

Lab1

-We will write a code from scratch to send string to uart0 and uart0 will display it on Board name : verastilepb (arm926ej-s) .

-This lab we will write c code ,linker script and startup code and use all binary utilities such as objdump, objcopy, nm and readelf

-in this lab we will write the whole code using only arm-none-eabi tool chain without any IDE.

From specs we found out :

Entry point of processor is : 0x10000

To activate UART0 you just write on UART0DR register (32bit).

And its address is :0x101f1000

Codes :

App.c :

```

C:\Users\HP\Downloads\Embedded Systems\unit3\lesson 2\lab1\APP.c - Sublime Text (UNREGISTERED)
File Edit Selection Find View Goto Tools Project Preferences Help
APP.c x uart.c x uart.h x startup.s x
1  #include "uart.h"
2  unsigned char string_buffer[100] = "Learn-in-depth:shady_mamdouh";
3  unsigned char const string_buffer2[100] = "Learn-in-depth:shady_mamdouh";
4  void main(void)
5  {
6      uart_send_string(string_buffer);
7  }

```

Uart.c :

```
C:\Users\HP\Downloads\Embedded Systems\unit3\lesson 2\lab1\uart.c - Sublime Text (UNREGISTERED)
File Edit Selection Find View Goto Tools Project Preferences Help

APP.c x uart.c x uart.h x startup.s x
1 #include "uart.h"
2 #define UART0DR *((volatile unsigned int* const)((unsigned int*)0x101f1000))
3 void uart_send_string (unsigned char *P_tx_string)
4 {
5     while (*P_tx_string != '\0')
6     {
7         UART0DR = (unsigned int)(*P_tx_string);
8         P_tx_string++;
9     }
10 }
```

Uart.h :

```
C:\Users\HP\Downloads\Embedded Systems\unit3\lesson 2\lab1\uart.h - Sublime Text (U
File Edit Selection Find View Goto Tools Project Preferences Help

APP.c x uart.c x uart.h
1 #ifndef _UART_H_
2 #define _UART_H_
3 void uart_send_string(unsigned char* P_tx_string);
4
5
6
7 #endif
```

Then we will open terminal and export path of toolchain to our directory

To generate app.o and uart.o with consideration of microcontroller architecture

.

MINGW64:/c/Users/HP/Desktop/lab1

```
HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ export PATH C:\ARM_TOOLCHAIN\arm-none-eabi\bin\: $PATH
bash: export: `C:\ARM_TOOLCHAIN\arm-none-eabi\bin\: /c/Users/HP/bin:/mingw64/bin:/usr
/local/bin:/usr/bin:/bin:/mingw64/bin:/usr/bin:/c/Users/HP/bin:/c/WinAVR-2010011
0/bin:/c/WinAVR-20100110/utils/bin:/c/Program': not a valid identifier
bash: export: `(x86)/Common': not a valid identifier
bash: export: `Files/Oracle/Java/javapath:/c/WINDOWS/system32:/c/WINDOWS:/c/WIND
OWS/System32/Wbem:/c/WINDOWS/System32/WindowsPowerShell/v1.0:/c/Program': not a
valid identifier
bash: export: `Files/PuTTY:/c/WINDOWS/System32/OpenSSH:/cmd:/c/ARM_TOOLCHAIN/bin
:/c/Users/HP/AppData/Local/Microsoft/windowsApps:/usr/bin/vendor_perl:/usr/bin/c
ore_perl': not a valid identifier

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-gcc.exe -c -mcpu=arm926ej-s -I . app.c -o app.o

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-gcc.exe -c -mcpu=arm926ej-s -I . uart.c -o uart.o

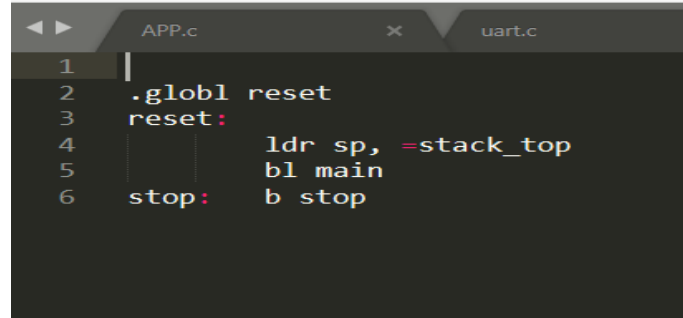
HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ AC
```

Startup.s :

We defined reset section as a global to be seen by linker script to make it an entry point .

C:\Users\HP\Downloads\Embedded Systems\unit3\lesson

```
File Edit Selection Find View Goto Tools Project P
```



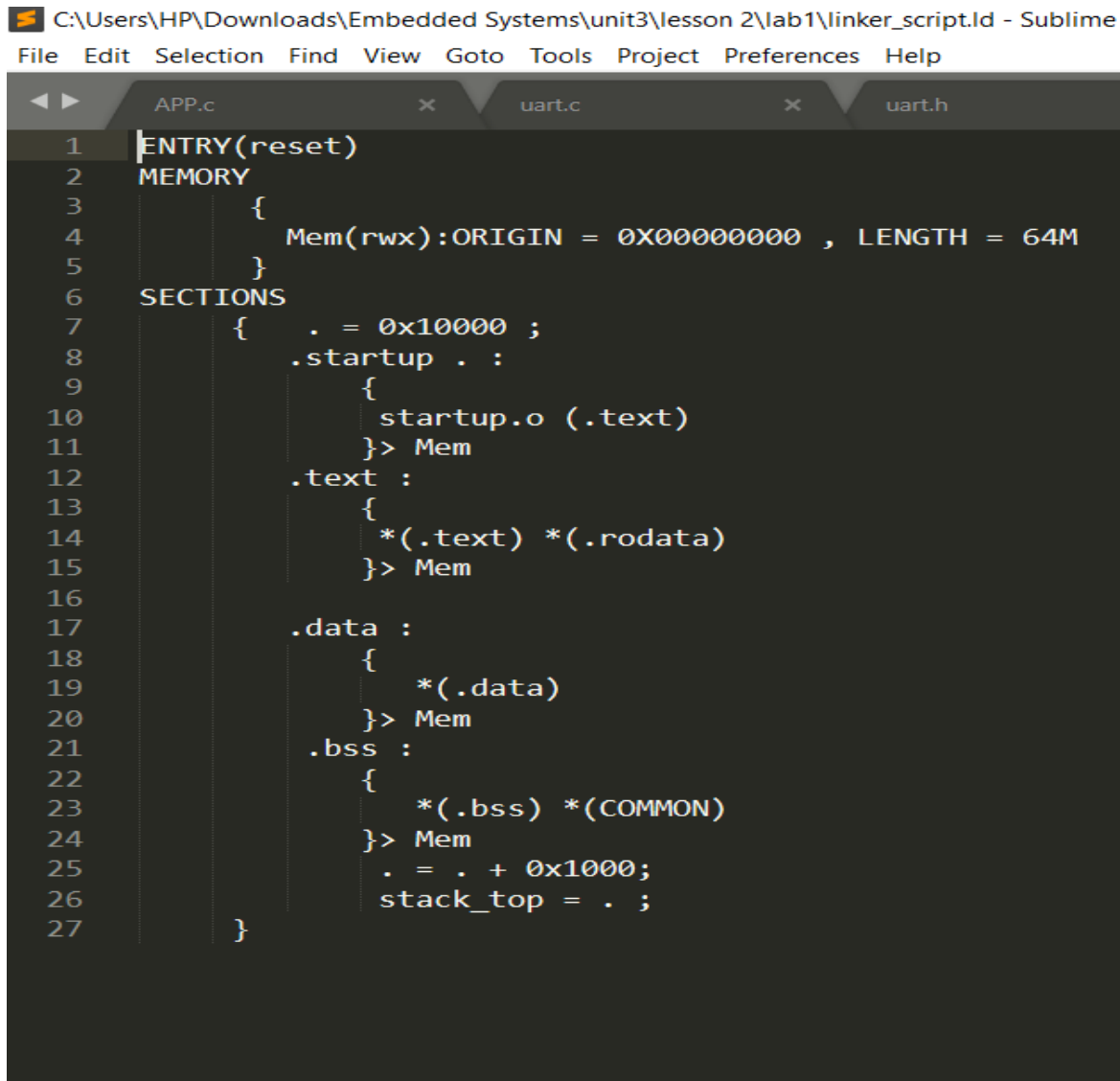
```
1 |
2 | .globl reset
3 | reset:
4 |     ldr sp, =stack_top
5 |     bl main
6 | stop: b stop
```

Then we will use commands to generate startup.o using assembler .

```
$ arm-none-eabi-as.exe -mcpu=arm926ej-s startup.s -o startup.o
```

Linker script :

In this section we control all memory locations, memory sizes , starting Point of our program and stack size .



```
C:\Users\HP\Downloads\Embedded Systems\unit3\lesson 2\lab1\linker_script.ld - Sublime
File Edit Selection Find View Goto Tools Project Preferences Help
APP.c x uart.c x uart.h
1 ENTRY(reset)
2 MEMORY
3 {
4     Mem(rwx):ORIGIN = 0X00000000 , LENGTH = 64M
5 }
6 SECTIONS
7 {
8     . = 0x10000 ;
9     .startup . :
10    {
11        startup.o (.text)
12    }> Mem
13    .text :
14    {
15        *(.text) *(.rodata)
16    }> Mem
17    .data :
18    {
19        *(.data)
20    }> Mem
21    .bss :
22    {
23        *(.bss) *(COMMON)
24    }> Mem
25    . = . + 0x1000;
26    stack_top = . ;
27 }
```

Then we will link all object files app.o, startup.o and uart.o with linker script using linker and generate our .elf file and .map file .

Then generate binary code that will be burnt on board.

```
HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-ld.exe -T linker_script.ld -Map=map_file.map app.o startup.o uar
t.o -o learn-in-depth.elf

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-objcopy.exe -O binary learn-in-depth.elf learn-in-depth.bin

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$
```

Now we will call qemu emulator to run the code on the board and see the expected output : *learn-in-depth<shady Mamdouh>*

```
HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-objcopy.exe -O binary learn-in-depth.elf learn-in-depth.bin

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ /c/qemu/qemu-system-arm.exe -M versatilepb -m 128M -nographic -kernel learn-in
-depth.bin
learn-in-depth<shady mamdouh>|
```

Lets use some binary utilities to differentiate between different stages of code :

1- Objdump -h & -d for startup.o and app.o :

We will find symbols that are not resolved and all addresses are not physical addresses because they are object files and as we know abject files are relocated image that will be resolved and allocated in linker with linker script

.

```

$ arm-none-eabi-objdump.exe -h startup.o

startup.o:      file format elf32-littlearm

Sections:
Idx Name          Size      VMA           LMA           File off  Algn
  0 .text          00000010  00000000  00000000  00000034  2**2
                  CONTENTS, ALLOC, LOAD, RELOC, READONLY, CODE
  1 .data          00000000  00000000  00000000  00000044  2**0
                  CONTENTS, ALLOC, LOAD, DATA
  2 .bss           00000000  00000000  00000000  00000044  2**0
                  ALLOC
  3 .ARM.attributes 00000022  00000000  00000000  00000044  2**0
                  CONTENTS, READONLY

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-objdump.exe -h app.o

app.o:          file format elf32-littlearm

Sections:
Idx Name          Size      VMA           LMA           File off  Algn
  0 .text          00000018  00000000  00000000  00000034  2**2
                  CONTENTS, ALLOC, LOAD, RELOC, READONLY, CODE
  1 .data          00000064  00000000  00000000  0000004c  2**2
                  CONTENTS, ALLOC, LOAD, DATA
  2 .bss           00000000  00000000  00000000  000000b0  2**0
                  ALLOC
  3 .rodata        00000064  00000000  00000000  000000b0  2**2
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  4 .comment       00000012  00000000  00000000  00000114  2**0
                  CONTENTS, READONLY
  5 .ARM.attributes 00000032  00000000  00000000  00000126  2**0
                  CONTENTS, READONLY

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-objdump.exe -D app.o

app.o:          file format elf32-littlearm

Disassembly of section .text:

00000000 <main>:
   0:  e92d4800      push    {fp, lr}
   4:  e28db004      add     fp, sp, #4
   8:  e59f0004      ldr     r0, [pc, #4]      ; 14 <main+0x14>
   c:  ebfffffe      bl     0 <uart_send_string>
  10:  e8bd8800      pop     {fp, pc}
  14:  00000000      andeq   r0, r0, r0

Disassembly of section .data:

```

So if we use objdump utility after linking stage we will find that all symbols have been resolved and all sections allocated in the expected addresses in the memory according to specs and our linker script .

```

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-objdump.exe -h learn-in-depth.elf

learn-in-depth.elf:      file format elf32-littlearm

Sections:
Idx Name          Size      VMA           LMA           File off  Algn
  0 .startup       00000010  00010000  00010000  00008000  2**2
    CONTENTS, ALLOC, LOAD, READONLY, CODE
  1 .text          000000cc  00010010  00010010  00008010  2**2
    CONTENTS, ALLOC, LOAD, READONLY, CODE
  2 .data          00000064  000100dc  000100dc  000080dc  2**2
    CONTENTS, ALLOC, LOAD, DATA
  3 .ARM.attributes 0000002e  00000000  00000000  00008140  2**0
    CONTENTS, READONLY
  4 .comment       00000011  00000000  00000000  0000816e  2**0
    CONTENTS, READONLY

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$

```

If we want to use more binary utilities such as nm :

In this picture we will see the symbols before and after linking :

The difference between app.o and learn-in-depth.elf appears in resolved symbols and real physical addresses .

```

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$ arm-none-eabi-nm.exe app.o learn-in-depth.elf

app.o:
00000000 T main
00000000 D string_buffer1
00000000 R string_buffer2
          U uart_send_string

learn-in-depth.elf:
00010010 T main
00010000 T reset
00011140 D stack_top
00010008 t stop
000100dc D string_buffer1
00010078 T string_buffer2
00010028 T uart_send_string

HP@DESKTOP-RR69RMG MINGW64 ~/Desktop/lab1
$

```