

# Microprocessor Systems Lab 1

## Checkoff and Grade Sheet

Partner 1 Name: \_\_\_\_\_

Partner 2 Name: \_\_\_\_\_

| Grade Component                  | Max.                | Points Awarded |           | TA Init.s | Date |
|----------------------------------|---------------------|----------------|-----------|-----------|------|
|                                  |                     | Partner 1      | Partner 2 |           |      |
| Performance Verification: Task 1 | 10 %                |                |           |           |      |
|                                  | Task 2 15 %         |                |           |           |      |
|                                  | Task 3 15 %         |                |           |           |      |
|                                  | Task 4 [Depth] 10 % |                |           |           |      |
| Documentation and Appearance     | 50 %                |                |           |           |      |
| Total:                           |                     |                |           |           |      |

### → Laboratory Goals

By completing this laboratory assignment, you will learn to:

1. To use the STM32CubeIDE IDE (Eclipse Based) designed for STM32 microcontrollers,
2. Program the STM32F769NI using the GNU ARM C Compiler (a.k.a. GCC ARM),
3. Produce an ANSI/VT100 terminal display in order to interact with the microcontroller connected to a computer via a serial terminal (e.g., ProComm Plus, PuTTY, picocom, etc.)
4. Perform basic digital Input/Output tasks.

### → Preparation

- Install STM32CubeIDE IDE and serial terminal: follow the [Install Guide](#).
- Purchase a [STM32F769I-DISCOVERY<sup>1</sup>](#) board and bring it to every class.
- Review the C language, specifically the utilities contained in [stdio.h](#).
- Read suggested materials below.

### → Reading and References

- R1. [Mastering STM32](#): Chapter 1 (Introduction) and Chapter 6 (GPIO)
- R2. [UM2033-stm32f769i-disco\\_Manual.pdf](#): Skim entirety
- R3. [stm32f769xx\\_Datasheet.pdf](#): Skim Chapters 1 and 2
- R4. [ES0334\\_stm32f76xxx\\_Errata.pdf](#): Skim
- R5. [RM0410-stm32f76xxx\\_Reference\\_Manual.pdf](#): Chapter 6 (notably, Section 6.4)
- R6. [UM1905-stm32f7\\_HAL\\_and\\_LL\\_Drivers.pdf](#): Chapter 2 (p.35,36 only), Chapter 26 (HAL GPIO)
- R7. [VT100-ANSI\\_Escape\\_Sequences.pdf](#)
- R8. [Lab01-ANSI\\_Term-GPIO\\_Template.zip](#): Project Template for Lab 1

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<sup>1</sup>In this class, we will generally refer to this as the DISCO board. The alternate NUCLEO-F767ZI may also be used.

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## ANSI PROGRAMMING TASKS FOR THE STM32

Communication between the microcontroller and a computer, for this class at least, will be achieved through a virtual serial connection provided by the USB connection. This serial connection uses the peripheral USART1 to generate a UART interface operating at 115200 baud. The code implementing this is provided by the libraries provided: `init.h/init.c`, `uart.h/uart.c`, and is called by the `Sys_Init()` function that should be called at the beginning of any program.

Input from the terminal keyboard and output to the terminal display can be done on a character-by-character basis by using the `getchar()` and `putchar()`, respectively. Additionally, `printf()` may be used to format and output strings to the display. This is essentially the same functionality you used extensively in ENGR-2350 Embedded Control.

The VT100/ANSI terminal standards allow for the terminal to be controlled more elegantly than simply writing line-by-line. This control is performed by sending special codes, or escape sequences, to the terminal. Functionalities enabled by these standards includes but are not limited to: screen erasing, cursor location control, background and font color changing and scrolling. These codes generally start with sending the character code for the <ESC> key (ASCII Value: Dec:27 Hex:0x1B Oct:033). A table of some of these escape codes is given in [R7](#).

### ◇ Task 1: Introduction to the User Interface

Write a simple program to run on the STM32F769NI that outputs the text “**The keyboard character is \*.**” whenever a printable character is pressed on the terminal keyboard, where `*` is replaced with the corresponding character. The program should halt when either <ESC> or the key combination `^[` are pressed. Note that the notation `^[` means that the keys <Control> and `[` are pressed together. Display a message at the top of the screen when the program starts indicating how to terminate the program.

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## ◇ Task 2: VT100/ANSI Terminal Control Sequences

To complete this task, you must modify the code from Task 1 to do the following. An example implementation of this task is given in Figures 1 and 2.

1. Display yellow characters on a blue background
2. Center the program's termination information on line 2.
3. Log any printable character to the screen between lines 4 and 14, with a 4 space margin on the left and right of the screen, starting at the top-left region of the space.
4. The log above should scroll when more space is needed; that is, when line 10 is full, all lines within the log should move up one to make more space. The original line 4 would be removed.
5. For when non-printable characters are pressed, have the program beep (or flash) and also add the **red text**: "**The received value \$XX is 'not printable'.**" at line 18. For each subsequent non-printable character, this line should be overwritten.
6. On the bottom left of the terminal, keep a log of the number of printable and non-printable characters received.

### NOTES:

1. A standard terminal is sized 80x24 characters. Depending on the terminal program you installed, your terminal may not be this size unless you manually size the window as such. You may assume for the purpose of this lab that you are targeting an 80x24 terminal.
2. The term "Escape sequence" doesn't necessarily imply that <ESC> is used. For example, \n and \t are also escape sequences.
3. If the terminal doesn't respond properly to escape sequences, it may no longer be in an ANSI compatible mode. Check your options or restart the program.
4. Scrolling of a scroll section only occurs when a newline character, \n, is written to the bottom of the scroll section.
5. Beep support is spotty for different terminal programs. Implementation of the beep will be considered successful as long as the functionality to produce the beep is implemented in the program code correctly.
6. The program may lock-up when more than one keyboard key is pressed. This issue may be ignored.
7. It is good practice to design the program top-down, then write the routines bottom-up. The routines should be written one at a time and tested thoroughly prior to integration.

```

                                PRESS <ESC> OR <CTL>+[ TO QUIT
-----
This is a test of the Emergency Broadcast System. For the next 60 se
conds, this station will conduct a test of the Emergency Broadcast S
ystem. This is only a test. <LOUD NOISES> ... This is a test of the
broadcast stations in your area. If this had been an actual emergenc
y, you would have heard official information, news or instructions.
This station serves the <REDACTED> area. This concludes this test of
the Emergency Broadcast System.
-----

The received value $0d is 'not printable'.

# of Characters Received:
Printable      Non-Printable
440            84

```

Figure 1: Example terminal for Task 2.

```

                                PRESS <ESC> OR <CTL>+[ TO QUIT
-----
ystem. This is only a test. <LOUD NOISES> ... This is a test of the
broadcast stations in your area. If this had been an actual emergenc
y, you would have heard official information, news or instructions.
This station serves the <REDACTED> area. This concludes this test of
the Emergency Broadcast System.....
.....
-----

The received value $0d is 'not printable'.

# of Characters Received:
Printable      Non-Printable
590            94

```

Figure 2: Example terminal for Task 2 with scrolled text.

## STM32 General Purpose Inputs and Outputs (GPIO)

The STM32F769NI has 159(!) general purpose input and output pins. Unfortunately, the DISCO board that we are using does not allow us access to all of these pins. Some have been dedicated to specific uses (e.g., LCD, microSD, on-board LEDs), while a limited number (22) are routed to the Arduino standard Uno V3 connectors CN9, CN11<sup>2</sup>, CN13, CN14. Please refer to Table 5 of [R2](#) for a complete mapping of these connectors. Be aware that PA4 on CN14 (labeled A1) is the only pin routed to these connectors that is not +5 V tolerant. *This pin should not be used until lab 4.*

The 159 pins of the STM32F769NI are broken up into ports, labeled GPIOA through GPIOK, with the naming convention of the pins following the format  $Px\#$ , where  $x$  is the port letter (A-K) and  $\#$  is the pin number (0-15). Ports GPIOA-J are 16-pin ports and GPIOK is an 8-pin port<sup>3</sup>.

Configuration and access to the GPIO pins is enabled through the registers listed in Section 6.4 of [R5](#). Access to each of the port registers is done through the struct pointer GPIOx; for example, to set the 0<sup>th</sup> bit of the MODER register for GPIOA, the command `GPIOA->MODER |= 0x00000001U`; could be used<sup>4</sup>.

In an effort to make the GPIO (and other peripherals) easier to configure and use, the Hardware Abstraction Layer (HAL) or Low-Layer (LL) drivers are given in [R6](#). These drivers provide “abstraction” functions, such that the programmer does not need to know and interface with the microcontroller registers. For this class, only the HAL driver set will be considered. GPIO configuration using the HAL drivers is done by defining a GPIO\_InitTypeDef struct, which contains all desired configuration information for a single pin. This struct is then passed to the HAL\_GPIO\_Init() along with the GPIO port register set reference pointer (e.g., GPIOA) to perform all the register modifications necessary to implement the configuration defined in the GPIO\_InitTypeDef struct. Additionally, there are abstraction functions given to read pin values, set pin values, etc.

For the GPIO functionality to work properly, each GPIO port needs its peripheral clock enabled. This may be done through the register AHB1ENR or the HAL functions `_HAL_RCC_GPIO[x]_CLK_ENABLE()`, where  $[x]$  is replaced with the desired port letter.

The steps necessary to read or set the voltage on a GPIO port pin are as follows<sup>5</sup>:

### Digital Input:

1. Enable the GPIO port peripheral clock
2. Set input mode
3. Internal pull-up/-down resistors
4. Read pin value

### Digital Output:

1. Enable the GPIO port peripheral clock
2. Set output mode
3. Configure output type
4. Set output speed
5. Set output value

<sup>2</sup>CN11 doesn't actually have any GPIOs connected to it, but it is part of the Arduino headers.

<sup>3</sup>Pins PJ6-11 and PK0-2 are not routed outside the chip, hence the 159 pins instead of 168.

<sup>4</sup>When reading the [R5](#), each register's name is followed by a set of parentheses containing a notation akin to the format: [MODULE]\_[REGISTER], e.g., GPIOx\_MODER. This implies that to access the register, the struct pointer [MODULE] needs to be accessed: [MODULE]->[REGISTER]. E.g.: GPIOA->MODER accesses register MODER within GPIOA

<sup>5</sup>Some of these steps listed may be implied through the default configuration

### ◇ Task 3: Port Input/Output

Configure the 769 and wire external electronics to properly execute the following tasks. While the team should generally work together on this task, one team member should implement this functionality using only registers while the other team member uses the HAL driver (two separate programs).

- Set each accessible on-board LED (LD1-LD4) port pin to function as a digital output.
- Set the Arduino Header pins D0 through D3 to be digital inputs with internal pull-up resistors enabled.
- Connect 4 digital lines of an Analog Discovery Board to D0-D3 pins. Configure these digital lines within Waveforms to be outputs (to use a switches).
- Continuously read the state of the switches and turn on or off an LED accordingly. The switch connected to D0 should control LD1, D1 controls LD2, etc.

NOTES:

1. LD4 uses inverted logic.
2. The grounds of the Analog Discovery Board and the DISCO board must be connected together for this to work properly.
3. Pins PA9 and PA10 are used to produce the UART link to the computer. If your UART link is not working, make sure that you have not modified these pins!
4. Be *very careful* not to modify pins PA13 and PA14. This may cause difficulty in programming the board.

### ◇ Task 4: [Depth] Maze

Using the code from the previous tasks as a template, build a terminal maze game. The maze should be at least 10x10 characters and can be constructed how ever you like. For example, the walls of the maze may be indicated by a color change, by | or \_ characters, by underlines, etc. The “player” in the maze should be represented how ever you like as well, though should be of different functionality than the walls (e.g., the player and walls cannot both be represented by a simple color change, even if the colors are different). Allow navigation of the maze through the WASD keys. Implement a pushbutton (the blue button on the DISCO board or one Analog Discovery digital line) to serve as a restart button and an LED to indicate completion of the maze.

NOTES:

1. Redrawing of the maze should limited: Do not redraw the whole screen each time the player moves.
2. Remember, “Depth” tasks can only be completed assuming that all previous tasks have been completed and checked off prior to the lab finish date on the course calendar.
3. Due to the blocking nature of receiving characters from the terminal, it is acceptable push the reset button then a keyboard key to allow the reset request to be registered by the program.