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DETECTION AND MONITORING OF ECG SIGNALS

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Abstract: Electrocardiography or Acronym (ECG) records the electrical heart planning electrical heart activity, as the heart produces a small electrical impulses spread through the heart muscle and cause a contraction, and can detect those pulses through the electric heart of the planning system, and turn the doctor to perform the electrical planning test usually to help him to find out the reason behind some of the symptoms such as palpitations or chest pain, and in some cases this is being detected as part of a routine check-ups, for example, before surgery. Do not produce any damage or pain because of the electric heart of the planning test. An this job We have made a special circle to amplify the small signal measured from the heart as well as to filter outside and internal noises and used The Laptop instead of an oscilloscope is used for monitoring the extracted ECG signal.

1.1 General Overview

Heart rate and its derivative, the heart rate variability, provide valuable information about a person's physiological state and health. Since heart rate (HR) can be extracted from a simple electrocardiogram (ECG) signal, it is a good candidate for embedding into commonly used health appliances for the aging population. To this end, heart rate monitoring is presently being included in the design of the Smart Rollator. A heart rate monitor typically begins with acquisition of the ECG signal through a set of skin electrodes. A specialized ECG amplifier is used to isolate the signal from most of the noise and further processing, either in hardware or software, extracts the heart beats. Power-line interference is a major component of noise in the ECG signal. This results from capacitive coupling to the body, electrodes, leads and circuit, as well as magnetic coupling to the loop created by the electrode leads [1-3] .

The common-mode (CM) signal from the body is typically the largest of these noise components. Its effects can be greatly mitigated by (a) using a differential amplifier with high input impedance and common-mode rejection ratio (CMRR), (b) reducing the source impedance of the input (i.e. reducing the skin-to-electrode interface impedance through skin preparation), and (c) effectively decoupling the circuit ground from earth

ground at power line frequency (60 Hz). Methods of doing these have been extensively discussed, simulated and tested in the literature [3].

The heart is a fist sized muscle within the thoracic cavity and its center lies approximately 1.5 cm to the left of the center line [63]. Its task is to pump blood throughout the body. The blood not only supplies the body with oxygen and remove metabolic wastes, it also for example regulates pH, body temperature and hormone transport [110]. During a lifetime one can expect the heart to contract about three billion times, so its endurance and reliability is of great importance [4].

1.2 Problem Statement

The ECG characteristic extraction system provides essential characteristics (intervals and amplitudes) to be used in subsequent automatic analysis. Currently, detection of these characteristics done and number of techniques has been proposed. Electrocardiogram is particularly authentic for patient observation and diagnosis. The extracted characteristic from the ECG signal plays a vital in diagnosing the cardiac problems and diseases. The most and main importance is to develop a quick and accurate methods for automatic ECG feature extraction. So, it is necessary that the characteristic extraction system carries out accurately. The objective of characteristic extraction is to find as few particulars as possible within ECG signal that would allow successful abnormality detection and efficient predictions.

2.2 A Brief History of the ECG:

The development of the ECG started in the mid-19th century with ideas concerning the role of electricity in the heart, then with the development of increasingly sensitive ways to measure this electricity. The early ECG machines were vast and required a water-cooled jacket! Technological advances in the early 20th century saw recording devices become increasingly small and by 1928 weighed ‘only’ 50 lbs (22 kg), described as being ‘portable’. Weight and size reduction continued and current devices weigh only a few pounds. The modern 12 leads of the ECG were formalized in 1942, with:

- the addition of the three augmented limb leads (aVR, aVL and aVF) Emanuel Goldberger; to the
- pre-existing three standard leads (I, II, III) so fully explored by the‘greats’ of the ECG, Einthoven, Lewis, Mackenzie, and Wilson; and the
- six chest leads (V for voltage 1–6, the technical aspects being formalized in 1938 by the American Heart Association and the British Cardiac Society). Subsequent years saw an explosion in ECG-based research, and> 150 000 articles on the ECG have now been published [31].

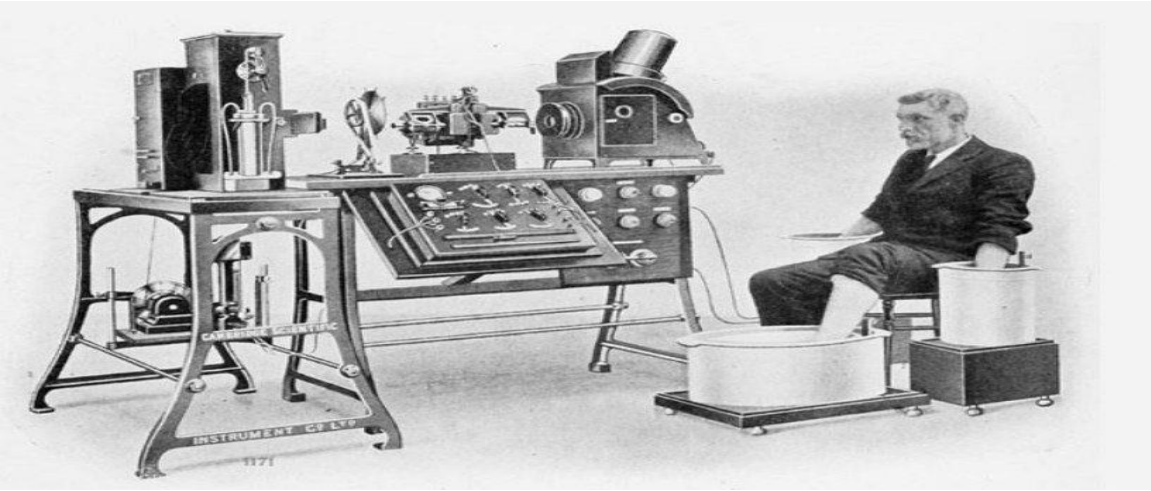


Figure 2.1. Photograph of a complete electrocardiography [32].

2.3 Anatomy of the Heart

The heart, a fist-sized muscular organ located in the mediastinum, is the central structure of the cardiovascular system. It is protected by the bony structures of the sternum anteriorly, the spinal column posteriorly, and the rib cage. The heart is roughly conical, with the base of the cone at the top of the heart and the apex (the pointed part) at the bottom. It is rotated slightly counterclockwise, with the apex tipped anteriorly so that the back surface of the heart actually lies over the diaphragm [33].

2.4 Physiology of the Heart:

Normal blood flow through the heart begins at the right atrium, which receives systemic venous blood from the superior and inferior venae cavae. Blood passes from the right atrium, across the tricuspid valve, to the right ventricle. It is then pumped across the pulmonary valve into the pulmonary artery. Outside the heart, the two branches (left and right) of the pulmonary artery distribute blood to the lungs for gas exchange in the pulmonary capillaries. Oxygenated blood returns to the heart's left atrium through four pulmonary veins. After passing across the mitral valve, blood enters the left ventricle, where it is pumped across the aortic valve and then enters the coronary arteries and the peripheral circulation through the aorta [34].

2.4.1 Mechanics of Heart Function

The mechanics of heart function are summarized in the following

- Cardiac cycle: Sequence of events in 1 heartbeat. Blood is pumped through the entire cardiovascular system.
- Systole: Contraction phase—usually refers to ventricular contraction.
- Diastole: Relaxation phase—the atria and ventricles are filling. Lasts longer than systole.
- Stroke volume (SV): Amount of blood ejected from either ventricle in a single contraction. Starling's Law of the Heart states that the degree of cardiac muscle stretch can increase the force of ejected blood. More blood filling the ventricles increases SV.
- Cardiac output (CO): Amount of blood pumped through the cardiovascular output system per min. CO = SV x Heart rate (HR) [34].

2.4.2 Properties of Cardiac Cells

Figure 2.4 shows Diastole and Atrial systolic phase. The cardiac cells properties are listed below

- Automaticity: Generates electrical impulse independently, without involving the nervous system.
- Excitability: Responds to electrical stimulation.
- Conductivity: Passes or propagates electrical impulses from cell to cell.
- Contractility: Shortens in response to electrical stimulation [33].

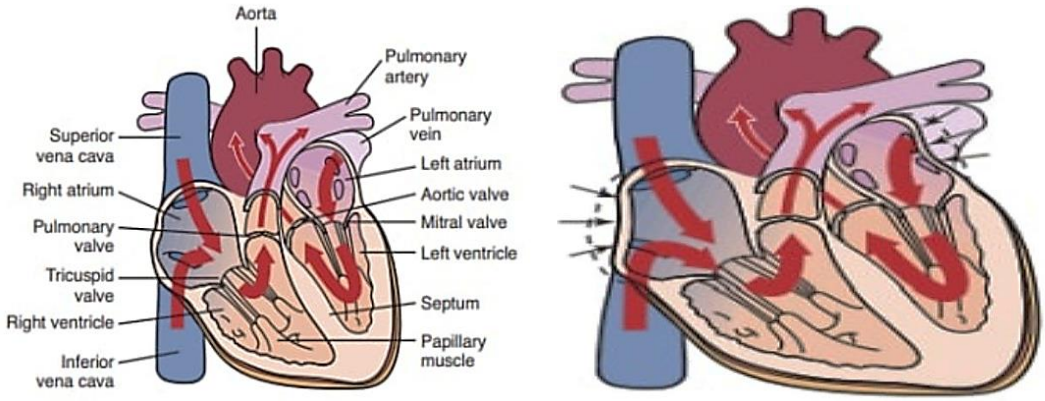


Figure 2.4. Diastole and Atrial systolic phase [34].

2.5 The Cardiac Conduction System

The illustration in Figure 2.5 shows the elements of the cardiac conduction system. Specialized fibers propagate electrical impulses throughout the heart's cells, causing the heart to contract [35].

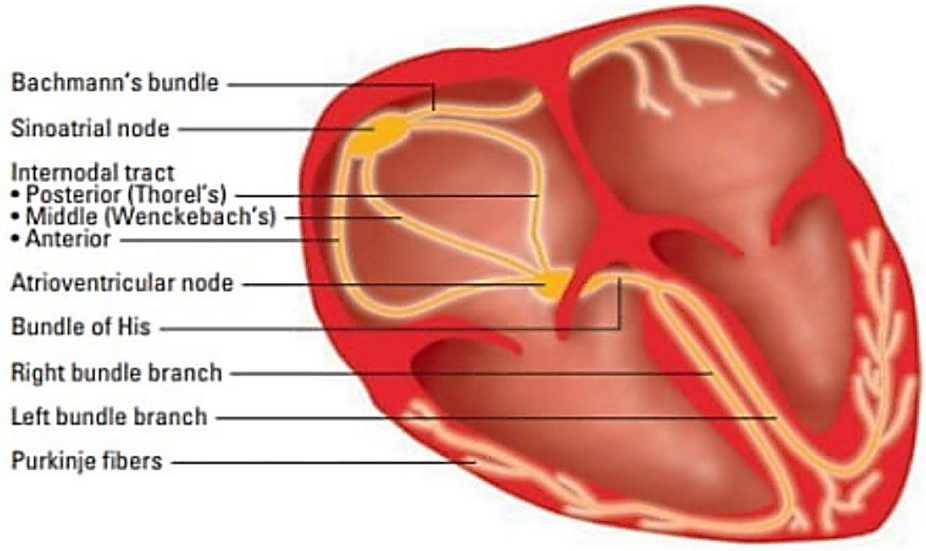


Figure 2.5. The elements of the cardiac conduction system [35].

Bachmann's bundle of nerves:

Impulses from the SA node next travel through Bachmann's bundle, tracts of tissue extending from the SA node to the left atrium. Impulses are thought to be transmitted throughout the right atrium through the anterior, middle, and posterior inter nodal tracts. Whether those tracts actually exist, however, is unclear. Impulse transmission through the right and left atria occurs so rapidly that the atria contract almost simultaneously [34].

AV: The slow node

The AV node, located in the inferior right atrium near the ostium of the coronary sinus, is responsible for delaying the impulses that reach it. Although the nodal tissue itself has no pacemaker cells, the tissue surrounding it (called junctional tissue) contains pacemaker cells that can fire at a rate of 40 to 60 times per minute [33].

Branch splitting:

The bundle of His, a tract of tissue extending into the ventricles next to the inter ventricular septum, resumes the rapid conduction of the impulse through the ventricles. The bundle eventually divides into the right and left bundle branches. The right bundle branch extends down the right side of the inter ventricular septum and through the right ventricle. The left bundle branch extends down the left side of the inter ventricular septum and through the left ventricle. The left bundle branch then splits into two branches, or fasciculi: the left anterior fasciculus, which extends through the anterior portion of the left ventricle, and the left posterior fasciculus, which runs through the lateral and posterior portions of the left ventricle. Impulses travel much faster down the left bundle branch (which feeds the larger, thicker-walled left ventricle) than the right bundle branch (which feeds the smaller, thinner- walled right ventricle). The difference in the conduction speed allows both ventricles to contract simultaneously. The entire network of specialized nervous tissue that extends through the ventricles is known as the His-Purkinje system [35].

Perky Purkinje:

Fibers Purkinje fibers extend from the bundle branches into the endocardium, deep into the myocardial tissue. These fibers conduct impulses rapidly through the muscle to assist in its depolarization and contraction. Purkinje fibers can also serve as a pacemaker and are able to discharge impulses at a rate of 20 to 40 times per minute, sometimes even more slowly. Purkinje fibers usually aren't activated as a pacemaker unless conduction through the bundle of His becomes blocked or a higher pacemaker (SA or AV node) doesn't generate an impulse [35].

3.1 DESIGN AND IMPLEMENTATION OF EGC SYSTEM

Physiological fundamentals investigation was the first step they had before working with ECG. What is significant is to have comprehensive information about heart, heart beat and its functionality. In each heart beat we can observe same set of electrical activities that describe the behavior of heart. As it can be seen in Figure 3.1, each heart beat consists of six steps.

These steps would be described as follows:

Atrium starts depolarizing.

Atrium depolarizes.

Ventricles start to depolarize at apex and atrium re-polarizes.

Ventricles depolarize.

Ventricles also start to re-polarize at apex.

Ventricles repolarize [38].

In the last step we can see a complete and normal heart signal that leads to produce different voltages. But signals generated by heart are very weak and also can be affected by some factors such as noise created by different reasons. Therefore, it is required to improve signals with amplifiers. For example, instrumentation amplifiers with high gain and high CMRR (common mode rejection ratio) can be really applicable for these kinds of purposes.

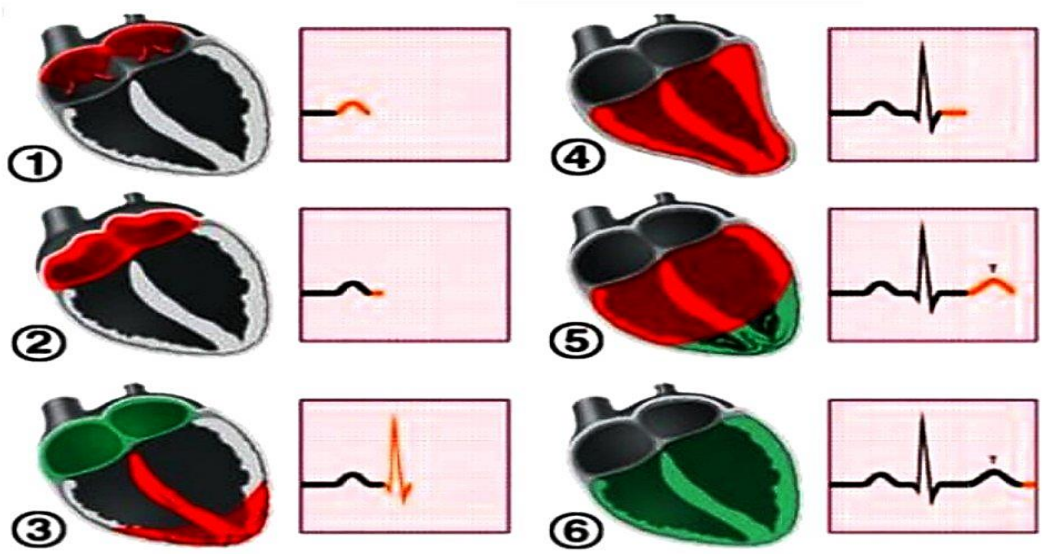


Figure 3.1. The electrical signal starts and finish in different parts of the heart [38].

3.2 Circuit Design

An ECG's job is to amplify the small signal measured from the heart as well as to filter outside and internal noises. The amplification is mainly implemented through a differential amplifier whereas filtering is completed through common and differential mode filtering. There is also the Right Leg Drive circuit which cancels noise and maintains the common mode voltage [39].

3.3 ECG Signals and System Diagram

The ECG transducer generates a signal stream with amplitude from 50 μV to 4 mV with frequency components concentrating at 0.5 to 100 Hz. Considering that the ECG signal is too weak and subjected to a variety of noises, the system in Figure 3.2 has been designed to obtain a clear ECG waveform [40].

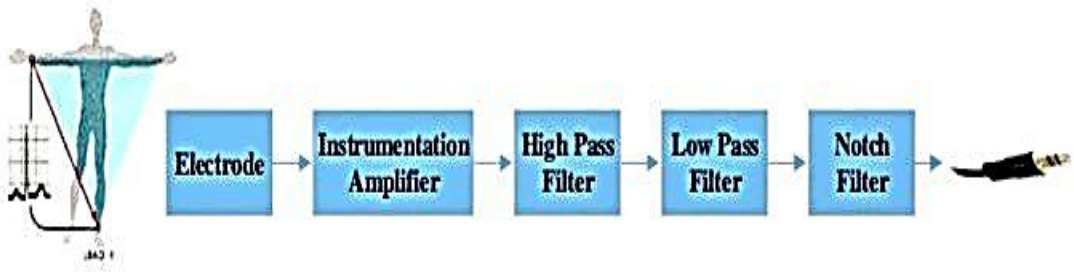


Figure 3.2. Block diagram of the ECG acquisition circuit [41].

3.4 Amplifier

ECG signals vary from the microvolt to the millivolt range. Due to this small range, the signals measured need to be amplified in order to be better interpreted. Typical bio-potential amplifiers have high input impedance and are designed for safety first. This is due to the fact that the signal amplified is being drawn from a living organism so precautions must be taken in order to prevent macro and micro shock. Isolation and protection circuitry are used to limit current through electrodes to safe levels. The output impedance of the amplifier should be very low to drive any external load with minimal distortion. Again, due to the small size of the signal, the gain should be large. Typically a gain of over 1000 is implemented in bio-potential

amplifier circuits. The amplifiers should have a high common mode rejection ratio to eliminate large offset signals. Finally, most bio-potential amplifiers are differential. Differential amplifiers are used to make sure that noise from the inputs are not amplified thus yielding a higher integrity signal. Differential amplifiers with such characteristics are difficult to find. Thus combinations of differential amplifiers are used to construct what is called an instrumentation amplifier. A basic three-op-amp instrumentation amplifier is shown in Figure (3.3) .

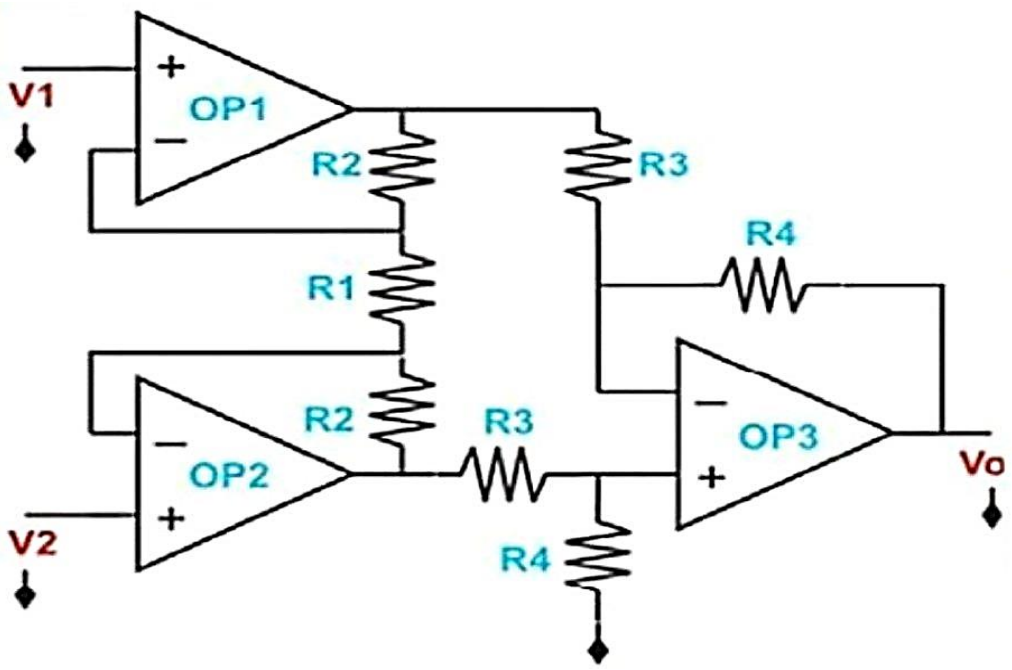


Figure 3.3. Basic Instrumentation Amplifier [39].

3.5 Artifacts Noise

The unwanted signals that are merged with ECG signal and sometimes create obstacles for the physicians from making a true diagnosis. Hence, it is necessary to remove them from ECG signals using proper signal processing methods. There are mainly four types of artifacts encountered in ECG signals: baseline wander, power line interference, EMG noise and electrode motion artifacts [42].

3.6 Right-Leg Drive Circuit

The right-leg drive circuit serves as a protective circuit against over-current to the body, aids common mode rejection of the preamplifier by sending the electrocardiogram signal got from the body back to the body but in a negative amplified manner. It consists of a buffer stage (to avoid loading the instrumentation amplifier internal circuitry) and an inverting amplifier stage (for negative amplification of the signal). At the output, the right-leg drive circuit is further connected to a high resistance resistor whose main function is to further protect the human for overcurrent from the mains and during transient. Figure 3.5 shows the right-leg drive circuit [43].

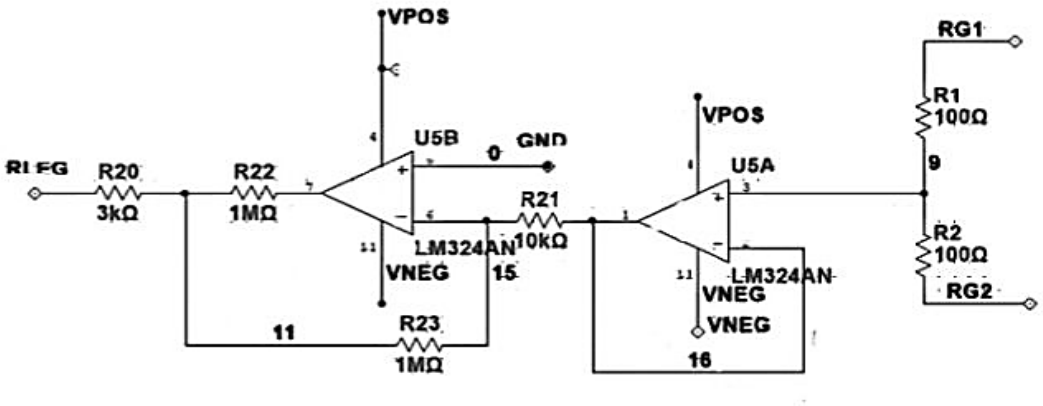


Figure 3.4. Right leg drive circuit [43].

3.7 Design and Implementation of EGC Electrodes

To obtain reliable measurements of bioelectric events, such as the ECG, the electrodes play major role in the measurement chain. If they are used incorrectly, they can introduce distortion several orders of magnitude larger than the ECG signal itself. The typical measurement system for ECG measurements consists of two or more electrodes attached to the skin and connected to a differential amplifier.

3.7.1 State of the ECG Electrodes

In Figure 3.5, a generic sketch of a conventional ECG electrode is shown. The top consists of a metal knob (dark gray), which is attached to a cable. It pierces the other layers to the bottom, where it is embedded in a conductive media, often a gel or a hydrogel. In between there is a layer of a plastic or paper disk which serves as a stabilizer (light gray) and an adhesive collar which is fastened to the skin. This construction deals with some of the possible sources of distortion. The adhesive skin tape makes the electrode firmly attached to the skin, while the stabilizer keep the skin in its center as still as possible. Still in this sense means that one point of the skin is prevented to move in relation to another within the center of the electrode. The gel improves conduction and serves as a medium to transfer the ionic charge in the skin to electrone borne in the electrode [44].

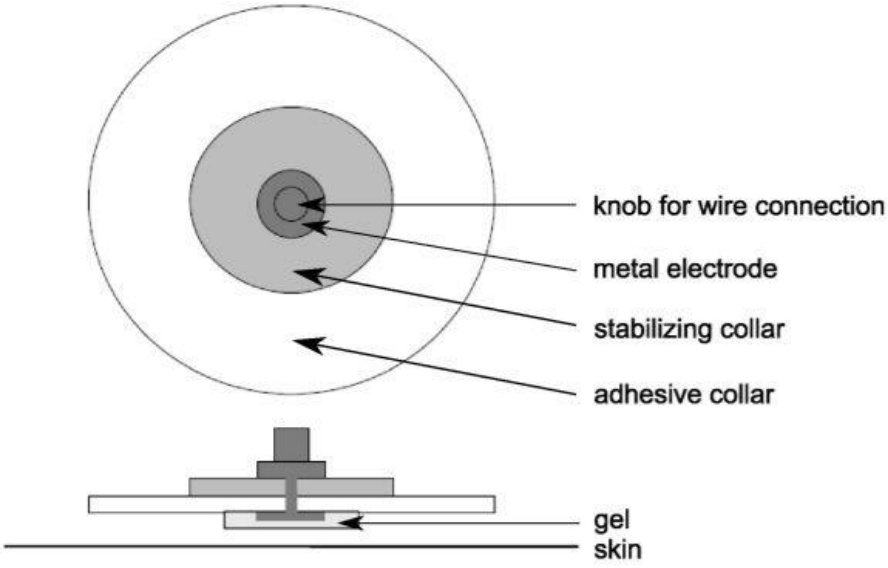


Figure 3.5.Top: the ECG electrode seen from above. Bottom panel, side view [44].

3.8 Design and implementation of the complete detection and monitoring system for ECG signals.

In this design, a metal isolated electrodes, instrumentation amplifier, and filters are used to extract the ECG signals. ±9V separate DC batteries are used to drive the prototype. The filters are used to remove noise and reduce its impact on the ECG signal. Here a 50Hz notch filter is used avoid the effect of the 50Hz AC source on the ECG signal, 1 Hz to 100Hz band-pass filter and 100Hz low-pass filter are used. The Laptop instead of an oscilloscope is used for monitoring the extracted ECG signal. The circuit diagram of the proposed ECG extracting and monitoring system is shown in Figure 3.6.

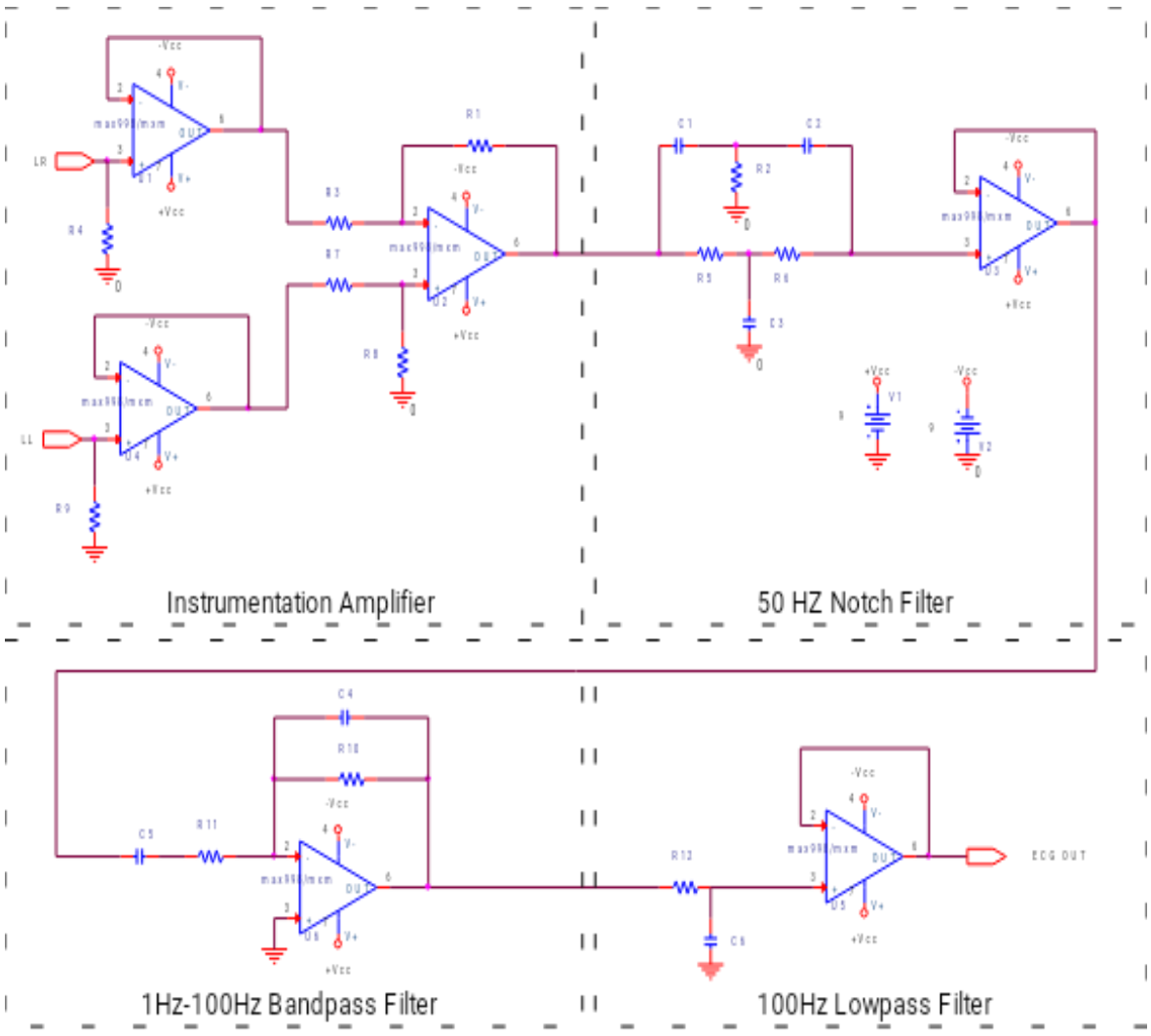


Figure 3.6. Circuit design ECG Signals

3.9 The Experimental Circuit

A picture of a prototype of the proposed detection and monitoring system is shown in Figure 3.7. Two 9V batteries are used to energize the implemented electronic circuit. Two metallic capacitive electrodes are devised to receive the ECG signals from the fingers of left and right hands. The prototype has high sensitivity to ECG signals even though the hand fingers are not really touching the electrode's insulators.

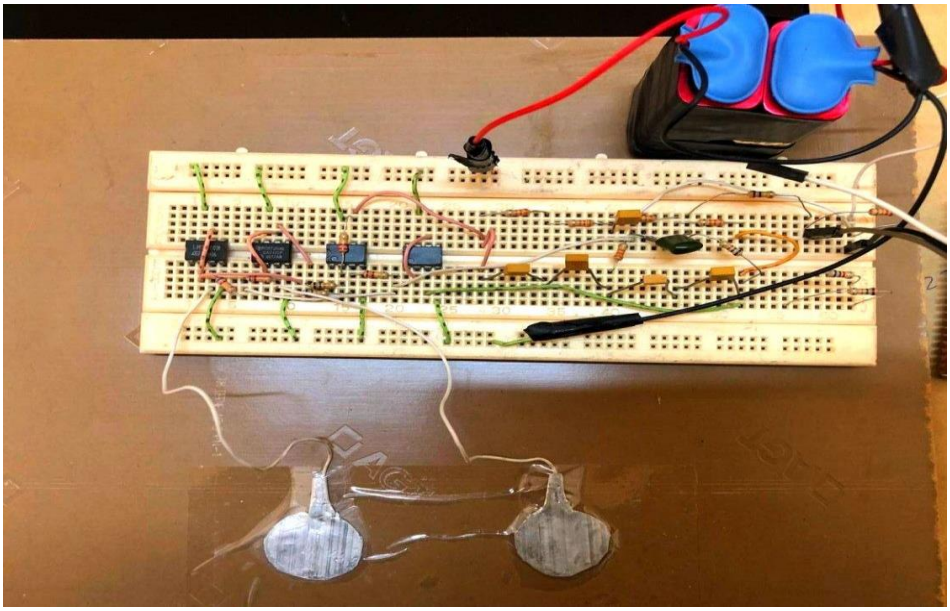


Figure 3.7. The practical circuit of the electrocardiogram.

4.1 RESULTS AND DISCUSSION

Many experimental tests were carried out on the practical circuit shown in Figure 3.7 to reveal its performance during different measurement situation. The results concern ECG signals from left hand alone, right hand alone, and both hands.

4.2 The Method of Measuring the ECG Signals

Placing the forefinger or any other finger on one or the two electrodes of the circuit and connecting the circuit output to the computer WINSCOPE, results in monitoring the ECG signal as shown in Figure 4.1.

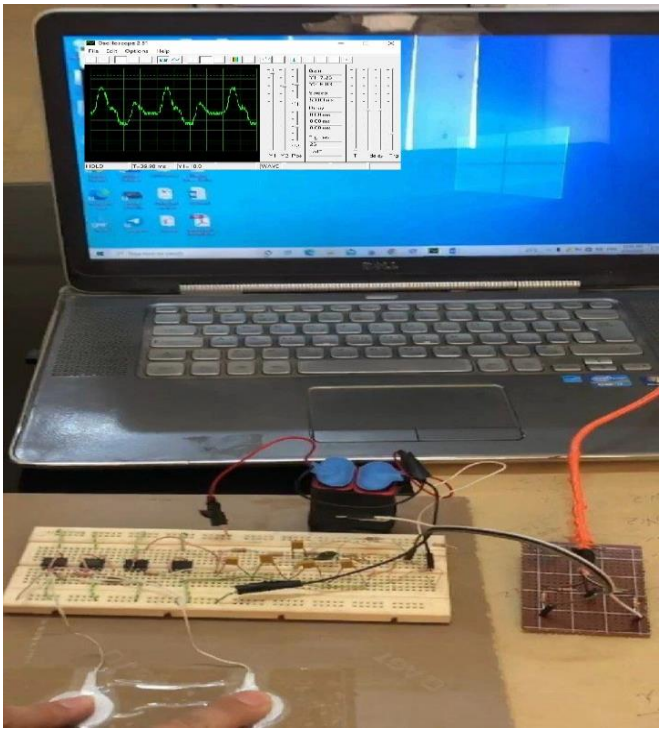


Figure 4.1. Practical Measurement of ECG signal.

4.3 Experimental Results of Left Hand ECG Signals

The left hand forefinger of a certain person, which was placed on the left hand electrode in the practical circuit revealed the output ECG signal shown in Figure 4.2. This is similar to ordinary ECG signal.

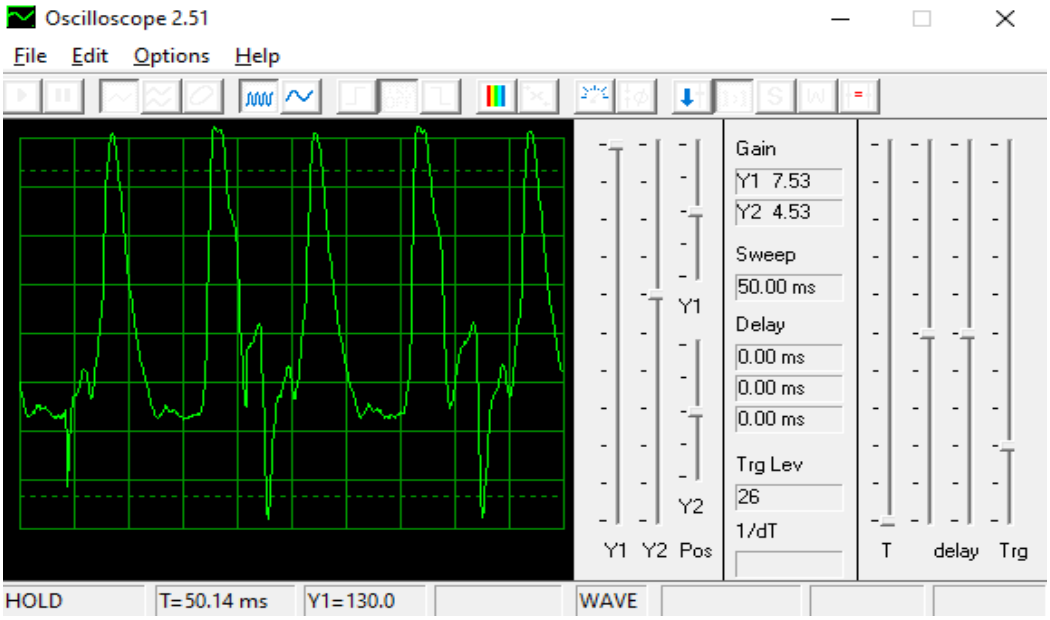


Figure 4.2. The left hand ECG signal for a certain person.

4.4 Experimental Results of Right Hand ECG Signals

The right hand forefinger of the same person in Figure 4.2 was placed on the right hand electrode in the practical circuit and consequently produced the output ECG signal shown in Figure 4.3. This signal is similar to the ordinary reversed ECG signal.

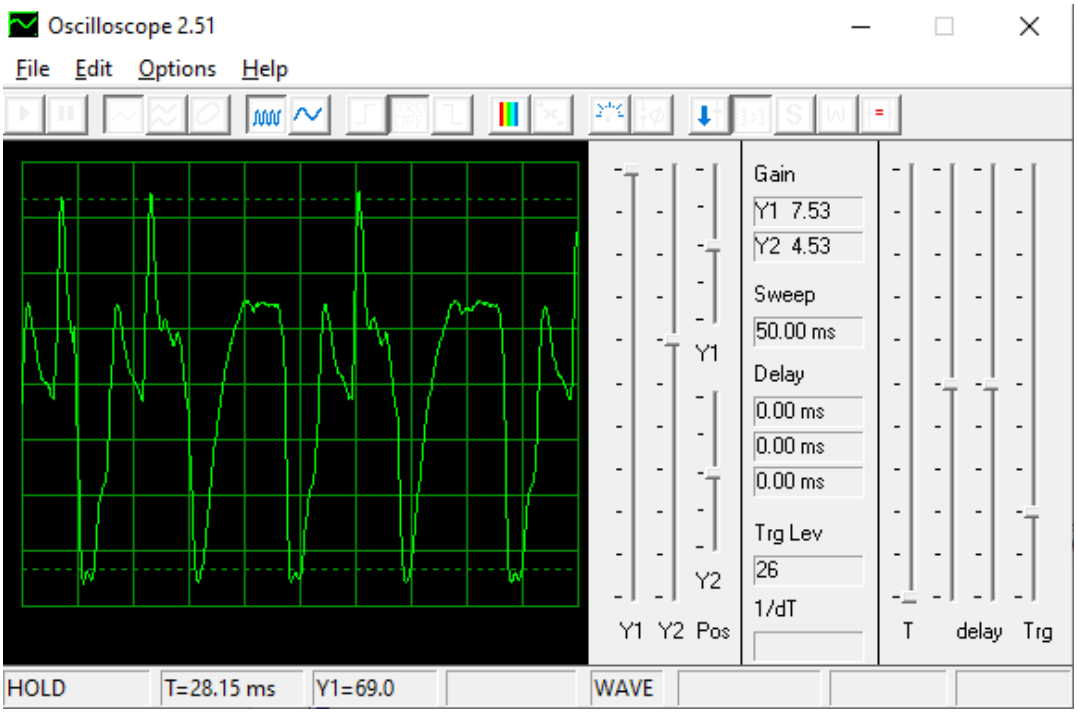


Figure 4.3. The right hand ECG signal for a certain person.

4.5 Experimental Results of Both left and Right Hands ECG

The person of interest in the first and second tests had placed his forefingers on their corresponding electrodes in the practical circuit. The output ECG signal of this is shown in Figure 4.4. This signal represents the voltage difference between the left hand electrode and the right hand electrode. The output signal in this test represent the most familiar ECG signal.

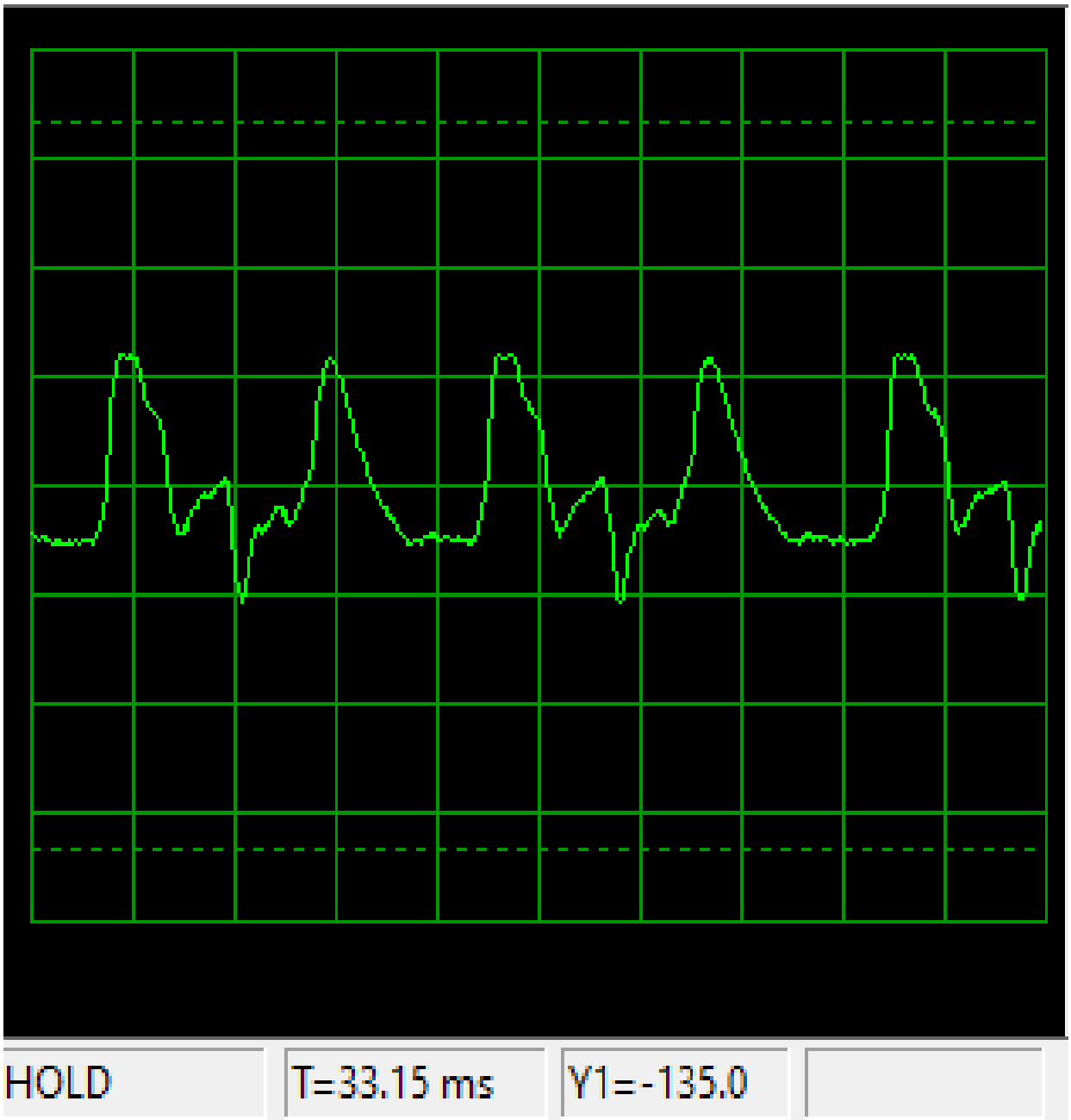


Figure 4.4. The measured ECG signal from left hand to right hand for a certain person.

4.6 Experimental Results of ECG signals for different persons

The first person tested for ECG measurement was 55 years old. His ECG signal for both hands is shown in Figure 4.5.

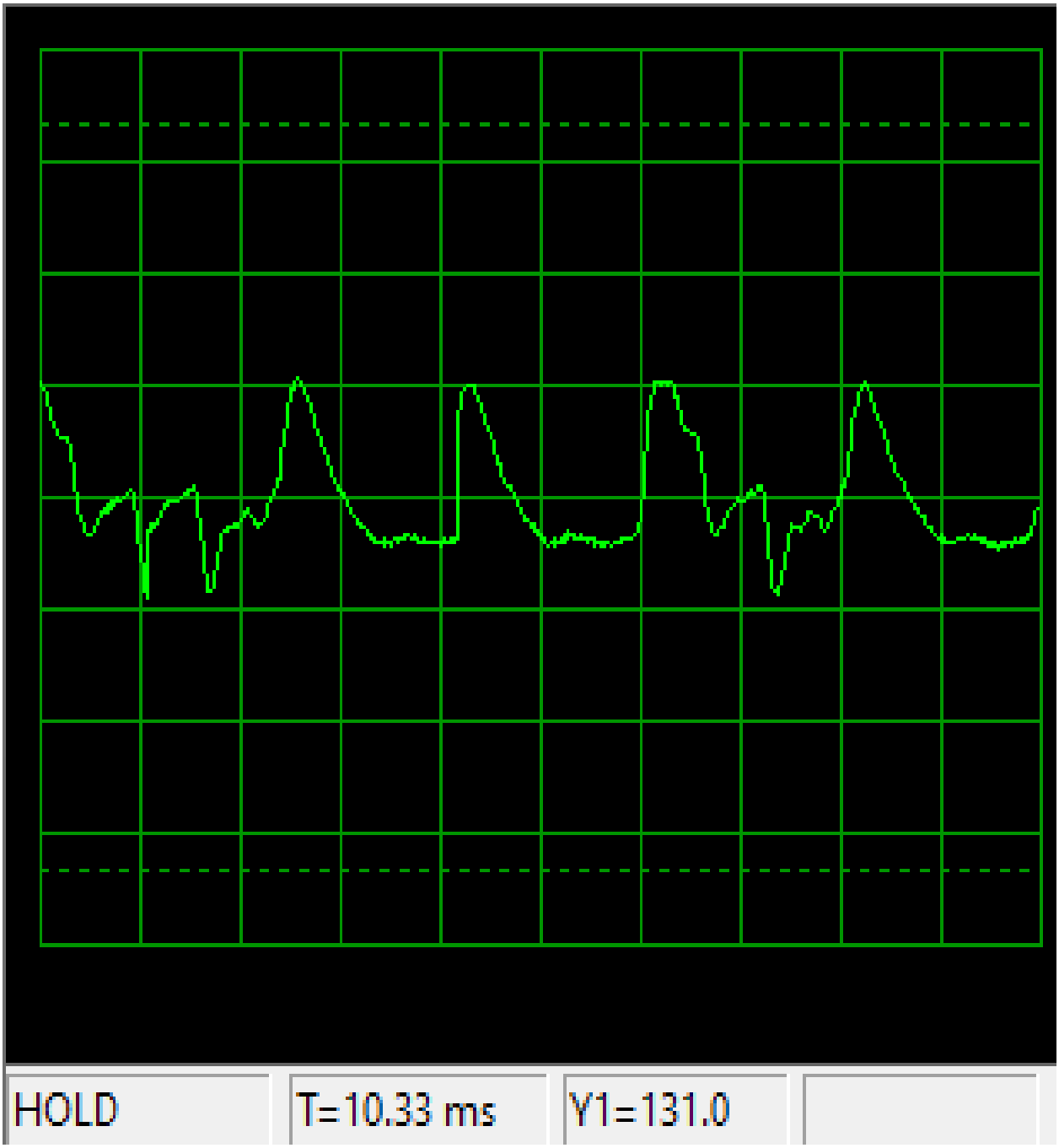


Figure 4.5. The measured ECG signal for 55 years old person.

The second person tested for ECG measurement was 30 years old. His ECG signal for both hands is shown in Figure 4.6.

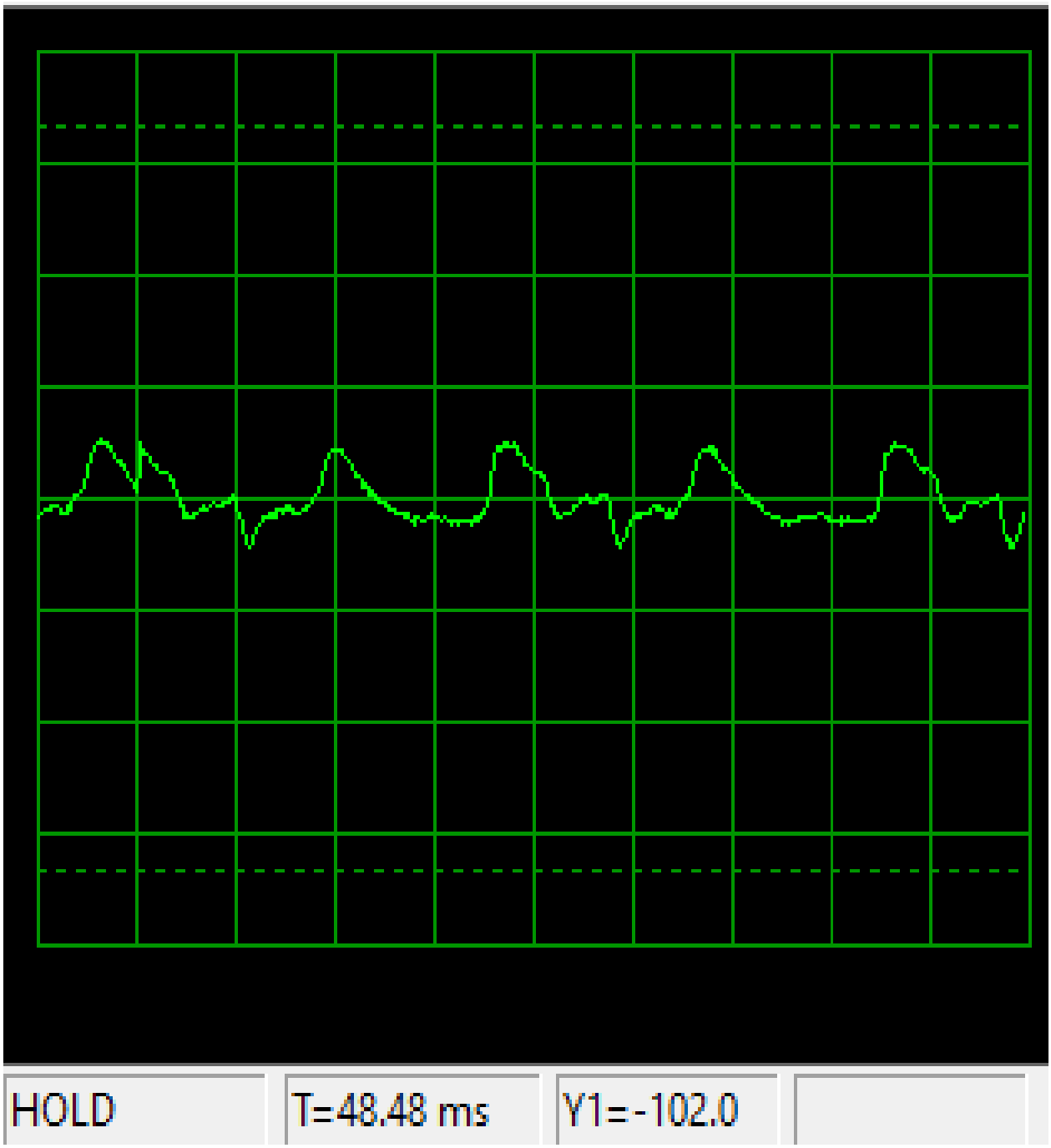


Figure 4.6. The measured ECG signal for 30 years old person.

The third person tested for ECG measurement was 35 years old. His ECG signal for both hands is shown in Figure 4.7.

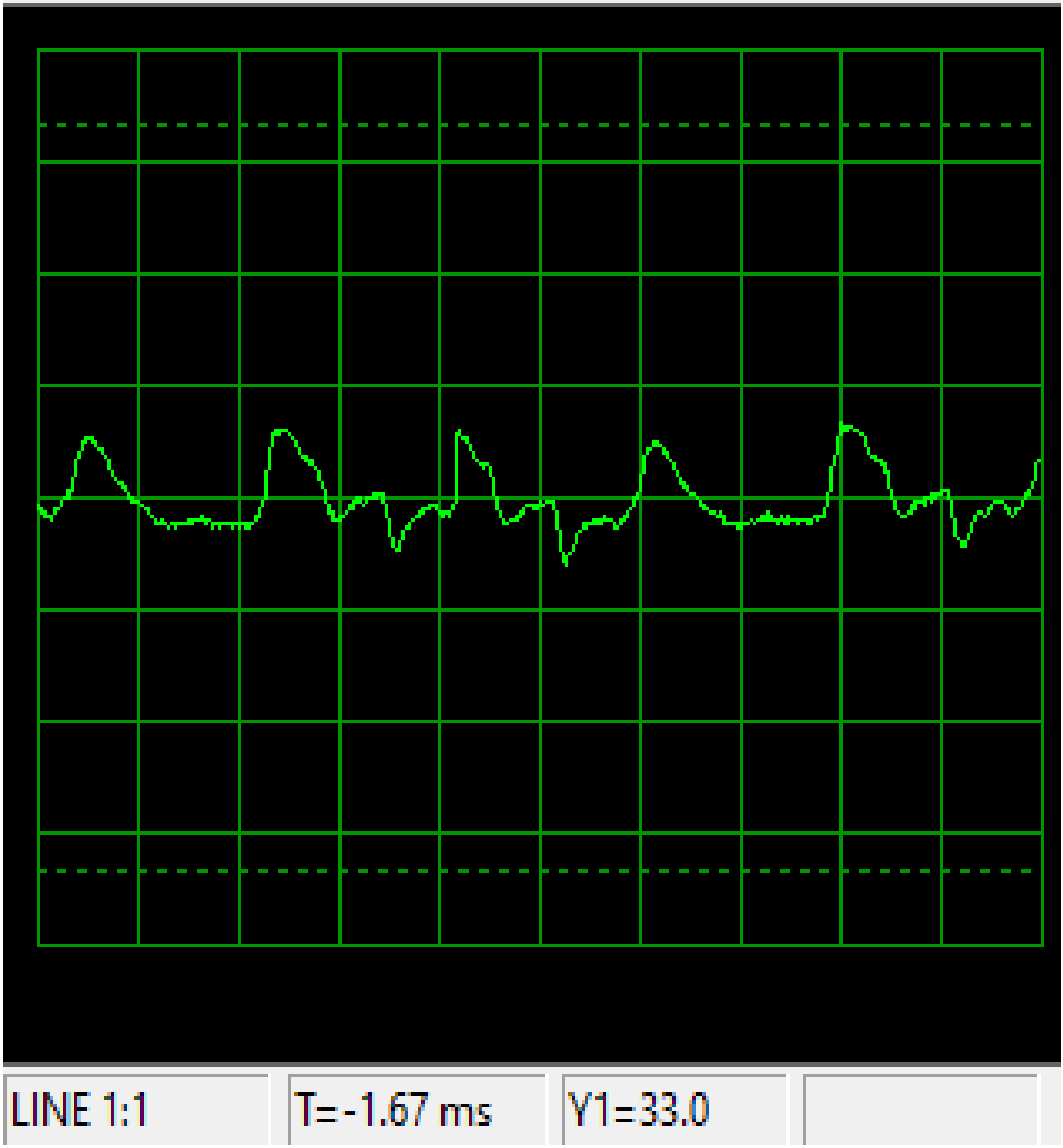


Figure 4.7. The measured ECG signal for 35 years old person.

5.1 Conclusion

In this work, many techniques of ECG signal detection and processing are reviewed. In addition a prototype of ECG detection and monitoring is implemented using low cost electronic components. The main difficulty encountered in this work is the avoidance of the 50Hz AC grid frequency component which saturates the intended ECG to be measured signal. Two high impedance dried capacitive electrodes are devised. They are designed for multiuse purposes. Both the implemented ECG system and devised electrodes have showed satisfactory performance.

5.2 Future Work

The future is summarized in adding a third electrode as reference for both left and right hand electrodes in order to avoid some of the ordinary ECG associating noises.

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