Solutions to Homework Problems

ENCE361 Embedded Systems 1

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Lecture 2

- Homework: What does the following code do?

```
CMP R0, #9;          // Compare R0 with 9
ITE GT;
ADDGT R1, R0, #55;   // If R0 ≥ 9, R0 = R0 + 55, converting R0 (A ~ F) to its ASCII code ('A' is 65)
ADDLE R1, R0, #48;   // If R0 ≤ 9, R0 = R0 + 48, converting R0 (0 ~ 9) to its ASCII code ('0' is 48)
```

Lecture 4 (1)

1. According to Shannon-Nyquist theorem, we must sample at more than twice the highest frequency to reproduce the original waveform. Why not sampling **at** twice the highest frequency?

Suppose we sample a sine wave $\sin(2\pi t)$ at twice the highest frequency which is 1Hz. The sampling frequency is 2Hz and the obtained samples are $\sin(2\pi*0.5n) = \sin(\pi n) = 0$, $n = 0, 1, 2, \ldots$ This means that we may interpret a signal if we sample at just twice the highest frequency. Increasing the sampling rate can mitigate this problem.

2. What is the condition called that refers to the distortion caused by sampling below the Nyquist rate?

Aliasing

Lecture 4 (2)

1. Slide 9 outlines and mathematically defines ideal sampling. What does $1/T_s$ represent and what units does it have?

T_s : sampling interval in seconds.

$1/T_s$: sampling frequency in Hz or samples/second.

2. If signal averaging (see slide 14) is used for sampling an input signal of with a highest frequency f_{max}, what is the relationship between M, f_{max} and the sampling rate f_s to ensure that the signal averaging operation does not introduce significant aliasing?

We need to sample with a sampling rate of at least $2*M*f_{max}$

Lecture 5

1. What type of ADC is used on the Tiva C-Series Launchpad?

   Successive-approximation based ADC

2. What common instrument uses a dual-slope integrating ADC?

   Instrument such as digital multimeter (DMM)

3. How many analog channels are supported by the Tiva C-Series Launchpad ADC?

   8

4. What is the range of quantisation error in volts for an 8-bit quantiser with an input range 0 – 3 V?

   Quantisation step $\Delta = (V_{max} - V_{min})/ 2^N = 3/2^8 = 11.7$ mV

   Range of quantisation error $[-\Delta/2, \Delta/2] = [-5.85, 5.85]$ mV

5. If the maximum signal frequency is 500 Hz and 12-bit quantization is being performed with signal averaging over 15 consecutive samples, what is the minimum sampling rate?

   $2 * 500 * 15 = 15$ kHz

Lecture 6

2. In the example with SNR = 20 dB shown on slide 12, the average power of the signal is 0.9 W (ignoring the DC offset). What is the average power of the noise?

   20 dB = $10\log_{10}$(signal power/noise power)

   Signal power = 0.9 W = 100 * noise power

   Noise power = 0.009 W

3. In slide 13, explain why the noise amplitude on the right (obtained via signal averaging with M=32) is significantly less than that on the left (obtained via signal averaging with M=16).

   The noise is periodic with a period of 100/2.5Hz = 40 samples. When M = 16, the noise samples within the averaging window may have the same sign, which leads to greatly reduced noise attenuation capability. When M = 32, the noise samples within the averaging window would cancel one another, which indicates strong noise suppression.

Lecture 7 (1)

1. Can the ADCdemo1.c program achieve a comparable performance without using interrupts? If so, how? If not, why not?

The ADC can be triggered using a general-purpose timer with periodic time-outs. This would be as effective as using SysTick interrupts to trigger the ADC.

The difficulty lies with storing the sampling results once they are obtained. Polling of the ADC to check if an ADC conversion is completed would have to be at least as frequent as the sampling rate. This leads to waste of processor clock cycles.

Lecture 7 (2)

1. In general, how can a compiler decide which of the registers need to have their contents saved as part of the context?

The compiler can look at which of the general purpose registers are being used in the compiled ISR; in principle only the contents of those registers (in addition to the Program Counter, Status Register and Link Register) need to be included in the context.

If a function is called with an ISR, it would be difficult for the compiler to discover the information about which registers are used within the function, so it has to assume that all registers will be used and need to be saved as context at the beginning of the ISR.