Tutorial 2

From 02-03 Paper:

Question 2 Motion Sensing

(a) By referring to the constructions and the operating principles, explain the main differences between the Synchro and the Resolver. Suggest reasons why the Synchro is more expensive, and has a better performance than the Resolver. (10 marks)

(b) Describe the construction and operating principle of a magnetic linear scale. Briefly describe how the signal output can be detected at zero velocity. (8 marks)

(c) The magnetic linear scale in (b) outputs a two-channel sine-cosine waveform. Explain how you could convert this output into absolute position and speed information. (7 marks)

From 03-04 Paper

Question 2 - Motion and Force Sensing

(a) By referring to a cross-sectional diagram of a linear optical encoder position sensor, explain the function of the collimator lens, the grid scale, the index scale, and the 5 photodiodes sensor head. (10 marks)

(b) Explain how absolute position and velocity can be determined from this optical encoder position sensor. (10 marks)

Question 3 – Motion Actuators

(a) Comment on the advantages and disadvantages of using (i) DC brush motor, (ii) AC brushless synchronous motor, and (iii) induction motor in high acceleration/deceleration and high precision motion applications. (8 marks)

(b) Explain the following characteristics of a stepper motor, and its limitations placed on the motion control performance. For each of the case, suggest a way of overcoming the limitation.

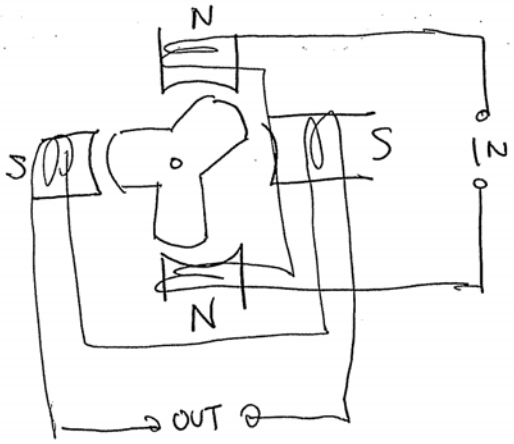
(i) The resonant regions
(ii) The minimum starting and stopping stepping rates
(iii) The vibration between steps (12 marks)

SOLUTION

Q2 02-03 Paper:

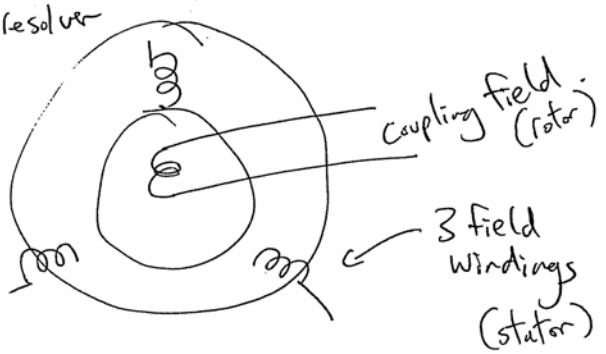
The resolver works on the detection of a magnetic field inside a rotary structure.

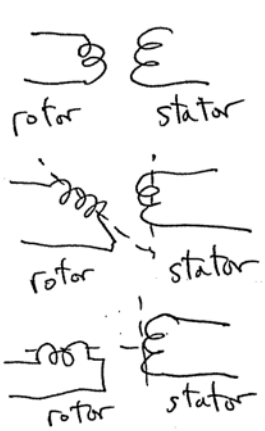
e.g. Construction of a 3x 6 pole-pair resolver



It acts like a transformer, with is primary/secondary windings coupling varied by a changing magnetic circuit.

Synchros are different from resolver that they include a third "field" winding. The 3 windings are 120° seperated from each other The extra winding forms a balanced condition which makes the synchro more precise than the resolver





max output

reduced output

no output.

Why Synchro is more expensive

(1) Contains more windings

(2) Usually the rotor contains winding. i.e. slip ring is needed

(3) If there is no slip ring, an additional transformer arrangement is used to couple the rotor signal to the out side world.

Synchro has a higher resolution

(1) It has one more coil to form a more balanced rotating magnetic field

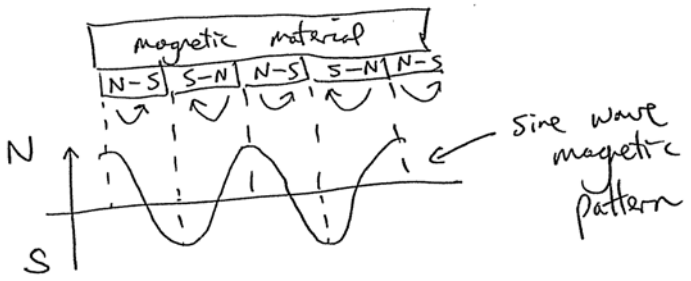
(2) The signal coupling efficiency is higher.

(3) Can inject higher signal level to increase the signal to noise ratio

(4) The primary and secondary winding are not winded close together.

Magnetic Linear Scale

* The scale is a magnetic track with a redefined magnetic pattern
* A read-head is used to detect the pattern
* The output has a fixed voltage output, but its phase will vary with position.



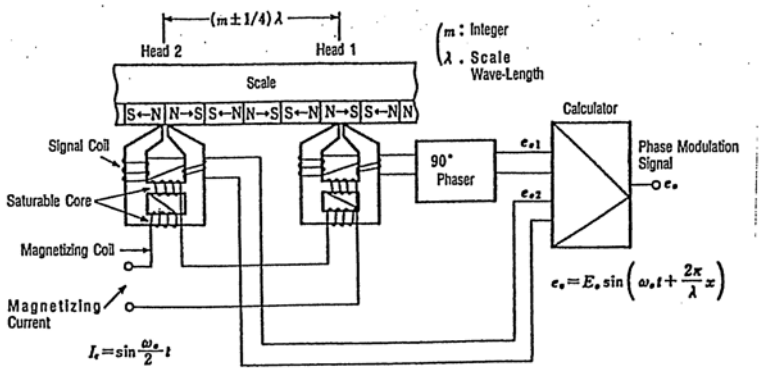
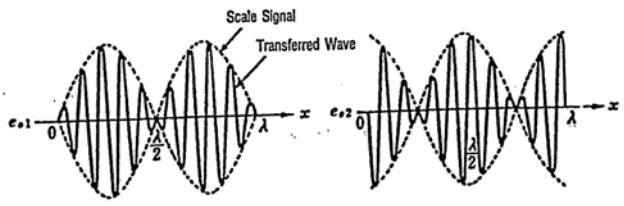


Figure 4.11. Structure, Positioning, and detecting circuit block diagram.

The overall block diagram

$$e_{o1} = E_o \sin\frac{2\pi}{\lambda}x \cdot \cos\ \omega_o t \qquad (4 \cdot 7)$$



Output waveform of the encoder

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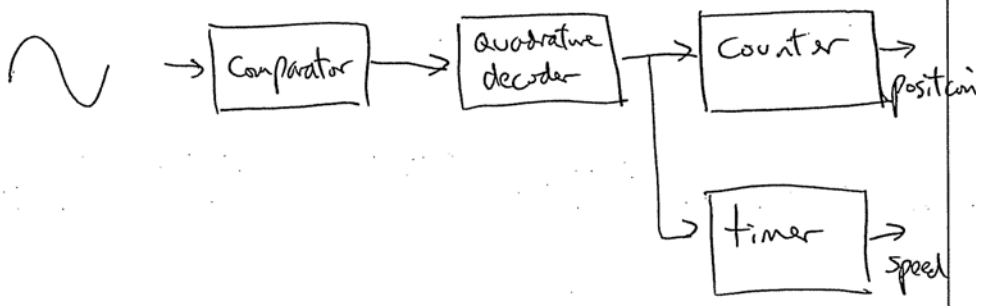
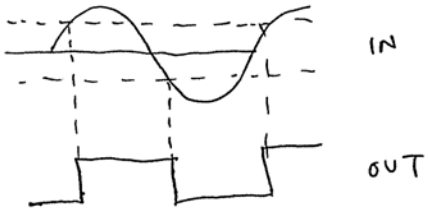
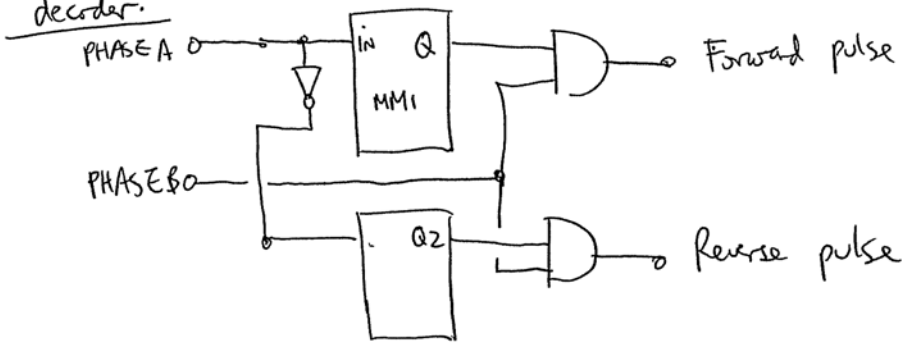
Since the signal is modulated, and a multi-gap head is used, so it can detect the signal even at zero velocity



Comparator : Normally a hysteresis comparator is used.



Quadrature decoder.

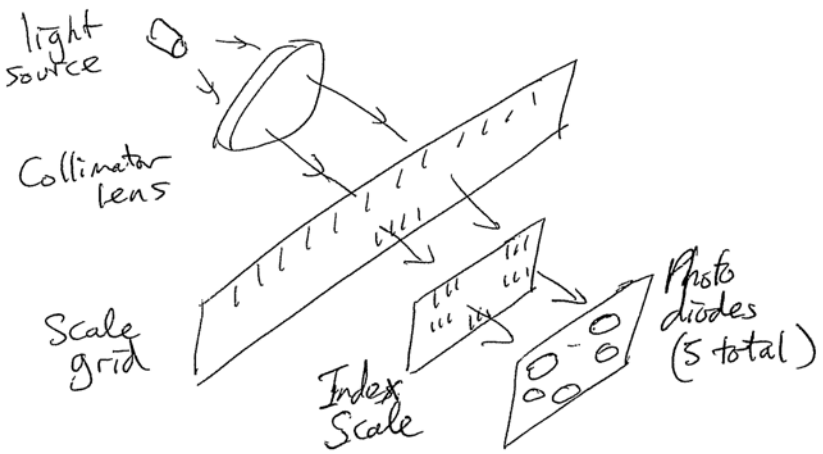


Counter — The counter feeds in the up/down count pulse from the decoder and provides the the absolute position value

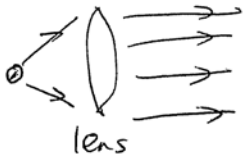
Timer — The timer measures the pulse interval duration to calculate the speed information

Q2 03-04 Paper

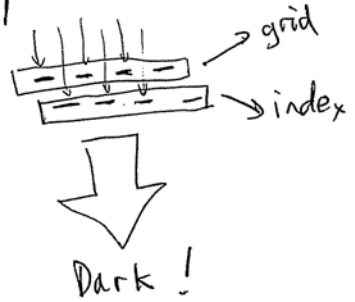
Cross - sectional diagram of a linear optical encoder

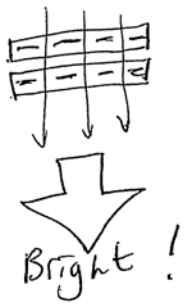


Collimator lens is to convert a point source into parallel rays



The grid scale, when combined with the index scale, provide the bright/dark light pattern





(a) The 5 photo heads are placed in strategic locations, in order to obtain the following signals:

phase A, $\overline{\text{phase A}}$

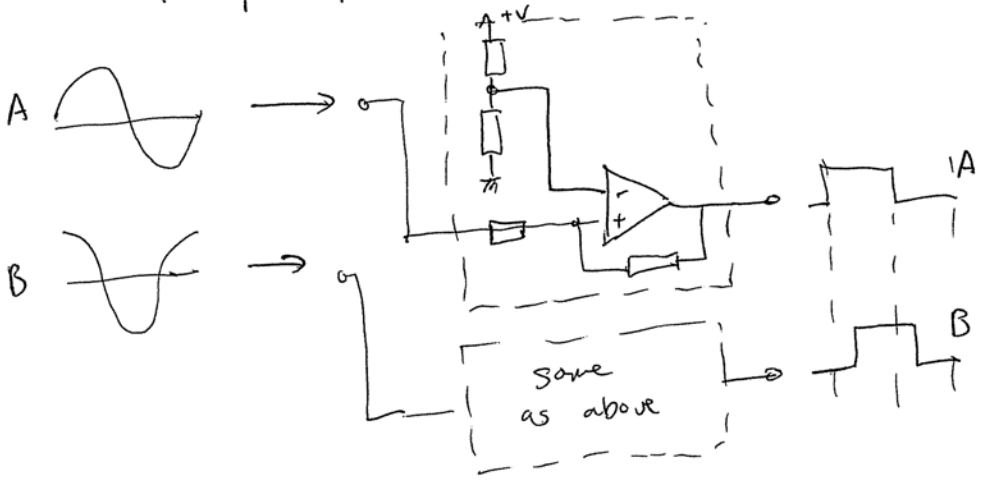
phase B, $\overline{\text{phase B}}$

index

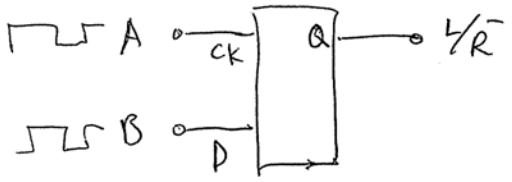
In order to ensure waveform symmetry both the positive (phase A) and negative ($\overline{\text{phase A}}$) signals are required

(b) The output of A and B are in a near sinusoidal wave form (sine + cosine)

1st step: pass through a hysteresis comparator



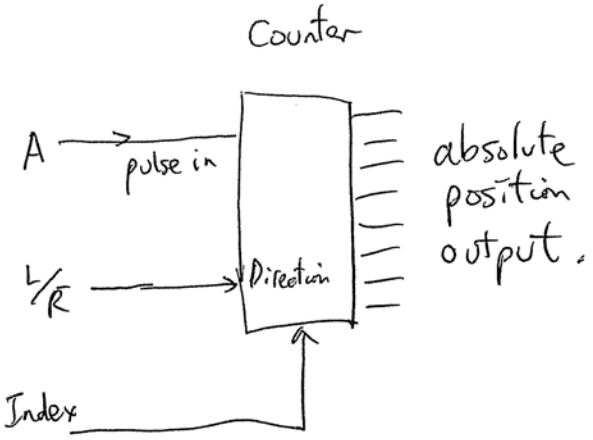
2nd step : Detect the rotation direction



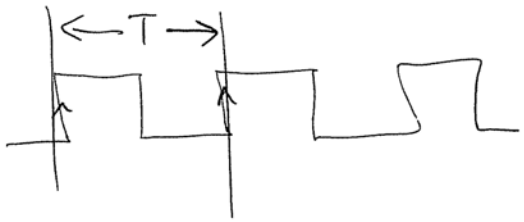
A is low when B is ↑

A is high when B is ↑

3rd : Count the pulse



4th Detect the speed by counting the period



$\omega \propto \frac{1}{T}$

Q3 03-04 Exam paper

DC Brush Motor

Advantages

1. Linear Characteristics, easy drive electronics
2. Torque, Speed proportional to V, I
3. High Power to size ratio, Small rotor Inertia

Disadvantages

1. Brush wears out, create sparks, EMI
2. Expensive (due to rare earth magnet)
3. Not robust under harsh environment
4. Heat difficult to dissipate

AC Brushless Motor

Advantages

1. Can overdrive the motor
2. Easy heat dissipation
3. No brush, more robust.

Disadvantages

1. Complicated drive + commutation
2. High inertia due to magnet rotor
3. Need extra wires to carry the commutation signal.

Induction

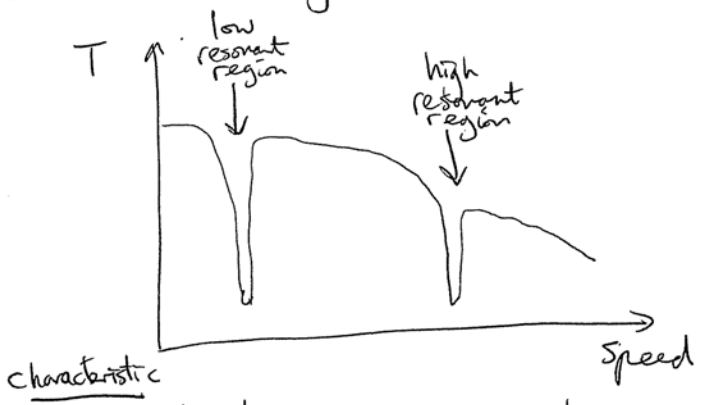
Advantages

1) Low cost, robust
2) Large size motor easy-to-make

Disadvantages

1) Nonlinear drive function, Complicate drive
2) Not suitable for precision control

The resonant regions



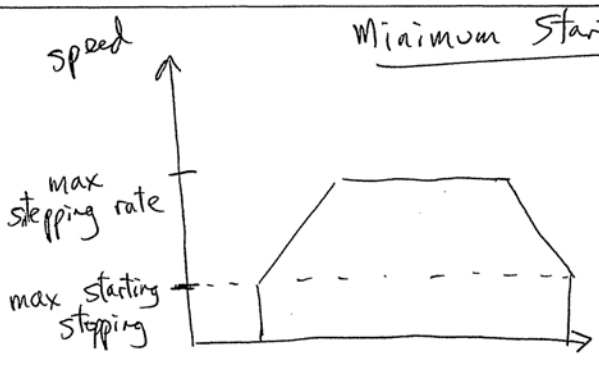
characteristic

* There exist two regions in stepper motor in which the torque output will drop drastically

* limitation will pose a problem if motor continues to run at these speeds. (e.g. draw a large circle for X-Y tables)

* overcome resonant will develop after a short while. There will be no effect if the motor do not stay at these speeds. Try to avoid these regions.

Minimum Starting / Stopping stepping rates

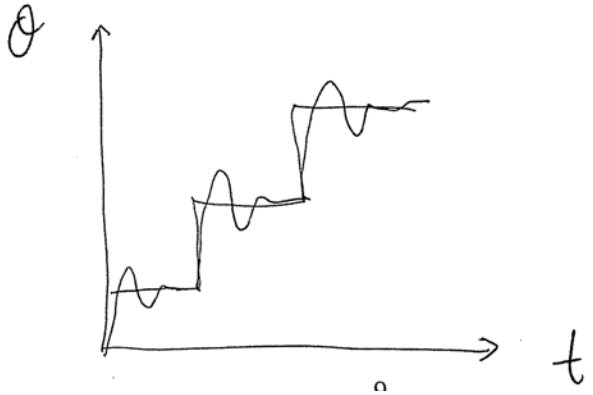


Characteristics - to avoid step slipping, stepping motor cannot start/stop above its "max starting/stopping" rate.

limitations - places a limitation on the maximum speed of the motor.

overcome - to drive the motor faster, one should start at a low rate, then slowly ramp up the speed until the motor reaches max velocity. The same ramp down procedure must be done before stopping

The vibration between steps



Characteristics - when the motor turns from one step to another, a vibration is caused. The vibration may be amplified under particular loading condition

limitation - Cause undue vibration to the mechanical. The structure may resonate and becomes noisy. It will also affect the overall accuracy

overcome - use half stepping or micro stepping to reduce the "jump-gap" and "overshoot between steps