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**COLLEGE OF ENGINEERING**

**DEPARTMENT OF COMPUTER ENGINEERING**

**COE 381: MICROPROCESSORS**

**MICROPROCESSOR CIRCUIT DESIGN**

**MAY 2022**

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## DECLARATION

We, the undersigned solemnly declare that the project report dubbed ‘MICROPROCESSOR CIRCUIT DESIGN’ is based on work conducted during study.

We assert the statements made and conclusions drawn are an outcome of our research work. We further certify that

- I. The work contained in the report is original and has been done by this team.
- II. The work has not been submitted to any other Institution for any other degree/certificate in this university or any other university.
- III. The guidelines provided by the university in authoring the report have been followed.
- IV. Whenever materials (data, theoretical analysis, and text) have been used from other sources, due credit to them in the text of the report and giving their details in the references have been given.

## **ABSTRACT**

A microprocessor is a computer processor where the data processing logic and control is included on a single integrated circuit, or a small number of integrated circuits. The microprocessor contains the arithmetic, logic, and control circuitry required to perform the functions of a computer's central processing unit. “Altera” integrated this concept into designing a simple microprocessor that performs operation on operands to produce a desired output.

## **DEDICATION**

We dedicate this project to God Almighty our creator, strong pillar, source of inspiration, wisdom, knowledge and understanding. He has been the source of our strength throughout this programme and on His wings only have we soared.

## **ACKNOWLEDGEMENTS**

We would like to express our special thanks of gratitude to Mr. J. Yankey, our Microprocessors lecturer and Sir Chris who gave us the excellent opportunity to work on this project, 'MICROPROCESSOR DESIGN CIRCUIT.' This project has helped learn and understand microprocessors better through research. We are very thankful.

Secondly, we would like to thank each group member for their various contributions and commitment to making this project a success.

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## INTRODUCTION

**NitroCompute** is a **16-bit processor** designed based on **Vonn Neuman architecture**. It consists of a **power supply**, an **Arithmetic and Logic Unit (ALU)**, **Registers**, a **Control Unit** and **Status Flags**. Components were designed **modularly**; only the **Control Unit** determines what should be done at what instance. **NitroCompute** helps to perform basic operations with corresponding **opcodes**, together forming an **instruction set**.

## POWER SUPPLY CIRCUIT

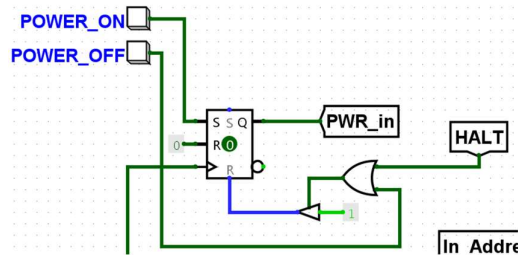


Figure 1.0

The **power supply** consists of a **SR-flip flop**. This is to ensure that the circuit stays active even if **Set** and **Reset** is **zero** once Set has an **initial one value**. The circuit is powered down either when a **halt instruction** from the **Control Unit** or the **power off button** which **toggles reset**.

| Set | Reset | Output    |
|-----|-------|-----------|
| 0   | 0     | No change |
| 0   | 1     | Reset     |
| 1   | 0     | Set       |
| 1   | 1     | invalid   |

Table 1.0

## FLAGS

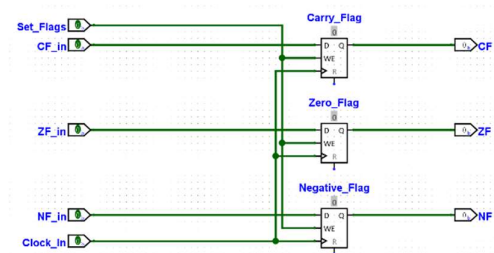


Figure 2.0

**Flags** are a modified kind of register that record the condition of a microprocessor's calculation. The status of each flag determines the microprocessor's next action, thus enabling it to make decisions.

The **Set flag** is connected to the **write enabled** which determines whether to set flag or not

**Clock** determines when values are updated

| Parameter | Description    |
|-----------|----------------|
| D         | Data in        |
| WE        | Write Enabled  |
| Q         | Output         |
| R         | Reset (unused) |

Table 2.0

## CARRY FLAG



Figure 2.1

The **Carry Flag** has a register to store the value of the flag. The **Carry Flag in (CF\_in)** receives carry data and sends it to the register. **Carry flag (CF)** outputs flag state to the control unit.

## ZERO FLAG



Figure 2.2

The **Zero Flag** has a register to store the value of the flag. The **Zero Flag in (ZF\_in)** receives data and send to register. **Zero Flag(ZF)** outputs flag state to the control unit.

## NEGATIVE FLAG



Figure 2.3

The **Negative Flag** has a register to store the value of the flag. The **Negative Flag in (NF\_in)** receives data and send to register. **Negative Flag(ZF)** outputs flag state to the control unit.



## REGISTERS

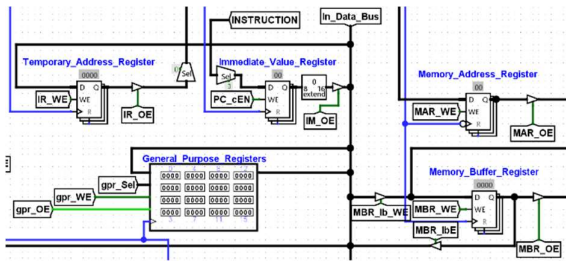


Figure 3.0

The temporary storage locations inside the Central processing Unit to store **data** and **addresses** is called a register.

## GENERAL PURPOSE REGISTERS

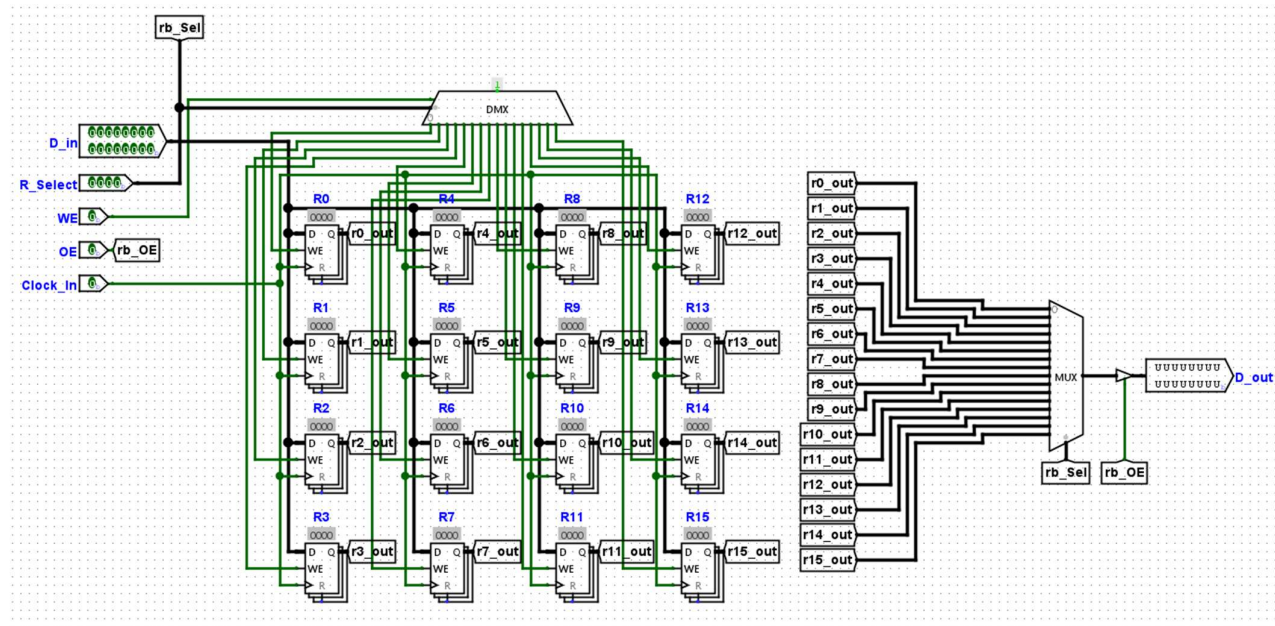


Figure 3.1

The **general-purpose register** can store a data or a memory location address. It is a **multipurpose register**. They can be used either by programmer or by a user. For NitroCompute, **Write Enabled (WE)** determines whether to store or not from **Data In (D\_in)**. **Output Enabled (OE)** determines whether to output the content of selected register. Register Bank Select (**Rb\_sel**) tunnel helps to select a register whose content should be displayed. The **Demultiplexer** helps to select a specific register based on **rb\_sel** value. The Multiplexer is used in selecting data to be outputted. **Register Bank Output Enabled (rb\_OE)** determines whether data stored in register should be outputted. **Data out (D\_out)** is the data being outputted.

## TEMPORARY ADDRESS REGISTER

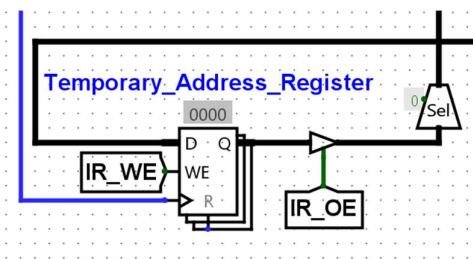


Figure 3.2

This **Address Register** was previously called the **Instruction Register**. It receives data from **the internal data bus**. Based on the **bit select** value, either the first eight bits or second eight bits would be selected. It consists of a **latch** as well as **write and output enablers** to decide whether to write data or to output its result. It also consists of a **controlled buffer** which determines whether the output should be sent to the internal address bus .

## IMMEDIATE VALUE REGISTER

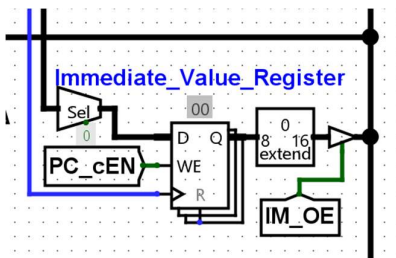


Figure 3.3

The **immediate value register** stores the immediate value in every instruction (**first eight bits**). It receives input from instruction and outputs data to the internal data bus . It consists of a **bit extender** to push additional zeros to the instruction bits to enable data to be compatible with the number of bits received on the data .

## MEMORY ADDRESS REGISTER

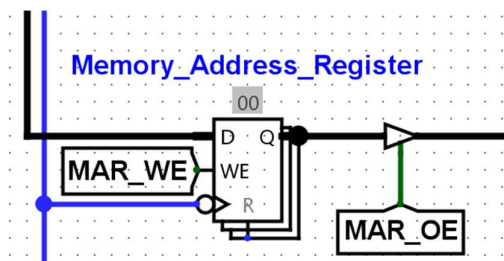


Figure 3.4

This register receives eight bits of data. It is **negatively clocked (enabled on falling edge)** to enable the program counter successfully to clock (**synchronization**). It also has a write enabler and output enabler to decide whether to write and store data values at each instance.

The memory address register pushes data to **the external address bus (RAM)**.

## MEMORY BUFFER REGISTER

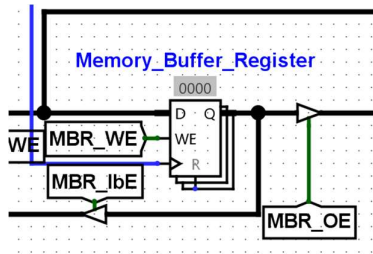


Figure 3.5

The memory buffer register is a **bridge** between the **internal and external data bus** . (Two-way bridge). It can **write** to both the **internal and external data bus** as well as **receive input** from either data bus . It has an **output enabler** which determines whether data should be pushed out of this register.

## RANDOM ACCESS MEMORY

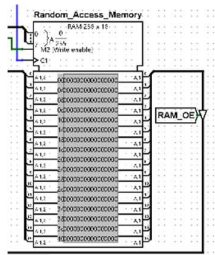


Figure 4.0

The **RAM** has a total of **256 x 16 bits** of data Its **first 128 bits** are for storing **addresses** and **second 128, for data**. It has a **write enabler** to determine whether data should be written to the **RAM** and an **output enabler** to determine whether data should be fed to the **external data bus**.

## REGISTER A AND B

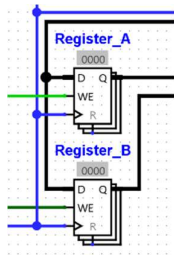


Figure 5.0

These are the only inputs to Arithmetic and Logic Unit. They serve as data input for ALU operations.

## PROGRAM COUNTER

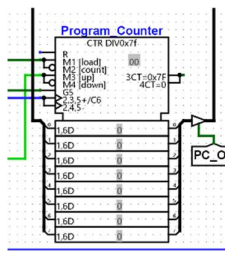


Figure 6.0

The **program counter** determines in what **order** instructions are fetched and executed. It can either **load and count but not both at an instance and count upwards or and downwards**. It also has a **count enable** as well as a **reset**. It has **memory to store count values**. It has an **output enabler** to decide whether to **write to internal data bus**. The Program Counter has max value **7f (hexadecimal)** after which it **restarts counting**

## ARITHMETIC AND LOGIC UNIT

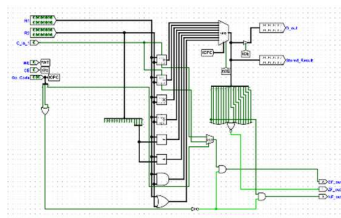


Figure 7.0

The Arithmetic and Logic Unit is a digital circuit used to perform arithmetic and logic operations. It represents the fundamental building block of the central processing unit.

The Instruction Format for an ALU is:

[**OPCODE**][**SOURCE1**][**SOURCE2**][**DESTINATION**]

Under this ALU, there are eight operations.

|     |   |             |   |                        |
|-----|---|-------------|---|------------------------|
| • 0 | - | <b>ADD</b>  | - | ADDITION               |
| • 1 | - | <b>SUB</b>  | - | SUBTRACTION            |
| • 2 | - | <b>MULT</b> | - | MULTIPLICATION         |
| • 3 | - | <b>DIV</b>  | - | DIVISION               |
| • 4 | - | <b>SHL</b>  | - | LOGICAL SHIFT LEFT     |
| • 5 | - | <b>SHR</b>  | - | LOGICAL SHIFT RIGHT    |
| • 6 | - | <b>AND</b>  | - | LOGICAL MULTIPLICATION |
| • 7 | - | <b>OR</b>   | - | LOGICAL ADDITION       |

The ALU receives data from **Register 1** and **Register 2 (Register A and B)**. Every operation aside **Logical Shift Left**, and **Logical Shift Right** use 16-bit values. All eight operations are performed on the operands. A **Multiplexer** and **Write Enabler (WE)** determine which output should be displayed and whether an operation should be performed. **Data Out (D\_out)** sends data to internal address bus. **Stored\_Result** shows current result. The **Negative Flag** and **Carry Flag** are only triggered by the **Add** and **Sub** operations. If the result of the operation exceeds sixteen bits, the **Carry Flag** is triggered. The **Negative flag** is triggered when the **Logical Union** of the result is **zero**.

For the **logical shift left and logical shift**, the **first operand** is **sixteen bits** and second is a **4-bit value (LSB)**. The **Operation Code** received from CU determines which operation output to be displayed. The **Output Enable (OE)** determines whether the result should be displayed.



## CONTROL UNIT

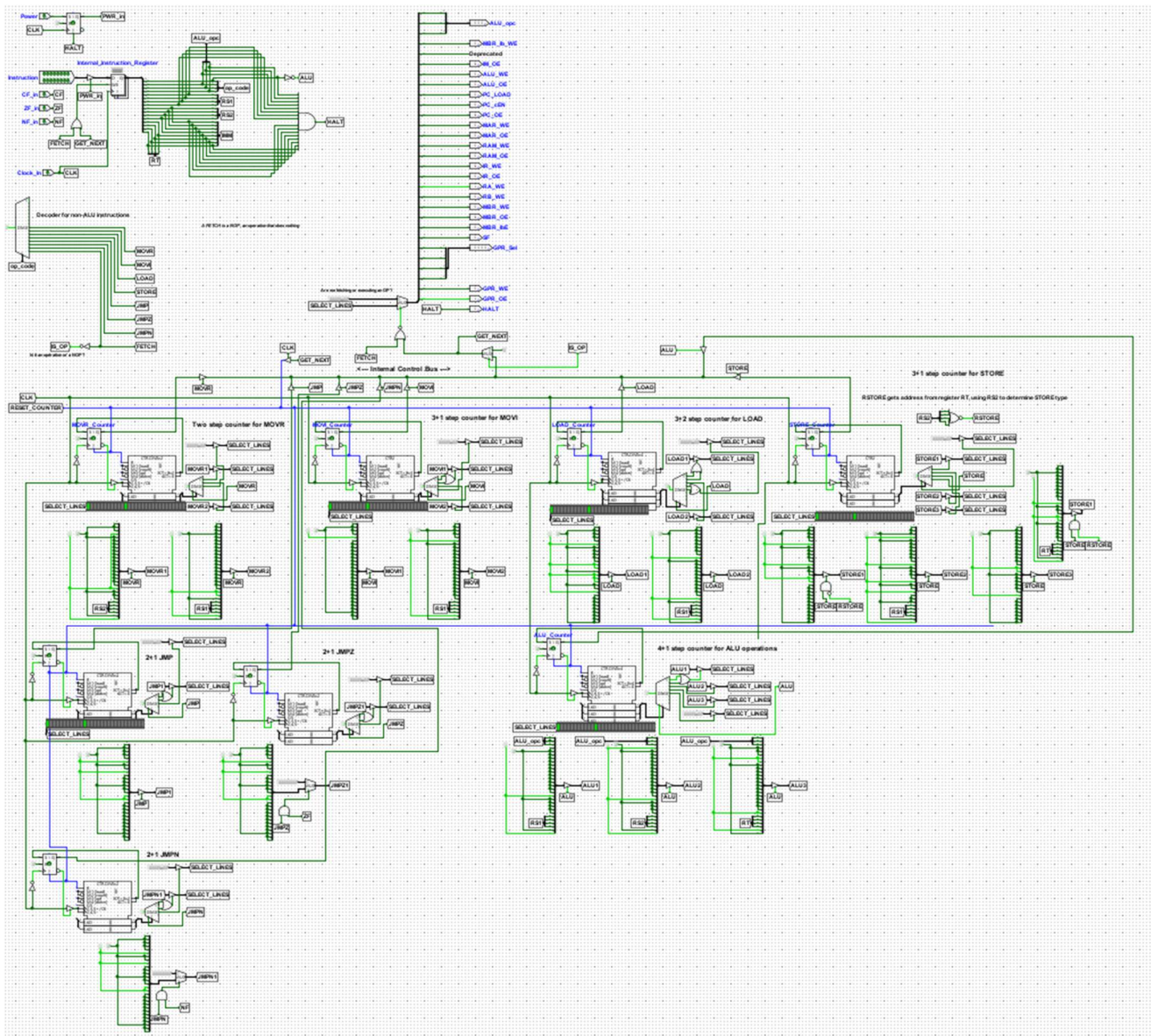


Figure 8.0

The **control unit** is the core of the entire **Central Processing Unit**. Its main operation is to **generate control signals** throughout the CPU to control when certain operations are performed. This control unit has **twenty-nine control signals from zero to twenty-eight**. For every operation, it checks for the **enabled control signals** and **generates a control sequence** for it to be performed.

The twenty-nine control signals are:

|                                                |   |   |
|------------------------------------------------|---|---|
| ALU_OPCODE                                     | - | 0 |
| ALU_OPCODE                                     | - | 1 |
| ALU_OPCODE                                     | - | 2 |
| MEMORYADDRESSREGISTER_INTERNALBUS_WRITEENABLED | - | 3 |
| IMMEDIATEVALUEREGISTER_WRITEENABLED            | - | 4 |
| IMMEDIATEVALUEREGISTER_OUTPUTENABLED           | - | 5 |

|                                                 |   |           |
|-------------------------------------------------|---|-----------|
| <b>ALU_WRITEENABLED</b>                         | - | <b>6</b>  |
| <b>ALU_OUTPUTENABLED</b>                        | - | <b>7</b>  |
| <b>PC_LOAD</b>                                  | - | <b>8</b>  |
| <b>PC_COUNTENABLED</b>                          | - | <b>9</b>  |
| <b>PC_OUTPUTENABLED</b>                         | - | <b>10</b> |
| <b>MEMORYADDRESSREGISTER_WRITEENABLED</b>       | - | <b>11</b> |
| <b>MEMORYADDRESSREGISTER_OUTPUTENABLED</b>      | - | <b>12</b> |
| <b>RAM_WRITEENABLED</b>                         | - | <b>13</b> |
| <b>RAM_OUTPUTENABLED</b>                        | - | <b>14</b> |
| <b>INSTRUCTIONREGISTER_WRITEENABLED</b>         | - | <b>15</b> |
| <b>INSTRUCTIONREGISTER_OUTPUTENABLED</b>        | - | <b>16</b> |
| <b>REGISTERA_WRITEENABLED</b>                   | - | <b>17</b> |
| <b>REGISTERB_WRITEENABLED</b>                   | - | <b>18</b> |
| <b>MEMORYBUFFERREGISTER_WRITEENABLED</b>        | - | <b>19</b> |
| <b>MEMORYBUFFERREGISTER_OUTPUTENABLED</b>       | - | <b>20</b> |
| <b>MEMORYBUFFERREGISTER_INTERNALBUSEENABLED</b> | - | <b>21</b> |
| <b>SET FLAG</b>                                 | - | <b>22</b> |
| <b>GENERALPURPOSEREGISTER_SELECT</b>            | - | <b>23</b> |
| <b>GENERALPURPOSEREGISTER_SELECT</b>            | - | <b>24</b> |
| <b>GENERALPURPOSEREGISTER_SELECT</b>            | - | <b>25</b> |
| <b>GENERALPURPOSEREGISTER_SELECT</b>            | - | <b>26</b> |
| <b>GENERALPURPOSEREGISTER_WRITEENABLED</b>      | - | <b>27</b> |
| <b>GENERALPURPOSEREGISTER_OUTPUTENABLED</b>     | - | <b>28</b> |

The Control Unit performs the following operations with the following selected signals.

## **MOVR**

This operation allows us to move the contents from one register to another register.

The syntax for a MOVR operation is,

**[MOVR] [RA],[RB]**

Where:

**MOVR** is the operation being performed

**RA** is the **DESTINATION** register

**RB** is the **SOURCE** register

**MOVR1 = 3,19,23,24,25,26**

**MOVR2 = 20,21,23,24,25,26,27**

## MOVI

This operation allows us to move an immediate value into a register

The syntax for a MOVI operation is,

**[MOVI] [RA],[IMME]**

Where:

**MOVI** is the operation being performed

**RA** is the **DESTINATION** register

**IMME** is the immediate value

**MOVI1 = 4**

**MOVI2 = 5,23,24,25,26,27**

## LOAD

This operation allows us to load contents in memory into a register

The syntax for a MOVI operation is,

**[LOAD] [RA],[ADDR]**

Where:

**LOAD** is the operation being performed

**RA** is the **DESTINATION** register

**ADDR** is the address location of the data in memory.

**LOAD1 = 5,11,12,14,15,16,19**

**LOAD2 = 5,21,23,24,25,26,27**

## STORE

This operation allows us to store the data from a register into memory.<sup>4</sup>

The syntax for a STORE operation is,

**[STORE] [RA],[ADDR]**

Where:

**STORE** is the operation being performed

**RA** field is the **SOURCE** register

**ADDR** is the address location to store the value

**STORE1= 5,11,15,16**

**STORE1\* = 11,15,16,23,24,25,26,28**

**STORE2 = 3,11,16,23,24,25,26,28**

**STORE3 = 12,13,20**

## JMP

This operation allows us to jump to a specified instruction location in memory.

The syntax for a JMP operation is,

**[JMP] [ADDR]**

Where:

**JMP** is the operation being performed

**ADDR** is the address location of the instruction to jump to

**JMP1 = 5,15,16**

## **JMPZ**

This operation allows us to jump to a specified instruction location in memory if the zero flag is enabled,  
The syntax for a JMPZ operation is,

**[JMPZ] [ADDR]**

Where:

**JMPZ** is the operation being performed

**ADDR** is the address location of the instruction to jump to

**JMPZ = 5,15,16**

## **JMPN**

This operation allows us to jump to a specified instruction location in memory if the negative flag is enabled.  
The syntax for a JMPN operation is,

**[JMPN] [ADDR]**

Where:

**JMPN** is the operation being performed

**ADDR** is the address location of the instruction to jump to

**JMPN = 5,15,16**

## **HALT**

This opcode halts the microprocessor

**0x5e00** is fed into the Multiplexer

The syntax for a HALT operation is.

**[HALT]**

Where:

**HALT** is the operation being performed

## **ALU OPERATIONS**

**[OPCODE][SOURCE1][SOURCE2][ DESTINATION]**

**ALU1 = 17,23,24,25,26,28**

**ALU2 = 3,18,23,24,24,25,26,28**

**ALU3 = 6,7,22,23,24,25,26,27**



## ASSEMBLER

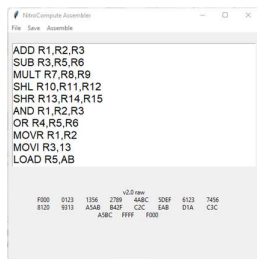


Figure 9.0

The NitroCompute Assembler was built using Python programming language and converts Assembly Language into hexadecimal code fed into The NitroCompute microprocessor. When executed, an application GUI which has a menu bar, text area and title bar appears.

The menu bar contains the following drop-down menus.

- File
  - Open: Allow user to provide input from a text file
  - Exit: Close application
- Save
  - Save: Store the content in the text area into a specified file.
- Assemble
  - Assemble: Allow user to convert the assembly code into a hexadecimal code and store the output into a specified file.

The text area is a rectangular area with a white background where the user can type the assembly code.

## CONCLUSION

In designing NitroCompute, efficiency and cost were considered. Although it is not an ideal microprocessor, it is a start-up to undergo reviews and performance improvements together with The NitroCompute Assembler.

## REFERENCES

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- Definition of Microprocessor, [Microprocessor - Wikipedia](#)
- Definition of Registers, [www.educba.com/register-in-microprocessor/](http://www.educba.com/register-in-microprocessor/)

## DEVELOPERS

[maxotuteye \(Max Otuteye\) \(github.com\)](#)

[hanskod \(Hansen Koduah\) \(github.com\)](#)

[dzeble \(github.com\)](#)

[Adaks \(github.com\)](#)

[Dillys3567 \(github.com\)](#)

[Eadanso \(github.com\)](#)

[Frank-app \(github.com\)](#)

## APPENDIX

<https://github.com/maxotuteye/nitro-compute.git>

|        |                                                             |
|--------|-------------------------------------------------------------|
| ADD    | - ADDITION                                                  |
| ADDR   | - ADDRESS LOCATION OF THE DATA IN MEMORY.                   |
| ALU    | - ARITHMETIC AND LOGIC UNIT                                 |
| AND    | - LOGICAL MULTIPLICATION                                    |
| CF_in  | - CARRY FLAG IN                                             |
| D_out  | - DATA OUT                                                  |
| DIV    | - DIVISION                                                  |
| HALT   | - STOP MICROPROCESSOR                                       |
| IMME   | - IMMEDIATE VALUE                                           |
| JMP    | - EXECUTE FROM SPECIFIED LOCATION IN MEMORY                 |
| JMPN   | - EXECUTE FROM LOCATION IF NEGATIVE FLAG IS TRIGGERED       |
| JMPZ   | - EXECUTE FROM SPECIFIED LOCATION IF ZERO FLAG IS TRIGGERED |
| LOAD   | - PUSH CONTENT IN MEMORY TO REGISTER                        |
| MOVI   | - IMMEDIATE VALUE TO REGISTER MOVE                          |
| MOVR   | - REGISTER TO REGISTER MOVE                                 |
| MULT   | - MULTIPLICATION                                            |
| NF_in  | - NEGATIVE FLAG IN                                          |
| NOP    | - STOP MICROPROCESSOR (NO OPERATION)                        |
| OE     | - OUTPUT ENABLED                                            |
| OR     | - LOGICAL ADDITION                                          |
| R1     | - REGISTER 1                                                |
| R2     | - REGISTER 2                                                |
| R3     | - REGISTER 3                                                |
| RA     | - REGISTER A                                                |
| RB     | - REGISTER B                                                |
| Rb_OE  | - REGISTER BANK OUTPUT ENABLED                              |
| Rb_sel | - REGISTER BANK SELECT                                      |
| RC     | - REGISTER C                                                |
| SHL    | - SHIFT LEFT                                                |
| SHR    | - SHIFT RIGHT                                               |
| STORE  | - SAVE DATA FROM REGISTER TO MEMORY                         |
| SUB    | - SUBTRACTION                                               |
| WE     | - WRITE ENABLED                                             |
| ZF_in  | - ZERO FLAG IN                                              |