Sections 8.2 - 8.5
Position, Velocity, and Acceleration (PVA) Sensors

**PVA Sensor Specifications**

Good website to start your search for sensor specifications: www.globalspec.com
- search for specifications
- spec sheets provided in PDF form

**Potentiometers**

- potentiometers (“pots”) are electrical resistance elements made in both
  - ___ & ___ form
- a mechanical motion of the wiper changes the output voltage in proportion to the wiper displacement

**LVDT**

- LVDT - L___ V___
  D___ T___
  - External AC voltage applied to a primary coil
  - AC voltages of the same frequency are induced in two secondary coils
  - The ___ in the two secondary voltages is proportional to the position of a ferromagnetic core (“armature”)

**Optical Encoders**

- Optical sensing of encoder position is used
- A light source (LED or ___) is placed on one side of the encoder disk
- A light detector (___) is on the other side

**Absolute Encoder**

- gives a ___ number of ___ patterns spread uniformly over 1 revolution.
- 3 output lines (or bits) and each line can be either “solid” or “clear”
- there are ___ = ___ patterns.

**Incremental Encoders**

- Two sensors (usually optical) are mounted such that one is halfway blocked by the “solid” area (Channel A) while the other is in the middle of the “clear” area (Channel B).
- Transitions between light/dark at A&B are counted (“___”) as disk rotates
- Direction of rotation detected by whether A goes dark first (___) or B goes dark first (___)
Question

• How could we use an inexpensive 1000 count/rev rotary encoder to measure linear position?

DC Tachometer

► a DC tachometer works in a similar fashion to the LVT, except
  ▪ magnet is fixed ("stator")
  ▪ "coil" of wire rotates inside the magnet
  ▪ produces a voltage ________________________________ to the angular ________________________________

► a DC motor works similarly, but
  ▪ voltage/current is input to wire coil, and
  ▪ velocity/torque is output from motor!

Timer-based Methods

► Definition of velocity is

► fix _____, measure _____ to determine velocity

OR

► fix _____, measure _____ to determine velocity

Event Counter / Timer

► Simply “counts” an external “event” - like closing a switch

► Usually counts transitions - from “off” to “on” or from “low” to “high”

► A ______ is an event counter which uses a ________ signal at known frequency
  ▪ need events to count
  ▪ need signal to start & stop the count

Average Velocity Timer Method

► Count events per fixed time interval
  ▪ the fixed time interval (1 sec) starts/stops counting

8 “lobes” on rotating wheel
**Average Velocity Timer Method**

"Clock" at 1000 Hz

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>...</th>
<th>997</th>
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<td>T1</td>
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ω = \frac{N \text{ lobes}}{1 \text{ sec}} \times \frac{1 \text{ rev}}{8 \text{ lobes}} \rightarrow \omega = \frac{\text{lobes}}{1 \text{ sec}} \times \frac{1 \text{ rev}}{8 \text{ lobes}} \times \frac{60 \text{ sec}}{1 \text{ min}} \rightarrow \text{RPM}

**“Instantaneous” Velocity Timer Method**

- Count known clock between events
- the external event starts/stops counting

Fix clock at 100 kHz
- Count number of clock cycles, k, from one lobe to the next

ω = \frac{1/8 \text{rev}}{k \text{ clocks}}

8 “lobes” on rotating wheel

**Instantaneous Velocity Timer Method**

"Clock" at 100,000 Hz

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | ... | 234 | 235 | ...
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<tr>
<td>Timing counter</td>
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ω = \frac{1/8 \text{rev}}{k \text{ clocks}} \times \frac{100,000 \text{ clocks}}{\text{sec}} \rightarrow \omega = \frac{1/8 \text{rev}}{\text{clocks}} \times \frac{100,000 \text{ clocks}}{\text{sec}} \times \frac{\text{rev}}{\text{sec}} \rightarrow \text{RPM}

**Handheld Tachometer**

- How does this device work?

**Velocity Measurement**

Optical Sensor

LED

Photo-transistor

+5V

~330Ω

+5V

~10kΩ

E₀
Position, Velocity, and Acceleration Sensors

Sketch “scope” output for 1 rev

\[1 2 3 4 5 6 0 1 2 3 4 5 6\]

\(\omega = 750 \text{ RPM}\)

16 slots/revolution

Magnetic Reed Switch

Magnet

\(+5V \quad E_0 \sim 5V\)

\(+5V \quad E_0 \sim 0V\)

Accelerometers

► Seismic / strain-gage based
► Piezo
► Piezo

Piezo-resistive Accelerometers

► Electrical output is ________________ to the ________________ motion of base.
► Similar to a strain-gauge accelerometer, but
  ▪ lighter weight,
  ▪ smaller size,
  ▪ higher output, and
  ▪ higher frequency response

Piezoelectric Accelerometers

► Compared to other types, piezoelectric accelerometers have advantages:
  ▪ ____________________________ - no external power required
  ▪ ruggedness- ____________________________
  ▪ high ____________________________ ratio-
    extremely wide dynamic range
  ▪ wide temperature range - a function of the crystal material used
  ▪ long term stability - proven track records

Typical Frequency Response

as shown in the Wilcoxon handout,
Vibration Measurement
See Section 25 of ME 360 Course Notes

Why monitor vibration?
► Vibrations produced by an industrial machine are a direct indication of the machine’s health
  ▪ monitoring programs record the machine’s ____________________ history
  ▪ allows ____________________ of problems and shuts down a machine before serious damage
► Vibration monitoring is also widely used as a diagnostic tool to determine the cause and location of a problem, and how to fix it.

How to choose between displacement, velocity and acceleration sensors.
► The three primary types of motion detected by vibration monitors are
  ▪ d__________________, v__________________, and a__________________.
► Choice between them depends on
  ▪ ____________________ of interest, and signal levels involved.

Displacement sensors
► Used for _____ frequency (__________ Hz) measurements only and for measuring very __________ amplitude displacements.
► Employed in applications such as shaft motion and clearance measurements.
► Traditionally displacement monitors have employed non-contacting proximity sensors and eddy probes.

Velocity sensors
► Used for ____________________ frequency (___________________ Hz) measurements.
► Act as a low-pass filter (reduce __________ frequency signals)
► Traditional velocity sensors employ an electromagnetic sensor to pick up the velocity signal

Acceleration sensors
► Used for the _______________ frequencies (____________________________)
► Three types of accelerometers:
  ▪ piezoelectric - Section 8.5.1
  ▪ strain gage (piezoresistive) - Section 8.5.2
  ▪ servo accelerometer - Section 8.5.3

Selection of PVA Sensors
► Several criteria can play a role in the selection of an appropriate sensor for a given PVA measurement task
  ▪ ____________________ of operation
  ▪ ____________________, repeatability, accuracy
  ▪ Analog or digital output
  ▪ Sensor size and weight
  ▪ Signal conditioning requirements
  ▪ ________________ response (or bandwidth)
Range of Operation
► Use sensor with specified range that ______ closely matches your ________________
  ▪ don’t use a yardstick (0-36 inches) to measure thickness of thin aluminum beam
  ▪ don’t use micrometer (0-1 inch) to measure width of room
  ▪ don’t use a 0-50 lb load cell to measure forces < 1 lb

Linearity, Repeatability, Accuracy
► ____________________________
carefully - be sure what you are buying
  ▪ in some cases accuracy is vital, in others repeatability is most important
► ______________ costs money - don’t buy more than you need for measurement task
► Note that ______________ is often specified instead of repeatability or accuracy

Analog / Digital Output
► What will be used to “read” the sensor output?
  ▪ Many ______________ outputs can be read with DMM or data acquisition systems (extra costs!)
  ▪ Most ______________ outputs can be directly read by computer
  ▶ but may not be convenient for human reading!

Sensor Size and Weight
► Will the specified sensor fit in the space available?
► Does the ______________ of the sensor significantly affect the system you are trying to measure?
  ▪ ______________ sensor negligible when measuring Space Shuttle acceleration
  ▪ ______________ sensor not negligible when measuring acceleration of hard drive read head

Signal Conditioning
► Consider ______________ system - not just the ______________/transducer
  ▪ is highly regulated ______________ required?
  ▪ is the output DC or AC (requires conditioning)
  ▪ does the output require ______________ before measurement?

Frequency Response
► “most” sensors act like ______________ systems (i.e., response is not ______________).
  ▶ if input frequencies are much less than sensor bandwidth
    \[ \omega_{\text{input}} \ll \omega_{\text{bandwidth}} \]
    ▶ can ignore __________ “filter” effects
  ▶ if input frequencies are same as or more than sensor bandwidth
    \[ \omega_{\text{input}} \approx \omega_{\text{bandwidth}} \]
    ▶ cannot ignore __________ “filter” effects