UNIT 1: FROM LAST TIME...

Mechatronic Design

- What is Mechatronics?
- Shelton’s Design Rules
- Traditional vs. Integrated design method
- Design trade-offs
UNIT 2:
ELECTRONIC SYSTEMS
AT THE END OF THIS SECTION, STUDENTS SHOULD BE ABLE TO:

- Explain the importance of electronic systems in mechatronics
- Identify basic electronic components
- Analyze simple electronic circuits
- Incorporate basic electronic systems into a mechatronic device
WHY DO ELECTRONIC SYSTEMS MATTER?

- Electrons are very fast!
  - Signals travel through twisted-pair copper wires at 0.4 to 0.7 times the speed of light
- Filter, amplify and switch signals quickly and efficiently
- Interface sensors and actuators with microcontrollers
- Accommodate high-speed signal processing
- Reasonably-priced tools are widely available
TOPICS

- **Part A:** Passive Electronics
- **Part B:** Active Electronics (Diodes)
- **Part C:** Active Electronics (Transistors)
- **Part D:** Analog Interfacing
UNIT 2:
ELECTRONIC SYSTEMS

PART A:
PASSIVE ELECTRONICS
ELECTRONIC COMPONENTS CLASSIFIED AS EITHER “PASSIVE” OR “ACTIVE”

- Passive
  - Does not require an external energy source
  - Stores or dissipates energy
  - Fundamental properties not altered by input
  - Resistors, capacitors, inductors, etc.

- Active
  - Requires an external energy source
  - Fundamental properties vary with input
  - Usually fabricated from semi-conductor materials
  - Diodes, transistors, integrated circuits, etc.

- Others define "active" and "passive" differently...
RESISTORS

Image: http://store.curiousinventor.com/guides/Surface_Mount_Soldering/Resistor/

Image: http://www.circuitstoday.com/working-of-resistors
RESISTORS DISSIPATE ENERGY AS HEAT

Standard power ratings for carbon composition resistors:

- **1/8 W** (~3.0 mm long x 1.8 mm dia.)
- **1/4 W** (~6.3 mm long x 2.2 mm dia.)
- **1/2 W** (~9.2 mm long x 3.2 mm dia.)
- **1 W** (~11 mm long x 5 mm dia.)
- **2 W** (~14 mm long x 6 mm dia.)

Image: [http://www.mikroe.com/old/books/keu/01.htm](http://www.mikroe.com/old/books/keu/01.htm)
WHY DO WE NEED RESISTORS?

1. Limit current flow (mostly)
2. Divide voltages (sometimes)
RESISTOR VALUES ARE NORMALLY INDICATED BY COLOR BANDS

1st Digit
0 1 2 3 4 5 6 7 8 9

2nd Digit
0 1 2 3 4 5 6 7 8 9

Multiplier
1 10 100 1K 10K 100K 1M 10M

Tolerance
± 10% ± 5% ± 2% ± 1% ± 0.5% ± 0.1% ± 0.25%

Silver
Gold
CAPACITORS STORE ENERGY AS AN ELECTRIC FIELD


Capacitance normally given in \( \mu F \) or \( pF \)
A FARAD IS A LARGE UNIT OF CAPACITANCE!

Which is why component capacitance is normally given in $\mu$F or pF:

\[
1 \text{ F} = 10^3 \text{ mF} = 10^6 \mu\text{F} = 10^9 \text{ nF} = 10^{12} \text{ pF}
\]
NON-POLARIZED CAPACITORS

- Ceramic (1 pF – 10 µF) and Film (10 pF – 100 µF)
- Low leakage current; long life
- Can be temperature sensitive
- Useful at high frequencies

POLARIZED CAPACITORS

- Aluminum and Tantalum Electrolytic
- Typically 1 \( \mu F \) – 0.1 F
- No AC without DC bias (may burst)!
- High leakage current; short life

Large capacitors can hold a significant charge for a long time. Treat them with respect!

WHY DO WE NEED CAPACITORS?

1. Energy storage
2. Signal coupling/decoupling
3. Noise filters
4. Tuned circuits
5. Power conditioning
CAPACITORS

473K 25V

Capacitance values for smaller capacitors are usually given in picofarads (pF). If there are just two numbers, read that value in pF. If there are three numbers, use the first two to establish a value in pF, then multiply by $10^X$, where X is the third number. However, if the third digit is 8, divide by 100, and if the third digit is 9, divide by 10. A letter code normally indicates capacitor tolerance, as in the provided table.

<table>
<thead>
<tr>
<th>Letter Code</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>1%</td>
</tr>
<tr>
<td>G</td>
<td>2%</td>
</tr>
<tr>
<td>H</td>
<td>3%</td>
</tr>
<tr>
<td>J</td>
<td>5%</td>
</tr>
<tr>
<td>K</td>
<td>10%</td>
</tr>
<tr>
<td>M</td>
<td>20%</td>
</tr>
<tr>
<td>Z</td>
<td>+80%, -20%</td>
</tr>
</tbody>
</table>

Jeff Shelton – 15 January 2015
INDUCTORS STORE ENERGY AS A MAGNETIC FIELD

Inductance normally given in mH

Image: http://www.eeweb.com/blog/andrew_carter/the-basics-of-inductor
WHY DO WE NEED INDUCTORS?

1. Analog filters
2. Actuators (motors, electromagnets, mechanical switches, etc.)
3. “Choke" off input ripple
INDUCTORS

Inductance values for smaller inductors are usually given in microHenries (\(\mu\text{H}\)). If there are just two numbers, read that value in \(\mu\text{H}\).

If there are three numbers, use the first two to establish a value in \(\mu\text{H}\), then multiply by \(10^X\), where \(X\) is the third number. However, if the third digit is 8, divide by 100, and if the third digit is 9, divide by 10.

If an "R" appears in the code, it acts as a decimal point, and there is no multiplier.

A letter code normally indicates inductor tolerance, as in the provided table.
ANALYZING PASSIVE ELECTRONIC CIRCUITS

Simple equations allow us to determine rate at which energy is being stored or dissipated
ELECTRON FLOW

Benjamin Franklin (1750) visualized electricity as an invisible fluid that flowed from areas of excess charge (positive) to areas with a deficiency of charge (negative). Thus, a large number of theoretical developments were based on what we now call "conventional" flow.

\[ + \quad V_s \quad R_L \quad - \]

"Conventional" current flow
ELECTRON FLOW

Unfortunately, Franklin guessed incorrectly! Electrons flow from a negative charge to a positive charge. For most circuit analysis, this is immaterial. However, to understand semiconductor theory in later lessons, we need to recognize the true direction of electron flow.
**BASIC RULES (REVIEW)**

Resistors
- $V = IR$

Capacitors
- $I = C \frac{dv}{dt}$

Inductors
- $V = L \frac{dl}{dt}$

Kirchhoff's Laws
- $\sum_{k=1}^{n} I_k = 0$ at any node
- $\sum_{k=1}^{n} V_k = 0$ around any closed circuit
Ohm’s Law

\[ V = IR \]
CAPACITORS

Charge–Voltage Relationship:

\[ Q = CV \]

Current–Voltage Relationship:

\[ I = C \frac{dV}{dt} \]
INDUCTORS

Current–Voltage Relationship:

\[ V = L \frac{dI}{dt} \]
KIRCHHOFF'S CURRENT LAW (KCL)

- \( \sum_{k=1}^{n} I_k = 0 \) at any node

- Elements in series experience the same current

\[ i_1 + i_2 + i_3 = 0 \]
QUICK CHECK

What is the current through $R_c$?
Kirchhoff's Voltage Law

- $\sum_{k=1}^{n} V_k = 0$ around any closed circuit

- Elements in parallel circuit experience the same voltage drop
QUICK CHECK

What is the voltage across $R_C$?
Circuit Analysis

A voltage divider partitions voltage in a linear manner across the divider elements.

\[ V_{out} = \frac{R_2}{R_1 + R_2} \cdot V_{in} \]
Determine the relationship between input and output signals

- Input: $V_s$
- Output: $V_C$

Diagram:

![Diagram](image URL)

- $R = 10k$
- $C = 5\mu F$
**STEP 1: APPLY KVL TO THE LOOP FORMED BY** $V_S$, $V_R$, AND $V_C$

\[-V_S + V_R + V_C = 0 \quad \Rightarrow \quad V_R = V_S - V_C\]
**STEP 2: APPLY OHM’S LAW AND KCL**

\[
\frac{V_s - V_c}{R} = i_r = i_c = C \frac{dV_c}{dt}
\]

\[\text{R} = 10k \quad \text{C} = 5 \text{uF}\]
STEP 3: SUBSTITUTE AND SIMPLIFY

\[
\frac{V_s - V_c}{R} = C \frac{dV_c}{dt}
\]

\[
V_s = RC \frac{dV_c}{dt} + V_c
\]

\[
(RC)\ddot{V}_c + V_c = V_s
\]

\[
\tau \ddot{x} + x = Ky
\]
STEP 4: INTERPRET MEANING

For canonical form $\tau \dot{x} + x = Ky$:

- **Cutoff Frequency:**

  $$\omega_{co} = \frac{1}{\tau} = \frac{1}{RC}$$

- **Magnitude Gain:**

  $$|G(j\omega)| = \frac{K}{\sqrt{1 + (\omega \tau)^2}} = \frac{1}{\sqrt{1 + (\omega RC)^2}}$$

- **Phase Shift:**

  $$\angle G(j\omega) = - \tan^{-1}(\omega \tau) = - \tan^{-1}(\omega RC)$$
ACTION ITEMS

1. Submit student questionnaire (or drop course) by 5 pm on Friday, 16 January
2. Purchase Arduino Uno (R3) and USB cable
3. First lab either 1/20 or 1/21