**Carleton University**

**Department of Systems and Computer Engineering**

**SYSC 3006 (Computer Organization) summer 2020**

**Lab / Assignment 4 – Answers file**

Student Name: ID#:

### Part 1 – [0.75-mark/5]

### 1-1 Control FSM Output Table

[0.75-mark] Complete the provided Control FSM Output Table for Part 1 for the Fetch, Decode, and Execution States for opcodes 0x01 (ADD) through 0x07 (NOT).

FSM Output ROM Table: **Fetch, Decode, and Execution States for opcodes 0x01 (ADD) through 0x07 (NOT)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **3 1** | **3 0** | **2 9** | **2 8** | **2 7** | **2 6** | **2 5** | **2 4** | **2 3** | **2 2** | **2 1** | **2 0** | **1 9** | **1 8** | **1 7** | **1 6** | **1 5** | **1 4** | **1 3** | **1 2** | **1 1** | **1 0** | **9** | **8** | **7** | **6** | **5** | **4** | **3** | **2** | **1** | **0** |  |
| **State**  **Hex encoding** | **Unused (0)** | **IRCE** | **PCOE** | **C1OE** | **AADD** | **MARCE** | **MAROE** | **MDRCE** | **MDROE** | **MDRget** | **MDRput** | **IBRead** | **IBWrite** | **AOP** | **ANOP** | **DR** | **SXR** | **SYR** | **RegSEL** | **RegLD** | **T1CE** | **T1OE** | **T2CE** | **T2OE** | **Q7+** | **Q6+** | **Q5+** | **Q4+** | **Q3+** | **Q2+** | **Q1+** | **Q0+** | **Hex**  **Encoding** |
| **F0**  **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Dead**  **7** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **1** | **1** | **0000 0007** |

### Part 2 – [0.75-mark/5]

### 2.1 - Control FSM Output Table

[0.75-mark] Complete the provided Control FSM Output Table for Part 2 for NOP Instruction Execution 3 States. This table will extend the Control FSM Output Table for Part 1 (same FSM Output ROM).

FSM Output ROM Table: **NOP Instruction Execution States**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **3 1** | **3 0** | **2 9** | **2 8** | **2 7** | **2 6** | **2 5** | **2 4** | **2 3** | **2 2** | **2 1** | **2 0** | **1 9** | **1 8** | **1 7** | **1 6** | **1 5** | **1 4** | **1 3** | **1 2** | **1 1** | **1 0** | **9** | **8** | **7** | **6** | **5** | **4** | **3** | **2** | **1** | **0** |  |
| **State**  **Hex encoding** | **Unused (0)** | **IRCE** | **PCOE** | **C1OE** | **AADD** | **MARCE** | **MAROE** | **MDRCE** | **MDROE** | **MDRget** | **MDRput** | **IBRead** | **IBWrite** | **AOP** | **ANOP** | **DR** | **SXR** | **SYR** | **RegSEL** | **RegLD** | **T1CE** | **T1OE** | **T2CE** | **T2OE** | **Q7+** | **Q6+** | **Q5+** | **Q4+** | **Q3+** | **Q2+** | **Q1+** | **Q0+** | **Hex**  **Encoding** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |

### Part 3 – [2.0-mark/5]

### 3.1 - Control FSM Output Table

[0.75-mark] Complete the provided Control FSM Output Table for Part 3 for NEG Instruction Execution States. This table will extend the Control FSM Output Table for Part 1 and 2 (same FSM Output ROM).

FSM Output ROM Table: **NEG Instruction Execution States**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **3 1** | **3 0** | **2 9** | **2 8** | **2 7** | **2 6** | **2 5** | **2 4** | **2 3** | **2 2** | **2 1** | **2 0** | **1 9** | **1 8** | **1 7** | **1 6** | **1 5** | **1 4** | **1 3** | **1 2** | **1 1** | **1 0** | **9** | **8** | **7** | **6** | **5** | **4** | **3** | **2** | **1** | **0** |  |
| **State**  **Hex encoding** | **Unused (0)** | **IRCE** | **PCOE** | **C1OE** | **AADD** | **MARCE** | **MAROE** | **MDRCE** | **MDROE** | **MDRget** | **MDRput** | **IBRead** | **IBWrite** | **AOP** | **ANOP** | **DR** | **SXR** | **SYR** | **RegSEL** | **RegLD** | **T1CE** | **T1OE** | **T2CE** | **T2OE** | **Q7+** | **Q6+** | **Q5+** | **Q4+** | **Q3+** | **Q2+** | **Q1+** | **Q0+** | **Hex**  **Encoding** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |

### 3.2 -

[0.50-mark] Describe how NEG instruction is executed at each execution state.

### 3.3 – Decode ROM Table

[0.75-mark] Complete the provided FSM Decode ROM Table to show any entries that must be programmed (for all parts).

**FSM Decode ROM Table**

|  |  |  |
| --- | --- | --- |
| Instruction | Address  (hex) | Contents  (hex) |
| NOP | 00 |  |
| ADD | 01 |  |
| SUB | 02 |  |
| MOV | 03 |  |
| AND | 04 |  |
| OR | 05 |  |
| XOR | 06 |  |
| NOT | 07 |  |
| NEG | 17 |  |

### Part 4 – Execution test [total of 1.5-mark/5]

### 4.1 – Instruction Table

[0.75-mark] Complete the provided Main Memory Table to contain the encodings of the Test Program instructions as indicated. Then program the words of this table into the Main Memory. Be sure to include the Main Memory contents exactly as given in the table.

**Main Memory Table**

|  |  |  |
| --- | --- | --- |
| Address  (hex) | Instruction | Encoding  (hex) |
| 0 | MOV  R2 🡨 [ R15 ] |  |
| 1 | NOT  R11 🡨 NOT [ R2 ] |  |
| 2 | MOV  R10 🡨 [ R15 ] |  |
| 3 | SUB  R15 🡨[ R10 ] – [ R11 ] |  |
| 4 | EEBB FFFF | Illegal instruction |
| 5 | NOP |  |
| 6 | NEG  R11 🡨 – [ R11 ] |  |

### 4.1 – Test Results

[0.75-mark] Cycle the System Clock through the execution of your Test program and show your logs here.

# Submission deadline

Must be submitted on cuLearn, locate (Assignment 4 submission) and follow instructions. Submission exact deadline (date and time) is displayed clearly within the Assignment 4 submission on cuLearn.

***Note: If you have any question please contact your respective group TA (see TA / group information posted on cuLearn) or use Discord class server.***

Good Luck