

Computer Science and Engineering

2021 Sample Midterm

Answer all questions in the space provided

Student Last Name: _____

Student Given Name: _____

Student ID. No: _____

Section	Points	Marks
A	40	
B	40	
C	20	
Total	100	

Section A

A1.

Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of $1.0E9$ and has an execution time of 1.1 s, while compiler B results in a dynamic instruction count of $1.2E9$ and an execution time of 1.5 s.

- a. Find the average CPI for each program given that the processor has a clock cycle time of 1 ns.
- b. Assume the compiled programs run on two different processors. If the execution times on the two processors are the same, how much faster is the clock of the processor running compiler A's code versus the clock of the processor running compiler B's code?
- c. A new compiler is developed that uses only $6.0E8$ instructions and has an average CPI of 1.1. What is the speedup of using this new compiler versus using compiler A or B on the original processor?

A2.

Assume that registers \$s0 and \$s1 hold the values 0x80000000 and 0xD0000000, respectively. What is the value of \$t0 for the following assembly code?

```
add $t0, $s0, $s1
add $t0, $t0, $s0
```

A3.

Provide a minimal set of MIPS instructions that may be used to implement the following pseudoinstruction:

```
not $t1, $t2
```

A4.

A5.

...

Section B

B1.

For the following C/Java statement, what is the corresponding MIPS assembly code? Assume that the variables f, g, h, and i are given and could be considered 32-bit integers as declared in a C program. Use a minimal number of MIPS assembly instructions.

```
f = g + (h - 5);
```

B2.

Give the binary representation of -67 in each of the following data representations

- (a) 8-bit one's complement
- (b) 8-bit two's complement
- (c) hex

B3.**B4.**

...

Section C

C1.

For the MIPS assembly instructions below, what is the corresponding C/Java statement? Assume that the variables f, g, h, i, and j are assigned to registers \$s0, \$s1, \$s2, \$s3, and \$s4, respectively. Assume that the base address of the arrays A and B are in registers \$s6 and \$s7, respectively.

```
sll $t0, $s0, 2
add $t0, $s6, $t0
sll $t1, $s1, 2
add $t1, $s7, $t1
lw $s0, 0($t0)
addi $t2, $t0, 4
lw $t0, 0($t2)
add $t0, $t0, $s0
sw $t0, 0($t1)
```

C2.

Provide the type, assembly language instruction, and binary representation of instruction described by the following MIPS fields:

op=0x28, rs=4, rt=8, const=0xd

C3.**C4.**

...

MIPS Reference Data

①



CORE INSTRUCTION SET

NAME, MNEMONIC	FOR-MAT	OPERATION (in Verilog)	OPCODE / FUNCT (Hex)
Add	add R	$R[rd] = R[rs] + R[rt]$	(1) 0 / 20 _{hex}
Add Immediate	addi I	$R[rt] = R[rs] + \text{SignExtImm}$	(1,2) 8 _{hex}
Add Imm. Unsigned	addiu I	$R[rt] = R[rs] + \text{SignExtImm}$	(2) 9 _{hex}
Add Unsigned	addu R	$R[rd] = R[rs] + R[rt]$	0 / 21 _{hex}
And	and R	$R[rd] = R[rs] \& R[rt]$	0 / 24 _{hex}
And Immediate	andi I	$R[rt] = R[rs] \& \text{ZeroExtImm}$	(3) c _{hex}
Branch On Equal	beq I	if(R[rs]==R[rt]) $PC = PC + 4 + \text{BranchAddr}$	(4) 4 _{hex}
Branch On Not Equal	bne I	if(R[rs]!=R[rt]) $PC = PC + 4 + \text{BranchAddr}$	(4) 5 _{hex}
Jump	j J	$PC = \text{JumpAddr}$	(5) 2 _{hex}
Jump And Link	jal J	$R[31] = PC + 8; PC = \text{JumpAddr}$	(5) 3 _{hex}
Jump Register	jr R	$PC = R[rs]$	0 / 08 _{hex}
Load Byte Unsigned	lbu I	$R[rt] = \{24'b0, M[R[rs] + \text{SignExtImm}](7:0)\}$	(2) 24 _{hex}
Load Halfword Unsigned	lhu I	$R[rt] = \{16'b0, M[R[rs] + \text{SignExtImm}](15:0)\}$	(2) 25 _{hex}
Load Linked	ll I	$R[rt] = M[R[rs] + \text{SignExtImm}]$	(2,7) 30 _{hex}
Load Upper Imm.	lui I	$R[rt] = \{\text{imm}, 16'b0\}$	f _{hex}
Load Word	lw I	$R[rt] = M[R[rs] + \text{SignExtImm}]$	(2) 23 _{hex}
Nor	nor R	$R[rd] = \sim (R[rs] R[rt])$	0 / 27 _{hex}
Or	or R	$R[rd] = R[rs] R[rt]$	0 / 25 _{hex}
Or Immediate	ori I	$R[rt] = R[rs] \text{ZeroExtImm}$	(3) d _{hex}
Set Less Than	slt R	$R[rd] = (R[rs] < R[rt]) ? 1 : 0$	0 / 24 _{hex}
Set Less Than Imm.	slti I	$R[rt] = (R[rs] < \text{SignExtImm}) ? 1 : 0$	(2) a _{hex}
Set Less Than Imm. Unsigned	sltiu I	$R[rt] = (R[rs] < \text{SignExtImm}) ? 1 : 0$	(2,6) b _{hex}
Set Less Than Unsig.	sltu R	$R[rd] = (R[rs] < R[rt]) ? 1 : 0$	(6) 0 / 2b _{hex}
Shift Left Logical	sll R	$R[rd] = R[rt] \ll \text{shamt}$	0 / 00 _{hex}
Shift Right Logical	srl R	$R[rd] = R[rt] \gg \text{shamt}$	0 / 02 _{hex}
Store Byte	sb I	$M[R[rs] + \text{SignExtImm}](7:0) = R[rt](7:0)$	(2) 28 _{hex}
Store Conditional	sc I	$M[R[rs] + \text{SignExtImm}] = R[rt]; R[rt] = (\text{atomic}) ? 1 : 0$	(2,7) 38 _{hex}
Store Halfword	sh I	$M[R[rs] + \text{SignExtImm}](15:0) = R[rt](15:0)$	(2) 29 _{hex}
Store Word	sw I	$M[R[rs] + \text{SignExtImm}] = R[rt]$	(2) 2b _{hex}
Subtract	sub R	$R[rd] = R[rs] - R[rt]$	(1) 0 / 22 _{hex}
Subtract Unsigned	subu R	$R[rd] = R[rs] - R[rt]$	0 / 23 _{hex}

- (1) May cause overflow exception
- (2) $\text{SignExtImm} = \{ 16\{\text{immediate}[15]\}, \text{immediate} \}$
- (3) $\text{ZeroExtImm} = \{ 16\{1'b'0\}, \text{immediate} \}$
- (4) $\text{BranchAddr} = \{ 14\{\text{immediate}[15]\}, \text{immediate}, 2'b'0 \}$
- (5) $\text{JumpAddr} = \{ PC + 4[31:28], \text{address}, 2'b'0 \}$
- (6) Operands considered unsigned numbers (vs. 2's comp.)
- (7) Atomic test&set pair; $R[rt] = 1$ if pair atomic, 0 if not atomic

BASIC INSTRUCTION FORMATS

R	opcode	rs	rt	rd	shamt	funct
	31	26 25	21 20	16 15	11 10	6 5
I	opcode	rs	rt	immediate		
	31	26 25	21 20	16 15		
J	opcode	address				
	31	26 25				

ARITHMETIC CORE INSTRUCTION SET

② OPCODE

NAME, MNEMONIC	FOR-MAT	OPERATION	OPCODE / FUNCT (Hex)
Branch On FP True	bc1t FI	if(FPcond)PC=PC+4+BranchAddr	(4) 11/8/1/--
Branch On FP False	bc1f FI	if(!FPcond)PC=PC+4+BranchAddr	(4) 11/8/0/--
Divide	div R	$Lo = R[rs]/R[rt]; Hi = R[rs]\%R[rt]$	0/--/--/1a
Divide Unsigned	divu R	$Lo = R[rs]/R[rt]; Hi = R[rs]\%R[rt]$	(6) 0/--/--/1b
FP Add Single	add.s FR	$F[fd] = F[fs] + F[ft]$	11/10/--/0
FP Add Double	add.d FR	$\{F[fd], F[fd+1]\} = \{F[fs], F[fs+1]\} + \{F[ft], F[ft+1]\}$	11/11/--/0
FP Compare Single	c.x.s* FR	$FPcond = (F[fs] \text{ op } F[ft]) ? 1 : 0$	11/10/--/y
FP Compare Double	c.x.d* FR	$FPcond = (\{F[fs], F[fs+1]\} \text{ op } \{F[ft], F[ft+1]\}) ? 1 : 0$	11/11/--/y
* (x is eq, lt, or le) (op is ==, <, or <=) (y is 32, 3c, or 3e)			
FP Divide Single	div.s FR	$F[fd] = F[fs] / F[ft]$	11/10/--/3
FP Divide Double	div.d FR	$\{F[fd], F[fd+1]\} = \{F[fs], F[fs+1]\} / \{F[ft], F[ft+1]\}$	11/11/--/3
FP Multiply Single	mul.s FR	$F[fd] = F[fs] * F[ft]$	11/10/--/2
FP Multiply Double	mul.d FR	$\{F[fd], F[fd+1]\} = \{F[fs], F[fs+1]\} * \{F[ft], F[ft+1]\}$	11/11/--/2
FP Subtract Single	sub.s FR	$F[fd] = F[fs] - F[ft]$	11/10/--/1
FP Subtract Double	sub.d FR	$\{F[fd], F[fd+1]\} = \{F[fs], F[fs+1]\} - \{F[ft], F[ft+1]\}$	11/11/--/1
Load FP Single	lwc1 I	$F[rt] = M[R[rs] + \text{SignExtImm}]$	(2) 31/--/--/0
Load FP Double	ldc1 I	$F[rt] = M[R[rs] + \text{SignExtImm}]; F[rt+1] = M[R[rs] + \text{SignExtImm} + 4]$	(2) 35/--/--/0
Move From Hi	mfhi R	$R[rd] = Hi$	0/--/--/10
Move From Lo	mfl0 R	$R[rd] = Lo$	0/--/--/12
Move From Control	mfc0 R	$R[rd] = CR[rs]$	10/0/0/--
Multiply	mult R	$\{Hi, Lo\} = R[rs] * R[rt]$	0/--/--/18
Multiply Unsigned	multu R	$\{Hi, Lo\} = R[rs] * R[rt]$	(6) 0/--/--/19
Shift Right Arith.	sra R	$R[rd] = R[rt] \gg \text{shamt}$	0/--/--/3
Store FP Single	swc1 I	$M[R[rs] + \text{SignExtImm}] = F[rt]$	(2) 39/--/--/0
Store FP Double	sdc1 I	$M[R[rs] + \text{SignExtImm}] = F[rt]; M[R[rs] + \text{SignExtImm} + 4] = F[rt+1]$	(2) 3d/--/--/0

FLOATING-POINT INSTRUCTION FORMATS

FR	opcode	fmt	ft	fs	fd	funct
	31	26 25	21 20	16 15	11 10	6 5
FI	opcode	fmt	ft	immediate		
	31	26 25	21 20	16 15		

PSEUDOINSTRUCTION SET

NAME	MNEMONIC	OPERATION
Branch Less Than	b1t	if(R[rs]<R[rt]) PC = Label
Branch Greater Than	bgt	if(R[rs]>R[rt]) PC = Label
Branch Less Than or Equal	b1e	if(R[rs]<=R[rt]) PC = Label
Branch Greater Than or Equal	bge	if(R[rs]>=R[rt]) PC = Label
Load Immediate	li	$R[rd] = \text{immediate}$
Move	move	$R[rd] = R[rs]$

REGISTER NAME, NUMBER, USE, CALL CONVENTION

NAME	NUMBER	USE	PRESERVED ACROSS A CALL?
\$zero	0	The Constant Value 0	N.A.
\$at	1	Assembler Temporary	No
\$v0-\$v1	2-3	Values for Function Results and Expression Evaluation	No
\$a0-\$a3	4-7	Arguments	No
\$t0-\$t7	8-15	Temporaries	No
\$s0-\$s7	16-23	Saved Temporaries	Yes
\$t8-\$t9	24-25	Temporaries	No
\$k0-\$k1	26-27	Reserved for OS Kernel	No
\$gp	28	Global Pointer	Yes
\$sp	29	Stack Pointer	Yes
\$fp	30	Frame Pointer	Yes
\$ra	31	Return Address	Yes

OPCODES, BASE CONVERSION, ASCII SYMBOLS

MIPS opcode (31:26)	(1) MIPS funct (5:0)	(2) MIPS funct (5:0)	Binary	Decimal	Hexa-decimal	ASCII Character	Decimal	Hexa-decimal	ASCII Character
(1)	sll	add _f	00 0000	0	0	NUL	64	40	@
		sub _f	00 0001	1	1	SOH	65	41	A
	j	mul _f	00 0010	2	2	STX	66	42	B
	jal	div _f	00 0011	3	3	ETX	67	43	C
	beq	sllv	00 0100	4	4	EOT	68	44	D
	bne	abs _f	00 0101	5	5	ENQ	69	45	E
	blez	srlv	00 0110	6	6	ACK	70	46	F
	bgtz	srav	00 0111	7	7	BEL	71	47	G
	addi	jr	00 1000	8	8	BS	72	48	H
	addiu	jalr	00 1001	9	9	HT	73	49	I
	slti	movz	00 1010	10	a	LF	74	4a	J
	sltiu	movn	00 1011	11	b	VT	75	4b	K
	andi	syscall	00 1100	12	c	FF	76	4c	L
	ori	break	00 1101	13	d	CR	77	4d	M
	xori	ceil _{w.f}	00 1110	14	e	SO	78	4e	N
	lui	sync	00 1111	15	f	SI	79	4f	O
(2)	mfhi		01 0000	16	10	DLE	80	50	P
	mthi		01 0001	17	11	DC1	81	51	Q
	mflo	movz _f	01 0010	18	12	DC2	82	52	R
	mtlo	movn _f	01 0011	19	13	DC3	83	53	S
			01 0100	20	14	DC4	84	54	T
			01 0101	21	15	NAK	85	55	U
			01 0110	22	16	SYN	86	56	V
			01 0111	23	17	ETB	87	57	W
	mult		01 1000	24	18	CAN	88	58	X
	multu		01 1001	25	19	EM	89	59	Y
	div		01 1010	26	1a	SUB	90	5a	Z
	divu		01 1011	27	1b	ESC	91	5b	[
			01 1100	28	1c	FS	92	5c	\
			01 1101	29	1d	GS	93	5d]
			01 1110	30	1e	RS	94	5e	^
			01 1111	31	1f	US	95	5f	_
	lb	add	10 0000	32	20	Space	96	60	~
	lbu	addu	10 0001	33	21	!	97	61	a
	lwl	sub	10 0010	34	22	"	98	62	b
	lw	subu	10 0011	35	23	#	99	63	c
	lbu	and	10 0100	36	24	\$	100	64	d
	lhu	or	10 0101	37	25	%	101	65	e
	lwr	xor	10 0110	38	26	&	102	66	f
		nor	10 0111	39	27	'	103	67	g
	sb		10 1000	40	28	(104	68	h
	sh		10 1001	41	29)	105	69	i
	swl	slt	10 1010	42	2a	*	106	6a	j
	sw	sltu	10 1011	43	2b	+	107	6b	k
			10 1100	44	2c	,	108	6c	l
			10 1101	45	2d	-	109	6d	m
			10 1110	46	2e	.	110	6e	n
	swr	cache	10 1111	47	2f	/	111	6f	o
	ll	tge	11 0000	48	30	0	112	70	p
	lwc1	tgeu	11 0001	49	31	1	113	71	q
	lwc2	tlft	11 0010	50	32	2	114	72	r
	pref	tlftu	11 0011	51	33	3	115	73	s
		teq	11 0100	52	34	4	116	74	t
	ldc1	c.ult _f	11 0101	53	35	5	117	75	u
	ldc2	c.ult _f	11 0110	54	36	6	118	76	v
		c.ole _f	11 0111	55	37	7	119	77	w
		c.ule _f	11 1000	56	38	8	120	78	x
	sc	c.sf _f	11 1001	57	39	9	121	79	y
	swc1	c.ngle _f	11 1010	58	3a	:	122	7a	z
	swc2	c.seq _f	11 1011	59	3b	;	123	7b	{
		c.ngl _f	11 1100	60	3c	<	124	7c	}
	sdcl	c.lt _f	11 1101	61	3d	=	125	7d	~
	sdcl	c.nge _f	11 1110	62	3e	>	126	7e	~
	sdcl	c.le _f	11 1111	63	3f	?	127	7f	DEL

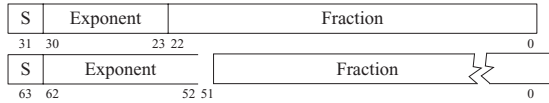
- (1) opcode(31:26) == 0
 (2) opcode(31:26) == 17_{ten} (11_{hex}); if fmt(25:21) == 16_{ten} (10_{hex}) f = s (single);
 if fmt(25:21) == 17_{ten} (11_{hex}) f = d (double)

IEEE 754 FLOATING-POINT STANDARD

$$(-1)^S \times (1 + \text{Fraction}) \times 2^{(\text{Exponent} - \text{Bias})}$$

where Single Precision Bias = 127,
 Double Precision Bias = 1023.

IEEE Single Precision and Double Precision Formats:

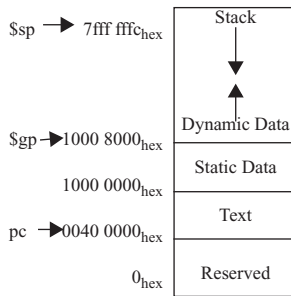


IEEE 754 Symbols

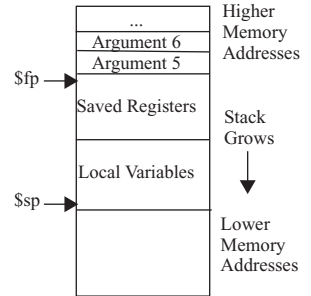
Exponent	Fraction	Object
0	0	± 0
0	≠ 0	± Denorm
1 to MAX - 1	anything	± Fl. Pt. Num.
MAX	0	±∞
MAX	≠ 0	NaN

S.P. MAX = 255, D.P. MAX = 2047

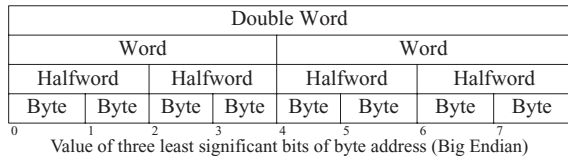
MEMORY ALLOCATION



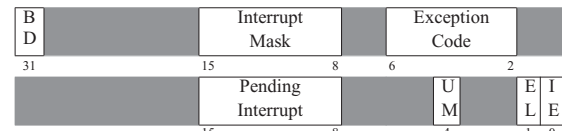
STACK FRAME



DATA ALIGNMENT



EXCEPTION CONTROL REGISTERS: CAUSE AND STATUS



BD = Branch Delay, UM = User Mode, EL = Exception Level, IE = Interrupt Enable

EXCEPTION CODES

Number	Name	Cause of Exception	Number	Name	Cause of Exception
0	Int	Interrupt (hardware)	9	Bp	Breakpoint Exception
4	AdEL	Address Error Exception (load or instruction fetch)	10	RI	Reserved Instruction Exception
5	AdES	Address Error Exception (store)	11	CpU	Coprocessor Unimplemented
6	IBE	Bus Error on Instruction Fetch	12	Ov	Arithmetic Overflow Exception
7	DBE	Bus Error on Load or Store	13	Tr	Trap
8	Sys	Syscall Exception	15	FPE	Floating Point Exception

SIZE PREFIXES (10^x for Disk, Communication; 2^x for Memory)

SIZE	PRE-FIX	SIZE	PRE-FIX	SIZE	PRE-FIX	SIZE	PRE-FIX
10 ³ , 2 ¹⁰	Kilo-	10 ¹⁵ , 2 ⁵⁰	Peta-	10 ⁻³	milli-	10 ⁻¹⁵	femto-
10 ⁶ , 2 ²⁰	Mega-	10 ¹⁸ , 2 ⁶⁰	Exa-	10 ⁻⁶	micro-	10 ⁻¹⁸	atto-
10 ⁹ , 2 ³⁰	Giga-	10 ²¹ , 2 ⁷⁰	Zetta-	10 ⁻⁹	nano-	10 ⁻²¹	zepto-
10 ¹² , 2 ⁴⁰	Tera-	10 ²⁴ , 2 ⁸⁰	Yotta-	10 ⁻¹²	pico-	10 ⁻²⁴	yocto-

The symbol for each prefix is just its first letter, except μ is used for micro.