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Medical Instrumentation Lab

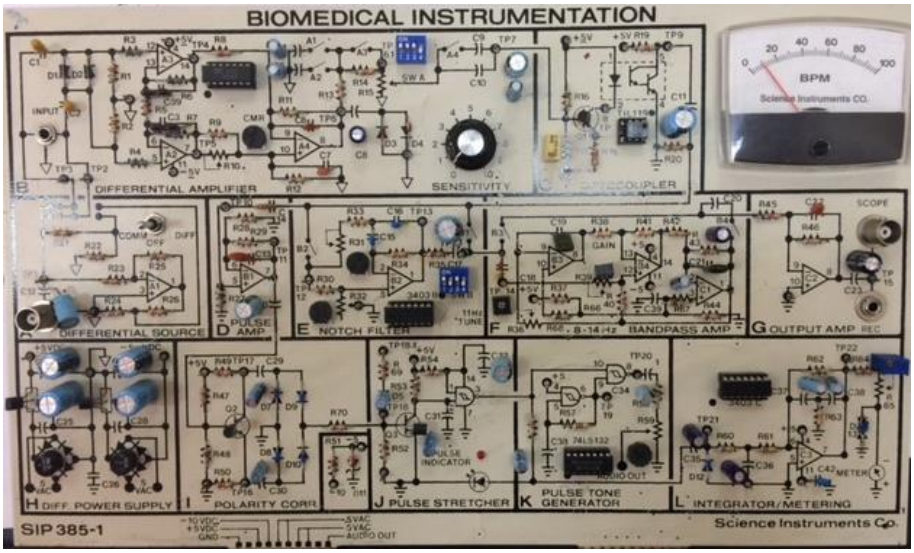
Basic concept of biomedical instrumentation

Introduction:

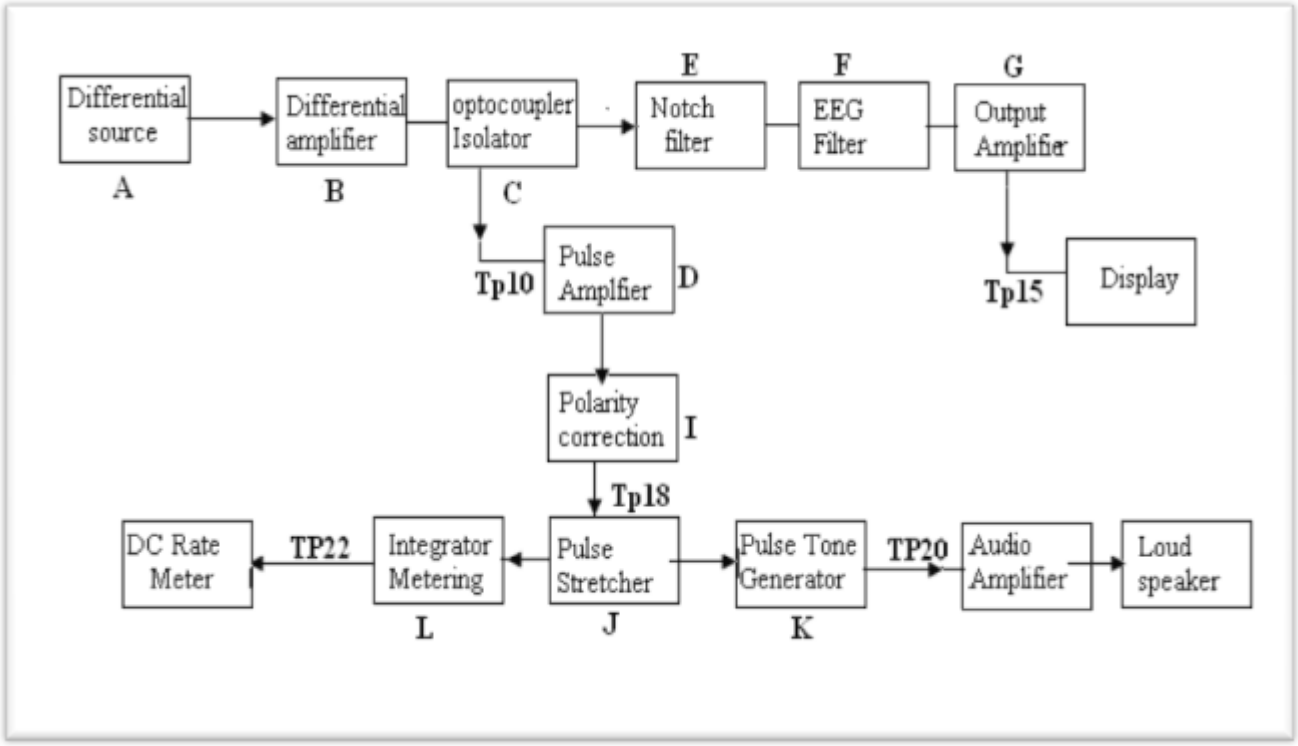
The human system like mechanical and electronic systems, has inputs stimulating control elements which in turn actuate output elements. Since human electronic and mechanical systems use similar means of control, the systems can be connected so that electronic and mechanical systems can be used to evaluate the performance of the human system. For the specific organs selected for study in this course, laboratory exercises have been designed to monitoring and recording body functions, analyzing the samples of humans signals and stimulating them.

This course contains a experimental panel SIP385-1 with a variety of cables and accessories. It provides training in basic monitoring circuitry, such as ECG, EEG, and EMG. The lab explains the electronic circuit of the Electrocardiograph (ECG) Instrument in addition to EMG and EEG, finally we study about the safety for medical devises.

The electrocardiograph recorder is an instrument, which can record the low-level voltages produced by the heart. Recorded from a patient's limbs and chest, these voltages produce a tracing called an electrocardiogram. Since magnetic power fields create common-mode signals, which interfere with the desired signal, special amplifier designs are needed.



Experimental panel SIP385-1



The block diagram of the circuit on panel SIP385-1

Finally we find the Oscilloscope, Function generator and Digital Multimeter by using the (NI ELVIS II)

NI ELVIS II

Medical Instrumentation Lab

Experiment 1: Differential Amplifiers

Objective:

1- Test and evaluate differential amplifiers as used in biomedical instrument.
2- Determine the gain and common-mode rejection ratio of differential amplifiers.

Material Required

- Insertion Panel SIP385-1.
- Jumper Lead.
- Oscilloscope (NI ELVIS II) .
- Function Generator (NI ELVIS II).

Introduction

Biological potentials on a patient are measured at two distant points. The body, however, also picks up undesired potentials from radiated magnetic fields. The instrument chosen to measure biological potentials must therefore be able to reduce these extraneous signals.

The input stage of a biological instrument typically employs a differential rather than a single- ended amplifier. The former is preferred because it has the capacity to amplify the differential signal and to attenuate the induced (common-mode) signal produced by magnetic fields, power line field (50 or 60Hz) and man-made electrical noise. A single- ended amplifier amplifies both the biological potential and induced voltage.

Of key importance is the ratio of [differential signal gain (A_{diff})] to the [common– mode gain (A_{com})]. This relationship is called common mode rejection ratio (CMRR) and is expressed by equation:

$$\mathbf{CMRR=20 \log A_{diff}/A_{com}}$$

The (CMRR) shows the ability of a differential amplifier to attenuate common–mode signals appearing simultaneously with differential signals.

In determining the CMRR, the two signals are adjusted at the input to produce the same output voltages ($V_{out\ com}$= $V_{out\ diff}$). Therefore, CMRR can be determined from the input voltages as shown below:

$$\mathbf{CMRR=V_{in\ com}/V_{in\ diff}}$$

Good amplifiers have CMRR values, which range from **+60dB to +100dB**.

The adverse effect of electrode contact resistance on signal input is an additional consideration. Losses incurred at the lead contacts with the skin decrease the available input signal to each amplifier. High input impedance of the amplifier minimizes the signal loss.

Since the LF347 has an input impedance of over 1012 ohms, only a very small portion of the input signal voltage would be lost. Since the LF347 is a quad as shown in **Figure (1-1)**, three of the amplifiers (A_2, A_3 and A_4)can be used for recording the ECG, EMG, or EEG signal voltage. Two amplifiers (A_2 and A_3) are used for the differential input, and one for a single-ended output amplifier. A typical circuit arrangement is shown in section B in the insertion panel. Amplifier A_1 is used in section A as an inverter.

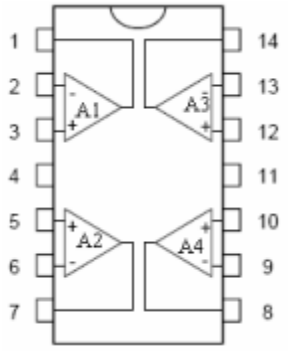


Figure (1-1)

Section A: Differential Source:

We use the function generator instead of an ECG simulator (or human) in the first exp's to perform the experimental procedure. Therefore, section A is used to develop two signals out of phase from a single-ended function generator and the

difference between them is in mV (to simulate the low-level voltages produced by the heart (QRS wave).

The following two equations are for the input voltages to the instrumentation amplifier (section B) when the mode switch in section A is set to the DIFF and COMM respectively:

DIFF:

$V_{Tp2} = -V_{Tp1} * R_{24}/(R_{24} + R_{26}) = -V_{Tp1}/1000$ $\quad V_{in\ diff} = V_{Tp3} - V_{Tp2} = 2 * V_{Tp1}/1000$

$V_{Tp3} = V_{Tp1} * R_{22}/(R_{22} + R_{21}) = V_{Tp1}/1000$

COMM:

$V_{Tp2} = V_{Tp3} = V_{Tp1}$ $\quad V_{in\ com} = V_{Tp2} + V_{Tp3} = 2 * V_{Tp1}$

Section B: Differential Amplifier:

The gain of the amplifier A_4 is determined by the ratio of the R_{11}/R_8 (100K Ohm/8.2K Ohm) resistors (A = 12.2). The gain of the two amplifiers (A_2 and A_3) is determined from:

$$\mathbf{A_{diff} = (1 + 2\ R_6/R_5) = 29.4}$$

The overall gain = Gain (A_2, A_3)* Gain (A_4) = 29.4* 12.2 = approx 358

The gain of the input stage can be controlled by varying the resistor (R_5) between pins **6** and **13**. As the resistor is made smaller, the gain is increased. This resistor should not be zero since the circuit might oscillate under high gain conditions.

In the circuit shown in the panel, resistors of 1% tolerance (or less) should be used, since both halves of the circuit must match. The value of potentiometer R10 should be adjusted to obtain the best balance of the two signals input to A_4. This balance achieves the highest possible CMRR.

Procedure:

1. Balancing the Differential Amplifier (A_4).

Input: Using the function generator feed a **10 Hz** sin wave and **5 V_{p-p}** into **T_{p1}** (Section A).

Output: Is taken from **T_{p6}** using the Oscilloscope.

a. Set the mode switch in section A to the **COMM** position.

b. Adjust R_{10} (section B) as necessary for **minimum sin wave** output at **T_{p6}**.

V_{TP6} = ……..

2. Single Ended Gain (One Input (T_{p3})).

Input: Using the function generator feed a **10 Hz** sin wave and **5 V_{p-p}** into **T_{p1}** (Section A).

Output: Is taken from **T_{p6}** using the Oscilloscope.

a. Set the mode switch in section A to the **DIFF** position.

b. Using alligator (jumper) lead, connect the **T_{p2}** input to the common (floating) ground.

c. Measure the V_{p-p} signal at:

V_{Tp4} ……..

V_{Tp5} ……..

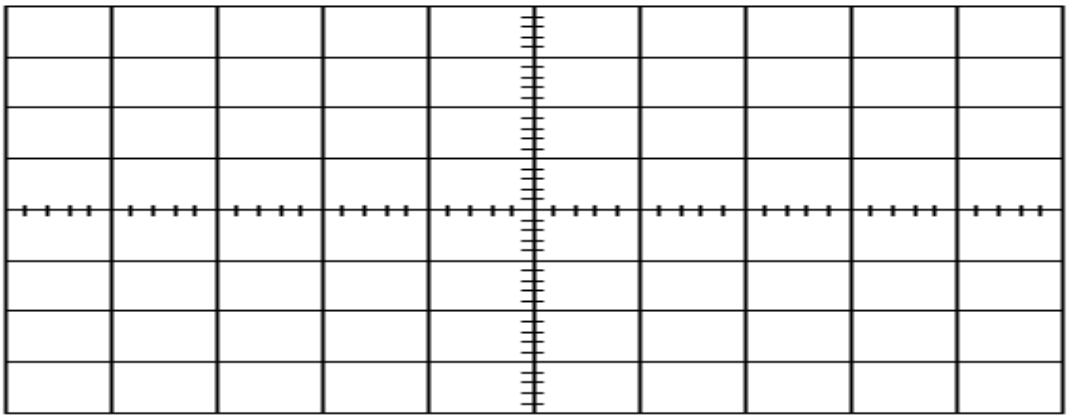
V_{Tp6} ……..

d. Calculate the single ended gain between V_{Tp3} and V_{Tp6}.

$$A_s = V_{TP6} / V_{TP3}$$

A_s= ……..

e. Using the Oscilloscope, connect T_{p4} to channel 1 and T_{p5} to channel 2 and draw the wave shapes of the signals.



Are the two signals out of phase (phase shift = 180)?.....

3. Differential Gain (Two inputs: V_{Tp2} and V_{Tp3}).

Input: Using the function generator feed a **10 Hz** sin wave and **8 V_{p-p}** into **T_{p1}** (Section A).

Output: Is taken from **T_{p6}** using the Oscilloscope.

a. Set the mode switch in section A to the **DIFF** position.

b. Remove the alligator lead from the **T_{p2}** input.

c. Calculate the differential gain for the instrumentation amplifier section (B).

$$A_{diff} = V_{TP6} / (V_{TP3} - V_{TP2})$$

V_{Tp6} = ……..

A_{diff} = ……..

4. Common Mode Rejection Ratio CMRR.

Input: Using the function generator feed a **10 Hz** sin wave and **8 V_{p-p}** into **T_{p1}** (Section A).

Output: Is taken from **T_{p6}** using the Oscilloscope.

a. Set the mode switch in section A to the **COMM** position.

b. Measure the $\mathbf{V_{p-p}}$ signal at:

$\mathbf{V_{Tp2}}$ **.....**

$\mathbf{V_{Tp3}}$ **.....**

$\mathbf{V_{Tp6}}$ **.....**

c. Calculate the common mode gain (A_{comm}).

$$\mathbf{A_{comm} = V_{TP6} / (V_{TP3} + V_{TP2})}$$

A_{comm} = ... (Must be << 1)

d. Calculate the CMRR.

CMRR = ...

Experiment 2: Band-pass, Notch and other filters

Objectives:

- Discuss the characteristics of active and passive filters.
- Understand and study the function of active notch filter.
- Measure the frequency response of the band pass and notch filters.

Material Required

- Insertion Panel SIP385-1.
- Digital Multimeter (NI ELVIS II).
- Oscilloscope (NI ELVIS II) .

Theory:

Often, real world signals of interest are mixed with undesirable noise signals (power line interference in ECG signals etc.). Circuits such as filters are used to attenuate the amplitudes of the signals, which are not desirable. Depending on the frequencies that are desirable, filters can be low-pass, high-pass, band-pass or notch filters. The principle of action of ideal filters is shown in **Figure (2-1)**:

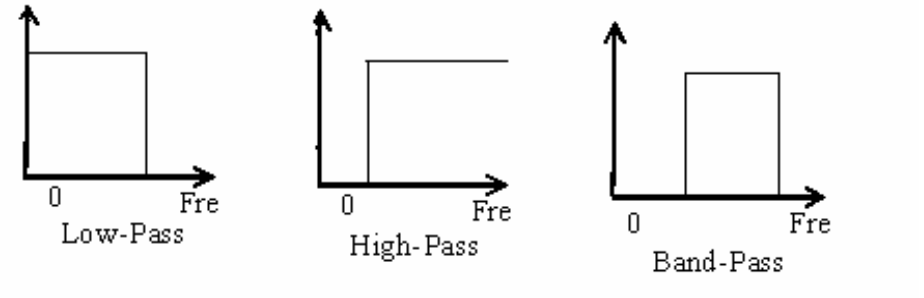


Figure (2-1)

Circuits made with real-world components cannot achieve the sharp cut-off characteristics of the ideal filters shown above, but with some degree of approximation, we can get fairly close. Filters are essential in circuits such as ECG monitors where a considerable degree of interference is picked up because of the

surrounding electrical equipment as well as the movements of the patient. Another area in which filters could be used is in hearing aids.

The frequency at which the output voltage (V_{out}) equals 0.707 x V_{in} is referred to as the high- or low- frequency roll-off point. This point is also defined as the frequency at which the output voltage has dropped by 3 dB (decibels). This point can be described as follows:

$$Vo = 0.707 * Vin$$

Voltage gains or losses, in dB, are given by:

$$G = 20 \log Vo / Vin$$

So the value of G at the roll-off frequency = 20 log (0.707). Therefore, G =-3dB the negative sign indicates that V_{out} was less than V_{in}. The difference in frequencies at the -3 dB roll-off points at the high and low ends of a response curve is called the bandwidth of a filter. The term bandwidth usually applies to band-pass and band- rejection (notch) filters.

Band-Pass and Band- Stop "Notch" Filters

A band-pass filter passes all signals that fall within a band defined by a lower und an upper frequency limit. It attenuates all other frequencies outside of this specified band. The bandwidth (BW) is defined as the difference between the upper cut-off frequency and the lower cut-off frequency as shown in Equation

$$BW = f_U - f_L$$

The frequency about which the pass band is centered is called the center frequency. It is defined as the geometric mean of the two cut-off frequencies as shown in Equation:

$$f_o = \sqrt{f_L f_U}$$

The sharpness of the response in the band-pass is measured by a quantity called Q. The Q of a filter, or of any tuned circuit, is the ratio of the center frequency to the bandwidth (BW). This expression is shown in Equation:

$$Q = f_o / BW$$

The instrumentation amplifier shown in Section B of the panel is also a bandpass filter, the high frequency roll off is caused by the following capacitors:

1. Feed-Back capacitors connected form an output to an input: C_{39}, C_3 and C_6 .
2. Stray Capacitors connected form an output or an input to ground, C_5 and C_7.

C_4 and C_5 are controlled by switch A_1 and A_2 respectively, for example when switch A_1 is closed (ON), C_4 is connected to T_{P6} through R_{13}, and when it is open (OFF), C_4 in not connected to T_{P6}.

The low frequency roll off is caused by the coupling capacitors connected in series with the input or with the output: C_1, C_2, C_9 and C_{10}, also C_9 and C_{10} are controlled by switch A_4.

Switch A_3 is used to control the amplitude of the signal at $T_{P6.1}$ as follows:

1. When **A_3** is **ON**, $V_{TP6.1}$= approx V_{TP6}.
2. When **A_3** is **OFF**, $V_{TP6.1} = V_{TP6} * R_{15}/(R_{15}+ R_{14}+ R_{13})$

Notch Filter:

The notch filter is also known as a band-stop, band- reject, or band-elimination filter. In effect, a notch filter performs in exactly the opposite way from a band pass filter. The notch filter rejects or attenuates all frequencies inside its response curve between the 3 dB points and passes all other frequencies. The bandwidth is defined as the difference in the frequencies at which the response is 3 dB down. These filters are often used to reduce 50 or 60 Hz signals in sensitive medical instruments such as EEGs and ECGs.

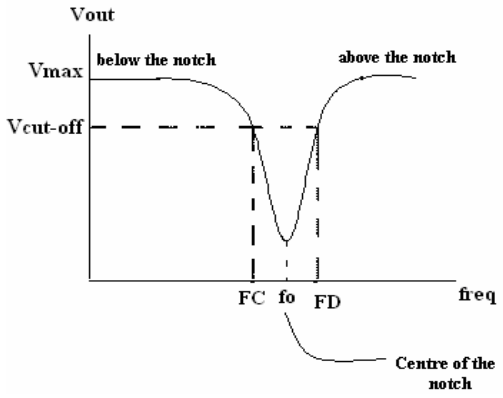


Figure (2-2)

Experimental Procedure:

- Band Pass Filter

1. Frequency Response of the differential Amplifier (Section B):

Note: Switch **A3** is **ON** for all procedure

Input: Using the function generator feed a **2 V_{p-p}** and sin wave with **5 HZ** into **T_{P1}.**

Output: Is taken from **$T_{P6.1}$** when both switches **A_1** and **A_2** are ON:

a. Set the mode switch in section A to the **DIFF** position.

b. Gradually increase the generator's frequency until you reach **maximum** output voltage.

c. Observe the frequency at which the amplifier's output (V_{TP6}) reaches a maximum.

Maximum $V_{TP6.1}$ = ……..

d. Calculate the cutoff voltage (-3dB point).

$$\mathbf{V\ (cutoff) = 0.707 * V_{TP6.1}\ (max)}$$

V (cutoff) = **……..**

c. Continue to increase the generator's frequency until the amplifier's output decreases to **V (cutoff)**; this frequency is called the upper cutoff frequency or high frequency roll- off.

Upper cutoff frequency = ...

d. Measure the voltage of upper cutoff frequency when both switches **A_1**&**A_2** are **OFF**.

- Notch filter (Section E).

Frequency Response of the notch filter (Section E)

Input: Using the function generator feed a **50 Hz** (F_o) sin wave and **4 V_{p-p}** into **T_{P12}**.

Output: Is taken from **T_{p13}** using the Oscilloscope.

a. Make **OFF** switches **B_1** and **B_2**.

b. Adjust the potentiometers **R_{32}** for **minimum sin wave** output, then adjust **R_{31}** to **minimize** output more :

Minimum V_{TP13} (at 50 Hz) = ...

c. Record the output voltage at **20Hz** (below the notch frequency) and **150Hz** (above the notch frequency).

V_{TP13} at 20 Hz = V_{TP13} at 150 Hz =.... .....

d. Calculate the degree of attenuation at the center of the notch in dB

$$G_{dB} = 20 * \log(V_{50} / V_{20})$$

G_{dB} = ...

e. Measure and record the frequencies at point C (**V_{TP13} at 20 Hz)** and point D (**V_{TP13} at 150 Hz)**:

Steps:

1. Calculate the output voltages at -3dB points:

$V_C = V_D = 0.707 * V_{out}$ at 20 Hz= ……

2. Beginning at 20Hz, slowly increase the generator's frequency until the output voltage decreases to V_C, Record this frequency as:

f_C = ……..

3. Beginning at 150 Hz, slowly decrease the generator's frequency until the output voltage decreases to V_D, Record this frequency as

f_D = ……..

f. Compute the width of the notch at its -3dB points:

$\Delta f = f_D - f_C$= .....

g. Compute and record the Q of the notch circuit:

Q= …….

Medical Instrumentation Lab

Experiment 3: Measurement the Noise Ratio of Signal and (CTR)

Objectives:

- Measuring the signal to noise ratio in a biomedical instrumentation amplifier.
- Measuring the Current Transfer Ratio (CTR) by Optocoupler and why the isolation.

Material Required

- Insertion Panel. SIP385-1
- Oscilloscope (NI ELVIS II) .
- Function Generator (NI ELVIS II) .
- DMM (NI ELVIS II) .
- Alligator Clip Leads.

Theory:

- Part 1: Noise in Biomedical Amplifier Systems

Noise is all the unwanted electronic signals coming in that you don't want to measure, you have to determine how noisy your circuit is, and justify the method you use to measure noise.

Noise in amplifiers can be caused both by the shot noise within active components and by the resistors connected to active components. Limiting the frequency response of the amplifier can reduce the noise levels in amplifiers. In a biomedical system, the input amplifier section is responsible for most of this noise. External and internal sources, as well as passive and active components, all contribute to this noise. Shot noise, intrinsic to solid-state device junctions, is possibly the greatest consideration. Patient electrodes also generate noise.

At very low levels, the wiring of printed circuit boards and cables introduces noise through ground loops. Taking a voltage measurement between two distant

points on the ground plane reveals the existence of microvolt variations. These, in turn, feed input signals to the amplifiers.

(Different grounds between test instruments also introduce noise. In high-gain, low-noise amplifiers, the grounds of test instruments should be secured to a common point in order to reduce ground loops.)

Power supplies, when their output impedance is not low enough (under a few ohms), are another source of noise. The noise may actually be a collection of pulses, spikes, and 50/60 or 120 Hz voltages. These voltages can usually be isolated by inserting RC filters between the power supply lines and the IC circuitry.

Noise level measurements

At low frequencies, the noise in biomedical amplifiers is of considerable importance. Low-frequency noise is in the range of 0.01 to 1 cycle. Drift voltages are also considered as noise. The range of 5-50 KHz is considered wide- band noise. When viewed on an oscilloscope, noise is measured from the peak-to-peak value. Since peaks are of various heights, noise measurements can only be approximated.

An amplifier with a gain of 100 might have a noise output of 400nV when its total input noise is 4nV. In order to measure such low-level signals, a high- gain oscilloscope with low noise is required. Typical oscilloscopes will measure voltage levels as low as +10 mV /cm. In addition, they themselves generate input noise in the microvolt range.

The most important noise sources in the panel and how to minimize it are summarized in the Table below.

No.	Noise sources	How to minimize it?
1	60 or 50 Hz power line interference	Notch filter (section E)
2	Circuit Noise (IC's)	Good Design and Good Components, BIFET amplifiers generally have low noise levels.
3	Other biopotentials, when measuring	Band-pass Filters, these biopotentials have

	ECG, everything else creates noise like other biopotentials (EEG, EMG or EOG)	characteristics frequencies (frequency response) as shown in Table 2
4	Motion artifacts (man-made noise)	Relaxed subject
5	Electrode Noise	High quality electrode and good contact

Noise Sources

We can control and change the frequency range in the panel (according to the biosignal we measure) using the control switches: A_1, A_2 and A_4.

- Part 2: Optoelectronic Components

Optoelectronics integrates semi-conductor based optical devices with solid-state technology in order to isolate and control electric circuits. When compared to mechanical sensing and switching elements optoelectronic components are smaller, faster, less expensive and more reliable.

Optoelectronics devices which provide high-voltage isolation along with low capacitance coupling , are often found in biomedical applications. These devices enable low voltage to safely control high power or high voltage isolation devices, patients who are connected via low resistance leads must be effectively protected from potential shock hazards. Isolation and control are achieved by a three-step process. First, an electrical signal is converted to light energy by an LED (light-emitting diode). The optical signal is then converted back into electrical energy by a photo detector. Finally, an amplifier is excited by the reconstituted signal.

In this experiment, the optocoupler portion of the amplifier system (section c) will be evaluated for:

CTR_{DC} and CTR_{AC}

In an optocoupler , the current transfer ratio (CTR) defines the gain of the device, like a gain of a transistor, this gain is the ratio of the transistor collector current to the LED current. The LED current varies with the setting of R_{17}.

Experimental Procedure:

Part 1: Noise To Signal Ratio

Note: Switch A_3 is (**ON**) in all steps of this experiment.

I. Measuring the output noise voltage (N_{out}):

Input: Use jumper leads to ground test points T_{P2} and T_{P3} so that there is no input signal.

Output: From $T_{P6.1}$ in all steps using the Oscilloscope.

a. Measure and record the N_{out} (p-p) with:

1. Both A_1 and A_2 (OFF), $V_{TP6.1}$ (N_{out}) = ……

2. A_1 (ON) and A_2 (OFF), $V_{TP6.1}$ (N_{out}) = …….

3. A_1 (OFF) and A_2 (ON), $V_{TP6.1}$ (N_{out}) = …….

4. Both A_1 and A_2 (ON), $V_{TP6.1}$ (N_{out}) = …….

II. Calculating the Input noise voltage (N_{in}).

Steps:

1. Measuring the total gain of the differential amplifier A_{diff}.

Input: Remove jumper leads to ground, set the mode switch in section A to the **DIFF** position then using the function generator feed a **$1V_{p-p}$, 10 Hz** sin wave into T_{P1}.

$V_{TP6.1}$ = …….

A_{diff} = …….

2. Compute the N_{in} levels for each of the N_{out} levels determined in step a using the following equation:

Input Noise = Output Noise (N_{out}) / Gain(A_{diff})

1. Both A_1 and A_2 (OFF) **Input Noise =** ……

2. A_1 (ON) and A_2 (OFF) **Input Noise =** ……

3. A_1 (OFF) and A_2 (ON) **Input Noise =** ……

4. Both A_1 and A_2 (ON) **Input Noise =** …….

III. Measuring the signal to noise ratio (S / N)

Input: Using the function generator feed your amplifier with a differential signal voltage of **0.5** V_{p-p} with **10 Hz** sin wave into T_{P1} With Both A_1 and A_2 (ON), Measure:

1. The signal voltage $V_{TP6.1}$**(S)**= …….

2. The N_{out} voltage **(N)**= ……

3. Calculate the **S / N**= ……

Part 2: Optocoupler

a. CTR_{DC}:

Remove any input voltage to the kit then adjust R_{17} for a voltage drop of 0.11 V across R_{18}.(Using **DMM** from NI ELVIS II)

Compute the LED current from the voltage drop across R_{18}=**220 Ω**, call this the forward current I_{f1}.

V_{R18}=…… I_{f1}=……

Determine the collector current from the voltage drop across $\mathbf{R_{19}}$ =**470 Ω**, call this $\mathbf{I_{c1}}$.

$\mathbf{V_{R19}}$=…… $\mathbf{I_{c1}}$=……

$$\mathbf{CTR_{DC} = I_{c1} / I_{f1} =}\ldots\ldots$$

b. CTR_{AC}:

Take another point for (I_f , I_c).

Vary $\mathbf{R_{17}}$ to increase the voltage drop across $\mathbf{R_{18}}$ to 0.16 V.

Compute the change in $\mathbf{I_c}$ over the change in $\mathbf{I_f}$.

$\mathbf{V_{R18}}$ =…… $\mathbf{I_{f2}}$ =……

$\mathbf{V_{R19}}$ =…… $\mathbf{I_{c2}}$ =……

$\mathbf{\Delta I_c = I_{c2} - I_{c1} =}\ldots\ldots$

$\mathbf{\Delta I_f = I_{f2} - I_{f1} =}\ldots\ldots$

$$\mathbf{CTR_{AC} = \Delta I_c / \Delta I_f =}\ldots\ldots$$

Experiment 4: Measurement The Electrocardiograph (ECG) signal

Objectives:

Apply and observe The Electrocardiograph (ECG) signal.

Material Required

- Insertion Panel. SIP385-1
- Oscilloscope (NI ELVIS II) .
- ECG Electrodes. S114
- Patient lead cable.
- Alligator Clip Leads.

Theory:

Electrical activity of the heart can be approximated by a dipole (a vector drawn between two opposite electrical charges) with time varying amplitude and orientation. For this simplified model, we will represent the cardiac dipole vector with M. If two electrical leads are connected to human body at two different locations, we can draw another vector in space, a, from one of the electrodes to the other. Electrical voltage observed between these two electrodes is given by the dot product of these two vectors.

Signal	Frequency Range (Hz)	Amplitude (mV)
ECG	0.3-30	QRS complex= 1mV
EMG	6-2000	Relaxed Muscle: 0.01-0.1 Contracted Muscle: 0 .3-0.5
EEG	0.3-50	0.002- 0.05

Biomedical Signals

A plot of the electrical potential developed in the heart is called an electrocardiogram (ECG). The ECG graphically depicts the amplitude and timing of this potential as it transits the conduction system. Figure below shows a typical ECG tracing. Note that the various peaks and valleys, called waves, are labeled with letters. Taken together, these waves characterize the sequence of events that comprise the cardiac electrical cycle.

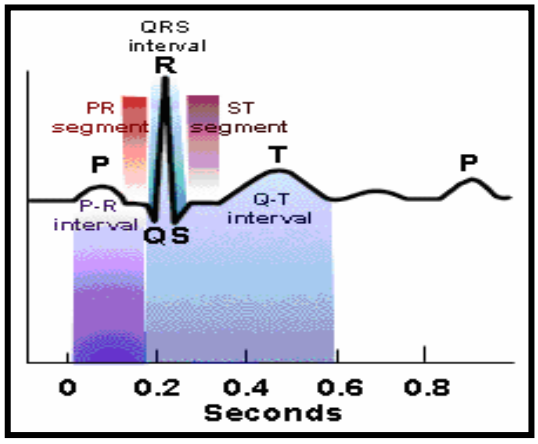


Figure (4-1) ECG Graphically

The **P** wave is generated when the **SA** node develops its initial potential. Signal transit through the atria to the **AV** node is indicated by the **P-Q** interval. The **R** wave, often called the **QRS** complex, is generated as this potential is conducted through the Bundles of His, the Purkinje system, and the ventricles. Repolarization, in preparation for the next stimulus, generates the **T** wave.

There are many different configurations to place the ECG electrodes on a patient. Three common ones are listed below :

Lead 1	+ LA – RA
Lead 2	+ LL – RA
Lead 3	+ LL – LA

ECG Lead configurations

An ECG Amplifier:

The circuit diagram of sections B show the ECG amplifier. Bio-potential signals are very weak signals. Even the strongest ECG signal has a magnitude of less than 10 mV. Furthermore, ECG signals have very low drive, i.e. source has very high output impedance. Therefore, an ECG amplifier is usually required to have the following properties:

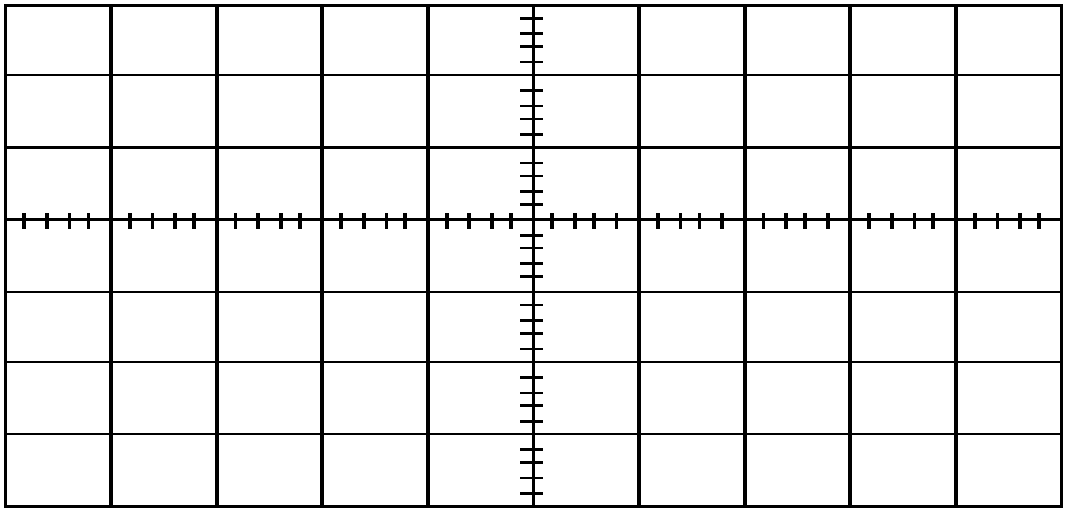
1. Capability to sense low amplitude signals in the range of 0.1 - 10 mV.
2. Very high input impedance, usually more than 5 Mega-Ohms.
3. Very low input leakage current, 1 micro-Amps or below.
4. Flat frequency response of 0.1 - 100 Hz.
5. A high common mode rejection ratio (CMRR).

Experimental Procedure:

Note: You should (**ON**) the switches $\mathbf{A_1}$, $\mathbf{A_2}$, $\mathbf{A_3}$, $\mathbf{A_4}$, $\mathbf{B_2}$ and $\mathbf{B_3}$.

1. Clean the skin area by alcohol sponges then put a gel for increase the conductivity .
2. Stick the electrodes on right arm (red one), left arm (green one) and right leg (black one).
3. Connect red lead to $\mathbf{T_{P2}}$, green lead to $\mathbf{T_{P3}}$ and black lead to any floating ground.
4. Display the output ($\mathbf{V_{TP15}}$) by the Oscilloscope.

5. Plot your output.



6. Calculate the heart rate (bpm)

Heart rate (bpm) = 60 / T

Where **T** is the time in seconds between two adjacent **R** waves.

Heart rate =……

Experiment 5: *Electromyograms(EMG)* & *Electroencephalograms (EEG*)

Objective:

1- Describe the action potentials of muscles as produced by the stimulation of nerves.
2- Describe the manner in which nerve stimulation causes muscles to contract.
3- Observe the EMG potential on the arm.
4- Describe how EEGs are recorded.
5- Observe and record EEG patterns on subjects.

Material Required

- Insertion Panel. SIP385-1
- ECG electrodes.
- Alcohol Pads and gel.
- ECG Cable.
- Oscilloscope (NI ELVIS II).
- Spectrum Analyzer (NI ELVIS II).

Theory:

Part 1: Electromyograms(EMG)

An electrical potential is generated when sodium is allowed to enter the cell's interior due to a change in the cell's membrane. Once the membrane becomes permeable to sodium, the combined (positive) effect of the sodium and potassium inside the cell is greater than the (negative) effect of the organic acids. This shift of positive charge along the inner surface of the cell membrane. The normal resting potential of the non-excited nerve is approximately (-85 mV). When the transfer takes place, the resting potential changes to (+60 mV). This change in cell potential, called **"Depolarization"**, is then transferred from cell to cell throughout the length of the nerve.

As sodium ions enter the cell, potassium actions diffuse outward. This diffusion restores the net positive charge on the membrane's outer surface and negative charge on its inner surface. Active mechanisms then return the sodium and potassium to their original locations; sodium ions are pumped out of the cell's interior, and potassium ions are transported inside. This pumping mechanism reestablishes the original ion gradients, and **"Repolarization"** is complete.

The EMG Recorder

The electromyogram, recorded on an EMG instrument, can be used to determine the nerve-muscle characteristics, attenuation in nerve conduction, and stress or tension level. Relaxed muscles may generate 10 to 100 micro volt, while muscle tension may produce 300 to 500 micro volt.

EMG differential amplifiers are similar to ECG and EEG amplifiers, except that EMG amplifiers have a higher gain than ECG amplifiers (less than EEG amplifiers), and a higher frequency response. For ECG the response is (0.3 – 30 Hz); for EMG (6 Hz to 2 KHz); and EEG (0.3 - 50 Hz).

In this laboratory exercise, you will make muscle potential measurements on your arm muscles. Although it is difficult to study the action of each muscle fiber. An electrode set placed on the forearm (one near the wrist and the other about eight inches away) will pick up the firing of action potentials as the fingers are gripped about an object. The tighter the grip, the stronger the muscle contraction which means the greater the number of action potentials.

Measurements will also be made on the biceps and triceps muscles as the arm is raised and lowered. Contraction of the biceps muscle raises the arm while contraction of the triceps muscle lowers it as **Figure (5-1)** below.

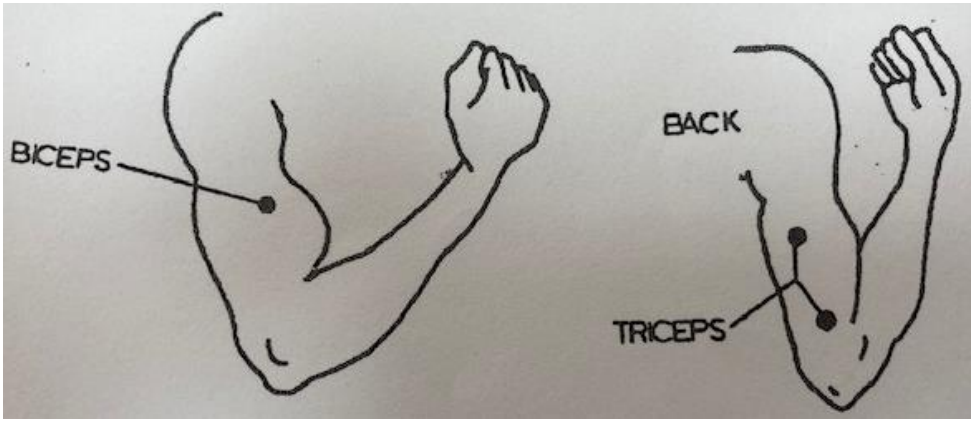


Figure (5-1) Biceps and Triceps Muscles

Part 2: *Electroencephalograms (EEG)*

The brain is a major center for measuring psychophysiological stimuli, for according physical disorders and for observing a wide range or physical events.

The brain is divided into three main areas: the medulla, the cerebellum and the cerebrum (cerebral cortex). The medulla connected to the spinal cord, controls involuntary reflexes, such as body temperature, breathing and pulse rate.

The cerebellum lying between the cerebrum and the medulla controls the voluntary muscular system responsible for the flexing of fingers, arms and legs.

The cerebrum is larger in human than in any other animal, except the dolphin. It is responsible for our sensations of pain and pleasure, thoughts, memory and our ability to learn and retain information.

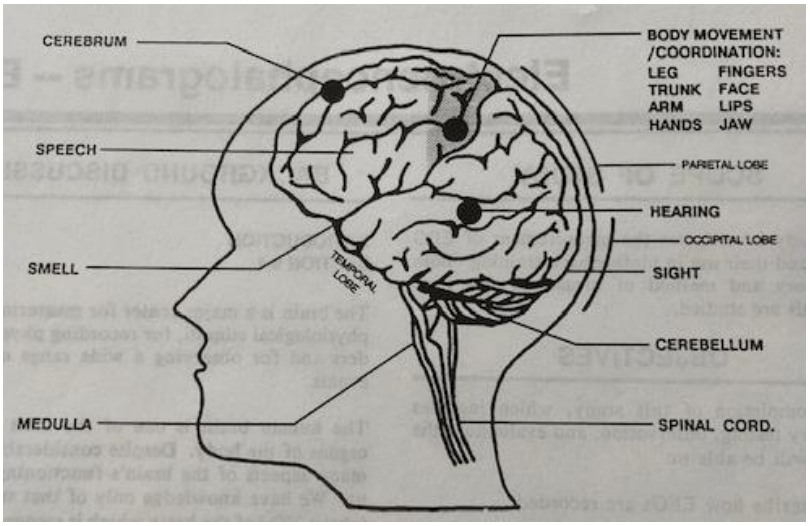


Figure (5-2) Brain Organization

Electrodes placed on the cortex (top of the head) and connected to high-gain amplifiers will record action potentials emanating both from the motor control centers of the body and from sensory receptors.

Types of brain waves

While a variety of potentials can be recorded by electrodes attached to the skull, only four major types of waves produced by brain and recorded by EEG

techniques are currently considered significant. These waves are listed in table below:

Type	Frequency Hz	Amplitude Micro V	Conditions
Delta	1 - 4	Varies	Deep Sleep
Theta	4 - 8	20 – 40	Deep Meditation & Dreaming
Alpha	8 - 14	30 – 50	Visualization & Meditation
Beta	14 - 50	5	wakefulness
Gamma	Up 50	Up 5	Heightened perception

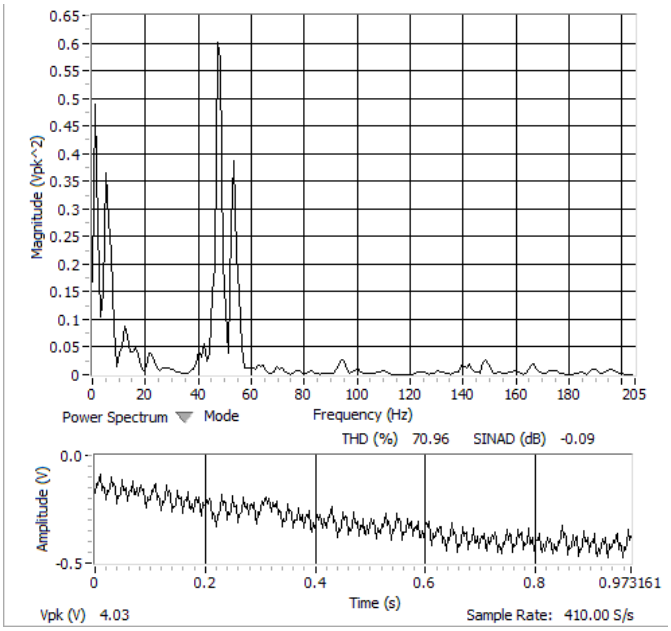


Figure (5-3) A normal EEG Theta, Alpha and Beta waves in frequency domain

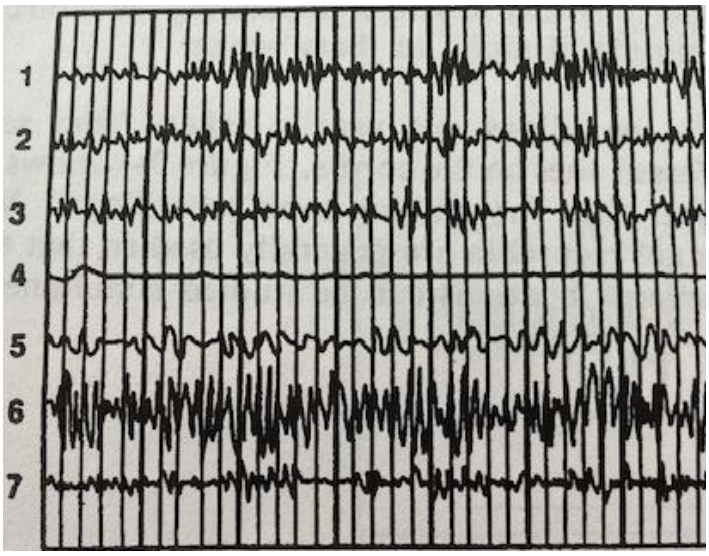


Figure (5-4) A normal EEG Theta, Alpha and Beta waves in time domain

Line 5 is a filtered theta wave with a frequency spacing of one vertical line (the time) is 0.2 seconds.

From F= 1/T

F= 1 / 0.2 = 5 Hz

Line 6 is a filtered alpha wave with a frequency spacing of three vertical lines. This indicates a frequency of 15 Hz.

F= 3 / 0.2 = 15 Hz

Line 7 is a filtered beta wave, lower in amplitude than theta waves and with a frequency spacing of four vertical lines. This indicates a frequency of 20 Hz.

F= 4 / 0.2 = 20 Hz

A reading of brain waves can indicate depth of sleep, effects of drugs and brain disease such as epilepsy. When epilepsy occurs, entire groups of neurons fire off major spiked potentials, whether the disease is localized in a single region of the brain or invades the entire organ. Brain lesions may also result in neuron discharges which travel down the spinal column and cause convulsions as well as muscular spasms.

EEG recording are usually taken from several different sites on the cortex. In figure shown below some typical sites for making such recording. Multichannel recorders are generally used so that events in several locations can be studied simultaneously.

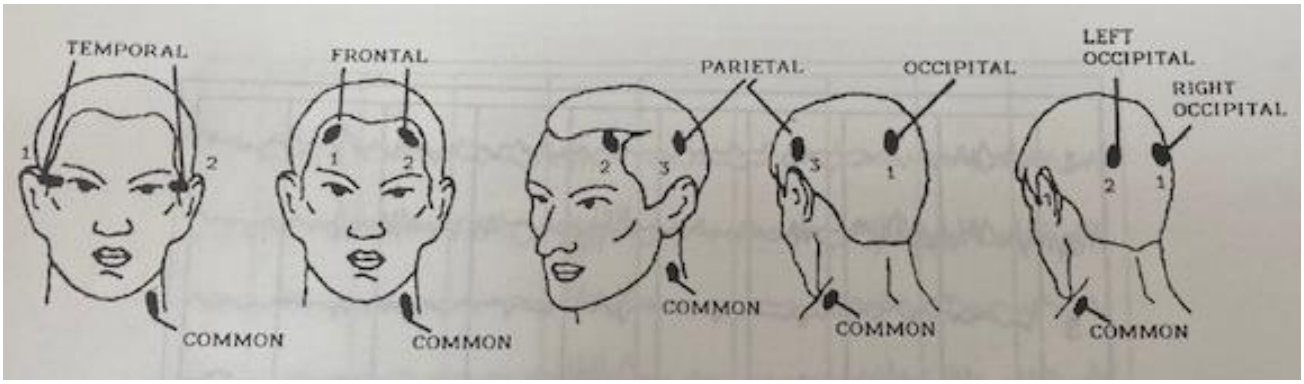


Figure (5-5) Typical Electrodes Attachment sites for EEG Recording

Since the EEG signal levels are very low in voltage amplitude (in order of 2-50 microvolt), high-gain amplifiers with well-designed filters must be used. The amplifiers must have a controllable gain of 10,000 to 1,000,000. With such amplifiers, eye blink, loose contacts, head motion, breathing and power line magnetic cause interference to the waves under study.

The contact area should be clean and electrode paste carefully applied. Since hair under electrodes causes high resistance and/or loose contacts, care must be exercised in securing electrodes.

Procedure:

Part 1: Electromyograms(EMG)

The instrumentation panel or EMG instrument is arranged for recording voltages in the **3 Hz** to **1 KHz** range.

1- The low frequency response of an amplifier system is limited either by reducing the value of the coupling capacitor or by inserting special filters. The high frequency roll-off is controlled by leaving switches $\mathbf{A_1}$ and $\mathbf{A_2}$ (**ON**) and the low end is rolled off at approximately **3 Hz** by $\mathbf{A_4}$ (**OFF**). Switch B_1,B_3 are (**ON**) and (**OFF**) B_2,B_4.

Since EMG signals are at the level of 20 to 200 micro volt, a much higher amplifier gain is required than is used for ECG. Switch A_3 (**ON**).

2- Initially fix the red lead, green lead and black lead on electrodes located.

3- Clean the skin area by alcohol sponges then put a gel for increase the conductivity, on the inner forearm. One electrode should be near the wrist; the other about 8 inches distant on the same forearm.

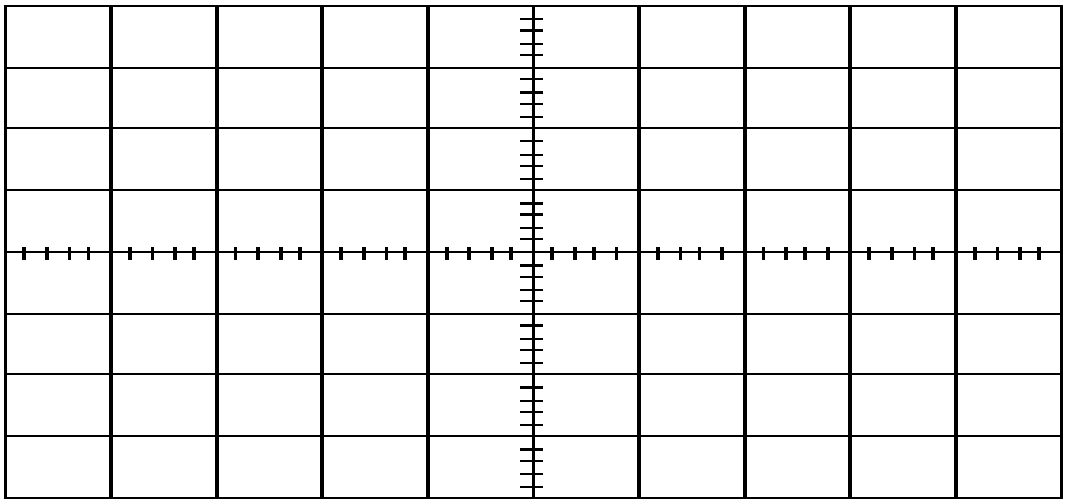
4- The black electrode should be centered in the area between the other two electrodes, not touching either one. This is the common electrode and it remains in this location during all tests.

5- Connect red lead to $\mathbf{T_{P2}}$, green lead to $\mathbf{T_{P3}}$ and black lead to any floating ground.

6- The arm with the attached electrodes should be relaxed on a table. Increase the sensitivity gain control of the EMG amplifier (section B) as necessary to obtain observable output wave shape.

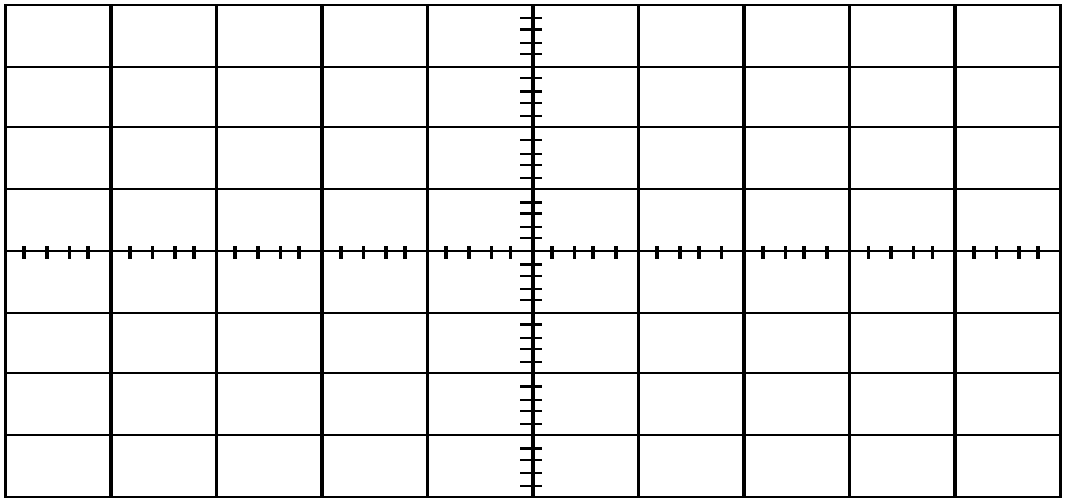
7- Display the output ($\mathbf{V_{TP15}}$) by the Oscilloscope.

8- Plot the output.



9- Place an easily gripped object in your hand, start squeezing the object and observe the base line, adjust the sensitivity control as necessary to obtain an effective scope display. Input signal range may vary according to the subject's strength and therefore, if the grip is strong, you may wish to lower the sensitivity level.

10- Plot the output.



11- Measure the spike amplitudes observed on the oscilloscope, the tone should first at random as the object is gripped and should stop when the muscle is relaxed.

Spike amplitude = ----------

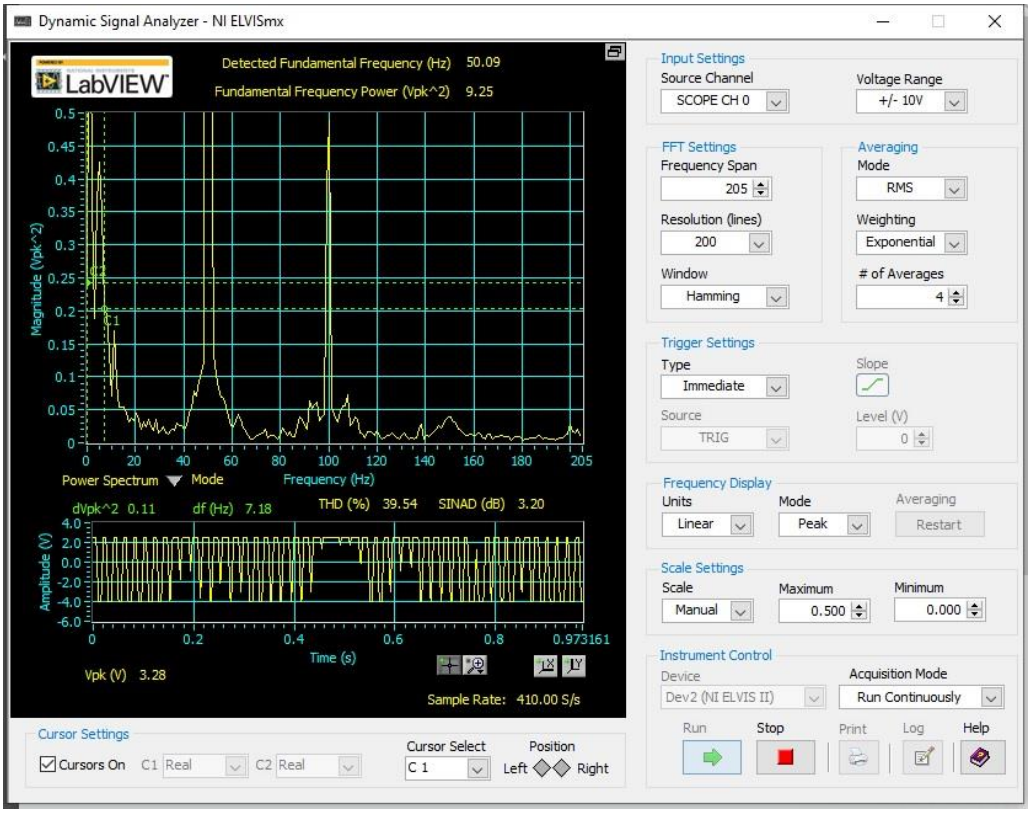
Part 2: *Electroencephalograms (EEG)*

1- First clean the site with alcohol pad and then attach the electrodes to the **frontal** recording site.

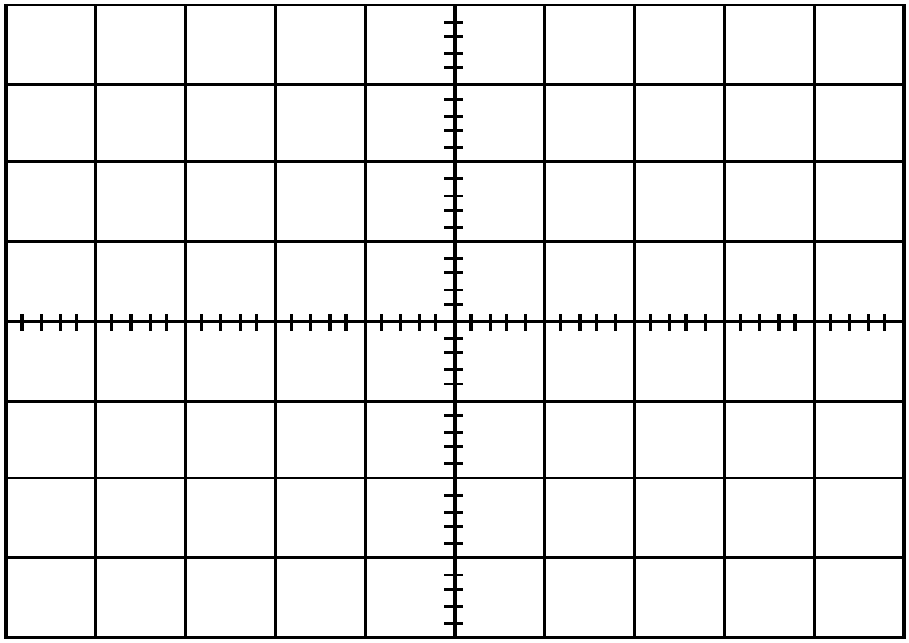
2- Connect leads to iworx device with setting: (**HPF= 0.3 Hz, LPF= 50 Hz** and the **gain= X100**), then connect it to Nocth filter $\mathbf{T_{P12}}$, make $\mathbf{B_1}$,$\mathbf{B_2}$ and $\mathbf{B_4}$ (**OFF**) but $\mathbf{B_3}$ (**ON**).

3- Display the output ($\mathbf{V_{TP15}}$) by EEG tracing on Spectrum Analyzer when the student open and close his eyes and determine if eye-blinking spikes are observed, if not readjust the sensitivity control on the panel until spikes are observed.

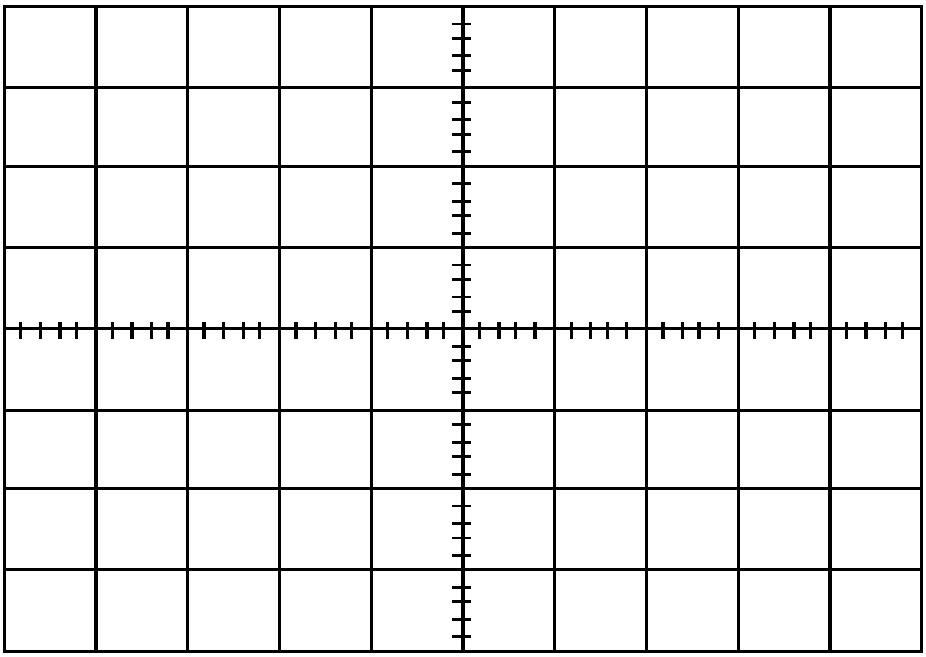
4- The setting of Spectrum Analyzer like figure show below



5- Plot the output when open and close his eyes.



Close eyes



Open eyes

Experiment 6: Analog to Pulse Shaping (Visual and Sound Indicator)

Objectives:

1- Use a Monostable oscillator in a practical timer application.

2- Utilize a Schmitt trigger circuit for controlling other circuits

3- Study an indicator circuits, which utilizes a pulsed LED and a loudspeaker.

Material Required:

- Insertion Panel SIP385-1.
- Function Generator (NI ELVIS II) .
- Oscilloscope (NI ELVIS II) .
- Alligator Clip Leads.

Theory:

Part I: Analog to Pulse Shaping:

The system of counting events such as pulse rate, respiratory rate, etc. requires that an analog signal be converted into pulsed events and displayed on a meter or recorder. In other words, analog signals must be timed and counted, events must be marked and or pulse periods must be indicated. To accomplish this, a portion of an analog signal is used to trigger a pulse-forming circuit. The amplitude, polarity, or rise time of a specific signal voltage is chosen as the trigger to activate an event marker.

Figure below shows the sequence that leads to a pulse count including the changes in the wave shape of the signal.

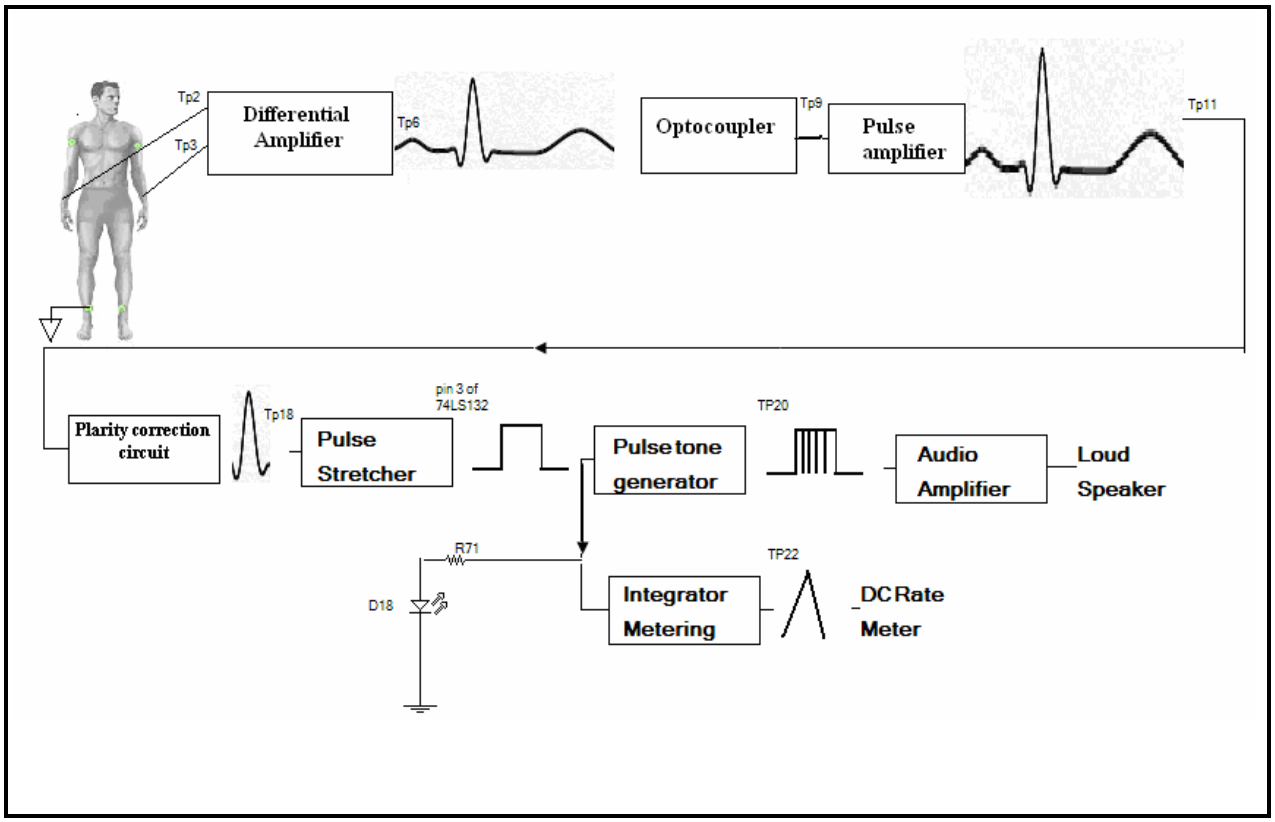


Figure (6-1)

1- Pulse Amplifier (section D): Amplify the signal.

2. Polarity correction Circuit (Section I): Clip off a portion of the signal to use its rise or fall time(R wave) to trigger the pulse stretcher circuit. In other words, this circuit removes P and T waves from the ECG complex to produce the trigger voltage(R wave) as shown the Figure # 1.

3- Section (I) consists of two circuits: Balanced Splitter (transistor Q2) and Full wave rectifier (D7- D10).

This polarity correcting circuit also makes use of the R wave as a trigger regardless of its polarity, it produces a pulse when it receives either a positive or a negative2 going input signal, and lead reversal is then no longer a problem. If the R wave would appear inverted at the pulse stretcher input, and if there were no polarity correcting circuit, the patient leads would have to be reversed.

4- Pulse stretching circuit: Converts the modified signal (R wave) into a rectangular pulse and stretches its duration (pulse width).

The rectangular pulse must have constant amplitude and pulse width, it is obtained from a Schmitt trigger NAND gate connected as Monostable oscillator. This circuit produces fixed amplitude and pulse width pulses.

This pulse could be obtained from a comparator, Schmitt trigger, or Overdriven amplifier. Each of these circuits produces fixed amplitude pulses. Although the amplitude is fixed, pulse width may change, so you must connect a circuit that produces fixed duration pulses, for example a 555 timer connected as monostable. See Figure # 2.

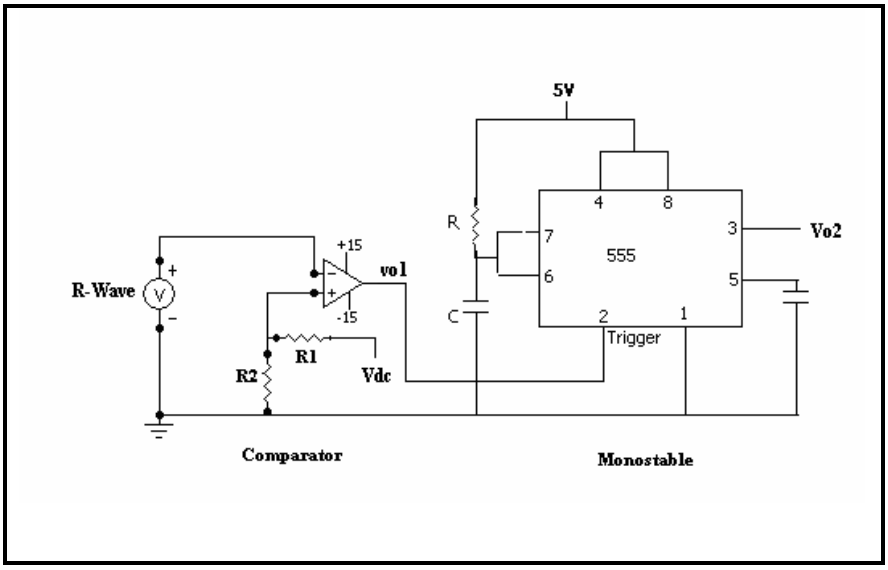


Figure (6-2)

Pulse width at V_{O2} = 1.1* R * C

The IC 74LS132 (section k) is a quad Schmitt trigger, as shown in Figure# 3. One of them used as a pulse stretcher (section J) which produces a positive pulse for each R wave, **R_{53}** and **C_{31}** set the on period (pulse width) of the pulse.

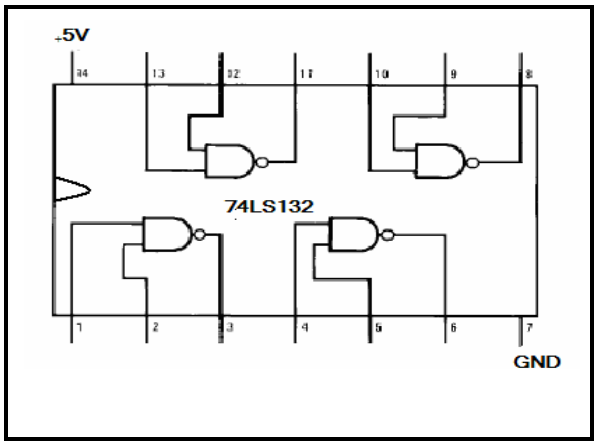


Figure (6-3)

Part II: Visual and sound pulse indicators:

Most monitoring equipment incorporates in its design both a visual and a sound indicator. Which are used to verify that either an event has just taken place or is currently in progress.

The visual indicator (LED, D18) is controlled by the pulse produced by the Schmitt trigger (pin 3 of 74LS132). The pulse width is approximately 0.1 second. Shorter pulse duration causes a chirpy sound, 0.1 second is a reasonable time when both visual and audio indicators are involved. Each time the Schmitt trigger is pulsed, the light flashes.

The other two Schmitt Trigger NAND gates of the IC74LS132 are used as a pulse tone generator as shown in Figure#4 below.

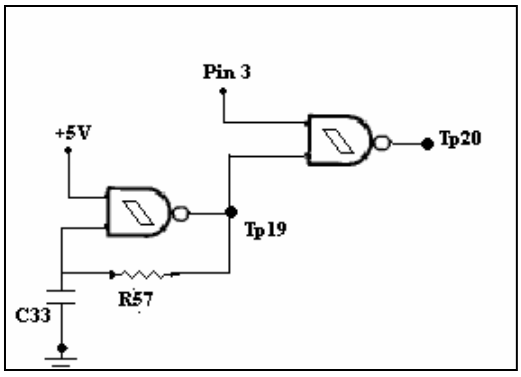


Figure (6-4)

The first NAND gate act as an oscillator that produces pulses within the normal human audio range (20 Hz – 20 KHz). The frequency of the audio pulses (T_{P19}) generated by the oscillator is controlled by R_{57} and C_{33} using the following equation:

$$f = 0.65 / R_{57}C_{33}$$

The second NAND gate inserts the audio pulses at T_{P19} with the pulses at Pin The wave shape at T_{P20} is shown in Figure# 1.

The IC74LS132, however, is not a power device and an audio amplifier would be needed as a follow up for driving a speaker (audio indicator).this circuit (audio amplifier) is already wired in the master builder and power supply base.

Audio pulses can be formed by using a 555-timer connected as a stable as shown in Figure #5 below.

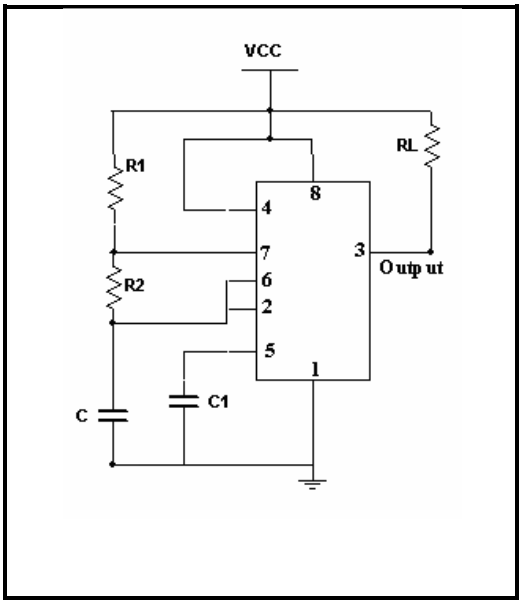


Figure (6-5)

And the frequency of the output pulses:

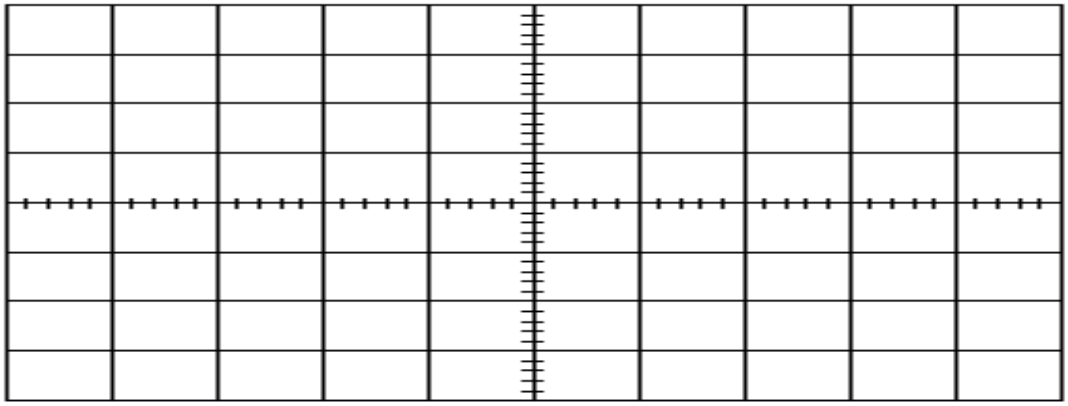
$$f = 1.44/(R_1 + 2R_2) * C$$

Experimental Procedures:

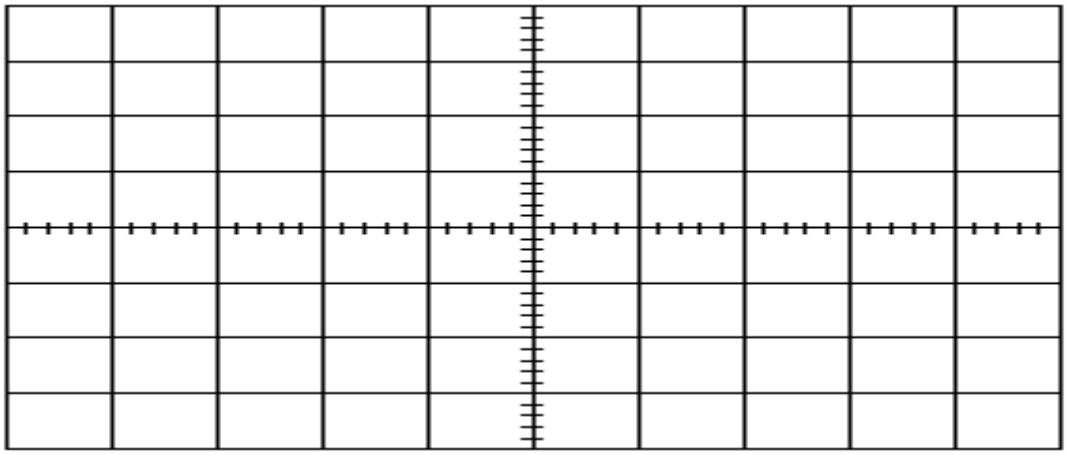
Note: You should make all switches (A1,A2,A3,A4,B1,B2,B3 and B4) OFF .

Use the function generator feed a square wave of 0.5 Vp-p with 2Hz into T_{P10} record the wave shapes at the following test points:

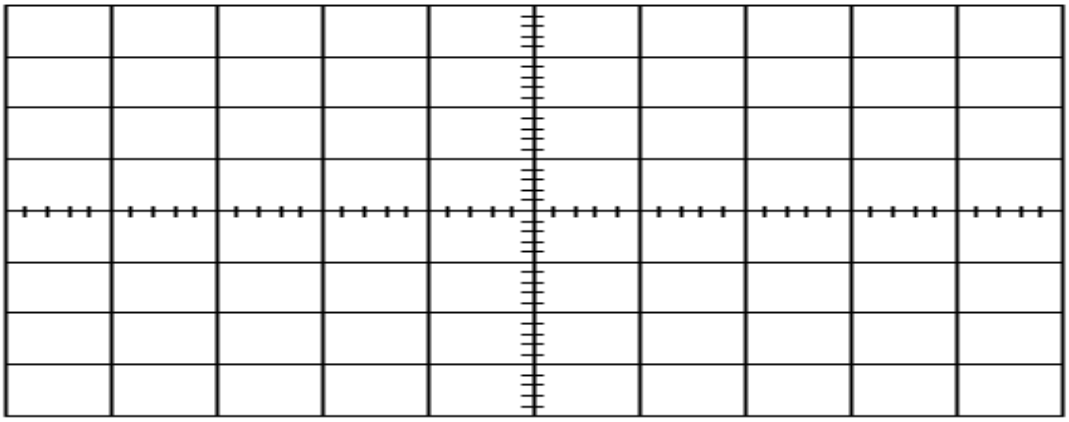
T_{P11}:



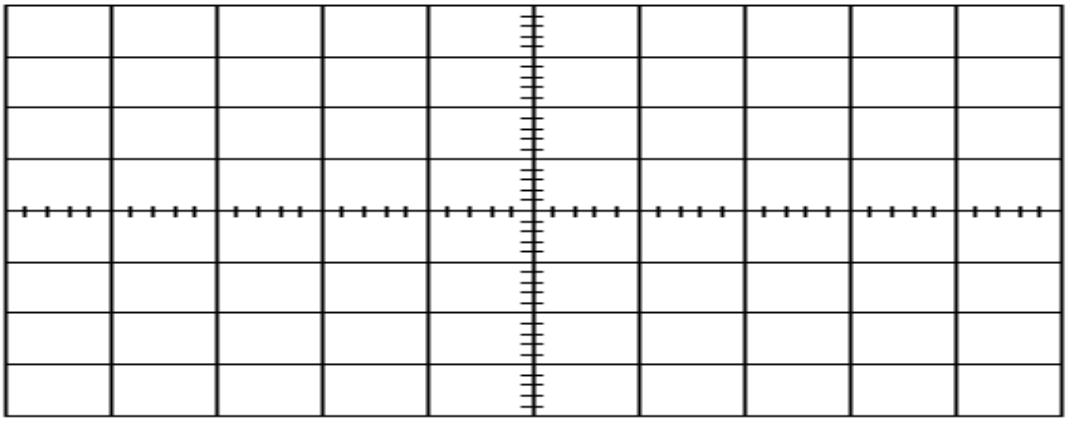
T_{P16}:



T_{P17}:



Output of the pulse stretcher (**pin 3** of 74LS132 IC)

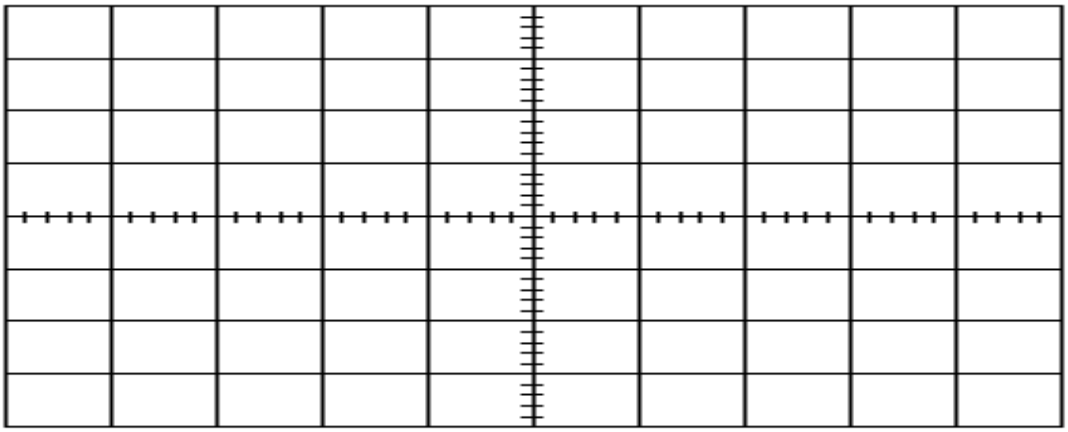


Width = ……..

Period = ……

Frequency=……

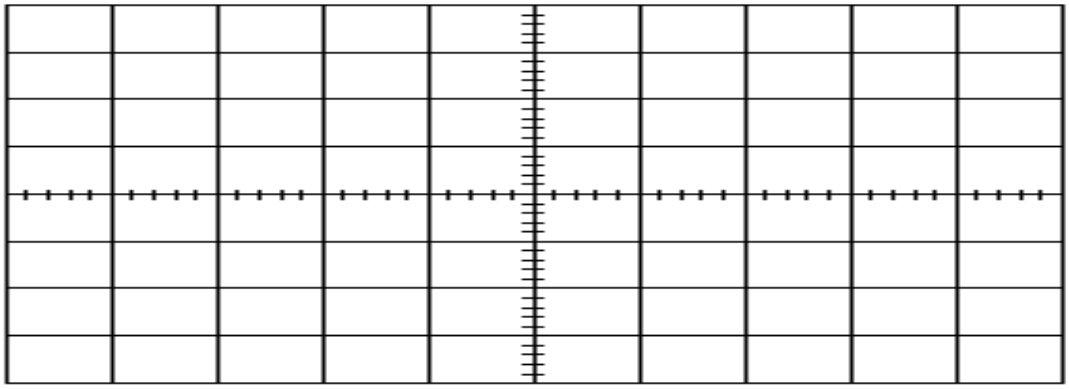
T_{P19}



Period = ……..

Frequency=……

T_{P20}



Medical Instrumentation Lab

Experiment 7: Rate Meters

Objectives:

- Study how the rate of a periodic signal can be counted.
- Develop and evaluate a circuit for averaging the pulse-rate of a signal.
- Study the double integrator circuit.

Material Required:

- Insertion Panel SIP385-1.
- Oscilloscope (NI ELVIS II) .
- Function Generator (NI ELVIS II) .

Theory:

The rate metering circuit converts varying pulses into stable pulses whose amplitude and width are fixed, but the frequency is variable as explained in the previous experiment. The metering circuit converts these frequency changes in to an average DC level which can be read by an analog meter.

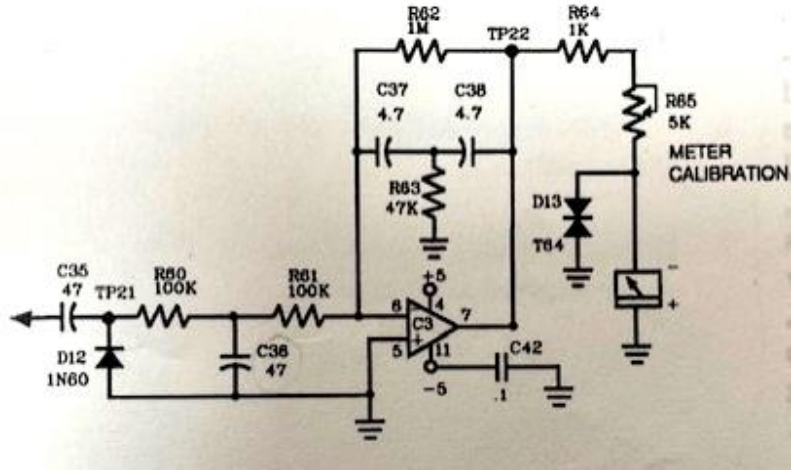


Figure (7-1)

The output pulses from the pulse stretcher circuit with constant amplitude and width are averaged per time using the double integrator circuit shown in section L of the panel, the wave shape of the output signal at $\mathbf{T_{P22}}$ is triangular with a negative DC level.

The double integrator requires 6 to 8 pulses (beats or R waves) for the meter to reach its averaging level, while the single integrator (one capacitor in the feedback) requires 15 to 18 pulses.

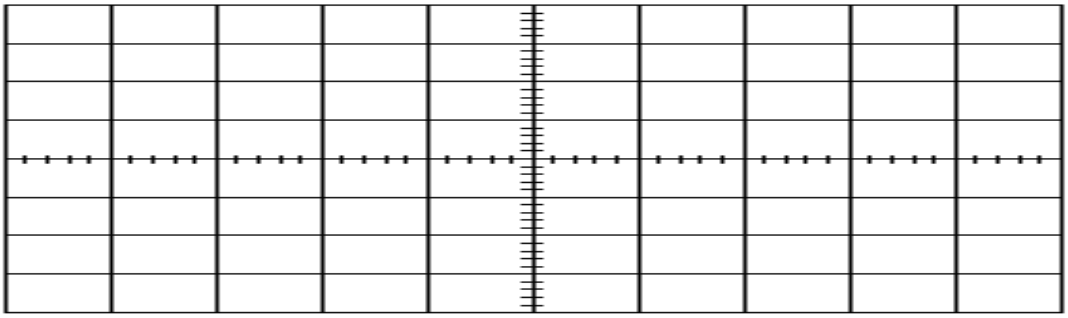
The averaging method of rate counting is one of two techniques used. The second method is pulse-to-pulse counting method: the period between pulses is counted with a frequency meter.

Experimental Procedures:

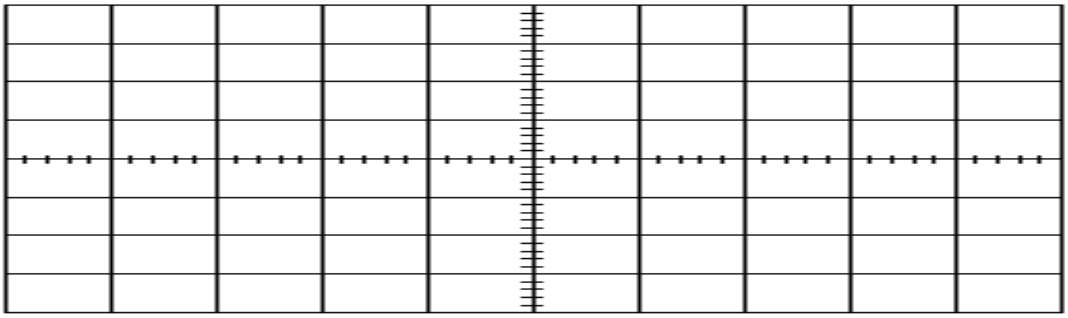
1- **Input:** Using the function generator feed a **1Hz** and positive pulses (square wave, amplitude = **2** $\mathbf{V_{p-p}}$ and Duty cycle = **10%**) into $T_{\mathbf{p18}}$ (section J).
2- **Output:** Is taken from $\mathbf{T_{p22}}$ by using channel (0) on Oscilloscope.
3- Open the Lab View file (**meter**) from desktop.
4- Calibrate the meter by change the value of gain to get **60 BPM** on meter.
5- Check the calibration linearity of the meter:

#	Frequency (Hz)	BPM
1	0.8	
2	1.2	
3	1.33	
4	1.5	
5	2	

6- Observe and record the wave shape at Tp21 with 1 Hz.



7- Observe and record the wave shape at Tp22 with 1 Hz.



Medical Instrumentation Lab

Experiment 8: Blood Pressure Measurement

Objectives:

- Learn the principle of measuring blood pressure without using a stethoscope.
- Studying how to measure blood pressure through an electronic circuit.

Material Required:

- Prototype board with NI ELVIS II base.
- BP Cuff.
- Oscilloscope (NI ELVIS II) .
- Pressure sensor MPX5050DP.
- Instrumentation Amplifier AD620AN.

Theory:

Blood pressure is the force of circulating blood on the walls of the arteries. There are two types of blood pressure:

Systolic blood pressure refers to the pressure inside your arteries when your heart is pumping.

Diastolic pressure is the pressure inside your arteries when your heart is resting between beats.

Blood pressure categories:

The five blood pressure ranges are:

Normal:

Blood pressure numbers of less than 120/80 mm Hg are considered within the normal range. If your results fall into this category, stick with heart-healthy habits like following a balanced diet and getting regular exercise.

Elevated:

Elevated blood pressure is when readings consistently range from 120-129 systolic and less than 80 mm Hg diastolic. People with elevated blood pressure are likely to develop high blood pressure unless steps are taken to control the condition.

Hypertension Stage 1:

Hypertension Stage 1 is when blood pressure consistently ranges from 130-139 systolic or 80-89 mm Hg diastolic. At this stage of high blood pressure, doctors are likely to prescribe lifestyle changes and may consider adding blood pressure medication for avoiding heart attack or stroke.

Hypertension Stage 2:

Hypertension Stage 2 is when blood pressure consistently ranges at 140/90 mm Hg or higher. At this stage of high blood pressure, doctors are likely to prescribe a combination of blood pressure medications and lifestyle changes.

Hypertensive crisis:

This stage of high blood pressure requires medical attention. If your blood pressure readings suddenly exceed 180/120 mm Hg, wait five minutes and then

test your blood pressure again. If your readings are still unusually high, contact your doctor immediately. If your blood pressure is higher than 180/120 mm Hg and you are experiencing signs of possible organ damage such as chest pain, shortness of breath, back pain, and weakness.

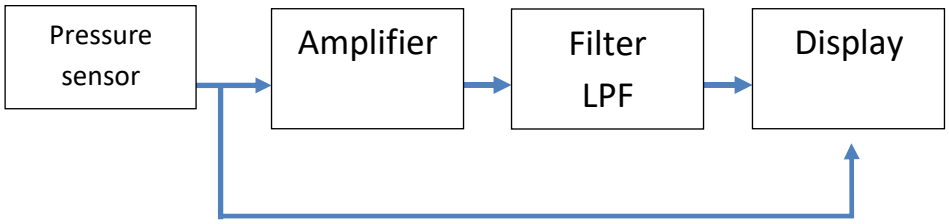
Why blood pressure is measured in mm Hg?

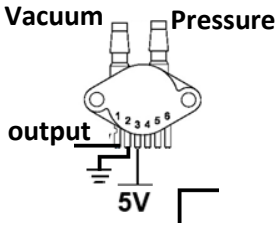
The abbreviation mm Hg means millimeters of mercury. Mercury was used in the first accurate pressure gauges and is still used in medical today as the standard unit of measurement for pressure.

Typical method for blood pressure measurement:

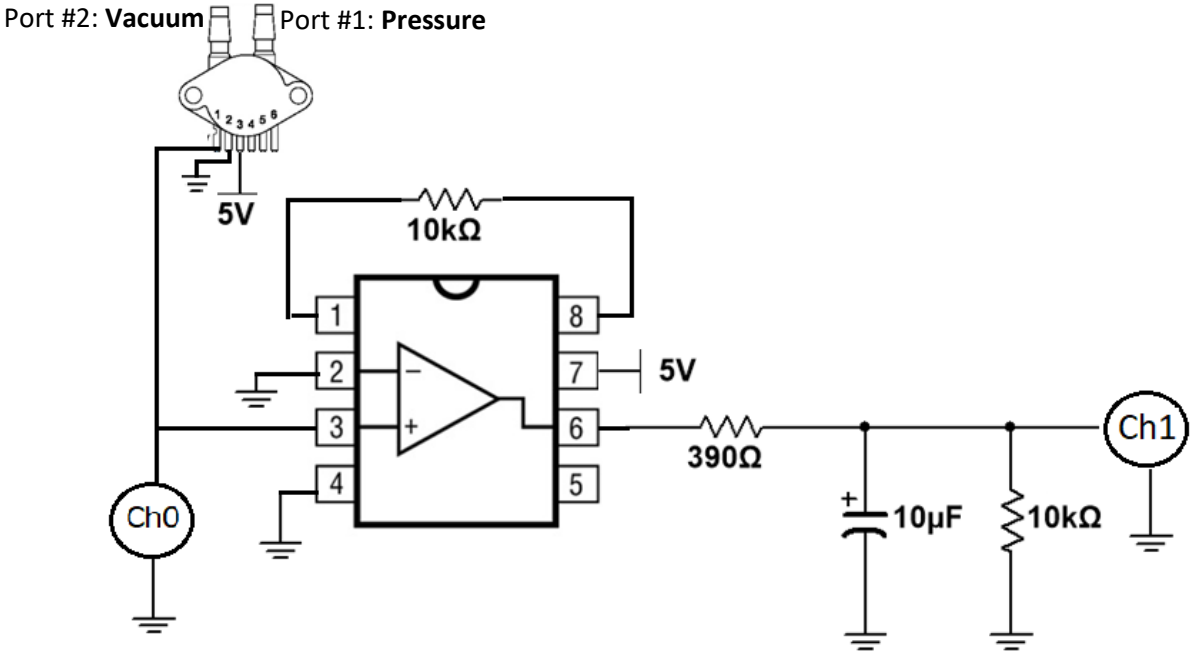
- When you're ready to take your blood pressure, sit quietly for three to five minutes beforehand. To begin, place the cuff on your bare upper arm one inch above the bend of your elbow. Pull the end of the cuff so that it's evenly tight around your arm.
- Place the disk of the stethoscope facedown under the cuff, just to the inner side of your upper arm.
- Squeeze the pump rapidly until the gauge reads 30 points above your usual systolic pressure. (Be sure to inflate the cuff rapidly). Stop squeezing. Turn the knob on the pump toward you (counterclockwise) to let the air out slowly.
- Let the pressure fall while listening for your heart sounds. Note the reading when you hear the first a heartbeat this is your systolic pressure. Then note when the beating sounds are stop this is your diastolic pressure.
- For more accuracy rest quietly and wait about one to two minutes before taking another measurement.

Experimental Procedures:





1- Connect the circuit below as the block diagram above:



2- Place the cuff on your bare upper arm one inch above the bend of your elbow.

3- Connect the cuff to the pressure sensor by using port#2 (pressure).

4- Display the **Ch0** and **Ch1** of Oscilloscope.

5- Squeeze the pump rapidly until the $\mathbf{V_{Rms}}$ reached above **2V**. Stop squeezing.

6- Turn the knob on the pump toward you (counterclockwise) to let the air out very slowly let the pressure fall while watching Oscilloscope screen note the

reading of $\mathbf{V_{Rms}}$ when you see the first wave (heartbeat) on screen this is Represent the systolic pressure.

(Sys) $\mathbf{V_{Rms}}$ = ……. V

7- Continue turning the knob on the pump toward you (counterclockwise), then note the reading of $\mathbf{V_{Rms}}$ when the wave signal (heartbeat) disappear on screen this is Represent the diastolic pressure.

(Dys)$\mathbf{V_{Rms}}$ = ……. V

From data sheet of sensor you must subtract minimum pressure **offset = …….** from $\mathbf{V_{Rms}}$ then dividing $\mathbf{V_{Rms}}$ /**0.09** to get systolic pressure in KPa.

(Sys) $\mathbf{V_{Rms}}$ – **offset** = …….. V

Sys = $\mathbf{V_{Rms}}$ / 0.09 = ……. Kpa

(Dys) $\mathbf{V_{Rms}}$ – **offset** = ……V

Dys = $\mathbf{V_{Rms}}$ / 0.09 = ……. Kpa

8- Convert the values of **Sys** and **Dys** to millimeters of mercury (**mmHg**) by using any website.

Sys =……. mmHg **Dys** =…….. mmHg

Medical Instrumentation Lab

Experiment 9: Safety Analyzer

Objective:

1- To understand the principles involved in performing electrical safety measurements on medical devices.
2- To perform acceptance tests on medical devices using an electrical safety analyzer that include main voltages, protective earth resistance, earth leakage current, enclosure leakage current, patient leakage current…etc.

Material Required

- International safety analyzer.
- Medical kit(ECG).

Theory:

Commercially available instruments called Electrical Safety Analyzer are available for testing. Both medical facility power systems and medical devices. These analyzers range in complexity from simple conversion boxes used with any voltage-ohmmeter to computerized automatic measurement systems. The features to consider are accuracy, ease of use, testing time, and cost.

Adequate electrical safety in health care facilities can be achieved at moderate cost by combining a good power-distribution systems, careful selection of well-designed equipment, periodic testing of power systems and equipment, and a modest training program for medical personal.

The Physiological effect of electrical current:

- The physiological effect of the current depends not only on either magnitude but also on the current pathway through the body, which in turn depend on the location of the contact.

- The effect of small current applied directly to the heart is often referred to as micro-shock.
- Electric current can affect the tissue in two different ways:
  1- The electrical energy dissipated in the tissue resistance can cause a temperature increase, if high enough, tissue damage can occur.
  2- An extraneous electric current of sufficient magnitude can cause local voltages that can trigger action potential and stimulate nerves, the stimulation of motor nerves or muscles causes contraction of muscle fiber in the muscles or muscle group.

Safety analyzer: can be defined as an instrument designed to be used for the quick and easy measurements of electrical leakage current, main voltages and power cord ground resistance of any electrically operated equipment in order to provide electrical safety of hospital instruments.

Leakage current: small current in μA flows between any adjacent insulated conductors that are of different potentials. The most important leakage current is that flows from all conductors in the device to lead wires connected either to the case or to patient.

There are two leakage current modes:

a. **Case leakage:** measures leakage current from equipment chassis to ground through the line cord, which may be measured internally then called Earth Leakage or externally by connecting the external lead (Red) to the input jack of the safety analyzer and the other end of the lead to the case of the unit under test.
b. **Lead Leakage:** measures leakage current between ECG leads and gourd.

Power Cord resistance:

Measures line cord ground resistance for the device under test using Kelvin Cable and internal current source.

Procedure:

Part1: Main Voltages Measurements

1- Connect the safety analyzer to an AC outlet.
2- Turn on the power via the main power switch on the right side of the safety analyzer.
3- The display will then indicate " MAIN MENU, INT, XTR, and CFG".
4- From the tactile keypad select (F1) form internal measurement (internal measurement allows you to accurately measure line voltage and line polarity.

Line voltage =…….

Line polarity is …….

Part 2: Case Leakage Measurements

1- Select F2 for external measurement.
2- The display will indicate "OPTIONAL FUNCTION"
3- Depress the switch labeled " CASE LAKAGE", the display will read "CASE LEAKAGE SELECT POLARITY"

Case leakage under normal polarity =.....

Case leakage under reverse polarity =.....

4- Depress F6 after polarity is selected, then open neutral tests can be performed.

Case leakage current =.....…

Part 3: Case Leakage: using external leads

1- Select case leakage.
2- Attach the external lead (Red) to the input Jack of the safety analyzer and the other end of the lead to the case of the unit under test.

Case Leakage under normal polarity =.....

Case leakage under reverse polarity =.....

Part 4: Leads Leakage

- Depress the leads leakage switch will display the leads leakage menu
  a- Leads leakage to ground

  b- Leads Leakage to LLF

Part 5: Power Cord Ground Resistance

1- Depress the switch labeled (resistance measurement), the display will read "POWER CORD RESISTANCE/ Connect K./vm Cable"
2- Attach the suitable Kelvin cable.
3- Press the "READ" switch.

Power Cord Ground Resistance = ...

Medical Instrumentation Lab

Experiment 10: Medical Ventilators

Introduction:

It is also known as a breathing machine, if a condition makes it very difficult for you to breathe or get enough oxygen into your blood. This condition is called respiratory failure. Mechanical ventilators are machines that act as bellows to move air in and out of your lungs. Your respiratory therapist and doctor set the ventilator to control how often it pushes air into your lungs and how much air you get. Ventilation is the movement of air into and out of the lungs, the ventilation has two main phases; inspiration and expiration (also known as inhale and exhale). Inspiration is the process of moving air into the lungs whereas expiration is the process of moving air out of the lungs.

Respiration:

The process of exchanging gases, it is the movement of oxygen (O_2) from the outside air to the cells within tissues, and the transport of carbon dioxide (CO_2) in the opposite direction.

The Human Respiratory System

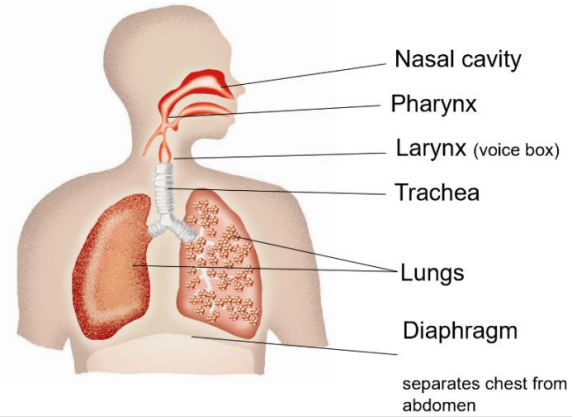


Figure (10-1)

Principle of Operation

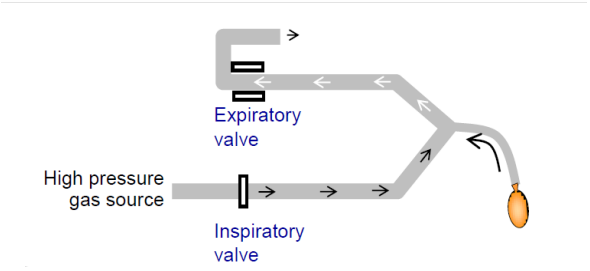


Figure (10-2)

Ventilation control modes:

1) Pressure mode.
2) Volume mode.
3) Dual mode.

Ventilation Parameters:

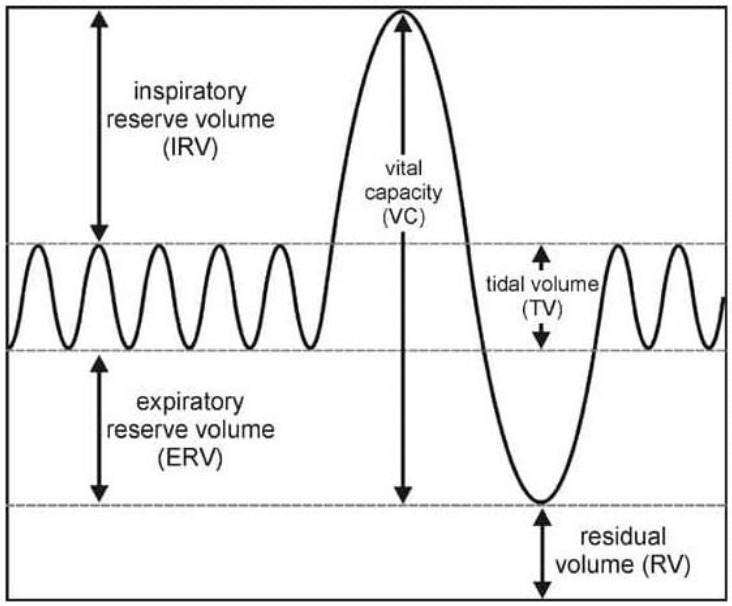


Figure (10-3)

- **Tidal Volume *(TV)*:** The volume of air moved into or out of the lungs during quiet breathing.
  - The value depends on the weight of the patient, 7 ml for every kilo of his weight.
  - In a healthy, young human adult, tidal volume is approximately 500 mL.
- **Residual Volume *(RV):*** The volume of air remaining in the lungs after a maximal exhalation.
- **Expiratory Reserve *Volume (ERV):*** The maximal volume of air that can be exhaled from the end-expiratory position.
- **Inspiratory Reserve *Volume (IRV):*** The maximal volume that can be inhaled from the end- inspiratory level.
- **Total Lung Capacity *(TLC):*** the volume in the lungs at maximal inflation (In a healthy, young human adult TLC ≈ 6000 ml).

- **Minute Volume *(MV):*** The total amount of air moved in or out of the lungs each minute.
- **Respiratory Rate *(BPM):*** Respiratory rate is the number of breathes taken in one minute.
  - Normal adult respiratory rate is 8-12 breaths per minute.
  - For infants the respiratory will be high around 20 to 40 breathes per minute.
- **Pressure waveforms:**

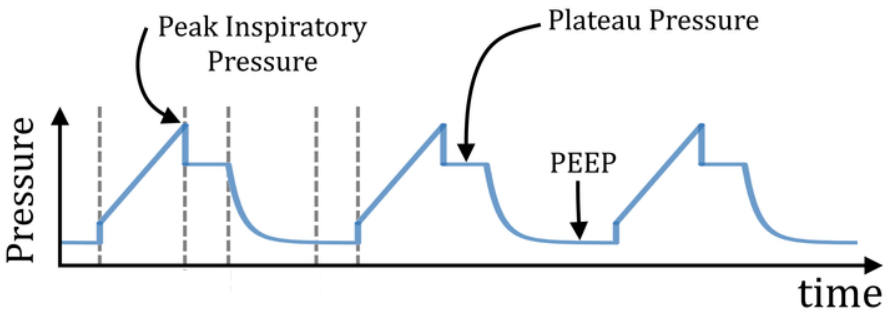


Figure (10-4)

- **Positive End-Expiratory Pressure (PEEP)**: The pressure in the lungs above atmospheric pressure that exists at the end of expiration:
  - It maintains a positive pressure in the lungs from the end of an exhalation to the beginning of the next inspiration.
  - Usual PEEP : 5 to 10 cm H_2O.
  - It limits lung emptying.
  - It Improves oxygenation (delivering oxygen to blood).
- **Peak inspiratory pressure (PIP):** The highest pressure reached during the inspiratory phase.
- **<u>I:E Ratio:</u>**
  - The I:E ratio is a ratio of inspiratory and expiratory time.
  - Usually the inspiration time is less than the expiration time.
  - It is a fundamental parameter that indicates whether the patient breathing pattern is normal.
- **Inspiration Time (Ti):** This is the time taken for the inspiration to complete and is usually denoted in seconds.

- **Expiration Time (Te):** This is the time taken for the expiration to complete and is usually denoted in seconds.
- **Inspiratory Flow Rate**: The rate at which gas is delivered to the patient during the inspiratory phase.
- **Fractional Inspired Oxygen Concentration (FiO_2)**
  - Oxygen is a important component of the gas mixture
  - This control allows the operator to control the concentration of oxygen delivered from 21 % to 100 %.
  - Mean Airway Pressure **(MAP):** It is the average pressure in the respiratory passage during ventilation.
- **Compliance**: The compliance of the lung is a measure of its ability to expand. Compliance is the change in volume divided by the change in the pressure: **Δ V/ ΔP**.

Types of medical ventilator technologies:

1- Tank technology:

Tank technology is an integral part of medical ventilators and refers to the use of compressed gas tanks to provide a reliable source of oxygen or air for the ventilator system. These tanks store pressurized gases and ensure a continuous supply during the operation of the ventilator. Here's an explanation of how tank technology is utilized in medical ventilators:

- **Gas Storage:** Compressed gas tanks, typically made of steel or aluminum are used to store medical-grade gases such as oxygen or air. These tanks are designed to withstand high pressures and have safety features such as pressure relief valves.

- **Gas Selection:** Ventilators equipped with tank technology usually have a gas selection mechanism that allows the user to choose between different gases based on the patient's requirements. Common options include pure oxygen, medical air, or a mixture of both.
- **Gas Delivery:** The compressed gas from the tanks is delivered to the ventilator system through a pressure regulator. The regulator reduces the high-pressure gas from the tank to a lower, more manageable pressure suitable for the ventilator's operation.

- **Backup and Redundancy:** Tank technology provides a backup or redundant gas supply in case of power outages or interruptions in the primary gas supply. This ensures that the ventilator can continue to function and deliver essential respiratory support to the patient.

- **Monitoring and Replacement:** The pressure level within the gas tanks is monitored to ensure an adequate supply. Ventilators typically have gauges or indicators that display the remaining gas pressure, enabling healthcare providers to know when it's time to replace or refill the tanks.

2- Piston technology:

Piston bellows technology in medical ventilators refers to the use of a piston-driven mechanism to generate airflow and control the delivery of oxygen or air to a patient who requires assistance with breathing. The brief explanation of how piston technology works in medical ventilators:

- **Piston Assembly:** The ventilator's piston assembly consists of a cylinder or chamber and a piston that moves back and forth within it. The piston is typically driven by an electric motor or a pneumatic system.

- **Airflow Generation:** When the piston moves in one direction (usually downward), it creates a negative pressure within the chamber. This negative pressure causes air or oxygen to be drawn into the chamber through an inlet valve.

- **Gas Compression:** As the piston reverses its direction and moves back (upward), the volume within the chamber decreases. This compression increases the pressure of the gases trapped in the chamber.

- **Gas Delivery:** The compressed gases are then directed through an outlet valve, which controls the flow and delivers the gases to the patient's airway. The rate and volume of gas delivery can be adjusted based on the patient's specific respiratory needs.

- **Timing and Control:** The movement of the piston is precisely controlled by the ventilator's electronic or mechanical control system. It regulates the piston's

speed, stroke length, and timing to ensure proper inhalation and exhalation cycles for the patient.

3- Turbine (blower) technology:

A recent study showed that turbine-based ventilators performed better than conventional ventilators on average, especially regarding the failure of supply lines. In addition, from the standpoint of high responsiveness to the patient's flow demand, constant-revolution blower systems with a proportional valve (PV) perform well. In the past, these systems were more responsive than dynamic blower systems. However, new research shows that dynamic blowers with a small blower wheel diameter and a high number of rotations per minute are also very responsive.

Methodology

The proposed system of the educational ventilator kit considers three main components: Pneumatic connections, conditioning circuits, and Data Acquisition System (DAQ).

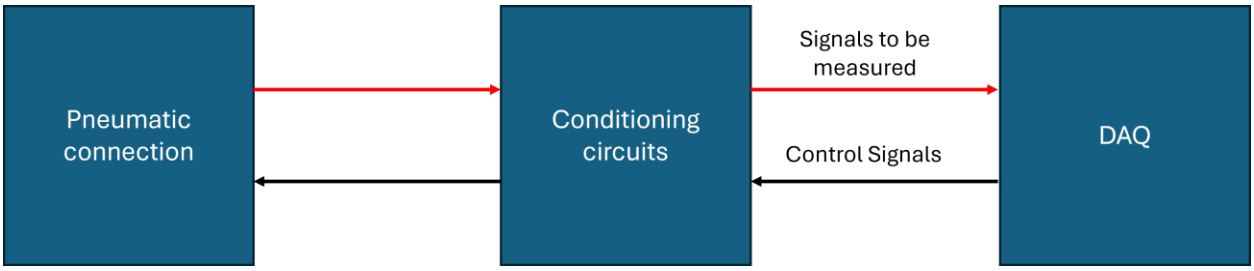


Figure (10-5) The basic block diagram

Pneumatic connections and process:

The device is designed to operate with the least infrastructure possible. It has been determined that installing a high-pressure air source would be unnecessary by using a high-speed blower to generate pressure. The pneumatic connection diagram of the ventilator is shown in Figure 2. The ventilator has also low-pressure oxygen inlet which can be taken from any oxygen source such as an oxygen cylinder with the pressure regulator. The oxygen concentration can be also controlled by using PV that control the oxygen flow. Solenoid valve (SV), check valves (CV), and air flow restrictors (R1 and R2) are also used to control the respiratory process. The internal connection between the pneumatic components has been completed using 6mm tubes, 8mm tubes, and quick fit connectors. An image for pneumatic components, connectors, and valves are shown in

Appendix B. Standardized 22-mm (male) and 15-mm (female) connectors facilitate ventilator connection to the patient (or a test lung) airway interface. Expired gas is released to the atmosphere by means of the exhaust valve, and because the inspiratory and expiratory tubing are discrete, these ventilators reduce CO2 rebreathing. Thus, the motor unit is protected from contamination. Finally, all pneumatic components are controlled by the main control circuit.

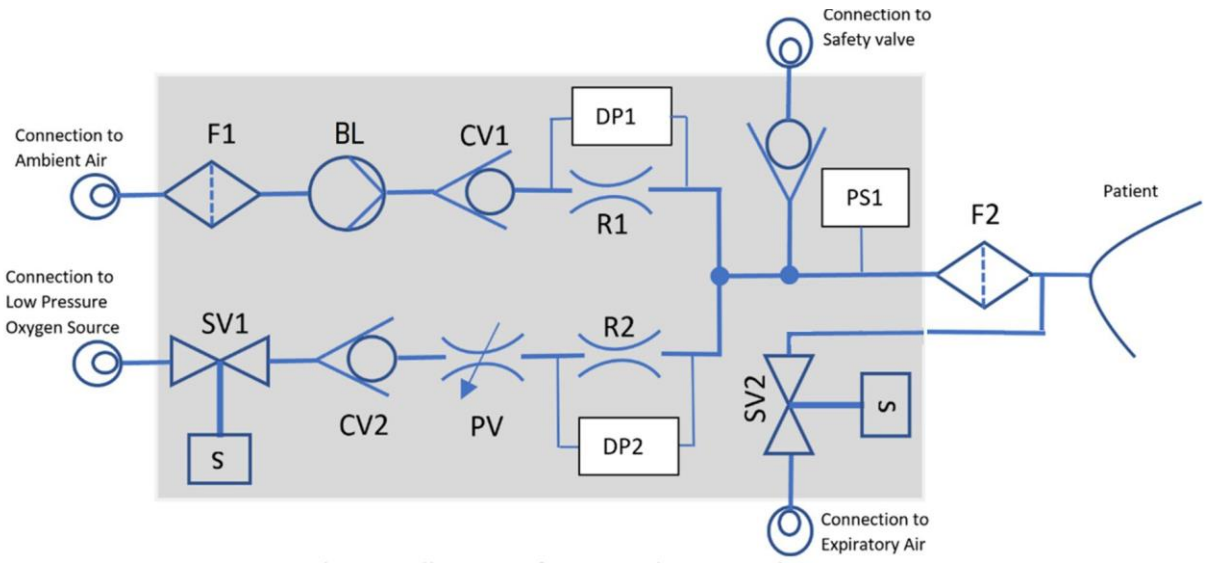


Figure (10-6) Diagram of pneumatic connection

Procedure:

Part 1: Measuring Pressure, TE, and BPM

1. Connect the test lung circuit to the inspiratory and expiratory connections on the test lung flange.

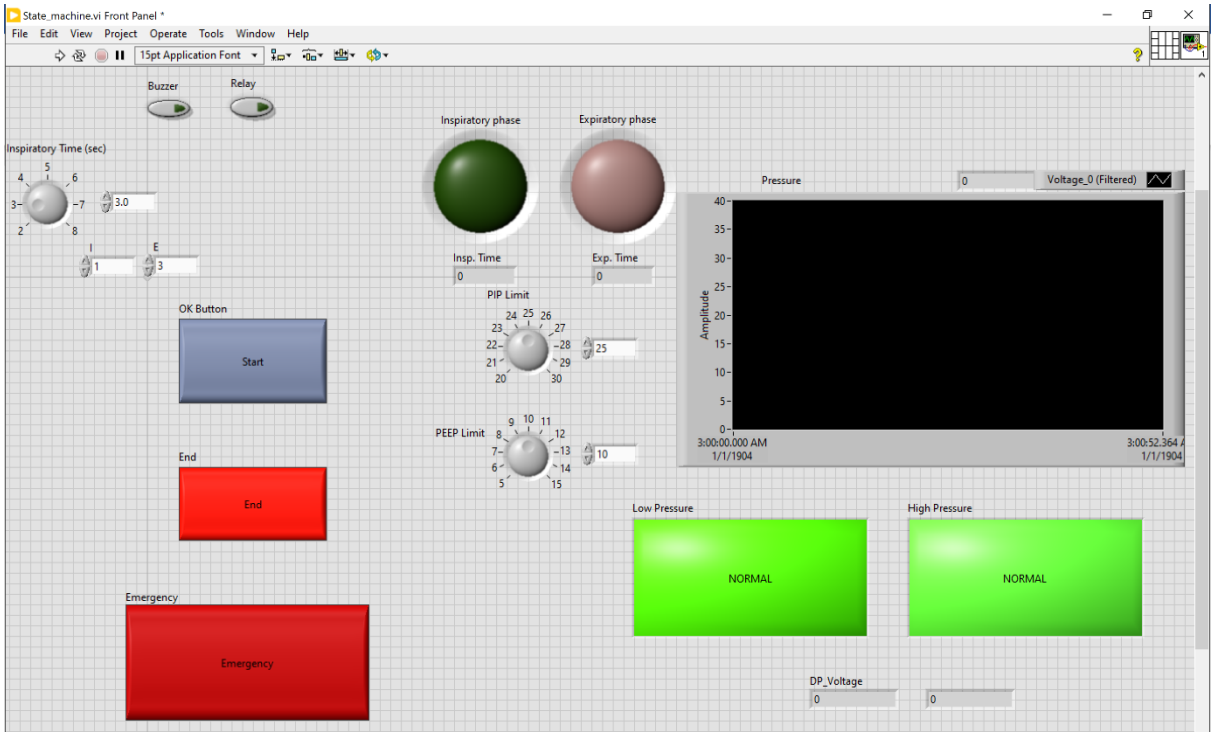
2. Initially, set the expiratory proportional valve (PV) knob to zero turns (fully-opened).

3. Set the blower speed knob to 70%.

4. Connect the conditioning circuit control pins to the Elvis kit-II as specified in the table below:

#	Conditioning Circuit Pin Name	Elvis Pin Name	Description
1	Expiratory Valve	DIO-0	Normally Open Valve
2	Buzzer	DIO-2	Alarm Buzzer
3	Blower_EN	DIO-3	Active High
4	Relay	DIO-4	Should be connected manually (Extra safety Procedure)
5	Pressure Sensor	AI-0	Analog channel
6	GND	GND	At least one GND wire

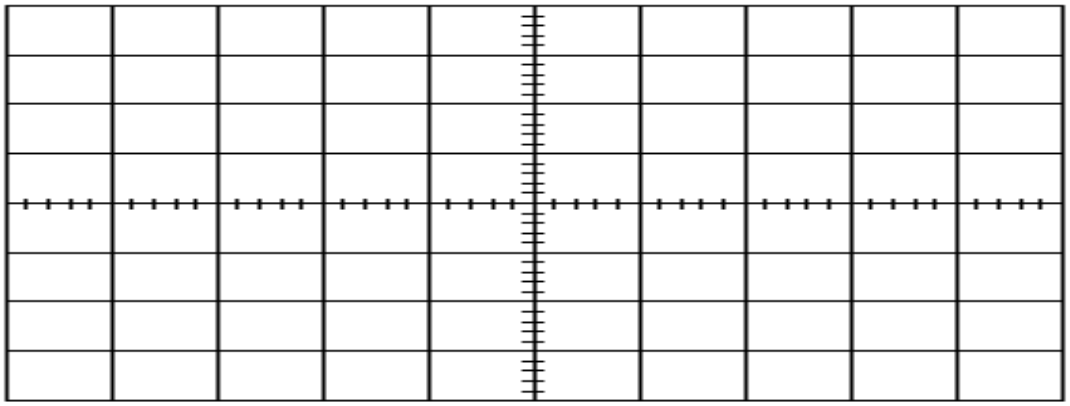
5. Open the LabVIEW (L.V) ventilator control system software.



6. on the L.V front panel, set the inspiratory time (Ti) to 3 seconds and the **I:E** ratio to **1:3** .

7. Run the software, then press start bottom.

8. Display and Record the pressure waveform.

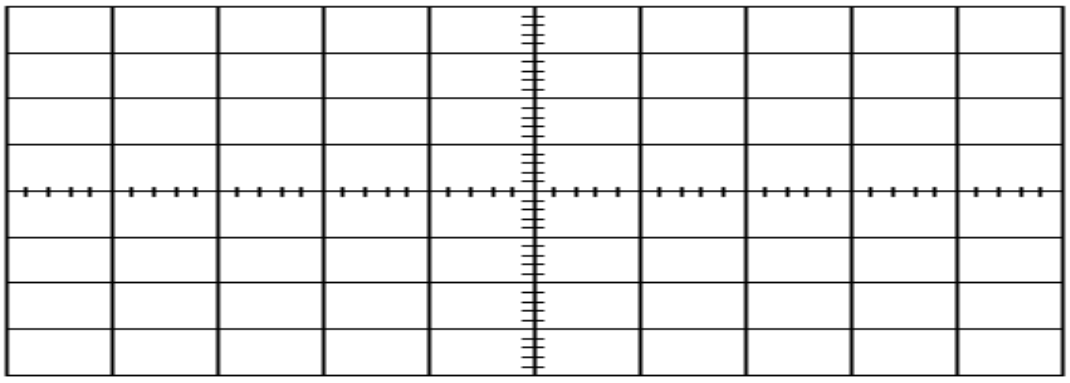


9. Measure the PIP (Peak Inspiratory Pressure) and PEEP (Positive End-Expiratory Pressure) after 5 cycles at least.

10. Measure and calculate the expiratory time (Te).

11. Measure and calculate the respiratory rate (BPM).

12. Change the I:E ratio to 1:4 and repeat steps 8 to 11.



13. comment on the results on both waveforms.

Part 2: Adjusting PIP and PEEP Pressure (Air Only):

1. Set the PIP to **15** cmH2O and the PEEP to **10** cmH2O.
2. Set the **Ti=3** sec and I:E ratio to **1:3** .
3. Adjust the expiratory proportional valve knob to make the minimum pressure close to the PEEP pressure limit.
4. Adjust the blower speed to make the maximum pressure close to the PIP limit.
5. Repeat steps 3 and 4 until the system stabilizes in both phases within (almost) the pressure control range.
6. record the blower duty cycle and PV scale.

Part 3: Testing Alarms:

1. To test for high pressure (resistance), press on the test lung softly, record the maximum pressure reached.
2. press on the test lung again harder. Observe the alarm and message appeared.
3. Test for low pressure, remove the test lung completely.
4. Observe the alarm and message appeared.