Discrete Input/Output System

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The discrete input/output (I/O) system provides the physical connection between the CPU and field devices.

Digital signals are non-continuous signals that have only two states—ON and OFF.

Through various interface circuits and field devices (limit switches, transducers, etc.), the controller senses and measures physical quantities (e.g., proximity, position, motion, level, temperature, pressure, current, and voltage) associated with a machine or process.

Based on the status of the devices sensed or the process values measured, the CPU issues commands that control the output field devices.
I/O Rack Enclosures and Table Mapping

► An I/O module is a plug-in–type assembly containing circuitry that communicates between a PLC and field devices.

► All I/O modules must be placed or inserted into a rack enclosure, usually referred to as a rack, within the PLC.

► The rack holds and organizes the programmable controller’s I/O modules, with a module’s rack location defining the I/O address of its connected device.
I/O Rack Enclosures and Table Mapping

► The I/O address is a unique number that identifies the input/output device during control program setup and execution.

► A rack recognizes the type of module connected to it (input or output) and the class of interface (discrete, analog, numerical, etc.).

► This module recognition is decoded on the back plane (i.e., the printed circuit board containing the data bus, power bus, and mating connectors) of the rack.
I/O Rack Enclosures

Figure 6-3. Example of an I/O rack enclosure.

Figure 6-4. Internal switches used to set I/O addresses.
I/O Rack Enclosures

Figure 6-5. Master racks (a) without I/O modules and (b) with I/O modules.

Figure 6-6. Local rack configuration.
I/O Rack Enclosures

Figure 6-7. Remote rack configuration.
Table Mapping

- PLC manufacturers set specifications for placing I/O modules in rack enclosures.
  - For example, some modules accommodate 2 to 16 field connections, while other modules require the user to follow certain I/O addressing regulations.

- Several factors determine the address location of each module.
  - The type of module, input or output, determines the first address location from left to right (0 for outputs, 1 for inputs).
  - The rack number and slot location of the module determine the next two address numbers.
  - The terminal connected to the I/O module (0 through 7) represents the last address digit.
I/O Rack and Table Mapping Example

- There can be up to 7 I/O racks; the first rack (0) is the master rack. Racks 1 through 7 may be local or remote. Each rack has eight slots available for I/O modules.
- PLC discrete I/O modules are available in 4 or 8 points (connections) per module (modularity). Maximum I/O capability is 512 points.
- The I/O image table is 8 bits wide.
- The octal numbering system is used.
- The type of module, input or output, is detected by the rack’s back plane circuitry. If the module is an input, a 1 is placed in front of its three-digit address. If the module is an output, a 0 is placed in front of its three-digit address.

Table 6-1. Specifications for the I/O rack enclosure example.
I/O Rack and Table Mapping Example

Figure 6.8. Illustration of the example I/O rack enclosure (x = 1 for inputs, 0 for outputs).
I/O Rack and Table Mapping Example

Figure 6.9. Diagrams of (a) an I/O table, (b) two 4-point I/O modules in one slot, and (c) an I/O table mapping.
The capacity of a single subsystem (rack) is normally 32, 64, 128, or 256 I/O points.

A large system with a maximum capacity of 1024 I/O points may have subsystem sizes of either 64 or 128 points—eight racks with 128 I/O, sixteen racks with 64 I/O, or some combination of both sizes equal to 1024 I/O.
I/O Modules serve four basic functions

- Termination
- Signal Conditioning
- Isolation
- Indication
I/O Module Selection

- Type of current (AC or DC)
- Voltage Level
- Number of terminals
PLC Instructions for Discrete Inputs

► A simplified 8-bit image table is shown
  - LS1 is known as input 014, which stands for rack 0, slot 1, connection 4.

► When an input signal is energized (ON), the input interface senses the field device’s supplied voltage and converts it to a logic-level signal (either 1 or 0), which indicates the status of that device.
Example

► For the rack configuration shown, determine the address for each field device wired to each input connection in the 8-bit discrete input module.

► Assume that the first four slots of this 64 I/O micro-PLC are filled with outputs and that the second four slots are filled with inputs.

Figure 6-14. Rack configuration for Example 6-1.
Example

Figure 6-14. Rack configuration for Example 6-1.

Figure 6-15. Field device addresses for the rack configuration in Example 6-1.
PLC Instructions for Discrete Inputs

- The most common class of input interfaces is digital (or discrete).

- Digital input interfaces have only two states
  - ON/OFF
  - OPEN/CLOSED
  - TRUE/FALSE

- Those states signify either 1 or 0.

Table 6-2. Discrete input devices.
A circuit breaker is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit.

Unlike a fuse, which operates once and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.
Proximity Switch: Inductive

 ► Principle: coil inductance vary as a metallic object is near.

Figure 8-10 - Inductive Proximity Sensor Sensing Target Object (Pepperl & Fuchs, Inc.)

Figure 8-11 - Inductive Proximity Sensor Signals (Pepperl & Fuchs, Inc.)
Principle: As the target is moved closer to the sensor face, the change in dielectric increases the capacitance of the internal capacitor.
Proximity Switch: Ultrasonic and Optical

![Diagram of Proximity Switch with Target and Transducer](image)

**Figure 8-18** - Thru-Beam Optical Sensor, Dark On (Pepperl & Fuchs, Inc.)
Proximity Switch: sink /source

Figure 8-3 - NPN Sensor Load Connection

Figure 8-5 - PNP Sensor Load Connection
Limit Switch
## Types of Discrete Inputs

<table>
<thead>
<tr>
<th>Input Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 volts AC/DC</td>
</tr>
<tr>
<td>48 volts AC/DC</td>
</tr>
<tr>
<td>120 volts AC/DC</td>
</tr>
<tr>
<td>230 volts AC/DC</td>
</tr>
<tr>
<td>TTL level</td>
</tr>
<tr>
<td>Nonvoltage</td>
</tr>
<tr>
<td>Isolated input</td>
</tr>
<tr>
<td>5–50 volts DC (sink/source)</td>
</tr>
</tbody>
</table>

*Table 6-3. Standard ratings for discrete input interfaces.*
AC/DC Inputs

► An AC/DC input circuit has two primary parts:
  - the power section
  - the logic section

► These sections are normally, but not always, coupled through a circuit that electrically separates them, providing isolation.
AC/DC Inputs

**Figure 6-18.** Device connections for (a) an AC input module and (b) a DC input module with common wire connection “C” used to complete the path from hot.
DC Inputs Sink/Source

► Compared with AC/DC modules, the DC input does not contain a bridge circuit.

► DC input module varies between 5 and 30 VDC.

▪ If a device *provides* current when it is ON, it is said to be sourcing current.
▪ If a device *receives* current when it is ON, it is said to be sinking current.

► The most common are sourcing field input devices and sinking input modules.
Figure 6-19. Current for (a) a sinking input module/sourcing input device and (b) a sourcing input module/sinking input device.
Figure 6-20. Field device connections for a sink/source DC input module.
Isolated AC/DC Inputs

Isolated input interfaces operate like standard AC/DC modules except that each input has a separate return, or *common*, line.

Figure 6-23. An 8-point standard input module used as an isolated module.
TTL Inputs

► **Transistor-transistor logic (TTL) input interfaces** allow controllers to accept signals from TTL-compatible devices, such as solid-state controls and sensing instruments.

► Most TTL input modules receive their power from within the rack enclosure; however, some interfaces require an external power source.

*Typical value

**Ground cable shield at one end only (Chassis mounting bolt)

**Figure 6-24. TTL input connection diagram.**
Multi-bit register/BCD input modules enhance input interfacing methods with the programmable controller through the use of standard thumbwheel switches.

This register, or BCD, configuration allows groups of bits to be input as a unit to accommodate devices requiring that bits be in parallel form.

Register/BCD interfaces accept voltages ranging from 5 VDC (TTL) to 24 VDC.

They are also grouped in modules containing 16 or 32 inputs.
Register / BCD Inputs

Figure 6-25. BCD interface inputting parameters into register/word locations in memory.

Figure 6-26. Register or BCD input module connection diagram.
Register / BCD Inputs

Figure 6-27. Multiplexing input module connection diagram.
PLC Instructions for Discrete Outputs

Output interface circuitry switches the supplied voltage from the PLC ON or OFF according to the status of the corresponding bit in the output image table.

This status (1 or 0) is set during the execution of the control program and is sent to the output module at the end of scan (output update).

- If the signal from the processor is 1, the output module will switch the supplied voltage (e.g., 120 VAC) to the output field device, turning the output ON.
- If the signal received from the processor is 0, the module will deactivate the field device by switching to 0 volts, thus turning it OFF.
PLC Instructions for Discrete Outputs

Figure 6-32. An 8-bit output image table with the module’s L2 connection completing the path from L1 to L2.
Example

► For the rack configuration shown in Figure, determine the addresses for each of the output field devices wired to the output connections in the 8-bit discrete input module.

► Assume that the first four slots of this 64 I/O micro-PLC are filled with outputs and that the second four are filled with inputs.

► The addressing scheme follows a rack-slot-connection convention

![Diagram of rack configuration for Example 6-3.](image-url)
Example

Figure 6-34. Rack configuration for Example 6-3.

Figure 6-35. Field device addresses for the outputs in Example 6-3.
## Discrete Outputs

### Table 6-4. Output field devices.

<table>
<thead>
<tr>
<th>Output Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarms</td>
</tr>
<tr>
<td>Control relays</td>
</tr>
<tr>
<td>Fans</td>
</tr>
<tr>
<td>Horns</td>
</tr>
<tr>
<td>Lights</td>
</tr>
<tr>
<td>Motor starters</td>
</tr>
<tr>
<td>Solenoids</td>
</tr>
<tr>
<td>Valves</td>
</tr>
</tbody>
</table>

### Table 6-5. Standard output ratings.

<table>
<thead>
<tr>
<th>Output Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>12–48 volts AC/DC</td>
</tr>
<tr>
<td>120 volts AC/DC</td>
</tr>
<tr>
<td>230 volts AC/DC</td>
</tr>
<tr>
<td>Contact (relay)</td>
</tr>
<tr>
<td>Isolated output</td>
</tr>
<tr>
<td>TTL level</td>
</tr>
<tr>
<td>5–50 volts DC (sink/source)</td>
</tr>
</tbody>
</table>


Solenoids

The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.
Relays

electromechanical relay

Contact
Arm
Coil

input gate
output gate
A valve is a device that regulates the flow of a fluid by opening, closing, or partially obstructing various passageways.
AC Output

Figure 6-36. AC output circuit block diagram.
AC Output

Logic 1—ON ("Switch" Closed)
Logic 0—OFF ("Switch" Open)

Figure 6-37. "Switch" function of an output interface.

Figure 6-39. AC output module connection diagram.
DC Output sink/source

Figure 6-40. Typical sourcing DC output circuit.

Figure 6-41. Field device connections for a sinking/sourcing DC output module.
Isolated DC and AC Outputs

Figure 6-42. Connection diagram for an isolated AC output interface.
TTL Output

Figure 6-43. Connection diagram for a TTL output module.
Register / BCD Outputs

Figure 6-44. Register/BCD output interface connected to seven-segment indicators.
Reference: *Programmable Controllers: Theory and Implementation* by Bryan and Bryan