# CPE 325: Intro to Embedded Computer System

## Lab11

## REVERSE ENGINEERING.

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**Date of Experiment**: 04/04/22

**Report Deadline**: 04/11/22

**Demonstration Deadline**: 04/12/22

# Introduction

This report introduces us to the concept of software reverse engineering. The purpose of this lab is to learn how to use some of the functionalities of the MSP430FG418 board to analyze software and determine its components. The tests performed in this lab will be to crack a binary file and disassemble a hexadecimal text file so we can extract assembly code.

# Theory

**Topic 1**: **ELF.**

ELF stands for Executable and Linkable Format, used for executable files, object files, shared libraries and core dumps. It is not bound by the ISA in the MSP430 or operating systems. The ELF contains the following segments:

- A file header (ELF file header).
- Program header table which tells the loader how to create a process image in memory.
- Section header table which describes sections that contain data referred to by entries in the program and section header tables.
- Segments that contain details needed for the execution of runtime.
- Sections that contain linking and relocation information.

They are also divided into sections that have a Name and Type, requested memory location at runtime and permissions (read, write etc).

**Topic 2**: **NAKEN UTILITY.**

Naken Utility is a disassembler developed by Michael Kohn and Joe Davisson that disassembles a hex file (passed as an input) and produces assembly code that can be analyzed, and reverse engineered. We use this tool on this lab to reverse engineer a provided hex file.

**Topic 3**: **MSP430 FLASHER.**

This is a utility program used to flash a hex file with executable on a target platform. The flasher retrieves code from the platform and stores it into an output file in hex or text format. Once the output is extracted, we can use the naken utility, discussed above, to strip it and extract the assembly file.

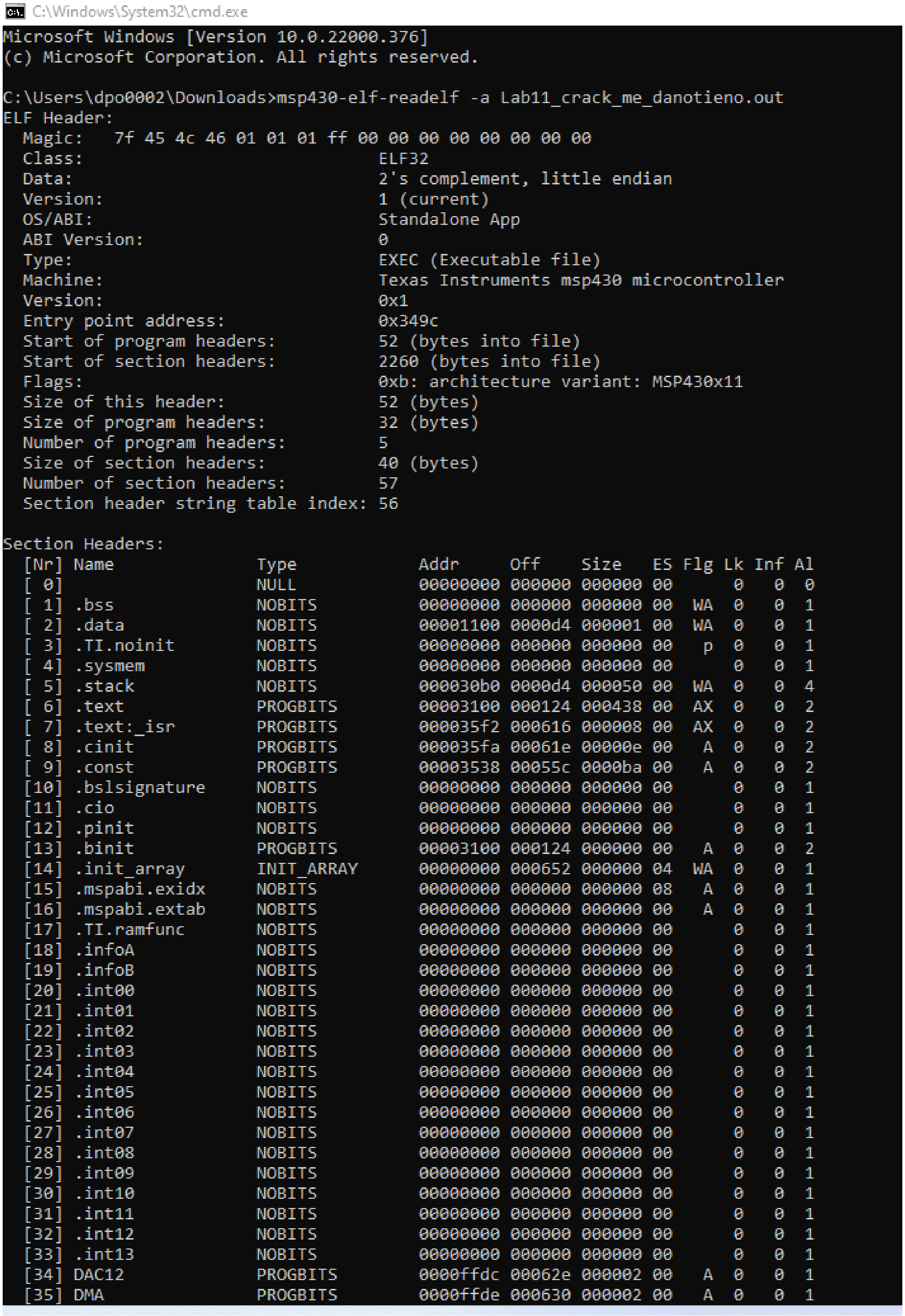
# Results & Observation

## Program 1:

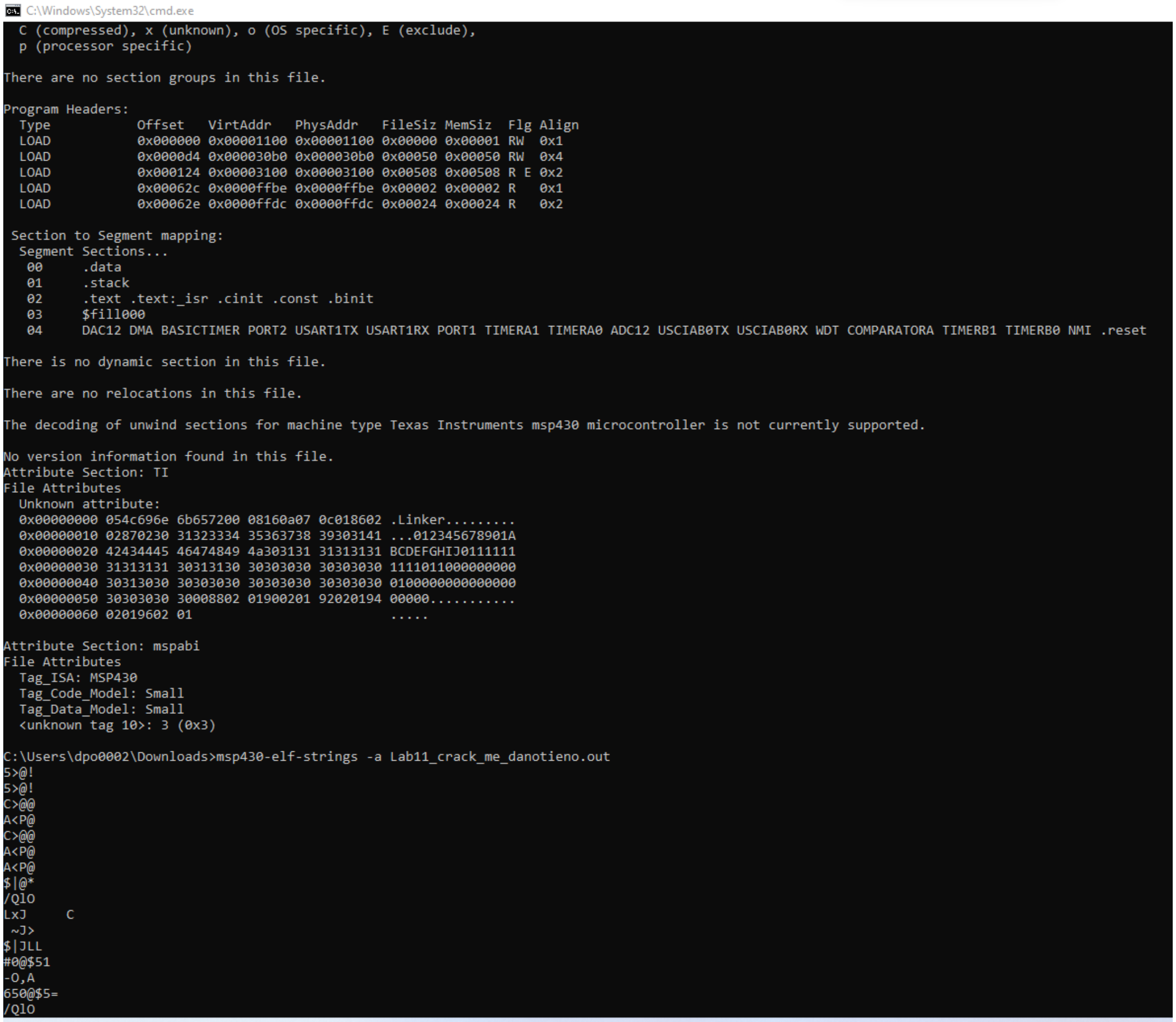
## Program Description:

The first part of this lab was to save a downloadable .out file that was provided and use the methods learned in the lab to determine the correct password from a list of possible passwords in the file. The steps followed to achieve that are documented below:

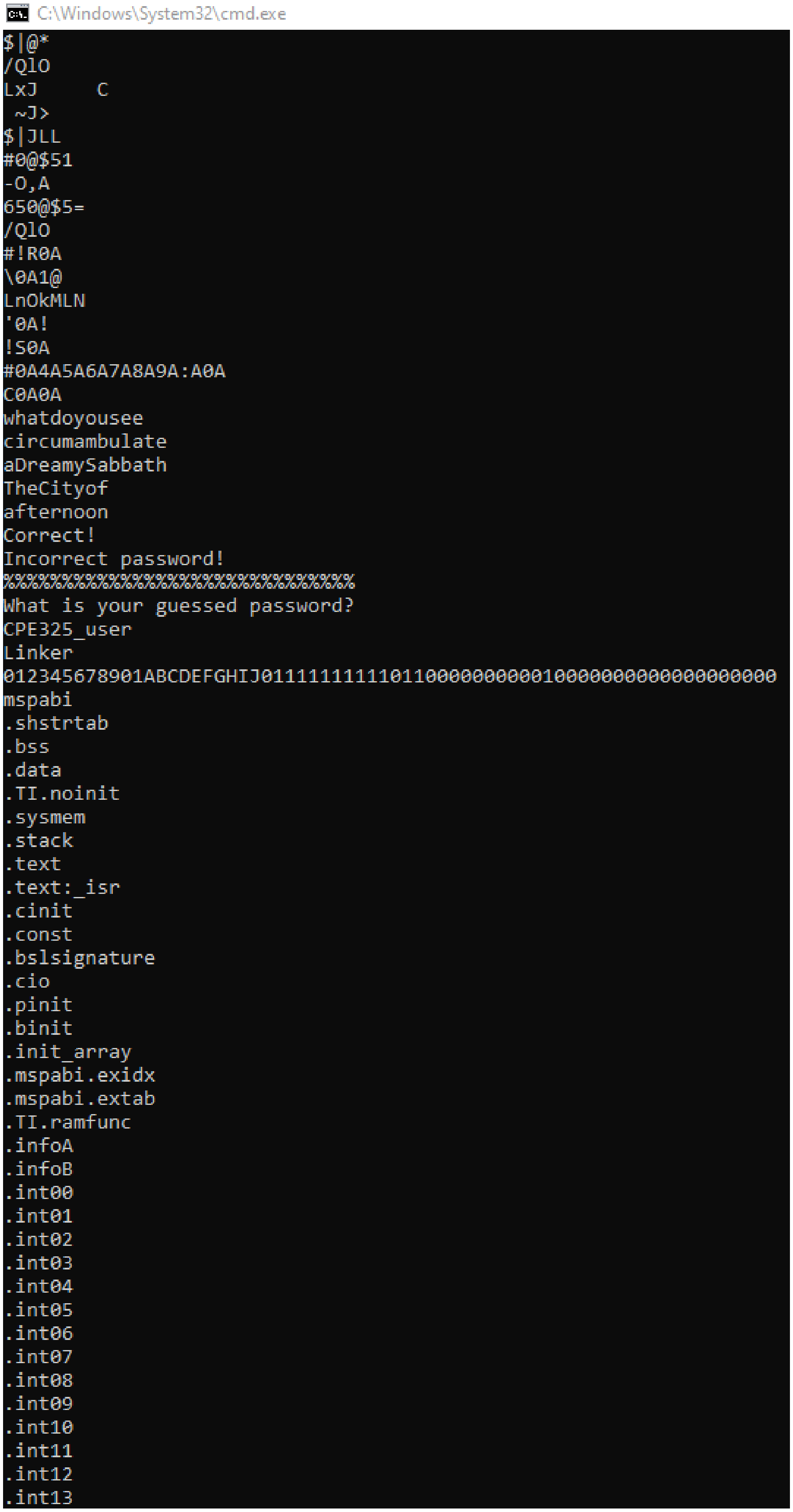
- STEP 1: File downloaded from Canvas and saved in local directory (used downloads folder).
- STEP 2: On CCS, I created a new project, connected the MSP430 board, and loaded the .out file to debug.
- STEP 3: MobaXterm launched, serial connection made with a baud rate of 115,200. Noted the display on the screen prompting for a password.
- STEP 4: Launched a command prompt window and typed in the following commands: msp430-elf-readelf -a Lab11_crack_me_danotieno.out to display the ELF Header, section headers, file attributes, passwords.



```
Microsoft Windows [Version 10.0.22000.376]
(c) Microsoft Corporation. All rights reserved.

C:\Users\dpo0002\Downloads>msp430-elf-readelf -a Lab11_crack_me_danotieno.out
ELF Header:
  Magic:   7f 45 4c 46 01 01 01 ff 00 00 00 00 00 00 00 00
  Class:                             ELF32
  Data:                              2's complement, little endian
  Version:                           1 (current)
  OS/ABI:                            Standalone App
  ABI Version:                       0
  Type:                              EXEC (Executable file)
  Machine:                           Texas Instruments msp430 microcontroller
  Version:                           0x1
  Entry point address:               0x349c
  Start of program headers:          52 (bytes into file)
  Start of section headers:          2260 (bytes into file)
  Flags:                             0xb: architecture variant: MSP430x11
  Size of this header:               52 (bytes)
  Size of program headers:           32 (bytes)
  Number of program headers:         5
  Size of section headers:           40 (bytes)
  Number of section headers:         57
  Section header string table index: 56

Section Headers:
  [Nr] Name              Type            Addr     Off    Size   ES Flg Lk Inf Al
  [ 0]                   NULL            00000000 000000 000000 00      0   0  0
  [ 1] .bss              NOBITS          00000000 000000 000000 00  WA  0   0  1
  [ 2] .data             NOBITS          00001100 0000d4 000001 00  WA  0   0  1
  [ 3] .TI.noinit        NOBITS          00000000 000000 000000 00   p  0   0  1
  [ 4] .sysmem           NOBITS          00000000 000000 000000 00      0   0  1
  [ 5] .stack            NOBITS          000030b0 0000d4 000050 00  WA  0   0  4
  [ 6] .text             PROGBITS        00003100 000124 000438 00  AX  0   0  2
  [ 7] .text:_isr        PROGBITS        000035f2 000616 000008 00  AX  0   0  2
  [ 8] .cinit            PROGBITS        000035fa 00061e 00000e 00   A  0   0  2
  [ 9] .const            PROGBITS        00003538 00055c 0000ba 00   A  0   0  2
  [10] .bslsignature     NOBITS          00000000 000000 000000 00      0   0  1
  [11] .cio              NOBITS          00000000 000000 000000 00      0   0  1
  [12] .pinit            NOBITS          00000000 000000 000000 00      0   0  1
  [13] .binit            PROGBITS        00003100 000124 000000 00   A  0   0  2
  [14] .init_array       INIT_ARRAY      00000000 000652 000000 04  WA  0   0  1
  [15] .mspabi.exidx     NOBITS          00000000 000000 000000 08   A  0   0  1
  [16] .mspabi.extab     NOBITS          00000000 000000 000000 00   A  0   0  1
  [17] .TI.ramfunc       NOBITS          00000000 000000 000000 00      0   0  1
  [18] .infoA            NOBITS          00000000 000000 000000 00      0   0  1
  [19] .infoB            NOBITS          00000000 000000 000000 00      0   0  1
  [20] .int00            NOBITS          00000000 000000 000000 00      0   0  1
  [21] .int01            NOBITS          00000000 000000 000000 00      0   0  1
  [22] .int02            NOBITS          00000000 000000 000000 00      0   0  1
  [23] .int03            NOBITS          00000000 000000 000000 00      0   0  1
  [24] .int04            NOBITS          00000000 000000 000000 00      0   0  1
  [25] .int05            NOBITS          00000000 000000 000000 00      0   0  1
  [26] .int06            NOBITS          00000000 000000 000000 00      0   0  1
  [27] .int07            NOBITS          00000000 000000 000000 00      0   0  1
  [28] .int08            NOBITS          00000000 000000 000000 00      0   0  1
  [29] .int09            NOBITS          00000000 000000 000000 00      0   0  1
  [30] .int10            NOBITS          00000000 000000 000000 00      0   0  1
  [31] .int11            NOBITS          00000000 000000 000000 00      0   0  1
  [32] .int12            NOBITS          00000000 000000 000000 00      0   0  1
  [33] .int13            NOBITS          00000000 000000 000000 00      0   0  1
  [34] DAC12             PROGBITS        0000ffdc 00062e 000002 00   A  0   0  1
  [35] DMA               PROGBITS        0000ffde 000630 000002 00   A  0   0  1
```

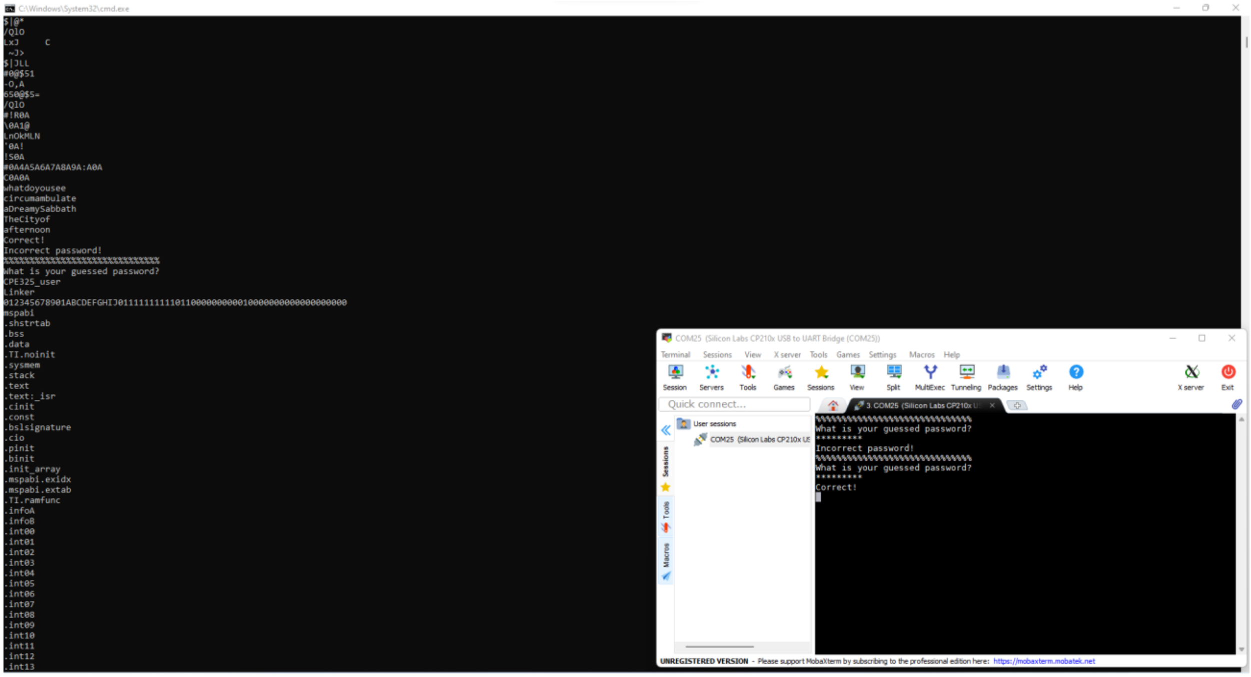


```
  C (compressed), x (unknown), o (OS specific), E (exclude),
  p (processor specific)

There are no section groups in this file.

Program Headers:
  Type           Offset   VirtAddr   PhysAddr   FileSiz MemSiz  Flg Align
  LOAD           0x000000 0x00001100 0x00001100 0x00000 0x00001 RW  0x1
  LOAD           0x0000d4 0x000030b0 0x000030b0 0x00050 0x00050 RW  0x4
  LOAD           0x000124 0x00003100 0x00003100 0x00508 0x00508 R E 0x2
  LOAD           0x00062c 0x0000ffbe 0x0000ffbe 0x00002 0x00002 R   0x1
  LOAD           0x00062e 0x0000ffdc 0x0000ffdc 0x00024 0x00024 R   0x2

 Section to Segment mapping:
  Segment Sections...
   00     .data
   01     .stack
   02     .text .text:_isr .cinit .const .binit
   03     $fill000
   04     DAC12 DMA BASICTIMER PORT2 USART1TX USART1RX PORT1 TIMERA1 TIMERA0 ADC12 USCIAB0TX USCIAB0RX WDT COMPARATORA TIMERB1 TIMERB0 NMI .reset

There is no dynamic section in this file.

There are no relocations in this file.

The decoding of unwind sections for machine type Texas Instruments msp430 microcontroller is not currently supported.

No version information found in this file.
Attribute Section: TI
File Attributes
  Unknown attribute:
  0x00000000 054c696e 6b657200 08160a07 0c018602 .Linker.........
  0x00000010 02870230 31323334 35363738 39303141 ...012345678901A
  0x00000020 42434445 46474849 4a303131 31313131 BCDEFGHIJ0111111
  0x00000030 31313131 30313130 30303030 30303030 1111011000000000
  0x00000040 30313030 30303030 30303030 30303030 0100000000000000
  0x00000050 30303030 30008802 01900201 92020194 00000...........
  0x00000060 02019602 01                         .....

Attribute Section: mspabi
File Attributes
  Tag_ISA: MSP430
  Tag_Code_Model: Small
  Tag_Data_Model: Small
  <unknown tag 10>: 3 (0x3)

C:\Users\dpo0002\Downloads>msp430-elf-strings -a Lab11_crack_me_danotieno.out
5>@!
5>@!
C>@@
A<P@
C>@@
A<P@
A<P@
$|@*
/QlO
LxJ     C
 ~J>
$|JLL
#0@$51
-O,A
650@$5=
/QlO
```



```
$|@*
/QlO
LxJ      C
 ~J>
$|JLL
#0@$51
-O,A
650@$5=
/QlO
#!R0A
\0A1@
LnOkMLN
'0A!
!S0A
#0A4A5A6A7A8A9A:A0A
C0A0A
whatdoyousee
circumambulate
aDreamySabbath
TheCityof
afternoon
Correct!
Incorrect password!
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
What is your guessed password?
CPE325_user
Linker
012345678901ABCDEFGHIJ01111111111011000000000010000000000000000000
mspabi
.shstrtab
.bss
.data
.TI.noinit
.sysmem
.stack
.text
.text:_isr
.cinit
.const
.bslsignature
.cio
.pinit
.binit
.init_array
.mspabi.exidx
.mspabi.extab
.TI.ramfunc
.infoA
.infoB
.int00
.int01
.int02
.int03
.int04
.int05
.int06
.int07
.int08
.int09
.int10
.int11
.int12
.int13
```

- Correct password guess: **TheCityof**



```
$|@*
/QlO
LxJ     C
 ~J>
$|JLL
#0@$51
-O,A
650@$5=
/QlO
#!R0A
\0A1@
LnOkMLN
'0A!
!S0A
#0A4A5A6A7A8A9A:A0A
C0A0A
whatdoyousee
circumambulate
aDreamySabbath
TheCityof
afternoon
Correct!
Incorrect password!
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
What is your guessed password?
CPE325_user
Linker
012345678901ABCDEFGHIJ0111111111101100000000000100000000000000000000
mspabi
.shstrtab
.bss
.data
.TI.noinit
.sysmem
.stack
.text
.text:_isr
.cinit
.const
.bslsignature
.cio
.pinit
.binit
.init_array
.mspabi.exidx
.mspabi.extab
.TI.ramfunc
.infoA
.infoB
.int00
.int01
.int02
.int03
.int04
.int05
.int06
.int07
.int08
.int09
.int10
.int11
.int12
.int13
```

COM25 (Silicon Labs CP210x USB to UART Bridge (COM25))
Terminal
Sessions
View
X server
Tools
Games
Settings
Macros
Help
Session
Servers
Tools
Games
Sessions
View
Split
MultiExec
Tunneling
Packages
Settings
Help
X server
Exit
Quick connect...
3. COM25 (Silicon Labs CP210x U
User sessions
COM25 (Silicon Labs CP210x US
Sessions
Tools
Macros
UNREGISTERED VERSION - Please support MobaXterm by subscribing to the professional edition here: https://mobaxterm.mobatek.net

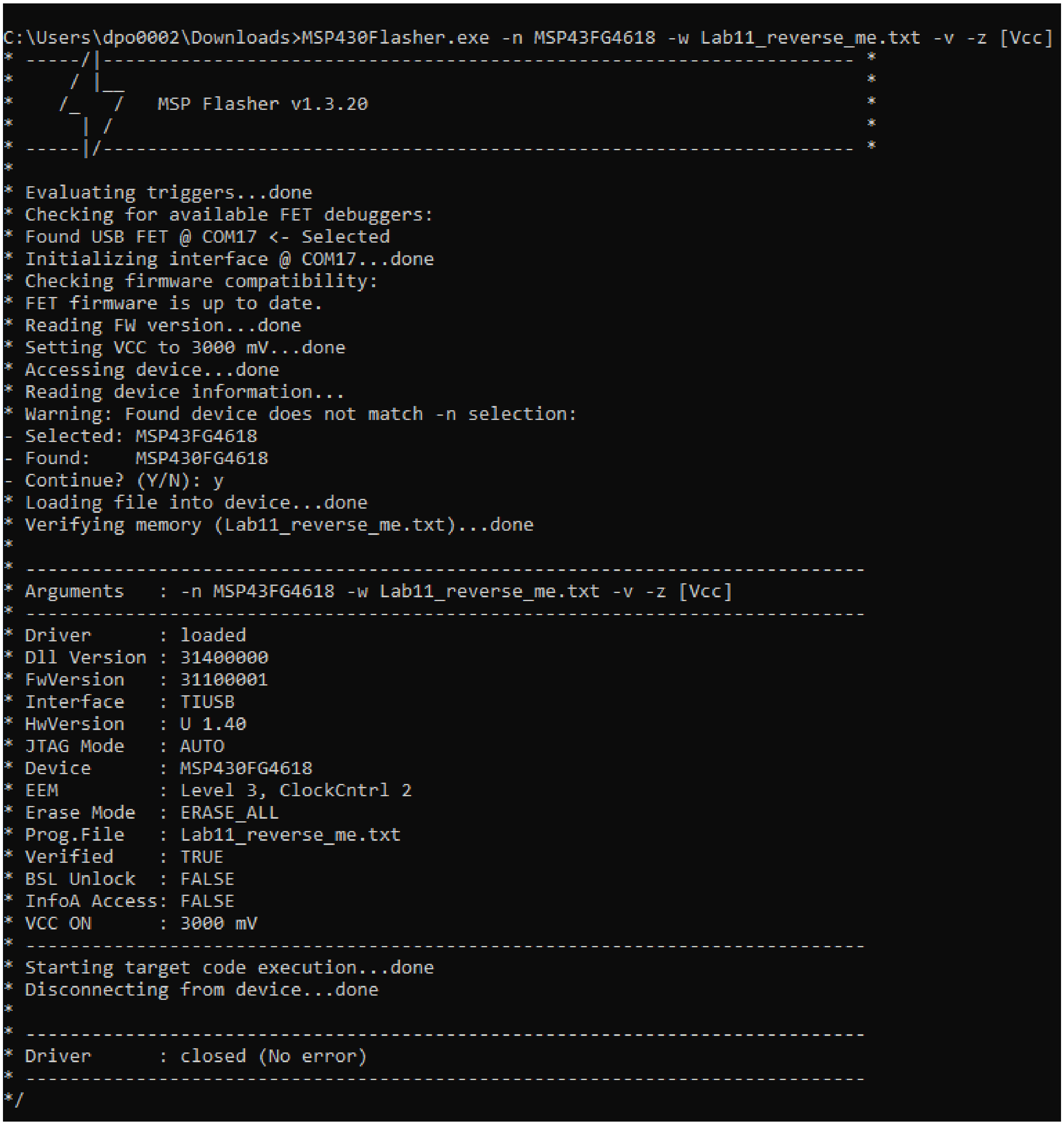
```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
What is your guessed password?
*********
Incorrect password!
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
What is your guessed password?
*********
Correct!
```

Question 3 (Details in the first screenshot above):

a. Magic Number: 7f 45 4c 46 01 01 ff 00 00 00 00 00 00 00 00.
b. Class of .out file: ELF32.
c. Machine the file was built for: Texas Instruments msp430 microcontroller.
d. Size of the header: 52 bytes.
e. Number of section headers: 57. (Verified by running the program twice).

Question 4:

a. Having programmed the Hex file using the MSP430, this was the output in the command window, I forgot to copy the HEX txt file in my USB thumb drive to include in this report, this can demonstrated in the lab.

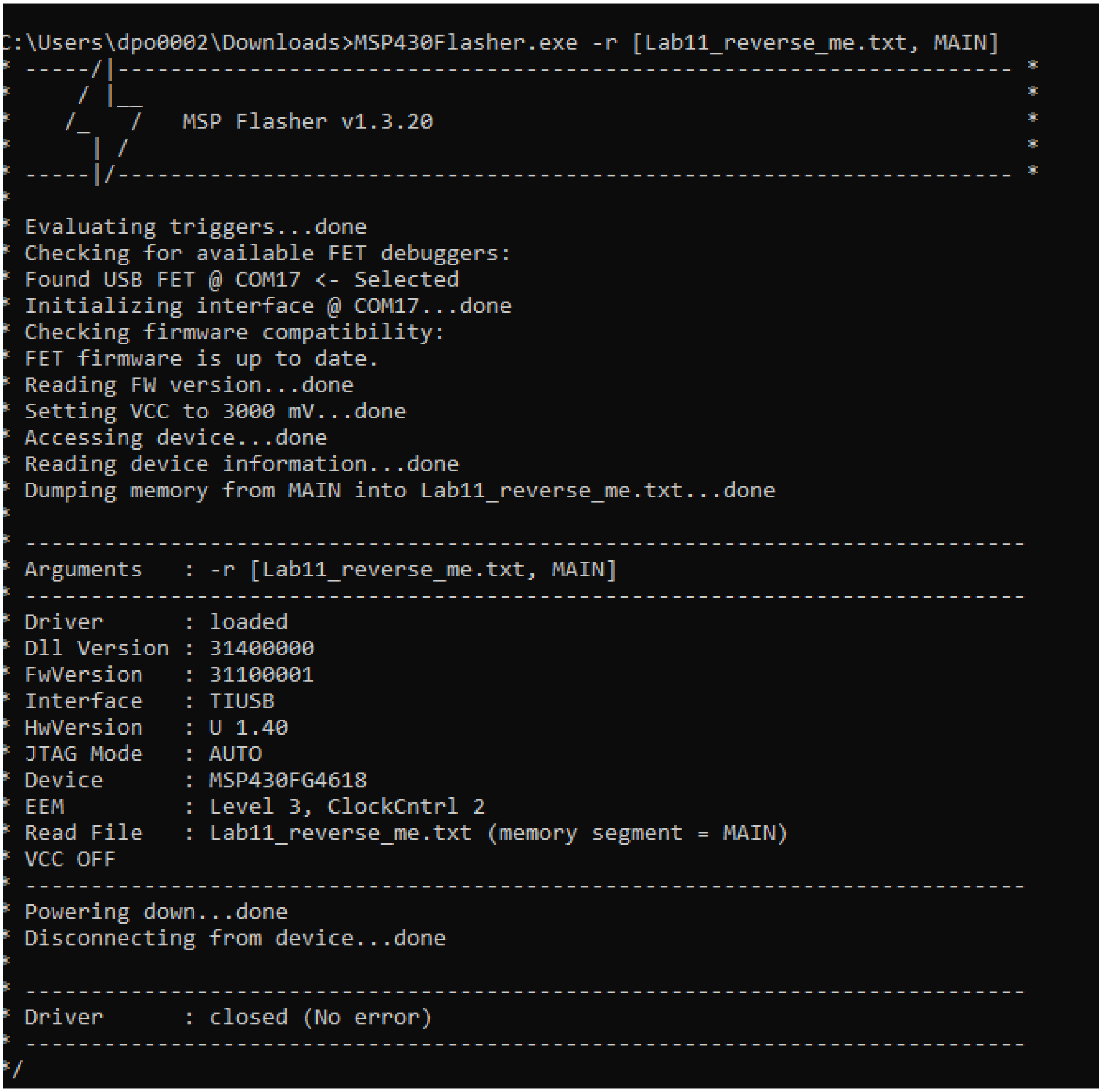


```
C:\Users\dpo0002\Downloads>MSP430Flasher.exe -n MSP43FG4618 -w Lab11_reverse_me.txt -v -z [Vcc]
* -----/|-------------------------------------------------------------------- *
*     / |__                                                                   *
*    /_   /   MSP Flasher v1.3.20                                             *
*      | /                                                                    *
* -----|/-------------------------------------------------------------------- *
*
* Evaluating triggers...done
* Checking for available FET debuggers:
* Found USB FET @ COM17 <- Selected
* Initializing interface @ COM17...done
* Checking firmware compatibility:
* FET firmware is up to date.
* Reading FW version...done
* Setting VCC to 3000 mV...done
* Accessing device...done
* Reading device information...
* Warning: Found device does not match -n selection:
- Selected: MSP43FG4618
- Found:    MSP430FG4618
- Continue? (Y/N): y
* Loading file into device...done
* Verifying memory (Lab11_reverse_me.txt)...done
*
* ----------------------------------------------------------------------------
* Arguments   : -n MSP43FG4618 -w Lab11_reverse_me.txt -v -z [Vcc]
* ----------------------------------------------------------------------------
* Driver      : loaded
* Dll Version : 31400000
* FwVersion   : 31100001
* Interface   : TIUSB
* HwVersion   : U 1.40
* JTAG Mode   : AUTO
* Device      : MSP430FG4618
* EEM         : Level 3, ClockCntrl 2
* Erase Mode  : ERASE_ALL
* Prog.File   : Lab11_reverse_me.txt
* Verified    : TRUE
* BSL Unlock  : FALSE
* InfoA Access: FALSE
* VCC ON      : 3000 mV
* ----------------------------------------------------------------------------
* Starting target code execution...done
* Disconnecting from device...done
*
* ----------------------------------------------------------------------------
* Driver      : closed (No error)
* ----------------------------------------------------------------------------
*/
```

In addition to the HEX file, I also tested the LEDs on the MSP430 board. S1 press toggled the yellow LED on and S2 press toggled the green LED on. However, these presses only worked once, meaning, the outputs were alternating, if, for instance a switch was pressed to turn on the LED, the second LED had to be turned on before we could get the first one to turn on again.

b. From the observation board, I can guess that the program toggles the LEDs in the MSP430 board.

c. Once the step above was completed, the following next two steps were taken to run the naken utility:



```
C:\Users\dpo0002\Downloads>MSP430Flasher.exe -r [Lab11_reverse_me.txt, MAIN]
* -----/|-------------------------------------------------------------------- *
*     / |__                                                                   *
*    /_   /   MSP Flasher v1.3.20                                             *
*      | /                                                                    *
* -----|/-------------------------------------------------------------------- *
*
* Evaluating triggers...done
* Checking for available FET debuggers:
* Found USB FET @ COM17 <- Selected
* Initializing interface @ COM17...done
* Checking firmware compatibility:
* FET firmware is up to date.
* Reading FW version...done
* Setting VCC to 3000 mV...done
* Accessing device...done
* Reading device information...done
* Dumping memory from MAIN into Lab11_reverse_me.txt...done
*
* ----------------------------------------------------------------------------
* Arguments   : -r [Lab11_reverse_me.txt, MAIN]
* ----------------------------------------------------------------------------
* Driver      : loaded
* Dll Version : 31400000
* FwVersion   : 31100001
* Interface   : TIUSB
* HwVersion   : U 1.40
* JTAG Mode   : AUTO
* Device      : MSP430FG4618
* EEM         : Level 3, ClockCntrl 2
* Read File   : Lab11_reverse_me.txt (memory segment = MAIN)
* VCC OFF
* ----------------------------------------------------------------------------
* Powering down...done
* Disconnecting from device...done
*
* ----------------------------------------------------------------------------
* Driver      : closed (No error)
* ----------------------------------------------------------------------------
*/
```

## Program Flowchart:

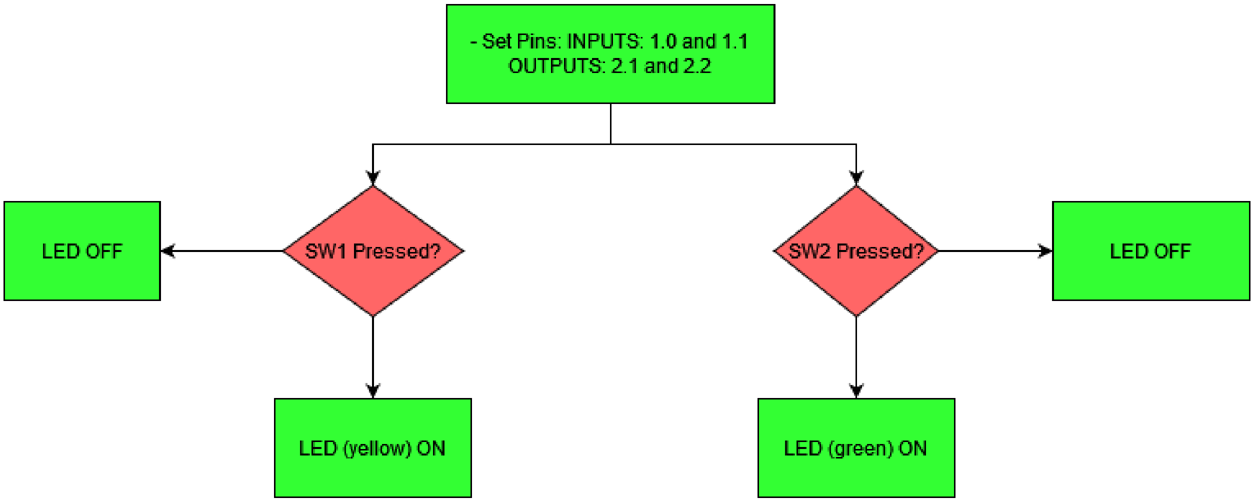


Figure 01: Program flowchart.

# Appendix

Table 01: Commented Assembly output.

```
naken_util - by Michael Kohn
                Joe Davisson
    Web: http://www.mikekohn.net/
  Email: mike@mikekohn.net

Version:

Loaded ti_txt Lab11_reverse_me.txt from 0x3100 to 0x1ffff
Type help for a list of commands.

Addr    Opcode Instruction                              Cycles
------- ------ ----------------------------------       ------
0x3100: 0x40b2 mov.w #0x5a80, &0x0120                5; STOP Watchdog
Timer.
0x3102: 0x5a80
0x3104: 0x0120
0x3106: 0xd2e2 bis.b #4, &0x002a                        4; Bit set.
0x3108: 0x002a
0x310a: 0xd3e2 bis.b #2, &0x002a                        4; Bit set.
0x310c: 0x002a
0x310e: 0xc2e2 bic.b #4, &0x0029                        4; Bit clear (P2.2).
0x3110: 0x0029
0x3112: 0xc3e2 bic.b #2, &0x0029                        4; Bit clear (P2.1).
0x3114: 0x0029
0x3116: 0xc3d2 bic.b #1, &0x0022                        4; Bit clear (P1.0).
0x3118: 0x0022
0x311a: 0xc3e2 bic.b #2, &0x0022                        4; Bit clear (P1.1).
0x311c: 0x0022
0x311e: 0xb3d2 bit.b #1, &0x0020                        4; Check if SW1
pressed.
0x3120: 0x0020
```

```
0x3122: 0x23fd jne 0x311e  (offset: -6)                 2; If not, jmp back
to instruction at 0x311e to check for SW2 via polling.
0x3124: 0x120d push.w r13                               3; Push R13 to
stack.
0x3126: 0x403d mov.w #0x1a08, r13                       2; Mov #0x1a08 into
R13.
0x3128: 0x1a08
0x312a: 0x831d sub.w #1, r13                            1; Subtract 1 from
R13.
0x312c: 0x23fe jne 0x312a  (offset: -4)                 2; JNE to 0x314c,
and keep decrementing by 1.
0x312e: 0x413d pop.w r13   --  mov.w @SP+, r13          2; Pop R13 from
Stack.
0x3130: 0x4303 nop   --  mov.w #0, CG                   1; Delay cycle.
0x3132: 0xd3e2 bis.b #2, &0x0029                        4;
0x3134: 0x0029
0x3136: 0xb3d2 bit.b #1, &0x0020                        4; Check if P2IN is
pressed.
0x3138: 0x0020
0x313a: 0x27fd jeq 0x3136  (offset: -6)                 2; JNE to 0x3158,
sw2 polling.
0x313c: 0xc3e2 bic.b #2, &0x0029                        4; Clear bit P2.1.
0x313e: 0x0029
0x3140: 0xb3e2 bit.b #2, &0x0020                        4; Check if P1IN
pressed.
0x3142: 0x0020
0x3144: 0x23fd jne 0x3140  (offset: -6)                 2; JNE to 0x3140,
check for SW2 press.
0x3146: 0x120d push.w r13                               3; Push R13 onto
stack.
0x3148: 0x403d mov.w #0x1a08, r13                       2; Mov #0x1a08 into
R13.
0x314a: 0x1a08
0x314c: 0x831d sub.w #1, r13                            1; subtract 1 from
R13.
0x314e: 0x23fe jne 0x314c  (offset: -4)                 2; JNE to 0x314c,
decrement by 1.
0x3150: 0x413d pop.w r13   --  mov.w @SP+, r13          2
0x3152: 0x4303 nop   --  mov.w #0, CG                   1; delay cycle.
0x3154: 0xd2e2 bis.b #4, &0x0029                        4; Turn on LED at
P2.2.
0x3156: 0x0029
0x3158: 0xb3e2 bit.b #2, &0x0020                        4; Turn on LED at
P2.1.
0x315a: 0x0020
0x315c: 0x27fd jeq 0x3158  (offset: -6)                 2; JNE to 0x3158,
polling for SW2 press.
0x315e: 0xc2e2 bic.b #4, &0x0029                        4; Clear bit for
P2DIR.
0x3160: 0x0029
0x3162: 0x3fdd jmp 0x311e  (offset: -70)                2; JMP to infinite
loop.
0x3164: 0x4031 mov.w #0x3100, SP                        2; Mov 0x3100 onto
stack pointer.
0x3166: 0x3100
0x3168: 0x12b0 call #0x317e                             5; Call subroutine.
0x316a: 0x317e
```

```
0x316c: 0x430c mov.w #0, r12                            1; Mov 0 into R12.
0x316e: 0x12b0 call #0x3100                             5; Call instruction
at 0x3100 (start of program).
0x3170: 0x3100
0x3172: 0x431c mov.w #1, r12                            1; Mov 1 into R12.
0x3174: 0x12b0 call #0x3178                             5; Call end of
program (0x449a).
0x3176: 0x3178
0x3178: 0x4303 nop   --  mov.w #0, CG                   1; Delay cycle.
0x317a: 0x3fff jmp 0x317a  (offset: -2)                 2; Jump to infinite
loop.
0x317c: 0x4303 nop   --  mov.w #0, CG                   1; Delay cycle.
0x317e: 0x431c mov.w #1, r12                            1; Move 1 into R12.
0x3180: 0x4130 ret   --  mov.w @SP+, PC                 3; Reti instruction
to exit subroutine.
0x3182: 0xd032 bis.w #0x0010, SR                        2; Set bit 2 of SR.
0x3184: 0x0010
0x3186: 0x3ffd jmp 0x3182  (offset: -6)                 2; Jump to infinite
loop.
0x3188: 0x4303 nop   --  mov.w #0, CG                   1; delay cycle.
0x318a: 0xffff and.b @r15+, -1(r15)                     5
0x318c: 0xffff
0x318e: 0xffff and.b @r15+, -1(r15)                     5
0x3190: 0xffff
0x3192: 0xffff and.b @r15+, -1(r15)                     5
0x3194: 0xffff
0x3196: 0xffff and.b @r15+, -1(r15)                     5
0x3198: 0xffff
0x319a: 0xffff and.b @r15+, -1(r15)                     5
0x319c: 0xffff
0x319e: 0xffff and.b @r15+, -1(r15)                     5
0x31a0: 0xffff
0x31a2: 0xffff and.b @r15+, -1(r15)                     5
```