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## **File Transfer Protocol Using MPLAB Harmony v3 TCP/IP Stack**

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### **Introduction**

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File Transfer Protocol (FTP) is an application layer protocol used to transfer files between local and remote hosts. It runs on top of the TCP, such as HTTP.

This document focuses on the FTP implementation of the MPLAB® Harmony v3 TCP/IP stack, available in the latest MPLAB Harmony v3 framework. It also provides an FTP client demonstration using the SAM E70. This demonstration implements an Ethernet bootloader using FTP, through which the SAM E70 client downloads a binary for self-programming from an FTP server.

#### **Abbreviations**

The following abbreviations are used in this document:

- FTP – File Transfer Protocol
- HTTP - Hypertext Transfer Protocol
- TCP/IP – Transmission Control Protocol/Internet Protocol
- DHCP - Dynamic Host Configuration Protocol
- DFP - Device Family Pack
- MHC - MPLAB Harmony Configurator

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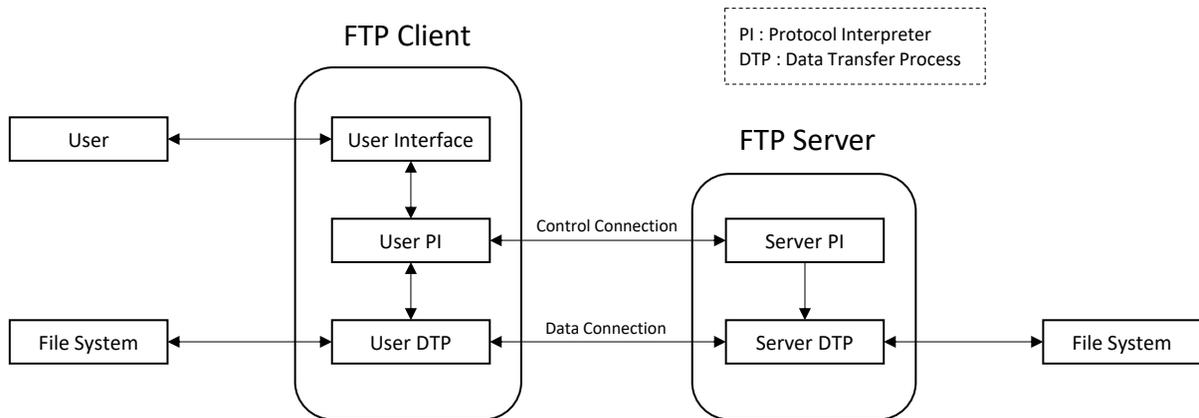
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## 1. FTP Overview

FTP is built on a client/server model architecture using separate control and data connections between the client and the server.

Figure 1-1. FTP Model



### 1.1 Client

A File Transfer Protocol client (FTP client) is a software that establishes a connection between a host computer and a remote FTP server. An FTP client provides the dual-direction transfer of data and files between two computers over TCP. An FTP client works on a client/server architecture, where the host computer is the client and the remote FTP server is the central server. It works when the host computer connects to the FTP server by specifying the domain, IP address, user name, and password of that server (in some cases, the port number also needs to be specified). After the user authentication, a connection is established between both the systems, and the host computer can upload data onto the FTP server. An FTP client generally supports one or multiple simultaneous file transfers. Moreover, most FTP clients can connect to multiple FTP servers simultaneously, providing status updates of the uploading process, and notifications about successful and failed transfers. The host computer can also download files from the FTP server using the FTP client.

### 1.2 Server

The FTP server enables downloading and uploading files. There could be access restrictions, which are determined by the FTP server administrator for downloading the various files and folders residing on the FTP server. Files residing on FTP servers can be retrieved by common web browsers, but they may not support protocol extensions, such as FTPS (FTP Secure). All file transfer protocol site addresses begin with 'ftp://'.

### 1.3 Connection

To transfer a file, the following TCP connections are used by the FTP in parallel: control connection and data connection.

**Control Connection:** FTP uses control connection for sending control information, such as user identification, password, commands to change the remote directory, and commands to retrieve and store files. The default port number for control connection is 21. All control connections are initiated on this port.

**Data connection:** For sending the file, FTP uses data connection. The default port number for data connection is 20. However, data connections are not always initiated on this port. Depending on the mode of operation, they may be initiated in other port numbers. For additional information, refer to [1.4 Operation Modes](#).

**Session:**

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 control information over this. When the server receives control information, it initiates a data connection to the client side. Only one file can be sent over one data connection. But the control connection remains active throughout the user session.

### 1.4 Operation Modes

FTP can operate in the following two modes, which determines how a data connection is established. In both cases, the control connection is established with an FTP server on port 21.

**Active Mode:** In Active mode, the server initiates the data channel connection. The sequence of connection is as follows:

- The client connects from a random port to port 21 on the FTP server. This is the control/command channel.
- Using the control connection, the client informs (through *PORT* command) the port number on which it is listening. This port will be used for the data channel.
- Server connects from port 20 to the client port designated for the data channel

Active mode is more secure for the server as it does not require unsecured ports to be open at the server end. It is the server that initiates the data connection to the client. However, it must be noted that Active mode is less secure for the clients.

Active mode may fail in cases where the client is behind a firewall as the firewall might block incoming server connections (for the data channel), if the random port of the server is not unblocked in the firewall.

**Passive Mode:** In passive mode, the client initiates the data channel connection.

- The client connects from a random port to port 21 on the FTP server. This is the control/command channel.
- Client issues the *PASV* command
- Server replies with a random port number for the data channel
- Client connects from a random port to the port number specified by the server

Passive mode is recommended for clients protected by a firewall, because no inbound connection requests to the client.

#### Modes based on Data Representation

FTP allows files to be transferred in several formats:

- ASCII mode: This mode is used for plain text files or ASCII-based files, such as an HTML file, text file, or PostScript. ASCII is the default transfer type.
- Binary mode: This mode is also known as Image mode, and it is used for transferring non-ASCII files, such as images, applications, and generated archive/cabinet files, such as .zip and .tar files. In this mode, the file is transferred without any conversion. This maintains an identical file structure on both machines. This is important for files such as pictures, music, and videos which must be exact copies to preserve integrity of the data.
- EBCDIC mode: This mode is used for plain text between hosts using the EBCDIC character set.

### 1.5 FTP Applications

FTP has a wide range of applications, which span from day-to-day business operations to data transfer from embedded systems. The following examples show some use cases:

- Organizations use FTP to allow employees to share files across different locations and branch offices.
- Employees use FTP to share files with coworkers and external business partners.
- IT teams use FTP to transfer data back to disaster recovery (DR) sites.
- Webmaster teams use FTP to transfer web pages, web application files, and images to their web server..
- Remote embedded systems use FTP to download application binary for firmware updates
- Retrieve log files stored in remotely operated MCUs and MPUs.

## 2. FTP in MPLAB Harmony v3

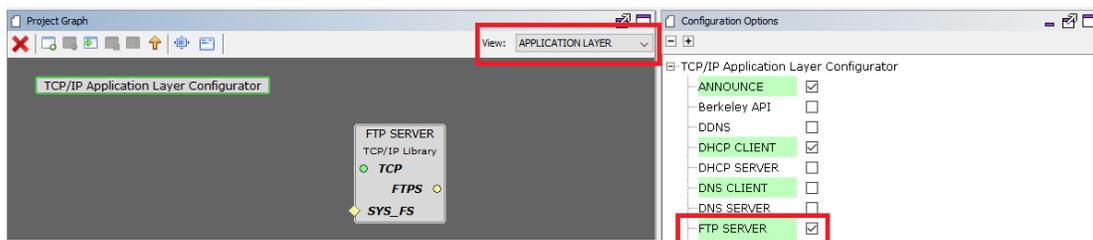
The TCP/IP stack library of [MPLAB Harmony v3](#) provides the API of the FTP module with a convenient 'C' language interface. It supports the FTP server and client, which facilitating the upload and download of files to an embedded client and server.

### 2.1 FTP Server Module

The interface to the FTP TCP/IP stack library is defined in the `ftp.h` header file. To use the FTP server in a project requires using the TCP/IP stack and a file system like FAT FS.

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

**Figure 2-1. Project Graph**



**Table 2-1. FTP Server Module Files**

File	Description
<code>ftp_config.h</code>	Configuration of the FTP server (from symbols generated in <code>configuration.h</code> )
<code>ftp.h</code>	Interface to the FTP server TCP/IP Stack library
<code>ftp.c</code>	Implementation of FTP server

Additional information on the FTP server module are found at [https://github.com/Microchip-MPLAB-Harmony/net/blob/master/doc/help\\_harmony\\_tcpip.pdf](https://github.com/Microchip-MPLAB-Harmony/net/blob/master/doc/help_harmony_tcpip.pdf).

### 2.2 FTP Client Module

The FTP client module enables transfer of data reliably and efficiently between different devices, without worrying about the different file storage systems among hosts.

**Table 2-2. FTP Client Module Files**

File	Description
<code>ftpc_config.h</code>	Configuration of the FTP Client (from symbols generated in <code>configuration.h</code> )
<code>ftpc.h</code>	Interface to the FTP client TCP/IP stack library
<code>ftpc.c</code>	Implementation of FTP client protocol

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

Table 2-3. 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_SetActiveMode 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 directory	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
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 the implementation of FTP commands, the client module provides a user interface through the USART terminal. This enables users to provide the required FTP command by entering into the terminal.

All FTP client commands start with the keyword 'ftpc', for example, *ftpc login <username> <pswd>* .

### 3. FTP Client: Bootloader Application

The following sections cover software and hardware required for this application, and it also covers overview of the application.

#### 3.1 Prerequisites

##### Hardware:

- SAM E70 Xplained Ultra evaluation kit – 1 No.
- SD card – 1 No.
- Ethernet cable (RJ45) – 1 No.
- USB cable – 1 No.

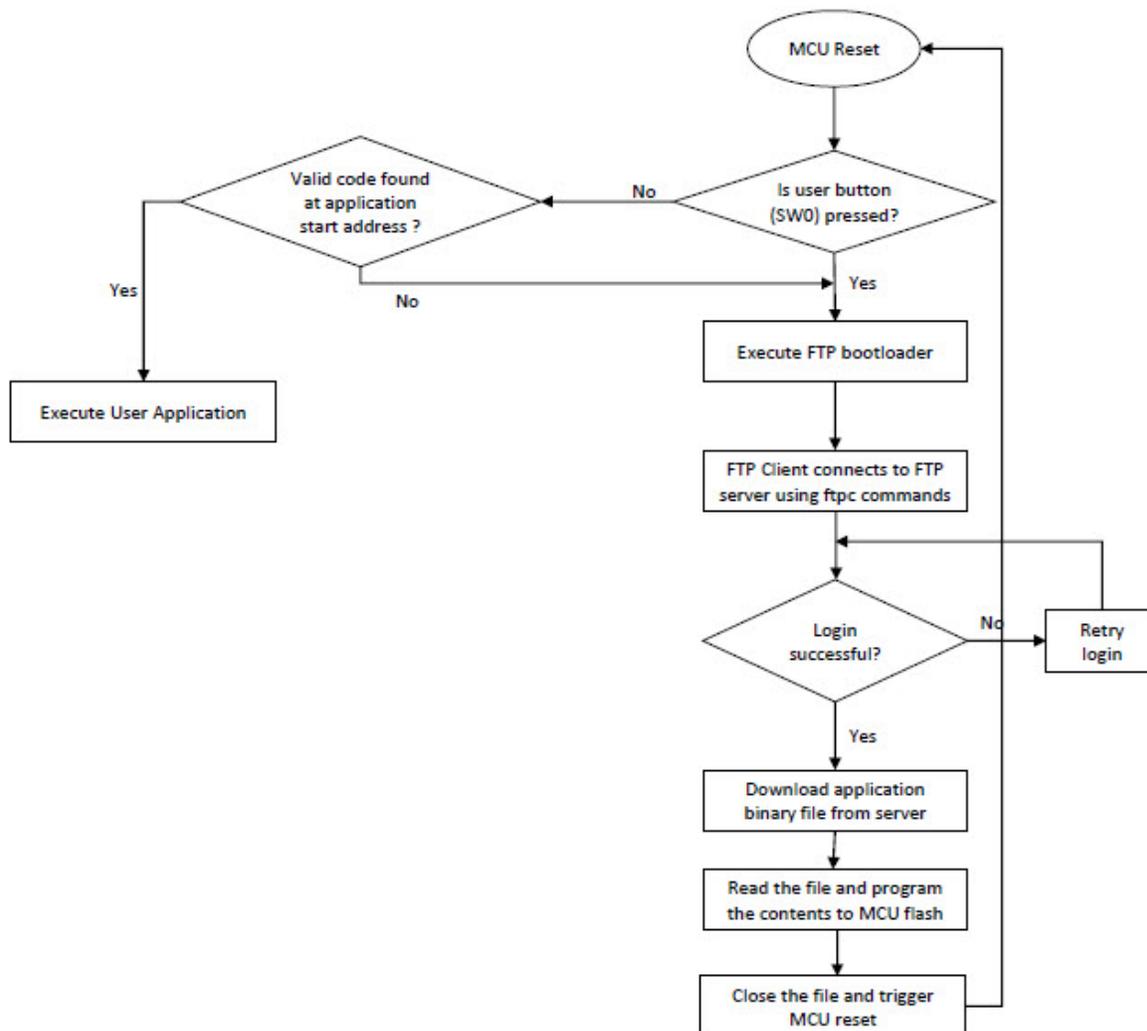
##### Software:

- MPLAB X IDE (v5.30)
- MPLAB XC32/32++ Compiler (v2.40)
- MPLAB Harmony Configurator (v3.4.0)
  - Harmony bsp repository, v3.5.0
  - Harmony csp repository, v3.5.2
  - Harmony core repository, v3.5.2
  - Harmony dev\_packs repository, 3.5.0
  - Harmony net repository v3.5.1

#### 3.2 Application Overview

This example demonstrates creating an application where an FTP client downloads a binary file from the FTP server, which in turn used to Flash the microcontroller. The FAT-FS File System with SDCARD as storage media is used in this application and the FTP client will write to and read from this FS.

Figure 3-1. Flow Diagram



### 3.2.1 Application Code

The user application for an FTP client must initiate the FTP connection request. Based on the server's response for the request, the username and password must be provided by the client for logging in. When the FTP client is successfully logged in, data can be transferred between the server and the client. In this application, the client downloads a binary file from the server and the downloaded file will be stored on an SD card. The binary is then flashed to the microcontroller.

The following code displays the application code for the FTP connection and login.

```

case APP_Connect_FTP:
    TCPIP_FTPC_Get_Status (ftpcHandle, &ftpcStatus);
    if (ftpcStatus.isConnected)
    {
        SYS_CONSOLE_MESSAGE ("FTP Client connected \r\n");
        appData.state = APP_Login_FTP;
        SYS_CONSOLE_MESSAGE ("Login with your credentials \r\nEg: ftpc login
        username psswd\r\n");
    }
    break;

case APP_Login_FTP:
    TCPIP_FTPC_Get_Status (ftpcHandle, &ftpcStatus);
    if (ftpcStatus.isLoggedIn)

```

```

{
    SYS_CONSOLE_MESSAGE ("FTP Client logged in \r\n");
    appData.state = APP_SET_CURRENT_DRIVE;
}
break;

```

### 3.2.2 Creating the Application

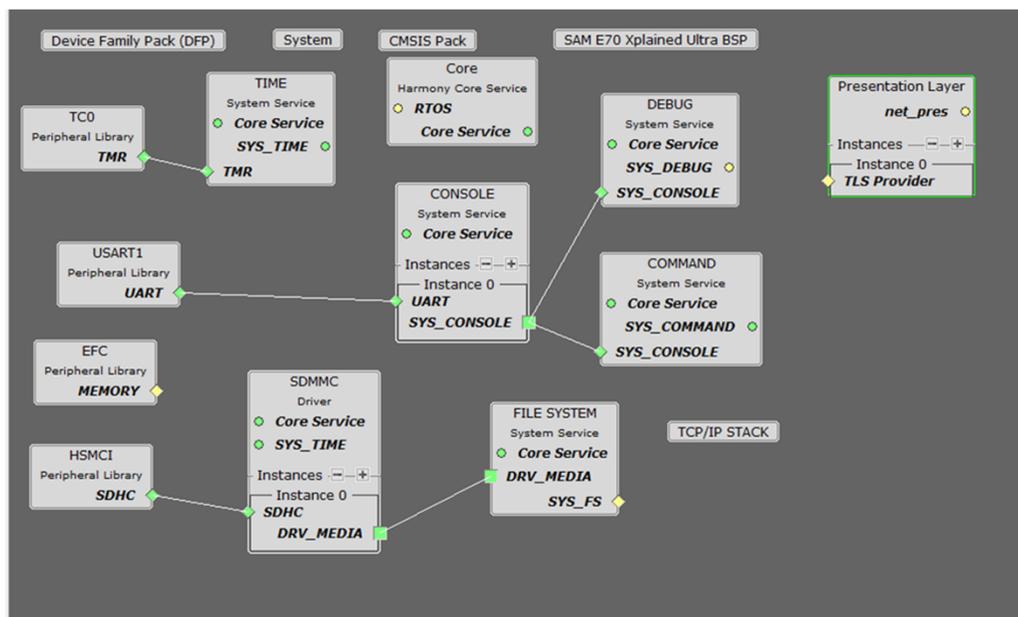
This application is created in MPLAB Harmony configurator as it provides an easy-to-use GUI that simplifies device setup, library selection, configuration and application development.

For additional information on the MHC, refer to <https://github.com/Microchip-MPLAB-Harmony/mhc/wiki>.

#### MPLAB Harmony Configuration

- To create a 32-bit MPLAB Harmony v3 project for the SAME70Q21B using MPLAB X IDE, refer to <https://microchipdeveloper.com/harmony3:same70-getting-started-training-module>
- By default, the Device Family Pack (DFP), System, CMSIS Pack and EFC will be present when the configuration is launched.
- For this demonstration, the Terminal communication, System service, File System, and TCP/IP features must be added.
- The harmony configuration file (.xml) with these components configured can be found in the source code of this application note (`ftp_bootloader\firmware\src\config\default\sam_e70_xult.xml`). Load this file from the MPLAB Harmony configurator: *MPLAB Harmony Configurator > File > Load State*.
- The following figure illustrates the complete project graph:

**Figure 3-2. Complete Project Graph**

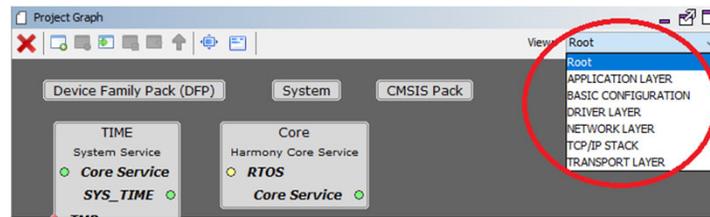


- Because this document focuses on FTP, the TCP/IP related configurations are highlighted below:

#### TCP/IP Harmony configuration

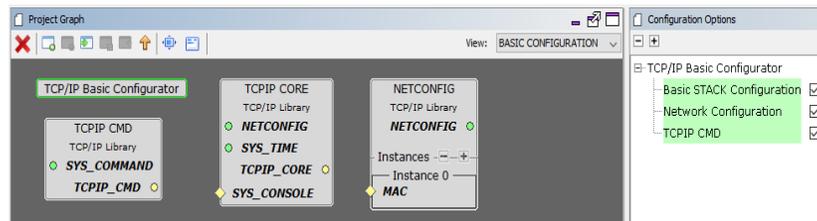
- For TCP/IP Basic Configurator, follow these steps:
  1. Adding the TCP/IP Basic Configurator will create a BASIC CONFIGURATION view. Different views can be selected as shown in the following figure.

Figure 3-3. Selecting Views



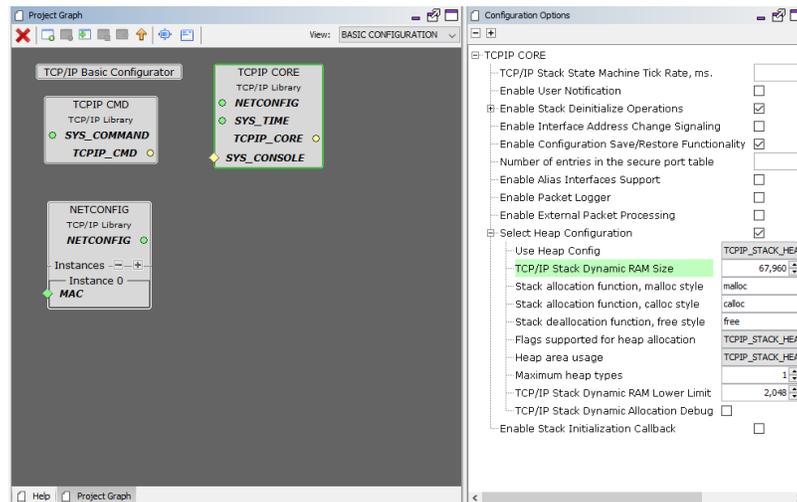
2. In the Basic Configurator view, TCPIP CMD, TCPIP CORE and NETCONFIG components are enabled.

Figure 3-4. Basic Configurator View



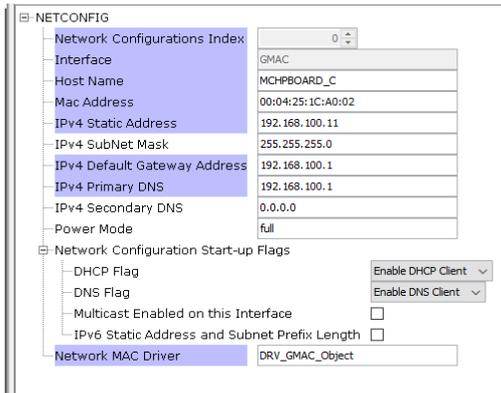
3. In the TCP/IP CORE configuration options, the TCP/IP Stack Dynamic RAM Size can be adjusted per the application requirement. For this example the RAM allocated is 67,960 bytes (66 KB).

Figure 3-5. Configuration Options



4. In NETCONFIG options, the necessary network details, such as IP address and gateway address are configured:

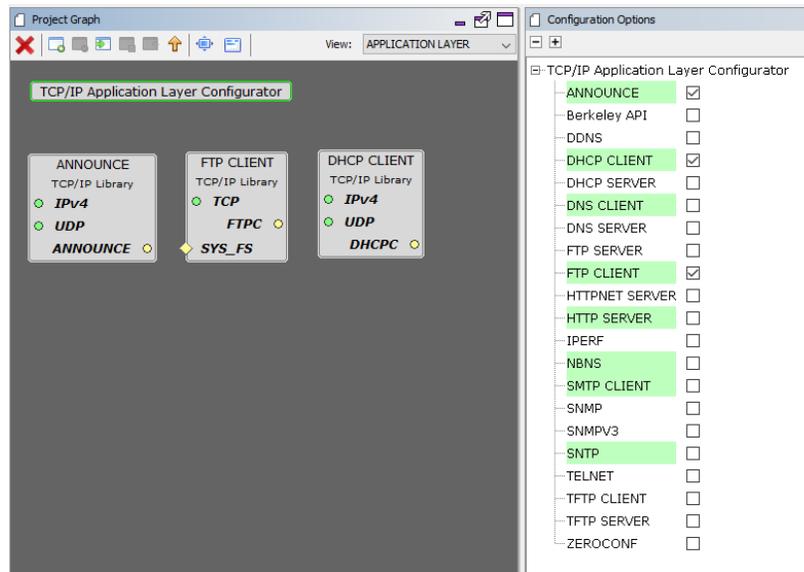
Figure 3-6. NETCONFIG Options



– TCP/IP Application Layer Configurator

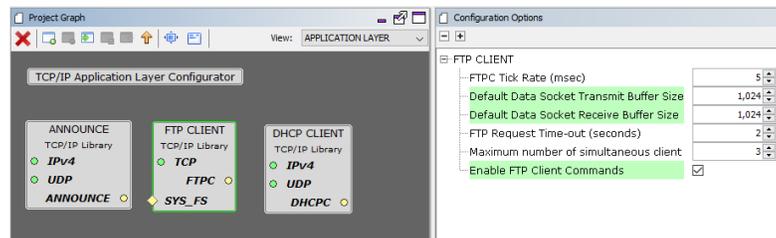
1. In the APPLICATION LAYER view, the TCP/IP Application Layer Configurator is used to enable ANNOUNCE, FTP CLIENT and DHCP CLIENT components. The ANNOUNCE module facilitates device discovery on the DHCP-enabled networks, while the DHCP CLIENT module allows the application to dynamically obtain an IP address from a DHCP server on the network.

Figure 3-7. APPLICATION LAYER View



2. In the FTP CLIENT configuration, the Enable FTP Client Commands option allows users to interact with the FTP client through a serial terminal. Transmit and receive buffer size can be increased as required (that is, 1,024).

Figure 3-8. FTP CLIENT Configuration



### 3.3 Running the Application

#### 3.3.1 Hardware Setup

Follow these steps to setup the hardware:

1. Ensure that the ERASE jumper is open.
2. Open the J805 Jumper..
3. Insert the LAN8740 PHY daughter board on the ETHERNET PHY MODULE header.
4. Connect the micro-USB cable from the computer to the DEBUG USB connector on the SAM E70 Xplained Ultra Evaluation Kit.
5. Establish a connection between the router/switch with the SAM E70 Xplained Ultra Evaluation Kit through the RJ45 connector. An IP address will be assigned to the kit by the DHCP server on the network. The kit can also be connected to the RJ45 port on the PC, hence a DHCP server may be unavailable and a pre-configured static IP address will be used by the kit.
6. Insert the SD card to the SD card slot on the backside of the hardware board.

#### 3.3.2 Programming the MCU

Follow these steps to program the MCU:

1. Open the project in MPLAB X IDE: (*File > Open Project*, and then browse to `ftp_bootloader\firmware\sam_e70_xult.X`).
2. Build and program the project to the target board by clicking  (Make and Program device icon).

#### 3.3.3 Setting up FTP Server

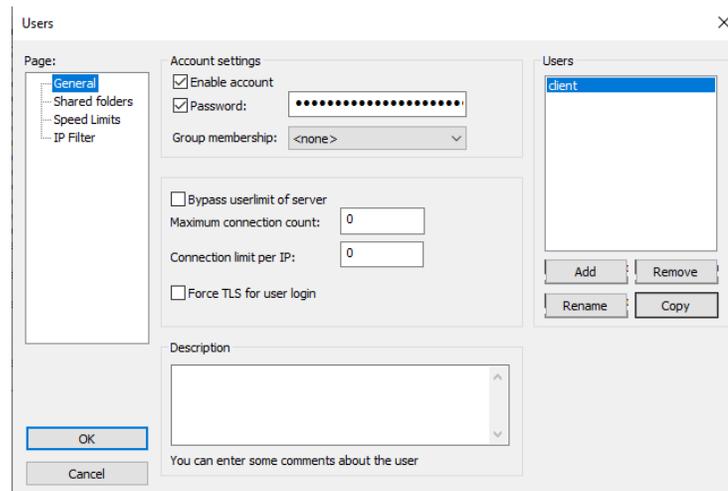
Before running the FTP client application, users need to follow these steps to setup the FTP server.

For this demonstration, the FileZilla Server Interface is used as the FTP server running on the user PC. Refer to <https://wiki.filezilla-project.org/Documentation> for additional information.

Follow these steps to setup FileZilla server::

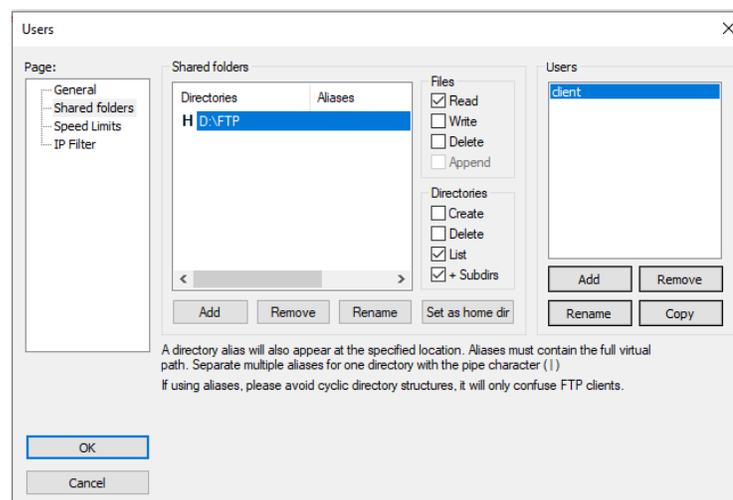
1. Open the FileZilla server interface.
2. In the pop-up window, enter a hostname, port, and password for the admin interface.
3. Click **Connect**.
4. Click  (user icon), or go to *Edit > User* for adding the client.
5. In the User window, click **General**. Add the client by clicking **Add**, and then enable the account and password. This will be the user name and password for connecting from the FTP client.

Figure 3-9. User Window



- In the Shared folders section, add the path of the folder where the binary to be downloaded is located.

Figure 3-10. Adding the Path



### 3.3.4 Connecting FTP Client

Follow these steps to connect the FTP client:

- From a terminal window application (ITera Term), connect to the COM port enumerated by the SAM E70 Xplained Ultra board.
- Restart the application (that is, reset the SAM E70 board).
- The IP address will be displayed on the terminal after it is ready, the user can connect to the FTP server by typing: `ftpc connect <host ip address>`.
- Upon successful connection, enter the login details: `ftpc login <username> <password>`.
- Once logged in, use the following `ftpc` to get the command to download a binary from the server: `ftpc get -a -a <test.bin>`.  
**Note:** Refer to the section [Appendix](#) for steps to generate a binary file.
- After the binary is successfully downloaded, it can be flashed to the MCU by using the boot command.

**Note:** This project is configured for a maximum binary file size of 7 KB. For binary files larger than this, increase APP\_DATA\_LEN macro in app.c file of the ftp\_bootloader project. If the binary file is larger than available RAM, the file can be read in chunks (instead of reading complete file into buffer) and programmed.

7. The MCU is reset automatically after the programming is complete, and the application code starts executing. Displaying the message: \*\*\*\* Executing Application code \*\*\*\*.

Figure 3-11. Output:

```

COM36 - Tera Term VT
File Edit Setup Control Window Help
TCP/IP Stack: Initialization Started
TCP/IP Stack: Initialization Ended - success
SYS_initialize: The FATFS File System is mounted
Interface GMAC on host MCHPBOARD_C - NBNS disabled
GMAC IP Address:192.168.100.11
Connect to FTP server using ftpc commands
Eg: ftpc connect 10.40.32.94

>ftpc connect 192.168.100.11
>220-FileZilla Server 0.9.60 beta
220-written by Tim Kosse <tim.kosse@filezilla-project.org>
220 Please visit https://filezilla-project.org/
Length = 143

Command Success
FTP Client connected
Login with your credentials
Eg: ftpc login username pswd

>ftpc login client Microchip
FIPC - Command Started
>USER client
Length = 13

331 Password required for client
Length = 34

PASS Microchip
Length = 16

230 Logged on
Length = 15

Command Success
FTP Client logged in
Use ftpc get command to download binary
Eg: ftpc get -a -a test.bin
Enter command 'boot' after receiving 'Command Success' message

>ftpc get -a -a test.bin
TYPE A
Length = 8

FIPC - Command Started
>200 Type set to A
Length = 19

PORT 10,40,32,34,229,43
Length = 25

200 Port command successful
Length = 29

RETR test.bin
Length = 15

150 Opening data channel for file download from server of "/test.bin"
Length = 71

Rx Data Len: 1024
Rx Data Len: 462
226 Successfully transferred "/test.bin"
Length = 42

Buffer Count: 2

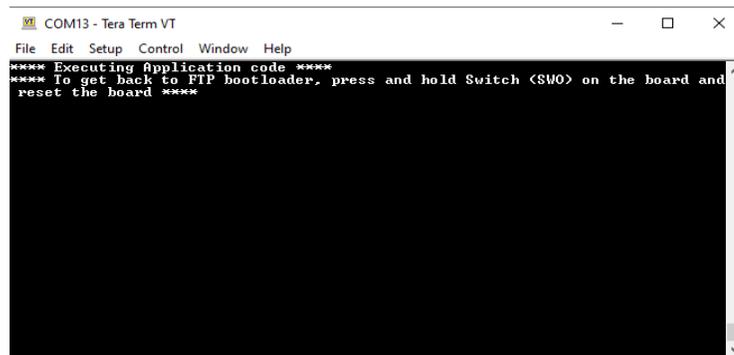
Command Success

>boot
>Opening test.bin ...
Resetting MCU to run application in 2

```

After the MCU reset, the following message is displayed, indicating that the MCU has been reprogrammed with a new application binary.

Figure 3-12.



The image shows a screenshot of a terminal window titled "COM13 - Tera Term VT". The window has a menu bar with "File", "Edit", "Setup", "Control", "Window", and "Help". The terminal output displays the following text:

```
**** Executing Application code ****  
**** To get back to FIP bootloader, press and hold Switch <SW0> on the board and  
reset the board ****
```

## **4. Troubleshooting**

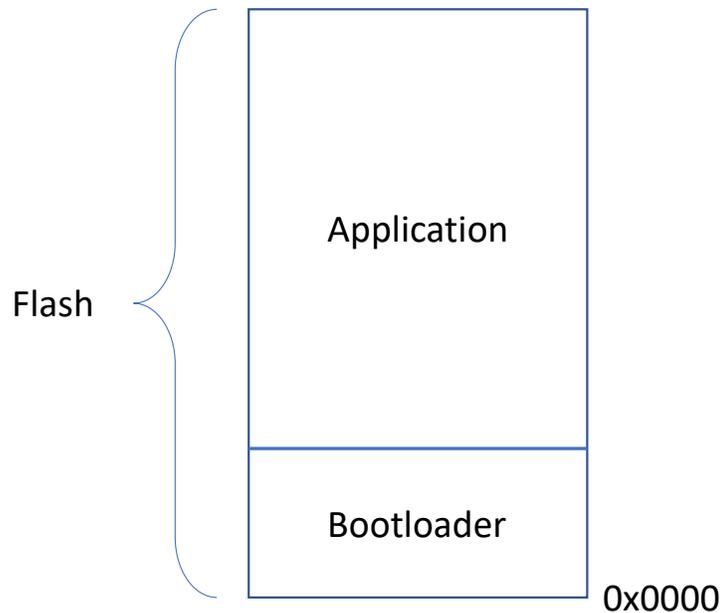
This section covers important error messages and appropriate workaround for that.

- “FTP timed out” - Server response time can be affected by the distance between the sites. If you see this message when connecting to a server, increase the Connect Timeout setting to give the server more time to respond during the login process.
- “Cannot open data connection” - If this error is encountered in a Windows system with the Firewall enabled, it may be due to the firewall blocking the connection on the corresponding FTP data port. Try disabling the firewall temporarily and see if the FTP connection succeeds. If the connection is successful with the firewall disabled, users can configure the firewall to allow the required port and enable it.
- Client unable to connect using PASV (passive) mode - Ensure that the server is configured to accept passive connection. For example, in the FileZilla server the passive mode can be enabled by disabling Active mode:  
*FileZilla Server > Server > Active.*

## 5. Appendix

### 5.1 Generating Application Binary Files

In general, for implementation where the bootloader is available in Flash, bootloaders are present at the base (starting) address of the Flash memory. The application is loaded to the memory in Flash, which is beyond the bootloader.



To generate the binary file of an application project in MPLAB X IDE, perform these actions:

1. Modify Application Start Address.
2. Execute the post build command to generate the bin file.

#### 5.1.1 Modifying Application Start Address

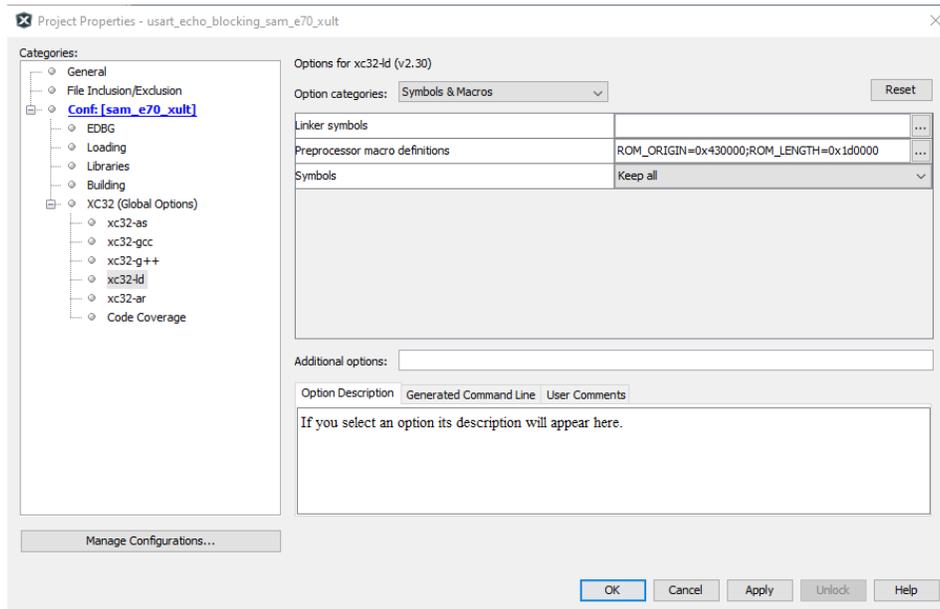
The application start address must be modified to generate a bin file starting from the desired memory location, beyond the memories taken by the bootloader.

To change the application start address, go to *Project Properties* > *xc32-ld* > *Option categories: Symbols & Macros*.

Users need to define the following macros:

- ROM\_ORIGIN=0x430000
- ROM\_LENGTH=0x1d0000

Figure 5-1. Project Properties



ROM Origin can be given as any address value which is beyond the size of the bootloader. ROM length can be the size of the memory available from ROM origin to the end of the memory.

### 5.1.2 Generating Binary File

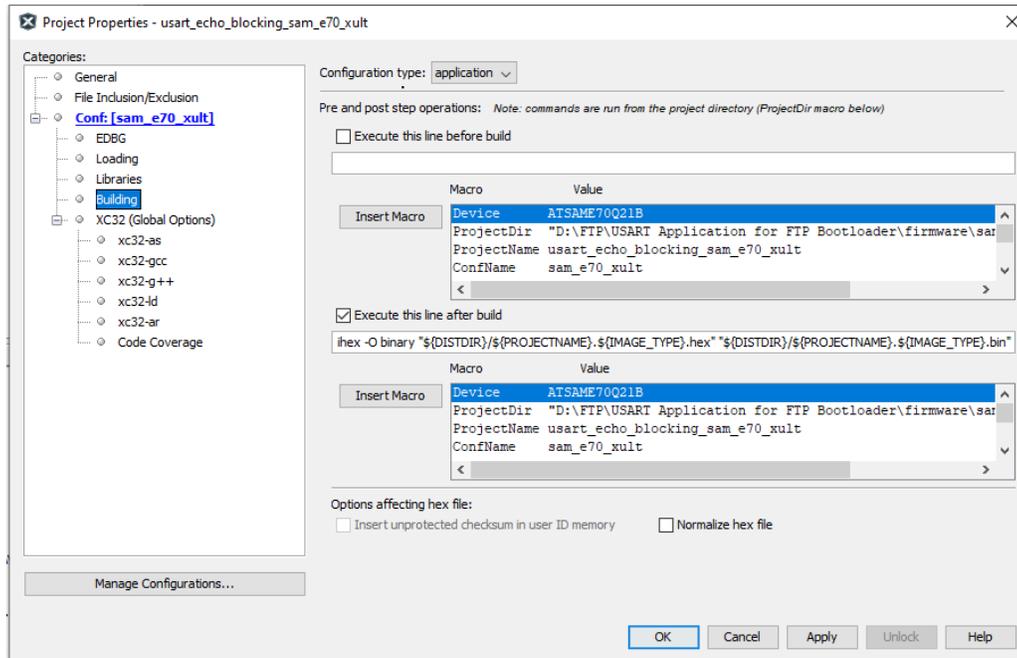
To generate the binary file follow these steps:

1. Go to *Project Properties* > *Building*.
2. Enable the “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 5-2. Generating Binary File

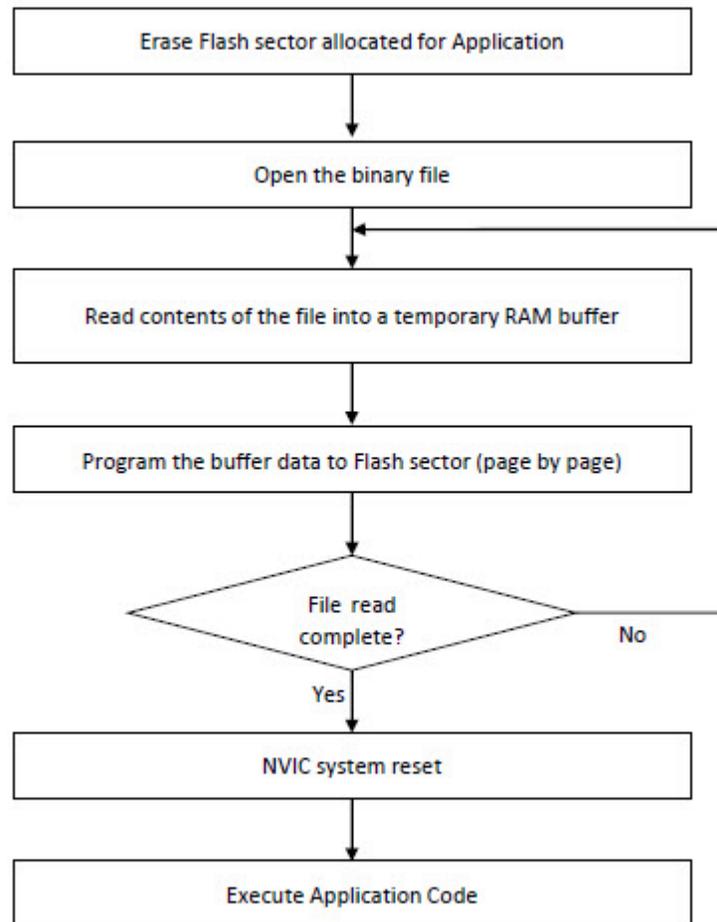


Building the project. The bin file output can be found in the following path: `<your_project>.\X\dist\<config_name>\production\`

## 5.2 Self-Programming of Downloaded Binary

Users can download the desired application binary from any FTP server 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.

**Figure 5-3. Programming Binary Flow Chart**



Implementation of erasing and programming the Flash sector can be found in the `APP_Flash_Task()` function in the source code of this application.

**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 application

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

## 6. References

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- How to Setup MPLAB Harmony v3 Software Development Framework:  
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- How to create first TCP/IP application: <https://github.com/Microchip-MPLAB-Harmony/net/wiki/Create-your-first-tcpip-ppllication>.
- MPLAB Harmony v2 to MPLAB Harmony v3 TCP/IP Application Migration Guide: <https://github.com/Microchip-MPLAB-Harmony/net/wiki/H2-to-H3-Migration>.

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