ITP272 SENSOR TECHNOLOGIES AND PROJECT

L04: Sensors and their Principles

CASE STUDY

Design a HAS with the following requirements

- "Home Secure" system that can be armed to monitor all doors and windows are closed when no one is at home. During "Armed" state, if any door or window is opened, an alarm will be sounded

- "Smart Light" system that can turn only the garden lights during when someone walks (laterally) across the garden nearby and there is insufficient light

- "Auto Cool" system where the fan can be turned on when temperature gets hot

CASE STUDY

Home Secure

- How to know whether door/window is open or closed?
- Human or other object cannot cause false reporting.

Smart Light

- How to know someone walks (laterally) across the garden nearby?
- How to know whether there is insufficient light?

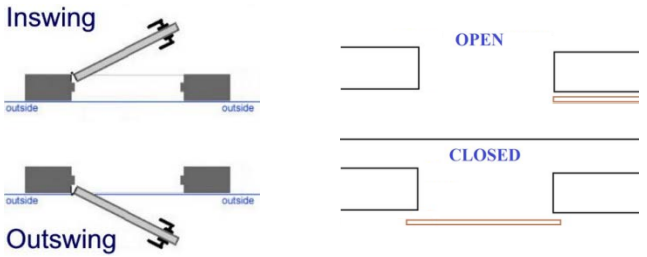
Auto Cool

- How to know whether temperature is hot?

CASE STUDY

Home Secure

- The door/window maybe swinging or sliding



- Just need detect 2 status
  - Fully closed
  - Not fully closed

- In this case, we just need to detect whether door is in its fully closed position. Thus we need to use a position sensor

AGENDA

- Position sensors

POSITION SENSORS

D

Position Sensors

- A sensor that senses for the location of object (people, animals or other items) in a monitored area

Categories / Types

- Limit switch
- Potentiometer
- Ultrasonic sensors
- Photoelectric sensors
- Hall Effect sensors

POSITION SENSORS

Limit Switch (Contact)

D

- A sensor that relies on its electromechanical actuator (push button) coming into contact with object to detect for position
- 2 states
  - Activated (turn on)
  - Deactivated (turn off)

- Detect presence rather than position (Machine Emergency stop)

Potentiometer (Contact)

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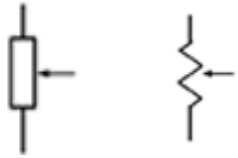
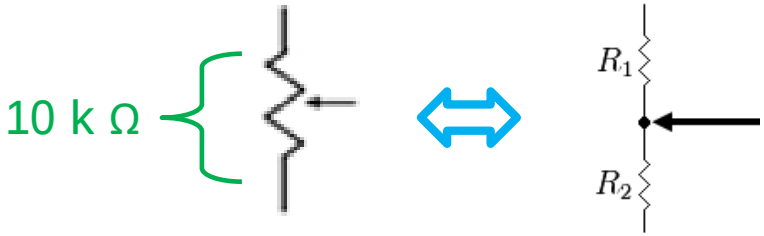
- A sensor that relies on variation of its resistance to determine position
- Used as adjustment knobs
  - Radios and Televisions

POSITION SENSORS

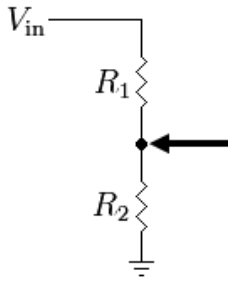
Potentiometer circuitry



- A potentiometer and many other sensors make use of the voltage divider concept to function.
- For a 10k Ω potentiometer
  - **$R_1 + R_2 = 10$ K Ω**



- Knob turned to different position gives a different value for R_1.
- As $R_1 + R_2 = 10$ K Ω, $R_2 = 10$ K – R_1
- A potentiometer is usually connected to
  - **A voltage source (Vin) and GND**



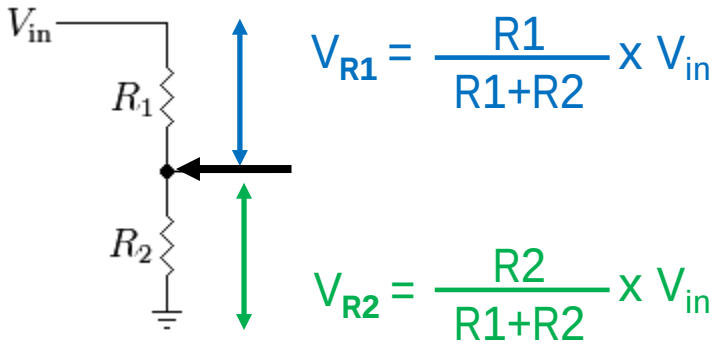
POSITION SENSORS

Potentiometer circuitry

- Given that
  - Knob at Position A gives R_1 = 2.5K Ω
  - Knob at Position B gives R_1 = 5k Ω
  - The potentiometer is connected to voltage of 3.3V

- For position A
  - R_2 = 10K – R_1 = 7.5 k
  - V_{in} = 3.3 V
  - V_{R2} = 7.5k / 10k * 3.3 = 2.475 V

- For position B
  - R_2 = 10K – R_1 = 5 k
  - V_{in} = 3.3 V
  - V_{R2} = 5k / 10k * 3.3 = 1.65 V



POSITION SENSORS

Ultrasonic Position Sensors (Non-Contact)

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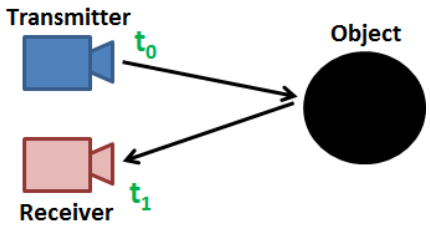
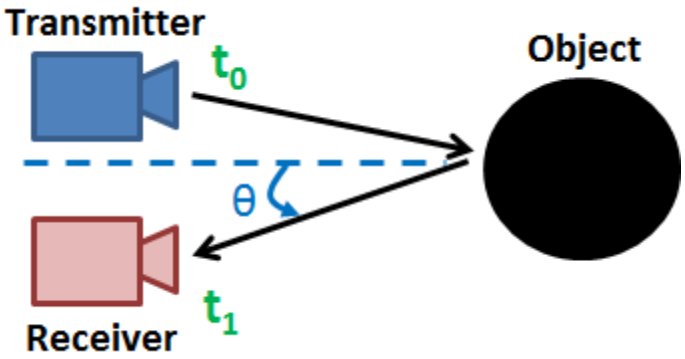
- A sensor that relies on timed reception of reflected acoustic (sound) waves signal for distance measurements
- Ultrasonic sound waves signal are in frequencies range beyond capabilities of human. (human can't hear them)
- Speed of ultrasonic waves is known
- Time taken for the signal to travel and reflected back is measured
- Time and speed are then used to determine the distance



POSITION SENSORS

Ultrasonic Position Sensors (Non-Contact)

- With the following definition
  - Time taken to reflect back be **t**. ie. $t = t_1 - t_0$
  - Speed of ultrasonic waves be **v**
  - Distance of object be **L**
- Formula to derive L is as follows

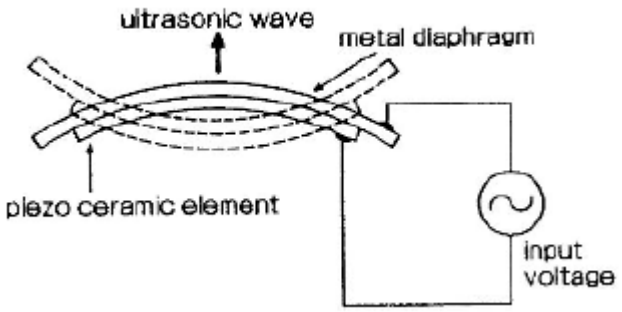


$$L = \frac{vt \cos \theta}{2}$$

POSITION SENSORS

Ultrasonic Position Sensors (Non-Contact)

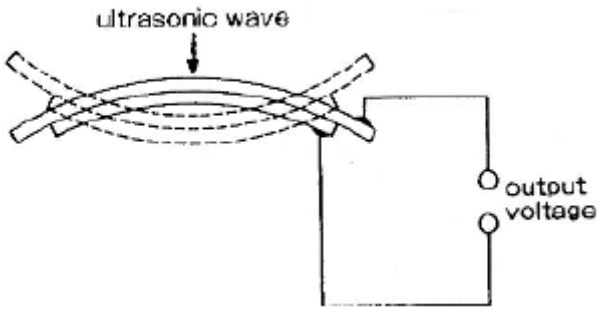
- Transmitter
  - Input voltage applied to the piezoelectric ceramic element causes it to flex and transmit ultrasonic waves
  - Piezoelectric device directly converts electrical energy into mechanical energy



POSITION SENSORS

Ultrasonic Position Sensors (Non-Contact)

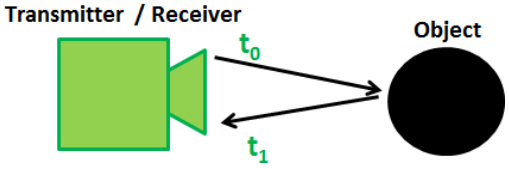
- Receiver
  - Incoming ultrasonic waves flex the piezoelectric ceramic element
  - piezoelectric device directly converts mechanical energy into electrical energy



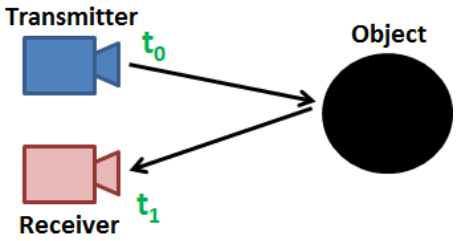
POSITION SENSORS

Ultrasonic Position Sensors Modes of operation

- Pulse Mode
  - The same piezoelectric element is used for both transmission and reception



- Continuous Transmission Mode
  - Separate piezoelectric elements are employed for the transmitter and receiver



POSITION SENSORS

Photoelectric (Non-Contact)

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- A sensor which is a optical device that relies on light beams presence to detect for position
- Can detect all types of material
- Consist of 2 modules
  - Emitter : A vibration-resistant LED (maybe infrared or visible red /green) that generates the light beam
  - Receiver: A phototransistor that receives the light beam from emitter and generate electrical output
- Presence of object is detected when light beam is “broken”

Categories / Types

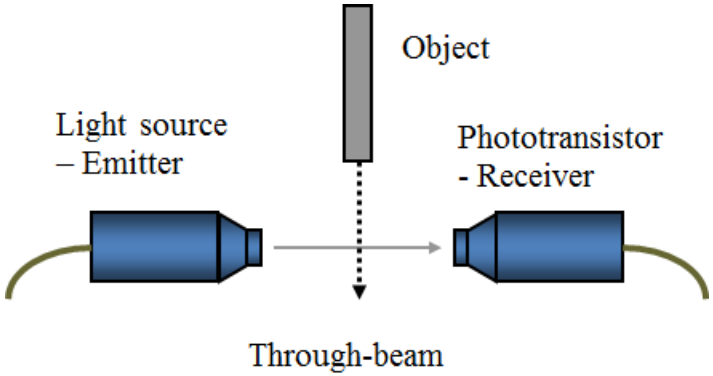
- Through-beam
- Retro-reflective
- Diffuse Scanning

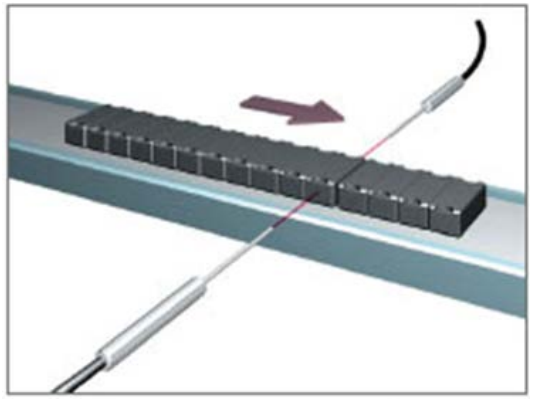
POSITION SENSORS

Through Beam Sensor

D

- A sensor that relies on non-reception of direct light beam to detect for presence of object
- Emitter and Receiver are in separate housing
- Light beam from emitter is directly shone on the receiver
- Used for long range detection (up to 100m)





Chip component detection

POSITION SENSORS

Retro-Reflective Sensor

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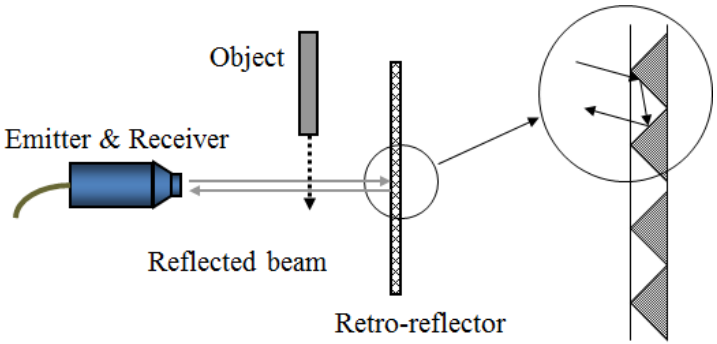
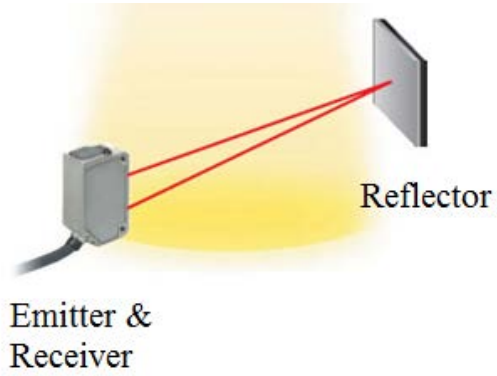
- A sensor that relies on non-reception of reflected light beam to detect for presence of object
- Emitter and Receiver are in same housing
- A retro-reflector is used to reflect the light beam from emitter back to the receiver
- Used for short/medium range detection (Up to 10m)



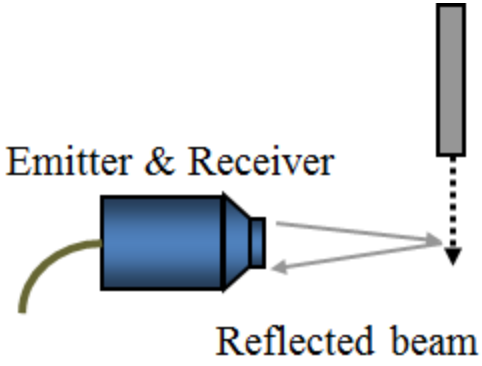


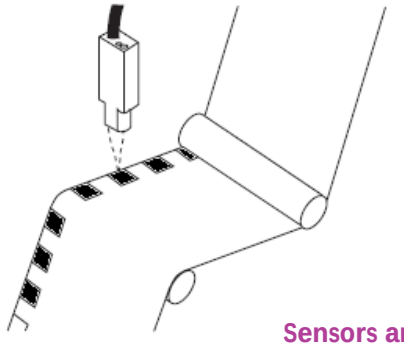
POSITION SENSORS

Diffuse Scanning Sensor

D

- A sensor that relies on reception of reflected light beam to detect for presence of object
- Emitter and Receiver are in same housing
- Light beam is reflected by object to the receiver
- Used for short range detection (Up to 10cm)
- Non-reflective target may further lower range
- Useful when there is limited space for having a retro-reflector



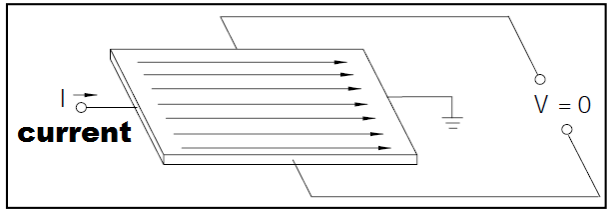


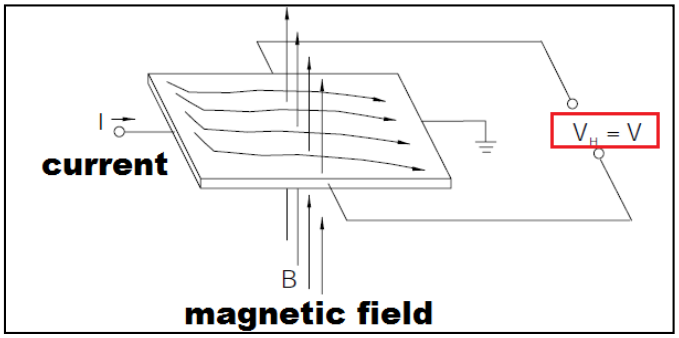
POSITION SENSORS

Hall Effect Sensor (Non-Contact)

D

- A sensor that relies on magnetic field strength to detect for position
- When a current-carrying conductor is placed into a magnetic field, a voltage will be generated perpendicular to both the current and the field. This principle is known as the Hall effect
- A thin sheet of conductive material (Hall element) is used to detect for magnetic field and converts to electrical voltage

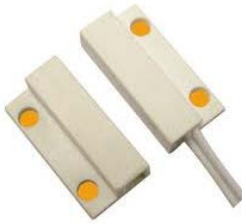




POSITION SENSORS

Hall Effect Sensor (Non-Contact)

- A hall effect sensor is used together with a magnet
- Sensor is usually mounted on the moving target and magnet is counted on the position in interest

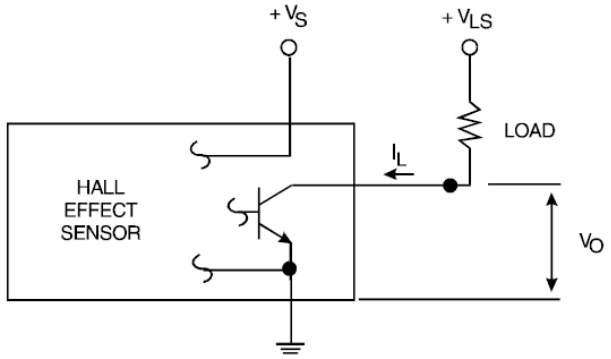


- The presence of the magnet signifies the specific object is in position of interest
- It does not require line of sight like photoelectric sensors
- Usually found in Home Security System

POSITION SENSORS

Hall Effect Sensor interfacing circuit

- When there is no magnetic field, the sensor is turned OFF like a transistor.
- No current flows through the LOAD. $I_L = 0$ and $V_O = V_{LS}$
- When there is presence of magnetic field, the sensor is turned ON.
- Current flows through. $V_O = 0$ V. (=> magnet is in position)
- V_O can be used to determine whether magnet is in position



POSITION SENSORS

Criteria for selection

- Contact or Non-Contact sensing
- Presence or Distance reporting
- Sensing principle

POSITION SENSORS

Criteria for selection

	Non-Contact Contact	Presence Position	Sensing Principle
Limit Switch	Contact	Presence	Mechanical contact
Potentiometer	Contact	Both	Mechanical displacement
ultrasonic	Non-Contact	Both	Acoustic waves
Photoelectric	Non-Contact	Presence	Light Beams
Hall Effect	Non-Contact	Presence	Magnetic field

CASE STUDY

Criteria for selection for Home Secure

- Contact or Non-Contact sensing
  - Non-Contact - To support both sliding and swinging (In and/or Out) mechanism
- Presence or Distance reporting
  - Presence – Just fully closed or not fully closed
- Sensing principle
  - Human/object obstruction cannot cause false reporting

CASE STUDY

Home Secure

	Non-Contact	Presence	Sensing Principle
Limit Switch	✗		
Potentiometer	✗		
ultrasonic			✗ See #
Photoelectric			✗ See #
Hall Effect	✓	✓	✓

As any human or obstruction will be detected by ultrasonic or photoelectric sensor, they were not suitable.

Hall effect sensor is suitable because it is a non-contact sensor and requirement is just to detect for presence.
A magnet attached to the door ensures that the closed door is detected correctly.

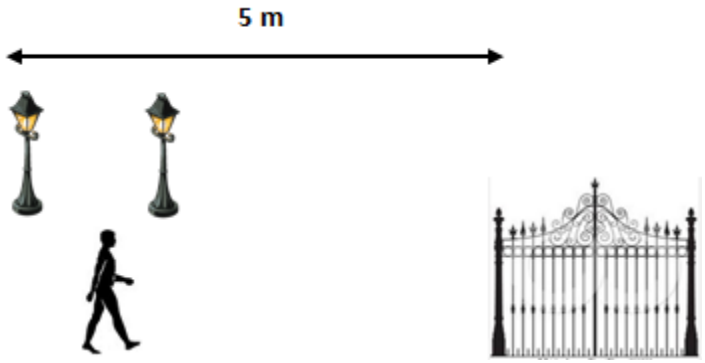
REVIEW QUESTIONS

REVIEW QUESTION

Autogate PTE LTD is designing a system that detects a target (person or any object) approaching. It turns on nearby lamp posts when target is 5m away. At a distance of 1 m, it will open the gate.

You are required to select a suitable position sensor for this system.

(a) List down the selection criteria for this sensor



REVIEW QUESTION

(b) You are asked to select between Hall effect sensor, Ultrasonic sensor and photoelectric sensor.

- Justify how the selected sensor meets all requirements
- List down why other sensors are not suitable

ANSWER

Criteria for selection

- Contact or Non-Contact sensing
  - Non-contact – Target approaching does not has contact with sensor
- Presence or Distance reporting
  - Distance – Need to be able to detect 5m and 1m
- Sensing principle
  - None

ANSWER

	Non-Contact	Distance	Principle of sensing
ultrasonic	✓	✓	✓
Photoelectric		✗ See #	
Hall Effect		✗ See #	

Both Photoelectric and Hall effect sensor can only detect for presence. They are not able to detect distance of target and thus are not suitable.

Ultrasonic sensor is suitable as it uses non-contact sensing and is able to report the distance.
It can sense distance of target approaching by measuring the reflected sound waves.

REVIEW QUESTION

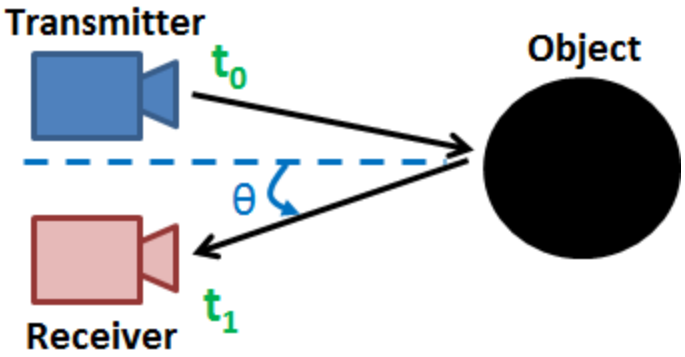
With the aid of diagram, describe the principle of operation of an Ultrasonic position sensor.

Answer:

- With the following definition
  - Time taken to reflect back be **t**. ie. $t = t_1 - t_0$
  - Speed of ultrasonic waves be **v**
  - Distance of object be **L**

- Formula to derive L is as follows

$$L = \frac{vt \cos \theta}{2}$$



REVIEW QUESTION

Ultrasonic position sensor relies on which of these to function?

A. Magnetic field
B. Light beam
C. Acoustic waves
D. Ultraviolet waves

Answers => C

REVIEW QUESTION

Which sensor relies on timed reception of reflected acoustic waves signal for distance measurements?

A. Ultrasonic sensor
B. Hall effect sensor
C. Retro-Reflective Sensor
D. Diffuse Scanning Sensor

Answers => A

REVIEW QUESTION

Which mode in the Ultrasonic Position sensor uses the same piezoelectric element for both transmission and reception?

A. Continuous Transmission
B. Monostatic
C. Pulse
D. Bistatic

Answers => C

REVIEW QUESTION

Which mode in the Ultrasonic Position sensor uses separate piezoelectric elements for the transmitter and receiver?

A. Continuous Transmission
B. Monostatic
C. Pulse
D. Bistatic

Answers => A

REVIEW QUESTION

Photoelectric position sensor relies on which of these to function?

A. Magnetic field
B. Light beam
C. Acoustic waves
D. Ultraviolet waves

Answers => B

REVIEW QUESTION

Which position sensor relies on light beams presence for detection?

A. Ultrasonic sensor
B. Hall effect sensor
C. Photoelectric Sensor
D. Microwave sensor

Answers => C

REVIEW QUESTION

Which of the following is not one of the Photoelectric sensor?

A. Through Beam Sensor
B. Retro-Reflective Sensor
C. Diffuse Scanning Sensor
D. Ultrasonic Beam sensor

Answers => D

REVIEW QUESTION

Hall Effect position sensor relies on which of these to function?

A. Magnetic field
B. Light beam
C. Acoustic waves
D. Ultraviolet waves

Answers => A

REVIEW QUESTION

Which of the following states that voltage is generated when a current-carrying conductor is placed into a magnetic field?

A. Doppler effect
B. Trilateration
C. Hall effect
D. Piezoelectric

Answers => C

REVIEW QUESTION

Which sensor is used together with a magnet for detection?

A. Ultrasonic
B. Hall effect
C. Photoelectric
D. Piezoelectric

Answers => B