AN IMPEDANCE CARDIOGRAPH

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AIM

To demonstrate an impedance cardiograph which is used as a non-invasive tool in cardiac output monitoring of mobile subject.

EQUIPMENT AND MATERIALS USED

(a) An impedance cardiograph - developed at IIT Bombay
(b) A ± 9 volt power supply, and batteries.
(c) A PC with Data acquisition card (PCL208 - DMS)
(d) A storage oscilloscope, (e) An exercise bicycle

INTRODUCTION

Monitoring of cardiac output is of great importance in sports medicine and hospital tests. The clinically standard methods such as thermodilution or dye dilution are invasive [1]. Impedance cardiography is a totally non-invasive technique which can be easily used on exercising subject [1-4]. It measures the impedance of the thoracic region at a very high frequency. Since the conductivity of blood is higher compared with other body tissues, and the volume of other body tissues remains almost the same in the thoracic region, the change in the thoracic impedance gives the change in the blood volume in the lungs [1].

A high frequency current is injected in the thorax by current electrodes. Voltage electrodes sense the voltage developed.
Demodulation gives the impedance waveform. Stroke volume (SV) is calculated according to the Kubicek equation,

$$SV = \rho \frac{L^2}{Z_o^2} \Delta Z$$

Where P is the blood resistivity, L the distance between the electrodes, Z_o the base impedance and ΔZ is the change in impedance, which can be calculated by Patterson's 'forward slope extrapolation method [3]

$$\Delta Z = \left(\frac{dZ}{dt}\right)^m \cdot LVET$$

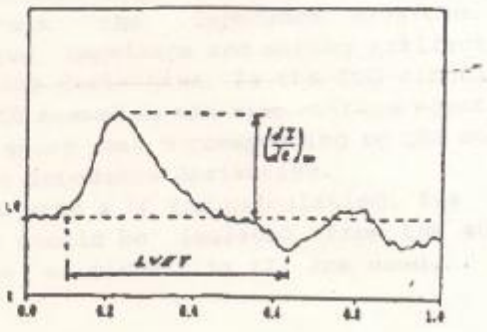

Figure 1: Averaged dZ/dt waveform

where $(dZ/dt)^m$ is the maximum value of (dZ/dt) and LVET is the left ventricular ejection time. Assuming that the early change in the impedance is due to arterial inflow only, the peak of the derivative gives the rate of inflow of blood. It multiplied by the LVET gives the change in impedance. Both $(dZ/dt)^m$ and LVET are calculated from the (dZ/dt) waveform as shown in Fig.1.

THE INSTRUMENT

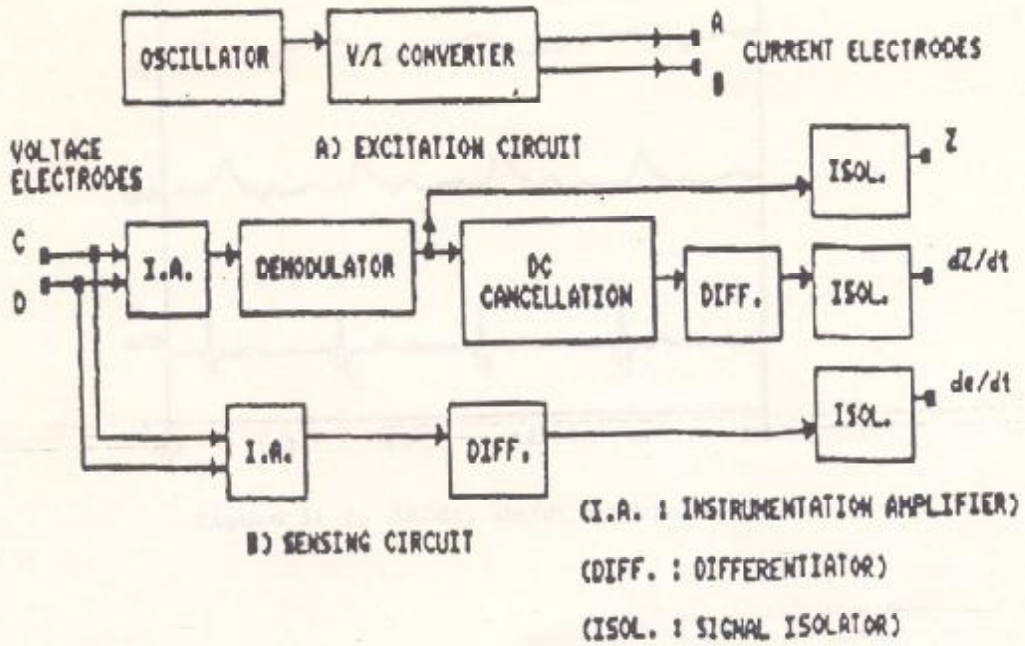

Figure 2: Overall setup

The instrument is based on earlier circuits reported by Qu et al. [5] and Joshi [6]. The block diagram of the instrument is shown in Fig. 2. A Wien bridge oscillator generates a 100 KHz sinusoidal voltage wave. A voltage to current converter converts it into a current waveform. Using tetrapolar configuration of electrodes [4], the current is injected in the thorax by two electrodes at the back. Two electrodes in the front sense the voltage developed between them. An instrumentation amplifier amplifies the voltage which is then demodulated to obtain the impedance waveform. A DC cancellation circuit removes the base impedance and motion artifacts. The differentiator then gives the impedance derivative. In the ECG circuit, the instrumentation amplifier gives the ECG sensed by the same voltage electrodes. It is then differentiated to obtain a sharp peak corresponding to QRS complex, which is used to ensemble average the impedance derivative.

The signals are then interfaced with a PC for calculation. The PC and CRO have high voltage sections which should be isolated from the subject. Hence opto-isolator circuits based on a circuit in [7] are used.

RESULTS

The circuit was assembled on a PCB. Typical waveforms obtained are shown in Fig.3. For these waveforms, the averaged (dZ/dt) waveform is shown in Fig. 1. The circuit was tested for exercising subjects and it was found that the LVET increased even when the heart rate increased at the onset of exercise. As the heart rate increased further, the LVET decreased.

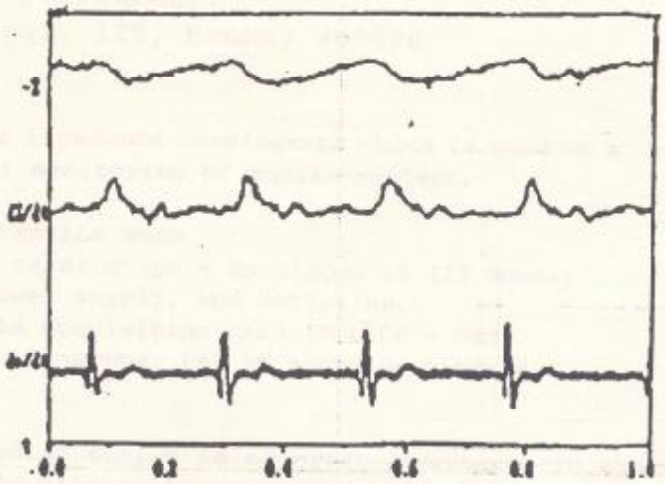

Figure 3: Z, dZ/dt, de/dt waveforms

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