Discrete Input/Output System

DR. TAREK A. TUTUNJI
PHILADELPHIA UNIVERSITY, JORDAN

Introduction to Discrete I/O Systems

- 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

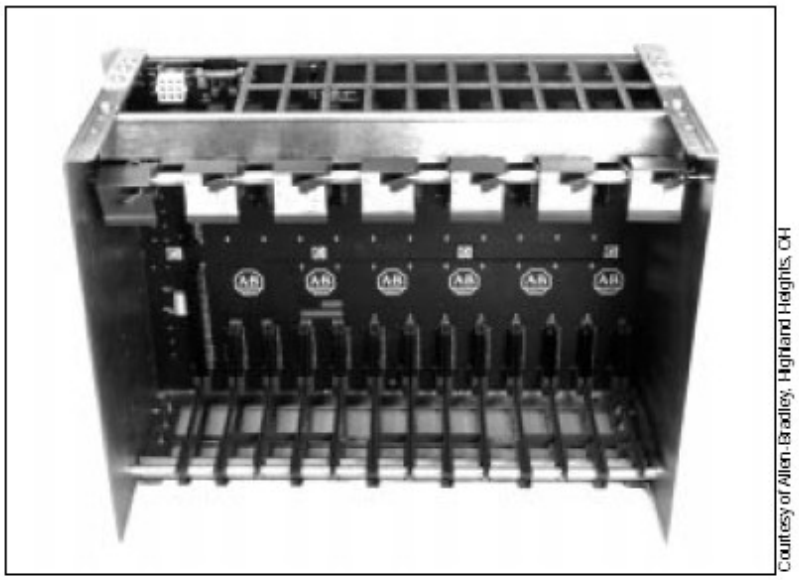


Figure 6-3. Example of an I/O rack enclosure.

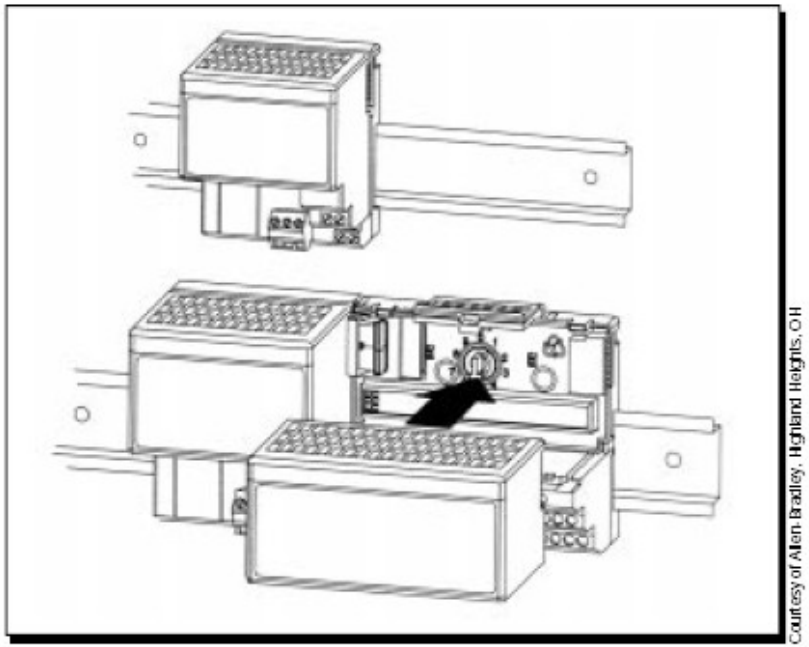


Figure 6-4. Internal switches used to set I/O addresses.

I/O Rack Enclosures

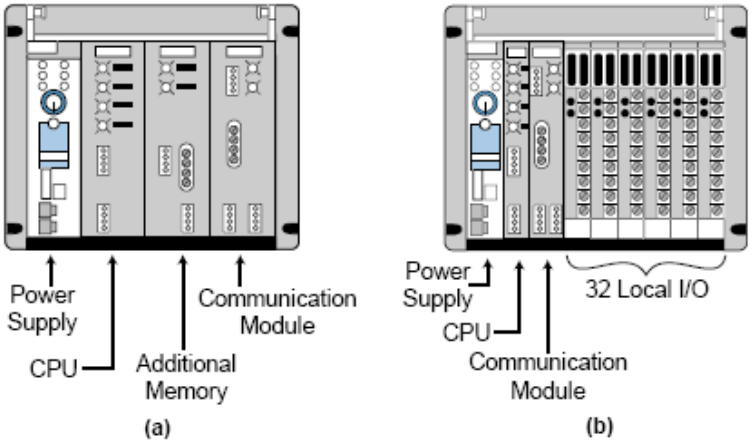


Figure 6-5. Master racks **(a)** without I/O modules and **(b)** with I/O modules.

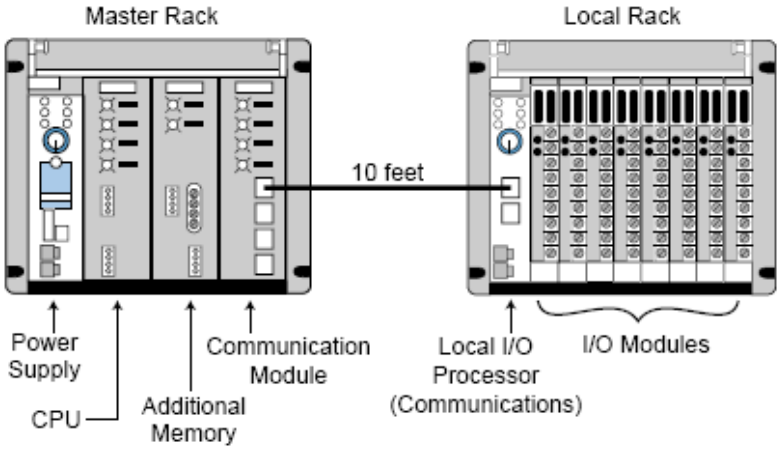


Figure 6-6. Local rack configuration.

I/O Rack Enclosures

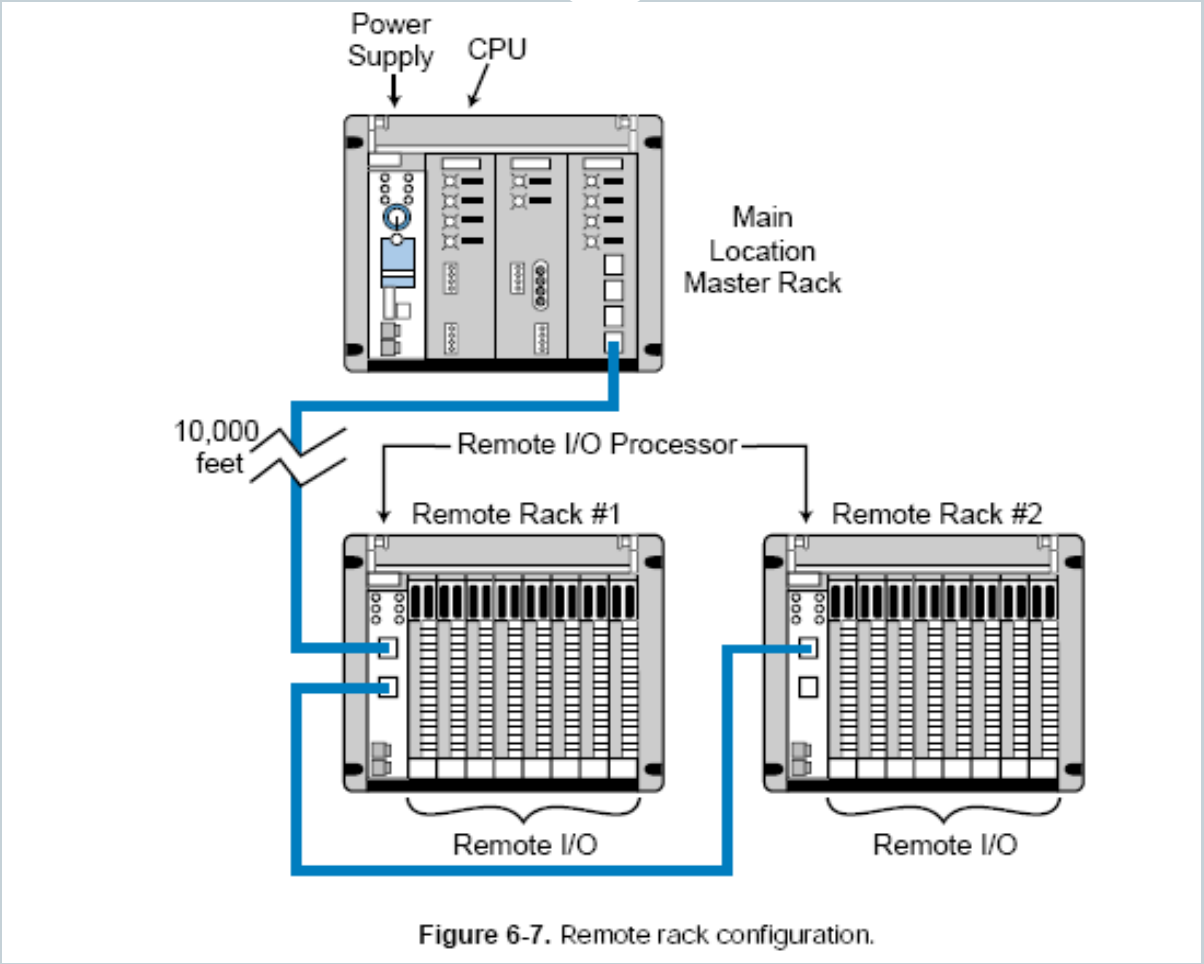
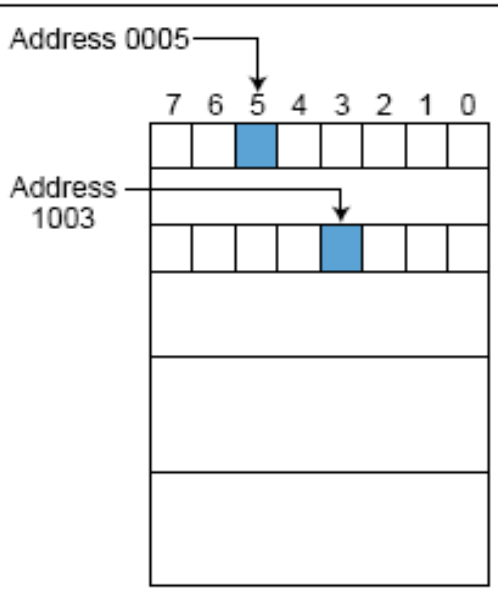


Figure 6-7. Remote rack configuration.

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

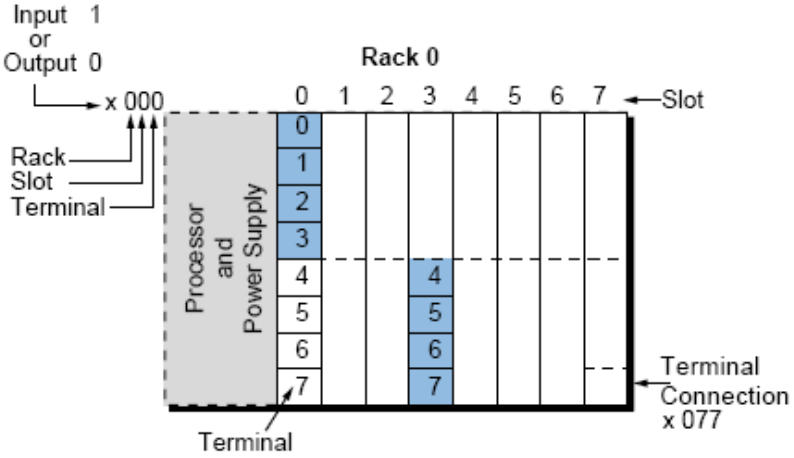
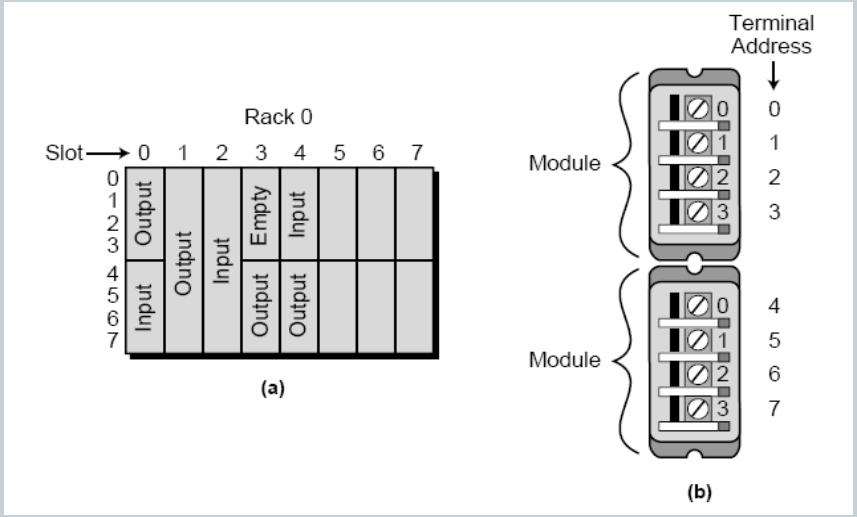
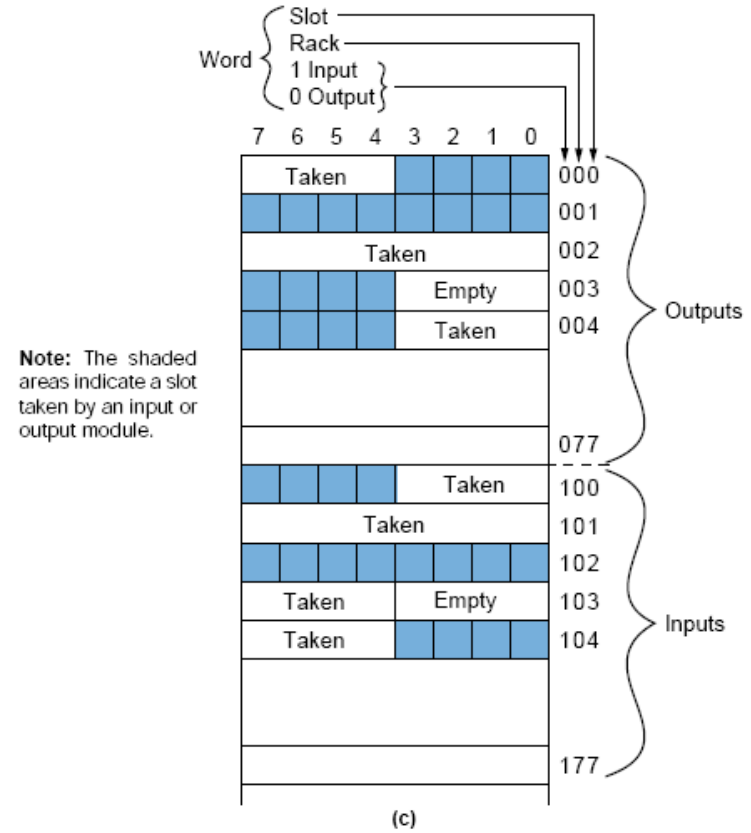


Figure 6-8. Illustration of the example I/O rack enclosure (x = 1 for inputs, 0 for outputs).

I/O Rack and Table Mapping Example





Note: The shaded areas indicate a slot taken by an input or output module.

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.

I/O Racks and 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.

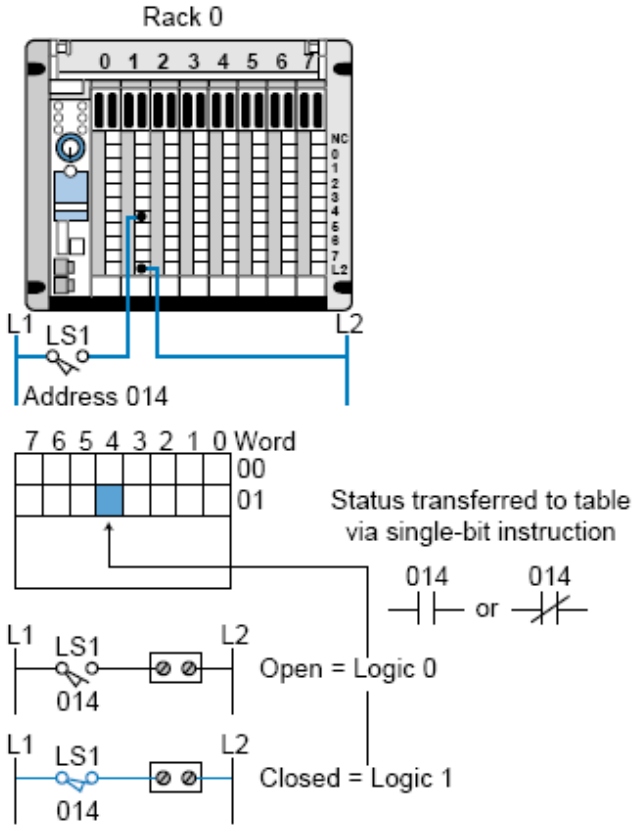


Figure 6-12. An 8-bit input image table.

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.

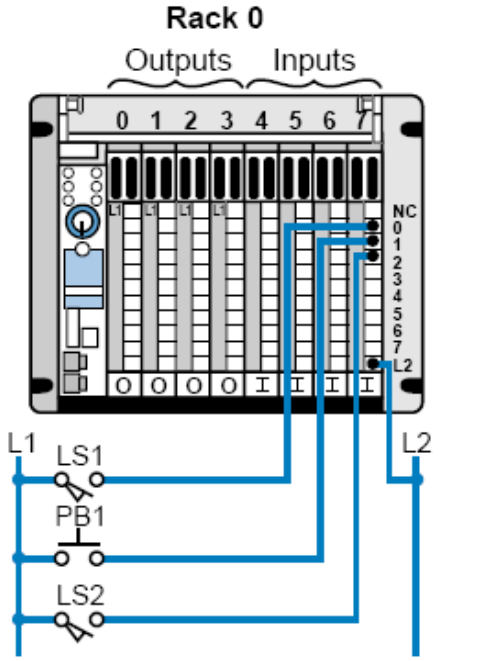


Figure 6-14. Rack configuration for Example 6-1.

Example

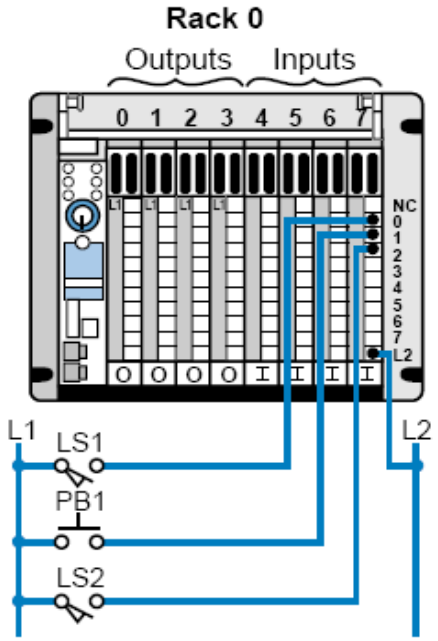


Figure 6-14. Rack configuration for Example 6-1.

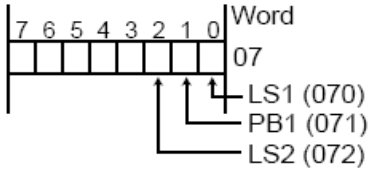


Figure 6-15. Field device addresses for the rack configuration in Example 6-1.

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.

Field Input Devices
Circuit breakers
Level switches
Limit switches
Motor starter contacts
Photoelectric eyes
Proximity switches
Push buttons
Relay contacts
Selector switches
Thumbwheel switches (TWS)

Table 6-2. Discrete input devices.

Circuit Breaker

- 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.

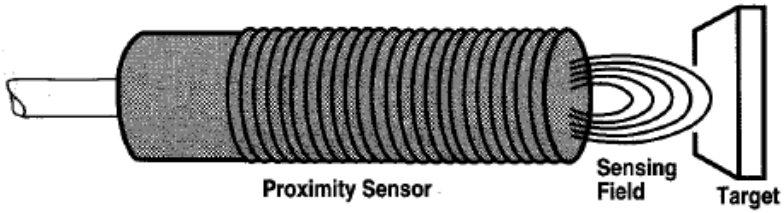


Figure 8-10 - Inductive Proximity Sensor Sensing Target Object (Pepperl & Fuchs, Inc.)

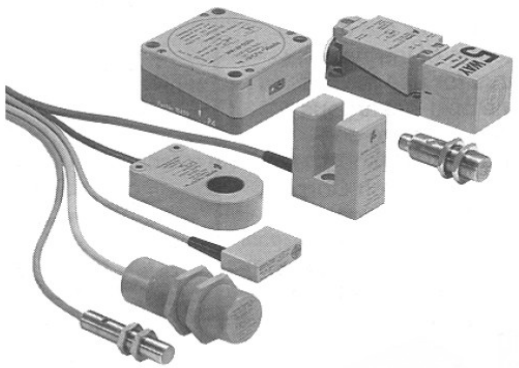


Figure 8-8 - Samples of Inductive Proximity Sensors (Pepperl & Fuchs, Inc.)

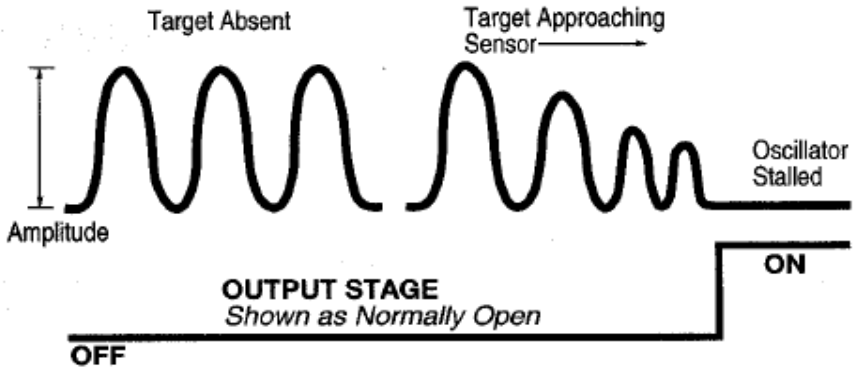


Figure 8-11 - Inductive Proximity Sensor Signals (Pepperl & Fuchs, Inc.)

Proximity Switch: Capacitive

- Principle: As the target is moved closer to the sensor face, the change in dielectric increases the capacitance of the internal capacitor

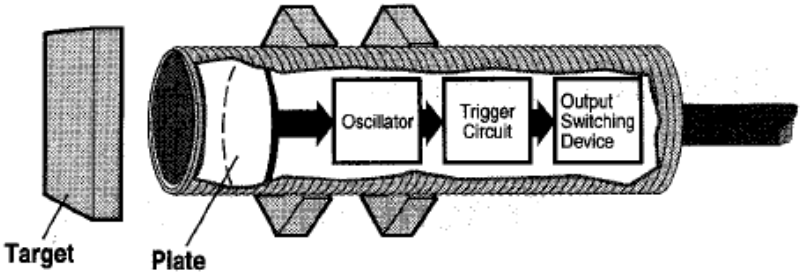


Figure 8-13 - Capacitive Proximity Sensor Internal Components (Pepperl & Fuchs, Inc.)

Figure 8-12 - Example of Capacitive Proximity Sensors (Pepperl & Fuchs, Inc.)

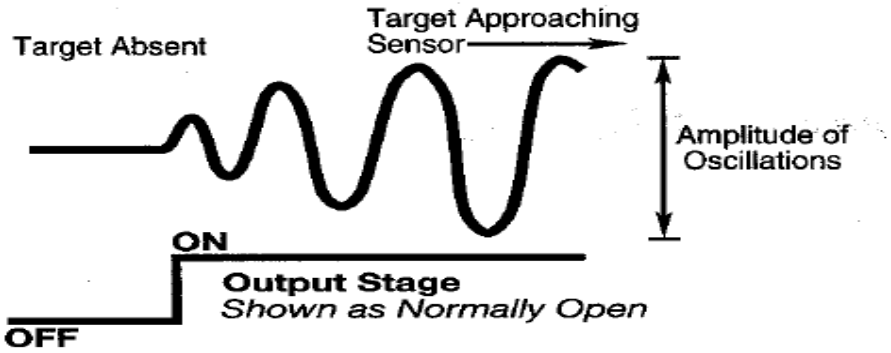
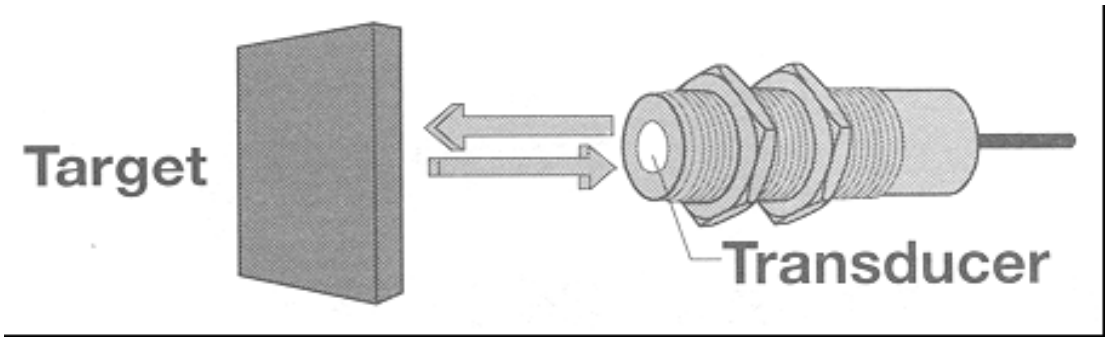


Figure 8-14 - Capacitive Proximity Sensor Signals (Pepperl & Fuchs, Inc.)

Proximity Switch: Ultrasonic and Optical



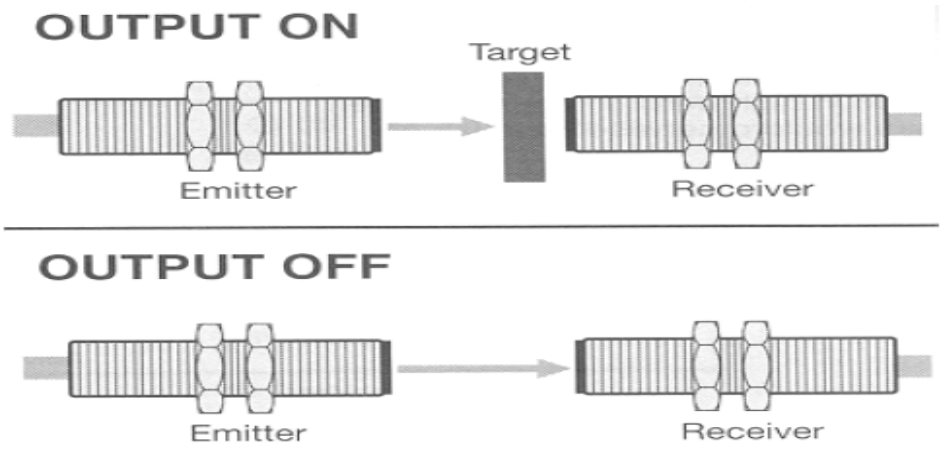


Figure 8-18 - Thru-Beam Optical Sensor, Dark On
(Pepperl & Fuchs, Inc.)

Proximity Switch: sink /source

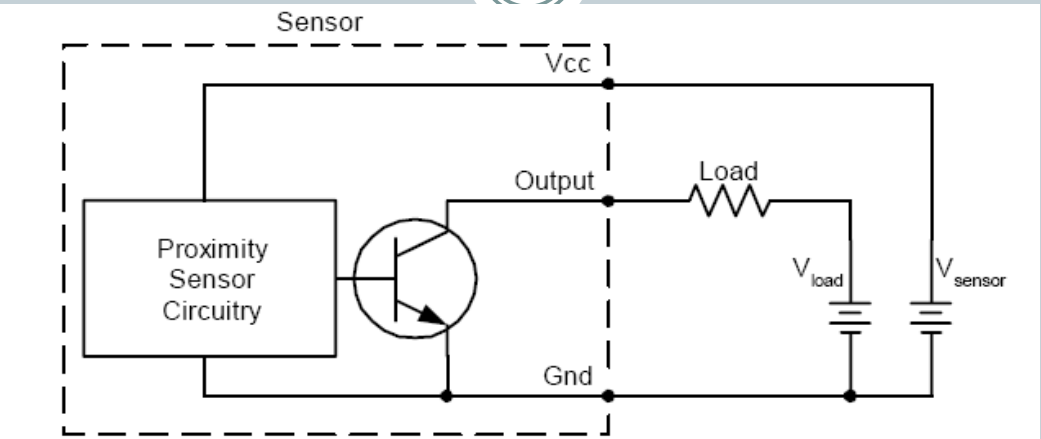


Figure 8-3 - NPN Sensor Load Connection

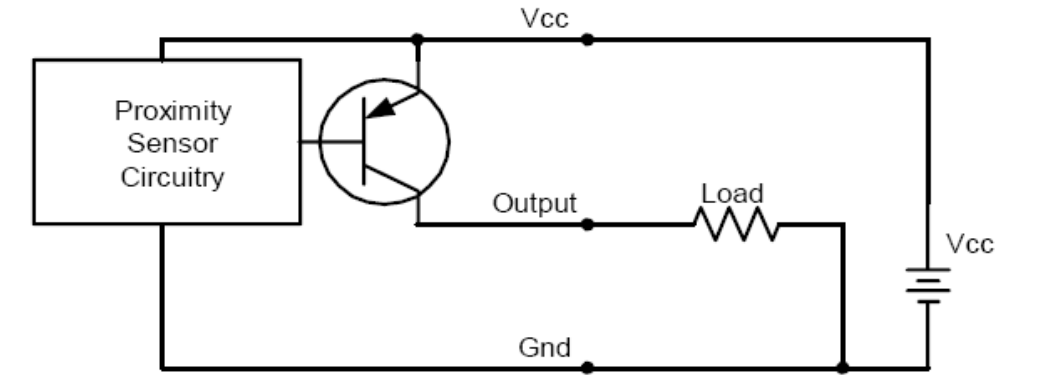
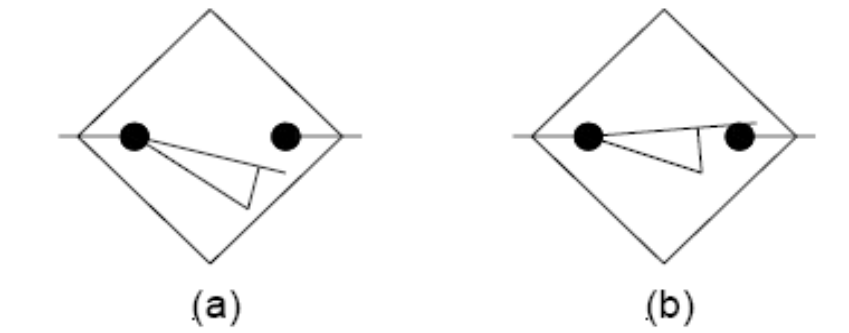


Figure 8-5 - PNP Sensor Load Connection

Limit Switch



Types of Discrete Inputs

Input Ratings
24 volts AC/DC
48 volts AC/DC
120 volts AC/DC
230 volts AC/DC
TTL level
Nonvoltage
Isolated input
5–50 volts DC (sink/source)

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.

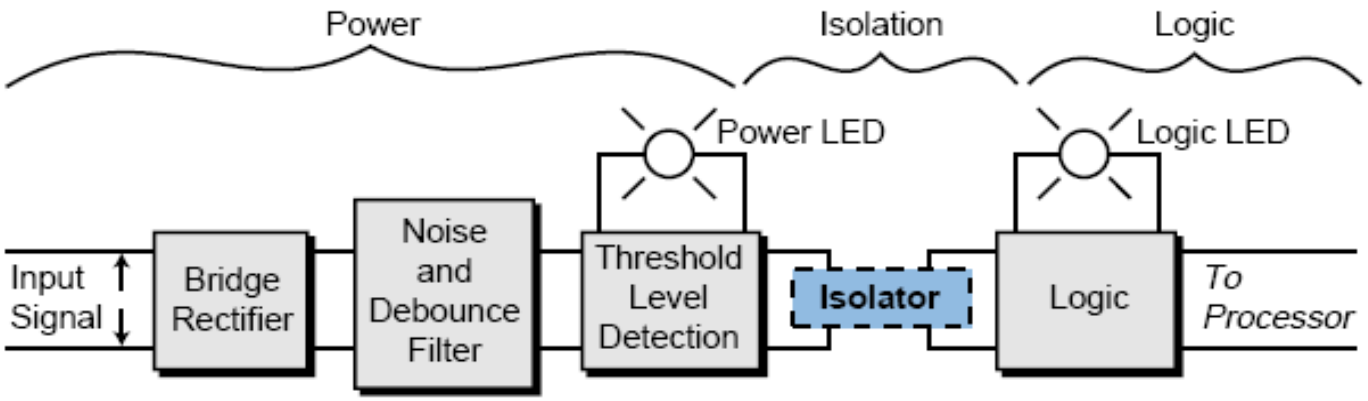


Figure 6-16. Block diagram of an AC/DC input circuit.

AC/DC Inputs

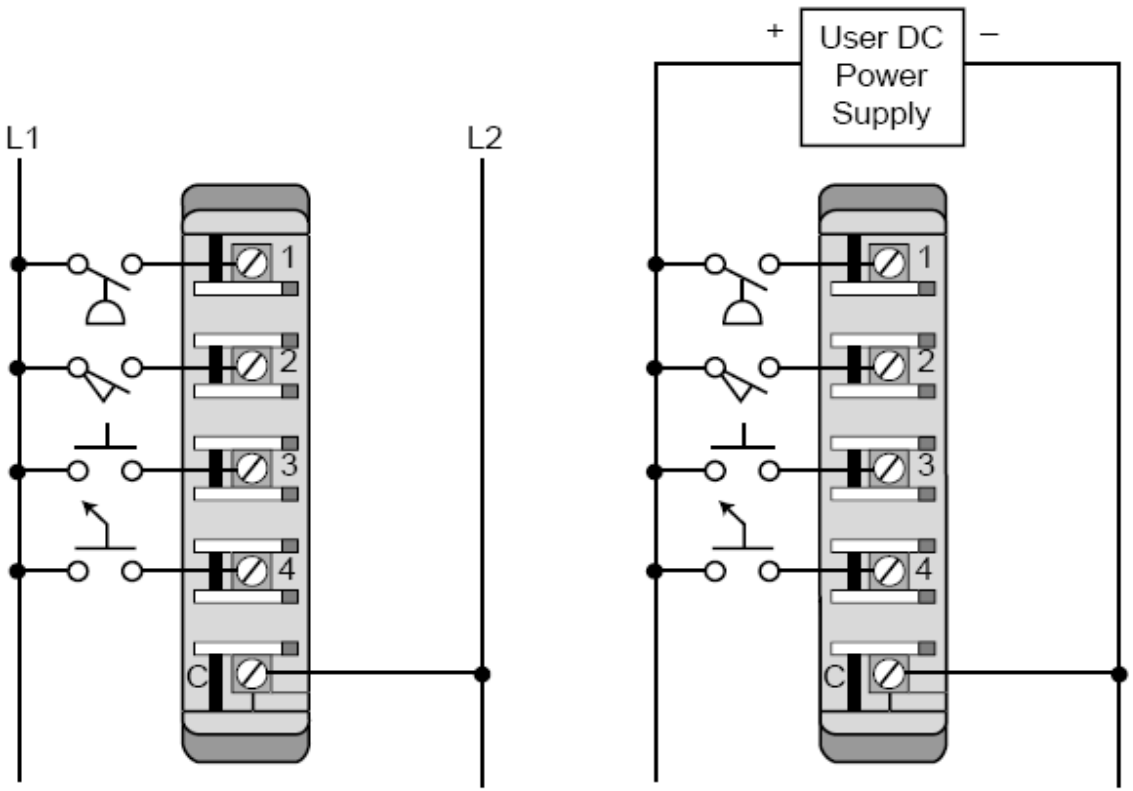


Figure 6-18. Device connections for **(a)** an AC input module and **(b)** a DC input module with common wire connection "C" used to complete the path from hot.

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.

DC Inputs Sink/Source

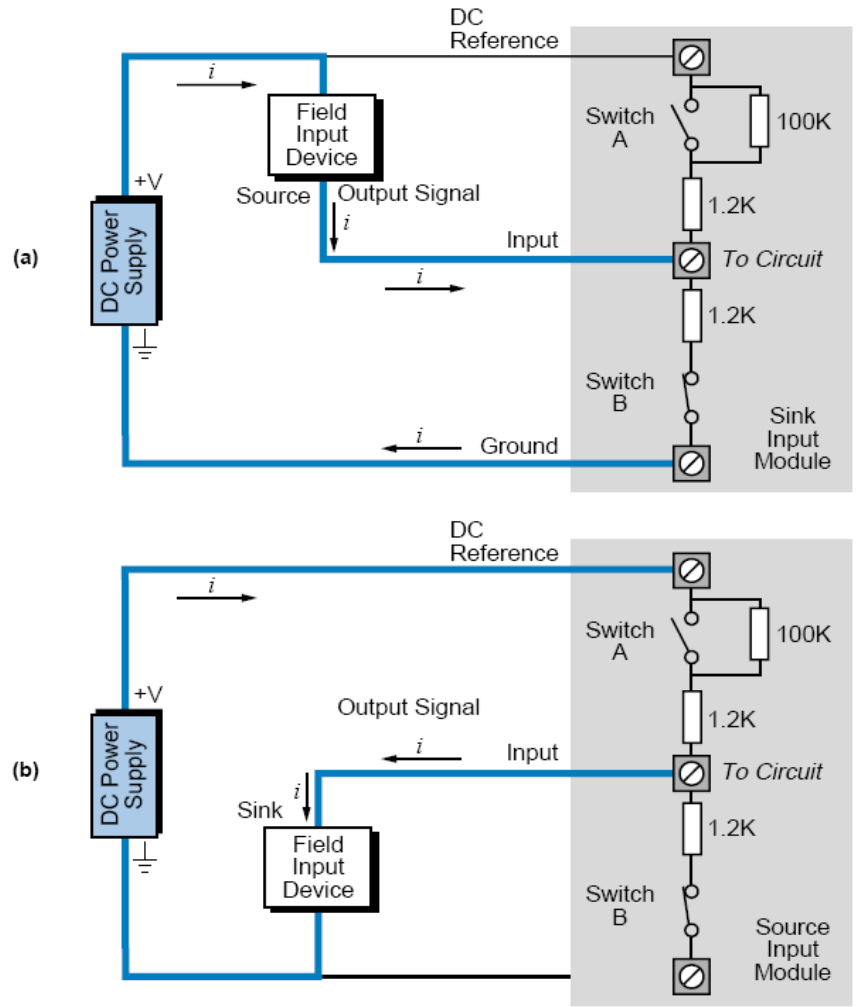


Figure 6-19. Current for **(a)** a sinking input module/sourcing input device and **(b)** a sourcing input module/sinking input device.

DC Inputs Sink/Source

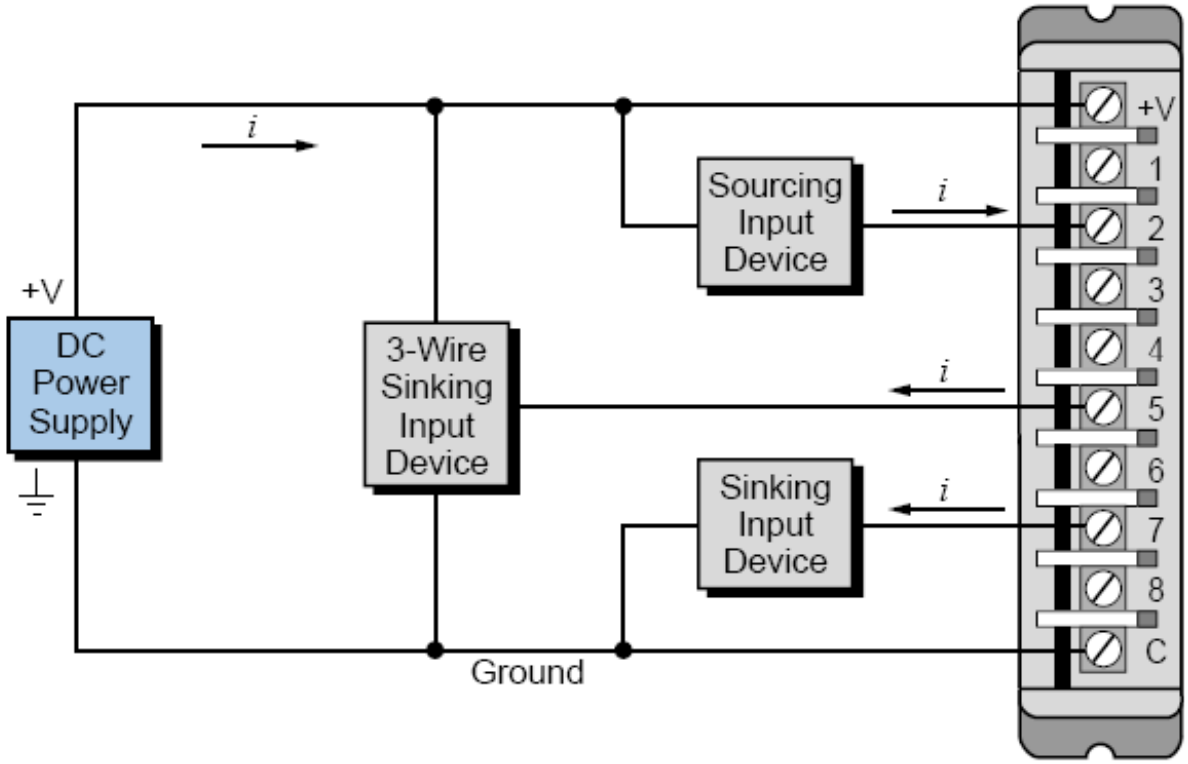


Figure 6-20. Field device connections for a sink/source DC input module.

Isolated AC/DC Inputs

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

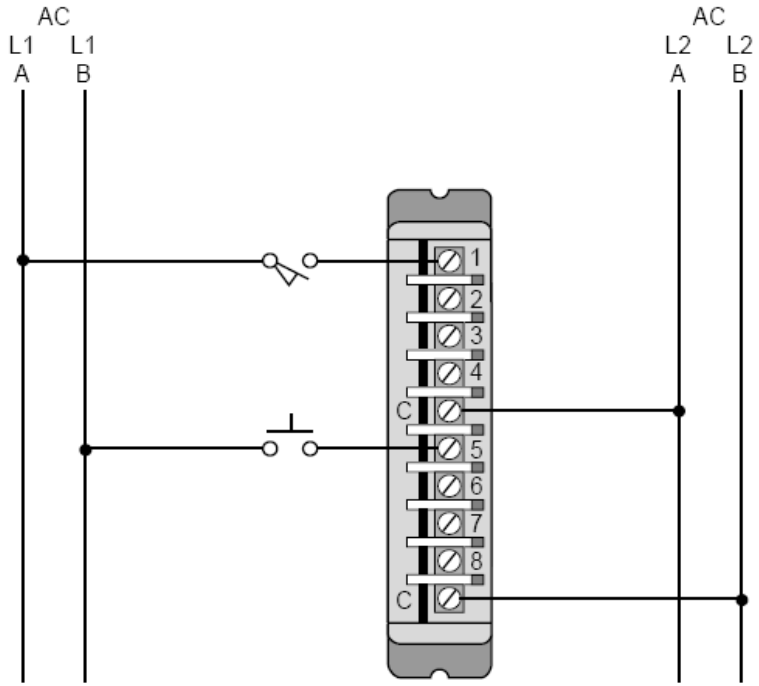


Figure 6-23. An 8-point standard input module used as an isolated module.

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.

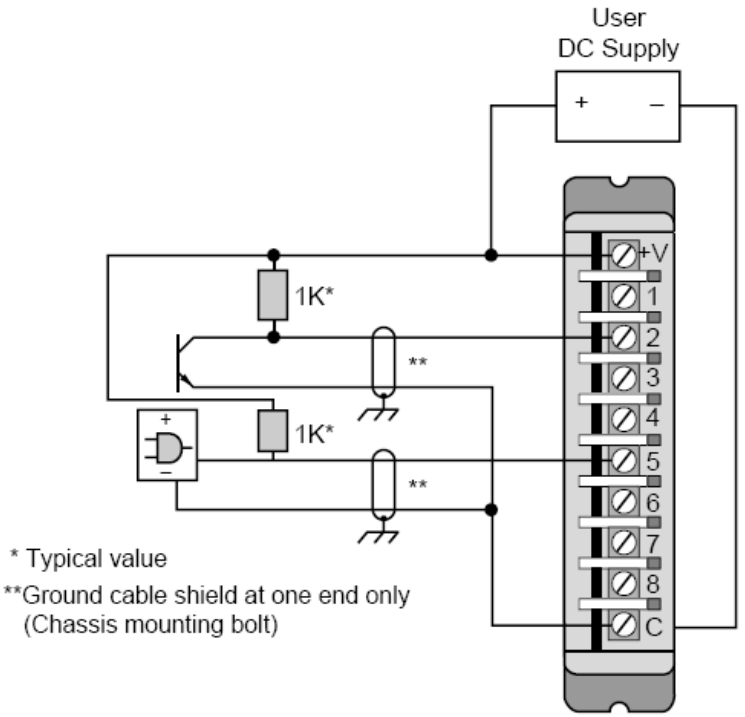


Figure 6-24. TTL input connection diagram.

Register / BCD Inputs

- 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

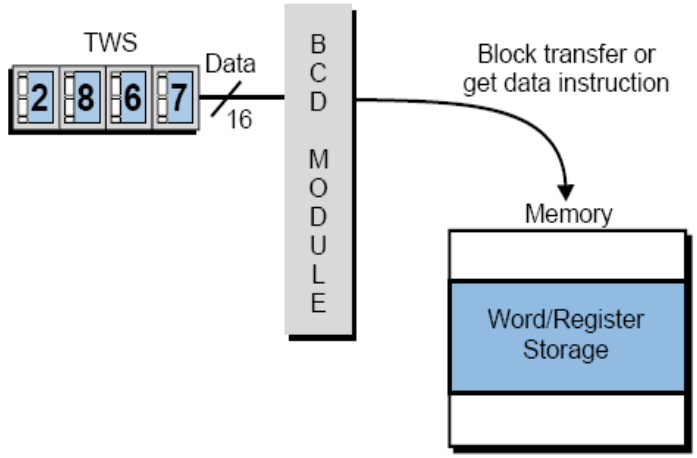


Figure 6-25. BCD interface inputting parameters into register/word locations in memory.

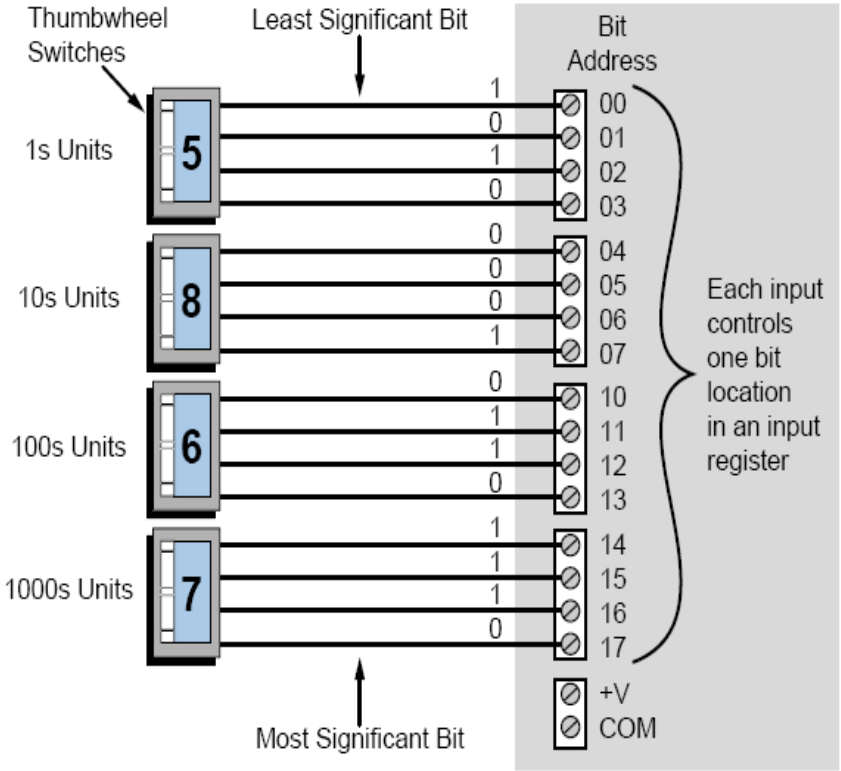


Figure 6-26. Register or BCD input module connection diagram.

Register / BCD Inputs

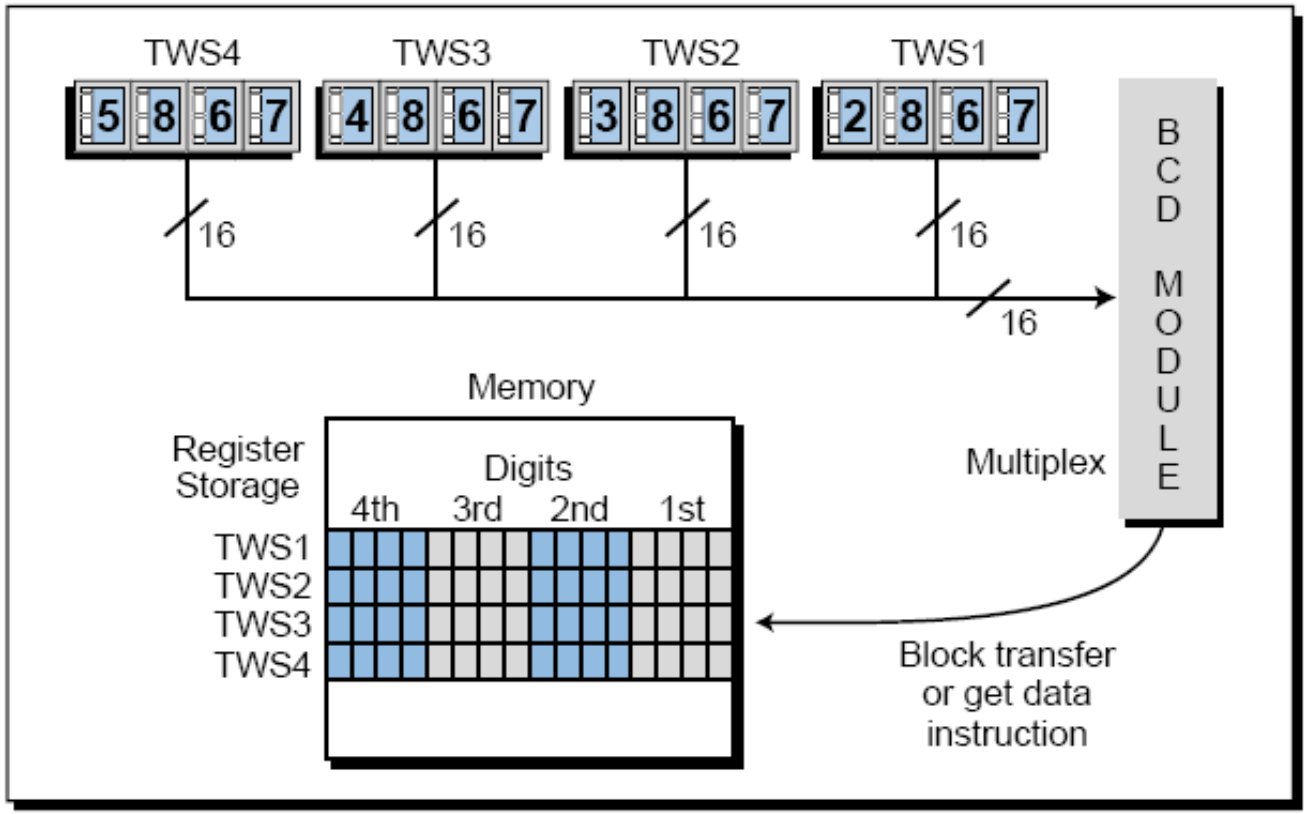


Figure 6-27. Multiplexing input module connection diagram.

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

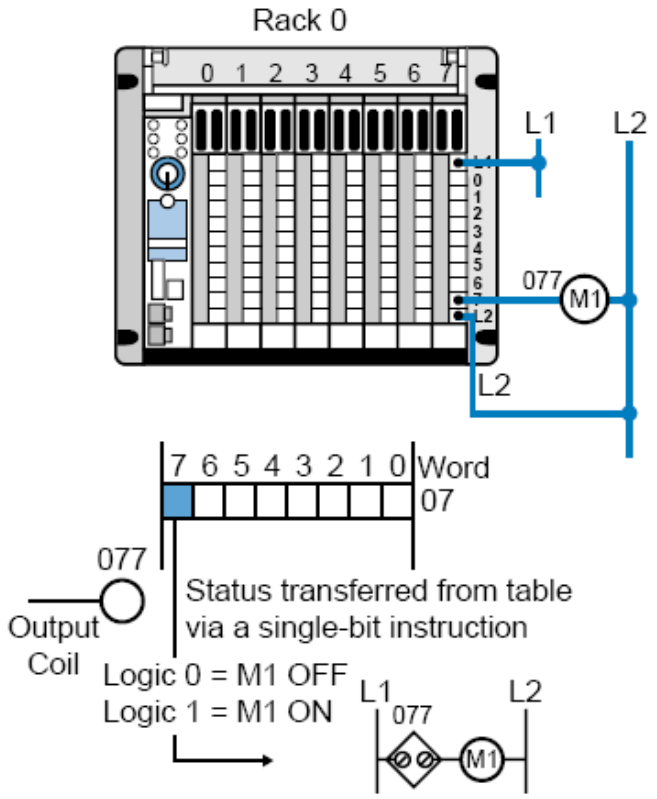


Figure 6-32. An 8-bit output image table with the module's L2 connection completing the path from L1 to L2.

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

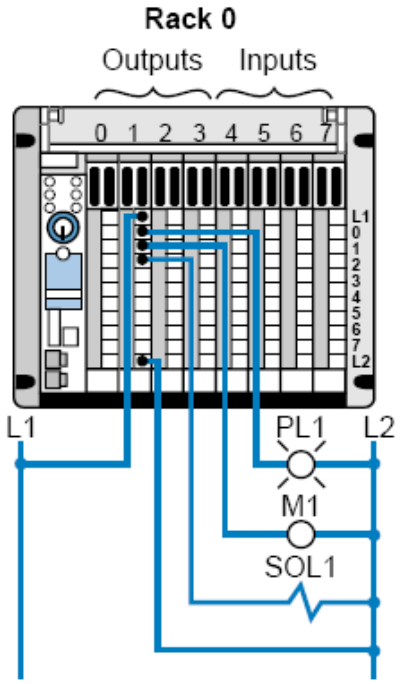


Figure 6-34. Rack configuration for Example 6-3.

Example

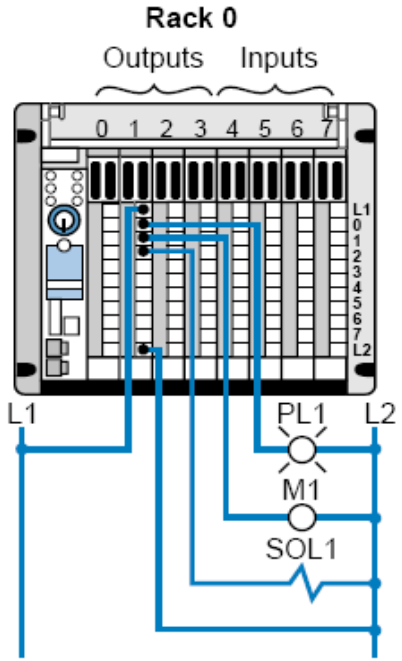


Figure 6-34. Rack configuration for Example 6-3.

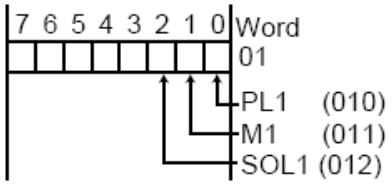


Figure 6-35. Field device addresses for the outputs in Example 6-3.

Discrete Outputs

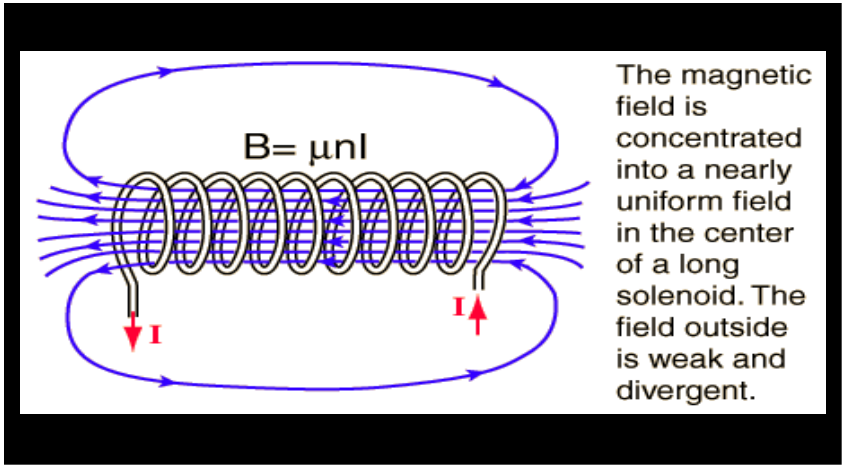
Output Devices
Alarms
Control relays
Fans
Horns
Lights
Motor starters
Solenoids
Valves

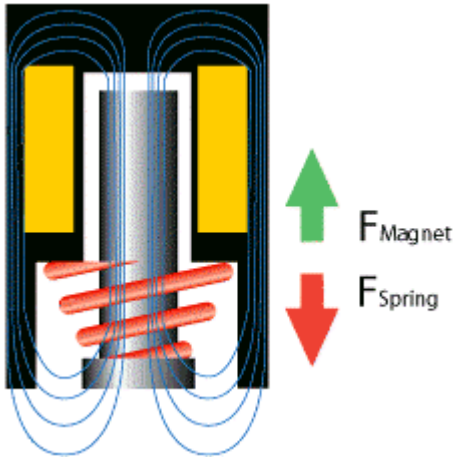
Table 6-4. Output field devices.

Output Ratings
12–48 volts AC/DC
120 volts AC/DC
230 volts AC/DC
Contact (relay)
Isolated output
TTL level
5–50 volts DC (sink/source)

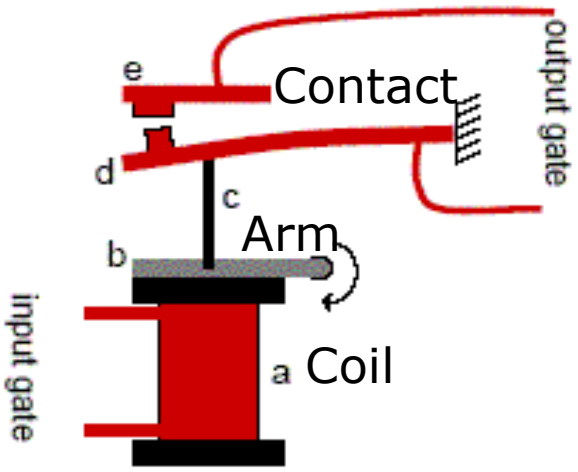
Table 6-5. Standard output ratings.

Solenoids

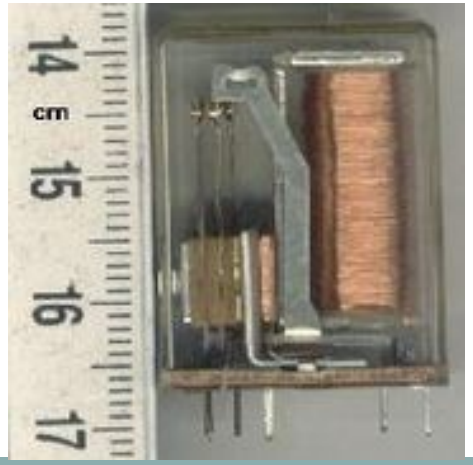

B= μnI
I
I
The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.


F Magnet
F Spring

Relays

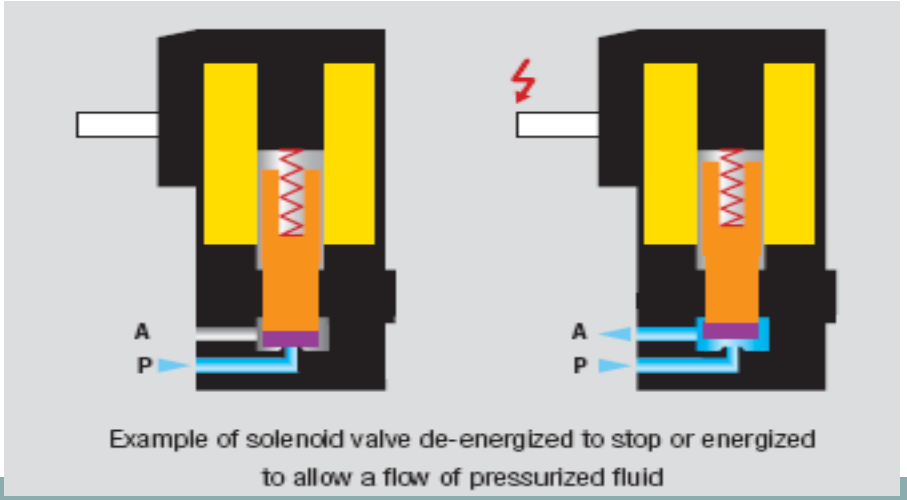


electromechanical relay



Valves

- A **valve** is a device that regulates the flow of a fluid by opening, closing, or partially obstructing various passageways



Example of solenoid valve de-energized to stop or energized to allow a flow of pressurized fluid

AC Output

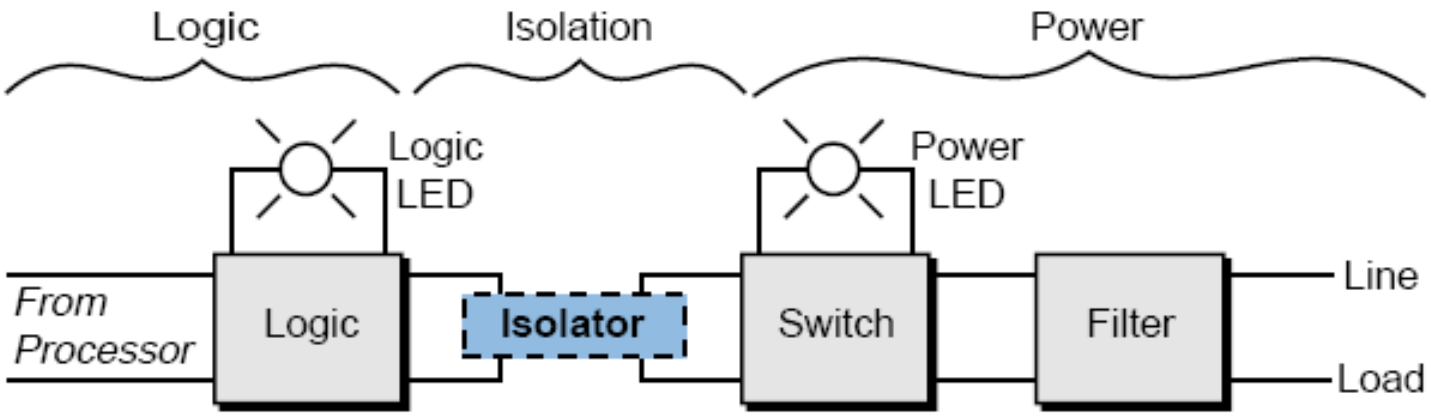


Figure 6-36. AC output circuit block diagram.

AC Output

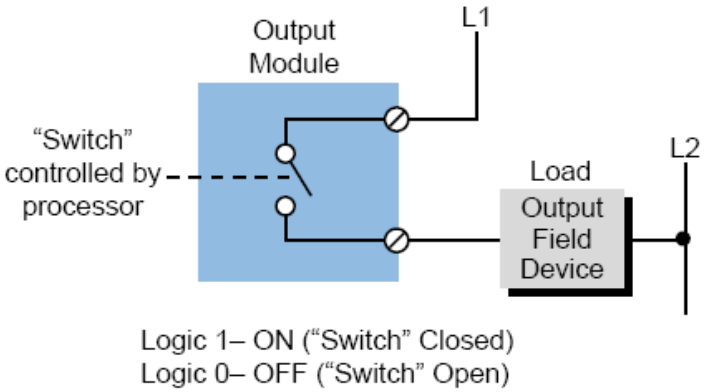


Figure 6-37. "Switch" function of an output interface.

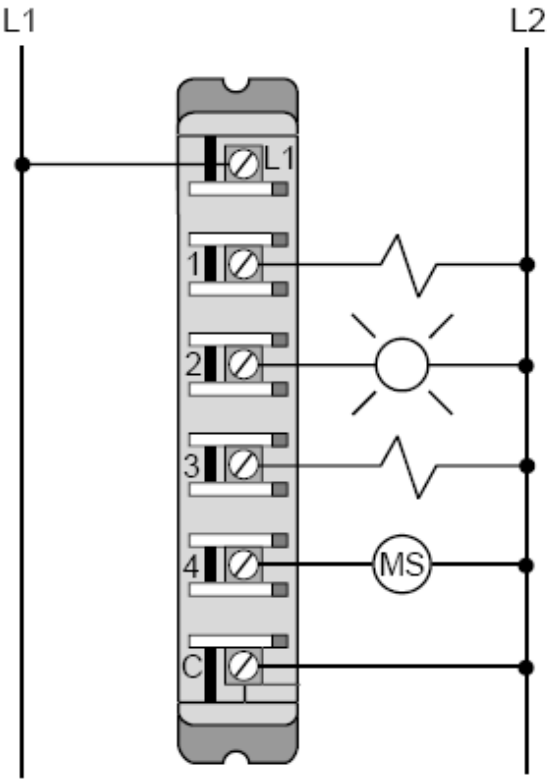


Figure 6-39. AC output module connection diagram.

DC Output sink/source

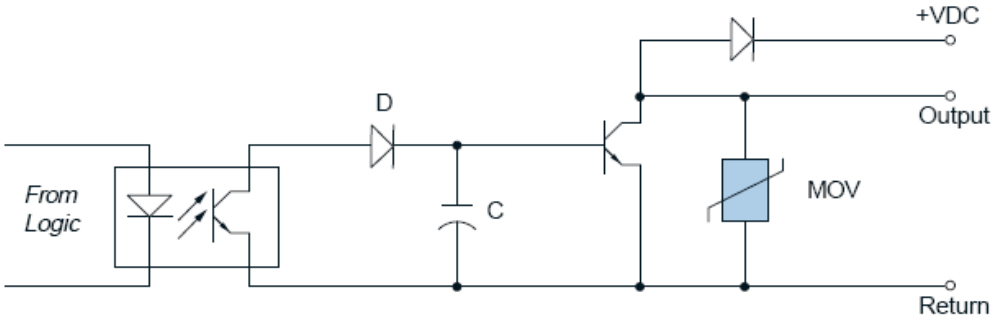


Figure 6-40. Typical sourcing DC output circuit.

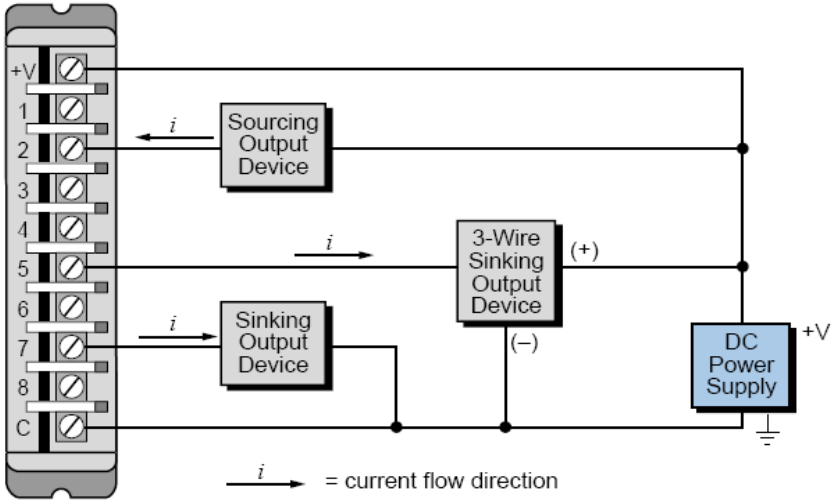


Figure 6-41. Field device connections for a sinking/sourcing DC output module.

Isolated DC and AC Outputs

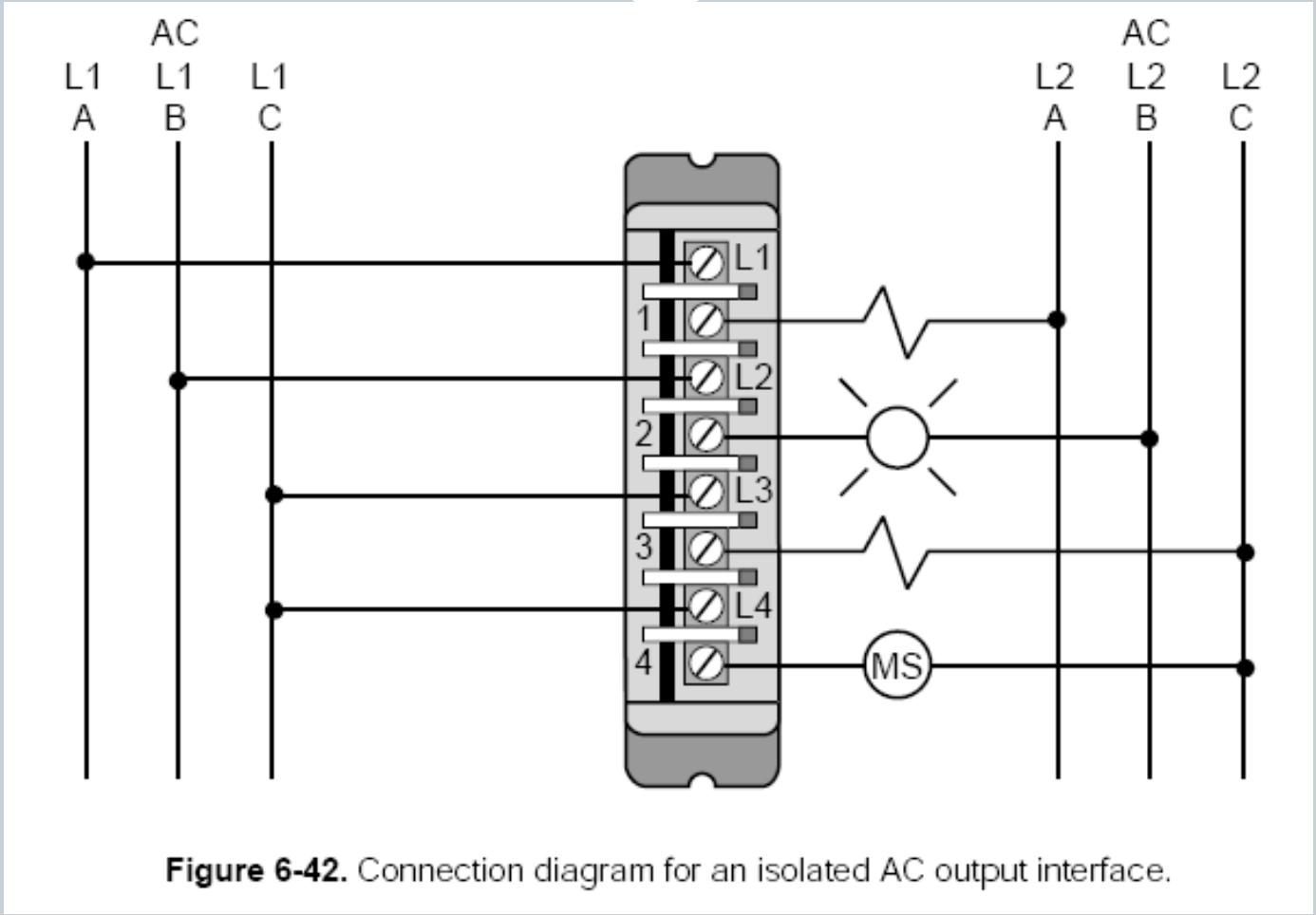


Figure 6-42. Connection diagram for an isolated AC output interface.

TTL Output

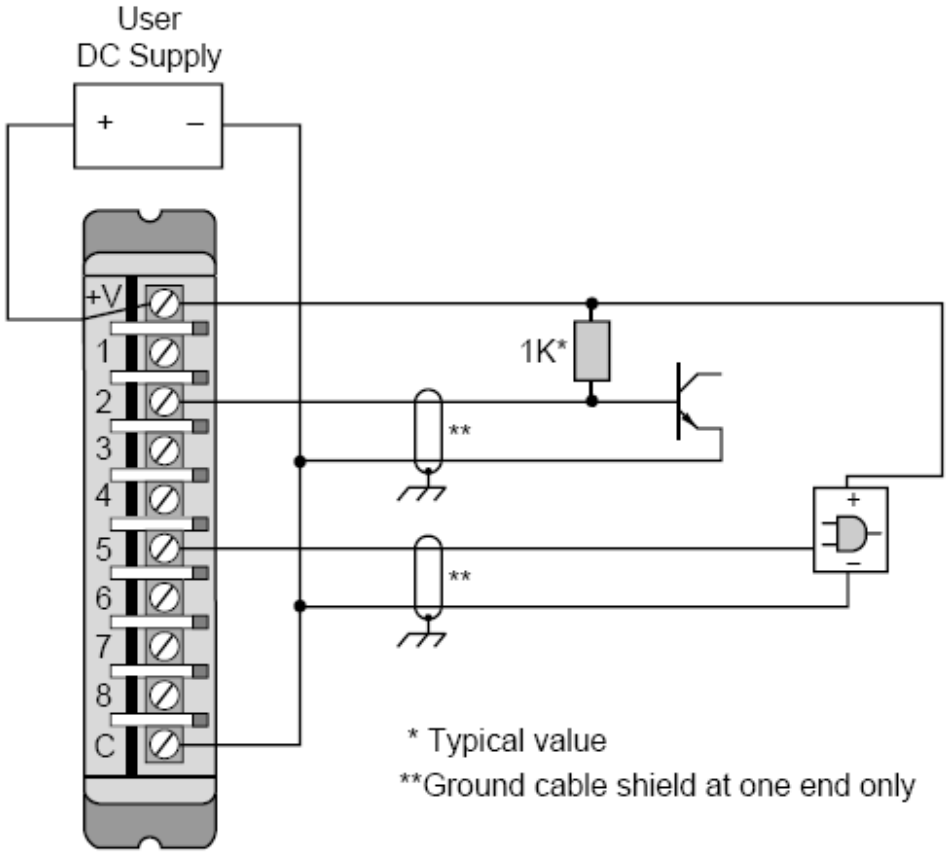


Figure 6-43. Connection diagram for a TTL output module.

Register / BCD Outputs

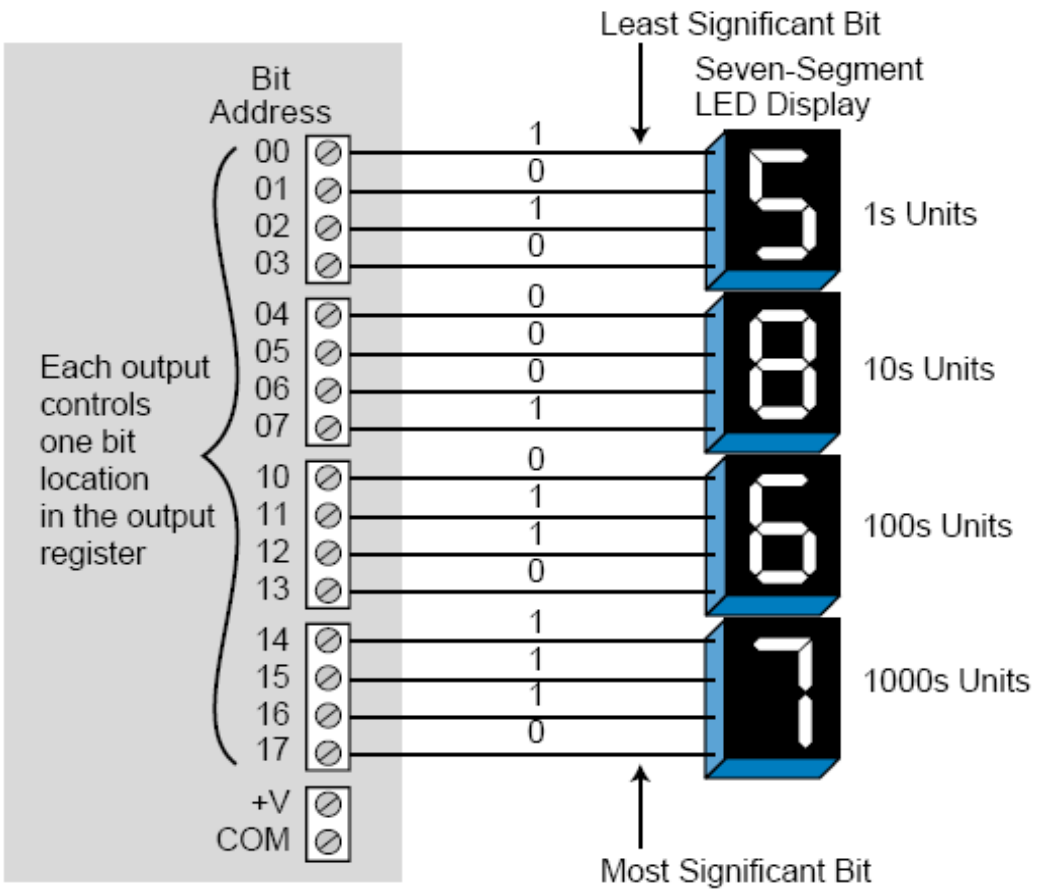


Figure 6-44. Register/BCD output interface connected to seven-segment indicators.

Reference: Programmable Controllers: Theory and Implementation by Bryan and Bryan