A data system for EHV DC transmission line studies

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ABSTRACT

An automatic data processing and recording system for the study of ±600-kV direct current transmission lines is described. The data consist of corona loss current, meteorological information, and radio interference, correlated with real time. A small stored-program digital computer controls: the sampling of the data, the reduction of the data as required, and the recording of the results on magnetic tape – in a computer compatible format. Design of the magnetic tape-computer interface is described in detail.

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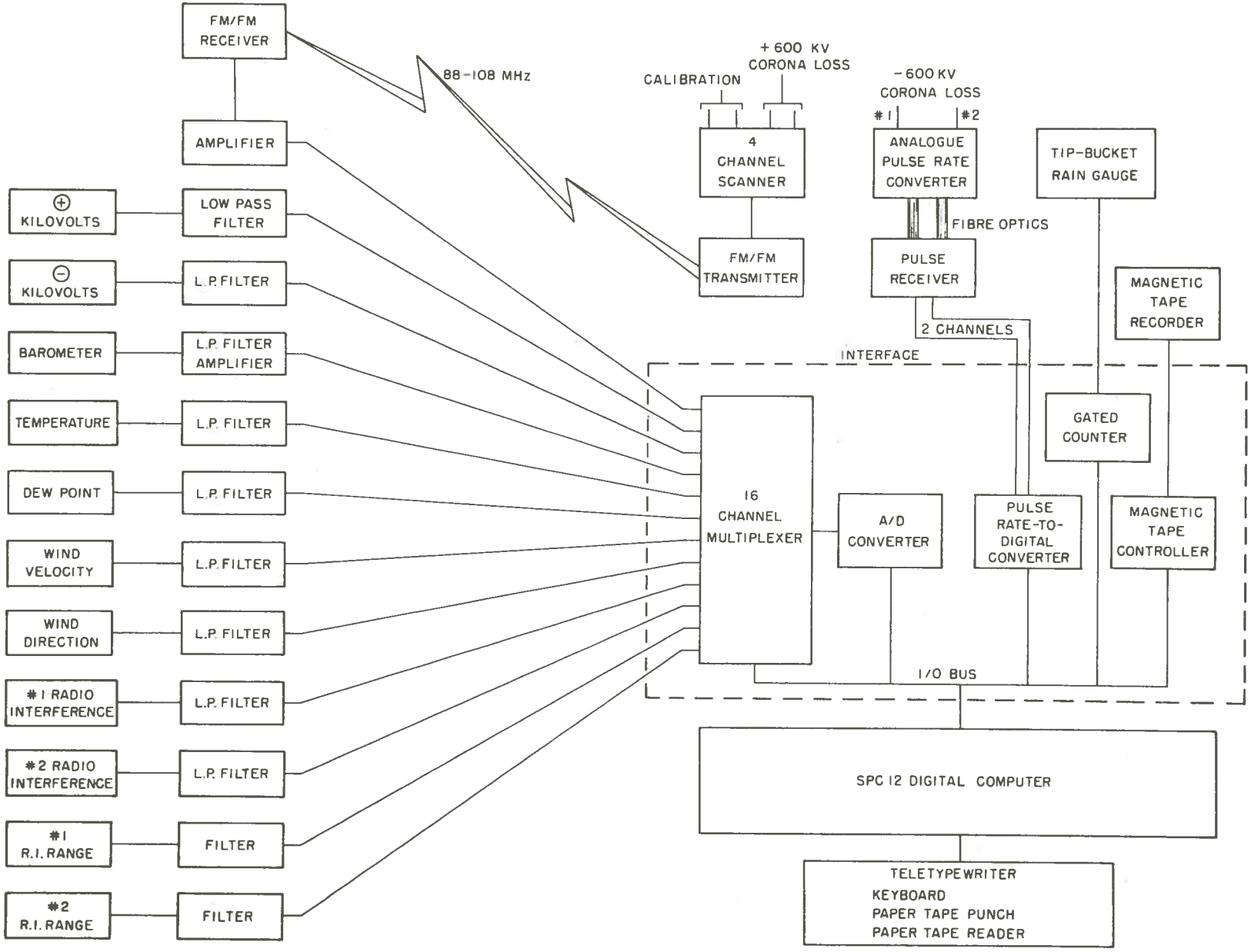

Figure 1 Data processing and recording system

A DATA SYSTEM FOR EHV DC TRANSMISSION LINE STUDIES

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Introduction

An automatic data processing and recording system, designed for carrying out studies on the characteristics of a ±600 kV dc transmission line, is shown in Fig. 1. A front view is shown in the photograph, Plate I. The system consists of

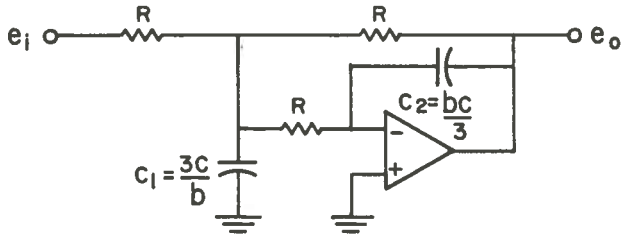
1. A stored-program digital processor
2. A 16-channel analog multiplexer preceded by low-pass active filters on each input channel
3. An A/D converter
4. Two digital channels – corona loss current
5. One digital channel – rain gauge
6. A read/write digital tape recorder.

The computer is type SPC-12 made by General Automation Inc. The processing unit uses six 12-bit programmable registers, a 12-bit input–output buss, and a core memory of 4000 8-bit bytes with a 2.16-μsec cycle time. Included in the computer system is a real-time clock and a power failure protect with automatic restart.

The multiplexer and the A/D converter were purchased completely interfaced and wired to the computer. The multiplexer can be extended to a maximum of 64 channels in 16-channel increments. The A/D converter has a 12-bit output and a full-scale input of ±5.10 volts. The digital output is in 'two's complement' format for negative input voltages. The conversion time is 40 μsec for 12 bits, although the system at present stores only 8-bit words of data.

The basic analog filter is a second order under-damped filter section, illustrated in Fig. 2. Two sections are cascaded to achieve a fourth order filter characteristic. The resistance, R, should be low compared to the input impedance of the operational amplifier in the filter.

A circuit diagram of the two-stage filter together with the frequency response is shown in Fig. 3. These filters are used in most of the analog input channels to reduce aliasing errors that may otherwise be introduced by the sampling process. To hold these errors within acceptable limits the filter cut-off frequency was made 0.05 Hz for a sampling frequency of 1 Hz.



Transfer function $e_o/e_i = 1/[1 + b(RC) + (RC)^2]$
where b = damping factor = 1.932 for 1st stage
= 1.616 for 2nd stage

Figure 2 Basic analog filter circuit

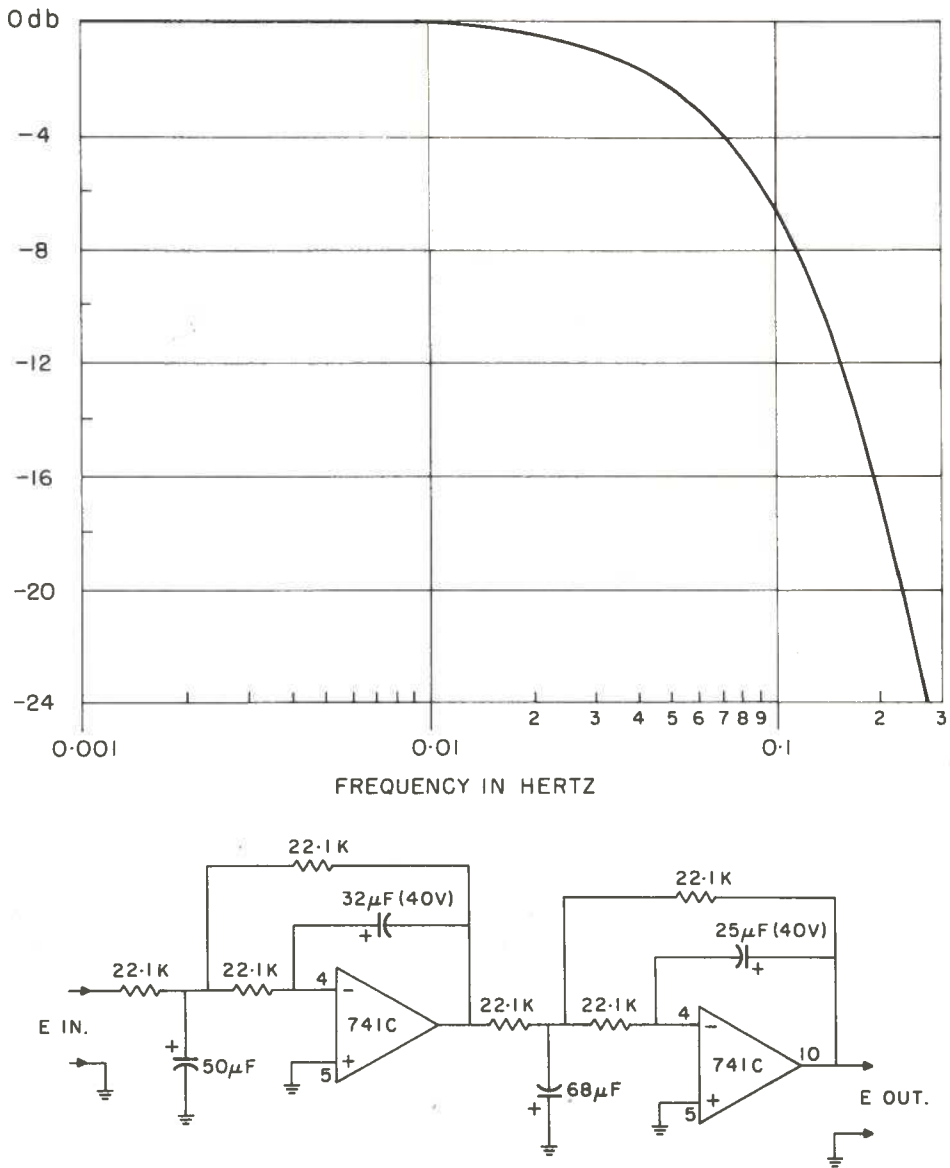


Figure 3 Low-pass filter circuit with frequency response

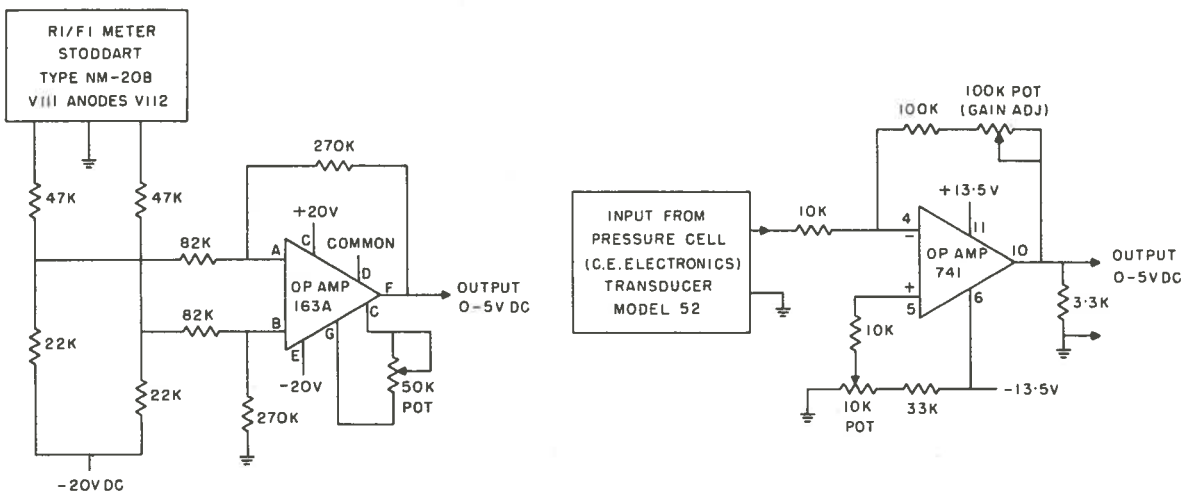


Figure 4 Signal conditioning circuits

Figure 4 shows the signal conditioning circuits for the barometric pressure and the radio interference (RI) meter. Since the RI meter output is at the +75-volt common level, it is necessary to bring this voltage to ground level to be compatible with the analog-to-digital converter requirements.

Two digital channels are used to measure corona loss currents on the negative high-voltage line. In each channel the analog value is converted to a pulse rate proportional to the loss current. This pulse signal drives a light emitting diode whose light output is transmitted to the ground instrumentation through a fiber optics conductor. The signal is then detected, amplified, and converted to a digital binary word by counting the number of pulses occurring in a 50-msec period. The counter output is then gated into the I/O buss under program control. The third digital channel, used to measure rainfall, counts the number of tips of rain gauge bucket. The counter is controlled by the computer, as in the other channels.

The magnetic tape recorder is a Model 7850-7 synchronous write–read machine made by Peripheral Equipment Corporation. Data are recorded in an NRZ-I, IBM-compatible format on 6 tracks with odd parity on the 7th track. Since the recorder contains no circuits for generating inter-record gaps, end-of-file gaps or parity bits, these functions must be provided by the computer and the interface units. The interface was designed and built at NRC to enable the computer to control and to transfer data to the recorder. A detailed description of the recorder/computer interface is given later in this report.

A list of the NRC detailed schematics is provided in Appendix A.

Programming

The system is controlled by a supervisor program 'System Executive' that calls up the various routines as required at specified time intervals. A listing of all operating programs and flow charts are included in Appendix B. The time of day is generated by programming, using the 3.0-msec period of the real-time clock (oscillator) in the computer hardware. The order in which routines are called is as follows:

1. A/D convert
2. Record
3. Wait
4. Print

The A/D converter routine operates at a rate of about 180 μsec per channel with a total scan period of 2.5 msec. After completing the analog channels, the three digital channels are scanned and stored in memory. All data are stored in a section of memory reserved for the purpose, each sample being an 8-bit byte. The data channels are scanned repeatedly until the block is full – except for three locations, which are used for storing the time in hours, minutes, and seconds.

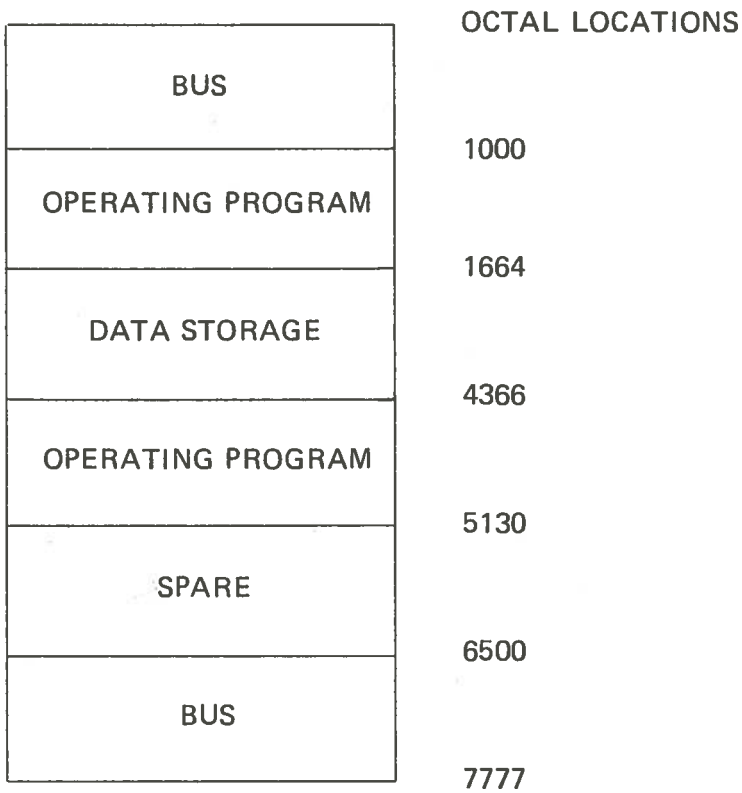
The recorder routine enables the recorder and tests for *recorder ready*. If true, a *forward run* command is given. Then, after a 63-msec delay to allow the tape recorder to attain full speed and to generate the $\frac{3}{4}$-inch inter-record gap, the data are recorded at a rate of about 7000 characters per second until the complete memory block has been transferred. This is followed by an inter-record gap command which causes an LRCC to be recorded, and the recorder stopped about 0.2 inch after the last character.

Each 8-bit word is recorded in 2-character format. The first character on tape contains the 2 most significant bits and the second character contains the 6 least significant bits. At present, a record consists of 2694 characters recorded at a density of 556 BPI occupying about $4\frac{7}{8}$ inches of tape.

At this data transfer rate, there is not enough time to service the real-time clock at the normal 3-msec intervals, so the clock interrupts are stored in a register temporarily. The clock is then brought up to the correct time at the end of the recording routine.

This routine is repeated, recording as many blocks of data as desired, followed by a wait period presently set at 3 minutes. During this wait period the data from the last scan, including the time-of-scan, are printed out on the typewriter in decimal form. The information from each scan is typed on one line so that successive printouts will form a column for each input channel and for the time. When no printout is wanted the teletypewriter is turned off. Since the data are stored and recorded in 8-bit binary code the resolution of the system is 1 in 256 or 0.4%.

The computer at present has a core memory of 4000_{10} 8-bit words as shown in the memory map. With the basic utility system (BUS) in residence there are 2880_{10} locations available for programming and data storage. Of this space the routines at present occupy 690 locations, and data storage occupies 1347 locations – a total of 2037_{10} locations.



MEMORY MAP

A complete cycle takes 6 minutes 12 seconds when the system is operated as follows: *a*) scan rate of one/second, *b*) 2 records made successively, *c*) a 3-minute wait period before starting the next cycle. Each cycle of operation uses $11\frac{1}{4}$ inches of magnetic tape, so that in 24 hours 218 feet would be used. Since a reel holds 600 feet of tape, it must be replaced every $2\frac{1}{2}$ days at this rate, or every 8 days if the equipment is operated for 8 hours per day.

Operating Procedure

1. Turn power on to all units except the computer.
2. Turn on computer power.
3. Load tape onto recorder transport.
4. Push POWER control on recorder momentarily.
5. Push LOAD control on recorder momentarily.
6. Push LOAD control on recorder a second time.

7. Push RESET button.
8. Push ON LINE control on recorder momentarily.
9. Push EOF control momentarily and at same time hold BOT control down for duration of tape motion (about 3 inches).

If power is turned off anywhere beyond the load point (BOT) the tape transport may be placed in the *ready* mode by repeating the procedure, steps 4 to 9, omitting step 6.

10. Initiate the BUS program to set the clock to the correct time as detailed in the following paragraphs.
11. Initiate the operating program.
12. At the completion of a test run, or at the end of a reel of tape, an *end-of-file* sequence must be recorded. This is accomplished by pressing the EOF control momentarily. The tape will move forward about 3 inches followed by the recording of one character (17_8), and an LRC character (17_8).

Loading a Program

If the loader located in memory between 0120_8 and 0477_8 has been altered, the bootstrap loader must first be entered from the console switches as described on page 14 of the SPC-12 Programmer's Manual. The loader program is then entered, using the punched paper tape reader as described on pages 15 and 16 of the manual. This procedure for initiating these programs is described in the next paragraph.

Initiating a Program

Refer to the photograph of the front panel, Plate I.

Once a program is loaded into the computer it must be initiated by the following procedure:

1. Set the data switches to 2100_8 (No operation); set the register switches to 5_8 (B register); (down is binary 1), and press the ENTER switch momentarily.
2. Press the LOAD-I switch momentarily.
3. Set the data switches to starting address of the desired program, less one; set the register switches to 4_8 (P register); and press the ENTER switch momentarily.
4. Move the R/I switch up and momentarily press the STEP switch to start the program.

To initiate the BUS program, enter address 6477_8 into the P register, and to initiate the operating program, enter address 1147_8 into the P register.

The loader program is initiated at location 0263_8.

Program Variables

There are several parameters in the system which can easily be changed simply by changing a word in memory. To accomplish this, the operating program is halted and the BUS program called up using the control switches on the computer console as described in the preceding paragraph. The appropriate locations are then modified, using the teletype as described under *Using the BUS Program* in the SPC manual, page 22.

Table of Variables

All numbers are octal, except where noted

	Location	Word	Remarks
1.	1212	376	Negative block count in each cycle
2.	1231	003	Minutes wait between cycles
3.	1134	261	Real-time clock rate, ±0.3% = ±1 bit
4.	1655 1666	102 LSB 005 MSB	Block size, 2503 characters
5.	1437 1440	103 LSB 005 MSB	Block size, 2503 characters
6.	1540	034	20 + number of analog channels
7.	1641 + N	000	'N' sets number of digital channels
8.	1627 1633	001 MSB 115 LSB	Pause between scans (515 X 3 msec)
9.	4402	021	Number of channels printed out

Item 3 provides a means of changing the real-time clock rate by ±1 bit which changes the seconds ±0.3% — a relatively coarse change.

Items 4, 5, 6 — When the number of analog channels is changed, the block size may also have to be changed to obtain an integral number of scans. That is, the block must not become full part way through a scan. The block size of item 4 includes the '0'th character and the three time-of-day characters — hours, minutes, seconds. The block size of item 5 does not use the '0'th character.

Item 7 — The number of digital channels is determined by the number of *function address words* starting at Location 1641_8 and followed by a word 000.

Item 8 — The pause between scans is specified in 3-msec increments (an octal number); for example, 515_8 specifies 999 decimal milliseconds.

Item 9 — This is the sum of the number of analog channels, digital channels, and the three time-of-day characters.

All routines necessary to operate the computer and the data system are recorded on punched paper tape. If any problems are encountered in the operation of the system, the first step should be to initiate the BUS program, then reload the operating program into memory from the paper tape. Any memory location can be checked or parts of any program can be run from the teletype, using BUS

Setting the Clock

To set the clock, use the BUS to store the desired starting time in locations 1131_8 (seconds), 1132_8 (minutes), and 1133_8 (hours). These values must be the octal number equivalent of the time of day, starting at 000 at midnight and ending at 027_8 hours, 073_8 minutes, 073_8 seconds (one second before midnight). The time is converted to decimal when it is printed out on the teletype.

Recommended Modifications and Additions

A hardware digital clock in place of the software computer clock would make programming somewhat easier. In the existing system the clock runs only when the operating program is running. When this program is stopped to bring in BUS, the clock must be reset. With a hardware clock this would not be necessary.

A set of punched paper tapes containing the arithmetic operations of add, subtract, multiply, and divide source programs are provided with the SPC-12 computer. These routines will perform either double precision (16 bits) or triple precision (24 bits) arithmetic. These routines should be resident in memory if the data are to be scaled, averaged, or any other arithmetic operation performed. All further processing of the data must be done on the IBM system 360 at the computation centre. Although this allows much more detailed and complex processing to be performed using Fortran or PL1 language, a playback of the data at the small computer may be useful. To have this capability, a hardware interface and a *read magnetic tape* program must be developed.

The system outputs one scan of data to the teletypewriter once each complete cycle, but it is actually typed only when the typewriter is turned on. To reduce wear on the mechanism, the typewriter is turned on manually only when an output is required, then turned off as soon as possible. An improvement in the system might be to program the power to the typewriter for the 15 seconds required to type one scan of data, at any desired interval, such as once per hour, or once very 12 scans.

Power Failure/Automatic Restart

In the event of a power failure, the computer automatically carries out an orderly shutdown so that core memory is undisturbed. At power turn-on, control is returned to the BUS program through the JUMP instruction at locations 0014_8 and 0015_8. If the

words 142, 150 (JMP 1150_8) are stored in these locations the operating program will be initiated at power turn-on. However, the system will not operate until the recorder is turned on and put on-line manually.

I/O Operation

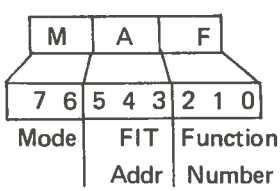
The SPC-12 computer communicates with peripheral devices connected to the input/output buss through a function interface translator (FIT). A block diagram of the FIT is shown in Fig. 5. The function address assignments, listed in Table 1, indicate the computer word necessary to perform a certain function with a selected device. A detailed description of the computer I/O operation is given in the SPC-12 Computer Reference Manual.

Table 1

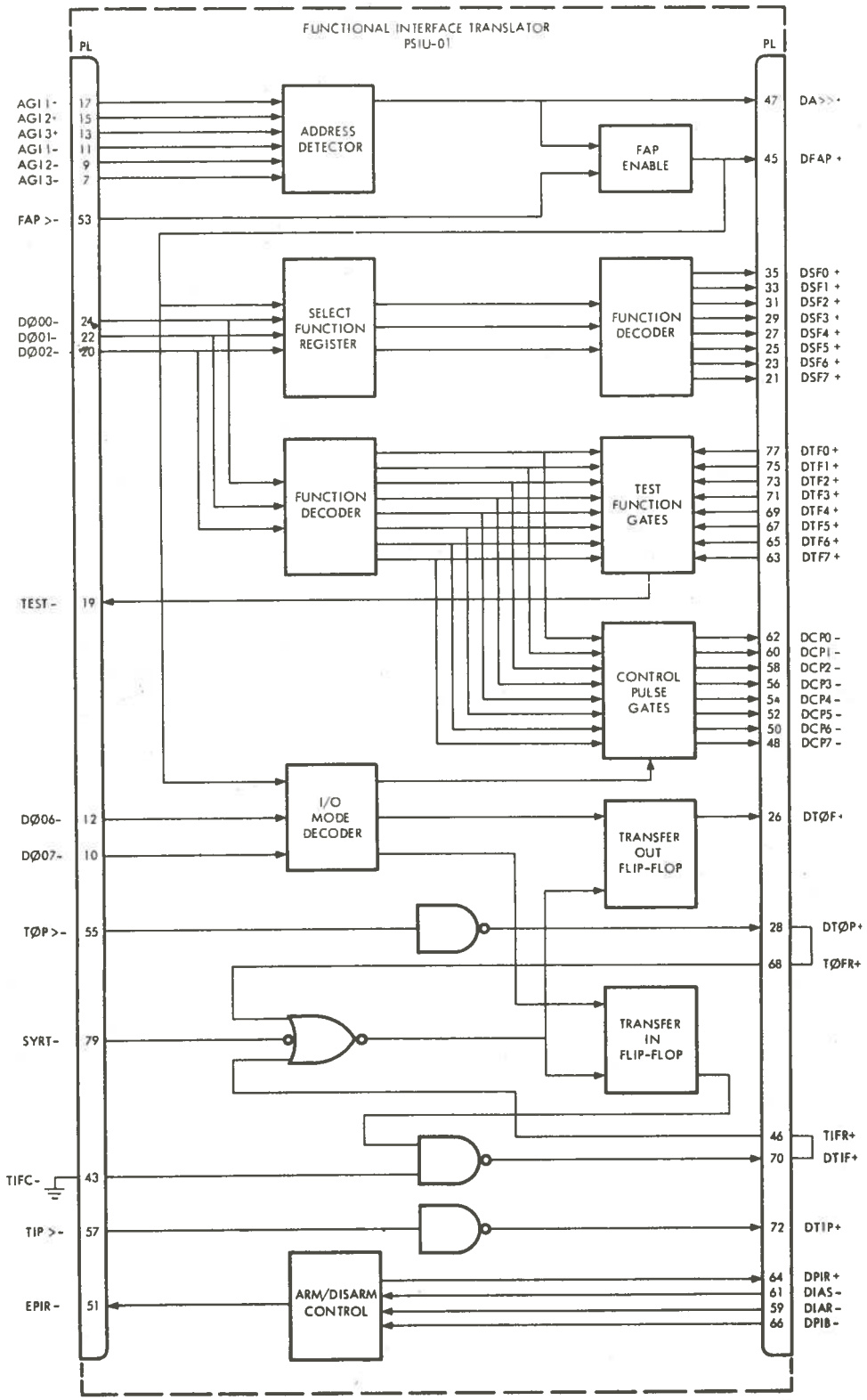
Function address word assignment sheet

FIT LOC B5

PAW FORMAT



	M A P	LOC	UNIT	FUNCTION
CONTROL PULSES	0 0 0	B3	DCP0	Enable Recorder
	0 0 1	B3	DCP1	Command FWD RUN
	0 0 2	B3	DCP2	Command LRC (REC)
	0 0 3			
	0 0 4			
	0 0 5			
	0 0 6	C5	DCP6	Disable MUX Switches
	0 0 7	C3	DCP7	Start Conversion
OUTPUT CHANNEL SELECTS	1 0 0			
	1 0 1			
	1 0 2			
	1 0 3			
	1 0 4	B3	DSF4, DTUF, DTOP	Output Data (REC)
	1 0 5			
	1 0 6	C5	DSF6, DTOF, DTOP	Load Switch Select Register
	1 0 7	C3	DSF7, DTOF, DTOP	Load Storage Register
INPUT CHANNEL SELECTS	2 0 0	B1	DSF0, DT1F	Input Data (No. 1 R/D Converter)
	2 0 1	B1	DSF1, DT1F	Input Data (No. 2 R/D Converter)
	2 0 2			
	2 0 3			
	2 0 4			
	2 0 5			
	2 0 6			
	2 0 7	C3	DSF7, DT1F	Read Storage Register
TEST FUNCTIONS	3 0 0	B2	DTF0	Test Recorder Ready
	3 0 1	B3	DTF1	Test Clock Magnetic Tape Interrupt
	3 0 2			
	3 0 3			
	3 0 4			
	3 0 5			
	3 0 6			
	3 0 7	C3	DTF7	Test Converter Busy

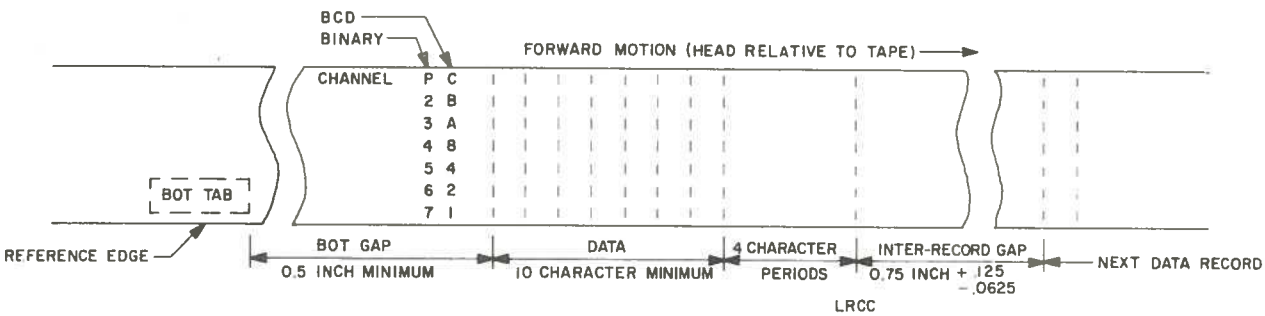


NOTE: TYPICAL CONFIGURATION FOR SERIAL NO. 208 AND ABOVE. FOR EARLIER VERSIONS OF FUNCTIONAL INTERFACE TRANSLATOR, SEE APPENDIX D.

Figure 5 Functional interface translator, functional diagram

Mag-Tape Interface Circuit

A circuit for interfacing the SPC-12 computer controller with the PEC Model 7850-7 synchronous write and read tape transport was designed and fabricated at NRC. The present design incorporates the write interface only. The data transfer from the computer to the magnetic tape is synchronized with the basic clock incorporated in the interface circuit. The data are recorded at a rate of 6.95 kHz using the IBM NRZ-1 7-track format and operating at 556 bpi. Figure 6 illustrates the track allocations and spacing. The mechanical and electrical specification of the tape transport is given in Table 2.



NOTES

1. Tape shown with oxide side up.
2. Channels 2 through 7 contain data bits in descending order of significance.
3. Channel P (parity) contains odd data parity for binary tapes, or even parity for BCD tapes.
4. Each bit of the LRCC is such that the total number of '1' bits in that track (including the LRCC) is even. It is possible in the 7-track format for this character to be all zeros, in which case a read data strobe will not be generated.
5. A file mark is a single character record having '1' bits in channels 4, 5, 6 and 7 for both the data character and the LRCC. This record is separated by 3.5 inches from the previous record and by a normal IRG (0.75 inch) from the following record.
6. Data packing density may be 200, 556, or 800 bits per inch.

Figure 6 7-track format

The interface connections to the transport are specified in the tape-recorder manual as follows:

Interface Inputs (Controller to Transport)

1. LOGIC LEVELS

True level = 0 to +0.4 volts
False level = +3 to +5 volts

2. SELECT (SLT)

A level which, when true, enables all of the cable drivers and receivers in the transport, thus connecting the transport to the controller.

Table 2

Mechanical and electrical specifications Model 7520

Tape (computer grade) Width (inches) Thickness (mil)	 0.5 1.5
Tape Tension (ounces)	7.0
Reel Diameter (inches)	7.0
Recording Mode (IBM compatible)	NRZI
Magnetic Head	Single Stack (with erase head)
Tape Speed (ips) Standard	12.5
Instantaneous Speed Variation (%)	±3
Long-Term Speed Variation (%)	±1
Rewind Speed (ips)	50 nominal
Interchannel Displacement Error* (static & dynamic)	
556 bpi (microinches)	200 maximum
Stop/Start Time (milliseconds)** (at 12.5 ips)	30 ± 2
Stop/Start Displacement (inch)	0.19 ± 0.02
Beginning of Tape (BOT) and End of Tape (EOT) Detectors	Photoelectric*** IBM compatible
Weight (pounds)	25
Dimensions Height (inches) Width (inches) Depth (inches) (from mounting surface) Depth (inches) (total)	 8.75 19.0 7.5 10.0
Operating Temperature (°C)	5 to 45
Altitude (feet)	0 to 20,000
Power (volts ac) ±10% (watts) maximum on high line (Hz)	 117 or 230 120 48 to 400
Mounting — Standard 19-inch retma rack	—
Electronics	All silicon

*This is defined as the maximum displacement between any two bits of a character when reading an IBM master tape on the transport in a forward direction.

**Start/Stop time is inversely proportional to the tape speed.

***Approximate distance from detection area to head gap equals 1.2 inches.

3. SYNCHRONOUS FORWARD COMMAND (SFC)

A level which, when true and the transport is ready, causes the tape to move forward at the specified velocity. When the level goes false, tape motion ceases. The velocity profile is trapezoidal with nominally equal rise and fall times (Fig. 7).

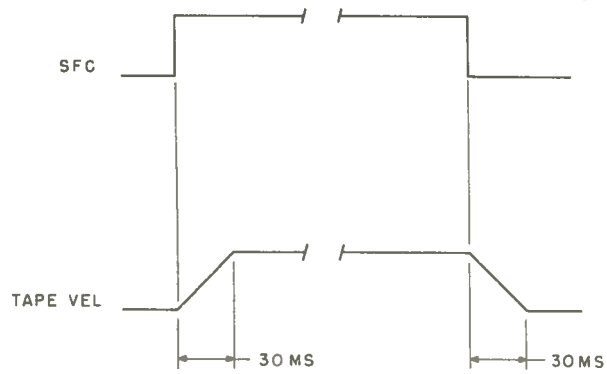


Figure 7 Tape velocity profile

4. SET WRITE STATUS (SWS)

A level which must be true for a minimum period of 20 μsec after the front edge of an SFC when the write mode of operation is required.

5. WRITE DATA LINES (WDP, WD2-7)

Levels which when true at write data strobe (WDS) time (when the transport is in write status) result in a data '1' being recorded on the corresponding tape track.

6. WRITE DATA STROBE (WDS)

A pulse (2 μsec minimum length) which is required to record each character. It samples each of the write data lines and triggers the appropriate flip-flops in the write register when a '1' is written. The WDP and WD2-7 levels must be steady during and for 0.5 μsec before and after WDS. Triggering of the write register is initiated by the trailing edge of WDS. The recording density is determined by the tape speed and the frequency of the WDS pulses. Frequency stability should normally be better than 25%.

7. WRITE AMPLIFIER RESET (WARS)

A pulse (2 μsec minimum) which causes the LRC character to be written on to tape four character spaces after the last data character has been written. The pulse resets the write register resulting in an even number of bits on each track in each record.

Interface Outputs (Transport to Controller)

1. READY (RDY)

A level which is true when the transport is ready to accept any external command, i.e., when

a) Tape tension is established
b) The initial load or rewind command has been completed
c) There is no subsequent rewind command in progress
d) The transport is on-line.

2. END OF TAPE (EOT)

A level which, when true, indicates that the EOT reflective tab is positioned under the photo-tab sensor.

The block schematic diagram of the magnetic tape interface circuit is shown in Fig. 8. In order to follow the operation of the magnetic tape interface circuit, it will be necessary to refer to the computer-tape transport interface signals tabulated in sequence in Table 3.

Table 3

Computer-recorder interface signals

Computer Instruction		Recorder Lines	Comments
DCP0 FOB	000	SLT	Enable recorder
DTF0 FOB	300	RDY	Test recorder ready?
DCP1 FOB	001	SFC	Forward run command
INE	–	–	Wait 63 msec (IRG)
DTF1 FOB	301	–	Test interface clock
DSF4, DTOF DTOP DOB	104	–	Output data to interface
–	–	WD2-WD7	6 data lines (recorder/interface) Data gated into recorder by interface clock
When data block complete			
DTF1 FOB	301	–	Test interface clock
DCP2 FOB	002	WARS	LRC command
–	–	SLT SFC	Interface stops recorder by generating RESET signal
		Coast after LRC	0.19 inch
		Acceleration distance	0.19 inch
		Full speed distance	0.37 inch
		Total IRG	0.75 inch

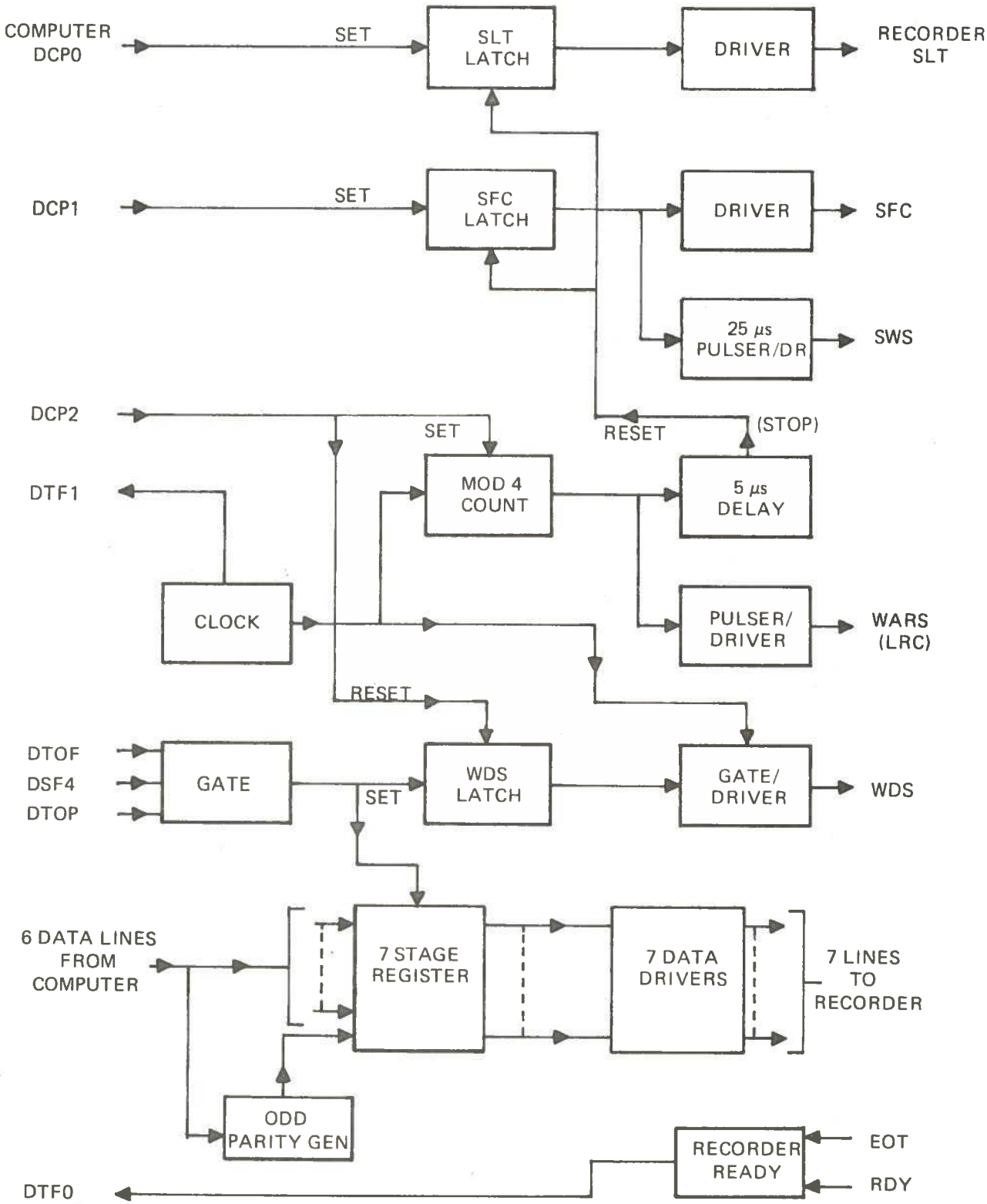


Figure 8 Computer–recorder interface

To initiate a recording sequence, the computer program outputs a signal on the computer DCP0 line (a pulse which goes low for true), and this signal sets the SLT latch which enables all of the interface drivers and receivers in the transport. Now the recorder ready (RDY) line assumes a true level (low level) indicating that the transport is ready for recording. This line is gated with the EOT line to produce a 'true high' level and is connected to the computer test line, DTF0. If the level is true, the computer outputs a negative-going pulse in the DCP1 line. This pulse sets the SFC latch and triggers the SWS 25-μsec single-shot flip-flop, causing the tape to move forward. The SWS pulse switches the recorder to the write mode.

As illustrated in Fig. 6, the inter-record gap between two data records has to be 0.75 inch. Assuming that the recorder has stopped after the last LRC character, and that the recorder coasts 0.19 inch after a stop command is initiated and takes 0.19 inch to attain uniform speed after start, we have to provide a blank spacing of 0.37 inch (0.75 inch - (0.19 + 0.19)) to provide the specified inter-record gap of 0.75 inch before the next data record is written. This corresponds to a wait period of 63 msec (at a tape speed of 12.5 ips) which the computer now provides, under program control. After the delay, the computer tests the interface clock generator for true condition (high level) at the computer test line DTF1. If the level is true, it outputs DSF4, DTOF and DTOP, about 30–35 μsec later, as shown in the clock timing diagram, Fig. 9. These lines are connected to a 3-input gate as shown in Fig. 8, the output of which transfers the data from the I/O buss to the data register and the recorder WD lines. Then, when the clock output goes low a WDS pulse is generated which causes the data to be written on the magnetic tape. This assures that the characters are recorded at intervals exactly synchronized with the interface clock. The data are now recorded at a rate of 6.95 kHz, corresponding to the repetition rate of the interface clock. Exclusive OR gates are used to generate odd-parity write data characters.

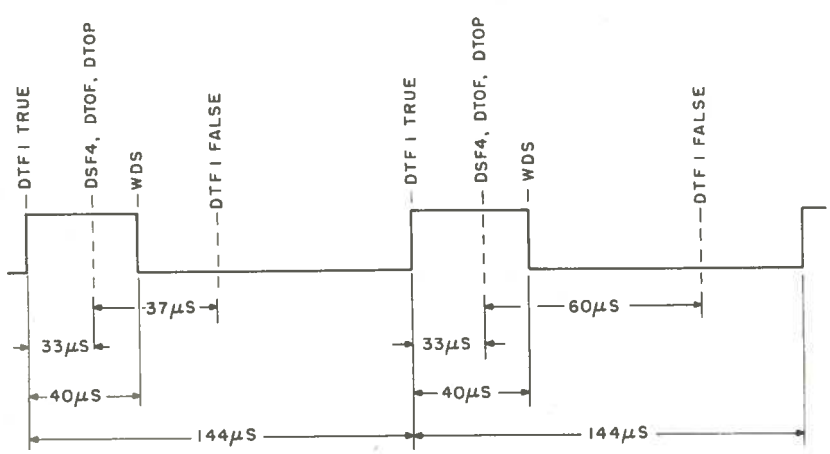


Figure 9 Interface clock timing diagram

As soon as a full block of data has been recorded, the computer outputs a negative-going pulse in the DCP2 line, which sets the LRC latch. This latch enables a counter circuit which generates a WARS pulse four characters after the last data character, causing the LRC character to be written onto tape. After a 5-μsec delay, the latches that control the SLT and SFC lines are reset, stopping the recorder. The entire sequence of operation is repeated for the next block of data.

When the power to the recorder is first switched on, the latches on the SLT and SFC lines must be reset manually by depressing the system reset button, before starting the recording, as described under the heading *Operating Procedure*. Included in the interface circuitry is a means of manually generating a BOT advance of 3 inches, and an EOF sequence.

Generation of End of File (EOF) and Beginning of Tape (BOT) gap

Manual operation of the EOF control initiates three events as shown in Fig. 10.

1. Starts a 250-msec one-shot
2. Sets the SLT, SFC latches, causing the recorder to run forward in the write mode
3. Loads the EOF character (17_8) into the data registers.

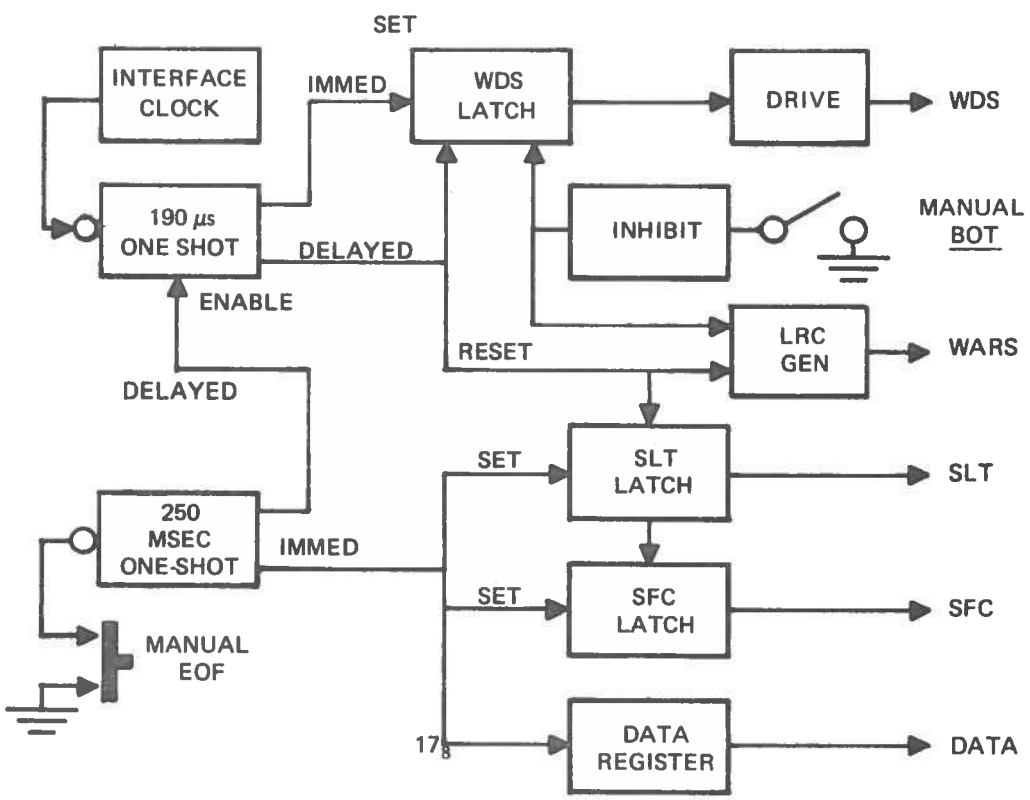


Figure 10 Manual EOF/BOT generator. Refer also to Fig. 8.

At the end of the 250-msec delay, at 190-μsec one-shot is enabled. Then the next clock pulse triggers the one-shot and enables gating circuits to generate only *one* write pulse (WDS) to the recorder. At the end of 190 μsec delay a 'stop' pulse is generated which initiates the LRC sequence and a reset pulse to the SLT, SFC latches, stopping the recorder.

Manual operation of the BOT control for the duration of an EOF sequence inhibits the recording of the two 17_8 characters, resulting in an erased section of tape about 3 inches long.

Appendix A

A list of NRC detail drawings and photographs follows:*

DS-15-1D	Corona loss to frequency converter
DS-15-2D	Computer/recorder interface, data board (B2)
DS-15-3D	Receiver for fibre optics system (corona loss)
DS-15-4D	Pulse rate to digital converter (B1)
DS-15-5D	Pulse rate to digital converter timing
DS-15-6C	I/O curves – voltage to digital converter
DS-15-7B	Signal conditioner – R.I. meter
DS-15-8B	Amplifier for pressure transducer (barometer)
DS-15-9C	Low pass filter for analog channels
DS-15-10D	SPC-12 computer/recorder interface control board (B3)
DS-15-11D	Data system for HV dc transmission line
DS-15-12B	Timing diagram
DS-15-13A	Amplifier for telemetry system
DS-15-14D	Inter board wiring
8855-G, E, F	Three circuit board photos B1, B2, B3.

*Available from:

Editorial Office,
Radio & Electrical Engineering Division,
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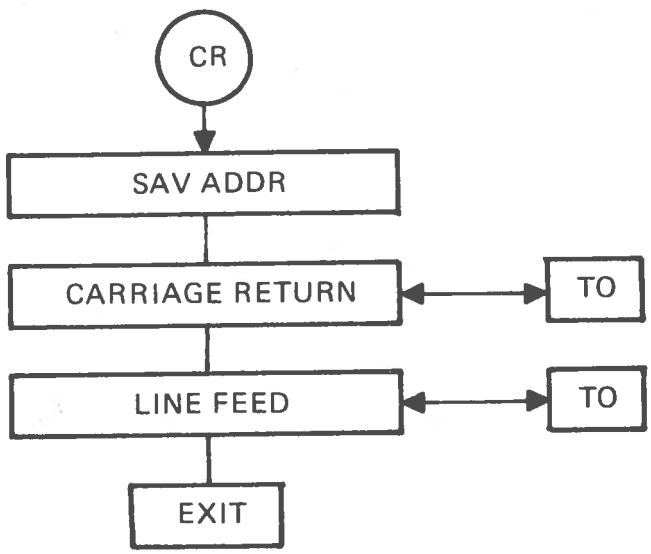
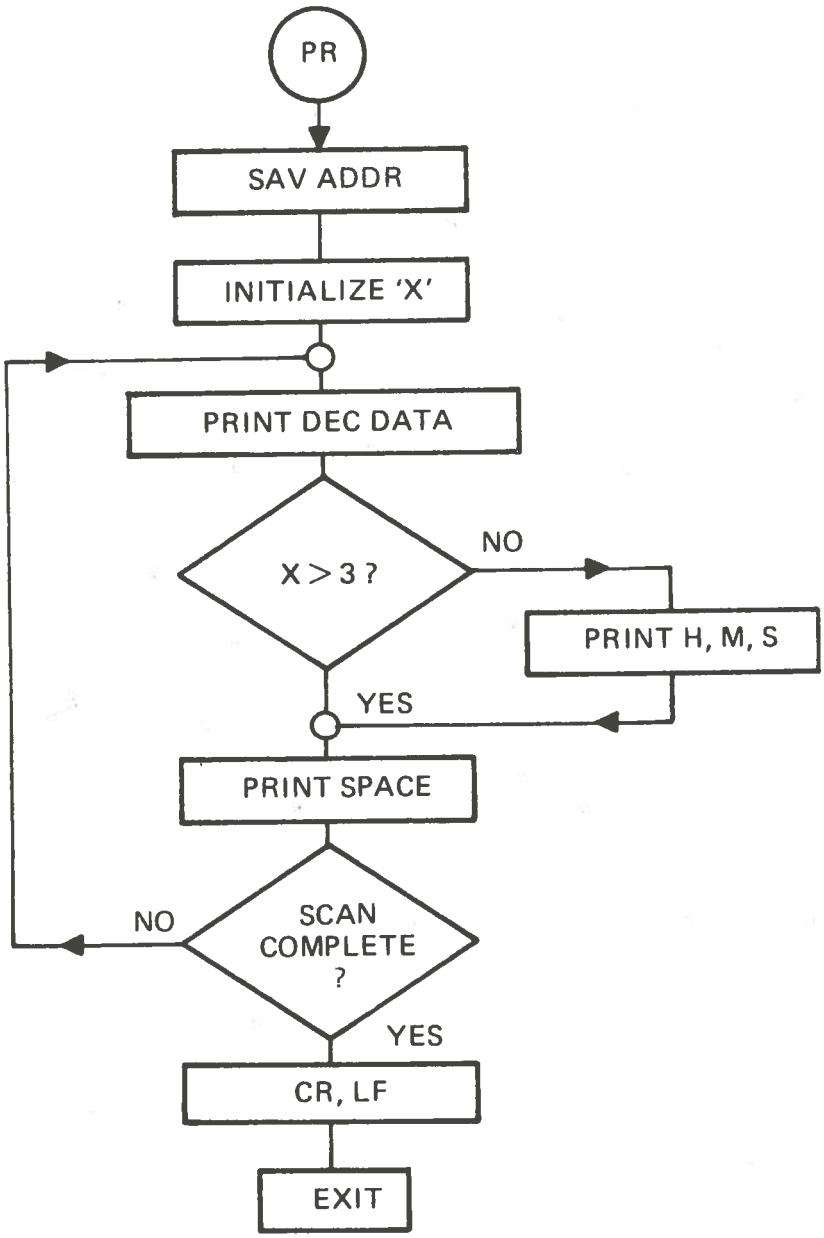
Ottawa 7, Ontario.

Appendix B

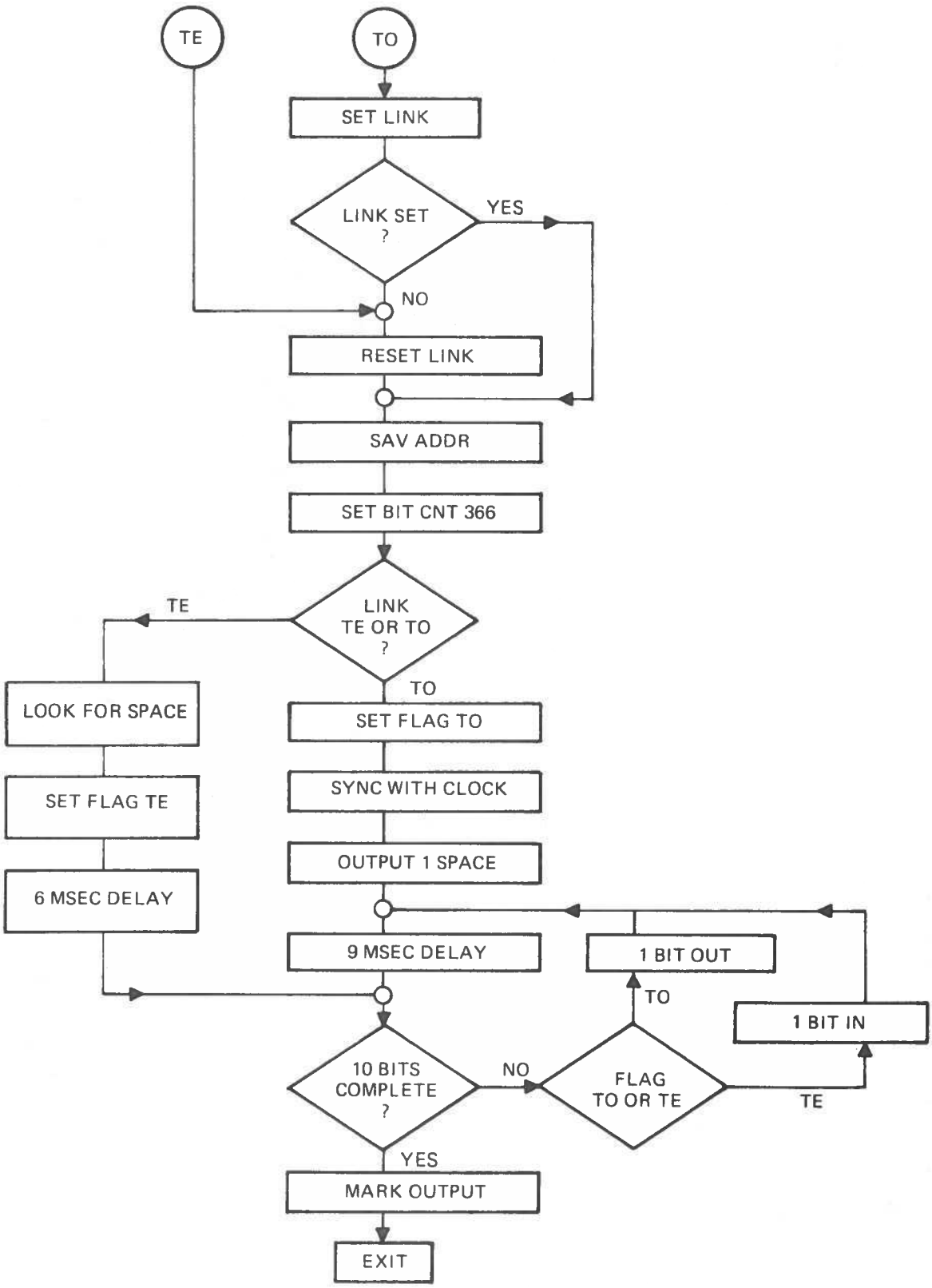
Flow diagrams and operating program listings

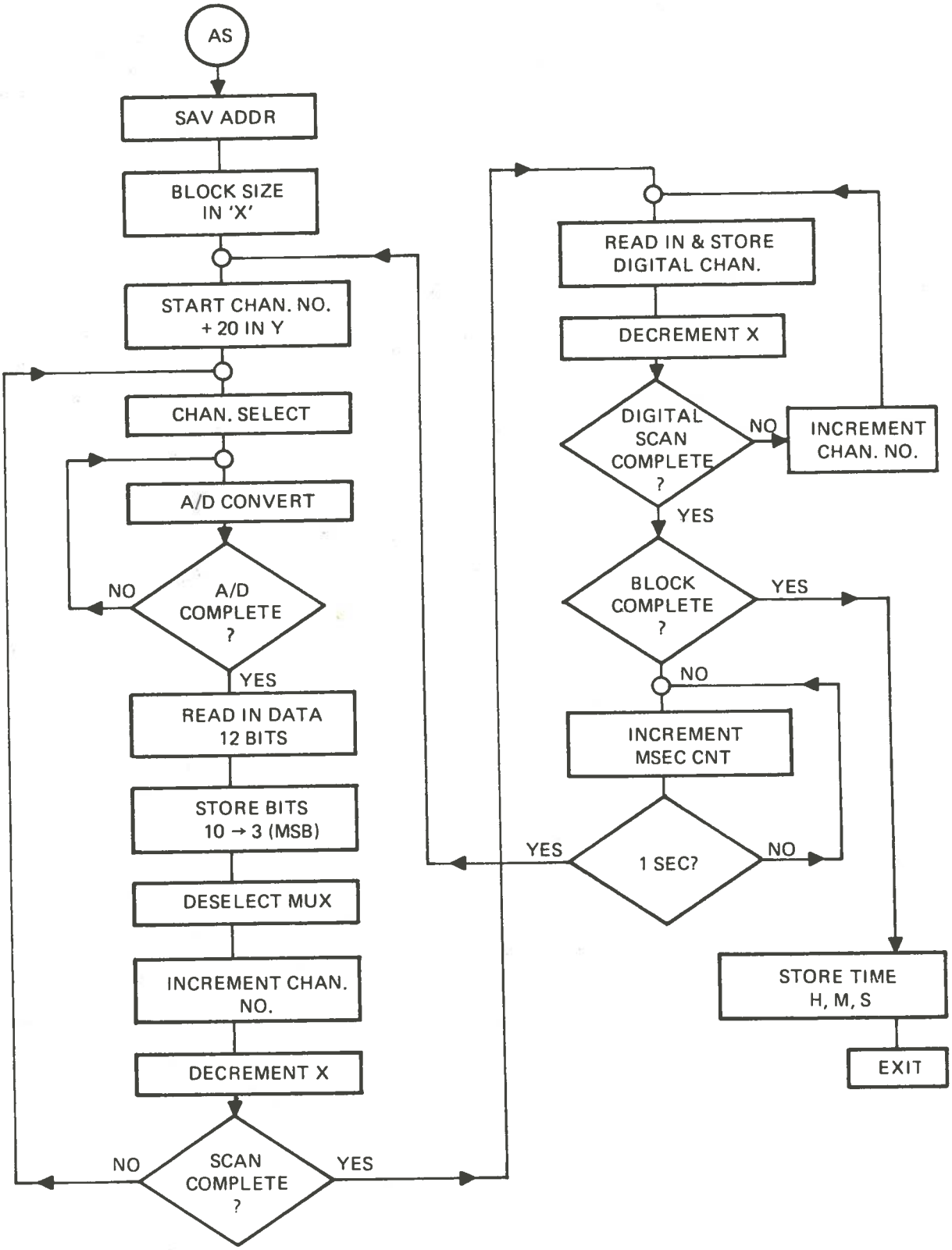


CARRIAGE RETURN/LINE FEED

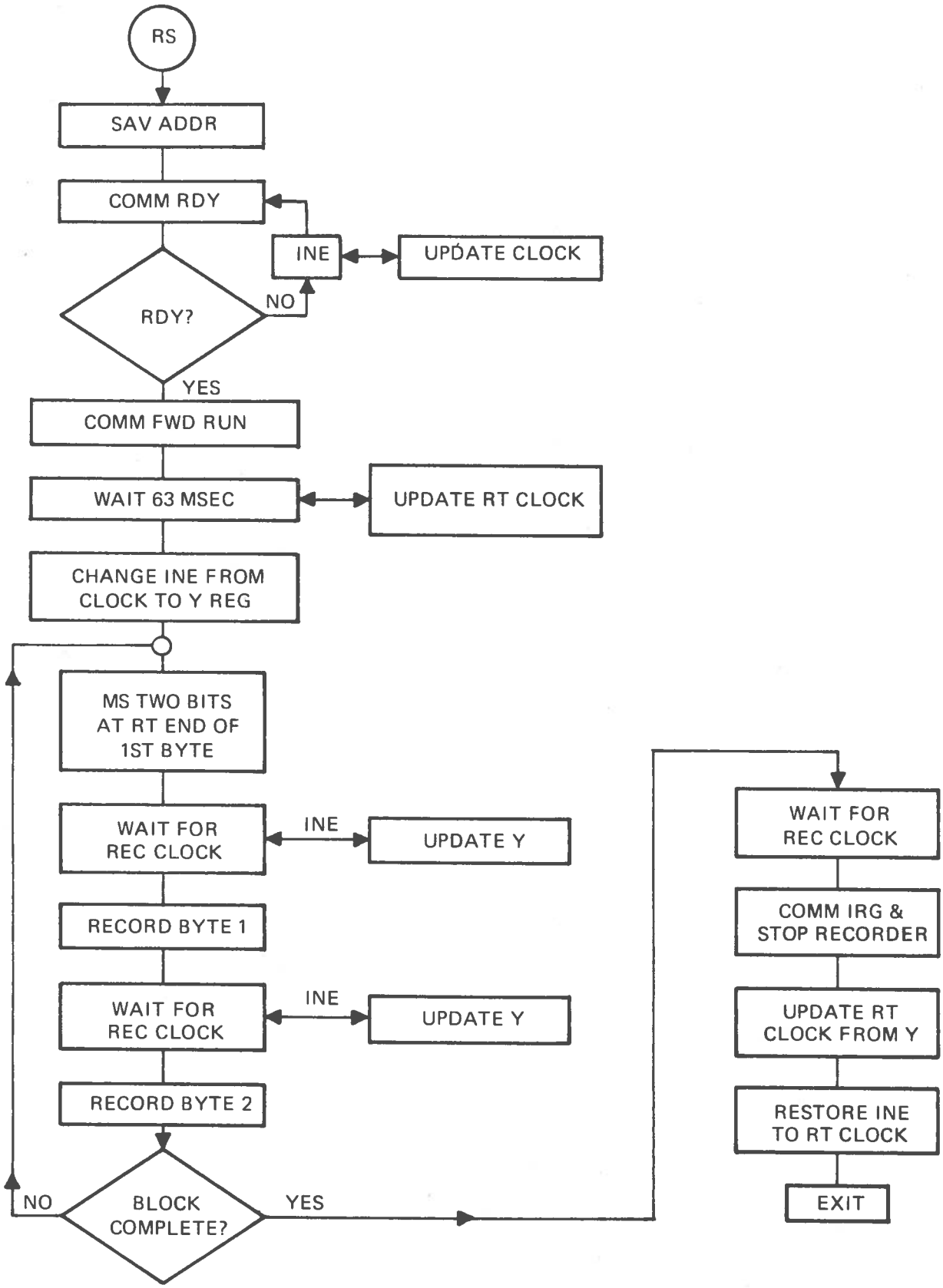


PRINT ONE SCAN

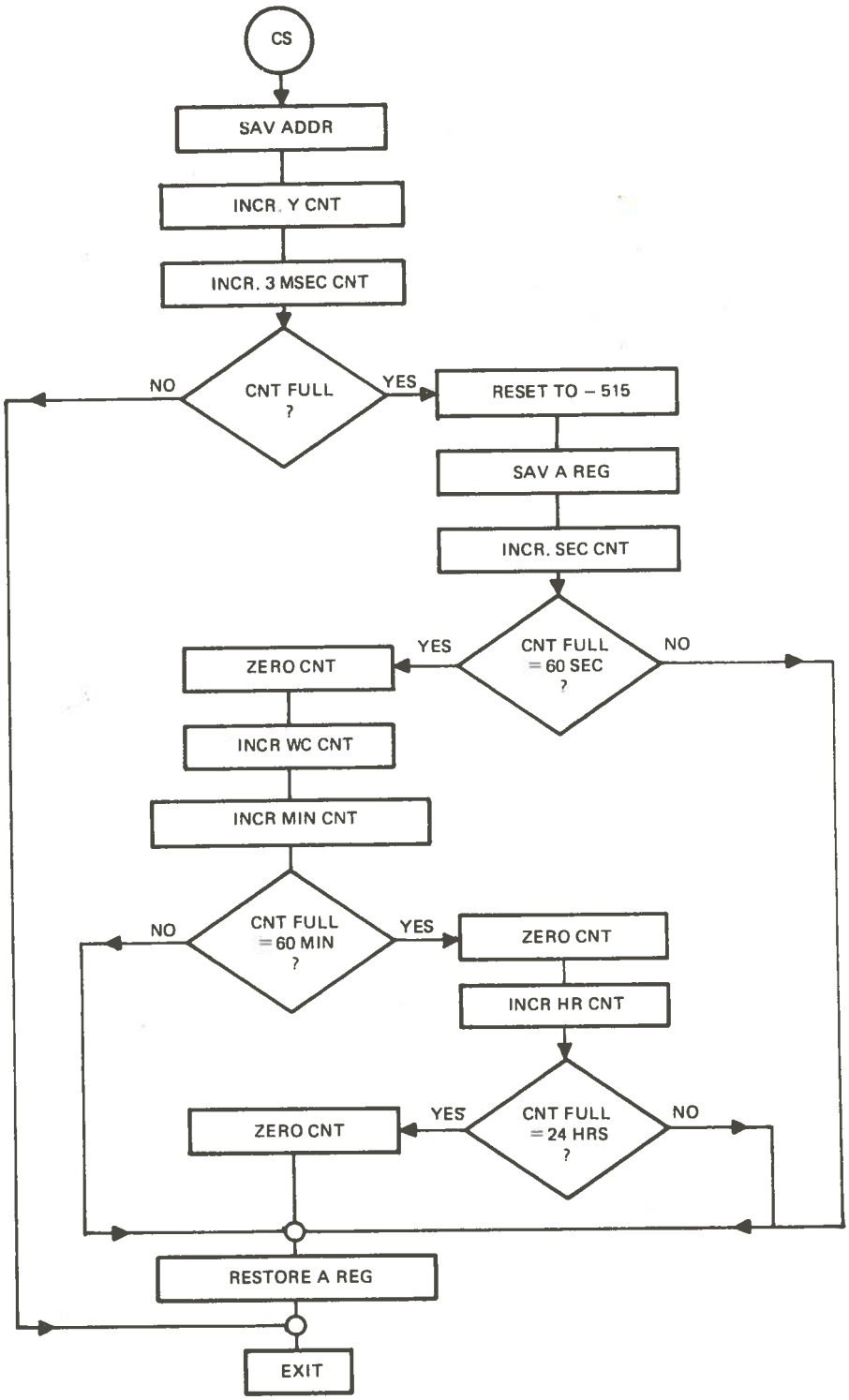

TE
TO
SET LINK
LINK SET ?
YES
NO
RESET LINK
SAV ADDR
SET BIT CNT 366
LINK TE OR TO ?
TE
TO
LOOK FOR SPACE
SET FLAG TE
6 MSEC DELAY
SET FLAG TO
SYNC WITH CLOCK
OUTPUT 1 SPACE
9 MSEC DELAY
1 BIT OUT
TO
1 BIT IN
10 BITS COMPLETE ?
NO
FLAG TO OR TE
TE
YES
MARK OUTPUT
EXIT



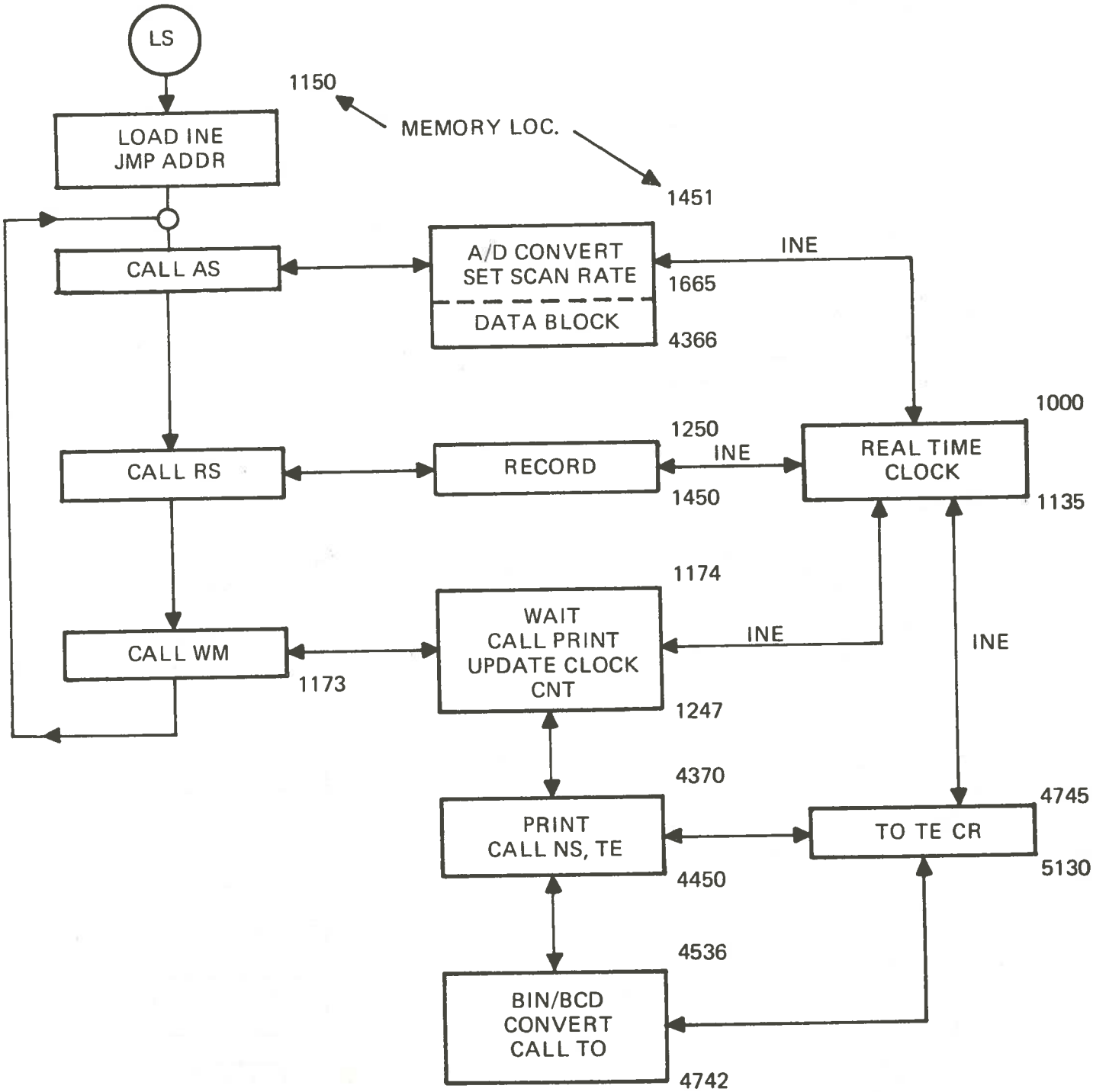
A/D CONVERT/STORE


RS
SAV ADDR
COMM RDY
INE
UPDATE CLOCK
RDY?
NO
YES
COMM FWD RUN
WAIT 63 MSEC
UPDATE RT CLOCK
CHANGE INE FROM CLOCK TO Y REG
MS TWO BITS AT RT END OF 1ST BYTE
WAIT FOR REC CLOCK
INE
UPDATE Y
RECORD BYTE 1
WAIT FOR REC CLOCK
INE
UPDATE Y
RECORD BYTE 2
NO
BLOCK COMPLETE?
YES
WAIT FOR REC CLOCK
COMM IRG & STOP RECORDER
UPDATE RT CLOCK FROM Y
RESTORE INE TO RT CLOCK
EXIT

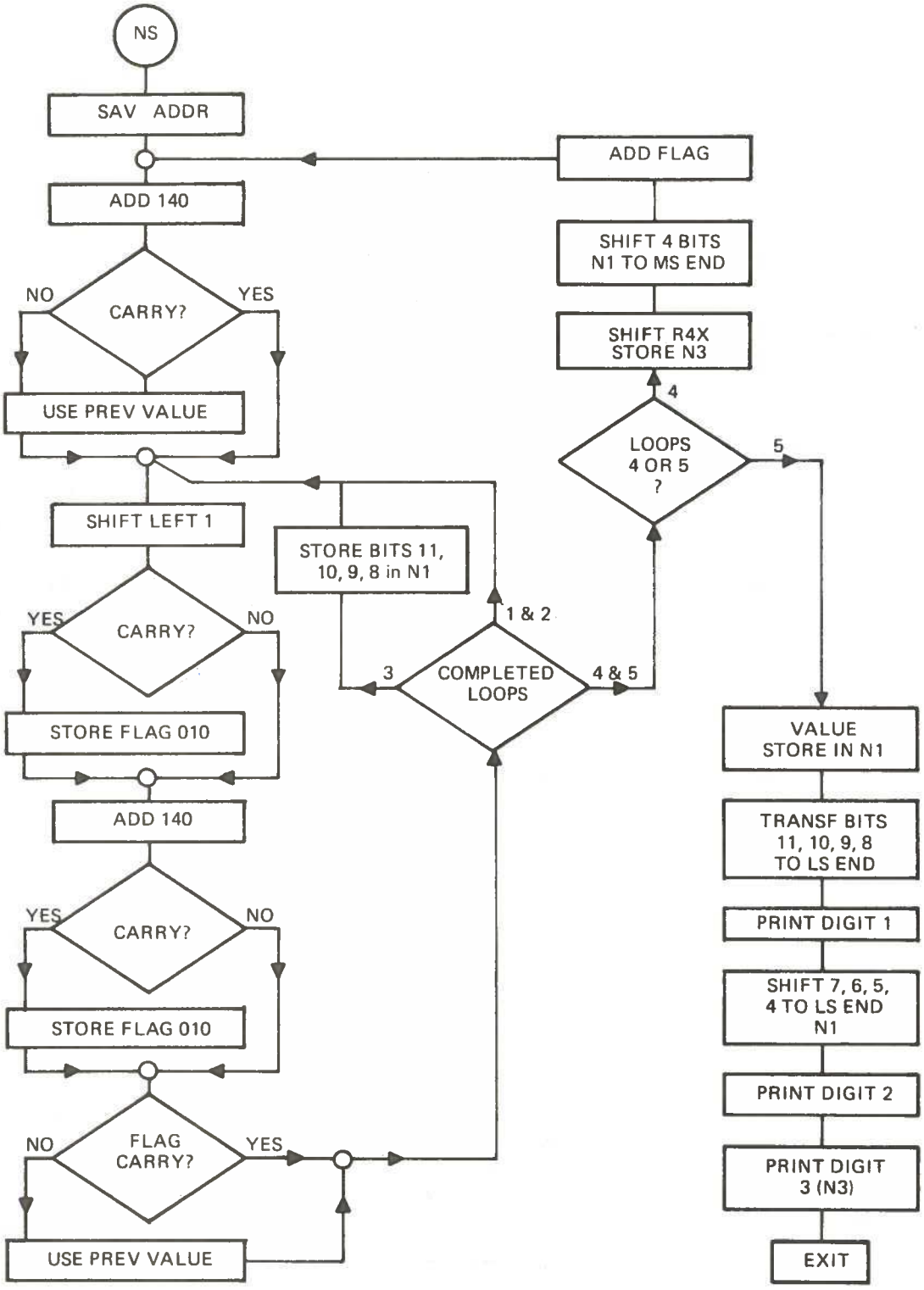
RECORD



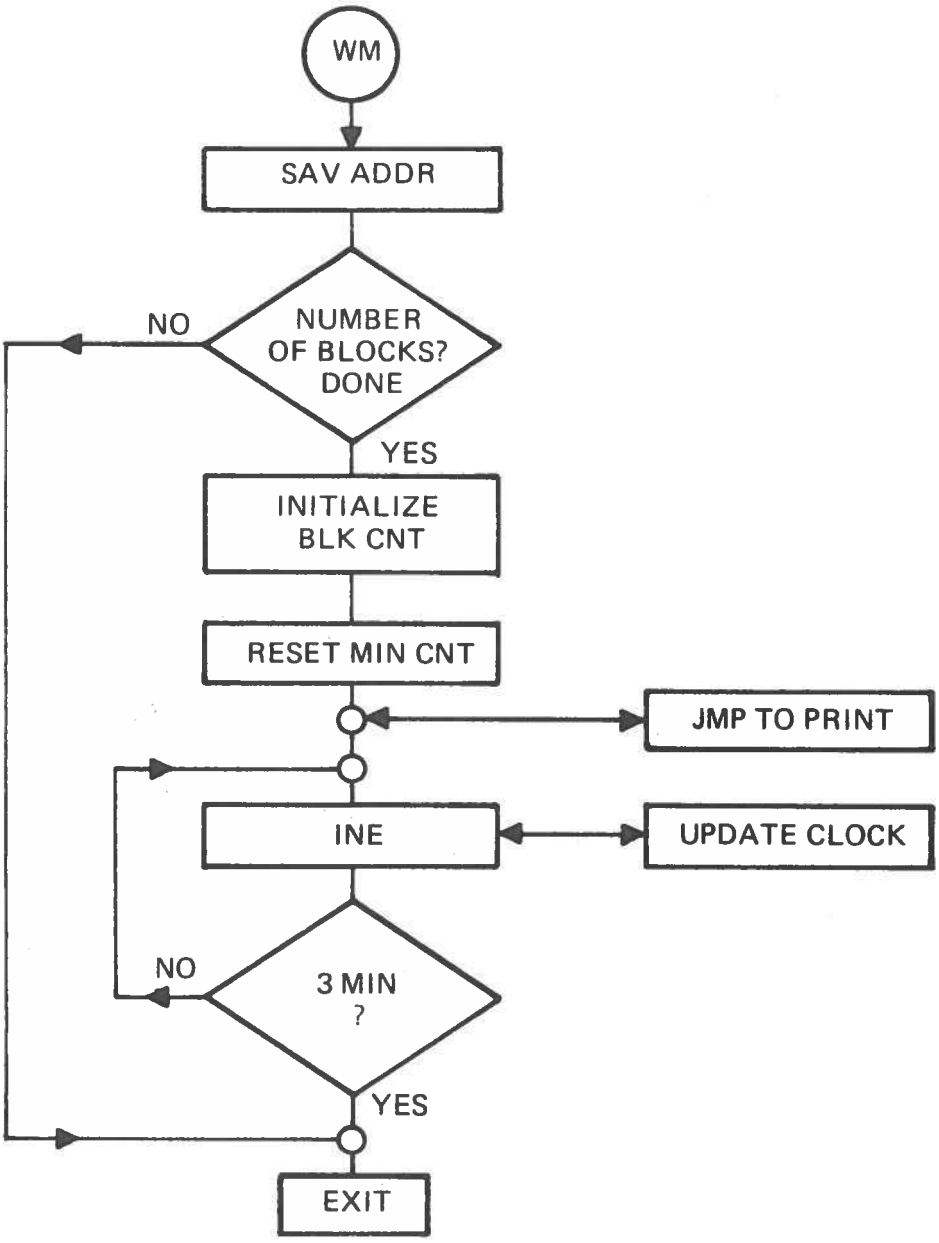
REAL TIME CLOCK



SYSTEM EXECUTIVE



CONVERT BINARY TO BCD



WAIT BETWEEN RECORDS

CALL/WAIT 1150/1173/1247

```
LS    1150    004    ALD  B,142
        51    115
        52    142
        53    300    STB  0012
        54    012                    LOAD CLOCK CALL FOR INE
        55    061    TBB
        56    061    TBB
        57    300    STB  0013
        60    013
LA      61    050    RIC  P,B
        62    143    JMP  AS         A/D CONVERT
        63    051
        64    050    RIC  P,B
        65    142    JMP  RS         RECORD
        66    250
        67    050    RIC  P,B
        70    142    JMP  WM         WAIT 3 MINUTES
        71    174
        72    142    JMP  LA         LOOP
        73    161
WM      74    302    STB  WA
        75    241
        76    061    TBB             SAV ADDR.
        77    302    STB  WA+1
      1200    242
        01    342    LDB  WB
        02    243
        03    057    RIC  B,B
        04    132    SKZ  4          BLOCKS DONE?
        05    302    STB  WB
        06    243                    NO, EXIT
        07    142    JMP  WX
        10    235
        11    021    ALD  A,376
        12    376                    YES, INITIALIZE BLK CNT
        13    302    STB  WB
        14    243
        15    061    TBB
        16    061    TBB             ZERO MIN CNT
        17    302    STB  WC
        20    240
        21    050    RIC  P,B        PRINT
        22    150    JMP  PR
        23    370
```

```
WL    1224    060    INE
        25    342    LDB  WC
        26    240
        27    041    RTR  B,A
        30    025    ASU  A,003
        31    003                        3 MIN WAIT
        32    135    SKP  2
        33    142    JMP  WL
        34    224
WX    1235    162    ELB  WA   1241
        36    241                        EXIT
        37    051    RIC  B,P
WC      40    000    ZC                 MINUTE CNT
WA      41    000    ZA                 SAV ADDR
        42    000
WB      43    000    ZC                 BLOCK CNT
        44    047    RTR  B,Z
        45    053    RIC  Y,Y           COUNTER FOR CLOCK DURING RECORI
        46    010    RDC  Z,P
        47    243
```

CLOCK 1000/1135

```
CS   1000   047   RTR  B,Z
       01   053   RIC  Y,Y        3 MSEC COUNTER
       02   162   ELB  CL-2
       03   127
       04   010   RIC  B,B
       05   155
       06   302   STB  CL-2       MSEC
       07   127
       10   014   TBB
       11   205
       12   302   STB  CL-1
       13   130
       14   131   SKZ  2
       15   142   JMP  CX
       16   124
       17   100
       20   100
       21   162   ELB  CA
       22   134
       23   302   STB  CL-2
       24   127
       25   061   TBB
       26   302   STB  CL-1
       27   130
       30   040   RTR  A,B
       31   302   STB  CH         SAV. 'A' REG.
       32   126
       33   342   LDB  CL
       34   131
       35   057   RIC  B,B
       36   100   NOP
       37   100   NOP
       40   100   NOP
       41   302   STB  CL         SECONDS
       42   131
       43   041   RTR  B,A
       44   025   ASU  A,074
       45   074
       46   131   SKZ  2
       47   142   JMP  CR
       50   121
       51   061   TBB
       52   061   TBB
       53   302   STB  CL         INITIATE SEC'S.
```

```
      1054    131
        55    342     LDB   WC          ┐
        56    240                       │
        57    057     RIC   B,B         │  MINUTE COUNTER
        60    302     STB   WC          │
        61    240                       ┘
        62    342     LDB   CL+1        ┐
        63    132                       │  MINUTE
        64    057     RIC   B,B         │
        65    302     STB   CL+1        │
        66    132                       ┘
        67    041     RTR   B,A
        70    025     ASU   A,074
        71    074
        72    131     SKZ   2
        73    142     JMP   CR
        74    121
        75    004     ALD   B,000       ┐
        76    115                       │
        77    000                       │  INITIATE MINUTES
      1100    302     STB   CL+1        │
        01    132                       ┘
        02    342     LDB   CL+2        ┐
        03    133                       │
        04    057     RIC   B,B         │
        05    302     STB   CL+2        │  HOURS
        06    133                       ┘
        07    041     RTR   B,A
        10    025     ASU   A,030
        11    030
        12    131     SKZ   2
        13    142     JMP   CR
        14    121
        15    061     TBB               ┐
        16    061     TBB               │  INITIATE HOURS
        17    302     STB   CL+2        │
        20    133                       ┘
CR      21    342     LDB   CH          ┐
        22    126                       │  RESTORE 'A' REG.
        23    041     RTR   B,A         ┘
CX      24    010     RDC   Z,P            EXIT
        25    243
CH      26    000     ZC                   SAV 'A' REG.
```

(CLOCK)

```
        1127    263     ZC    MS
          30    016     AC    MS
CL        31    000     ZC    S.        CLOCK
          32    000     ZC    M.
          33    000     ZC    H.
CA        34    261     ZA              MSEC COUNTER START
          35    016
```

A/D CONVERT & STORE

```
AS    1451    303     STB   AV          ┐
        52    251                       │
        53    061     TBB               │  SAV ADDR.
        54    303     STB   AV+1        │
        55    252                       ┘
        56    163     ELB   AN          ┐
        57    255                       │  INITIALIZE X=BLOCK INDEX
        60    043     RTR   B,X         ┘
AC      61    004     ALD   Y,020       ┐  INITIALIZE Y=CH. COUNT + 20
        62    112                       │       MUX
        63    020                       ┘
AM      64    343     LDB   AX          ┐
        65    257                       │  COMM CH. SEL.
        66    063     FOB               ┘
        67    044     RTR   Y,B
        70    064     DOB
        71    343     LDB   AQ          ┐  COMM A/D CONVERT
        72    260                       │
        73    063     FOB               ┘
        74    343     LDB   AT          ┐
        75    261                       │
        76    063     FOB               ┘  TEST A/D CONVERT.
        77    121     SKT   2
      1500    143     JMP   *-2(FOB)
        01    076
        02    343     LDB   AR          ┐
        03    262                       │
        04    063     FOB               │  READ-IN DATA
        05    052     RDC   B,B         │
        06    065     DIB               ┘
        07    047     RTR   B,Z         ┐
        10    041     RTR   B,A         │
        11    066     SHR   A           │
        12    066     SHR   A           │
        13    066     SHR   A           │
        14    040     RTR   A,B         │
        15    010     RTR   ZZ,A        │  PUT 8 MSB'S IN REG. B.
        16    307                       │
        17    071     PLR               │
        20    070     SHL   A           │
        21    070     SHL   A           │
        22    070     SHL   A           │
        23    070     SHL   A           ┘
```

(A/D CONVERT & STORE)

```
      1524    022     AAD  A,B
        25    040     RTR  A,B
        26    323     STB  AB,X        STORE BITS 10,9,8,7,6,5,4,3.
        27    264
        30    343     LDB  AD
        31    263                      MUX DESELECT COMM.
        32    063     FOB
        33    010     RDC  X,X
        34    211
        35    053     RIC  Y,Y
        36    056     RTR  Y,A
        37    027     AXR  A,032
        40    032
        41    131     SKZ  2           SCAN COMPLETE? 12(8)=10(10) CHANNELS
        42    143     JMP  AM          NO, LOOP
        43    064
        44    163     ELB  AA          YES
        45    253
        46    045     RTR  B,Y
AF      47    000     GOL  B,Y
        50    205
        51    111     SKN  2           2 CHANNELS COMPLETE? - DIGITAL?
        52    143     JMP  AJ          YES
        53    170
        54    063     FOB              NO,
        55    052     RDC  B,B
        56    065     DIB              READ IN & STORE 2 DIGITAL CHAN.
        57    323     STB  AB,X
        60    264
        61    010     RDC  X,X
        62    211
        63    053     RIC  Y,Y
        64    143     JMP  AF          LOOP
        65    147
        66    000
        67    000
AJ      70    042     RTR  X,B
        71    061     TBB
        72    131     SKZ  2           MSB OF X=0?
        73    143     JMP  SR          NO
        74    220
        75    010     RTR  X,A         YES
        76    301
```

```
      1577    025    ASU  A,002
      1600    002
        01    131    SKZ  2          X=2?
        02    143    JMP  SR         NO, X > 2
        03    220
AK      04    362    LDB  CL,X       YES,
        05    131                    STORE TIME H.M.S.
        06    323    STB  AB,X
        07    264
        10    010    RDC  X,X
        11    211
        12    115    SKM  2          X=-1?
        13    143    JMP  AK         NO
        14    204
        15    163    ELB  AV
        16    251                    YES, EXIT.
        17    051    RIC  B,P
SR      20    004    AZE  Y
        21    002
        22    060    INE             TIME 1 SECOND
        23    010    RTR  Y,Z
        24    332
        25    004    ASU  ZZ,001
        26    217
        27    001
        30    112    SKN  4
        31    004    ASU  Z,115
        32    213
        33    115
        34    135    SKP  2          Y=400 + 115? = 1 second
        35    143    JMP  SR+2       NO, LOOP
        36    222
        37    143    JMP  AC         YES NEW SCAN
        40    061
AL      41    200    ZC              1 CORONA LOSS FAW
        42    201    ZC              2 CORONA LOSS FAW
        43    000    ZC
        44    000
        45    000
        46    000
        47    000
        50    000
AV      51    000    ZA              SAV ADDR
        52    000
```

(A/D CONVERT & STORE)

AA	1653	241	ZA	ADDR OF AL
	54	003		
AN	55	102	ZA	BLOCK SIZE
	56	005		
AX	57	106	ZC	FAW CH. SEL MUX
AQ	60	007	ZC	FAW A/D CONV.
AT	61	307	ZC	FAW A/D TEST
AR	62	207	ZC	FAW READ IN DATA
AD	63	006	ZC	FAW MUX DESELECT
AB	64	000	ZR	
	.	.	.	
	.	.	.	
	.	.	.	DATA BLOCK
	.	.	.	
	.	.	.	
	4366	000	.	

```
RS    1250    303    STB   RA
        51    047
        52    014    TBB                  SAV ADDR.
        53    205
        54    303    STB   RA+1
        55    050
        56    343    LDB   RY             DCPO-RDY COMM
        57    041
        60    063    FOB
        61    343    LDB   RR             DTFO-TEST RECORDER
        62    042
        63    063    FOB
        64    122    SKT   4              REC. READY?
        65    060    INE
        66    100    NOP
        67    142    JMP   *-11(8)        NO LOOP
        70    256
        71    343    LDB   RF             DCP1-FWD RUN COMM.
        72    043
        73    063    FOB
        74    004    ALD   Y,353
        75    112
        76    353
RW      77    060    INE   1              WAIT 63 MSEC = 25(8) CNT at 3 MSEC
      1300    010    RTR   Y,Y
        01    322
        02    135    SKP   2
        03    142    JMP   RW
        04    277
        05    163    ELB   RB
        06    037                         INITIALIZE X(2503)
        07    043    RTR   B,X
        10    343    LDB   RX    1435
        11    035                         CHANGE "INE JMP" ADDR.
        12    300    STB   0013
        13    013
        14    100    NOP
        15    100
        16    100    NOP
        17    004    AZE   Y
        20    002
RM      21    363    LDB   (AB-1)X
        22    263
```

(RECORD)

```
1323    047     RTR   B,Z
  24    004     AAD   Z,B
  25    303                        TEMP STORE MSB
  26    046     RTR   Z,B
  27    004     AAD   Z,B
  30    303
  31    010     RTR   ZZ,B
  32    357
  33    303     STB   RT
  34    036
  35    343     LDB   RC
  36    044
1337    063     FOB                CLOCK TEST FOR MS BYTE
  40    121     SKT   2
  41    142     JMP   *-2(FOB)
  42    337
  43    343     LDB   RO
  44    045
  45    063     FOB                RECORD MSB
  46    343     LDB   RT
  47    036
  50    064     DOB
  51    060     INE                UPDATE COUNTER Y FOR CLOCK
  52    343     LDB   RC
  53    044
1354    063     FOB                CLOCK TEST FOR LS BYTE
  55    101     SKF   2
  56    142     JMP   *-2(FOB)
  57    354
  60    343     LDB   RO
  61    045
  62    063     FOB                RECORD LSB
  63    363     LDB   (AB-1)X
  64    263
  65    064     DOB
  66    010     RDC   X,X
  67    211
  70    112     SKN   4            TEST BLOCK COUNTER
  71    010     RTR   X,B
  72    351
  73    061     TBB
  74    131     SKZ   2            BLOCK COMPLETE?
  75    142     JMP   RM   1321    NO,LOOP
  76    321
```

(RECORD)

```
          1377    343     LDB   RC          ┐
          1400    044                       │
            01    063     FOB               │   TEST CLOCK
            02    101     SKF   2           │
            03    143     JMP   *-3(FOB)    │
            04    001                       ┘
            05    343     LDB   RG          ┐
            06    046                       │   IRG COMM.
            07    063     FOB               ┘
            10    010     RIC   Y,X
            11    112
            12    010     RDC   P,B         ┐
            13    254                       │
            14    010     RDC   X,X         │   UPDATE CLOCK
            15    211                       │
            16    131     SKZ   2           │
            17    142     JMP   CS(1000)    ┘
            20    000
            21    061     TBB               ┐
            22    061     TBB               │   RESTORE CLOCK
            23    300     STB   0013        ┘
            24    013
            25    163     ELB   RA          ┐   EXIT
            26    047                       ┘
            27    051     RIC   B,P
            30    000
            31    000
            32    000
            33    000
            34    000
RX          35    244     ZC
RT          36    000
RB          37    103     ZA                ┐   BLOCK SIZE = 2503
            40    005                       ┘
RY          41    000     ZC                    DCPO   RDY COMM
RR          42    300     ZC                    DTFO   RDY TEST
RF          43    001     ZC                    DCP1   F. RUN COMM
RC          44    301     ZC                    DTF1   CLOCK TEST
RO          45    104     ZC                    DSF41  DATA OUT
RG          46    002     ZC                    DCP2   IRG COMM
RA          47    000     ZA                ┐   SAV ADDR.
            50    000                       ┘
```

PRINT DATA ACROSS LINE

```
PR    4370    311    STB   PA          ┐
        71    047                       │  SAV ADDR.
        72    061    TBB                │
        73    311    STB   PA+1         │
        74    050                       ┘
        75    100    NOP
        76    100    NOP
        77    100    NOP
      4400    004    ALD   X,017        INITIALIZE 'X'
        01    111
        02    017
PD      03    363    LDB   (AB-1),X     ┐
        04    263                       │
        05    041    RTR   B,A          │  PRINT DEC. DATA
        06    050    RIC   P,B          │
        07    151    JMP   NS           │
        10    136                       ┘
        11    010    RTR   X,A          ┐
        12    301                       │
        13    025    ASU   A,004        │  X > 3?
        14    004                       │
        15    137    SKP   6            ┘
        16    371    LDB   (PC-1),X     ┐
        17    043                       │  NO
        20    041    RTR   B,A          │  PRINT H,M,S
        21    050    RIC   P,B          │
        22    151    JMP   TO           │
        23    345                       ┘
        24    021    ALD   A,240        ┐
        25    240                       │  YES
        26    050    RIC   P,B          │  PRINT SPACE
        27    151    JMP   TO           │
        30    345                       ┘
        31    010    RDC   X,X
        32    211
        33    131    SKZ                SCAN COMPLETE?
        34    151    JMP   PD           NO, LOOP
        35    003
        36    050    RIC   P,B          ┐  YES
        37    152    JMP   CR           ┘  CRLF
        40    105
        41    171    ELB   PA
        42    047                       EXIT
        43    051    RIC   B,P
PC      44    323    ZC                 S
        45    315    ZC                 M
        46    310    ZC                 H
PA      47    000    ZA                 ┐  SAV ADDR
        50    000                       ┘
```

BIN/BCD CONVERT - 8 BITS TO 3 DIGITS 4536/4742

```
NS    4536    311    STB   NA
        37    336
        40    061    TBB                 SAV. ADDR.
        41    311    STB   NA+1
        42    337
        43    004    ALD   Z,003
        44    113
        45    003
NR      46    071    PLR
        47    055    RTR   A,Y
        50    351    LDB   NC
        51    340
        52    022    AAD   A,B           (ADD 140)
        53    125    SKS   2             CARRY?
        54    100    NOOP
        55    056    RTR   Y,A           NO
NL      56    071    PLR                 YES
        57    061    TBB
        60    061    TBB                 ZERO FLAG
        61    311    STB   NF
        62    343
        63    040    RTR   A,B
        64    022    AAD   A,B           SHIFT LEFT 1
        65    055    RTR   A,Y
        66    100    NOP
        67    106    SKR   4
        70    351    LDB   NG
        71    344
        72    311    STB   NF            CARRY FLAG (010)
        73    343
        74    351    LDB   NC            ADD 140
        75    340
        76    022    AAD   A,B
        77    100    NOP
      4600    106    SKR   4             CARRY?
        01    351    LDB   NG            YES, PUT 010 IN FLAG
        02    344
        03    311    STB   NF
        04    343
        05    351    LDB   NF            NO
        06    343
        07    111    SKN   2             TEST FLAG
        10    056    RTR   Y,A
        11    100    NOOP
```

(BIN/BCD CONVERT)

```
        4612    010     RDC   Z,Z
          13    233
          14    135     SKP   2
          15    151     JMP   NN
          16    226
          17    112     SKN   4
          20    040     RTR   A,B          ┐
          21    061     TBB                │   END OF 3RD LOOP
          22    311     STB   N1           │
          23    341                        ┘
          24    151     JMP   NL               END OF 1st, 2nd, 3rd LOOPS
          25    156
NN        26    010     RIC   Z,Z
          27    133
          30    131     SKZ   2
          31    151     JMP   NP               END OF 5th LOOP
          32    263
          33    010     RDC   Z,Z
          34    233
          35    066     SHR   A            ┐
          36    066     SHR   A            │
          37    066     SHR   A            │
          40    066     SHR   A            │
          41    010     RTR   A,B          │
          42    350                        │
          43    311     STB   N3           │   #3 DIGIT
          44    342                        │
          45    351     LDB   N1           │
          46    341                        │
          47    100     NOP   NOP          │
          50    100                        │
          51    041     RTR   B,A          │   END 4th LOOP
          52    067     SHC   A            │
          53    067     SHC   A            │
          54    067     SHC   A            │
          55    067     SHC   A            │
          56    351     LDB   NF           │
          57    343                        │
          60    022     AAD   A,B          │
          61    151     JMP   NR           │
          62    146                        ┘
NP        63    040     RTR   A,B
```

```
        4664    311     STB   N1
          65    341
          66    061     TBB
          67    041     RTR   B,A
          70    023     AAD   A,260
          71    260
          72    050     RIC   P,B
          73    151     JMP   TO          PRINT DIGIT #1
          74    345
          75    351     LDB   N1
          76    341
          77    041     RTR   B,A
        4700    066     SHR   A
          01    066     SHR   A
          02    066     SHR   A
          03    066     SHR   A
          04    023     AAD   A,260
          05    260
          06    050     RIC   P,B
          07    151     JMP   TO          PRINT DIGIT #2
          10    345
          11    351     LDB   N3
          12    342
          13    041     RTR   B,A
          14    023     AAD   A,260
          15    260
          16    050     RIC   P,B
          17    151     JMP   TO          PRINT DIGIT #3
          20    345
          21    171     ELB   NA
          22    336
          23    051     RIC   B,P
          24    000
          25    000
          26    000
          27    000
          30    000
          31    000
          32    000
          33    000
          34    000
          35    000
NA        36    000     ZA    0000
          37    000
```

(BIN/BCD CONVERT)

```
NC    4740      140      ZC    140
N1      41      000      ZC    000
N3      42      000      ZC    000
NF      43      000      ZC    000
NG      44      000      ZC    010
```

TTY I/O TO,TE, 4745/5130

```
TO    4745    072    PLS          PRINT OUT
        46    125    SKS  2
TE      47    071    PLR          READ IN
        50    100    NOOP
        51    312    STB  TB
        52    101
        53    061    TBB          SAV ADDR.
        54    312    STB  TB+1
        55    102
        56    352    LDB  TA
        57    100
        60    312    STB  TC      SET BIT CNT 366
        61    103
        62    125    SKS  2
        63    152    JMP  T3
        64    050
        65    004    AZE  Y
        66    002
        67    044    RTR  Y,B
        70    312    STB  TF      ZERO FLAG FOR TO
        71    104
T1      72    060    INE
        73    010    RTR  Y,Y     CLOCK SYNC
        74    322
        75    111    SKN  2
        76    151    JMP  T1
        77    372
      5000    014    SHRO B       SPACE OUT
        01    105
        02    004    ALD  Y,375
        03    112
T2      04    375
        05    060    INE
        06    010    RTR  Y,Y     9 MSEC DELAY
        07    322
        10    131    SKZ  2
        11    152    JMP  T2
        12    005
        13    352    LDB  TC
        14    103
        15    057    RIC  B,B     COUNT BITS
        16    312    STB  TC
        17    103
        20    106    SKR  4
```

```
5021    014     SHLO B          MARK OUT
  22    115
  23    152     JMP  T2-3
  24    002
  25    116     SKM  4
  26    172     ELB  TB         EXIT
  27    101
  30    010     RIC  B,P
  31    145
  32    352     LDB  TF
  33    104
  34    132     SKZ  4
  35    014     SHIO A          BITS IN.
  36    140
  37    152     JMP  T2-3
  40    002
  41    014     SHCO A          BITS OUT
  42    120
  43    030     AOR  A,200
  44    200
  45    152     JMP  T2-3
  46    002
  47    100     NOOP
  50    014     SHI  A
  51    040
  52    132     SKZ  4          LOOK FOR SPACE
  53    060     INE
  54    152     JMP  T3
  55    050
  56    100     NOOP
  57    004     ALD  Y,376
  60    112
  61    376     STB  TF         376 IN FLAG FOR TE
  62    312
  63    104
  64    152     JMP  T2         6 MSEC DELAY
  65    005
  66    000
  67    000
  70    000
  71    000
  72    000
  73    000
  74    000
  75    000
  76    000
  77    000
```

```
TA      5100    366     ZC              BIT CNT START
TB        01    000     ZA              SAV. ADDR.
          02    000
TC        03    000     ZC              BIT COUNTER
TF        04    000     ZC
CR        05    312     STB   CA
          06    127
          07    061     TBB             SAVE ADDR
          10    312     STB   CA+1
          11    130
          12    021     ALD   A,215
          13    215
          14    050     RIC   P,B       CARRIAGE RETURN
          15    151     JMP   TO
          16    345
          17    021     ALD   A,212
          20    212
          21    050     RIC   P,B       LINE FEED
          22    151     JMP   TO
          23    345
          24    172     ELB   CA
          25    127
          26    051     RIC   B,P
CA        27    000     ZA    0000
          30    000
```

Plate I Front panel of data processing system