Making the right choices : Motors / sensors

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Steppers and servos get closer

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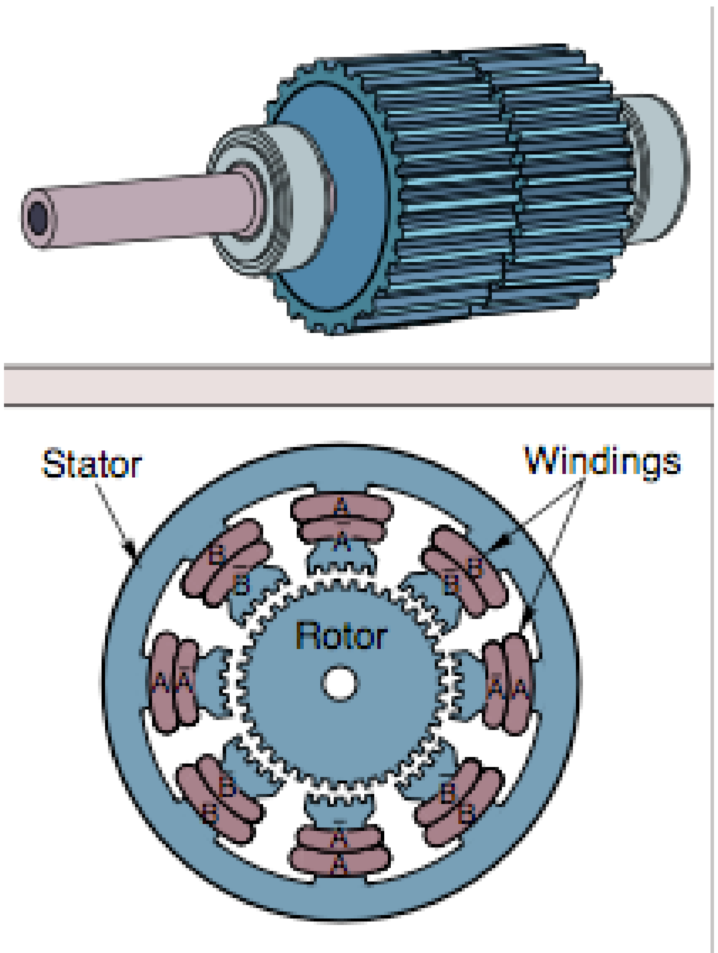
There was a day when the design decision of whether to specify a step motor system over a servo system was simple. If you needed repeated motions with good accuracy at low speed, stepper sys-

It used to be easy to choose between a step motor and a servo. Today, the choice is less clear-cut, but the benefit is greater design flexibility.

Stepper

Given pre-determined voltage pulses, moves in predictable, discrete angular increments (eg. 7.5 deg, 0.18deg)



Can be operated open-loop, thus no encoder related electronics needed

Error is non-accumulative

Need to know :

a) Running /Acceleration torque
   Compare with max. torque at required speed that the motor can provide
a) Load inertia < 10*motor inertia
   (1:1 ratio for higher speeds)
c) Speed range eg. 200deg/sec
   Quicker pulses mean high speed
   Motor is inductor in series with resistance, thus current (or torque) takes time to build up. Thus you might have to go to higher voltages to get to higher speeds.
d) Might loose steps if overloaded

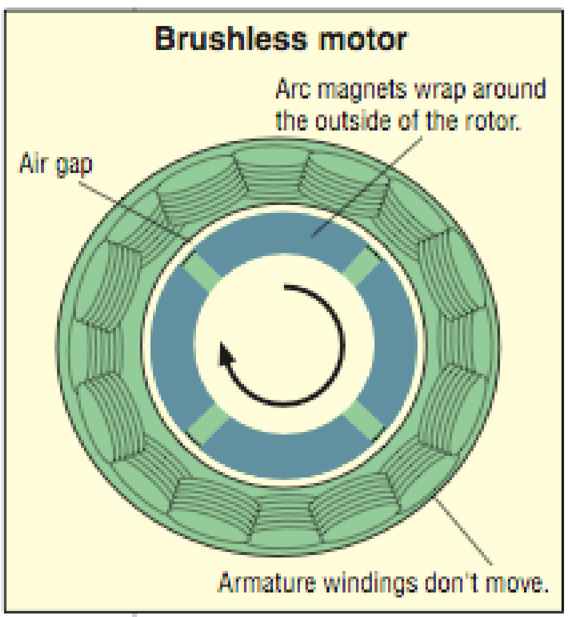
Servo

AC or DC, closed loop

Permanent magnet DC brush motor : Achieves commutation by mechanical brushes. Cheap since no electronic controller required (specially for low power operations where control could be the lead cost)

Brushless DC motor : Commutation is electronically achieved

Saves space , windings are outside thus helps cooling, efficient since no power loss in brush voltage drop and brush friction, less rotor inertia



Operated in close-loop, thus feedback/encoder related electronics needed

Errors can be corrected by the controller

Need to know :

a) Running /Acceleration torque
   Compare with max. torque at required speed that the motor can provide

a) Load inertia < 10*motor inertia
   (1:1 ratio for higher speeds)

Steppers vs. Servos

Open Loop step-motor or Closed-loop servo motor : **5 Grand Questions**

1. Is load constant or variable ?

   Office printer vs. machine tool - Stepper can not take a overload, servo can.
   Close-loop servo can recover position after a overload cycle (stepper can not)

2. Motor running at greater than 1,000 rpm or less than 1,000rpm

   See curve on next slide : Higher pole count vs. lower pole count

3. Can the application tolerate position loss?

   Servos are usually operating close loop, while steppers usually are open-loop

4. Do you need positioning resolution higher than 1.8deg?

   Open loop stepper can give a 200steps/rev. resolution while a close loop servo could as high as 1000 steps/rev.
   (tricks for stepper motors : microstepping and 5-phase motors)

5. How much load-inertia can you tolerate?

   For stepper motors, do not go higher than a 10:1 ratio of load inertia vs. motor inertia. For servo motors, that could go as high as 50:1. For higher dynamic performance (fast acceleration/de acceleration) keep the ratio 1:1

Finally, size your motor : Calculate the maximum torque at speed needed. Choose a motor which gives you a higher value from torque-speed curve.

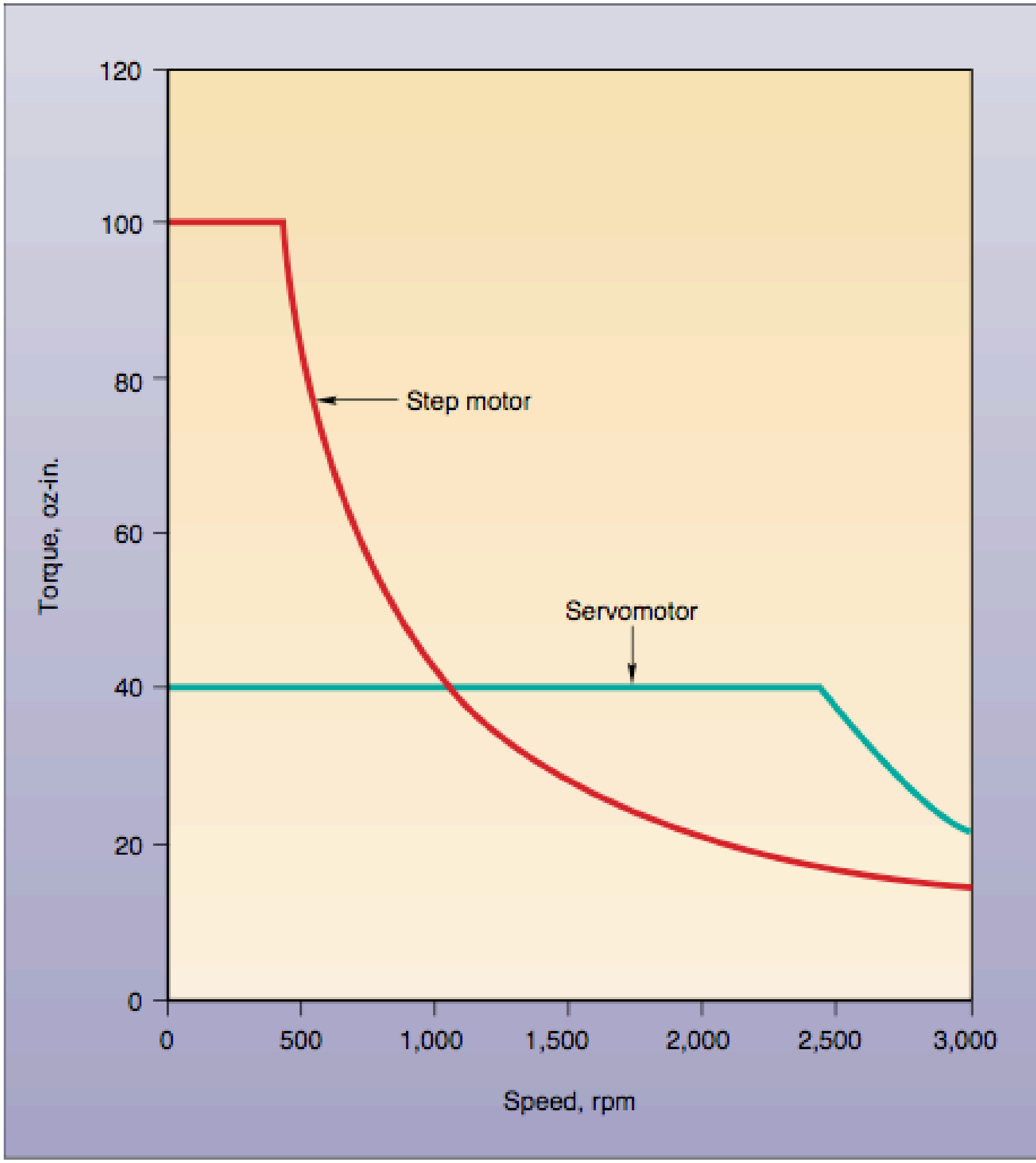


Figure 1 — Torque vs. speed curves for typical step motor and ac or dc servomotor of equivalent physical size and material content. Step motor tends to produce higher torque at lower speeds than a servomotor, which can deliver constant torque into a much higher speed range than a step motor. Moreover, in the higher speed range, the servomotor can deliver higher torque than the step motor. The challenge: Use the one you need.

Summary

Stepper : High torque in small package at speeds typically less that 1,000rpm

Paper feed in a line printer is an example

Servo : suited when a wide range of speeds needed, with high speeds

When torque control is important

Fine tuning your motor selection

Mechanical ways to balance the ratio of load inertia: motor inertia

- Remove as much mass from the load
- Mechanical speed reduction : eg. 3:1 reduction using timing belts. Load inertia reduced by 9 times. Brushless servos are happy even at higher speeds.

Balance load power rate with motor power rates

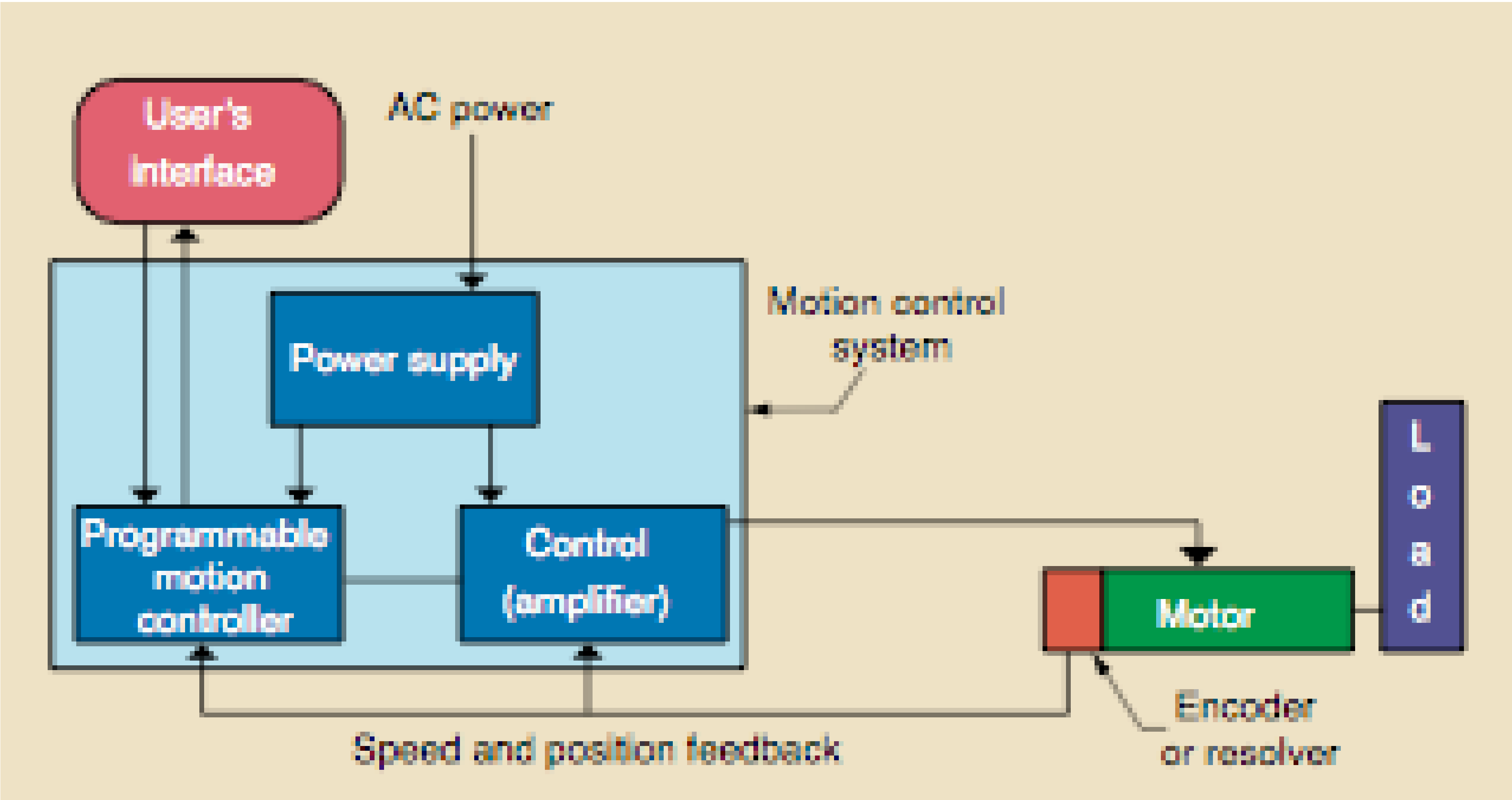
$$P'_m = T_{pk}^2 \div J_m$$

where:

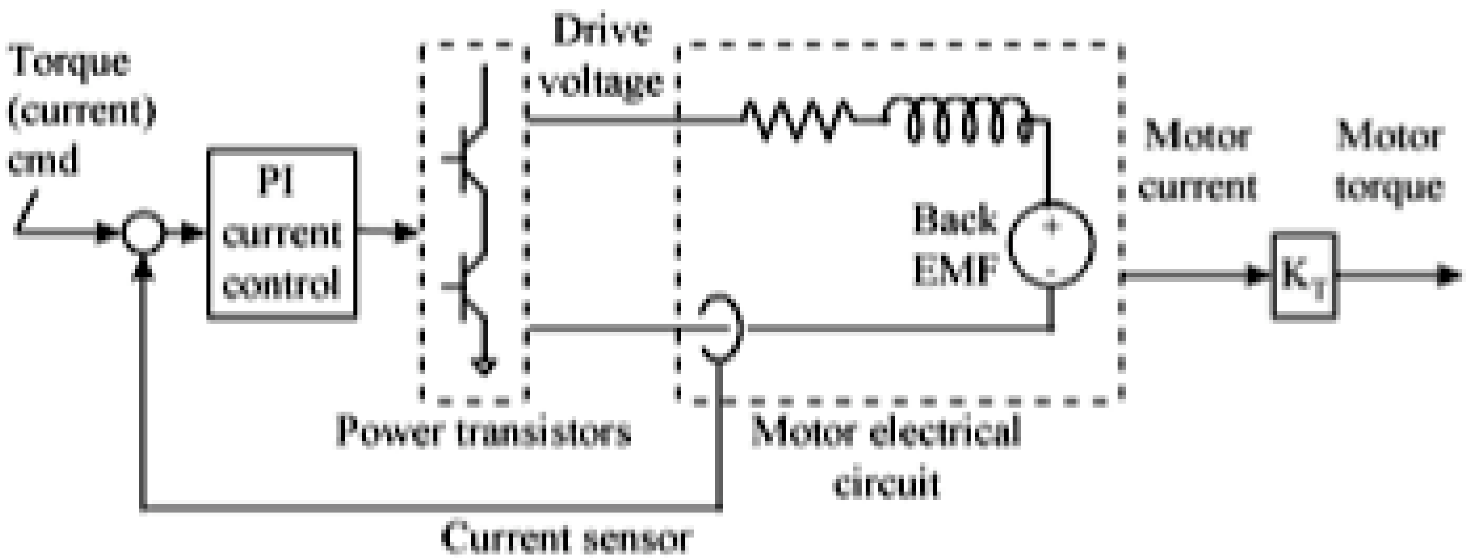
P'_m = Motor power rate

T_{pk} = Motor peak torque

J_m = Motor inertia


User's interface
AC power
Power supply
Motion control system
Programmable motion controller
Control (amplifier)
Motor
L
o
a
d
Encoder or resolver
Speed and position feedback

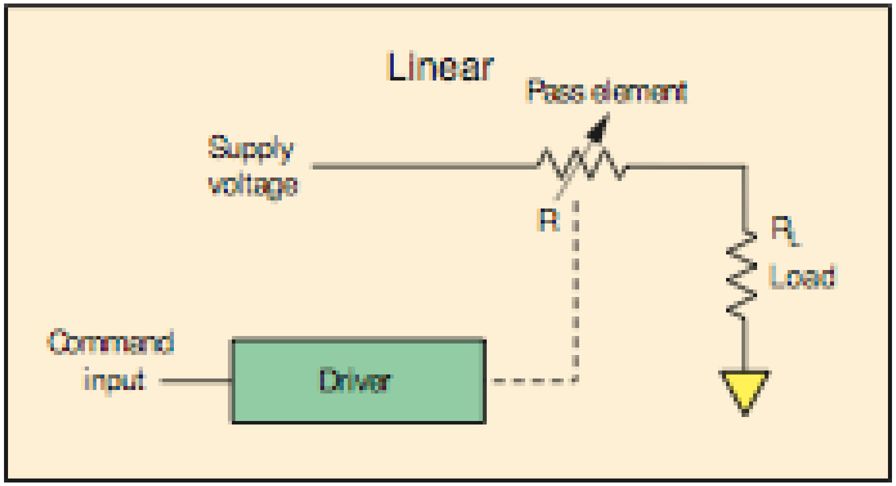
Feedback loops for the servo



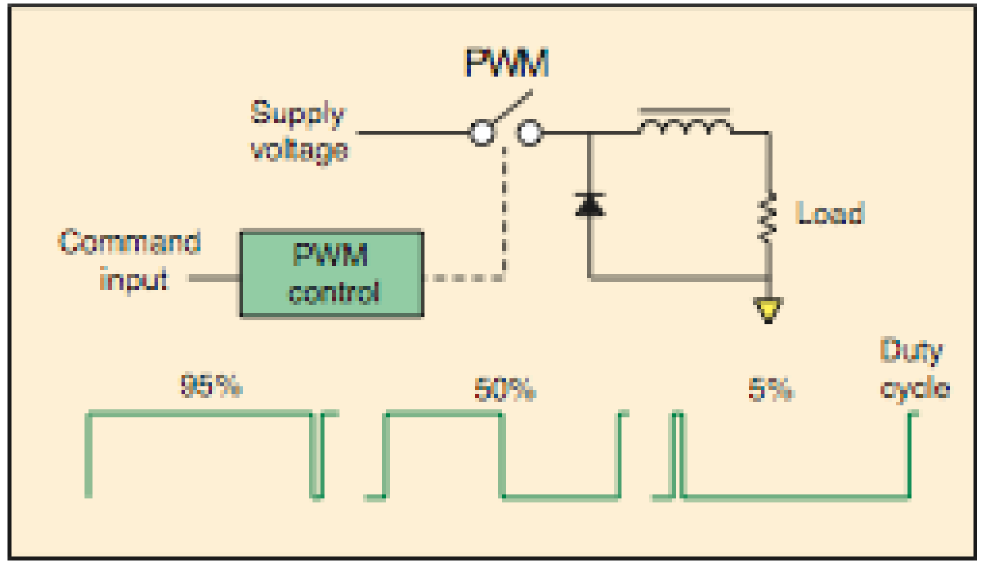
Servo drive amplifier : gets a input signal from controller and provide operating voltage and current output for the motor

Linear amplifier : Inefficient thus used for low-power amplification, consider thermal characterstics of the output stage and breakdown voltage for the Transistors.

PWM (Pulse Width modulated) amplifier : Very efficient, switch output voltage At freq. Upto 50MHz , average value of voltage is the output voltage.



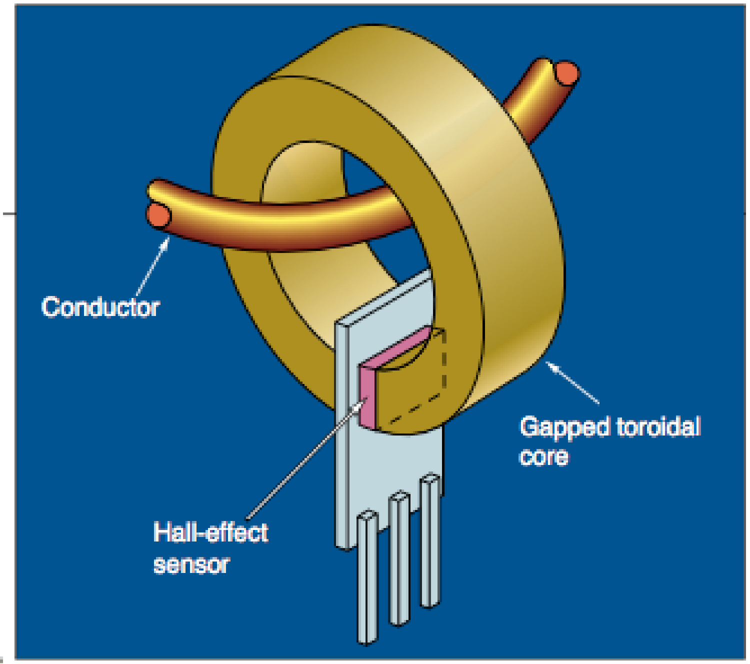
Linear amplifiers vary the resistance of a pass element to regulate power. Efficiency is fine at the extremes — losses are minimal when $R = 0$ or ∞ — but suffers elsewhere, bottoming out at midrange ($R = R_L$) where the amount of energy wasted as heat in the amplifier equals that delivered to the load.

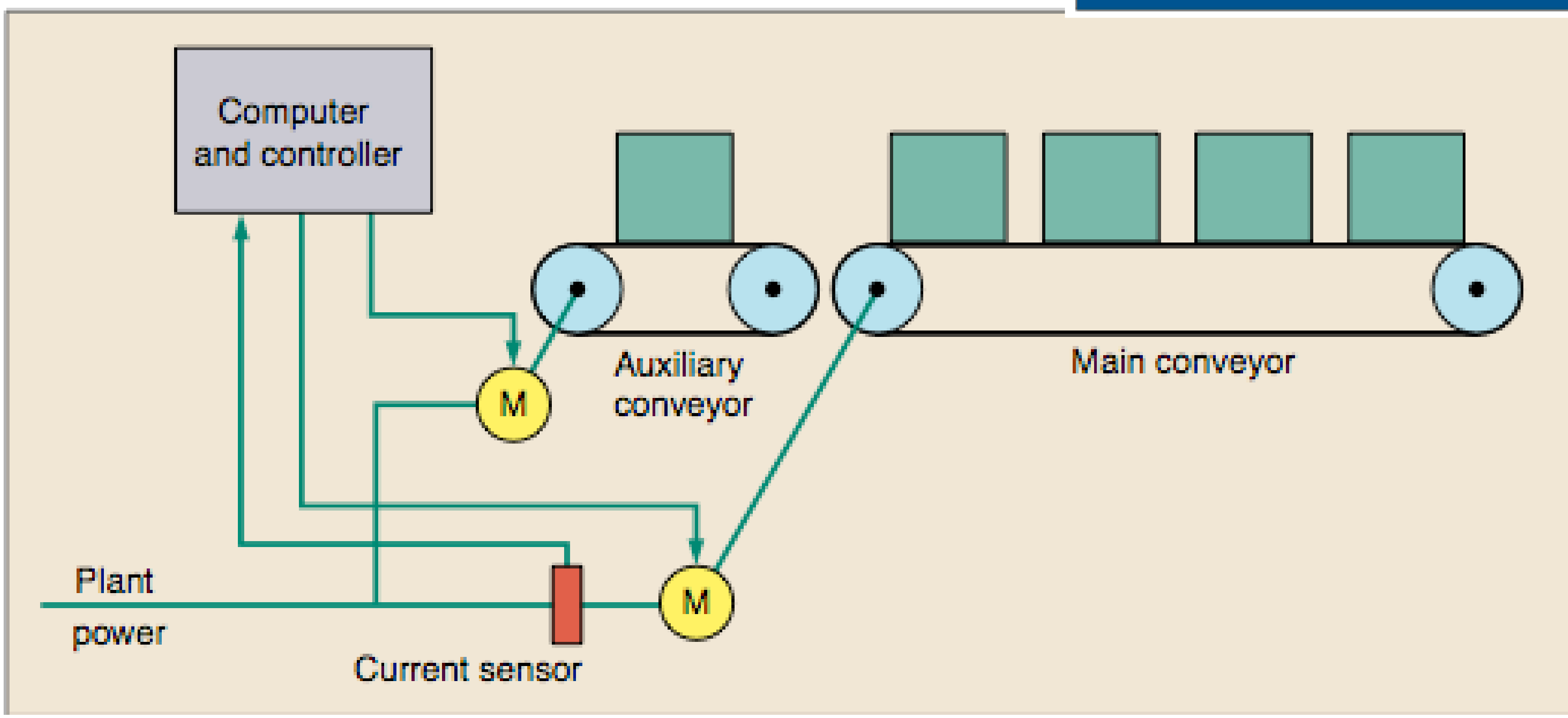


The output of a PWM amplifier is either zero or tied to the supply voltage, holding losses to a minimum. As the duty cycle changes to deliver more or less power, efficiency remains essentially constant.

Comparison of digital feedback devices for motors				
Device	**Max. temp. C**	**Relative cost**	**Benefits**	**Constraints**
Hall-effect device	110	$6	Inexpensive, easy to install	Relies on magnet pole definition for trigger, temperature sensitive, no position feed back, can only be used to com-mutate BLDC motors
Encoder with com-mutation track	120	$80-350	Precision depends on line count. Can be very precise.	Temperature
Absolute encoder	90-100	$450-1,000	Accuracy, precise positioning	Expensive, sensitive to vibration
Resolver	200	$30-60	High temperature, rugged construction	See note*

Hall effect sensor : feedback control for the servo





Age old battle between hydraulic vs. electric systems

Table 1 — Comparison of hydraulic and electrical motion control systems

Selection criteria	Hydraulic	Electrical
Power.	10 to 20 hp or more.	10 to 20 hp or less.
System cost.	Higher.	Lower.
Power density of motor or actuator.	High. Hydraulic motor may be ¼ the size of equivalent brushless motor.	Low.
Environmental.	Requires periodic clean-up and disposal of fluid.	Requires care in disposal of rare earth magnets.
Safety.	High pressure systems may need safety enclosures.	No special precautions.
Servo capabilities.	Controls end position points. Difficult to control motion profile between end points.	Controls motion profile (velocity, position, and torque or force).
Positioning accuracy.	Within a few thousandths of an inch (typical).	Within a few ten thousandths of an inch (typical).

Fluid flow inertia is order's of magnitude higher than electron flow inertia since the density is drastically different.

Choosing the right Power semiconductor

Factors

- Speed
- Gain
- Efficiency
- Control method (current vs. voltage)

- SCR (silcion controlled rectifier), GTO (gate turn-off device), GTR (Giant Power Transistor), IGBT (Insulated Gate Bi-polar Transistor)

Relative power-semiconductor characteristics

Type	Speed	Gain	Efficiency	Control method	Max. rating, A
SCR	Slow	Medium	Low	Current	10,000
GTO	Medium	Medium	Low	Current	10,000
GTR	Fast	Low	Medium	Current	2,000
IGBT	Fastest	High	High	Voltage	2,000

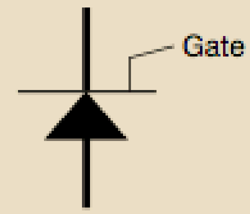


Figure 1 — Silicon controlled rectifier (SCR), also known as a thyristor. It conducts current during a positive half cycle from the time sufficient voltage is applied to the gate to the end of that half cycle.

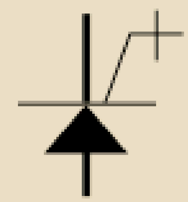


Figure 2 — Gate turn off thyristor (GTO). Similar to an SCR, except a GTO can be turned *on* and *off* by the voltage to the gate. Positive voltage turns the GTO *on* and a negative voltage turns it *off*.

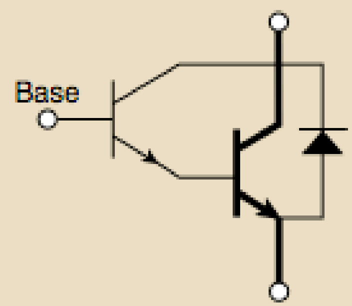


Figure 3 — Giant transistor (GTR) in a Darlington configuration so the transistor amplifies the signal to the base of the GTR.

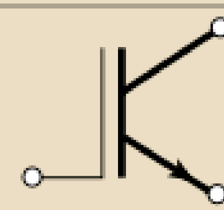


Figure 4 — Insulated-gate bipolar transistor (IGBT) is the most common power device used in current general-purpose and servo drive controllers. It can operate with carrier (also called chopping and modulation) frequencies to more than 20 kHz.