SOLUTIONS

CPE 233 Winter 2019 Midterm

1. RAT ASSEMBLY MEMORY CONTENTS - 10 pts

Assume the register file and scratch pad memory have the initial values below. Recall that arithmetic instructions load the Carry and Zero flags and Logic instructions clear the Carry flag and load the Zero flag. All other instructions do not affect the flags.

```
ROL: Rd \leftarrow Rd(6:0) & Rd(7), C \leftarrow Rd(7)
LSR: Rd \leftarrow C & Rd(7:1), C \leftarrow Rd(0)
ASR: Rd \leftarrow Rd(7) & Rd(7) & Rd(6:1), C \leftarrow Rd(0)
```

```
.CSEG

.ORG 0x30

30 LD R1, (R4)

31 ADDC R2, R4

31 EXOR R30, skip4

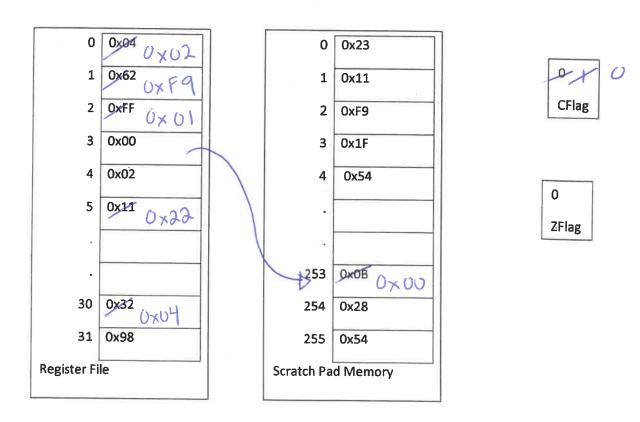
33 ST R3, (0xFD)

34 BREQ skip

35 ROL R5

36 Skip: LSR R0
```

Modify the register file, scratch ram, cflag and zflag according to the execution of the program. Write your answers in hex.



2. CALCULATE THE TIMING OF THE FOLLOWING RAT PROGRAM

Recall the RAT CPU runs at 50MHz, and each instruction takes two clock cycles, so each instruction takes 40ns. Write an equation (in terms of A and B) that calculates the amount of time it takes to execute the following program. You can assume A and B are not zero.

.CSEG 8 pts

.ORG 0x01

main: MOV R2, A

Out1: ADD R20, 0x01

SUB R2, 0x01

MOV R3, B

Out2: ADD R21, 0x01

SUB R3, 0x01

BRNE Out2

OR R2, 0x00

BRNE Out1

√BRN End

SUB R21, 0x03 X skippe d
SUB R22, 0x03

End: VOUT R21, 0xFF

time = [(3B+5)A+4]40ns

3. DRAW A FLOWCHART AND WRITE RAT CODE - 10 pts

Draw a flowchart and write a short RAT assembly program to implement the following:

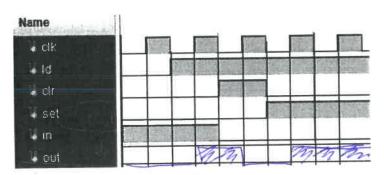
Read in a value from Port 0x22. If the value is odd, add 3 to the value and output the result to Port 0x23. Otherwise, output the value to port 0x24 ten times (must use a loop). Have your program repeat indefinitely. Use R0 for the input value and R1 for the output value.

.EQU IN_PORT = 0x22	
.EQU OUT_PORT = 0x24	
.CSEG	- start
.ORG 0x01	
Start:	Read val 4es
IN RU, IN-PORT	
MW RI, RO	
TEST RO, 0x01	- yes is val
BREQ even	yes 15 Val
ADD R1, 3	_ / / / / / / / / / / / / / / / / / / /
RI, 0x23	
BRN Start	$-\sqrt{res=val+3}$ $i=10$
1 00.00 00 15	
even: MOV R2, 10	- _
BREQ Start	- Voutput res/
OUT RI OUT PORT	- Youtput res / i==0?
BRA las	
SUB B2. 1	- no
BRN 1000	
	/output val/
-	- / /
X	-
the same of the sa	
	_

4. RAT TIMING DIAGRAMS

4 pts

a. Fill in all of the boxes for output (out) of this rising-edge triggered flag register. Of the control signals, set has the highest precedence and ld has the lowest precedence.



b. Fill in the 18-bit machine code and complete the timing diagram of the RAT CPU for the following code. Fill in any box that is non-zero.

4 pts

.CSEG

.ORG 0x23
main: IN R2, 0x64
ADD R2, 0xFF
SUBC R2, 0x32
BRN main

17 1	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
F		0	O	i	O	Û	0	Ţ	U	0	1	ι	O	U	1	0	υ
1	O	1	O	O	U	0	0	U	0	1	1	1	1	L	ι	1	1
ì	υ	i	Ţ	1	U	0	U	1	0	O	U	1	1	U	U	ł	C
v	0	1	O	U	U	O	0	V	1	0	U	U	1	1	U	O	(

(then half)
Tobs

	All values	in	nex					BRN	AND	ıN	ADD	App	- C 100 -				
	Instruction	IN	ADO	App	SUBC	SUBC	BIN	AME	(1)	APP	100	Sel	SUBC				
	⊈ dk																
	₩ State	ST_20	ST_70	ST RO	ST NO	ST_MI	ST_FC	87_R0	\$T 7D	81_E0	ST_FO	87 IO	ST_FO				
2	to pc_count(9.0)	0x24	24	25	2625	26	26	27	23	24	24	25	25				
١	w pc_ld							m									
	₩ in_port[7:0]	0x01					(0xA3										
(& alu_opy_sel			m		mm						un					
ı	◆ alu_sel[3 0]					3											
5	W P.2						CD	CD	CD	CD	A3	A3	AZ				
1	in c_flag_ld			m		en						en					
١	M z_flag_id			m		m						222					
2	₩ port_id(7.0)	64	FF	FF	32	32	18	18		64	FF	FF	32				
0			-		6)	•			•	•							

AND	17	16	15	14	13	12	11	1.0	9	8	7	6	5	4	3	2	1
AME EX, ime		O:	0	0	THE SPRINGER	_	T/PX	1	All Control	Fee	T k		_	- C - CV-	40 II will		
OR	17		15	14	13		11	a e ros						4 · ·	-	1.700	
	1	9	Q	R FOREITZES		I ex	100	10	e e	B Sales	7	5	5	lev-	3	2	1
	1	and the second	150	day's	40 -46		-	III		His		iki	.#	K	k	k	k ;
EXCR	17	of the last	15	14	13	12	11	10	9	8	7	6	5	4	3	2	. 1
EXIA EK, ame	1	0	0	1,	0	Ø	F/X	1 EX	1X	3X	k:	k	k	k	k	L	k
TEST	17	96	15	14	13	12	91	10	9	В	7	6	Б	4	2	2	1
TEST EX. 1888.	-1	9	0	1	1	rΧ	4%	tX	fX	XIX.	ic	k	, k	*	X.	k.	
ADD	17	16	15	14	13	12	11	10	9	B	7	6	6	4	3	2	1
ADD EN 1888.	4	0		0	0	125	148	TX	ex.	1X	k		Ĭ.	1	k	K	k
ADDC	17	16	15	14	12	12	91	10	4	8	7	6	5	4	3	2	1
ADED Ex, see	132	0		9		nX.	1X	EX	(tX	rX	k	lk	k	k		'K'	
SUB	17	16	15	14	13	12	11	10	6	В	7	6	Б	4	3	2	10000
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CMC FE, inc.		Elevan I	-	-0-1		fX.	EX.	120	123	4X	k'	K	k	şk'	k	k	ik!
204	17	145	15	14	13	12	11	10,	9	6	7	5	Б	4	2	2	\$
IN EX, inc.	國軍		0	0		†X	IX	7X	18	1X		4.9	, K		k.		k
OUT	17	16	15	14	,53	12	11	10	S	8	7	5	5	4	3	2	1
GUI rx, imm.		1	0	1	0	eX:	12	rx.	(X)	18	k'	k	k	.	4.	I.	
MOV	17	16	15	14	13	12	11	10	9	ś	7	6	8	4	13	2	1
NOV re, inc	1	1	0		7	ŧΧ	138	zΧ	1X	1X	k	k	k.	k	k.		
ID	17	95	15	14	13	12	11	10	9	6	7	6	5	4	B	2	3
LD regime	3	1	1	0	0	rx:	£X,	1X	īΧ	131	k		k				4
ST	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
ET sk,im	240	1	1	0		X	TX	120	1X	TX.	k			41	R	4	K

BRN	17	16	15	54	13	12	11	10	9	6	7	6	5	4	3	2	1	ņ
pez isbel	0.	9	1	B	0	88	åà	àà	aa	aa	22	88	88	aa	88	-	Ŏ	'o
CALL	17	16	15	-14	13	12	11	10	9	8	7	6	6	4	3	2	1	Đ
CALL latel	0	3	4	0	0	aa	äa	BB	åä	aa	aa	88	aa	88	âa	-	0	1
BREQ	17	16	15	14	13	12	111	10	5	8	7	5	6	4	а	2	1	ø
nerg label	0	0	1	0	ō	aa	Aá	aa	8a	22	88	88	80	aa	aa	-	1	0
BRME	17	15	15	54-	13	12	11	10	9	8	7	6	6	4.	3	2	í	0
BRANT label	0	0	4	0	0	aa	aa	aa	aa	æā	aa	ââ	aa	aa	æ	Ŀ	1	1
BRCS	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2.	1	£
BKCS label	0	0.	1	0	1	aa	aa	âŝ	aa	88	aa	AB	àá	áä	aa	-	0	0
BRCC	17	16	15	14	13	12	11	10	9	B	7	5	5	4	a	.2	1	8
isdal babal	0	0		0	1	áa	<u>Ba</u>	aa	ää	aa	aa	88	aa	aa	aa	-	0	1

