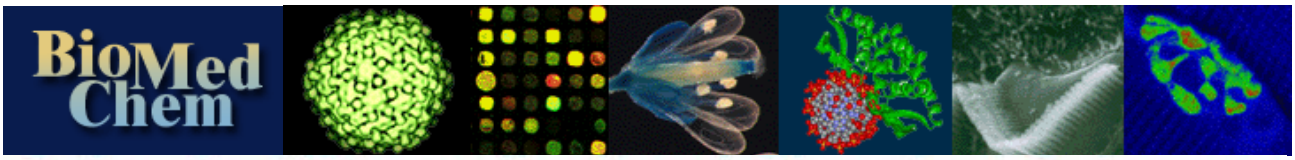


School of Biomedical and Chemical Sciences

THE UNIVERSITY OF WESTERN AUSTRALIA

FACULTY OF Life and Physical Sciences

First Semester **June 2001**

Student Number _____

Surname _____

Given name _____

Audiological Instrumentation 511

INSTRUCTIONS

Time allowed: 3 hours

Reading time: 10 minutes

This paper contain 2 parts on 10 pages

Part A is worth 30 marks & contains short answers
ANSWER ALL QUESTIONS IN AN ANSWER BOOKLET

Part B is worth 70 marks& contains 5 essays
ANSWER 4 of the 5 ESSAYS

The University of Western Australia

Part A – Short answer questions. Answer in the spaces provided.
Answer ALL questions which are worth equal marks.

Imagine you are developing a Macedonian version of a speech discrimination test already available in English. You have paid $1000 to the great Macedonian actress, Ms. Lena Guleva (visiting from Skopje to perform for The Perth International Festival), and another $1000 to an unknown and highly suspect local recording studio. The studio have finally provided you with an audio CD of Lena's speech material. On listening to the CD, you are moved by Lena's rendition of "The Australian Hearing AB Word List in G#minor", but notice a background noise on all recordings, and a distinct rasping character to her voice. It sounds like distortion! You check your sound system with a music CD and it sounds fine. You then record a track from the CD as a wave file using the program Sound Forge, using 16 bit resolution and a 44.1kHz sample rate, and analyse the sound quality using the spectrum analysis facility in Sound Forge. A sample of the recorded time waveform is shown in Figure 1A, and the spectrum of this sound sample is shown in Figure 1B. Answer the following questions.

(a) What is meant by the statement that your recording is made with 16 bit resolution?

(b) What is meant by the term "quantization noise", and explain whether you would expect the quantization noise to be larger or smaller with 16 bit rather than 8 bit resolution?

(c) What is meant by a 44.1kHz sample rate?

(d) There are three major problems with the waveform recorded on the CD, as shown in Figure 1A that could be causing the problems during CD playback? What three problems can you see?

Figure 1A Sample time waveform from your audio CD

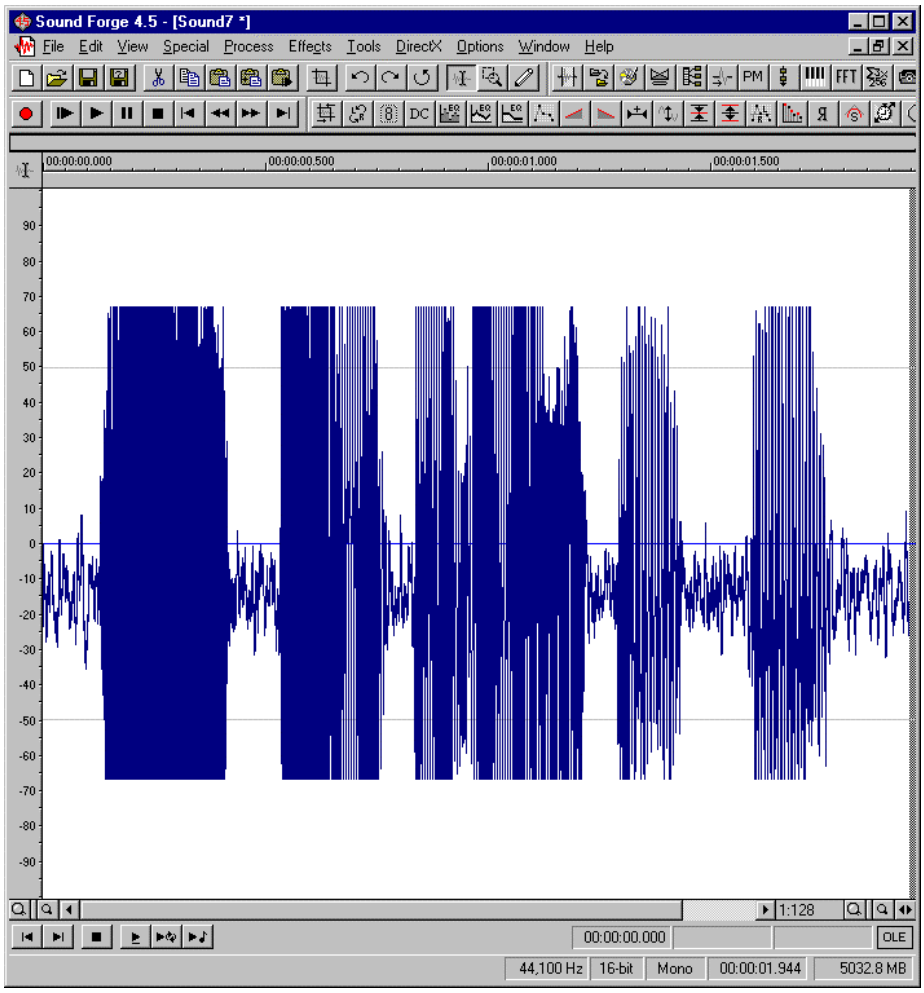
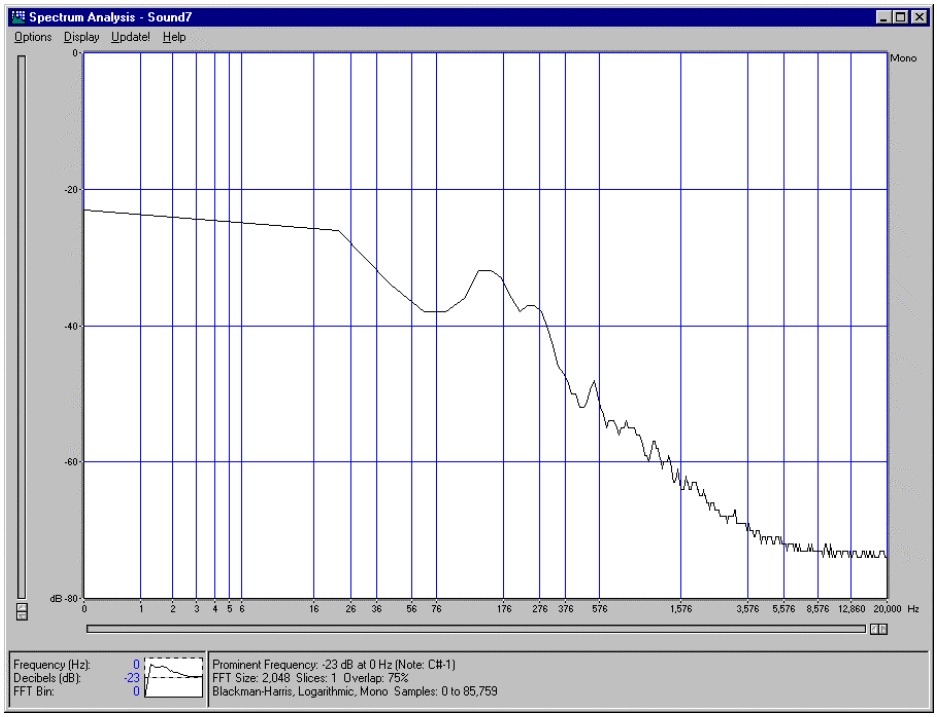


Figure 1B spectrum of sample time waveform of Figure 1A



(e) In the gap between words in your speech CD, you notice a background noise. You sample the signal in the gap between words (Figure 1C), and obtain the spectrum of this background noise. Describe the nature of the background noise.

(f) Is there a DC offset in the recording, and if so, what is it?

(g) If the Sound Forge displays the time waveform in millivolts on the vertical scale, what is the approximate amplitude of the speech signal and of the background noise?

(h) From the time-waveform, estimate the signal-to-noise ratio of the CD recording in linear and logarithmic terms?

(i) Is there any distortion evident in the time waveform of Figure 1A, and if so, describe the distortion and suggest how it might appear in the signal's spectrum in Figure 1B?

Figure 1C Sample of the sound signal between words in the speech signal

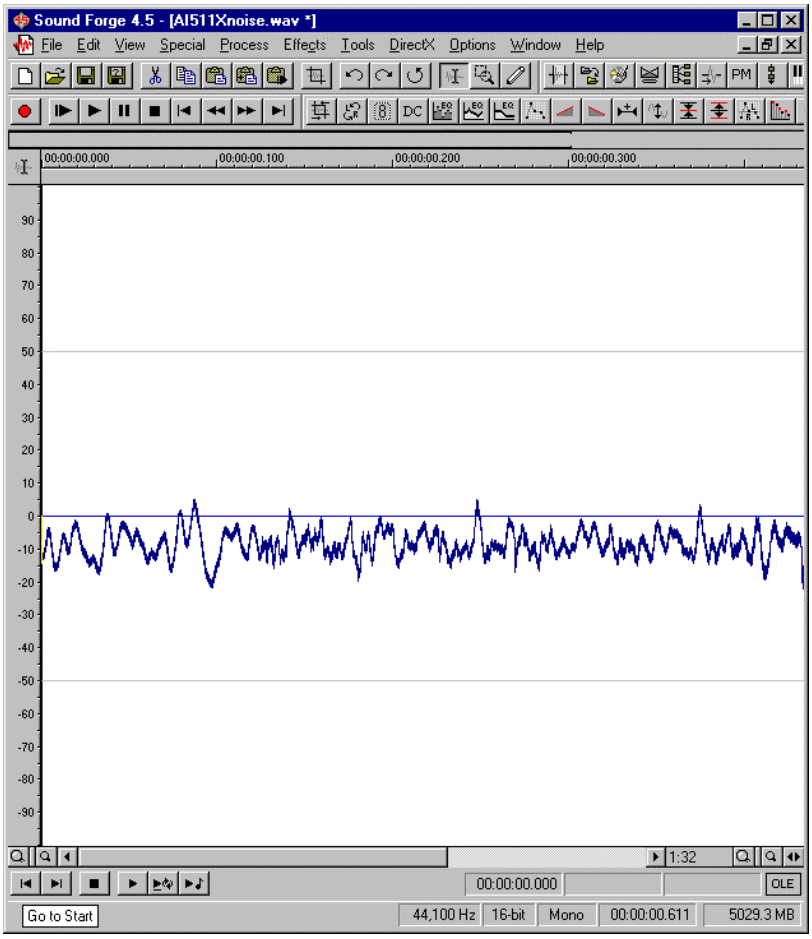
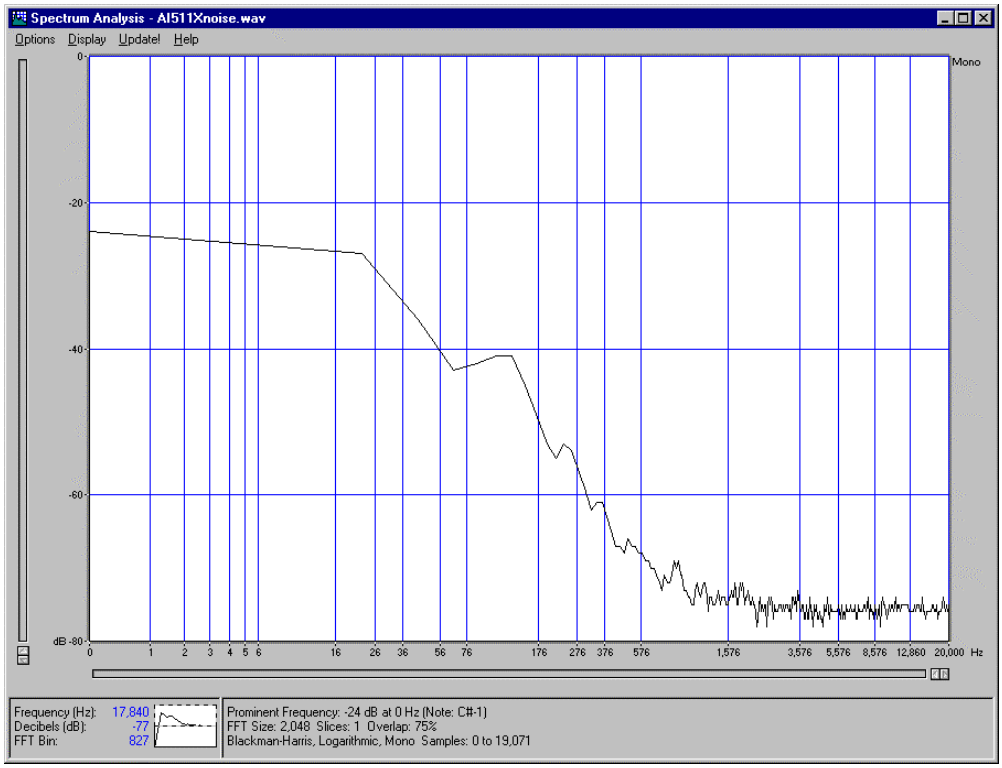


Figure 1D Spectrum of the non-voice signal of Figure 1C



(j) The sound recording of the CD also has a distinct muffled sound to it. What feature in the spectrum of the signal in Figure 1B is consistent with this observation?

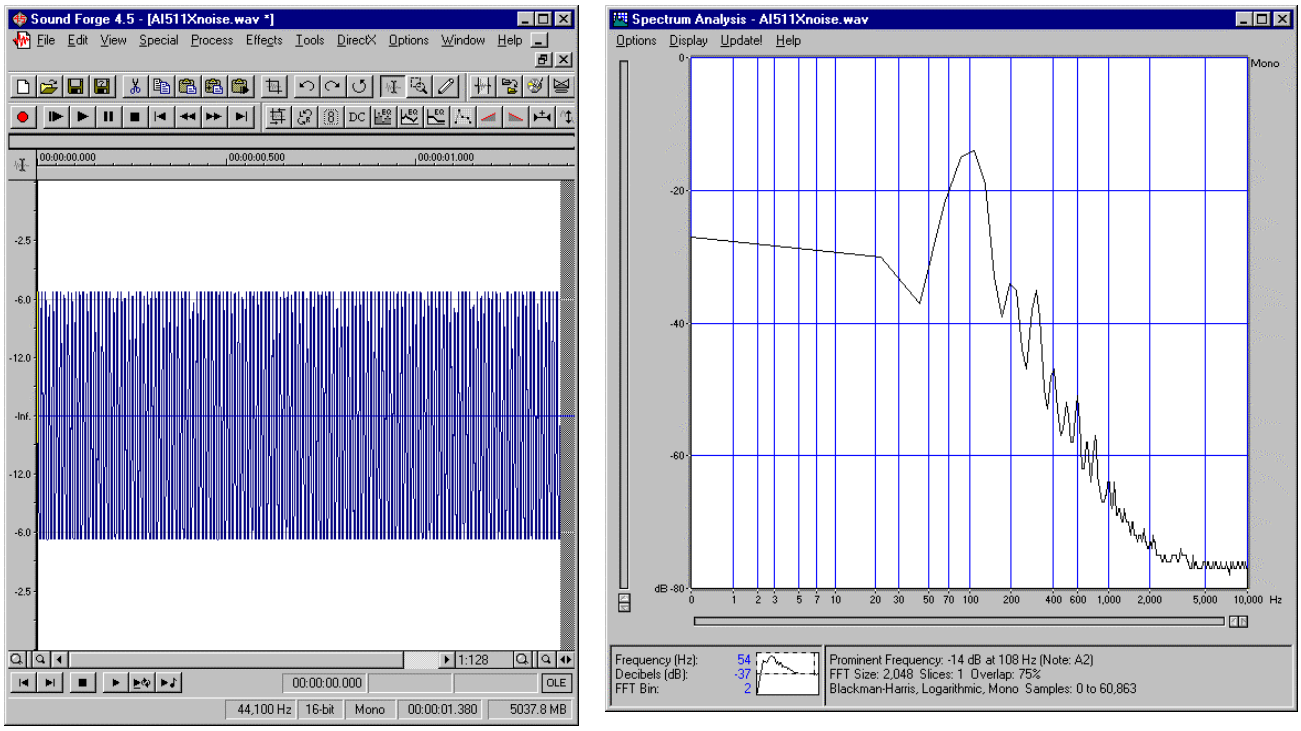


Figure 2. The time waveform (left) and spectrum (right) of the 100Hz test sinusoid.

(k) The 100Hz test tone that you required on the CD also seemed to have problems, as shown in Figure 2 above. What is wrong with the test tone, and explain the problem in terms of its time waveform and its spectrum in Figure 2? Comment on the frequency components evident in spectrum of Figure 2

After correcting the problems with your speech test, you change your employer and become head audiologist at a large teaching hospital. One of your responsibilities is the co-ordination of a large neonatal screening program, based on Auditory Brainstem Response (ABR) averaging. Part of your role is the selection of the equipment. You are also required to set-up and run the electro-cochleography (ECoG) facility for the new cochlear implant program. Your big hope is that the same equipment can be used for both purposes. The specifications for the input amplifier of one ABR machine are shown in Figure *. In particular you are interested in the noise performance and frequency response of the system. There are a few facts you have noted in considering the equipment.

(a) The ABR signal at the skin has an amplitude of 1μVpp.

(b) The electromyographic (EMG) signal from interfering muscles during ABR has an amplitude of 100μVpp.

(c) The ECoG signals range from 1μVpp for the compound action potential near threshold

(d) The low-frequency cochlear microphonic (CM) at high sound levels is about 1mVpp.

(e) You also hope to measure the summating potential (SP) evoked by 100ms tone-bursts.

(f) The averager is also capable of averaging up to 10,000 presentations of the stimulus.

What does the term "1μVpp" mean?

Consider the ABR signal (1μVpp) in the presence of the EMG signal (100μVpp). What is the signal-to-noise ratio in linear terms and in logarithmic terms?

If you could average the ABR over 10,000 stimulus presentations, what would be the new signal-to-noise ratio?

What does such a signal to noise ratio mean in practical terms? That is, what would the final averaged waveform look like in terms of the signal versus the noise?

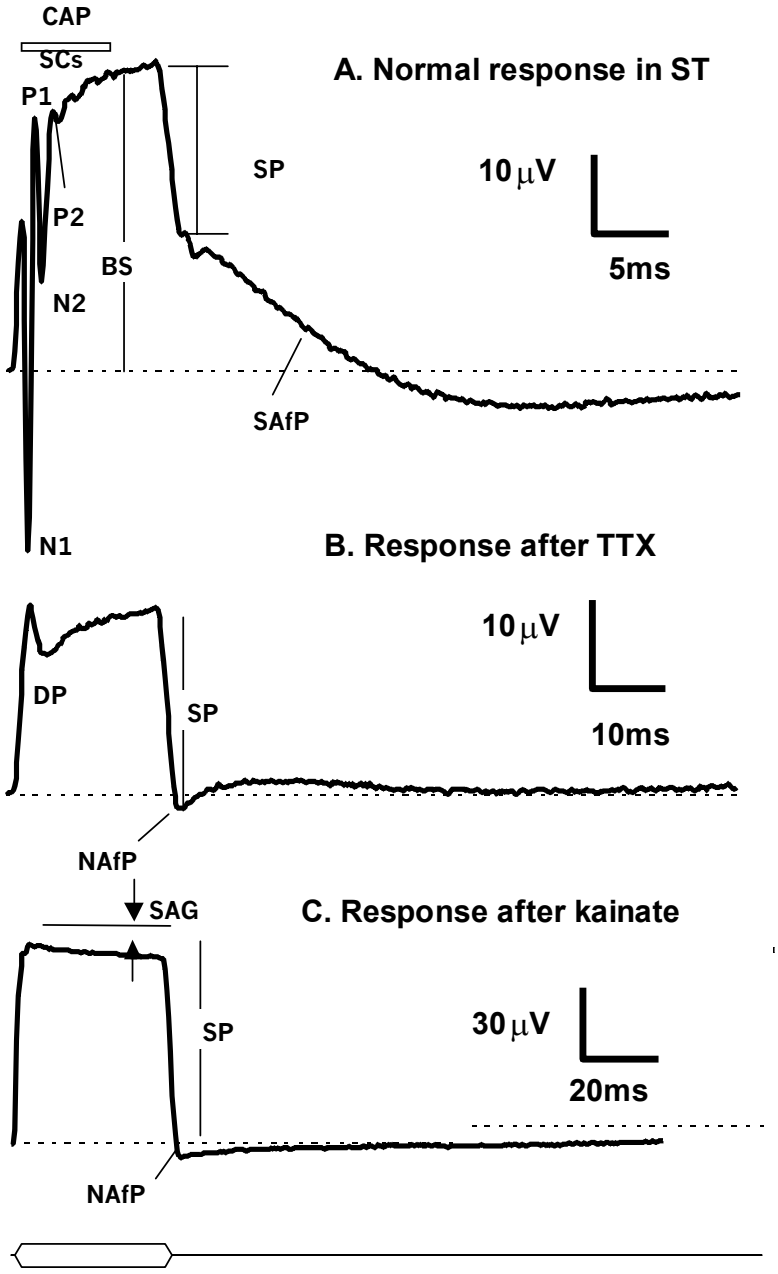


Figure 5. Waveforms recorded at the round window in response to a high-frequency tone-burst at 10kHz. The filter bandwidth was 1Hz to 3kHz, and the waveforms have been averaged over 200 stimulus presentations. (A) Normal waveform, (B) after tetrodotoxin which blocks neural action potentials but not neurotransmission, and (C) after block of neurotransmission by the drug kainate (only the CM and SP remain).

Essay Questions.

Write an essay on four of the following 5 topics.

1. Write an essay on the feedback equation, including reference to the open-loop gain (A), the feedback gain (β), the total loop gain (Aβ) and the closed loop gain (G). Define these terms and give an example of the relevance of the feedback equation to audiology (for example, within the cochlea or in hearing aid design).

2. Write and essay on the differences between an Helmholtz resonator and an organ pipe resonance. Explain what determines the resonances in each case, and explain how this is relevant to acoustic probe tubes and in-the-ear calibration of hearing aids.

3. Write an essay on spectral analysis of complex sounds, and the role of distortion in determining the harmonic content of sound. You should mention the importance of distortion symmetry in determining a sound's harmonic content, and describe how the frequencies of the two tones fed through a distorting system are related to the frequencies of the system's output. Also describe the issue of phase distortion and waveform shape.

4. A filter/amplifier can be specified in many ways, but most often the system's gain, distortion and signal-to-noise ratio are provided, together with the filter specifications. Explain the meaning of the terms gain, distortion, signal-to-noise ratio and dynamic range, and describe in detail how the performance of a filter is specified.

5. Explain the workings of dynamic (magnetic) microphones and electret/condensor microphones, and of a typical magnetic speaker. How is the performance of a microphone and speaker specified, and what determines the frequency response of these devices?