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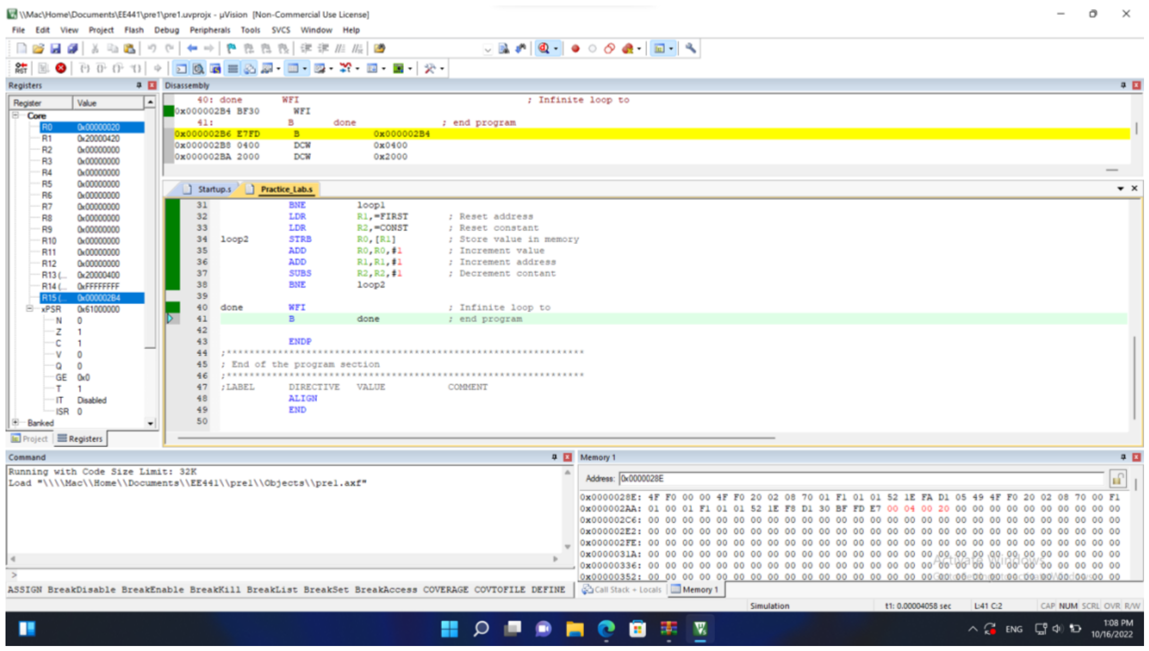
17.10.2022

EE 447 Introduction to Microprocessors
Preliminary Work – 1

1) *Build, run and understand Practice Lab.s*



```
\\Mac\Home\Documents\EE441\pre1\pre1.uvprojx - µVision  [Non-Commercial Use License]

Registers
Register      Value
Core
  R0          0x00000020
  R1          0x20000420
  R2          0x00000000
  R3          0x00000000
  R4          0x00000000
  R5          0x00000000
  R6          0x00000000
  R7          0x00000000
  R8          0x00000000
  R9          0x00000000
  R10         0x00000000
  R11         0x00000000
  R12         0x00000000
  R13 (...    0x20000400
  R14 (...    0xFFFFFFFF
  R15 (...    0x000002B4
  xPSR        0x61000000
    N         0
    Z         1
    C         1
    V         0
    Q         0
    GE        0x0
    T         1
    IT        Disabled
    ISR       0
Banked
```

```
Disassembly
    40: done        WFI                                   ; Infinite loop to
0x000002B4 BF30      WFI
    41:             B        done                ; end program
0x000002B6 E7FD      B              0x000002B4
0x000002B8 0400      DCW            0x0400
0x000002BA 2000      DCW            0x2000
```

Startup.s | Practice_Lab.s

```
                BNE         loop1
                LDR         R1,=FIRST           ; Reset address
                LDR         R2,=CONST           ; Reset constant
loop2           STRB        R0,[R1]             ; Store value in memory
                ADD         R0,R0,#1            ; Increment value
                ADD         R1,R1,#1            ; Increment address
                SUBS        R2,R2,#1            ; Decrement contant
                BNE         loop2

done            WFI                             ; Infinite loop to
                B           done                ; end program

                ENDP
;***************************************************************
; End of the program section
;***************************************************************
;LABEL          DIRECTIVE   VALUE               COMMENT
                ALIGN
                END
```

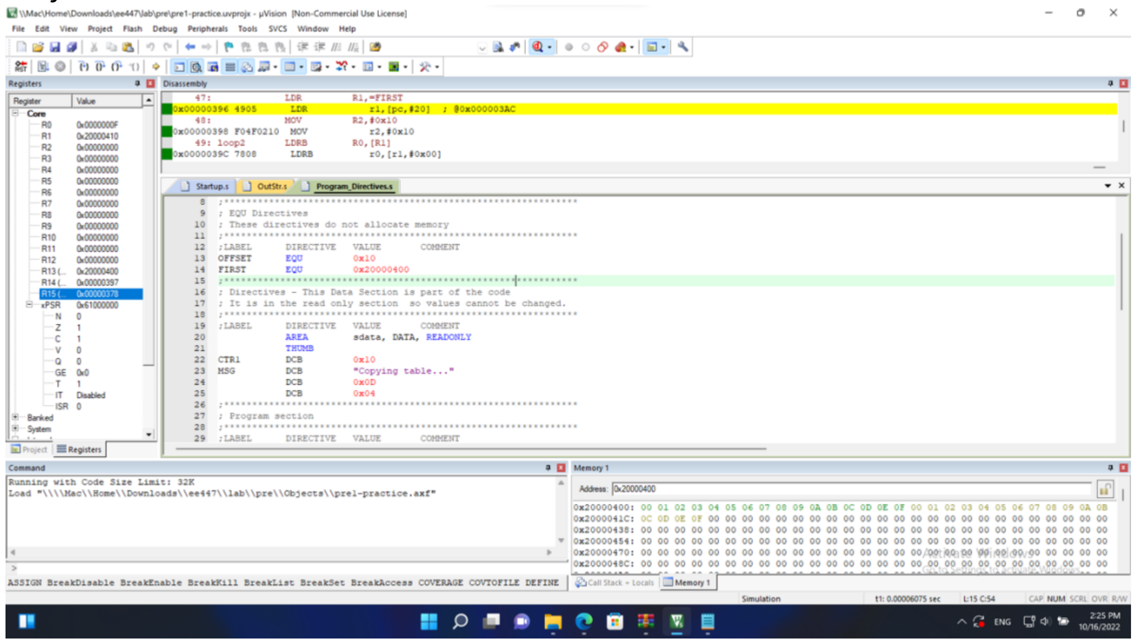
```
Command
Running with Code Size Limit: 32K
Load "\\\\Mac\\Home\\Documents\\EE441\\pre1\\Objects\\pre1.axf"

ASSIGN BreakDisable BreakEnable BreakKill BreakList BreakSet BreakAccess COVERAGE COVTOFILE DEFINE
```

```
Memory 1
Address: 0x0000028E
0x0000028E: 4F F0 00 00 4F F0 20 02 08 70 01 F1 01 01 52 1E FA D1 05 49 4F F0 20 02 08 70 00 F1
0x000002AA: 01 00 01 F1 01 01 52 1E F8 D1 30 BF FD E7 00 04 00 20 00 00 00 00 00 00 00 00 00 00
0x000002C6: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x000002E2: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x000002FE: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x0000031A: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00000336: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00000352: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Simulation    t1: 0.00004058 sec    L:41 C:2
```

2) *Build, run and understand Program Directives.s. You have to add OutStr.s to your project folder.*



```
\\Mac\Home\Downloads\ee447\lab\pre\pre1-practice.uvprojx - µVision  [Non-Commercial Use License]

Registers
Register      Value
Core
  R0          0x0000000F
  R1          0x20000410
  R2          0x00000000
  R3          0x00000000
  R4          0x00000000
  R5          0x00000000
  R6          0x00000000
  R7          0x00000000
  R8          0x00000000
  R9          0x00000000
  R10         0x00000000
  R11         0x00000000
  R12         0x00000000
  R13 (...    0x20000400
  R14 (...    0x00000397
  R15 (...    0x00000378
  xPSR        0x61000000
    N         0
    Z         1
    C         1
    V         0
    Q         0
    GE        0x0
    T         1
    IT        Disabled
    ISR       0
Banked
System
```

```
Disassembly
    47:             LDR          R1,=FIRST
0x00000396 4905      LDR            r1,[pc,#20]  ; @0x000003AC
    48:             MOV          R2,#0x10
0x00000398 F04F0210  MOV            r2,#0x10
    49: loop2       LDRB         R0,[R1]
0x0000039C 7808      LDRB           r0,[r1,#0x00]
```

Startup.s | OutStr.s | Program_Directives.s

```
;***************************************************************
; EQU Directives
; These directives do not allocate memory
;***************************************************************
;LABEL          DIRECTIVE   VALUE       COMMENT
OFFSET          EQU         0x10
FIRST           EQU         0x20000400
;***************************************************************
; Directives - This Data Section is part of the code
; It is in the read only section  so values cannot be changed.
;***************************************************************
;LABEL          DIRECTIVE   VALUE       COMMENT
                AREA        sdata, DATA, READONLY
                THUMB
CTR1            DCB         0x10
MSG             DCB         "Copying table..."
                DCB         0x0D
                DCB         0x04
;***************************************************************
; Program section
;***************************************************************
;LABEL          DIRECTIVE   VALUE       COMMENT
```

```
Command
Running with Code Size Limit: 32K
Load "\\\\Mac\\Home\\Downloads\\ee447\\lab\\pre\\Objects\\pre1-practice.axf"

ASSIGN BreakDisable BreakEnable BreakKill BreakList BreakSet BreakAccess COVERAGE COVTOFILE DEFINE
```

```
Memory 1
Address: 0x20000400
0x20000400: 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F 00 01 02 03 04 05 06 07 08 09 0A 0B
0x2000041C: 0C 0D 0E 0F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000438: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000454: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000470: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x2000048C: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Simulation    t1: 0.00006075 sec    L:15 C:54
```

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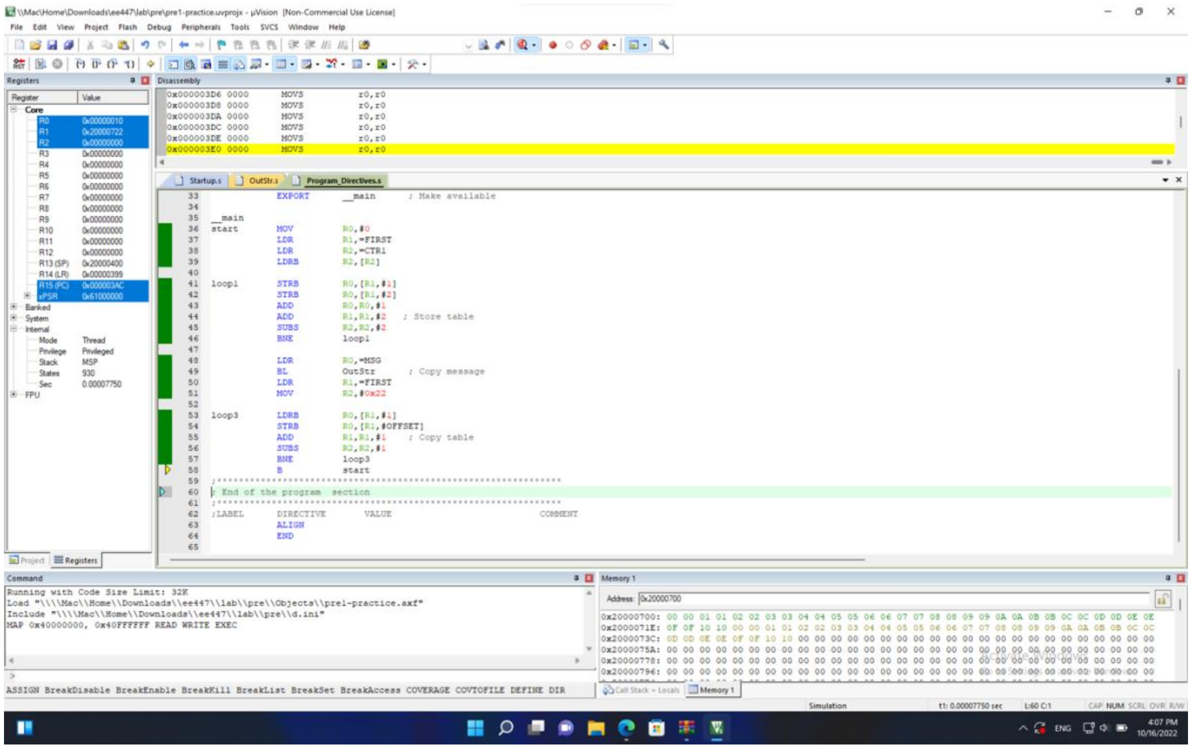
3) *Make the following modifications on Program Directives.s. This time you will create and copy a different table.*



Register	Value
R0	0x00000010
R1	0x20000722
R2	0x00000000
R3	0x00000000
R4	0x00000000
R5	0x00000000
R6	0x00000000
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x00000000
R11	0x00000000
R12	0x00000000
R13 (SP)	0x20000400
R14 (LR)	0x00000399
R15 (PC)	0x000003AC
xPSR	0x61000000
Mode	Thread
Privilege	Privileged
Stack	MSP
States	930
Sec	0.00007750

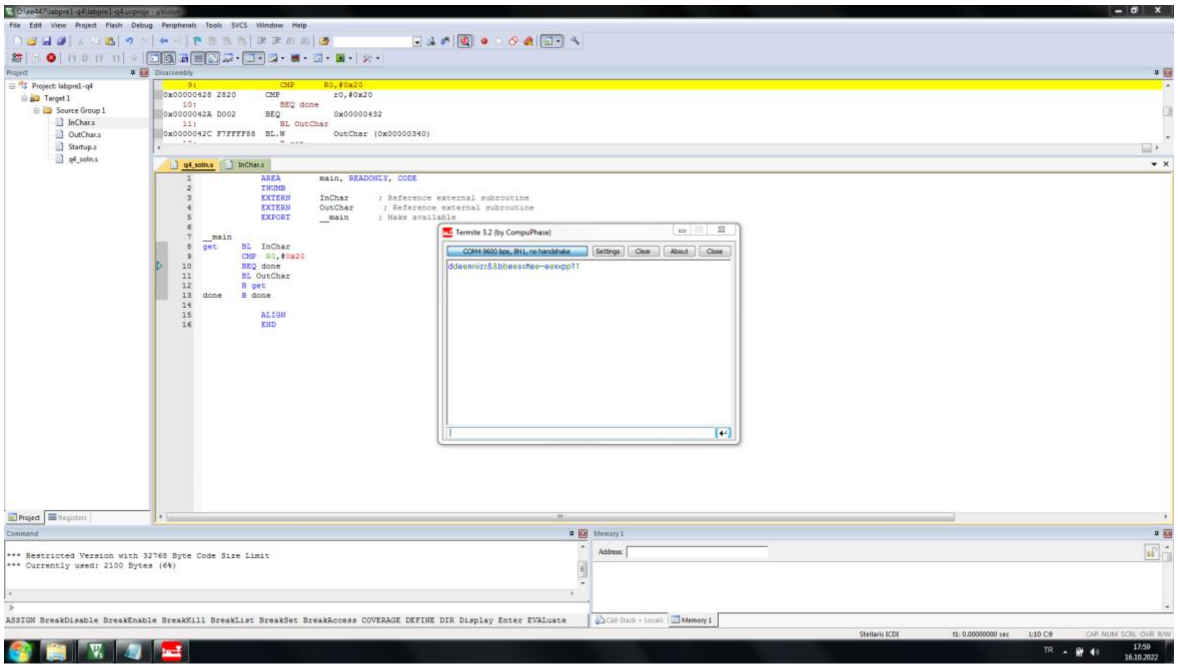
```
0x000003D6 0000      MOVS        r0,r0
0x000003D8 0000      MOVS        r0,r0
0x000003DA 0000      MOVS        r0,r0
0x000003DC 0000      MOVS        r0,r0
0x000003DE 0000      MOVS        r0,r0
0x000003E0 0000      MOVS        r0,r0
```

```
            EXPORT      __main      ; Make available

__main
start       MOV         R0,#0
            LDR         R1,=FIRST
            LDR         R2,=CTR1
            LDRB        R2,[R2]

loop1       STRB        R0,[R1,#1]
            STRB        R0,[R1,#2]
            ADD         R0,R0,#1
            ADD         R1,R1,#2    ; Store table
            SUBS        R2,R2,#2
            BNE         loop1

            LDR         R0,=MSG
            BL          OutStr      ; Copy message
            LDR         R1,=FIRST
            MOV         R2,#0x22

loop3       LDRB        R0,[R1,#1]
            STRB        R0,[R1,#OFFSET]
            ADD         R1,R1,#1    ; Copy table
            SUBS        R2,R2,#1
            BNE         loop3
            B           start
;*******************************************************************
; End of the program  section
;*******************************************************************
;LABEL      DIRECTIVE       VALUE                       COMMENT
            ALIGN
            END
```

```
Running with Code Size Limit: 32K
Load "\\\\Mac\\Home\\Downloads\\ee447\\lab\\pre\\Objects\\pre1-practice.axf"
Include "\\\\Mac\\Home\\Downloads\\ee447\\lab\\pre\\d.ini"
MAP 0x40000000, 0x40FFFFFF READ WRITE EXEC
```

```
Address: 0x20000700
0x20000700: 00 00 01 01 02 02 03 03 04 04 05 05 06 06 07 07 08 08 09 09 0A 0A 0B 0B 0C 0C 0D 0D 0E 0E
0x2000071E: 0F 0F 10 10 00 00 01 01 02 02 03 03 04 04 05 05 06 06 07 07 08 08 09 09 0A 0A 0B 0B 0C 0C
0x2000073C: 0D 0D 0E 0E 0F 0F 10 10 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x2000075A: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000778: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000796: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

4) *Write the program given in 1.10. You will have to add InChar.s, OutChar.s to your project folder.*



```
     9:                 CMP        R0,#0x20
0x00000428 2820      CMP           r0,#0x20
    10:                 BEQ done
0x0000042A D002      BEQ           0x00000432
    11:                 BL OutChar
0x0000042C F7FFFF88  BL.W          OutChar (0x00000340)
```

```
                AREA        main, READONLY, CODE
                THUMB
                EXTERN      InChar      ; Reference external subroutine
                EXTERN      OutChar     ; Reference external subroutine
                EXPORT      __main      ; Make available

__main
get         BL  InChar
            CMP  R0,#0x20
            BEQ done
            BL OutChar
            B get
done        B done

                ALIGN
                END
```

```
COM4 9600 bps, 8N1, no handshake
ddeenniizz&&bbeessttee--eexxpp11
```

```
*** Restricted Version with 32768 Byte Code Size Limit
*** Currently used: 2100 Bytes (6%)
```

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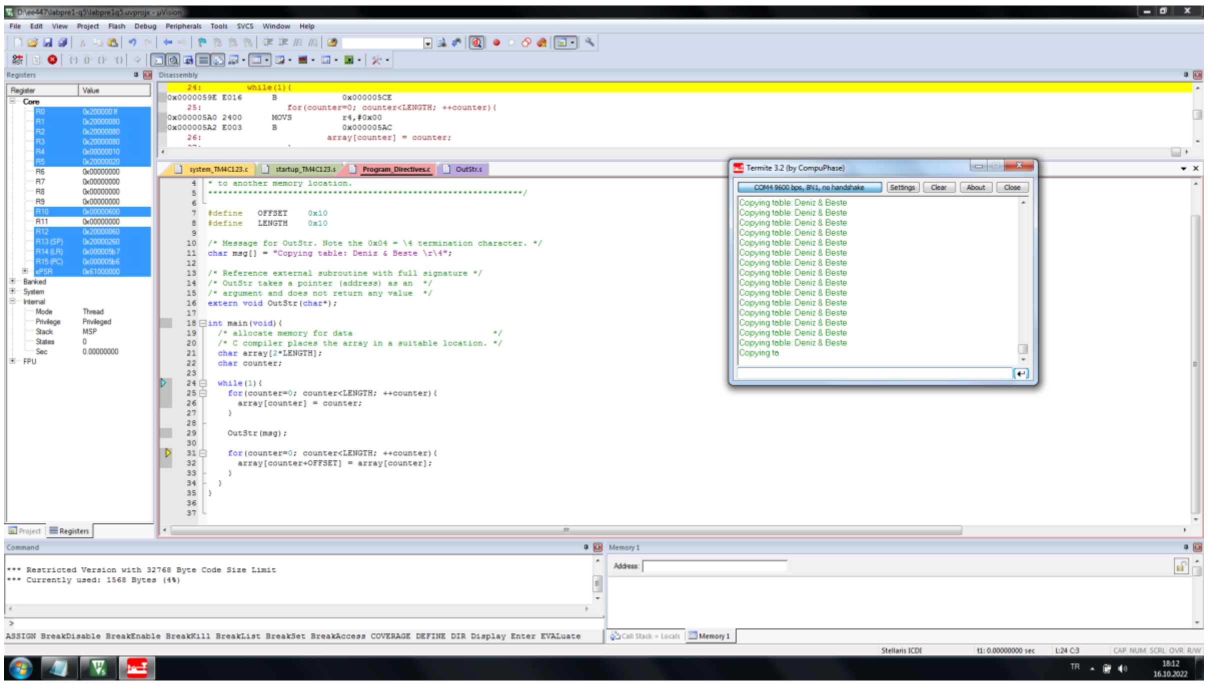
Program Code for Part 4

```
        AREA        main, READONLY, CODE
           THUMB
           EXTERN      InChar      ; Reference external subroutine
           EXTERN      OutChar      ; Reference external subroutine
           EXPORT      __main      ; Make available

__main
get     BL          InChar
                    CMP      R0,#0x20
                    BEQ done
                    BL OutChar
                    B get
done    B done

           ALIGN
           END
```

5) *Build, run and understand Program Directives.c. You have to add OutStr.s to your project.*



Register	Value
Core	
R0	0x2000001f
R1	0x20000080
R2	0x20000080
R3	0x20000080
R4	0x00000010
R5	0x20000020
R6	0x00000000
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x00000600
R11	0x00000000
R12	0x20000060
R13 (SP)	0x20000260
R14 (LR)	0x000005b7
R15 (PC)	0x000005b6
xPSR	0x61000000
Banked	
System	
Internal	
Mode	Thread
Privilege	Privileged
Stack	MSP
States	0
Sec	0.00000000
FPU	

```
    24:         while(1){
0x0000059E E016      B           0x000005CE
    25:             for(counter=0; counter<LENGTH; ++counter){
0x000005A0 2400      MOVS        r4,#0x00
0x000005A2 E003      B           0x000005AC
    26:                 array[counter] = counter;
```

```c
* to another memory location.
***************************************************************/

#define   OFFSET    0x10
#define   LENGTH    0x10

/* Message for OutStr. Note the 0x04 = \4 termination character. */
char msg[] = "Copying table: Deniz & Beste \r\4";

/* Reference external subroutine with full signature */
/* OutStr takes a pointer (address) as an  */
/* argument and does not return any value  */
extern void OutStr(char*);

int main(void){
  /* allocate memory for data                          */
  /* C compiler places the array in a suitable location. */
  char array[2*LENGTH];
  char counter;

  while(1){
    for(counter=0; counter<LENGTH; ++counter){
      array[counter] = counter;
    }

    OutStr(msg);

    for(counter=0; counter<LENGTH; ++counter){
      array[counter+OFFSET] = array[counter];
    }
  }
}
```

COM4 9600 bps, 8N1, no handshake

```
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying table: Deniz & Beste
Copying ta
```

```
*** Restricted Version with 32768 Byte Code Size Limit
*** Currently used: 1568 Bytes (4%)

>
ASSIGN BreakDisable BreakEnable BreakKill BreakList BreakSet BreakAccess COVERAGE DEFINE DIR Display Enter EVALuate
```

Stellaris ICDI   t1: 0.00000000 sec   L:24 C:3   CAP NUM SCRL OVR R/W
TR 18:12 16.10.2022

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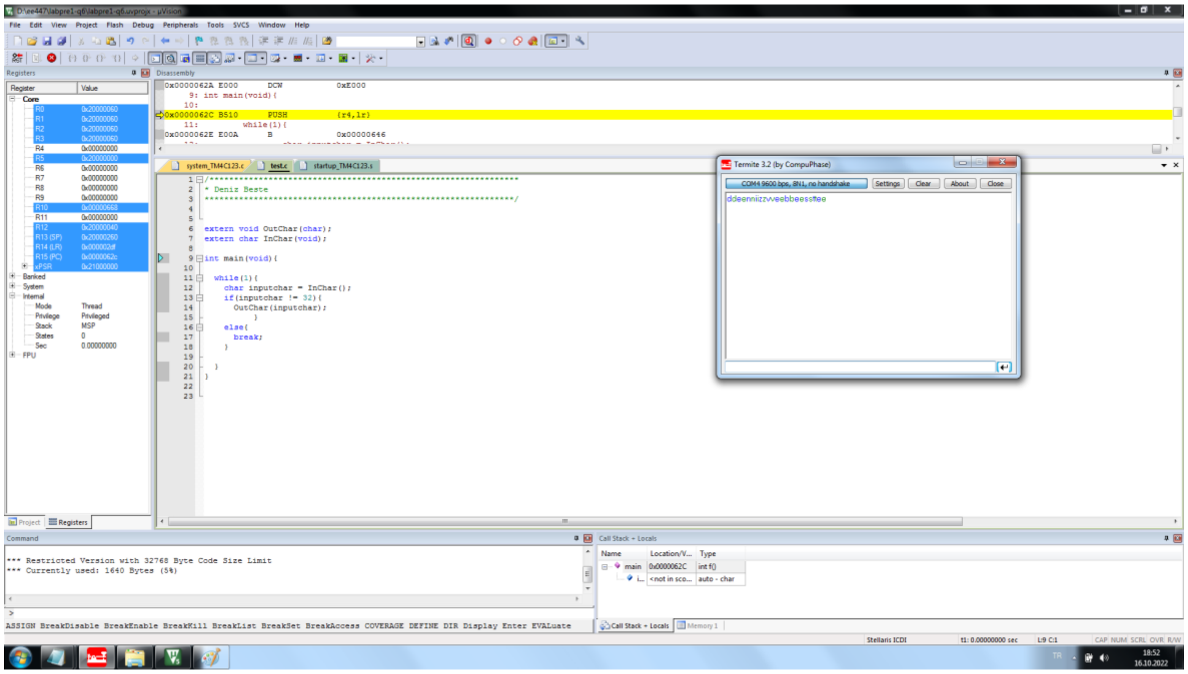
6) *Rewrite the program given in 1.10 in C language. You will have to add InChar.s, OutChar.s to your project.*



D:\ee447\labpre1-q6\labpre1-q6.uvprojx - µVision

Register	Value
Core	
R0	0x20000060
R1	0x20000060
R2	0x20000060
R3	0x20000060
R4	0x00000000
R5	0x20000000
R6	0x00000000
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x00000668
R11	0x00000000
R12	0x20000040
R13 (SP)	0x20000260
R14 (LR)	0x000002df
R15 (PC)	0x0000062c
xPSR	0x21000000
Banked	
System	
Internal	
Mode	Thread
Privilege	Privileged
Stack	MSP
States	0
Sec	0.00000000
FPU	

```
0x0000062A E000      DCW          0xE000
     9: int main(void){
    10:
0x0000062C B510      PUSH         {r4,lr}
    11:          while(1){
0x0000062E E00A      B            0x00000646
```

```
/*****************************************************************
* Deniz Beste
*****************************************************************/


extern void OutChar(char);
extern char InChar(void);

int main(void){

  while(1){
    char inputchar = InChar();
    if(inputchar != 32){
      OutChar(inputchar);
        }
    else{
      break;
    }

  }
}
```

Termite 3.2 (by CompuPhase)

COM4 9600 bps, 8N1, no handshake

```
ddeenniizzvveebbeessttee
```

```
*** Restricted Version with 32768 Byte Code Size Limit
*** Currently used: 1640 Bytes (5%)
```

```
ASSIGN BreakDisable BreakEnable BreakKill BreakList BreakSet BreakAccess COVERAGE DEFINE DIR Display Enter EVALuate
```

Name	Location/V...	Type
main	0x0000062C	int f()
i...	<not in sco...	auto - char

Stellaris ICDI   t1: 0.00000000 sec   L:9 C:1

18:52 16.10.2022

C Code for Part 6

```
/*****************************************************************
* Deniz Beste
*****************************************************************/


extern void OutChar(char);
extern char InChar(void);

int main(void){

        while(1){
                char inputchar = InChar();
                if(inputchar != 32){
                        OutChar(inputchar);
                                        }
                else{
                        break;
                }

        }
}
```