HANOI UNIVERSITY OF SCIENCE & TECHNOLOGY
SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY

FINAL PROJECT REPORT

IT3280E – ASSEMBLY LANGUAGE AND COMPUTER ARCHITECTURE LAB

Course information

Course ID	Course title	Class ID
IT3280E	Assembly language and Computer architecture Lab	143684

Student information

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I. Task 10: Simple calculator

1. Problem description

Use Key Matrix and 7-segments LEDs to implement a simple calculator that support +, -, *, /, % with integer operands. - - - - - -

- Press a for addition
- Press b for subtraction
- Press c for multiplication
- Press d for division
- Press e for division with remainder
- Press f to get the result

Detail requirements: -

- When pressing digital key, show the last two digits on LEDs. For example, press 1 → show 01, press 2 → show 12, press 3 → show 23. - - -
- After entering an operand, press + - * / % to select the operation.
- After pressing f (=) , calculate and show two digits at the right of the result on LEDs.
- Can calculate continuously (use Calculator on Windows for reference)

2. Instructions for running the program

a) Instructions

Step 1: Run the program, open Digital Lab Sim, Connects to MIPS.

Step 2: Enter the first number -> enter the operand -> enter the second number

Step 3: Enter 'f' (alias for '=')

b) Node

- *Wait for the Digital Lab Sim to load the number correctly (the key on the screen turn green)*
- *Exception handling*
  - *Didive by zero*: The program tracks the second number entered by the user. If it is '0' and the operand is '/' or '%', the program will raise the error.
- *Consecutively enter 1 number and 2 operands, the program will consider the second number is '0' and calculate the result with the first operand.*
- *The program currently cannot consecutively calculate many operands at once (one calculation contains only one operand)*
- *When handling '-' operand, if the result is negative (<0), the program will show '00' on the LED and normal printing at RUN I/O.*

3. Code explanation

Initialization: Initialize used values on the program

```
.eqv    SEVENSEG_LEFT   0xFFFF0011      # Address of the LEFT LED
.eqv    SEVENSEG_RIGHT  0xFFFF0010      # Address of the RIGHT LED
.eqv    IN_ADDRESS_HEXA_KEYBOARD        0xFFFF0012
.eqv    OUT_ADDRESS_HEXA_KEYBOARD       0xFFFF0014

.data
# Values corresponding to LED digits
zero:           .byte 0x3f
one:            .byte 0x6
two:            .byte 0x5b
three:          .byte 0x4f
four:           .byte 0x66
five:           .byte 0x6d
six:            .byte 0x7d
seven:          .byte 0x7
eight:          .byte 0x7f
nine:           .byte 0x6f

mess1:  .asciiz         "Can not divide by 0!\n"

.text
main:

Init:
        li      $t0, SEVENSEG_LEFT      # Variable contains value of the LEFT LED
        li      $t5, SEVENSEG_RIGHT     # Variable contains value of the RIGHT LED
        li      $s0, 0                  # Variable contains type of input: (0: digit), (1: operand)
        li      $s1, 0                  # Variable on the LEFT LED
        li      $s2, 0                  # Variable on the RIGHT LED
        li      $s3, 0                  # Variable contains type of operand (1: +, 2: -, 3: *, 4: /, 5: %)
        li      $s4, 0                  # The first number
        li      $s5, 0                  # The second number
        li      $s6, 0                  # Result
        li      $t9, 0                  # Temp value

        li      $t1, IN_ADDRESS_HEXA_KEYBOARD   # Variable contronls keyboard rows and enable keyboard interrupt
        li      $t2, OUT_ADDRESS_HEXA_KEYBOARD  # Variable contains key locations
        li      $t3, 0x80                       # bit used to enable keyboard interrupt and enable check each keyboard row
        sb      $t3, 0($t1)
        li      $t7, 0                  # Variable contains value of number on the LED
        li      $t4, 0                  # Byte showed on LED (0->9)
```

Main

Main sectiion:

- Set up keyboard input and interrupt handling
- The program enters an infinite loop waiting for keyboard interrupts

```
43  First_value:
44          li      $t7, 0                  # Value of needed to be showed initial bit
45          addi    $sp,$sp, 4              # Push to stack
46          sb      $t7, 0($sp)
47          lb      $t4, zero               # First bit to be showed
48          addi    $sp, $sp, 4             # Push to stack
49          sb      $t4, 0($sp)
50
51  Loop1:
52          nop
53          nop
54          nop
55          nop
56          b       Loop1           # Wait for interrupt
57          nop
58          nop
59          nop
60          nop
61          b       Loop1
62          nop
63          nop
64          nop
65          nop
66          b       Loop1
67  end_loop1:
68
69  # Handle interrupt
70  # -> Show clicked key on the LED
71  # Check each row for clicked row
72  end_main:
73          li      $v0, 10
74          syscall
75
```

Interrupt Handling:

- Upon an interrupt, the program checks each keyboard row to determine the pressed key
- Exstract the pressed key
- Depend on the clicked key, the programs sets various variables to perform mathematical operations

```
77  .ktext 0x80000180
78  # If row contains clicked key
79  # -> Move to that row
80          jal     check_row1              # Check row 1
81          bnez    $t3, convert_row1       # t3 != 0 -> clicked key, find clicked key on the row -> exstract that key
82          nop
83
84          jal     check_row2              # The same go to row 2...
85          bnez    $t3, convert_row2
86          nop
87
88          jal     check_row3
89          bnez    $t3, convert_row3
90          nop
91
92          jal     check_row4
93          bnez    $t3, convert_row4
94
```

```
95  # Functions check for clicked key on the row or not
96  check_row1:
97          addi    $sp, $sp, 4
98          sw      $ra, 0($sp)             # Store -> can be changed
99          li      $t3, 0x81               # Execute interrupt
100         sb      $t3, 0($t1)
101         jal     Get_value               # Get location of clicked key (if existed)
102         lw      $ra, 0($sp)
103         addi    $sp, $sp, -4
104         jr      $ra
```

```
136 # Exstract the value of clicked key
137 Get_value:
138         addi    $sp, $sp, 4
139         sw      $ra, 0($sp)
140         li      $t2, OUT_ADDRESS_HEXA_KEYBOARD  # Address containing location of clicked key
141         lb      $t3, 0($t2)                     # Load the location
142         lw      $ra, 0($sp)
143         addi    $sp, $sp, -4
144         jr      $ra
145
146 # Convert from location -> value of the LED
147 convert_row1:
148         beq     $t3, 0x11, case_0               # Digit 0
149         beq     $t3, 0x21, case_1               # Digit 1
150         beq     $t3, 0x41, case_2               # Digit 2
151         beq     $t3, 0xffffff81, case_3         # Digit 3
152 case_0:
153         lb      $t4,zero        # t4 = 0, value of "0" on Digital Lab Sim
154         li      $t7,0           # t7 = 0
155         j       update_tg
156 case_1:
157         lb      $t4,one         # So on
158         li      $t7,1
159         j       update_tg
160 case_2:
161         lb      $t4,two
162         li      $t7,2
163         j       update_tg
164 case_3:
165         lb      $t4, three
166         li      $t7, 3
167         j       update_tg
168
```

```
# Convert the number on LED -> value of the second number
set_second_number:
        beq     $s3, 1, addition
        beq     $s3, 2, substraction
        beq     $s3, 3, multiplication
        beq     $s3, 4, division
        beq     $s3, 5, find_remainder

addition:
        add     $s6, $s5, $s4
        li      $s3, 0
        li      $t9, 0
        j       print_addition
        nop
```

Display Results and Resetting:

- Convert the result into digits and displays them on the left and right of LED
- Reset varios variables and LEDs for the next input

```
print_addition:
        li      $v0, 1
        move    $a0, $s4
        syscall
        li      $s4, 0          # reset the first number to 0

        li      $v0, 11
        li      $a0, '+'
        syscall

        li      $v0, 1
        move    $a0, $s5
        syscall
        li      $s5, 0          # Reset the second number to 0

        li      $v0, 11
        li      $a0, '='
        syscall

        li      $v0, 1
        move    $a0, $s6
        syscall
        nop

        li      $v0, 11
        li      $a0, '\n'
        syscall
        li      $s7, 100
        div     $s6, $s7
        mfhi    $s6             # Exstract 2 last digit of the result
        j show_result_in_led    # Show it
        nop
```

Handling exception:

- Prompt “Can not divide by 0” when meeting this error

```
402 divide_by_0:
403         li      $v0, 55
404         la      $a0, mess1
405         li      $a1, 0
406         syscall
407         j       reset_led
408
```

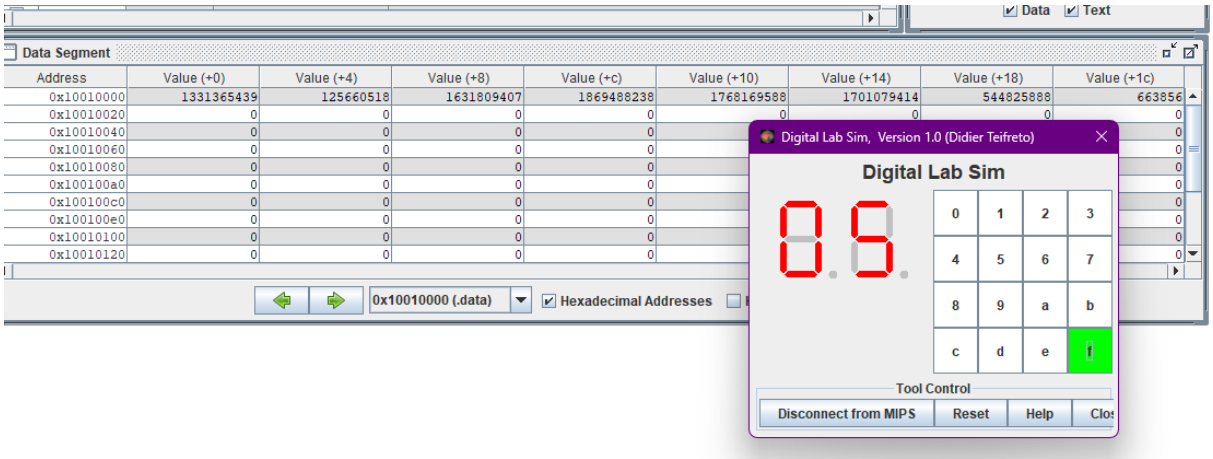
Source Code:

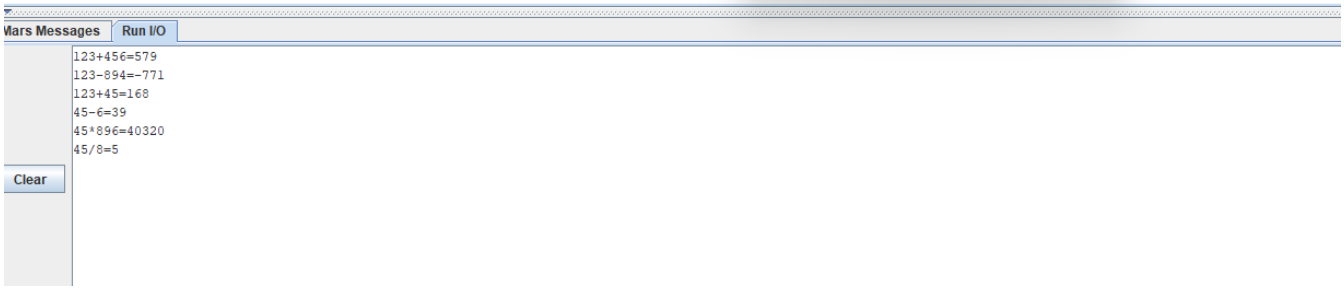
Task10_Gr4_TranAnh_20215179.asm

4. Result demonstration

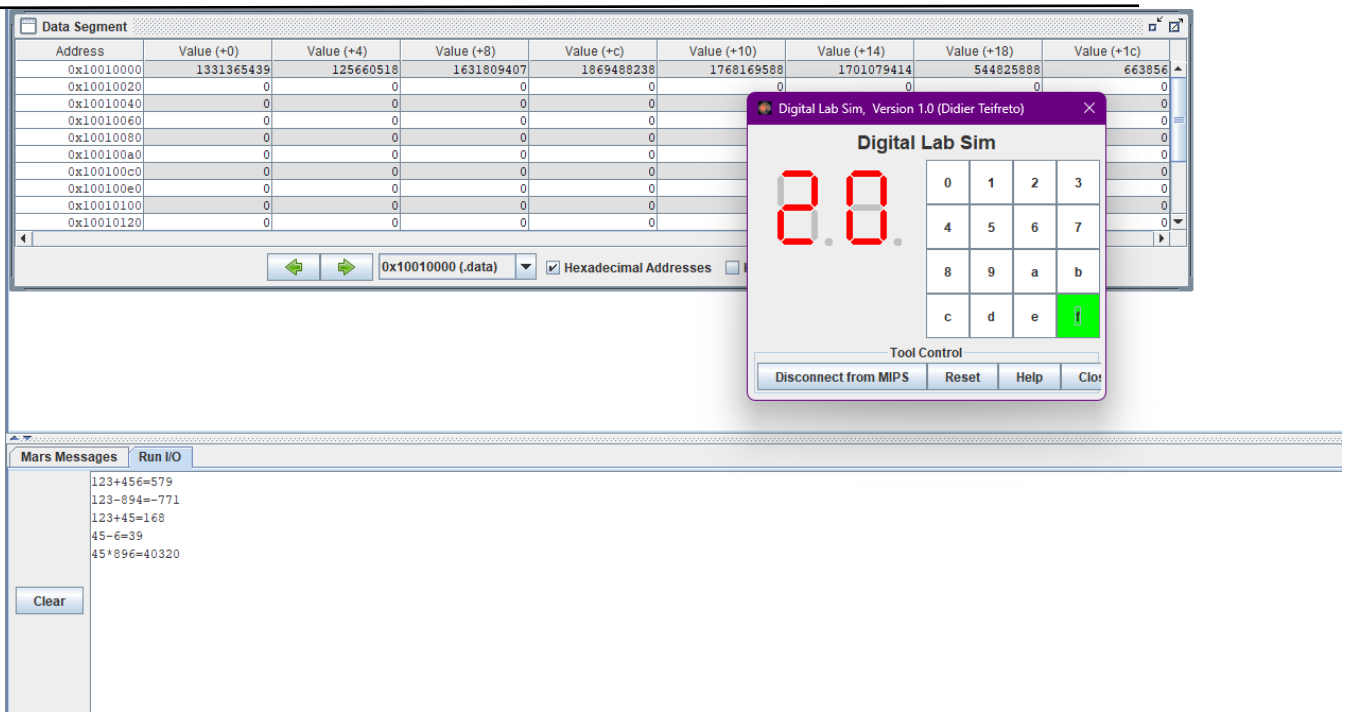
a) Normal cases:

45 / 8 = 5

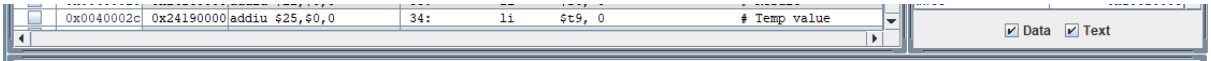


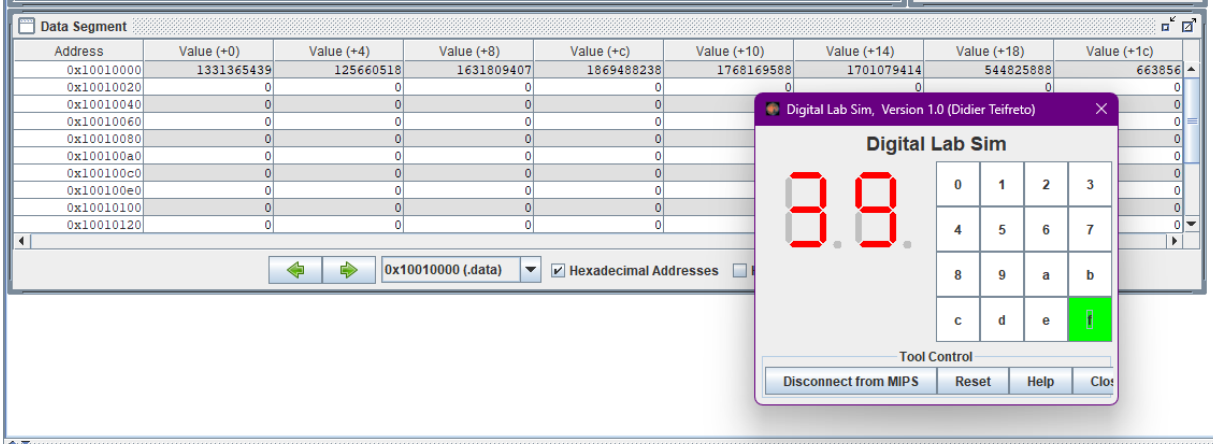


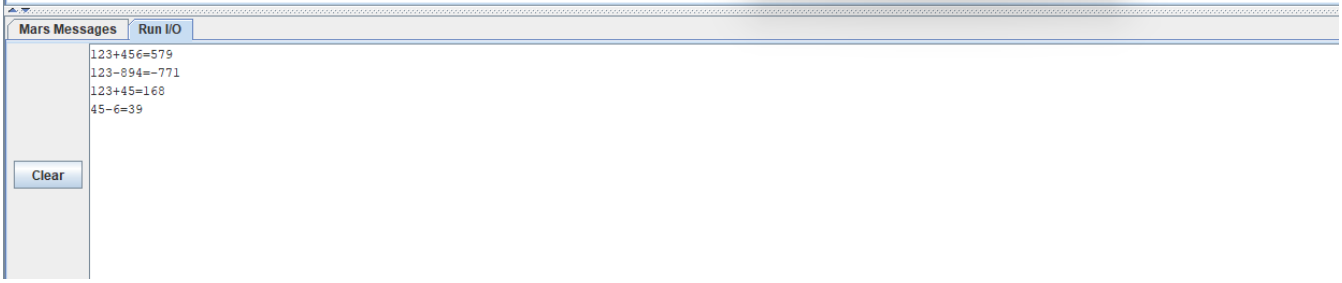
45 * 896 = 40320



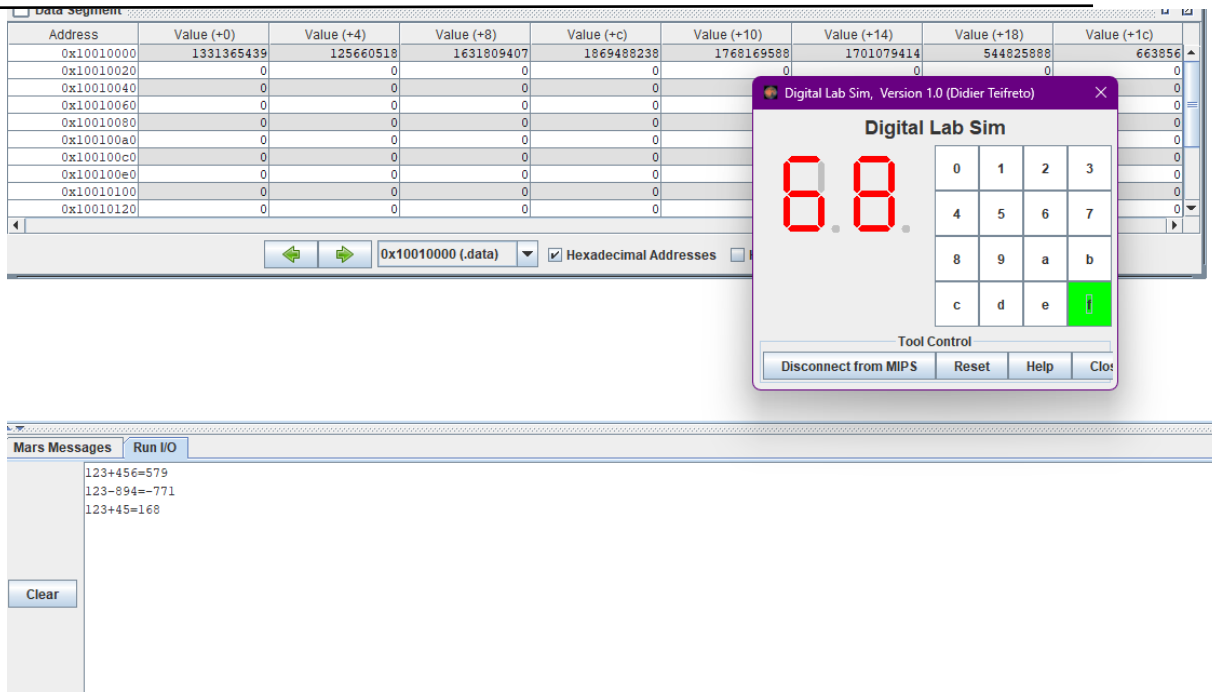
45 – 6 = 39





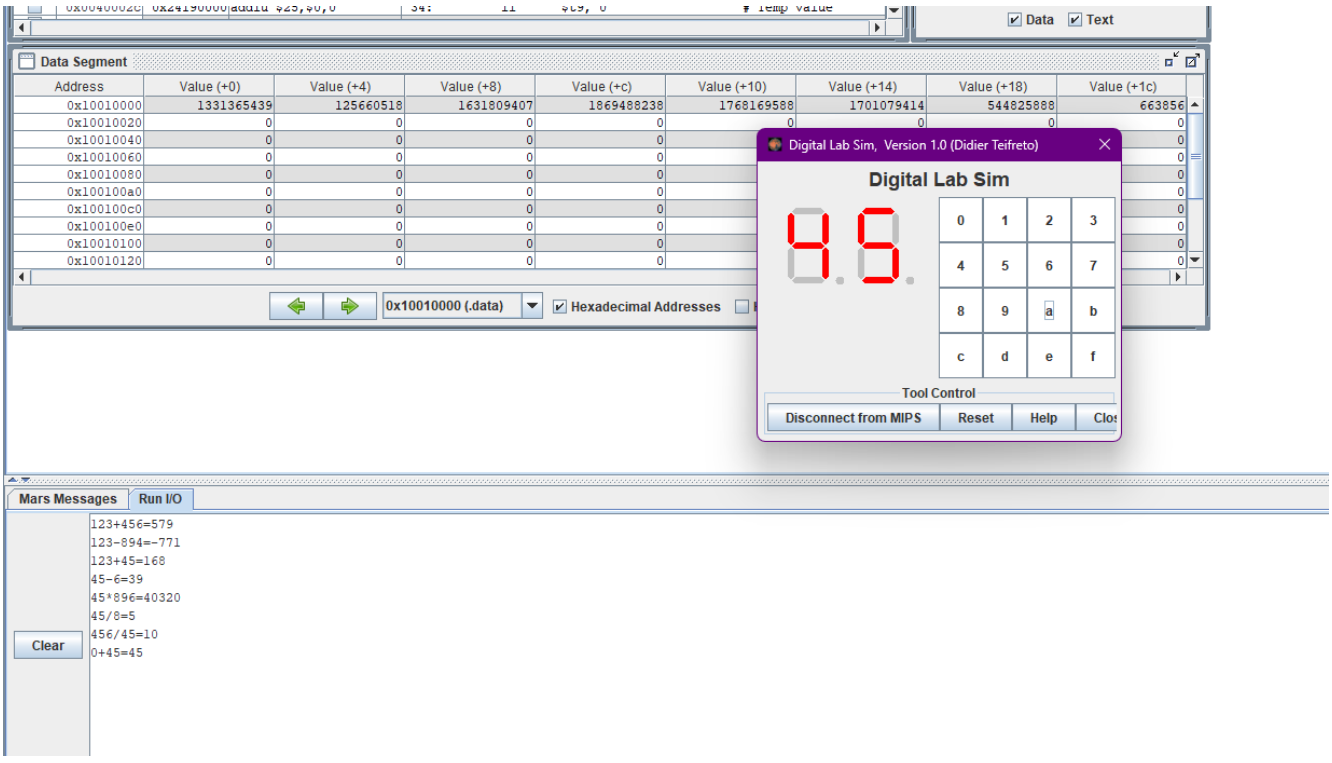


123 + 45 = 168

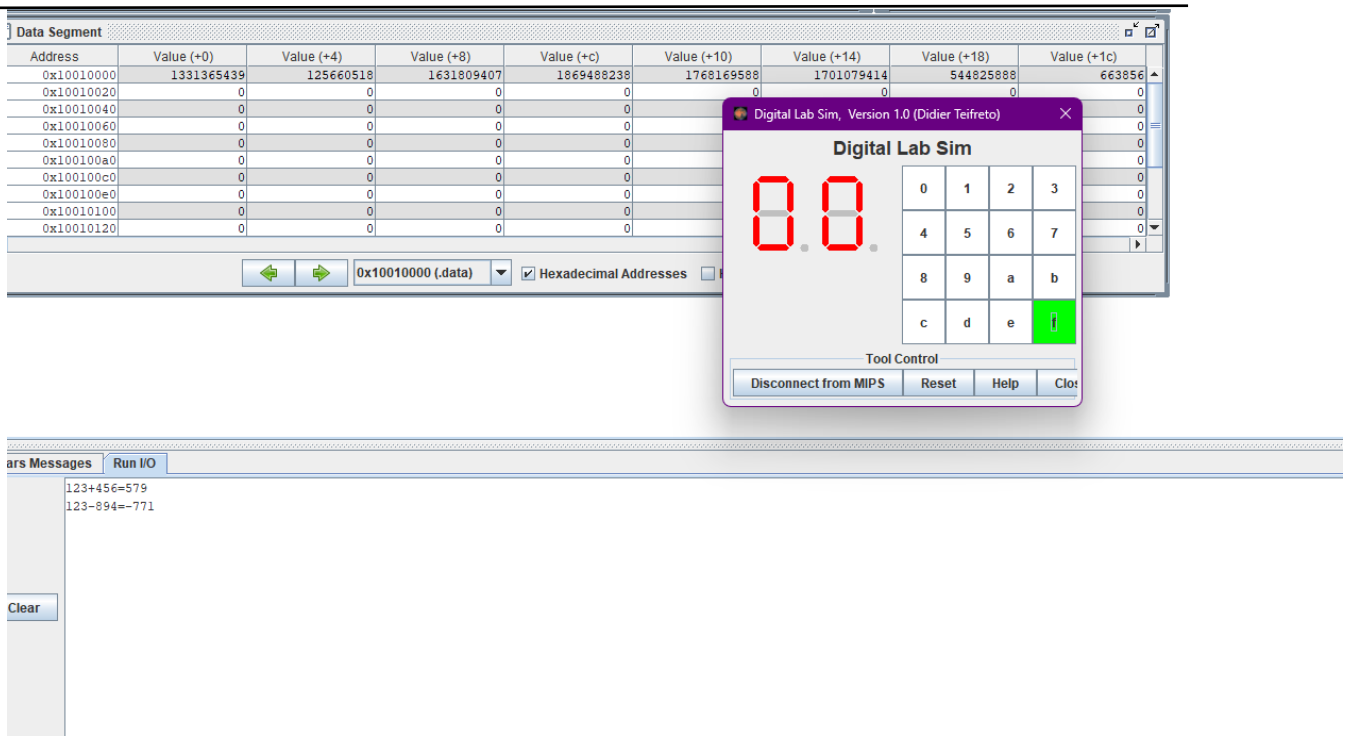


b) Handling exception:

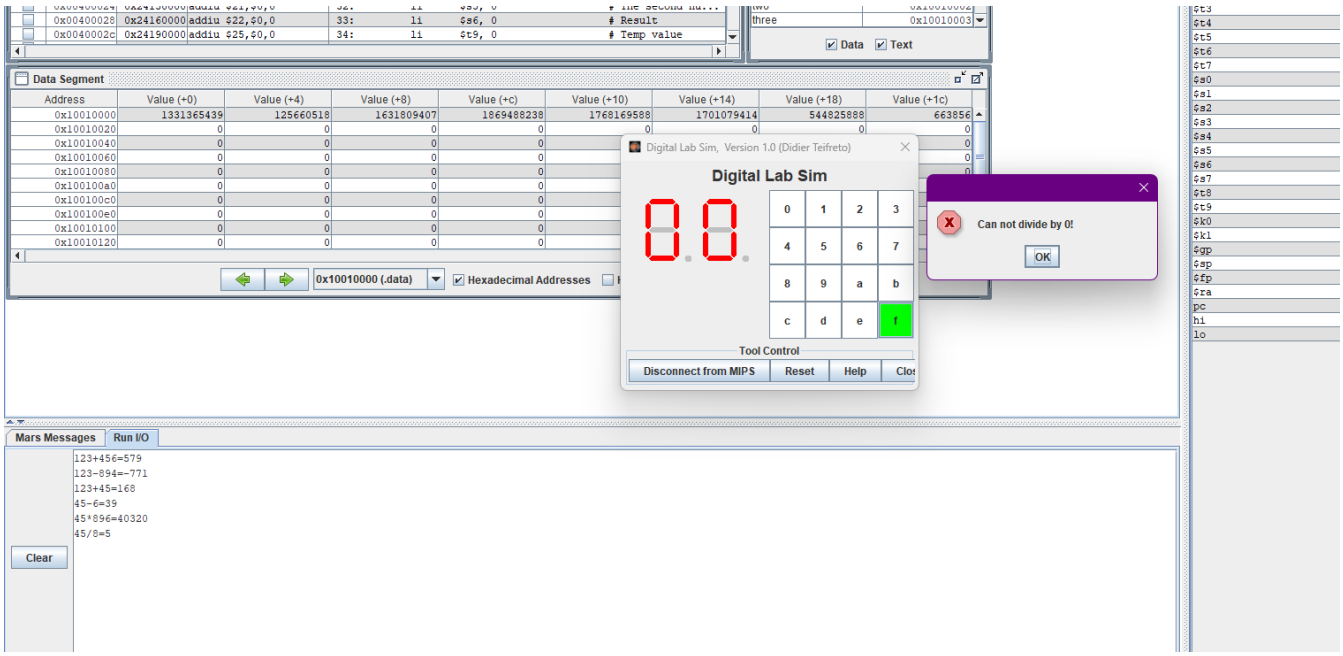
Consecutively enter



Negative result



Divide by 0



II. Task 2: Moving a ball in the bitmap display:

1. Problem description:

Create a program that displays a movable round ball on the bitmap screen. If the ball touches the edge of the screen, it will move in the opposite direction. Requirement:

- Set display width and height to 512 pixels, unit width and height to 1 pixel.
- The direction of movement depends on the key pressed from the keyboard. (W moves up, S moves down, A moves left, D moves right, Z speeds up, X slows down).
- The default position is the center of the screen.

2. Instructions for running the program:

- **Step 1:** Assemble the program, open "Bitmap Display" and "Keyboard and Display MMIO Simulator", Connects to MIPS.
- **Step 2:** Set the Display Height in Pixels to 512 on the Bitmap Display
- **Step 3**: Enter W moves up, S moves down, A moves left, D moves right, Z speeds up, X slows down into "Keyboard and Display MMIO Simulator" and watch the circle move.

3. Algorithm:

- Initialization.
  - Center of the circle coordinate: x, y.
  - Radius of the circle: R
  - Direction of the circle: dx = 1 (right), -1 (left); dy = 1 (down), -1 (up).
  - The array that contains the coordinate of pixels surrounding the center to make a circle: circle.
  - Each pixel coordinates to make a circle: px, py.
- Find the coordinates of each pixel relative to the center of the circle.
  - For px = 1 to R, $py^2 = R^2 - px^2$ => px, py
  - Then other 3 pixels on the other sides of the circle (-px,py), (px,-py), (-px,-py)
  - Save all the coordinate to the circle array.
- Input and read the input on the keyboard.
- Each case of key pressed: W moves up, S moves down, A moves left, D moves right, Z speeds up, X slows down
- Check if the circle hits the edge, if yes, then reverse the direction

4. Code Explanation:

a) Initialization:

Initialize the value

```
.eqv MONITOR_SCREEN 0x10010000 #Dia chi bat dau cua bo nho man hinh

.eqv KEY_CODE   0xFFFF0004
.eqv KEY_READY  0xFFFF0000

.data
circle:         .word

.text
initialize:
        # center
        li      $s0, 256                # x = 256
        li      $s1, 256                # y = 256
        # direction that the circle is moving
        li      $s2, 1                  # dx = 1
        li      $s3, 0                  # dy = 0
        # radius
        li      $s4, 20                 # R = 20
        # sleep time
        li      $a0, 50                 # t = 50
        jal     circle_push
```

Then do the procedure to push into the circle array

b) Circle push

Initialize some value for calculation

```
circle_push:
        addi    $sp, $sp, -4
        sw      $ra, 0($sp)
        la      $s5, circle     # $s5 = pointer of the "circle" array
        mul     $a3, $s4, $s4   # $a3 = R*R
        add     $s7, $0, $0     # px = 0
```

Calculation to find the coordinate of each pixel relative to the center of the circle.

Loop for R times,

$py^2 = R^2 - px^2$ => px, py

```
circle_cal_loop:
        bgt     $s7, $s4, circle_end
        mul     $t0, $s7, $s7   # $t0 = px^2
        sub     $a2, $a3, $t0   # $a2 = R^2 - px^2 = py^2
        beqz    $a2, cal_continue
        jal     root            # $a2 = py
cal_continue:
        move    $a1, $s7        # $a1 = px
        li      $s6, 0
```

If py = 0 then continue else

Procedure to find the square root of py^2

```
191   root:
192           li      $t0, 0
193           li      $t1, 0
194           move    $t2, $a2
195           div     $t3, $a2, 2
196   root_loop:
197           div     $t4, $a2, $t2
198           add     $t4, $t2, $t4
199           div     $t2, $t4, 2
200           addi    $t1, $t1, 1
201           blt     $t1, $t3, root_loop
202           move    $a2, $t2
203           jr      $ra
204
```

Save all the coordinates to the array then repeat the circle_push

```
159   # Saving (px, py), (-px, py), (-px, -py), (px, -py)
160   push:
161           jal     push_save
162           sub     $a1, $0, $a1
163           jal     push_save
164           sub     $a2, $0, $a2
165           jal     push_save
166           sub     $a1, $0, $a1
167           jal     push_save
168   # then save (-py, px), (py, px), (py, -px), (-py, -px)
169           move    $t0, $a1        # Swap px and -py
170           move    $a1, $a2
171           move    $a2, $t0
172           addi    $s6, $s6, 1
173           beq     $s6, 2, push_finish
174           j       push
175   push_finish:
176           addi    $s7, $s7, 1
177           j       circle_cal_loop
178
179   push_save:
180           sw      $a1, 0($s5)     # Store px
181           sw      $a2, 4($s5)     # Store py
182           addi    $s5, $s5, 8     # Move the pointer
183           jr      $ra
```

After finding all the coordinates, save the end address for later use.

```
185   circle_end:
186         move    $v1, $s5        # Save the end address of the "circle" array
187         lw      $ra, 0($sp)
188         addi    $sp, $sp, 4
189         jr      $ra
190
```

Input and read the input on the keyboard, check edge and cases for different keys pressed.

```
24  input:
25          li      $k0, KEY_READY
26          lw      $t0, 0($k0)
27          bne     $t0, 1, hit_edge
28          li      $k0, KEY_CODE
29          lw      $t0, 0($k0)
30          beq     $t0, 'a', pressed_a
31          beq     $t0, 'd', pressed_d
32          beq     $t0, 's', pressed_s
33          beq     $t0, 'w', pressed_w
34          beq     $t0, 'x', pressed_x
35          beq     $t0, 'z', pressed_z
```

Find which edge the circle moving toward to

```
66  hit_edge:
67          beq     $s2, 1, right_edge
68          beq     $s2, -1, left_edge
69          beq     $s3, -1, up_edge
70          beq     $s3, 1, down_edge
71          j       move_circle
```

Check if the pixel closest to the edge hit the edge yet

If yes, then reverse the direction of the circle

```
73  right_edge:
74          add     $t0, $s0, $s4   # Rightest side of the circle
75          beq     $t0, 511, reverse
76          j       move_circle
77
78  left_edge:
79          sub     $t0, $s0, $s4   # Leftest side of the circle
80          beq     $t0, 1, reverse
81          j       move_circle
82
83  down_edge:
84          add     $t0, $s1, $s4   # Downest side of the circle
85          bge     $t0, 511, reverse
86          j       move_circle
87
88  up_edge:
89          sub     $t0, $s1, $s4   #Upest side of the circle
90          ble     $t0, 1, reverse
91          j       move_circle
92
93  reverse:
94          sub     $s2, $0, $s2    # dx = -dx
95          sub     $s3, $0, $s3    # dy = -dy
96          j       move_circle
```

Move the circle by erasing the old circle then set the center's coordinate to the direction the circle is moving.

```
98  move_circle:
99          li      $s5, 0          # Set color to black
100         jal     draw_circle     # Erase the old circle
101
102         add     $s0, $s0, $s2   # Set the center of the new circle
103         add     $s1, $s1, $s3
104         li      $s5, 0x00FFFF00 # Set color to yellow
105         jal     draw_circle     # Draw the new circle
106
```

Get the coordinate in the circle array then draw the pixels.

```
112 draw_circle:
113         addi    $sp, $sp, -4    # Save $ra
114         sw      $ra, 0($sp)
115         la      $s6, circle     # pointer to the circle array
116
117 draw_loop:
118         beq     $s6, $v1, draw_end      # Stop when $s6 = $v1 (pointer at the end of the array)
119         lw      $a1, 0($s6)             # Get px
120         lw      $a2, 4($s6)             # Get py
121         jal     draw
122         addi    $s6, $s6, 8             # Move the pointer
123         j       draw_loop
124
125 draw_end:
126         lw      $ra, 0($sp)
127         addi    $sp, $sp, 4
128         jr      $ra
```

Find the coordinate relative to the monitor screen.

```
draw:
        li      $t0, MONITOR_SCREEN
        add     $t1, $s0, $a1
        add     $t2, $s1, $a2
        sll     $t2, $t2, 9     # Move to y coordinate
        add     $t2, $t2, $t1   # Move to x coordinate
        sll     $t2, $t2, 2     # Multiply by 4 for address
        add     $t0, $t0, $t2
        sw      $s5, 0($t0)
        jr      $ra
```

Each case of keys pressed the check again if the circle hit the edge.

```
pressed_a:
        li      $s2, -1         # dx = -1
        li      $s3, 0          # dy = 0
        j       hit_edge

pressed_d:
        li      $s2, 1          # dx = 1
        li      $s3, 0          # dy = 0
        j       hit_edge

pressed_s:
        li      $s3, 1          # dy = 1
        li      $s2, 0          # dx = 0
        j       hit_edge

pressed_w:
        li      $s3, -1         # dy = -1
        li      $s2, 0          # dx = 0
        j       hit_edge

```

Cases whether speed up or slow down the circle: adding sleep time or subtracting sleep time

```
pressed_x:
        addi    $a0, $a0, 10    # t += 10
        j       hit_edge

pressed_z:
        beq     $a0, 0, hit_edge
        addi    $a0, $a0, -10   # t -= 10
        j       hit_edge
```

Loop over from the input of the keyboard.

```
107 loop:
108         li $v0, 32              # Sleep
109         syscall
110         j       input           # Renew the cycle
```

5. Result: