

CENG3420

Lab 3-1: LC-3b Datapath

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Overview

Introduction

Lab3-1 Assignment

Golden Results



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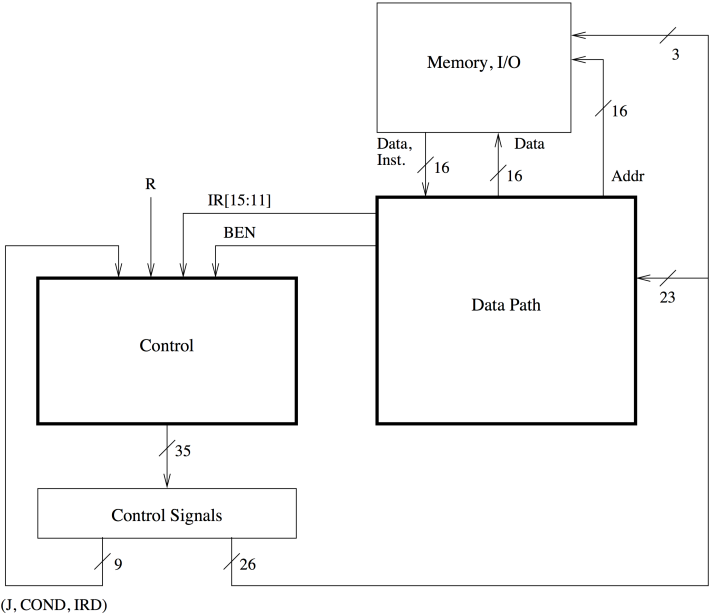
The Slides are self-contained? **NO!**

Do please refer to following document:

- ▶ [LC-3b-datapath.pdf](#)
- ▶ [LC-3b-ISA.pdf](#)



LC-3b Microarchitecture



Input of Control Structure (7 bits)

- ▶ **R**: indicate whether memory data is ready (`System_Latches::READY`)
- ▶ **BEN**: indicate whether BR been taken (`System_Latches::BEN`)
- ▶ **IR[15:11]**: current instruction (`System_Latches::IR`)



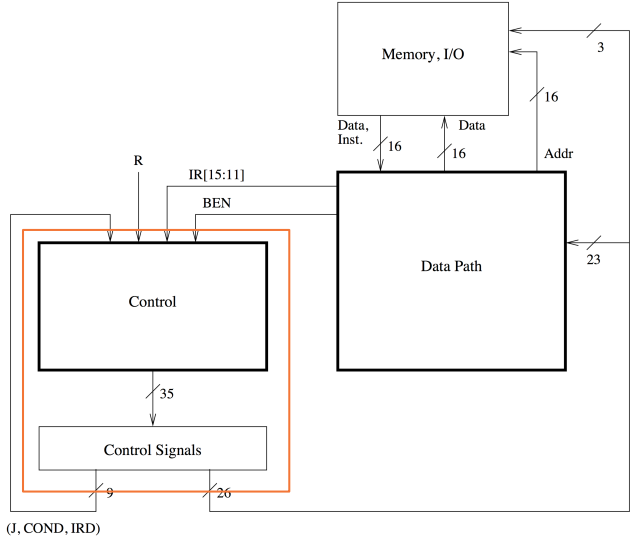
Output of Control Structure: (35 bits)

```
44
45 /******//
46 /* Definition of bit order in control store word. */
47 /******//
48 enum CS_BITS {
49     IRD,
50     COND1, COND0,
51     J5, J4, J3, J2, J1, J0,
52     LD_MAR,
53     LD_MDR,
54     LD_IR,
55     LD_BEN,
56     LD_REG,
57     LD_CC,
58     LD_PC,
59     GATE_PC,
60     GATE_MDR,
61     GATE_ALU,
62     GATE_MARMUX,
63     GATE_SHF,
64     PCMUX1, PCMUX0,
65     DRMUX,
66     SR1MUX,
67     ADDR1MUX,
68     ADDR2MUX1, ADDR2MUX0,
69     MARMUX,
70     ALUK1, ALUK0,
71     MIO_EN,
72     R_W,
73     DATA_SIZE,
74     LSHF1,
75     CONTROL_STORE_BITS
76 } CS_BITS;
```

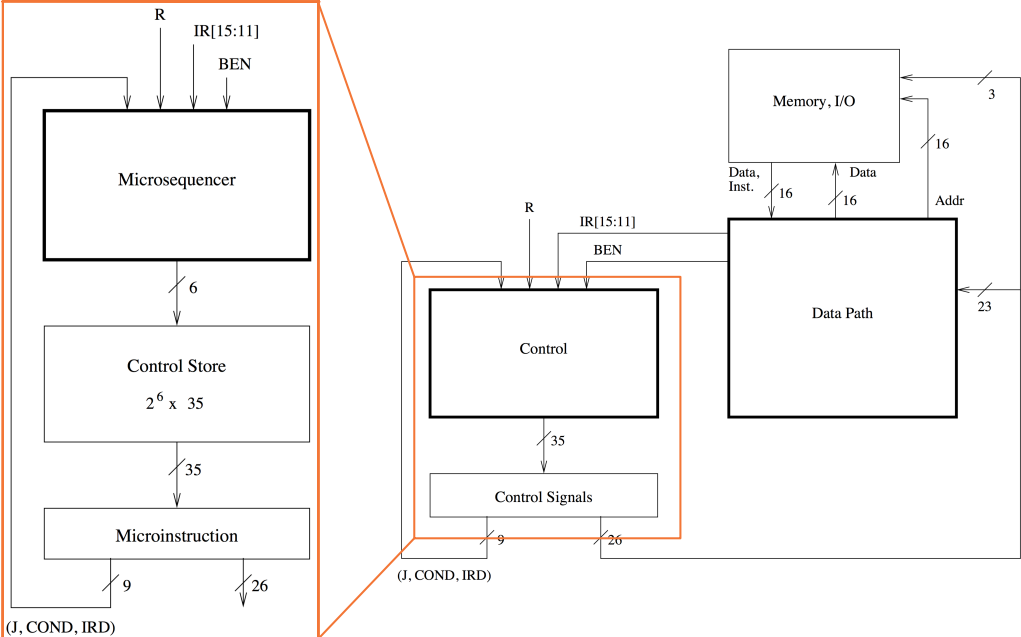
- ▶ 26 bits to control data path
- ▶ J[5:0], COND[1:0],IRD: generate address of control structure for next clock cycle



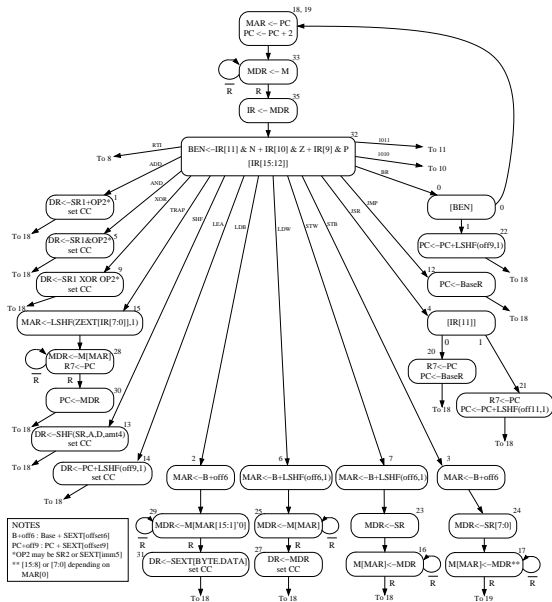
LC-3b Control Structure



LC-3b Control Structure



How's Microsequencer Actually Working?



Good News!

- ▶ Part of FSM has been provided
- ▶ See file “*ucode3*”

```
107
108 /*****/
109 /* The control store rom. */
110 /*****/
111 int CONTROL_STORE[CONTROL_STORE_ROWS][CONTROL_STORE_BITS];
112
```



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Operations in One Clock Cycle

In "lc3bsim3-1.c":

```
void cycle()
{
    eval_micro_sequencer();
    cycle_memory();
    eval_bus_drivers();
    drive_bus();
    latch_datapath_values();

    CURRENT_LATCHES = NEXT_LATCHES;

    CYCLE_COUNT++;
}
```



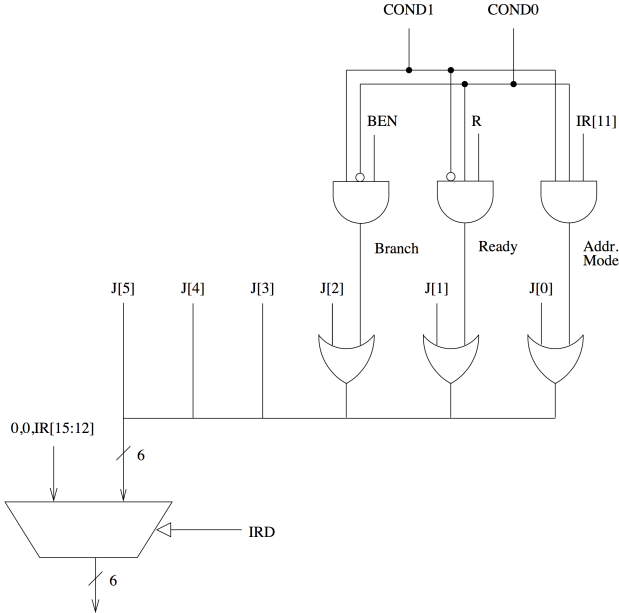
Lab3-1 Assignment

```
442
443 /*
444 * Evaluate the address of the next state according to the
445 * micro sequencer logic. Latch the next microinstruction.
446 */
447 void eval_micro_sequencer()
448 {
449     /*
450     * Lab3-1 assignment
451     *
452     * (the following lines are functionally wrong)
453     */
454     NEXT_LATCHES.STATE_NUMBER = 0;
455     memcpy(NEXT_LATCHES.MICROINSTRUCTION, CONTROL_STORE[NEXT_LATCHES.STATE_NUMBER], sizeof(int)*CONTROL_STORE_BITS);
456 }
457 }
458
```

- ▶ **Input:** CURRENT_LATCHES
- ▶ **Output:** NEXT_LATCHES.MICROINSTRUCTION



Lab3-1 Assignment Tips



Lab3-1 Assignment Tips (cont.)

Some functions may help:

- ▶ `GetCOND()`
- ▶ `GetIRD()`
- ▶ `GetJ()`
- ▶ `partVal()`



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Assignment Package

- ▶ `lc3bsim3-1.c`, `lc3bsim3-1.h`: codes to work on
- ▶ `libems3-1.a`: library
- ▶ `ucode3`: FSM
- ▶ Makefile
- ▶ `bench`: folder with benchmarks

Run the simulator:

1. `make`, then binary “`lc3bsim3-1`” is generated
2. `./lc3bsim3-1 ucode3 bench/toupper.cod`



Golden Results – case toupper.cod

1. run 6

Simulating for 6 cycles...

```
MemCycleCnt = 0
MEM_EN = 0, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 0
MEM_EN = 1, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 1
MEM_EN = 1, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 2
MEM_EN = 1, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 3
MEM_EN = 1, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 4
MEM_EN = 1, R_W = 0, WE0 = 0, WE1 = 0
```



Golden Results – case toupper.cod (cont.)

2. rdump

Current register/bus values :

```
-----  
Cycle Count   : 6  
PC            : 0x3002  
IR            : 0x0000  
STATE_NUMBER  : 0x0023  
  
BUS           : 0x0000  
MDR           : 0xe00f  
MAR           : 0x3000  
CCs: N = 0   Z = 1   P = 0  
Registers:  
0: 0x0000  
1: 0x0000  
2: 0x0000  
3: 0x0000  
4: 0x0000  
5: 0x0000  
6: 0x0000  
7: 0x0000
```



Golden Results – case toupper.cod (cont.)

3. Go on run 1

```
Simulating for 1 cycles...
```

```
MemCycleCnt = 1
```

```
MEM_EN = 0, R_W = 0, WE0 = 0, WE1 = 0
```



Golden Results – case toupper.cod (cont.)

4. rdump

Current register/bus values :

```
-----  
Cycle Count   : 7  
PC            : 0x3002  
IR           : 0xe00f  
STATE_NUMBER : 0x0020  
  
BUS          : 0xe00f  
MDR         : 0xe00f  
MAR         : 0x3000  
CCs: N = 0  Z = 1  P = 0  
Registers:  
0: 0x0000  
1: 0x0000  
2: 0x0000  
3: 0x0000  
4: 0x0000  
5: 0x0000  
6: 0x0000  
7: 0x0000
```



Golden Results – case toupper.cod (cont.)

5. Go on run 5

Simulating for 5 cycles...

```
MemCycleCnt = 0
MEM_EN = 0, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 0
MEM_EN = 0, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 0
MEM_EN = 0, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 0
MEM_EN = 1, R_W = 0, WE0 = 0, WE1 = 0
MemCycleCnt = 1
MEM_EN = 1, R_W = 0, WE0 = 0, WE1 = 0
```



Golden Results – case toupper.cod (cont.)

6. rdump

Current register/bus values :

```
-----  
Cycle Count   : 12  
PC            : 0x3004  
IR           : 0xe00f  
STATE_NUMBER : 0x0021  
  
BUS          : 0x0000  
MDR         : 0x0000  
MAR         : 0x3002  
CCs: N = 0  Z = 1  P = 0  
Registers:  
0: 0x3020  
1: 0x0000  
2: 0x0000  
3: 0x0000  
4: 0x0000  
5: 0x0000  
6: 0x0000  
7: 0x0000
```



Thanks. For any question: byu@cse.cuhk.edu.hk

