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DESIGN AND DEVELOPMENT OF ELECTRICAL AND MECHANICAL INSTRUMENTS--ETC(U)

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DESIGN AND DEVELOPMENT OF ELECTRICAL AND
MECHANICAL INSTRUMENTS FOR THE
AURORAL-E PROGRAM

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Preface

We wish to acknowledge Robert E. Shupe for providing engineering services on this contract. This work was done under Air Force Geophysics Laboratory contract F19628-80-C-0116.

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1. INTRODUCTION

The Auroral E-Program consisted of four rocket payloads which were launched from the Poker Flat Research Range, Fairbanks, Alaska, on March 6, 1981. This report describes the engineering activities carried out during the development of the A10.903 payload. The payload experiment consisted of a double-probed electric field instrument to measure ac and dc electric fields, a density strip for measuring electron densities, and an automatic gain control (AGC) unit. A block diagram of this experiment is shown in Figure 1.

2. OBJECTIVES

Auroral-E Program objectives were to obtain in-situ measurements of several atmospheric and ionospheric parameters during a continuous diffuse aurora. Other goals of the rocket program were to have nearly simultaneous measurements of the energy and angular distribution of electron and proton flux, optical emissions from atomic and molecular atmospheric constituents, ion species, electron densities, neutral and mass densities, neutral and electron temperatures, neutral winds and electric fields. The rocket measurements were also coordinated with passes of a satellite which provided precipitating electron and proton measurements. The AFGL Airborne Ionospheric

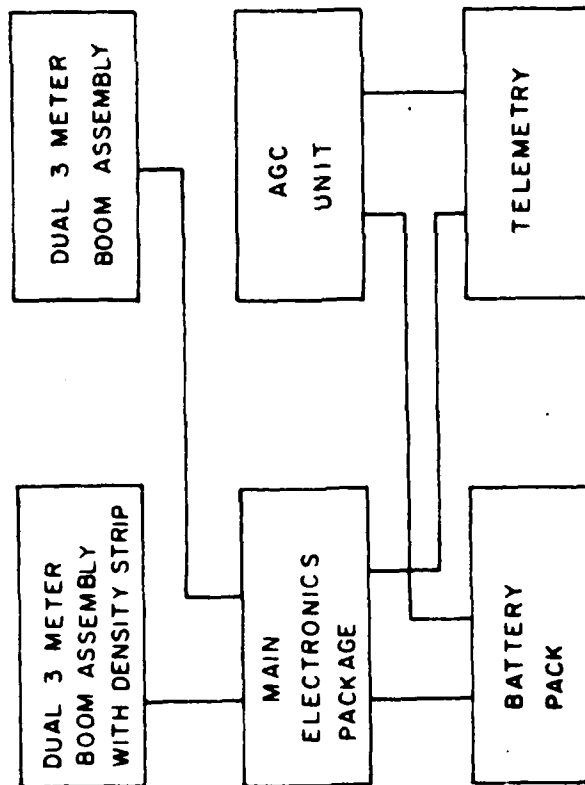
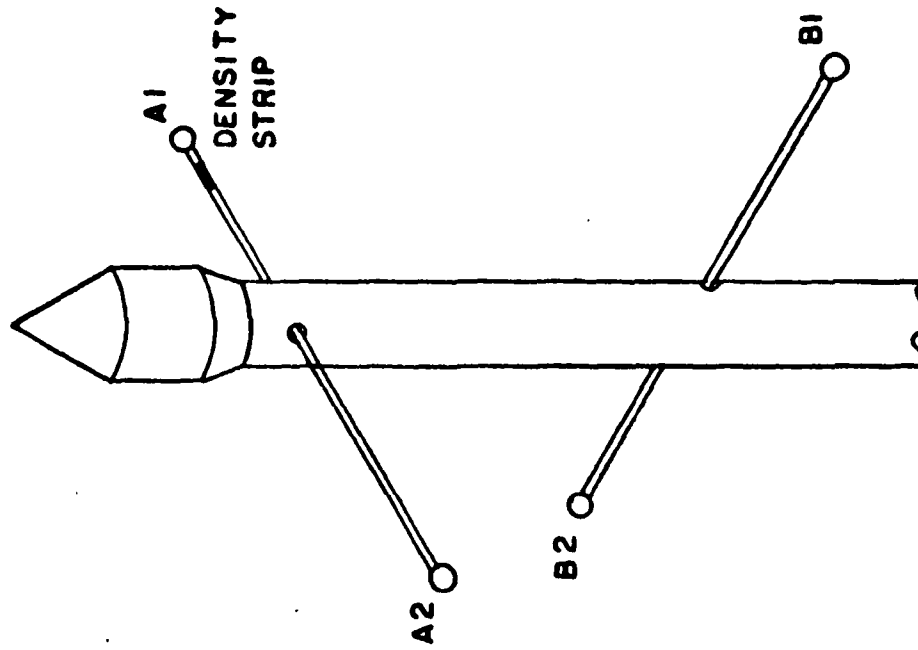


Figure 1 System Block Diagram

Observatory made passes near each rocket launch and measured auroral optical emissions as well as ionospheric parameters. In addition, ground-based measurements of electron density profiles in the region of the rocket trajectories were provided by the Chatanika Radar Site.

3. INSTRUMENTATION

3.1 BACKGROUND

Instrumentation for the Electric Field experiment consisted of a flight system and two ground support equipment (GSE) consoles. The flight system consisted of a main electronics package (MEP), two 3-meter boom assemblies, and an automatic gain control (AGC) unit. These flight units are shown in Figures 2, 3, and 4 respectively. In flight, the method of measurement was to deploy the two mutually perpendicular dipoles (3-meter boom assemblies) normal to the rocket spin axis with a separation of $57\frac{3}{4}$ " between the fore and aft dipoles. These perpendicular dipoles were deployed at T+60 seconds (80 KM) slowing the spin rate from 5.5 rps to 3.8 rps. The mutual potential differences between pairs of spherical sensors ($1\frac{3}{8}$ " diameter) mounted at the dipole tips, with a 3-meter separation, yield the vector electric fields. These field signals were processed by the MEP and AGC units as shown in the electrical block diagram, Figure 5. Also, a conducting strip, located near the A1 spherical sensor, yielded



Figure 2 Main Electronic Package

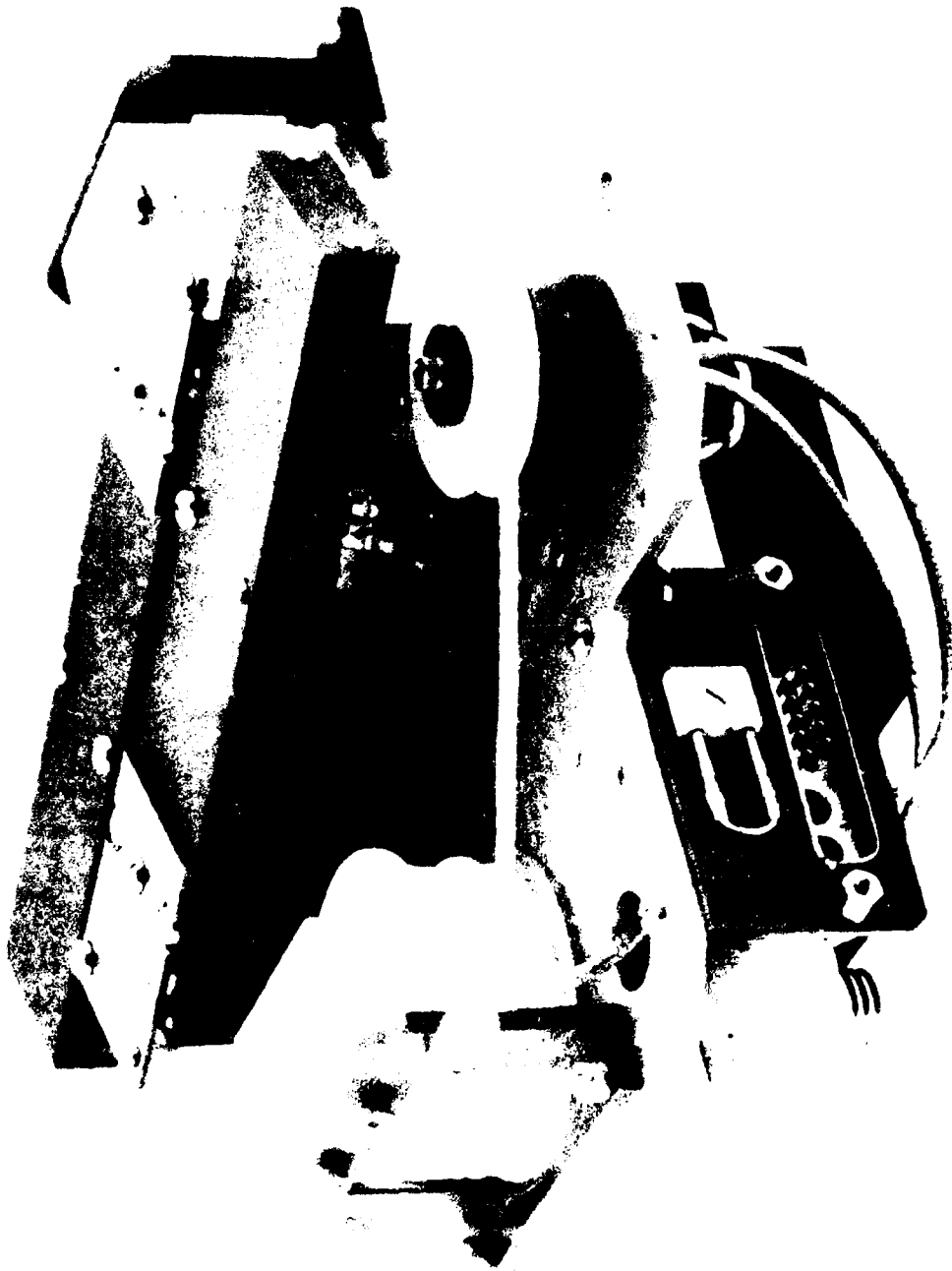


Figure 3 3-Meter Boom Assembly



Figure 4 Automatic Gain Control Unit

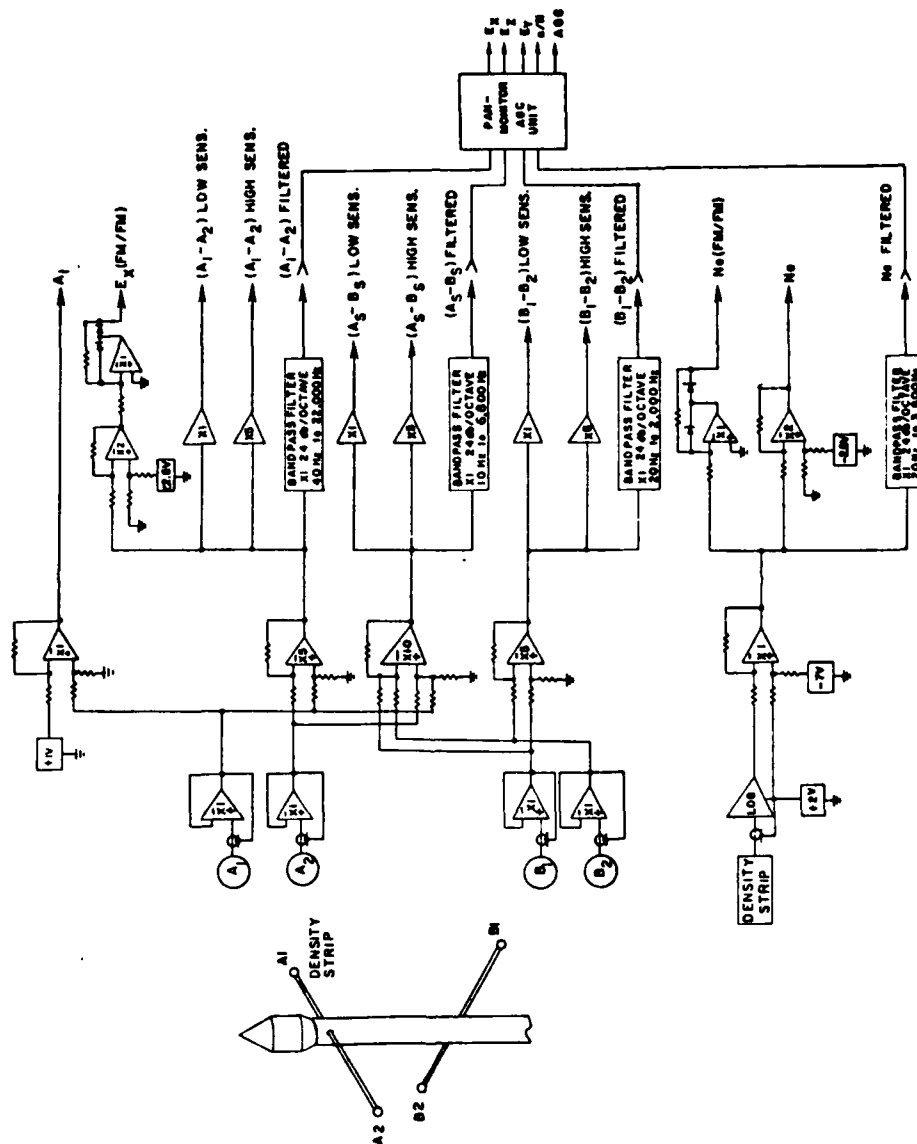


Figure 5 Electrical Block Diagram

the electron signal for the density measurement. This signal was also processed by the MEP and AGC units.

The GSE units were used for initial debugging, burn-in calibration and payload integration. One unit was a passive chassis for interfacing the MEP, the test equipment, and the AGC unit, with the input signals plus power. The other GSE unit (called the AGC console) received a serial digital data line from the AGC unit and displayed its content. This AGC console is shown in Figure 6.

3.2 3-METER BOOM ASSEMBLY

The procurement of the two 3-meter boom assemblies was accomplished under another AFGL contract. However, flight preparation work was done under this contract. The electrical connections were wired to the interface connectors. Also, a special removal tool was designed and fabricated for removing the $1\frac{3}{8}$ " diameter spherical sensors. The sensors were mounted on the boom assemblies with 12 in-lbs of torque for integration and vibration tests. Then the sensors were removed for shipping using the special tool. At the launch site, the spheres were sand blasted with a fine grit and then coated with 3 coats of Aerodag G. Just prior to the rocket skin being installed for the last time, the sensors were then installed again with 12 in-lbs of torque.

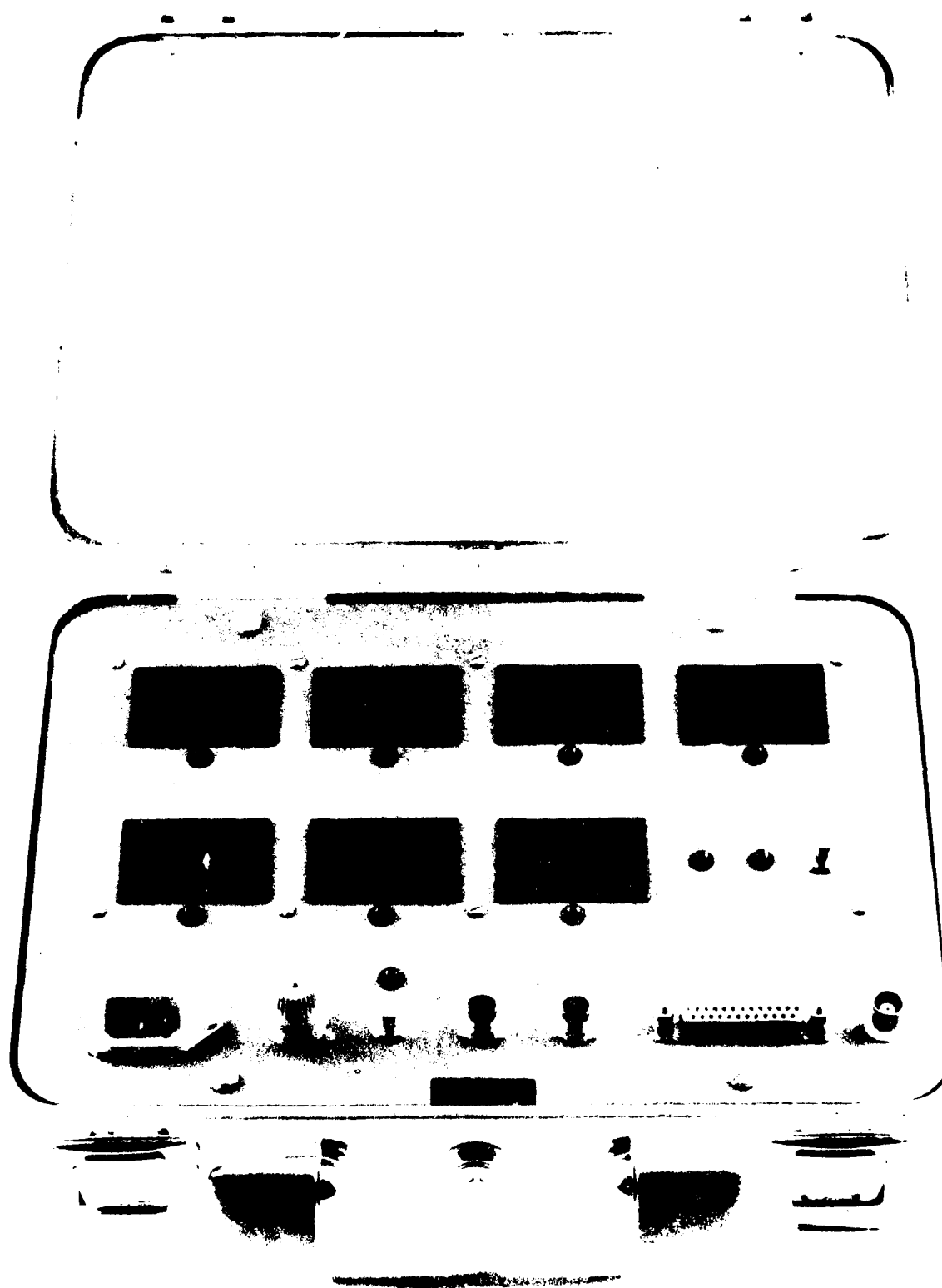


Figure 6 AGC Console

Although the booms could not be deployed before launch to determine their deployment characteristics, a linear potentiometer monitor circuit was designed into their mechanical drive train by the manufacturer to monitor the deployment progression. With known potentiometer resistance values, monitor circuits were designed to give telemetry values of +3V stowed and -4V deployed. In flight, the monitor circuit noted the fore dipole deployed in 4.5 seconds and the aft dipole deployed in 6.0 seconds.

3.3 MAIN ELECTRONICS PACKAGE

As shown in Figure 2, the MEP unit consisted of a mechanical housing, four printed circuit cards, and a dc to dc power converter (not visible) located in the base of the unit. Behind the front connector plate there was an interconnecting harness which provided electrical connections internally and externally. Externally, the MEP was connected to the boom assemblies, AGC unit, +28 volt battery pack, and a telemetry system.

The mechanical housing used for the MEP was the DMSP satellite SSI/E engineering test model (ETM). This housing required only one alteration which involved enlarging one connector slot on the front connector plate. Modifications to the built-in dc to dc power converter were more extensive. The ± 15 volt regulated secondary current limit was redesigned to yield an output of ± 60 mA. An unregulated ± 15 volt floating

secondary was redesigned to incorporate a regulator circuit for sourcing an electrometer circuit. Also, several regulated offset supply lines were designed into the secondary of the converter. All unused secondary circuit modules were removed for reliability and weight reasons.

The processing circuits were designed under the previous contract, F19628-77-C-0122. Under the present contract, the circuits were developed and finalized and then designed onto the four printed circuit (PC) boards. The schematic shown in Figure 7 is of the top PC board which processed the density signals. A logarithmic electrometer (U1, U2, U3, and Q1) was used on the input to change the electron current signals into electron voltage signals. With the logarithmic electrometer referenced to a +2 volt bias (U12), the electrometer output had to be level shifted (U4) with respect to the telemetry system common. Operational amplifier (op amp) U13 is used for shifting the log electrometer output scale and op amp U14 is used to shift the PCM data output lines. Buffers U5 and U10 are used for driving electron density (N_e) signals to the FM/FM and PCM data lines respectively. Op amps U6 through U9 combined to form a four-pole bandpass filter which limited ac signals between 20 Hz and 3,800 Hz. These ac output signals were sent to the AGC unit. Op amps U15 and U11 formed a temperature circuit which was connected to a PCM telemetry data line.

The second board down in the PC stack was the electrometer board whose schematic is shown in Figure 8. Input signals from the boom sensors (A1, A2, B1, and B2) are connected to the electrometer amplifiers (U1 through U4 respectively). From these electrometer outputs, difference amplifiers U7, U8, U9 yield the vector electric field measurements which are buffered on the difference board and are also connected to the filter PC board. Sensor A1's electrometer output (U1) was offset (U6) and buffered (U5) to drive a PCM data line. Also located on this board were the two boom deployment monitor circuits (U10 and U11) which were connected to PCM data lines. Another temperature circuit (U12) was located on this board and was also connected to a PCM data line. Op amp U13 formed an offset voltage for the filter circuits.

The third board down in the PC stack was the difference amplifier board as shown in the schematic in Figure 9. Difference signal (A1-A2) was buffered into low (U3) and high (U4) gain signals which were connected to PCM data lines. The (A1-A2) difference signal was also offset (U1) and buffered (U2) to form the Ex signal which was connected to an FM/FM data line. The $(A_s - B_s)$ and the (B1-B2) signal lines were also buffered (by U5, U6 and by U7, U8, respectively) developing buffered signals into low and high gain data lines which were connected to the PCM telemetry unit.

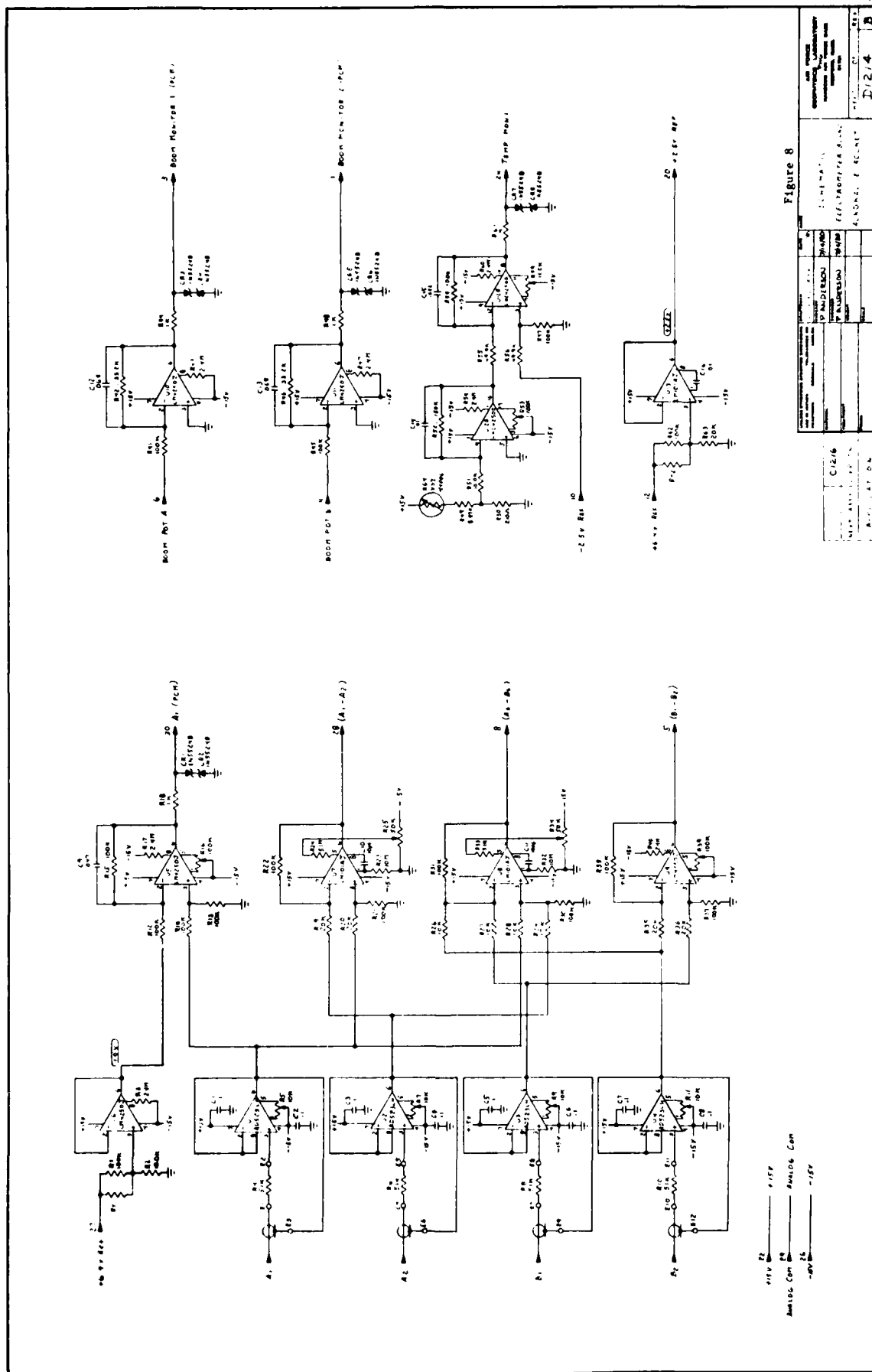


Figure 7

NOTES:

2. $\pm 0.1\% R_T$ $\pm 0.05\%$ LOSS OVER A $100\text{ }^{\circ}\text{C}$ ΔT INPUT ($\alpha = 10^{-4}$), $R_T = R_{T0}$

[illegible]



On the bottom of the PC stack was the filter PC board whose schematic is shown in Figure 10. Located on this PC board were three bandpass filters. Op amps U1 through U4 limit the (A_s-B_s) signal to between 10 Hz and 6,800 Hz; op amps U5 through U8 limit the (B1-B2) signal to between 20 Hz and 2,000 Hz; op amps U9 through U12 limit the (A1-A2) signal to between 40 Hz and 22,000 Hz. These three filtered ac signals were connected to the AGC unit.

A new interconnection harness was designed for interfacing the PC boards, power supply, and external connectors. The interconnection diagram is shown in Figure 11.

3.4 AUTOMATIC GAIN CONTROL UNIT

The automatic gain control (AGC) unit was purchased under the previous contract, F19628-77-C-0122. This unit received four ac signals (N_e , A1-A2, A_s-B_s , and B1-B2) from the MEP unit. These signals were constantly sampled and the gain was automatically adjusted to maintain a constant ac analog on the four output ($\Delta n/N$, ΔE_x , ΔE_z , and ΔE_y) data lines. Gain status of each of the four data channels used was updated each second and formulated into an output serial digital data stream as shown in Figure 12 (3 of the 7 available data channels were not used). These outputs were connected to the FM/FM telemetry section. Power for this unit was provided by the AFGL rocket group from ± 18 volt battery packs.

3.5 GROUND SUPPORT EQUIPMENT

Ground support equipment was designed and developed under this contract. The MEP was a free running unit which received power from a battery eliminator, processed ac and dc signals from sensor simulators and sent signals to either the AGC unit or to the rocket telemetry system. These MEP interfaces were integrated by designing and fabricating a passive chassis. This chassis provided jacks for the power leads, BNC connectors for the input signals, BNC connectors for the telemetry data points, and a Cannon connector for interfacing with the AGC unit.

The AGC Console (Figure 6) was designed to operate off the 120 volt ac power line and display the serial digital data from the AGC data line of the AGC unit. Data from the AGC line was decoded and displayed as a gain number (0 = no gain, 11 = maximum gain) by a $1\frac{1}{2}$ -digit seven-segment display for the appropriate data channel. The consoles' front panel has two warning LED indicators, one for a bit frame error (BTFR) and the other for a word frame error (WDFR). Operation of the console required only the depressing of the reset button. The circuitry then looked for the sync word (all ones's). This was confirmed by the WDFR LED indicator turning on with the reset command and turning off when the sync word was received. Also, with the reset command, the data channel $1\frac{1}{2}$ -digit displays would blank and then begin to fill with data after the sync word was received.

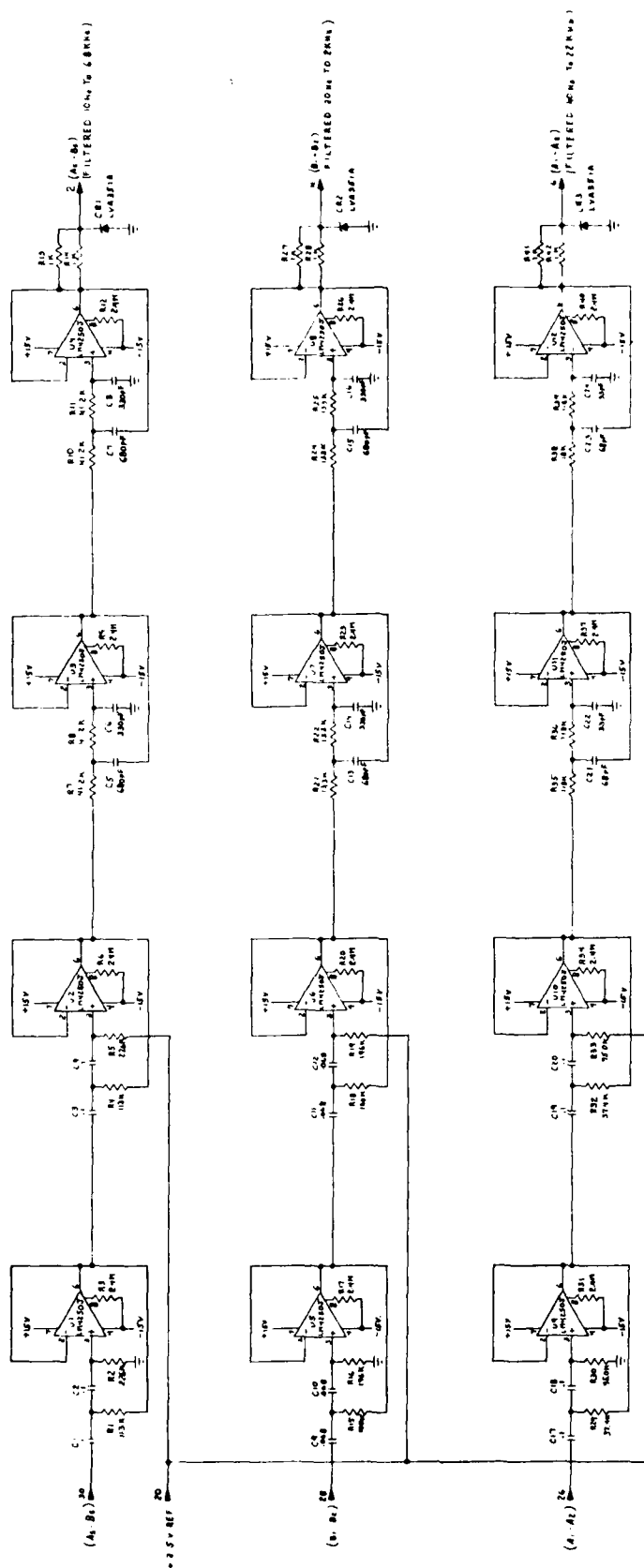


Figure 10

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(continued)

Figure 1 shows a schematic diagram of a 2D lattice structure. It consists of a square grid of sites. A central site is labeled '1'. To its right is a site labeled '2'. Above site 1 is a site labeled '3'. To the right of site 3 is a site labeled '4'. Below site 1 is a site labeled '5'. To the right of site 5 is a site labeled '6'. The horizontal bonds are labeled 'a' and the vertical bonds are labeled 'b'.

Diagram illustrating the word format for the 10-bit data. The format is shown as a sequence of bits: t_b , START, A_0 , A_1 , A_2 , D_0 , D_1 , D_2 , D_3 , STOP, STOP. The data portion (A and D bits) is labeled "10 BITS".



Figure 12 Serial Telemetry Data Format

The AGC Console was designed in three sections in order to be easily servicable. Section one contained all of the electronic circuitry located on a wire wrap board as shown in the schematic in Figure 13. Section two contained the display components mounted on a vector board as shown in the schematic in Figure 14. Section three contained the power supply and the front panel components as shown in the schematic in Figure 15.

The AGC console was initially debugged with the aid of the Tektronix microprocessor development system (MDL) and a bench top TI 990 microcomputer. Table 1 shows the console debugging software written for the TI 990 and stored on a Tektronix MDL floppy disc. With this program , all of the console's characteristics were checked automatically when the console received a test serial data stream from the TI 990.

4. INTEGRATION SUPPORT

The above system was supported at AFGL during the debug, burn-in, calibration, integration, and vibration phases. Both authors traveled to Poker Flat Research Range in Fairbanks, Alaska, to support integration and launch preparations.

Table 1

Software - AGC Console Test

Tektronix: TMS 9900 ASM V3.3

Page 1

00001	F000	>	ORG 0F000H
00002	F000 0020	WS	BLDCK 32
00003	F020 02E0F000	ST	LWPI WS
00004	F024 0202F000		LI R2,0FB00H
00005	F028 02030073		LI R3,0073H
00006	F02C 02048200		LI R4,8200H
00007	F030 0205FF00		LI R5,0FF00H
00008	F034 020701F4		LI R7,01F4H
00009	F038 020C0180		LI R12,180H
00010	F03C 101F		SRO 31
00011	F03E 3204		LDCR R4,8
00012	F040 3205		LDCR R5,8
00013	F042 3307		LDCR R7,12
00014	F044 02084200	L1	LI R8,4200H
00015	F048 1E0D	L2	SBZ 13
00016	F04A 1F19	L3	TB 25
00017	F04C 13FE		JED L3
00018	F04E 1D0D		SBO 13
00019	F050 1E14		SBZ 20
00020	F052 0608		DEC R8
00021	F054 16F9		JNE L2
00022	F056 1E0D		SBZ 13
00023	F058 3232		LDCR *R2+,8
00024	F05A 1D10		SBO 16
00025	F05C 1F16	L4	TB 22
00026	F05E 16FE		JNE L4
00027	F060 1E10		SBZ 16
00028	F062 0603		DEC R3
00029	F064 16EF		JNE L1
00030	F066 02068300		LI R6,8300H
00031	F06A 1D0E		SBO 14
00032	F06C 3206		LDCR R6,8
00033	F06E 02090000		LI R9,0000H
00034	F072 3209		LDCR R9,8
00035	F074 1D10		SBO 16
00036	F076 1F16	L5	TB 22
00037	F078 16FE		JNE L5
00038	F07A 04600080		R 080H
00039	F800	>	ORG 0FB00H
00040	F800 7F0001020304		BYTE 7FH,00H,01H,02H,03H,04H,05H,06H,08H,09H,0AH,0BH,0CH,0DH,0EH,10H
00040	F806 050608090A0B		
00040	F80C 0C0D0E10		
00041	F810 111213141516	BYTE	11H,12H,13H,14H,15H,16H,18H,19H,1AH,1BH,1CH,1DH,1EH,20H,21H,22H
00041	F816 18191A1B1C1D		
00041	F81C 1E202122		
00042	F820 232425262829	BYTE	23H,24H,25H,26H,28H,29H,2AH,2BH,2CH,2DH,2EH,30H,31H,32H,33H,34H
00042	F826 2A2B2C2D2E30		
00042	F82C 31323334		
00043	F830 353638393A3B	BYTE	35H,36H,38H,39H,3AH,3BH,3CH,3DH,3EH,40H,41H,42H,43H,44H,45H,46H
00043	F836 3C3D3E404142		
00043	F83C 43444546		
00044	F840 48494A4B4C4D	BYTE	48H,49H,4AH,4BH,4CH,4DH,4EH,50H,51H,52H,53H,54H,55H,56H,58H,59H
00044	F846 4E5051525354		

Tektronix: TMS 9900 ASM V3.3

Page 2

00044	F84C 55565859		
00045	F850 5A5B5C5D5E60	BYTE	5AH,5BH,5CH,5DH,5EH,60H,61H,62H,63H,64H,65H,66H,68H,69H,6AH,6BH
00045	F856 616263646566		
00045	F85C 68696A6B		
00046	F860 6C6D6E707172	BYTE	6CH,6DH,6EH,70H,71H,72H,73H,74H,75H,76H,78H,79H,7AH,7BH,7CH,7DH
00046	F866 737475767879		
00046	F86C 7A7B7C7D		
00047	F870 7E707070	BYTE	7EH,07H,07H,00H
00048			