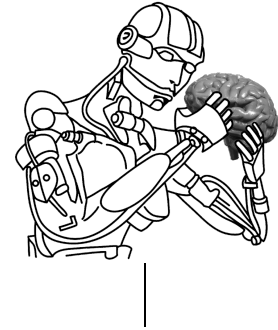
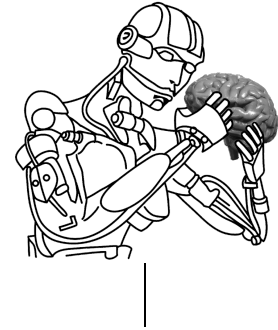


CS545—Contents XIV



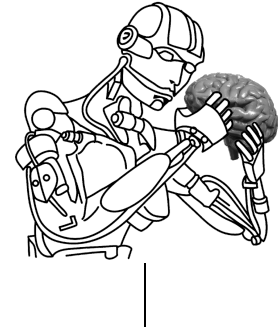
- Components of a Robotic System
 - Power Supplies and Power Amplifiers
 - Actuators
 - Transmission
 - Sensors
- Signal Processing
 - Linear filtering
 - Simple filtering
 - Optimal filtering
- Reading Assignment for Next Class
 - See <http://www-clmc.usc.edu/~cs545>

Power Supplies and Amplifiers



- Power Supply
 - Primary source of power
 - Electric
 - Hydraulic
 - Pneumatic
 - Mechanical
- Power Amplifier
 - Regulates the amount of power provided by the power supply
 - Electric
 - Usually current control
 - Pulse-Width Modulation (PWM)
 - Hydraulic & Pneumatic
 - Electro-hydraulic (pneumatic) valves

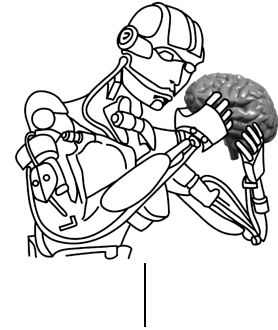
Power Supplies Examples



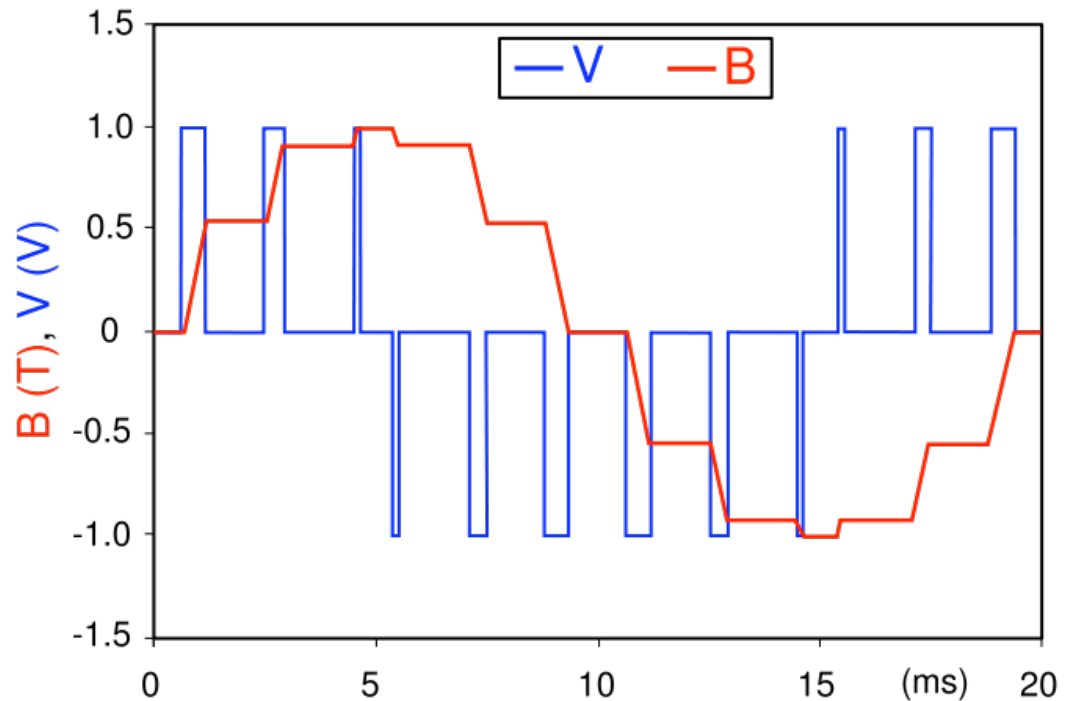
- Hydraulic Pumps



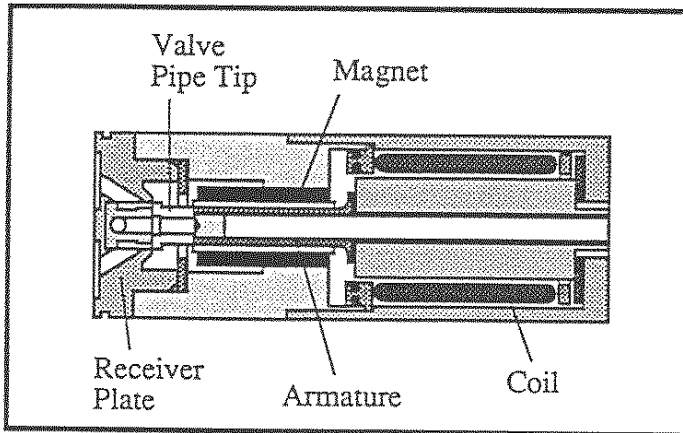
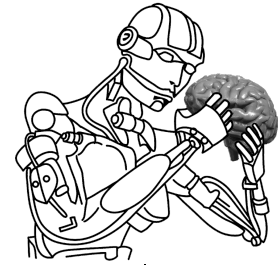
Pulse Width Modulation



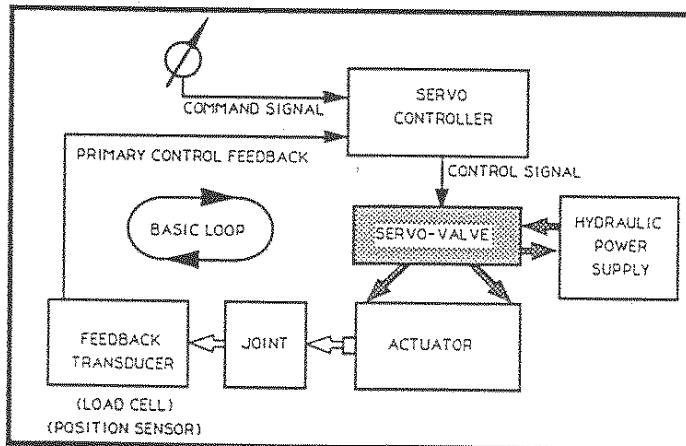
- A simplified example of pulse-width modulated (PWM) voltage supply to a magnetic circuit. The voltage (blue waveform) in a magnetic circuit is proportional to the rate of change of the flux density (red waveform). Therefore, by using PWM supply the resultant flux density can be controlled with relative ease. This method is commonly used for supplying electric motors, in which the torque is proportional to the flux density. As can be seen, with a series of appropriately modulated voltage impulses the resultant flux density can be modulated to be close to desired sinusoidal waveform. In the example shown (for 50 Hz), for clarity the switching frequency is 600 Hz, in real devices the switching frequency is much higher - even up to 10 kHz or higher. Of course, for higher fundamental frequency the switching frequencies would be even higher.



Hydraulic Valves



Cut away view

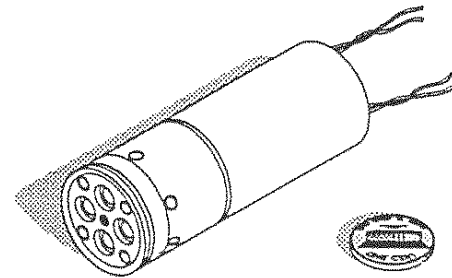


Specifications

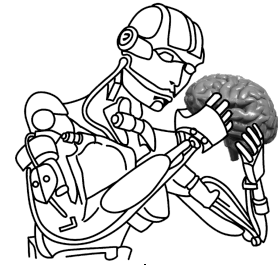
Supply Pressure	0-3000 psi
Size	2.16 cu. in.
Weight	4.96 oz.
Rated Flow	
No load	2.0 gpm @ 3000 psi
Max. internal leakage	
at null	0.2 gpm @ 3000 psi
Rated Current	± 1 amp
Coil Resistance	8 Ω
Electrical Connection	2 wire cable
Working Fluid	Industrial grade hydraulic oil

Manifolding Options:

- 1) Stand alone unit
- 2) Mounted to manifold plate
- 3) As part of integrated actuator



Hydraulic Control Circuit



SARCOS
RESEARCH CORPORATION

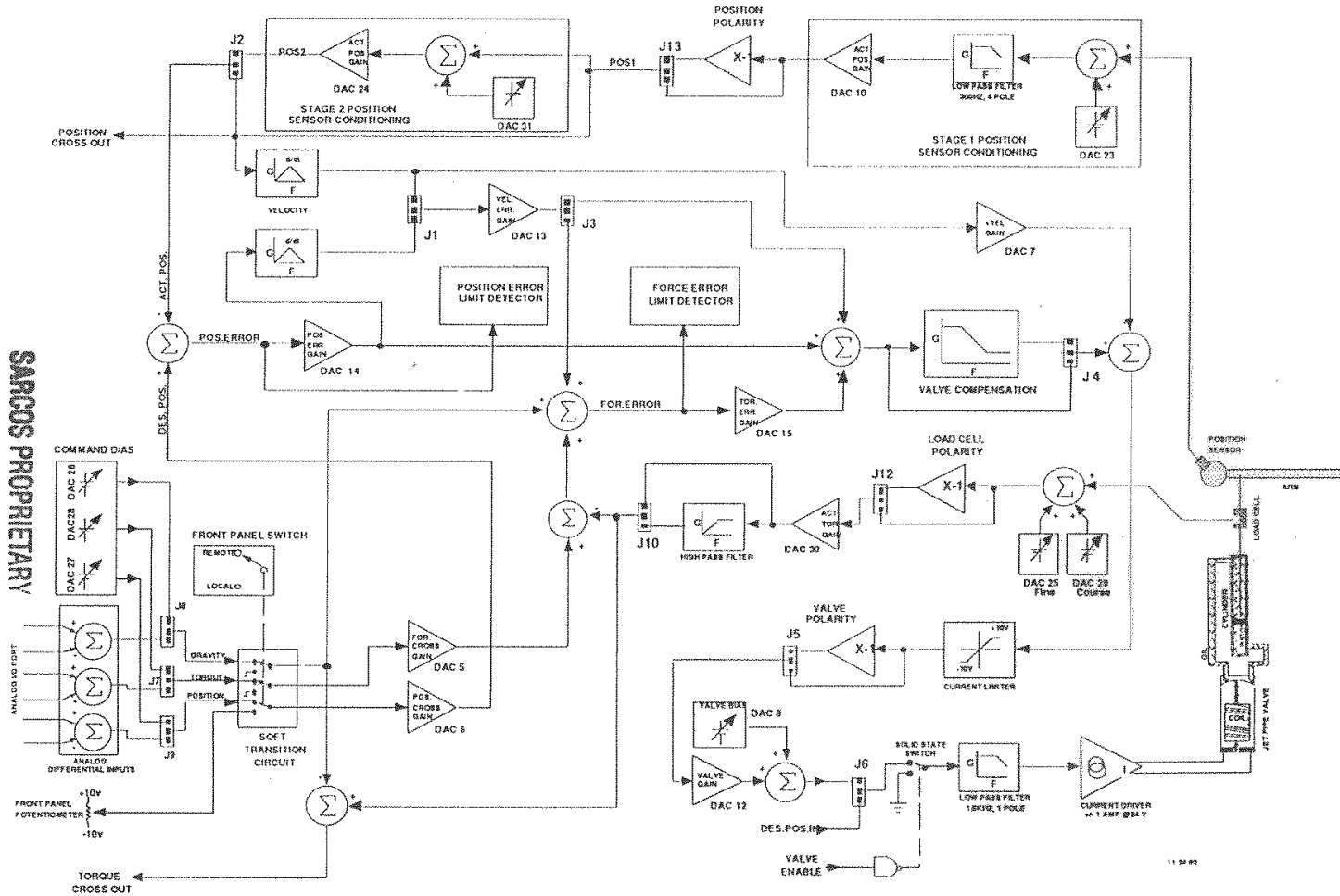
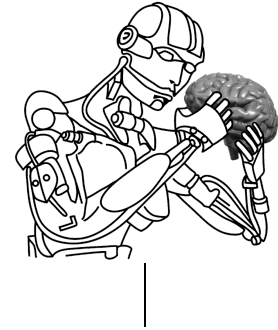


Figure 1-2. AJC2.1 Block Diagram

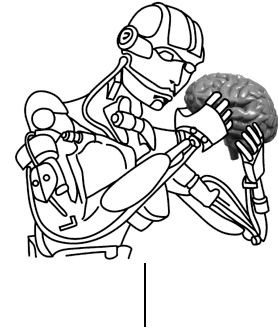
SARCOS PROPRIETARY

Actuators



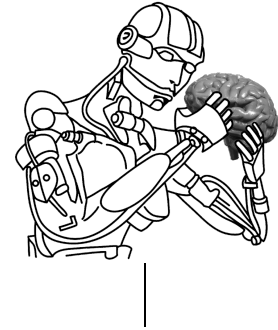
- Electric Motors
 - Clean
 - Heavy (Torque motors)
 - Light & Transmission box
 - Need amplifier
- Hydraulic Motors
 - Light weight
 - Heavy pump needed
 - Messy?
 - Strong!
 - Expensive
- Pneumatic Motors
 - Light weight
 - Clean
 - Compliant
 - Need compressor
 - Not very strong

Actuators (cont'd)



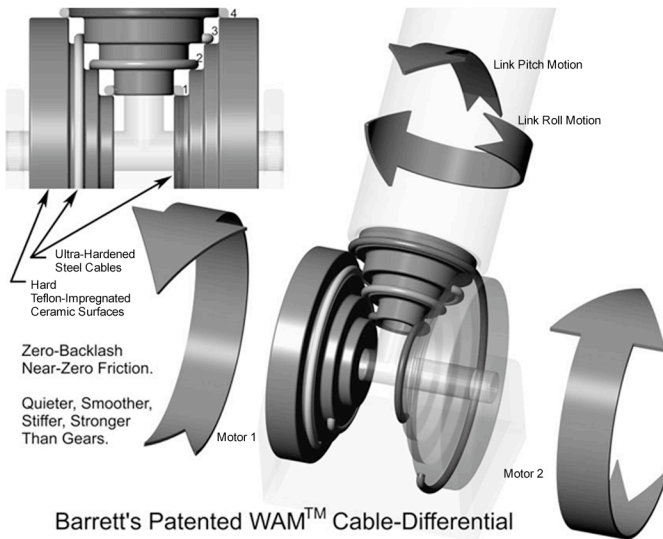
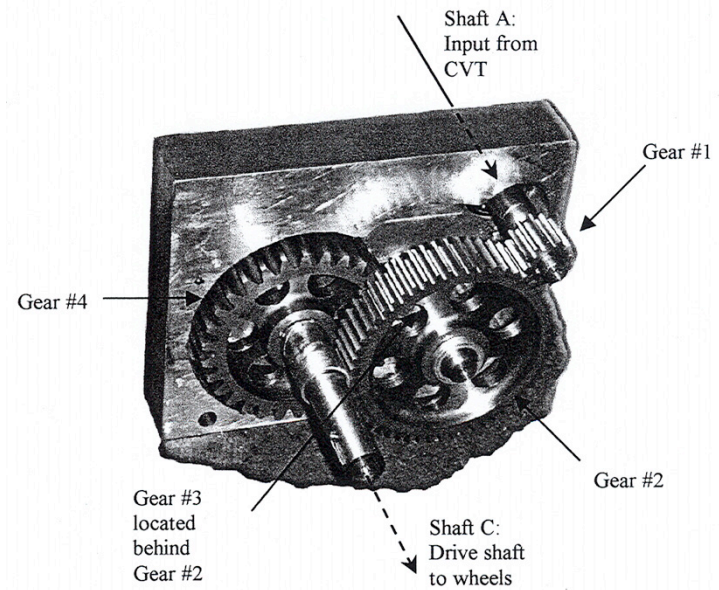
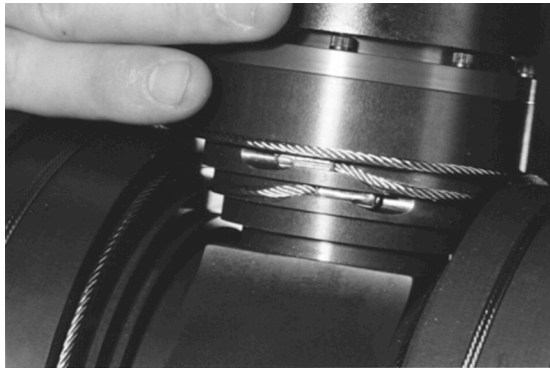
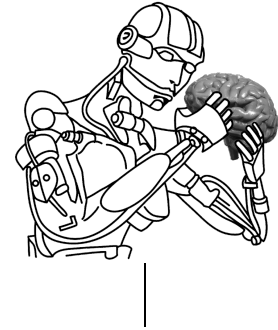
- Desirable Properties of Actuators
 - low inertia
 - High power-to-weight ratio
 - High acceleration
 - Robust to overload
 - Wide velocity range
 - Positioning accuracy
 - Smooth motion (no torque ripples, friction, stiction, etc.)

Transmission

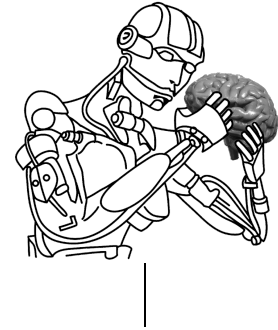


- Transmission Types
 - Gears
 - Pullies and belts or chains
 - No (direct drive)
- Properties
 - Backlash?
 - Friction (not backdrivable)
 - Amplification of inertia of motor
 - Usually used for electric motors
 - Transmission ratio up to 1:300 or more

Gears and Pulleys

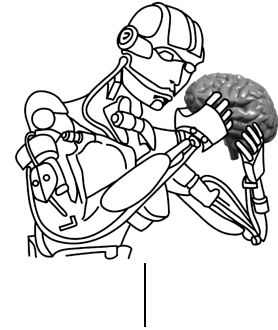


Sensors



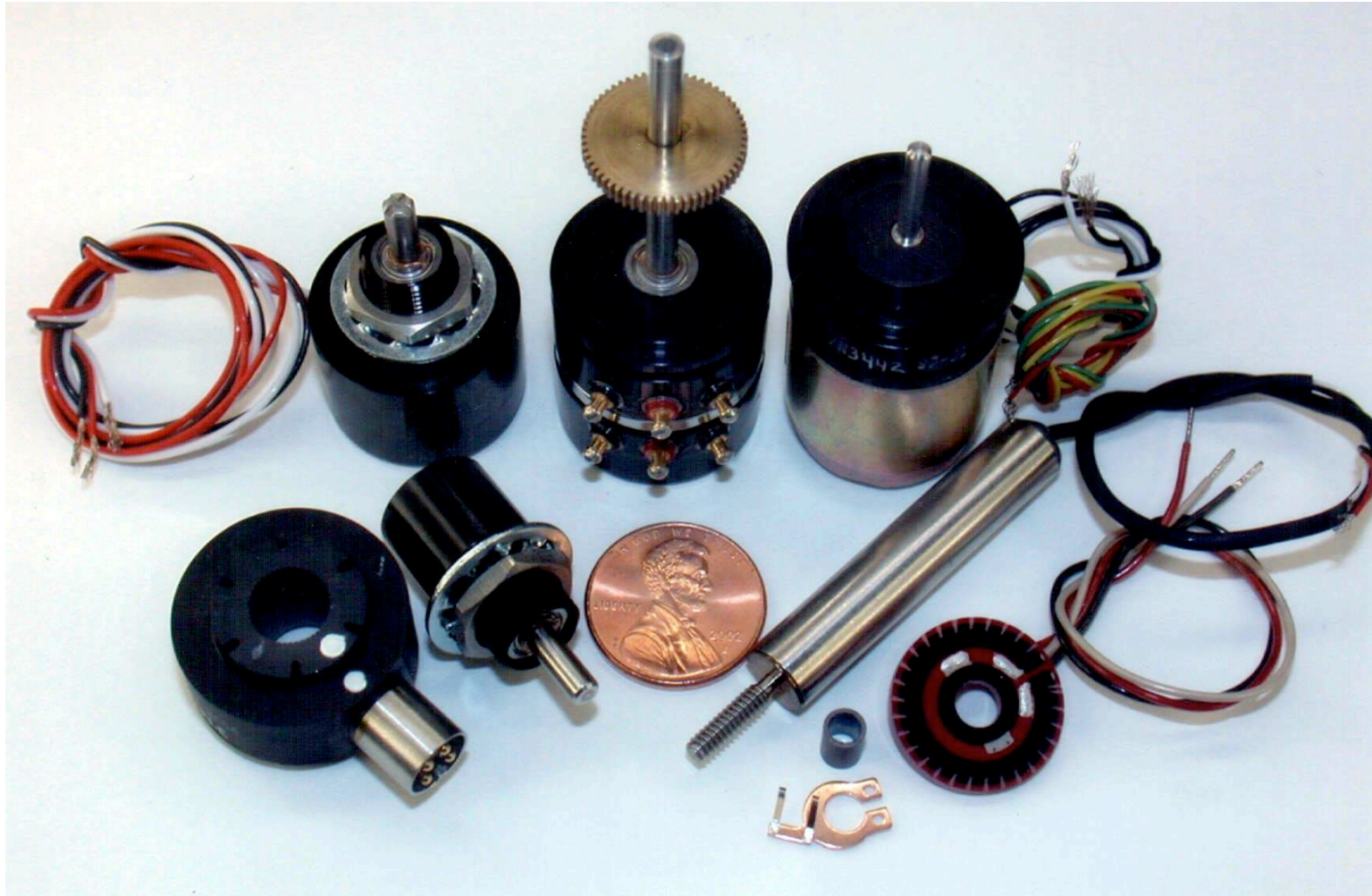
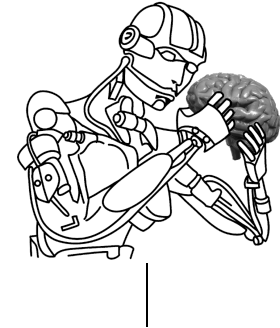
- Sensor types
 - Tactile sensors
 - Proximity sensors
 - Range sensors
 - Vision systems
 - Position sensors (linear and rotary)
 - Velocity sensors (linear and rotary)
 - Acceleration sensors (linear and rotary)
 - Force sensors (linear and torque)
- Analog and Digital sensors exist
- Absolute and Incremental sensors exist

Potentiometers

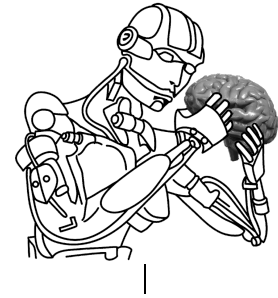


- Pros
 - Cheap
 - Small
 - Linear and rotary version
 - Absolute values
- Cons
 - Noisy
 - Mechanical interaction
 - Require Analog-to-Digital converter
 - Medium resolution (12-16 bit)

Potentiometer Examples

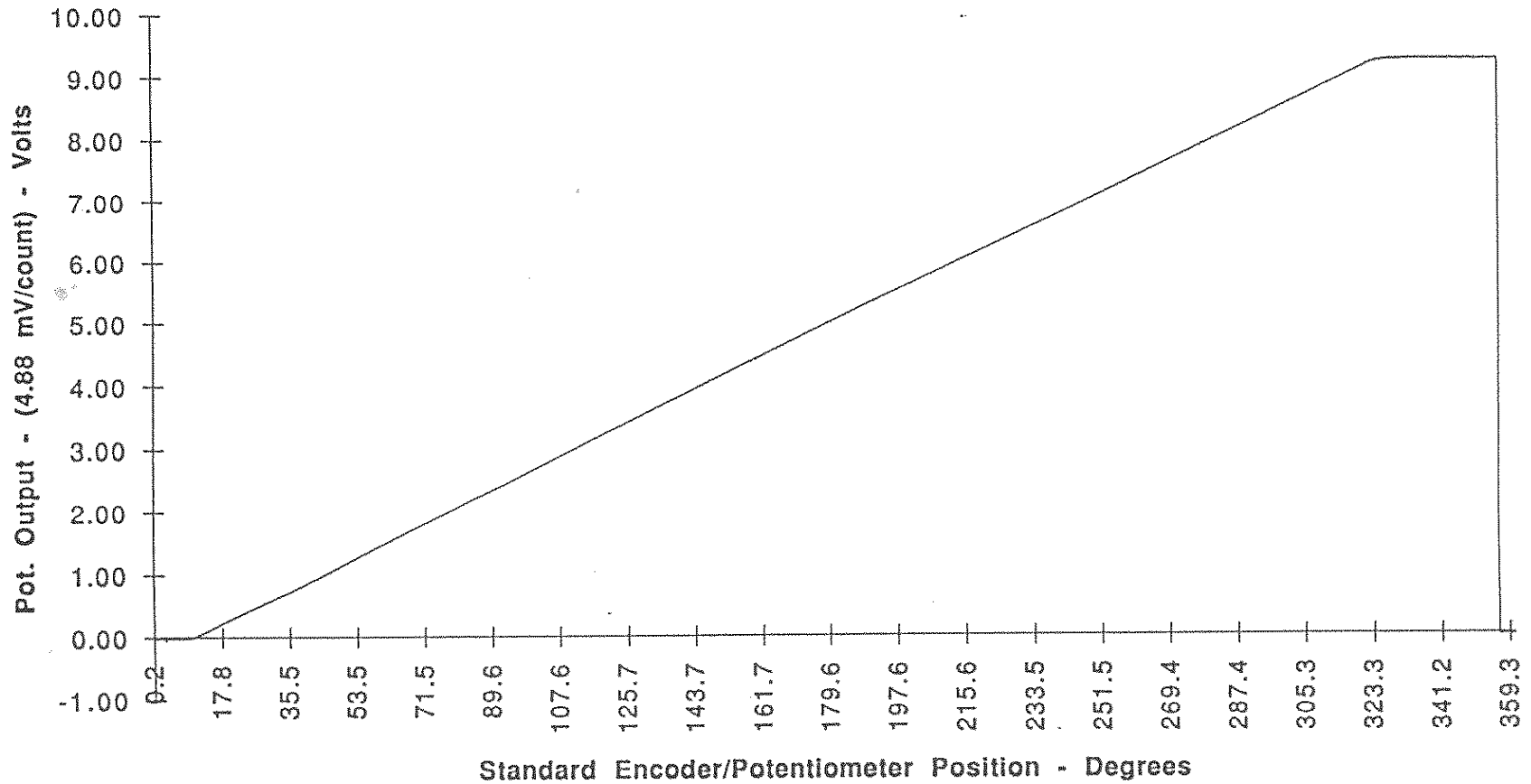


Calibration Line of Pots

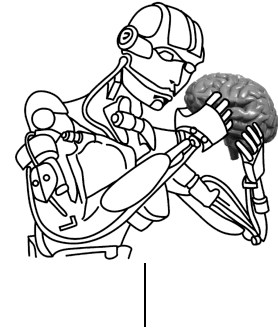


JDK POTENTIOMETER LINEARITY TEST

JDK Potentiometer - S/N:3617 P/N:6009-2033(10K) Lin.:±0.5%

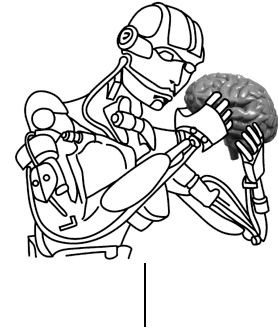


Optical Encoder

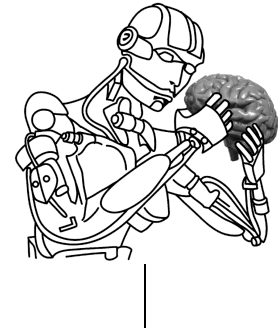


- Pros
 - High resolution (expensive)
 - Low resolution (cheap)
 - Very clean data
 - No A/D conversion
- Cons
 - Expensive or low resolution
 - Bulky
 - Special hardware needed for counting (quadrature)
 - Usually incremental (not absolute)

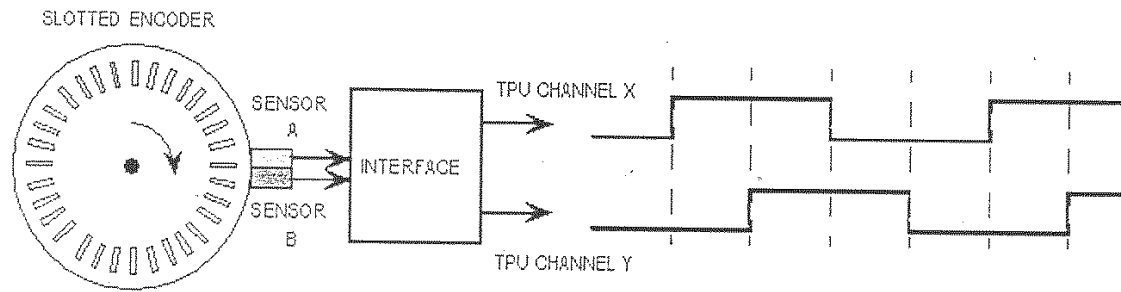
Optical Encoder Examples



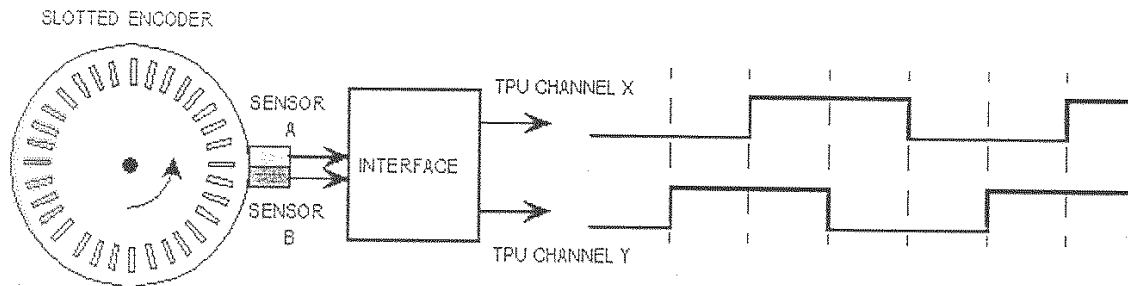
Quadrature



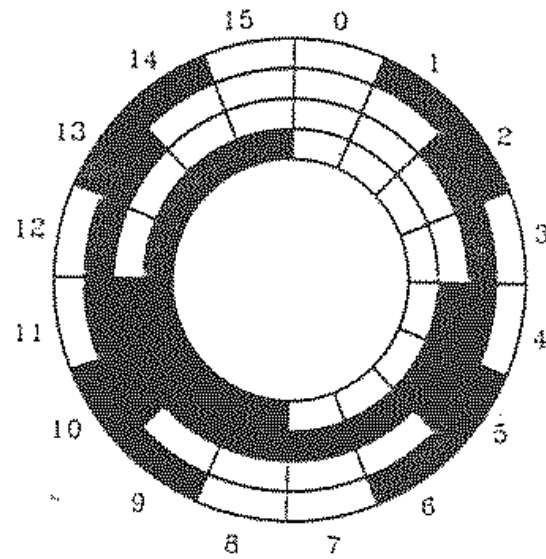
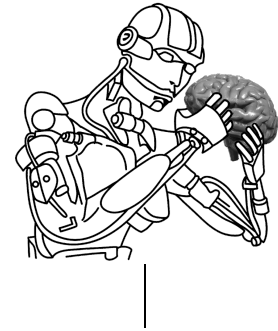
CASE A — CHANNEL X LEADING CHANNEL Y



CASE B — CHANNEL X LAGGING CHANNEL Y



Absolute Optical Encoders

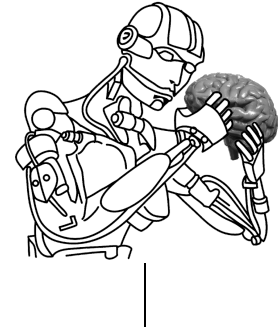


#
0
1
2
3
4
5
6
7

FIGURE 8.7

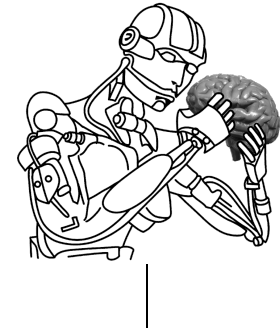
Schematic representation of an absolute encoder with Gray-code table.

Force Sensors



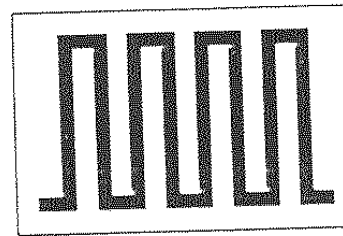
- Based on Strain Gages and Wheat-Stone bridge
- Properties
 - Noisy
 - Require special hardware to mount (material that “stretches”)
 - Require careful mounting techniques
 - Multiple strain ages are needed to make sensory more noise and temperature resistant

Force Sensor Example

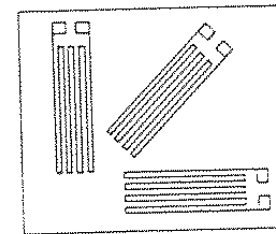


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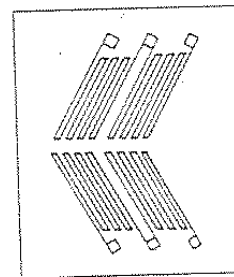
Figure 10.16
Standard patterns for metal
foil strain gauges.
(a) Linear;
(b) rosette;
(c) torque;
(d) diaphragm.



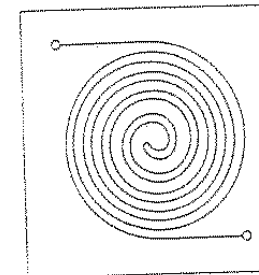
(a)



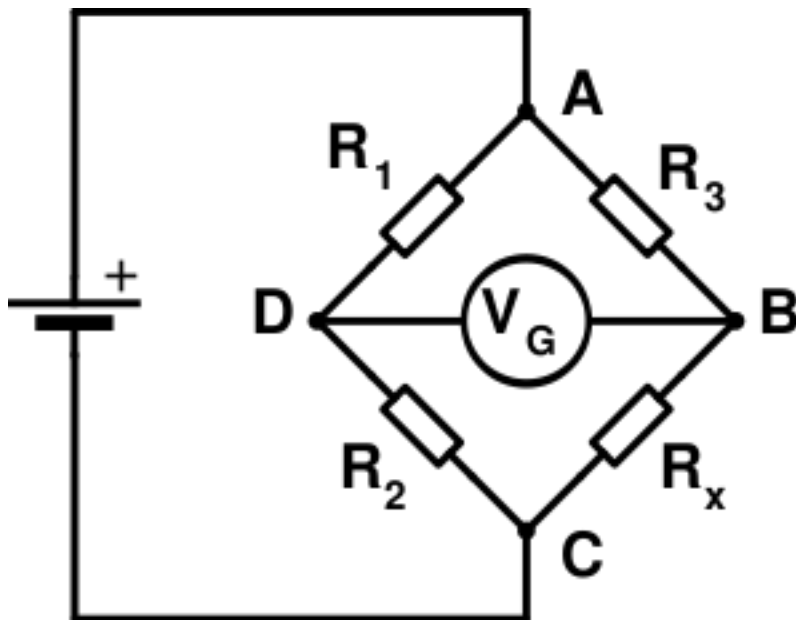
(b)



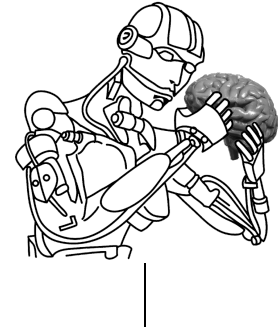
(c)



(d)

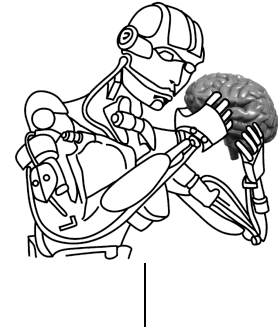


Data Filtering



- Noisy data need to be processed before it can be used for controlling a robot
- Possible processing techniques:
 - Analog filtering
 - Requires special hardware
 - Digital filtering
 - Can be done on a computer

Digital Filtering

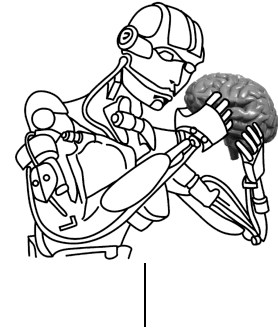


- Mostly done by linear filtering

$$y_n = \sum_{k=0}^M c_k x_{n-k} + \sum_{j=1}^N d_j y_{n-j}$$

- Two special cases:
 - Finite Impulse Response Filter (FIR)
 - $N=0$, which means no recursive inputs
 - More easy to design
 - More robust
 - Infinite Impulse Response Filter (IIR)
 - $N \neq 0$
 - Can go unstable
 - More complex design (stability analysis is needed!)
 - Less robust
 - Better filtering properties

Digital Filter (cont'd)



- Typical Filters
 - Butterworth
 - Matlab: “butter”
 - Chebyshev
 - Matlab: “cheby1” or “cheby2”
 - Elliptic
 - Matlab: “ellip”