2019 MASTERs Conference

23075 IoT6

Simplifying TCP/IP Applications with MPLAB® Harmony

Hands-On

Lab Manual

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Microchip Technology Inc.

MICROCHIP

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Introduction

This Lab Manual provides the step by step procedure to complete two labs in the MASTERs 23075 IoT6 Class.

If you don’t know how TCP/IP works but you have to add network connectivity to your product, this is the right class for you. We will teach you the basics of TCP/IP, how the client-server model works, what ports and sockets are and how applications use them to create TCP/IP connections. The class will also teach you the fundamentals of network analysis with the well-known tool Wireshark. The hands-on part of the class utilizes Microchip's 32-bit MCUs with MPLAB® Harmony. You can learn the architecture and the fundamentals of the Harmony TCP/IP stack to interface your TCP/IP application with some common stack APIs. To make your life easier, the FreeRTOS™ task schedular is used to simplify your application programming.

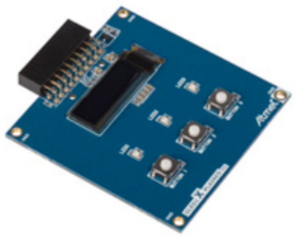
In Lab 1 we will open a TCP project, do some stack re-configuration and a connectivity check and in Lab 2 we will show an Application integration for local access, using the example of a Vending machine. Finally in Lab 3 we will make an Application integration for external access, using the example of a Weather Service.

Hardware Requirements

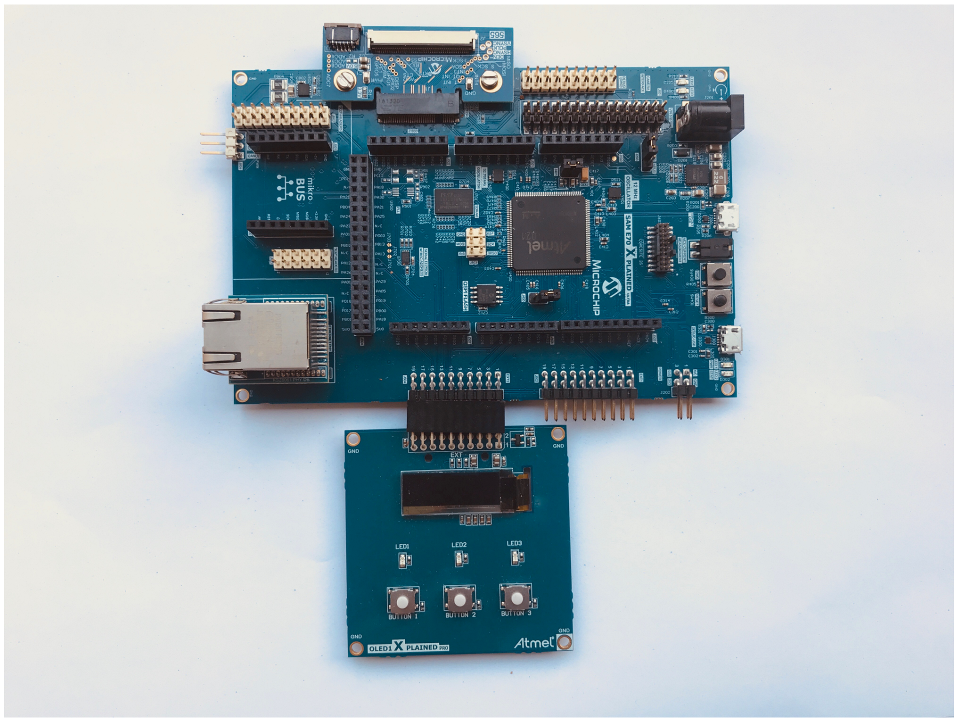
The following hardware is required:

- **SAM E70 Xpained Ultra** (Microchip Part Number: DM320113)
    - https://www.microchip.com/DevelopmentTools/ProductDetails/PartNO/DM320113

- OLED1 Xplained Pro extension kit (Microchip Part Number: ATOLED1-XPRO)
    - https://www.microchip.com/Developmenttools/ProductDetails/ATOLED1-XPRO



- **Cat 5 Ethernet Patch Cable**
- **USB Male A to USB Male B Micro Cable**



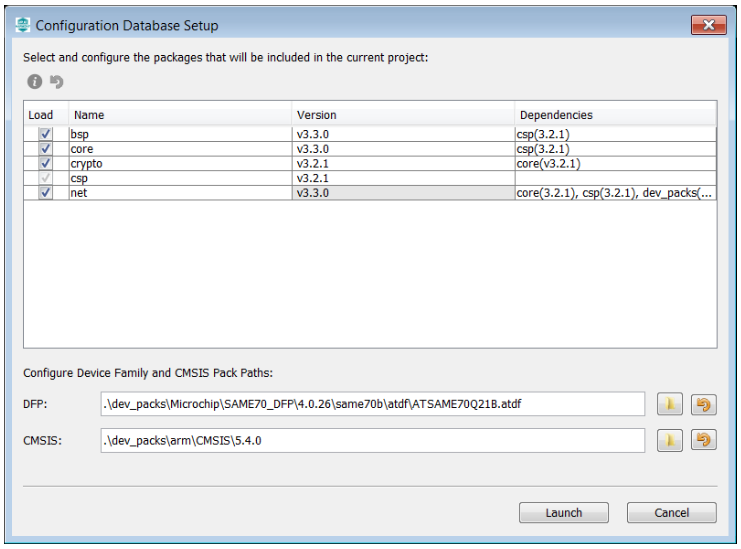
Software Requirements

The following software is required:

- **Microchip MPLAB X IDE v5.20**
  - http://www.microchip.com/mplab
- **Microchip MPLAB XC32 Compiler v2.15**
  - http://www.microchip.com/mplab/compilers
- **Microchip MPLAB Harmony 3**
  - http://www.microchip.com/mplab/mplab-harmony
- **Microchip MPLAB Harmony Configuration (MHC) Tool Plugin v3.3.0.1**
- **Tera Term v4.95**

The Lab1, Lab2 and Lab3 class expects a Harmony 3 with the following subset of Versions (Tags)

To make it more easy in the class for the attendees, the folder C:/MASTERs/23075 already contains this H3 Checkout


Configuration Database Setup

Select and configure the packages that will be included in the current project:

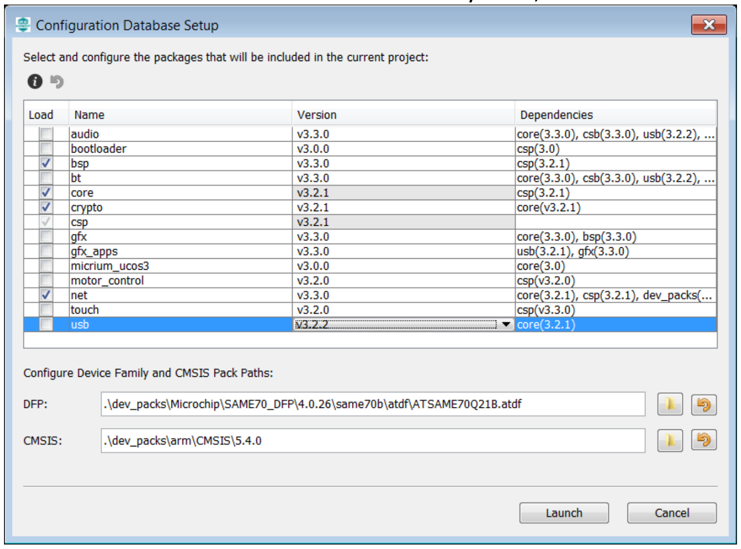
Load	Name	Version	Dependencies
✓	bsp	v3.3.0	csp(3.2.1)
✓	core	v3.3.0	csp(3.2.1)
✓	crypto	v3.2.1	core(v3.2.1)
✓	csp	v3.2.1	
✓	net	v3.3.0	core(3.2.1), csp(3.2.1), dev_packs(...

Configure Device Family and CMSIS Pack Paths:

DFP: .\dev_packs\Microchip\SAME70_DFP\4.0.26\same70b\atdf\ATSAME70Q21B.atdf

CMSIS: .\dev_packs\arm\CMSIS\5.4.0

In the (optional) case a standard Harmony 3 installation is used, in the MHC configuration the **csp** v3.2.1 and **core** v3.2.1 must be selected. This can be done by clicking on the sub module and select in the drop down menu, the above mentioned version.
The following checkout could take several minutes. The checkout is only local, no external Github access will be used.


Configuration Database Setup

Select and configure the packages that will be included in the current project:

Load	Name	Version	Dependencies
	audio	v3.3.0	core(3.3.0), csb(3.3.0), usb(3.2.2), ...
	bootloader	v3.0.0	csp(3.0)
✓	bsp	v3.3.0	csp(3.2.1)
	bt	v3.3.0	core(3.3.0), csb(3.3.0), usb(3.2.2), ...
✓	core	v3.2.1	csp(3.2.1)
✓	crypto	v3.2.1	core(v3.2.1)
✓	csp	v3.2.1	
	gfx	v3.3.0	core(3.3.0), bsp(3.3.0)
	gfx_apps	v3.3.0	usb(3.2.1), gfx(3.3.0)
	micrium_ucos3	v3.0.0	core(3.0)
	motor_control	v3.2.0	csp(v3.2.0)
✓	net	v3.3.0	core(3.2.1), csp(3.2.1), dev_packs(...
	touch	v3.2.0	csp(v3.3.0)
	usb	v3.2.2	core(3.2.1)

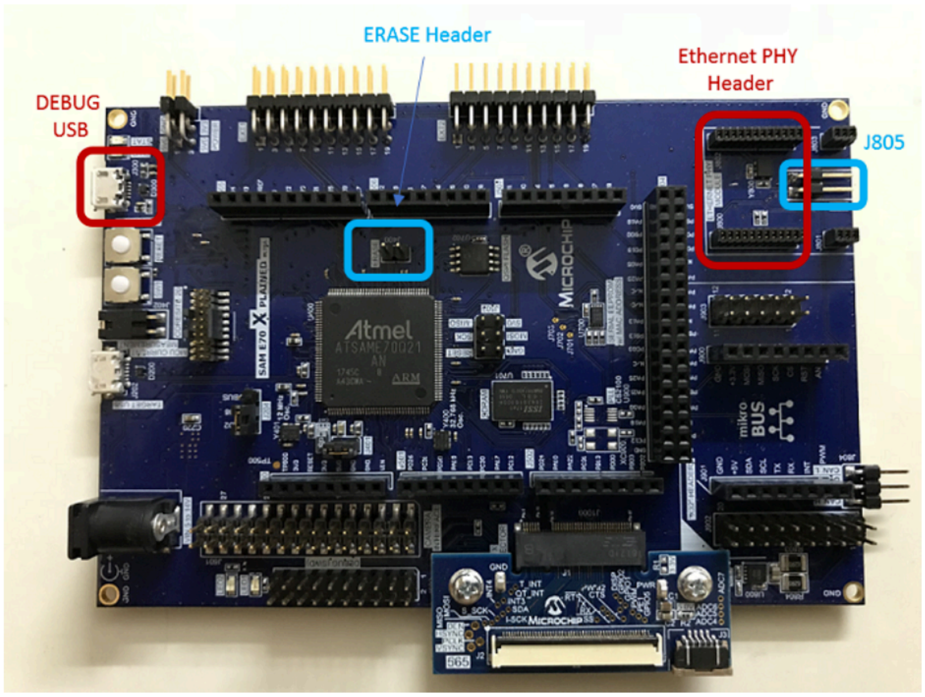
Configure Device Family and CMSIS Pack Paths:

DFP: .\dev_packs\Microchip\SAME70_DFP\4.0.26\same70b\atdf\ATSAME70Q21B.atdf

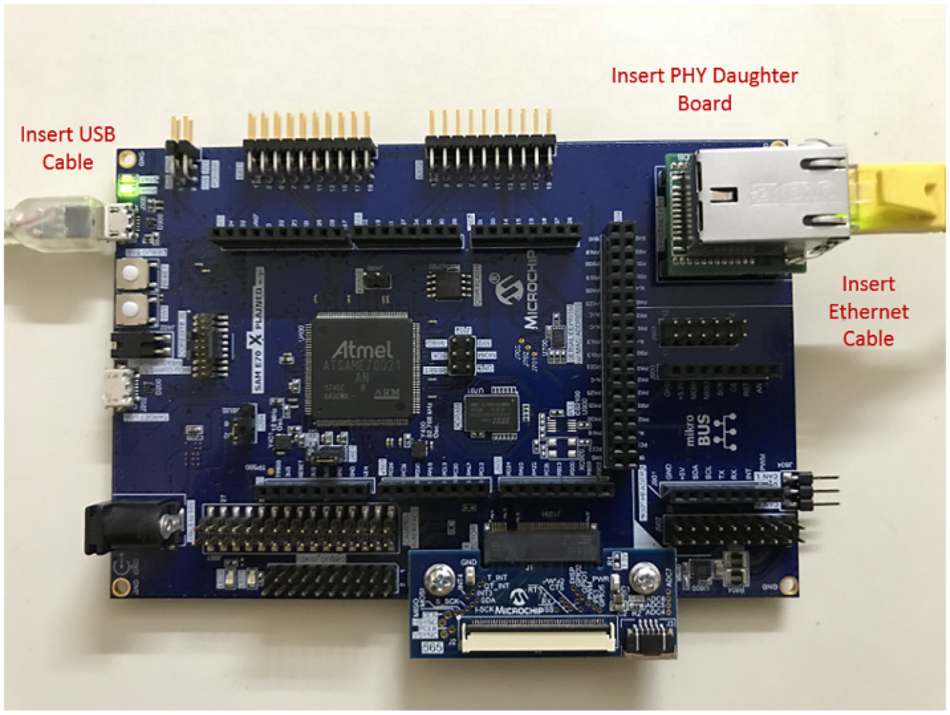
CMSIS: .\dev_packs\arm\CMSIS\5.4.0

How to connect the USB and the CAT5 Network cable to the board

- Ensure the Erase jumper is open
- Open the J805 jumper



- Insert the LAN8740 PHY daughter board on the ETHERNET PHY MODULE header.
- Connect the micro USB cable from the computer to the DEBUG USB connector on the SAM E70 Xplained Ultra Evaluation Kit
- Establish a connection between the router/switch with the SAM E70 Xplained Ultra Evaluation Kit through the RJ45 connector



Lab 1

Overview

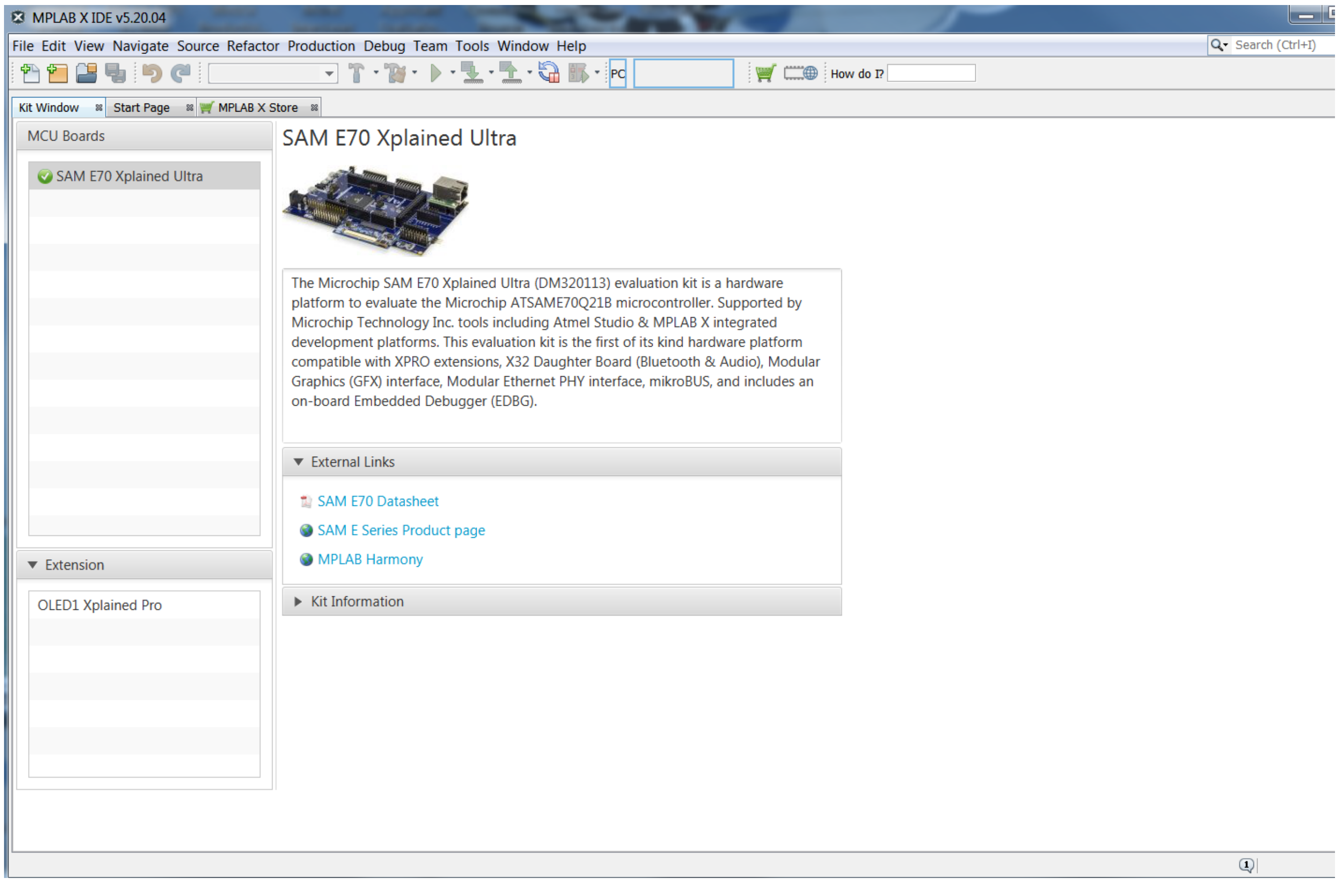
Lab 1 will show you how to open an existing TCP/IP MPLAB Harmony 3 Project and using the MPLAB Harmony Configuration (MHC) Tool. The project will incorporate basic TCP/IP functionality to allow the SAM E70 Xplained Ultra to connect to an Ethernet Network, along with a simple application to flash a "Heartbeat" LED every 500ms. Once the project is generated and programmed onto the development kit, you will use a number of techniques to validate that the PIC is connected to a network and determine its IP Address. The concepts that will be covered in this lab include:

- Open a SAM E70 MPLAB X Project
- Configuring the MPLAB Harmony path
- Configuring the TCP/IP Stack options, including:
    - Network Configuration of the Host Name
    - TCP/IP Services including Dynamic Host Configuration Protocol Client, ICMPv4 Server (for Ping testing) & Announce Discovery Tool
    - Bandwidth testing with "iperf"
- Configuring the Harmony Console and Command Service for monitoring and control of the TCP/IP stack via a Terminal Client running on a USB CDC Interface (Emulated RS232 COM Port).
  Toggling the IO Pin that drives USER_LED0 on the SAM E70 Xplained UltraSAM E70 Xplained Ultra
- Using the Windows Command Line Ping Tool and the Microchip TCP/IP Discovery tools to test connectivity of your SAM E70 Xplained UltraSAM E70 Xplained Ultra on the network
- Use the Console and Command System to get help on available TCPIP Commands and execute a command to get information about the network configuration.

Lab Procedure

Starting MPLAB X IDE

1.1. Start MPLAB X IDE by double clicking on the MPLAB X IDE v5.20 icon found on the Windows desktop.

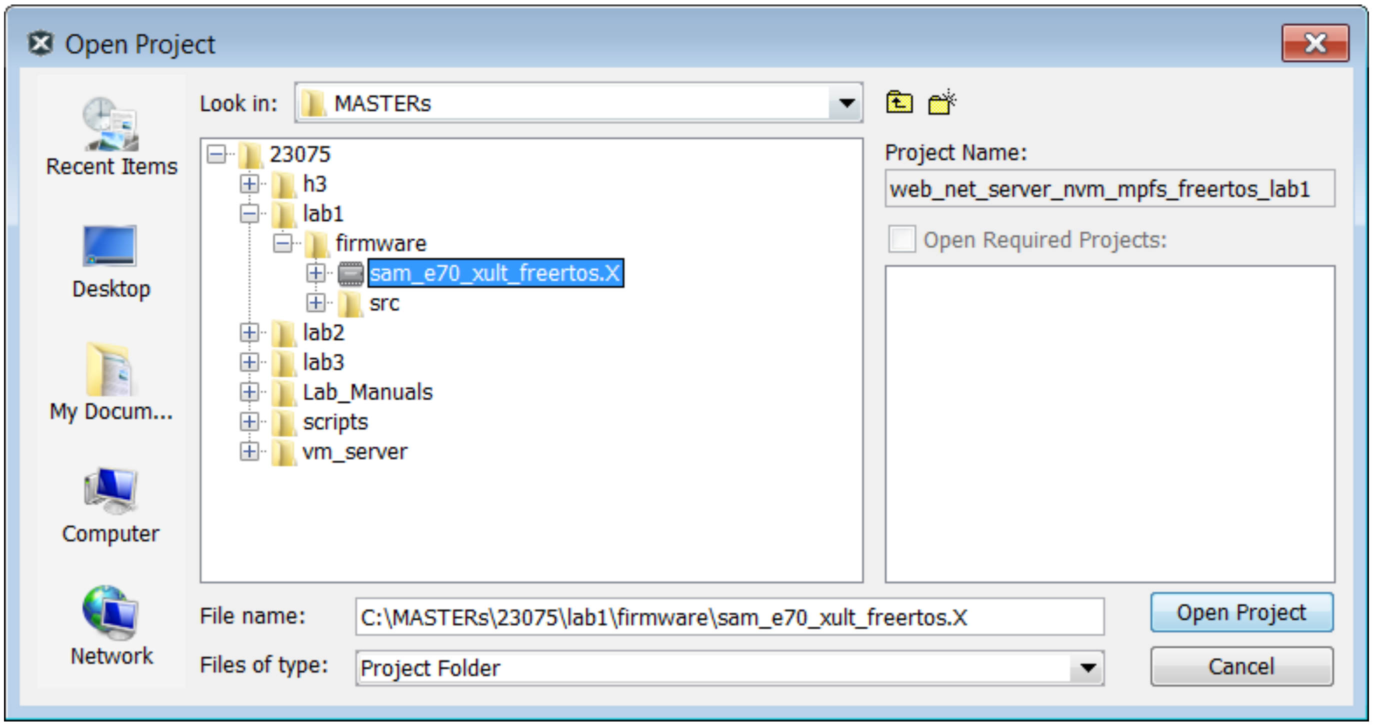


SAM E70 Xplained Ultra

The Microchip SAM E70 Xplained Ultra (DM320113) evaluation kit is a hardware platform to evaluate the Microchip ATSAME70Q21B microcontroller. Supported by Microchip Technology Inc. tools including Atmel Studio & MPLAB X integrated development platforms. This evaluation kit is the first of its kind hardware platform compatible with XPRO extensions, X32 Daughter Board (Bluetooth & Audio), Modular Graphics (GFX) interface, Modular Ethernet PHY interface, mikroBUS, and includes an on-board Embedded Debugger (EDBG).

Project Load, modify with MHC, Generate, build and run

1. Open Project by choosing File➤Open Project… from the main menu and select lab1 project

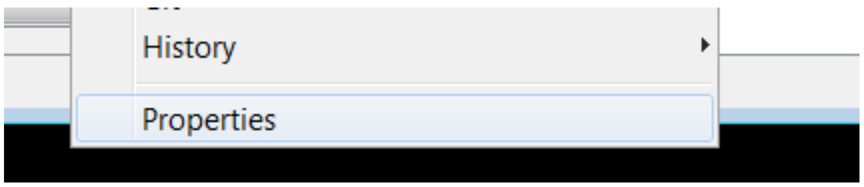


Project Name: web_net_server_nvm_mpfs_freertos_lab1

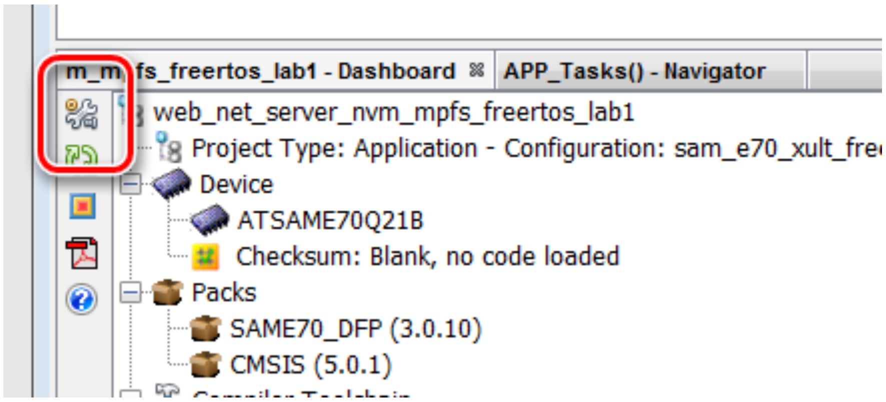
File name: C:\MASTERs\23075\lab1\firmware\sam_e70_xult_freertos.X

Files of type: Project Folder

2. Open Project Properties by choosing
   a. File➤Project Properties from the main menu
   b. Or select with a right click the project node in the project windows and select at the bottom

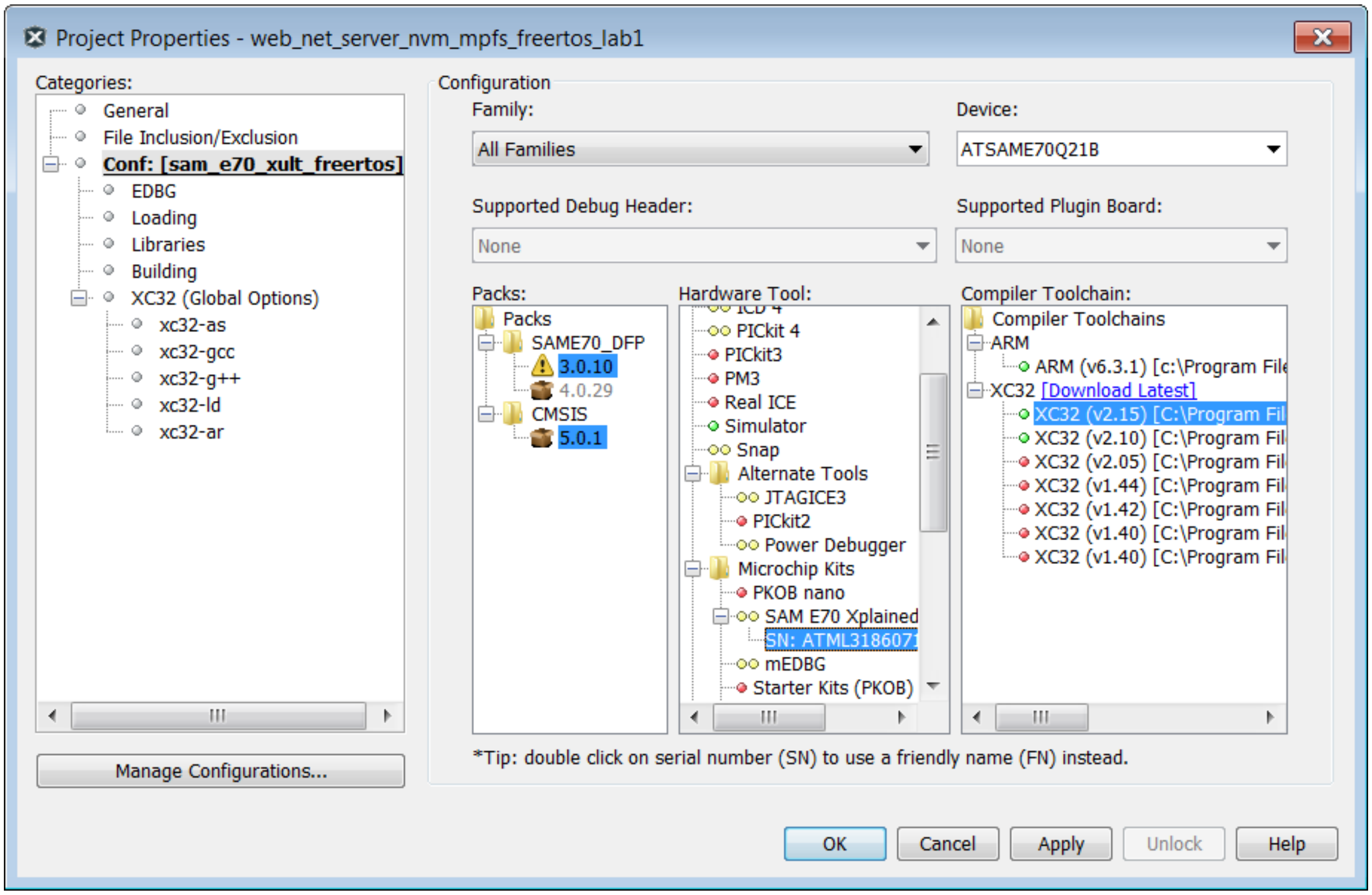


   c. Or select the toolbox in the Dashboard



web_net_server_nvm_mpfs_freertos_lab1
Project Type: Application - Configuration: sam_e70_xult_fre
Device
ATSAME70Q21B
Checksum: Blank, no code loaded
Packs
SAME70_DFP (3.0.10)
CMSIS (5.0.1)

3. Select the XC32 Compiler v2.15
4. Select the SAME70 Xplained by clicking on the SN: Number



Project Properties - web_net_server_nvm_mpfs_freertos_lab1

Categories: General, File Inclusion/Exclusion, Conf: [sam_e70_xult_freertos], EDBG, Loading, Libraries, Building, XC32 (Global Options), xc32-as, xc32-gcc, xc32-g++, xc32-ld, xc32-ar

Family: All Families
Device: ATSAME70Q21B
Supported Debug Header: None
Supported Plugin Board: None

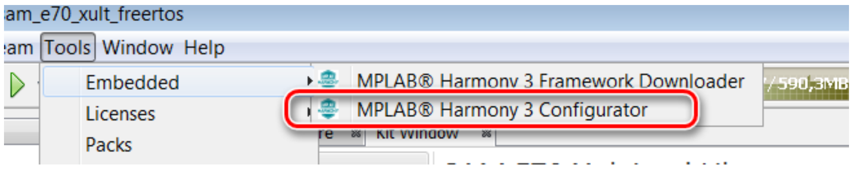
Packs: SAME70_DFP 3.0.10, 4.0.29; CMSIS 5.0.1

Hardware Tool: ICD 4, PICkit 4, PICkit3, PM3, Real ICE, Simulator, Snap, Alternate Tools, JTAGICE3, PICkit2, Power Debugger, Microchip Kits, PKOB nano, SAM E70 Xplained, SN: ATML318607, mEDBG, Starter Kits (PKOB)

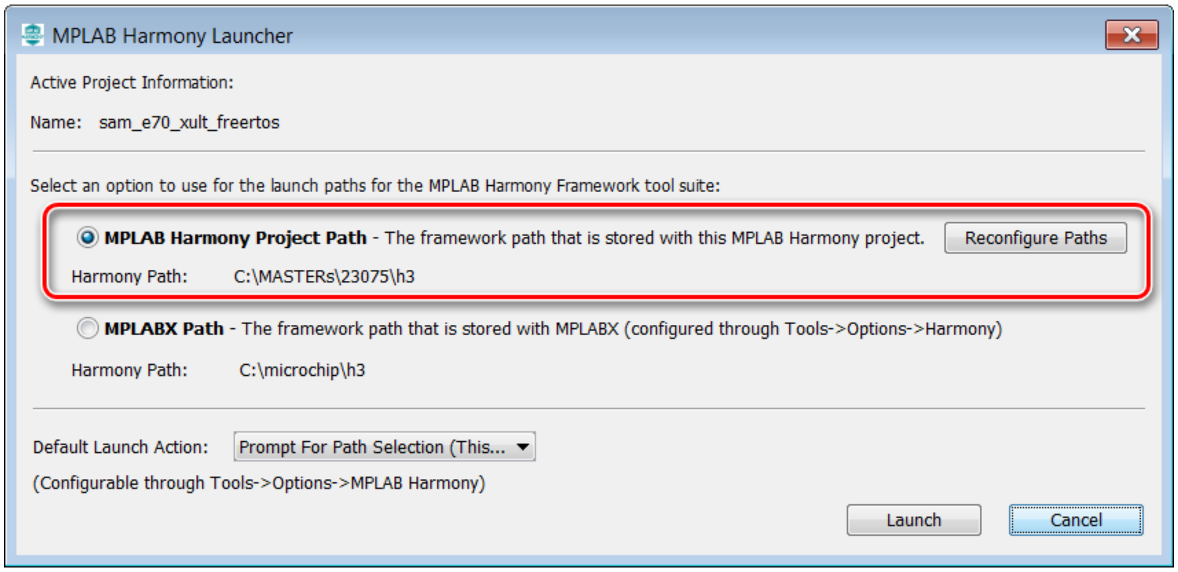
Compiler Toolchain: ARM (v6.3.1) [c:\Program File; XC32 [Download Latest]; XC32 (v2.15) [C:\Program Fil; XC32 (v2.10) [C:\Program Fil; XC32 (v2.05) [C:\Program Fil; XC32 (v1.44) [C:\Program Fil; XC32 (v1.42) [C:\Program Fil; XC32 (v1.40) [C:\Program Fil; XC32 (v1.40) [C:\Program Fil

*Tip: double click on serial number (SN) to use a friendly name (FN) instead.

5. Select from the Tools Menu the Harmony 3 Configurator


am_e70_xult_freertos
Tools
Window
Help
Embedded
Licenses
Packs
MPLAB® Harmony 3 Framework Downloader
MPLAB® Harmony 3 Configurator

6. Ensure the H3 Path is set to “C:\MASTERs\23075\h3\”



MPLAB Harmony Launcher

Active Project Information:

Name: sam_e70_xult_freertos

Select an option to use for the launch paths for the MPLAB Harmony Framework tool suite:

MPLAB Harmony Project Path - The framework path that is stored with this MPLAB Harmony project.

Harmony Path: C:\MASTERs\23075\h3

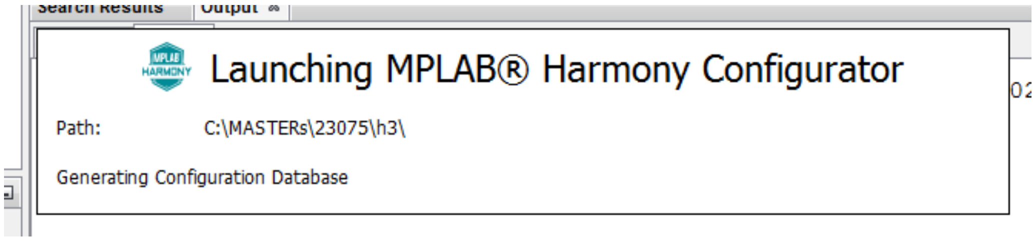
MPLABX Path - The framework path that is stored with MPLABX (configured through Tools->Options->Harmony)

Harmony Path: C:\microchip\h3

Default Launch Action: Prompt For Path Selection (This...

(Configurable through Tools->Options->MPLAB Harmony)

7. Select “Launch”



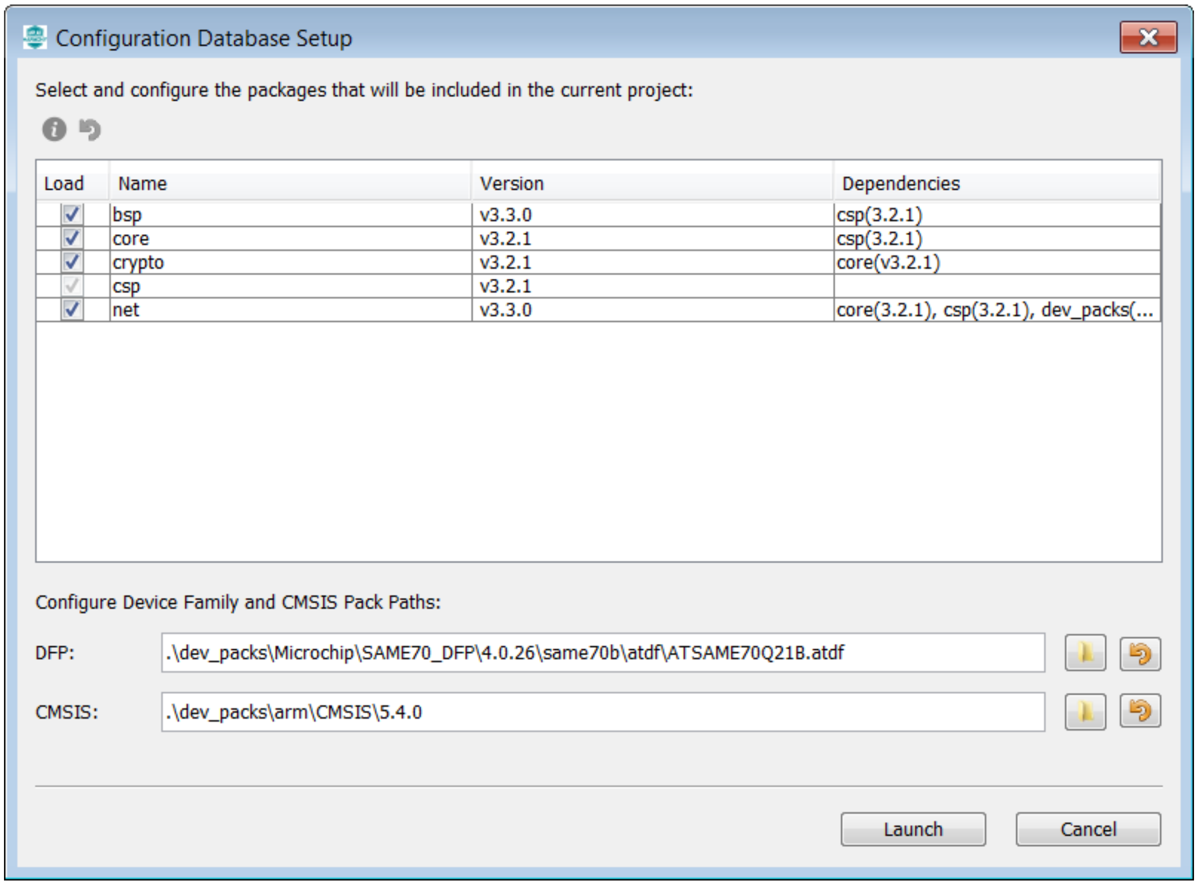
Launching MPLAB® Harmony Configurator

Path: C:\MASTERs\23075\h3\

Generating Configuration Database

The first time the MHC is started, it can take up to 2 Minutes before the Configuration Database is prepared

8. In the next window the H3 parts and their used Version Numbers are displayed



Configuration Database Setup

Select and configure the packages that will be included in the current project:

Load	Name	Version	Dependencies
✓	bsp	v3.3.0	csp(3.2.1)
✓	core	v3.2.1	csp(3.2.1)
✓	crypto	v3.2.1	core(v3.2.1)
✓	csp	v3.2.1	
✓	net	v3.3.0	core(3.2.1), csp(3.2.1), dev_packs(...

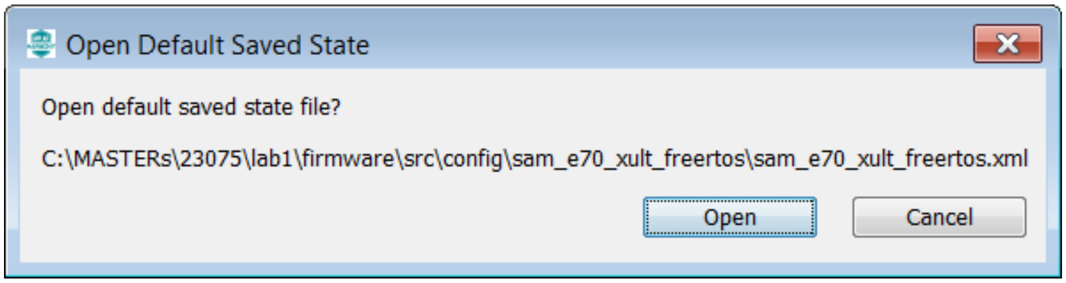
Configure Device Family and CMSIS Pack Paths:

DFP: .\dev_packs\Microchip\SAME70_DFP\4.0.26\same70b\atdf\ATSAME70Q21B.atdf

CMSIS: .\dev_packs\arm\CMSIS\5.4.0

Click on “Launch”

9. Open the saved state file

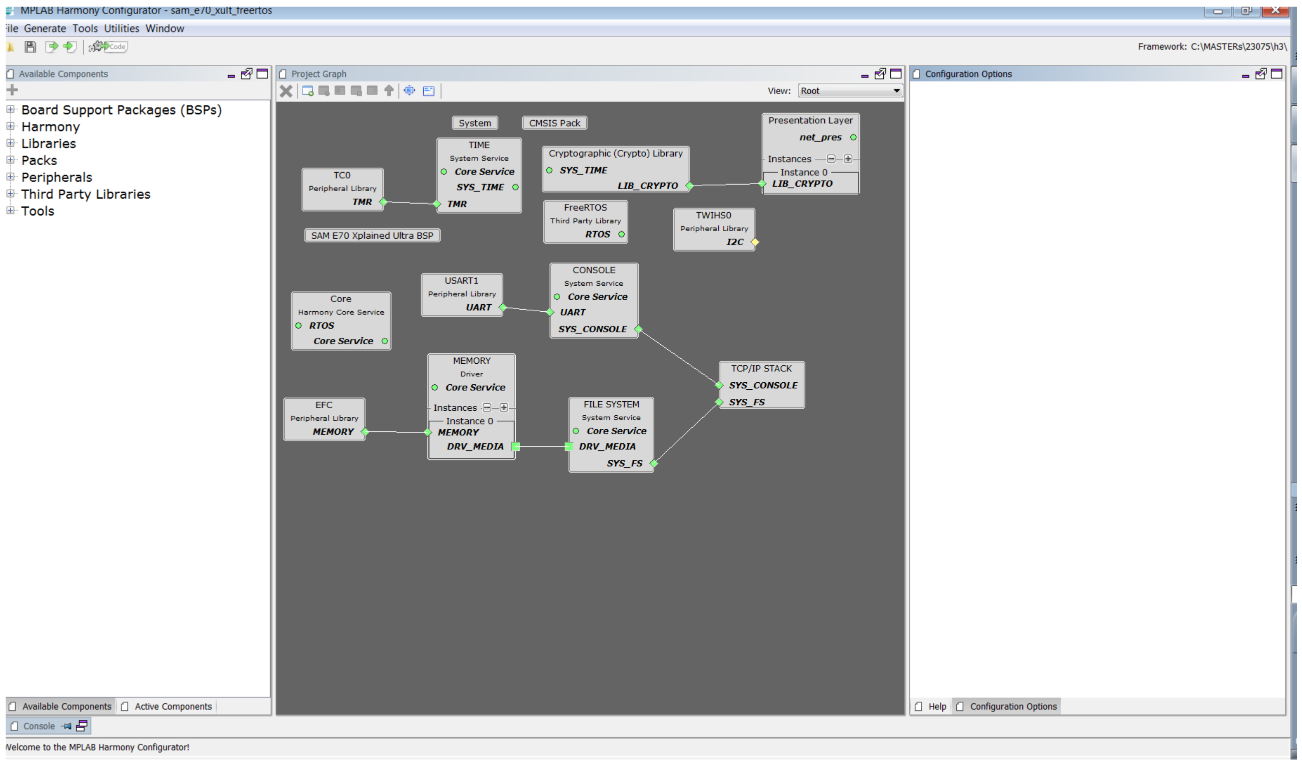


Open Default Saved State

Open default saved state file?

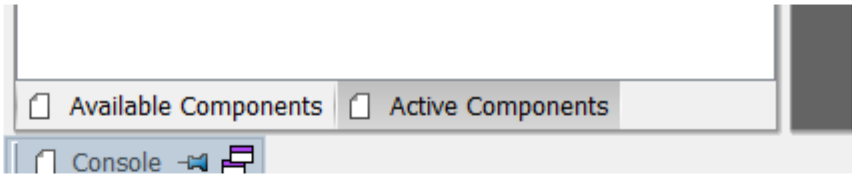
C:\MASTERs\23075\lab1\firmware\src\config\sam_e70_xult_freertos\sam_e70_xult_freertos.xml

10. The MHC is up and running

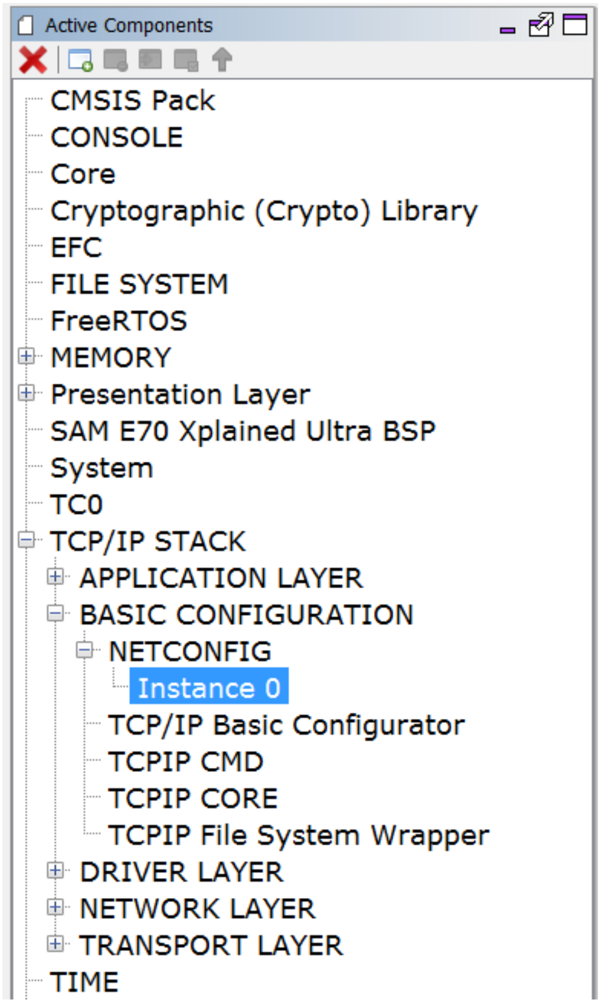

MPLAB Harmony Configurator - sam_e70_xult_freertos
File Generate Tools Utilities Window
Framework: C:\MASTERs\23075\h3\
Available Components
Board Support Packages (BSPs)
Harmony
Libraries
Packs
Peripherals
Third Party Libraries
Tools
Project Graph
View: Root
System
CMSIS Pack
TIME System Service Core Service SYS_TIME TMR
TC0 Peripheral Library TMR
Cryptographic (Crypto) Library SYS_TIME LIB_CRYPTO
Presentation Layer net_pres Instances Instance 0 LIB_CRYPTO
FreeRTOS Third Party Library RTOS
TWIHS0 Peripheral Library I2C
SAM E70 Xplained Ultra BSP
USART1 Peripheral Library UART
CONSOLE System Service Core Service UART SYS_CONSOLE
Core Harmony Core Service RTOS Core Service
MEMORY Driver Core Service Instances Instance 0 MEMORY DRV_MEDIA
EFC Peripheral Library MEMORY
FILE SYSTEM System Service Core Service DRV_MEDIA SYS_FS
TCP/IP STACK SYS_CONSOLE SYS_FS
Configuration Options
Available Components
Active Components
Help
Configuration Options
Console

Welcome to the MPLAB Harmony Configurator!

11. Select Active Components (left below)

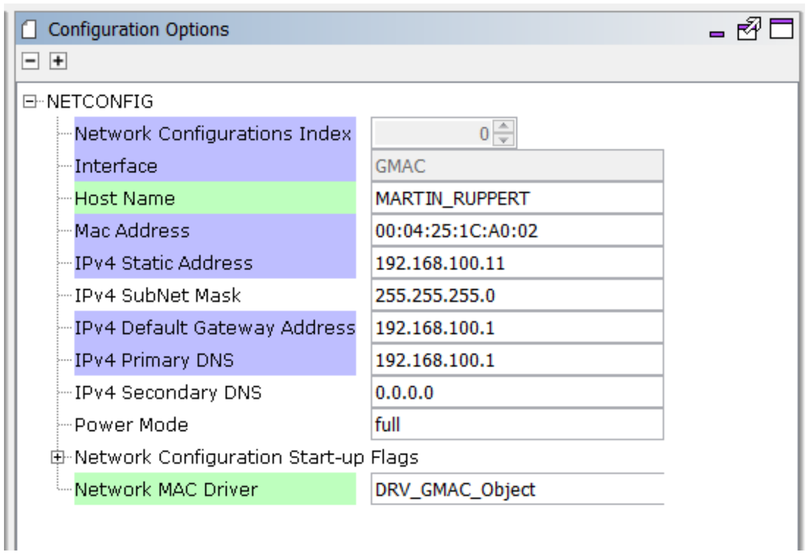


12. Select the Instance 0 in Active Components



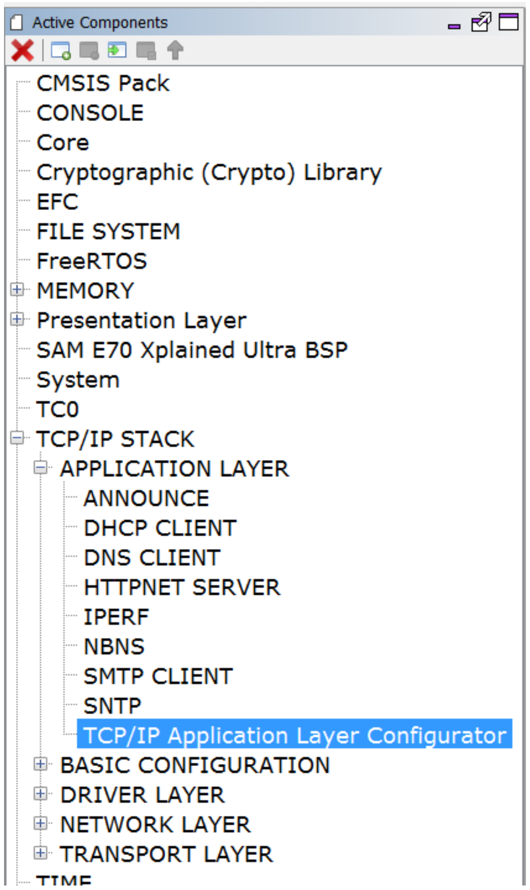
13. And change in the Configuration Options (on the right side) the Host Name to something meaningful for you.

The Host name can be identified in the Network.



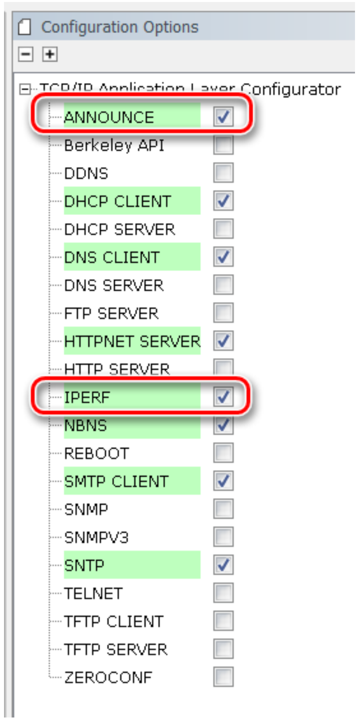
Network Configurations Index	0
Interface	GMAC
Host Name	MARTIN_RUPPERT
Mac Address	00:04:25:1C:A0:02
IPv4 Static Address	192.168.100.11
IPv4 SubNet Mask	255.255.255.0
IPv4 Default Gateway Address	192.168.100.1
IPv4 Primary DNS	192.168.100.1
IPv4 Secondary DNS	0.0.0.0
Power Mode	full
Network Configuration Start-up Flags	
Network MAC Driver	DRV_GMAC_Object

14. Select "TCP/IP Application Layer Configuration" in Active Components


Active Components

- CMSIS Pack
- CONSOLE
- Core
- Cryptographic (Crypto) Library
- EFC
- FILE SYSTEM
- FreeRTOS
- MEMORY
- Presentation Layer
- SAM E70 Xplained Ultra BSP
- System
- TC0
- TCP/IP STACK
  - APPLICATION LAYER
    - ANNOUNCE
    - DHCP CLIENT
    - DNS CLIENT
    - HTTPNET SERVER
    - IPERF
    - NBNS
    - SMTP CLIENT
    - SNTP
    - TCP/IP Application Layer Configurator
  - BASIC CONFIGURATION
  - DRIVER LAYER
  - NETWORK LAYER
  - TRANSPORT LAYER
- TIME

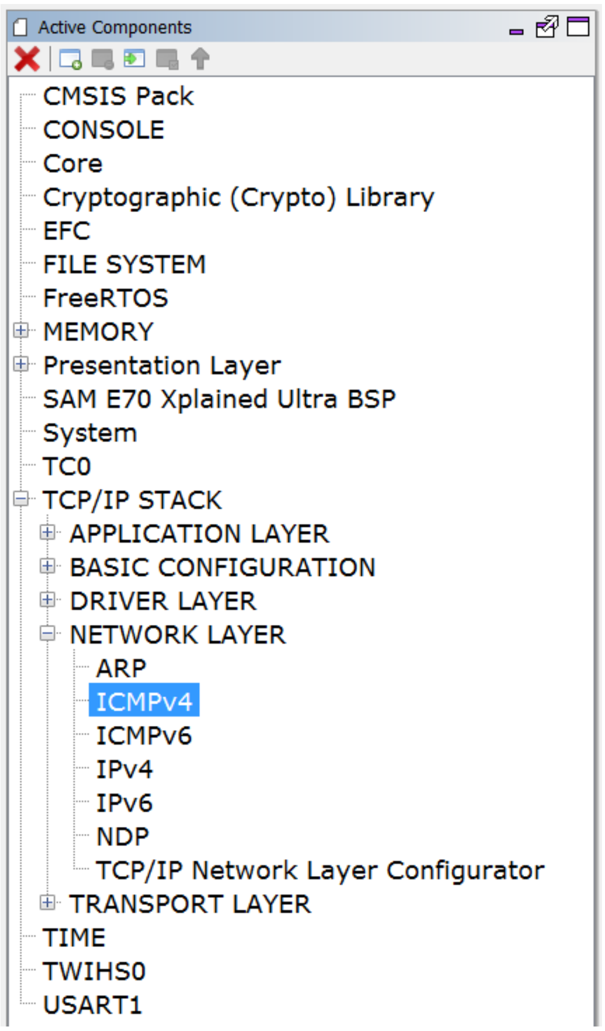
15. Ensure that ANNOUNCE and IPERF are selected


Configuration Options

TCP/IP Application Layer Configurator

ANNOUNCE	✓
Berkeley API	
DDNS	
DHCP CLIENT	✓
DHCP SERVER	
DNS CLIENT	✓
DNS SERVER	
FTP SERVER	
HTTPNET SERVER	✓
HTTP SERVER	
IPERF	✓
NBNS	✓
REBOOT	
SMTP CLIENT	✓
SNMP	
SNMPV3	
SNTP	✓
TELNET	
TFTP CLIENT	
TFTP SERVER	
ZEROCONF	

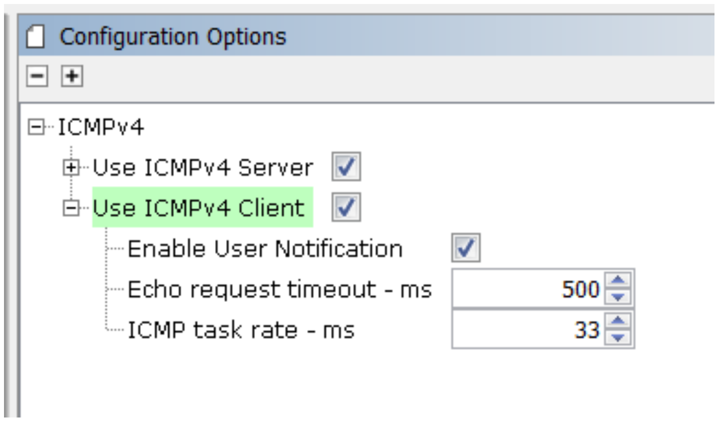
16. Select ICMPv4 in the Active Components



Active Components

- CMSIS Pack
- CONSOLE
- Core
- Cryptographic (Crypto) Library
- EFC
- FILE SYSTEM
- FreeRTOS
- MEMORY
- Presentation Layer
- SAM E70 Xplained Ultra BSP
- System
- TC0
- TCP/IP STACK
  - APPLICATION LAYER
  - BASIC CONFIGURATION
  - DRIVER LAYER
  - NETWORK LAYER
    - ARP
    - ICMPv4
    - ICMPv6
    - IPv4
    - IPv6
    - NDP
    - TCP/IP Network Layer Configurator
  - TRANSPORT LAYER
- TIME
- TWIHS0
- USART1

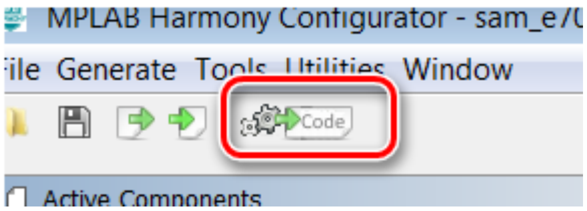
17. And ensure that the "Use ICMPv4 Client" is selected



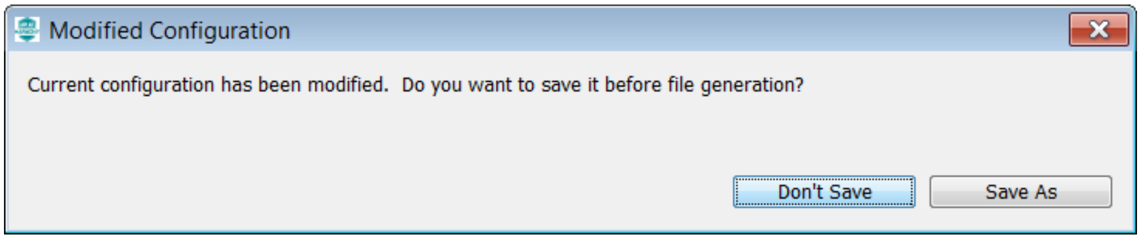
Configuration Options

- ICMPv4
  - Use ICMPv4 Server ✓
  - Use ICMPv4 Client ✓
    - Enable User Notification ✓
    - Echo request timeout - ms 500
    - ICMP task rate - ms 33

18. Select "Code" (Generate Code)

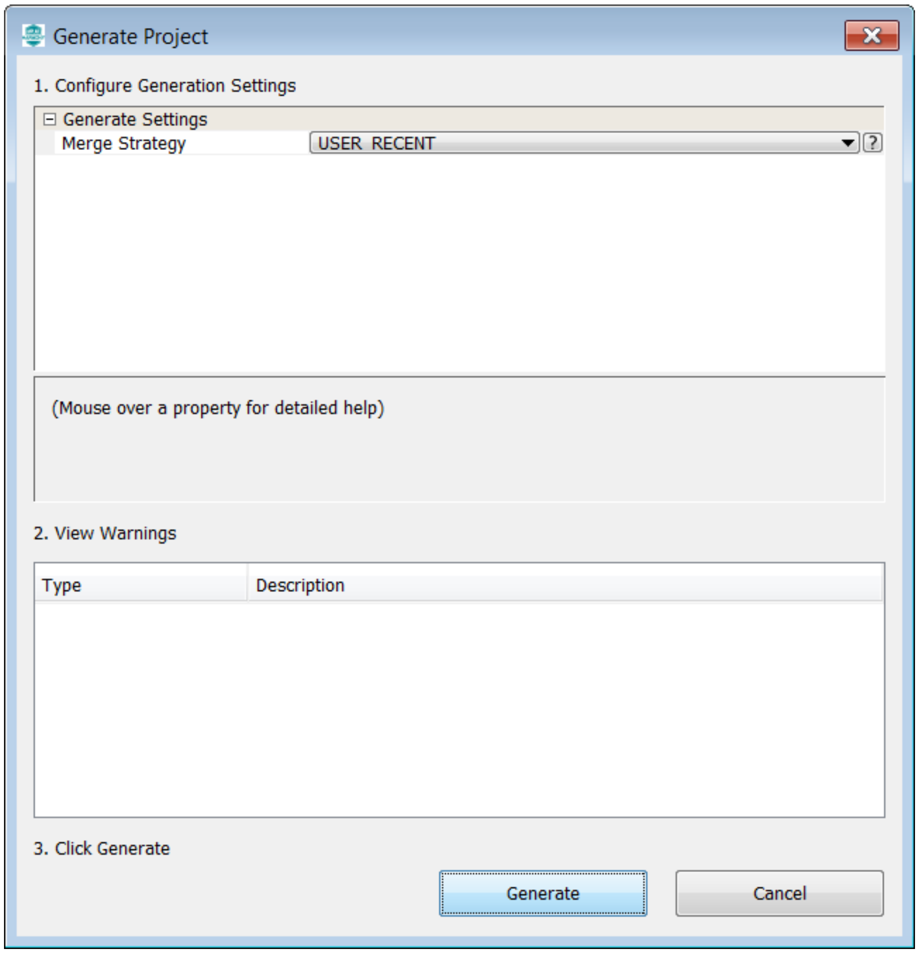

MPLAB Harmony Configurator - sam_e7(
ile Generate Tools Utilities Window
Code
Active Components

19. Select Don't Save



Current configuration has been modified. Do you want to save it before file generation?

20. Select Generate



1. Configure Generation Settings

Generate Settings

Merge Strategy USER_RECENT

(Mouse over a property for detailed help)

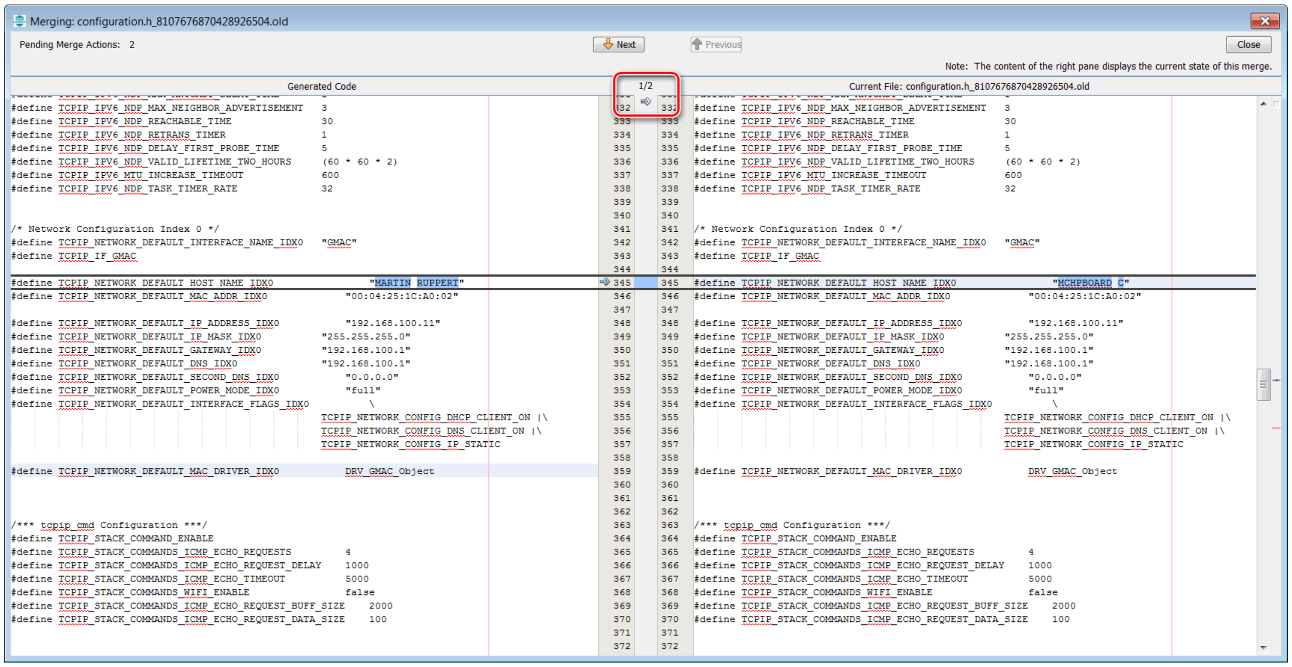
2. View Warnings

Type	Description

3. Click Generate

21. Some Files will be changed and the MHC is asking in a “diff” window, if the changes should be taken over.

    Accept all changes in the file by clicking on the Arrow in the middle above.


Merging: configuration.h_8107676870428926504.old
Pending Merge Actions: 2
Next
Previous
Close
Note: The content of the right pane displays the current state of this merge.
Generated Code
1/2
Current File: configuration.h_8107676870428926504.old

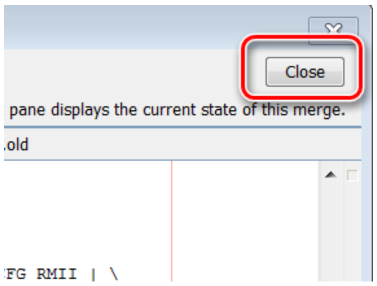
Generated Code:

```
#define TCPIP_IPV6_NDP_MAX_NEIGHBOR_ADVERTISEMENT   3
#define TCPIP_IPV6_NDP_REACHABLE_TIME               30
#define TCPIP_IPV6_NDP_RETRANS_TIMER                1
#define TCPIP_IPV6_NDP_DELAY_FIRST_PROBE_TIME       5
#define TCPIP_IPV6_NDP_VALID_LIFETIME_TWO_HOURS     (60 * 60 * 2)
#define TCPIP_IPV6_MTU_INCREASE_TIMEOUT             600
#define TCPIP_IPV6_NDP_TASK_TIMER_RATE              32


/* Network Configuration Index 0 */
#define TCPIP_NETWORK_DEFAULT_INTERFACE_NAME_IDX0   "GMAC"
#define TCPIP_IF_GMAC

#define TCPIP_NETWORK_DEFAULT_HOST_NAME_IDX0              "MARTIN RUPPERT"
#define TCPIP_NETWORK_DEFAULT_MAC_ADDR_IDX0           "00:04:25:1C:A0:02"

#define TCPIP_NETWORK_DEFAULT_IP_ADDRESS_IDX0         "192.168.100.11"
#define TCPIP_NETWORK_DEFAULT_IP_MASK_IDX0        "255.255.255.0"
#define TCPIP_NETWORK_DEFAULT_GATEWAY_IDX0        "192.168.100.1"
#define TCPIP_NETWORK_DEFAULT_DNS_IDX0            "192.168.100.1"
#define TCPIP_NETWORK_DEFAULT_SECOND_DNS_IDX0         "0.0.0.0"
#define TCPIP_NETWORK_DEFAULT_POWER_MODE_IDX0         "full"
#define TCPIP_NETWORK_DEFAULT_INTERFACE_FLAGS_IDX0        \
                                                  TCPIP_NETWORK_CONFIG_DHCP_CLIENT_ON |\
                                                  TCPIP_NETWORK_CONFIG_DNS_CLIENT_ON |\
                                                  TCPIP_NETWORK_CONFIG_IP_STATIC

#define TCPIP_NETWORK_DEFAULT_MAC_DRIVER_IDX0         DRV_GMAC_Object



/*** tcpip_cmd Configuration ***/
#define TCPIP_STACK_COMMAND_ENABLE
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUESTS         4
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUEST_DELAY    1000
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_TIMEOUT          5000
#define TCPIP_STACK_COMMANDS_WIFI_ENABLE                false
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUEST_BUFF_SIZE    2000
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUEST_DATA_SIZE    100
```

Current File:

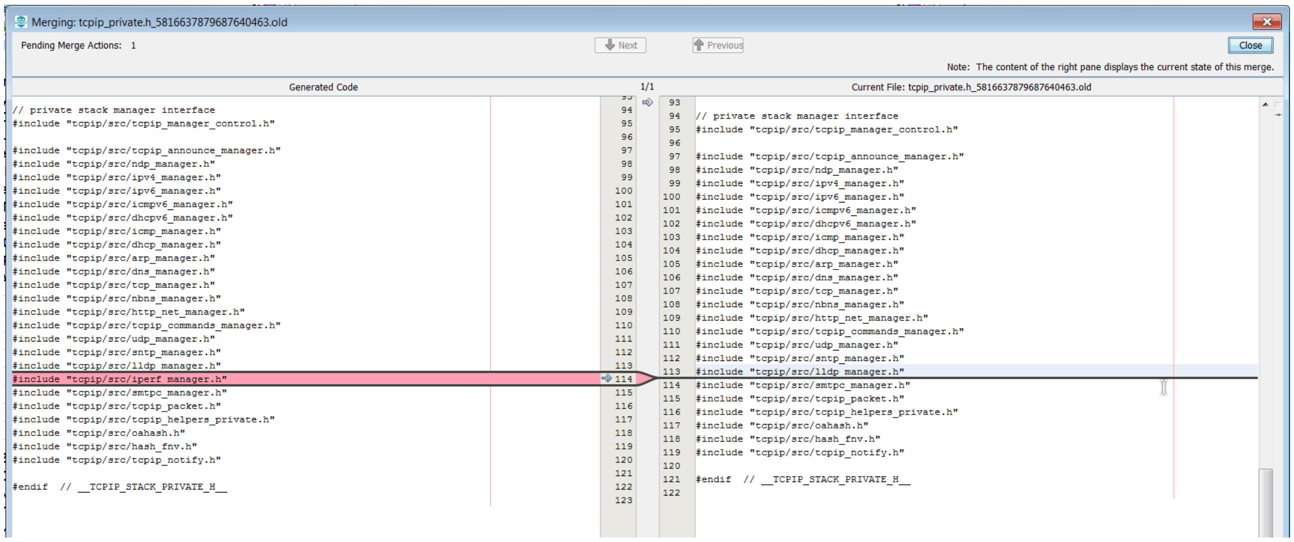
```
#define TCPIP_IPV6_NDP_MAX_NEIGHBOR_ADVERTISEMENT   3
#define TCPIP_IPV6_NDP_REACHABLE_TIME               30
#define TCPIP_IPV6_NDP_RETRANS_TIMER                1
#define TCPIP_IPV6_NDP_DELAY_FIRST_PROBE_TIME       5
#define TCPIP_IPV6_NDP_VALID_LIFETIME_TWO_HOURS     (60 * 60 * 2)
#define TCPIP_IPV6_MTU_INCREASE_TIMEOUT             600
#define TCPIP_IPV6_NDP_TASK_TIMER_RATE              32


/* Network Configuration Index 0 */
#define TCPIP_NETWORK_DEFAULT_INTERFACE_NAME_IDX0   "GMAC"
#define TCPIP_IF_GMAC

#define TCPIP_NETWORK_DEFAULT_HOST_NAME_IDX0              "MCHPBOARD_C"
#define TCPIP_NETWORK_DEFAULT_MAC_ADDR_IDX0           "00:04:25:1C:A0:02"

#define TCPIP_NETWORK_DEFAULT_IP_ADDRESS_IDX0         "192.168.100.11"
#define TCPIP_NETWORK_DEFAULT_IP_MASK_IDX0        "255.255.255.0"
#define TCPIP_NETWORK_DEFAULT_GATEWAY_IDX0        "192.168.100.1"
#define TCPIP_NETWORK_DEFAULT_DNS_IDX0            "192.168.100.1"
#define TCPIP_NETWORK_DEFAULT_SECOND_DNS_IDX0         "0.0.0.0"
#define TCPIP_NETWORK_DEFAULT_POWER_MODE_IDX0         "full"
#define TCPIP_NETWORK_DEFAULT_INTERFACE_FLAGS_IDX0        \
                                                  TCPIP_NETWORK_CONFIG_DHCP_CLIENT_ON |\
                                                  TCPIP_NETWORK_CONFIG_DNS_CLIENT_ON |\
                                                  TCPIP_NETWORK_CONFIG_IP_STATIC

#define TCPIP_NETWORK_DEFAULT_MAC_DRIVER_IDX0         DRV_GMAC_Object



/*** tcpip_cmd Configuration ***/
#define TCPIP_STACK_COMMAND_ENABLE
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUESTS         4
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUEST_DELAY    1000
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_TIMEOUT          5000
#define TCPIP_STACK_COMMANDS_WIFI_ENABLE                false
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUEST_BUFF_SIZE    2000
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUEST_DATA_SIZE    100
```

22. Then click on close in the upper right corner



```
FG RMII | \
```

23. Same for the next 2 diff windows


Merging: tcpip_private.h_5816637879687640463.old
Pending Merge Actions: 1
Next
Previous
Close
Note: The content of the right pane displays the current state of this merge.
Generated Code
1/1
Current File: tcpip_private.h_5816637879687640463.old

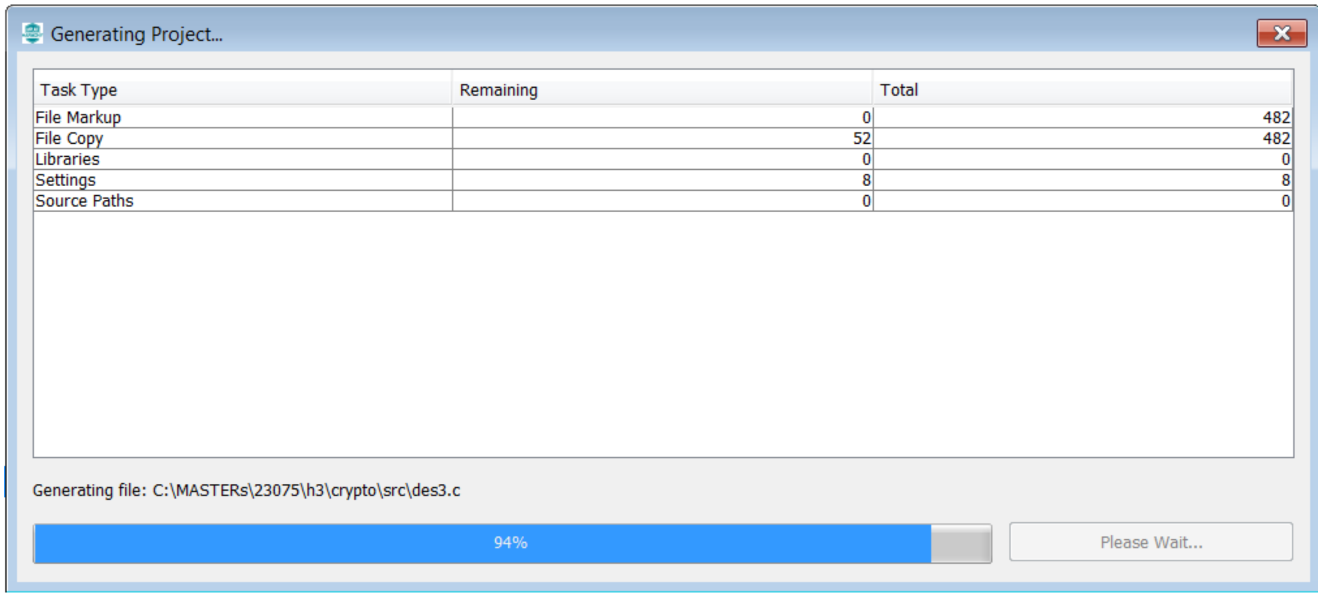
Generated Code:

```
// private stack manager interface
#include "tcpip/src/tcpip_manager_control.h"

#include "tcpip/src/tcpip_announce_manager.h"
#include "tcpip/src/ndp_manager.h"
#include "tcpip/src/ipv4_manager.h"
#include "tcpip/src/ipv6_manager.h"
#include "tcpip/src/icmpv6_manager.h"
#include "tcpip/src/dhcpv6_manager.h"
#include "tcpip/src/icmp_manager.h"
#include "tcpip/src/dhcp_manager.h"
#include "tcpip/src/arp_manager.h"
#include "tcpip/src/dns_manager.h"
#include "tcpip/src/tcp_manager.h"
#include "tcpip/src/nbns_manager.h"
#include "tcpip/src/http_net_manager.h"
#include "tcpip/src/tcpip_commands_manager.h"
#include "tcpip/src/udp_manager.h"
#include "tcpip/src/sntp_manager.h"
#include "tcpip/src/lldp_manager.h"
#include "tcpip/src/iperf_manager.h"
#include "tcpip/src/smtpc_manager.h"
#include "tcpip/src/tcpip_packet.h"
#include "tcpip/src/tcpip_helpers_private.h"
#include "tcpip/src/oahash.h"
#include "tcpip/src/hash_fnv.h"
#include "tcpip/src/tcpip_notify.h"

#endif  // __TCPIP_STACK_PRIVATE_H__
```

Current File:

```
// private stack manager interface
#include "tcpip/src/tcpip_manager_control.h"

#include "tcpip/src/tcpip_announce_manager.h"
#include "tcpip/src/ndp_manager.h"
#include "tcpip/src/ipv4_manager.h"
#include "tcpip/src/ipv6_manager.h"
#include "tcpip/src/icmpv6_manager.h"
#include "tcpip/src/dhcpv6_manager.h"
#include "tcpip/src/icmp_manager.h"
#include "tcpip/src/dhcp_manager.h"
#include "tcpip/src/arp_manager.h"
#include "tcpip/src/dns_manager.h"
#include "tcpip/src/tcp_manager.h"
#include "tcpip/src/nbns_manager.h"
#include "tcpip/src/http_net_manager.h"
#include "tcpip/src/tcpip_commands_manager.h"
#include "tcpip/src/udp_manager.h"
#include "tcpip/src/sntp_manager.h"
#include "tcpip/src/lldp_manager.h"
#include "tcpip/src/smtpc_manager.h"
#include "tcpip/src/tcpip_packet.h"
#include "tcpip/src/tcpip_helpers_private.h"
#include "tcpip/src/oahash.h"
#include "tcpip/src/hash_fnv.h"
#include "tcpip/src/tcpip_notify.h"

#endif  // __TCPIP_STACK_PRIVATE_H__
```

24. The whole process is displayed with a progress bar

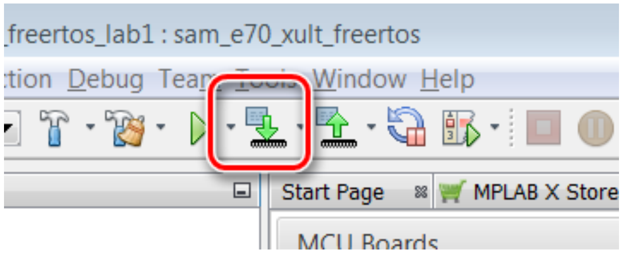


Generating Project...

Task Type	Remaining	Total
File Markup	0	482
File Copy	52	482
Libraries	0	0
Settings	8	8
Source Paths	0	0

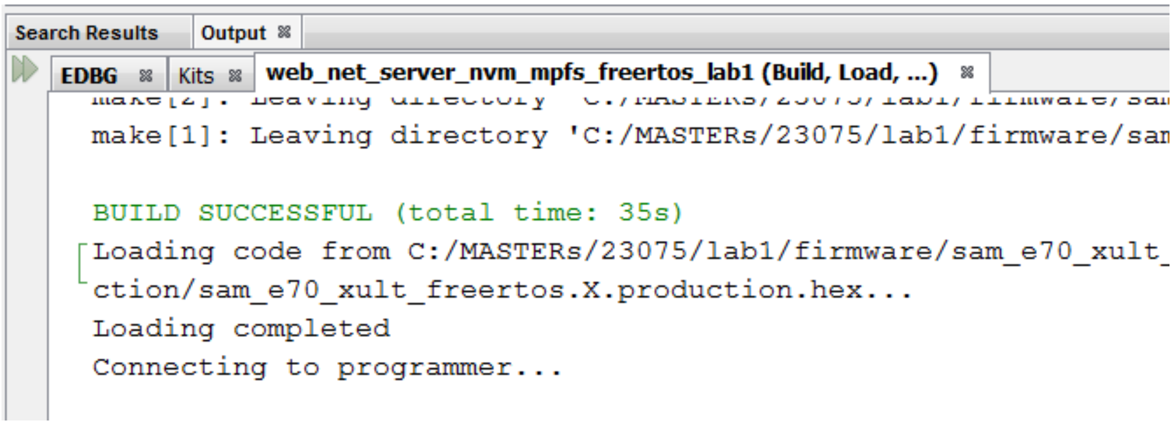
Generating file: C:\MASTERs\23075\h3\crypto\src\des3.c

25. Back again in the main window of MPLABX, click on the "Make and Program Device" button



freertos_lab1 : sam_e70_xult_freertos
tion Debug Team Tools Window Help
Start Page
MPLAB X Store
MCU Boards

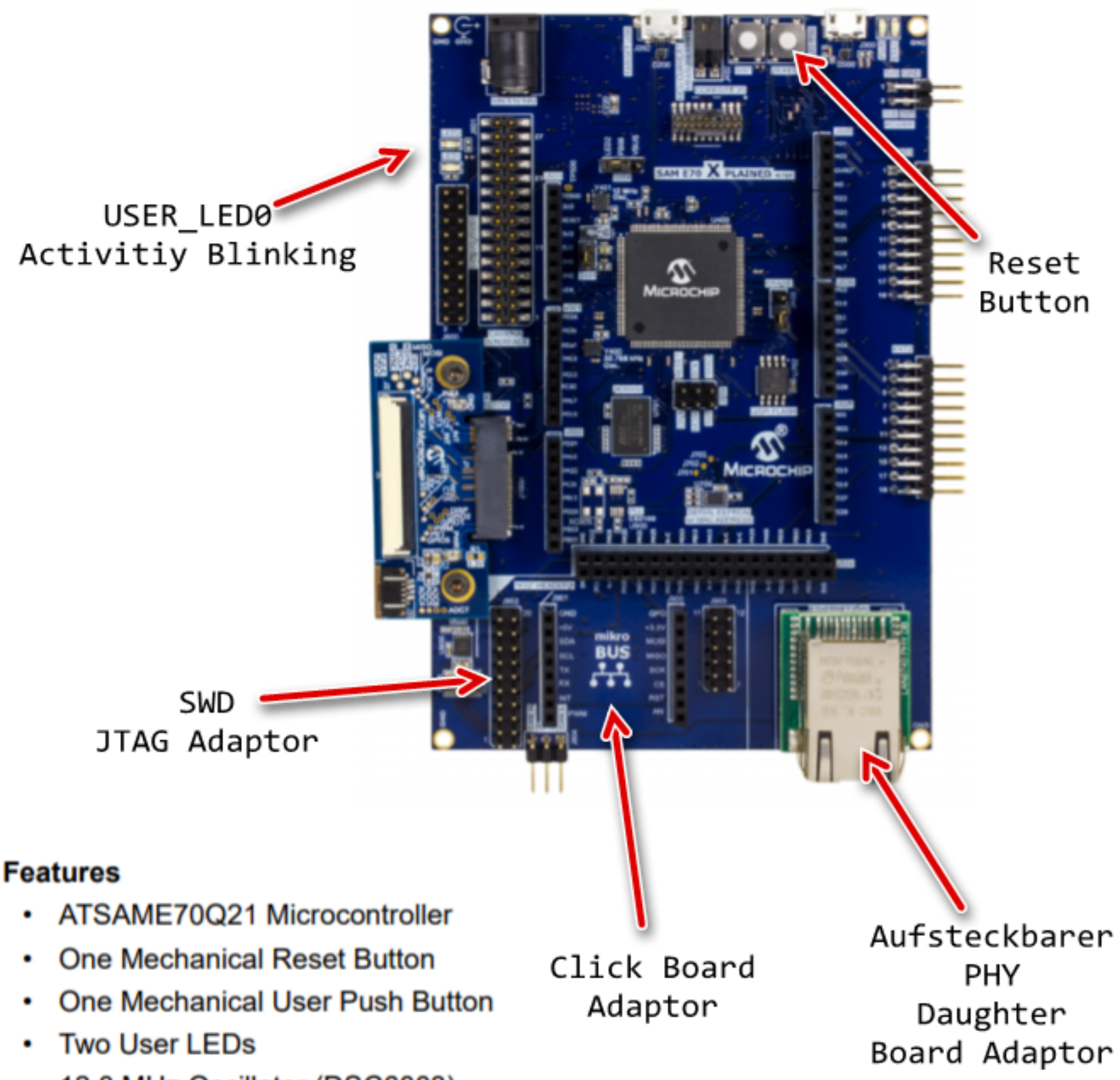
26. After successful build, the SAME70 is programmed automatically



```
make[1]: Leaving directory 'C:/MASTERs/23075/lab1/firmware/sam

BUILD SUCCESSFUL (total time: 35s)
Loading code from C:/MASTERs/23075/lab1/firmware/sam_e70_xult_
ction/sam_e70_xult_freertos.X.production.hex...
Loading completed
Connecting to programmer...
```

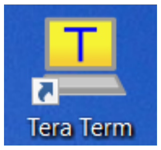
27. The programming take about 30 seconds with on Board Debugger Check whether the USER_LED0 Activity is Blinking

Figure 1. SAM E70 Xplained Ultra Evaluation Kit with PHY Daughter Board

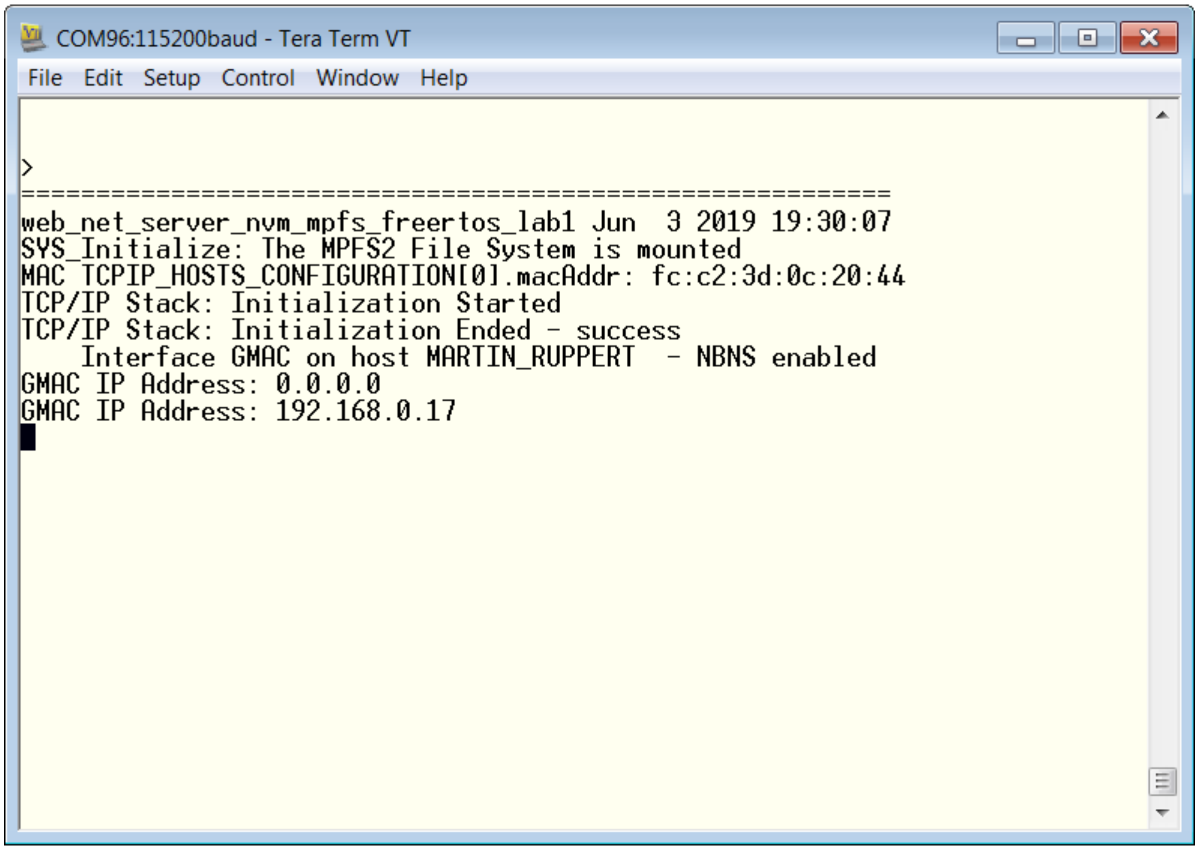


Features

- ATSAME70Q21 Microcontroller
- One Mechanical Reset Button
- One Mechanical User Push Button
- Two User LEDs
- 12.0 MHz Oscillator (DSC6003)
- 32.768 kHz Oscillator (DSC6083)
- 2-MB SDRAM
- 4-MB QSPI Flash (SST26VF032BA)

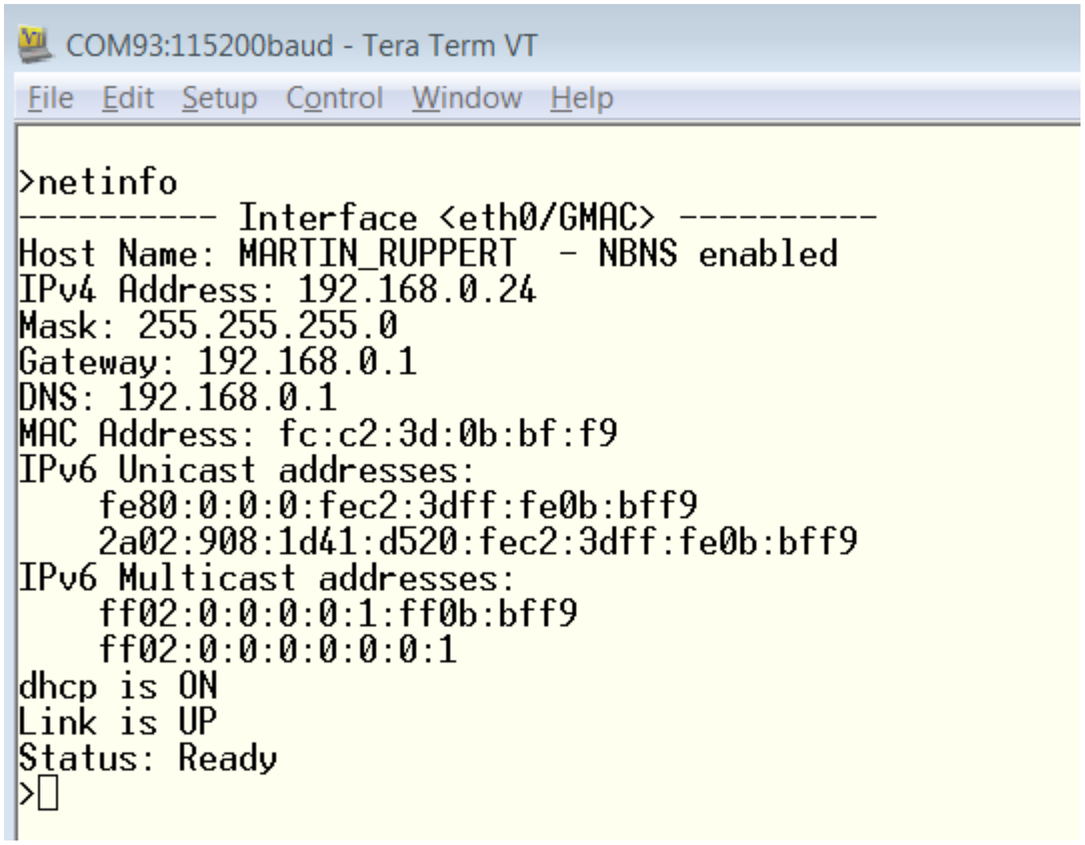
28. Open Terra Term Terminal Program  and select under Setup->Serial Port the COM Port and the Baudrate 115200 (in this case a COM96, but could be a different COM Port number in your case).

    The press the Reset Button of the Board and let the Firmware restart. You should see the start message with the Lab name and the build timestamp at first, followed by the MAC Address from EEPROM.
29. After some small time, the IP Address should be change from 0.0.0.0 to a valid address


COM96:115200baud - Tera Term VT
File Edit Setup Control Window Help

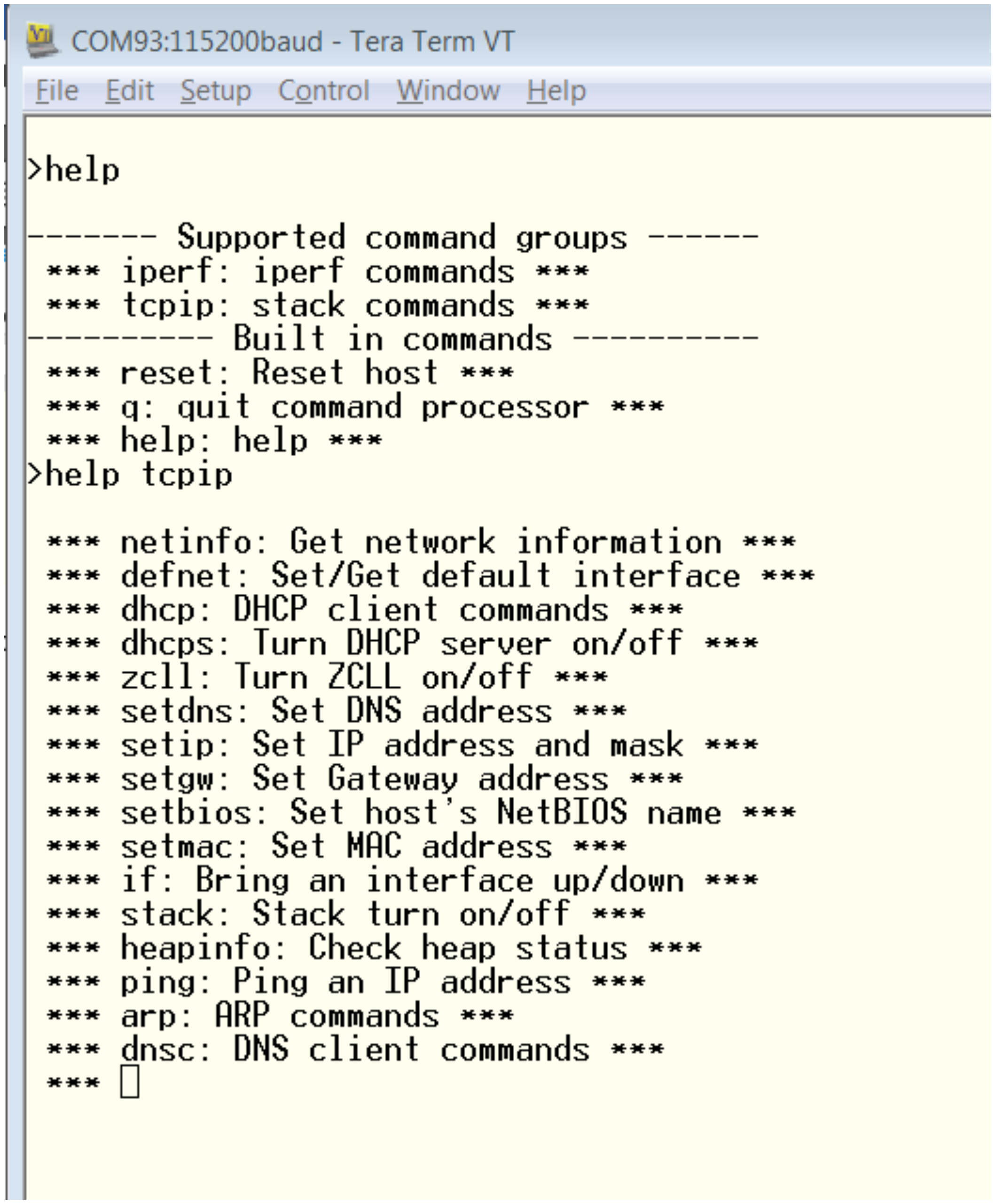
```
>
==========================================================
web_net_server_nvm_mpfs_freertos_lab1 Jun  3 2019 19:30:07
SYS_Initialize: The MPFS2 File System is mounted
MAC TCPIP_HOSTS_CONFIGURATION[0].macAddr: fc:c2:3d:0c:20:44
TCP/IP Stack: Initialization Started
TCP/IP Stack: Initialization Ended - success
    Interface GMAC on host MARTIN_RUPPERT  - NBNS enabled
GMAC IP Address: 0.0.0.0
GMAC IP Address: 192.168.0.17
```

30. To check the basic information about the network enter the `netinfo` command and press **Enter**.


COM93:115200baud - Tera Term VT
File Edit Setup Control Window Help

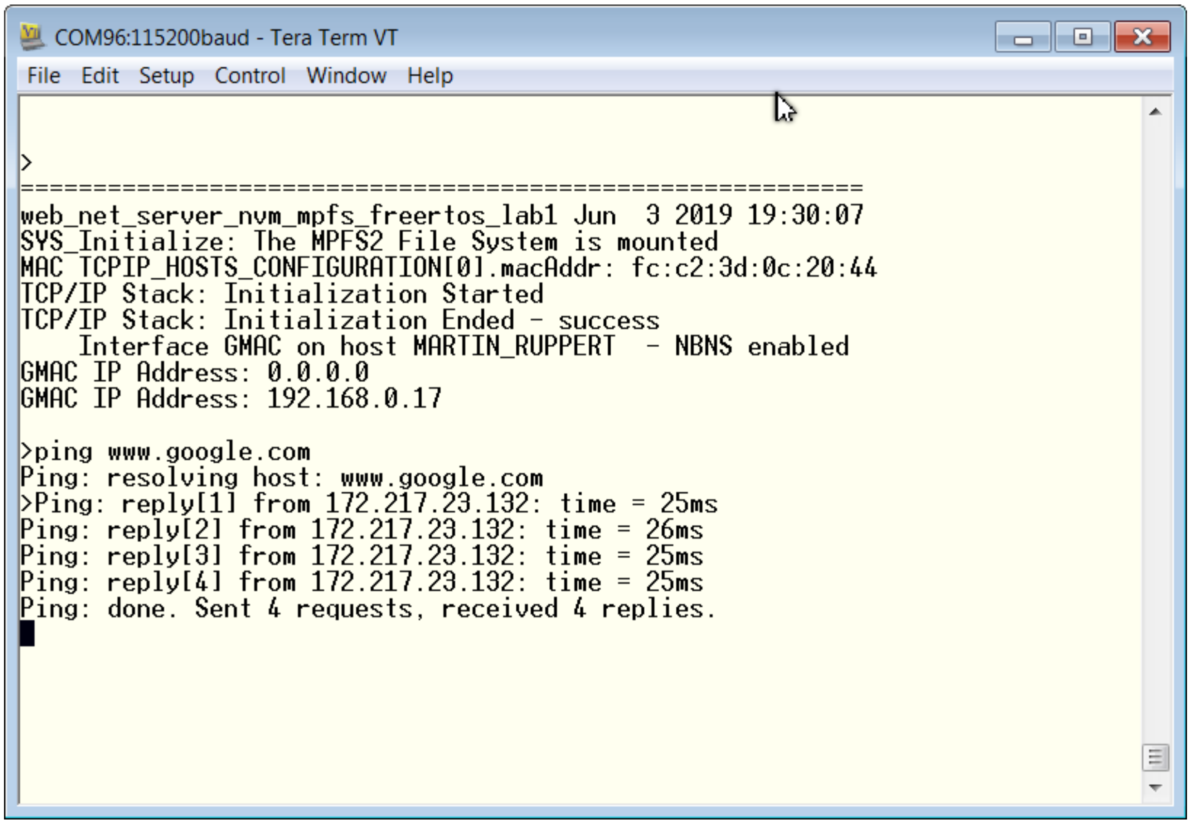
```
>netinfo
---------- Interface <eth0/GMAC> ----------
Host Name: MARTIN_RUPPERT  - NBNS enabled
IPv4 Address: 192.168.0.24
Mask: 255.255.255.0
Gateway: 192.168.0.1
DNS: 192.168.0.1
MAC Address: fc:c2:3d:0b:bf:f9
IPv6 Unicast addresses:
    fe80:0:0:0:fec2:3dff:fe0b:bff9
    2a02:908:1d41:d520:fec2:3dff:fe0b:bff9
IPv6 Multicast addresses:
    ff02:0:0:0:0:1:ff0b:bff9
    ff02:0:0:0:0:0:0:1
dhcp is ON
Link is UP
Status: Ready
>
```

31. A help shows the available commands


COM93:115200baud - Tera Term VT
File Edit Setup Control Window Help

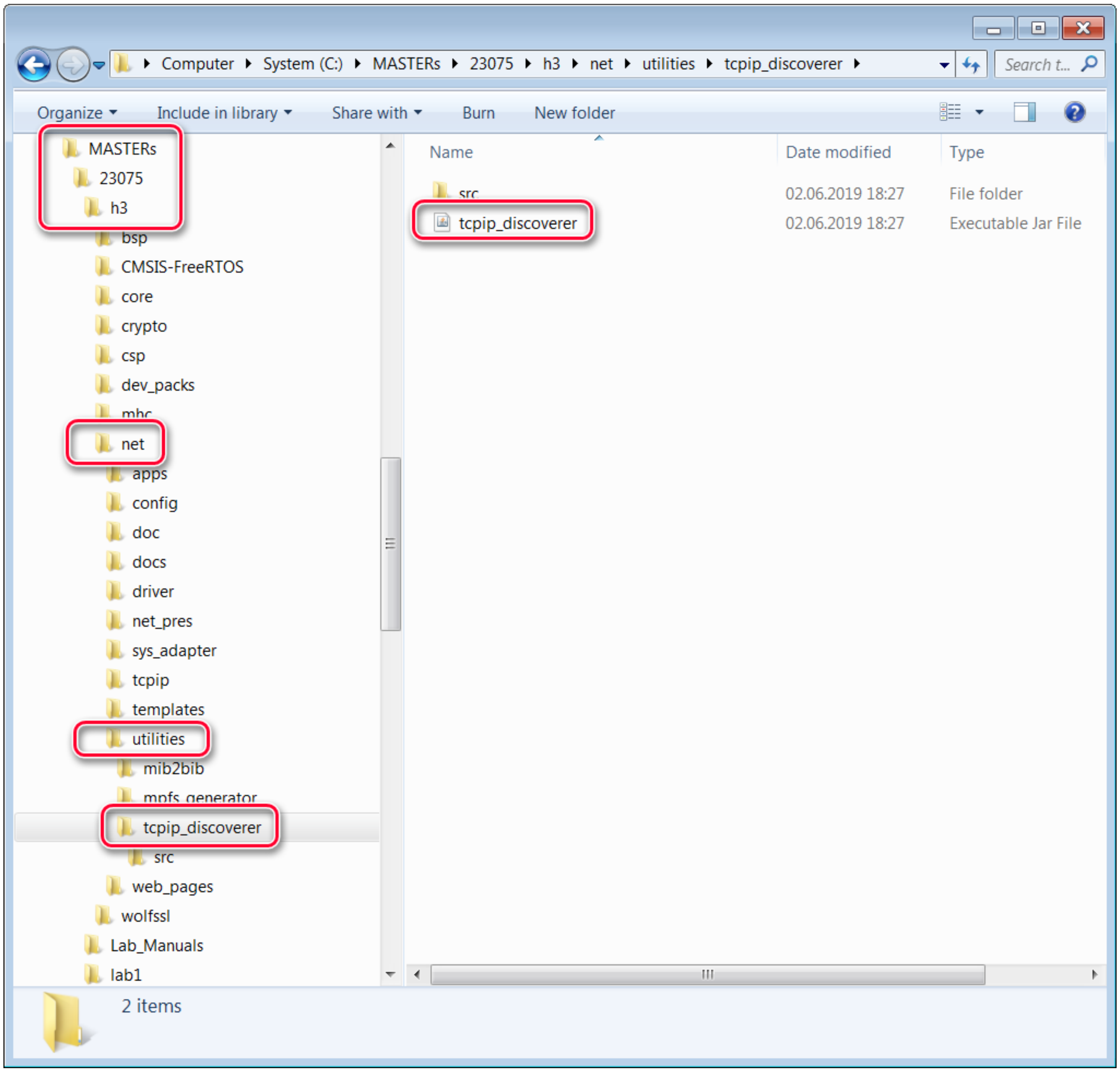
```
>help

------- Supported command groups ------
 *** iperf: iperf commands ***
 *** tcpip: stack commands ***
---------- Built in commands ----------
 *** reset: Reset host ***
 *** q: quit command processor ***
 *** help: help ***
>help tcpip

 *** netinfo: Get network information ***
 *** defnet: Set/Get default interface ***
 *** dhcp: DHCP client commands ***
 *** dhcps: Turn DHCP server on/off ***
 *** zcll: Turn ZCLL on/off ***
 *** setdns: Set DNS address ***
 *** setip: Set IP address and mask ***
 *** setgw: Set Gateway address ***
 *** setbios: Set host's NetBIOS name ***
 *** setmac: Set MAC address ***
 *** if: Bring an interface up/down ***
 *** stack: Stack turn on/off ***
 *** heapinfo: Check heap status ***
 *** ping: Ping an IP address ***
 *** arp: ARP commands ***
 *** dnsc: DNS client commands ***
 ***
```

32. As a first simple test you can ping an external Server or anything else you like (Maybe the board of your class neighbor?)


COM96:115200baud - Tera Term VT
File Edit Setup Control Window Help

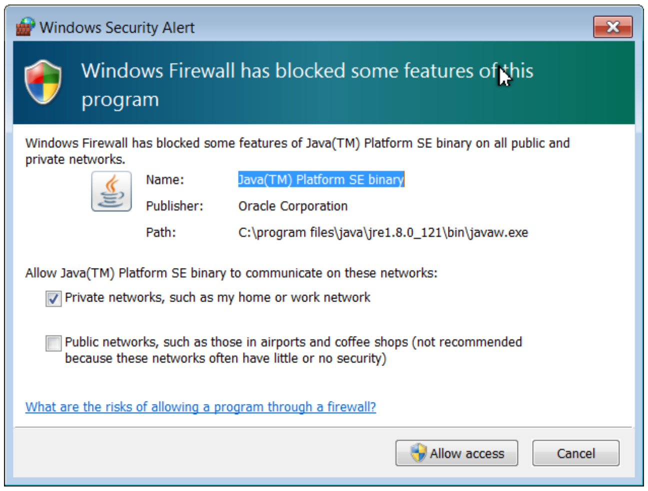
```
>
==========================================================
web_net_server_nvm_mpfs_freertos_lab1 Jun  3 2019 19:30:07
SYS_Initialize: The MPFS2 File System is mounted
MAC TCPIP_HOSTS_CONFIGURATION[0].macAddr: fc:c2:3d:0c:20:44
TCP/IP Stack: Initialization Started
TCP/IP Stack: Initialization Ended - success
    Interface GMAC on host MARTIN_RUPPERT  - NBNS enabled
GMAC IP Address: 0.0.0.0
GMAC IP Address: 192.168.0.17

>ping www.google.com
Ping: resolving host: www.google.com
>Ping: reply[1] from 172.217.23.132: time = 25ms
Ping: reply[2] from 172.217.23.132: time = 26ms
Ping: reply[3] from 172.217.23.132: time = 25ms
Ping: reply[4] from 172.217.23.132: time = 25ms
Ping: done. Sent 4 requests, received 4 replies.
```

33. Select the **tcpip_discoverer** tool from



Name	Date modified	Type
src	02.06.2019 18:27	File folder
tcpip_discoverer	02.06.2019 18:27	Executable Jar File

34. If Windows is asking for permissions allow the access


Windows Security Alert

Windows Firewall has blocked some features of this program

Windows Firewall has blocked some features of Java(TM) Platform SE binary on all public and private networks.

Name: Java(TM) Platform SE binary
Publisher: Oracle Corporation
Path: C:\program files\java\jre1.8.0_121\bin\javaw.exe

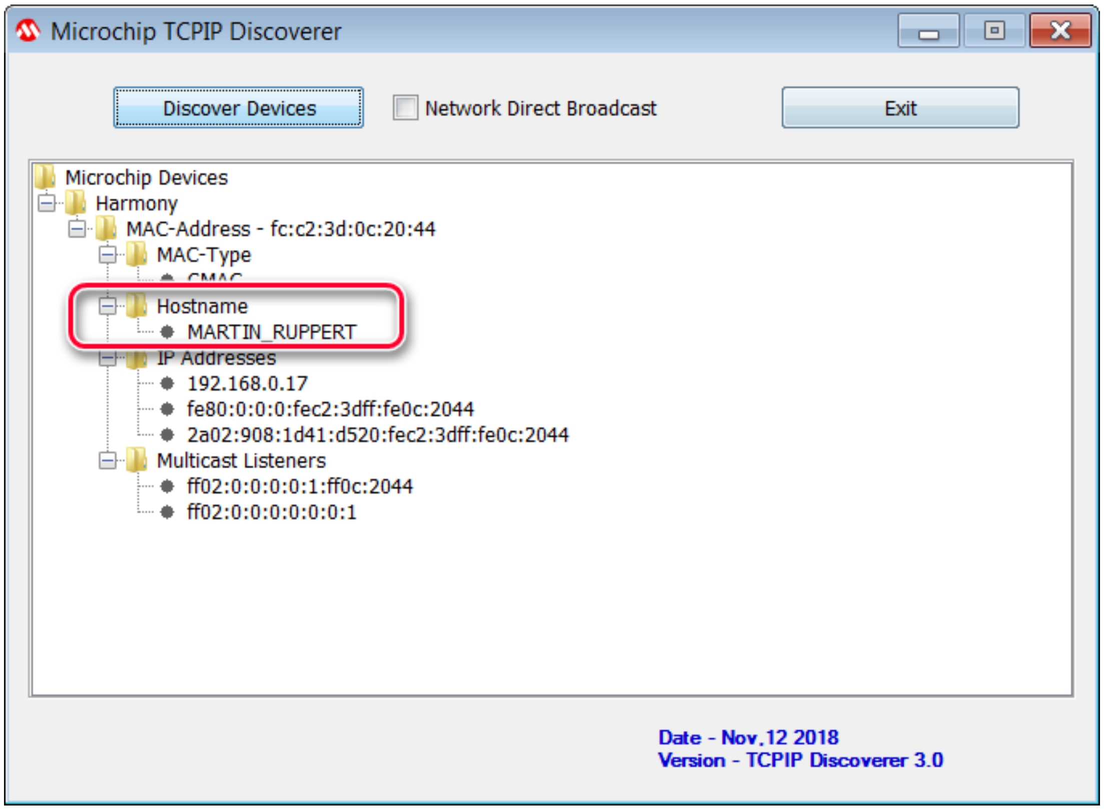
Allow Java(TM) Platform SE binary to communicate on these networks:

- [✓] Private networks, such as my home or work network
- [ ] Public networks, such as those in airports and coffee shops (not recommended because these networks often have little or no security)

What are the risks of allowing a program through a firewall?

35. The TCP Discover should list all boards in the classroom. We have made this tool to help you to find your board in the network. The source codes of this tool (Java) are part of the H3.

    You can identify your board by the Host Name that has select in an earlier step. The Host Name is also known to the DHCP server and is listed in their typical Web Interfaces as a connected device.


Microchip TCPIP Discoverer

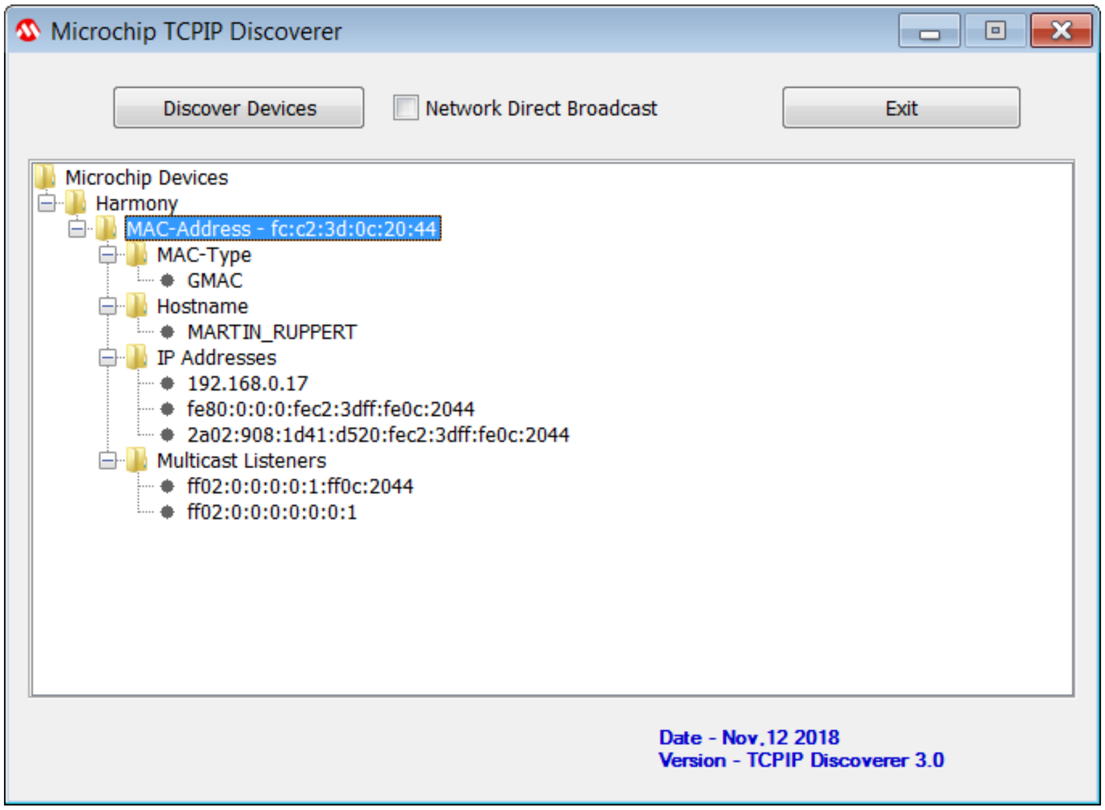
```
Microchip Devices
  Harmony
    MAC-Address - fc:c2:3d:0c:20:44
      MAC-Type
        GMAC
      Hostname
        MARTIN_RUPPERT
      IP Addresses
        192.168.0.17
        fe80:0:0:0:fec2:3dff:fe0c:2044
        2a02:908:1d41:d520:fec2:3dff:fe0c:2044
      Multicast Listeners
        ff02:0:0:0:0:1:ff0c:2044
        ff02:0:0:0:0:0:0:1
```

Date - Nov,12 2018
Version - TCPIP Discoverer 3.0

Press the **Discover Devices** button: The tool will send a UDP broadcast on port 30303, with the packet “Discovery, who is out there?” All H3 devices running the Announce service will respond to this broadcast, by sending a return broadcast on port 30303. The broadcast packet contains data on the type of interface used, the Host Name, MAC and IP Address. The Discover tool listens to all broadcasts on port 30303 and will show found devices under the Microchip

Devices tree. You can identify your device by looking for the host name that you entered in MHC Setup process. The Microchip TCPIP Discoverer tool also shows the IP address for your board.

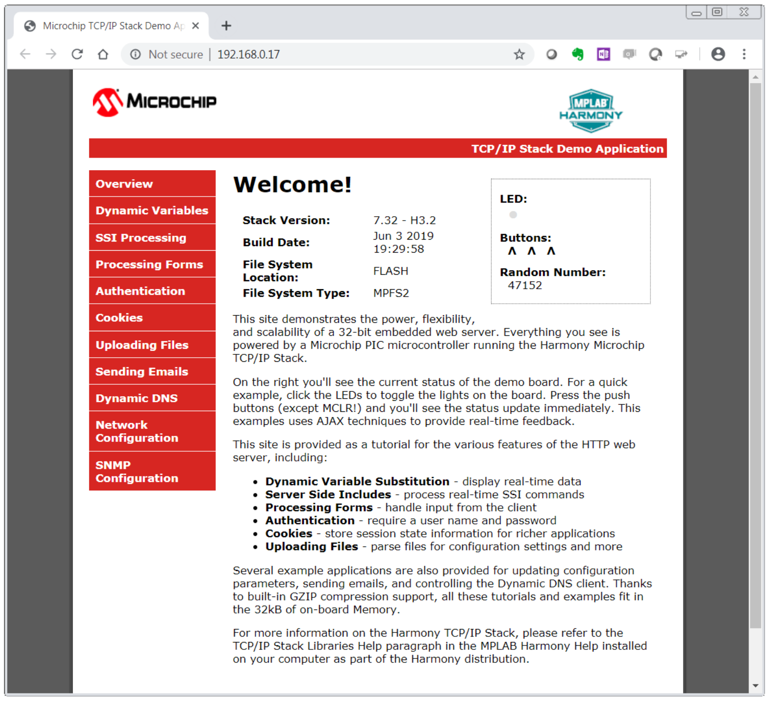
36. A double click on the **MAC-Address** line will put you in your default Internet Browser



```
Microchip Devices
  Harmony
    MAC-Address - fc:c2:3d:0c:20:44
      MAC-Type
        GMAC
      Hostname
        MARTIN_RUPPERT
      IP Addresses
        192.168.0.17
        fe80:0:0:0:fec2:3dff:fe0c:2044
        2a02:908:1d41:d520:fec2:3dff:fe0c:2044
      Multicast Listeners
        ff02:0:0:0:0:1:ff0c:2044
        ff02:0:0:0:0:0:0:1
```

Date - Nov.12 2018
Version - TCPIP Discoverer 3.0

37. And the Webpage is displayed. Please take some time an play with the sub menus to find out the capabilities of or H3 Web Server



Welcome!

Stack Version:	7.32 - H3.2
Build Date:	Jun 3 2019 19:29:58
File System Location:	FLASH
File System Type:	MPFS2

LED:

Buttons:
∧ ∧ ∧

Random Number:
47152

This site demonstrates the power, flexibility, and scalability of a 32-bit embedded web server. Everything you see is powered by a Microchip PIC microcontroller running the Harmony Microchip TCP/IP Stack.

On the right you'll see the current status of the demo board. For a quick example, click the LEDs to toggle the lights on the board. Press the push buttons (except MCLR!) and you'll see the status update immediately. This examples uses AJAX techniques to provide real-time feedback.

This site is provided as a tutorial for the various features of the HTTP web server, including:

- **Dynamic Variable Substitution** - display real-time data
- **Server Side Includes** - process real-time SSI commands
- **Processing Forms** - handle input from the client
- **Authentication** - require a user name and password
- **Cookies** - store session state information for richer applications
- **Uploading Files** - parse files for configuration settings and more

Several example applications are also provided for updating configuration parameters, sending emails, and controlling the Dynamic DNS client. Thanks to built-in GZIP compression support, all these tutorials and examples fit in the 32kB of on-board Memory.

For more information on the Harmony TCP/IP Stack, please refer to the TCP/IP Stack Libraries Help paragraph in the MPLAB Harmony Help installed on your computer as part of the Harmony distribution.

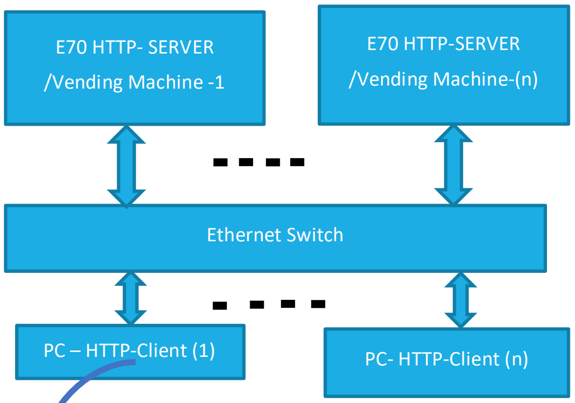
37. Congratulations, you have completed Lab 1!

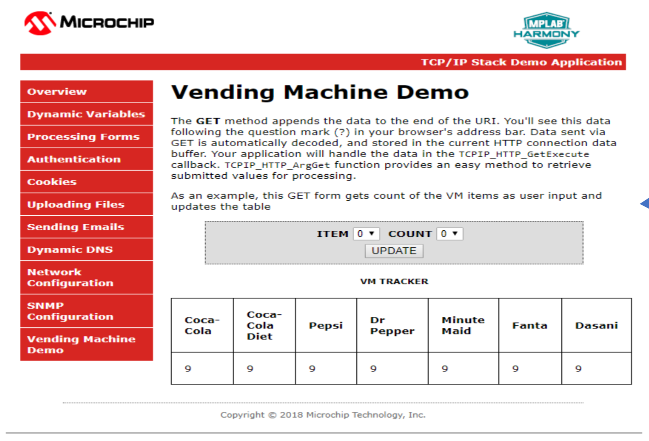
Lab 2

Overview

You will be implementing an embedded network application to update and track status of an Vending Machine (VM). The implementation is sectioned into two modules.

TASK 1:
The task is to interface the up/down and select buttons and an OLED of a Vending Machine to the HTTP-Server. The HTTP-Server keeps track of the items in the Vending Machine.
The HTTP- Client (PC-web page) talks to the HTTP- server and displays the status of the Vending Machine. The HTTP-Client also sends out an update request to the HTTP- server using Ethernet Interface.


E70 HTTP- SERVER /Vending Machine -1
E70 HTTP-SERVER /Vending Machine-(n)
Ethernet Switch
PC – HTTP-Client (1)
PC- HTTP-Client (n)



Vending Machine Demo

The **GET** method appends the data to the end of the URI. You'll see this data following the question mark (?) in your browser's address bar. Data sent via GET is automatically decoded, and stored in the current HTTP connection data buffer. Your application will handle the data in the `TCPIP_HTTP_GetExecute` callback. `TCPIP_HTTP_ArgGet` function provides an easy method to retrieve submitted values for processing.

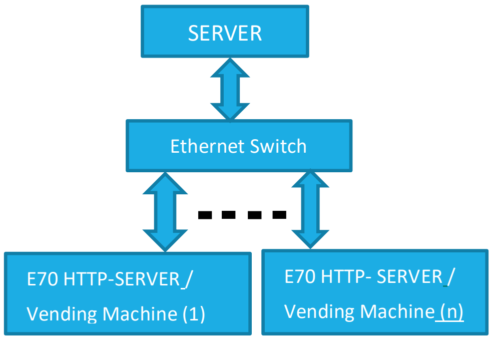
As an example, this GET form gets count of the VM items as user input and updates the table

VM TRACKER

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	Minute Maid	Fanta	Dasani
9	9	9	9	9	9	9

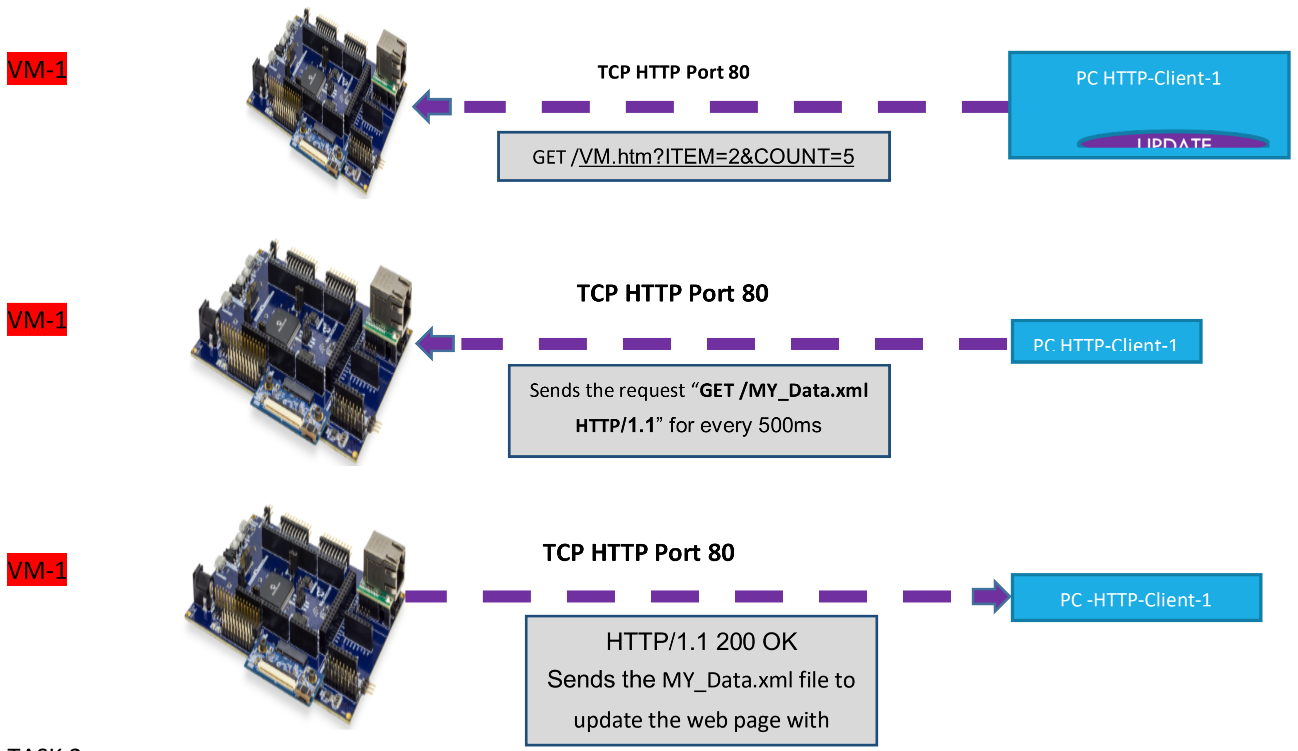
Copyright © 2018 Microchip Technology, Inc.

TASK 2:
The task is to make all the VMs in the class network to talk to a server. When a Bay of a VM is empty it sends out a message to a common server.
An example Message:
"Message: 1 from Martin: The Pepsi Bay is empty"
The Message number (1) and the Host name (Martin) together forms a unique Message and makes it easy to differentiate your message from other VMs on the network server and the number helps to find the recent ones.

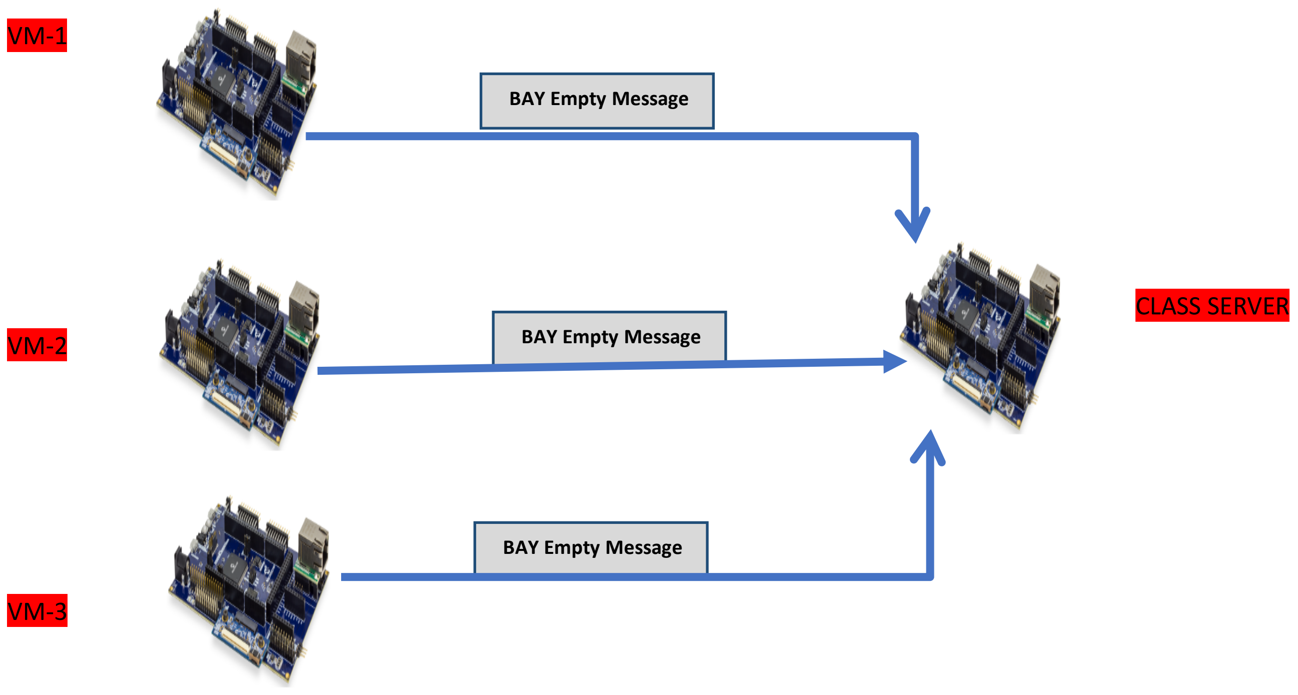

SERVER
Ethernet Switch
E70 HTTP-SERVER / Vending Machine (1)
E70 HTTP- SERVER / Vending Machine (n)

Data Protocol

TASK1


VM-1
TCP HTTP Port 80
PC HTTP-Client-1
UPDATE
GET /VM.htm?ITEM=2&COUNT=5
VM-1
TCP HTTP Port 80
PC HTTP-Client-1
Sends the request "GET /MY_Data.xml HTTP/1.1" for every 500ms
VM-1
TCP HTTP Port 80
PC -HTTP-Client-1
HTTP/1.1 200 OK
Sends the MY_Data.xml file to update the web page with

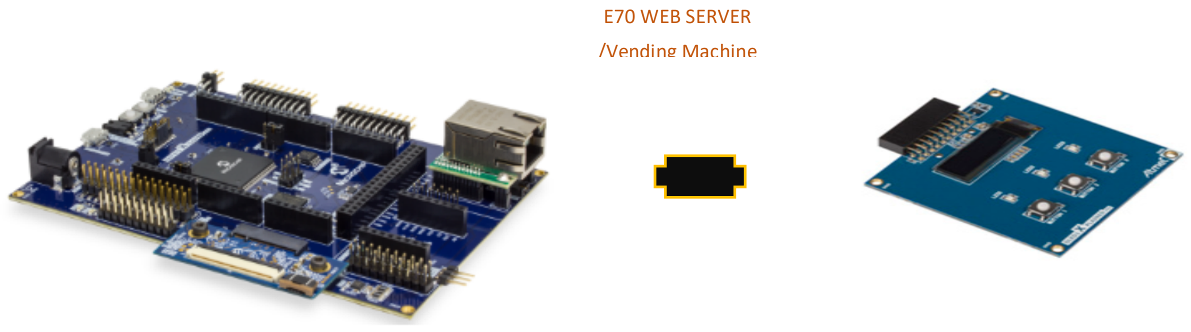
TASK 2


VM-1
BAY Empty Message
VM-2
BAY Empty Message
CLASS SERVER
VM-3
BAY Empty Message

Application Implementation

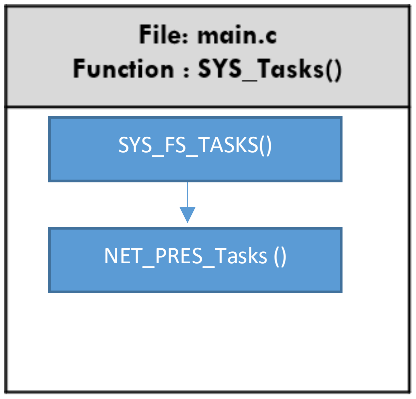
The Vending Machine demo (Task 1 and 2) is implemented using "**SAM E70 Xplained Ultra Evaluation Kit** "and "**OLED1 Xplained Pro Extension Kit".** The OLED Xplained pro has three buttons, LEDs and an OLED.

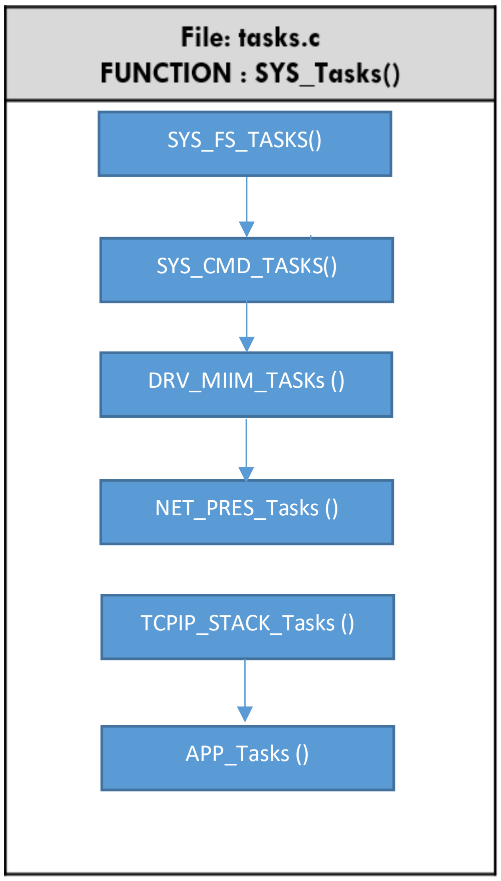
- The VM application uses Button 1(Down) and 2(UP) to scroll through the VM items and Button 3 to select an item from the Vending Machine.
- The LEDs above the button indicates a button press with a blink.
- The OLED is used to display the name and their corresponding number of the items in a Vending Machine.
- When select button(B3) is pressed the HTTP-Server will decrement the count of an item and updates the HTTP-Client(Web page)through ethernet interface.



The Vending machine demo runs the below user applications in conjunction with MPLAB Harmony TCP/IP Stack:

- **OLED and Button Contoller** (MMI_Tasks): Manages the operation of the OLED display , Buttons and LEDs.
- **Application Contoller** (app_Tasks()): manages all high level network communications with client and server.





Lab Procedure

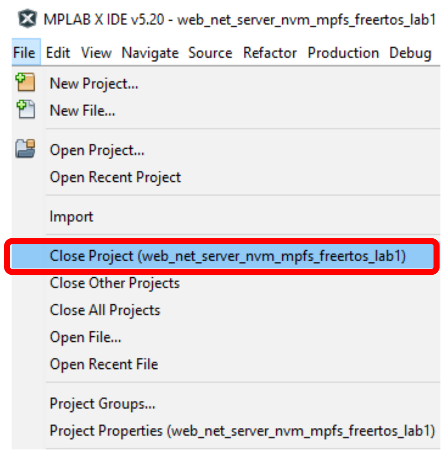
In Lab 1, you configured a new MPLAB Harmony Project from scratch that included the TCP/IP Stack middleware and a LED Flasher. The project you created in Lab 1 will be used as the starting point for Lab 2.. The source code for the OLED and Button Controller are included into the project.

You will learn about several Harmony TCP/IP API functions by adding the necessary APIs into the application source code to manage the TCP Sockets and data exchanged with socket. You will also learn how the dynamic variables in a web page are handled by the server. Finally, you will get to use the Packet Sender software tool to perform isolated testing of the embedded application prior to connecting your VM implementation to the server on the network.

Lab Procedure

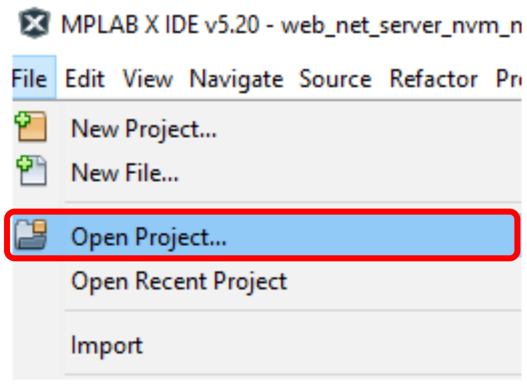
Project Setup

1.2. Close Lab 1 project by choosing **<u>File➤Close Project(lab1)</u>** in the main menu.


MPLAB X IDE v5.20 - web_net_server_nvm_mpfs_freertos_lab1

File Edit View Navigate Source Refactor Production Debug
New Project...
New File...
Open Project...
Open Recent Project
Import
Close Project (web_net_server_nvm_mpfs_freertos_lab1)
Close Other Projects
Close All Projects
Open File...
Open Recent File
Project Groups...
Project Properties (web_net_server_nvm_mpfs_freertos_lab1)

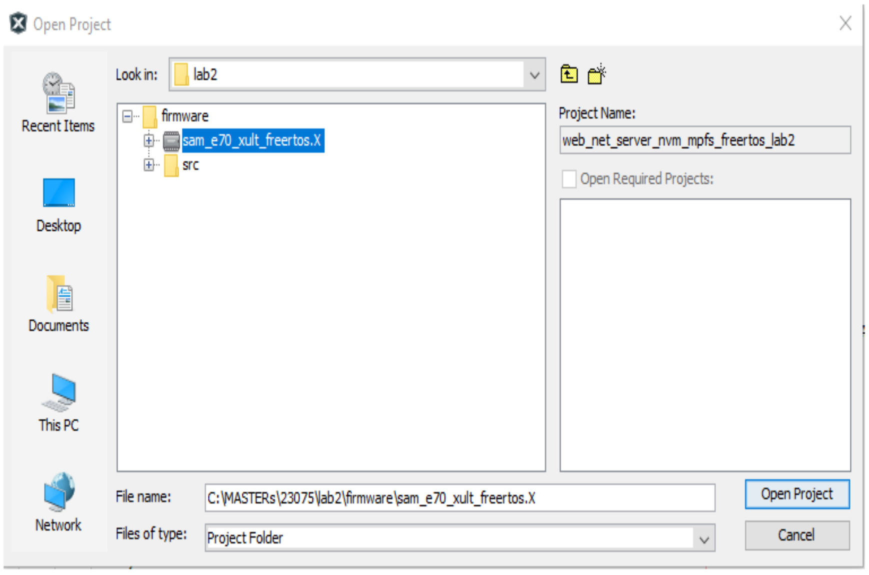
1.3. The project for Lab 2 has already been setup in advance. The project is a working implementation of Lab 1 that has been renamed to web_net_server_nvm_mpfs_lab2, and has a number of files added including mmi.c and modified app.c file are added to the project. To open the Lab 2 project, choose **<u>File➤Open Project</u>** in the main menu.


MPLAB X IDE v5.20 - web_net_server_nvm_n

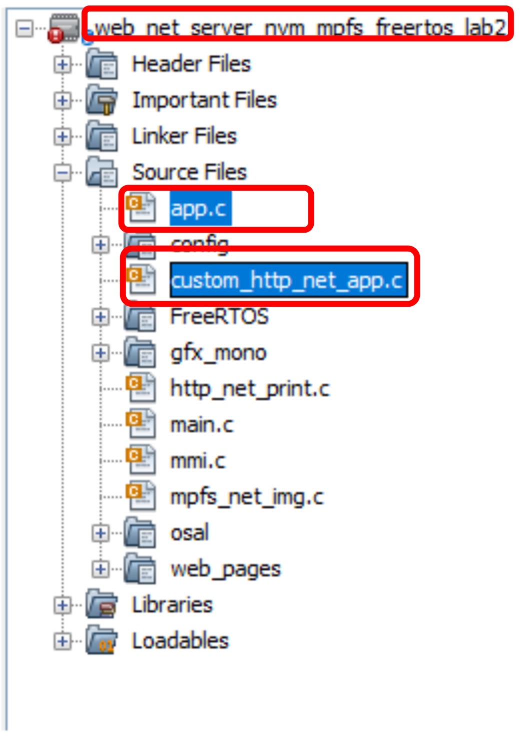
1.4. In the **Open Project** window, enter ***C:\MASTERs\21070\ web_net_server_nvm_mpfs_lab2\firmware*** into the **File name** text box or navigate to the file .

1.5. Click on ***sam_e70_xult_freetos.X*** icon in the file list.

1.6. Press **Open Project.**



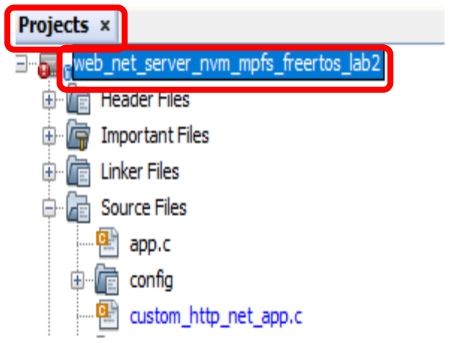
1.7. The source and header structure for the project is shown below.

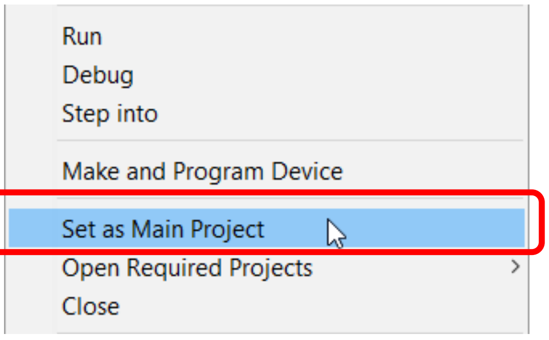


MHC Code Generation

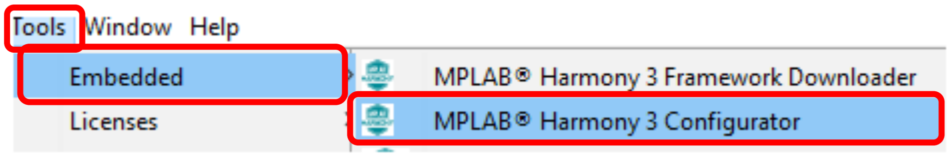
1.8. The project configurations are already set, and we are going to look on the configurations and generate the code. (steps 1.8 -1.22)

1.9. Before the MHC Configuration tool can be used, you need to set lab2 as the main project, by right clicking on the **web_net_server_nvm_mpfs_lab2** folder under the **Projects** window, and choosing Set as Main Project in the popup menu.

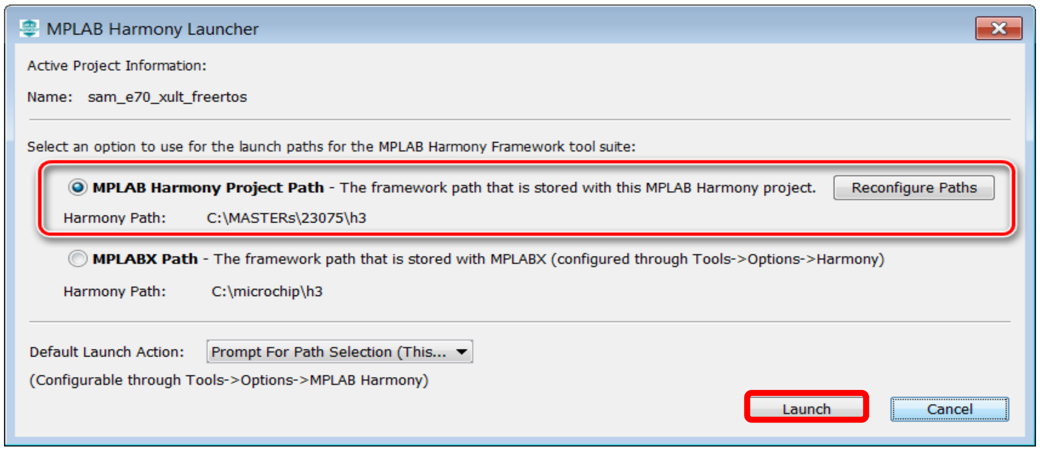




1.10. To launch MHC, choose <u>**Tools➤Embedded➤MPLAB Harmony 3 Configurator**</u> in the main menu.


Tools
Window
Help
Embedded
Licenses
MPLAB® Harmony 3 Framework Downloader
MPLAB® Harmony 3 Configurator

1.11. In the **MPLAB Harmony Launcher** dialog box, make sure the path states `C:\MASTERs\23075\h3` and click on **Launch**.



MPLAB Harmony Launcher

Active Project Information:

Name: sam_e70_xult_freertos

Select an option to use for the launch paths for the MPLAB Harmony Framework tool suite:

(●) **MPLAB Harmony Project Path** - The framework path that is stored with this MPLAB Harmony project. Reconfigure Paths

Harmony Path: C:\MASTERs\23075\h3

( ) **MPLABX Path** - The framework path that is stored with MPLABX (configured through Tools->Options->Harmony)

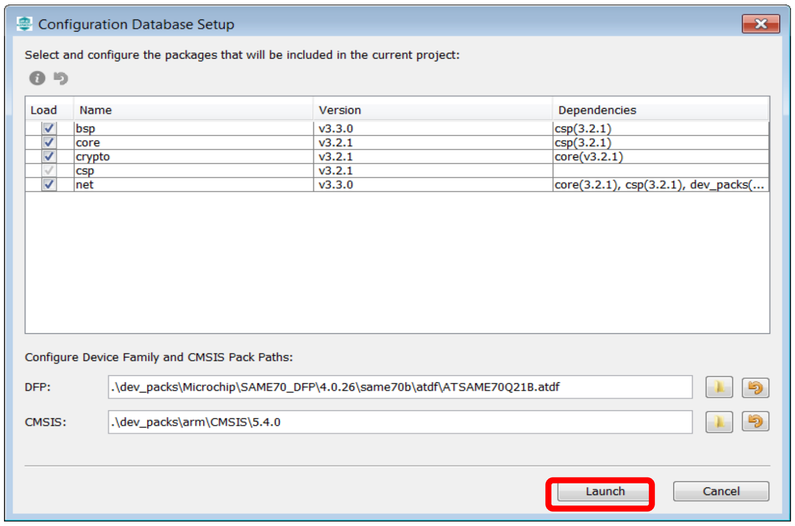
Harmony Path: C:\microchip\h3

Default Launch Action: Prompt For Path Selection (This...

(Configurable through Tools->Options->MPLAB Harmony)

Launch Cancel

1.12. In the nest window the H3 parts and their used Version Number are displayed. Click on **Launch**



Configuration Database Setup

Select and configure the packages that will be included in the current project:

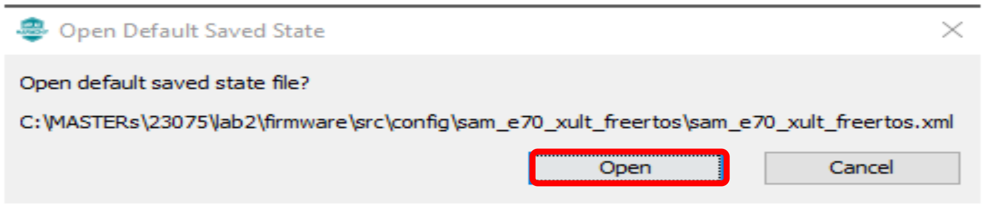
Load	Name	Version	Dependencies
✓	bsp	v3.3.0	csp(3.2.1)
✓	core	v3.2.1	csp(3.2.1)
✓	crypto	v3.2.1	core(v3.2.1)
✓	csp	v3.2.1	
✓	net	v3.3.0	core(3.2.1), csp(3.2.1), dev_packs(...

Configure Device Family and CMSIS Pack Paths:

DFP: .\dev_packs\Microchip\SAME70_DFP\4.0.26\same70b\atdf\ATSAME70Q21B.atdf

CMSIS: .\dev_packs\arm\CMSIS\5.4.0

1.13. Open the saved state file



Open Default Saved State

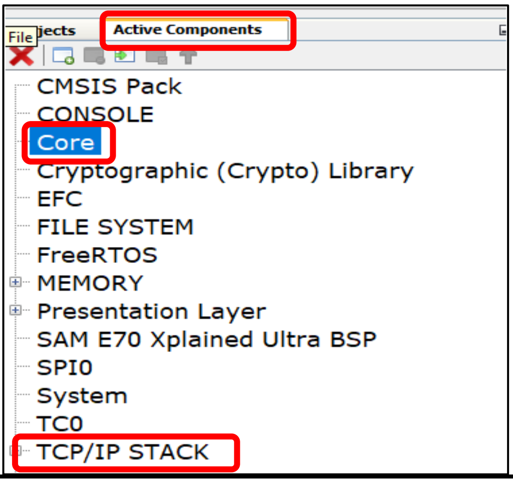
Open default saved state file?

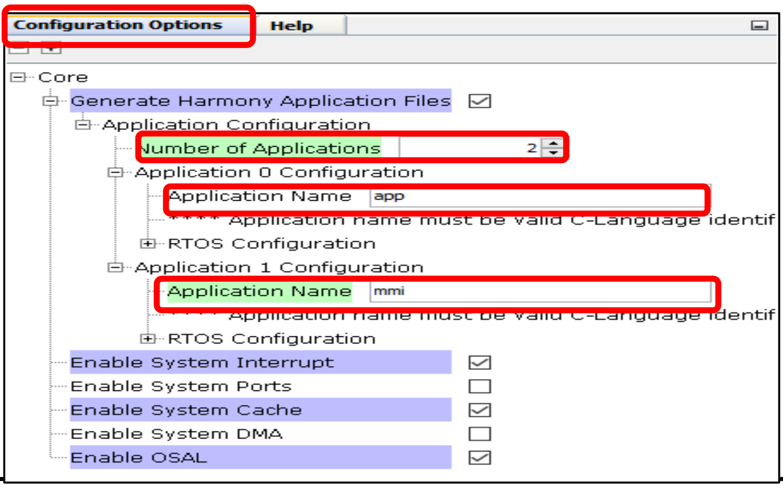
C:\MASTERs\23075\lab2\firmware\src\config\sam_e70_xult_freertos\sam_e70_xult_freertos.xml

1.14. Explore and look on the configurations tree by clicking on the modules under Active Components (step 1.14 and 1.15- can be skipped and continue from 1.16).

1.15. Click and check the "**Core"** option under Active Components. On right hand side the Configuration options are displayed, check the "**Number of Applications** "options under Configuration Options which is set to 2.Expand both Application 0 and 1 Configuration trees, and the Application Name is set to **app** (Application Interface) for Application 0, and **mmi**(Man Managed Interface for buttons, leds and OLED)for Application 1.

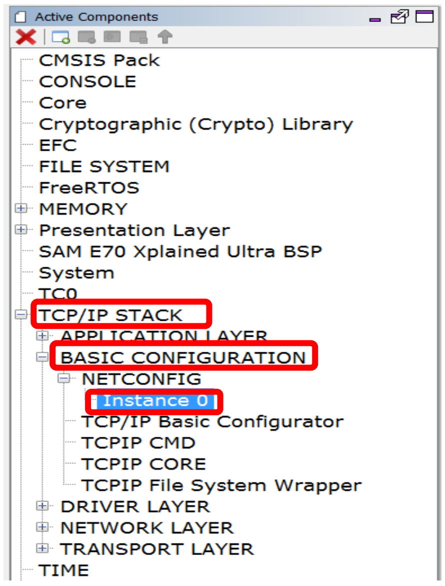
1.16. Check on **TCP/IP Stack** under Active components and its configuration under **Configuration options**.



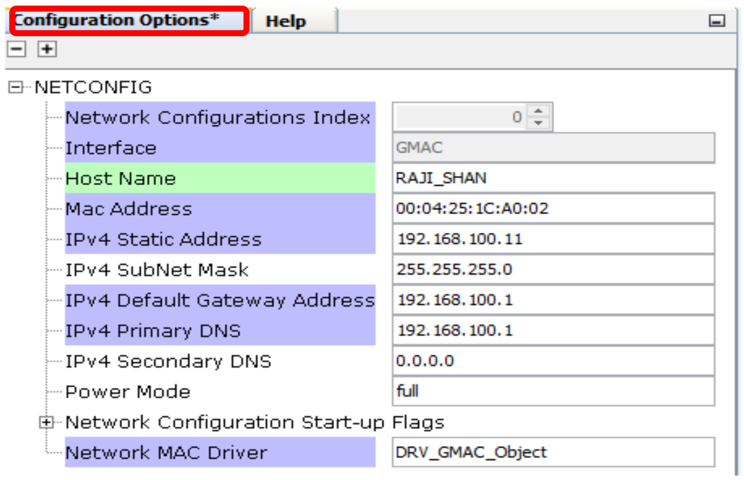


```
Core
  Generate Harmony Application Files   ☑
    Application Configuration
      Number of Applications   2
      Application 0 Configuration
        Application Name   app
        **** Application name must be valid C-Language identif
        RTOS Configuration
      Application 1 Configuration
        Application Name   mmi
        **** Application name must be valid C-Language identif
        RTOS Configuration
  Enable System Interrupt   ☑
  Enable System Ports       ☐
  Enable System Cache       ☑
  Enable System DMA         ☐
  Enable OSAL               ☑
```

1.17. Select the **Instance 0** in the **TCP/IP stack** under **Active Components** to enter the HOST Name **(TCP/IP STACK->BASIC CONFIGURATION->Instance 0).** And change in the **Configuration Options** (displayed on the right side of MPlabx) the Host Name to your firstname_lastname. The Host name can be identified in the Network.



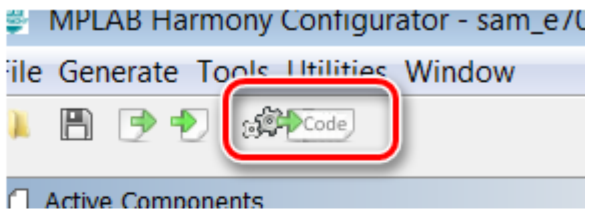
```
Active Components
 CMSIS Pack
 CONSOLE
 Core
 Cryptographic (Crypto) Library
 EFC
 FILE SYSTEM
 FreeRTOS
⊞ MEMORY
⊞ Presentation Layer
 SAM E70 Xplained Ultra BSP
 System
 TC0
⊟ TCP/IP STACK
   ⊞ APPLICATION LAYER
   ⊟ BASIC CONFIGURATION
      ⊟ NETCONFIG
         Instance 0
      TCP/IP Basic Configurator
      TCPIP CMD
      TCPIP CORE
      TCPIP File System Wrapper
   ⊞ DRIVER LAYER
   ⊞ NETWORK LAYER
   ⊞ TRANSPORT LAYER
 TIME
```



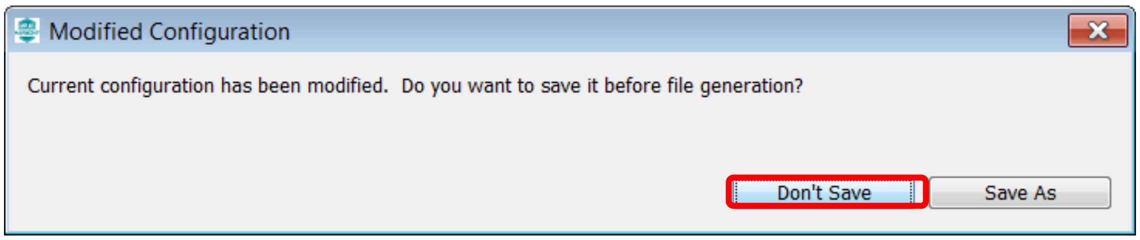
⊟ NETCONFIG

Network Configurations Index	0
Interface	GMAC
Host Name	RAJI_SHAN
Mac Address	00:04:25:1C:A0:02
IPv4 Static Address	192.168.100.11
IPv4 SubNet Mask	255.255.255.0
IPv4 Default Gateway Address	192.168.100.1
IPv4 Primary DNS	192.168.100.1
IPv4 Secondary DNS	0.0.0.0
Power Mode	full
⊞ Network Configuration Start-up Flags	
Network MAC Driver	DRV_GMAC_Object

1.18. Select "Code" (Generate Code) which is under the menu tabs.


MPLAB Harmony Configurator - sam_e7
ile Generate Tools Utilities Window
Code
Active Components

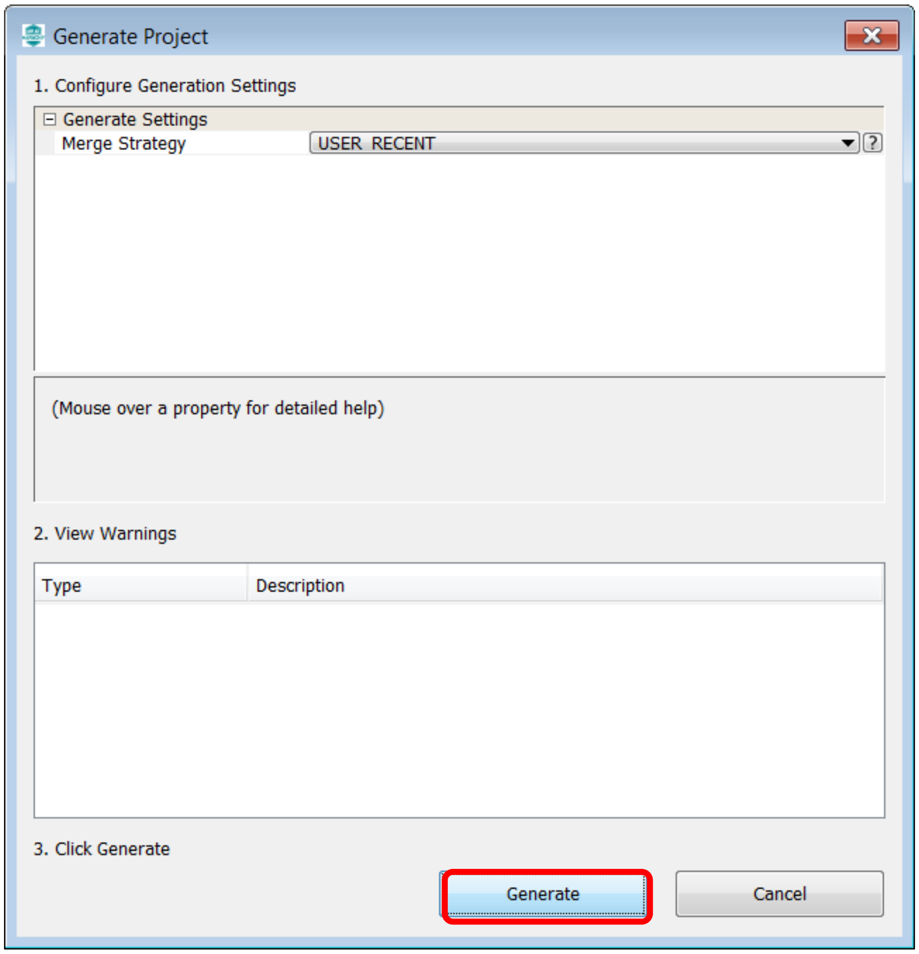
1.19. Select Don't Save



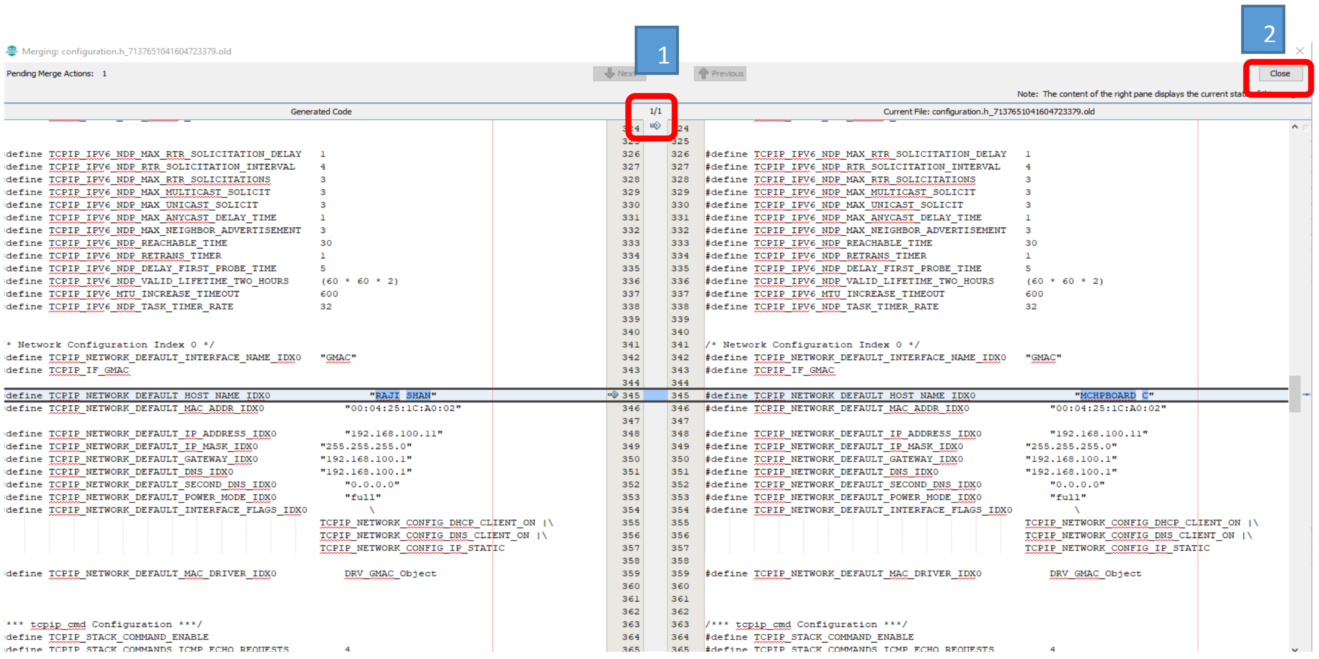
Modified Configuration

Current configuration has been modified. Do you want to save it before file generation?

1.20. Select Generate



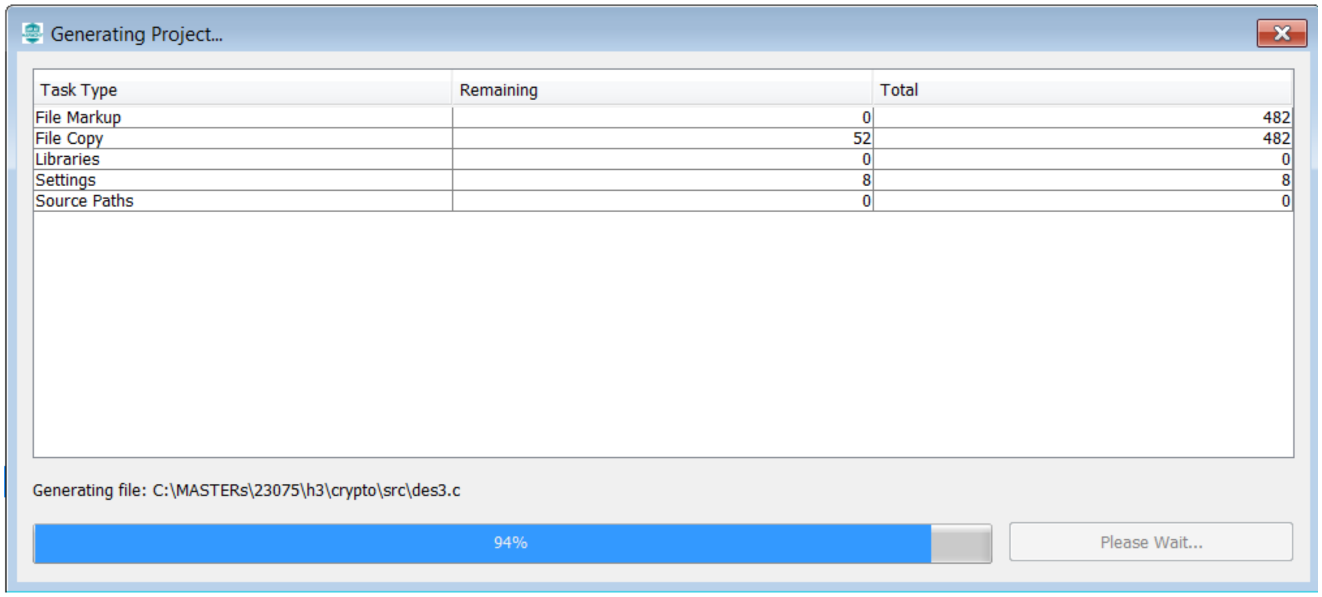
1.21. Some Files will be changed, and the MHC is asking in a "diff" window, if the changes should be taken over. Accept all changes in the file by clicking on the Arrow in the middle above and then close.


Merging: configuration.h_7137651041604723379.old
Pending Merge Actions: 1
Next
Previous
Close
1
2
1/1
Note: The content of the right pane displays the current stat
Generated Code
Current File: configuration.h_7137651041604723379.old

```
:define TCPIP_IPV6_NDP_MAX_RTR_SOLICITATION_DELAY   1
:define TCPIP_IPV6_NDP_RTR_SOLICITATION_INTERVAL    4
:define TCPIP_IPV6_NDP_MAX_RTR_SOLICITATIONS        3
:define TCPIP_IPV6_NDP_MAX_MULTICAST_SOLICIT        3
:define TCPIP_IPV6_NDP_MAX_UNICAST_SOLICIT          3
:define TCPIP_IPV6_NDP_MAX_ANYCAST_DELAY_TIME       1
:define TCPIP_IPV6_NDP_MAX_NEIGHBOR_ADVERTISEMENT   3
:define TCPIP_IPV6_NDP_REACHABLE_TIME               30
:define TCPIP_IPV6_NDP_RETRANS_TIMER                1
:define TCPIP_IPV6_NDP_DELAY_FIRST_PROBE_TIME       5
:define TCPIP_IPV6_NDP_VALID_LIFETIME_TWO_HOURS     (60 * 60 * 2)
:define TCPIP_IPV6_MTU_INCREASE_TIMEOUT             600
:define TCPIP_IPV6_NDP_TASK_TIMER_RATE              32


'* Network Configuration Index 0 */
:define TCPIP_NETWORK_DEFAULT_INTERFACE_NAME_IDX0   "GMAC"
:define TCPIP_IF_GMAC

:define TCPIP_NETWORK_DEFAULT_HOST_NAME_IDX0                "RAJI SHAN"
:define TCPIP_NETWORK_DEFAULT_MAC_ADDR_IDX0             "00:04:25:1C:A0:02"

:define TCPIP_NETWORK_DEFAULT_IP_ADDRESS_IDX0           "192.168.100.11"
:define TCPIP_NETWORK_DEFAULT_IP_MASK_IDX0          "255.255.255.0"
:define TCPIP_NETWORK_DEFAULT_GATEWAY_IDX0          "192.168.100.1"
:define TCPIP_NETWORK_DEFAULT_DNS_IDX0              "192.168.100.1"
:define TCPIP_NETWORK_DEFAULT_SECOND_DNS_IDX0           "0.0.0.0"
:define TCPIP_NETWORK_DEFAULT_POWER_MODE_IDX0           "full"
:define TCPIP_NETWORK_DEFAULT_INTERFACE_FLAGS_IDX0          \
                                                    TCPIP_NETWORK_CONFIG_DHCP_CLIENT_ON |\
                                                    TCPIP_NETWORK_CONFIG_DNS_CLIENT_ON |\
                                                    TCPIP_NETWORK_CONFIG_IP_STATIC

:define TCPIP_NETWORK_DEFAULT_MAC_DRIVER_IDX0           DRV_GMAC_Object



'*** tcpip_cmd Configuration ***/
:define TCPIP_STACK_COMMAND_ENABLE
:define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUESTS         4
```

```
#define TCPIP_IPV6_NDP_MAX_RTR_SOLICITATION_DELAY   1
#define TCPIP_IPV6_NDP_RTR_SOLICITATION_INTERVAL    4
#define TCPIP_IPV6_NDP_MAX_RTR_SOLICITATIONS        3
#define TCPIP_IPV6_NDP_MAX_MULTICAST_SOLICIT        3
#define TCPIP_IPV6_NDP_MAX_UNICAST_SOLICIT          3
#define TCPIP_IPV6_NDP_MAX_ANYCAST_DELAY_TIME       1
#define TCPIP_IPV6_NDP_MAX_NEIGHBOR_ADVERTISEMENT   3
#define TCPIP_IPV6_NDP_REACHABLE_TIME               30
#define TCPIP_IPV6_NDP_RETRANS_TIMER                1
#define TCPIP_IPV6_NDP_DELAY_FIRST_PROBE_TIME       5
#define TCPIP_IPV6_NDP_VALID_LIFETIME_TWO_HOURS     (60 * 60 * 2)
#define TCPIP_IPV6_MTU_INCREASE_TIMEOUT             600
#define TCPIP_IPV6_NDP_TASK_TIMER_RATE              32


/* Network Configuration Index 0 */
#define TCPIP_NETWORK_DEFAULT_INTERFACE_NAME_IDX0   "GMAC"
#define TCPIP_IF_GMAC

#define TCPIP_NETWORK_DEFAULT_HOST_NAME_IDX0                "MCHPBOARD_C"
#define TCPIP_NETWORK_DEFAULT_MAC_ADDR_IDX0             "00:04:25:1C:A0:02"

#define TCPIP_NETWORK_DEFAULT_IP_ADDRESS_IDX0           "192.168.100.11"
#define TCPIP_NETWORK_DEFAULT_IP_MASK_IDX0          "255.255.255.0"
#define TCPIP_NETWORK_DEFAULT_GATEWAY_IDX0          "192.168.100.1"
#define TCPIP_NETWORK_DEFAULT_DNS_IDX0              "192.168.100.1"
#define TCPIP_NETWORK_DEFAULT_SECOND_DNS_IDX0           "0.0.0.0"
#define TCPIP_NETWORK_DEFAULT_POWER_MODE_IDX0           "full"
#define TCPIP_NETWORK_DEFAULT_INTERFACE_FLAGS_IDX0          \
                                                    TCPIP_NETWORK_CONFIG_DHCP_CLIENT_ON |\
                                                    TCPIP_NETWORK_CONFIG_DNS_CLIENT_ON |\
                                                    TCPIP_NETWORK_CONFIG_IP_STATIC

#define TCPIP_NETWORK_DEFAULT_MAC_DRIVER_IDX0           DRV_GMAC_Object



/*** tcpip_cmd Configuration ***/
#define TCPIP_STACK_COMMAND_ENABLE
#define TCPIP_STACK_COMMANDS_ICMP_ECHO_REQUESTS         4
```

1.22. The whole process is displayed with a progress bar

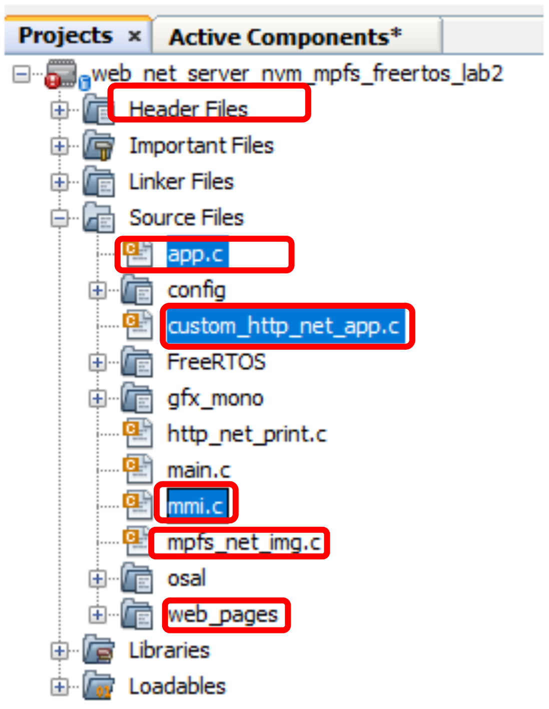

Generating Project...

Task Type	Remaining	Total
File Markup	0	482
File Copy	52	482
Libraries	0	0
Settings	8	8
Source Paths	0	0

Generating file: C:\MASTERs\23075\h3\crypto\src\des3.c

1.23. After the MHC has finished generating the project, go to the **Projects** Window and expand the ***Header Files*** and ***Source Files*** to see the source/header files for the *app and mmi* application file and TCP/IP stack files.

- The WEB page source code for the VM application is found under the folder web-pages->VM.htm
- The hex file for the web page is in mpfs_net_img.c which is generated using the utility MPFS- generator which comes along with Harmony net package.

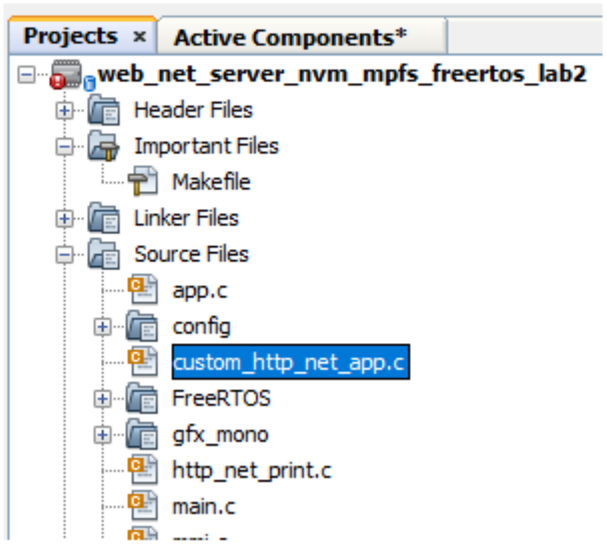


Application Source and Header File SetupTASK1:

In the VM application when an VM ITEM update is initiated by the HTTP- client (WEB PAGE) it sends out a GET command that needs to be processed by the HTTP-Server. The get command is sent along with the argument of the VM "Item" to be updated and its "Count" which are processed by the HTTP-Server. In Harmony TCP/IP stack GET command is handled by the function TCPIP_HTTP_NET_ConnectionGetExecute ().

Follow the procedure under to include the code that process the GET request from HTTP-CLient: -

1.24. Click and Open the file custom_http_net_app.c. Search for the function TCPIP_HTTP_NET_ConnectionGetExecute () (Approx. Line.No. 247) in which the below code snippets need to be inserted.



1.25. Find the TODO[1] and insert the below code starting from the line mentioned as ***"//<--Insert the solution for TODO[4] starting on this line"*** . Code can be inserted either by typing or copy and paste which is provided for your convenience at the end of the file (custom_http_net_app.c).

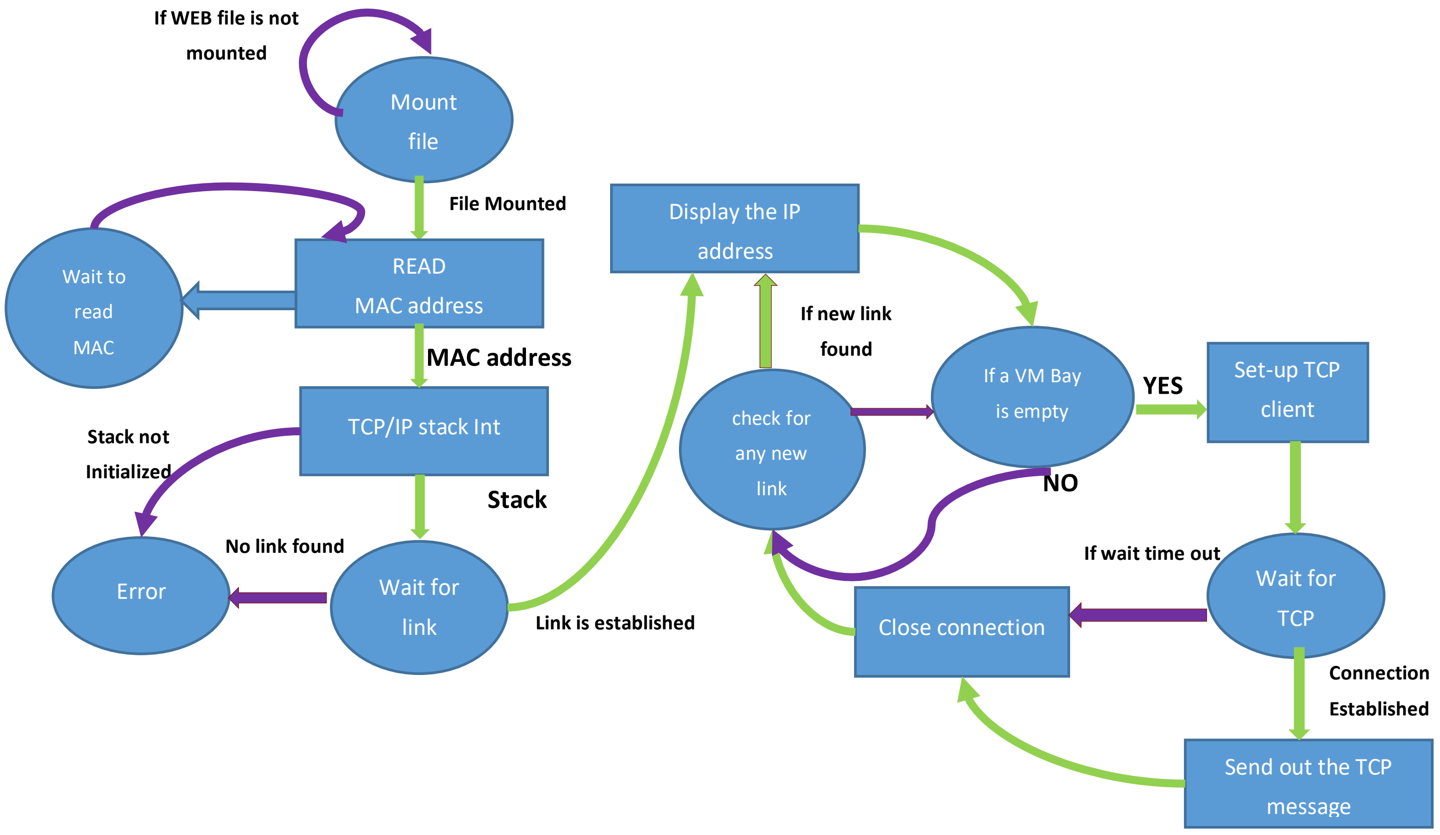
```
ptr = TCPIP_HTTP_NET_ArgGet(httpDataBuff, (const uint8_t *)"ITEM");
```

1.26. Find the TODO[2] and insert the code snippet starting from the line mentioned as ***"//<--Insert the solution for Item 2 starting on this line"*** . Code can be inserted either by typing or copy and paste which is provided for your convenience at the end of the file (custom_http_net_app.c).

```
ptr = TCPIP_HTTP_NET_ArgGet(httpDataBuff, (const uint8_t *)"COUNT");

VM_Count[Update_Item]=*ptr;
```

TASK 2:

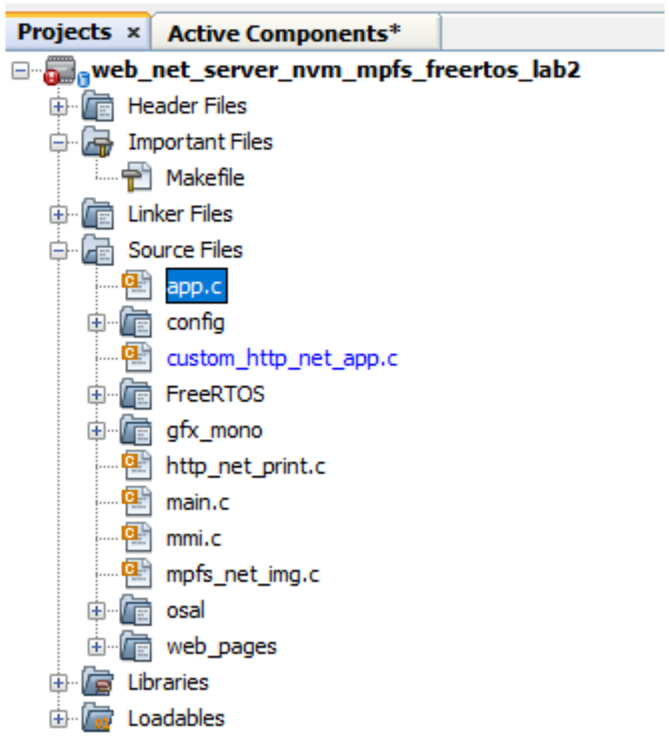
When a Bay of the VM is empty it sends out the message to the common server. The sate machine to open a socket to send message and close socket is shown below



In this section, you will gain some experience with the use of Harmony TCP/IP API functions. The app.c source is missing lines of code. All missing code specifically relates to management of the setting up the TCP Client such as opening or closing the socket, checking if the socket is connected, checking if data is available, and writing data to the socket. Your task is to read the description for each missing item, select the appropriate Harmony TCP/IP API, and fill in the missing line of code.

1.27. The first step to do is get the **common server's IP address**. Get the address from the presenter and make a note.

1.28. Click and Open the file app.c. and find the function APP_Tasks (). (Approx. Line.No. 200) in which the below code snippets are inserted.



```
web_net_server_nvm_mpfs_freertos_lab2
  Header Files
  Important Files
    Makefile
  Linker Files
  Source Files
    app.c
    config
    custom_http_net_app.c
    FreeRTOS
    gfx_mono
    http_net_print.c
    main.c
    mmi.c
    mpfs_net_img.c
    osal
    web_pages
  Libraries
  Loadables
```

1.29. Find the TODO[3] in which common SERVER IP address is entered. Replace the x with the common server IP address ().

For example: if the server IP address is 192.168.0.108 replace

- * x1 with 192
- * x2 with 168
- * x3 with 0
- * x4 with 108

1.30. Find TODO[4] and add the below snippet to Open a socket for TCP_Client . Code can be inserted either by typing or copy and paste the code which is provided for your convenience at the end of the file (app.c).

```
appData.socket = TCPIP_TCP_ClientOpen(IP_ADDRESS_TYPE_IPV4,

appData.port,

(IP_MULTI_ADDRESS*) & addr);
```

1.31. Find TODO[5] and add the below snippet to check the TCP connection is established 0.

Insert the code in the line mentioned as ***"//<--Insert the solution for TODO[5] starting on this line"***

Code can be inserted either by typing or copy and paste the code which is provided for your convenience at the end of the file (app.c).

```
if (!TCPIP_TCP_IsConnected(appData.socket))
```

1.32. Find TODO[6] and add the below snippet to check the TCP connection is established .

Insert the code in the line mentioned as ***"//<--Insert the solution for TODO[6] starting on this line"***

Code can be inserted either by typing or copy and paste the code which is provided for your convenience at the end of the file (app.c).

```
if (TCPIP_TCP_PutIsReady(appData.socket) == 0)
```

1.33. Find TODO[7] and add the below snippet to send the message to the common server once a TCP connection at port 80 is established .

Insert the code in the line mentioned as ***"//<--Insert the solution for TODO[7] starting on this line"***

Code can be inserted either by typing or copy and paste the code which is provided for your convenience at the end of the file (app.c).

```
sprintf(buffer, "MSG:%d from %s : %s is empty", (int) MessageCounter++, (char *)
TCPIP_HOSTS_CONFIGURATION[0].macAddr, (char *) VM_Items[bay_index - 1]);

SYS_CONSOLE_PRINT("Sending message: %s\r\n", buffer);

TCPIP_TCP_ArrayPut(appData.socket, (uint8_t*) buffer, strlen(buffer));
```

1.34. Find TODO[8] and add the below snippet to close the TCP Client socket.

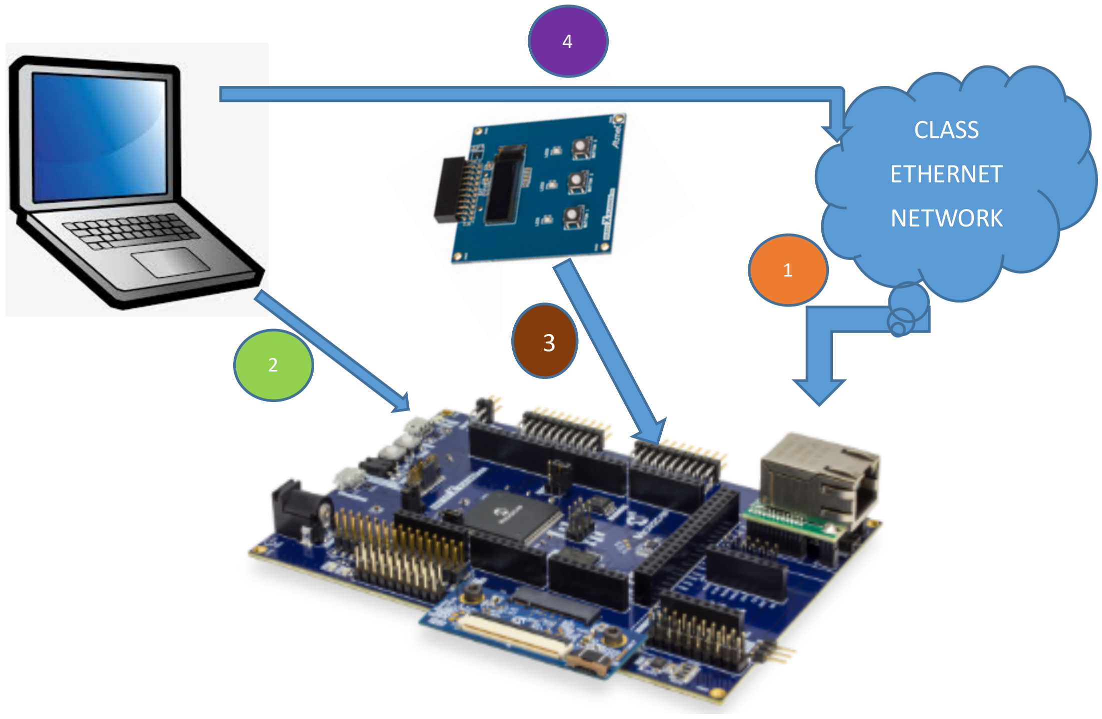
Insert the code in the line mentioned as ***"//<--Insert the solution for TODO[8] starting on this line"***

Code can be inserted either by typing or copy and paste the code which is provided for your convenience at the end of the file (app.c).

```
TCPIP_TCP_Close(appData.socket);
```

Hardware Setup

This hardware setup is common to both TASK1 and TASK2. After adding the required code for the application, make the hardware connections to programme the device and to see the output



1.35. Network Connection

1 Cable: CAT5 Ethernet Cable supplied with Starter Kit
Connection: RJ45 Jack from the class network to PCB Top RJ45 Jack(make sure the jumper below the Ethernet PHY module is taken off)

1.36. Programming and Console Connection

2 Cable USB Male A to USB Male B Micro cable
Connection: USB Debug Port on PCB Top to Laptop USB Port

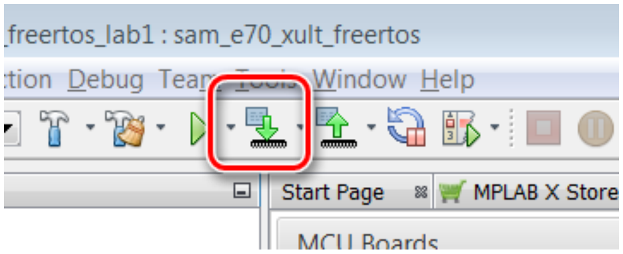
1.37. OLED1 Xplained Pro Connection

3 OLED1 X PLAINED PRO
Connection: Connect the OLED x PLAINED PRO to the EXT 2 of the board (Extension close to Ethernet PHY)

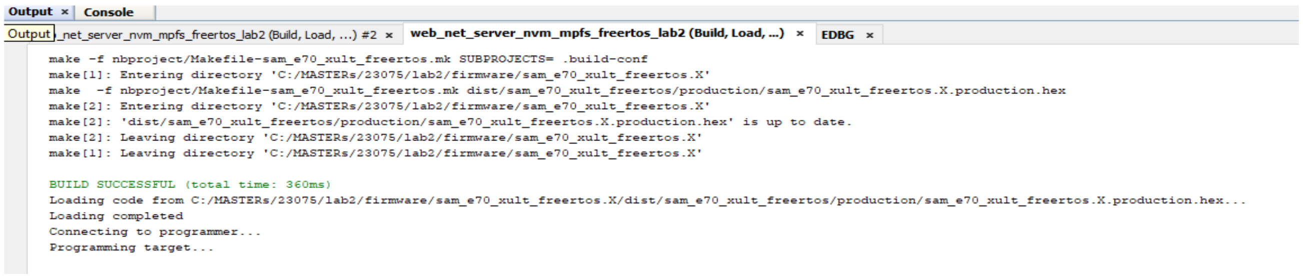
1.38. PC

4 PC needs to be connected to the Class network or
It can be connected to the wireless network

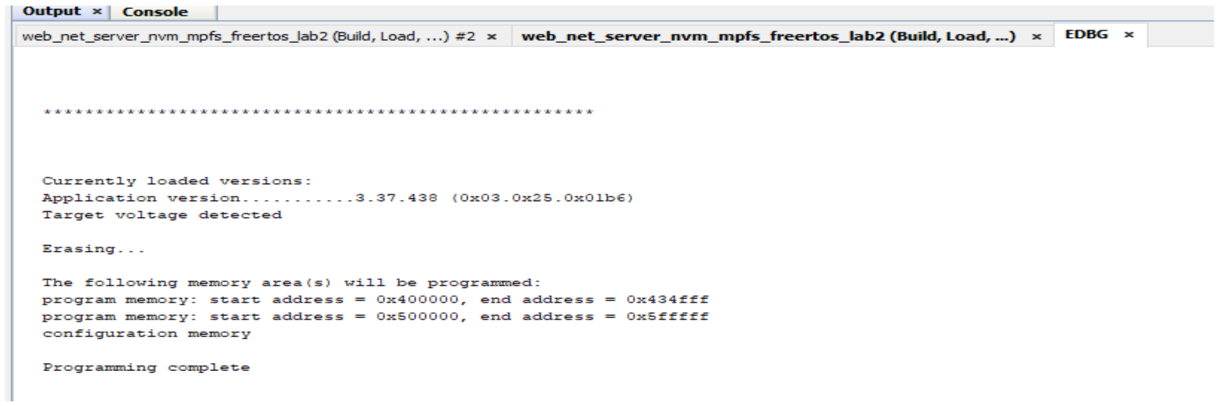
1.39. In the main window of MPLABX, click on the “Make and Program Device” button


freertos_lab1 : sam_e70_xult_freertos
tion Debug Team Tools Window Help
Start Page
MPLAB X Store
MCU Boards

1.40. After successful build, the SAME70 is programmed automatically. Build and Programming are monitored on the output window at the bottom of the MPLAB X IDE screen.


Output
Console
Output
_net_server_nvm_mpfs_freertos_lab2 (Build, Load, ...) #2
web_net_server_nvm_mpfs_freertos_lab2 (Build, Load, ...)
EDBG

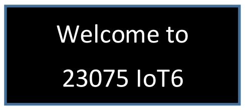
```
make -f nbproject/Makefile-sam_e70_xult_freertos.mk SUBPROJECTS= .build-conf
make[1]: Entering directory 'C:/MASTERs/23075/lab2/firmware/sam_e70_xult_freertos.X'
make  -f nbproject/Makefile-sam_e70_xult_freertos.mk dist/sam_e70_xult_freertos/production/sam_e70_xult_freertos.X.production.hex
make[2]: Entering directory 'C:/MASTERs/23075/lab2/firmware/sam_e70_xult_freertos.X'
make[2]: 'dist/sam_e70_xult_freertos/production/sam_e70_xult_freertos.X.production.hex' is up to date.
make[2]: Leaving directory 'C:/MASTERs/23075/lab2/firmware/sam_e70_xult_freertos.X'
make[1]: Leaving directory 'C:/MASTERs/23075/lab2/firmware/sam_e70_xult_freertos.X'

BUILD SUCCESSFUL (total time: 360ms)
Loading code from C:/MASTERs/23075/lab2/firmware/sam_e70_xult_freertos.X/dist/sam_e70_xult_freertos/production/sam_e70_xult_freertos.X.production.hex...
Loading completed
Connecting to programmer...
Programming target...
```

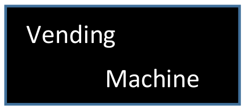

Output
Console
web_net_server_nvm_mpfs_freertos_lab2 (Build, Load, ...) #2
web_net_server_nvm_mpfs_freertos_lab2 (Build, Load, ...)
EDBG

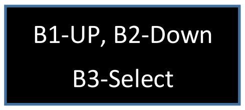
```
*****************************************************


Currently loaded versions:
Application version...........3.37.438 (0x03.0x25.0x01b6)
Target voltage detected

Erasing...

The following memory area(s) will be programmed:
program memory: start address = 0x400000, end address = 0x434fff
program memory: start address = 0x500000, end address = 0x5fffff
configuration memory

Programming complete
```

1.41. Immediately after programming, you can see the text on the OLED screen in series like the screens below.

Use the Buttons 1 and 2 (Previous and Next item) on the OLED1 Xplained pro to scroll through the items of the Vending Machine.


Welcome to
23075 IoT6


Vending
Machine

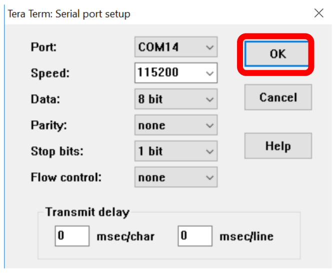

B1-UP, B2-Down
B3-Select

1.Coco-Cola 9

1.42. Now open a Tera Term to see the status of the HTTP server and its IP address.

If Tera Term is still open from Lab 1, click on the window title bar to make it active. If Tera Term needs to be re-opened and configured, refer the below steps.

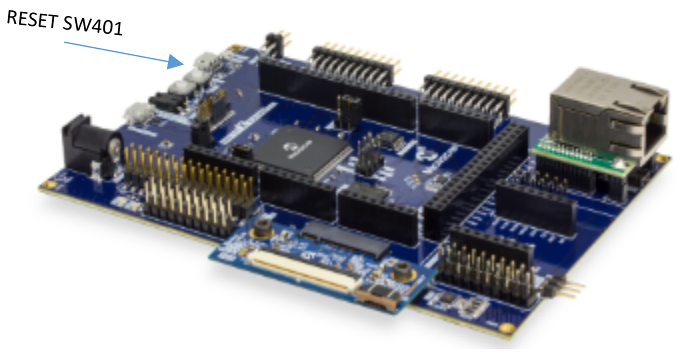
Open Terra Term Terminal Program and select under" **Setup->Serial Port"** (in this case a COM14, but could be a different COM Port number in your case) set the speed to 115200.Match the below set-up and click "OK "


Tera Term: Serial port setup

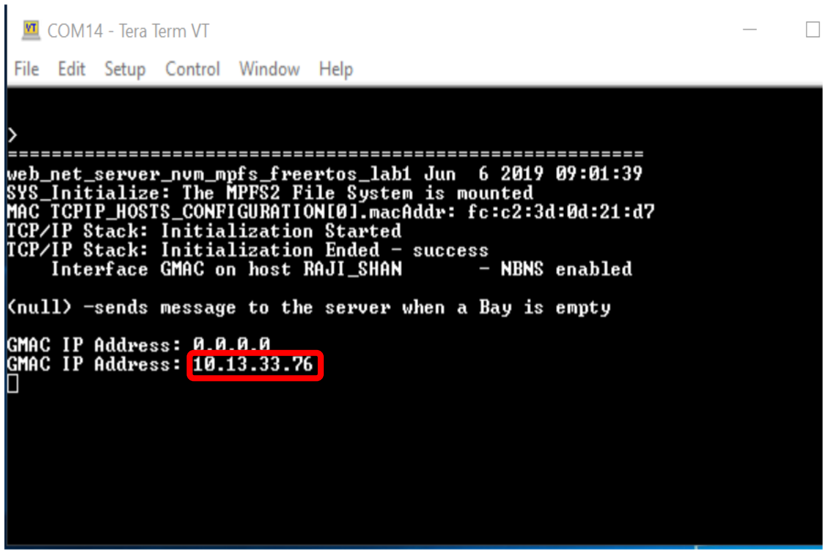
Port:	COM14
Speed:	115200
Data:	8 bit
Parity:	none
Stop bits:	1 bit
Flow control:	none

Transmit delay: 0 msec/char 0 msec/line

1.43. Reset the Board and let the Firmware restart.

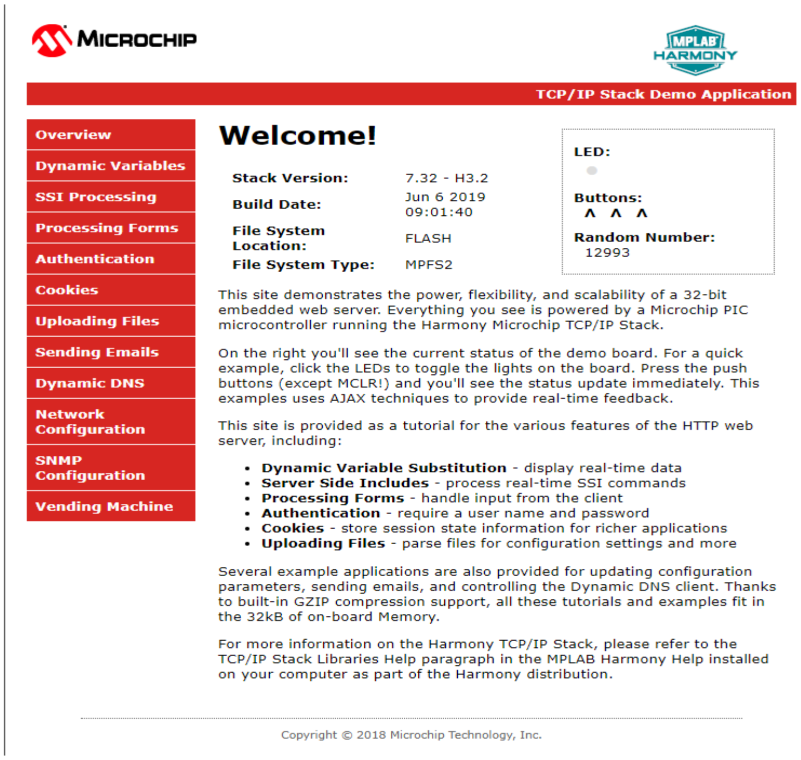


1.44. After some small time, the IP Address should change from 0.0.0.0 to a valid address. Take time to go through the Initialization messages, MAC address, Host name and the IP address of the HTTP- server displayed on the tera term terminal.



```
>
==========================================================
web_net_server_nvm_mpfs_freertos_lab1 Jun  6 2019 09:01:39
SYS_Initialize: The MPFS2 File System is mounted
MAC TCPIP_HOSTS_CONFIGURATION[0].macAddr: fc:c2:3d:0d:21:d7
TCP/IP Stack: Initialization Started
TCP/IP Stack: Initialization Ended - success
    Interface GMAC on host RAJI_SHAN       - NBNS enabled

(null) -sends message to the server when a Bay is empty

GMAC IP Address: 0.0.0.0
GMAC IP Address: 10.13.33.76
```

1.45. Open a web browser and enter the HTTP- Server IP address that you got on the tera term in the previous step. This opens a web page (HTTP-Client)



TCP/IP Stack Demo Application

Overview | Dynamic Variables | SSI Processing | Processing Forms | Authentication | Cookies | Uploading Files | Sending Emails | Dynamic DNS | Network Configuration | SNMP Configuration | Vending Machine

Welcome!

Stack Version:	7.32 - H3.2
Build Date:	Jun 6 2019 09:01:40
File System Location:	FLASH
File System Type:	MPFS2

LED:

Buttons: ^ ^ ^

Random Number: 12993

This site demonstrates the power, flexibility, and scalability of a 32-bit embedded web server. Everything you see is powered by a Microchip PIC microcontroller running the Harmony Microchip TCP/IP Stack.

On the right you'll see the current status of the demo board. For a quick example, click the LEDs to toggle the lights on the board. Press the push buttons (except MCLR!) and you'll see the status update immediately. This examples uses AJAX techniques to provide real-time feedback.

This site is provided as a tutorial for the various features of the HTTP web server, including:

- **Dynamic Variable Substitution** - display real-time data
- **Server Side Includes** - process real-time SSI commands
- **Processing Forms** - handle input from the client
- **Authentication** - require a user name and password
- **Cookies** - store session state information for richer applications
- **Uploading Files** - parse files for configuration settings and more

Several example applications are also provided for updating configuration parameters, sending emails, and controlling the Dynamic DNS client. Thanks to built-in GZIP compression support, all these tutorials and examples fit in the 32kB of on-board Memory.

For more information on the Harmony TCP/IP Stack, please refer to the TCP/IP Stack Libraries Help paragraph in the MPLAB Harmony Help installed on your computer as part of the Harmony distribution.

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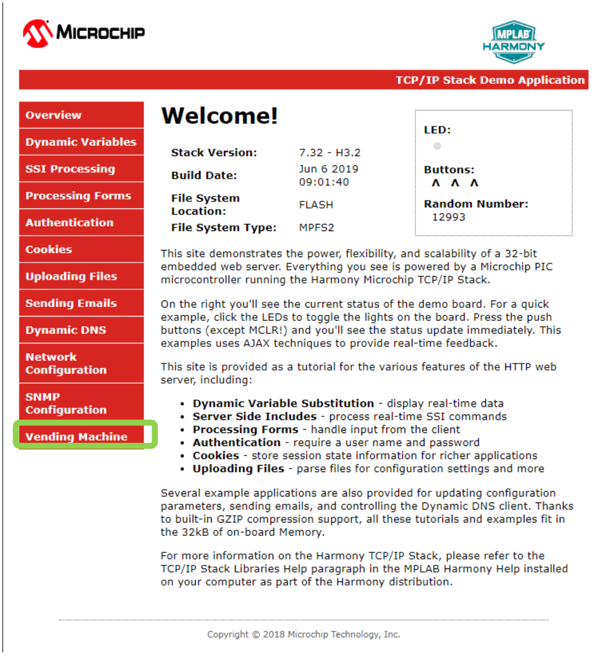
1.46. Click on the Vending Machine tab to see the page for the Vending Machine Demo.



TCP/IP Stack Demo Application

Overview | Dynamic Variables | SSI Processing | Processing Forms | Authentication | Cookies | Uploading Files | Sending Emails | Dynamic DNS | Network Configuration | SNMP Configuration | Vending Machine

Welcome!

Stack Version: 7.32 - H3.2
Build Date: Jun 6 2019 09:01:40
File System Location: FLASH
File System Type: MPFS2

LED:
Buttons: ^ ^ ^
Random Number: 12993

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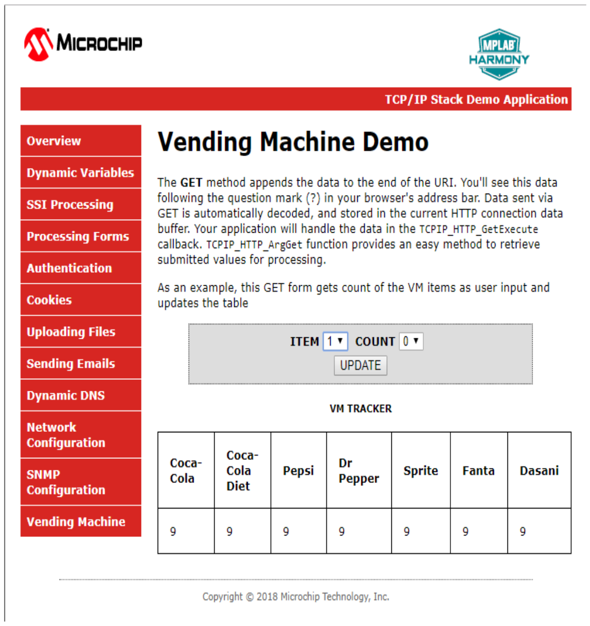

TCP/IP Stack Demo Application

Overview | Dynamic Variables | SSI Processing | Processing Forms | Authentication | Cookies | Uploading Files | Sending Emails | Dynamic DNS | Network Configuration | SNMP Configuration | Vending Machine

Vending Machine Demo

The **GET** method appends the data to the end of the URI. You'll see this data following the question mark (?) in your browser's address bar. Data sent via GET is automatically decoded, and stored in the current HTTP connection data buffer. Your application will handle the data in the `TCPIP_HTTP_GetExecute` callback. `TCPIP_HTTP_ArgGet` function provides an easy method to retrieve submitted values for processing.

As an example, this GET form gets count of the VM items as user input and updates the table

ITEM 1 ▾ COUNT 0 ▾
UPDATE

VM TRACKER

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	Sprite	Fanta	Dasani
9	9	9	9	9	9	9

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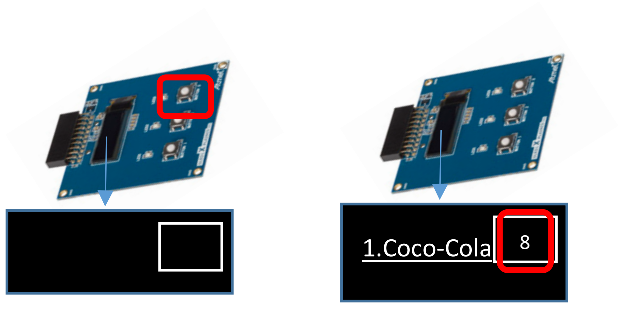
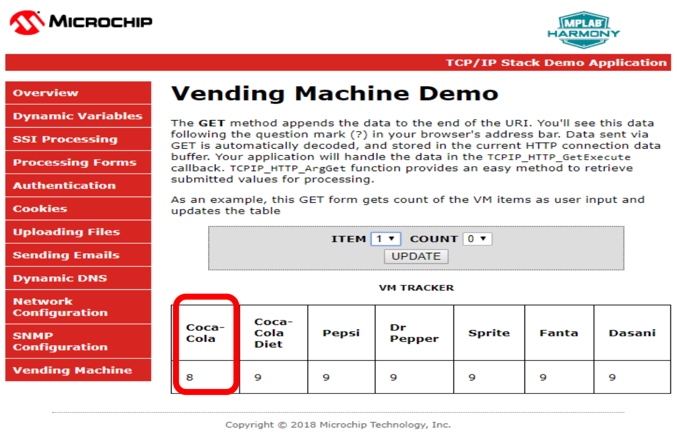
1.47. Use the Button 3 on the OLED to pick an item from the VM. The count of the corresponding item on the OLED scren will be decremented by 1 and is reflected on the Web page as well as on the OLED screen.





Vending Machine Demo

The GET method appends the data to the end of the URI. You'll see this data following the question mark (?) in your browser's address bar. Data sent via GET is automatically decoded, and stored in the current HTTP connection data buffer. Your application will handle the data in the TCPIP_HTTP_GetExecute callback. TCPIP_HTTP_ArgGet function provides an easy method to retrieve submitted values for processing.

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VM TRACKER

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	Sprite	Fanta	Dasani
8	9	9	9	9	9	9

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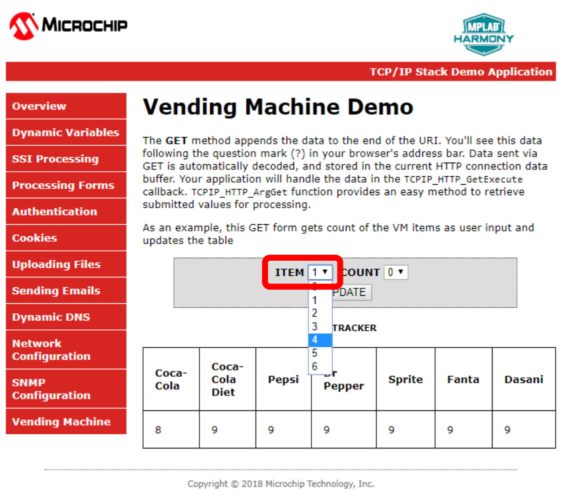
1.48. Check on the VM update. Pick an item and the count to be changed on the WEB page from the **ITEM** and **COUNT** drop down menu. Select update. When an update is selected the WEB page will send a GET command along with the ITEM number and COUNT to the HTTP-server. The HTTP-server decodes the GET command and displays it on the VM diaply (OLED).



Vending Machine Demo

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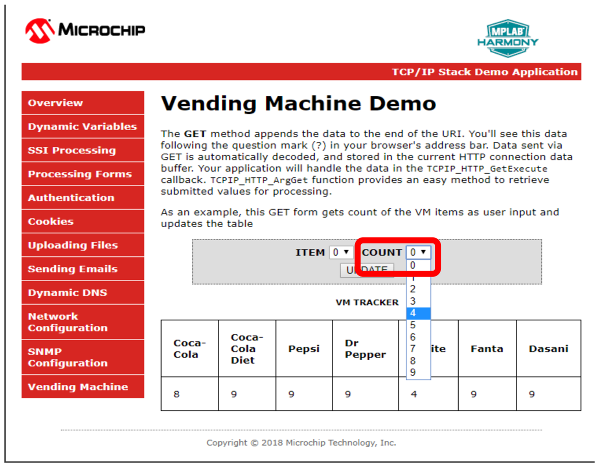
VM TRACKER

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	Sprite	Fanta	Dasani
8	9	9	9	9	9	9

Copyright © 2018 Microchip Technology, Inc.



Vending Machine Demo

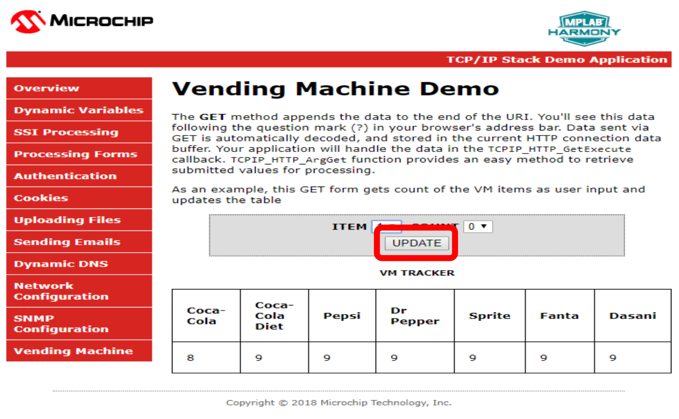
The GET method appends the data to the end of the URI. You'll see this data following the question mark (?) in your browser's address bar. Data sent via GET is automatically decoded, and stored in the current HTTP connection data buffer. Your application will handle the data in the TCPIP_HTTP_GetExecute callback. TCPIP_HTTP_ArgGet function provides an easy method to retrieve submitted values for processing.

As an example, this GET form gets count of the VM items as user input and updates the table

VM TRACKER

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	ite	Fanta	Dasani
8	9	9	9	4	9	9

Copyright © 2018 Microchip Technology, Inc.



Vending Machine Demo

The GET method appends the data to the end of the URI. You'll see this data following the question mark (?) in your browser's address bar. Data sent via GET is automatically decoded, and stored in the current HTTP connection data buffer. Your application will handle the data in the TCPIP_HTTP_GetExecute callback. TCPIP_HTTP_ArgGet function provides an easy method to retrieve submitted values for processing.

As an example, this GET form gets count of the VM items as user input and updates the table

VM TRACKER

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	Sprite	Fanta	Dasani
8	9	9	9	9	9	9

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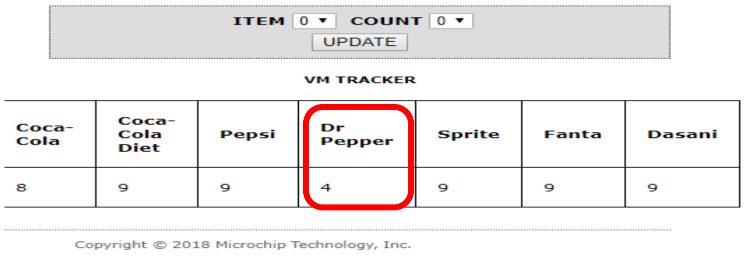
Example:

On the web page ITEM 4 and its count will be changed to 4 and, also on the OLED.



VM TRACKER

Coca-Cola	Coca-Cola Diet	Pepsi	Dr Pepper	Sprite	Fanta	Dasani
8	9	9	4	9	9	9

Copyright © 2018 Microchip Technology, Inc.

You have successfully completed TASK 1 and let's move on to TASK 2.

1.49. To test Task 2, one or more Bay of the VM machine must be Zero. Press the select Button 3 and make one or more item to zero count. After few second you can see the messages " Sending VM status " , "Starting Connection" and "TCP Socket Connected" and the "BAY Empty message" and TCP client closed on the tera term.

1.50. Look at the presenter's screen to identify your message.

MSG:338 from fc:c2:3d:0d:21:d7 : 2.Diet-Coke is empty

Message No. MAC address which is unique for each VM Bay empty message

Lab 3

Overview

In many IoT applications, JSON is commonly used as a format in order to transport high-level data in an effective way. It is generally an alternative to XML. Consider the following example of describing a person named Raji-Niklas Ruppert in JSON-format:

```
{
    “firstName” : “Raji-Niklas”,
    “lastName” : “Ruppert”,
    “age” : 30,
    “address” : {
        “streetAddress” : “2355 W Chandler Blvd”,
        “city” : “Chandler”,
        “state” : “AZ”,
        “postalCode” : “85224”,
    }
}
```

Using this format makes it very easy to communicate between applications requiring information about Raji-Niklas Ruppert.

The advantage of using JSON in embedded applications is that because it is easy to read for humans, it is simple to parse and make use of. Due to this, it is commonly used to transmit data between a server and a web application. In this lab we are going to implement an embedded application fetching weather data from a web server. When the application accesses a specific URL specifying a command with a geographic location, the web server will respond by sending the current weather in JSON-format to the web application. The application will be running on our SAME70-boards.

In this lab we will only do very simple parsing (which is one of the strengths using JSON), using standard string operations. There are however more sophisticated parsers which can be used for more robust and complex applications, while still only consuming a very limited footprint.

The weather service used in this lab is https://openweathermap.org/. With OpenWeatherMap, there are several services such as hourly forecast, UV Index, Air pollution and more, all outputting in JSON. With the free account there are limited option to only use the “Current Weather Data” service. With this service you can request the current weather from different geographic locations. Depending on by which method (City ID, ZIP Code, Coordinates etc.) the URL call will be slightly different. A full description of the API can be found here: https://openweathermap.org/current. For this lab we will fetch current weather by city. The following URL for this is:

http://api.openweathermap.org/data/2.5/weather?q=**{CITY}**&APPID=**{API Key}**

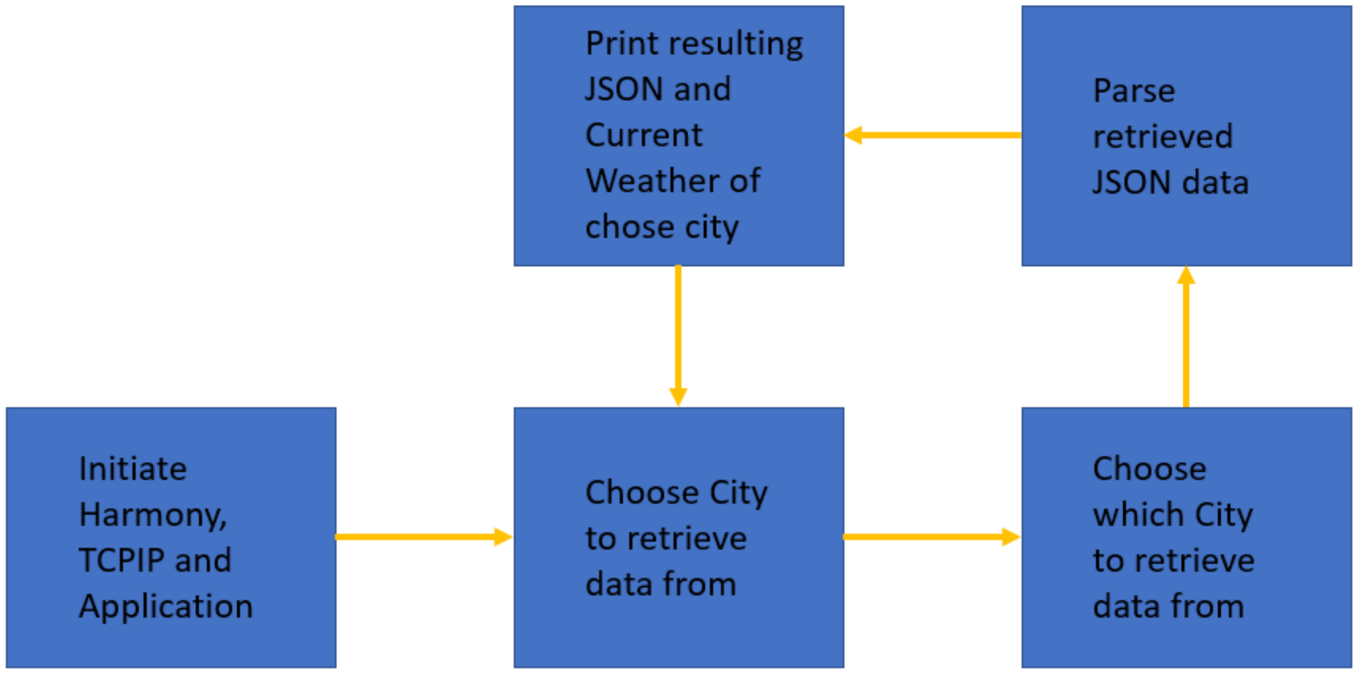
The API Key is unique to each user. This is also how OpenWeatherMap tracks how many requests you attempt. The API Key is a 15-byte long hexadecimal string. It can look like this:

```
ed3da58111974261002c2af4f8e8e81f
```

In most JSON API:s there is also a well defined format specified, which tells you where the different objects and strings are located in the JSON-message. From OpenWeatherMap:

```
{"coord":{"lon":-122.09,"lat":37.39},
"sys":{"type":3,"id":168940,"message":0.0297,"country":"US","sunrise":1427723751,"sunset":14
27768967},
"weather":[{"id":800,"main":"Clear","description":"Sky is Clear","icon":"01n"}],
"base":"stations",
"main":{"temp":285.68,"humidity":74,"pressure":1016.8,"temp_min":284.82,"temp_max":286.48},
"wind":{"speed":0.96,"deg":285.001},
"clouds":{"all":0},
"dt":1427700245,
"id":0,
"name":"Mountain View",
"cod":200}
```

Application Flow

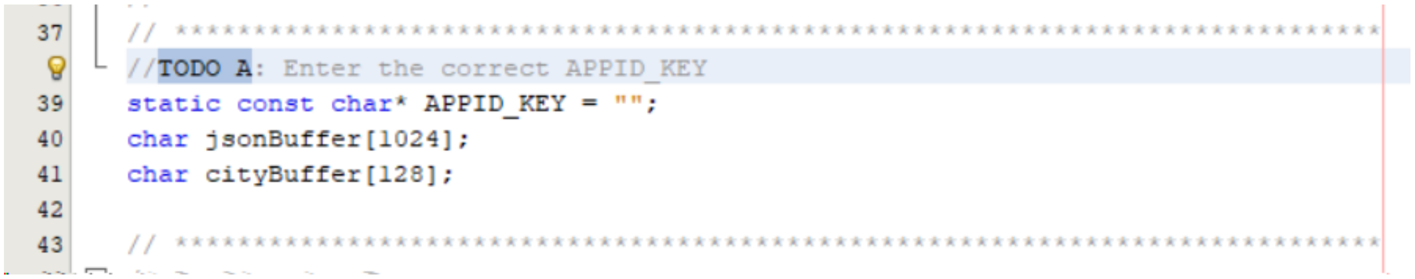

Print resulting JSON and Current Weather of chose city
Parse retrieved JSON data
Initiate Harmony, TCPIP and Application
Choose City to retrieve data from
Choose which City to retrieve data from

Lab Outline

- In the the source code file app,c are TODO's. At this places you have to change the source codes. At the bottom of the app.c you find the solutions. Either you think about what you have to change, or you just copy the solution at the right place.
- The main purpose of this class is to point you to the crucial points in an Harmony 3 application and not to let you write a complete TCP application
- The pre-made template is built from the Harmony example project, tcpip_tcp_client.
- First, we will need to declare the APPID_KEY.
- We will then set the host & port of the remote connection static as we will only connect to OpenWeatherMap.
- After this, we will redirect the user input from the command console to a char* buffer to be used in the application.
- Now we have all information required to build the URL from the introduction.
- When we have connected and requested the data, we need to parse the resulting JSON- string (the whole JSON containing the current weather will be in one string).
- Typically, good practice when you debug JSON-strings is to print the resulting string for you to view with your own eyes that it looks correct.
- At last, redirect the application to go back to accepting user input.

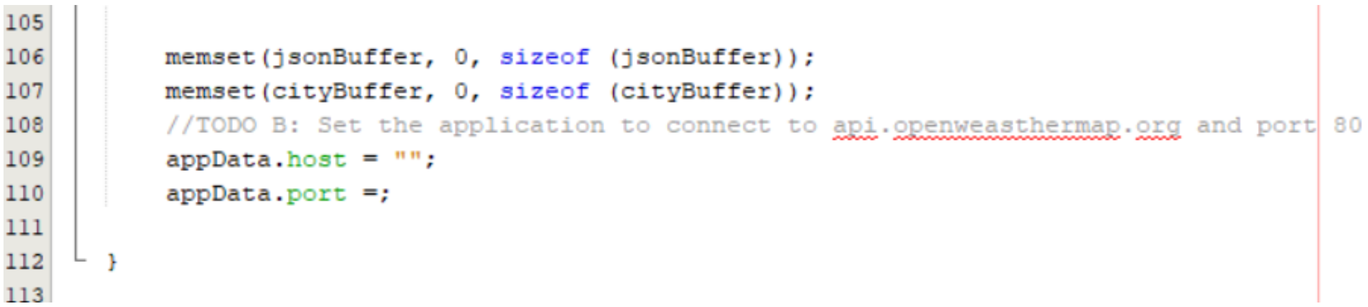
Lab Procedure

1. Start by closing any open projects in MPLAB X IDE.
2. Open a new project and choose lab3 -> Firmware -> sam_e70_xult_freertos.X.
3. Open the file app.c located under source files.
4. Go to (CTRL+F) “TODO A”. Enter the correct APPID_KEY. Either you create your own account on OpenWeatherMap or you take the one written I the class.



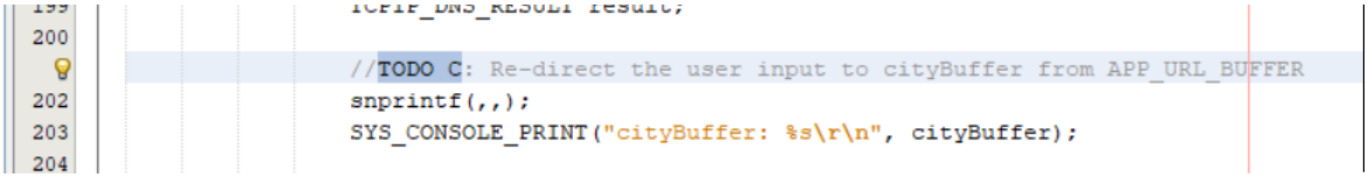
```
// ******************************************************************************
//TODO A: Enter the correct APPID_KEY
static const char* APPID_KEY = "";
char jsonBuffer[1024];
char cityBuffer[128];

// ******************************************************************************
```

5. Now scroll down to “TODO B”, the function APP_Initialize.
6. Set the application to connect to the host api.openweathermap.org and the port to 80. This is set to 80 because this call will be over HTTP.



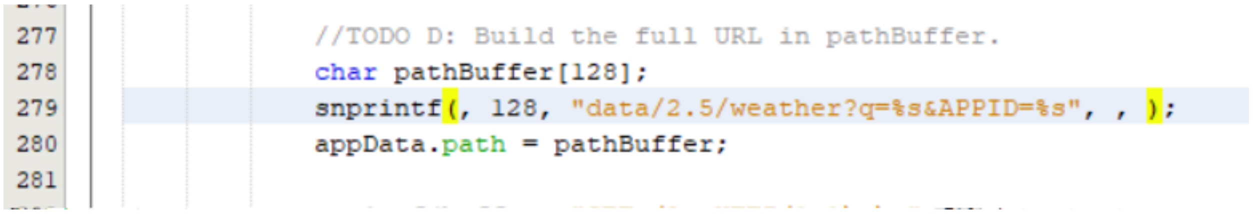
```

    memset(jsonBuffer, 0, sizeof (jsonBuffer));
    memset(cityBuffer, 0, sizeof (cityBuffer));
    //TODO B: Set the application to connect to api.openweasthermap.org and port 80
    appData.host = "";
    appData.port =;

}

```

7. Re-direct the user input from APP_URL_BUFFER to the cityBuffer array. This can be done in several ways, but one is to use the built-in C function **snprintf**(char* dest, size_t size, const char *format, …). The first argument is the destination buffer (cityBuffer), the second one is the max size to be copied (128, because that is specified in the declaration) and the formatted input in this scenario is APP_URL_BUFFER. This can be found in “TODO C”.



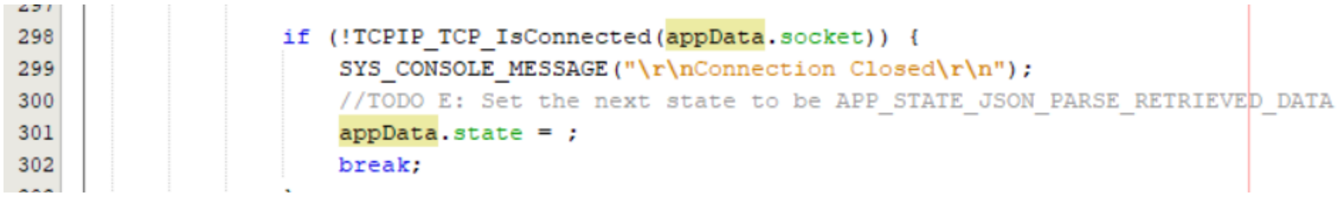
```
            TCPIP_DNS_RESULT result;

            //TODO C: Re-direct the user input to cityBuffer from APP_URL_BUFFER
            snprintf(,,);
            SYS_CONSOLE_PRINT("cityBuffer: %s\r\n", cityBuffer);

```

8. Scroll down to “TODO D”, the state APP_TCPIP_WAIT_FOR_CONNECTION. In this state we will wait for a connection to be established. Once established we will send a GET command with the full URL in the format specified in the introduction: http://api.openweathermap.org/data/2.5/weather?q=**{CITY}**&APPID=**{API Key}**.



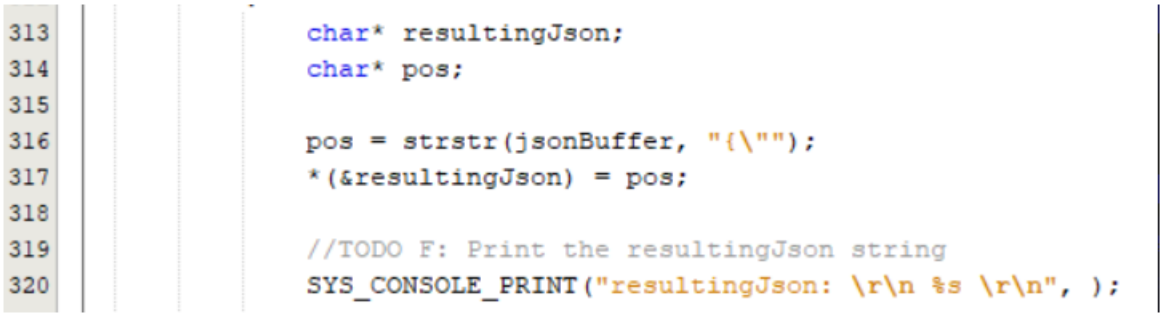
```
                //TODO D: Build the full URL in pathBuffer.
                char pathBuffer[128];
                snprintf(, 128, "data/2.5/weather?q=%s&APPID=%s", , );
                appData.path = pathBuffer;

```

9. Once the request is sent to the server, the application will go into the APP_TCIPIP_WAIT_FOR_RESPONSE state. Once the connection is closed, set the next state to be APP_STATE_JSON_PARSE_RETRIEVED_DATA.



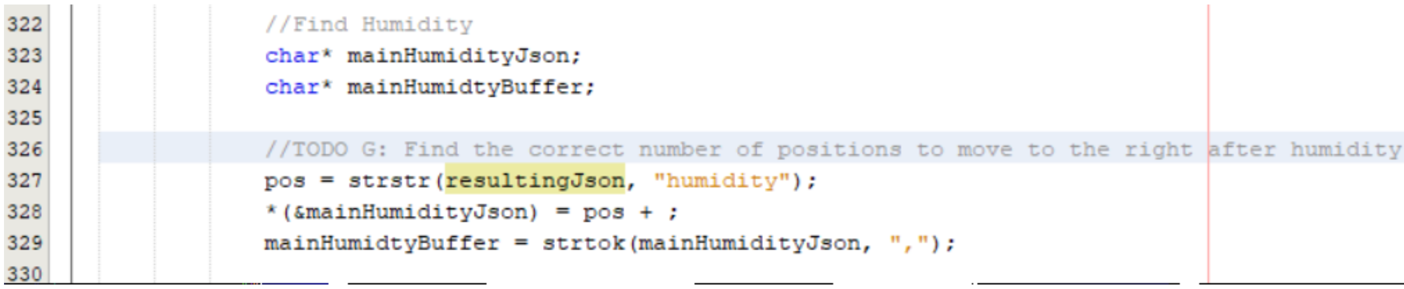
```
if (!TCPIP_TCP_IsConnected(appData.socket)) {
    SYS_CONSOLE_MESSAGE("\r\nConnection Closed\r\n");
    //TODO E: Set the next state to be APP_STATE_JSON_PARSE_RETRIEVED_DATA
    appData.state = ;
    break;
```

10. Now go down in the state APP_STATE_JSON_PARSE_RETRIEVED_DATA. One of the first things we want to do after we have sorted out the JSON-part of the retrieved data is to print the raw JSON-string. This helps us debug & analyse.



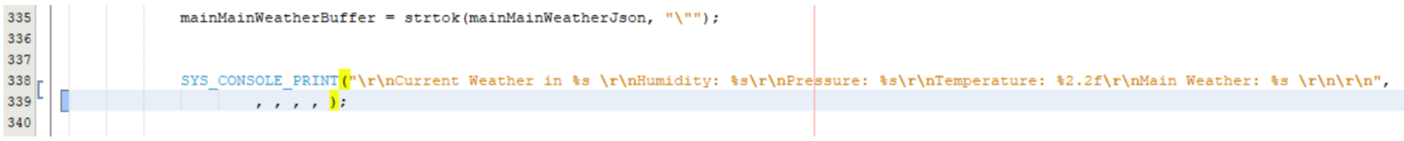
```
char* resultingJson;
char* pos;

pos = strstr(jsonBuffer, "{\"");
*(&resultingJson) = pos;

//TODO F: Print the resultingJson string
SYS_CONSOLE_PRINT("resultingJson: \r\n %s \r\n", );
```

11. In a real application, we would need to first know the format of the JSON message in order to be able to parse it correctly. To make this lab more efficiently, we will do this backwards. If you look at this example piece of API response from OpenWeatherMap found in the introduction section to this lab. Looking at the format from the API, we need to calculate in what position the value of humidity start. The function strstr will cut the resulting Json string at the first occurrence of "humidity". A hint is to look at the other blocks where you parse the temperature, pressure and main weather.



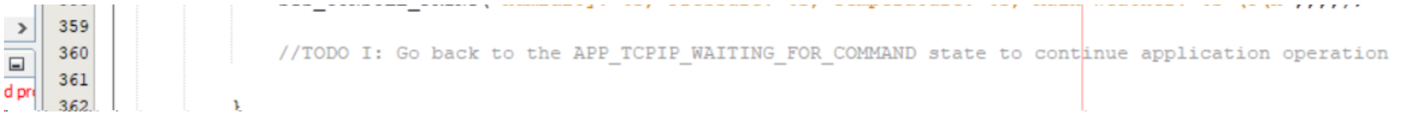
```
//Find Humidity
char* mainHumidityJson;
char* mainHumidtyBuffer;

//TODO G: Find the correct number of positions to move to the right after humidity
pos = strstr(resultingJson, "humidity");
*(&mainHumidityJson) = pos + ;
mainHumidtyBuffer = strtok(mainHumidityJson, ",");
```

12. Once the parsing is done, we wish to print the values of the main weather, pressure, temperature and humidity.



```
mainMainWeatherBuffer = strtok(mainMainWeatherJson, "\"");


SYS_CONSOLE_PRINT("\r\nCurrent Weather in %s \r\nHumidity: %s\r\nPressure: %s\r\nTemperature: %2.2f\r\nMain Weather: %s \r\n\r\n",
        , , , , );
```

13. Now to complete the loop, we want to go back to the APP_TCPIP_WAITING_FOR_COMMAND state once the JSON-parsing and printing is done.

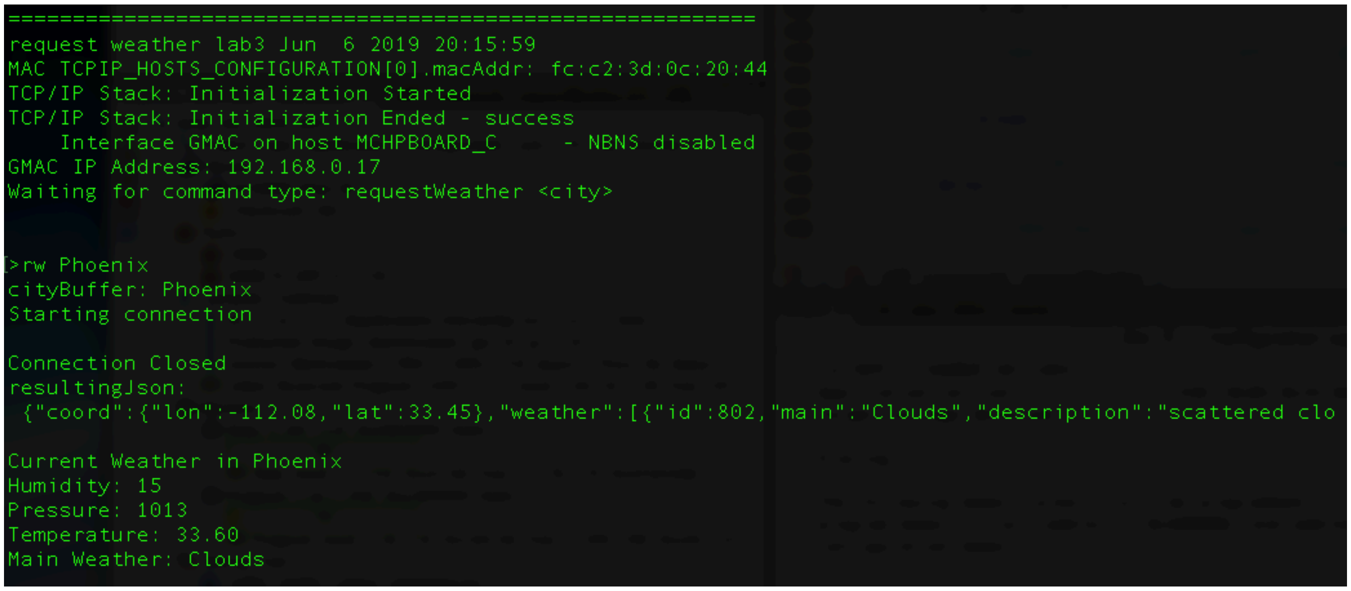


```
//TODO I: Go back to the APP_TCPIP_WAITING_FOR_COMMAND state to continue application operation

}
```

14. When the build process was correct, then program the E70
15. Open the Terminal program, press the Reset Button
16. When “>” is prompter you can put in “`requestWeather <city>`”

    Or the short form: ”`rw <city>`”

    For ex. “`rw Phoenix`”



```
==========================================================
request weather lab3 Jun  6 2019 20:15:59
MAC TCPIP_HOSTS_CONFIGURATION[0].macAddr: fc:c2:3d:0c:20:44
TCP/IP Stack: Initialization Started
TCP/IP Stack: Initialization Ended - success
    Interface GMAC on host MCHPBOARD_C     - NBNS disabled
GMAC IP Address: 192.168.0.17
Waiting for command type: requestWeather <city>


>rw Phoenix
cityBuffer: Phoenix
Starting connection

Connection Closed
resultingJson:
 {"coord":{"lon":-112.08,"lat":33.45},"weather":[{"id":802,"main":"Clouds","description":"scattered clo

Current Weather in Phoenix
Humidity: 15
Pressure: 1013
Temperature: 33.60
Main Weather: Clouds
```

17. At this point you reached the end of the class and can walk outside to check if the current weather report was correct

MPLAB® Harmony TCP/IP Stack

TCP Module API Function List

Socket Management Functions

TCPIP_TCP_ServerOpen	Opens a TCP socket as a server.
TCPIP_TCP_ClientOpen	Opens a TCP socket as a client.
TCPIP_TCP_Close	Disconnects an open socket and destroys the socket handle, releasing the associated resources.
TCPIP_TCP_Connect	Connects a client socket.
TCPIP_TCP_Bind	Binds a socket to a local address.
TCPIP_TCP_RemoteBind	Binds a socket to a remote address.
TCPIP_TCP_IsConnected	Determines if a socket has an established connection.
TCPIP_TCP_WasReset	Self-clearing semaphore indicating socket reset.
TCPIP_TCP_Disconnect	Disconnects an open socket.
TCPIP_TCP_Abort	Aborts a connection.
TCPIP_TCP_OptionsGet	Allows getting the options for a socket like: current RX/TX buffer size, etc.
TCPIP_TCP_OptionsSet	Allows setting options to a socket like adjust RX/TX buffer size, etc.
TCPIP_TCP_SocketInfoGet	Obtains information about a currently open socket.
TCPIP_TCP_SocketNetGet	Gets the current network interface of an TCP socket.
TCPIP_TCP_SocketNetSet	Sets the interface for an TCP socket
TCPIP_TCP_SignalHandlerDeregister	Deregisters a previously registered TCP socket signal handler.
TCPIP_TCP_SignalHandlerRegister	Registers a TCP socket signal handler.
TCPIP_TCP_Task	Standard TCP/IP stack module task function.

Transmit Data Functions

TCPIP_TCP_Put	Writes a single byte to a TCP socket.
TCPIP_TCP_PutIsReady	Determines how much free space is available in the TCP TX buffer.
TCPIP_TCP_StringPut	Writes a null-terminated string to a TCP socket.
TCPIP_TCP_ArrayPut	Writes an array from a buffer to a TCP socket.
TCPIP_TCP_Flush	Immediately transmits all pending TX data.
TCPIP_TCP_FifoTxFullGet	Determines how many bytes are pending in the TCP TX FIFO.
TCPIP_TCP_FifoTxFreeGet	Determines how many bytes are free and could be written in the TCP TX FIFO.

Receive Data Transfer Functions

TCPIP_TCP_ArrayFind	Searches for a string in the TCP RX buffer.
TCPIP_TCP_Find	Searches for a byte in the TCP RX buffer.
TCPIP_TCP_Get	Retrieves a single byte to a TCP socket.
TCPIP_TCP_Peek	Peaks at one byte in the TCP RX buffer/FIFO without removing it from the buffer.
TCPIP_TCP_Discard	Discards any pending data in the RCP RX FIFO.
TCPIP_TCP_FifoRxFreeGet	Determines how many bytes are free in the RX buffer/FIFO.
TCPIP_TCP_FifoSizeAdjust	Adjusts the relative sizes of the RX and TX buffers.
TCPIP_TCP_FifoRxFullGet	Determines how many bytes are pending in the RX buffer/FIFO.
TCPIP_TCP_GetIsReady	Determines how many bytes can be read from the TCP RX buffer.
TCPIP_TCP_ArrayGet	Reads an array of data bytes from a TCP socket's RX buffer/FIFO.
TCPIP_TCP_ArrayPeek	Reads a specified number of data bytes from the TCP RX buffer/FIFO without removing them from the buffer.

UDP Module API Function List

Socket Management Functions

TCPIP_UDP_ServerOpen	Opens a UDP socket as a server.
TCPIP_UDP_ClientOpen	Opens a UDP socket as a client.
TCPIP_UDP_IsOpened	Determines if a socket was opened.
TCPIP_UDP_IsConnected	Determines if a socket has an established connection.
TCPIP_UDP_Bind	Bind a socket to a local address and port. This function is meant for client sockets. It assigns a specific source address and port for a socket.
TCPIP_UDP_RemoteBind	Bind a socket to a remote address This function is meant for server sockets.
TCPIP_UDP_Close	Closes a UDP socket and frees the handle.
TCPIP_UDP_OptionsGet	Allows getting the options for a socket such as current RX/TX buffer size, etc.
TCPIP_UDP_OptionsSet	Allows setting options to a socket like adjust RX/TX buffer size, etc
TCPIP_UDP_SocketInfoGet	Returns information about a selected UDP socket.
TCPIP_UDP_SocketNetGet	Gets the network interface of an UDP socket
TCPIP_UDP_SocketNetSet	Sets the network interface for an UDP socket
TCPIP_UDP_TxOffsetSet	Moves the pointer within the TX buffer.
TCPIP_UDP_SourceIPAddressSet	Sets the source IP address of a socket
TCPIP_UDP_BcastIPV4AddressSet	Sets the broadcast IP address of a socket Allows an UDP socket to send broadcasts.
TCPIP_UDP_DestinationIPAddressSet	Sets the destination IP address of a socket
TCPIP_UDP_DestinationPortSet	Sets the destination port of a socket
TCPIP_UDP_Disconnect	Disconnects a UDP socket and re-initializes it.
TCPIP_UDP_SignalHandlerDeregister	Deregisters a previously registered UDP socket signal handler.
TCPIP_UDP_SignalHandlerRegister	Registers a UDP socket signal handler.
TCPIP_UDP_Task Standard	TCP/IP stack module task function.

Transmit Data Functions

TCPIP_UDP_PutIsReady	Determines how many bytes can be written to the UDP socket.
TCPIP_UDP_TxPutIsReady	Determines how many bytes can be written to the UDP socket.
TCPIP_UDP_ArrayPut	Writes an array of bytes to the UDP socket.
TCPIP_UDP_StringPut	Writes a null-terminated string to the UDP socket.
TCPIP_UDP_Put	Writes a byte to the UDP socket.
TCPIP_UDP_TxCountGet	Returns the amount of bytes written into the UDP socket.
TCPIP_UDP_Flush	Transmits all pending data in a UDP socket.

Receive Data Transfer Functions

TCPIP_UDP_GetIsReady	Determines how many bytes can be read from the UDP socket.
TCPIP_UDP_ArrayGet	Reads an array of bytes from the UDP socket.
TCPIP_UDP_Get	Reads a byte from the UDP socket.
TCPIP_UDP_RxOffsetSet	Moves the read pointer within the socket RX buffer.
TCPIP_UDP_Discard	Discards any remaining RX data from a UDP socket.

Harmony TCP/IP API Subset For all Lab's

TCP Socket Management Functions

TCPIP_TCP_ArrayGet Function

This function reads an array of data bytes from a TCP socket's RX buffer/FIFO. The data is removed from the FIFO in the process.

Function Prototype

```
uint16_t TCPIP_TCP_ArrayGet(
    TCP_SOCKET hTCP,
    uint8_t* buffer,
    uint16_t len
);
```

Preconditions

TCP is initialized.

Parameters

Parameter	Description
hTCP	The socket from which data is to be read.
buffer	Pointer to the array to store data that was read.
len	Number of bytes to be read.

Returns

Type	Description
uint16_t	The number of bytes read from the socket. If less than **len**, the RX FIFO buffer became empty or the socket is not connected.

TCPIP_TCP_ClientOpen Function

Provides a unified method for opening TCP client sockets. Sockets are created at the TCP module initialization, and can be claimed with this function and freed using **TCPIP_TCP_Abort** or **TCPIP_TCP_Close**. If the remoteAddress != 0 (and the address pointed by remoteAddress != 0) then the socket will immediately initiate a connection to the remote host.

Function Prototoype

```
TCP_SOCKET TCPIP_TCP_ClientOpen(
    IP_ADDRESS_TYPE addType,
    TCP_PORT remotePort,
    IP_MULTI_ADDRESS* remoteAddress
);
```

Preconditions

TCP is initialized.

Parameters

Parameter	Description
addType	The type of address being used. Valid values are: IP_ADDRESS_TYPE_IPV4 or IP_ADDRESS_TYPE_IPV6
remotePort	TCP port to connect to. The local port for client sockets will be automatically picked by the TCP module.
remoteAddress	The remote address to be used

Returns

Type	Description
TCP_SOCKET	Handle - Save this handle and use it when calling all other TCP APIs. If no sockets of the specified type were available to be opened, the handle will contain a value equal to INVALID_SOCKET.

TCPIP_TCP_Close Function

Graceful Option Set: If the graceful option is set for the socket (default), a TCPIP_TCP_Disconnect will be tried. If the linger option is set (default) the TCPIP_TCP_Disconnect will try to send any queued TX data before issuing FIN. If the FIN send operation fails or the socket is not connected the abort is generated.

Graceful Option Not Set: If the graceful option is not set, or the previous step could not send the FIN, a TCPIP_TCP_Abort is called, sending a RST to the remote node. Communication is closed, the socket is no longer valid and the associated resources are freed.

Function Prototype

```
void TCPIP_TCP_Close(
    TCP_SOCKET hTCP
);
```

Preconditions

TCP socket should have been opened with **TCPIP_TCP_ServerOpen/TCPIP_TCP_ClientOpen**.

hTCP - valid socket

Parameters

Parameter	Description
hTCP	Handle to the socket to disconnect and close.

Returns

Type	Description
Void	None

TCPIP_TCP_GetIsReady Function

Call this function to determine how many bytes can be read from the TCP RX buffer. If this function returns zero, the application must return to the main stack loop before continuing in order to wait for more data to arrive.

Function Prototype

```
uint16_t TCPIP_TCP_GetIsReady(
    TCP_SOCKET hTCP
);
```

Preconditions

TCP is initialized.

Parameters

Parameter	Description
hTCP	The socket to check.

Returns

Type	Description
uint16_t	The number of bytes available to be read from the TCP RX buffer.

TCPIP_TCP_IsConnected Function

This function determines if a socket has an established connection to a remote node. Call this function after calling **`TCPIP_TCP_ServerOpen()/TCPIP_TCP_ClientOpen()`** to determine when the connection is set up and ready for use.

Function Prototype

```
bool TCPIP_TCP_IsConnected(
    TCP_SOCKET hTCP
);
```

Preconditions

TCP is initialized.

Parameters

Parameter	Description
hTCP	The TCP socket to check.

Returns

Type	Description
bool	True: the socket is connected
	False: the socket is disconnected

TCPIP_TCP_PutIsReady Function

Call this function to determine how many bytes can be written to the TCP TX buffer. If this function returns zero, the application must return to the main stack loop before continuing in order to transmit more data.

Function Prototype

```
uint16_t TCPIP_TCP_PutIsReady(
    TCP_SOCKET hTCP
);
```

Preconditions

TCP is initialized.

Parameters

Parameter	Description
hTCP	The socket from which data is to be written.

Returns

Type	Description
`uint16_t`	The number of bytes available to be written in the TCP TX buffer.

TCPIP_TCP_StringPut Function

This function writes a null-terminated string to a TCP socket. The null-terminator is not copied to the socket.

Function Prototype

```
const uint8_t* TCPIP_TCP_StringPut(
    TCP_SOCKET hTCP,
    const uint8_t* Data
);
```

Preconditions

TCP is initialized.

Parameters

Parameter	Description
hTCP	The socket from which data is to be written.
const uint8_t*	**Data**

Returns

Type	Description
const uint8_t*	Pointer to the byte following the last byte written to the socket. If this pointer does not dereference to a NULL byte, the buffer became full or the socket is not connected.

TCPIP_TCP_WasReset Function

This function is a self-clearing semaphore indicating whether or not a socket has been disconnected since the previous call. This function works for all possible disconnections: a call to **`TCPIP_TCP_Disconnect`**, a FIN from the remote node, or an acknowledgment timeout caused by the loss of a network link. It also returns true after the first call to **`TCPIP_TCP_Initialize`**. Applications should use this function to reset their state machines.

Function Prototype

```
bool TCPIP_TCP_WasReset(
    TCP_SOCKET hTCP
);
```

Preconditions

TCP is initialized.

Parameters

Parameter	Description
hTCP	The TCP socket to check.

Returns

Type	Description
bool	true: the socket was disconnected since the previous call false: the socket remained connected since the previous call

UDP Socket Management Functions

TCPIP_UDP_ArrayGet Function

This function reads an array of bytes from the UDP socket, while adjusting the current read pointer and decrementing the remaining bytes available. TCPIP_UDP_GetIsReady should be used before calling this function to get the number of the available bytes in the socket.

Function Prototype

```
uint16_t TCPIP_UDP_ArrayGet(
    UDP_SOCKET hUDP,
    uint8_t * cData,
    uint16_t wDataLen
);
```

Preconditions

UDP socket should have been opened with TCPIP_UDP_ServerOpen/TCPIP_UDP_ClientOpen.

hUDP - valid socket

Parameters

Parameter	Description
hUDP	UDP Socket Handle
cData	The buffer to receive the bytes being read. If NULL, the bytes are simply discarded
wDataLen	Number of bytes to be read from the socket.

Returns

Type	Description
uint16_t	The number of bytes successfully read from the UDP buffer. If this value is less than wDataLen, then the buffer was emptied and no more data is available.

TCPIP_UDP_Close Function

Closes a UDP socket and frees the handle. Call this function to release a socket and return it to the pool for use by future communications.

Function Prototoype

```
void TCPIP_UDP_Close(
    UDP_SOCKET hUDP
);
```

Preconditions

UDP socket should have been opened with TCPIP_UDP_ServerOpen/TCPIP_UDP_ClientOpen.

hUDP - valid socket

Parameters

Parameter	Description
hUDP	UDP Socket Handle

Returns

Type	Description
void	None

TCPIP_UDP_GetIsReady Function

This function will return the number of bytes that are available in the specified UDP socket RX buffer. The UDP socket queues incoming RX packets in an internal queue. If currently there is no RX packet processed (as a result of retrieving all available bytes with `TCPIP_UDP_ArrayGet`, for example), this call will advance the RX packet to be processed to the next queued packet. If a RX packet is currently processed, the call will return the number of bytes left to be read from this packet.

Function Prototype

```
uint16_t TCPIP_UDP_GetIsReady(
    UDP_SOCKET hUDP
);
```

Preconditions

UDP socket should have been opened with `TCPIP_UDP_ServerOpen/TCPIP_UDP_ClientOpen`.

hUDP parameter is a valid socket

Parameters

Parameter	Description
hUDP	UDP Socket Handle

Returns

Type	Description
uint16_t	The number of bytes that can be read from the socket.

TCPIP_UDP_ServerOpen Function

Provides a unified method for opening UDP server sockets.

Function Prototype

```
UDP_SOCKET TCPIP_UDP_ServerOpen(
    IP_ADDRESS_TYPE addType,
    UDP_PORT localPort,
    IP_MULTI_ADDRESS* localAddress
);
```

Preconditions

UDP is initialized.

Parameters

Parameter	Description
IP_ADDRESS_TYPE **addType**	The type of address being used. **IP_ADDRESS_TYPE_IPV4** or **IP_ADDRESS_TYPE_IPV6**.
UDP_PORT localPort	UDP port on which to listen for connections
IP_MULTI_ADDRESS* localAddress	Local IP address to use. Can be 0 (NULL) if any incoming interface will do.

Returns

Type	Description
UDP_SOCKET	Handle - Save this handle and use it when calling all other UDP APIs. If no sockets of the specified type were available to be opened, the handle will contain a value equal to INVALID_SOCKET.

TCPIP_UDP_SocketInfoGet Function

This function will fill a user passed UDP_SOCKET_INFO structure with status of the selected socket

Function Prototype

```
bool TCPIP_UDP_SocketInfoGet(
    UDP_SOCKET hUDP,
    UDP_SOCKET_INFO* pInfo
);
```

Preconditions

UDP socket should have been opened with TCPIP_UDP_ServerOpen()/TCPIP_UDP_ClientOpen()().

hUDP - valid socket

pInfo - valid address of a UDP_SOCKET_INFO structure

Parameters

Parameter	Description
hUDP	UDP Socket Handle
pInfo	Pointer to UDP_SOCKET_INFO to receive socket information

Returns

Type	Description
bool	true if call succeeded false if no such socket or invalid pinfo.

UDP_SOCKET_INFO Structure

Holds information about a UDP Socket

Structure

```
typedef struct {
  IP_ADDRESS_TYPE addressType;
  IP_MULTI_ADDRESS remoteIPaddress;
  IP_MULTI_ADDRESS localIPaddress;
  IP_MULTI_ADDRESS sourceIPaddress;
  IP_MULTI_ADDRESS destIPaddress;
  UDP_PORT remotePort;
  UDP_PORT localPort;
  TCPIP_NET_HANDLE hNet;
} UDP_SOCKET_INFO;
```

Members

Type	Member Name	Description
IP_ADDRESS_TYPE	addressType	address type of the socket
IP_MULTI_ADDRESS	remoteIPaddress	current socket destination address
IP_MULTI_ADDRESS	localIPaddress	current socket source address
IP_MULTI_ADDRESS	sourceIPaddress	source address of the last packet
IP_MULTI_ADDRESS	destIPaddress	destination address of the last packet
UDP_PORT	remotePort	Port number associated with remote node
UDP_PORT	localPort	local port number
TCPIP_NET_HANDLE	hNet	associated interface

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