

Homework 14



Homework 14 is due on Wednesday, May 20, at the start of the lecture. Remember to include your *Discussions section* (e.g. ED1) and follow the complete Homework submission guidelines.

Please ask all questions about this assignment during the office hours, or post them on [piazza](#).

LC-3 datapath and control word

1. LC-3 condition codes

The LC-3 has three condition code flip-flops N, Z, and P. The states of these flip-flops indicate whether the last value on the processor bus was a negative, zero, or positive number in two's-complement representation. The P flip-flop is not necessary.

1. Redefine the BR instruction format so that bit IR[9] = 1 means "NOT", and IR[11] and IR[10] retain their meanings, checking flip-flops N and Z. Write a table with eight entries for IR[11:9] = 000, ..., 111 and explain what kind of branch condition each defines. For example, with the new format, IR[11:9] = 111 means branch if not (negative or zero), that is, branch if positive.
2. Redefine the boolean expression for the BEN flip-flop in State 32 of the LC-3 state machine for this new BR instruction format. Hint: have we seen a method to control whether a Boolean expression is inverted or not?

2. LC-3 control signals

Based on the LC3 state diagram and LC3 datapath, complete (fill in 0's, 1's, x's as appropriate) the table below necessary to execute the following: STI (states 11, 29, 31, 23, 16), LD (states 2, 25, 27), JMP (state 12), and DECODE (state 32). Make sure to include the required number of bits for all control signals.

	11	29	31	23	16	2	25	27	12	32
LD.BEN										
LD.MAR										
LD.MDR										
LD.IR										
LD.PC										
LD.REG										
LD.CC										
GateMARMux										
GateMDR										
GateALU										
GatePC										
MARMUX										
PCMUX										
ADDR1MUX										
ADDR2MUX										
DRMUX										
SR1MUX										
ALUK										
MIO.EN										
R.W										

3. LC-3 control word

Write the RTL statement(s) for the following control words, based on the LC3 architecture and the control word format presented in discussion 14. Do not use terms like 'SR' or 'DR': use the specific IR bits by name (e.g. IR[11:9] instead of DR). Note that the control word may define multiple RTL statements.

- 0822200₁₆
- 0484042₁₆
- 0CA2200₁₆

Note that some control word(s) define(s) multiple RTL statements. Hint: check LD.xx values.



Show your work, such as binary representation of hex value, corresponding values of all control signals, according to the control signals defined in this hex number, what are the RTLs, etc. If you show us an answer without derivation, you will receive no credit for it in the final exam!

Also, a reminder:

- When you are referring to a register, IR[x:x] is only a three-digit binary number, say e.g. IR[11:9]=111.
- If you want to refer to a register, it should be R(IR[11:9]), not directly IR[11:9]

4. LC-3 datapath

Refer to the LC-3 datapath given to you in discussion 14. Find two different paths that can be used to implement the following RTL statement: PC ← SR1, where SR1 is specified by IR[8:6]. For each path, write down GATE and MUX control signals below. Use don't cares when possible and make sure to specify the required number of control bits for each signal.

signal	path 1	path 2
GateMARMUX		
GateMDR		
GateALU		
GatePC		
MARMUX		
PCMUX		
ADDR1MUX		
ADDR2MUX		
DRMUX		
SR1MUX		
ALUK		