CIS009-2, Mechatronics
Signals & Motors

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Outline

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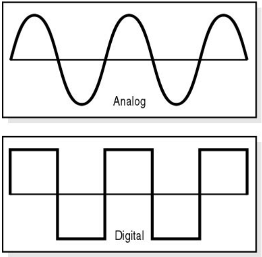
Digital signals

Signals

- Two types of signals exist:

Analogue signal In an analogue signal voltages and currents continuously change with time.

Digital signal In a digital signal voltages are switched on and off. Thus, the signal consists of a train of pulses.



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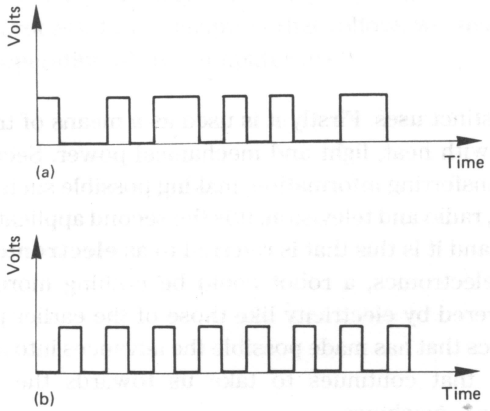
Digital Signal



- (a) A digital signal containg information
- (b) Timing pulses produced a clock used for distinguishing

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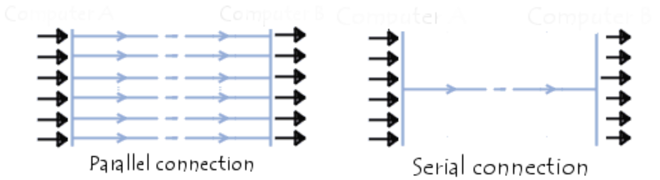
Transmission of digital signals

- Two methods are used:

  Parallel transmission Uses several wires in parallel to carry the electrical signal corresponding to a different bit in the message.

  Serial transmission Individual bits which constitute the information can be sent one by one, down a single pair of wires.



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Information encoding

Encoding information

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- We use a simple example to illustrate how information can be encoded in digital format.
- For example we could encode temperature information using 2 bits as:
    - 1, 1 Very hot (i.e.two pulses in succession).
    - 1, 0 Hot (i.e.a pulse followed by a space).
    - 0, 1 Warm (i.e. a space followed by a pulse).
    - 0, 0 Cold (i.e. two spaces in succession).
- NOTE: Using 4 bits will allow the temperature to be represented to 16 levels

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Digital to analogue conversion

Digital circuits

- These use or produce digital signals. Three categories exist:

  Logic circuits Circuits with digital signals as both inputs and outputs

  Analogue-Digital Converter (ADC) This has an analogue input and a digital output.

  Digital-Analogue Converter (DAC) This has a digital input and an analogue output.

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Digital-Analogue Converter (DAC)

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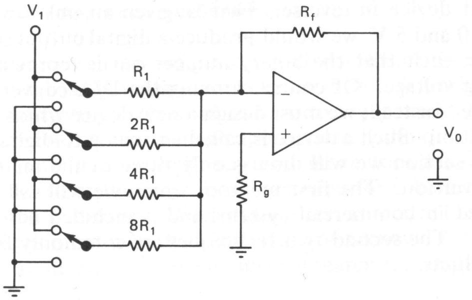
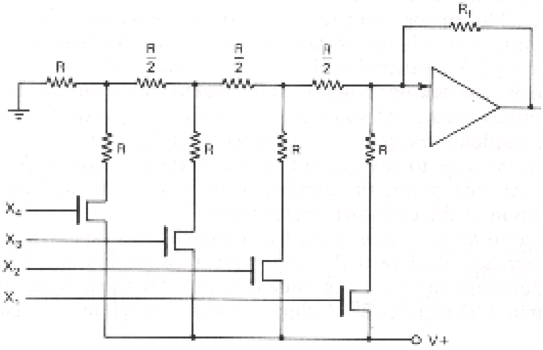


A 4-bit D/A converter now, $V_0 = -\frac{V_1 R_f}{R_1}\left[X_1 + \frac{X_2}{2} + \frac{X_3}{4} + \frac{X_4}{8}\right]$

- Note that the resistors are in the ratio of 2^0, 2^1, 2^2 and 2^3. It is difficult to fabricate these array of resistors on a single chip therefore the following alternative is preferred.

Digital-Analogue Converter (DAC)



$R - 2R$ implementation of a D/A converter.

- Commercial implementation of DAC. Note that the switches in previous diagram have been realised with field effect transistors

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Analogue to digital conversion

Steps in converting analogue

- signals to digital form
  - Sample the analogue signal at regular short intervals.
  - The sampled signals are coded using binary digits.
  - In practice we need a digital to analogue converter to implement it.

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Analogue-Digital Converter (ADC)

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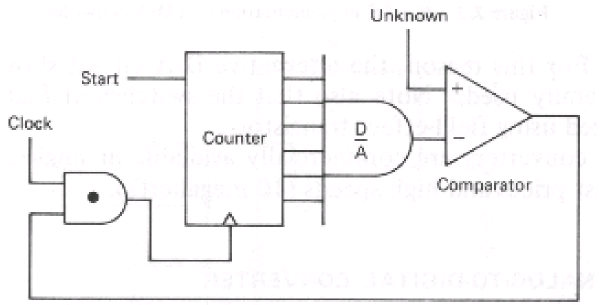
- Three types exist:

  Linear search converter The simplest of all A-D converters.

  Successive approximation converter

  Flash converter The fastest method to encode an analogue signal to a digital form.

Linear Search Converter (ADC)



A simple A/D converter.

- It consists of a Counter, D-A,Comparator and NAND gate

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Linear Search Converter

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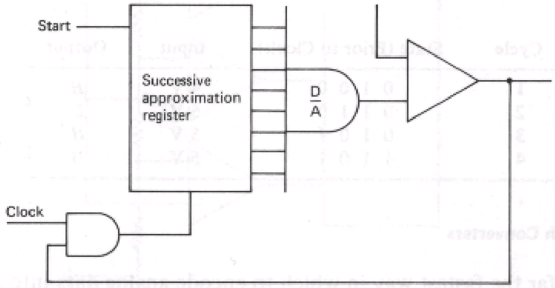
- How it works:
  - The analogue comparator has the property that if the voltage on the + input is greater than voltage on the - input the output is binary “1” (typically 5V) otherwise “0” (typically 0V). The sequence of operation is as follows:
    1. Set the counter to zero
    2. Apply signal to be converted at the unknown terminal
    3. Start counter. The D-A converts the counting sequence into volts
    4. If the - input is greater than + input, the comparator output becomes zero disabling the AND gate and stopping the counter. The number in the counter is the best approximation.

Successive Approximation Converter (ADC)



Successive approximation A/D converter.

- This is the same as the Linear serch technique except that counter is replaced with a Successive Approximation register.

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Algorithm for successive approximation (ADC)

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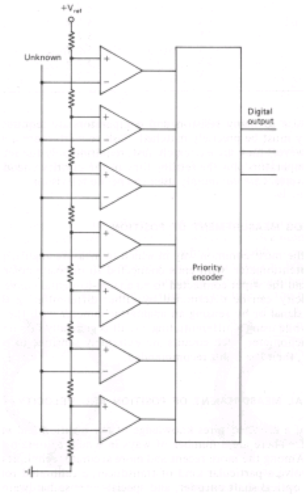
1. Let the variable M represent the most significant bit.
2. Set M bit to 1
3. If the D-A output exceeds the unknown, set the M bit to 0
4. Let the variable M represent the next most significant bit.
5. If all bits have been checked stop; elso go to 2.

Flash Converter (ADC)



A 3-bit flash encoder.

- A resistive divider network of 2^n resistors divide the reference voltage into many equal increments.
- The unknown is applied inputs exceeding the unknown are on,; all others are off.
- The comparator code is is converted to a binary code by the priority encoder

Computers

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Microprocessor

- Microprocessors, logic gates, A-D and D-A are parts of robotic systems.
- Microprocessor and logic gates are studied in Computer Systems Architecture and will not be discussed here.
- Both A-D and D-A are interfaces of robotics system to the real world.

Computers used in automation

Mainframes Large computer with large word length (> 32 bits).

Mini-computers

Microcomputers

Programmable logic controllers This are computers dedicated for control purposes.

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Programmable logic controller

- Responds to sensors
- Can make decisions about the sensors according what it is programmed to do.
- Can be programmed to simulate PI, PD and PID controllers.
- Some control applications of PLC are:
  - Industrial equipment such as motors, pumps and valves, Furnaces, packaging machinery.

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Bus systems

- All computers make use of address, data and control bus systems as summarised below:
    - Address bus is used to carry the address of memory locations.
    - Data bus is used to carry the computer word, The larger the data bus the more powerful the computer is.
    - Control bus carries control signals suc as READ/WRITE, INTERRUPT etc, signals.

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I/O management

- Memory mapped I/O
- Isolated I/O Addressing
- Input/Output Ports
- Parallel I/O Ports
- Programmable I/O Ports

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DC MOTORS

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Electric motors

- Three basic characteristics of electric motors are:
  - Power
  - Torque
  - Speed

Power

- One can distinguish between two types of power

  Electrical power A measure of electricity used by the motor.

  Mechanical power The power (work) produced by the motor. Measurement of Power (in Watts). 1hp=745.7Watts.

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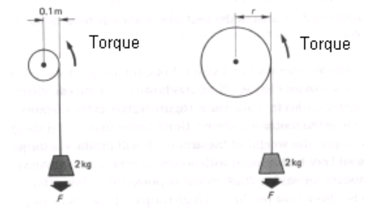
Torque

- This is the turning force a motor is able to produce. The force multiplied by the shortest distance measured from the axis of rotation to the line along which the force acts. It is measured in Newton-meters (Nm)

- Left Diagram Torque required to lift weight $= 20 \times 0.1 = 2$ Nm
- Right Diagram A larger Torque is required to lift the same weight since the pulley is larger.



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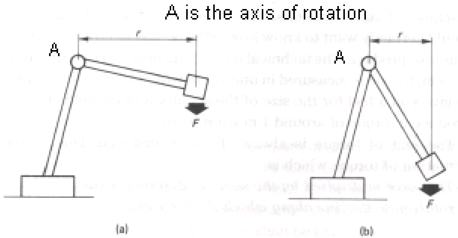
Example

- Torque exerted on a robot motor as the arm is moved about



The torque decreases as the load moves inwards towards the axis of the motor

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Speed

- The speed (R) of a motor is measured in revolutions per minute (RPM). It is the link between Power(P) and Torque(T).

$$T = 10\frac{P}{R} \text{ Newton Metres}$$

- where P is in Watts and R is in revolutions per second

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Types of electric motors

AC motors Operated by alternating current electricity.

DC motors Operated by direct current electricity.

Stepper motor Operated by pulses of electricity

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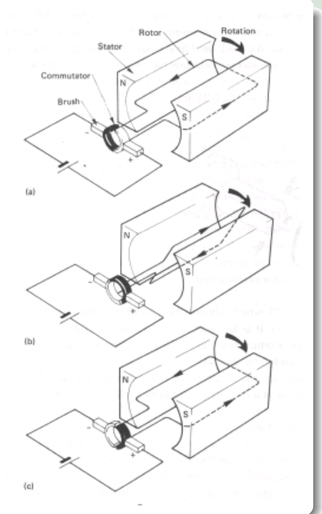
Principle of a DC motor

- Current is led into the coil through the brushes which are held in contact with the commutator by springs.
- The current in the coil produces a magnet field which repels the magnet field of the stator (permanent magnet) and causes the coil to rotate in the direction shown by the arrow.
- The commutator shown has only 2 segments. In practice, several segments with corresponding coils can be used.



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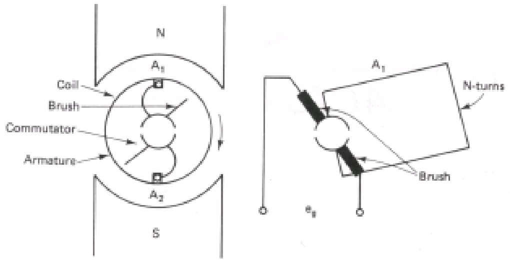
Relationship between Torque and armature current



$$T = K_t \phi_F I_a$$

- T =Torque, K_t =a constant, ϕ_F =Flux of magnetic field and I_a =armature current (i.e. current in coil)

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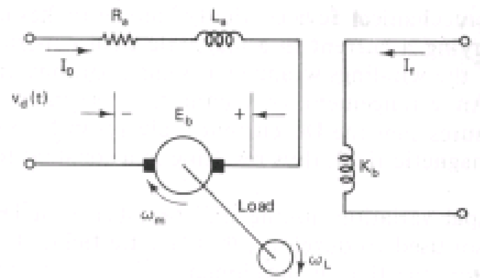
Current is supplied by a separate source to the field winding



$$T = K_t K_f I_f I_a$$

- K_t , K_f are constants, I_a and I_f are armature current and field currents. K_f depends on the permeability of the iron used, Generating an electromagnet field instead of permanent magnet field

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Categorising motors by their field windings

- Series wound motor
- Shunt wound motor
- Compound wound motor
- Permanent magnetic field

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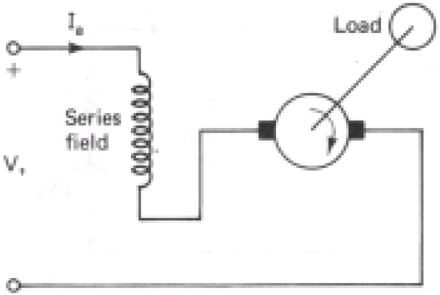
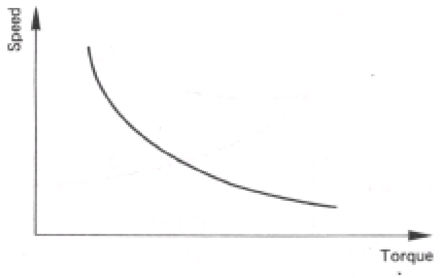
Series wound motor



$$T = K_t K_f I_a^2$$

Characteristics of a series wound motor



- Speed versus Torque

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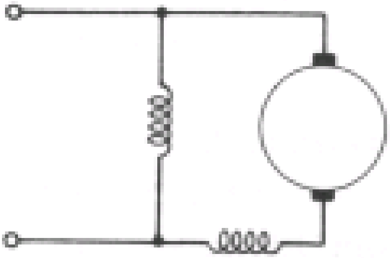
Compound wound motor



- A) Motor can be differentially compounded
- B) Commutatively compounded

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Characteristics of compound wound motor

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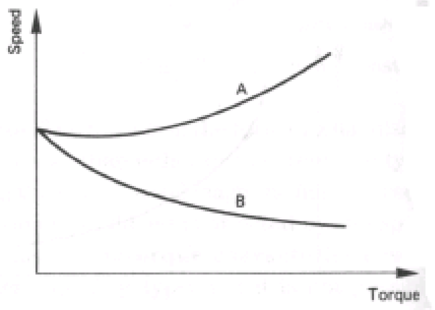
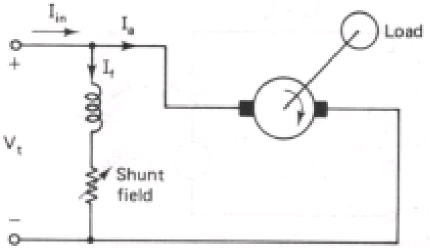


- Speed versus Torque
- Note that differentially wound motors can attain dangerous speeds if the maximum load is exceeded.

Shunt wound motor



- If voltage V_t is held constant then the torque varies linearly as with the armature current I_a.

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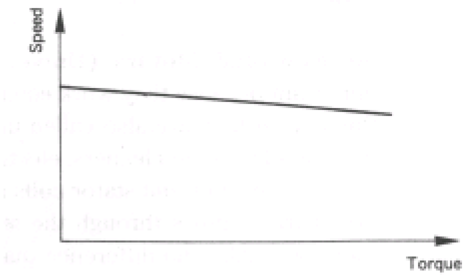
Characteristics of shunt wound motor



- As speed reduces torque increases

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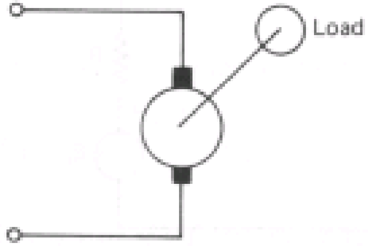
Permanent magnet motor



$$T = K_{pm} I_a$$

- Used mainly for servo motors. K_{pm} is the field constant and I_a is the armature current

DC motor loading

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Load on a DC motor

- Primary loads on motors are: Friction, Inertia, and constant or varying Torque loads.
- A rotating system in the absence of outside forces obeys:
    - $T = J\ddot{\theta} + F\dot{\theta}$ where
    - $T =$ Torque
    - $\theta =$ angular position
    - $\dot{\theta} =$ angular velocity
    - $\ddot{\theta} =$ angular acceleration

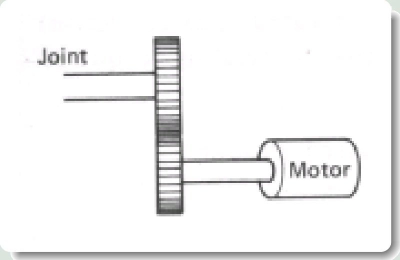
Load on a DC motor

- DC motors have high rotational velocities but low torque. Therefore, gearing is needed to increase torque and reduce motor speed.

- Assume a gear ratio N then,

$$T_{\text{applied to load}} = NT_{\text{applied to motor}}$$

$$\dot{\theta}_{\text{load}} = \frac{1}{N}\dot{\theta}_{\text{motor}}$$



Load on a DC motor

- The load is divided by the square of the gear ratio. Therefore, the equivalent inertia J_{eq} and the equivalent friction F_{eq} seen by the motor are give by:

$$J_{eq} = J_a + \frac{1}{N^2} J_l$$
$$F_{eq} = F_a + \frac{1}{N^2} F_l$$

- J_a and F_a are the inertia and friction of the motor
- J_l and F_l are the inertia and friction of the load

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Stepper motor

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Stepper Motor

- Operate on pulses.
- Each time a pulse is sent to the controller the motor steps (i.e rotates by a small angle),
- The angle of rotation can be from 1.5 to 30 degrees.
- Can be made to rotate faster or slower by sending more or fewer pulses.
- Computer controlled.

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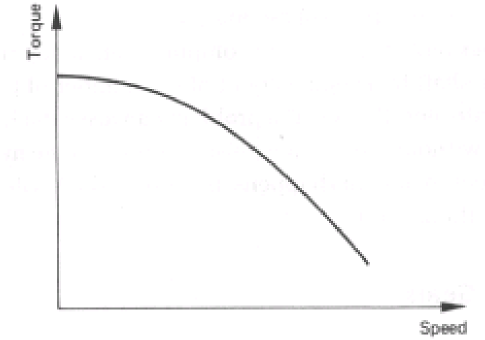
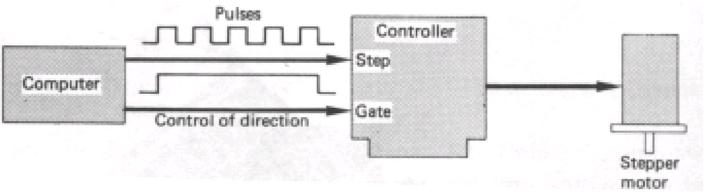
Torque-Speed characteristics



- Torque versus speed

Computer control of a stepper motor



- Controlling a stepper motor

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