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LIGHTNING DETECTION & RANGING SYSTEM
LDAR
SYSTEM DESCRIPTION & PERFORMANCE OBJECTIVES

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LDAR

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APPROVAL

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SUMMARY

The performance objectives, the instrumentation, the data processing, the data recording, the data reduction, and the software for the LDAR Lightning Detection and Ranging System are discussed.

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I. INTRODUCTION

Valuable lightning and system-performance data were collected by LDAR during the 1976 Thunderstorm II project.

Since 1976, the capability and the accuracy of the LDAR system has been improved by reconfiguration of the network, the addition of new ground stations, the addition of electric field sensors, the addition of digital waveform recorders, and the completion of a new software package to collect, process, and record the data.

The addition of electric field sensors gave the system the capability to determine the position, the waveshape, the rate of rise, and the peak current of ground strikes. The addition of two new ground stations to form a new Y configuration gave the system an improvement in reliability and accuracy by providing a completely independent hyperbolic system with which to check the LDAR data. Excessive power line noise at one of the stations was corrected by relocation of the station in 1978.

II. PERFORMANCE OBJECTIVES

The primary performance obj. tives of the LDAR System are to:

1. Detect and determine the position (X, Y, Z) of the numerous electrical discharges associated with thunderstorm activity, and display the position of the electrical discharges on a PPI and RHI plot. Transmit and display the PPI and RHI plots of electrical discharge activity to the KSC weather office for use in tracking the position and movement of thunderstorm activity.

2. Measure and record electric field waveform data in order to:

a. Determine the position of ground strikes at KSC.

b. Determine the rate of rise and peak currents of ground strikes at KSC.

Uses of the LDAR data are to:

a. track thunderstorms,

b. provide size and a measure of the electrical activity of the storm,

c. help explain interaction of wind flow and electrical activity,

d. establish a firm basis for the relation of field strength/distance to the active electrical centers in a thunderstorm, using airborne electric field measurements,

e. establish the pattern of ground strikes for KSC, clarify the one-to-one cone of protection theory, and investigate the attractive effects of large buildings,

f. determine statistics for the number of strikes per flash,

g. measure the peak current per flash,

h. measure the rate of rise of current in ground strikes,

i. measure the velocity of the ground strike current, for ground strikes produced by the triggered-lightning experiment.

III. DETAILED DISCUSSION

A. REMOTE SITES

There are six remote stations. The location of the stations is shown in Figure 1. Two basic measurements are made: the time-of-arrival of the envelope of the pulsed 60-80 MHz portion of the RF signal emitted by the lightning, and the electric field (E-field) waveform. We will discuss the measurement of these two signals separately.

1. LDAR SIGNAL TRANSMISSION

The transmission of the LDAR signal from the remote site to the central station differs, depending on whether a Type 1 or a Type 2 Receiving Station is used. We will discuss these in turn. A Type 1 Receiving Station differs from a Type 2 in the manner of transmission of the signal to the central station. In the Type 1 Station instrumentation the LDAR and the E-field signals are sent separately by wideband cable. In the Type 2 instrumentation system, the two signals are combined and sent via microwave link.

FIGURE 1

MAP

RECEIVER SITES

i. The Type 1 Receiving Station, Figure 2

Figure 2 shows the signal flow of the LDAR signal at a remote site employing the Type 1 instrumentation.

Starting at the LDAR, vertically-polarized, omnidirectional, 40-100 MHz antenna A-1* the signal passes to a 60-80 MHz bandpass filter A-2. The LDAR signal then passes through a log IF amplifier A-3 having an 80 db dynamic range, which amplifies and envelope detects the incoming LDAR signal. The detected LDAR signal then comes to a switch S1, which is used for delay line calibration. Switch S2 permits the substitution of a 1 MHz sine wave test signal in place of the LDAR signal. The purpose of the 1 MHz sine wave signal is to check the data transmission system, as well as to provide a calibration signal for the tape recorders at the central site.

Three, W1, W2, and W3, of the six remote stations use Type 1 Receiving Station instrumentation. The other three, M1, M2, and M3, use the Type 2 Type.

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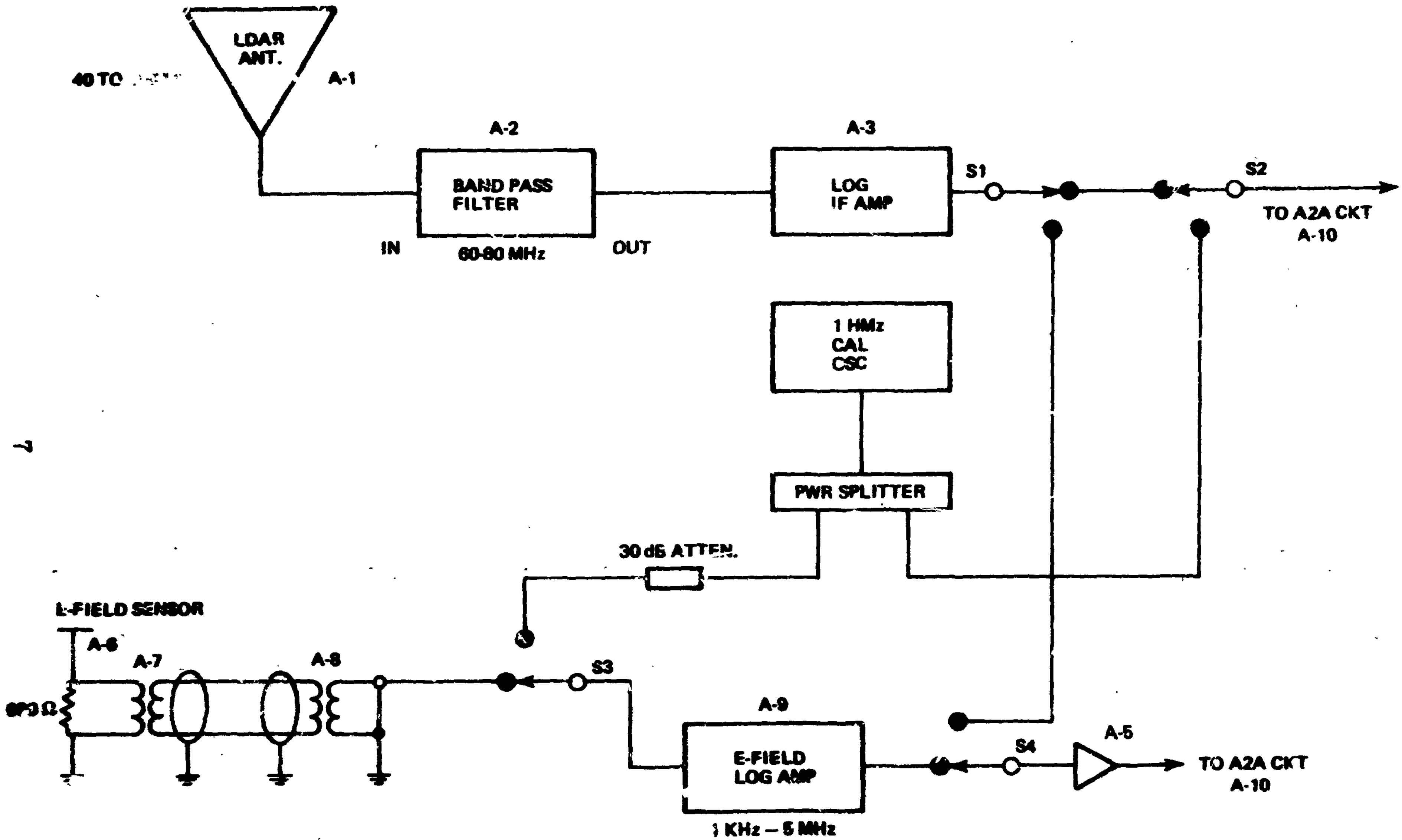
*The numbers A-1, A-2, etc. refer to data sheets given in the Appendix.

Figure 2. Remote Site, Type 1 Receiving Station



CAL OSC OUTPUT
1 MHz 2V PEAK TO PEAK INTO 50 Ω AT OUTPUT OF SPLITTER

ii. Type 2 Type Receiving Station, Figure 3

In the Type 2 Receiving Station the LDAR signal is not sent separately but is combined with the E-field signal for transmission by microwave link to the central station.

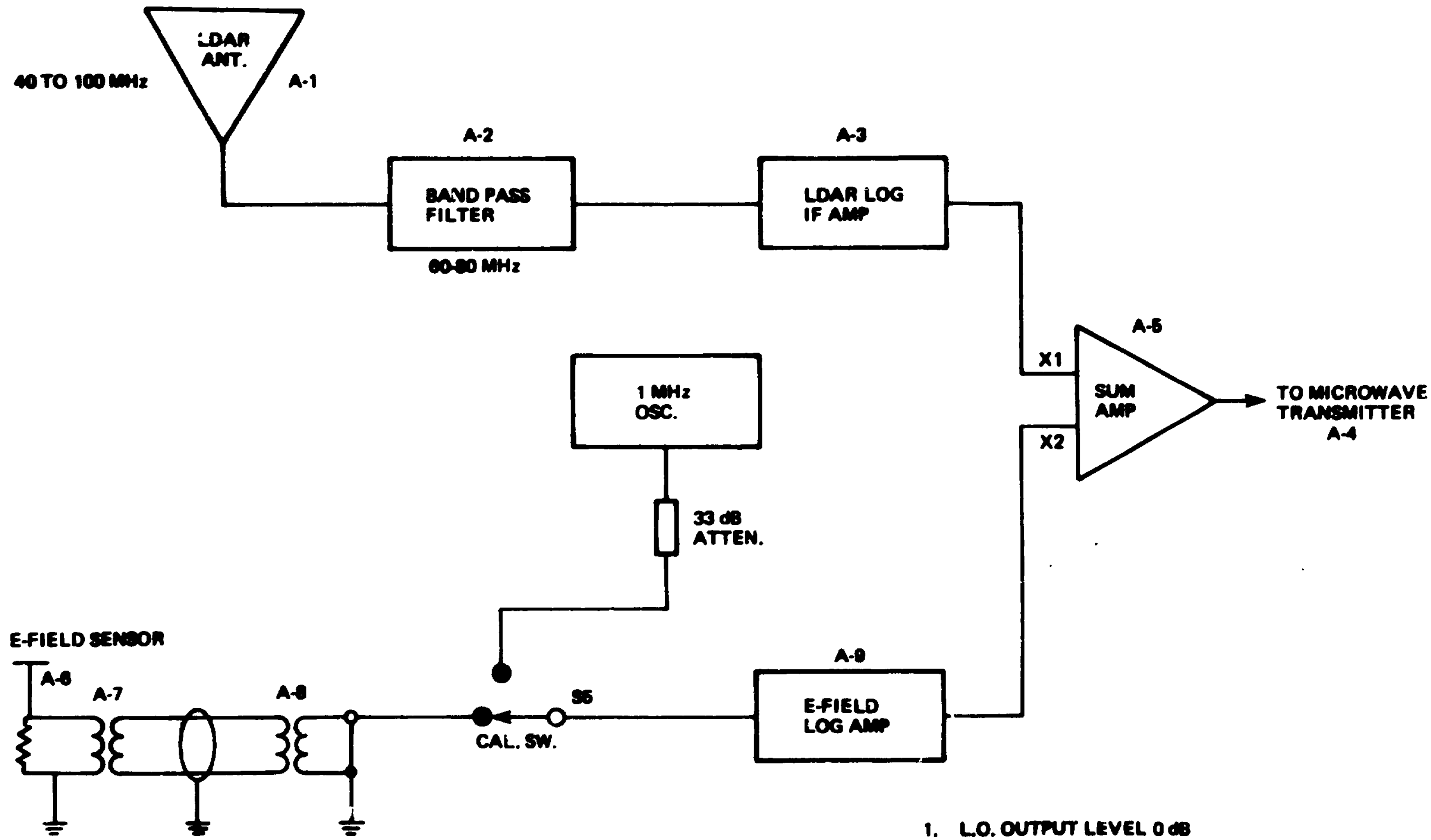
In the Type 2 Receiving Station instrumentation, Figure 3, the LDAR portion differs by the absence of switches S1 and S2, and the absence of a video cable. Data transmission checks previously effected by switch S2 are now accomplished by switch S5, which is used to inject a 1 MHz calibration signal. Before transmission by microwave link A-4 the LDAR signal is combined in a summing amplifier A-5 with a second signal (either the 1 MHz calibration signal or the E-field signal). A different microwave frequency, near 7.5 GHz, is used at each of the three remote sites M1, M2, and M3.

2. The E-field Signal Transmission

i. Type 1 Receiving Station Figure 2

The E-field signal is picked up by a sensing plate A-6, which is designed to respond to changes in the electrical field over the frequency range 1 KHz to 5 MHz. A 600:124 ohm

Figure 3. Remote Site, Type 2 Receiving Station



1. L.O. OUTPUT LEVEL 0 dB
2. CAL. OUTPUT LEVEL 20V PEAK TO PEAK 50 Ω
3. SUM AMPLIFIER CHANNELS HAVE EQUAL GAIN

matching transformer A-7 couples the signal to a balanced coaxial transmission line approximately 200 meters long. A 124:50 ohm matching transformer A-8 converts back to an unbalanced signal. From the transformer the signal goes to a switch S3 designed to permit the insertion of a 1 MHz calibration signal. The output of switch S3 goes to a bipolar logarithmic amplifier A-9. The log compressed signals pass to switch S4 which is inserted to permit calibration of the line delays, as will be explained later. From the switch the signal passes to a line driver amplifier (one half of summing amplifier A-5) to a separate wideband cable A2A-2, A-10 for transmission to the central site.

ii. <u>Type 2 Receiving Station, Figure 3</u>

The electric field signal flow for a Type 2 Receiving Station is shown in Figure 3. The signal flow is similar to that already explained for the Type 1 Receiving Station. Switch S4 is not needed, since the line delay checks are accomplished by the summing amplifier A-5, and the signal transmission checks are accomplished by use of switch S5. A line driver is not used. Instead the signal passes to a summing amplifier A-5 where it is combined with the LDAR signal. The combined signal modulates the 7.5 GHz microwave link A-4 for transmission to the central site.

Summing the LDAR signal on a single link without filtering is possible because the two signals are separated in time as well as in frequency.

The electric field signals and the LDAR signals do not occur at the same time on a microsecond scale. The electric field signal corresponds to ground strikes. The LDAR signals correspond to electrical discharges in the clouds. LDAR signals are not observed during ground strikes.

The energy in the electric field waveform signals is primarily confined to frequencies below 1 MHz. The energy in the LDAR is primarily confined to frequencies above 1 MHz.

3. Calibration of the Remote Site Transmission Links

The transmission links to the remote sites require calibration of their transmission characteristics and their time delays.

The transmission characteristics of the links must be checked in order to assure the quality of the data transmission.

The time delays must be measured in order to determine the true difference in the times of arrival. For the LDAR System, this problem is solved by the use of an artificial lightning generator at a fixed, known position, the Vertical Assembly Building, VAB. Time delays from the VAB to the remote sites are readily calculated from the survey data. The measured delays will differ from the true delays by the additional delays in transmission from the remote sites to the central station. Knowing the true delay, it is a simple matter to set in appropriate delays in units of 0.05 microseconds steps provided for in the Biomation boxes and further to introduce even smaller corrections via the software until the measured delays correspond exactly to the delays calculated from the survey data. Having corrected for the transmission line delays in this manner, all that is necessary is to check the delays from time to time. Past experience has shown the delays to be very constant.

The most direct way to determine the delays in the E-field transmission links to the remote sites is to use a lightning generator that will simulate a ground strike, inducing a usable signal in the remote E-field sensors. However, such a simulator is not currently available.

We will therefore, use the output from the LDAR receiver to provide a calibration pulse for the electric field measurement portion of the system. Using an LDAR antenna at each remote site, excited by the LDAR lightning simulator at the VAB, we have available signals of know delays at each of the six remote sites. As in the case of LDAR lines, the observed delays at the central station can be compensated to correct the delays in the video cables from the remote sites.

1. <u>Transmission Characteristics of the Data Links</u>

Because of the difference in the switching, we will discuss the implementation of the calibration and control switching for the Type 1 and the Type 2 Receiving Stations separately.

i. <u>Type 1 Receiving Station, Figure 3</u>

The schematic for the Type 1 Receiving Station has already been presented in Figure 2.

There are two wideband video cables whose transmission characteristics needs to be checked. Energizing switch S2 connects a 1 MHz sine wave signal of know amplitude to the input of the wideband video cable A2A-1, A-10. The transmission characteristics are evaluated by measuring the output at the central site.

Energizing switch S3 connects a 1 MHz sine wave signal of known amplitude to the input of the bipolar log amplifier A-9, which feeds the second wideband videocable, A2A-2, A-10, Measurement of the output at the central site provides us with the transmission characteristics of the combination of the log amplifier and the A2A-2 line, permitting us to evaluate their performance. Since the input signal is a sine wave, the transfer characteristics of the combination of log amplifier and A2A-2 line can be determined and used by the computer to provide an anti-log function that is required to reconstruct the waveform.

ii. Type 2 Receiving Station, Figure 3

The schematic for the Type 2 Receiving Station has already been presented in Figure 3. No wideband video cables need be monitored here, since the signal is transmitted by a microwave link. The overall transmission characteristic of the logarithmic amplifier A-9 and the microwave link A-4 determined by applying a 1 MHz signal of known amplitude to the input of the logarithmic amplifier by means of switch S5. Measurement of the output of the microwav link at the central site provides us with the required transmission characteristic.

2. Transmission Line Delays

i. Type 1 Receiving Station, Figure 2

The schematic for the Type 1 Receiving Station was given in Figure 2.

To calibrate the delays in the wideband A2A-1 video cable A-10, the switches S1 and S2 are left in the unenergized position shown. The LDAR signal passes through switches S1 and S2 directly to the A2A cable. Delay calibration is effected by operation the lightning simulator on the VAB and comparing the delay measured at the central station with the calculated delay. The difference between the calculated and measured delays gives the line delay corrections.

To calibrate the delay in the wideband video cable A2A-2, an LDAR signal is substituted for the E-field waveform signal by energizing switches S1 and S4. This feeds the LDAR signal to the line driver amplifier (one half of summing amplifier A-5) and to the A1A-2 wideband cable. The difference between delay measured at the central site and the calculated delay provides us with the delay of the line driver/A2A-2 line combination.

ii. <u>Type 2 Receiving Station, Figure 3</u>

The link delay for the electric-field waveform signal is the same as that for the LDAR signal, since both signals use the same microwave link, Figure 3. Therefore, no extra switch or calibration is required. The LDAR link delay is determined in the usual way by operating the lightning simulator and taking the difference between the calculated and the observed delays.

B. CENTRAL STATION

The interconnection diagram of the central station instrumentation is shown in Figure 4. In addition to receiving data from the remote stations, the central station receives off-the-air signals which are used for comparison with the remote signals to effect the crucial measurement - the difference in the time-of-arrival.

A considerable amount of redundancy is incorporated in the remote stations. Only three of the six remote stations are required in order to obtain data. The other three stations constitute a completely independent hyperbolic system, which is used to check the validity and accuracy of the data.

1. The LDAR Signal Flow

The signal flow up to the calibration switch is identical to that already discussed for the remote site. From the LDAR Antenna A-1, the signal flows through a 60-80 MHz bandpass filter A-2, a logarithmic amplifier A-3 to a calibration switch S6 which permits the insertion of a 1 MHz signal for calibration purposes. From the calibration switch, the signal is fed into a wideband video switch. In this case the switch is used as a distribution amplifier. One output feeds the LDAR signal directly into the input of a Biomation Model 8100 transient recorder A-11. A second output from the video switch (distribution amplifier) A-12 is used to drive a second distribution amplifier A-13 which feeds the signal to wideband analog tape recorders A-14.

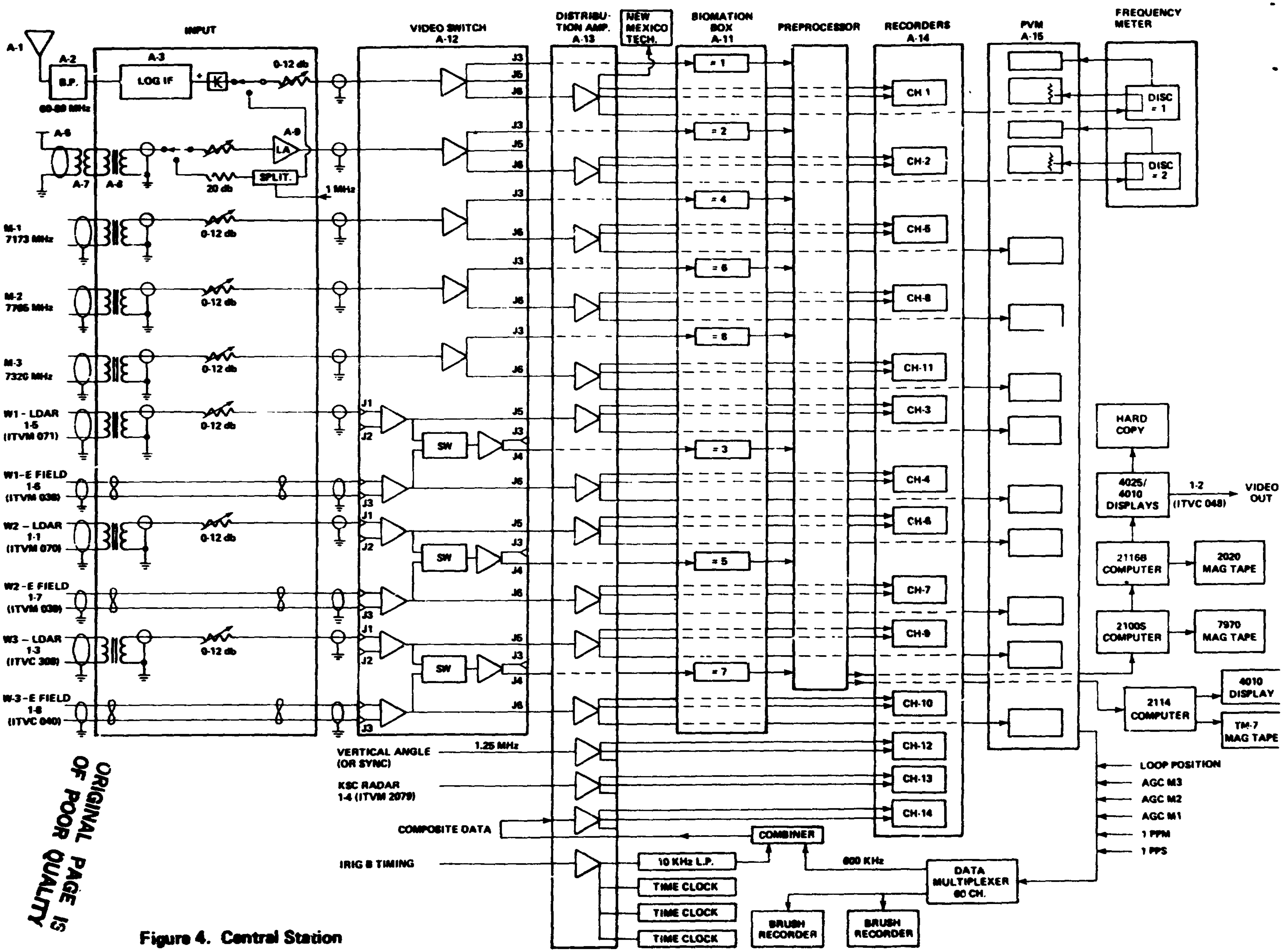


Figure 4. Central Station

ORIGINAL PAGE IS
OF POOR QUALITY

In this instance, the video switch performs no switching function but is included in the circuit primarily to equilize the time delays for all circuits.

2. The E-Field Signal

The central station uses the same type of electric field sensing plate A-6 as is used at the remote sites. The signal flow path from the plate sensor to the logarithmic amplifier A-9 is the same as the remote sites with the addition of a step attenuator (0 to 12 db, 1 db steps) prior to the input of the log amplifier. The output of the amplifier is fed to a wide-band video switch which acts as both a distribution amplifier and a time delay equalizer. One output from the switch is fed directly to the input of Biomation transient recorder #2, A-11.

This transient recorder is used to trigger the system on positive (+) electric field changes and digitally records the waveform data from the E-field plate sensor. The second output from the video switch is used to drive a second distribution amplifier A-13. The outputs from this amplifier are fed to a wideband analog recorder A-14 and are also fed to the frequency meter (discriminator) and to peak-reading voltmeter A-15. The frequency meter and peak voltmeter are used as ancillary monitoring equipment and are not required for system function.

3. The Data Lines

There are nine remote data lines feeding into the input unit which is located at the central LDAR site. Three of the lines originate from remote Type 2 Receiver Station and contain composite LDAR and E-field data (LDAR and E-field data are summed together and transmitted by microwave link to the central site). These lines are designated M-1, M-2, and M-3 on Figure 1. The composite signals enter through microwave receivers located on the roof of the Central site. From there, the signals are sent over balanced coaxial cables (approximately 30 meters long) to minimize the pickup of spurious signals. The balanced signal lines are converted into single-ended signals by the input transformers. The signals are then routed through step attenuators to the input of the video switch unit. Since both signals are combined (LDAR and E-field), it is not necessary to provide a switching function. As in the case of the local signals the video switch is used only as a distribution amplifier and a signal delay equalizer. One output from the video switch is fed directly to the input of a Biomation transient recorder. The signal from M-1 is fed to Biomation transient recorder #4, M-2 is fed to #6, and M-3 is fed to #8. The second output from the video switch is used to drive a distribution amplifier A-13. The output from the distribution amplifier is fed to analog recorders 1 and 2, A-14 (see also Fig. 7).

A third output is fed to a peak-reading voltmeter A-15 (one for each channel). The peak voltmeters are to gather data on the level of signals being received and they also provide a realtime indication of the relative signal level from each of the stations. Such an indication is useful in determining that all stations are functioning. Six additional lines are available from the Type 1 Receiving Stations. The data from the remote stations is transmitted via wideband A2A lines A-10 (5 MHz bandwidth). The three circuits that carry LDAR data are designated W-1 LDAR, W-2 LDAR, and W-3 LDAR. These circuits are of the balanced configuration and are converted to a single unbalanced configuration by an input matching transformer (124:50 ohms) A-8. The signals from the matching transformer are fed through step attenuators to the J-1 input of a wideband video switch.

A second input to each of the video switches comes from the second circuit from each of the Type 1 Receiver remote stations. These circuits carry the E-field data and are designated W-1 E-field, W-2 E-field, and W-3 E-field, in Figure 4. These E-field circuits are of the balanced configuration and are fed directly into a balanced input (input J3) of the video switch. The video switch performs both a switching and a feed-through function. The LDAR signals applied to the input J1 appear on the output connector J5 unswitched. Likewise the

E-field data which is applied to input connector J3 appears at output connector J6 as an unswitched signal in an unbalanced (signal ended) configuration. The signal appearing at output connector J4 is the switched function and can be either of the input signals depending upon the switching command. The normal unswitched output is the LDAR signal. In both cases the unswitched outputs J5 and J6 are both fed to distribution amplifiers A-13 which in turn drives analog recorders 1 and 2, A-14 and provide an output to the peak-reading voltmeter system.

The switched output J4 is connected directly to the input of a Biomation transient recorder. The signals from the W-1 site is fed to Biomation transient recorder #3, W-2 site to recorder 5, and W-3 site to recorder #7.

The trigger circuits of Biomation transient recorders #1 and #2 are used to control the video switch. As previously noted, Biomation transient recorder #1 is used to record the waveform data from the local LDAR signal. When the LDAR signal exceeds a predetermined level, the system is triggered. Likewise when the local E-field waveform signal exceeds a predetermined level, Biomation transient recorder #2 is triggered. The trigger outputs from transient Biomation recorders #1 and #2 are combined so that trigger will provide a trigger signal to all other recorders in the system. In addition the trigger signals from recorders 1 and 2 are logically combined such that a trigger from Biomation transient recorder #2 (E-field) without a trigger from recorder 1 (LDAR) will trigger the system and cause the wideband video switch to switch to the alternate state (E-field data to the Biomation recorders.) The switch activates when E-field change are detected without detectable LDAR signals.

4. The Video Switch

The video switch shown in Figure 4, fulfills an important function. Depending on the trigger signal it passes either the LDAR or the E-field signal to Biomation Units 3, 5 and 7. There are actually eight switches A-12 in the video switch unit. Three switches (3, 5, and 7) are required for actual switching of remote lines. The additional switches are required for the central station LDAR and E-field signals. While these latter two switches do not actually perform a switching function, (since they are connected all tne time), they serve an important function in equalizing the time delays and frequency response characteristics.

C. Data Processing and Digital Recording

The flow chart for the data processing and digital recording is shown in Figure 5, which represents a portion of Figure 4. We show here a preprocessor, three computers, three digital recorders, and a display terminal.

Functionally the system processes LDAR at a limited rate, displays it locally, and also transmits a display to the weather office, and to Patrick AF Base. In addition the system records LDAR data at a much higher rate in a digital format for later processing and analysis, and records electric field waveform data.

1. The Preprocessor

The preprocessor fulfills an important function in that it greatly expedites the data flow rate, by a factor of at least 10 to 1. The preprocessor receives serially-digitized data in parallel from eight Biomation Units. Biomation Unit 1 supplies the digitized, central station LDAR signal. Biomation Unit 2 supplies the digitized central station electric field waveform signal. The next six Biomation Units supply the digitized remote station data, which can be either LDAR or E-field waveform signals, depending on the video switch positions.

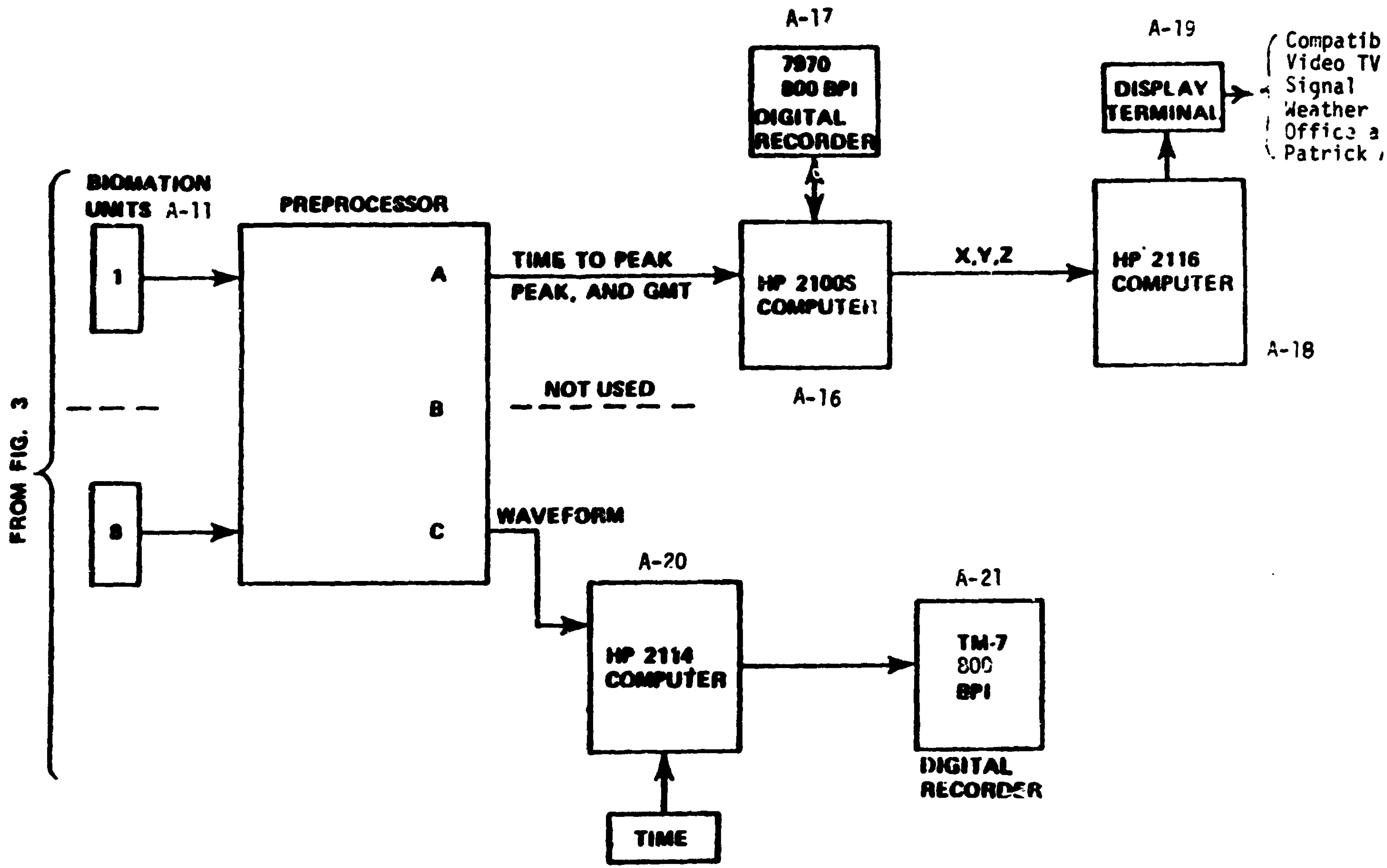


FIGURE 5. DIGITAL DATA PROCESSING AND RECORDING

The preprocessor determines the time to peak and the peak value of each of the LDAR signals, and delivers this data to output A, and also to output B. It delivers the digitized waveform of each of the E-field waveform signals at the output terminal C, and it delivers a sync pulse.

The preprocessor also conducts several data checks. By conducting these tests in hardware, rather than software, processing time is reduced. Amplitude checks of the data assures that it is above a selected minimum level and below the saturation level. Time checks assure that the delays for each station lie within the limits dictated by system geometry. The amplitude check eliminates noisy as well as saturated data. The time check eliminates false data points.

The operation of the preprocessor clarified by Figure 6, in which a protion of Figure 4 is also shown, in particular, the video switch which switches from LDAR to E-field waveform data since the operation of the preprocessor depends on whether the data is LDAR or E-field waveform data.

Video switch S8 is shown linked to switch S9 in the preprocessor. In operation, a signal from the video switch unit operated a gate S9 in the preprocessor. When the video switch is in the LDAR position, the gate S9 is open. When the video switch is in the E-field data position, the gate S9 is closed, connecting the Time and Amplitude sub-unit to the data storage register.

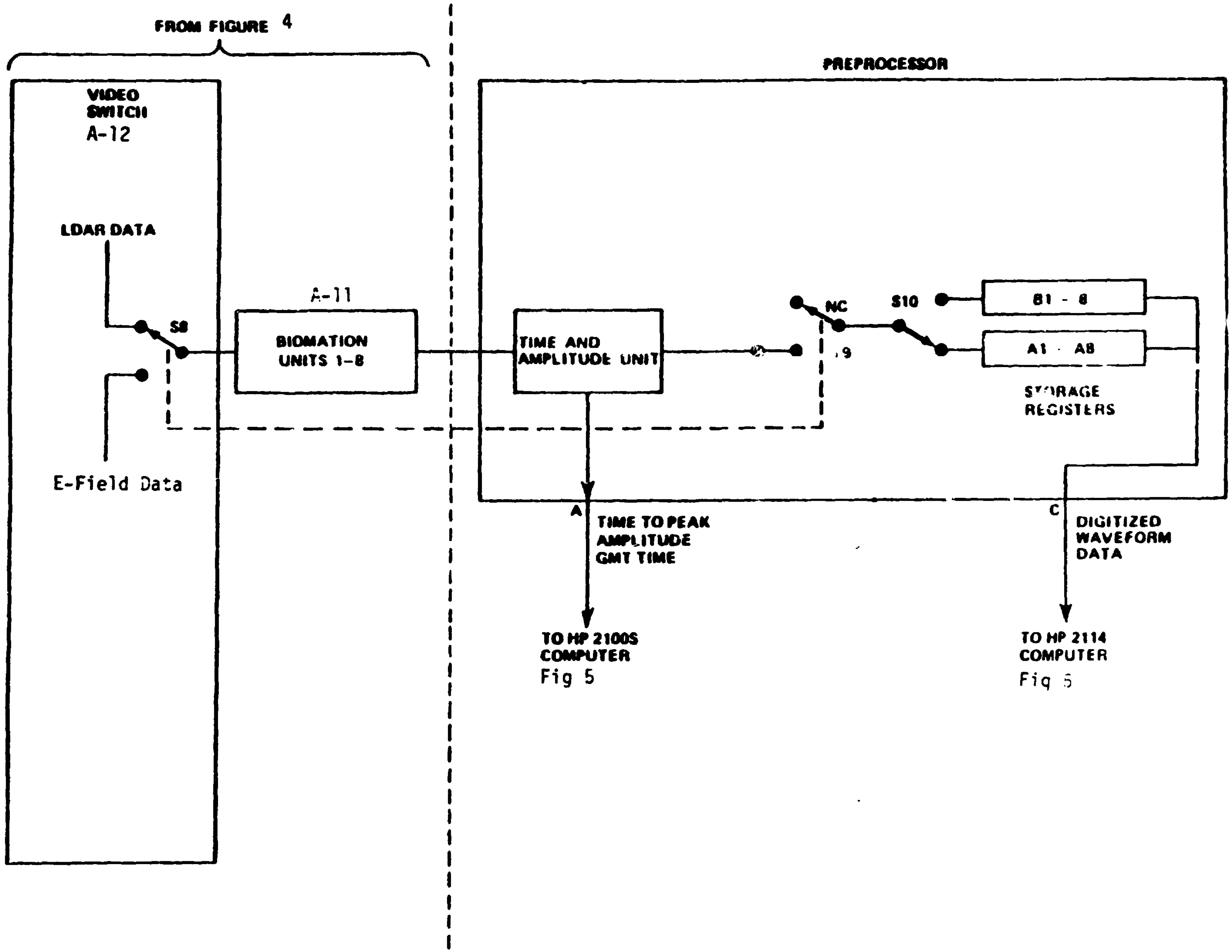


FIGURE 6. PREPROCESSOR FUNCTIONAL DIAGRAM

When operating in the LDAR data mode (switch S8 up), switch S9 is open, interrupting the data flow to the storage registers. Hence there is no output at terminal C in this mode. Instead the data output appears at terminal A, and consists of the time to peak, amplitude of the peak and GMT, to a resolution of one millisecond.

In the E-field waveform mode, the gate S9 is closed, and data flows from the Time and Amplitude sub-unit to the storage registers, here shown as A1-A8 and B1-B8, since there are eight A and eight B registers, one for each of the eight Biomation units (Units 1-8) that feed their input into the preprocessor in a manner similar to the one unit that is illustrated in the figure. Digitized waveform data, buffered by the storage registers, appears at output terminal C. Time to peak data is available at output A Figure 5 during waveform processing. The switch signal overrides the amplitude and time constraints.

For E-field signals, switch S10 is initially in the A1-A8 position. The preprocessor loads memory A1 with the 2048 8-bit words (100us of data) that make up the E-field waveform. When memories A1-A8 are completely loaded, switch S10 moves to the B1-B8 position, and the preprocessor is ready to load the next E-field waveform into memories B1-B8. Since the loading time is 2 milliseconds and the unloading time is some 7 seconds, the above arrangement makes is possible to record two E-field signal waveforms as close as 2 milliseconds. However, the third waveform must wait 7 seconds.

Data from Biomation box 1 has the time of day coded into the last 25 words of the 2048 words of output data.

2. Digital Data Processing and Display of LDAR Signals, Figure 4

In real time either LDAR or electric field waveform data is processed by the Biomation Units, depending on the position of the video switch.

If the video switch is in the LDAR position (see Figure 4) the Biomation transient recorders capture 100 μs segments of LDAR data, which they pass over to the Preprocessor Unit for processing.

The times of arrival and amplitudes of the peaks of the seven LDAR signals are determined by the preprocessor from the digitized input waveforms. The time required by the preprocessor to scan the incoming Biomation data and to determine the peak and the time to the peak is 2.048 milliseconds, which is considerably less than the 40 milliseconds that it takes the 2100S computer to process the data. To avoid losing data in periods of high density data bursts, a data buffer is provided that will permit the system to accept high density data up to a data rate of 500 per second corresponding to a 2 millisecond interval. The buffer function is fulfilled by a 240 word by 16-bit First-In-First-Out (FIFO) buffer.

The output of the FIFO buffer feeds the preprocessor output terminal A (Figures 5 and 6), supplying time to peak, and local GMT time data to the 2100S computer A-16.

The 2100S computer stores the incoming data in a word buffer within the 2100S computer. When the buffer is full, the data is recorded on the 7970 digital tape recorder A-17 at 800 BPI.

The 2100S software attempts to compute the X,Y,Z for all valid data, as time permits, using an assembly language program that takes some 40 milliseconds to solve the hyperbolic equations that determine the position X, Y, Z. Data is read sequentially from the buffer. If the buffer fills up before all the data is processed, the buffer contents are stored on the 7970 digital tape recorder A-17. New data is then stored in the buffer and real time processing continues. When the data is stored it is lost to real time processing.

The computed X_1,Y_1, Z_1, squared and X_2, Y_2, Z_2 squared data is fed to the 2116 computer A-18, which conducts a number of checks on the quality of the data and in particular compares the position determined by the two independent LDAR networks. Unless the data from the two independent systems agrees closely, the data is rejected. This is a very important feature of the system and assures that only high quality data will be presented on the display to the weather office. The programs in the 2116 computer plot the data in a PPI presentation on a Tektronix 2025 Terminal A-19. Remote data is provided by a TV compatible video signal which is sent by wideband cable to the Weather Office and to Patrick AF Base.

Data recorded by the 7970 recorder A-17 can be played back, post test, to the 2100S computer A-16 which solves the hyperbolic equations, and passes the X,Y,Z position data onto the 2116 computer A-18 for checks and for plotting in the manner already discussed. This data processing is serial. All valid data is processed.

3. Digital Processing of E-Field Data

When the video switch is in the electric-field waveform position, Biomation Units No. 2 to 8 capture 100 microsecond segments of electric-field waveform data. The LDAR waveform is also recorded. This data is fed to the preprocessor in parallel at a rate of one word per microsecond. The preprocessor formats the data and passes it onto the HP 2114 Computer A-20, which packs eight Biomation unit waveforms, together with GMT time, (to a resolution of 1 millisecond) into a matrix for recording on the TM-7 digital recorder A-21.

When the system is triggered by Biomation unit #2, the video switches are programmed to switch to the E-field position. Biomation units #2, 3, and 5 will then record E-field data. Biomation unit #1 records normal LDAR data from the central site, and Biomation units #4, 6, and 8 will record a composite E-field and LDAR data.

4. <u>Analog Recording of E-Field Waveform Data</u>

Analog recorders are used to record incoming electric field and LDAR waveform data.

Recording of the electric field waveform data is shown in Figure 7. The signal can represent any of six remote lines or any of two central station signals, as shown earlier in Figure 4. For illustrative purposes we show, and we discuss, only one of the eight signals.

We start with the raw E-field signal at the distribution amplifier A-13 shown in Figure 4. As we show in Figure 7, output of the distribution amplifier A-13 goes to the input of an Ampex FR 1800, 1 inch. 120 IPS, 100 Hz to 1.5 MHz analog tape recorder A-14, labeled Recorder 1. Output 2 consisting of the same signal is fed to another Ampex FR 1800 analog tape recorder, labeled Recorder 2. The functions of the two recorders is to permit the continuous recording of data. As Recorder 1 nears the end of its tape, Recorder 2 is readied, and is switched in at the moment Recorder 1 ceases. In turn, while Recorder 2 is nearing the end of its tape, Recorder 1 is readied to take over as Recorder 2 reaches the end of its tape. The channel assignments used are given in Table I. Output 3 goes to a peak reading voltmeter, A-18 which is used to check system operation.

As Figure 7 shows, we also record the sync pulse, radar signals, and housekeeping data on channels 12, 13, and 14. The sync pulse is provided as a marker to show which data is being processed by the LDAR system.

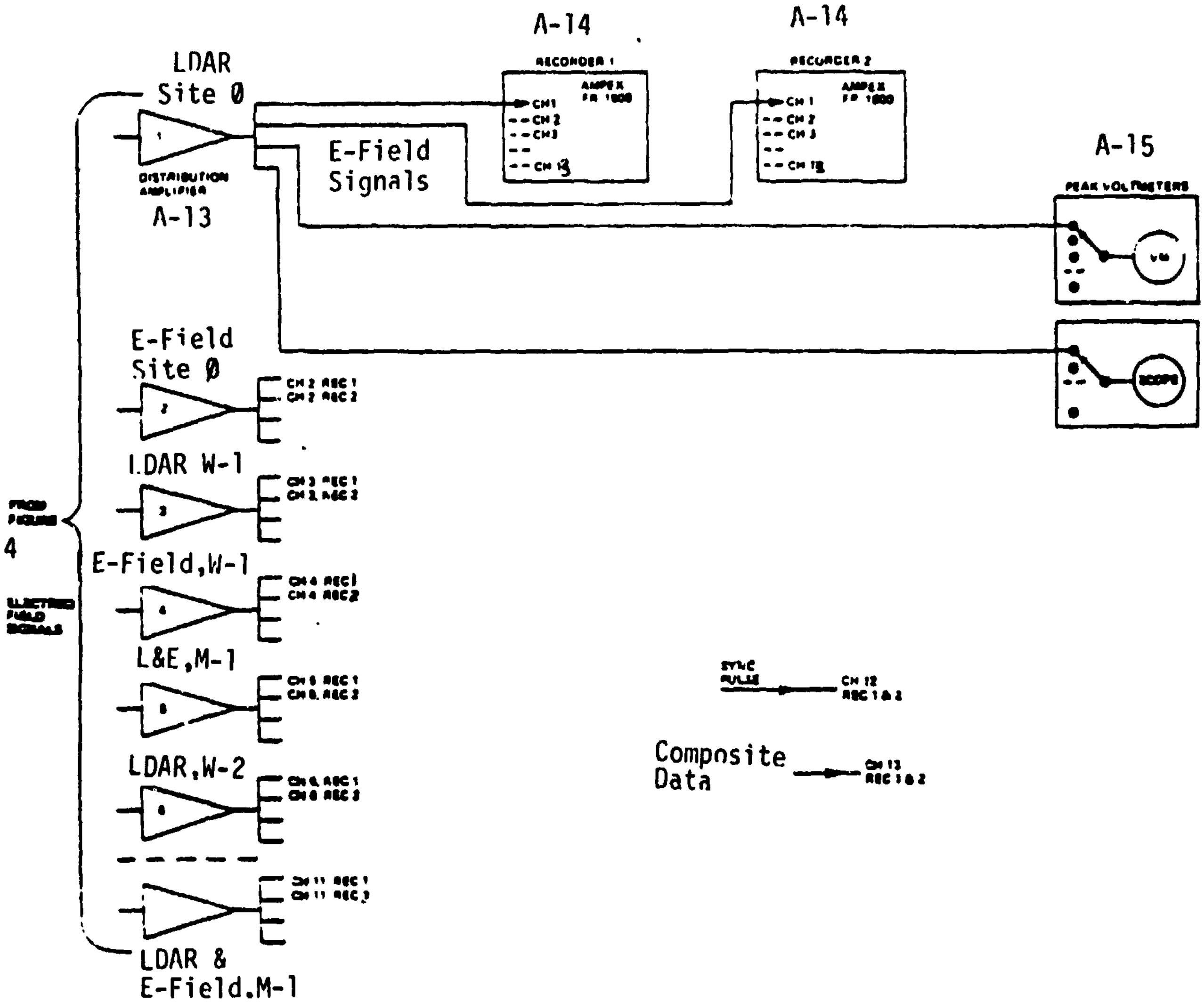


FIGURE 7 ANALOG RECORDING, SIGNAL FLOW

TABLE I

CHANNEL ASSIGNMENT, ANALOG RECORDERS 1 AND 2

Channel	1	Raw LDAR, Site 0
	2	Raw E-Field, Site 0
	3	Raw LDAR, Site W-1
	4	Raw E-Field, Site W-1
	5	Raw LDAR and E-Field, Site M-1
	6	Raw LDAR, Site W-2
	7	Raw E-Field, Site W-2
	8	Raw LDAR and E-Field, Site M-2
	9	Raw LDAR, Site W-3
	10	Raw E-Field, Site W-3
	11	Raw LDAR and E-Field, Site M-3
	12	Sync
	13	Composite Data
		(a) IRIG B Timing
		(b) Multiplexed Data
		(c) Audio Notes, Annotation

IV. SOFTWARE

Three Hewlett Packard computers, Numbers 2100S, 2114, and 2116 are used to process the digital data, as illustrated in Figure 5. The software for these computers will be discussed in turn.

1. The 2100S Computer, A-20

Program 1 performs several functions: (1) it inputs data from the FIFO buffer (see Section III C.2) and stores it in an internal buffer. As long as data is available from the FIFO buffer, the program will continue to input data into the internal buffer. When the internal buffer is filled, the program records the data in the buffer on the 7970 digital tape recorder, A-17. If the program finds no new data in the FIFO buffer, (2) it proceeds to the next unprocessed data point in the internal buffer and tests the data for sign, and for the difference in the time of arrivals. The signs may not all be of the same sign, and the maximum difference in the time of arrival for each leg must be less than the length of the leg dictates. If the test is passed, (3) the program calls up an assembly language subroutine which solves the hyperbolic equations and computes X, Y, and Z squared two times, once for each of two independent sets of three remote receiving stations. The program passes this data to the 2116 computer A-18 for plotting. If either test fails, the program goes back to get new data from the FIFO buffer. If the 2116B is busy and cannot accept data, it returns to FIFO.

The program utilizes the characteristics of lightning data to minimize data loss during the 40 milliseconds that is required to solve the hyperbolic equations. During bursts of data, when there is no time to take 40 milliseconds to solve the hyperbolic equations, all the data coming in is stored for recording. Solution of the hyperbolic equations (and hence plotting of the data) is delayed for an instant, until there is a momentary pause in the incoming data.

Program No. 2 is an off-line program which computes the constants used in the hyperbolic solution for any given geometric configuration on the three remote and the one central station. This program is required when a new site is set up, or when an established site is moved.

2. <u>The 2114 Computer, A-20</u>

Program 3 inputs waveform data from the preprocessor. Waveform data is inputted by the program from the preprocessor as a 16-bit word. The program also supplies a signal to the preprocessor to unpack data from the A and B storage buffers as soon as it makes use of this data. Waveform data is stored in a storage area, and is outputted to a digital tape recorder TM-7, A-25 in a matrix suitable for recording, each time the matrix is filled.

3. <u>The 2116 Computer, A-18</u>

Program 4 performs checks on the input data points and plots them on an LDAR display. The program inputs data from the 2100S A-15, and compares the X1, Y1, Z1 coordinates computed by the 2100S computer for LDAR configuration No. 1 with the X2, Y2, Z2 coordinates computed for the independent configuration No. 2. Unless the coordinates agree, the data point is rejected.

V. DATA REDUCTION

1. LDAR Data

As discussed in Section III C.2 under LDAR Data Processing and Digital Recording all LDAR data points greater than 2 milliseconds apart are recorded by a 7970 Digital Recorder A-17 A-17 in a format that provides the peaks, the time to peaks, and GMT time to a resolution of one millisecond for all six remote and one central station site. To play this data back, we use the 7970 digital tape recorder A-17 shown in Figure 5, to input the data to the 2100S computer A-16. The 2100S computer calculates X, Y, and Z and outputs this data to the 2116 computer, A-18. This processing is the same as that already described in Section IV.

The displayed data, if desired, can be recorded on a magnetic disc, facilitating data analysis by allowing rapid access for slicing.

2. Waveform Data

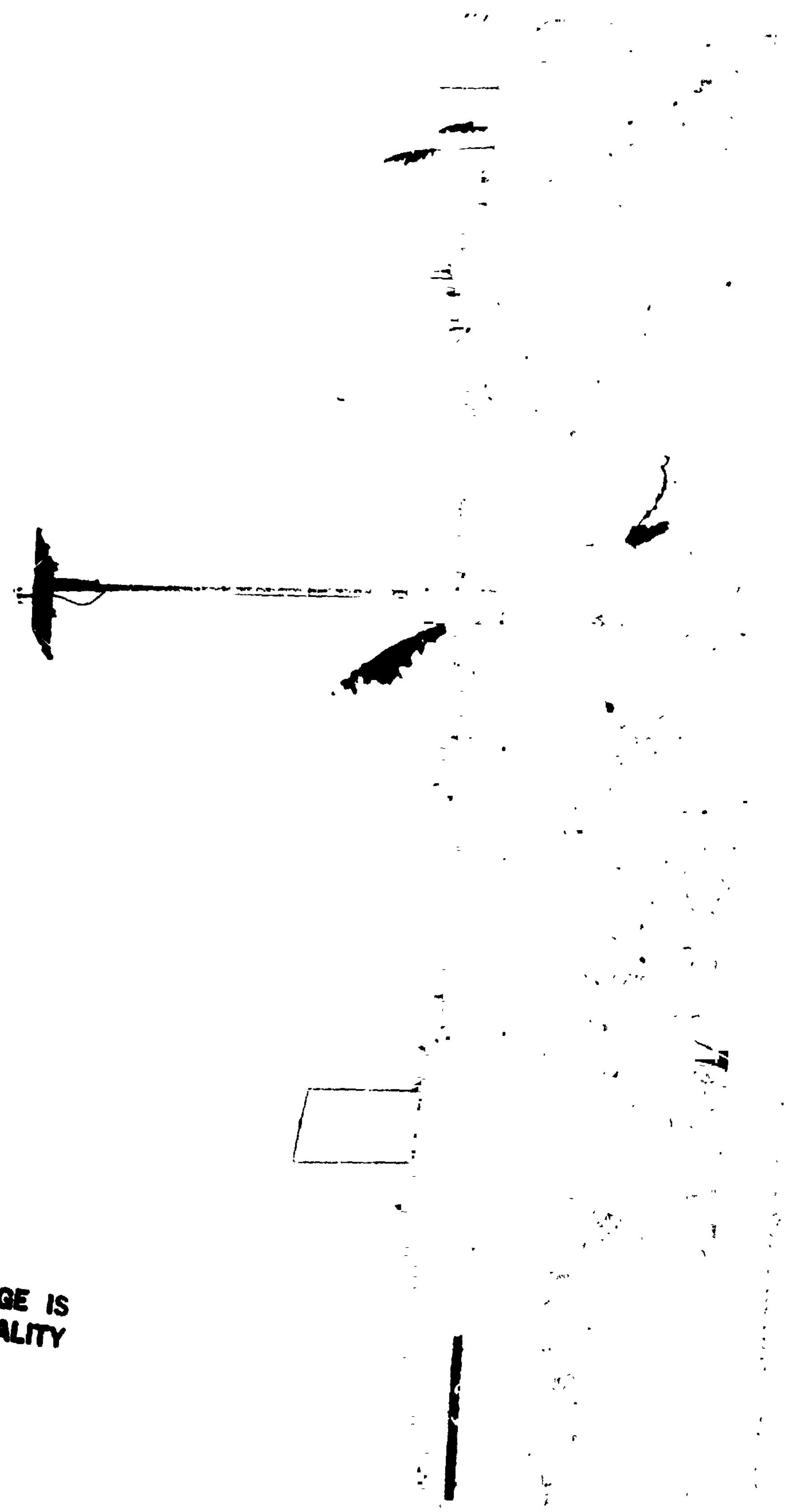
Waveform data that was recorded on the TM-7 recorder A-21 (see Section III C.3) is played back on the 7970 recorder A-17 and fed into the 2100S computer A-16 (see Figure 5). The time delays required for ground strike location is determined by the cursor readout features of the display terminal A-22.

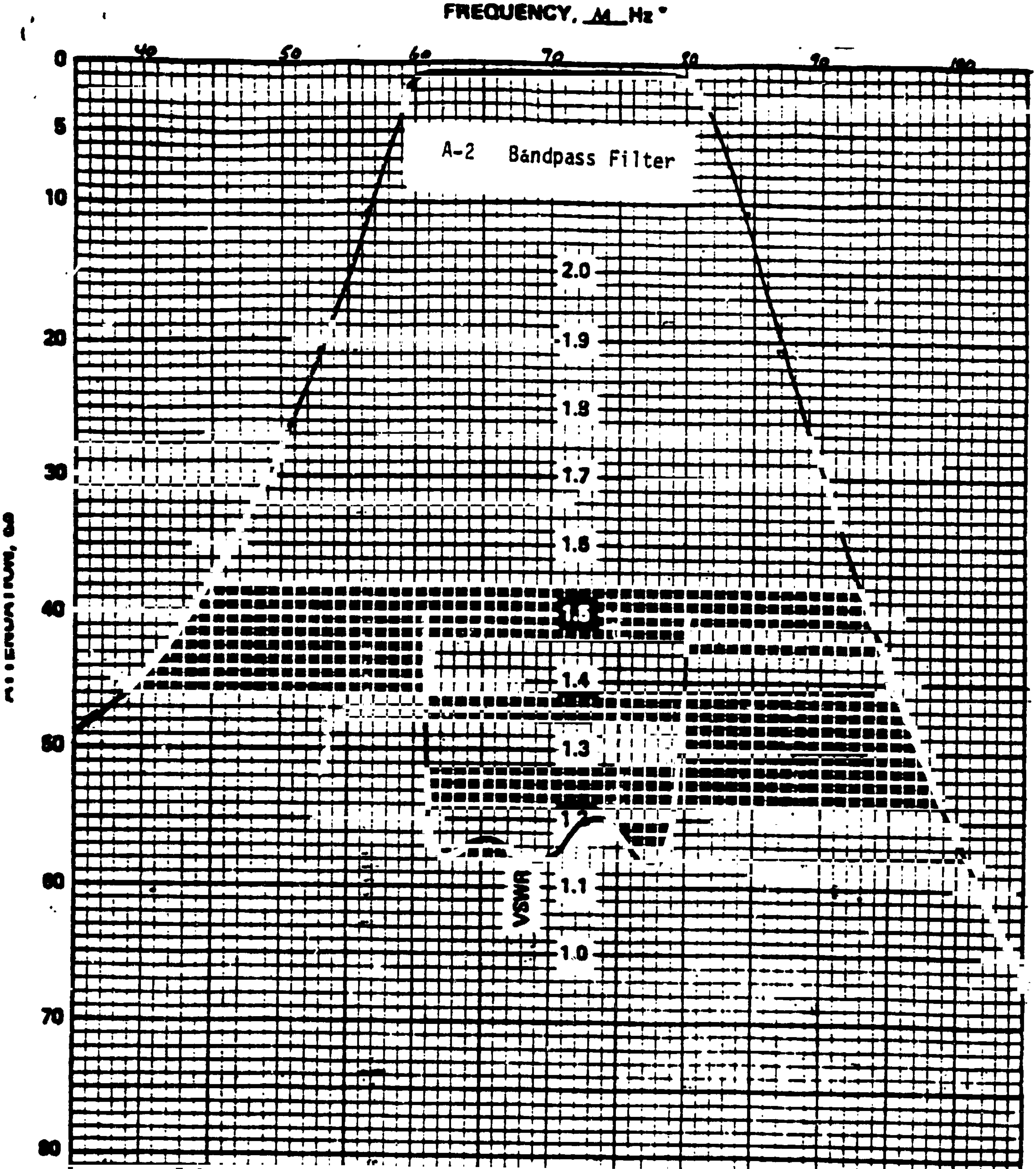
Ground strike positions X, Y are computed from the time delays using the assembly language subroutine for solving the hyperbolic equations, with modified constants to account for the difference in the placement of the sensors.

APPENDIX

A-1	LDAR Antenna
A-2	Bandpass Filter
A-3	Log IF Amplifier
A-4	Microwave Link
A-5	Line Driver Summer 9804
A-6	Electric Field Sensing Plate
A-7	Matching Transformer
A-8	Matching Transformer
A-9	Bipolar Logarithmic Amplifier
A-10	A2A Wideband Video Cable
A-11	Biomation Transient Recorder
A-12	Video Switch/Distribution Amplifier
A-13	Telemet Distribution Amplifier
A-14	Ampex FR 1800 Analog Recorder
A-15	Peak-Reading Voltmeter
A-16	HP 2100S Computer
A-17	7970 Digital Tape Recorder
A-18	HP 2116 Computer
A-19	Tektronix Terminal
A-20	HP 2114 Computer
A-21	TM-7 Digital Tape Recorder
A-22	4010 Computer Display Terminal

A-1 [illegible]





PART NO: BRI5-70-CC30 CUSTOMER NO: [illegible] P.O. [illegible] 5/25/78

SERIAL NO: 1-6 Q.C.-MECH: [illegible] Q.C. ELECT. [illegible]

ITEM: OF: TESTED BY: Km PROD. [illegible] DATE: 5-22-78

FREQ. Hz	LOSS db	VSWR	FREQ. Hz	LOSS db	VSWR
f_1 5.5MHZ	1.8				
f_0 70MHZ	0.8				
f_2 90.5MHZ	1.8				

CIR Q TEL INC.

10504 WHEATLEY STREET
KENSINGTON, MARYLAND 20795

TYPE: BRI5-70 CC 30

* K - KILO, M - MEGA, G - GIGA

F600-000-001-A-00

A-3 Log IF Amplifier

Test Data is provided on all RHG products. Additionally, RHG will provide dependable and rapid service, technical assistance and assure product support to our customers. Warranty provisions are outlined on the attached sheet.

ELECTRICAL TEST DATA

MODEL NO: LST40HH27MAT DATE: March 21, 1977

SERIAL NO: 10-680-1B DATA TAKEN BY: C.J.S.

CENTER FREQUENCY:	40 MHz
3 DB BANDWIDTH:	25 MHz
INPUT IMPEDANCE:	50 Ω
INPUT VSWR:	1.2:1
LINEAR IF GAIN:	OK
DYNAMIC RANGE:	>80 dB
LOG ACCURACY:	<±1 dB
OUTPUT VOLTAGE RANGE:	SEE CURVE
RISETIME:	≤ 50 nsec
POWER DRAIN:	+12 V at 50 mA -12 V at 55 mA

COMMENTS:

LIMITED IF OUT +3 dBm

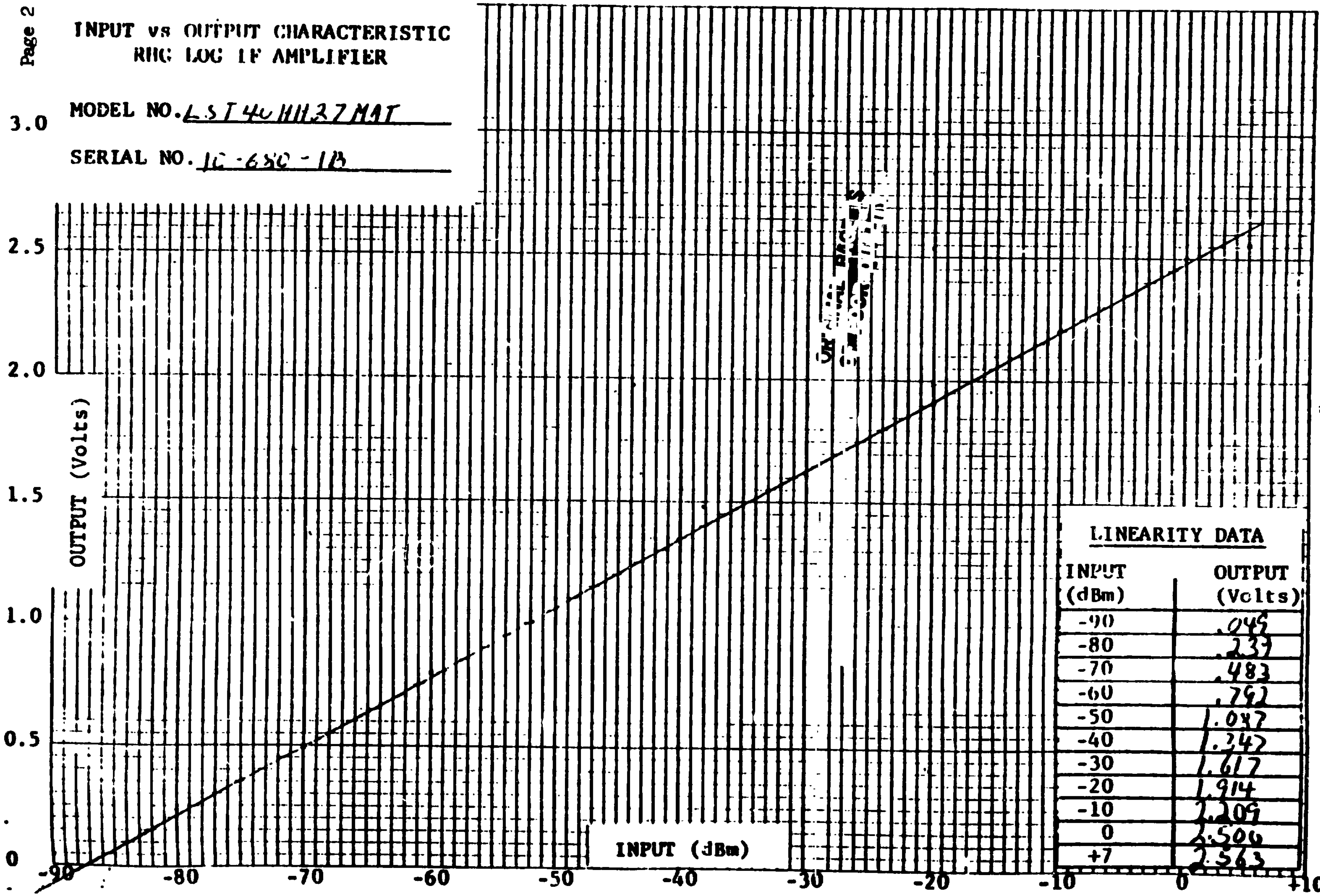
MATCHING DATA SEE 10-680-1A

RHG ELECTRONICS LABORATORY, INC. 161 EAST INDUSTRY COURT DEER PARK, N.Y. 11729 (516) 242 1100 TWX 510-227-6083

INPUT vs OUTPUT CHARACTERISTIC
RHG LOG IF AMPLIFIER

MODEL NO. LST 40 HH37 MAT

SERIAL NO. IC-680-1B



LINEARITY DATA

INPUT (dBm)	OUTPUT (Volts)
-90	.045
-80	.237
-70	.483
-60	.792
-50	1.037
-40	1.342
-30	1.617
-20	1.914
-10	2.209
0	2.506
+7	2.563

A-4 Microwave Link

RHG ELECTRONICS LABORATORY

MODEL NO. MLRW7.1AG91 DATE 8/18/75

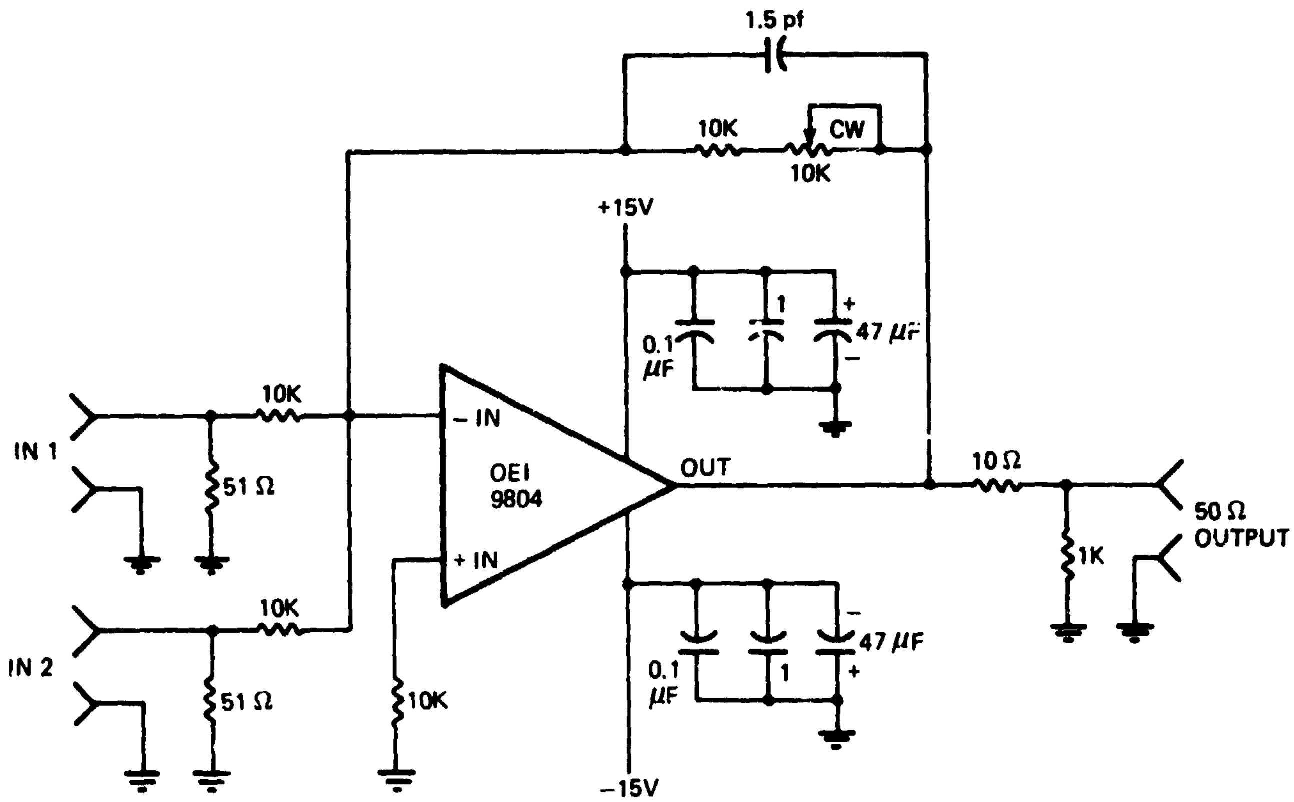
SERIAL NO. 8-626-1B DATA BY LMW

6.0 SIGNAL STRENGTH AND NOISE

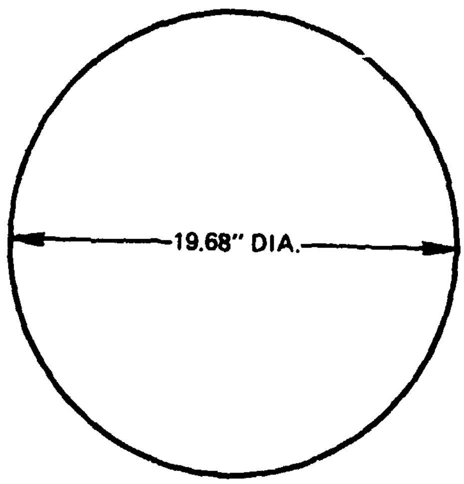
RF LEVEL	LOG VOLTAGE (into 1000 Ohm)		SIGNAL TO NOISE (EIA WEIGHTED) *	
-10	+3.42	VDC	66	dB
-20	+2.99	VDC	66	dB
-30	+2.54	VDC	66	dB
-40	+1.94	VDC	65	dB
-50	+1.39	VDC	60	dB
-60	+0.42	VDC	52	dB
-70	+0.48	VDC	42	dB
-75	+0.25	VDC	34	dB
-80	+0.02	VDC	21	dB
No Signal	-0.04	VDC	--	dB

* NOISE MEASURED WITH VIDEO GAIN SET TO PRODUCE 1V p-p OUT INTO 75 OHM WITH A DEVIATION OF 8 MHz.

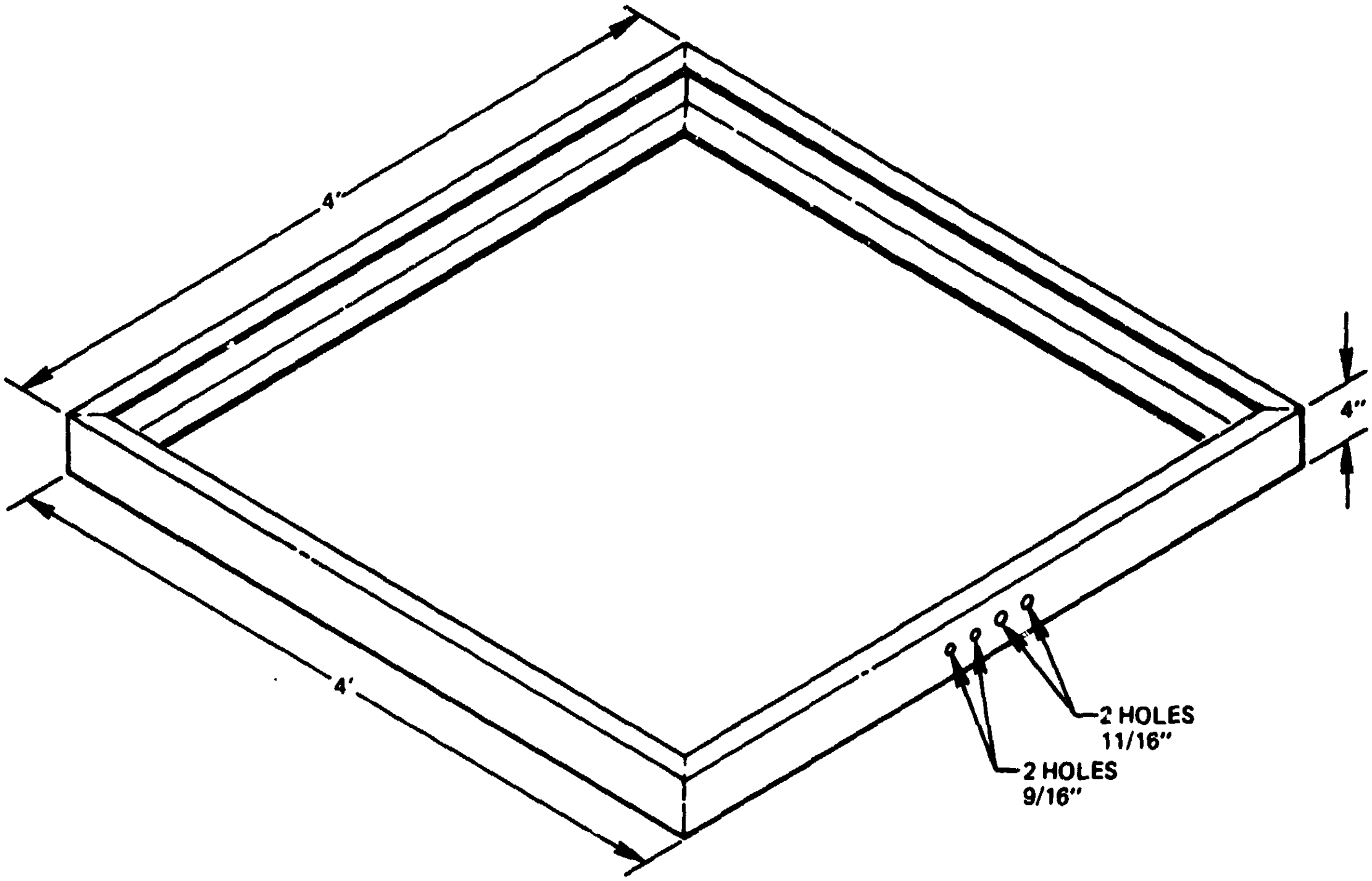
A-5 Line Driver Summer 9804

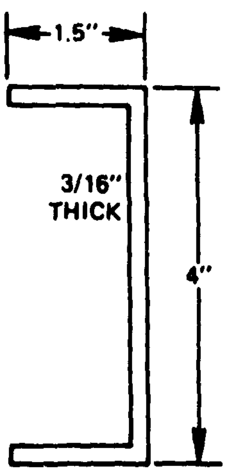


DISC ASSEMBLY
(ALUMINUM, 3/16" THICK, ANY HARDNESS)

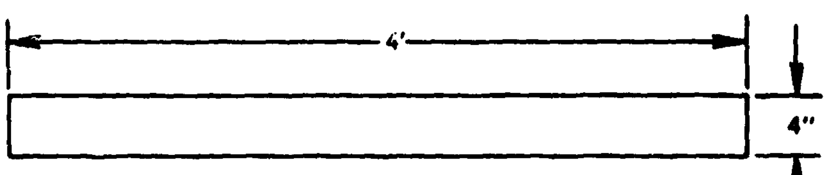


FRAME ASSEMBLY
(MAKE FROM ALUMINUM CHANNEL)



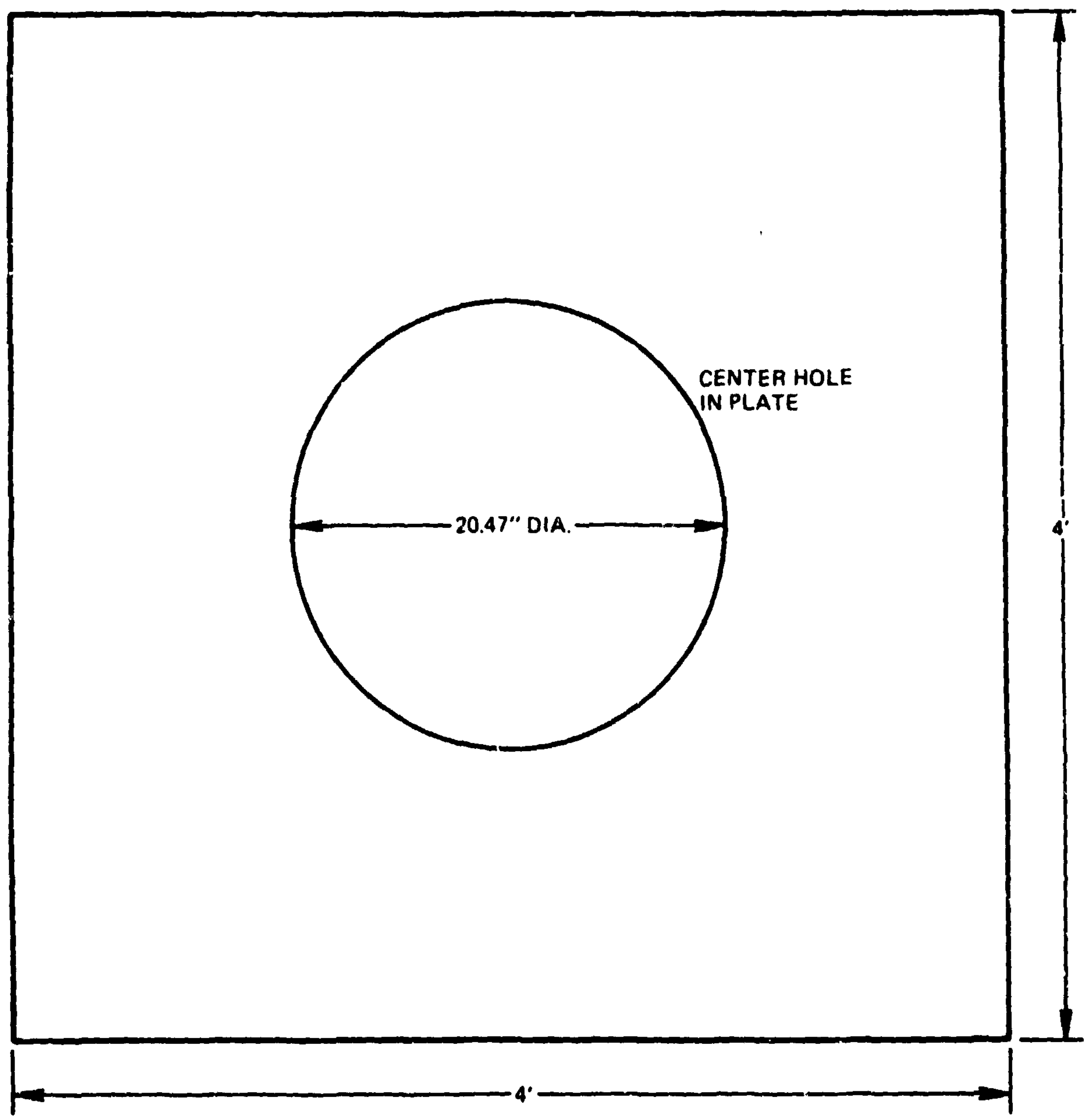


MATERIAL



END VIEW/SIDE VIEW

PLATE ASSEMBLY
(MAKE FROM 3/16" ALUMINUM – T6 HARDNESS)



Matching Transformer

WIDEBAND TRANSFORMERS

UNBALANCED TO BALANCED TRANSFORMERS

Balanced secondaries center-tapped and dc-isolated from primaries. Mid-band insertion loss less than 0.5 dB. Bandwidth defined at low frequency end by 3 dB drop from mid-band response, at high end by max. VSWR of 1.25.

LOW POWER SERIES (1W)

Series	Radio Frequency		Medium Frequency		Video	
Cases	8A, 8B, H8		8A, 8B		1A, 1B	
Unb./Bal. (Ω)	Type No.	Bandwidth MHz	Type No.	Bandwidth MHz	Type No.	Bandwidth MHz
50:50	0001	.1-125	0010	.01-80	0009	.001-25
50:75	0101	.1-125	0111	.01-80	0104	.001-25
50:90	0200	.1-125	0202	.01-60	0203	.001-20
50:100	0300	.1-100	0301	.01-40	0311	.001-20
50:124	0307	.1-120	[illegible]	.01-40	0308	[illegible]
50:125	[illegible]	.1-100	0312	.01-60	0303	.001-18
50:150	0400	.1-100	0401	.01-40	0415	.001-15
50:200	0500	.1-100	0520	.01-60	0511	.001-15
50:300	0501	.1-100	0521	.01-50	0517	.001-12
50:450	0600	.1-55	0602	.01-40	0603	.001-10
50:600	0700	.1-45	0703	.01-32	0708	.001-8
50:800	0800	.1-40	0801	.01-25	0802	.001-7
50:1200	0900	.1-30	0902	.01-15	0904	.001-6
75:50	1000	.1-100	1001	.01-50	1002	.001-25
75:75	1100	.1-100	1112	.01-60	1102	.001-25
75:90	1200	.1-100	1201	.01-40	1202	.001-20
75:100	1300	.1-100	1310	.01-60	1314	.001-20
75:124	1302	.1-120	1311	.01-60	1301	.001-20
75:135	1317	.1-100	1315	.01-60	1312	.001-20
75:150	1400	.1-100	1405	.01-60	1404	.001-16
75:200	1500	.1-100	1513	.01-40	1519	.001-15
75:300	1501	.1-100	1514	.01-50	1502	.001-13
75:450	1600	.1-60	1601	.01-40	1602	.001-12
75:600	1700	.1-60	1707	.01-32	1704	.001-10
75:800	1800	.1-30	1801	.01-20	1802	.001-12
75:1200	1900	.1-33	1905	.01-15	1902	.001-9
75:1850	1906	.1-15	1901	.01-8	1903	.001-6

A-8

Line Matching Transformer

WIDEBAND TRANSFORMERS

UNBALANCED TO BALANCED TRANSFORMERS

Balanced secondaries center-tapped and dc-isolated from primaries. Mid-band insertion loss less than 0.5 dB. Bandwidth defined at low frequency end by 3 dB drop from mid-band response, at high end by max. VSWR of 1.25.

LOW POWER SERIES (1W)

Series	Radio Frequency		Medium Frequency		Video	
Cases	8A, 8B, HB		8A, 8B		1A, 1B	
Pri./Sec. (Ω)	Type No.	Bandwidth MHz	Type No.	Bandwidth MHz	Type No.	Bandwidth MHz
50:50	0001	.1-125	0010	.01-80	0009	.001-25
50:75	0101	.1-125	0111	.01-80	0104	.001-25
50:90	0200	.1-125	0202	.01-60	0203	.001-20
50:100	0300	.1-100	0301	.01-60	0311	.001-20
50:124	0307	.1-100	0302	.01-50	0308	.001-20
50:135	0310	.1-100	0312	.01-60	0303	.001-18
50:150	0400	.1-100	0401	.01-60	0415	.001-15
50:200	0500	.1-100	0520	.01-60	0511	.001-15
50:300	0501	.1-100	0521	.01-50	0517	.001-12
50:450	0600	.1-55	0602	.01-40	0603	.001-10
50:600	0700	.1-65	0703	.01-32	0706	.001-8
50:800	0800	.1-60	0801	.01-25	0802	.001-7
50:1200	0900	.1-30	0902	.01-15	0904	.001-6
75:50	1000	.1-100	1001	.01-50	1002	.001-25
75:75	1100	.1-100	1112	.01-60	1102	.001-25
75:90	1200	.1-100	1201	.01-60	1202	.001-20
75:100	1300	.1-100	1310	.01-60	1314	.001-20
75:124	1302	.1-100	1311	.01-60	1301	.001-20
75:135	1317	.1-100	1315	.01-60	1312	.001-20
75:150	1400	.1-100	1405	.01-60	1404	.001-16
75:200	1500	.1-100	1513	.01-60	1516	.001-15
75:300	1501	.1-100	1514	.01-50	1502	.001-15
75:450	1600	.1-80	1601	.01-40	1602	.001-12
75:600	1700	.1-60	1707	.01-32	1704	.001-10
75:800	1800	.1-30	1801	.01-20	1802	.001-10
75:1200	1900	.1-35	1905	.01-15	1912	.001-9
75:1850	1906	.1-15	1901	.01-8	1903	.001-6

North Hills Electronics, INC.

GLEN COVE, N.Y. 11542 • 516-671-5700

1.0 SPECIFICATION OF MODEL 2540

1.1 Transfer Function	Biploar Logarithmic Amplifier
1.2 Dynamic Range	60dB minimum each input 100dB minimum cascaded
1.3 Maximum Logarithmic Error	±3% of output maximum ±1% of output typical
1.4 Input	
1.4.1 Dynamic Range	10 millivolts to 10 volts full scale each input 100uvolts to 10 volts full scale cascaded
1.4.2 Resistance	600 ohms - input A 2000 ohms - input B
1.4.3 Polarity	Bipolar
1.4.4 Offset Voltage	±30 volts maximum
1.4.5 Bias Current	-30 amps maximum
1.4.6 Power Supply Sensitivity	±30 volts/volt maximum
1.4.7 Warm-Up Time	3 minutes maximum for ±10 millivolts
1.4.8 Warm-Up Time	15 minutes maximum for ±1.0 millivolt
1.5 Output	
1.5.1 Dynamic Range	±10 volts full scale
1.5.2 Coefficient	1.5 volts/decade typical
1.5.3 Dynamic Resistance	20 ohms maximum
1.5.4 Minimum Load Resistance	250 ohms for full output swing
1.5.5 Polarity	non-inverted or inverted
1.5.6 Temperature Coefficient	±0.15%/°C maximum

1.6 Frequency Response	
1.6.1 Lower -3dB Frequency	Externally determined, see Section 5.0

SPECIFICATIONS OF MODEL 2540[1]

1.6.2 Upper - 3dB Frequency - Large Signal	5HH$_Z$ minimum
1.6.3 Upper - 3dB Frequency - Incremental	10MH$_Z$ minimum
1.6.4 Slewing Rate	±150 volts/second minimum
1.7 Temperature Environmental	
1.7.1 Operating Range	-55°C to +75°C
1.7.2 Storage Range	-65°C to +100°C
1.7.3 Thermal Resistance of Module	12°C/watt maximum
1.7.4 Quiescent Temperature Rise	49° above ambient maximum
1.8 Power Required	
1.8.1 Minimum Voltage	±12 volts
1.8.2 Nominal Rated Voltage	±15 volts
1.8.3 Maximum Voltage	±16 volts
1.8.4 Quiescent Supply Current	±135 milliamps maximum
1.8.5 Quiescent Power Dissipation	4050 milliwatts maximum
1.9 Size	3.125 inches by 2.625 inches by 0.625 inch high 7.94 cm by 6.67 cm by 1.59 cm high
1.10 Weight	5.3 ounce 150 gm
1.11 Socket	OEI Model 11028

NOTES: 1 - The above specifications are measured at ±15 volts supply and 25° ambient.

OEI
Optical Electronics Inc. P.O. Box 11140 * Tucson, Arizona 85734
Phone (502) 624-8358

1.12 MTBF-per-MIL-HDBK-217B-GF	87,000 hours

SPECIFICATIONS OF MODEL 9801[1]

1.8.2 Nominal Rated Voltage	±15 volts
1.8.3 Maximum Voltage	±18 volts
1.8.4 Quiescent Supply Current	±33 milliamps maximum
1.8.5 Quiescent Power Dissipation	990 milliwatts maximum
1.9 Size	1.125 inch square by 0.375 inch high 2.86 cm square by 0.95 cm high
1.10 Weight	0.6 ounce 17 gm
1.11 Socket	OEI Model 11026
1.12 MTBF-per-MIL-HDBK-217B-GF	275,000 hours

1.13 SPECIFICATIONS OF MODEL 9804M3

All specifications are identical except for the following:

1.5.1 Output Swing	±10 volts minimum into a 500 ohm load
1.5.2 Maximum Load Resistance	±20 milliamps minimum
1.5.4 Minimum Load Resistance	500 ohms for full output swing
1.7.1 Operating Temperature Range	-55°C to +125°C
1.7.2 Storage Temperature Range	-65°C to +125°C

NOTES: 1 - The above specifications are measured at ±15 volts supply and 25° ambient.

OEI

Optical Electronics Inc. P.O. Box 11140 * Tucson, Arizona 85734

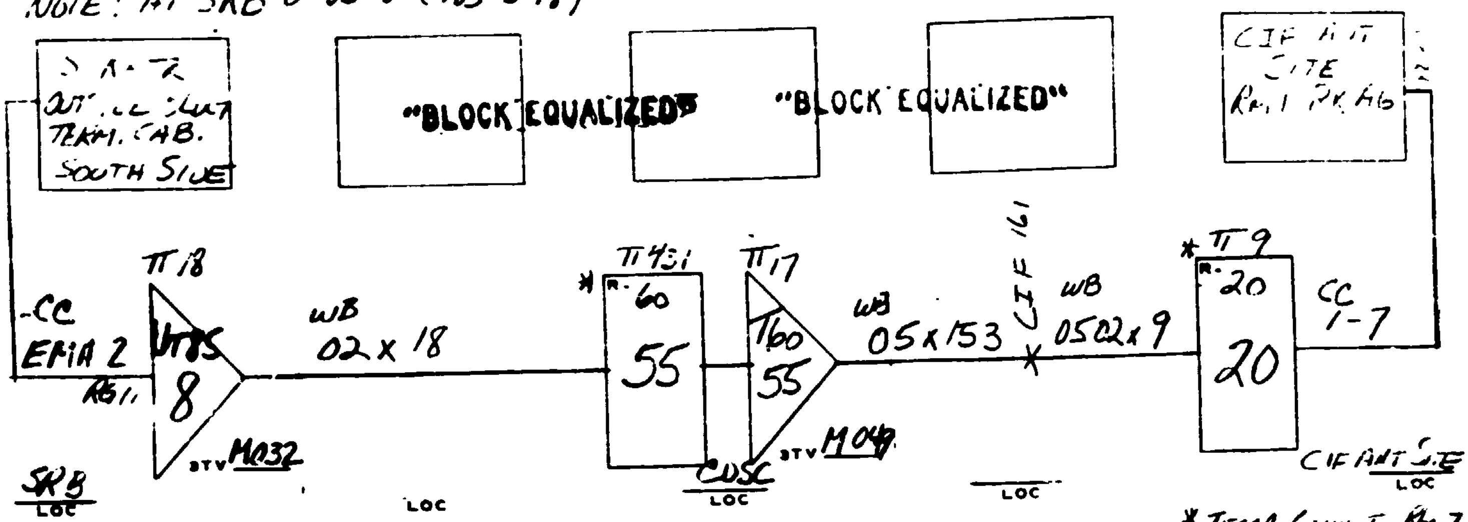
Phone (502) 624-8358

CIRCUIT TYPE	CIRC	CIRCUIT NUMBER
DATA	A-10 A2A Wideband Video Cable SOUTH KPTR. GROUND STRIKE	1TV M0039

WORK ORDER NO.	DATE	CARD NUMBER	ISSUE	USER	ASSOCIATED CIRCUIT
SX 02262	5-15-78	1	1	IN-TEL-32	

CIRCUIT LAYOUT

NOTE: AT SRB UT85-8 (T85-578) IS 345 EQUIP.



SHARED WITH

* TEMP CONN. TO R85-55

* TEMP CONN TO R60-7

NASA/KSC JUN/73

KSC FORM 7-421 (REV. 9/69)

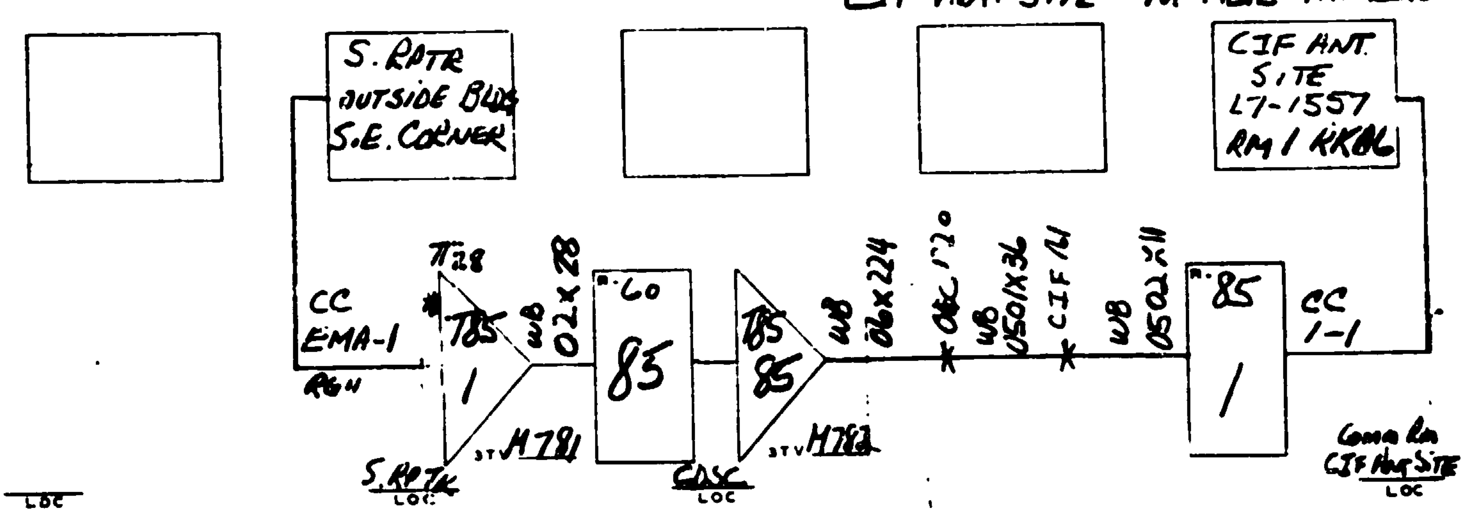
CIRCUIT TYPE	CIRCUIT DESIGNATION	CIRCUIT NUMBER
DATA	SOUTH RPTR TO CIF ANT SITE	1TVM0039

CIRCUIT TYPE	CIRCUIT DESIGNATION	CIRCUIT NUMBER
DATA	EMA LIGHTNING STUDY CIRCUIT	1TV M070

WORK ORDER NO.	DATE	CARD NUMBER	ISSUE	USER	ASSOCIATED CIRCUIT
CZ 8937B	5-26-77	1	4	IN-TEL-32	

CIRCUIT LAYOUT

CIF ANT. SITE - M MEAS TK REQD



SHARED WITH

*NOTE: TERMINATE RING SIDE OF EQUIP IN CABLE AT SECONDARY P/P + POSITION IMPEDANCE SWITCH TO UNBALANCE

NASA/KSC JUN/73

KSC FORM 7-421 (REV. 9/69)

CIRCUIT TYPE	CIRCUIT DESIGNATION	CIRCUIT NUMBER
DATA	S RPTR BLDG TO CIF ANTENNA SITE	1TVM070

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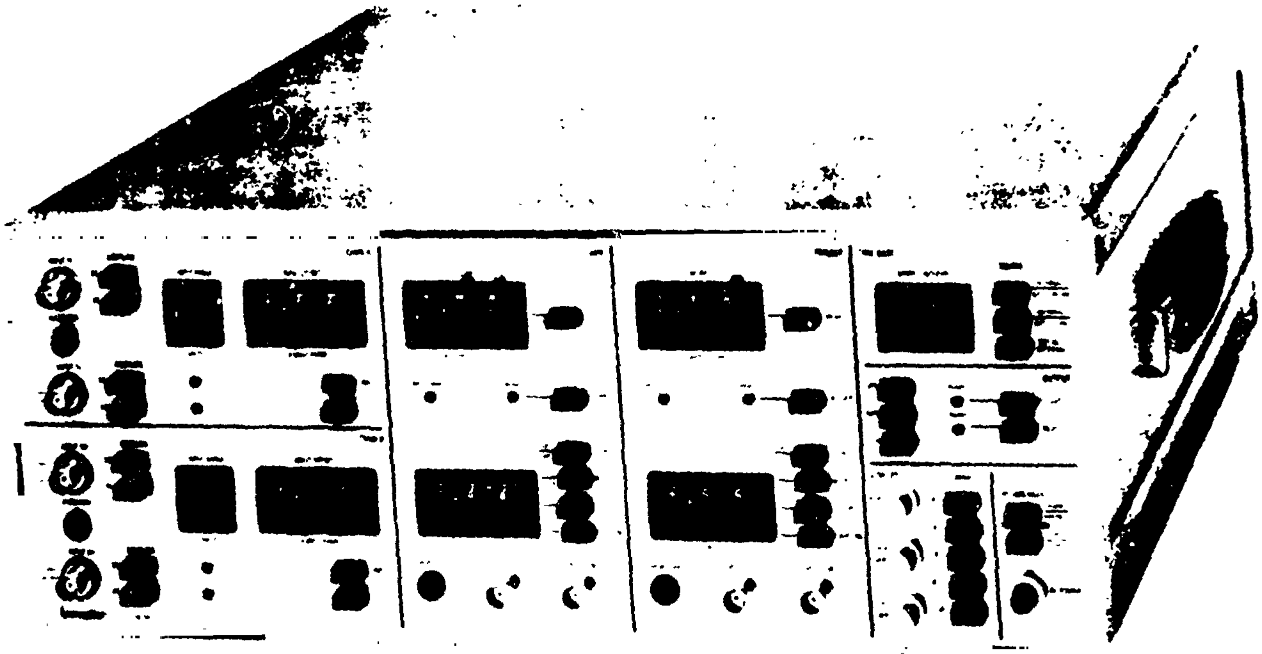
A-11 Biomation Transient Recorder

biomation

MODEL 8100 TRANSIENT RECORDER

Technical Data 6/15/72



REAL-TIME 8-BIT A-D CONVERSION AND STORAGE AT 100 MHz

ORIGINAL PAGE IS OF POOR QUALITY

FEATURES

- High speed data acquisition with 2000 point buffer storage.
- Captures transient waveforms or recurring signals.
- Wide frequency response of DC to 25 MHz.
- Versatile Arm and Trigger circuits with settable delays.
- Selectable sample intervals; 10 nsec.-10 sec. or external sampling.
- Two differential inputs: 50 mV to 5 V full scale input ranges.
- Flexible record modes including unique prior-event "pre-trigger" operation and dual sample rate recording.
- Analog output for CRT, plot or strip-chart recorders.
- Binary output for digital processors or bulk storage devices.
- Fully programmable via 16-bit instruction-exchange interface.
- "Tri-state" output lines and "address" field allow up to 8 units on single I/O bus.

biomation 10411 bubb road, cupertino, california 95014 (408) 255-9500

1.4 Specifications

Analog Input Characteristics:

Input Channels	Two independent channels, each differential or single-ended. Dual channel operation (inputs sampled alternately) is permissible for sample intervals of 100 nsec or greater.
Input Impedance	50 ohm, each input to ground. Unit will accommodate standard FET active probes to achieve 10 megohm, 10 pf input impedance with 10:1 voltage division.
Input Voltage Range	±50 mV to ±5 V full scale (100 mV to 10 V peak to-peak). Independent selection on each channel by 7 position (1-2-5 sequence) lever switch. Attenuator accuracy ±3% on any position.
Maximum Input Voltage	25 V peak, 8 V RMS
Input Coupling	AC or DC for each input of each channel. Time constant of 100 μs on AC coupling.
Input Offset	0 to ±0.99 of full scale, selection in increments of 0.01 of full scale.
Input Indicators	± offscale indicators to indicate signals beyond range of ADC
Input Bandwidth	DC to 25 MHz for DC coupling on all ranges. Low frequency 3 db cutoff of 1.5 kHz on AC coupling.
Overload Recovery	Less than 10 ns for recovery from 500% (5X) overload. Less than 50 ns for 10X overload. Subject to maximum input voltages above.
Common Mode Rejection	40 db from DC to 10 MHz.
DC Stability	Drift, including offset of less than 5% of full scale over 24 hours.
Gain Stability	Gain changes less than 3% over 24 hours, less than 1% over 10 minutes.

Analog-to-Digital Converter:

Resolution	8 bits (1 part in 256) at all sampling rates.
Aperture Time	Less than 2 nanoseconds.
Bit Rate	800 mega-bits per second at 0.01 μs sample intervals.

Time Base and Memory:

Sample Interval	Internal: 0.01 μs to 10 sec in 1-2-5 sequence with range multipliers of μs, ms and sec. External: from separate signal source. Pulse of +3 V to 0 V; risetime ≤ pulse width or 50 ns, whichever is smaller, minimum width of 10 ns, restricted to sample intervals of 20 ns or longer. Nonlinear rates must remain in bands of <0.25 ms, 0.25 ms to 1.0 ms, >1.0 ms.
Memory Length	2024 data words, shared 1012 per channel in dual channel operation. First 50 words store events immediately preceding trigger.
Total Record Time	2048 x Sample Interval; varies from 20 μs to 20,000 sec (5.55 hr.) when using internal sample interval selection.
Time Base	100 MHz crystal controlled oscillator.

Arm and Trigger Characteristics:*

Auto	Arm/Trigger provided periodically by internal circuits.
Input	A. Manual by push button. B. Internal from either channel. C. External from separate 50Ω and 1 KΩ input connectors.
Slope	Positive or negative selectable.
Coupling	AC or DC selectable (DC only for internal, dual channel).
Level	Adjustable from 0 to ±0.99 in increments of 0.01 of input range for internal; increments of 0.05 V (50Ω input) or 0.5 V (1 KΩ input) for external.
Width	>50 ns.
Amplitude Change	>200 mV external or 5% of input range for internal.
Maximum Inputs	50Ω input, 25 V peak or 8 V RMS; 1 KΩ input, 100 V peak or 30 V RMS.
Delay	0 to 9990 Sample Intervals, selectable in increments of 10 Sample Intervals.
Delay Stability/Accuracy	± one Sample Interval.
Synchronizing Connections	Rear panel BNC connections to permit simultaneous Arming and/or Triggering of multiple Model 8100 units.

*These specifications apply separately to the Arm and the Trigger functions.

SPECIFICATIONS (CONT.)

Data Recording Modes:

Normal	Trigger input is enabled after (delayed) Arm signal. Recording begins at (delayed) Trigger signal. Recording stops after 2048 sample intervals.
Pre-trigger	Recording begins at Arm signal. Recording stops at (delayed) Trigger signal. This mode provides storage of wave-shapes *preceding* the trigger and allows user to "look back in time."
Dual Time Base	This mode permits the recording to start at one sampling rate and switch to another sampling rate during the sampling time. It is usable with either Normal or Pre-trigger operation. This mode is not usable when one sample interval is greater than 0.5 ms and the other sample interval is less than 0.5 ms or whenever the second sample interval is 0.01 μsec.

Display Output:

Horizontal Deflection Voltage (X)	Sweep ramp of +1 V peak amplitude, 1 ms duration. Origin adjustable between −1 V and +0.2 V. Expansion of sweep selectable at X1, X2, X5 or X10 (1 V, 2 V, 5 V, 10 V ramp).
Vertical Deflection Voltage (Y)	.8 V full scale, amplitude adjustable from .5 to 1.2 V. Origin adjustable ±1 X full scale. Independent level adjustments for channels A and B.
Trigger (Z)	0 to +5 V pulse for blanking, or for triggering scopes with internal time base. Also output as a 5 V to 0 pulse ($\bar{Z}$).
Display Calibrate	Full scale square wave with period of 400 samples.

Plot and Digital Outputs:

Off	Plot or Digital outputs not available. Unit automatically reverts to Display Output when not recording.
Auto	Single data output (2048 words) available beginning at end of recording. Reverts to Display Output after data output completed.
Edit	Output mode enabled upon demand.
Plot Output	0 to +1 V output for XT plotter or strip chart recorder. Initiated (when in "edit" output mode) by digital instruction or momentary front panel pushbutton. Standard output rate of 10 ms/point (20 sec total), 20 ms/point for dual channel records.
Pen Output	1.0 ms positive TTL pulse coincident with start of plot output. 0 to +3 V amplitude – optionally inverted. Also optional as a +3 V signal level during the duration of the plot.
Digital Output	Initiated (when in "edit" output mode) by digital command or momentary front panel pushbutton. See below for rates and levels.

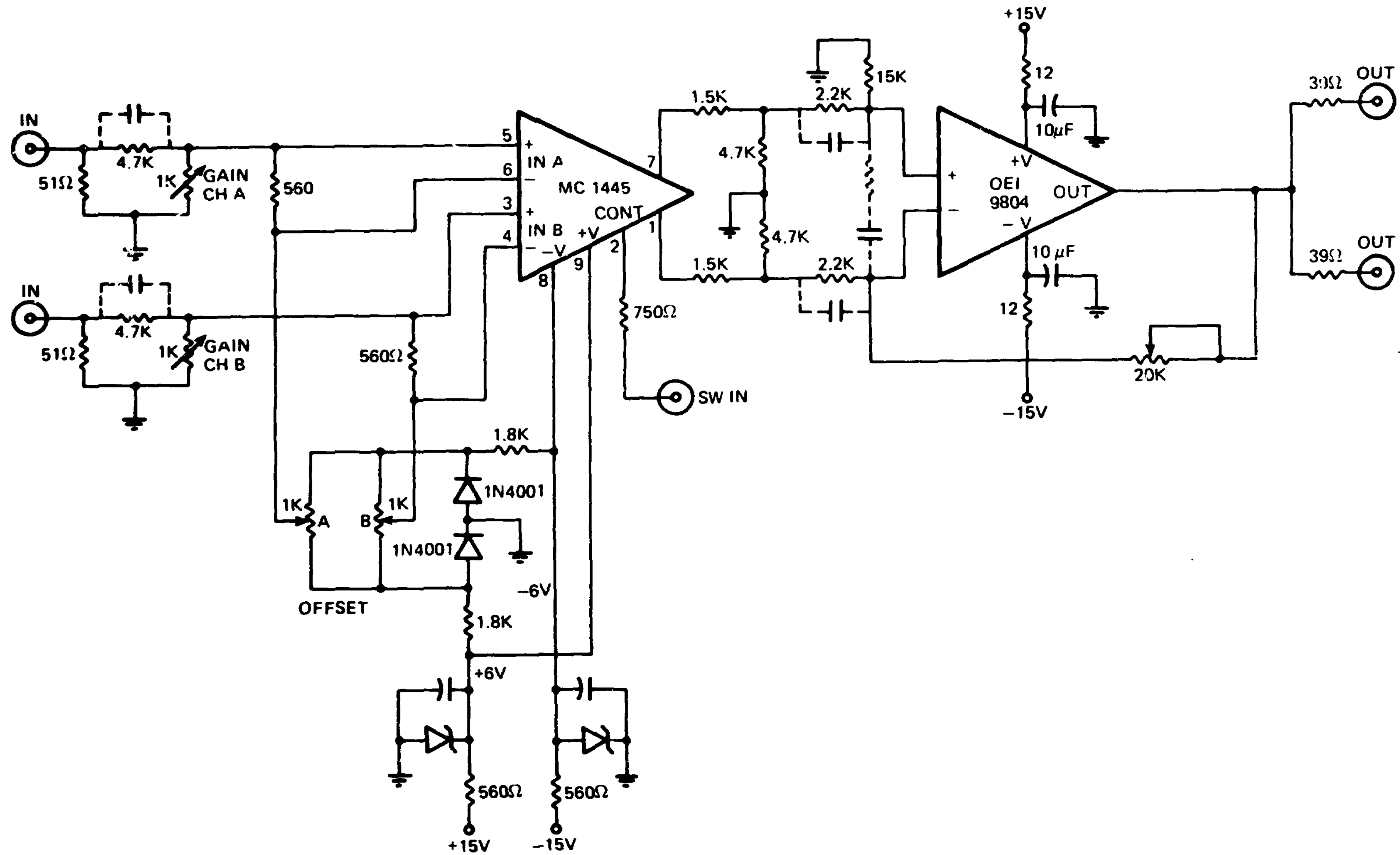
Digital Interfaces:

Programmability	All front panel controls are programmable except display adjustments and power switch.
Program Input	16 bit parallel TTL levels (0 to +5 V). Selectable positive or negative true. One-in-eight address assignment and 3-bit address field.
Data Output	8 bit parallel, TTL levels, "open" when not "addressed." Selectable positive or negative true. Asynchronous transfer under flag/command "handshake" control. Average data rates continuous from 1×10^4 to 2×10^6 words/sec. Data rates less than 1×10^4 words/sec will exhibit up to 1.0 ms latency.
Control Signals	"Command" input. "Flag" output. TTL (0 to +5 V) positive or negative true.

Miscellaneous:

Size	Height: 6.25" (16 cm) Width: 17" (43 cm) Depth: 21" (53 cm), exclusive of front panel controls and connectors.
Weight	Approx. 60 lbs (27.2 Kg.)
Power	Approx. 200 W, 115/230 V RMS, 50 60 Hz.
Warranty	All Biomation products are warranted against defects in materials and workmanship for one year from date of delivery.
Accessories	Each unit is supplied with a line-cord, extender cards, two copies of the Operating and Service Manual and a digital interface mating connector.

A-12 Video Switch/Distribution Amplifier



A-13 Telemet Distribution Amplifier

DESCRIPTION AND PURPOSE

The Telechrome* Video Distribution Amplifier Model 3200-A1 is intended for video signal distribution in both color and monochrome TV systems. Designed, primarily, as a unity gain device; each Model 3200-A1 provides four identical and isolated outputs for a single composite or non-composite input. Up to eight amplifiers may be installed on one frame to provide a total of 32 outputs for 8 inputs.

The Model 3200-A1 is a non-inverting, line driving amplifier for feeding video equipment requiring a nominal 1.0 v p-p input from a 75 ohm transmission line. Its gain is continuously variable from 0.8 to 2.0; frequency response is flat ±0.5 db from 30 Hz to 10 MHz. Each amplifier has its own internal regulated power supply and is operated from a 105-125 vac line supply connected through the frame.

SPECIFICATIONS

AC line supply - - - - - - - - - - - - - - - - -	105-125vac 50-60Hz, 2.0 watts (nom.)
Input Signal, comp or noncomp video - - - - -	0.5-1.25 v p-p for 1 v p-p out.
Output Signals - - - - - - - - - - - - - - - - -	Four identical video signals 1 v p-p nominal.
Isolation at 500 KHz - - - - - - - - - - - - -	Greater than 32 db.
Isolation at 5 MHz - - - - - - - - - - - - - -	Greater than 27 db.

Transfer Characteristics (Unity Gain at 1 volt nominal)

Input Impedance - - - - - - - - - - - - - - -	40 K ohm at 500 KHz.
Output Impedance - - - - - - - - - - - - - -	75 ohm ± 1 ohm.
Gain -	Variable 0.8 to 2.0
Frequency Response - - - - - - - - - - - - -	± 0.5 db 30 Hz to 10 MHz
Differential Gain - - - - - - - - - - - - - -	Less than 0.3%
Differential Phase - - - - - - - - - - - - -	Less than 0.4°
Tilt on 60 Hz window - - - - - - - - - - - -	Less than 1%
Bounce for 1.0 v Step - - - - - - - - - - -	Less than 12%
Ripple -	Not greater than 1.0 mv p-p
Signal to Noise Ratio (peak to peak) - - - -	Greater than 60db
Cross-Talk (output to input) - - - - - - - -	Less than 80 db

Physical Characteristics

Width -	2.00"
Height -	3.15"
Depth -	9.00"
Weight -	20 oz.

EQUIPMENT SUPPLIED

Since the model 3200-A1 is a completely self-contained unit designed to plug into the Model 4000-A1 or 4000-B1 frame, accessories are supplied for the frame rather than the amplifier. Quantities of accessories are determined by the individual purchase order and may include the following items which are classified optional:

Video Distribution Amplifier Unit - - - - -	Model 3200-A1
Mounting Fram (optional) - - - - - - - - - -	Model 4000-A1/4000-B1
Frame Extendor (optional) - - - - - - - - -	TMC Model 4102-A1
Blank Panels (optional) - - - - - - - - - -	TMC Model 4100-A1
75 ohm Terminations (optional) - - - - - - - -	TMC Drawing No. AS-0017-2

TELEMET COMPANY
AMITYVILLE, N. Y.

* Brand Name

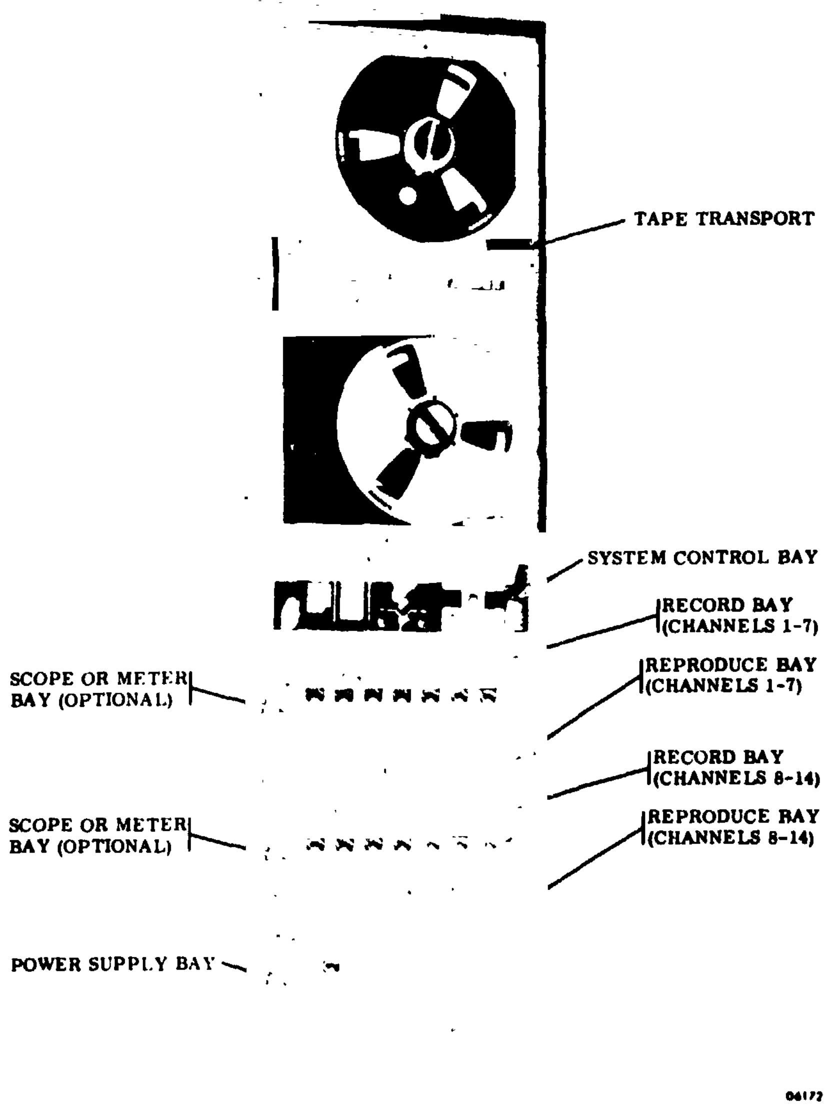


Figure 1. 1-1 FR-1800H Recorder/Reproducer

Table 1.2-1. Specifications - FR-1800H Recorder/Reproducer (Continued)

DESCRIPTION	CHARACTERISTICS
Transport (Continued)	**Tape Speed Accuracy:** ±0.2%
	Tape Width: 1/2-in. and one in.
	Tape Thickness: 1.0 and 1.5 mil base polyester.
	Reel Size: 10-1/2 or 14-in. Ampex Precision or NAB reels.
	Start Time: 8 seconds maximum to reach stable speed of 120 ips.
	Stop Time: 4 seconds maximum at 120 ips.
	Fast Wind Time: 5 minutes maximum for a 14 in. reel with 7200 feet of tape.
	Flutter: Peak-to-Peak instantaneous speed variation.

Speed (ips)	Bandpass	% Peak-to-Peak Flutter tape Servo
120	0.2 Hz to 10 kHz	0.20
60	0.2 Hz to 10 kHz	0.25
30	0.2 Hz to 5 kHz	0.35
15	0.2 Hz to 2.5 kHz	0.40
7-1/2	0.2 Hz to 1.25	0.45

Table 1.2-1 Specifications - FR-1800H Recorder/Reproducer (Continued)

<table>
<tr><th>DESCRIPTION</th><th>CHARACTERISTICS</th></tr>
<tr><td rowspan="2">Transport (Continued)</td><td>Flutter: (Continued)

<table>
<tr><th>Speed (ips)</th><th>Bandpass</th><th>% Peak-to-Peak Flutter tape Servo</th></tr>
<tr><td>3-3/4</td><td>0.2 Hz to 625 Hz</td><td>0.60</td></tr>
<tr><td>1-7/8</td><td>0.2 Hz to 312 Hz</td><td>0.80</td></tr>
</table></td></tr>
<tr><td>Dynamic Skew:
±0.15 microseconds or less at 120 ips ou adjacent tracks in the same head stack.</td></tr>
<tr><td rowspan="7">Heads</td><td>Number of Tracks:
1/2-inch tape - 7 tracks
One-inch tape - 14 tracks</td></tr>
<tr><td>Track Width:
0.050 (±0.005) in.</td></tr>
<tr><td>Track Spacing:
0.070 in.</td></tr>
<tr><td>Head Spacing:
1.500 (±0.01 in.)</td></tr>
<tr><td>Head Life:
1000 hours</td></tr>
<tr><td>Gap Azimuth:
±1 minute of arc.</td></tr>
</table>

AMPEX

Table 1.2-1. Specifications - FR-1800H Recorder/Reproducer (Continued)

DESCRIPTION	CHARACTERISTICS
Direct System 1.5 MHz	Frequency Response: Zero db reference level is the mid-point of the excursions of the response curve. Amplitude variations ±3 db. Tape Speed (ips) / Bandwidth / S/N RMS Signal/* RMS Noise 120 / 400 Hz to 1500 kHz / 28 db 60 / 400 Hz to 750 kHz / 28 db 30 / 400 Hz to 375 kHz / 26 db 15 / 400 Hz to 185 kHz / 26 db 7-1/2 / 400 Hz to 90 kHz / 26 db 3-3/4 / 400 Hz to 45 kHz / 24 db
	Harmonic Distortion: Total of any signal in the passband 3% when recorded at normal output. Normal record level is defined as input level which produces 1% third harmonic distortion of a 1 kHz sinusoidal signal at the desired speed with a second harmonic distortion of a 1 kHz signal adjusted to less than 0.5%. The foregoing applies to only one tape speed.
	Input Level: 0.25 to 25V rms adjustable to produce normal record level.

*Measured at output of a bandpass filter having 18 db/octave attenuation beyond limits stated.

Table 1. 2-1. Specifications - FR-1800H Recorder/Reproducer (Continued)

DESCRIPTION	CHARACTERISTICS
Direct System 1. 5 MHz (Continued)	Input impedance: 1000 ohms (±20%) unbalanced to ground; 150 pf maximum capacitance.
	Output Level and Load: 4 speed - - 1. 5V rms maximum into 100 ohms 2 speed - - 1. 5V rms maximum into 75 ohms
Frequency Shift Modulation (FSM)	PCM Transfer Rate: 2400 bits per inch per track with not more than one bit error in 10^4 bits per digital track and 1000 bits per inch per track with no more than 1 bit error in 10^5 bits per digital track.
	Input Level and Format: 0. 0 (±1) volt produces lower frequency. 5 to 20V (selectable either polarity) produces higher frequency. Normal input format is NRZ change or NRZ Mark digital.
	Input Rise Time: 1. 5 µsec between 10% and 90% levels.
	Input Impedance: 1000 ohms, unbalanced to ground in parallel with 150 pf maximum capacitance.
	Output Level and Format: Binary output of 0. 0 (±1) volt and -11 (±1) volt. The higher recorded frequency may be chosen to represent either the nominal 0V or the -11V.

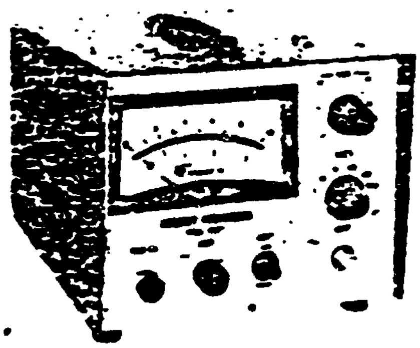
A-15 Peak Reading Voltmeter

MICRO INSTRUMENT CO.

POWER INSTRUMENT DIVISION

TRANSIENT MEASUREMENT INSTRUMENTS & SYSTEMS

SERIES 5200



MODEL 5201C

PRECISION METER READOUT TRANSIENT VOLTMETER

The Model 5201C Transient Voltmeter is the basic instrument in a family of instruments that Micro Instrument Co. has developed and named "Memory Voltmeters." Just as the name implies, these instruments have circuitry that remembers the maximum applied peak voltage. Useful in many measurements that were previously cumbersome or impractical, these instruments are in wide use throughout the Power Utility and Electronic Industries.

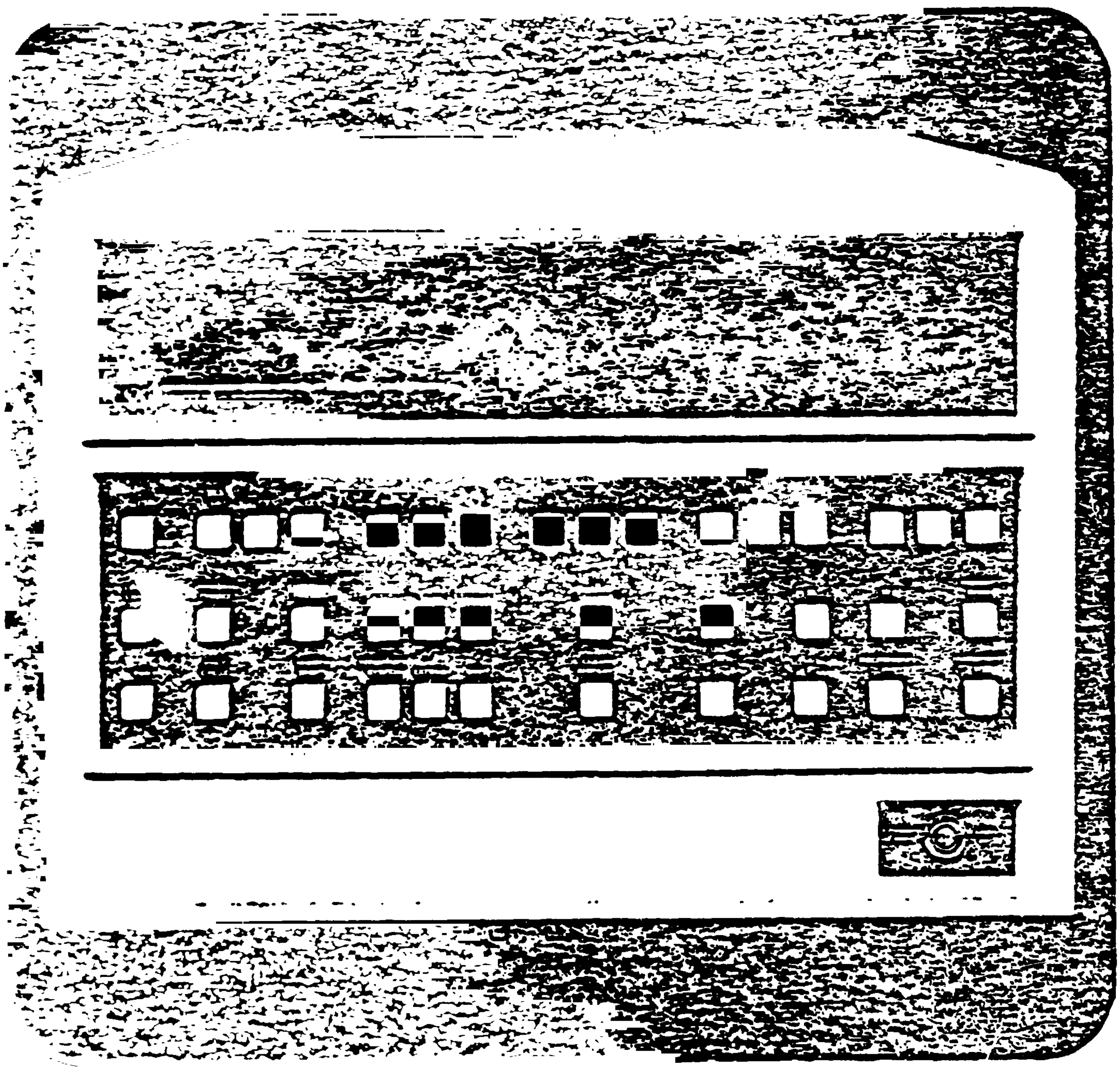
The basic instrument covers a range of voltages from 3 volts to 1000 volts full scale. It will measure any voltage within this range and hold the highest peak reading until reset. Frequencies that may be measured are from DC to approximately 20 MHz which include transients, single or repetitive pulses as short as 50 nanoseconds (.05 microseconds). Features include a sturdy dual-shielded portable cabinet construction; selectable maximum frequency response control gate circuit for special measurements and optional High Voltage Range Extender Probes including 3 kV, 10 kV and 30 kV full scale. The instrument may be battery operated for remote location work, see Model 5298 for details.

1.2 SPECIFICATIONS -

Input	- Single-ended BNC ungrounded input. May be operated up to 1000V peak above ground. Case grounded.
Voltage Range	- 0-3, 10, 30, 100, 300, 1000V. To 30kV with optional probes.
Input Impedance	- 10 megohms (1000V Range) to 30K ohms (3V Range) depending on range.
Pulse Width Range	- DC to 50 nsec (single pulse).
Accuracy	- ±3% of full scale, dc to 50 nsec.
Readout	- 5" taut-band, mirror-backed 1% meter.
Reset Modes	- 1) Manual, with front panel switch or remote contact closure. 2) Automatic (50 msec intervals, adjustable up to 5 sec after end of measurement). 3) Recorder (automatic reset adjustable from 50 msec to 5 sec after end of measurement).
Reset Time	- 100μsec nominal, with no dead-time or loss of response during reset.
Operating Modes	- 1) Reads peak positive. 2) Reads peak negative. 3) Reads maximum peak of positive or negative.
Memory	- Electronic memory retains readings permanently, until reset by operator or command signal, or until advanced to a higher reading due to a greater amplitude input signal. Readings held during momentary power interruptions.

DC Analog Output	- 0 to 1 V or 3 V positive, ±2%, depending on range. Short circuit safe.
AC Analog Output	- Simultaneous peak positive and negative outputs. 2 1/2 nominal, decaying to zero in 100 ms at full scale.
Response	- Five selectable positions: NORM (wide band), 1, 10, 100 ms and 1 ms pulse widths. Response is approximately 3 dB down at these points and limits the response at approximately 0 dB/octave rate.
Gate Circuit	- Permits sample-and-hold or synchronized measurements via externally applied gating pulses of approximately 5 to 10 V.
Temperature Range	- 0° to 50°C operating.
RFI and Noise Rejection	- Internal multistage LC pi line filter provided.
Input Power	- 115 V or 230 V AC, ±10%, 50 - 400 Hz, 15 VA, or ±24 V DC, 100 mA maximum, battery operation. Model 5201CR - 115 V AC, 60 Hz standard. 230 V AC, 50 Hz or ±24 V DC optionally available.
Mechanical	- 5201C-1, 5201C-2, 5201CR - Dual shielded rack mounting enclosure 7" x 19" x 12".
Accessories	- 3 1/2 foot shielded input cable and technical manual provided.
Options	- High voltage proves: 3 kV, 10 kV and 30 kV probes supplied with insulated shielded cable frequency compensated for pulse applications.

A-16 HP 2100S Computer



GENERAL SPECIFICATIONS

BASIC CHARACTERISTICS

- 16-bit word length; 17th bit for memory parity checking
- Parallel logic
- Power fail interrupt, with automatic restart
- Rack-mountable

MEMORY

- Magnetic core storage
- 980 nanosecond cycle time
- Parity generation and checking is standard in all units
- Three memory sizes available, 16K, 24K, or 32K words, field-expandable by plug-in cards
- 1024-word page size
- Protected 64-word block for stored loader

PROCESSOR

- 86 basic instructions, including extended arithmetic
- Up to eight instructions may be combined into one word (register reference group)
- Unlimited levels of indirect addressing allowed
- Illuminated control pushbuttons allow simultaneous display and control of internal functions
- All instructions fully executed in 1.96 microseconds, except ISZ and extended arithmetic (2.94 to 16.7 microseconds)
- Only 980 nanoseconds added for each level of indirect addressing
- All microinstructions except those performing I/O or core memory accesses are fully executed in 196 nanoseconds
- Memory and I/O protection is standard

REGISTERS

- 8 Standard Registers
  - Accumulators: Two (A and B), 16 bits each. Directly addressable.
  - Memory Control: Three (T, P, M), 16 bits each
  - Supplementary: Two (Overflow and Extend), one bit each
  - Manual Data: One 16-bit switch register
- 7 Microprocessor Registers
  - Accumulators: Six (Q, F, and four scratch pad), 16 bits each
  - Interrupt Control: Central Interrupt Register, 6 bits

SOFTWARE

- FORTRAN, FORTRAN IV, ALGOL, and BASIC languages
- Extended Assembly language
- Editor, subroutine library, Formatter, and Debug routine
- Several Operating systems, including
  - Basic Control System (BCS)
  - Magnetic Tape System (MTS)
  - Disc Operating System (DOS)
  - Time-Shared BASIC System
  - Real-Time Executive System (RTE)

MICROPROGRAMMING SOFTWARE

- Microassembler (BCS or DOS)
- Micro Debug Editor (BCS or DOS)
- Programmable ROM Writer (BCS)
- Drivers and Diagnostics (BCS or DOS)
- Writable Control Store Input/Output Utility Routine (BCS or DOS)
- Library of Contributed Microprograms

INPUT/OUTPUT SYSTEM

- 12 internal I/O channels, externally expandable to 43
- Optional multiplexed I/O extends capacity to 54 channels; may be plugged into any slot
- All channels buffered and bi-directional
- Multilevel priority interrupt for device servicing
- Peripherals interfaced simply with plug-in cards
- Dual-channel direct memory access, can transfer 1,020,400 words per second
- General-purpose interface cards available

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HEWLETT PACKARD

OPERATING AND SERVICE MANUAL

PART 1

7970B/7970C

DIGITAL MAGNETIC TAPE UNITS

OPERATION AND GENERAL INFORMATION

Serial Numbers Prefixed: 1329

Note

This manual may be backdated to cover earlier versions of the tape unit by incorporating appropriate backdating information from appendix A.

07970-90323

PRINTED: AUG 1973

SECTION I
DESCRIPTION

1-1. MANUAL SCOPE.

1-2. This manual provides operating and service information for standard product configurations of the HP 7970B/7970C Digital Magnetic Tape Units. (See figure 1-1.) Special product configurations are described by manual supplements attached to this manual. The 7970B is recognized under the component program of the Underwriters Laboratories Inc., and is similar to the 7970C. This manual is applicable to both models.

1-3. This manual is divided into 5 parts. Part 1 contains general information, installation instructions, and operating procedures. Part 1 is applicable to all standard tape units. Part 2 contains a description of the transport, transport theory, performance checkout procedures, adjustment procedures, and an illustrated parts breakdown of the tape transport portion of the tape unit. Part 2 is applicable to all standard tape units. Part 3 contains a description of the read data modules and provides maintenance information for tape units equipped with read data modules. Part 4 contains a description of the write data modules and provides maintenance information for tape units equipped with write data modules. Part 5 contains a description of the read/read (seven- or nine-track read only) modules and provides maintenance information for tape units equipped with read/read modules.

1-4. IDENTIFICATION.

1-5. Each tape unit has a model plate and a serial number plate attached to the transformer assembly. The model plate indicates the tape speed of the unit and the model configuration.

1-6. Table 1-1 lists the standard configuration option numbers that will be shown on the model plate. The model plate also lists factory installed elective options. (Refer to table 1-2.) Special configuration and special factory installed options also appear on the model plate. When special product considerations exist (indicated by alphanumeric option numbers) the information is provided by special modification notices, supplemental to the standard manual.

1-7. The serial number plate contains a two-section serial number (0000A-00000). The first four digits are a serial number prefix. The five-digit number identifies a specific tape unit. If the serial number prefix on the tape unit does not agree with the number on the title pages of this manual, there are differences between the tape unit and the information contained in this manual. These differences are described in manual supplements available at the nearest HP Sales and Service Office.

Table 1-1. Standard Configuration Option Numbers

SPEEDS	R/W	R/O	BASE	TRACKS
10 - 20.9 IPS	121	122	123	NINE
21 - 37.5 IPS	STD	125	126	
37.6 - 45 IPS	127	128	129	
10 - 20.9 IPS	130	131	132	SEVEN
21 - 37.5 IPS	133	134	135	
37.6 - 45 IPS	136	137	138	
10 - 20.9 IPS	—	139	—	SEVEN/ NINE (R/R)
21 - 37.5 IPS	—	140	—	
37.6 - 45 IPS	—	141	—	

Table 1-2. Elective Option Numbers

NUMBER	DESCRIPTION
006	Triple Density Select
007	Unit Select
012	HP Logo
013	Read Parity (Seven- or Nine-Track)
014	Write Parity (Nine-Track)
015	Write Parity (Seven-Track)
016	Door Interlock Switch
017	Black Paint
023	Installation Kit

1-8. Printed-circuit assemblies are identified by a letter, a series code, and a division code on the assembly (e.g. A-1010-42). The letter identifies the revision of the etched trace pattern on the unloaded printed-circuit board. The four-digit series code pertains to the electrical characteristics of the loaded printed-circuit assembly and the positions of the components. The division code identifies the Hewlett-Packard division that manufactured the printed-circuit assembly. If the series numbers of the tape unit printed-circuit assemblies do not agree with the series numbers shown on the schematics and title pages of this manual, there are differences between the tape unit and the information in this manual. These differences are described in manual supplements available at the nearest HP Sales and Service Office.

TAPE SPEED

10 to 45 ips

REEL DIAMETER

Up to 10.50 inches (266.7 mm)

TAPE (Computer Grade)

Width: 0.5 inches (12.7 mm)
Thickness: 1.5 mils

TAPE TENSION

8.5 oz. nominal

REWIND SPEED

160 ips

FAST FORWARD

160 ips

INSTANTANEOUS SPEED VARIATION

±3% (measured bit-to-bit)

LONG-TERM SP VARIATION

±1%

FAST FORWARD, FAST REVERSE, START/STOP CHARACTERISTICS

Distance: 40 inches, nominal start (25 ips)
69 inches, nominal start (37.5 and 45 ips)
31 inches, nominal stop (37.5 and 45 ips)

Time: 0.7 second, maximum

START/STOP TIMES

15 ms (at 25 ips)
10 ms (at 37.5 ips)
8.33 ms (at 45 ips)

START/STOP TAPE TRAVEL

0.187 ± 0.020 inch (4.7625 ± 0.508 mm)

REEL MOTOR BRAKING

Dynamic

RECORDING MODE

NRZI (industry compatible)

MAGNETIC HEAD ASSEMBLY

Standard: seven- or nine-track, erase, write and read
Gap Scatter (Measured Optically)
Read Stack: 150 μin., maximum
Write Stack: 150 μin., maximum

SKEW

Static Skew: The per channel, one-shot deskewing technique is utilized in the write (forward) and read (forward and reverse) circuitry effectively eliminating static skew.

Dynamic Skew: ±200 uin. (read after write), maximum

HEAD GUIDE SPACING

Industry compatible

WRITE HEAD TO READ HEAD CROSSTALK

<5% (of read signal)

READ HEAD CHANNEL TO READ HEAD CHANNEL CROSSTALK

<-30 dB

BEGINNING-OF-TAPE AND END-OF-TAPE REFLECTIVE STRIP DETECTION

Photoelectric, industry compatible

OPERATING ENVIRONMENT

Ambient Temperature: +32° to +131°F (0° to 55°C)
Relative Humidity: 20 to 80% (non-condensing)
Altitude: 10,000 ft (3.048 m)

POWER REQUIREMENTS

115 or 230 (±10%) Vac
48 to 66 Hz, single phase
400 VA, maximum (on high line)

DIMENSIONS

Height: 24 inches (609.6 mm)
Width: 19 inches (482.6 mm)
Depth: 12 inches (304.8 mm) (rack space)
Overall Depth: 15.75 inches (391 mm)

WEIGHT

130 lb maximum (56.7 kilograms)

TRANSPORT MOUNTING

Vertical: Standard 19 inches (482.6 mm) Retma rack

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For general computation and systems
Models 2114B, 2115A, 2116B

Specifications

	2116B	2115A	2114B
Core Memory			
Word size (bits)	16	16	16
Parity check with interrupt	Optional	Optional	Optional
Basic configuration size (words)	8K	4K	4K
Maximum size in mainframe	16K	8K	8K
Maximum size using extender	32K	—	—
Direct memory access	Optional	Optional	Optional
Memory area protect	Optional	—	—
Cycle time (us)	1.6	2.0	2.0
Instruction execution speed (us)			
Store word	3.2	4.0	4.0
Add (full word)	3.2	4.0	4.0
Multiply (subroutine)	120	150	150
Divide (subroutine)	300	375	375
Multiply (hardware option)	19.2	24.0	—
Divide (hardware option)	20.8	26.0	—
Number of basic instructions	70	70	70
Multilevel indirect addressing	Yes	Yes	Yes
Priority interrupt system			
Number of prewired input/output slots in mainframe	16	8	7
Maximum number of I-O slots using extender	48	24	24
Number of devices that can be interfaced using multiplexed I/O	—	—	56
Hardware			
Circuitry	CTL I.C.	CTL I.C.	CTL TTL I.C.
Power failure protection	Yes	Yes	Yes
Automatic restart	Optional	Optional	Optional
Height	31½"	12¼"	12¼"
Width	16¾"	16¾"	16¾"
Depth	19¾"	24⅛"*	24⅛"
Environmental temperature	0° to 55°C	10° to 40°C	10° to 40°C
Environmental relative humidity (at 40°C)	95%	80%	80%
Prices			
with 4K memory	—	$14,500	$ 8,500
with 8K memory	$24,000**	19,500	13,000

Interface Kits

● Prices for the following options are for the Interface Kit only; order by Interface Kit number. For example: To order the Relay Output Register, specify Interface Kit 12551B.

NAME	CAPABILITY	BASIC KIT NO.	PERIPHERAL	PRICE 115 V, 60 Hz	230 V, 50 Hz
TIME BASE GENERATOR	Generates real time intervals in decade steps from 100 µs to 1000 sec (derived from crystal oscillator). Used as source of timed interrupts for software clock.	12539A	None required	1,000	1,000
DATA-PHONE INTERFACE	Interfaces computer with Bell System Data Phone service.	12540A	Bell System Data Set 103A	1,300	Not Available
RELAY OUTPUT REGISTER	Provides 16 form-A contacts for operating external devices. (Interface kit includes 48-pin mating connector.)	12551B	Determined by user	500	600
16-BIT GENERAL PURPOSE DUPLEX REGISTER	Dual 16-bit flip-flop register. Permits bi-directional transfer of information between computer and external devices. (Interface kit includes 48-pin mating connector.)	12554A	Determined by user	750	750
D-A CONVERTER	Provides two D-A conversion channels, 8 bits/channel.	12555A	Determined by user	1,000	1,000
MICROCIRCUIT INTERFACE	Dual 16-bit flip-flop register. Permits bi-directional data transfer between computer and external device at DTL/TTL voltage levels. (Interface kit includes cable and mating connector.)	12566A	Determined by user	750	750
8-BIT GENERAL PURPOSE DUPLEX REGISTER	Dual 8-bit flip-flop register. Permits bi-directional transfer of information between computer and external devices. (Interface kit includes 48-pin mating connector.)	12597A	Determined by user	600	600

4025 TEKTRONIX

From Alphanumerics to Graphics. Now your terminals can keep pace with your needs.

Computer Display Terminal

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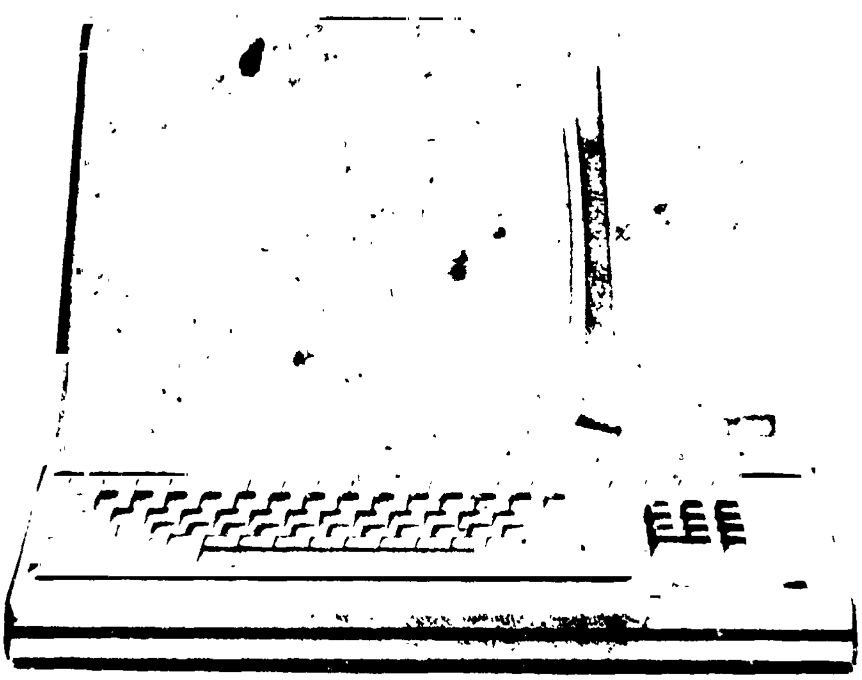

The 4025 takes you beyond alphanumerics. When you're ready to go beyond data entry and editing, the 4025 is the terminal that can take you there The 4025 gives you the unique ability to expand your terminal from basic alphanumerics, to forms ruling and then into graphics No other terminal has such versatility. With all its options, the 4025 provides unmatched report generation capability

Start with an ASCII character set and finger tip editing. The 4025 can display a full 34 lines of 80 characters each on its 12-inch diagonal display screen The complete upper and lower case ASCII character set is provided The green-on-black display with adjustable brightness level is easy on the eyes

The keyboard is arranged in an office typewriter configuration, making it familiar to new users. Predefined editing keys allow you to insert, delete and input lines and characters Thirteen user definable keys plus virtually any other key on the keyboard can be redefined to generate a command or character string at the touch of a finger

A 4 K memory is standard with the 4025, expandable to 32 K, allowing buffering and scrolling of hundreds and even thousands of words

Add the versatile Forms Ruling option. The 4025 Forms Ruling option can duplicate essentially any form Visual attributes include enhanced, blank, blinking, inverted and underlined fields Logical attributes include protected fields, modified, alphanumeric or numeric only The "send modify" command and stream lines data entry by transferring only the modified, keyed-in data to the host The fixed format remains, ready for the next series of entries Develop or duplicate forms of any complexity with a variety of single and multiple horizontal and vertical rules selected from the Ruling Character Set. Expandable memory and scrolling let you create forms far beyond the length of the display screen

To make data entry and editing easier, you can divide the display screen into two separate display areas each with independent scrolling You use the monitor area to communicate with the host and the workspace area for the form itself

GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. Volume Two is the second in a series of three publications that document the Hewlett-Packard Model 2114B Computer (Figure 1-1). This volume contains detailed descriptions, instructions, and diagrams applicable to installation, maintenance, troubleshooting, and repair. Unless otherwise noted, or to the extent specified in future updating or backdating supplements, this publication is applicable to HP 2114B Computers having serial number prefix 930- and subsequent.

1-3. The information in Volume Two is intended for users who have been trained in, or are familiar with, the operation and maintenance of this or similar Computers in the Hewlett-Packard line. A thorough understanding of the information presented in the Specifications and Basic Operation manual, Volume One in this series of publications, is essential to using and understanding the instructions presented.

1-4. The purpose of Volume Two is twofold: first it provides general information, installation instructions, and overall maintenance data for the Computer and its accessory items; second it provides testing, troubleshooting, and repair instructions for major functional areas within the Computer (see Figure 1-2). These are the Central Processor, the Memory System, the Timing System, the Control Display System, and the Power Supply. The Input/Output System is documented separately in the Input/Output System Operation manual, Volume Three in this series of publications. Computer options are documented in separate manuals that supplement the information given in Volume Two and Three, as applicable.

1-5. The Sections and Appendixes of Volume Two contain the following information:

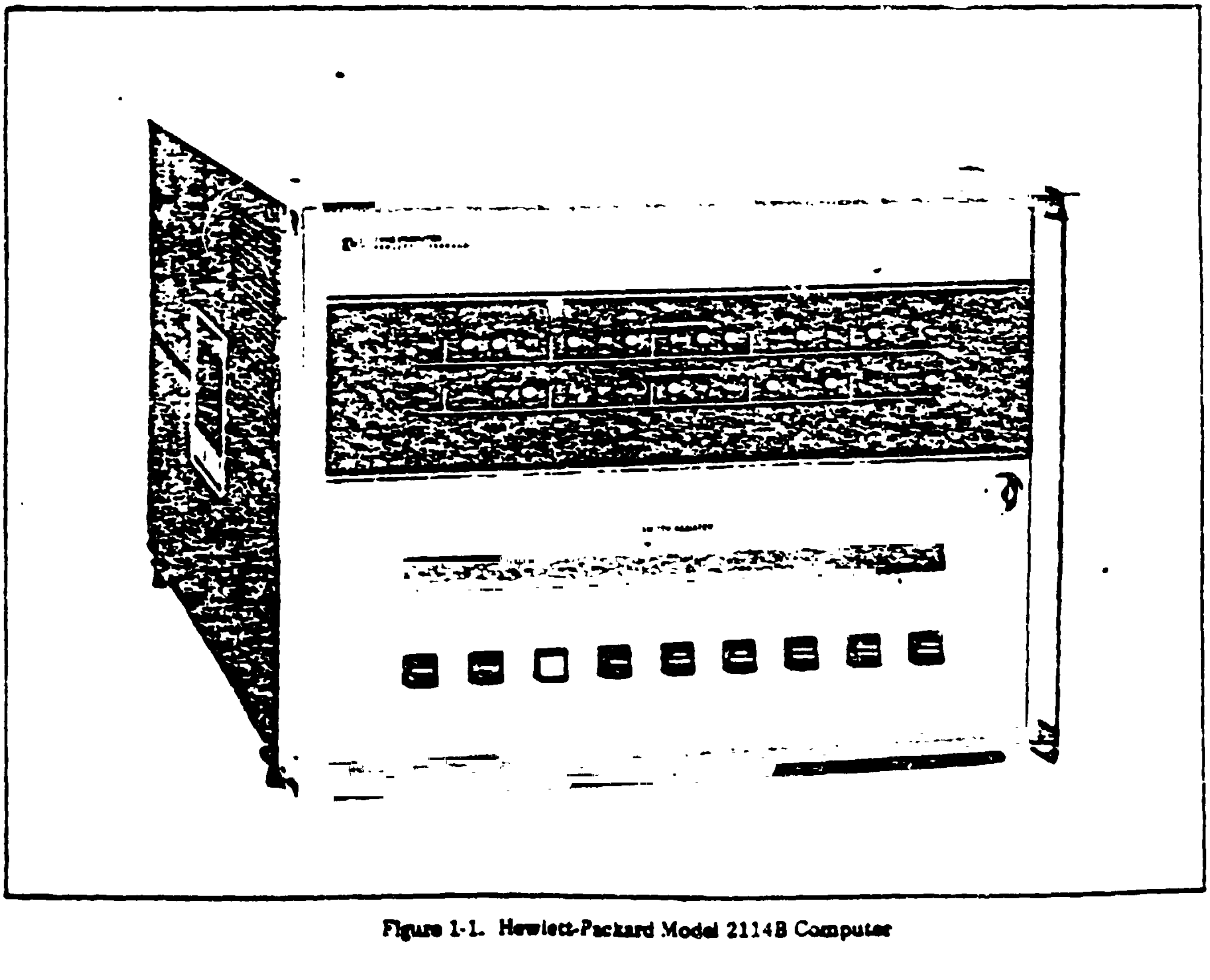

Figure 1-1. Hewlett-Packard Model 2114B Computer

Specifications

	2116B	2115A	2114B
Core Memory			
Word size (bits)	16	16	16
Parity check with interrupt	Optional	Optional	Optional
Basic configuration size (words)	8K	4K	4K
Maximum size in mainframe	16K	8K	8K
Maximum size using extender	32K	—	—
Direct memory access	Optional	Optional	Optional
Memory area protect	Optional	—	—
Cycle time (us)	1.6	2.0	2.0
Instruction execution speed (us)			
Store word	3.2	4.0	4.0
Add (full word)	3.2	4.0	4.0
Multiply (subroutine)	120	150	150
Divide (subroutine)	300	375	375
Multiply (hardware option)	19.2	24.0	—
Divide (hardware option)	20.8	25.0	—
Number of basic instructions	70	70	70
Multilevel indirect addressing	Yes	Yes	Yes
Priority interrupt system			
Number of prewired input/output slots in mainframe	16	8	7
Maximum number of I-O slots using extender	48	24	24
Number of devices that can be interfaced using multiplexed I/O	—	—	56
Hardware			
Circuitry	DTL, IC	DTL, IC	DTL, TTL, IC
Power failure protection	Yes	Yes	Yes
Automatic restart	Optional	Optional	Optional
Height	31½"	12¼"	12¼"
Width	16¾"	16¾"	16¾"
Depth	19¾"	24½"*	24½"
Environmental temperature	0° to 55°C	10° to 40°C	10° to 40°C
Environmental relative humidity at 40°C	95%	90%	90%
Prices			
with 4K memory	—	$14,500	$8,500
with 8K memory	$24,000**	19,500	13,300

Interface Kits

● Prices for the following options are for the interface kit only; order by interface kit number.
For example: To order the Relay Output Register, specify interface kit 12551B

NAME	CAPABILITY	BASIC KIT NO.	PERIPHERAL	PRICE 115 V, 60 Hz	PRICE 230 V, 50 Hz
TIME BASE GENERATOR	Generates real time intervals in decade steps from 100 us to 1000 sec (derived from crystal oscillator). Used as source of timed interrupts for software clock.	12539A	None required	1,000	1,000
DATA PHONE INTERFACE	Interfaces computer with Bell System Data Phone service.	12540A	Bell System Data Set 103A	1,000	Not Available
RELAY OUTPUT REGISTER	Provides 16 form A contacts for operating external devices. Interface kit includes 48-pin mating connector.	12551B	Determined by user	600	600
16-BIT GENERAL PURPOSE DUPLEX REGISTER	Dual 16-bit flip-flop register. Permits bi-directional transfer of information between computer and external devices. Interface kit includes 48-pin mating connector.	12554A	Determined by user	750	750
D-A CONVERTER	Provides two D-A conversion channels, 8 bits/channel	12555A	Determined by user	1,000	1,000
MICROCIRCUIT INTERFACE	Dual 16-bit flip-flop register. Permits bi-directional data transfer between computer and external device at DTL/TTL voltage levels. Interface kit includes cable and mating connector.	12566A	Determined by user	750	750
8-BIT GENERAL PURPOSE DUPLEX REGISTER	Dual 8 bit flip-flop register. Permits bi-directional transfer of information between computer and external devices. Interface kit includes 48-pin mating connector.	12597A	Determined by user	500	500

*Power Supply Unit in 2115A is 10¼" high, 16¾" wide, and 18¾" deep
**Prices for 2116B with 16K, 24K or 32K memory are available upon request.

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A-21 TM-7 Digital Tape Recorder

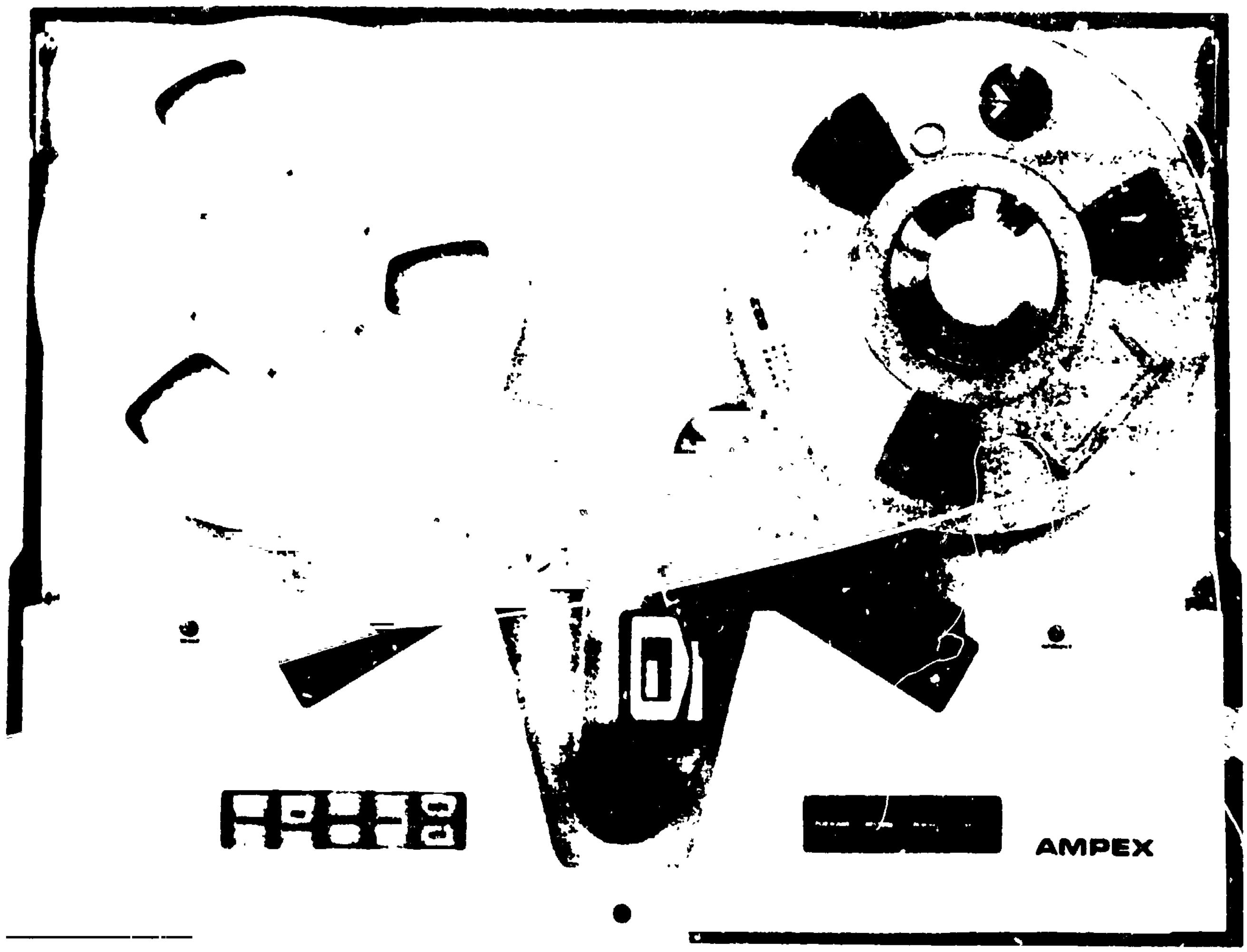

Figure 1-1.
TM-7 Tape Transport

TABLE 1-1.
PERFORMANCE CHARACTERISTICS

TAPE WIDTH	1/2 inch tape Ampex, IBM, or NAB reels
TAPE SPEEDS	36 ips standard Speeds to 45 ips optional
REWIND SPEED	2,400 ft. can be rewound in less than 3 minutes
START/STOP TIME	Start Time: 10 ms Stop Time: 10 ms
START DISTANCE AT 36 IPS	0.156 min., 0.2[illegible]4 max.
STOP DISTANCE AT 36 IPS	0.133 min., 0.195 max.
LONG TERM SPEED VARIATION	3% or less of operational speed
INSTANTANEOUS SPEED VARIATION SHORT TERM	ISV = 5% or less of operational speed 10 ms after start command
INTERCHANNEL TIME DISPLACEMENT (ITD) AT 36 IPS	Peak Dynamic Skew: 6 μsec Static Skew: 7 μsec ITD: 10 μsec
POWER REQUIREMENTS	Voltage: 117 VAC nominal, or 200-250 VAC incrementally tapped Frequency: 48 to 62 cps

A-[illegible]

Fig. 1 1. 4010 Computer Display Terminal.

Fig 2 12 Hard Copy Operation

HARD COPY MODE (Make Copy) 4010-1. The Hard Copy Mode is used to generate a permanent copy of the Terminal display. With the 4010 1 and a Hard Copy unit, the user can obtain a hard copy as follows

Step 1. Check to be sure that the hard copy unit is connected to the 4010 1

Step 2. After insuring that the terminal display is correct, press CTRL SHIFT K simultaneously, then CTRL W keys, or press the MAKE COPY switch on the 4010 1. The Hard Copy unit then sends a signal that sweeps the entire 4010-1 display in about 5 seconds. A copy is thus generated. A copy can also be initiated from the computer if the program calls for one.