ECE 120 Third Midterm Exam
Fall 2016

Tuesday, November 15, 2016

Name: SOLUTIONS NetID: _____

Discussion Section:

9:00 AM		
10:00 AM		
11:00 AM	[ ] AB1	[ ] AB8
12:00 PM	[ ] AB2	[ ] AB9
1:00 PM	[ ] AB3	[ ] ABA
2:00 PM	[ ] AB4	[ ] ABB
3:00 PM	[ ] AB5	
4:00 PM	[ ] AB6	[ ] ABC
5:00 PM	[ ] AB7	[ ] ABD

- **Be sure that your exam booklet has 8 pages.**
- **Write your name, netid and check discussion section on the title page.**
- **Do not tear the exam booklet apart, except for the last two pages.**
- **Use backs of pages for scratch work if needed.**
- **This is a closed book exam. You may not use a calculator.**
- **You are allowed one handwritten 8.5 x 11" sheet of notes (both sides).**
- **Absolutely no interaction between students is allowed.**
- **Clearly indicate any assumptions that you make.**
- **The questions are not weighted equally. Budget your time accordingly.**
- **Show your work.**

Problem 1	16 points	_____
Problem 2	23 points	_____
Problem 3	15 points	_____
Problem 4	10 points	_____
Problem 5	16 points	_____
Total	80 points	_____

Problem 1 (16 points): FSM Design

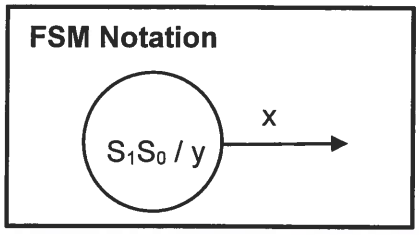
In this problem you will implement a **011** sequence recognizer. The circuit has one input ***x***, one output ***y***, and the output is 1 if and only if the pattern **011** has been detected in the input stream.

Example:

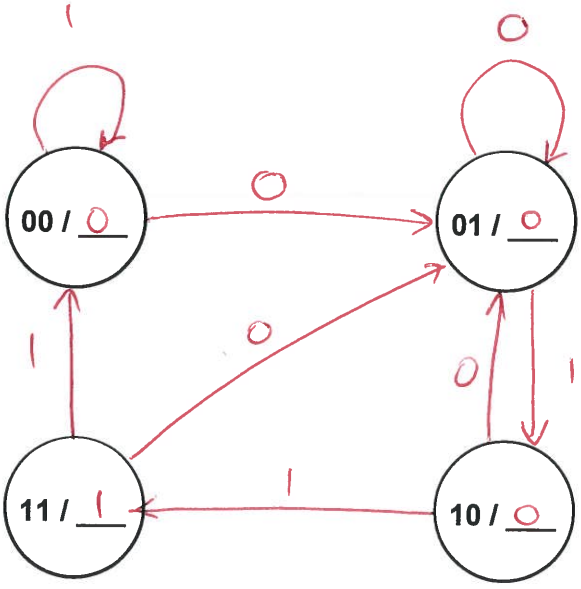
Input:	***x*** =	0	0	0	0	0	1	0	1	0	0	1	1	1	0	0	1	0	1	1	0	1	1	1	.	.	.
Output:	***y*** =		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	.	.	.

Note that the output sequence is delayed by 1 clock cycle compared to the input sequence because the output is a function of the flip-flop outputs.

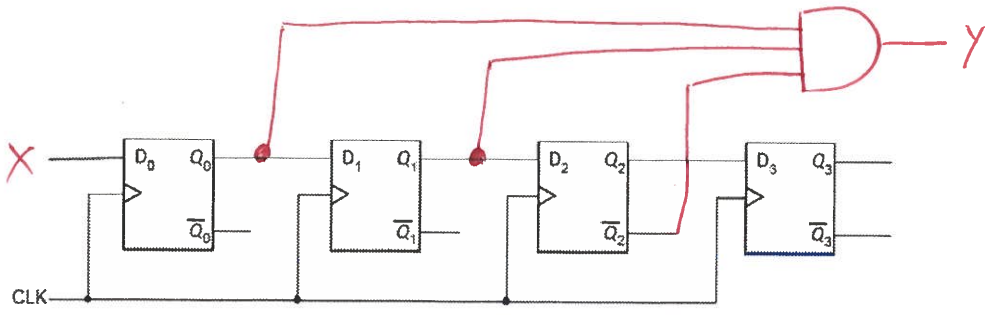
1. **(11 points)** Draw the *Moore* state diagram, labeling the output and inputs. Give the meaning of each state.



State	Meaning
"Start" 00	Nothing seen
01	'0' seen
10	'01' seen
11	'011' seen



2. **(5 points)** Shown below is a 4-bit **shift register**, constructed with 4 positive-edge-triggered D flip-flops. Use this shift register and **only one gate** (NOT, AND, OR, NAND, NOR, XOR, or XNOR) to implement a circuit which recognizes **011** *just like the example at the top of the page*. Be sure to label input ***x*** and output ***y***.

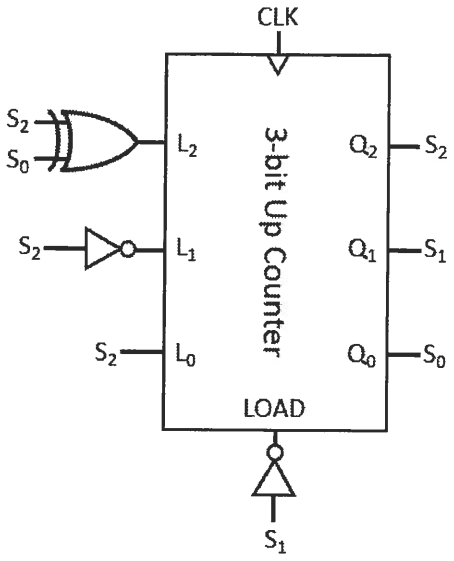


Problem 2 (23 points): FSM Analysis

1. **(13 points)** The 3-bit binary up counter shown to the right has parallel load. If LOAD=1, the counter loads the input value $L_2L_1L_0$ into $Q_2Q_1Q_0$ in the next clock cycle; if LOAD=0, $Q_2Q_1Q_0$ counts up.

   Fill out the state-transition table below for state $S_2S_1S_0$. Start by filling out the LOAD column.

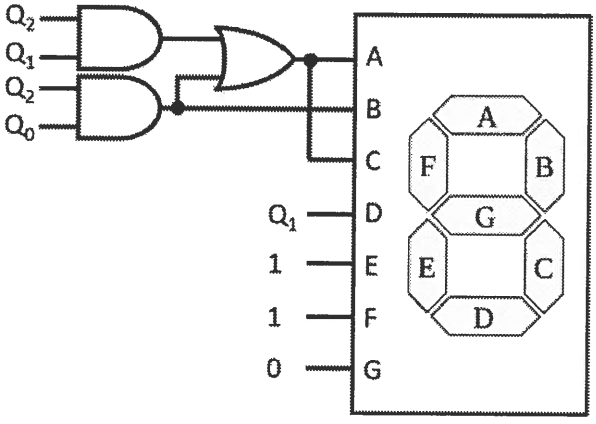
S_2	S_1	S_0	LOAD	S_2^+	S_1^+	S_0^+
0	0	0	1	0	1	0
0	0	1	1	1	1	0
0	1	0	0	0	1	1
0	1	1	0	1	0	0
1	0	0	1	1	0	1
1	0	1	1	0	0	1
1	1	0	0	1	1	1
1	1	1	0	0	0	0

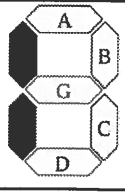
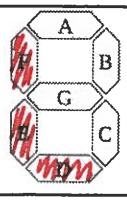
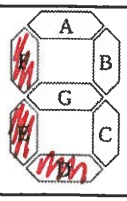
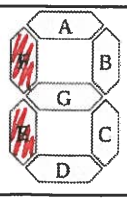
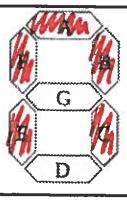
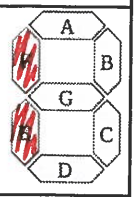


2. **(10 points)** In this part, we use a 3-bit modulo-6 binary up counter $Q_2Q_1Q_0$ (not shown in the figure) to light up the 7-segment LED display shown to the right. For example, the segment marked 'A' lights up if the input A=1.

   In the table below, the sequence of states $Q_2Q_1Q_0$ generated by the counter is given to you, starting with the state 001 in clock cycle #1.

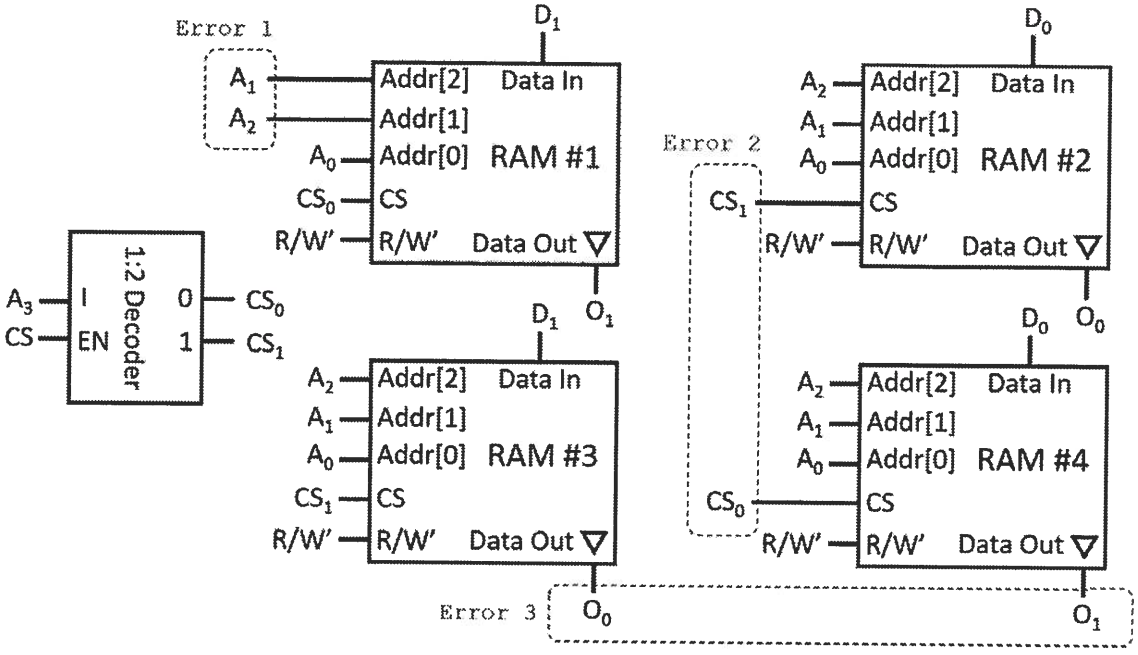
   Fill in the LED segments that light up in each clock cycle. The first one has been done for you.



cycle	#1	#2	#3	#4	#5	#6
$Q_2Q_1Q_0$	001	010	011	100	101	000
seven segment display						

Problem 3 (15 points): Memory

A careless engineer attempted to build a 16x2 RAM out of a 1:2 decoder and four 8x1 RAMs. The 16x2 RAM is intended to have two Data-In bits D_1D_0, four address bits $A_3A_2A_1A_0$, chip select CS, read/not-write R/W', and two Data-Out bits O_1O_0. Unfortunately, the engineer switched 3 pairs of connections compared to the conventional design. The mistakes are shown in the diagram as Errors 1 to 3.



1. **(12 points)** Suppose a user attempts to write (CS=1 and R/W'=0) into the faulty 16x2 RAM with data D_1D_0 = 01 at address $A_3A_2A_1A_0$ = 0101. Indicate in the table below which of the 8x1 RAMs are accessed by **circling YES or NO for each RAM**. If an 8x1 RAM is accessed, also write down the 1-bit Data-In and the 3-bit address Addr[2:0] for that 8x1 RAM.

RAM #1 Accessed? (YES) / NO Data-In 0 Addr[2:0] 011	RAM #2 Accessed? YES / (NO) Data-In _____ Addr[2:0] _____
RAM #3 Accessed? YES / (NO) Data-In _____ Addr[2:0] _____	RAM #4 Accessed? (YES) / NO Data-In 1 Addr[2:0] 101

2. **(3 points)** If you want to make a functional 16x2 RAM by correcting the **minimal number of errors**, which error(s) must you fix?

Circle the error(s) that MUST be fixed: Error 1 Error 2 (Error 3)

Problem 4 (10 points): von Neumann Model

For each question, ***CIRCLE EXACTLY ONE ANSWER.***

In the von Neumann model, where is the program stored?

processing unit | output | MAR | PC | memory

What is the first step of instruction processing in a computer based on the von Neumann model?

EXECUTE | READ OPERANDS | DECODE | FETCH | INCREMENT PC

Operands for instructions in a computer based on the von Neumann model **can NOT be found in** which of the following?

memory | tri-state buffers | register file | input | PC

Which of the following contains the address of the next instruction to be executed by the computer?

ALU | MDR | PC | IR | MAR

In the von Neumann model, the memory includes which of the following?

MAR | register file | KBDR | FSM | control unit

Problem 5 (16 points): LC-3 Interpretation and Assembly

The registers of an LC-3 processor currently have the values shown in the table to the right.

R0	x0111	R4	bits	PC	x3001
R1	x3002	R5	bits	IR	xE622
R2	x1175	R6	bits	MAR	x3000
R3	x3023	R7	bits	MDR	xE622

The table to the right shows some of the contents of the LC-3 processor's memory.

When the bits represent instructions, an interpretation has been provided for you in RTL.

address	contents	RTL interpretation
x3000	1110 0110 0010 0010	R3 ← PC + x0022
x3001	0110 0010 1100 0001	R1 ← M[R3 + 1]
x3002	1001 0100 0111 1111	R2 ← NOT R1
x3003	0111 0100 1100 0010	M[R3 + 2] ← R2
	...	...
x3023	0000 1111 0000 0101	PC ← PC + xFF05
x3024	0001 0011 0001 0100	(data: x1314)
x3025	1101 1010 1011 1100	(data: xDABC)
x3026	0000 0000 0000 0000	(no operation)

Here's the question:

The LC-3 processor **PROCESSES THREE INSTRUCTIONS**.

1. **(7 points)** Write a complete list of the sequence of values taken by the MAR register as the LC-3 processes these instructions. Use only as many lines as are necessary.

#1: x3000 (initial value)

#2: x3001

#3: x3024

#4: x3002

#5: x3003

#6: x3025

#7:

#8:

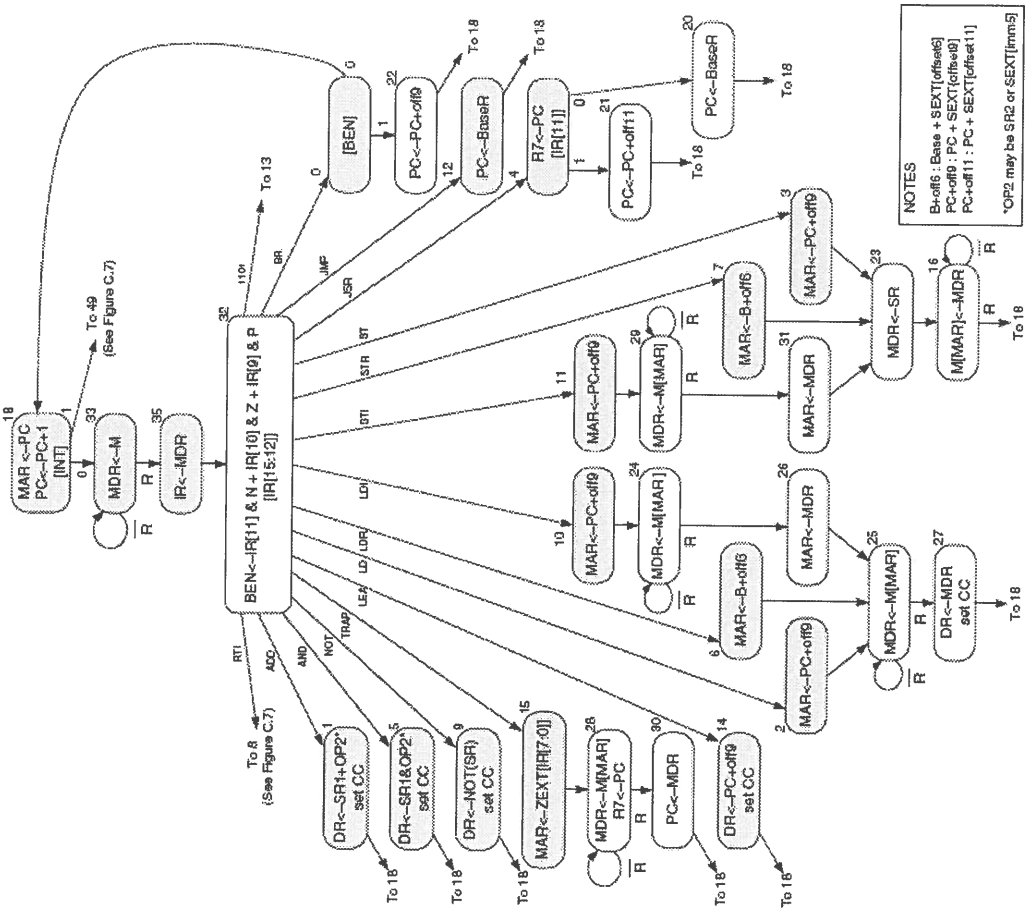
2. **(9 points)** Complete the tables below with the **FINAL** values (after processing of three instructions) of each register and memory location. If you cannot know a particular value, write "bits." *Note: You **must write your answers in hexadecimal**.*

R0	x0111
R1	x1314
...	
R4	bits

PC	x3004
IR	x74C2
MDR	xECEB

memory address	contents
x3002	x947F
...	
x3024	x1314
x3025	xECEB

LC-3 FSM



LC-3 Instructions

NOTES: RTL corresponds to execution (after fetch!); JSRR not shown

ADD | 0001 | DR | SR1 | 0 | 00 | SR2 — ADD DR, SR1, SR2

DR ← SR1 + SR2, Setcc

ADD | 0001 | DR | SR1 | 1 | imm5 — ADD DR, SR1, *imm5*

DR ← SR1 + SEXT(imm5), Setcc

AND | 0101 | DR | SR1 | 0 | 00 | SR2 — AND DR, SR1, SR2

DR ← SR1 AND SR2, Setcc

AND | 0101 | DR | SR1 | 1 | imm5 — AND DR, SR1, *imm5*

DR ← SR1 AND SEXT(imm5), Setcc

BR | 0000 | n | z | p | PCoffset9 — BR{nzp} *PCoffset9*

((n AND N) OR (z AND Z) OR (p AND P)):
PC ← PC + SEXT(PCoffset9)

JMP | 1100 | 000 | BaseR | 000000 — JMP BaseR

PC ← BaseR

JSR | 0100 | 1 | PCoffset11 — JSR *PCoffset11*

R7 ← PC, PC ← PC + SEXT(PCoffset11)

TRAP | 1111 | 0000 | trapvect8 — TRAP *trapvect8*

R7 ← PC, PC ← M[ZEXT(trapvect8)]

LD | 0010 | DR | PCoffset9 — LD DR, *PCoffset9*

DR ← M[PC + SEXT(PCoffset9)], Setcc

LDI | 1010 | DR | PCoffset9 — LDI DR, *PCoffset9*

DR ← M[M[PC + SEXT(PCoffset9)]], Setcc

LDR | 0110 | DR | BaseR | offset6 — LDR DR, BaseR, *offset6*

DR ← M[BaseR + SEXT(offset6)], Setcc

LEA | 1110 | DR | PCoffset9 — LEA DR, *PCoffset9*

DR ← PC + SEXT(PCoffset9), Setcc

NOT | 1001 | DR | SR | 111111 — NOT DR, SR

DR ← NOT SR, Setcc

ST | 0011 | SR | PCoffset9 — ST SR, *PCoffset9*

M[PC + SEXT(PCoffset9)] ← SR

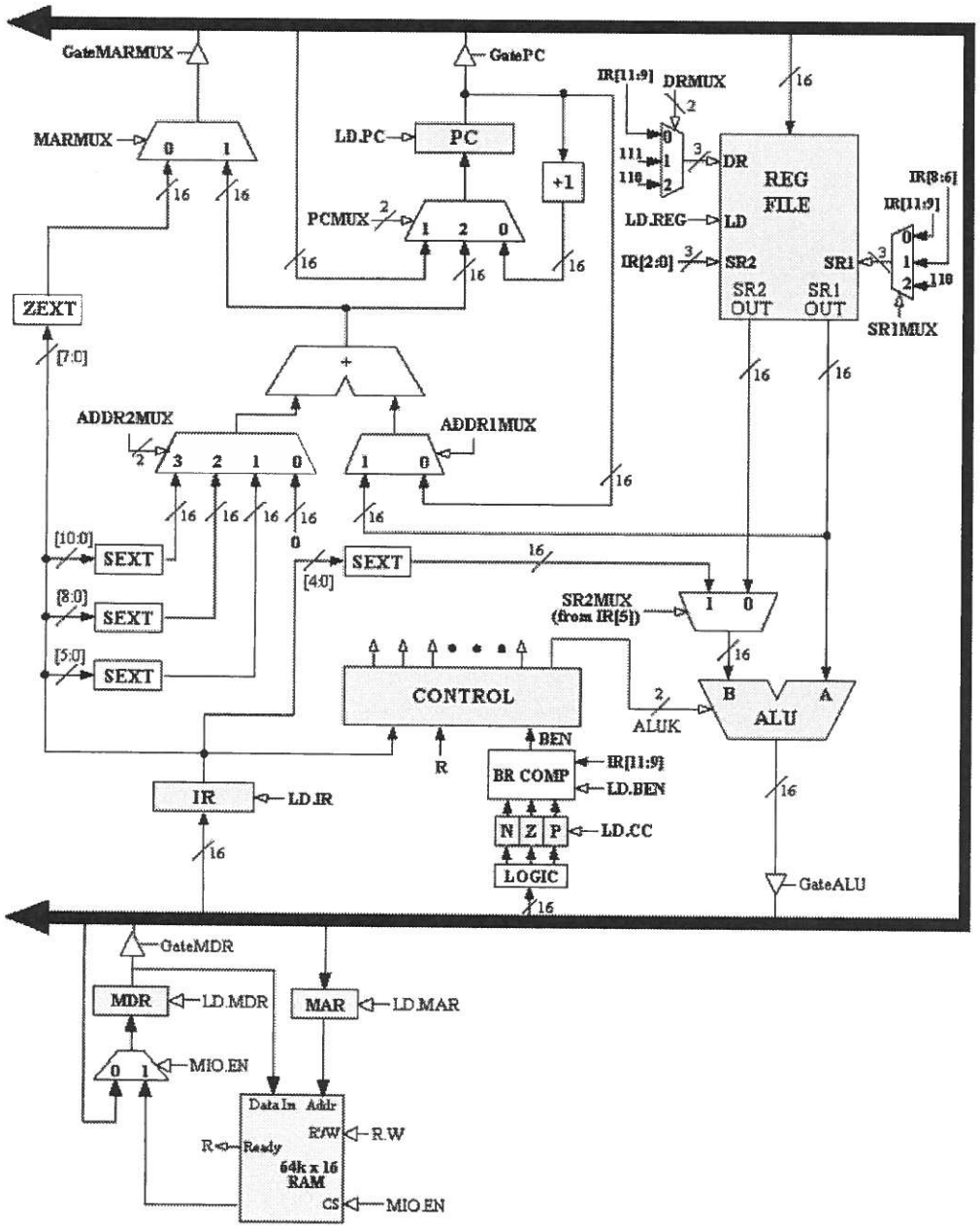
STI | 1011 | SR | PCoffset9 — STI SR, *PCoffset9*

M[M[PC + SEXT(PCoffset9)]] ← SR

STR | 0111 | SR | BaseR | offset6 — STR SR, BaseR, *offset6*

M[BaseR + SEXT(offset6)] ← SR

LC-3 Datapath



LC-3 Datapath Control Signals

Signal	Description
LD.MAR	= 1, MAR is loaded
LD.MDR	= 1, MDR is loaded
LD.IR	= 1, IR is loaded
LD.PC	= 1, PC is loaded
LD.REG	= 1, register file is loaded
LD.BEN	= 1, updates Branch Enable (BEN) bit
LD.CC	= 1, updates status bits from system bus
MARMUX	= 0, chooses ZEXT IR[7:0] = 1, chooses address adder output
ADDR1MUX	= 0, chooses PC = 1, chooses reg file SR1OUT
ADDR2MUX	= 00, chooses "0...00" = 01, chooses SEXT IR[5:0] = 10, chooses SEXT IR[8:0] = 11, chooses SEXT IR[10:0]
PCMUX	= 00, chooses PC + 1 = 01, chooses system bus = 10. chooses address adder output
SR1MUX	= 00, chooses IR[11:9] = 01, chooses IR[8:6] = 10, chooses "110"
GateMARMUX	= 1, MARMUX output is put onto system bus
GateMDR	= 1, MDR contents are put onto system bus
GateALU	= 1, ALU output is put onto system bus
GatePC	= 1, PC contents are put onto system bus
MIO.EN	= 1, Enables memory, chooses memory output for MDR input = 0, Disables memory, chooses system bus for MDR input
R.W	= 1, M[MAR]<-MDR when MIO.EN = 1 = 0, MDR<-M[MAR] when MIO.EN = 1
ALUK	= 00, ADD = 01, AND = 10, NOT A = 11, PASS A
DRMUX	= 00, chooses IR[11:9] = 01, chooses "111" = 10, chooses "110"