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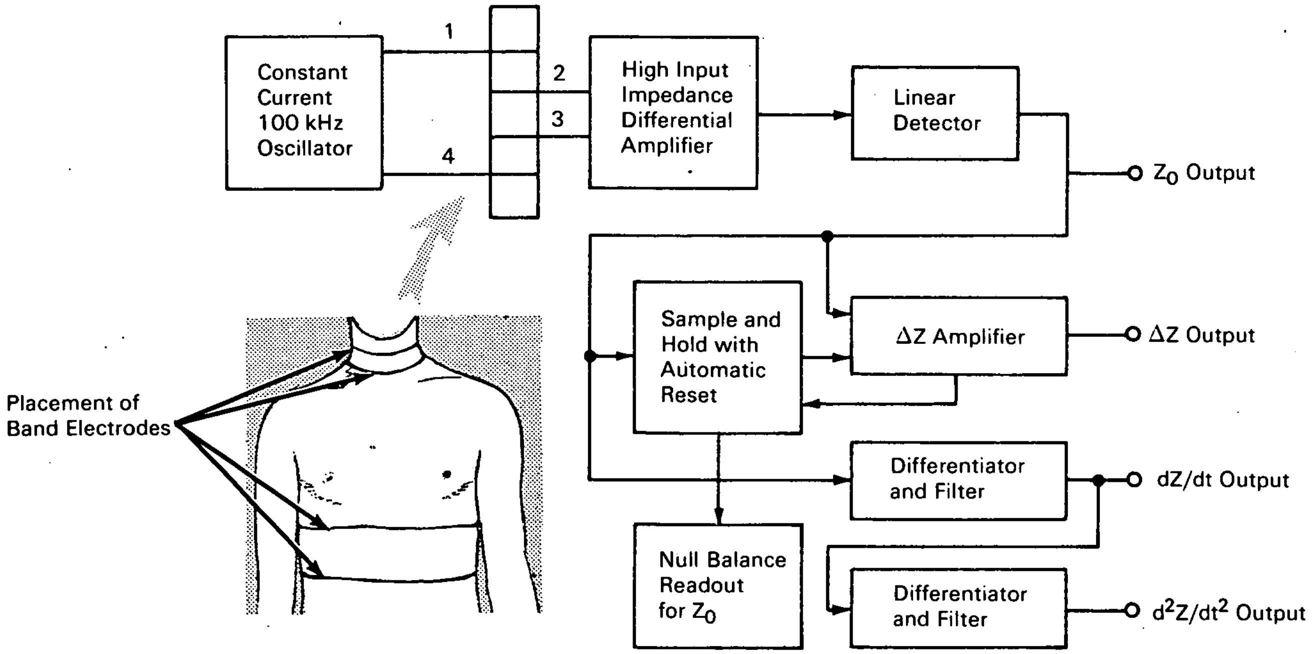
NASA TECH BRIEF

New Electrical Impedance Plethysmograph Monitors Cardiac Output



A four-electrode impedance plethysmograph has been developed to satisfy a need in medical clinics and research laboratories for a simple, bloodless method of measuring ventricular stroke volume or cardiac output of humans. In using the instrument, two band electrodes are placed around the subject's neck, a third band is placed around the thorax at the level of the xiphisternal joint, and a fourth band around the lower abdomen. The electrodes at the upper neck and the abdomen are excited by a 100 kHz sinusoidal current and the resultant voltage (impedance) changes occurring with the cardiac cycle are monitored from the other two electrodes. Stroke volume is calculated from the first time derivative (dz/dt) of the impedance change data, using a formula relating impedance change to volume change in a conducting medium. The new instrument is automatic, operates with only one recording channel, and minimizes patient discomfort.

As shown in the block diagram, current from the 100-kHz oscillator is fed to the thorax (bands 1 and 4) by means of coaxial cables. These have electrically driven shields to reduce the effective cable capacity and thereby maintain high output impedance at the electrodes. The voltage from the thorax (bands 2, 3) is recorded by a differential amplifier having coaxial leads. The use of this amplifier allows a ground to be placed anywhere on the body. The differential input impedance of the amplifier measured at the cable ends using 100 kHz current is 10^5 ohms. Positive feedback

(continued overleaf)

is used on the input to reduce the effects of cable capacity. The common mode rejection is 50 dB at 100 kHz. The output of the differential amplifier is fed to a linear detector, whose output in turn is fed to a stable sample and hold circuit and to the ΔZ (impedance change) amplifier. This amplifier also receives an input from the sample and hold circuit and subtracts the two inputs to give the ΔZ output.

The sample portion of the sample and hold circuit can be operated either manually by a switch or automatically. The automatic operation is achieved by sensing the output of the ΔZ amplifier and then sampling when the output exceeds an adjustable preset limit. This allows the system to record the small ΔZ changes due to the cardiac signal; but if respiration, movement, or other artifact causes a larger change in ΔZ, the system will automatically rebalance in approximately 40 milliseconds. The output of the detector is also fed to two analog differentiators to give the first and second time derivatives (dz/dt and d^2z/dt^2 respectively). The null balance circuit connected to the sample and hold output, nulls an accurate dc voltage against the output of the sample and hold circuit to accurately measure the value of the mean impedance Z_0.

Significant electrical features of this impedance plethysmograph are as follows:

1. High output impedance (10^5 ohms) at the electrodes for the current source.
2. High input impedance (10^5 ohms) at the electrodes for the voltage pickup system.
3. Use of a floating electrode system, not requiring grounding.
4. One percent absolute accuracy and linearity
5. Fully automatic operation, with a balancing time of 40 milliseconds.
6. Manual balancing that requires only the movement of one switch.
7. A low-noise first derivative output (80 mv peak to peak).

Note:

Complete technical details may be obtained from:
Technology Utilization Officer
Manned Spacecraft Center
Houston, Texas 77058
Reference: B68-10220

Patent status:

No patent action is contemplated by NASA.

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