UNIVERSITY OF SWAZILAND

MAIN EXAMINATION 2005/2006

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRONIC ENGINEERING

TITLE OF PAPER: DIGITAL SIGNAL PROCESSORS

COURSE NUMBER: E420

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. **Answer any <u>FOUR</u> (4) of the following six questions.**
2. **Each question carries 25 marks.**

THIS PAPER SHOULD NOT BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR

THIS PAPER CONTAINS SEVEN (7) PAGES INCLUDING THIS PAGE

QUESTION 1

(a) A waveform is sampled at 1 KHz, the sampled voltages being 0.25, 1.5, 1.0, 0.25 V. By means of DFT, determine the Fourier transform of the waveform. What is the first harmonic frequency? What is the Fourier component at the first harmonic frequency?

[15 marks]

(b) The analog input to a DSP system is digitized at a rate of 50 KHz with uniform quantization. Assuming a sine wave input with a peak-to-peak amplitude of ±5 V, find the minimum number of bits for the ADC to achieve a SQNR of at least 90 dB.

[10 marks]

QUESTION 2

(a) By means of the method of residues, obtain the first three samples of the signal corresponding to the z-transform:

$$X(z) = \frac{z^2 + 2z + 1}{z^2 + 1.5z + 0.56}$$

[10 marks]

(b) Find and sketch the z-plane poles and zeros of the transfer function:

$$H(z) = \frac{(z+1)(z^2 + 1.6z + 0.68)}{z^3 + 0.8z^2}$$

Determine the magnitude and phase of the system's frequency response at dc, ¼ and ½ the sampling frequency.

[15 marks]

QUESTION 3

(a) A time-limited digital signal x(n) has just four nonzero sample values, starting at n = 0:

4, -2, 1, 1

(i) Write down the difference equation of the causal, minimum-delay, matched filter for this signal.

[2 marks]

(ii) Calculate the output sample values from the filter when the signal sample sequence (-2, 4, -2, 1, 1, 2) is delivered to its input, using cross correlation. At what instant does the peak output value occur?

[13 marks]

(b) Determine the output of an electrical system of impulse response function {0, 0.5, 0.65. 0.35, 0} when the input {0, 2.5, 5.0, 0} (volts) is applied, by convolution.

[10 marks]

QUESTION 4

(a) Obtain the coefficients and then write the difference equation of a seven-tap (N = 7) linear phase high-pass filter using the Hanning window to satisfy the following amplitude response specifications:

Sampling frequency	10 KHz
Cutoff frequency	1.2 KHz

Ideal impulse response $h_D(n)$ for a high-pass filter is given by

$$h_D(n) = -2f_c \frac{\sin(n\omega_c)}{n\omega_c}, \qquad n \neq 0$$
$$= 1 - 2f_c, \qquad n = 0$$

For the Hanning window,

$$w(n) = 0.5 + 0.5\cos\left(\frac{2\pi n}{N}\right)$$

[13 marks]

(b) An analog filter is to be converted into an equivalent IIR digital low-pass filter with a cutoff frequency of 5 KHz and a sampling frequency of 25 KHz. The analog filter has the transfer function:

$$H(s) = \frac{1}{s^2 + 2s + 1}$$

Obtain suitable coefficients for the IIR digital filter using the bilinear z-transform method. (Hint: low-pass to low-pass transformation is given by $s = \frac{s}{\omega_p}$.)

[10 marks]

QUESTION 5

(a) A 60 Hz sinusoidal signal is sampled at 500 samples per second and analyzed using a 64-point FFT.

(i) Which spectral two coefficients will be the largest?

[5 marks]

(ii) Find the sampling rate closest to 500 samples/second which will eliminate spectral leakage.

[5 marks]

(b) By means of an 8-point FFT, obtain the power density spectrum of the data {0, 1, 0, 1, 0, 1, 0, 1}. Use the window function {0, 0.5, 1, 1, 1, 1, 0.5, 0}.

[15 marks]

QUESTION 6

(a) Briefly explain how the following techniques enhance throughput in digital signal processors.

(i) Harvard architecture
(ii) Pipelining
(iii) Hardware multiplier-accumulator;
(iv) very long instruction word architecture;
(v) Single instruction, multiple data (SIMD).

[15 marks]

(b) A digital signal processor has a multiplier-accumulator with three pipe stages. Assume a memory access time of 120 ns, multiplication time of 100 ns, addition time of 100 ns, and overhead of 5 ns at each pipe stage. Determine the throughput of the MAC.

[5 marks]

(c) Represent the number 0.7825 as a Q7 number.

[5 marks]