

For the Realisation of the Design of Electrocardiogram for the Monitoring of the Physiology of Human Heart

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Abstract: This study presents a sources design and realization of the Electrocardiogram (ECG) amplifier whose output can be monitored in a Personal Computer (PC) or Laptop. The electrocardiogram is an electrical recording of the physiological health status of the human heart. The human skin surface generates electrical signals called biosignals or biopotentials, which have a low amplitude range of between 0.1-5 mv and a frequency range of 0.1-250 Hz. The electronic circuit chosen to implement this design is the instrumentation amplifier, a first order low pass and high pass filter. Two stainless electrodes will be incorporated in the design to obtain the biosignals from the skin, which serves as input to the electrocardiogram and a hardware interface will be incorporated in the design to link the circuit with any personal computer or Laptop.

Key words: Biopotentials, instrumentation amplifier, high and low pass filters, physiology, human heart, ECG

INTRODUCTION

Electrocardiogram (ECG) is a medical instrument that detects cardiac (heart) abnormalities by measuring the electrical activity generated by the heart as it contrasts or pump blood through arteries for human existences. The instrument that records these activities either the abnormal or proper functioning of the heart is the electrocardiogram. It records the electrical activities of the heart muscle as obtain from the surface of the skin, the observation can be recorded with a personal computer or laptop computer. Some of the heart abnormalities that can be detected by the electrocardiogram include (Lehrl and Fischer, 1990):

- Enlargement of the heart
- Congenital heart defects
- Abnormal rhythm (arrhythmia)-rapid, slow or irregular heart beats
- Damage to the heart such as when one of the heart's arteries is blocked
- Imbalances in the blood chemicals (electrolytes) that control heart activity (Brozio, 2000)

The necessity for this research and design became imperative as the (quiet killer), herpension is rampant in Ekpoma Edo state, Nigeria. This simple designs can be produced on a small scale and can be used at home to

enable the user of the electrocardiogram know their heart status and prevent the sudden death caused by hypertension.

The research work for the design of the electrocardiogram was investigated and tested at Irrua teaching hospital, Irrua Edo state, Nigeria, where some patient heart were monitored as shown in Fig. 1 and 2.

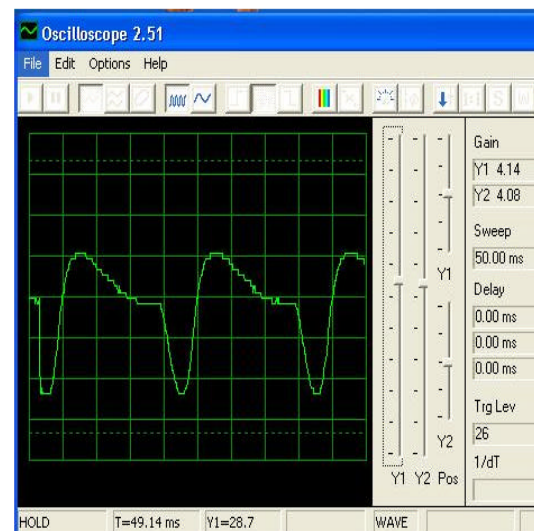


Fig. 1: The diagram showing the waveform of a patient monitored through electrocardiogram, augmented Ventricular (aVr) right foot of a patient

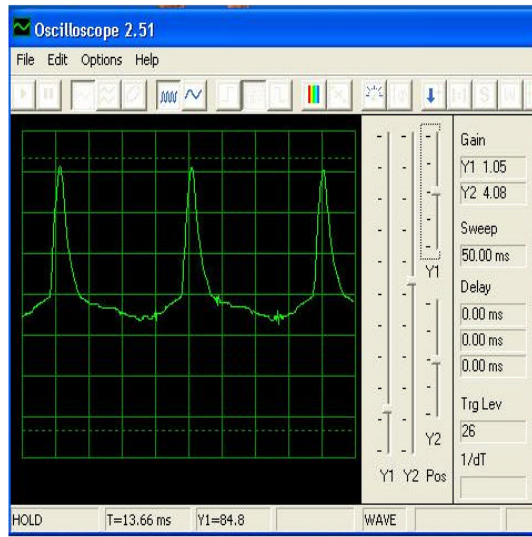


Fig. 2: The diagram showing the waveform of a patient monitored through electrocardiogram, normal waveform of a healthy patient

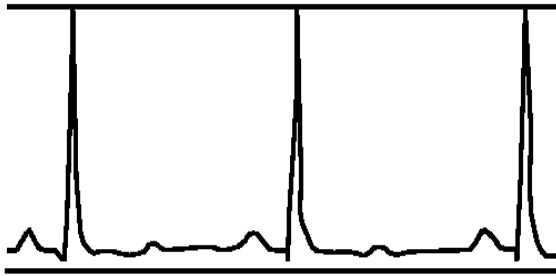


Fig. 3: A signal from human body monitored from electrocardiogram

THE ELECTROCARDIOGRAM MEASUREMENT SYSTEM

The human body is full of electrical signals which can be detected, these signals comes from nerve impulses, which can cause muscle contractions. The voltage which can be monitored ranges from microvolt and up to 2 millivolts can be monitored from the muscles or skin.

Because skin resistance can be high and to increase the sensitivity in the area to where the monitoring is to be observed conducting pastes or gels are often used for the signals to be pick easily (Fig. 3).

The varying voltages as a result of the flow of blood from the heart and back are pick up and send to the electrocardiogram for analysis.

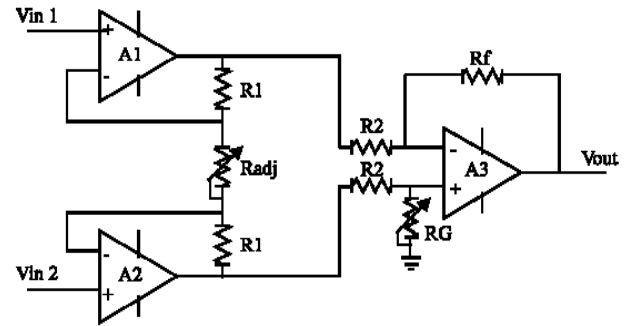


Fig. 4: A circuit diagram of instrumentation amplifier

THE INSTRUMENTATION AMPLIFIER FOR THE ELECTROCARDIOGRAM

The instrumentation amplifier is a valuable circuit in applications where small signal voltage can be measured precisely and it is used widely in the biomedical field and the instrumentation amplifier is useful where precise small signal amplification is required. The diagram in Fig. 4 showed the instrumentation amplifier which is an integral part of the electrocardiogram.

The resistor R_f is made variable to allow common mode voltage signals to be balanced out boosting the Common Mode Rejection Ratio (CMRR) of the circuit.

The overall gain of the circuit is determined by

$$A_v = \frac{R_f}{R_2} \frac{2R_1}{R_{adj}} + 1 \quad (1)$$

The instrumentation amplifier consists of 3 op-amps and 4 precision resistors. It is a combination of 2 non-inverting buffers and a voltage difference amplifier, (Schamroth, 2002) the buffers provide extremely high input impedance to the amplifier. This is to ensure that the transducer is not unduly loaded due to the amplifier. The differential amplifier provides the circuit gain and also very high Common Rejection Ratio (CMRR).

OPERATIONAL AMPLIFIER DIFFERENTIATOR

A differentiator responds only to changes in input signal. A differentiator is a circuit whose output signal is a derivative of its input waveform. Its main application is for wave shaping. A simple design of the operational amplifier differentiator is shown in diagram of Fig. 5.

The resistor R_m is to limit the high frequency (noise) gain of the circuit

$$F_{\omega} = \frac{1}{2\pi R_m C \text{ in } 1} \quad (2)$$

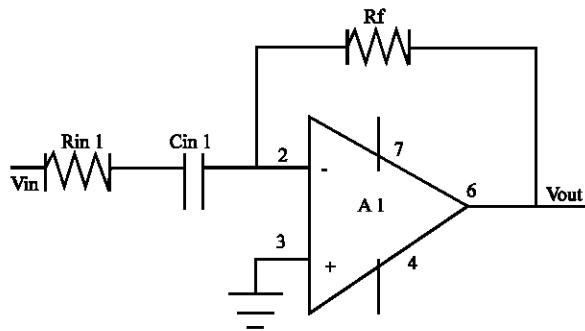


Fig. 5: Op Amp differentiator circuit

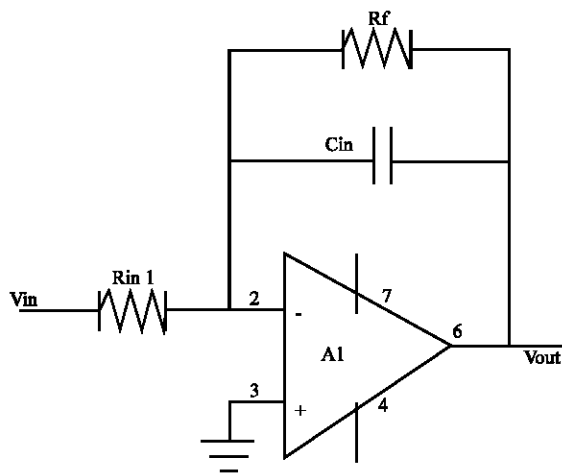


Fig. 6: Op Amp differentiator circuit

OPERATIONAL AMPLIFIER INTEGRATORS

An integrator takes the sum of an input signal over the interval of time that the signal is applied.

The resistor R_f supplies a dc path (offset voltage) to reduce the low frequency gain and therefore improve stability for frequencies below cutoff frequency of the integrator, the operating frequency is denoted by

$$F_{oper} = \frac{1}{2\pi R_{in} C_{in}} \quad (3)$$

The basic operation of the operational amplifier is shown in the diagram of Fig. 6.

OPERATIONAL PRINCIPLE OF THE ELECTROCARDIOGRAM

The basic design of the electrocardiogram consists of four stages namely:

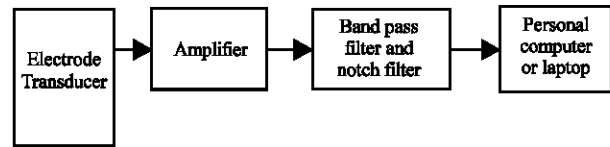


Fig. 7: Block diagram of the ECG electrocardiogram

- The first stage is a transducer AgCl or stainless steel electrodes that convert the signal from the skin into electrical voltage
- The second stage is an instrument which has a high Common Mode Rejection Ratio (CMRR) and high gain (Lu, 2004)
- The third stage is a band pass filter of 0.5-100 Hz band width, it is implemented by cascading a low filter (differentiator) and a high pass filter (integrator), this stage also consists of the notch filter and the last stage is the output display. The diagram of Fig. 7 is the block diagram representing the Electrocardiogram

The signal detected by the electrodes is fed into the input stage of amps A_1 and A_2 , the buffer op amps provide a good impedance matching since they have high input resistance, as the skin resistance is very high, this stage has gain of 50, the output of amps A_1 and A_2 , is passed to the differential amplifier, which has gain 20, thus the signal is amplified by 1000 (Charles, 1979).

The output from the instrumentation amplifier is filter by the pass band filter. The pass band filter consists of a differentiator and an integrator. The differentiator serves as the high pass filter by passing all frequencies above its operating frequency, the differentiator functions as an inverting amplifier.

The integrator functions as an inverting amplifier for frequencies below its operating frequency. The integrator passes frequencies below as a low pass filter. The notch filter filters out the supply frequency noise available on the body and finally the output filter stage is fed into the personal computer or laptop. The complete diagram of the electrocardiogram is shown in Fig. 8.

The following samples are the electrocardiogram waveforms obtained when the electrodes were held in different human bodies.

The diagram in Fig. 1 and 2 shows the different waveforms monitored with the electrocardiogram when the heart is contracting or relaxing.

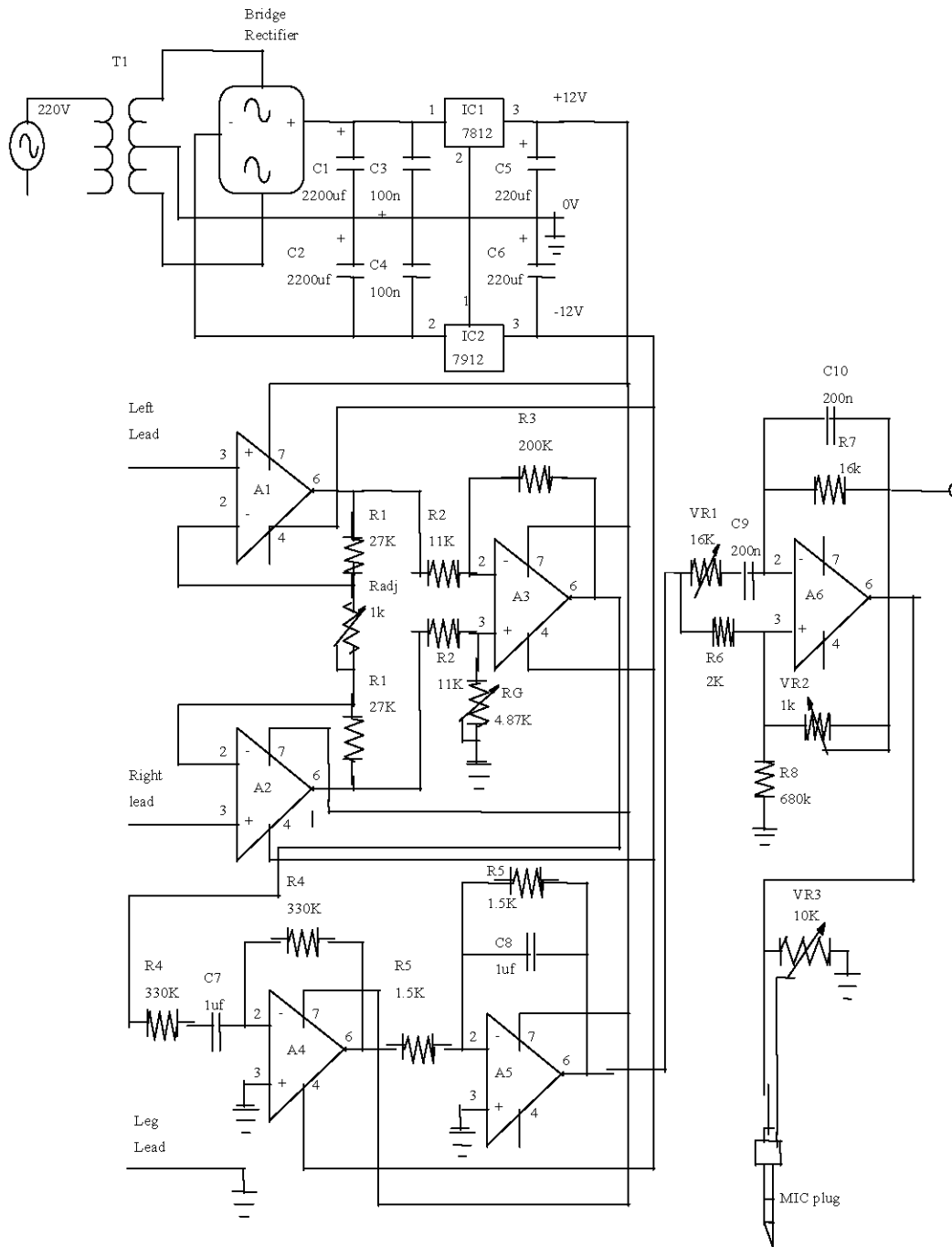


Fig. 8: Complete circuit diagram of the electrocardiogram amplifier

CONCLUSION

The electrocardiogram design will be realized by the simple design analysis adopted in this study, it is mostly suitable for domestic usage,

which will enable one ascertain the state of one heart status, which can be achieved at home and the print out from the personal computer or laptop can be sent to a medical doctor for evaluation.

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