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:
- Proximity Switches

Analog:
- Air Flow Sensor

- 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

- **Power Supply**
- **Central Processing Unit (CPU)**
- **Input Section**
  - Switches
  - Sensors
  - Smart Devices...
- **Output Section**
  - Motor Starters
  - Lights, Valves
  - Smart Devices...
- **Memory**
- **Programming Unit**

*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 $\rightarrow$ (250 VAC Input Module) $\rightarrow$ low-level DC Signal

*Identify the input module in your lab PLC; How many 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 many output devices does it take?*
Basic PLC Architecture
# Control System Hardware

## A Comparison

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