Faculty Orientation Program
TE E&TC (2015 Pattern)

Unit –6
Mechatronics Systems in Automobile

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Unit 6
Mechatronics Systems in Automobile

- Boat Autopilot
- High Speed tilting trains
- Automatic car parking systems
- Engine Management systems
- Antilock Brake systems (ABS)
- CNC Machines

  (Only Black Diagram and explanation)

Case study 1

Boat Autopilot

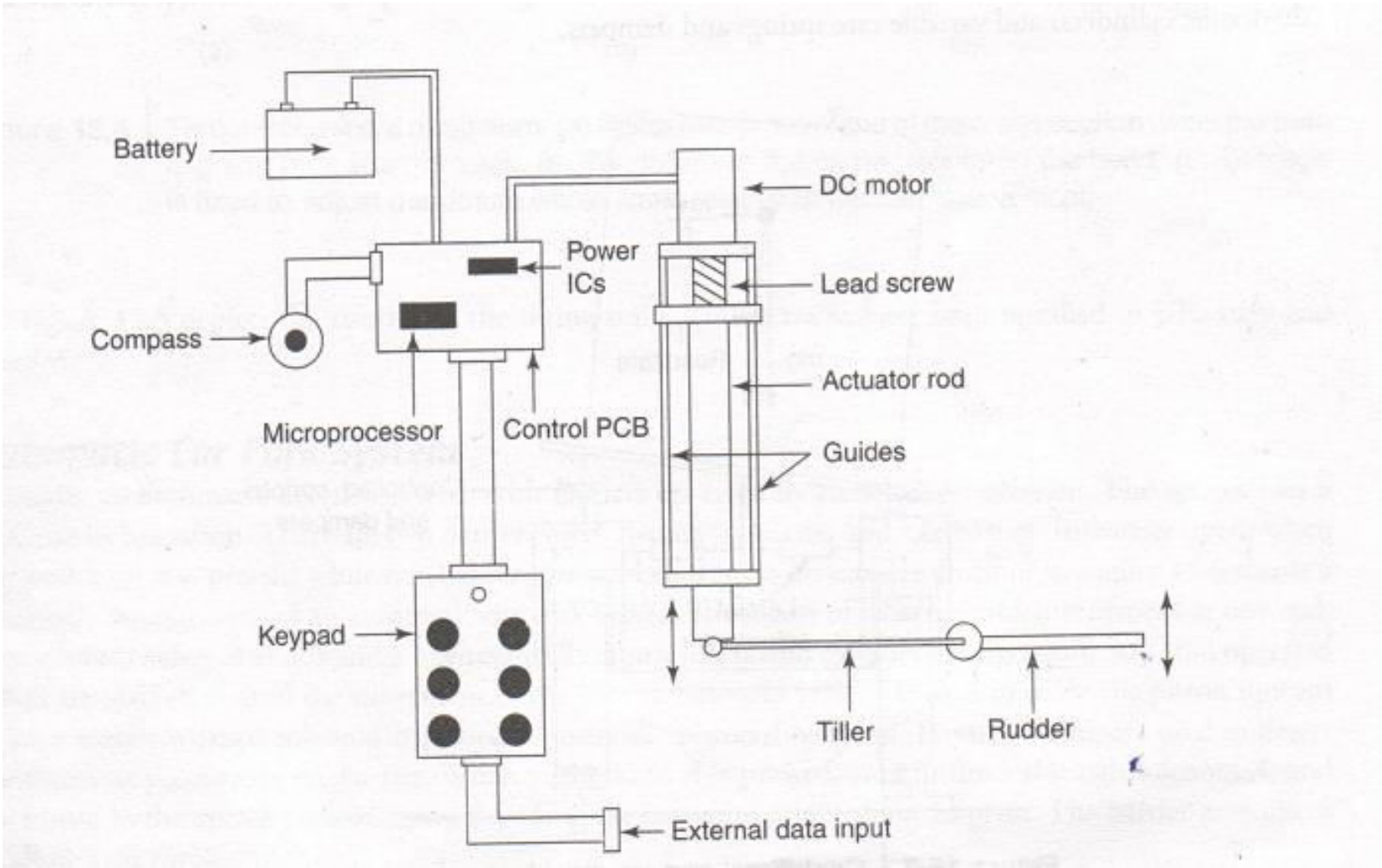
Why Boat Autopilot??

- The objective is to automate the movement of the boat once the direction and destination is fixed.
- Keeps you free, from manipulating the wheel for hours at a time during long cruises
- Saves fuel because in most cases the machine can hold a straighter course than any man.
- It’ll have to fight currents, waves, and wind without losing its way.
- You’ll save time and free to do other work.

Auto pilot continues……

- The autopilot takes over and goes on correcting the course of drive continuously so that direction does not change substantially.
- The latest and greatest autopilot control heads are quite advanced, armed with adaptive software that can even “learn” how your boat reacts to different sea conditions and speeds, through time.

Schematic arrangement of Boat Autopilot



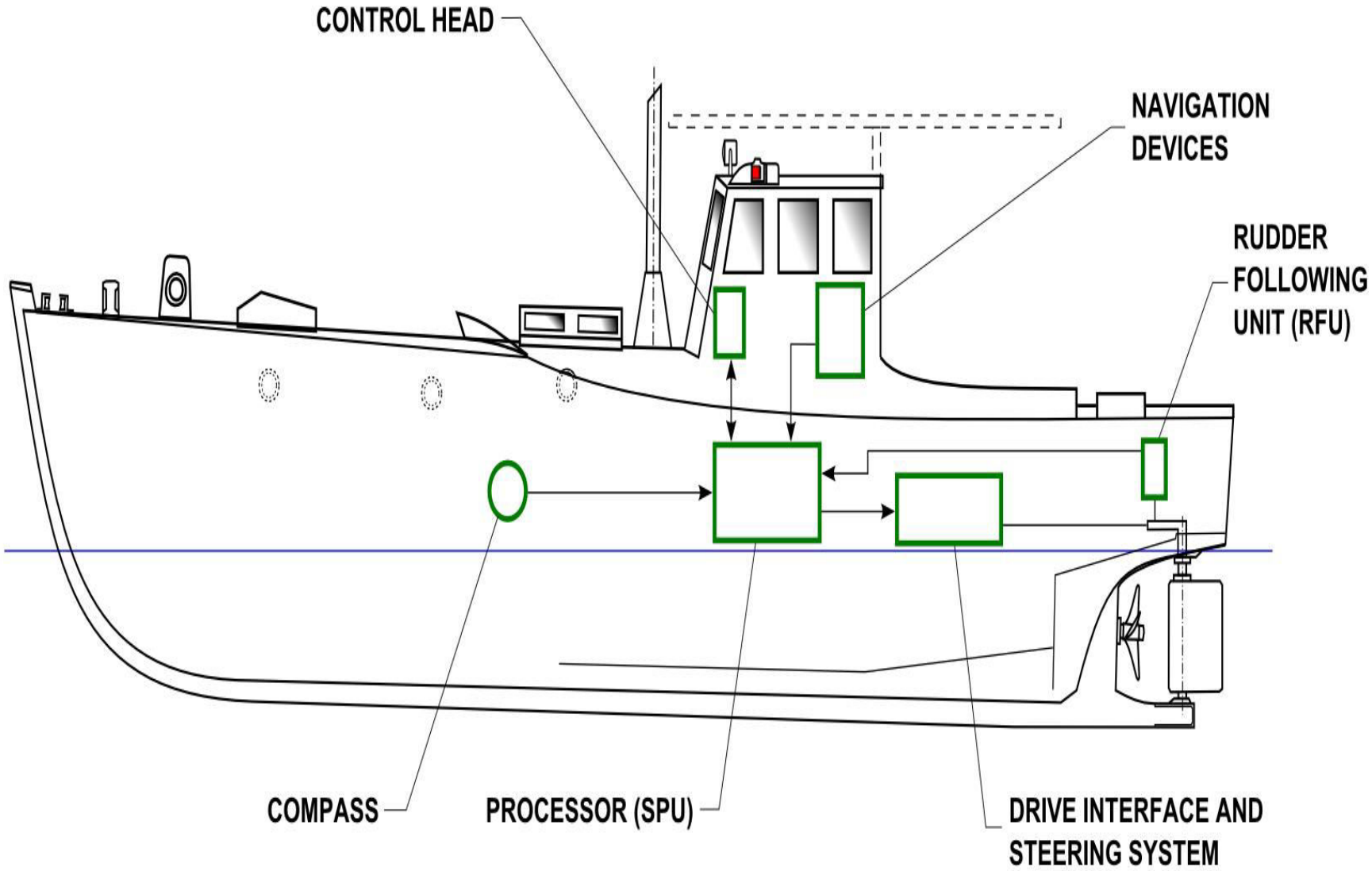
Working of Boat Autopilot

- The user has to setup the boat using landmark or boat mariner's compass and then push the pushbutton on.
- The direction is measured by compass linked with microprocessor. The output of the microprocessor through power IC board to DC motor.
- The mechanical drive is then taken through a double reduction belt drive to a to a screw which propels the hollow ram, to turn the rudder angle.

Working of Boat Autopilot

- Mechanical design should meet the requirements of a tiller force generated at specific angles and rate of rotation taking into account of hydrodynamic forces due to specific rudder configuration.

- Based on the size of the components, required power levels of the driver and required power electronics are calculated.


CONTROL HEAD
NAVIGATION DEVICES
RUDDER FOLLOWING UNIT (RFU)
COMPASS
PROCESSOR (SPU)
DRIVE INTERFACE AND STEERING SYSTEM

Case study 2

High Speed tilting trains

High Speed Tilt Train

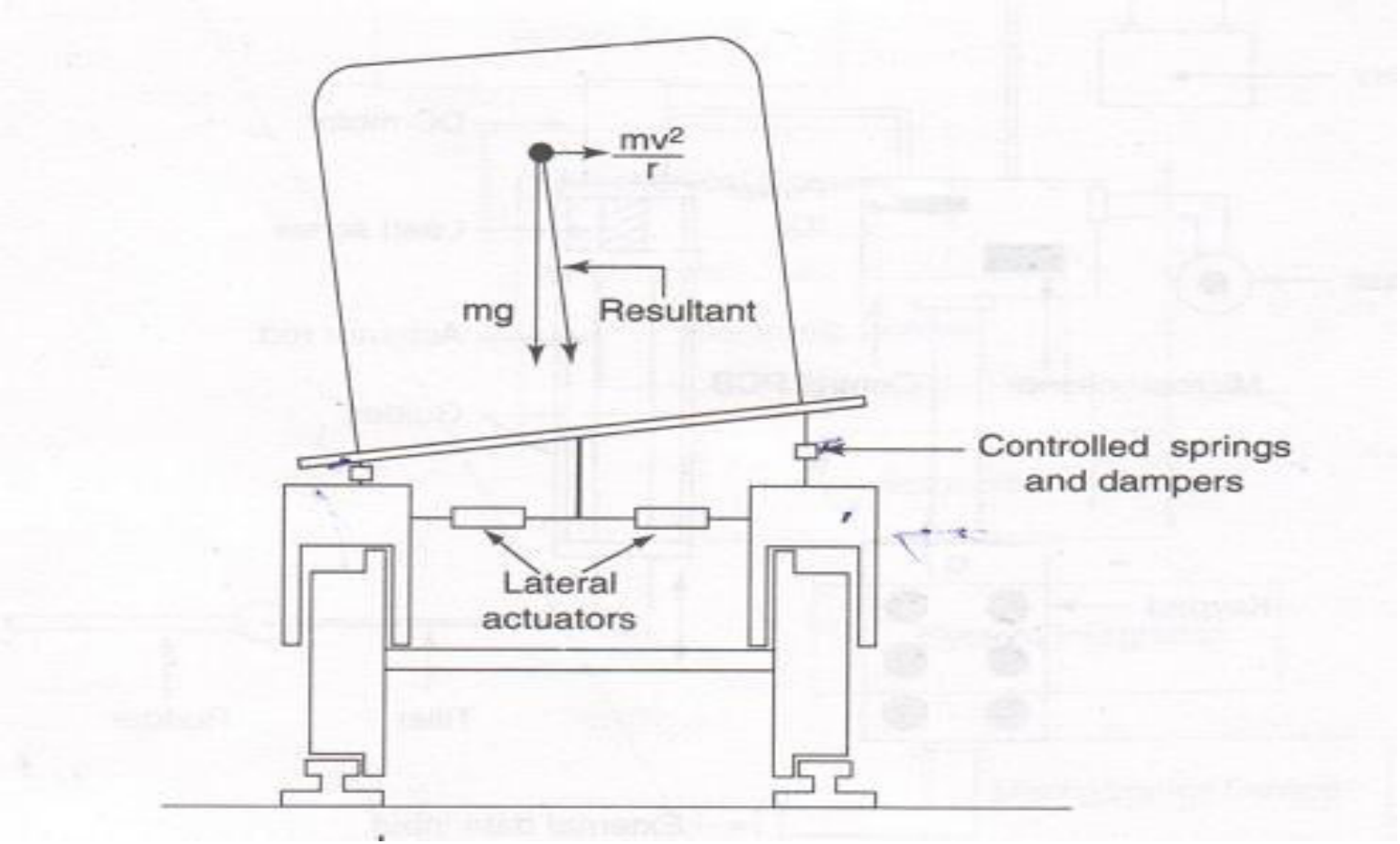
- When the train is passing a corner, the passengers experience a lateral force that is proportional to V^2/r.

  (Banking effect)
- This causes severe discomfort when the speed exceeds a limit. This also causes radial forces on the track and tracks wears out.
- The conventional solution is to make track inclined so that forces are normal to the floor of the carriage body. However, if the speed is lower or higher for which inclination is designed then again it causes discomfort.

High Speed Tilt Train

- Some tracks are made for certain trains and specifically designed for designed speed. But the problem comes with existing tracks.
- The solution of the problem is tilting trains. Here the carriage floor is tilted when negotiating a bend so that the forces are normal to floor of the carriage and causes less discomfort to the user.
- The degree of the tilt is controlled to match the speed of the train.

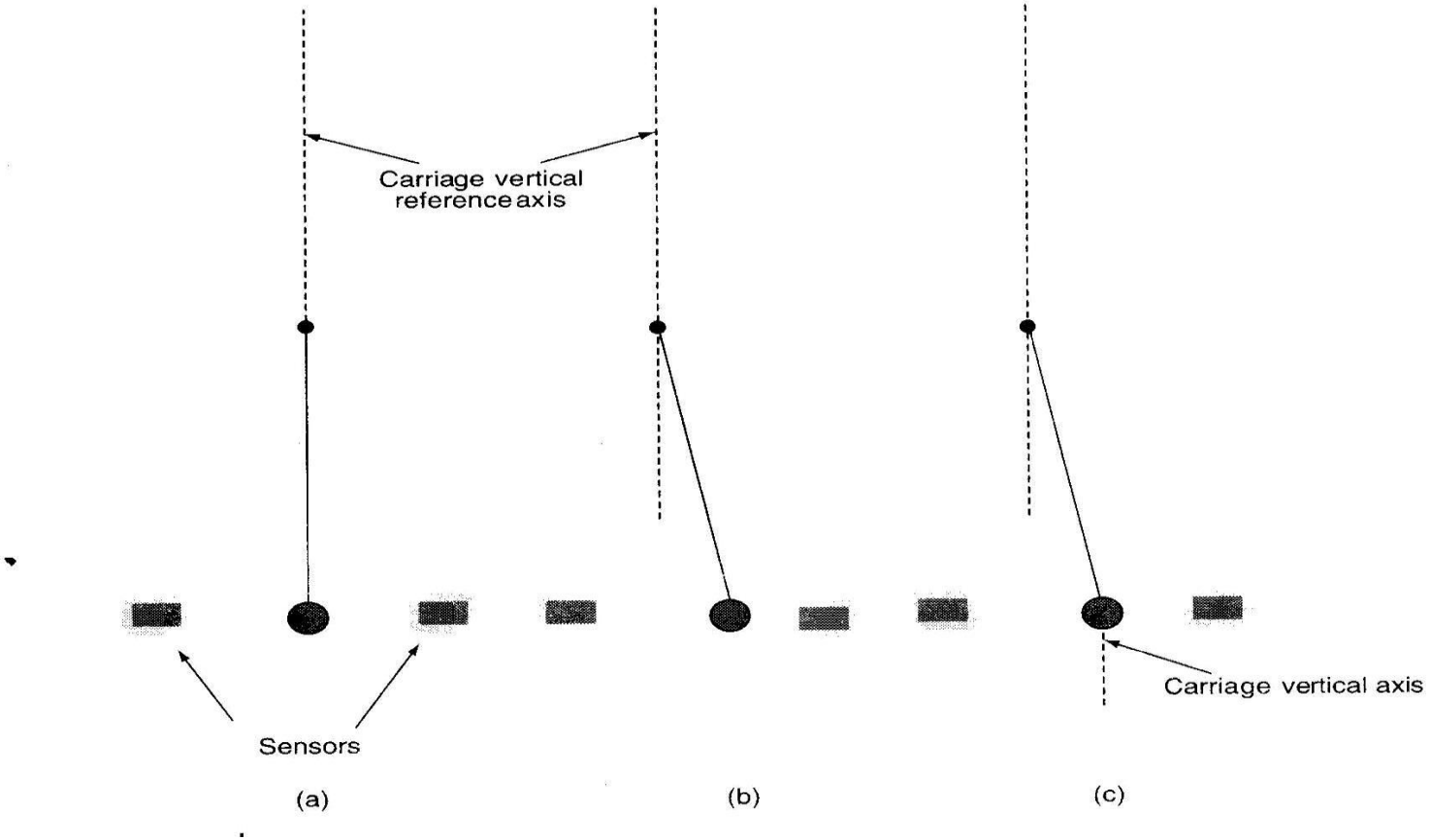
High Speed Tilt Train



High Speed Tilt Train

- The train uses active suspension controlled by onboard computer.
- Controlled variable rate springs and dampers act to provide additional control so that lateral actuators provide the tilting force as per the speed.
- Operation of the tilting mechanism is controlled by sensor information which is in the form of pendulum.
- As the train takes the bend, the pendulum gets displaced outward towards the circumference of the bend.

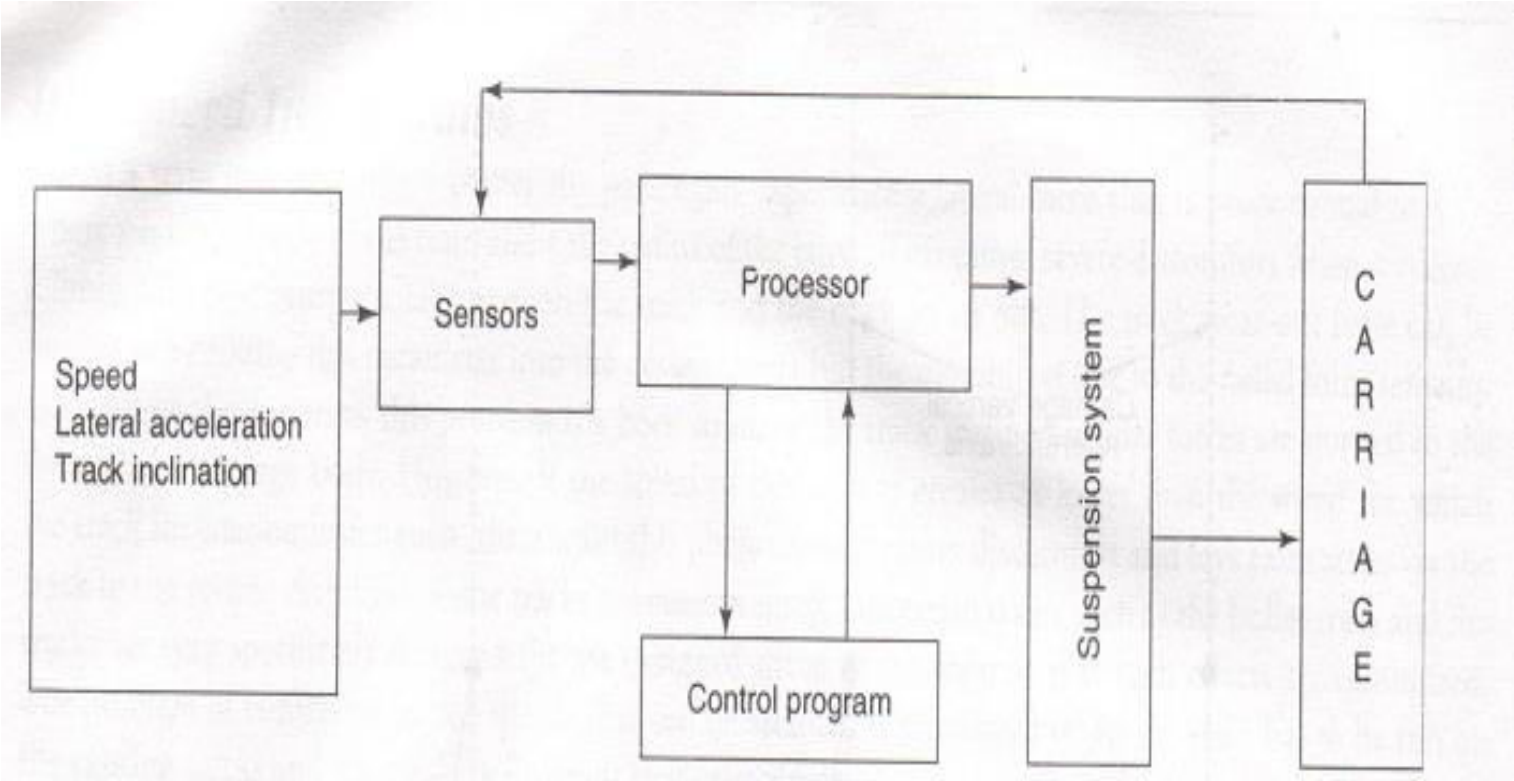
Control using a pendulum



High Speed Tilt Train

- The tilt angle of the carriage would be adjusted to bring back the displacement of the pendulum relative to the carriage vertical within the definite limits.
- Controlled variable rate springs and dampers act to provide additional control so that lateral actuators provide the tilting force as per the speed.

Control schematic of the tilting train



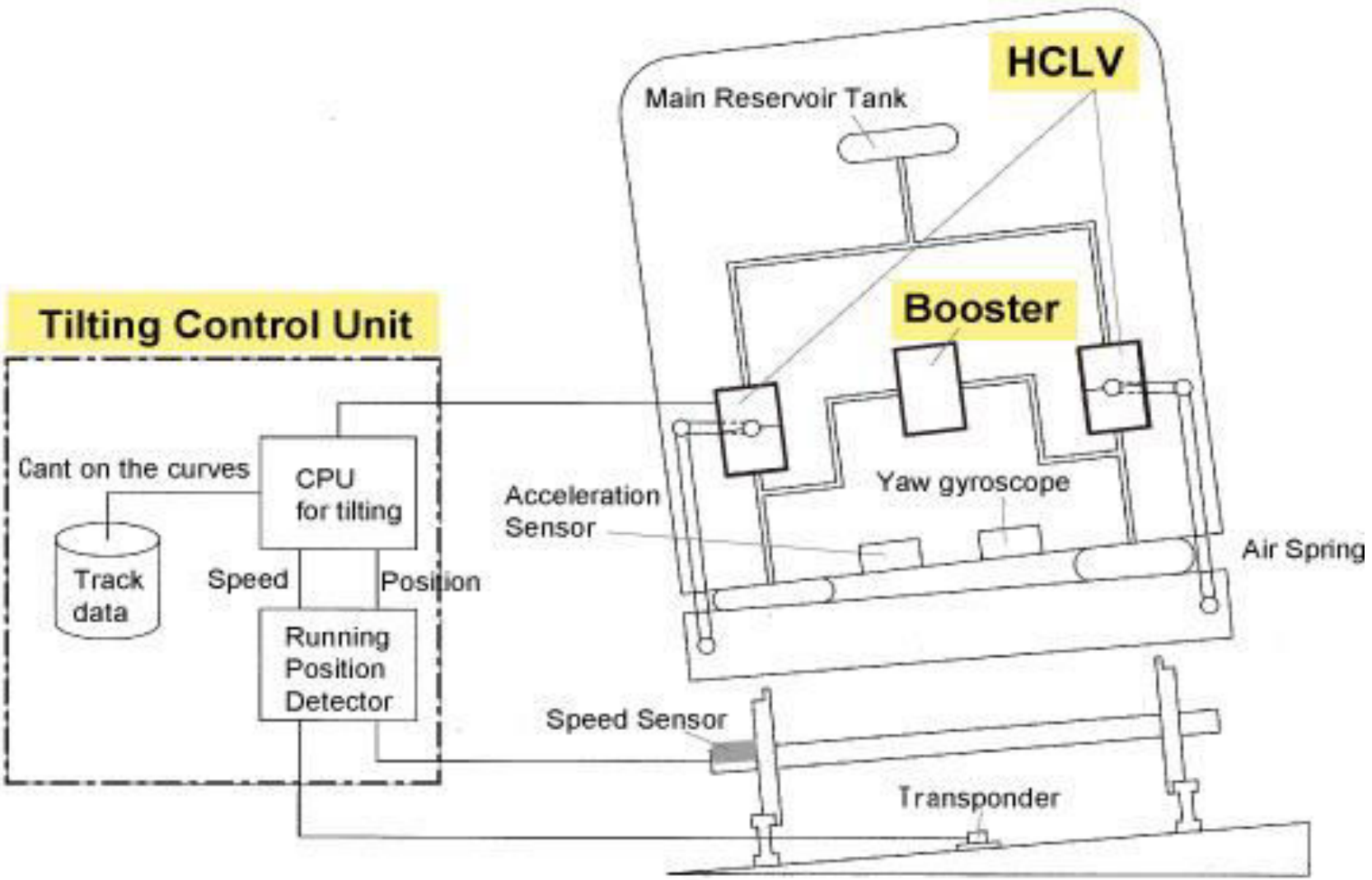

HCLV
Main Reservoir Tank
Booster
Tilting Control Unit
Cant on the curves
CPU
for tilting
Track
data
Speed
Position
Running
Position
Detector
Acceleration
Sensor
Yaw gyroscope
Air Spring
Speed Sensor
Transponder

Fig. 1

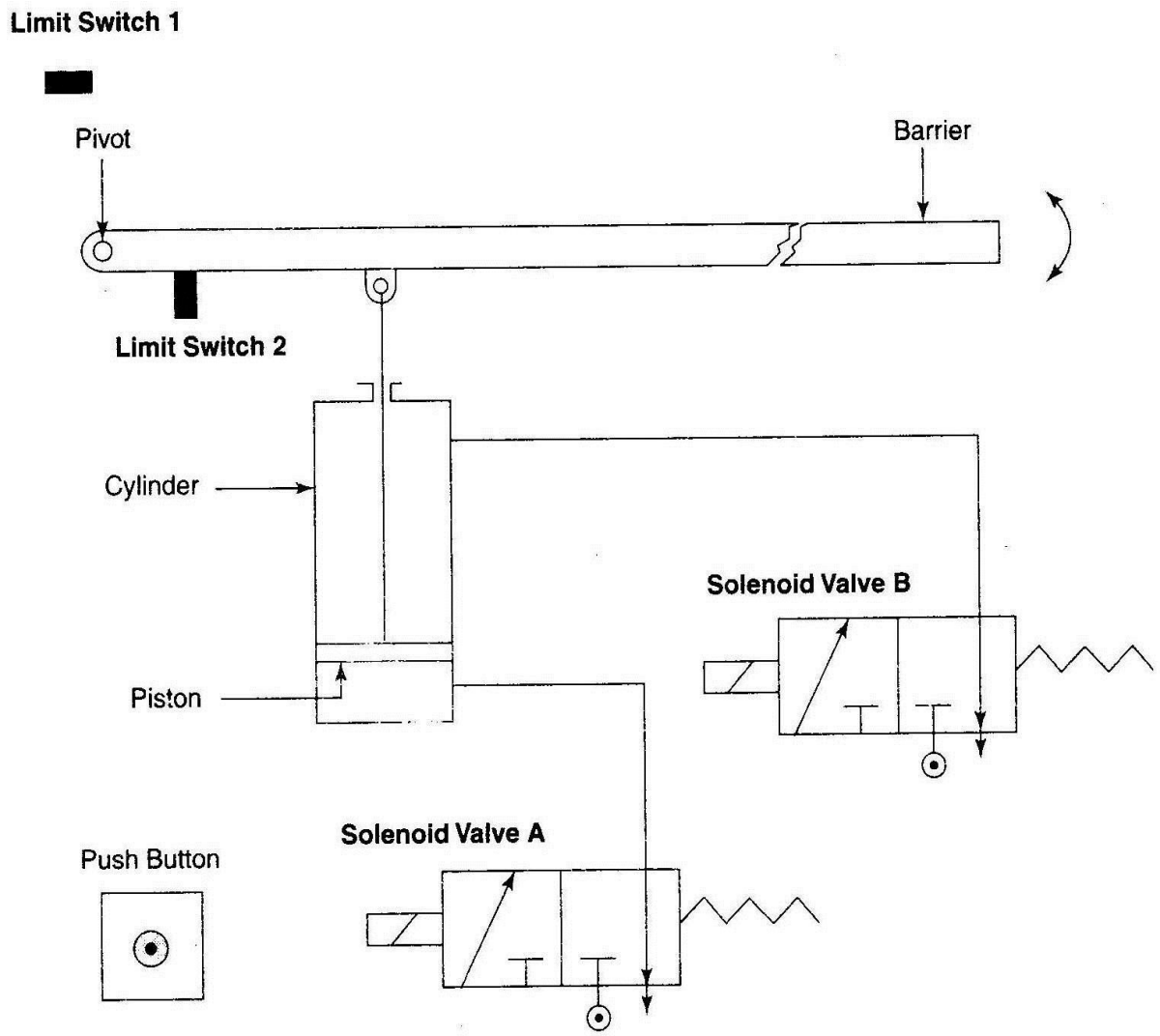
Case study 3

Automatic car parking systems

Automatic car parking systems

- There are automatic car parking system controlled by pushbutton. The system uses a PLC for its operation.
- There are two barriers used, namely in- barrier and out-barrier. In-barrier opens when the pushbutton is pressed while the out-barrier opens when the car is detected in front of the gate.
- The system consists of barrier operated with solenoid valves A & B and a pneumatically operated cylinder. Solenoid operated valves are used to control the movement of the pistons.

Car Park System



Automatic car parking systems

- Limit switches are used to detect the foremost position of the barrier.
- The solenoid valve A is used to move the piston upward in turn barrier whereas solenoid B is used to move the piston downward.
- When pushbutton A is pressed, Current flows through solenoid A, and the piston in the cylinder moves upward causing the barrier to rotate and opens to allow the car.

Automatic car parking systems

- When the barrier hits the limit switch 1, it will turns on the timer to give a required time delay.
- After the time delay, the solenoid B is activated which brings the barrier downward by retracting piston cylinder.
- Similar principle is adopted for exit barrier.

Sequence of operations

If a car is at the entry barrier and the car park is not full, open the entry gate.

While the entry gate is open, run a timer.

When the gate is open, increment the car count.

When the timer is done, close the entry gate.

When a car is at the exit barrier, latch open the exit gate.

While the exit gate is open, run a timer.

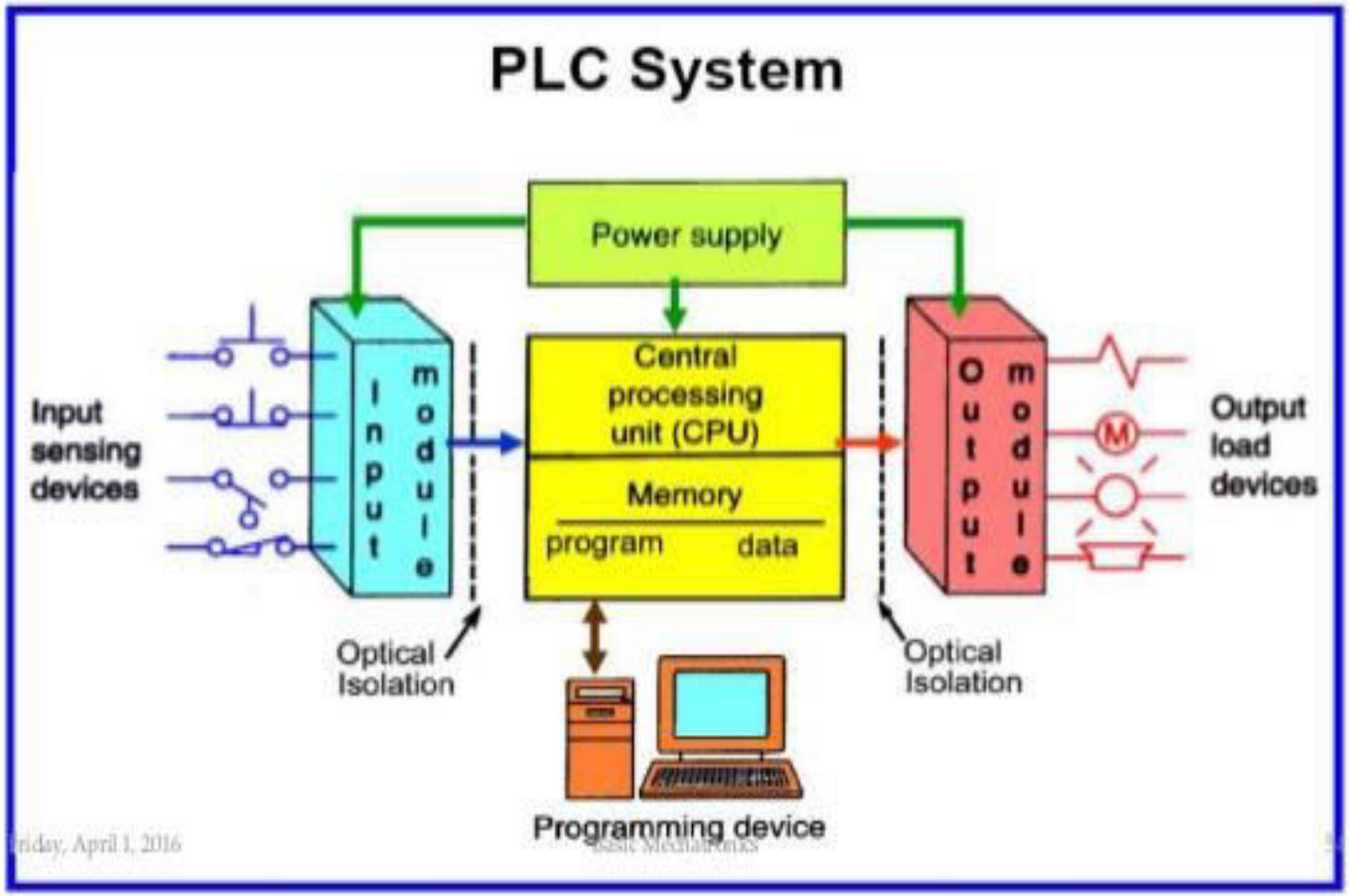
When the exit gate is open, decrement the car count.

When the timer is done, close the gate.

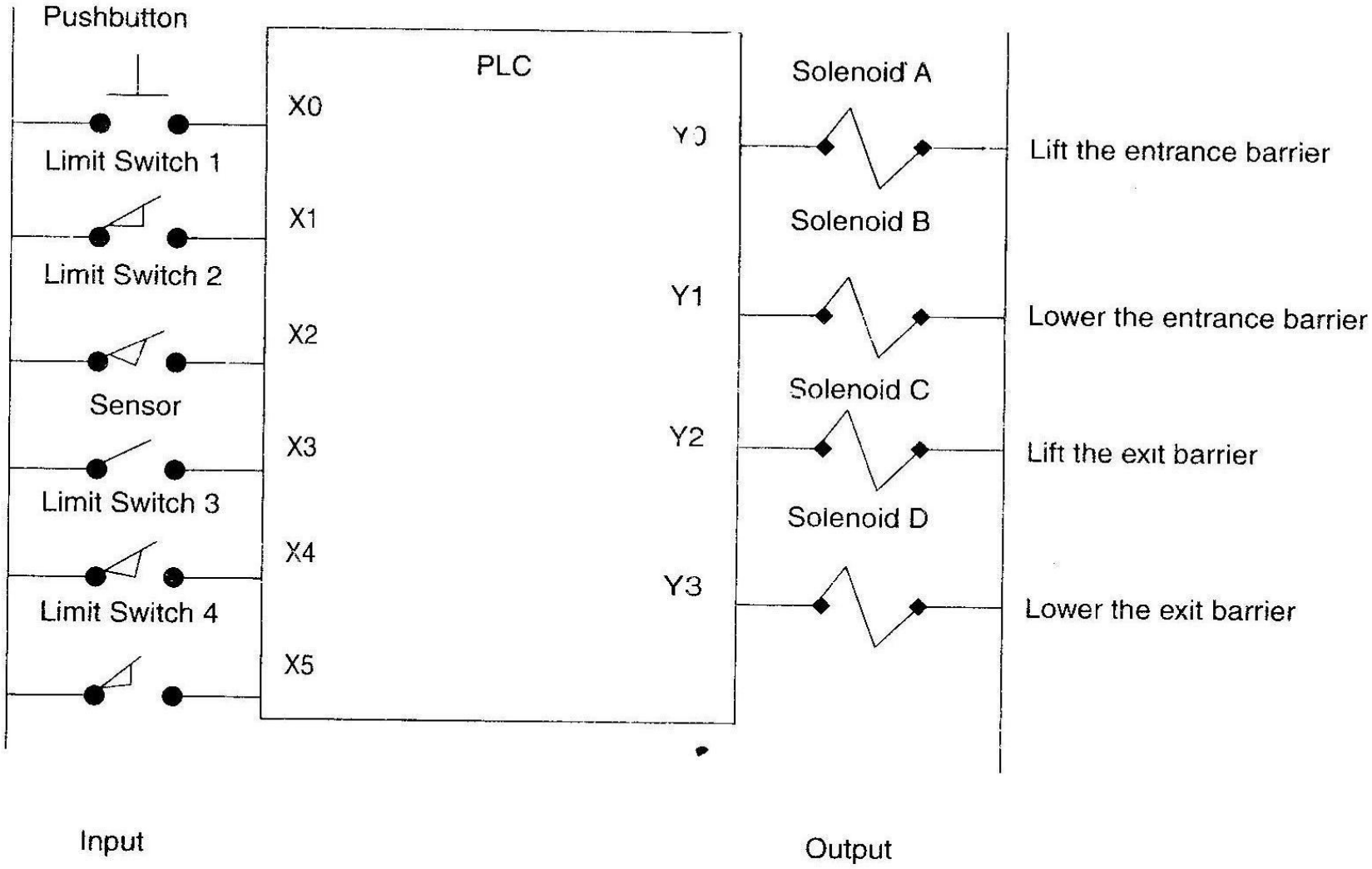
When the counter is at maximum, light Full.

Set the lit state of Spaces to the opposite of Full.

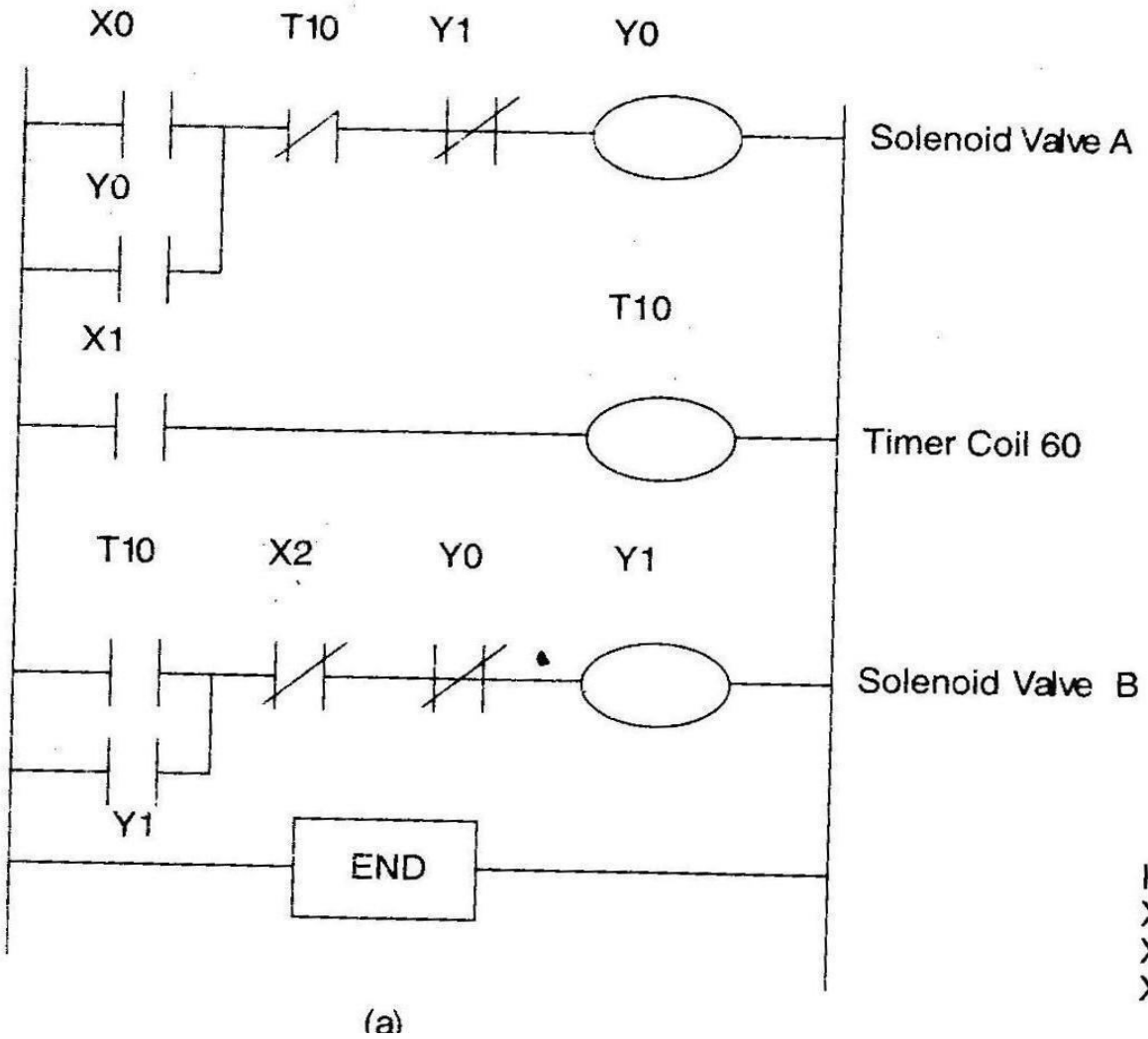
BASICS OF A PLC.



PLC arrangement to operate barriers



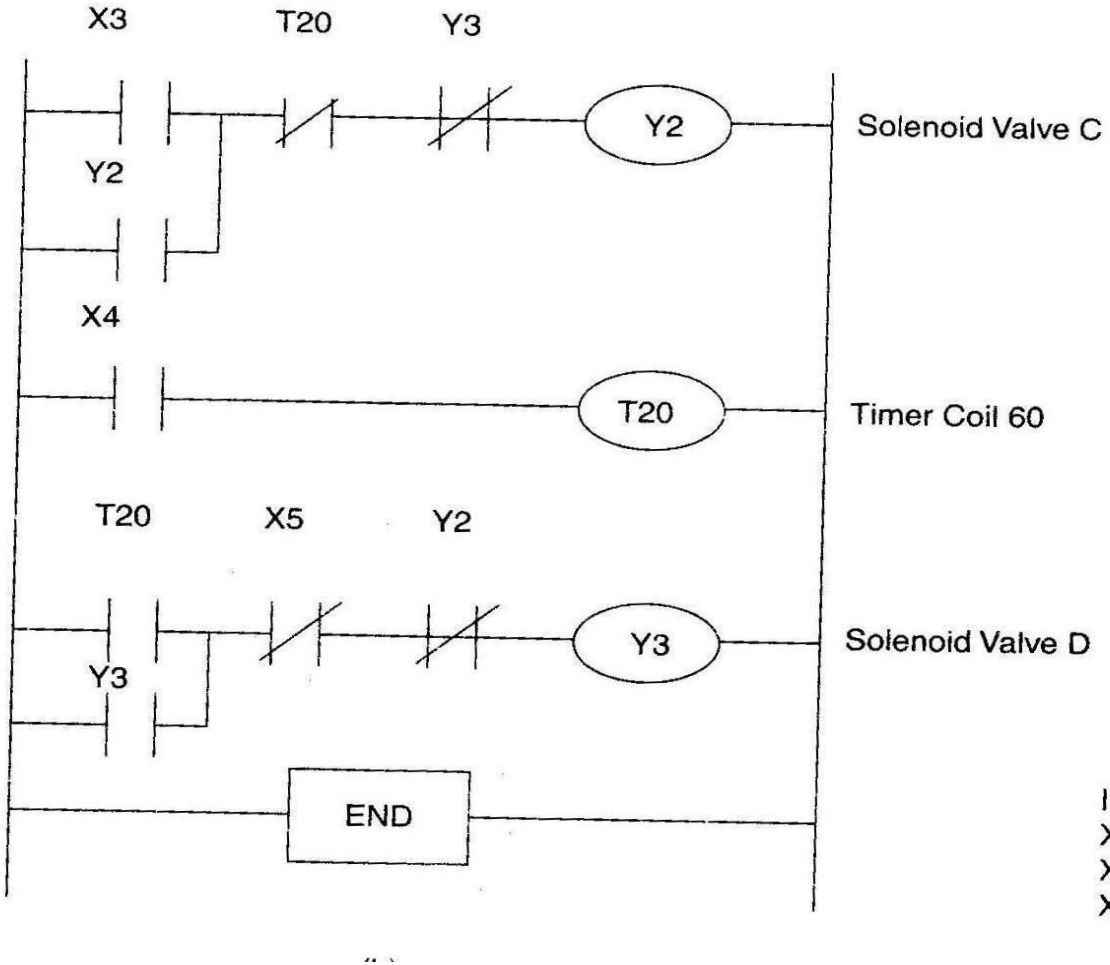
Ladder diagram for the input



(a)

Input devices:
X0 – Pushbutton to open the barrier
X1 – Limit switch 1
X2 – Limit switch 2

Ladder diagram for the output



Input devices:
X3 – Sensor to open the barrier
X4 – Limit switch 3
X2 -- Limit switch 4

Case study 4

Engine Management Systems

Automotive Sensors & Actuators

•Automotive manufacturers are continuously increasing the use of electronics systems to

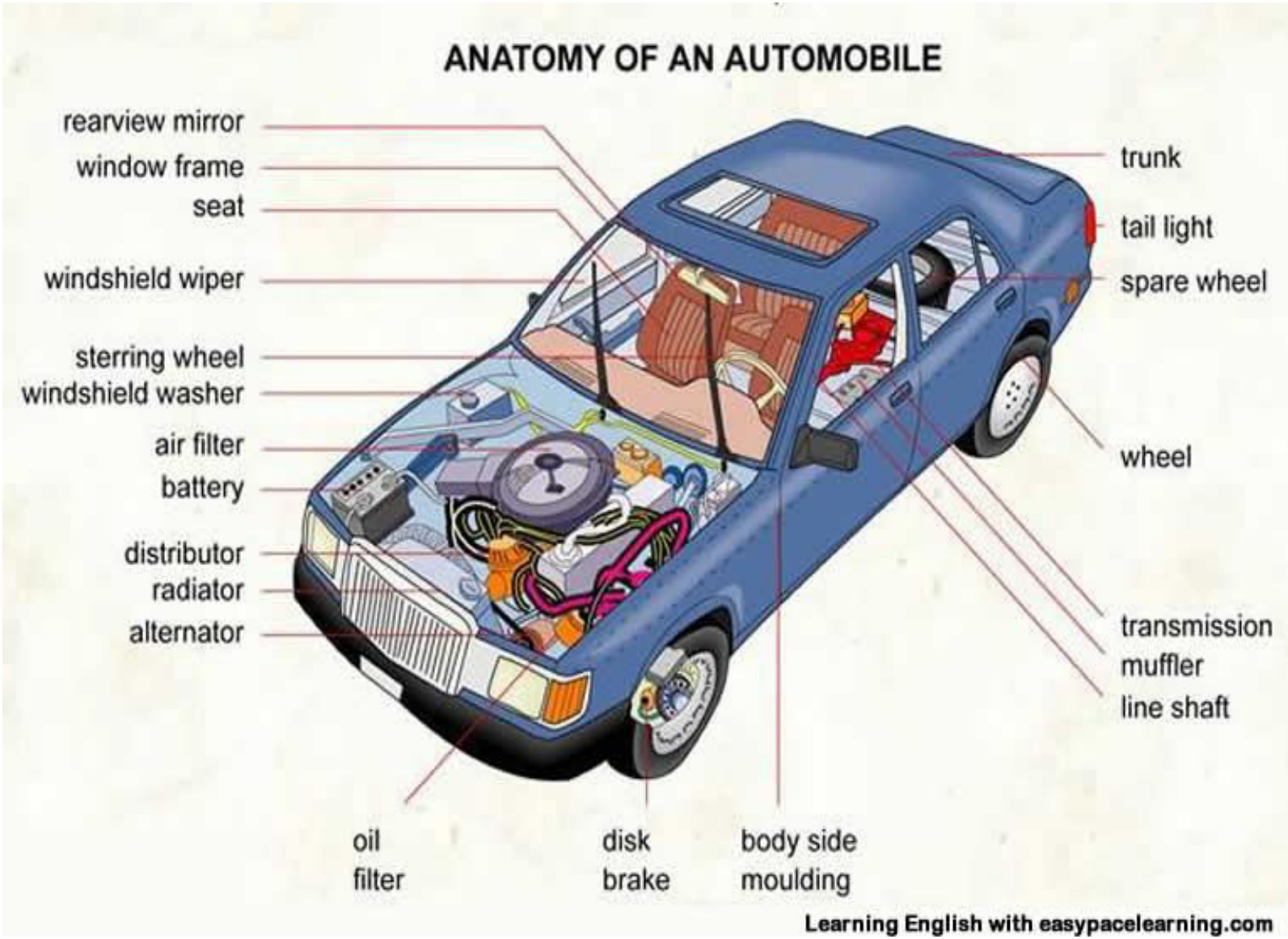
– improve vehicle performance

– Safety

– passenger comfort.

•Sensors and actuators integrated with automotive control computers help optimize vehicle performance while improving reliability and durability.

Sensor- Input


ANATOMY OF AN AUTOMOBILE
rearview mirror
window frame
seat
windshield wiper
sterring wheel
windshield washer
air filter
battery
distributor
radiator
alternator
trunk
tail light
spare wheel
wheel
transmission
muffler
line shaft
oil filter
disk brake
body side moulding
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Engine Mangement systems

- Many auto majors are developing eco friendly clean engine systems. Further through the development of high efficiency torque transmissions and it offers small enhancements in fuel efficiency.
- To protect our environment from air pollution and global warming, stringent regulations are issued to reduce gas emission and improve fuel efficiency.
- An electronic engine management system is made of sensors, actuators and microprocessor.

Engine Mangement systems

- Electronic management systems monitor and gather data from various number of sensors in the engine and continuously adjust the fuel supply and injection timing.
- This minimizes emissions and maximizes fuel efficiency. Engine electronic also features self diagnostic functions and provide enhanced engine protection.

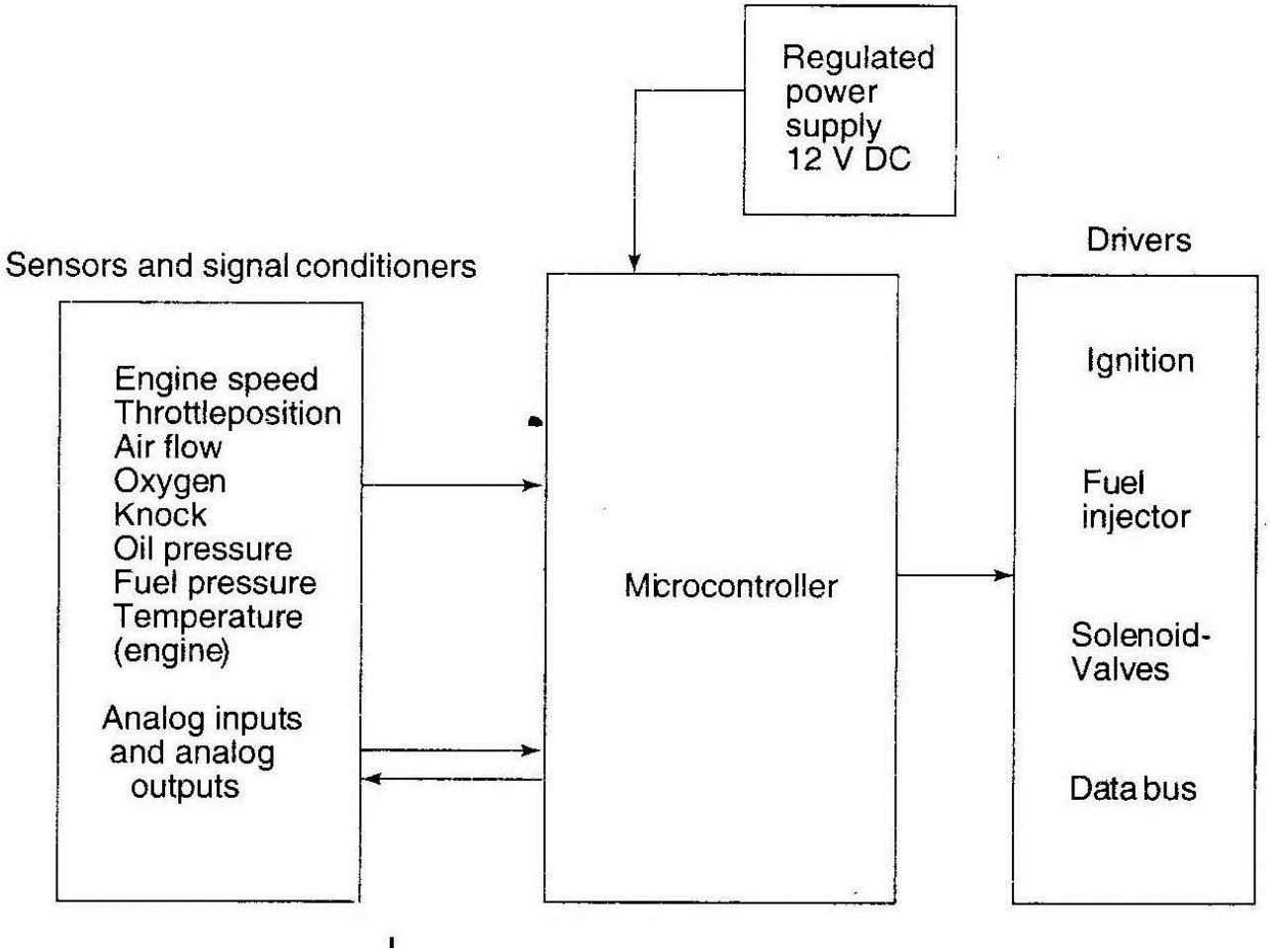
Engine Mangement systems

- Components of Electronic management systems: An Electronic Control Unit (ECU), Fuel delivery system (typically Fuel injection), an ignition system and number of sensors.
- Sensors provide feedback to ECU indicating how engine is running so that ECU can make necessary adjustments about fuel delivery and ignition system.
- Based on sensor information, ECU can decide that engine needs a maintenance and can show warning displays or warning lights.

Engine Mangement systems

- 1) Electronic Control Unit (ECU): It takes input from various sensors to continually optimize engine operation and performance. If more fuel consumption, ECU adjusts spark timings to solve the problem.
- 2) Fuel delivery system : Senses the amount of fuel and adjusts the fuel delivery.

Engine Management system Schematic



Sensors in Engine Management systems

- 1) Throttle position sensors: It lets ECU know that how far open the throttle is and used to control fuel delivery and spark timing.
- Throttle valve directly adjusts the amount of air entering the engine, indirectly controlling the charge (fuel + air) burned on each cycle due to the fuel injector.
- 2) EGO sensors: It indicates amount of oxygen in exhaust gas. If it is high or low, it does not provide proper air to fuel ratio and affects engine power, smoothness, fuel efficiency.

Sensors in Engine Management systems

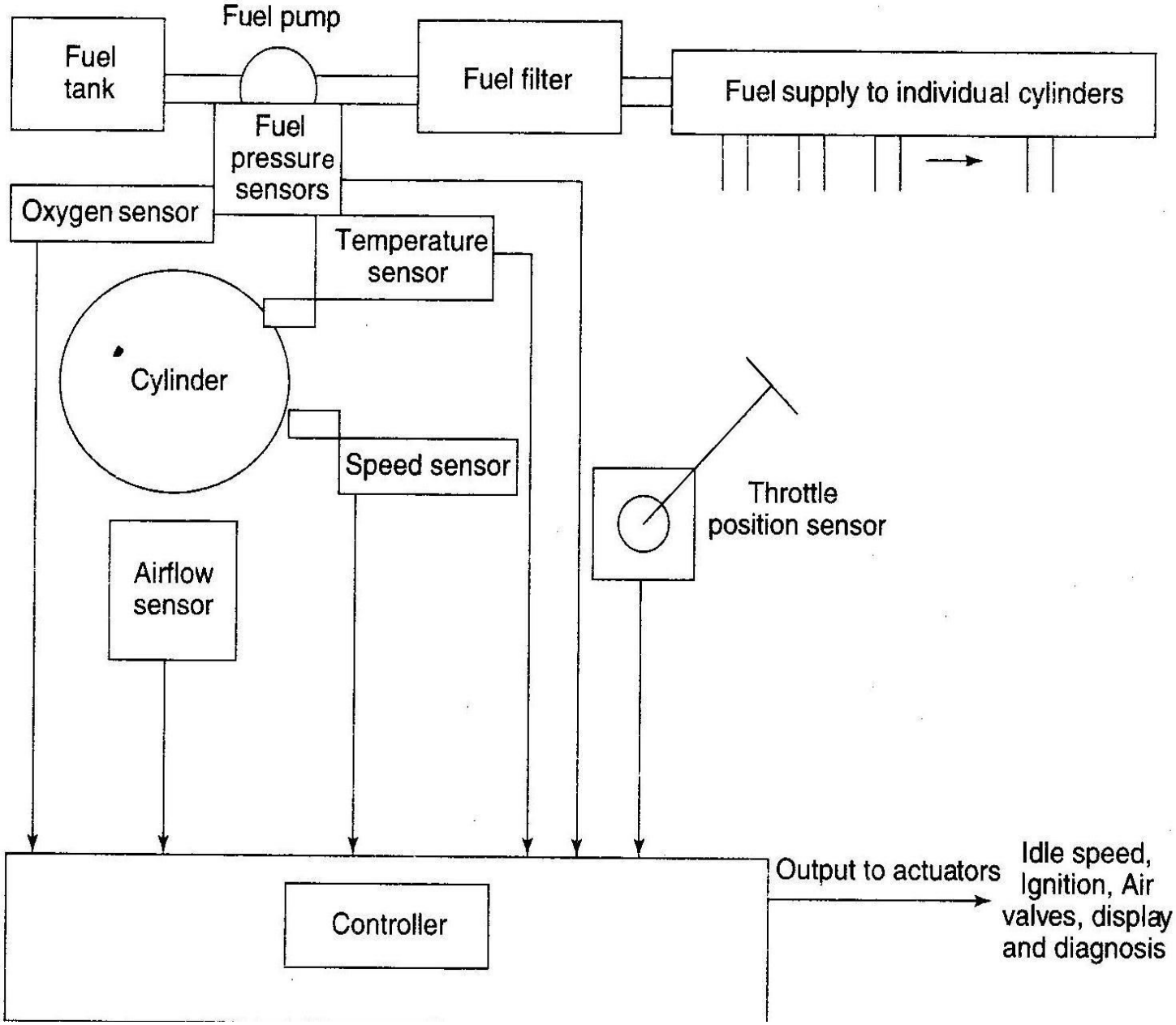
- 3) MAP sensors: It measures degree of vacuum in engine intake. The amount of vacuum depends on speed and throttle opening. If vacuum is more, engine is idle and this to provide optimum fuel delivery and spark timing.
- 4) Temperature sensors: They can use to report to user on dashboard, report to ECU to make cooling fans or ti richen for fuel mixtures for easier starting.

Sensors in Engine Management systems

- 5) Speed/ Timing sensors: They provide information to ECU how fast the engine is running and this is to control fuel and injection. Also it will make sure that engine is not running more than safe operating limits.
- Timing information determines when exactly fuel injectors should be actuated and when spark plugs should be fired.
- 6) Coolant temperature sensors: It will tell how hot or cold the engine is. It is used to activate engine functions.

Sensors in Engine Management systems

- 7) Intake air temperature sensors: It regulates intake air temperature.
- 8) Crankshaft position sensors: The ECU needs to know how fast the engine is spinning and where the crankshaft is in its rotation.


Fuel pump
Fuel tank
Fuel filter
Fuel supply to individual cylinders
Fuel pressure sensors
Oxygen sensor
Temperature sensor
Cylinder
Speed sensor
Throttle position sensor
Airflow sensor
Controller
Output to actuators
Idle speed, Ignition, Air valves, display and diagnosis

Case study 5

Antilock Brake systems (ABS)

Antilock Brake systems (ABS)

- An ABS is a system on motor vehicles which prevents the wheels from locking while braking. Stopping safely is a most important function a motor vehicle can perform.
- An ABS allows the driver to maintain steering control under heavy braking by preventing a skid and allow the wheel to continue roll forward.
- ABS generally offers improved vehicle control and decreases stopping distances on dry and slippery surfaces.

Antilock Brake systems (ABS)

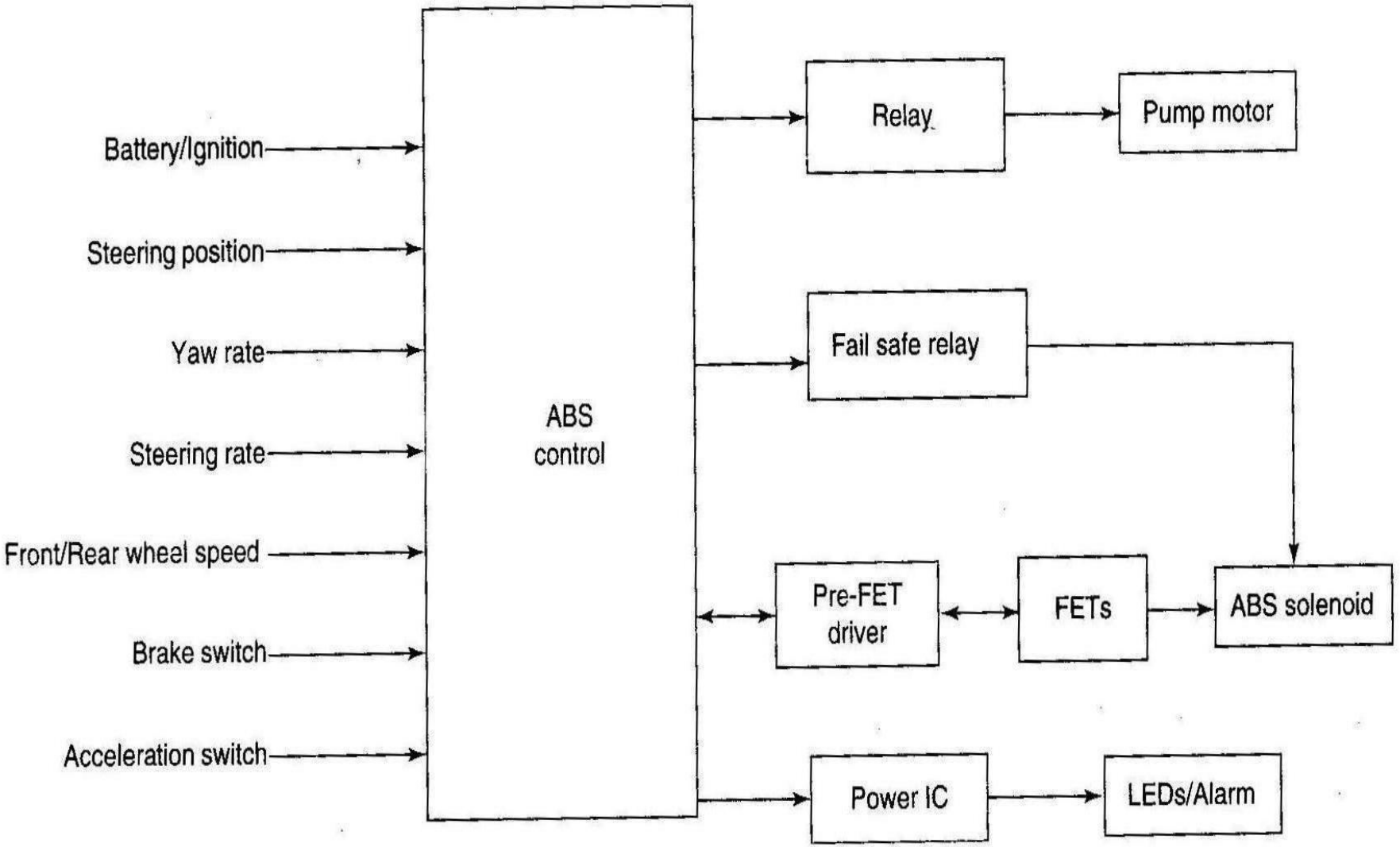
- A typical ABS consists of 4 speed sensors one for each vehicle., a central electronic unit and two or more hydraulic valves.
- The electronic unit constantly monitors te rotation speed of each vehicle. As long as brakes are not applied, all the monitored wheels are at same speed and no action.
- If however brakes applied, one or more wheels suddenly begins to reduce the speed at a higher rate than others, indicating an wheel lock up and skid. The controller then activates the antilock system.

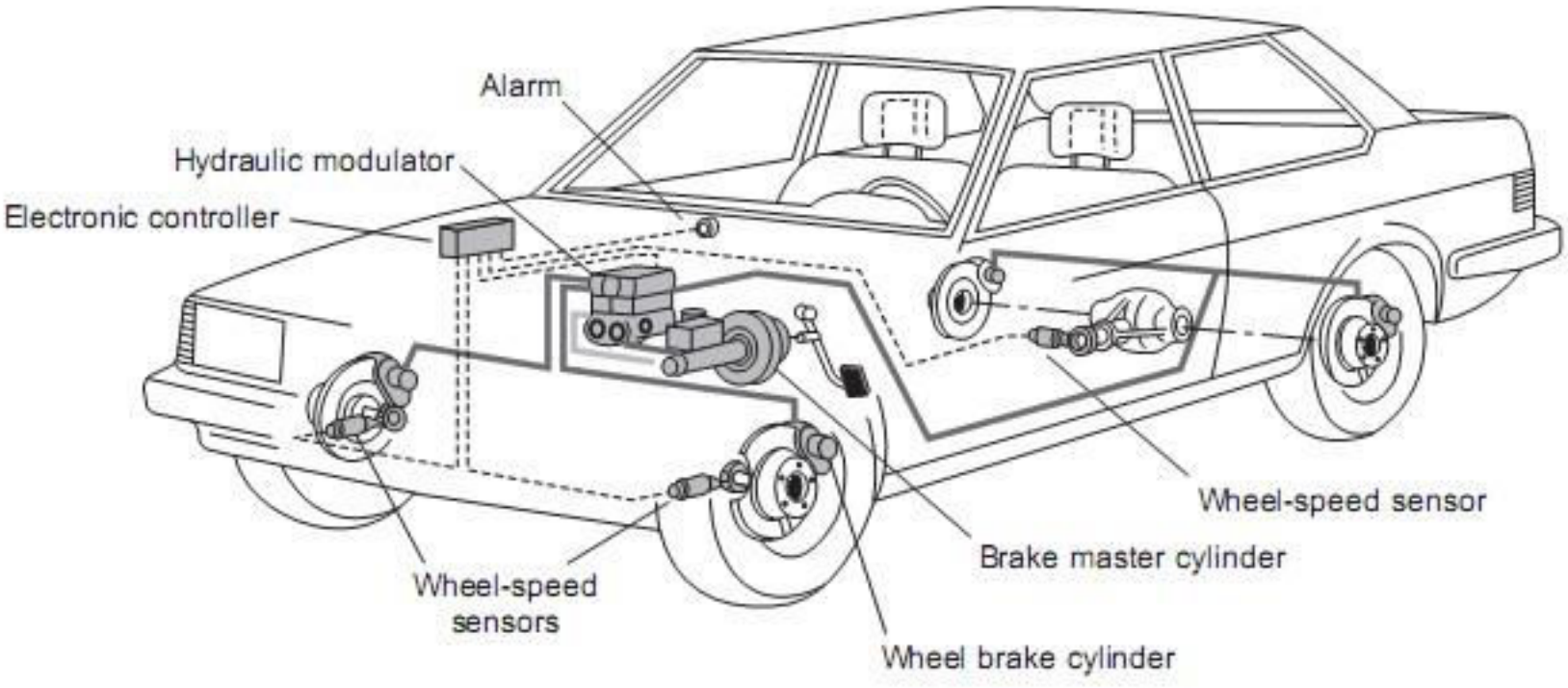
Antilock Brake systems (ABS)

- When it senses that any one wheels is rotating considerable slower than the others, it moves the valves to decrease the pressure on braking system, effectively reducing the braking force on that wheels.
- The wheels then runs faster and when they turn too fast, the force is reapplied.
- The entire ABS system is hard real time system, whereas the subsystems that runs self diagnostics is considered soft real time system.

WORKING OF ABS

- If a wheel-speed sensor signals a lock up - the ECU sends a current to the hydraulic unit. This energizes the solenoid valve.
- The action of the valve isolates the brake circuit from the master cylinder. This stops the braking pressure at that wheel from rising, and keeps it constant. It allows wheel velocity to increase and slip to decrease.
- When the velocity increases, ECU re-applies the brake pressure to restrict the wheel slip to a particular value.
- Hydraulic control unit controls the brake pressure in each wheel cylinder based on the inputs from the system sensor. This in result controls the wheel speed.

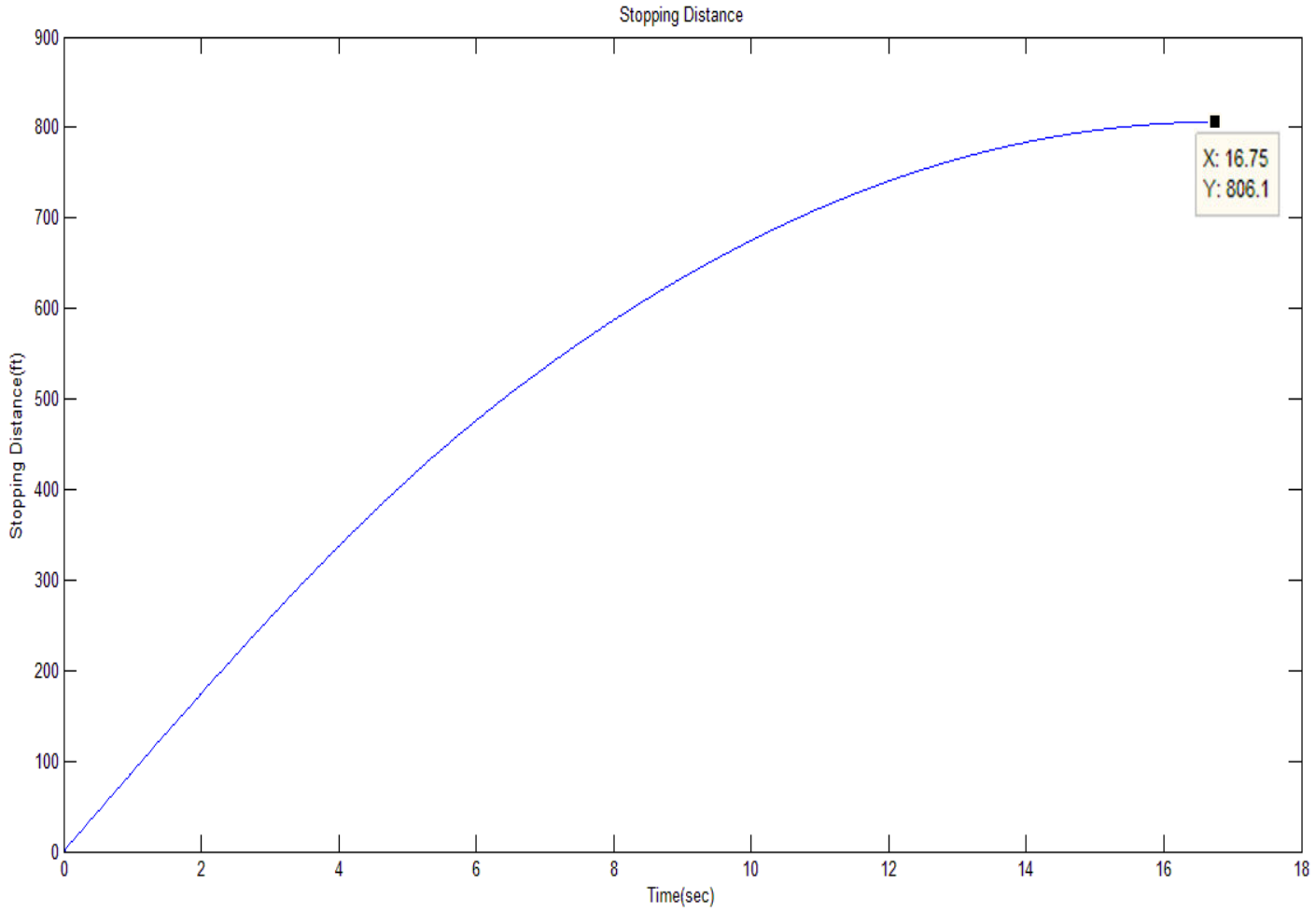

Battery/Ignition
Steering position
Yaw rate
Steering rate
Front/Rear wheel speed
Brake switch
Acceleration switch
ABS control
Relay
Pump motor
Fail safe relay
Pre-FET driver
FETs
ABS solenoid
Power IC
LEDs/Alarm



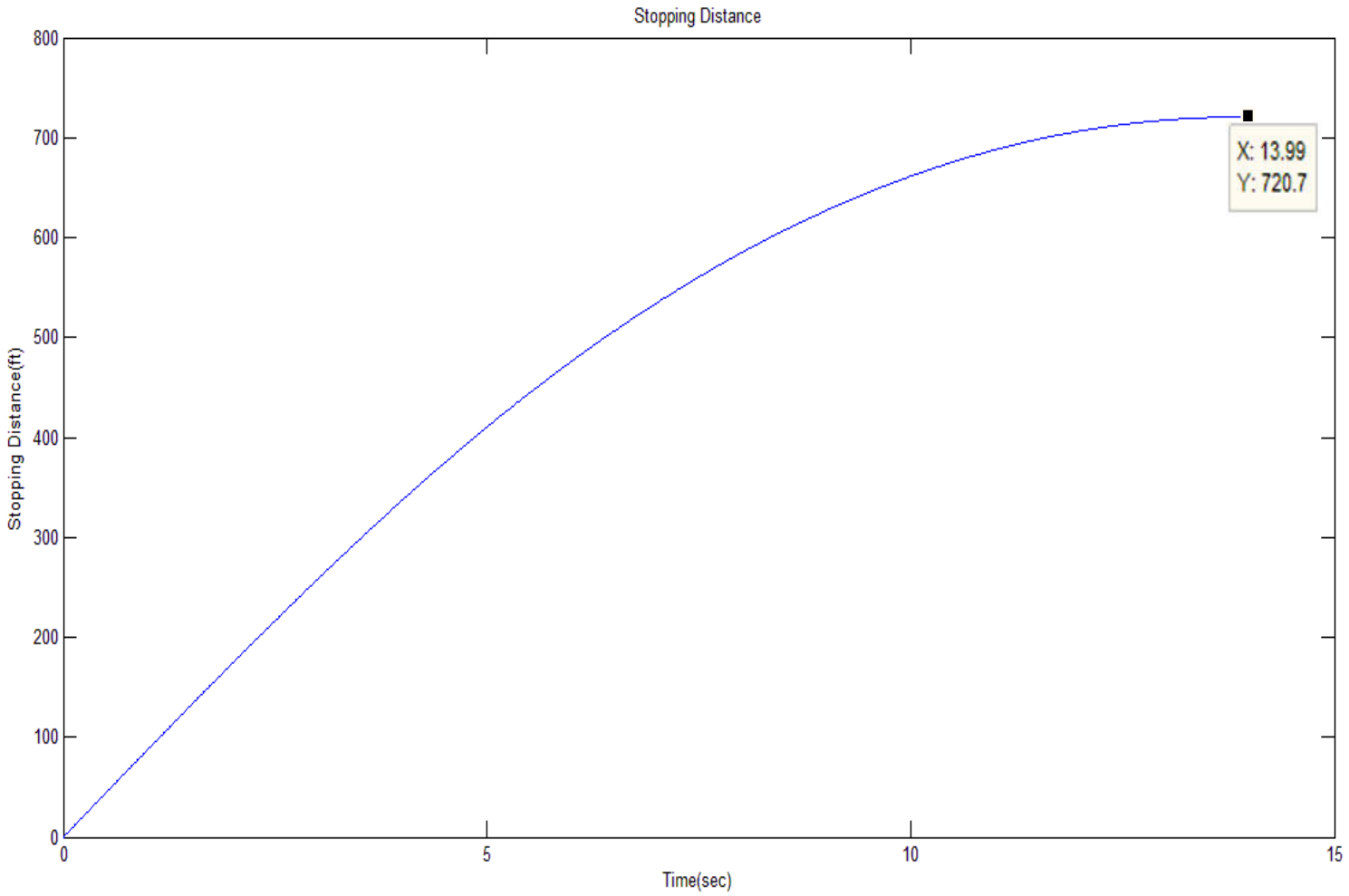
Antiskid braking system (ABS)

- All electronic signals come to the electronic controller (ECU)
- The ECU controls the hydraulic modulator
  - To control the Brake line pressure in Brake master cylinder

STOPPING DISTANCE (WITHOUT ABS)



STOPPING DISTANCE (WITH ABS)



CONCLUSION

- It is inferred that ABS improves the braking performance.
- The stopping distance after using ABS system has considerably reduced.
- The error in slip and desired slip is used to manipulate brake pressure in brake cylinder.

Case study 6

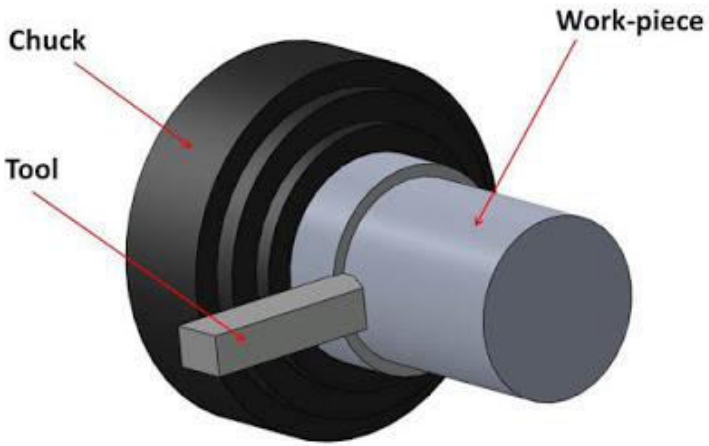
CNC Machines

(Only Black Diagram and explanation)

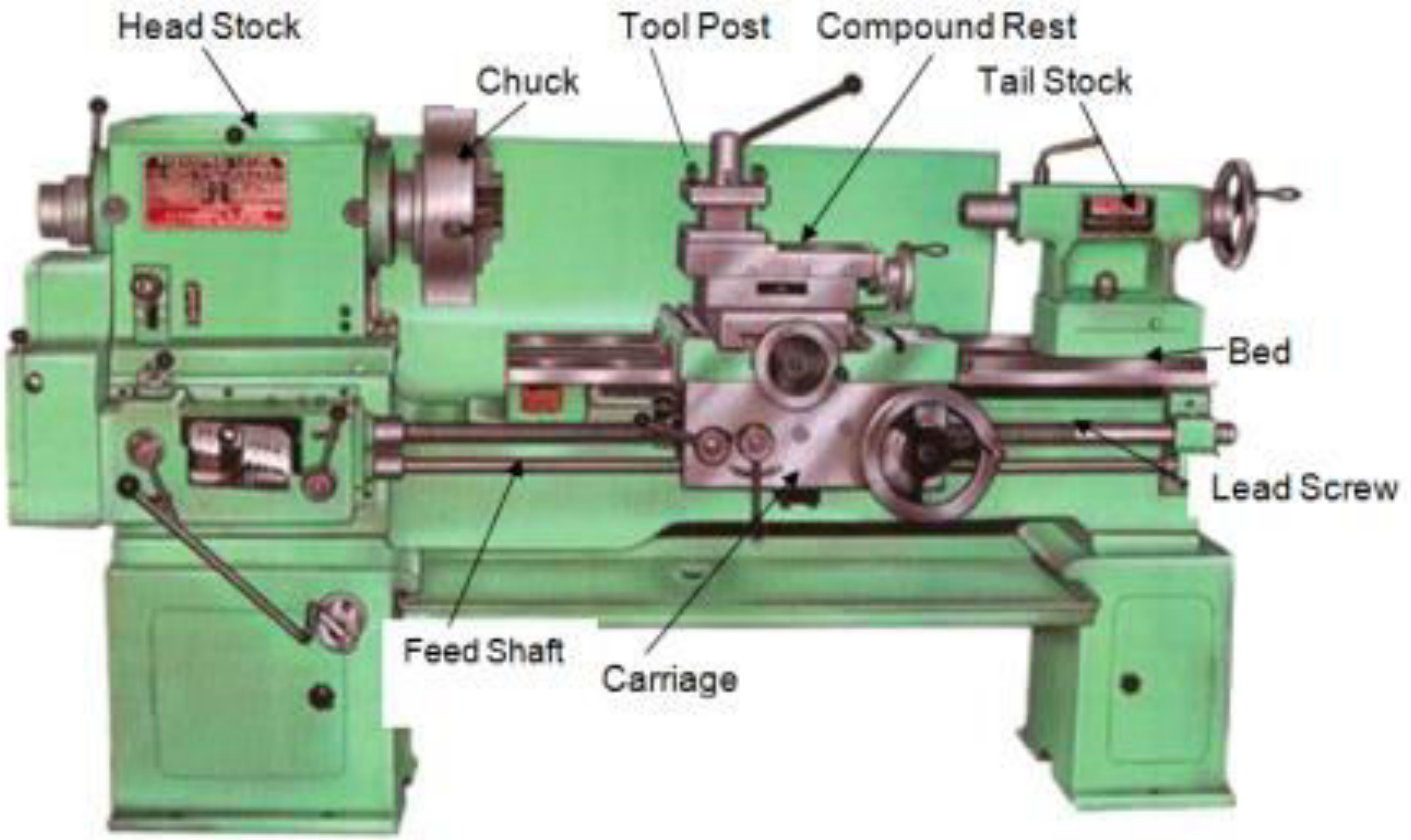
Basic principle of Lathe

•Lathe machine is a basic machine which is used in every metal forming industries. It is combination of many parts which works together to perform a desire function.
•A lathe machine is used to machine cylindrical work piece which is 360 degree symmetrical form the axis of rotation.

•It used to perform turning, chamfering, boring, facing, internal threading, shaping, slot cutting etc. on cylindrical work piece.



Parts of Lathe



Numerical Control (NC)machines

- Numerical control (NC) is a method employed for controlling the motions of a machine tool slide and its auxiliary function with an input in the form of numerical data.
- A system in which actions are controlled by direct insertion of numerical data at some point is known as NC system.
- The system automatically interpret at least some portion of this data. The numerical data which are required for producing a part are maintained on a punched tape known as part program.

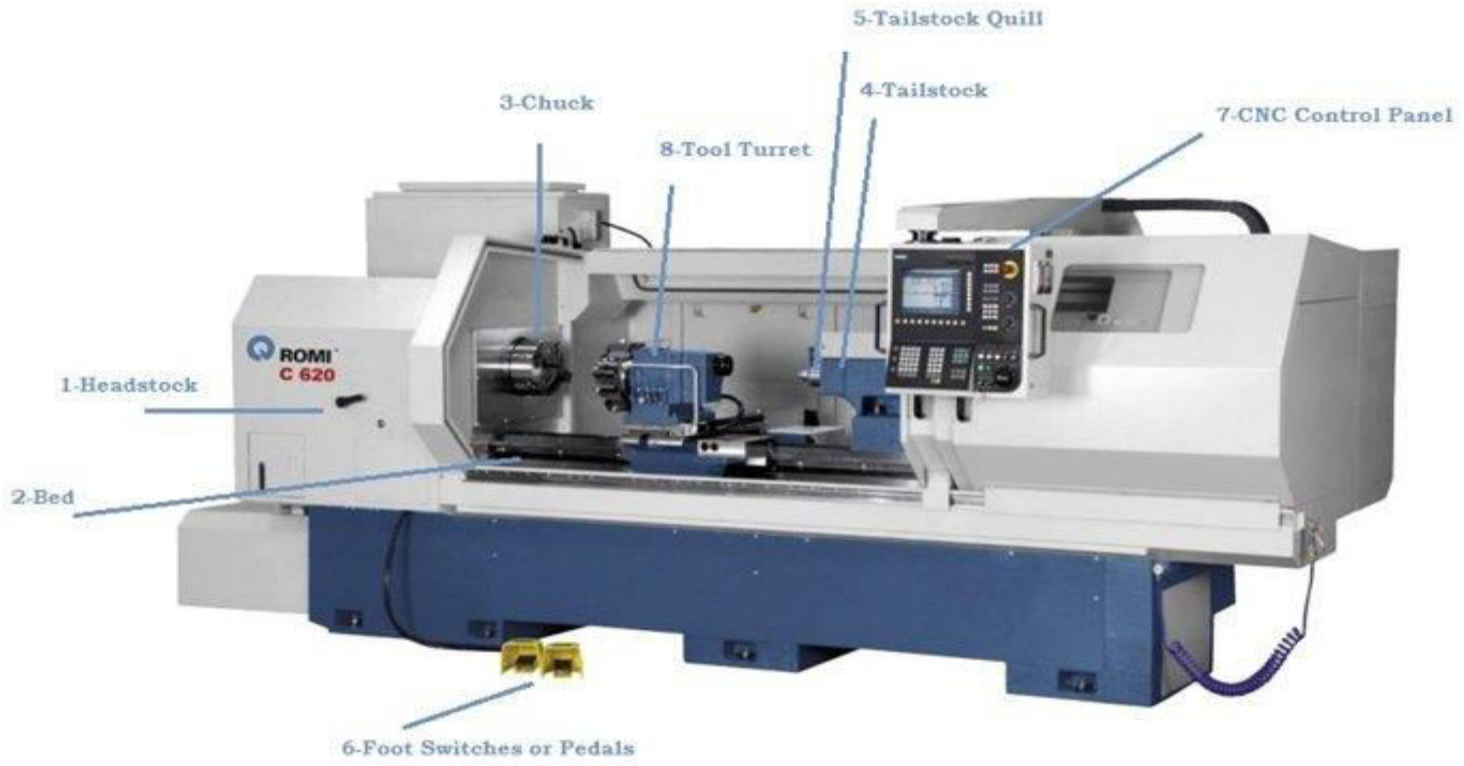
Computer Numerical Control.

- Production equipment with a CNC is a major component of computer aided design/ manufacturing (CAD/CAM). This technology is applied for large scale industries of material processing equipment.
- A computer Numerical Control (CNC) is a microprocessor based system to store and process the data for the control of slide motions and auxiliary functions of the machine tools.
- CNC machine controls operation of various machine members such as slides, spindle etc as per sequence programmed.

Computer Numerical Control.

- The main advantage of CNC is that the skills of the operator are removed and part production is made automatic.
- The CNC systems are constructed with an NC unit integrated with a programmable logic controller (PLC) and sometimes additional external PLC. The NC controls the spindle movement and the speeds and feeds in machining. It calculates the traversing paths of the of the axes as defined by inputs.
- The PLC controls the peripheral actuating elements of the machine such as solenoid, relay coils etc.

Parts of CNC Lathe



CNC Lathe

Advantages of CNC machine

1. It can produce jobs with highest and same accuracy and precision than any other manual machine. There is no variation in the parts manufactured.
2. Highly skilled operator is not required to operate CNC.
3. Increase in flexibility.
4. It has the capability to produce complex design.
5. The modern design software, allows the designer to simulate the manufacturer of his/her idea. And this removes the need of making a prototype.
6. Fewer workers are required to operate a CNC machine and saves labor cost.
7. It can be run for 24 hours of a day.

Disadvantages

Despite of having so many advantages, a CNC machine has some disadvantages too.

1. The cost of the CNC machine is very high as compared with manually operated machine.
2. Special programming knowledge (G & M codes) is required.
3. The maintenance cost of CNC is quite high.

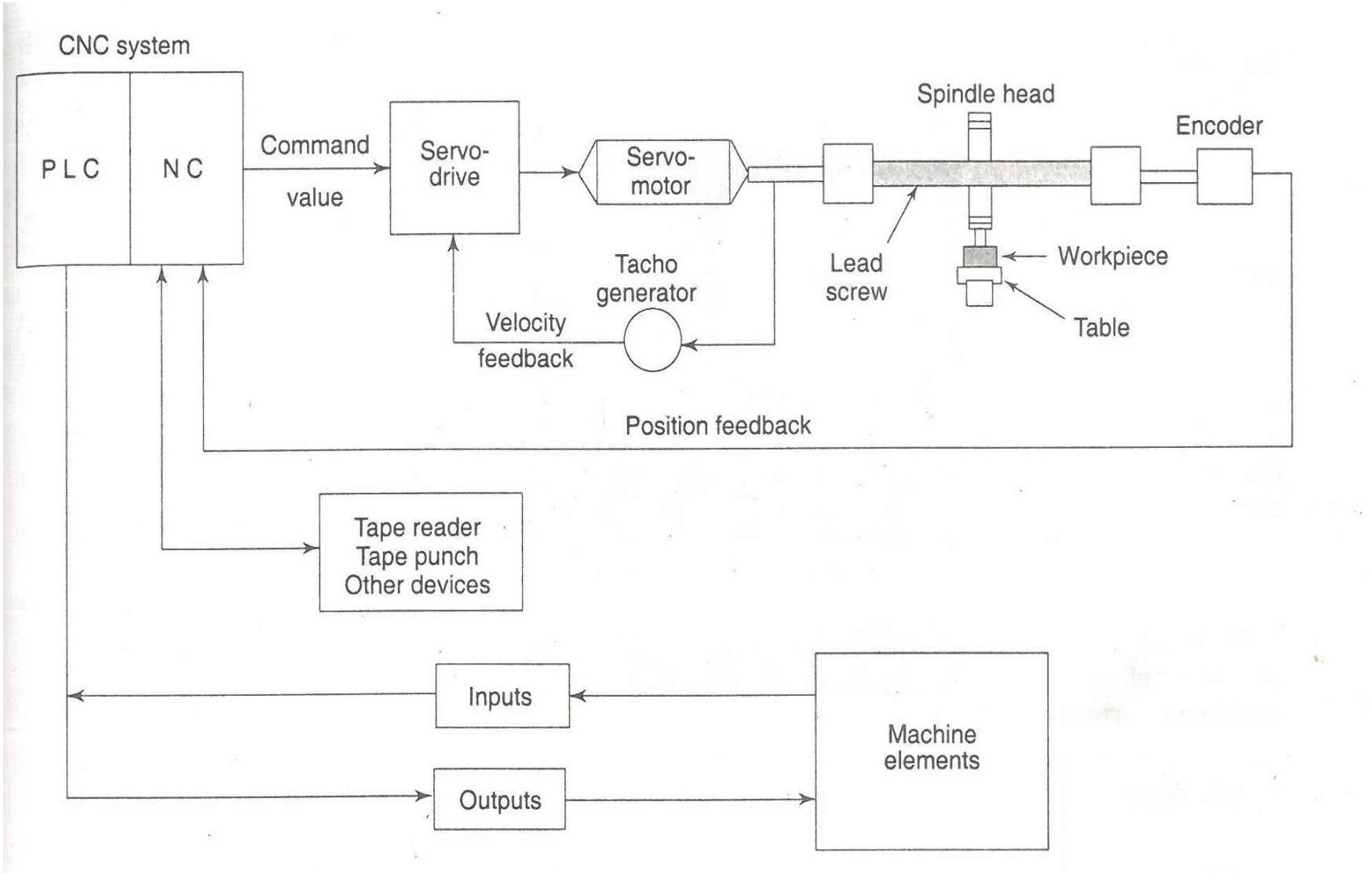
Application of CNC Machine

- The machine tools that comes with the CNC are lathe, mills, shaper, welding etc.
- The industries that are using CNC machines are automotive industry, metal removing industries, electrical discharge machining industries, wood industries etc.

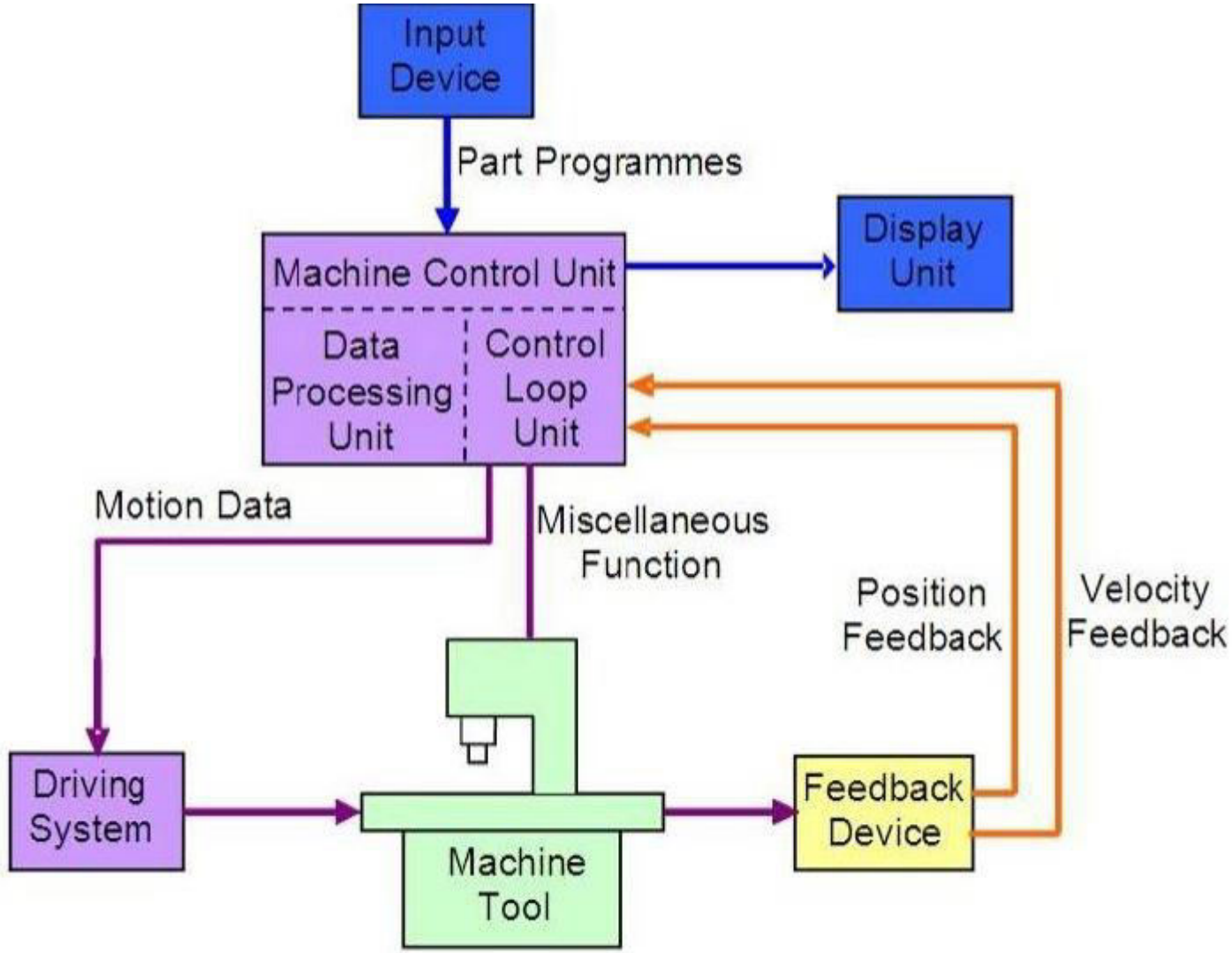
Computer Numerical Control.

- Position and part accuracy depends on CNC machine computer control algorithms, the system resolution and basic mechanical machine inaccuracies.
- A CNC machine consists of following 6 major elements:
  i. Input Device
  ii. Machine Control Unit
  iii. Machine Tool
  iv. Driving System
  v. Feedback Devices
  vi. Display Unit
-

Schematic Diagram of CNC machine



Block diagram of CNC Machine



Input devices

- The main parts of the CNC machine are
  (i) Input Devices: used to input the part program in the CNC machine. Devices are punch tape reader, magnetic tape reader and computer via RS-232-C communication.

Central Processing Unit

- The CPU is the heart and it accepts information stored in the memory as part program. The data is decoded and transformed into specific position control and velocity control signals.
- It also the movement of the control axis or spindle and whenever this does not match with the programmed values, a corrective action is taken.
- All the compensations for machine inaccuracies like lead screw error, backlash etc. are calculated by the CPU.
- Also some safety checks are also built and corrective action is taken.

Speed Control Unit

- The unit acts in unison with the CPU for the movement of the machine axes. The CPU sends the control signal generated for the movement of the axes to the servo control unit.
- The servo control unit converts these signals into suitable analog and digital signal fed to the servo drive for the machine tool axes movement.

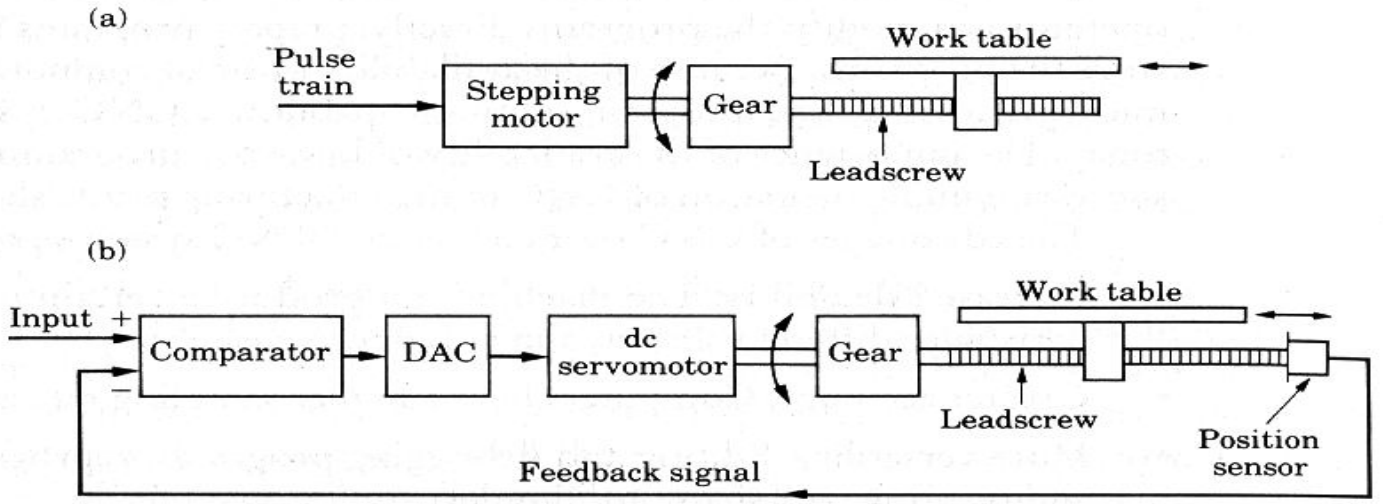
Servo Control Unit

- The decoded position and velocity control signals, generated by the CPU forms the input to servo control unit. This unit generates suitable command values.
- These drives this unit which interfaced with axes and spindle motor. This unit receives position feedback from linear scales, rotary encoders etc.
- The velocity feedback are received through tacho generators and this feedback is processed by CPU.
- Thus, the servo control unit performs the data communication between machine tool and the CPU.

Machine Tool Unit

- **Machine Tool:** A CNC machine tool always has a slide table and a spindle to control of the position and speed. The machine table is controlled in X and Y axis direction and the spindle is controlled in the Z axis direction.
- **Driving System:** amplifier circuits, drive motors and ball lead screw.
- The MCU feeds the signals (i.e. of position and speed) of each axis to the amplifier circuits.
- The control signals are than used to actuate the drive motors. And the actuated drive motors rotate the ball lead screw to position the machine table.

Position and Velocity feedback



In open loop systems the slide may overshoot or may not reach desired position because of inertia, wear and tear and friction and results machine inaccuracies.

In closed loop systems the position sensors are used to constantly correct slide movements to achieve given position.

For proper surface finishing or contouring, velocity feedback is necessary to produce correct interpolations and also specified acceleration and declaration velocities.

Operator Control Panel

- The operator control panel provides the user interface to facilitate two way communication between user and CNC machine. This consists of 2 parts. Video display Unit and keyboard.
- Video display unit: It displays the status of various parameters.

  - Complete information on the current block being executed.

  - Actual position, current feed rate, spindle speed.

  - Active G functions, miscellaneous functions.

  - Main program number, subroutine number

  - Alarm messages

Operator Control Panel

- The keyboard is provided for following purpose:

  - Editing of part programs, tool data, machine parameters.

  - Selection of different pages for viewing

Machine Control Panel

- It is the direct interface between the operator and the NC system, enabling the operation of the machine through the CNC system.
- During program execution, the CNC controls the axis motion, spindle function or tool function depending on part program stored in memory. Prior to the start of machining process, machine should be prepared with specific tasks like

  - Establishing a correct reference point.
  - Loading system memory with required part program
  - Loading and checking of tool & zero offsets etc.

Machine Control Panel

- It reads the coded instructions fed into it.
- It decodes the coded instruction.
- It implements interpolation (linear, circular and helical) to generate axis motion commands.
- It feeds the axis motion commands to the amplifier circuits for driving the axis mechanisms.
- It receives the feedback signals of position and speed for each drive axis.
- It implements the auxiliary control functions such as coolant or spindle on/off and tool change.

Feedback and Display Unit

- **Feedback System:** It contains position and speed transducers that continuously monitor the position and speed of the cutting tool located at any instant.
- The MCU receives the signals from these transducers and uses the difference between the reference and feedback signals to generate the control signals for correcting the position and speed errors.

- **Display Unit:** A monitor is used to display the programs, commands and other useful data of CNC machine.

Peripherals

- These include sensor interface, provision for communication equipment, Programming units, printer, tape reader, punch interface system.
- Programmable Logic Controller (PLC):
- A PLC matches the NC to the machine. PLCs are basically introduced as replacement for for hard wired relay control panels. They were developed to be reprogrammed without hardware changes when requirements were altered and thus are reusable.
- PLCs are now available with increased functions, more memory and large input/ output capabilities.

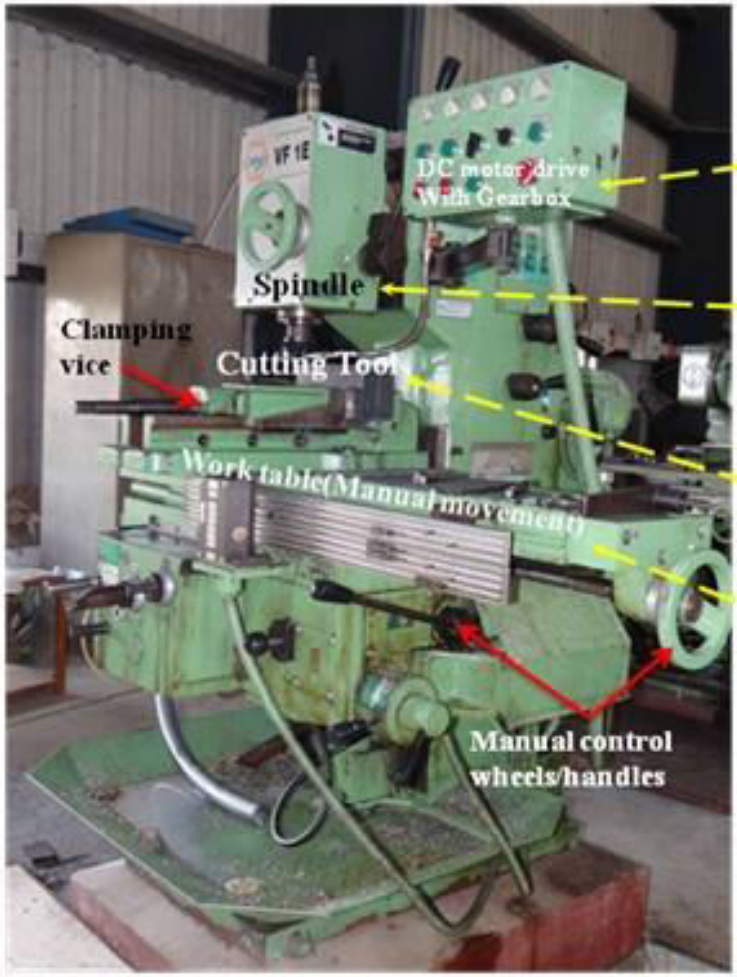
How CNC Machine Works

- 1.First the part program is inserted into the MCU of the CNC.
- 2.In MCU all the data process takes place and according to the program prepared, it prepares all the motion commands and sends it to the driving system.
- 3.The drive system works as the motion commands are send by MCU. Drive system controls the motion and velocity of the machine tool.

How CNC Machine Works

- 4.Feedback system, records the position and velocity measurement of the machine tool and sends a feedback signal to the MCU.
- 5.In MCU, the feedback signals are compared with the reference signals and if there are errors, it corrects it and sends new signals to the machine tool for the right operation to happen.
- 6.A display unit is used to see all the commands, programs and other important data. It acts as the eye of the machine.

Conventional Milling Machine



CNC Machine Tool

Comparision of Conventional NC and CNC m/c

Conventional	NC	CNC
More manual work	less	Very less
More Skilled labour	less	less
Accuracy is less	more	more
Less flexibility	more	most
Part programming is not required	required	Reprogramming is easy
Machining is done every time	Programming and punched tape are read each time	Programming and punched tape are read once
Simulation can't b done	possible	possible
More suitable for low production rate	More suitable for medium production rate	More suitable for mass production

Thank You !!

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Coin Counter case study