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EXPERIMENTAL SYSTEM FOR THE NONINVASIVE DETECTION OF AIR BUBBLES IN TISSUES

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NOTICES

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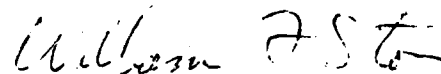
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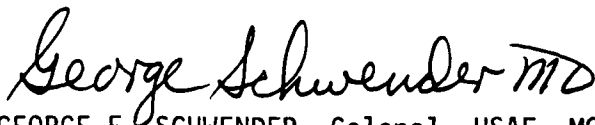
This report has been reviewed and is approved for publication.



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EXPERIMENTAL SYSTEM FOR THE NONINVASIVE DETECTION OF AIR BUBBLES IN TISSUES

PART I: INSTRUCTION MANUAL

INTRODUCTION

The air-bubble detection system was designed to detect the changes in the microwave absorption properties of tissues -- these changes could be caused by the introduction of air bubbles due to exposure to high altitudes. The system basically transmits a low-level modulated microwave signal through the tissue and monitors the changes in the amplitude of the received signal. The output signal from the detection circuitry can be monitored using an oscilloscope or strip-chart recorder.

The system is powered by $\pm 8V$ and $+12 V$ DC. The DC voltages are generated from the AC line using a standard AC/DC supply and post-regulators. This assembly is housed in a separate enclosure that is electrically isolated from the microwave enclosure.

The following section details the procedure to follow when using the air-bubble detection system.

USER INSTRUCTIONS

The use of the air-bubble detection system can best be described with the aid of Figures 1 and 2. Figure 1 is a sketch of the front and rear of the microwave enclosure, and Figure 2 is the schematic for the signal processor.

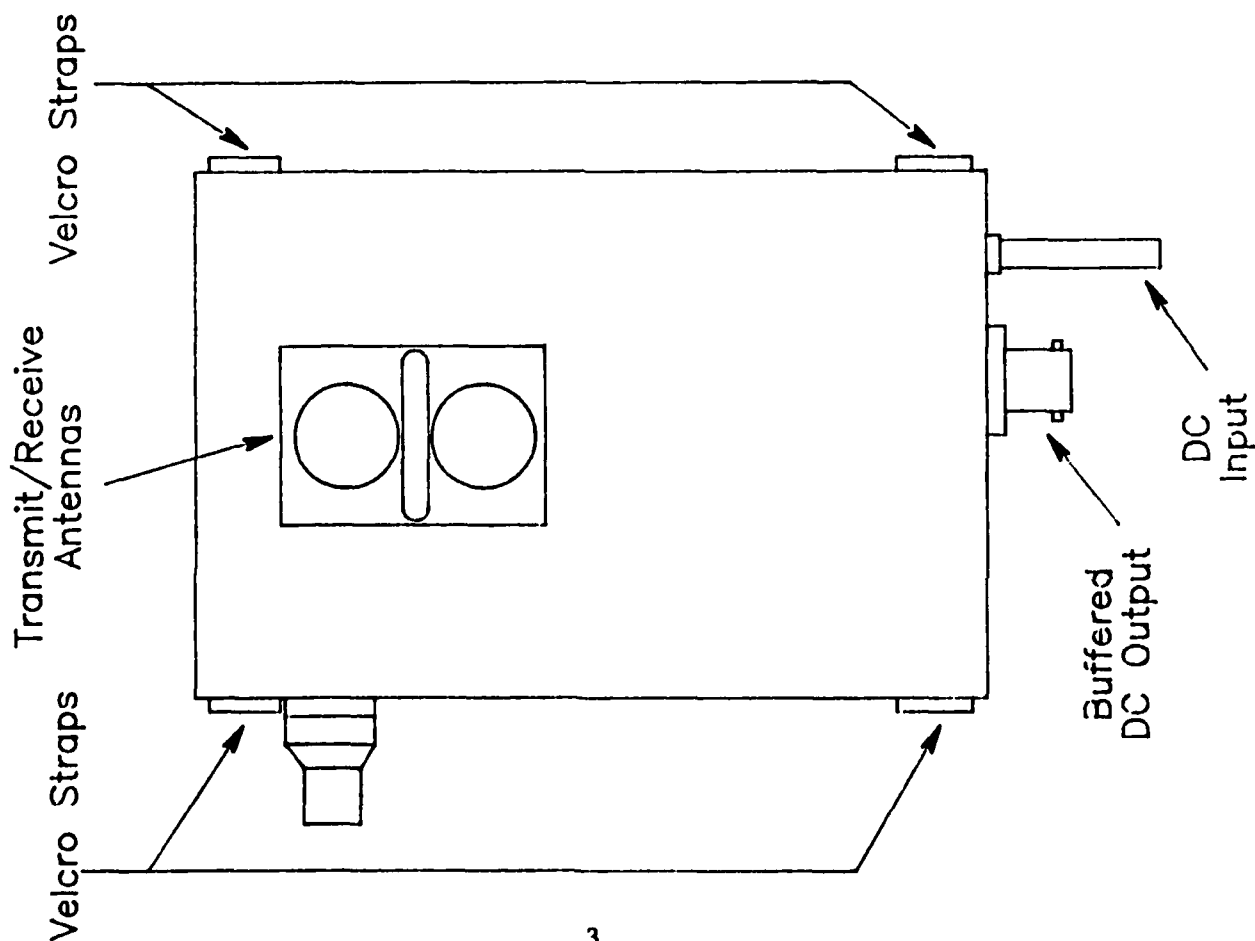
The "Fine Balance Adjust" and "Coarse Balance Adjust" in the rear view of Figure 1 are the 100K-ohm and 500K-ohm potentiometers that are in series between pins 3 and 16 of the AD524 instrumentation amplifier connected to the "REEL IN" and "FWD IN" signals. These pots adjust the amplitude of the reference signal to the second AD524. The "Sensitivity Adjust" is the 100-ohm potentiometer connected between pins 3 and 16 of the second AD524. This pot adjusts the amplitude of the difference between the reference and received signals.

To operate the system, follow the step-by-step procedure:

STEP 1: Connect the DC input cable on the microwave enclosure to the DC socket on the power supply enclosure. **NOTE** - this connector is keyed and will only go one way. Push the connector on the socket until it clicks and locks in place.

- STEP 2: Attach one end of the coaxial cable, supplied with the system, to the "Buffered DC Output" connector on the bottom of the microwave enclosure. The connector is a push-and-twist-on/push-and-twist-off type of bayonet connector. Attach the other end of the cable to an oscilloscope or strip-chart recorder.
- STEP 3: Attach the microwave enclosure to the back of the leg using the Velcro straps. The transmit/receive antennas should make intimate contact with the tissues just below the knee.
- STEP 4: Plug the power supply into a standard 110 VAC receptacle to turn on the system.
- STEP 5: Unlock the "Fine Balance Adjust" knob by moving the lever on the knob to the left. Adjust the knob until a dip is seen in the buffered DC output voltage. If a dip is found, proceed to STEP 9.
- STEP 6: Set the "Fine Balance Adjust" to zero, and slowly adjust the "Coarse Balance Adjust" over its full range looking for the dip. NOTE - the full clockwise and full counter-clockwise ends-of-travel are denoted by a click in the potentiometer. If a dip is found, proceed to STEP 9.
- STEP 7: Repeat STEP 6 with the "Fine Balance Adjust" set to 10. If a dip is found, proceed to STEP 9.
- STEP 8: Turn the "Sensitivity Adjust" pot counter-clockwise until the buffered DC output voltage begins to decrease. Repeat STEPS 6 and 7.
- STEP 9: Adjust the sensitivity so that the dip in the buffered DC output voltage is approximately at 1 volt.
- STEP 10: Monitor the output voltage for changes to this baseline voltage.

FRONT VIEW



REAR VIEW

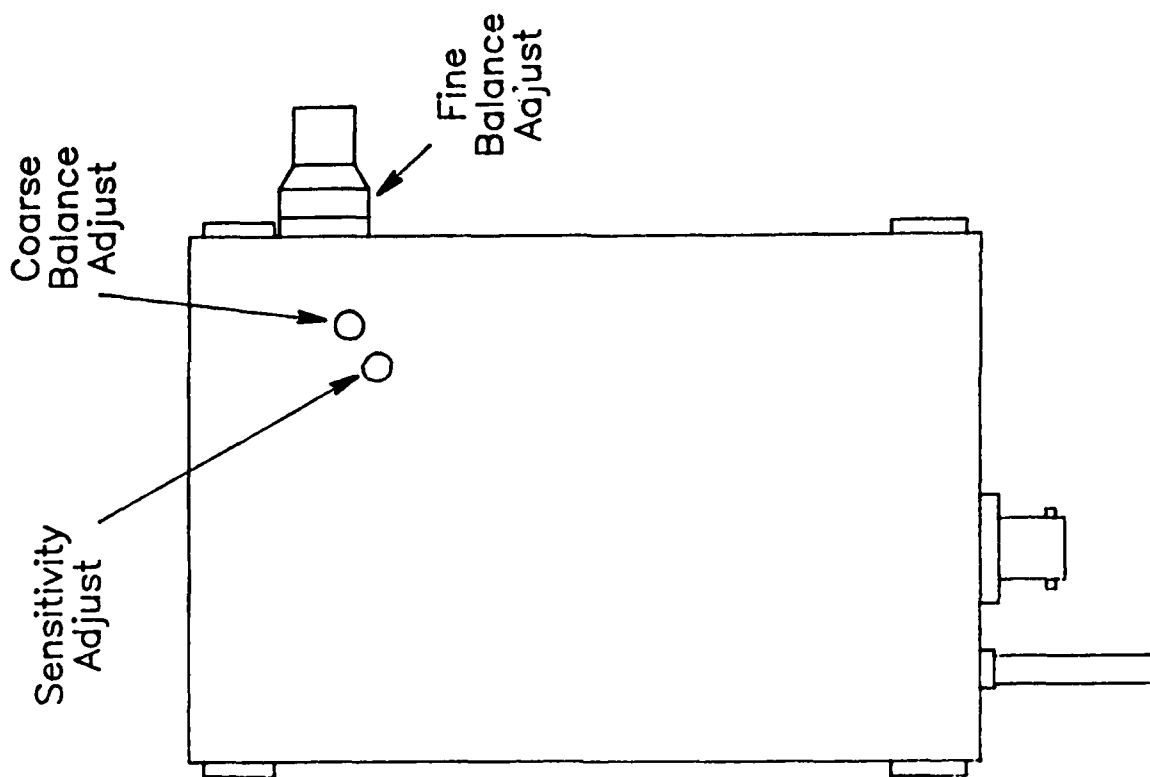


Figure 1. Front and rear views of the microwave enclosure of the air-bubble detection system.

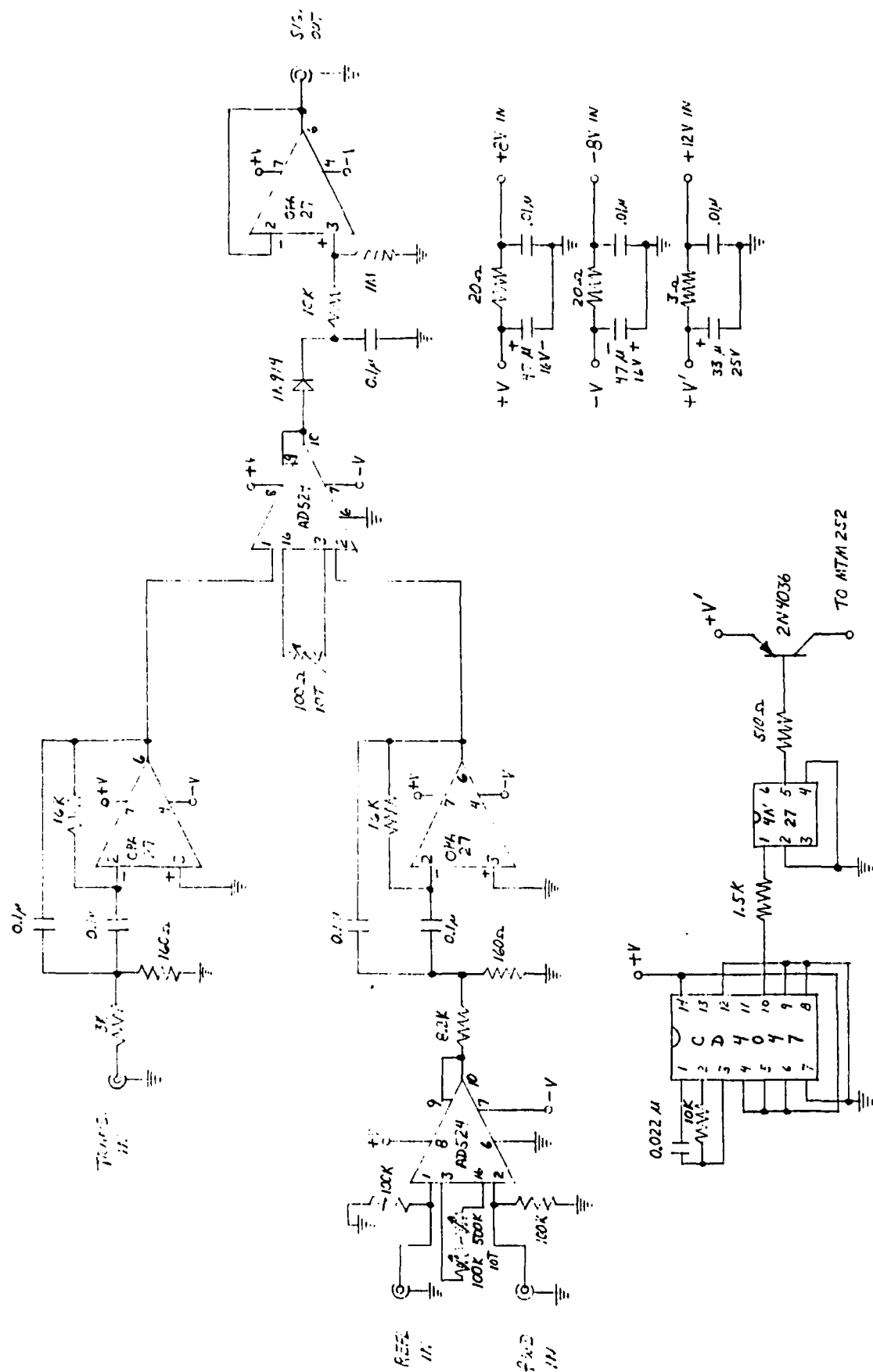


Figure 2. Schematic diagram for the I-F processing circuitry in the microwave enclosure of the air-bubble detection system.

PART II: SYSTEM SAFETY HAZARD ANALYSIS

INTRODUCTION

The air-bubble detector, at this development stage, is an experimental proof-of-concept device; and, as such, no attempts were made to miniaturize the device, or make it battery-operable, or assemble it into a production quality package. Good safety practices were adhered to, however, both in the AC/DC power supply and the microwave design.

AC/DC SUPPLY SAFETY

A block-schematic of the AC/DC supply is shown in Figure 3. The P23-020 power supply was purchased from Semiconductor Circuits Incorporated, Windham, NH. The supply converts 105-125 VAC into ± 15 VDC @ ± 100 ma. The input/output, input/case, and output/case isolation is specified at 1500 VAC, 50/60 Hz indefinitely. The 3-terminal post-regulators provide the isolated voltages needed to power the air-bubble detector circuitry. The total AC line draw is approximately 0.1A under normal operating conditions; and, therefore, the fuse in the AC line filter is specified as a normal 1/4 A fuse. The AC/DC supply is housed in an aluminum enclosure tied to AC ground. The microwave and I-F processing circuitry is also in an aluminum enclosure. This enclosure is tied to "COM," which is isolated from AC ground by the 1500 VAC spec. of the P23-020.

MICROWAVE SAFETY

The latest safety standards for microwave radiation are set by The American National Standards Institute (ANSI) and published as C95.1 - 1982. The air-bubble detector operates at the microwave oven frequency of 2450 \pm 50 MHz and, therefore, can radiate a maximum power density of 5 mW/cm².

The microwave energy is generated by an MTM-252 oscillator purchased from Westec Communications, Inc., Scottsdale, AZ. The oscillator is pulsed on and off at a frequency of 1 kHz and a duty cycle of 40%. The oscillator output is specified at +13 dBm (20 mW). The power density of the microwave energy that is transmitted from the air-bubble detector is calculated using

$$P_D = \frac{P_o \cdot D \cdot 10^{-L/10}}{A} \quad (1)$$

where P_o = oscillator output = 20 mW

D = duty cycle = 40%

L = loss between oscillator and antenna = 1 dB

and A = effective area of transmit antenna = π cm₂.

The maximum power density output, using Eq. 1, is therefore 2 mW/cm².

Leakage radiation was measured using a Narda Microwave Corporation radiation monitor (Model 8611 meter and model 8621B E-field probe). The leakage under normal operating conditions (that is, with the air-bubble detector

against human tissue) could not be detected on the most sensitive range of the instrument. The maximum leakage that could be measured by partially loading the transmitting antenna with the finger was 0.05 mW/cm^2 .

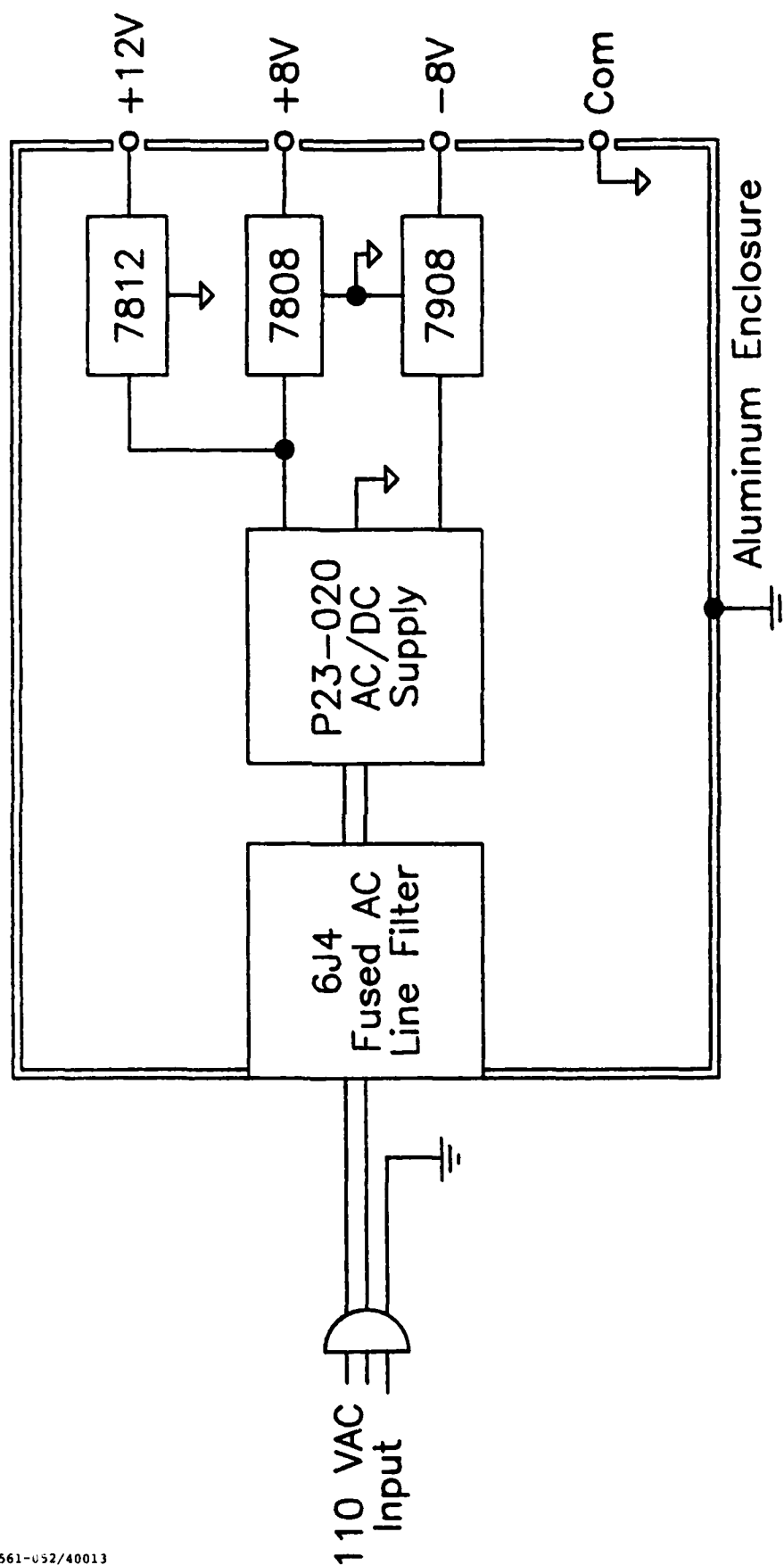


Figure 3. Block-schematic of the AC/DC power supply.