A Miniaturized Fifteen-Channel Telemetry Transmitter for Upper Atmosphere Research[1]

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For several years the AN/DKT-7 telemetry transmitter has been used for obtaining upper atmosphere data from sounding rockets. The AN/DKT-7 is a fifteen-channel transmitter that utilizes the pulse-position technique of transmitting telemetry information. This type of telemetry has been outmoded in some respects in recent years by other types of telemetry such as FM/FM, PAM/FM, and by the most recent type of telemetry called pulse-code modulation. However, it is still in use for some purposes, and this paper is concerned with recent improvements in the transmitter.

The outstanding features of the pulse-position telemetry, such as is used by the AN/DKT-7, is that one can obtain high values of peak radio frequency power while the average power is low. The modulation equipment has a minimum of components; hence, the cost per channel is lower than with some other types of telemetry. The main disadvantage of pulse-position telemetry is that the sampling rate is low; consequently, it will not detect sudden changes in transducer information with this characteristically low frequency response. In newer telemetry circuits, which are

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in general transistorized, the design of radio-frequency power-amplifier stages is limited to those of low power with the present status of radio-frequency transistors.

The National Aeronautics and Space Administration has used the AN/DKT-7 telemetry transmitter to a considerable extent for upper-atmosphere research in some of the larger sounding rockets such as the Aerobee.

This paper describes the design and construction of a miniature, transistorized version of the transmitter, which would be compatible with the AN/FKR-1 ground receiving equipment, also used with the AN/DKT-7 transmitter. The miniature transmitter was needed for use in smaller rockets, and also in larger rockets where space and power are at a premium.

No detailed specifications were given concerning the performance of the new miniaturized circuit. Such features as the pulse-position accuracy and the linearity were to be as precise as could be designed with transistor circuits. The initial stage of the circuit development was to include a transistorized version of a radio-frequency transmitter. This transmitter was to feature an RF pulse-power output with a peak value as high as could be attained with the state-of-the-art transistor development at the time of circuit design. As the work progressed, it was decided that most effort should be directed toward the pulse-position modulator circuits and that design of the RF portion should be deferred to a later time. It was also believed that the unit would perform better if a tube version of an RF transmitter were used in conjunction with a pulse-position modulator. The remaining circuits were not necessarily intended to be direct transistorized versions of the AN/DKT-7 circuits but were designed to accomplish the same results as the original circuits. Such things as the data commutator and the voltage-sensitive delay-generator could very well be different types of circuits than those previously used in the tube version.

CIRCUIT FEATURES

Reference may be made to Figs. 1 and 2 which illustrate a block diagram and a set of idealized waveform drawings for the miniaturized telemetry transmitter modulator. The main purpose of the entire circuit is to convert 15 channels of external transducer information which appears as voltage signals in the range of 0 to +5 volts DC at the 15 input connectors of the data commutator. These voltages appear continuously and must be sampled in sequence to produce a series of output pulses which vary in time position as a function of the voltage level of the input information. The input information, generally stated to be derived from transducers, may be the outputs of such things as magnetometers, accelerometers, photocell amplifier outputs, battery voltages, and many others. The output pulse-position information appears as a pulse which is displaced in time from a fixed pulse known as the five-kilocycle synch pulse shown in Fig. 2. This synchronizing pulse is absent from the output series of pulses; nevertheless, the time measurements are made from the internally generated five-kilocycle synch. A frame synchronizing pulse, known as the triple pulse, is transmitted along with the data pulses and is utilized by the ground station equipment for generating a series of reference pulses corresponding to the airborne five-kilocycle pulses. By oscillographic display of the data, with respect to the synchronizing pulses at the ground station, meaningful data information may be obtained. The data pulses and the triple pulse from the airborne pulse-position modulator are used to modulate a pulse-type radio frequency transmitter whose signal is in turn received by the ground station equipment. After radio frequency demodulation, the data pulses are used to intensity-modulate

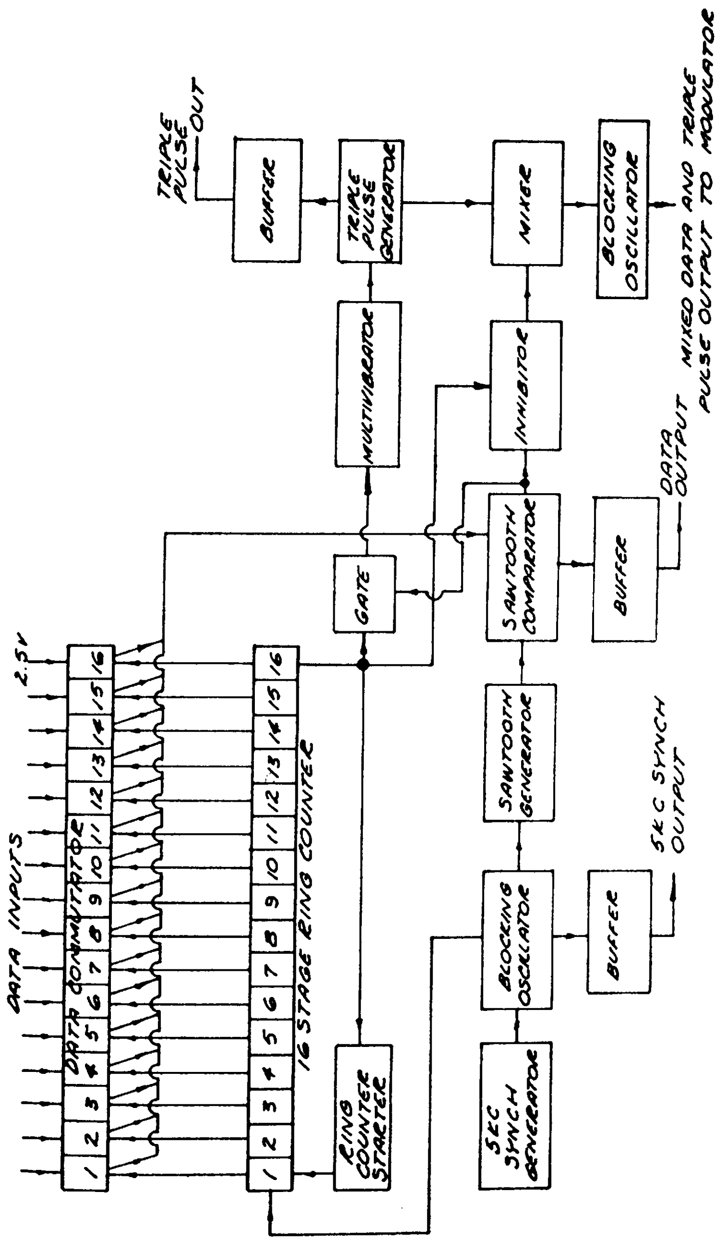

Figure 1. Block Diagram of Pulse-Position Modulator

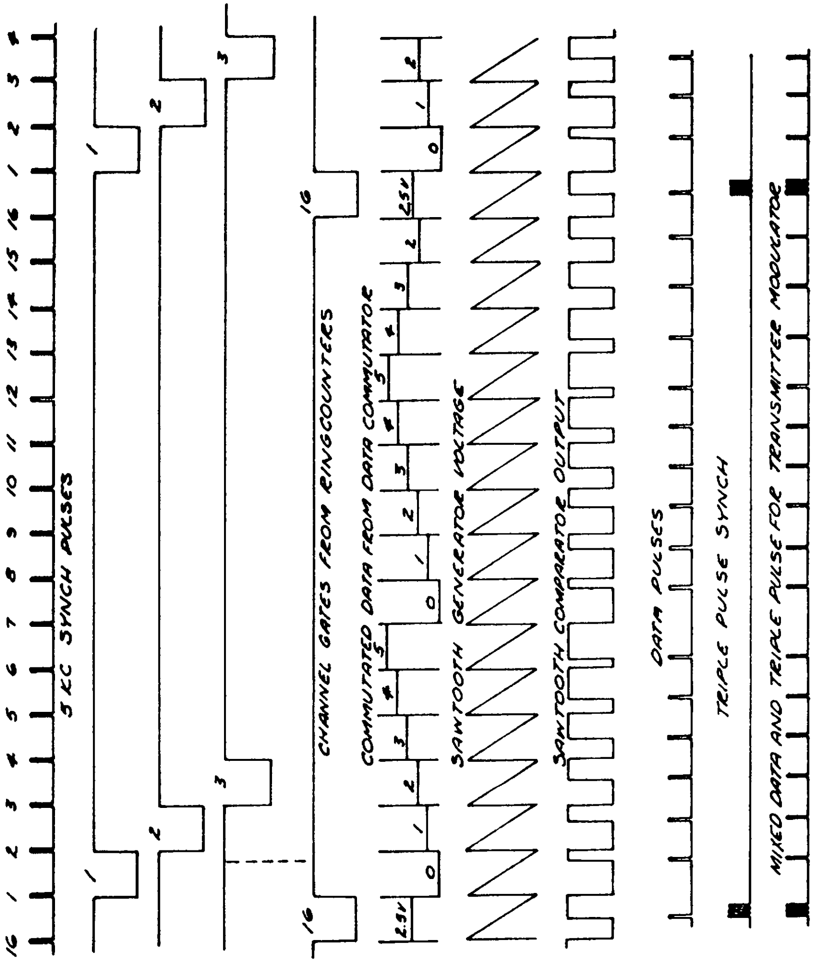

Figure 2. Waveform Diagram for Pulse-Position Modulator

several oscilloscopes for presentation of data on strip chart recordings. Two or three oscilloscopes may be arranged to display the 15 channels of information.

Data Commutation

The data commutator consists essentially of two types of circuits which contain several circuit elements. These two types of circuits are the 16-stage ring counter and the data commutator illustrated in Fig. 1. The ring counter consists of 16 stages of multilayer solid state devices called binistors. These devices inherently have two stable states, conducting and not conducting, and may be visualized as a pair of transistors connected in cascade. The ring counter stages are connected in such fashion that one device is normally conducting current while the others are in the "off" state. A series of triggers from the five-kilocycle synch source is used to turn the conducting binistor off and, in doing so, the output of this binistor switches the following transistor to the "on" state. This circuit action continues in sequence and a series of gates are generated in sequence as illustrated. The ring counter usually does not begin to function upon first application of power because all stages are off. The ring-counter starter, which consists of a unijunction sawtooth oscillator, is used to initiate the counting sequence. The starter circuit also has the feature of preventing more than one stage of the ring counter from simultaneously being in the "on" condition. This is accomplished by proper choice of time-constant elements in the ring counter starter circuits.

The data commutator is made of 16 stages, each of which contains two emitter followers. The input emitter follower is an NPN transistor, while the output emitter follower is a PNP transistor. All of the output emitter followers have a common load resistor; consequently, the 16 input voltages appear at the common output. The 16 gates from the ring counter are applied in sequence to the data commutator circuit and cause each stage to allow its input data to be transferred to the common output. The 16 input voltages include a 2.5-volt input which is used to position the triple pulse in the middle of the sixteenth channel. The fifteen remaining data input voltages originate at the transducers. The input impedance of the data commutator is 100,000 ohms or more. There is very little if any cross-talk or inter-channel interference appearing at the output. Fig. 2 illustrates commutated voltage levels which vary as stairsteps with levels between zero and five volts. The 2.5-volt level corresponds to channel 16, which is the channel assigned for the triple-pulse synch generation.

Voltage-Sensitive Delay-Generator

After the 16 pieces of input data are mixed into one output from the data commutator, they are applied to the voltage-sensitive delay-generator. This is the circuit which produces the pulse-position output data, a function of the input data voltages. The delay generator consists essentially of a sawtooth generator which produces a sawtooth which is very nearly linear, and a sawtooth comparator which compares each level of commutated data voltages to a corresponding level along the sawtooth. It produces an output pulse corresponding to the time at which the sawtooth voltage equals the data voltage.

The sawtooth generator consists essentially of a resistance-capacitance charging circuit whose energy is discharged by triggering a PNP shunt transistor with a pulse from the five-kilocycle synchronizing generator. The five-kilocycle source, as shown on the block diagram, consists of a five-kilocycle sine wave generator and a blocking oscillator for supplying the pulse. The sawtooth generator is a circuit with bootstrap feedback from temperature-compensated emitter followers to improve the linearity and to make the circuit unsusceptible to slope and linearity variations with temperature.

The circuit following the sawtooth generator, called the sawtooth comparator, consists of two PNP transistors with a common emitter resistor. During the period of time at which each commutator channel is gated, there appears a DC voltage level from the commutator which causes conduction of one of the two transistors by being applied at its base circuit. The other transistor, which has the sawtooth applied to its base, is biased in the nonconducting state by the common emitter resistor, and will not conduct until such time as the sawtooth voltage exceeds the data voltage. When conduction occurs, a signal is taken from the collector circuit of the transistor with the applied sawtooth. This wavefront of conduction is further shaped in high gain transistor stages and a square wave is produced as shown in Fig. 2. After the square wave is passed through a differentiating circuit, the data pulses are produced. These data pulses, as shown, include a pulse corresponding to the 2.5-volt input to the commutator which is used to synchronize the triple pulse. The five-kilocycle synchronizing source corresponds to a channel width of 200 microseconds. The time excursion of the output channels are adjusted so that an input DC voltage variation from zero to five volts will create a time variation of the output pulses from 25 to 175 microseconds from the five-kilocycle reference pulse. This creates a 50 microsecond guard band between channels.

Triple Pulse Generator

The data from the sawtooth comparator is passed along to a gating circuit which is connected to the output gate from the sixteenth stage of the ring counter. This sixteenth gate allows only the pulse corresponding to the 2.5-volt input to be passed to the multivibrator as shown in the block diagram. This multivibrator generates a pulse whose duration is approximately 24 microseconds, and this pulse is used to gate an inductance-capacitance ringing circuit which oscillates at a frequency of 125 kilocycles for the duration of the multivibrator pulse. Three pulses spaced at eight microseconds are generated from the oscillating circuit and, after being shaped, they are mixed with the data pulses from the sawtooth comparator. In order to eliminate interference from the triggering pulse for the multivibrator, which corresponds to the 2.5-volt input data, an inhibitor is used to eliminate that pulse from the series of data pulses from the sawtooth comparator. The mixed triple pulse and data-output pulse are used to trigger a blocking oscillator which, in turn, is connected to an output jack for use with an external modulator and radio-frequency transmitter. It may be seen that the triple pulse is also brought out of the unit as a separate signal from the mixed data and triple pulse. The output of the five-kilocycle synchronizing blocking oscillator is also passed through a buffer stage and brought out of the circuit. These separate outputs are made available in case auxiliary equipment such as pulse-code data modulating equipment would be used with this miniaturized pulse-position modulator.

Power Supply

The power supply for the miniaturized telemetry package consists of an input DC voltage regulator which supplies approximately 22 volts to a transistorized transverter with bridge rectifiers and filters at the output. The input regulator maintains the voltage for the transverter at a constant level while the source voltage from the batteries may vary due to battery life. The nominal battery source voltage is 28 volts DC. The output voltages from the transverter are +6, +12, -6, and -18 volts DC.

Physical Configuration

The miniaturized telemetry modulator is housed in a cylindrical container four inches in diameter and ten inches long. The various sections of the circuit are contained on etched circuit cards which are circular in form and are equipped with a disconnect plug on one edge. A distribution strip is available on one side of the container and seven circular etched cards may be plugged into the distribution strip. Transducer input terminals and battery power terminals are available at connectors on the top of the container. Coaxial connectors on the lid are used for pulse connectors. The transverter power supply is contained in the lower portion of the cylinder. The unit may be pressurized; however, this is not necessary for its operation.

All circuits have been designed to perform over a temperature range between -40°C and +60°C. Since several of the circuits are direct-coupled, considerable care was taken in design to prevent voltage drift with temperature changes. It is estimated that the time accuracy of each channel will be within one per cent of the channel excursion. The first prototype was not constructed with encapsulated components. Encapsulation techniques could be used in later models to help resist damage due to vibration and shock.

SUMMARY

A miniature telemetry modulator has been designed for use in conjunction with a separate radio-frequency transmitting unit. The combination may be used as a rocket-borne fifteen-channel pulse-position transmitter in conjunction with existing ground receiving equipment. It has similar performance features to those of the AN/DKT-7, a larger and heavier airborne transmitter. It can be used to convert as many as 15 separate sources of voltage data into pulse-time information, which is then transmitted to the ground equipment for decoding.