CS 2614: Computer Organization

Assembly Programming Project

Spring 2025

<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's version of assembly language program to code and test the given problem.

Problem Statement:

Given a **2-digits odd decimal number *n* as user input**, write an assembly language program to **calculate the sum of odd positive numbers up to that odd decimal number, and then display the sum in octal number**.

n (user input) will be **exactly a two-digits odd decimal number**, not more and not fewer. Here are the examples:

1. Take the input *n* (user input) as $\mathbf{09_{10}}$, your program will first calculate the sum of the positive numbers up to that number (1 + 3 + 5 + 7 + 9) = 25_{10}, then display the result's octal equivalent of "$\mathbf{31_8}$" as the output. It is also fine if your program gives "**0031**" as the output.
2. If *n* (user input) is $\mathbf{99_{10}}$, your program will first calculate the sum of the positive numbers up to that number (1 + 3 + 5 + 7 + 9 + … + 99) = 2500_{10}, then display the result's octal equivalent of "$\mathbf{4704_8}$" as the output.

You need to take the input characters using INP in Assembler, calculate the sum of its odd numbers in a loop, convert the result, and display the output. You **should not** hardcode the input/output numbers and **should not** use the direct formula to get the result. For example, a code such as this: `if (n==3) then printf("4");` is not allowed.

Hint:

The following pseudo-code demonstrates the logic for calculating the sum of odd numbers up to an input number and then output the result in octal. Please note that this program utilizes low-level functions not readily available in the assembly language, such as: conversion of ASCII-hexadecimal value to numeric-decimal value, for loop structure, and decimal-to-octal conversion.

```
int n, sum = 0;

// Taking user input
printf("Enter a decimal number: ");
scanf("%d", &n);

// Summing odd numbers up to n
for (int i = 1; i <= n; i += 2) {
    sum += i;
}

// Printing sum in octal
printf("Sum of odd numbers up to %d in octal: %o\n", n, sum);
```

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

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

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

Project Description:

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

The design document should describe 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 criteriabelow**.

Questions you should address:

- How to achieve looping in assembly language? (Hints: assembly language has no built-in *while* loop and *for* loop)
- Specifically, what are the loop conditions (initial values, end values, increments in each step, stopping conditions)?

These questions are only a general guideline. The objective is to help you get started working on the project and be able to **dissect the problem** into smaller procedures (like all other programming problems). The reasonable page length is 2.

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

Critical Elements	**Percentage Distribution**
The use of the assembly instructions in the problem-solving approaches	20%
How to take in and convert input characters into decimal number	20%
Loop conditions for calculating the sum	20%
How to convert the result into octal number and display it	20%
Articulation of response such as grammar, syntax, and organization	20%
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. If your program cannot be run on the simulator, you will get a 20% grade deduction.

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 its decimal number	20%
Correctness of output in showing the sum in octal	20%
Total	**100%**

Submission guidelines:

a) Design Document: **.pdf** or **.docx** (**due Saturday, April 5, 2025, on Canvas**)
b) Assembly program: **.txt** only (**due Wednesday, April 16, 2025, on Canvas**)

Both submissions should be placed in the appropriate file uploads on Canvas by the deadline. **Please check your submission**. If we cannot open it, then you will be penalized for any resubmission lateness. You will demonstrate your programs to the TAs during a 15-minute timeslot in the period from April 28th to May 2nd, 2025 (Appointment slots will be posted on Canvas for you to reserve your project demonstration schedule).

Note: Again, in the project you must use loop functionality to achieve the output. Pre-defined values or answers in the code are NOT accepted. Also, any plagiarism WILL BE REPORTED to OU Academic Integrity office.

Late penalty:

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

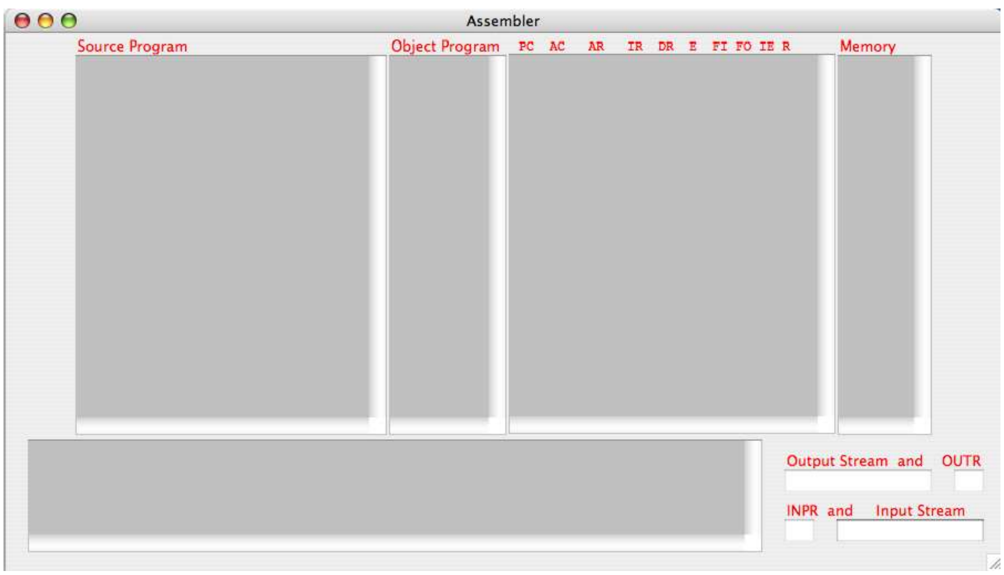
Helpful Resources

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 the instructions given 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.
- If your screen resolution is too high, the simulator's interface will not show all views correctly. Please lower your screen resolution.



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 INP to read inputs, you can type the inputs in the"input Stream" text box. Outputs from OUT will be shown in Output Stream.

NOTE: ALWAYS TRY TO COMPILE THE CODE, GIVE INP 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 output stream

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

Instructions Table

Symbol	Hexadecimal code
AND	0 or 8
ADD	1 or 9
LDA	2 or A
STA	3 or B
BUN	4 or C
BSA	5 or D
ISZ	6 or E
CLA	7800
CLE	7400
CMA	7200
CME	7100
CIR	7080
CIL	7040
INC	7020
SPA	7010
SNA	7008
SZA	7004
SZE	7002
HLT	7001
INP	F800
OUT	F400
SKI	F200
SKO	F100
ION	F080
IOF	F040

Book Reference

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