UNIVERSITY OF GLASGOW

Degrees of MEng, BEng, MSc and BSc in Engineering

Embedded Processors 2 (ENG2029)

Friday 1st May 2015
09.30 – 11.30

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

Attempt all questions

An electronic calculator may be used provided that it does not have a facility for either textual storage or display, or for graphical display.

continued overleaf

Q1 (a) Explain why the I/O pins on a microcontroller have to be initialised before they are used. [2]

The following code, Figure Q1, is executed on a Cortex M0+ microcontroller.

```
#include "mbed.h"

DigitalOut gpo(PTD7);
AnalogOut Aout(PTE30);
unsigned int count, dacvalue;

int main() {
    count=0;
    dacvalue=0;
    while(1) {
        gpo=count & 1;
        Aout.write_u16(dacvalue);
        count++;
        dacvalue++;
    }
}
```

Figure Q1

(b) Which lines of code are responsible for the initialisation of the I/O ports? [2]

(c) The waveform observed at pin 30 of Port E has a period of 8.64 ms. Sketch the waveform. [4]

(d) Sketch the waveform at pin 7 of Port D. [4]

(e) If clock frequency of this Cortex M0+ processor is 48MHz, estimate the number of clock cycles which are occupied by one pass through the loop. [2]

(f) What changes in the original program would be necessary if the period of the waveform at pin 30 of Port was to be reduced to 540 μs? The maximum value of the waveform should remain unaltered. [3]

(g) What changes in the original program would be necessary if the maximum value of waveform at pin 30 of Port E was to be halved? The period of the waveform should remain unaltered. [3]

continued overleaf

Q2 (a) A C program reads from an ADC to measure the voltage across a capacitor. The voltage is first measured just before a switch is closed to allow the capacitor to discharge and thereafter the measurement is repeated at 1ms intervals with the results being stored in an array of 16-bit integers. A dump of the locations in memory where this array has been stored is shown below in Figure Q2A. Determine the number of bits of the ADC and the time constant of the capacitor discharge. [10]

```
1000 FF 0F 18 0D B8 0A C7 08
1008 30 07 E2 05 D1 04 F1 03
1010 3A 03 A4 02 2A 02 C5 01
1018 73 01 30 01 F9 00 CB 00
```

Figure Q2A

(b) A C program contains 3 variables `x`, `y` and `z`, which are all floating point numbers stored in the standard IEEE format. The variable `x`=13.0 and `y`=19.0. Figure Q2B is a memory dump of the area used to store these variables. Verify that the variables `x` and `y` are correctly stored in memory. What are their addresses? Hence find where `z` is stored and determine the value of `z`. [10]

```
1000 03 FF C0 04 C0 04 DE 5B
1008 E3 01 D1 1E 00 FF 34 00
1010 7B 5B 12 32 00 00 C0 C0
1018 00 00 98 41 00 00 50 41
1020 00 00 4E 01 6C 59 00 00
```

Figure Q2B

Q3 (a) By considering a 4-bit number

$$P = P_3 \times 2^3 + P_2 \times 2^2 + P_1 \times 2^1 + P_0 \times 2^0$$

prove that the process of taking the 2's complement of a number gives us a number which represents the negative of the original number, provided that the arithmetic is carried out within 4 bits. [8]

(b) Starting from a 4-bit full adder, design an arithmetic unit which will either add or subtract two 4-bit numbers, A and B. Draw a diagram of your design which shows clearly the external components connected to the inputs of the 4-bit adder and any control lines which are required. [8]

(c) Explain, with reference to the arithmetic unit of part (b), how:

i) two 4-bit numbers A and B can be added and [2]

ii) two 4-bit numbers A and B can be subtracted. [2]

continued overleaf

Q4 (a) What feature distinguishes the Harvard and von Neumann styles of computer architecture? Explain why the designers of the ARM Cortex M3 used a form of Harvard Architecture which incorporated separate buses for:

(i) fetching instruction,

(ii) retrieving constants and

(iii) loading or storing variables in RAM, and performing I/O. [8]

(b) The program of Figure Q4 is executed on a *Freescale Freedom Board*, which has a Cortex M0+ processor operating at a clock speed of 48 MHz.

```
#include "mbed.h"

DigitalOut gpo(PTD6);
AnalogOut Aout(PTE30);
AnalogIn Ain(PTB1);
unsigned int i,j;

int main() {
    i=0;
    j=0;
    while(1) {
        gpo=j & 1;
        j++;
        i=Ain.read_u16();
        Aout.write_u16(i);
        wait(0.001);

    }
}
```

Figure Q4

(i) Sketch the output you would expect to see at pin D6. [4]

(ii) If a 100 Hz sine wave is connected at the input pin B1, sketch what you would expect to see at output pin E30. On the same diagram show the input signal connected to B1. [8]

continued overleaf

Q5 (a) Describe the way in which data can be transmitted between two microcontrollers in asynchronous serial format. In your answer define what is meant by the terms *start bit, stop bit,* and *baud rate*. [6]

(b) The following program, Figure Q5, is executed on a *Freescale Freedom* Board. Sketch the waveforms as observed at pins A2 and D7. You answer should show the transmission of 2 characters. [7]

```
#include "mbed.h"

DigitalOut gpo(PTD7);
Serial async_port(PTA2,PTA1);
char x,count;

int main() {
    async_port.baud(9600);
    x=0x35;
    count=0;

    while(1) {
        gpo=count & 1;
        async_port.putc(x);
        count++;
    }
}
```

Figure Q5

(c) This continuous stream of transmitted data is received by a second *Freedom* Board. However, when the receiving board is restarted, it sometimes receives another character instead of 0x35. Explain why this happens and determine one possible alternative character. [7]

End of question paper