Chapter 1: Introduction to PLCs

Intro to PLC

Learning objectives

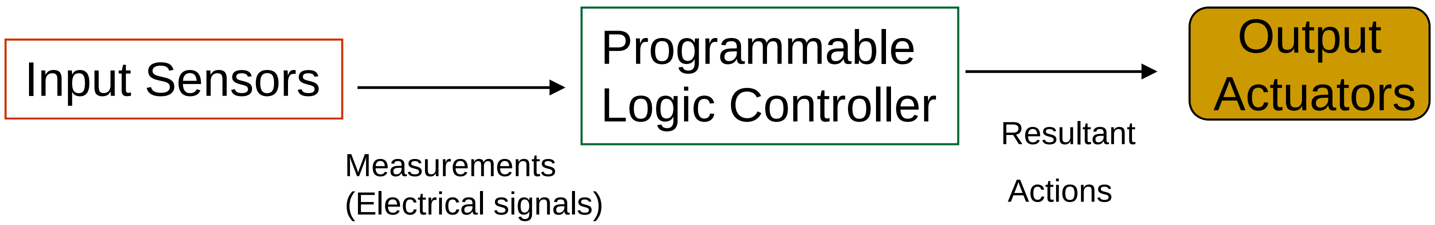
- **Two ways to categorize a control system**
- **Overview of PLCs**
- **Differences between PLC, relay and PC-based control**
- **Basic PLC architecture**

Automatic Control in Manufacturing
Why Automatic Control is necessary

- **To improve the quality and lower the cost of production.**
- **To increase the production rate.**
- **To attain optimal performance.**
- **To relieve the drudgery of many routine, repetitive manual operations:**
  - **Metal matching sequences**
  - **Product assembly lines**
  - **Batch chemical processes**

Profitability usually depends on productivity and automation is a means towards greater productivity

Automatic Control System
Basic Elements



- Input Sensors: Convert physical phenomena (for example, position) to electrical signal.
- Output Actuators: Convert electrical signal to a physical action, for example, air valve or motor.
- Programmable Logic Controller: Using the measurements, calculates control actions.

Programmable Logic Controllers
Major Types

- Programmable Logic Control (PLC)
  - Developed initially out of Automotive Industry
- Distributed Control System (DCS)
  - Employed in the Chemical Industry

DCS and PLC systems are merging into one device:
Programmable Electronic System (PES)

Our focus is on PLCs. We will talk more about this shortly

Automatic Control System
Major Types of Sensors/Actuators

- Discrete Control Systems:
  - Dominated by Discrete Sensors and Actuators:
    - Take one of two values:
      - On/off, Open/Closed, running/Stopped, extend/retract
- Analog Control System:
  - Dominated by Analog Sensors and Actuators
    - Take an infinite number of values (continuous stream)
      - Position, acceleration, temperature, flow

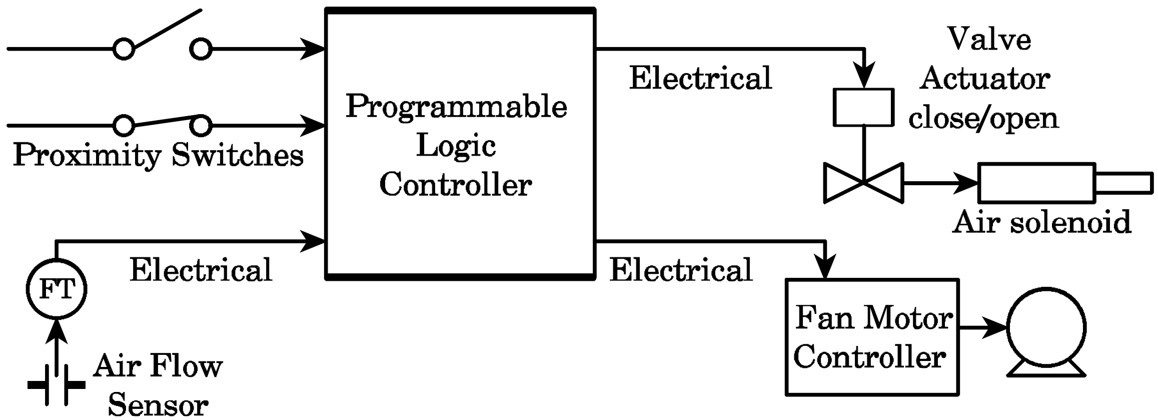
Automatic Control System

Continuous Vs. Discrete Control

- Most real programmable logic control systems are a combination of continuous and discrete sensors and actuators.

Discrete:

Analog:



HVAC System

- Discrete elements:
  - proximity switches (sensors)
  - control valve for air solenoid (actuators)
- Continuous (Analog) elements:
  - air flow sensor
  - command speed to fan motor controller

Automatic Control System
Type of Process

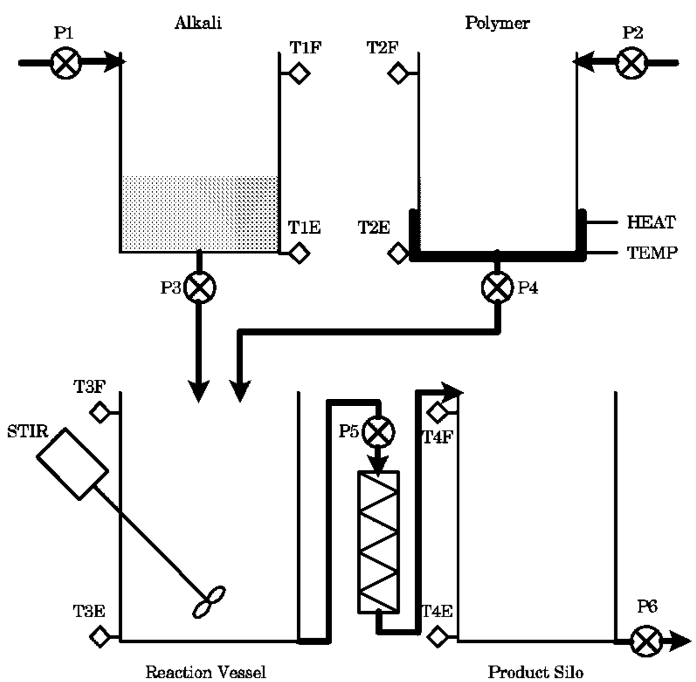
- Industrial Manufacturing processes are classified based on the behavior of the actuator's output:

- Continuous Process
  - Material passes in a continuous stream through the processing equipment:
    - Steel Rolling Mill

Automatic Control System

Type of Process (Batch)

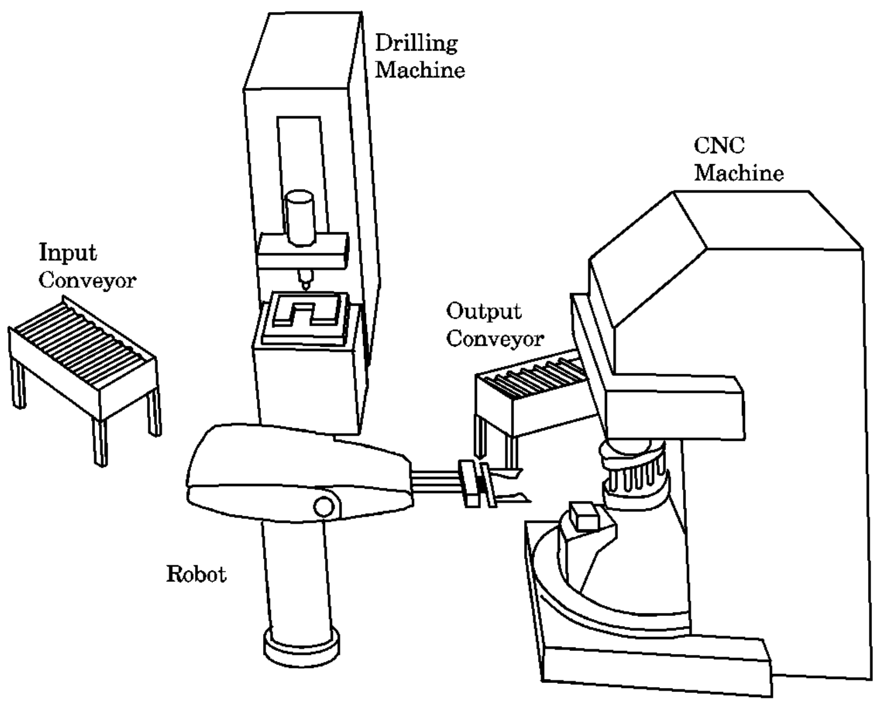
- Batch Process
  - Actuators produce Finite quantities (batch) of materials. The input materials typically assume a defined order of processing actions



Automatic Control System

Type of Process (Discrete)

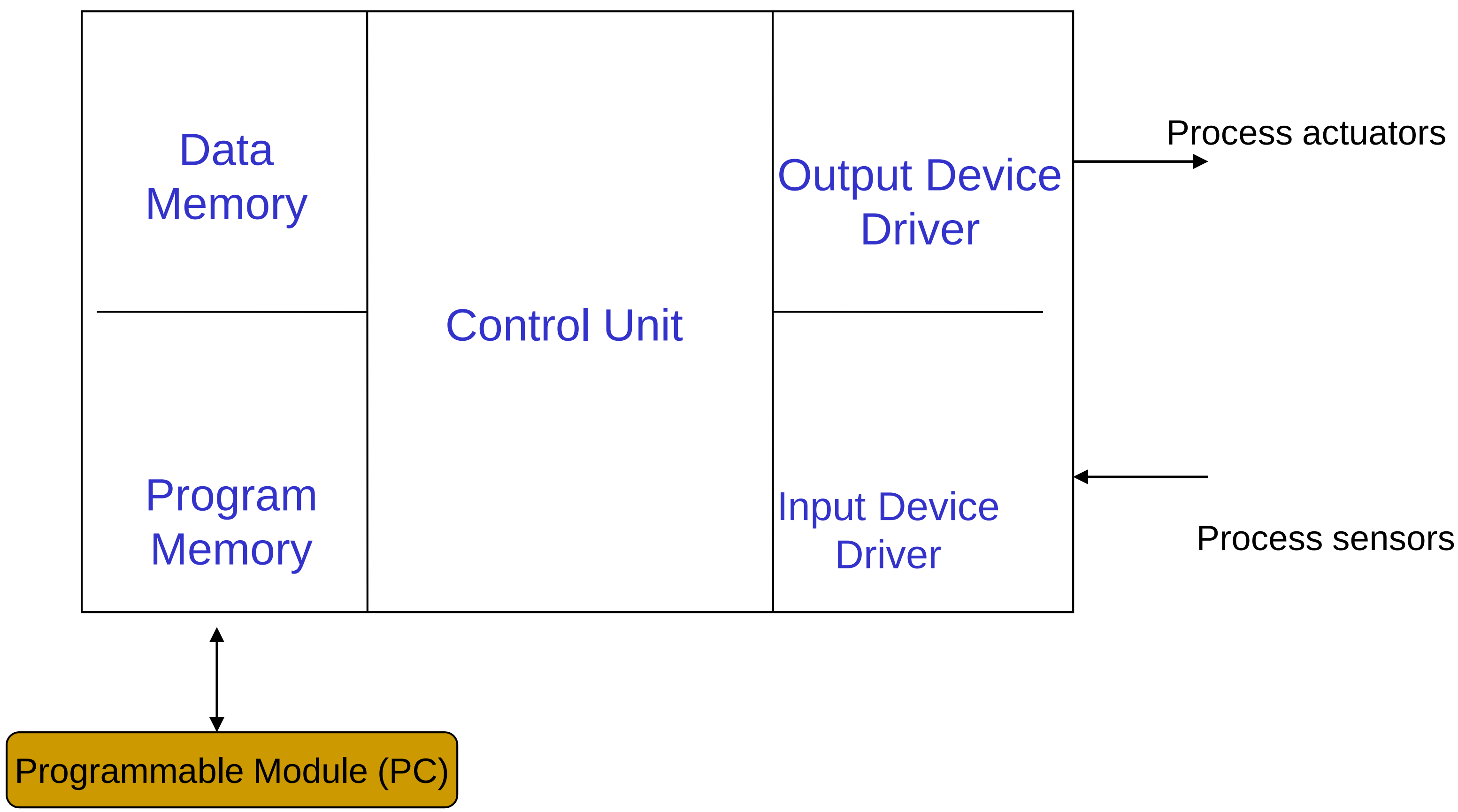
- **Discrete-**Parts Manufacturing
  - A specified quantity of materials moves as a unit (group of parts) between workstations, on an assembly line/conveyor belt. Each unit has a unique id. A unit may be modified (drilled, painted etc) at a workstation. What is the output of the actuators?



Programmable Logic Control
PLC

- PLC – is an "Industrial" Computer
  - Hardware & Software adapted to Industrial Environment and Electrical Technician
- Why Programmable Logic Control?
  - PLC is the *work horse* of industrial automation
  - Production processes go through a fixed repetitive sequence of operation with logical steps
  - Electronic Relays were used prior to PLCs:
    - Control systems were hard-wired using relays, timers and logical units
    - Control system had to be re-wired for new applications
    - Inflexible and time consuming
    - Resulted in product delays, high production costs…

PLC Overview

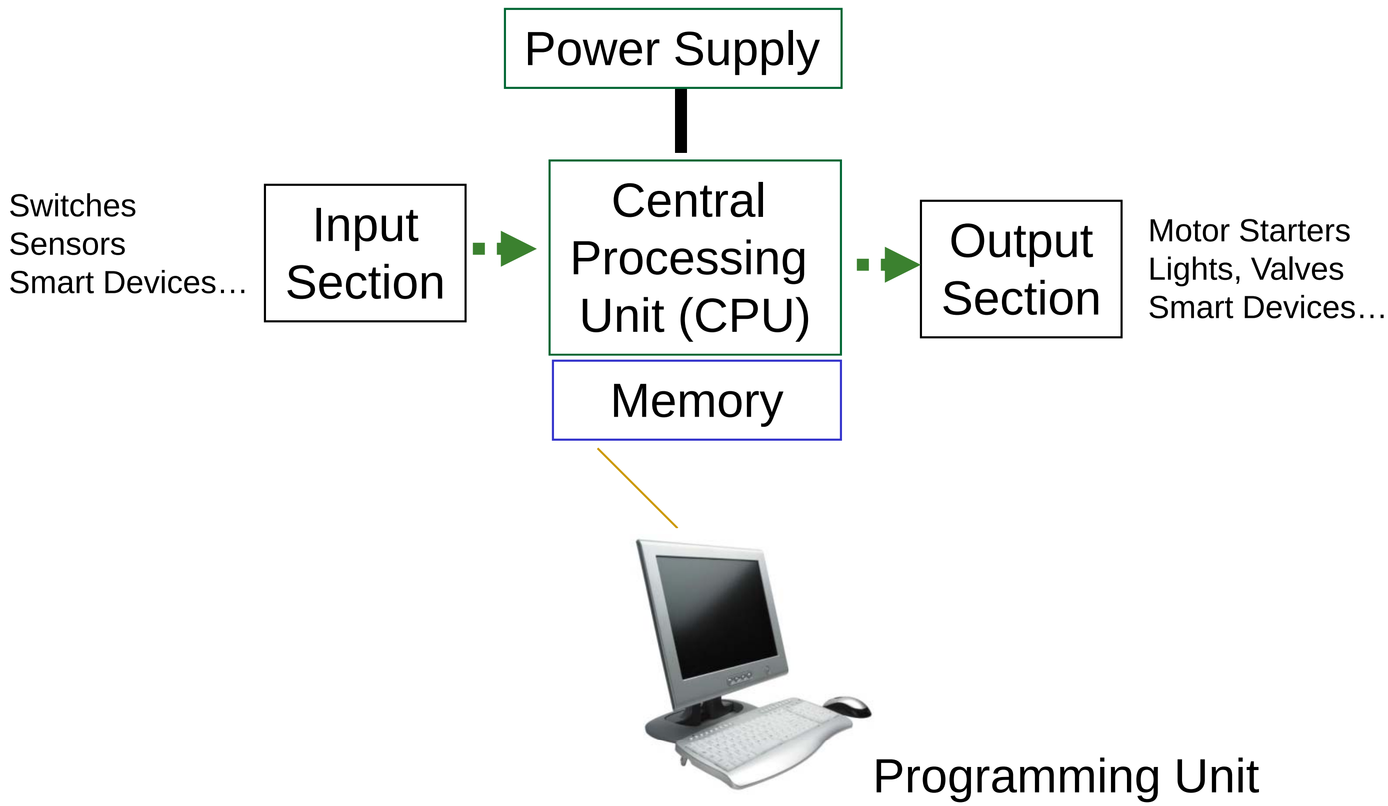


PLC Overview

A PLC consists of 4 main parts:

- Program Memory: Stores instructions for logical control sequence
- Data Memory: Stores status of switches, interlocks, past and current values of data items
- Output Devices: Hardware/software drivers for industrial process actuators
  - Solenoid switches, motors, valves
- Input Devices: Hardware/software drivers for industrial process sensors
  - Switch status sensors, proximity detectors, interlock settings …
- Central Processing Unit: Brain of the PLC

PLC Components



Protects CPU from Real-world input

PLC Components
Central Processing Unit (CPU)

- CPU
  - Contains one or more processors to control the PLC
  - Handles communication with other components
  - Handles computations: executes OS, manages memory, monitors inputs, evaluates the user logic (“ladder logic”)
  - Programming language: ladder logic

- Lab PLC CPU (Rockwell)
  - Keyswitch is used to switch between different CPU modes
    - Program Mode
    - Run Mode
    - Remote Mode

Lab PLC
CPU Modes

- Program Mode: All outputs are forced to off condition regardless of their state in logic:
  - Develop and download your program in memory
- Run Mode: PLC continuously scans and executes your ladder logic
- Remote Mode: Allows you to remotely control the CPU mode from your computer: Switch between Program and Run modes from your computer

PLC Components
Memory

- PLC Memory stores OS memory and application memory
- OS Memory: The OS is burned into ROM by manufacturer and controls system software used to program PLC

  ROM is non-volatile
- Application Memory:
  - Stores status of inputs and outputs, i.e. I/O Image tables as patterns of 0 and 1 (binary digits)
  - Stores contents of variables in user programs: “timers”, “counters”
- Random Access Memory:
  - Your programs run/execute in the RAM.
  - RAM is volatile – All data items in the RAM are lost if power is turned off
  - Mode

PLC
Input/Output Modules

- Input Module:
  - Takes inputs from the outside world from any device (protects the CPU)
  - Converts real-world logic to CPU logic

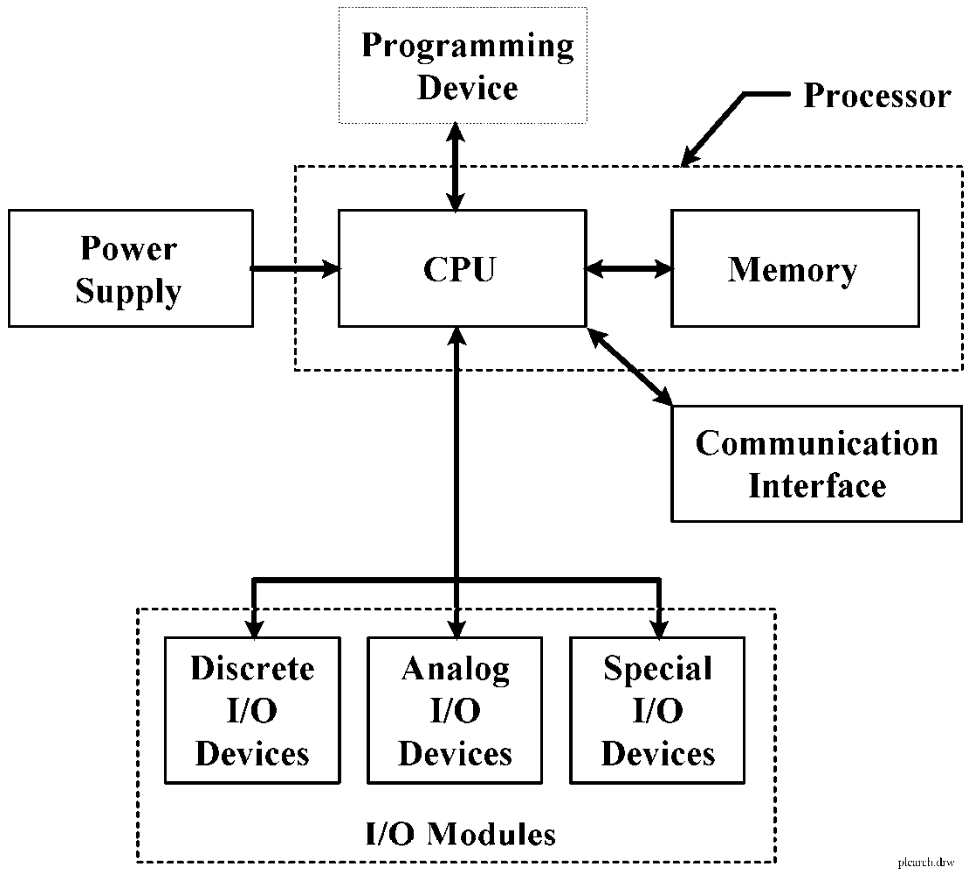
250 VAC Device → (**250 VAC Input Module**) → low-level DC Signal

Identify the input module in your lab PLC; How may inputs does it take?

- Output Module:
  - Provides connection to the real-world output devices
  - Output modules can handle DC or AC voltages to output digital or analog signals

Identify the output module in your lab PLC; How may output devices does it take?

Basic PLC Architecture



Control System Hardware

A **Comparison**

Characteristic	*Relay Systems*	*Computers*	*PLC Systems*
Price per func.	Fairly low	Low	Low
Physical size	Bulky	Fairly compact	Compact
Oper. Speed	Slow	Fairly fast	Fast
Industrial environment	Excellent	Fair to good	Good
Design	Time-consuming	Usually simple	Simple
Complicated operations	No	Yes	Yes
Installation	Time-consuming	Simple to complex	Simple
Easy to change function	Very difficult	Usually simple	Very simple
Ease of maintenance	Poor - many contacts	Fair - several custom boards	Good - few std. cards
Recovery from power failure	0 sec.	1 - 100 sec.	1 - 3 sec.

PLCs Vs. Computers

The architecture of the PLC is basically the same as of a general-purpose computer.

Industrial Environment - Can be placed in areas with substantial amount of: Electrical noise

- Electromagnetic interference
- Mechanical vibration
- Extreme temperatures (140° F)
- Non-condensing humidity (95%)

Reliability – Built to run continuously for years. (Compare with Windows OS)

Easily maintained by plant technicians - Hardware interfaces easily connected. Modular and self-diagnosing interface circuits pinpoint malfunctions and are easily replaced. **Programmed using ladder logic**, easy to learn.

Executes a single program in orderly and sequential fashion - Most medium to large PLCs have instructions that allow subroutine calling, interrupt routines, and bypass of certain instructions. Also, many PLCs can have modules that implement higher-level languages, e.g., BASIC.

Recovers quickly from power failure – No boot-up procedure. Diagnostic self-tests and resumes running.