CS 2614: Computer Organization

Assembly Programming Project

Fall 2023

<u>NOTE</u>: This is an individual assignment. You must do it individually and **not in** Groups.

The UNIVERSITY of OKLAHOMA
Gallogly College of Engineering
School of Computer Science

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This project is divided into two parts: 1) Design document, and 2) Assembly program. In the design document phase, you will submit a typed description of problem-solving approaches and algorithm used to solve the given problem. In the assembly program phase, you will write the class version of assembly language program to code and test the given problem.

Problem Statement:

Given a **hexadecimal number *n* as user input**, write an assembly language program to convert the given **hexadecimal number (*n*) to decimal number** and **display the biggest digit of all the digits**.

n (user input) will be a **two-digit hexadecimal number**, not more and not fewer. An example, take the input *n* (user input) as **10_{16}**,your program will first convert **10_{16}** to decimal equivalent “**16_{10}**”, and then your program should output “6” since it is the biggest digit. Another example, if *n* (user input) is **BC_{16}**, your program will first convert **BC_{16}** to decimal equivalent “**188_{10}**”, and then your program should output “8” since it is the biggest digit.

You need to take the inputs through INPR in Assembler, convert the input character into hexadecimal number, convert the hexadecimal number into decimal number, have a loop to get each digit, and check the biggest digit of the number. You **should not** hardcode the input/output numbers and **should not** give the direct formula to get the final result. For example, a code such as this: `if (n==10) then printf(“6”);` is not allowed.

Below is the ASCII table that shows the conversion from character to decimal and hexadecimal.

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Hint:

The following pseudo-code demonstrates the logic for checking the biggest digit of number n, where n is the given input. Please note that this program utilizes low-level functions not readily available in the assembly language, such as: ASCII-to-numeric conversion, hexadecimal-to-decimal conversion, integer division, and modulus operation.

```
int number;  // The input number
int digit1, digit2, digit3;       // The digits of the decimal number
int largestDigit = 0;  // The variable for storing the biggest digit

printf("Enter a hexadecimal number: ");
scanf("%x", &number);

digit1 = number / 100;
number = number % 100;
digit2 = number / 10;
digit3 = number % 10;

largestDigit = (digit1 > digit2) ? ((digit1 > digit3) ? digit1 : digit3) :
((digit2 > digit3) ? digit2 : digit3);

printf("The largest digit is: %d\n", largestDigit);
```

The integer division ('/') and modulus operation ('%') can be implemented using the following pseudo-code.

```
while (dividend >= divisor) {
    dividend -= divisor;
    quotient++;
}
printf("Quotient: %d\n", quotient);
printf("Remainder: %d\n", dividend);
```

Please also note that these are just hints. You are free to use any algorithms as long as they produce the correct results, and the results are not hard-coded.

Project Description:

1. *Part A: Design document* ***(at least one page)***

The design document should describe, using flow charts or C-like pseudo-codes for each subroutine,how you will implement the program using the assembly language. Submit a typed description of the problem-solving approaches you will use to solve the given problem. Use words and be descriptive!
– What I am looking for here is that you know how the assembler works and that you are comfortable working with it. **It would be best if you wrote an explanation for each item in the grading criteria below**.

Questions you should address:

- How to achieve looping in assembly language (Hints: assembly language has no *while* or *for* loop built in)?
- Specifically, what are the loop conditions (initialize value, end value, increment on each step…)

These questions are only a general guideline. The objective is to help you getstarted working on the project and able to **dissect the problem** into smaller procedures (like all the other programming problems).

Grading criteria for the Design Document *(Worth 20% of the project)*

Critical Elements	Percentage Distribution
Problem solving approaches	35%
How to convert input character to decimal and the biggest digit check	20%
Loop conditions to exit the loops	20%
Articulation of response such as free of errors, grammar, syntax, and organization	25%
Total	**100%**

2. *Part B: Assembly Program*

Submit an assembly program to solve the given problem. To get started, you need to download and run the assembler simulator (Assembler.jar) from Canvas. The instructions to download, run the simulator then compile and run the code are specified in the "*Helpful Resource*" section below. Your program should be stored **in a plain text file** and able to be executed on the simulator.

Grading criteria for the Assembly Program *(Worth 80% of the project)*

Critical Elements	Percentage Distribution
Well Commented Code	20%
Variable initialization	20%
Get input *N* from user	20%
Converting N to equivalent decimal	20%
Correctness of output in showing the biggest digit check	20%
Total	**100%**

<u>Submission guidelines:</u>

a) Design Document: **.pdf** or **.docx** (**due Saturday, November 11, 2023, on Canvas**)
b) Assembly program: **.txt** only (**due Tuesday, November 21, 2023, on Canvas**)

Both submissions should be placed in the appropriate file uploads on Canvas by the deadline. Youwill demonstrate your programs to the TAs from December 4 to December 8, 2023 (A poll link will be posted on Canvas to reserve your slot for the project demonstration).

<u>Note:</u> Again, in the project you must use loop functionality to achieve the output. Pre-defined values or answers in the code are NOT accepted.

<u>Late penalty:</u>

a) Late Design Documents will **NOT** be accepted.
b) The penalty for late submissions of the assembly program will be **15% PER DAY.**

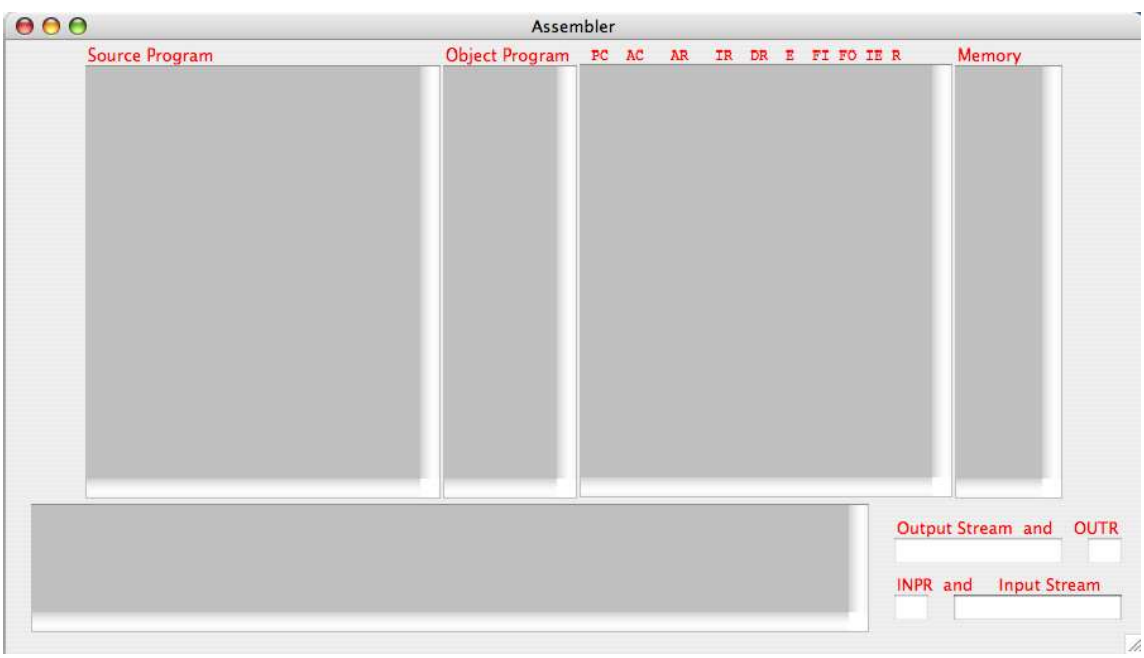
<u>Helpful Resources</u>

Assembler Simulator for the Programming Assignment

Download the assembler simulator from the Canvas. The assembler simulator is written in Java, **you need to have Java Runtime Environment (JRE) installed to run this program**. Follow thegiven instructions to run and use the simulator.

A1. To run the Simulator:

- Double click on the program (Assembler.jar).
- You will get the following interface to read, compile and run your code.



A2. To use the Simulator:

- **Read your source program:**
  1. From the menu: File -> Open -> Select your Program (*must be .txt file*)or
  2. Simply copy and paste your program to the text box under “Source Program”
  3. One demo program is available with the simulator (File-> Demo Source File)

- **Compile your program:**
  From the menu: Tools -> Compile

- **Run your program:**
  From the menu: Tools -> Execute -> Run or Walk (step by step). Values of registers and memory will be shown.

- **Inputs/Outputs:**
  If your program uses INPR to read inputs, you can type the inputs in the“input Stream” text box. Outputs from OUTR will be shown in Output Stream.

NOTE: ALWAYS TRY TO COMPILE THE CODE, GIVE INPR TO READ INPUTS AND THEN RUN YOUR PROGRAM.

A3. Instructions Review:

There are three groups of instructions in this assembler:

- Memory Reference Instructions
- Non memory Reference Instructions
- Pseudo Instructions (i.e., Assembler directive instructions)

Memory Reference Instructions (MRI)

Direct Addressing: opcode operand e.g., ADD num
Memory word at location 'num' is added to accumulator AC. i.e., AC = AC + M[num];
Here, effective address of the operand is 'num'

Indirect Addressing: opcode operand I e.g., ADD num I
Memory word of memory word at location 'num' is added to AC. i.e., AC = AC + [M[num]]
Here, effective address of the operand is M[num].

MRI Instructions: (In the following, “addr” denotes effective address.)

AND xxx AND xxx I
Logical AND of effective memory word to AC i.e.,
AC = AC and M[addr];

ADD xxx ADD xxx I
Add effective memory word to AC.
i.e., AC = AC + M[addr];

LDA xxx LDA xxx I

Load effective memory word to AC.
i.e., AC = M[addr];

STA xxx STA xxx I
Store content of AC to effective memory word. i.e.,
M[addr] = AC;

BUN xxx BUN xxx I
Branch, unconditionally, to effective address. i.e.,
PC = addr;

BSA xxx BSA xxx I
Address of next instruction (i.e., PC) is stored in effective memory word. Then,execute the instruction following the effective address.
i.e., M[addr] = PC; PC = addr + 1;
Note: BSA is useful to save the return address and to branch to a procedure.

ISZ xxx ISZ xxx I
Increment memory word. If incremented value is 0, increment PC (i.e., skip next instruction).
i.e., M[addr] = M[addr] + 1; if (M[addr] == 0) PC = PC + 1;
Note: ISZ is used to count iterative loops.

Non-Memory Reference Instructions

These instructions do not have the operand part or the addressing mode.

CLA Clear AC

CLE Clear E, the extended bit of AC

CMA Complement AC

CME Complement E

CIR Circular shift to the Right on AC and E

CIL Circular shift to the Left on AC and E

INC Increment AC

SPA Skip next instruction, if AC is Positive, i.e., if (AC(15) = 0) PC = PC + 1;

SNA Skip next instruction, if AC is Negative, i.e., if (AC(15) = 1) PC = PC + 1;

SZA Skip next instruction, if AC is Zero, i.e., if (AC == 0) PC = PC + 1;
(Note: SPA, SNA, and SZA are used in conditional branching.)

SZE Skip next instruction, if E is Zero, i.e., if (E == 0) PC = PC + 1;

HLT Halt the execution

INP Input a character from INPR to low-order bits of AC

OUT Output a character from low-order bits of AC to OUTR

SKI Skip on Input flag

Pseudo Instructions

ORG hhh	Instruction listed in the following line will be placed at address 'hhh' (Hex) DECn
	Decimal number 'n' will be placed in the memory word
HEX n	Hexadecimal number 'n' will be placed in the memory word
END	Denotes the end of assembly language source program

Book Reference

Sections 5.3, 5.5, 5.6, 5.7, 6.3 of Computer System Architecture (3e) by M. Morris