ECE0202: Embedded Systems and Interfacing

Lab 4: Keypad Scanning (in assembly)
Due: 3/21/21 at 11:59pm

Objectives

- **Understand I/O multiplexing technique**
- **Be familiar with keypad scanning algorithms**
- **Implement software debouncing**

Pre-Lab Reading

- **Chapter 14.9 Keypad Scanning**

Deliverables – total 100 points

- **(40 points) – demonstration of keypad scanning that displays the pressed character on the Tera Term.**
- **(35 points) – Code submission. Code should use software debouncing and be well-written and commented.**
- **(25 points) Submission of the pre-lab register tables and post-lab questions. Indicate how each group member participates and contributes to the lab at the end of the lab report.**
- **(10 points extra credit) Display the last pressed 6 characters, in order, on the Tera Term.**
- **Indicate each group member's Participation and Contribution.**

Please submit your code as *.s files and your schematic as a pdf

Keyboard Interface

The 4x4 keypad used in this lab requires 8 pins (4 row pins and 4 column pins). In this lab, the connection between the keypad and the discovery kit is shown in the following table.

Row	R1 → PC0	R2 →PC1	R3 →PC2	R4 →PC3
Column	C1 → PB1	C2 → PB2	C3 → PB3	C4 → PB5

All pins of the input port (C1, C2, C3, and C4) are pulled up to 3V via 2.2kΩ resistors already placed on the Discovery board; however, the output port pins (R1, R2, R3, and R4) will require us to configure pull-up resistors. Within the processor, each GPIO pin can be pulled up via an internal resistor (between 20 and 55kΩ), but the internal pull-up current capability is too weak, and therefore an external pull-up resistor is required, as drawn in Fig. 1.

When looking at the front side of the keypad, the pins on the connector from left to right are:

R1 – R2 – R3 – R4 – C1 – C2 – C3 – C4

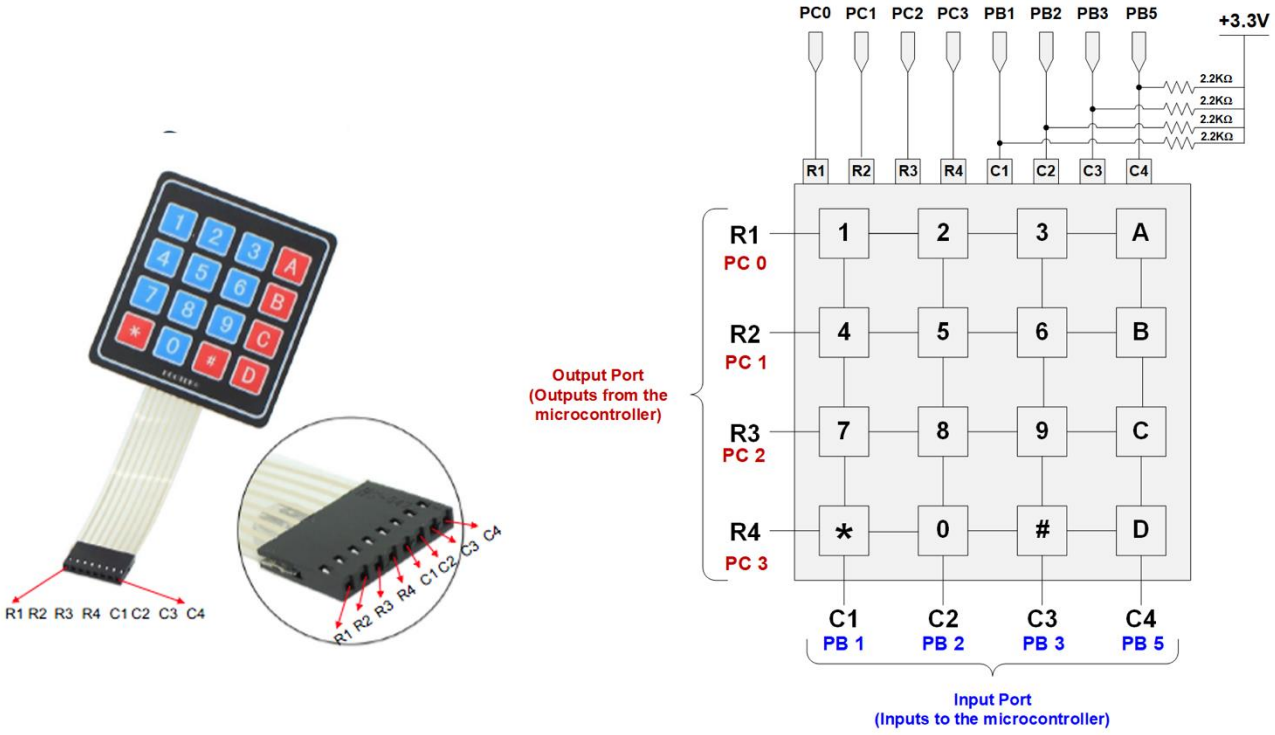


Figure 1- Picture and schematic of the keypad

The maximum current a GPIO pin can source or sink is 20 mA. When calculating the value of external pull-up resistors, make sure that the current does not exceed 20 mA. For example:

$$\frac{3\ V}{2.2\ k\Omega} = 1.4\ mA$$

On the Nucleo board, all pins in the input port (PB1, PB2, PB3, and PB5) are connected to ground via a 100 nF capacitor. A very short delay should be added before reading the input port, as seen later in the software flowchart.

ASCII

In order to write to the Tera Term, you must store the code for an ASCII character into a memory location. In lab 1, the string to be displayed on the Tera Term is stored at a memory location called “str”. This can also be used as the memory location that stores the character you display in this lab.

To display a character on the Tera Term, you must store the associated ASCII code in the memory location “str”, load the memory address of “str” into r0, and then run the instruction *BL USART2_Write*.
The following table gives ASCII codes for many characters. Note that these are in decimal!

ASCII value	Character	ASCII value	Character	ASCII value	Character
000	^@	043	+	086	V
001	^A	044	,	087	W
002	^B	045	-	088	X
003	^C	046	.	089	Y
004	^D	047	/	090	Z
005	^E	048	0	091	[
006	^F	049	1	092	\
007	^G	050	2	093	]
008	^H	051	3	094	^
009	^I	052	4	095	_
010	^J	053	5	096	`
011	^K	054	6	097	a
012	^L	055	7	098	b
013	^M	056	8	099	c
014	^N	057	9	100	d
015	^O	158	:	101	e
016	^P	059	;	102	f
017	^Q	060	<	103	g
018	^R	061	=	104	h
019	^S	062	>	105	i
020	^T	063	?	106	j
021	^U	064	@	107	k
022	^V	065	A	108	l
023	^W	066	B	109	m
024	^X	067	C	110	n
025	^Y	068	D	111	o
026	^Z	069	E	112	p
027	^[	070	F	113	q
028	^\	071	G	114	r
029	^]	072	H	115	s
030	^^	073	I	116	t
031	^-	074	J	117	u
032	[space]	075	K	118	v
033	!	076	L	119	w
034	"	077	M	120	x
035	#	078	N	121	y
036	$	079	O	122	z
037	%	080	P	123	{
038	&	081	Q	124	|
039	'	082	R	125	}
040	(	083	S	126	~
041	)	084	T	127	DEL
042	*	085	U		

Figure 2 - ASCII character codes. From https://ee.hawaii.edu/~tep/EE160/Book/chap4/subsection2.1.1.1.html

Software Flowchart

The following software flowchart is a modified version of that shown in textbook chapter 14.9, and should be used as a general guide for writing the program used in this lab.

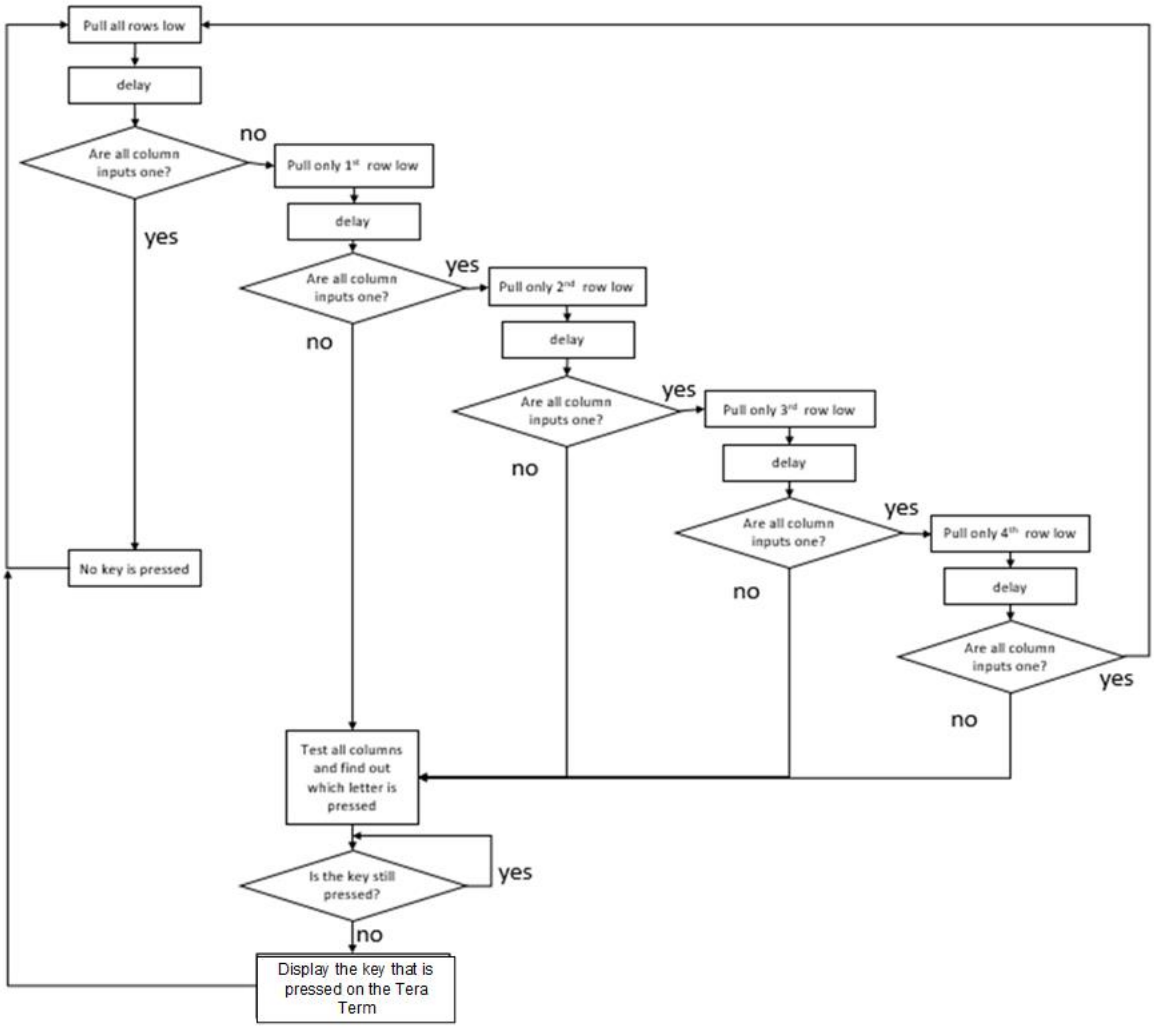


Figure 3 - Software Flowchart for the keypad scanning algorithm

Pre-Lab Register Tables (5 points)

Configure Port C: Pin 0, 1, 2, and 3 as Digital Output

GPIO Mode: Digital Input (00), Digital Output (01), Alternative Function (10), Analog (11)

Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MODER	MODER15[1:0]		MODER14[1:0]		MODER13[1:0]		MODER12[1:0]		MODER11[1:0]		MODER10[1:0]		MODER9[1:0]		MODER8[1:0]		MODER7[1:0]		MODER6[1:0]		MODER5[1:0]		MODER4[1:0]		MODER3[1:0]		MODER2[1:0]		MODER1[1:0]		MODER0[1:0]	
MASK																					...	0	0	0	1	1	1	1	1	1	1	1
VALUE																					...	X	X	X	0	1	0	1	0	1	0	1

GPIOC Mode Register MASK Value = 0x FF (in HEX)

GPIOC Mode Register Value = 0x 55 (in HEX)

Configure Port B: Pin 1, 2, 3, and 5 as Digital Input

GPIO Mode: Digital Input (00), Digital Output (01), Alternative Function (10), Analog (11)

Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MODER	MODER15[1:0]		MODER14[1:0]		MODER13[1:0]		MODER12[1:0]		MODER11[1:0]		MODER10[1:0]		MODER9[1:0]		MODER8[1:0]		MODER7[1:0]		MODER6[1:0]		MODER5[1:0]		MODER4[1:0]		MODER3[1:0]		MODER2[1:0]		MODER1[1:0]		MODER0[1:0]	
MASK																	...	0	0	0	1	1	0	0	1	1	1	1	1	1	0	0
VALUE																	...	X	X	X	0	0	X	X	0	0	0	0	0	0	X	X

GPIOB Mode Register MASK Value = 0x CFC (in HEX)

GPIOB Mode Register Value = 0x 0 (in HEX)

Write to Port C: Pins 0, 1, 2, and 3 connect to the rows of the keypad

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ODR	Pin 31	Pin 30	Pin 29	Pin 28	Pin 27	Pin 26	Pin 25	Pin 24	Pin 23	Pin 22	Pin 21	Pin 20	Pin 19	Pin 18	Pin 17	Pin 16	Pin 15	Pin 14	Pin 13	Pin 12	Pin 11	Pin 10	Pin 9	Pin 8	Pin 7	Pin 6	Pin 5	Pin 4	Pin 3	Pin 2	Pin 1	Pin 0
Value																																

Value written to PORTC ODR in order to pull down all rows: 0xF **(in HEX)**

Value written to PORTC ODR in order to pull down row 1: 0x1 **(in HEX)**

Value written to PORTC ODR in order to pull down row 2: 0x2 **(in HEX)**

Value written to PORTC ODR in order to pull down row 3: 0x4 **(in HEX)**

Value written to PORTC ODR in order to pull down row 4: 0x8 **(in HEX)**

Read from Port B: Pins 1, 2, 3, and 5 connect to the columns of the keypad

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ODR	Pin 31	Pin 30	Pin 29	Pin 28	Pin 27	Pin 26	Pin 25	Pin 24	Pin 23	Pin 22	Pin 21	Pin 20	Pin 19	Pin 18	Pin 17	Pin 16	Pin 15	Pin 14	Pin 13	Pin 12	Pin 11	Pin 10	Pin 9	Pin 8	Pin 7	Pin 6	Pin 5	Pin 4	Pin 3	Pin 2	Pin 1	Pin 0
Value																																

Mask to check if a button from column 1 has been pressed: 0x2 **(in HEX)**

Mask to check if a button from column 2 has been pressed: 0x4 **(in HEX)**

Mask to check if a button from column 3 has been pressed: 0x8 **(in HEX)**

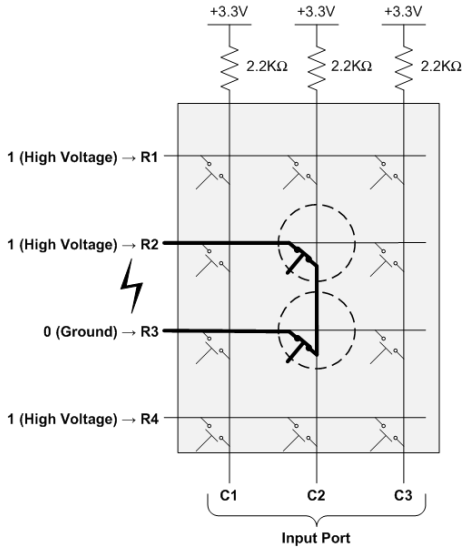
Mask to check if a button from column 4 has been pressed: 0x20 **(in HEX)**

Post-Lab Questions (20 points)

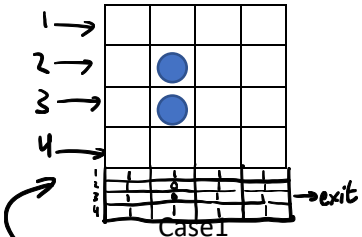
Please include answers to the following questions with your submission of the pre-lab register contents:

1. How is software debouncing implemented in your program? (3 points)
   Debouncing waits for input to stabilize before reading buttons
2. What do we mean when we say that the STM32L4's internal pull-up resistors are too weak for this application? (5 points)
   The internal resistors' current capacities are too low
3. When multiple keys are pressed, there could be a short circuit (as shown in the figure). How to configure the output GPIO to avoid this scenario? (7 points)

Set output to open drain & put circuit in HiZ state

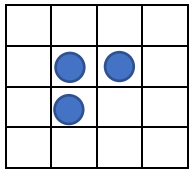


4. In the following 2 cases, can the scan algorithm correctly detect all keys pressed? If so, how to modify the flowchart (figure 4) of the scan algorithm. If not, explain the reason. (5 points)



Case1

See last page



Case2

same as left, but set up cols to read multiple vals

● Means the keys that are simultaneously pressed.

Participation and Contribution

Please indicate the participation and contribution for each group member using the following table.

Name	Participation and Contribution