Sections 8.2 - 8.5

Position, Velocity, and
Acceleration (PVA) Sensors

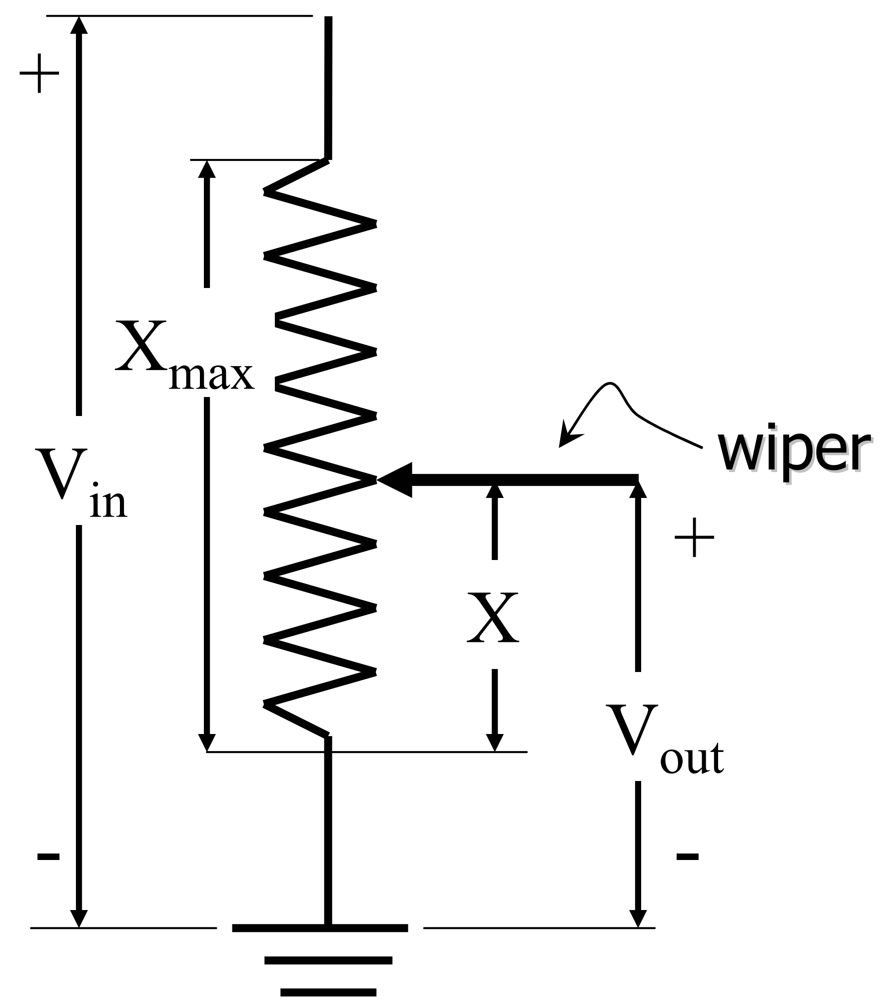
PVA Sensor Specifications

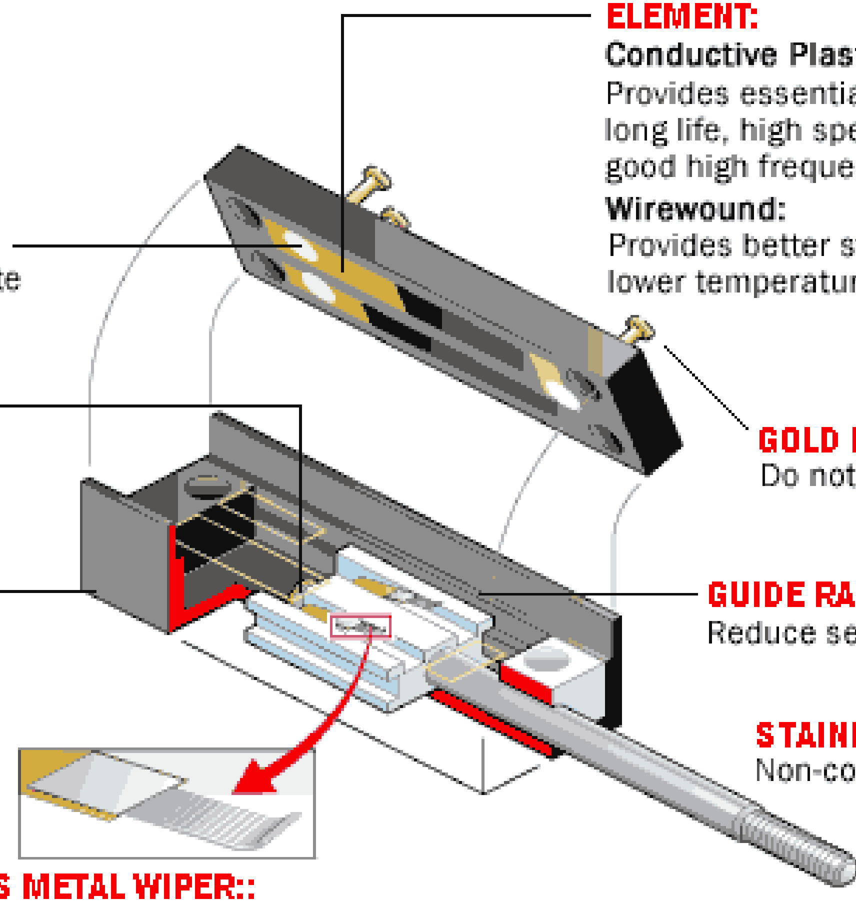
Two websites to start your search for sensor specifications:

- www.globalspec.com
  - search for specifications
  - spec sheets provided in PDF form
- www.motioncontrol.com
  - primarily links to manufacturer

Potentiometers (pp. 232-233 of text)

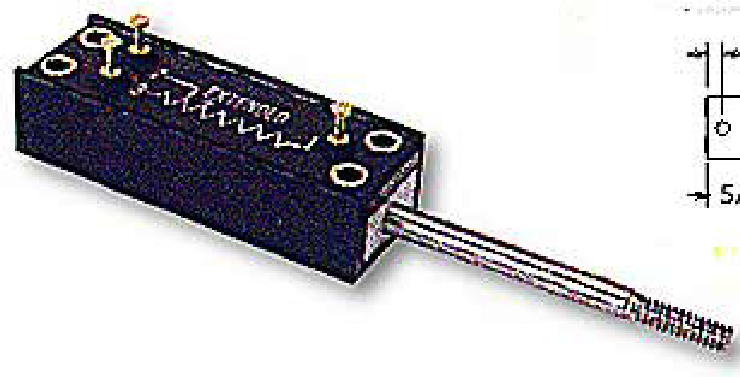
- potentiometers ("pots") are electrical resistance elements made in both _linear_ & _rotary_ form
- a mechanical motion of the wiper changes the output voltage in proportion to the wiper displacement

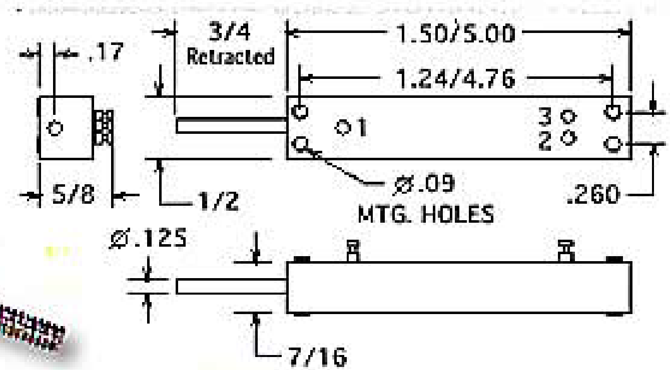




http://www.mod-pot.com

LCP12 Conductive Plastic Precision Linear Motion Potentiometer





Stroke length	Standard Resistance Values*	Power Rating (watts)
12	500, 1K, 2K, 5K, 10K	.2
25	500, 1K, 2K, 5K, 10K	.4
50	500, 1K, 2K, 5K, 10K	.7
100	500, 1K, 2K, 5K, 10K	1.2

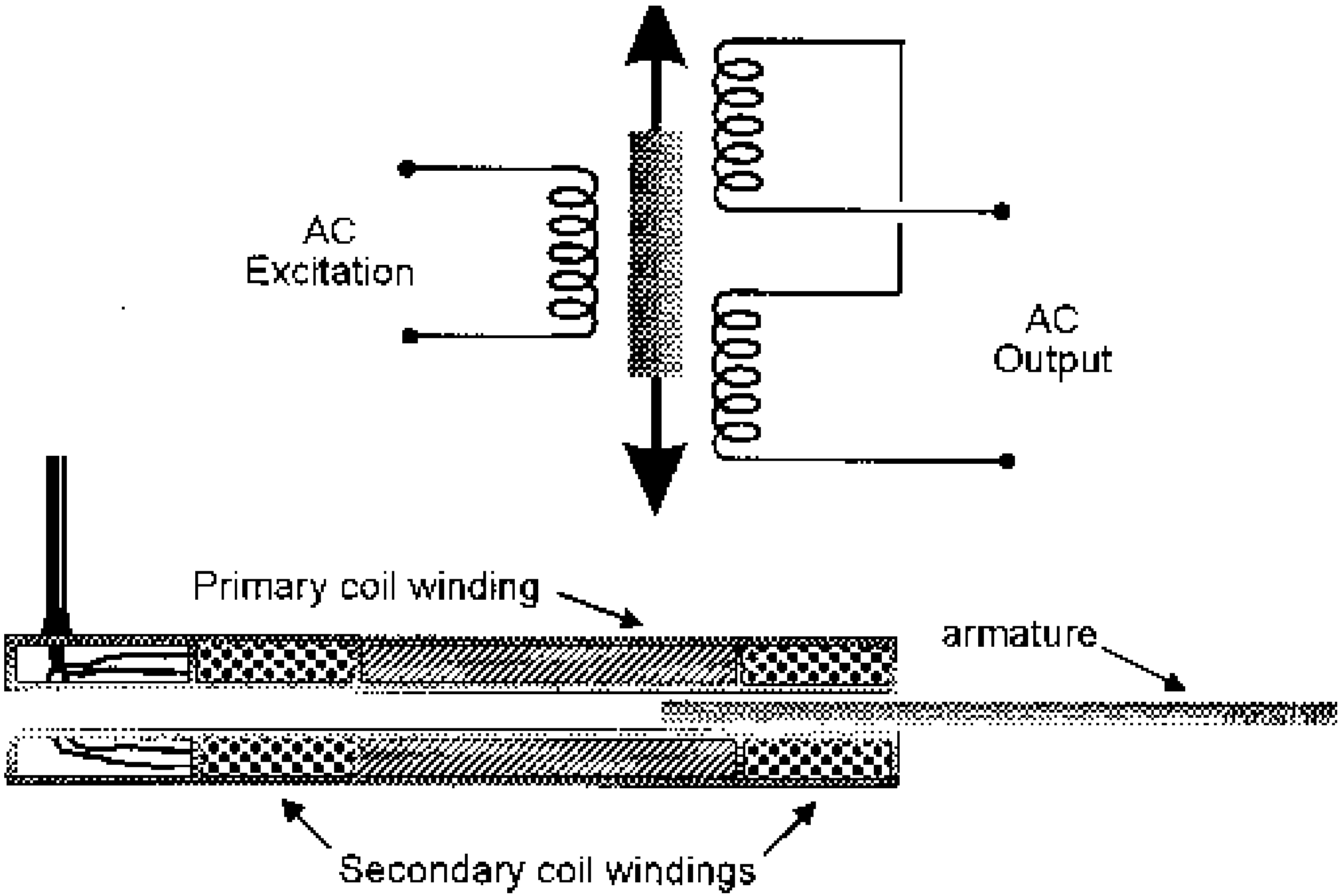
- Resistance Tolerance: 20% Standard
- Linearity Tolerance 0.5% to 1.5% Standard
- Life Expectancy: 20 million strokes
- Recommended for:
  - Medical Equipment (non-life support)
  - Industrial
  - Test & Lab Equipment

http://www.mod-pot.com

LVDT (pp. 233-236 of text)

- LVDT – Linear Variable Differential Transformer
  - External ___ voltage applied to a primary coil
  - ___ voltages of the same frequency are induced in two secondary coils
  - The difference in the two secondary voltages is proportional to the position of a ferromagnetic core (“armature”)

LVDT Construction - Fig. 8.11

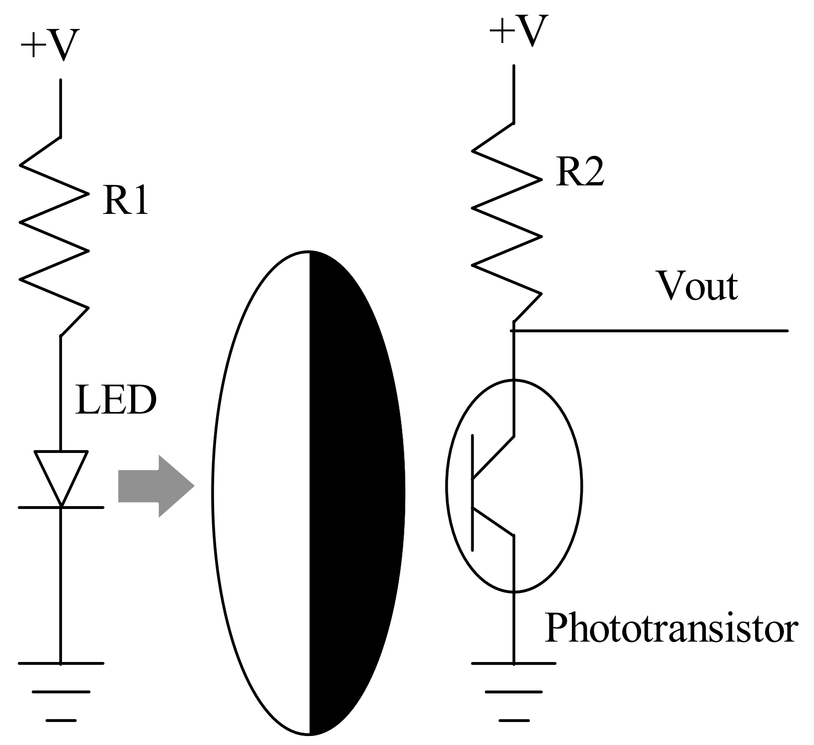


Blank Slide

- Functioning of an LVDT:

Optical Encoders

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



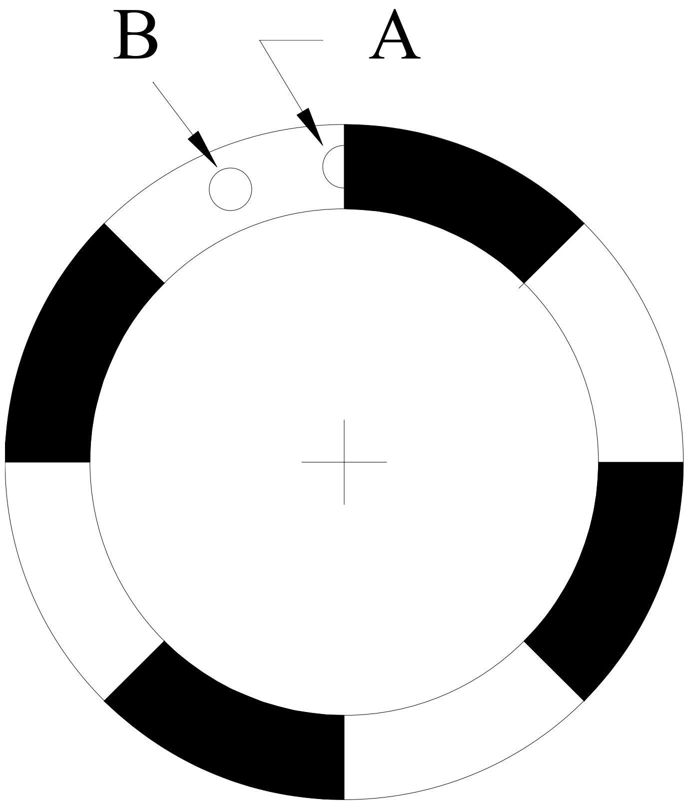
(What's a transistor?)

Blank Slide

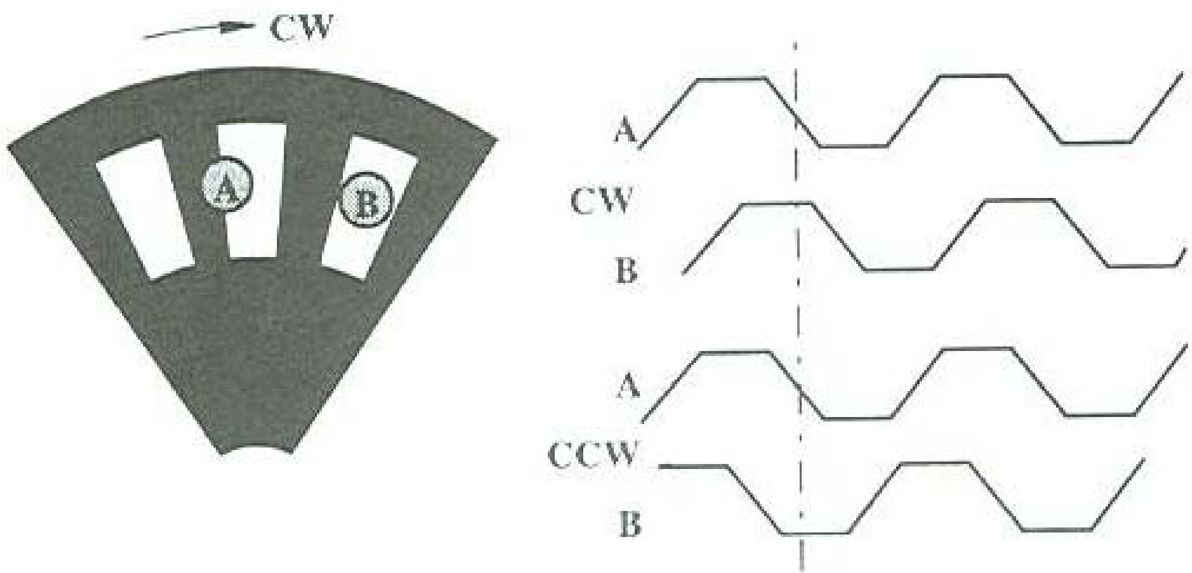
- Functioning of a transistor:

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).

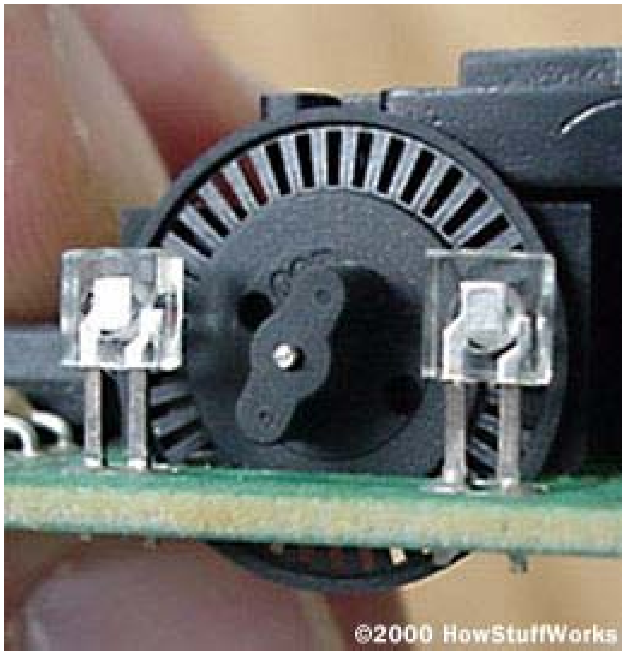


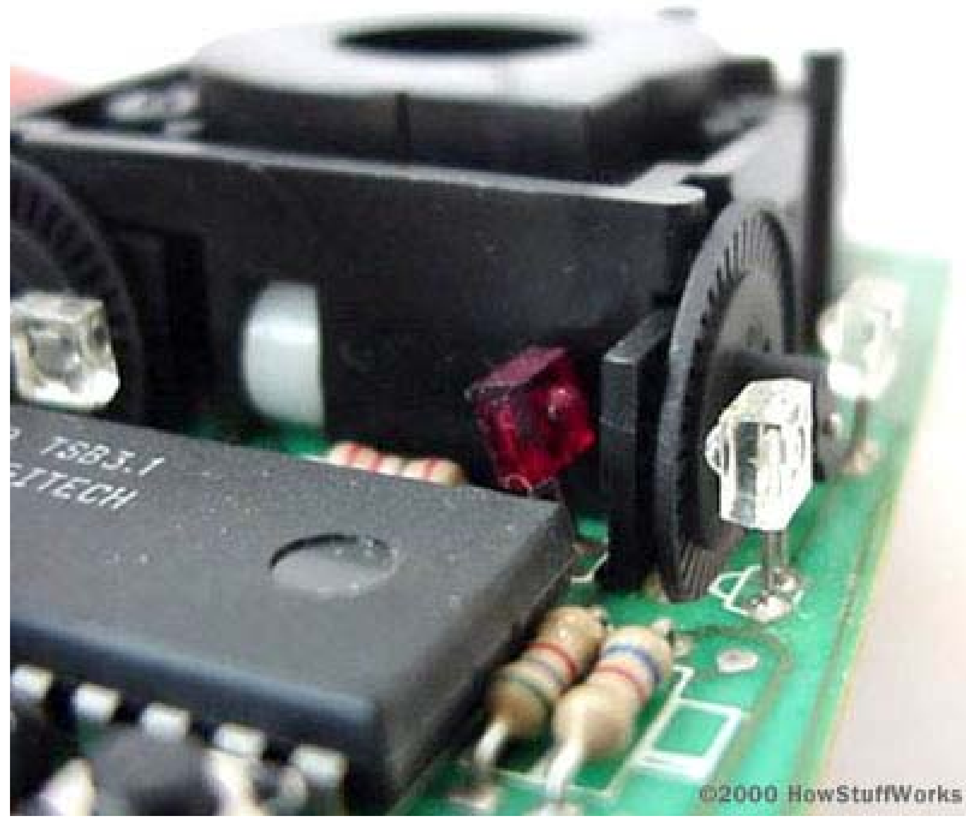
How it works



Fraden, Jacob, Handbook of Modern Sensors, AIP Press, Woodbury, New York, 1997.

Ever seen one of these?





http://www.howstuffworks.com

What else do you need?

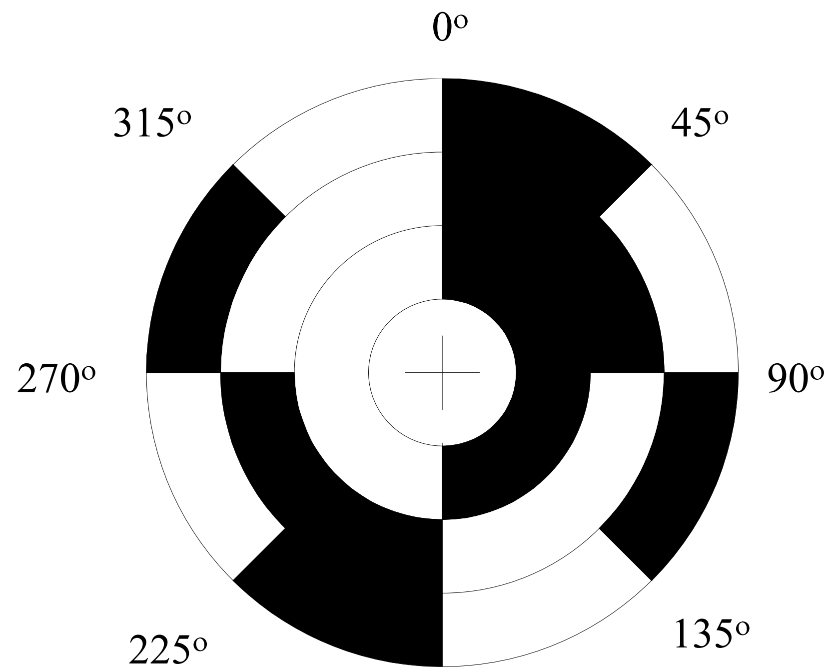
- Encoder chip:

http://www.howstuffworks.com

- Converts encoder pulses into 8-bit (or more?) “words” that translate to x- and y-position.

Absolute Encoder

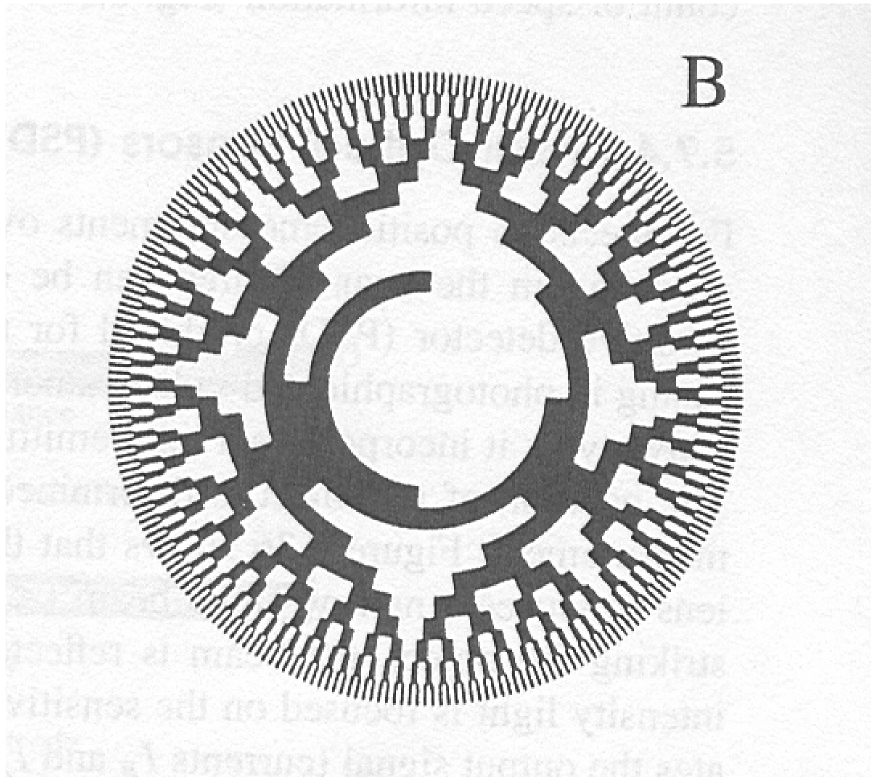
- gives a finite number of unique patterns spread uniformly over 1 revolution.
- 3 output lines (or bits) and each line can be either "solid" or "clear"
- 3-bits = 8 patterns.



(How many phototransistors do you need??)

(Are you limited to three lines?)

Are you limited to three lines?



Fraden, Jacob, Handbook of Modern Sensors,
AIP Press, Woodbury, New York, 1997.

Now, how many phototransistors do you need?

Question #1 - Measure linear position of a cylinder

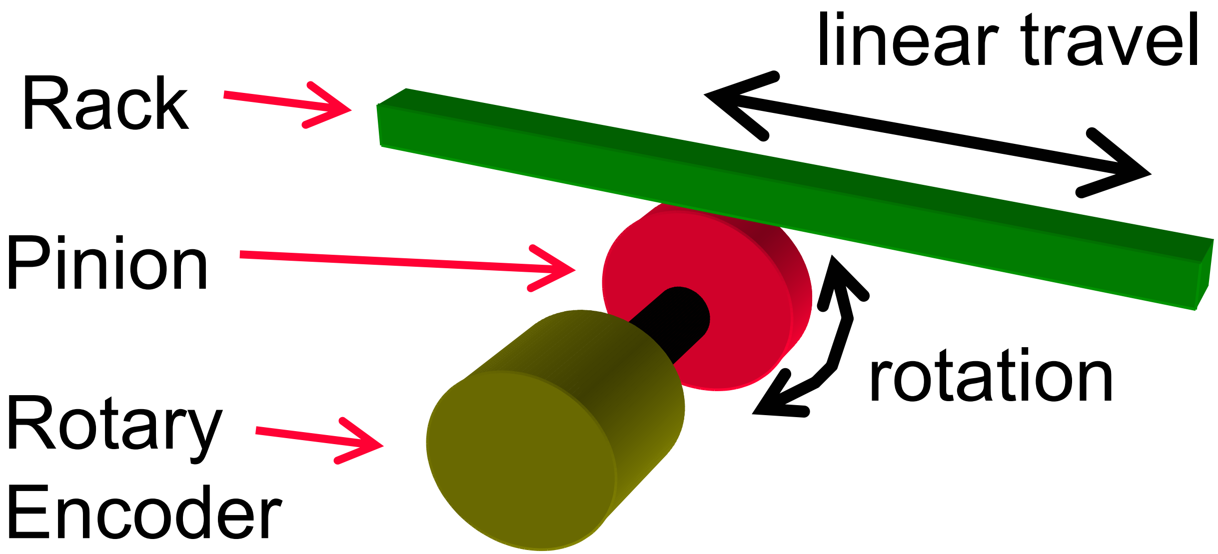
- Desired stroke of 1 inch
- At least 1% linearity / accuracy
- Possibilities:
  - Linear potentiometer
  - LVDT
  - Linear encoder
  - Inductive (non-contact)
  - Ultrasonic (non-contact)

Question

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

Question

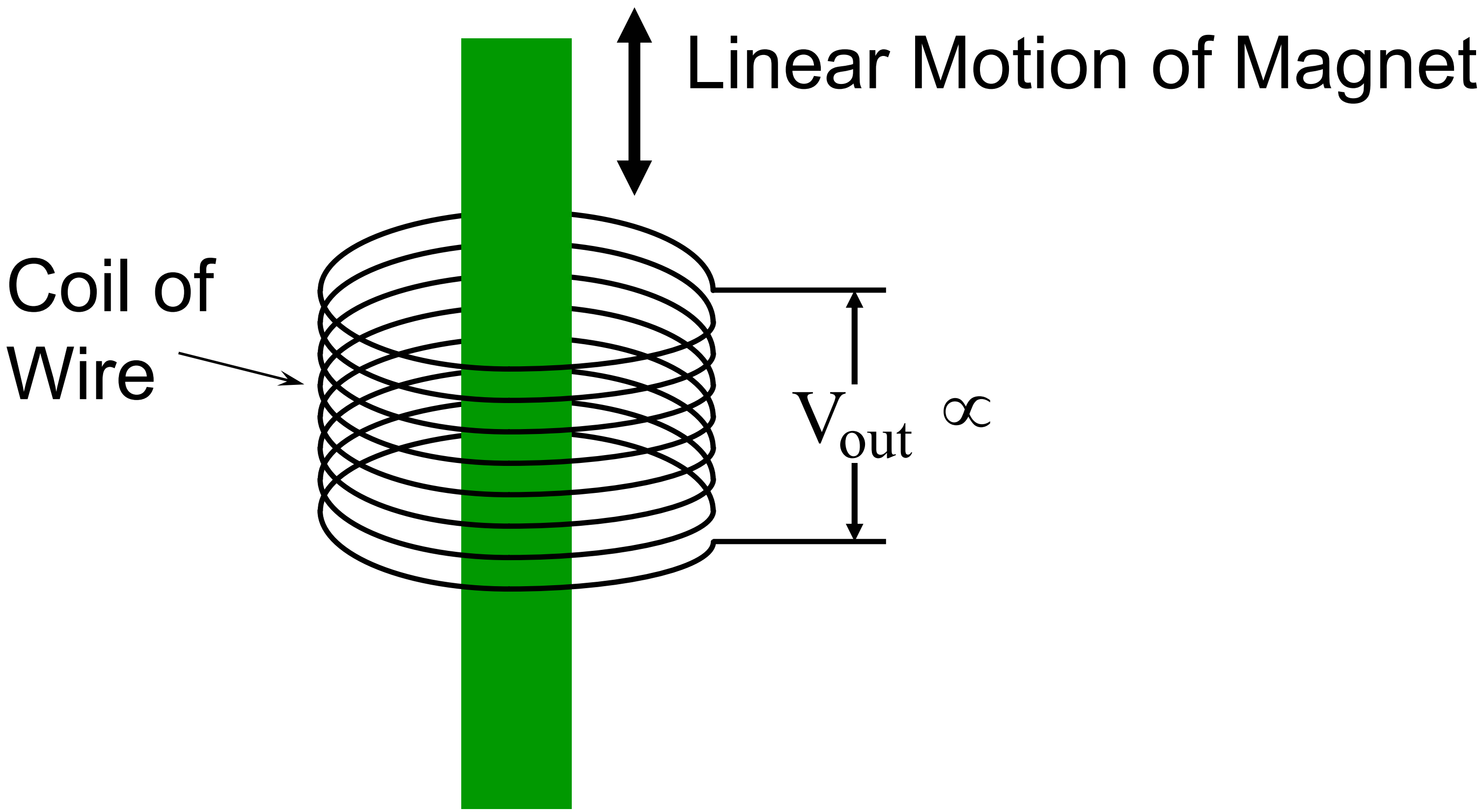
- With a "perfect" gear (or pulley) with a pitch diameter of 0.937 inches, what is the uncertainty in any linear position measurement?



Velocity Sensing

- Analog Methods
- Digital / Timer Methods

Linear Velocity Transducer – LVT (pp. 206-207 of text)



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 proportional to the angular velocity
- a DC <u>motor</u> works similarly, but
  - voltage/current is input to wire coil, and
  - velocity/torque is output from motor!

Timer-based Methods

- Definition of velocity is

$$v =$$

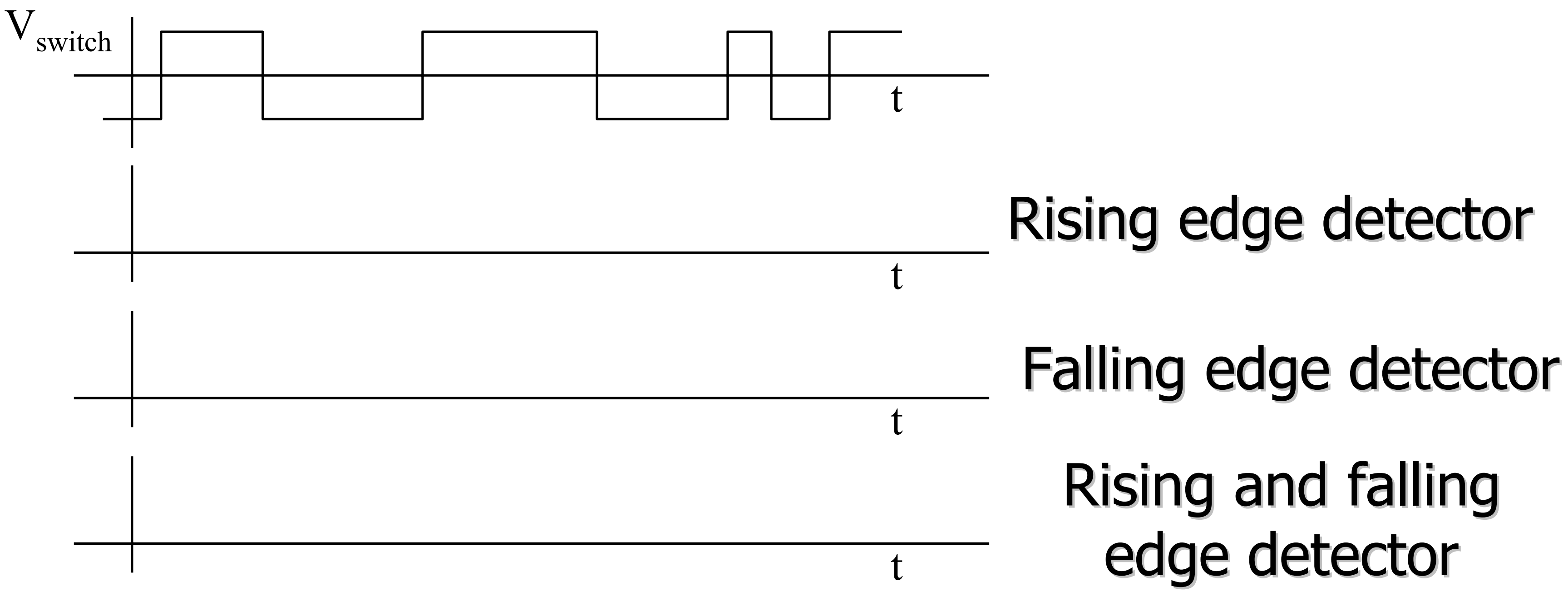
- fix ____, measure __ to determine velocity

OR

- fix __, measure ____ to determine velocity

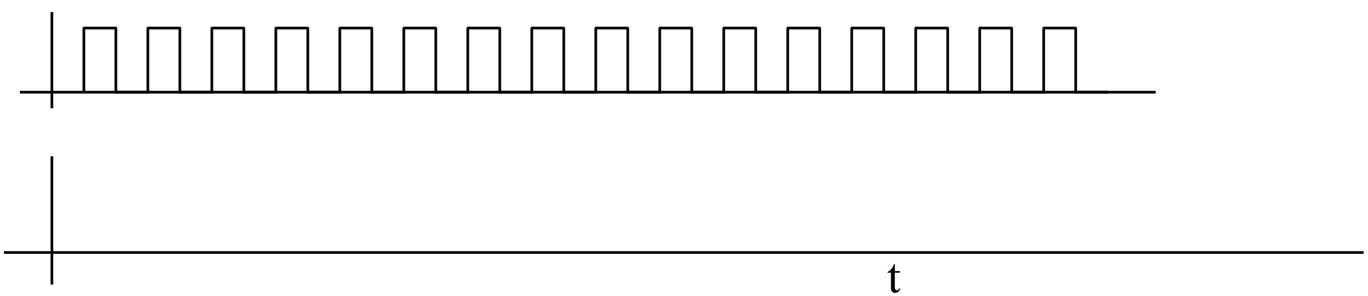
Event Counter / Timer

- Simply "counts" an external "event" - like <u>closing a switch</u>
- Usually counts transitions - from "off" to "on" or from "low" to "high"



Event Counter / Timer

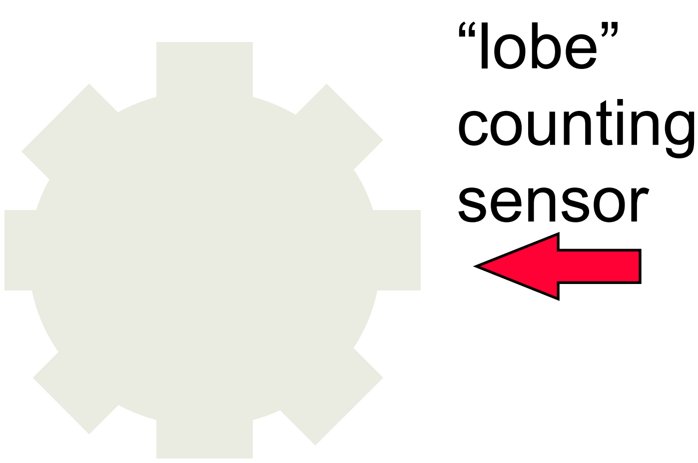
- A “timer” is an event counter which uses a “clock” signal at known frequency
  - need events to count
  - need signal to start & stop the count



Average Velocity Timer Method

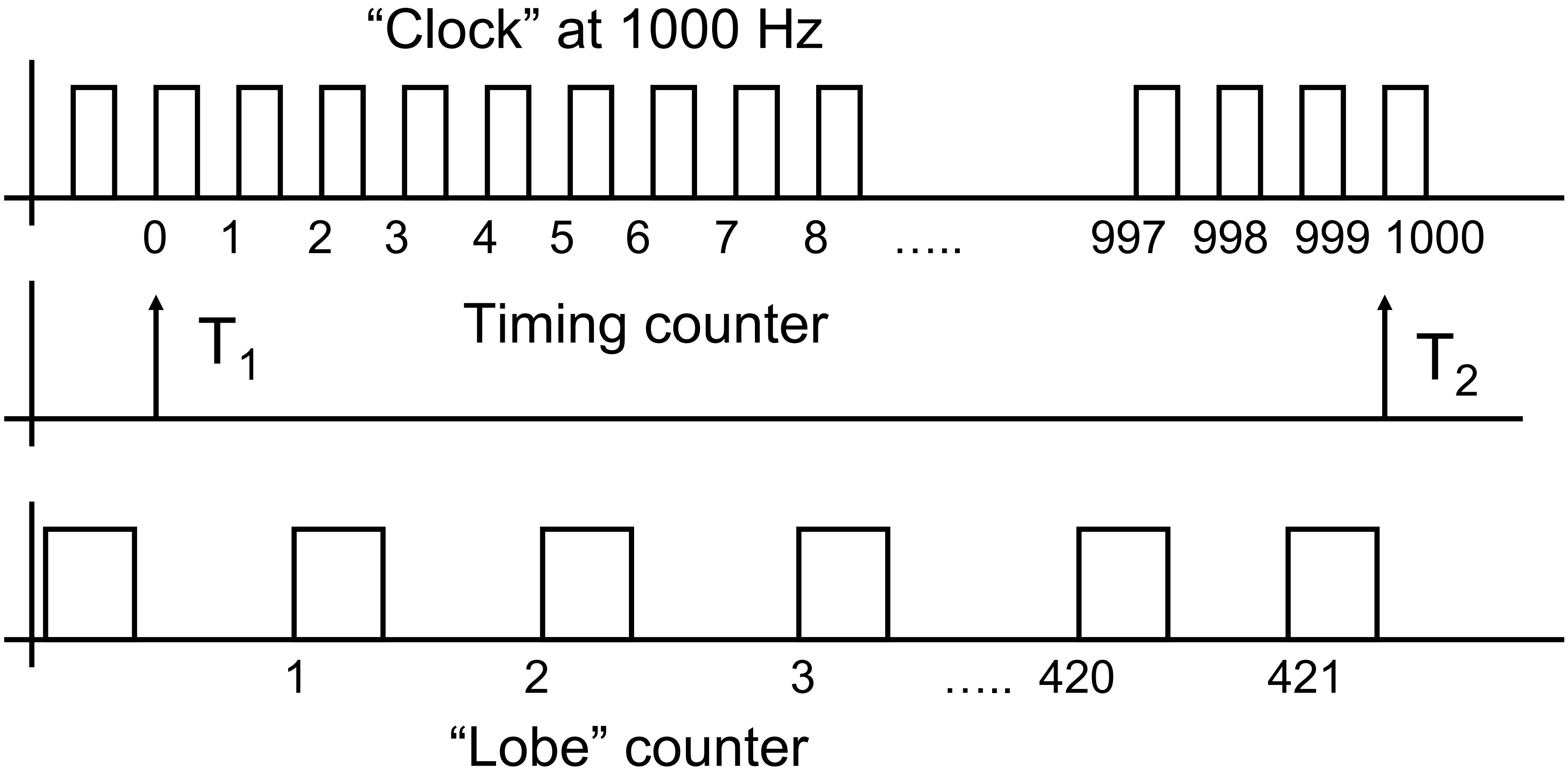
- Count events per fixed time interval
  - the fixed time interval (1 sec) starts/stops counting

$$\omega =$$



8 “lobes”on rotating wheel

Average Velocity Timer Method

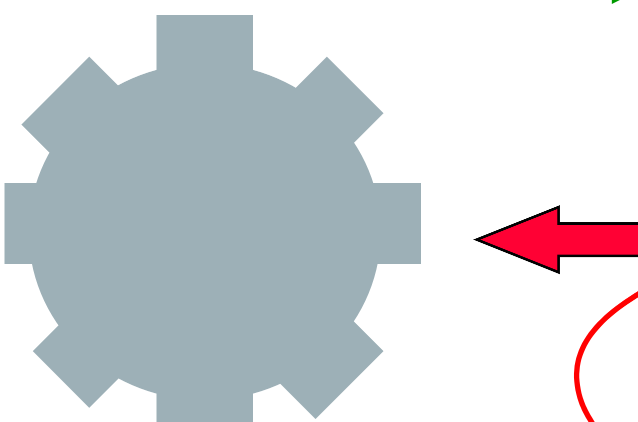


$$\omega = \frac{\mathrm{N}\ lobes}{1\sec} * \frac{1\,rev}{8\,lobes} \quad \rightarrow \quad \omega =$$

“Instantaneous” Velocity Timer Method

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

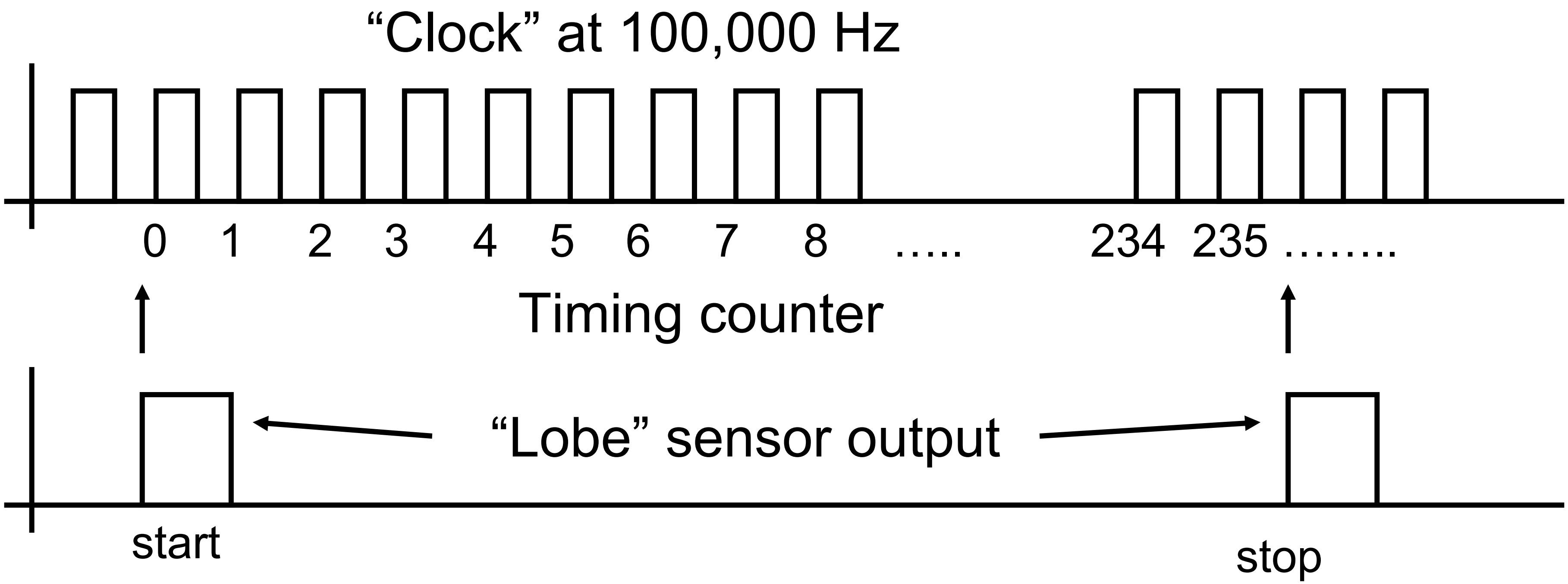
- Fix clock at 100 kHz
- Count number of ______ ________ from one lobe to the next



8 “lobes”on rotating wheel

$$\omega =$$

Instantaneous Velocity Timer Method

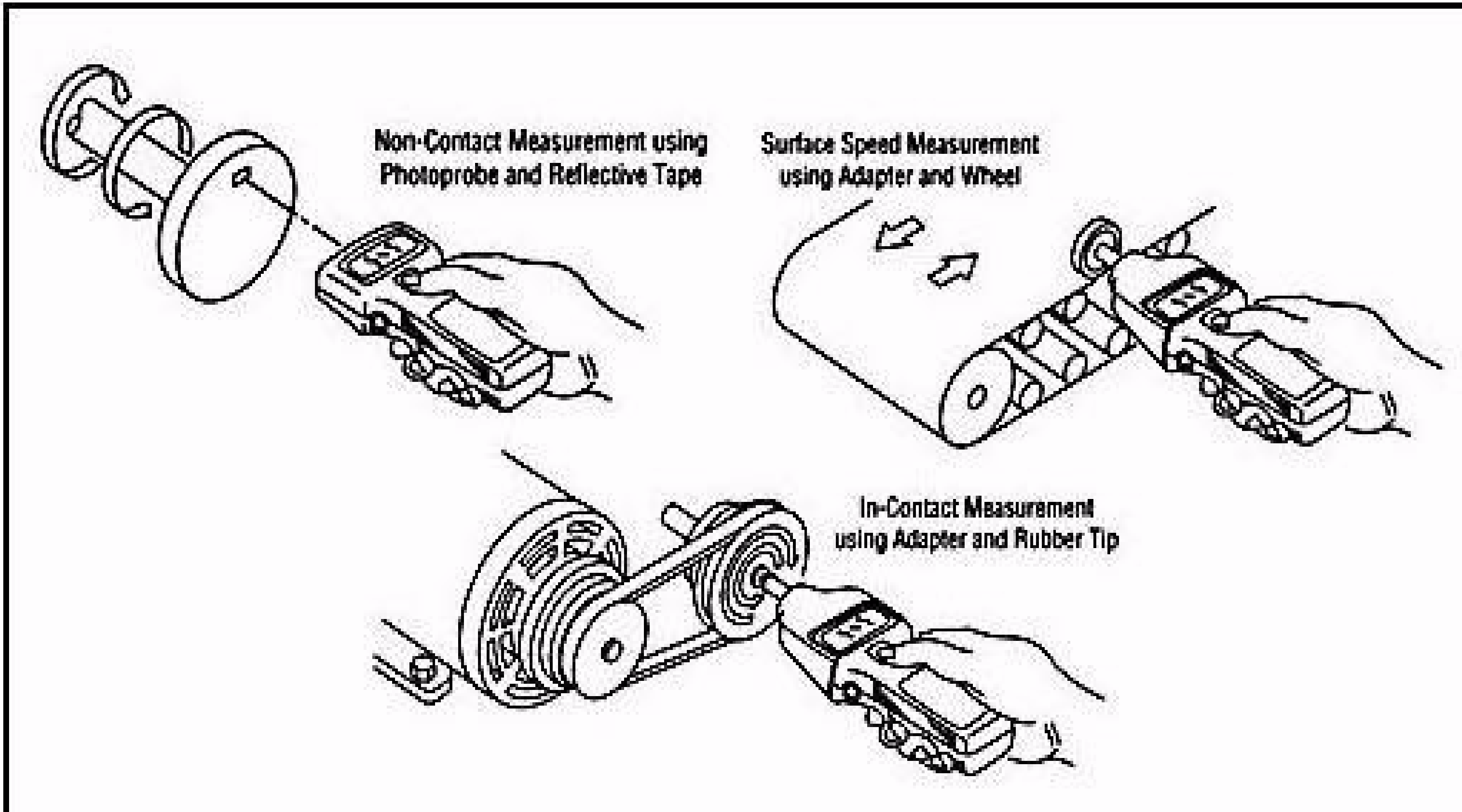


$$\omega = \frac{1/8\,rev}{\text{k}\ clocks} * \frac{100,000\ clocks}{\text{sec}}$$

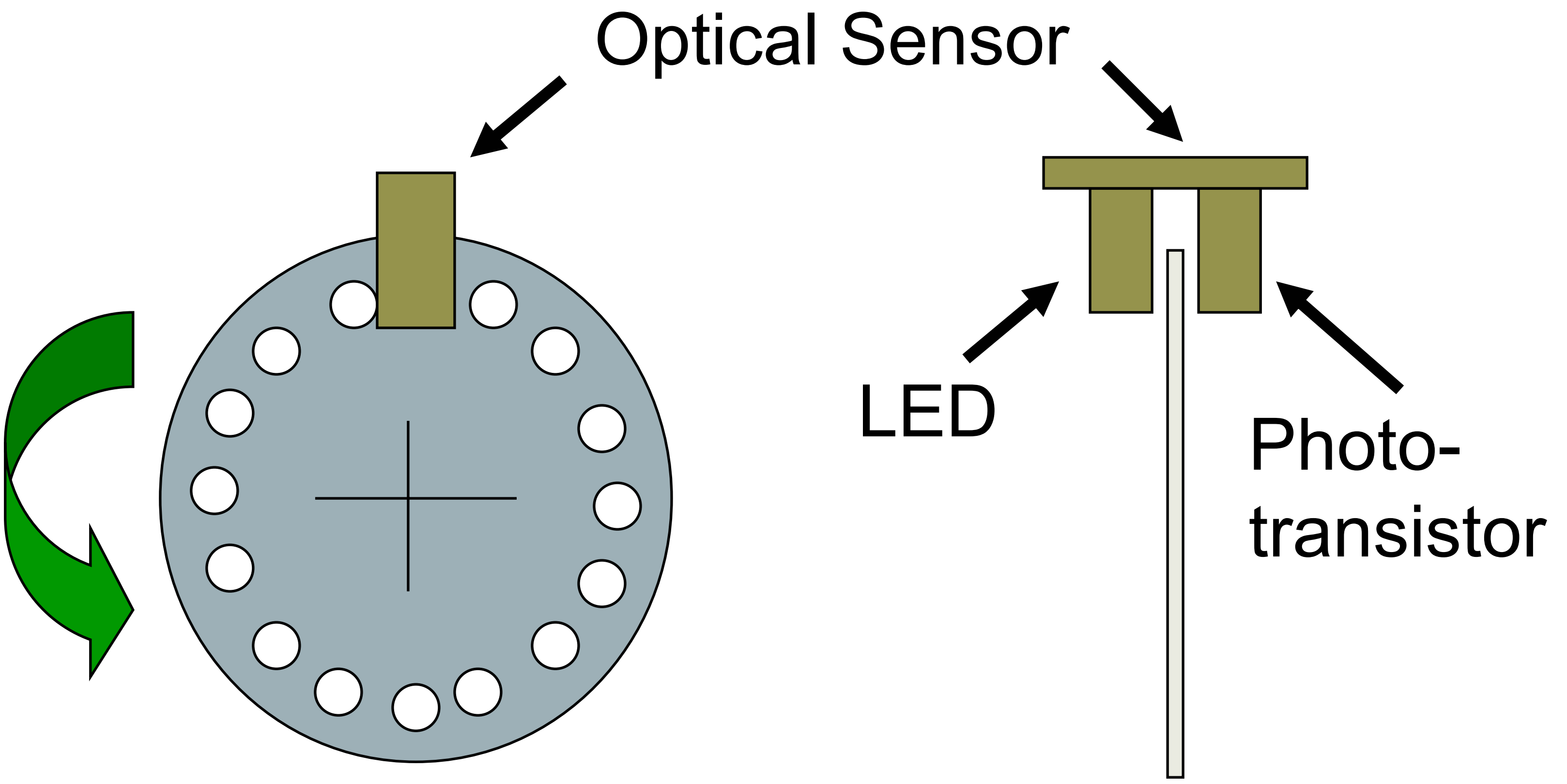
$$\rightarrow \omega =$$

Handheld Tachometer

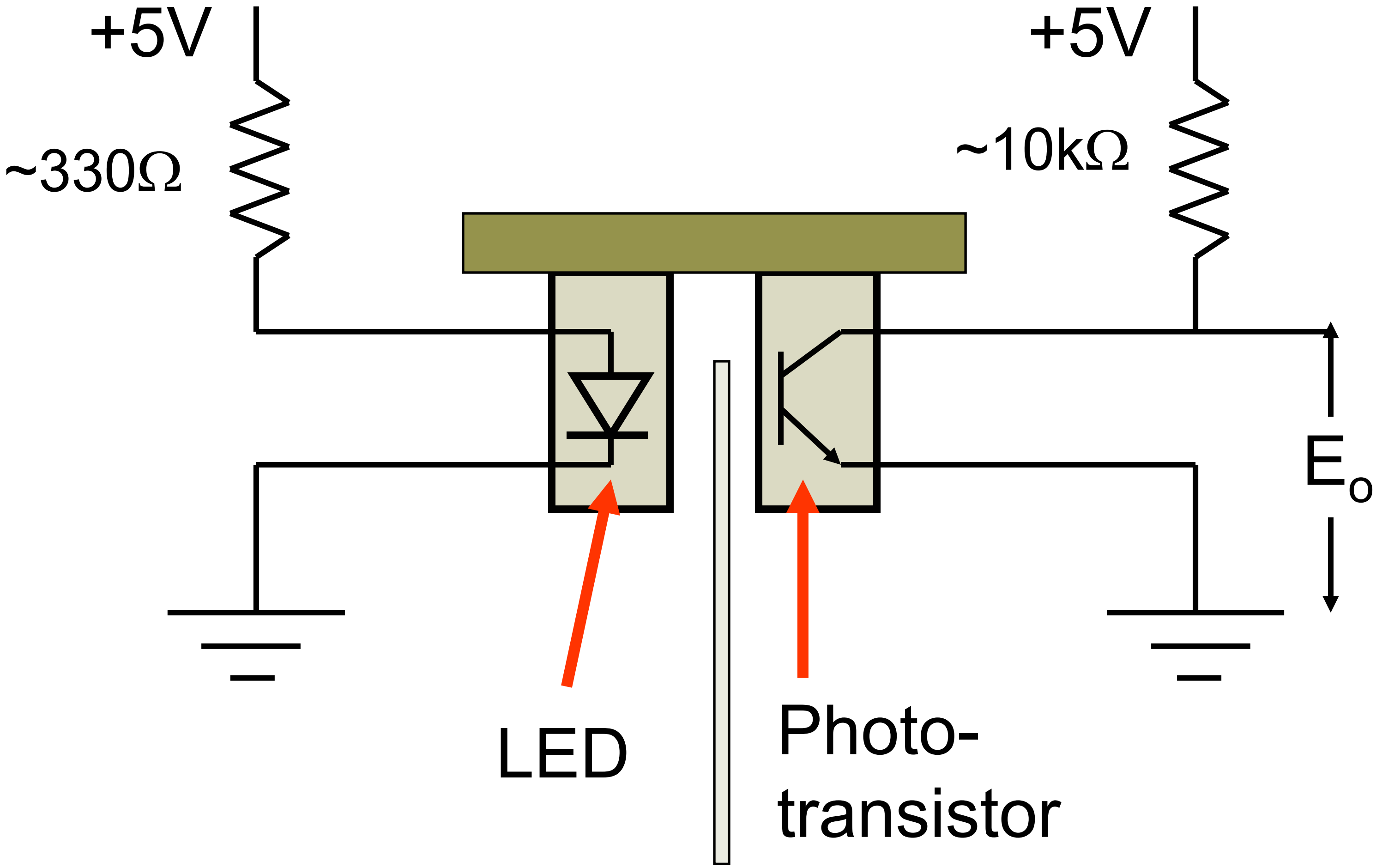
- How does this device work?



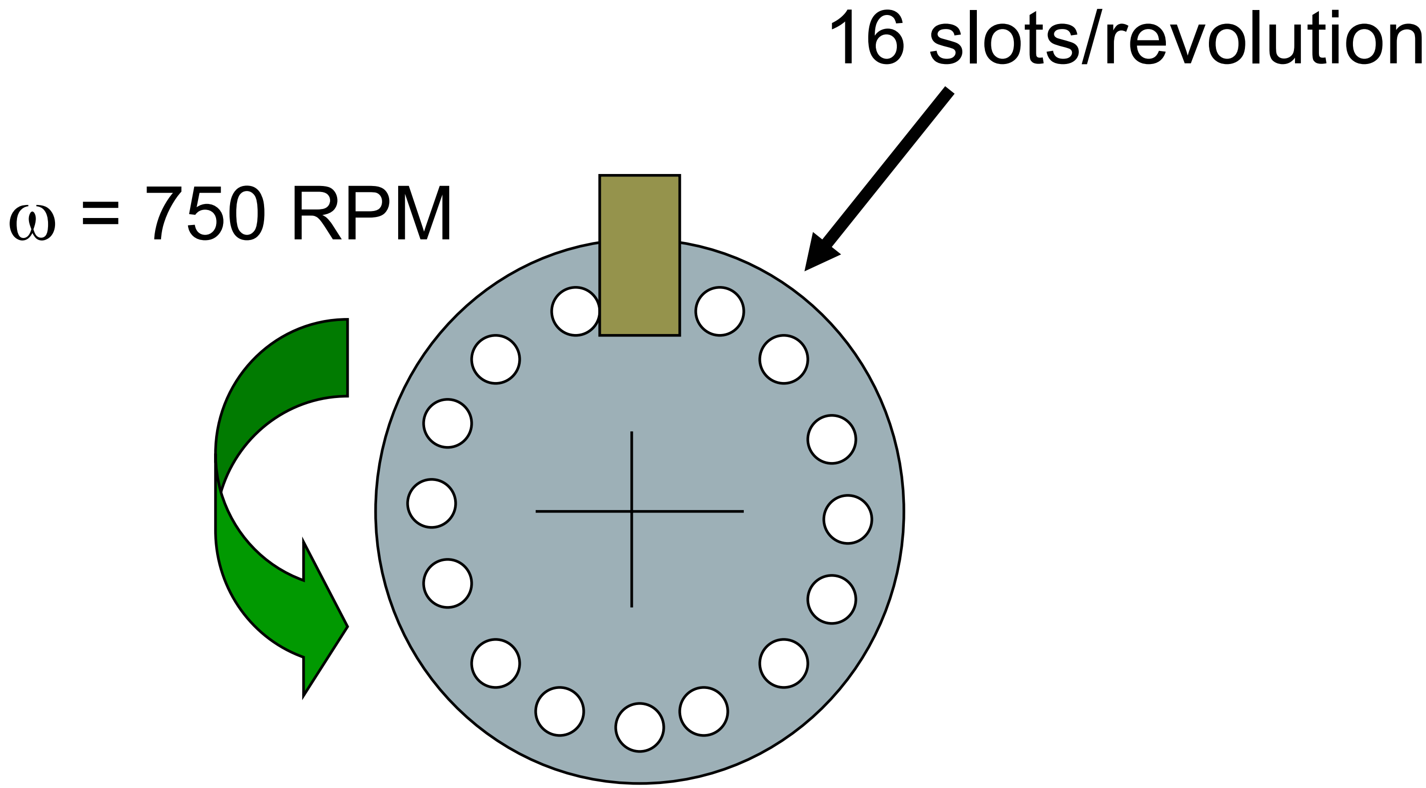
Velocity Measurement



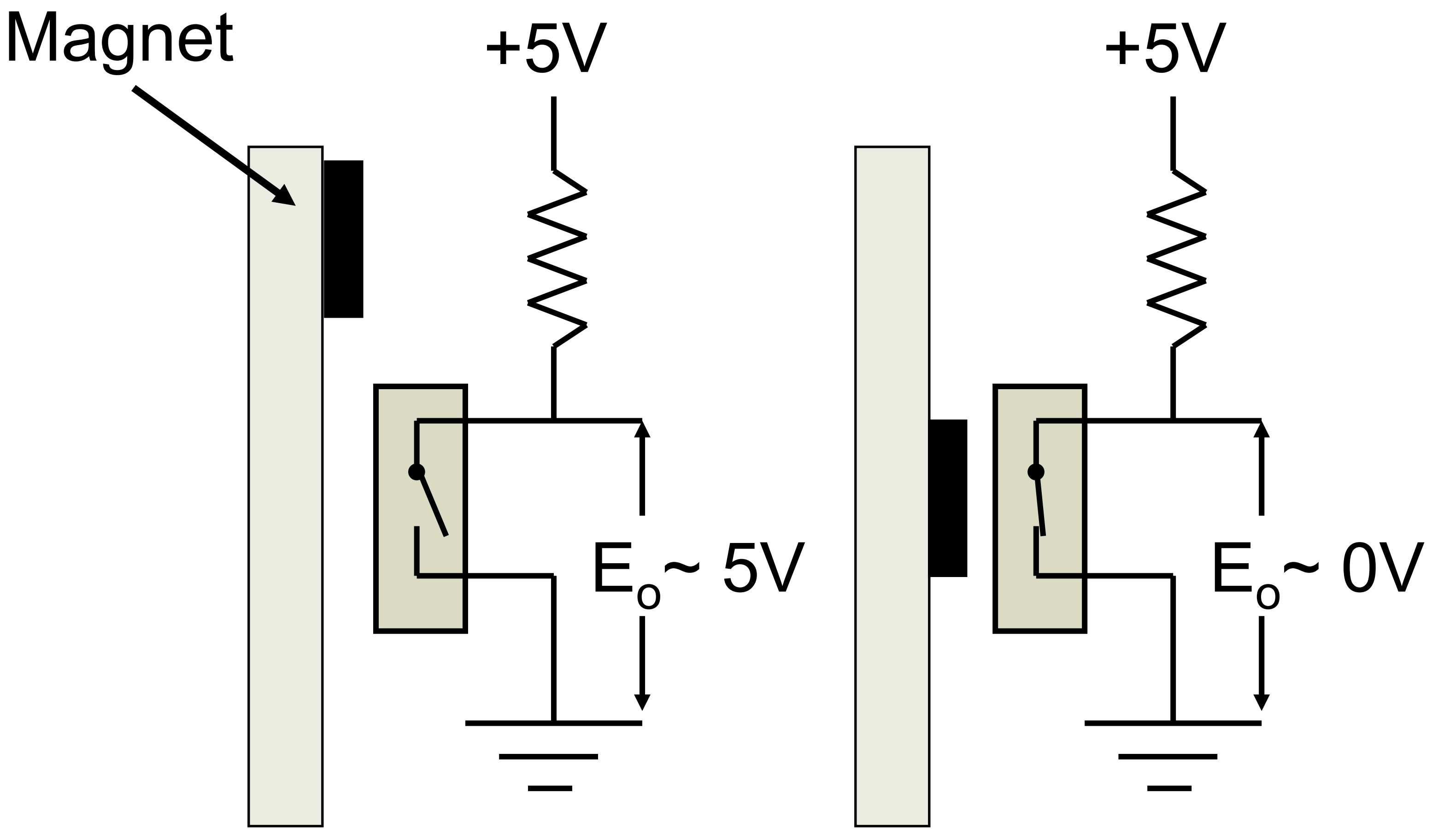
Velocity Measurement



Sketch “scope” output for 1 rev

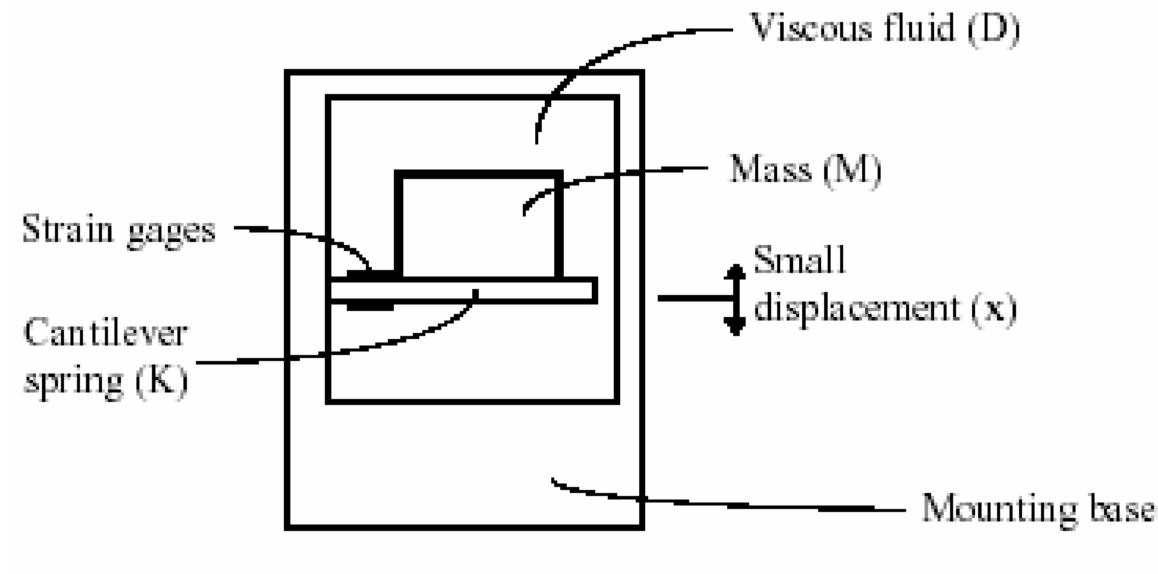


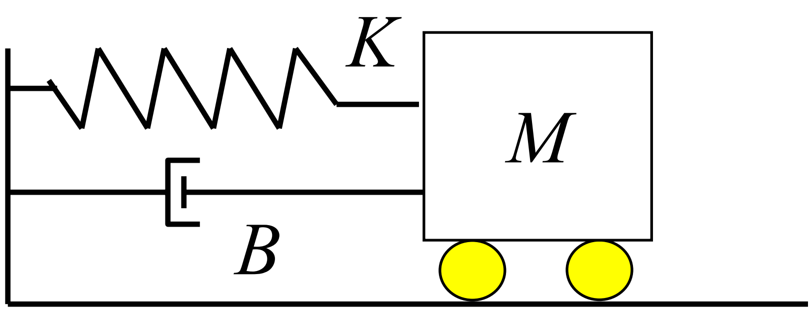
Magnetic Reed Switch

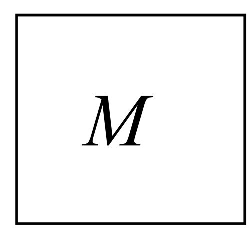


Velocity Sensing

Strain Gage Accelerometer







Piezoresistive Accelerometers

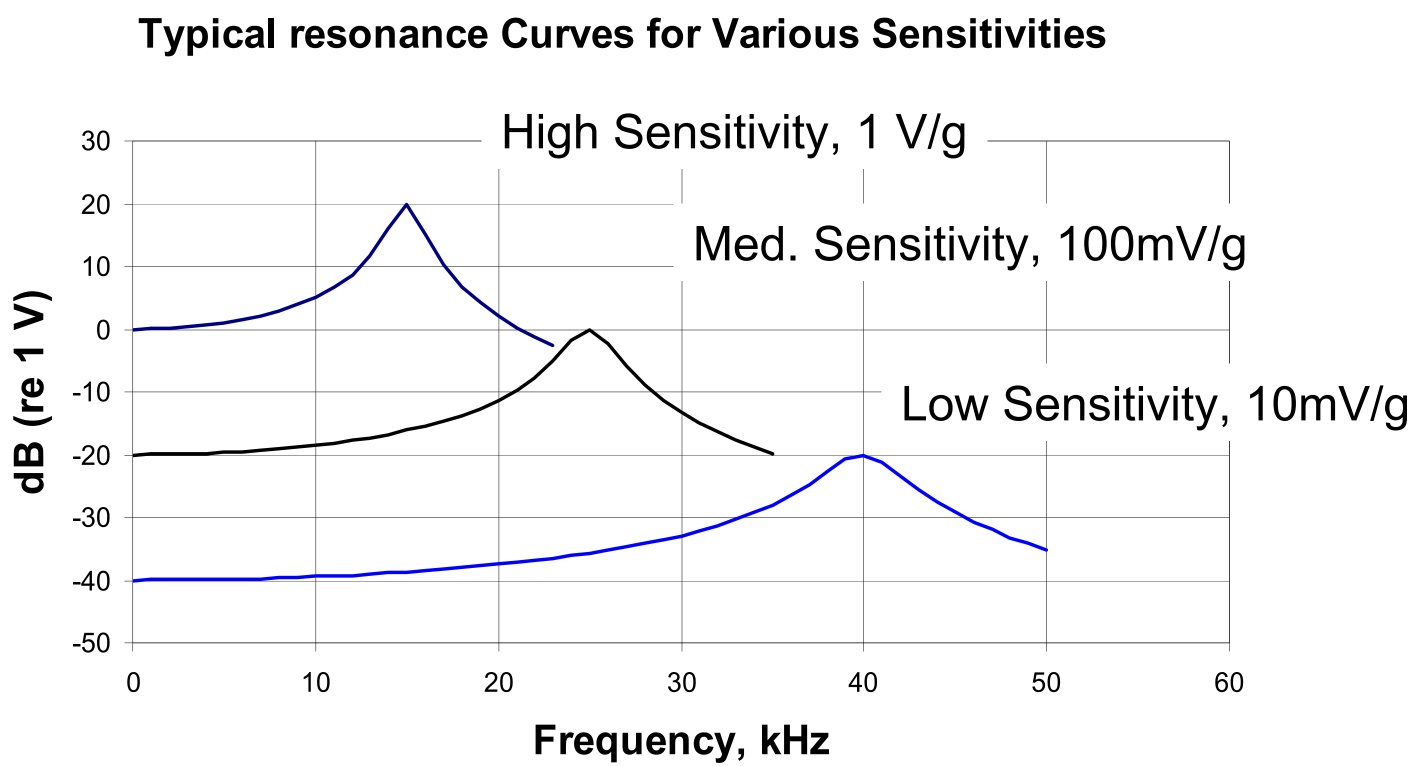
- Electrical output is proportional to the acceleration motion of base.
- Similar to a strain-gauge accelerometer, but
  - lighter weight,
  - smaller size,
  - higher output, and
  - higher frequency response

Piezoelectric Accelerometers

- Compared to other types, piezoelectric accelerometers have advantages:
  - self-generating-no external power required
  - ruggedness-no moving parts
  - high signal-to-noise 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 (p. 105) handout,



Why monitor vibration?

- Vibrations produced by an industrial machine are a direct indication of the machine’s health
  - monitoring programs record the machine's vibration history
  - allows prediction of problems and shut downs 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
  - displacement,
  - velocity, and
  - acceleration.
- Choice between them depends on
  - frequencies of interest, and
  - signal levels involved.

Displacement sensors

- Used for low frequency (1 to 100 Hz) measurements only and for measuring very low 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 medium to low frequency (1 to 1000 Hz) measurements.
- Act as a low-pass filter (reduce high frequency signals)
- Traditional velocity sensors employ an electromagnetic sensor to pick up the velocity signal

Acceleration sensors

- Used for the highest frequencies (100 Hz and up)
- 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
  - Range of operation
  - Linearity, repeatability, accuracy
  - Analog or digital output
  - Sensor size and weight
  - Signal conditioning requirements
  - Frequency response (or bandwidth)

Range of Operation

- Use sensor with specified range that most closely matches your requirements
  - 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

- Read manufacturers specifications carefully - be sure what you are buying
  - in some cases accuracy is vital, in others repeatability is most important
- Accuracy costs money - don't buy more than you need for measurement task
- Note that resolution is often specified instead of repeatability or accuracy

Analog / Digital Output

- What will be used to “read” the sensor output?
  - Many analog outputs can be read with DMM or data acquisition systems (extra costs!)
  - Most digital 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 mass/weight of the sensor significantly affect the system you are trying to measure?
  - 25 kg sensor ___________ when measuring Space Shuttle acceleration
  - 25 g sensor ________________ when measuring acceleration of hard drive read head

Signal Conditioning

- Consider entire system - not just the sensor/transducer
  - is highly regulated DC power required?
  - is the output DC or AC (requires conditioning)
  - does the output require amplification before measurement?

Frequency Response

- "Most" sensors act like 1st order, low pass filters
- If input frequencies are much less than sensor bandwidth…
  - ______________________
- If input frequencies are same as or more than sensor bandwidth…
  - _________________________