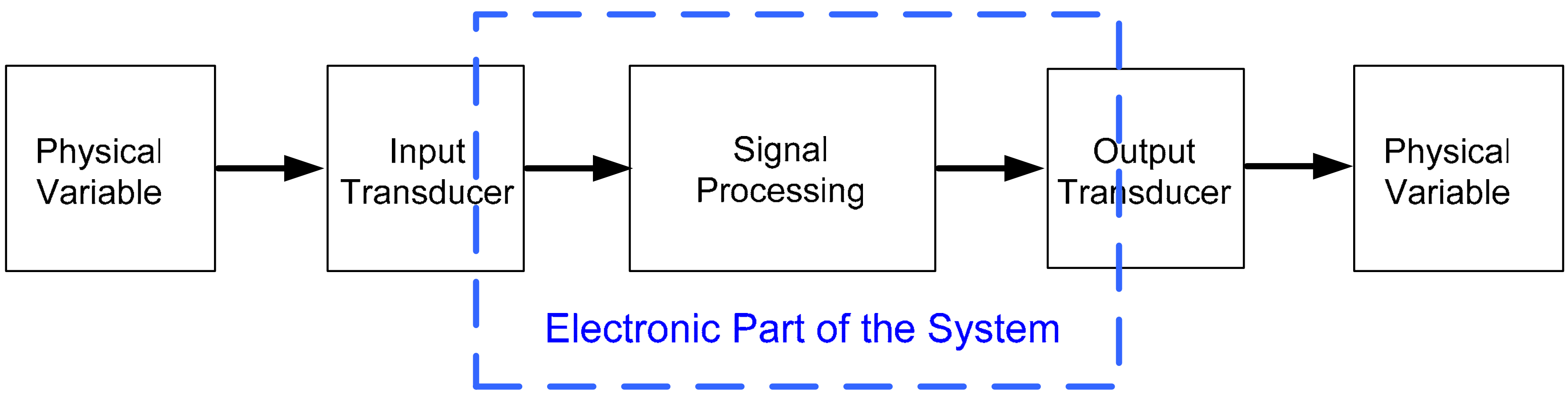
EE 230

Lecture 2

Background Materials

Quiz 1

A typical electronic system is shown below. Give three different types of physical variables that one could encounter in such a system.



And the number is ?

1 3 8

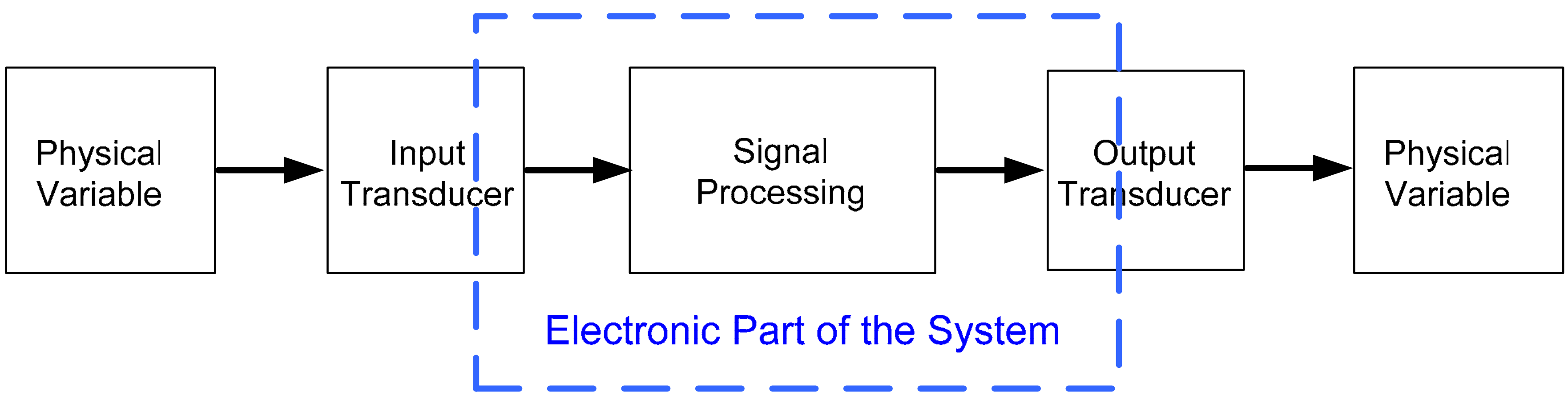
5 7 4

2 6

9 7

Quiz 1

A typical electronic system is shown below. Give three different types of physical variables that one could encounter in such a system.

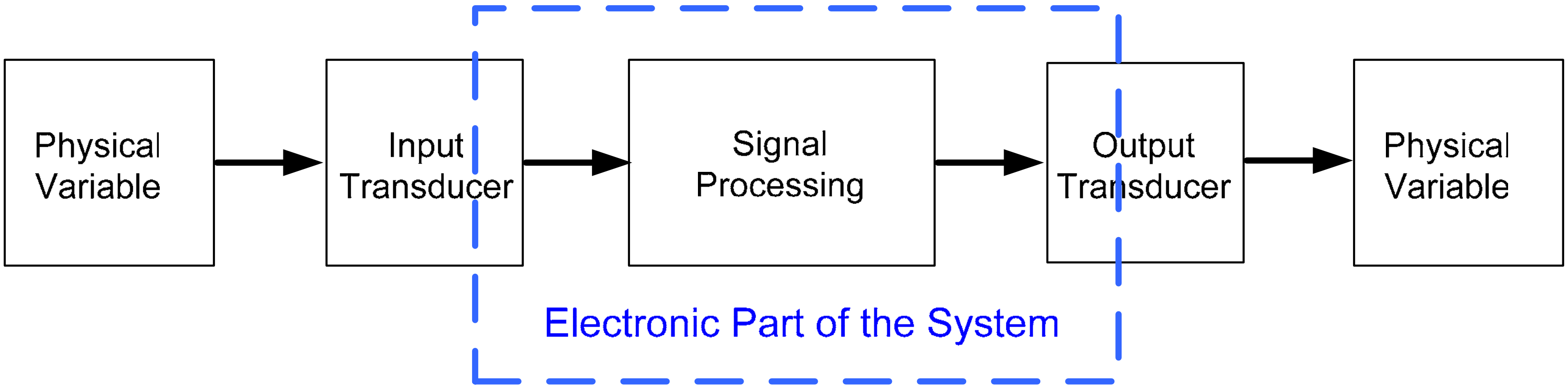


Solution: Time, temperature, pressure, light level, sound pressure level, force, …..

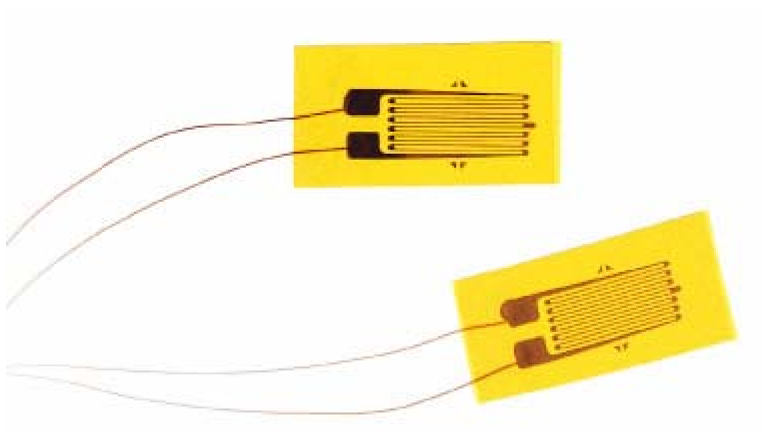
Review from Last Time

Electronics business is one the largest sectors in the world economy

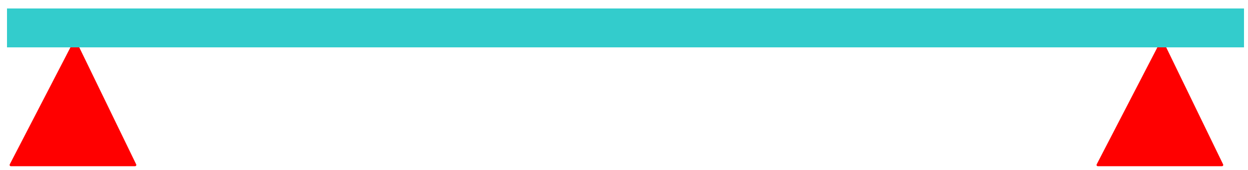
worldwide sales from semiconductors alone projected to be at the $250 Billion level in 2006



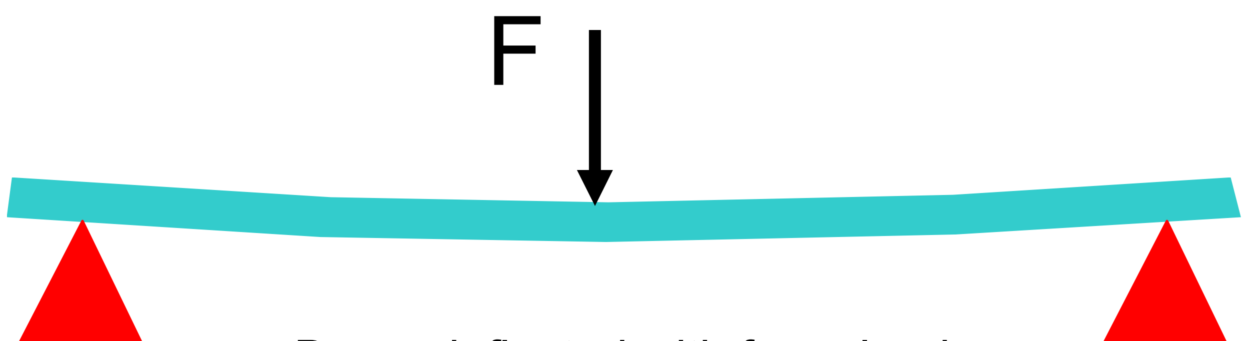
Example of electronic system: Force Measurement with Foil Strain Gauges



Force Measurement with Foil Strain Gauges

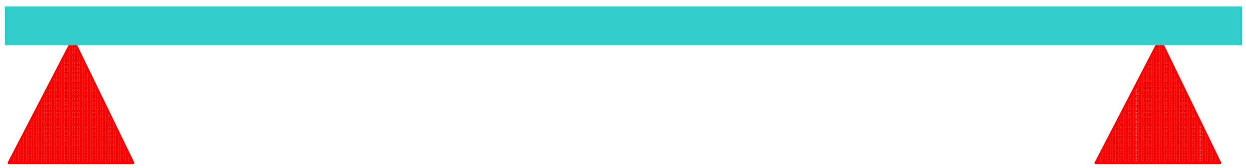


Beam supported at two points

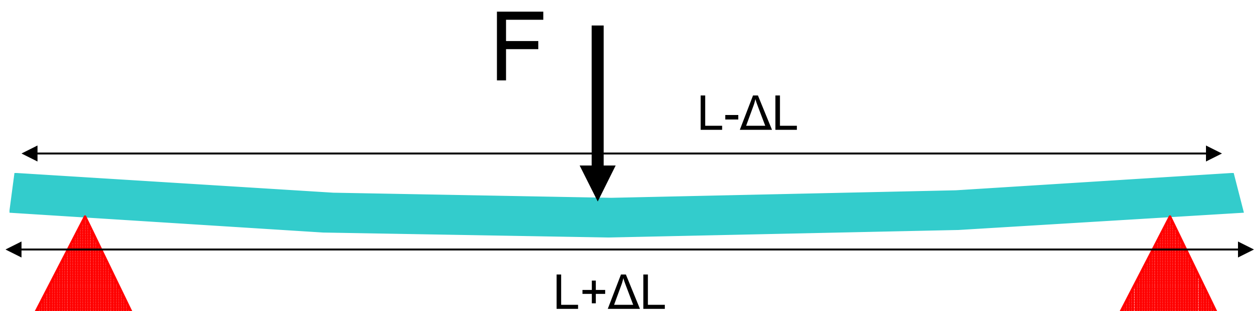


Beam deflected with force load

Force Measurement with Foil Strain Gauges

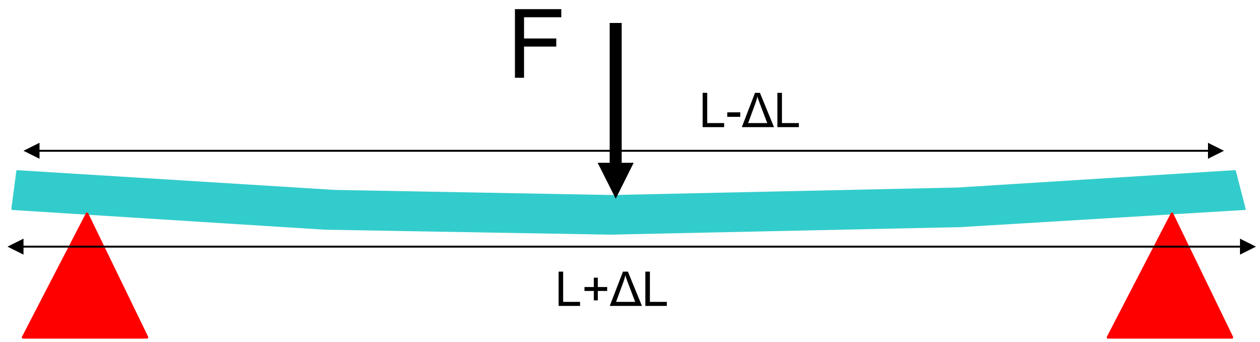


Beam supported at two points



Beam deflected with force load

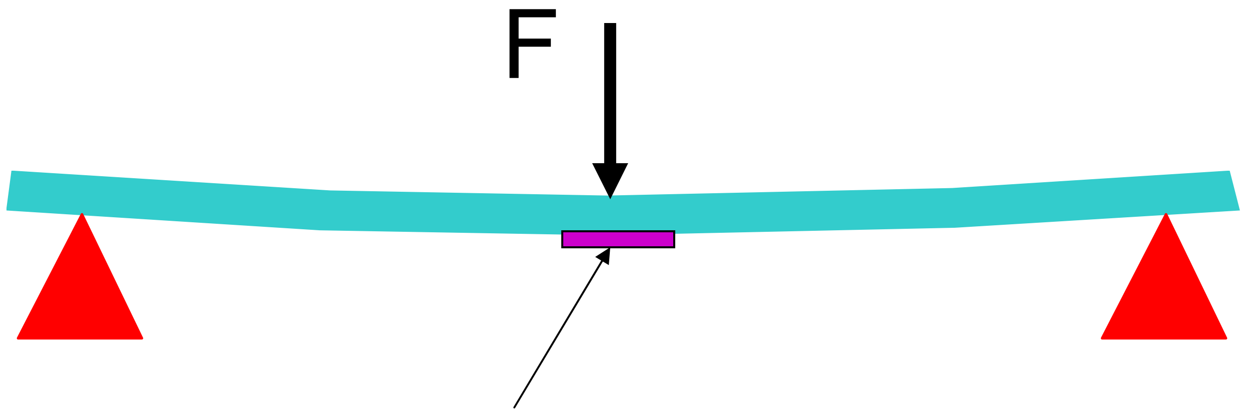
ΔL/L is often very small



If L=100ft, the thickness of the beam is 1 foot, and the deflection is 0.1ft, it can be shown that ΔL is approximately 4E-3 feet

Thus, ΔL/L is approximately 4E-5

$\varepsilon = \Delta L/L$ is defined to be the strain on the surface

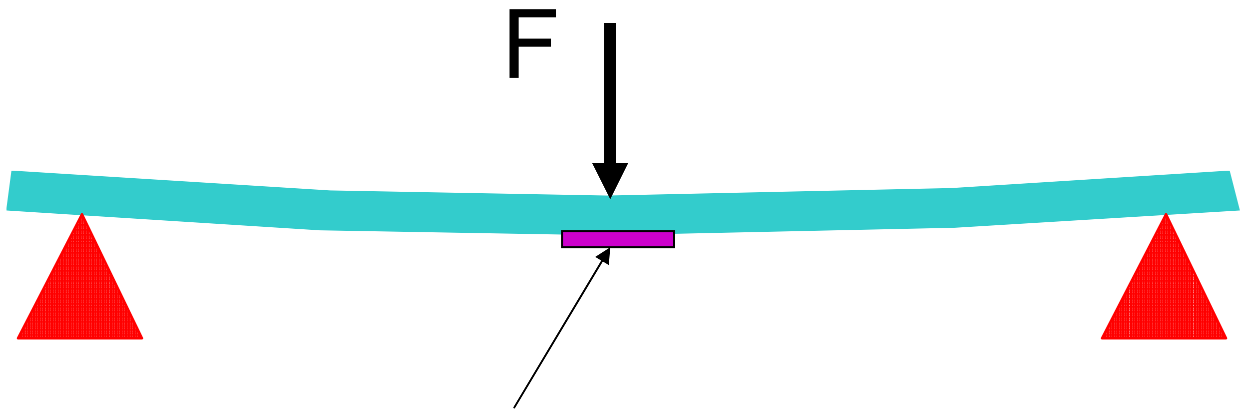


Strain gage mounted to measure
the change in length (strain)

Strain gauge characterization

$$GF = \frac{\Delta R / R}{\Delta L / L} = \frac{\Delta R / R}{\varepsilon}$$

Typical GF for foil strain gauges are around 2

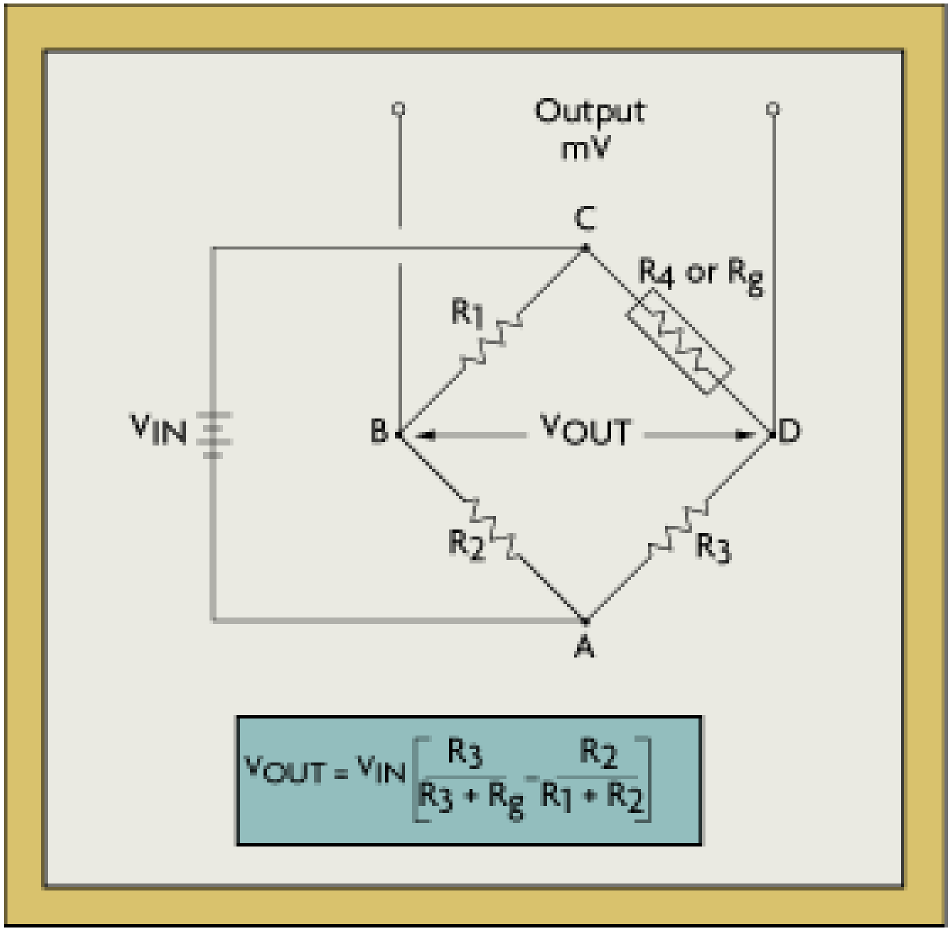


For the sample loaded beam

$$\Delta R / R = \varepsilon \, GF \cong 9E-5$$

Thus, if the unstrained resistor is $R=30.0000000\Omega$,
the strained resistor would be $R_{ST}=30.0027\Omega$

Bridge circuits that is widely used to measure the change in resistance



If $R_1=R_2=R_3=30.00000\Omega$ and $V_{IN}=5V$, then

$V_{OUT}=112.5\mu V$

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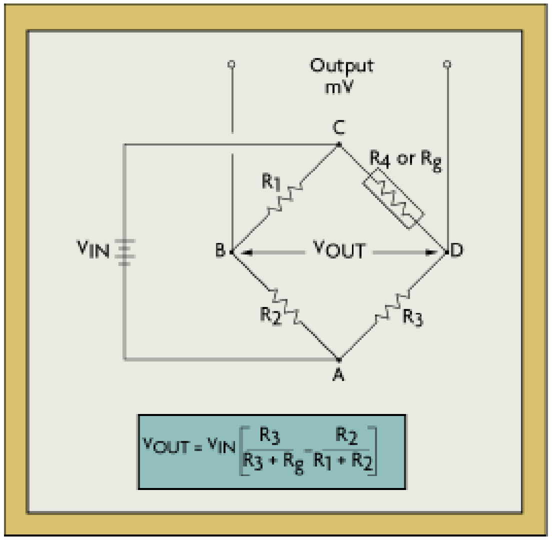
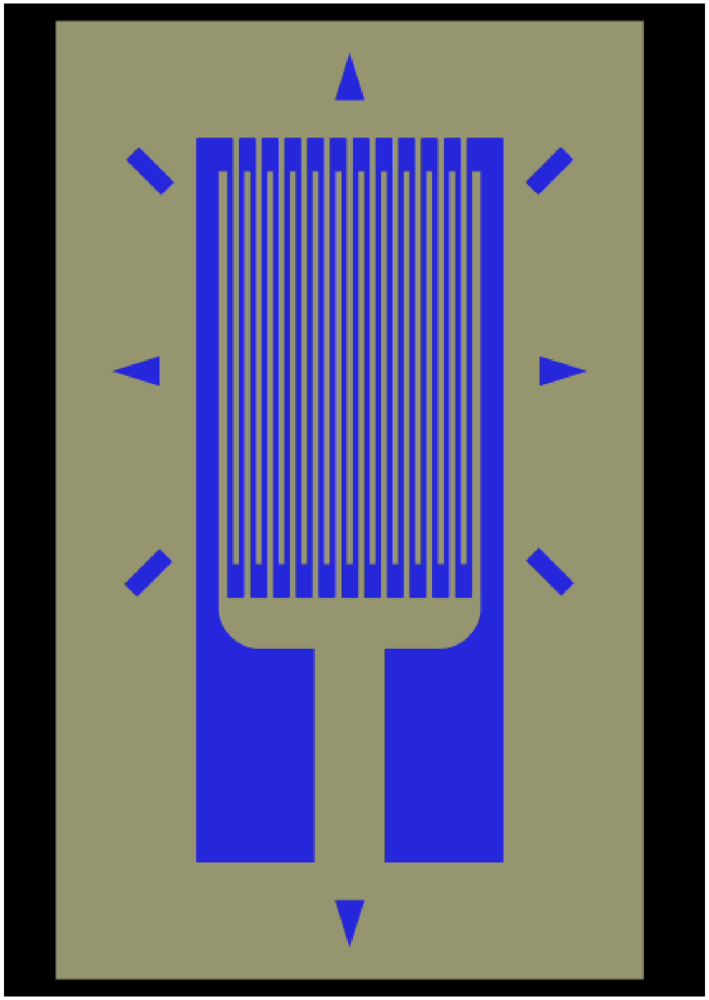


If $R_1=R_2=R_3=30.00000\Omega$ and $V_{IN}=5V$, then

$V_{OUT}=112.5\mu V$

- Often V_{OUT} must be accurately determined (0.01% or better)
- Resistor accuracy is really important
- Temperature or environment can be critically important
- Cost for force (weight) measurement systems can be high

Strain Gauges



Load Cells

Button-Style Compression Load Cells

Load Cells

Signal Processing

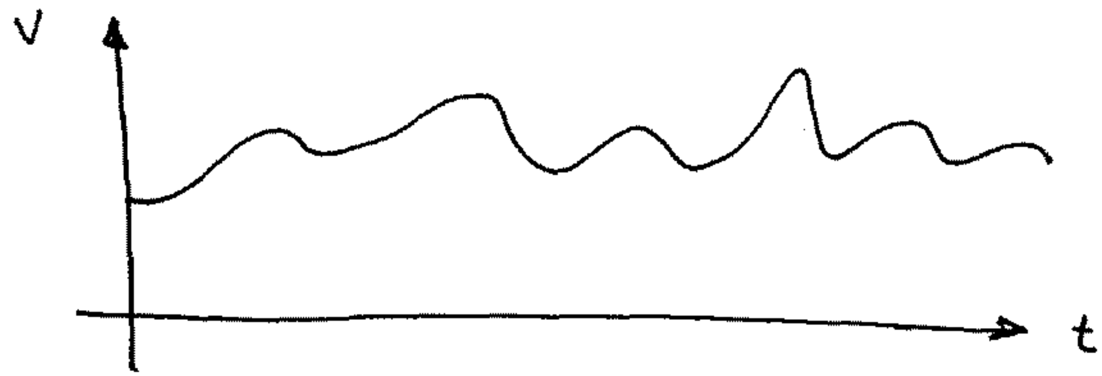
- Often includes a combination of digital and analog circuits

- May contain only digital circuits

- May contain only analog circuits

- Signals can be very small

Signals:

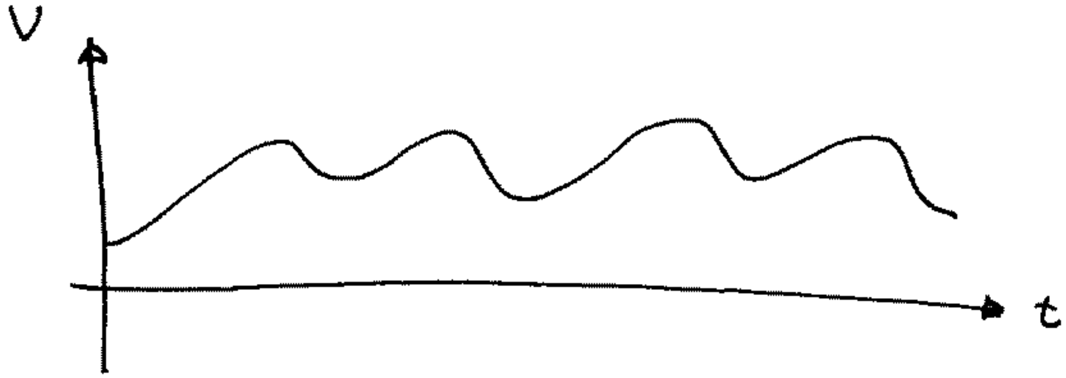


Analog Signal

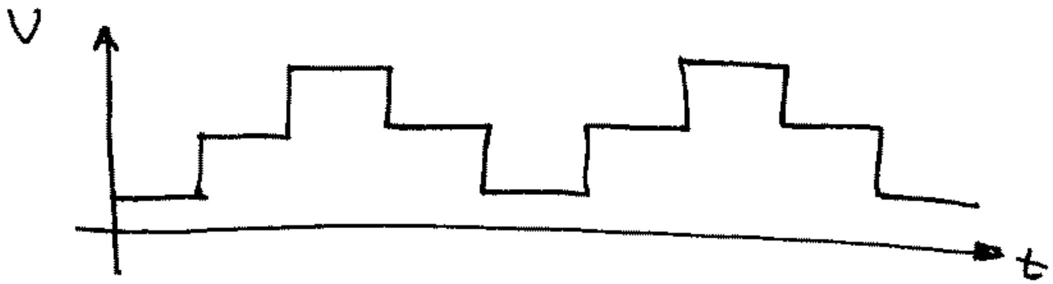
Digital Signal

Analog Signals

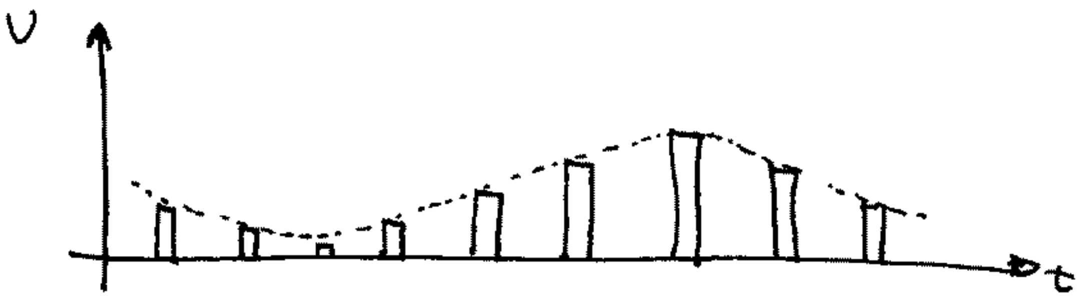
- Continuous time / Continuous Amplitude
- Continuous time / Discrete Amplitude
- Discrete time / Continuous Amplitude
- Discrete time / Discrete Amplitude



CT/CA



CT/DA



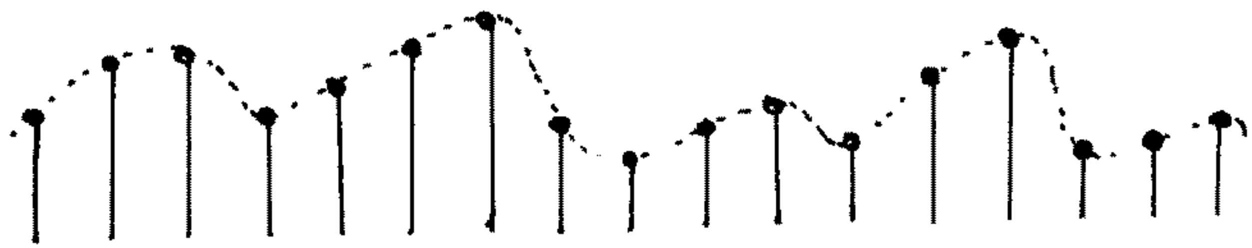
DT/CA

DT/DA

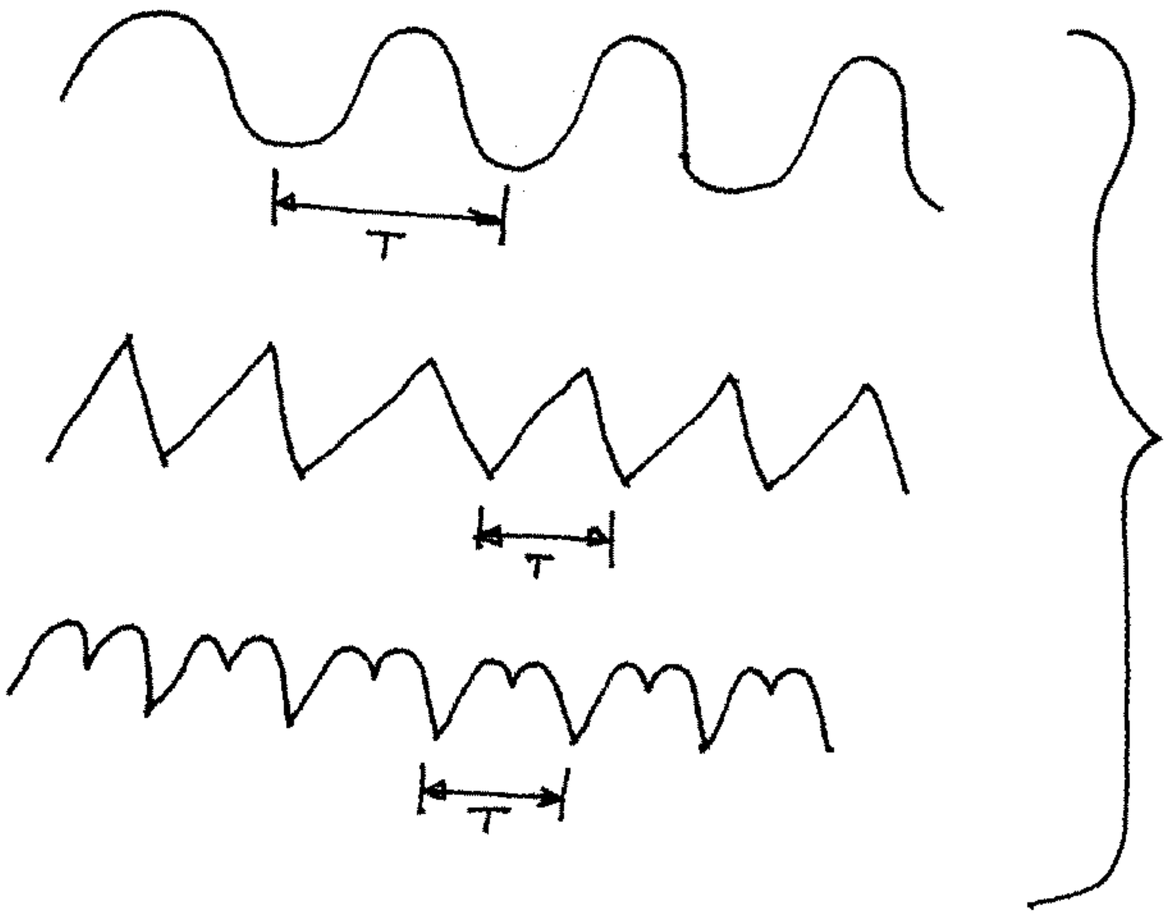
Digital Signals

- Often special case of DT/DA where only two amplitude levels

Discrete Time Signals often Obtained By Sampling Continuous Time / Continuous Amplitude signal.



Many continuous-time signals nearly periodic



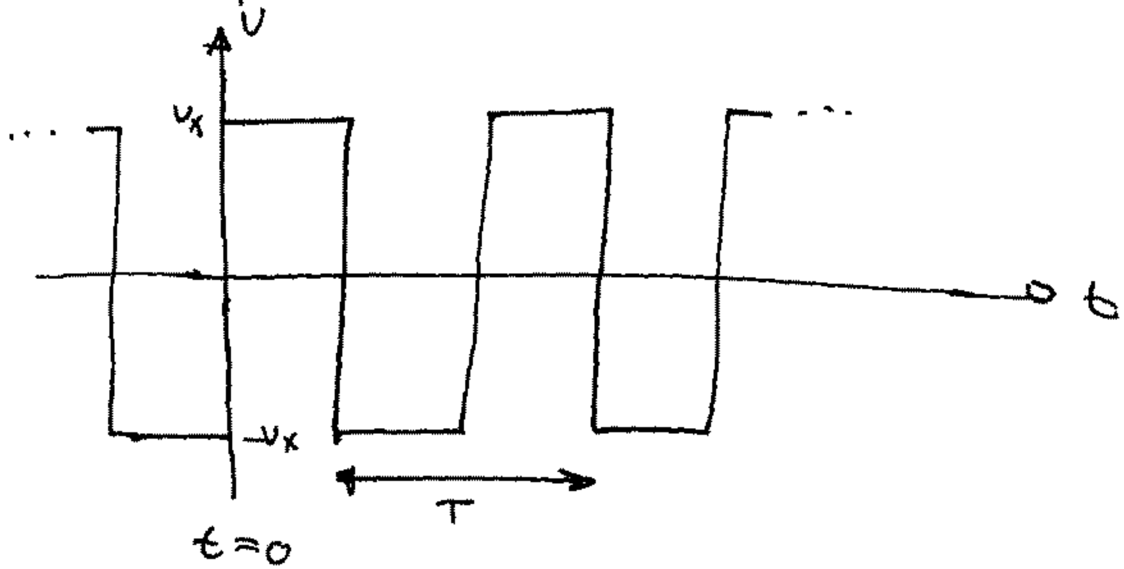
$$V_o(t + kT) = V_o(t)$$

Theorem: If $f(t)$ is periodic with period T, then $f(t)$ can be expressed as $$f(t) = \sum_{k=0}^{\infty} A_k \sin(k\omega t + \Theta_k)$$

where A_k & Θ_k are constants and $\omega = \frac{2\pi}{T} = 2\pi f$

- This is termed the Fourier Series Representation
- $\langle A_k, \Theta_k \rangle_{k=0}^{\infty}$ termed frequency spectrum of $f(t)$
- $f(t) \longleftrightarrow F(\omega)$ represent a transform pair

Example:

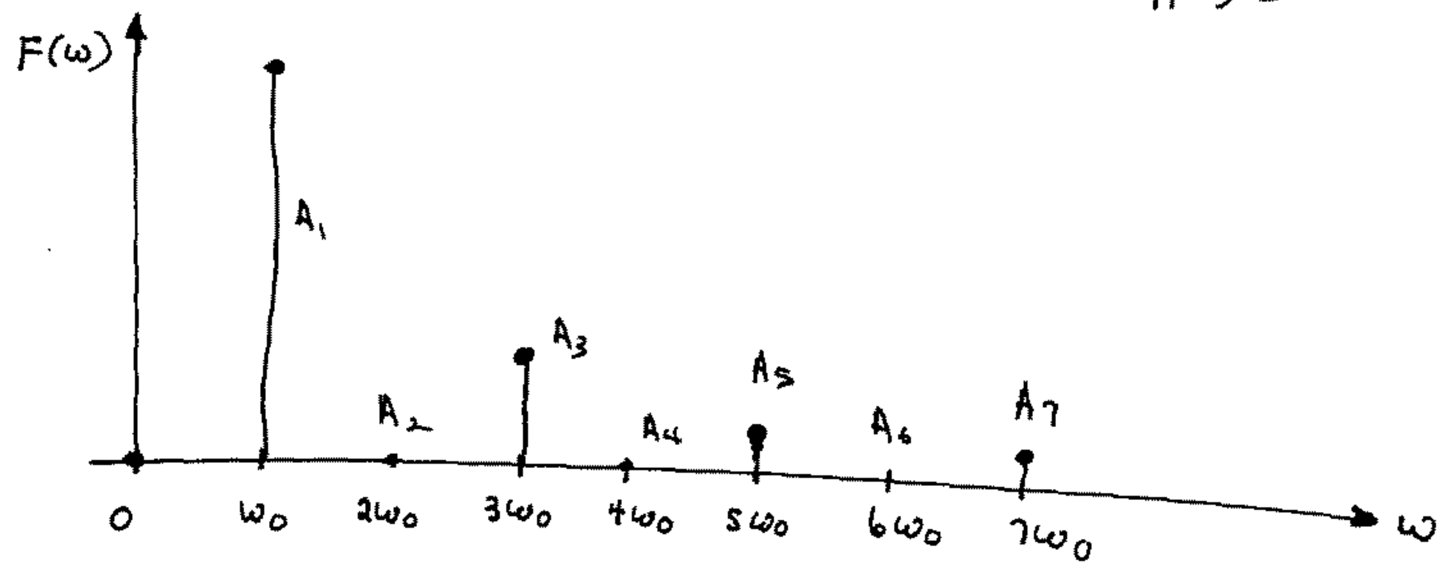


$$V_{sq}(t) = \frac{4V_x}{\pi}\left(\sin\omega_0 t + \frac{1}{3}\sin 3\omega_0 t + \frac{1}{5}\sin 5\omega_0 t + \cdots\right)$$

$$V_{sq}(t) = \frac{4V_x}{\pi}\sum_{\substack{k=1 \\ k\ \text{odd}}}^{\infty}\frac{\sin(k\omega_0 t)}{k}$$

where $\omega_0 = \frac{2\pi}{T}$

$$F(\omega) = \frac{4V_x}{\pi}, 0, \left(\frac{4V_x}{\pi}\right)\frac{1}{3}, 0, \left(\frac{4V_x}{\pi}\right)\frac{1}{5}, 0, \ldots$$



A_1 termed fundamental

A_2 termed second harmonic

⋮

A_K termed the kth harmonic

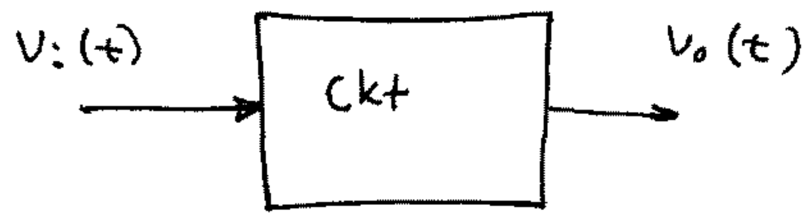
- Nonperiodic Signals Can Also Be Represented in the frequency domain
- Fourier Transform used for this purpose
- Discrete Time Signals Can Also Be Represented in the frequency domain
- Discrete Fourier Transform (DFT) used for this purpose

- Often interested in knowing how sinusoidal signals propagate through a circuit

- Often design circuits so that sinusoidal signals will propagate through the circuit in a predetermined way

- This is the major reason a strong emphasis on analyzing circuits with sinusoidal excitations was made in EE 201

Linearity



- A circuit is linear if

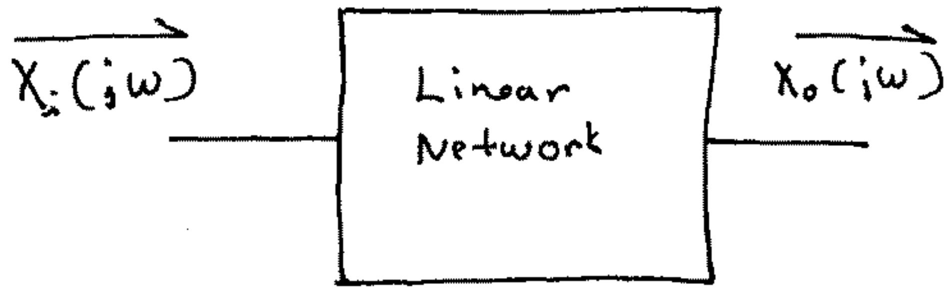
$$V_o(a_1 V_1 + a_2 V_2) = a_1 V_o(V_1) + a_2 V_o(V_2)$$

for all V_1, V_2 and all a_1, a_2

- If a circuit is linear, the dc transfer characteristics is a straight line

- If the dc transfer characteristics are not a straight line, the circuit is not linear

Properties of Linear Networks



$$\frac{\overrightarrow{X_o(j\omega)}}{\overrightarrow{X_i(j\omega)}} = T_p(j\omega)$$

$T_p(j\omega)$ is called the <u>phasor transfer function</u>

$$T_p(j\omega) = |T_p(j\omega)|\, e^{j(\arg(T(j\omega)))}$$

$$= |T_p(j\omega)|\, e^{j\Theta} \qquad \Theta = \arg(T(j\omega))$$

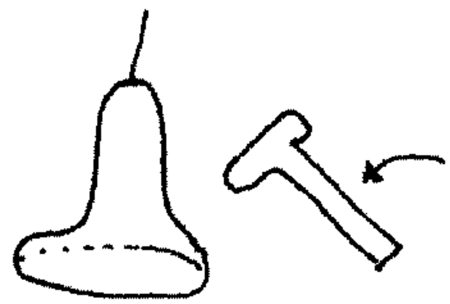
If a sinusoidal input is applied to a linear system, no harmonics are present in the output

If a sinusoidal input is applied to a nonlinear system, harmonic components often appear in the output

If a sinusoidal input is applied to a system and harmonic components appear in the output, the system is nonlinear.

The introduction of harmonics by a nonlinear system introduces distortion <u>and</u> distortion (even small amounts) is very undesirable in many applications

Example:



- Striking a bell results in a nearly sinusoidal waveform that sounds pleasurable
- If the sinusoidal output were altered in an amplifier or by a fault in the bell, the sound would usually be very objectionable