Electronic System of the HCO/ATM Spectroheliometer

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The Harvard College Observatory (HCO) ultraviolet scanning polychromator-spectroheliometer is one of the scientific instruments that comprise the Apollo Telescope Mount (ATM). It contains seven ultraviolet detectors that will be rastered across the solar disk. The seven detectors are mounted at strategic uv wavelengths and will provide information that will indicate temperature distribution of small areas of the sun. For other studies the spectrum can be shifted over the range 300 Å to 1350 Å. The electronics system including detectors, preamplifiers, hybrid counters, an inflight test system, and temperature monitors are described in detail.

Introduction

THE Harvard College Observatory (HCO) spectrometer (S-055A), which is part of the Apollo Telescope Mount (ATM), is basically a high-resolution spectroheliometer. It incorporates a mechanical raster system that can scan a 5 arcmin square on the solar disk with 5 arcsec resolution and that provides data to construct solar radiation intensity plots (spectroheliograms) for narrow bands of spectral space over the range 300 Å to 1350 Å. There are seven detectors mounted at fixed positions around the Rowland Circle of the spectrometer. The spectrometer grating can be rotated in increments that shift the spectra by 0.2 Å; thus, a nearly continuous spectral scan can be performed. In addition, the astronaut can point the instrument manually and/or adjust the spectral orientation manually. Thus, the spectrometer can be operated in three modes: raster scan, spectral scan, or manual control.

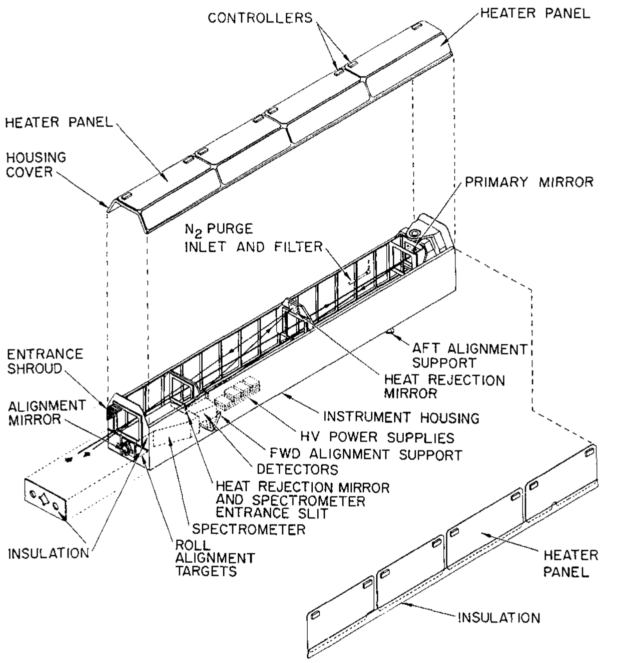

Fig. 1 Mechanical layout of the HCO/ATM ultraviolet scanning polychromator-spectroheliometer (courtesy Ball Brothers Research Corp.).

The astronaut's control of the instrument, with occasional guidance from the scientists at HCO, should result in a better understanding of solar flare mechanisms and an improved ability to predict flare activity.[1] Additional goals of the experiment are to obtain high-resolution structural information about plage regions, solar filaments, the chromosphere, and the limb of the solar disk.[2,3]

The general instrument layout is shown in Fig. 1. An equivalent optical path is shown in Fig. 2. Ultraviolet light enters through the entrance aperture, is deflected by the primary mirror that is movable about two axes, and is focused on the spectrometer entrance slit. The light that passes through the slit is reflected by the rotatable grating onto the 7-channel electron multiplier detectors. Spatial scanning of the solar disk is accomplished by rotation of the primary mirror whereas spectral scanning is accomplished by rotation of the spectrometer grating.

The electronic system is shown in Fig. 3. Three subsystems make up the complete system: primary data handling, optical control and monitoring, and power and temperature monitoring. This paper is devoted primarily to the description of the primary data handling subsystem. The primary mirror control system, which is the heart of the optical control and monitoring subsystem, has been described previously.[4] The temperature monitors that comprise the bulk of power and temperature monitoring subsystem will be described briefly.

Primary Data-Handling Subsystem

This subsystem consists of control logic, a test generator, the counters and logic for the astronaut's real-time display, and seven identical detector-counter-buffer assemblies. The 7 detectors, which simultaneously monitor spectral lines of interest, are of the continuous channel electron multiplier

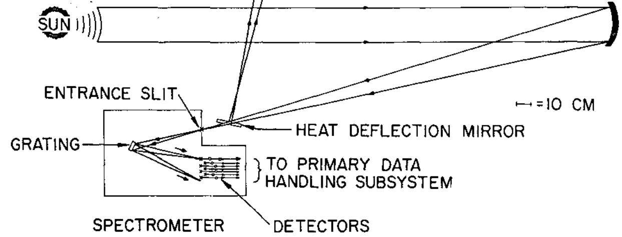

Fig. 2 Optical schematic diagram.

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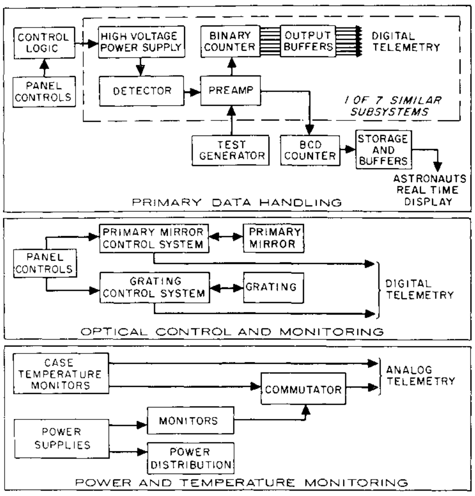

Fig. 3 Electronic system block diagram.

(Channeltron†) type selected primarily for their small size. The operating principles of Channeltrons have been described previously.[5,6] From a practical standpoint they are operated in much the same manner as standard photomultiplier tubes. The output pulses from each detector are capacitively coupled into an emitter follower whose output is amplified by the μA702A integrated-circuit operational amplifier and is used to trigger an MC951F integrated circuit monostable multivibrator (Fig. 4). The pulse output of the monostable multivibrator is directly coupled into the 16-stage binary counters. The simplicity of the preamplifiers permitted them to be built into the same package as the detectors, thus eliminating stray capacity problems normally associated with emitter follower pulse amplifiers.

The seven identical 16-stage binary counters are synchronized to the ATM master clock (Fig. 5). For 620 μsec following the master clock pulse, the first monostable multivibrator inhibits counting. During this period, the telemetry system reads the output data. As the 620-μsec monostable returns to its quiescent state, the 10-μsec monostable is triggered, resetting the counters. This system is straightforward and reliable; if any counter fails, it does not affect the other six counters. The key parameters of this system are dead-time stability and maximum counting frequency. The dead time is determined by the two monostable multivibrators. The 620-μsec monostable was designed for maximal stability; i.e., 1) it is operated from +15 v to minimize the change in pulse duration as V_{BE} changes with temperature, and 2) precision components are used in the time-constant network. The 10-μsec monostable accounts for less than 2% of the dead time, so that stability is not a major consideration in its design. Dead-time stability is thus better than ± 1 μsec, which is negligible compared with the counting period (40 msec).

The desire to design counters with a maximum possible counting frequency is mitigated somewhat by the typical space program constraints (i.e., minimize size, weight, and

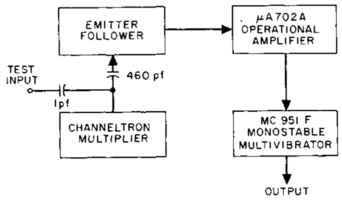

Fig. 4 Detector amplifier block diagram.

† Channeltron is a registered trademark of the Bendix Research Lab, Southfield, Mich.

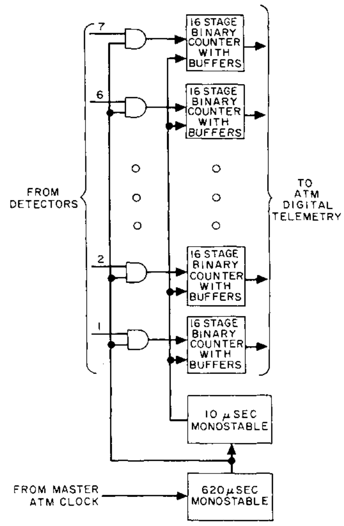

Fig. 5 Counter block diagram.

power). The binary counters were selected from Amelco's MEMA (Micro Electronic Modular Assembly) line of hybrid circuits. The package is 1.1 in. long by 0.83 in. wide with 36 leads on 0.05-in. centers along the two long sides. The 36 leads include common power lines, a direct reset line, 16 individual direct set lines, and 16 individual output lines. The main advantage of a hybrid assembly (aside from the obvious size and weight savings) is that the flip-flop elements could be selected from the Amelco 500 series line to maximize counting frequency with minimum power consumption. Key parameters of the three types of flip-flops in the 500 series are tabulated in Table 1. For a counter operating at 6 MHz, the count rates for the first 5 stages are as given in Table 2. Thus, the counter is made with one 579 flip-flop, three 539 flip-flops, and twelve 509 flip-flops. The typical total power consumption is a little over 100 mw. Designing for higher counting rates would have increased the power by 20% without real benefit, since the Channeltron and its preamplifier are limited to about 5 MHz.

The interface buffers that couple the counter outputs into the ATM telemetry system are conventional complementary two-transistor buffer circuits. For the astronaut's aid in

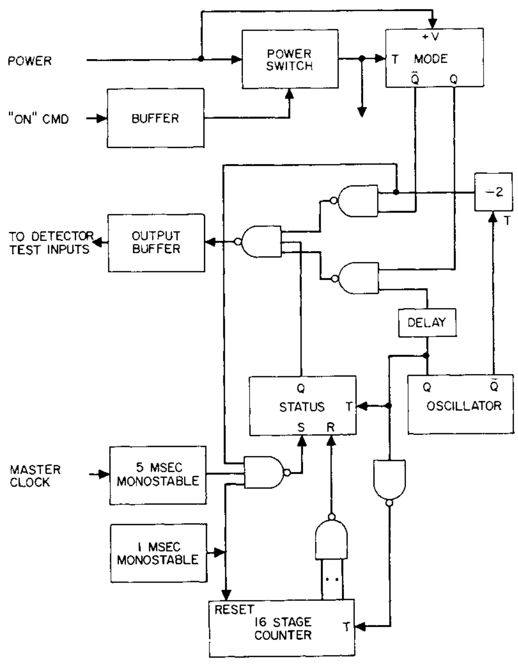

Fig. 6 Test generator circuit diagram.

Table 1 Characteristics of Amelco 500 series flip-flops

Flip-flop type	Counting frequency	Power consumption
509	500 KHz	4 mw
539	3 MHz	12 mw
579	10 MHz	24 mw

manual scanning with the instrument, real time intensity data from spectrometer channel No. 1 or No. 3 (switch selected from the astronaut's panel) can be displayed on the command console. The indicator on the astronaut's panel accepts counting data in 8-4-2-1 BCD, whereas the counters described previously count in true binary. This dichotomy was resolved by the construction of a 5-digit BCD counter that operates in parallel with the binary counters.

The test generator consists of a pulse generator that, upon astronaut command, generates a known length burst of pulses which is capacitively coupled into the detector preamplifier test input (see Fig. 4). Two pulse burst lengths are used. They are 0101010101010101_2 (= 21845_{10}) and 1010101010101010_2 (= 43690_{10}). Together they test each counter output line at both the 0 and the 1 level and can therefore pinpoint faults in the counters, buffers, or the telemetry system. The two sequences are easily generated as the first is a binary submultiple of the second. The generation technique uses the same time period for each burst so that the two frequencies are generated, thus providing data on preamplifier or counter frequency response degradation if any should occur.

The circuit for the test generator is shown in Fig. 6. The output of a 1.6 MHz astable multivibrator is counted in a 16-bit binary counter. When the preset number of pulses have been generated, the status flip-flop is reset and the output is gated off. The next 24 Hz ATM clock pulse resets the 16-bit counter, and the process repeats. If the unit is commanded OFF and then ON again, the mode flip-flop is toggled, and the oscillator frequency is divided by two, thus halving the number of output pulses. The pulse burst begins about 5 msec after the 24 Hz ATM clock pulse. The astable multivibrator frequency of 1.6 MHz was selected to generate the required number of pulses about 5 msec before the next 24 Hz clock pulse. Thus, the ATM master clock synchronizes the test generator pulse train with the rest of the primary data system.

Temperature Monitors

A network of 20 to 30 temperature sensors is used, so that the case bending and optical defocusing can be computed in the event of a failure in the thermal control system, and data can be salvaged. Obviously such a monitoring network is feasible only if economical, compact, and reliable temperature monitors are available. An extensive study indicated that the best sensor for this application is a miniature interchangeable thermistor.[7] A simple circuit (Fig. 7) was developed to convert the approximately exponential resistance temperature characteristics of the thermistor into a nearly linear voltage-temperature relationship directly suitable for the ATM telemetry system. The computer-selected input resistor to the operational amplifier, R_{IN}, causes the closed-loop amplifier gain to vary inversely with the thermistor sensitivity.[8] The monitor features high thermal sensitivity and excellent stability. A computer program is used to optimize the value of each resistor used in the monitors; this permits a degree of optimality previously unobtainable.

Table 2 Count rates for first 5 stages of 6 MHz counter

Stage	Count rate	Flip-flop type
1	6 MHz	579
2	3 MHz	539
3	1.5 MHz	539
4	750 KHz	539
5	375 KHz	509

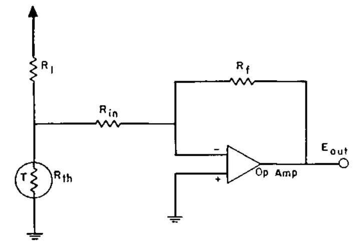

Fig. 7 Basic temperature monitor circuit diagram.

Conclusion

The electronics system of the spectrometer for the ATM is designed to take full advantage of small size and lightweight modern solid-state components (e.g., continuous channel electron multipliers and hybrid integrated counters). It simultaneously monitors the intensity of seven UV wavelengths with a resolution of 2^{-16} of the maximum count. Straightforward digital counting techniques yield a high reliability system. Two basic test facilities are used; a test generator that generates known length sequences of pulses to verify the primary data handling system, and a large network of thermistors to monitor the instrument case temperature.

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