Week 11

Assignment 1:

Create a new project, type in, and build the program of Home Assignment 1. Upgrade the source code so that it could defect all 16 key buttons, from 0 to F.

- Code:

```
#-----------------------------------------------------
#       col 0x1 col 0x2 col 0x4 col 0x8
#
# row 0x1   0    1    2    3
#       0x11    0x21    0x41    0x81
#
# row 0x2   4    5    6    7
#       0x12    0x22    0x42    0x82
#
# row 0x4   8    9    a    b
#       0x14    0x24    0x44    0x84
#
# row 0x8   c    d    e    f
#       0x18    0x28    0x48    0x88
#
#-----------------------------------------------------
# command row number of hexadecimal keyboard (bit 0 to 3)
# Eg. assign 0x1, to get key button 0,1,2,3
# assign 0x2, to get key button 4,5,6,7
# NOTE must reassign value for this address before reading,
# eventhough you only want to scan 1 row
.eqv IN_ADRESS_HEXA_KEYBOARD 0xFFFF0012
# receive row and column of the key pressed, 0 if not key pressed
# Eg. equal 0x11, means that key button 0 pressed.
# Eg. equal 0x28, means that key button D pressed.
.eqv OUT_ADRESS_HEXA_KEYBOARD 0xFFFF0014

.text
main:
    li $t1, IN_ADRESS_HEXA_KEYBOARD
    li $t2, OUT_ADRESS_HEXA_KEYBOARD
    li $t3, 0x08    # check row 4 with key C, D, E, F
    li $t4, 0x1
    li $t5, 0x2
    li $t6, 0x4
polling:
    sb $t3, 0($t1)      # must reassign expected row
    lb $a0, 0($t2)      # read scan code of key button
    bnez $a0, print

    sb $t4, 0($t1)      # must reassign expected row
    lb $a0, 0($t2)      # read scan code of key button
    bnez $a0, print

    sb $t5, 0($t1)      # must reassign expected row
    lb $a0, 0($t2)      # read scan code of key button
    bnez $a0, print

    sb $t6, 0($t1)      # must reassign expected row
    lb $a0, 0($t2)      # read scan code of key button
    bnez $a0, print

print:
    li $v0, 34      # print integer (hexa)
    syscall
sleep:
    li $a0, 100     # sleep 100ms
    li $v0, 32
    syscall

back_to_polling:
    j polling       # continue polling
```

- Giải thích:
  - Các giá trị 0x1, 0x2, 0x4, 0x8 tương ứng với row 1, 2, 3, 4 trong digital lab slim
  - Trong mỗi row, $a0 nhận được pressed (tức là giá trị khác 0) thì sẽ được in ra màn hình console

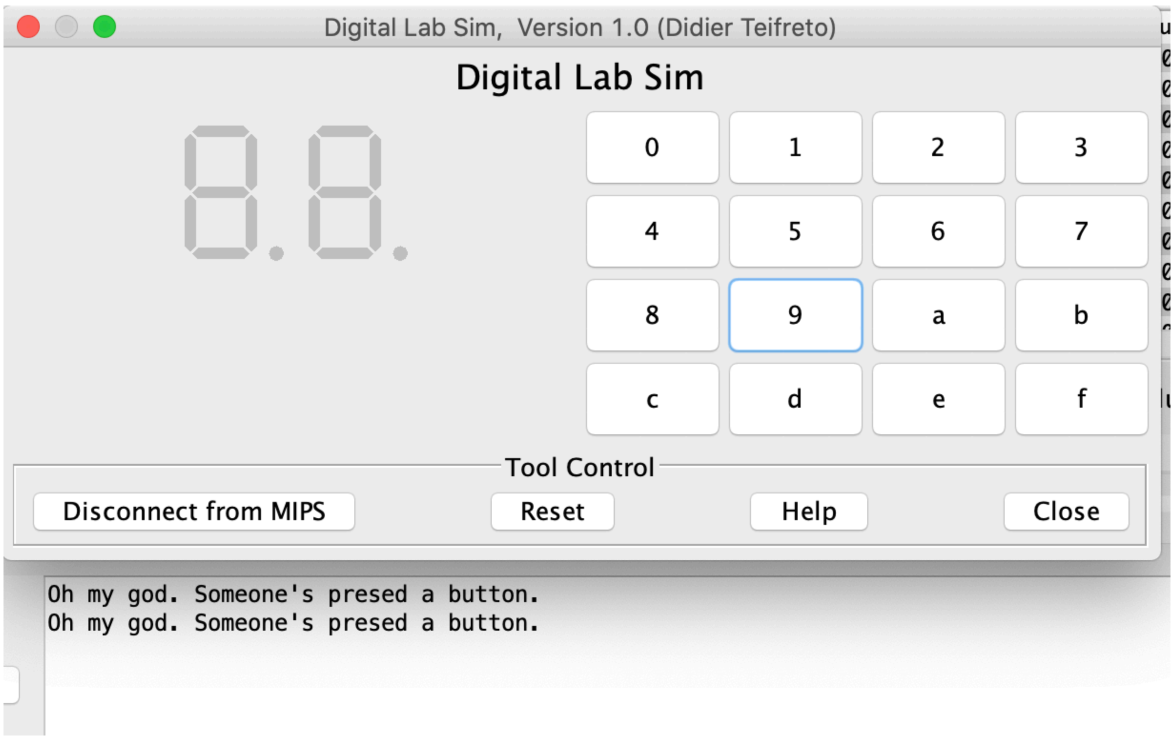
Asignment 2:

Create a new project, type in, and build the program of Home Assignment 2.

- Code:

```
.eqv IN_ADRESS_HEXA_KEYBOARD 0xFFFF0012

.data
Message: .asciiz "Oh my god. Someone's presed a button.\n"
#~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
# MAIN Procedure
#~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
.text
main:
    #---------------------------------------------------------
    # Enable interrupts you expect
    #---------------------------------------------------------
    # Enable the interrupt of Keyboard matrix 4x4 of Digital Lab Sim
    li $t1, IN_ADRESS_HEXA_KEYBOARD
    li $t3, 0x80            # bit 7 of = 1 to enable interrupt
    sb    $t3,   0($t1)

    #---------------------------------------------------------
    # No-end loop, main program, to demo the effective of interrupt
    #---------------------------------------------------------
Loop:   nop
        nop
        nop
        nop
        b       Loop            # Wait for interrupt
end_main:

#~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
# GENERAL INTERRUPT SERVED ROUTINE for all interrupts
#~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
.ktext 0x80000180
    #--------------------------------------------------------
    # Processing
    #--------------------------------------------------------
IntSR:
    addi $v0, $zero, 4      # show message
    la $a0, Message
    syscall
    #--------------------------------------------------------
    # Evaluate the return address of main routine
    #epc <= epc + 4
    #--------------------------------------------------------
next_pc:
    mfc0 $at, $14       # $at <= Coproc0.$14 = Coproc0.epc
    addi $at, $at, 4    # $at = $at + 4 (next instruction)
    mtc0 $at, $14       # Coproc0.$14 = Coproc0.epc <= $at
return:
    eret            # Return from exception
```

- Kết quả:



```
Oh my god. Someone's presed a button.
Oh my god. Someone's presed a button.
```

Assignment 3:

Create a new project, type in, and build the program of Home Assignment 3. Upgrade the source code so that it could defect all 16 key buttons, from 0 to F.

- Code:

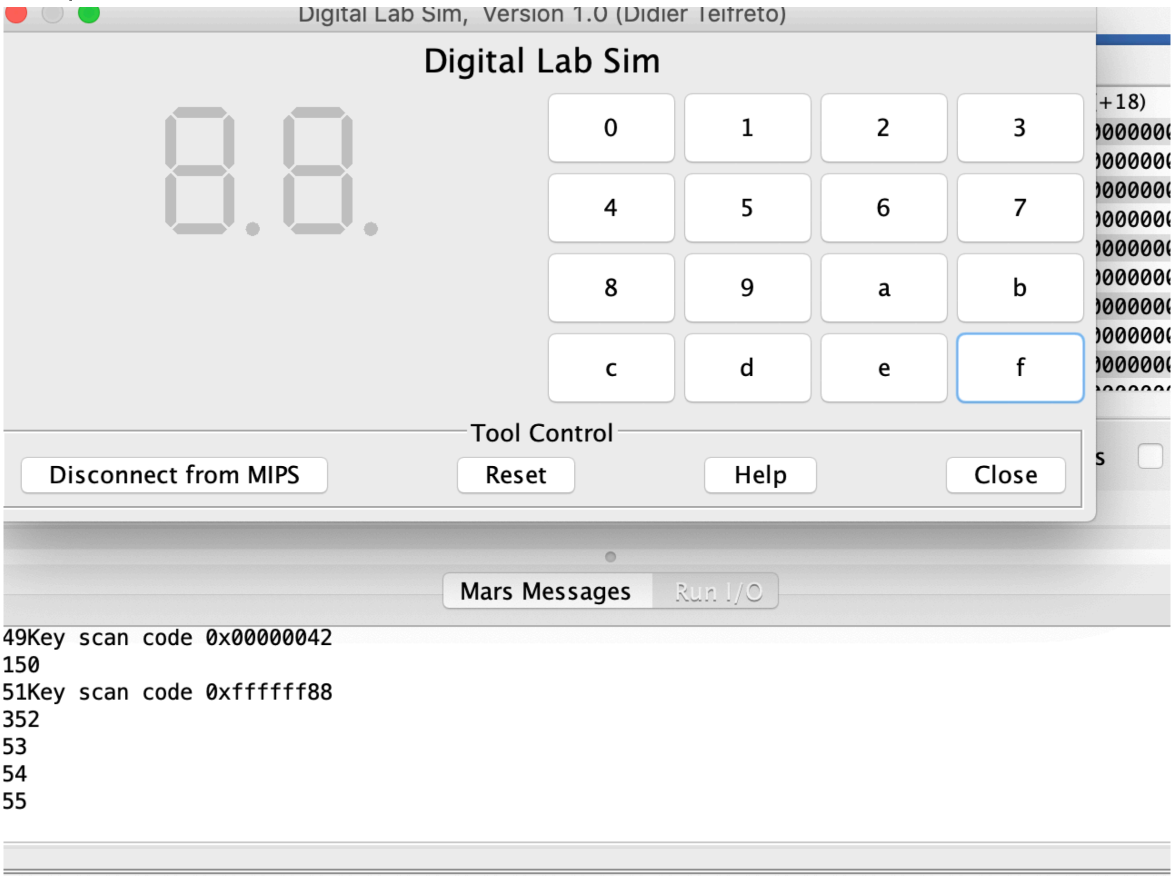
```
.eqv IN_ADRESS_HEXA_KEYBOARD 0xFFFF0012
.eqv OUT_ADRESS_HEXA_KEYBOARD 0xFFFF0014
.data
    Message: .asciiz "Key scan code "
 #~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 # MAIN Procedure
 #~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
.text
main:
    #---------------------------------------------------------
    # Enable interrupts you expect
    #---------------------------------------------------------
    # Enable the interrupt of Keyboard matrix 4x4 of Digital Lab Sim
    li $t1, IN_ADRESS_HEXA_KEYBOARD
    li $t3, 0x80            # bit 7 = 1 to enable
    sb $t3, 0($t1)
    #---------------------------------------------------------
    # Loop an print sequence numbers
    #---------------------------------------------------------
```

```
    xor $s0,$s0,$s0         # count=$s0=0
Loop:
    addi $s0, $s0, 1        # count = count + 1
prn_seq:
    addi $v0,$zero,1
    add $a0,$s0,$zero       # print auto sequence number
    syscall
prn_eol:
    addi $v0,$zero,11       # print endofline
    li $a0,'\n'
    syscall
sleep:
    addi $v0,$zero,32
    li $a0,300          # sleep 300 ms
    syscall
    nop             # WARNING: nop is mandatory here.
    b Loop              # Loop
end_main:

#~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
# GENERAL INTERRUPT SERVED ROUTINE for all interrupts
#~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
.ktext 0x80000180
    #-----------------------------------------------------
    # SAVE the current REG FILE to stack
    #-----------------------------------------------------
IntSR:
    addi $sp,$sp,4          # Save $ra because we may change it later
    sw $ra,0($sp)
    addi $sp,$sp,4          # Save $at because we may change it later
    sw $at,0($sp)
    addi $sp,$sp,4          # Save $sp because we may change it later
    sw $v0,0($sp)
    addi $sp,$sp,4          # Save $a0 because we may change it later
    sw $a0,0($sp)
    addi $sp,$sp,4          # Save $t1 because we may change it later
    sw $t1,0($sp)
    addi $sp,$sp,4          # Save $t3 because we may change it later
    sw $t3,0($sp)
    #------------------------------------------------------
    # Processing
    #------------------------------------------------------
prn_msg:
    addi $v0, $zero, 4
    la $a0, Message
    syscall
get_cod:
    li $t1, IN_ADRESS_HEXA_KEYBOARD
```

```
    li $t3, 0x88            # check row 4 and re-enable bit 7
    sb $t3, 0($t1)          # must reassign expected row
    li $t1, OUT_ADRESS_HEXA_KEYBOARD
    lb $a0, 0($t1)
    bnez $a0, prn_cod

    li $t1, IN_ADRESS_HEXA_KEYBOARD
    li $t3, 0x81            # check row 1 and re-enable bit 7
    sb $t3, 0($t1)          # must reassign expected row
    li $t1, OUT_ADRESS_HEXA_KEYBOARD
    lb $a0, 0($t1)
    bnez $a0, prn_cod

    li $t1, IN_ADRESS_HEXA_KEYBOARD
    li $t3, 0x82            # check row 4 and re-enable bit 7
    sb $t3, 0($t1)          # must reassign expected row
    li $t1, OUT_ADRESS_HEXA_KEYBOARD
    lb $a0, 0($t1)
    bnez $a0, prn_cod

    li $t1, IN_ADRESS_HEXA_KEYBOARD
    li $t3, 0x84            # check row 4 and re-enable bit 7
    sb $t3, 0($t1)          # must reassign expected row
    li $t1, OUT_ADRESS_HEXA_KEYBOARD
    lb $a0, 0($t1)
    bnez $a0, prn_cod

prn_cod:
    li $v0,34
    syscall
    li $v0,11
    li $a0,'\n'             # print endofline
    syscall
    #---------------------------------------------------------
    # Evaluate the return address of main routine
    # epc <=epc+4
    #---------------------------------------------------------
next_pc:
    mfc0 $at, $14           # $at <= Coproc0.$14 = Coproc0.epc
    addi $at, $at, 4        # $at = $at + 4 (next instruction)
    mtc0 $at, $14           # Coproc0.$14 = Coproc0.epc <= $at
    #---------------------------------------------------------
    # RESTORE the REG FILE from STACK
    #---------------------------------------------------------
restore:
    lw $t3, 0($sp)          # Restore the registers from stack
    addi $sp,$sp,-4
        lw $t1, 0($sp)          # Restore the registers from stack
```

```
            addi $sp, $sp, -4
            lw $a0, 0($sp)          # Restore the registers from stack
            addi $sp, $sp, -4
            lw $v0, 0($sp)          # Restore the registers from stack
            addi $sp, $sp, -4
            lw $ra, 0($sp)          # Restore the registers from stack
            addi $sp, $sp, -4
            lw $ra, 0($sp)          # Restore the registers from stack
            addi $sp, $sp, -4
return:
        eret                    # Return from exception
```

- Kết quả:



```
49Key scan code 0x00000042
150
51Key scan code 0xffffff88
352
53
54
55
```

- Giải thích:
    - Gán $t3 lần lượt là 0x81, 0x82, 0x84, 0x88 tương ứng với row 1, 2, 3, 4
    - Trong mỗi row, $a0 nhận được pressed (tức là giá trị khác 0) thì sẽ được in ra màn hình console (jump prn_cod) ### Assignment 4:
      Create a new project, type in, and build the program of Home Assignment 4.

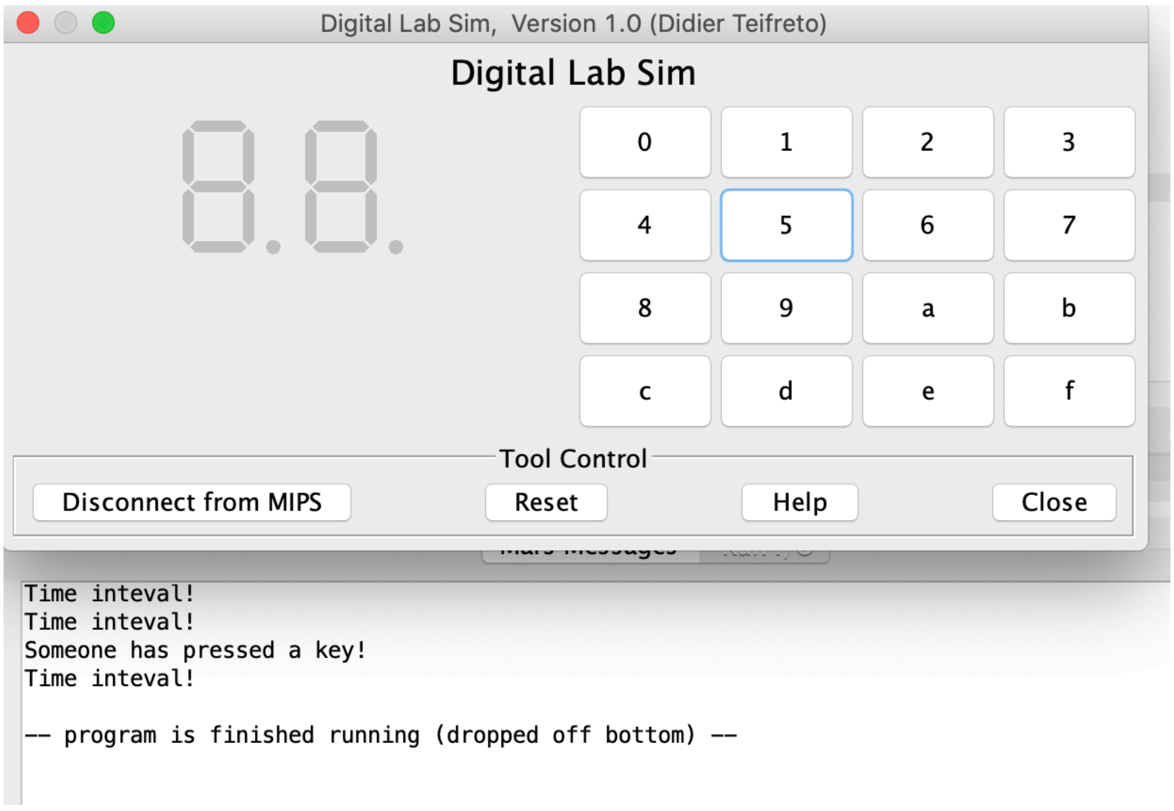
- Code:

```
    .eqv IN_ADRESS_HEXA_KEYBOARD 0xFFFF0012
.eqv COUNTER 0xFFFF0013         # Time Counter
```

```
.eqv MASK_CAUSE_COUNTER 0x00000400  # Bit 10: Counter interrupt
.eqv MASK_CAUSE_KEYMATRIX 0x00000800    # Bit 11: Key matrix interr
upt

.data
    msg_keypress: .asciiz "Someone has pressed a key!\n"
    msg_counter: .asciiz "Time inteval!\n"
    #~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    # MAIN Procedure
    #~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
.text
main:
    #---------------------------------------------------------
    # Enable interrupts you expect
    #---------------------------------------------------------
    # Enable the interrupt of Keyboard matrix 4x4 of Digital Lab Sim
    li $t1, IN_ADRESS_HEXA_KEYBOARD
    li $t3, 0x80            # bit 7 = 1 to enable
    sb $t3, 0($t1)

    # Enable the interrupt of TimeCounter of Digital Lab Sim
    li $t1, COUNTER
    sb $t1, 0($t1)

    #---------------------------------------------------------
    # Loop an print sequence numbers
    #---------------------------------------------------------
Loop:
    nop
    nop
    nop
sleep:
    addi $v0,$zero,32       # BUG: must sleep to wait for Time
Counter:
    li $a0, 200         # sleep 300 ms
    syscall
    nop             # WARNING: nop is mandatory here.
    b Loop
end_main:

#~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
# GENERAL INTERRUPT SERVED ROUTINE for all interrupts
#~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
.ktext 0x80000180
IntSR:  #--------------------------------------------------------
    # Temporary disable interrupt
    #--------------------------------------------------------
dis_int:
```

```
    li $t1, COUNTER         # BUG: must disable with Time Counter
    sb $zero, 0($t1)
    # no need to disable keyboard matrix interrupt
    #---------------------------------------------------------
    # Processing
    #---------------------------------------------------------
get_caus:
    mfc0 $t1, $13           # $t1 = Coproc0.cause
IsCount:
    li $t2, MASK_CAUSE_COUNTER  # if Cause value confirm Counter..
    and $at, $t1,$t2
    beq $at,$t2, Counter_Intr
IsKeyMa:
    li $t2, MASK_CAUSE_KEYMATRIX    # if Cause value confirm Key..
    and $at, $t1,$t2
    beq $at,$t2, Keymatrix_Intr
others:
    j end_process           # other cases
Keymatrix_Intr:
    li $v0, 4           # Processing Key Matrix Interrupt
    la $a0, msg_keypress
    syscall
    j end_process
Counter_Intr:
    li $v0, 4           # Processing Counter Interrupt
    la $a0, msg_counter
    syscall
    j end_process
end_process:
    mtc0 $zero, $13         # Must clear cause reg
en_int: #---------------------------------------------------------
    # Re-enable interrupt
    #---------------------------------------------------------
    li $t1, COUNTER
    sb $t1, 0($t1)
    #---------------------------------------------------------
    # Evaluate the return address of main routine
    # epc <= epc + 4
    #---------------------------------------------------------
next_pc:
    mfc0 $at, $14       # $at <= Coproc0.$14 = Coproc0.epc
    addi $at, $at, 4    # $at = $at + 4 (next instruction)
    mtc0 $at, $14       # Coproc0.$14 = Coproc0.epc <= $at
return:
    eret            # Return from exception%
```

- Kết quả:



```
Time inteval!
Time inteval!
Someone has pressed a key!
Time inteval!

-- program is finished running (dropped off bottom) --
```

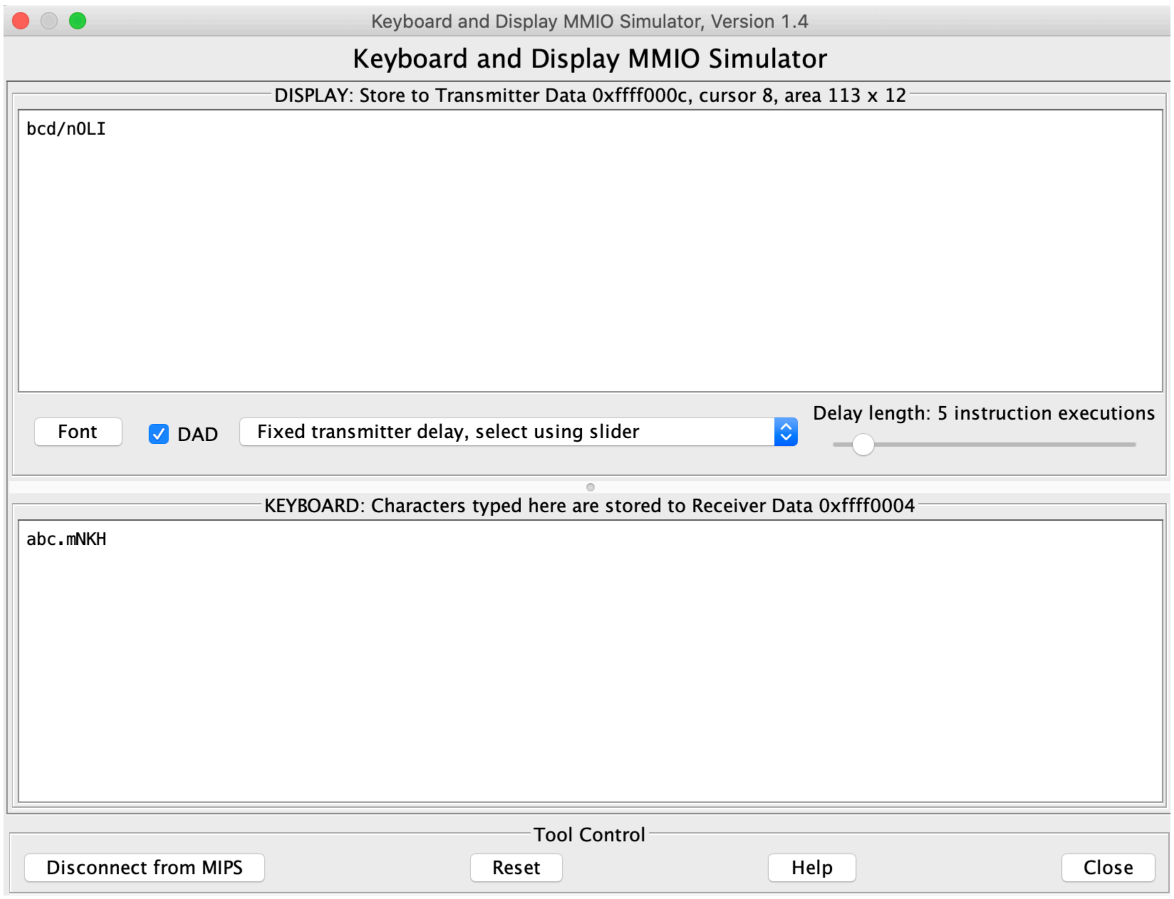
Assignment 5:

Create a new project, type in, and build the program of Home Assignment 5.

- Code:

```
.eqv KEY_CODE 0xFFFF0004    # ASCII code from keyboard, 1 byte
.eqv KEY_READY 0xFFFF0000   # =1 if has a new keycode ?
                # Auto clear after lw
.eqv DISPLAY_CODE 0xFFFF000C    # ASCII code to show, 1 byte
.eqv DISPLAY_READY 0xFFFF0008   # =1 if the display has already to
do
                # Auto clear after sw
.eqv MASK_CAUSE_KEYBOARD 0x0000034 # Keyboard Cause
.text
    li $k0, KEY_CODE
    li $k1, KEY_READY

    li $s0, DISPLAY_CODE
    li $s1, DISPLAY_READY
loop:   nop
WaitForKey:
    lw $t1, 0($k1)      # $t1 = [$k1] = KEY_READY
    beq $t1, $zero, WaitForKey # if $t1 == 0 then Polling
MakeIntR:
    teqi $t1, 1         # if $t0 = 1 then raise an Interrupt
    j loop
    #----------------------------------------------------------------
    # Interrupt subroutine
    #----------------------------------------------------------------
.ktext 0x80000180
get_caus:
    mfc0 $t1, $13       # $t1 = Coproc0.cause
IsCount:
    li $t2, MASK_CAUSE_KEYBOARD# if Cause value confirm Keyboard..
    and $at, $t1,$t2
    beq $at,$t2, Counter_Keyboard
    j end_process
Counter_Keyboard:
ReadKey:
    lw $t0, 0($k0)      # $t0 = [$k0] = KEY_CODE
WaitForDis:
    lw $t2, 0($s1)      # $t2 = [$s1] = DISPLAY_READY
    beq $t2, $zero, WaitForDis # if $t2 == 0 then Polling
Encrypt: addi $t0, $t0, 1   # change input key
ShowKey: sw $t0, 0($s0)     # show key
    nop
end_process:
next_pc:
    mfc0 $at, $14       # $at <= Coproc0.$14 = Coproc0.epc
    addi $at, $at, 4    # $at = $at + 4 (next instruction)
    mtc0 $at, $14       # Coproc0.$14 = Coproc0.epc <= $at
return: eret            # Return from exception
```

- Kết quả:



Keyboard and Display MMIO Simulator, Version 1.4

Keyboard and Display MMIO Simulator

DISPLAY: Store to Transmitter Data 0xffff000c, cursor 8, area 113 x 12

```
bcd/n0LI
```

Font
DAD
Fixed transmitter delay, select using slider
Delay length: 5 instruction executions

KEYBOARD: Characters typed here are stored to Receiver Data 0xffff0004

```
abc.mNKH
```

Tool Control
Disconnect from MIPS
Reset
Help
Close