CEC Continuing Education Center

DesignNews

Understanding Industrial Controls with an ESP32

Day 4: OpenPLC and ESP32 Industrial Controls-Part 1

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Dr. Don Wilcher

Visit ‘Lecturer Profile’ in your console for more details.

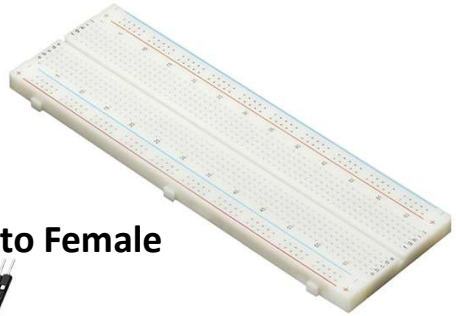
Course Kit and Materials

ESP32-DEVKITC-VIE

Adafruit Parts Pal Kit

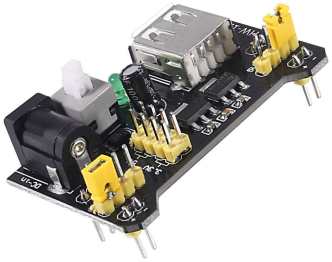
Jumper Wires: Male to Male

Solderless Breadboard x2



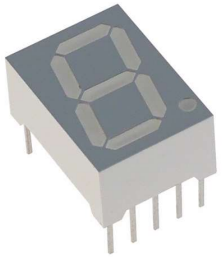
Jumper Wires: Male to Female

Solderless Breadboard Power Supply



5V Relay Module, 5V Indicator Light LED

7 Segment LED Display, Common Cathode



Standard Motor, 9100 RPM 6VDC

Agenda:

- OpenPLC Introduction
- Programmable Logic Controller (PLC) Architecture
- OpenPLC Software Set Up
- Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller

Research Perspective

"Programmable logic controllers (PLCs) provide an ecosystem of relatively simple software logic, robust and ruggedized hardware, networks with controllable real-time behaviors, and extensive availability of interoperable components such as sensors and actuators" (Sehr et al., 2021).

Course Question
Can an ESP32 microcontroller contribute to the Industrial Controls field?

OpenPLC Introduction

- OpenPLC is an open-source industrial control platform that allows the transformation of:
  a) popular microcontrollers into a programmable logic controller (PLC).
  b) Raspberry Pi Single Board Computers (SBCs) into a PLC.
- OpenPLC is a fully functional open-source PLC based on the International Electrotechnical Commission (IEC standard 61131-3 on Functional Programmable Languages.

OpenPLC Introduction. . .

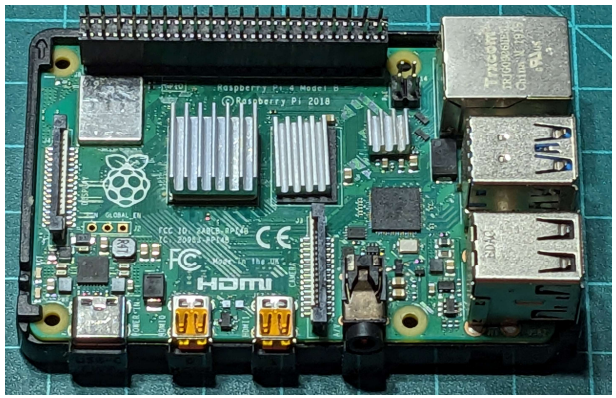
- There are five functional programming languages associated with the IEC standard.
  a) Structured Text (ST) (Text based)
  b) Instruction List (IL) (Text based)
  c) Ladder Diagram (LD) (Graphical based)
  d) Sequence Function Chart (SFC) (Graphical based)
  e) Function Block Diagram (FBD) (Graphical based)
- The most common programming language used with the PLC is the LD.

OpenPLC Introduction. . .

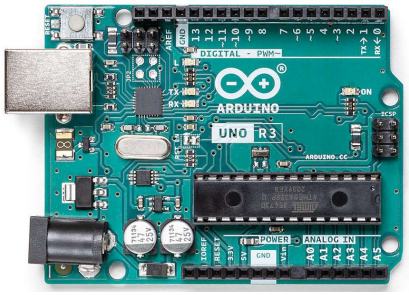
- The technical development path of the OpenPLC platform consisted of several iterative versions of the open-source programming language toolchain.
- OpenPLC Version 3 provides support for a variety of embedded devices and platforms like:
  a) Arduino varieties
  b) ESP32
  c) ESP8266
  d) Raspberry Pi

OpenPLC Introduction. . .

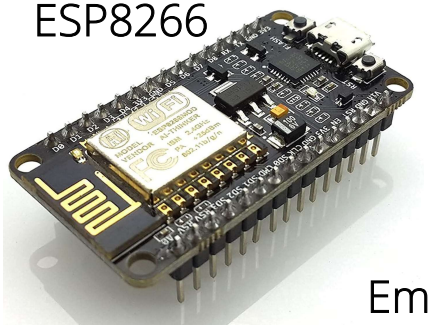
Raspberry Pi 4B



Arduino Uno

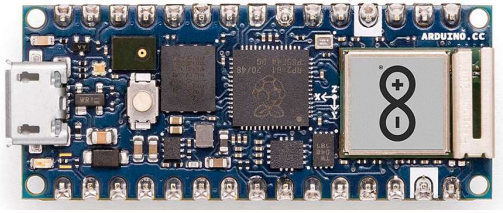


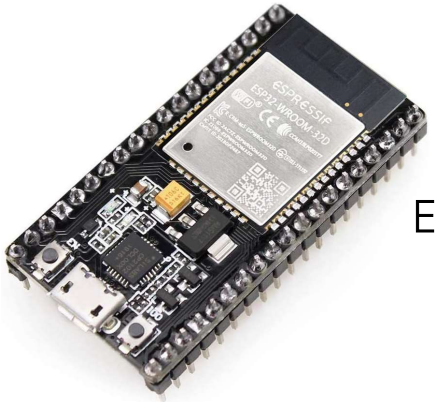
ESP8266



Embedded Devices and Platforms Supported by OpenPLC

Arduino Nano RP2040 Connect





ESP32

Question 1

Which embedded device is not supported by OpenPLC Version 3?

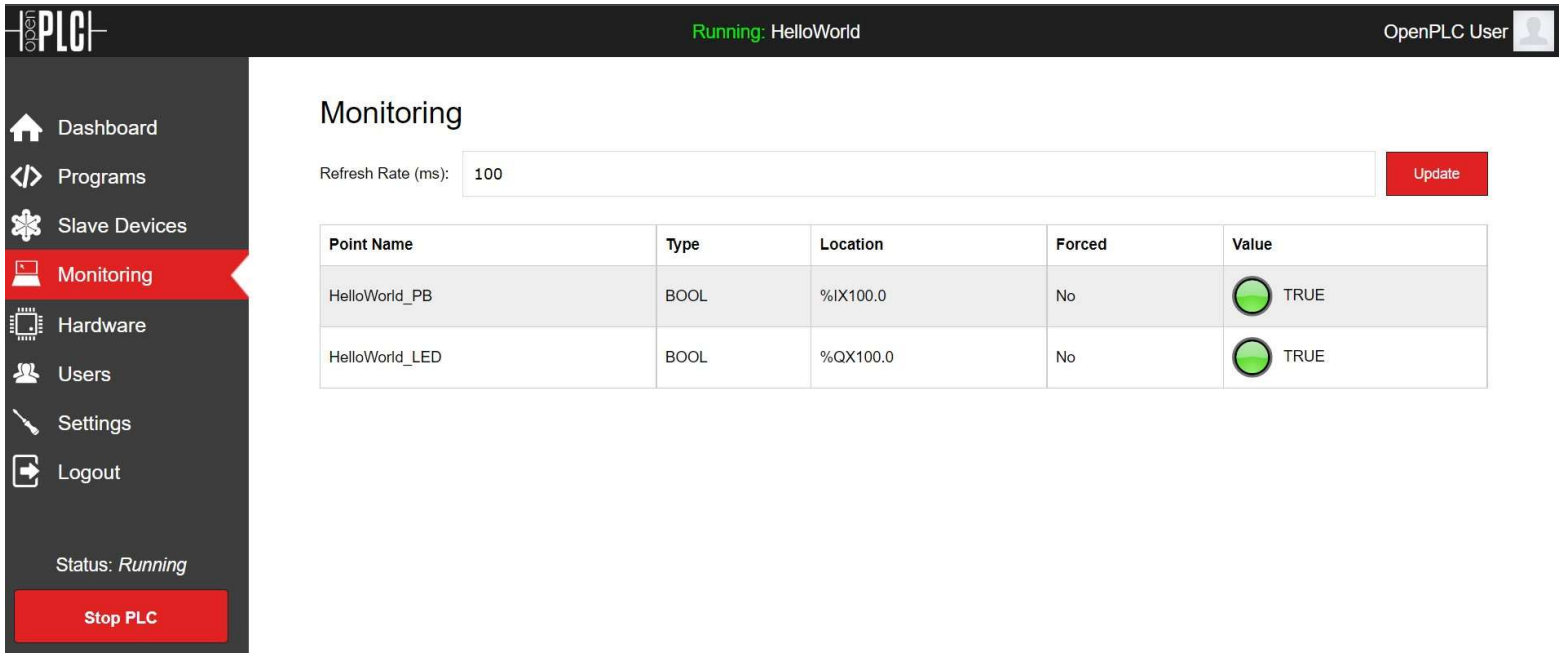
a) Arduino varieties
b) nRF51822
c) ESP32
d) ESP8266

OpenPLC Introduction. . .

- OpenPLC Version 3 software can run ST code on a target Microchip ATMEGA32 8-bit microcontroller.
- A runtime feature allows installing C-code on the Raspberry Pi.
- The runtime feature provides a dashboard to display the Raspberry Pi-based PLC input and output devices.
- The Broadcom (BCM) microcontrollers supported by version 3 software are:
  a) BCM 2711(Raspberry Pi version 4B)
  b) BCM 2937(Raspberry Pi version 3B)

OpenPLC Introduction. . .

Example OpenPLC Runtime Environment



Programmable Logic Controller (PLC) Architecture

- A typical PLC can be divided into five components.
  a) Central Processing Unit (CPU)
  b) Input/Output Devices
  c) Optoisolators
  d) Memory
  e) Power Supply
- The term architecture refers to the PLC physical components or hardware.
- There are two types of architecture: Open and Closed

Programmable Logic Controller (PLC) Architecture. . .

What are Open and Closed Architecture Systems?

- An Open Architecture consists of off-the-shelf components that conform to an approved standard.
- A Closed Architecture is a proprietary system.
- Proprietary systems are difficult to connect due to using non-off-the-shelf components.

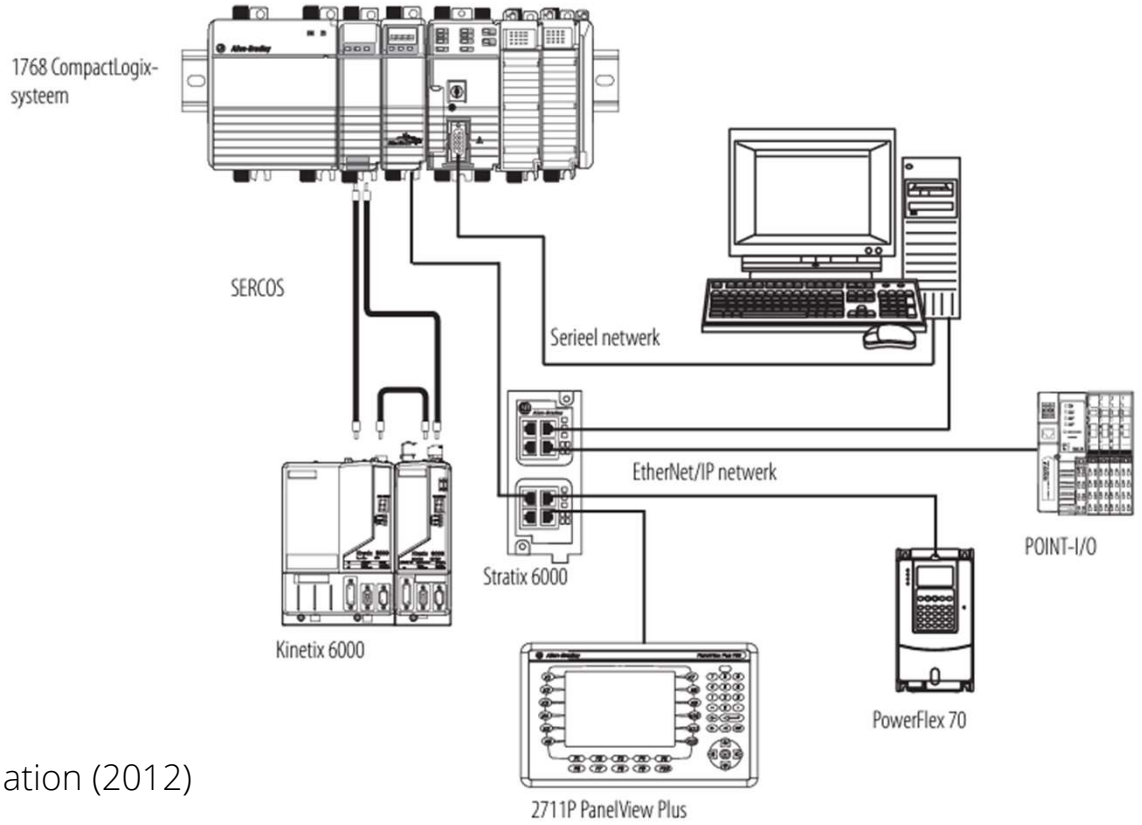
Programmable Logic Controller (PLC) Architecture. . .

Classical Examples of Open Architecture Systems

IBM PC

Apple IIc

Programmable Logic Controller (PLC) Architecture. . .



Example of Open Architecture PLC System

Rockwell Automation (2012)

Programmable Logic Controller (PLC) Architecture. . .

Examples of Closed Architecture Systems

Apple iPhone

Samsung Tablet

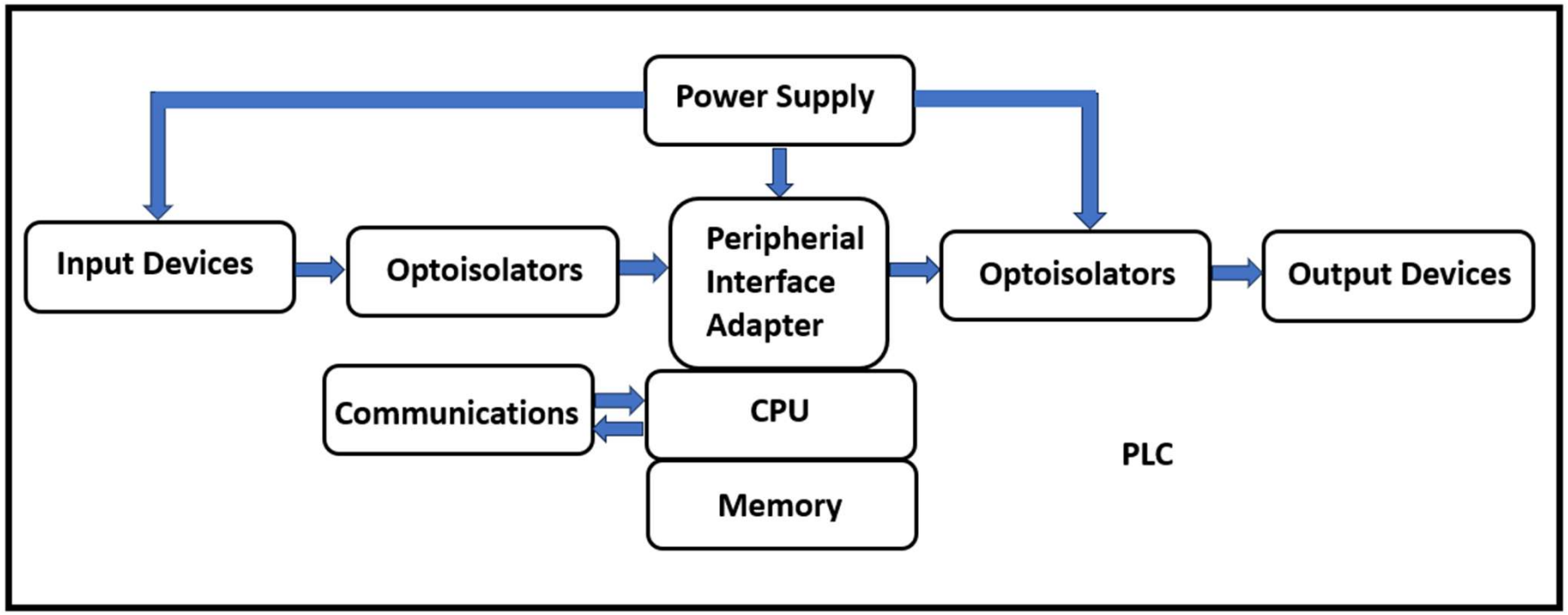
Programmable Logic Controller (PLC) Architecture. . .

Example of A Closed PLC Architecture System

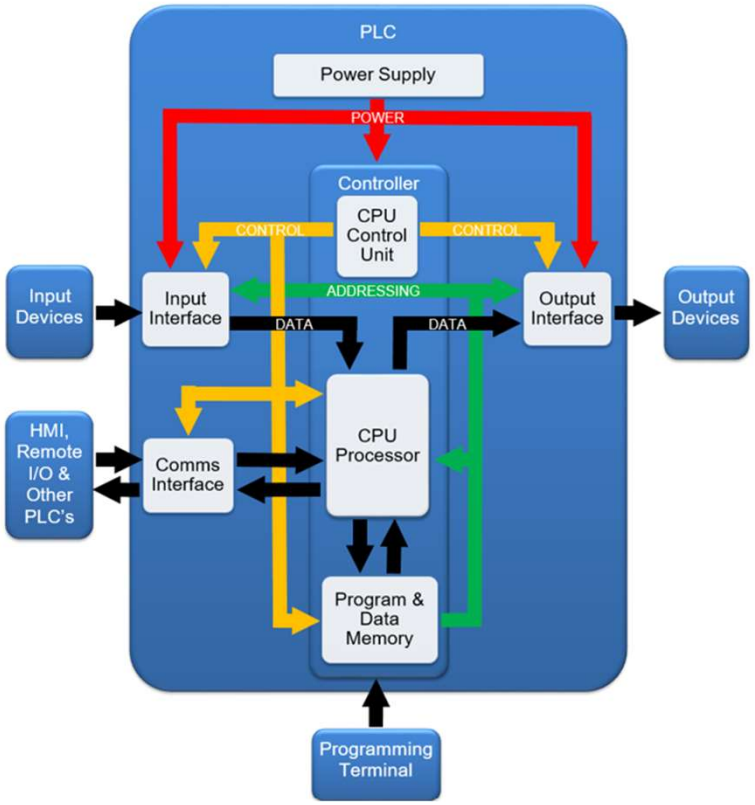
ABB (n.d.)

Programmable Logic Controller (PLC) Architecture. . .

Top Level Design



Programmable Logic Controller (PLC) Architecture. . .

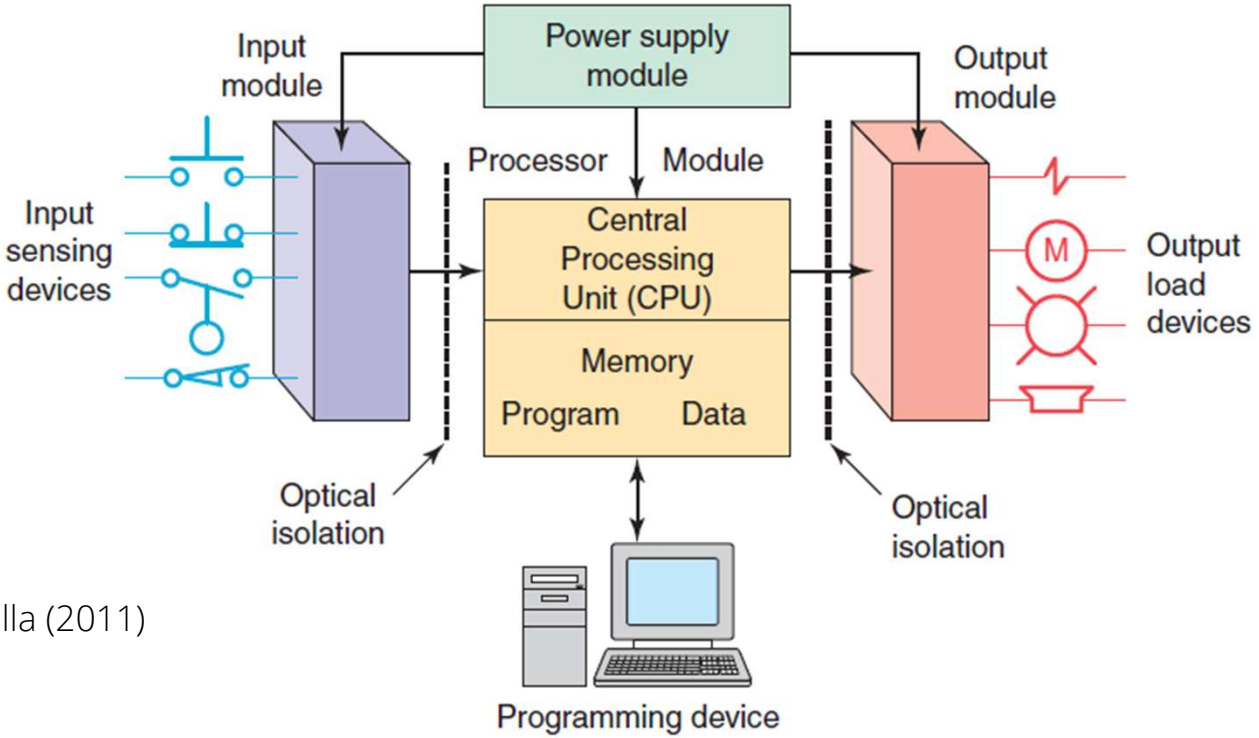


Top Level Design

LadderLogicWorld (n.d.)

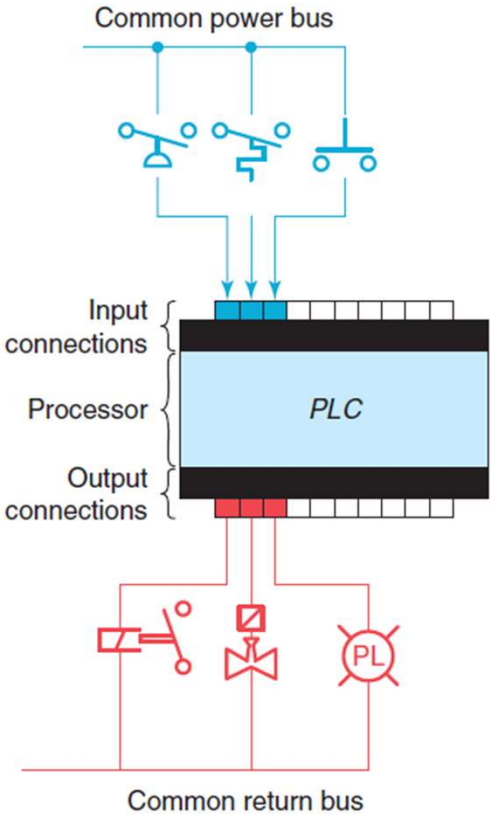
Programmable Logic Controller (PLC) Architecture. . .

Component Level Design)



Petruzella (2011)

Programmable Logic Controller (PLC) Architecture. . .



Input/Output Configuration

Petruzella (2011)

Question 2

What is an Open Architecture System?

a) A system that uses off-the-shelf components that conform to an approved standard.

b) A system that uses special components that conform to an approved standard.

c) A system that is difficult to connect due to using non-off-the-shelf components.

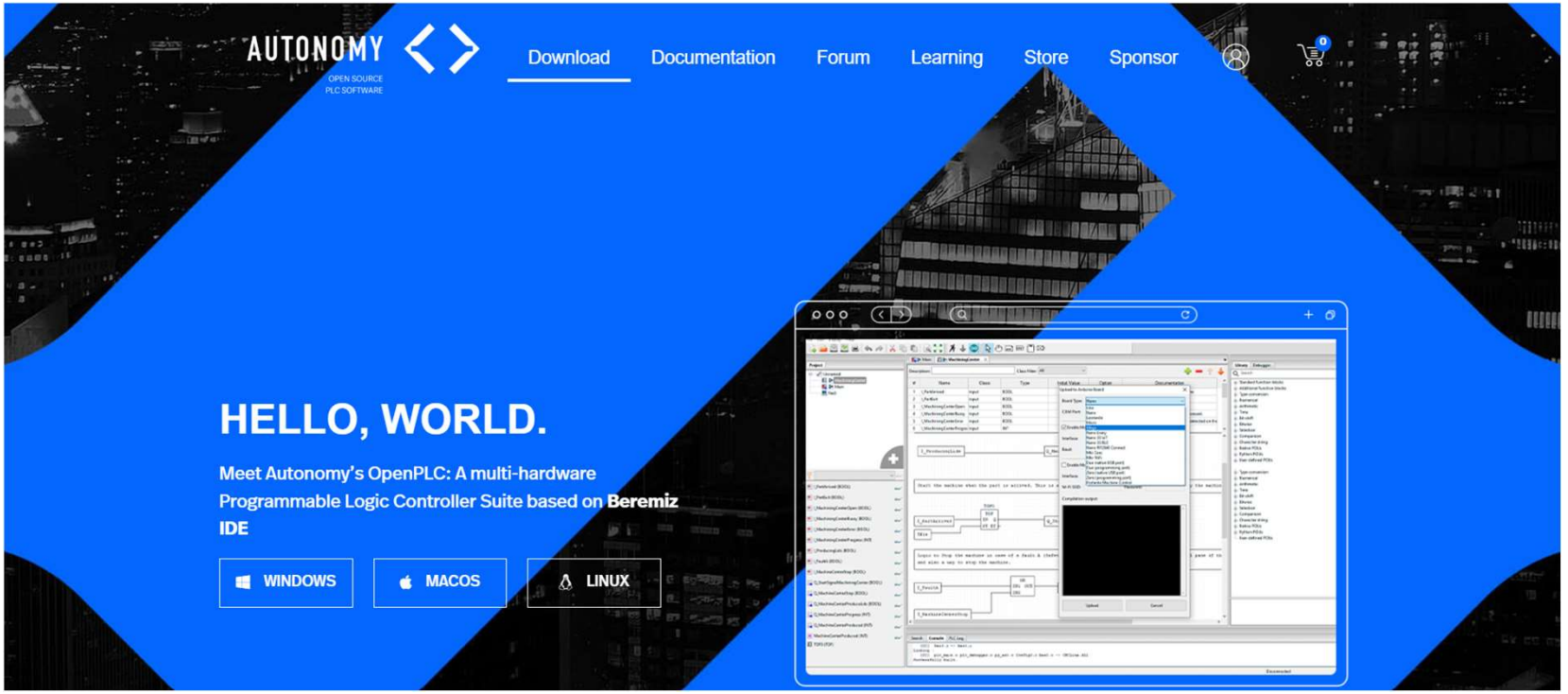
d) none of the above

OpenPLC Software Set Up

Steps:

1. The first step in setting up the OpenPLC platform is downloading the software.
2. Go to the Autonomy website to obtain the OpenPLC software.
   https://autonomylogic.com/
3. Download and Install the OpenPLC software on your development machine.
4. Run the OpenPLC software on your development machine.
5. Build your ladder diagram (LD) (ladder logic program).
6. Download the LD to the ESP32.
7. Test the LD on the ESP32.

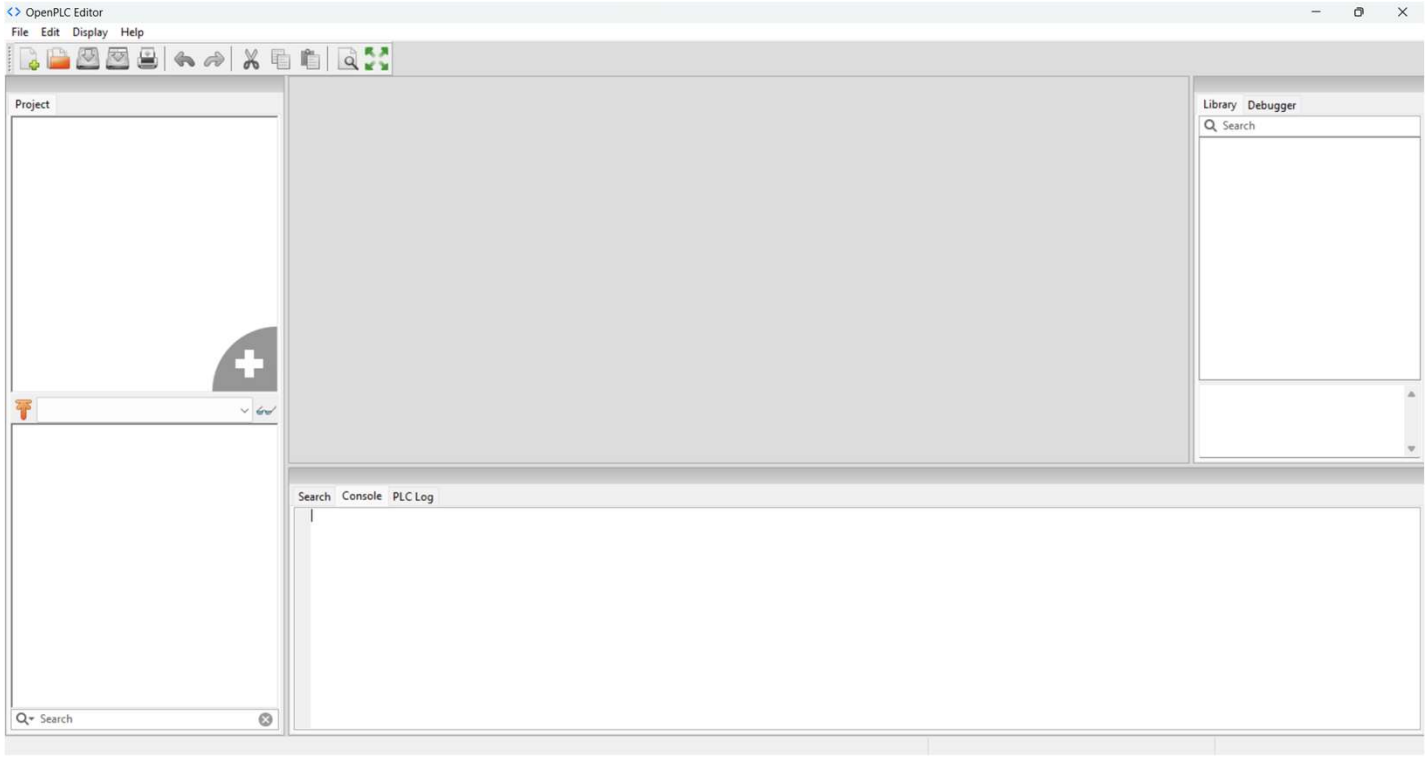
OpenPLC Software Set Up. . .



Autonomy-OpenPLC website

OpenPLC Software Set Up . . .

Step 4: Run the OpenPLC software on your development machine.



OpenPLC Software Set Up . . .

Step 4: Run the OpenPLC software on your development machine.

ESP32 GPIO-Physical Addressing

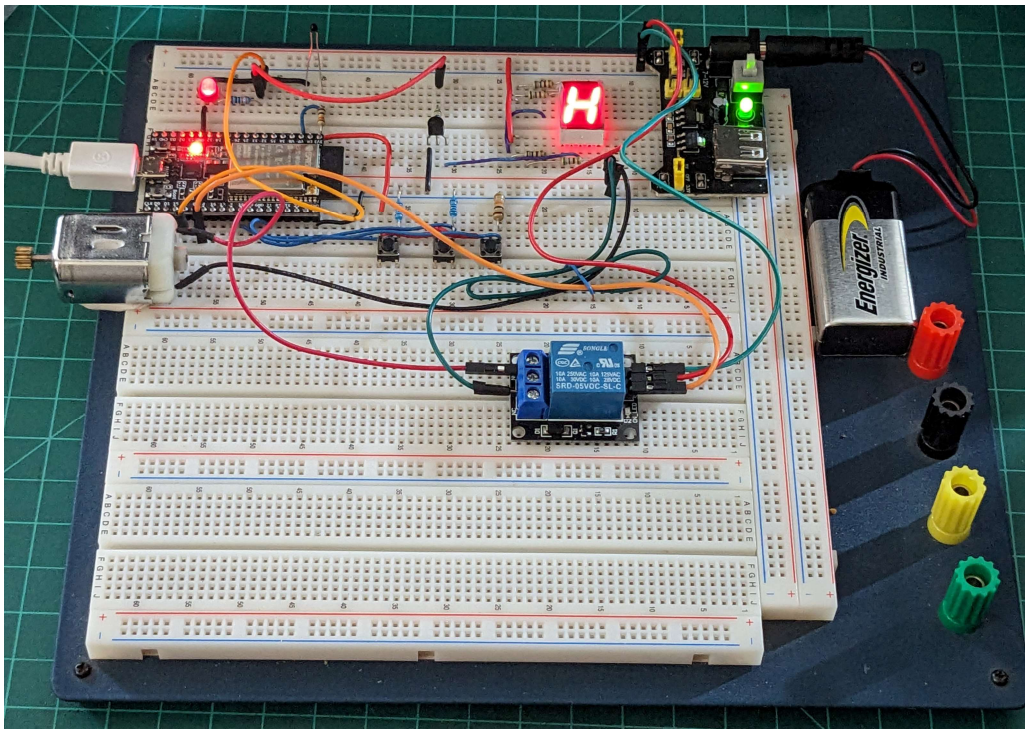
esp32		
Digital In	17, 18, 19, 21, 22, 23, 27, 32 33	%IX0.0 - %IX0.7 %IX1.0 - %IX1.0
Digital Out	01, 02, 03, 04, 05, 12, 13, 14 15, 16	%QX0.0 - %QX0.7 %QX1.0 - %QX1.1
Analog In	34, 35, 36, 39	%IW0 - %IW3
Analog Out	25, 26	%QW0 - %QW1

Question 3

On slide 29, what is the physical address for GPIO pin 5?

a) %QX0.4
b) %QX0.0
c) %QX0.5
d) none of the above

Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller

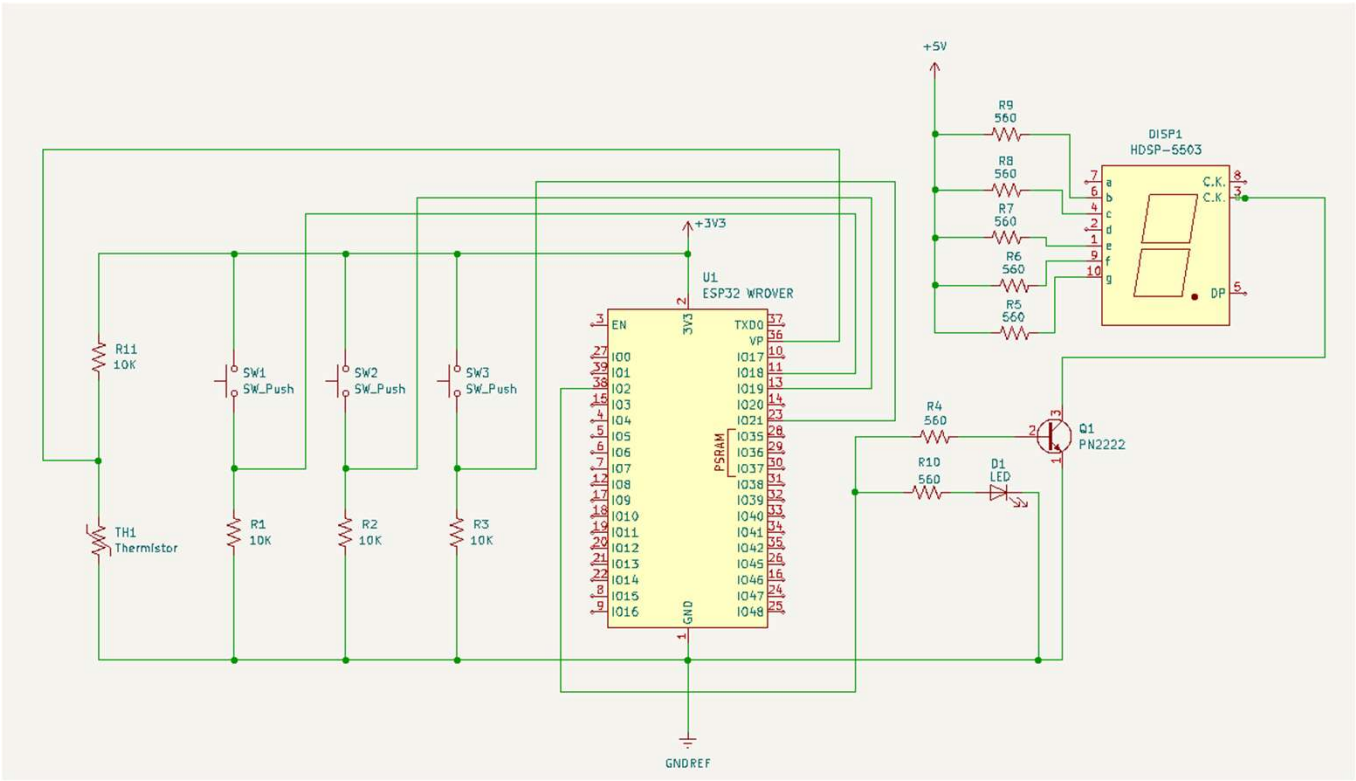


Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

Participant Learning Objectives:

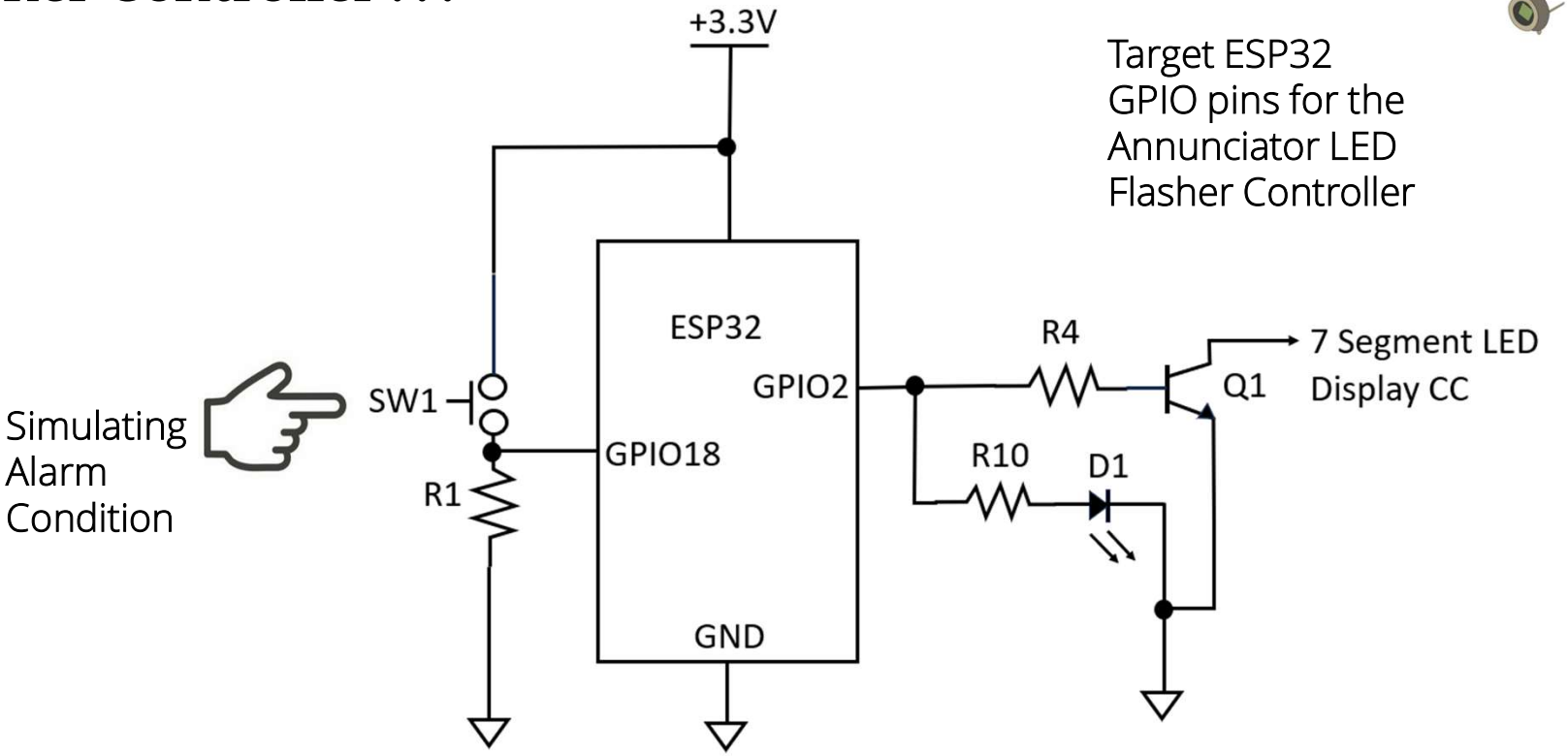
- Participants will learn to modify the OpenPLC Blink LD to detect a pushbutton switch actuation.
- Participants will learn to assign Physical I/O addresses to an ESP32 microcontroller GPIO pins.
- Participants will learn to transfer the modified Blink LD to the ESP32 microcontroller.
- Participants will learn to test the Annunciator LED Flasher Controller on the ESP32 Micro Trainer.

Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .



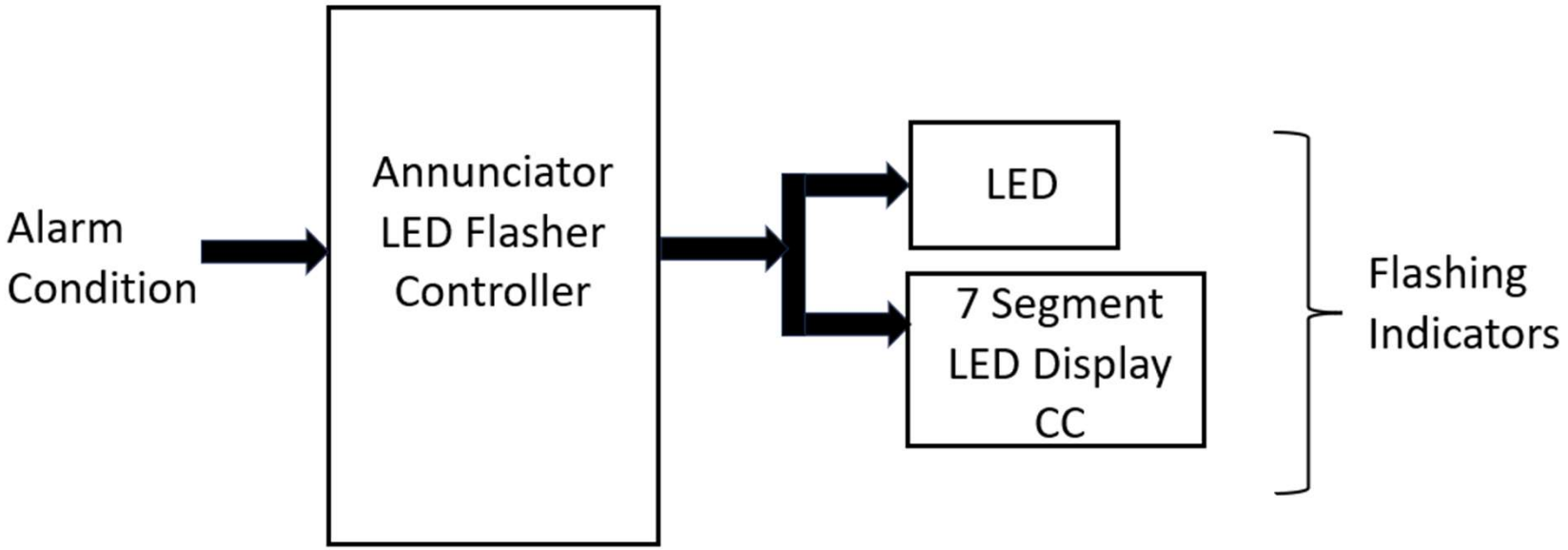
Partial ESP32 Micro Trainer Electronic Circuit Schematic Diagram

Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller . . .



Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

Concept Block Diagram



Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

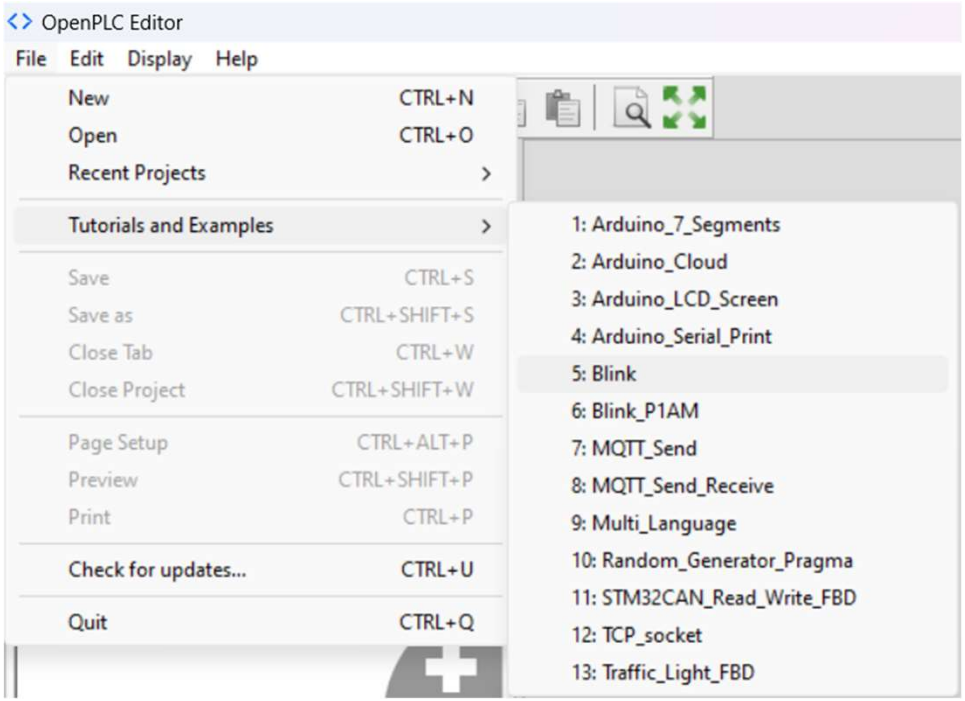
Building the Annunciator LED Controller

Steps:

1. Create a project folder.
2. Name the folder “Annunciator_LED_Controller
3. Open OpenPLC software
4. Click on Files>Tutorial and Examples>Blink

Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

Step 4:



Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

This panel will appear on the Screen:

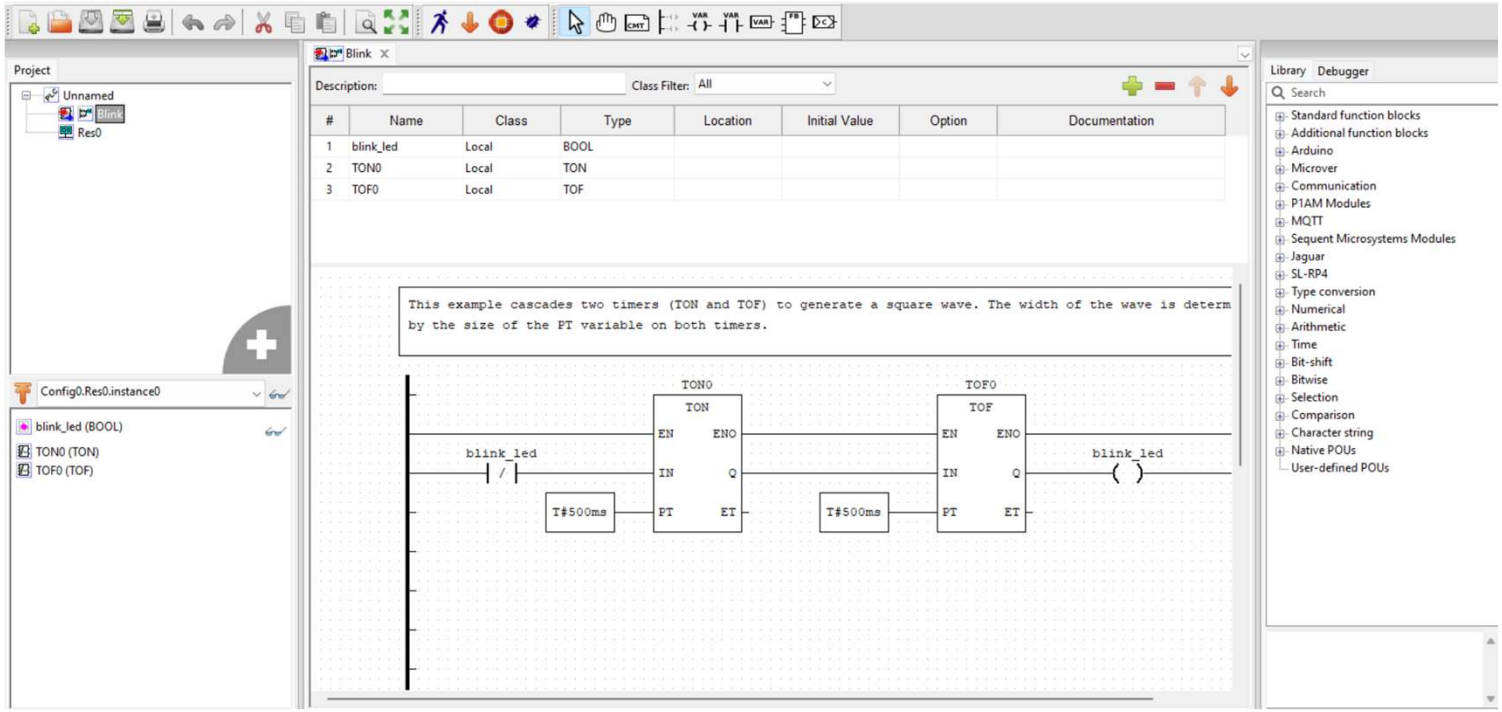
Question 4

What is the name of the LD used to create the Annunciator LED Flasher Controller?

a) Flasher
b) Blinker
c) Switcher
d) Blink

Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

The OpenPLC Editor with the Blink LD will appear on the Screen:



Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

Creating a Tag – "Alarm_Condition":

A "blink_led0" tag will be created and placed on the spreadsheet listing.

Click the "+" sign

Description: Class Filter: All

#	Name	Class	Type	Location	Initial Value	Option	Documentation
1	blink_led	Local	BOOL				
2	blink_led0	Local	BOOL				
3	TON0	Local	TON				
4	TOF0	Local	TOF				

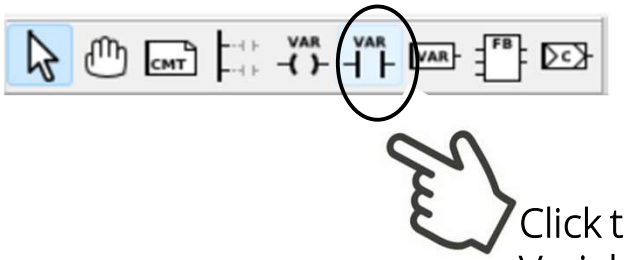
Double-click in the blink_led0 cell. Rename the tag as "Alarm_Condition".
Click on the Save As and rename the LD as "Annunciator_LED_Controller". Save the rename LD in the Annunciator_LED_Controller folder.

Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

Alarm_Condition Tag is created!

Description: Class Filter:

#	Name	Class	Type
1	blink_led	Local	BOOL
2	Alarm_Condition	Local	BOOL
3	TON0	Local	TON
4	TOF0	Local	TOF

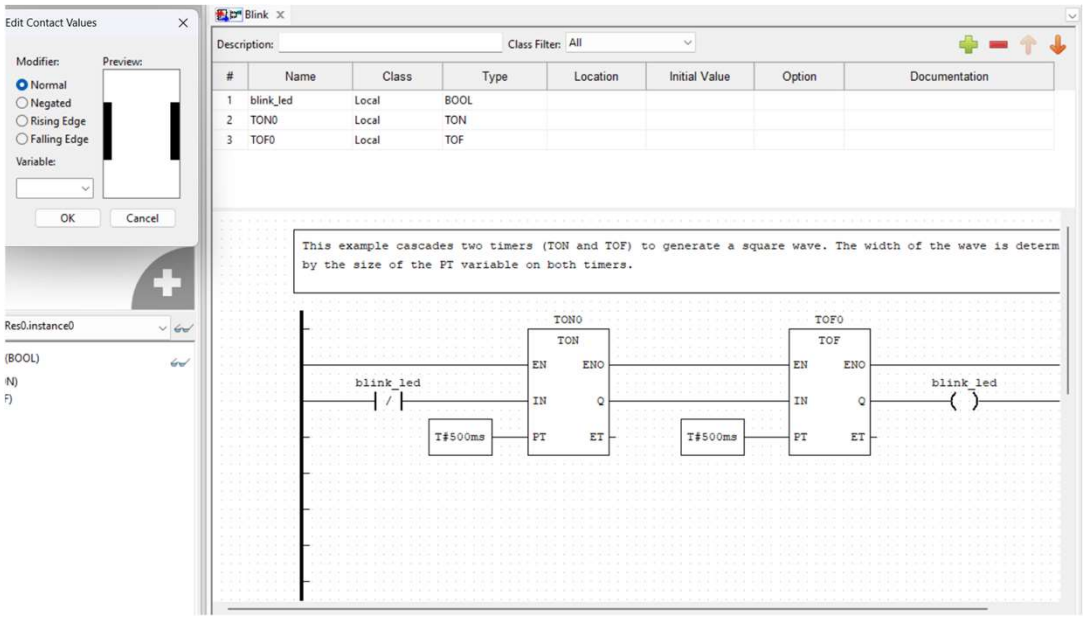


Click this Variable (VAR) Contact symbol

The OpenPLC Editor with the Blink LD will appear on the Screen:

Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

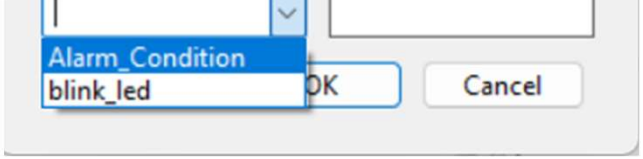
Click anywhere within the Blink LD editor, the following pane will be displayed on the screen.



Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

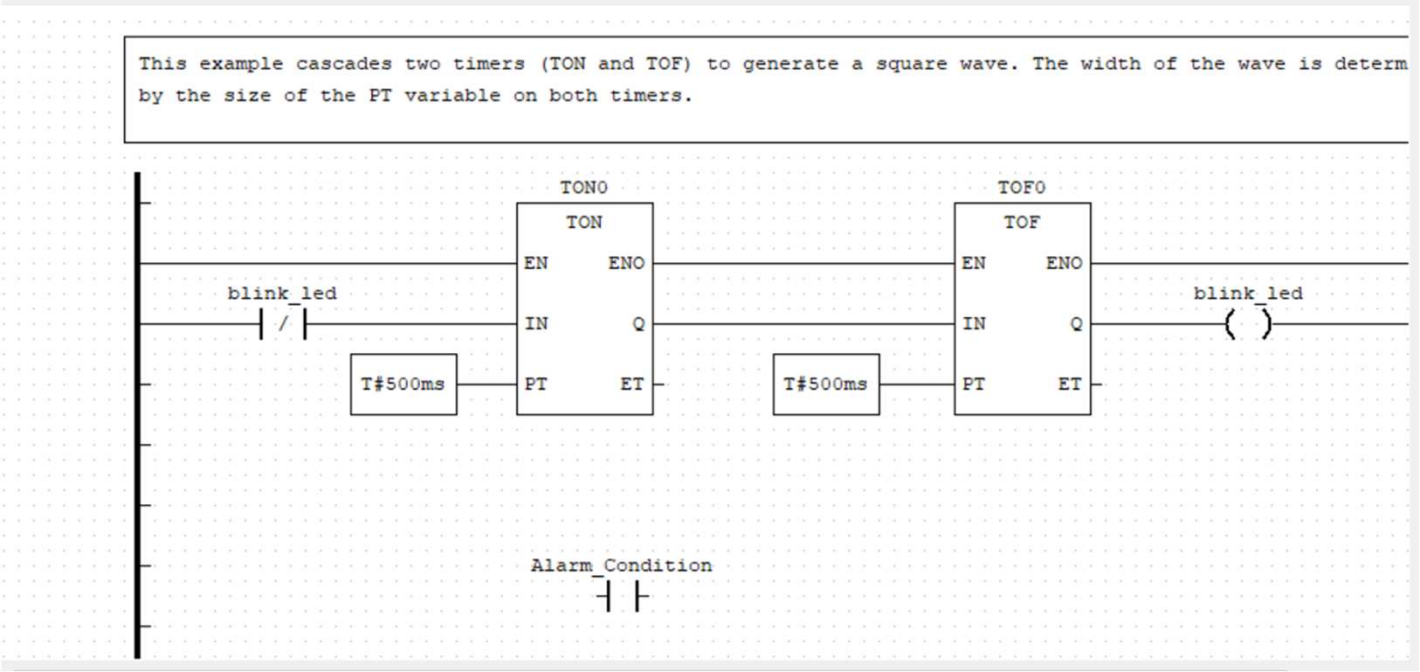
Assigning Alarm_Condition tag to the VAR Contact:

Click the Down arrow button and select Alarm_Condition. Click the OK button.



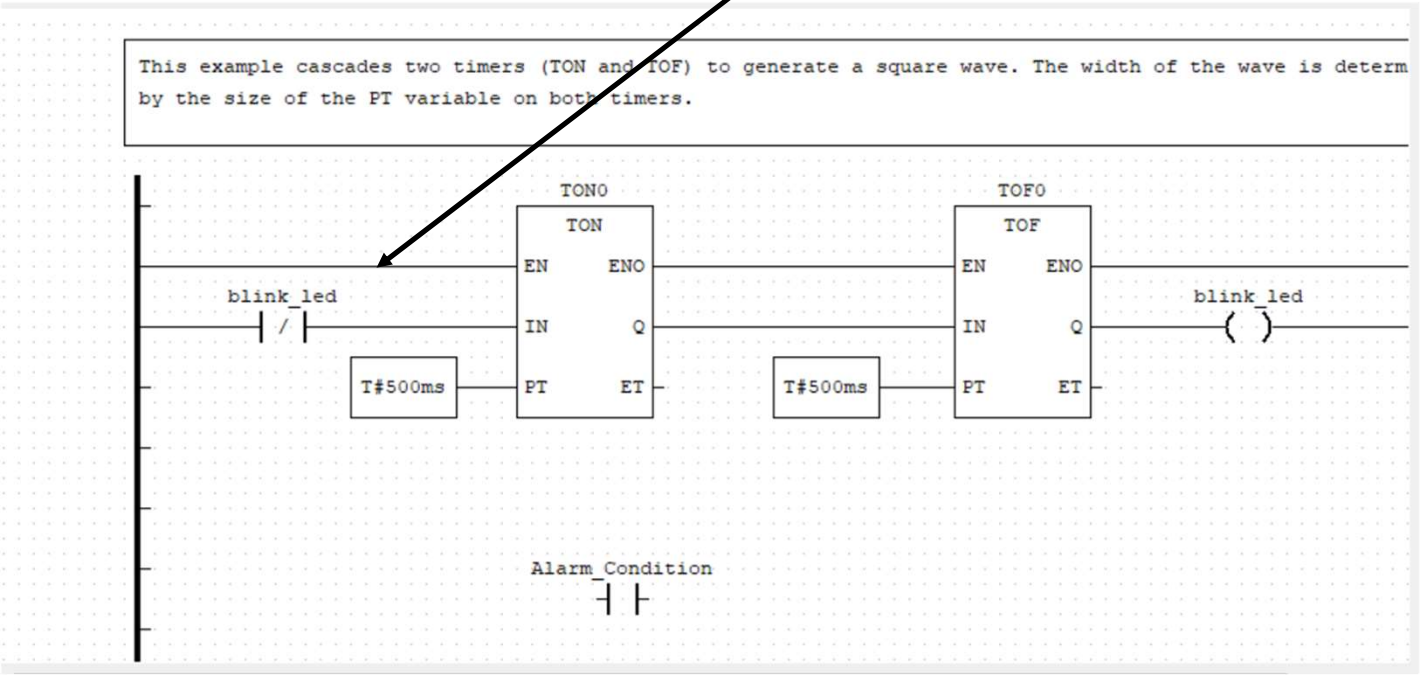
Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

Alarm_Condition VAR Contact will be placed on the LD:



Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

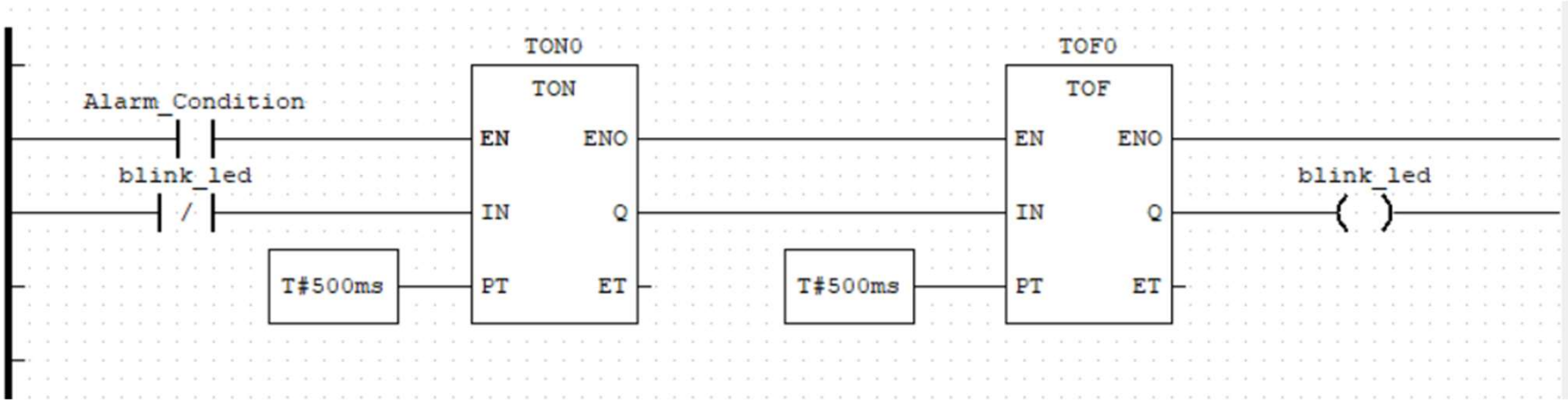
Delete the "EN" line.



Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

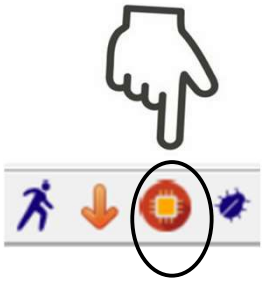
Wiring the Alarm_Condition VAR Contact to the TON timer:

Click on the left side of the VAR contact and drag a line to the left power rail. Click on the right side of the VAR contact and drag a line to the TON EN input.

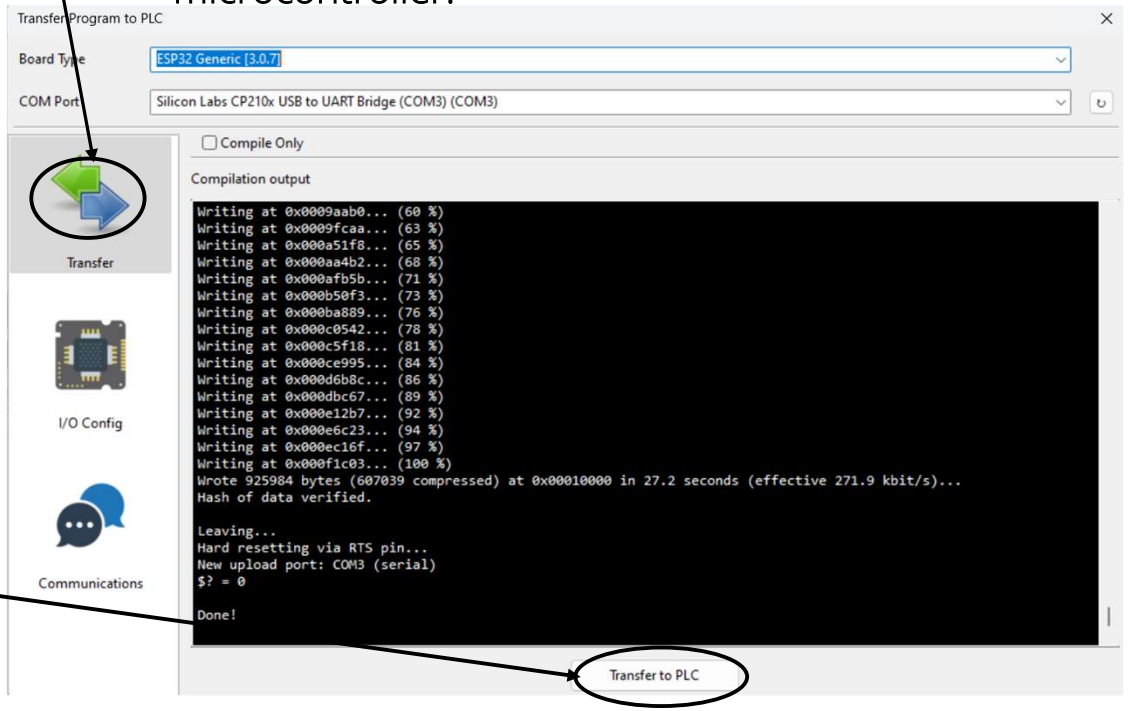


Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

1 Click the Transfer program to PLC icon



Click the Transfer icon to select the Board type and the COM port to connect with the ESP32 microcontroller. 2



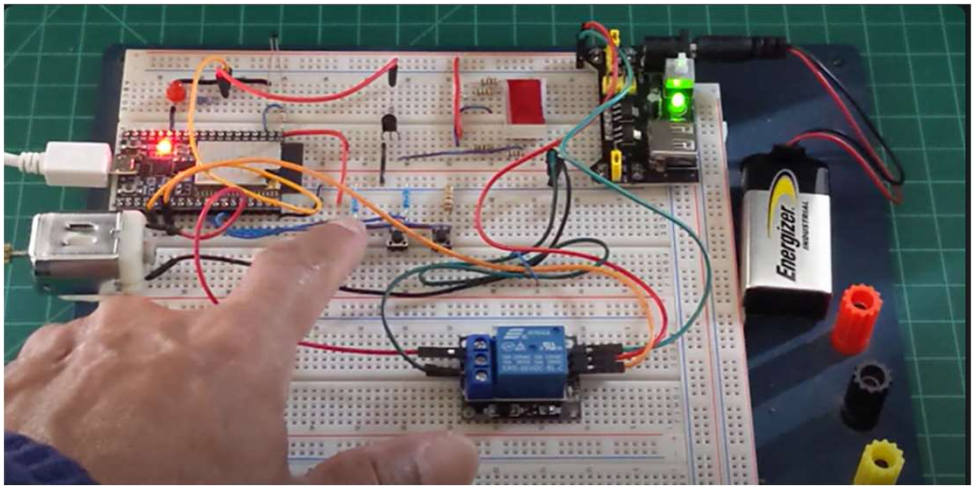
3 Click the Transfer to PLC button to load the Annunciator LD to the ESP32 microcontroller.

Note:
The first time transferring the LD to the ESP32 will take several minutes, depending on the various software packages that are installed.

Lab: Build An ESP32 OpenPLC Annunciator LED Flasher Controller. . .

Press the SW1 pushbutton switch The LED and the 7-Segment LED display (letter H) will flash. Releasing the pushbutton switch, both visual devices will stop flashing.

Functional ESP32 OpenPLC Annunciator LED Flasher Controller



Watch the Video Clip!

https://www.youtube.com/watch?v=PF_OoM2oZvQ

Question 5

What symbol was used to create the Alarm_Condition tag?

a) VAR Coil
b) FB
c) VAR Contact
d) CMT

Thank you for attending

Please consider the resources below:

ABB. (n.d.). *AC500*. https://new.abb.com/plc/programmable-logic-controllers-plcs/ac500

LadderLogicWorld. (n.d.). *The basics of how plc architectures work*. https://ladderlogicworld.com/plc-architecture/ https://ladderlogicworld.com/plc-architecture/

Petruzella, F. D. (2011). *Programmable logic controllers* (4th ed.) McGraw-Hill.

Rockwell Automation. (2012). *Compactlogix-systeem* [PDF]. https://literature.rockwellautomation.com/idc/groups/literature/documents/sg/1769-sg001_-en-p.pdf

Sehr, M.A, Lohstroh, M., Weber, M., Ugaide, I., Witte, M., Neidig, J., Hoeme, S., Niknami, M., & Lee, E.A. (2021). Programmable logic controllers in the context of industry 4.0. *IEEE Transactions On Industrial Informatics* 17(5), 3523 – 3535. https://ieeexplore.ieee.org/document/9134804

Wilcher, D. (2024). *Understanding industrial controls with an esp32*. GitHub. https://github.com/DWilcher/DesignNews-WebinarCode/blob/main/December_24_Webinar_Code.zip

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