Concordia University

Lab 4: Flow control

COEN 311

Lab Section: SN-X

Computer Organization and Software

Penoelo Thibeaud

40212017

Lab Instructor: T. Obuchowicz and Milad Khanchi

Performed on : November 8, 2023

Submitted on : November 22, 2023

I certify that this submission is my original work and meets the Faculty’s Expectations of Originality

# Objective:

This report explores the principles of flow control in assembly language. Key areas of our lectures are put on test. That include conditional branches, looping mechanisms and ASCII character manipulation. By utilizing the ARM assembly language and debugging with GNU Debugger (gdb),we examine the efficiency and functionality of these low-level operations on ASCII character.

# Introduction:

Flow control is a key component in programming , orchestrating the sequence and execution of various instructions and statements. While high-level languages like C++ employ constructs such as 'if', 'while', and 'for' to manage flow control, assembly language, low level languages approach is to use of branch instructions, manipulation of comparison flags, and to establish loop patterns. This lab is designed to bridge the conceptual and practical gap between high-level language constructs and their corresponding low-level assembly language counterparts, offering a comprehensive understanding and hands-on experience in the mechanisms of flow control in assembly programming.

# Procedure (Methods):

The procedure followed in this lab involved several key activities before and during the lab.

## Steps Followed:

1. Translating C++ flow control statements into ARM assembly language.
2. Developing an assembly language program to convert ASCII characters from lowercase to uppercase.
3. Employing gdb to step through the assembly code, ensuring the logic matches the intended flow control.
4. Analyzing loop implementation variations and the impact of conditional branches on program control.

# Results and Discussion:

The primary outcome of the lab was a fully functional ASCII conversion program. Key highlights include:

* The program successfully replicated the logic of 'if' statements in assembly language, using conditional branches to direct program flow.
* We employed a combination of cmp, subs, and beq instructions to construct efficient looping mechanisms in the assembly program.
* Debugging Outcomes: Utilizing gdb for debugging sessions, we confirmed the successful conversion of the input string to uppercase, validating the logic and flow of the assembly code.

## Questions:

1. Will the following ARM assembly language program produce the same output as that given in the Introduction section of this lab (simple\_loop.s)?

@Question code-----

add r0, r0, r3

subs r2, r2, #1 @update the codes flag here (0,1,0,0)

add r1, r1, #1

bne top

@simple\_loop.s code-----

addr1,r1,#1

sub r2, r2, #1

cmp r2, #0 @update the code flag here (0,1,0,0)

bne top

* Both snippet code will use the register R2 to control the loop and decrement it until the it reaches zero. Once it reach 0, the result (sum of num) is stored in the sum variable.

# Conclusion:

The lab provided a practical application of flow control concepts in assembly language programming. It equipped the students with critical skills vital for low-level programming tasks, emphasizing the ability to translate high-level logic into assembly language and to rigorously verify its correctness using debugging tools.

# Annexe:

## Here is my Converter.s:

.syntax unified

.cpu cortex-m4

.thumb

.data

message: .ascii "juMping JAck flaSh #1"

lastchar: .byte 0

.text

.global start

start:

ldr r0, =message

convert\_loop:

ldrb r1, [r0]

cmp r1, #0

beq end\_conversion

cmp r1, #'a'

blt next\_char

cmp r1, #'z'

bgt next\_char

sub r1, r1, #32

strb r1, [r0]

next\_char:

add r0, r0, #1

b convert\_loop

end\_conversion:

b end\_conversion

.end

## Here is my Converter.lst:

ARM GAS Converter.s page 1

1 .syntax unified

2 .cpu cortex-m4

3 .thumb

4

5 .data

6 0000 6A754D70 message: .ascii "juMping JAck flaSh #1"

6 696E6720

6 4A41636B

6 20666C61

6 53682023

7 0015 00 lastchar: .byte 0 @ NULL since last char would be a byte full of 0

8

9 .text

10 .global start

11 start:

12 0000 0748 ldr r0, =message @ Load the address of the message into r0 -> for(i in message) array[i]=messa

13

14 convert\_loop:

15 0002 0178 ldrb r1, [r0] @ x=array[i]

16 0004 0029 cmp r1, #0 @ if(x==0)

17 0006 09D0 beq end\_conversion @ goto end\_conversion -> end loop

18

19 0008 6129 cmp r1, #'a' @ if(x<'a')

20 000a 04DB blt next\_char @ goto next\_char ->skip itteration

21 000c 7A29 cmp r1, #'z' @ if (x>'z')

22 000e 02DC bgt next\_char @ goto next\_char ->skip itteration

23

24 0010 A1F12001 sub r1, r1, #32 @ x=x-32

25 0014 0170 strb r1, [r0] @ array[i]=x

26

27 next\_char:

28 0016 00F10100 add r0, r0, #1 @ i++

29 001a F2E7 b convert\_loop @ repeat loop

30

31 end\_conversion:

32 001c FEE7 b end\_conversion @ End of the program, enter an infinite loop

33

34 001e 00000000 .end

34 0000

## Here is my terminal content:

[becker] [/home/p/p\_thibe] > cd COEN311

[becker] [/home/p/p\_thibe/COEN311] > cd code/lab4

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > ls -l

total 128

-rw-rw---- 1 p\_thibe p\_thibe 162 Nov 7 22:31 ~$212017\_Lab\_report\_4.docx

-rw-rw---- 1 p\_thibe p\_thibe 20915 Nov 7 22:31 40212017\_Lab\_report\_4.docx

-rwxrwx--- 1 p\_thibe p\_thibe 66852 Nov 8 17:09 Converter.elf

-rw-rw---- 1 p\_thibe p\_thibe 1679 Nov 8 17:09 Converter.lst

-rw-rw---- 1 p\_thibe p\_thibe 1652 Nov 8 17:09 Converter.o

-rw-rw---- 1 p\_thibe p\_thibe 894 Nov 7 22:31 Converter.s

-rw-rw---- 1 p\_thibe p\_thibe 60092 Nov 7 22:31 lab4.pdf

drwxrwx--- 2 p\_thibe p\_thibe 4096 Nov 7 22:47 Question\_1

-rw-rw---- 1 p\_thibe p\_thibe 170 Oct 4 15:49 stm32f334r8\_ALL\_IN\_RAM.ld

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > arm-none-eabi-as -g Converter.s -o Converter.o -al=Converter.lst

arm-none-eabi-as: Command not found.

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > module load COEN311

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > arm-none-eabi-as -g Converter.s -o Converter.o -al=Converter.lst

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > arm-none-eabi-ld Converter.o -o Converter.elf -T stm32f334r8\_ALL\_IN\_RAM.ld

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > openocd -f board/st\_nucleo\_f3.cfg

Open On-Chip Debugger 0.11.0

Licensed under GNU GPL v2

For bug reports, read

http://openocd.org/doc/doxygen/bugs.html

Info : The selected transport took over low-level target control. The results might differ compared to plain JTAG/SWD

srst\_only separate srst\_nogate srst\_open\_drain connect\_deassert\_srst

Info : Listening on port 6666 for tcl connections

Info : Listening on port 4444 for telnet connections

Info : clock speed 1000 kHz

Info : STLINK V2J33M25 (API v2) VID:PID 0483:374B

Info : Target voltage: 3.247613

Info : stm32f3x.cpu: hardware has 6 breakpoints, 4 watchpoints

Info : starting gdb server for stm32f3x.cpu on 3333

Info : Listening on port 3333 for gdb connections

Info : accepting 'gdb' connection on tcp/3333

Info : device id = 0x10016438

Info : flash size = 64kbytes

Info : Unable to match requested speed 1000 kHz, using 950 kHz

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target halted due to debug-request, current mode: Thread

xPSR: 00000000 pc: 0xd0092900 msp: 0x78014804

Info : halted: PC: 0xdc02297a

Info : dropped 'gdb' connection

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Info : halted: PC: 0x20000008

Info : halted: PC: 0x2000000a

Info : halted: PC: 0x2000000c

Info : halted: PC: 0x2000000e

Info : halted: PC: 0x20000010

Info : halted: PC: 0x20000014

Info : halted: PC: 0x20000016

Info : halted: PC: 0x2000001a

Info : halted: PC: 0x20000002

Info : halted: PC: 0x20000004

Info : halted: PC: 0x20000006

Info : halted: PC: 0x20000008

Info : halted: PC: 0x2000000a

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-----------------------------------------------------------

[becker] [/home/p/p\_thibe] > cd COEN311/code/lab4

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > module load COEN311

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > arm-none-eabi-gdb Converter.elf

GNU gdb (GNU Toolchain for the Arm Architecture 11.2-2022.02 (arm-11.14)) 11.2.90.20220202-git

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This GDB was configured as "--host=x86\_64-pc-linux-gnu --target=arm-none-eabi".

Type "show configuration" for configuration details.

For bug reporting instructions, please see:

<https://bugs.linaro.org/>.

Find the GDB manual and other documentation resources online at:

<http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".

Type "apropos word" to search for commands related to "word"...

Reading symbols from Converter.elf...

(gdb) target extended-remote localhost:3333

Remote debugging using localhost:3333

convert\_loop () at Converter.s:24

24 sub r1, r1, #32 @ x=x-32

(gdb) monitor reset halt

Unable to match requested speed 1000 kHz, using 950 kHz

Unable to match requested speed 1000 kHz, using 950 kHz

target halted due to debug-request, current mode: Thread

xPSR: 00000000 pc: 0xd0092900 msp: 0x78014804

(gdb) load

Loading section .text, size 0x24 lma 0x20000000

Loading section .data, size 0x16 lma 0x20000024

Start address 0x20000000, load size 58

Transfer rate: 56 KB/sec, 29 bytes/write.

(gdb) break start

Breakpoint 1 at 0x20000000: file Converter.s, line 12.

(gdb) continue

Continuing.

^C

Program received signal SIGINT, Interrupt.

0xdc02297a in ?? ()

(gdb) x/22xc &message

0x20000024: 106 'j' 117 'u' 77 'M' 112 'p' 105 'i' 110 'n' 103 'g' 32 ' '

0x2000002c: 74 'J' 65 'A' 99 'c' 107 'k' 32 ' ' 102 'f' 108 'l' 97 'a'

0x20000034: 83 'S' 104 'h' 32 ' ' 35 '#' 49 '1' 0 '\000'

(gdb) stepi

halted: PC: 0xdc02297a

0xdc02297a in ?? ()

(gdb) load

Loading section .text, size 0x24 lma 0x20000000

Loading section .data, size 0x16 lma 0x20000024

Start address 0x20000000, load size 58

Transfer rate: 56 KB/sec, 29 bytes/write.

(gdb) break start

Note: breakpoint 1 also set at pc 0x20000000.

Breakpoint 2 at 0x20000000: file Converter.s, line 12.

(gdb) continue

Continuing.

Breakpoint 1, start () at Converter.s:12

12 ldr r0, =message @ Load the address of the message into r0 -> for(i in message) array[i]=message[i]

(gdb) quit

A debugging session is active.

Inferior 1 [Remote target] will be detached.

Quit anyway? (y or n) y

Detaching from program: /nfs/home/p/p\_thibe/COEN311/code/lab4/Converter.elf, Remote target

[Inferior 1 (Remote target) detached]

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > arm-none-eabi-gdb Converter.elf

GNU gdb (GNU Toolchain for the Arm Architecture 11.2-2022.02 (arm-11.14)) 11.2.90.20220202-git

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For help, type "help".

Type "apropos word" to search for commands related to "word"...

Reading symbols from Converter.elf...

(gdb) target extended-remote localhost:3333

Remote debugging using localhost:3333

start () at Converter.s:12

12 ldr r0, =message @ Load the address of the message into r0 -> for(i in message) array[i]=message[i]

(gdb) monitor reset halt

Unable to match requested speed 1000 kHz, using 950 kHz

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target halted due to debug-request, current mode: Thread

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Start address 0x20000000, load size 58

Transfer rate: 56 KB/sec, 29 bytes/write.

(gdb) break start

Breakpoint 1 at 0x20000000: file Converter.s, line 12.

(gdb) continue

Continuing.

halted: PC: 0xdc02297a

^C

Program received signal SIGINT, Interrupt.

0xdc02297a in ?? ()

(gdb) load

Loading section .text, size 0x24 lma 0x20000000

Loading section .data, size 0x16 lma 0x20000024

Start address 0x20000000, load size 58

Transfer rate: 56 KB/sec, 29 bytes/write.

(gdb) break start

Note: breakpoint 1 also set at pc 0x20000000.

Breakpoint 2 at 0x20000000: file Converter.s, line 12.

(gdb) continue

Continuing.

Breakpoint 1, start () at Converter.s:12

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(gdb) quit

A debugging session is active.

Inferior 1 [Remote target] will be detached.

Quit anyway? (y or n) y

Detaching from program: /nfs/home/p/p\_thibe/COEN311/code/lab4/Converter.elf, Remote target

[Inferior 1 (Remote target) detached]

[becker] [/home/p/p\_thibe/COEN311/code/lab4] > arm-none-eabi-gdb Converter.elf

GNU gdb (GNU Toolchain for the Arm Architecture 11.2-2022.02 (arm-11.14)) 11.2.90.20220202-git

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Breakpoint 1, start () at Converter.s:12

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(gdb) x/22xc &message

0x20000024: 106 'j' 117 'u' 77 'M' 112 'p' 105 'i' 110 'n' 103 'g' 32 ' '

0x2000002c: 74 'J' 65 'A' 99 'c' 107 'k' 32 ' ' 102 'f' 108 'l' 97 'a'

0x20000034: 83 'S' 104 'h' 32 ' ' 35 '#' 49 '1' 0 '\000'

(gdb) info register

r0 0x0 0

r1 0x0 0

r2 0x0 0

r3 0x0 0

r4 0x0 0

r5 0x0 0

r6 0x0 0

r7 0x0 0

r8 0x0 0

r9 0x0 0

r10 0x0 0

r11 0x0 0

r12 0x0 0

sp 0x780147e0 0x780147e0

lr 0xfffffff9 -7

pc 0x20000000 0x20000000 <start>

xPSR 0x1000003 16777219

fpscr 0x0 0

msp 0x780147e0 0x780147e0

psp 0x0 0x0

primask 0x0 0

basepri 0x0 0

faultmask 0x0 0

control 0x0 0

(gdb) stepi

halted: PC: 0x20000002

convert\_loop () at Converter.s:15

15 ldrb r1, [r0] @ x=array[i]

(gdb) stepi

halted: PC: 0x20000004

16 cmp r1, #0 @ if(x==0)

(gdb) stepi

halted: PC: 0x20000006

17 beq end\_conversion @ goto end\_conversion -> end loop

(gdb) stepi

halted: PC: 0x20000008

19 cmp r1, #'a' @ if(x<'a')

(gdb) stepi

halted: PC: 0x2000000a

20 blt next\_char @ goto next\_char ->skip itteration

(gdb) stepi

halted: PC: 0x2000000c

21 cmp r1, #'z' @ if (x>'z')

(gdb) stepi

halted: PC: 0x2000000e

22 bgt next\_char @ goto next\_char ->skip itteration

(gdb) stepi

halted: PC: 0x20000010

24 sub r1, r1, #32 @ x=x-32

(gdb) stepi

halted: PC: 0x20000014

25 strb r1, [r0] @ array[i]=x

(gdb) stepi

halted: PC: 0x20000016

next\_char () at Converter.s:28

28 add r0, r0, #1 @ i++

(gdb) stepi

halted: PC: 0x2000001a

29 b convert\_loop @ repeat loop

(gdb) stepi

halted: PC: 0x20000002

convert\_loop () at Converter.s:15

15 ldrb r1, [r0] @ x=array[i]

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(gdb) stepi

halted: PC: 0x2000000c

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20 blt next\_char @ goto next\_char ->skip itteration

(gdb) stepi

halted: PC: 0x20000016

next\_char () at Converter.s:28

28 add r0, r0, #1 @ i++

(gdb) x/22xc &message

0x20000024: 74 'J' 85 'U' 77 'M' 112 'p' 105 'i' 110 'n' 103 'g' 32 ' '

0x2000002c: 74 'J' 65 'A' 99 'c' 107 'k' 32 ' ' 102 'f' 108 'l' 97 'a'

0x20000034: 83 'S' 104 'h' 32 ' ' 35 '#' 49 '1' 0 '\000'

(gdb) info register

r0 0x20000026 536870950

r1 0x4d 77

r2 0x0 0

r3 0x0 0

r4 0x0 0

r5 0x0 0

r6 0x0 0

r7 0x0 0

r8 0x0 0

r9 0x0 0

r10 0x0 0

r11 0x0 0

r12 0x0 0

sp 0x780147e0 0x780147e0

lr 0xfffffff9 -7

pc 0x20000016 0x20000016 <next\_char>

xPSR 0x81000003 -2130706429

fpscr 0x0 0

msp 0x780147e0 0x780147e0

psp 0x0 0x0

primask 0x0 0

basepri 0x0 0

faultmask 0x0 0

control 0x0 0

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22 bgt next\_char @ goto next\_char ->skip itteration

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(gdb) stepi

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21 cmp r1, #'z' @ if (x>'z')

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halted: PC: 0x2000000e

22 bgt next\_char @ goto next\_char ->skip itteration

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halted: PC: 0x20000010

24 sub r1, r1, #32 @ x=x-32

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halted: PC: 0x20000014

25 strb r1, [r0] @ array[i]=x

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next\_char () at Converter.s:28

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29 b convert\_loop @ repeat loop

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(gdb) x/22xc &message

0x20000024: 74 'J' 85 'U' 77 'M' 80 'P' 73 'I' 78 'N' 71 'G' 32 ' '

0x2000002c: 74 'J' 65 'A' 67 'C' 75 'K' 32 ' ' 70 'F' 76 'L' 65 'A'

0x20000034: 83 'S' 72 'H' 32 ' ' 35 '#' 49 '1' 0 '\000'

(gdb) stepi

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15 ldrb r1, [r0] @ x=array[i]

(gdb) stepi

halted: PC: 0x20000004

16 cmp r1, #0 @ if(x==0)

(gdb) stepi

halted: PC: 0x20000006

17 beq end\_conversion @ goto end\_conversion -> end loop

(gdb) stepi

halted: PC: 0x20000008

19 cmp r1, #'a' @ if(x<'a')

(gdb) stepi

halted: PC: 0x2000000a

20 blt next\_char @ goto next\_char ->skip itteration

(gdb) stepi

halted: PC: 0x20000016

next\_char () at Converter.s:28

28 add r0, r0, #1 @ i++

(gdb) stepi

halted: PC: 0x2000001a

29 b convert\_loop @ repeat loop

(gdb) stepi

halted: PC: 0x20000002

convert\_loop () at Converter.s:15

15 ldrb r1, [r0] @ x=array[i]

(gdb) stepi

halted: PC: 0x20000004

16 cmp r1, #0 @ if(x==0)

(gdb) stepi

halted: PC: 0x20000006

17 beq end\_conversion @ goto end\_conversion -> end loop

(gdb) stepi

halted: PC: 0x2000001c

end\_conversion () at Converter.s:32

32 b end\_conversion @ End of the program, enter an infinite loop

(gdb) stepi

halted: PC: 0x2000001c

32 b end\_conversion @ End of the program, enter an infinite loop

(gdb) stepi

halted: PC: 0x2000001c

32 b end\_conversion @ End of the program, enter an infinite loop

(gdb) stepi

halted: PC: 0x2000001c

32 b end\_conversion @ End of the program, enter an infinite loop

(gdb) stepi

halted: PC: 0x2000001c

32 b end\_conversion @ End of the program, enter an infinite loop

(gdb) stepi

halted: PC: 0x2000001c

32 b end\_conversion @ End of the program, enter an infinite loop

(gdb) x/22xc &message

0x20000024: 74 'J' 85 'U' 77 'M' 80 'P' 73 'I' 78 'N' 71 'G' 32 ' '

0x2000002c: 74 'J' 65 'A' 67 'C' 75 'K' 32 ' ' 70 'F' 76 'L' 65 'A'

0x20000034: 83 'S' 72 'H' 32 ' ' 35 '#' 49 '1' 0 '\000'

(gdb)