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

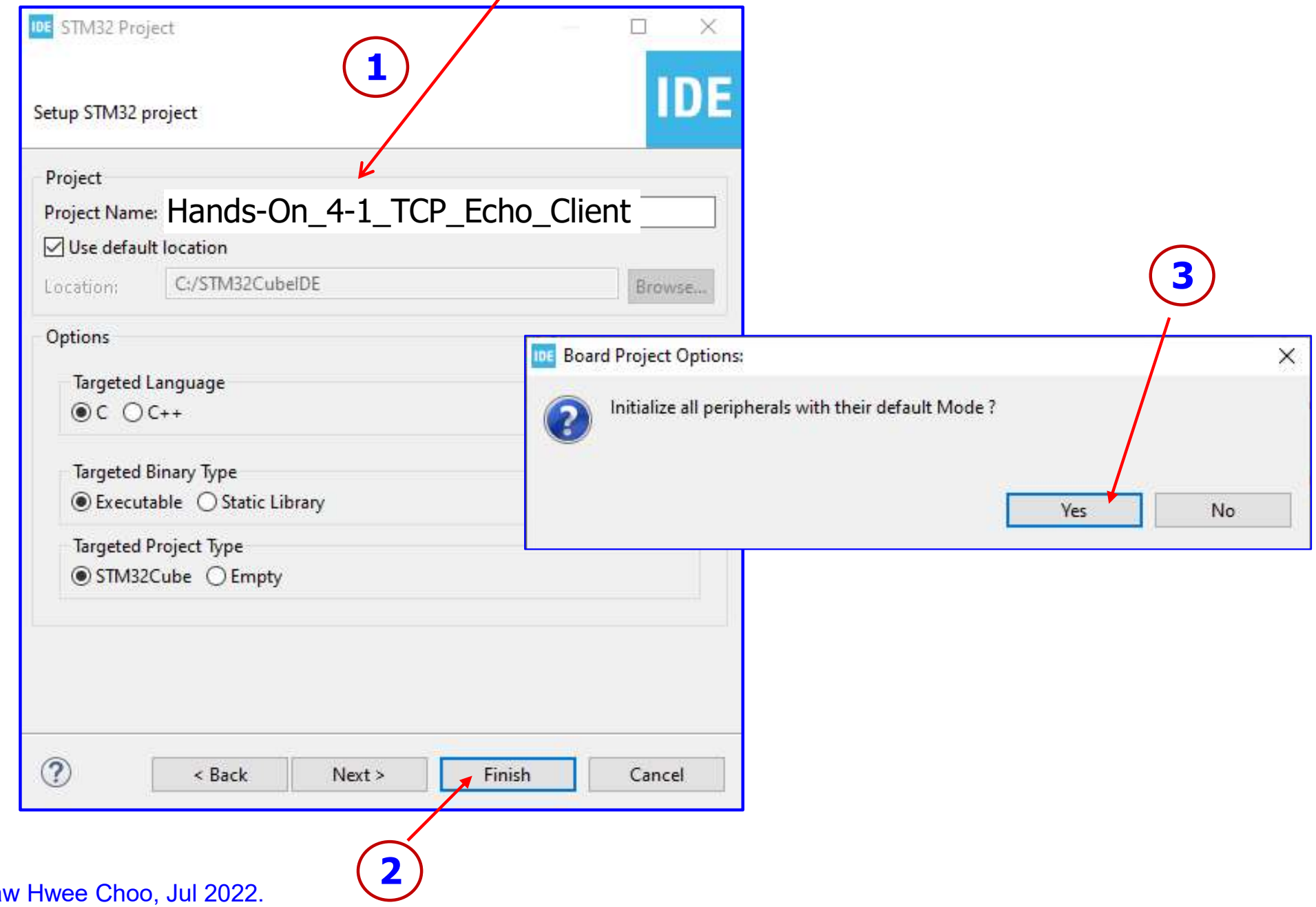
The aims of this hands-on session are to

- 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

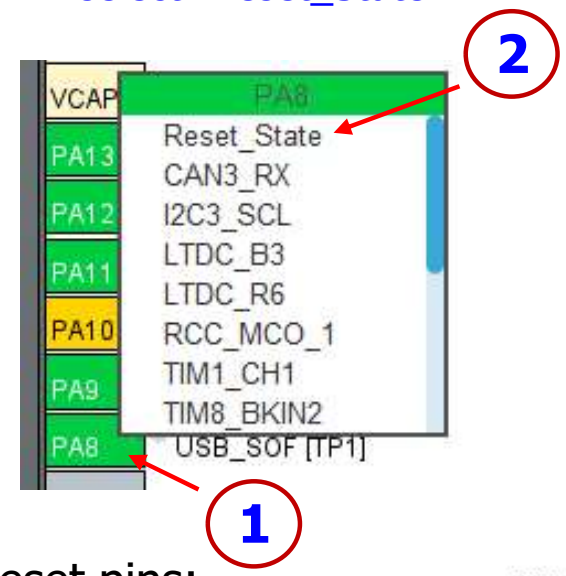
Enter Project Name: Hands-On_4-1_TCP_Echo_Client



Hands-On LwIP TCP Echo Client

Reset Unused Pins

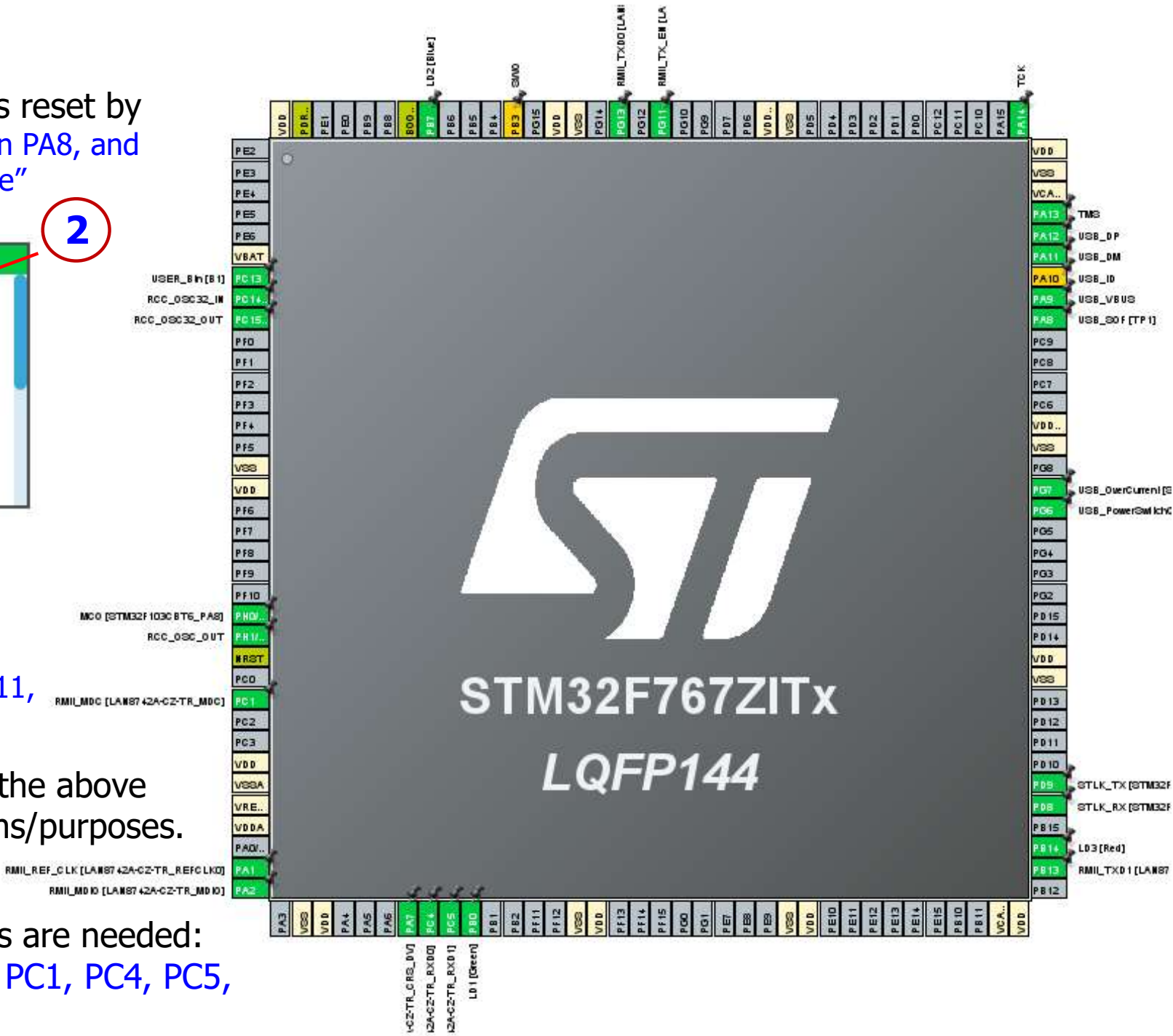
For example, PA8 is reset by
- left-click on the pin PA8, and
- select "Reset_State"



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

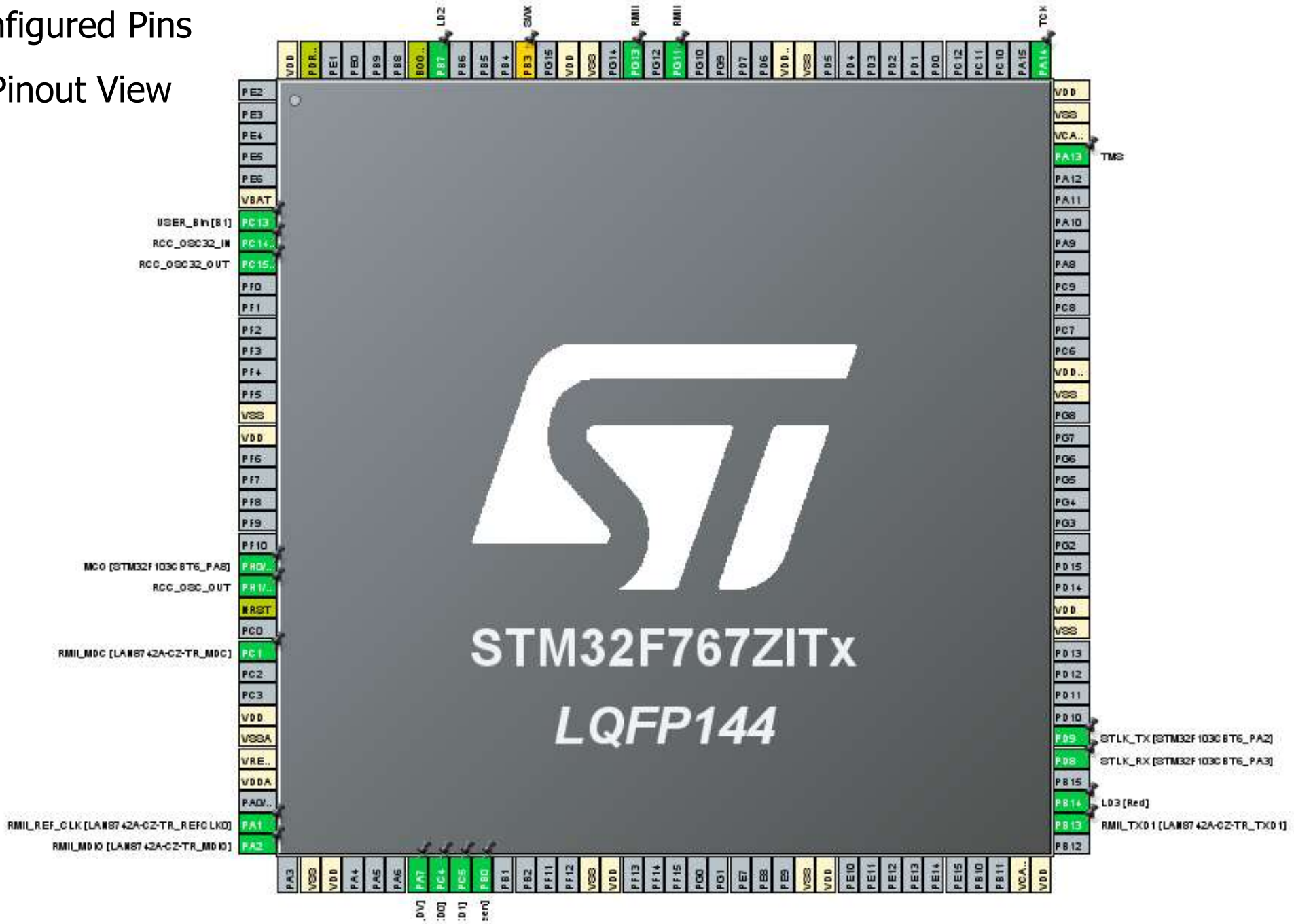
Note that do not use the above pins for other functions/purposes.

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



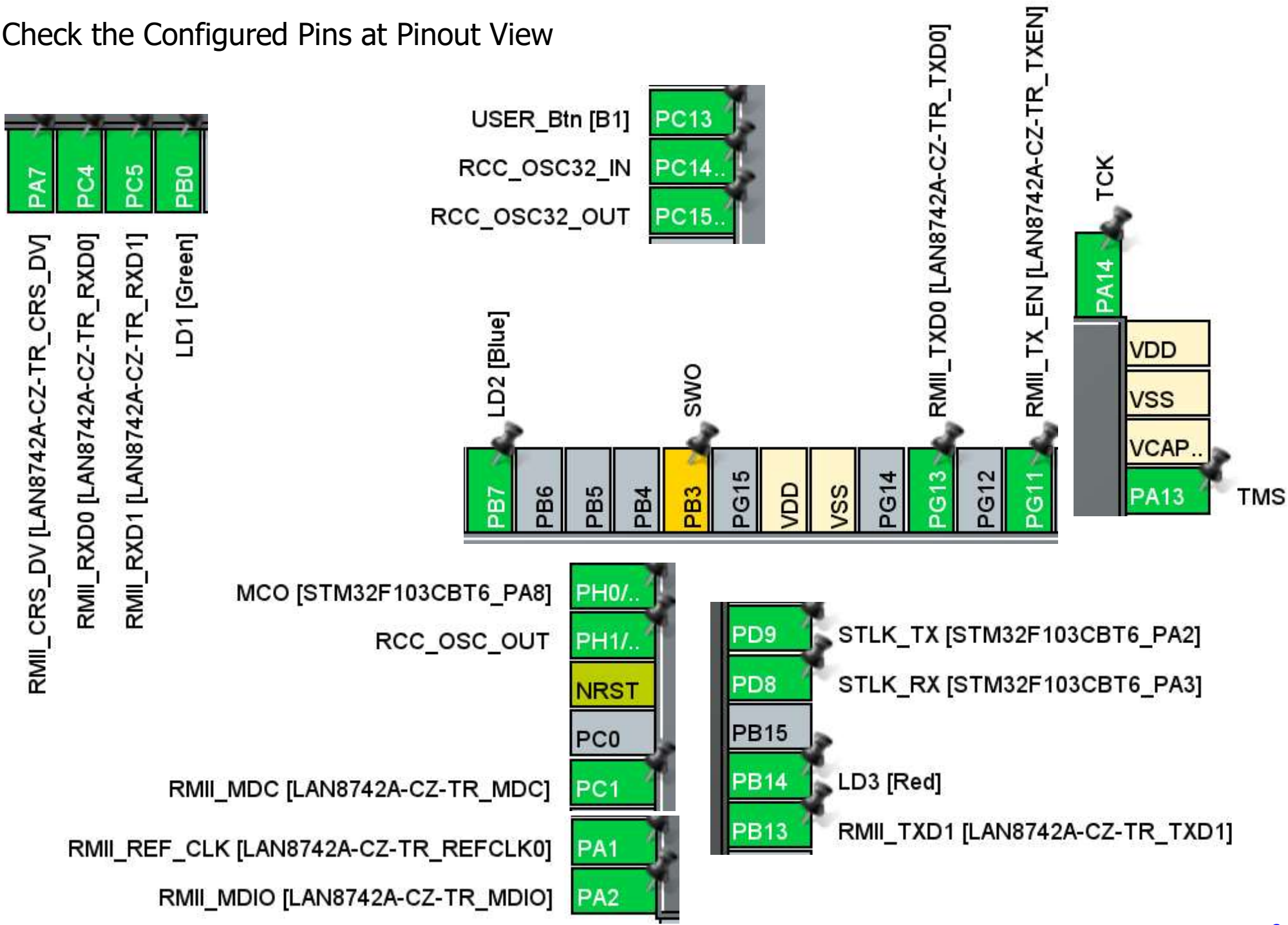
Hands-On LwIP TCP Echo Client

Check the Configured Pins at Pinout View



Hands-On LwIP TCP Echo Client

Check the Configured Pins at Pinout View

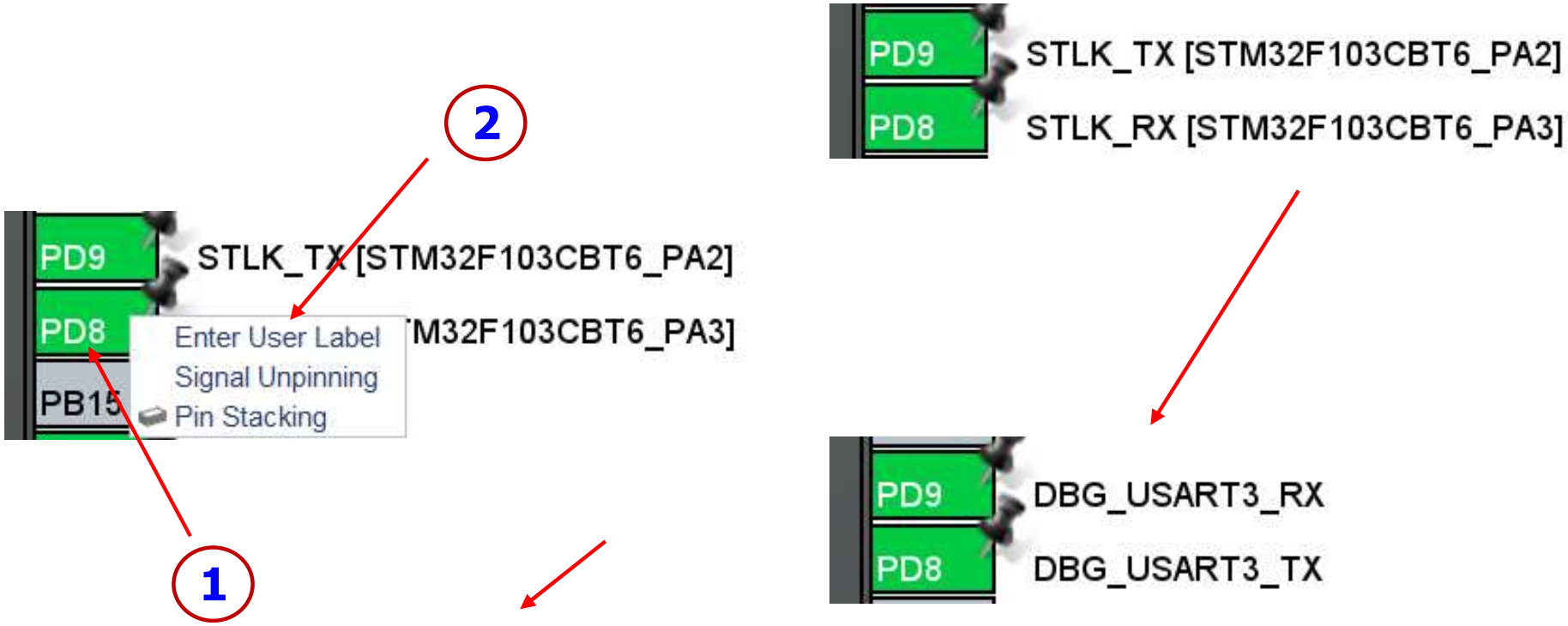


Hands-On LwIP TCP Echo Client

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"

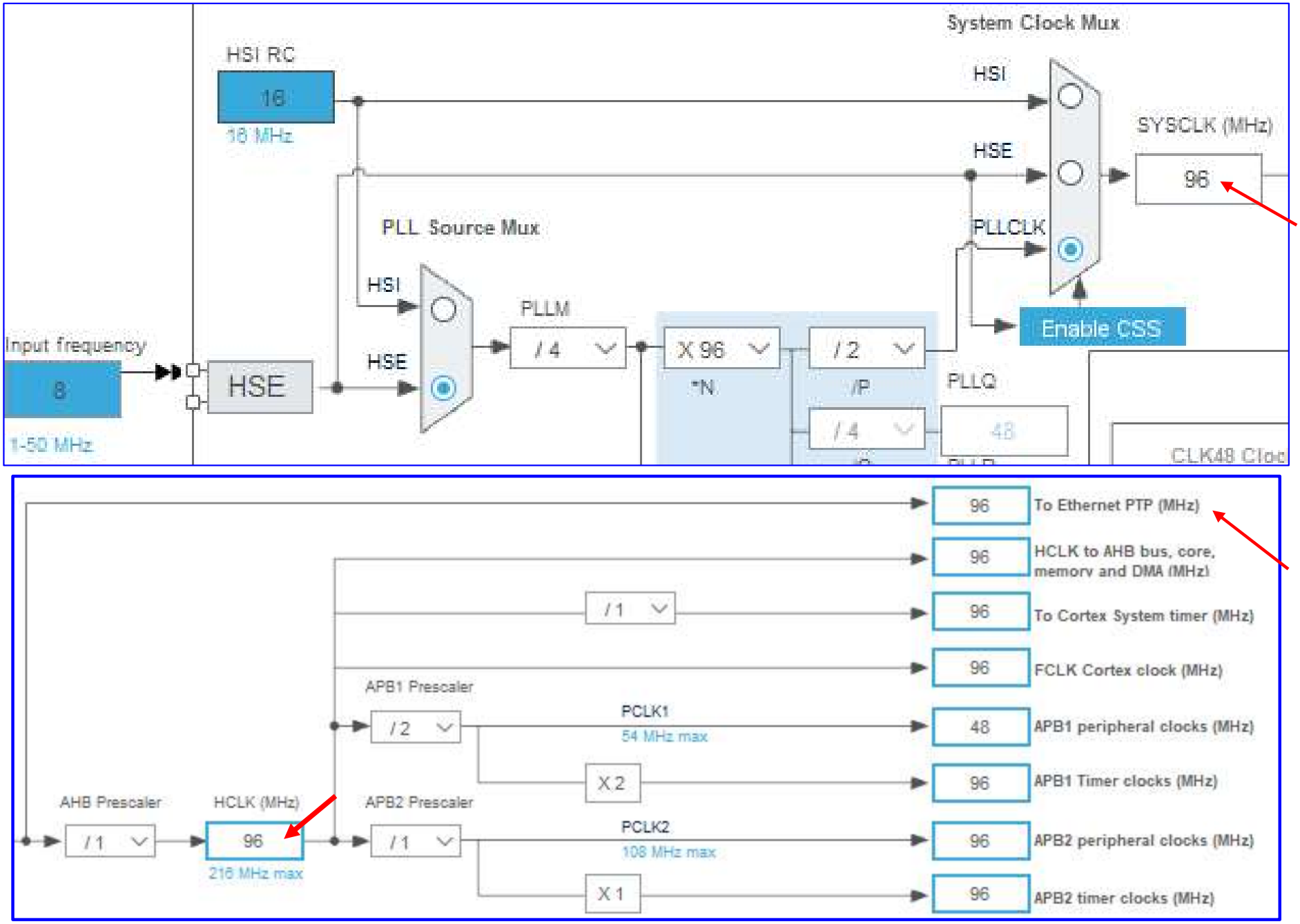


PD9: DBG_USART3_RX
PD8: DBG_USART3_TX

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

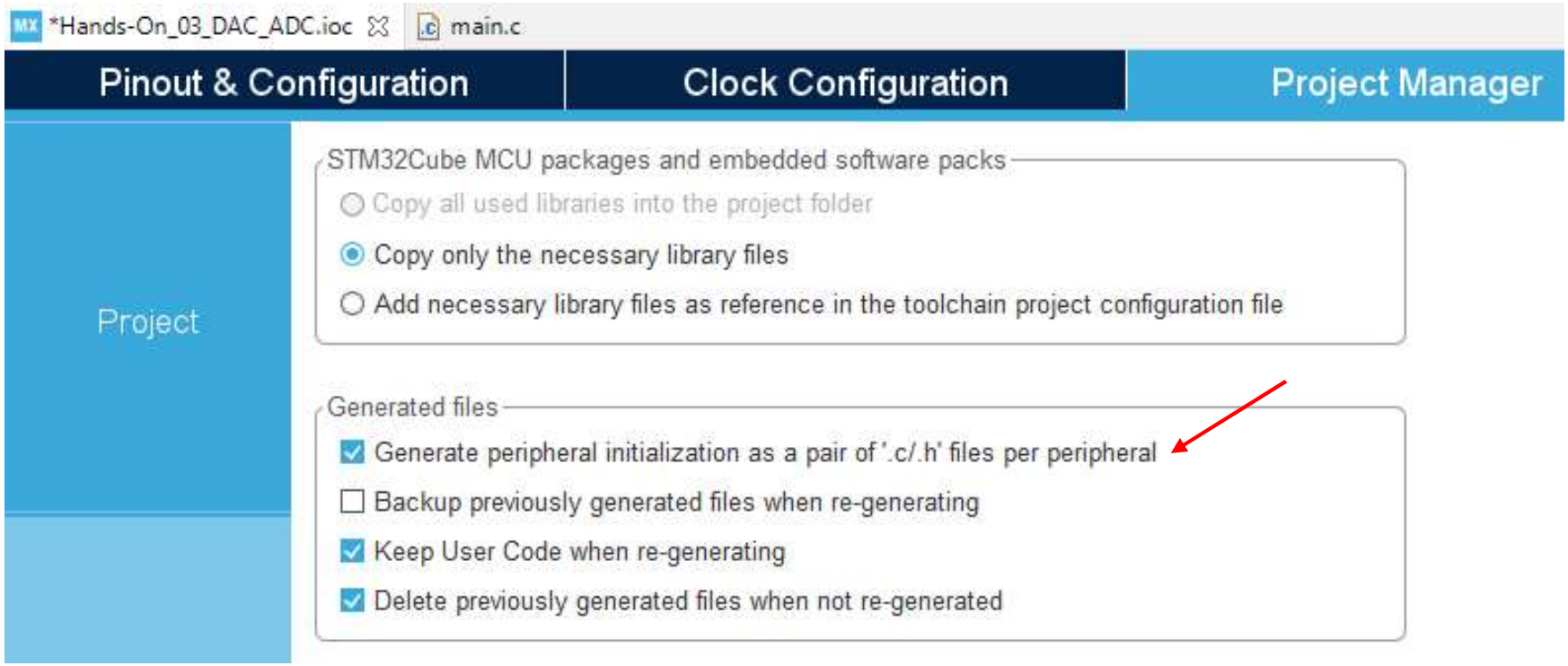
Hands-On LwIP TCP Echo Client

Clock Configuration: Use Default Settings



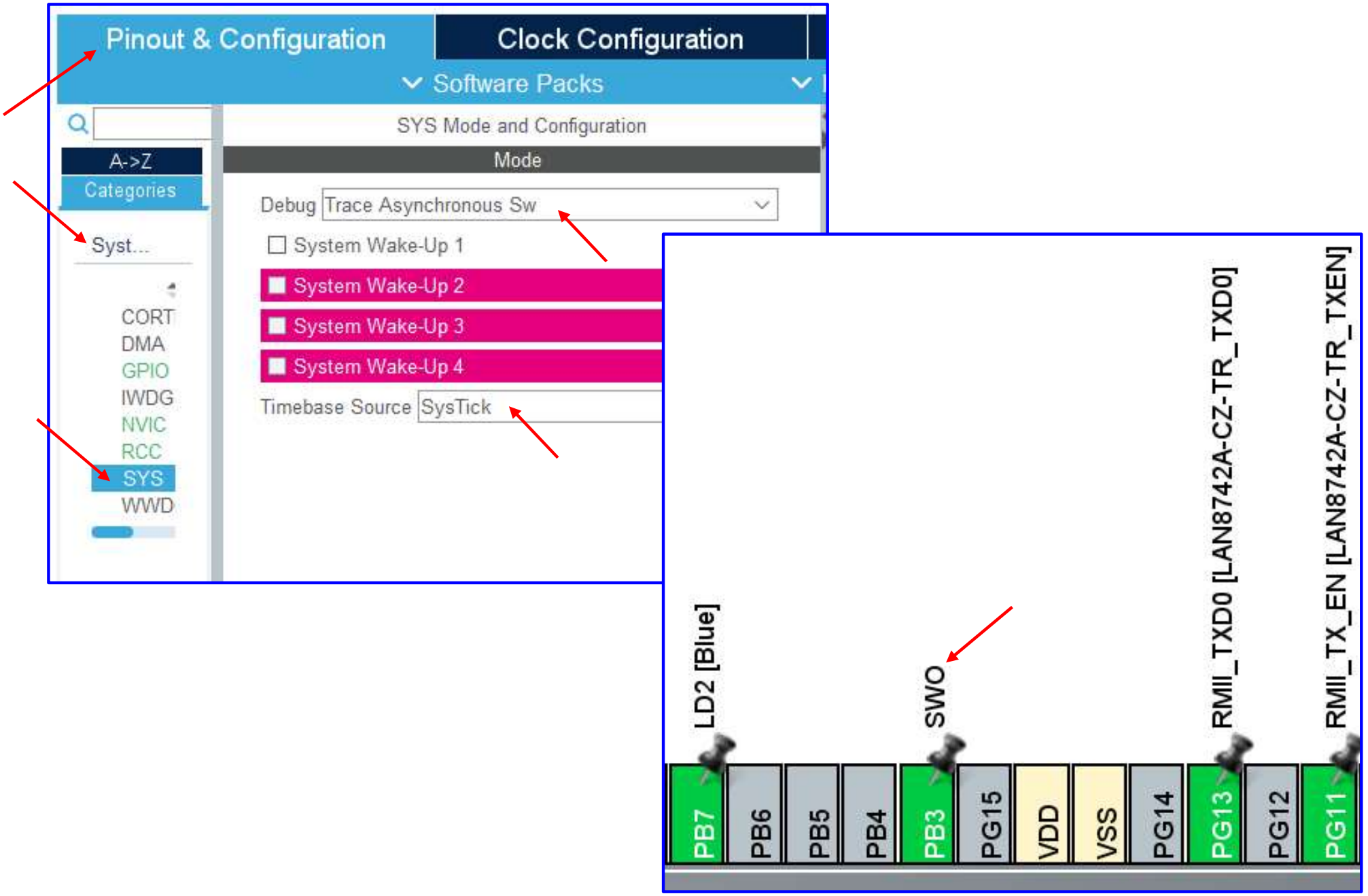
Hands-On LwIP TCP Echo Client

- 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



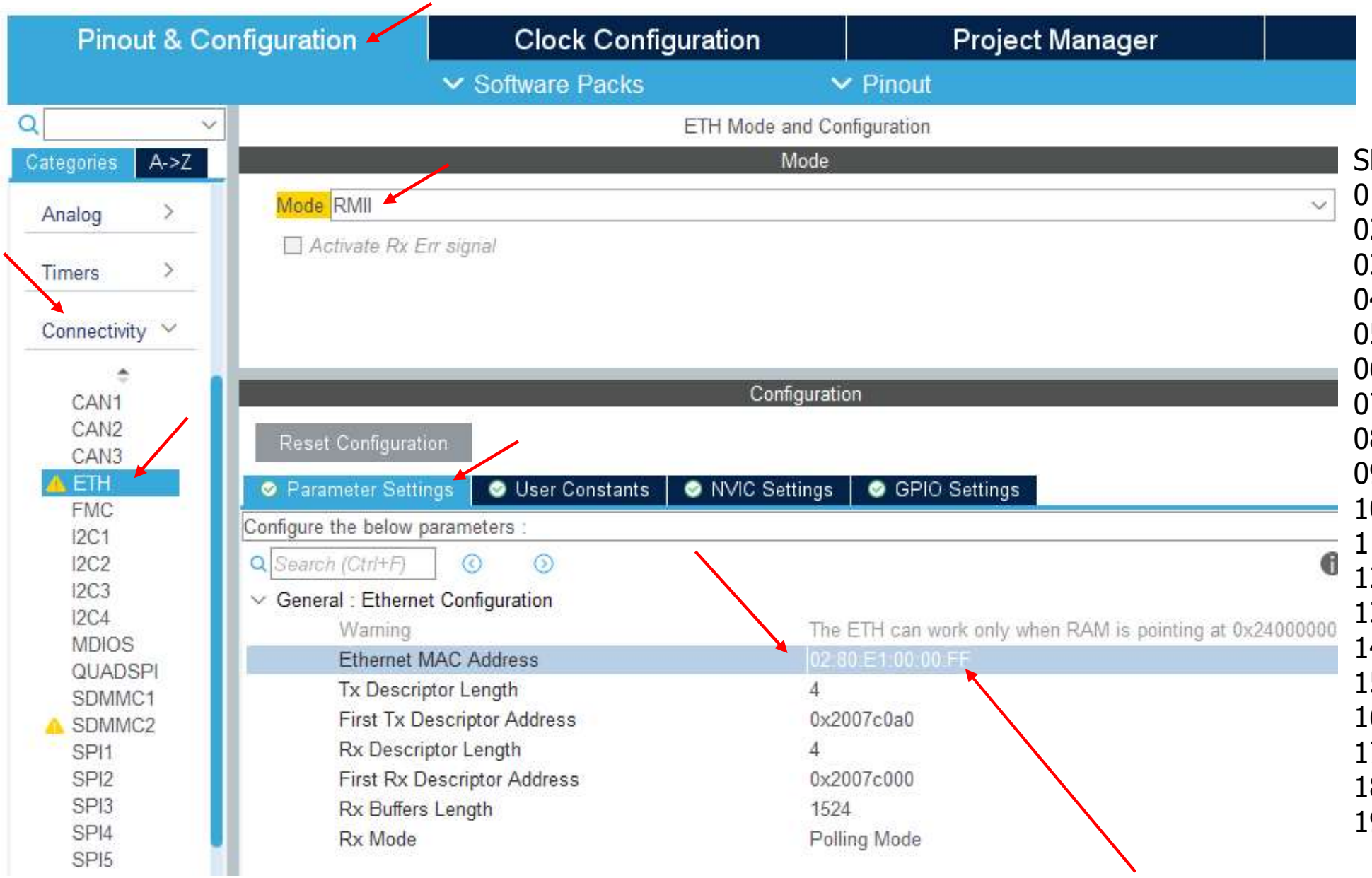
Hands-On LwIP TCP Echo Client

Pinout & Configuration



Hands-On LwIP TCP Echo Client

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

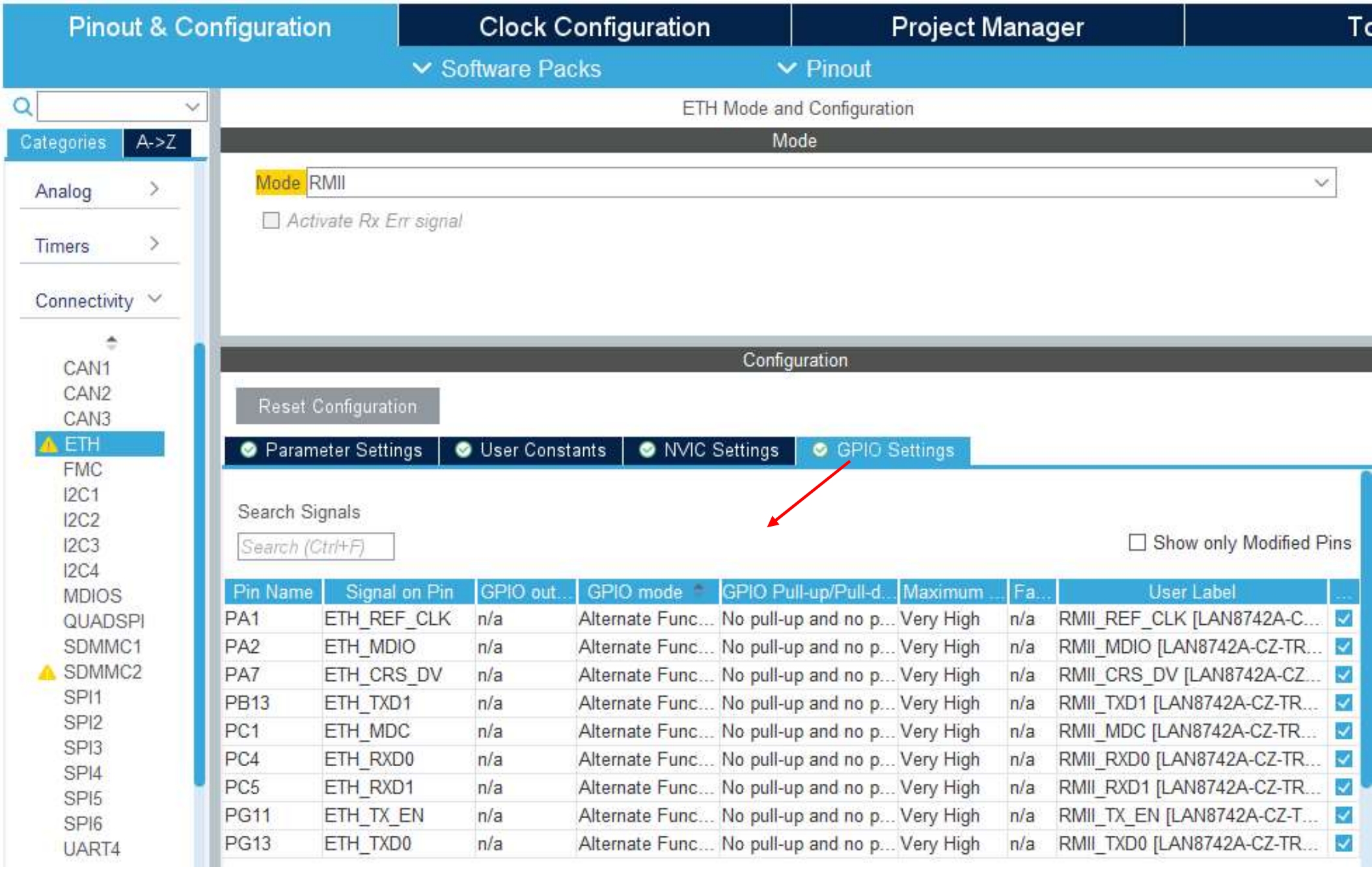


SN -> XX
01 -> A1
02 -> A2
03 -> A3
04 -> A4
05 -> A5
06 -> A6
07 -> A7
08 -> A8
09 -> A9
10 -> AA
11 -> B1
12 -> B2
13 -> B3
14 -> B4
15 -> B5
16 -> B6
17 -> B7
18 -> B8
19 -> B9

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

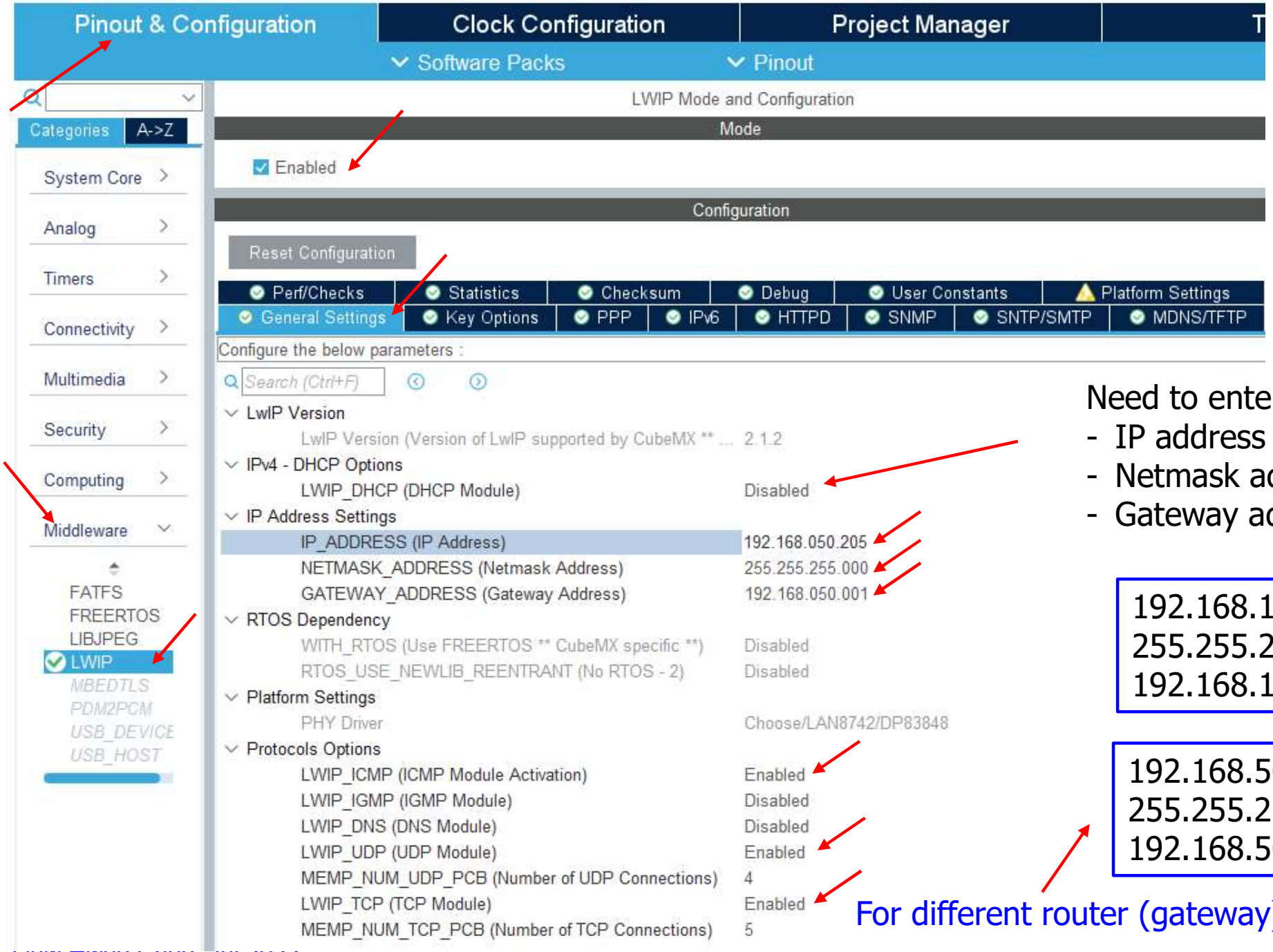
Hands-On LwIP TCP Echo Client

Ethernet (ETH) Configuration: GPIO Settings (Default)



Hands-On LwIP TCP Echo Client

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



Need to enter:
- IP address
- Netmask address
- Gateway address

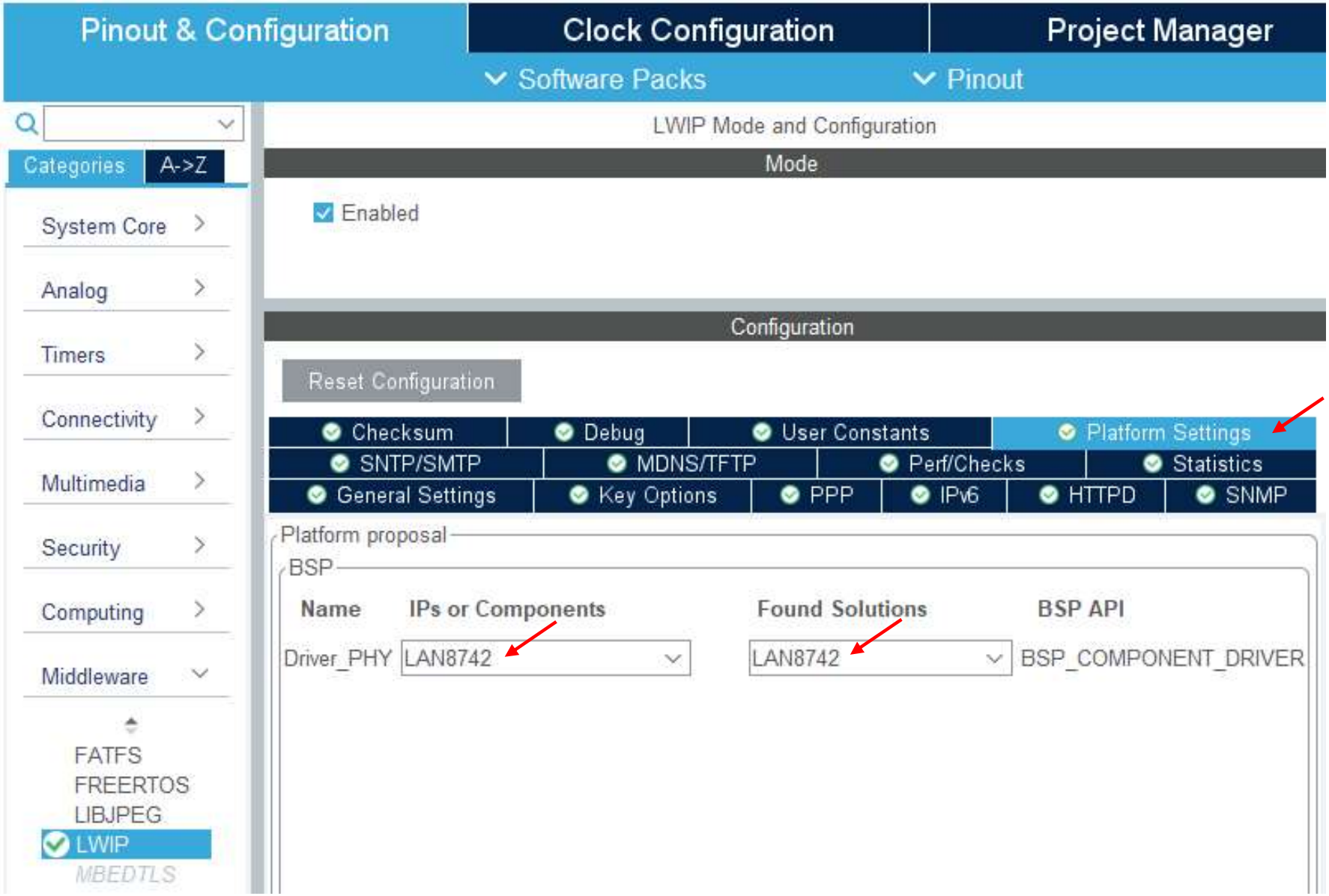
192.168.1.205
255.255.255.0
192.168.1.1

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



Hands-On LwIP TCP Echo Client

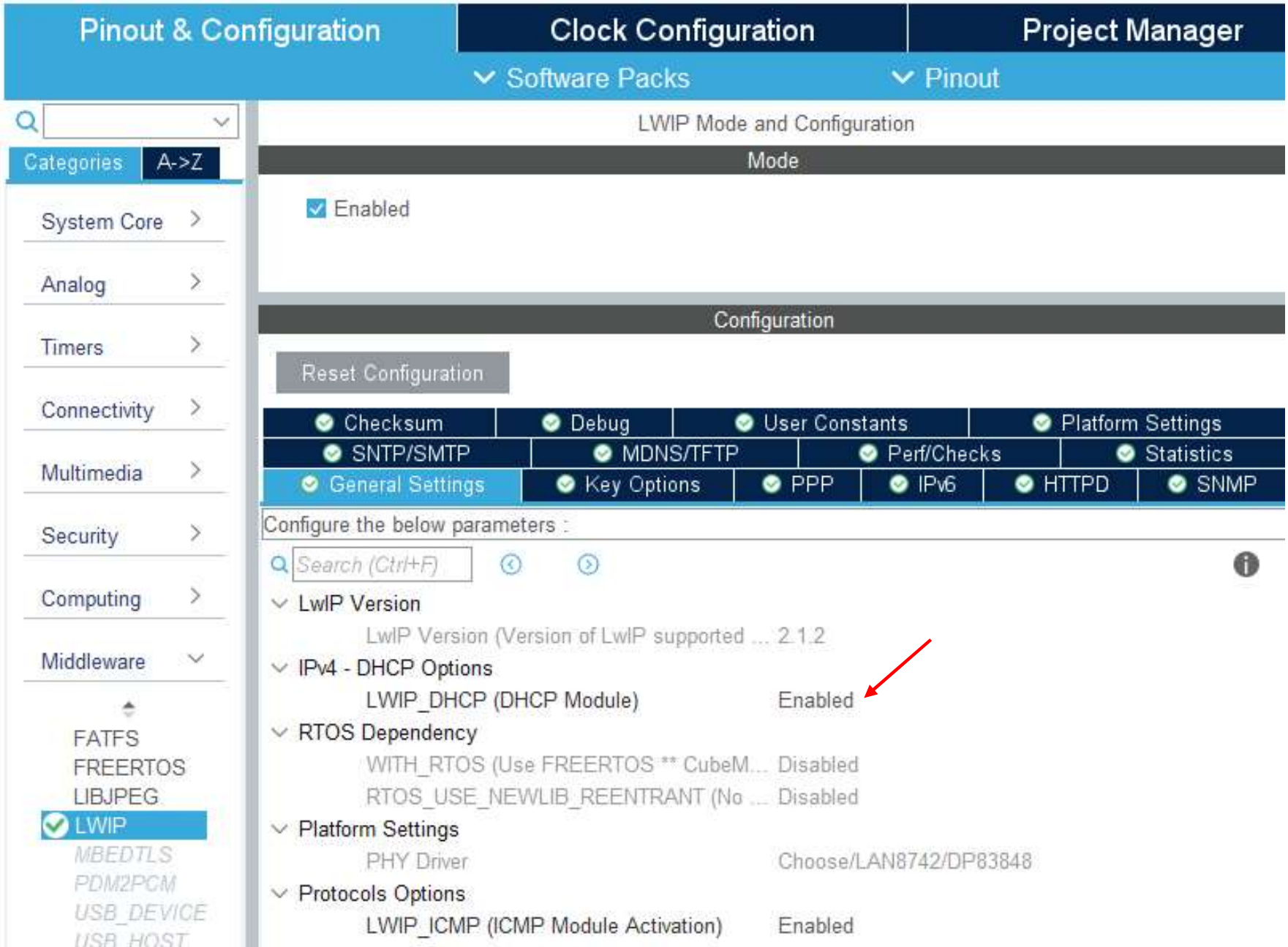
MAC and IP Addresses

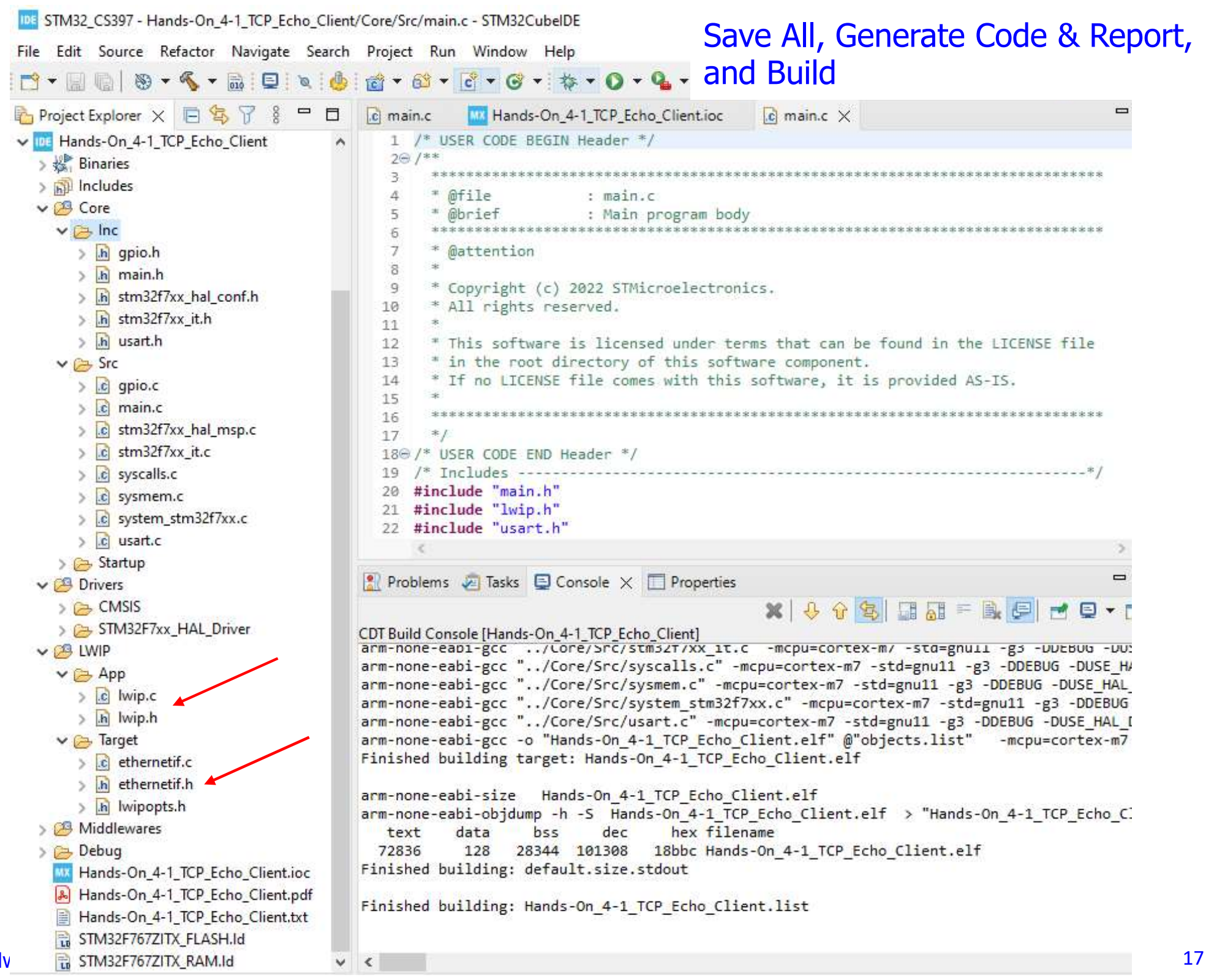
Enter Ethernet MAC Address: 02 : 80 : E1 : 00 : 00 : XX
XX is based on student serial number: XX = A1, A2, A3, ..., B9

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

Hands-On LwIP TCP Echo Client

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

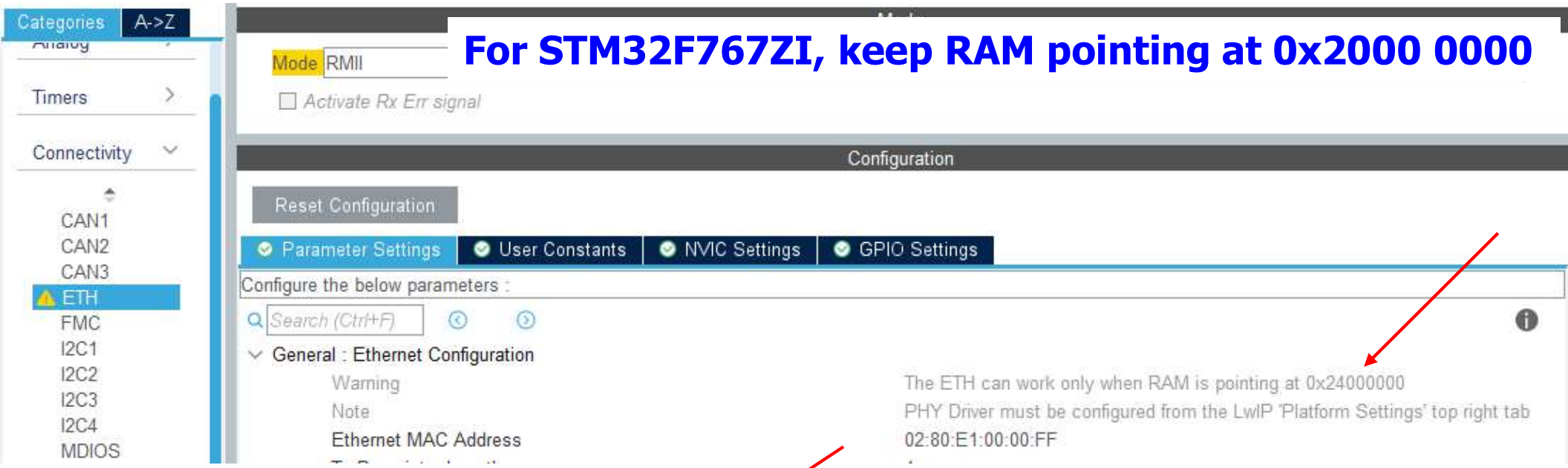




Save All, Generate Code & Report, and Build

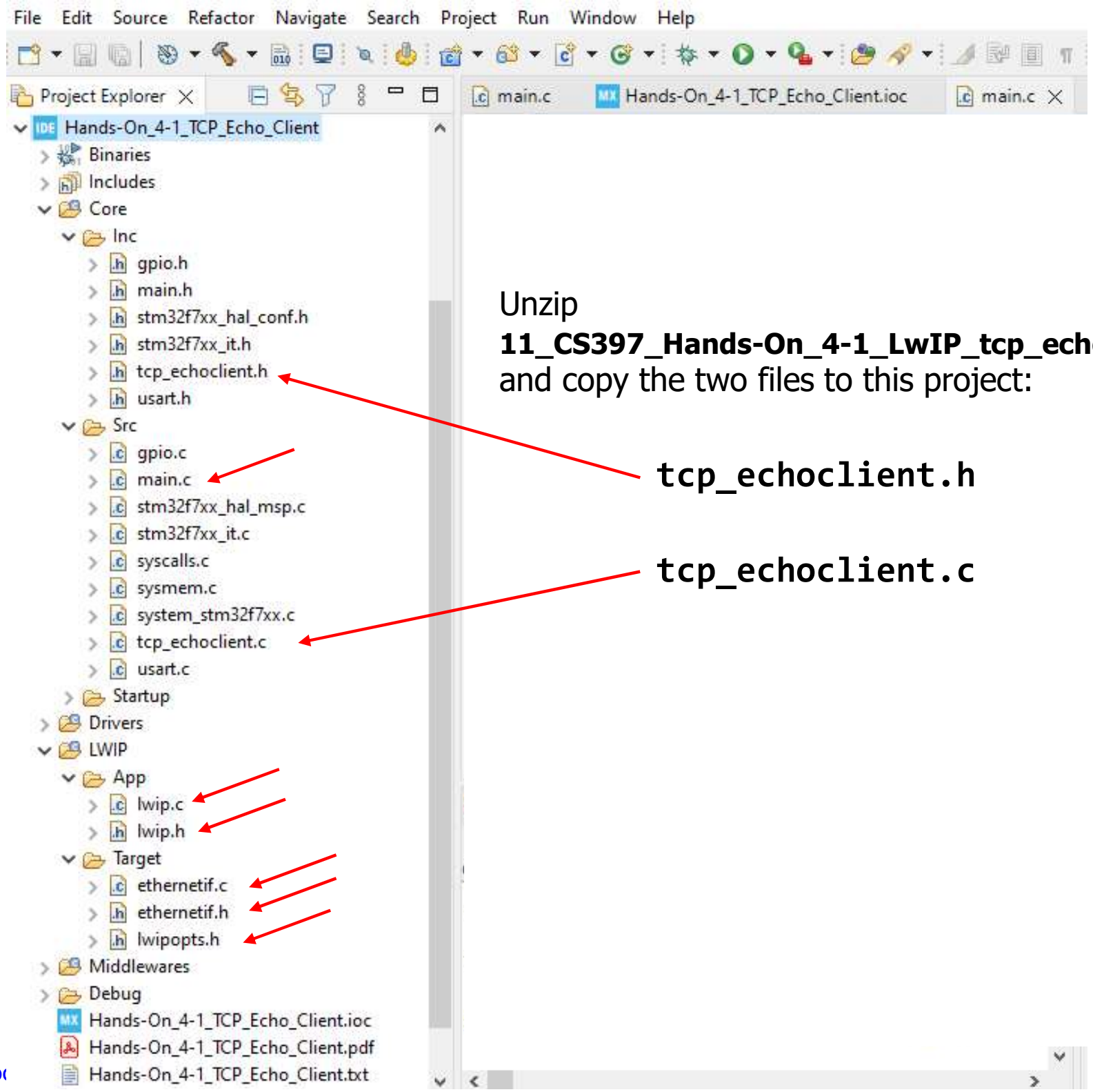
Hands-On LwIP TCP Echo Client

RAM Pointing at 0x2400 0000 ???




```
/* 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
}
```



Unzip **11_CS397_Hands-On_4-1_LwIP_tcp_echoclient.zip**, and copy the two files to this project:

`tcp_echoclient.h`

`tcp_echoclient.c`

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**

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
```

```
/* 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
```

Specify your PC's IP address

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

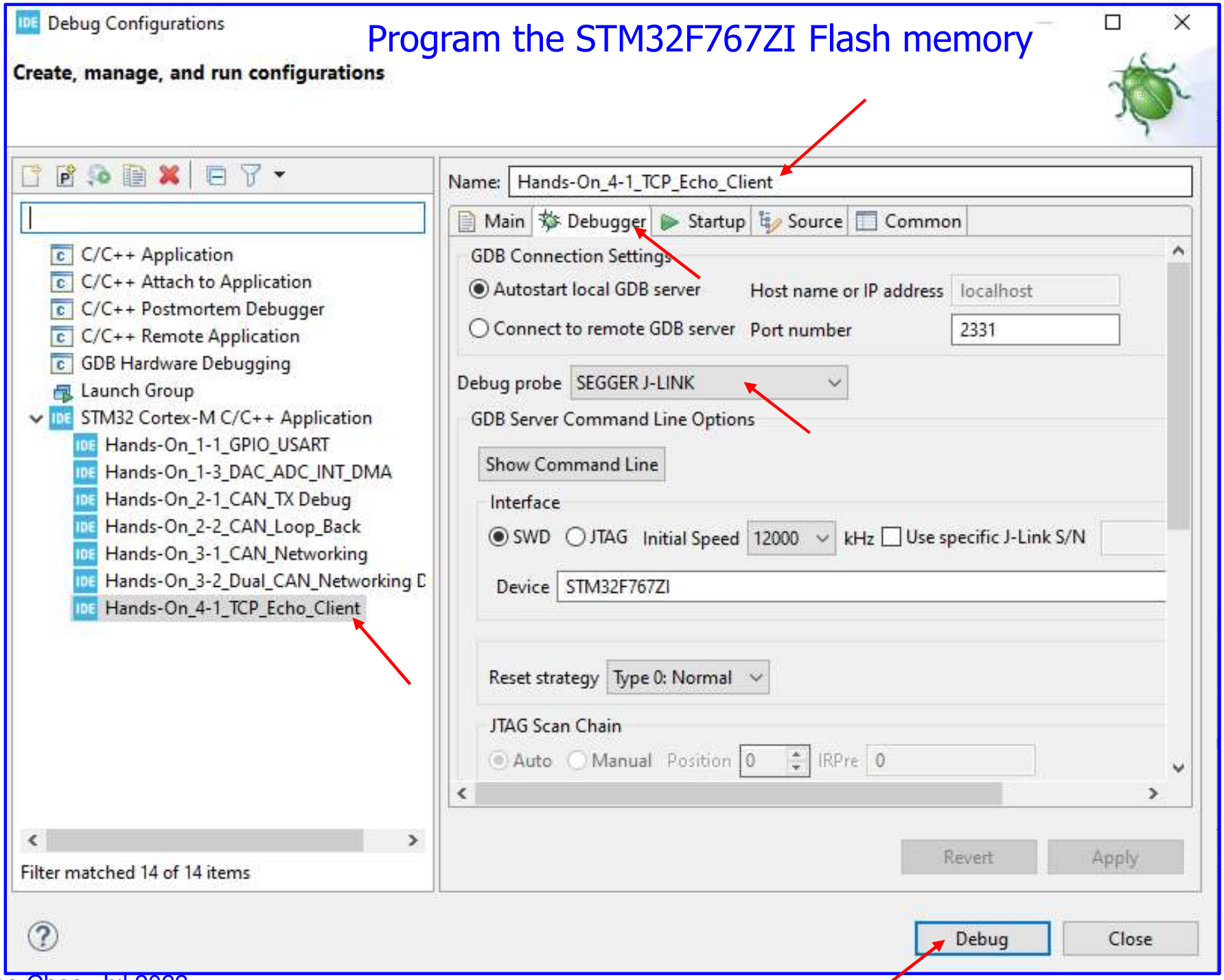
Generated Code in **`Lwip.c`**

```
/* 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 */

  /* Initilialize 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



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:

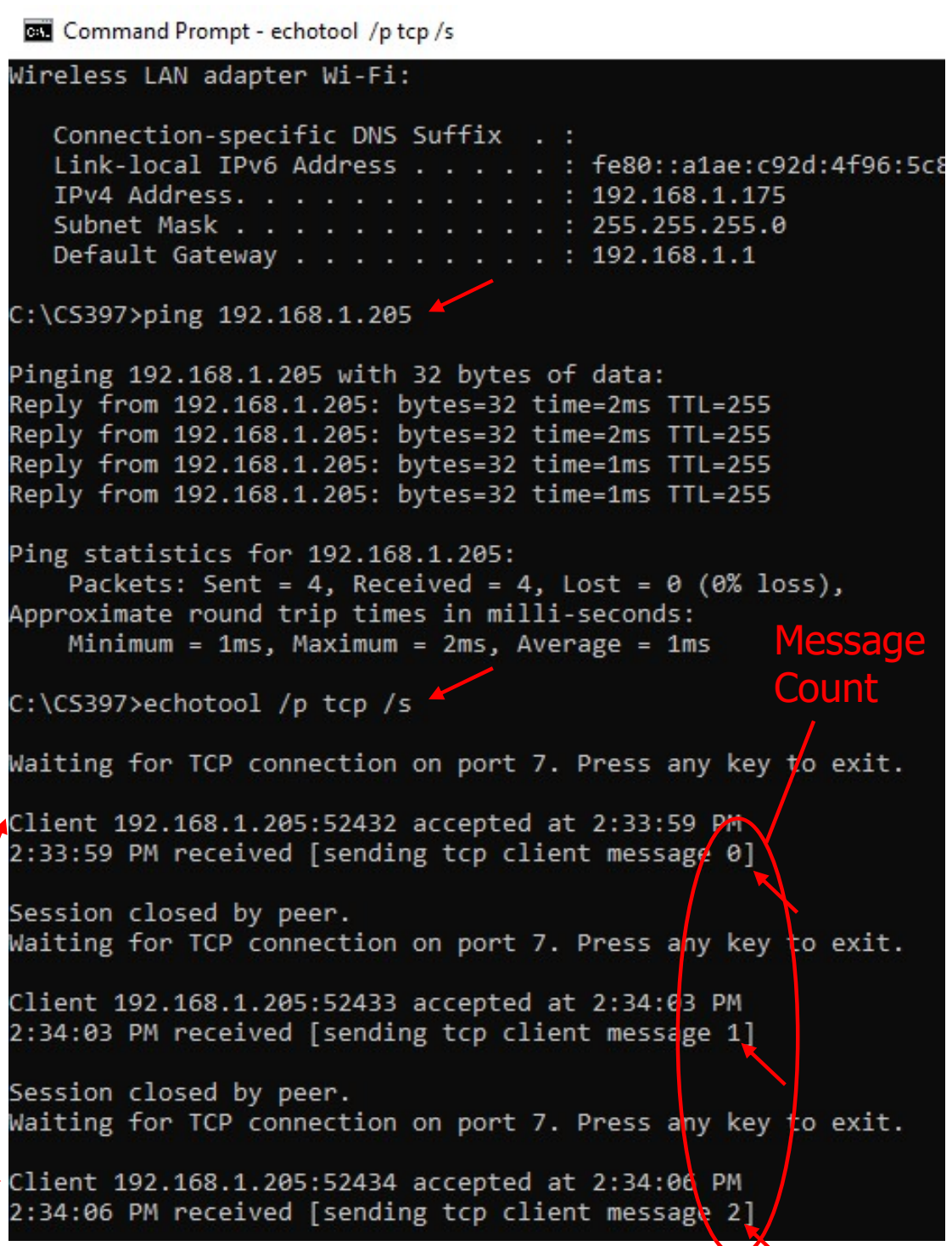
   - /p tcp is the TCP protocol (TCP protocol)
   - /s is the actual mode of connection (Server mode)
6. When the user-button on the board (Nucleo-F767ZI) is pressed, LD2 is toggled, and the client sends a string and the server echoes back the same string to the client.

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.



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 *is* assigned by IANA for this port, and *is*: standardized, specified, or widely used for such.
Unofficial	Described protocol *is not* assigned by IANA for this port, but *is*: standardized, specified, or widely used for such.
Assigned	Described protocol *is* assigned by IANA for this port,[2] but *is not*: standardized, specified, or widely used for such.
No	Described protocol *is not*: 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
