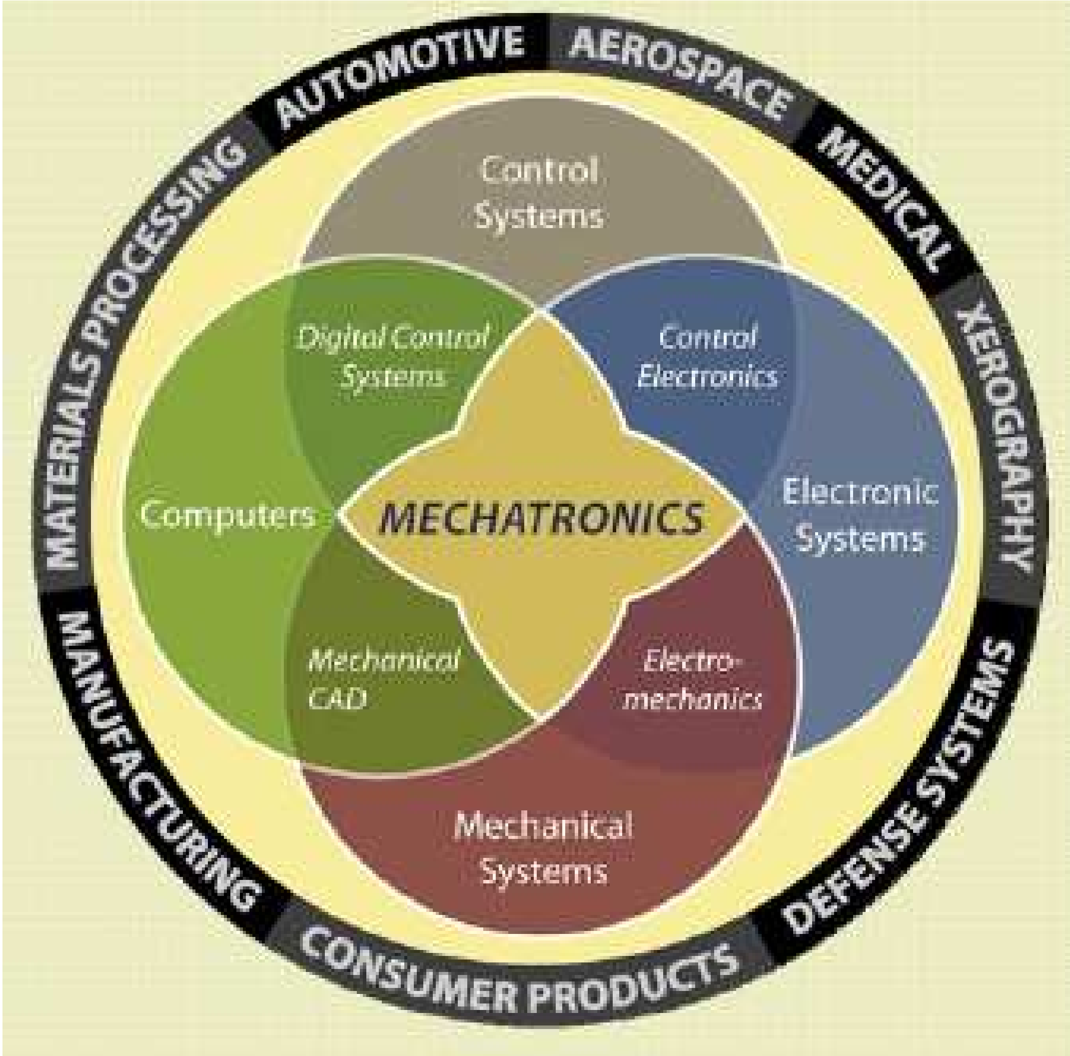
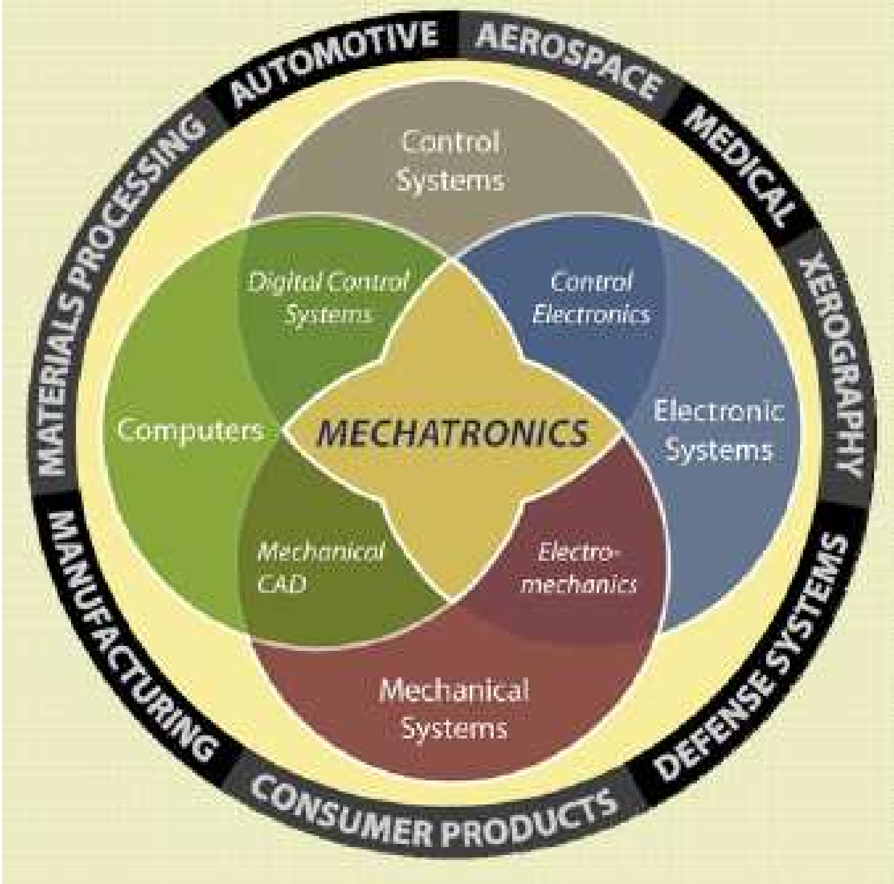
Introduction to Mechatronics

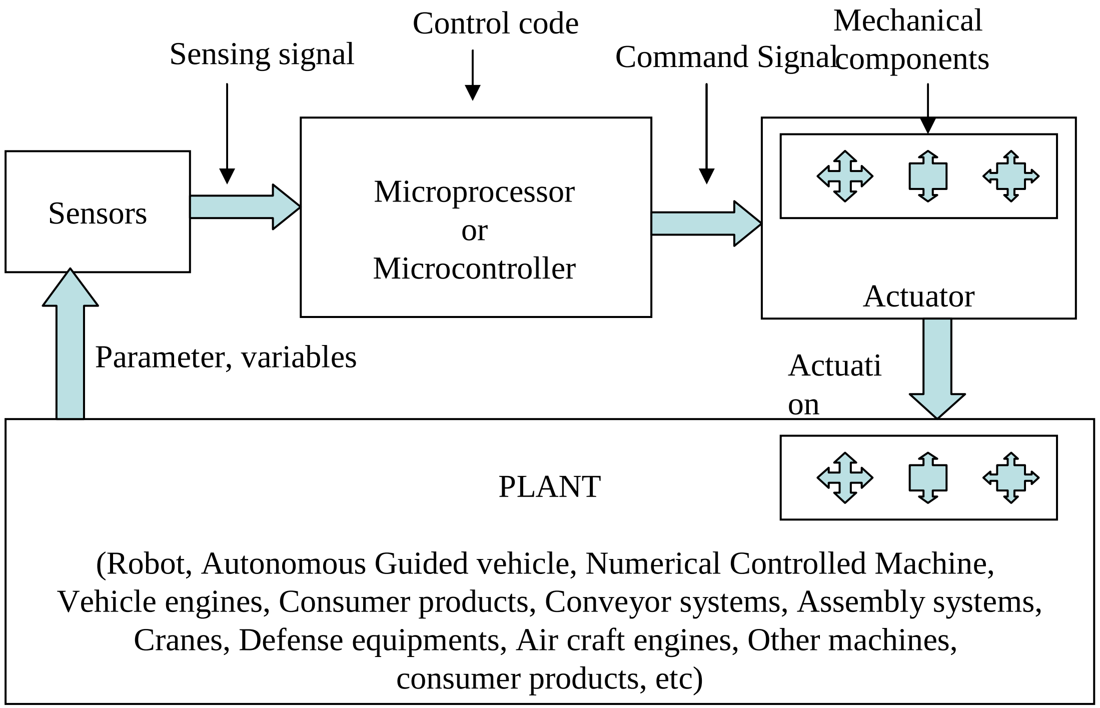


Definition of Mechatronics

Mechatronics basically refers to mechanical electronic systems and normally described as a synergistic combination of mechanics, electrical, electronics, computer and control which, when combined, make possible the generation of simple, more economic, and reliable systems.



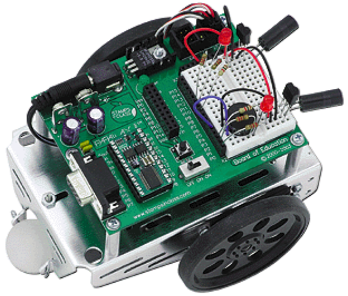
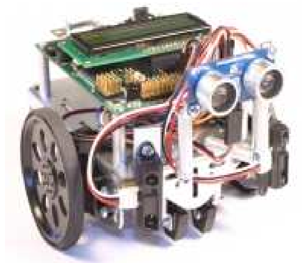
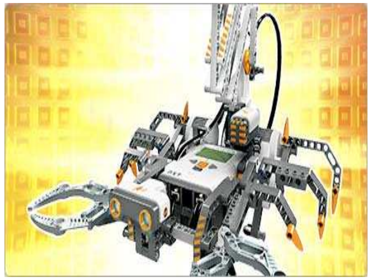
The term "mechatronics" was first assigned by Mr. Tetsuro Mori, a senior engineer of the Japanese company Yaskawa, in 1969.



Physically, a mechatronic system is composed of four prime components. They are sensors, actuators, controllers and mechanical components. Figure shows a schematic diagram of a mechatronic system integrated with all the above components.

Example 1 of Mechatronic Systems

Robot

Robot examples

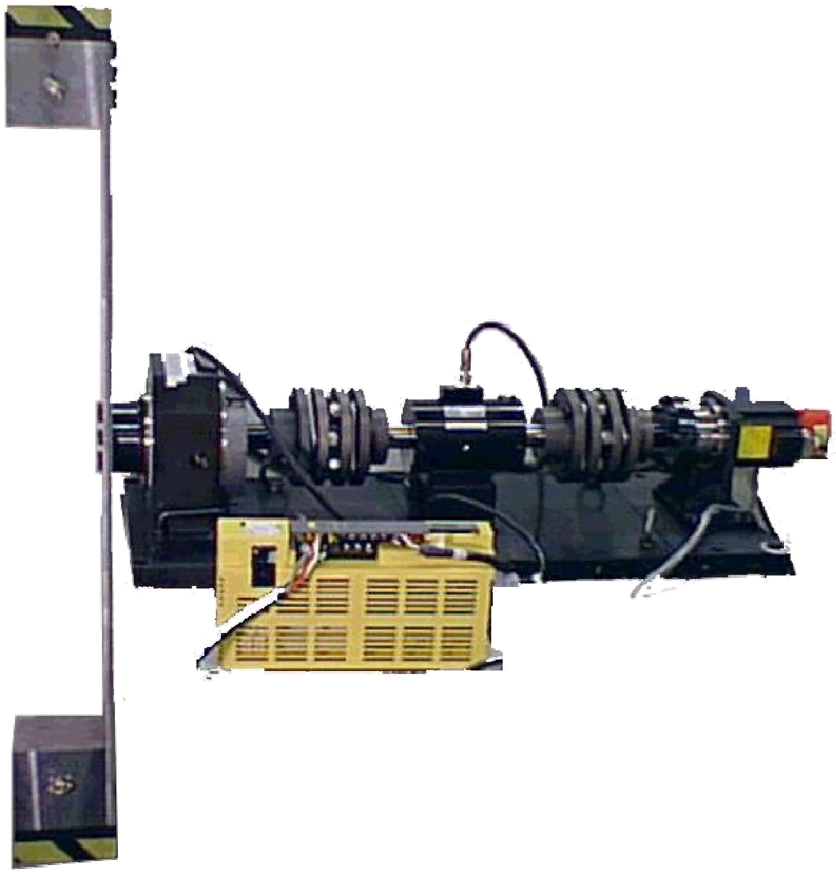




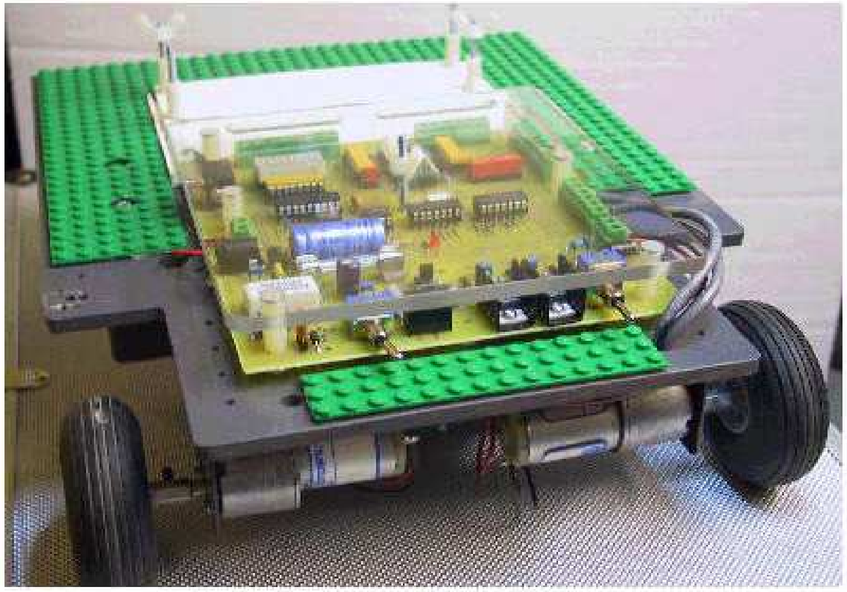

Robot sensors

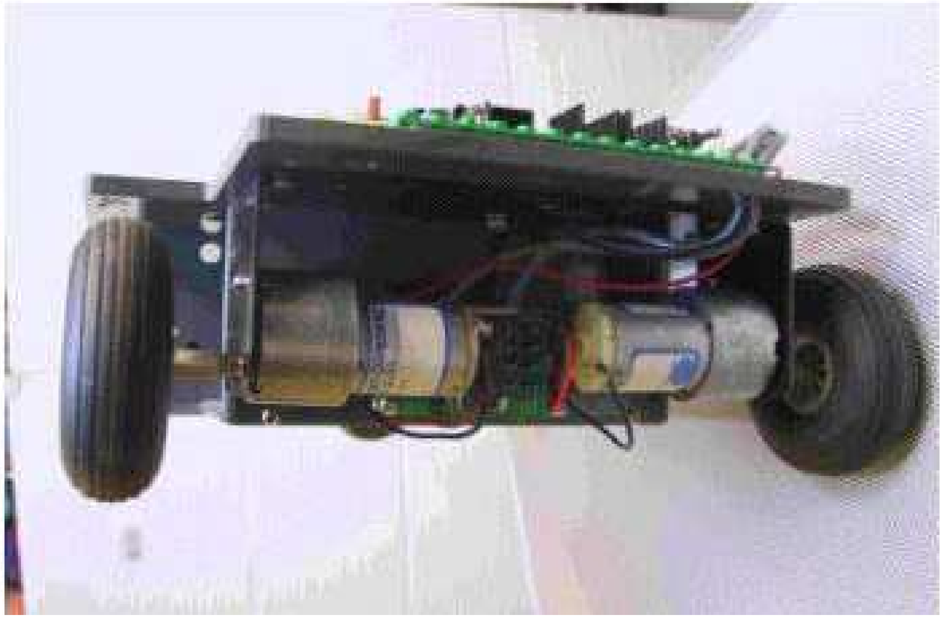
Example2 of Mechatronic Systems

Motion and Force Control of an Indirect Drive Robot



Examples: 3 of Mechatronic Systems





program to track straight line
• program for collision avoidance in outside corridor

Example: 4 of Mechatronic Systems

A computer disk drive is an example of a rotary mechatronic system

• Requires

– Accurate positioning of the magnetic read head

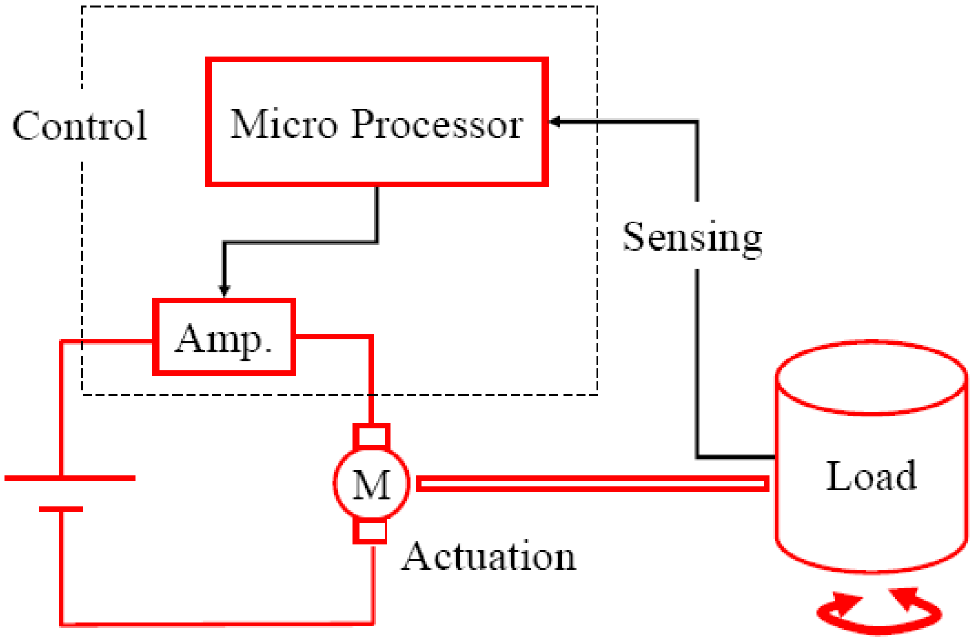
– Precise control of media speed

– Extraction of digital data from magnetic media

Example: 5 of Mechatronic Systems

Washing Machine

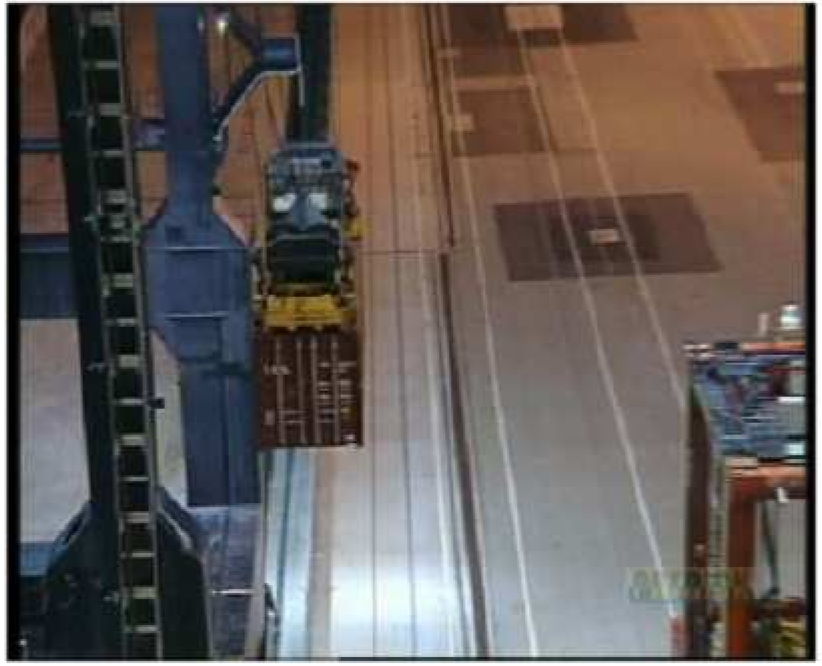
- System Requirements
  - Understanding of load sizes
  - Receptacle to hold clothes
  - ‘Plumbing’ (depth measurement)
  - Agitation of drum
  - Ease of use, Reliability
  - Low Cost
- Actuators
  - AC or DC Motors
  - Water inlet/drain
- Sensors
  - Water level
  - Load speed/balance



Example: 6 of Mechatronic Systems

Mechatronic is every where

Cargo Handling



- Automated Straddle Carriers
- Automated Crane Systems
- Automated movement vehicles

Example: 7 of Mechatronic Systems

Mechatronic is every where

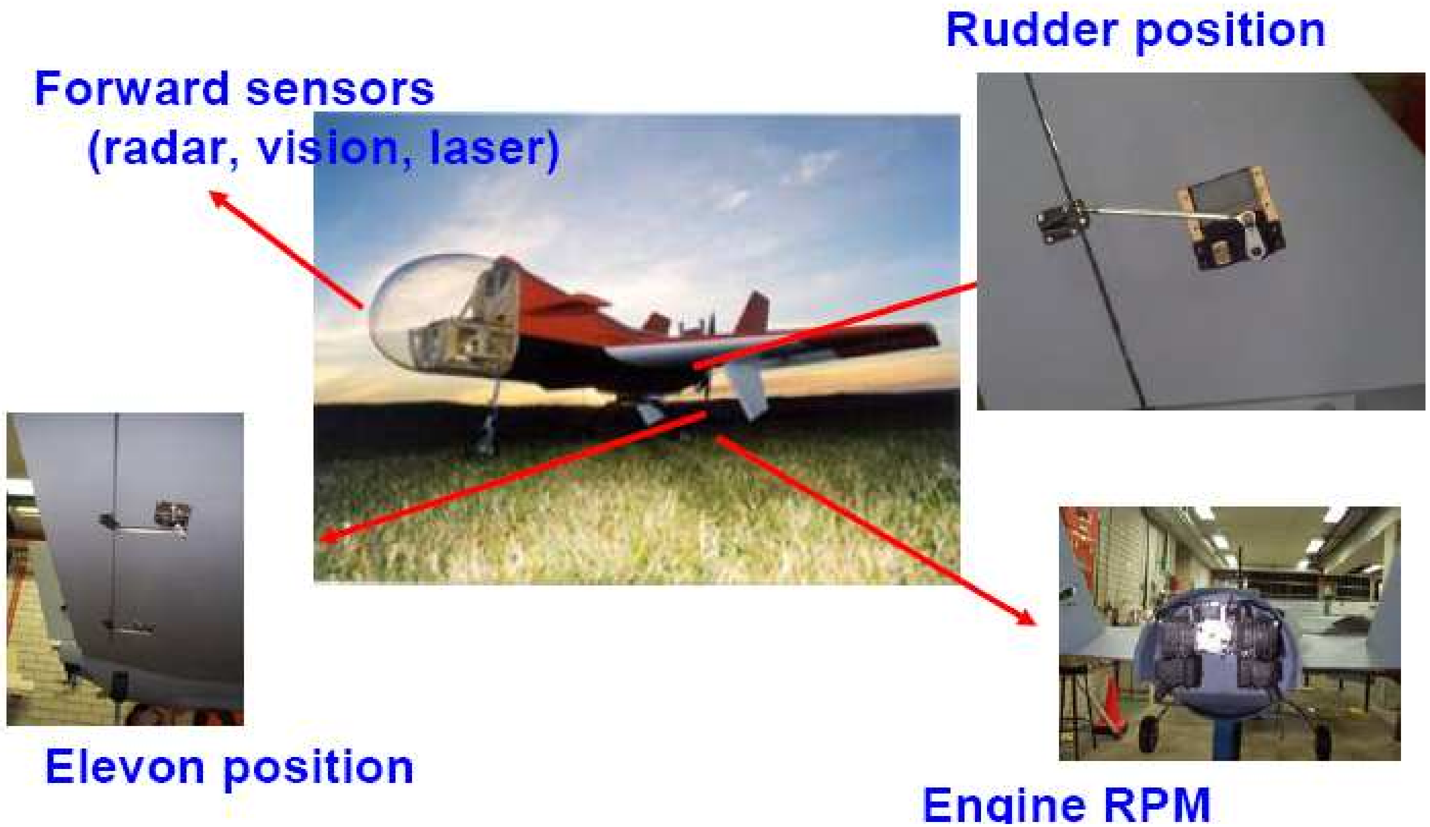
Subsea Vehicles

- Control of vehicle performed using on-board computer
- Sensors include sonar, vision, inertial, compass and pressure
- Used for building models of underlying reef structure

Example: 8 of Mechatronic Systems

Mechatronic is every where

Autonomous Flight Control Systems



Example: 9 of Mechatronic Systems

Mechatronic is every where

Mining Applications

Units to be Covered

Module 1: Introduction to Mechatronics System Design:
Introduction to Mechatronics system, Elements of Mechatronics system: Sensor, actuator, plant, and controller, Applications of Mechatronics system, Systems like CDROM and scanner: exploration of internal components and their functionality.

Module 2: Integrated Mechanical-Electronics Design and Microprocessor Fundamentals:
Integrated mechanical-electronics design philosophy, Examples of real-life Mechatronics systems, Smart sensor concept, Utility of compliant mechanisms in Mechatronics, Microprocessor building blocks, Combinational and sequential logic elements, Memory, timing, and instruction execution fundamentals, Example of a primitive microprocessor.

Module 3: Microcontrollers for Mechatronics and Mathematical Modeling:
Microcontrollers for Mechatronics, Philosophy of programming interfaces, Setting sampling time, Getting started with TIVA programming, Microcontroller programming philosophy with emphasis on TIVA, Programming different interfaces like PWM, QEI, etc., Mathematical modelling of Mechatronics systems, Modelling friction, DC motor, Lagrange formulation for system dynamics.

Module 4: Control Systems in Mechatronics:
Dynamics of a 2R manipulator, Simulation using MAT lab, Selection of sensors and actuators, Concept of feedback and closed-loop control, Mathematical representations of systems, Control design in the linear domain, Basics of Lyapunov theory for nonlinear control, Notions of stability, Lyapunov theorems and their application, Trajectory tracking control development based on Lyapunov theory.

Module 5: Signal Processing and Practical Implementations:
Basics of sampling a signal, Signal processing, Digital systems and filters for Mechatronics system implementation, Research examples/case studies of the development of novel Mechatronics systems:3D micro-printer, Hele Shaw system for micro fabrication

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Our approach to cover essential units

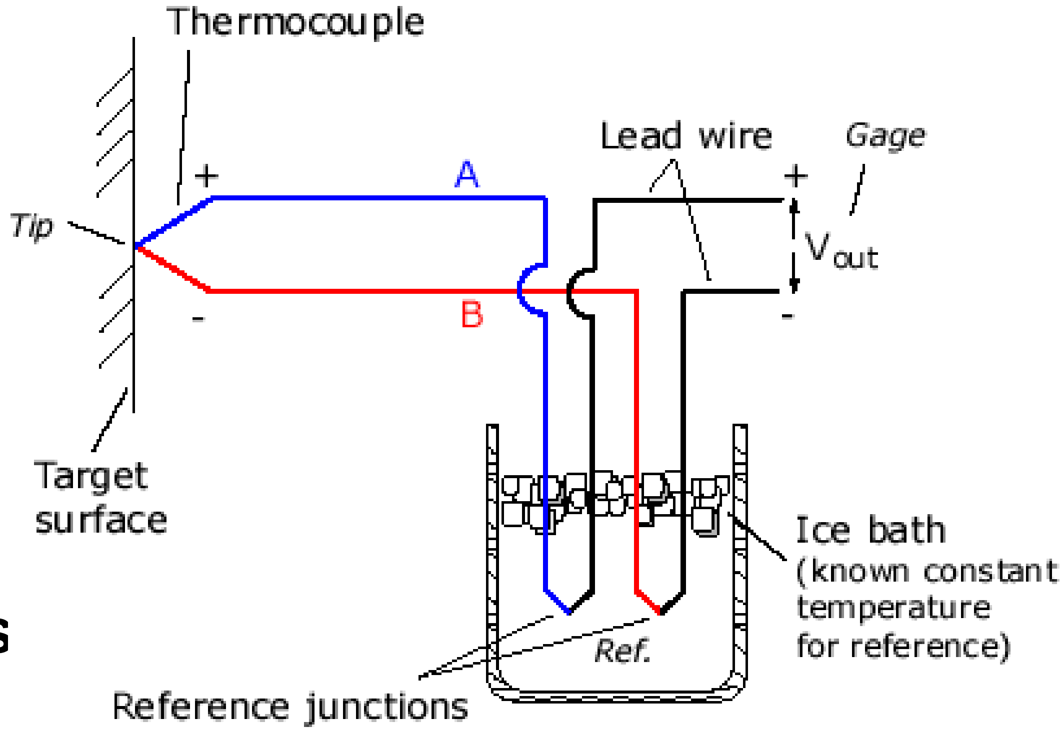
- Lectures,
- Exercises,
- Assignments ,
- Projects and presentation

Assessment Methods:

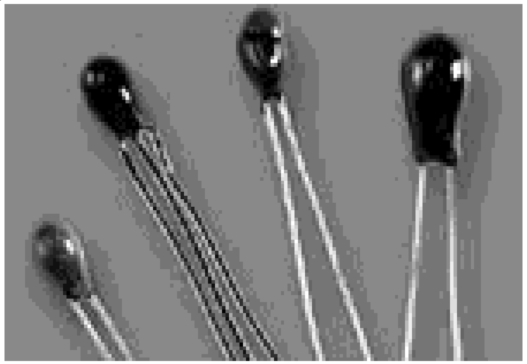
Method	**Quantity**	**(Marks)**
Practical	2	50
Midterm Exam(s)& Assignment	2	30
Final Exam	1	70

Sensors and Signal Conditioning

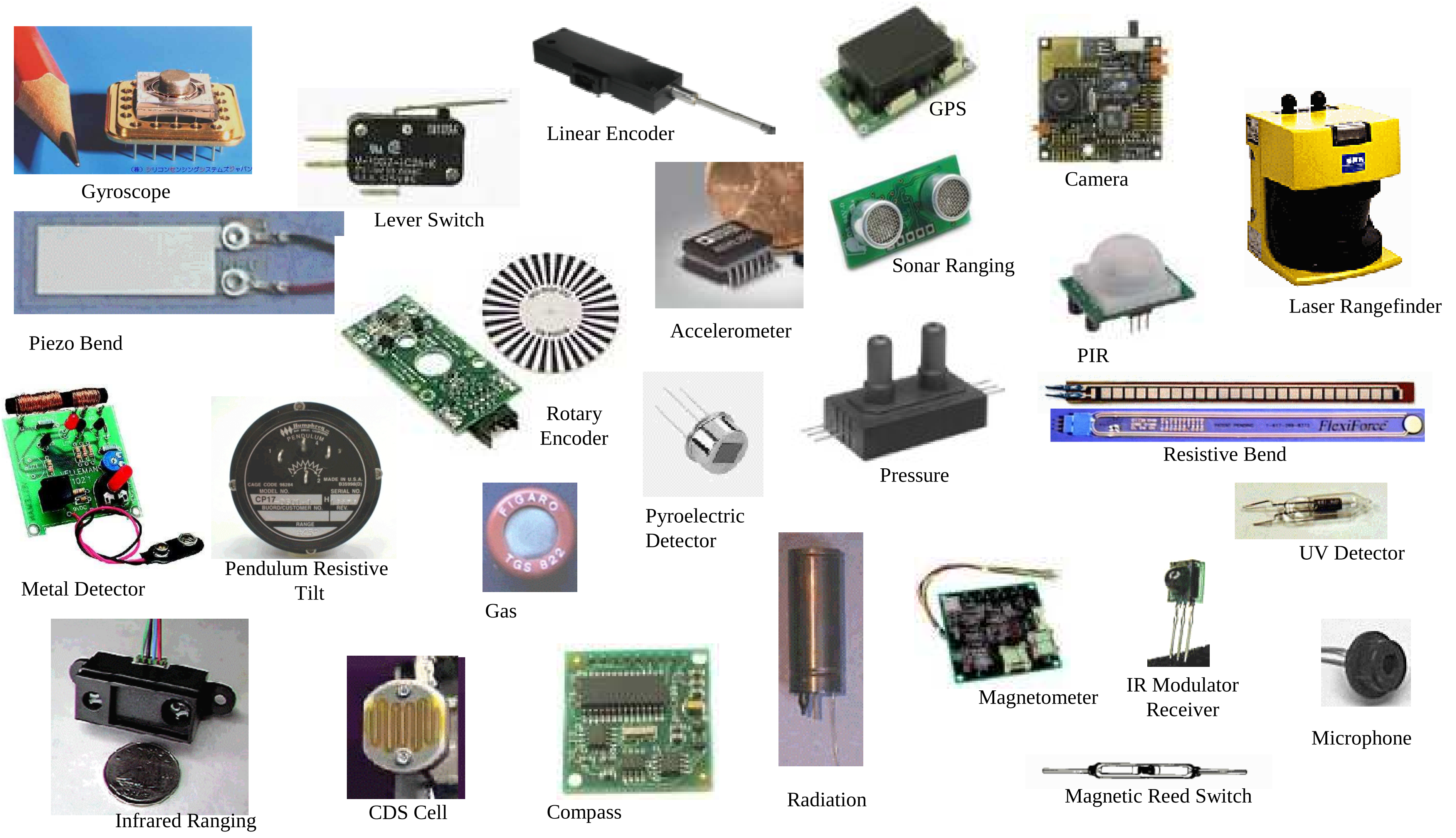
- **Sensors performance: Range, span, accuracy, sensitivity, errors,.. Resolution**
- **Displacement, position, motion and velocity sensors,**
- **Fluid sensors, liquid flow, liquid level**
- **Temperature sensors**
- **Light sensors**



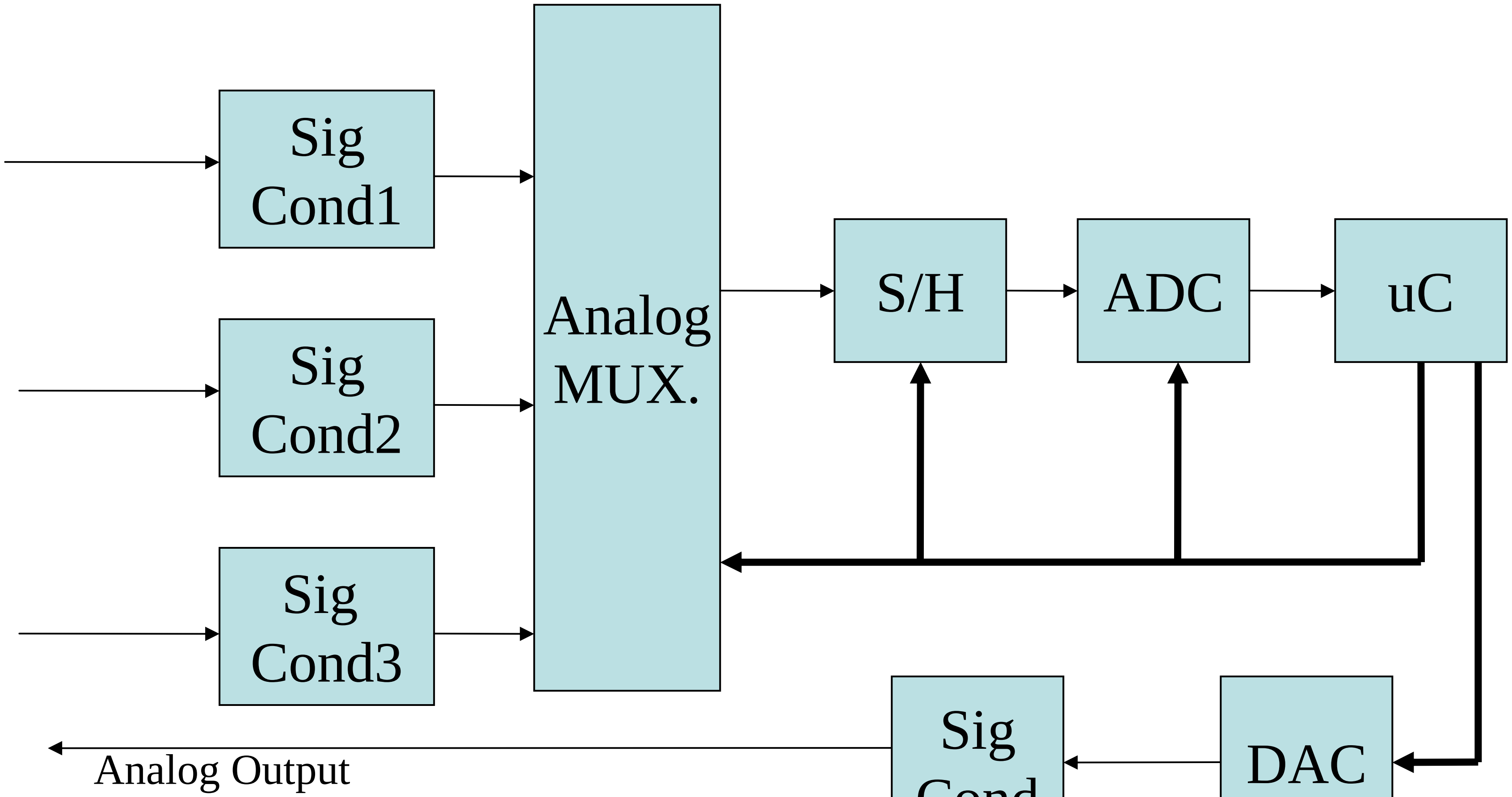
Thermistors



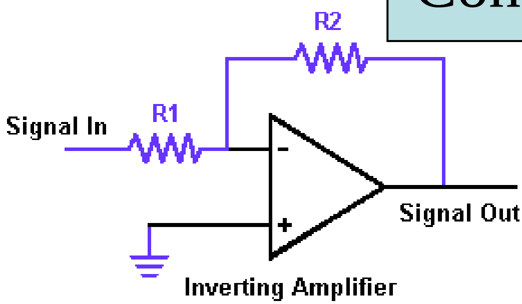
A collection of Sensors

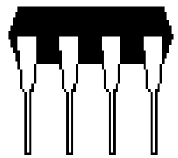


Signal conditioning circuits



- Opamps circuit
- ADC/DAC circuits
- Wheatstone bridge

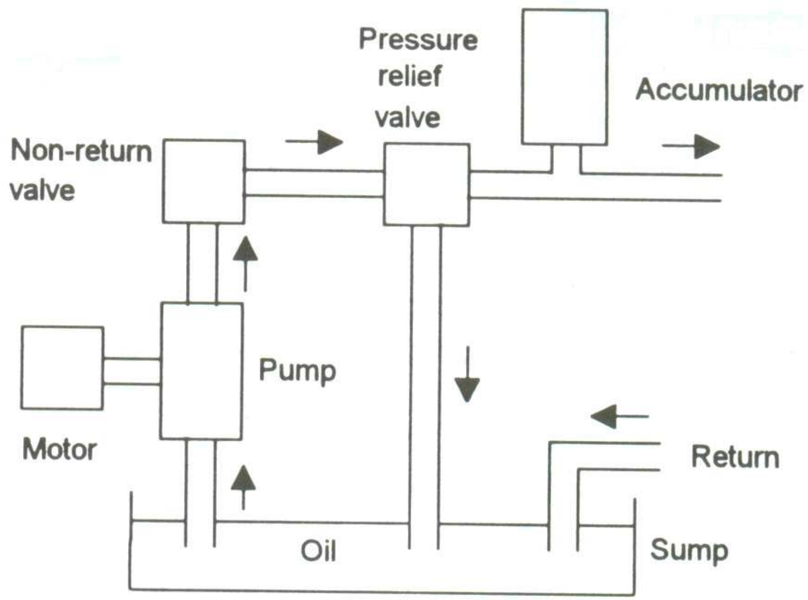


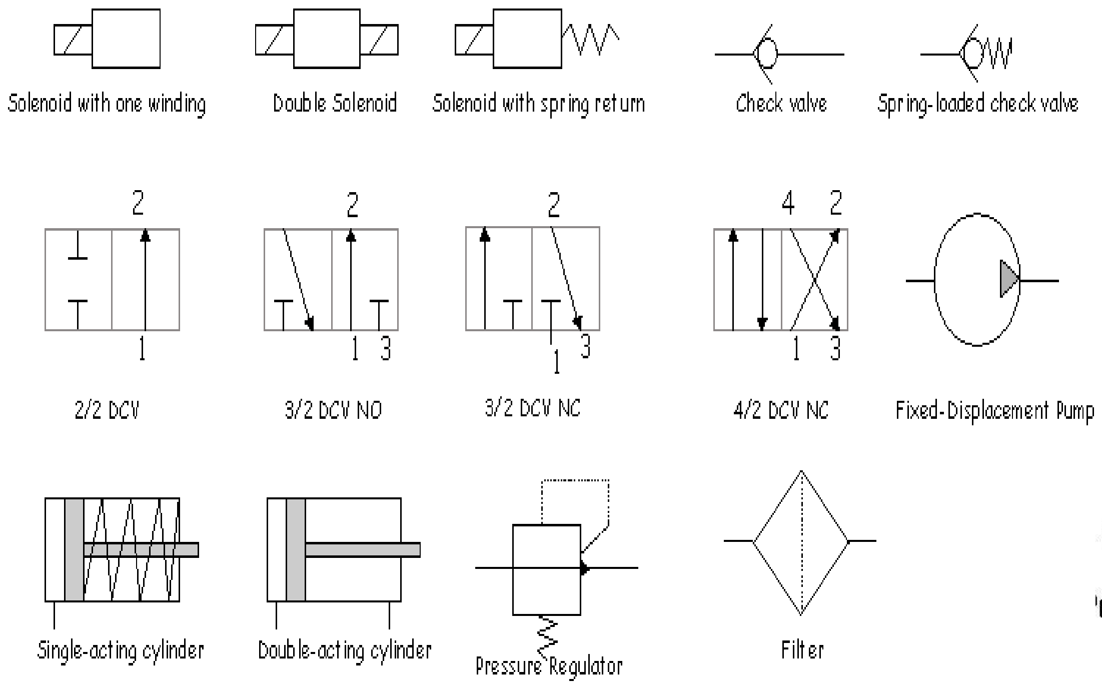


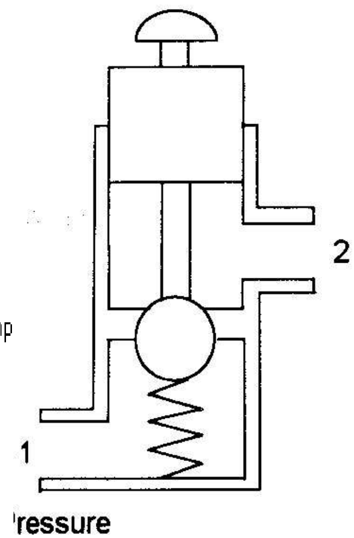
Actuating System: Pneumatic and Hydraulic

Hydraulic Power Supply

- Pump
- Check valve
- Accumulator
- Pressure relief valve
- Directional control valve
- Pressure control valve
- Process control valve







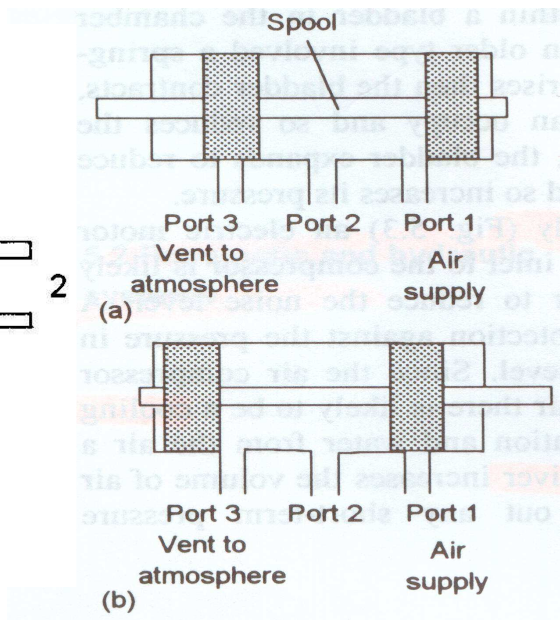
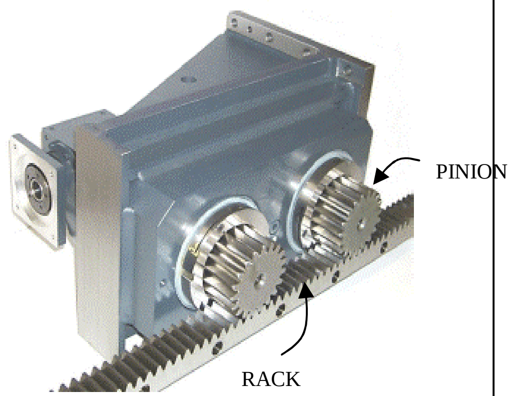
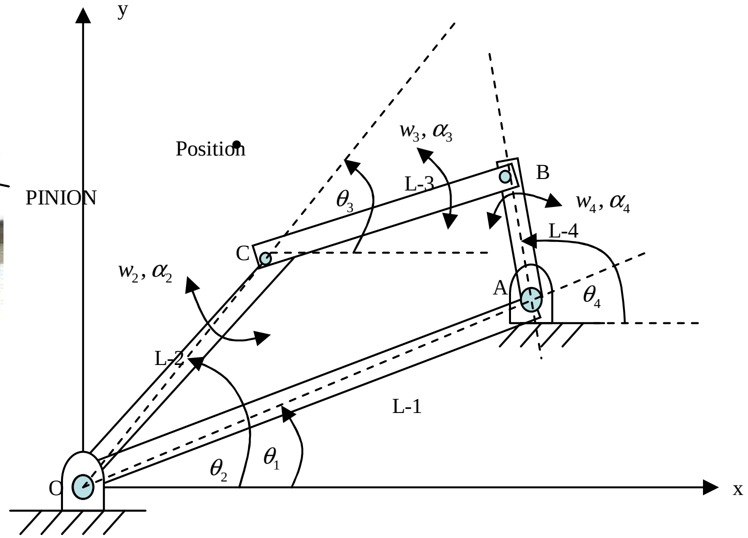


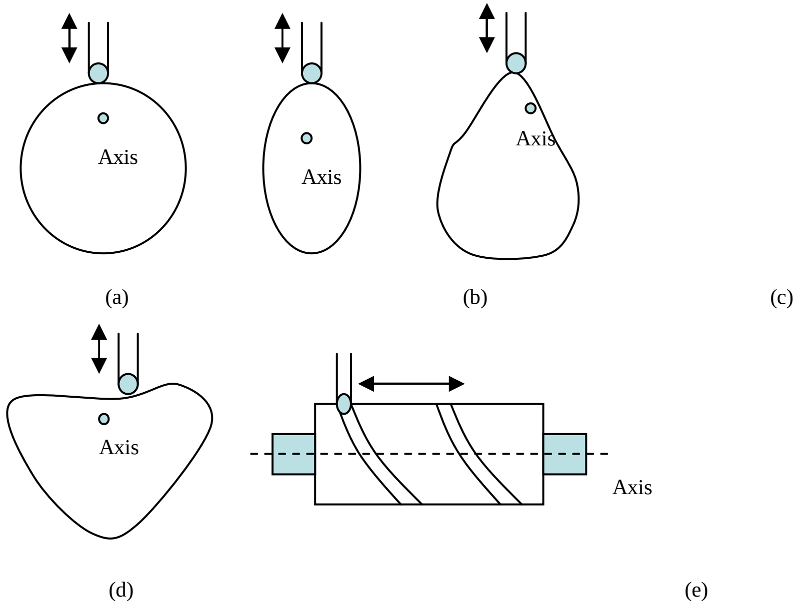
Fig. 5.4 Spool valve

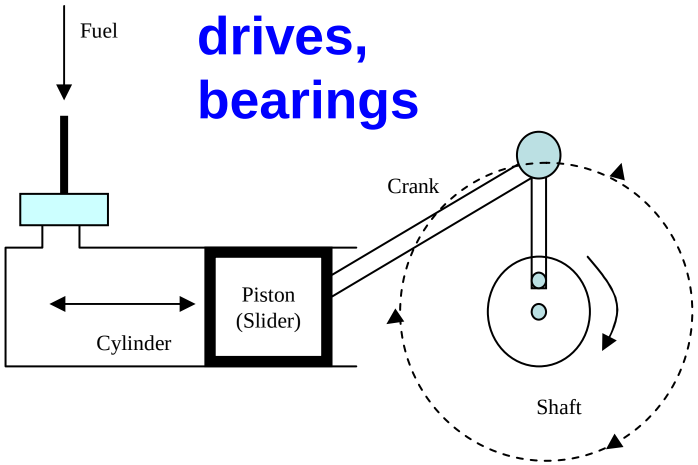
Actuating System: Mechanical

- Types of motion
  - Freedom
  - Kinematic chains, bar chain links, slider-crank mechanism
  - Cams, gear trains
  - Belt and chain drives, bearings









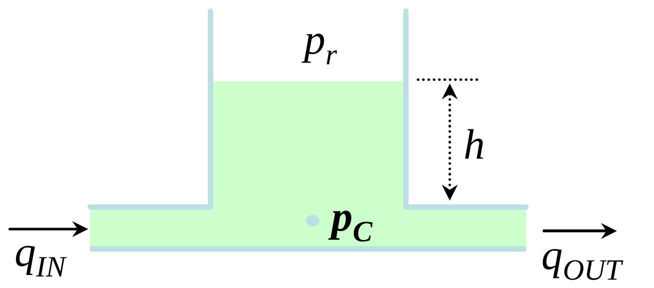
Electrical Actuation

- Switching devices
  - Mechanical switches
    - Keyboards, limit switches, switches
  - Relays
  - Solid-state switches
    - Diodes, thyristors, transistors
  - On-Off
- Solenoids
  - Push something
    - Starter solenoid, pneumatic or hydraulic valve
- Drive systems
  - DC., AC., or stepper motors
  - How to achieve speed control

System Modeling: Mathematical Modeling

- **Understand System Function and Identify Input/Output Variables**
- **Draw Simplified Schematics Using Basic Elements**
- **Develop Mathematical Model**

Ex: *Consider an open tank with a constant cross-sectional area, A:*



the rate of change in pressure, *p*,
the input flow rate, q_{IN} ,
the output flow rate, q_{OUT}

$$p_C = \rho g h + p_r \;=\; p_{Cr} = \rho g h$$

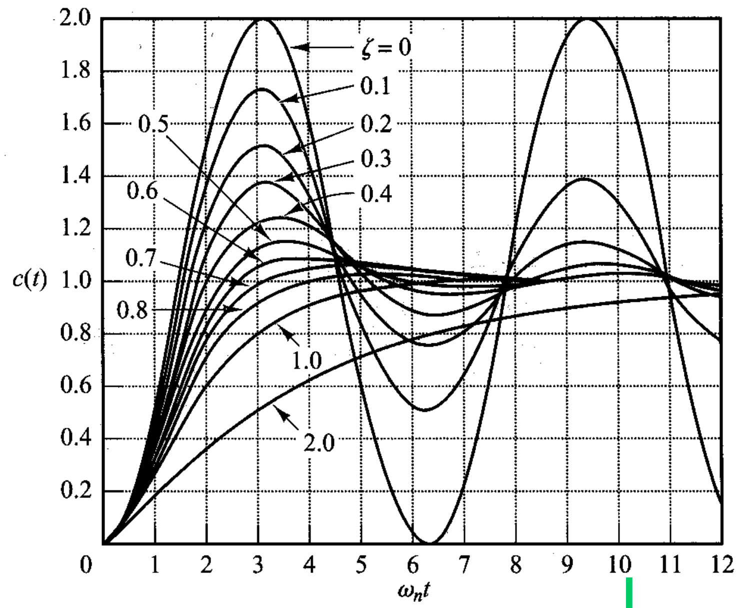
$$q_{IN} - q_{OUT} = \frac{d}{dt}(Volum) = \frac{d}{dt}(Ah) = A\dot{h}$$

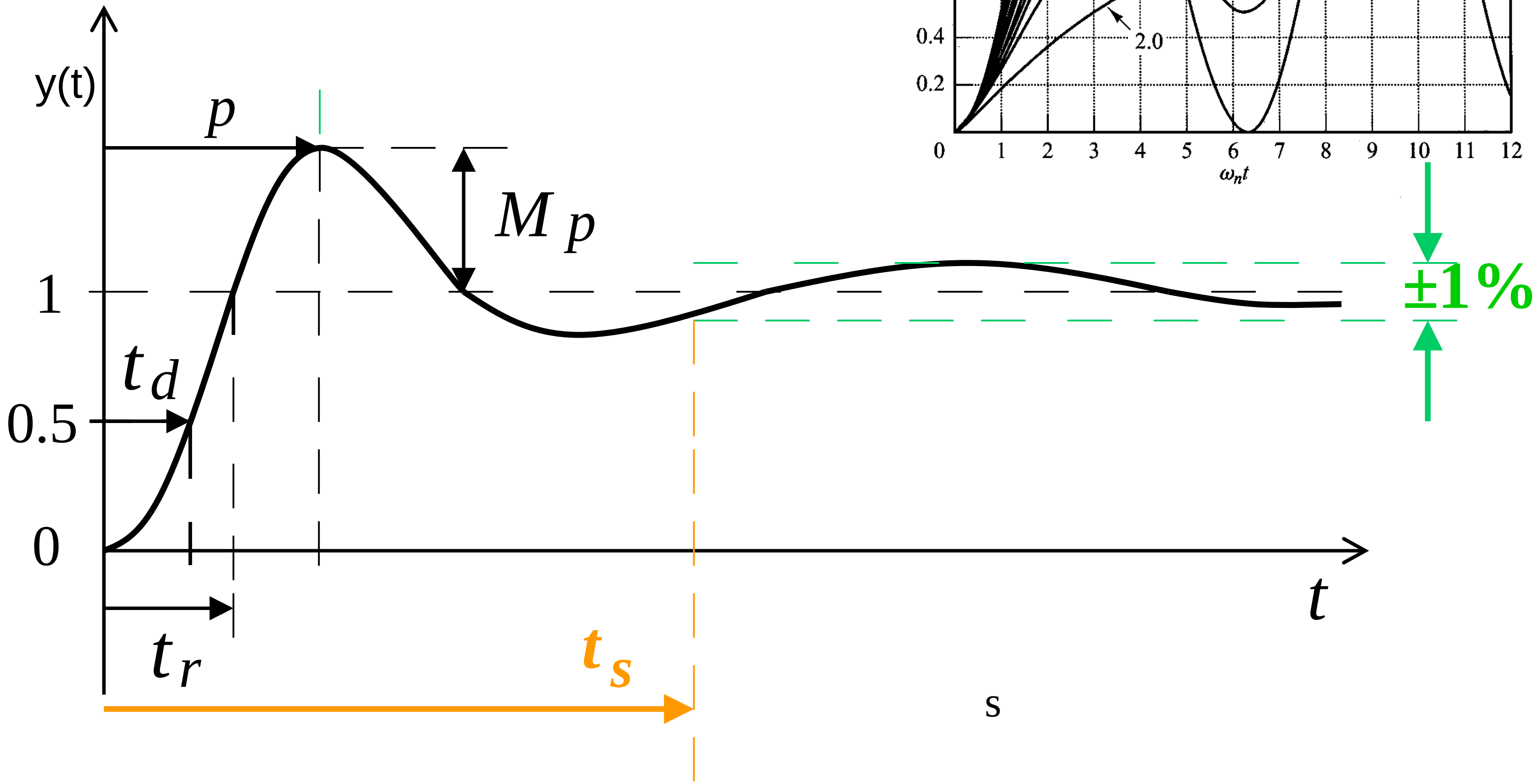
$$\dot{p}_{Cr} = \rho g \dot{h}$$

$$\Rightarrow \; C = \frac{q_{IN} - q_{OUT}}{\dot{p}_{Cr}} = \frac{A\dot{h}}{\rho g \dot{h}} = \frac{A}{\rho g}$$

System Response .

- Dynamic response
- Transient and steady state response
- First and second order system
- Frequency response system





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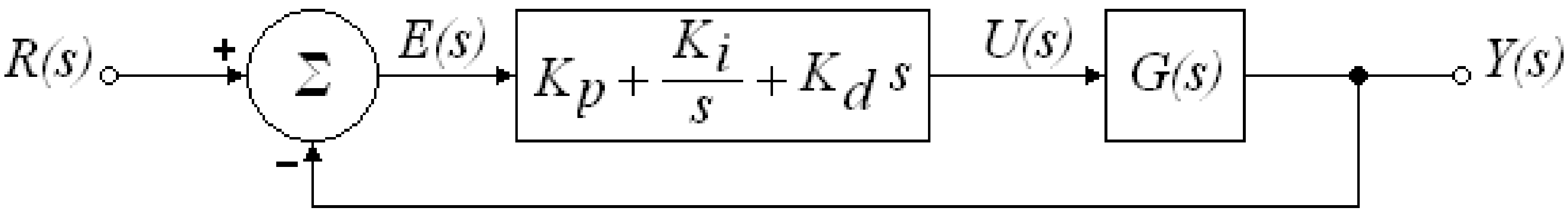
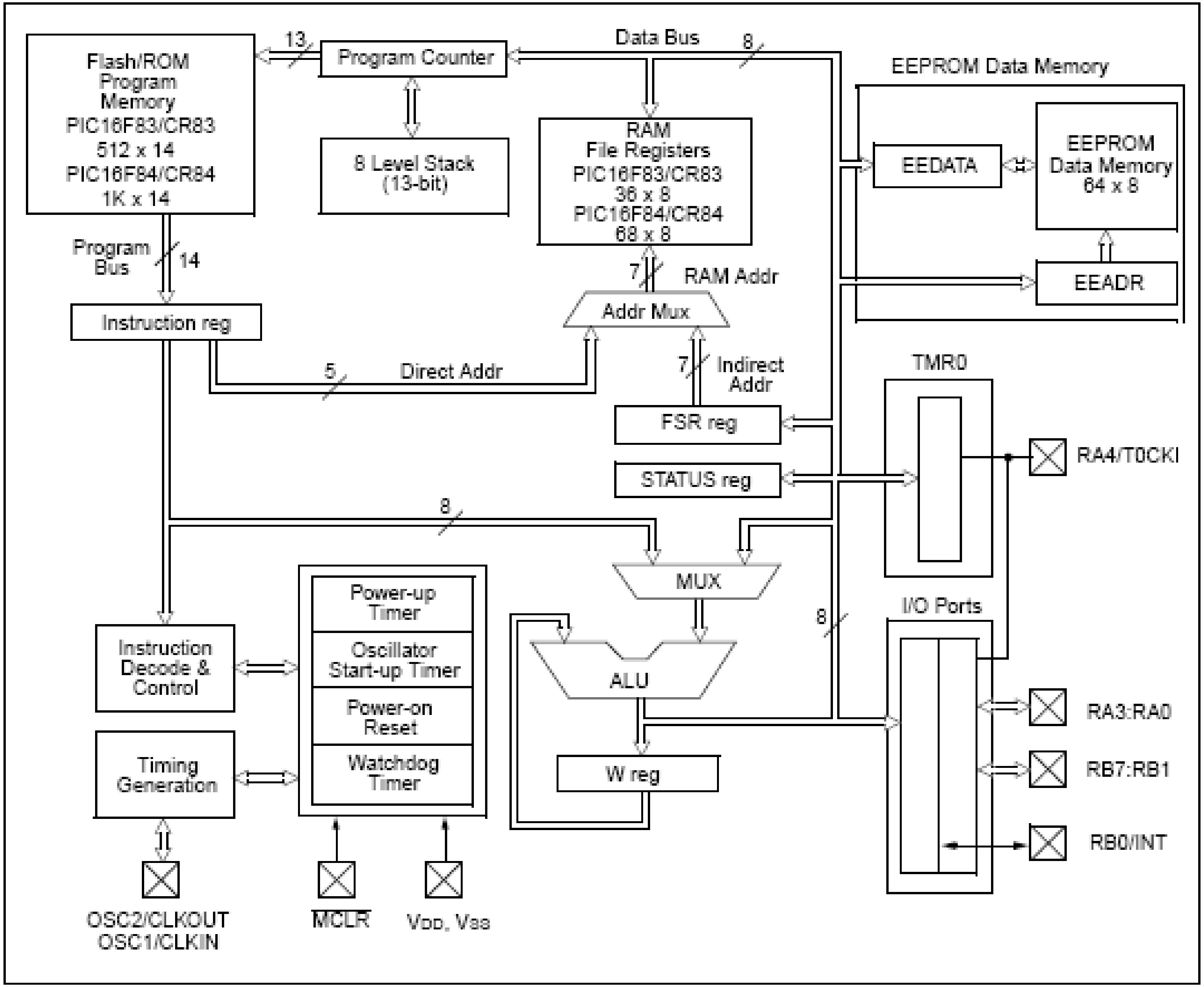
Closed Loop Control.

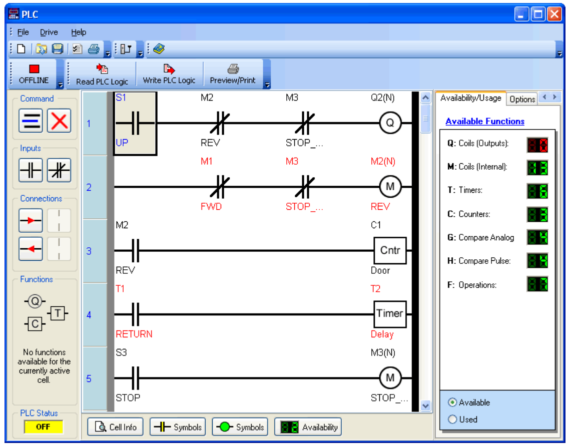
- Closed loop controls
- P, PI,PID controllers
- Digital Controllers
- Implementing control modes
- Adaptive control



Microprocessors / Microcontroller systems

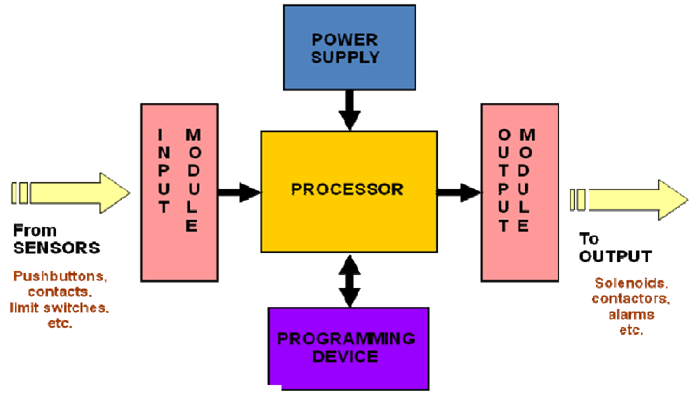


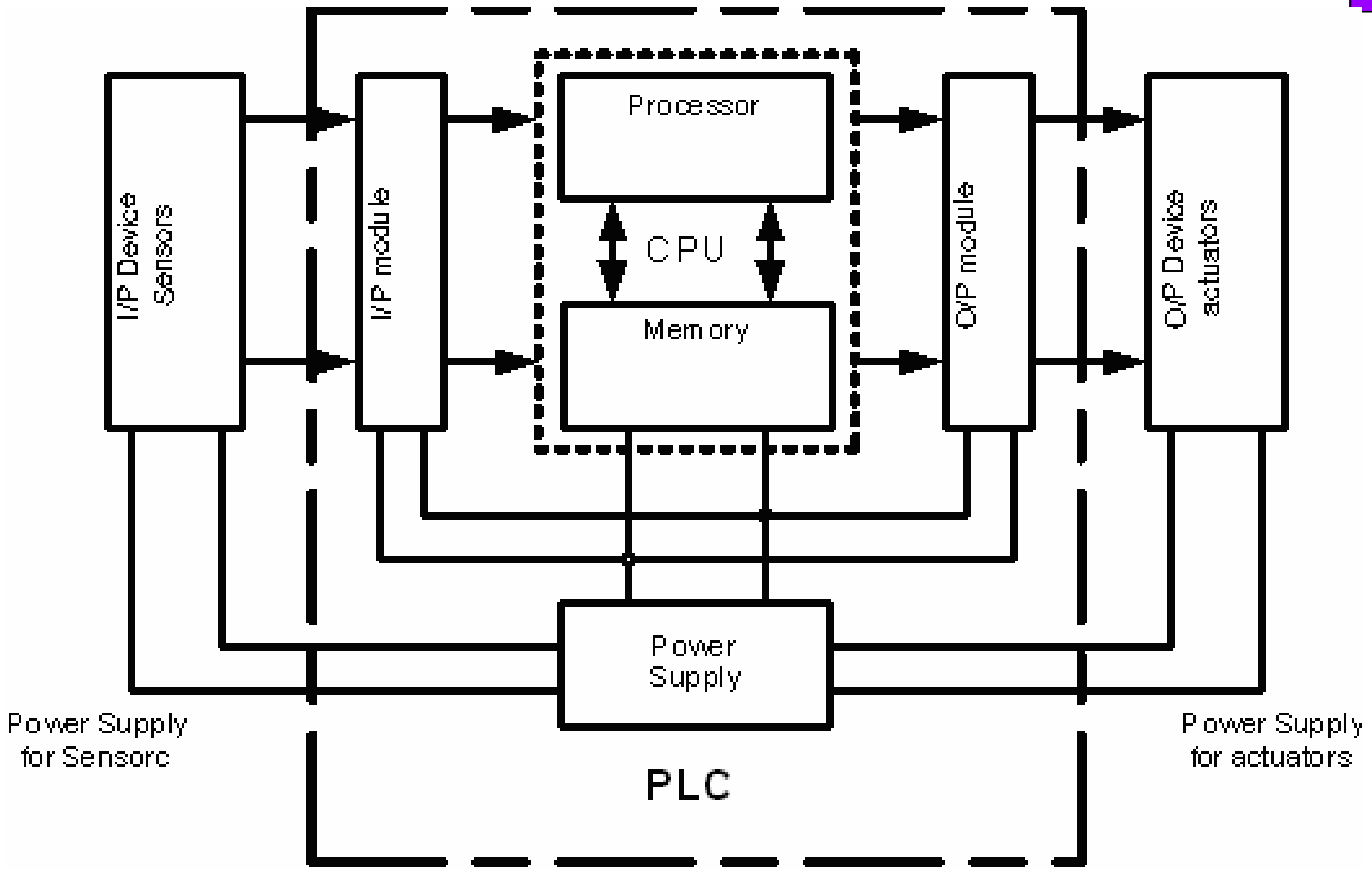
PLC System


PLC
File Drive Help
OFFLINE
Read PLC Logic
Write PLC Logic
Preview/Print
Command
Inputs
Connections
Functions
No functions available for the currently active cell.
PLC Status
OFF
S1
UP
M2
REV
M3
STOP_...
Q2(N)
Q
M1
FWD
M2(N)
M
C1
Cntr
Door
T1
RETURN
T2
Timer
Delay
S3
STOP
M3(N)
Availability/Usage
Options
Available Functions
Q: Coils (Outputs):
M: Coils (Internal):
T: Timers:
C: Counters:
G: Compare Analog:
H: Compare Pulse:
F: Operations:
Available
Used
Cell Info
Symbols
Availability

PLC system

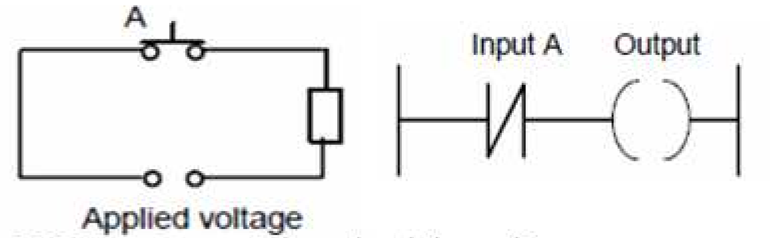
Major Components of a Common PLC



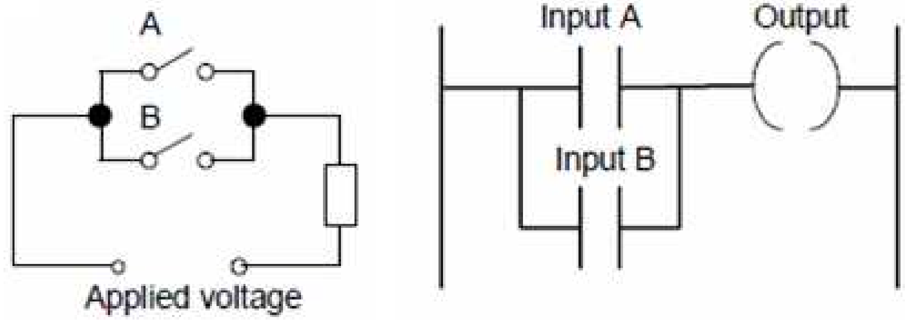


PLC system

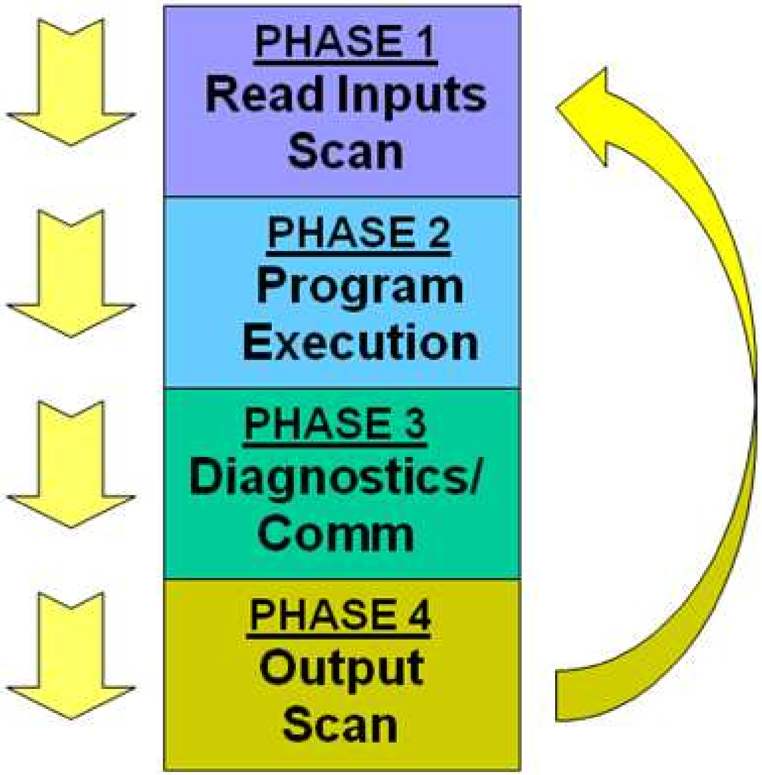
- **PLC programming**
- **PLC Ladder and functional block**

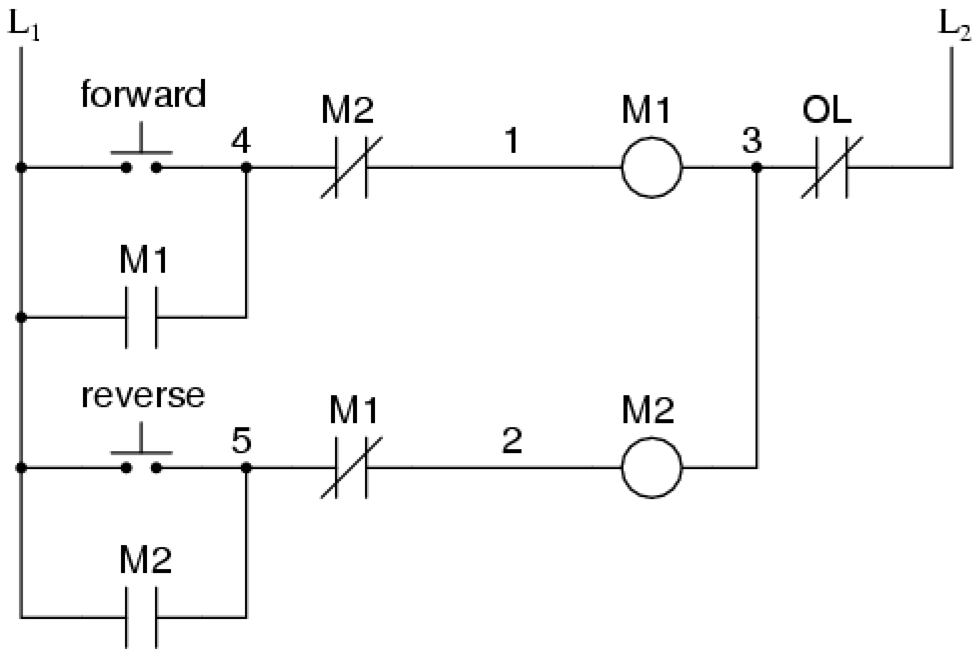


***NOT** gate with a ladder diagram rung*

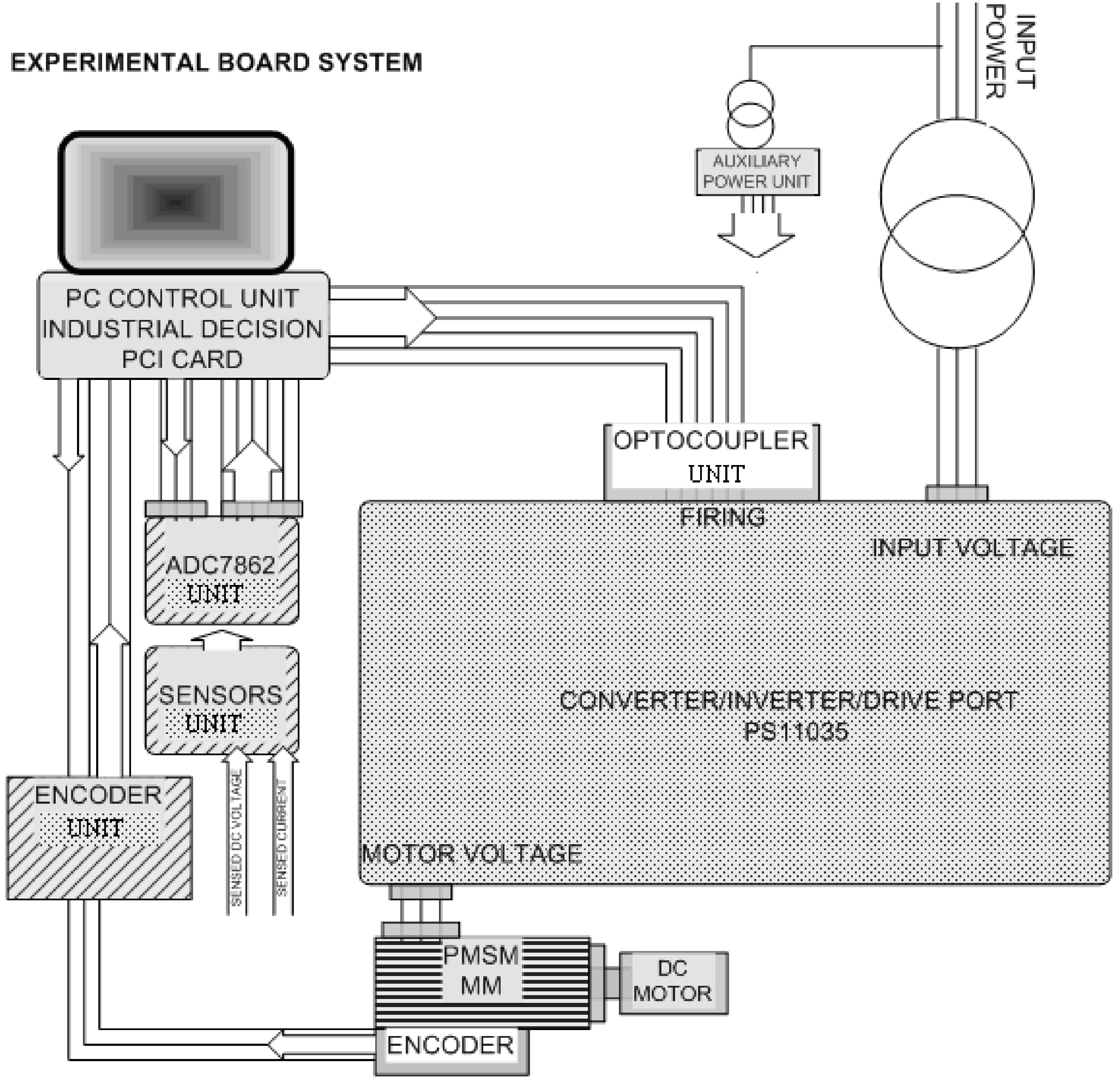


***OR** gate with a ladder diagram rung*

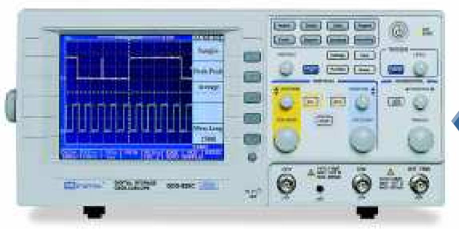


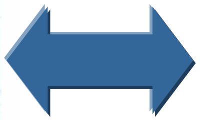


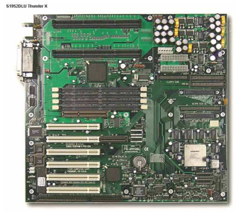
Case Study: Motor Control



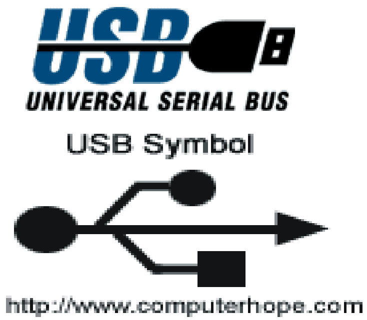
PC-based Measurement and Control







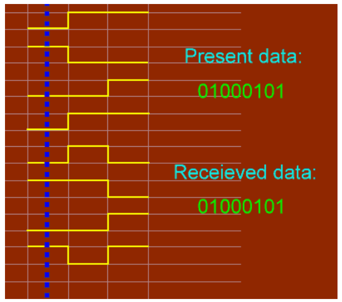
Pc Board

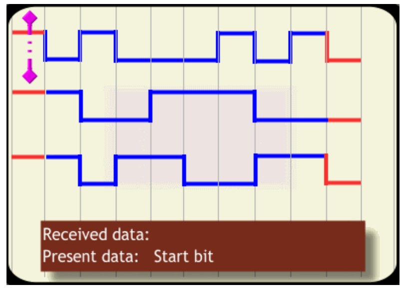


CAN BUS

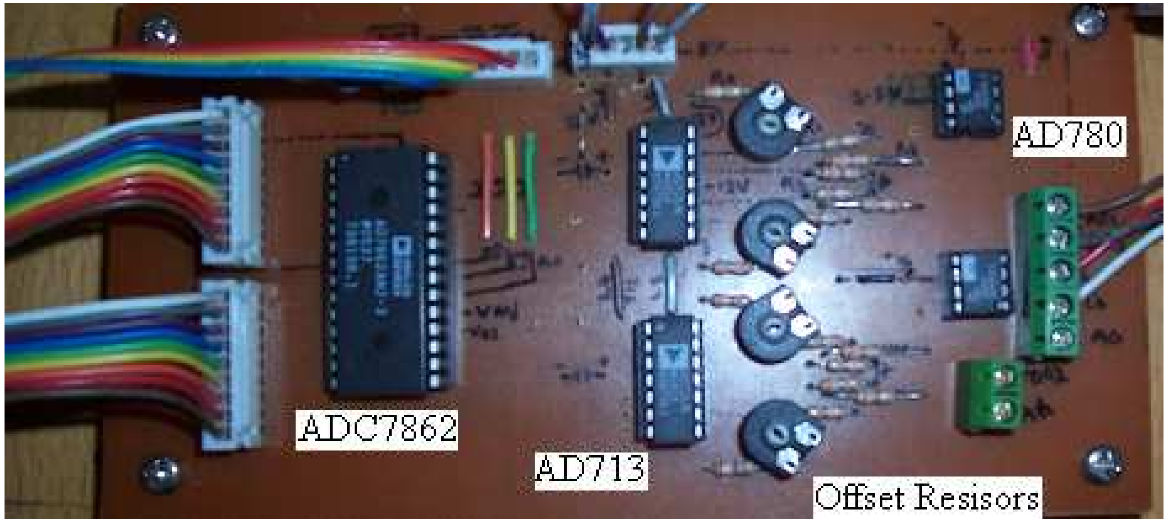
GPIB

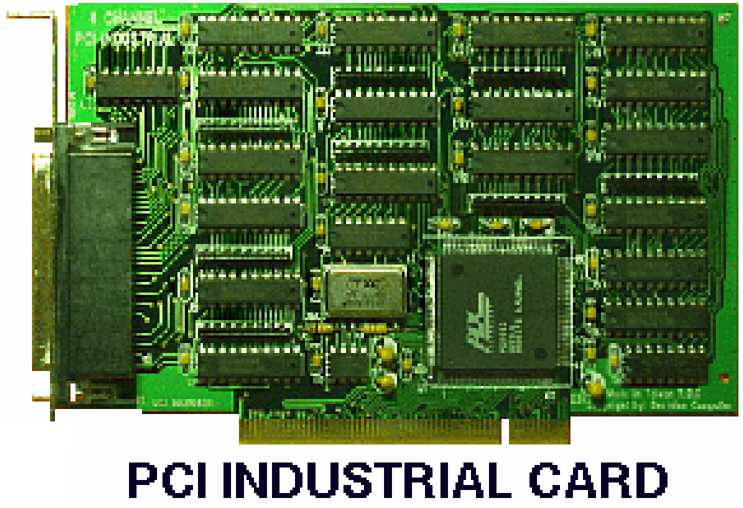
Serial/paralell

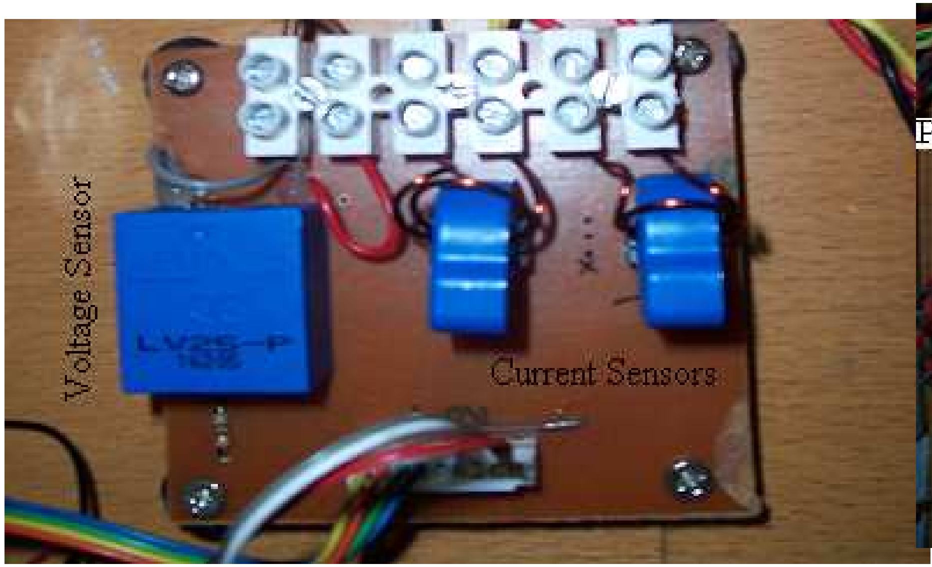


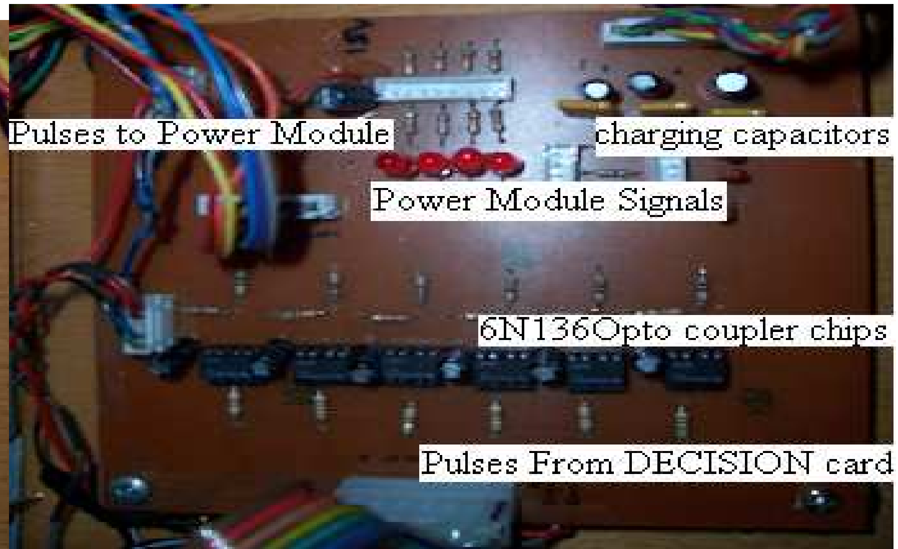


Case Study: Motor Control









Projects

- Select one of the Mechatronic components and write , present and submit your projects
- Examples:
- Sensors:
- Robot sensor
- Biomedical engineering sensors
- PIC, 8051
- PLC
- …….etc
- DC motor speed control
- Washing machine mechanism
- ...etc......
- Starting of IM with PLC
- Temperature measurement and display with 8051