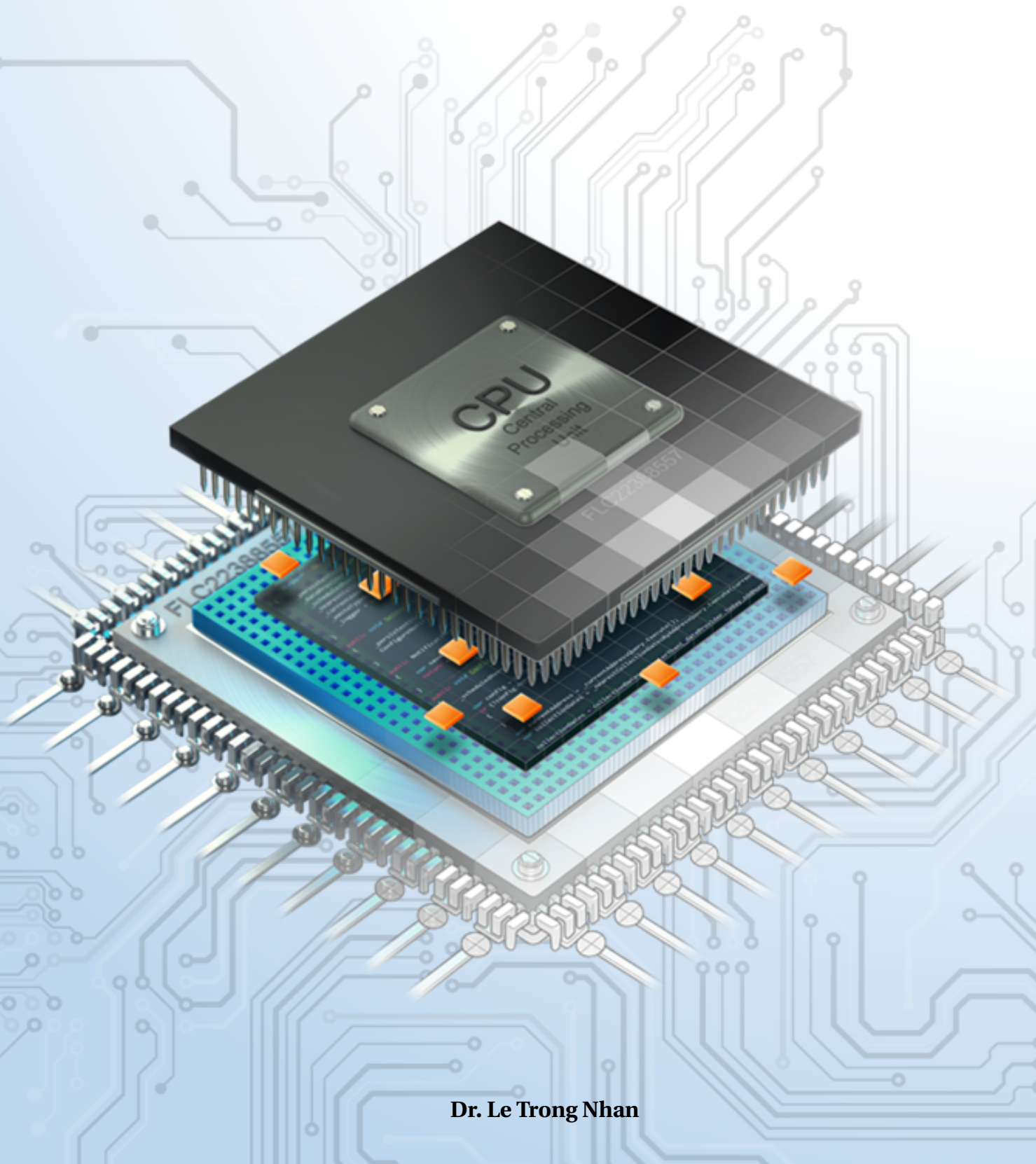




HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY
COMPUTER ENGINEERING

Microcontroller



Dr. Le Trong Nhan

Mục lục

Chapter 1. Flow and Error Control in Communication	7
1 Introduction	8
2 Proteus simulation platform	9
3 Project configurations	10
3.1 UART Configuration	10
3.2 ADC Input	11
4 UART loop-back communication	11
5 Sensor reading	12
6 Project description	13
6.1 Command parser	13
7 Project implementation	15
7.1 Proteus Schematic và link GitHub	15
7.2 Finite State Machine	16
7.2.1 Command parser FSM	16
7.2.2 UART Communication FSM	17
7.3 Source code:	17
7.3.1 Thư viện và các định nghĩa:	17
7.3.2 UART callback function:	18
7.3.3 Command parser FSM:	18
7.3.4 UART Communication FSM	21
7.3.5 Timer interrupt:	22
7.3.6 super loop in main function	22

CHƯƠNG 1

Flow and Error Control in Communication



1 Introduction

Flow control and Error control are the two main responsibilities of the data link layer, which is a communication channel for node-to-node delivery of the data. The functions of the flow and error control are explained as follows.

Flow control mainly coordinates with the amount of data that can be sent before receiving an acknowledgment from the receiver and it is one of the major duties of the data link layer. For most of the communications, flow control is a set of procedures that mainly tells the sender how much data the sender can send before it must wait for an acknowledgment from the receiver.

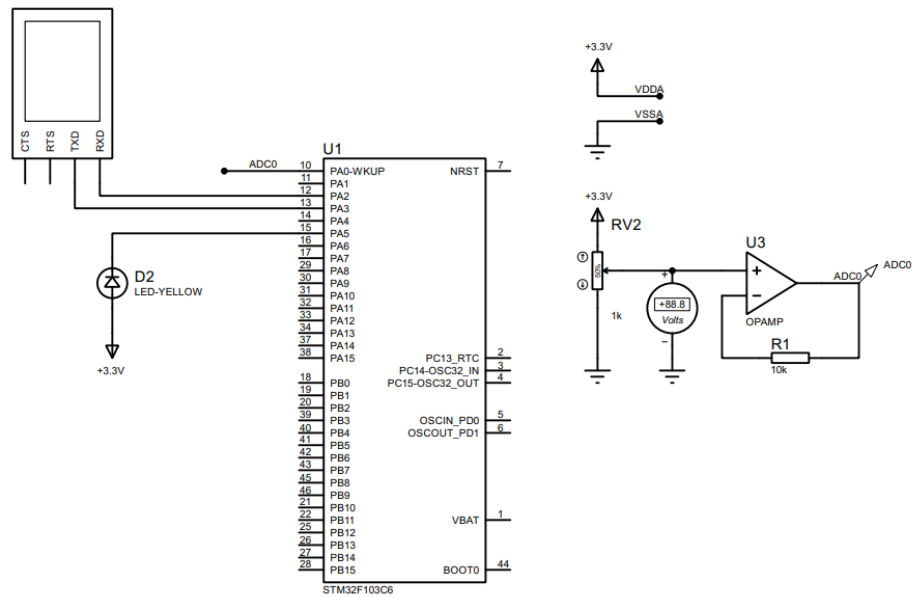
A critical issue, but not really frequently occurred, in the flow control is that the processing rate is slower than the transmission rate. Due to this reason each receiving device has a block of memory that is commonly known as buffer, that is used to store the incoming data until this data will be processed. In case the buffer begins to fill-up then the receiver must be able to tell the sender to halt the transmission until once again the receiver become able to receive.

Meanwhile, error control contains both error detection and error correction. It mainly allows the receiver to inform the sender about any damaged or lost frames during the transmission and then it coordinates with the re-transmission of those frames by the sender.

The term Error control in the communications mainly refers to the methods of error detection and re-transmission. Error control is mainly implemented in a simple way and that is whenever there is an error detected during the exchange, then specified frames are re-transmitted and this process is also referred to as Automatic Repeat request (ARQ).

The target in this lab is to implement a UART communication between the STM32 and a simulated terminal. A data request is sent from the terminal to the STM32. Afterward, computations are performed at the STM32 before a data packet is sent to the terminal. The terminal is supposed to reply an ACK to confirm the communication successfully or not.

2 Proteus simulation platform



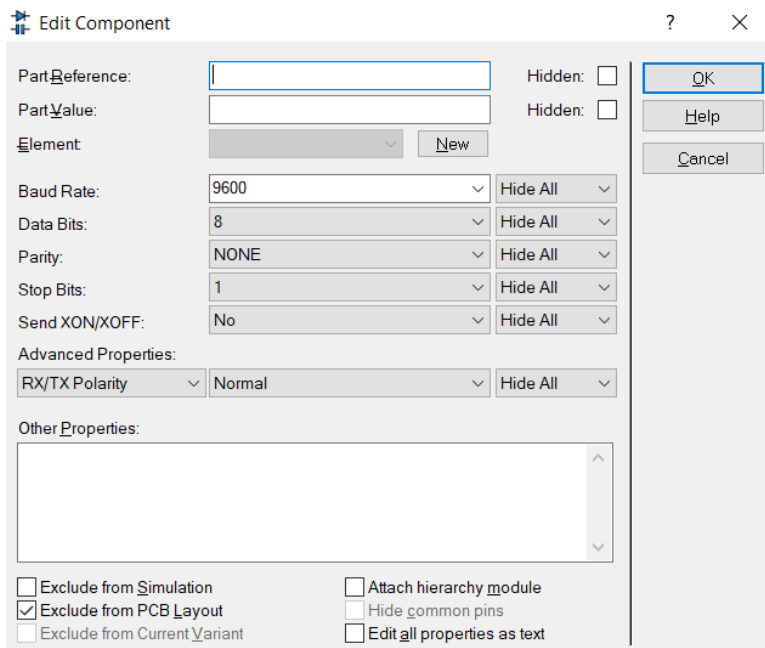
Hình 1.1: Simulation circuit on Proteus

Some new components are listed bellow:

- Terminal: Right click, choose Place, Virtual Instrument, then select VIRTUAL TERMINAL.
- Variable resistor (RV2): Right click, choose Place, From Library, and search for the POT-HG device. The value of this device is set to the default 1k.
- Volt meter (for debug): Right click, choose Place, Virtual Instrument, the select DC VOLTMETER.
- OPAMP (U3): Right click, choose Place, From Library, and search for the OPAMP device.

The opamp is used to design a voltage follower circuit, which is one of the most popular applications for opamp. In this case, it is used to design an adc input signal, which is connected to pin PA0 of the MCU.

Double click on the virtual terminal and set its baudrate to 9600, 8 data bits, no parity and 1 stop bit, as follows:



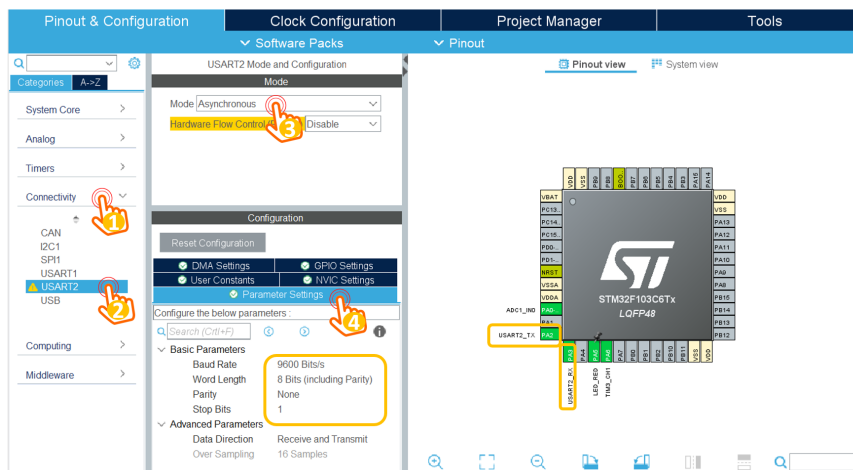
Hình 1.2: Terminal configuration

3 Project configurations

A new project is created with following configurations, concerning the UART for communications and ADC input for sensor reading. The pin PA5 should be an GPIO output, for LED blinky.

3.1 UART Configuration

From the ioc file, select **Connectivity**, and then select the **USART2**. The parameter settings for UART channel 2 (USART2) module are depicted as follows:









Hình 1.3: UART configuration in STMCube

The UART channel in this lab is the Asynchronous mode, 9600 bits/s with no Parity and 1 stop bit. After the uart is configured, the pins PA2 (Tx) and PA3(Rx) are

enabled.

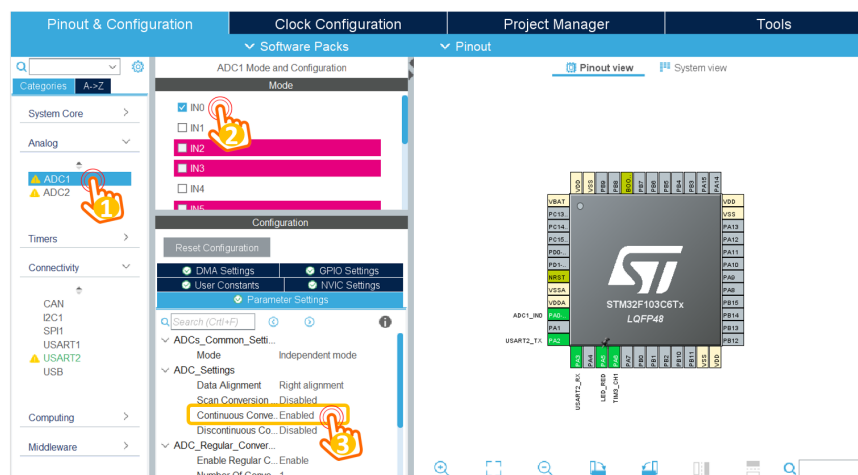
Finally, the NVIC settings are checked to enable the UART interrupt, as follows:

 DMA Settings	 GPIO Settings	
 User Constants	 NVIC Settings	
 Parameter Settings		
NVIC Interrupt Table	Enabled	Preemption P
USART2 global interrupt		0

Hình 1.4: Enable UART interrupt

3.2 ADC Input

In order to read a voltage signal from a simulated sensor, this module is required. By selecting on **Analog**, then **ADC1**, following configurations are required:



Hình 1.5: Enable UART interrupt

The ADC pin is configured to PA0 of the STM32, which is shown in the pinout view dialog.

Finally, the PA5 is configured as a GPIO output, connected to a blinky LED.

4 UART loop-back communication

This source is required to add in the main.c file, to verify the UART communication channel: sending back any character received from the terminal, which is well-known as the loop-back communication.

```
1 /* USER CODE BEGIN 0 */
2 uint8_t temp = 0;
3
```

```

4 void HAL_UART_RxCpltCallback(UART_HandleTypeDef *huart){
5     if(huart->Instance == USART2){
6         HAL_UART_Transmit(&huart2, &temp, 1, 50);
7         HAL_UART_Receive_IT(&huart2, &temp, 1);
8     }
9 }
10 /* USER CODE END 0 */

```

Program 1.1: Implement the UART interrupt service routine

When a character (or a byte) is received, this interrupt service routine is invoked. After the character is sent to the terminal, the interrupt is activated again. This source code should be placed in a user-defined section.

Finally, in the main function, the proposed source code is presented as follows:

```

1 int main(void)
2 {
3     HAL_Init();
4     SystemClock_Config();
5
6     MX_GPIO_Init();
7     MX_USART2_UART_Init();
8     MX_ADC1_Init();
9
10    HAL_UART_Receive_IT(&huart2, &temp, 1);
11
12    while (1)
13    {
14        HAL_GPIO_TogglePin(LED_RED_GPIO_Port, LED_RED_Pin);
15        HAL_Delay(500);
16    }
17
18 }

```

Program 1.2: Implement the main function

5 Sensor reading

A simple source code to read adc value from PA0 is presented as follows:

```

1 uint32_t ADC_value = 0;
2 while (1)
3 {
4     HAL_GPIO_TogglePin(LED_RED_GPIO_Port, LED_RED_Pin);
5     ADC_value = HAL_ADC_GetValue(&hadc1);
6     HAL_UART_Transmit(&huart2, (void *)str, sprintf(str, "%d\n",
7     , ADC_value), 1000);
8     HAL_Delay(500);
9 }

```

Program 1.3: ADC reading from AN0

Every half of second, the ADC value is read and its value is sent to the console. It is worth noticing that the number ADC_value is convert to ascii character by using the sprintf function.

The default ADC in STM32 is 13 bits, meaning that 5V is converted to 4096 decimal value. If the input is 2.5V, ADC_value is 2048.

6 Project description

In this lab, a simple communication protocol is implemented as follows:

- From the console, user types **!RST#** to ask for a sensory data.
- The STM32 response the ADC_value, following a format **!ADC=1234#**, where 1234 presents for the value of ADC_value variable.
- The user ends the communication by sending **!OK#**

The timeout for waiting the **!OK#** at STM32 is 3 seconds. After this period, its packet is sent again. **The value is kept as the previous packet.**

6.1 Command parser

This module is used to received a command from the console. As the reception process is implement by an interrupt, the complexity is considered seriously. The proposed implementation is given as follows.

Firstly, the received character is added into a buffer, and a flag is set to indicate that there is a new data.

```
1 #define MAX_BUFFER_SIZE 30
2 uint8_t temp = 0;
3 uint8_t buffer[MAX_BUFFER_SIZE];
4 uint8_t index_buffer = 0;
5 uint8_t buffer_flag = 0;
6 void HAL_UART_RxCpltCallback(UART_HandleTypeDef *huart){
7     if(huart->Instance == USART2){
8
9         //HAL_UART_Transmit(&huart2, &temp, 1, 50);
10        buffer[index_buffer++] = temp;
11        if(index_buffer == 30) index_buffer = 0;
12
13        buffer_flag = 1;
14        HAL_UART_Receive_IT(&huart2, &temp, 1);
15    }
16 }
```

Program 1.4: Add the received character into a buffer

A state machine to extract a command is implemented in the while(1) of the main function, as follows:

```

1 while (1){
2     if(buffer_flag == 1){
3         command_parser_fsm();
4         buffer_flag = 0;
5     }
6 }

```

Program 1.5: State machine to extract the command

The output of the command parser is to set **command_flag** and **command_data**. In this project, there are two commands, **RTS** and **OK**. The program skeleton is proposed as follows:

```

1 while (1){
2     if(buffer_flag == 1){
3         command_parser_fsm();
4         buffer_flag = 0;
5     }
6     uart_communiation_fsm();
7 }

```

Program 1.6: Program structure

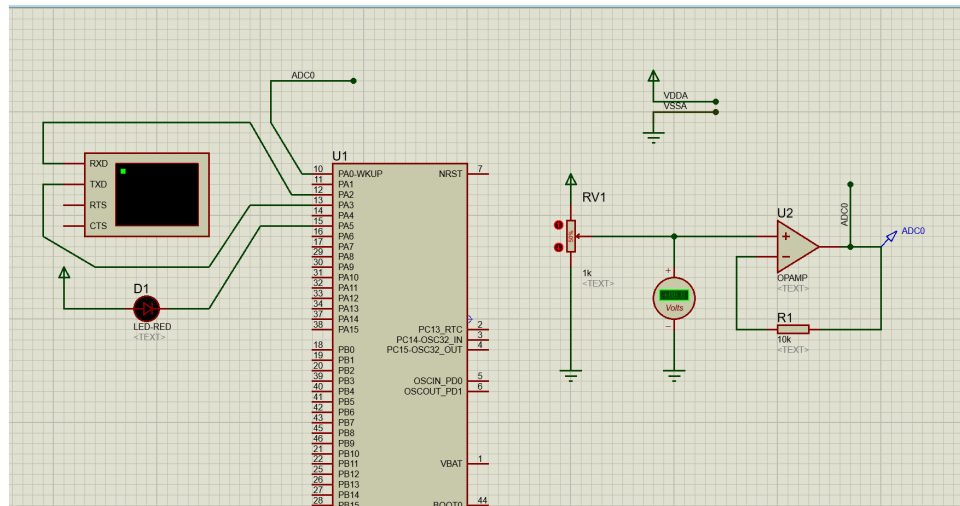
7 Project implementation

Students are proposed to implement 2 FSM in separated modules. Students are asked to design the FSM before their implementations in STM32Cube.

7.1 Proteus Schematic và link GitHub

In this exercise, I'm using:

- 1 Virtual Terminal
- 1 OPAMP
- 1 DC VOLTMETER
- 1 POT-HG device

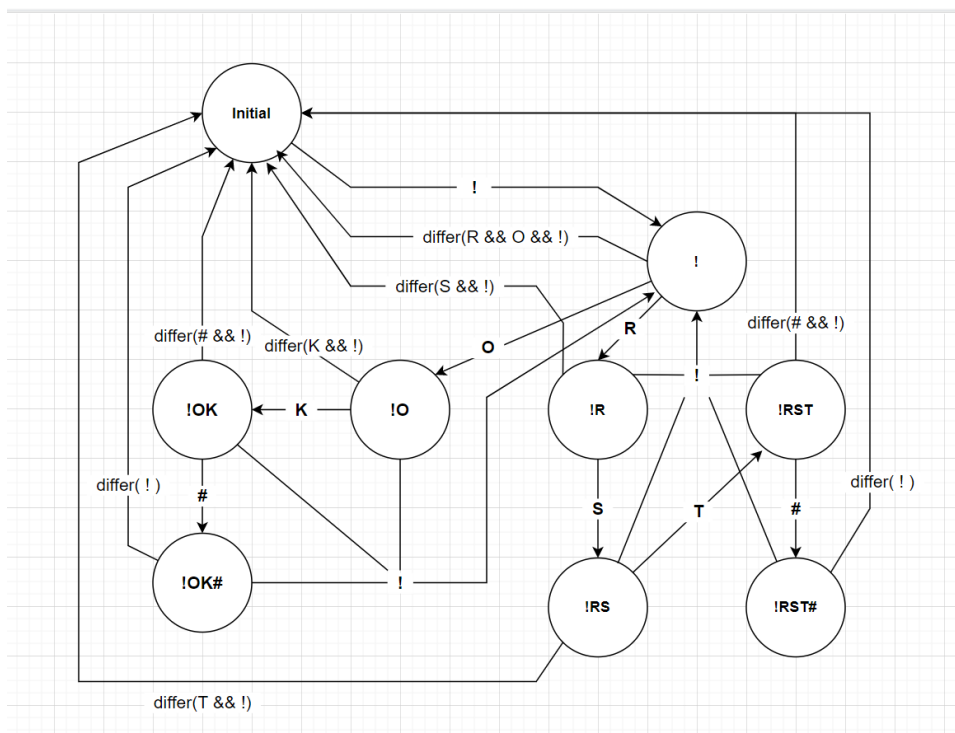


Hình 1.6: Simulation circuit on Proteus. For more information please check this [GitHub](#)

7.2 Finite State Machine

7.2.1 Command parser FSM

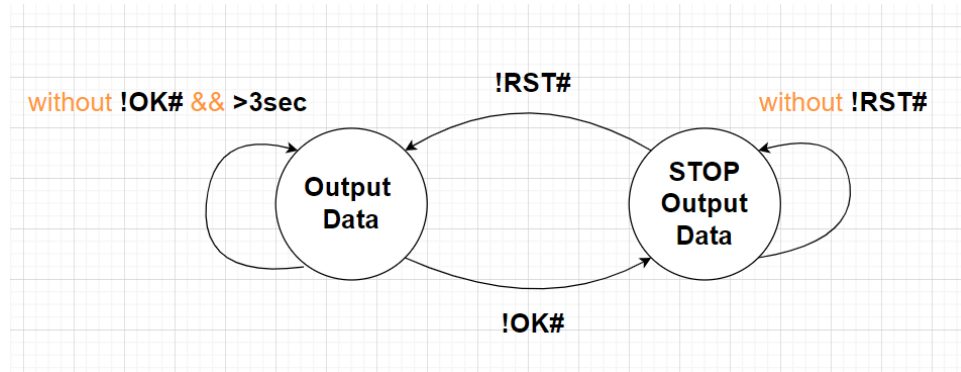
Ta đặt trạng thái đầu tiên là "**Initial**" là trạng thái bắt đầu. Như ta thấy, cả **!RST#** và **!OK#** đều giống nhau ở **!**. Như vậy để đọc được comment thì dấu hiệu là ở **!**, khi ở trạng thái bắt đầu "**Initial**" ta nhập **!** thì sẽ tiến tới trạng thái "**R**". Cứ tiếp tục, nếu đọc được ký tự tiếp theo, sẽ tiến tới state tiếp theo. Và ngược lại, nếu đọc được ký tự lạ sẽ quay về trạng thái bắt đầu **Initial**



Hình 1.7: Command Parser FSM. For more information please check this [GitHub](#)

7.2.2 UART Communication FSM

Khi đang trong quá trình output data, nếu có tín hiệu **!OK#** thì sẽ ngừng việc output data lại, và tương tự nếu có tín hiệu **!RST#** thì sẽ chuyển từ trạng thái stop sang trạng thái output data.



Hình 1.8: UART Communication FSM. For more information please check this [GitHub](#)

7.3 Source code:

For more information please check this [GitHub](#).

7.3.1 Thư viện và các định nghĩa:

```
1 #include "main.h"
2 #include <stdio.h>
3 #include <stdlib.h>
4
5 #define MAX_BUFFER_SIZE 30
6
7 const int TIME_OUT = 3000;
8
9 #define INITIAL 0
10 #define DOT 1
11
12 #define DOT_R 2
13 #define DOT_RS 3
14 #define DOT_RST 4
15 #define DOT_RST_HASH 5
16
17 #define DOT_0 6
18 #define DOT_OK 7
19 #define DOT_OK_HASH 8
```

Program 1.7: Thêm thư viện và định nghĩa

7.3.2 UART callback function:

```
1 // ----- BEGIN UART CallBack ----- //
2 // -----//
3 uint8_t temp = 0;
4 uint8_t buffer[MAX_BUFFER_SIZE];
5 uint8_t index_buffer = 0;
6 uint8_t buffer_flag = 0;
7
8 uint32_t ADC_value = 9;
9 const int MAX_COUNT = 300;
10 int enableClock = FALSE;
11 int counter = 300;
12 char str[50];
13
14 void HAL_UART_RxCpltCallback(UART_HandleTypeDef* huart){
15     if(huart->Instance == USART2){
16         buffer[index_buffer++] = temp;
17         if(index_buffer == MAX_BUFFER_SIZE) index_buffer = 0;
18         buffer_flag = 1;
19         HAL_UART_Receive_IT(&huart2 , &temp , 1);
20     }
21 }
```

Program 1.8: UART callback function

7.3.3 Command parser FSM:

```
1 // ----- BEGIN COMMAND PARSER FSM ----- //
2 // -----//
3 int cur_State = INITIAL;
4
5 int isRST = 0;
6 int isOK = 0;
7
8 void command_parser_fsm()
9 {
10     switch (cur_State)
11     {
12         case INITIAL:
13             if (temp == (int) '!')
14             {
15                 cur_State = DOT;
16             }
17             break;
18
19         case DOT:
20             if (temp == (int) '!')
21             {
```

```

22         cur_State = DOT;
23     }
24     else if (temp == (int)'R')
25     {
26         cur_State = DOT_R;
27     }
28     else if (temp == (int)'O')
29     {
30         cur_State = DOT_O;
31     }
32     else
33     {
34         cur_State = INITIAL;
35     }
36     break;
37
38 case DOT_R:
39     if (temp == (int) '!')
40     {
41         cur_State = DOT;
42     }
43     else if (temp == (int)'S')
44     {
45         cur_State = DOT_RS;
46     }
47     else
48     {
49         cur_State = INITIAL;
50     }
51     break;
52
53 case DOT_RS:
54     if (temp == (int) '!')
55     {
56         cur_State = DOT;
57     }
58     else if (temp == (int)'T')
59     {
60         cur_State = DOT_RST;
61     }
62     else
63     {
64         cur_State = INITIAL;
65     }
66     break;
67
68 case DOT_RST:
69     if (temp == (int) '!')
70     {

```

```

71         cur_State = DOT;
72     }
73     else if (temp == (int)'#')
74     {
75         isRST = 1;
76         ADC_value = HAL_ADC_GetValue(&hadc1);
77         HAL_UART_Transmit(&huart2, (void *)str, sprintf
78 (str, "!ADC= %lu#\r\n", ADC_value), 1000);
79         cur_State = DOT_RST_HASH;
80     }
81     else
82     {
83         cur_State = INITIAL;
84     }
85     break;
86
87 case DOT_RST_HASH:
88     if (temp == (int) '!')
89     {
90         cur_State = DOT;
91     }
92     else
93     {
94         cur_State = INITIAL;
95     }
96     break;
97
98 case DOT_0:
99     if (temp == (int) '!')
100     {
101         cur_State = DOT;
102     }
103     else if (temp == (int) 'K')
104     {
105         cur_State = DOT_OK;
106     }
107     else
108     {
109         cur_State = INITIAL;
110     }
111     break;
112
113 case DOT_OK:
114     if (temp == (int) '!')
115     {
116         cur_State = DOT;
117     }
118     else if (temp == (int) '#')
119     {

```

```

119         isOK = TRUE;
120         cur_State = DOT_OK_HASH;
121     }
122     else
123     {
124         cur_State = INITIAL;
125     }
126     break;
127
128     case DOT_OK_HASH:
129         if (temp == (int) '!')
130         {
131             cur_State = DOT;
132         }
133         else
134         {
135             cur_State = INITIAL;
136         }
137         break;
138     }
139 }

```

Program 1.9: Command parser fsm

7.3.4 UART Communication FSM

```

1 // ----- BEGIN UART FSM ----- //
2 // ----- //
3 int isPrint = 0;
4
5 void uart_communication_fsm()
6 {
7     if (isOK)
8     {
9         isOK = 0;
10        isRST = 0;
11        isPrint = 0;
12        enableClock = 0;
13        counter = MAX_COUNT;
14    }
15
16    if (isRST)
17    {
18        enableClock = 1;
19        if (isPrint)
20        {
21            HAL_UART_Transmit(&huart2, (void *)str, sizeof(
str), 1000);
22            isPrint = 0;

```

```

23     }
24 }
25 }

```

Program 1.10: UART Communication FSM

7.3.5 Timer interrupt:

```

1 // ----- BEGIN TIMER INTERRUPT ----- //
2 // ----- //
3 void HAL_TIM_PeriodElapsedCallback(TIM_HandleTypeDef *htim)
4 {
5     if (enableClock)
6     {
7         if (counter <= 0)
8         {
9             isPrint = 1;
10            counter = MAX_COUNT;
11        }
12        else
13        {
14            counter--;
15        }
16    }
17 }

```

Program 1.11: Timer interrupt

7.3.6 super loop in main function

```

1 /* Infinite loop */
2 /* USER CODE BEGIN WHILE */
3 HAL_TIM_Base_Start_IT(&htim2);
4 HAL_UART_Receive_IT(&huart2, &temp, 1);
5 HAL_ADC_Start(&hadc1);
6 while (1)
7 {
8     if (buffer_flag)
9     {
10        HAL_GPIO_TogglePin(GPIOA, GPIO_PIN_5);
11        command_parser_fsm();
12        buffer_flag = 0;
13    }
14
15    uart_communication_fsm();
16    /* USER CODE END WHILE */
17 }

```

Program 1.12: Main function