ASD TECHNICAL REPORT 61-290

A MULTICHANNEL PERSONAL TELEMETRY SYSTEM USING PULSE POSITION MODULATION

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BIOMEDICAL LABORATORY
AEROSPACE MEDICAL LABORATORY

JULY 1961

AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
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NOTICES

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PROJECT No. 7222
TASK No. 71751

AERONAUTICAL SYSTEMS DIVISION
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UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

McGregor & Werner, Inc., Dayton, O.
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FOREWORD

This report was prepared by the Medical Electronics Sections, Biophysics Branch, Biomedical Laboratory, Aerospace Medical Laboratory, under Project Number 7222, "Biophysics of Flight," Task Number 71751, "Specialized Instrumentation." The period of preparation was May 1960 through April 1961.

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Captain Kenneth Robins
Captain George Potor
Mr. James Lovin
Mr. Erich Gienapp

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ABSTRACT

A personal telemetry system using the pulse position modulation technique has been developed. The laboratory model transmits heart rate, respiration rate, and body temperature within a range of 100 feet. Compared with FM - FM Systems this system has the advantage of very low power consumption (20 milliwatts), light weight (6 ounces with batteries for 80 hours continuous operation), small size (4-3/4 by 3-1/2 by 1 inches), and sufficient accuracy and stability (2 percent baseline stability) for physiological measurements. An inexpensive, small, single-track tape recorder may be used for recording; and an extremely simple and inexpensive playback system can be used for scope display. Although more complex equipment is required for the playback system to standard penwriters, this penwriter decoding unit is not any more complicated than standard FM discriminators. Simple, reliable, switching-type circuits which work over a wide temperature range are used, and there is no problem with crosstalk between channels. The limitations of this personal telemetry system are: (a) the frequency capability for each channel is 0 to 40 cps; (b) it is limited to a maximum of 6 channels; and (c) speciai playback equipment is required.

PUBLICATION REVIEW

J. W. Heim

J. W. HEIM
Technical Director
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A MULTICHANNEL PERSONAL TELEMETRY SYSTEM USING PULSE POSITION MODULATION

INTRODUCTION

A personal telemetry system is a self-contained,lightweight unit for transmitting physiological data from a human subject to a nearby receiving station. An ideal system should not encumber the subject in any way. Maximum transmitting range may be limited to approximately 300 feet with six channels the upper limit in most cases. Most physiological measurements do not require an accuracy of more than 5 percent because of their normal excepted tolerances. Since the transmitting unit is worn close to the body, the required temperature operating range may also be limited for most cases from 10° to 100° F.

APPLICATIONS

During the past year questions about personal telemetry systems were asked by different groups. Physiological monitoring of the astronauts is one application which will become more important in the near future. At present certain industries are interested in monitoring workers under stressful conditions, such as heat, vibration, etc. There also are some plans for using such a system in hospitals to monitor patients with critical heart conditions. Probably the most important application at present is in basic physiological and psychophysiological research. A great number of measurements were made under hospital and laboratory conditions, but comparatively little is known about the different physiological parameters in unencumbered everyday living situations.

SOLUTIONS

Modern miniaturizing techniques make it possible to build a miniature model of a standard FM-FM telemetry system. Certain compromises between performance, weight, power consumption, operations time, etc., are necessary but do not necessarily exclude the usefulness of this approach.

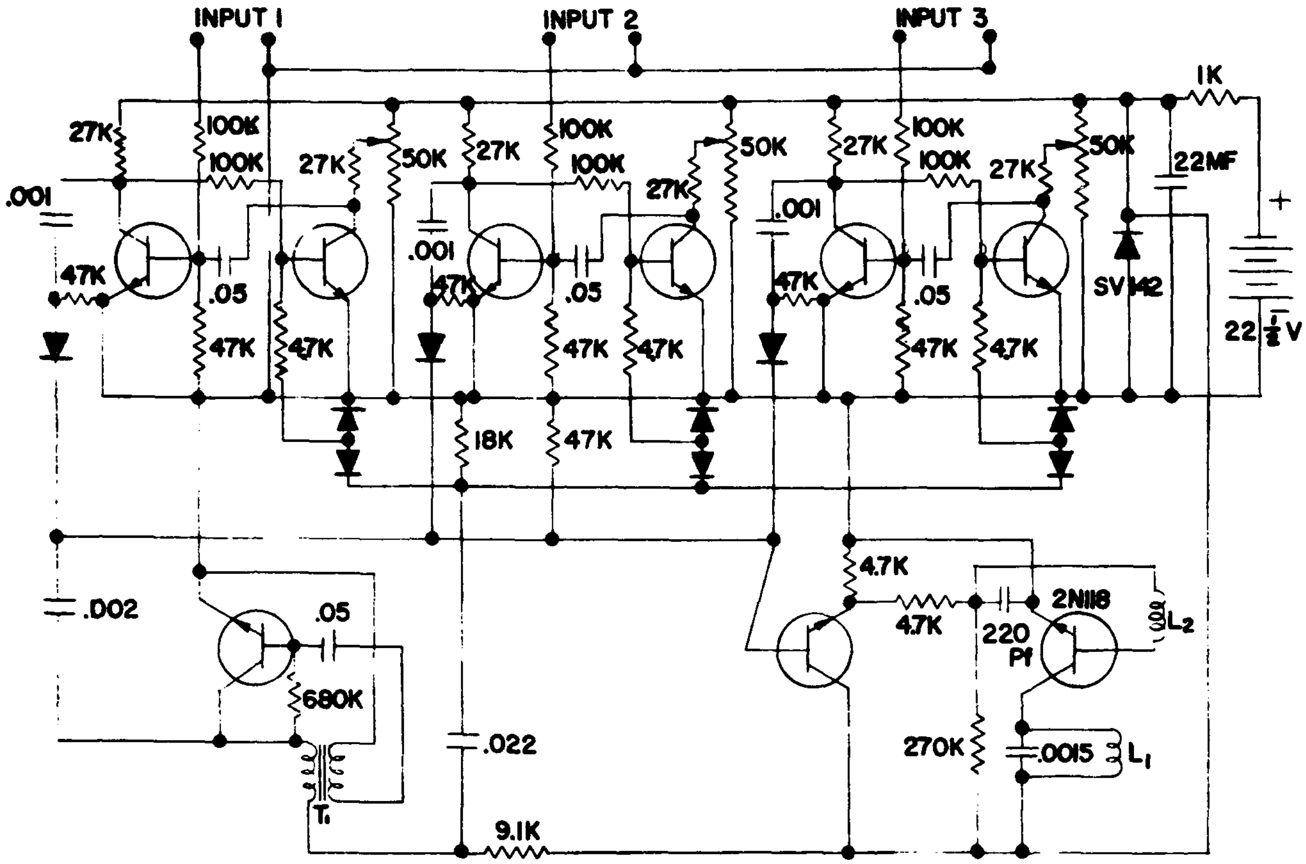
While looking for other solutions for a personal telemetry system, we decided to investigate pulse position modulation (PPM) for multiplexing in a small low-power consuming unit. Two different models were built and tested and are described in this paper. At the present time final comparison with other systems cannot be made, because not enough experience in longtime tests is available. However, many test results indicate that the PPM system is very practical for use in the special field of personal telemetry.

EXPERIMENTAL UNITS

During the investigation, two three-channel laboratory models with different time-modulation principles were built. Multivibrators were used in the first model, which is called the "MV Model." The second model, "ST Model," has a saw-toothed voltage. Both units are completely self-contained, built with standard size components, and transmit heart rate, respiration rate, and body temperature on one radio frequency.

The MV Model

The circuit diagram in figure 1 shows three delay multivibrator units, which are triggered from a blocking oscillator simultaneously at a rate of approximately 200 pulses per second. The pulse duration of each multivibrator is modulated with the signal voltage fed into the "input" terminals 1, 2, and 3. Terminal 1 receives a (1/2 volt) signal from the output of an ECG amplifier with a gain of approximately 2000. Terminal 2 is connected with a variable resistance respiration transducer, and Terminal 3 receives a signal (body temperature) from the output of a d-c amplifier with a thermistor bridge connected to the input terminals.



All not marked Transistors are 2N332 Transistron.

All not marked Diodes are IN486.

Figure 1. Three Channel PPM Telemetry Unit, (Without Amplifiers) MV Model

The pulse from each multivibrator is differentiated, 0.001 microfarads (mf) and 47 kilohm (k) and connected through a diode to the base of an emitter-follower stage which modulates the transmitter. The base-line position of each pulse may be adjusted with the 50 k potentiometer in each multivibrator circuit. The transmitter in this model is a standard-type oscillator circuit with Loop Antenna (L_1) and Feed Back Winding (L_2), in the form of a loop antenna around the mounting board of the unit.

Characteristics:

Power consumption	22-1/2 v 5 ma = 113 mw
Operation time with built-in battery	16 hours
Useful transmitting range	30 feet
Radio frequency	1800 kc
Frequency response for each channel	0 - 40 cps
Operating temperature range	20 - 100° F
Baseline stability over an 8-hour period	better than 5 percent
Weight	28 ounces
Size	8 by 4-1/4 by 2 inches

This model performed satisfactorily, but improvements in size, weight, transmission range, and power consumption were desirable.

The ST Model

In the second model (figure 2), not only another principle of operation was employed, but also miniature components were used. Figure 3 is a complete diagram for this unit. Its blocking oscillator (200 pulses per second) generates a saw-toothed voltage by discharge of a capacitor (0.05 mf) in the collector circuit of the third transistor. After two cascaded emitter-follower stages, the saw-toothed voltage is split three ways into three resistors, 33 k, 18 k, and 18 k, for mixing separately with the three signal voltages (ECG from the output off the ECG amplifier, respiration, and body temperature). The mixed voltages are used for triggering three Schmitt triggers. Output from the Schmitt triggers is differentiated, rectified, and used for modulating the transmitter (push-pull oscillator) (lower right hand in diagram). L_1 and L_2 are built into a loop antenna which is worn around the neck of the subject.

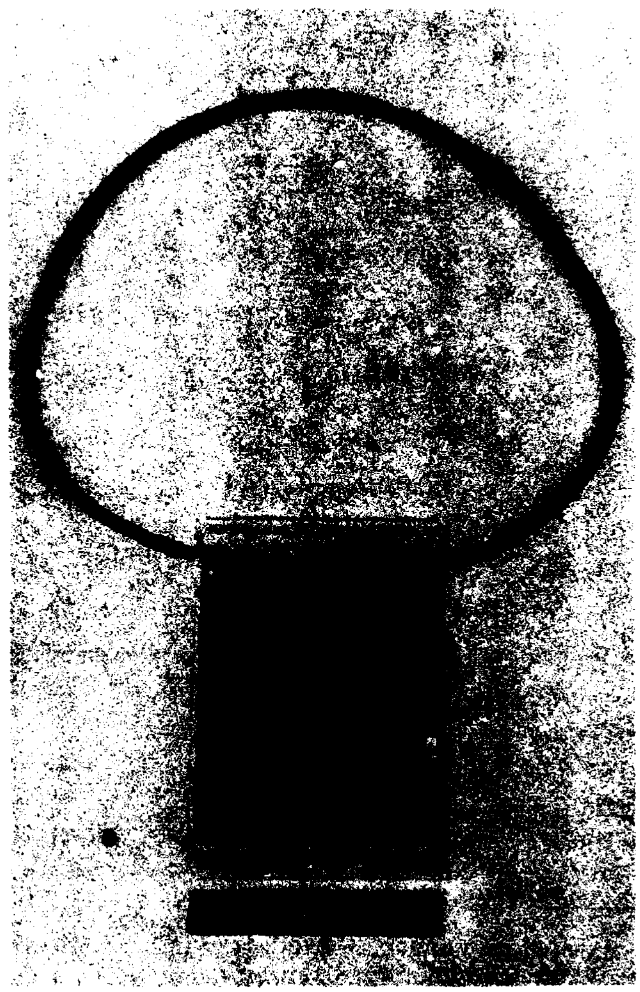


Figure 2. Transmitting Unit, ST Model

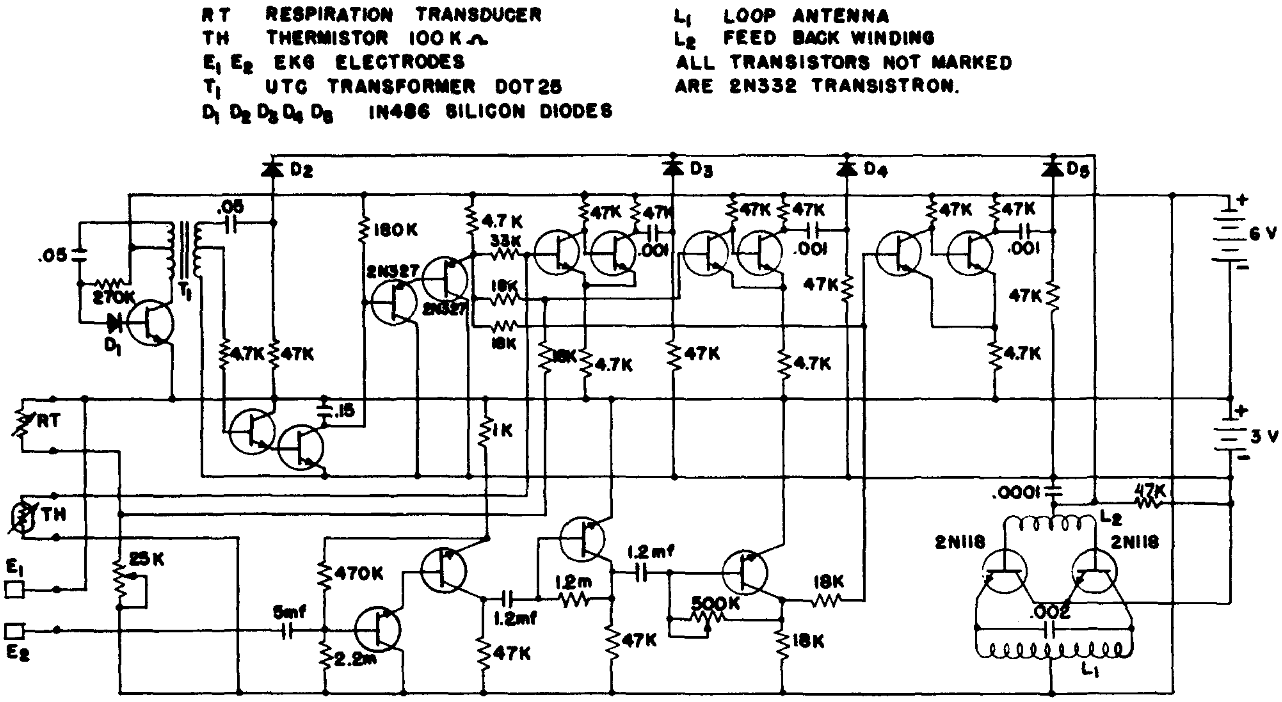


Figure 3. Three Channel PPM Telemetry Unit
ST Model

Characteristics:

Power consumption	6 volt 3 ma, 3 v 0.8 ma = 20 mw
Operational time with built-in battery	80 hours
Useful transmitting range	100 feet
Radio frequency	3 , 8 mc
Frequency response for each channel	0 - 40 cps
Operating temperature range	0 - 100° F
Baseline stability over an 8-hour period	better than 2 percent
Weight	6 ounces complete with battery (without case)
Size	4-3/4 by 3-1/2 by 1 inches

RECORDING AND PLAYBACK

Tape Recording

For permanent recording the pulse position modulated signal may be picked up with a standard receiver, feeding a single track magnetic tape recorder with a frequency response up to 7 kc. An inexpensive portable recorder may be used without seriously sacrificing accuracy.

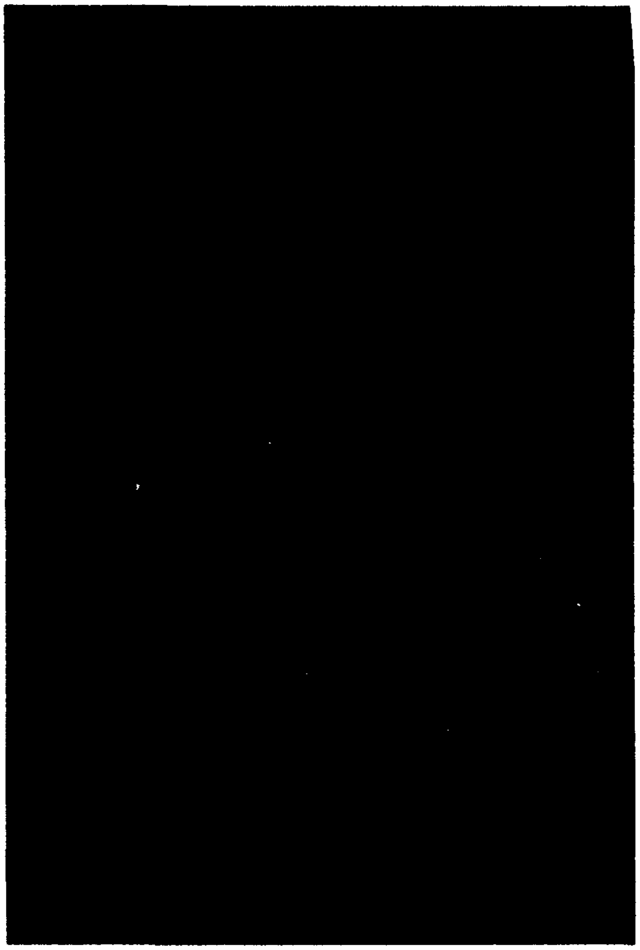


Figure 4. Receiving and Decoding Unit For Oscilloscope Display

Oscilloscope Displays

The simplest playback decoder system is an oscilloscope shown in figure 4. The circuit diagram is shown in figure 5. After an emitter-follower stage the pulses from the receiver trigger two one-shot multivibrators. The one on top has a pulse width of 4 msec and its triggering level is higher. Only the synchronizing pulses, which are approximately five times higher in amplitude and width, are able to trigger this multivibrator. Pulses from this multivibrator discharge the 0.05 mf capacitor, which is recharged through the 320 k resistor. Only a small part of the charging voltage is used to achieve linear saw-toothed voltage which is connected to the vertical amplifier of an oscilloscope (approximately 3 volt peak to peak). The second multivibrator shown in the lower part of the diagram produces pulses about 70 microseconds long, which are used to modulate the brightness of the CRT. This simple, inexpensive decoder principle may be used as a quick look facility or for photographic recording. A sample recording is shown in figure 6.

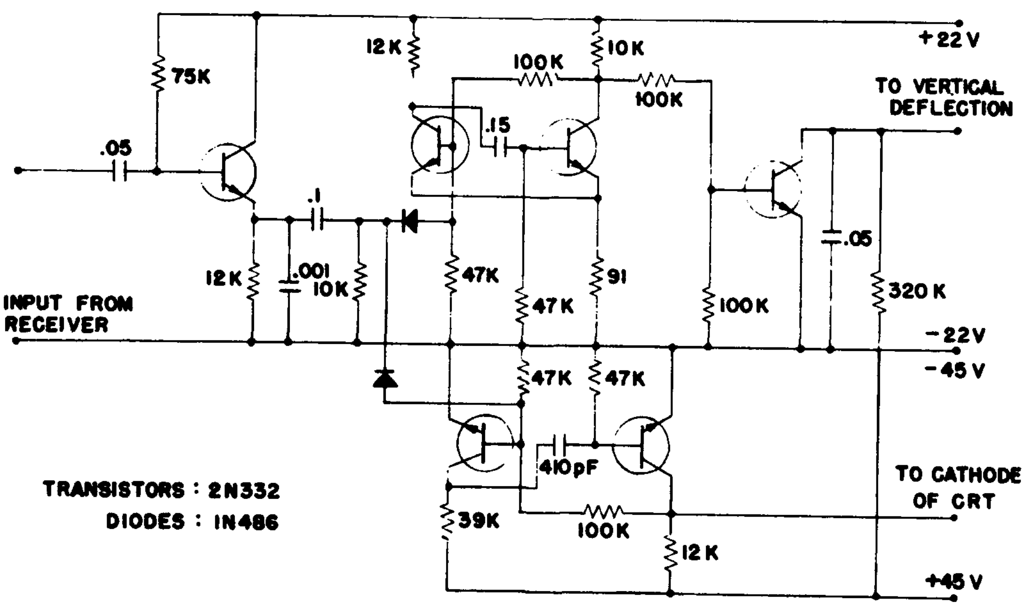


Figure 5. PPM Decoder Unit for Oscilloscope Display

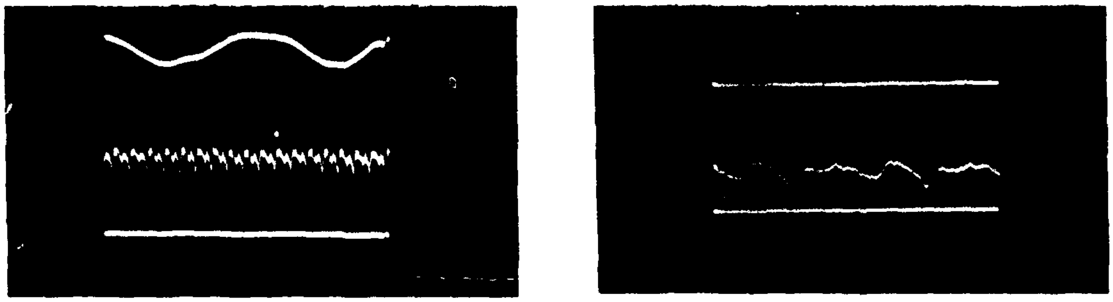


Figure 6. Photograph from Oscilloscope Screen Using Decoder System

Multistylus Recordings*

Figure 7 shows a block diagram for using the multistylus recorder. This type of recording, like the oscilloscope display previously described, makes it possible to use the whole recording paper width for all channels. If slow varying measurements with the highest degree of accuracy are wanted (like body temperature), this feature may be important.

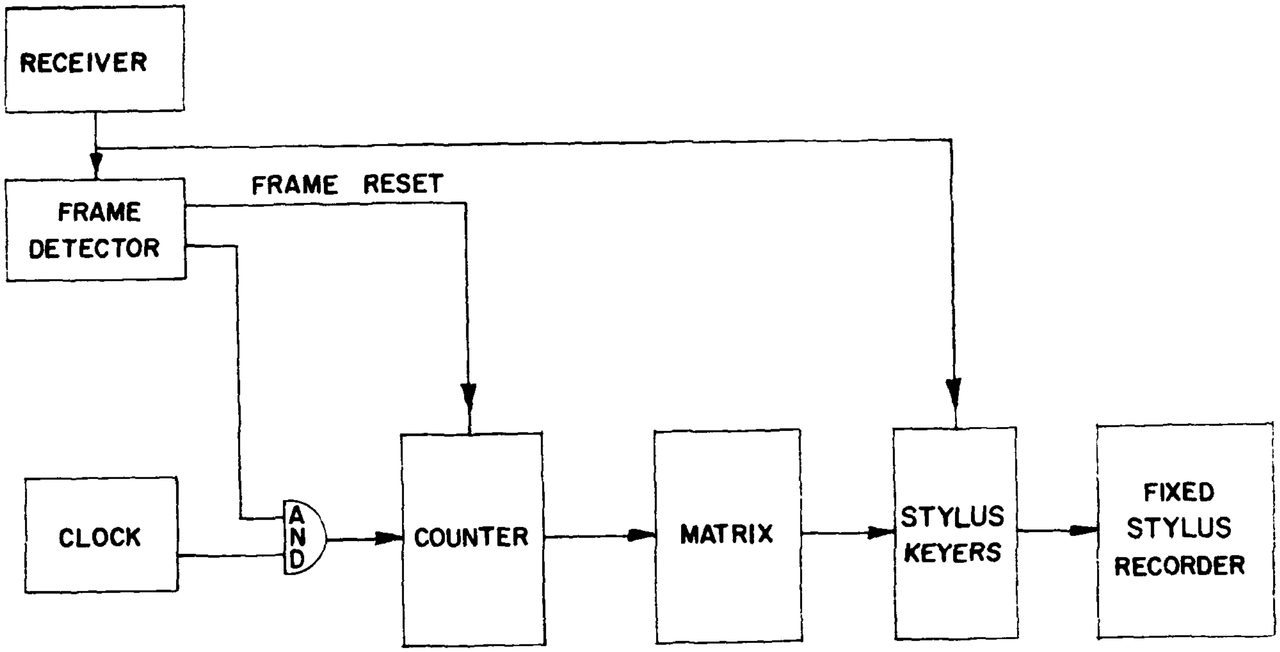


Figure 7. Block Diagram for PPM Recorder (Multistylus Recorder)

*The recording method was used through the cooperation of Radiation, Inc.

Penwriteout Recording

Recording the PPM signal on a multichannel pen recorder requires more elaborate circuitry. Figure 8 shows the block diagram for one solution, tested on a laboratory model. The synchronizing pulses (after separation) trigger the first one shot multivibration, M_1, which triggers in turn the multivibrator, M_2 (trailing edge from pulse of M_1 is used), and the trailing edge of the pulse from M_2 triggers M_3. Each multivibrator pulse activates a saw-toothed generator the output of which is gated twice. The first gate is operated from the multivibrator and acts as channel selector. The second gate is opened from the signal pulses. Capacitors, C_1, C_2, and C_3, store charges according to the position of the signal pulses. In figure 9 the actual circuits for only two channels are shown, since the third channel is identical. Tube 6AG5 resembles the first-channel selector gate, while the 12AX7 bidirectional triode gate is triggered from the limited signal pulses. A cathode follower delivers an output voltage from each channel of approximately 8 volts requiring only a single power stage (not shown) to drive a pen motor. Two units employing this circuit were built and tested, one for a 3-channel system and the other for a 6. Under laboratory conditions the circuit proved to be stable with a zero-line deviation from less than 1 percent for an 8-hour period. A sample recording is shown in figure 10.

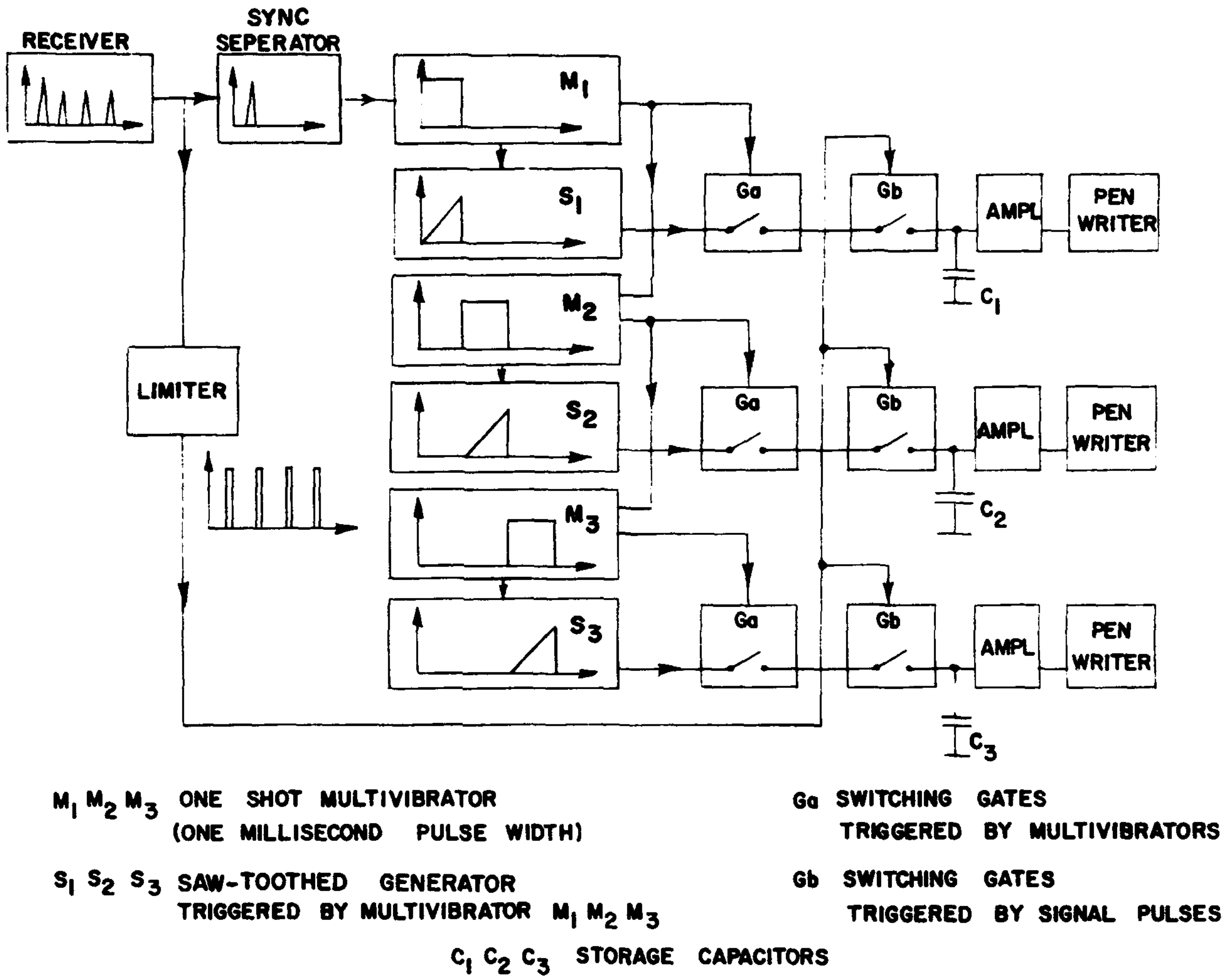
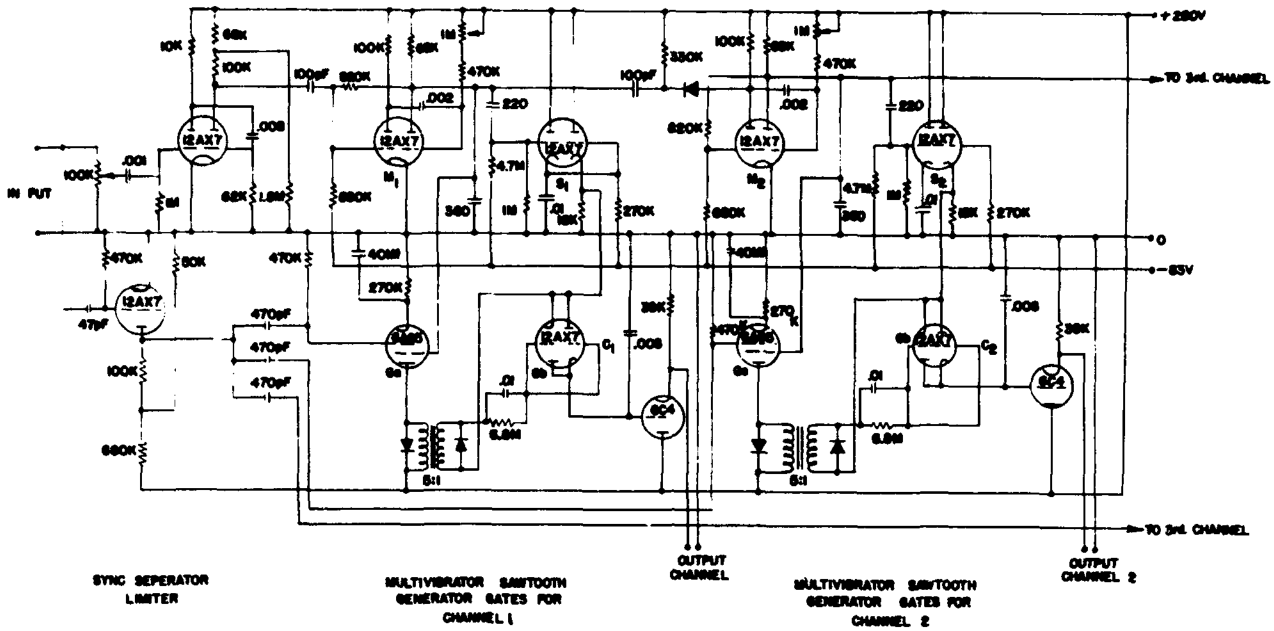


Figure 8. Block Diagram for PPM Decoder Penwriter Display



Antenna and Receiver

The loop antenna employed in the transmitting unit consists of two 9-inch diameter turns. It is designed to be worn around the neck to suspend the telemetry package (figure 11). This antenna shows null if it is in a 90-degree angle to the receiving antenna. Using two receivers within 90-degree angle relation provides one solution to this problem. Very good results may also be obtained with one receiver using two loop antennas arranged in 90-degree angle relation and specially phased. To accomplish this, both receiving loop antennas are tuned separately with a variable capacitor and their signals mixed through two 100-k resistors. Each antenna is first tuned separately to the correct frequency. After this procedure the capacity of one tuning capacitor is slightly increased and the other decreased by a small amount. If this is done correctly, rotating the transmitting antenna should show a minimum signal instead of a complete null. A few corrections on the two tuning capacitors should then provide an almost constant signal when the transmitting antenna is rotated in one plane. The signals on the LC circuits have a phase shift of 90 degrees.

The usual audioamplifier of a communication receiver is not suitable because of ringing and broadening of the pulses. Using a standard communication receiver, the output was taken from the second detector diode. According to FCC regulations a field strength of 15 microvolt/m in a distance of $\frac{\lambda}{2\pi}$ from the transmitter should not be exceeded by an unlicensed transmitter. For a frequency of 2 m C this distance is 72 feet. For most applications of personal telemetry systems, the necessary range is less than 72 feet. For certain experiments requiring operation over greater distances crystal-controlled transmitters using citizen band or a specially cleared frequency would be used. A more efficient antenna system and increased power output might also be required.

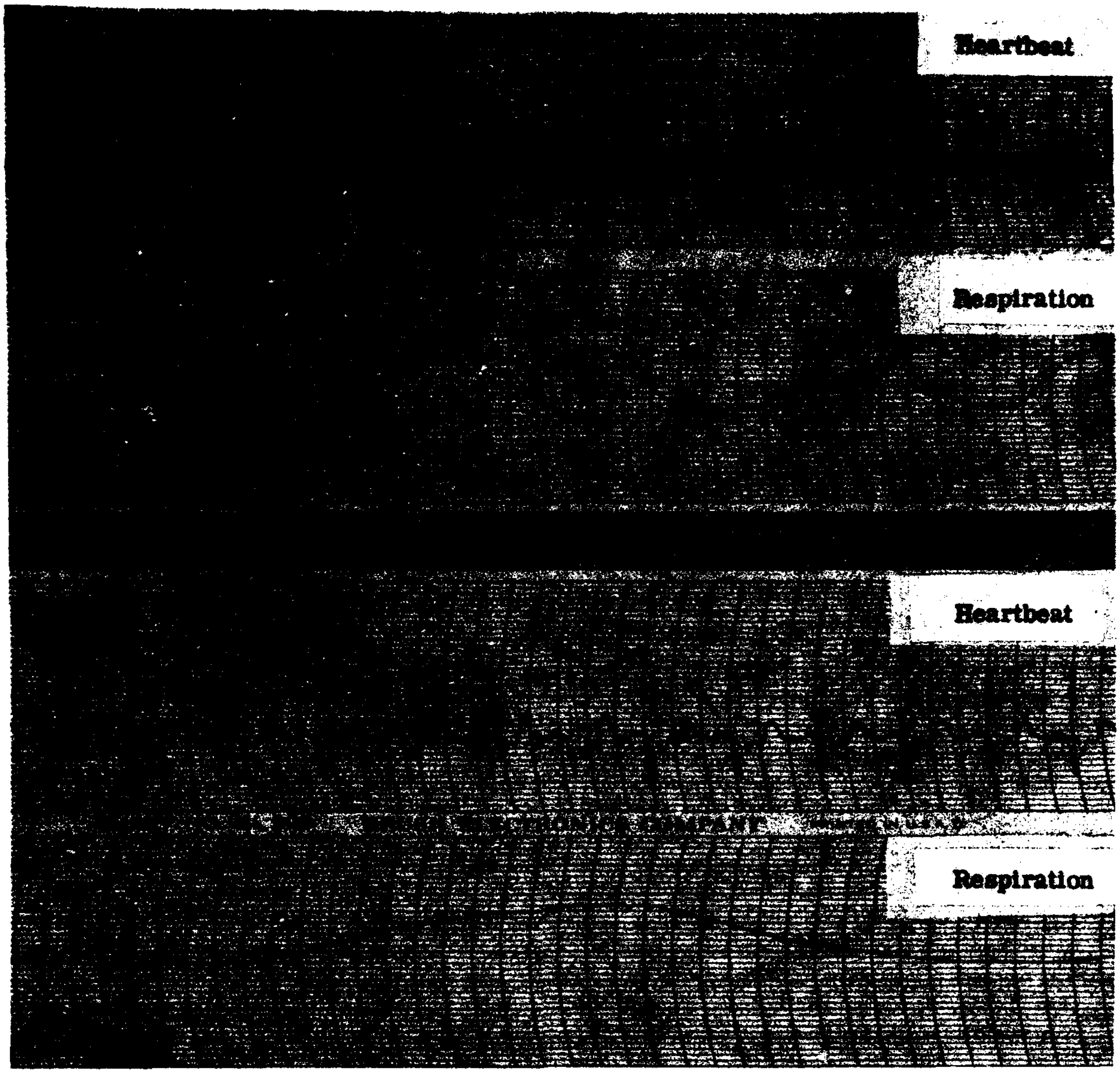


Figure 10. Recording with Brush Penwriter and Amplifier Connected to Decoder System Figure 6. Subject Walking. (The body temperature channel was recorded on a separate recorder not shown.)

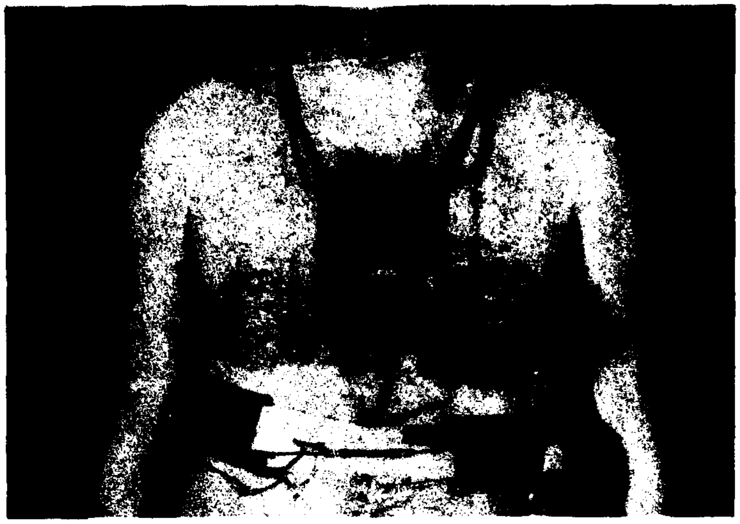


Figure 11. Personal Telemetry Unit (ST Model) and Transducer Belt Attached to the Body

CONCLUSIONS

This investigation on pulse-position modulation for personal telemetry systems has been made as a feasibility study only. No time or effort was spent to make the systems suitable for commercial production. All component values are the original ones used in the experimental models. Since especial transistors have wide tolerances some adjustments will probably be necessary when using these circuits. We considered this work only in its first stage. Very little work has been done in optimizing the transmitter itself. Also, multiplexing circuits may be improved. The principle of pulse-position modulation appears excellent from certain aspects for use in personal telemetry systems for the following reasons:

1. Low power consumption

2. Simple reliable circuits

3. No problems with crosstalk

4. Sufficient accuracy and stability for physiological measurements

5. Inexpensive small single-track tape recorders may be used

6. Playback system for scope display extremely simple and inexpensive

7. Although more complex equipment is required for playback to standard penwriter, this is not overly complicated for standard FM discriminators.

The limitations of this personal telemetry system are: (a) the frequency capability for each channel is 0 to 40 cps; (b) it is limited to a maximum of 6 channels; and (c) special playback equipment is required.

The advantages of this PPM system are limited to the specific application stated for its use in this report. However, in personal telemetry systems where necessary compromises must be made between number of channels, weight, power consumption, accuracy, and general ecomony, the PPM system is favored.

ASD TR 61-290

Aeronautical Systems Division, Aerospace Medical Laboratory, Wright-Patterson Air Force Base, Ohio
A MULTICHANNEL PERSONAL TELEMETRY SYSTEM USING PULSE POSITION MODULATION, by A. R. Marko, M. A. McLennan, and E. G. Correll, July 1961, 16p. incl. illus. (Proj. 7222; Task 71751)
Unclassified report

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