Answer all four questions.

1. Respiratory effort belts are widely used to monitor respiration noninvasively and continuously e.g. in sleep studies. Respiratory effort belts give qualitative information about the movement of the chest and abdomen, and with calibration (e.g. to spirometer signal) they can be used quantitatively to measure continuous respiratory volume and airflow. The sum of the volume change of the chest and abdomen is equivalent to the volume measured at the mouth. A prediction of the respiratory airflow can be calculated from the respiratory effort belt signals by using multiple linear regression.

   a. Formulate and explain this linear model, which estimates the respiratory airflow from the time-synchronized chest and abdomen respiratory effort belt signals. (3p)

   b. How can the linear model be extended with more regressor variables? (1p)

   c. Describe at least two methods/measures which evaluate the adequacy of the predicted respiratory airflow signals. (2p)

2. Schematic block diagram in Figure 1 depicts a filter described in the course material.

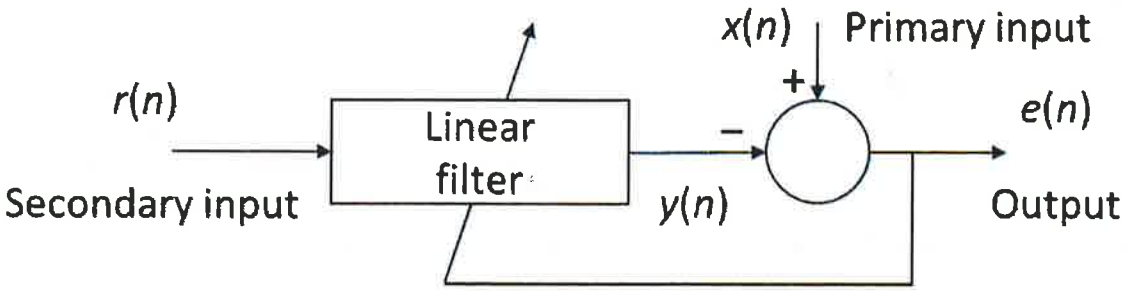

Figure 1 Block diagram of a filter.

   a. Based on the course material, describe in detail what this kind of filter does and what are the inputs and outputs of this filter. How are the input signals produced? You can use equations to strengthen your answer. How does this relate to interfering signal component removal? (3p)

   b. We would like to measure the ECG signal of a fetus. However, we find out that there are interfering signal components that are somehow summed with the desired signal. Using the filter in Figure 1 as a building block, describe in detail a procedure that will eliminate power-line interference, and the mother's ECG from abdominal signal that we have measured (containing in practice fetus ECG, power-line interference, and mother ECG) to get the fetus's ECG signal. Why can't we apply simple FIR-filtering? (3p)

3. Analysis of activity

   a. The EMG signal is the electrical signal associated with muscular contraction. Level of activity of the EMG signal increases with muscular force. Describe at least three methods for activity level estimation of the EMG signal. Illustrate your answers with relevant drawings. (3p)

   b. You are given the simultaneously recorded signals of muscle force and EMG. Describe the use of the activity level measurements described above with answering the following questions. What preprocessing is necessary for the EMG signal? What objective method can you use to determine which is the best activity level method for estimating the contraction force? Is it possible to make use of all the activity level measures? If yes, how? If not, why? (3p)

4. ECG signal filtering

   detrend

   Your task is to clean the ECG signal presented in Figure 2 for further processing, e.g. event detection.

   Frequency responses of 2 filters to be used are shown in Figure 3A and 3B.

   averaging

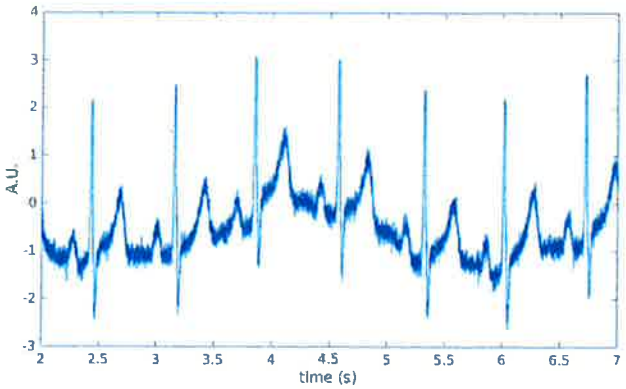

Figure 2 ECG signal

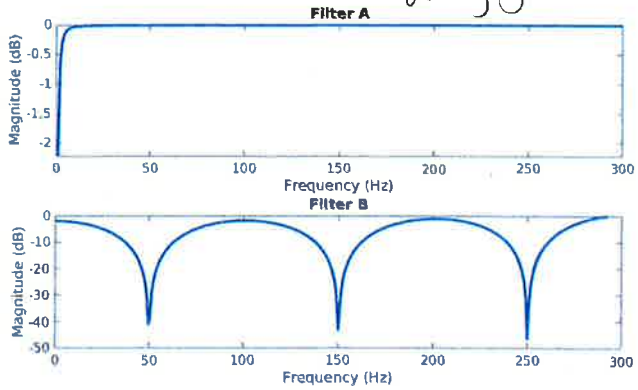

Figure 3 Filter frequency responses

   a. What kind of filter's frequency response is in Figure 3A? Explain what this filter does, why it is useful for an ECG signal. Draw the result of applying only this filter to the ECG signal. (2p)

   b. What kind of filter's frequency response is in Figure 3B? Explain what this filter does, why it is useful for an ECG signal. Draw the result of applying only this filter to the ECG signal. (2p)

   c. How can you combine the effects of both filters in practice? Draw the result of applying the combined filter to the ECG signal in Figure 2. (1p)

   d. What other filter could be used to improve the ECG signal quality for further processing? Give an example and explain what that filter does. (1p)