

Embedded Systems

CS 397

TRIMESTER 3, AY 2021/22

Hands-On 4-1

Ethernet – LwIP TCP Echo Client

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Hands-On LwIP TCP Echo Client

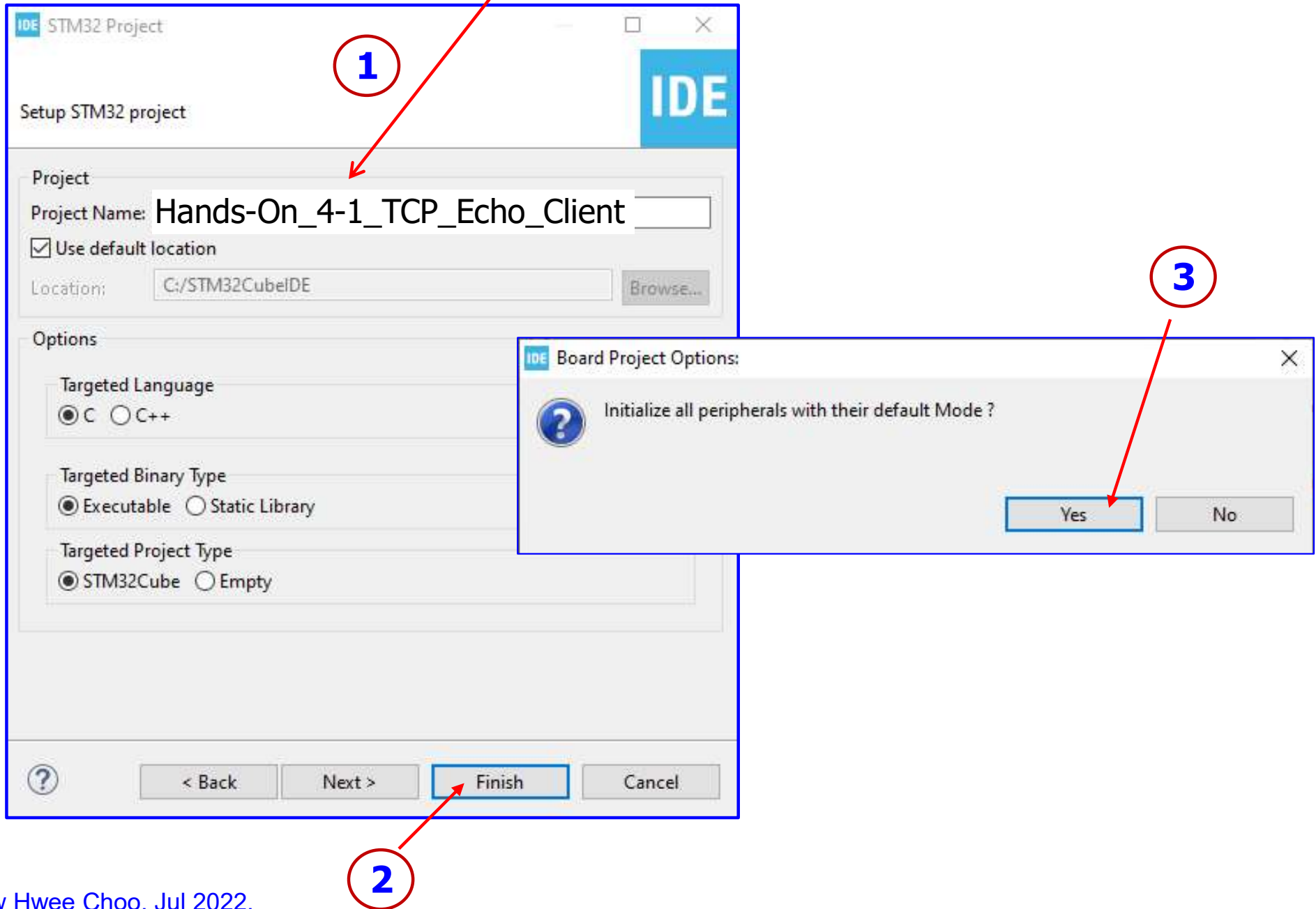
Objectives

The aims of this hands-on session are to

- implement a STM32 (STM32CubeIDE) project
- set up the Ethernet – LwIP TCP Echo Client application using STM32F767 microcontroller
- configure and program the Ethernet peripheral to make the microcontroller as a TCP echo client for communicating with a server
- test the developed program using the echotool.exe software
- build up the knowledge of Ethernet application development
 - Run [STM32CubeIDE](#)
 - [Select workspace: C:\STM32_CS397](#)
 - [File -> Close All Editors](#)
 - Start a [New STM32 Project](#)
 - Select the [Nucleo-F767ZI Board](#)

Hands-On LwIP TCP Echo Client

Enter Project Name: Hands-On_4-1_TCP_Echo_Client

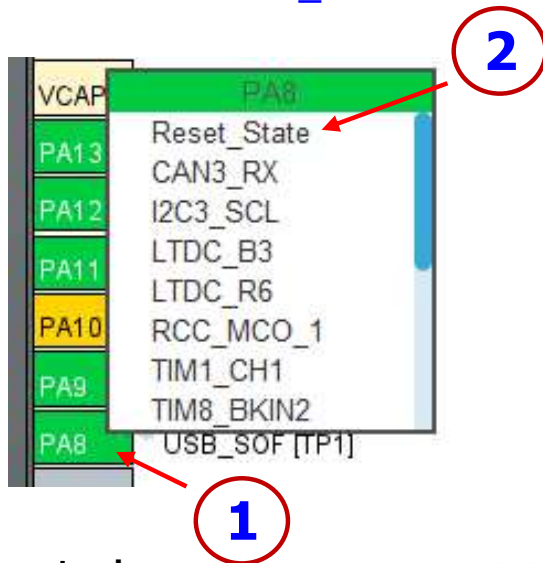


Hands-On LwIP TCP Echo Client

Reset Unused Pins

For example, PA8 is reset by

- left-click on the pin PA8, and
- select "Reset_State"

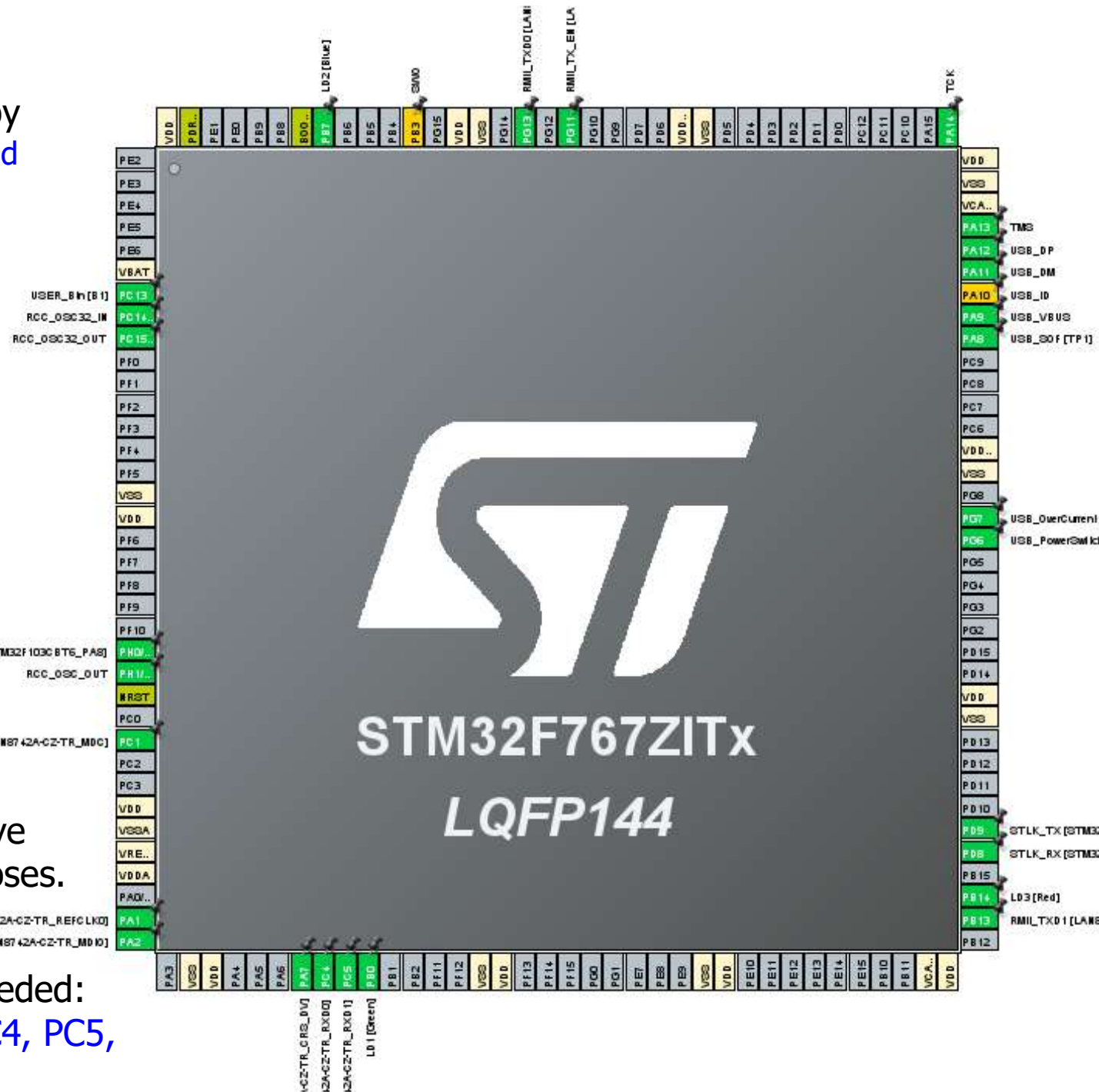


Reset pins:

- USB related:
PA8, PA9, PA10, PA11,
PA12, PG6, & PG7.

Note that do not use the above pins for other functions/purposes.

Note: ETH (RMII) pins are needed:
PA1, PA2, PA7, PB13, PC1, PC4, PC5,
PG11, & PG13.

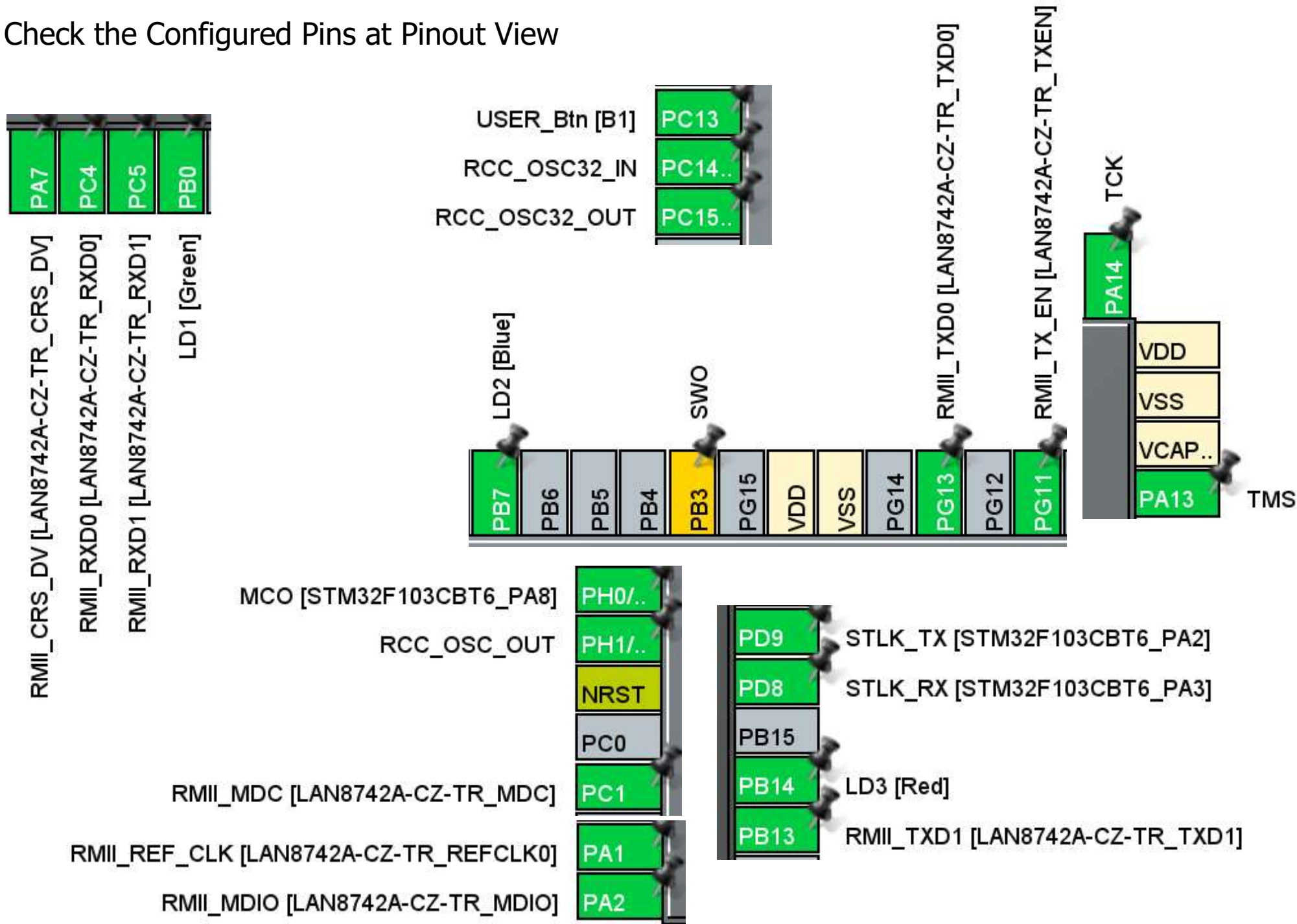


Check the Configured Pins at Pinout View



Hands-On LwIP TCP Echo Client

Check the Configured Pins at Pinout View

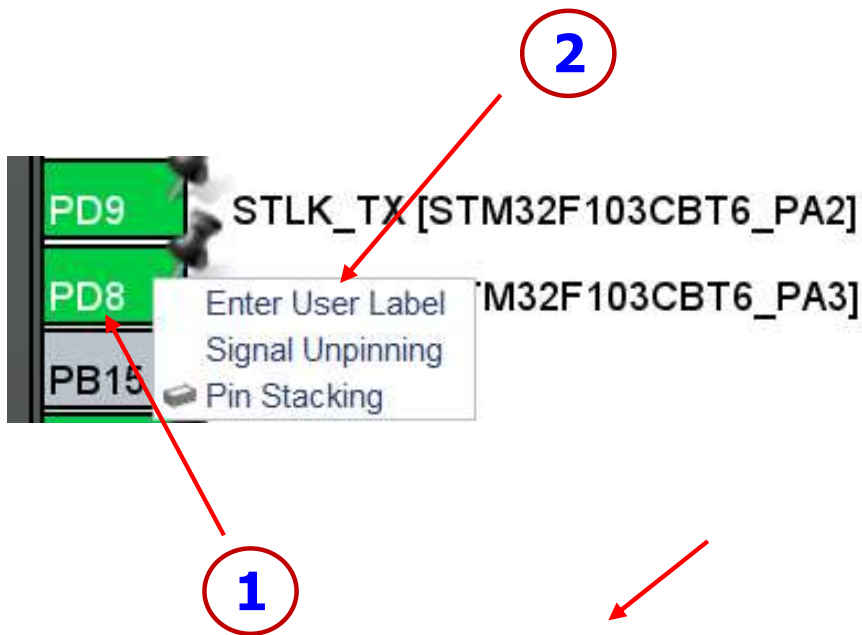


Hands-On LwIP TCP Echo Client

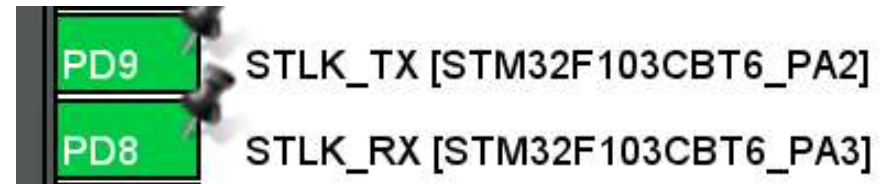
Rename PD8 and PD9 for USART3

For example, the pin PD8 can be renamed by

1. Right-click on the pin PD8, and
2. Select "Enter User Label"



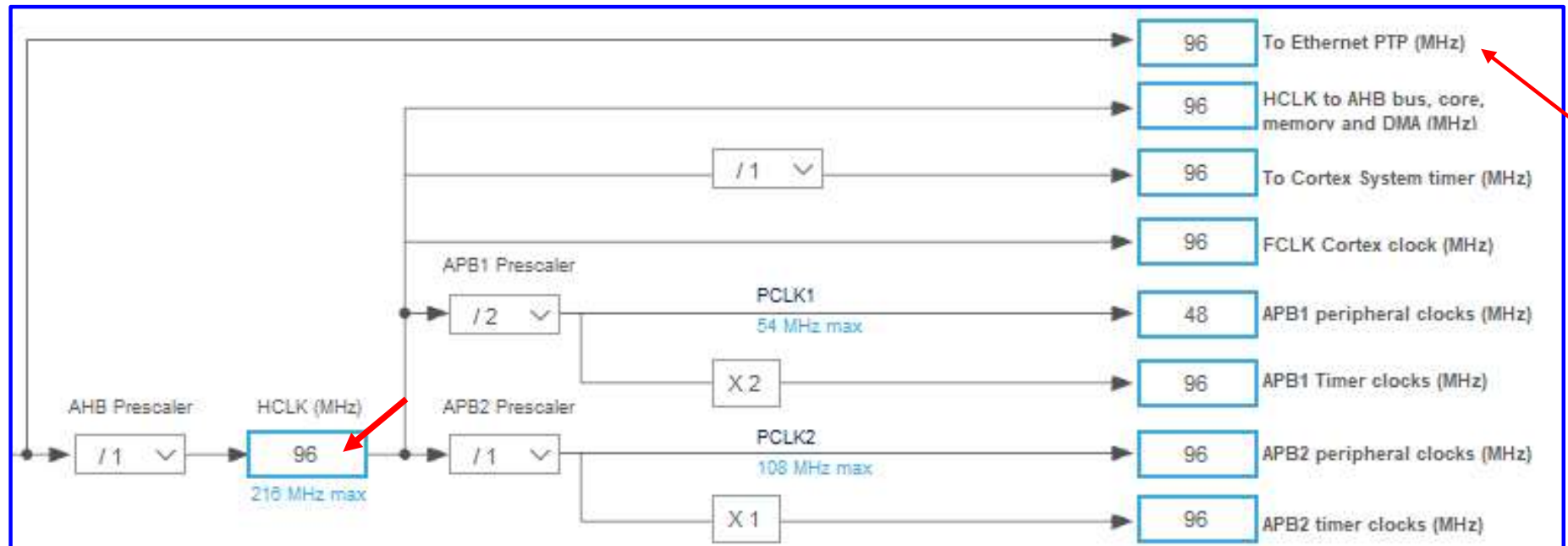
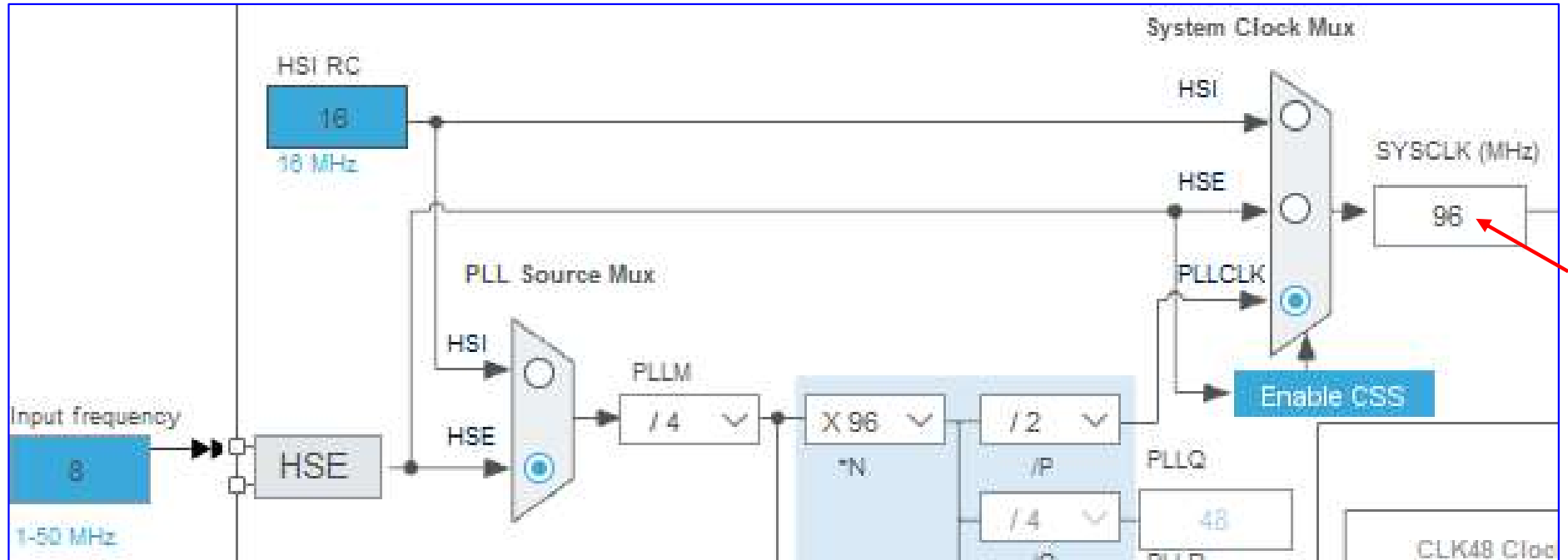
PD9: DBG_USART3_RX
PD8: DBG_USART3_TX



Note: Ctrl-c and Ctrl-v can be used to cut & paste the pin names.

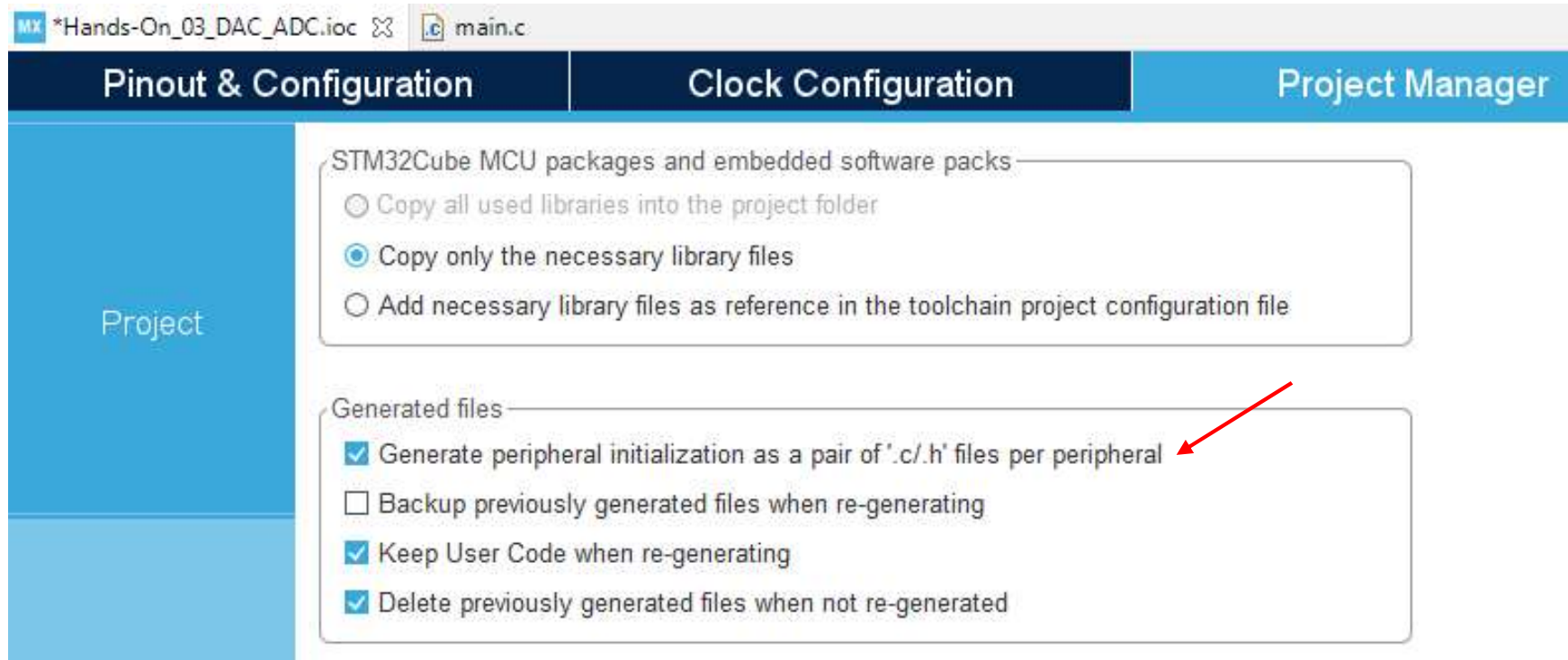
Hands-On LwIP TCP Echo Client

Clock Configuration: Use Default Settings



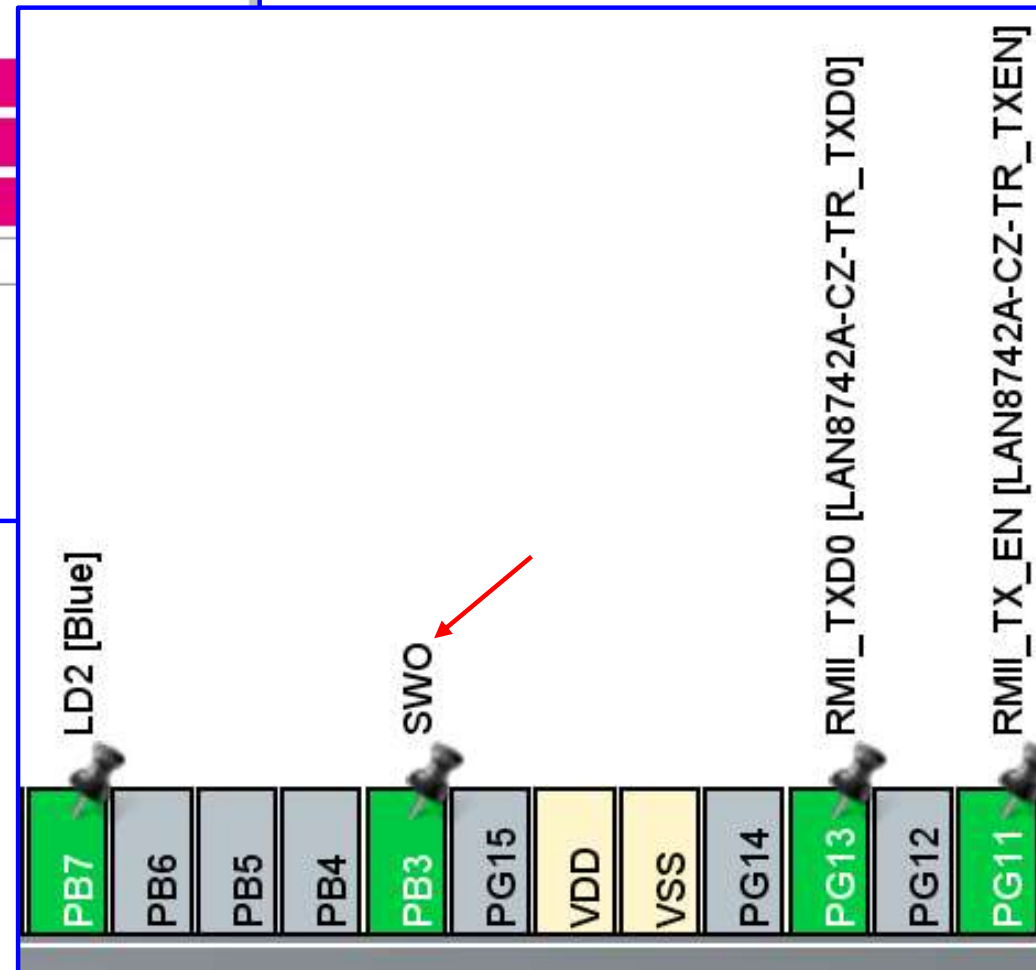
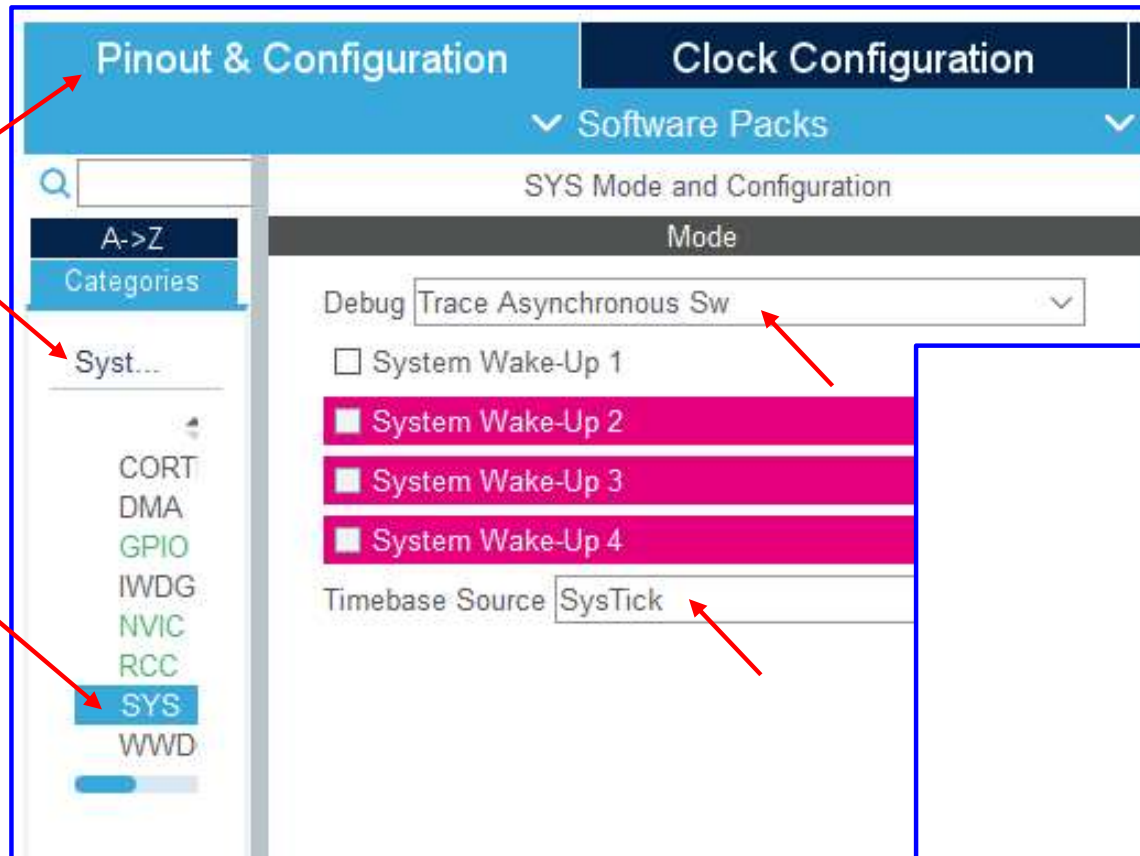
Hands-On LwIP TCP Echo Client

- Keep default settings for LD1 [Green], LD2 [Blue], LD3 [Red], USER_Btn [B1], & USART3
- Enable Interrupt for EXTI line[15:10] for USER_Btn [B1]
- Set Project Manager – Generate ... a pair of '.c/.h' files per peripheral



Hands-On LwIP TCP Echo Client

Pinout & Configuration



Hands-On LwIP TCP Echo Client

Ethernet (ETH) Configuration: select ETH, RMII Mode, enter MAC Address

Pinout & Configuration | Clock Configuration | Project Manager

Software Packs | Pinout

ETH Mode and Configuration

Mode: RMII

☐ Activate Rx Err signal

Configuration

Reset Configuration

Parameter Settings | User Constants | NVIC Settings | GPIO Settings

Configure the below parameters :

Search (Ctrl+F)

General : Ethernet Configuration

Warning: The ETH can work only when RAM is pointing at 0x24000000

Parameter	Value
Ethernet MAC Address	02:80:E1:00:00:FF
Tx Descriptor Length	4
First Tx Descriptor Address	0x2007c0a0
Rx Descriptor Length	4
First Rx Descriptor Address	0x2007c000
Rx Buffers Length	1524
Rx Mode	Polling Mode

SN -> XX
01 -> A1
02 -> A2
03 -> A3
04 -> A4
05 -> A5
06 -> A6
07 -> A7
08 -> A8
09 -> A9
10 -> AA
11 -> B1
12 -> B2
13 -> B3
14 -> B4
15 -> B5
16 -> B6
17 -> B7
18 -> B8
19 -> B9

Enter Ethernet MAC Address: 02 : 80 : E1 : 00 : 00 : XX
XX is based on student SN: XX = A1, A2, A3, ..., B9

Hands-On LwIP TCP Echo Client

Ethernet (ETH) Configuration: GPIO Settings (Default)

Pinout & Configuration

Clock Configuration

Project Manager

To

Software PacksPinout

Q

CategoriesA-Z

Analog>

Timers>

Connectivity

CAN1

CAN2

CAN3

⚠ ETH

FMC

I2C1

I2C2

I2C3

I2C4

MDIOS

QUADSPI

SDMMC1

⚠ SDMMC2

SPI1

SPI2

SPI3

SPI4

SPI5

SPI6

UART4

ETH Mode and Configuration

Mode

ModeRMII

☐ Activate Rx Err signal

Configuration

Reset Configuration

✔ Parameter Settings

✔ User Constants

✔ NVIC Settings

✔ GPIO Settings

Search Signals

Search (Ctrl+F)

☐ Show only Modified Pins

Pin Name	Signal on Pin	GPIO out...	GPIO mode	GPIO Pull-up/Pull-d...	Maximum ...	Fa...	User Label	
PA1	ETH_REF_CLK	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_REF_CLK [LAN8742A-C...	✔
PA2	ETH_MDIO	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_MDIO [LAN8742A-CZ-TR...	✔
PA7	ETH_CRS_DV	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_CRS_DV [LAN8742A-CZ...	✔
PB13	ETH_TXD1	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_TXD1 [LAN8742A-CZ-TR...	✔
PC1	ETH_MDC	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_MDC [LAN8742A-CZ-TR...	✔
PC4	ETH_RXD0	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_RXD0 [LAN8742A-CZ-TR...	✔
PC5	ETH_RXD1	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_RXD1 [LAN8742A-CZ-TR...	✔
PG11	ETH_TX_EN	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_TX_EN [LAN8742A-CZ-T...	✔
PG13	ETH_TXD0	n/a	Alternate Func...	No pull-up and no p...	Very High	n/a	RMII_TXD0 [LAN8742A-CZ-TR...	✔

Hands-On LwIP TCP Echo Client

Select Middleware – LWIP, Enabled, Disabled DHCP and enter IP Address Settings

The screenshot shows the STM32CubeMX Pinout & Configuration window. The left sidebar has a red arrow pointing to the 'Middleware' category, and another red arrow pointing to the 'LWIP' option, which is checked. The main window has a red arrow pointing to the 'Enabled' checkbox under the 'Mode' section. Another red arrow points to the 'General Settings' tab. The 'Configuration' section shows various settings, with red arrows pointing to 'LWIP Version' (2.1.2), 'IPv4 - DHCP Options' (Disabled), 'IP Address Settings' (IP_ADDRESS: 192.168.050.205, NETMASK_ADDRESS: 255.255.255.000, GATEWAY_ADDRESS: 192.168.050.001), 'RTOS Dependency' (WITH_RTOS: Disabled, RTOS_USE_NEWLIB_REENTRANT: Disabled), 'Platform Settings' (PHY Driver: Choose/LAN8742/DP83848), and 'Protocols Options' (LWIP_ICMP: Enabled, LWIP_IGMP: Disabled, LWIP_DNS: Disabled, LWIP_UDP: Enabled, MEMP_NUM_UDP_PCB: 4, LWIP_TCP: Enabled, MEMP_NUM_TCP_PCB: 5).

Need to enter:

- IP address
- Netmask address
- Gateway address

192.168.1.205
255.255.255.0
192.168.1.1

192.168.50.205
255.255.255.0
192.168.50.1

For different router (gateway):

Hands-On LwIP TCP Echo Client

Middleware – enter Platform Settings

The screenshot shows the 'Pinout & Configuration' tab in a software development environment. The left sidebar contains a search bar and a list of categories: System Core, Analog, Timers, Connectivity, Multimedia, Security, Computing, and Middleware. The 'Middleware' category is expanded, showing options like FATFS, FREERTOS, LIBJPEG, LWIP (selected), and MBEDTLS. The main area is titled 'LWIP Mode and Configuration'. It has a 'Mode' section with a checkbox for 'Enabled'. Below this is a 'Configuration' section with a 'Reset Configuration' button and a grid of settings: Checksum, Debug, User Constants, Platform Settings (highlighted with a red arrow), SNTP/SMTP, MDNS/TFTP, Perf/Checks, Statistics, General Settings, Key Options, PPP, IPv6, HTTPD, and SNMP. At the bottom, the 'Platform proposal' section shows a table with columns: Name, IPs or Components, Found Solutions, and BSP API. The table contains one row for 'Driver_PHY' with 'LAN8742' selected in both the 'IPs or Components' and 'Found Solutions' columns (indicated by red arrows), and 'BSP_COMPONENT_DRIVER' in the 'BSP API' column.

Name	IPs or Components	Found Solutions	BSP API
Driver_PHY	LAN8742	LAN8742	BSP_COMPONENT_DRIVER

Hands-On LwIP TCP Echo Client

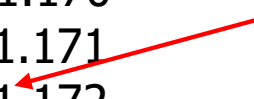
MAC and IP Addresses

Enter Ethernet MAC Address: 02 : 80 : E1 : 00 : 00 : XX

XX is based on student serial number: XX = A1, A2, A3, ..., B9

SN	- -	XX	- -	IP
01	- -	A1	- -	192.168.1.161
02	- -	A2	- -	192.168.1.162
03	- -	A3	- -	192.168.1.163
04	- -	A4	- -	192.168.1.164
05	- -	A5	- -	192.168.1.165
06	- -	A6	- -	192.168.1.166
07	- -	A7	- -	192.168.1.167
08	- -	A8	- -	192.168.1.168
09	- -	A9	- -	192.168.1.169
10	- -	AA	- -	192.168.1.170
11	- -	B1	- -	192.168.1.171
12	- -	B2	- -	192.168.1.172
13	- -	B3	- -	192.168.1.173
14	- -	B4	- -	192.168.1.174
15	- -	B5	- -	192.168.1.175
16	- -	B6	- -	192.168.1.176
17	- -	B7	- -	192.168.1.177
18	- -	B8	- -	192.168.1.178
19	- -	B9	- -	192.168.1.179

50 [For different
router (gateway)]



Hands-On LwIP TCP Echo Client

Note: Dynamic address allocation "DHCP" is also possible; however, you need to find the IP address if needed.

The screenshot shows the STM32CubeMX Pinout & Configuration tab. The left sidebar lists various categories: System Core, Analog, Timers, Connectivity, Multimedia, Security, Computing, and Middleware. The 'LWIP' option is selected under the 'Middleware' category. The main area displays the 'LWIP Mode and Configuration' settings. The 'Mode' section shows 'Enabled' with a checked checkbox. The 'Configuration' section includes a 'Reset Configuration' button and a grid of configuration options, all of which are checked: Checksum, Debug, User Constants, Platform Settings, SNTP/SMTP, MDNS/TFTP, Perf/Checks, Statistics, General Settings, Key Options, PPP, IPv6, HTTPD, and SNMP. Below this grid, a section titled 'Configure the below parameters :' lists several parameters with their current values: 'LwIP Version' is 2.1.2; 'IPv4 - DHCP Options' shows 'LWIP_DHCP (DHCP Module)' is 'Enabled' (highlighted with a red arrow); 'RTOS Dependency' shows 'WITH_RTOS (Use FREERTOS ** CubeM...' is 'Disabled' and 'RTOS_USE_NEWLIB_REENTRANT (No ...' is 'Disabled'; 'Platform Settings' shows 'PHY Driver' is 'Choose/LAN8742/DP83848'; and 'Protocols Options' shows 'LWIP_ICMP (ICMP Module Activation)' is 'Enabled'.

Category	Sub-category	Parameter	Value	
Middleware	LWIP	Mode	Enabled	
		Configuration	Checksum	Enabled
			Debug	Enabled
			User Constants	Enabled
			Platform Settings	Enabled
			SNTP/SMTP	Enabled
			MDNS/TFTP	Enabled
			Perf/Checks	Enabled
			Statistics	Enabled
			General Settings	Enabled
			Key Options	Enabled
			PPP	Enabled
			IPv6	Enabled
			HTTPD	Enabled
			SNMP	Enabled
Configure the below parameters :				
LwIP Version	LwIP Version (Version of LwIP supported ...	2.1.2		
IPv4 - DHCP Options	LWIP_DHCP (DHCP Module)	Enabled		
RTOS Dependency	WITH_RTOS (Use FREERTOS ** CubeM...	Disabled		
	RTOS_USE_NEWLIB_REENTRANT (No ...	Disabled		
Platform Settings	PHY Driver	Choose/LAN8742/DP83848		
Protocols Options	LWIP_ICMP (ICMP Module Activation)	Enabled		

File Edit Source Refactor Navigate Search Project Run Window Help

Project Explorer X

- Hands-On_4-1_TCP_Echo_Client
 - Binaries
 - Includes
 - Core
 - Inc
 - gpio.h
 - main.h
 - stm32f7xx_hal_conf.h
 - stm32f7xx_it.h
 - usart.h
 - Src
 - gpio.c
 - main.c
 - stm32f7xx_hal_msp.c
 - stm32f7xx_it.c
 - syscalls.c
 - systemem.c
 - system_stm32f7xx.c
 - usart.c
 - Startup
 - Drivers
 - CMSIS
 - STM32F7xx_HAL_Driver
 - LWIP
 - App
 - lwip.c
 - lwip.h
 - Target
 - ethernetif.c
 - ethernetif.h
 - lwipopts.h
 - Middlewares
 - Debug
 - Hands-On_4-1_TCP_Echo_Client.ioc
 - Hands-On_4-1_TCP_Echo_Client.pdf
 - Hands-On_4-1_TCP_Echo_Client.txt
 - STM32F767ZITX_FLASH.ld
 - STM32F767ZITX_RAM.ld

main.c Hands-On_4-1_TCP_Echo_Client.ioc main.c X

```

1  /* USER CODE BEGIN Header */
2  /**
3   *
4   * @file          : main.c
5   * @brief         : Main program body
6   *
7   * @attention
8   *
9   * Copyright (c) 2022 STMicroelectronics.
10  * All rights reserved.
11  *
12  * This software is licensed under terms that can be found in the LICENSE file
13  * in the root directory of this software component.
14  * If no LICENSE file comes with this software, it is provided AS-IS.
15  *
16  */
17  /* USER CODE END Header */
18  /* Includes -----*/
19  #include "main.h"
20  #include "lwip.h"
21  #include "usart.h"

```

Problems Tasks Console X Properties

CDT Build Console [Hands-On_4-1_TCP_Echo_Client]

```

arm-none-eabi-gcc ../Core/Src/stm32f7xx_it.c -mcpu=cortex-m7 -std=gnu11 -g3 -DDEBUG -DUSE_HAL
arm-none-eabi-gcc ../Core/Src/syscalls.c -mcpu=cortex-m7 -std=gnu11 -g3 -DDEBUG -DUSE_HAL
arm-none-eabi-gcc ../Core/Src/systemem.c -mcpu=cortex-m7 -std=gnu11 -g3 -DDEBUG -DUSE_HAL
arm-none-eabi-gcc ../Core/Src/system_stm32f7xx.c -mcpu=cortex-m7 -std=gnu11 -g3 -DDEBUG -DUSE_HAL
arm-none-eabi-gcc ../Core/Src/usart.c -mcpu=cortex-m7 -std=gnu11 -g3 -DDEBUG -DUSE_HAL
arm-none-eabi-gcc -o "Hands-On_4-1_TCP_Echo_Client.elf" @"objects.list" -mcpu=cortex-m7
Finished building target: Hands-On_4-1_TCP_Echo_Client.elf

arm-none-eabi-size Hands-On_4-1_TCP_Echo_Client.elf
arm-none-eabi-objdump -h -S Hands-On_4-1_TCP_Echo_Client.elf > "Hands-On_4-1_TCP_Echo_C
text    data    bss    dec    hex filename
72836   128   28344  101308  18bbc Hands-On_4-1_TCP_Echo_Client.elf
Finished building: default.size.stdout

Finished building: Hands-On_4-1_TCP_Echo_Client.list

```

Hands-On LwIP TCP Echo Client

RAM Pointing at 0x2400 0000 ???

Categories A->Z

Analogy

Timers >

Connectivity >

CAN1

CAN2

CAN3

⚠ ETH

FMC

I2C1

I2C2

I2C3

I2C4

MDIOS

Mode RMII

☐ Activate Rx Err signal

For STM32F767ZI, keep RAM pointing at 0x2000 0000

Configuration

Reset Configuration

Parameter Settings User Constants NVIC Settings GPIO Settings

Configure the below parameters :

Search (Ctrl+F)

General : Ethernet Configuration

Warning

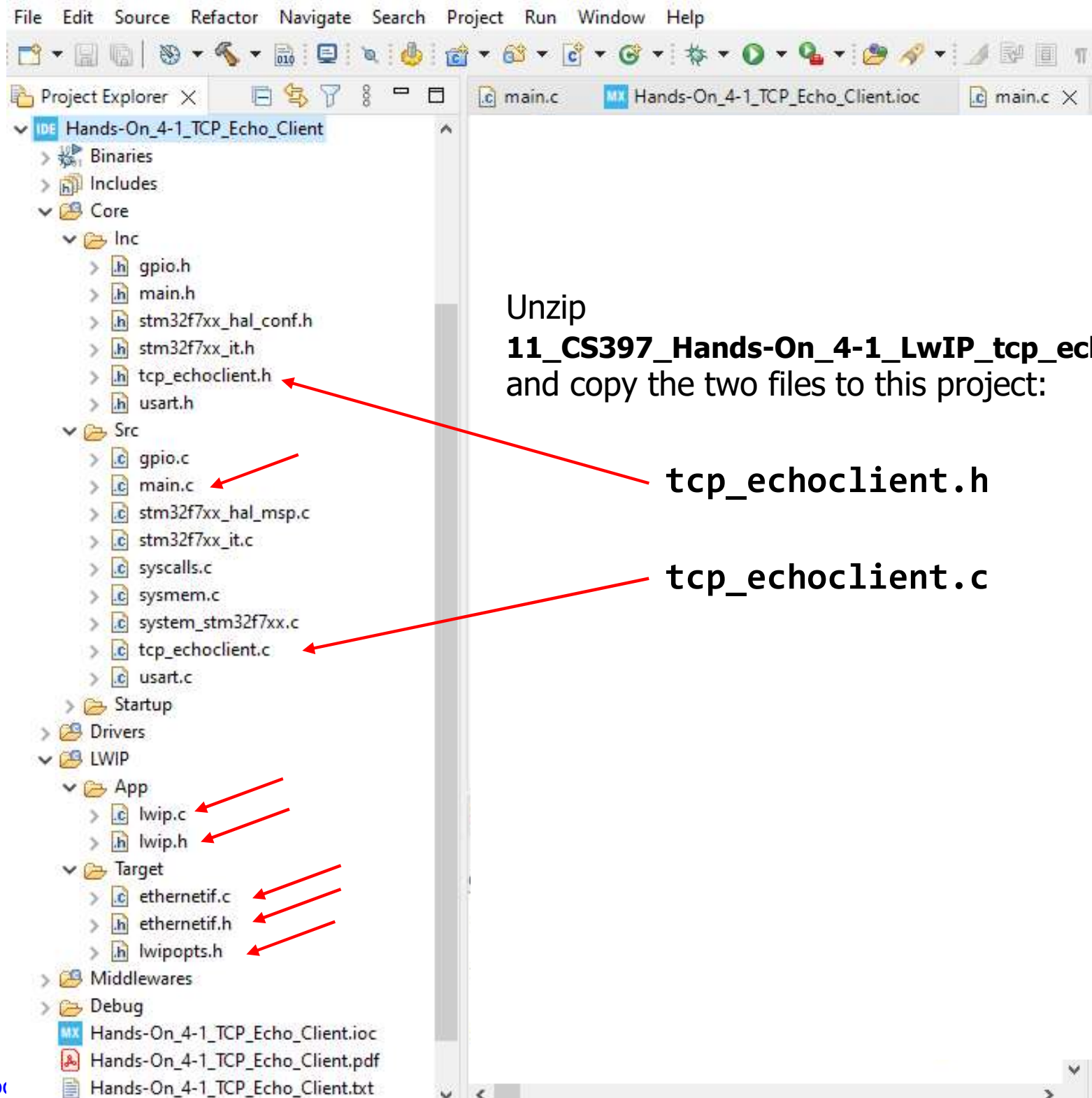
Note

Ethernet MAC Address

The ETH can work only when RAM is pointing at 0x24000000
PHY Driver must be configured from the LwIP 'Platform Settings' top right tab
02:80:E1:00:00:FF

```
/* STM32F767ZITX_FLASH.ld */  
/* Memories definition */  
MEMORY  
{  
    RAM      (xrw)      : ORIGIN = 0x20000000, LENGTH = 512K  
    FLASH    (rx)       : ORIGIN = 0x8000000,  LENGTH = 2048K  
}
```

```
/* STM32F767ZITX_RAM.ld */  
/* Memories definition */  
MEMORY  
{  
    RAM      (xrw)      : ORIGIN = 0x20000000, LENGTH = 512K  
    FLASH    (rx)       : ORIGIN = 0x8000000,  LENGTH = 2048K  
}
```

Hands-On LwIP TCP Echo Client

Add Code to **main.c**

```
/* Private includes */
/* USER CODE BEGIN Includes */

#include "tcp_echoclient.h"

/* USER CODE END Includes */

/* USER CODE BEGIN 2 */
/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{
    MX_LWIP_Process();
    /* USER CODE END WHILE */

    /* USER CODE BEGIN 3 */
}
/* USER CODE END 3 */
}
```

```
/* USER CODE BEGIN 4 */
void HAL_GPIO_EXTI_Callback(uint16_t GPIO_Pin)
{
    if(GPIO_Pin == GPIO_PIN_13)
    {
        HAL_GPIO_TogglePin(GPIOB, LD2_Pin);

        // connect to TCP server
        tcp_echoclient_connect();
    }
}
/* USER CODE END 4 */
```

Purpose and Test procedure:

UM1713 User manual

Developing applications on STM32Cube
with LwIP TCP/IP stack

Section 6 Using the LwIP applications

6.1.1 TCP echo client

Hands-On LwIP TCP Echo Client

Modify Code in `tcp_echoclient.c`


```
/* Includes */
#include "main.h"
#include "lwip/debug.h"
#include "lwip/stats.h"
#include "lwip/tcp.h"
#include "lwip/memp.h"
#include <stdio.h>
#include <string.h>
#include "tcp_echoclient.h"
```

```
// Your PC's IP address
#define DEST_IP_ADDR0 (uint8_t)192
#define DEST_IP_ADDR1 (uint8_t)168
#define DEST_IP_ADDR2 (uint8_t)1
#define DEST_IP_ADDR3 (uint8_t)175

#define DEST_PORT (uint32_t)7
```

For a different router (gateway):

```
#define DEST_IP_ADDR0 (uint8_t)192
#define DEST_IP_ADDR1 (uint8_t)168
#define DEST_IP_ADDR2 (uint8_t)50
#define DEST_IP_ADDR3 (uint8_t)175
```



Specify your PC's IP address

There lines are added to the original `tcp_echoclient.c`



Hands-On LwIP TCP Echo Client

Generated Code in Lwip.c

```
/* LwIP initialization function */
```

```
void MX_LWIP_Init(void)
```

```
{
```

```
    /* IP addresses initialization */
```

```
    IP_ADDRESS[0] = 192;
```

```
    IP_ADDRESS[1] = 168;
```

```
    IP_ADDRESS[2] = 1;
```

```
    IP_ADDRESS[3] = 205;
```

```
    NETMASK_ADDRESS[0] = 255;
```

```
    NETMASK_ADDRESS[1] = 255;
```

```
    NETMASK_ADDRESS[2] = 255;
```

```
    NETMASK_ADDRESS[3] = 0;
```

```
    GATEWAY_ADDRESS[0] = 192;
```

```
    GATEWAY_ADDRESS[1] = 168;
```

```
    GATEWAY_ADDRESS[2] = 1;
```

```
    GATEWAY_ADDRESS[3] = 1;
```

```
/* USER CODE BEGIN IP_ADDRESSES */
```

```
/* USER CODE END IP_ADDRESSES */
```

```
/* Initialize the LwIP stack without RTOS */
```

```
lwip_init();
```

```
/* IP addresses initialization without DHCP (IPv4) */
```

```
IP4_ADDR(&ipaddr, IP_ADDRESS[0], IP_ADDRESS[1], IP_ADDRESS[2], IP_ADDRESS[3]);
```

```
IP4_ADDR(&netmask, NETMASK_ADDRESS[0], NETMASK_ADDRESS[1], NETMASK_ADDRESS[2], NETMASK_ADDRESS[3]);
```

```
IP4_ADDR(&gw, GATEWAY_ADDRESS[0], GATEWAY_ADDRESS[1], GATEWAY_ADDRESS[2], GATEWAY_ADDRESS[3]);
```

```
/* add the network interface (IPv4/IPv6) without RTOS */
```

```
netif_add(&gnetif, &ipaddr, &netmask, &gw, NULL, &ethernetif_init, &ethernet_input);
```

For a different router (gateway):

```
IP_ADDRESS[0] = 192;
```

```
IP_ADDRESS[1] = 168;
```

```
IP_ADDRESS[2] = 50;
```

```
IP_ADDRESS[3] = 205;
```

```
NETMASK_ADDRESS[0] = 255;
```

```
NETMASK_ADDRESS[1] = 255;
```

```
NETMASK_ADDRESS[2] = 255;
```

```
NETMASK_ADDRESS[3] = 0;
```

```
GATEWAY_ADDRESS[0] = 192;
```

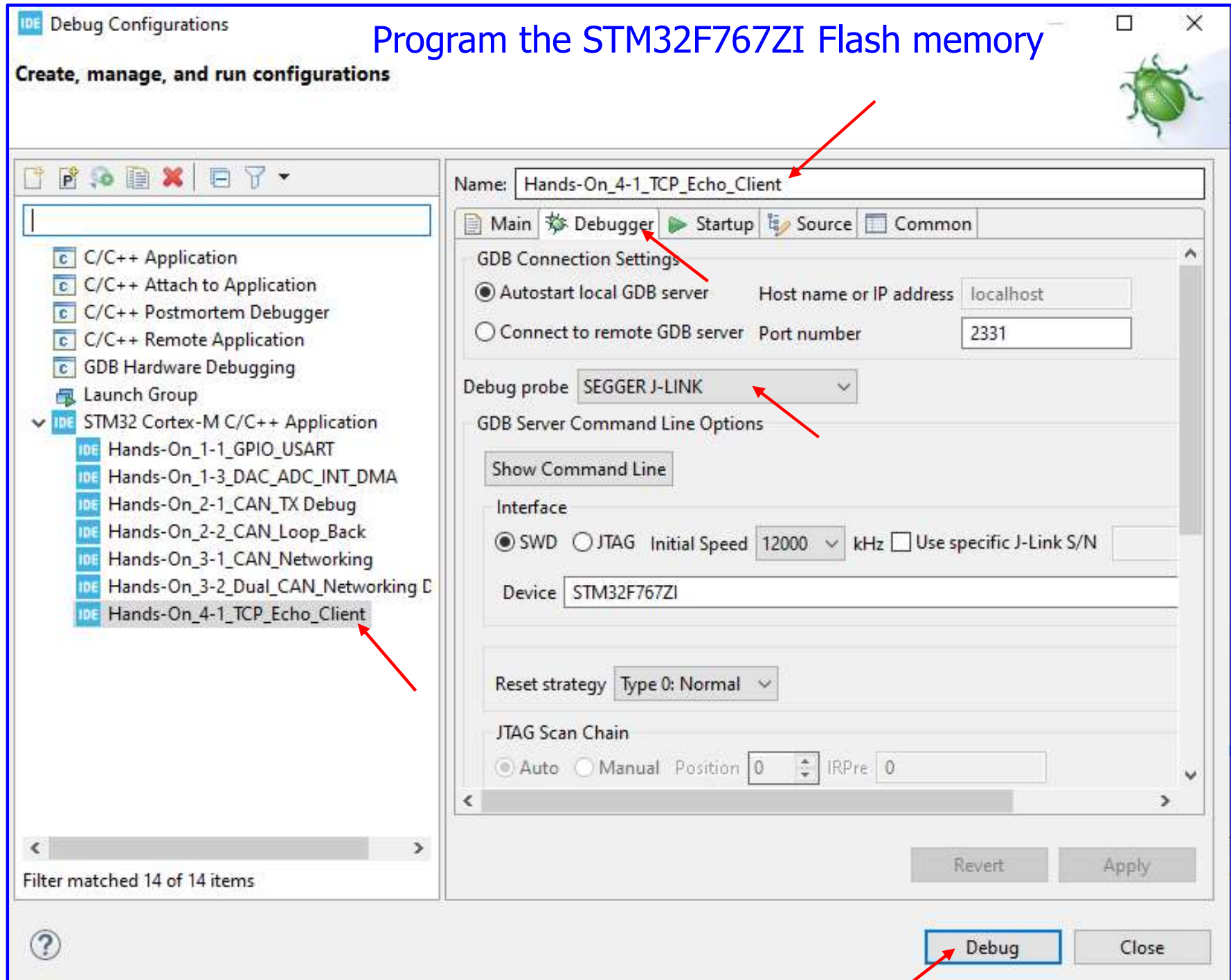
```
GATEWAY_ADDRESS[1] = 168;
```

```
GATEWAY_ADDRESS[2] = 50;
```

```
GATEWAY_ADDRESS[3] = 1;
```

Hands-On LwIP TCP Echo Client

Program the STM32F767ZI Flash memory



Hands-On LwIP TCP Echo Client

Application Testing – LwIP TCP Echo Client

This application is used to test a basic TCP connection. The STM32 MCU acts as a TCP client that connects to the TCP server (a remote PC). The client sends a string and the server echoes back the same string to the client.

To test the TCP echo client application, follow these steps:

1. Build and program the project code into the STM32F767ZI Flash memory.
2. Run the project code in the STM32 MCU.
3. On the remote PC, create a folder **c:\CS397** and copy **echotool.exe** to it
4. Open a command prompt window and go to **c:\CS397**
5. At the command prompt, enter:

C:\CS397>echotool /p tcp /s

where:

- /p tcp is the TCP protocol (TCP protocol)
 - /s is the actual mode of connection (Server mode)
6. When the user-button on the board (Nucleo-F767ZI) is pressed, LD2 is toggled, and the client sends a string and the server echoes back the same string to the client.

Hands-On LwIP TCP Echo Client

Note:

1. Make sure the remote PC IP address is identical to the address defined in the **tcp_echoclient.c** file.
2. Create another application with the dynamic address allocation "DHCP" for testing.
3. Figure shows an example of the command string and module response.
4. Use **c:\>ipconfig** to find PC's IP address, netmask address, and gateway address.
5. Use **ping** to check the IP address

Need to press the user-button to get the response/echo.

```
Command Prompt - echotool /p tcp /s

Wireless LAN adapter Wi-Fi:

    Connection-specific DNS Suffix  . : 
    Link-local IPv6 Address . . . . . : fe80::a1ae:c92d:4f96:5c8
    IPv4 Address. . . . . : 192.168.1.175
    Subnet Mask . . . . . : 255.255.255.0
    Default Gateway . . . . . : 192.168.1.1

C:\CS397>ping 192.168.1.205

Pinging 192.168.1.205 with 32 bytes of data:
Reply from 192.168.1.205: bytes=32 time=2ms TTL=255
Reply from 192.168.1.205: bytes=32 time=2ms TTL=255
Reply from 192.168.1.205: bytes=32 time=1ms TTL=255
Reply from 192.168.1.205: bytes=32 time=1ms TTL=255

Ping statistics for 192.168.1.205:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 1ms, Maximum = 2ms, Average = 1ms

C:\CS397>echotool /p tcp /s

Waiting for TCP connection on port 7. Press any key to exit.
Client 192.168.1.205:52432 accepted at 2:33:59 PM
2:33:59 PM received [sending tcp client message 0]
Session closed by peer.
Waiting for TCP connection on port 7. Press any key to exit.
Client 192.168.1.205:52433 accepted at 2:34:03 PM
2:34:03 PM received [sending tcp client message 1]
Session closed by peer.
Waiting for TCP connection on port 7. Press any key to exit.
Client 192.168.1.205:52434 accepted at 2:34:06 PM
2:34:06 PM received [sending tcp client message 2]
```

Message
Count

The Results of LwIP TCP Echo Client

Hands-On LwIP TCP Echo Client

List of TCP and UDP port numbers

https://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers

Well-known ports [hide]

Port	TCP	UDP	SCTP	DCCP	Description
0	Reserved	Reserved			In programming APIs (not in communication between hosts), requests a system-allocated (dynamic) port ^[6]
1	Yes	Assigned			TCP Port Service Multiplexer (TCPMUX). Historic. Both TCP and UDP have been assigned to TCPMUX by IANA, ^[2] but by design only TCP is specified. ^[7]
2	Assigned	Assigned			compressnet (Management Utility)
3	Assigned	Assigned			compressnet (Compression Process)
5	Assigned	Assigned			Remote Job Entry ^[8] was historically using socket 5 in its old socket form, while MIB PIM has identified it as TCP/5 ^[9] and IANA has assigned both TCP and UDP 5 to it.
7	Yes	Yes			Echo Protocol ^{[10][11]}

Legend of TCP and UDP protocol table cells for port numbers

Cell	Description
Yes	Described protocol <i>is</i> assigned by IANA for this port, and <i>is</i> : standardized, specified, or widely used for such.
Unofficial	Described protocol <i>is not</i> assigned by IANA for this port, but <i>is</i> : standardized, specified, or widely used for such.
Assigned	Described protocol <i>is</i> assigned by IANA for this port, ^[2] but <i>is not</i> : standardized, specified, or widely used for such.
No	Described protocol <i>is not</i> : assigned by IANA for this port, standardized, specified, or widely used for such.
Reserved	Port is reserved by IANA, ^[2] generally to prevent collision having its previous use removed. ^{[3][4]} The port number may be available for assignment upon request to IANA. ^[3]

Hands-On LwIP TCP Echo Client

Router Information

1. Router 1 (AX86S)

SSID : RT-AX86S-CS397 RT-AX86S-CS397_5G

Key : CS397wifi

Subnet Mask : 255.255.255.0

Gateway : 192.168.50.1

2. Router 2 (AX5400)

SSID : RT-AX5400-CS397 RT-AX5400-CS397_5G

Key : CS397wifi

Subnet Mask : 255.255.255.0

Gateway : 192.168.50.1

3. Router 3 (N56U)

SSID : RT-N56U-CS397

Key : CS397wifi

Subnet Mask : 255.255.255.0

Gateway : 192.168.1.1
