AN4833

File Transfer Protocol Using MPLAB Harmony v3 TCP/IP Stack for SAM E54 MCU

Introduction

The File Transfer Protocol (FTP) is a standard internet protocol provided by TCP/IP for transmitting files from one device to another. It is an application layer protocol within the TCP/IP stack layers. An embedded FTP client/server is an excellent addition to any network-enabled device. The FTP client module will enable your application to upload and download files from any FTP server. This protocol enables data transfer reliably and efficiently between different devices without worrying about the file storage systems of a Host.

This document focuses on the FTP implementation of the MPLAB® Harmony v3 TCP/IP stack. It also provides a combined FTP client and FTP server demonstration using the SAM E54 microcontroller. The FTP client application has an Ethernet bootloader that downloads the application binary from the FTP server and updates the firmware by self-programming.

Abbreviations

- FTP: File Transfer Protocol
- HTTP: Hypertext Transfer Protocol
- TCP/IP: Transmission Control Protocol/Internet Protocol
- DHCP: Dynamic Host Configuration Protocol
- DFP: Device Family Pack
- MCC: MPLAB Code Configurator

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1. FTP Overview

FTP is built on a client/server model architecture using separate control and data connections between the client and the server. An FTP client establishes a connection between a Host and a remote FTP server, providing dual-direction data transfer and files between two computers over TCP. It works when the client connects to the FTP server by specifying the domain, IP address, port, username, and password. After user authentication, a connection is established between both systems, and the Host computer can upload data onto the FTP server. There could be access restrictions, which the FTP server administrator determines for downloading the various files and folders residing on the FTP server.

The FTP relies on two connections between the client and server: a control connection for controlling the conversation and a data connection for transmitting file content. When an FTP session is started between a client and a server, the client initiates a control TCP connection with the server side. The client sends the control information over this. When the server receives the control information, it initiates a data connection to the client side. FTP sessions work in active or passive mode, determining how the data connection is established and whether the client/server initiates the transfer. Additional information on FTP modes and connections can be found in the FTP document AN3475.

2. Application Overview

This document demonstrates the use of an FTP server and an FTP client in a network by using two SAM E54 Xplained Pro Evaluation Kits, where one will be the FTP server and the other evaluation board will be the FTP client. Each FTP client and FTP server has its own file system media. The SD card on the IO1 Xpro board acts as the storage medium for the file system and is used by the client/server boards for the file transfer. This application mainly focuses on the FTP network where the client logs into the server and downloads the application binary file to load the application.

Figure 2-1. SAM E54 as Client and Server Model

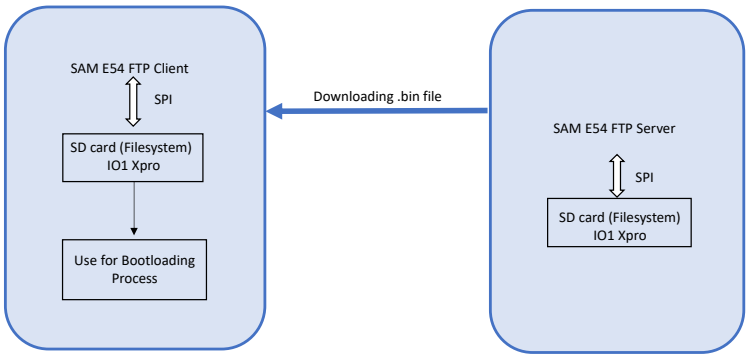
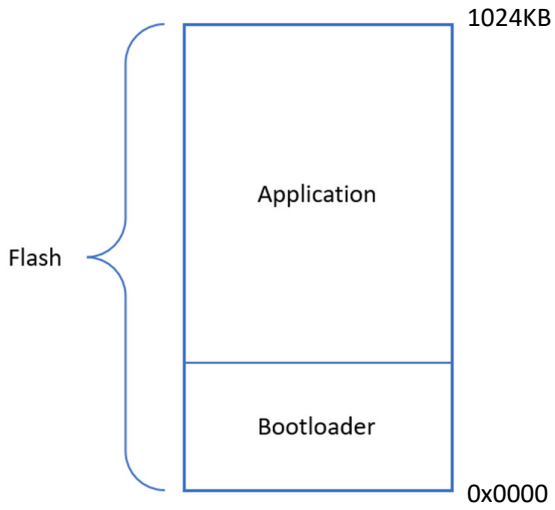


Figure 2-2. Memory for Application and Bootloader



3. Hardware and Software Requirements

This section describes the hardware and software prerequisites used for this application.

Hardware:

- SAM E54 Xplained Pro Evaluation Kit – 2 Nos
- IO1 Xplained Pro – 2 Nos
- Micro SD card – 2 Nos
- Ethernet cable (RJ45) – 1 No
- USB cable – 2 Nos

Software:

- MPLAB X IDE (v6.00)
- MPLAB XC32 compiler (v4.10)
- MPLAB Code Configurator (v5.1.17)
  - Harmony bsp repository v3.13.0 (Github bsp)
  - Harmony csp repository v3.13.1 (Github csp)
  - Harmony core repository v3.11.1 (Github core)
  - Harmony dev_packs repository v3.13.0 (Github dev_packs)
  - Harmony net repository v3.8.0 (Github net)
  - Harmony Crypto repository v3.7.6 (Github crypto)

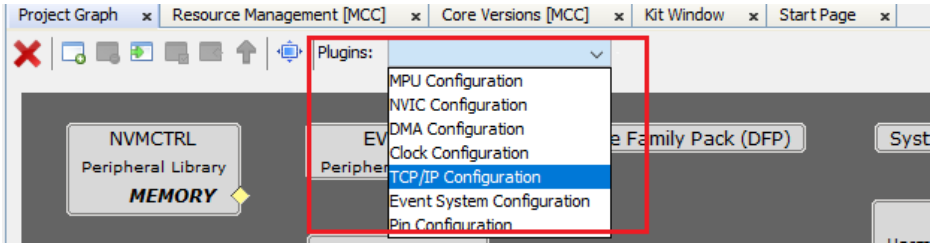
4. FTP in MPLAB Harmony v3

The MPLAB Harmony v3 TCP/IP Stack Library provides the API of the FTP module with a convenient 'C' language interface. It supports the FTP server and client, which facilitates the upload and download of files.

4.1 TCP/IP Configurator

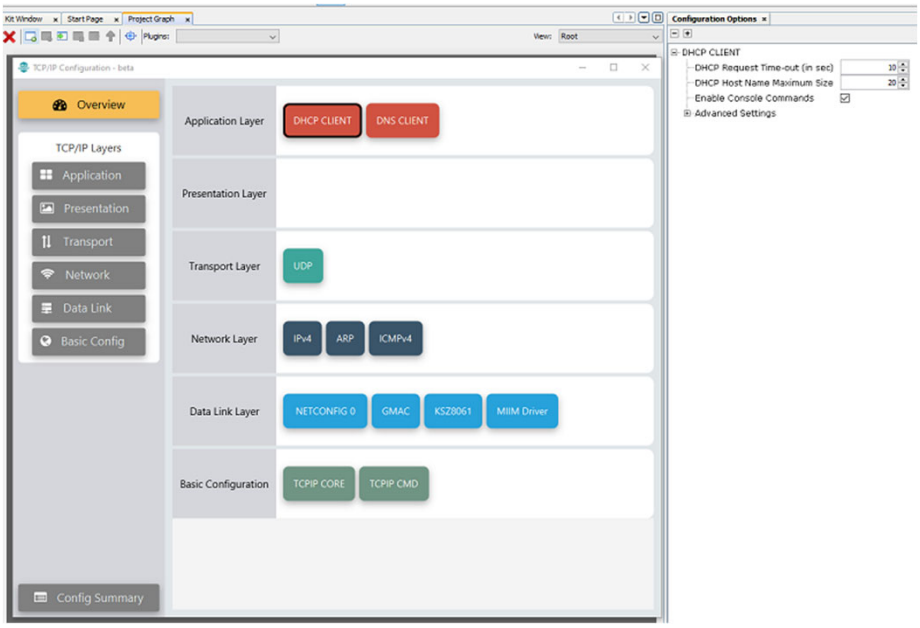
MPLAB Harmony v3 configuration uses an easy-to-use GUI, the MPLAB Code Configurator (MCC), which simplifies device setup, library selection, configuration, and application development. A TCP/IP Configurator plugin is available for the TCP/IP Configuration. This enables a user to graphically add or remove TCP/IP functionality to the MPLAB Harmony v3 project and configure each component per the application demand. The TCP/IP Configurator plugin can be selected from the Plugins drop-down list in the Project Graph window.

Figure 4-1. TCP/IP Configurator



The TCP/IP Configurator window initializes with a graphical overview of the different TCP/IP layers. Selecting each layer displays the available components. Choose the component needed for the application from the 'Available Components' list by clicking '+' or dragging and dropping to add selected components. A pop-up window will be shown for adding any unsatisfied dependencies on the component being selected. Select any added TCP/IP component and add the configuration in the 'Configuration Options' in the project Graph.

Figure 4-2. TCP/IP Configurator Overview



Note: The 'docs' folder in the local repository of 'net' contains more information on the configurator.

4.2 FTP Server Module

The FTP server capability facilitates the uploading and downloading of files from an embedded device. The FTP TCP/IP stack library interface is defined in the `ftp.h` header file. To use the FTP server, the project requires using the TCP/IP stack and a file system (FAT FS in this project).

The FTP server can be enabled in the MPLAB Harmony v3 TCP/IP project using the MCC: *Project Graph* > *Plugin* > *TCP/IP Configuration* > *Application Layer* > *Add FTP Server*.

Figure 4-3. FTP Server in TCP/IP Configurator

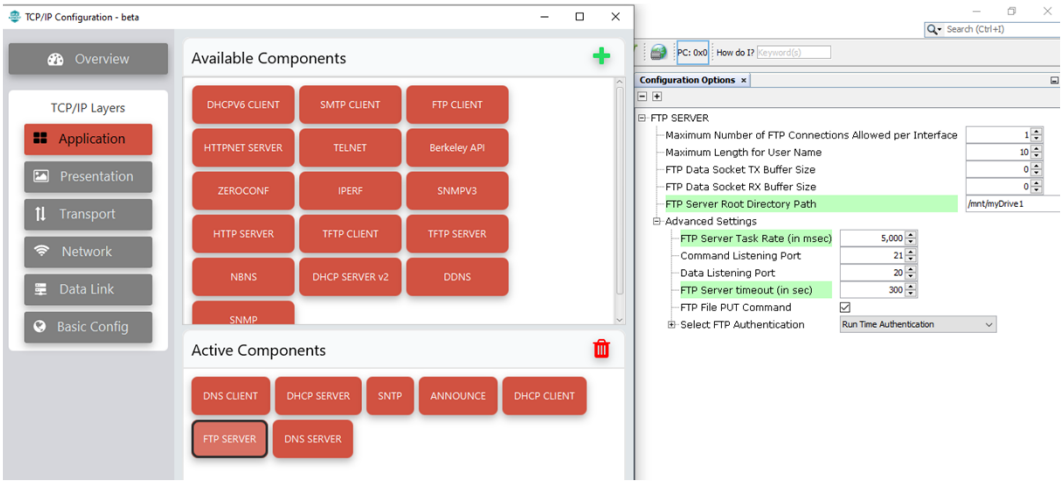


Table 4-1. FTP Server Module Files

File	Description
`ftp.h`	Interface to the FTP server TCP/IP Stack library
`ftp.c`	Implementation of FTP server

4.3 FTP Client Module

The FTP client module enables the transfer of data reliably and efficiently between different devices without worrying about the different file storage systems among Hosts. The FTP client TCP/IP stack library interface is defined in the `ftpc.h` header file.

The FTP client can be enabled in the MPLAB Harmony v3 TCP/IP project using the MCC: *Project Graph* > *Plugin* > *TCP/IP Configuration* > *Application Layer* > *Add FTP Client*.

Figure 4-4. FTP Client in TCP/IP Configurator

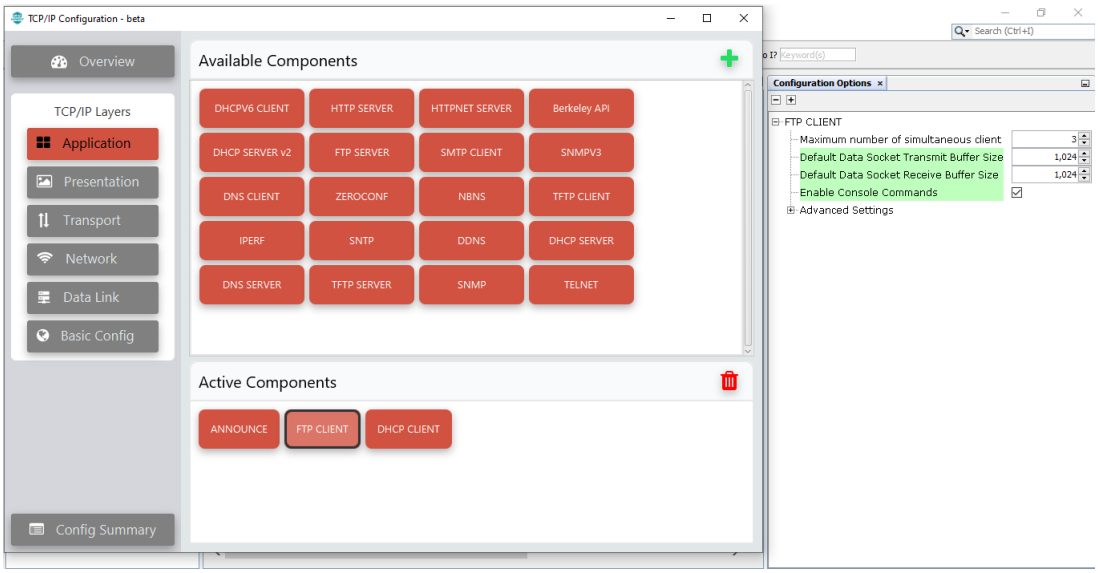


Table 4-2. FTP Client Module Files

File	Description
`ftpc.h`	Interface to the FTP client TCP/IP stack library
`ftpc.c`	Implementation of the FTP client protocol

The following table displays the FTP commands supported by the FTPC module.

Table 4-3. FTP Commands Supported by the FTPC Module

FTP COMMAND	STACK COMMAND TYPE	FUNCTION NAME
USER: Send username	`TCPIP_FTPC_CMD_USER`	`TCPIP_FTPC_Login`
PASS: Send password	`TCPIP_FTPC_CMD_PASS`	`TCPIP_FTPC_Login`
ACCT: Send account information	`TCPIP_FTPC_CMD_ACCT`	`TCPIP_FTPC_Login`
TYPE: Set transfer type	`TCPIP_FTPC_CMD_TYPE`	`TCPIP_FTPC_SetType`
STRU: Set file transfer structure	`TCPIP_FTPC_CMD_STRU`	`TCPIP_FTPC_SetStruct`
MODE: Set transfer mode	`TCPIP_FTPC_CMD_MODE`	`TCPIP_FTPC_SetMode`
PASV: Enter passive mode	`TCPIP_FTPC_CMD_PASV`	`TCPIP_FTPC_SetPassiveMode`
PORT: Open a data port	`TCPIP_FTPC_CMD_PORT`	`TCPIP_FTPC_Connect`
RETR: Retrieve a remote file	`TCPIP_FTPC_CMD_GET`	`TCPIP_FTPC_GetFile`
STOR: Store a file on the remote host	`TCPIP_FTPC_CMD_PUT`	`TCPIP_FTPC_PutFile`
NLST: Name list of remote directories	`TCPIP_FTPC_CMD_NLST`	`TCPIP_FTPC_NameList`
LIST: List remote files	`TCPIP_FTPC_CMD_LIST`	`TCPIP_FTPC_List`
DELE: Delete a remote file	`TCPIP_FTPC_CMD_DELE`	`TCPIP_FTPC_DeleteFile`
CWD: Change working directory	`TCPIP_FTPC_CMD_CWD`	`TCPIP_FTPC_Change_Dir`
CDUP: CWD to the parent of the current directory	`TCPIP_FTPC_CMD_CDUP`	`TCPIP_FTPC_ChangeToParentDir`

.....continued		
FTP COMMAND	**STACK COMMAND TYPE**	**FUNCTION NAME**
MKD: Make a remote directory	TCPIP_FTPC_CMD_MKD	TCPIP_FTPC_MakeDir
RMD: Remove a remote directory	TCPIP_FTPC_CMD_RMD	TCPIP_FTPC_RemoveDir
PWD: Print working directory	TCPIP_FTPC_CMD_PWD	TCPIP_FTPC_Get_WorkingDir
QUIT: Terminate the connection	N/A	TCPIP_FTPC_Logout

In addition to implementing the FTP commands, the client module provides a user interface through the USART terminal. This enables users to provide the required FTP command by entering the terminal. All FTP client commands start with the keyword ‘ftpc’, for example, `ftpc login <username> <pswd>` .

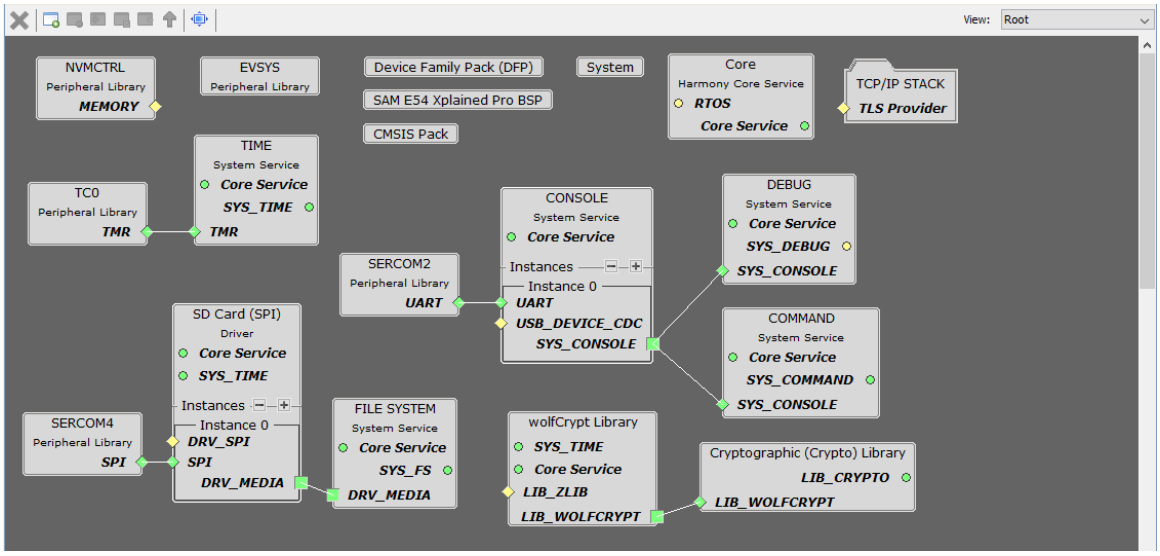
5. FTP Client and Server: Application Implementation

This section covers the prerequisites for creating the application.

5.1 MPLAB Harmony v3 Configuration

- To create a 32-bit MPLAB Harmony v3 project for the SAME54P20A using MPLAB X IDE, refer to https://microchipdeveloper.com/harmony3:same54-getting-started-training-module.
- By default, the Device Family Pack (DFP), System, CMSIS Pack, NVMCTRL and EVSYS will be present when the configuration is launched.
- The SD Card (SPI) Driver is added to provide the interface for the SD Card from the IO1 Xplained Pro Board.
- The System services, including the CONSOLE, COMMAND, DEBUG, TIME, File System, and TCP/IP features, must be added along with the required satisfiers as shown below.

Figure 5-1. FTP Client/Server Project Graph

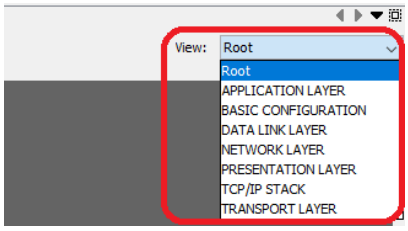


5.2 TCP/IP MPLAB Harmony v3 Configuration

To configure TCP/IP Basic Configurator for client and server, use the following steps:

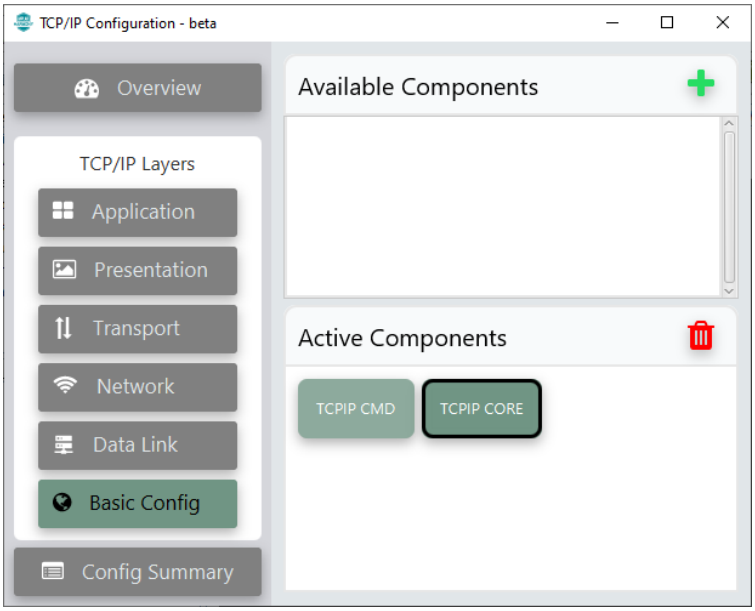
1. The TCP/IP Configurator will open a window as mentioned in the TCP/IP Configurator section. Once the selected contents are added, a view can be observed through the TCP/IP Configurator or the Project Graph. Different views can be selected through the Project Graph as shown in the following figure:

   Figure 5-2. Selecting Views



2. In the Basic Configuration view, TCPIP CMD and TCPIP CORE components are enabled.

Figure 5-3. Basic Configurator



Note: In the TCP/IP CORE configuration options, the TCP/IP Stack Dynamic RAM size can be adjusted per the application requirement.

3. The network interface is configured to the necessary PHY connection in the Data Link configuration options. Ensure that the required network details, such as IP address and gateway address, are configured for both the client and the server. The internal ethernet driver (GMAC) is enabled with the KSZ8091 PHY driver for the SAME54 demonstration. The SAME54 Xplained Pro Evaluation Kit has the KSZ8091 present. The MIIM Driver supports asynchronous read/write and scan operations for accessing the external PHY registers and notifications when the MIIM operations have been completed.

Figure 5-4. Data Link Configuration

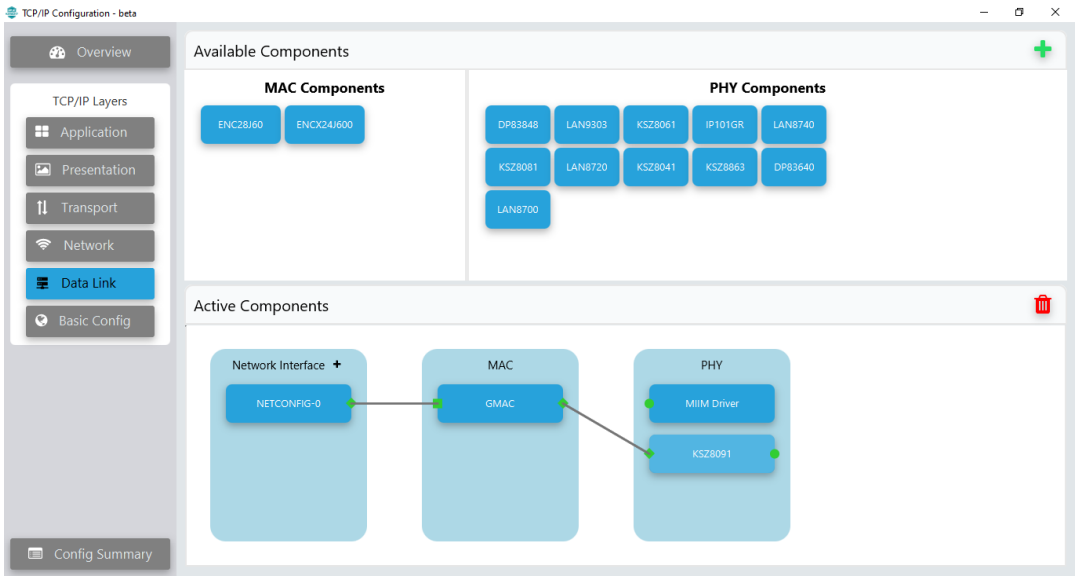
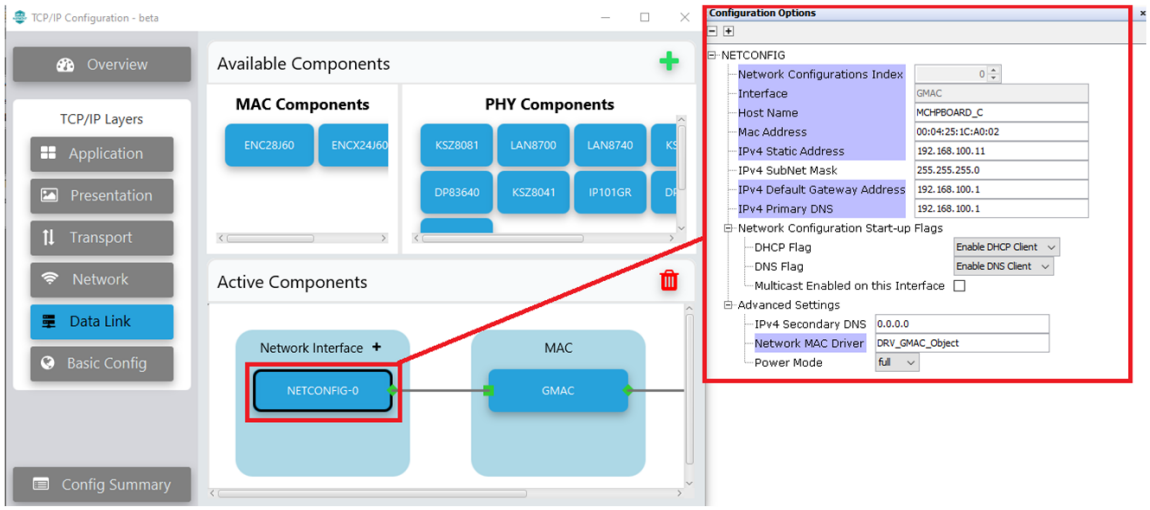


Figure 5-5. NETCONFIG Options



Note: This configuration of the network components can be done either by clicking the components on the project graph, or clicking the components in the TCP/IP configuration plugin. This is also applicable to other TCP/IP network components of the MPLAB Code Configurator's graphical user interface (GUI).

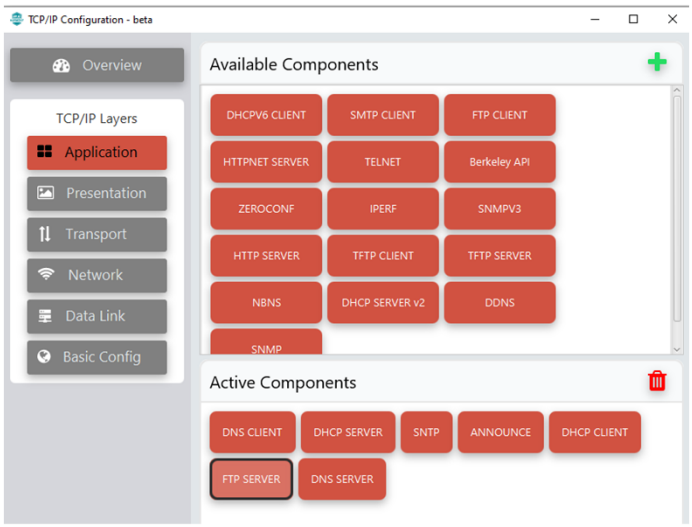
5.2.1 FTP Server Configurations

TCP/IP Application Layer Configuration

Follow these steps to configure the TCP/IP Application Layer:

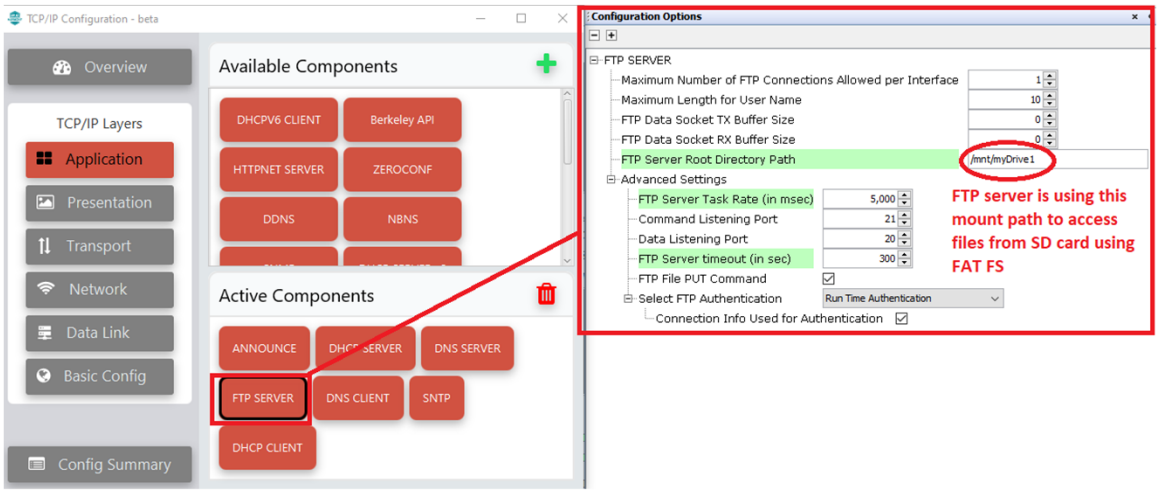
- In the TCP/IP Configuration window, under TCP/IP Layers, click "Application".
- In the Application Layer view, the TCP/IP Application Layer Configurator enables the following components: ANNOUNCE, FTP SERVER, DHCP Server, SNTP and DNS CLIENT.
- The ANNOUNCE module facilitates device discovery on the DHCP-enabled networks, while the DHCP CLIENT module allows the application to dynamically obtain an IP address from a DHCP server on the network.
  Note: The addition of the FTP server component would be sufficient for an FTP server project and the FTP client component would be sufficient for an FTP client project along with DNS. Those mentioned above are additional network protocols.

Figure 5-6. FTP Server Application Layer Configuration



- The FTP server uses the FAT FS to access files from SDCARD media. In the FTP SERVER configuration, configure the FTP server root directory path as shown in the following figure:

Figure 5-7. FTP Server Configuration



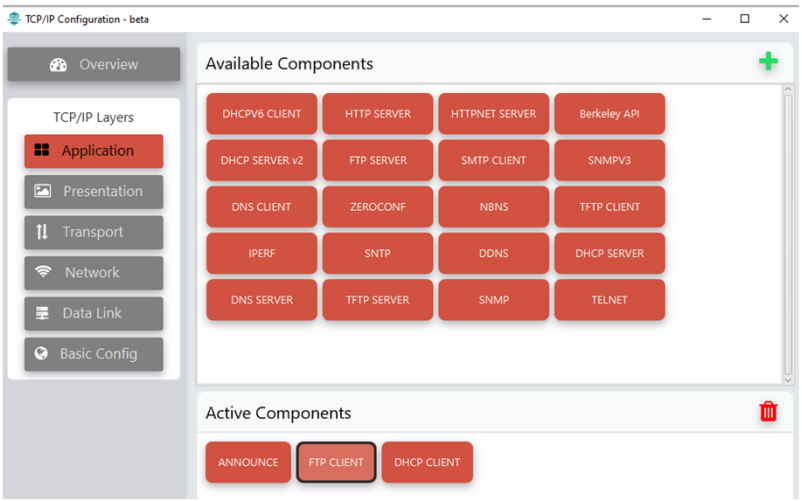
5.2.2 FTP Client Configuration

TCP/IP Application Layer Configuration

Follow these steps to configure the TCP/IP Application Layer:

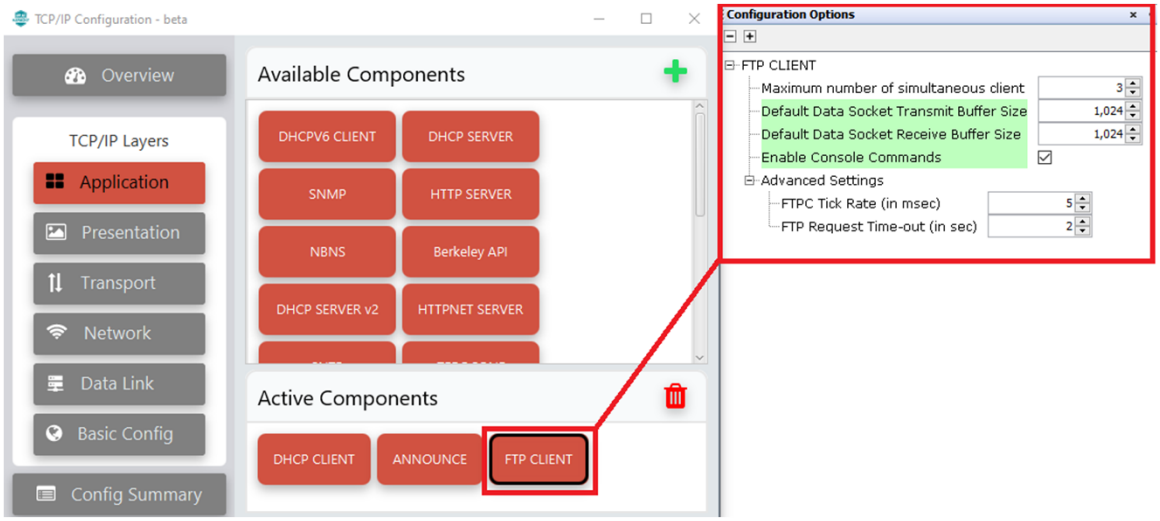
- For client, in the TCP/IP Application Layer Configurator, the ANNOUNCE, FTP CLIENT, and DHCP CLIENT components are enabled:

Figure 5-8. FTP Client Application Layer Configurator View



- In the FTP CLIENT Configuration, the Enable console commands option allows users to interact with the FTP client through a serial terminal. The transmit and receive buffer size can be increased as required (up to 1,024 bytes).

Figure 5-9. FTP Client Configuration



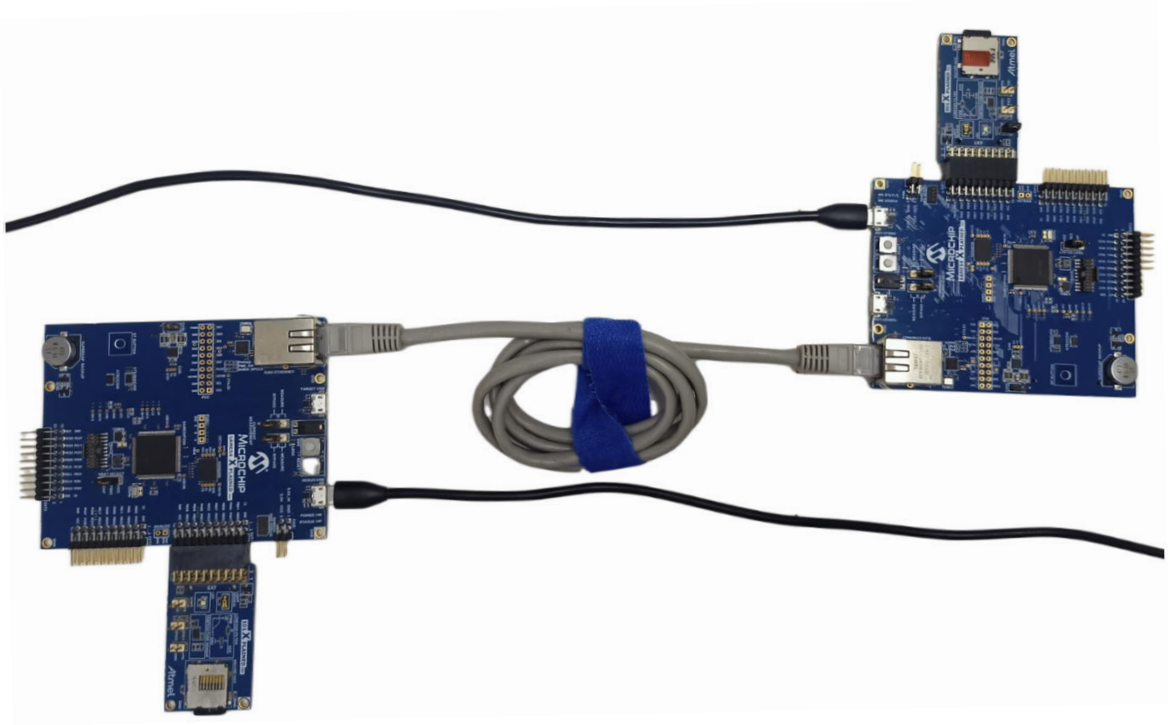
5.3 Running the Application

5.3.1 Hardware Setup

Follow these steps to setting up the hardware:

1. Attach the IO1 Xpro board to the EXT1 of the SAME54 Xplained Pro Evaluation Kit.
2. Insert the Micro SD card into the Micro SD card slot on the backside of the IO1 Xpro boards. Ensure that the SD Card in the FTP Server contains the binary (`test.bin`) to be downloaded by the FTP Client.
3. Connect the micro-USB cable from the computer to the DEBUG USB connector on the SAM E54 Xplained Pro Evaluation Kit.
4. Connect the RJ45 ports of both SAM E54 Xplained Pro Evaluation Kits through the RJ45 cable, as shown in the following figure:

Figure 5-10. SAM E54 Client/Server Connection



5.3.2 Programming the MCU

Follow these steps to program the MCU:

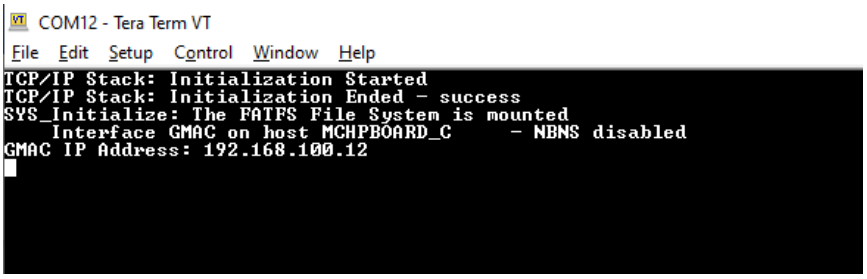
1. Download the FTP client and FTP server projects (provided with this document, alternatively users can download it here FTP Client and FTP Server).
2. Open the project in MPLAB X IDE (*File > Open Project and then browse to same54_ftp_client\firmware\ftp_client_sam_e54_xpro.X* and *same54_ftp_server\firmware\ftp_server_sam_e54_xpro.X*).
3. Build and program the project to the target board by clicking  (make and program device icon) for both boards, the client project (`ftp_client_sam_e54_xpro`) in one SAM E54 Xplained Pro Evaluation Kit board, and the server project (`ftp_server_sam_e54_xpro`) in the other.

5.3.3 Connecting FTP Server

Follow these steps to connecting the FTP server:

1. Power up the FTP Server board through the Debug USB port.
2. Flash the FTP Server project in the SAM E54 Xplained Pro Evaluation Kit FTP Server Board and open the terminal (Tera Term) *same54_ftp_server\firmware\ftp_server_sam_e54_xpro.X* .
3. After Flashing, the FTP Server will complete the initialization and the console will print the server IP address as shown in the following figure.

Figure 5-11. FTP Server Console Output



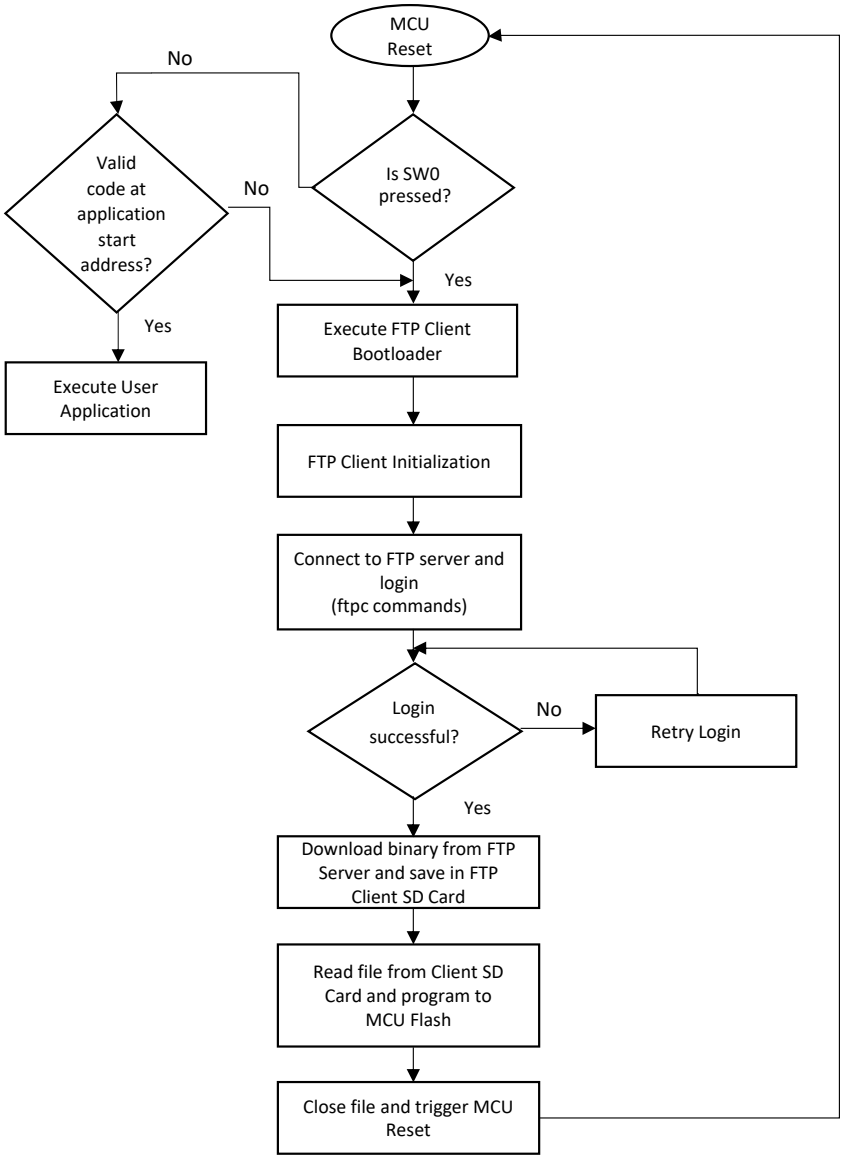
Note: Before connecting to the SAM E54 FTP client project (Ethernet bootloader), copy the application binary file (`same54_ftp_client/utilities/test.bin`) to the MicroSD Card in the IO1 Xpro extension of the FTP Server board. This binary will be downloaded by the client and performs the bootloading.

5.3.4 Connecting FTP Client

The user application for an FTP client must initiate the FTP connection request. Based on the server's response to the request, the client must provide the username and password for logging in. Data can be transferred between the server and the client when the FTP client is successfully logged in. (The user's own client/server, such as Windows Client, Embedded Server/Embedded Client, or Linux server, and so on can be used for the application).

In this application, the client downloads a binary file from the server and the downloaded file will be stored on an SD card on the IO1 Xpro of the client board. The binary is then programmed to the microcontroller.

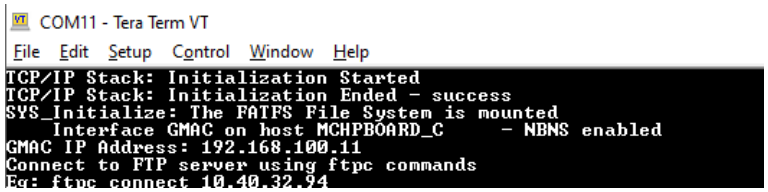
Figure 5-12. Flow Diagram of FTP Bootloader in the FTP Client



Use the following steps to connect to the FTP client:

1. From a serial terminal window application (Tera Term), connect to the COM port enumerated by the SAM E54 Xplained Pro Evaluation Kit.
2. Restart the application (reset the SAM E54 Xplained Pro Evaluation Kit).
3. The IP address will be displayed on the terminal as shown in the following figure.

   Figure 5-13. FTP Client Initialization



4. The user can then connect to the FTP server by typing: `ftpc connect <server ip address>`.

5. Upon successful connection, enter the login details: `ftpc login <username> <password>`.
6. Once logged in, use the following `ftpc` to get the command to download a binary from the server: `ftpc get -a -a <test.bin>`. The 'Command Success' indicates the binary is successfully downloaded.
7. Once the 'Command Success' message is received, enter the command 'boot'. The 'boot' is the command defined to start the bootloading of the downloaded binary.
8. The MCU is reset after the programming is complete and the application code starts executing.

Notes:

- The Binary files must be used for downloading and bootloading.
- The source code contains a `same54_ftp_client/utilities/test.bin` for LED Flashing. This binary must be saved in the SD Card of the SAM E54 Xplained Pro Evaluation Kit programmed with the SAME54 FTP server project.

Figure 5-14. Output

6. Appendix

6.1 Generating Application Binary Files (Test Application Configurations)

Typically, the embedded firmware has the bootloader programmed at the base address of the Flash memory. The application image follows the bootloader code in the Flash memory. To generate the binary file of an application project in MPLAB X IDE, perform the steps as shown in the following sections.

6.1.1 Disable Generate Fuse Settings

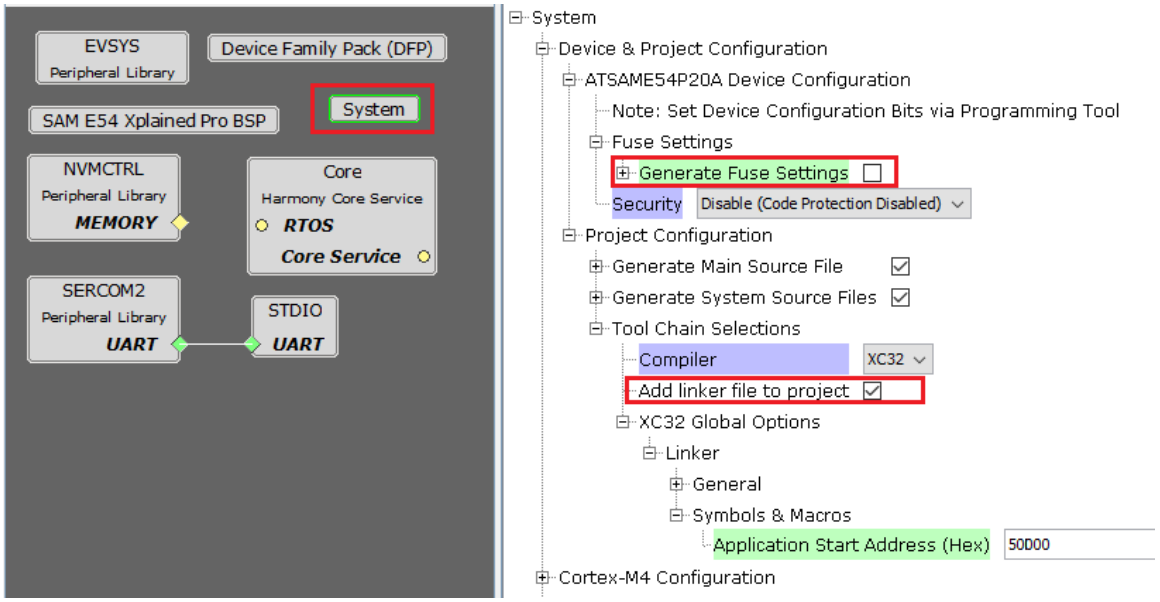
Generally, the fuse configuration settings of the SAM MCU are programmed through the programming tool. The fuse settings are disabled in the test application, as the application is being programmed through the bootloader. Enabling the fuse settings increases the size of the binary file.

6.1.2 Modify Application Start Address (Hex)

The application start address value must be equal to or greater than the Flash base address + bootloader size. It must match the value provided to the bootloader code during the generation. The bootloader will use the application start address value to jump to the application at the device reset.

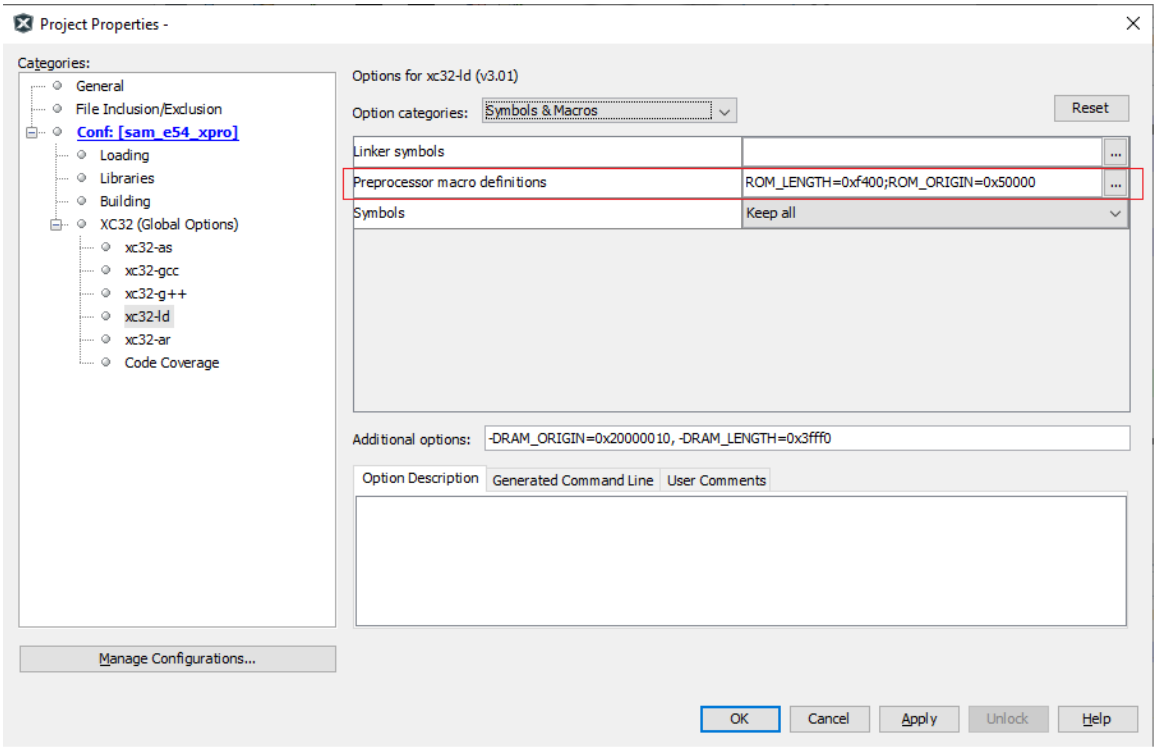
The fuse settings and the application start address can be modified using the MCC. Launch the MCC and configure the 'System' component as shown in the following figure.

Figure 6-1. System Setting Configuration in MCC



To change the application's start address, navigate to *Project Properties > xc32-ld > Option categories: Symbols & Macros*. Users need to define the `ROM_ORIGIN` and `ROM_LENGTH` macros.

Figure 6-2. Project Properties



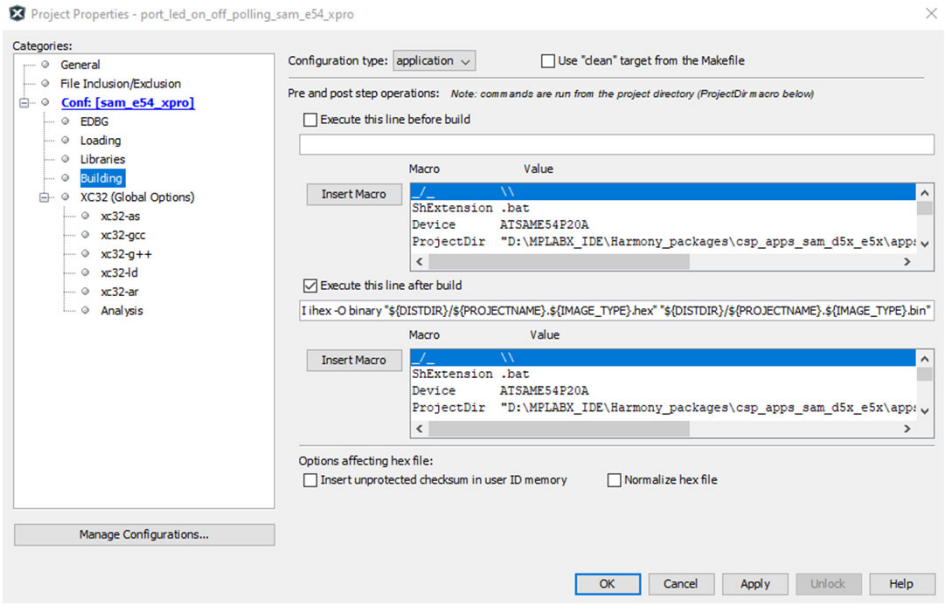
6.1.3 Generate the Binary File in MPLAB X IDE

To generate the binary file, follow these steps:

1. Go to *Project Properties* > *Building*.
2. Select Execute this line after build option, and then insert the following command:

```
${MP_CC_DIR}\xc32-objcopy -I ihex -O binary "${DISTDIR}/${PROJECTNAME}.${IMAGE_TYPE}.hex"
"${DISTDIR}/${PROJECTNAME}.${IMAGE_TYPE}.bin"
```

Figure 6-3. Bin File Generation

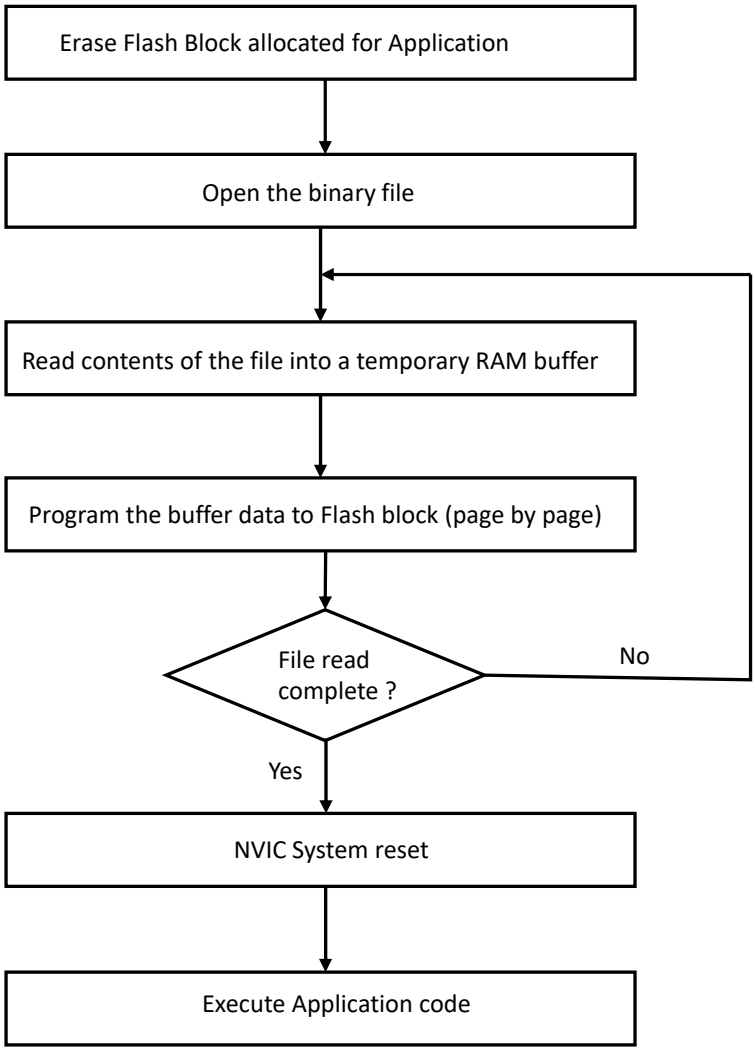


After building the project. The bin file output can be found in the following path: *<your_project>.X\dist\<config_name>\production*.

6.2 Self-Programming of Downloaded Binary

Users can download the required application binary from any FTP server (any FTP server can be used) using the FTP client application demonstrated in this document. Once the binary file is downloaded into the client file system, it can be programmed to the MCU's Flash memory, as shown in the following flow chart. Implementation of erasing and programming the Flash sector can be found in the `APP_Flash_Task()` function (`same54_ftp_client\firmware\src\app.c`) in the source code of this application.

Figure 6-4. Programming the Binary



6.3 Application Code Entry

Upon every reset, the bootloader code checks for the following:

- User button press (SW0)
- A valid application code in the Flash address allocated for the application

If either of these conditions is true, the execution jumps to the user application code without executing the FTP client bootloader.

Note: For additional information, refer to this document AN3475.

7. References

- The Microchip TCP/IP stack:
  ww1.microchip.com/downloads/en/appnotes/00833c.pdf
- MPLAB® Harmony v3 TCP/IP Help:
  microchip-mplab-harmony.github.io/net/frames.html?frmname=topic&frmfile=index.html
- RFC 959:
  datatracker.ietf.org/doc/html/rfc959
- Harmony v3 Microchip Developer Help:
  microchipdeveloper.com/harmony3:start
- MPLAB Harmony GitHub wiki:
  github.com/Microchip-MPLAB-Harmony/Microchip-MPLAB-Harmony.github.io/wiki
- How to create first TCP/IP application:
  github.com/Microchip-MPLAB-Harmony/net/wiki/Create-your-first-tcpip-application
- MPLAB Harmony v2 to MPLAB Harmony v3 TCP/IP Application Migration Guide:
  microchip-mplab-harmony.github.io/quick_docs/source/migration/tcpiip_harmoy2_to_harmony_3/readme.html
- Application Configuration Settings with Bootloader:
  microchip-mplab-harmony.github.io/bootloader_apps_uart/apps/docs/readme_configure_application_sam.html#configuring-an-application-to-be-bootloaded-for-cortex-m-based-mcus
- MPLAB Harmony v3 is configurable through MPLAB Code Configurator (MCC). Refer to the below links for specific instructions to use MPLAB Harmony v3 with MCC.
  - Create a new MPLAB Harmony v3 project using MCC
  - Update and Configure an Existing MHC-based MPLAB Harmony v3 Project to MCC-based project
  - Getting Started with MPLAB Harmony v3 Using MPLAB Code Configurator
  - MPLAB Code Configurator Content Manager for MPLAB Harmony v3 Projects
- MPLAB® Code Configurator Overview with MPLAB Harmony Content:
  microchipdeveloper.com/harmony3:mcc-overview

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