RESEARCH AND DEVELOPMENT WORK ON PERSONAL TELEMETRY SYSTEMS

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Introduction The term “personal telemetry system” has been applied to small size,self-contained, short range telemetry units, which are employed to obtain physiological measurements from an unencumbered human or animal subject. Main applications of such systems are medical research and medical monitoring to provide maximum safety for astronauts and test pilots. The technical requirements as stated by life scientists are presenting a wide range of engineering problems with some of them not solved by the present state-of-the-art. Research and development work in industry and Government laboratories has produced a number of practical solutions, but is still continuing in order to improve performance and extend the range of applications. Investigations on different multiplexing methods for use in personal telemetry have been started in the Aerospace Medical Research Laboratories (AMRL) at Wright-Patterson Air Force Base in the year 1959 and are continuing. The most important results and conclusions of this work are the subject of this communication.

Research Planning Considerations Aerospace medical research is mainly concerned with monitoring basically healthy subjects in flight vehicles or under simulated flight conditions. The monitored subject has to perform some missions requiring physical and mental activity which is in opposition to most hospital measurements where the patient remains preferably in a relaxed passive state. The statements above determine the following engineering aspects for a personal telemetry system in aerospace medicine.

1. Transmitting Range: A reliable transmitting range of approximately 100 to 200 feet is sufficient. Low power transmitters (below 100 MW input) already developed to a high degree of perfection are available which fulfill easily the transmitting range requirement even without a special antenna. No time and effort has been spent for the transmitter configuration itself, but a simple oscillator circuit with the tank coil as the radiating element has been employed in the laboratory models. Frequency modulation as well as the broadcast FM band (88-108 Mc) was used for the convenience of using readily available FM receivers. Recording of the signals may be performed on-board of a flight

vehicle of the information can be retransmitted to a ground station using the standard telemetry system of the airplane or spacecraft.

2. Frequency Response: The frequency content of physiological signals extends from DC to about 10, 000 cps. However, a number of biological signals which are most valuable for medical research as well as for safety monitoring, do not contain significant information above 70 cps. An active subject produces muscle potentials which interfere with electrocardiogram or other low level signals. Filters are used to reduce muscle potential interference, but are also limiting the useful bandwidth for the signal. Since the medical diagnosis is well established with standard laboratory methods, the personal telemetry monitoring system shall indicate variations of measurements caused by stress or unknown factors. A number of comparison experiments revealed a bandwidth from DC to 40 cps as the optimum compromise for monitoring the following signals on an active health subject: Electrocardiogram, Electroencephalogram, Electrooculogram, Galvanic skin response, Temperature.

3. Additional Factors: Low power consumption, small size, light weight, maximum stability, and reliability are additional important factors in aerospace applications.

Multiplexing Methods Personal telemetry systems using frequency modulated subcarrier oscillators have been developed to a satisfactory level of performance. Center frequency stability problems which plagued the miniature systems several years ago have been solved with special circuit design and the use of new semiconductor components. An analysis of the factors outlined previously indicated promising aspects for the investigation of other multiplexing methods -- especially pulse position and pulse duration modulation. A number of three-channel and seven-channel pulse position and pulse duration modulated laboratory models have been investigated and are published in technical reports. The circuit design of a further improved seven-channel pulse duration modulated system was then used as a basis for development and construction of three miniaturized transmitting units on Air Force contract.

The circuit diagram, Figure 1, shows a unijunction transistor clock pulse generator which produces 1600 pulses per second, triggering a binary counter (3 flip-flops for seven-channel system) and a saw tooth generator. The seven physiological signals are processed to voltage amplitudes of one volt and connected sequentially by the counter operated diode gates to the level sensing amplifier. The level sensing circuit receives also the linear ramp function voltage from the saw tooth generator and produces therefore a sequence of rectangular pulses, which are modulated in pulse width by the seven physiological signals. One diode gate (Channel 8) connects a positive bias to the level sensor and produces a gap after a train of seven pulses. This gap is used in the decoder to establish frame synchronization. It may be emphasized that there are only two circuits which affect the stability and accuracy of the whole system -- the saw tooth generator, and the level sensing circuit. However, any deviation of either circuit affects all channels in the same manner, and may therefore easily be detected by using one channel for a calibration signal. The degree of microminiaturization without excessive cost may also be deduced from the circuit diagram. Flip-flops, diode gates, comparators (level sensors) are already mass produced and available as microelectronic building blocks with excellent performance specifications at reasonable cost.

The saw tooth generator and the clock generator may be assembled from standard small components. A count of components and a comparison with the number of components in a typical miniature FM personal telemetry unit reveals that the pulse duration system uses less than half as many components than the FM unit. The advantages of this multiplexer circuit for use in personal telemetry may be resumed in the following points:

1. Extreme low power consumption (30 MW typically for seven-channel).
2. High baseline and gain stability (±0.3 per cent under normal laboratory conditions).
3. Simple calibration of all channels.
4. Microminiaturization to a high degree already available with shelf item microelectronic circuits.
5. Low number of components, smaller size, weight.
6. Lower costs (cost of components for the described seven-channel unit is in the order of $400).
7. High reliability - a mean time between failure in excess of 2000 hours has been calculated.

The specifications of the miniaturized personal telemetry units are:

1. Number of channels: Seven (two electrocardiogram channels, one electroencephalogram or electrooculogram, impedance pneumograph, basal galvanic skin resistance, specific galvanic skin response, body or skin temperature.
2. Size and weight: 4 1/4" x 2 1/4" x 3/4", 11 ounces complete with battery for 30 hours operation.
3. Power consumption: 8 volts 10 MA
4. Transmitting range: 200 feet.
5. Baseline and amplitude stability: ±0.3 per cent for an 8-hour period under laboratory conditions (temperature 74°F ±3°) 0.8 per cent variation with temperature change from 32°F to 76°F.
6. Transmitter: Input power approximately 24 MW DC. Frequency range: 88 to 108 Mc tunable. Stability: 0.5 per cent for a temperature range from 32°F to 100°F.
7. Frame repetition rate: 200 frames per second.

A boxcar detector circuit in the decoder instead of a simple low pass filter will reproduce frequency components up to 100 cps with this frame repetition rate, according to the sampling theorem. For practical comparison with other systems, however, the usable bandwidth may be considered 0 to 50 cps.

Summary Investigations of pulse duration multiplexing resulted in the development of a seven-channel personal telemetry unit. Theoretical analysis and field tests revealed advantages of the pulse duration approach, depending upon the acceptability of the limited frequency response. For a number of selected physiological measurements under the specified conditions, the described system is considered superior in terms of performance, and more economic because of fewer components compared to the FM system.

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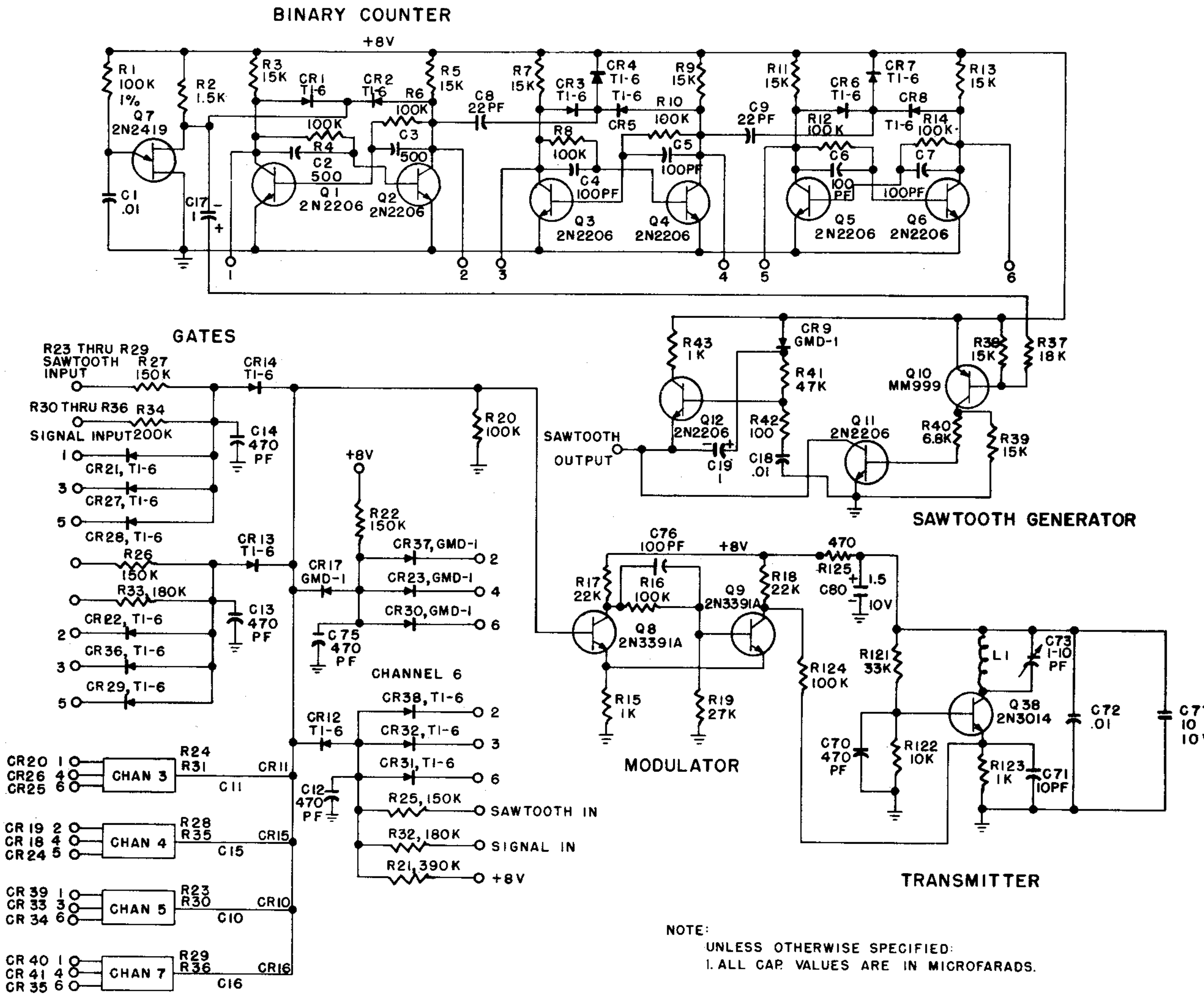

Fig. 1-Circuit Diagram