4357. Embedded Firmware Essentials
Homework #2
Jae Yang Park (jaeyangp@gmail.com)

Source

```
//
// HW#02
// Jae Yang Park
//
// Input: Pin# 12 (P0.17)
// Output: Pin# 29 (P0.5)
//

#include "mbed.h"
#include "lpc1768_gpio.h"

#define P0_5_OUT    (unsigned char)(1 << 5)
#define P0_17_IN    (unsigned char)(1 << 1)
#define BIT2_H              (unsigned char)(1 << 1)
#define BIT5_H              (unsigned char)(1 << 5)

Serial pc(USBTX, USBRX);

unsigned char buffer[1024];

void toggle(void)
{
          GPIO0_FIO0DIR0 = P0_5_OUT;   // set P0.5 to output

          while (1) {
                    GPIO0_FIO0SET0 |= BIT5_H;
                    wait_ms(50);
                    GPIO0_FIO0CLR0 |= BIT5_H;
                    wait_ms(50);
          }
}

void sampling(unsigned char *buf)
{
          register unsigned char r0, r1, r2, r3, r4, r5, r6, r7;

          GPIO0_FIO0DIR2 = 0x00;

          r0 = GPIO0_FIO0PIN2;
          r1 = GPIO0_FIO0PIN2;
          r2 = GPIO0_FIO0PIN2;
          r3 = GPIO0_FIO0PIN2;
          r4 = GPIO0_FIO0PIN2;
          r5 = GPIO0_FIO0PIN2;
          r6 = GPIO0_FIO0PIN2;
          r7 = GPIO0_FIO0PIN2;

          buf[0] = r0;
          buf[1] = r1;
          buf[2] = r2;
          buf[3] = r3;
          buf[4] = r4;
          buf[5] = r5;
          buf[6] = r6;
          buf[7] = r7;
}

void serial_prt(void)
{
          int i;
          for (i = 0; i < 1024; i++) {
                    if (*(buffer + i) == 0xfd)
```

```
                        pc.printf("0");
                else
                        pc.printf("1");

                if ((i > 0) && (i % 128) == 0) pc.printf("\n\r");
        }

        pc.printf("\n\r");
        pc.printf("done\n\r");
}

int main(void)
{
        //toggle();

        unsigned char *p = buffer;

        while (p < &buffer[1023]) {
                sampling(p);
                p += 8;
        }

        serial_prt();

        return 0;
}
```

Dump file (after removed mbed functions)

-O0

```
LPC1768.elf:     file format elf32-littlearm

Disassembly of section .text:

00000000 <g_pfnVectors>:
   0:     00 24 00 10 c5 00 00 00 00 00 00 00 00 00 00 00     .$..............
  10:     dd 00 00 00 dd 00 00 00 dd 00 00 00 00 00 00 00     ................
          ...
  2c:     dd 00 00 00 dd 00 00 00 00 00 00 00 dd 00 00 00     ................
  3c:     dd 00 00 00 dd 00 00 00 dd 00 00 00 dd 00 00 00     ................
  4c:     dd 00 00 00 dd 00 00 00 dd 00 00 00 dd 00 00 00     ................
  5c:     dd 00 00 00 dd 00 00 00 dd 00 00 00 dd 00 00 00     ................
  6c:     dd 00 00 00 dd 00 00 00 dd 00 00 00 dd 00 00 00     ................
  7c:     dd 00 00 00 dd 00 00 00 dd 00 00 00 dd 00 00 00     ................
  8c:     dd 00 00 00 dd 00 00 00 dd 00 00 00 dd 00 00 00     ................
  9c:     dd 00 00 00 dd 00 00 00 dd 00 00 00 dd 00 00 00     ................
  ac:     dd 00 00 00 dd 00 00 00 dd 00 00 00 dd 00 00 00     ................
  bc:     dd 00 00 00 dd 00 00 00                             ........

000000c4 <Reset_Handler>:
  c4:     4668            mov     r0, sp
  c6:     f020 0107       bic.w   r1, r0, #7
  ca:     468d            mov     sp, r1
  cc:     b501            push    {r0, lr}
  ce:     f000 f851       bl      174 <main>
  d2:     e8bd 4001       ldmia.w sp!, {r0, lr}
  d6:     4685            mov     sp, r0
  d8:     4770            bx      lr
  da:     bf00            nop

000000dc <Default_Handler>:
  dc:     e7fe            b.n     dc <Default_Handler>
  de:     bf00            nop

000000e0 < Z8samplingPh>:
  e0:     e92d 0ff0       stmdb   sp!, {r4, r5, r6, r7, r8, r9, sl, fp}
  e4:     b082            sub     sp, #8
  e6:     9001            str     r0, [sp, #4]
  e8:     4b20            ldr     r3, [pc, #128]     ; (16c < Z8samplingPh+0x8c>)
  ea:     2200            movs    r2, #0
  ec:     701a            strb    r2, [r3, #0]
```

```
  ee:     4b20              ldr     r3, [pc, #128]      ; (170 <_Z8samplingPh+0x90>)
  f0:     781b              ldrb    r3, [r3, #0]
  f2:     fa5f fb83         uxtb.w  fp, r3
  f6:     4b1e              ldr     r3, [pc, #120]      ; (170 <_Z8samplingPh+0x90>)
  f8:     781b              ldrb    r3, [r3, #0]
  fa:     fa5f fa83         uxtb.w  sl, r3
  fe:     4b1c              ldr     r3, [pc, #112]      ; (170 <_Z8samplingPh+0x90>)
 100:     781b              ldrb    r3, [r3, #0]
 102:     fa5f f983         uxtb.w  r9, r3
 106:     4b1a              ldr     r3, [pc, #104]      ; (170 <_Z8samplingPh+0x90>)
 108:     781b              ldrb    r3, [r3, #0]
 10a:     fa5f f883         uxtb.w  r8, r3
 10e:     4b18              ldr     r3, [pc, #96]       ; (170 <_Z8samplingPh+0x90>)
 110:     781b              ldrb    r3, [r3, #0]
 112:     b2df              uxtb    r7, r3
 114:     4b16              ldr     r3, [pc, #88]       ; (170 <_Z8samplingPh+0x90>)
 116:     781b              ldrb    r3, [r3, #0]
 118:     b2de              uxtb    r6, r3
 11a:     4b15              ldr     r3, [pc, #84]       ; (170 <_Z8samplingPh+0x90>)
 11c:     781b              ldrb    r3, [r3, #0]
 11e:     b2dd              uxtb    r5, r3
 120:     4b13              ldr     r3, [pc, #76]       ; (170 <_Z8samplingPh+0x90>)
 122:     781b              ldrb    r3, [r3, #0]
 124:     b2dc              uxtb    r4, r3
 126:     9b01              ldr     r3, [sp, #4]
 128:     465a              mov     r2, fp
 12a:     701a              strb    r2, [r3, #0]
 12c:     9b01              ldr     r3, [sp, #4]
 12e:     3301              adds    r3, #1
 130:     4652              mov     r2, sl
 132:     701a              strb    r2, [r3, #0]
 134:     9b01              ldr     r3, [sp, #4]
 136:     3302              adds    r3, #2
 138:     464a              mov     r2, r9
 13a:     701a              strb    r2, [r3, #0]
 13c:     9b01              ldr     r3, [sp, #4]
 13e:     3303              adds    r3, #3
 140:     4642              mov     r2, r8
 142:     701a              strb    r2, [r3, #0]
 144:     9b01              ldr     r3, [sp, #4]
 146:     3304              adds    r3, #4
 148:     463a              mov     r2, r7
 14a:     701a              strb    r2, [r3, #0]
 14c:     9b01              ldr     r3, [sp, #4]
 14e:     3305              adds    r3, #5
 150:     4632              mov     r2, r6
 152:     701a              strb    r2, [r3, #0]
 154:     9b01              ldr     r3, [sp, #4]
 156:     3306              adds    r3, #6
 158:     462a              mov     r2, r5
 15a:     701a              strb    r2, [r3, #0]
 15c:     9b01              ldr     r3, [sp, #4]
 15e:     3307              adds    r3, #7
 160:     4622              mov     r2, r4
 162:     701a              strb    r2, [r3, #0]
 164:     b002              add     sp, #8
 166:     e8bd 0ff0         ldmia.w sp!, {r4, r5, r6, r7, r8, r9, sl, fp}
 16a:     4770              bx      lr
 16c:     2009c002  .word   0x2009c002
 170:     2009c016  .word   0x2009c016

00000174 <main>:
 174:     b500              push    {lr}
 176:     b083              sub     sp, #12
 178:     4b08              ldr     r3, [pc, #32]       ; (19c <main+0x28>)
 17a:     9301              str     r3, [sp, #4]
 17c:     e005              b.n     18a <main+0x16>
 17e:     9801              ldr     r0, [sp, #4]
 180:     f7ff ffae         bl      e0 <_Z8samplingPh>
 184:     9b01              ldr     r3, [sp, #4]
 186:     3308              adds    r3, #8
```

```
 188:     9301              str      r3, [sp, #4]
 18a:     9b01              ldr      r3, [sp, #4]
 18c:     4a04              ldr      r2, [pc, #16]      ; (1a0 <main+0x2c>)
 18e:     4293              cmp      r3, r2
 190:     d3f5              bcc.n    17e <main+0xa>
 192:     2300              movs     r3, #0
 194:     4618              mov      r0, r3
 196:     b003              add      sp, #12
 198:     f85d fb04         ldr.w    pc, [sp], #4
 19c:     10000000  .word    0x10000000
 1a0:     100003ff  .word    0x100003ff
```

-O3

```
LPC1768.elf:     file format elf32-littlearm

Disassembly of section .text:

00000000 <g pfnVectors>:
   0:     00 24 00 10 c9 00 00 00 00 00 00 00 00 00 00 00     .$..............
  10:     c5 00 00 00 c5 00 00 00 c5 00 00 00 00 00 00 00     ................
          ...
  2c:     c5 00 00 00 c5 00 00 00 00 00 00 00 c5 00 00 00     ................
  3c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  4c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  5c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  6c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  7c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  8c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  9c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  ac:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  bc:     c5 00 00 00 c5 00 00 00                             ........

000000c4 <Default_Handler>:
  c4:     e7fe              b.n      c4 <Default_Handler>
  c6:     bf00              nop

000000c8 <Reset Handler>:
  c8:     4668              mov      r0, sp
  ca:     f020 0107         bic.w    r1, r0, #7
  ce:     468d              mov      sp, r1
  d0:     b501              push     {r0, lr}
  d2:     f000 f805         bl       e0 <main>
  d6:     e8bd 4001         ldmia.w  sp!, {r0, lr}
  da:     4685              mov      sp, r0
  dc:     4770              bx       lr
  de:     bf00              nop

000000e0 <main>:
  e0:     e92d 47f0         stmdb    sp!, {r4, r5, r6, r7, r8, r9, sl, lr}
  e4:     f04f 0a00         mov.w    sl, #0
  e8:     4b13              ldr      r3, [pc, #76]      ; (138 <main+0x58>)
  ea:     f8df 9054         ldr.w    r9, [pc, #84]      ; 140 <main+0x60>
  ee:     4a13              ldr      r2, [pc, #76]      ; (13c <main+0x5c>)
  f0:     f203 38ff         addw     r8, r3, #1023      ; 0x3ff
  f4:     f889 a000         strb.w   sl, [r9]
  f8:     f892 c000         ldrb.w   ip, [r2]
  fc:     f892 e000         ldrb.w   lr, [r2]
 100:     7817              ldrb     r7, [r2, #0]
 102:     7816              ldrb     r6, [r2, #0]
 104:     7815              ldrb     r5, [r2, #0]
 106:     7814              ldrb     r4, [r2, #0]
 108:     7810              ldrb     r0, [r2, #0]
 10a:     7811              ldrb     r1, [r2, #0]
 10c:     3308              adds     r3, #8
 10e:     f803 cc08         strb.w   ip, [r3, #-8]
 112:     f803 ec07         strb.w   lr, [r3, #-7]
 116:     f803 7c06         strb.w   r7, [r3, #-6]
 11a:     f803 6c05         strb.w   r6, [r3, #-5]
 11e:     f803 5c04         strb.w   r5, [r3, #-4]
 122:     f803 4c03         strb.w   r4, [r3, #-3]
```

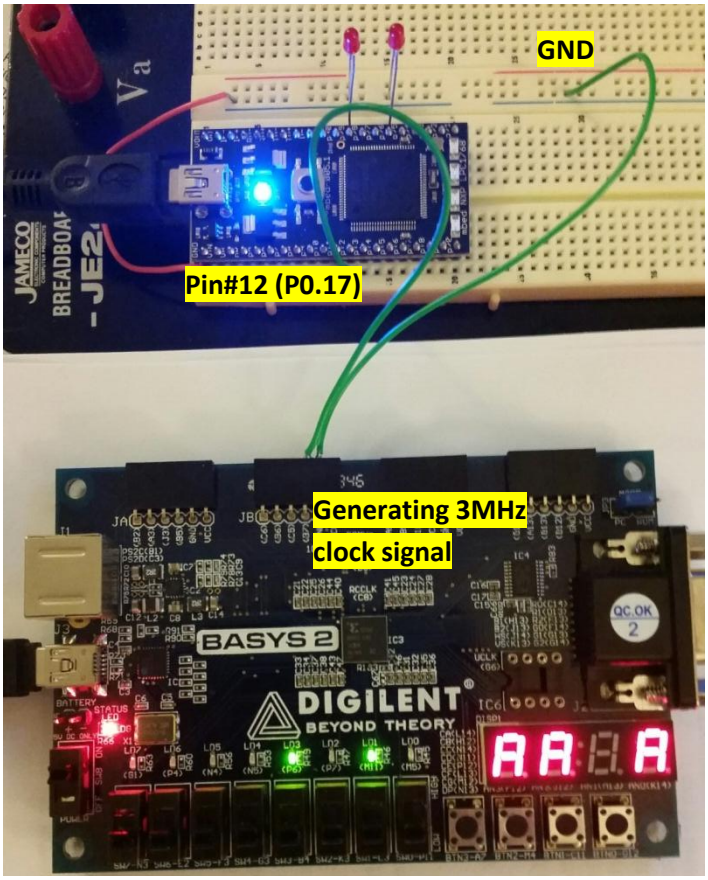
```
 126:     f803 0c02          strb.w    r0, [r3, #-2]
 12a:     f803 1c01          strb.w    r1, [r3, #-1]
 12e:     4543               cmp       r3, r8
 130:     d3e0               bcc.n     f4 <main+0x14>
 132:     2000               movs      r0, #0
 134:     e8bd 87f0          ldmia.w   sp!, {r4, r5, r6, r7, r8, r9, sl, pc}
 138:     10000000  .word    0x10000000
 13c:     2009c016  .word    0x2009c016
 140:     2009c002  .word    0x2009c002
```

-Os

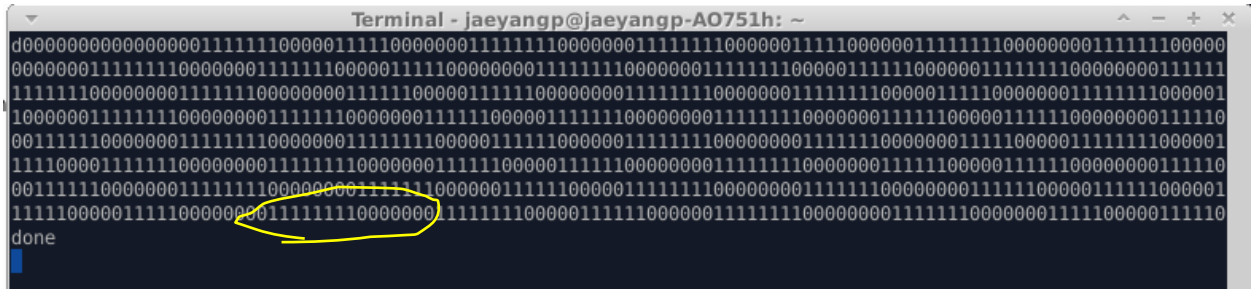
```
LPC1768.elf:     file format elf32-littlearm

Disassembly of section .text:

00000000 <g_pfnVectors>:
   0:     00 24 00 10 c7 00 00 00 00 00 00 00 00 00 00 00     .$..............
  10:     c5 00 00 00 c5 00 00 00 c5 00 00 00 00 00 00 00     ................
          ...
  2c:     c5 00 00 00 c5 00 00 00 00 00 00 00 c5 00 00 00     ................
  3c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  4c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  5c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  6c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  7c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  8c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  9c:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  ac:     c5 00 00 00 c5 00 00 00 c5 00 00 00 c5 00 00 00     ................
  bc:     c5 00 00 00 c5 00 00 00                             ........

000000c4 <Default_Handler>:
  c4:     e7fe               b.n       c4 <Default_Handler>

000000c6 <Reset_Handler>:
  c6:     4668               mov       r0, sp
  c8:     f020 0107          bic.w     r1, r0, #7
  cc:     468d               mov       sp, r1
  ce:     b501               push      {r0, lr}
  d0:     f000 f81e          bl        110 <main>
  d4:     e8bd 4001          ldmia.w   sp!, {r0, lr}
  d8:     4685               mov       sp, r0
  da:     4770               bx        lr

000000dc <_Z8samplingPh>:
  dc:     b5f0               push      {r4, r5, r6, r7, lr}
  de:     4b0b               ldr       r3, [pc, #44]      ; (10c <_Z8samplingPh+0x30>)
  e0:     2200               movs      r2, #0
  e2:     701a               strb      r2, [r3, #0]
  e4:     f893 e014          ldrb.w    lr, [r3, #20]
  e8:     7d1f               ldrb      r7, [r3, #20]
  ea:     7d1e               ldrb      r6, [r3, #20]
  ec:     7d1d               ldrb      r5, [r3, #20]
  ee:     7d1c               ldrb      r4, [r3, #20]
  f0:     7d19               ldrb      r1, [r3, #20]
  f2:     7d1a               ldrb      r2, [r3, #20]
  f4:     3314               adds      r3, #20
  f6:     781b               ldrb      r3, [r3, #0]
  f8:     f880 e000          strb.w    lr, [r0]
  fc:     7047               strb      r7, [r0, #1]
  fe:     7086               strb      r6, [r0, #2]
 100:     70c5               strb      r5, [r0, #3]
 102:     7104               strb      r4, [r0, #4]
 104:     7141               strb      r1, [r0, #5]
 106:     7182               strb      r2, [r0, #6]
 108:     71c3               strb      r3, [r0, #7]
 10a:     bdf0               pop       {r4, r5, r6, r7, pc}
 10c:     2009c002  .word    0x2009c002

00000110 <main>:
 110:     b510               push      {r4, lr}
```

```
112:    4c05                ldr     r4, [pc, #20]      ; (128 <main+0x18>)
114:    4620                mov     r0, r4
116:    f7ff ffe1           bl      dc <_Z8samplingPh>
11a:    4b04                ldr     r3, [pc, #16]      ; (12c <main+0x1c>)
11c:    3408                adds    r4, #8
11e:    429c                cmp     r4, r3
120:    d3f8                bcc.n   114 <main+0x4>
122:    2000                movs    r0, #0
124:    bd10                pop     {r4, pc}
126:    bf00                nop
128:    10000000  .word     0x10000000
12c:    100003ff  .word     0x100003ff
```

Hardware configuration



Serial console window



Sampling Rate calculation
Input signal frequency: **3MHz**
# of sampling: **14 samples**
Sampling rate: **42 MHz**

In the above dump file, with **–O0** option 3 instructions are spent for 1 sampling.
However, with optimization, 1 instruction is needed for 1 sampling.
So, in the non-optimization code, sampling speed will be reduced with 30% (about 12MHz)

Total spent hours: 17 hours

- mbed hardware setting and testing: 5
- Signal generation and test: 5
- mbed signal sampling test: 4
- Report: 3

QUIZ#1

Q1: Is there any compile error with the following code (if any)?

```
unsigned int Arr[16];
3[Arr] = 7;
```

Explain: With gcc, there's no compile error or warning.
Variable name shouldn't be started number and number itself.

Q2: What is the difference between the following 3 statements?

```
const int * px; px is pointer to int const
int const * px; px is pointer to const int
int * const px; px is const pointer to int
```

Is there any compile error for the following cases?

case1: no compile error

```
int x = 13;
const int * px;
px = & x;
```

case 2: no compile error

```
int x = 13;
int const * px;
px = & x;
```

case 3: compile error

```
int x = 13;
int * const px;
px = & x;
```

Explain: px is const pointer to int. So, &x cannot be assigned to px.

Q3: Write a function to set or clear ith bit of a 32-bit register.

Where ith (0-based) := {0, 1, 2, …, 31 }

```
void reg_set(volatile unsigned int * pReg, int ith)
{
    pReg = pReg | (1 << ith);
}
void reg_clear(volatile unsigned int * pReg, int ith)
{
    pReg = pReg & (~(1 << ith));
}
```

Q4: Write a swap function in C.

```
void swap(unsigned int * px, unsigned int *py)
{
    unsigned int ptemp;
    ptemp = *px;
    *px = *py;
    *py = ptemp;
}
```

Q5: What is the output of the following code? (Given: sizeof(unsigned int) is 4) Page 34

```
unsigned int Arr[16];
unsigned int a0 = (unsigned int) &Arr[0];
```

```
unsigned int a3 = (unsigned int) &Arr[3];
printf("%d\n", a3 – a0);

output:12
```

QUIZ #2

Q1: How many microcontrollers in the mbed LPC1768 board?

about 5 (Cortex-M3, Flash memory controller, Power management, Interface microcontroller, Ethernet controller)

Q2: What is the size (in GB) of the Flash Memory ("USB Dsik") of the LPC1768?

16Mbit = 2MB = 0.002GB

Q3: Name 3 functions (or features) that mbed USB cable provided:

1. Power supply
2. USB Disk
3. Serial communication

Q4: What is the name of the Ethernet PHY chip in the mbed board (LPC1768)?

TI DP83848J

Q5: Reference LPC17xx_UM10360.pdf (Chapter 2)

What are the GPIO address window?

0x2009 C000 – 0x2009 FFFF