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EHF SHELF POWER MONITOR AND CONTROLLER

by

R. Addison

This work was sponsored by the Department of National Defence, Chief of Research and Development Branch, Task No. 32A.

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R. Addison*

(Radar and Communications Technology Branch)

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* With DREO/ED but on secondment to the Space Systems Directorate of CRC.

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1 INTRODUCTION

In 1981, the Military Satellite Communications (MILSATCOM) section of Communications Research Centre (CRC) installed an Extremely-High Frequency (EHF) ground terminal to use the Lincoln Experimental Satellites LES 8 and LES 9. The antenna was put on top of the elevator shaft and covered with a radome. See Figure 1.1, CRC EHF Ground Terminal. The shelf on the back of the dish was used to house the Radio Frequency (RF) equipment. The Intermediate Frequency (IF) and baseband equipment was installed in a lab three floors below.

It was desired that the shelf be configurable to various operating modes. The possible choices were: LES 8 or LES 9 satellites, receive only or transmit/receive, and dish or horn antenna on the satellite (the antennas had slightly different frequencies).

The distance between the two installations suggested remote control of the shelf hardware. Such a system was built to monitor power levels and to control the operating modes of the shelf. This enabled rapid diagnosis of problems and quick changes of configuration without leaving the lab.

This document first explains the hardware used in the monitoring and controlling system. This includes the previously existing system, the shelf computer and the display panel. See Figure 1.2, EHF Ground Terminal Block Diagram for the system diagram.

Finally, the software developed for the shelf computer will be covered. The program listing is included as Appendix I, ROM Program Listing.

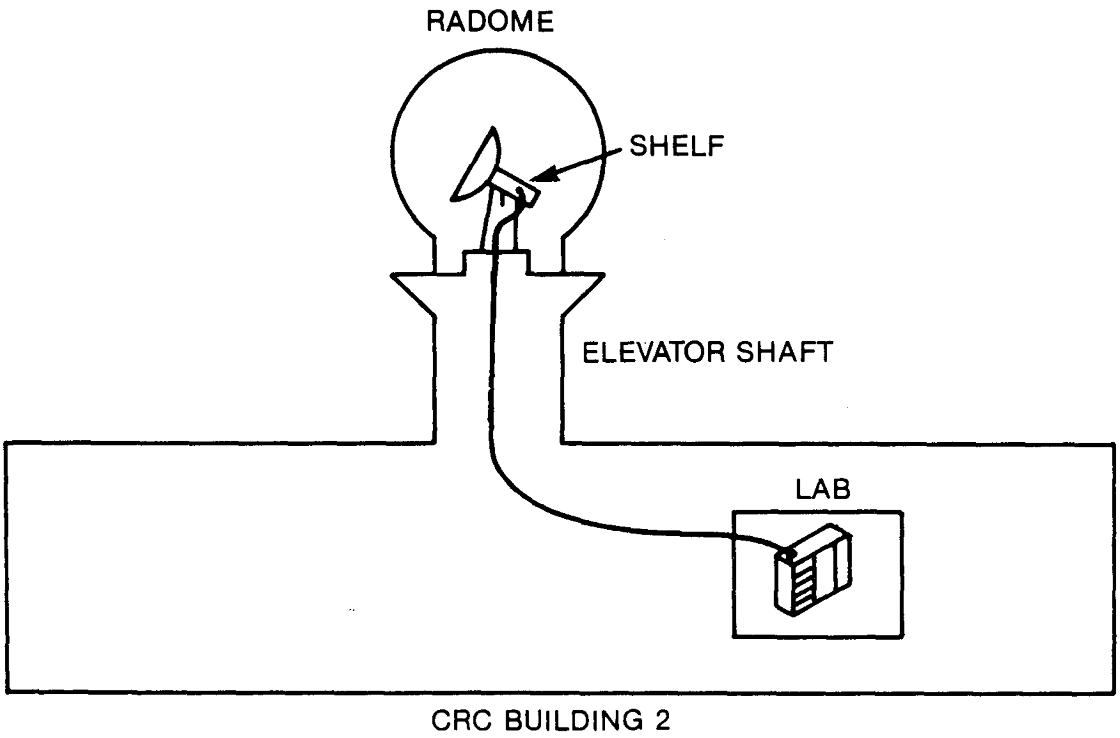

Fig. 1.1 CRC EHF Ground Terminal

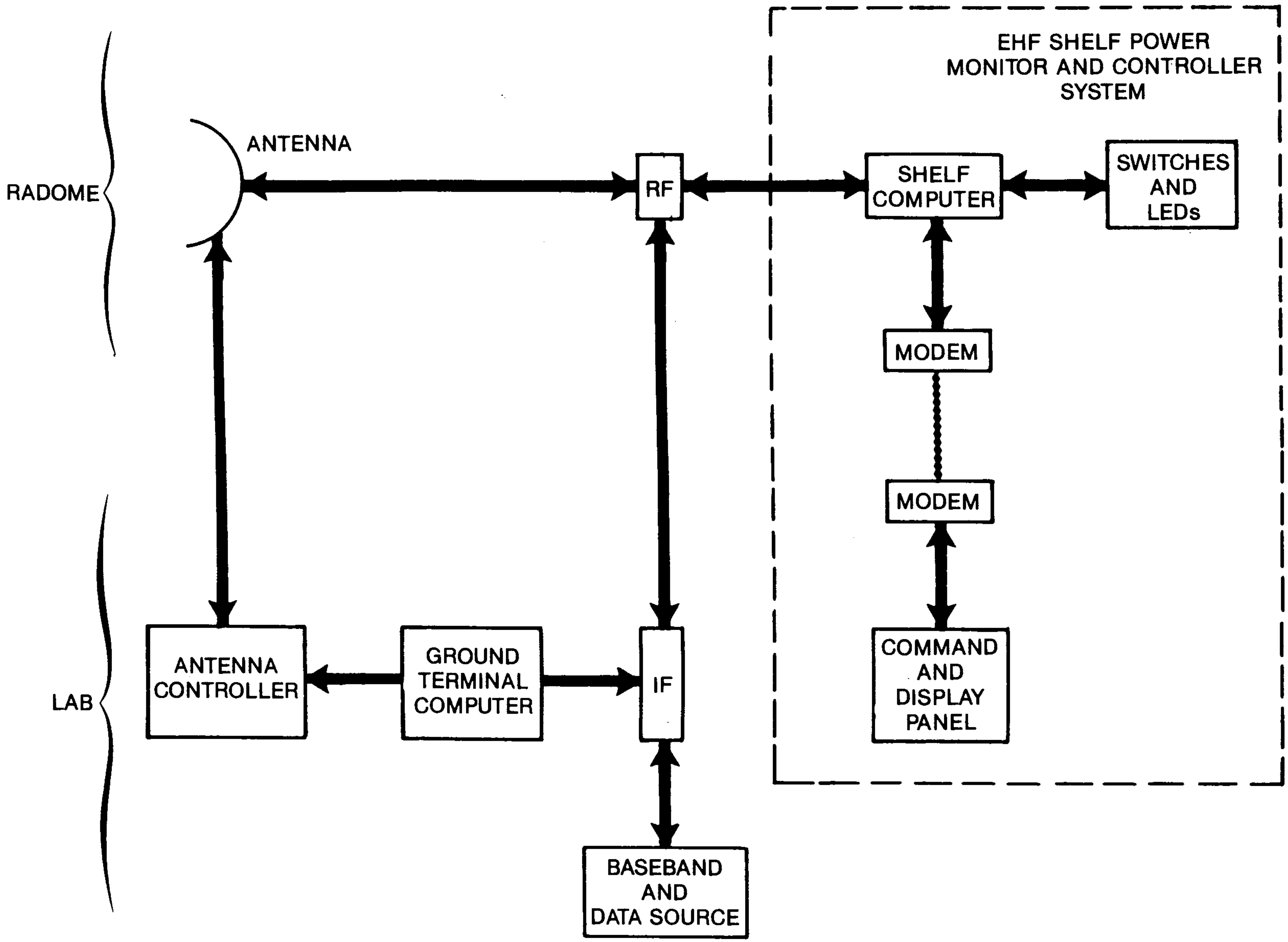

Fig. 1.2 EHF Ground Terminal Block Diagram

2 HARDWARE

The hardware consists of the shelf computer that takes the measurements and controls the microwave switches, and a command and display panel located three floors below. See Figure 1.2, EHF Ground Terminal Block Diagram.

2.1 EXISTING HARDWARE

When the shelf was designed, provision was made for remote control, but no computer was installed. Instead, the modes were selected by Dual-In-Line (DIP) switches and Light Emitting Diodes (LEDs) indicated the position of the waveguide switches. To change modes, one had to climb to the dome and change the switches.

Later, an LSI 11 computer was incorporated to control the switches and to monitor the power levels. An analog acquisition board was built, as well as a display panel. The system was controlled by a terminal that was co-located with the display panel in the lab.

The previous display panel consisted of a display board and a communications board. The display board showed five three-digit power levels, each with a LED to indicate valid (green) or invalid (flashing red) data. The communications board intercepted all data to the terminal and passed on the data that was not addressed to the display panel.

2.1.1 Problems With The Old System -

The previous system was not reliable. A redesign of the system was required to fix the following problems:

1. One of the analog signals was low enough to be affected by the noise of the analog acquisition system. This could be corrected by decreasing the noise level of the existing board or by using a different board with better characteristics.

2. The system required a VT100 Terminal to control the operation of the shelf. This VT100 had to be dedicated to a task which took about five minutes per day.

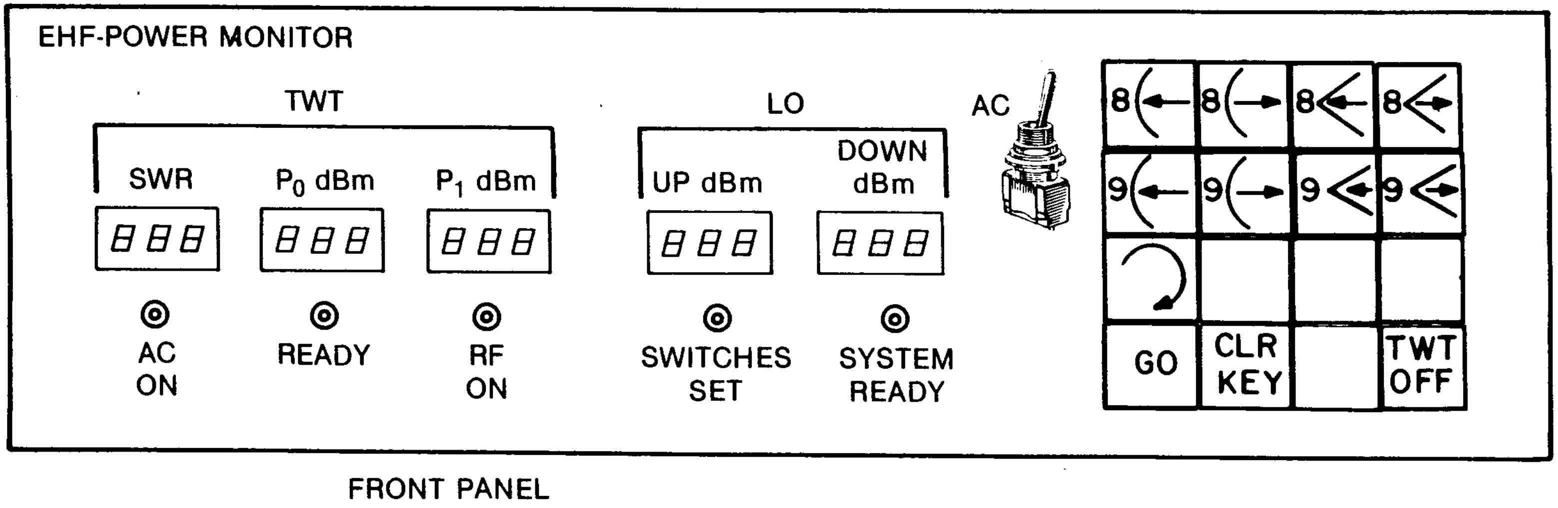

Fig. 2.1 Front Panel

3. The existing communication board was unreliable and required periodic maintenance. The communication protocol was not robust and could cause the panel to enter illegal states.

4. The panel powered up displaying erroneous data.

2.1.2 Changes Implemented -

The following changes were made to fix the above mentioned problems:

1. To solve the noise problem, a new analog acquisition board was used. This board had the advantage of programmable gain, differential inputs and a more mature design. These characteristics served to reduce the noise effects to a tolerable level.

2. A keypad was added to the front panel to command the different modes of operation. See Figure 2.1, Front Panel. The LEDs used to indicate valid/invalid data on the display panel were reassigned to system status LEDs. This enabled the VT100 to be freed for other projects.

3. The entire communication board was redesigned. The new design amounted to significant parts reduction and improved reliability. The communications protocol was also changed to increase the robustness. The protocol is further described in Appendix D, Communications Protocol.

4. A power up reset was implemented to ensure that the displays were initialized. Also a LED minus sign was added to improve the appearance of negative power levels.

5. A rear panel containing power supplies and external connectors was added to the display panel.

2.2 EHF SHELF HARDWARE

The control hardware on the shelf is comprised of the shelf computer, its parallel Input/Output (I/O) board with switch drivers, and waveguide switches. Also controlled are several coaxial switches and some power relays. To sense the power levels, there are microwave diode detectors. The calibration curves of the detectors can be found in Appendix A, Microwave Detector Calibration.

2.2.1 Shelf Computer -

The shelf computer contains four boards. They are:

1. KD11-HA LSI 11/2 Processor Board with EIS and FIS
2. MXV11-A Multifunction Board
3. ADV11-C Analog Input Board
4. Special Purpose Parallel I/O and Switch Driver Board

With the exception of the special purpose parallel I/O Board, all the boards are standard Digital Equipment Corporation (DEC) boards and are documented in the Microcomputers and Memories Manual, and the Microcomputer Interfaces Manual, both available from DEC. The parallel I/O board is detailed in the next section.

The LSI 11/2 processor supports the standard PDP 11 instruction set. The Extended Instruction Set (EIS) gives the processor fixed point multiply and divide capability. The four basic floating point operations are provided by the Floating point Instruction Set (FIS).

The MXV11-A Multifunction board provides the minimum support required by the processor. It contains 16K words of Random Access Memory (RAM) and 4K words of program Read Only Memory (ROM). Also on board are two serial ports, one of which is used to communicate with the display panel. The other serial port is unused.

The ADV11-C Analog Input board can sample up to eight channels using differential inputs with 12 bit resolution. Only five of the eight channels are used in this application. The important feature of this board is the programmable gain (1X, 2X, 4X or 8X) which enables the low level signals to be accurately digitized.

2.2.2 Special Purpose Parallel I/O And Switch Driver Board -

For a block diagram, see Appendix E, Special Purpose Parallel I/O and Switch Driver Board Block Diagram.

The special purpose parallel I/O and switch driver board was built in the CRC MILSATCOM lab to control the microwave switches and to display their positions. Initially, the computer control of this board was bypassed. Front panel switches provided the control. When the processor was installed, the board was designed to respond to computer control as well.

The LSI 11 Q-BUS interface of this board looks like two 16 bit parallel ports - one input (read only) and one output (read or write). The input bits are TTL levels indicating the positions of the switches, and status of the Travelling Wave Tube (TWT) amplifier. The output bits are converted to appropriate levels to drive the switches and relays. For bit assignments, see Appendix B, Special Purpose Parallel I/O Bit Assignments.

There are eight latching waveguide switches which, when switching, require two amps of current. To have all eight switch at once would require a hefty power supply. In order to minimize the power requirements, only one switch is changed at a time. A sequencer is used so that within two seconds all switches can be changed. This sequencing through the switches is done automatically by circuitry on the board and is transparent to the user.

2.2.3 Communications With Panel -

Command and display information are passed by serial link between the shelf and the display panel. The shelf communicates by the console port of MXV11 multi-function board in the LSI 11. The character-serial (asynchronous) signal passes through a Gandalf LDS 120 modem, down three floors, and through another LDS 120. The signal then enters the AY-3-1015 Universal Asynchronous Receiver/Transmitter (UART) on the communication board.

The characteristics of the asynchronous serial link are: 1200 baud data rate, 8 bits, no parity, 1 stop bit and RS232-C signal levels. All control lines are held in the active state.

For information on panel-to-shelf communications, see Appendix C, Keypad Codes.

For detailed information on the shelf-to-panel communications, see Appendix D, Communications Protocol.

2.3 COMMAND AND DISPLAY PANEL

The command and display panel consists of five numeric displays, five status displays, an AC switch and indicator LED, and a command keypad.

Three decimal digits make up each numeric display. The displays show TWT output SWR, TWT output power, TWT input power, LO power for upconverter, and LO power for downconverter.

The status displays are green LEDs below the numeric displays. They indicate TWT AC power on, TWT ready, TWT RF switched on, all waveguide switches set, and system ready.

The command keypad functions are described in Appendix C, Keypad Codes.

2.3.1 Installation And Configuration Information -

The only configurable option is the baud rate of the communications board. The switch settings are detailed in Appendix F, Communications Board Schematics.

The RS232-C interface on the back looks like a terminal (DTE). Both Request To Send (RTS pin 4) and Data Terminal Ready (DTR pin 20) are pulled high. The interface is as detailed in Section 2.2.3, Communications with Panel.

2.3.2 Front Panel Operation -

For a diagram of the front panel, see Figure 2.1, Front Panel.

Upon power up, all displays are set to zero and the status LEDs are turned off. The default mode is LES 8, receive only, using the dish. The LO power levels are monitored and the TWT is off.

To change modes, push the appropriate mode button (any of the eight LES 8/9 buttons or the local loopback) followed by the GO button. If the wrong button is pushed, press CLR KEY and start again.

If a receive only mode (green buttons) is chosen, the TWT displays will show OFF. The waveguide switches will then be set. Successful setting of the switches will cause the SWITCHES SET light to go on. If, after a minute, the light is not on then there is a problem on the shelf. After the switches are set, the SYSTEM READY light should come on to indicate that the TWT and switches are all properly configured. The shelf is now ready for operation.

If a transmit mode (pink buttons) is chosen, all displays will become active. As with receive only mode, the SWITCHES SET light indicates that the waveguide switches are properly set. The transmit mode requires the Hughes TWT amplifier which needs a five minute warm up period. After the switches are set, the TWT is turned on (AC ON light). If it was in standby (AC ON, TWT READY already lit), it will be ready right away, otherwise there is a five minute wait for the READY light. When it is ready, the RF is switched on. Now the system is properly configured and ready to operate, so the SYSTEM READY light is turned on.

When switching into a receive only mode after transmitting, the TWT is not turned completely off. Instead, it is put on standby. This is indicated by AC ON, READY lit and RF ON turned off. If it is desired to switch the TWT off from the standby mode, press the TWT OFF button. This will immediately turn off the TWT, but leave the system in the current mode.

All non-labelled keys on the keypad are inactive and ignored.

2.3.3 Communications Board -

For schematics, see Appendix F, Communications Board Schematics.

The heart of the communications board is the AY-3-1015D UART. This integrated circuit receives characters from the keypad encoder and transmits them serially to the shelf. It also receives the display information and routes the data to the display board. The baud rate is supplied by the K1135A Dual Baud Rate Generator. The rate used is 1200 baud, but the chip is DIP switch configurable for 16 different baud rates. Only one channel of the generator is required, the other is unused.

The keypad, found on the front panel, is a four by four switch matrix. This is scanned by the 74C922 Keyboard Encoder which generates four bit codes for each key press. These codes are strobed into the UART using a 74LS221 Dual Monostable Multivibrator (one-shot) to shape the strobe. The UART takes in eight bits but the keyboard encoder only generates four. This leaves four bits to be hardwired. The least significant bit (b0) is set to zero (thus only even keycodes are generated). The next four bits (b1 - b4) are connected to the keyboard encoder. The upper three bits (b5-b7) are set so that the keycodes generated start at decimal 64 (ASCII '@'). This ensures that all keycodes are printable ASCII characters.

When a break occurs, the Framing Error (FE) pin of the UART is asserted. This, combined with some gates, causes the High/Low Byte flip-flop to be reset at the end of the break. The High/Low Byte flip-flop is used to generate a strobe that latches the first byte in the High Byte latch. The flip-flop also generates a strobe for the display board that latches the entire word when the second byte is received.

The TTL signal levels to and from the UART are converted to RS232-C levels by the MC1488 Driver and by the MC1489 Receiver.

2.3.4 Display Board -

For schematics, see Appendix G, Display Board Schematics.

The display board contains the circuitry to demultiplex the display information and to display five 3-digit numbers. The information is latched on a signal from the communications board. The upper bit (b15) of the word from the latch is ignored. The next three significant bits (b12-b14) are routed to the most significant digit of the display cells. The bits (b8-b11) go to the middle digit of the display. The next four bits (b4-b7) go to the least significant digit of the display. The three bits (b1-b3) are interpreted as the display cell address. Valid values are 1 to 5. The least significant bit of the low byte (b0) is routed to the status light of the display cell.

Upon receiving a strobe from the demultiplexer, a display cell will latch the digits and the status bit. The latches drive TI 311 Hexadecimal displays. The status bit will cause the LED to turn green if set, and cause it to turn off if reset.

Also on this board is a 74LS121 Monostable Multivibrator to provide the power-up reset. This resets the 74LS373 Octal Latches used in the display cells.

For more information on the display cell addresses, see Appendix D, Communications Protocol.

2.3.5 Rear Panel And Power Supply -

For schematics, see Appendix H, Rear Panel and Power Supply Schematics.

On the rear panel is the DC power supply hardware and the DB25 connector for the RS232-C interface. The AC come in on a removable power cord, is fused and switched on the live wire, and then is connected to two DATEL power supply modules. The modules are the USM 5/5 (5V @ 5A) and the BPM 15/200 (+15V @ 200mA, -15V @ 200mA). The DC ground is connected to the third prong of the AC plug.

3 SOFTWARE

The program for the controlling computer, POWMON, is stored entirely in 4K words of ROM on the MXV11 Multifunction Board. The source was written in PDP 11 assembler language using an RT 11 operating system.

In general, the design of the software was not limited by space, capabilities or time. The MXV11 board can handle up to 8K words of ROM. The LSI 11 is a very powerful processor and was not required to use its full capabilities. Also, the displaying of the power levels is not a time critical task. In summary, the design of the power level monitoring system was without major constraints.

A program listing can be found in Appendix I, ROM Program Listing. This listing contains many comments that will complement the software description.

3.1 PROGRAM CODING METHODS

The original version of the program POWMON was almost exclusively written in MACROs. MACROs look similar to subroutines, but cause inline code to be generated at assembly time. These constructs are assembly language analogues of the ADA generics. Unfortunately, due to the limitations of the assembler, small changes in the program often caused assembler errors (this was due to the length limit on local symbol blocks). Another problem was that the program used almost all of the available 4K word ROM space (up to 8K words could be used, but the ROMs required would be more expensive and harder to program).

The difficulties incurred in updating the program forced a rewriting of the code. The major change was that many of the functions previously implemented by use of MACROs were done using subroutines. This had the advantage of decreasing the memory requirement and facilitating updates. MACROs are complex assembler structures and are not easy to interpret even for advanced programmers. The conversion to subroutines improved the readability of the code.

3.2 MODE AND COMMAND SELECTION

When a key is pressed on the front panel, an ASCII keycode is transmitted to the computer. The interrupt service routine then interprets this character. If a mode key was pressed, the associated mode pointer is saved in a memory location. If the CLR KEY was pushed, then this memory location is cleared. When the GO key is pressed, a flag is set to alert the main program to change modes. The TWT OFF key causes the previous mode to be reselected, but with the TWT turned off. All other keys are ignored.

The main program detects the flag set by GO or TWT OFF and takes appropriate action. For a transmit and receive mode, the microwave switches are set and the TWT is turned on. The program waits for the TWT to be ready before proceeding with normal monitoring. A receive mode selection puts the TWT into standby if it was on. It is turned off if the TWT OFF key was pressed. The microwave switches are set and then normal monitoring takes place.

3.3 DATA ACQUISITION AND CONVERSION

For each channel, the 'MON' MACRO invokes the 'MONSUB' subroutine. Given the channel number, the subroutine 'READ' selects the correct analog-to-digital scale and then polls the ADV11 Analog Input Board to get the value. Eight values are taken and averaged in subroutine 'MONSUB'.

These values are converted by direct table lookup in subroutine 'LOOKUP' to dBm power levels. The results are checked by 'CHECK' to ensure they are within design limits. If not, 'CHECK' turns off the TWT amplifier to protect it from damage. This is readily visible on the display as the TWT AC ON status light will go off.

The reflected power measurements are not used directly. The difference (in dB) between the output power and reflected power is used to calculate the SWR ratio by table lookup. This

SWR is checked to ensure it is within limits as specified by the Hughes TWT manual.

The lookup tables can be found in the end of the software listing of Appendix I, ROM Program Listing. The tables are graphically depicted in Appendix A, Microwave Detector Calibration.

3.4 DATA AND STATUS DISPLAY

After the values have been calculated, they are converted to BCD. When in receive only mode, the TWT power measurements are not displayed. The letters "OFF" are shown in the display to indicated that the TWT is off. The status bit and display address are tacked onto the word by subroutine 'ADR'. The status bits are stored in an array called 'LIGHTS', and are turned on by the MACRO 'LIGHT', off by the MACRO 'DARK'. The program continually loops through the data acquisition, conversion and display unless interrupted by a mode change command.

4 CONCLUSION

This system has been in operation in the final form since June 1983. During this time, it has performed as designed and successfully facilitated reconfiguration and trouble shooting of the EHF ground terminal.

One possible improvement would be to add a reset key to the keypad. When the program is waiting for the TWT to be ready, all mode changes are ignored. If one wants to changes the mode (maybe the wrong button was pressed), one has to wait the five minutes for the TWT to warm up. A reset key would bring the program out of this waiting loop.

Another improvement would be to enlarge the lookup tables to have finer steps in the numeric display. An alternate solution would be to use the existing tables to interpolate.

APPENDIX A

MICROWAVE DETECTOR CALIBRATION

There are five microwave detectors on the shelf. They measure:

1.	Downconverter Local Oscillator Power	12.380 GHz
2.	Upconverter Local Oscillator Power	12.580 GHz
3.	TWT Input Power	36.840 GHz
4.	TWT Output Power	36.840 GHz
5.	TWT Output Reflected Power	36.840 GHz

Though the LOs have slightly different frequencies, their calibration curves are identical. Thus, there is only one LO calibration required.

The four graphs, Figures A1.1 to A1.4, depict the lookup tables used in the software. They take into account all the coupling attenuation and give direct power levels based on the Analog to Digital conversion count. This count is proportional to the voltage put out by the detectors.

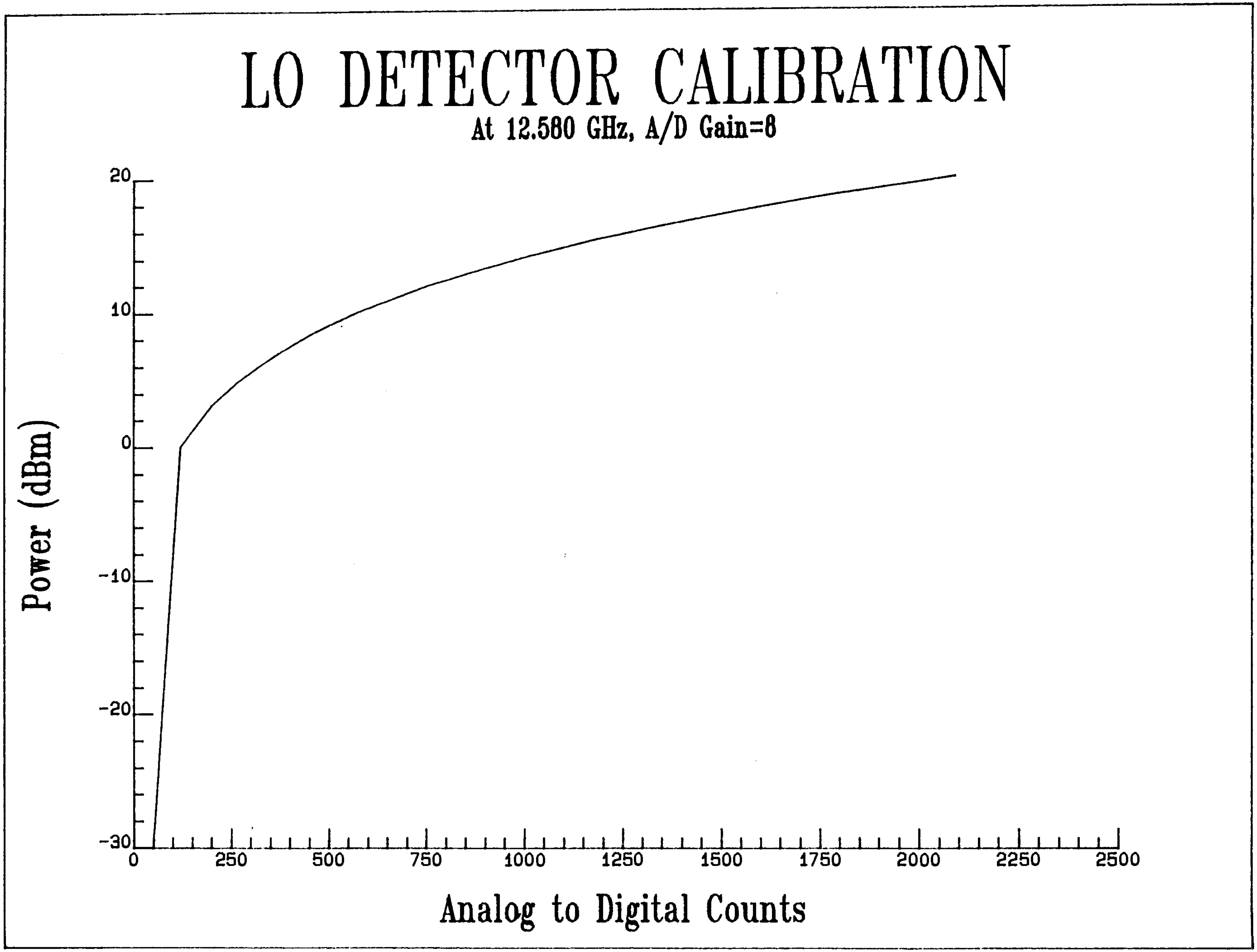

Fig. A1.1 LO Detector Calibration

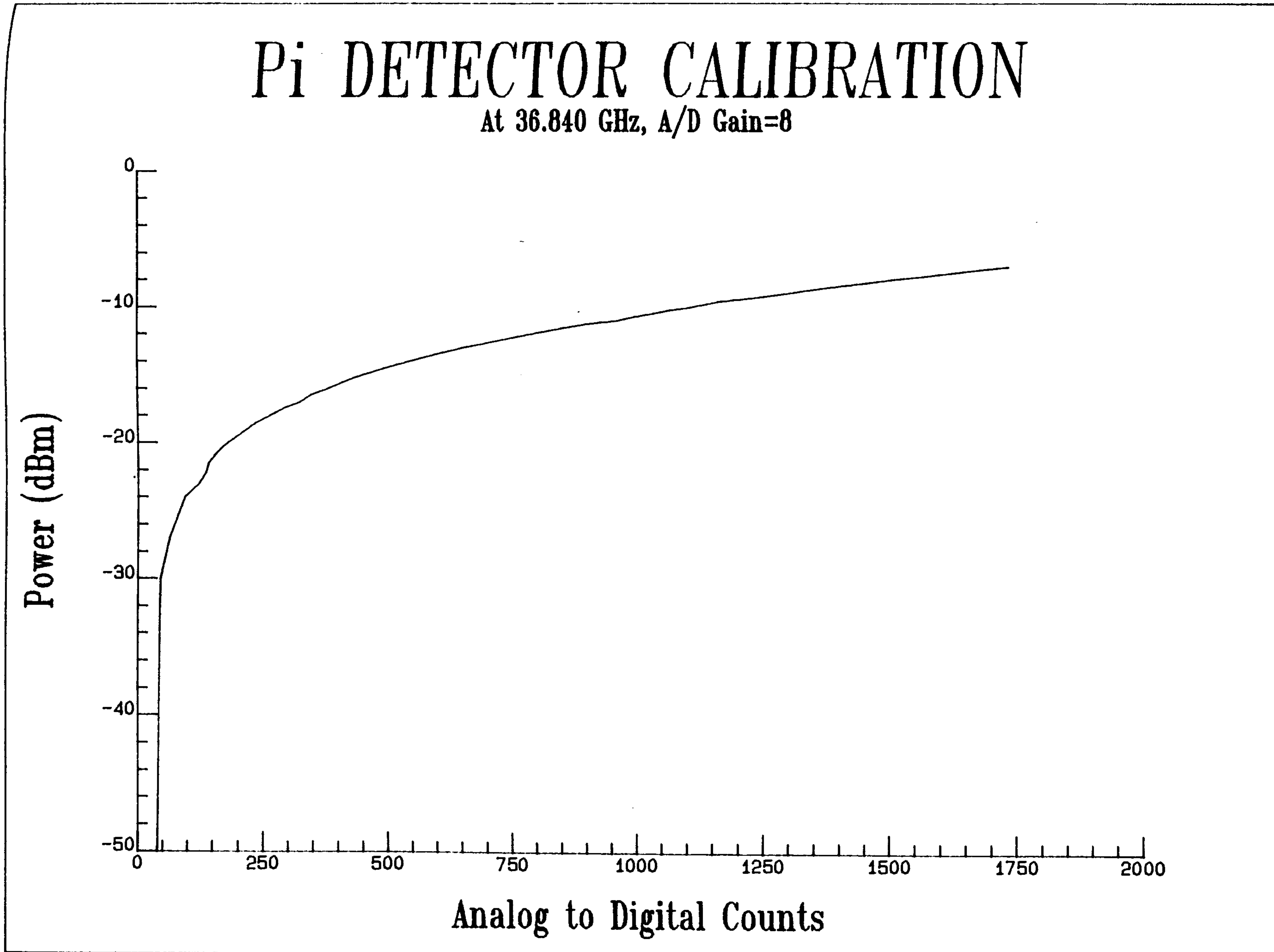

Fig. A1.2 P_i Detector Calibration

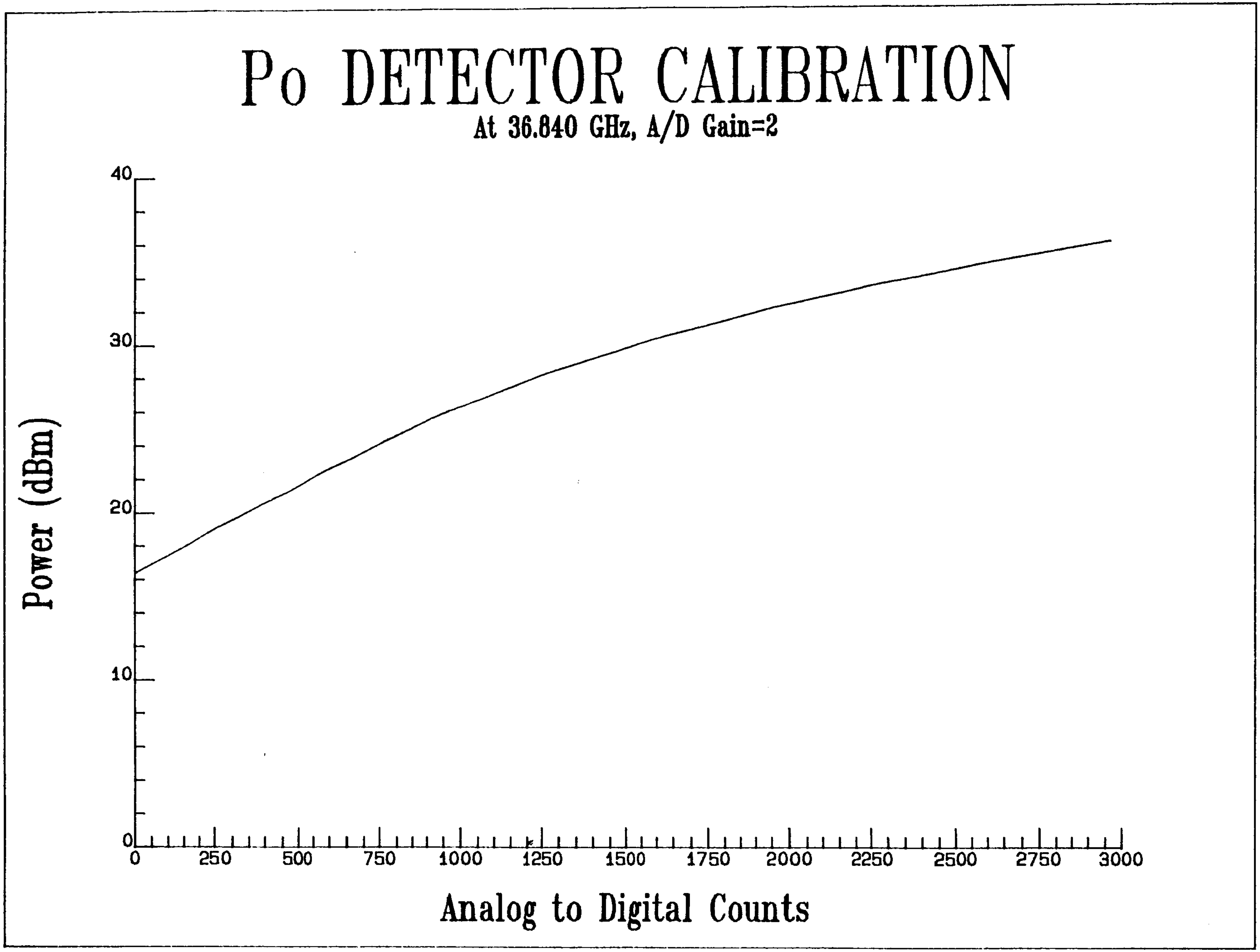

Fig. A1.3 Po Detector Calibration

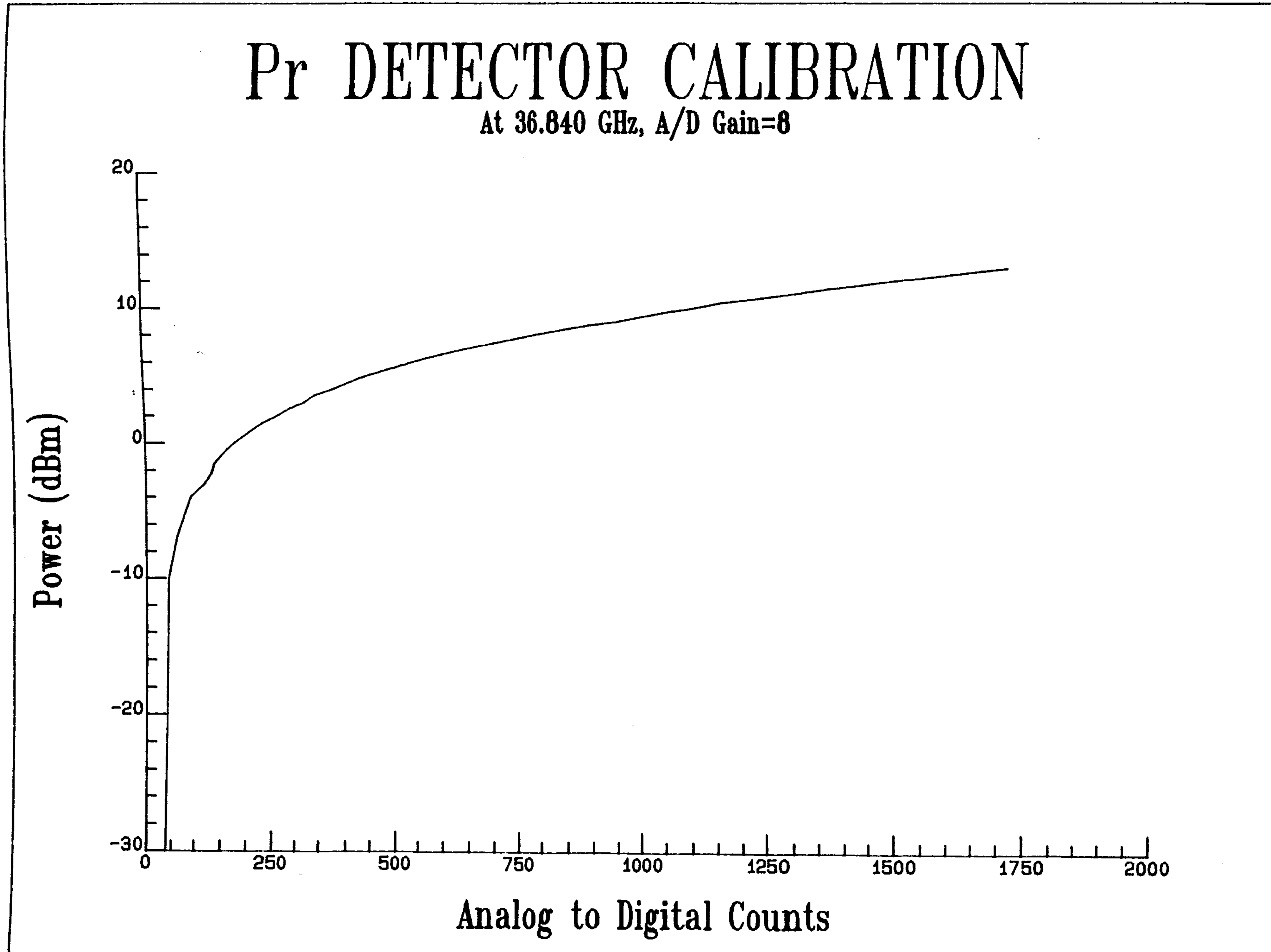

Fig. A1.4 Pr Detector Calibration

APPENDIX B

SPECIAL PURPOSE PARALLEL I/O BIT ASSIGNMENTS

The output port assignments are:

bits 0-6	0 = LES 8	1 = LES 9
bit 7	0 = normal	1 = loopback
bits 8-9	0 = dish	1 = horn
bit 10	0 = LES 8	1 = LES 9
bit 11	0 = normal	1 = loopback
bit 12	-unassigned-	
bit 13	0 = WJ AC off	1 = WJ AC on
bit 14	0 = TWT AC off	1 = TWT AC on
bit 15	0 = TWT RF off	1 = TWT RF on

To select LES 8 or LES 9 operation, all applicable bits must be set to the LES 8 or LES 9 mode and the loopback bits (b7 & b11) must be put to normal. To select local loopback, the LES 8/LES 9 bits (b0-b6 & b10) must be set to LES 8 and the loopback bits must be set to loopback.

Bit 13 turns on the Watkins-Johnson amplifier. Bit 14 turns on the Hughes Travelling-Wave Tube amplifier. The TWT RF (b15) must be set in all modes that transmit.

The input port bit assignments are feedbacks from the switches for bits 0-13. Their interpretation is the same as the output port. Bit 14 indicates the TWT ready and bit 15 is unassigned.

APPENDIX C

KEYPAD CODES

Code(Decimal,ASCII)	Key	Meaning
Mode Keys		
64, @	8 <- (	LES 8, Receive only, Dish
66, B	8 (->	LES 8, Transmit and receive, Dish
68, D	8 <- <	LES 8, Receive only, Horn
70, F	8 < ->	LES 8, Transmit and receive, Horn
72, H	9 <- (	LES 9, Receive only, Dish
74, J	9 (->	LES 9, Transmit and receive, Dish
76, L	9 <- <	LES 9, Receive only, Horn
78, N	9 < ->	LES 9, Transmit and receive, Horn
80, P	---\ <---/	Local loopback mode
-unused- 82-86		Unallocated
Command Keys		
88, X	GO	Change mode to last pressed key
90, Z	CLR KEY	Clear last pressed mode key
-unused- 92		Unallocated
Command Key		
94, ^	TWT OFF	Turn off TWT (TWT is left in standby when not in use)

The code (or its ASCII representation) is the byte generated by the UART and sent to the shelf when the key is pressed. Note that no odd numbered codes are generated and that all codes are printable ASCII characters.

Mode keys must be terminated with the GO key to take effect. Modes are either green (receive only mode) or pink (transmit/receive mode).

Command keys (all yellow keys) are acted upon immediately.

All unlabelled keys are inactive and ignored.

APPENDIX D

COMMUNICATIONS PROTOCOL

Each display consists of three BCD digits. This means that 12 bits are required for the numeric display. If one bit is assigned to the status light, that leaves three bits to address the display. Actually, only 11 bits are used for the numeric display. The most significant digit can only take on values 0 to 7.

Each display modification consists of four 8 bit bytes - high byte, low byte and then two guard bytes. The messages are interpreted as follows:

High byte	
bits 0-3	Middle digit (BCD encoded)
4-6	Most significant digit (3 bits only)
7	Ignored by communications board
Low byte	
bit 0	Status light
1-3	Display address (1-5)
4-7	Least significant digit (BCD encoded)
Guard byte	
bits 0-7	all 1s
Guard byte	
bits 0-7	all 1s

One guard byte is necessary to allow the latch circuitry to return to initial state prior to the next update. The other byte is used to ensure an even number of bytes (for the High/Low Byte flip-flop).

Prior to sending a set of five new values, a break is sent. This causes the communications board to reset the High/Low Byte flip-flop. If the an error in the communication line caused the flip-flop to be in the wrong state (expecting a high byte when a low one is being sent), this break ensures that the flip-flop starts at the proper state.

The display addresses used are as follows:

Address	Numeric Display	Status Light
5*	Down LO Power	SYSTEM READY
1	Up LO Power	SWITCHES SET
2	TWT Pi	TWT RF ON
3	TWT Po	TWT READY
4	TWT SWR	TWT AC ON

*Address 5 originally was address 0. When a break was transmitted, it would be interpreted as a zero word for address 0 which would clear the display cell. To circumvent this problem, that display cell was reassigned to address 5. In the software, references to address 0 are interpreted as references to address 5.

APPENDIX E

SPECIAL PURPOSE PARALLEL I/O AND SWITCH DRIVER BOARD BLOCK DIAGRAM

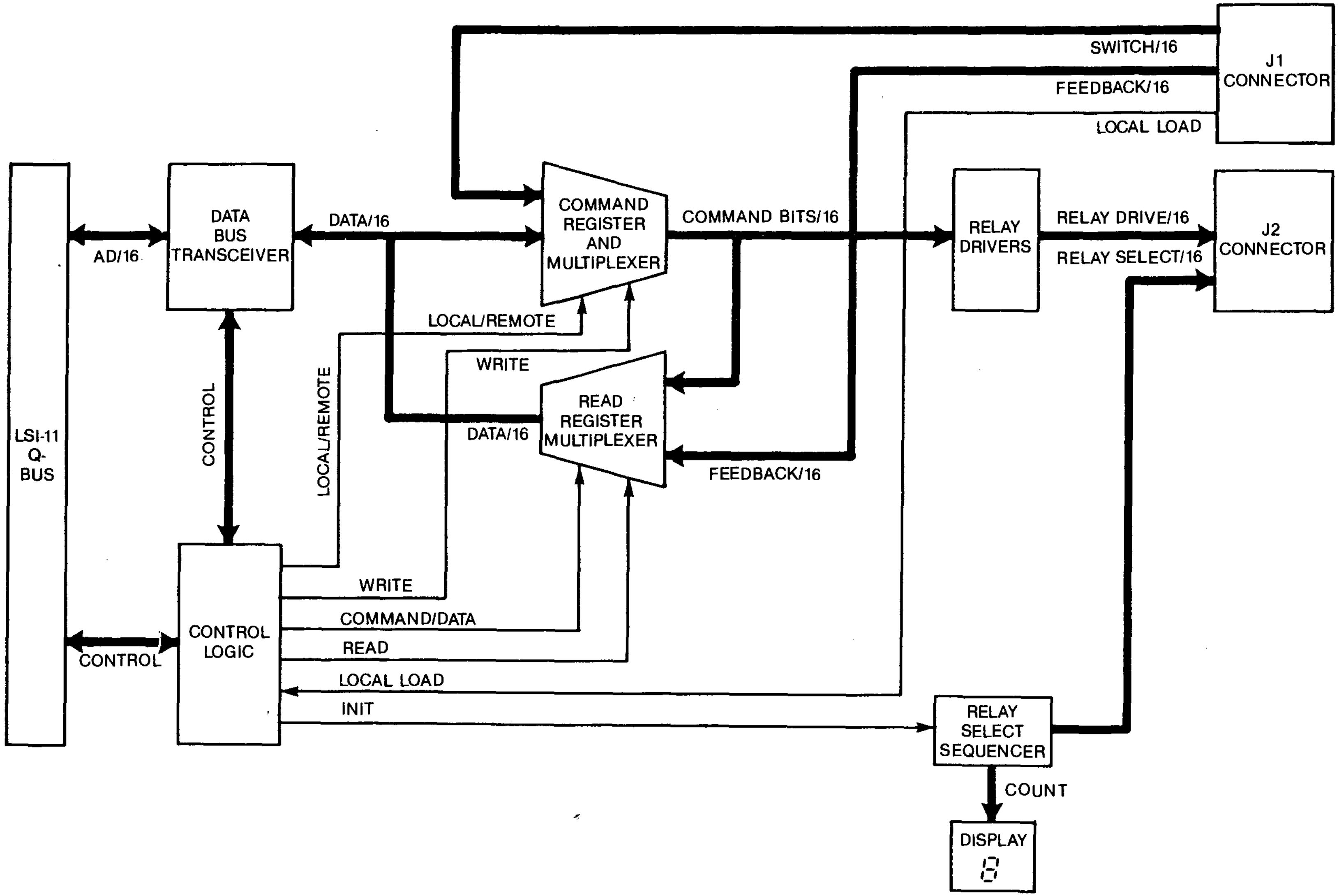

Fig. E1 Special Purpose Parallel I/O and Switch Driver Board Block Diagram

APPENDIX F

COMMUNICATIONS BOARD SCHEMATICS

Communications Board Components

Connectors:

- J4 Terminal block, 4 wide, DC power, from rear panel
- J6 8 pin socket, RS232 port, to rear panel
- J7 8 pin socket, keypad interface, to front panel
- J8 16 pin socket, parallel data, to display board
- J9 Quick release plug, power-up reset, from display board

Switches:

- S2 Keypad switch matrix, found on front panel
- S3 DIP switch, 4 wide, baud rate selector

Integrated Circuits:

- U1 MC1488P, RS232 line driver
- U2 MC1489P, RS232 line receiver
- U3 74LS221, Dual monostable multivibrators
- U4 74LS374, Octal latch
- U5 74C922, 16 key encoder
- U6 74LS74, Dual D flip-flops
- U7 74LS27, Triple 3-input NOR
- U8 74LS00, Quad 2-input NAND
- U9 AY-3-1015, UART
- U10 K1135A, Dual baud rate generator
- U11 MC7812CT, +12V regulator

Discrete Components:

- R1-R4 10kOhm, 1/4W
- C1-C8 C271K5, 270pF
- + other unlabelled resistors and capacitors on the schematics

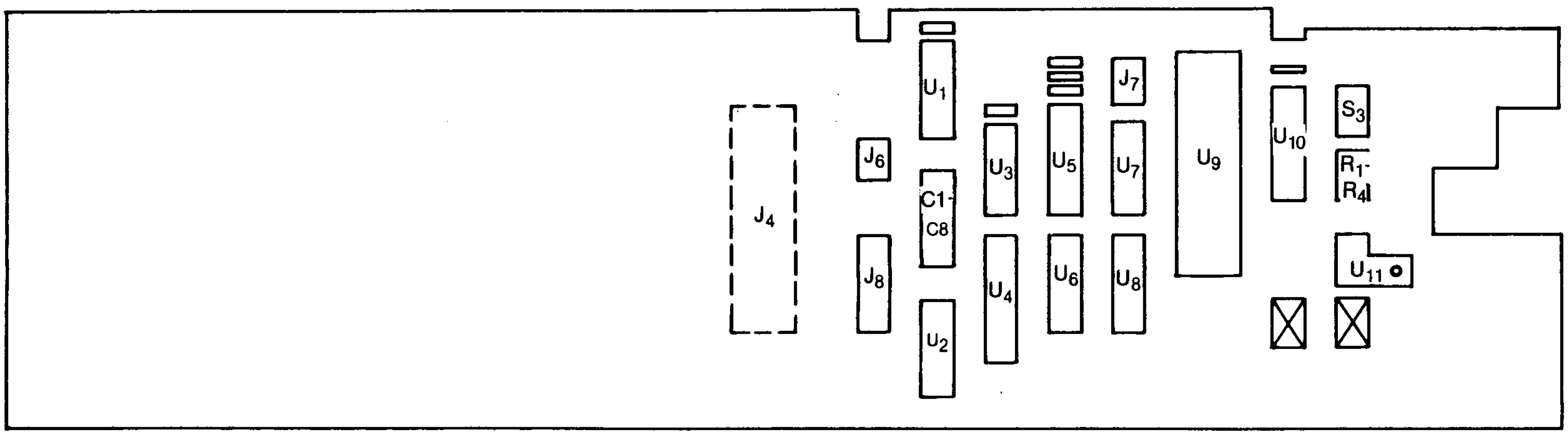

Fig. F1 Communications Board Layout

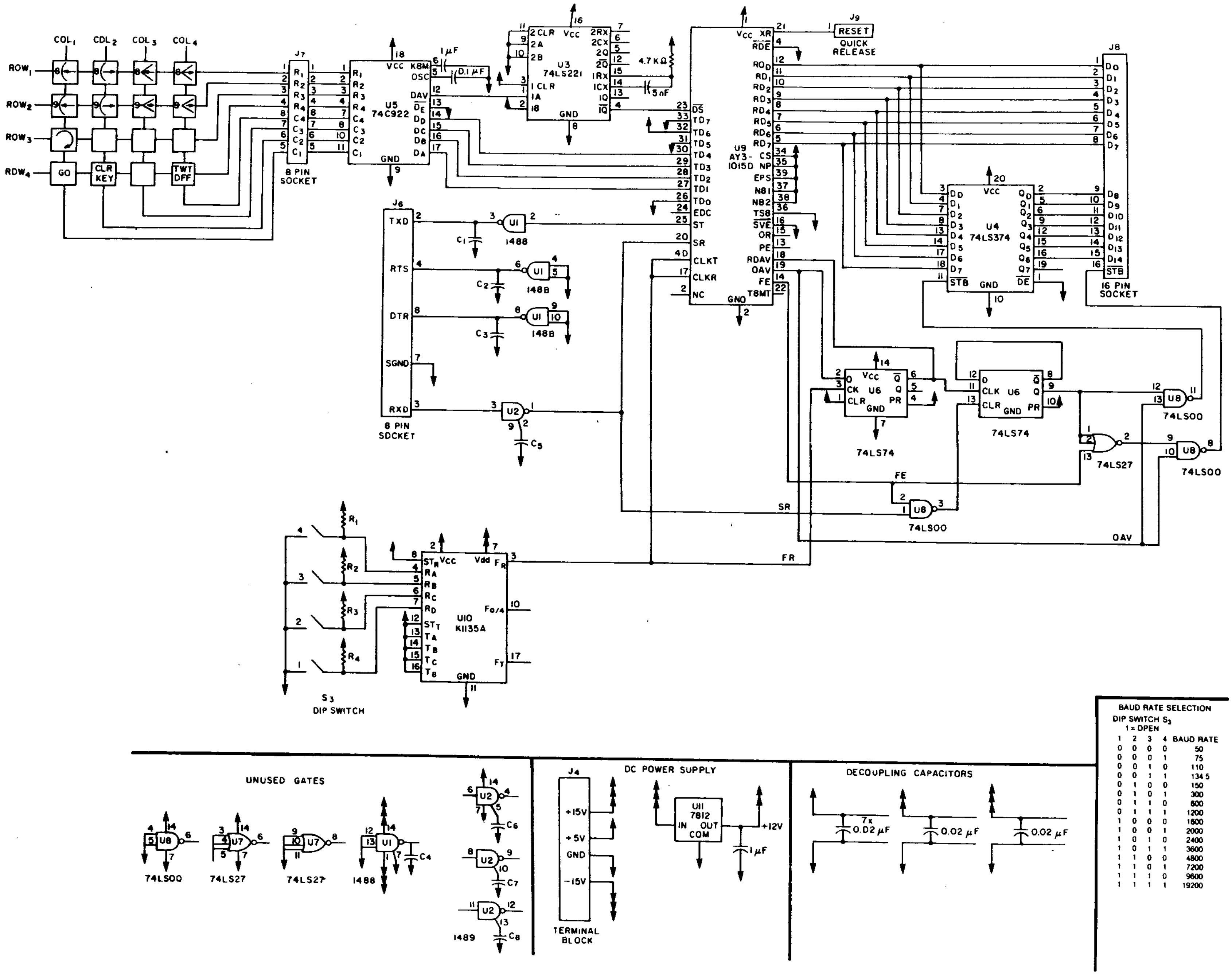

Fig. F2 Communications Board Schematic

APPENDIX G

DISPLAY BOARD SCHEMATICS

<u>Display Board Components</u>

Connectors:
- J5 Terminal block, 2 wide, DC power, from rear panel
- J8 16 pin socket, parallel data, from communications board
- J9 Quick release plug, power-up reset, to comm. board

Integrated Circuits:
- U12 74LS374, Octal latch with tristate outputs
- U13 7404, Hex inverters
- U14 74LS374, Octal latch with tristate outputs
- U15 74LS138, 3 to 8 line decoder
- U16 74LS08, Quad 2-input AND
- U17 SE555N, Timer
- U18 7432, Quad 2-input OR
- U19 74121, Monostable multivibrator
- U20-U24 7400, Quad 2-input NAND
- U25-U29 74LS373, Octal latch with clear
- U30-U34 74LS373, Octal latch with clear

Display Elements:
- L1-L5 Red/Green bidirectional LEDs, indicate status
- L6-L10 TIL311, Hexadecimal displays with logic
- L11-L15 TIL311, Hexadecimal displays with logic
- L16-L20 TIL311, Hexadecimal displays with logic
- L21 Bar LED DIP, 2-wide, used as minus sign
- L22 Red LED, used as AC power indicator

Discrete Components:
- R5 1615-391G, Resistor DIP, 390 Ohms x 15, common pin
- R6 1413-331G, Resistor DIP, 330 Ohms x 13, common pin
- + other unlabelled resistors and capacitors on the schematics

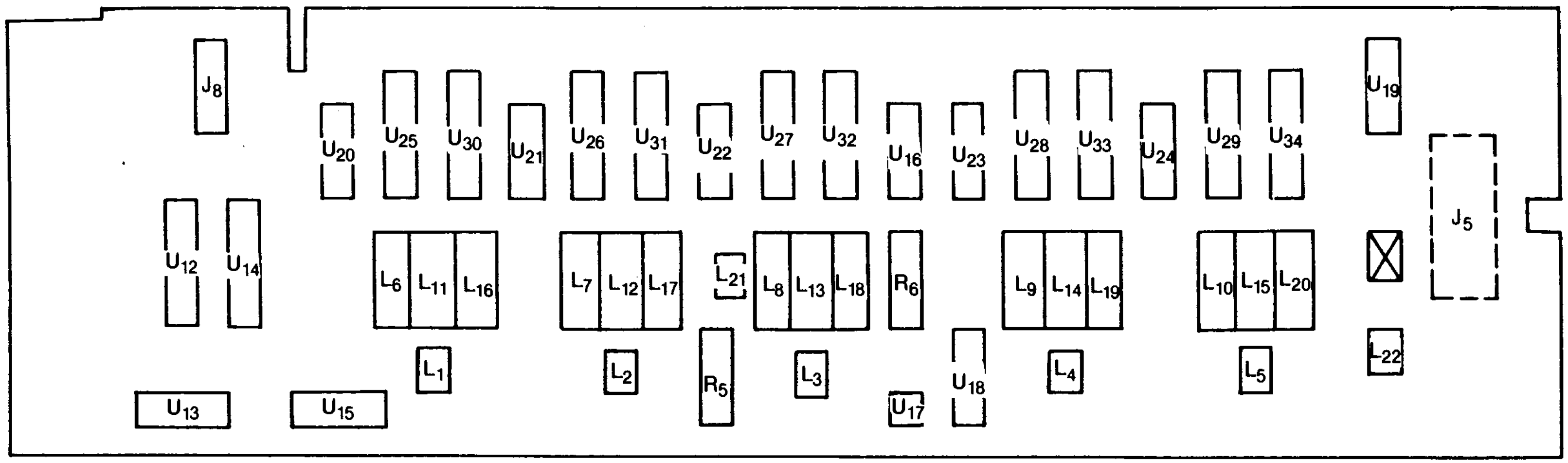

Fig. G1 Display Board Layout

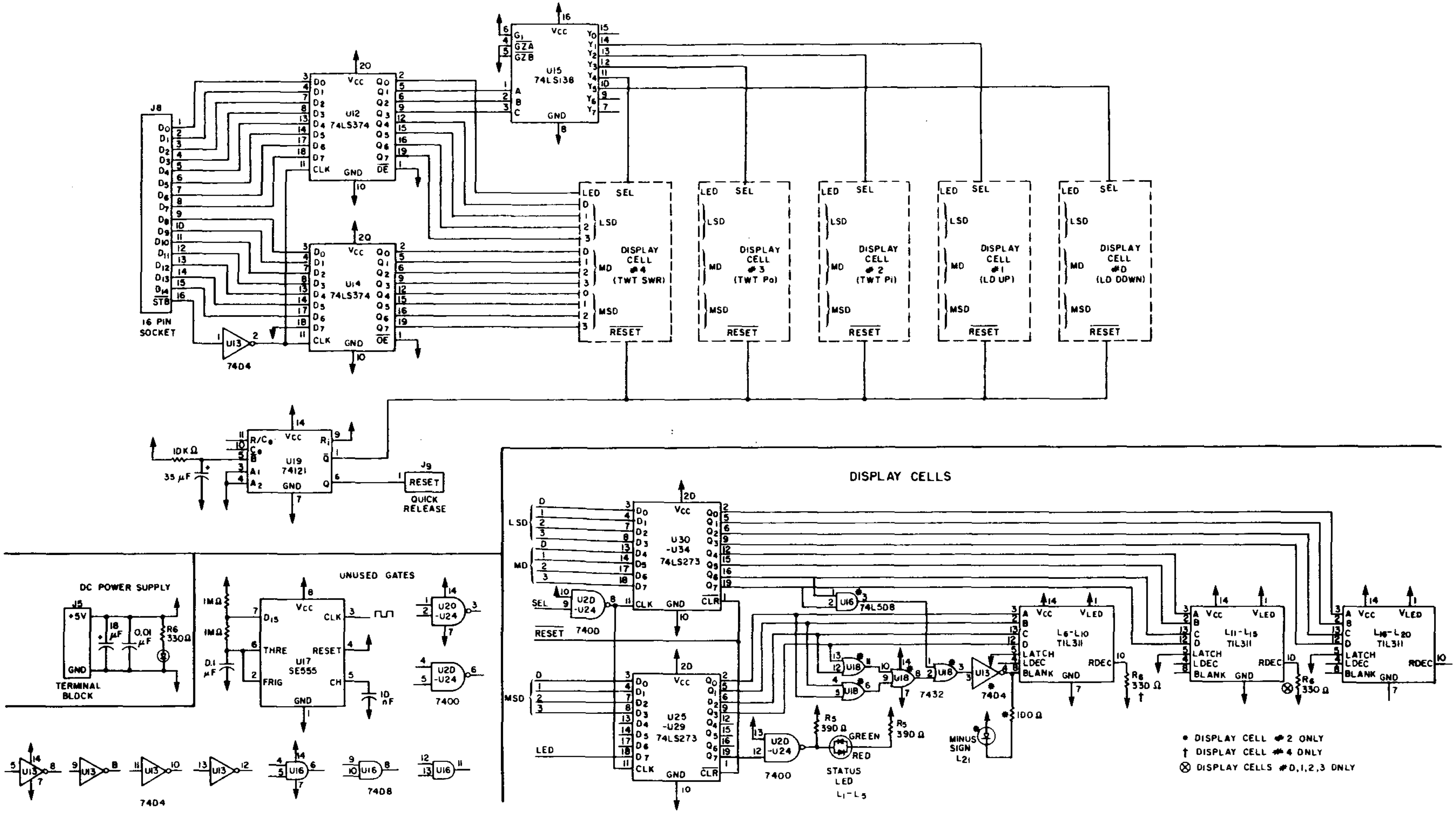

Fig. G2 Display Board Schematic

APPENDIX H

REAR PANEL AND POWER SUPPLY SCHEMATICS

Rear Panel and Power Supply Components

Connectors:

J1 AC receptacle
J2 DB25 female, for RS232 port, looks like a DTE
J3 Quick release plugs(2), to AC switch on front panel
J4 Terminal block, 4 wide, DC power, to communications board
J5 Terminal block, 2 wide, DC power, to display board
J6 8 pin socket, for RS232 port, from communications board

Switches:

S1 Toggle switch, SPDT, for switching AC, on front panel

Fuses:

F1 250V @ 1A, AC power

Power Supply Modules:

M1 USM-5/5, 5V @ 5A
M2 BPM-15/200, +/-15V @ 200mA

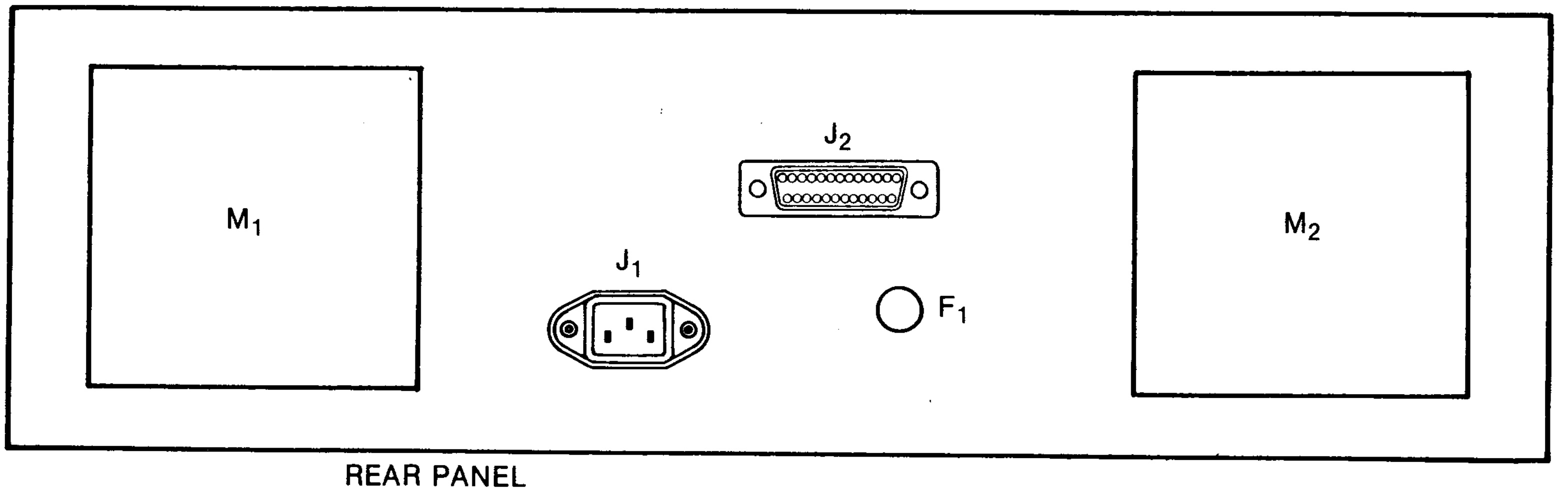

Fig. H1 Rear Panel Layout

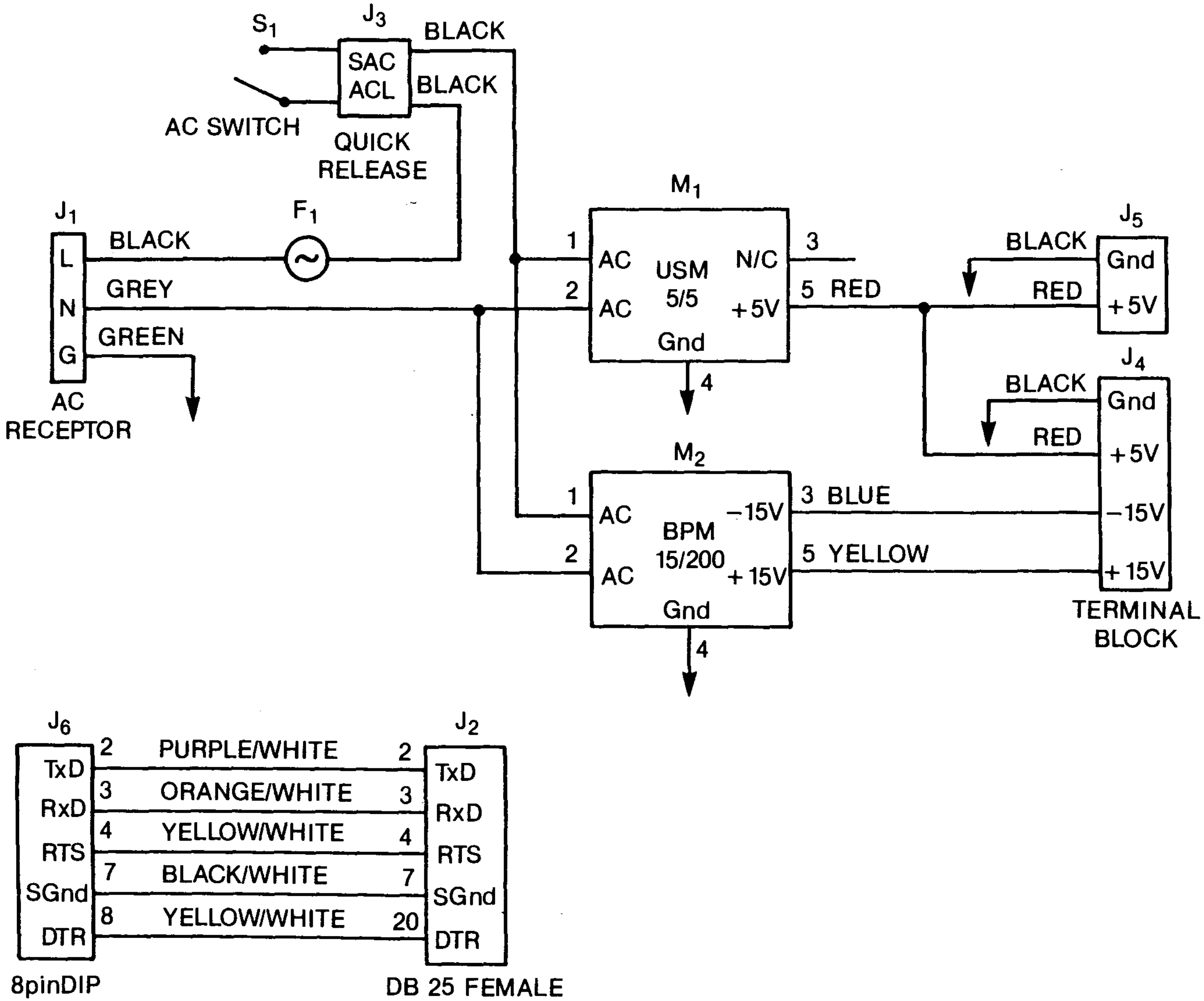

Fig. H2 Rear Panel and Power Supply Schematic

APPENDIX I

ROM PROGRAM LISTING

```
.TITLE POWMON - VERSION 1 REV04   29 Jun 83

;************************************************************************
;
                                        ;REV04 generated by Robin Addison
                                        ;                  29 Jun 83
                                        ;CHANGES:  1.  Use the AXV-11 board for
                                        ;          A/D and use a lookup table
                                        ;          to produce dBm.
                                        ;          2.  Use modified interface
                                        ;          front panel and respond to
                                        ;          keypad.
                                        ;          3.  Rewrite of main code to
                                        ;          improve program flow.
                                        ;          4.  Reformatting of code and
                                        ;          comments to improve readability.
;
;************************************************************************
;
                                        ;REV03 GENERATED BY DAVE SIM 1983-05-03
                                        ;CHANGES: LEAVE TWT AC POWER ON AFTER
                                        ;         FIRST TIME SELECTED.
                                        ;         CNTL/R CLEARS THIS FUNCTION
                                        ;         NEXT TIME RX MODE SELECTED.
;
;************************************************************************
;
                                        ;REV02 GENERATED BY DAVE SIM 1983-04-29
                                        ;CHANGES: REMOVE SOME JUMPS IN FLOW
                                        ;         ADD MORE FEEDBACK MESSAGES
;
;************************************************************************

                                        ;REV01 GENERATED BY DAVE SIM 1983-04-18
                                        ;ADDITIONS: TRAP CATCHERS
                                        ;           STACK SETUP
                                        ;           INTERRUPT SVC FOR KBD
                                        ;           TRANSLATE DEFAULTS TO LES8
                                        ;              DISH CROSSLINK RECEIVER

;************************************************************************
```

```
;===========================================================================
;       This file contains source code for the interactive power level
; monitoring system. Information on the desired mode of operation is entered
; via the keypad.  The program sets various switches to achieve that mode,
; checks these settings and changes over to power monitor mode. In this mode
; of operation a display is updated with five items:
;           (1)  TWT Output Power
;           (2)  TWT Input  Power
;           (3)  TWT VSWR
;           (4)  LO Up Power
;           (5)  LO Down Power
;
;              """"""""""""""""""""""""""""""""""""""""""
;              "   Writer:  Mike Colven    "
;              "                           "
;              "   For:     EHF SatCom     "
;              "                           "
;              "   Date:    Sept. 82       "
;              """"""""""""""""""""""""""""""""""""""""""
;
;
;---------------------------------------------------------------------------
```

```
;==========================================================================
;                               DECLARATIONS
;--------------------------------------------------------------------------

POWER   = %4
OFFPOW  = 377
NOMASK  = 0
SWREG   = 170000                ;PATCH TO 130000 FOR TESTING
FBREG   = 170002                ;PATCH TO 130000 FOR TESTING
DISP    = 177566

TXCSR   = 177564                ;Communications interface -
TXBUF   = 177566                ; Tx to display panel
RXCSR   = 177560                ; Rx from keypad
RXBUF   = 177562

ADCSR   = 170400                ;Analog to digital converter
ADBUF   = 170402
DAABUF  = 170404
DABBUF  = 170406
ADGO    = 1
SCALE2  = 4
SCALE8  = 14

RX      = 000000                ;Switch register definitions
TX      = 160000
TRANLA  = 004200
DISH    = 000000
HORN    = 001400
LES8    = 000000
LES9    = 002177
TWTBIT  = 160000
TWTRF   = 100000
TWTAC   = 040000
TWTRDY  = 040000
WJON    = 020000

;==========================================================================
;                  INITIALIZE TRAP AND INTERRUPT AREAS
;--------------------------------------------------------------------------

        .ASECT

        .       = 4
        .WORD   .+2,HALT                ;Time out
        .WORD   .+2,HALT                ;Reserved
        .WORD   .+2,HALT                ;BPT
        .WORD   .+2,HALT                ;IOT
        .WORD   1000,340                ;Power fail

        .       = 60                    ;Console
        .WORD   KBINTR,340

        .       = 100                   ;Clock
        .WORD   .+2,RTI

        .CSECT
```

```
;=====================================================================
;                          MACRO DEFINITIONS
;---------------------------------------------------------------------

.MACRO  BCD     POWER,?STEP             ;Converts the binary POWER to a
        CLR     R1                      ; BCD representation
        TST     POWER
        BGE     STEP
        NEG     POWER
STEP:   COUNT   POWER,#100.             ;Find the hundreds
        SHFT4   R1
        COUNT   POWER,#10.              ;Find the tens
        SHFT4   R1
        COUNT   POWER,#1                ;Find the ones
        MOV     R1,POWER
.ENDM


.MACRO  COUNT   A,B,?LOOP,?ST           ;Finds the number of Bs in A
LOOP:   CMP     A,B                     ; ie:  (R1) = INT(A/B)
        BLT     ST
        INC     R1
        SUB     B,A
        BR      LOOP
ST:
.ENDM


.MACRO  DARK    X                       ;Macro to turn off light X
        MOV     #X,R0
        ASL     R0
        CLR     LIGHTS(R0)
        MON     X
.ENDM


.MACRO  LIGHT   X                       ;Macro to turn on light X
        MOV     #X,R0
        ASL     R0
        MOV     #1,LIGHTS(R0)
        MON     X
.ENDM


.MACRO  MON     DISN                    ;Macro invokes the monitoring
        MOV     #DISN,R2                ; subroutine
        CALL    MONSUB
.ENDM
```

```
.MACRO  MDS     A                ;This macro is used to move information to
        MOV     A,R5             ; the display.
        SWAB    R5
        CALL    DISEND           ;Send high byte
        SWAB    R5
        CALL    DISEND           ;Send low byte
        MOV     #177,R5          ;Send two FFH to clear latches
        CALL    DISEND
        CALL    DISEND
.ENDM


.MACRO  OFF     DISN             ;This macro moves the word 'OFF' to the
        MOV     #OFFPOW,POWER    ; display.  By looking up the correct number
        MOV     #DISN,R2         ; in memory.
        CALL    ADR
.ENDM


.MACRO  PAUSE                    ;This macro forces a pause with N=229
        MOV     R0,-(SP)
        MOV     #229.,R0
        CALL    PWAIT
        MOV     (SP)+,R0
.ENDM


.MACRO  SHFT4   X                ;This macro shifts left by 4
        ASL     X                ; effectively multiplying by 16
        ASL     X
        ASL     X
        ASL     X
.ENDM
```

```
;=========================================================================
;                           MAIN PROGRAM
;-------------------------------------------------------------------------

START:   CLR     TWTFLG          ;Begin with TWT flag off
RESTRT:  CLR     @#RXCSR         ;Ensure no interrupts
         CLR     CMDRDY          ;Fake KBD ready bit
         CLR     CMDWRD          ;Fake KBD data
         MOV     #120000,SP      ;Set up stack in RAM area
         CLR     R0
         MTPS    R0              ;Clear processor status
         TSTB    @#RXBUF         ;Clear ready bit
         MOV     #100,@#RXCSR    ;Enable keypad interupts

MAIN:    CLR     LIGHT0
         CLR     LIGHT1
         CLR     LIGHT2
         CLR     LIGHT3
         CLR     LIGHT4

         CLR     RFON                    ;TWT RF on flag
         INC     RFON                    ;Set it for startup monitoring

         MOV     #1,DSBUF                ;Clear display panel
         MOV     #17,@#DISP
         CALL    DOBRK                   ;Output break to reset display
INIT:    MDS     DSBUF
         ADD     #2,DSBUF
         CMP     DSBUF,#17
         BLT     INIT
         MOV     #1,DSBUF

;        Begin power monitoring and check for keypad input

MONIT:   TSTB    CMDRDY          ;Keypad hit?
         BMI     1$
         JMP     TEST            ;No - monitor mode
1$:      CLR     CMDRDY          ;Yes - clear flag
         TST     CMDWRD          ;Put in command lookup offset
         BMI     2$              ; if CMDWRD=-1 then use previous command
         MOV     CMDWRD,TABIN
2$:      DARK    0               ;Turn off all lights
         DARK    1
         DARK    2
         DARK    3
         DARK    4
         CMP     TABIN,#16.
         BEQ     TXSET
         BIT     #2,TABIN
         BNE     TXSET

RXSET:   CLR     RFON            ;Receive mode only
         CALL    SWISET
         CALL    TWTOFF
         LIGHT   0               ;Turn on SYSTEM READY light
         JMP     RXMON
```

```
TXSET:  MOV     #1,RFON         ;Transmit or translate mode
        CALL    SWISET
        CALL    TWTON
        LIGHT   0               ;Turn on SYSTEM READY light
        JMP     TXMON

TEST:   TST     RFON            ;Is Tx flag set?
        BEQ     RXMON           ;No - Rx monit mode
        JMP     @#TXMON         ;Yes - Tx monit mode

RXMON:  CALL    DOBRK
        CALL    BITCHK
        OFF     2               ;Display 'OFF'
        OFF     3               ; in TWT display
        OFF     4               ;  section
        MON     1               ;Read power
        MON     0               ; from LO'S
        JMP     @#MONIT         ;Loop in monitor mode

TXMON:  CALL    DOBRK
        CALL    BITCHK
        MON     2               ;Read power
        MON     3               ; from TWT input
        MON     4               ;  and output
        MON     1               ;Read power
        MON     0               ; from LO'S
        JMP     @#MONIT         ;Loop in monitor mode
```

```
;==========================================================================
;                              SUBROUTINES
;--------------------------------------------------------------------------


;
;       ADR - determines the address for a data word to the display
;
ADR:    .REPT   3                       ;Address to the BCD information that is
                ASL     POWER           ; transmitted to the display.
        .ENDR                           ;Move left three bits
        MOV     R2,R3                   ;If channel 0, send out to display
        TST     R3                      ; address 5 - change in wiring
        BGT     1$
        MOV     #5,R3
1$:     ADD     R3,POWER                ;Append the display address to POWER
        ASL     POWER
        MOV     R2,R3
        ASL     R3
        ADD     LIGHTS(R3),POWER                ;Set light bit
        MDS     POWER
        RETURN


;
;       BITCHK - ensures the LIGHT registers reflect the status of the
;                feedback bits
;
BITCHK: MOV     @#FBREG,FBBUF
        CLR     LIGHT4                  ;Check AC ON
        BIT     #WJON,FBBUF
        BEQ     1$
        MOV     #1,LIGHT4
1$:     CLR     LIGHT3                  ;Check READY
        BIT     #TWTRDY,FBBUF
        BEQ     2$
        MOV     #1,LIGHT3
2$:     CLR     LIGHT2                  ;Check RF ON
        BIT     #TWTRF,FBBUF
        BEQ     3$
        MOV     #1,LIGHT2
3$:     RETURN
```

```
;
;       CHECK - ensures that the values sampled are within acceptable limits
;
CHECK:  BR      CHKOK
        CMP     R2,#4
        BEQ     CHKSWR
        CMP     R2,#2
        BNE     CHKOK
CHKPI:  CMP     POWER,#20.              ;Maximum is -2.0dB
        BLE     CHKBAD                  ;Note Pi is negative at display
        BR      CHKOK                   ; but not in storage
CHKSWR: TST     OLDPO                   ;If no output power, do not check SWR
        BEQ     CHKOK
        CMP     POWER,#150.             ;Maximum is 1.50
        BGE     CHKBAD
        BR      CHKOK
CHKBAD: MOV     TABIN,R1
        MOV     LMTBL(R1),LMBUF
        BIC     #TWTBIT,LMBUF
        MOV     LMBUF,@#SWREG
CHKOK:  RETURN


;
;       DISEND - send byte to display
;
DISEND: TSTB    @#TXCSR         ;Send the lower byte of R5 to the serial line
        BPL     DISEND
        MOVB    R5,@#DISP
        RETURN



;
;       DOBRK - outputs break to display
;
DOBRK:  MOV     #200.,R0                ;Wait to ensure all characters sent
        CALL    PWAIT
        BIS     #1,@#TXCSR              ;Start break
        MOV     #80.,R0                 ;Wait a period
        CALL    PWAIT
        BIC     #1,@#TXCSR              ;End break
        MOV     #200.,R0                ;Wait to ensure line up for stop bits
        CALL    PWAIT
        RETURN
```

```
;
;       LOOKUP - converts sample count to actual unit values via lookup tables
;
LOOKUP: CMP     R2,#1
        BLE     LOLOOK                              ;For channels 0-1, LO lookup
        CMP     R2,#2
        BEQ     PILOOK                              ;For channel 2, TWT Pi lookup
        CMP     R2,#3
        BEQ     POLOOK                              ;For channel 3, TWT Po lookup
        CMP     R2,#4
        BEQ     PRLOOK                              ;For channel 4,  lookup
        JMP     SWRCAL                              ;For SWR calc, SWR lookup

LOLOOK: .REPT   5               ;Divide by 32
                ASR     R4
        .ENDR
        MOV     #799.,R2
        CMP     R4,#65.
        BGE     NUMRDY
        ASL     R4
        MOV     LOPWR(R4),R2
        TST     R2
        BGE     NUMRDY
        CLR     R2
NUMRDY: MOV     R2,R4
        RETURN

PILOOK: .REPT   4               ;Divide by 16
                ASR     R4
        .ENDR
        CLR     R2
        CMP     R4,#65.
        BGE     NUMRD2
        ASL     R4
        MOV     PIPWR(R4),R2
        TST     R2
        BGE     NUMRD2
        MOV     #799.,R2
NUMRD2: MOV     R2,R4
        RETURN

POLOOK: .REPT   5               ;Divide by 32
                ASR     R4
        .ENDR
        MOV     #799.,R2
        CMP     R4,#93.
        BGE     NUMRD3
        ASL     R4
        MOV     POPWR(R4),R2
        TST     R2
        BGE     NUMRD3
        CLR     R2
NUMRD3: MOV     R2,R4
        RETURN
```

```
PRLOOK: .REPT   4                  ;Divide by 16
                ASR     R4
        .ENDR
        MOV     #799.,R2
        CMP     R4,#94.
        BGE     NUMRD4
        ASL     R4
        MOV     PRPWR(R4),R2
NUMRD4: MOV     R2,R4
        RETURN

SWRCAL: .REPT   3                  ;Divide by 8
                ASR     R4
        .ENDR
        MOV     #799.,R2
        TST     R4
        BLT     NUMRD5
        MOV     #100.,R2
        CMP     R4,#64.
        BGE     NUMRD5
        ASL     R4
        MOV     SWR(R4),R2
        TST     R2
        BGE     NUMRD5
        MOV     #799.,R2
NUMRD5: MOV     R2,R4
        RETURN
```

```
;
;       MONSUB - monitoring routine, invoked by macro MON
;
MONSUB: CLR     SUMPOW
        CLR     SUMCNT
        MOV     R2,CHANNO
GETSPL: MOV     CHANNO,R2                   ;Get information from A/D converter
        CALL    READ                        ; and input to the variable power.
        ADD     R4,SUMPOW
        INC     SUMCNT
        CMP     SUMCNT,#8.
        BNE     GETSPL
        MOV     SUMPOW,R4           ;Once the total of 8 samples is available,
        ASR     R4                  ; average them.
        ASR     R4
        ASR     R4
        MOV     CHANNO,R2           ;Convert raw count to power levels
        CALL    LOOKUP

        CMP     CHANNO,#3
        BLT     DOCHK               ;No more processing on channels 0 - 2
        BEQ     TWTPO
        BGT     TWTPR

TWTPO:  MOV     R4,OLDPO            ;Save the value for later computation on SWR
        BR      DOCHK

TWTPR:  SUB     OLDPO,R4            ;Find difference between relect and output
        NEG     R4                  ; power in dB.
        MOV     #5,R2
        CALL    LOOKUP              ;Convert to SWR
        BR      DOCHK

DOCHK:  MOV     CHANNO,R2           ;Ensure that the power readings are within
        CALL    CHECK               ; safe limits.
        BCD     POWER               ;Take the number in POWER and change it to BCD
        MOV     CHANNO,R2
        CALL    ADR                 ;Display the result by appending address bits
        RETURN                      ; to the BCD information


;
;       PWAIT - waiting procedure, used between samples and for break
;
PWAIT:  CLR     R3                  ;Waiting routine.  The algorithm used is:
        INC     R3                  ;       T = K(N*N+N)/2
        CLR     R2                  ;       K = speed of ADD instruction
1$:     ADD     #1,R2               ;       N = constant to give correct pause
        CMP     R3,R2
        BNE     1$
        ADD     #1,R3
        CLR     R2
        CMP     R0,R3               ;N is the number to which R3 is compared
        BNE     1$
        RETURN
```

```
;
;       READ - takes readings
;
; This subroutine gets the A/D converted value of power from a particular
; channel indicated by disn. This is received by the A/D as a DC voltage level
; from microwave detectors.
;       R2 contains the channel number
;               0 = LO down
;               1 = LO up
;               2 = Pi to TWT
;               3 = Po of TWT
;               4 = Pr - reflected power from load
;       R4 will contain the conversion count
READ:   MOV     #SCALE8,R4                      ;Normal scale 8X for
        CMP     R2,#3                           ; channels 0-2 and 4
        BNE     1$
        MOV     #SCALE2,R4                      ; 2X for channel 3
1$:     BIS     #ADGO,R4                        ;Set go bit
        SWAB    R2                              ;Move channel number to bit
                                                ; positions 8-11
        ADD     R2,R4                           ;Set channel number
        MOV     R4,@#ADCSR                      ;Start conversion and wait
2$:     TSTB    @#ADCSR                         ; for sample
        BPL     2$
        MOV     @#ADBUF,R4
        RETURN


;
;       SWISET - sets the configurations on the shelf
;
SWISET: MOV     TABIN,R1        ;Get config word
        MOV     IMTBL(R1),IMBUF
        BIS     TWTFLG,IMBUF    ;OR in TWT bits if they were previously set
        MOV     IMBUF,@#SWREG   ;Drive switches
        BIC     #TWTBIT,IMBUF
        MOV     #TWTBIT,MASK
        CALL    WAITNG
        LIGHT   1               ;Turn on SWITCHES SET light
        RETURN


;
;       TWTOFF - turns off the TWT unless it should be in standby
;
TWTOFF: MOV     @#FBREG,FBBUF   ;Get actual configuration
        BIT     #WJON,FBBUF
        BEQ     TWTOK
WASON:  LIGHT   4
        TST     TWTFLG          ;Should TWT be standby?
        BNE     TWTOK
TURNOF: MOV     TABIN,R1        ;Get config word
        MOV     IMTBL(R1),IMBUF
        MOV     IMBUF,@#SWREG   ;Drive switches
        MOV     #NOMASK,MASK
        CALL    WAITNG
        DARK    4
TWTOK:  RETURN
```

```
;
;       TWTON - turns on the TWT for Tx or translate
;
TWTON:  MOV     TABIN,R1
        MOV     LMTBL(R1),LMBUF
        MOV     LMBUF,@#SWREG               ;Set for WJ & TWT on and RF on
TWJON:  MOV     #WJON,LMBUF
        MOV     #^C<WJON>,MASK              ;Mask off everything but WJON bit
        CALL    WAITNG
        LIGHT   4
TREADY: MOV     @#FBREG,FBBUF
        BIT     #TWTRDY,FBBUF
        BEQ     TREADY
        LIGHT   3
TRFON:  MOV     #TWTRF,LMBUF
        MOV     #^C<TWTRF>,MASK             ;Mask off everything but TWTRF bit
        CALL    WAITNG
        LIGHT   2
        MOV     #TWTAC+WJON,TWTFLG
        RETURN


;
;       WAITNG - a subroutine that waits for a switch to be set
;                   The subroutine reads the feedback register, MASKs off
;               don't care bits and compares it with LMBUF.  It does this
;               a maximum of 60 times with pauses in between.  If after
;               these 60 trys, the switches aren't set, the subroutine
;               aborts the setup procedure and jumps into the monitor mode.
;
WAITNG: CLR     R0
1$:     CMP     R0,#60.         ;60 tries?
        BEQ     TIMOUT          ;Yes - error
        INC     R0              ;Count tries
        PAUSE                   ;Wait for switches to toggle
        MOV     @#FBREG,FBBUF   ;Read position of switches
        BIC     MASK,FBBUF      ;Clear bits in mask
        CMP     FBBUF,LMBUF     ;Switches set yet?
        BNE     1$              ;No - try again
        RETURN
TIMOUT: MOV     (SP)+,R0        ;Pop off return address to TWTON/OFF or SWISET
        MOV     (SP)+,R0        ;Pop off return address to RX/TXSET
        MOV     #1,RFON         ;Ensure all points are monitored
        JMP     TEST            ;Return to monitoring but don't change lights
```

```
;===========================================================================
;                                    Interrupt routines
;---------------------------------------------------------------------------

KBINTR: CLR     @#RXCSR            ;Disable interrupts
        CLR     TEMP1
        MOVB    @#RXBUF,TEMP1      ;Fake keypad data buffer
        BIC     #200,TEMP1         ;Mask off parity bit
        BIT     #1,TEMP1           ;Ensure an even numbered key
        BNE     RETINT
        CMP     TEMP1,#64.         ;Validate keys -
        BLT     RETINT             ;        between 64 and 80
        CMP     TEMP1,#80.
        BLE     VALKEY
        CMP     TEMP1,#88.         ;GO
        BEQ     GOKEY
        CMP     TEMP1,#90.         ;CLEAR KEY
        BEQ     CLRKEY
        CMP     TEMP1,#94.         ;TWT OFF
        BEQ     TWTKEY
        BR      RETINT
VALKEY: MOV     TEMP1,CMDWRD
        SUB     #64.,CMDWRD
        BR      RETINT
GOKEY:  MOVB    #200,CMDRDY        ;Fake keypad CSR ready bit
        BR      RETINT
CLRKEY: CLR     CMDWRD
        BR      RETINT
TWTKEY: CLR     TWTFLG             ;Turn off TWT with no change to switches
        MOV     #177777,CMDWRD
        MOVB    #200,CMDRDY
        BR      RETINT
RETINT: MOV     #100,@#RXCSR       ;Enable keypad interrupts
        RTI
```

```
;===========================================================================
;                              CONSTANT AREAS
;---------------------------------------------------------------------------

LOPWR:  ;Lookup table for LO power readings

        .WORD      -600.,-60.,-27., -9.,  4., 18., 28., 38.
        .WORD        46., 53., 60., 67., 72., 78., 83., 88.
        .WORD        92., 97.,101.,105.,109.,112.,115.,118.
        .WORD       122.,125.,128.,130.,133.,136.,138.,141.
        .WORD       143.,146.,148.,150.,152.,154.,156.,158.
        .WORD       160.,162.,164.,166.,168.,170.,171.,173.
        .WORD       175.,176.,178.,179.,181.,183.,184.,186.
        .WORD       187.,188.,190.,191.,192.,194.,195.,196.
        .WORD       198.

PIPWR:  ;Lookup table for TWT power input readings

        .WORD       799.,799.,252.,195.,169.,153.,139.,133.
        .WORD       127.,114.,107.,101., 97., 93., 89., 84.
        .WORD        81., 78., 75., 73., 70., 67., 64., 62.
        .WORD        60., 57., 54., 52., 50., 48., 46., 45.
        .WORD        43., 41., 39., 38., 36., 35., 33., 32.
        .WORD        30., 29., 28., 27., 25., 24., 23., 22.
        .WORD        21., 19., 18., 17., 16., 15., 14., 13.
        .WORD        12., 11., 11., 10.,  9.,  8.,  7.,  6.
        .WORD         0.

POPWR:  ;Lookup table for TWT power output readings

        .WORD         0.,168.,173.,177.,180.,184.,187.,190.
        .WORD       193.,195.,198.,201.,205.,209.,213.,216.
        .WORD       219.,222.,225.,227.,230.,233.,237.,240.
        .WORD       243.,246.,249.,252.,254.,257.,260.,262.
        .WORD       265.,268.,270.,272.,275.,277.,279.,281.
        .WORD       284.,286.,288.,290.,292.,294.,296.,298.
        .WORD       299.,301.,303.,305.,306.,308.,310.,312.
        .WORD       313.,315.,316.,318.,319.,321.,322.,324.
        .WORD       325.,327.,328.,329.,331.,332.,334.,335.
        .WORD       336.,337.,339.,340.,341.,342.,344.,345.
        .WORD       346.,347.,348.,349.,350.,352.,353.,354.
        .WORD       355.,356.,357.,358.,359.
```

```
PRPWR:  ;Lookup table for reflected power

        .WORD    -999.,-367.,-152.,-95.,-69.,-53.,-39.,-33.
        .WORD     -27.,-14., -7., -1.,  2.,  6., 11., 15.
        .WORD      18., 21., 24., 26., 29., 32., 35., 37.
        .WORD      39., 42., 45., 47., 49., 51., 53., 54.
        .WORD      56., 58., 60., 61., 63., 64., 66., 67.
        .WORD      69., 70., 71., 72., 74., 75., 76., 77.
        .WORD      78., 80., 81., 82., 83., 84., 85., 86.
        .WORD      87., 88., 88., 89., 90., 91., 92., 93.
        .WORD      94., 95., 97., 98., 99.,100.,101.,102.
        .WORD     103.,104.,105.,105.,106.,107.,108.,108.
        .WORD     109.,110.,111.,112.,112.,113.,114.,115.
        .WORD     116.,116.,117.,118.,118.,119.

SWR:    ;Lookup table for SWR calculations

        .WORD     799.,290.,281.,272.,263.,255.,246.,237.
        .WORD     228.,219.,211.,202.,193.,184.,175.,167.
        .WORD     159.,152.,147.,141.,137.,133.,130.,128.
        .WORD     125.,123.,120.,118.,116.,114.,114.,112.
        .WORD     111.,110.,109.,108.,107.,106.,106.,105.
        .WORD     105.,104.,104.,103.,103.,103.,103.,102.
        .WORD     102.,102.,102.,101.,101.,101.,101.,101.
        .WORD     101.,100.,100.,100.,100.,100.,100.

LMTBL:  ;Lookup table for switch configurations based on command key

        .WORD   LES8+DISH+RX
        .WORD   LES8+DISH+TX
        .WORD   LES8+HORN+RX
        .WORD   LES8+HORN+TX
        .WORD   LES9+DISH+RX
        .WORD   LES9+DISH+TX
        .WORD   LES9+HORN+RX
        .WORD   LES9+HORN+TX
        .WORD   LES8+DISH+TX+TRANLA
```

```
;===========================================================================
;                 RAM AREA FOR VOLATILE MEMORY LOCATIONS
;---------------------------------------------------------------------------

        .       = START+77000

LIGHTS:                     ;Status bits for lights
LIGHT0: .WORD               ; SYSTEM READY
LIGHT1: .WORD               ; SWITCHES SET
LIGHT2: .WORD               ; RF ON
LIGHT3: .WORD               ; READY
LIGHT4: .WORD               ; AC ON
DSBUF:  .WORD               ;Location used when initializing
IMBUF:  .WORD               ;Command word to be sent
FBBUF:  .WORD               ;Feedback of switch settings
RFON:   .WORD               ;Flag - TWT required or stuck on
TABIN:  .WORD               ;Points to configuration
TWTFLG: .WORD               ;Flags TWT previously on
SUMPOW: .WORD               ;Sum of power readings
SUMCNT: .WORD               ;Count of power readings summed in SUMPOW
OLDPO:  .WORD               ;Last Po reading - used for SWR calculations
CHANNO: .WORD               ;Channel number
TEMP1:  .WORD               ;Temporary location
CMDRDY: .WORD               ;Command ready flag
CMDWRD: .WORD               ;Command key entered
MASK:   .WORD               ;Mask used by WAITNG to check bits

        .END START
```

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13. ABSTRACT

In 1981 CRAD sponsored the development of an experimental 36/38 GHz satellite communications ground terminal in order to permit further experimental work with the Lincoln experimental satellites (LES 8/9). Due to the physical separation of the RF and antenna installation from the IF and baseband equipment, it was desired to have a remote control and monitor facility for the ground terminal. This subsystem is described in this report.

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