Biomedical Signal Processing

1. (20%) Analog-to-digital converter (ADC) converts an analog voltage to an equivalent digital number. (a) Explain the two slicing characteristics of ADC, the sampling and quantization, and give examples. (b) Explain the aliasing effect and propose two strategies to deal with aliasing. Give examples.

2. (30%) A group, or ensemble, of time responses averaged together on a point to point basis means ensemble averaging or synchronized averaging. (a) Given two essential requirements to apply ensemble averaging. (b) For the signal with additive random noise of zero mean that is uncorrelated with the signal. Explain the change of SNR corresponding to M epochs or trials of synchronized signals are averaged.

3. (30%) The function of a filter is to retain the components in certain frequency ranges and reject components in other ranges. There are various types of filters such as low-pass, high-pass, band-pass filters, etc. (a) For the noisy ECG signals in Figs. 3-1 and 3-2, which type of filter should be applied to each noisy signal? Explain the frequency characteristics of the signal and noise for each case. (b) For a signal with sampling rate of 1000 Hz, design a digital notch filter by placing the zeros at 60 and -60 Hz in the z-plane to remove 60Hz power-line noise.

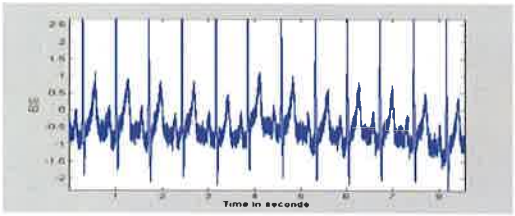


Fig. 3-1

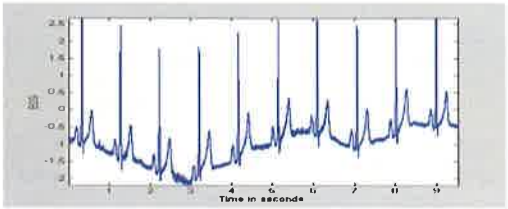
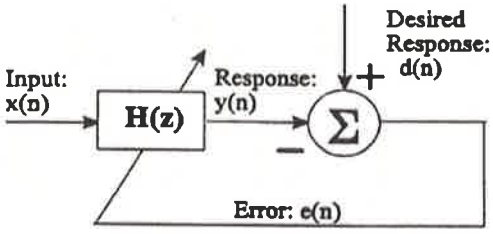


Fig. 3-2

4. (20%) For an adaptive filter as shown in Fig. 4, derive the negative gradient of the error function with respect to $b_n(k)$ at time step n. Assume the error function is the sum of squared error between the filter output y(n) and the desired output d(n).



$$y(n) = \sum_{k=0}^{L-1} b_n(k)x(n-k)$$

Fig. 4