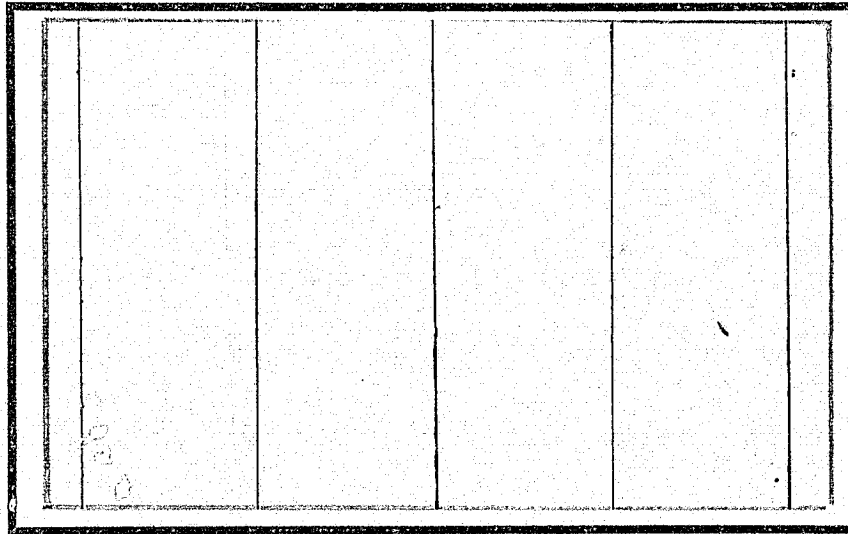


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FOUR-CHANNEL PULSE-TO-PULSE COMMUTATED  
SUPER-LOKI ROCKET METEOROLOGICAL  
PARACHUTESONDE (ELECTRONICS) (Utah Univ.)  
35 p HC \$4.00

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DEPARTMENT OF ELECTRICAL ENGINEERING  
UNIVERSITY OF UTAH  
SALT LAKE CITY, UTAH



UNIVERSITY OF UTAH  
FOUR-CHANNEL PULSE-TO-PULSE COMMUTATED  
SUPER-LOKI ROCKET METEOROLOGICAL  
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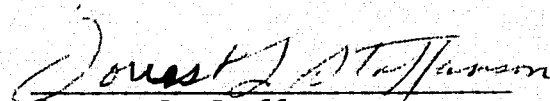
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Contract NAS6-2627

K. W. Atwood and D. A. Soss

for

NASA Wallops Flight Center  
National Aeronautics and Space Administration

March 1976

  
Forrest L. Staffanson  
Principal Investigator

Electrical Engineering Department  
University of Utah

## FOREWORD

The electronics of the original pulse-to-pulse units were designed by Robert M. Garn under Contract NAS6-1908. Subsequent redesign and improvements in construction procedures were made by the authors and by Mark W. Watts, graduate research assistant in the Instrumentation Research Laboratory, for the High Altitude Sensor Research Project under Contract NAS6-2627.

Pulse-to-pulse commutation was motivated by the radiation diversity temperature sensor concept which requires the near-simultaneous monitoring of three thermistors but through conventional meteorological telemetry systems. The availability of the University of Utah precision meteorological data digitizer (University of Utah Engineering College Report UTEC 75-104) enables accurate recording and subsequent automatic decommutating and processing of the data by digital computer.

Real-time digital decommutation is possible, and indeed a unit has been designed by Gus H. Liapis for the purpose of displaying the four signals during flight on a four-channel (analog) pen recorder. Furthermore, an interface has been designed by John P. Fisher which converts the Liapis digital decommutated data into an analog form ("pulse pairs" delayed 0.1 second apart) suitable as input to the Wallops Real-Time Meteorological Data Processing System (RTMDPS). Thus pulse-to-pulse data can be pen-recorded in the conventional way during flight, and digitally processed and recorded in real time,

without modification to the existing RTMDPS, without losing near-simultaneity of the 0.4-second samples.

TABLE OF CONTENTS

	Page
FOREWORD . . . . .	i
LIST OF FIGURES . . . . .	iv
I. INTRODUCTION . . . . .	1
II. CIRCUIT DESCRIPTION . . . . .	3
A. The Battery . . . . .	3
B. The Solid-State Relay . . . . .	3
C. The Electronic Commutator . . . . .	6
D. The Oscillator . . . . .	9
E. The Fail-Safe Circuit . . . . .	11
F. The Transmitter Control Circuit . . . . .	14
G. The Transmitter . . . . .	14
III. SONDE OPERATING PROCEDURES . . . . .	18
APPENDIX . . . . .	19

## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	A typical data pulse train . . . . .	2
2	Block diagram -- Utah Pulse-to-Pulse Rocketsonde . . . . .	4
3	Solid-state relay and battery, Utah Pulse-to-Pulse Rocketsonde . . . . .	5
4	Commutator, Utah Pulse-to-Pulse Rocketsonde . . . . .	7
5	Oscillator, Utah Pulse-to-Pulse Rocketsonde . . . . .	10
6	Fail-safe, Utah Pulse-to-Pulse Rocketsonde . . . . .	12
7	Transmitter control, Utah Pulse-to-Pulse Rocketsonde . . . . .	15
8	Transmitter, Utah Pulse-to-Pulse Rocketsonde. Manufactured by Space Data Corporation . . . . .	17
A.1	DATASONDE Control Unit (P/N 501-100) schematic . . . . .	20
A.2	The Utah Pulse-to-Pulse Rocketsonde configuration (side view) . . . . .	21
A.3	The solid-state relay printed circuit board of the Utah Pulse-to-Pulse Rocketsonde . . . . .	22
A.4	The commutator printed circuit board of the Utah Pulse-to-Pulse Rocketsonde . . . . .	23
A.5	The oscillator printed circuit board (top view) of the Utah Pulse-to-Pulse Rocketsonde . . . . .	24
A.6	The oscillator printed circuit board (bottom view) of the Utah Pulse-to-Pulse Rocketsonde . . . . .	25
A.7	The fail-safe printed circuit board of the Utah Pulse-to-Pulse Rocketsonde . . . . .	26
A.8	The transmitter control printed circuit board of the Utah Pulse-to-Pulse Rocketsonde . . . . .	27
A.9	The circuit boards and transmitter unit . . . . .	28
A.10	The sonde ready for encapsulation . . . . .	29

## I. INTRODUCTION

The Utah "Pulse-to-Pulse" Rocketsonde is an electronic and temperature-sensor package. The model described in this report is designed for the 2-1/8-inch dart of the SUPER-LOKI meteorological rocket. In flight, the sonde descends by parachute from rocket apogees of about 75 kilometers. As the sonde descends, it transmits air temperature data back to ground radio receiving stations. This report describes the electronic design and operation of the sonde.

The sonde is designed to measure and transmit three temperatures almost simultaneously. Actually, the sonde sequentially samples the temperature sensors and a reference. However, since the time interval between samples is quite small (5 ms to 50 ms), all three temperatures are sampled many times each second. The temperature sensors are miniature bead thermistors in the airstream, while the reference is the fixed total resistance of the circuit. The sonde produces a series of voltage pulses with the time period between pulses proportional to the respective resistance being sampled that period. An electronic commutator switches after each pulse, in turn, from one resistive element to the next. Consequently, the output signal from the commutator is a voltage pulse train as shown in Fig. 1. Four time intervals (separated by narrow voltage pulses) are required for each commutator cycle, and the sequence is continually repeated. The shortest time interval in the four-interval cycle is always the reference time period. The time interval between pulses varies from



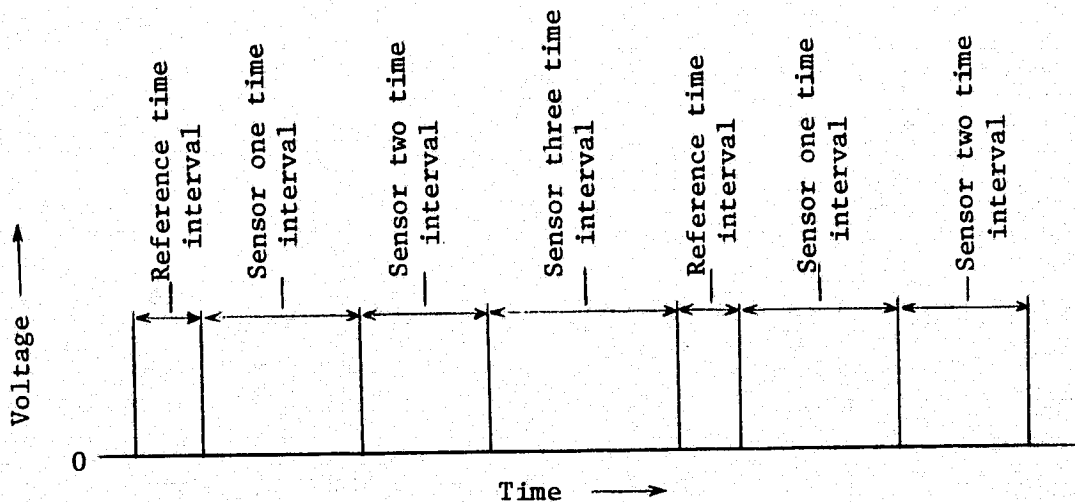


Fig. 1. A typical data pulse train.

about 5 ms to about 50 ms, and the pulse duration is approximately 100  $\mu$ s.

The signal from the commutator is applied to a modulator and transmitter circuit which produces a burst of 403 MHz signal whenever a pulse is present.

The Utah radiosonde is entirely solid state except for a single vacuum tube in the transmitter assembly. CMOS devices are used extensively to minimize power consumption. In fact, the power drawn by the rest of the sonde is negligible compared to the power drawn by the transmitter section of the system.

## II. CIRCUIT DESCRIPTION

A block diagram of the Utah Pulse-to-Pulse Rocketsonde is given in Fig. 2. In order to understand the operation of the system, each block must be considered in more detail.

### A. The Battery

A battery furnishes power to the sonde and is composed of six NiCad cells, type CH500T, connected in series to produce 7.5 volts with 500 milliampere-hour capacity. The current drawn by the sonde varies with the pulse repetition rate, but a fully charged battery will operate the sonde for over one hour.

### B. The Solid-State Relay

The solid-state relay circuit connects or disconnects the battery from the remainder of the sonde circuitry. The circuit of this solid-state relay is shown in Fig. 3. Control signals to activate this solid-state relay are generated in a DATASONDE Control Unit P/N 501-100 and sent through an umbilical cord to the sonde. (The DATASONDE Control Unit requires no modifications to operate the Utah sonde.) A schematic diagram of the P/N 501-100 DATASONDE Control Unit is given in Fig. A.1 of the appendix.

In order to charge the sonde battery, a current of about 50 mA is applied between pins 8 and 5 of the umbilical connector. The battery voltage can also be measured between pins 5 and 8. An external power supply of between 6 V and 8 V may be applied to pins 5 and 3

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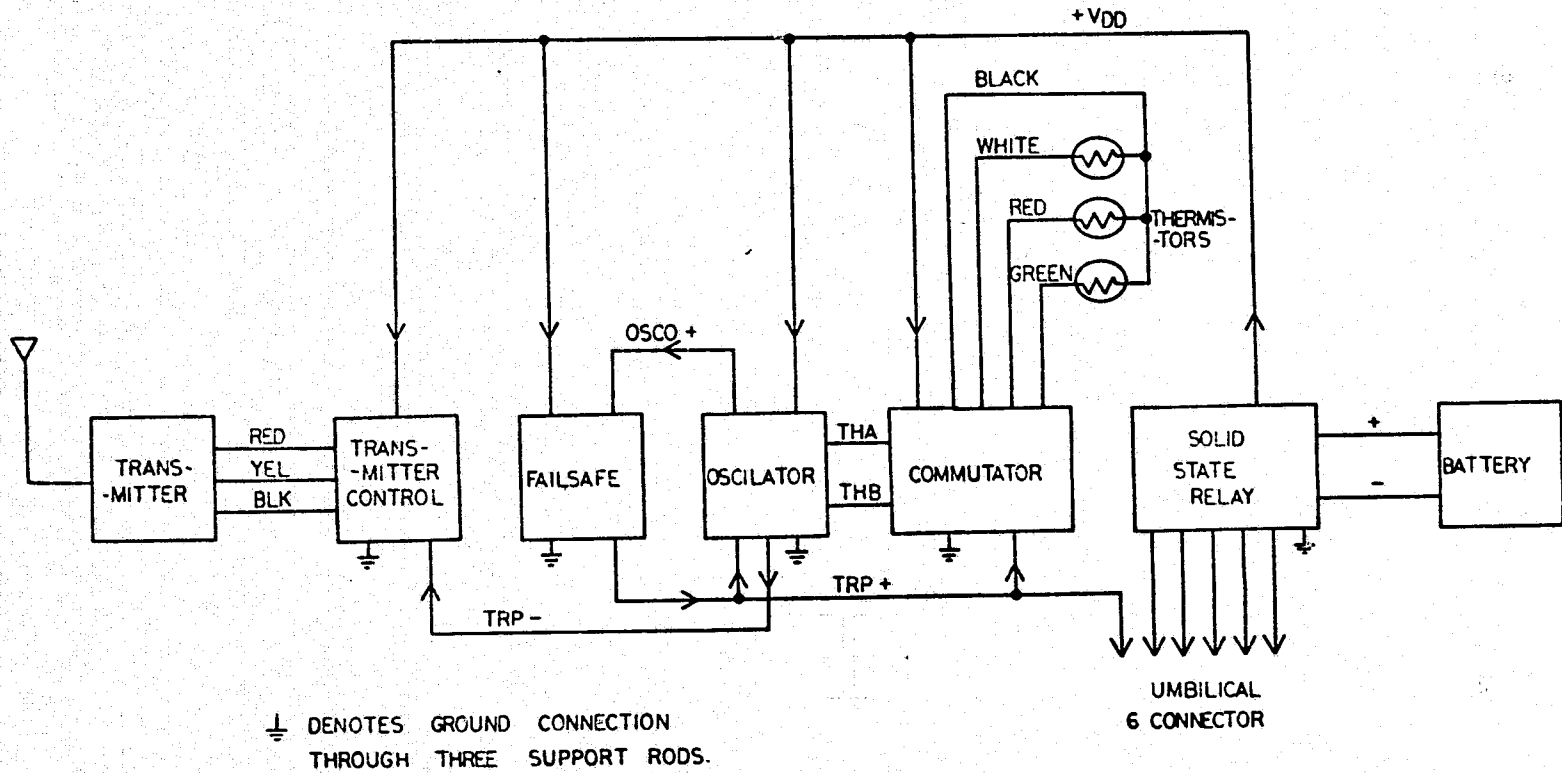


Fig. 2. Block diagram -- Utah Pulse-to-Pulse Rocketsonde.

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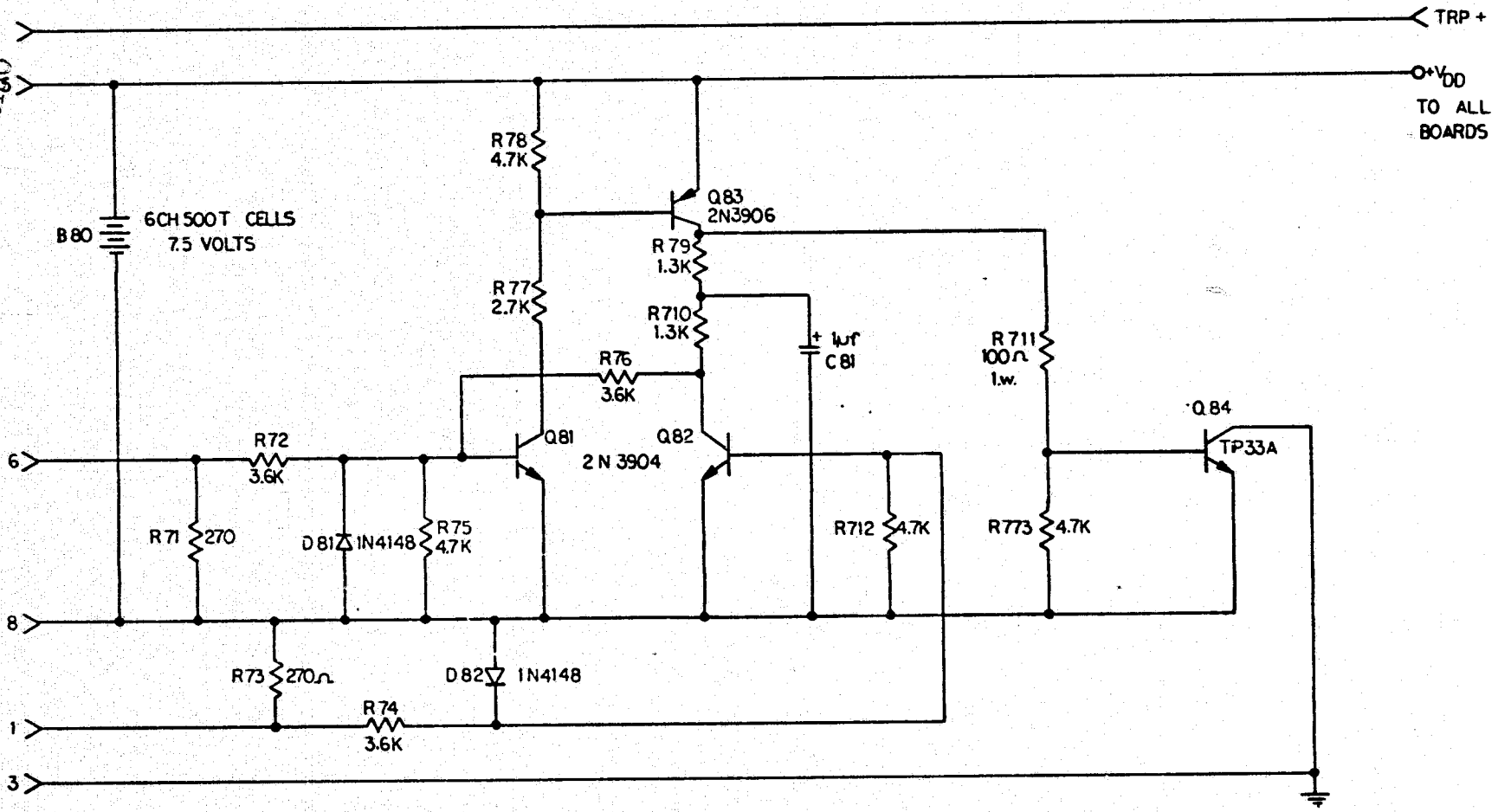


Fig. 3. Solid-state relay and battery, Utah Pulse-to-Pulse Rocketsonde.

(of the umbilical connector) in order to operate the radiosonde independently of its internal battery.

When a positive current pulse is applied to pin 6 (of the umbilical connector), transistor Q81 begins to conduct. Current through Q81 starts Q83 conducting, and current through Q81 latches both Q83 and Q81 in the conducting state. Transistor Q83 also supplies current to the base of Q84 through resistor R711. Transistor Q84 saturates and provides a current path from the ground of the radiosonde to the negative terminal of the battery. Thus Q84 acts as a switch to turn the radiosonde on or off.

A positive current pulse on pin 1 causes Q82 to saturate, which turns Q81 off. When Q81 is turned off, the latch composed of Q83 and Q81 is unlatched. Then Q84 is in the cutoff state and the sonde is turned off.

Only leakage currents are drawn when the solid-state relay is turned off. Capacitor C81 adds noise immunity to the circuit by providing a low impedance path to ground for any narrow noise pulses which may enter the circuit. A signal TRP+ (which will be discussed later) is also available at the umbilical connector for testing purposes.

### C. The Electronic Commutator

The circuit diagram for the electronic commutator circuit is given in Fig. 4. The commutator itself is the CMOS integrated circuit Z41 (type CD4066AF). This integrated circuit (IC) sequentially connects

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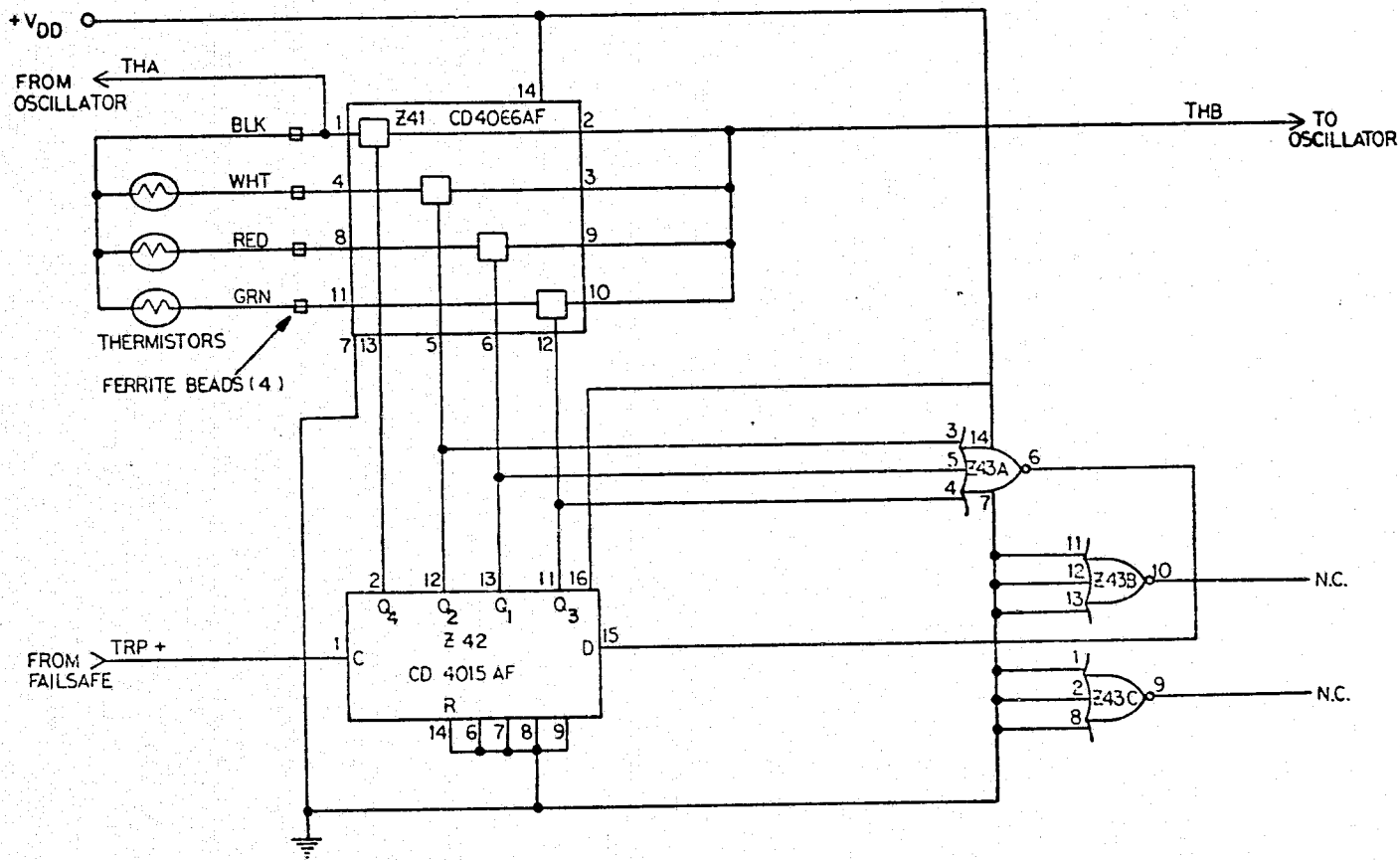


Fig. 4. Commutator, Utah Pulse-to-Pulse Rocketsonde.

a reference resistance (a short circuit in this case) and three thermistors (temperature sensors) into the oscillator circuit. A common lead (THA) is connected to each of the four resistances and the oscillator circuit. Another lead (THB) connects from the IC No. Z41 to the oscillator circuit. When pin 13 of Z41 is high, pins 1 and 2 are effectively shorted together and the reference resistance is connected to the oscillator. Similarly, a high signal on pin 5 connects the white thermistor lead to the oscillator. A high signal on pin 6 connects the red thermistor lead to the oscillator and a high signal on pin 12 connects the green thermistor lead to the oscillator.

The signals to pins 5, 6, 12, and 13 of Z41 are generated by IC No. Z42 (type CD4015AF) which is a shift register. The data enter pin 15 of Z42 from pin 6 of Z43A which is a three-input NOR gate. Note that if  $Q_1$ ,  $Q_2$ , and  $Q_3$  of Z42 are each zero, the signal on pin 15 (Z42) is high. Each time a pulse appears on line TRP+ (or pin 1 of Z42), the Q signals are shifted. Thus the first pulse on TRP+ shifts a high to  $Q_1$ . With  $Q_1$  high, the output of Z43A and pin 15 (Z42) is low. The second pulse on TRP+ shifts the high to  $Q_2$ , and  $Q_1$  becomes low. Pin 15 (Z42) remains low. The third pulse on TRP+ shifts  $Q_3$  high with  $Q_2$ ,  $Q_1$ , and pin 15 low. The fourth pulse on TRP+ shifts  $Q_4$  high with  $Q_3$ ,  $Q_2$ , and  $Q_1$  all low. However, pin 15 will now be high so the sequence will be repeated.

Integrated circuit Z43 contains three NOR gates. Since only one gate is required by this circuit, the input terminals to the other

two gates are returned to ground to disable these gates.

From the foregoing circuit description, the sequence of thermistor activation is:

Reference: red: white: green: reference: red: etc.

#### D. The Oscillator

The oscillator is a precision resistance to time converter. The circuit diagram of this oscillator is given in Fig. 5. This circuit produces a square wave with a period that is dependent upon the resistance between terminals THA and THB which are connected to the commutator circuit. The relationship between resistance in the commutator circuit and square wave period is not linear because a fixed resistance R35 is placed in series with the commutator. Since one of the channels is a reference of zero resistance, the nonlinear effect can be removed when the data are processed in a computer.

The resistors R31, R32, R33, and R34 form a voltage divider that sets the thresholds of comparators Z31 and Z32 at  $V_{DD}/2$  and  $V_{DD}/4$  volts, respectively. The output of comparators Z31 (pin 6) will be high (greater than 4 V) whenever the voltage at terminal THB is greater than  $V_{DD}/2$ . Similarly, the output of comparator Z32 (pin 6) will be high (greater than 4 V) whenever the voltage at terminal THB is less than  $V_{DD}/4$ . The outputs of comparators Z31 and Z32 alternately set and reset the bistable multivibrator made up of NOR gates Z33B and Z33C. Thus the comparators and the bistable multivibrator together form a precision Schmidt trigger circuit. Integrated circuit



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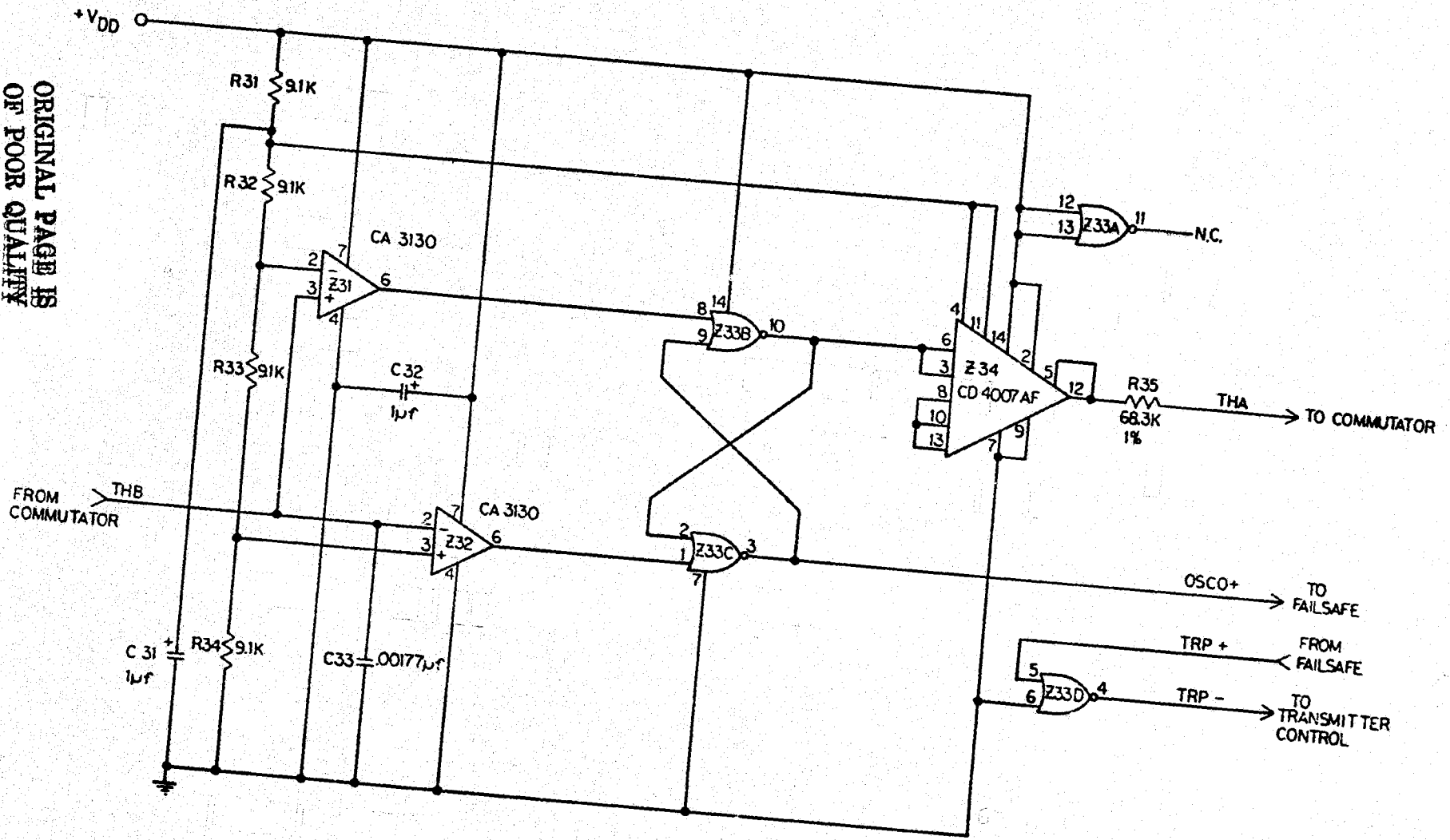


Fig. 5. Oscillator, Utah Pulse-to-Pulse Rocketsonde.

Z34 is connected as an analog switch. When the input of Z34 (pins 6 and 3) is high, the amplifier is saturated and the output voltage (pins 5 and 12) rises to the value of the drain supply voltage on pins 4 and 11. The resistors R31, R32, R33, and R34 set this drain supply voltage at  $3 V_{DD}/4$ . When the input of Z34 is low, the output is connected essentially to ground. Thus, the output of Z34 alternately charges and discharges capacitor C33 through resistor R35, the commutator, and the selected sensor. Thus, an astable multivibrator is formed that has a period proportional to the value of the capacitor C33 and the sum of resistor R35, a fixed unknown resistance (in the commutator, operational amplifier, and comparator of about 250 ohms), and the sensor.

The NOR gate Z33D is used as an inverting buffer for the transmit pulse TRP+. The NOR gate 233A is not used.

#### E. The Fail-Safe Circuit

The fail-safe circuit has three functions. First, it divides the output of the oscillator by 32 to determine when to transmit a pulse. Second, it causes pulses to be transmitted in the event of the failure of the oscillator or a sensor. Finally, it controls the width of the transmitted pulses. The diagram of this circuit is given in Fig. 6.

The oscillator produces a square wave with a frequency between 500 Hz and 6400 Hz. This signal is denoted as OSCO+ and is applied to pin 1 of Z21. The Z21 (type CD4024AT) is used as a divide by 32

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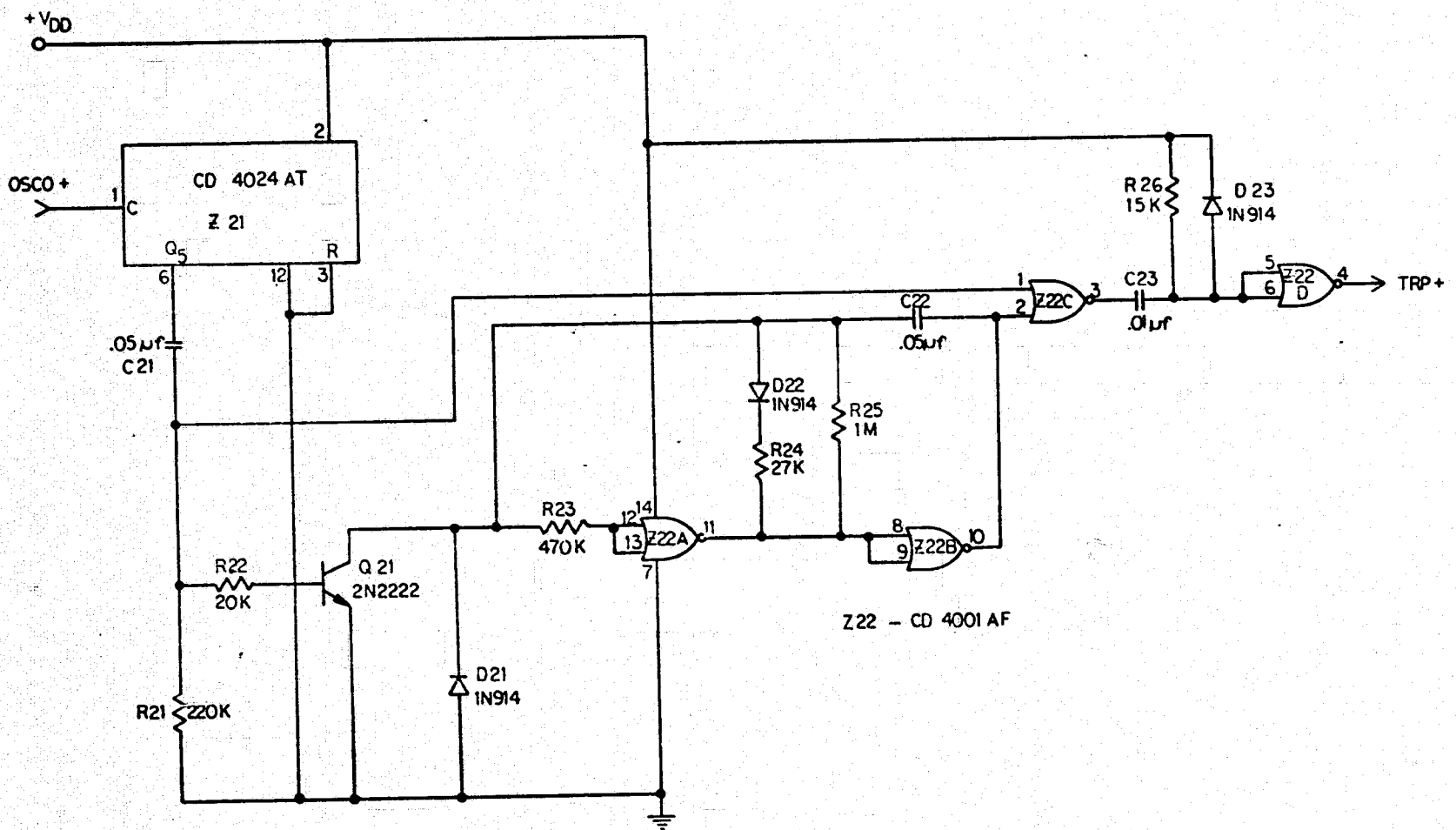


Fig. 6. Fail-safe, Utah Pulse-to-Pulse Rocketsonde.

counter. Therefore the output signal on pin 6 is a square wave with a frequency between 16 Hz and 200 Hz. By using 32 cycles from the oscillator to produce one output pulse from the sonde, slight variations from cycle to cycle should average out.

The output signal from the counter passes through C21. The combination of C21 and its resistive load produces pulses with approximately one millisecond duration. These pulses appear at pin 1 of NOR gate Z22C. When the input, pin 1, of Z22C goes high, a 100  $\mu$ s positive-going pulse, TRP+, is generated by the circuit consisting of Z22C, Z22D, R26, C23, and D23. The width of the pulse is determined by R26 and C23. Diode D23 provides the discharge path for C23. The same pulse that generates the TRP+ pulse is connected through R22 to the base of Q21. Transistor Q21 resets the fail-safe oscillator made up of Z22A, Z22B, R23, D22, R24, R25, and C22. The output of this oscillator (pin 10 of Z22B) remains low when the oscillator is reset. If this oscillator is not reset more often than once every 60 ms, a one-ms pulse will be produced. The fail-safe oscillator will continue to produce a one-ms pulse every 60 milliseconds until transistor Q21 resets the oscillator.

Thus, if a sensor is broken, the fail-safe circuit will generate a pulse on TRP+ to step the commutator onto the next sensor. However, the period between pulses will be longer than the time interval of a normal sensor so the broken sensor can be noted. Of course, if the oscillator should cease to operate, the fail-safe oscillator will take over, but the period between pulses will be much longer than that

of a normally operating sonde. The only data received in this case indicate that the oscillator is not operating.

#### F. The Transmitter Control Circuit

The transmitter control circuit amplifies the low-power signal TRP- from the CMOS gates on the oscillator board to a power level sufficient to drive the transmitter section. The circuit of the transmitter control is shown in Fig. 7.

The low-power TRP- signal is applied to the base of Q11 which acts as a common-emitter amplifier. Normally the TRP- signal is high and Q11 is cut off. When a negative pulse is applied to TRP-, transistor Q11 is saturated and a positive pulse appears across R12. This positive pulse is applied to the base of Q12 which is normally cut off. Transistor Q12 acts as an emitter-follower and the positive pulse on the base produces a positive pulse on the emitter of Q12. This positive pulse is then used to drive the transmitter circuit.

The resistor R13 limits the drive current to the transmitter to a value of about 600 mA. During the positive signal pulse, charge is removed from C11 by the base of Q12. During the period between pulses, C11 is recharged through R14.

The capacitor C12 is placed on the transmitter control board to supply part of the large current pulse which the transmitter requires when it is transmitting a pulse.

#### G. The Transmitter

The transmitter assembly is manufactured by Space Data Corporation.

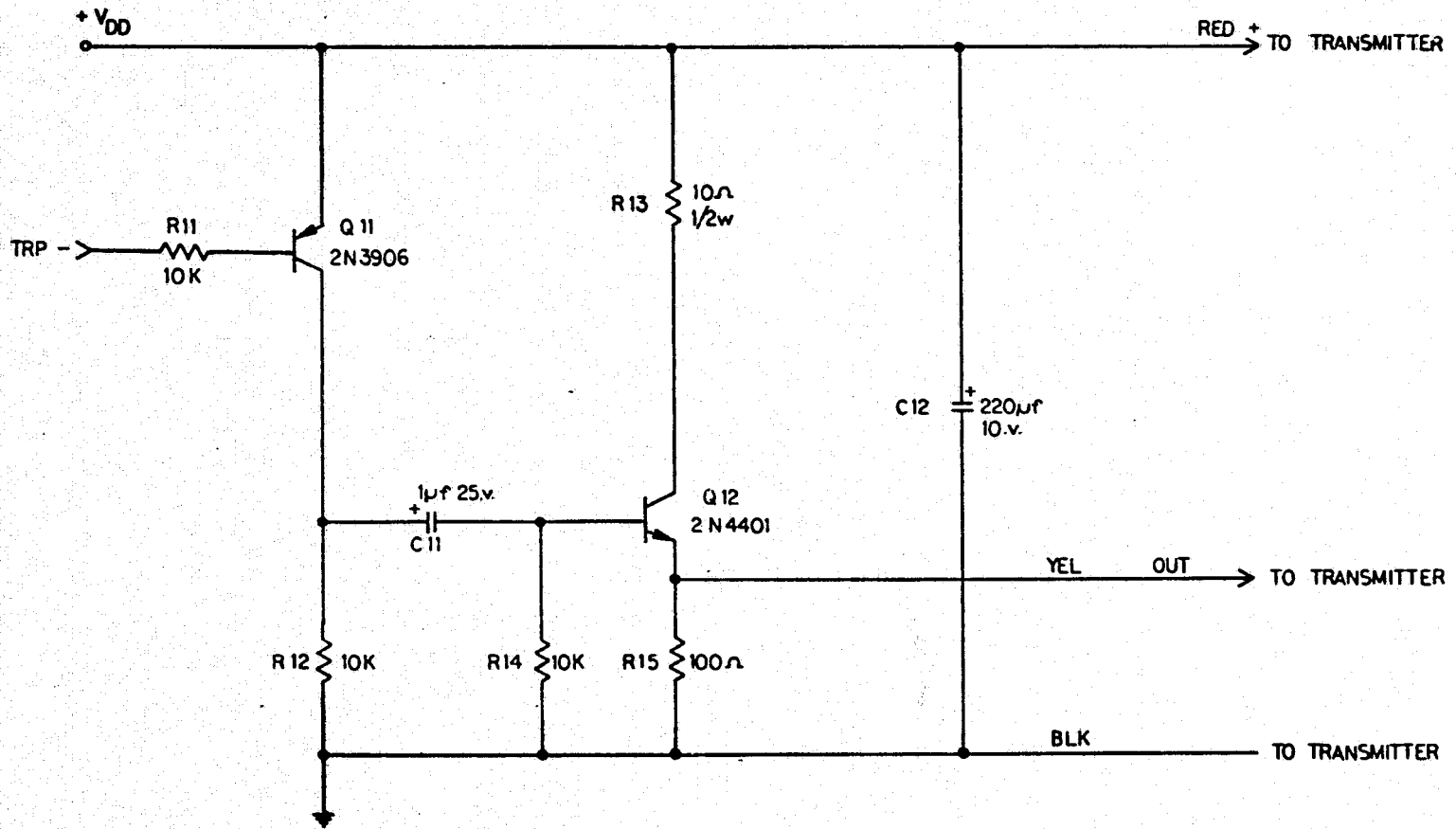


Fig. 7. Transmitter control, Utah Pulse-to-Pulse Rocketsonde.

It is used in other sondes and is purchased as an assembled unit.

The circuit diagram of this unit is shown in Fig. 8.

The power supply is connected between the red and black leads. When a positive pulse (from the transmitter control) is applied to the yellow lead (the base of Q7), transistor Q7 is saturated. Current begins to flow through the winding of transformer T1. This current is limited by the inductive effect of the winding according to the relation:

$$V = L \frac{di}{dt} \quad (1)$$

Since V is constant and L is essentially constant,  $di/dt$  is a constant. The constant change of current in winding 1-2 produces a constant change of magnetic flux lines in the transformer. The constant change of flux lines in turn produces a high constant voltage in winding 3-4. Thus, a positive dc signal is applied to the plate of the vacuum tube, V1, for the duration of the pulse on the base of transistor Q7.

The vacuum tube, V1, is connected as an oscillator and produces a burst of 403 MHz RF as long as the pulse TRP- is present.

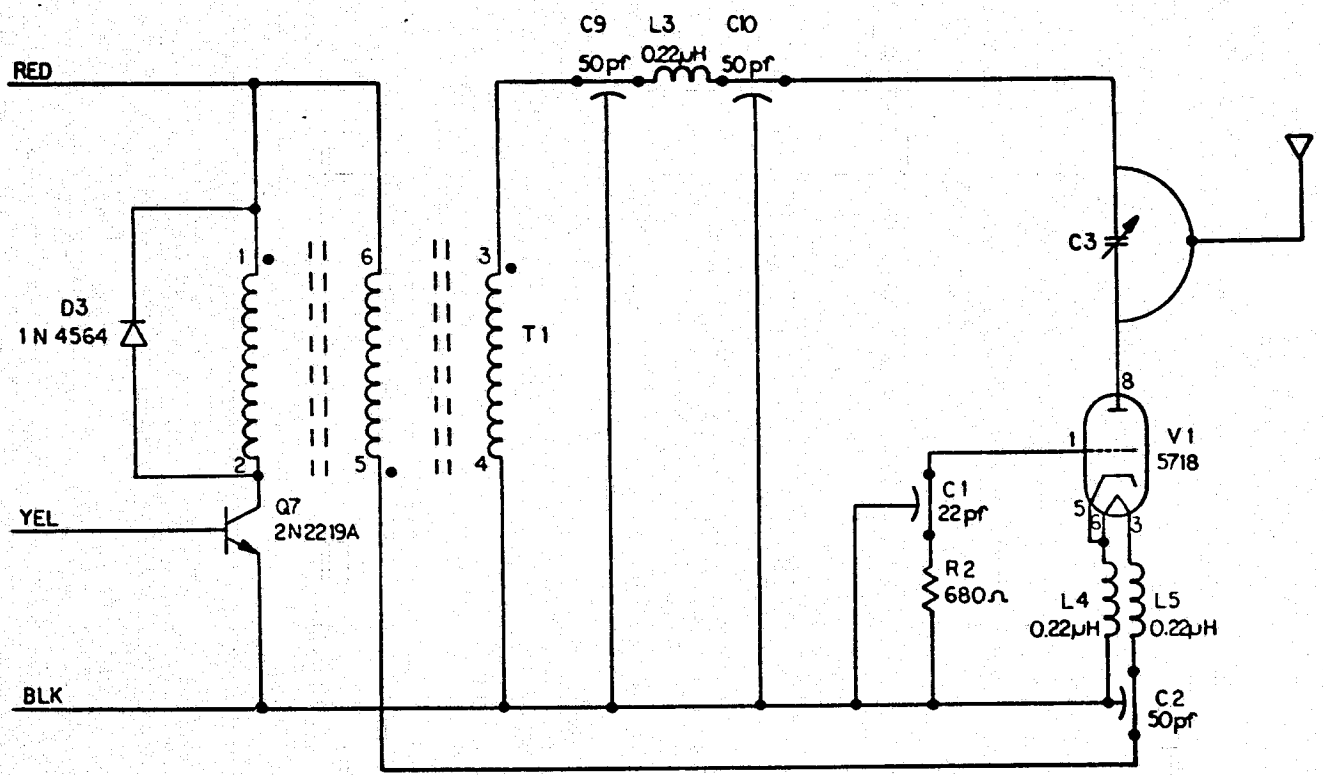


Fig. 8. Transmitter, Utah Pulse-to-Pulse Rocketsonde. Manufactured by Space Data Corporation.



### III. SONDE OPERATING PROCEDURES

The Utah Pulse-to-Pulse Rocketsonde is designed to be compatible with the Space Data Corporation DATASONDE Control Unit and with the procedure outlined in its manual. The only deviation from this manual occurs in charging the sonde battery. In charging these batteries, the following procedure should be observed:

- A. Charge the batteries using the lowest current setting possible (about 60 mA).
- B. Charge fully discharged batteries for twelve to fourteen hours. If the batteries are not fully discharged, charge approximately one hour for each ten minutes of sonde operation.
- C. Discontinue charging if the lower portion of the sonde becomes warm.
- D. Fully charged batteries will measure 8.0 V to 8.5 V. The nominal battery voltage is 7.5 volts.
- E. Do not discharge the batteries below 6.5 V.

## APPENDIX

The circuit diagram for the DATASONDE Control Unit P/N 501-100 is given in Fig. A.1.

Figure A.2 shows the configuration of the Utah sonde when viewed from the side. The various printed circuit boards are labeled for easy identification. Figures A.3 through A.8 show the circuit component layouts for five of the printed circuit boards used in the sonde. A photograph of the printed circuit boards and transmitter unit is given in Fig. A.9. The total assembled sonde (before encapsulation) is shown in Fig. A.10.

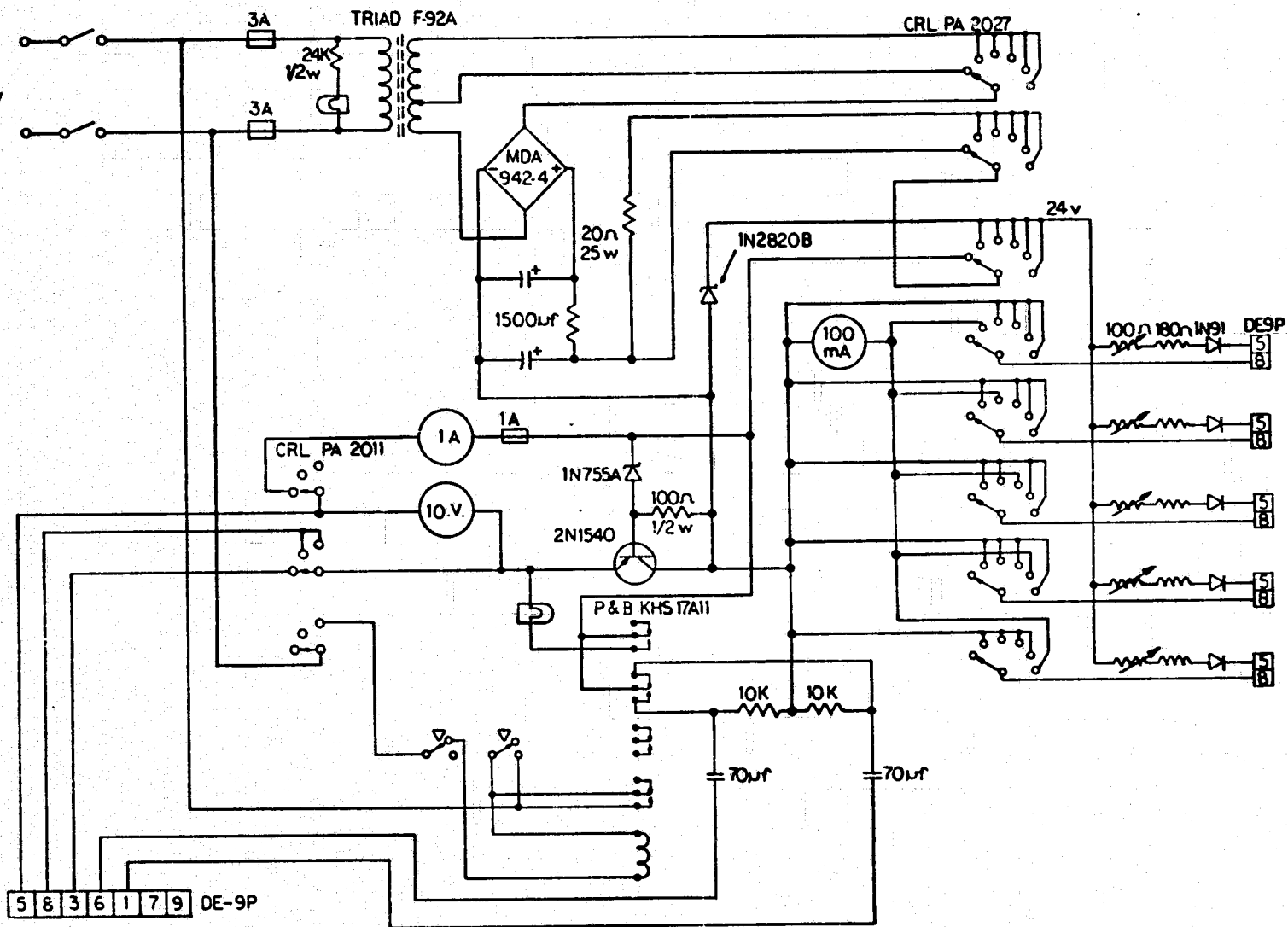


Fig. A.1. DATASONDE Control Unit (P/N 501-100) schematic.

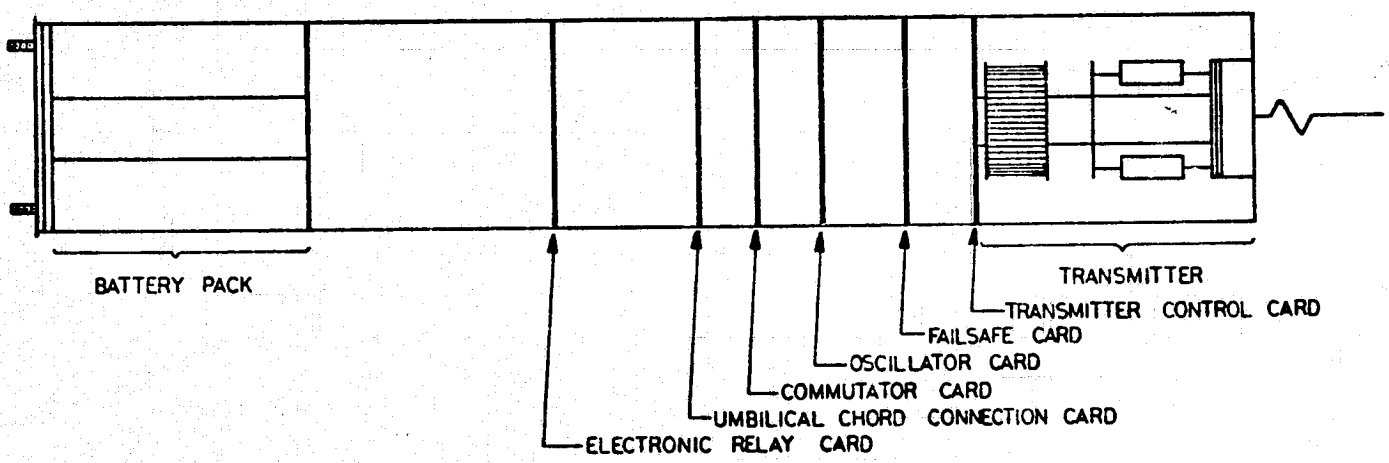


Fig. A.2. The Utah Pulse-to-Pulse Rocketsonde configuration (side view).

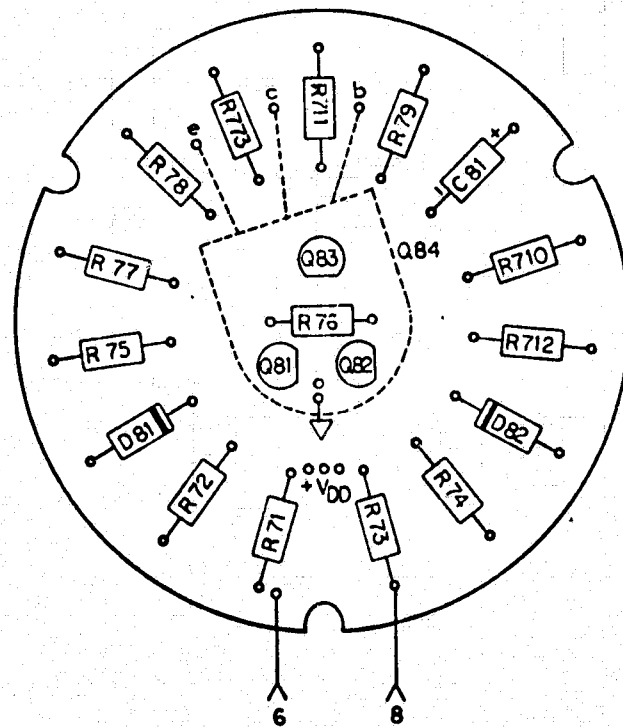


Fig. A.3. The solid-state relay printed circuit board of the Utah Pulse-to-Pulse Rocketsonde.

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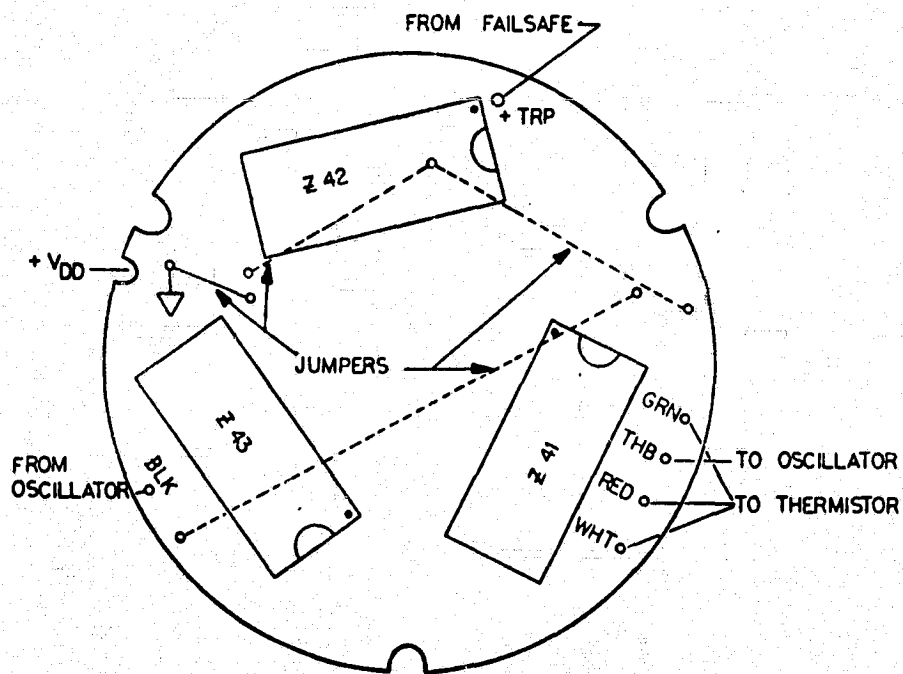


Fig. A.4. The commutator printed circuit board of the Utah Pulse-to-Pulse Rocketsonde.

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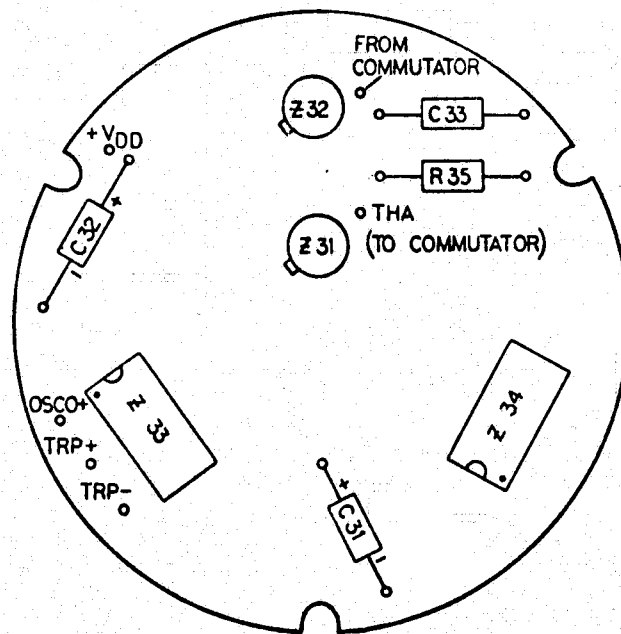


Fig. A.5. The oscillator printed circuit board (top view) of the Utah Pulse-to-Pulse Rocketsonde.

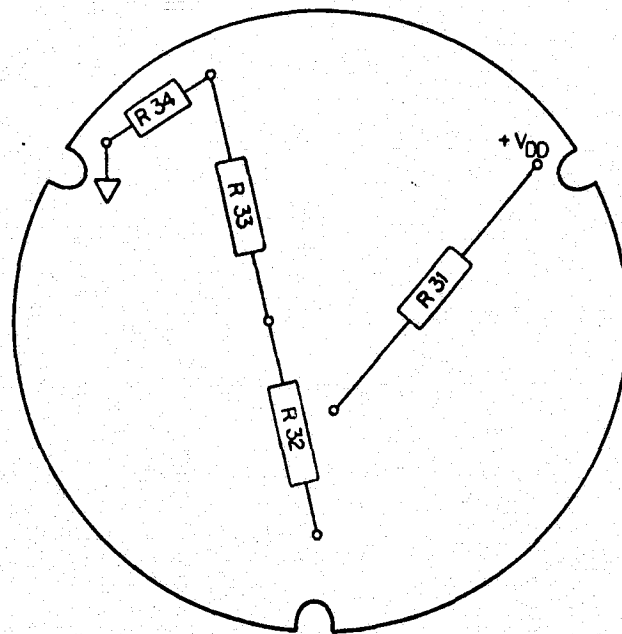


Fig. A.6. The oscillator printed circuit board (bottom view) of the Utah Pulse-to-Pulse Rocketsonde.



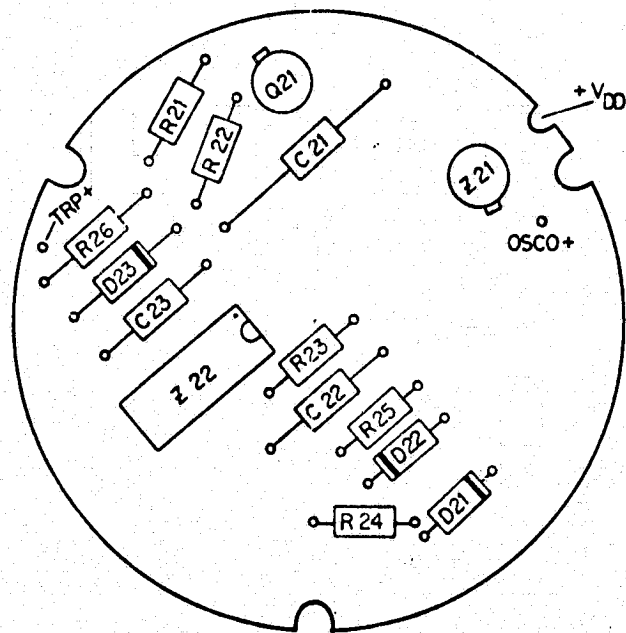


Fig. A.7. The fail-safe printed circuit board of the Utah Pulse-to-Pulse Rocketsonde.

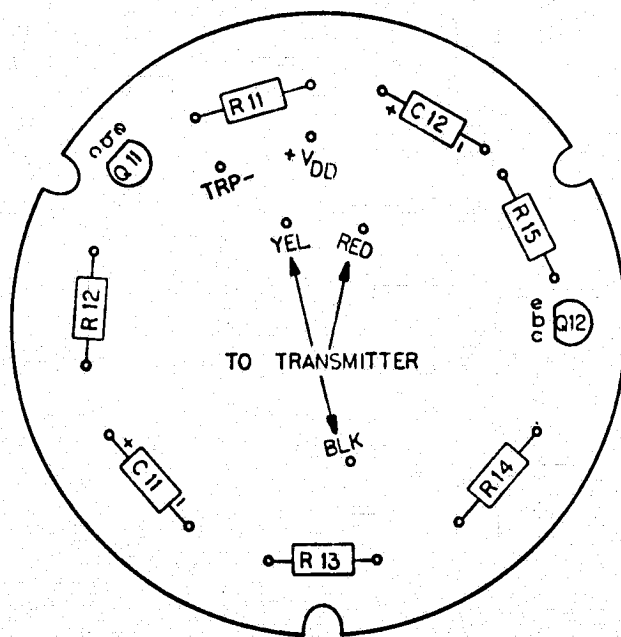


Fig. A.8. The transmitter control printed circuit board of the Utah Pulse-to-Pulse Rocketsonde.

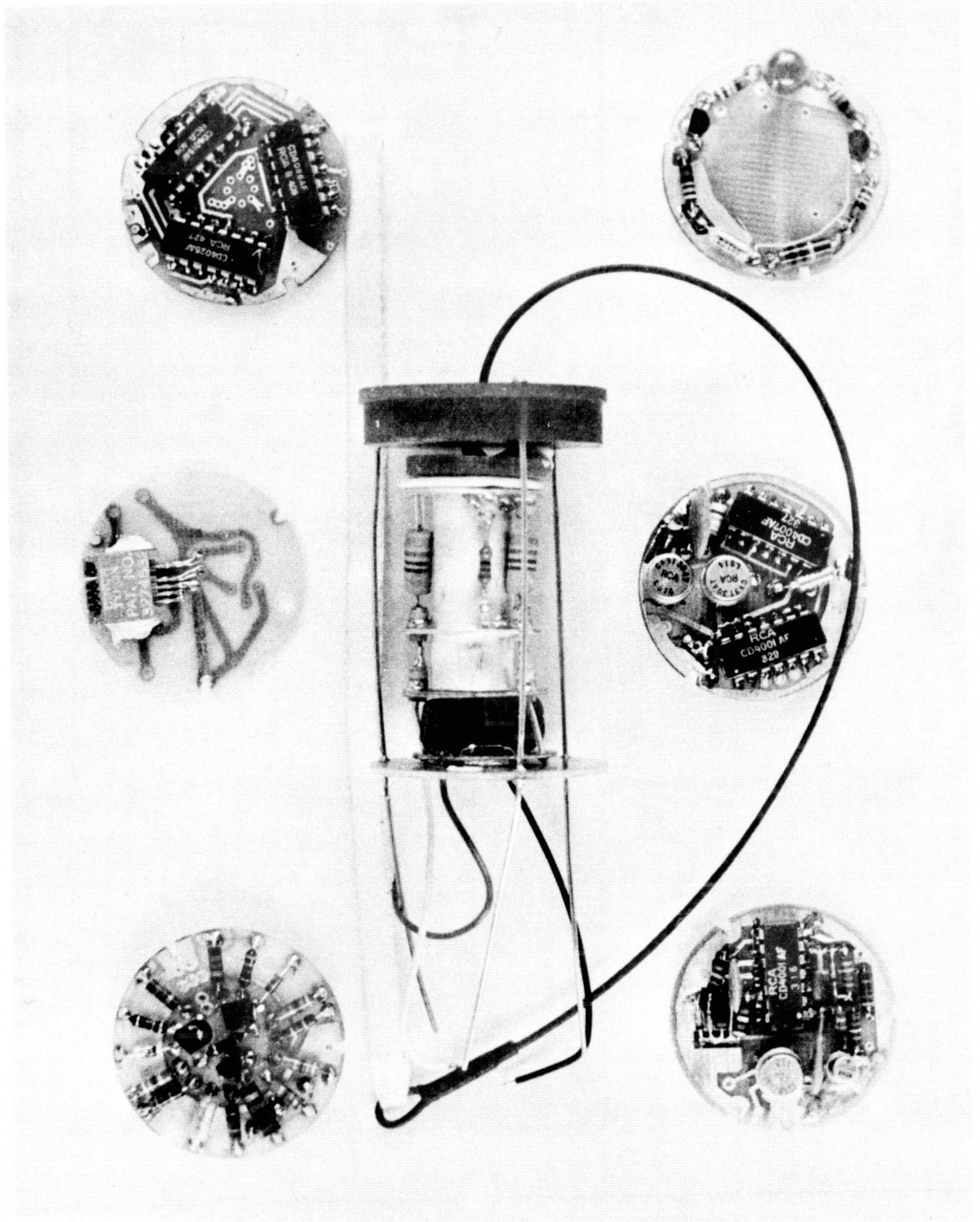


Fig. A.9. The circuit boards and transmitter unit.

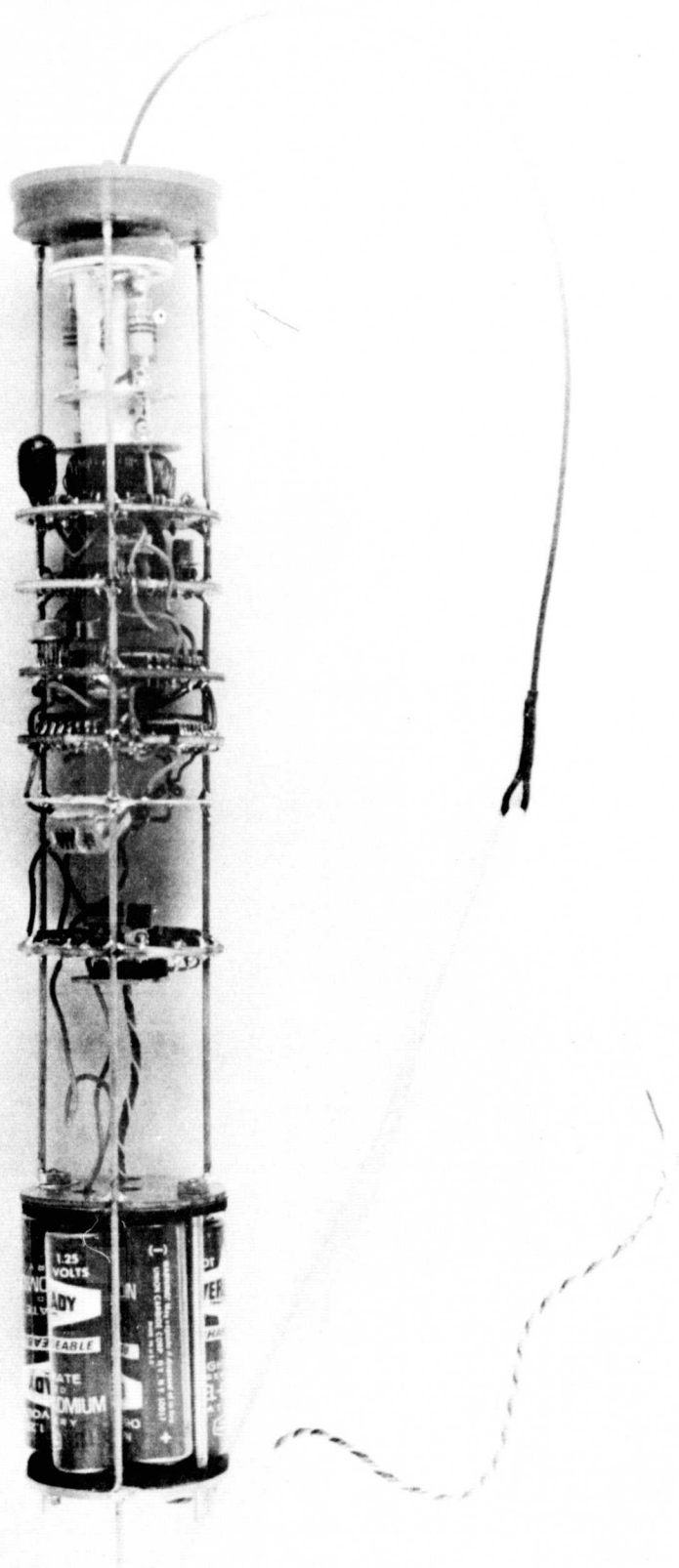


Fig. A.10. The sonde ready for encapsulation.

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