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PAPER 5.3

AIROSCOPE COMMAND SYSTEM

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ABSTRACT

A PCM telemetry command system is presented having a capacity of 256 unique commands, an end-to-end actuation time of less than 250 milliseconds, and an address plus complementary command code to provide security against the acceptance of anything but intended commands. The system consists of a ground-based ENCODER and a balloon-borne DECODER, both built using low-current drain, high reliability CMOS logic elements. Commands are normally issued by a simple switch closure to +5VDC on the appropriate input line, however as a backup mode, the 8-bit command may be entered manually on 8 toggle switches and executed via a SEND button. In any case, the command is then serialized into a BiØ-L PCM bit stream and sent via a P-Band radio link to the DECODER aloft. All 256 outputs from the DECODER are buffered through drivers and thus may be used to drive CMOS, TTL, or DTL logic.

INTRODUCTION

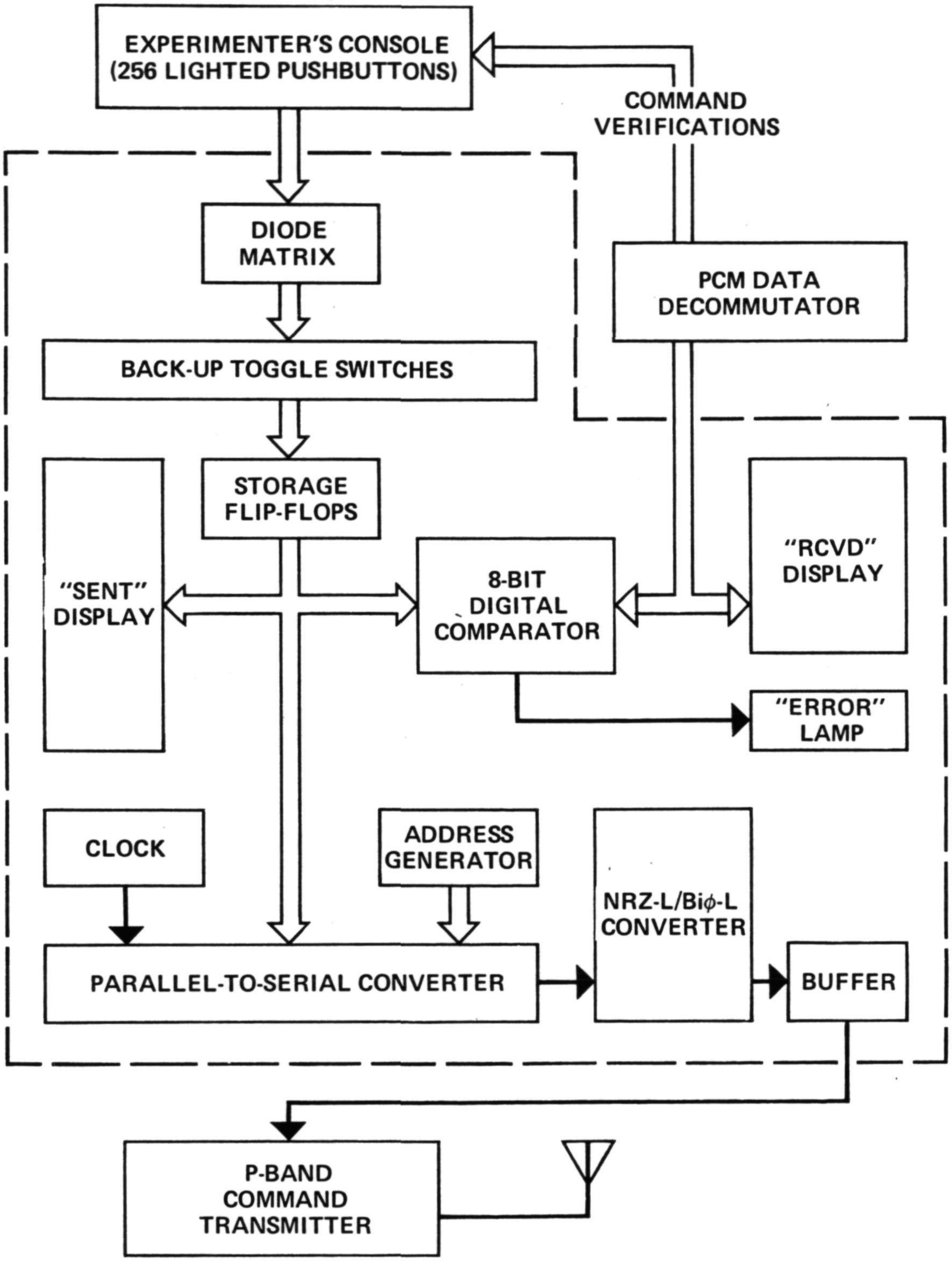
At the inception of the AIROscope redesign effort an attempt was made, primarily through the National Center for Atmospheric Research (NCAR), to determine what command subsystems had been used in the past on balloon systems. It was found that, in general, the systems in use suffered from excessive operational complexity, restricted capability in terms of the total number of discrete commands which could be delivered, and they were not sufficiently generalized to permit the flexibility required by a constantly changing mission science program.

Consequently, it was determined that a Command Encoder-Decoder system would be built in-house using the latest mil-spec temperature range, low current CMOS logic elements. The 256 commands provided by a system based on an 8-bit command word were considered more than adequate for all currently planned AIROscope missions and sufficient to permit a reasonable degree of expansion on foreseeable future missions. Beyond that, two or more such systems operated in parallel could clearly provide nearly unlimited expansion capability, if desired. The parts cost for this system was less than $2500 and the required delivery schedule for all hardware was met.

ENCODER DESCRIPTION

The various functions performed by the Command Encoder may be understood by referring to the Functional Diagram in Figure 1. In addition, a detailed Schematic Diagram is provided in Figure 2 for the convenience of the reader who would actually like to construct a similar system for his own use.

Referring to the functional diagram, the first function within the dashed outline enclosing the Command Encoder itself is the Diode Matrix.



$\overline{C}_1 C_1 \overline{C}_2 C_2 \overline{C}_3 C_3 \overline{C}_4 C_4 \overline{C}_5 C_5 \overline{C}_6 C_6 \overline{C}_7 C_7 \overline{C}_8 C_8 A_1 A_2 A_3 A_4 A_5 A_6 A_7 A_8$

Figure 1. Command Encoder Functional Diagram

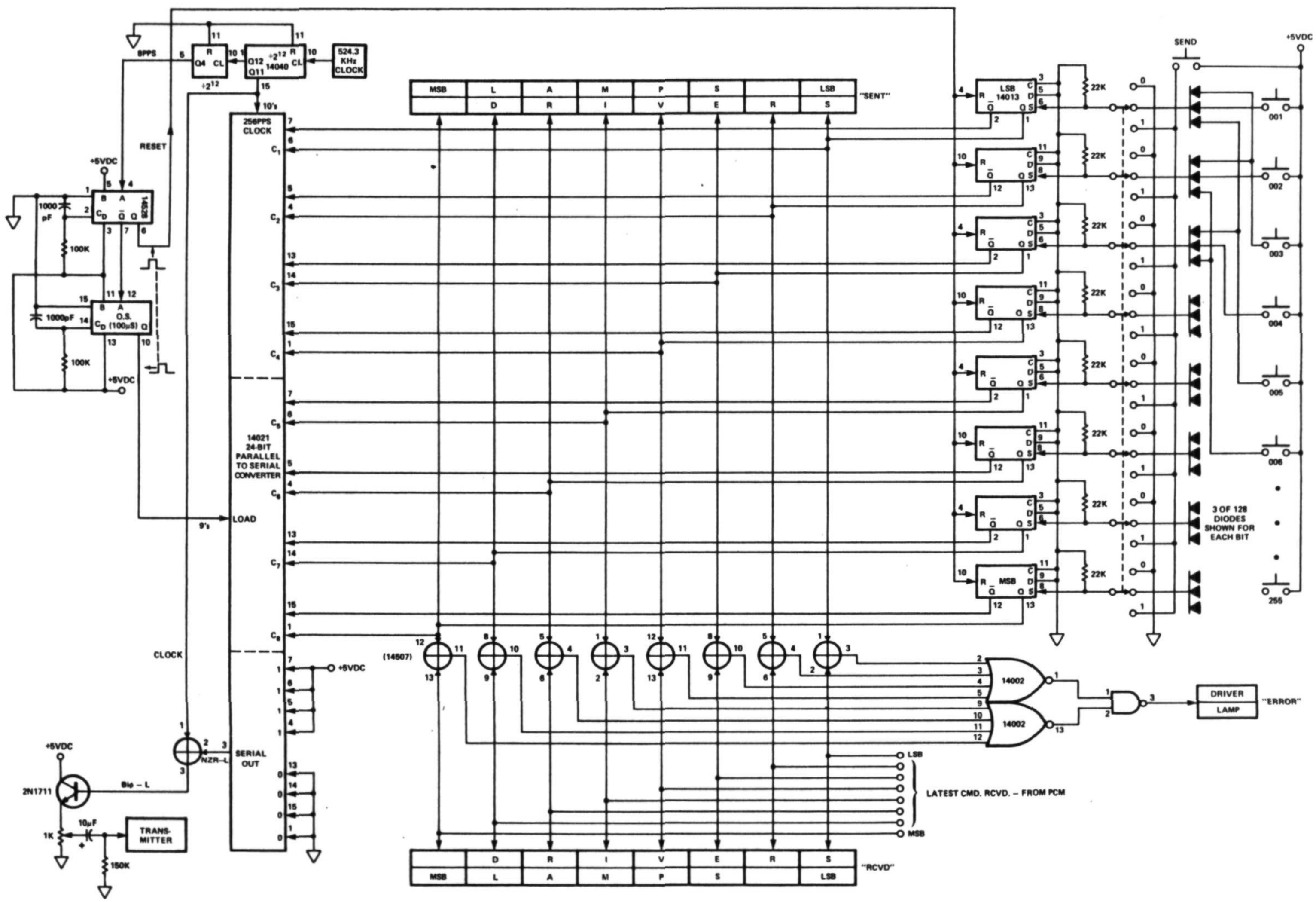


Figure 2. Command Encoder Schematic Diagram

This is an array of 1024 discrete diodes arranged in such a fashion that the actuation of a single (one of a possible 256) normally open switch is encoded into the appropriate "ones" and "zeroes" which make up the 8-bit command. The Backup Toggle Switches permit the operator to bypass the Experimenter's Console and the Diode Matrix and to generate a command directly by switching in the desired 8 command bits and by pressing the SEND button. Regardless of how these 8 bits are generated, they are then entered into the Storage Flip-Flops, the outputs of which are routed to the SENT Display, to the Digital Comparator for comparison with the latest command received by the gondola (RCVD), and to the Parallel-to-Serial Converter. The 8 command bits, along with their complements and an 8-bit recognition address word are simultaneously loaded into the Parallel-to-Serial Converter and clocked out at a rate of 256 bits per second. Every 1/8 second the Clock also updates the Storage Flip-Flops and loads the Parallel-to-Serial Converter. The now serialized NRZ-L bit stream is converted into a BiØ-L PCM code to improve the reliability of transmission and to permit direct tape recording. Finally it goes through a buffer stage where it is made compatible with the input of the Command Transmitter. This up-link UHF transmitter operates in the P-band and develops 10 watts of r.f. power.

Two different levels of command verification are provided by the AIROscope system. One results from the comparison of the SENT command with the RCVD command in the Command Encoder itself where any disagreement between the two results in the lighting of the ERROR lamp. A second type of command verification is provided for the AIROscope via the PCM Data Subsystem wherein up to 110 discrete "on-off" digital data channels may be employed to monitor the status of various commandable subsystems on the gondola. These status indications are used to light the appropriate pushbuttons on the Experimenter's Console to immediately feed back to the operator the information that the command sent was properly received and that the system to which the command was issued did, in fact, respond.

It is important to note that the Encoder is continually encoding <u>some</u> command, i.e., when no command button is being pressed, the command 000 is sent. This command is processed like any other command on the gondola and its output may be used as a "reset" or a "ready" indication. Even more important is the fact that such an arrangement permits one to check at any time on the continuity of <u>all</u> major links in both the Command Subsystem and the PCM Data Subsystem by simply observing the status of the ERROR lamp.

DECODER DESCRIPTION

The functions performed by the Command Decoder are depicted in Figures 3 and 4. On the gondola the P-Band signal is received by the Command Receiver, buffered to re-create a signal with 0 and 5 volt levels, and reconverted from BiØ-L to NRZ-L plus a clock line. The NRZ-L bit stream is then clocked into the Serial-to-Parallel Converter, the contents of which are constantly being examined by the Valid Command Recognition circuitry. This circuitry verifies that each command bit is immediately preceded by its complement and that these 16 bits are followed by the correct 8-bit recognition address code. If, and only if, all these criteria are met, a "Load" pulse is generated which loads this 8-bit command into a set of 8

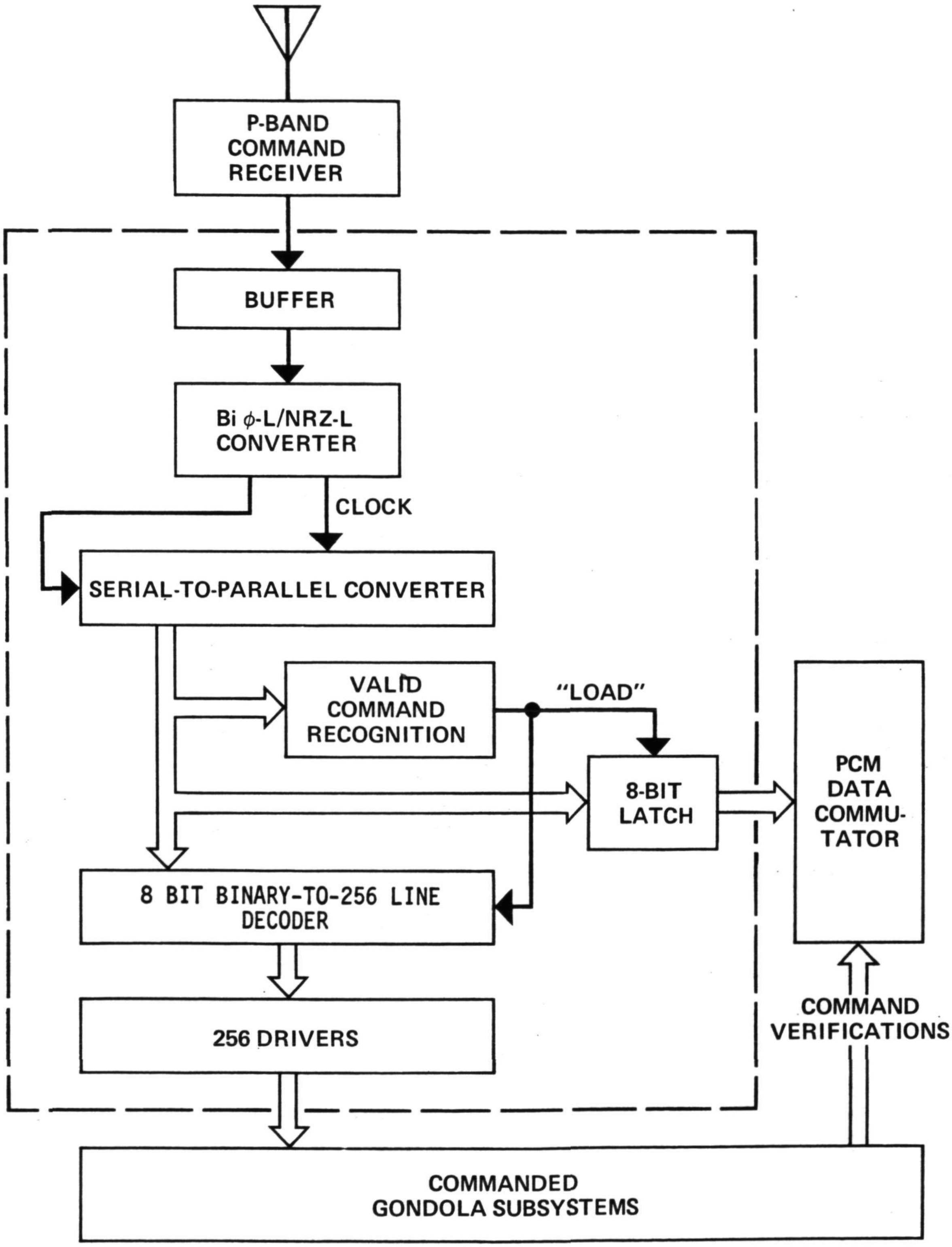


Figure 3. Command Decoder Functional Diagram

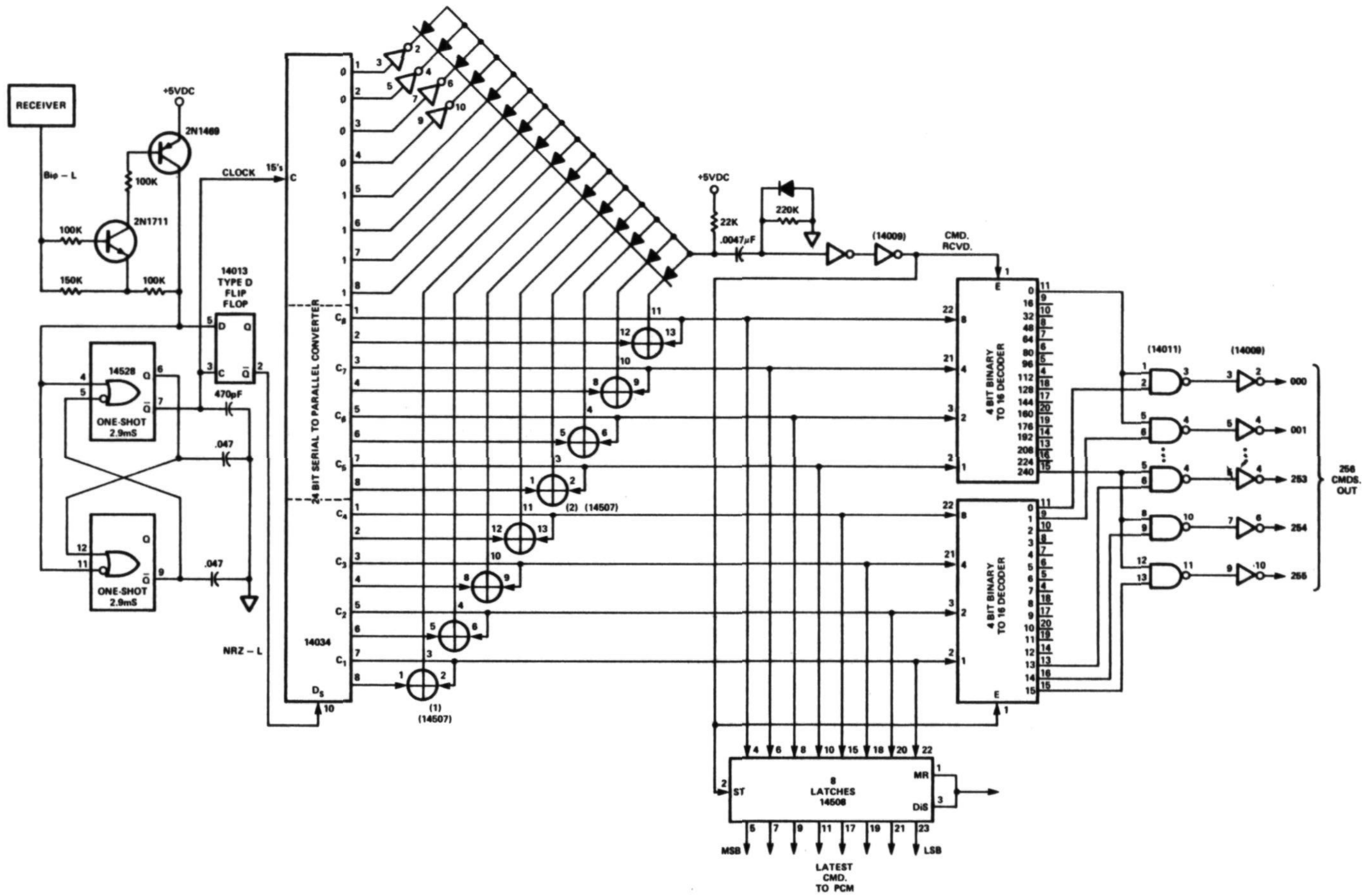


Figure 4. Command Decoder Schematic Diagram

latches which are examined 8 times per second by the PCM Data Commutator for transmission to the ground as the RCVD command. The "Load" pulse also enters the 8-bit command into the 8 Bit Binary-to-256 Line Decoder which routes the command to the proper one of the 256 possible lines as dictated by the 8-bit binary command number. Each output line is buffered through a CMOS driver so that it is capable of interfacing with CMOS, TTL, or DTL 5 volt logic systems.

PERFORMANCE AND OPERATIONAL CONSIDERATIONS

Whenever a command is issued by the operator, the time required for it to be encoded, placed on the serial bit stream, and transmitted to the gondola is between 125 and 250 milliseconds. This is due to the fact that, if the command button is pressed sometime during the clocking out of the Parallel-to-Serial Converter, one must wait up to 125 milliseconds for the desired command to be loaded into the Converter. Then, another 125 milliseconds is required for the clocking out of one complete 'command plus address' sequence. Essentially simultaneously with the generation of this first complete 'command plus address' sequence, the decoder in the gondola is clocking it into its Serial-to-Parallel Converter. Thus, by the time the command is fully serialized on the ground, it has also been entered into the Decoder aloft, verified as a valid command, and directed as a +5 volt logic level to the appropriate gondola subsystem. At most an additional 125 milliseconds is required for either of the two previously mentioned levels of command verification to be telemetered via the PCM Data Subsystem back to the ground station. Thus, the maximum total time required for the issuance and final verification of a typical command is 375 milliseconds.

When the operator presses a command button and holds it in, the appropriate output line on the gondola will rise to a +5 volt level and, in the absence of telemetry drop-outs, will stay at +5 volts until the command button is released (at which time command 000 is decoded). The shortest command which can be given lasts 125 milliseconds. The longest command is indefinite, however, it must be noted that the characteristics of this design dictate that ONLY ONE command may be given at a time. If two different commands were given simultaneously, a third command, most likely unrelated to either, would probably be generated. This caveat turns out not to be too restrictive but it does present some operational constraints which must be reflected in the design of the overall Control and Data system. If it is desired that a gondola subsystem be activated for more than a few seconds, a latch may be built into that subsystem and two commands may be assigned, one to set the latch and another to reset it.

The availability of only 8 command bits at a time also has system design implications. For example, one cannot simply command a motor to position a shaft to one of several thousand possible orientations. What must be done is to have one command which rotates the shaft, another command to stop its rotation, and a 10-bit telemetry word which reports back to the ground station operator the exact orientation of the shaft. This method of achieving precise control over subsystems on the gondola has proved to be totally acceptable for the implementation of all investigations proposed thus far for the AIROscope.

An additional and particularly useful feature of this design is that the Command Encoder and the Command Decoder may be connected directly together with a single BNC coaxial cable (bypassing the r.f. link) for use during pre-flight ground testing. The Encoder can thus function independently of the rest of the ground station, as a piece of ground support equipment with which any of the 256 commands can be generated and the desired gondola subsystems exercised.

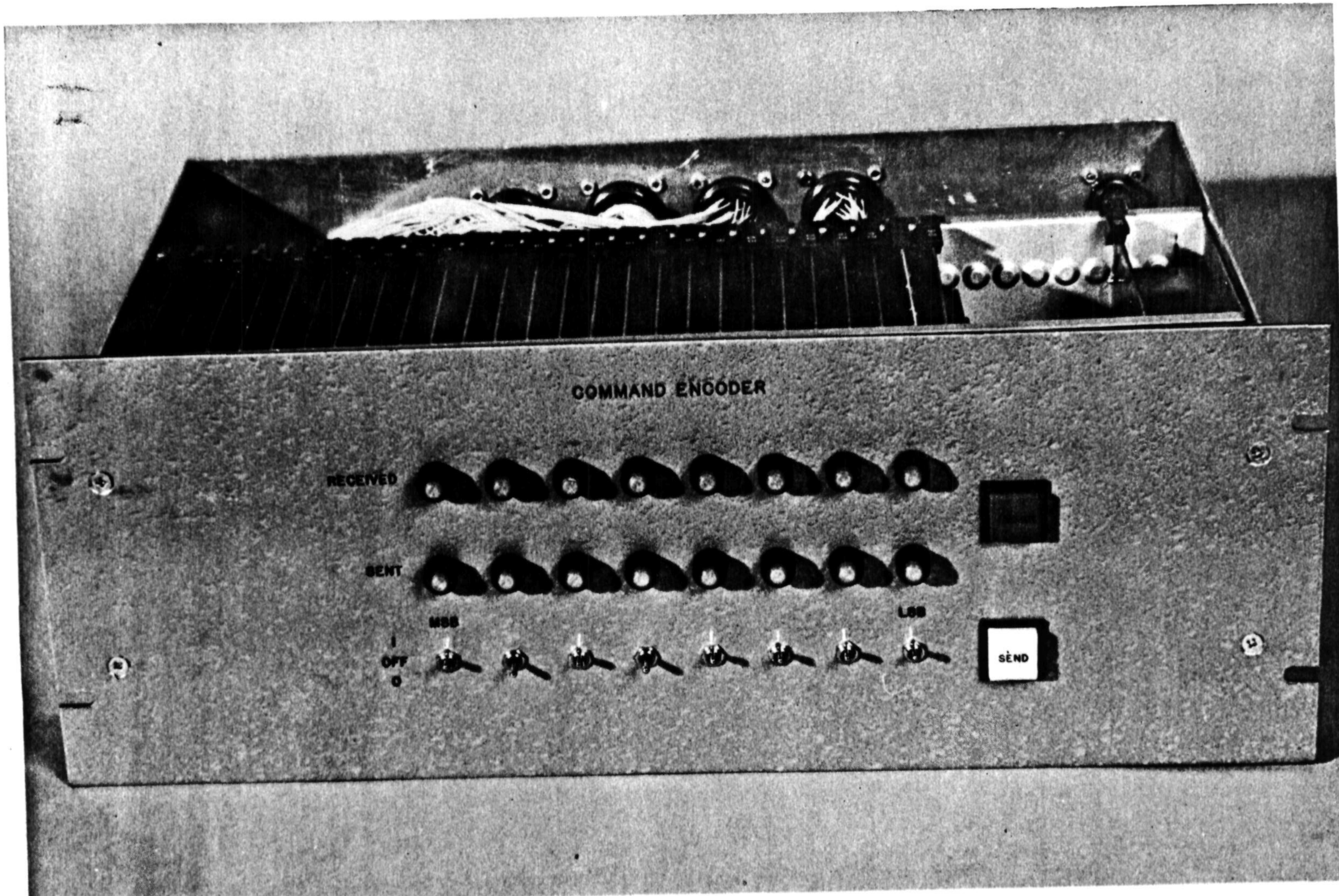


Figure 5. Command Encoder Hardware

DISCUSSION SUMMARY — PAPER 5.3

No discussion.