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Github: Assignment 3 Code
Course: ES 215: Computer Organization and Architecture

Note: Comments in the code might end up getting truncated in the report. Please refer to the github repository in case the code isn't printed correctly.

Table of Contents

Q1

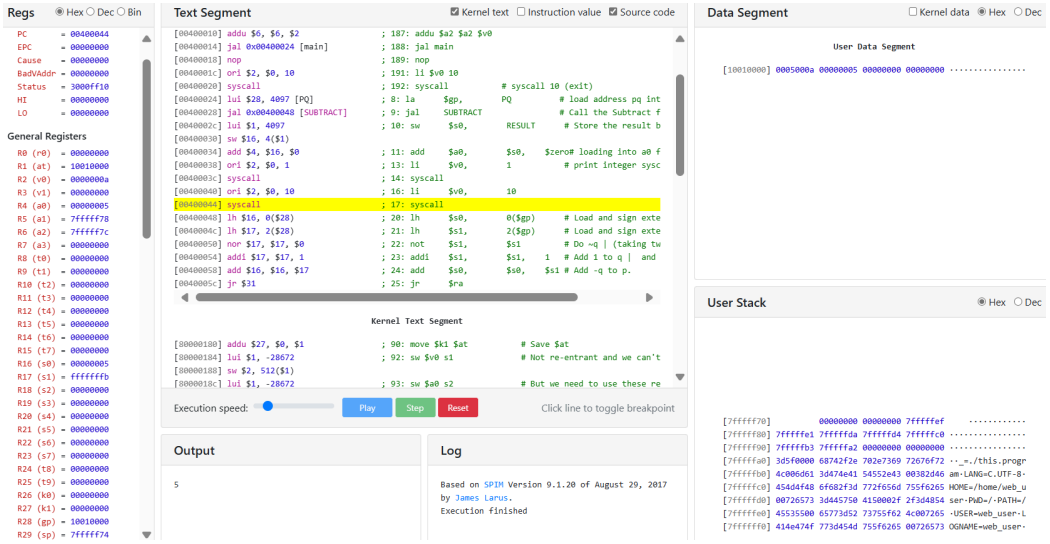
Write a program in assembly language to subtract two 16 bit numbers without using the subtraction instruction. Note: the numbers have to be fetched from the memory.

C++ Code:

```
int subtract(int16_t a, int16_t b)
{
    int32_t p = a; // sign extension from
    int32_t q = b; // 16 to 32 bits

    q = ~q;
    q = q + 1;
    return p+q;
}
```

MIPS Assembly Code:

```
.data
PQ:     .half   10, 5                   # Example value for p and q
RESULT: .word   0                       # To store the result

.text
        .globl  main
main:
    la      $gp,        PQ              # load address pq into gp
    jal     SUBTRACT                    # Call the Subtract functior
    sw      $s0,        RESULT          # Store the result back to m
    add     $a0,        $s0,    $zero   # loading into a0 for printi

    li      $v0,        1               # print integer syscall code
    syscall

    li      $v0,        10
    syscall

SUBTRACT:
    lh      $s0,        0($gp)          # Load and sign extend a to
    lh      $s1,        2($gp)          # Load and sign extend b to
    not     $s1,        $s1             # Do ~q | (taking two's comp
    addi    $s1,        $s1,    1       # Add 1 to q |  and getting
    add     $s0,        $s0,    $s1     # Add -q to p.
    jr      $ra
```



Assembly code's Output is 5. (Correct: 10 - 5 = 5)

Q2

Write an assembly language program to find an average of 15 numbers stored at consecutive locations in memory.

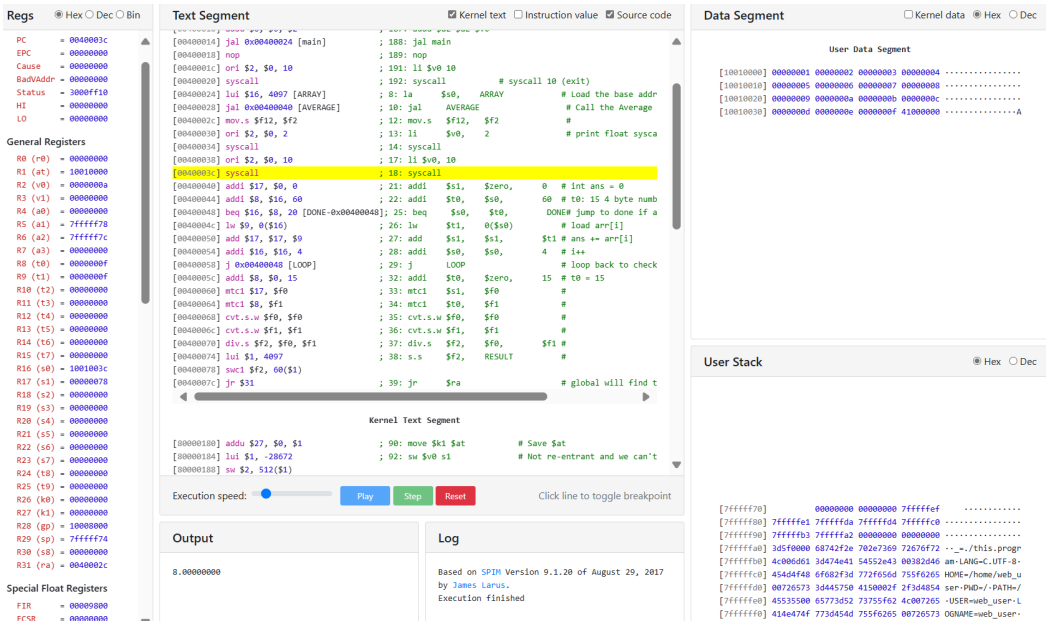
C++ Code:

```
float average(int arr[])
{
    int ans = 0;
    int i = 0;
    while(i<15)
    {
        ans += arr[i];
        i++;
    }

    return ans/15.00;
}
```

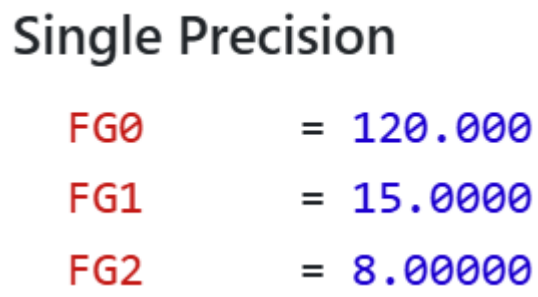
MIPS Assembly Code:

```
.data
ARRAY: .word 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15  # E>
RESULT: .word 0   # To store the result

.text
.globl main
main:
    la      $s0,    ARRAY           # Load the base address of the

    jal     AVERAGE                 # Call the Average function

    mov.s   $f12,   $f2             #
    li      $v0,    2               # print float syscall code
    syscall

    # Exit the program
    li $v0, 10
    syscall

AVERAGE:                            # array address comes in $s0 (as
```

```
    addi    $s1,    $zero,      0   # int ans = 0
    addi    $t0,    $s0,        60  # t0: 15 4 byte numbers ahead of

LOOP:
    beq     $s0,    $t0,        DONE# jump to done if at array end
    lw      $t1,    0($s0)          # load arr[i]
    add     $s1,    $s1,        $t1 # ans += arr[i]
    addi    $s0,    $s0,        4   # i++
    j       LOOP                    # loop back to check condition

DONE:
    addi    $t0,    $zero,      15  # t0 = 15
    mtc1    $s1,    $f0             #
    mtc1    $t0,    $f1             #
    cvt.s.w $f0,    $f0             #
    cvt.s.w $f1,    $f1             #
    div.s   $f2,    $f0,        $f1 #
    s.s     $f2,    RESULT          #
    jr      $ra                     # global will find their answer
```



Code output is 8. (correct)



floating point registers state

Q3

Write an assembly language program to find an LCM of two numbers stored at consecutive locations in memory

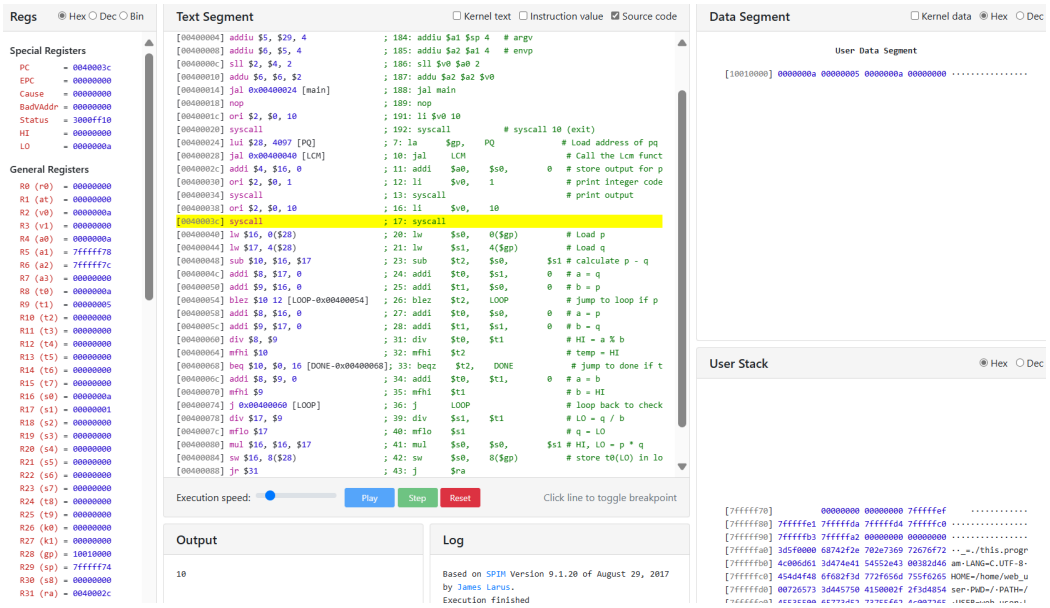
C++ Code:

```
int lcm(int p, int q)
{
    int temp, a{p}, b{q};
    if(b > a)
    {
        temp = b;
        b = a;
        a = b;
    }

    temp = a % b;
    while(temp != 0)
    {
        a = b;
        b = temp;
        temp = a % b;
    }

    return p * (q / b);
}
```

Assembly Code:

```
.data
num1:   .word   5                               # First number
```

```
num2:   .word   3                               # Second number
result: .word   0                               # To store the resul

.text
        .globl  main
main:
    # Load the numbers into registers
    lw      $t0,        num1                    # a = num1
    lw      $t1,        num2                    # b = num2
    lw      $t2,        result                  # ans = 0 (result)

    # Initialize temporary registers
    move    $t3,        $zero                   # int i = 0;

multiply:
    beq     $t3,        32,     end_multiply    # while(i < 32){
    andi    $t4,        $t1,    1               # b & 1
    beq     $t4,        $zero,  skip_add        # if(b & 1)
    add     $t2,        $t2,    $t0             # ans += a;

skip_add:
    sll     $t0,        $t0,    1               # a <<= 1;
    srl     $t1,        $t1,    1               # b >>= 1;
    addi    $t3,        $t3,    1               # i++;
    j       multiply                            # }

end_multiply:
    # Store the result back to memory
    sw      $t2,        result

    # Exit the program
    li      $v0,        10
    syscall
```



lcm output 10 for 5, 10 input

Q4

Write an assembly language program to calculate multiplication of two numbers without using MUL commands.

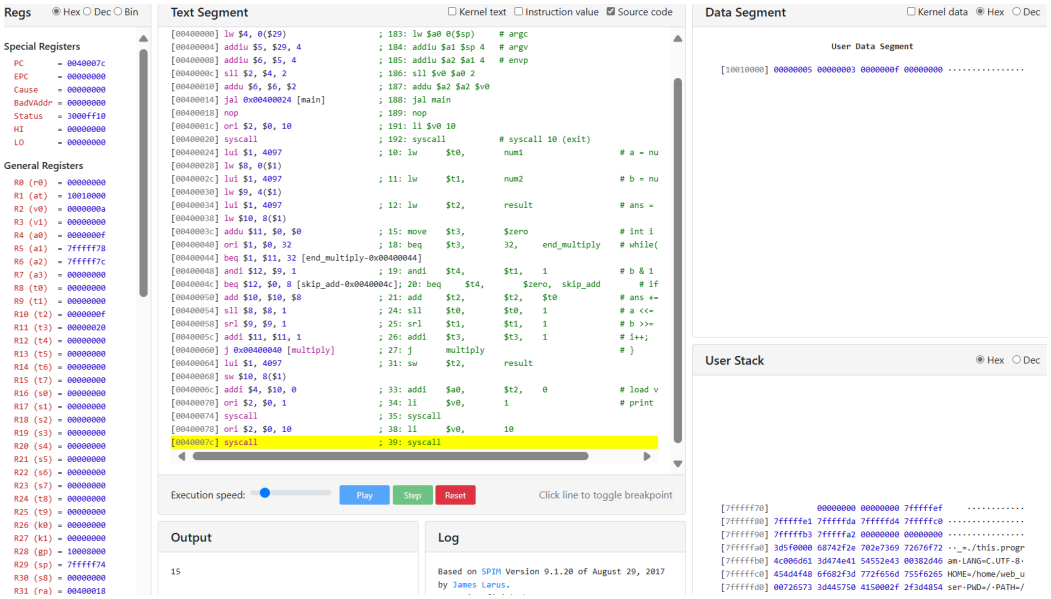
C++ Code:

```
int multiply(uint32_t a, uint32_t b)
{ // negative integers get static casted.
    uint32_t ans = 0;
    int i = 0;
    while(i < 32)
    {
        if(b & 1) ans += a;
        a <<= 1;
        b >>= 1;
        i++;
    }
    return ans; //return performs static cast
}
```

Assembly Code:

```
.data
num1:    .word    5                                  # First number
```

```
num2:   .word   3                               # Second number
result: .word   0                               # To store the resul

.text
.globl  main
main:
    # Load the numbers into registers
    lw      $t0,        num1                    # a = num1
    lw      $t1,        num2                    # b = num2
    lw      $t2,        result                  # ans = 0 (result)

    # Initialize temporary registers
    move    $t3,        $zero                   # int i = 0;

multiply:
    beq     $t3,        32,     end_multiply    # while(i < 32){
    andi    $t4,        $t1,    1               # b & 1
    beq     $t4,        $zero,  skip_add        # if(b & 1)
    add     $t2,        $t2,    $t0             # ans += a;

skip_add:
    sll     $t0,        $t0,    1               # a <<= 1;
    srl     $t1,        $t1,    1               # b >>= 1;
    addi    $t3,        $t3,    1               # i++;
    j       multiply                            # }

end_multiply:
    # Store the result back to memory
    sw      $t2,        result

    addi    $a0,        $t2,    0               # load value into a0
    li      $v0,        1                       # print integer
    syscall

    # Exit the program
    li      $v0,        10
    syscall
```



Output is correct

Q5

Write an assembly language program to find a given number in the list of 10 numbers (assuming the numbers are sorted). If found store 1 in output, else store 2 in output.The given number has been loaded from X location in memory, the output has to be stored at the next location and if found store the number of iterations and the index of the element at the next at the next consecutive locations, if found.

C++ Code:

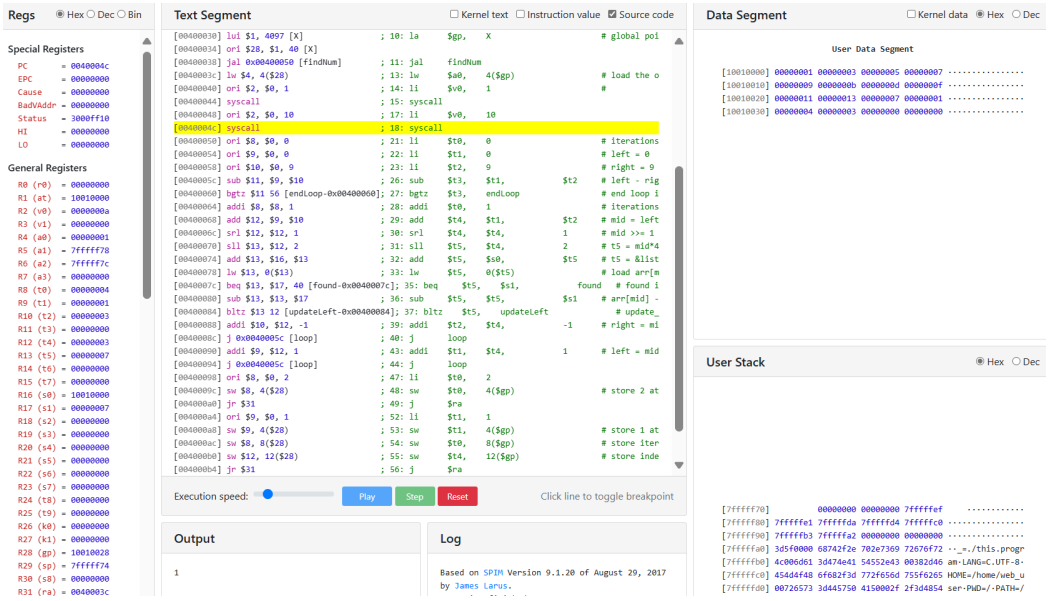
```
tuple<int, int, int> findNum(int arr[], int X)
{
    int iterations = 0;
    int left = 0;
    int right = 9;
    while(left <= right)
    {
        iterations++;
        int mid = (left + right) >> 1;
        if(arr[mid] == X) return {1, iterations, mid};
        else if(arr[mid] < X) left = mid + 1;
        else right = mid - 1;
    }
```

```
    return {2, -1, -1};
}
```

Assmbly Code

```
.data
list: .word 1, 3, 5, 7, 9, 11, 13, 15, 17, 19  # Sorted list of 10 r
X:    .word 7, 0, -1, -1                        # Given number to fir

.text
.globl main
main:
    la      $s0,    list                    # Load base address of t
    lw      $s1,    X
    la      $gp,    X                       # global pointer at X's
    jal     findNum

    lw      $a0,    4($gp)                  # load the output for pr
    li      $v0,    1                       #
    syscall

    li      $v0,    10
    syscall

findNum:
    li      $t0,    0                       # iterations = 0
    li      $t1,    0                       # left = 0
    li      $t2,    9                       # right = 9

loop:
    sub     $t3,    $t1,            $t2     # left - right
    bgtz    $t3,    endLoop                 # end loop if left > rig
    addi    $t0,    1                       # iterations++
    add     $t4,    $t1,            $t2     # mid = left + right
    srl     $t4,    $t4,            1       # mid >>= 1
    sll     $t5,    $t4,            2       # t5 = mid*4
    add     $t5,    $s0,            $t5     # t5 = &list + 4*(mid)
    lw      $t5,    0($t5)                  # load arr[mid]

    beq     $t5,    $s1,            found   # found if arr[mid] = X
    sub     $t5,    $t5,            $s1     # arr[mid] - X
    bltz    $t5,    updateLeft              # update_left if arr[mid

    addi    $t2,    $t4,            -1      # right = mid - 1
    j       loop
```

```
updateLeft:
    addi    $t1,    $t4,            1       # left = mid + 1
    j       loop

endLoop:
    li      $t0,    2
    sw      $t0,    4($gp)                  # store 2 at output (rig
    j       $ra

found:
    li      $t1,    1
    sw      $t1,    4($gp)                  # store 1 at output
    sw      $t0,    8($gp)                  # store iterations
    sw      $t4,    12($gp)                 # store index of X
    j       $ra
```



output as 1. 4 iterations, and 3 index stored in data segment.

Q6

Write an assembly language program to find a character in a string.

C++ Code:

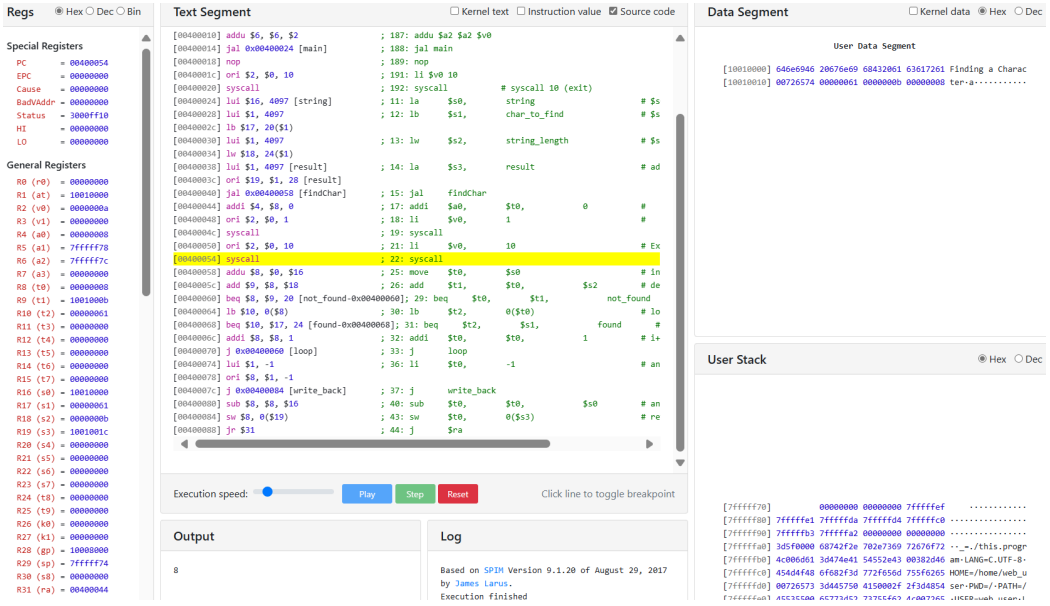
```
int findChar(char arr[], char c, int arrLength)
{// function returns -1 if not found, otherwise
// returns index of c in string
```

```
    int i = 0;
    while(i < arrLength)
    {
        if(arr[i] == c) return i;
        i++;
    }
    return -1;
}
```

Assembly Code:

```
.data
string:         .asciiz "Finding a Character"       # Example string
char_to_find:   .byte   'a'                         # c = 'a'
string_length:  .word   11
result:         .word   0

.text
.globl  main

main:
    la      $s0,        string                      # $s0 = arr[]
    lb      $s1,        char_to_find                # $s1 = c
    lw      $s2,        string_length               # $s2 = arrLengt
    la      $s3,        result                      # address to sto
    jal     findChar

    addi    $a0,        $t0,            0           #
    li      $v0,        1                           #
    syscall

    li      $v0,        10                          # Exitting the p
    syscall

findChar:
    move    $t0,        $s0                         # int i = 0
    add     $t1,        $t0,            $s2         # define array e

loop:
    beq     $t0,        $t1,            not_found   # end if i==arrL
    lb      $t2,        0($t0)                      # load arr[i]
    beq     $t2,        $s1,            found       # if arr[i] == c
    addi    $t0,        $t0,            1           # i++
    j       loop
```

```
not_found:
    li      $t0,        -1                      # ans = -1
    j       write_back

found:
    sub     $t0,        $t0,            $s0     # ans = &arr[i]

write_back:
    sw      $t0,        0($s3)                  # return ans
    j       $ra
```



Output for the code (8 as index of first occurence of a)