LESSON 18: INTRODUCTION TO PROGRAMMABLE LOGIC CONTROLLERS

ET 438 b Digital Control and Data Acquisition

Department of Technology

Learning Objectives

After this presentation you will be able to:

- Identify the key parts of a programmable logic controller (PLC)
- Explain how a PLC functions in the run mode
- Identify various types of input/output modules used with PLC processors
- Identify file structure type for a typical PLC family of processors.

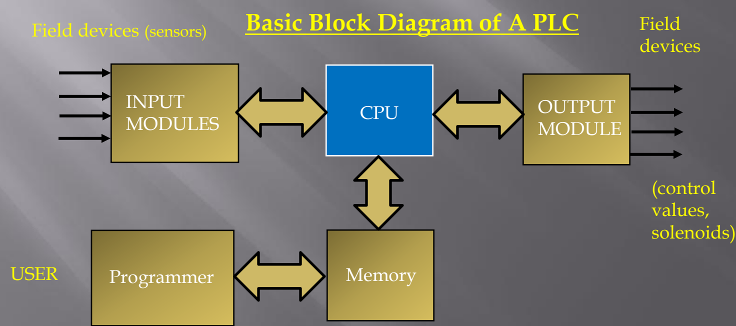
Programmable Logic Controllers (PLC)

Microprocessor-based controller that implements ladder logic through software and hardware interface.

Definition of PLC

Digital apparatus using programmable memory and stored programs for implementing **Logic Timing Sequencing Counting**

Basic Block Diagram of A PLC



PLC Operation in Run Mode

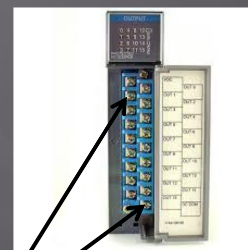
1. Scan all Inputs
   Detect change in status of field devices (Limit switches Pressure switches, etc.)
2. Execute control program based on user logic design
3. Test output status against program values.
4. Update output to fit changes dictated by input change

Time from 1 to 4 called scan time. Can be important in programs

Typical PLC Input/Output Modules

PLC I/O designed to connect to industrial devices

I/O grouped on cards with 8, 16, 24,32 inputs



1 set terminals (com, n) = 1 I/O point

Dry contacts (standard switches)
motor contactors
Pressure, temperature, limit, flow switches

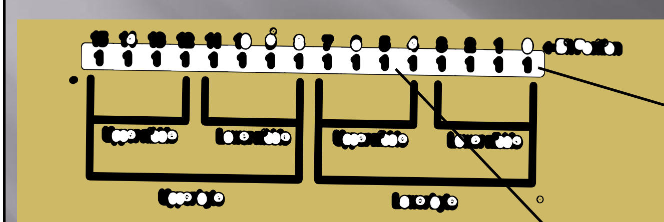
Solid state sensors (electronic)
proximity switches, photo eyes etc.

Voltage levels 24 - 240 Vac 24-240 Vdc
TTL levels, Sourcing and sinking I/O

PLC I/O Interfacing

PLC's use memory mapped I/O

PLC uses microprocessors with 8-16 bit words. Each I/O point identified by location in memory. Terminals have unique addresses represented by decimal, octal or binary number. (commonly decimal)



Each memory word maps to group of I/O points

Bits represent status of I/O field devices 1=on, 0=off

PLC I/O Interfacing

For expandable PLCs

Level 3: I/O point. Type of point and terminal number

Level 2: Slot identifier (type of I/O card)

Level 1: Rack or chassis identifier

I/O Status Table

1	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	Word 1
																Word 2
																Word 3
																Word 4
																Word 5
																Word 6

Non-expandable PLCs use fixed addressing: All slot 0

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PLC I/O Interfacing

Addressing of I/O cards (Allen-Bradley (A-B))

A-B uses decimal expandable addressing for most PLCs

X:n

- Function I/O
- Slot Number

Addressing Specific I/O points (Allen-Bradley)

X:n/p

- Function I/O
- Slot Number
- Terminal Number

For fixed PLC designs, all I/O addressed to slot 0

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PLC I/O Interfacing

I/O Addressing Examples

Function	Chassis Slot	Terminal #	Address
input	1	4	I:1/4
output	2	13	O:2/13
input	3	2	I:3/2
input	4	4	I:4/4

Note: Decimal addressing used above

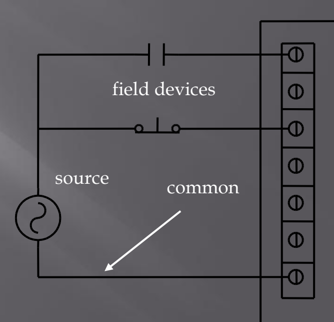
Other PLC data types:
Bit data, unsigned integer, signed integer, BCD (binary coded decimal 0-9 binary)

Input Modules

Sequential control uses discrete (binary) inputs (on/off) from field devices (switches sensors, etc.)

Typical Type of Input Modules

Ac	Dc
24, 48, 120, 240 V	24, 48, 1-60 120 Vdc
120, 240 V isolated	sink/source 5-50 Vdc
24 Vac/dc	5 V TTL
	5/12 V TTL



Input module considered load of field device (switch)

Input Module Specifications

Voltage	Inputs	Points per Common	Backplane Current Draw at 5 VDC	Maximum Signal Delay	Maximum Off-State Current	Input Current Nominal	Maximum Inrush Current
85 to 132 VAC	4	4	0.035 Amps	ON = 35ms OFF = 45ms	2mA	12mA at 120 VAC	0.8A
	8	8	0.050 Amps	ON = 35ms OFF = 45ms	2mA	12mA at 120 VAC	0.8A
	16	16	0.085 Amps	ON = 35ms OFF = 45ms	2mA	12mA at 120 VAC	0.8A
170 to 265 VAC	4	4	0.035 Amps	ON = 35ms OFF = 45ms	2mA	12mA at 240 VAC	1.6A
	8	8	0.050 Amps	ON = 35ms OFF = 45ms	2mA	12mA at 240 VAC	1.6A
	16	16	0.085 Amps	ON = 35ms OFF = 45ms	2mA	12mA at 240 VAC	1.6A

Figure 4-7 AC input module specifications for Allen-Bradley SLC 500 120 VAC and 240 VAC input modules. (Compiled from Allen-Bradley Discrete I/O modules data.)

Explanation of Specifications

Backplane draw current - module current drawn by electronics
Maximum signal delay - time required for PLC to sense change in field device and store it in memory
Maximum off state current - max current that can flow so that input remains in off state. (leakage I from solid state sensors
Nominal input current - current drawn by the input point with nominal voltage applied

Input Module Specifications

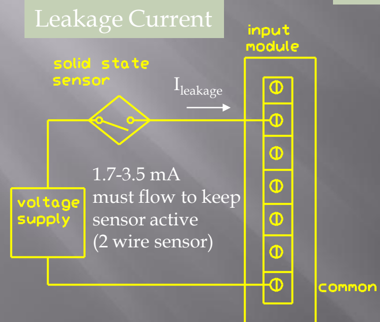
Additional Specifications

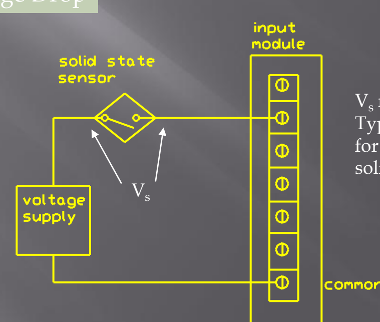
- Voltage Drop
- Leakage Current
- Load Current
- Power-up Delay

→ Useful when applying active (solid-state) switches and proximity sensors

Voltage Drop

Leakage Current



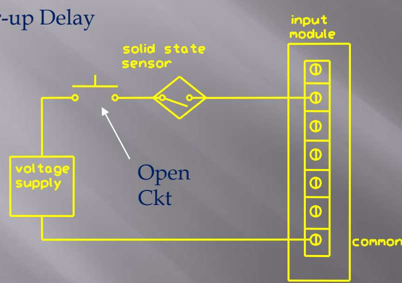


V_s must be low
Typically 6-10 for 2-wire solid state sensor

Inputs with Solid State Sensors

When solid-state 2-wire sensor is used with switch, sensor will be inactive until circuit is completed

Power-up Delay

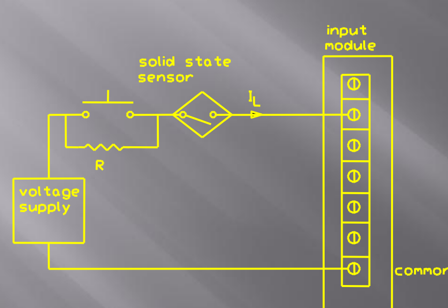


Dealing with power up delay - add parallel resistor.

Must allow enough current to activate sensor but not turn on input module

Inputs with Solid State Sensors

Dealing with power up delay - add parallel resistor.



Example: size R V_s = 115 Vac
I_L = 1.7 mA

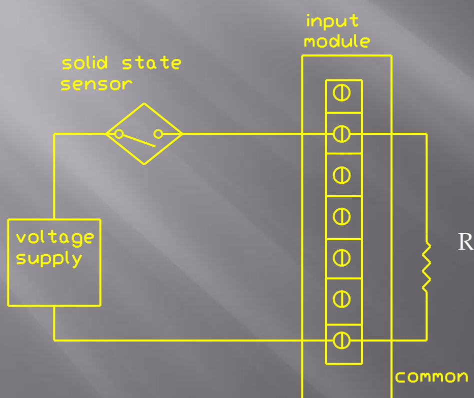
R = 115 V/ 1.7 mA

R = 67.647 kΩ

Inputs with Solid State Sensors

Minimum load current-lowest I value that keeps the sensor active

May need to parallel a resistor with the input card if it has a high impedance input or sensor needs more current than card can handle without turning on the input

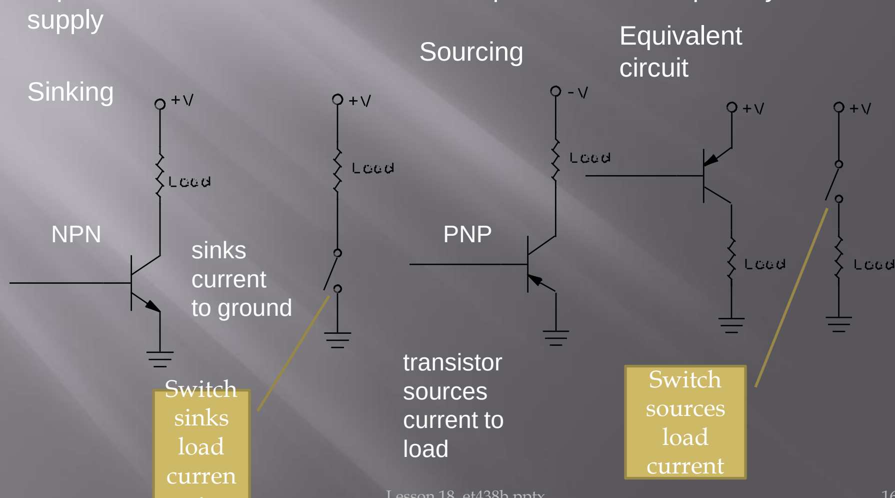


R called bleeder resistor. Usually sized according to manufacturer charts

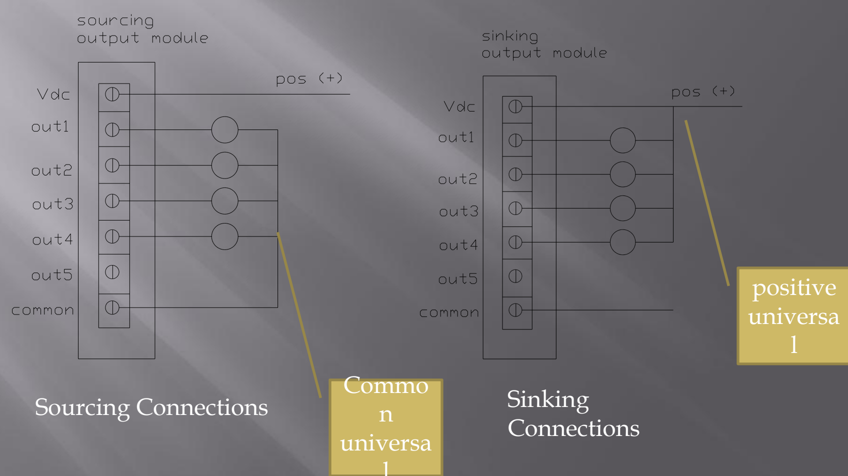
Based on concept of current division

Sourcing and Sinking Inputs

Dc input modules can either be sources or sinks for dc current. This depends on the transistor used in the input card and the polarity of the dc supply

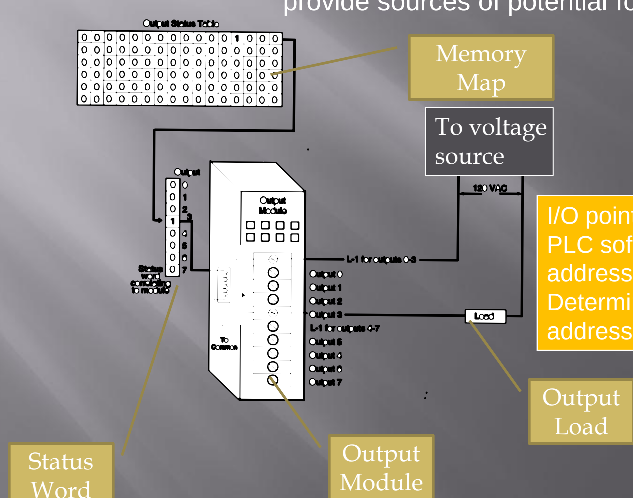


Sourcing and Sinking Output Modules



Relationship Between I/O Hardware and Memory

Field I/O device is considered load. Must provide sources of potential for I/O

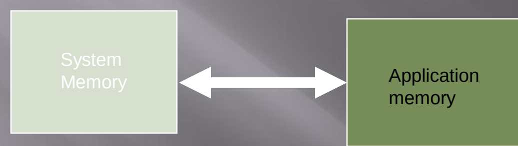


I/O points mapped to memory by PLC software. Users must specify address when programming. Determined by I/O hardware address

PLC Data File Structures

Typical structure Allen-Bradley SLC500 Series

Memory structure



ROM
holds PLC Operating
system

RAM
Holds user programs
and data files
I/O maps, programs
battery back-up

PLC DATA FILE STRUCTURES

File ID number	
0	Output Image
1	Input Image
2	Status
3	Bit
4	Timer
5	Counter
6	Control
7	Integer
8	Reserved
9	Network Comm.
10-255	User defined

Bit, timer, counter, integer data defined by user

AB SLC 500 Data File Identifiers

File Type	File ID	File Number
Output status	O	0
Input status	I	1
Processor Status	S	2
Bit file	B	3
Timer	T	4
Counter	C	5
Control	R	6
Integer	N	7
Float Point	F	8

PLC DATA FILE STRUCTURES

File 0 - Output image   single memory words

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	addr.
Unused								0	1	0	0	0	1	1	0	O:1
																O:2
																O:5

Slot address

Point Map

Address depends on slot location of the Output card and number of points

OUTPUT IMAGE FILE

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	addr.
x																O:2
	Invalid							x								O:5
x																O:6
		Invalid						x								O:7

Each card assigned a word, unused bits are not addressable

PLC has an 16 output card in slot 2
An 8 output card in slot 5
A 16 output card in slot 6
An 8 output card in slot 7

INPUT IMAGE FILE

File 1 - Input image single memory words

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	addr.
																I:0
																I:3
																I:4

Slot address

Each card assigned a word, unused bits are not addressable

Address depends on slot location of the input card and number of points. Similar to Output map.

PLC DATA FILE STRUCTURES

File 2 - Processor Status File

Contains information about how PLC and its operating system is functioning

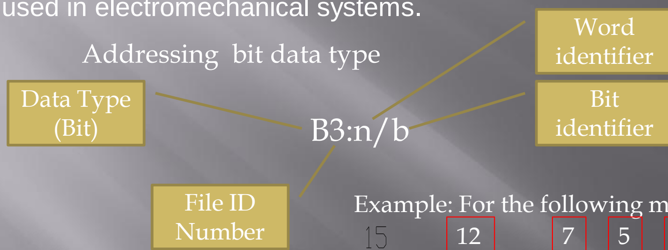
Typical Information

monitoring and clearing hardware and software faults
setting of watchdog timer value
runtime errors
I/O errors
average scan times

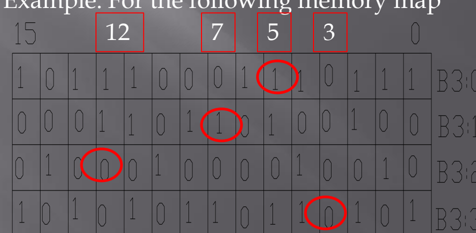
PLC Data File Structures

File 3 - The Bit File Bit files used to represent control relays that were used in electromechanical systems.

Addressing bit data type



Example: For the following memory map



Determine the bit value associated with the addresses

Addresses	Bit value
B3:0/5	1
B3:1/7	1
B3:2/12	0
B3:3/3	0

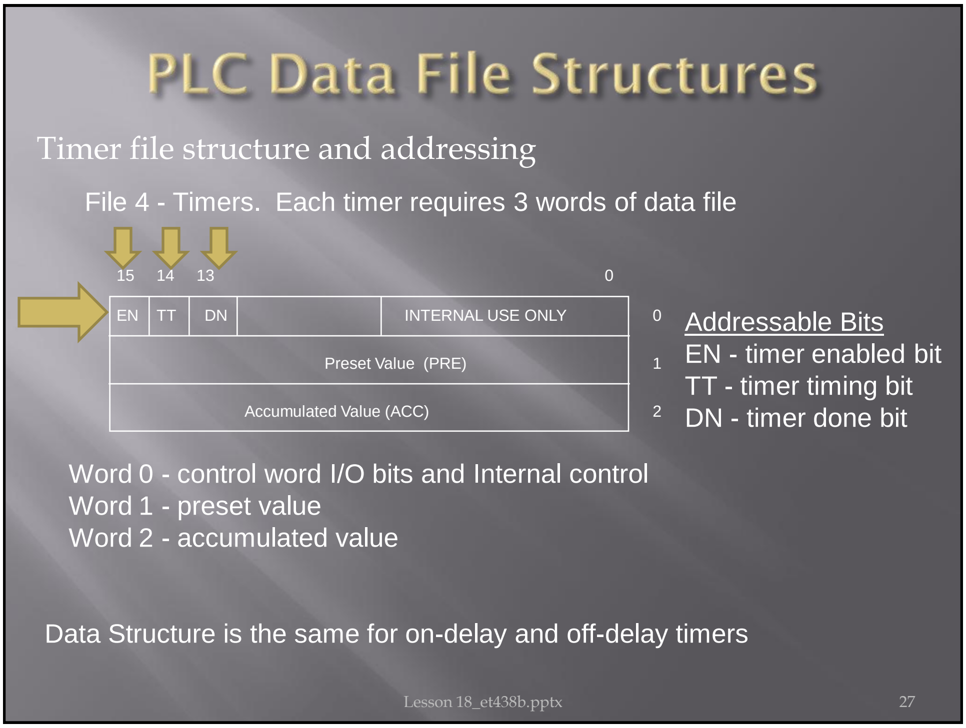
PLC Data File Structures

Identifying individual bits

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	addr.
																B3:0
						1										B3:1
							0									B3:2
																B3:3

B3:1/9

B3:2/8


PLC Data File Structures
Timer file structure and addressing
File 4 - Timers. Each timer requires 3 words of data file
15 14 13 0
EN TT DN INTERNAL USE ONLY 0
Preset Value (PRE) 1
Accumulated Value (ACC) 2
Addressable Bits
EN - timer enabled bit
TT - timer timing bit
DN - timer done bit
Word 0 - control word I/O bits and Internal control
Word 1 - preset value
Word 2 - accumulated value
Data Structure is the same for on-delay and off-delay timers
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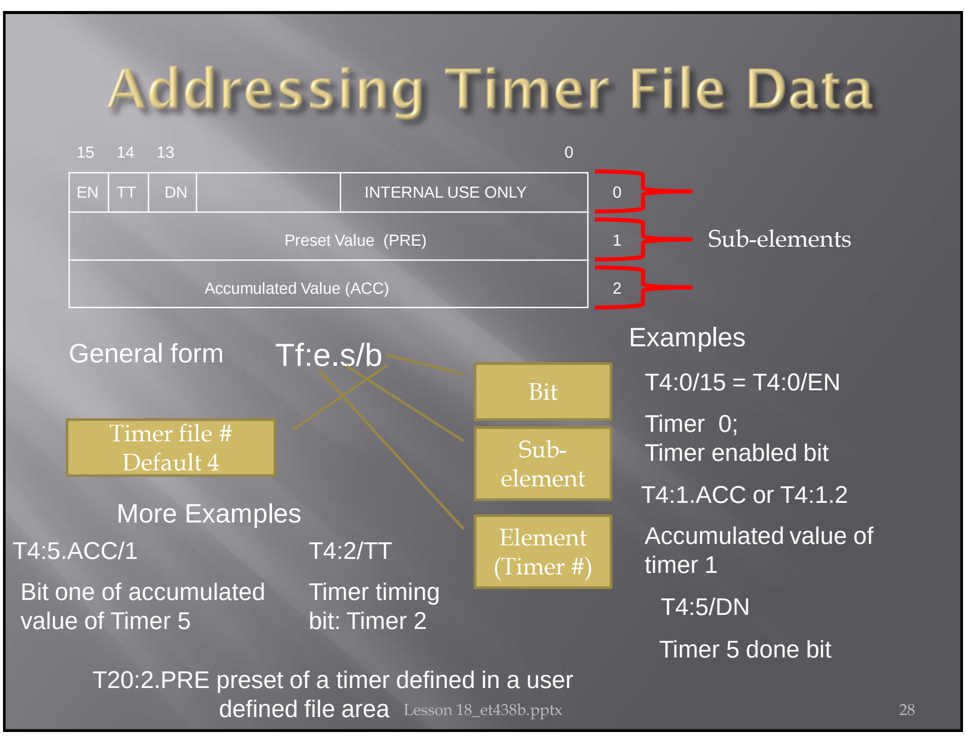
Addressing Timer File Data
15 14 13 0
EN TT DN INTERNAL USE ONLY 0
Preset Value (PRE) 1
Accumulated Value (ACC) 2
Sub-elements
General form
Tf:e.s/b
Timer file #
Default 4
Bit
Sub-element
Element
(Timer #)
Examples
T4:0/15 = T4:0/EN
Timer 0;
Timer enabled bit
T4:1.ACC or T4:1.2
Accumulated value of timer 1
T4:5/DN
Timer 5 done bit
More Examples
T4:5.ACC/1
Bit one of accumulated value of Timer 5
T4:2/TT
Timer timing bit: Timer 2
T20:2.PRE preset of a timer defined in a user defined file area
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Counter File Structure

File 5 - Counters

Each counter defined by three words in data file

15	14	13				0	
CU	CD	DN	OV	UN	UA	INTERNAL USE ONLY	0
Preset Value (PRE)							1
Accumulated Value (ACC)							2

Word 0 - control word I/O bits and Internal control
Word 1 - preset value
Word 2 - accumulated value

Addressable Bits

CU - counter up enabled bit
CD - counter down enabled bit
DN - counter done bit
OV - counter overflow bit
UN - counter underflow bit
UA - update accumulated value (only certain models)
PRE - preset value
ACC -accumulated value

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COUNTER FILE STRUCTURE

15	14	13				0	
CU	CD	DN	OV	UN	UA	INTERNAL USE ONLY	0
Preset Value (PRE)							1
Accumulated Value (ACC)							2

General form Cf:e.s/b

Counter file # Default 5

Bit

Sub-element

Element (Counter #)

More Examples

C20:2.PRE

Preset of a counter defined in a user defined file area

Examples

C5:0/15 = C5:0/CU

Counter 0 count up bit

C5:1.ACC or C5:1.2

Accumulated value of counter

C5:5/DN

Counter 5 done bit

C5:5.ACC/1

Bit 1 of accumulated value of counter 5

C5:2/CD

Count down enable bit for counter 2

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Control And Integer Files

File 6 -Control File

Used to store status information for bit operations and stack control operations

File 7 – Integer Data

Integer Data types
Signed integer (16 bit): range 0 -+- 32767
Unsigned integer (16 bit) range 0 - 65535

Addressing Integer values
Each integer requires 1 word

N7:n

Word identifier

Integer data Type

File ID Number

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End Lesson 18: Introduction to Programmable Logic Controllers

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