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
https://www.microchip.com/en-us/tools-resources/configure/mplab-code-configurator

[2] MPLAB Code Configurator Getting Started
https://microchipdeveloper.com/mcc:start

[3] SAM E54 Curiosity Ultra Development Board
https://www.microchip.com/Developmenttools/ProductDetails/DM320210

[4] SAM E70 Xplained Ultra Evaluation Kit
https://www.microchip.com/Developmenttools/ProductDetails/DM320113

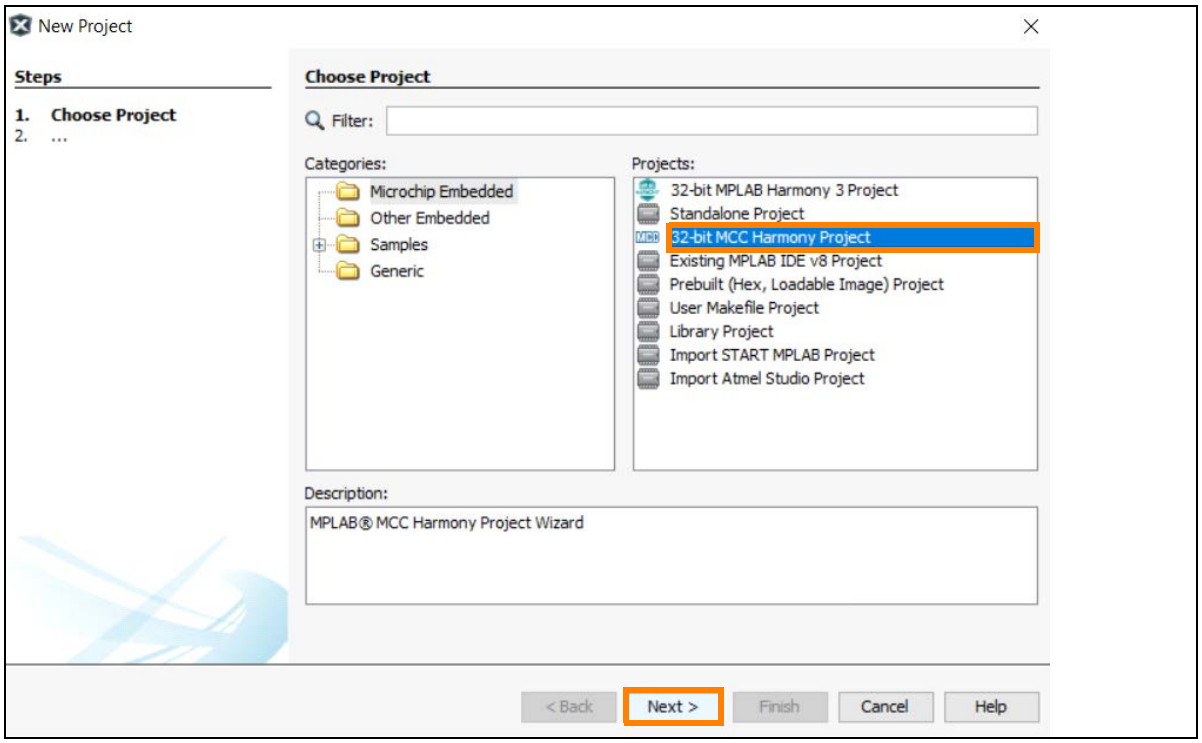
1.3 Abbreviations

Abbreviation	Definition
CSMA/CD	Carrier-Sense Multiple Access/Collision Detection
EDBG	Embedded Debugger
MCC	MPLAB Code Configurator
NVIC	Nested Vectored Interrupt Controller
PLCA	Physical Layer Collision Avoidance

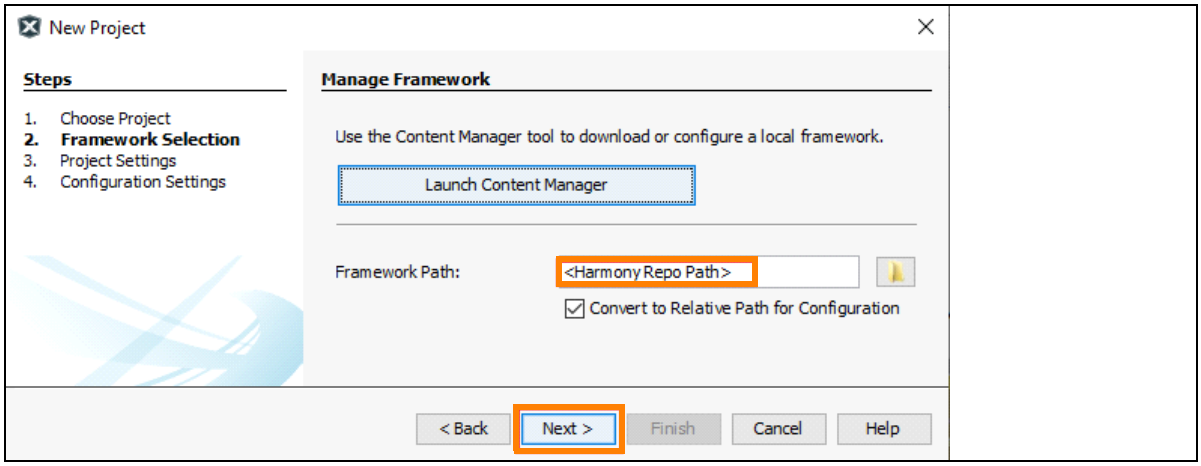
2.0 CREATE A NEW MCC HARMONY PROJECT

2.1 Create a New Project

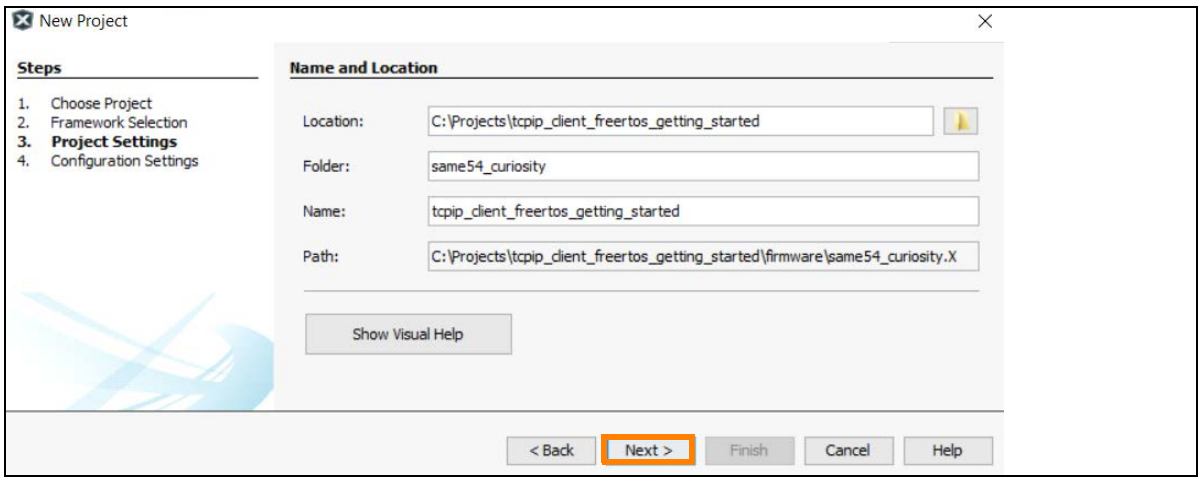
1. Open MPLAB X IDE.
2. Create a new project by either
   a) clicking the new project icon  or
   b) by selecting *File* > *New Project*.
3. In the “New Project” window select “32-bit MCC Harmony Project”.
4. Click **Next**.



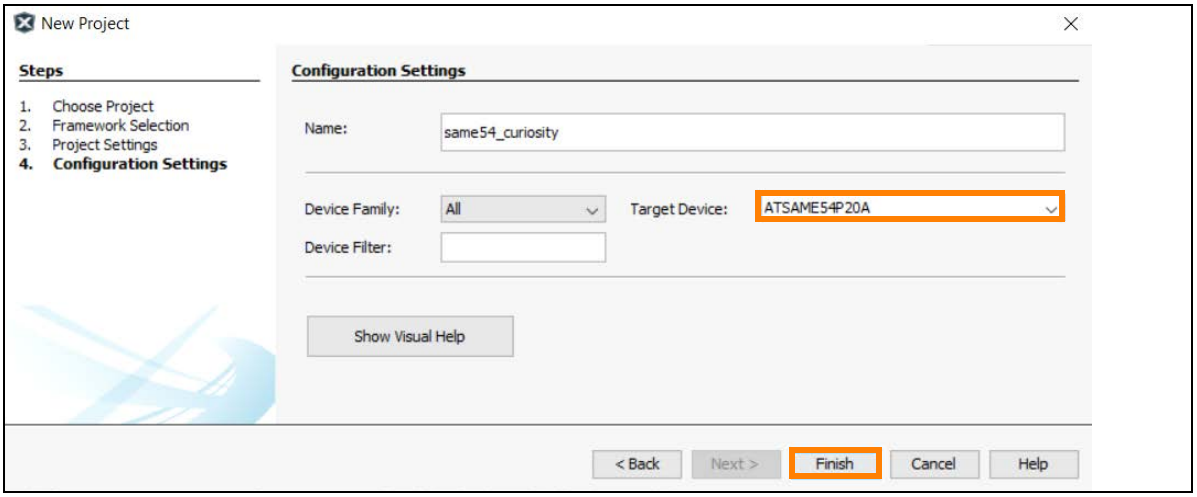
5. In the “Framework Path”, enter the path of the folder to which the MCC Harmony packages are downloaded.
6. Click **Next**.



7. In the “Project Setting” dialog window:
   a) Fill in or select the information needed as follows:
      - Location:
        First, create a “*tcpip_client_getting_started”* folder in the location of your choice (for example, create the application project inside the *C:\Projects* folder).
        Note: Use an appropriate name. (We used “*tcpip_client_freertos_getting_started*” for the FreeRTOS application.)
        Then enter the path in this field.
      - Folder:
        Enter a project folder name (for example, *same54_curiosity*).
      - Name:
        Enter a project name (i.e. “*tcpip_client_freertos_getting_started*”).
        (If you have a bare-metal project, you can enter as project name “*tcpip_client_getting_started”*.)
      - Path:
        The information entered in the above fields auto populates the *Path*.
   b) Click **Next**.

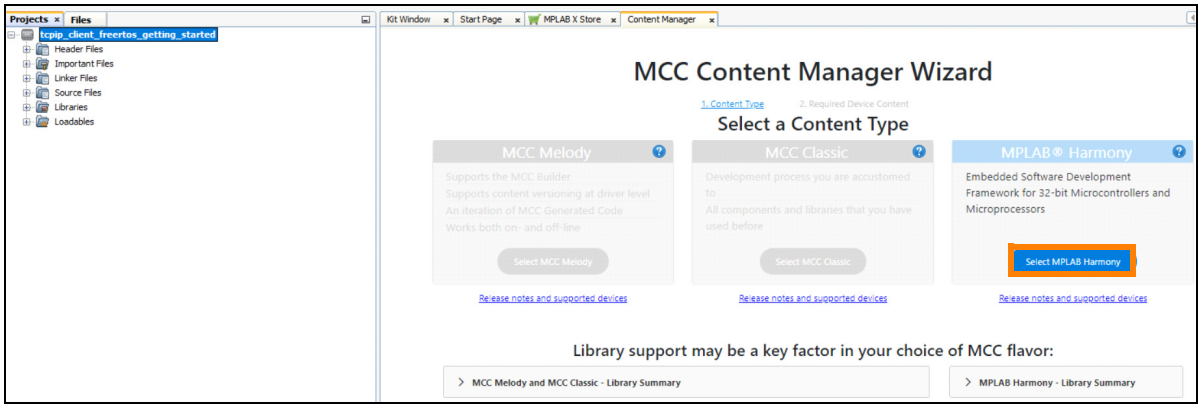


8. In the “Configuration Settings” dialog window:
   a) Fill in or select the information needed as follows:
      - Name:
        Enter the configuration name (for example, “*same54_curiosity*”).
      - Target Device:
        Select “ATSAME54P20A” (the target device is running on a SAM E54 Curiosity Ultra Development Board [3]).
   b) Click **Finish**.



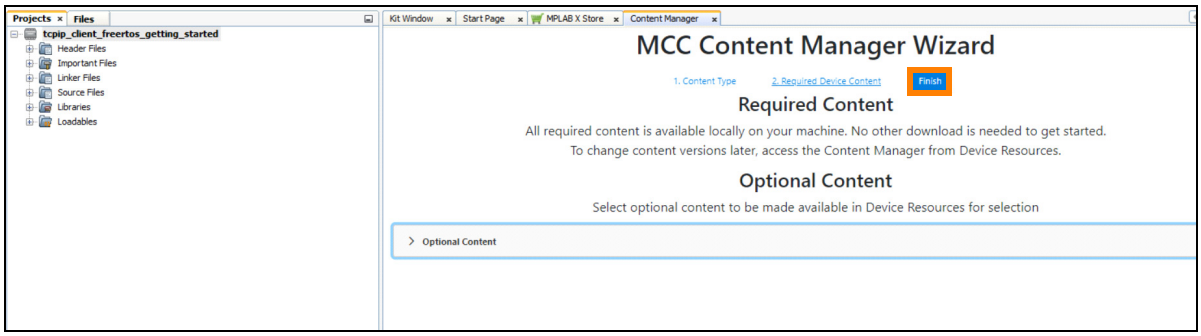
When you create an MCC project, the Content Manager page opens and you can select the MCC flavor, based on the project.

9. In the MCC Content Manager Wizard, click **Select MPLAB Harmony**.



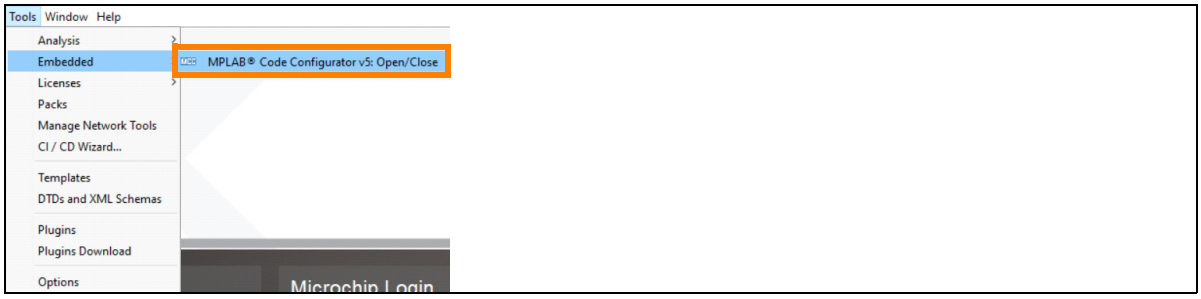
When you create an MCC project for the first time, you need to download all required device content libraries.

10. Once the download is completed, click **Finish**.

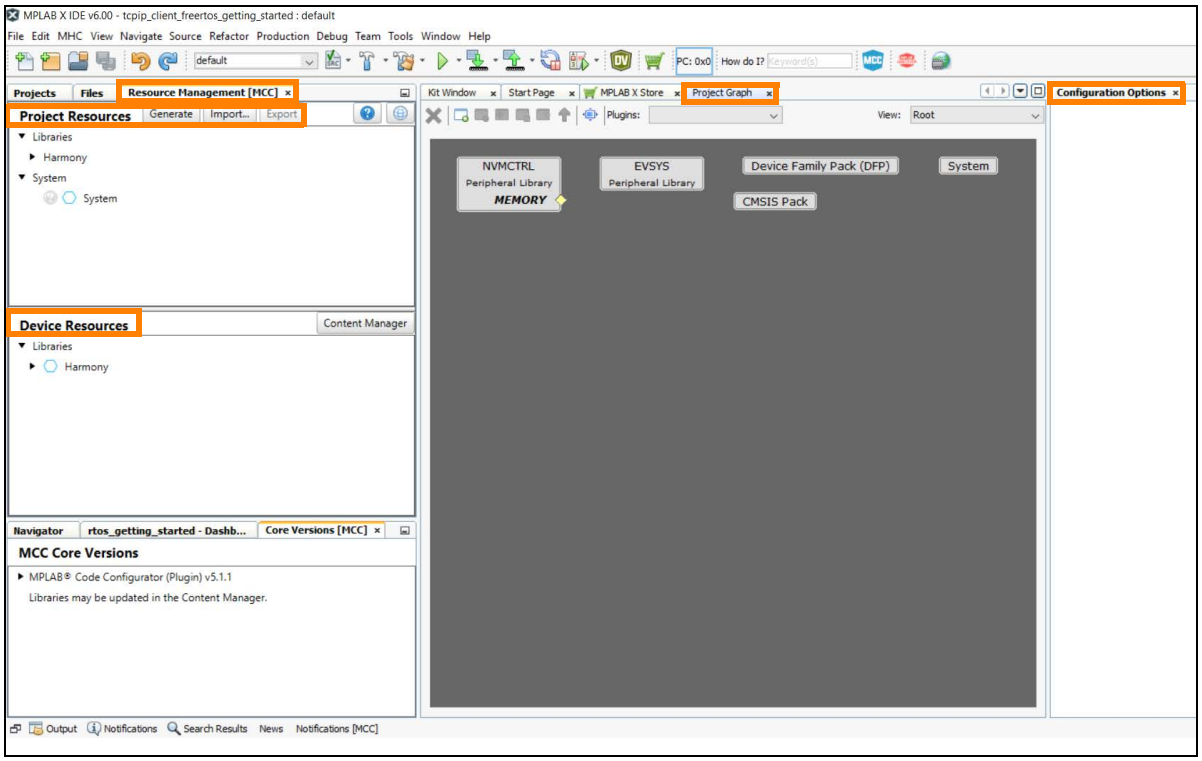


Note: Version numbers may differ. Therefore, always use the latest versions.

If the above dialog window does not appear, the MCC can be launched under *Tools* > *Embedded*, by selecting "MPLAB Code Configurator v5".



The default MCC looks as shown below.



The different parts of the MCC are:

- Resource Management (MCC)
- Project Resources
- Device Resources
- Project Graph
- Configuration Options

Depending upon application needs, the necessary components can be added from the “Project Resources”.

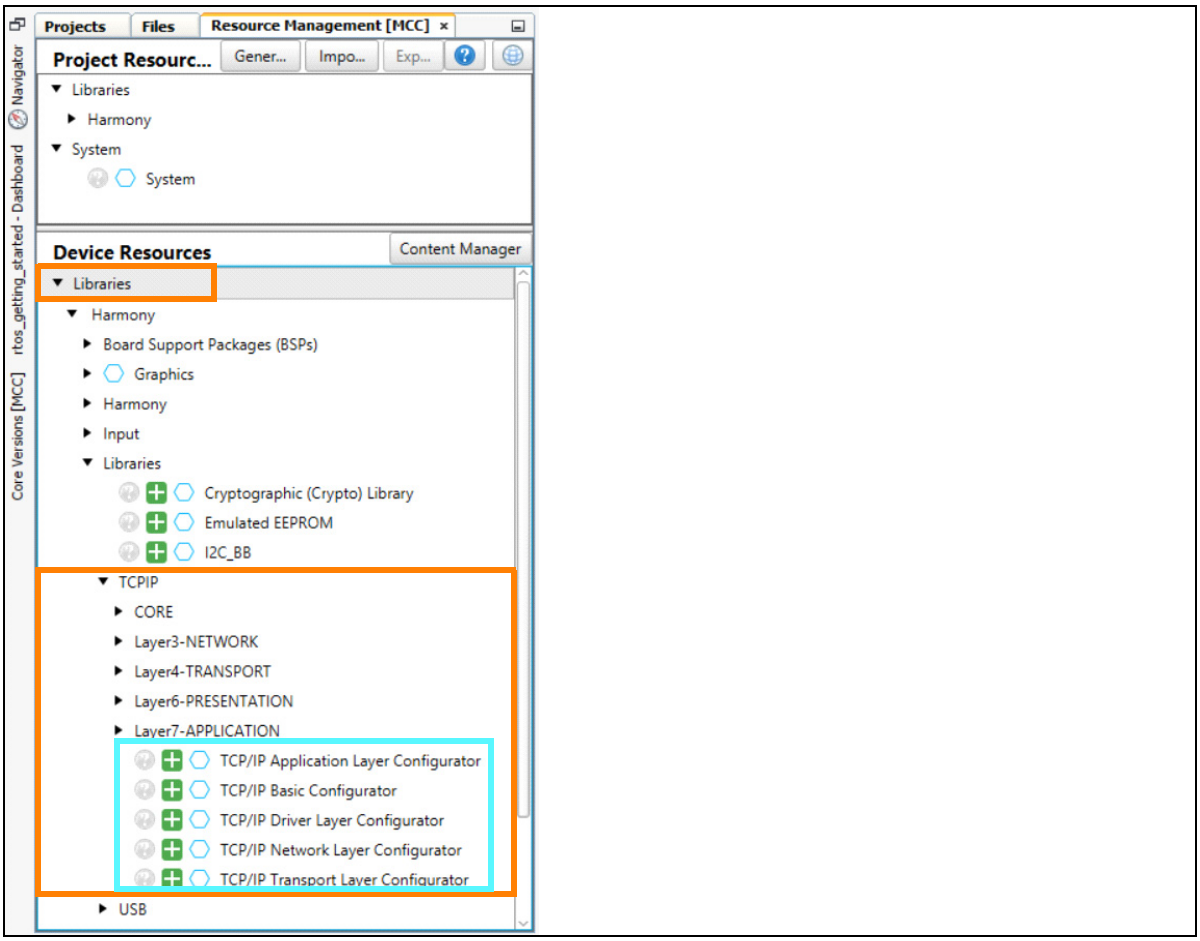
Basic components needed for creating a project are available in the “Project Graph” by default.

2.2 Add TCP/IP Components

In this section we configure the components based on application needs.

The TCP/IP components can be added from the “Project Resources” tab.

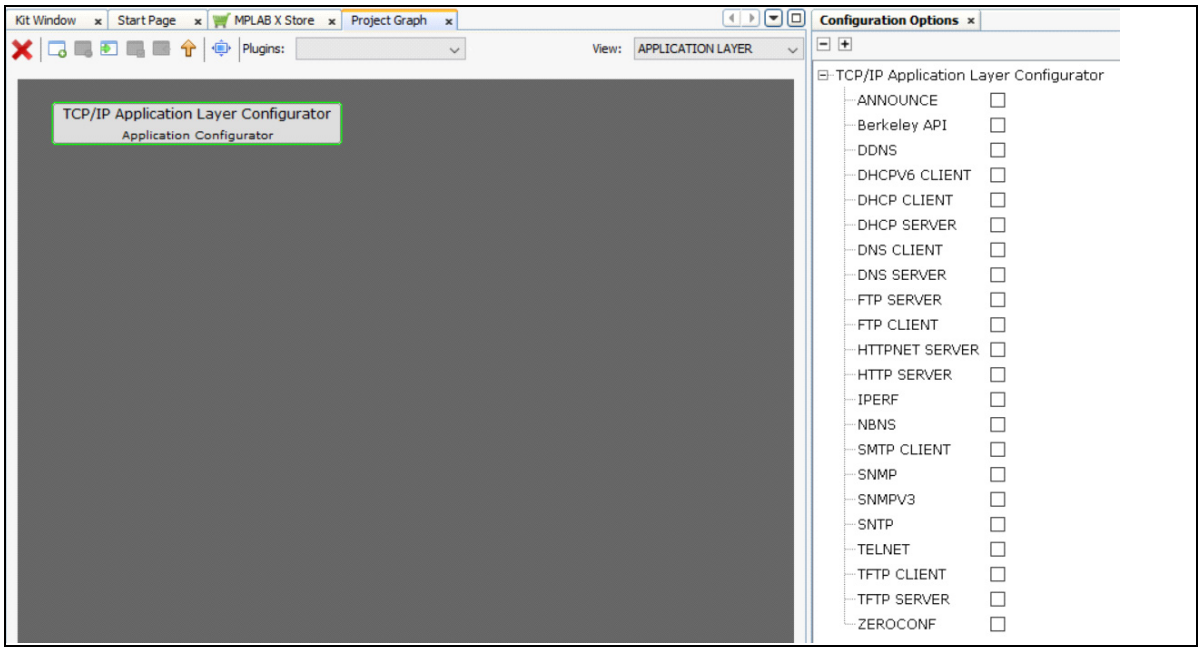
1. Go to *Project Resources* > *Libraries* > *TCPIP*.
   The TCP/IP components are categorized into different groups. For each group, a configurator is available.
   These configurators are:
   - TCP/IP Application Layer Configurator
   - TCP/IP Basic Configurator
   - TCP/IP Driver Layer Configurator
   - TCP/IP Network Layer Configurator
   - TCP/IP Transport Layer Configurator



Note: It is recommended to add the TCP/IP components using these configurators. When components are added by using configurators, dependent modules will be activated automatically.

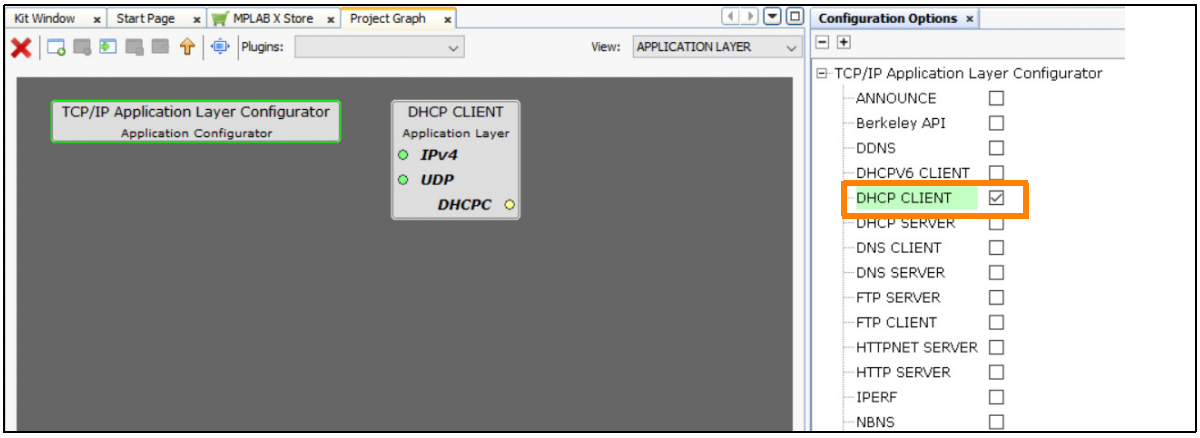
2.3 Application Layer Configurator

1. Select the “TCP/IP Application Layer Configurator” and double click.
   This step adds the “TCP/IP Application Layer Configurator” inside the “APPLICATION LAYER” group.
   This step also creates a hierarchy of groups as *Root >TCP/IP STACK >APPLICATION LAYER*.
2. Click “TCP/IP Application Layer Configurator”.
   See the configurations options on the right-hand side.

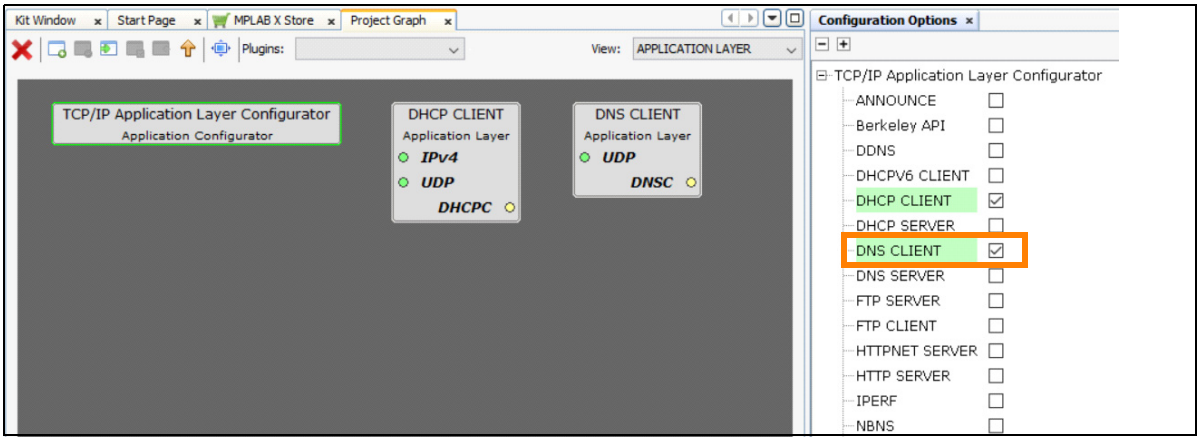


   Different application protocols supported in the MPLAB Harmony TCP/IP stack are listed.
3. Start selecting the required TCP/IP application layer protocols from the “Configuration Options” on the right-hand side.
4. For the Getting Started demo, select “DHCP CLIENT”.
   The following steps auto-activate all dependent components.
   a) Click **Yes** to add the “Harmony Core” component.
   b) If you have a bare-metal project, click **No** for the “FreeRTOS” component.
      If you have a FreeRTOS project, click **Yes** for the “FreeRTOS” component and add necessary FreeRTOS settings (see FreeRTOS Configuration).
   c) Click **Yes** to add the “TIME(sys_time)” component.
   d) Click **Yes** to add the “CONSOLE(sys_console)” component.
   e) Click **Yes** to add the “TCP/IP STACK CONFIGURATION” component.
   f) Click **Yes** to add the “DEBUG(sys_debug)” component.
   g) Click **Yes** to connect the “sys_debug” component.
   h) Click **Yes** to add the “IPv4(tcpipIPv4)” component in TCP/IP Network Layer.
   i) Click **Yes** to add the “ARP(tcpipArp)” component in TCP/IP Network Layer.
   j) Click **Yes** to add the “UDP(tcpipUdp)” component in TCP/IP Transport Layer.

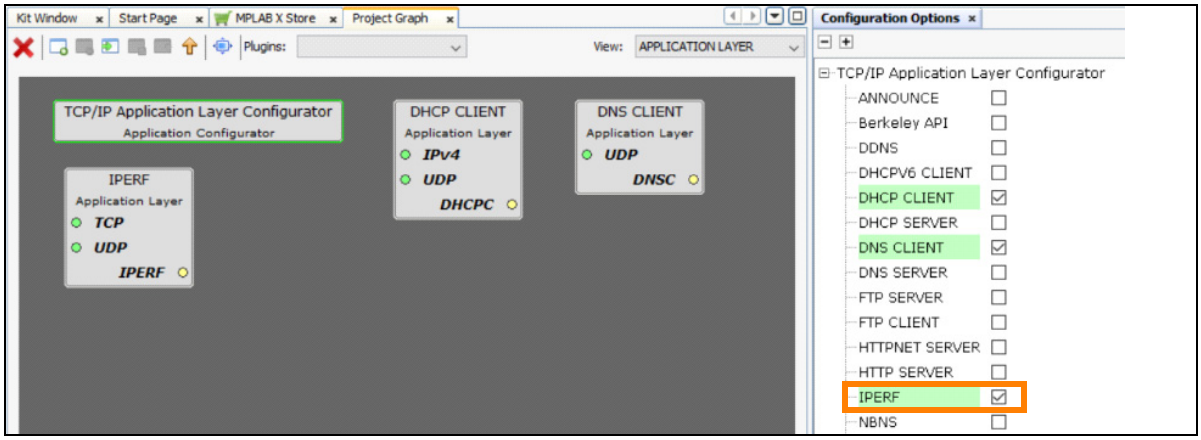
After the auto-activation of dependent components, the “DHCP CLIENT” component is added to the “Project Graph”.



5. Check the “DNS CLIENT” in the “TCP/IP Application Layer Configurator”.
   This adds the “DNS CLIENT” component to the “Project Graph”.

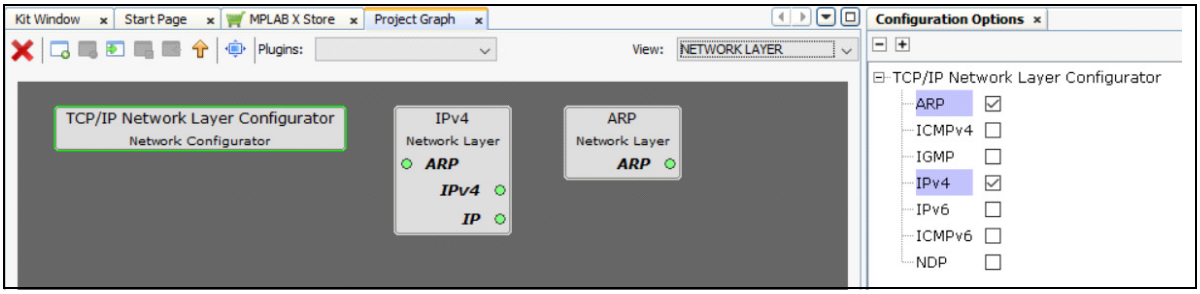


6. Check the “IPERF” module.
   The following steps auto-activate all dependent components.
   a) Click **Yes** to add the “TCP” component.
   b) Click **Yes** to add the “lib_crypto” component.
   c) Click **Yes** to add the “lib_wolfcrypt” component.
   d) Click **Yes** to add the connection “lib_wolfcrypt”.

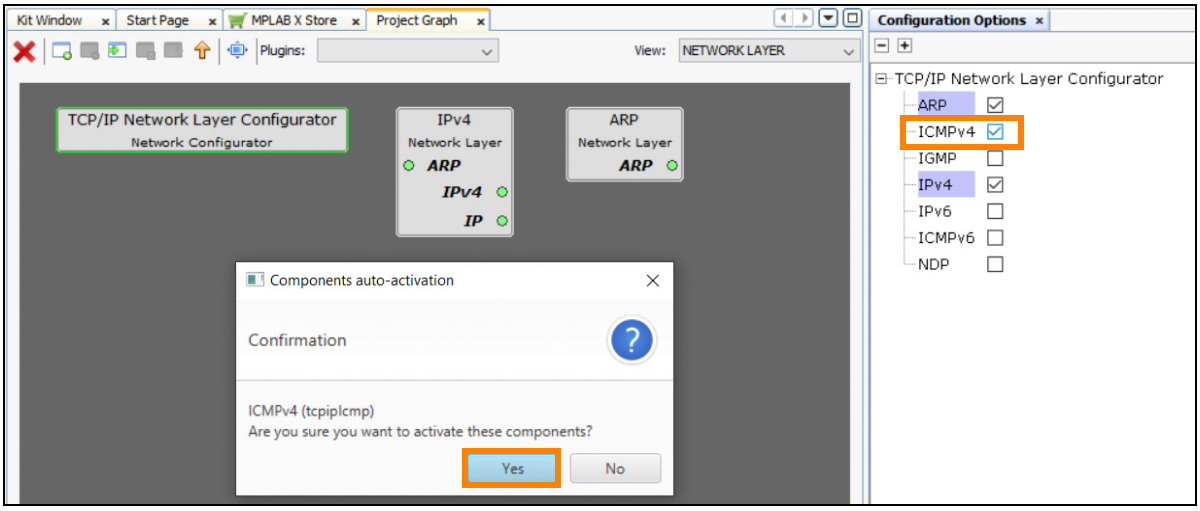


2.4 Network Layer Configurator

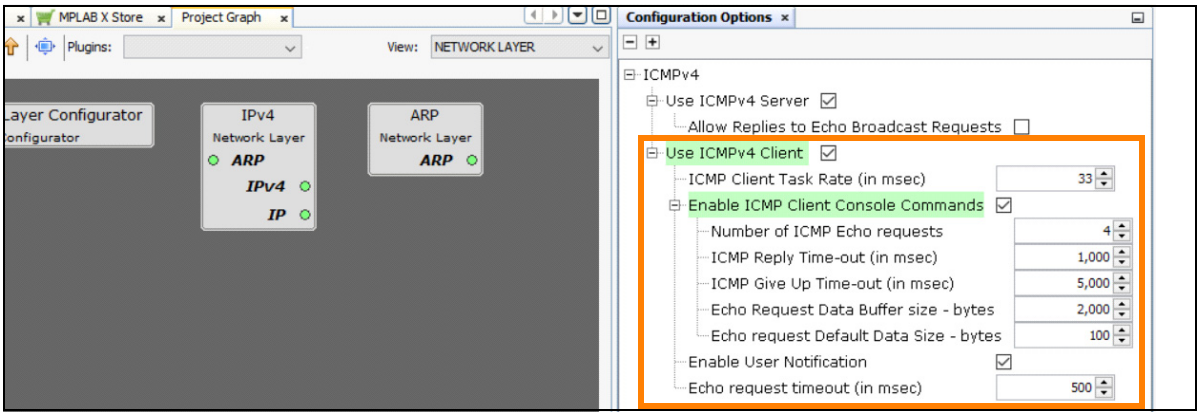
1. Go back to the “TCP/IP STACK” layer.
   a) Double click “NETWORK LAYER”.
   b) Click “TCP/IP Network Layer Configurator”.



2. Add the “ICMPv4” protocol support for this demo.
3. Click **Yes**.
   This adds the “ICMPv4” component in the “TCP/IP Network Layer Configurator”.

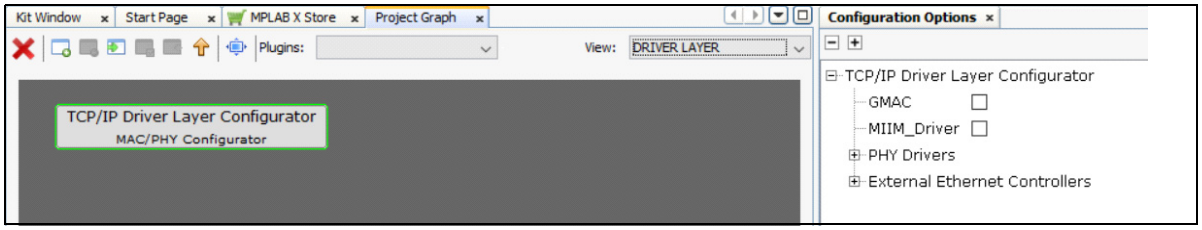


4. To enable “ping operation” from the SAM E54 Curiosity Ultra Development Board [3],
   a) select “ICMPv4” and
   b) make the settings as shown below.

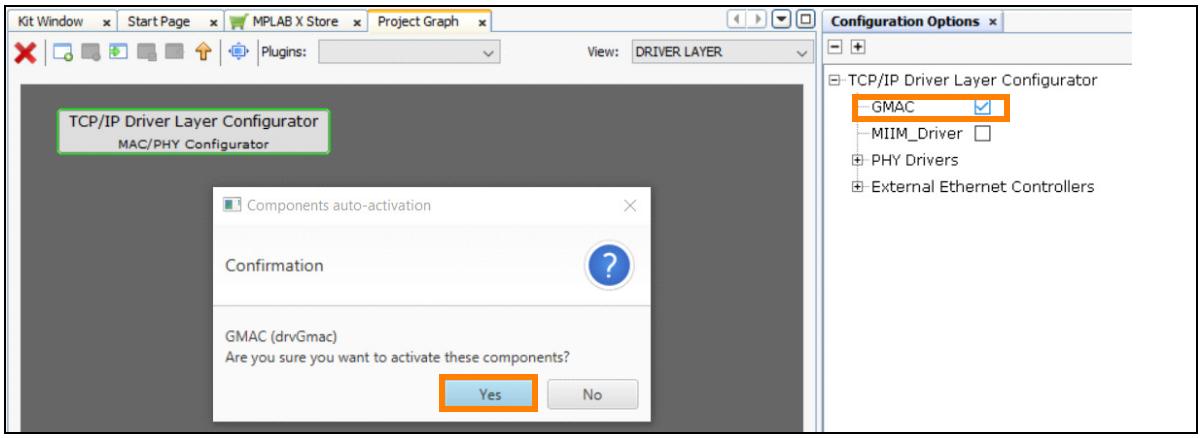


2.5 Driver Layer Configurator

1. In the “Project Graph” select “DRIVER LAYER” from the “View” drop-down menu.
2. Click “TCP/IP Driver Layer Configurator”.



3. Add the “Ethernet MAC driver”.
   For SAM E54, the internal MAC is called “GMAC” (for PIC32M devices, the internal MAC is called “ETHMAC”).
4. Click **Yes**.
   This adds the “GMAC” component in the “TCP/IP Driver Layer Configurator”.

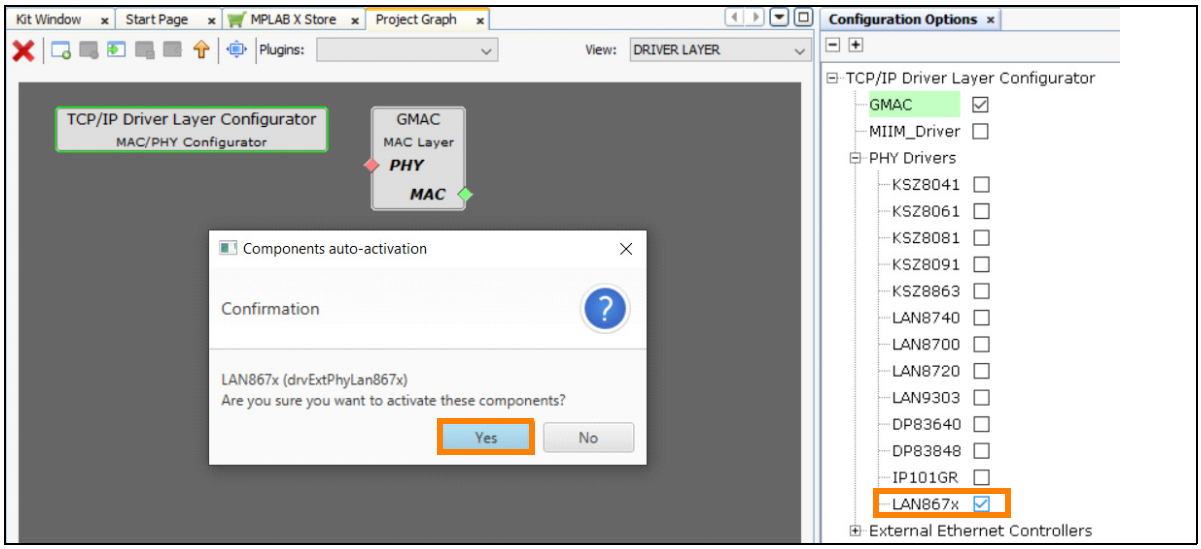


   This step auto-activates all dependent components.
5. Click **Yes** to add the component “BASIC CONFIGURATION” and make connection GMAC component.

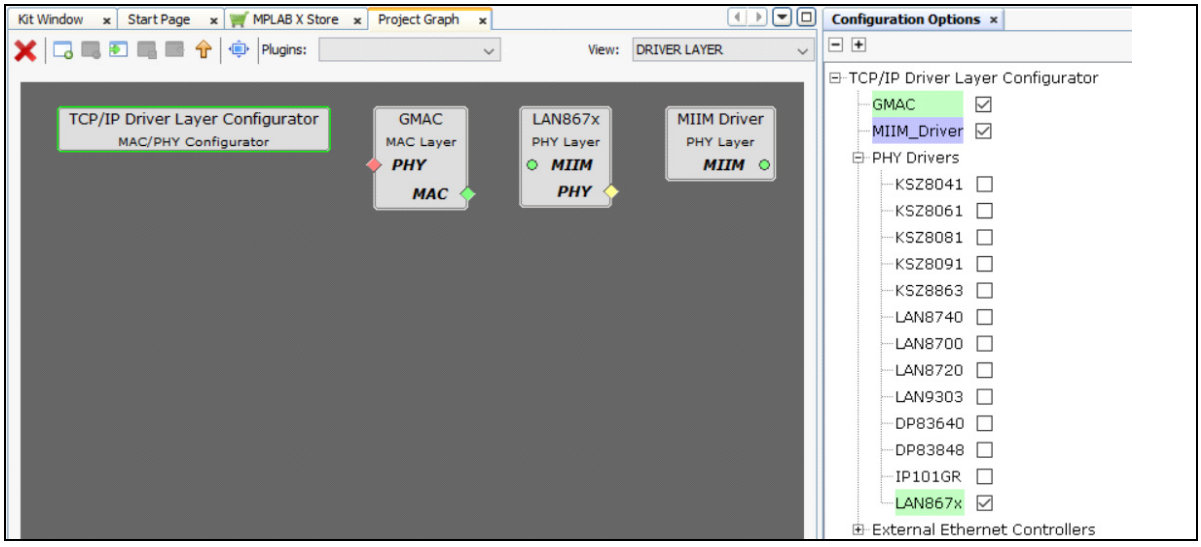
6. Add the Ethernet PHY driver.

   For the SAM E54 Curiosity Ultra Development Board with the LAN867x PHY daughter board, select the PHY device “LAN867x”.
   (See the development board user’s guide [3] to identify the Ethernet PHY device supported by the hardware.)

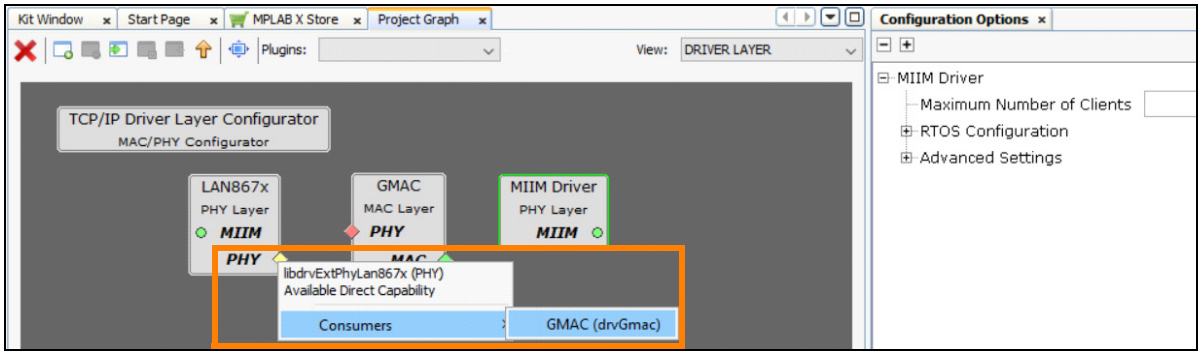
7. Click **Yes**.
   This adds the “LAN867x” component in the TCP/IP Driver Layer.
   The PHY driver addition triggers the auto-activation of the “MIIM_Driver”.



8. Click **Yes**.
   This adds the “MIIM_Driver” component in the TCP/IP Driver Layer.

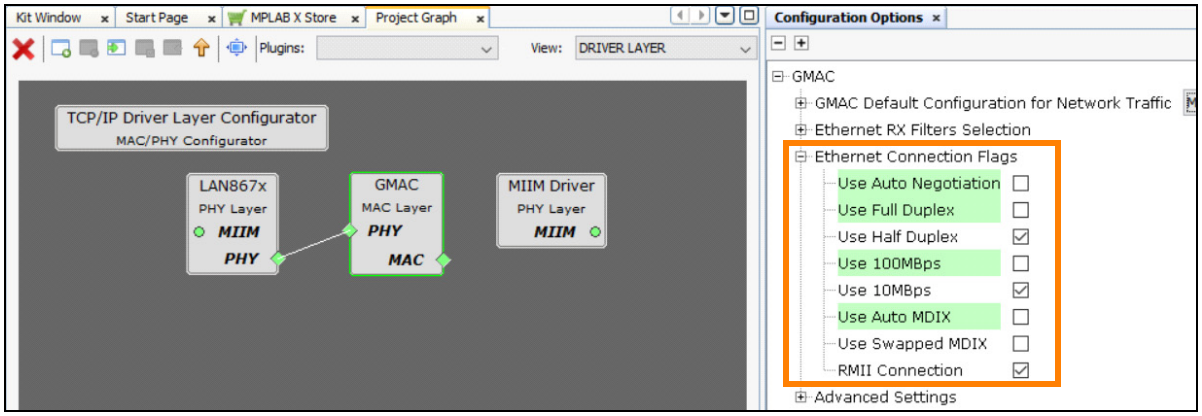


9. Add the dependency between the LAN867x and the GMAC component.
   a) To find the satisfier, right click the yellow diamond next to “PHY” on the LAN867x component.
   b) Select “GMAC” as the consumer.



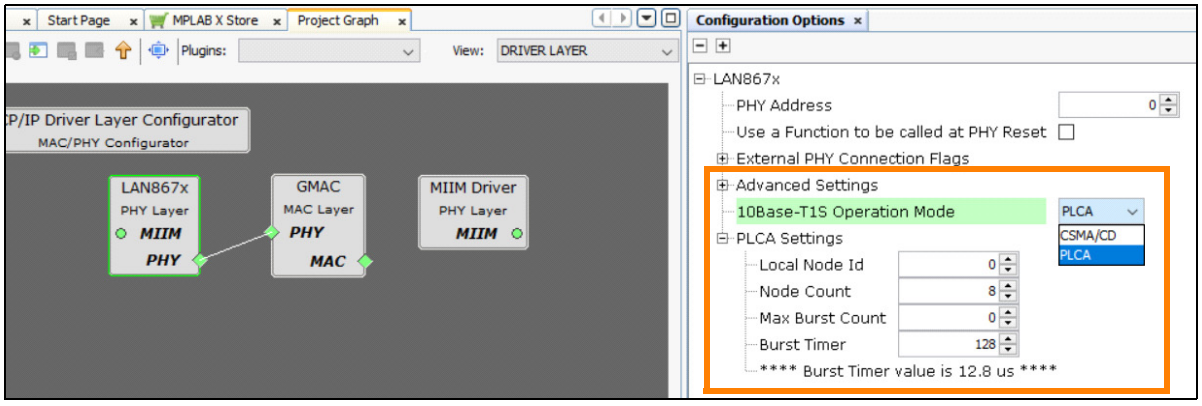
10. Configure the GMAC to work in 10BASE-T1S mode.

    Set “Ethernet Connection Flags” to operate in 10 Mbps, half duplex as shown below.



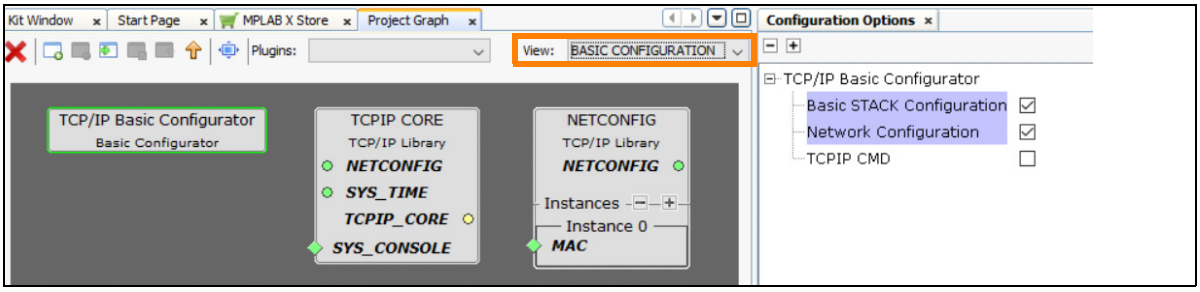
11. Configure the PHY to operate in PLCA or CSMA/CD mode, as you wish.

    In case of PLCA mode, set “Local Node Id” and “Node Count” as shown below.
    Note: The “Local Node Id” must be unique for each node.
    In the example below the “Node Count” is 8; this means the value of the “Local Node Id” must be in the range of 0...7.

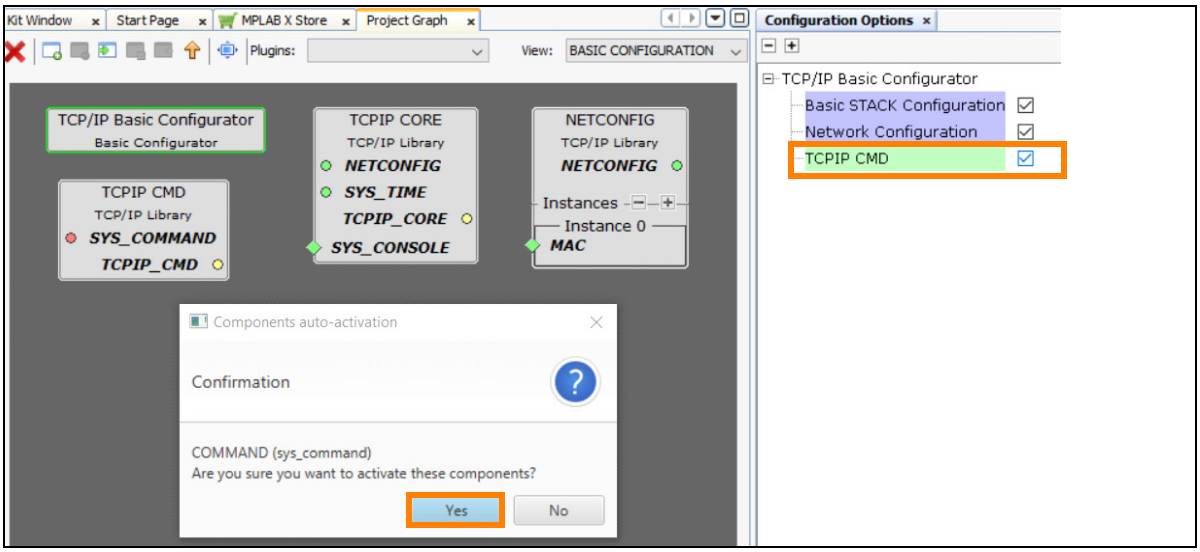


2.6 Basic Configuration

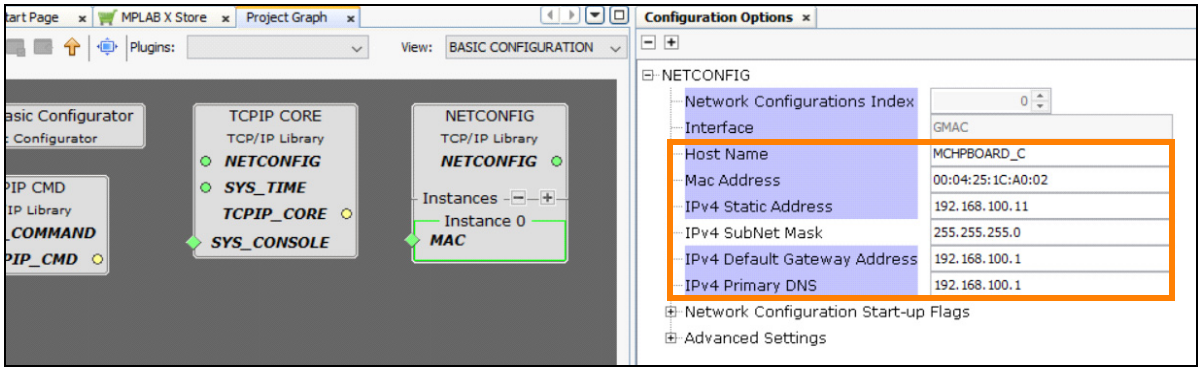
1. In the “Project Graph” select “BASIC CONFIGURATION” from the “View” drop-down menu.



2. Click “TCP/IP Basic Configurator”.
3. “Basic STACK Configuration” and “Network Configuration” are already auto-activated, during previous steps.
4. Add “TCPIP CMD” in the “TCP/IP Basic Configurator”.
5. Click **Yes**.
   This connects the “COMMAND” component with the “Console”.
   This step will auto-activate all dependent components.
6. Click **Yes**.
   This adds the “sys_command” component.



7. To modify the IP address or MAC address,
   a) select NETCONFIG and
   b) choose Instance 0 – MAC.
   In the configuration window you can see the IP address and MAC address. You can modify them as you wish, see below.

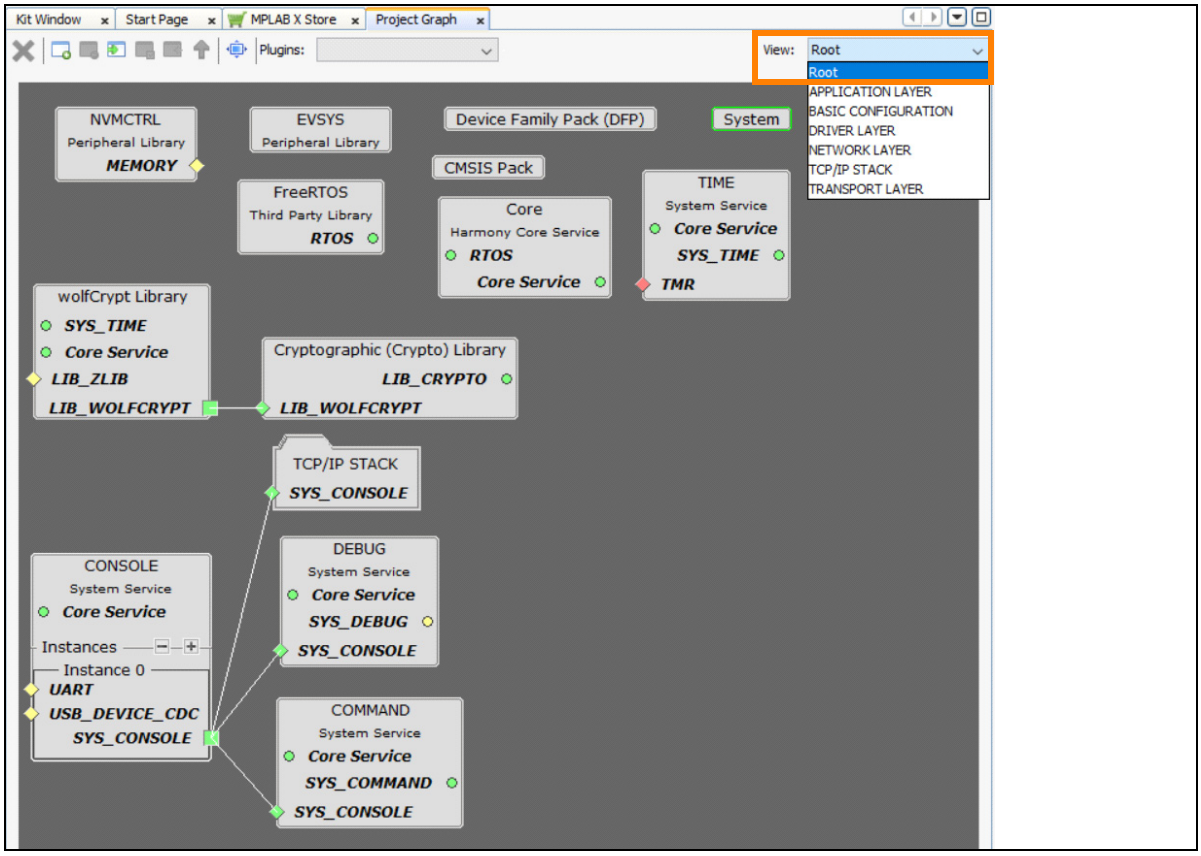


2.7 Add/Configure Additional Components

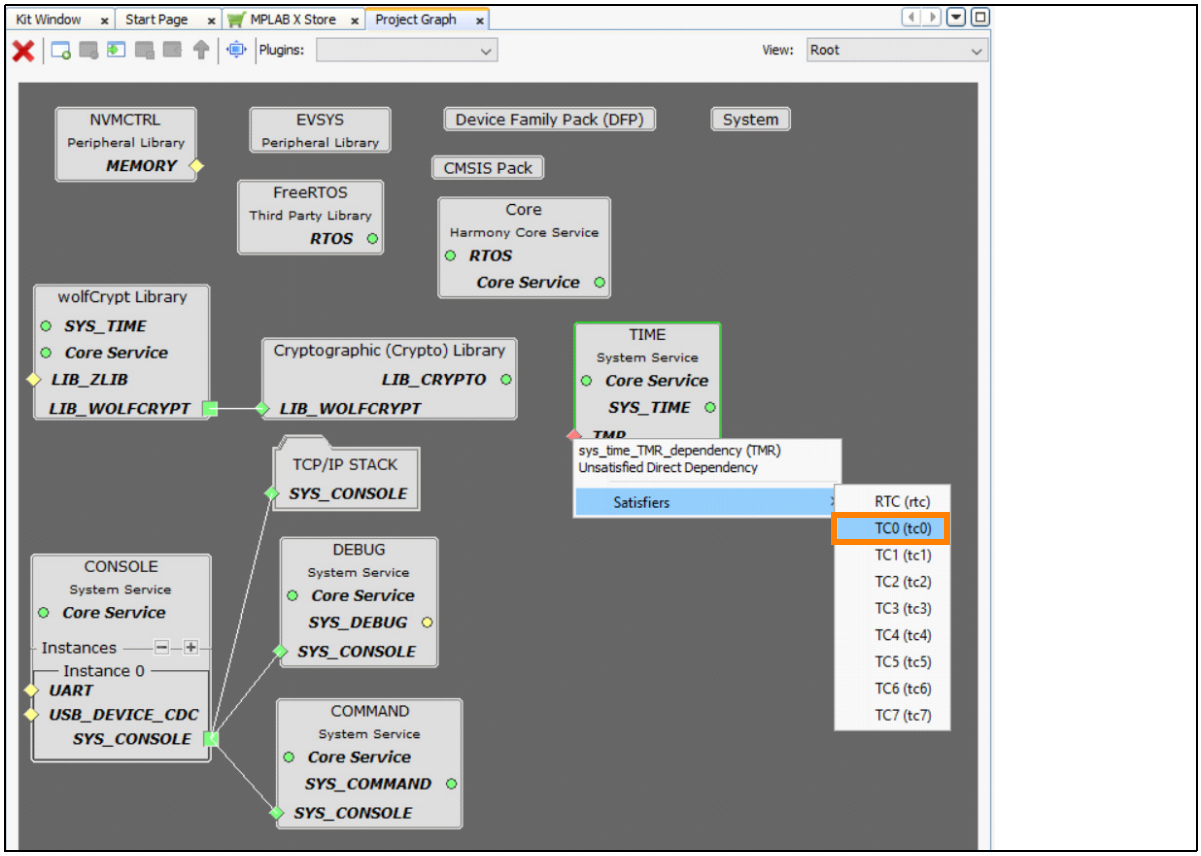
The “tcpip_client_freertos_getting_started” demo implementation needs a few MPLAB Harmony components. In this section, we will add and configure the required components.

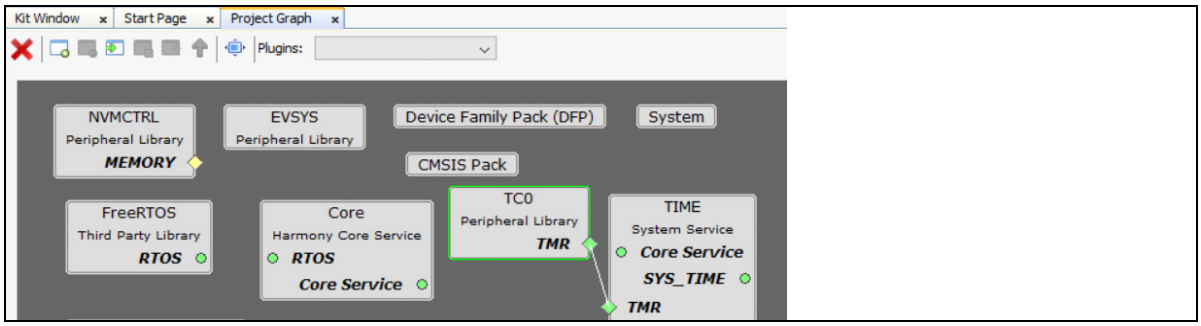
1. In the “Project Graph” select “Root” from the “View” drop-down menu.
   The “Root” layer looks as shown below.

   Note: Red and yellow diamond-shaped buttons indicate unsatisfied dependencies.

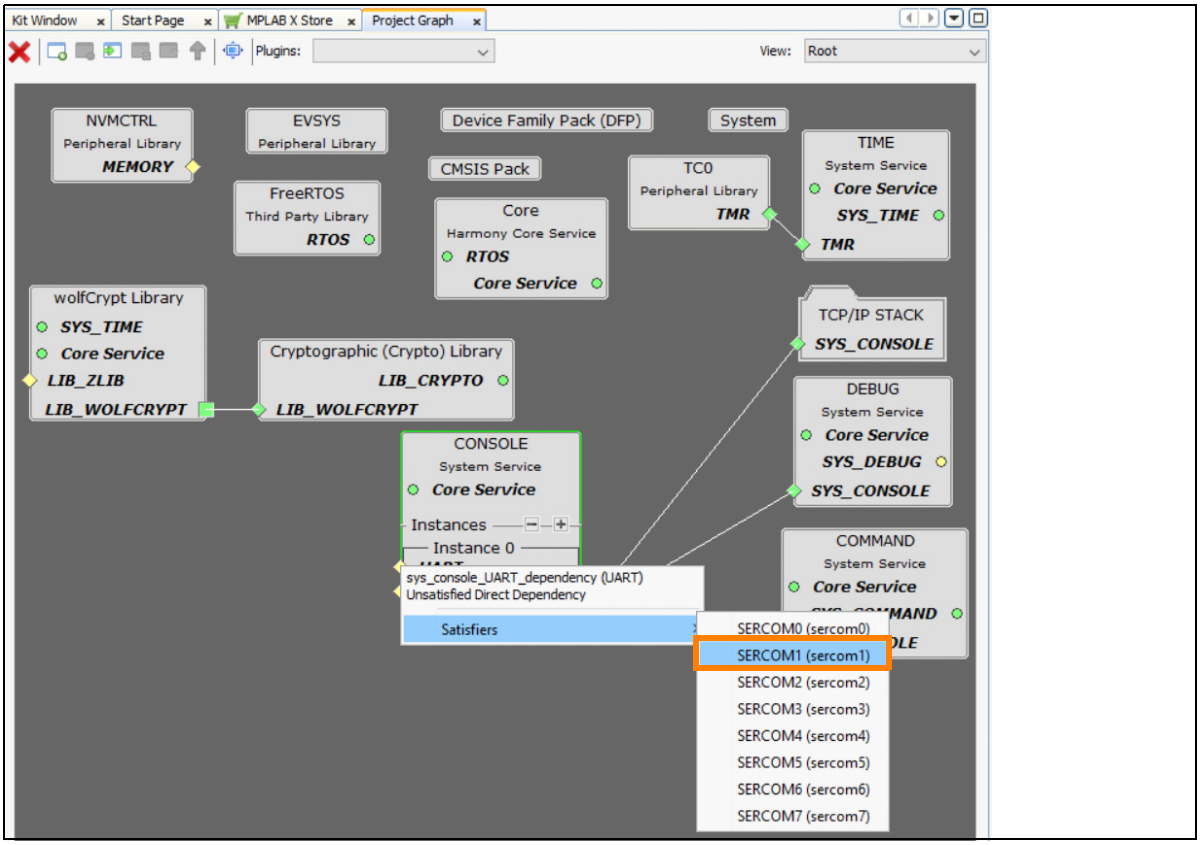


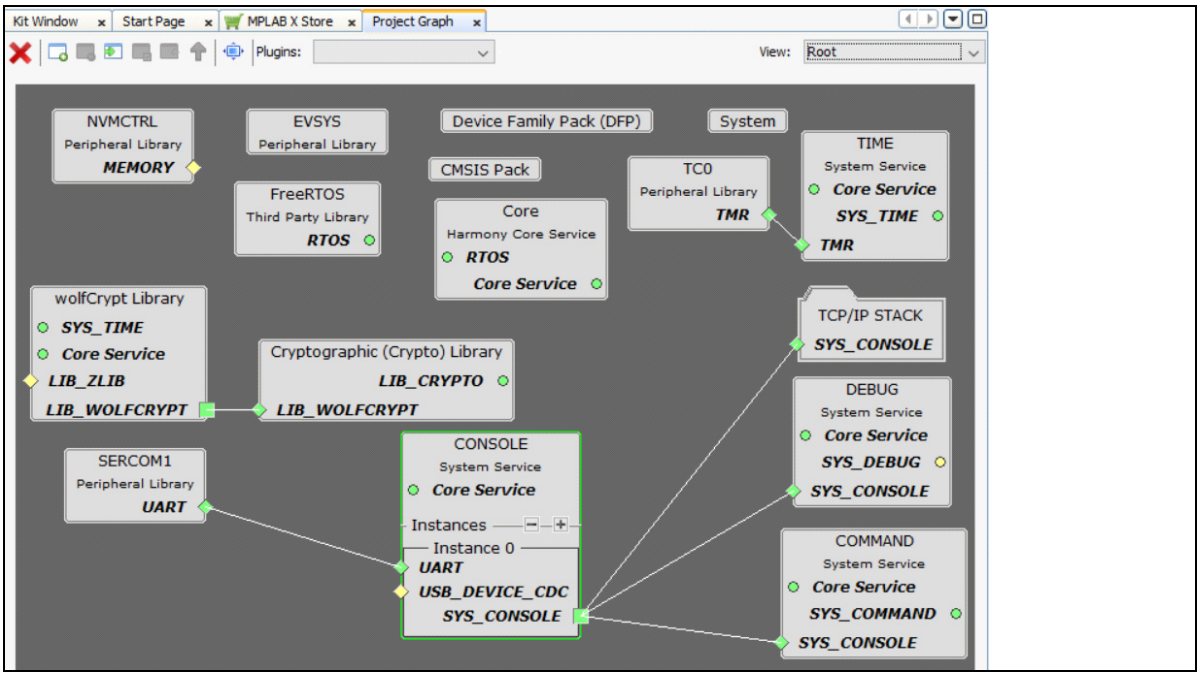
2. Add “TC0” to satisfy the “TMR” dependency.
   a) To find the satisfier, right click the red diamond next to “TMR”.
   b) Select “TC0”.



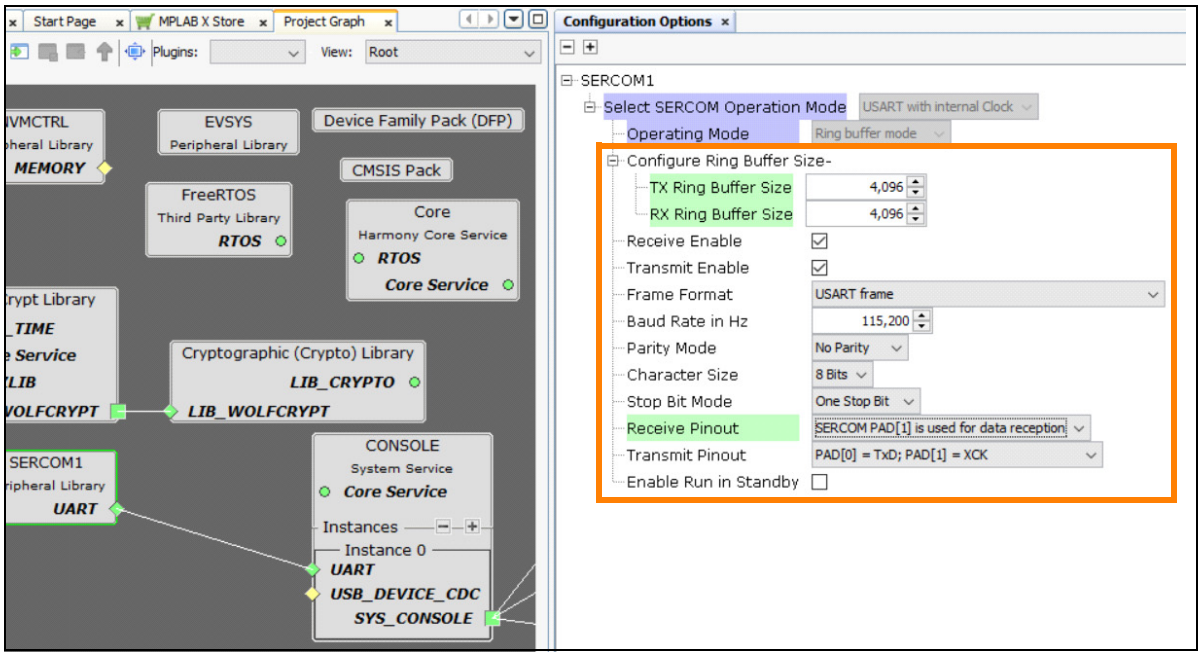


3. Add “SERCOM1” to satisfy UART dependency.
   a) To find the satisfier, right click the yellow diamond next to “UART”.
   b) Select “SERCOM1”.

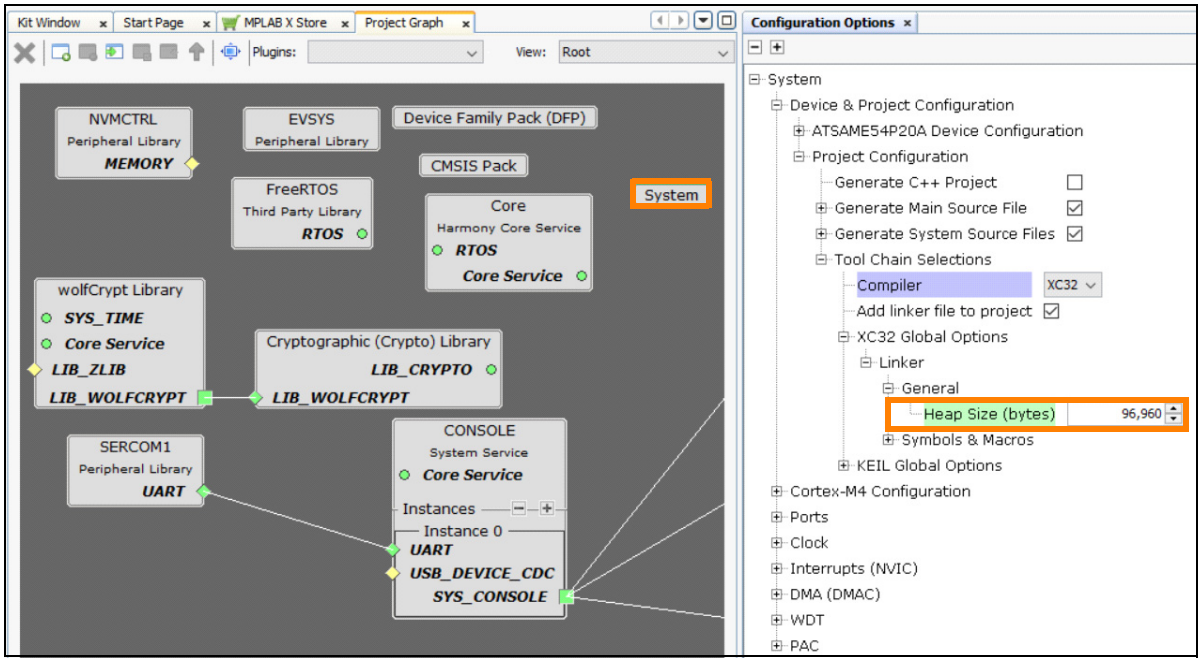




4. Configure “SERCOM1” as shown below.



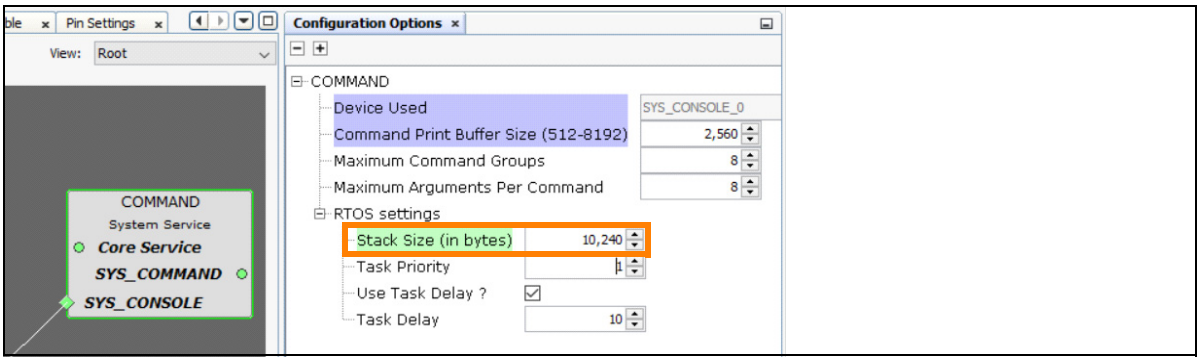
5. Select “System” in the “Project Graph” window.
6. In the “Configuration Options” window set the “Heap Size (bytes)” either to “44960” for a bare-metal project or to “96960” for a FreeRTOS project.
   The “Project Graph” should look like shown below.



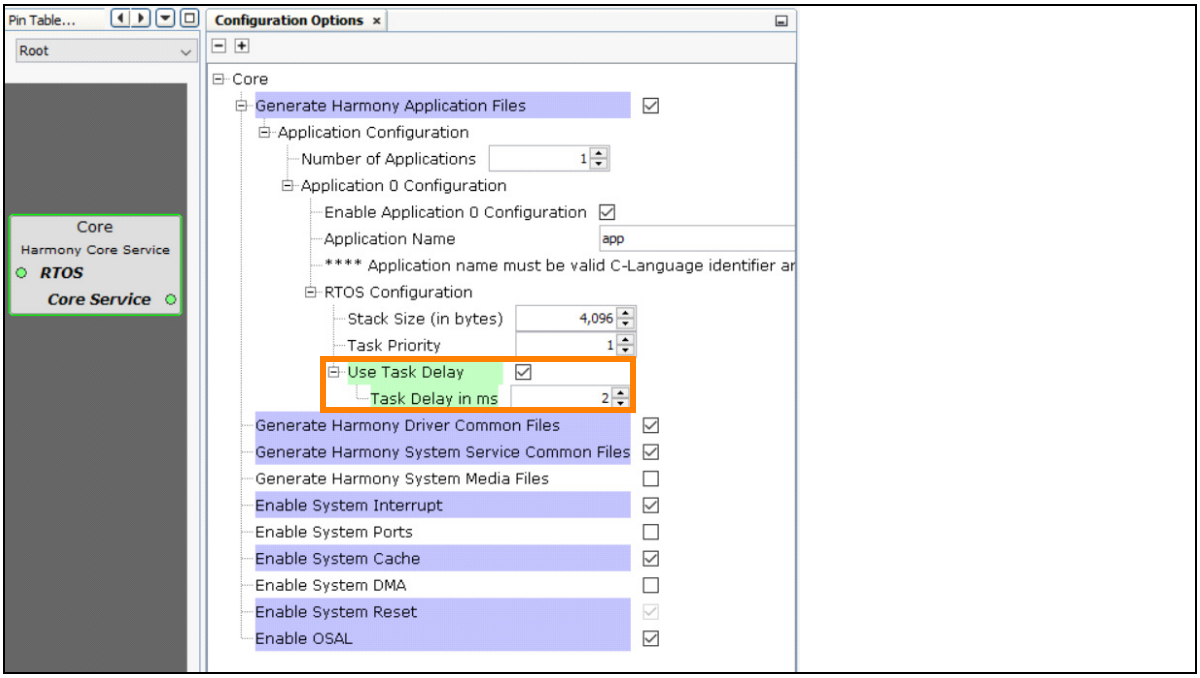
2.8 FreeRTOS Configuration

Note: The configuration settings described in this section are required only for a FreeRTOS project.

1. In the “Project Graph” window select “Command”.
2. In the “Configuration Options” window, set the “Stack Size (in bytes)” to “10240”.



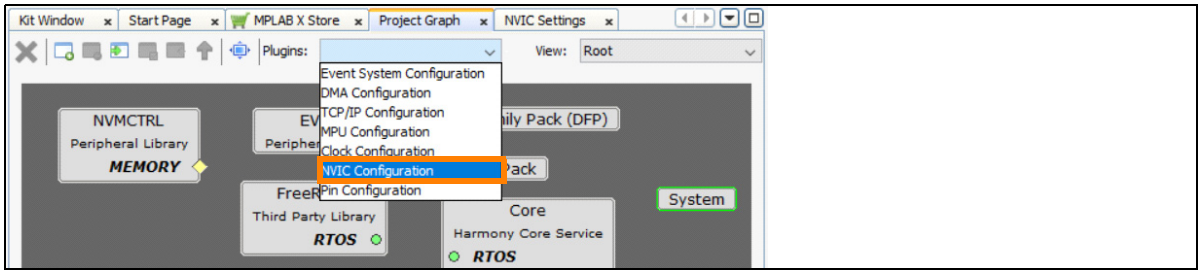
3. Configure “Core” as shown below.



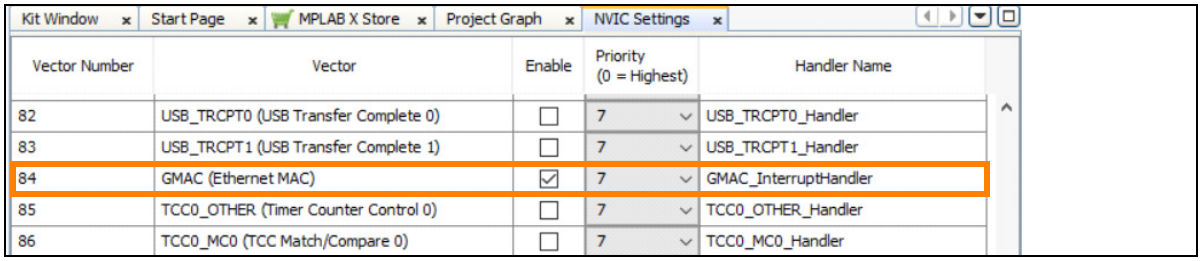
2.9 NVIC Configuration

The Nested Vectored Interrupt Controller (NVIC) is for the configuration of the interrupts. This configuration is applicable for SAM devices only.

1. Open “NVIC Configuration”.



2. Make sure the “GMAC (Ethernet MAC)” interrupt is enabled.

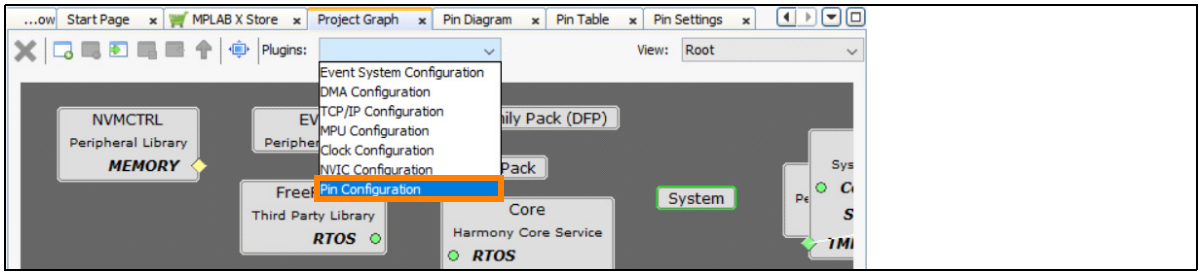


Vector Number	Vector	Enable	Priority (0 = Highest)	Handler Name
82	USB_TRCPT0 (USB Transfer Complete 0)	☐	7	USB_TRCPT0_Handler
83	USB_TRCPT1 (USB Transfer Complete 1)	☐	7	USB_TRCPT1_Handler
84	GMAC (Ethernet MAC)	☑	7	GMAC_InterruptHandler
85	TCC0_OTHER (Timer Counter Control 0)	☐	7	TCC0_OTHER_Handler
86	TCC0_MC0 (TCC Match/Compare 0)	☐	7	TCC0_MC0_Handler

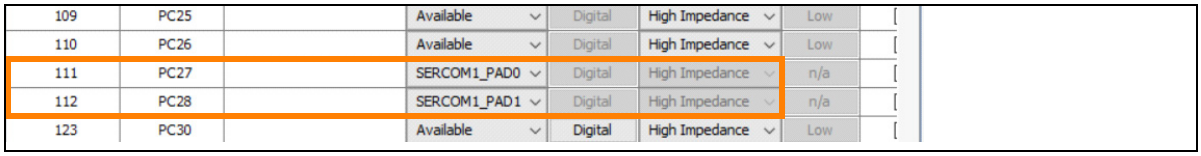
2.10 Pin Configuration

The I/O pins on the device can have alternate functions other than the general purpose I/O function. Here, we will configure the functionality of the I/O pins required for this demo.

1. Open “Pin Configuration”.

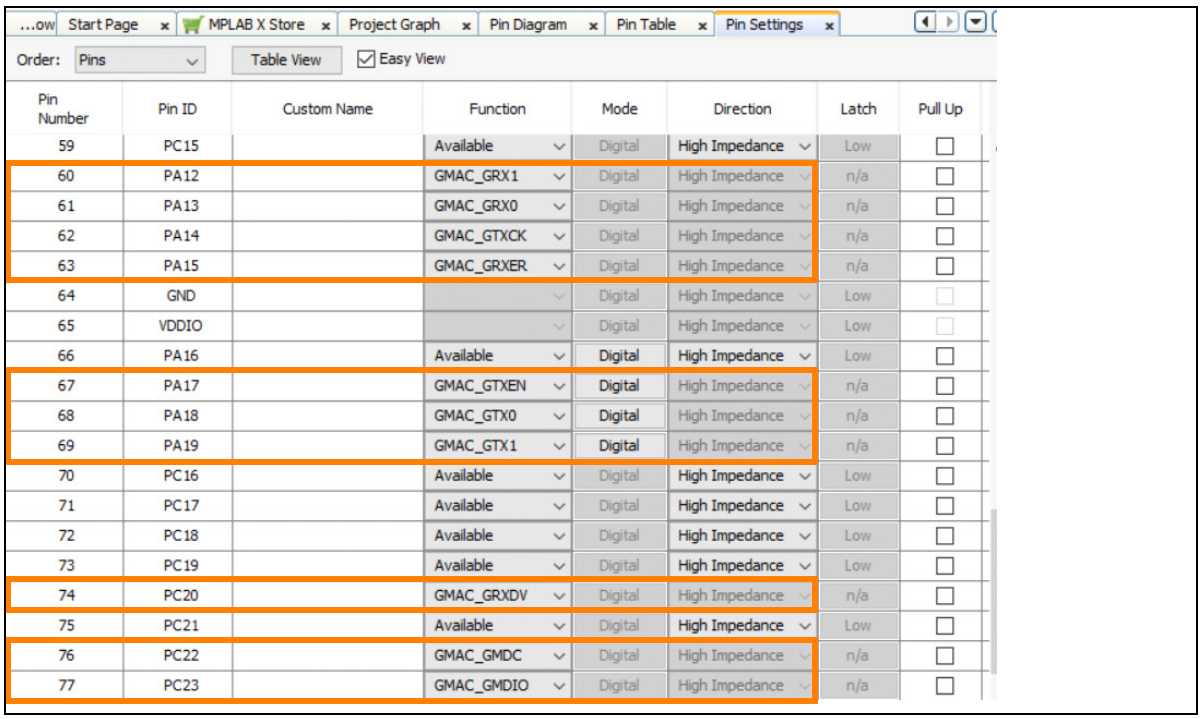


2. Configure the pins for “SERCOM1” as shown below.



109	PC25		Available	Digital	High Impedance	Low	
110	PC26		Available	Digital	High Impedance	Low	
111	PC27		SERCOM1_PAD0	Digital	High Impedance	n/a	
112	PC28		SERCOM1_PAD1	Digital	High Impedance	n/a	
123	PC30		Available	Digital	High Impedance	Low	

3. Configure the pins for “GMAC”.



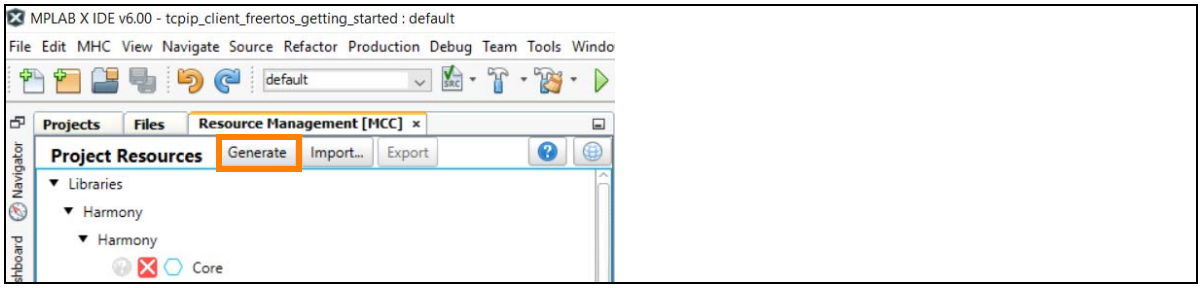
Order: Pins | Table View | Easy View

Pin Number	Pin ID	Custom Name	Function	Mode	Direction	Latch	Pull Up
59	PC15		Available	Digital	High Impedance	Low	
60	PA12		GMAC_GRX1	Digital	High Impedance	n/a	
61	PA13		GMAC_GRX0	Digital	High Impedance	n/a	
62	PA14		GMAC_GTXCK	Digital	High Impedance	n/a	
63	PA15		GMAC_GRXER	Digital	High Impedance	n/a	
64	GND			Digital	High Impedance	Low	
65	VDDIO			Digital	High Impedance	Low	
66	PA16		Available	Digital	High Impedance	Low	
67	PA17		GMAC_GTXEN	Digital	High Impedance	n/a	
68	PA18		GMAC_GTX0	Digital	High Impedance	n/a	
69	PA19		GMAC_GTX1	Digital	High Impedance	n/a	
70	PC16		Available	Digital	High Impedance	Low	
71	PC17		Available	Digital	High Impedance	Low	
72	PC18		Available	Digital	High Impedance	Low	
73	PC19		Available	Digital	High Impedance	Low	
74	PC20		GMAC_GRXDV	Digital	High Impedance	n/a	
75	PC21		Available	Digital	High Impedance	Low	
76	PC22		GMAC_GMDC	Digital	High Impedance	n/a	
77	PC23		GMAC_GMDIO	Digital	High Impedance	n/a	

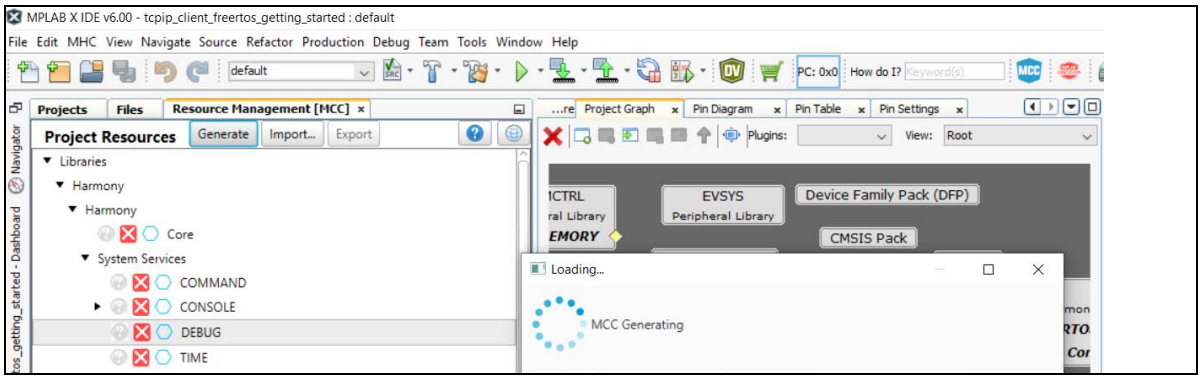
2.11 Code Generation

Once MPLAB Harmony components have been added by using the MCC “Project Graph”, it is time to generate the source files based on the configurations.

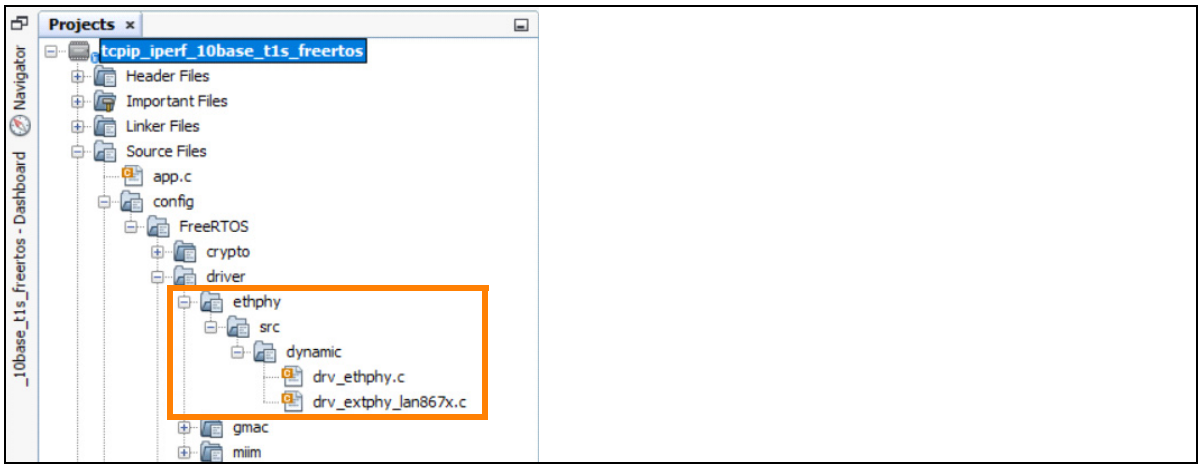
1. To start the code generation, click the **Generate** button (see below).



Code generation is running.

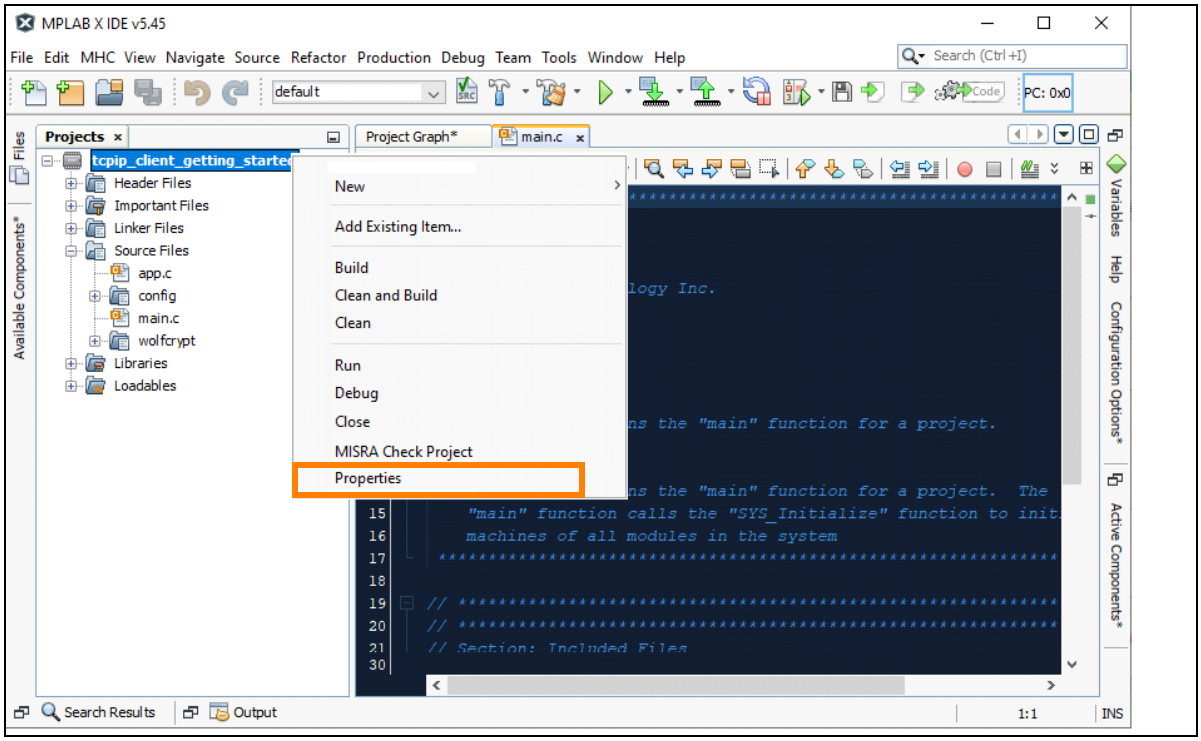


2. After successful code generation, verify if the file *drv_extphy_lan867x.c* has been added in the “Projects” tab. For this purpose, click the “Projects” tab on the left-hand side.
The result should look as follows:



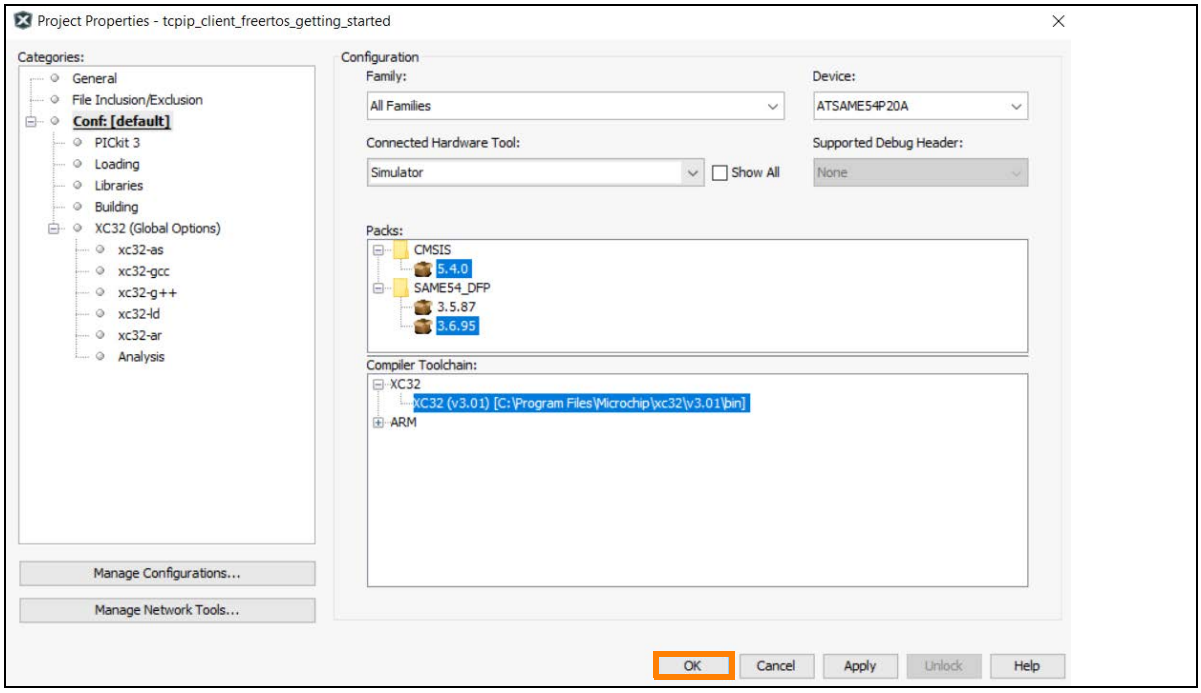
2.12 Build the Application

1. Open the project “Properties” by right clicking on the project name “tcpip_client_freertos_getting_started”.



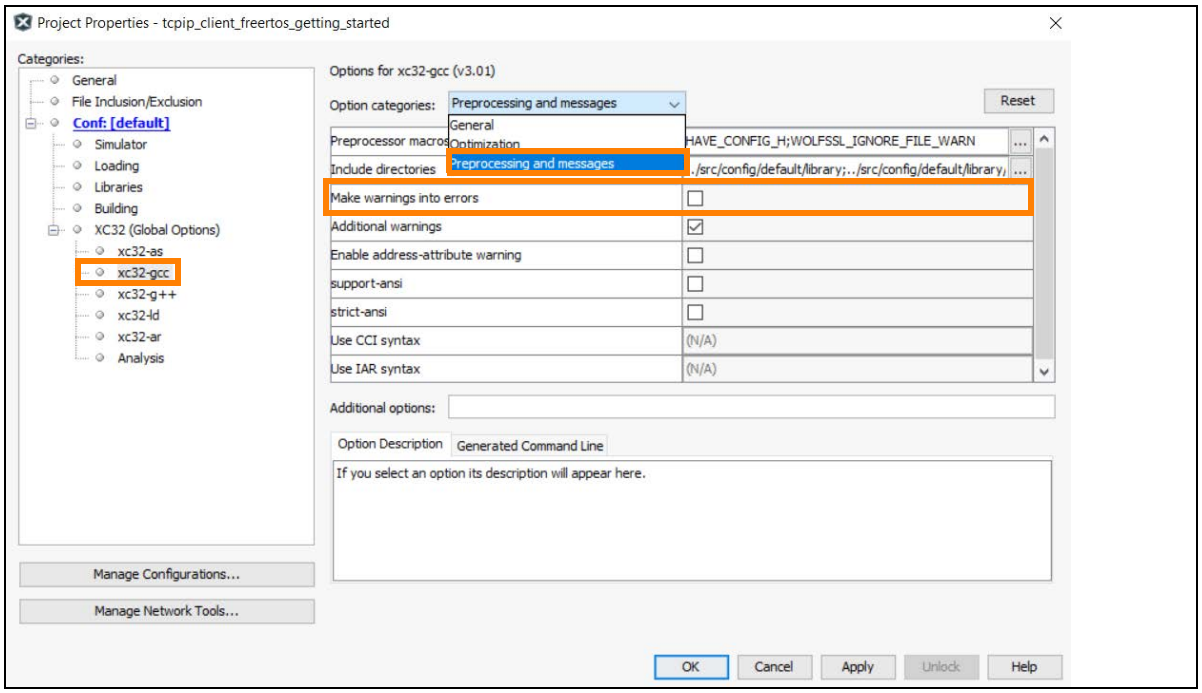
2. Make sure the “XC32” compiler tool chain is selected.

   Note: Version numbers may differ. Therefore, always use the latest versions.

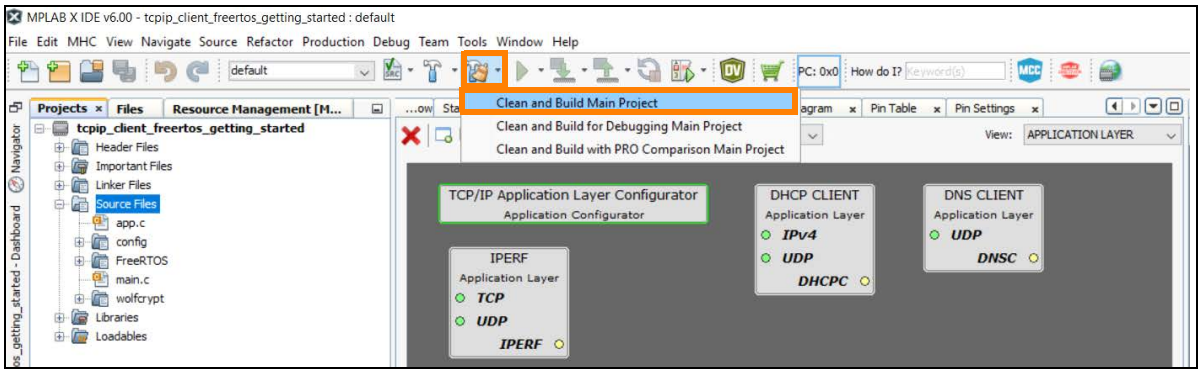


3. Click **OK**.

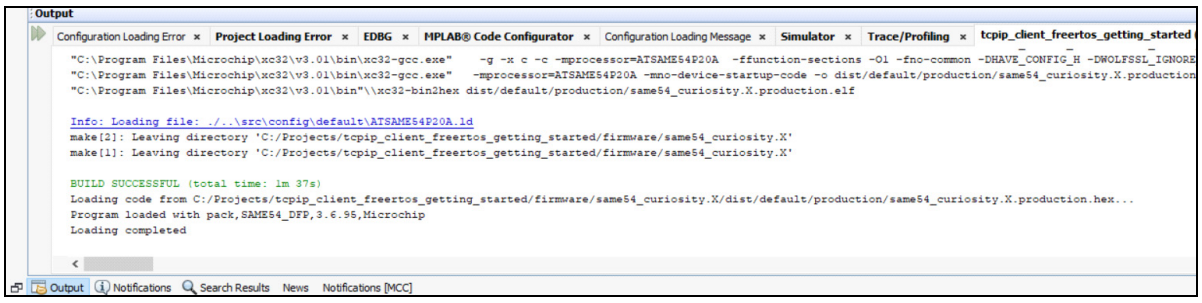
4. Follow the steps below to disable the feature that turns warnings into errors.
   a) In the “Project Properties” window select “xc32-gcc”.
   b) From the “Option categories” drop down list select “Preprocessing and messages”.
   c) Uncheck “Make warnings into errors”.



5. Click **OK**.
6. Build the application by clicking on “Clean and Build Main Project”.



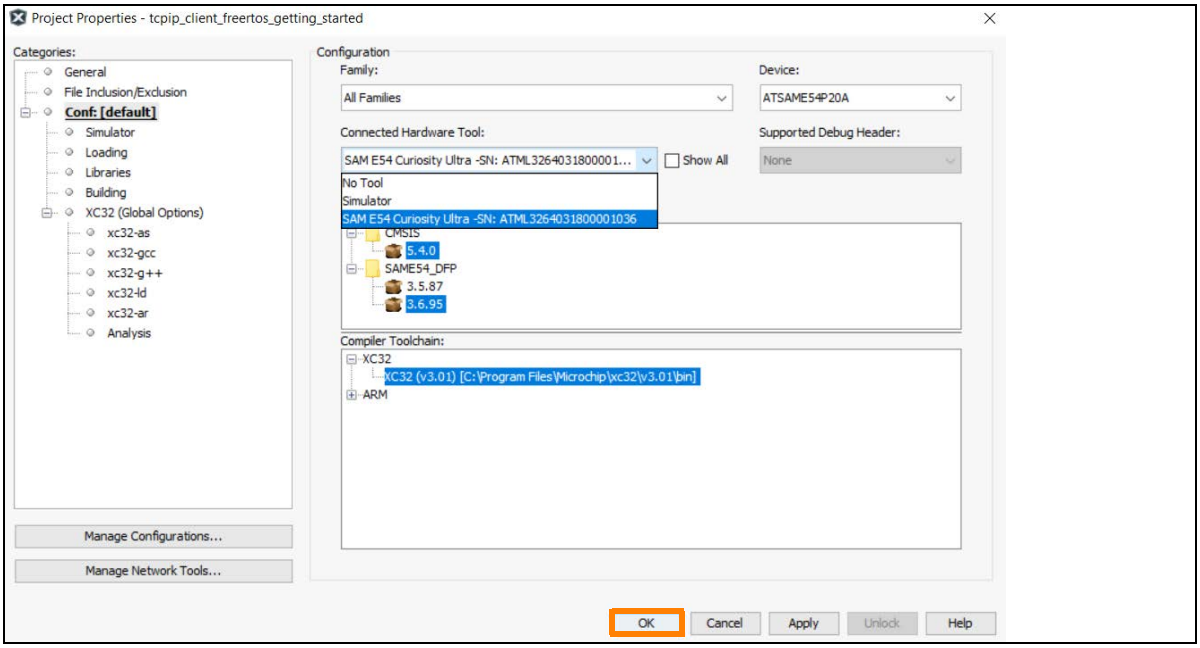
7. Verify the build results. Make sure that the build was successful.



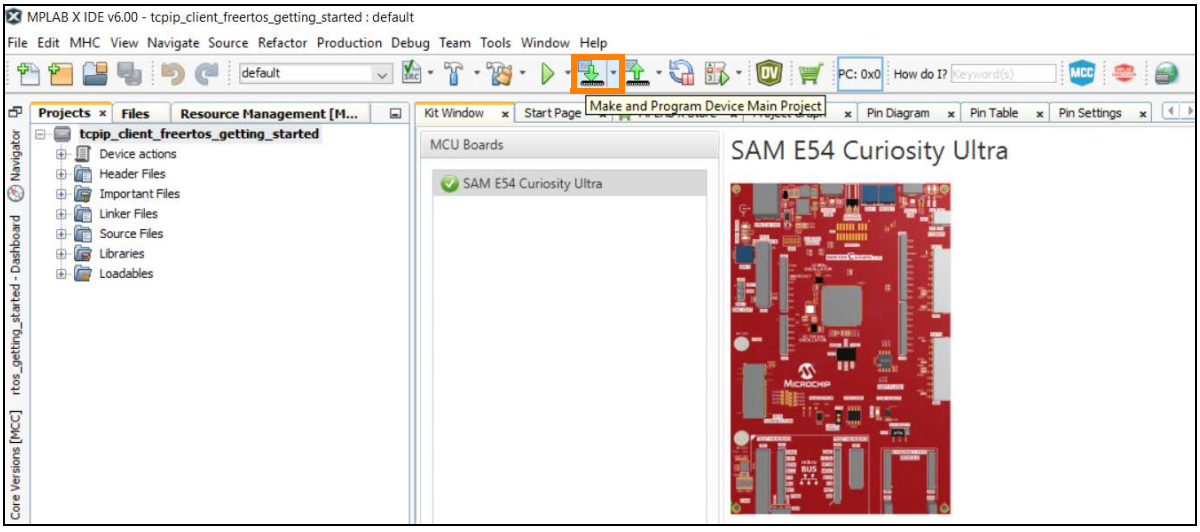
2.13 Program the Application

Now, the project is ready to be programmed on the hardware board. Refer to the hardware user's guide to see the different programming options supported.
The SAM E54 Curiosity Ultra Development Board [3] can be programmed using the on-board Embedded Debugger (EDBG).

1. Connect a Micro-USB cable from the computer to the DEBUG USB port on the SAM E54 Curiosity Ultra Development Board.
2. Open the "Project Properties".
3. Under Connected hardware, select "SAM E54 Curiosity Ultra".
4. Click **OK**.



5. Program the application by clicking on the **Make and Program Device Main Project** button (see below).



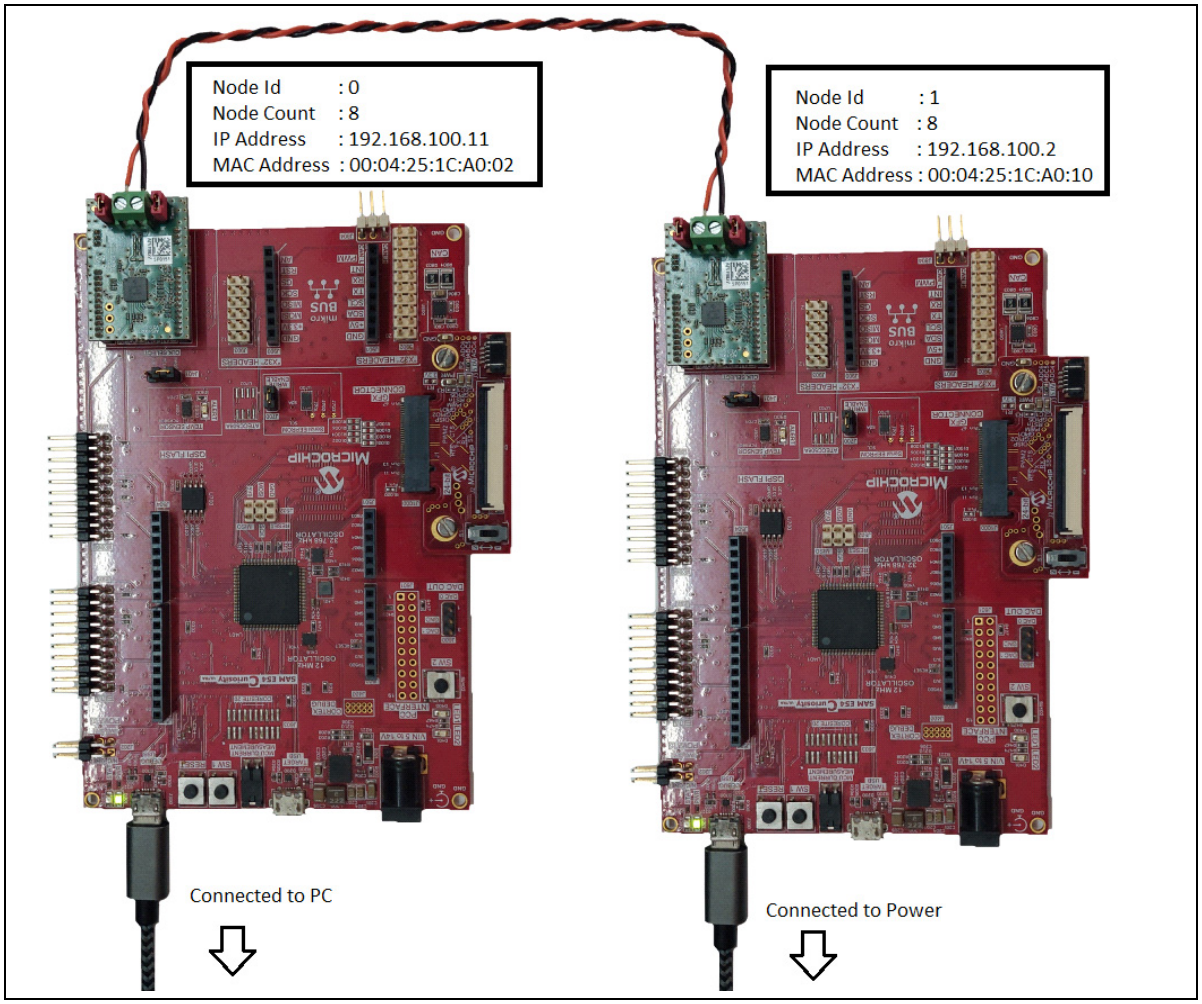
6. Make sure that the programming was successful.

2.14 Test the Application

Testing the application is done by using different console commands.

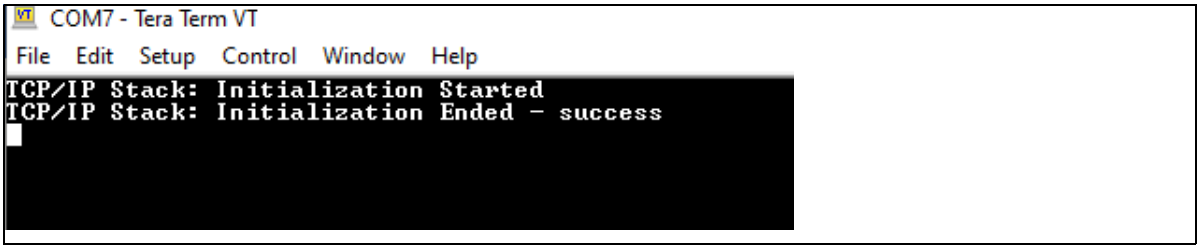
Before you start, do the following:

1. Establish a physical wiring with another 10BASE-T1S node.
2. Make sure the PLCA settings are correct.
3. Set the IP address of both nodes correctly.

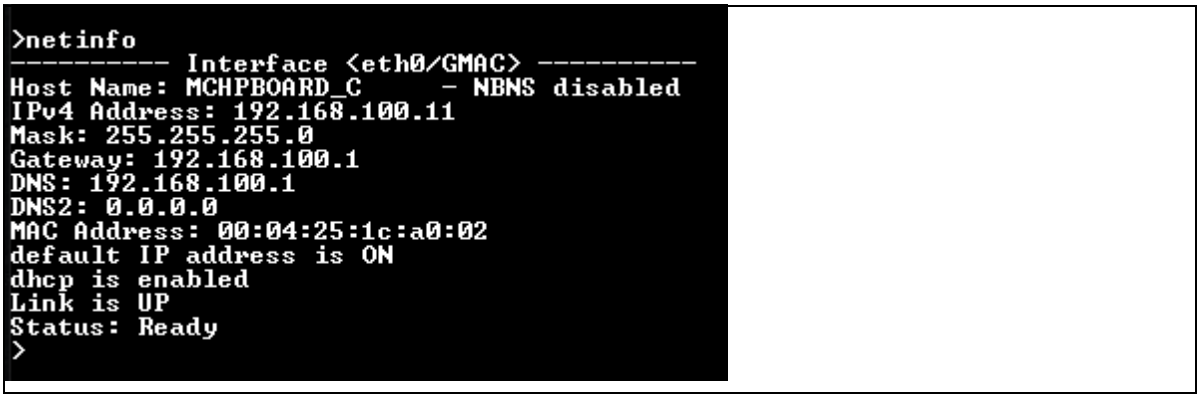


There will be a virtual COM port enumerated when a Micro-USB cable from the computer is connected to the DEBUG USB port on the SAM E54 Curiosity Ultra Development Board [3].

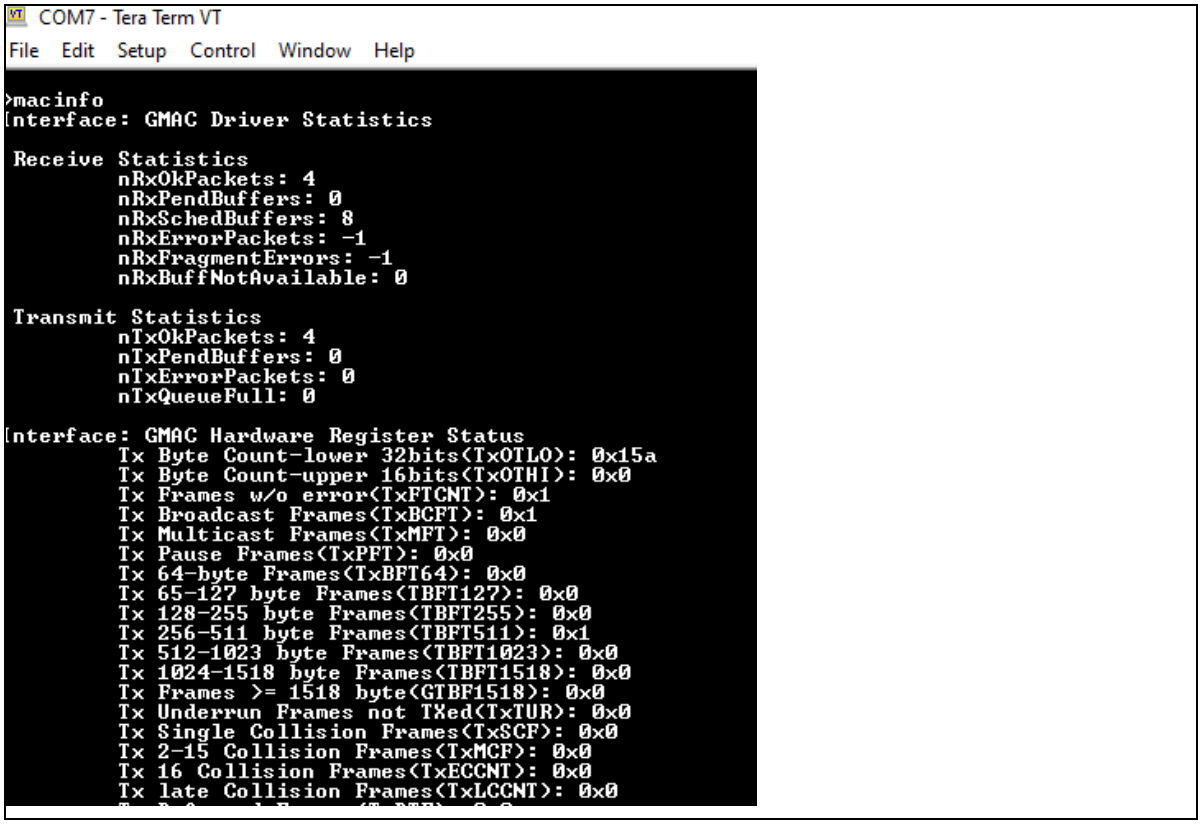
1. Open a terminal application (e.g., TeraTerm).
2. Configure the baud rate for “115200”.
3. Press the **Reset** button on the SAM E54 Curiosity Ultra Development Board.
   The following messages become visible in the terminal window.



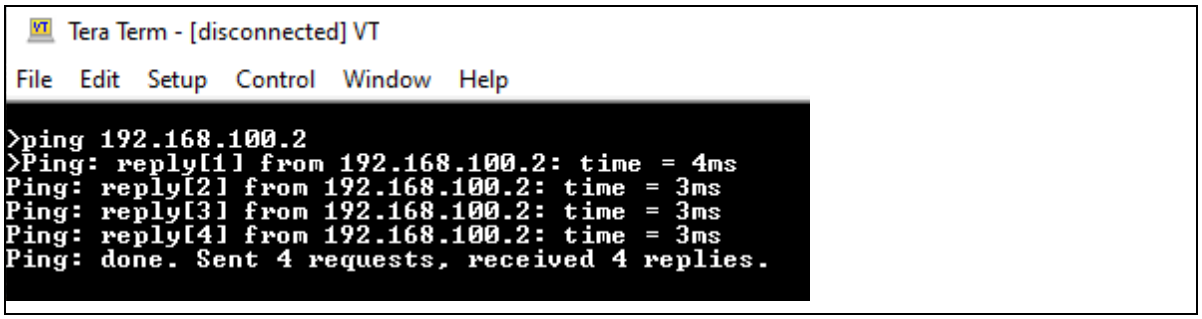
4. Type *netinfo* in the terminal window.
5. Press **Enter** to see the network status.



6. Type *macinfo* in the terminal window.
7. Press **Enter** to see the MAC status.



8. Type *ping <Ip address of other node>* in the terminal window.
   You should get a reply for your request if the network was established.



You have successfully created and tested your first TCP/IP application.

3.0 EXAMPLE FIRMWARE

The example project (included in the zip file) shows how to configure the LAN867x PHY and use the API to read and write to PHY registers.

The example supports the following operations via terminal:

- Miim register read and write
- Iperf support
- Ping support
- DNS and DHCP support

3.1 Main File Description

3.1.1 LAN867x PHY DRIVER

The PHY driver is located in the example folder, at *firmware\src\config\default\driver\ethphy\src\dynamic*. It consists of two files, which are:

- *drv_extphy_lan867x.h*
- *drv_extphy_lan867x.c*

The files provide

- the functions to configure the PHY on initial startup,
- address and bit-mapping for each register of the PHY and
- APIs to access and modify PHY registers.

The following three methods are used to access and modify a register value of the PHY.

- This method is used to write a value to the register.

```
DRV_MIIM_RESULT Lan867x_Write_Register
(LAN867X_REG_OBJ * clientObj, const uint32_t regAddr, uint16_t wData):
```

- This method is used to read a value from the register.

```
DRV_MIIM_RESULT Lan867x_Read_Register
(LAN867X_REG_OBJ * clientObj, const uint32_t regAddr, uint16_t *rData):
```

- This method is used to write a value to a register based on a bit mask.

```
DRV_MIIM_RESULT Lan867x_Write_Bit_Register
(LAN867X_REG_OBJ * clientObj, const uint32_t regAddr, uint16_t mask, uint16_t wData):
```

3.1.2 app.c

The *app.c* file contains an example on how to access a PHY register and modify it if necessary.

1. To access the register, open an instance of miim driver.
   This is done in the method *local_miim_init()*.
2. To read from a PHY register, you can use the method `Lan867x_Read_Register`.
   In the example you can see that in method *APP_Task()*, under switch case APP_READ_OPERATION_MODE.

   ```
   opRes=Lan867x_Read_Register(&clientObj,PHY_PLCA_CONTROL_0,&data);
   ```

   Here, it is reading the value of the *PHY_PLCA_CONTROL_0* register and writing the value to the *data* variable.
3. To write to a PHY register, you can use the method `Lan867x_Write_Register`.
   In the example you can see that in method *APP_Task()*, under switch case APP_WRITE_PLCA_CONFIGURATION.

   ```
   data = F2R_(0, PHY_PLCA_CTRL1_ID0) | F2R_(5, PHY_PLCA_CTRL1_NCNT);
   opRes = Lan867x_Write_Register (&clientObj, PHY_PLCA_CONTROL_1, data);
   ```

   Here, it is writing the value of *data,* to the *PHY_PLCA_CONTROL_1* register.
4. Once the register operation is done, close the miim instance.
   This is done in method *local_miim_close ()*.

APPENDIX A: REVISION HISTORY

Revision	Date	Section/Figure/Entry	Correction
DS00004131C	2022-04-13	General	• Updated document with “MPLAB Code Configurator” contents • Removed “MPLAB Harmony 3 Content Manager and Configurator” information • Added “FreeRTOS” related information
DS00004131B	2021-08-31	Section 2.3, "Application Layer Configurator"	Added step 6
		Section 2.4, “Transport Layer Configurator”	Removed
		Section 2.5, "Driver Layer Configurator"	• Updated picture in step 8 • Added step 9 • Updated picture in step 10 • Added a note in step 11
DS00004131A	2021-07-22	Initial version of this document	

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