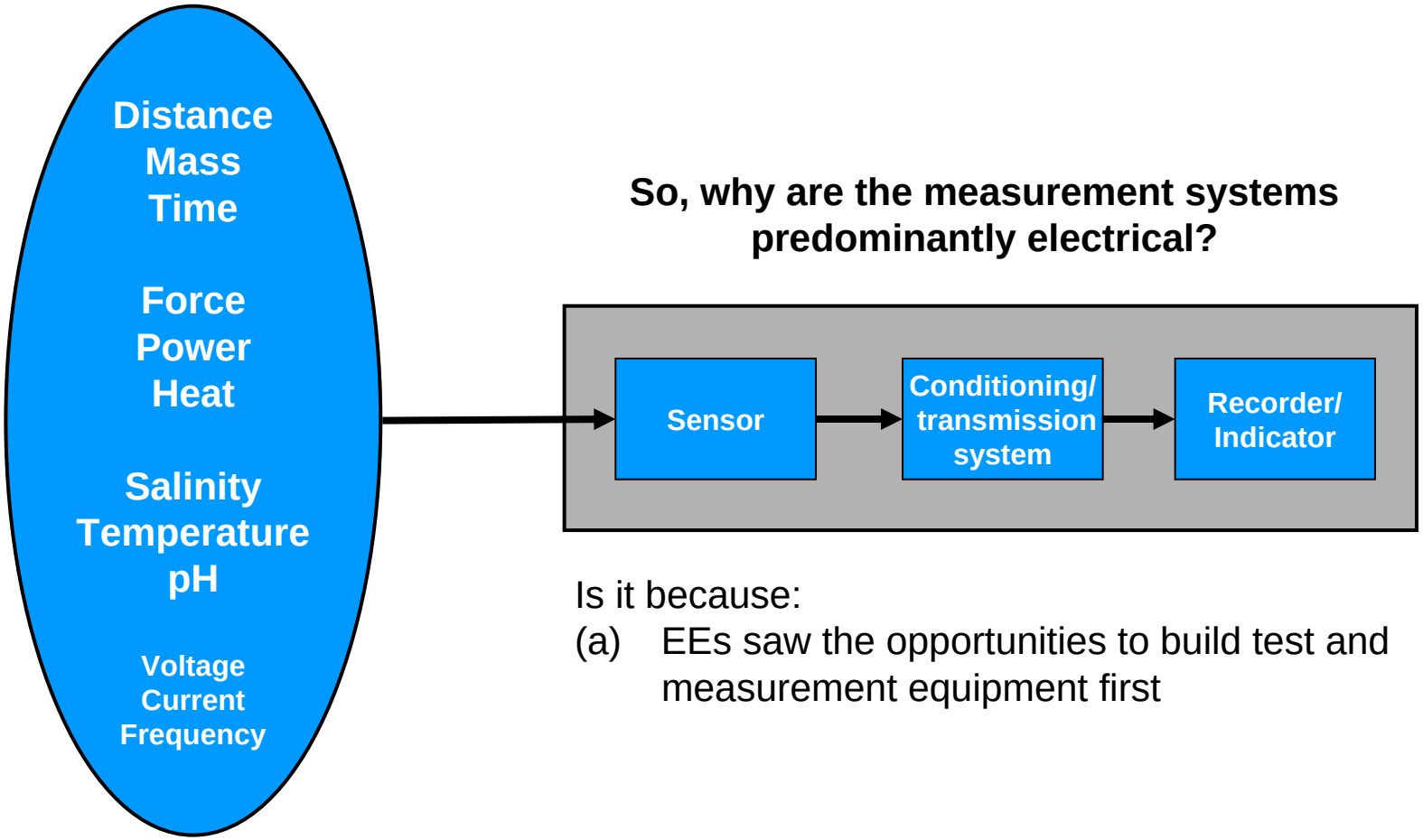

So, why are the measurement systems predominantly electrical?

Is it because:

(a) EEs saw the opportunities to build test and measurement equipment first

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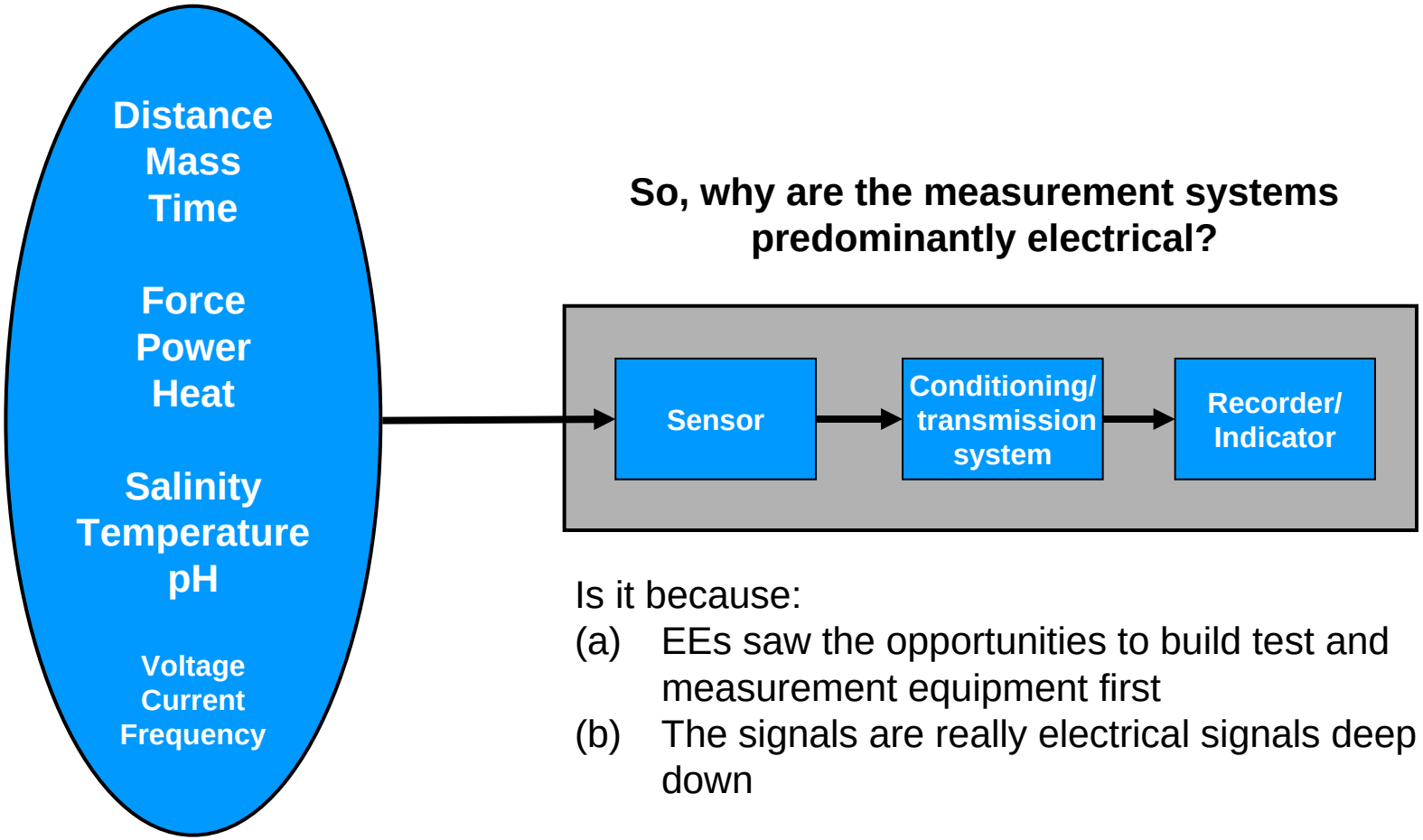

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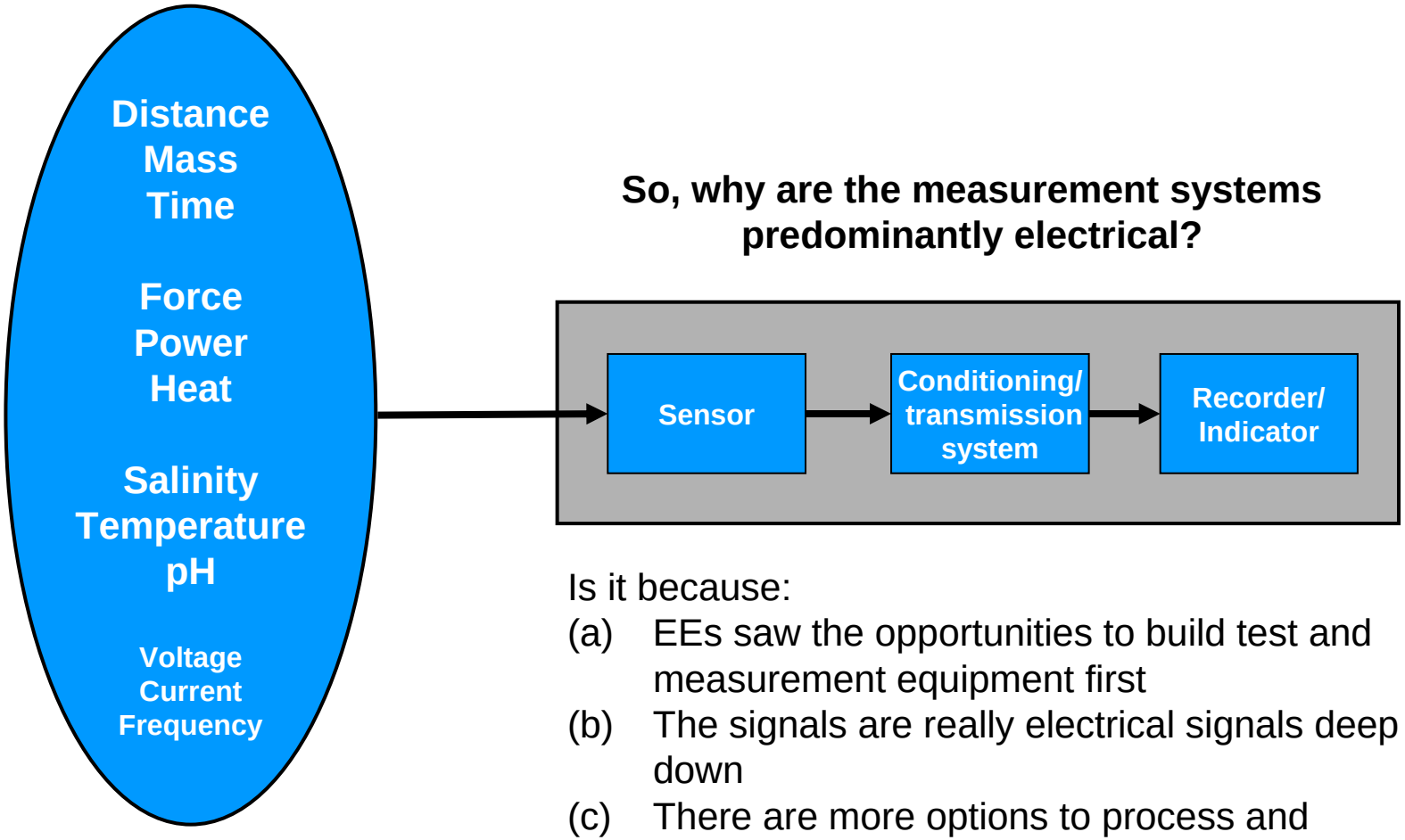

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(c) There are more options to process and transmit signals in electrical form

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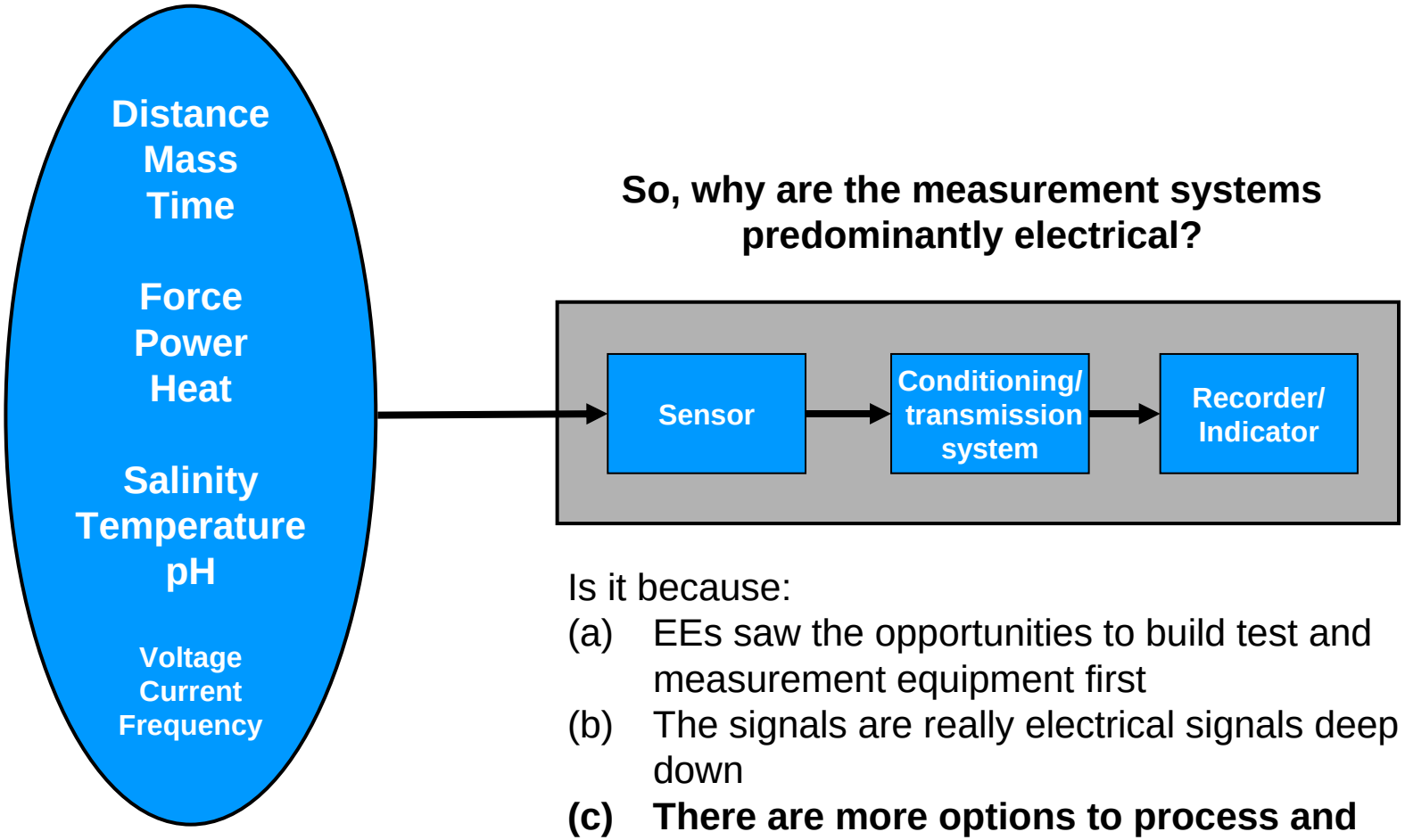

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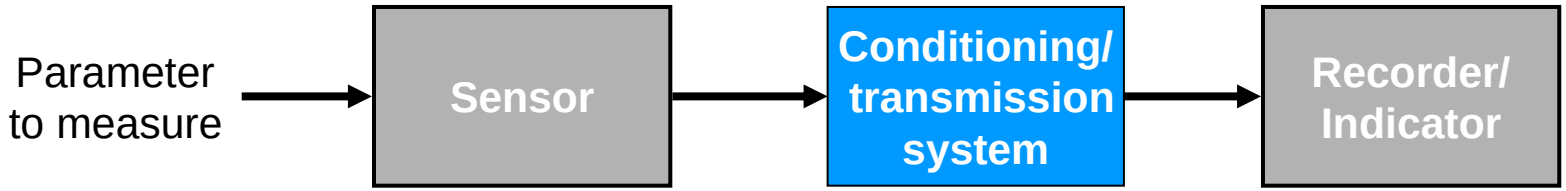
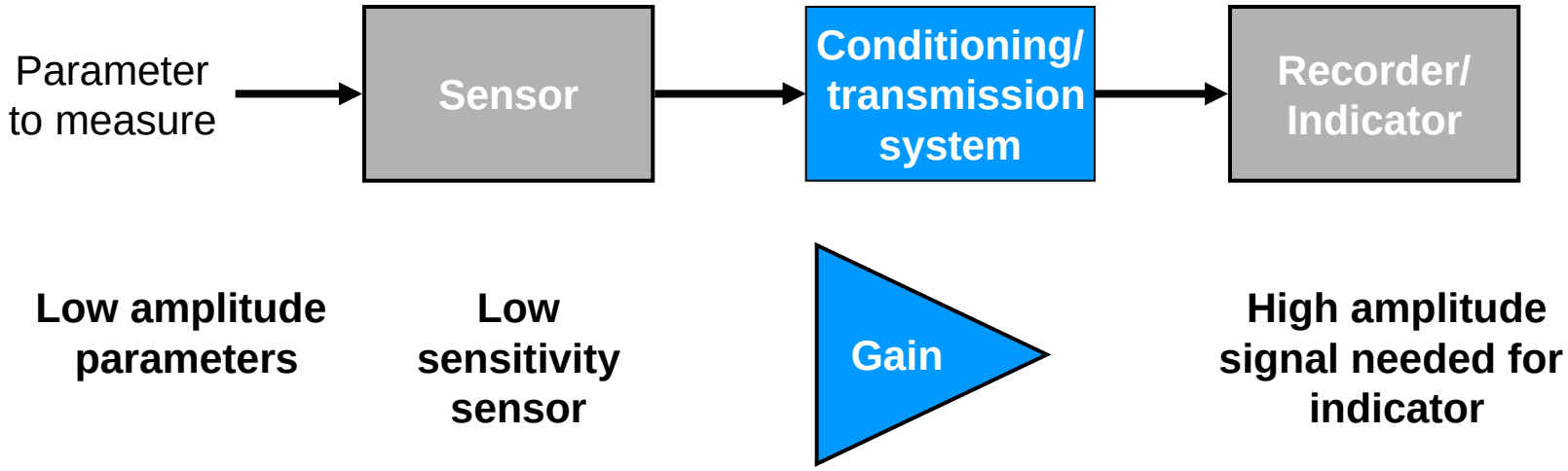
Signal Conditioning And Transformation



Signal Conditioning And Transformation

- Amplification



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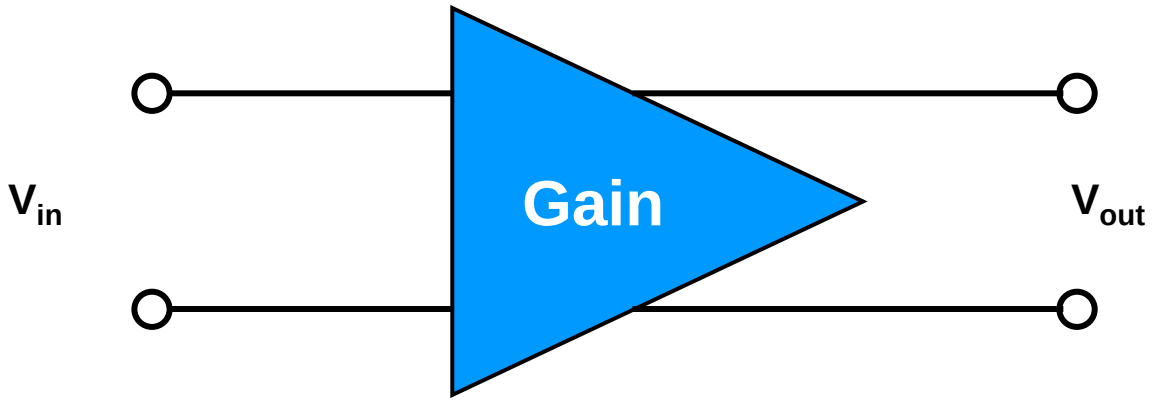
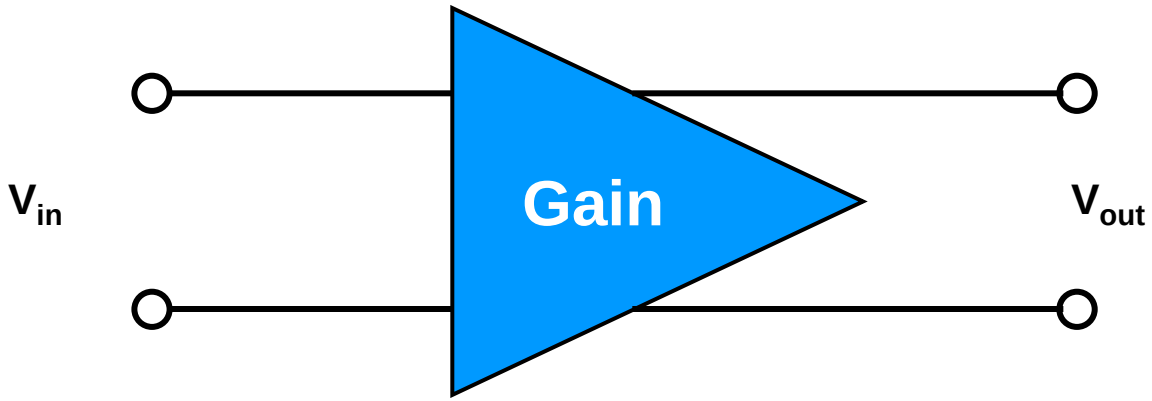


$$G = \frac{V_{out}}{V_{in}}$$

Signal Conditioning And Transformation

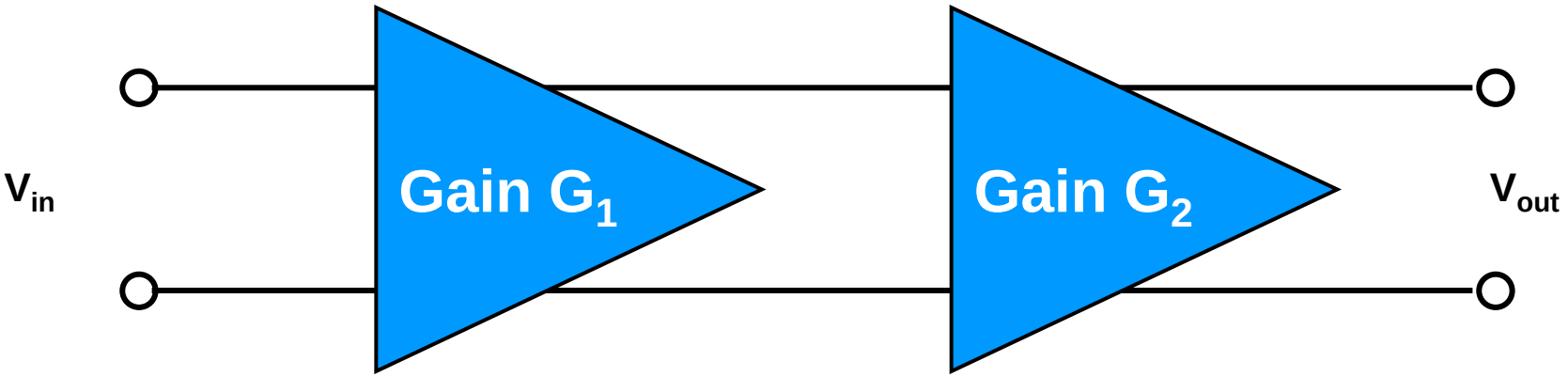
- Amplification



$$G_{dB} = 20 \bullet \log_{10}\left(\frac{V_{out}}{V_{in}}\right)$$

Signal Conditioning And Transformation

- Amplification

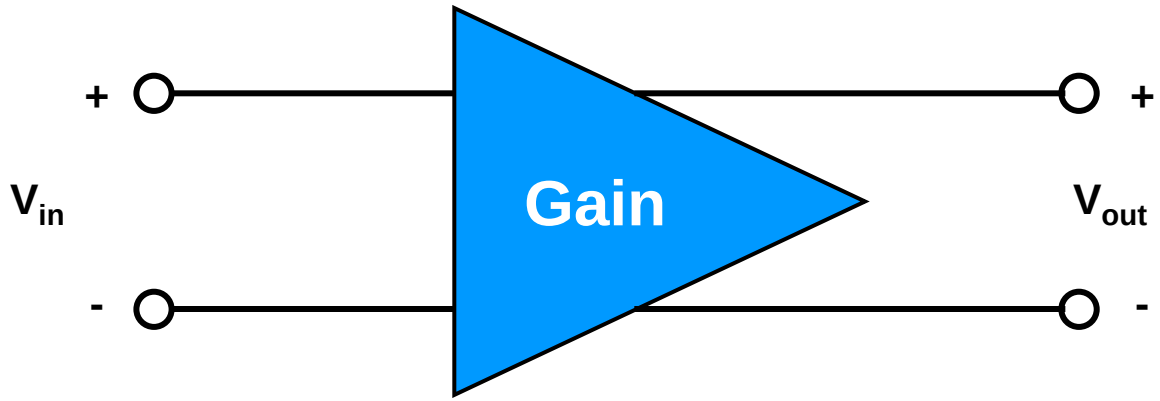


$$G_{overall} = G_1 \bullet G_2$$

$$G_{overall_{dB}} = G_{1_{dB}} + G_{2_{dB}}$$

Signal Conditioning And Transformation

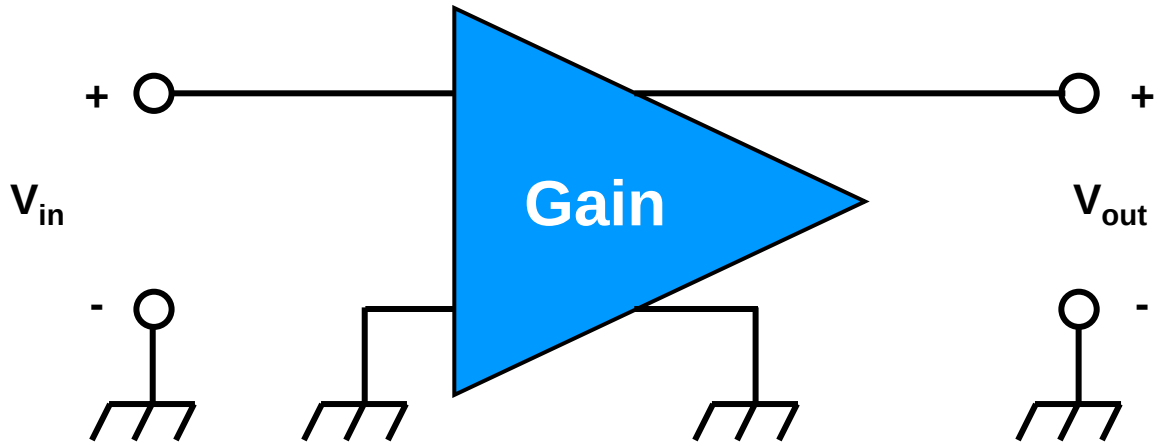
- Amplification



Balanced inputs/outputs

Signal Conditioning And Transformation

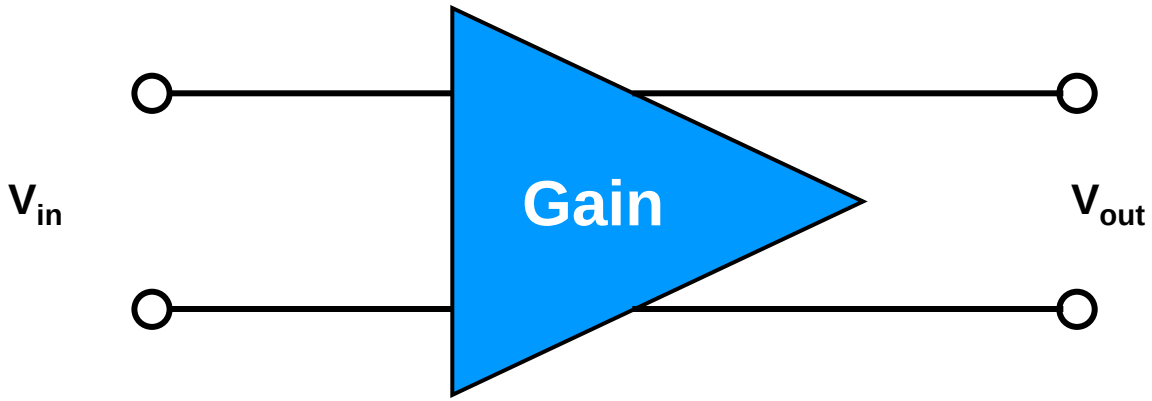
- Amplification



Unbalanced (single-ended) inputs/outputs

Signal Conditioning And Transformation

- Attenuation

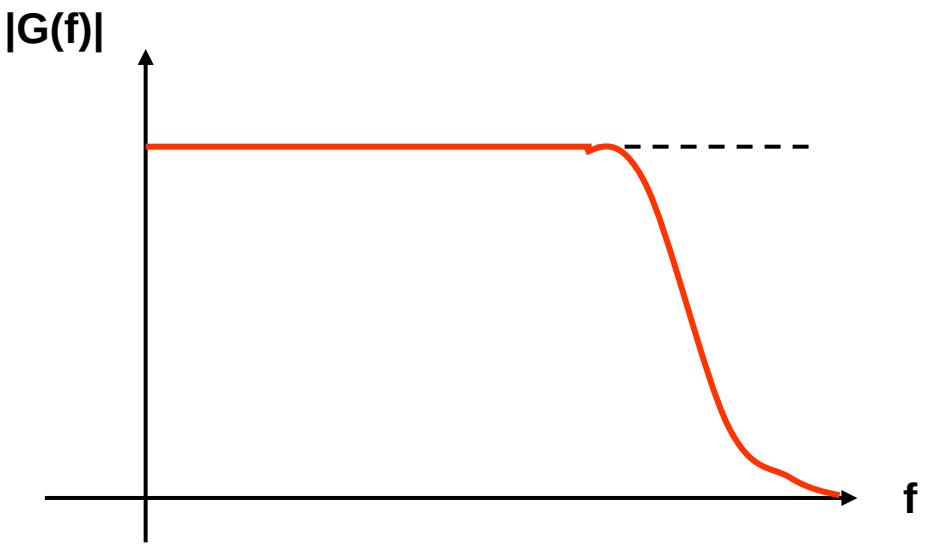


$$G < 1$$

$$G_{dB} < 0$$

Signal Conditioning And Transformation

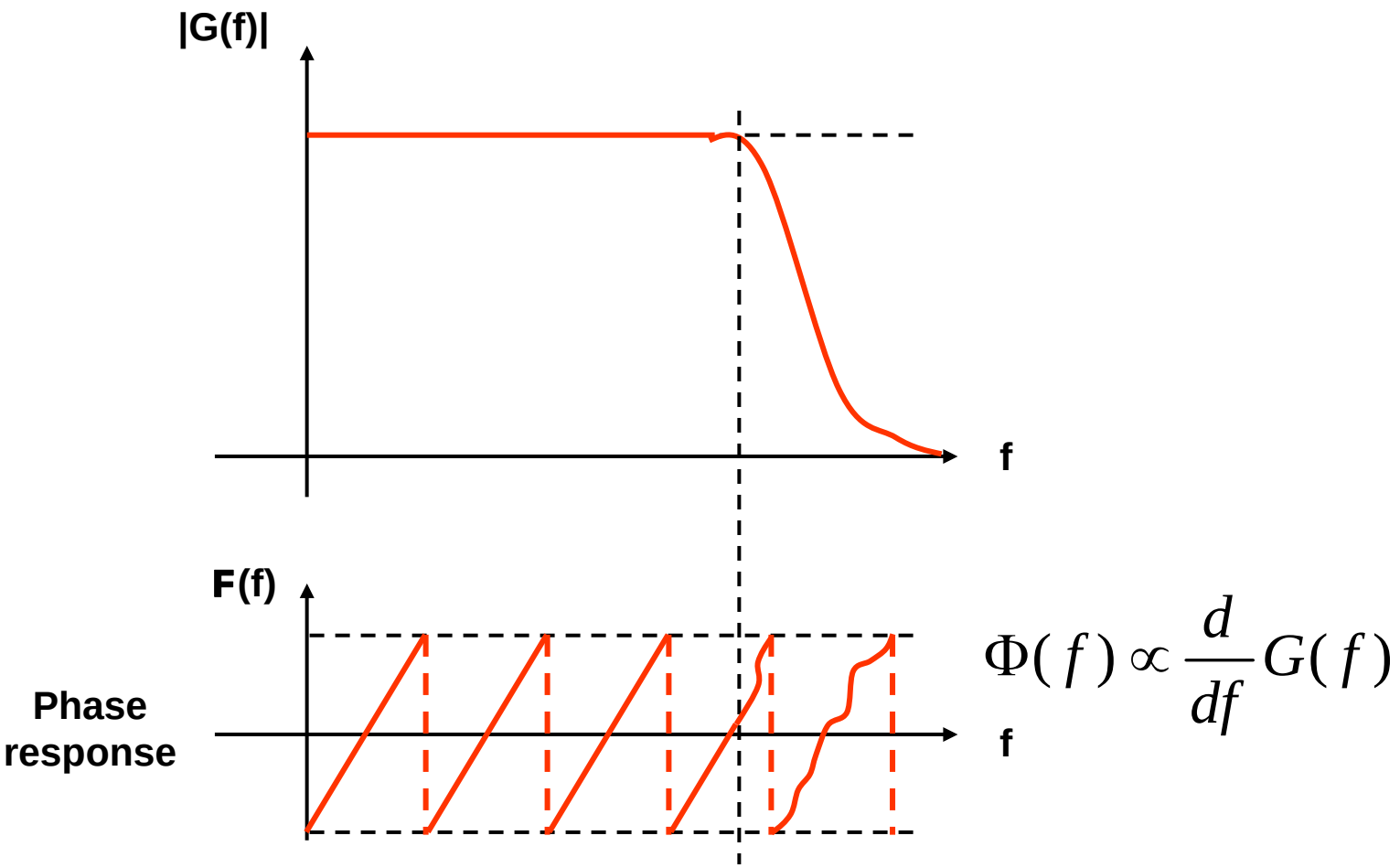
- Amplifier characteristics



Lowpass frequency response

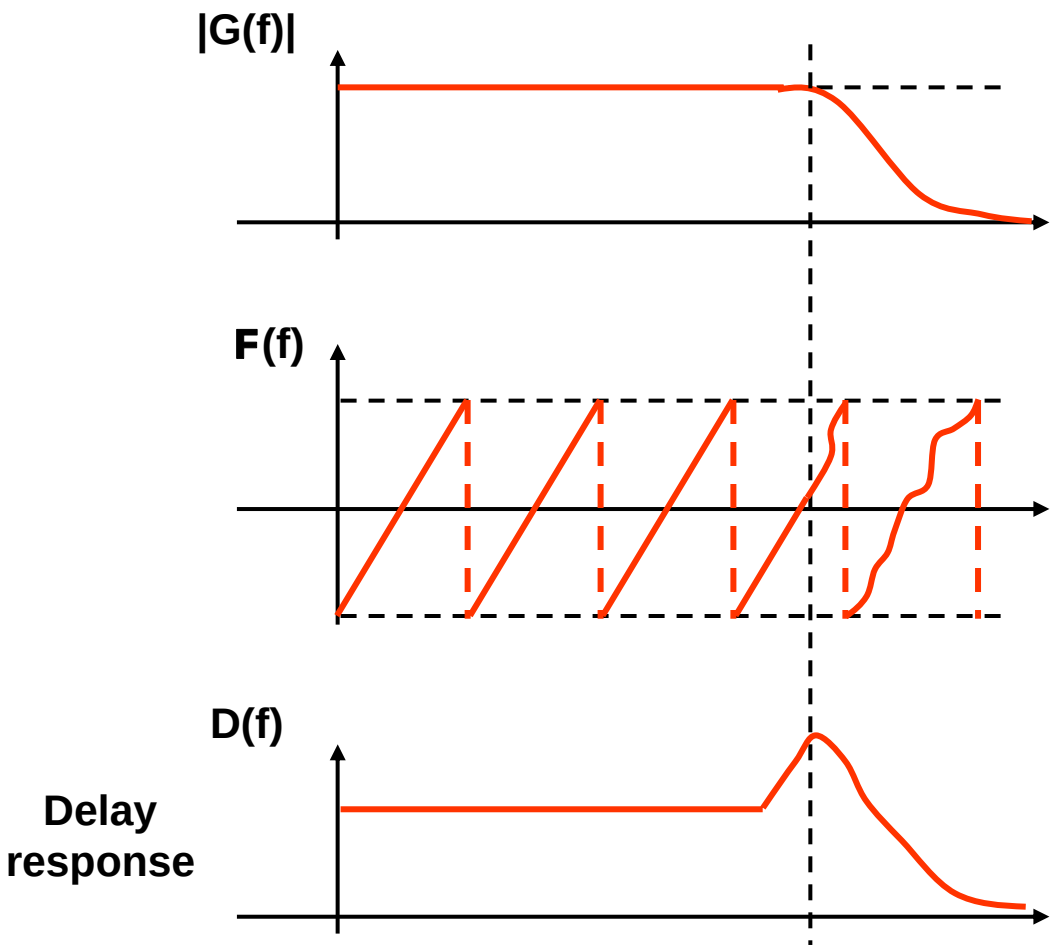
Signal Conditioning And Transformation

- Amplifier characteristics



Signal Conditioning And Transformation

- Amplifier characteristics

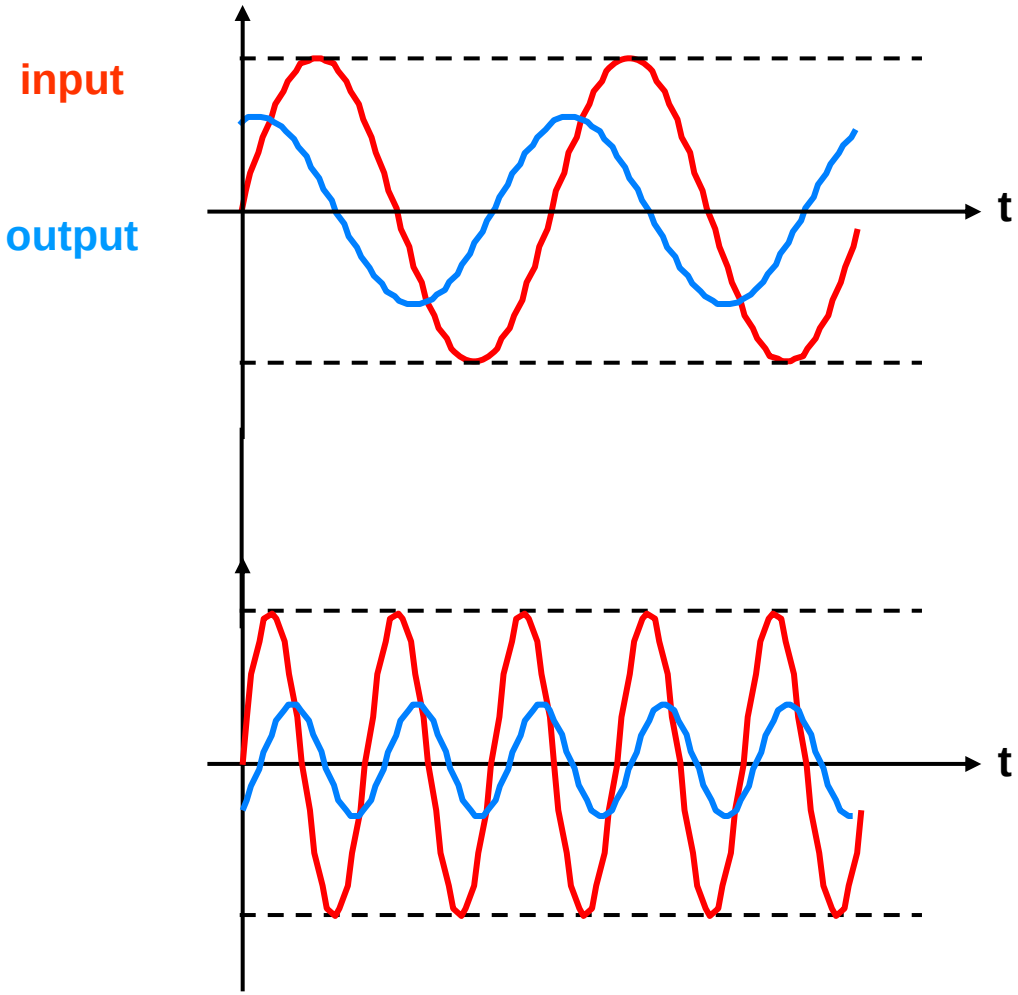


$$\Phi(f) \propto \frac{d}{df} G(f)$$

$$D(f) \propto \frac{d}{df} \Phi(f)$$

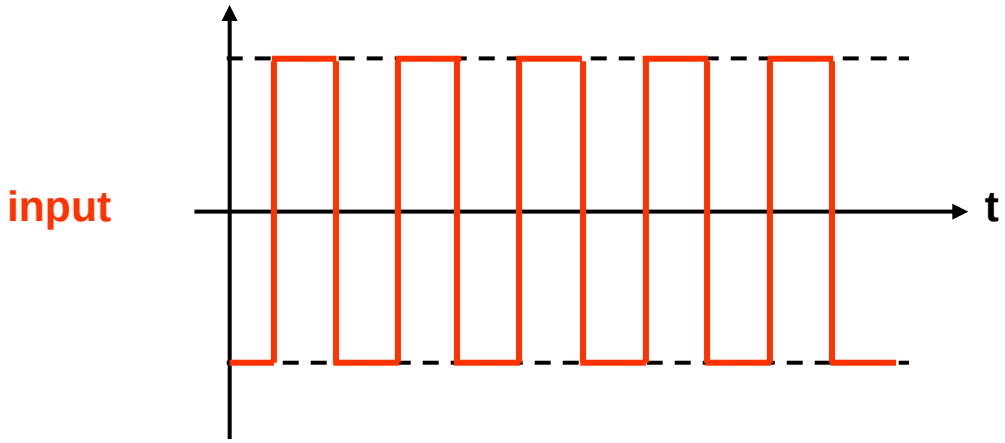
Effect Of Phase-Shift Variation

- Sinusoidal signals:



Effect Of Phase-Shift Variation

- Non-sinusoidal signals:



$$\sum_{i=1}^{\infty} \frac{\sin((2 \bullet i + 1) \bullet 2\pi f)}{2 \bullet i + 1}$$

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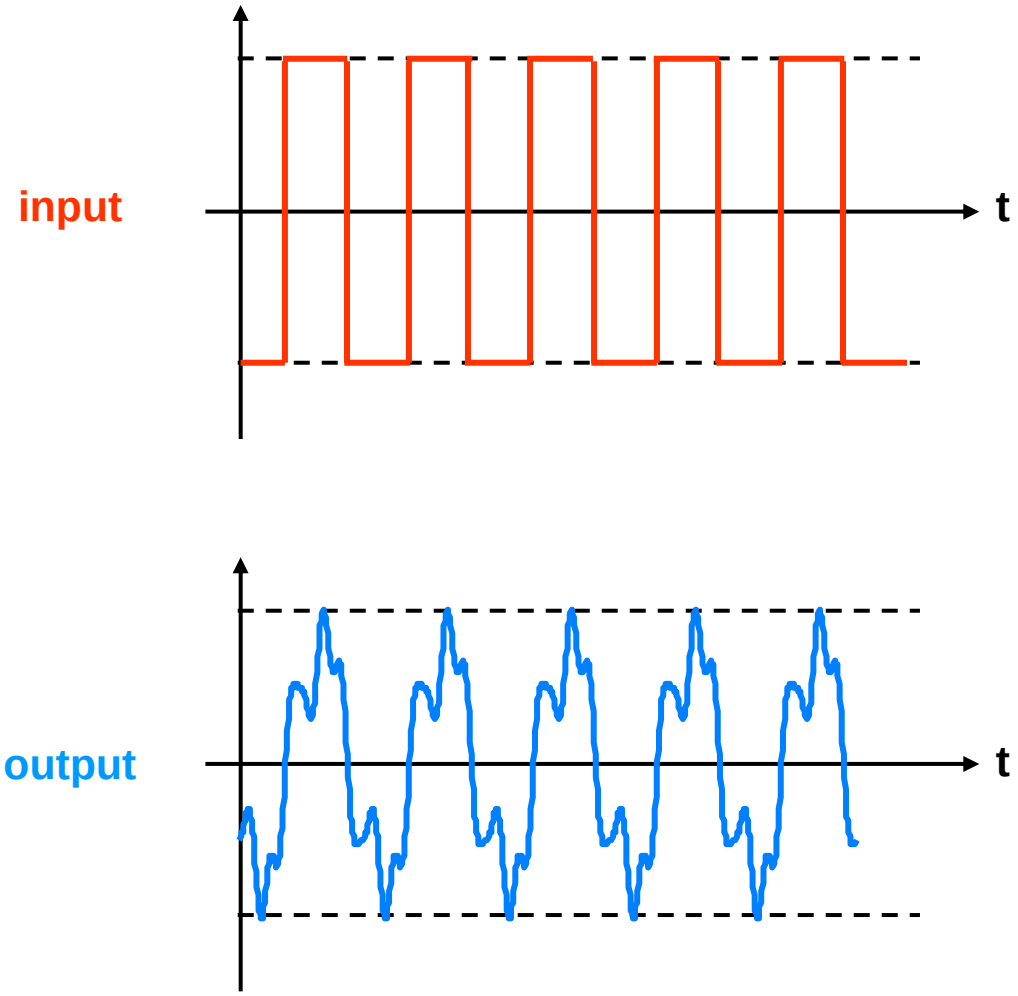
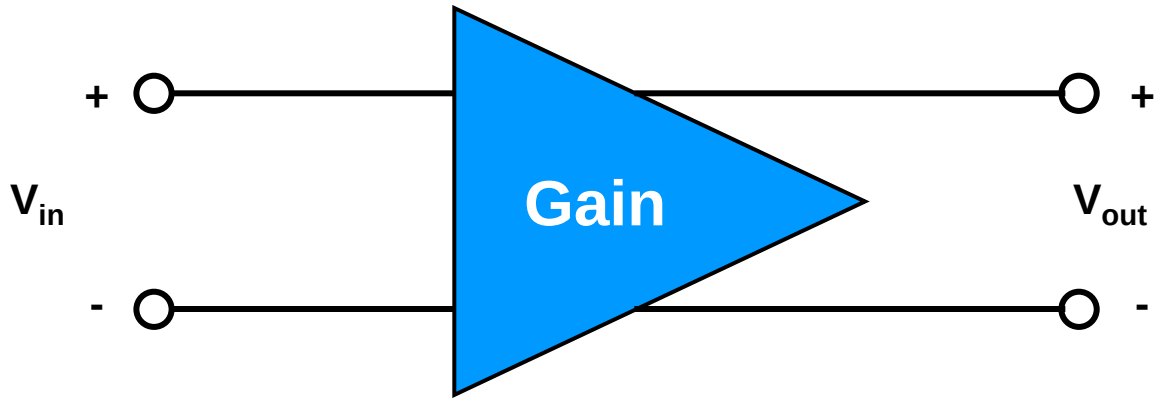


$$\sum_{i=1}^{\infty} \frac{\sin((2 \bullet i + 1) \bullet 2\pi f)}{2 \bullet i + 1}$$

Signal Conditioning And Transformation

- Other amplifier impairments – Common Mode Rejection Ratio



Ideally:

$$V_{out} = G \bullet (V_{in}^{+} - V_{in}^{-})$$

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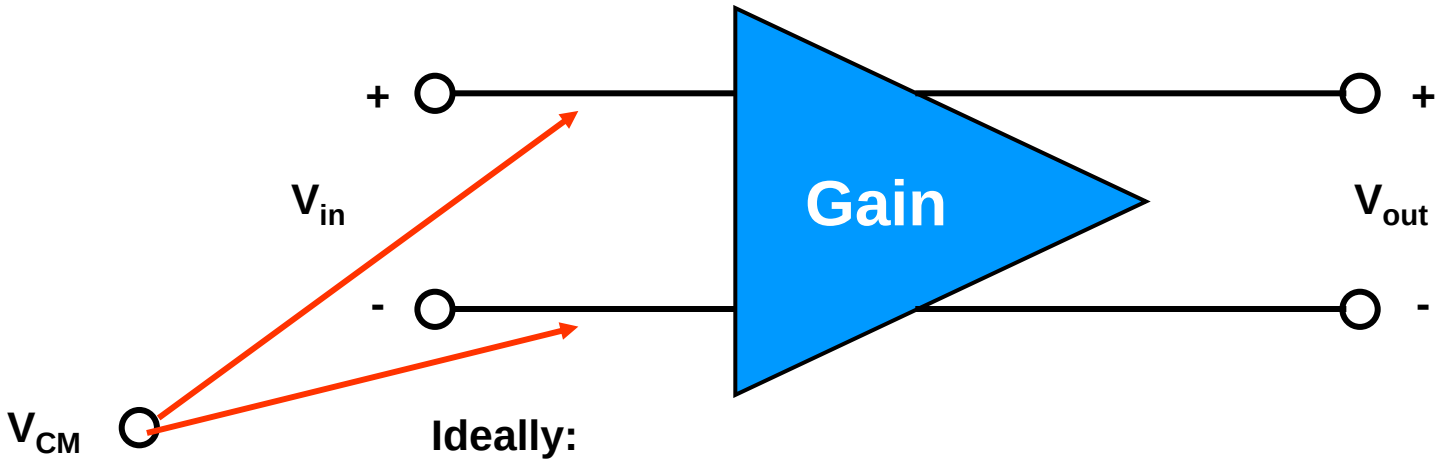

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$$V_{out} = G \bullet (V_{in}^{+} - V_{in}^{-})$$

Practically:

$$V_{out} = G_{diff} \bullet (V_{in}^{+} - V_{in}^{-}) + G_{CM} \bullet (V_{CM})$$

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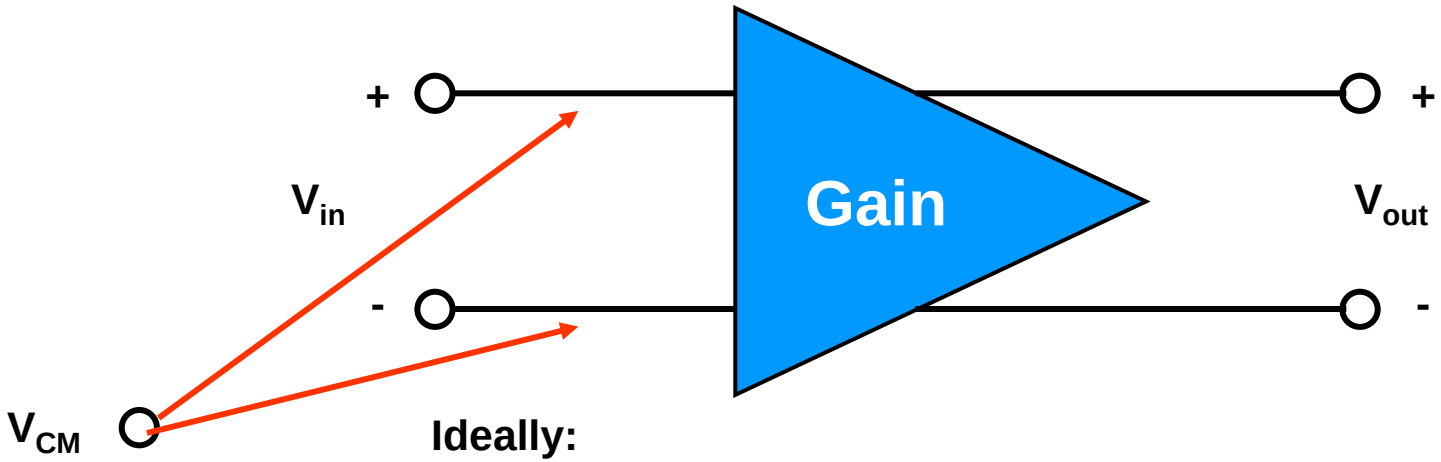

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Practically:

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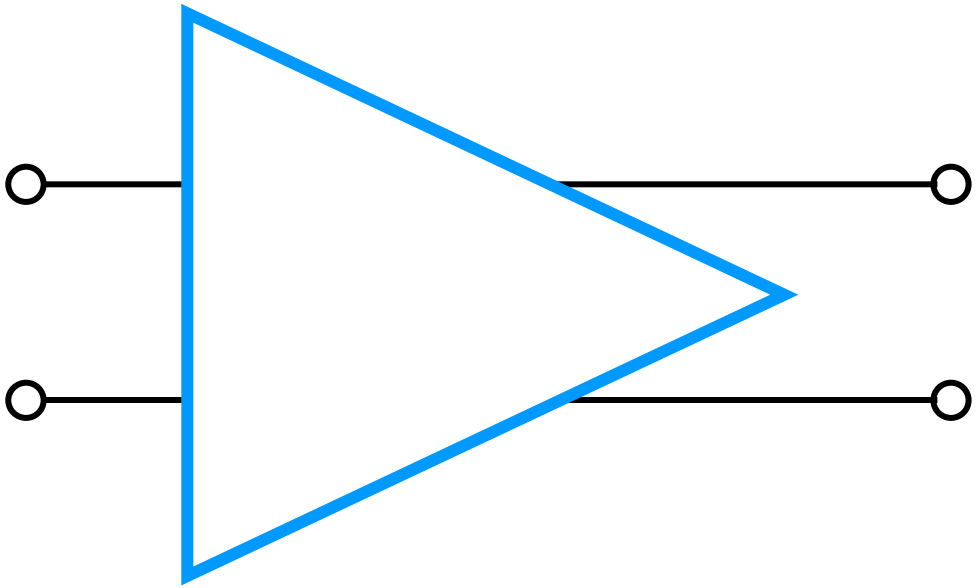
$$CMRR = 20 \bullet \log\left(\frac{G_{diff}}{G_{CM}}\right)$$

Signal Conditioning And Transformation

- Amplifier impedance



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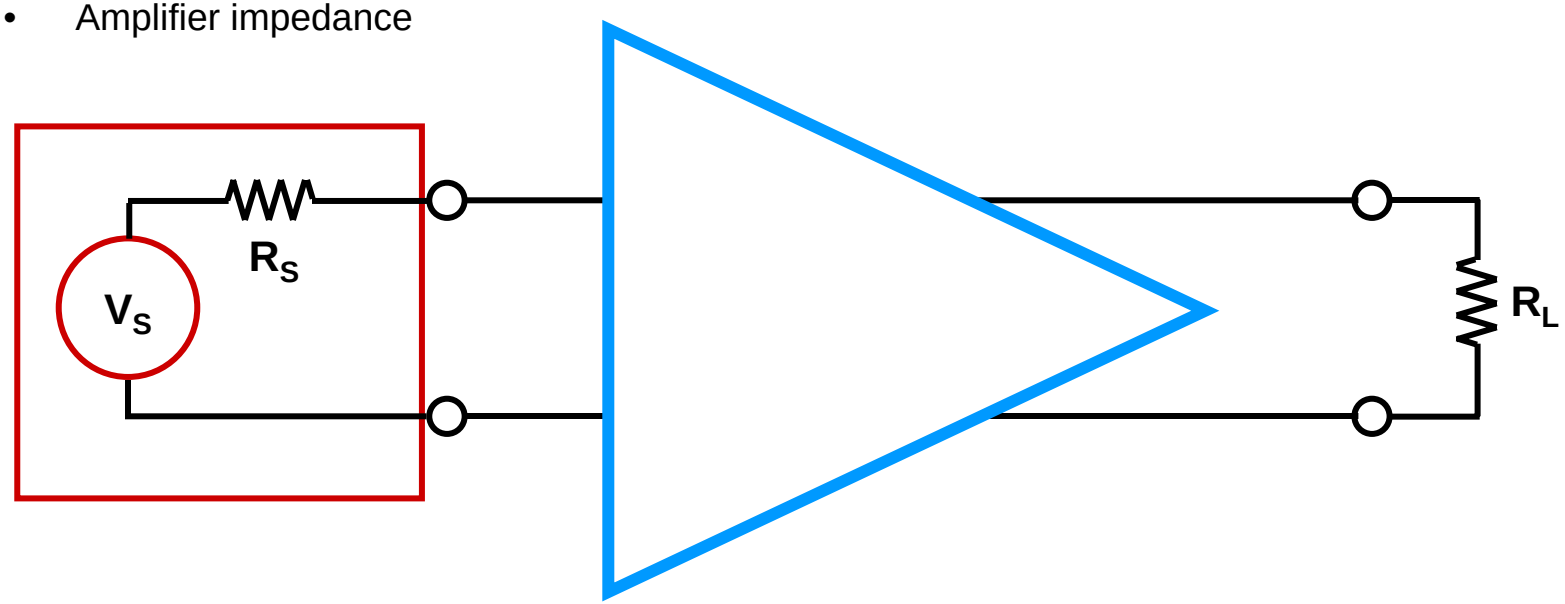

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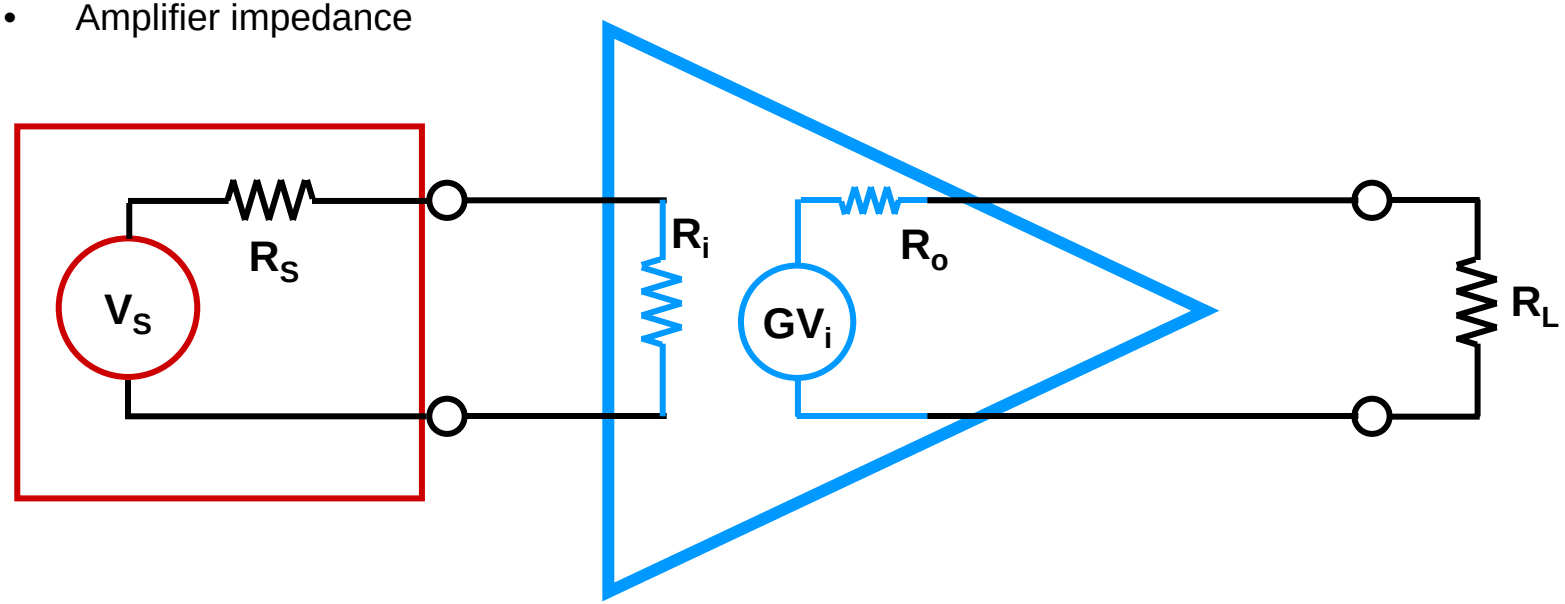

For greatest voltage gain, best frequency response:

$$R_i \rightarrow \infty$$

$$R_o \rightarrow 0$$

Next topics

- Signal conditioning, transformation
  - Amplifiers
    - DC drift
    - Operational Amplifiers
  - Filtering
    - Filter families
  - Integration, differentiation, comparison
- Indicators and recording devices
  - Voltage
  - Waveforms
  - Frequency
  - Spectrum
- Transmission
  - Signal level considerations
  - Interference sources
  - Ground loops
  - Rationale for digital signal transmission