MICROPROCESSOR LAB EXPERIMENT 4

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Introduction :

- In this experiment, we are going to learn how to program the micro controller **ATmega8**.
- This experiment involves ,
  - Introduction to the assembly language.
  - Write a program in assembly language to display the maximum and minimum of 10 numbers stored in **FLASH** memory.
  - Write a program in assembly language to add 10 numbers stored in flash memory and store it in the register.
  - Sort 5 numbers stored in flash memory in arbitrary order and write the final results to data memory
- In this report , we have included the code of the tasks and our experience with the assembly language.

ATmega-8 and Microchip studio :

- Atmega-8 is an 8-bit RISC single-chip microcontroller developed by Atmel.
- The number 8 in its name represents that it can operate 8 bits at a time while processing the information i.e in a way it represents the capacity of the microcontroller.
- Some features of AVR microcontroller are
  - I/O ports.
  - Internal instructions flash memory
  - SRAM upto 16KB
  - Timers
- Flash memory is used to store the programs whatever we have written in the microchip studio.
- Each instruction will occupy the size of 2 bytes/16 bits in flash memory except for the instructions like **STS** , **JMP** which will occupy 4 bytes in the memory.
- For example the following code ,

  ```
  LDI R16,0x01
  ```

  will occupy 2 bytes in the memory.
- Flash memory also has 32 registers (from R0 to R31) with three pointers ,
  - Z pointer : R30 and R31
  - Y pointer : R28 and R27
  - X pointer : R25 and R26
- These registers are used to hold memory in addition to having SRAM whose address starts from 0x60.
- We will see the instructions to implement the logic in the following sections.

Instructions used :

Instruction	Usage
LDI Rx,Rd	Load the value **Rd** in the register **Rx**
LD Rx,Rm	Load the value stored in the memory address **Rm** in the register **Rx**
LPM Rx,Rm	Load the value stored in the program memory address **Rm** in the register **Rx**
ST Rm,Rx	Store the address of the register **Rx** in the pointer **Rm**
MOV Rm1,Rm2	Copy the value stored in the register **Rm1** to the register **Rm2**
SUB Rm1,Rm2	Subtract the value stored in **Rm1** from the value stored in **Rm2** register and store the result in **Rm1**
CP Rm1,Rm2	Compare the values of the registers **Rm1** and **Rm2** and raise the following flags in the status registers - Sign flag - Negative flag - Carry flag if the first value is smaller than the second value.
DEC Rm	Decrease the value in the register **Rm** by an unit.

Finding the sum of numbers

Introduction :

- This task involves iterating through the registers and finding the sum
- It will always take n computations where n is the total number of values.

Code for Sum

```
.CSEG


LDI ZL, LOW(NUM<<1) ; Load the Z pointer with the array NUM
LDI ZH, HIGH(NUM<<1) ; Load the Z pointer with the array NUM

; R16 will always store the sum of the array
LPM R16, Z+ ; Load the first value of array

LDI R18, 0x09 ; Counter

LOOP :
        LPM R17,Z+ ; Load the next value to R17
        ADD R16,R17 ; Adding
        DEC R18 ; dereasing the counter
BRNE LOOP

NOP

NUM: .db 0x01,0x09,0x08,0x00,0x16,0x12,0x13,0x14,0x15,0x19
```

Usage of registers in flash memory in this code :

Registers	Usage
R18	Counter variable
R16 and **R17**	To store sum and temporary variable to store the loaded value
Z pointer	Store the array address to flash memory where the values are given.

Process

- Getting the values from the array and storing in a temporary variable.
- Adding the loaded value to the current sum
- Updating the sum

Finding the maximum and minimum number

Introduction :

- This task involves iterating through the registers and finding the minimum and maximum number
- It will always take n computations where n is the total number of values.

Code for minimum:

```
.CSEG

LDI ZL, LOW(NUM<<1) ; Load the Z pointer with the array NUM
LDI ZH, HIGH(NUM<<1) ; Load the Z pointer with the array NUM

; R16 will always store the minimum value of the array
LPM R16, Z+ ; Load the first value of array to min

LDI R18, 0x09 ; Counter

LOOP :
        LPM R17,Z+ ; Load the next value to R17
        CP R16,R17 ; Compare
        BRLO CDT ; This will go to CDT by skipping the next line if R16 < R17
        MOV R16,R17
        CDT:
                DEC R18 ; dereasing the counter
BRNE LOOP

NOP

NUM: .db 0x01,0x09,0x08,0x00,0x16,0x12,0x13,0x14,0x15,0x19
```

Code for maximum:

```
.CSEG

LDI ZL, LOW(NUM<<1) ; Load the Z pointer with the array NUM
LDI ZH, HIGH(NUM<<1) ; Load the Z pointer with the array NUM

; R16 will always store the maximum value of the array
LPM R16, Z+ ; Load the first value of array to max

LDI R18, 0x09 ; Counter

LOOP :
        LPM R17,Z+ ; Load the next value to R17
        CP R16,R17 ; Compare
        BRSH CDT ; This will go to CDT by skipping the next line if R16 > R17
        MOV R16,R17
        CDT:
                DEC R18 ; dereasing the counter
BRNE LOOP

NOP

NUM: .db 0x01,0x09,0x08,0x00,0x16,0x12,0x13,0x14,0x15,0x19
```

Usage of registers in flash memory in this code :

Registers	Usage
R18	Counter variable
R16 and **R17**	To store min or max and temporary variable to store the loaded value
Z pointer	Store the array address where the values are given.

Process

- Getting the values from the array and storing in a temporary variable.
- Comparing with current min or max with the new value from the array
- Changing min or max if required or restarting the loop with a decrease in the counter variable

Sorting the stored numbers in the Flash memory

Introduction :

- This task involves the knowledge of iterating through the registers multiple times and comparing the values in the given memory addresses.
- We have implemented the bubble sort algorithm to sort the array.
- At the worst case (numbers are in descending order), it will take $n*(n-1)/2$ computations to implement sorting.

Code :

```
.CSEG

LDI ZL,LOW(NUM<<1) ; Load the Z pointer with the array NUM
LDI ZH,HIGH(NUM<<1) ; Load the Z pointer with the array NUM

LDI YL,LOW(0x60) ; Load the Y pointer with the register stored in SRAM
LDI YH,HIGH(0x60) ; Load the Y pointer with the register stored in SRAM

LPM R25,Z+ ; Storing the first value of the array in R25
ST Y+,R25 ; Storing R25 into the register in SRAM

LDI R22,0x04 ; R22 will store the number of elements to intake from NUM (5-1)

LOOP :
        LDI R23,0x05 ; R23 will store the number of sortings that it has to do
        SUB R23,R22 ; R23 will be 5 - Current iteration i.e R22

        LPM R25,Z+ ; Storing the first value of the array in R25
        ST Y+,R25 ; Storing R25 into the register in SRAM

        MOV XL,YL ; Creating a X pointer to iterate through the sorting process
        MOV XH,YH ; Copying the current address stored in Y pointer in the X pointer

        LD R25,-X ; To shift to the last stored elements
        LOOP1 :
                LD R25,X ; Loading the current value stored at X to R25
                LD R24,-X ; Loading the current value stored at -X to R25

                CP R24,R25; Comparing the values
                BRLO CDT ; This will skip the next lines and jump to CDT if R24 < R25 (No swapping require

                ST X+,R25 ; Swapping current position with R25
                ST X,R24 ; Swapping right adjacent position with R24
                LD R24,-X ; Moving back to the left adjacent position inorder to continue the loop

                CDT:
                DEC R23 ; Decreasing thr counter
        BRNE LOOP1 ; Running through the loop
        DEC R22 ; Decreasing thr counter
BRNE LOOP ; Running through the loop

NOP
NUM: .db 0x01,0x11,0x08,0x05,0x02
```

Usage of registers in flash memory in this code :

Registers	Usage
R22	Counter variable to iterate through the list.
R23	Counter variable to reiterate through the stored elements to check for swapping.
R24 and **R25**	Temporary registers to store the values at pointers and used to swap if necessary.
Z pointer	Store the array address where the values are given.
Y pointer	Store the SRAM register address so that we can iterate through the contiguous registers to store the values.
X pointer	Store the current Y pointer so that we can iterate backwards to check for swapping.

Processes :

- Let us analyse the above code in terms of three processes.
  - Getting the values from the array.
  - Iterating backward to check if we have to swap.
  - Swapping condition.

Getting the values from the array :

- The register **R25** is used as a temporary register to assign the value at **Z** to the register which is at the memory **Y**.
- The code which do this process is

```
LDI ZL,LOW(NUM<<1)
LDI ZH,HIGH(NUM<<1)

LDI YL,LOW(0x60)
LDI YH,HIGH(0x60)

LPM R25,Z+
ST Y+,R25
```

Iterating backward to check for swapping :

- We would need an another pointer to store the current pointer values so that we can back propagate which is done by,

```
MOV XL,YL
MOV XH,YH
```

- But Y pointer will store the address of the next register to be used. So we should iterate back once before entering the loop which is done by

```
LD R25,-X
```

- The number of times that the loop should back propagate is determined by the number of elements stored which is $\boxed{5 - \textbf{R22}}$ which is done by,

```
LDI R23,0x05
SUB R23,R22
```

Swapping condition :

- We have to check the values stored in the registers at memory locations of the current position and the previous position which is done by ,

```
LD R25,X
LD R24,-X
CP R24,R25
```

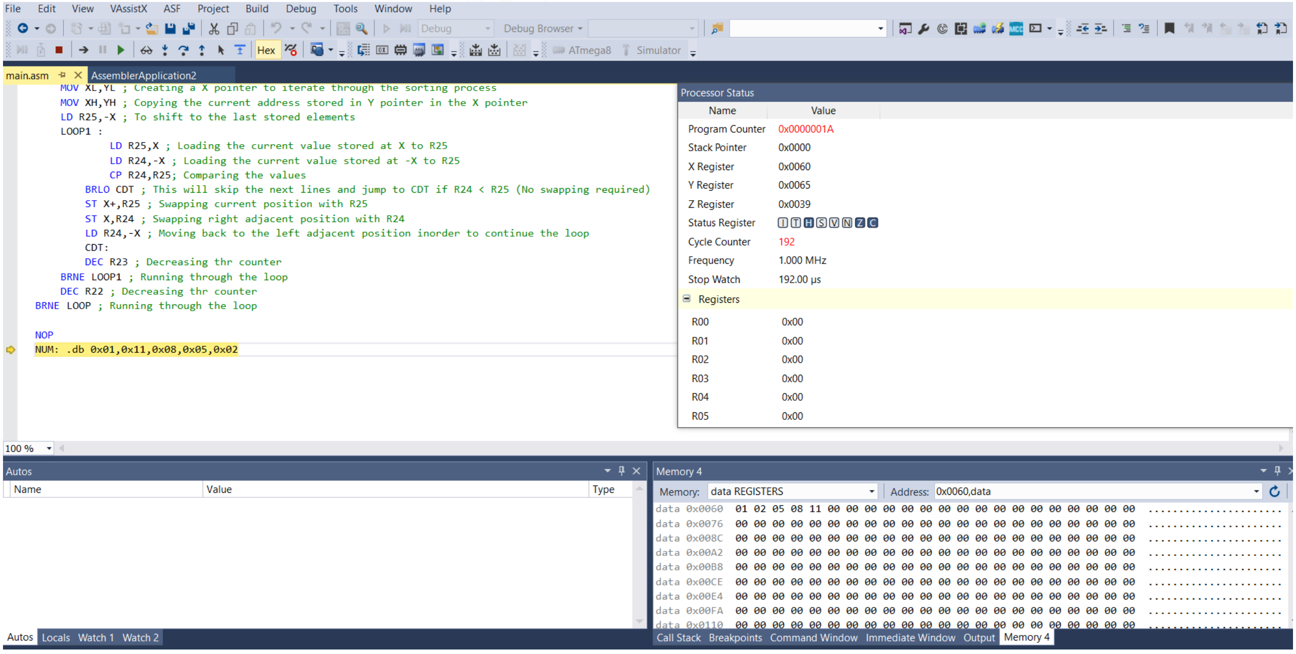
- If the first value is greater than the second one , we have to swap the values else nothing should be done which is represented as ,

```
BRLO CDT

ST X+,R25
ST X,R24
LD R24,-X

CDT:
   DEC R23
```

Result :



```
    MOV XL,YL ; Creating a X pointer to iterate through the sorting process
    MOV XH,YH ; Copying the current address stored in Y pointer in the X pointer
    LD R25,-X ; To shift to the last stored elements
    LOOP1 :
            LD R25,X ; Loading the current value stored at X to R25
            LD R24,-X ; Loading the current value stored at -X to R25
            CP R24,R25; Comparing the values
        BRLO CDT ; This will skip the next lines and jump to CDT if R24 < R25 (No swapping required)
        ST X+,R25 ; Swapping current position with R25
        ST X,R24 ; Swapping right adjacent position with R24
        LD R24,-X ; Moving back to the left adjacent position inorder to continue the loop
        CDT:
        DEC R23 ; Decreasing thr counter
    BRNE LOOP1 ; Running through the loop
    DEC R22 ; Decreasing thr counter
BRNE LOOP ; Running through the loop

NOP
NUM: .db 0x01,0x11,0x08,0x05,0x02
```

Processor Status

Name	Value
Program Counter	0x0000001A
Stack Pointer	0x0000
X Register	0x0060
Y Register	0x0065
Z Register	0x0039
Status Register	I T H S V N Z C
Cycle Counter	192
Frequency	1.000 MHz
Stop Watch	192.00 µs
⊟ Registers	
R00	0x00
R01	0x00
R02	0x00
R03	0x00
R04	0x00
R05	0x00

Memory: data REGISTERS   Address: 0x0060,data

```
data 0x0060  01 02 05 08 11 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
data 0x0076  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
data 0x008C  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
data 0x00A2  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
data 0x00B8  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
data 0x00CE  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
data 0x00E4  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
data 0x00FA  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
data 0x0110  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ......................
```