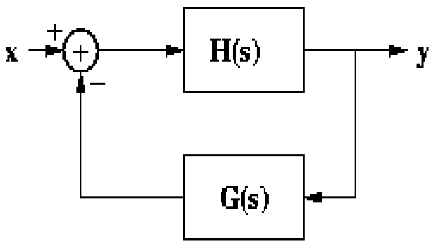
L16.1 Controlling Position

Servomechanisms are of this form:



$$\frac{Y(s)}{X(s)} = \frac{H(s)}{1 + G(s)\,H(s)}$$

Some General Features of Servos:

They are feedback circuits.
Natural frequencies are 'zeros' of 1+G(s)H(s).
System is unstable if these zeros are in the right half plane.
'Negative' feedback becomes positive with 180 degree phase shift.

Putting an integrator into H(s) drives steady error to zero.
But high order systems are more likely to have RHP zeros.
Time delay and high gain lead to RHP zeros.

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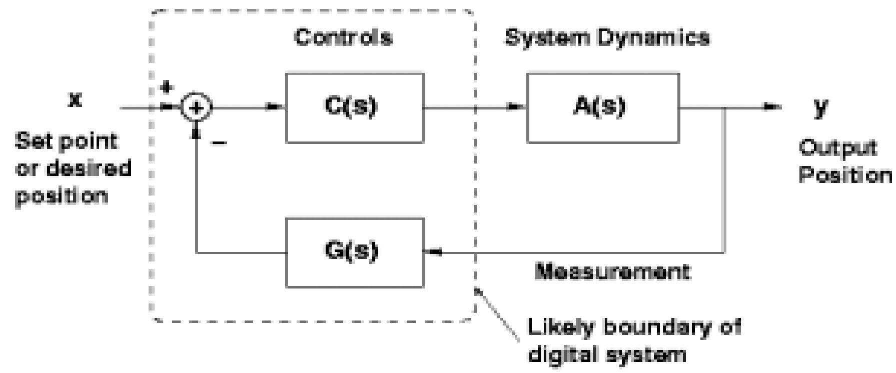
L16.2 Digital Servos

Major parts of the system are digital.
    Digital systems are more flexible to design.
    More repeatable (not subject to gain drift)

Analog parts are important,
    But in many cases can be avoided.

But, note that digital servos have fixed (or worse, stochastic) time delays.



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L16.3 Analog Position Measurement

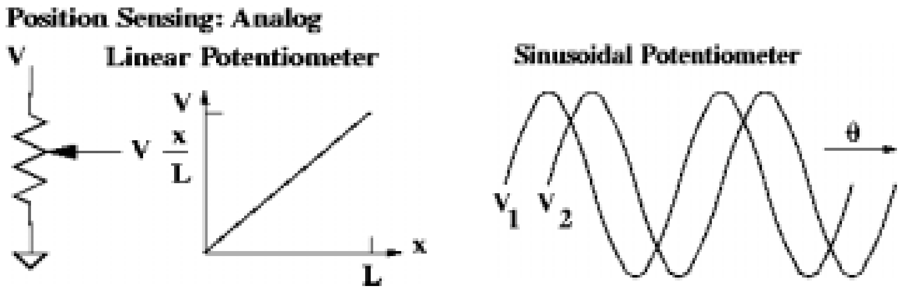
Voltage is proportional to position.

Linear or rotary potentiometer can be used.

Accuracy limited by that of potentiometer.

Accuracy limited by voltage source.

Two sinusoidal potentiometers are used.
    V1 = V0 cos ()
    V2 = V0 sin ()
This can be done magnetically too.
    Requires complex analog detection.
    Is called a Resolver.
These are still analog.
    Accuracy limited
    Subject to drift
    Complex calculations



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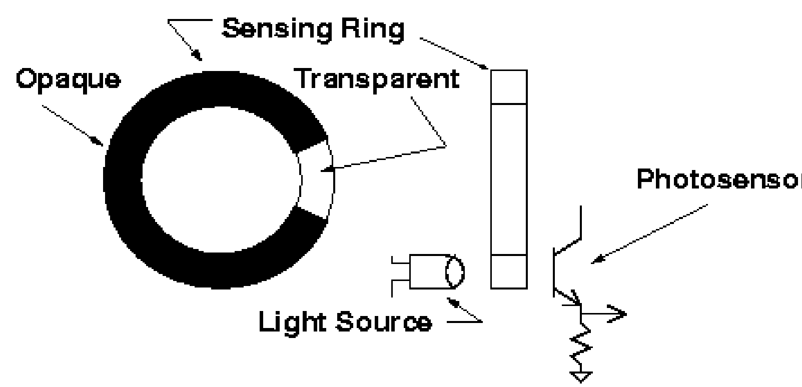
L16.4 Digital Position Measurement

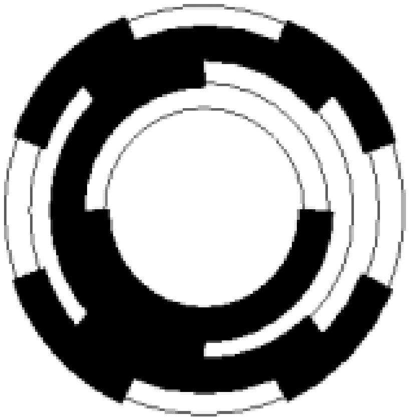
Sense light transmission

    Typically through a transparent sector
    Gives a reading over a range of positions.
    May need a lot of sensors.



L16.5 Digital Absolute Position

Low Resolution Absolute Sensor



Here is a 4–bit (22.5 degree) resolution wheel.
One source per sensor bit

Can make these wider.
Resolution is

$$\frac{360^{o}}{2^{N}}$$

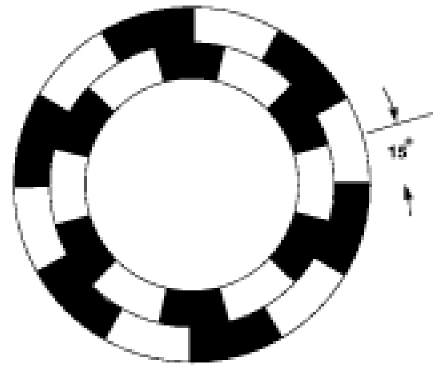
Use a Gray Code to eliminate chatter.

0	0	0	0
0	0	0	1
0	0	1	1
0	0	1	0
0	1	1	0
0	1	1	1
0	1	0	1
0	1	0	0
1	1	0	0
1	1	0	1
1	1	1	1
1	1	1	0
1	0	1	0
1	0	1	1
1	0	0	1
1	0	0	0

L16.6 Two−Phase Encoder

Two Source-Sensor Sets

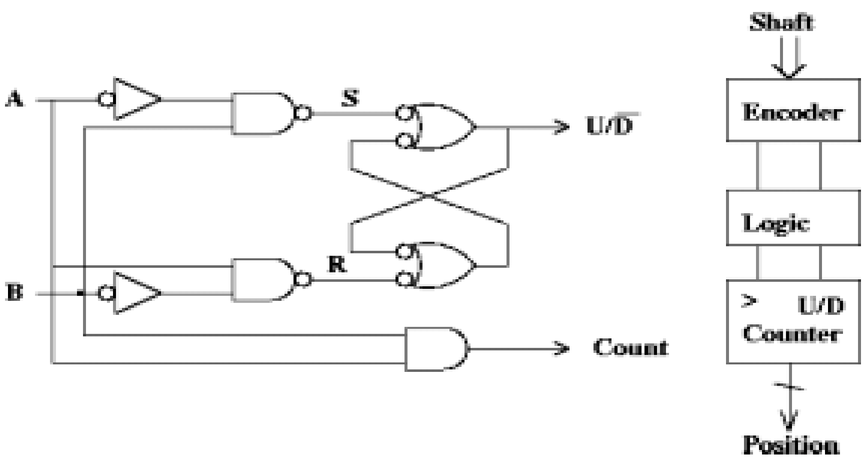
Offset by half sector width
This example has 30 degree sectors.
And 15 degree resolution



L16.7 Use of Two−Phase Encoder

This circuit generates:

An Up/Down signal (CW or CCW)
A Count Signal (Edge Encountered)

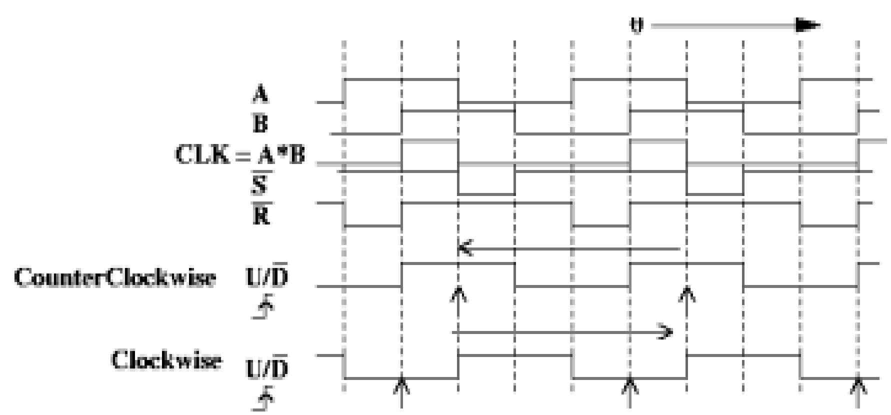


L16.8 Waveforms

A and B are sensor signals.

Rotating one way, Count Edge is when U/D is high.

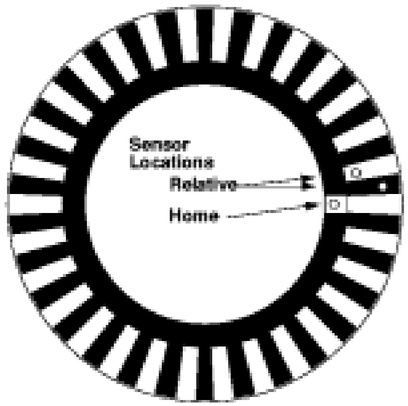
Rotating other way, Count Edge is when U/D is low.



L16.9 Another Way of Making an Encoder

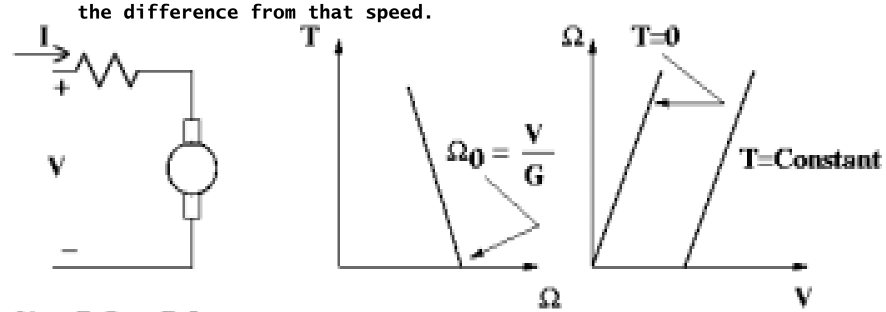
Displace sensors by 1/2 band.

Add a "home" row to sense the absolute position.



L16.10 Motors

Simple servomechanisms are made with DC motors.
    Servo Strategy: Command torque by setting current and measure speed.
DC Motor Model is simple:
    Resistance in series with a voltage source
    Motor produces torque.
    Mechanical system (controlled system) determines speed produced by torque.
Permanent Magnet DC Motors are very commonly used:
    `Back Voltage' proportional to speed
    Torque proportional to current
    Running open loop, there is a `zero torque' speed and torque proportional to the difference from that speed.

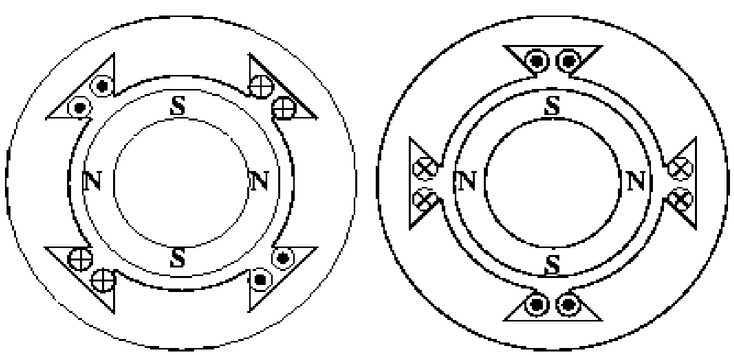


$$V = G\Omega + RI$$

L16.11 Stepper Motors

Digital motors

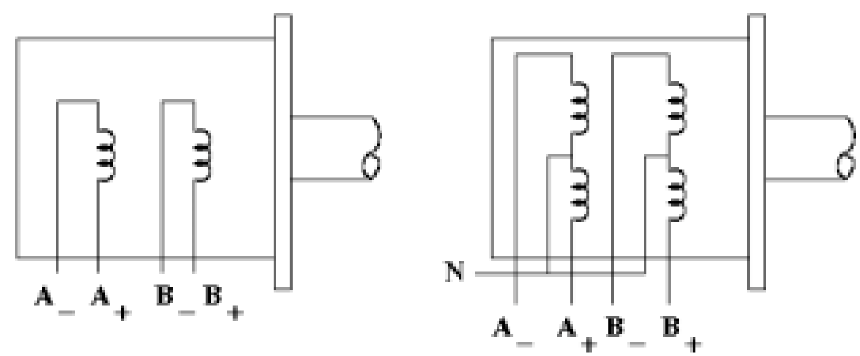
Two "stacks" (phases)
Usually biased by permanent magnets
Move a discrete distance per 'step'.
This is an axial view cut through both of two sections.



L16.12 Stepper Motor Windings

Two distinct 'phases'

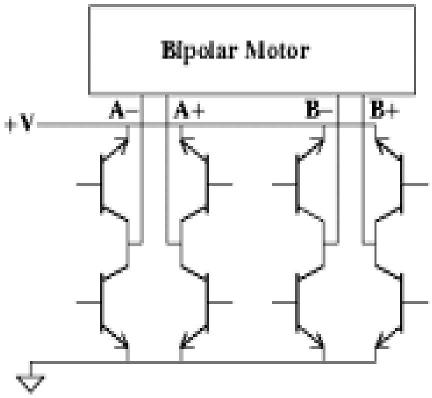
May be driven as distinct windings,
Or may be driven as 'bifilar' windings.
Bifilar is easier but less efficient.

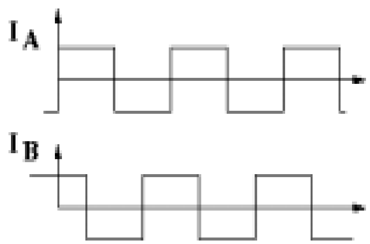


L16.13 Bipolar Winding

Driven by 'H-Bridges' of transistors

Can put current through windings in either direction.
But note upper transistor drive is tricky.
Uses all of the winding.





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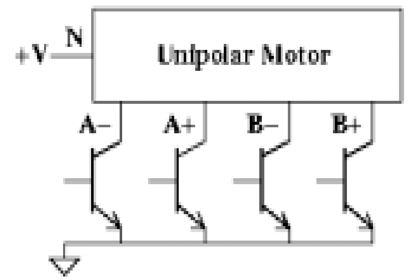
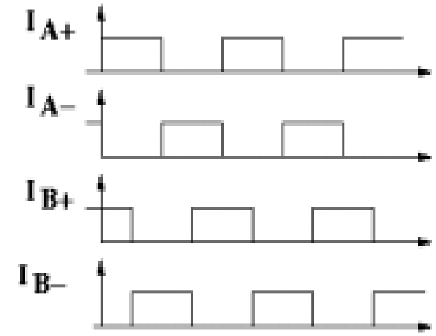
L16.14 Bifilar Winding

Driven by four transistors to ground.

Note the center of winding is held `high',

Transistors are between winding and ground.
NPN bipolars work well.
Transistor drives are easily handled.





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L16.15 Motors Run In Either Direction

Current drive strategy

Clockwise ↓ / Counter–Clockwise ↑

Step	I_A	I_B
1	+	+
2	+	–
3	–	–
4	–	+

Bipolar winding

Step	I_{A+}	I_{A-}	I_{B+}	I_{B-}
1	1	0	1	0
2	1	0	0	1
3	0	1	0	1
4	0	1	1	0

Bifilar winding

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L16.16 Dynamics Are Important

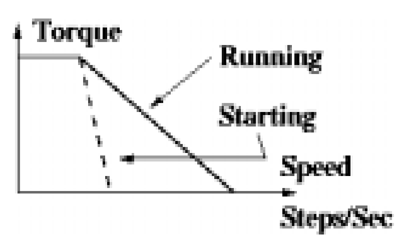
Stepper can hold a certain torque.

Stepper can carry more torque at low speed.

At high speed, torque must be de-rated.

Motors draw CURRENT! Make sure your power supply is adequate by measuring the power supply voltage.

Need to make sure devices can handle current and torque.



Must sometimes 'ramp up' speed.
Holding torque is limited by heating and by saturation.