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AIRBORNE TELEMETRY CALIBRATOR TYPE 4X4, MOD I

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GODDARD SPACE FLIGHT CENTER

GREENBELT, MD.

AIRBORNE TELEMETRY CALIBRATOR

TYPE 4X4, MOD I

By

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and

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SUMMARY

29959

The development and operating characteristics of a new, sixteen channel, airborne telemetry calibrator are described. The unit was designed and developed at Goddard Space Flight Center to fulfill increasingly stringent requirements by scientists and experimenters for enhanced accuracy and reliability in transmitted data, and to meet the needs of the sounding rocket program for a smaller, lighter, more stable unit. The Type 4X4 Calibrator is now operational as proven, flight qualified equipment.

author

LIST OF ILLUSTRATIONS

AIRBORNE TELEMETRY CALIBRATOR

TYPE 4X4, MOD I

INTRODUCTION

The continuing record of successful sounding rocket flights has provided scientists and experimenters with an increasing mass of data. With greater knowledge of the upper atmosphere it has become possible to direct scientific investigation and experiments toward more precisely defined areas. Refinement of objectives has created a parallel requirement for improved precision in data handling and validation.

One effective means of providing both qualitative and quantitative controls for recorded data is the flight calibrator. Since the inception of the sounding rocket program, a variety of electro-mechanical and electronic calibrators, representing many different design concepts, have been used. Some were commercial items, others represented the work of Goddard or other government agencies. These units offered a wide range of options in calibration method, number of channels calibrated, number of steps, calibration levels and sequencing schemes. Flight calibrators have been used on a majority of sounding rocket flights to date, and are included with the telemetry systems for nearly every flight presently scheduled.

The calibrator described below and shown in Figure 1 has been derived from broad experience gained through use of a variety of different models. Development of the 4X4 Calibrator was begun when the commercial units then in use exhibited an undesirable sensitivity to radio frequency interference and to transients in the power supply. The size of the commercial unit, particularly the height, was also undesirable as a continuing source of difficulty in system packaging. As experiments and the associated equipment achieve higher levels of sophistication, competition for ounces and cubic inches of the payload is intensified.

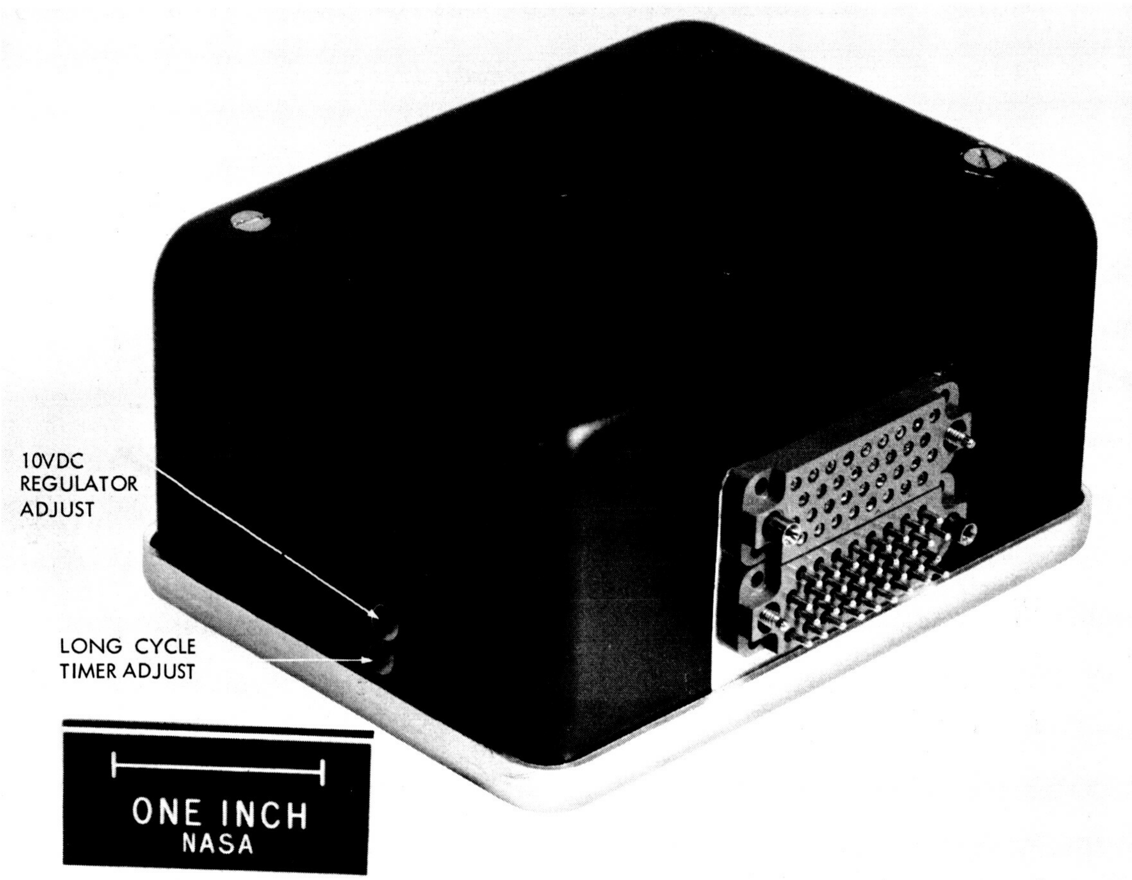


Figure 1 - Flight Calibrator, Type 4X4, Mod I

The design goals may then be briefly summarized as: functional stability; accuracy; size reduction; and fail-safe operation. The last goal is inherent in all calibrator designs to assure that any malfunction or failure affecting the calibrator will not cut off the data channels. The connecter arrangement of the commercial unit was retained so that build-up of payloads and instrumentation could be carried on without rewiring or rearranging interconnection circuits. A secondary design goal, was the elimination of the need for an accessory unit required with the commercial units to effect an automatic change in calibration step width.

The entire development program, including design, fabrication, and qualification of the prototype for flight, was accomplished in less than two months. The first prototype was installed in the payload for Aerobee 150, Flight 4.52 UG as shown in Figure 2, and successfully flown from White Sands Missile Range on 3 November 1964. Following the successful operational use of the first prototype, production quantities of the calibrator were ordered and are now being delivered.

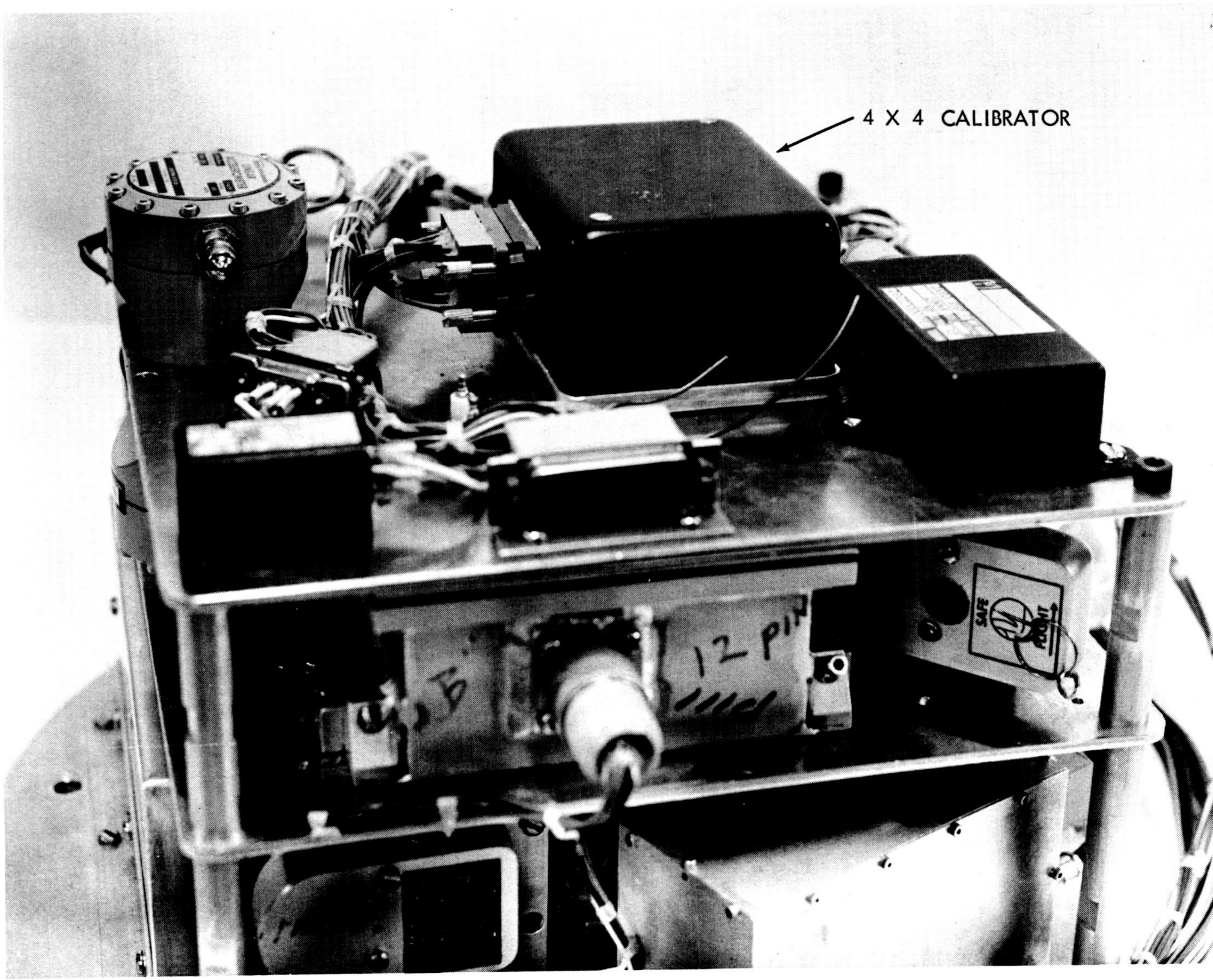


Figure 2 - Type 4X4 Calibrator Installed for Aerobee Flight

THEORY OF OPERATION

Regardless of differences in the details of design, all flight calibrators are intended to periodically provide a series of precisely controlled voltage steps to the airborne telemetry system. In a few instances, these calibration steps have been imposed upon the data signals. The more common technique, more readily recognized and interpreted, interrupts the data signals and inserts the calibration steps as shown in Figure 3.

The example selected for Figure 3 is a preliminary check of the instrumentation and telemetry equipment installed for Aerobee flight 4.50 UG. Simulated signals were used for the experiment data channels since the experimental payload was not yet integrated with the system. Channels 1 and 2, at the left of the chart, were connected to 30 segment, 1 rps commutators with an assortment of simulated data inputs applied. The channel 2 trace exhibits evidence that several inputs are slightly negative. Should this condition appear in the course of prelaunch checks, it would indicate the need for a detailed checkout of the affected data channel for possible connection error, malfunction or perhaps some additional signal conditioning. Appearance of these characteristics in the course of the flight strongly suggests failure or malfunction of the data source.

Thermally induced drift in either the transmitting or receiving systems is also readily detected since the amplitude of the calibration steps will reflect the variation. Since data levels will vary proportionately, it is possible to use the calibration steps to compensate for the drift and maintain accuracy of the received data.

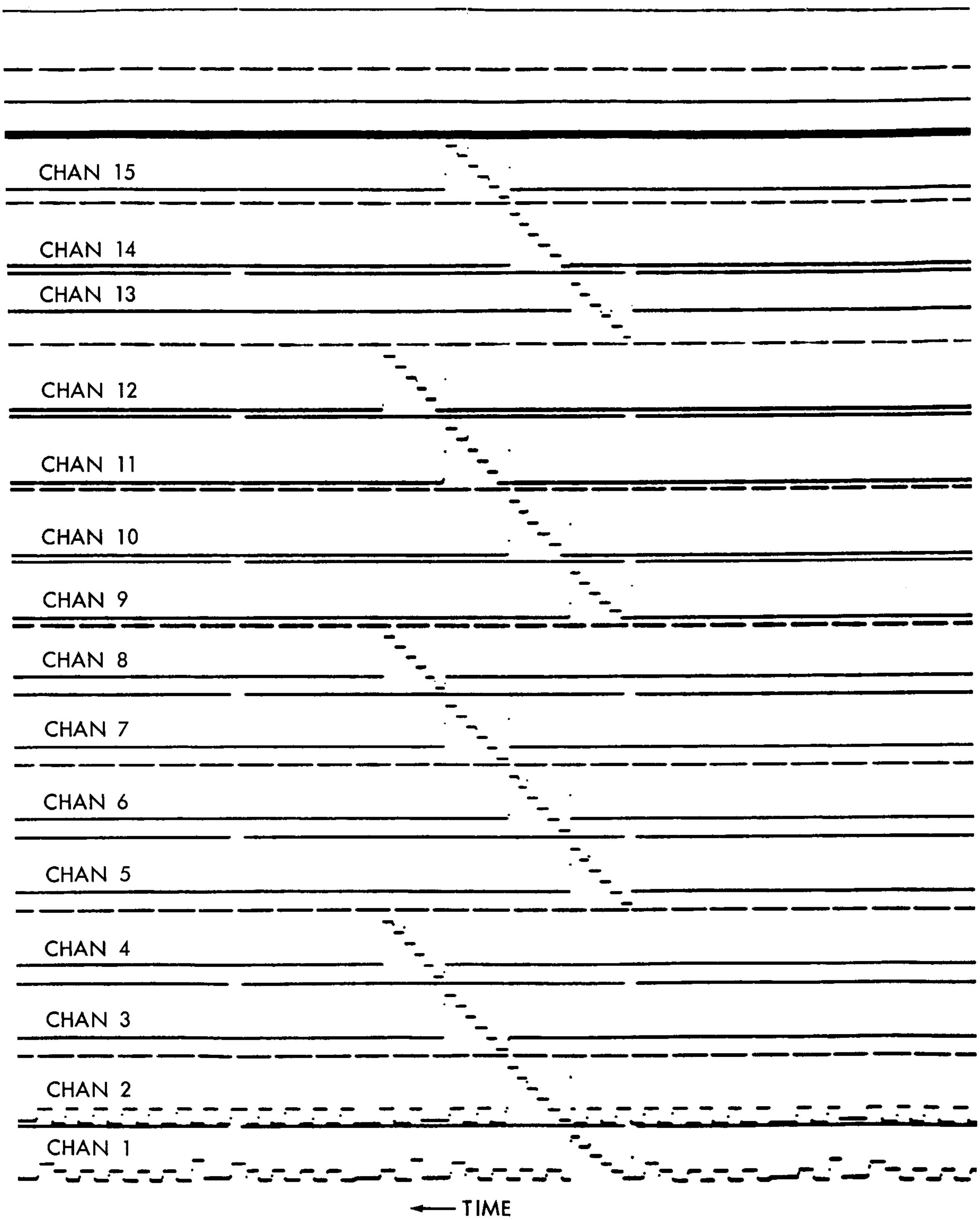


Figure 3 - Oscillograph Record of Calibrated Data

DESIGN PHASE

Meeting the two major design goals entailed somewhat contradictory solutions. Size reduction inherently seeks to eliminate components while improved stability is most frequently obtained by additional circuits. The problem of stability was resolved by providing a three-stage regulator system. Actual increase of components for this circuit was quite small. Size reduction was attacked through functional analysis of the operating cycle of the existing commercial calibrator. It quickly became apparent that the individual calibration of sixteen channels, one at a time, offered the most productive area for elimination of circuits and components. In the commercial unit, each channel required a relay and a driver circuit. A "four by four" calibration scheme, using four-pole, double-throw relays to simultaneously calibrate four channels with each series of voltage steps, was substituted for the single channel sequencing. The number of relays and driver circuits was reduced from 16 to 4 with an additional saving realized through a simpler counting sequence.

At this point, with a reasonably firm concept of the physical bulk of components, attention was directed to mechanical arrangement and packaging. The technique of functional "cordwood" modules, used earlier to good effect, was adopted. The modules were then interconnected through "mother" boards as shown in Figures 4 through 7. Following final assembly and bench checks of operation, the calibrator was potted using Emerson and Cuming medium density Eccofoam FPH.

The prototypes were qualified for flight under environmental tests for shock, vibration, and temperature, for Aerobee, Nike-Apache and Javelin rockets. Production units will be flight qualified under a recently developed general sounding rocket environmental test program.

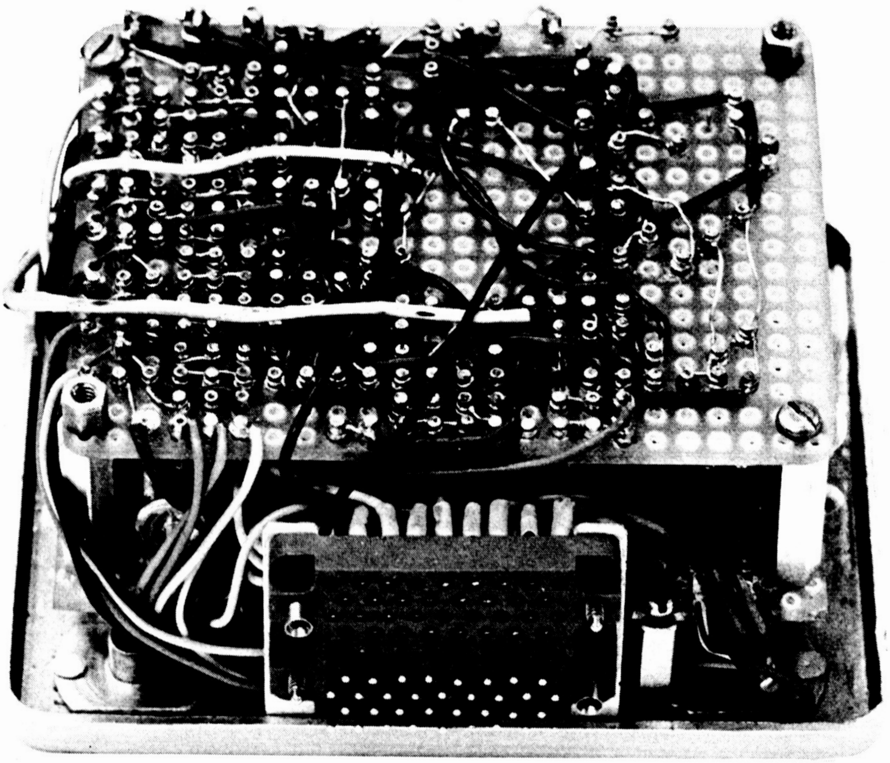


Figure 4 - Calibrator with Cover Removed

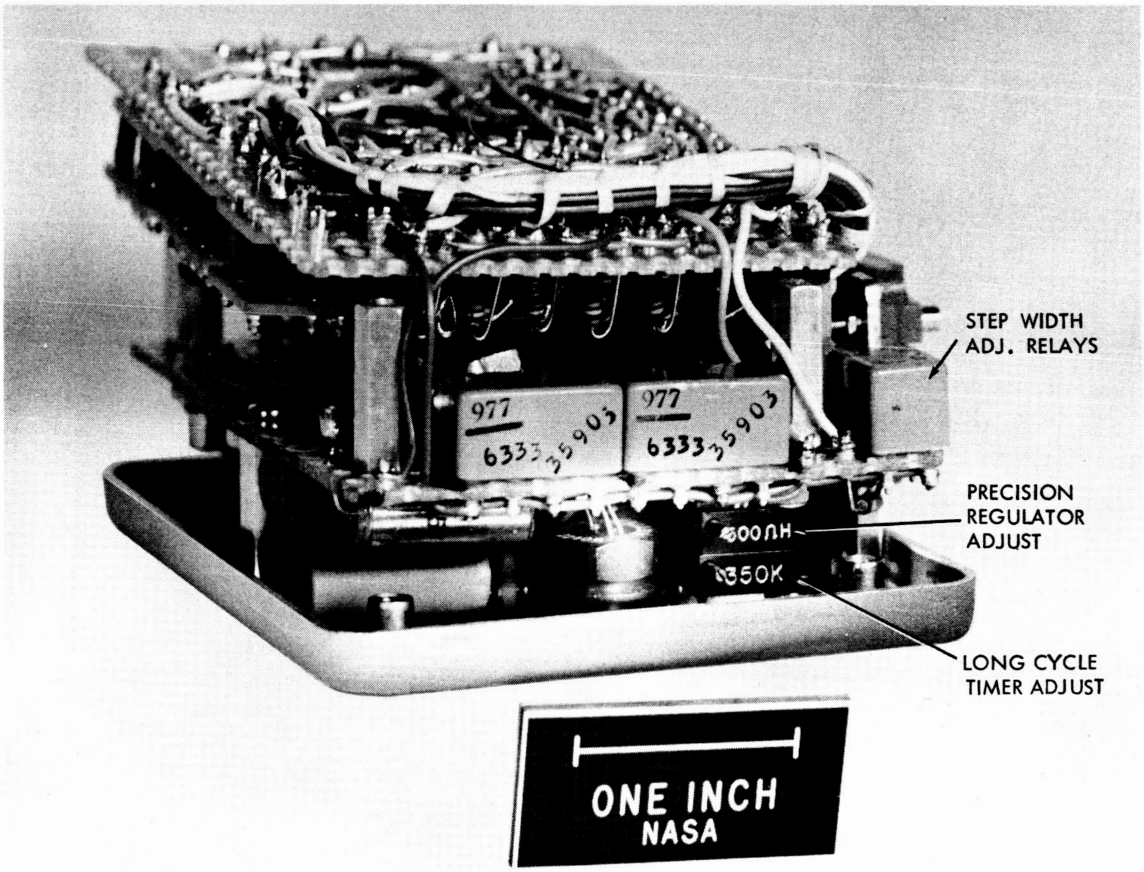


Figure 5 - Side View of Calibrator

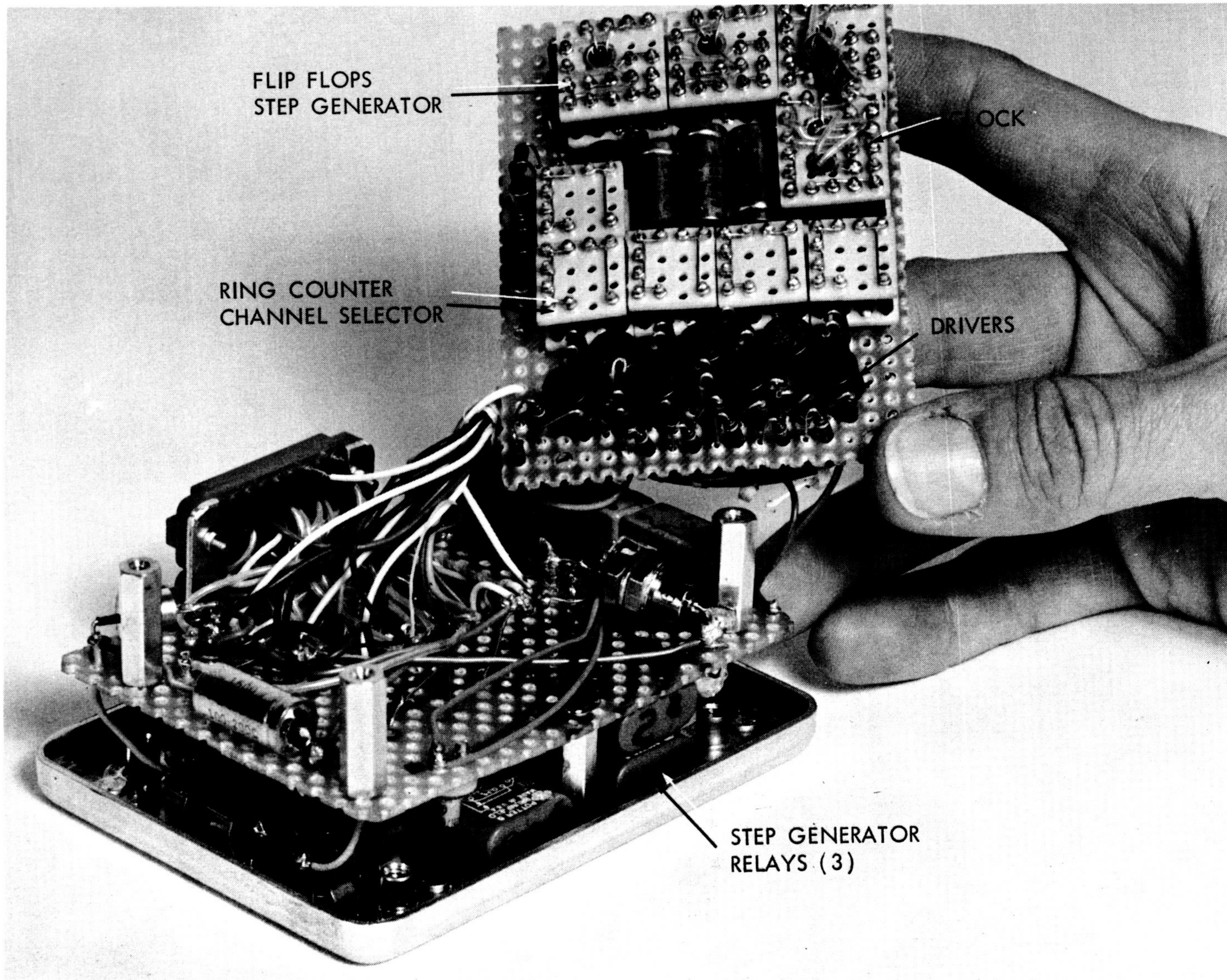


Figure 6 - Calibrator Component Boards and Relays

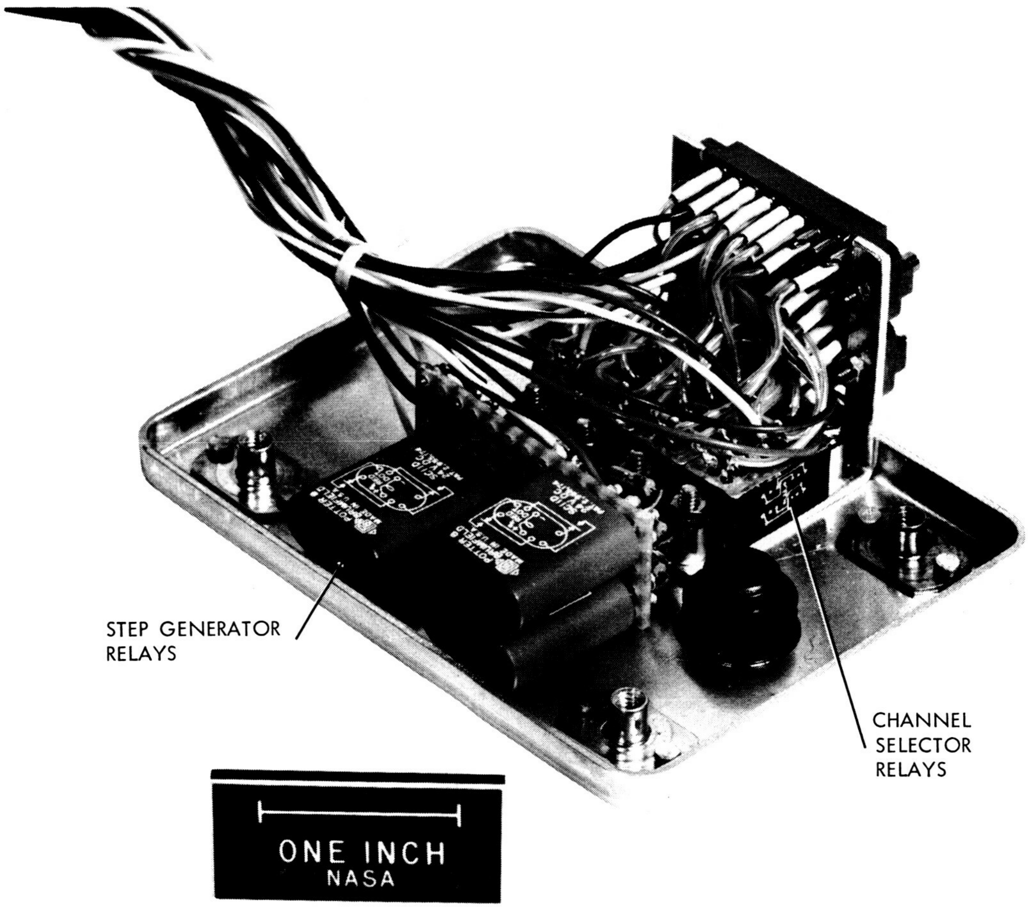
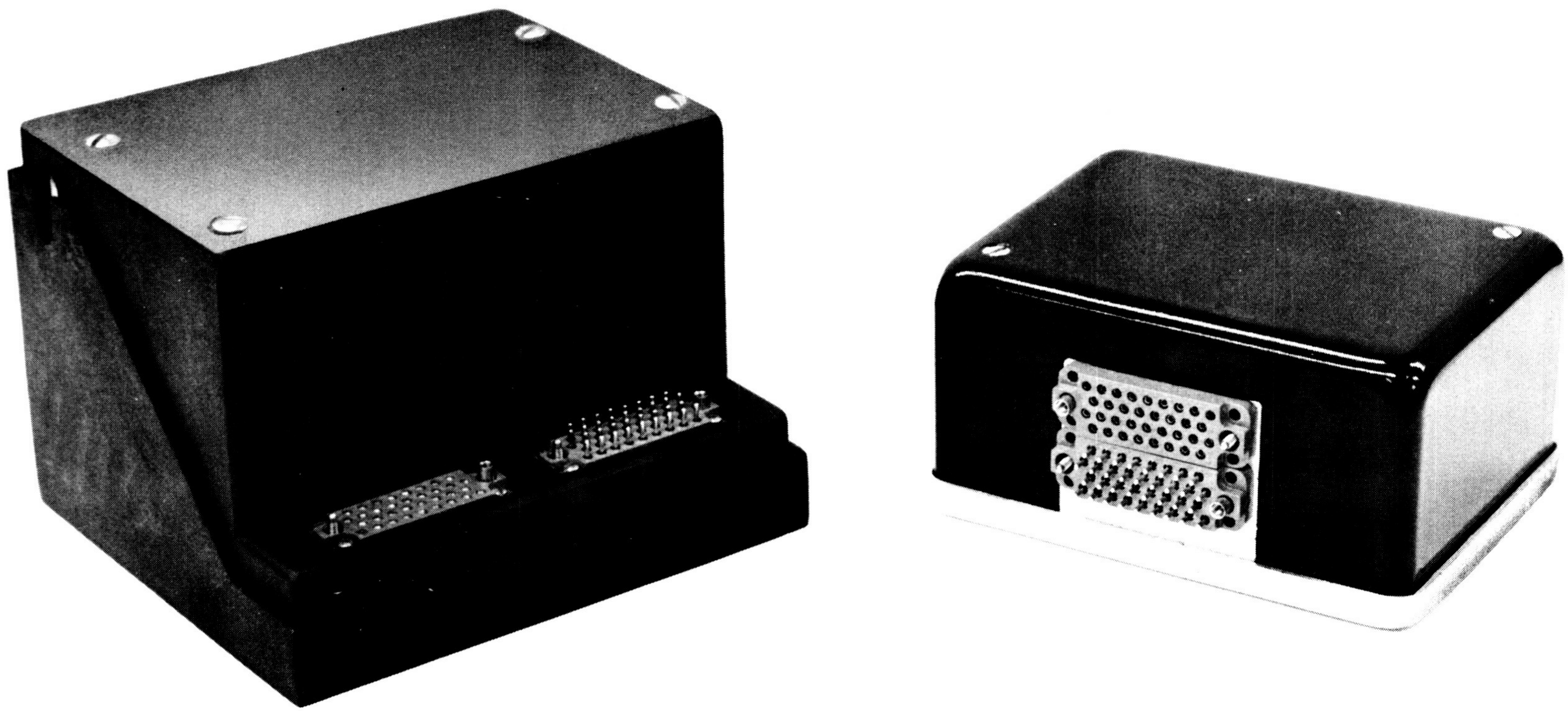


Figure 7 - Lower Deck of Calibrator



COMMERCIAL UNIT 4 X 4 CALIBRATOR

Figure 8 - Comparison of Type 4X4 Calibrator with Commercial Unit

DESCRIPTION

The major physical and electrical characteristics are summarized below. Selected characteristics of the commercial unit are also noted for comparison. Figure 8 provides a visual comparison of the units.

PHYSICAL CHARACTERISTICS	4X4	COMM.	% REDUCTION
Height (inches)	2	3 1/8	36
Volume (cubic inches)	24	50	52
Weight (ounces)	22	44	50

ELECTRICAL CHARACTERISTICS	
Number of Channels	16
Calibration Steps	6
Step Accuracy (%)	0.1
Step Width (range)	20-200 msec
Autocalibrate Cycle	5-60 seconds*
Power Consumption at 26-35 VDC Input	
During Calibration	320 ma
Between Calibrations	220 ma

ENVIRONMENTAL	
Temperature	-20° C to $+70^{\circ}$ C
Vibration (all axes)	
Sinusoidal	24-3,000 cps, 15 G
Random	24-3,000 cps, 20 G
Shock (all axes)	40 G in 11 msec

*Note: Normal adjustment range.

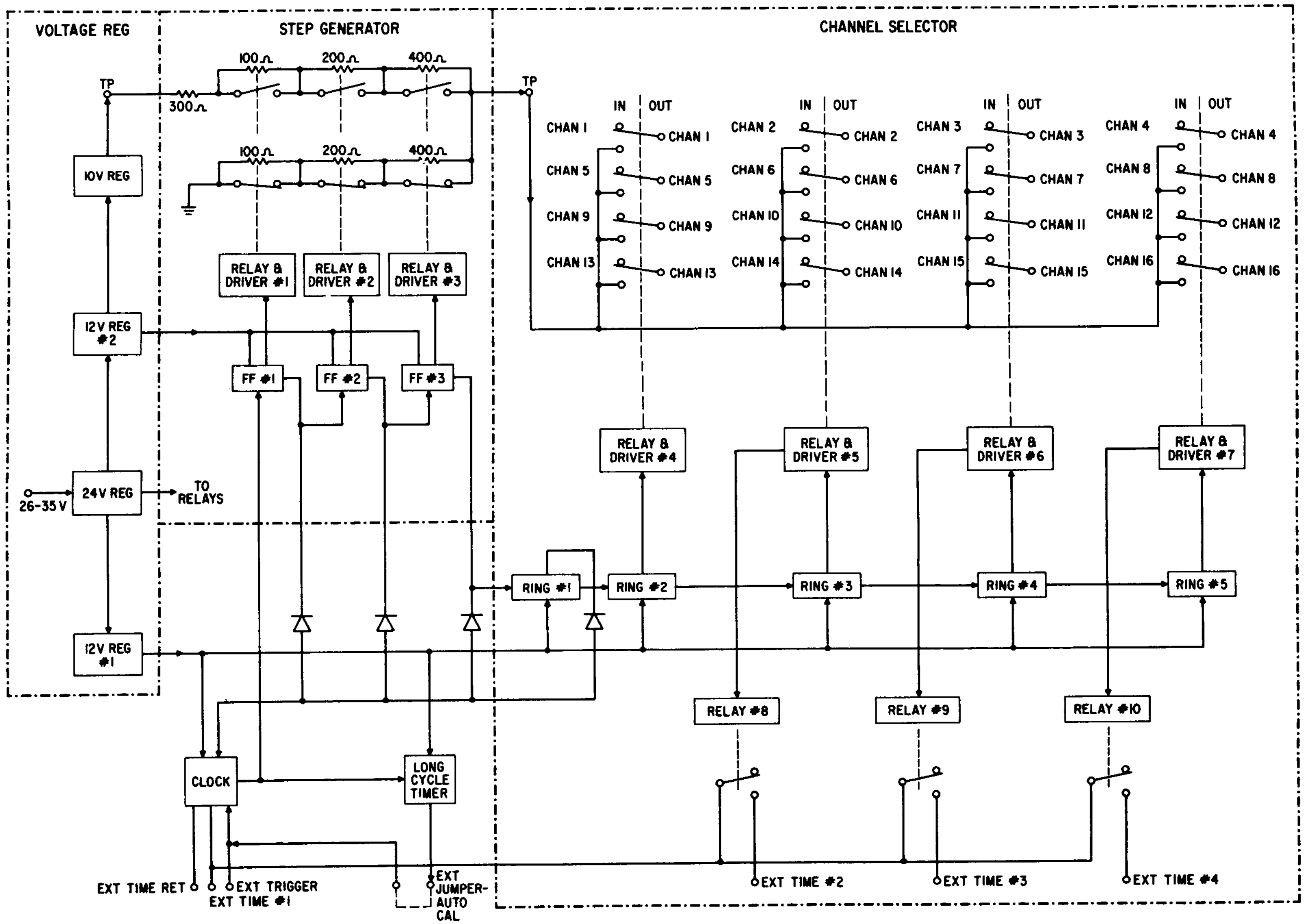


Figure 9 - Block Diagram

OPERATION

As may be seen from the Block Diagram, Figure 9, the calibrator incorporates five functional networks. Voltage regulation; clock; step generator; channel selector; and the long cycle timer. Each of these networks will be described in detail below.

VOLTAGE REGULATION NETWORK

External power for the calibrator is usually taken from a standard battery pack which provides a nominal 28 VDC. The actual levels may range from 35 VDC at system turn-on to 26 VDC in the final moments of a flight. The battery pack, since it is often a common source for both telemetry system and experiment, as well as other instrumentation, is subject to combined transient loads from all these devices. Three-stage regulation is provided by the calibrator voltage regulation network to assure accuracy of the calibration steps and reliable operation of the other circuits.

First level of regulation is at 24 VDC. This level provides power for the relays and is connected to two separate second-stage 12 volt regulators. One 12 volt regulator powers the ring counters which control channel selection, the clock-multivibrator, and the long cycle timer. The second 12 volt regulator powers the flip-flops which control the voltage step generator and the third-stage, 10 volt precision regulator. The final regulation stage incorporates a potentiometer adjustment (See Figure 1) for fine adjustment of the 10 volt level. The 10 volt regulated voltage supplies the voltage divider network of the voltage step generator. Regulation is maintained within $\pm 0.1\%$ throughout the operation temperature range.

CLOCK-MULTIVIBRATOR

The clock-multivibrator controls duration of the individual calibration voltage steps and is designed to provide a normal step width in the range of 20 to 30 milliseconds. This basic setting is suitable for PPM telemetry and for FM/FM systems in the middle and high frequency response channels (IRIG channels 9 through 18.) External connections are provided for addition of capacitors to increase the clock period sufficiently to be compatible with the low frequency response bands. These are arranged to permit the longer step width to be applied to all four calibration cycles, to the second, third or fourth cycle, or to any combination of these.

STEP VOLTAGE GENERATOR

The output of the clock-multivibrator drives three flip-flops, connected to operate as a "count of six" binary counter. The binary counter actuates three double-pole, double throw relays through driver circuits. Actuation of the relays has the effect of transferring the corresponding resistance value from above to below the calibration voltage output. The position shown in the block diagram reflects a binary count of 000 and a calibration voltage of 0. At this point, the current path is through the upper tier of precision resistors and the calibration output is directly connected to ground. When the first relay is actuated, the upper 100 ohm resistor is bypassed and a corresponding 100 ohm in the lower tier is inserted between calibration output and ground, producing the 1 volt step. Impedance of the voltage divider network between the 10 volt regulated output and ground is a constant 1000 ohms for each step of the calibration.

CHANNEL SEQUENCE SELECTOR

The channel sequence selector includes: a five-stage ring counter; four relay driver circuits similar to those used with the step generator relays; and four four-pole, double-throw relays. The ring counter is indexed by the negative-going pulse when the binary counter of the voltage step generator returns to the "000" state following the 5 volt step. The first stage of the ring counter holds in an "off" state through the timer cycle between calibration cycles and during the first sequence of calibration voltages. These are not applied to the data outputs, since the initial clock pulse is not predictable and can be so short that the zero voltage step is undetectable.

Referring to the Block Diagram, Figure 9, as each relay is actuated by the corresponding ring counter stage and driver circuit, incoming signals of the four related data channels are disconnected from the calibrator outputs and the step voltages are inserted. The third, fourth and fifth rings also actuate single-pole, double-throw relays through the driver circuits to close a paralleling circuit from the clock-oscillator to pins on the external connector designated"External Time Control 2, 3, and 4". Capacitors may be connected between these pins and the External Time Control Return pin to effect selective expansion of the calibration step width for application to the low frequency response FM/FM bands as outlined in the description of the clock-multivibrator, above.

LONG CYCLE TIMER

When the fourth sequence of calibration steps is completed, the clock-multivibrator is gated off. Two options are provided for initiating the succeeding calibration cycle. An external signal, generated by a timer, a command receiver, a pressure switch, or some similar device can be applied to initiate the cycle, or a jumper wire connecting the pins designated as "Autocalibrate" will actuate the internal long cycle timer, a unijunction relaxation oscillator. Potentiometer adjustment (see Figure 1) varies the charging rate of a capacitor and controls the time span between calibration cycles. During the calibrate cycle, the capacitor is shorted out by a transistor switch so that the charging time will remain constant regardless of the calibration cycle time.

CONCLUSION

The flight calibrator described above is now operational and available for use with sounding rocket telemetry and instrumentation systems. The new calibrator offers improved operational stability over earlier models in addition to substantial savings in weight, total volume, and power consumption.