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 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 of the largest sectors in the world economy.

Worldwide sales from semiconductors alone are 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

$\Delta L/L$ is often very small
If $L=100\text{ft}$, the thickness of the beam is 1 foot, and the deflection is 0.1ft, it can be shown that $\Delta L$ is approximately $4E-3$ feet.

Thus, $\Delta L/L$ is approximately $4E-5$.

$\varepsilon = \Delta L/L$ is defined to be the strain on the surface.
Typical GF for foil strain gauges are around 2

Strain gauge characterization

\[ \text{GF} = \frac{\Delta R}{R} = \frac{\Delta L}{L} = \frac{\Delta R}{R} \frac{1}{\varepsilon} \]

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

For the sample loaded beam

\[ \frac{\Delta R}{R} = \varepsilon \cdot GF \approx 9 \times 10^{-5} \]

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

$$V_{OUT} = 112.5\mu V$$
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 $V_{OUT}=112.5\mu V$

- 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
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
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

\[
V_0(t + kT) = V_0(t)
\]
Theorem: If \( f(t) \) is periodic with period \( T \), then \( f(t) \) can be expressed as

\[
f(t) = \sum_{k=0}^{\infty} A_k \sin \left( k \omega t + \Theta_k \right)
\]

where \( A_k \) and \( \Theta_k \) 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 \( f(t) \).
- \( f(t) \leftrightarrow F(\omega) \) represent a transform pair.
Example:

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

\[ V_{sq}(t) = \frac{4V_x}{\gamma} \sum_{k=1}^{\infty} \frac{\sin (k \omega_0 t)}{k} \]

where \( \omega_0 = \frac{2\pi}{T} \)
\[ F(\omega) = \frac{4U_x}{\eta}, 0, \left(\frac{4U_x}{\eta}\right)^{\frac{1}{3}}, 0, \left(\frac{4U_x}{\eta}\right)^{\frac{1}{5}}, 0, \ldots \]

\begin{align*}
A_1 & \text{ termed fundamental} \\
A_2 & \text{ termed second harmonic} \\
\vdots & \\
A_k & \text{ termed the } k\text{th harmonic}
\end{align*}
- 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 EE201
A circuit is linear if

\[ V_o \left( a_1 U_1 + a_2 U_2 \right) = a_1 V_o(U_1) + a_2 V_o(U_2) \]

for all \( U_1, U_2 \) 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

\[ \frac{X_o(\Im \omega)}{X_i(\Im \omega)} = T_p(\Im \omega) \]

\( T_p(\Im \omega) \) is called the phasor transfer function

\[ T_p(\Im \omega) = |T_p(\Im \omega)| e^{j(\arg(T(\Im \omega)))} \]

\[ = |T_p(\Im \omega)| e^{j\Theta} \quad \Theta = \arg(T(\Im \omega)) \]
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 and 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.