Microprocessors ETI 2407
Assignment I

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1 Question One

Write an assembly program that displays whole numbers and their squares. A user should input the last number. The output below shows what would happen if a user entered 5. What is the highest value you could enter that gave correct results? Explain why this number is the limit and what can be done to improve this limit:

x	x^2
1	1
2	4
3	9
4	16
5	25

1.1 Answer Explanation

Highest value entered that gave the correct result is 181 i.e., $floor\left(\sqrt{\frac{2^{16}}{2}}\right)$. Highest number giving result $= 2^{16}$. Registers (AX) store 16 bit values. However, if this program was using a signed representation, the maximum would be:

$$\frac{2^{16}}{2} = 32,767$$

For a 32 *bit* answer, the result is placed in DX:AX or effectively, if using a single 32 bit register, EAX. This program does compute the answer upto a max of $65,556$ therefore, but since we are only printing from AX (using

emu8086 print_num procedure), and haven't manually implemented printing from DX:AX, the maximum result we get is similar to that of a signed value.

What can be done to improve the limit? Print the entire result from EAX for a 2^{16} value. Beyond that, we can't go as the addresses only access 64 KB of addressable memory

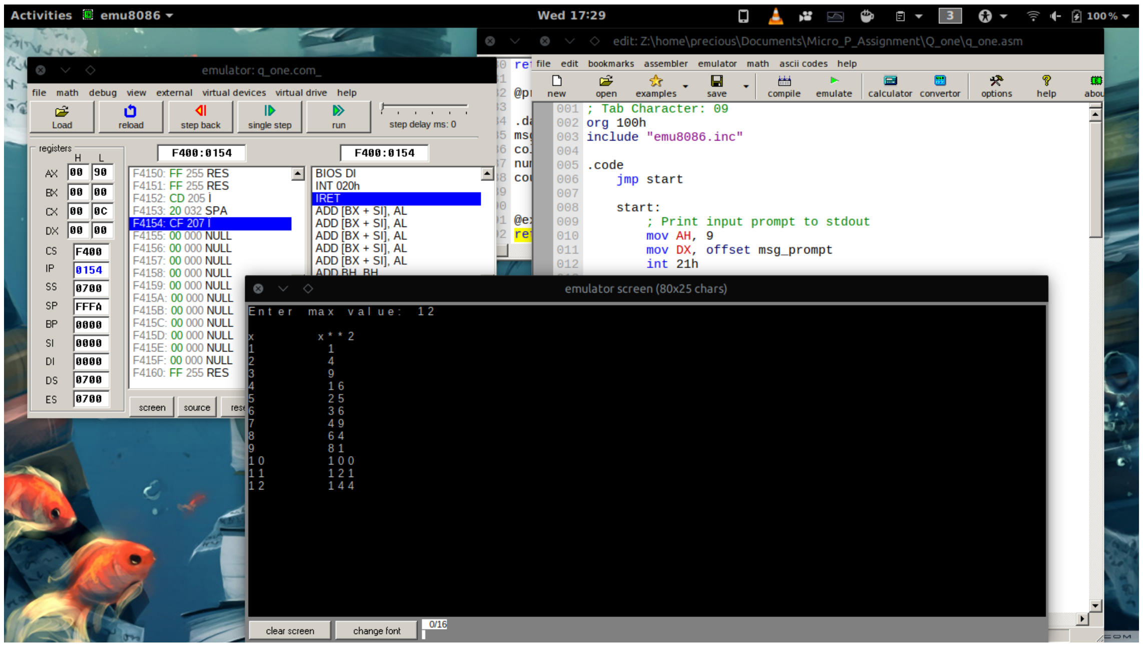
1.2 Pseudo-code

```
1. Get maximum value $x$ from user
2. initialize loop counter $c$ to 1
3. while $c <= x$
     • print $c$
     • print $c \times c$
     • end loop
```

1.3 Code

```
; Tab Character: 09
org 100h
include "emu8086.inc"

.code
    jmp start

    start:
        ; Print input prompt to stdout
        mov AH, 9
        mov DX, offset msg_prompt
        int 21h

        ; Read number
        ; Stored in CX
        call scan_num

        ; Print column header to stdout
        mov AH, 9
        mov DX, offset col_header
        int 21h

        mov number, CX

        print_and_mul:
            call @print_new_line


            ; Multiple the number (X * X)
            call muliply_


        inc count ; count ++

        ; If count <= number, multiply and print
        cmp count, CX
        jle print_and_mul


     jmp @exit


;Multiplication procedure
muliply_ proc
        mov AX, count
        push AX ; Preserve AX. Calling @print_tab overwrites AX
        call print_num ; Print X

        call @print_tab ; Print tab

        pop AX
        MUL count ; X * X

        ; Print X^2 from AX
        call print_num
    ret
muliply_ endp


; Prints a new line
@print_new_line proc

        mov DL, 0xa
        mov AH, 2
        int 21h

        mov DL, 0xd
        mov AH, 2
        int 21h

        ret
@print_new_line endp

; Prints a tab character
@print_tab proc
    mov DL, 09
    mov AH, 2
    int 21h

    ret

@print_tab endp

.data
    msg_prompt db "Enter max value: $", 0xa, 0xd
    col_header db 0xa, 0xd, 0xa, 0xd, "x      x**2", "$"
    number dw ?
    count dw 1


@exit:
    ret

    DEFINE_SCAN_NUM
    DEFINE_PRINT_NUM
    DEFINE_PRINT_NUM_UNS

    end

; Highest number giving result = 2^16
; Registers (AX) store 16 bit values. However, if this program was
    using a signed
; representation, the maximum would be (2^16)/2 = 32,767

; For a 32bit answer, the result is placed in DX:AX or effectively
    in EAX (32 bit)
; This program does compute the answer upto a max of 65,556
    therefore
; but since we are only printing from AX, and haven't manually
    implemented
; printing from DX:AX, the maximum result we get is similar to that
     of a signed value.

; WHAT CAN BE DONE TO IMPROVE THE LIMIT?
; Print the entire result from EAX for a 2^16 value. Beyond that,
    we can't go as the addresses
; only access 64KB of addressible memory
```

1.4 Program Output


```
Enter max value: 12

x        x**2
1          1
2          4
3          9
4         16
5         25
6         36
7         49
8         64
9         81
10       100
11       121
12       144
```

```
; Tab Character: 09
org 100h
include "emu8086.inc"

.code
    jmp start

    start:
        ; Print input prompt to stdout
        mov AH, 9
        mov DX, offset msg_prompt
        int 21h
```

```
registers
     H   L
AX   00  90
BX   00  00
CX   00  0C
DX   00  00
CS   F400
IP   0154
SS   0700
SP   FFFA
BP   0000
SI   0000
DI   0000
DS   0700
ES   0700
```

```
F400:0154
F4150: FF 255 RES
F4151: FF 255 RES
F4152: CD 205 Í
F4153: 20 032 SPA
F4154: CF 207 Ï
F4155: 00 000 NULL
F4156: 00 000 NULL
F4157: 00 000 NULL
F4158: 00 000 NULL
F4159: 00 000 NULL
F415A: 00 000 NULL
F415B: 00 000 NULL
F415C: 00 000 NULL
F415D: 00 000 NULL
F415E: 00 000 NULL
F415F: 00 000 NULL
F4160: FF 255 RES
```

```
F400:0154
BIOS DI
INT 020h
IRET
ADD [BX + SI], AL
ADD [BX + SI], AL
ADD [BX + SI], AL
ADD [BX + SI], AL
ADD [BX + SI], AL
ADD BH, BH
```

Figure 1: A screenshot of the output from running script 1.3

2 Question Two

Write a program that allows you convert from a number to the corresponding ASCII value.

E.g., if a user enters 35, the output should be #.

The program should also have a provision for displaying the ASCII value of an entered character.

E.g., if a user enters $*$, the output should be 42.

At the start of the program, a user should choose the option between the 2 modes (either ASCII value to character OR character to ASCII value). NB: Your code should be able to deal with erroneous input appropriately

E.g. entering a number above 255.

2.1 Psedo-code

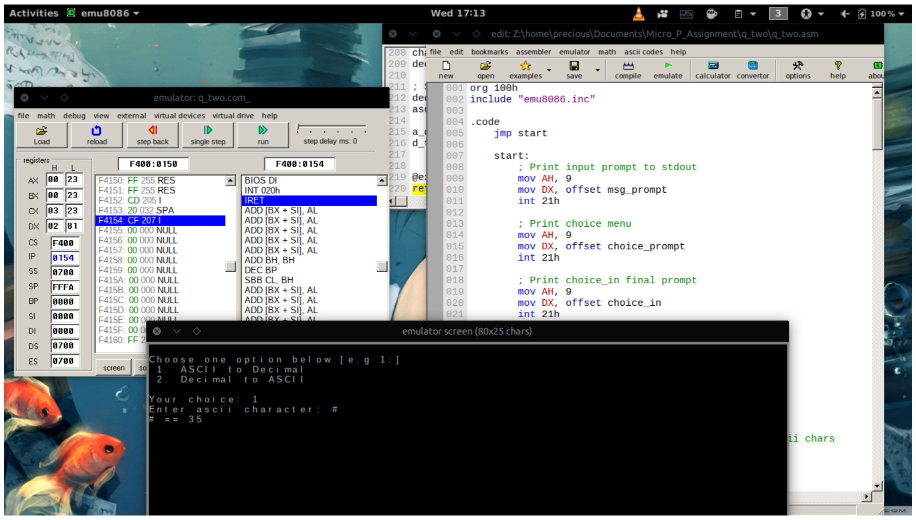
```
1. Select program mode
       a) ASCII to Decimal
       b) Decimal to ASCII

2. Get input from user *input*
     • If mode ($b$) and input$>255$, **error**

3. Initialize ASCII counter $c$. Initialize DEC counter $d$

4. **Start loop:**
     • **If** *input* **is equal** to $ASCII\{c\}$, (where $ASCII$ is the set of all ASCII
       characters $[0:255]$)
               print $ASCII\{c\}$, print $DEC\{d\}$, (where $DEC$ is an
               enumeration of the $ASCII$ set $[0_d : 255_d]$)
       **end loop**
```

2.2 Code

```
org 100h
include "emu8086.inc"

.code
    jmp start

    start:
        ; Print input prompt to stdout
        mov AH, 9
        mov DX, offset msg_prompt
        int 21h

        ; Print choice menu
        mov AH, 9
        mov DX, offset choice_prompt
        int 21h

        ; Print choice_in final prompt
        mov AH, 9
        mov DX, offset choice_in
        int 21h

        ; Read number
        ; Stored in CX
        ; call scan_num

        ; Read user choice
        ; Char stored in AL
        mov AH, 01h
        int 21h

        ; This part was testing inc & printing of ascii chars
        ;mov CL,  char

        ;do_it:
        ;    mov AH, 2
        ;    mov DL, CL
        ;    int 21h
        ;
        ;    mov AX, dec_counter
        ;    call print_num

        ;    inc dec_counter

        ;loop do_it


        call @process_choice

        jmp @exit


; Determine the selected user mode
@process_choice proc
    cmp AL, '1'
    je ascii_to_dec

    cmp AL, '2'
    je dec_to_ascii

    jmp unknown_entry

    ret
@process_choice endp


unknown_entry:
   mov AH, 09
   mov DX, offset unknown_prompt
   int 21h

   jmp @exit

ascii_to_dec:
    mov AH, 09
    mov DX, offset a_d_prompt
    int 21h

    ; read character
    ; Stored in AL
    mov AH, 1
    int 21h

    mov ascii_input, AL
    ; Convert ascii character to dec

    mov DL, 0 ; This is a flag used by the below callee
    call @get_equivalent_ascii

    jmp @exit

dec_to_ascii:
    mov AH, 09
    mov DX, offset d_to_a_prompt
    int 21h

    ; Read number
    ; Stored in CX
    call scan_num

    ; Beyond 255? Err
    cmp CX, 255
    jg illegal_dec

    ; Mov read value to variable
    ; CX [CL] will be used for loop
    mov dec_input, CX

    mov DL, 1 ; Flag used by below callee
    call @get_equivalent_ascii

    jmp @exit


; Prints out Error and  halts process
; for decimal values beyond 255
illegal_dec:
    mov AH, 09
    mov DX, offset illegal_dec_p
    int 21h

    jmp @exit


; Prints a tab character
@print_tab proc
```

```
    mov DL, 09
    mov AH, 2
    int 21h

    ret

@print_tab endp


; Prints a new line
@print_new_line proc

        mov DL, 0xa
        mov AH, 2
        int 21h

        mov DL, 0xd
        mov AH, 2
        int 21h

        ret
@print_new_line endp


; Finds the ASCII equivalent of DECIMAL
; Loops through all ASCII characters
; O(n) Time complexity where n is 255
@get_equivalent_ascii proc

    mov BX, dec_counter ; For comparison, store addr in 16-bit reg
    mov CL, char ; ASCII 255 controls loop

    do_it:
        ; DL = 0 -> ASCII to DEC, DL = 1 -> DEC to ASCII
        cmp DL, 0
        je cmp_character

        ; Check if BX matches input
        ; Yes? Break loop, print matching Char
        ; No? Try next character
        cmp BX, dec_input
        je print_answ

        jmp dec_step ; skip the cmp character part since we are
    doing
                         ; DEC to ASCII

        cmp_character:
            cmp CL, ascii_input
            je print_answ

        dec_step:
            dec BX

    loop do_it

    print_answ:
       call @print_new_line
       ; Print the character the loop stopped at
        mov AH, 2
        mov DL, CL
        int 21h

        mov AH, 09
        mov DX, offset space_eq
        int 21h

        ; Print its DEC equivalent
        mov AX, BX
        call print_num

        ret
@get_equivalent_ascii endp

.data
    msg_prompt db 0xa, 0xd, "Choose one option below [e.g 1:] $"
    unknown_prompt db 0xa, 0xd, "That's a strange choice dude/
    dudelady. GoodBye", 0xa, 0xd, "$"
    choice_prompt dw 0xa, 0xd, "1. ASCII to Decimal", 0xa, 0xd, "2.
     Decimal to ASCII", 0xa, 0xd, "$"
    choice_in db 0xa, 0xd, "Your choice: ", "$"
    illegal_dec_p db 0xa, 0xd, 0xa, 0xd, "Oopsy! ASCII shouldn't
    exceed 255D$"
    space_eq db " == $"

    choice db ?
    char db 255d
    dec_counter dw 255d

    ; Stores user inputs
    dec_input dw ?
    ascii_input db ?

    a_d_prompt db 0xa, 0xd, "Enter ascii character: $"
    d_to_a_prompt db 0xa, 0xd, "Enter decimal value of character: $
    "


@exit:
    ret

    DEFINE_SCAN_NUM
    DEFINE_PRINT_NUM
    DEFINE_PRINT_NUM_UNS


    end
```

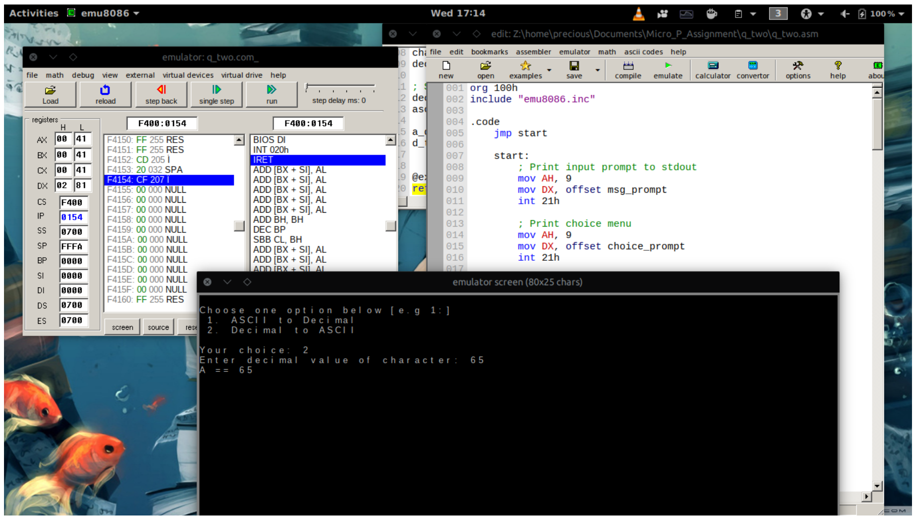
2.3 Program Output


Activities
emu8086
Wed 17:13
emulator: q_two.com_
edit: Z:\home\precious\Documents\Micro_P_Assignment\q_two\q_two.asm
emulator screen (80x25 chars)

```
org 100h
include "emu8086.inc"

.code
    jmp start

    start:
        ; Print input prompt to stdout
        mov AH, 9
        mov DX, offset msg_prompt
        int 21h

        ; Print choice menu
        mov AH, 9
        mov DX, offset choice_prompt
        int 21h

        ; Print choice_in final prompt
        mov AH, 9
        mov DX, offset choice_in
        int 21h
```

```
Choose one option below [e.g 1:]
 1. ASCII to Decimal
 2. Decimal to ASCII

Your choice: 1
Enter ascii character: #
# == 35
```

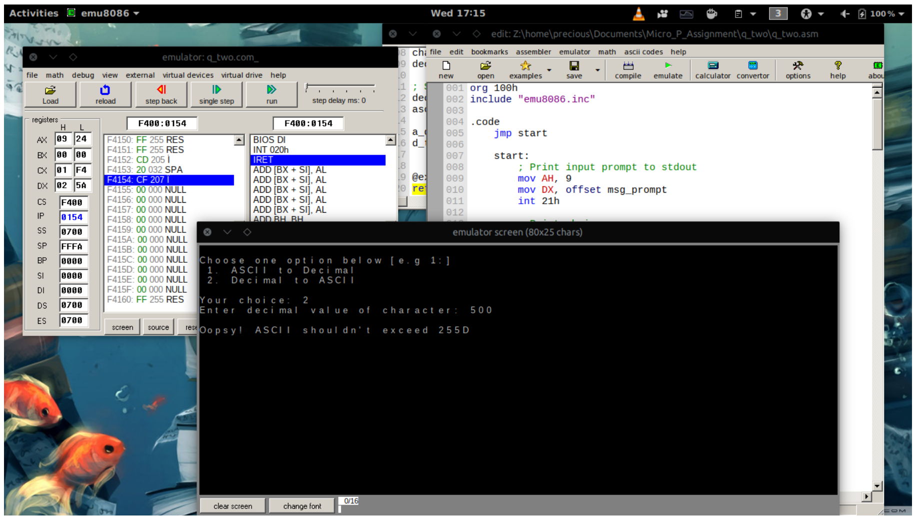
Figure 2: A screenshot of the output from running script 2.2. **Converting ASCII to decimal**



```
org 100h
include "emu8086.inc"

.code
    jmp start

    start:
        ; Print input prompt to stdout
        mov AH, 9
        mov DX, offset msg_prompt
        int 21h

        ; Print choice menu
        mov AH, 9
        mov DX, offset choice_prompt
        int 21h
```

```
Choose one option below [e.g 1:]
 1. ASCII to Decimal
 2. Decimal to ASCII

Your choice: 2
Enter decimal value of character: 65
A == 65
```

Figure 3: A screenshot of the output from running script 2.2. **Converting decimal to ASCII**



```
org 100h
include "emu8086.inc"

.code
    jmp start

    start:
        ; Print input prompt to stdout
        mov AH, 9
        mov DX, offset msg_prompt
        int 21h
```

```
Choose one option below [e.g 1:]
 1. ASCII to Decimal
 2. Decimal to ASCII

Your choice: 2
Enter decimal value of character: 500
Oopsy! ASCII shouldn't exceed 255D
```

Figure 4: A screenshot of the output from running script 2.2. **Error on Decimal value greater that** 255

3 Question Three

Develop a virus that changes the letters being typed randomly into other letters and thus frustrates the user. E.g. if he intends to type *Hello boss*, it could instead display something like *Sdupl dwsp*. (For simplicity, assume that the email will be written into your running program. i.e., you do not need to write code for attacking the browser, **though if you do that, come get a cookie**).

After writing your code, describe what would happen if a user typed 1234?

3.1 Answer Explanation

If the user types "*1234?*" the program will output "1234?" to stdout(See Figure 5). The program only changes alphabetical ASCII inputs. i.e., $65 - 90$ and $97 - 122$. The rest of the inputs are printed as keyed in by the user.

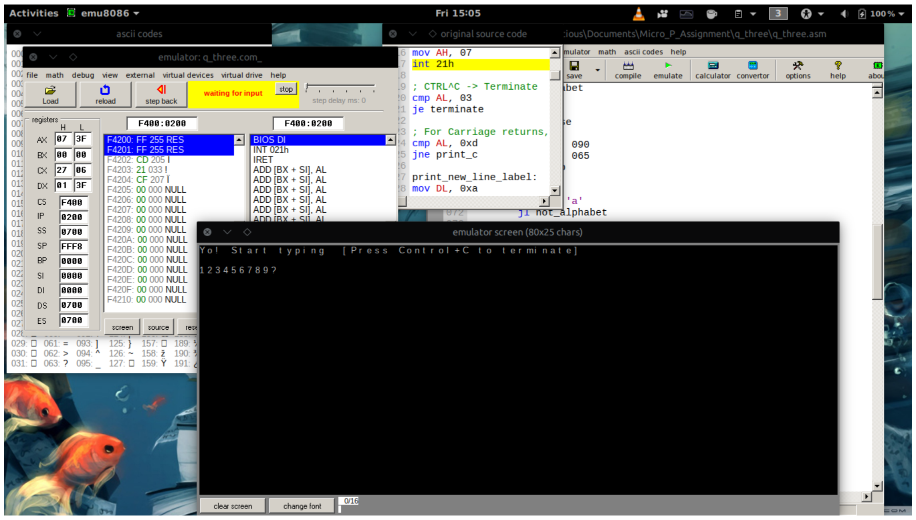
3.2 Pseudo-code

1. **Loop:**
    - (a) Get character c from user without echo
    - **If** c is an alphabet:
      Alter the value of c randomly
    - Print the value of c
    - Go back to **(a)**

3.3 Code

```
org 100h
include "emu8086.inc"

.code
    jmp start

    start:
        ; Print input prompt
        mov AH, 09
        mov DX,  offset prompt
        int 21h

        mov CX, 10000 ; Loop counter
        get_input:
            ; Get std input
            mov AH, 07
            int 21h

            ; CTRL^C -> Terminate
            cmp AL, 03
            je terminate

            ; For Carriage returns, print a new line
            cmp AL, 0xd
            jne print_c

            print_new_line_label:
                mov DL, 0xa
                mov AH, 2
                int 21h

                mov DL, 0xd
                mov AH, 2
                int 21h

            print_c:
                ; Print character
                ; Stored in AL

                 mov char, AL
                 call @randomize_char

            ; Create infinite loop
            ; If CX = 1, set to to 10000 again
            cmp CX, 1
            jg continue_loop
            mov CX, 10000


        continue_loop:
            loop get_input

    jmp @exit

@randomize_char proc
    mov AL, char
    cmp AL, 'A'
    jl not_alphabet

    cmp AL, 'Z'
    jg lower_case

    mov upper_b, 090
    mov lower_b, 065
    jmp make_cmp

    lower_case:
        cmp AL, 'a'
        jl not_alphabet

        cmp AL, 'z'
        jg not_alphabet

        mov upper_b, 122
        mov lower_b, 097

    make_cmp:

        mov BL, upper_b
        mov DL, lower_b

        sub BL, DL

        sub upper_b, AL
        mov AL, upper_b
        ; div BL

        add AL, lower_b ; random (mod) BL + lower_b


        ; Avoid non chars between 090 and 097
        cmp AL, 090
        jle print_chr


        check_if_char:
            cmp AL, 097
            jl add_char

            jmp print_chr

        add_char:
            add AL, 20


         print_chr:
            mov AH, 02
            mov DL, AL
            int 21h

            jmp end_rand

    ; Print non-alphabets without change
    not_alphabet:
        mov AH, 02
        mov DL, AL
        int 21h

    end_rand:
        ret
@randomize_char endp

; Terminates program
terminate:
   mov AH, 09
   lea DX, prompt_term
   int 21h

   jmp @exit


.data
    prompt db "Yo! Start typing  [Press Control+C to terminate]", 0
    xa, 0xd, 0xa, 0xd, "$"
    prompt_term db 0xa, 0xd, 0xa, 0xd, 09,
        "** Process terminated by user. Bye dude/dudelady **" , 0xa
    , 0xd, "$"
    char db ?
    upper_b db ?
    lower_b db ?

@exit:
    ret
    end
```

3.4 Program Output

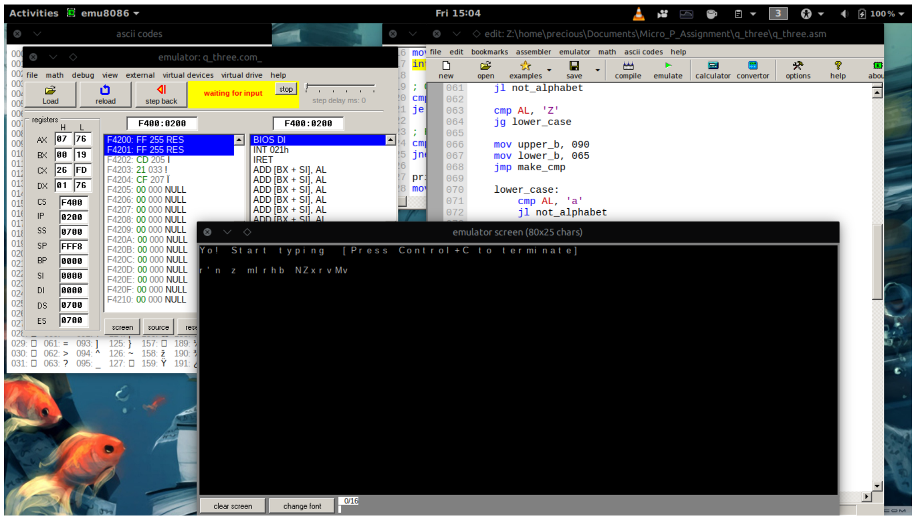


```
mov AH, 07
int 21h

; CTRL^C -> Terminate
cmp AL, 03
je terminate

; For Carriage returns,
cmp AL, 0xd
jne print_c

print_new_line_label:
mov DL, 0xa
```

```
Yo! Start typing [Press Control+C to terminate]

123456789?
```

```
F4200: FF 255 RES     BIOS DI
F4201: FF 255 RES     INT 021h
F4202: CD 205 Í       IRET
F4203: 21 033 !       ADD [BX + SI], AL
F4204: CF 207 Ï       ADD [BX + SI], AL
F4205: 00 000 NULL    ADD [BX + SI], AL
F4206: 00 000 NULL    ADD [BX + SI], AL
F4207: 00 000 NULL    ADD [BX + SI], AL
```

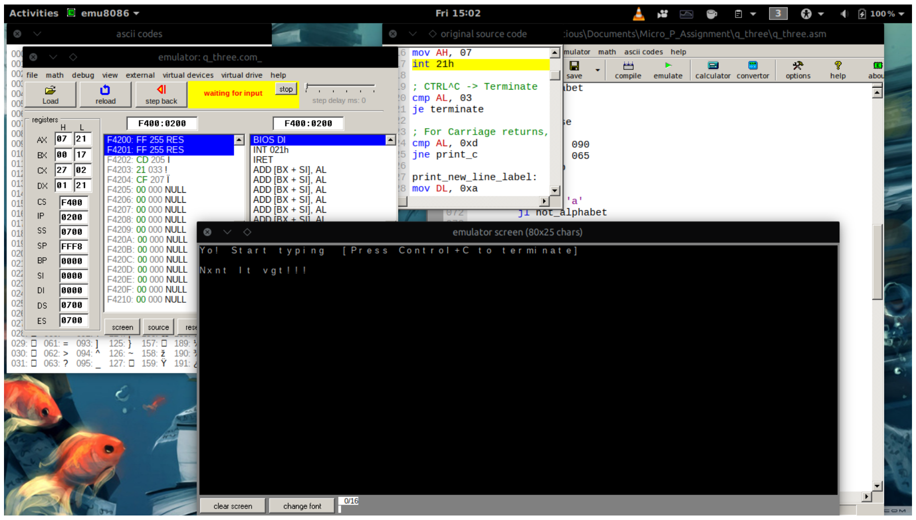
Figure 5: A screenshot of the output from running script 3.3. **An input of "1234?" outputs "1234?"**



```
edit: Z:\home\precious\Documents\Micro_P_Assignment\q_three\q_three.asm

    jl not_alphabet

    cmp AL, 'Z'
    jg lower_case

    mov upper_b, 090
    mov lower_b, 065
    jmp make_cmp

    lower_case:
        cmp AL, 'a'
        jl not_alphabet
```

```
Yo!  Start typing  [Press Control+C to terminate]

r'n z  mlrhb  NZxrvMv
```

Figure 6: A screenshot of the output from running script 3.3. **The output of the input *"I'm a noisy machine"***



```
mov AH, 07
int 21h

; CTRL^C -> Terminate
cmp AL, 03
je terminate

; For Carriage returns,
cmp AL, 0xd
jne print_c

print_new_line_label:
mov DL, 0xa
```

```
Yo!  Start typing  [Press Control+C to terminate]

Nxnt  It  vgt!!!
```

Figure 7: A screenshot of the output from running script 3.3. **The output of the input *"make me cry!!!"***

4 Question Four

Explain the following code and what it does. What output does it produce?

```
start:
  mov AL, 200
  mov CX, 1
  mov BL,5
  div BL
  mov BL,AL
  shl CX,3
somewhere:
  mov AH, 2
  mov DL, 30h
  test BL, 10000000b
  jz elsewhere
  mov DL, 31h
elsewhere:
  int 21h
  shl BL, 1
  loop somewhere
```

4.1 Answer Explanation

Short Answer:
This sketch **performs division** on two digits and **prints the result** to stdout. The exact details are mentioned as comments in sketch 4.2

4.2 Code explanation

```
; TEXT STARTS HERE

; What does the sketch do? What it's output?

; Short answer: The sketch divides 200 by 5 and prints the result
  to stdout
;               in binary form

; For detailed explanation, See Comments added in the sketch

; TEXT ENDS HERE

start:
    mov AL, 200 ; Store dividend in 8-bit register AL
                ; 11001000b

    mov CX, 1   ; Assign 1 to CX. The loop counter

    mov BL,5    ; Store divisor in in BL
                ; 00000101b

    div BL      ; Perform division  -> 200 / 5 -> AL / BL
                ; 40D -> 00101000b

    ; Move AL value to BL. Why? Printing to stdout
    ; requires a system call number in AH
    ; before calling an interrupt.
    ; That overwrites AL
    mov BL, AL

    shl CX,3    ;  1 << 3 = 1000b = 8d = no. of bits in BL

somewhere:
    mov AH, 2        ; Call number to  write char to stdout
    mov DL, 30h      ; DL = '0'

    ; AND BL with 10000000b
    ; If MSB is zero, jmp to elsewhere
    test BL, 10000000b
    jz elsewhere

    ; Else, MSB = 1
    ; DL = '1'
    mov DL, 31h

elsewhere:
    int 21h      ; Print ascii value in DL
    shl BL, 1    ; BL << 1. Test next MSB

    ; Repeat until CX = 0
    ; i.e 8d times
    loop somewhere

;  Final Stdoutput -> 00101000b [40d]
```