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The Hawaiian Volcano Observatory  
Polling Telemetry System  
For Low Frequency Data Acquisition

by

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**THE HAWAIIAN VOLCANO OBSERVATORY  
POLLING TELEMETRY SYSTEM  
FOR LOW FREQUENCY DATA ACQUISITION**

**CONTENTS**

	Page No.
Introduction	3.
System Description	4.
Control System	7.
General Description	8.
Apple Interface	10.
Radio Interface	16.
Radio System	20.
Audio Monitor	22.
Remote Field System	24.
General Description	25.
Electronics Box	27.
DTMF Decoder Board	29.
Mux & Control Board	35.
VCO Board	47.
DC Convertor Board	51.
Motherboard	54.
Field Radio System	57.
Radio Repeater	60.
Operation	61.
References	63.

**FIGURES**

No.		
1.	System Block Diagram	5.
2.	Control System Diagram	9.
3.	Apple Interface Schematic	11.
4.	Apple Interface Timing Diagram	14.
5.	Apple Interface Layout	15.
6.	Radio Interface Schematic	18.
7.	Radio Interface Layout	19.
8.	Audio Monitor Schematic	23.
9.	Remote System Pictorial	26.
10.	Electronics Box Diagram	28.
11.	DTMF Decoder Schematic	30.
12.	DTMF Decoder Layout	34.
13.	Mux & Control Signal Flow Diagram	36.
14.	Mux & Control Schematic	38.
15.	Mux & Control Timing Diagram	40.
16.	Serial Data Train Diagram	42.
17.	Mux & Control Layout	46.
18.	FSK4 VCO Schematic	48.
19.	FSK4 VCO Programming	49.
20.	FSK4 VCO Layout	50.
21.	Dc Convertor Schematic	52.
22.	Dc Convertor Layout	53.
23.	Motherboard Schematic	55.

continued next page

## FIGURES, cont.

24.	Motherboard Layout	56.
25.	Radio Box Diagram	58.

## TABLES

1.	Apple Interface Parts List	64.
2.	Radio Interface Parts List	65.
3.	Electronics Box Parts List	66.
4.	Electronics Box Pin Designations, I	67.
5.	Electronics Box Pin Designations, II	68.
6.	DTMF Decoder Parts List	69.
7.	Mux & Control Parts List	70.
8.	FSK4 VCO Parts List	72.
9.	DC Converter Parts List	73.
10.	Motherboard Parts List	74.
11.	Radio System Parts List and Pin Designation	75.

## INTRODUCTION

The Hawaiian Volcano Observatory Polling Telemetry System was designed to replace the "Multichannel Digital Telemetry System" (Roger, 1976) built by Menlo Park and installed at HVO in the mid 1970's. The old telemetry system was experiencing many problems due to age and unavailability of more units and parts.

The HVO Polling Telemetry System was designed to meet the following specifications: 1) must operate on a 12 volt battery, 2) must have low power consumption, 3) must accept an analog input range of  $\pm 5$  volts with 12 bit resolution, 4) must accept at least 8 input channels, and 5) sampling interval must be remotely controlled. This has been accomplished with the first field units operating in 1984. By early 1988, the old digital telemetry system had been completely replaced.

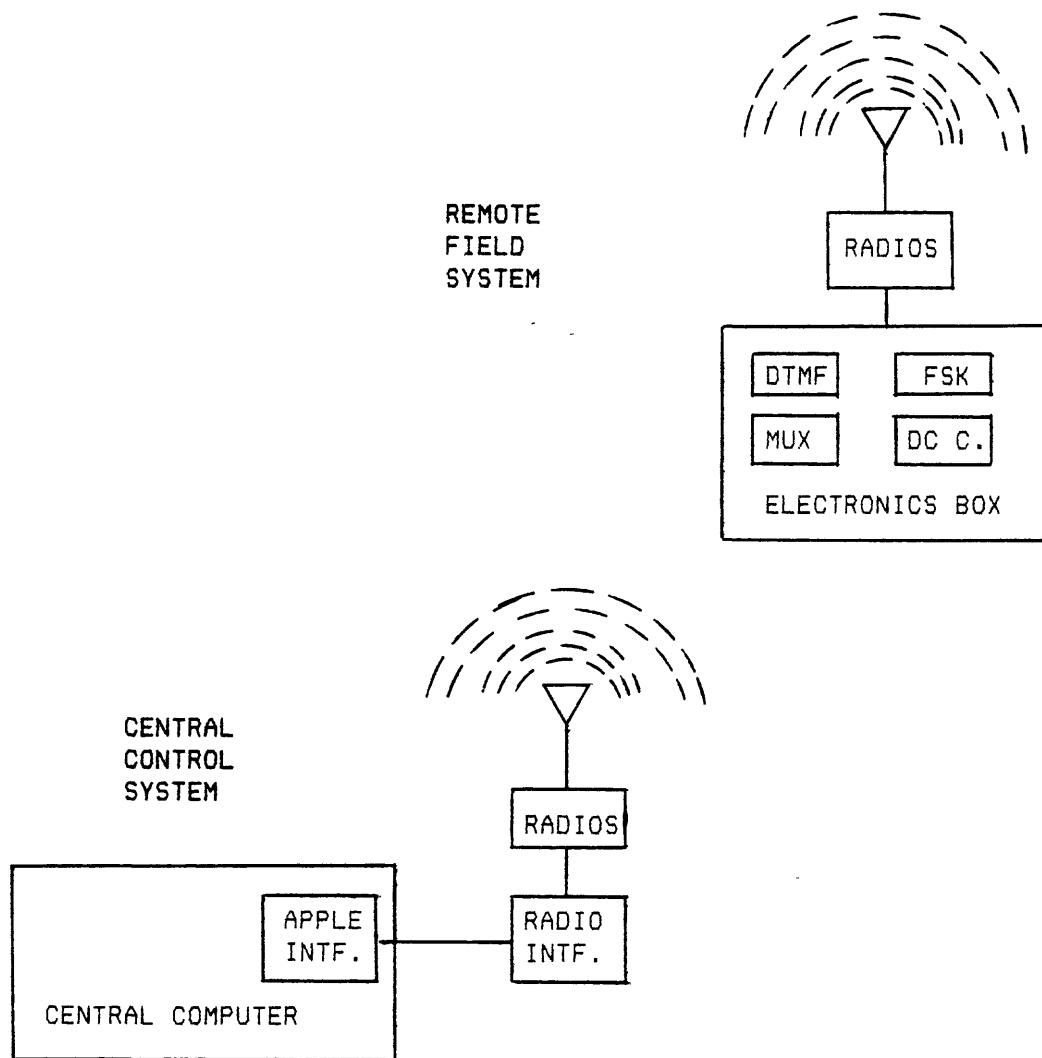
A computer in the observatory controls the data acquisition or sampling interval from remote stations through 2-way radio communication. Being an interrogation or polled system, only two radio frequencies are necessary for the system; one frequency for simplex (direct) communication and the other frequency for communicating through a repeater. The design of the system limits the number of stations to 256, with each station capable of transmitting data from up to 8 channels. The sampling interval is set by the computer and ranges from once a minute to once a day. Data is acquired from sensors only when polled by the computer, so only low frequency or slowly changing measurements can be usefully acquired.

## SYSTEM DESCRIPTION

The HVO Polling System consists of two sections, the central control system and the remote field units. The central control system resides in the observatory and consists of a computer and the hardware to receive and transmit messages through radios. The field units are located in areas where remote field measurements are desired from various monitoring instruments. (See fig. 1)

The central control system determines the sample interval for the remote field units and logs the data. The control system consists of an Apple II computer, program software, the Apple Interface board, the Radio Interface Board, and the radio system. When the computer decides that a station must be polled, it activates the radio transmitter through the Apple Interface card and the Radio Interface board. A message is then transmitted that will turn on the selected station. After the message is transmitted, the radio transmitter is turned off, the radio receiver is activated and the computer awaits the return data from the station. If none is received or the data contains errors, the computer will re-poll the station. Once successful (all data is acceptable), the computer will log the data and wait until the next polling interval. The computer will try five times to gather data from a station, and if not successful, will save whatever data it did receive in a error log and also log that it was not successful in gathering data from that station at that time.

A remote field unit consist of an electronics package and a radio package (see fig. 1 and 9). The electronics package (or digital box) contains the following cards: the DTMF Decoder board,



SYSTEM BLOCK DIAGRAM

FIG. 1

the MUX & CONTROL board, the DC Convertor board, the FSK board, and the Motherboard. The radio container holds the radio transceiver. The remote field units are always on standby, awaiting a call from the controlling computer. Whenever it detects calling, it compares the message it receives with its own programming. If there is a match, it will power up, transmit its data, then return to standby. If there is no match, it will ignore the call and stay on standby. The radio receiver is always on during standby. When the station powers up, the transmitter is activated so that the station can transmit the data to the computer.

The remainder of this report describes each of the components of the system, the design and operation of the circuit, with a schematic and parts layout diagram.

This report is meant to provide a system description and a reference for repair and operation of the equipment designed by the authors, and as such will not discuss the operation and requirements of the Apple Computer and its software. Operation and questions concerning the computer should refer to USGS open file report no. 87-633, (English, 1987).

## THE CONTROL SYSTEM GENERAL DESCRIPTION

The central control system consists of an Apple II computer, an Apple Interface board, a Radio Interface board, and radio transmission equipment (see fig. 2).

The Apple computer controls the operation of the polling system. The polling period, error checking, and data logging are software controlled. The data the Apple computer collects is saved to disk and also automatically uploaded to a VAX 11/750 computer for display, analysis, and archival.

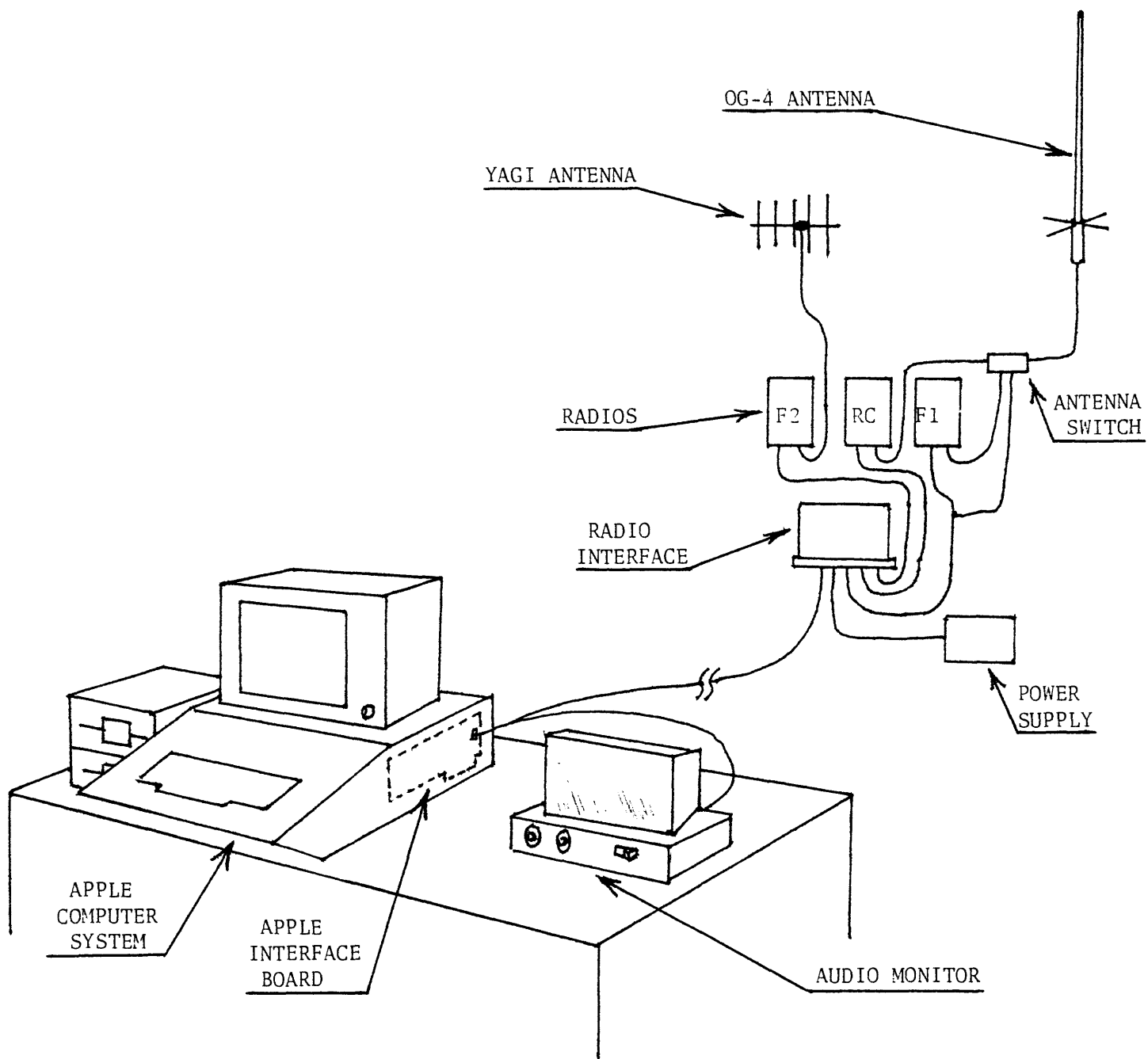
The Apple Interface board plugs into the Apple computer expansion slot. The board interfaces information between the Apple computer bus and the Radio Interface board. Its digital outputs control the radios and the DTMF encoder. It also converts FSK (Frequency Shift Key) signals from the radio receiver to digital logic signals.

The Radio Interface board converts the control signals from the Apple Interface board to power signals that turn radios and antenna switches on. The audio signal level for the radio transmitters are also set on this board.

The radio transmission system includes radio transmitters, a radio receiver, an antenna switch, two antennas, and a power supply for the radios.

The audio monitor provides an audible check of station calling and data reception.





CONTROL SYSTEM DIAGRAM

FIG. 2

## APPLE INTERFACE BOARD

The Apple Interface board interconnects the computer with the Radio Interface board. It contains the DTMF tone generator and the FSK discriminator circuitry (see fig 3). The Apple Interface board plugs into the Apple Computer expansion slot.

### DETAILED CIRCUIT DESCRIPTION

U2, a R6522 Versital Interface Adaptor, interfaces with the Apple bus to control the U3 tone generator and the U4 discriminator (fig. 3). It also provides the logic control lines that turn on the appropriate radio. U2 is controlled by software running on the Apple computer.

Pins 2, 3, and 4 of U2 provide the logic levels needed to turn on the selected radio at the appropriate time. Pins 10 through 16 of U2 are the control lines to the U3 tone generator. The signal levels on pins 2 thru 4 and 10 thru 16 are set by computer software through the computer bus. Diodes D1 through D7 are installed to prevent current flowing to U2. Pin U2-17 is the square wave data input from the U4 Discriminator IC through U1D Invertor to the data bus.

U1, a 4049 Hex Inverting Buffer, uses its A, B, and C buffers to convert the phase 01 clock signal of the Apple bus to provide the phase 02 clock signal that U2 requires. U1 inverts and delays

- UNLESS NOTED,
1. RESISTORS 5%, 1/4W
  2. RESISTOR R7= 2%.
  3. CAPACITORS ARE CERAMIC
  4. CAPACITOR C3 IS POLYCARBONATE
  5. DISCRIMINATOR SPECS  
HI: 2200HZ LO: 1200HZ  
CF: 1700HZ RATE: 600BPS
  6. DIODES ARE 1N914

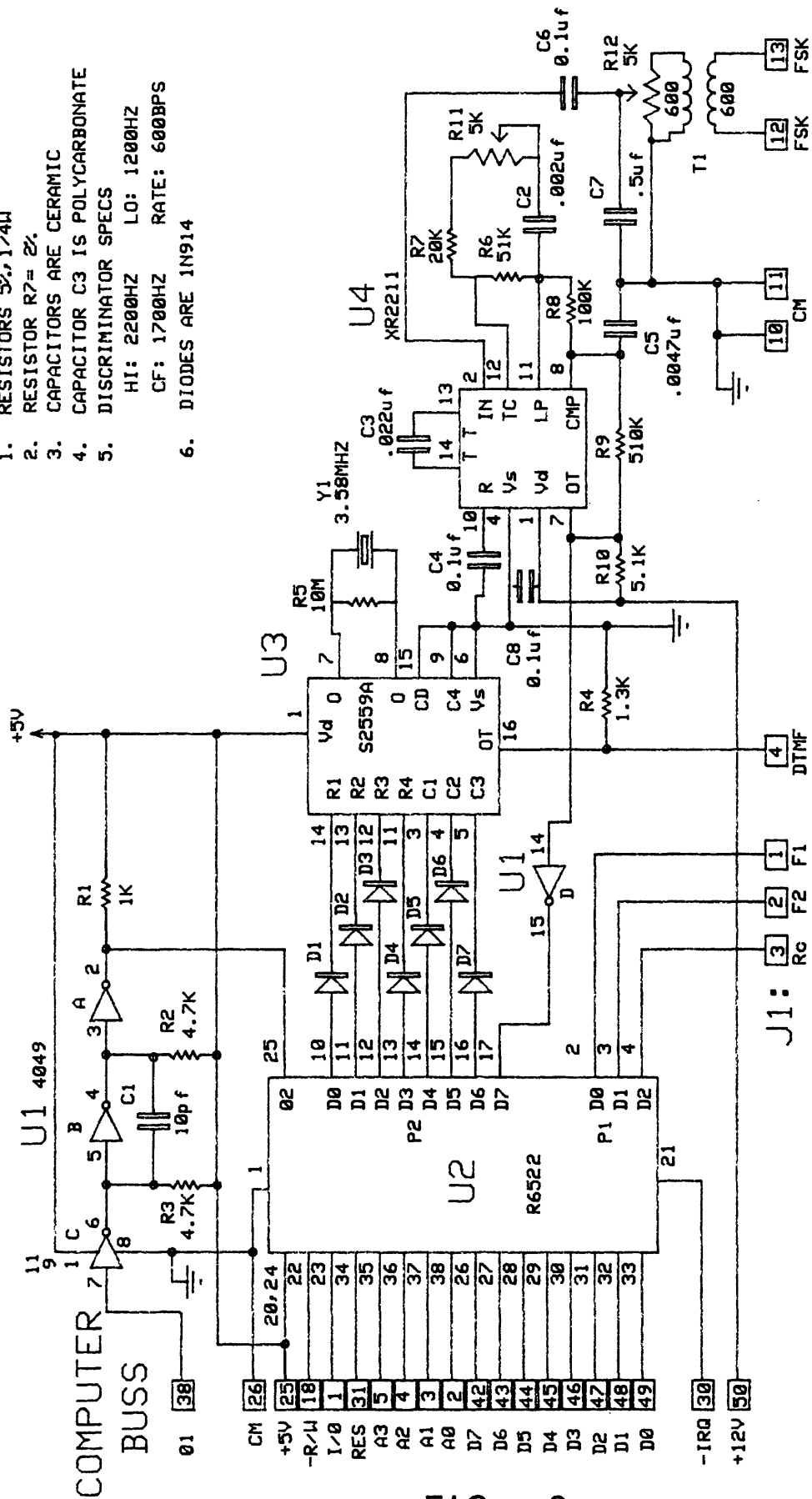


FIG. 3

# APPLE INTERFACE SCHEMATIC

DRAWN  
GP 8-25-88

DESIGNED  
GP & KH 11-83

APPLE INTERFACE  
HVO INTERROGATION SYSTEM

the 01 clock signal by 80 nanoseconds to produce a simulated 02 clock signal. U1-D inverts the output of U4 before sending the signal on to U2.

U3, a AMI S2559A DTMF Tone generator, produces the tones necessary to activate the remote field units. U3 is controlled by U2, which provides the logic level patterns on the row inputs (pins 11 thru 14) and the column inputs (pins 3 thru 5) similar to a telephone keypad. The output level of U3-16, is 440 to 800 mVrms. It is sent to the Radio Interface board through the J1 connector.

DTMF (Dual-Tone-Multiple-Frequency) is the system that "touch-tone" phones use when dialing. When a key on the telephone is depressed two tones are produced, one signifying the row and one signifying the column. With each key having two indentifying tones, the chance for random noise to produce false coding is greatly reduced.

U4, an Exar XR2211 FSK Demodulator, converts the FSK audio input into a corresponding square wave signal. The mark/space frequencies are 1200 and 2200 Hz, with a center frequency of 1700 Hz. The input level to U4 is set by adjusting R12, while R11 is to fine tune the frequency. U4-7, the discriminator square wave output, is inverted by U1-D before entering U2 and the computer bus.

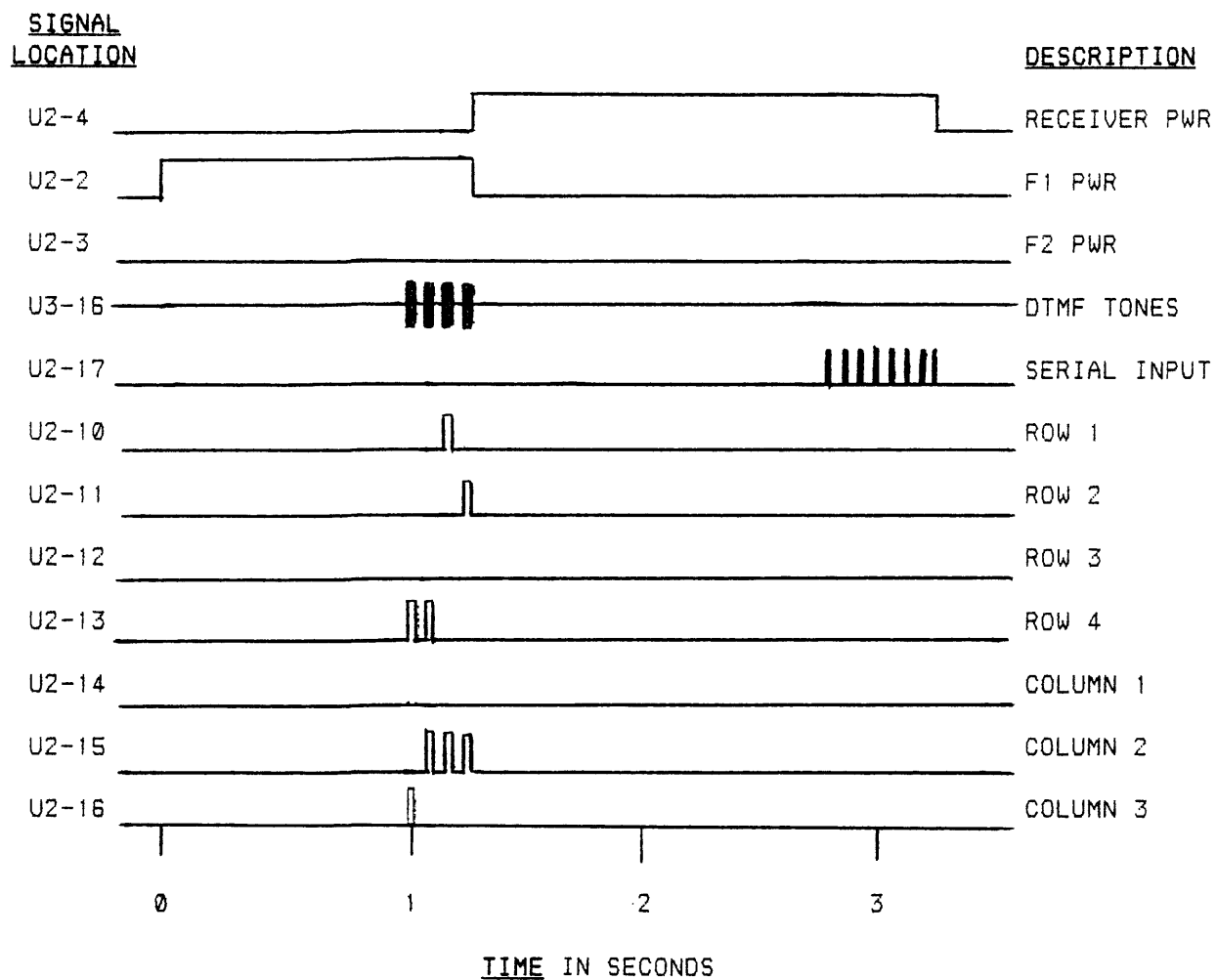
The FSK input to the Apple Interface board, U4-2, is transformer coupled by T1 to the radio receiver. This eliminates any ground loop problems if the radios are located at a distance from the computer.

The J1 connector connects the signals from this board to the Radio Interface board.

Figure 4 shows a typical timing sequence of activating radios, calling a station, and receiving a return signal.

Figure 5 displays the parts layout for the Apple Interface board.

Table 1 is the Apple Interface Parts List.



NOTE: 1. TIMING DIAGRAM DEPICTS CALLING STATION #025, TRANSMITTER F1  
 2. VOLTAGE LEVELS ARE 0 TO 5 VOLTS

## APPLE INTERFACE TIMING DIAGRAM

FIG. 4

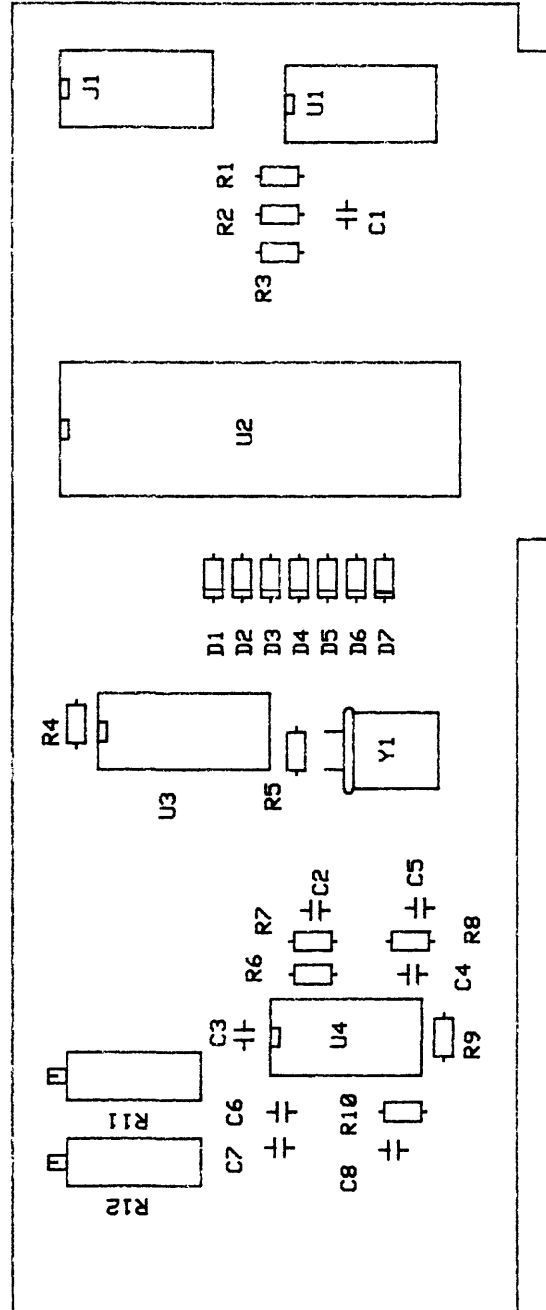


FIG. 5

# APPLE INTERFACE PARTS LAYOUT

DRAIN GP 12-8-88	APPLE INTERFACE HVO INTERROGATION SYSTEM
DESIGNED GP & KH 11-83	

## RADIO INTERFACE BOARD

The Radio Interface Board connects the Apple interface board with the radios. The board is designed to control two radio transmitters, one radio receiver, and an antenna switch. All connections concerning power and audio signals to the radios come from this board.

### **CIRCUIT DESCRIPTION**

The three circuits controlling the radios on this board are similiar. Because one description is sufficient the F2 radio circuit will be used. See Fig 6, Radio Interface Schematic. A high logic level on the F2 Trigger (+5V) from the Apple Interface board turns on Q4, a MPSA14 NPN Darlington transistor. When the Q4 conducts, it turns on Q3, a 2N4403 PNP general purpose switch, which then provides power to the radio. The 2N4403 can provide up to 150 ma at 12V to the radio.

The DTMF signal is sent to the two transmitters through a 5K pot (R5), which is used to adjust the signal level. The DTMF level is typically set at 1 volt peak-peak.

The FSK signal from the radio receiver is routed through the board for easier troubleshooting. The FSK level, also set at 1 volt peak-peak, is set with the receiver output adjustment on the radio.

To reduce the number of antennas from three to two, an antenna switch was added to the system. The antenna coaxial switch



switches the antenna between the radio receiver and the F1 radio transmitter. The antenna switch is activated when F1 is powered, allowing F1 to transmit out of the same antenna used by the radio receiver.

The current requirements of the coaxial switch could not be met by a 2N4403, so a 2N5976 is used for Q1. Q1 supplies power for both the antenna switch and the F1 transmitter. When the F1 trigger is turned on, the F1 radio transmitter is powered up and the antenna switch switches to connect the transmitter to the antenna. When the Q1 (2N5976) turns off, the F1 transmitter shuts down and the coaxial switch releases, reconnecting the antenna to the receiver. The 2N5976 transistor can provide up to 2 amps of current.

Figure 7 displays the parts layout of the Radio Interface board.

Table 2 is the Radio Interface Parts List.

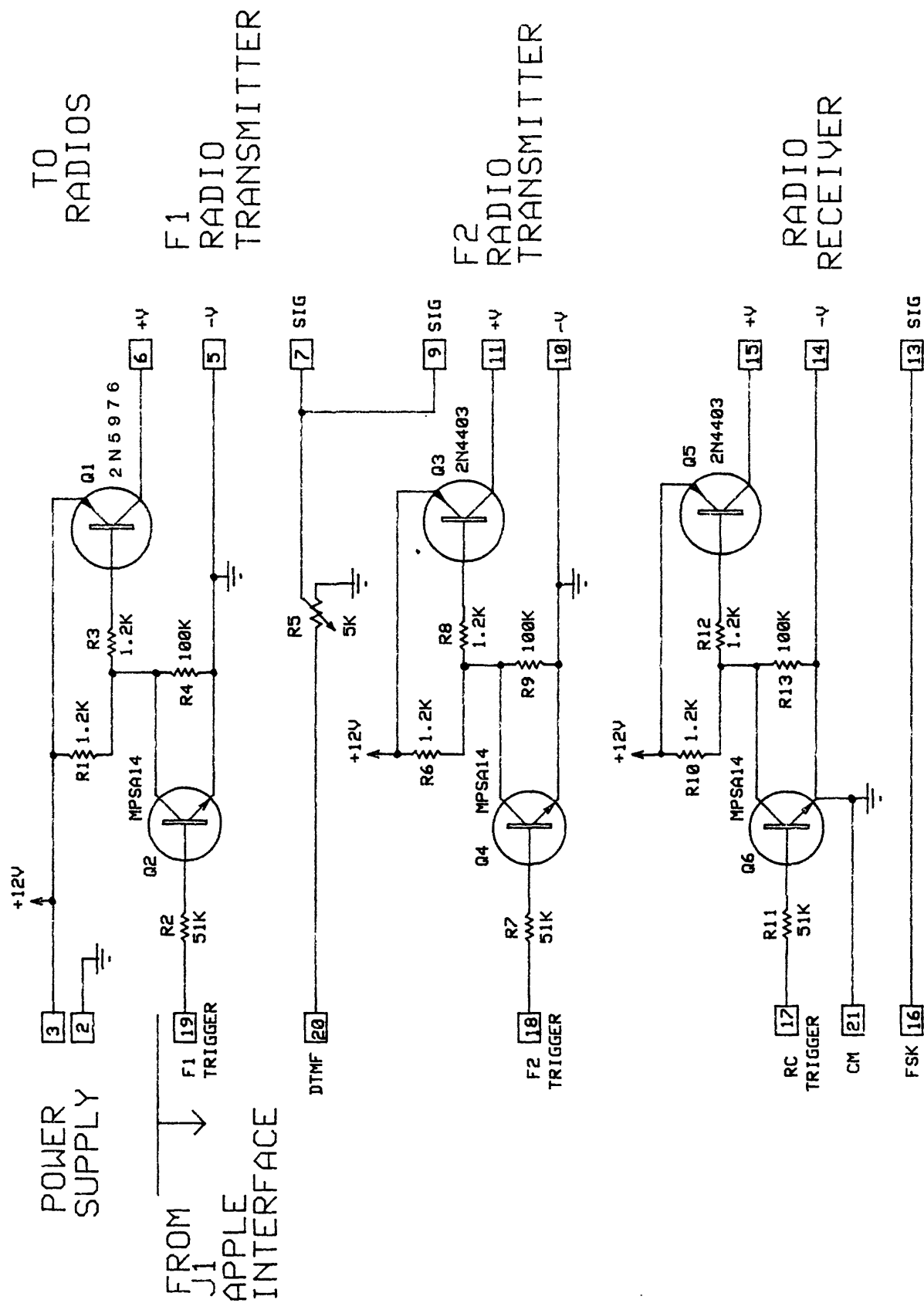


FIG. 6

# RADIO INTERFACE SCHEMATIC

□ : CARD EDGE CONNECTOR & PIN NO.

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RADIO INTERFACE  
HVO INTERROGATION SYSTEM

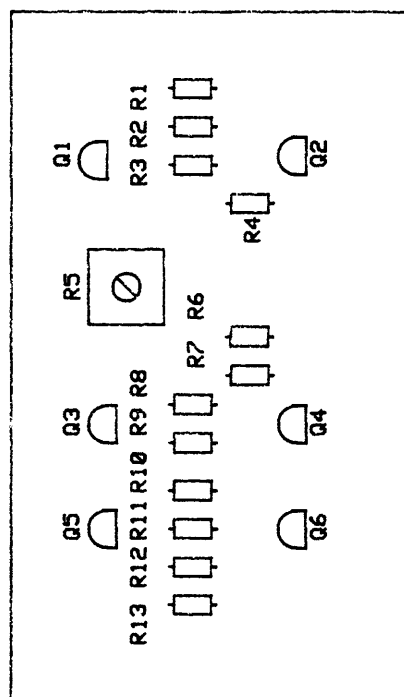


FIG. 7

# RADIO INTERFACE PARTS LAYOUT

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GP 12-8-88

DESIGNED

KH 1983

RADIO INTERFACE

HVO INTERROGATION SYSTEM

## RADIO SYSTEM

The Radio System section describes the equipment and specifications of the radios and the antennas.

The radio transmitters used are Monitron model TR-150, VHF NBFM radio transmitters. These are solid state, narrow band, FM transmitters. The radios require 12 volts DC, consume 60 to 120 ma, depending upon output power which is adjustable from 50 to 500 mW. The radios we use are normally set to 100 mW output power.

The radio receiver used is Monitron model R15F, a VHF NBFM receiver. The receiver is a solid state, double-conversion, narrow band, FM receiver. The radio receiver requires 20 ma at 12 volt DC. The audio output level is adjusted to 1 volt P-P.

The radios are designated F1, F2, and Rc. The 'F' denotes transmitter and Rc denotes receiver. F1 and Rc at the HVO are operate at 171.2187 Mhz in frequency. The F2 transmits at 166.4187 Mhz. All sites within line of sight of HVO utilize the F1 frequency for direct radio communication. The F2 frequency is used to communicate with a repeater on Mauna Kea to increase area coverage of the telemetry system. When the central computer calls a site using the F2 frequency, the radio repeater on Mauna Kea turns on and repeats the message and the remote site response.

A coaxial switch, Magnacraft W120X-14, switches the main antenna between the F1 and Rc radios. In the normal state, the antenna is connected to the receiver. When the computer begins calling and the F1 transmitter is selected, the switch connects radio F1 to the antenna as the F1 radio is energized. When F1 is

shut down, the switch releases and reconnects the antenna to Rc. This switch requires 12 volts and 1.4 watts of power to operate.

Two antennas are used for radio communication. The main antenna is a Scala OG-4, an omni directional, vertically polarized antenna with 4 db gain. The OG-4 is connected to the coaxial switch for use with the F1 and Rc radios. The OG-4 is used for all radio reception from field stations. The second antenna is a Scala CA5-150V, a vertically polarized antenna with 9db gain. This antenna is only used when the F2 radio transmits, and is aimed at the radio repeater site on Mauna Kea.

The radios and switch require a 12 volt power supply that can provide a minimum of 500 ma. With the F1 radio transmitting and the antenna switch activated, current consumption is measured at 250 ma.

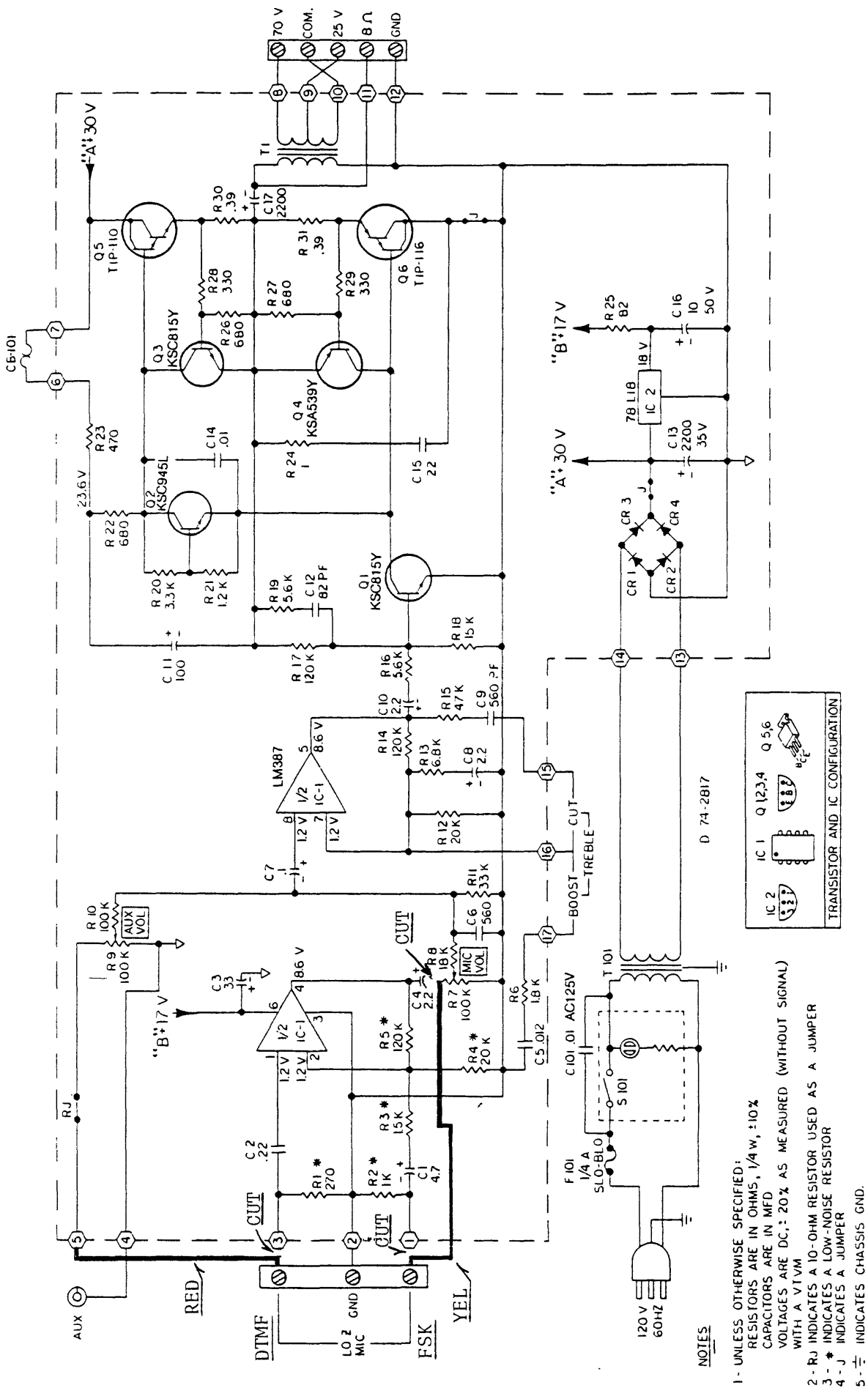
## AUDIO MONITOR

A speaker and amplifier is used to provide an audible monitor of the polling operation. The DTMF code and the FSK signals are monitored and broadcasted on the speaker. We have found that trouble-shooting and repair times can be reduced by being able to listen to these signals.

A 6W utility amplifier Bogen model GA-6A and an 8 ohm speaker comprise the monitor. The mixer section of the amplifier has two inputs, a low impedance microphone input and a high impedance auxiliary input. The low impedance input is modified to be identical to the high impedance input. The microphone input block was also rewired so that both the DTMF and FSK signals are connected to the block. The auxiliary input connector has been disabled. Terminal 3 of the mike block is designated the DTMF input, and is connected internally to the auxiliary input circuitry. Terminal 1 of the mike block is for the FSK input, which is internally wired to bypass the low impedance circuitry. The changes made to the audio monitor are indicated by thickened lines in the schematic (fig. 8).

Each audio signal can be individually adjusted by volume control knobs to desired levels, MIC control for the FSK and the AUX control for the DTMF signal.

The schematic depicted in Fig. 8 is from the operators guide and instruction manual that accompanies the Bogen utility amplifier.



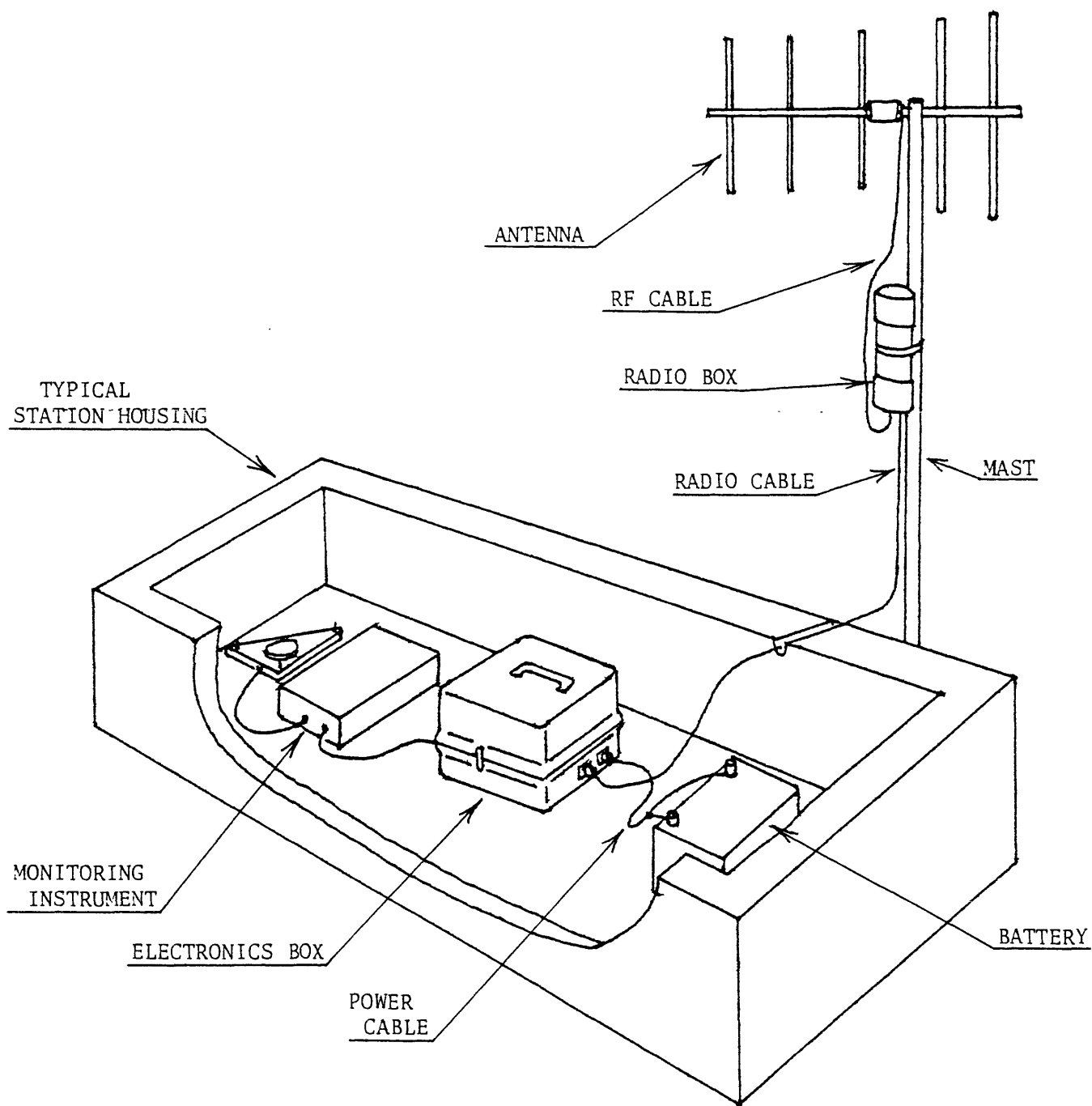
— Schematic diagram, Model GA-6A

FIG. 8

## REMOTE FIELD SYSTEM GENERAL DESCRIPTION

The remote field system consists of two packages: the electronics package, the radio package; and external pieces such as batteries, masts, and antennas. The electronics package consists of several circuit boards which handle site activation and data transmission. The radio system includes the radio package, cables, and antenna with masts. See fig. 9.





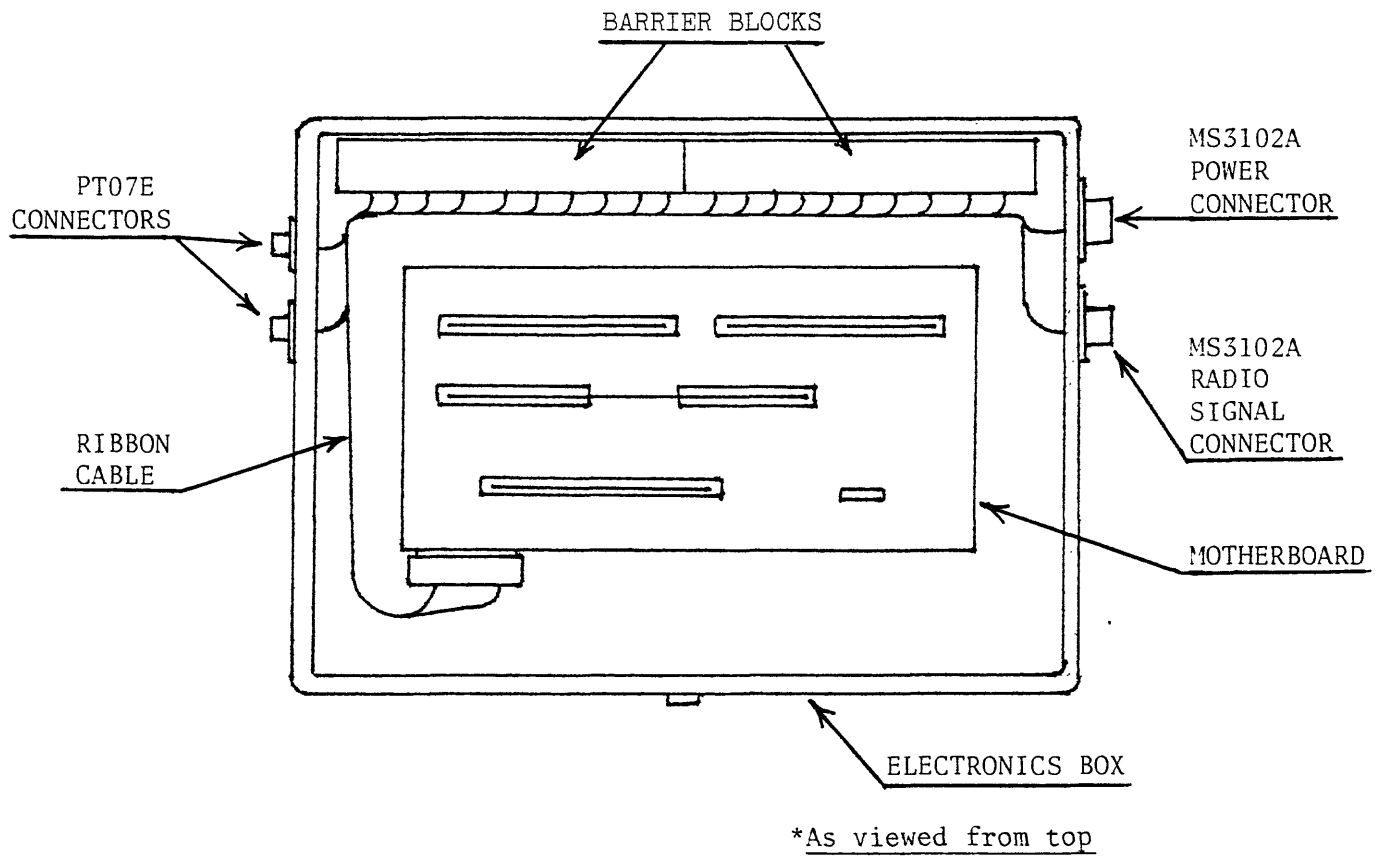
REMOTE SYSTEM PICTORIAL

FIG. 9

## THE ELECTRONICS PACKAGE

The electronics package (or digital box) contains and protects the following boards: 1)the DTMF Decoder board that controls the powering up a station by comparing its programming with that sent by the central computer, 2)the Mux & Control board that handles the power switching, data digitization, and data formatting, 3) the DC Convertor that converts the battery voltage to the voltages required by the digital box, 4)the FSK4 VCO that converts the data from the Mux & Control board to one that is acceptable by the radios, and 5)the Motherboard that holds the above boards and interconnects them (fig. 10). Each board will be discussed in detail in following sections.

Connectors are mounted on the electronics box to allow easy connection of power and signals. An MS3102A-14S-9S bulkhead connector is used as the power input for the remote field system. An MS3102A-14S-5S is used for all power and signals to and from the radio box. A Bendix PT07E-8-4P is used for all instrument signals entering the electronics box. Two barrier terminal blocks, Cinch 10-140-Y, are mounted inside the electronics box. All cables, such as power, signal, and ribbon are connected to the barrier block. A Digikey R505-36-ND ribbon cable with a card end connector that plugs onto the motherboard transfers all signals and power between the motherboard and the barrier blocks. These connectors allow easy replacement of components, and the barrier blocks allow easy checking of all signals and power systems. See Tables 4 & 5 for pin designations.



ELECTRONICS BOX DIAGRAM

FIG. 10

## DTMF DECODER BOARD

### GENERAL DESCRIPTION

The DTMF (Dual-Tone-Multiple-Frequency) Decoder board monitors the radio receiver audio output for the correct code sequence that will tell it to turn on the station. The board compares the codes that it detects with its own programming. If it detects a match, it sends the power up signals to the Mux & Control board.

The DTMF code format was chosen for its ease in application, wide product selection, and high resistance to noise interference. The DTMF (commonly known as Touch Tone) was developed by telephone companies as a more rapid and accurate means of dialing. Each key on a push-button telephone, when depressed, causes two specified tones to be transmitted. A DTMF decoder can easily identify when valid tones are transmitted, and which key was activated.

The central control computer first transmits a reset tone, then the three number code that activates the station to be polled. The reset tone is transmitted first to clear any number that may have spuriously activated part of the decoder board.

The DTMF board can decode the numbers 0 thru 9 plus the '#' and '\*' characters. The '#' and '\*' characters are reserved for board resetting. The decoder requires a minimum of 20 milliseconds to identify a character with a minimum of 10 milliseconds between characters. Dipswitchs S1, S2, and S3 (see fig. 11) are set sequentially to match the station identification number. There are two timers on board, the first with a 3 second timeout and the

second with a 1.5 second timeout. The first timer starts upon detection of the first number that is received and will then reset the card in three seconds. This is to take care of any spurious noise that may have triggered the station, and long enough to allow hand DTMF triggering of the card. The second timer, activated after a valid three number tone sequence is received, sets a low logic level which causes the digital system to power up. After allowing 1.5 seconds for components to stabilize, a change to a high logic level will initiate the digitization and data transmission.

#### DETAILED CIRCUIT DESCRIPTION

U1 is a SSI201 DTMF decoder capable of decoding 0 thru 9, A thru D, and the characters \* and #. See Fig. 11. The input signal to U1-12 must be between 10 and 3000mv RMS. The output is a four line hexadecimal code on pins 1, 22, 21, and 20. U1-18 signals a valid tone detection by going high.

U3 is a 4514, a 4 to 16 line decoder, which translates the four line hexadecimal code to one of 16 single output lines. Of these 16 output lines only 12 are used. Code outputs 1 thru 10 are sent to the three programming switches S1, S2, and S3. Code outputs 11 and 12, signifying '\*' and '#', are sent to U2-11 and 12 for use in resetting the board. U2 is a 4001 dual NOR gate with inverter. The inverter of U2, pins 5 and 6, inverts the strobe line from U1-18 to U3-23. U3-23 is the inhibit line, and must be low when U3 is converting. The U2 NOR gate input pins 11 and 12 take the # and \* characters from U3 thru the NOR gate to trigger the reset lines of U4 and U5.

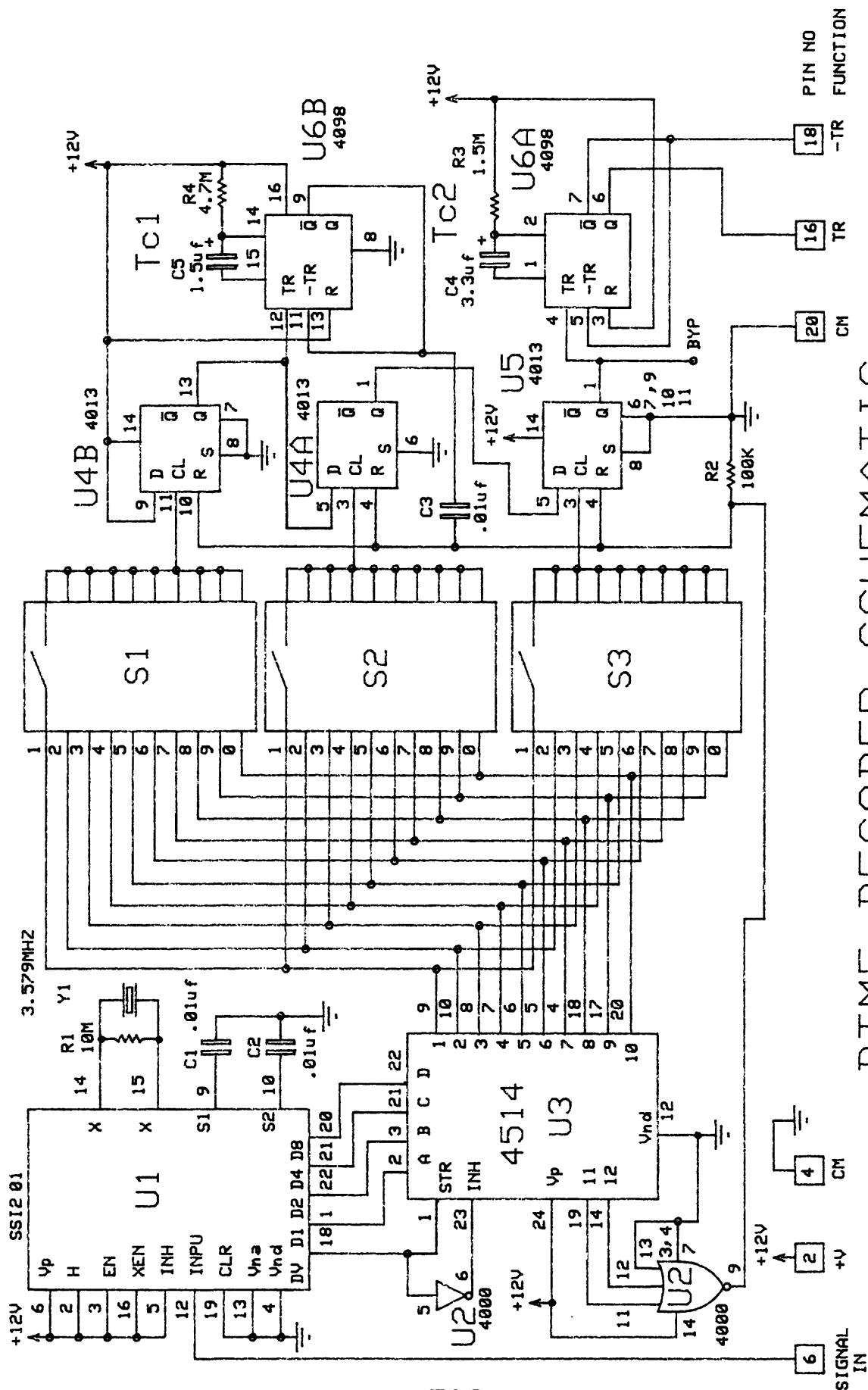


FIG. 11

1.  $T_{c1} = 3 \text{ SEC}$
2.  $T_{c2} = 1.5 \text{ SEC}$
3. # RESETS U4 & U5, BUT NOT U6

# DTMF DECODER SCHEMATIC

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DTMF DECODER  
HVO INTERROGATION SYSTEM

U4 and U5 are 4013 flip flops, used to convert voltage levels from U3 and the switches into pulses that can trigger the timers of U6. The components of the 4013's are cascaded to allow triggering only in the programmed sequence. The first decoded number from U3 passing if it is selected thru S1 sets U4B which sets both U6A, the 3 second timer (Tc1), and U4A. U4A, after being set by U4B and then triggered by the second coded number passing thru S2, sets U5A. U5A, after being set by U4B and then being triggered by the third station number matching S3, triggers U6A (Tc2) the 1.5 second timer. This section was designed so that numbers transmitted only in the correct sequence would be able to set the flip flops. The flip flops will not set Tc2 unless they are activated in the correct sequence. The setting of switches S1, S2, and S3 are covered in the Operation section, page 62.

U6, a 4098, is a dual monostable multivibrator. Section U6B handles the 3 second timer (Tc1) and section U6A handles the 1.5 second timer. (Tc2). The U6B timer is set by U4B when a number matching S1 is detected, whether from noise or from actual computer activation. After Tc1 times out in 3 seconds, the  $\bar{Q}$  of U6B will reset U4 and U5. This timer is set with a long time constant to allow hand DTMF triggering of the board, which takes longer than computer calling.

The Q output of section U6A provides the high logic level (TR) for station powerup and the  $\bar{Q}$  of section U6A provides another high logic level ( $\overline{TR}$ ) to start data digitization. The TR and the  $\overline{TR}$  from U6A go to the Mux & Control board. The TR starts the power up section of the Mux board. The 1.5 second period allows the components of the station time to power up and stabilize, and upon

time out allows the station to begin operation. The Mux board requires both of these signals to operate.

The TR input of U6A, normally set by U5, can also be set manually. Injecting a 12V signal to the spot labeled BYP, will cause the station to power up and operate (See fig. 11 and 12). This is useful for testing purposes without requiring the computer or DTMF triggering.

The DTMF card is powered up at all times, consuming 25 ma of current. This is necessary to be able to respond when the computer calls the station.

Fig. 12 depicts the parts layout of the DTMF Decoder.

Table 6 is the DTMF Decoder Parts List.



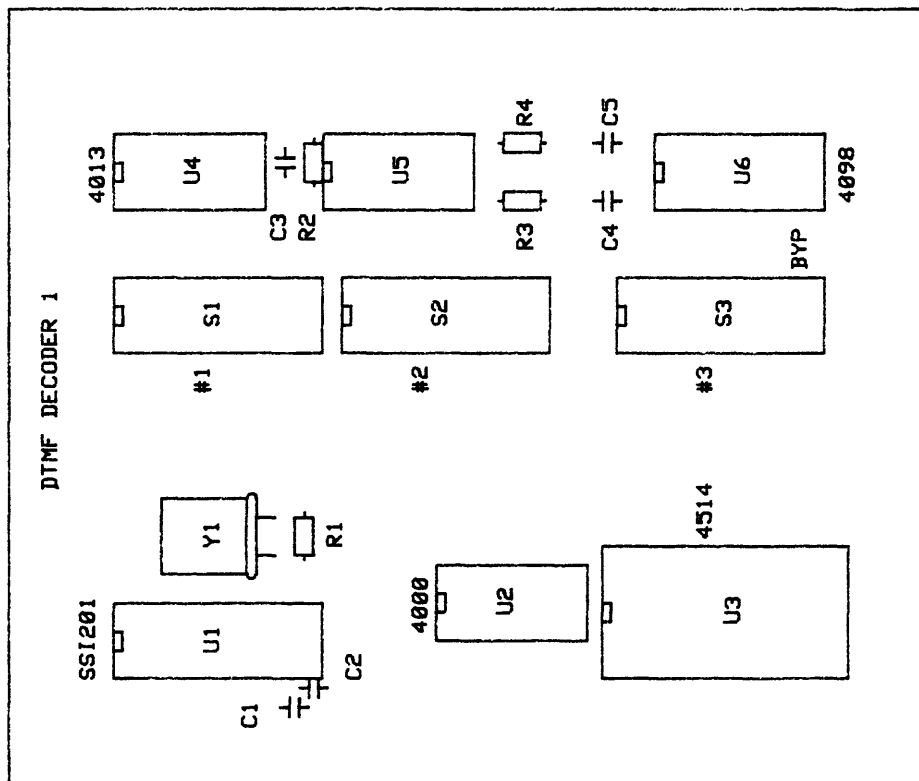


FIG. 12

# DTMF DECODER PARTS LAYOUT

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GP 12-7-88

DESIGNED

GP 9-83

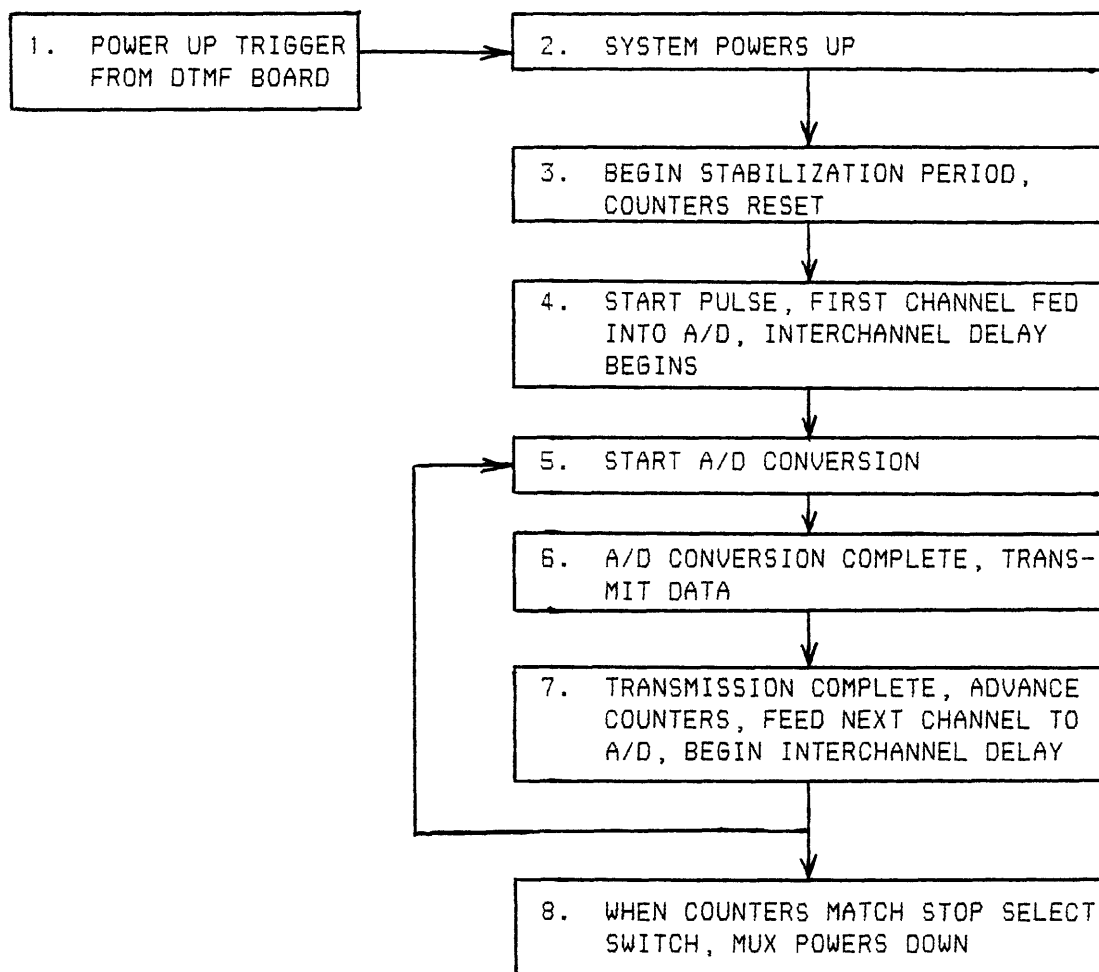
DTMF DECODER  
HVO INTERROGATION SYSTEM

## MUX & CONTROL BOARD

### GENERAL BOARD DESCRIPTION

The Mux & Control board contains the circuitry that controls the power up of the system, the analog switching and digitizing, the clocking of the data output, and the battery monitor circuit. One section of the board is continuously powered and the works on switched power. The board is capable of handling 8 single ended analog inputs of a +5V to -5V range. A 12 bit analog to digital convertor (A/D) is used providing data resolution of 2.44 mv per bit. The battery monitor divides the battery voltage to bring the voltage within the 5V range. The divided voltage can be fed into one of the analog inputs if desired. The data rate is set at 600 bps, but can be changed to 300 bps if desired by moving a jumper.

A general signal flow block diagram is pictured in Fig. 13. A short explanation follows. (1) A high logic level trigger (TR) from the DTMF board sets U1 which (2) turns the power transistor on and powers up all components. After a short stabilization period during which all counters are reset, (3) TR goes low and  $\overline{\text{TR}}$  goes high, which (4) initiates the start pulse for the system, allows the counters to count, sets the analog switch to the first channel which is then fed to the A/D. After a delay, the (5) A/D does a conversion, signals that it is finished, and then (6) the data transmission for the first channel commences. (7) After the first channel data transmission is completed, counters are advanced for the next data channel to be presented to (5) the A/D and another delay commences. After all data channels are transmitted, (8) a reset pulse to U1 turns off the power to the system.



SIGNAL FLOW BLOCK DIAGRAM

FIG. 13

## DETAILED BOARD DESCRIPTION

### POWER SYSTEMS

There are several power systems on this board. The two most important ones are the 12V CONSTANT and the 12V SW. The 12V CONSTANT power system is constantly on battery power and is not switched on and off. Only IC's U1 and U5 on the Mux board use 12V CONSTANT. The 12V SW means 12 volt switched power system. The switched power system only has power when the DTMF board tells the Mux board to power up. All components except for U1 and U5 on the Mux board are on switched power.

There is also  $\pm 15$  and +10 volt DC power systems. The  $\pm 15$  volt systems are produced by the DC Converter board and powered by the 12V SW. The 10V (volt) system is provided by Q4, which regulates the +15V down to 10.000V for use by U9, U12, and U18. Q4 is a LH0070 voltage reference made by National Semiconductor. The  $\overline{12V\ SW}$  circuit provides +12V DC power only when the Mux board is powered down; when the Mux powers up this power system is shut down. Q2, which provides  $\overline{12V\ SW}$  is in the circuit for any need that requires power only when the station is in a standby state.

### CIRCUIT OPERATION

The TR (from U6B of the DTMF board) is changed from a logic level to a pulse by C1/R1 before setting U1B-9 and U1A-7. See Fig. 14 for Mux & Control Schematic and Fig. 15 for Mux Timing signal Diagram. U1, a 4027 JK flip flop, is on 12V CONSTANT (Power). U1B after being set, turns off Q2 and turns on Q1 and Q3. Q1 and Q2 are 2N4403 transistors, general purpose switches. Q3 is

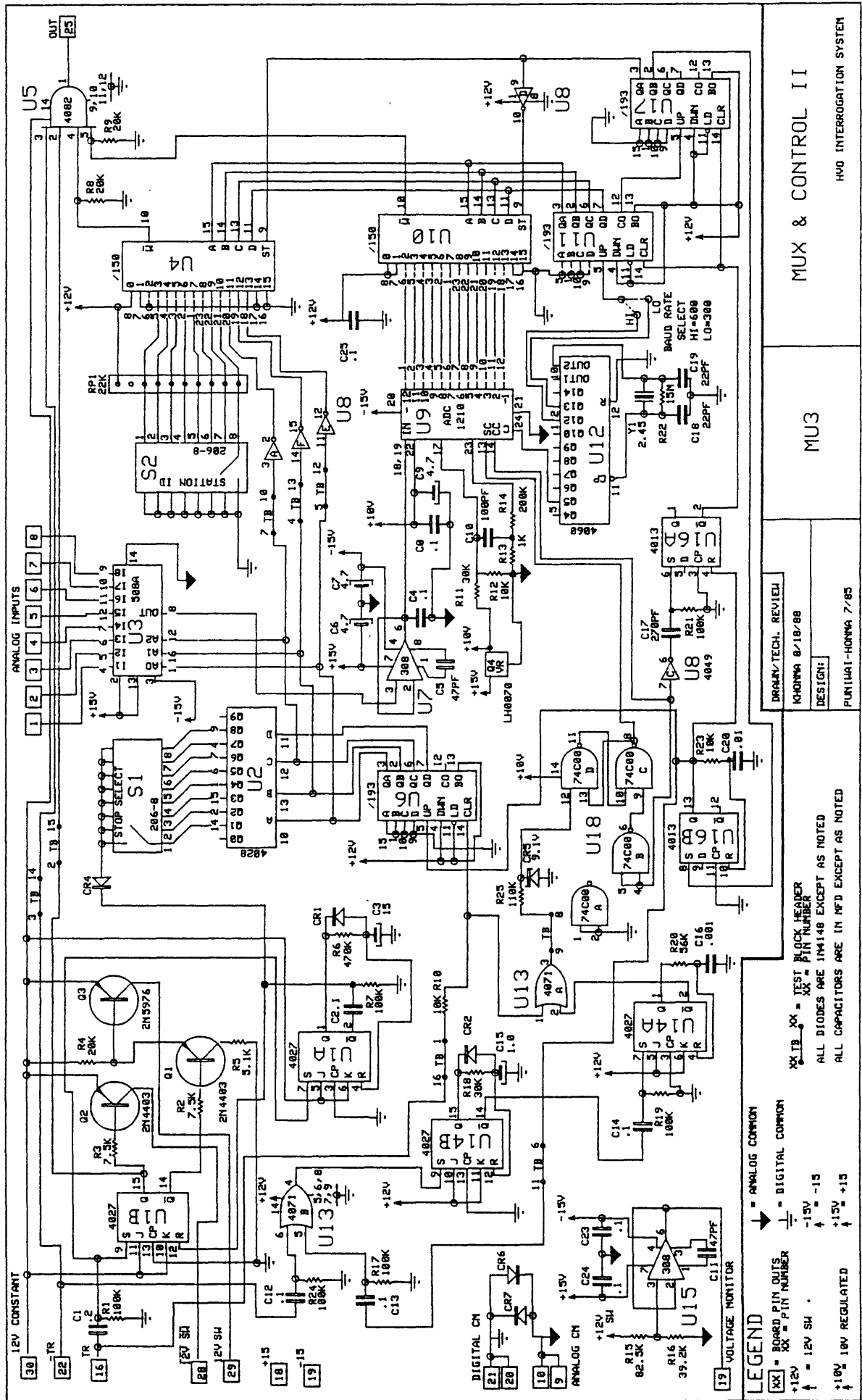
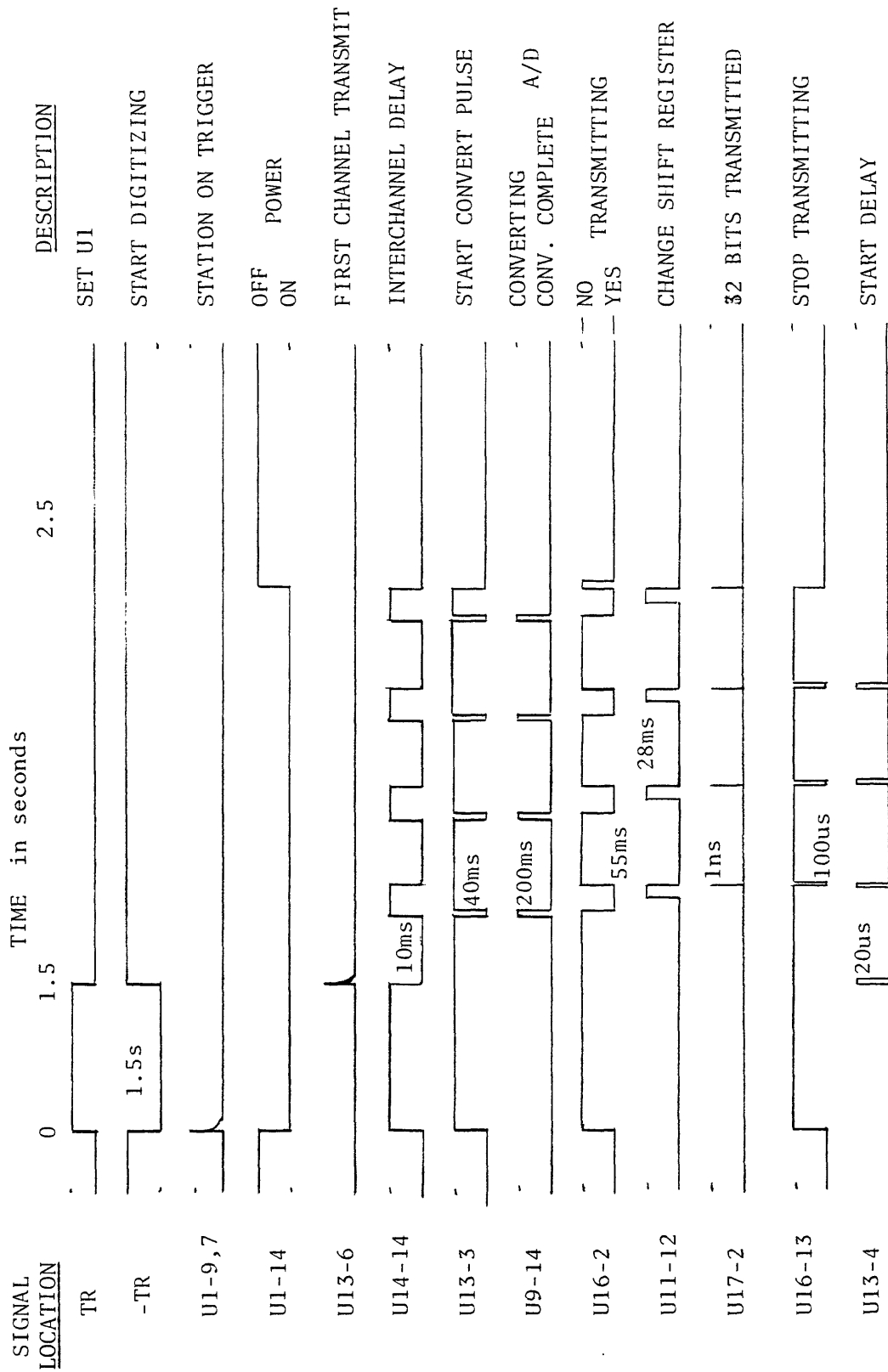


FIG. 14

a 2N5976 power transistor, capable of providing 2 amps for the 12V SW (switched power circuits). When Q3 is turned on, it provides power to all circuitry in the electronics box (MUX, FSK, & DC convertor boards) that are not constantly powered up. Q3 is also used to control the radio switch. The TR line is also used to: 1) reset the counter, U6, that selects the analog input to be digitized, and 2) inhibits U13A, to prevent premature conversion of data. The TR line is high for 1.5 seconds, at which time it goes low and allows the U6 counter and the U13A gate to operate normally. R10 is used to limit current sinking through U6 and U13A from TR while these IC's are not powered and TR is high.

When TR goes low, the CLR line of U6 is released and the outputs all go to the low state. U6 is a 74C193, a binary up/down counter. With all the outputs low, the channel ID bus line (the U6 outputs QA,QB,QC,QD) feeds a channel 0 ID (binary 000) to U2, U3, and U8A, F, & E. U2, a 4028 BCD to decimal decoder, decodes the channel ID buss line into one of eight lines. The circuitry following U2 will be covered in detail later. U3 is a Harris HI-508A 8 channel CMOS analog multiplexer. With the U3 address lines set at channel 0, analog input 1 is switched in. The output of U3-8, an analog voltage, is fed to U7 which buffers the line before reaching U9. U7 and U9 will be discussed in detail later. U8A, F, & E (parts of a 4049 hex inverting buffer) invert and feed the channel ID information to U4.

$\overline{\text{TR}}$ , also from the DTMF board, provides the first start conversion pulse to U13B and also prevents spurious data from leaving through U5 before the system is in normal operation. U5 is a 4082 AND gate. Upon the  $\overline{\text{TR}}$  transition from low to high, C12 and



MUX TIMING SIGNAL DIAGRAM

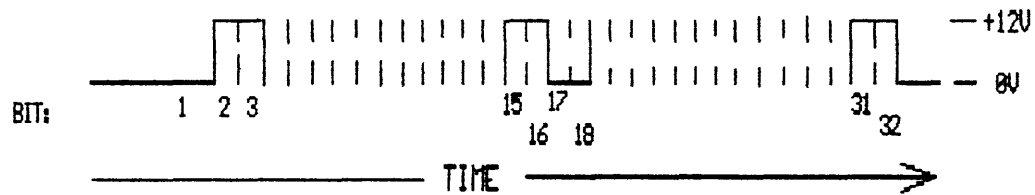
FIG. 15

R24 changes the logic level to a pulse going into U13B, pin 6. U13 is a 4071 quad OR gate. The output of U13B sets U14B, which has a time constant set at 30ms. The 30ms time constant is designated as the Interchannel Delay. U14 is a 4027 dual JK flip flop. This time constant is needed to allow the analog voltage switched into U9 (the A/D) from U3 and U7 time to stabilize. Upon completion of the delay, U14B-14 goes high and C14/R19 changes the logic level into a pulse which sets U14A. U14A has a time constant set at 56us, a pulse length determined by U9 requirements. Upon completion of the 56us delay, the pulse from U14A passes through U13A and on to U18. R25 and CR5 drop the 12V logic level to 10V, to match the power levels of U18 and U9. U18 is set up as a flip-flop to give U9 a  $\overline{SC}$  (start conversion) pulse synchronized with  $\overline{CC}$  (conversion complete) to meet U9 requirements. U9 is a National Semiconductor ADC1210, a 12-bit CMOS analog to digital converter. U9 converts the analog voltage at its input into a 12 bit digital signal at its output, pins 1 thru 12. When U9 has completed the digitization, it signals by taking pin 14, the  $\overline{CC}$  (conversion complete), high. The  $\overline{CC}$  is inverted by U8C, then converted by C17/R21 into a pulse which sets U16A. U16 is a 4013 dual D flip flop. With U16A-2 low, counters U11 and U17 commence counting and clock out 32 pulses. U11 and U17 are 74C193 binary counters. U11 first provides U4 then U10 sixteen timing pulses each.

U4 and U10 are 74C150, 16 line to 1 line multiplexers. Both U4 and U10 sample the information presented to their 32 parallel inputs and transmit the information out in a serial train of 32 bits. The first three bits out of U4 are framing bits, the next 8 are station ID, the next 3 are channel ID, and the last two are



## SERIAL BIT TRAIN



BIT	DESCRIPTION
1	ALWAYS LOW, BEFORE AND AFTER TRANSMISSION
2,3	FRAMING BITS, ALWAYS HIGH
4-11	STATION ID
12-14	CHANNEL ID
15,16	FRAMING BITS, ALWAYS HIGH
17,18	FRAMING BITS, ALWAYS LOW
19-30	DATA
31,32	FRAMING BITS, ALWAYS HIGH

FIG. 16

framing bits (fig. 16). After U11 has counted its first 16 bits, it advances the U17 counter to one and then counts another 16 bits. U10 now transmits its 16 bits of information. U10 transmits two framing bits, 12 bits of data, then two framing bits. The outputs of U4-10 and U10-10 go to U5, a 4082 AND Gate. All U5 inputs must be high before a positive bit can be transmitted. U17, during the first 16 bit transmission of U11/U4, disables U10 and allows U4 to output its data by having U17-3 low. During the second 16 bit transmission of U11/U10, U17-3 goes high and disables U4, allowing U10 to transmit. U8D inverts the signal from U17-3, to provide the correct signal to U10. The clocking of data by U11 is controlled by the U12-1. U12 is a 4060 14 stage binary counter. Jumpers labeled HI and LO are to select data transmission rate, HI (U12-1) is 600 bps and LO (U12-2) is 300 bps. U12-5 also provides a 76.8 Khz signal to U9. Upon completion of 32 bits, U11-12 pulses U17 which increments to 2. U17-2 sets U16B, which resets U16A, which stops U11 and U17 from counting. U16B also sends a pulse to U6 and to U13B. The pulse to U6-5 advances the counter by one, which increments the channel bus to 1 (from 0), which causes U3 to switch to channel two and the stop select section to channel 1. The pulse from U16B to U13-5 sets U14B. This starts another interchannel delay before commencing start conversion for the second channel. The sequence of pulses will then occur as outlined previously, for the amount of channels to be transmitted. U16B, whose time constant is set at 1ms, is also used as a pulse stretcher from U17-2. Our test equipment could never see the output pulse of U17, so U16B is used as a guarantee that U6 and U13 will be triggered correctly and consistently.

U1A is also set when U1B is set by the TR pulse. U1A is designed with a 7 second time constant. In the event that the stations powers up and does not shut down, seven seconds after power up U1A will force the system to shut down.

U2 and S1 comprise the stop select section. U2, a 4028 BCD to decimal convertor, converts the Channel ID bus information to one of ten outputs. Eight of those outputs are connected to S1, the stop select switch bank with eight switches. Switch S1 is set for the number of channels to transmit. If, for example, we want four channels to be transmitted, S1-4 is set to on. After four channels have been transmitted and counter U6 is advanced to channel 5, a high pulse from U2-15 (signifying channel 5 on the channel bus) passes through S1-4 through CR4 and resets U1B-12. This causes the MUX to power down and prevent a fifth channel from transmitting. If S1 is not set, the station will continue to transmit until U1A forces the system to shut down.

S2 and RP1 comprise the station id section. The S2 switch settings must match the DTMF Decoder board settings and the software settings on the central computer, otherwise the computer will reject the data. The S2 switch must be set in binary fashion, not decimal like the DTMF board and the computer. RP1 (22K ohm resistor package) pulls the open switches high so there is no floating of the inputs to U4.

U7 and U15 are LM308 operational amplifiers. U7 is used to buffer the analog voltage between U3-8 and U9-18. U15 is used to buffer and divide the battery voltage (12V SW) so that it can be accepted by the analog input IC U3. R15 and R16 form a voltage divider on the switched power circuit, dividing the battery voltage

by 3.1 to be just under the +5V limit. Connecting the Battery Monitor output to one of the input channels provides a useful remote system check on battery status.

CR6 and CR7 are installed across the digital and analog common to prevent voltage buildup in either common circuit.

The points labeled TB on the schematic are located on the test block. Important signal lines are brought through the test block for easier troubleshooting. Test block pin numbers are noted.

Fig. 17 is the Mux & Control Parts layout.

Table 7 is the Mux & Control Parts List.

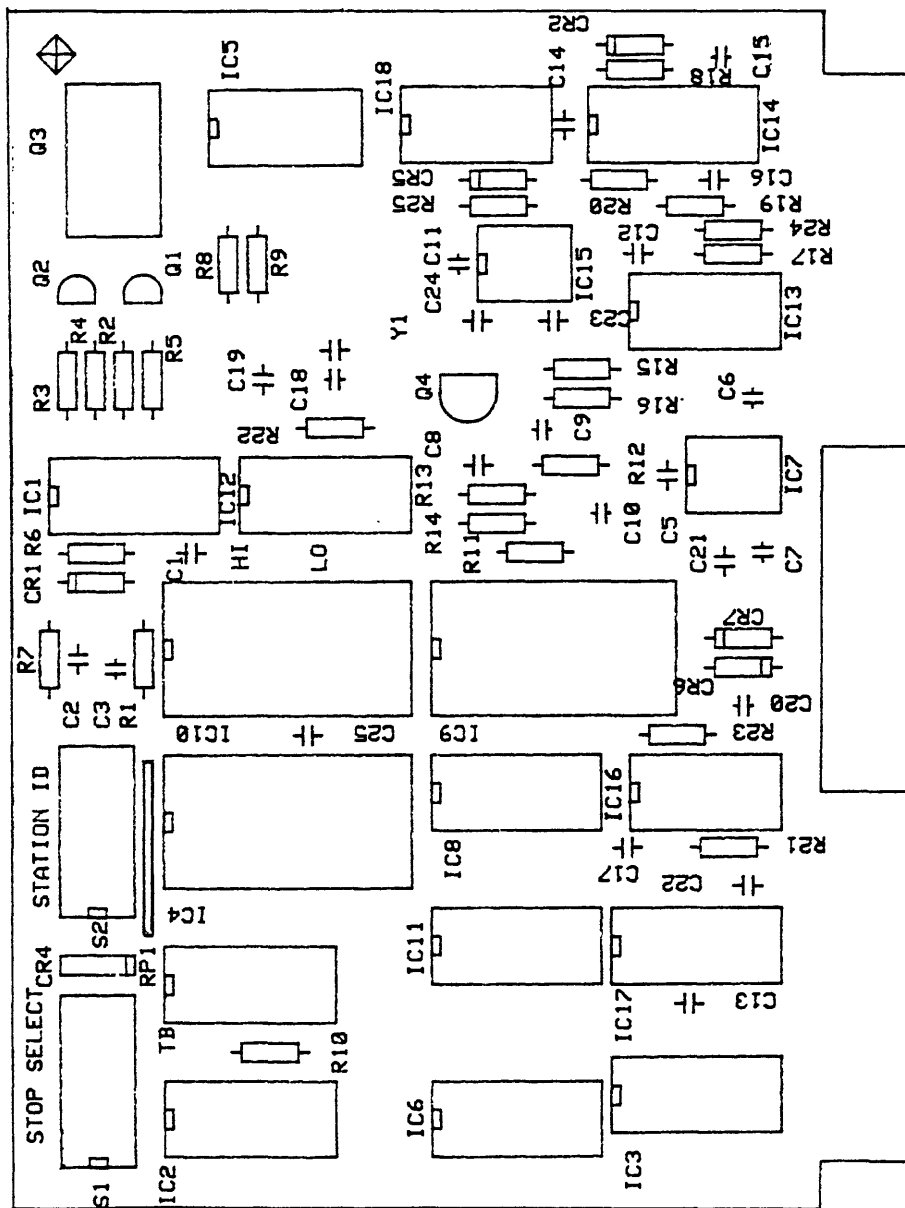


FIG. 17

# MUX & CONTROL II PARTS LAYOUT

DRAWN  
GP 12-9-88

DESIGNED  
GP 1987

MUX & CONTROL II BOARD  
HVO INTERROGATION SYSTEM

## VCO BOARD

The VCO is used to convert the digital serial bit train into FSK (Frequency Shift Key) tones for data transmission over the radios. The VCO (voltage controlled oscillator) in use, called FSK4, was designed by E. G. Jensen of the U.S.G.S., (Written communication, 1977) See fig. 18. A detailed theory of design and logic of operation will not be covered here, only how to set up the VCO for operation.

The VCO is designed to accept 0 to +12V logic levels, square wave serial data, and transforms the data into sine wave signals of 1200 and 2200 hz. The 0 volt logic level is transmitted as the lower frequency at 1200 hz and the +12V logic level is transmitted as the upper frequency of 2200 hz. The frequencies are set by programming the dividers IC5 (1200hz) and IC2 (2200hz). The programming for this VCO is depicted in fig 19. The small 'x's denote where jumpers should be cut, and thicker lines where jumpers should be left in place.

The crystal frequency can be finely tuned by adjusting C2, and the output level can be adjusted by varying R20. See fig. 20 for FSK4 VCO Layout. The output level is typically set at 1 volt peak to peak for a 1Khz deviation in the radio transmission.

Table 8 is the VCO Parts List.

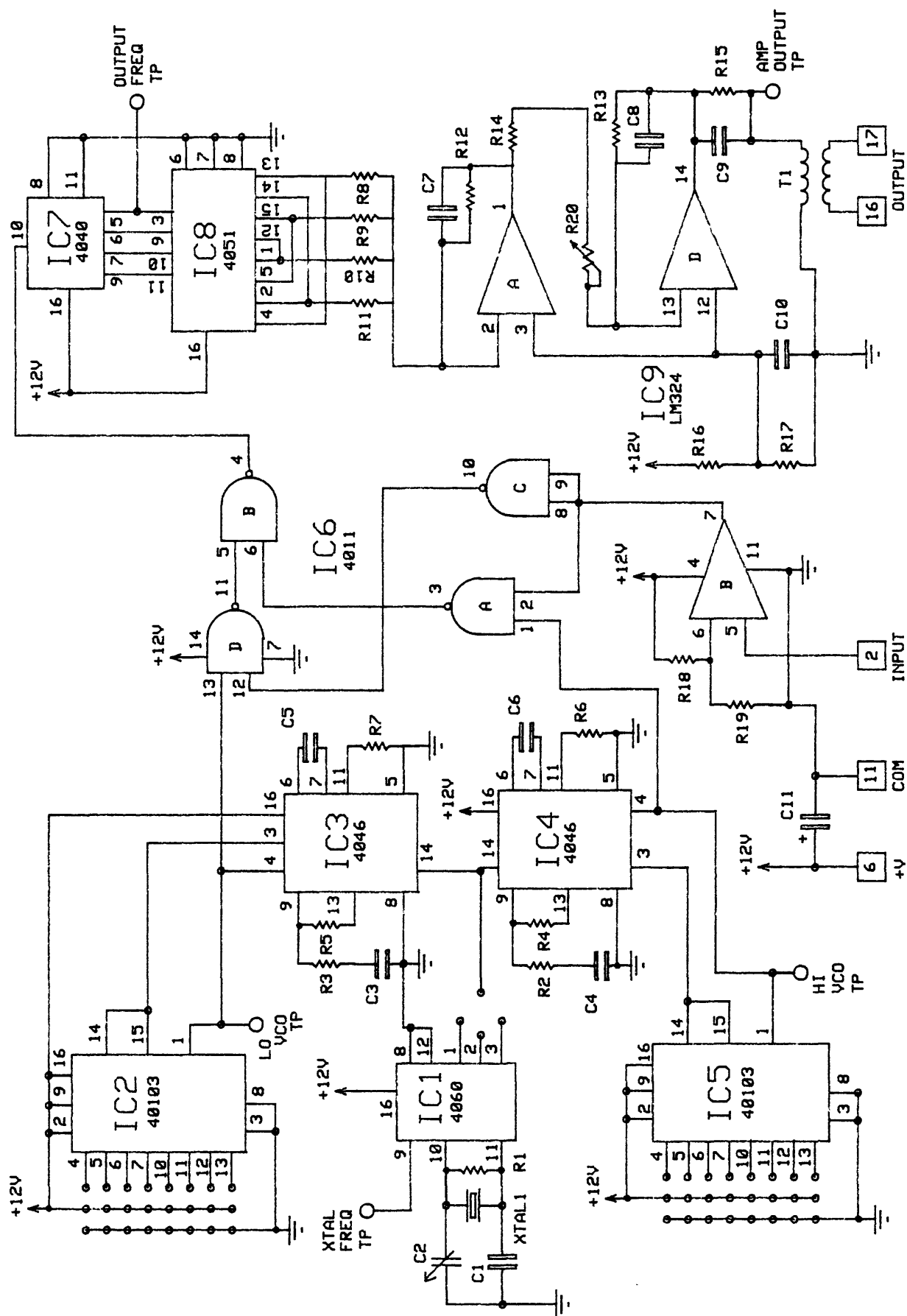
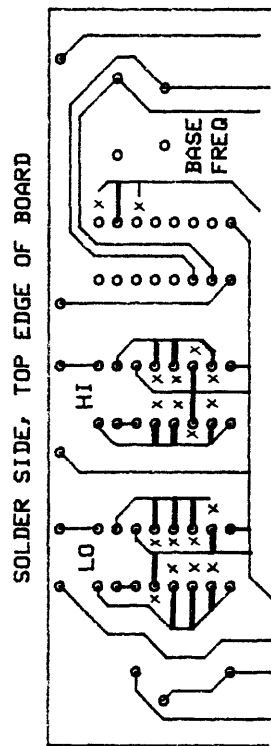


FIG. 18

# FSK4 VCO SCHEMATIC

DESIGNED E. G. JENSEN	FSK4 VCO HVO INTERROGATION SYSTEM
--------------------------	--------------------------------------

GP 12-6-88



# FSK4 VCO BOARD PROGRAMMING GUIDE

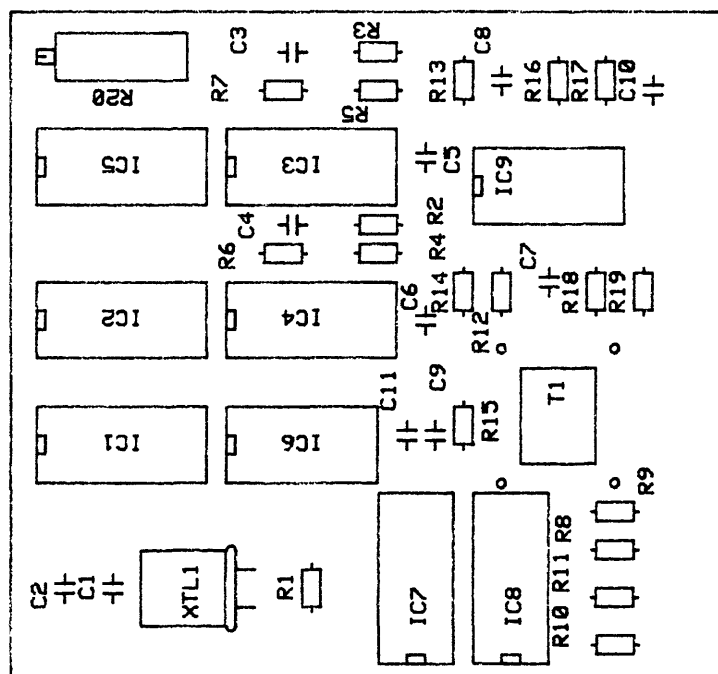
LO FREQUENCY: 1200 HZ      HI FREQUENCY: 2200 HZ      CENTER FREQUENCY: 1700 HZ

DRAWN GP 12-7-88
DESIGNED E. G. JENSEN

FSK4 VCO  
HVO INTERROGATION SYSTEM

FIG. 19





# FSK4 VCO PARTS LAYOUT

FIG. 20

DRAWN

GP 12-2-88

DESIGNED

E. G. JENSEN

FSK4 VCO BOARD

HVO INTERROGATION SYSTEM

## DC CONVERTER BOARD

The DC Converter board converts the 12V battery supply to various other DC volatages. It is designed to use a variety of voltage converter modules (made by Integrated Circuits Incorporated) for differing input and differing output voltage requirements. See fig. 21.

The power for the converter board is supplied via the switched power circuit of the Mux board. When Q3 of the Mux board is switched on, it provides 12V to power this board, which then supplies power to the circuits that require the  $\pm 15V$ .

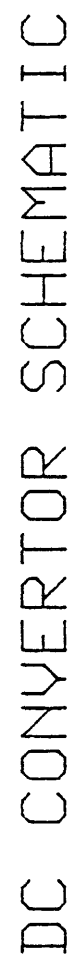
For use in the HVO polling system, the DIP121515 made by Integrated Circuits Inc., is used. This voltage module requires a 9 to 15 volt input and provides regulated  $\pm 15$  volts out, with 25mv RMS of ripple. The DIP121515 can provide up to 80ma of current for each side.

A 68uf tantalum capacitor (C5) is necessary on the input of the DIP121515 to provide the surge current draw when the IC powers up. The tantalum capacitors C1 and C3 are required by the DIP12-1515 for energy storage, and the ceramic capacitors C2 and C4 are used to attenuate high frequencies on the output ripple.

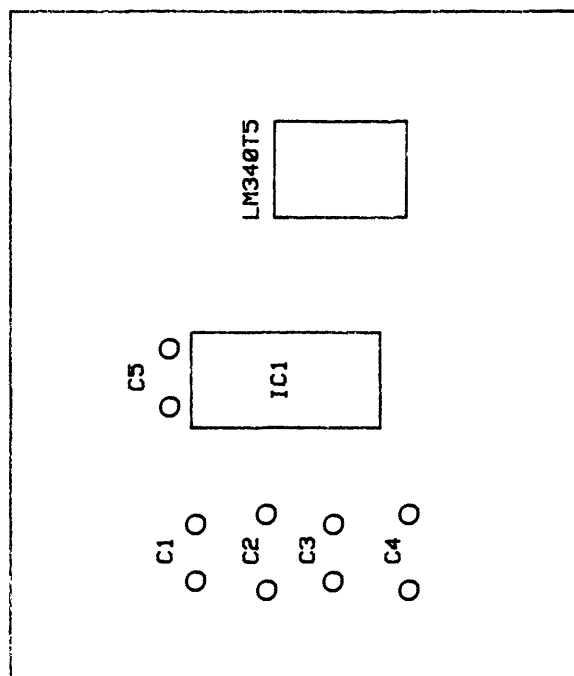
If a switched 5 volt supply is required for accessory equipment, an LM340KT-5 can be added to the board to provide the required voltage. The LM340 can supply up to 1 amp of power.

Figure 22 depicts the parts layout of the DC Converter board.

Table 8 is the DC Convertor Parts List.



DC CONVERTOR	DRAIN	GP 8/22/88
HVO INTERROGATION SYSTEM	DESIGNED	



# DC CONVERTOR BOARD PARTS LAYOUT COMPONENT SIDE VIEW

FIG. 22

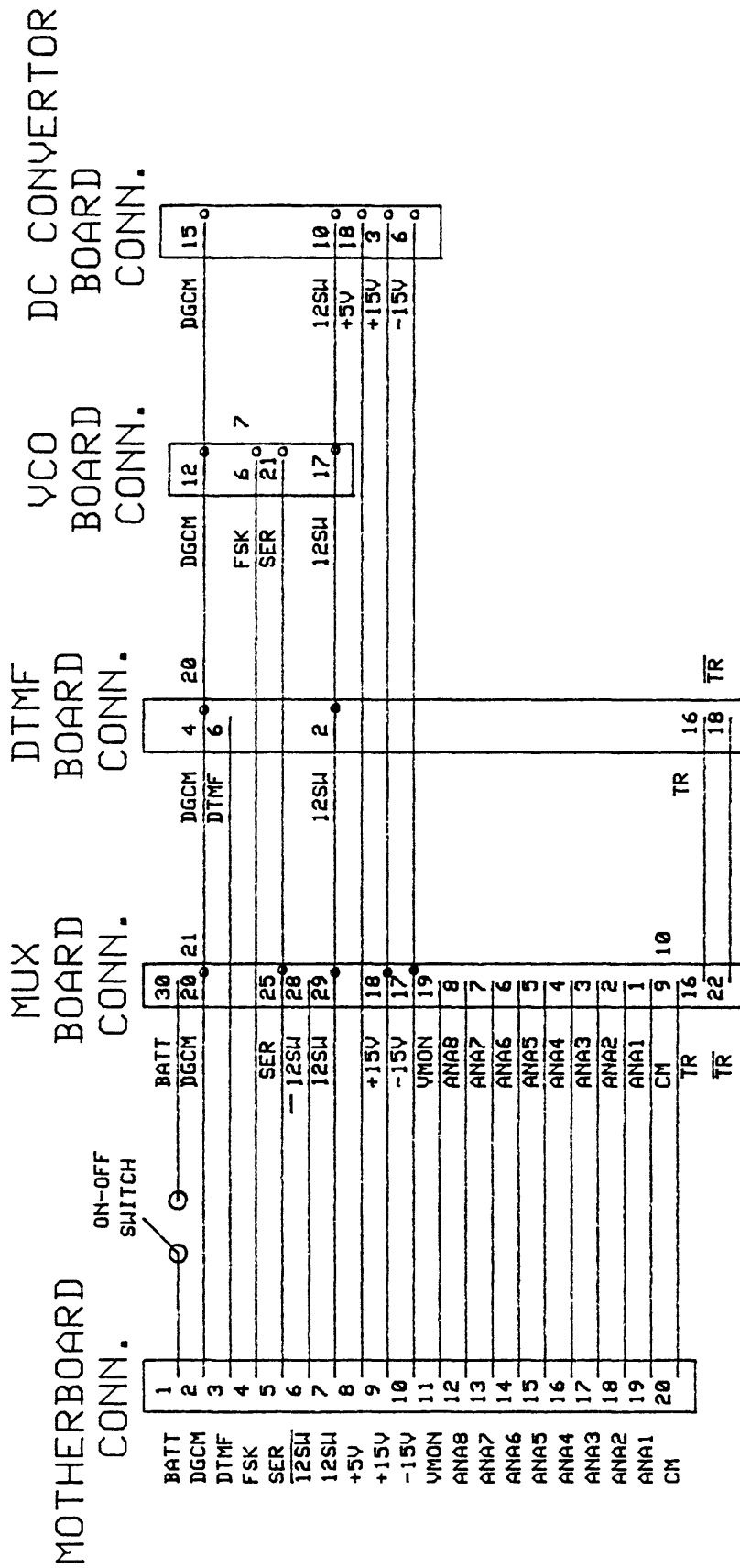
DRAIN GP 12-2-88 DESIGNED GP 1983	DC CONVERTOR BOARD
	HVO INTERROGATION SYSTEM

## MOTHERBOARD

The motherboard lays in the bottom of the electronics box. The motherboard provides the means of connecting signals and power to the different boards and to external inputs. On it is mounted an on-off switch, card end connectors for each electronics board, and a ribbon cable with a card end connector to connect the motherboard to the barrier boards.

The boards that plug into the motherboard include the DTMF Decoder, the Mux & control, the DC Convertor, and the FSK board. The DTMF, FSK, and the DC Convertor all mount on 22 pin, .156" spacing card edge connectors. The Mux & Control board mounts on two 15 pin, .125" spacing card edge connectors. See fig. 23 for Motherboard Schematic and fig. 24 for Motherboard Layout.

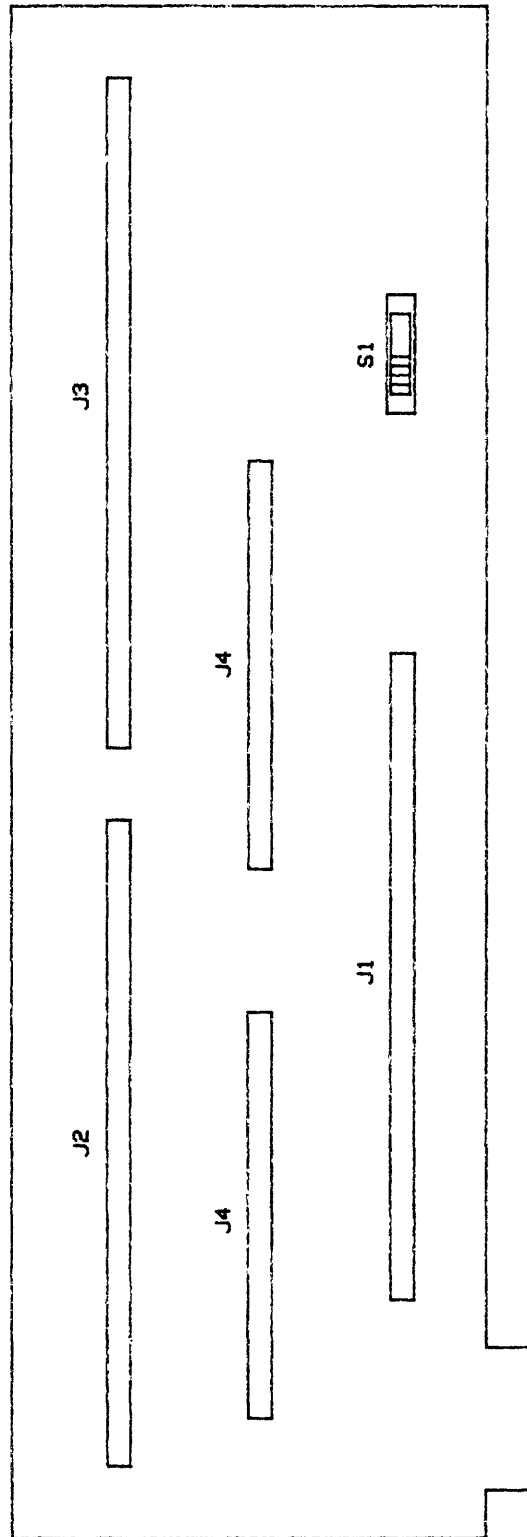
The on-off switch controls all power to the digital box and radio box from the batteries.



# MOTHERBOARD SCHEMATIC

FIG. 23

DRAIN	GP 8/22/88	MOTHERBOARD
	DESIGNED G PUNITUAL 1983	
		HVO INTERROGATION SYSTEM



# MOTHERBOARD PARTS LAYOUT

FIG. 24

DRAWN

GP 8-22-88

DESIGNED

G PUNITIAI 1983

MOTHERBOARD  
HVO INTERROGATION SYSTEM

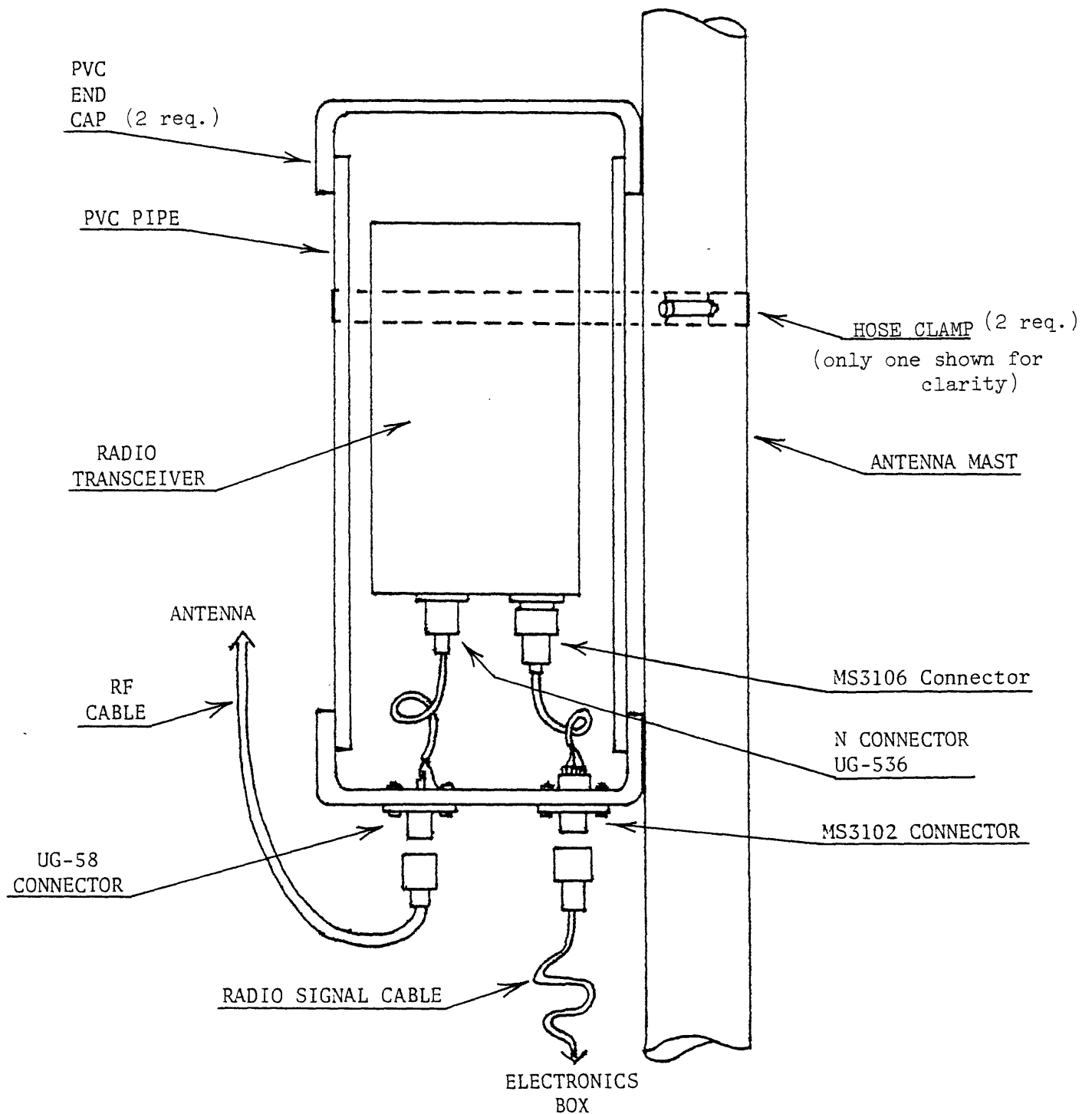
## FIELD RADIO SYSTEM

### **RADIO CONTAINER**

The radios (or transceiver) are mounted in a environmental container. The currently favored container is 4" diameter PVC pipe fitted with end caps. Bulkhead connectors for power/signal and antennas are mounted on one of the caps. See fig. 25 for Radio Container Diagram. The two types of radios that are currently used are Condel mo. TRS-20A and Monitron mo. TR-15.

The PVC or ABS type pipes are cut to 8" with end caps fitted on both ends. On one of the caps is mounted two connectors, one for the power and signal wires and the other for the RF output. The power and signal bulkhead connector is an MS3102A-14S-5S, and the RF passes through a UG-58A type N panel receptacle. Both caps are glued to the pipe with a silicone sealant to prevent corrosive air from entering the enclosure. The sealer can be easily removed to access the radios. The power and signal wires from the 'MS' type bulkhead connector are terminated with a MS3106A-14S-5P straight connector. The MS straight connector plugs onto the radio, the bulkhead MS connector is used with a cable to connect with the electronics box. A short jumper from the RF panel connector is terminated with a type 'N' male to connect to the radio. The female side of the RF panel connector uses an RF cable with two 'N' connectors to connect to the antenna. The completed radio container is usually mounted to a mast with two hose clamps. See Table 11 for MS pin designations, color codes, and radio box parts list.





RADIO BOX CROSS SECTIONAL VIEW

FIG. 25

## **RADIOS**

Both the Condel and Monitron radios used in the radio box are transceivers, containing both a radio receiver and a radio transmitter. There is a switch which transfers power and antenna connections between the receiver and transmitter.

The only adjustments on the transceiver is a squelch and a output level. The squelch is adjusted to the most sensitive position before the squelch is broken, and the output level is adjusted for 1 volt peak to peak.

Stations that have line of site with the HVO receive and transmit on the F1 radio frequency, 171.219 Mhz. Stations that do not have line of site with the HVO operate with the repeater on Mauna Kea. The stations using the repeater transmit on 166.4187 Mhz and receive on 171.219 Mhz.

## **ANTENNAS**

Most sites use a gain antenna because of the low RF power levels. A Scala CA5-150V, a vertically polarized yagi antenna with 9 db, is the antenna used for remote stations. Stations within 5 miles of the observatory utilize a simple whip antenna for radio communication.

## REMOTE RADIO REPEATER

The radio repeater is used to retransmit information between the central computer and stations that do not have line-of-site contact with the observatory.

The repeater currently used is model VR-10 by the Monitron Corporation. The repeater contains a model R15F receiver, a TR150 transmitter, and a transmitter controller board. The normal standby state of the repeater has only the receiver on. When the receiver detects any RF carrier on its frequency, it turns on the transmitter to repeat any information the receiver receives. The radio receiver receives on 166.4187 Mhz, and the transmitter transmits on 171.219 Mhz.

The repeater requires a 12 volt power source and antenna for operation. A Scala CA5-150V yagi gain antenna is used with the repeater.

## OPERATION

This section provides instructions to operate a field unit and have it accessed by the control computer.

The first job to be done in setting up a station is to program the host computer with the station information. This includes the station name, station id number, transmitter frequency number, polling period, subnet id, number of channels, Mux serial number, zero volt bit count, battery conversion factor, and battery status flag. Refer to OFR 87-633.

The next job entails programming the digital box and requires setting switches on the Mux & Control and DTMF board.

The three dipswitches on the DTMF board will be set first. The switches must be set in sequential order (first S1, then S2 and finally S3) to match the station id number that was programmed into the computer. If, for example, the station id number on the computer is 025, then set switch #1 on the DTMF board to 0, switch #2 to 2, and switch #3 to 5. The DTMF board will now send the appropriate signals to activate the Mux card only after the computer transmits the DTMF code " 0 2 5".

The next task is to set the Station Id switch (S2) on the Mux card. This switch is programmed in binary code. The eight positions on the dipswitch allow 256 units, which limits this system to 256 stations. So, the decimal number 025 (from the example) must be converted to a binary number, which is 10011000 in binary base 2. Set dipswitch S2 position 1 (S2-1) to On, S2-2 to off, S2-3 to off, S2-4 to on, S2-5 to on, and S2-6, 7, and 8 to off. S2-1 is binary  $2^7$  and S2-8 is binary  $2^0$ . The information from

S2 is transmitted with each channel of data, which the host computer will then verify before accepting the data. This check will also insure that the data that is received is from the same station that the computer called.

The last switch to set is S1 on the Mux card, the Stop Select. Simply count how many channels of information is to be sent and set that number on the switch to on. The rest of the switches must be set to off. Example; if four channels of data are to be sent, set S1-4 to on and all other switches to off. The number of channels set should coincide with the computer program, if it is less than the computer expects it will repeatedly try to gather data. If it is more than computer is programmed for, the computer will ignore the excess channels.

## REFERENCES CITED

1. Roger, J., Johnston, M. J. S., Mortensen, C., and Myren, G., 1977, A Multi-channel Digital Telemetry System for Low Frequency Geophysical Data: U.S. Geological Survey Open-File Report 77-490, p. 111.
2. English, T. T., 1987, HVO Polling Telemetry System for Low Frequency Data Acquisition: Software Users' Guide: U. S. Geological Survey Open-File Report 87-633, 51 p.

## APPLE INTERFACE PARTS LIST

<u>DESG</u>	<u>DESCRIPTION</u>	<u>QTY</u>
U1	CD4049BE Invertor	1
U2	6522 Versastile Interface Adaptor	1
U3	S2559A Tone Generator	1
U4	XR2211 FSK Demodulator	1
R1	1K, 1/4W, 5% Resistor	1
R2, 3	4.7K Resistor	2
R4	1.3K Resistor	1
R5	10M Resistor	1
R6	51K Resistor	1
R7	20K Resistor	1
R8	100K Resistor	1
R9	510K Resistor	1
R10	5.1K Resistor	1
R11, 12	5K, 20 turn, 3/4" rectangular Potentiometer	2
C1	10pf Ceramic Capacitor	1
C2	0.002μf Ceramic Capacitor	1
C3	0.022μf Ceramic Capacitor	1
C4, 6, 8	0.1μf Ceramic Capacitor	3
C5	0.0047μf Ceramic Capacitor	1
C7	0.5μf Ceramic Capacitor	1
Y1	3.58 Mhz Crystal	1
T1	42LH016 Mouser Transformer	1
D1 thru D7	1N914 Diode	7
J1	14 DIP Header w/ribbon cable	1
	14 DIP Socket	2
	16 DIP Socket	2
	40 DIP Socket	1

TABLE 1

## RADIO INTERFACE PARTS LIST

<u>DESG</u>	<u>DESCRIPTION</u>	<u>QTY</u>
Q2, 4, 6	MPSA14 Transistor	3
Q3, 5	2N4403 Transistor	2
Q1	2N5976 Transistor	1
R2, 7, 11	51K, 1/4W, 5% Resistor	3
R4, 9, 13	100K Resistor	3
R1, 3, 6, 8, 10, 12	1.2K Resistor	6
R5	5K, Weston 850 Potentiometer	1

TABLE 2



ELECTRONICS BOX PARTS LIST

<u>DESG.</u>	<u>DESCRIPTION</u>	<u>QTY</u>
Container	Skydyne 99380	1
Connectors	MS3102A-14S-5S (Radio)	1
	MS3106A-14S-9S (Power)	1
	Bendix PT07E-8-4P	2
Barrier board	Cinch 10-140-Y	2
Cable	Digikey R505-36-ND	1
Hardware	Standoffs 4-40 x 1/2"	6
	Screws 4-40 x 1/2"	28
	Washers #4	14
	Lockwashers #4	8
	Nuts 4-40	12
	Corner L Brackets 1.5 x 1.5"	4
1. Misc. Cable	2 Conductor cable, one end fitted with a MS3106A-14S-9P straight connector and the other end with two spade lugs for connection to system battery	

TABLE 3

# ELECTRONICS BOX PIN DESIGNATIONS I

<u>PIN NO</u>	<u>MUX &amp; CONTROL</u>	<u>MOTHERB./ BARRIER</u>	<u>RIBBON CC</u>	<u>DC CONV</u>	<u>DTMF DECODER</u>	<u>FSK VCO</u>	<u>PIN NO.</u>
1	ANA. 1	BATT	BR				1
2	" 2	DIG CM	RD		+12V	IN	2
3	" 3	DTMF	OR	+15V			3
4	" 4	FSK	YW		CM		4
5	" 5	SER OUT	GN				5
6	" 6	-12V SW	BU	-15V	DTMF	+15V	6
7	" 7	12V SW	PU			CM	7
8	" 8	+5V SW	GY				8
9	" CM	+15V	WH				9
10	" CM	-15V	BK	+12V			10
11		V MON	BR				11
12		ANA. 8	RD				12
13		" 7	OR				13
14		" 6	YW				14
15		" 5	GN	CM			15
16	TR	" 4	BU		TR	CM	16
17	-15V	" 3	PU			FSK	17
18	+15V	" 2	GY	+5V	-TR		18
19	V MON	" 1	WH				19
20	DIG CM	" CM	BK		CM		20
21	DIG CM						21
22	-TR						22
23							23
24							24
25	SER OUT						25
26							26
27							27
28	12V SW						28
29	12V SW						29
30	+12V						30

TABLE 4

# ELECTRONICS BOX CONNECTOR PIN DESIGNATIONS

<u>PIN</u>	<u>MS3102A-14S-5</u>	<u>MS3102A-14S-9S</u>	<sup>1</sup> <u>PT07E-8-4P</u>	<sup>2</sup> <u>PT07E-8-4P</u>
A	Common	Common	Input Ch 1	Input Ch 4
B	+12 Volt	+12 Volt	Input Ch 2	Input Ch 5
C	DTMF		Input Ch 3	Input Ch 6
D	Switch		Common	Common
E	FSK			

## BARRIER BLOCK FUNCTIONAL PLACEMENT

LEFT										RIGHT									
BATT.	GND.	DTMF	FSK	SER.OUT.	12V.SW	12V.SW	5V.SW.	+15V.	-15V.	V.MON.	ANA.8	ANA.7	ANA.6	ANA.5	ANA.4	ANA.3	ANA.2	ANA.1	GND.

TABLE 5

DTMF DECODER PARTS LIST

<u>DESG.</u>	<u>DESCRIPTION</u>	<u>QTY</u>
U1	SSI201 DTMF Decoder	1
U2	4000 Invertor	1
U3	4514 4 to 16 Line Decoder	1
U4,5	4013 D Flip-Flop	2
U6	4098 Multivibrator	1
R1	10M, 1/4W, 5% Resistor	1
R2	100K Resistor	1
R3	1.5M Resistor	1
R4	4.7M Resistor	1
C1, 2, 3	0.01uf Ceramic Capacitor	3
C4	3.3uf Tantalum Capacitor	1
C5	1.5uf Tantalum Capacitor	1
Y1	3.579 Mhz Crystal	1
S1, 2, 3	76SB10 Grayhill Dipswitch	3
	14 DIP Socket	3
	16 DIP Socket	1
	22 DIP Socket	1
	24 DIP Socket	1

TABLE 6

MUX & CONTROL PARTS LIST

<u>DESG.</u>	<u>DESCRIPTION</u>	<u>QTY</u>
U1, 14	4027 Dual Flip Flop	2
U2	4028 Decoder	1
U3	HI508A Multiplexer	1
U4, 10	74C150 Shift Register	2
U5	4082 And Gate	1
U6, 11, 17	74C193 Counter	3
U7, 15	LM308 Op Amp	2
U8	4049 Inverter	1
U9	ADC1210 A/D Convertor	1
U12	4060 Counter	1
U13	4071 Or Gate	1
U16	4013 D Flip Flop	1
U18	74C00 Nor Gate	1
R1, 7, 17, 19 21, 24	100K, 1/4W, 5% Resistor	6
R2, 3	7.5K Resistor	2
R4, 8, 9	20K Resistor	3
R5	5.1K Resistor	1
R6	470K Resistor	1
R10, 12, 23	10K Resistor	3
R11, 18	30K Resistor	2
R13	1K Resistor	1
R14	200K Resistor	1
R15	82.5K, 1% Resistor	1
R16	39.2K, 1% Resistor	1
R20	56K Resistor	1
R22	15M Resistor	1
R25	110K Resistor	1
RP1	22K, 9 Resistor pack	1
C1,	0.2μf Ceramic Capacitor	1
C2, 8, 12, 13 14, 21, 22, 23, 24, 25	0.1μf Ceramic Capacitor	10
C3	15μf Tantalum Capacitor	1
C5, C11	47pf Ceramic Capacitor	2
C6, 7, 9	4.7μf Tantalum Capacitor	3
C10	100pf Ceramic Capacitor	1
C15	1.0μf Tantalum Capacitor	1
C16	0.001μf Ceramic Capacitor	1
C17	270pf Ceramic Capacitor	1
C18, 19	22pf Ceramic Capacitor	2
C20	0.01μf Ceramic Capacitor	1

TABLE 7, cont. next page

MUX & CONTROL PARTS LIST cont.

<u>DESG.</u>	<u>DESCRIPTION</u>	<u>QTY</u>
CR1, 2, 4, 6, 7	1N4148 Diode	5
CR5	9.1V Zener Diode	1
Q1, Q2	2N4403 Transistor	2
Q3	2N5976 Transistor	1
Q4	LH0070-1H Voltage Regulator	1
Y1	2.4576 Mhz Crystal	1
S1, S2	206-8 CTS Dipswitch	2
TB1	16 DIP Header	1
	8 DIP Socket	2
	14 DIP Socket	4
	16 DIP Socket	9
	24 DIP Socket	3

There is no CR3 and no C4.

TABLE 7, cont.

# FSK4 VCO PARTS LIST

<u>DESG.</u>	<u>DESCRIPTION</u>	<u>QTY</u>
C1	10pf Ceramic Capacitor	1
C2	15-60pf Trimmer Capacitor	1
C3, 4, 10	0.1μf Ceramic Capacitor	3
C5, 6	680pf Ceramic Capacitor	2
C7, 8	680pf Ceramic Capacitor	2
C9	4.7μf Electrolytic Capacitor	1
C11	15μf Electrolytic Capacitor	1
IC1	CD4060BE Counter	1
IC2, 5	CD40103BE	2
IC3, 4	CD4046BE	2
IC6	CD4011BE	1
IC7	CD4040BE	1
IC8	CD4051BE	1
IC9	LM324N Op Amp	1
R1	15M, 5%, 1/4W Resistor	1
R2, 3	100K, 5% Resistor	2
R4, 5	200K, 5% Resistor	2
R6, 7	27K, 5% Resistor	2
R8	1M, 1% Resistor	1
R9	232K, 1% Resistor	1
R10	200K, 1% Resistor	1
R11	348K, 1% Resistor	1
R12, 13	68K, 5% Resistor	2
R14	47K, 5% Resistor	1
R15	1K, 5% Resistor	1
R16, 17	510K, 5% Resistor	2
R18	750K, 5% Resistor	1
R19	160K, 5% Resistor	1
R20	500K, 20 turn Potentiometer	1
T1	500:600 Ohm Transformer	1
XTL1	1.310720Mhz Crystal	1

TABLE 8

# DC CONVERTER PARTS LIST

<u>DESG</u>	<u>DESCRIPTION</u>	<u>QTY</u>
U1	DIP121515 Voltage Conv.	1
C1, 3	150 $\mu$ f Tantalum Capacitor	2
C2, 4	0.1 $\mu$ f Ceramic Capacitor	2
C5	68 $\mu$ f Tantalum Capacitor	1

TABLE 9



# MOTHERBOARD PARTS LIST

<u>DESG.</u>	<u>DESCRIPTION</u>	<u>QTY</u>
J1, 2, 3	22 Pin, .156" spacing, PC mount, C.E. connector	3
J4, 5	15 Pin, .125" spacing, PC mount, C.E. connector	2
S1	On-Off switch	1
Hardware	4-40 x 3/4" screw	6
	4-40 Nut	6
	#4 lockwasher	6

TABLE 10

## RADIO CONTAINER PARTS LIST

<u>DESCRIPTION</u>	<u>QTY</u>
4" PVC or ABS pipe, 8"	1
4" PVC end cap	2
Hose Clamp	1
MS3102A14S-5S Bulkhead Connector	1
MS3106A14S-5P Straight Connector	1
Type N Bulkhead Connector, UG-58	1
Type N Straight Connector	1
Radio signal cable, 5 wire, each end fitted with a MS3106A14S-5P (connects radio box with digital box)	1
Cable, RF, each end fitted with a type N (connects radio box with antenna)	1

### RADIO MS CONNECTOR PIN DESIGNATION AND COLOR CODE

<u>PIN</u>	<u>COLOR</u>	<u>DESIGNATION</u>
A	BLK	CM
B	ORG	POWER
C	YEL	DTMF
D	RED	SWITCH
E	BRN	FSK

TABLE 11