Department of Mechatronic Engineering

2017-2018 Academic Year

Fifth Year **Second Semester Examination**

Marking Scheme of McE-52066 Sensors for Mechatronic System

Date: 2.10.2018 (TUE) **Time: 9:00 to 12:00 noon**

……………………………………………………………………………………………...

Ques No.	Solution	Marks
1.(a.)	i. control actions ii. output signals iii. control signal iv. Passive Transducer v.variable-inductance transducers	
1.(b.)	i.3. Passive transducer ii. 2. Decrease iii. 3. Digital iv. 3.Thermocouple v.1. Ferromagnetic vi. 2. Displacement of a contact slider on a resistance vii. 1.Proximity Sensor viii. 4.Both 1 and 2 are correct ix. 2. Vary unequally depending on the core position x. 4.All of the above xi. 1.Shaft encoder xii. Mutual inductance xiii. 1.Encoder xiv. 3.seeback effect xv. 4. acceleration	

Ques No.	Solution	Marks
2.(a.)	Digital signals (or digital representation of information) have several advantages in comparison with analog signals. 1. Digital signals are less susceptible to noise, disturbances, or parameter variation in instruments because data can be generated, represented, transmitted, and processed as binary words consisting of bits, which possess two identifiable states. 2. Complex signal processing with very high accuracy and speed is possible through digital means (hardware implementation is faster than software implementation). 3. High reliability in a system can be achieved by minimizing analog hardware components. 4. Large amounts of data can be stored using compact, high-density data storage methods. 5. Data can be stored or maintained for very long periods of time without any drift or disruption by adverse environmental conditions. 6. Fast data transmission is possible over long distances with no attenuation and with less dynamic delays, compared to analog signals. 7. Digital signals use low voltages (e.g., 0–12 V DC) and low power. 8. Digital devices typically have low overall cost.	10 Marks
2.(b.)	The displacement resolution of an incremental encoder depends on the following factors: 1. Number of windows on the code track (or disk diameter) 2. Gear ratio 3. Word size of the measurement buffer.	5 Marks
2.(c.)	Solution, d = diameter of encoder disk ω = number of windows per unit diameter of disk r = word size (bits) of the angle measurement r = 12 , ω = 500/cm d = ? $\Delta\theta_{\mathrm{p}} = \frac{1}{4}\left(\frac{360}{wd}\right)^{\circ}$, Physical resolution $\Delta\theta_{\mathrm{d}} = \left(\frac{360}{2^r}\right)^{\circ}$, digital resolution	5 marks
Ques	Solution	Marks

No.		
2.(c.)	For an ideal design, $\Delta\theta_p = \Delta\theta_d$ $$\frac{360}{4 \text{ x } \omega\text{d}} = \frac{360}{2^r}$$ $$\frac{2^r}{2^2} = \omega\text{d}$$ $$\omega\text{d} = 2^{r-2}$$ Substitute, r=15, ω = 700/cm $$\omega\text{d} = 2^{15-2}$$ $$\text{d} = \frac{2^{15-2}}{700}$$ $$\text{d} = 11.7 \text{ cm}$$	
3.(a.)	For a general position u of the pot slider arm, suppose that the resistance in the output (pick-off) segment of the coil is $$R_\theta = \frac{\theta}{\theta_{max}} R_c$$ where Rc is the total resistance of the potentiometer coil. The current balance at the sliding contact (node) point gives $$\frac{v_{\text{ref}} - v_{\text{o}}}{R_{\text{c}} - R_\theta} = \frac{v_{\text{o}}}{R_\theta} + \frac{v_{\text{o}}}{R_{\text{L}}} \qquad \text{.................. (i)}$$ where RL is the load resistance. Multiply throughout Equation (i) by Rc $$\frac{v_{\text{ref}} - v_{\text{o}}}{1 - \theta/\theta_{\text{max}}} = \frac{v_{\text{o}}}{\theta/\theta_{\text{max}}} + \frac{v_{\text{o}}}{R_{\text{L}}/R_{\text{c}}}$$	10 marks

Ques	Solution	Mark

No		s
3.(a.)	By using straightforward algebra, $$\frac{v_o}{v_{ref}} = \left[\frac{(\theta/\theta_{max})(R_L/R_C)}{(R_L/R_c + (\theta/\theta_{max}) - (\theta/\theta_{max})^2)}\right]$$ $$e = \frac{(v_o/v_{ref} - \theta/\theta_{max})}{\theta/\theta_{max}} 100\%$$	
3.(b.)	Discuss about the Mutual-Induction Proximity Sensor with schematic diagram and its some typical applications. . The insulating E core carries the primary winding in its middle limb. The two end limbs carry secondary windings, which are connected in series. Unlike the LVDT and the RVDT, the two voltages induced in the secondary winding segments are additive in this case. The region of the moving surface (target object) that faces the coils has to be made of ferromagnetic material so that as the object moves, the magnetic reluctance and the flux linkage between the primary and the secondary coils change. This, in turn, changes the induced voltage in the secondary coil, and this voltage change is a measure of the displacement. Hence, these proximity sensors should be used only for measuring small displacements (e.g., in a typical linear range of 5.0 mm or 0.2 in.), unless accurate nonlinear typical calibration curves are available. Since the proximity sensor is a noncontacting device, mechanical loading is small and the product life is high. Proximity sensors are used in a wide variety of applications pertaining to noncontacting displacement sensing and dimensional gaging. Some typical applications are 1. Measurement and control of the gap between a robotic welding torch head and the work surface 2. Gaging the thickness of metal plates in manufacturing operations (e.g., rolling and forming) 3. Detecting surface irregularities in machined parts 4. Angular speed measurement at steady state, by counting the number of rotations per unit time	10 Ms

<table>
<tr>
<td>4.(a.)</td>
<td>

5. Measurement of vibration in rotating machinery and structures

6. Level detection (e.g., in the filling, bottling, and chemical process industries)

7. Monitoring of bearing assembly processes

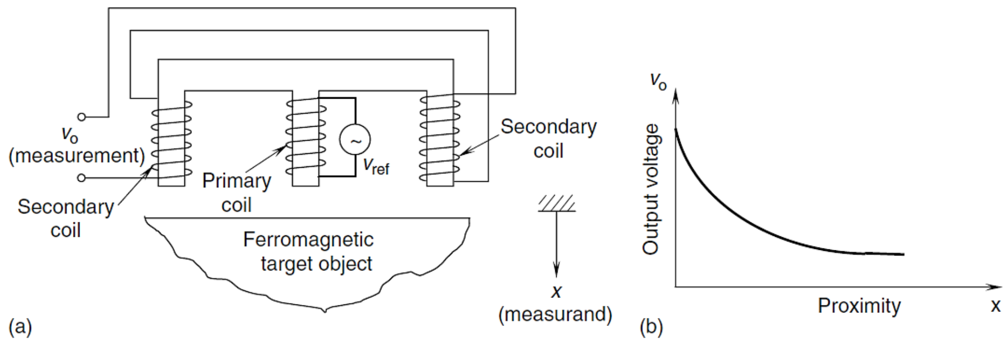


Figure: Schematic diagram of a mutual-induction proximity sensor

Assume that quadrature signals are not used

Speed = 1 rev/s

With 500 windows, we have 500 pulses/s

i. Pulse-counting method

Counting period $= \frac{1}{10}$ Hz = 0.1 s

Pulse count (in 0.1 s) = 500 x 0.1 = 50

Percentage resolution $= 1/50$ x 100% =2%

ii. Pulse-timing method

At 500 pulses/s,

Pulse period = 1/500 s $= 2 \times 10^{-3}$ s

With a 10 MHz clock,

Clock count = $10 \times 10^{6} \times 2 \times 10^{-3} = 20 \times 10^{3}$

Percentage resolution $= \frac{1}{20 \times 10^3} \times 100\%$

$= 0.005\ \%$

</td>
<td>10 Ms</td>
</tr>
<tr>
<td>Ques No</td>
<td>Solution</td>
<td>Marks</td>
</tr>
</table>

	Speed= 100 rev/s N = 500 windows, pulses = 50,000 pulses/s i. Pulse-counting method Pulse count (in 0.1 s) = 50,000 x 0.1 = 5000 Percentage resolution $= \frac{1}{5000}$ x 100% = 0.02% ii. Pulse-timing method At 50,000 pulses/s, Pulse period $= \frac{1}{50000}$ s = 20 x 10^{-6} With a 10 MHz clock, Clock count = 10 x10^{6} x 20 x 10^{-6} = 200 Percentage resolution = $\frac{1}{200}$ x 100 % = 0.5%	

Speed (rev/s)	Pulse_Counting Method(%)	Pulse_Timing Method(%)
1.0	2	0.005
100	0.02	0.5

	Therefore, pulse counting method is more suitable for measuring high speeds. In the pulse-timing method, the resolution degrades with speed, and hence it is more suitable for measuring low speeds.	
4.(b.)	Digital resolution, $\Delta\, \theta_d = \frac{\theta_{max}}{2^{r-1}}$ $M = 2^{r-1}$ $\theta_{max} = \pm 180$ or $\theta_{max} = 360$ $\theta_{max} = \theta_{min} + (M-1)\, \Delta\, \theta$ (displacement resolution) $\theta_{max} = \theta_{min} + (2^{r-1}-1)\, \Delta\, \theta_d$ (digital resolution)	10 Ms
4.(b.)	$\theta_{max} = \frac{\theta_{max}}{2^{r-1}} + (2^{r-1}-1)\, \Delta\, \theta_d$	

$$(2^{r-1}-1)\,\Delta\,\theta_d = \frac{\theta_{\max}\ (2^{r-1}-1)}{2^{r-1}}$$

$$\Delta\,\theta_d = \frac{\theta_{\max}\ (2^{r-1}-1)}{(2^{r-1}-1)2^{r-1}}$$

$$\Delta\,\theta_d = \frac{\theta_{max}}{2^{r-1}}$$

$$\Delta\,\theta_p = \frac{360}{4\mathrm{N}}$$

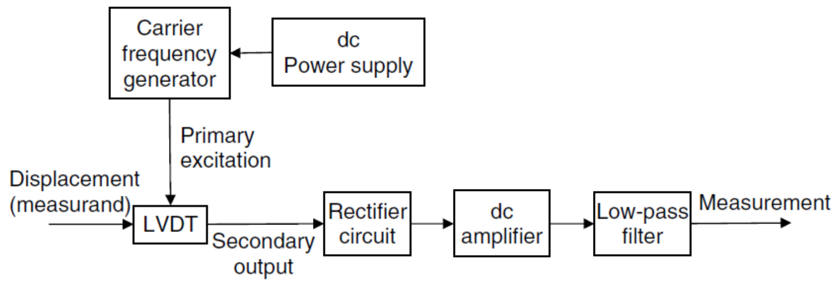
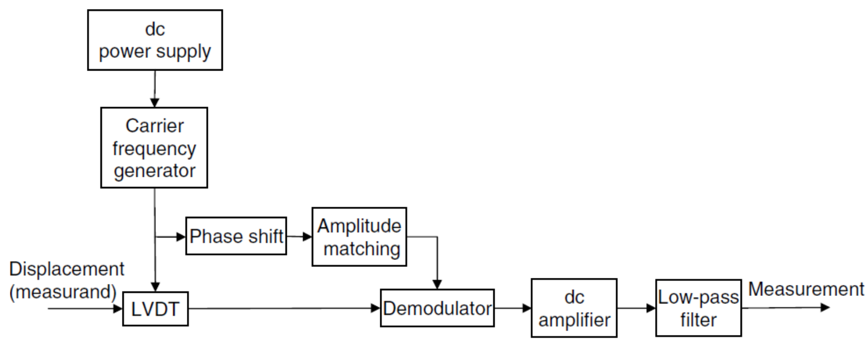
$$\Delta\,\theta_p = \frac{360}{4\mathrm{N}}$$

5.(a.) Two methods are commonly used to interpret the crude output signal from a differential transformer: rectification and demodulation. Block diagram representations of these two procedures are given in Figure.

In the first method (rectification) the ac output from the differential transformer is rectified to obtain a dc signal. This signal is amplified and then low-pass filtered to eliminate any high-frequency noise components. The amplitude of the resulting signal provides the transducer reading. In this method, phase shift in the LVDT output has to be checked separately to determine the direction of motion.

In the second method (demodulation) the carrier frequency component is rejected from the output signal by comparing it with a phase-shifted and amplitude-adjusted version of the primary (reference) signal. Note that phase shifting is necessary because, as discussed earlier, the output signal is not in phase with the reference signal. The result is the modulating signal (proportional to x), which is subsequently amplified and filtered.

Ques N0	Solution	Marks

5.(b.)	 (a) Rectification  (b) Demodulation Figure :Signal-conditioning methods for a differential transformer (a) Rectification and (b) Demodulation The primary advantages of the resolver include 1. Fine resolution and high accuracy 2. Low output impedance (high signal levels) 3. Small size (e.g., 10 mm diameter) 4. Direct availability of the sine and cos functions of the measured angles Its main limitations are 1. Nonlinear output signals (an advantage in some applications where trigonometric functions of the rotations are needed); 2. Bandwidth limited by supply frequency; 3. Slip-rings and brushes would be needed if complete and multiple rotations have to be measured (which adds mechanical loading and also creates component wear, oxidation, and thermal and noise problems).	10 Ms