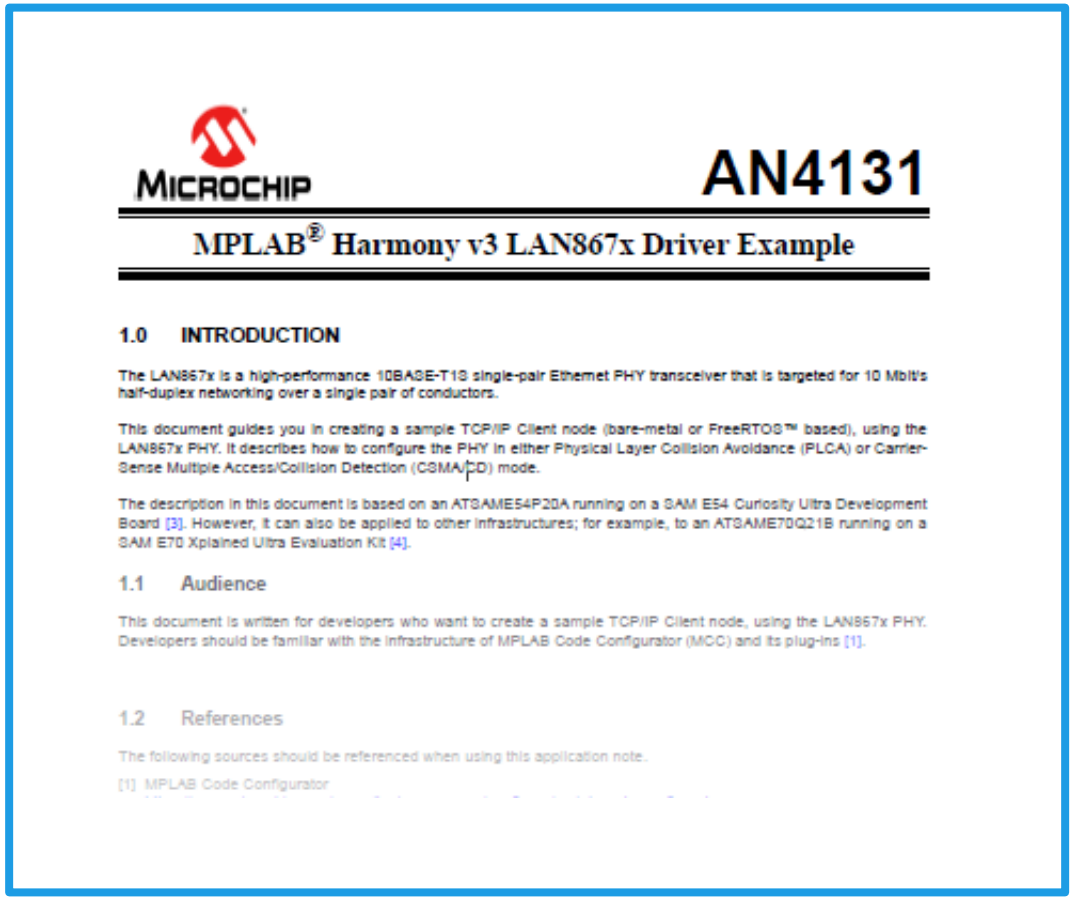
10Base-T1S Hands-On Training

Lab Manual

MICROCHIP

Goal of this Hands-On Class

- Present a demonstration of an example of Single Pair Ethernet communication over 10BASE-T1S
- Use LAN8670 RMII evaluation board with SAME54 Curiosity Ultra
- Based on Application Note AN4131



MICROCHIP

AN4131

MPLAB® Harmony v3 LAN867x Driver Example

1.0 INTRODUCTION

The LAN867x is a high-performance 10BASE-T1S single-pair Ethernet PHY transceiver that is targeted for 10 Mbit/s half-duplex networking over a single pair of conductors.

This document guides you in creating a sample TCP/IP Client node (bare-metal or FreeRTOS™ based), using the LAN867x PHY. It describes how to configure the PHY in either Physical Layer Collision Avoidance (PLCA) or Carrier-Sense Multiple Access/Collision Detection (CSMA/CD) mode.

The description in this document is based on an ATSAME54P20A running on a SAM E54 Curiosity Ultra Development Board [3]. However, it can also be applied to other infrastructures; for example, to an ATSAME70Q21B running on a SAM E70 Xplained Ultra Evaluation Kit [4].

1.1 Audience

This document is written for developers who want to create a sample TCP/IP Client node, using the LAN867x PHY. Developers should be familiar with the infrastructure of MPLAB Code Configurator (MCC) and its plug-ins [1].

1.2 References

The following sources should be referenced when using this application note.

[1] MPLAB Code Configurator

- Link to AN4131 is given here and is also available on LAN8670 Product Page

MICROCHIP

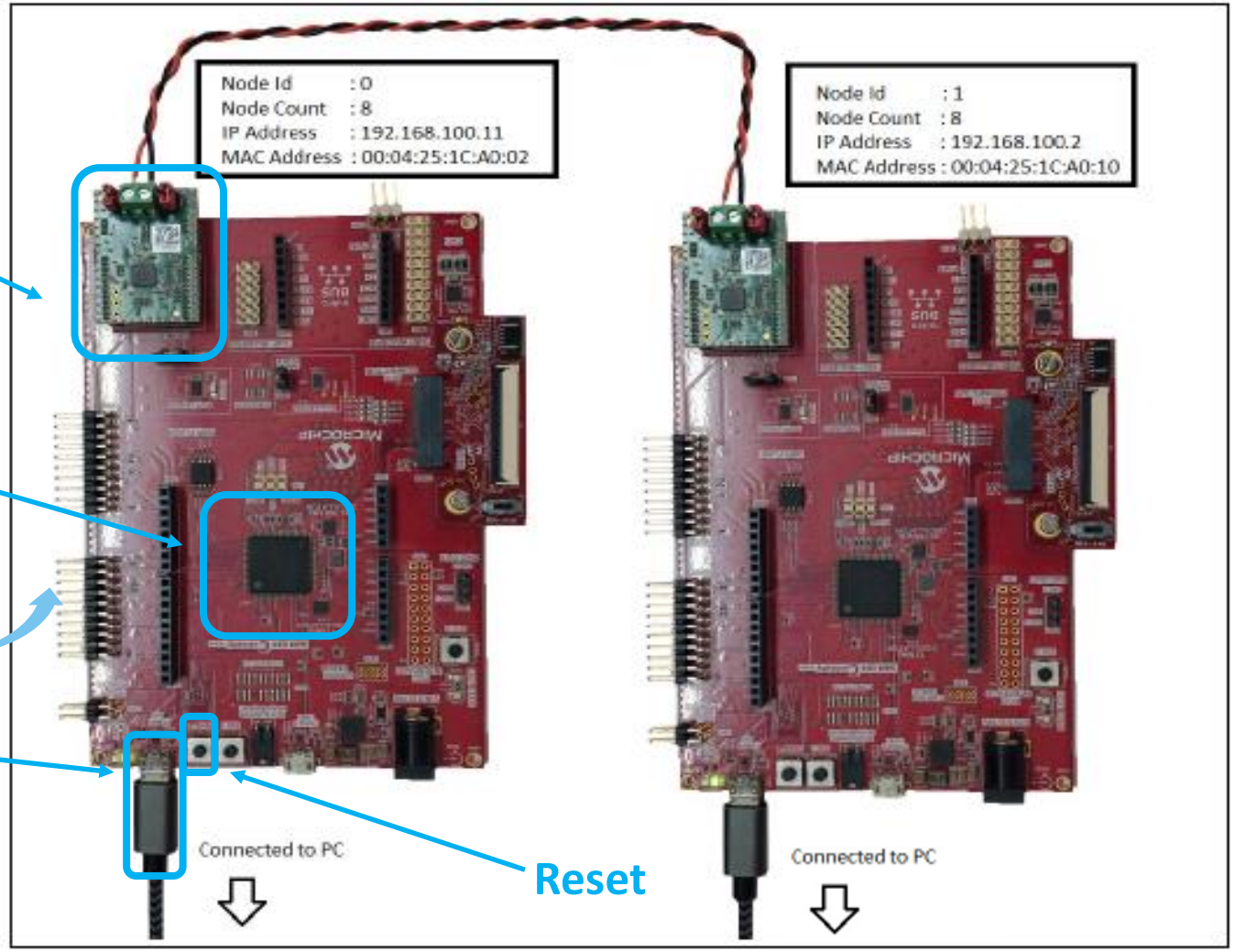
LAN8670 RMII evaluation board with SAME54 Curiosity Ultra

Ethernet Interface with RMII mounted with EVB-LAN8670-RMII to 10BASE-T1S interface card

ATSAME54P20A

On board EDBG debugger

USB Debugger Interface



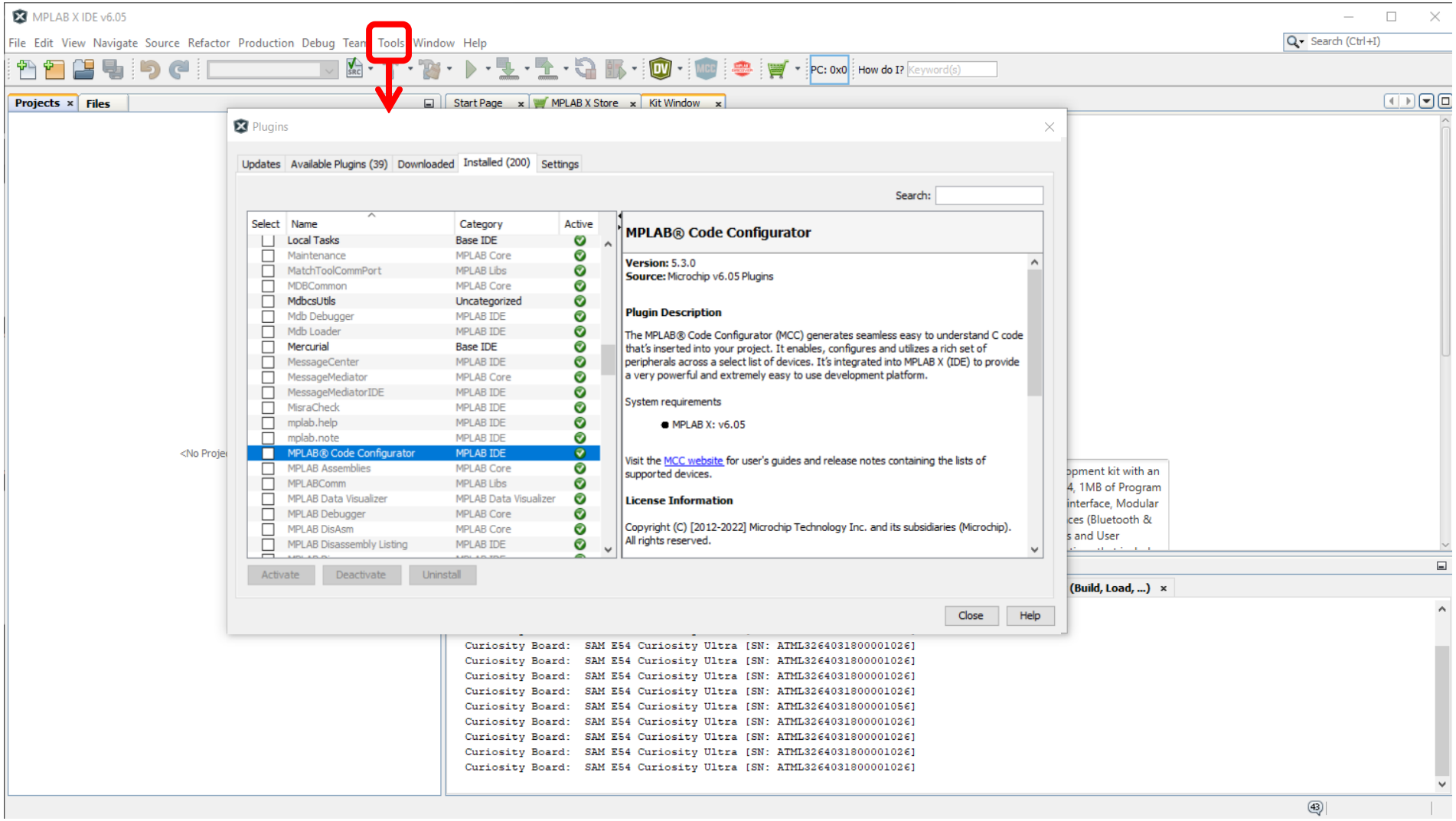
Project Setup

Step-by-Step Guide to Creating the Project

Step 1

Having opened MPLAB X v6.05 (See Useful Links and References) , in **Tools > Plugins,** check that you have MPLAB Code Configurator installed.

If it is not there, look in **Available Plugins** and install it from there.

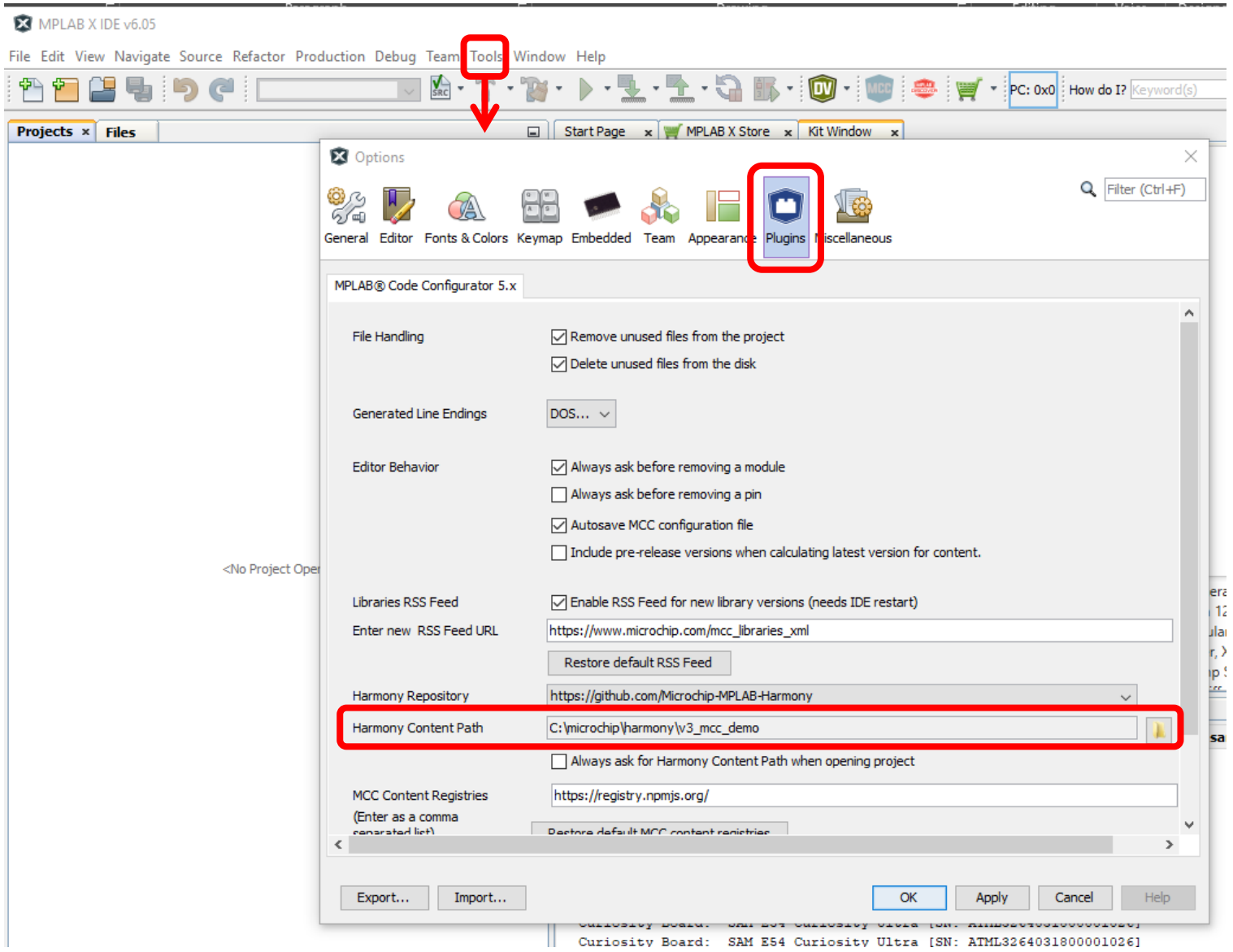


Step 2

In **Tools > Options**, go to the **Plugins** tab.

<u>If you have not used Harmony in the past:</u> In your Folders on your machine you need to create an empty folder where all of the harmony libraries will be downloaded to. Having created this folder, put the folder location in the **Harmony Content Path** in as shown.

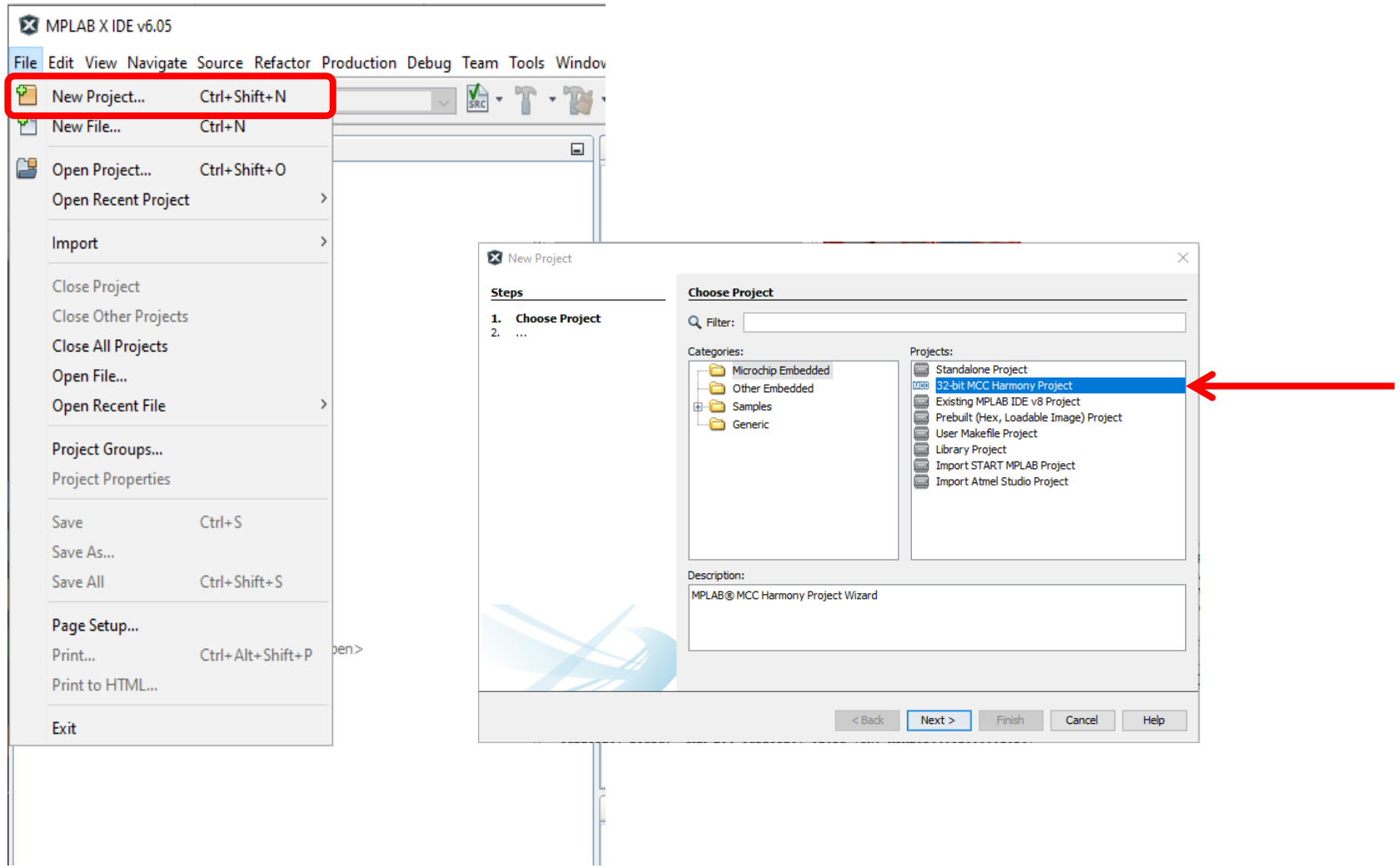
<u>If you are a Harmony user:</u> if you have used Harmony before, you will have already created a repository for all of the libraries, and you can use this same folder for the purposes of this class.



Step 3

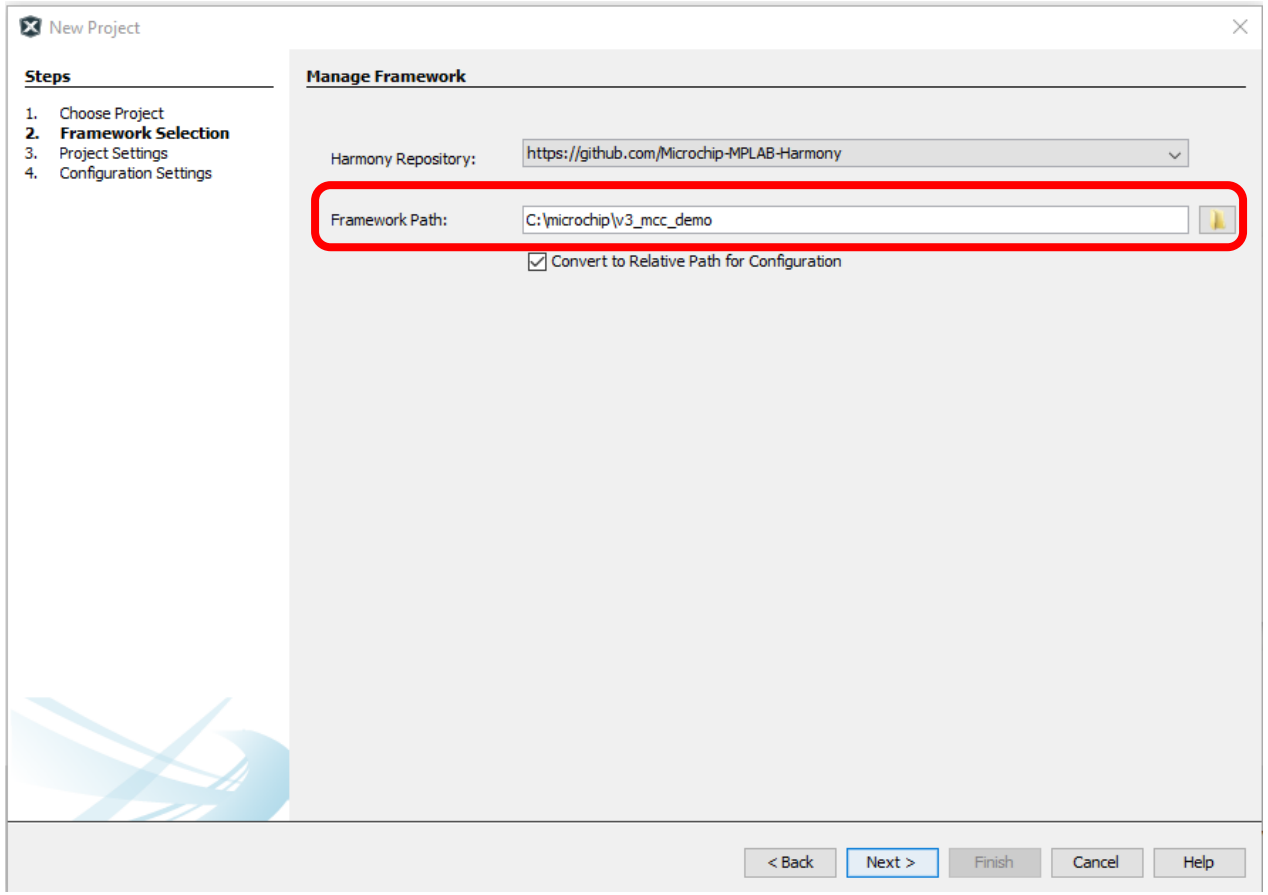
In MPLAB X 6.05, go **File > New Project…**

Select **32-bit MCC Harmony Project** and click **Next>**



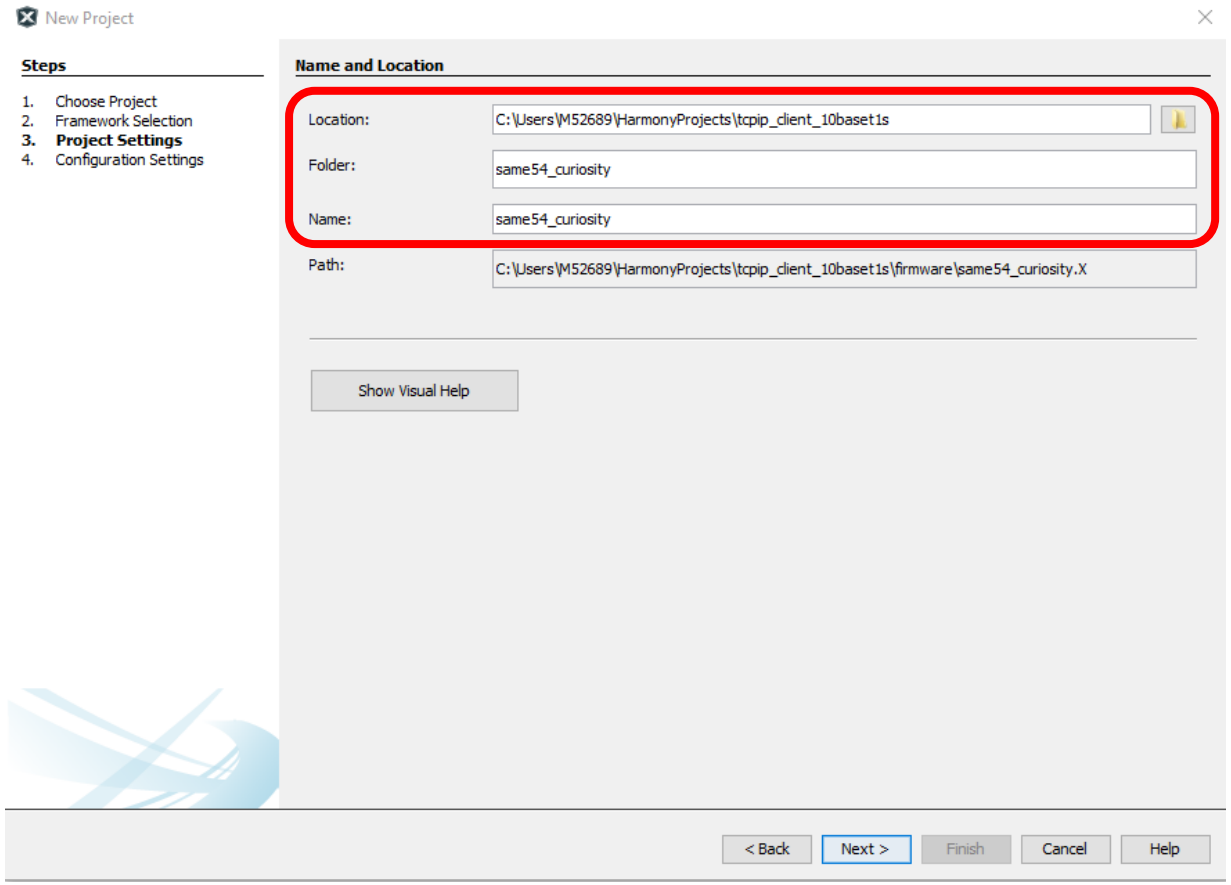
Step 4

The Framework Path needs to be the same as you specified in the Tools>Options>Plugins **Harmony Content Path** in the Step 2.



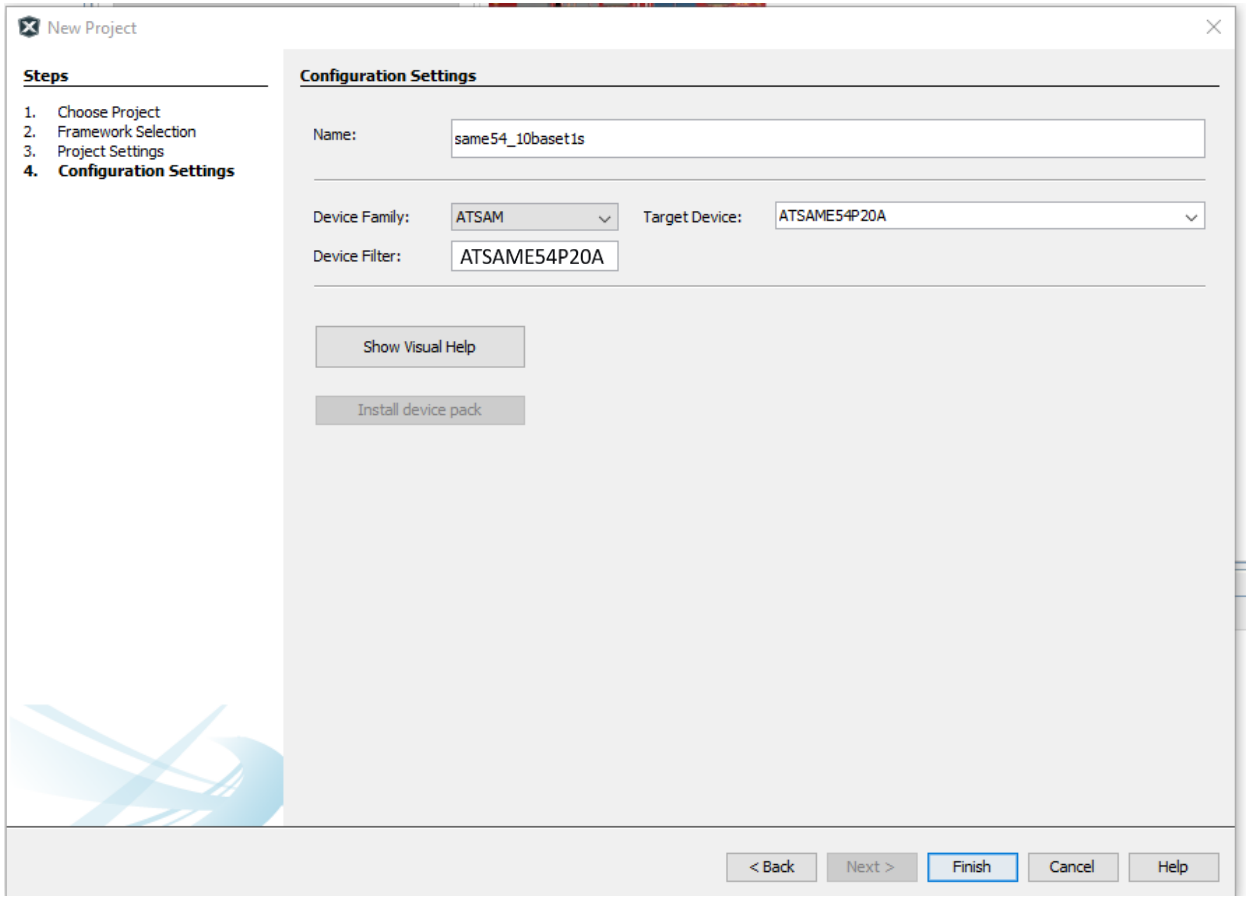
Step 5

Specify the **Location, Folder and Name** of the project (Tip – Show Visual Help is really useful to understand the differences between these.). Click **Next >.**



Step 6

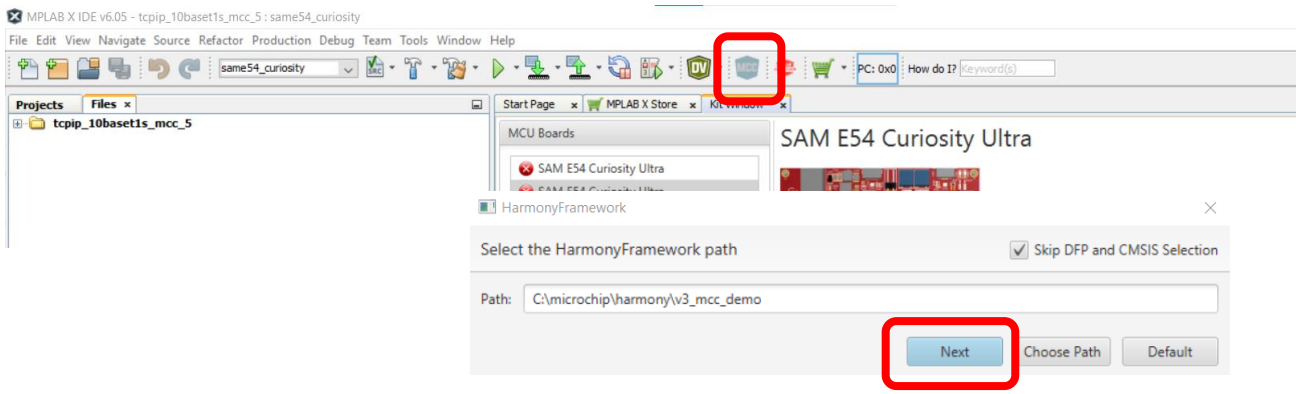
Choose a **Configuration Name** and select the **Device Family** as ATSAM, and **Target Device** as ATSAME54P20A. (Tip: copy/paste ATSAME54P20A into the Device Filter and this will find the device quickly) Click **Finish.**



Step 7

MCC should now open automatically. If it doesn't, use the blue MCC button to open MCC

- This button can also be used to close MCC if it is open
- Check the Framework path is correct and click Next

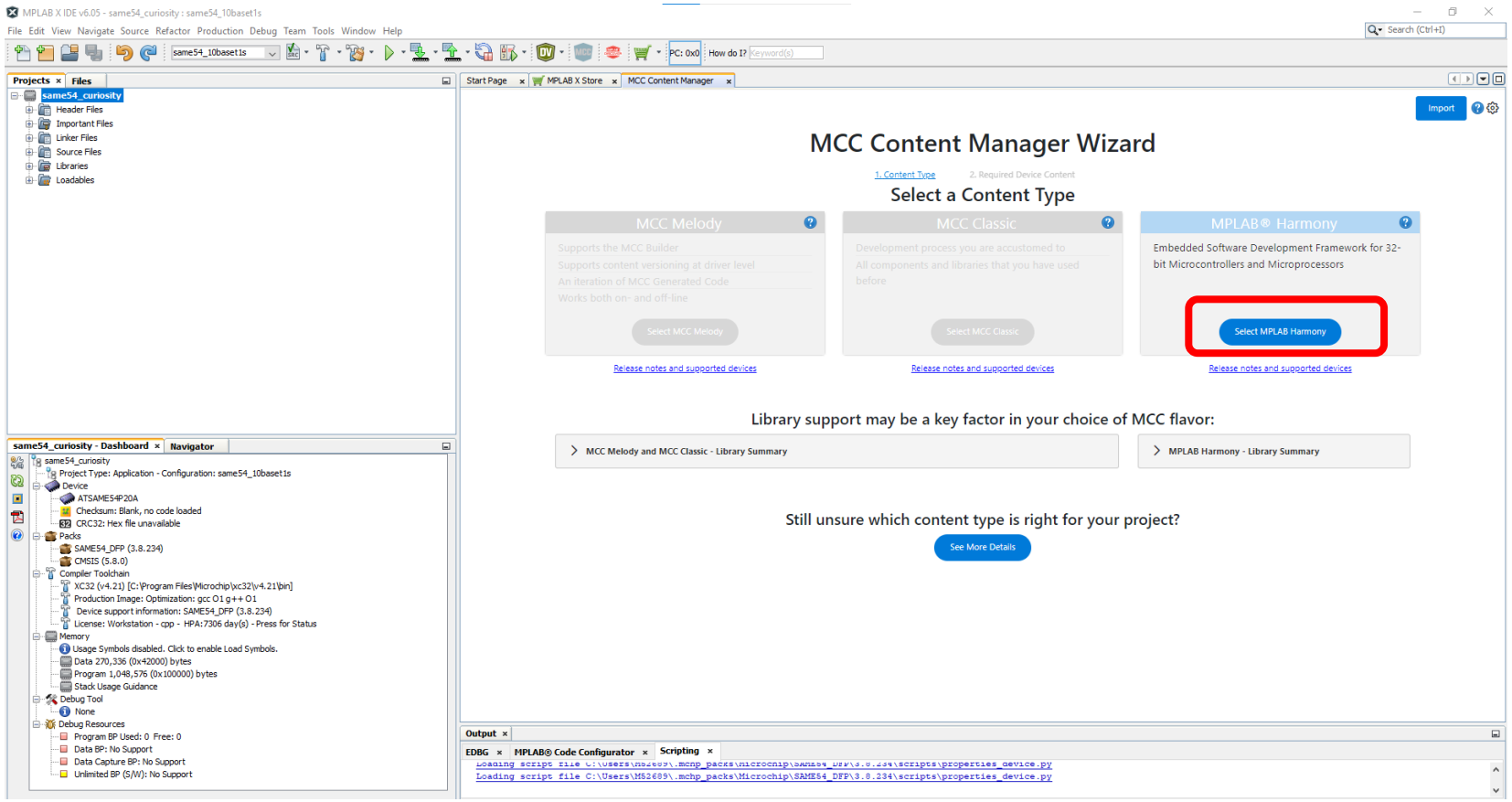


Step 8

You have now created your project and opened MCC. The next step is to download the necessary Harmony Content libraries for the demo to run.

You can now see your project in the Projects pane on the left, and on the right the tab for the MCC Content Manager.

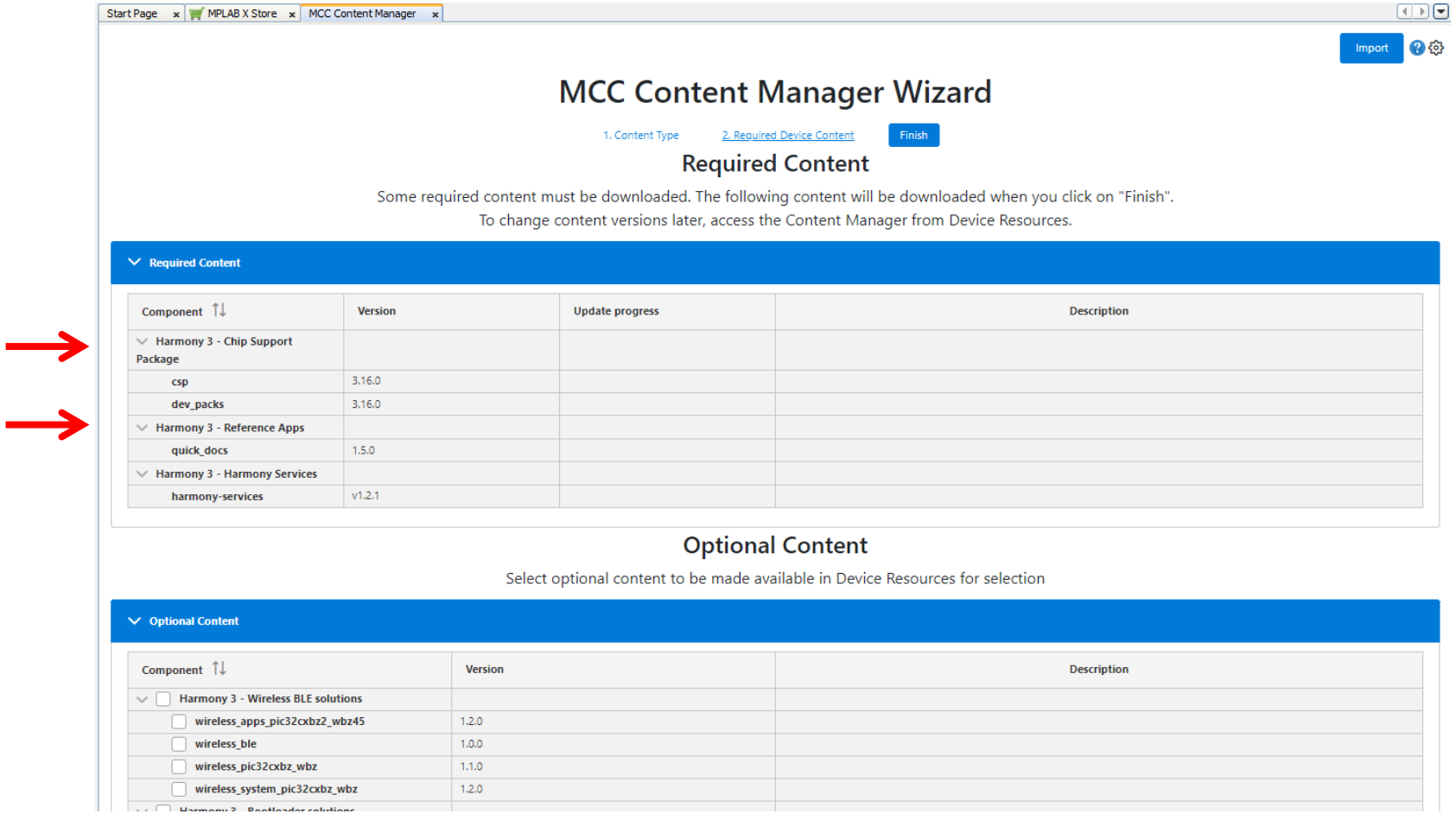
Click on **Select MPLAB Harmony** for the **Content Type**.



Step 9

Focussing on the **MCC Content Manager Wizard**, you can see that there are two types of Content, Required Content and Optional Content. Required Content is necessary for any Harmony project, but everything else is application dependent.

Click on the “down arrow” to see the names of each package.



Step 10

From the list of Optional Packages, you will need:

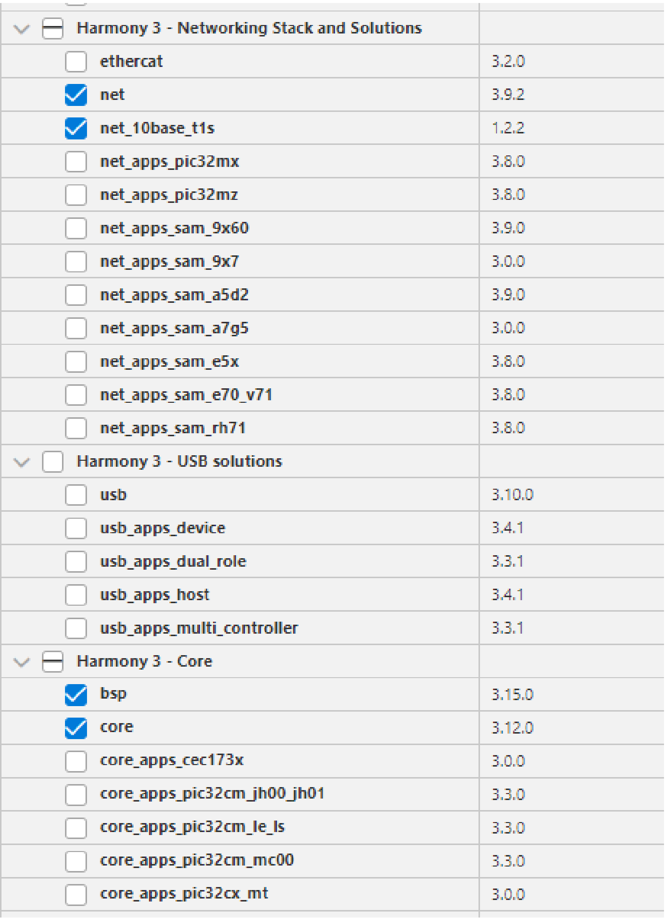
net
net_10base_t1s
bsp
core
crypto
wolfssl
CMSIS-FreeRTOS

Note: The versions shown here are not necessarily the most up-to-date ones, but please choose the most up-to-date versions available for each pack.

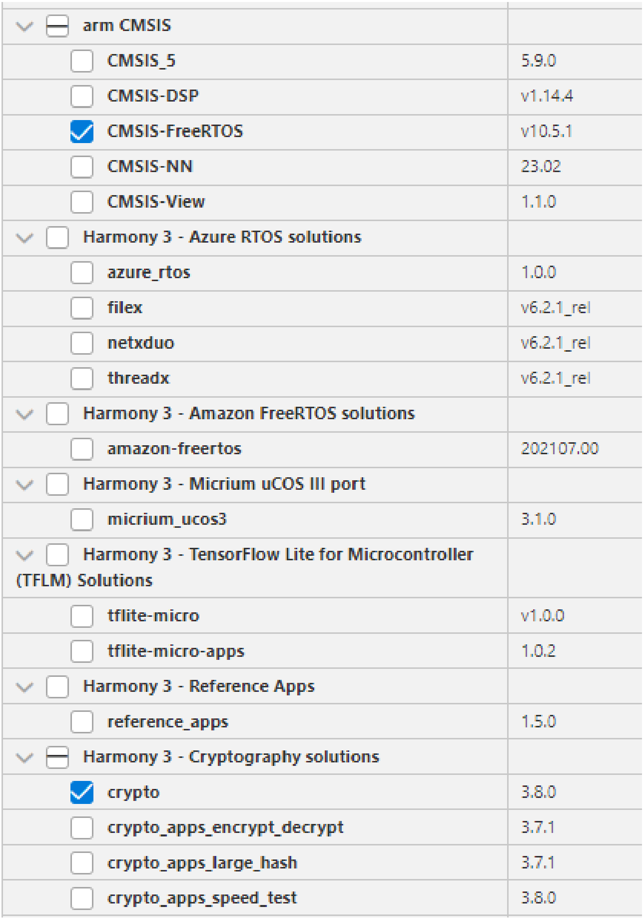
Scroll back up to the top and click Finish.

The packages will start downloading from Github into the Harmony Content Folder.

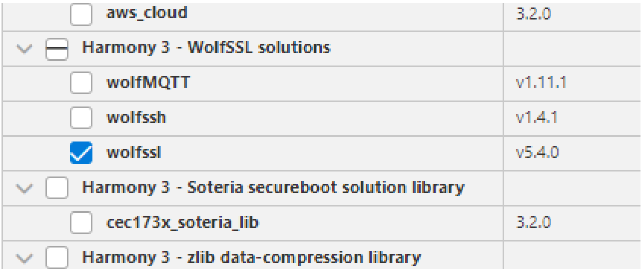
Use the Update progress column to view the installation progress.



Harmony 3 - Networking Stack and Solutions	
ethercat	3.2.0
net	3.9.2
net_10base_t1s	1.2.2
net_apps_pic32mx	3.8.0
net_apps_pic32mz	3.8.0
net_apps_sam_9x60	3.9.0
net_apps_sam_9x7	3.0.0
net_apps_sam_a5d2	3.9.0
net_apps_sam_a7g5	3.0.0
net_apps_sam_e5x	3.8.0
net_apps_sam_e70_v71	3.8.0
net_apps_sam_rh71	3.8.0
Harmony 3 - USB solutions	
usb	3.10.0
usb_apps_device	3.4.1
usb_apps_dual_role	3.3.1
usb_apps_host	3.4.1
usb_apps_multi_controller	3.3.1
Harmony 3 - Core	
bsp	3.15.0
core	3.12.0
core_apps_cec173x	3.0.0
core_apps_pic32cm_jh00_jh01	3.3.0
core_apps_pic32cm_le_ls	3.3.0
core_apps_pic32cm_mc00	3.3.0
core_apps_pic32cx_mt	3.0.0



arm CMSIS	
CMSIS_5	5.9.0
CMSIS-DSP	v1.14.4
CMSIS-FreeRTOS	v10.5.1
CMSIS-NN	23.02
CMSIS-View	1.1.0
Harmony 3 - Azure RTOS solutions	
azure_rtos	1.0.0
filex	v6.2.1_rel
netxduo	v6.2.1_rel
threadx	v6.2.1_rel
Harmony 3 - Amazon FreeRTOS solutions	
amazon-freertos	202107.00
Harmony 3 - Micrium uCOS III port	
micrium_ucos3	3.1.0
Harmony 3 - TensorFlow Lite for Microcontroller (TFLM) Solutions	
tflite-micro	v1.0.0
tflite-micro-apps	1.0.2
Harmony 3 - Reference Apps	
reference_apps	1.5.0
Harmony 3 - Cryptography solutions	
crypto	3.8.0
crypto_apps_encrypt_decrypt	3.7.1
crypto_apps_large_hash	3.7.1
crypto_apps_speed_test	3.8.0



aws_cloud	3.2.0
Harmony 3 - WolfSSL solutions	
wolfMQTT	v1.11.1
wolfssh	v1.4.1
wolfssl	v5.4.0
Harmony 3 - Soteria secureboot solution library	
cec173x_soteria_lib	3.2.0
Harmony 3 - zlib data-compression library	

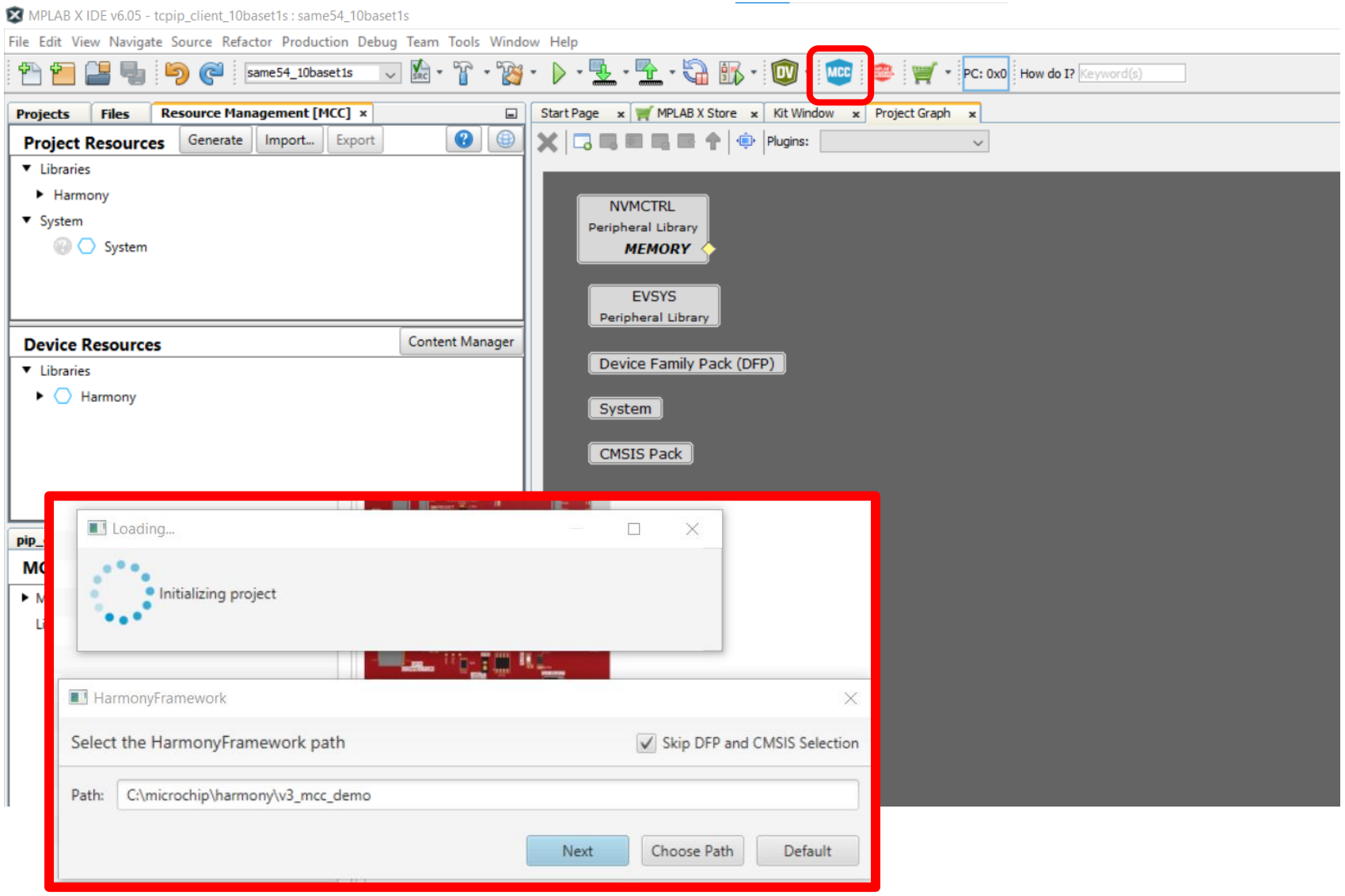
Note : it is helpful to have a fast internet connection for this step!

MICROCHIP

Step 11

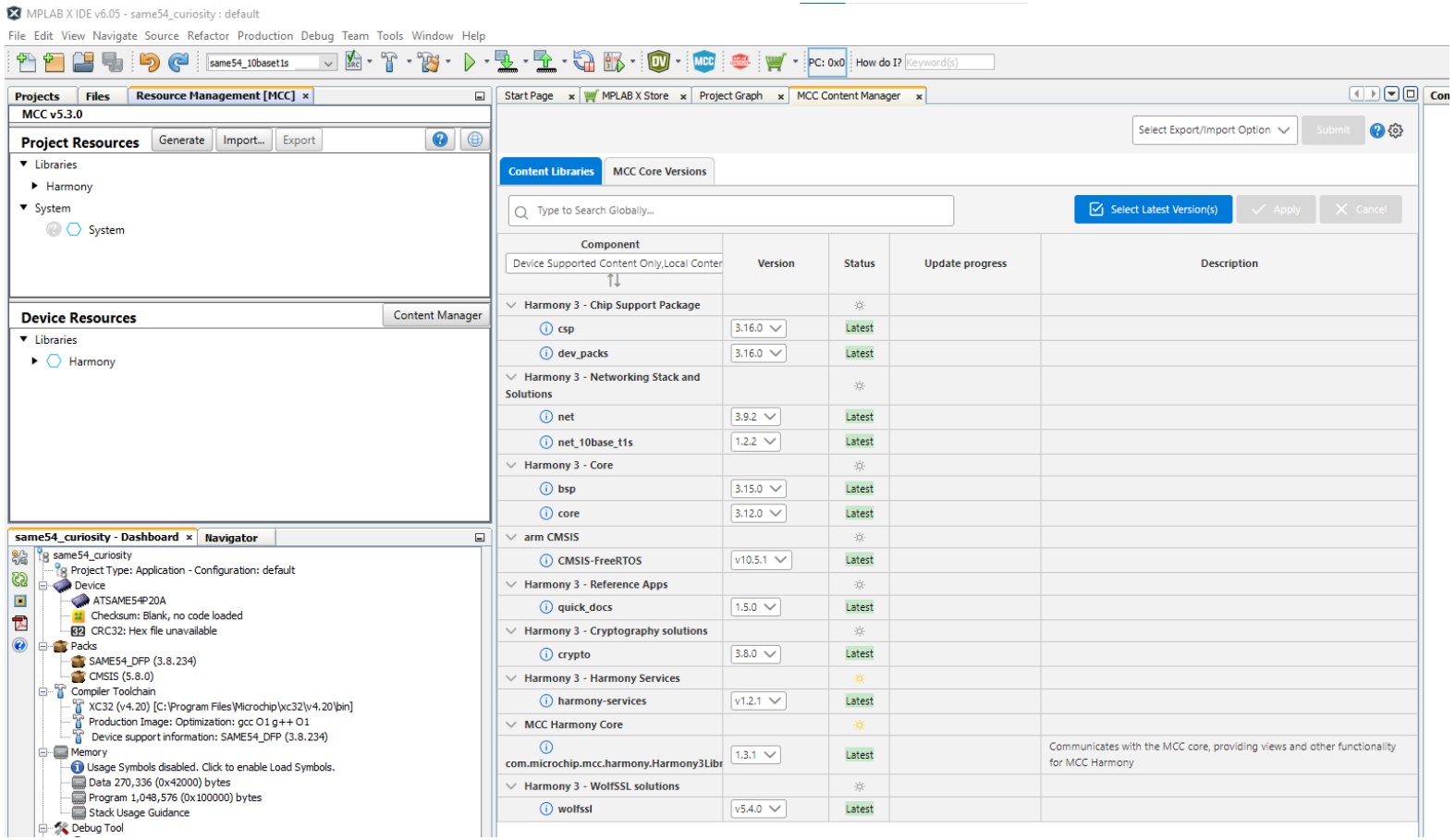
Once the libraries have downloaded, the project should open in MCC automatically. If it doesn't, then you can open MCC by clicking on the MCC button at the top of the MPLAB X window.

If the Harmony Framework path box appears, make sure that it has the same path that you specified originally for the project and for the Plugin Options in the earlier steps.



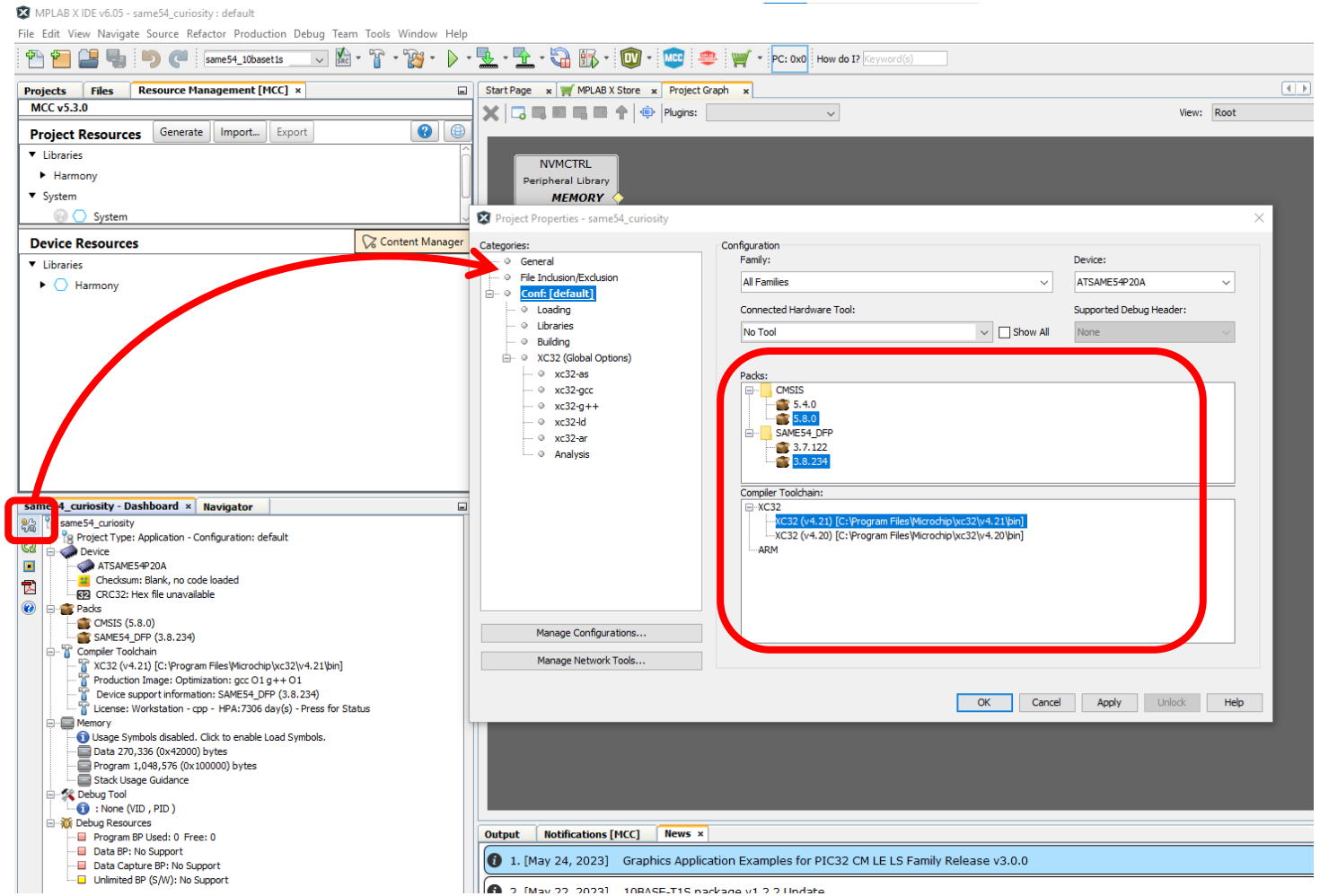
Step 12

Open the Content Manager and view the packages that have been downloaded (tip: use the down arrows beside the package headings to view all of the packages)



Step 13

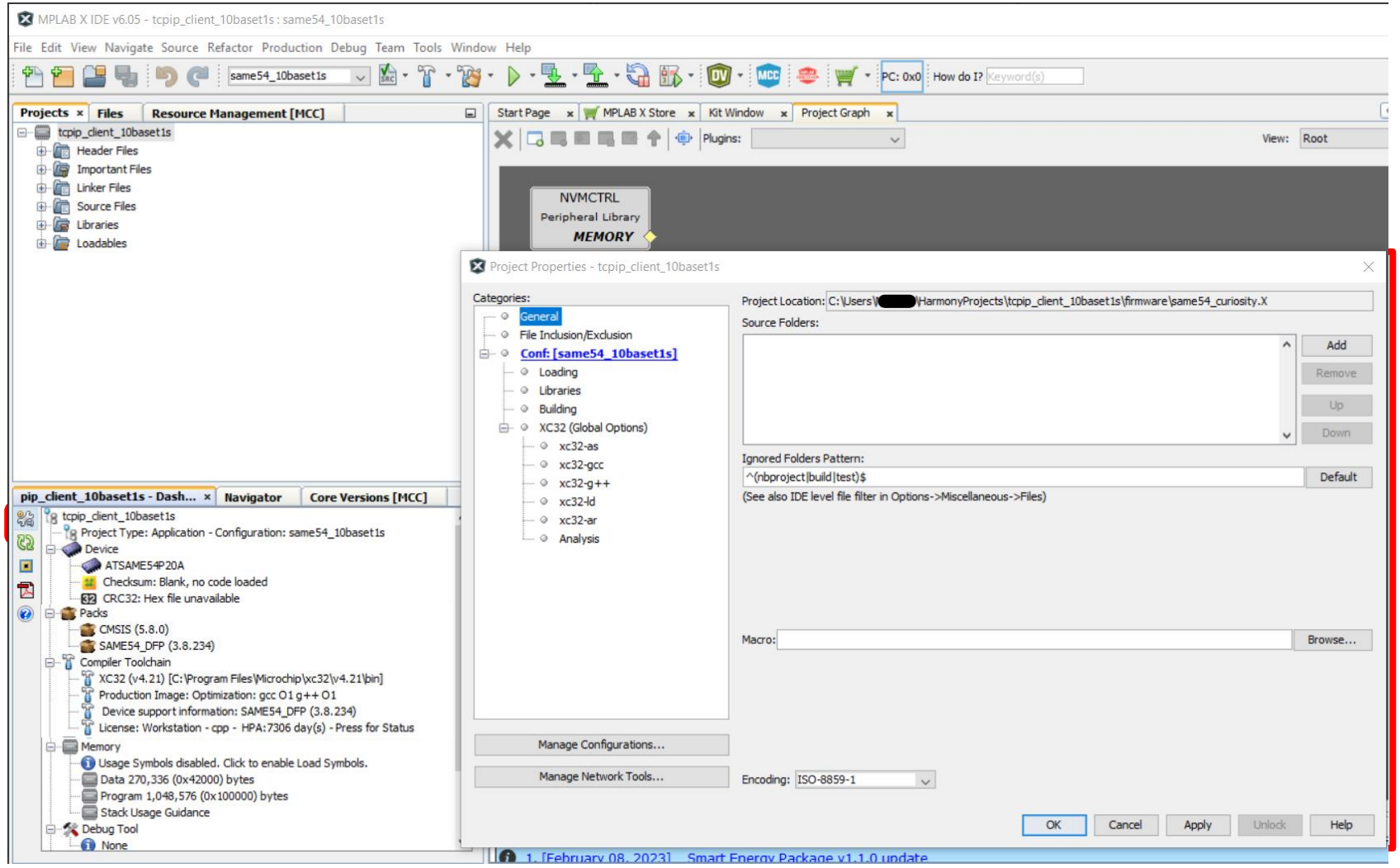
Check that you have the most up-to-date Device Pack and that your XC32 compiler is included in the project. To do this, open the Project Properties and view the Packs and Compiler Toolchain.



Step 14

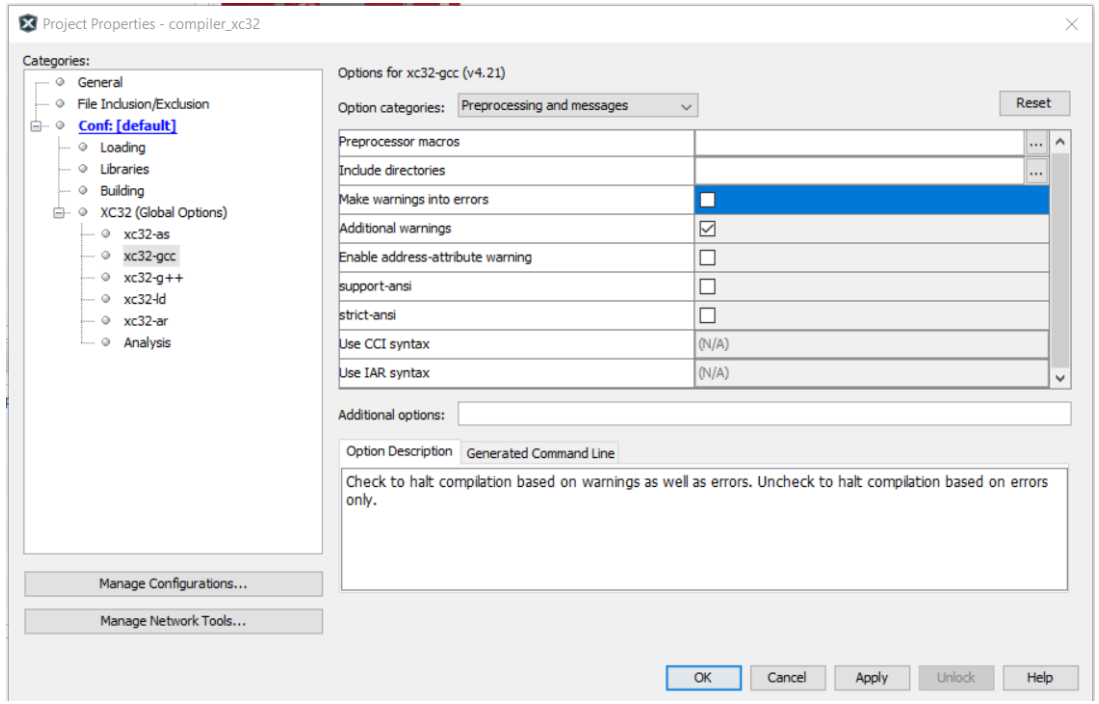
Now you are all set!
Take note of the location of your project, you can do this by opening the Project Properties and going to the General category, and viewing the Project Location.

You will be able to close the project now, and re-open it during the 10BaseT1S class.

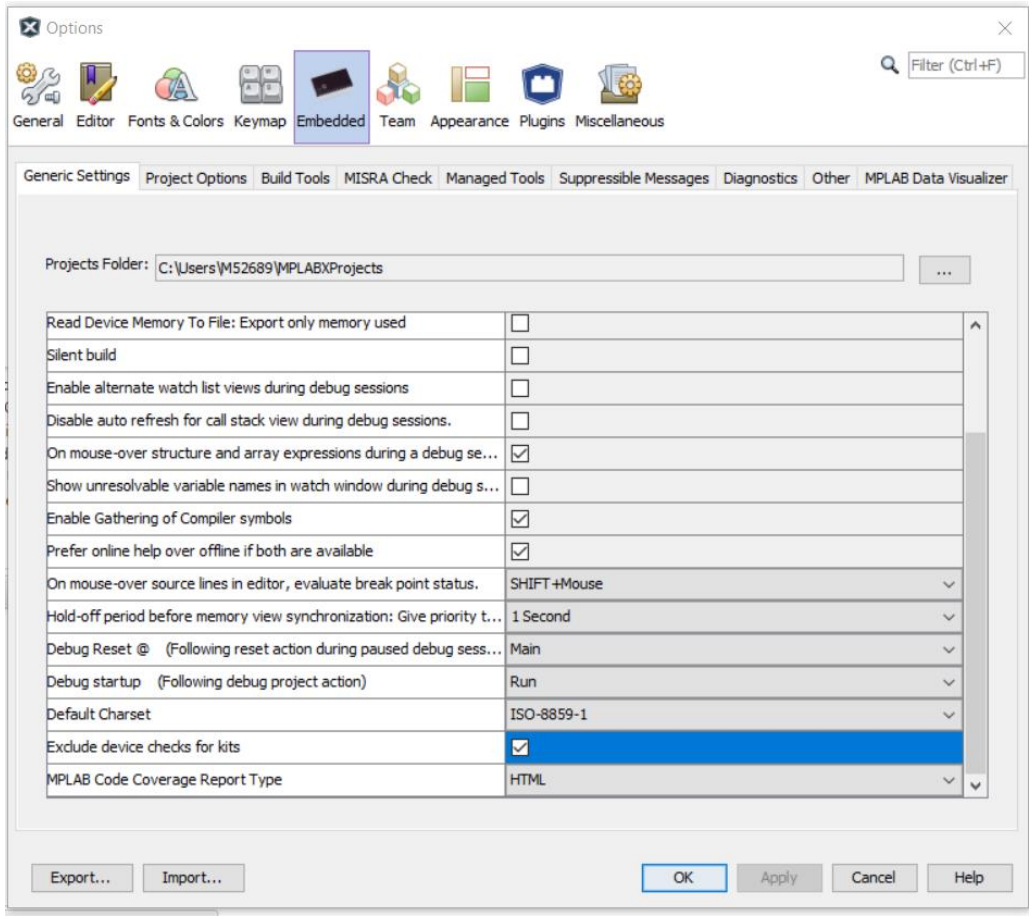


Additional settings that could cause problems!

In Project Properties, uncheck “Make warnings into errors”



In Options > Embedded, check “Exclude device checks for kits”

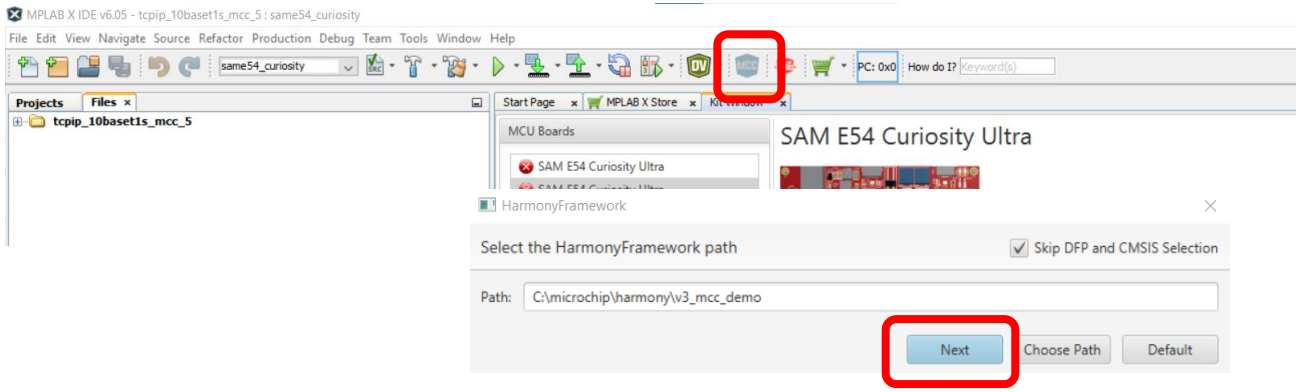


MICROCHIP

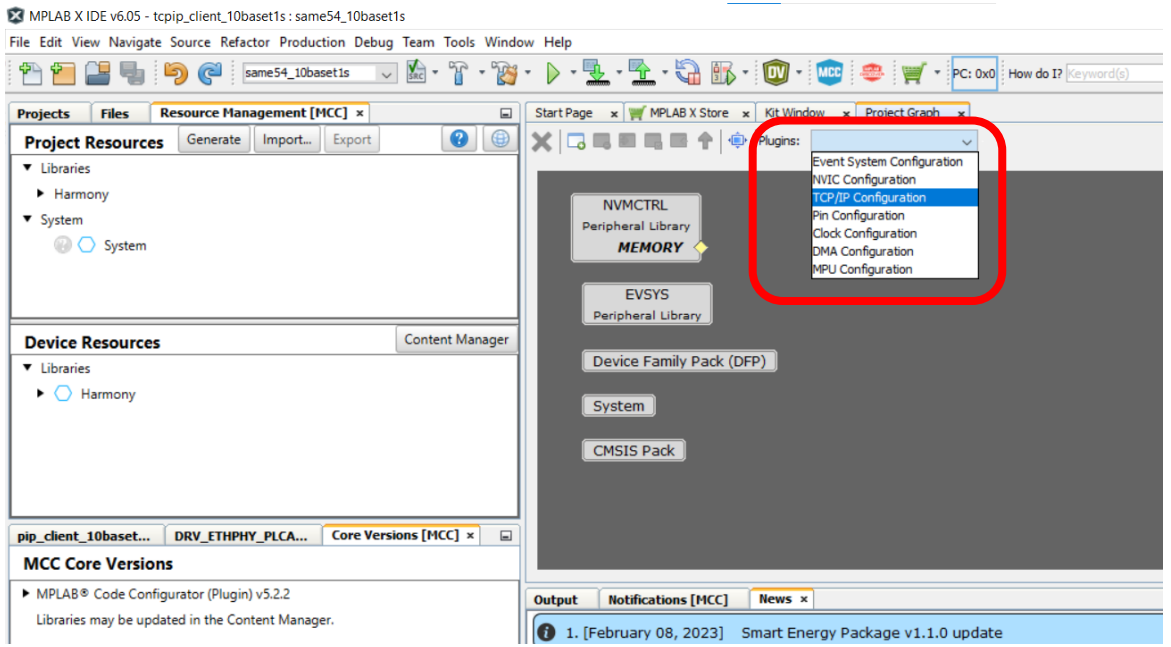
Configuring the Project in MCC

Open MCC and the TCP/IP Configuration Tool

- To open (or close) MCC, click on the blue MCC button
- Make sure to check that the Harmony Framework Path is correct in the popup box, as per Step 11



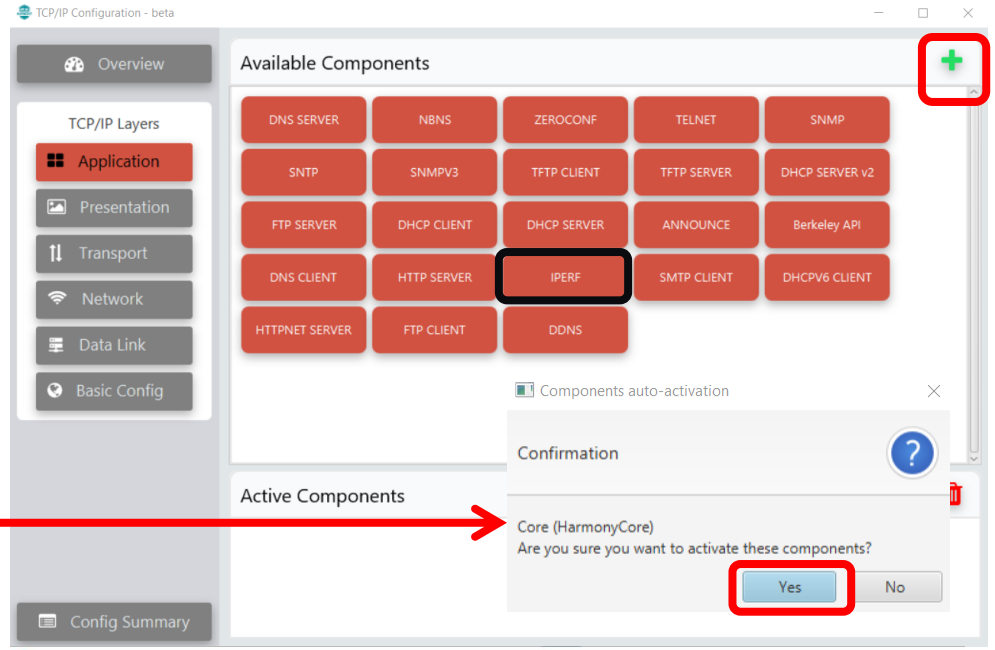
- Start by opening the TCP/IP Configuration Plugin

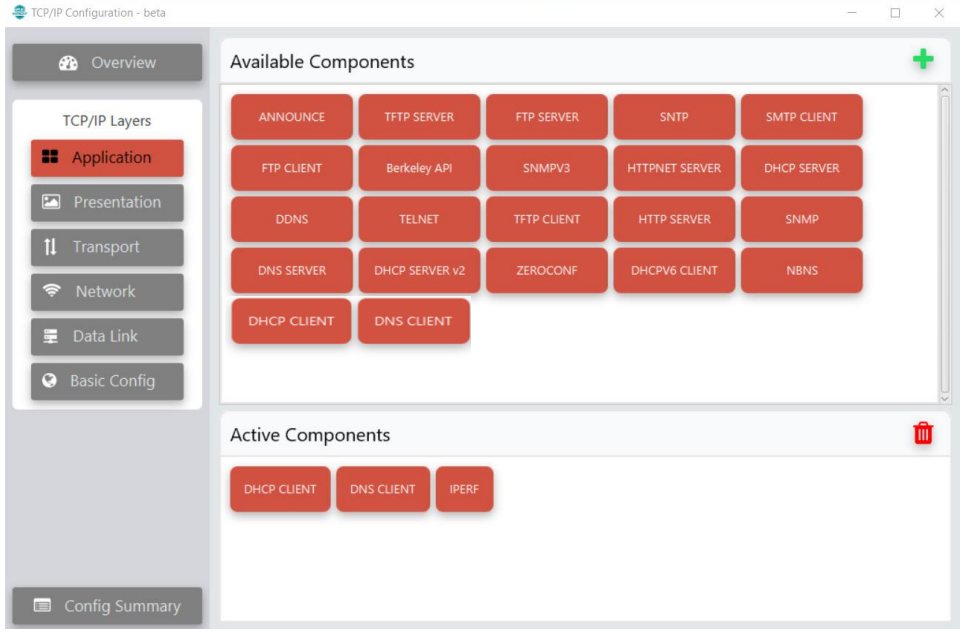


MICROCHIP

TCP/IP: Application Layer

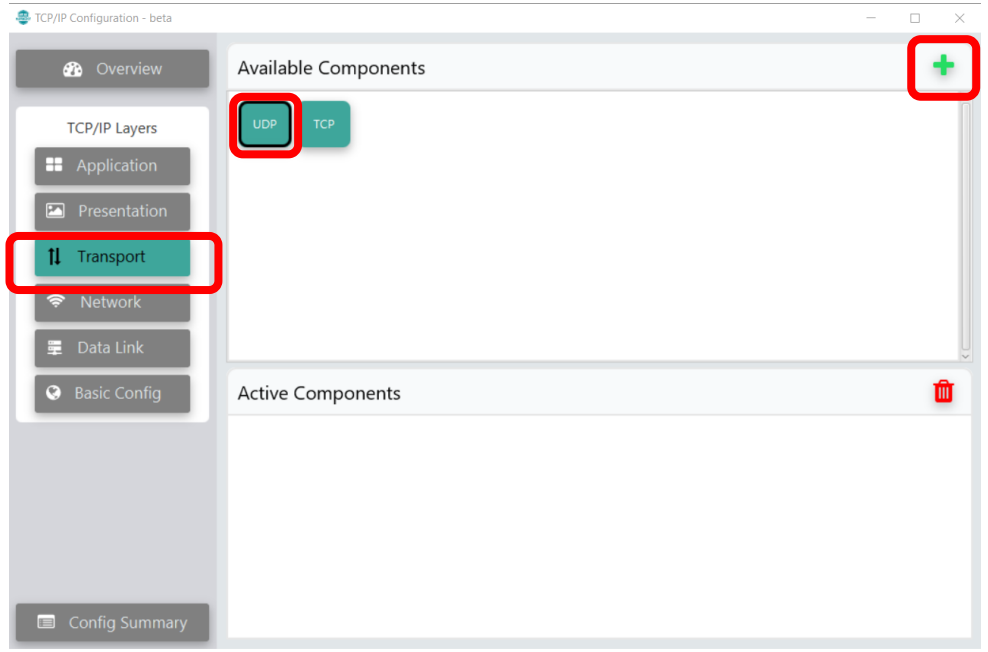
- In the TCP/IP Configuration tool, in the Application Layer, Select IPERF and click +
- Click Yes to activate the Harmony Core component, and No for FreeRTOS (not needed for this demo)
- Also add DNS CLIENT and DHCP CLIENT



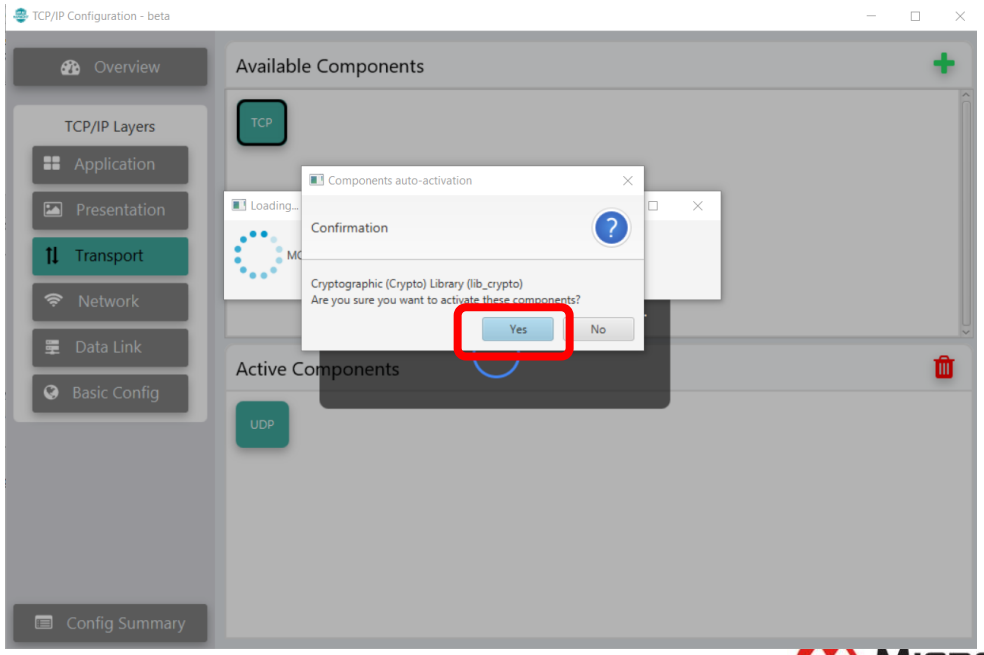


TCP/IP: Transport Layer

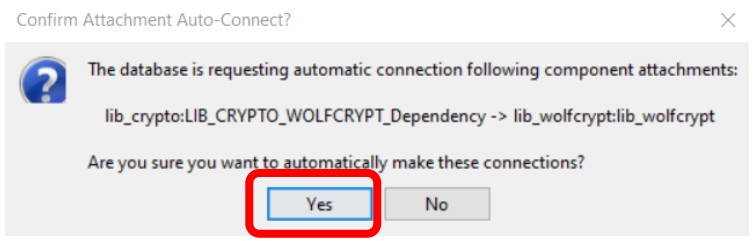
- In the Transport Layer, add the UDP Component in the same way



- Add the TCP Component, which needs the Crypto library and the WolfSSL libraries, click Yes to add these

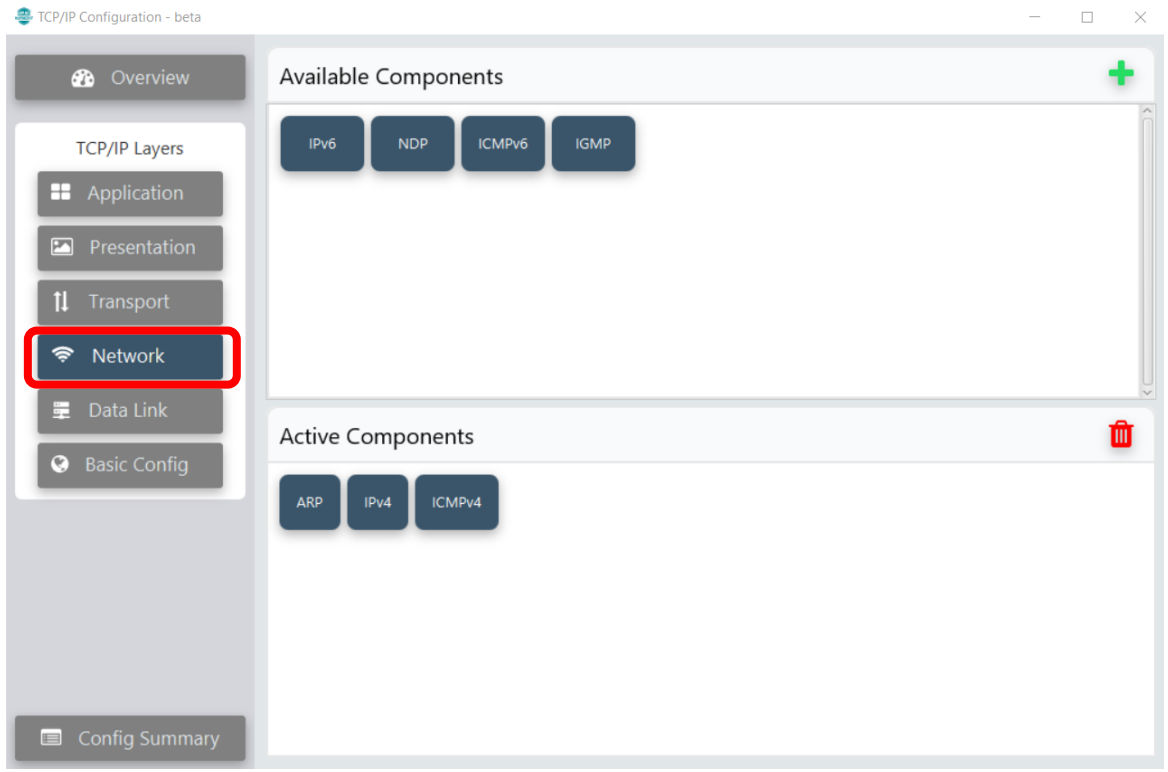


Note: this pop-up sometimes is hidden behind the various MPLABX windows, you may not see it until a later point, just make sure to click Yes when it appears



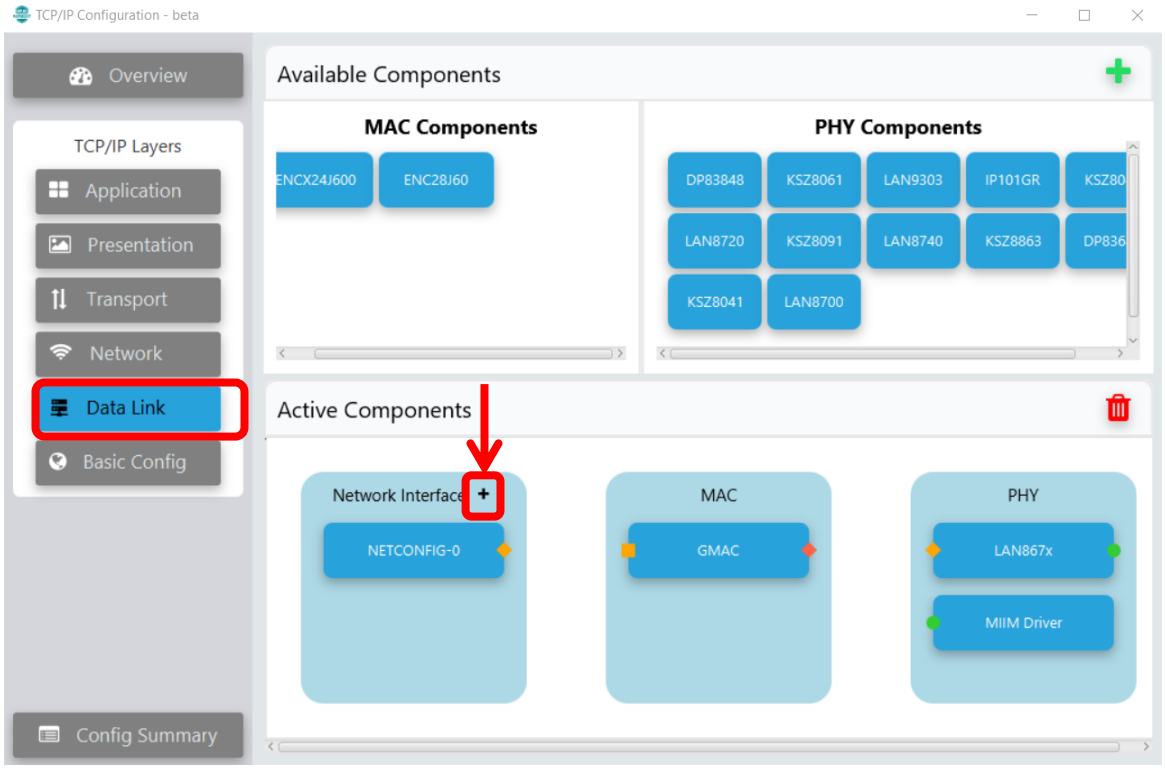
TCP/IP: Network Layer

- **In the Network Layer, add the ARP, IPv4 and ICMPv4 components**



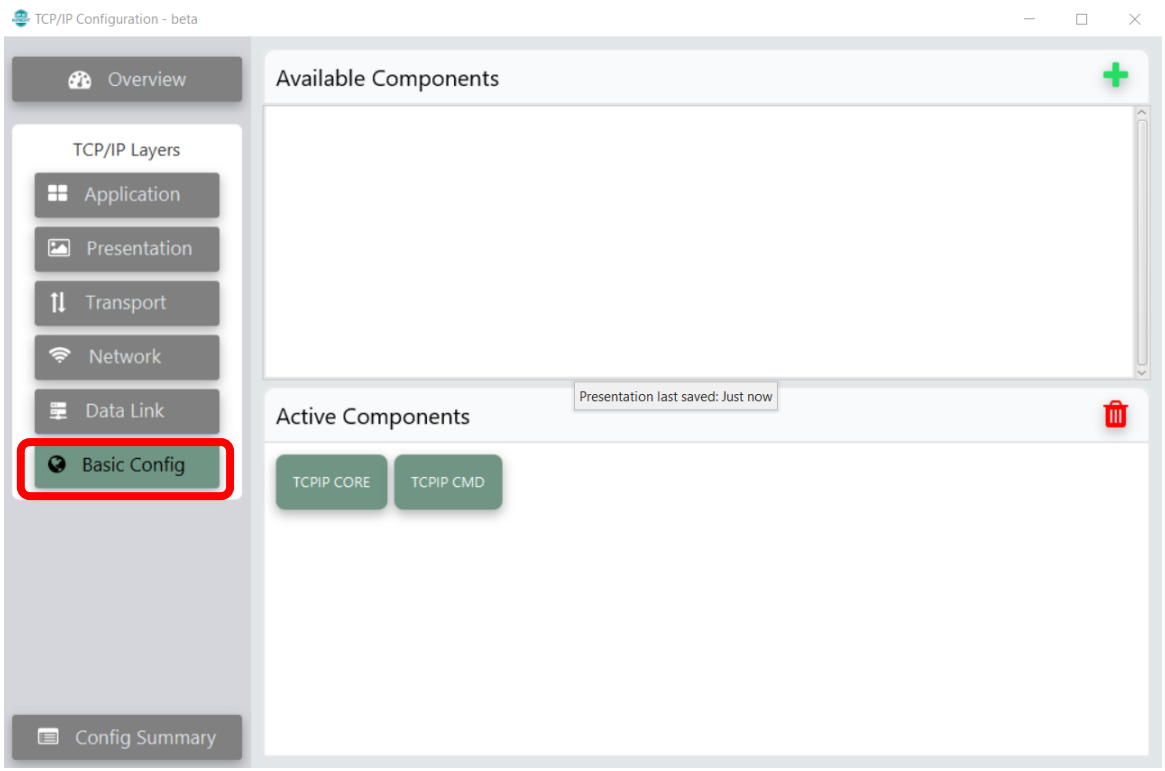
TCP/IP: Data Link Layer

- In the Data Link Layer, add the GMAC component, the LAN867x and MIIM Driver components
- Click the “+” beside Network Interface to add the NETCONFIG-0 component



TCP/IP: Basic Config

- In Basic Config, the TCPIP Core is there already
- Add the TCPIP CMD component

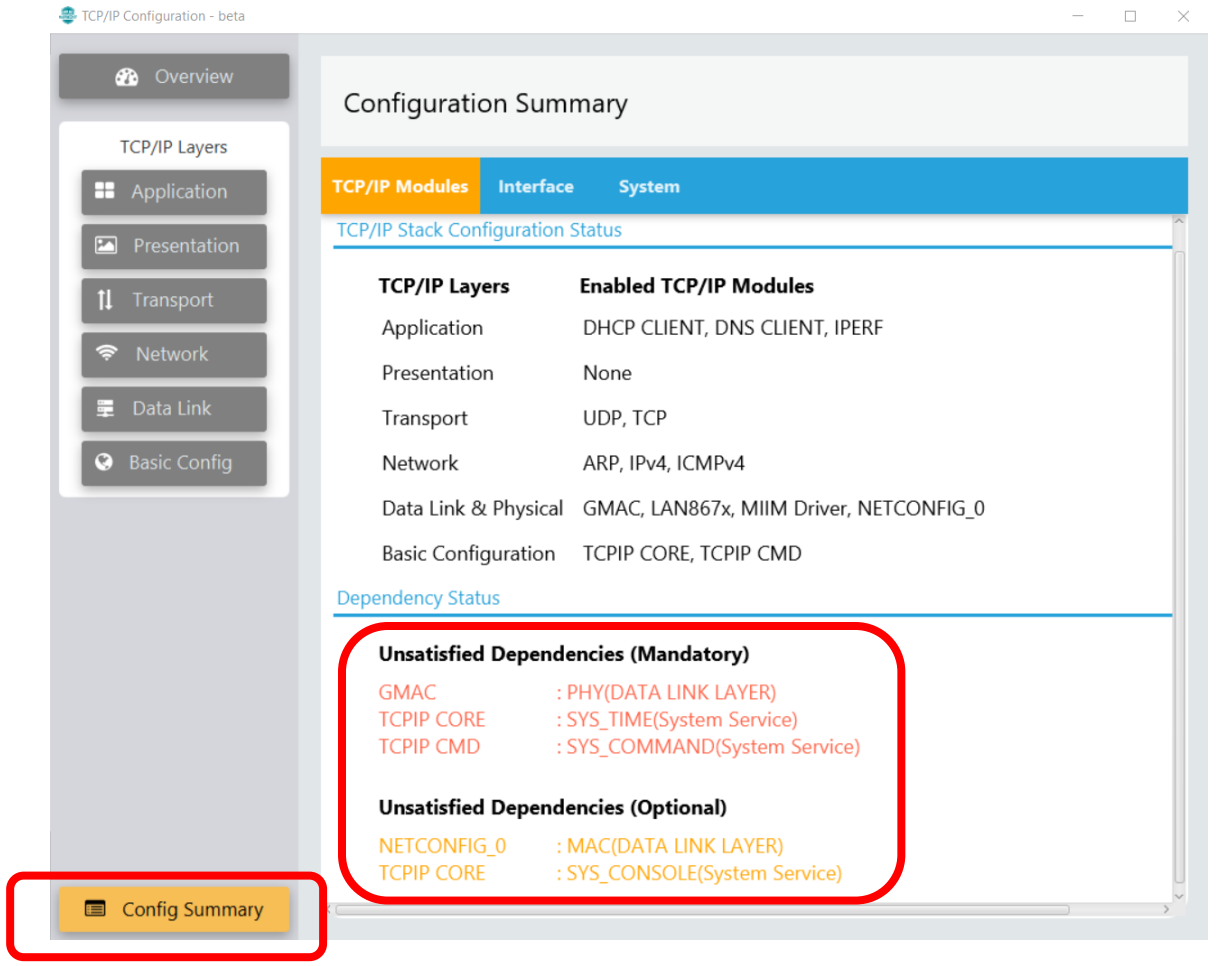


Overview

- **The Overview of the TCP/IP Configurator should now be populated with the necessary components for the stack**

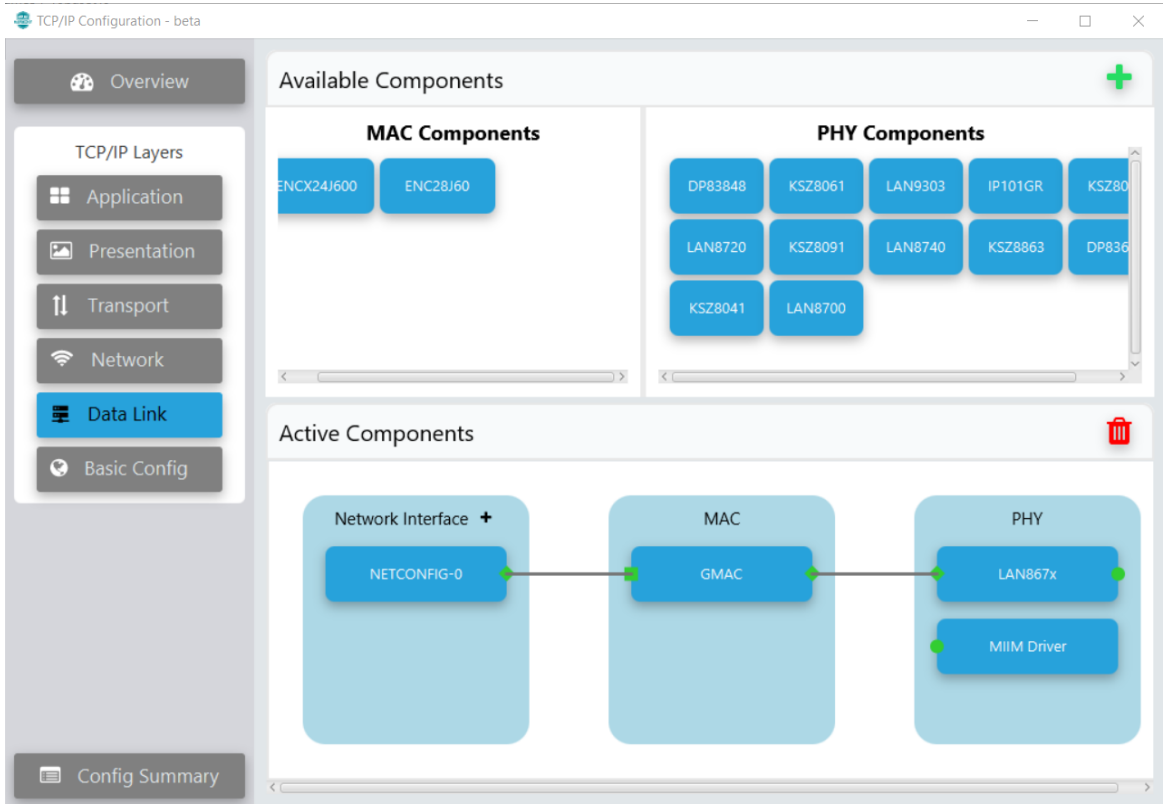
Config Summary

- Check the Config Summary to see what has been included
- Note the Unsatisfied Dependencies, these are elements of the project that the components require in order to work, and they must be satisfied.



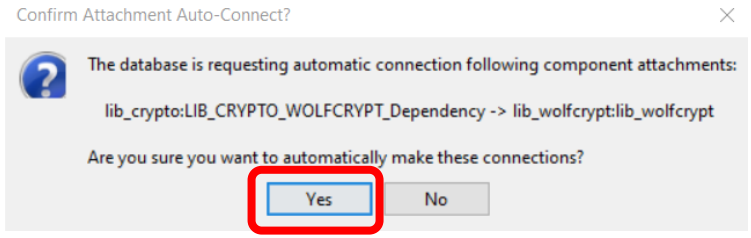
TCP/IP Data Link Dependencies

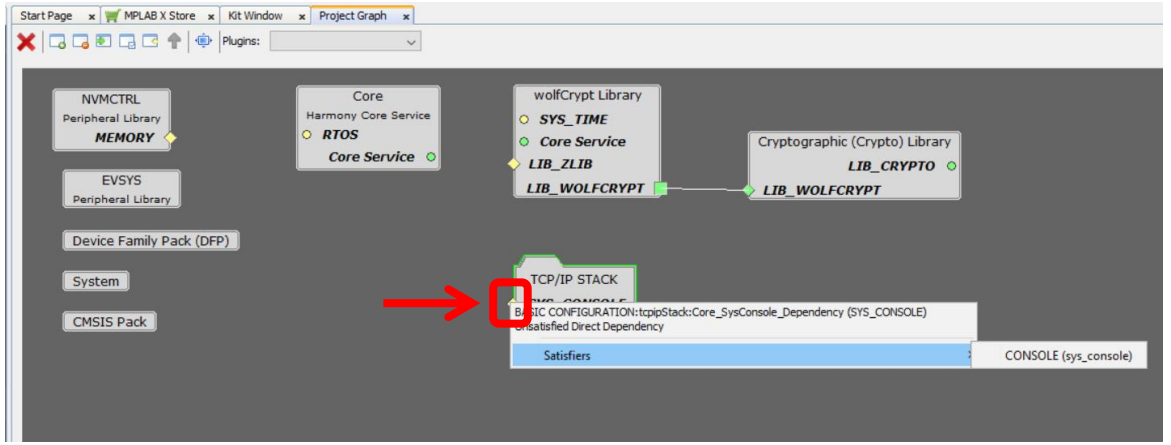
- **In the Data Link Layer, connect NETCONFIG-0 to GMAC**
- **Connect GMAC to LAN867x PHY driver**
  - To do these connections, simply use the mouse to “draw” a line between the red/orange dots on the components

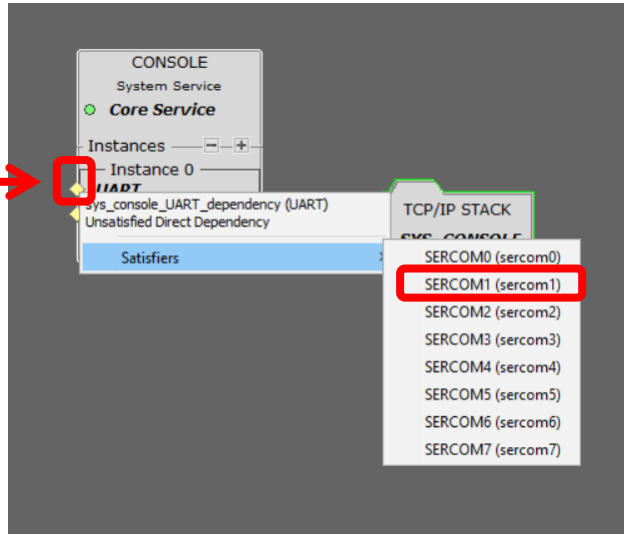


System Console

- **Return the to Project Graph, you should see the TCP/IP Stack and the WolfCrypt components. (You may need to accept the Wolfcrypt dependency confirmation popup at this point if you have not already)**
- **Use the Project Graph to add the System Console to the project**
  - Do this by right-clicking on the yellow diamond “SYS_CONSOLE” and select Satisfiers > CONSOLE (sys_console)
- **The System Service Console is now added to the project graph**
- **This Console needs a UART instance, right click on the yellow diamond labelled “UART” and select SERCOM1**





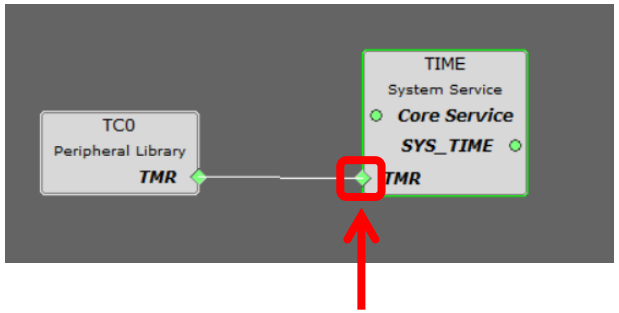


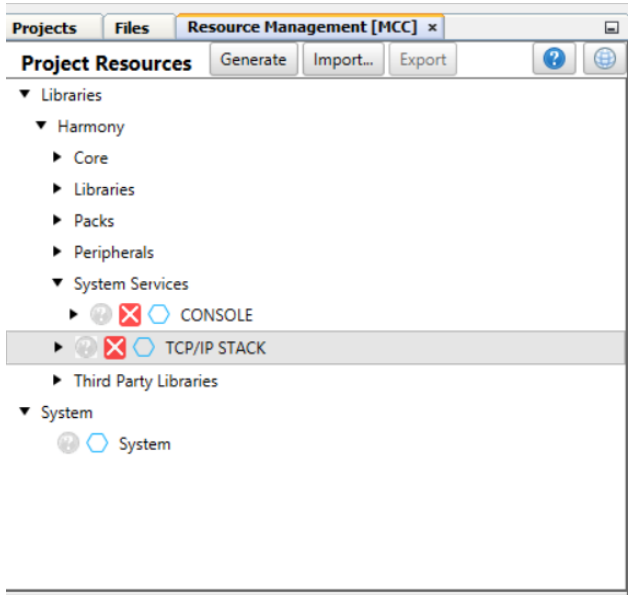
MICROCHIP

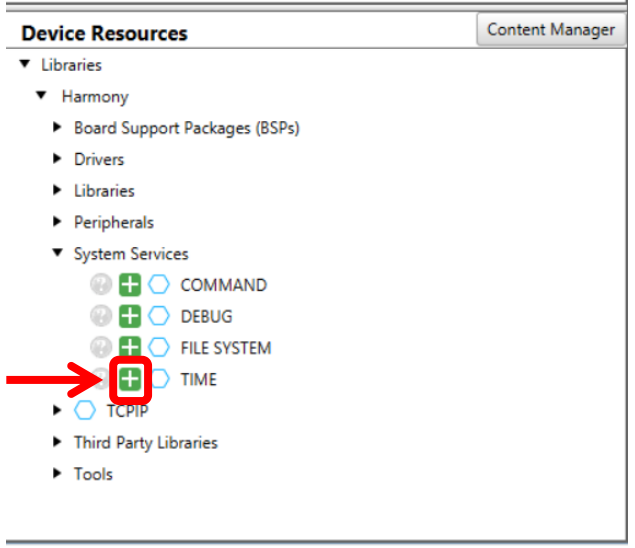
TIME System Service

- Add the TIME System Service from the Device Resources window, which is located in Libraries > Harmony > System Services
- Do this by clicking on the “+” beside the TIME system service

- Right click on the yellow diamond labelled “TMR” and select TC0 as the timer for the project (the diamond will turn green when TC0 is added)



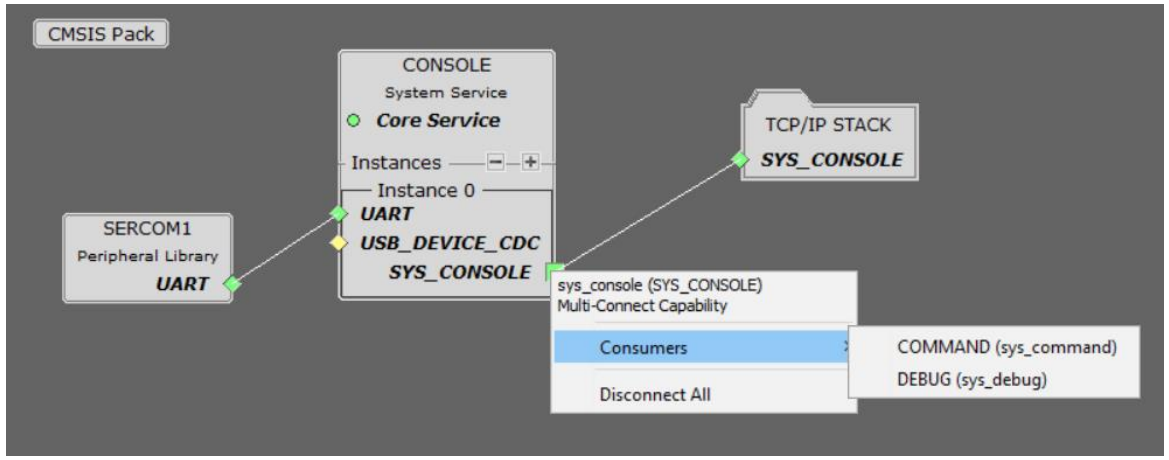




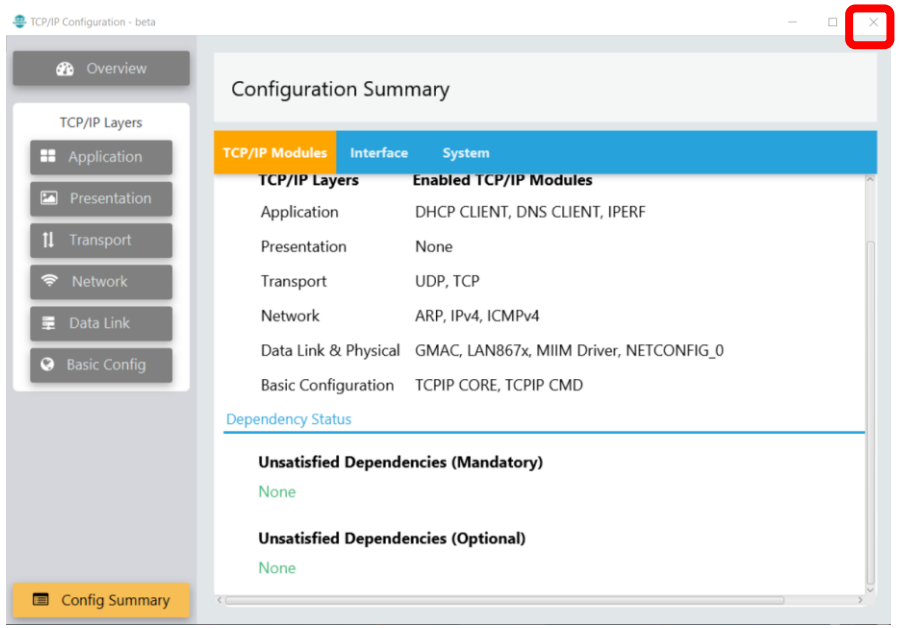
MICROCHIP

COMMAND and DEBUG

- Add the COMMAND (sys_command) and DEBUG (sys_debug) as Consumers for the Console System Service, along with the TCP/IP Stack.
- Do this by right clicking on the green square labelled “SYS_CONSOLE” and selecting these components, one at a time



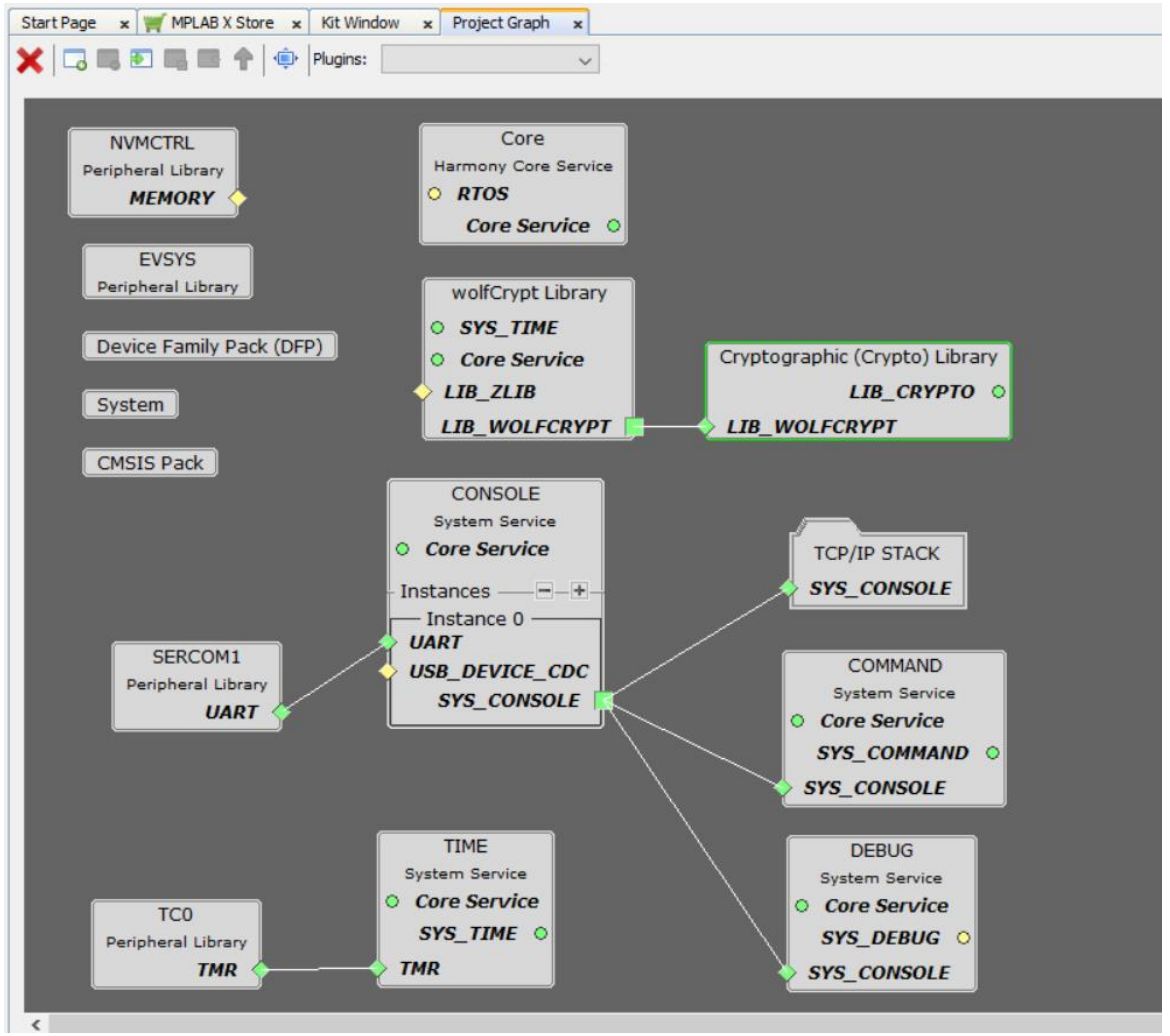
- The TCP/IP Config Summary should now have no unsatisfied dependencies
- Close the TCP/IP Configuration Tool at this point



MICROCHIP

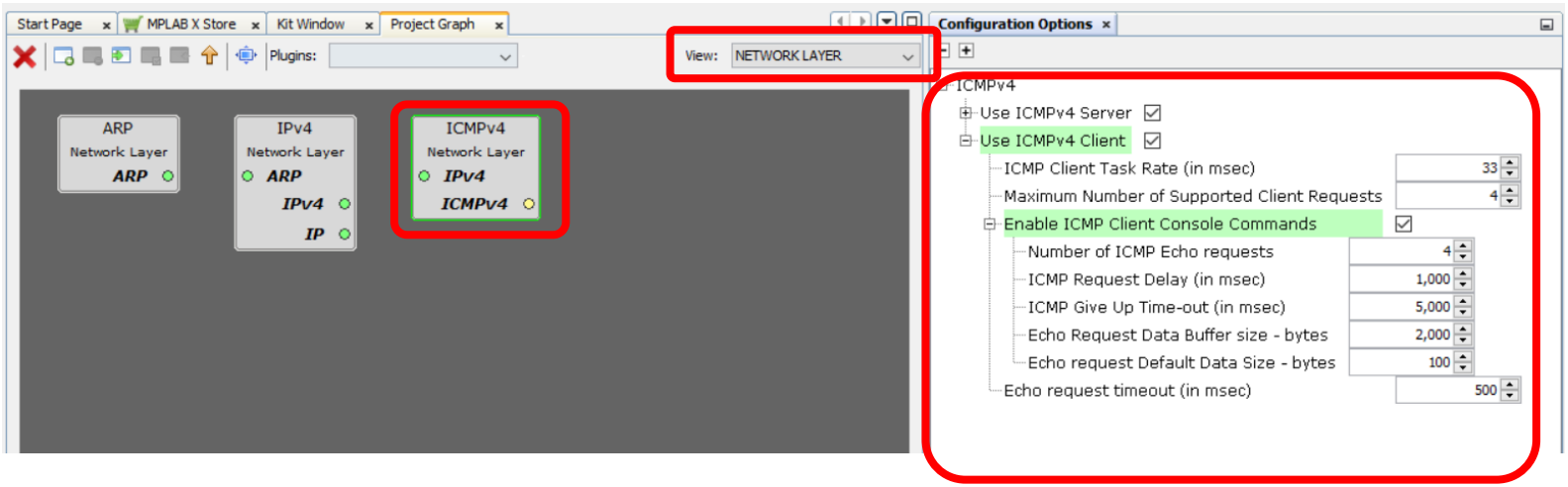
Project Graph

- **The project graph should now contain all of the necessary components**



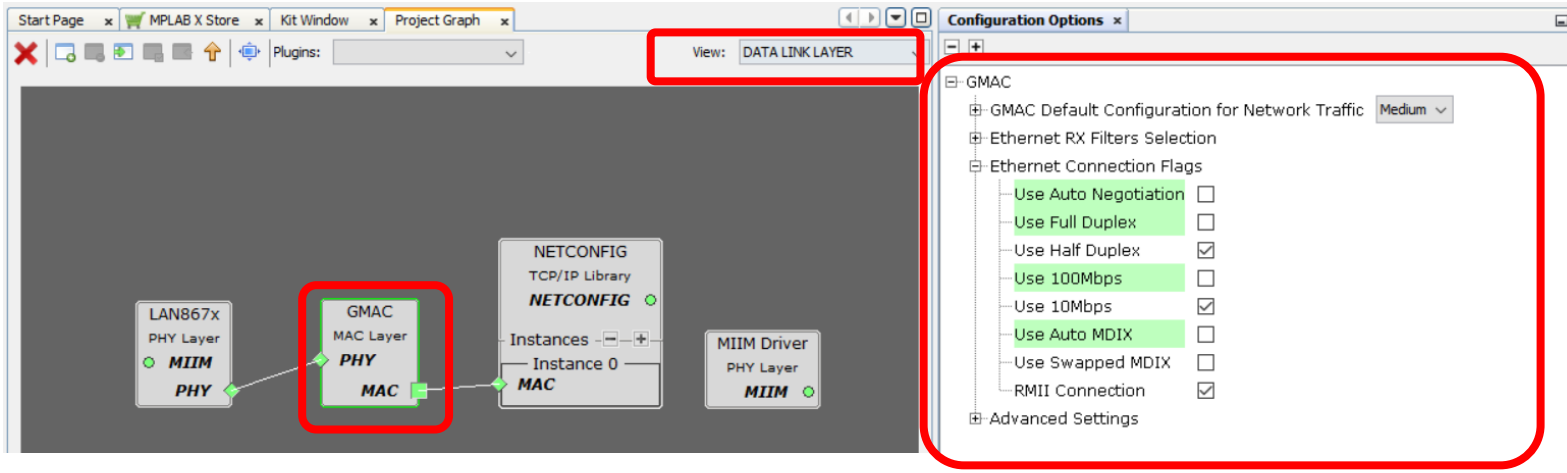
Network Layer Settings

- **In the Network Layer, Select to Use ICMPv4 Client, and Enable ICMP Client Console Commands**

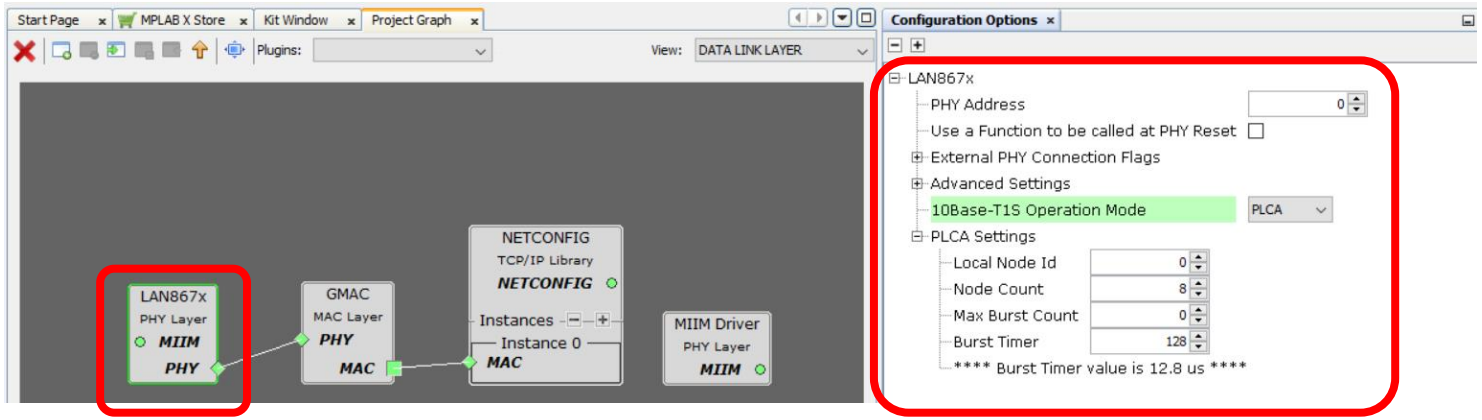


Data Link Layer Settings

- In the Data Link Layer, click on the GMAC component and set the Ethernet Connection Flags as shown



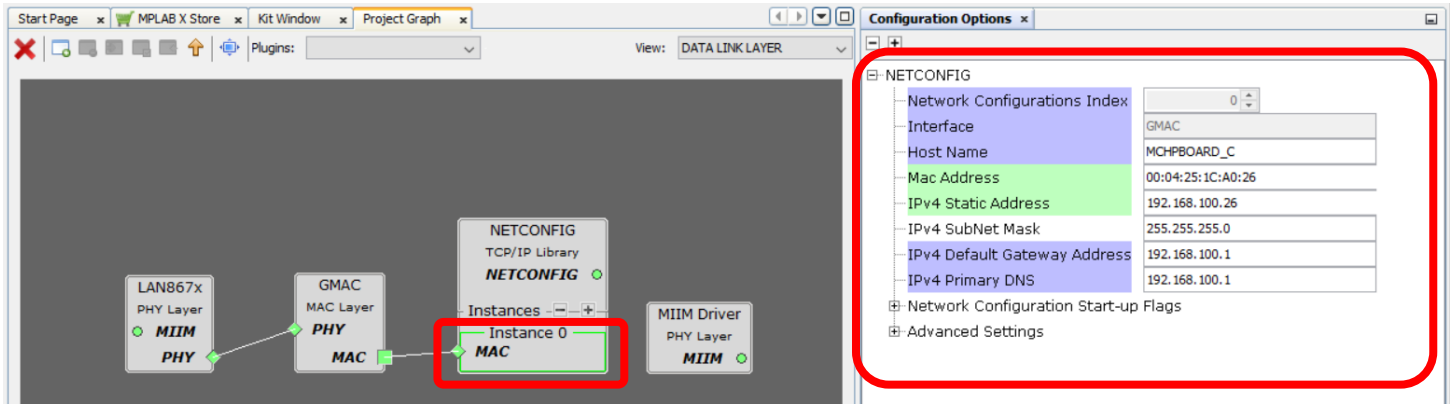
- Click on the LAN867x PHY Layer component and select the Advanced Settings to use PLCA, leave the other settings as is



MICROCHIP

Network Configuration

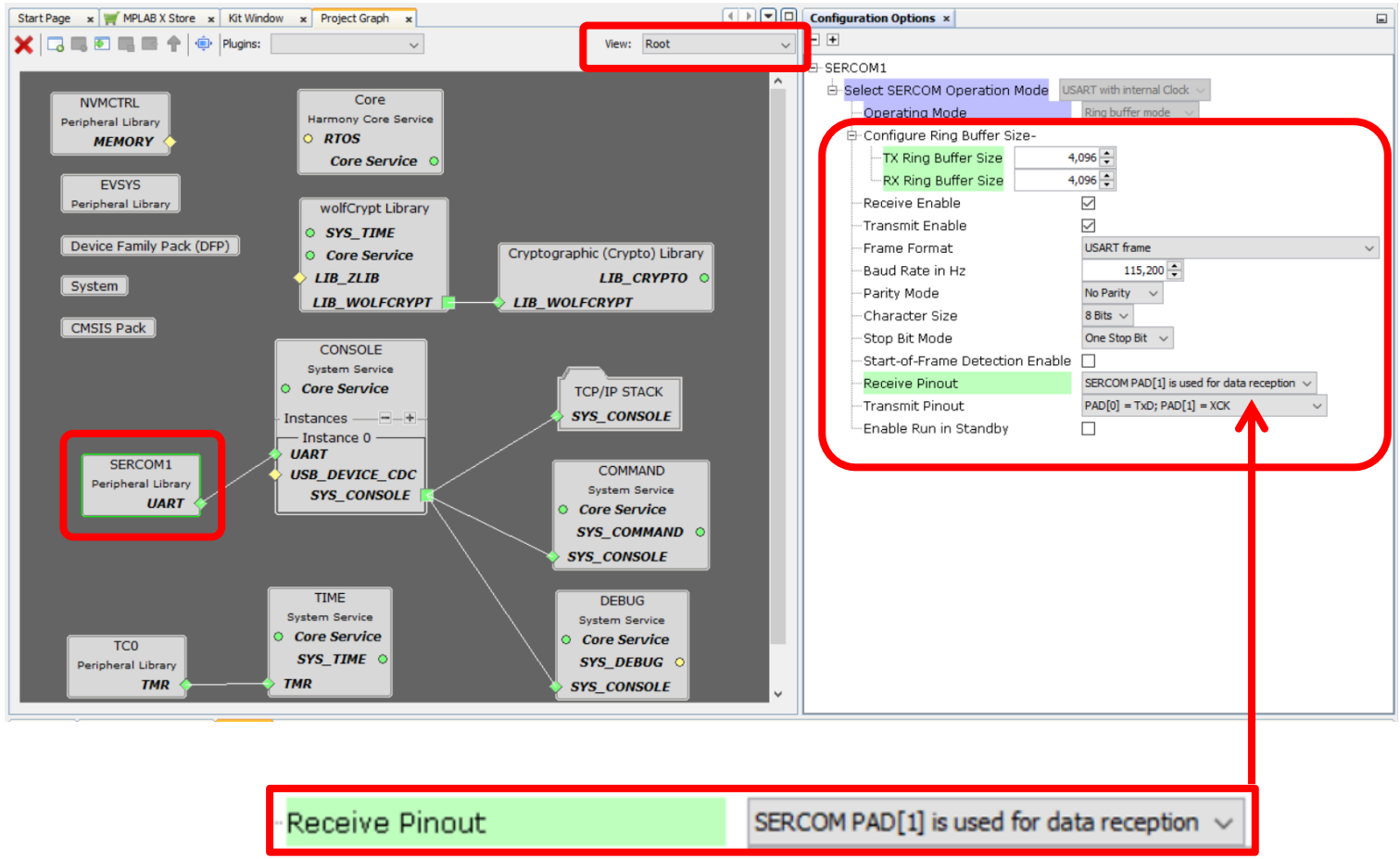
- Observe the network configuration settings in the NETCONFIG component, change the MAC address and IP Address.
- Each of the two boards will need distinct MAC addresses
- They will also need distinct IP Addresses which will need to be on the same network subnet with distinct node numbers, here “26” is used



SERCOM Configuration

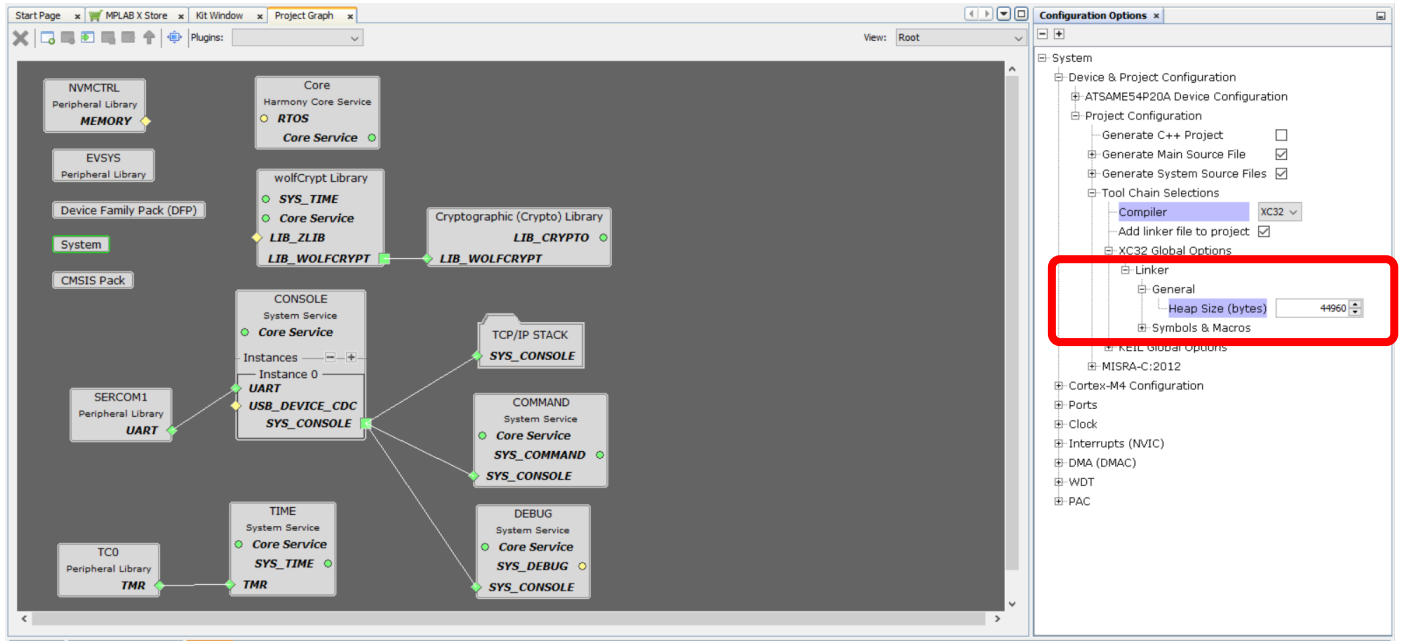
- **In the Root layer of the Project Graph, configure SERCOM1 to increase the TX and RX Ring Buffer Size to 4096**
- **Set the Receive Pinout to:**

  "SERCOM PAD[1] is used for data reception"



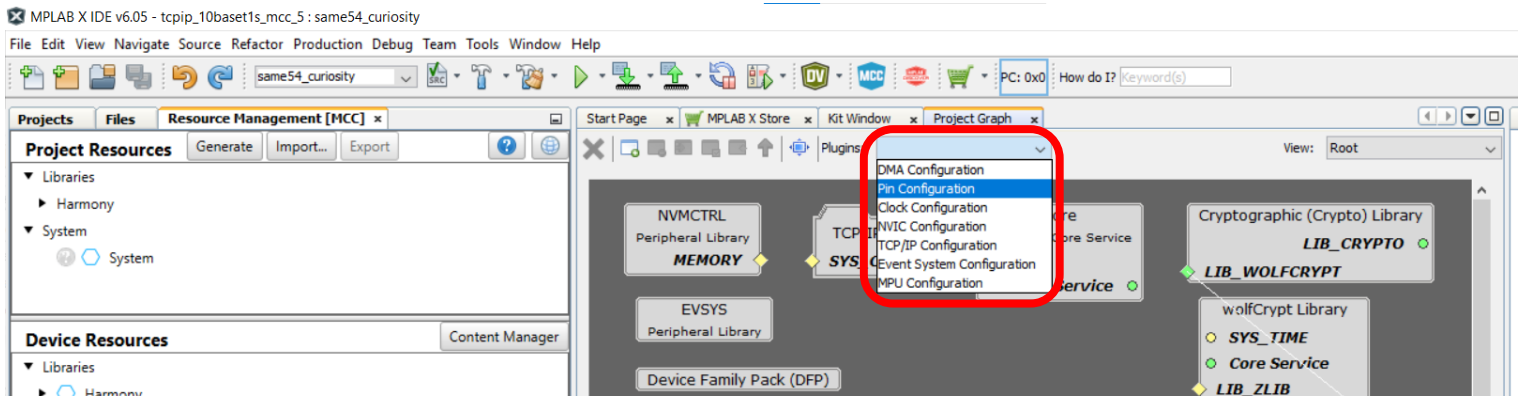
Heap Size

- **Select the System component, and change the Heap Size to 44960 bytes as shown**



Pin Configuration Tool

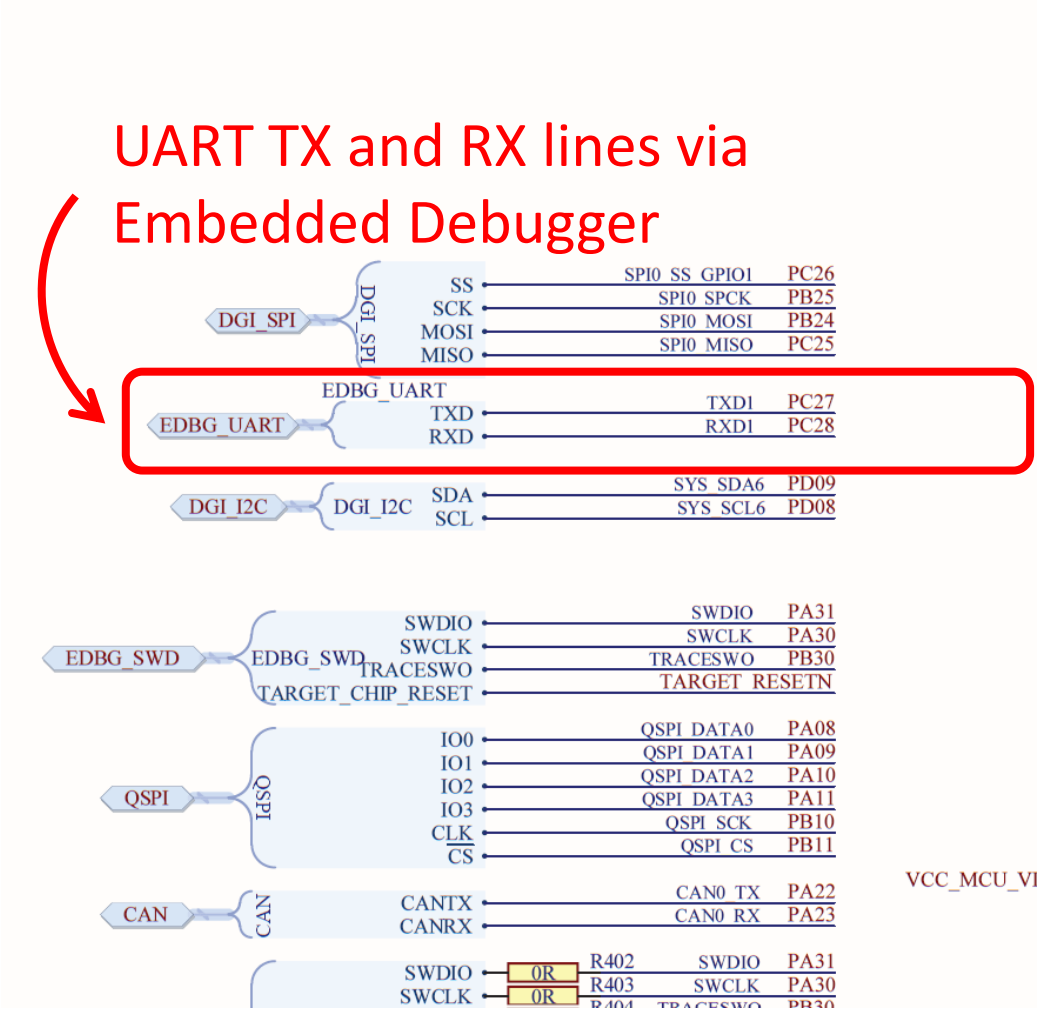
- **Open the Pin Configuration Tool in the Plugins dropdown menu**



Check the schematic to see the pin connections for the ethernet and UART pins (below are snapshots from Evaluation Board Schematic)

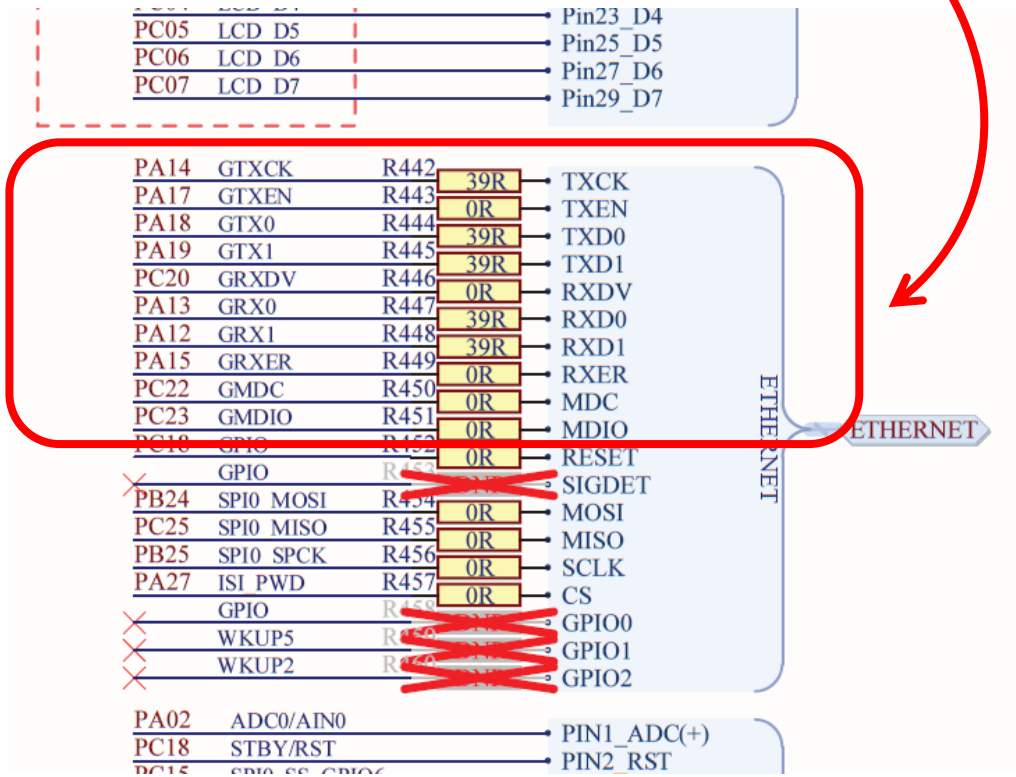
UART Pin Configuration

UART TX and RX lines via Embedded Debugger



GMAC Pin Configuration

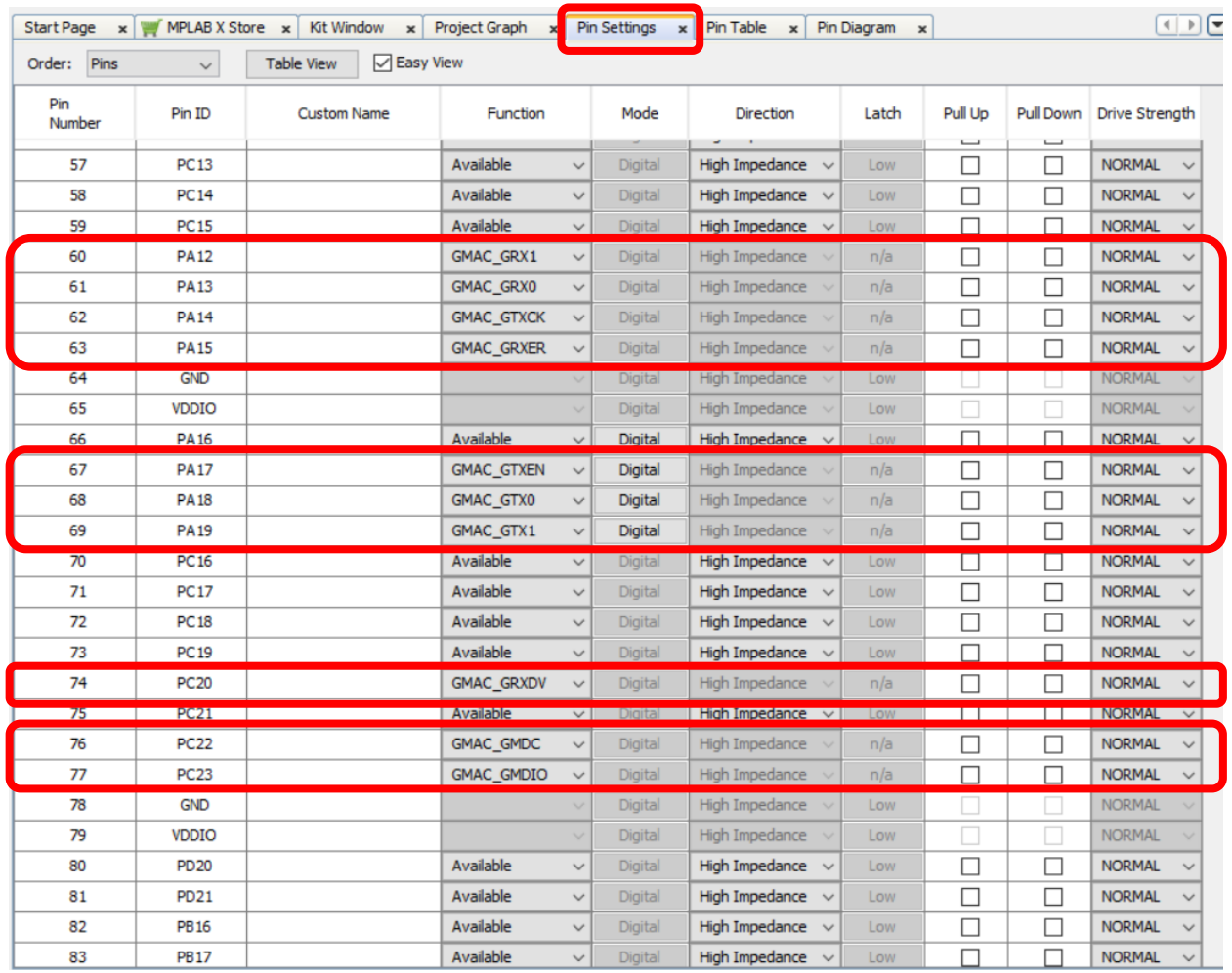
RMII Ethernet Signals and Configuration



MICROCHIP

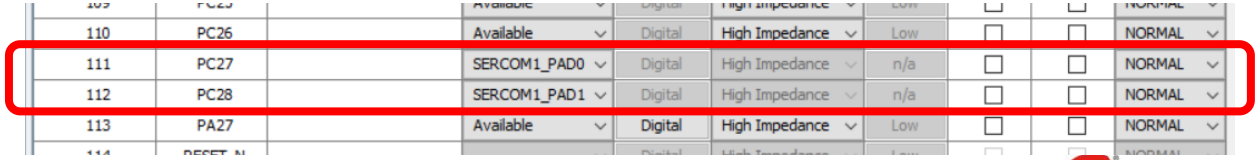
Pin Configuration Tool

- Having checked the schematic to see the connections on the board, use the Pin Configuration Tool to set up the pins.
- The Pin Settings tab is the easiest way to do this. Select the values shown for PA12, PA13, PA14, PA15, PA17, PA18, PA19, PC20, PC22 and PC23, to match with the board connections.



Pin Number	Pin ID	Custom Name	Function	Mode	Direction	Latch	Pull Up	Pull Down	Drive Strength
57	PC13		Available	Digital	High Impedance	Low			NORMAL
58	PC14		Available	Digital	High Impedance	Low			NORMAL
59	PC15		Available	Digital	High Impedance	Low			NORMAL
60	PA12		GMAC_GRX1	Digital	High Impedance	n/a			NORMAL
61	PA13		GMAC_GRX0	Digital	High Impedance	n/a			NORMAL
62	PA14		GMAC_GTXCK	Digital	High Impedance	n/a			NORMAL
63	PA15		GMAC_GRXER	Digital	High Impedance	n/a			NORMAL
64	GND			Digital	High Impedance	Low			NORMAL
65	VDDIO			Digital	High Impedance	Low			NORMAL
66	PA16		Available	Digital	High Impedance	Low			NORMAL
67	PA17		GMAC_GTXEN	Digital	High Impedance	n/a			NORMAL
68	PA18		GMAC_GTX0	Digital	High Impedance	n/a			NORMAL
69	PA19		GMAC_GTX1	Digital	High Impedance	n/a			NORMAL
70	PC16		Available	Digital	High Impedance	Low			NORMAL
71	PC17		Available	Digital	High Impedance	Low			NORMAL
72	PC18		Available	Digital	High Impedance	Low			NORMAL
73	PC19		Available	Digital	High Impedance	Low			NORMAL
74	PC20		GMAC_GRXDV	Digital	High Impedance	n/a			NORMAL
75	PC21		Available	Digital	High Impedance	Low			NORMAL
76	PC22		GMAC_GMDC	Digital	High Impedance	n/a			NORMAL
77	PC23		GMAC_GMDIO	Digital	High Impedance	n/a			NORMAL
78	GND			Digital	High Impedance	Low			NORMAL
79	VDDIO			Digital	High Impedance	Low			NORMAL
80	PD20		Available	Digital	High Impedance	Low			NORMAL
81	PD21		Available	Digital	High Impedance	Low			NORMAL
82	PB16		Available	Digital	High Impedance	Low			NORMAL
83	PB17		Available	Digital	High Impedance	Low			NORMAL

- Set the UART connections on pins PC27 and PC28

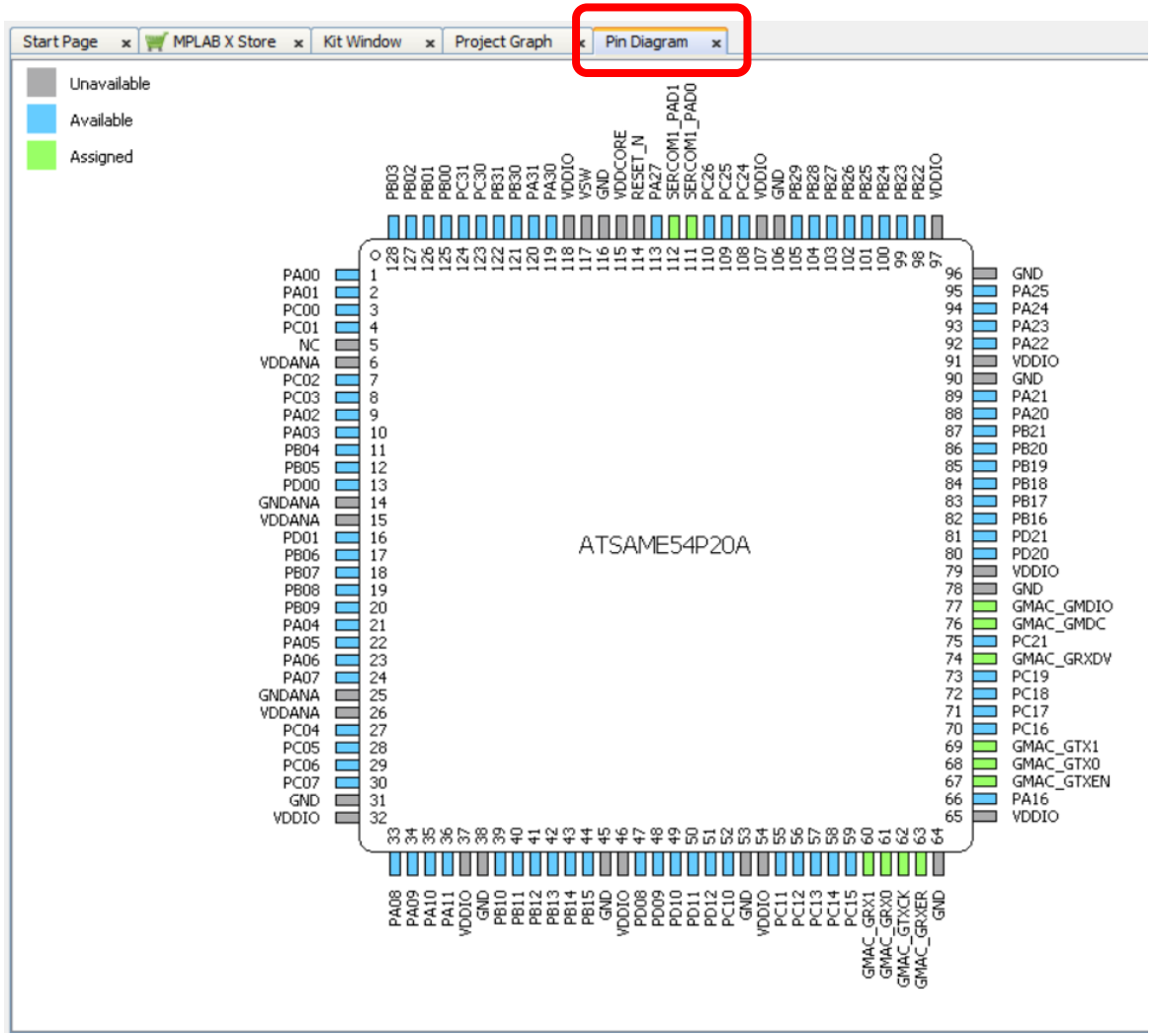


110	PC26		Available	Digital	High Impedance	Low			NORMAL
111	PC27		SERCOM1_PAD0	Digital	High Impedance	n/a			NORMAL
112	PC28		SERCOM1_PAD1	Digital	High Impedance	n/a			NORMAL
113	PA27		Available	Digital	High Impedance	Low			NORMAL

MICROCHIP

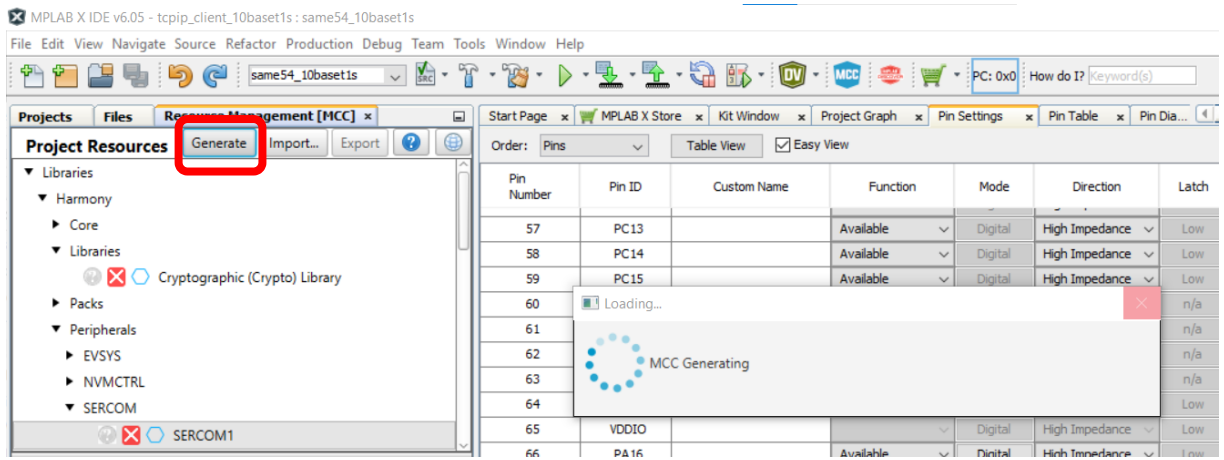
Pin Diagram

- **The Pin Diagram should now look as shown – the pins that are green are the ones that have been configured using the Pin Settings**



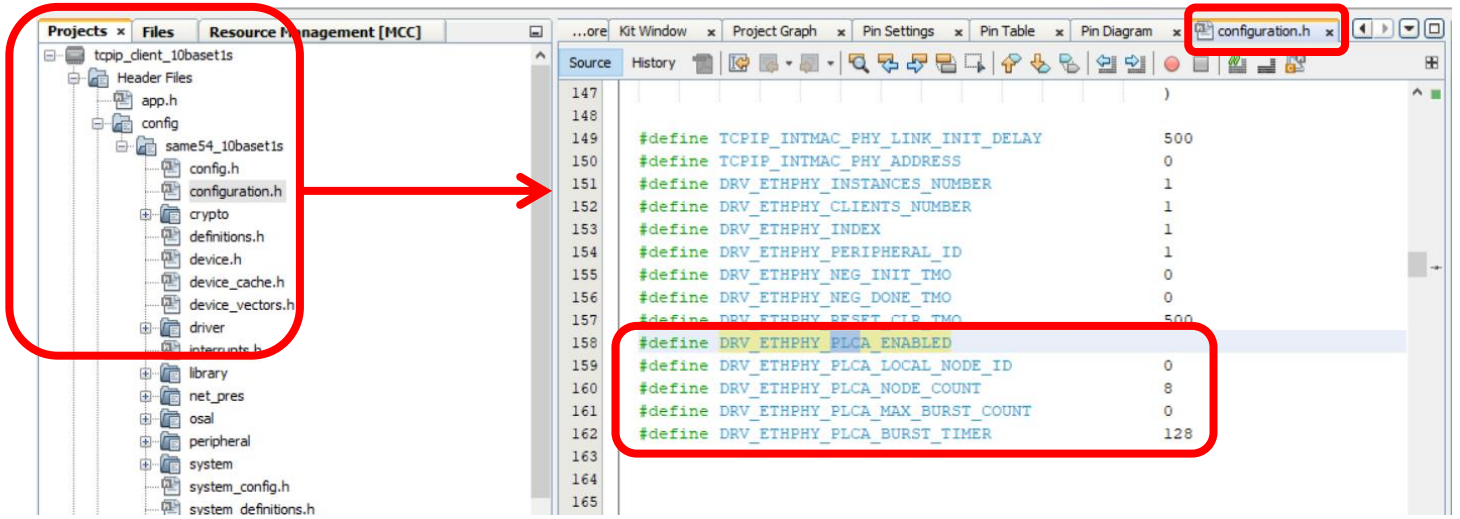
Generate the Code

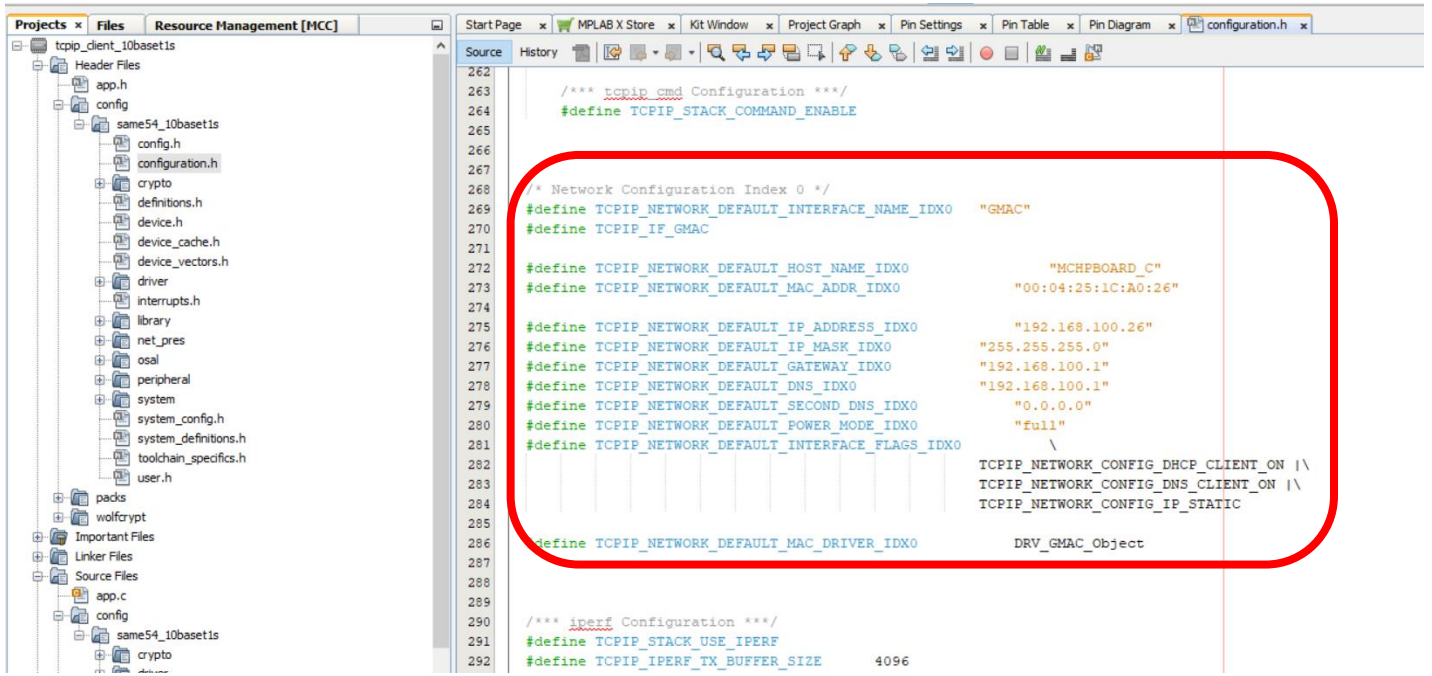
- **In Resource Management[MCC], use the Generate button to create the code for the project**



Configuration.h

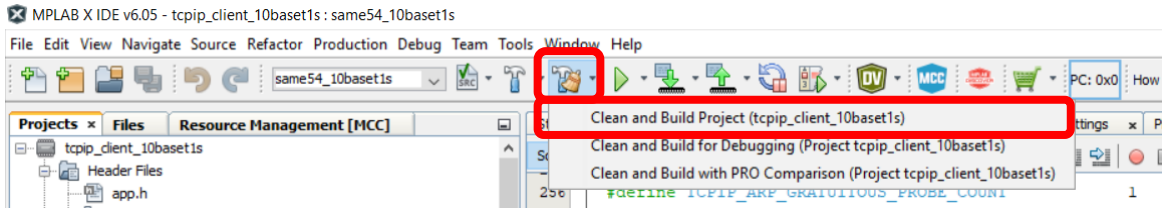
- **The Project is now populated**
- **Check the configuration.h Header File**
  - The PLCA settings and the Network Configuration settings can be seen in this file
  - Check that the PLCA settings are correct
  - Check that the IP Address and MAC Address are correct
  - These can be changed in this file if necessary
    - But any changes in this file will not be reflected back into the MCC Project Graph settings



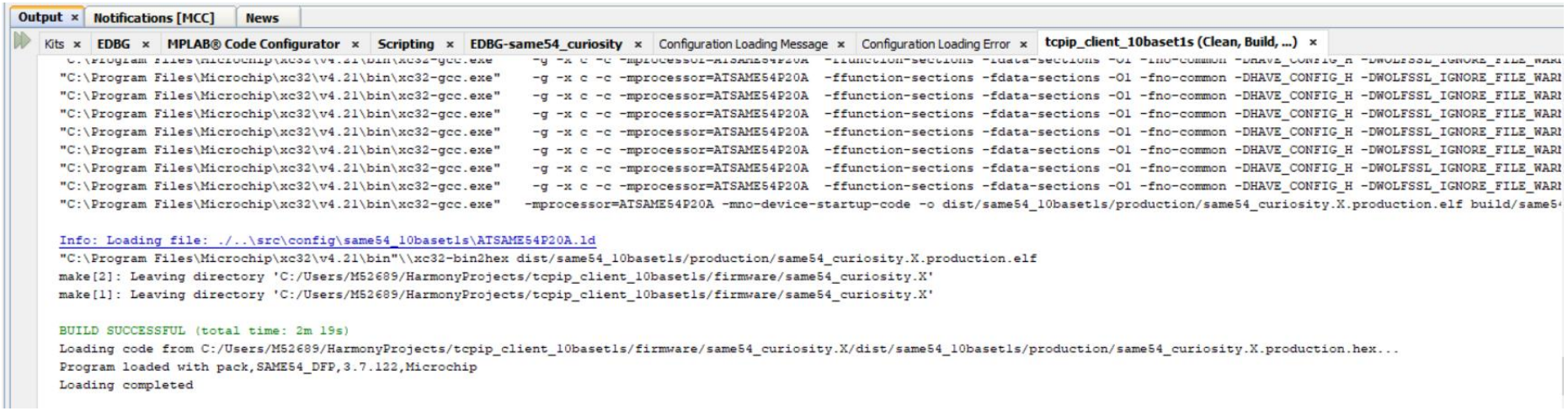


Build the Project and Program the Device

- **Clean and Build the Project**

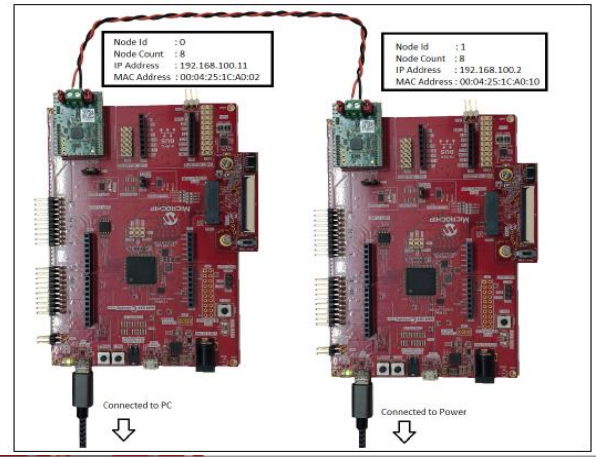


- **Check the output of the Build to make sure it was successful, similar to what is shown.**

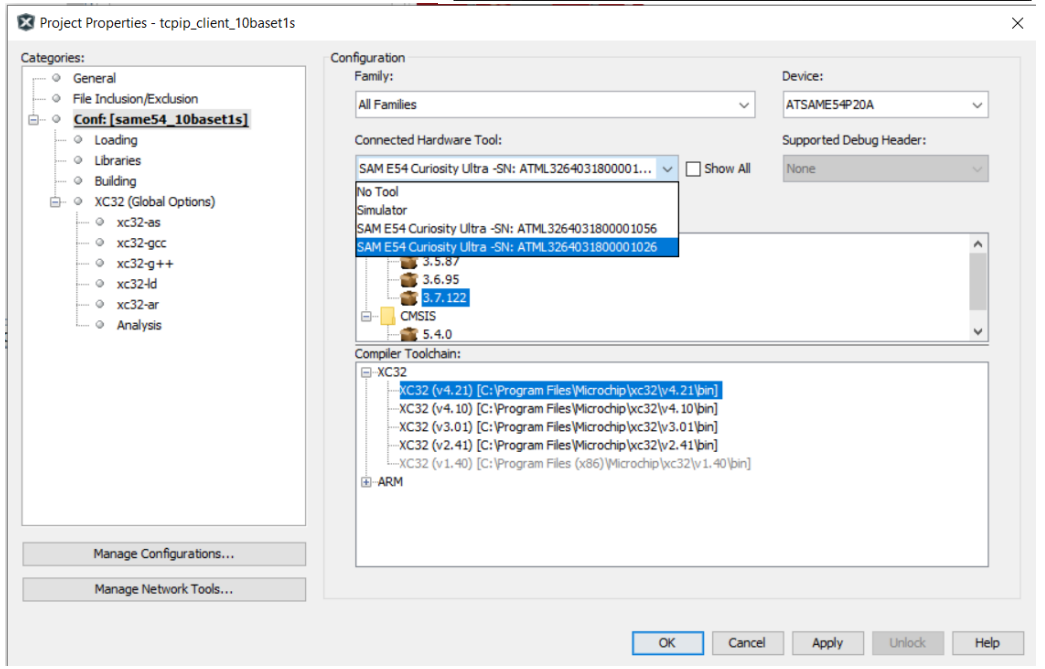


Program the Node 0 Board

- Connect the boards to the PC

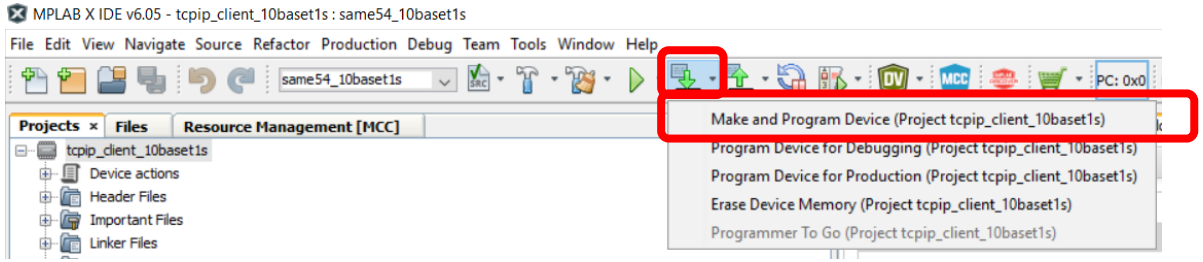


- In the Project Properties, check the Connected Hardware Tool list dropdown menu and select which board to program
- This board will be the PLCA Node 0 board



Program the Node 0 Board

- Use Make and Program Device to program the board.

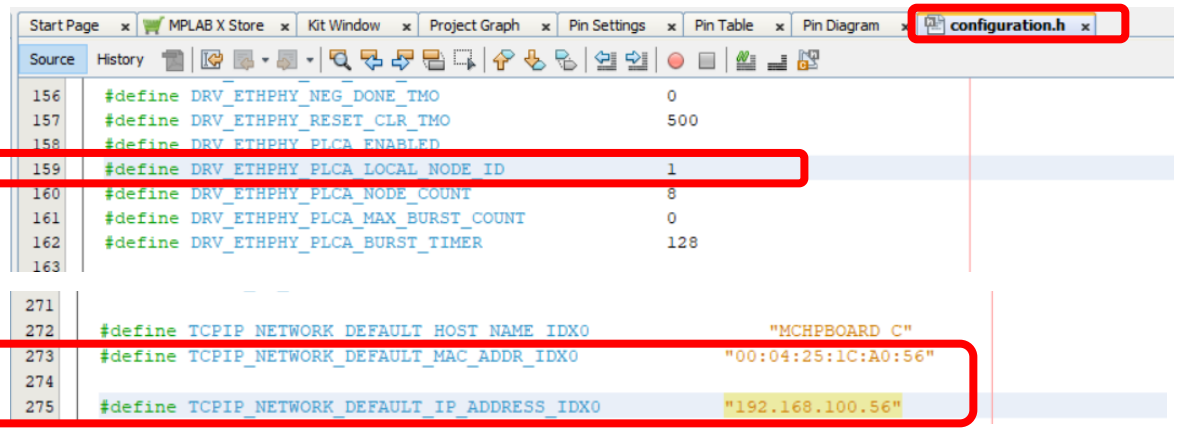


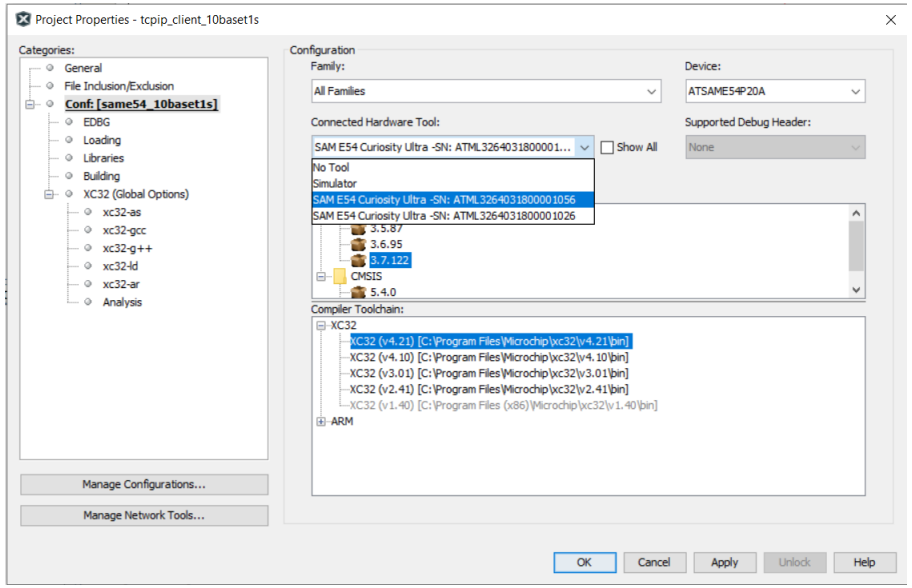
- Check the output to make sure there were no errors

MICROCHIP

Program the Node 1 Board

- In configuration.h, change the Node ID to 1 and change the MAC and IP Address so that they are distinct from the Node 0 Board
- In Project Properties, change the Connected Hardware Tool to the other board
- Repeat the “Make and Build Main Project” and “Make and Program Device” steps
- The boards are now programmed

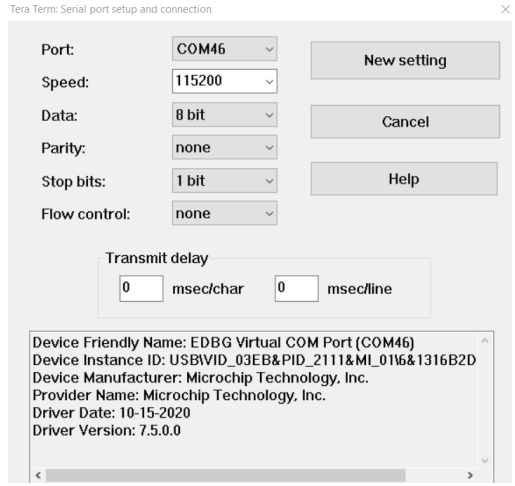


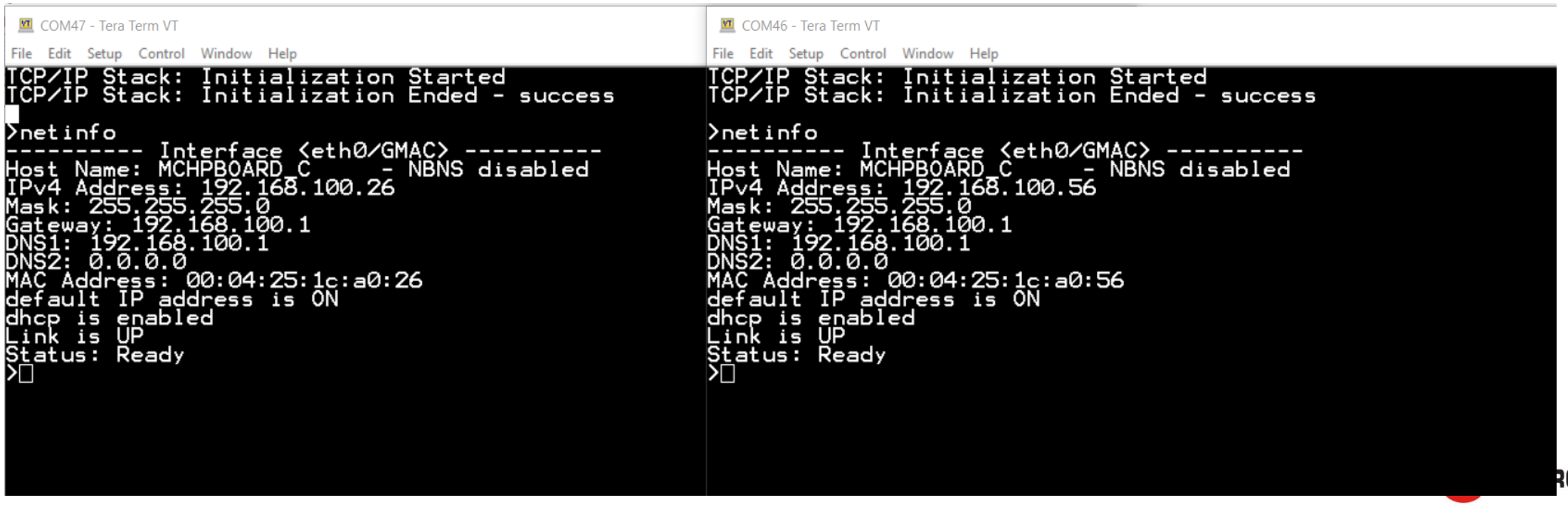


MICROCHIP

Test

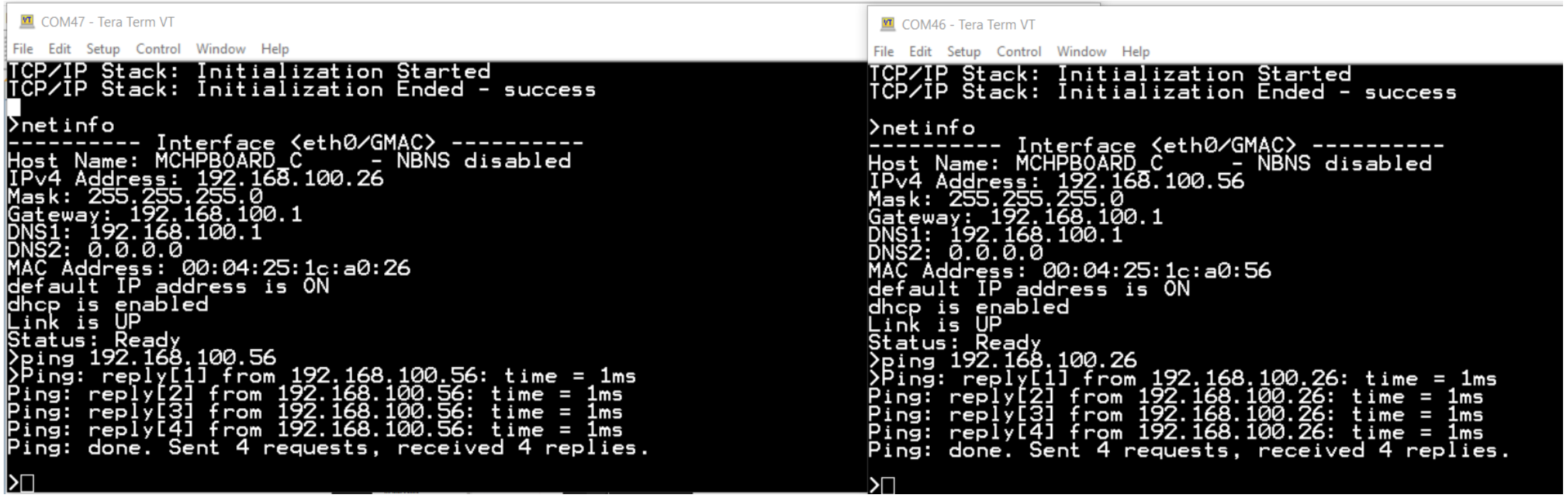
- **Open a serial connection to both boards using the settings shown**
- **Reset both boards using the Reset button on the board**
  - You should see the TCP/IP Stack Initialization messages to show the stack is working
- **Use the "`netinfo`" command to show the Network Configuration**
  - Tip – wait a few moments after resetting the boards to allow the link to establish





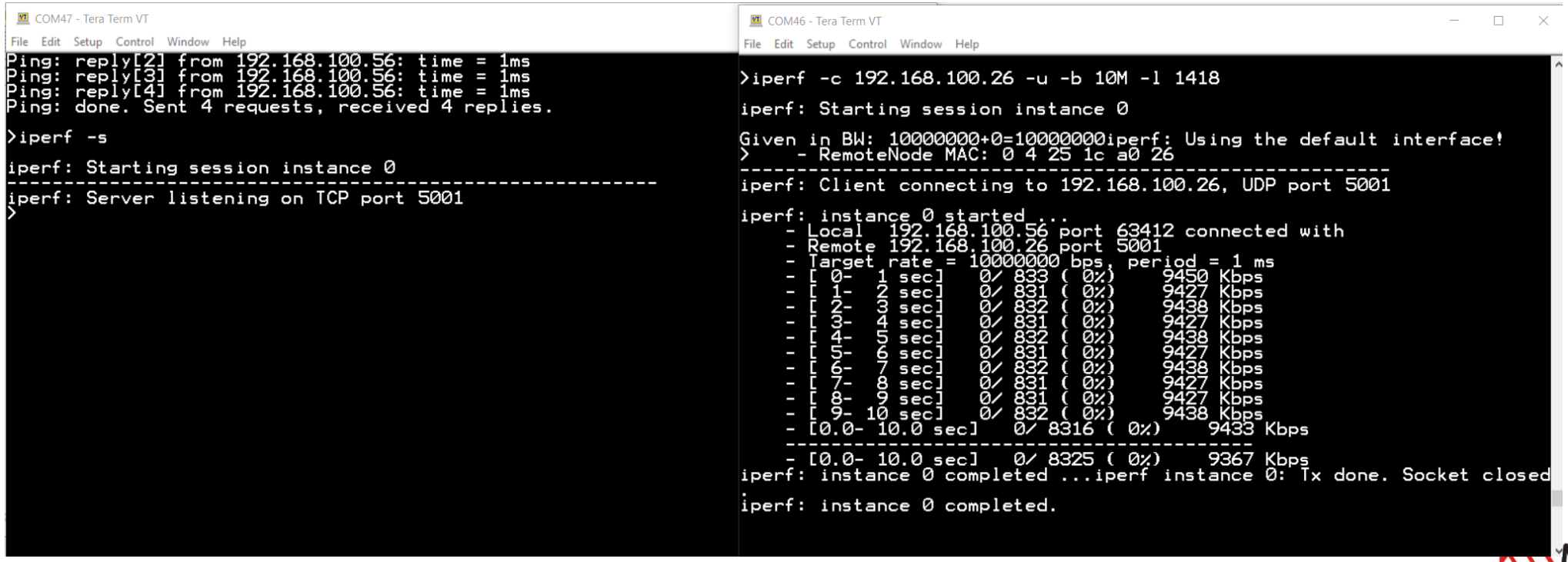
Ping test

- Use the "`ping`" command to check the link



iperf

- On one terminal type "`iperf -s`" to initiate the iperf server on that node
- On the other terminal type "`iperf -c 192.168.100.xx -u -b 10M -l 1418`" to test the speed of the link
- Try other ethernet frame length options other than 1418, such as 700 and 300 to show the reduction of the bandwidth when the length of the frame is limited in this way



Useful Links and References

For more information…

- **For installing the necessary software, see:**
  - MPLAB® X IDE Essentials - 01: Installation and Ecosystem – YouTube
    - Make sure to download the latest XC32 Compiler v4.21 as well as MPLAB X v6.05 and MCC Plugin v5.2.2 as shown in this video
    - We won't need the Data Visualizer for this class, you can skip that part
- **For more about creating a project:**
  - Creating a MPLAB® Harmony Project in MCC – YouTube
- **Further reading:**
  - Learn MPLAB X Integrated Development Environment (IDE) | Microchip Technology

Demo Project

- **There is a demo project checked into the Github Harmony repository that you will have downloaded already in the net_10base_t1s library as part of the Optional Packages list during the project setup**
- **Use File > Open Project and navigate to this library, and choose from the freertos or non-freertos versions**
  - Note: in order to generate and compile these projects, you will still need to have downloaded the necessary packages as described in the project setup