Chapter 4
Blood Pressure and Sounds

(Part II)
Heart Sounds and Phonocardiography

4.9 Heart Sounds and Phonocardiography

Heart sounds are vibrations or sounds due to the acceleration or deceleration of blood during heart muscle contractions, whereas *murmurs* (a type of heart sounds) are considered vibrations or sounds due to blood turbulence. *Phonocardiography* is the recording of heart sounds.

4.9.1 Heart Sounds

The auscultation of the heart provides valuable information to the clinician concerning the functional integrity of the heart. Figure 4.9-1 shows basic hear sounds and Figure 4.9-2 gives their correlation to other cardiac signals.

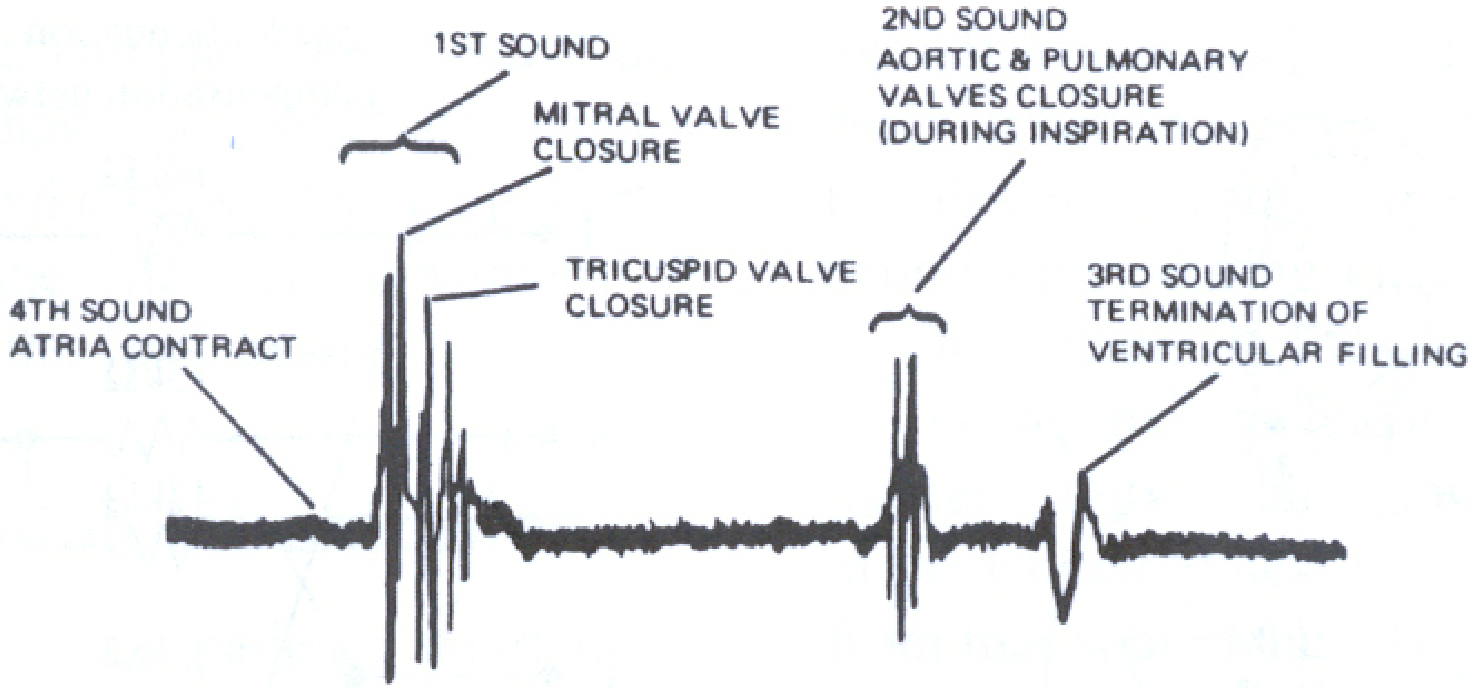


Figure 4.9-1 Basic heart sounds (from HP).

The first heart sound is generated at the termination of the atrial contractions, just at the onset of ventricular contraction. This sounds is generally attributed to movement of blood into the ventricles, the artioventricular (AV) valves closing, and the sudden cessation of blood flow in the atria. Splitting of the first heart sound is defined as an asynchronous closure of the tricuspid and the mitral valves.

The second heart sound is a low frequency vibration associated with the closing of the semilunar valves - the aortic and pulmonary valves. This sound is coincident with the completion of the T wave of the ECG.

The third heart sound corresponds to the sudden cessation of the ventricular rapid-filling. This low-amplitude, low frequency vibration is audible in children and in some adults.

The fourth heart sound occurs when the atria contracts and propel blood into the ventricles. This sound with very low amplitude and low frequency is not audible, but may be recorded by the phonocardiography (PCG).

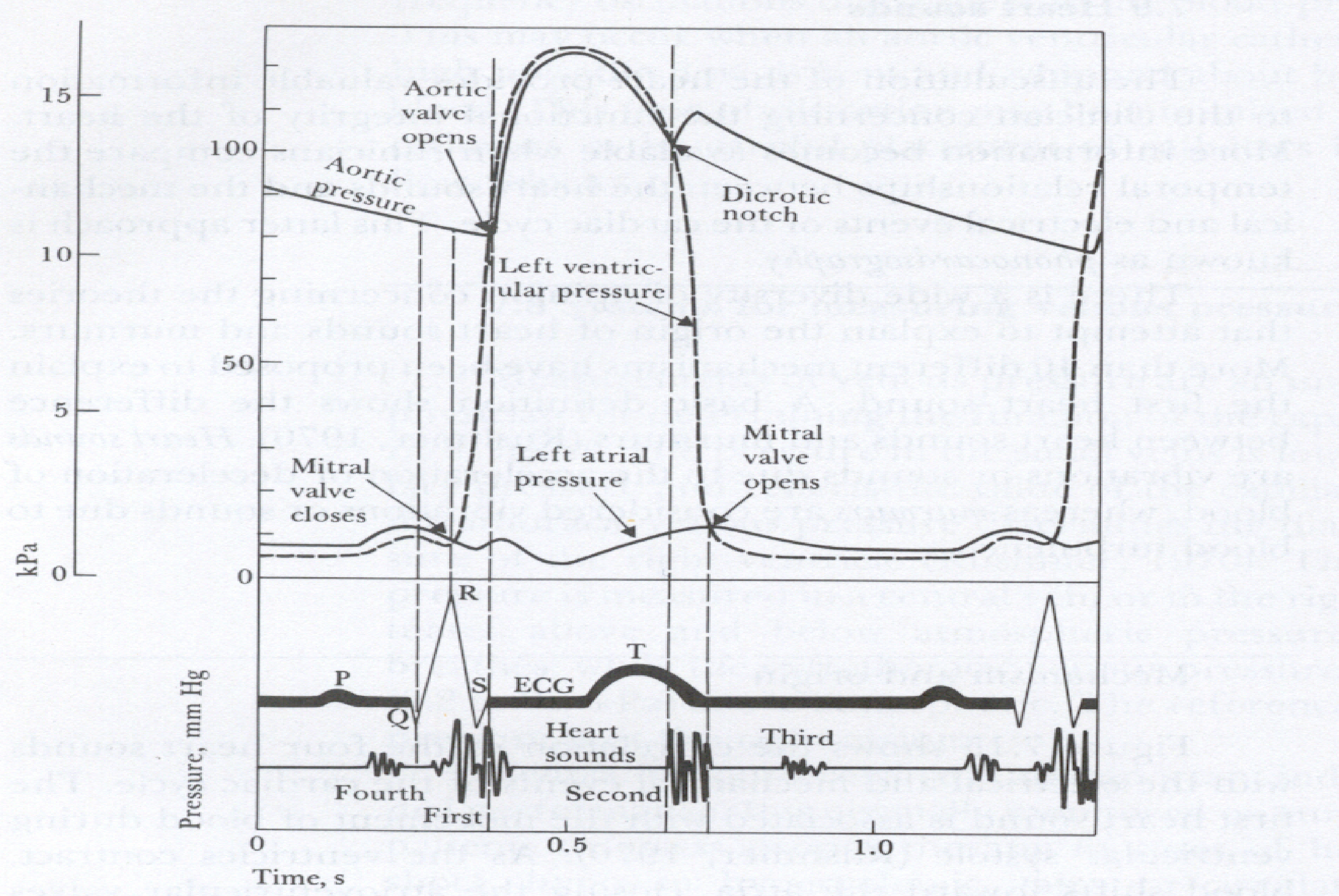


Figure 4.9-2 Correlation of four heart sounds with electrical and mechanical events of cardiac cycle.

The sources of most murmurs, developed by turbulence in rapidly moving blood, are known. Murmurs are common in children during early systolic phase; they are normally heard in nearly all adults after exercise. Abnormal murmurs may caused by stenoses and insufficiencies (leaks) at the aortic, pulmonary, and mitral valves. They are detected by noting the time of their occurrence in the cardiac cycle and their location at the time of measurement.

4.9.2 Auscultation and Stethoscopes

Heart sounds travel through the body from the heart and major blood vessels to the body surface. The physician can hear those sounds with a stethoscope. Basic heart sounds occur mostly in the frequency range of 20 to 200 Hz. Certain heart murmurs produce sounds in the 1000-Hz region, and some frequency components exist down to 4 or 5 Hz. Some researchers even reported that heart sounds and murmurs have small amplitudes with frequencies as low as 0.1 Hz and as high as 2000 Hz.

Stethoscopes: Historical and Current

- Has been used for almost 200 years, and still being used nowadays for screening and diagnosis in primary health care.

Monaural Stethoscope
(1819 ~ 1900)

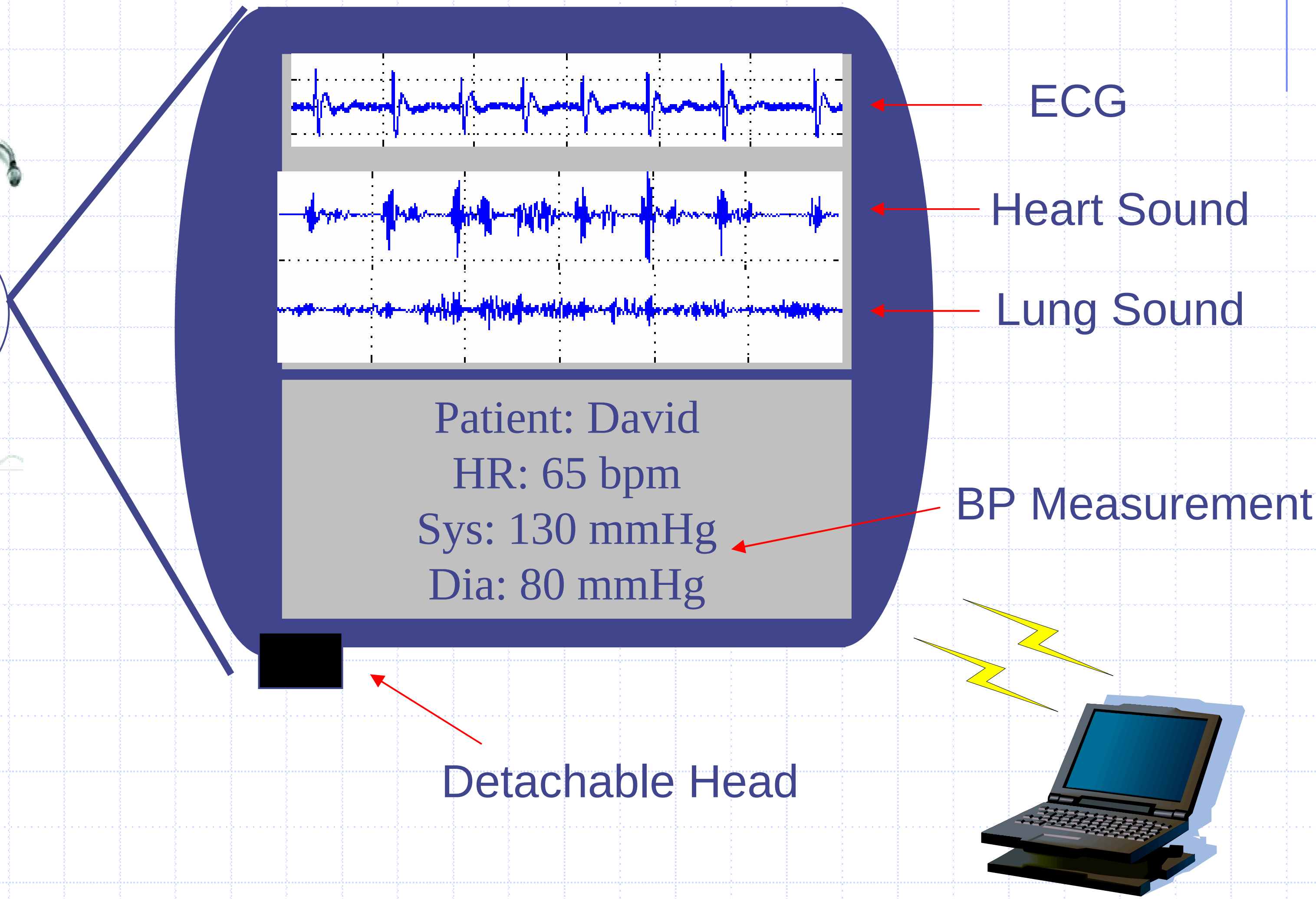
Modern Mechanical Stethoscope *(current)*

Electronic Stethoscope
(current)

Wireless Multifunction Stethoscope

(Signal processing: Adaptive signal separation, motion artifact reduction, feature extraction algorithm, BWT, HOS)

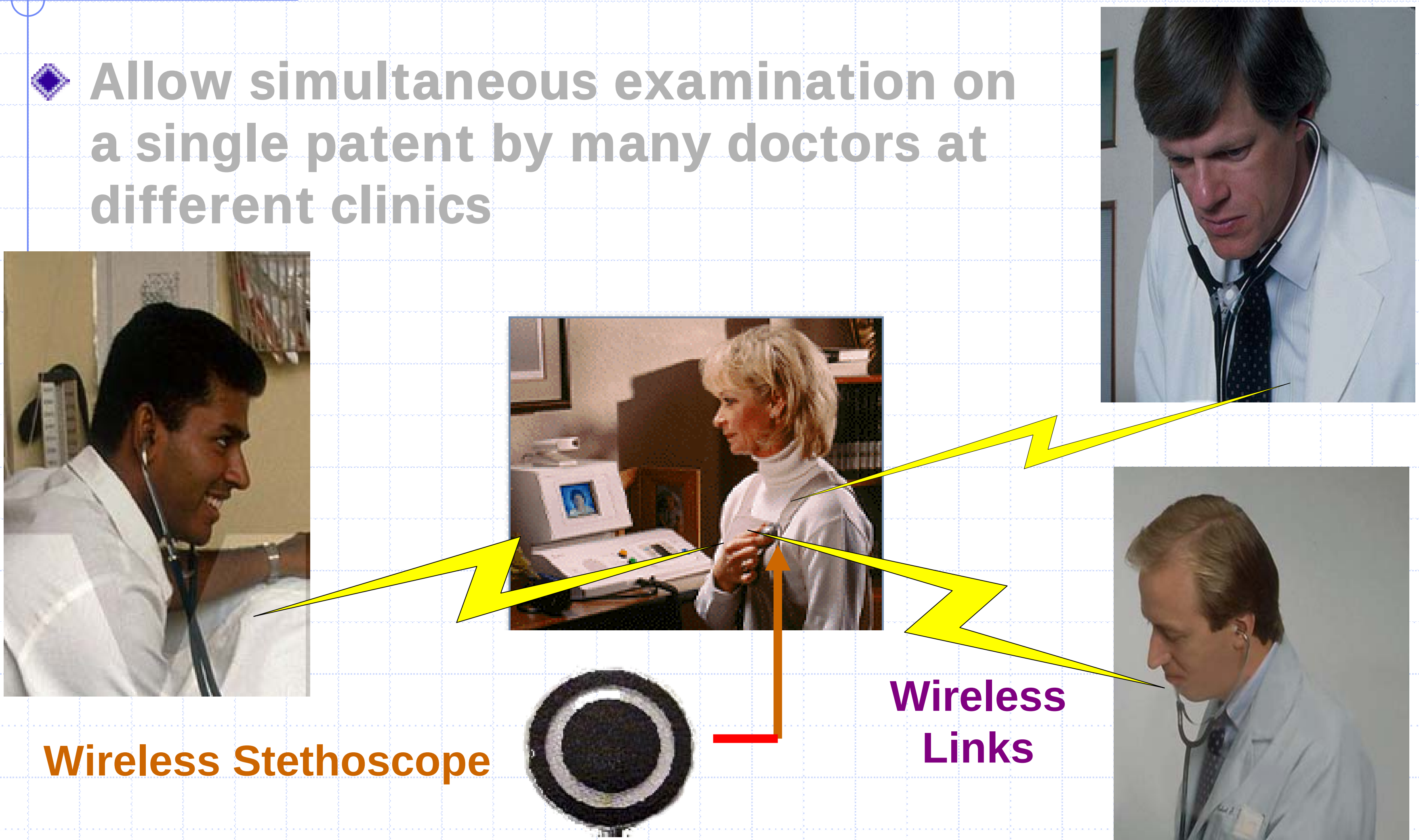
(source: http://www.pulsonic.ch/)




Mobile Medical Station 4:12
Acoustic signal
Sys Dia
User ID
User Name
Info
Sys mmHg
Dia mmHg
bpm
Serial Port
Connect
Reset
iPAQ
Pocket PC

Applications of Wireless Stethoscope

- Allow simultaneous examination on a single patent by many doctors at different clinics



Originally physicians listened to patient's heart sounds by putting their ears on the patient's chest. For reasons of propriety and convenience the stethoscope came to use to transmit heart sounds from the chest wall to the human ear. However, the variability in interpretation of the sounds stems from the user's auditory acuity and training. Moreover, the technique used to apply the stethoscope can greatly affect the sounds perceived. Figure 4.9-3 shows a typical frequency-response curve for a stethoscope. It is clear from Figure 4.9-3 that the mechanical stethoscope has an uneven frequency response, with many resonance peaks. When the stethoscope chest piece is firmly applied, low frequencies are attenuated more than high frequencies.

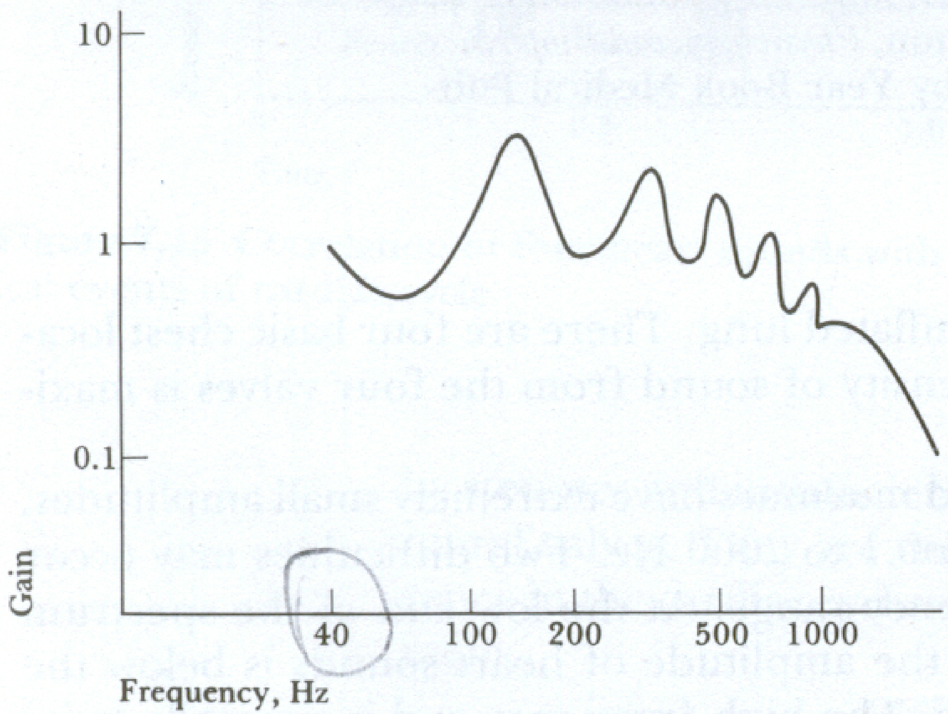


Figure 7.17 Typical frequency-response curve for a stethoscope, found by applying a known audiofrequency signal to the bell of a stethoscope by means of a headphone-coupler arrangement. Audio output of stethoscope earpiece was monitored by means of a coupler microphone system. (From P.Y. Ertel, M. Lawrence, R.K. Brown, and A.M. Stern, *Stethoscope Acoustics* I, "The Doctor and his Stethoscope." Circulation 34, 1966; by permission of American Heart Association.)

Figure 4.9-3 Typical frequency-response curve for a stethoscope.

Many types of electronic stethoscopes have been proposed by engineers. These devices have selectable frequency-response characteristics ranging from the "ideal" flat-response case and selected bandpass to typical mechanical-stethoscope responses. Physicians, however, have not generally accepted these electronic stethoscopes, mainly because they are unfamiliar with the sounds heard with them. Their size, portability, convenience, and resemblance to the mechanical one are other important considerations.

4.9.3 Phonocardiography

Phonocardiography is an mechano-electronic recording technique of heart sounds and murmurs. It is valuable in that it not only eliminates the subjective interpretation of these sounds, but also makes possible an evaluation of the heart sounds and murmurs with respect to the electrical (such as ECG) and mechanical (carotid pulse recorded in the midneck region) events in the cardiac cycle. It is also valuable in locating the sources of various heart sounds.

A PCG machine is usually consist of four main parts: a microphone or PCG transducer, filtering (mechanical and electrical), processing unit, and display. For wireless PCG, it will have a transmitter, a receiver and an interface between the PCG transducer and the transmitter.

The PCG transducer is a contact or air-coupled acoustical microphone held against the patient's chest. Various types of microphones are used, but most are the piezoelectric crystal or dynamic type of construction. Figure 4.9-4 shows a HP 21050A transducer for PCG recordings.

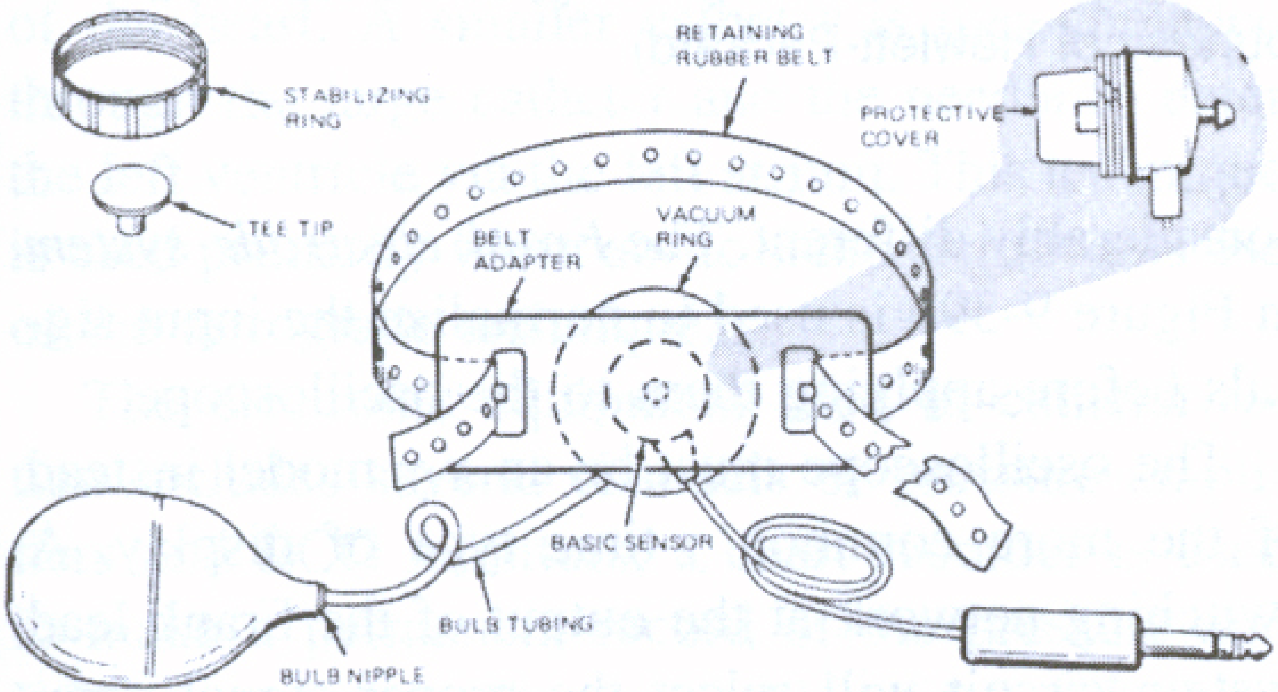


Figure 9-38

21050A sensor and accessories. (Reprinted courtesy of Hewlett-Packard)

Figure 4.9-4 A HP 21050A transducer and accessories

Figure 4.9-5 shows that the piezoelectric (crystal) microphone is more sensitive than the dynamic (based on Faraday's principle) microphone at low frequencies. The crystal microphone can be used for essentially all PCG measurements. The dynamic microphone, on the other hand, has a higher output voltage than the crystal. But it cannot be used for pulse-wave recordings because of its inadequate low-frequency response.

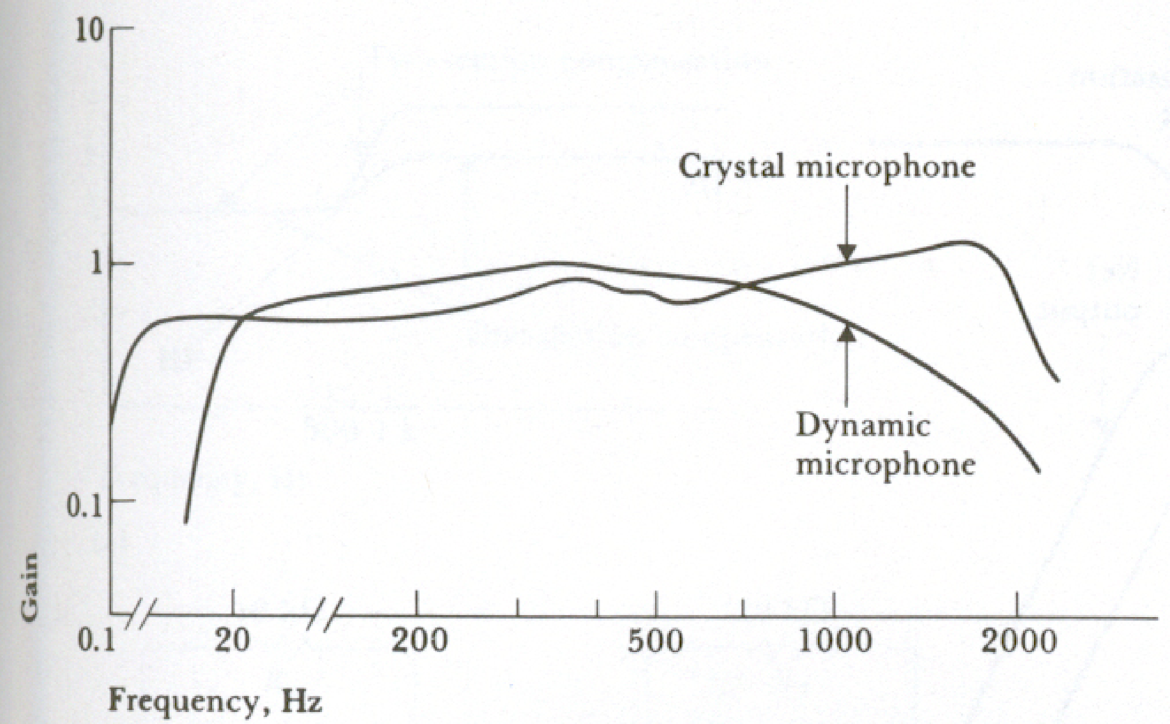


Figure 7.20 Typical frequency response for crystal and dynamic microphones.

Figure 4.9-5 Typical frequency response for crystal and dynamic microphones.

The crystal microphone generally costs less. The dynamic microphone uses a moving coil coupled to the acoustical diaphragm. The dynamic microphone is used when it is desirable to have a signal frequency response similar to that of the mechanical stethoscope. An air-coupled crystal microphone with a time constant of 2-s is often used for apex PCG recordings.

Mechanical filtering of heart sounds and murmurs is possible by a careful selection of the size of the diaphragm and microphone bell. The larger the diameter of the diaphragm, the lower the maximum frequency response of the system. Electronic filtering can be used to selectively record or listen to desired frequency bands.

Signal processing/conditioning is used to reproduce the heart sounds over the actual frequency range (25-2000 Hz for heart sounds and murmurs, and 0.1-100 Hz for pulse waves). It is possible to compensate for an inadequate frequency response in the recording device by pre-emphasizing these heart-sound frequencies in the amplifier (see Figure 4.9-6).

Spectral analysis has been used successfully in studying PCG signals. This method allows for an analysis of the instantaneous sound energy during a given time interval (say, 5-ms) throughout the heartbeat. The spectral features of PCG signal can be used for studying arterial and other heart diseases.

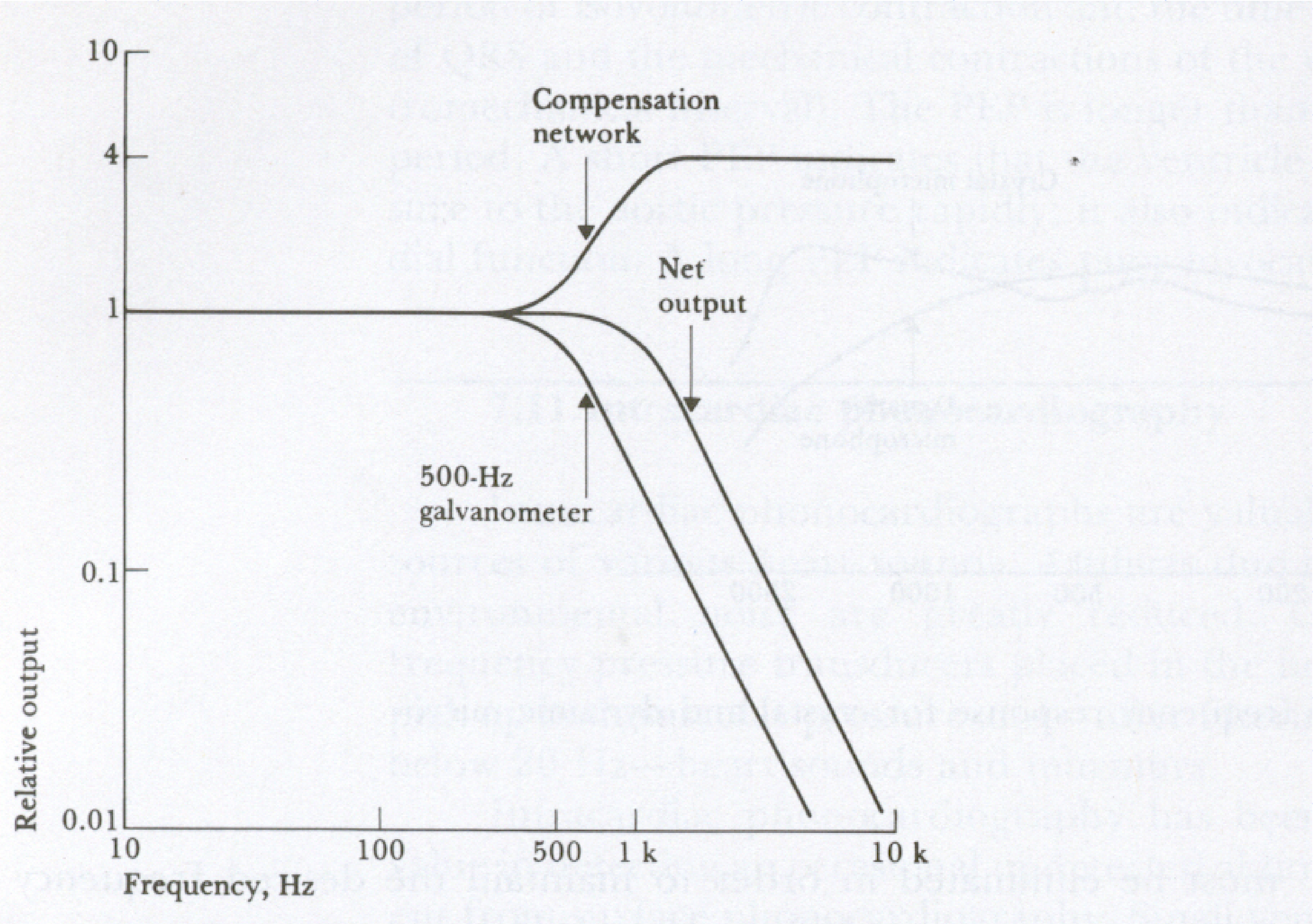


Figure 4.9-6 Frequency response for a 500-Hz galvanometer with and without a compensation network. The compensation extends the bandwidth out to 1000 Hz (J.G.Webster).

There are optimal recording sites for the various heart sounds or PCG signals. Because of the acoustical properties of the transmission path, heart sound waves are attenuated but not reflected. Figure 4.9-7 shows four basic chest locations at which the intensity of sound from the four valves is maximized.

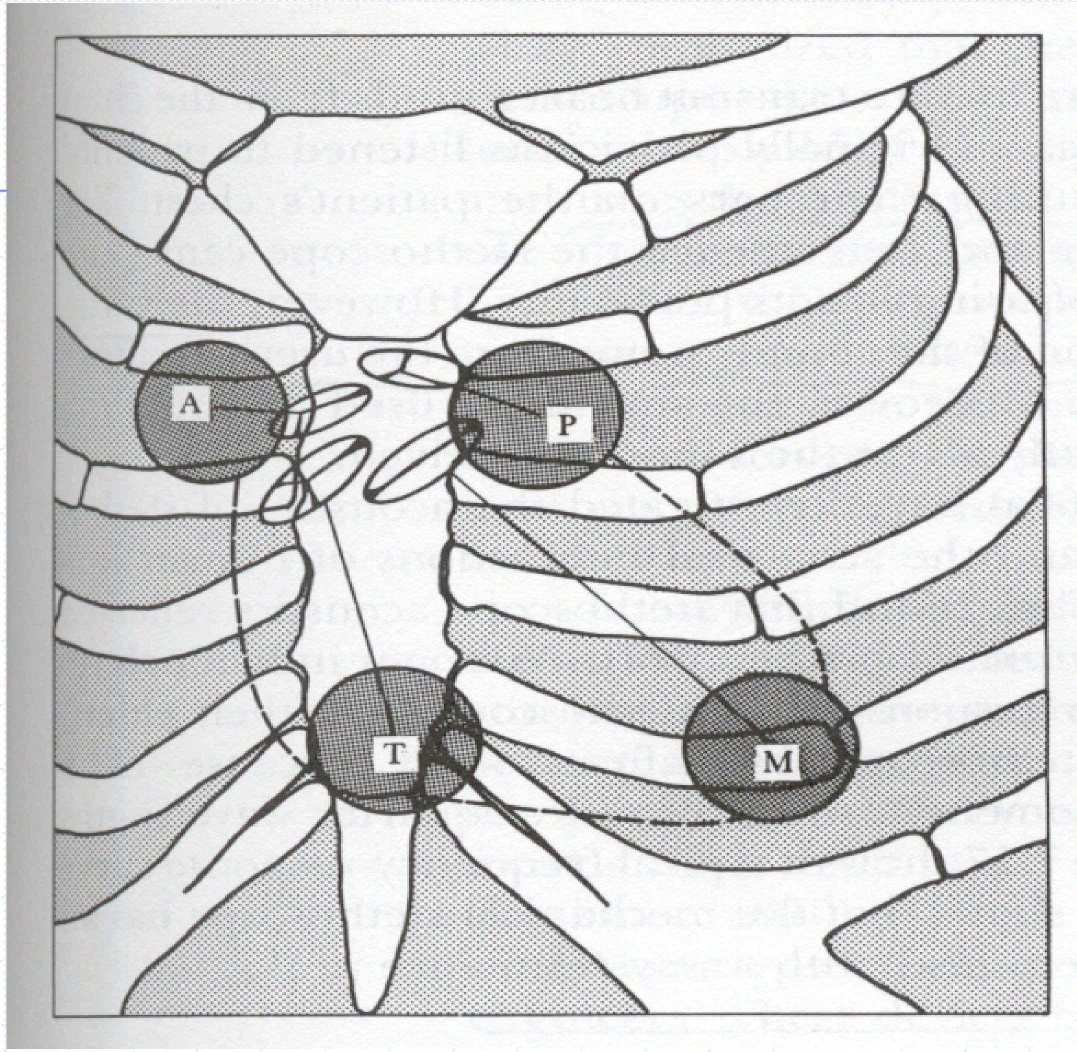


Figure 4.9-7 four basic chest locations at which the intensity of sound from the four valves is maximized

4.10 Questions (Assignment # 2)

1. Figure 4.10-1 shows a compensation network that can increase the bandwith from 500 to 1000 Hz when connected in series with the PCG machine that has the frequency response similar to that in Figure 4.9-6. If we choose C = 0.064F and Gain = 2.0, find the values for R1, R2, and R3 such that the circuit in Figure 4.10-1 will increase the bandwith from 500 to 1000 Hz.

2. Draw a block diagram to show the main components of a PCG machine and explain the function(s) of each main component.

3. Explain why a 2-s time constant is used for an air-coupled microphone to record the apical PCG signals.

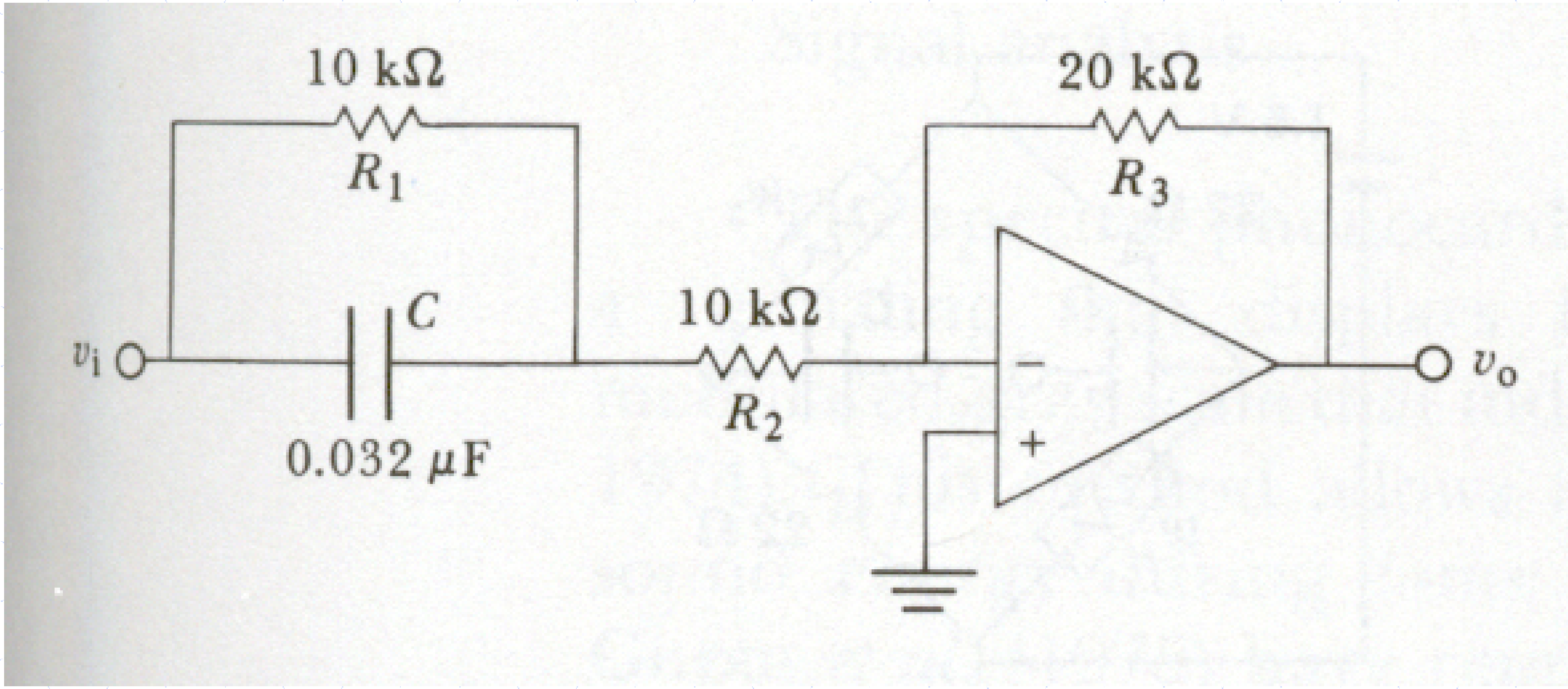


Figure 4.10-1 One-section compensation circuit.