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DEMONSTRATION OF ADAPTIVE RANDOM REPORTING GOES DATA COLLECTION--ETC(U)

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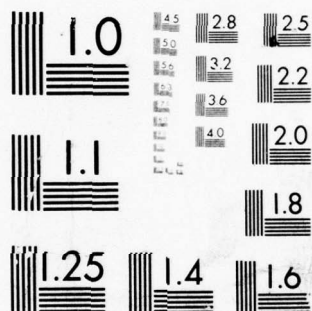
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New England Division has demonstrated a random reporting capability for collecting data using a standard 1500Hz channel on NOAA's GOES satellite. The new mode has several advantages over scheduled or interrogation modes used to collect hydrometeorologic data required in reservoir regulation in New England. In the random reporting system, hundreds of data collection platforms transmit on a single channel at proper (random) time intervals to insure an acceptable probability of reception. Several techniques have been incorporated to improve reception probabilities, the main ones being a short message (less than 2 seconds).

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and an adaptive algorithm programmed into each platform. This algorithm assures sufficient transmissions during critical times, yet relieves the system of superfluous messages during normal periods when no new or important information has been generated. The demonstration has confirmed that, even without the adaptive feature, at least 200 platforms will report successfully (with 90% probability) within an hour; and the research has revealed future enhancements which could increase the number of platforms by an order of magnitude. A new platform designed around readily available components is now operable and is expected to bring costs within reach of many users.

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Sutron Report No. SCR-333-78-006

FINAL REPORT
NED CORPS OF ENGINEERS

DEMONSTRATION OF ADAPTIVE RANDOM REPORTING
GOES DATA COLLECTION SYSTEM

January 15, 1979

Prepared for:

Mr. Tim Buckelew
U.S. Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02151

The Sutron Corporation
1925 North Lynn Street, Suite 700
Arlington, Virginia 22209

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I. INTRODUCTION

The Sutron Corporation, under contract to the New England Division of the Department of the Army Corps of Engineers, has developed and successfully demonstrated an adaptive random reporting data collection system that uses the National Environmental Satellite Service's Geostationary Operational Environmental Satellites (GOES) Data Collection System (DCS). The Sutron system is designed to collect data from various types of remote sensing instruments and transmit those data to a central receiving site using the GOES DCS as a relay system. With the Sutron system, data are transmitted to the satellite in a random reporting mode, i.e., there is no scheduled time for the platform to report data as in self-timed systems, and no external control is needed to initiate data transmission as in interrogation systems. In the random reporting system each remote platform establishes its own transmission schedule on the basis of a user-developed algorithm called an adaptive transmission rate algorithm, which changes the transmission rate as the platform data changes.

The Sutron system, with its adaptive remote transmitter, has the following advantages over current self-timed and interrogation data collection systems:

- the quantity of data provided from remote sites is controlled by the users' performance specifications;
- system response time is controlled by user performance criteria;
- the size, complexity, reliability, and power consumption of remote site equipment are significantly improved over self-timed or interrogation mode equipment; and
- GOES DCS channel utilization is improved over both self-timed or interrogation mode operation for most hydrometeorological (hydromet) data collection activities.

Sutron successfully demonstrated its adaptive random reporting system during tests for the Corps of Engineers on 6 and 7 December 1978.

II. PROJECT OBJECTIVES

The program to design, develop, and demonstrate an adaptive random reporting system was divided into the following three tasks:

- Sutron was to design an adaptive random reporting system that would have a 90 percent probability of receiving one message an hour from each of 100 remote data collection platforms operating on a single frequency channel. The theory underlying this system was to be developed and tested by computer modeling. The reporting algorithm was to be developed in conjunction with the New England Corps of Engineers hydrologists. (The Sutron/Corps of Engineers contract was modified in October 1978 and the system was required to meet the Corps of Engineers performance objective of 200 data collection platforms operating on a single channel with a 90 percent probability of receiving one message each hour);
- The key element in the Sutron random reporting system is a fast acquisition demodulator to be installed at the Waltham GOES receive site. Testing was to be done at Waltham; and
- Sutron was to design, build, and install four "smart" DCPs using microprocessor technology. These DCPs were to be capable of executing the reporting rate algorithm developed in Task A. These four DCPs are to be used to simulate 200 or more random reporting units operating on a fixed random regime. Sutron was to supply a test set which would setup and test the DCP for operation.

A final report would provide engineering documentation that included sufficient information so that the Corps of Engineers could draft specifications for possible future procurement of equipment supplied under terms of this contract.

III. DESCRIPTION OF ADAPTIVE RANDOM REPORTING

Random reporting is the transmission of sensor data from a remote site without external timing or control. An understanding of random reporting from remote sites requires an understanding of the statistics of transmitting data through a single channel. For such transmission three basic assumptions are made:

- performance can be defined over a finite time (1 hr in this case);
- a single remote unit transmitting at a rate of $\underline{n}$ times per hour is equivalent to 2 remote units transmitting at $1/2 \underline{n}$ times per hour; and
- the temporal scattering of transmissions is sufficiently random that the laws of probability are applicable.

The details of the development of the equations that describe random reporting performance are given in Appendix A. The equation from which performance is defined is

$$P_s(1) = e^{-\frac{2tM}{T}} \quad (\text{Eq. 1})$$

where $P_s(1)$ = the probability of successfully receiving a given transmission,

t = the length of time of a transmission,

M = the number of transmitters operating in the communications channel, and

T = the average length of time between transmission of all transmitters operating in a channel.

A few other basic equations are

$$P_f = 1 - P_s(1), \quad (\text{Eq. 2})$$

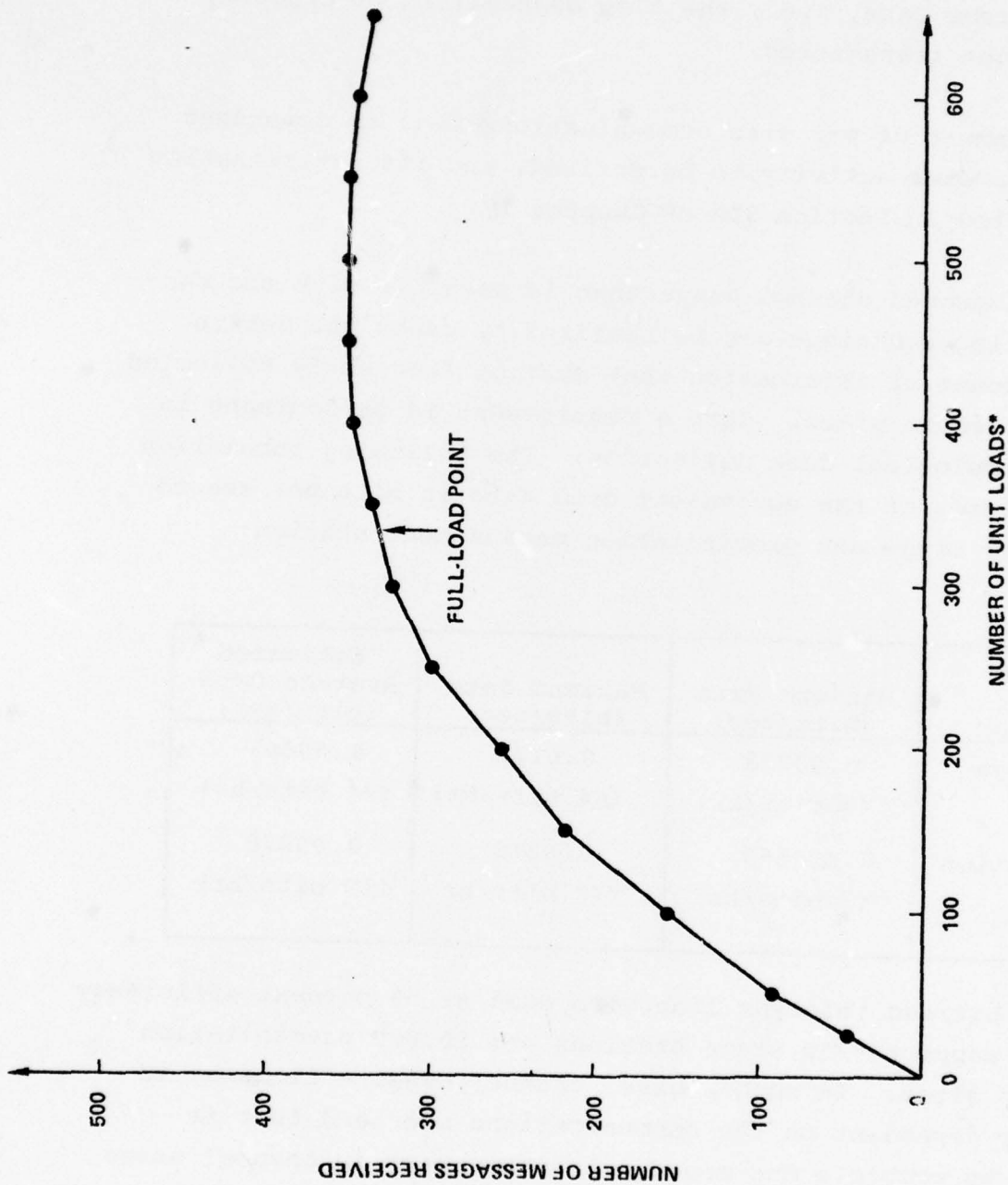
where P_f = the probability of failure of a given single transmission; and

$$P_s(n) = (1 - P_f)^n, \quad (\text{Eq. 3})$$

where $P_s(n)$ = the probability of receiving one message in n tries.

Since each remote transmitter can have variable transmission rates that are dependent on parametric activity and algorithm coefficients, a unit communication load is here defined for each remote site as one transmission every 30 min. A fully loaded channel is defined as one in which the average message rate is one message per hour per remote, where that remote is transmitting twice per hour and the probability of successfully receiving three transmissions, $P_s(3)$, is 90 percent.

A single transmission requires a message length of 1.86 sec. (Further discussion on the design of this message is given in Section 4 of Chapter IV.) From these definitions, it is possible to plot the number of received messages per channel as a function of the number of unit loads working into the channel (Figure 1). The full-load point on the curve is the point at which the number of messages received equals the number of unit transmission loads. This number is the average reception of one message per hour per unit load. From this curve, it may also be seen that even if the channel is subjected to much higher loading, it will not result in catastrophic failure. It only means the remote units are "working harder" (i.e., the same or smaller number of transmissions would be received but more transmission attempts would be



*UNIT LOAD = TWO TRANSMISSIONS PER HOUR

FIGURE 1: CHANNEL THROUGHPUT WITH 1.86-SEC MESSAGE

required) to get the same amount of information through the channel. The expanded scale in Figure 2 shows what happens in the extreme case, i.e., the slow degradation of capacity with messages transmitted.

Assignment of per site communications load is dependent on the parameter activity to be defined, and its determination is delineated in Section 3.2 of Chapter IV.

The improved channel usage that is possible with the random reporting technique can be realized by users who desire a small amount of information that must be frequently collected from many remote sites. Such a requirement is predominant in hydrometeorological data collection. The following tabulation is an analyses of the equivalent data rate in bits per second for a river stage and precipitation measurement station:

Parameter	Minimum Rate (bits/sec)	Maximum Rate (bits/sec)	Estimated Average Rate (bits/sec)
River Stage	0.00222 (8 bits/hr)	0.0177 (64 bits/hr)	0.00667 (24 bits/hr)
Precipitation	0.000555 (2 bits/hr)	0.0216 (78 bits/hr)	0.00278 (10 bits/hr)

If a 110 bit/sec teletype line were used at 50 percent efficiency it would support 8250 stage stations and 20,000 precipitation reporting sites. In such a case, channel usage efficiency is primarily dependent on the communications overhead that is required to complete one message. Improvement in channel usage improvement is compared in two cases with the self-timed reporting in a 1-min time window.

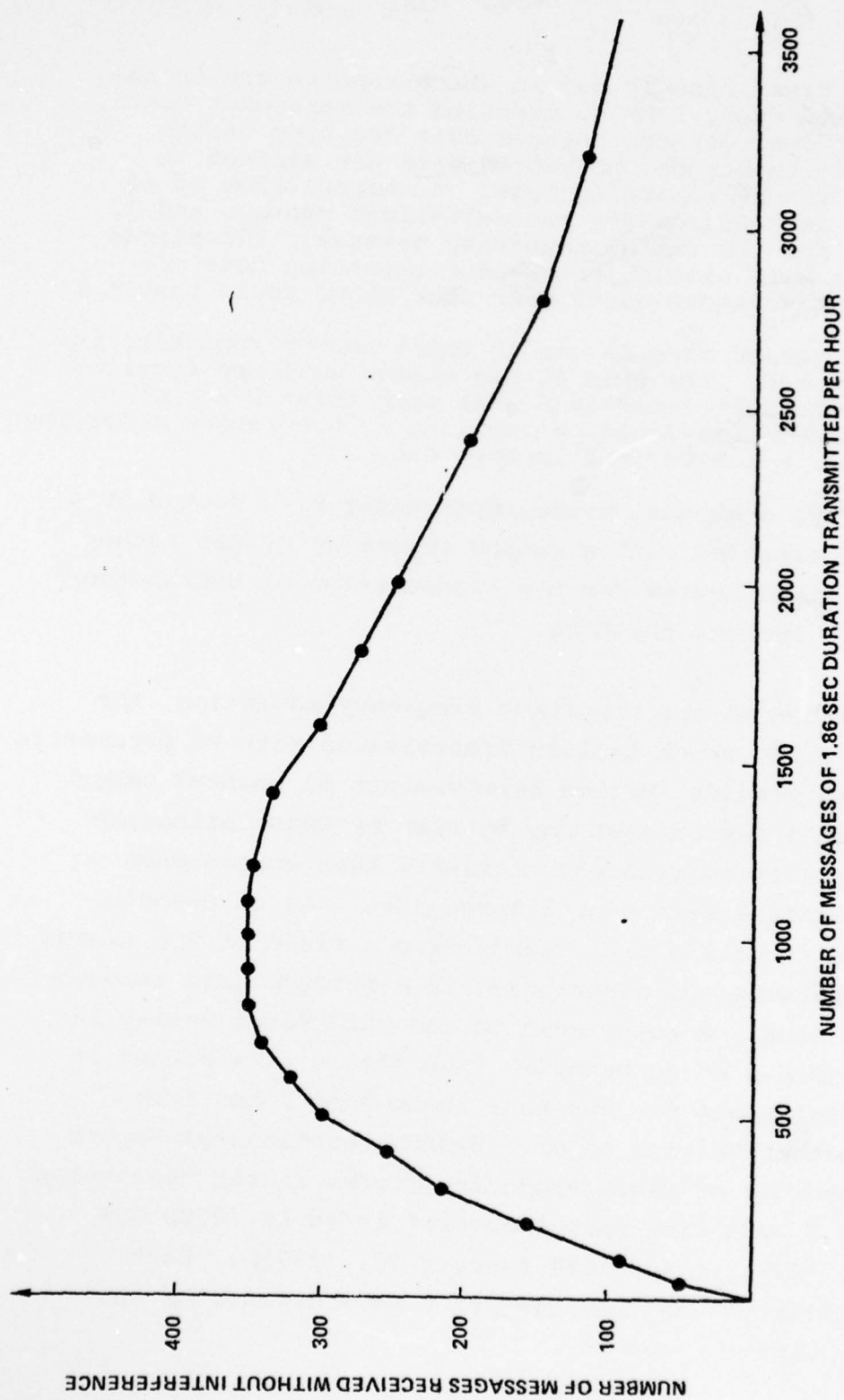
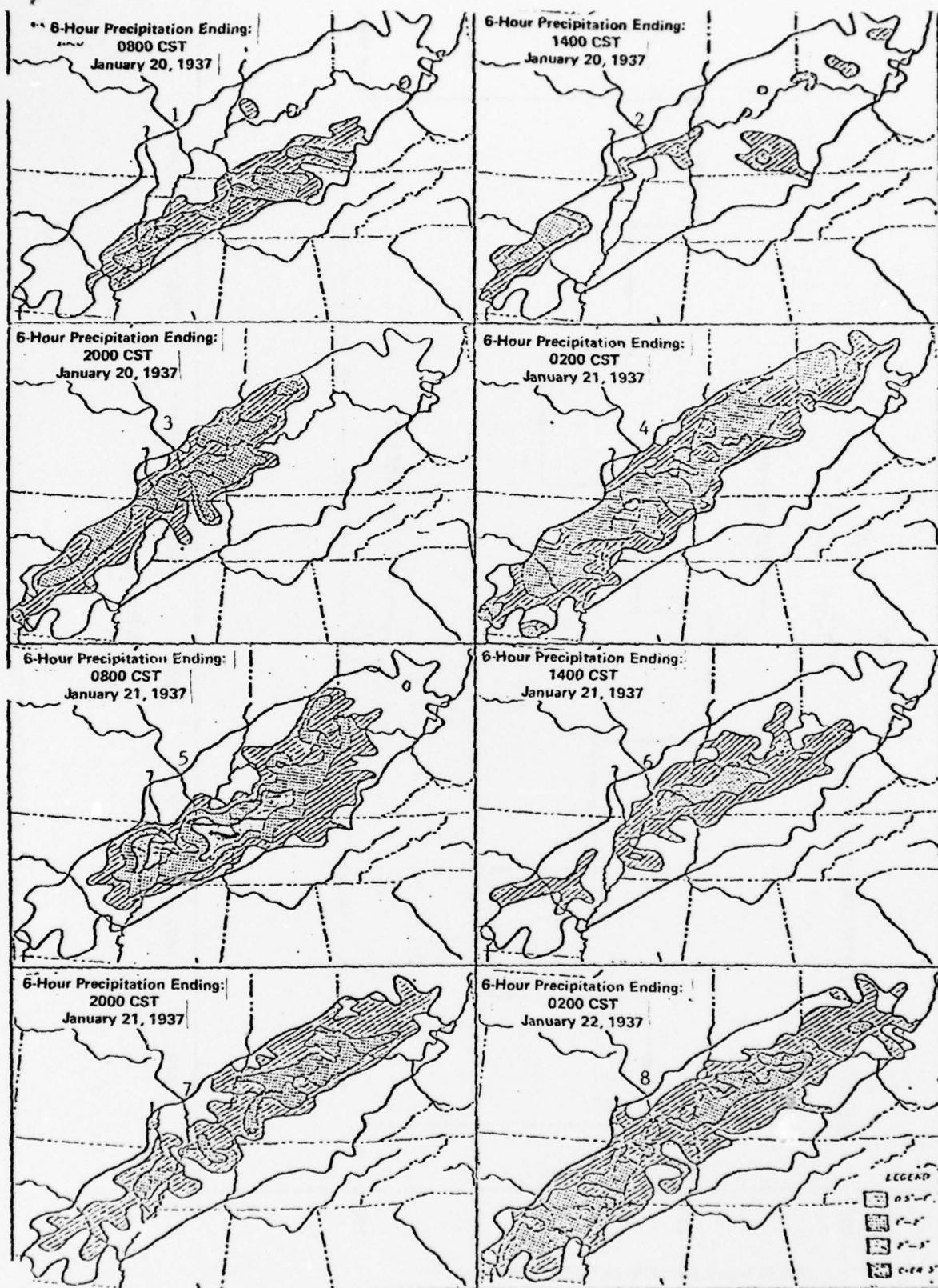


Figure 2. EXPANDED SCALE OF RANDOM REPORTING CHANNEL THROUGHPUT

- The first case is one in which reports are transmitted every 3 hr to describe the parameter over that 3-hr period. Stored data are used in the self-timed mode; no stored data are assumed in the random reporting case. A channel time of 60 sec is required for the self-timed message and 12 sec for the random reporting message. (If stored data were used in the random reporting case comparative improvement over that shown would result.)
- The second case is one in which hourly reporting is required. The same 60-sec window would be required in the self-timed case, but only about 5 sec of channel time would be required in the random reporting mode, a twelve-fold improvement.

Conservatively, a channel usage improvement by a factor of 4 to 10 can be expected with a random reporting system rather than a self-timed system for the transmission of hydrometeorological data through the GOES.

In addition to the reporting frequency advantage, the adaptive feature, which tailors transmission rate to parametric activity, can provide further improvements in channel usage. This additional improvement may be seen by considering the large variability in parameter activity that occurs when reporting rainfall data over a large area. As an example, consider the reporting performance from a field of 500 random reporting transmitters distributed in a uniform grid throughout a storm area. A storm area in the Ohio River valley is shown in Figure 3 as an example. [The figure is a series of eight isohyets plots for six-hour increments taken from National Weather Service Report, Hydrometeorological Report #34, "Meteorology of Flood Producing Storms in the Mississippi River Basin." The time period covered is 48-hr (0200 CST January 20, 1937, to 0200 CST January 22, 1937)]. Each remote transmitter was reporting at a rate defined by the equation in Figure 4 and is



Incremental Isohyetal Patterns
Parts of ten States

Figure 3. 1936 OHIO RIVER BASIN RAIN STORM

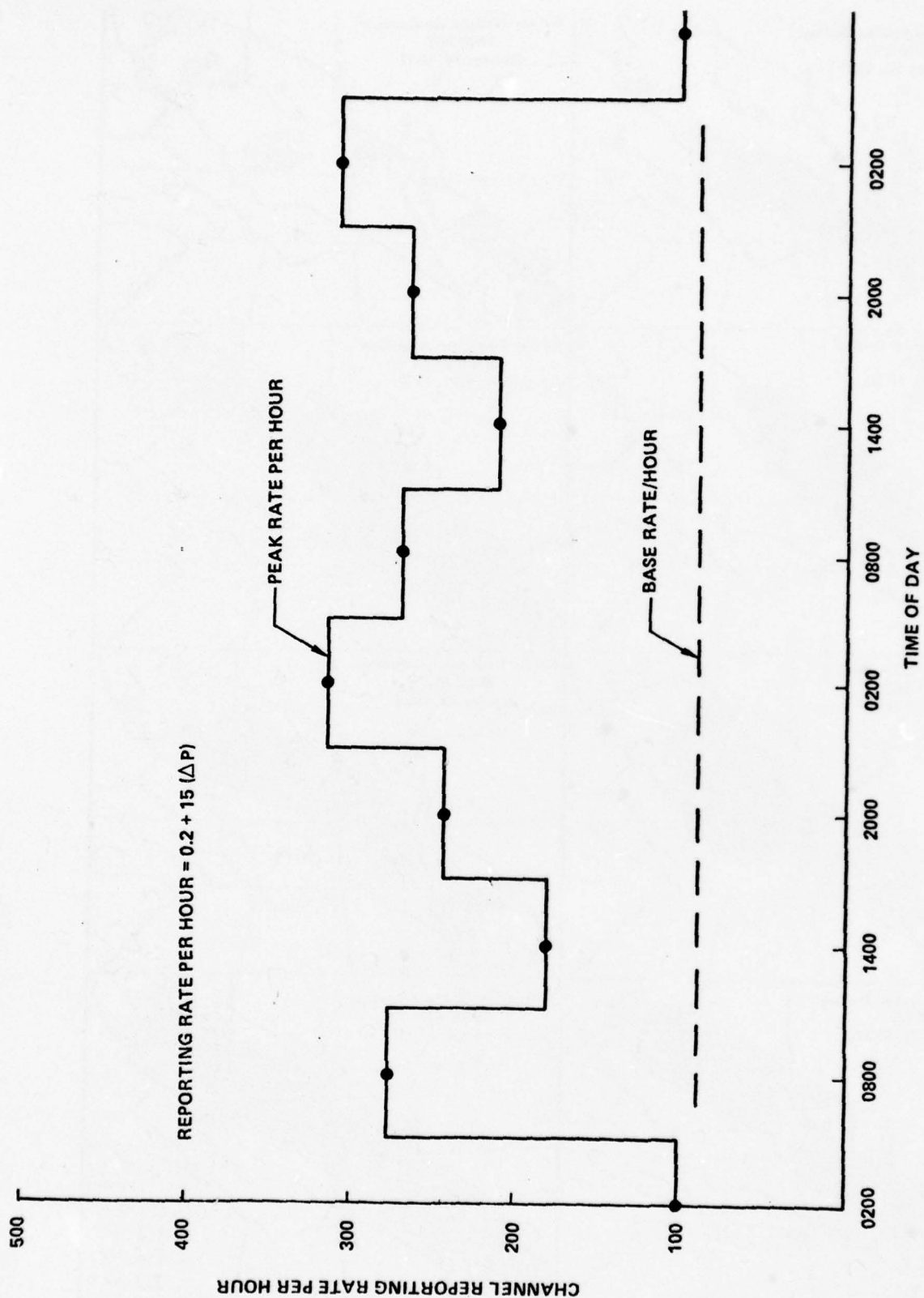


Figure 4. 500-STATION PRECIPITATION PERFORMANCE

$$\text{Transmissions per hour} = 0.2 + 15(\Delta P)$$

where ΔP = incremental accumulated precipitation (in./hr)

The number of hourly transmissions from this field during the 48-hour period is shown in Figure 4. The peak rate is 330 transmissions/hr, which is equivalent to 165 unit loads (Figure 1). About 225 of those 330 transmissions (about 70 percent) would be received.

Individual site performance for a 1 in./hr rate of accumulation is 15.2 reports/hr. Ten of these transmissions would be received, giving a reporting interval of 6 min. In this case, 500 stations were supported by one channel, resulting in one report received for every 0.16 in. of accumulated rainfall.

IV. SYSTEM COMPONENTS

1. SATELLITE

The Geostationary Operational Environmental Satellite (GOES) system is an environmental data collection system operated by the National Oceanic and Atmospheric Administration (NOAA). Three satellites are in synchronous orbit at all times; one each at 75°W, 105°W, and 135°W longitude. The satellite at 105°W is considered a spare. The most familiar product of GOES is the meteorological imagery shown each day on local television newscasts. In addition to the three U.S. satellites, identical satellites are supported by Japan, European nations, and the Soviet Union. These satellites have been operational for about 5 years.

As part of its environmental monitoring capability, NOAA also supports a substantial communication system (Figure 5). Two sets of uplink and downlink frequencies are used, the first at 2034.9 (uplink) and 1694.5 MHz (downlink) for communications between the spacecraft and large receiver systems and the second at 401.8 MHz (uplink) and 468.8 MHz (downlink) is for communications with remote low-power transmitters. The 468.8 MHz downlink is a narrowband command-and-control link that is monitored for unique command words by all remote stations equipped to receive the signal. In addition to command words, a National Bureau of Standards (NBS) time code is also transmitted on this link. The 401.8 MHz uplink capacity is divided into about 250 1.5-KHz-wide channels, which permits low-data-rate, low-power, remote communication. The remote transmitters are characterized by 13- dB to 3- dB antenna gains with transmission power from 5 to 40 w, respectively.

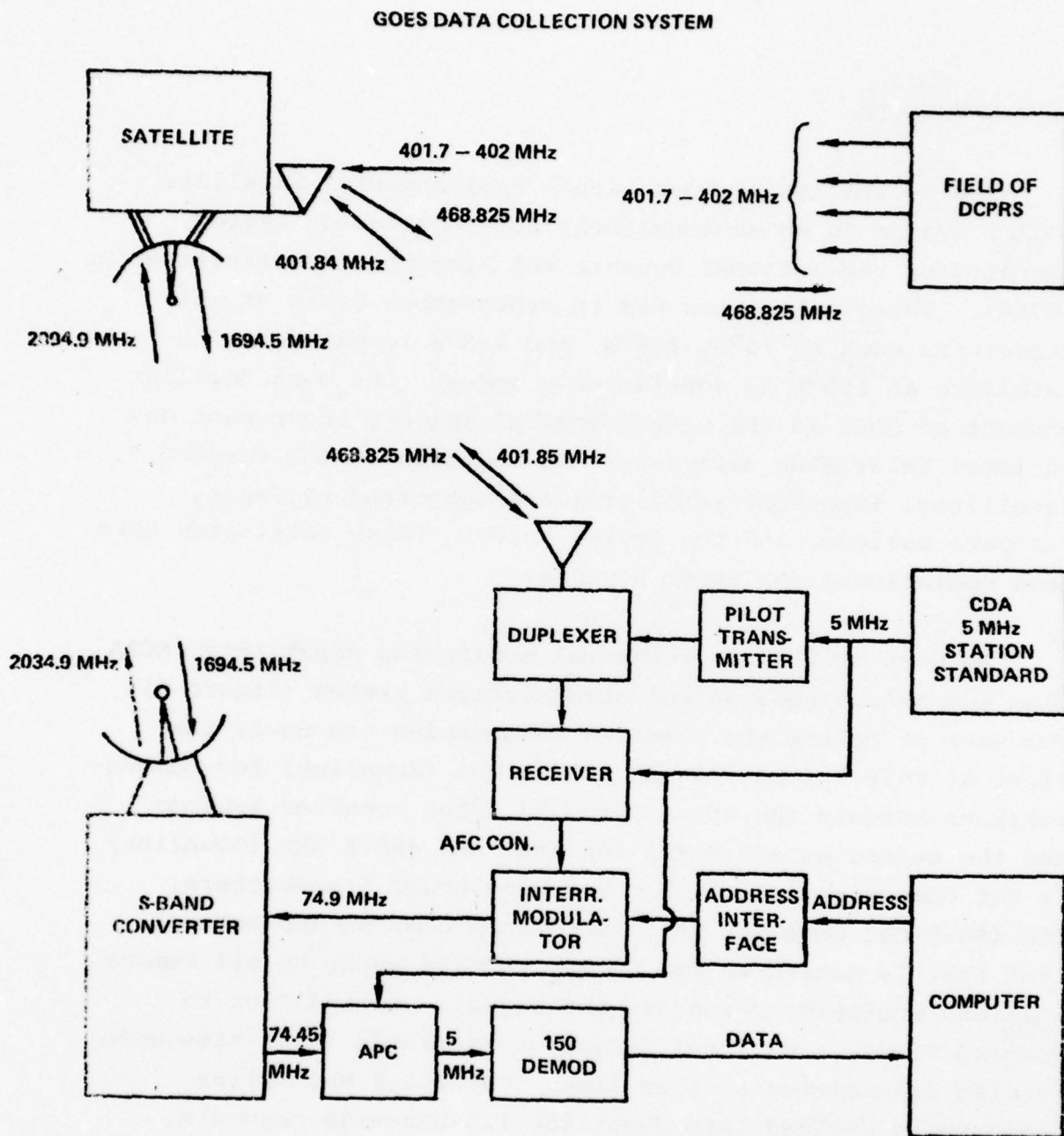


Figure 5. GOES DCS SYSTEM FREQUENCY PLAN

Figure 6 is a block diagram of the total GOES DCS. The major components are

- the satellites;
- command-and-data acquisition system at Wallops Island, Virginia, that includes:
 - five receiving systems using 40- to 60-ft diameter parabolic dish antennas,
 - a redundant disk-supported computer system that acquires and forwards received data to the National Meteorological Center (NMC) (one day of data is backed up at the Wallops computers),
 - triple redundant lines to the NMC,
 - uninterruptable power sources, and
 - a system by which each channel is tested at least once per day using a test transmitter (ten operators are scheduled to maintain the DCS system year round);
- a redundant computer system at NMC that transmits data to users either by leased line or dial-in line (one day of backup data are stored at NMC); and
- users receive sites (not shown in Figure 6), which are equivalent to a small-scale Wallops Island site.

2. RANDOM REPORTING DATA COLLECTION PLATFORM (RR/DCP)

The Sutron RR/DCP is designed to collect data from various types of remote sensing instruments and transmit them using the the Geostationary Operational Environmental Satellite (GOES) data collection system (DCS) to a central receive site. The Sutron RR/DCP reports data in a random reporting mode, meaning that there is no scheduled time for each platform to report. However, each platform bases its own transmission schedule on an algorithm called an adaptive transmission rate algorithm.

This algorithm uses constants supplied by the user at setup time and actual platform data to compute a transmission rate that changes as the platform data changes.

The Sutron RR/DCP designed for the Corps of Engineers testing consists of a microprocessor, transmitter, instrumentation interface, microterminal, and power supply. These components are discussed in the following subsections. A listing of RR/DCP features and hardware specifications is given in Tables 1 and 2.

2.1 Microprocessor

The Sutron RR/DCP is a microprocessor-controlled data collection platform. The microprocessor performs the functions of (1) collecting data, (2) formatting data, (3) transmitting data, (4) timing, and (5) adapting the transmission rate to changes in data. These and related RR/DCP functions are executed by an executive program and associated subroutines, which are stored in erasable programmable read-only memory (EPROM).

The RR/DCP is also equipped with the RCA UT-5 operating system ROM, which allows an operator using the microterminal to execute RR/DCP functions separate from the executive program. This capability allows the RR/DCP to be fully exercised and tested. Even new programs may be written and executed without any hardware changes using the UT-5 operating system.

The Sutron RR/DCP uses the RCA 1802 microprocessor with 3.3 kbytes memory to perform its control functions. Appendix D gives flowcharts, memory maps, register assignments, and a machine code listing for all RR/DCP software.

Table 1. RR/DCP FEATURES

- Adaptive reporting rates based on local platform data and user data requirements.
- 36 mw average power consumption.
- Compatibility with random reporting channels.
- Operating system (RCA UT-5) permits wide use of microprocessor to exercise existing programs and write/run new ones.
- Easy set up/testing using a hand held terminal with 8 digit LED display and keyboard.
- A 12-bit analog-to-digital (A/D) converter with an accuracy of ± 0.05 percent of full scale.
- Serial digital interface to instruments such as "tipping bucket" rain gauge.
- Operator selection of adaptive reporting parameters: base rate, alert rate, warning rate, alert level threshold, warning level, slope factors.
- Internal backup battery power to random access memory (RAM) to allow off-site set up of platform.
- Fool proof start-up hardware ensures that the platform will operate when left at remote site.

Table 2. HARDWARE SPECIFICATIONS

DIMENSIONS:	Length 10 $\frac{1}{2}$ in. Width 6 in. Height 3 $\frac{1}{2}$ in.
WEIGHT:	ca 7 lb
CONTROLS:	Microterminal data entry that execute four self-test programs
CONNECTORS:	Power and instrumentation: 12 pins Microterminal : 20 pins
ENCLOSURE:	Environmentally sealed
POWER REQUIREMENTS:	ca 36 mw (assuming two transmissions/hr) and a 10-volt transmitter, 30 watts peak
POWER SUPPLY:	12V lead-acid battery suggested
OPERATING TEMPERATURE:	-25°C to 55°C (two-day thermal time constant with 1-in. polyurethane foam container)
TRANSMITTER:	GOES DCS compatible; standard: 10-watt transmitter with 10dB antenna

2.2 Transmitter

The transmitter used by the RR/DCP is a 10-watt GOES DCS compatible transmitter. A 10dB, 401.8 MHz antenna is used with the transmitter. The microprocessor controls the transmitter in order to send a message using the format shown in Table 3.

2.3 Instrumentation Interface

The Sutron RR/DCP is equipped with an analog data interface and a serial digital data interface. The analog interface is designed to convert analog signals to a 12-bit binary word with a conversion accuracy of ± 0.05 percent of full scale. The analog signals must be between 0 and 1 volt. A 1-volt reference (capable of supplying 10 ma) is available for instrumentation. Data are read every 8 min and whenever a transmission is made. Each analog measurement takes about 2 sec.

A serial-digital data interface is provided to accommodate the tipping bucket rain gauge. The serial digital interface causes a counter in memory to be incremented with each pulse on the serial digital data line.

The RR/DCP can accommodate either two analog data inputs or one analog and one serial-digital data input. For the Corps of Engineers demonstration the DCP was limited to two parameters although additional parameters may be accommodated.

Table 3. TRANSMISSION TIMES AND FORMATS

Function	Time (sec)	Format
Carrier	0.50	
Clock	0.48	48 bits 1-0 pattern
MLS	0.15	15 bits
ID	0.31	31 bits (unique platform identifier)
Data	0.32	Byte 1 X1 B₅B₄B₃B₂B₁B₀ Bits 0-5 Parameter 2 Byte 2 X1 B₁₁B₁₀B₉B₈B₇B₆ Bits 6-11 Parameter 2 Byte 3 X1 B₅B₄B₃B₂B₁B₀ Bits 0-5 Parameter 1 Byte 4 X1 B₁₁B₁₀B₉B₈B₇B₆ Bits 6-11 Parameter 1 X indicates odd parity
EOT	0.08	8 bits EOT character
TOTAL	1.84	

2.4 Microterminal

The microterminal is the control device used to set up and test the RR/DCP. It is a hand-held terminal with an eight digit LED display and 23 keys. Instructions are entered through the keyboard to run test programs, examine memory, and enter platform constants. The eight-digit display is used to display data and test results. The microterminal is programmed to operate both with hexadecimal (HEX) numbers and with decimal numbers.

2.5 Power Supply

The RR/DCP power supply utilizes a 12-volt battery and delivers a maximum of 0.5 amps at 6.1 volts to the logic section. The RR/DCP power consumption is shown in Table 4. Since the average power consumption is about 36 mw, a 10 amp-hr, 12-volt battery would last 90 days, and a 40 amp-hr, 12-volt battery would last 360 days. Therefore, in most applications no solar panels are required. The power supply has over voltage and reverse voltage protection so that a fuse will blow when output voltage is greater than 7 volts or when power is applied in reverse.

3. INSTALLATION

There are several steps to the installation of the RR/DCP: instrumentation must be selected and interfaced to the platform, values must be selected to control the adaptive transmission rate algorithm and entered into the platform, and the platform should be tested. This section gives details on these steps. A sample setup test sheet is shown in Figure 7.

Table 4. RR/DCP POWER CONSUMPTION

Function	Duty Cycle	Average Consumption	
		Current (ma)	Power (mw)
Data Acquisition	20 ma for 4-sec every 8 min	0.17	2
Transmission twice per hour (1 unit load)	2.0 amp for 1.86-sec every 30 min	2.1	26
Continuous	Microprocessor calculating at slow rate	0.7	8
TOTAL		~3.0	36

Date: _____ Operator: _____

Location: _____

HEX ENTRIES – PROCEDURES 1

ADDRESS	CONTENTS	SETUP	DESCRIPTION
8C62			31 Bit ID Code
8C63			"
8C64			"
8C65			"
8C52			00 FDC Precip. 01 Bucket

DECIMAL ENTRIES – PROCEDURES 2

ADDRESS	CONTENTS	SETUP	DESCRIPTION
8C36			Base Transmission Rate x 100 (Trans/hr x 100)
8C38			Alert Transmission Rate x 100 (Trans/hr x 100)
8C3A			Flood Transmission Rate x 100 (Trans/hr x 100)
8C3C			Number 0-100 dependent on stream
8C3E			Precip. Multiplier
8C40			Alert Level x 100 (ft x 100)
8C42			Flood Level x 100 (ft x 100)
8C2C			Current Stage x 100 (ft x 100)
8C32			Current Precip. Level x 100 (in. x 100)

Figure 7. RR/DCP CHECK-OUT SHEET

TESTING/CALIBRATING PROGRAMS

168\$P	8C28 _____	Minimum Stage Level
170\$P	8C2A _____	Minimum Precip. Level; If "1" Appears Bucket Is Selected
178\$P	8C2C _____	Current Stage
	8C32 _____	Current Precip.
180\$P		Transmits Values at 8C66
158\$P	8C46 _____	RF FWD
	8C48 _____	RF REF

Figure 7. RR/DCP CHECK-OUT SHEET (Cont'd)

3.1 Instrumentation

The instrumentation is connected to the RR/DCP through the J5 connector mounted on the side of the DCP enclosure. Pin assignments for J5 are given in Table 5.

A voltage of 0 to 1 volt on Pin E gives an internal reading of 0 to 4000 for Parameter 1; the same voltage on Pin J gives an internal reading of 0-1000 for Parameter 2. The 1-volt reference on Pins F and K is supplied as an interface between the DCP and a variety of sensors.

When the system is used to monitor river stage and precipitation levels, Parameter 1 is best suited for the stage and Parameter 2 is best suited for precipitation. In this configuration, the 0 to 4000 internal range of Parameter 1 corresponds to river stages of 0 to 40.00 ft with a resolution of 0.01 ft. Similarly, the 0-1000 internal range of Parameter 2 corresponds to precipitation of 0 to 10.00 in. with a resolution of 0.01 in.

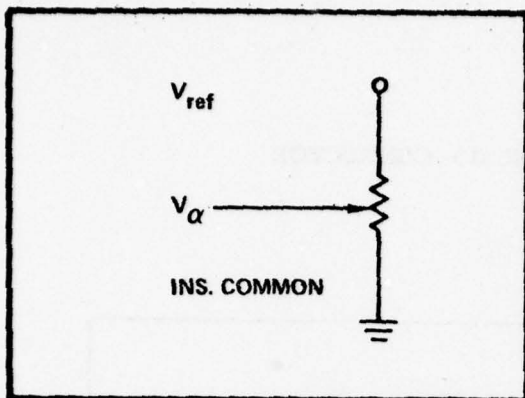
The reference voltage supplied to the output connector is used internally as full-scale reference; therefore, it should also be used as the external instrumentation full-scale reference voltage. All internal measurements are scaled to this reference. Figure 8 shows a typical setup using a potentiometric sensor and one with a YSI linear thermister network.

The serial-digital interface can be used instead of the analog interface for Parameter 2. This interface counts the pulses on Pin D, the tipping bucket line. Figure 9 shows its connection to a tipping bucket rain gauge.

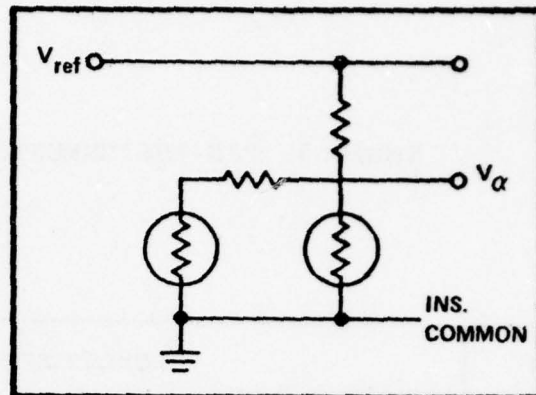
The RR/DCP is designed to calibrate instruments with which it interfaces. Since the position of a potentiometer is

Table 5. PIN ASSIGNMENTS FOR J5 CONNECTOR

PIN	FUNCTION
A	+12 volts - battery (+)
B	no connection
C	power common-battery (-)
D	tipping bucket line
E	V_{α} (0-1 volt) analog input for parameter 1
F	V_{ref} (+1 volt 10ma) instrument reference voltage
H	instrument common
J	V_{β} (0-1 volt) analog input for parameter 2
K	V_{ref} (+1 volt 10ma) instrument reference voltage
L	instrument common
M	no connection
N	no connection



A. POTENTIOMETRIC SENSOR



B. LINEAR THERMISTER NETWORK

Figure 8. TYPICAL INSTRUMENTATION SETUP

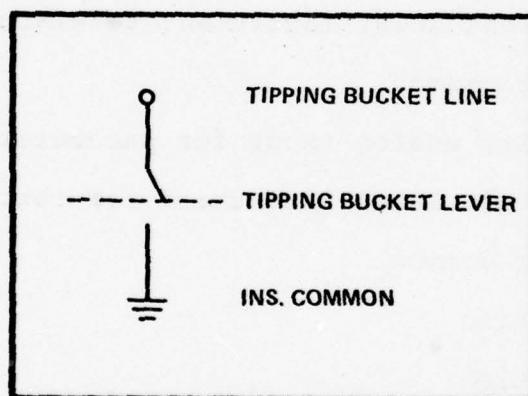


Figure 9. SERIAL-DIGITAL INTERFACE CONNECTION TO TIPPING BUCKET RAIN GUAGE

probably unknown when it is attached to the RR/DCP, calibration becomes necessary. The potentiometer must be aligned so that its full-scale operation corresponds to the full-scale RR/DCP reading range. The RR/DCP assists in this alignment process by accepting an operator input of the current potentiometer value and then computing the minimum real-world value it will read (i.e., the value at $V=0$). If this value is different from the desired minimum of the instrument, adjustments are necessary. In the case of a stage monitor with float, pulley, and wheel, the wheel must be rotated and the test performed again until the minimum value desired is achieved. The actual minimum of the instrument does not need to be zero.

In the case of non-zero minimum, the RR/DCP will continue to transmit its reading ranging from 0-4000 and 0-1000, but the minimum value must be added to the transmitted value to determine the actual level. For example, if the minimum were 50 (00.50 ft) and the transmitted value were 1000 (10.00 ft), the actual stage would be 1050 (10.50 ft).

3.2 Rate Selection

The operator controls the adaptive transmission rate algorithms by selecting values to enter at set up time. Values are required at set-up time for the base transmission rate, alert transmission rate, warning transmission rate, alert level, warning level, and slope factors. The rate at which data are transmitted depends on the values for these rates and levels and the measurements the RR/DCP makes of its instrumentation. The following discussion presents the procedures used to select values for the RR/DCP. A discussion of how to enter the values into the RR/DCP is given in Section 3.3.

Equations 4 and 5 are simplified versions of the transmission rate calculation equations.

$$\text{Rate } 1 = R_i + A|\Delta\alpha| \quad (\text{Eq. 4})$$

$$i = 1, 3$$

$$\text{Rate } 2 = R_1 + B|\Delta\beta| \quad (\text{Eq. 5})$$

where Rate 1, Rate 2 = transmission/hr(T/hr) for parameters 1 and 2,

α = parameter 1 (i.e., stages)

β = parameter 2 (i.e., precipitation)

R_1 = base transmission rate (T/hr),

R_2 = alert transmission rate (T/hr),

R_3 = warning transmission rate (T/hr),

A,B = slope factors,

$\Delta\alpha$ = change in α^* /hr (based on 16-min sample), and

$\Delta\beta$ = change in β^* /hr (based on 8-min sample).

*Hourly change in alpha and beta.

and

$R_i = R_1$ if α is below the alert level

$R_i = R_2$ if α is below the warning level

$R_i = R_3$ if α is above the warning level

Figure 10 illustrates the rate calculations of the DCP in instances in which the river stage is Parameter 1. The three curves correspond to α being below the alert level, α being below the warning level and α being at or above the

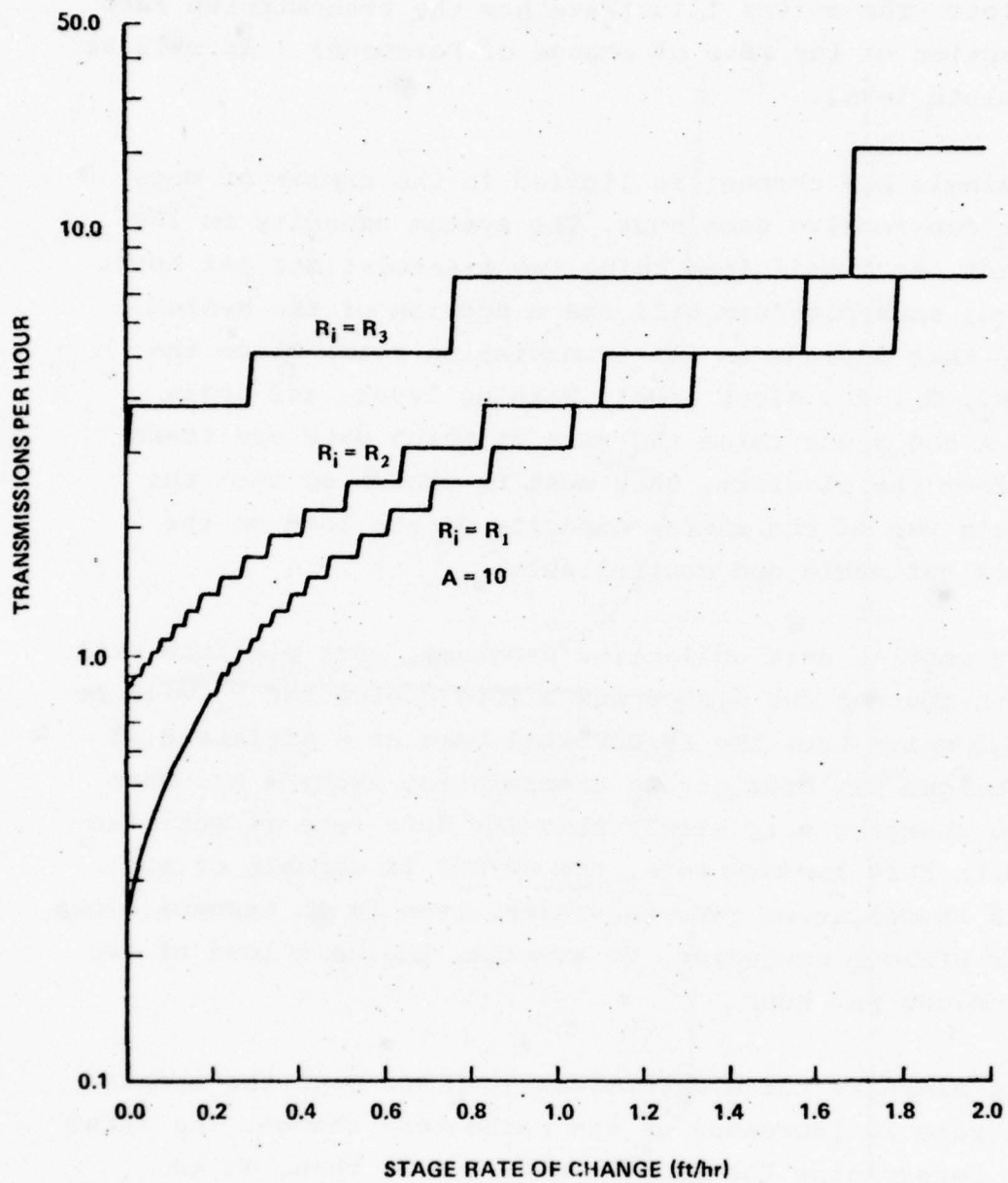


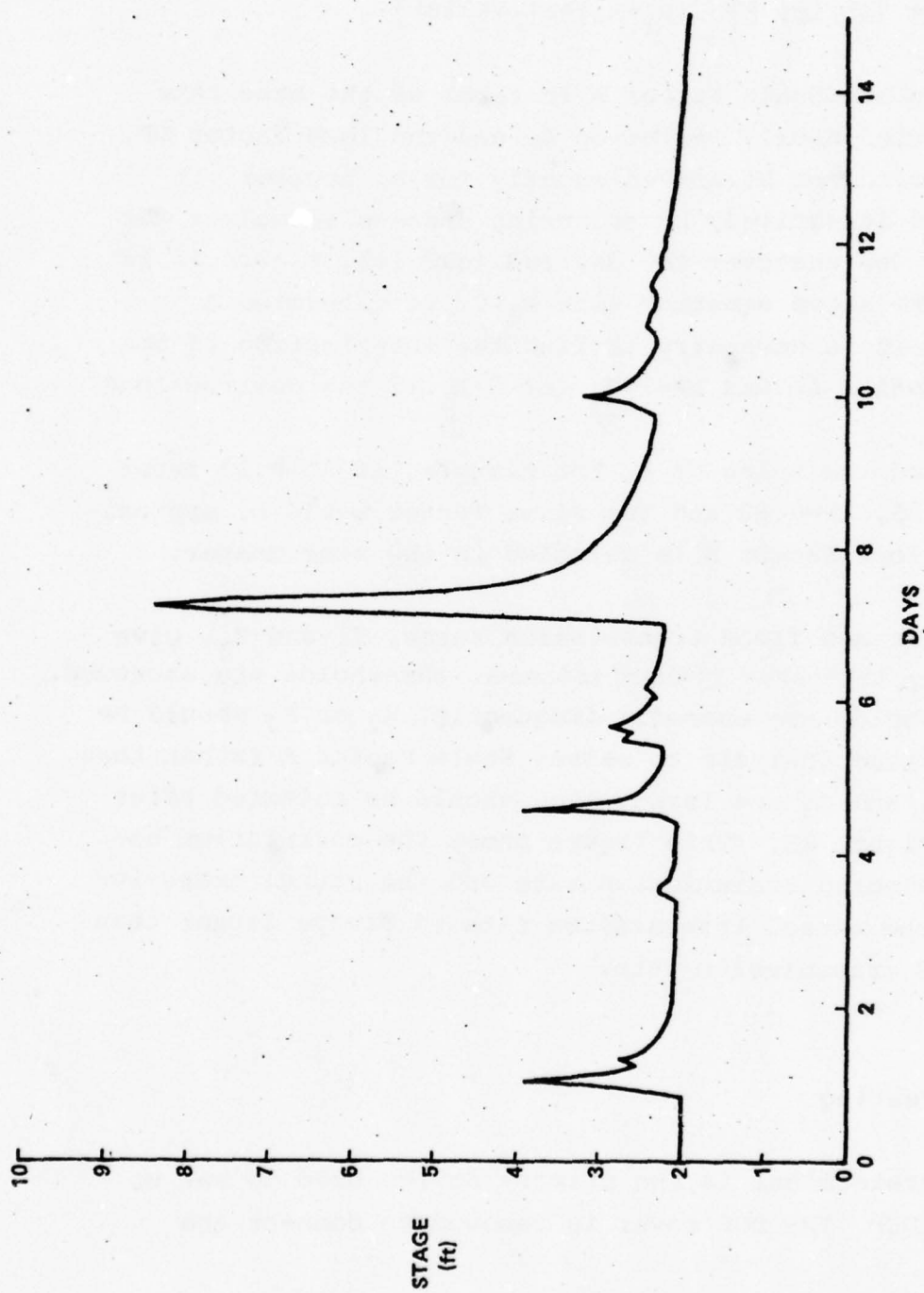
Figure 10. TRANSMISSION RATE ADAPTS TO PARAMETER VARIATIONS

warning level. Slope Factor A is the same in each of the three plots. The curves illustrate how the transmission rate is a function of the rate of change of Parameter 1 as well as its absolute level.

A single DCS channel is limited in the number of messages it can receive each hour. The system capacity is 300 unit loads, each unit load being two transmissions per hour. Therefore, each platform will use a portion of the system capacity that depends on its transmission rate. Since the values R_1 , R_2 , R_3 , Alert level, Warning level, and Scale Factors A and B determine the rate at which data are transmitted from the platform, they must be chosen so that the platform's use of the system capacity or the load on the system is definable and controllable.

For routine data collection programs, each platform will be a unit load on the system and a good choice for R_1 will be .25, which means that the RR/DCP will make at a minimum 0.25 transmissions per hour or one transmission every 4 hr. When data are changing very slowly this low data rate is satisfactory. With this low base rate, the RR/DCP is capable of substantial transmission rate increases, even to 15 transmissions per hour without exceeding, on average, the unit load of two transmissions per hour.

The Slope Factor A determines just how much the transmission rate is increased as the parameters change. The first step in determining the proper value for A, then, is to estimate the expected hourly variation for the parameter. This value can be estimated or calculated. Hydrographs, such as those shown in Figure 11, can be used in the estimation.



IV-21

Figure 11. SAMPLE CALCULATION OF $\bar{\Delta}\alpha$

Scale factor can then be determined either algebraically or graphically. The equation for the algebraic method is

$$LF = 7.5 / \int [15 / (R_1 + A \cdot |\Delta\alpha| \cdot 16/60)] ,$$

which defines the Scale Factor A in terms of the base rate R_1 , the expected hourly variation $\Delta\alpha$ and the load factor LF. This equation cannot be solved exactly for A; however, it can be solved iteratively by selecting successive values for A until $LF=1$ (or whatever the desired load is). Figure 12 is a graph of the above equation with $R_1=0$. To determine A graphically, it is necessary to find the intersection of the lines that define $\Delta\alpha$ and $LF=1-\frac{R_1}{2}$ (or $2-\frac{R_1}{2}$ if the desired load

is 2) and read the value of A. For example, if $\Delta\alpha=0.20$ ft/hr and R_1 is 0.25, $LF=0.88$ and the slope factor would be approximately 34. Slope Factor B is selected in the same manner.

The alert and flood transmission rates, R_2 and R_3 , give substantially increased transmissions as thresholds are exceeded. If the thresholds are exceeded frequently, R_2 or R_3 should be used in the load analysis to select Scale Factor A rather than R_1 . When R_2 and R_3 are large, they should be selected after consulting Figure 13. This figure shows the correlation between the selected transmission rate and the actual transmission rate; the actual transmission rate is always larger than the selected transmission rate.

3.3 Set Up Testing

The microterminal is the primary device used to set up and test RR/DCP. The DCP cover is removed to connect the

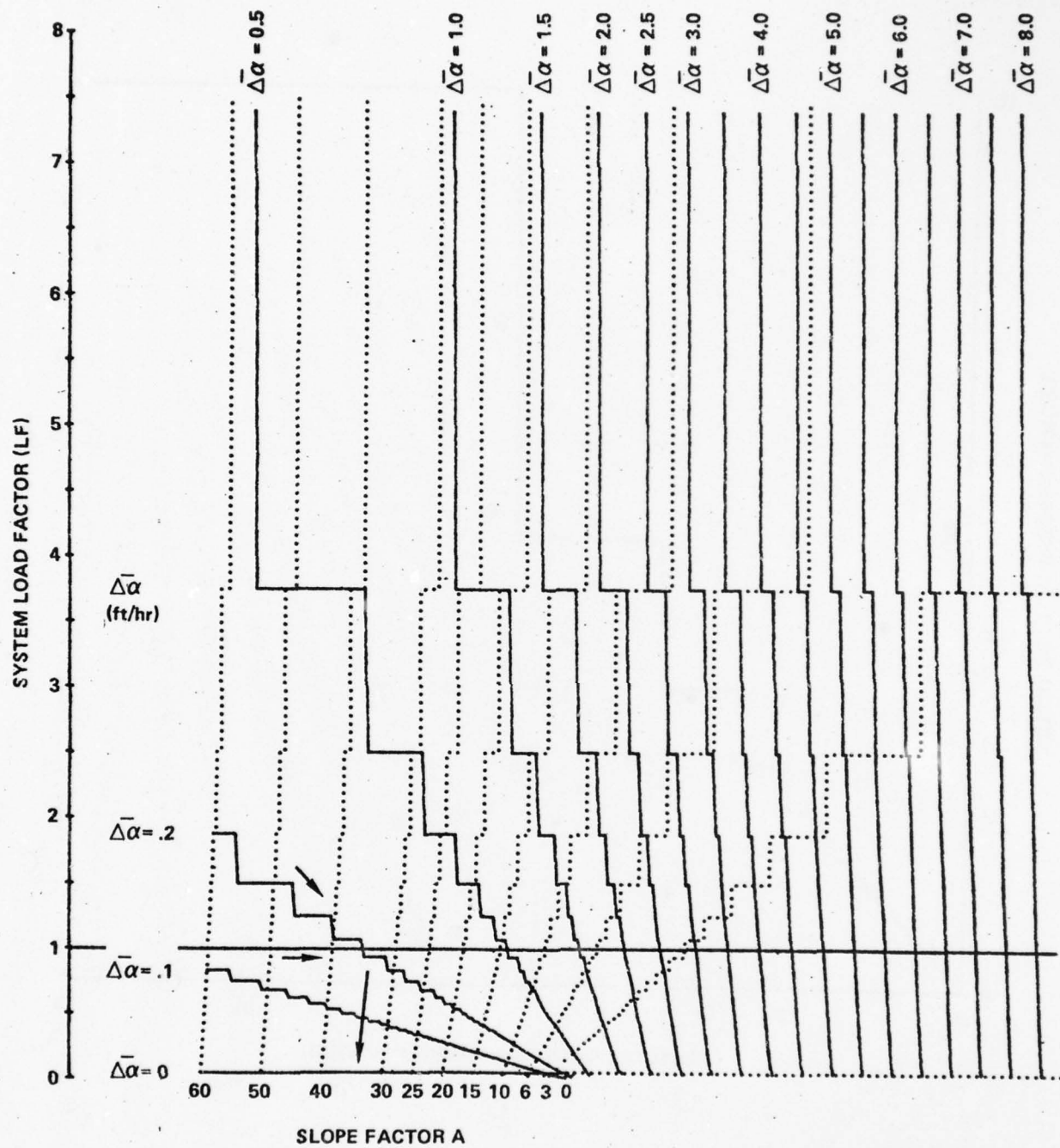


Figure 12. SYSTEM LOADING VS. SLOPE FACTOR

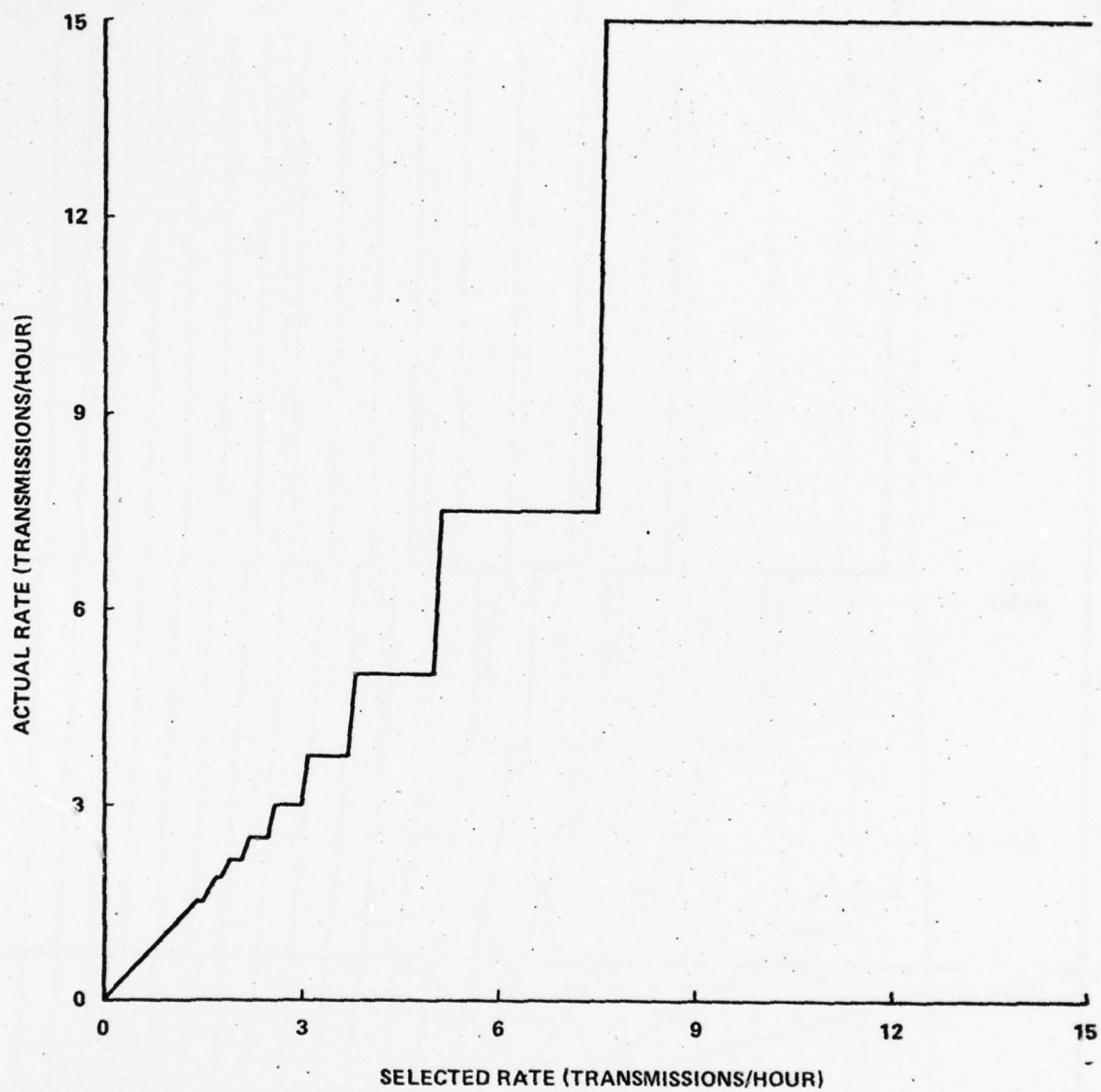


Figure 13. COMPARISON OF SELECTED RATE AND ACTUAL RATE

```

C .....
C      LOFAK
C
C      ROUTINE TO SOLVE LOAD FACTOR
C      EQUATION FOR GOES RRDCS.
C
C      RMC & TDB      6 MARCH 1979
C .....

```

XFM=9999.

```

ACCEPT 'LOAD FACTOR:  ',XLF
ACCEPT 'BASE RATE:    ',R1
ACCEPT 'RATE OF CHANGE: ',DA

```

```

      LI=0
      AB=0.
      DO 120 K=1,2
      AS=10.** (2.-K)
      DO 100 I=0,9
      AT=AB+AS*I
      J=INT(15./(R1+AT*ABS(DA)*16./60.))
      IF(J.EQ.0)GO TO 100
      CLF=7.5/J
      DLF=CLF-XLF
      IF(ABS(DLF).LT.ABS(XFM))LI=I
      IF(ABS(DLF).LT.ABS(XFM))XFM=DLF
100   CONTINUE

      IF(LI.EQ.0)GO TO 120
      IF(XFM.EQ.0)GO TO 200
      IF(XFM.GT.0)LI=LI-1
      AB=AB+LI*AS
      LI=0
120   CONTINUE

200   WRITE(10,210)AB,XFM

210   FORMAT(/"      A=",F8.2,"      +/- "
,F7.4/)
      STOP
      END

```

microterminal, which can be used to perform the following functions:

- enter and display HEX number,
- enter and display decimal number,
- calibrate α ,
- calibrate β ,
- acquire data,
- transmit data, and
- measure forward radio frequency (RF) power and reflected RF power.

A sample checkout sheet for the RR/DCP and the procedures used to exercise the RR/DCP functions are presented in Appendix D.

Once the constants are entered into the RR/DCP and the instruments are calibrated, the DCP is ready to run. Operation of the DCP can be initiated by removal of the microterminal or by removal and reapplication of power with the microterminal removed. Either way, the RR/DCP will begin to operate and will send its first transmission within 2 min.

4. DEMODULATOR/BIT SYNCHRONIZER

The key to the operation of a random reporting system is the reduction of the transmitted message overhead time required to transfer one message word. Before now, the GOES DCS message structure has been:

- 5 sec unmodulated carrier (carrier acquisition),
- 2.5 sec alternating 1's and 0's (bit synchronization),

0.15 sec frame synch word, (MLS sequence),
0.31 sec 31 bits of station identification, data (ASCII
at 100 bits/sec),
.32 sec 3 EOT words,

8.04 sec total message overhead time.

The data part of the message will require 0.12 to 20 sec depending on whether stored data techniques are used at the remote site. By far the largest portion of message overhead is in the unmodulated carrier and 1's and 0's pattern used by the demodulator to acquire carrier and bit synchronization. Therefore, it appears that the message length could be most readily reduced by decreasing those times. An increase in the data rate would also be an effective method for increasing efficiency when longer message lengths are required. Message length might be slightly decreased by eliminating the ASCII format and reworking the ID, MLS, and EOT formats.

In this effort, Sutron concentrated on applying new demodulator techniques to the reduction of carrier acquisition time and bit synchronization time. Sutron developed an approach that reduced both of these times; carrier time and bit synchronization time were each reduced to 0.5 sec.

A functional block diagram of demodulator carrier acquisition is shown in Figure 14. New circuitry was added to a standard phase-lock loop with a ramp search function. (This circuit approach is currently used in existing GOES DCS demodulators.) In this case the ramp search function* has been replaced by a circuit that measures the frequency difference between the voltage-controlled crystal oscillator

*Described in Phaselock Techniques, Floyd Gardner, John Wiley and Sons, 1966, New York, New York.

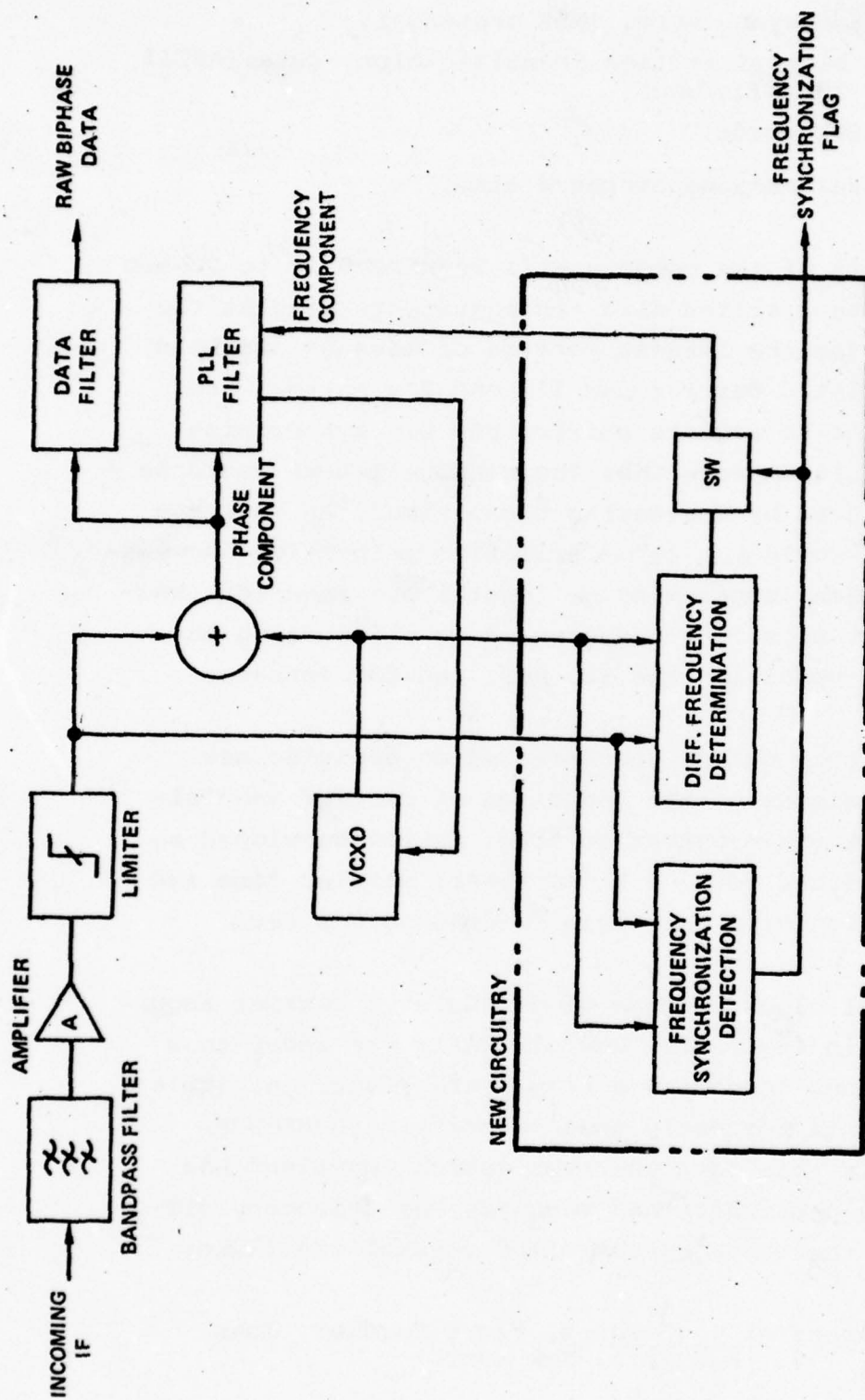


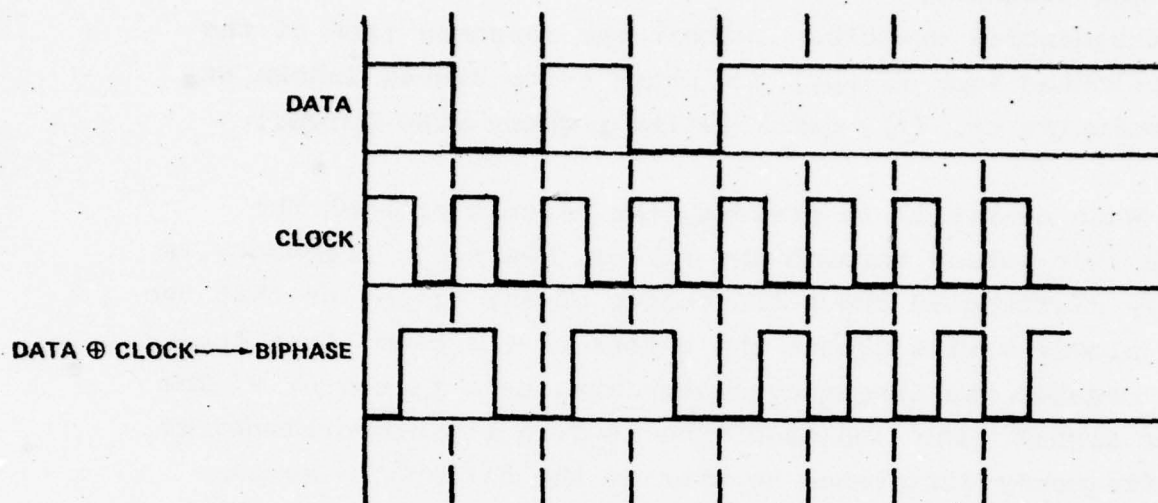
Figure 14. DEMODULATOR CARRIER ACQUISITION
FUNCTIONAL BLOCK DIAGRAM

(VCXO) and the incoming signal. Prior to frequency lock, the predominant signal that is used to drive the VCXO originates from the frequency difference detection circuit. When the two frequencies are close (within the response time of the phase-locked loop filter) the phase error signal (shown as an exclusive or, $\oplus$, gate) is the primary VCXO driver.

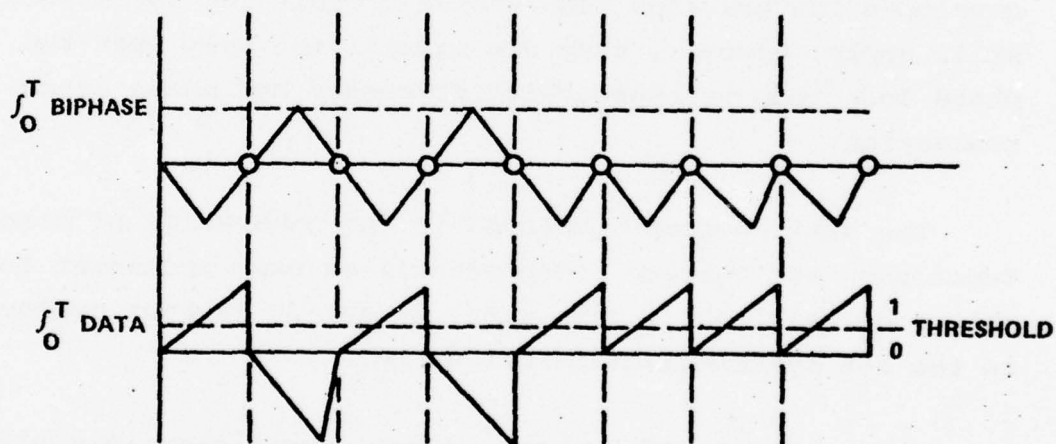
When no signal is present, the circuit acts on the noise that passes through the filter. The noise frequency is evenly distributed about the center of the filter so that the VCXO slowly varies around the center of the band. This feature reduces the frequency search area by a factor of 2. The error signal sign and magnitude is directly proportional to the frequency difference so that as the difference becomes small, the error signal decreases, which in turn decreases the rate of closing of the VCXO and signal. The equations developed for previous ramp search circuit configurations still apply; however, they are significant only when the phase lock loop is approaching frequency and phase synchronization.

The basic concept employed is the separation of circuit functions that operate independently on each pertinent information set available. This same concept is further employed in the bit synchronization circuitry.

Data are encoded at each remote transmitter in a biphasic format. The code is generated by digitally multiplying exclusive data with 100-Hz data clock. The generation of this code is shown in the top part of Figure 15, while the lower part of the figure shows the integral of the biphasic resultant and data that are in perfect bit synchronization over one clock period. The integral of $B\phi$ is zero at the end of each clock period.



BIPHASE GENERATION



CLOCK INFORMATION IS PRESENT EACH SYMBOL TIME.
CLOCK ERROR DATA DECISIONS ARE BASED ON ONE SYMBOL TIME.

Figure 15. BIPHASE DATA GENERATION AND DEMODULATION

Figure 16 is an illustration of the generation of an error signal by a clock that is lagging the remote transmitter clock which is generating the biphase data. The error causes a non-zero answer from the integral at the end of the bit period. The value of this error voltage is proportional to the degree of phase desynchronization. This integral can only have non-zero value when there is a data transition. The polarity of this lack of phase synchronization is determined by combining the output of the data integral and $B\phi$ integral.

Since a key assumption is that the clock frequency is known, the unknown to be resolved is phase synchronization. Another assumption is that if phase synchronization can be made over three bit periods, a coherent signal is present. Current remote transmitter specifications require ± 0.1 percent accuracy on the 100-Hz data clock. Since this data clock already must be generated by a crystal oscillator, it is recommended that either (a) the clock frequency be derived from the transmitter oscillator so that at the demodulator once frequency synchronization occurs, then the VCXO can provide the matching data or (b) that the specifications be modified to require data clock frequency to be accurate to within ± 0.01 percent. The latter method is more easily accomplished since 0.01 percent accurate crystal oscillators are common.

Figure 17 is a functional block diagram of the demodulator bit synchronizer and data decoder. The new element is the digital phase shifter, which is proportionally driven by the $B\phi$ integral error signal. Previous designs use a digitally stepped VCXO, an approach that produces less than optimum clock acquisition and tracking performance because the phase is unknown rather than the frequency.

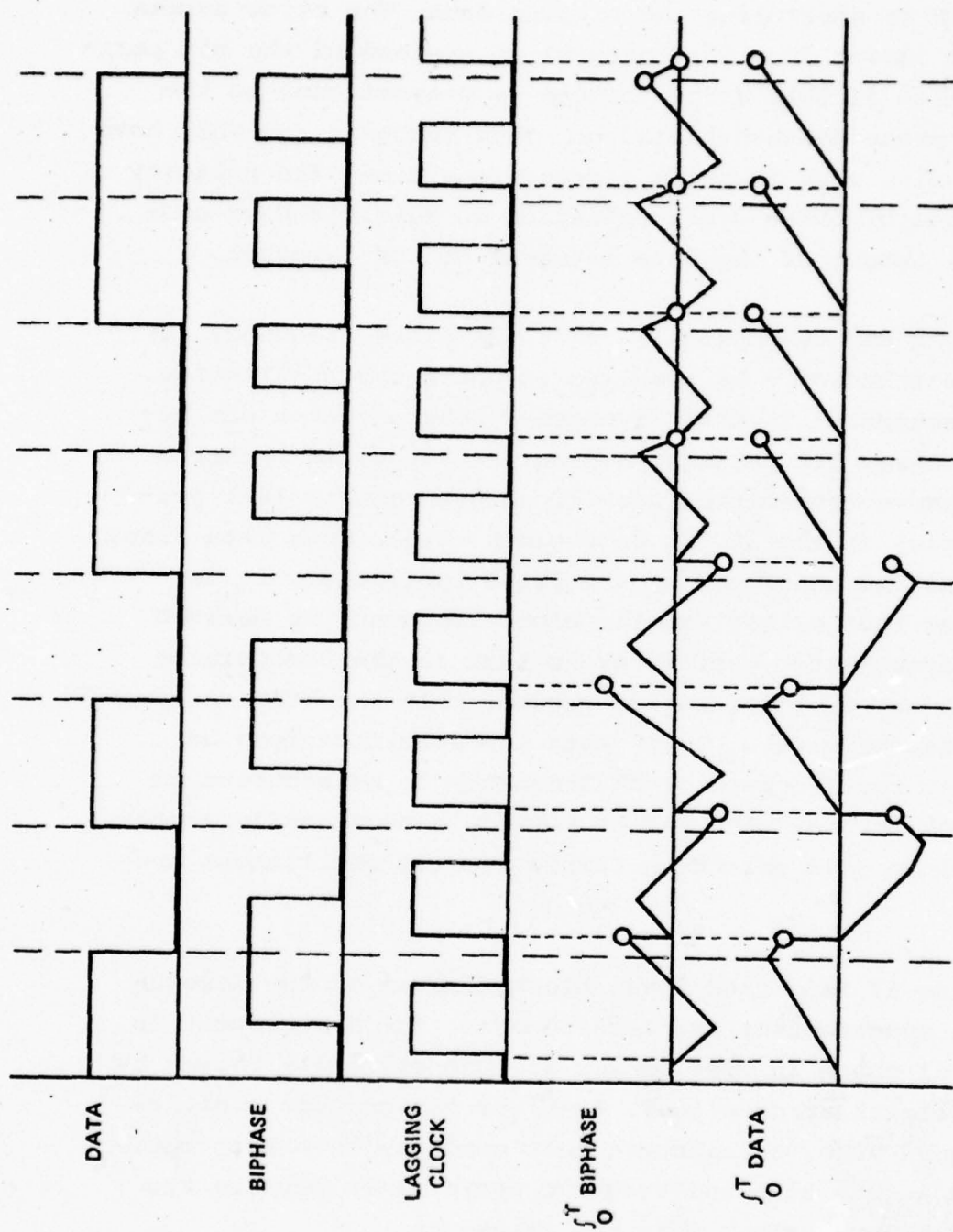


Figure 16. BIPHASE CLOCK GENERATION SYNCHRONIZATION ERROR SIGNAL

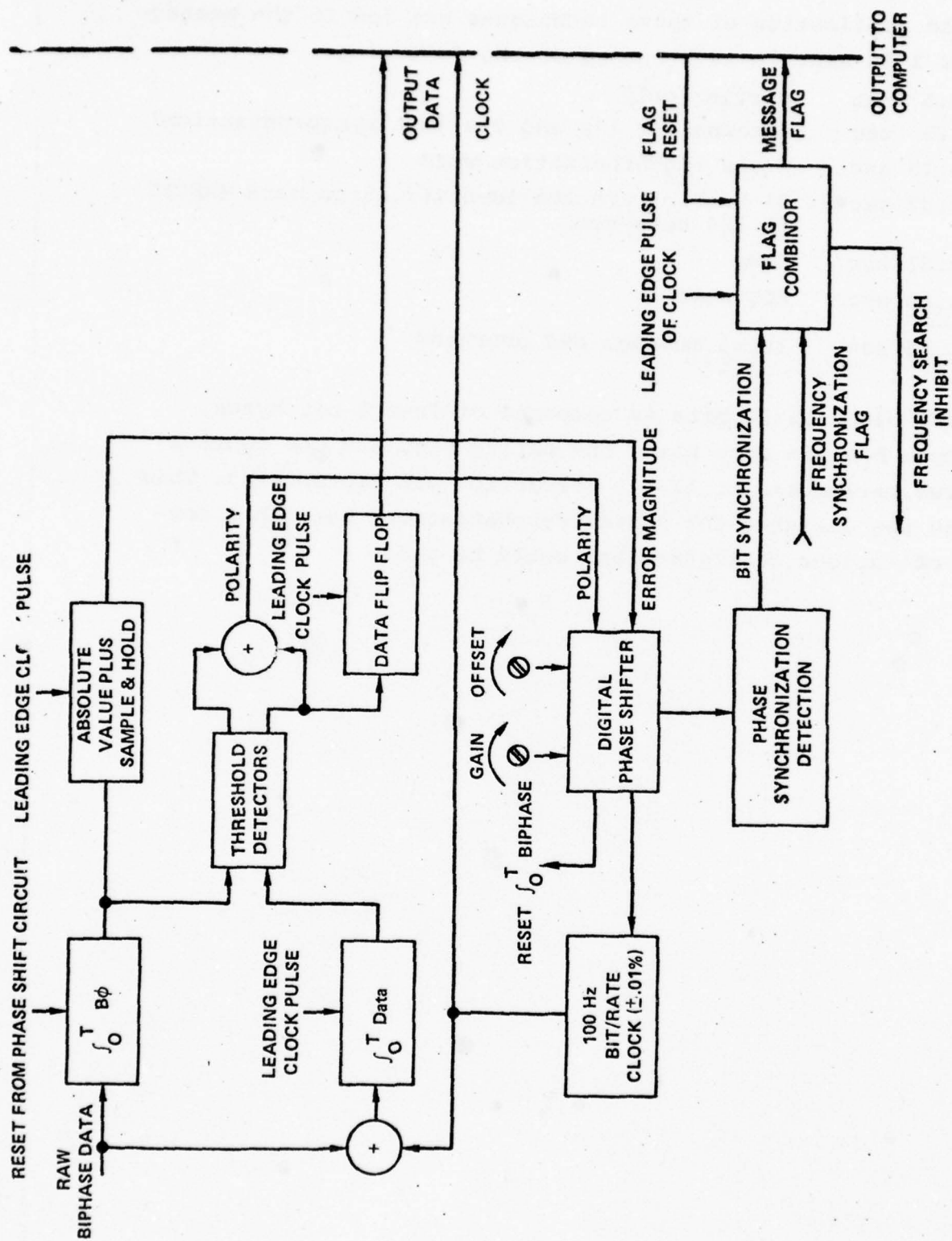


Figure 17. FUNCTIONAL BLOCK DIAGRAM OF DEMODULATOR
BIT SYNCHRONIZER AND DATA DECODER

The application of these techniques has led to the message size of 1.86 sec. It is composed of the following:

0.5 sec	carrier only
0.5 sec	alternating 1's and 0's (bit synchronization)
0.15 sec	frame synchronization word
0.31 sec	31 bits of station identification data (ASCII at 100 bits/sec)
0.32 sec	data
0.08 sec	EOT word
1.86 sec	total message and overhead

The data block of 32 bits is composed of four 8-bit bytes. Each byte has six data bits, one parity bit, and one control bit. Two parameters of 12-bit resolution are transmitted. This message was designed for system demonstration, but other messages of various configurations could be used.

V. ERROR DETECTION AND CORRECTION

Each bit decision i.e., the decision whether the symbol period contains a 1 or 0 is made over one-clock period only. The energy is integrated over the entire period and a 1 or 0 decision is made based on the value of the integral. Figure 16 graphically shows the development of that integral which is identified by the $\int^T$ data terminology. The value of that integral also shows the likelihood or probability that a correct decision was made. By observing the output of that circuit on an oscilloscope, one can assess the quality of the message. Assigning value equal to the integral value to that bit in addition to the one/zero symbol would add a quality indicator to each bit which would point to message areas that would have a high probability of error.

Each data byte also includes an odd parity bit plus a bit which is always a one. Checking these bits is also an error indicator.

Probably one of the best overall indicators is to compare the received parameter value with that received in previous messages coupled with an expected parameter change over the given time period. Expected parameter change could be derived from known situation configurations and data derived from interstation relationships, e.g., a station located upstream or downstream from the station in question.

Further improvements in error detection/correction can only be attained through the addition of information to the transmitted message. This can take the form of additional parity data which could be used to correct single bit errors per 64-bit block or of convolutionally encoding transmitted

data so that bit decisions could be spread over greater than one clock period. Operating a decoder (such as that offered by Linkabit Corp.) uses an integration length of 7-clock periods and a code rate of 2, i.e., two bits are transmitted for every data bit. This has the disadvantage of requiring twice as much data to be transmitted (3 dB data rate loss) but since error correction can be made, there is a design gain of 4.6 dB in equivalent signal-to-noise performance for a net gain of 1.6 dB.

Automatic monitoring of signal quality indicators such as the bit decision integral can be used to operate a directed maintenance program which may significantly alleviate the problem of data loss caused by malfunctioning remote sites.

VI. RANDOM REPORTING TEST DEMONSTRATION

The culmination of the Sutron design and development of a random reporting data collection system was a demonstration of the reception of data from the equivalent of at least 200 remote sites transmitting twice an hour. This demonstration was performed in conjunction with the New England Division of the U.S. Army Corps of Engineers GOES DCS downlink at Waltham, Massachusetts. The receiving dish size was 15 feet; the preamp had a 280°K noise temperature; and the phase-lock receiver was designed by FG Engineering, Inc. The probability of successful reception of a single message was 0.684 (i.e., the probability of failing to receive one message would be 0.316; this would provide a probability of 0.90 of receiving data from a given station in 1 hr if the remote unit transmitted twice an hour). Three transmitters were programmed to randomly transmit 160 times an hour with a 1.86-sec message. The theoretical probability of successfully receiving each transmitted message is calculated to be 0.69. Before each remote station transmission, a counter was incremented once and transmitted as the precipitation reading so that the number of transmissions from each remote unit was known. A sample of the received data is shown in Table 5. In total, about 8,000 messages were transmitted over a 2-day test period. An hourly summary of these data is presented in Appendix E.

Two data periods - 0700 to 0803 on 12/7/78 and 0610 to 0730 on 12/8/78 - were closely analyzed. Summary data on the 12/7 period is shown in Table 6. Of the 386 transmissions sent, 287, or 74.4 percent, were successfully received. Figure 18 is a plot of 10-min groupings of performance during the 8 December

Table 5. SAMPLE OF DATA COLLECTED DURING THE RANDOM REPORTING TEST DEMONSTRATION

Received ID	Demodulator Channel No.	Date	Reception Time	Raw Hex Data	Transmission Count	Stage Input
9950575E	4	12/ 7/78	22:19:51	52C452E904 PPT=	2.74	STAGE= 26.42
9950574E	4	12/ 7/78	22:20:16	7661404004 PPT=	21.66	STAGE= 0.00
9950574E	4	12/ 7/78	22:20:31	F761404004 PPT=	21.67	STAGE= 0.00
9950575E	4	12/ 7/78	22:20:46	D3C452E984 PPT=	2.75	STAGE= 26.42
9950574E	4	12/ 7/78	22:21:11	F861404004 PPT=	21.68	STAGE= 0.00
9950575E	4	12/ 7/78	22:21:34	54C452E904 PPT=	2.76	STAGE= 26.42
9950574E	4	12/ 7/78	22:21:43	7961404004 PPT=	21.69	STAGE= 0.00
9950575E	4	12/ 7/78	22:21:54	D5C452E904 PPT=	2.77	STAGE= 26.42
9950574E	4	12/ 7/78	22:21:59	FB61404084 PPT=	21.71	STAGE= 0.00
9950574E	4	12/ 7/78	22:22:13	7C61404004 PPT=	21.72	STAGE= 0.00
9950575E	4	12/ 7/78	22:22:24	D6C452E904 PPT=	2.78	STAGE= 26.42
9950534E	4	12/ 7/78	22:22:48	FD61404004 PPT=	21.73	STAGE= 0.00
9950573E	4	12/ 7/78	22:22:50	E0C4404004 PPT=	2.89	STAGE= 0.00
9950575E	4	12/ 7/78	22:22:58	57C452E904 PPT=	2.79	STAGE= 26.42
9950573E	4	12/ 7/78	22:23: 7	61C4404000 PPT=	2.89	STAGE= 0.00
9950574E	4	12/ 7/78	22:23:43	FE61404004 PPT=	21.74	STAGE= 0.00
9950575E	4	12/ 7/78	22:23:53	DAC452E906 PPT=	2.82	STAGE= 26.42
9978574E	4	12/ 7/78	22:24:36	7765444006 PPT=	24.23	STAGE= 0.04
9950554E	4	12/ 7/78	22:25:26	4062404004 PPT=	21.76	STAGE= 0.00
9950574E	4	12/ 7/78	22:25:29	C162404004 PPT=	21.77	STAGE= 0.00
9950574E	4	12/ 7/78	22:25:37	C262404004 PPT=	21.78	STAGE= 0.00
9950574E	4	12/ 7/78	22:25:41	4362404044 PPT=	21.79	STAGE= 0.00
9950574E	4	12/ 7/78	22:26:10	D462404004 PPT=	21.96	STAGE= 0.00
9950575E	4	12/ 7/78	22:26:21	5EC452E904 PPT=	2.86	STAGE= 26.42
9950574E	4	12/ 7/78	22:26:24	4562404004 PPT=	21.81	STAGE= 0.00
9950574E	4	12/ 7/78	22:26:49	4562404004 PPT=	21.82	STAGE= 0.00
9950575E	4	12/ 7/78	22:27:12	DFC452E984 PPT=	2.87	STAGE= 26.42
9950574E	4	12/ 7/78	22:27:39	C762404004 PPT=	21.83	STAGE= 0.00
9950575E	4	12/ 7/78	22:28: 9	E0C452E984 PPT=	2.88	STAGE= 26.42
9950575E	4	12/ 7/78	22:28:27	61C452E904 PPT=	2.89	STAGE= 26.42
9950574E	4	12/ 7/78	22:28:34	C862404004 PPT=	21.84	STAGE= 0.00
9950575E	4	12/ 7/78	22:28:37	4C452E904 PPT=	2.90	STAGE= 26.42
9950575E	4	12/ 7/78	22:28:57	3C452E904 PPT=	2.91	STAGE= 26.42
9950574E	4	12/ 7/78	22:29: 5	4962404084 PPT=	21.85	STAGE= 0.00
9950575E	4	12/ 7/78	22:29:25	E5C452E904 PPT=	2.93	STAGE= 26.42
9950574E	4	12/ 7/78	22:29:49	4A62404004 PPT=	21.86	STAGE= 0.00

Table 6. SUMMARY DATA TAKEN ON 7 DECEMBER 1978

Transmitter Identification	Transmissions	Number Received	Percent Received
995C575E	137	87	0.635
995C574E	122	103	0.844
995C571E	127	97	0.764
Composite	386	287	0.744

Theoretical Probability (from Eq. 1):

$$P_s = e^{\frac{-2tm}{T}} \quad (\text{Eq. 1})$$

$$M = 3;$$

$$t = 1.86; \text{ and}$$

$$T = \frac{3767}{386} = 9.76 \text{ sec for three sites or } 29.28 \text{ for one site}$$

$$P_s = e^{\frac{-(2)(3)(1.86)}{29.28}} = e^{-0.381} = 0.683$$

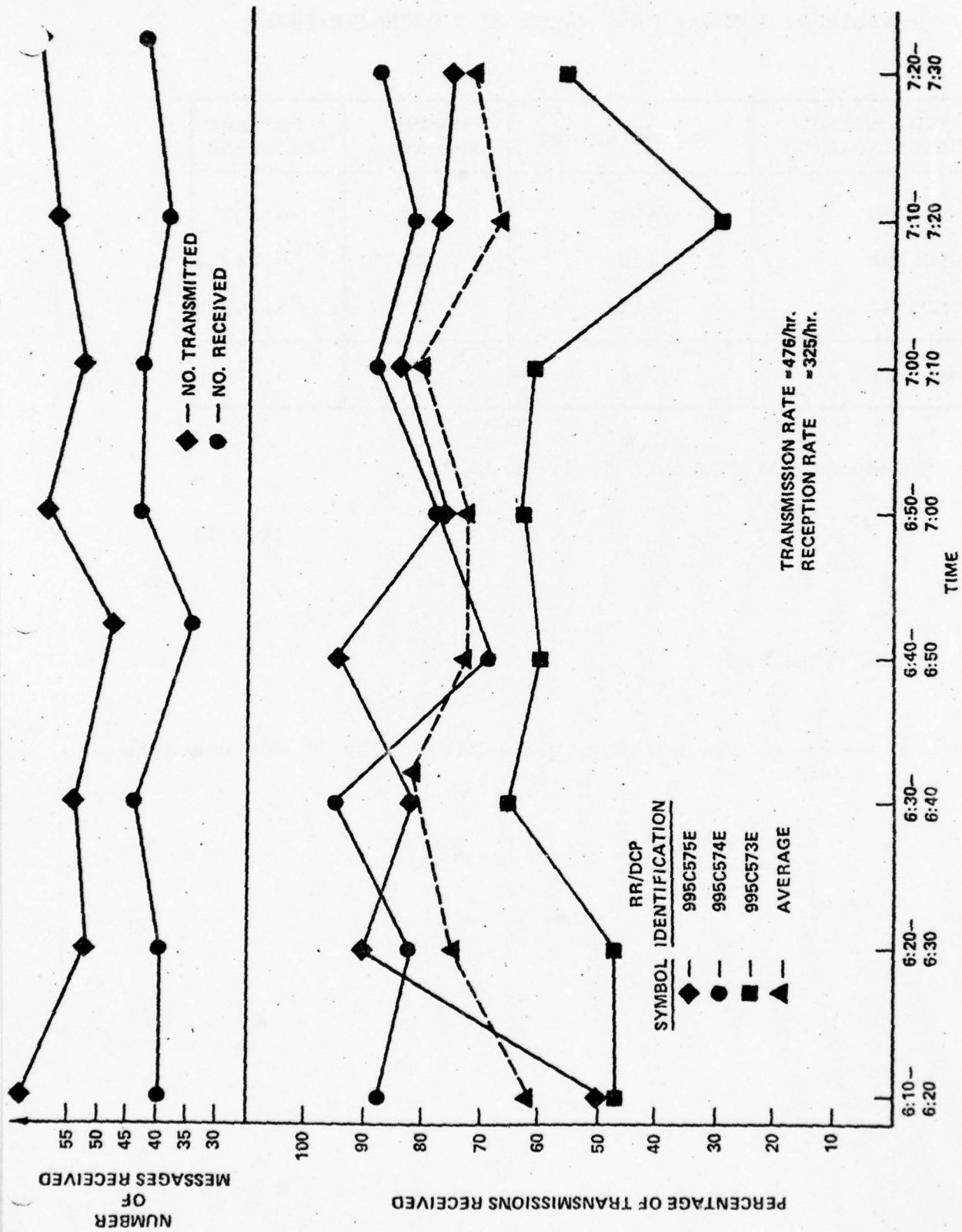


FIGURE 18: RANDOM REPORTING PERFORMANCE TEST

period. Summary calculations for this period are made in Table 7. Theoretical calculations indicated that 68.9 percent of data should have been received, and 68.3 percent of the data were received during this experiment period. Thus, theory and experimental results are in very close agreement.

Table 7. THEORETICAL COMPUTATIONS (FROM EQ. 1)

$$P_s = e^{\frac{-2tM}{T}} \quad (\text{Eq. 1})$$

$$t = 1.86 \text{ sec}$$

$$T_{\text{system}} = \frac{80 \times 60 \text{ sec}}{476 \text{ transmissions}} = \sim 10 \text{ sec}$$

$$T_{\text{unit}} = 30 \text{ sec}$$

$$M = 3$$

$$P_s = \frac{-(2) (1.86) (3)}{30} = e^{-0.372} = 0.689$$

$$P_s \text{ (theoretical)} = 0.69$$

$$P_s \text{ (experimental)} = \frac{325}{476} = 0.683$$

Two practical phenomena were observed but did not seem to significantly impact the overall results.

- (1) The effective message length is expected to be slightly less than 1.86 sec since frequency acquisition takes place in less than the allotted 0.5 sec and lost EOTs are not seen. $T_{\text{eff}} = 1.7 \text{ sec} + P_s = 0.71$. This may be affected somewhat by the release time of the demod ; and
- (2) transmitter 3E was at times over ridden by 5E or 4E which had stronger power output.

VII. SUMMARY

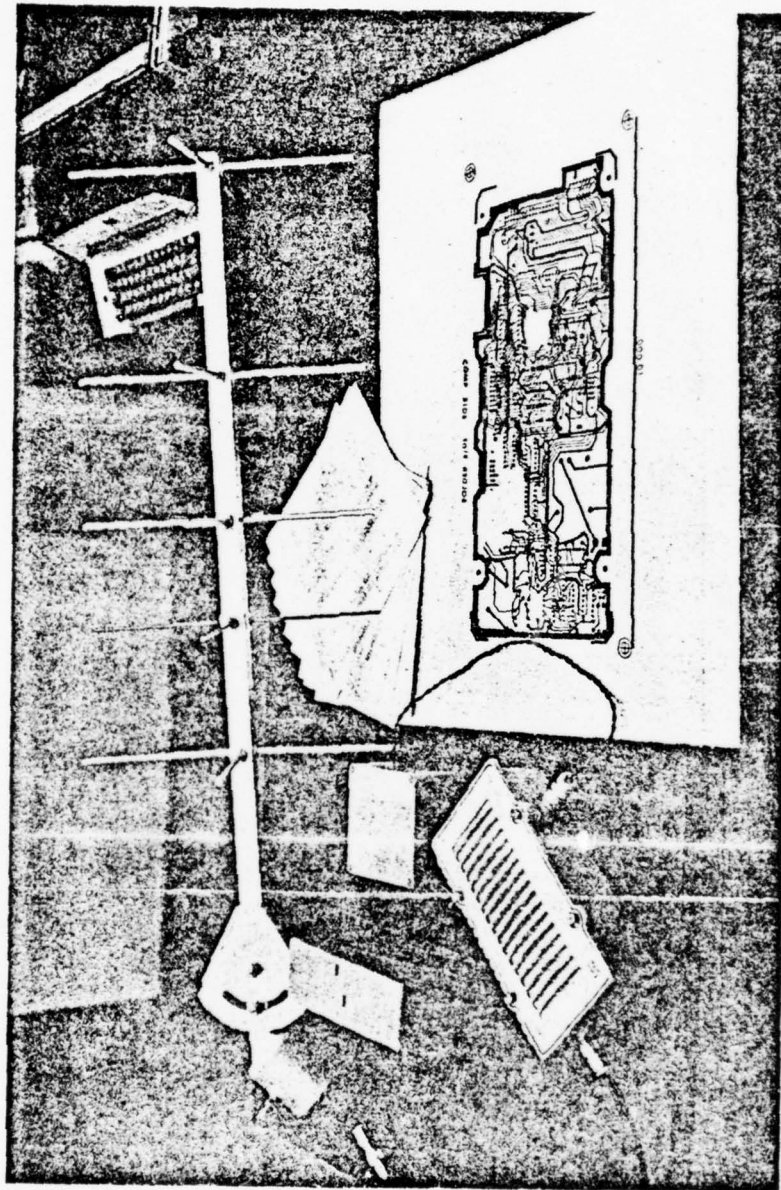
The demonstration of random reporting showed that the probability equations used to describe system performance are credible; experimental and theoretical results were virtually identical. Any further improvements in reducing the message length can be calculated from the theoretical equations given.

The addition of adaptive capability to the remote platform permits tailoring of data throughput to parametric activity. This tailoring results in improved communication channel usage as well as in improved response time to events of interest. This response time, i.e., time to receipt of data, may be as short as a few minutes. Total channel performance given in Figures 5 and 6 show the relative safety in determining remote site reporting rate algorithm coefficients. Even if the average reporting rate is somewhat higher than expected, no disaster will befall the channel performance; only slow degradation will take place.

The performance achieved exceeds that required in the modified statement of work, i.e., from a field of 240 stations operating at two transmissions per hour, the probability of message reception in any given hour for a single station will be 90 percent. This was demonstrated by an equivalent system configuration. An experimental value of probability of failure of one message was 0.316, which gives a probability of failure from the reception of any two messages to be $(.316)^2$ or 10 percent, the resultant probability of success to be 90 percent. Better channel performance can be achieved by defining the observed throughput in terms of average throughput per transmitter. In this case, about 325 transmitters could be accommo-

dated per channel, transmitting at an average rate of two transmissions per hour.

Development of adaptive random reporting operation resulted in a remote transmitter which has considerably reduced parts count (19 small-scale integrated circuit packages and 10 large-scale integrated circuit (IC) packages, total circuit board area required is about 120 in.² - previous implementation required about 78 IC's and 240 in.² of circuit board area) and reduced power consumption. Power consumption required by self-timed units is about 250 milliwatts and for the random reporting unit reporting twice per hour is about 36 milliwatts - a sevenfold improvement. Power consumption to one-half this value is reasonable to expect with some further development.



ADAPTIVE RANDOM REPORTING DCP

APPENDIX A

DISCUSSION OF ADAPTIVE RANDOM REPORTING

The equation that describes adaptive random reporting system performance was derived in the Computer Sciences Corporation* (CSC) study done for the National Aeronautics and Space Administration (NASA) LANDSAT Data Collection System. It takes into account spectral as well as time dispersion. Since Sutron is considering only one-channel operation, time dispersion is of interest. If more than one demodulator is operated on a channel, it would be feasible to consider increasing channel capacity by spectral dispersion. However, this can only be accomplished if some improvement can be made in the modulation technique to reduce spectral splatter caused by binary phase modulation.

If one data collection platform (DCP) is transmitting, there is a finite probability that a second DCP transmission may interfere with the first. If there is no relationship between the two transmission times, the probability of failure is**

$$Pf_1 = \frac{2t}{T}$$

and

$$\bar{P}f_1 = 1 - \frac{2t}{T}$$

* ERTS-A Data Collection System Description, prepared for NASA Goddard Space Flight Center, Contract No. NAS-5-11242, Computer Sciences Corporation.

**Ibid.

where

t = transmission time and

T = remote transmitter off time.

The probability of no interference from M DCPs is

$$P_{sm} = (\bar{P}f_1)^M \quad \text{probability of successful reception in a field of } M \text{ interferers}$$

where

$$\begin{aligned} P_{sm} &= \text{probability of successful reception in a field of } M \text{ interferers and} \\ M &= \text{the number of interfering transmissions.} \end{aligned}$$

The probability of being interfered with by M DCPs is

$$P_{fm} = 1 - P_{sm} = 1 - (\bar{P}f_1)^M = 1 - \left(\frac{2t}{T}\right)^M$$

where

$$P_{fm} = \text{the probability of failure in a field of } M \text{ interferers.}$$

If one DCP tries to transmit n times during the observation period, then

$$\bar{P}_{fm} = \{1 - (1 - \frac{2t}{T})^M\}^n.$$

Now from series expansion, where $\alpha = \frac{2t}{T}$,

$$(1-\alpha)^M = 1 - \alpha M + \frac{\alpha^2}{2} M (M-1) - \frac{\alpha^3}{2} (M) (M-2).$$

If M is large, then

$$(1-\alpha)^M = 1 - \alpha M + \frac{\alpha^2 M^2}{2} - \frac{\alpha^3 M^3}{3} + \dots,$$

which is the same expansion as $e^{-\alpha M}$. Now substituting back

$$P_{fm} = (1 - 3\frac{-2tM}{T})^n.$$

As can be seen, the object of this exercise is to develop a manageable equation that is generally applicable. Since it is possible to select the observation period (unlike a polar orbiting satellite), we need go no further with the development of the equation. Now the probability of successfully receiving a single message is (m suffix dropped)

$$P_s = 1 - P_f$$

or

$$P_s = 1 - (1 - 3 - \frac{2tM}{M})^n$$

where

P_s is the probability of successfully receiving a transmission in a given observation time,

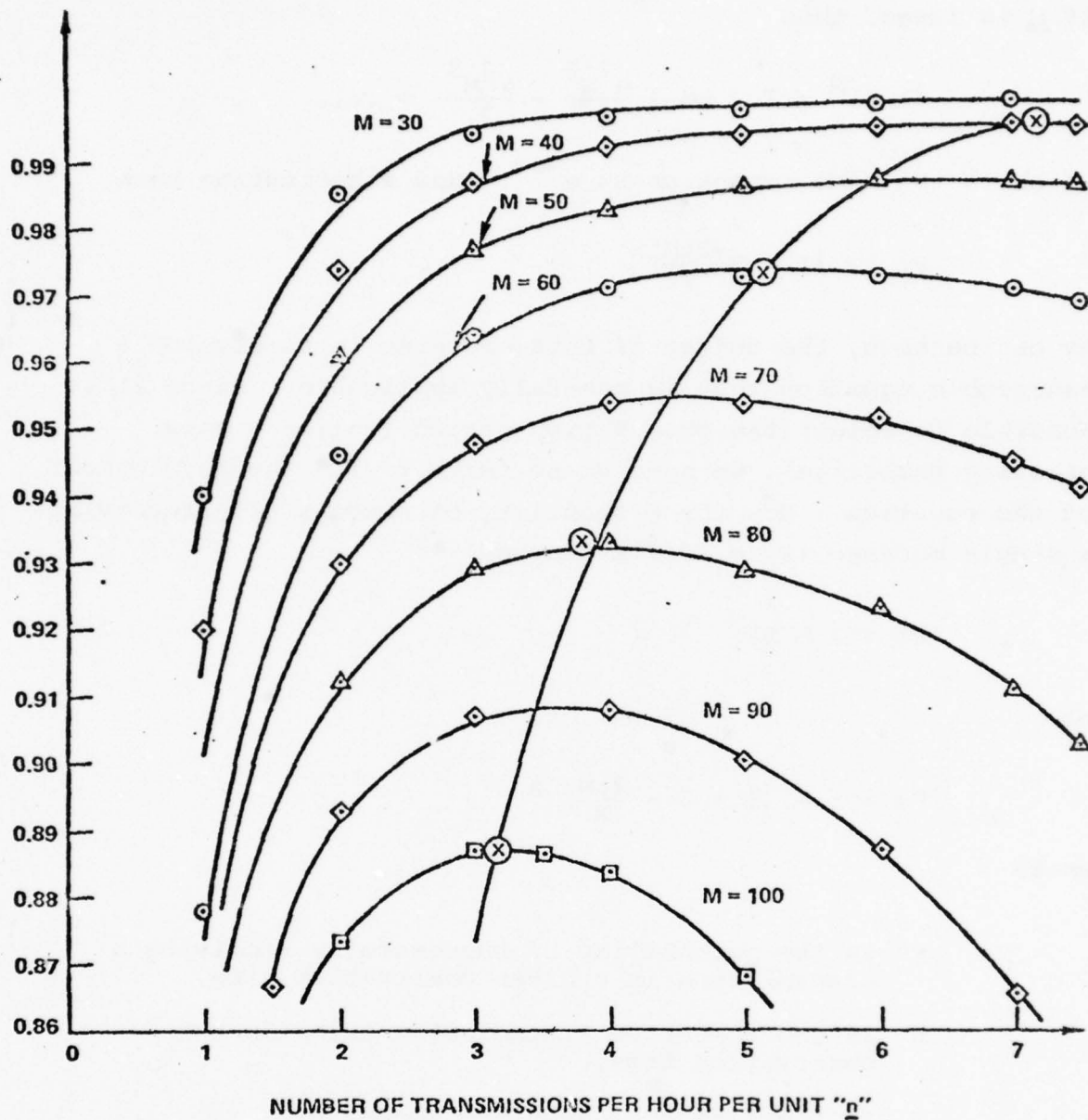
n is the number of transmission tries in the observation time,

t is the length of each transmission,

T is the time interval between transmissions, and

M is the number of transmitters operating in the channel of interest.

The following two curves are different presentations of this equation. A few example calculations for Figure 1 are:



(X) = LOCUS OF OPTIMUM " n "
 M = NUMBER OF UNITS PER CHANNEL

Figure 1
 Plot of $P_s = (1 - e^{-\frac{2tM}{T}})^n$
 n = variable 1-7
 M = variable 30-100
 t = 4 sec
 T = 3600 sec/ n

Example 1: $n = 2$ $t = 4$
 $M = 100$ $T = 3600/2 = 1800$

$$\begin{aligned} P_s &= 1 - (1 - e^{-(2 \times 4 \times 100) - 1800})^2 \\ &= 1 - (1 - e^{-.444})^2 = 1 - (1 - .64)^2 \\ &= 1 - (.36)^2 = 1 - .128 \end{aligned}$$

$$P_s = .872$$

Example 2: $n = 3$ $t = 4$
 $M = 50$ $T = 3600/3 = 1200$

$$\begin{aligned} P_s &= 1 - (1 - e^{-(2 \times 4 \times 50) - 1200})^3 \\ &= 1 - (1 - e^{-.333})^3 = 1 - (1 - .717)^3 \\ &= 1 - (.283)^3 = 1 - .023 \end{aligned}$$

$$P_s = .977$$

For a fixed regime random reporting system this curve suggests that for a maximum throughput about three transmissions per window are required but, if slightly lower throughput is permissible by 1 or 2 percent, then power consumption can be reduced by about 30 percent. If too many messages are transmitted, throughput can actually decrease, but not sharply.

Figure 2 uses the probability of failure of a single message as a performance index for a fixed regime random reporting system. These curves can be read several ways. First, select a desired P_f and read up to the number of permissible stations reporting a four-second message three times per hour; e.g., if $P_{f_1} = .5$;

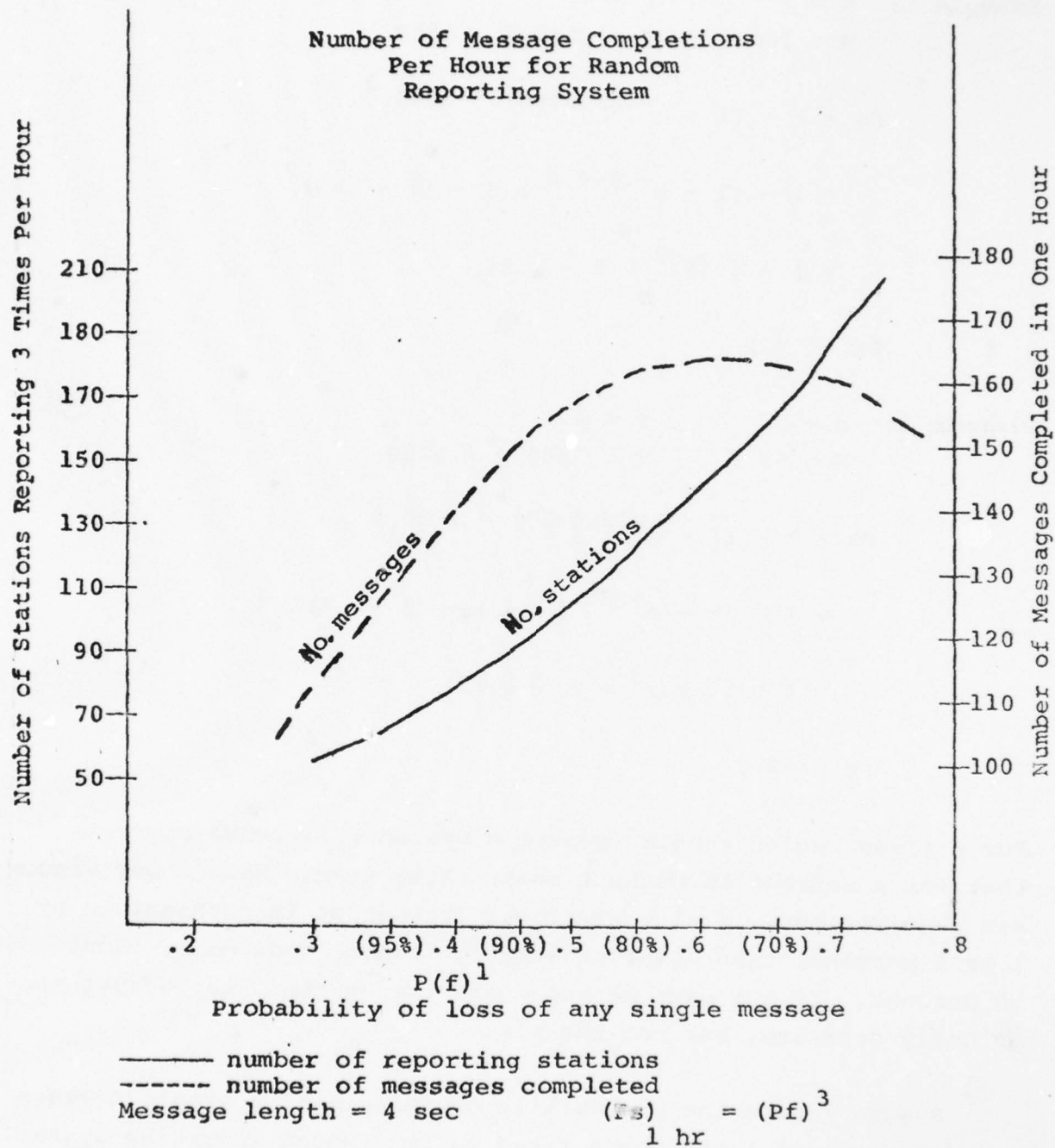


Figure 2. RANDOM REPORTING DCS SYSTEM THROUGHPUT

$M = 100$, number of completed messages = 150, and if M is selected as 150, $Pf_1 = .68$, and the number of completed messages is 160. Two calculation examples are:

Example 1:

$$Pf_1 = 1 = 3^{-2tM/T}$$

$$e^{-2tM/T} = 1 - Pf_1$$

$$\frac{-2tM}{T} = \ln (1 - Pf_1)$$

$$M = \frac{T}{2t} \ln (1 - Pf_1)$$

for $Pf_1 = .5, t = 4, T = 1200$

$$M = - \frac{1200}{8} \ln (.5) = -150 (\ln .5)$$

$$M = -\ln (-.69) = 104$$

If a large number of transmission samples are made then the total number of received messages for a sample period is the total number of messages transmitted times the probability of successful reception. For this case:

$$N_R = (.5) (104) (3) = 156$$

Example 2:

$$M = 150, t = 4, T = 1200$$

$$Pf_1 = 1 - e^{-2tM/T} = 1 - e^{-(2 \times 4 \times 250) - 1200}$$

$$Pf_1 = 1 - .368 = .632$$

$$\text{Total messages } N_R = (1 - .632)(150 \times 3)$$

$$N_R = 166$$

These numbers approximately agree with those picked from the curves.

Figure 3 shows the cumulative probability of reception of a single DCP operating in a fixed regime three messages per hour mode. For a system with 104 DCPs operating on a channel where $Pf_1 = .5$, 50 percent of each group of 10 messages will have 5 or more completed messages, and also 10 percent of each group of 10 will have 7 or more and 90 percent will have 3 or more messages complete, or otherwise stated there is about a 90 percent change of receiving one of three transmissions. From these three curves, the nature of any fixed regime random reporting design can be determined by manipulating the exponential coefficient $\frac{2tM}{T}$. For example, the coefficient will be identical if t is multiplied by one-half and M multiplied by two.

To verify that this equation is correct a hypothetical fixed regime system was modeled using computer generated random numbers.

The characteristic equation for the random reporting system is:

$$P_s = 1 - (1 - e^{-2tM/T})^n$$

Although this equation accurately describes system performance, an actual model of the system performance would provide better evidence that it does work.

The system design gives the following calculated values
when $M = 130$, $P_s = 0.927$

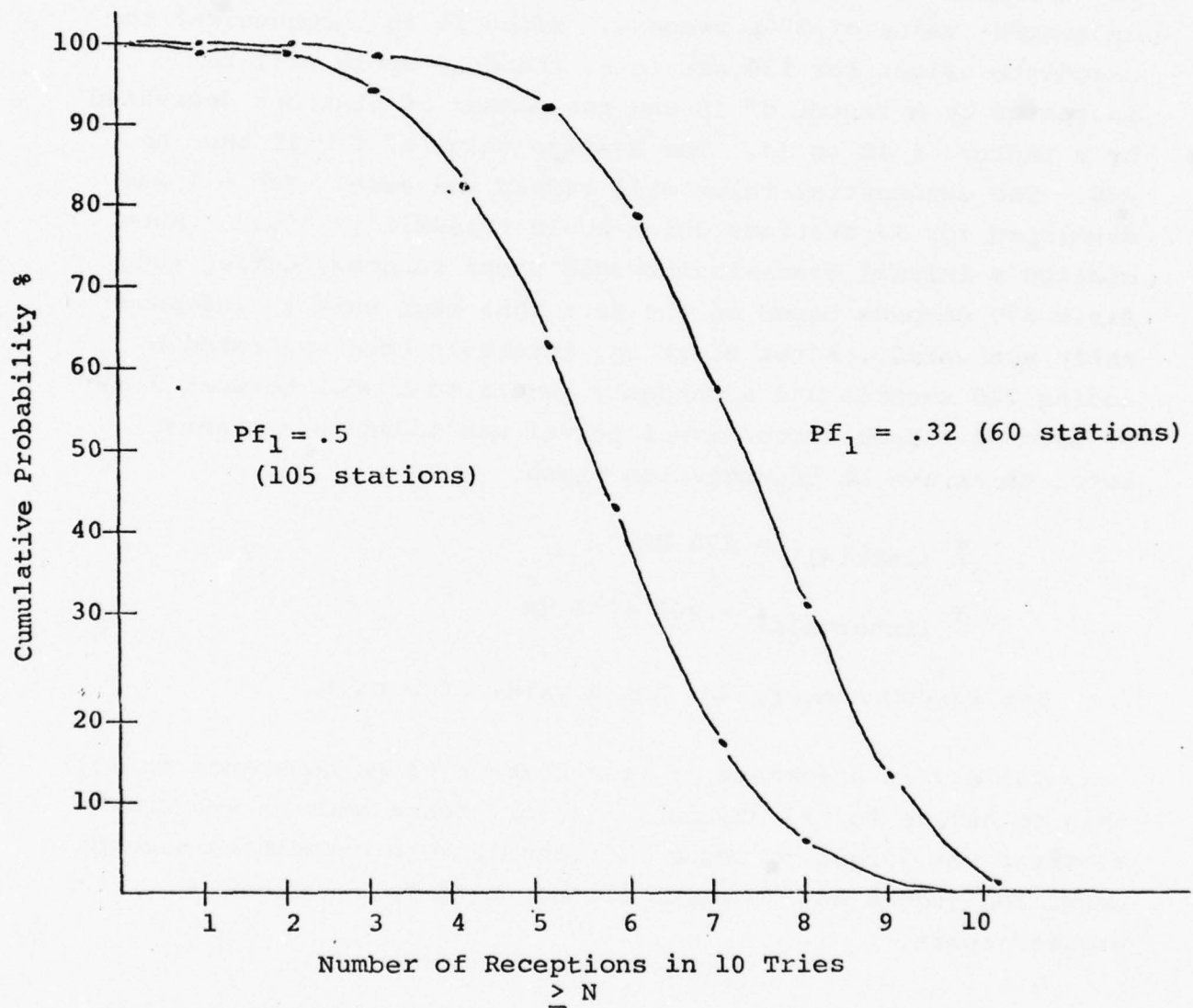


Figure 3. CUMULATIVE PROBABILITY FOR RECEPTION $\geq N$
IN 10 TRIES FOR A SINGLE DCP

$n = 2,$	$P_{f1} = 0.27$	Observation Time
$T = 2700 \text{ sec},$	$P_{fs} = 0.073$	$= 1\frac{1}{2} \text{ hour}$
$t = 3.4 \text{ sec},$	$P_{f3} = 0.0188$	

The approach is to generate random transmission intervals with an average value of 2700 seconds. Since it is inconvenient to calculate values for 130 stations, the duty cycle will be increased by a factor of 10 and the number of stations decreased by a factor of 10 to 13. The average value of T will then be 270. The exponential value will remain the same. Table 1 was developed for 13 stations which would transmit 13 times. Each station's initial transmission would occur randomly during the first 270 seconds based on the fact that each unit is independently activated. After start up, intervals were generated by adding 243 seconds and a randomly generated number between 0 and 54 seconds. Each successive interval was added to a running total to arrive at transmission times.

$$T \text{ (initial)} = 270 \text{ NR}$$

$$T \text{ (intervals)} = 243 + 54 \text{ NR}$$

The random number, NR, has a value of 0 to 1.

Table 2 is a summary of transmission times generated using this technique for 13 stations. Interference between two transmissions was judged to occur if transmissions were three seconds apart and judged not to occur if they were four seconds or greater apart.

A total of 45 transmissions were interfered with, and two transmissions interfering twice in a row occurred ten times. Dividing these numbers by the number of possible transmissions gives:

$$Pf_1 = 0.266, Pf_2 = 0.064, Pf_3 = 0.019.$$

Table 1. RANDOM TRANSMISSION TABLE

No. Failed Transmissions	Unit No.	Transmission No.												
		1	2	3	4	5	6	7	8	9	10	11	12	13
	1	15	299	576	834	1077	1373	1628	1904	2159	2455	2736	3033	3316
2				X							□			
	2	118	395	658	953	1238	1490	1755	2000	2292	2540	2825	3119	3375
4						X		X	X				X	
	3	195	433	722	998	1214	1533	1795	2061	2328	2584	2838	3084	3349
1			X											
	4	166	433	691	938	1231	1475	1729	1982	2276	2568	2861	3118	3390
3			X								X		X	
	5	243	535	790	1053	1307	1551	1847	2111	2403	2695	2942	3217	3510
5		X			X	O	X		O					
	6	201	457	705	962	1235	1483	1757	2002	2298	2566	2809	3105	3363
7					O	X		X	X		X	X		X
	7	172	435	678	964	1218	1465	1738	1935	2258	2514	2807	3072	3358
3			X		O							X		
	8	64	329	57	845	1132	1419	1697	1964	2241	2526	2801	3088	3362
2				X										
	9	245	519	794	1047	1290	1548	1842	2114	2360	2614	2908	3182	3448
6		X	O		□		O		O				O	
	10	219	516	810	1056	1348	1635	1889	2181	2458	2705	3001	3255	3521
4		O	O		X					□				
	11	152	437	734	992	1284	1547	1834	2118	2366	2643	2887	3179	3475
3			X				O						O	
	12	206	499	772	1058	1304	1552	1826	2103	2387	2663	2917	3191	3461
3					X	O	X							
	13	221	506	754	1049	1315	1599	1872	2129	2382	2677	2973	3228	3491
2		O			□									
45	No. Interfered With	4	6	2	7	4	4	2	4	1	3	2	4	2

$$P_{f1} = \frac{45}{169} = 0.266$$

$$P_{f2} = \frac{10}{156} = 0.064$$

Rule: Within 3 Sec. Have Interfered
4 Sec. or Greater No Interference

X }
O } Denotes Transmission Interfered With
□ }

The results from the random model are extremely close to the calculated answers. If additional stations and a greater number of transmissions were calculated, the number of interferences per station will be closer to calculated values.

ADAPTIVE RANDOM REPORTING

Now that a fixed regime random reporting network has been fully described, it is fairly easy to make the jump to an adaptive rate random reporting system if the randomness hypothesis is maintained, i.e., even if a station transmits at a higher rate, it is equivalent to two stations transmitting at a one-half rate. From the previous curve, Figure 2, it can be seen that a random reporting channel can be said to be at maximum utilization when 160 stations are transmitting at three times an hour a four-second message, or otherwise stated 480 messages transmitted, one-third received, 1920 seconds total on transmitter time, for a total approximate channel busy time of 50 percent. A more power conservative operating region is to operate at an equivalent 104 station load, or about 312 messages per hour transmitted with 156 receptions and a 50 percent probability of reception of each transmitted message. This channel characterization would be true for any mix of DCPs which randomly generate 312 messages of four-second length per hour.

APPENDIX B

DEMODULATOR ENGINEERING SPECIFICATIONS

INPUT

Frequency - Pilot tone center is at 10.000 MHz. Each input channel is located with respect to the 10 MHz intermediate frequency

Power: 0 dBm to -40 dBm

Power Supply - +5 volts at 5% tolerance

+5 volt requires .4 amps

-5 volt requires .2 amps

Performance - Carrier acquisition time - <.5 sec with incoming frequency within $\pm$ 600 Hz of channel center.

Bit synchronization time - <.5 sec with incoming data rate within .1% of 100 Hz clock rate.

Signal/noise - performance dependence on signal to noise ratio of incoming signal not as yet established.

OUTPUT

3 lines presented to a serial computer port which is interrupt driven.

Line #1 - Data - positive logic

Line #2 - Interrupt flag - negative logic - The presentation

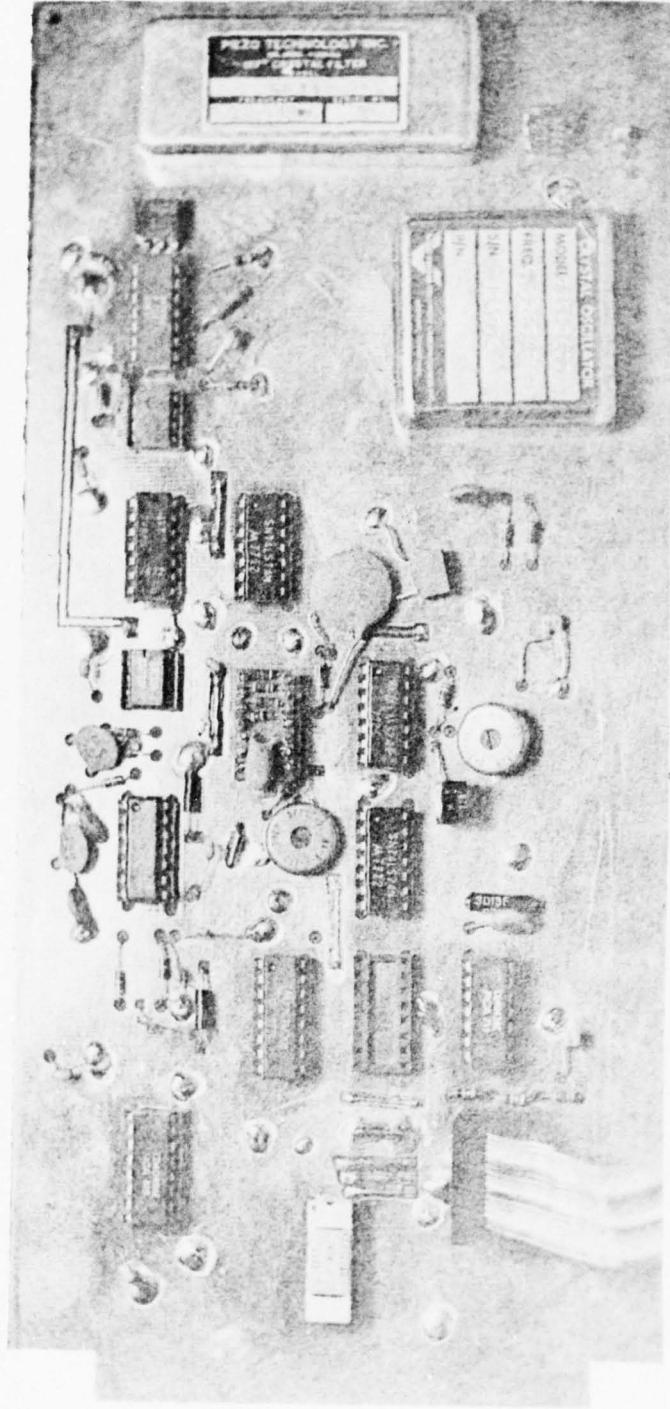
of this flag means that both frequency and bit synchronization are present and that data has been clocked into the output flip-flop. The computer has 10 milliseconds (one clock period) to acquire this data bit.

Line #3 - Reset line negative logic after acquiring the data bit from the data line a 10 microsecond react pulse is required to reset the interrupt flag.

10 MHz FRONT END

PLL FILTER

FREQUENCY LOCK
DECISION CKTS



FREQ DIFF
D/A CONVERSION

Figure B-1. DEMODULATOR CARRIER ACQUISITION CARD

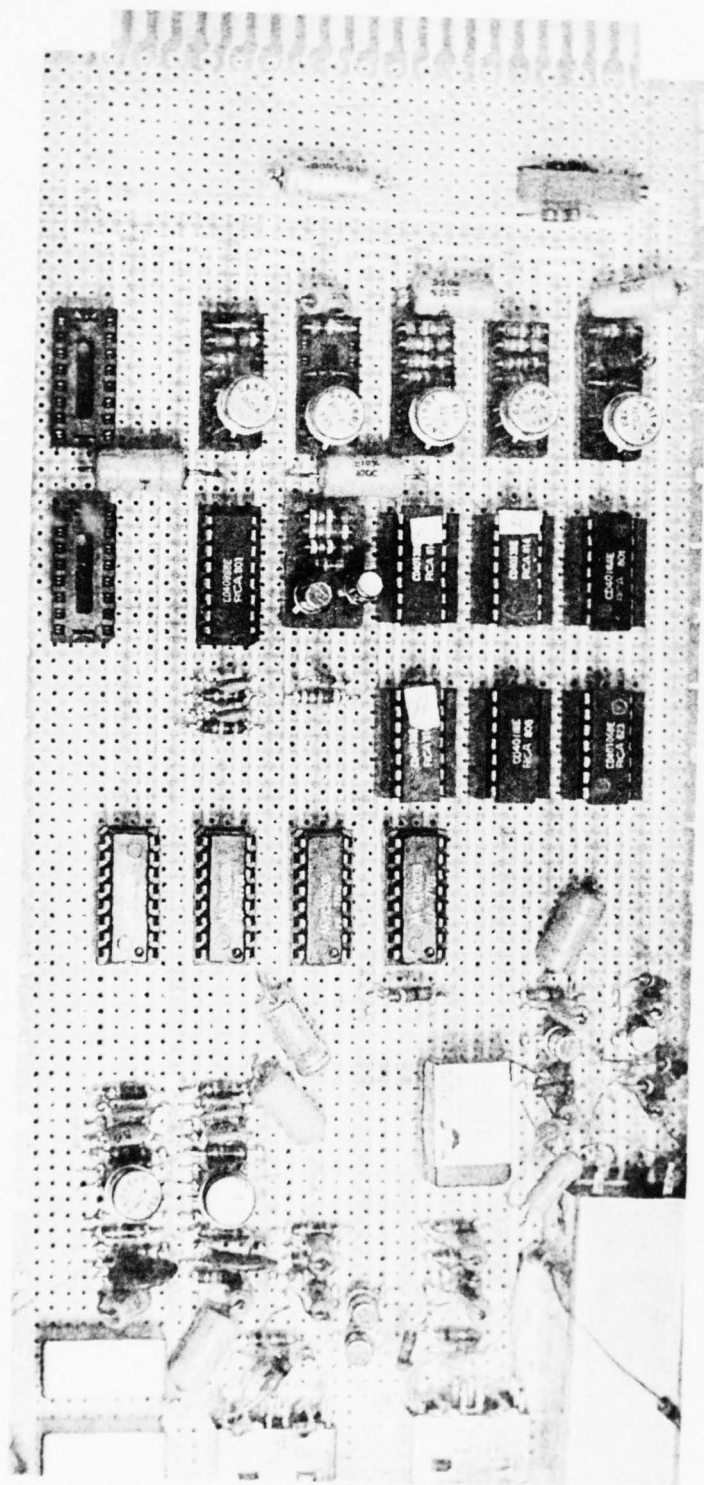


Figure B-2. DEMODULATOR DIGITAL, CLOCK PHASE SHIFT,
BIT SYNCHRONIZER, AND FREQUENCY DIFFERENCE
MEASUREMENT FOR CARRIER SEARCH

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FIGURE C13	-	UTILITY ROUTINE

TABLE I. REGISTER ASSIGNMENT

INTERNAL CPU REGISTER USE FOR RR/DCP

R0	-	
R1	-	
R2	-	STACK POINTER
R(3)	-	PROGRAM COUNTER
R(4)*	-	PROGRAM COUNTER FOR CALL ROUTINE
R(5)*	-	PROGRAM COUNTER FOR RETURN ROUTINE
R(6)*	-	POINTER TO RETURN LOCATION AND ARGUMENTS PASSED BY THE CALLING PROGRAM
R7	-	R7.1 (cycles since last transmission) R7.0 (transmission at current rate)
R8	-	RAM POINTER (R8.1 must be left at 8C)
R9	-	MULTIPLE USE
RA	-	" "
RB	-	" "
RC	-	" "
RD	-	" "
RE	-	" "
RF	-	" "

*NOTE: THE STANDARD CALL-RETURN TECHNIQUE IS USED IN ALL
RR/DCP SOFTWARE.

Table II. MEMORY MAP

MEMORY MAP - ROM

LOCATION	USE
0000	EXECUTIVE PROGRAM
.	
.	
0145	
158	UTILITY ROUTINES
.	
.	
1F2	
0200	TRANSMITTER SUBROUTINE
.	
.	
02C0	
02C1	FREQUENCY TO DIGITAL CONVERSION ROUTINE
.	
.	
02EB	
02EC	RANDOM # GENERATOR SUBROUTINE
.	
0300	
0302	ENCODE DATA FOR TRANSMITTER SUB.
.	
.	
034A	
034D	UPDATE TRANSMISSION RATES SUB.
.	
.	
0390	
0393	CALCULATE STAGE RATE SUB.
.	
.	
03EE	
03F2	GENERAL CALCULATION SUBROUTINE
.	
.	
042E	

Table II. MEMORY MAP (CONT.)

LOCATION	USE
0431	DELAY SUBROUTINE
.	
.	
0444	
0447	READ TIPPING BUCKET
.	INTERFACE
.	SUBROUTINE
.	
0460	
0447	CONTROL INSTRUMENT
.	INTERFACE
.	SUBROUTINE
.	
0488	
0491	PART OF DECIMAL
.	DISPLAY PROGRAM
.	
04C1	
04C3	UTILITY ROUTINES CONT'D.
.	
.	
04F3	
0500	DECIMAL DISPLAY
.	PROGRAM
.	
05FE	
C000	RCA MATH ROM
.	
.	
C3FF	
8000	RCA UTILITY ROM
.	UT5
.	
81FF	

Table II. MEMORY MAP (CONT.)

MEMORY MAP - RAM

LOCATION	USE
8C00	RAM FOR UT5
.	
8C1F	
8C20	FREQUENCY OF SYSTEM VOLTAGE (Hz)
8C22	FREQUENCY OF GROUND VOLTAGE (Hz)
8C24	FREQUENCY OF STAGE ($\alpha 1$) INPUT (Hz)
8C26	FREQUENCY OF PRECIP ($\beta 2$) INPUT (Hz)
8C28	STAGE (P1) MINIMUM VALUE (Ft x 100)
8C2A	PRECIP (P2) MINIMUM VALUE (in x 100)
8C2C	CURRENT STAGE (P1) (Ft x 100)
8C2E	STAGE (P1) 8 min ago (Ft x 100)
8C30	STAGE (P1) 16 min ago (Ft x 100)
8C32	CURRENT PRECIP (P2) (in x 100) (0-4000)
8C34	PRECIP (P2) 8 min ago *in x 100) (0-1000)
8C36	R1, BASE TRANSMISSION RATE (T/Hr x 100)
8C38	R2, ALERT TRANSMISSION RATE (T/Hr x 100)
8C3A	R3, FLOOD TRANSMISSION RATE (T/Hr x 100)
8C3C	A, STAGE (P1) SLOPE FACTOR (0-100)
8C3E	B, PRECIP (P2) SLOPE FACTOR (0-100)
8C40	ALERT LEVEL (Ft x 100)
8C42	FLOOD LEVEL (Ft x 100)
8C44	RANDOM #
8C46	TRANSMITTER RF FOREWARD POWER (v x 100)
8C48	TRANSMITTER RF REFLECTED POWER (v x 100)
8C4A	CURRENT TRANSMISSION RATE
8C4B	BACKUP RATE
8C4C	BACKUP RATE
8C4D	RATE COMPUTED FROM P1
8C4E	RATE COMPUTED FROM P2
8C4F	NOT USED
8C50	TEST
8C51	TEST
8C52	PARAMETER 2 SELECT: BUCKET OR FREQUENCY
8C53	
8C54	
8C55	
8C56	
8C57	NOT USED
8C58	NOT USED
8C59	
8C5A	USED AS SCRATCH PAD AND FOR BINARY DECIMAL CONVERSION
.	
8C61	

Table II. MEMORY MAP (CONT.)

LOCATION	USE
8C62	PLATFORM ID
.	
.	
8C65	
8C66	RAW DATA THAT WILL BE ENCODED
.	
.	
8C69	
8C6A	ENCODED DATA THAT WILL BE
.	TRANSMITTED
.	
8C6D	
.	

Table III. EPROM CHIP 1

7M0 100															
0000	C081	08FF	FFF8	8CB8	F800	A7F8	EEB7	F850;							
0010	A8F8	0158	18F8	0058	F844	A8F8	0058	18F8;							
0020	0558	F84A	A8F8	FF58	1858	1858	F868	A8F8;							
0030	0058	1858	3050	FFFF	FFFF	FFFF	FFFF	FFFF;							
0040	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF;							
0050	F851	A808	3AD4	F801	58D4	C249	8C2E	D4C2;							
0060	5BD4	C24D	D4C2	5BD4	C249	8C2C	D4C2	5BD4;							
0070	0465	E365	00D4	03F2	2422	0FA0	6628	2CF8;							
0080	52A8	083A	91D4	03F2	2622	03E8	682A	3230;							
0090	9BD4	C249	8C68	D4C2	578C	32F8	54A8	0832;							
00A0	A5F8	0058	D5F8	50A8	0832	C1F8	0058	D4C2;							
00B0	498C	2CD4	C25B	D4C2	5BD4	C249	8C32	D4C2;							
00C0	5BD4	0393	2C30	3C4D	D403	B132	343E	4ED4;							
00D0	034D	30DC	F800	58D4	0431	009A	E8F8	4AA8;							
00E0	97FC	01B7	F7CB	0139	F800	B717	D402	EC9F;							
00F0	FA0F	BFD4	0435	D404	65D4	03F2	2422	0FA0							
7M100 100															
0100	6628	5AF8	52A8	08CA	0114	D403	F226	2203;							
0110	E868	2A5A	D403	02D4	0200	0604	F853	A808;							
0120	3226	F800	58D5	D4C2	498C	449F	FA0F	BFD4;							
0130	C00D	0FFF	D404	3530	3ED4	0431	10D4	D404;							
0140	3110	E3C0	0050	FFFF	FFFF	FFFF	FFFF	FFFF;							
0150	FFFF	FFFF	FFFF	FFFF	F801	B3F8	96A3	D3FF;							
0160	F804	B3F8	FEA3	D3FF	F804	B3F8	D6A3	D3FF;							
0170	F801	B3F8	C0A3	D3FF	F804	B3F8	C3A3	D3FF;							
0180	F801	B3F8	88A3	D3FF	F88C	B8F8	53A8	F801;							
0190	58D4	0114	30BD	D402	C1BE	2ED4	02C1	BF30;							
01A0	D404	65D4	03F2	2E22	03E8	465F	5FD4	03F2;							
01B0	3022	03E8	485F	5FF8	46A8	E365	00C0	0503;							
01C0	F852	A8F8	8CB8	0832	E0F8	61AF	98BF	EFF8;							
01D0	0173	F880	7373	7373	7373	5FD4	816C	30DB;							
01E0	D404	65D4	03F2	2226	03E8	6632	2AF8	2AA8;							
01F0	C005	03FF	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF;							

Table IV. EPROM CHIP 2

^C															
.7M200 100															
0200	E365	88D4	02AF	192D	E365	98C4	C4C4	F88C;							
0210	B8C4	C4D4	02AF	324E	7AC4	341A	3C1C	C4C4;							
0220	D402	AF00	013C	257B	46AD	F808	ACF8	AAAF;							
0230	D402	7800	2D8D	3A2D	F822	AFD4	0278	00F8;							
0240	EBAF	D402	7800	F861	A8F8	03AD	18D4	0276;							
0250	012D	8D3A	4C18	F807	ACD4	0276	01F8	69AB;							
0260	46AD	18D4	0276	002D	8D3A	62F8	04AF	D402;							
0270	7800	E365	00D5	08AF	E6F8	00F1	3282	8FFE;							
0280	3084	8FF6	AF3B	943C	877A	D402	AF00	013C;							
0290	8F7B	309F	3C94	7BD4	02AF	0001	3C9C	7A2C;							
02A0	8C3A	A8F8	08AC	16D5	D402	AF00	0130	7846;							
02B0	BE46	AE2E	9E3A	BC8E	32C0	30B3	8E8E	30B3;							
02C0	D5E6	6546	A8F8	00AF	BFAE	F84C	BDF8	8FAD;							
02D0	3DE0	8E3A	DD1F	1E2D	9D3A	D030	E68E	30D7;							
02E0	F800	AEAE	30D7	9F58	188F	58D5	D4C2	498C;							
02F0	44D4	C04F	0300	9FFA	7FBF	D4C2	578C	44D5							
.7M300 100															
0300	0C35	98B9	F86A	A9F8	6AAB	F802	AD28	08FA;							
0310	3FBF	D403	2A08	7E7E	7EFA	0352	2808	FEFE;							
0320	F1BF	D403	2A2D	8D3A	0DD5	F800	AFF8	06AC;							
0330	9F59	9FF6	3B37	1FBF	2C8C	3A32	8FF6	3345;							
0340	09F9	4030	4809	F9C0	5919	D5FE	FEE8	87FF;							
0350	043B	60F8	4BA8	72AF	F028	738F	73F8	00A7;							
0360	F84D	A872	BFF7	336C	F0AF	3070	9FAF	F0BF;							
0370	F84A	A89F	F733	7F9F	58F8	00A7	1830	869F;							
0380	18F7	3386	9F58	8FF7	338C	8F58	189F	58E2;							
0390	D5FF	FFF8	36A8	D4C2	498C	2CD4	C262	8C40;							
03A0	3BB4	F838	A8D4	C262	8C42	3BB4	F83A	A830;							
03B0	B4F8	36A8	988D	46AD	D4C2	4D46	ADD4	C031;							
03C0	D403	E146	ADD4	C053	88AD	D4C1	D5D4	C257;							
03D0	8C5A	D4C2	5205	DCD4	C0A1	8C5A	46AD	8F5D;							
03E0	D59F	FE3B	EE9F	FBFF	BF8F	FBFF	AF1F	D5FD;							
03F0	FDFF	D4C2	498C	20D4	C02D	8C22	D4C2	578C							

Table V. EPROM CHIP 3

7M400 100															
0400	5C46	ADD4	C24D	46AD	D4C0	31D4	C257	8C5A;							
0410	46BF	46AF	D4C0	4F8C	5AF8	5CAD	D4C0	B746;							
0420	ADD4	C25B	46AD	D4C1	D546	ADD4	C25B	D500;							
0430	0046	BF46	AFD4	02AF	0007	2F9F	3A42	8F3A;							
0440	35D5	9F3A	35D4	C249	8C68	D4C1	EB01	00F8;							
0450	FFAD	E83F	5D61	2F8D	325D	2D30	5362	D4C2;							
0460	578C	68D5	FFE3	6528	D402	AF19	2DD4	02C1;							
0470	2822	D402	C129	20D4	02C1	2A24	F852	A808;							
0480	3A89	D402	C12B	2630	8CD4	0445	D5FF	FFFF;							
0490	FF3E	A894	BAF8	22AA	6C4A	F332	A48A	FF36;							
04A0	33A9	3099	8AFF	23AA	D5F8	00BA	D5F8	61AF;							
04B0	EFF8	1073	7373	7373	F880	7373	F80B	73C0;							
04C0	05D1	00F8	8CB8	F854	A8F8	0158	D400	6FF8;							
04D0	20A8	C005	03FF	D404	65D4	03F2	2224	0FA0;							
04E0	662C	28F8	28A8	C005	03FF	FFFF	FFFF	FFFF;							
04F0	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF	FFFF	36FE							
7M500 100															
0500	F820	A8F8	8CB8	BFEF	F861	AF88	FA0F	F910;							
0510	7388	F6F6	F6F6	F910	73F8	0C73	F80B	73F8;							
0520	8073	7373	F80A	5FF8	5AAF	D481	6CF8	01BA;							
0530	D404	91F8	61AF	9A32	2DF6	3227	8AFB	1232;							
0540	530F	2F5F	1F8A	F910	5FF8	5AAF	D481	6C36;							
0550	4C30	272F	4FFE	FEFE	FE52	0FFA	0FF1	A836;							
0560	5FF8	00A7	88AD	98BD	D4C2	4DD4	C30A	8C5C;							
0570	06D4	C252	8C5C	0F52	F880	5F2F	5F2F	025F;							
0580	D481	6CF8	01BA	D404	919A	3283	F632	808A;							
0590	FB12	32D8	8AFB	103A	A287	3A9E	1738	2787;							
05A0	CA04	AD87	325F	8AFB	0B3A	AF8A	5F30	D18A;							
05B0	FB0D	3AB8	8A5F	30D1	F804	ADF8	5EAF	0F2F;							
05C0	5F2D	8D32	C91F	1F30	BE1F	8AF9	105F	F85D;							
05D0	AFF8	5AAF	D481	6C36	D430	80F8	5AAF	0F1F;							
05E0	1F5F	D4C2	9F8C	5C06	98BD	88AD	D4C2	5B18;							
05F0	1836	F130	03FF	FFFF	FFFF	FFFF	FFFF	FFFF							

Table VI. RCA MATH ROM

7MC000 100

C000	9EAC	9FBE	8EBF	8FAE	9FAF	8CBF	D586	AD96;
C010	BD16	1630	1946	BD46	ADED	9FF3	521D	8FF5;
C020	AF2D	9F75	BF02	FE3B	2C9F	F3FE	D546	BD46;
C030	ADED	9FF6	529F	F3FA	80E2	F452	1DED	8FF7;
C040	AF2D	9F77	BFE2	F0FE	3B4E	529F	F3FE	D546;
C050	BD46	ADED	9FF3	FAB0	BCF8	10AC	F800	BEAE;
C060	2C9F	F6BF	8F76	AF9E	3B76	1D8C	3A79	8EF7;
C070	AE2D	9E77	BE9C	FE30	838E	F4AE	2D9E	74BE;
C080	CFF0	FE9E	76BE	8E76	AE3B	8F9F	F980	BF8C;
C090	3A60	9FFE	8EC7	FBFF	3A9E	9EC7	FBFF	FCFF;
C0A0	D546	BD46	ADED	9FFE	F800	C7F8	FFBE	AE4D;
C0B0	F12D	FD00	3BB7	D59E	BC8E	ACFE	AE9E	7EBE;
C0C0	9FFE	33CD	8C3A	CE9C	FB40	32D7	381E	9CFA;
C0D0	C0FD	00FE	C3C1	569C	EDF3	FE1D	8E33	E6F7;
C0E0	AE2D	9E77	30EB	F4AE	2D9E	74BE	9CFE	CBC0;
C0F0	FA9E	FBFF	BE8E	FBFF	AE1E	9EC2	C103	FE33

7MC100 100

C100	5B30	548E	FCFE	3356	FBFF	3A39	9CFA	8032;
C110	54F4	3356	1D8F	F4AE	2D9F	74BE	1DF0	F62D;
C120	9EC7	FC80	BEFE	9CFA	803A	2F3B	5430	5B33;
C130	569E	3A5B	3E32	5430	5B9C	F3FE	3314	9CFE;
C140	3B54	1DF0	2DF6	8F3A	5B9F	3350	3254	305B;
C150	FB80	3A5B	FF00	9CBE	8CAE	D59C	BE8C	AE9E;
C160	FEF8	90C7	F850	AC8E	FEAE	9E7E	BE8F	FEAF;
C170	9F7E	BF3B	761E	ED8C	F3FE	1D8E	3B85	F7AE;
C180	2D9E	7730	8AF4	AE2D	9E74	BE2C	8CFA	7F3B;
C190	941F	F980	ACFA	3F3A	6733	B038	1FF3	FE1D;
C1A0	8E33	AAF4	AE2D	9E74	30AF	F7AE	2D9E	77BE;
C1B0	9E3A	B68E	32C1	8CFE	FE9E	CFFB	80FC	803B;
C1C0	9CF0	FE3B	D08F	FBFF	AF9F	FBFF	BF1F	FC00;
C1D0	D546	BD46	ADED	9FF3	FB80	521D	8FF4	AF2D;
C1E0	9F74	BF02	FE3B	EA9F	F3FE	D586	AD96	BD16;
C1F0	1630	D592	BD82	AD1D	1D1D	30D5	92BD	82AD

Table VI. RCA MATH ROM (CONT.)

```

7MC200 100
C200 1D1D E20D 732D 0D73 9F5D 8F1D 5D2D D58D;
C210 E273 9D52 92BD 82AD 221D 1D1D 8E73 9E73;
C220 0D73 2D0D 739C 5D1D 8C5D D512 92BD 82AD;
C230 1D1D 1D1D 1D1D 4DBC 0BAC 2D42 5D1D 425D;
C240 42BE 42AE 42BD 02AD D546 BD46 AD4D BF4D;
C250 AFD5 46BF 46AF D546 BD46 AD9F 5D1D 8F5D;
C260 1DD5 46BD 46AD ED9F F3FA 803A 769F F73A;
C270 771D 8FF7 2D38 F4D5 1616 D59F FE9F 3A78;
C280 8F32 7A30 78FF 00C8 FC00 1292 BD82 AD1D;
C290 1D3B 984D BF0D AF2D 425D 1D02 5D1D D546;
C2A0 BA46 AA46 FF01 ABF8 00AF BFOA FB0D BB1A;
C2B0 E20A FA0F 528F F4AF 9F7C 00BF 33EF 2B8B;
C2C0 32F0 8FFE 739F 7E73 33ED F802 528F FEAFF;
C2D0 9F7E BF33 ED02 32DC FF01 30CC 129F F4BF;
C2E0 33EE 128F F4AF 9F7C 00BF 3BAF C812 12D5;
C2F0 9FFC 803A FC8F 3AFC 9BFC FFD5 33FB 9B3A

7MC300 100
C300 098F FD00 AF9F 7D00 BFD5 46BA 46AA 46FF;
C310 01AB BBF8 0FAD 9FFE F80B 3B29 8FFD 00AF;
C320 9F7D 00BF F80D C8F8 005A 8B32 321A 2B30;
C330 27E2 9BAB 8FFE AF9F 7EBF 0A7C 005A 8D3A;
C340 42D5 0A7E 5AFF 0A3B 4A5A 2A2B 8B3A 4233;
C350 412D 9B52 8AF4 AA9A 7C00 BA30 32D3 E296;
C360 7386 7393 B683 A646 B346 A330 5DD3 96B3;
C370 86A3 E212 72A6 F0B6 306D 0000 0000 0000;
C380 0000 0000 0000 0000 0000 0000 0000 0000;
C390 0000 0000 0000 0000 0000 0000 0000 0000;
C3A0 0000 0000 0000 0000 0000 0000 0000 0000;
C3B0 0000 0000 0000 0000 0000 0000 0000 0000;
C3C0 0000 0000 0000 0000 0000 0000 0000 0000;
C3D0 0000 0000 0000 0000 0000 0000 0000 0000;
C3E0 0000 0000 0000 0000 0000 0000 0000 0000;
C3F0 0000 0000 0000 0000 0000 0000 0000 0000

```

Table VII. RCA UT-5 ROM

.7MB000 100

8000	7100	0203	0405	0607	0809	0A0B	0C0D	0E0F;
8010	01F8	80B3	F8FE	A3C0	810E	F800	A794	BDF8;
8020	80AB	E222	228B	5247	FA0F	FC36	AD4D	BB64;
8030	8CFA	0132	3F8B	FA0F	3A44	9BFA	BF30	458B;
8040	FAFC	323A	9B52	63D4	8147	E363	FFE2	87FF;
8050	063B	54D5	8BF6	ABFA	F33A	2330	4ED4	801A;
8060	365D	D480	1A8C	FA01	326D	D480	D33E	62D4;
8070	801A	94BA	F822	AA6C	4AF3	3283	8AFF	3633;
8080	5D30	788A	FF23	AAFA	F03A	90D4	809E	305D;
8090	8AFA	0FFC	9AAA	93BA	4AA3	FAF0	F6FE	8CFA;
80A0	0132	E59F	FEFE	FEFE	528F	F6F6	F6F6	F1BF;
80B0	8FFE	FEFE	FE52	8AF1	AFF8	00A7	9FF6	F6F6;
80C0	F657	179F	FA0F	5717	8FF6	F6F6	F657	178F;
80D0	FA0F	574F	AE2F	F804	A78E	F6F6	F6F6	5717;
80E0	8EFA	0F57	D58E	FEFE	FEFE	528A	F1AE	30D6;
80F0	9FB0	8FA0	E0D0	8E5F	1F38	1CC0	8102	F800

.7MB100 100

8100	BFAF	D480	B9C0	805D	F800	B3F8	05A3	F881;
8110	B4B5	F8E4	A4F8	F4A5	F88C	B2B7	F81F	A2AC;
8120	E2D3	0A8E	8081	4E40	412E	2021	1E10	1106;
8130	0804	0209	010C	447D	C151	7852	425D	4050;
8140	4862	C661	C2CA	FFF8	20AD	2D8D	3A4A	D5F8;
8150	81B3	F858	A3C0	810E	F800	BFAF	1FF8	80A8;
8160	D480	B9D4	801A	2888	3A63	305C	F880	AEF8;
8170	81BD	0FFA	803A	9722	228E	520F	FA0F	FC36;
8180	AD4D	BE0F	FA10	328C	9EFA	BFBE	649E	5263;
8190	D481	47E3	63FF	E21F	8EF6	AE3A	722F	2F2F;
81A0	2F2F	2F2F	2FD5	F88C	BFF8	00AF	9AF6	F6F6;
81B0	F65F	1F9A	FA0F	5F1F	8AF6	F6F6	F65F	1F8A;
81C0	FA0F	5F1F	9BF6	F6F6	F65F	1F9B	FA0F	5F1F;
81D0	8BF6	F6F6	F65F	1F8B	FA0F	5FF8	00AF	D481;
81E0	6CD5	00D3	E296	7386	7393	B683	A646	B346;
81F0	A330	E3D3	96B3	86A3	E212	72A6	F0B6	30F3

Table VIII. RAM

```

7M8C00 100
8C00 0000 0000 0C00 0000 0000 0000 0000 0000;
8C10 0000 0000 0000 0000 0000 7102 4301 04C7;
8C20 1930 0000 13E3 14FA 0000 0000 0C56 0C56;
8C30 0C56 0341 0341 0000 0000 0000 0000 0000;
8C40 0000 0000 3D09 0000 0000 DCDC DCDC DC00;
8C50 0001 0000 0000 0000 0000 0340 1930 000C;
8C60 0010 0000 0000 0C56 0340 40CD D6F1 0000;
8C70 0000 0000 0000 0000 0000 0000 0000 0000;
8C80 0000 0000 0000 0000 0000 0000 0000 0000;
8C90 0000 0000 0000 0000 0000 0000 0000 0000;
8CA0 0000 0000 0000 0000 0000 0000 0000 0000;
8CB0 0000 0000 0000 0000 0000 0000 0000 0000;
8CC0 0C00 0000 0000 0000 0000 0000 0000 0000;
8CD0 0000 0000 0000 0000 0000 0000 0000 0000;
8CE0 0000 0000 0000 0000 0000 0000 0000 0000;
8CF0 0000 0000 0000 0000 0000 0000 0000 0000

```

Figure C1
EXECUTIVE PROGRAM
FLOWCHART

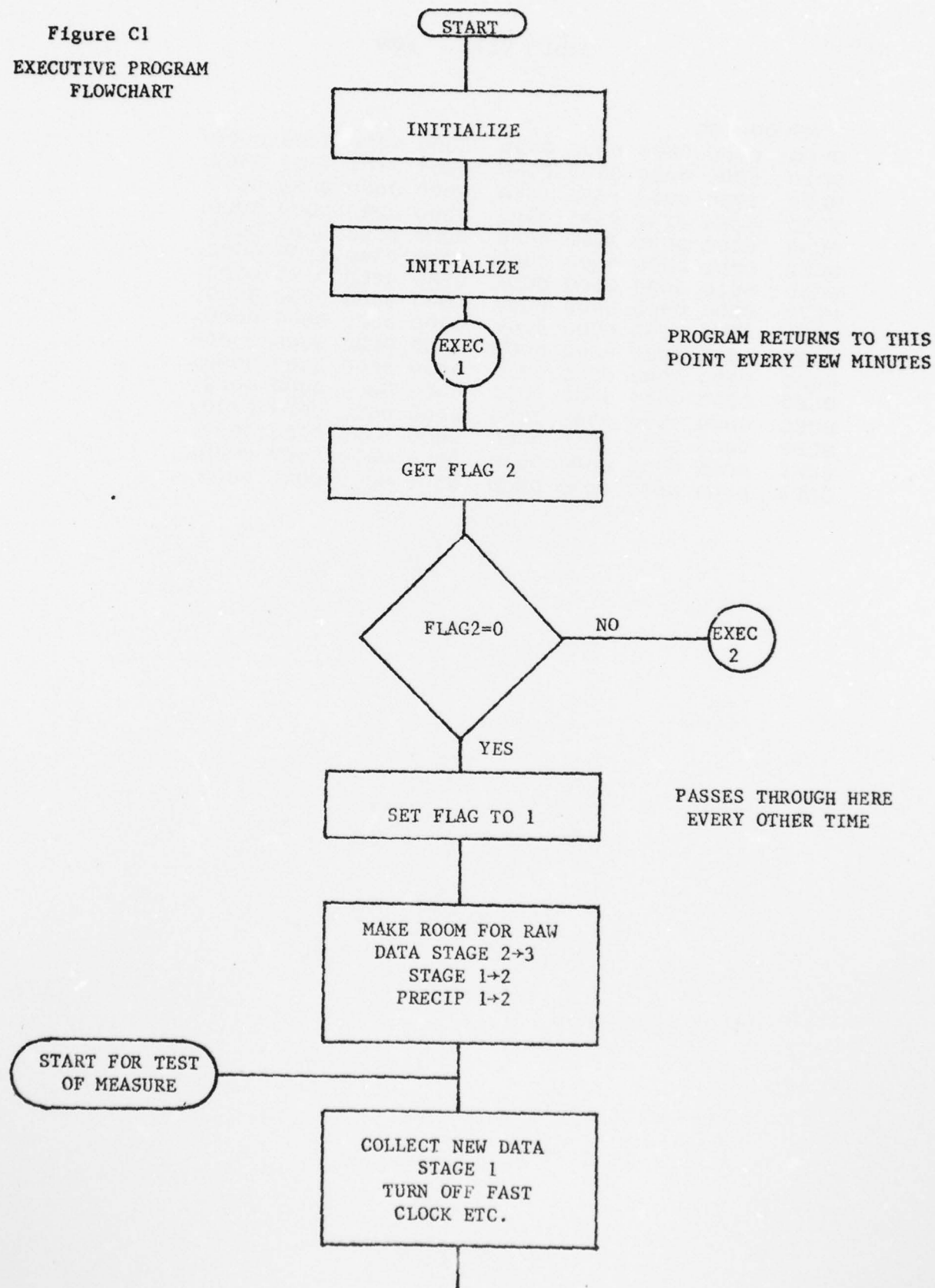


Figure C1
EXECUTIVE PROGRAM
FLOWCHART
(CONT'D)

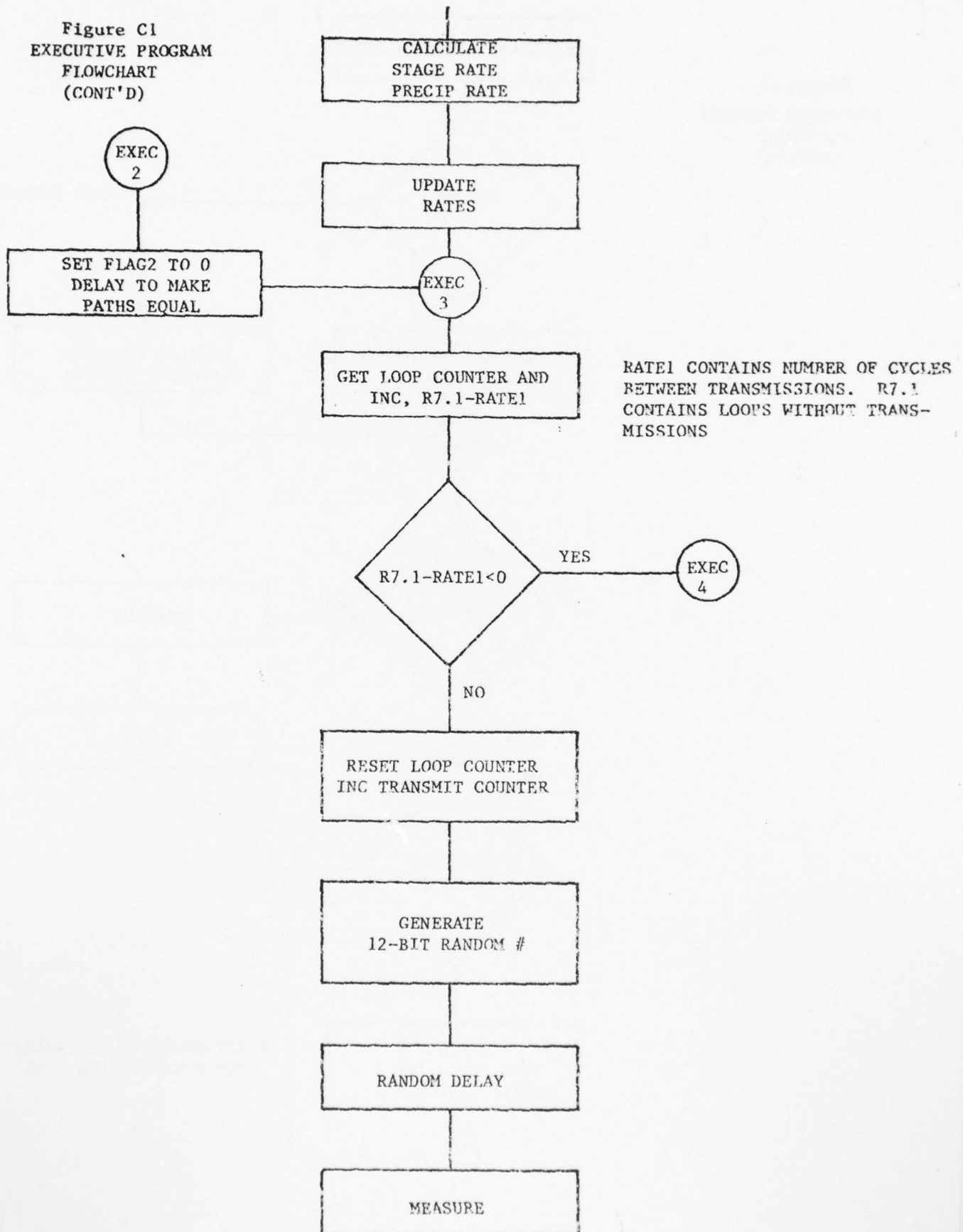


Figure C1
EXECUTIVE PROGRAM
FLOWCHART
(CONT'D)

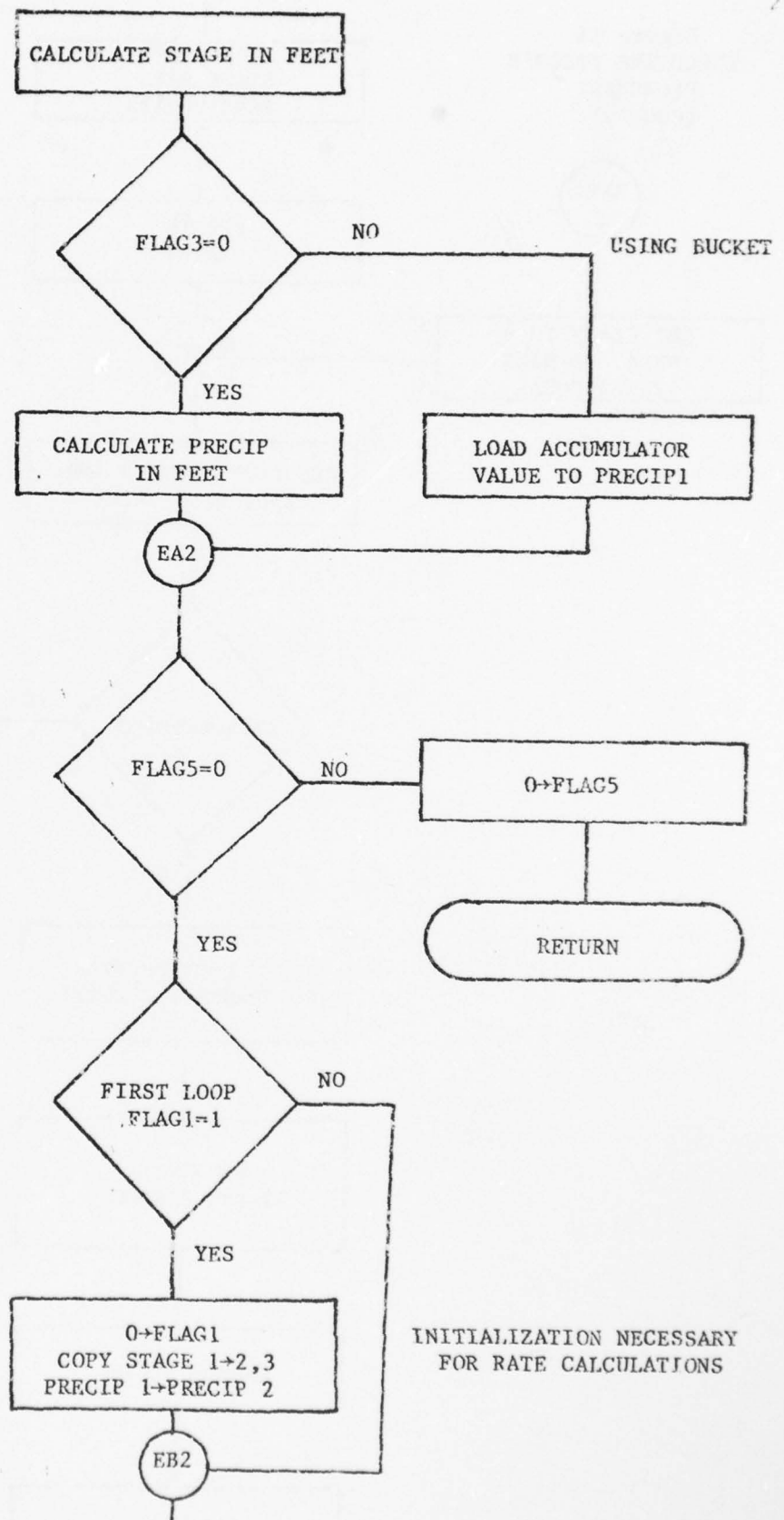
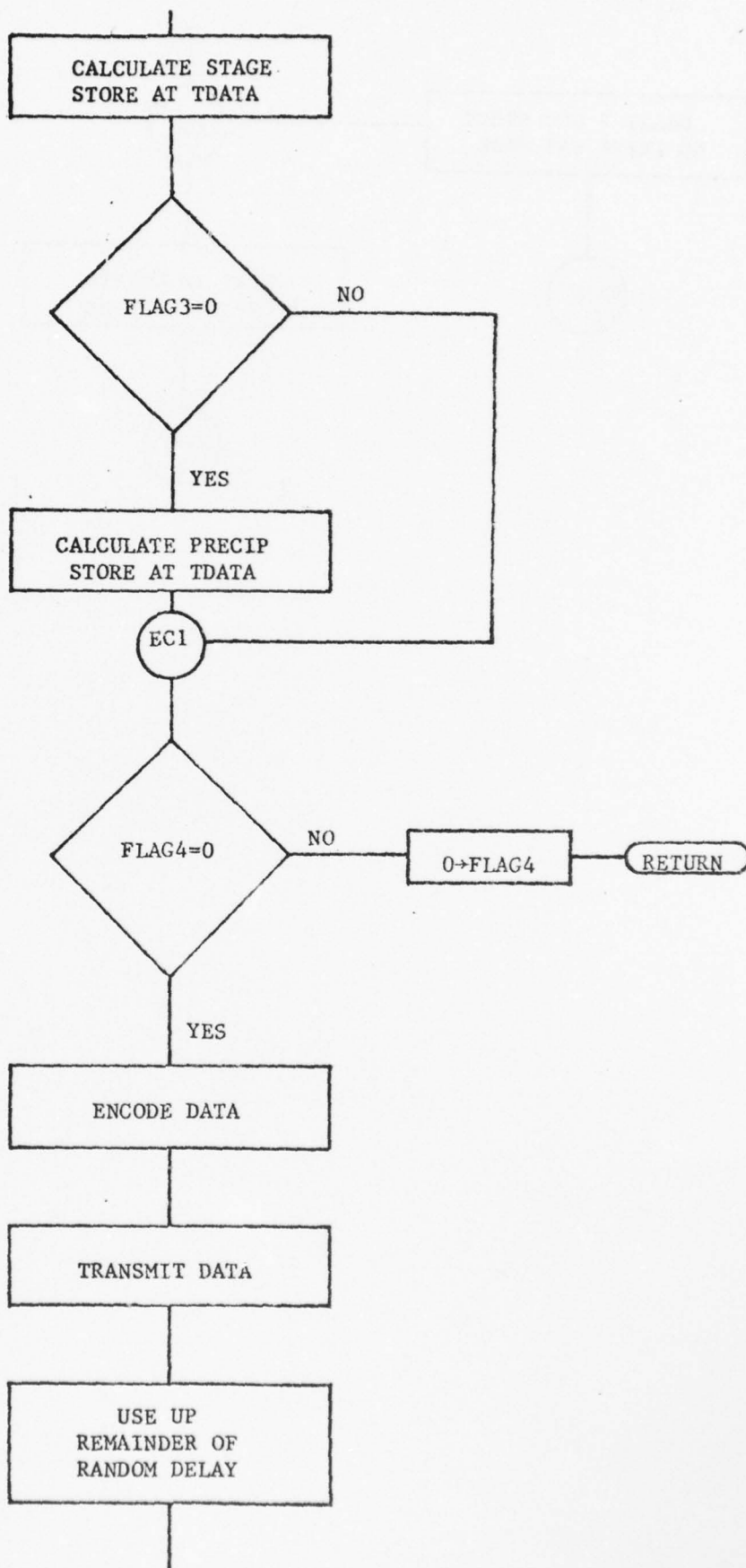


Figure C1
EXECUTIVE PROGRAM
FLOWCHART
(CONT'D)



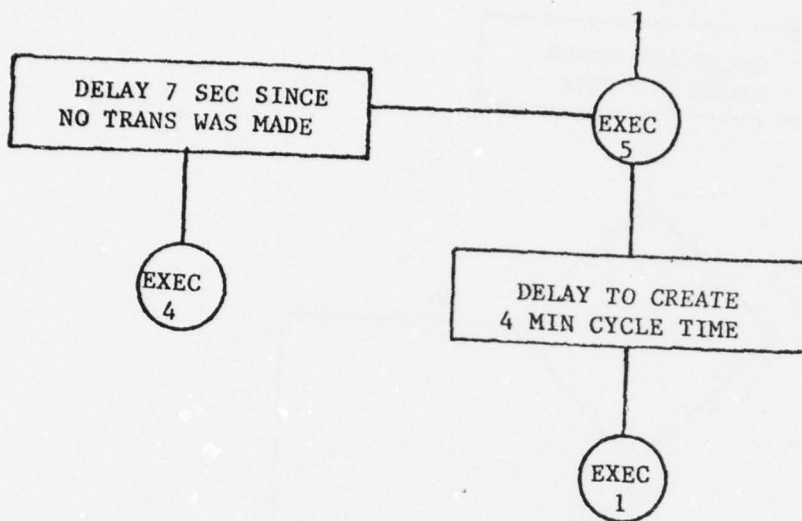


Figure C1
EXECUTIVE PROGRAM
FLOWCHART
(CONT'D)

AD-A067 290

SUTRON CORP ARLINGTON VA

DEMONSTRATION OF ADAPTIVE RANDOM REPORTING GOES

F/G 17/2.1
DATA COLLECTION--ETC(U)

JAN 79 D M PREBLE

DACW33-78-C-0176

SCR-333-78-006

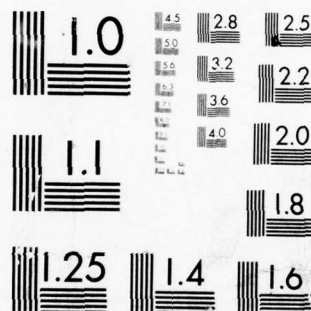
NL

UNCLASSIFIED

2 OF 2

AD
A067 290





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Figure C2
TRANSMITTER SUBROUTINE

Note: Transmitter program
takes encoded data at TBUF
and transmits it.

To use the program,
execute:

SEP CALL
,A(GXMIT)
,#06
(6x8 clock
bits)
,#04
(04 bytes
data)

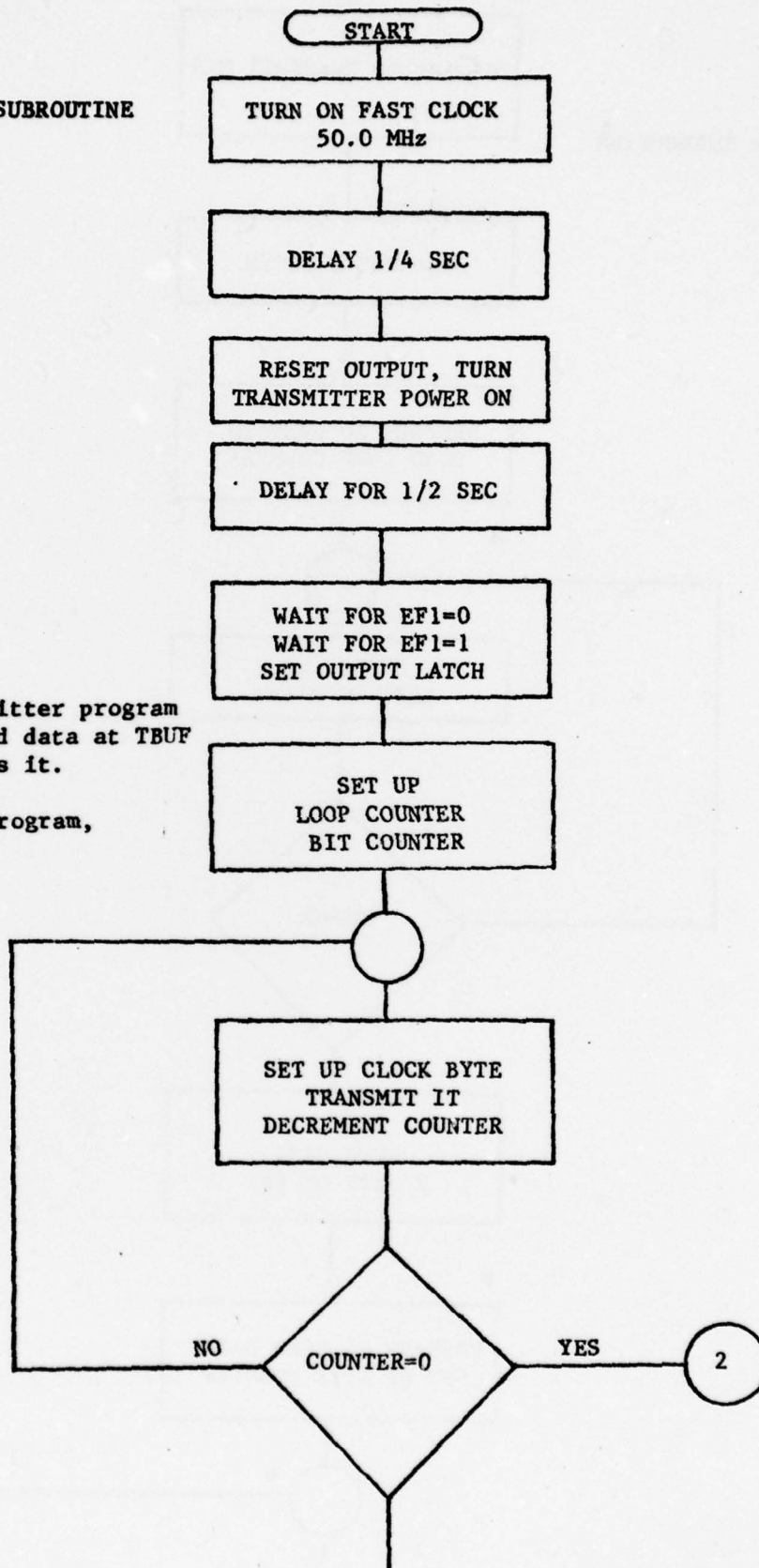


Figure C2
TRANSMITTER SUBROUTINE
(CONT'D)

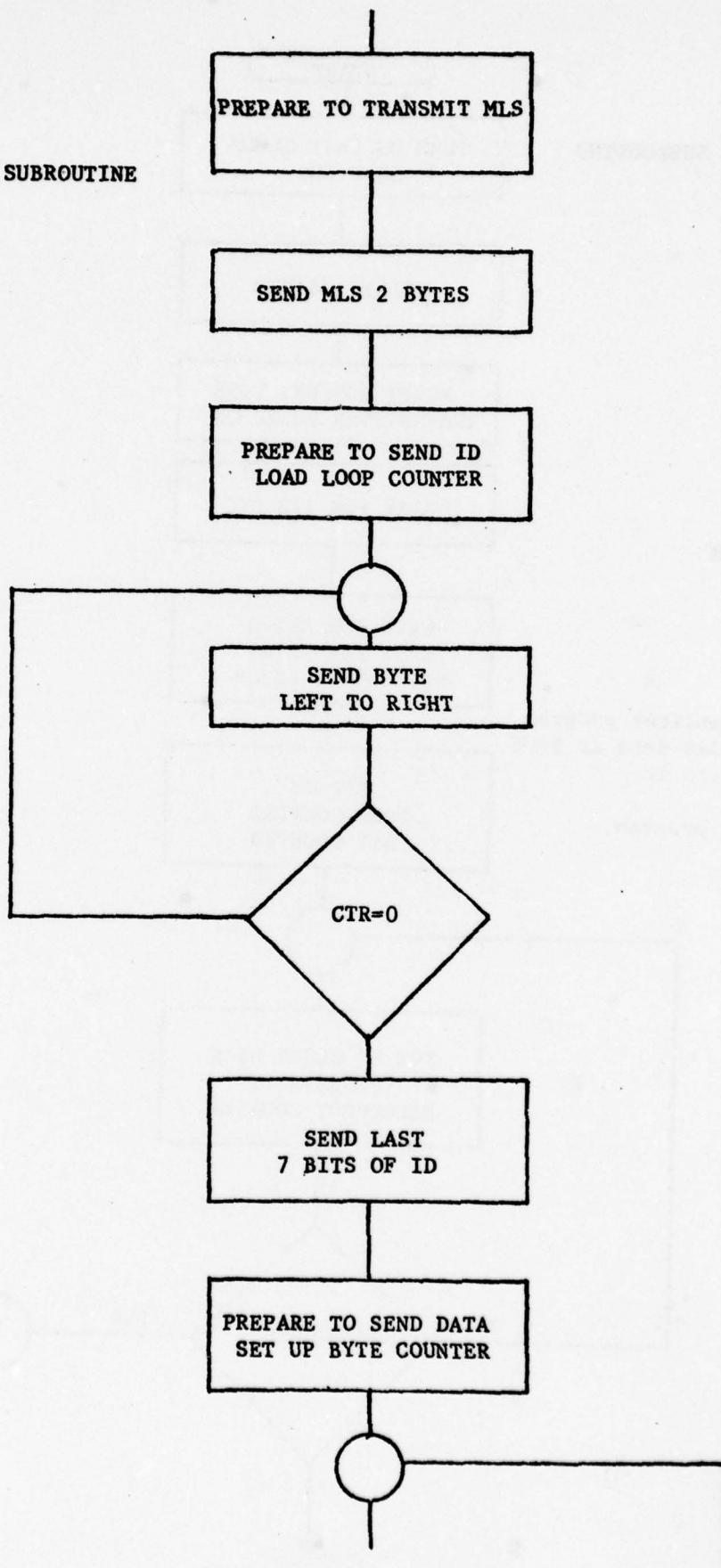
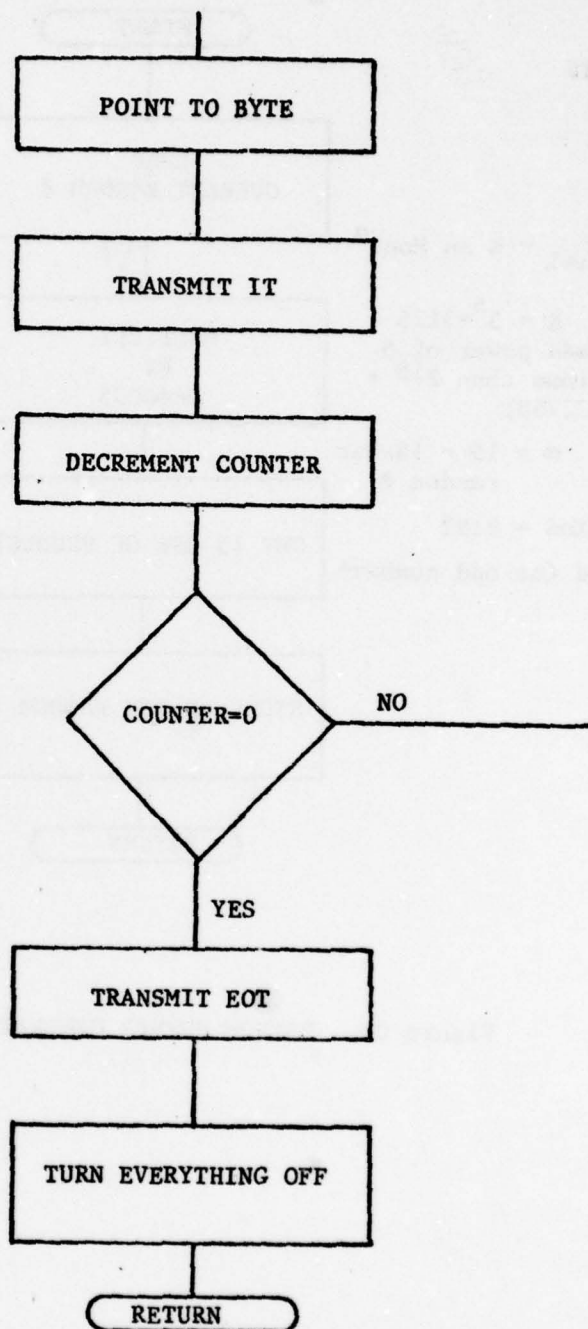


Figure C2
TRANSMITTER SUBROUTINE
(CONT'D)



TO USE EXECUTE
SEP CALL
,A(RND)

Equations: $R_{n+1} = K R_n \text{ Mod } 2^N$

$K = 5^5 = 3125$
(add power of 5
less than $2^{15} =$
32768)

$N = 15 = 15\text{-bit}$
random #

$2^{N-2} = \text{period} = 8192$

$R_0 = \text{seed (an odd number)}$

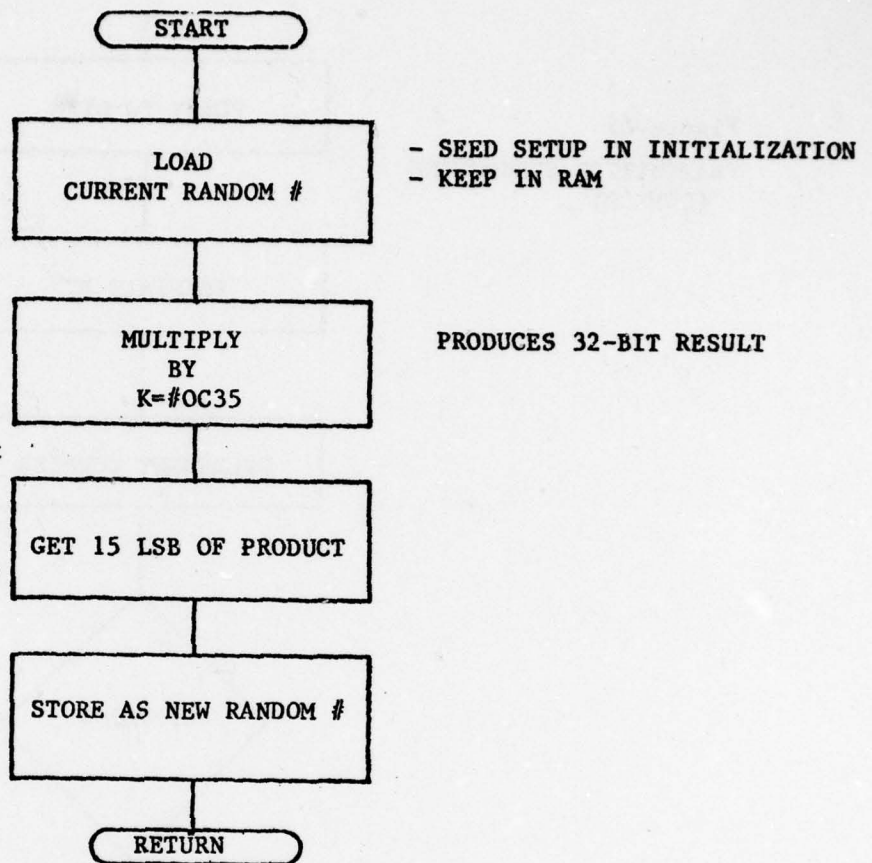


Figure C3. RANDOM NUMBER GENERATOR SUBROUTINE

Figure C4
FDC SUBROUTINE

TO USE, EXECUTE:

SEP CALL
,A(FDC)
,A.O(DEVICE)
,A.O(RAMSTORAGE)

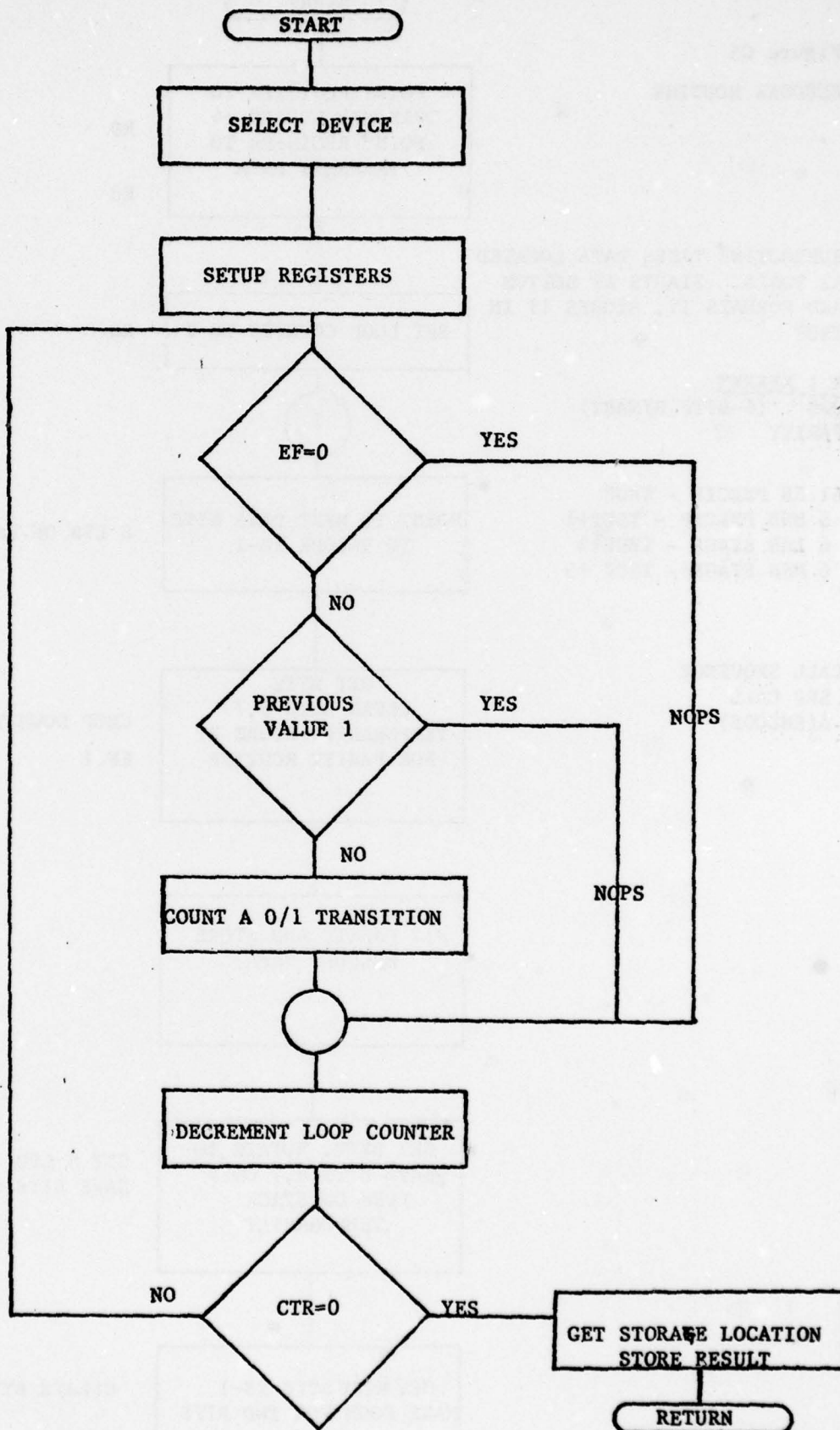


Figure C5
ENCODER ROUTINE

SUBROUTINE TAKES DATA LOCATED
AT TDATA. STARTS AT BOTTOM
AND FORMATS IT, STORES IT IN
TBUF

X 1 XXXXX
ODD (6-BITS BINARY)
PARITY

61 SB PRECIP - TBUF
6 MSB PRECIP - TBUT+1
6 LSB STAGE - TBUS+2
6 MSB STAGE - TBUF +3

CALL SEQUENCE
SEP CALL
A(ENCODE)

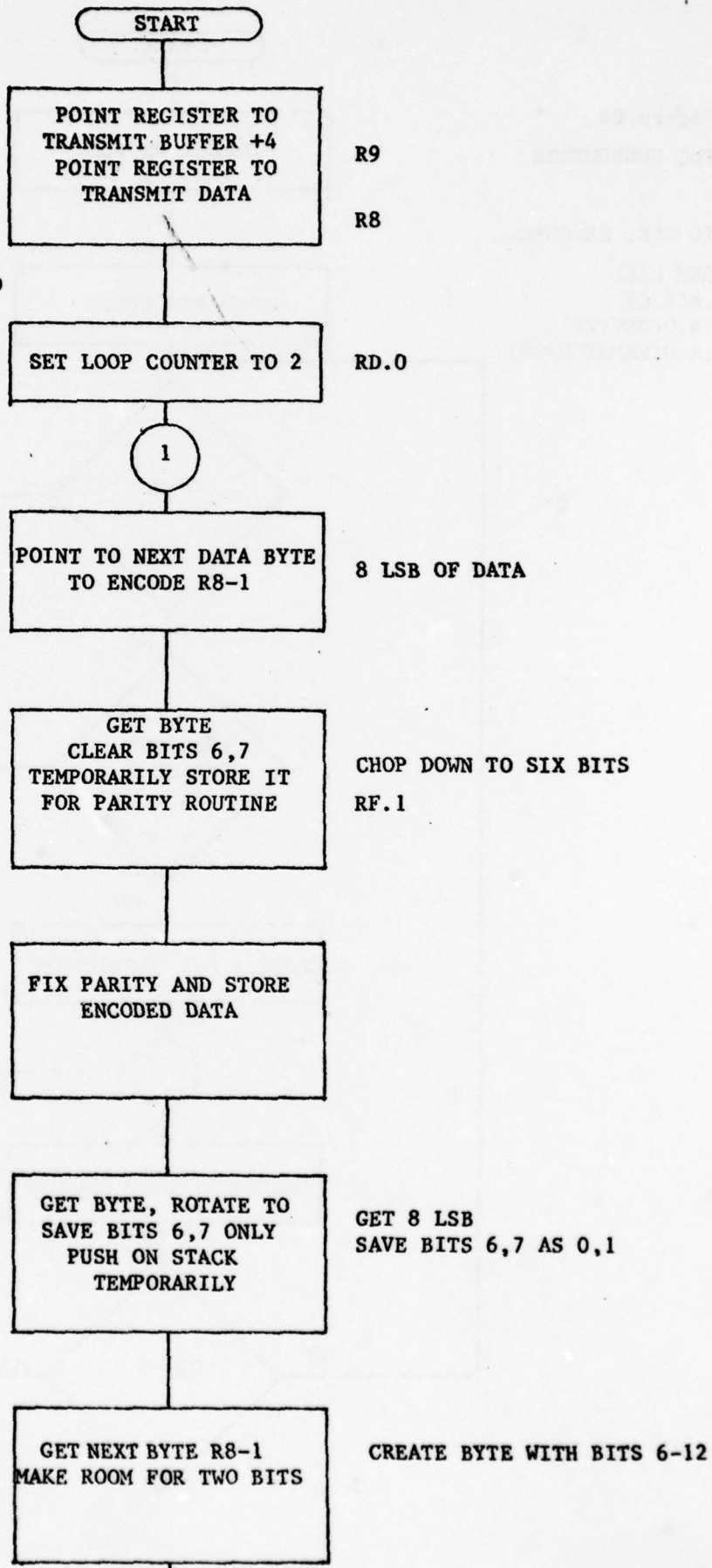


Figure C5
ENCODER ROUTINE
(CONT'D)

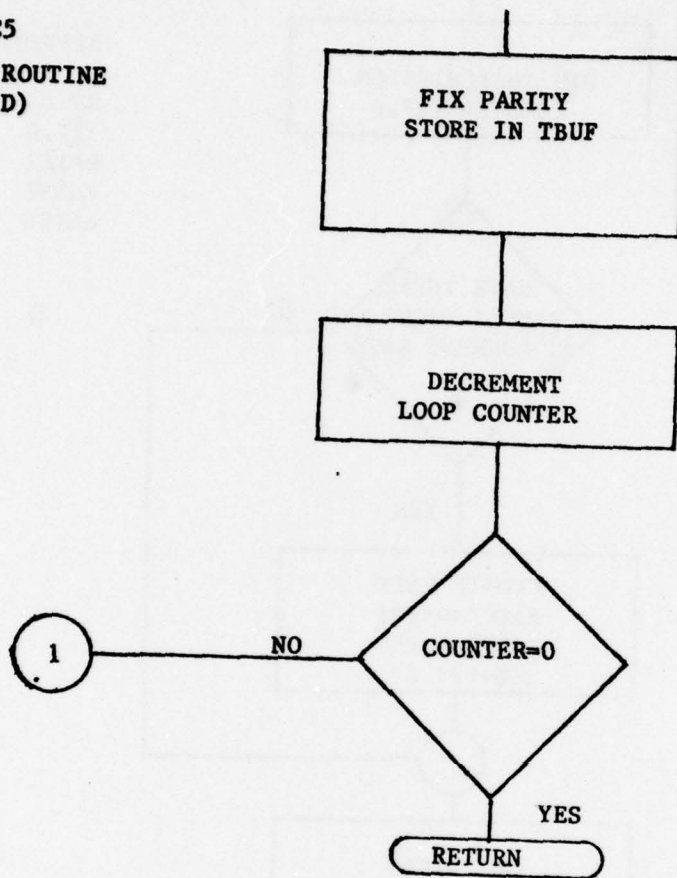


Figure C6

RATE UPDATE ROUTINE

NOTE: MIN VALUE GIVES MAX
NUMBER OF TRANSMISSIONS

TO EXECUTE:

SEP CALL
,A(UPDATE)

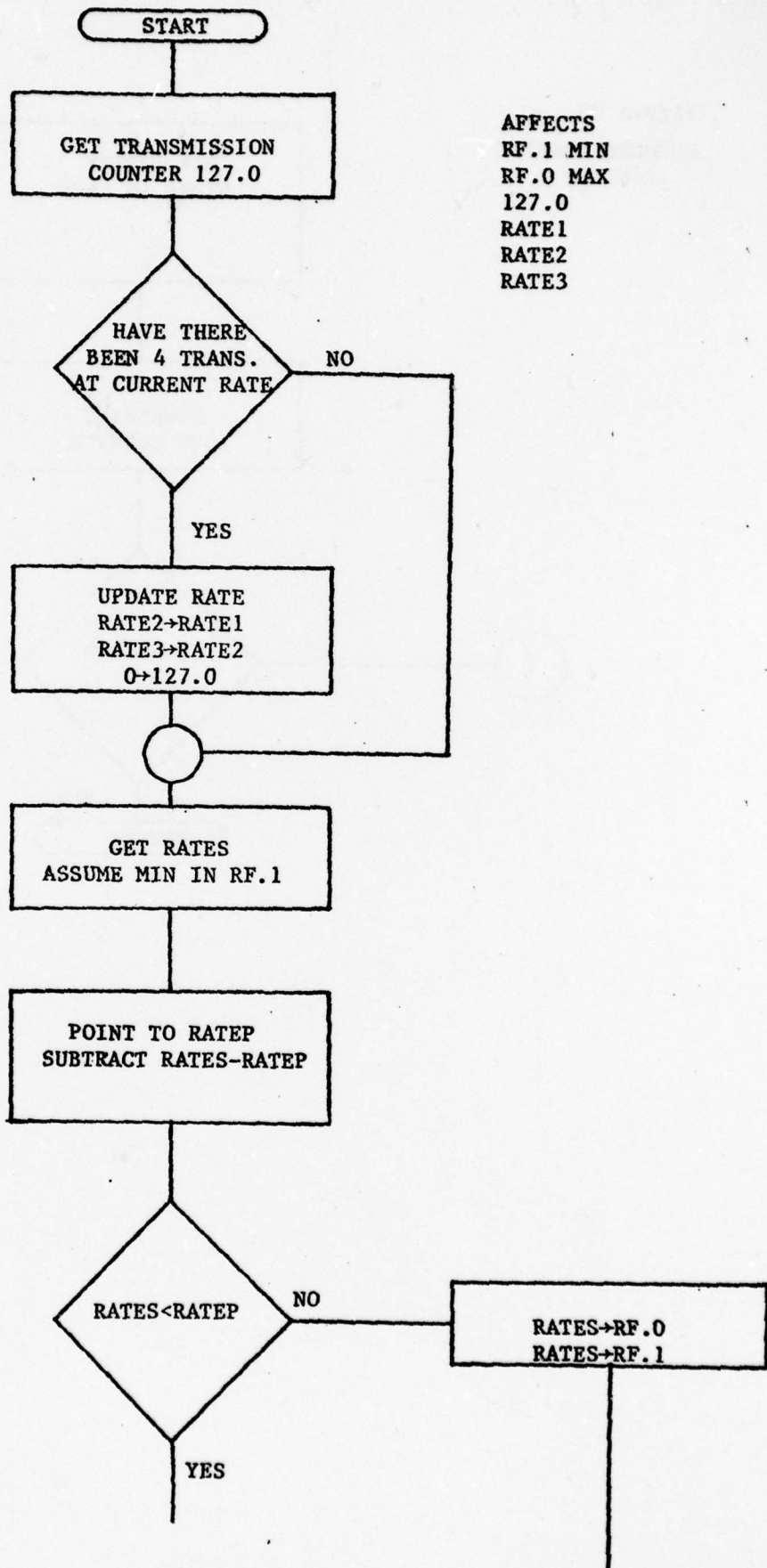


Figure C6
RATE ROUTINE
(CONT'D)

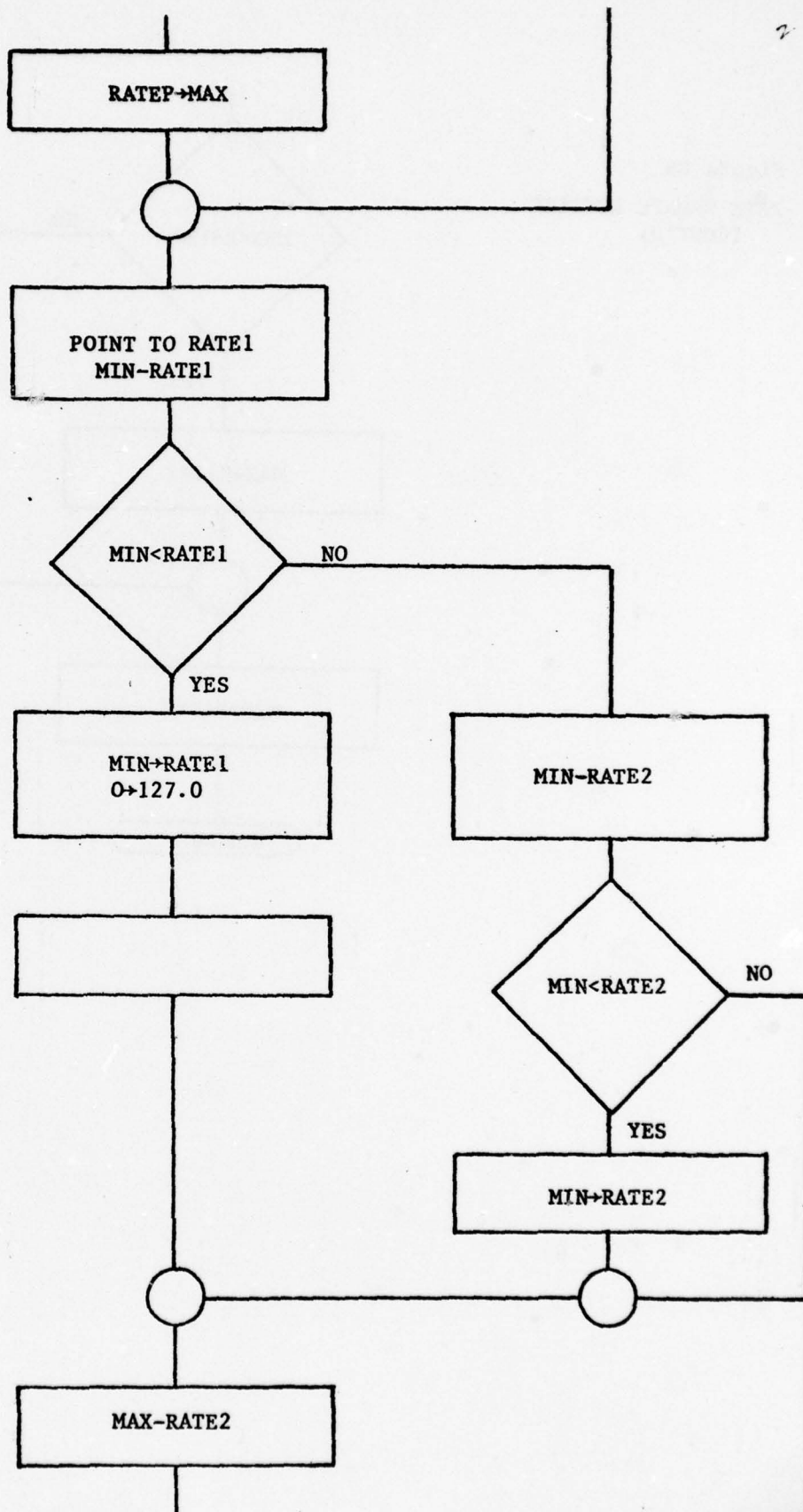


Figure C6
RATE UPDATE ROUTINE
(CONT'D)

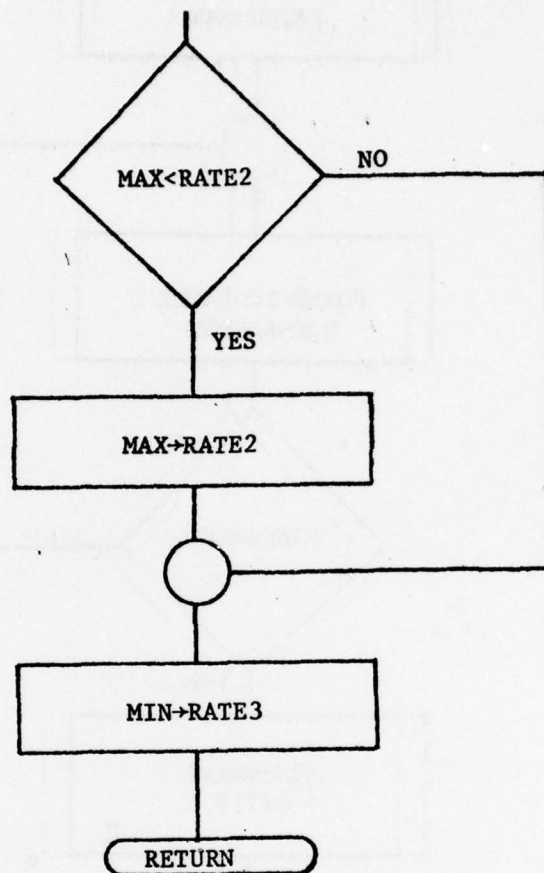


Figure C7
RATE CALCULATION SUBROUTINE

20 NOV 78

$$F = 1500/E$$

$$E = A + B/C - D$$

F is in 4 min loops/TRANS.

A is in trans/hr x 100.

1500 is loops/hr x 100.

CALL SEQUENCE

SEP CALL

, A (CALCSR)

, A.O (C)

, A.O (D)

, A.O (B)

, A.O (STORAGE POINTER)

TO CALCULATE STAGE RATE EXECUTE

SEP CALL

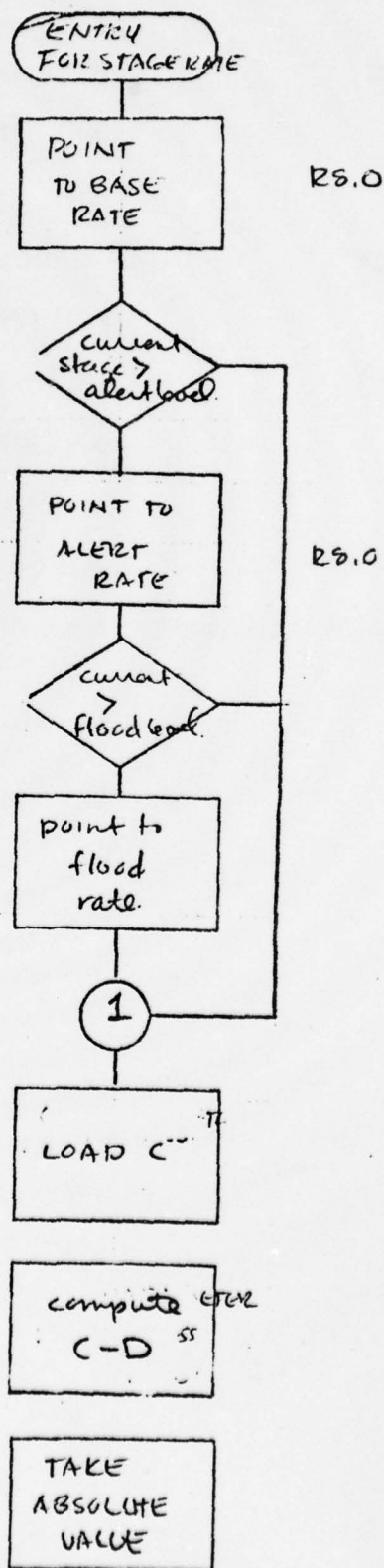
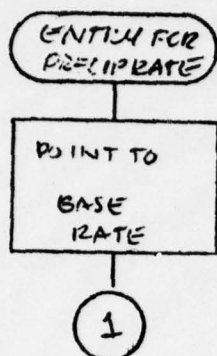
, A (CALCSE)

, A.O (STAGE 1)

, A.O (STAGE 3)

, A.O (CON 1)

, A.O (RATES)



compute
B(C-D)

add
A to result

STORE
RESULT

LOAD 1500,
DIVIDE BY
RESULT ABOVE

STORE AT
LOCATION
SELECTED

RETURN

GENERAL CALCULATION SUBROUTINE

$$G = A * (D - E) / (B - C) + F = \frac{RANGE * (F_{MAX} - F_{MIN})}{(F_{MAX} - F_{MIN})} + MIN$$

utilizes math ROM. $= \frac{RANGE * (F_{MIN} - F_{MAX})}{(F_{MAX} - F_{MIN})} + CURRENT\ VALUE$

call sequence.

SEP CALL

,A(CALL)

,A.O(D)

,A.O(E)

,A

,A.O(TDATA)

,A.O(F)

,A.O(DESTINATION)

to calc current stage.

SEP CALL

,A(CALL)

,A.O(FSTAGE)

,A.O(FMIN)

,4000₁₆

,A.O(TDATA)

,A.O(SMIN)

,A.O(STAGE)

to calc min stage

SEP CALL

,A(CALL)

,A.O(FMIN)

,A.O(FSTAGE)

,4000₁₆

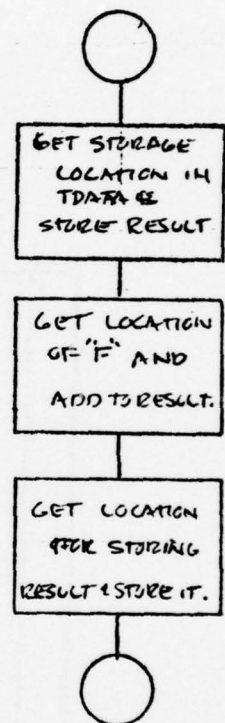
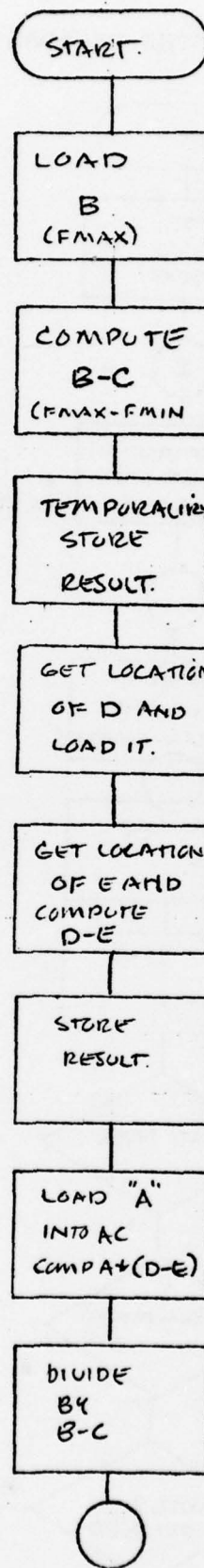
,A.O(:)

,A.O(STAGE)

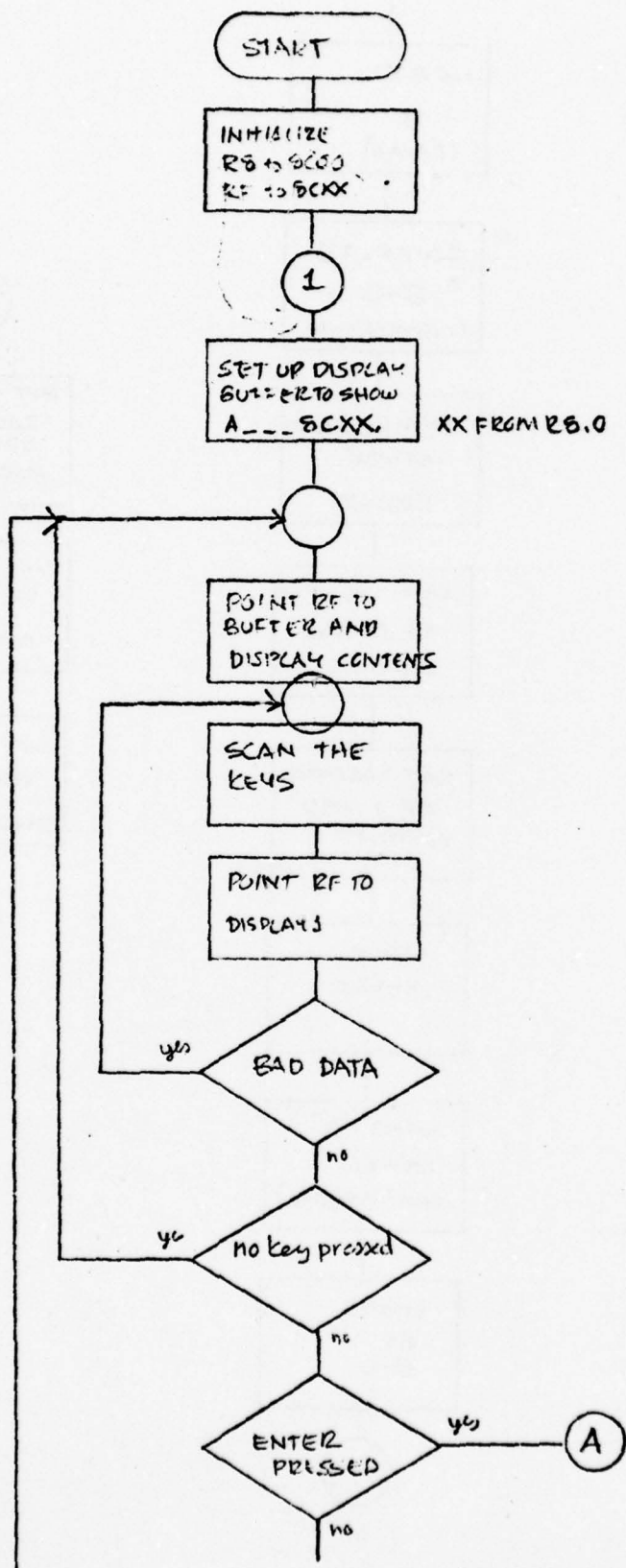
,A.O(SMIN)

20 NOV 76.

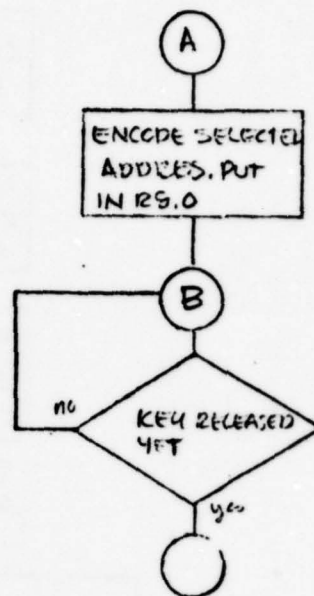
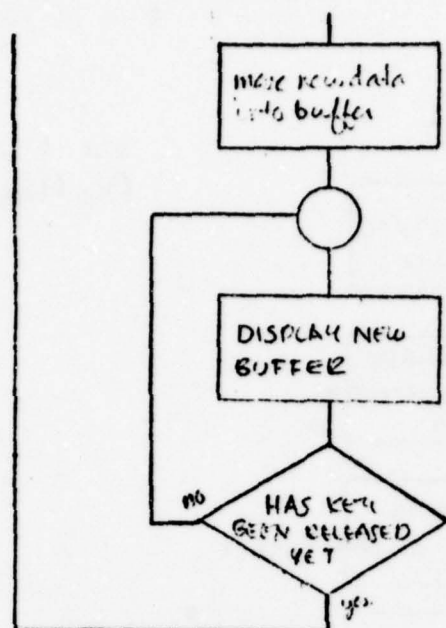
UTILIZES REGISTERS
 SCRT R3, R4, R5, R6
 R6 TO PASS parameters
 MATH REGISTERS.



UTILITY ROUTINE TO ENTER DECIMAL NUMBERS/READ MEMORY

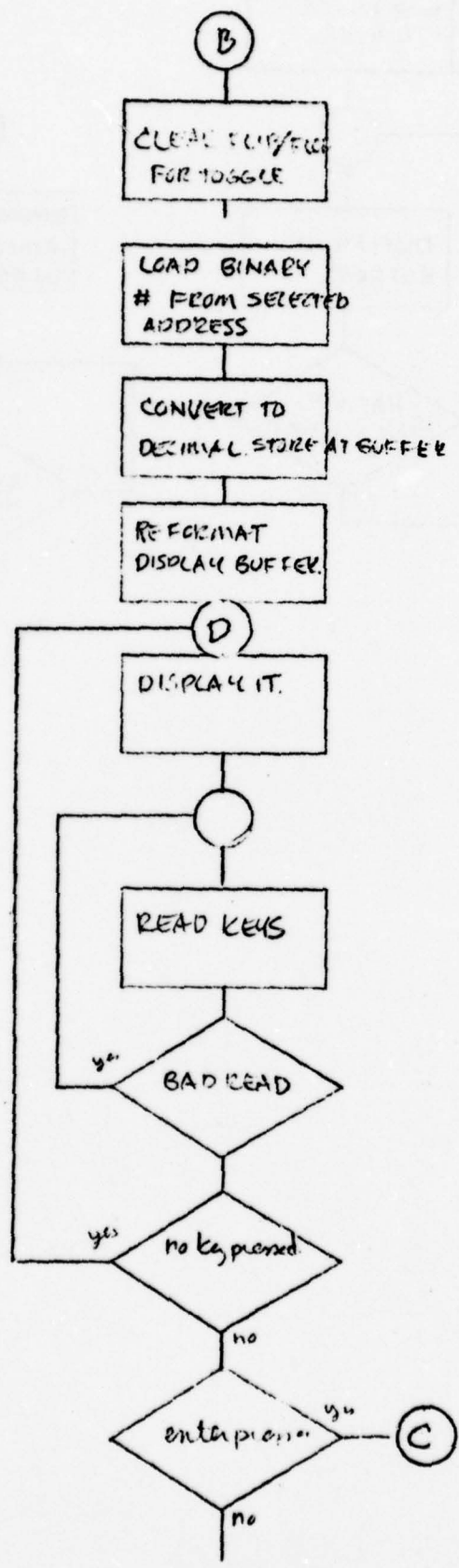


(2)

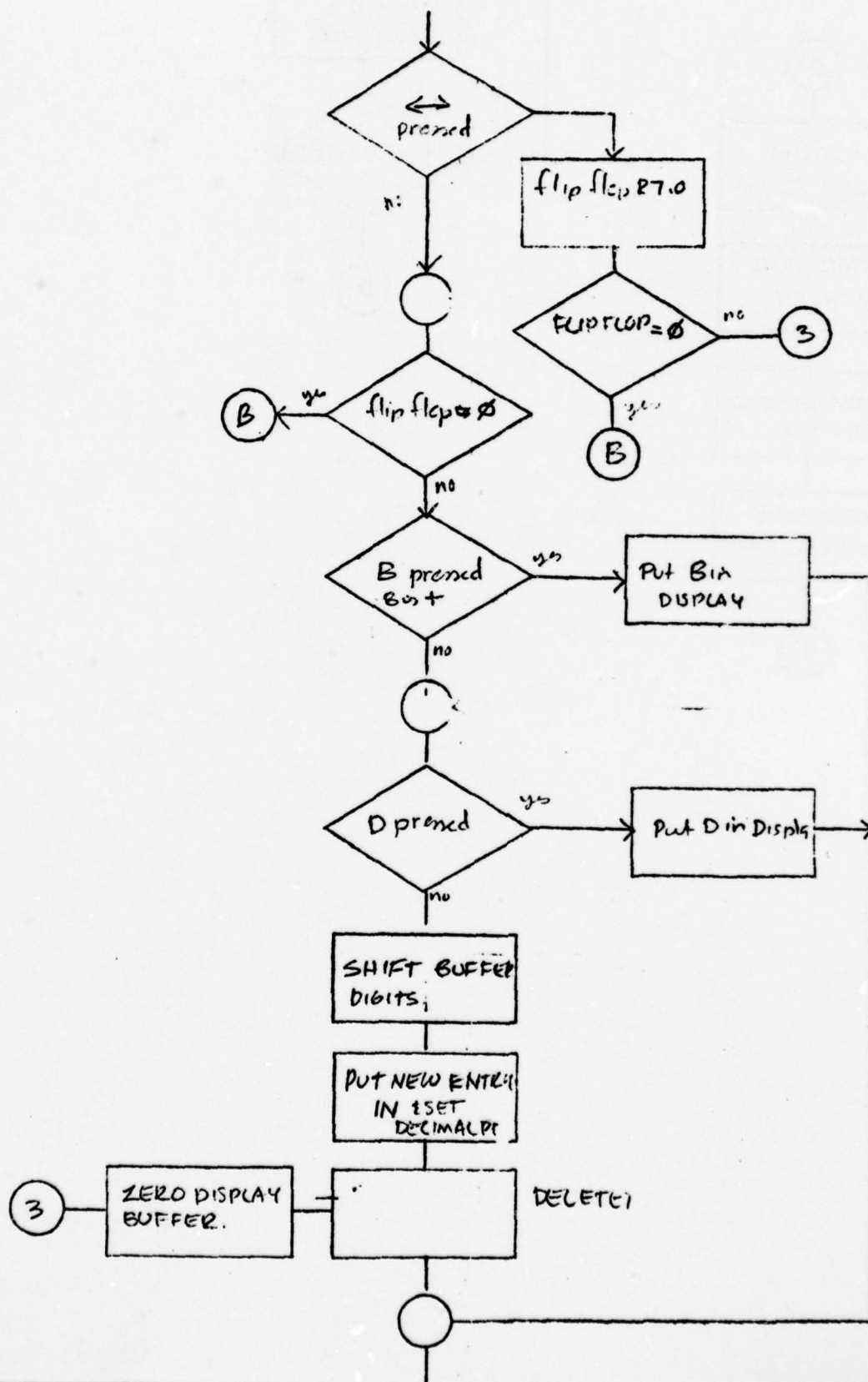


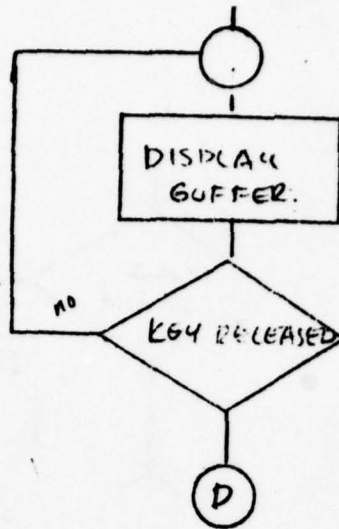
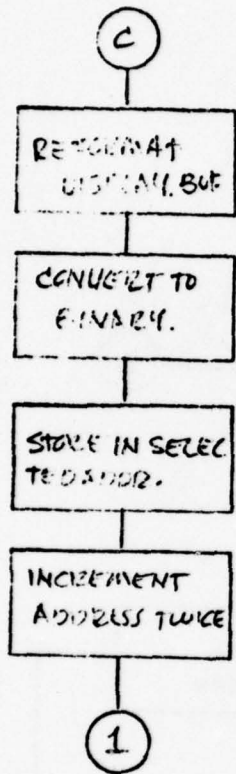
3

use B7.0 as the toggle flip flop.



4





5

RR/DCP CHECK-OUT SHEET

Date: _____ Operator: _____

Location: _____

HEX ENTRIES - PROCEDURE 1

ADDRESS	CONTENTS	SETUP	DESCRIPTION
8C62			31 Bit ID Code
8C63			"
8C64			"
8C65			"
8C52			00 FDC Precip 01 Bucket

DECIMAL ENTRIES - PROCEDURE 2

ADDRESS	CONTENTS	SETUP	DESCRIPTION
8C36			R ₁ , Base Transmission Rate x 100 (Trans/Hr x 100)
8C38			R ₂ , Alert Transmission Rate x 100 (Trans/Hr x 100)
8C3A			R ₃ , Flood Transmission Rate x 100 (Trans/Hr x 100)
8C3C			A, Slore factor stage stream (0-100)
8C3E			B, Slore factor - Precip. (0-100)
8C40			Alert Level x 100 (feet x 100)
8C42			Flood Level x 100 (feet x 100)
8C2C			Current Stage x 100 (feet x 100)
8C32			Current Precip Level x 100 (inches x 100)

TESTING/CALIBRATING PROGRAMS

168\$P	8C28 _____	Minimum Stage Level
170\$P	8C2A _____	Minimum Precip Level if "1" appears bucket is selected
178\$P	8C2C _____	Current Stage
	8C32 _____	Current Precip
180\$P		Transmits Values at 8C66
158\$P	8C46 _____	RF FWD
	8C48 _____	RF REF

PROCEDURE 1 - DISPLAYING/ENTERING HEX NUMBERS

<u>PRESS KEY</u>	<u>DISPLAY</u>		<u>COMMENTS</u>
	<u>ADDRESS</u>	<u>BYTE</u>	
R	---	---	Resets processor
RU	0000.	C0	Runs utility program at location 8000. Dots in address field indicate a new address can be entered. Address entries shift in display from right to left. The contents of that address immediately displayed. To look at the next and subsequent locations, press "inc".
8	0008.	XX	
C	008C.	XX	
6	08C6.	XX	
2	8C62.	XX	
	8C62	XX.	To alter a byte in memory, press ↔ until the field select dots are in the byte field. Pressing ↔ again will shift the select to the address field.
CE	8C62	CE.	With byte field selected key entries go to byte field. Merely retype the byte if a mistake is made. This applies to the address selection also.
inc	8C63	XX.	inc moves the byte displayed (before inc pressed) into the selected memory. The next address is selected and displayed.

X indicates that the contents are indeterminate.

PROCEDURE 2 - DISPLAYING/ENTERING DECIMAL NUMBERS

<u>PRESS KEY</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
R	-----	resets processor
RU	000.0. CO	runs utility program
160	0160. F8	selects address 160
\$P	A 8C20.	runs program at address 160.
36	A 8C36.	The A means the address mode is selected. Only the last two digits of the address can be altered. Press keys until desired address is displayed.
inc	b 0 0100	Displays the contents of that address.
	"b" is positive sign "d" is negative sign	The keyboard is locked so that the contents cannot be changed until "inc" is pressed. Pressing "inc" moves displayed data back to memory and returns to the address select mode.
	b 0. 00.00.	Pressing ↔ once allows new data to be input. Key entries are considered decimal entries. Typing a d or b will change the sign to d or b. Entries shift in the display from right to left.
inc	A 8C38.	Pressing ↔ again will restore the original contents of memory to display and lock the keyboard as before. The value last displayed is moved to memory and the program returns to the address select mode until the next address displayed.

RR/DCP OPERATOR INSTRUCTIONS

CALIBRATING STAGE (PARAMETER 1)

- (1) Enter current stage into address 8C2C using Procedure 2.
- (2) Press R, RU, 168, \$P. This will run a program which measures the stage, and computes the minimum value achievable assuming the current stage is correct.
- (3) After measuring and calculating (5 sec), the program will jump to the decimal display program. The address of SMIN (Stage Minimum) will be displayed. Press "inc" to see the contents. Note the sign "b" is +, "d" is negative.
- (4) If this value is lower than the instruments desired minimum slip the belt off and rotate the wheel. Each turn is equivalent to 1 foot.
- (5) Run the calibration program and adjust the wheel until the proper minimum is computed.

CALIBRATING PRECIPITATION (PARAMETER 2)

- (1) Precip does not need to be calibrated if the bucket method is used to measure precip levels. Running the program with the bucket selected (01 in 8C52) will display a 1.
- (2) Enter current precip level in 8C52.
- (3) Press R, RU, 170, \$P. This will run a program which measures the precip level, and computes the minimum value achievable assuming the current precip level is correct. After measuring and calculating (5 sec), the program will jump to the Decimal Display/Enter Program.
- (4) The address of PMIN (Precip Minimum) will be displayed. Press "inc" to see the contents. Note the sign "b" is +, "d" is negative.
- (5) If this value is lower than the instruments actual minimum, slip the belt off the gear and rotate the gear. Each turn is equivalent to .25 inches.

- (5) Run the calibration program and adjust the gear until the proper minimum is computed.

ACQUIRE DATA

- (1) To exercise the data acquisition program press R, RU, 178, \$P.
- (2) The program will measure the parameters, calculate the values and branch to the decimal display program. The contents of memory can then be examined.

TRANSMIT

- (1) To exercise the transmitter press R, RU, 180, \$P.
- (2) The normal transmission will be made using the 10 located at 8C62. After the transmission RF act and RF reflected will be measured. The program will branch to the decimal display program so the resultant values can be examined.

MEASURING TRANSMIT POWER

- (1) To measure transmit power, press R, RU, 158, \$P.
- (2) The microprocessor will measure RF-FWD and RF-REF, then branch to the decimal display program. The values at location 8C46 (RF-FWD) and 8C48 (RF-REF) should correspond to values set for that transmitter.

APPENDIX D

TABLE I	-	PART LIST BOARD #1 - CPU BOARD
TABLE II	-	PART LIST BOARD #2 - MEMORY BOARD
FIGURE D.1	-	BOARD #1 LAYOUT
FIGURE D.2	-	BOARD #2 LAYOUT
FIGURE D.3	-	CPU, STARTUP, CLOCK SECTION
FIGURE D.4	-	MEMORY SECTION
FIGURE D.5	-	INSTRUMENTATION INTERFACE SECTION
FIGURE D.6	-	200 Hz OSCILLATION SECTION
FIGURE D.7	-	TCXO POWER SECTION
FIGURE D.8	-	POWER SUPPLY SECTION

Table I. PARTS LIST FOR BOARD #1 CPU BOARD

BOARD 1

U1, U16	CD4040 AE
U2	CDP1802 CD
U3	CD4028 B
U4	CD4049 UB
U5	CD4050 B
U6	CD4001 B
U7	CDP1852 CD
U8, U9	CD4011 A
U10	CD4051 B
U11	CD4016 A
U12	AD537 KD
U13	CD4098 B
U14	CD40106 B
U15	CD4068 B
U17	CD4007

CPU BOARD

R1	20k	CR1	1N757	C1	1uf.	MODEL 254-38609
R2	100k	Q1	2N2222.	C2, C3	5pf	TC XQ Vectra 50.2223
R3	4.7k	Q2	2N2906	C4	.1ufd	X1 32.768k. MODEL 7710
R4	10k	CR2	5.1V zener	C5	.001ufd	
R5	47Ω	CR3	1N4148	C6	.01ufd	
R6	1M	Q3	CA3160	C7	.1ufd.	
R7	22M.	Q4	2N2906	C8	.001ufd.	
R8	1.5M			C9	10ufd	
R9	150k			C10	.01	
R10	10k			C11	.015ufd.	
R11	1k.			C12	.01	
R12	4.7k			C13	1ufd	
R13	390k ?			C14	1ufd.	
R14	1M			C15-C20	.01ufd.	
R15	1M.			C21	33pf.	
R16	100k					
R17	100k					
R18	100k	R20	10k			
R19	470k.	R31	10k.			
R20	2.2M.		RF chdce.			
R21, 22, 23, 24	100k.	R32	1M			
R25	1k	R33	1k.			
R26	2.2k.					
R27.	4.7k					
R28	909Ω.					
R29	1k.					

Table II. PARTS LIST FOR BOARD #2 - MEMORY

U1-U3	1M6604 W6
U4	CDP1832
U5	CDP2582
U6, U7	CDP1822
U8	CDP1852CD
U9	CD4555B
C10	CD4049UB
C11	CD4023B
C12	CD4013A.

R1	47 Ω	CR1	1N4148	Q1	2N2906
R2	100 Ω	CR2	1N4148	Q2	2N2222
R3	10K	CR3	TS5600	Q3	2N2222.
R4	470 Ω	CR4	TS5600	Q4	2N5190
R5	4.7 K.	CR5	1N4148	Q4	CA7018 3018
R6	470K	CR6	1N5344		
R7	1.0M	CR7	1N5344.	C1	10uFd
R8	100K.	CR8	MR500.	C2	10uFd.
R9	470K			C3	.01 uFd.
R10	47K.	SCR1	2N4441	C4	.001
R11	1.0M.			C5-C12	.01
R12	10K,				
R13	24K.				

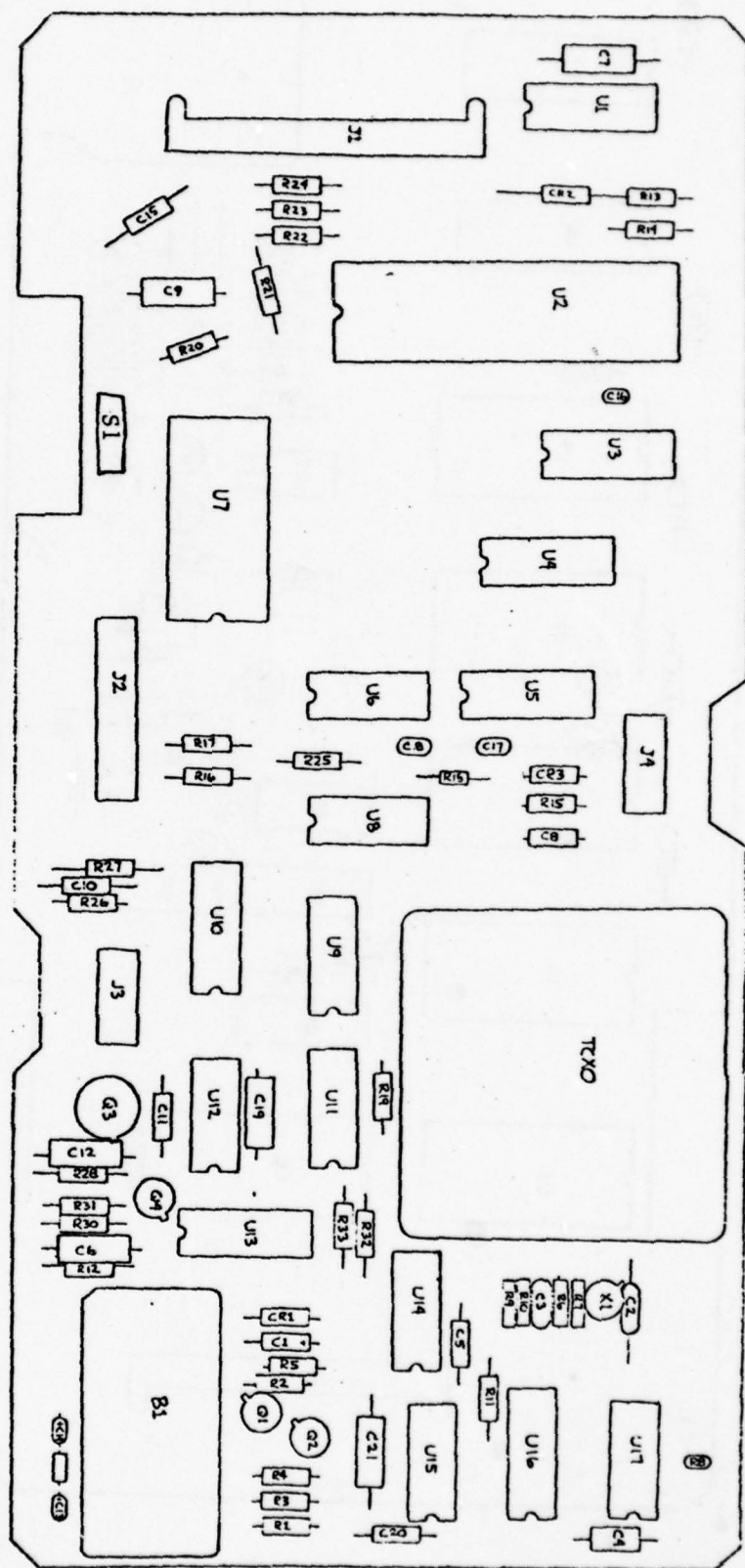


Figure D.1. CPU LAYOUT BOARD #1

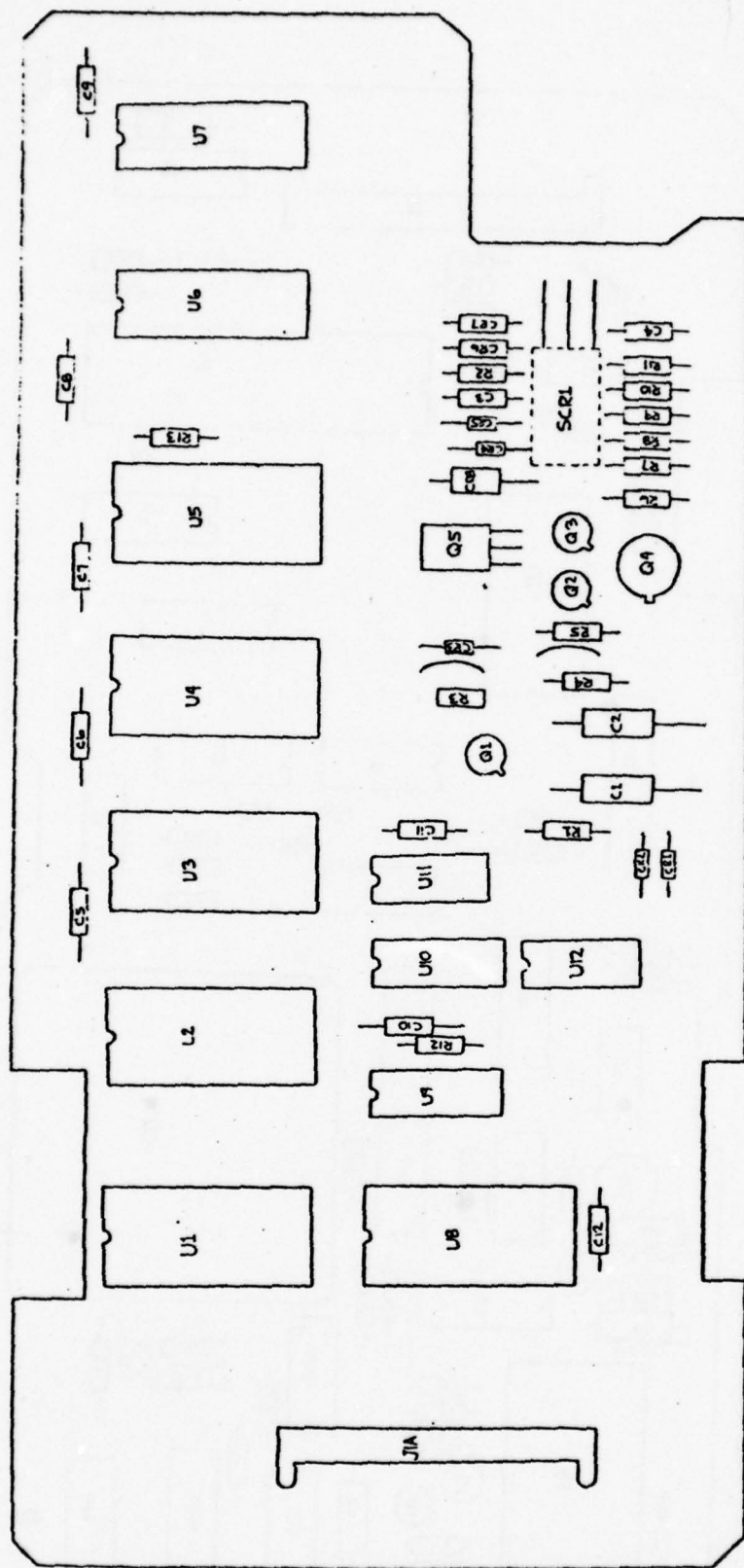


Figure D.2. MEMORY LAYOUT BOARD #2

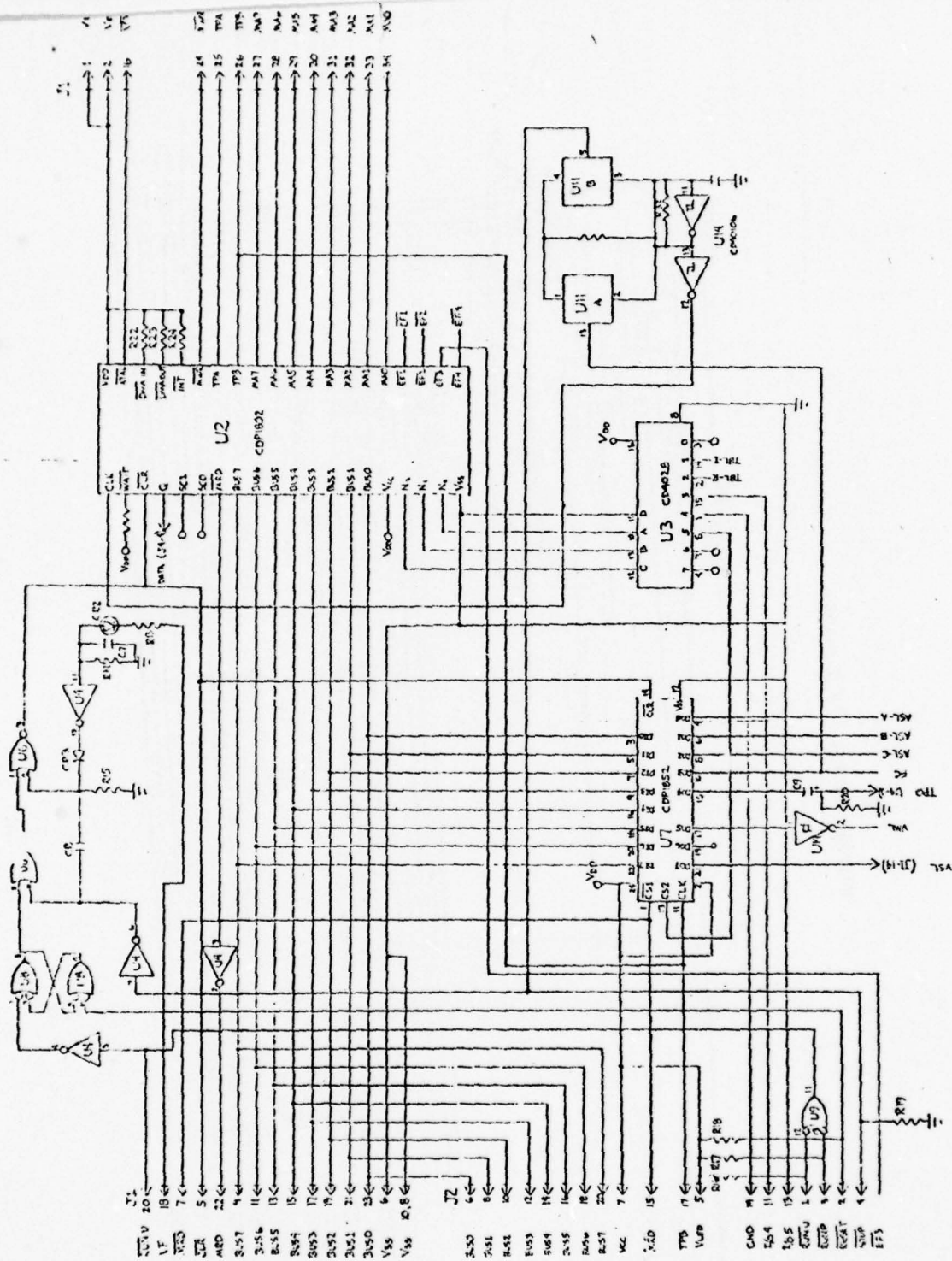


Figure D.3. CPU, STARTUP CONTROL, CLOCK

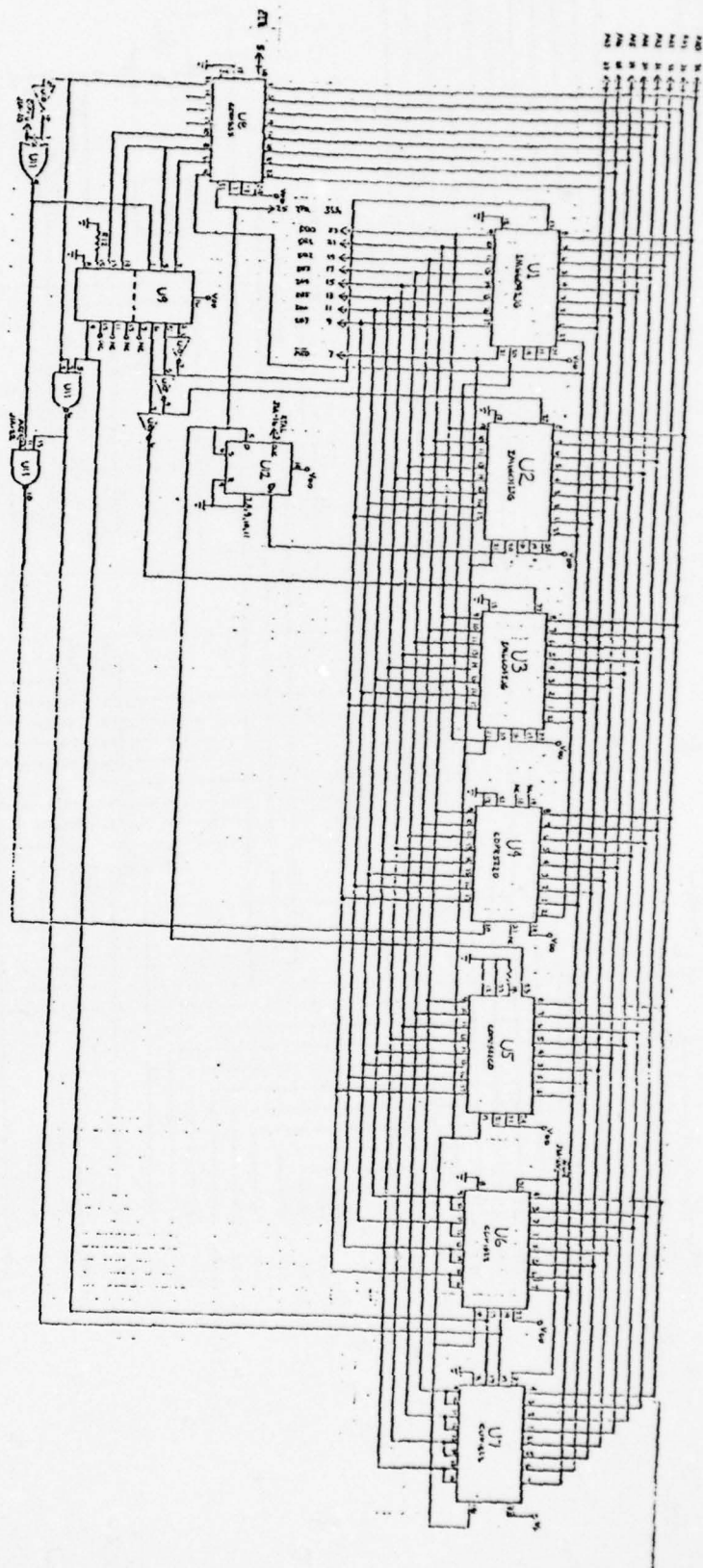


Figure D.4. MEMORY SECTION

DCP1-2

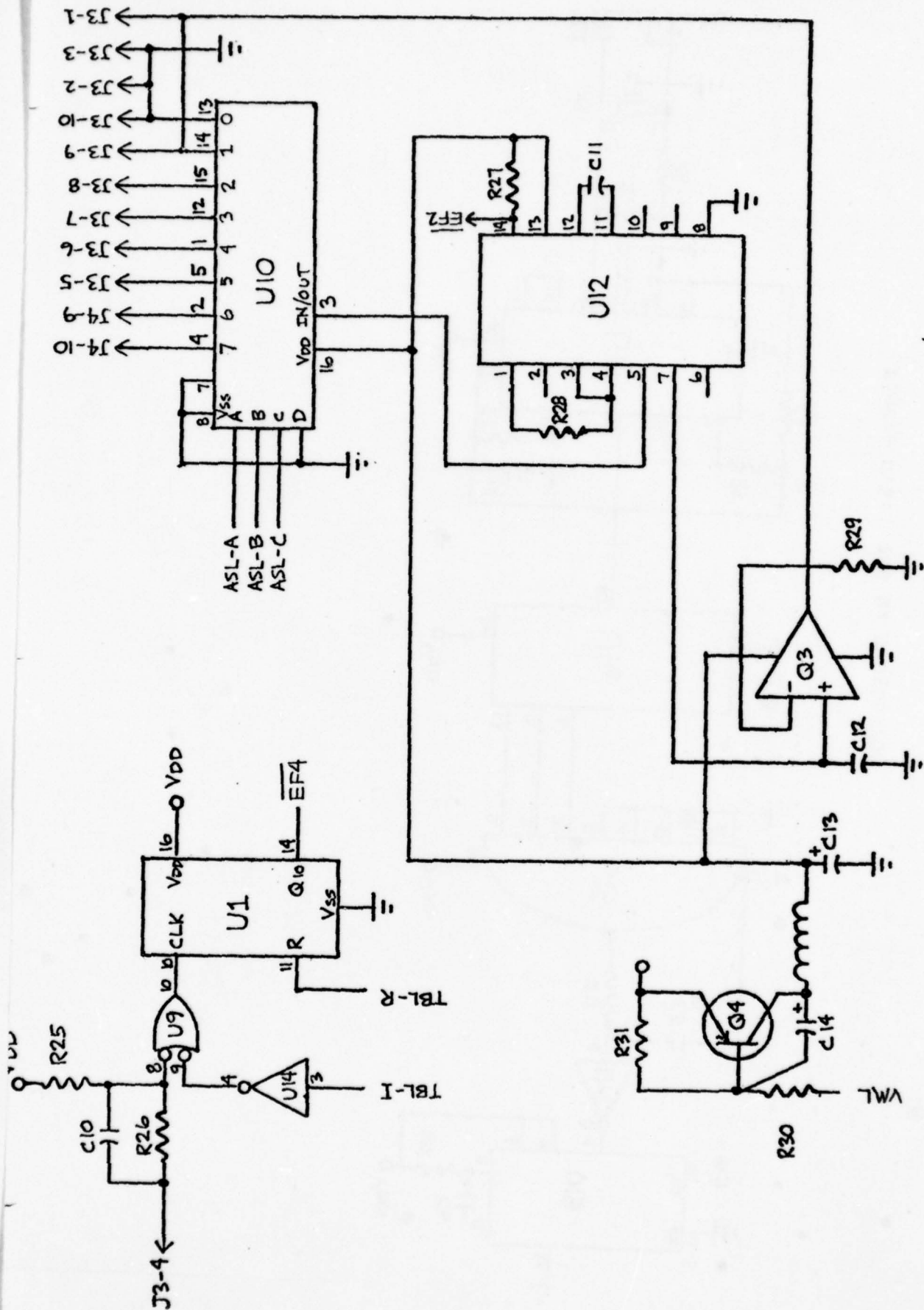


Figure D.5 INSTRUMENTATION INTERFACE

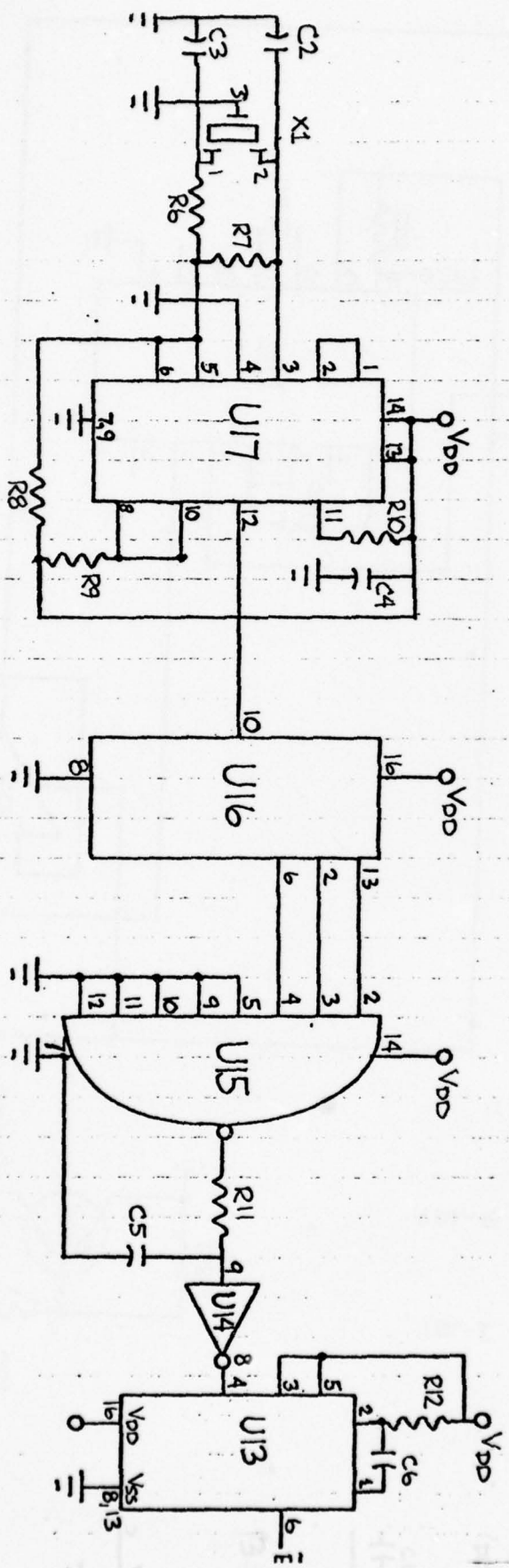


Figure D.6. 200 Hz OSCILLATOR

DCP1-4 12/76

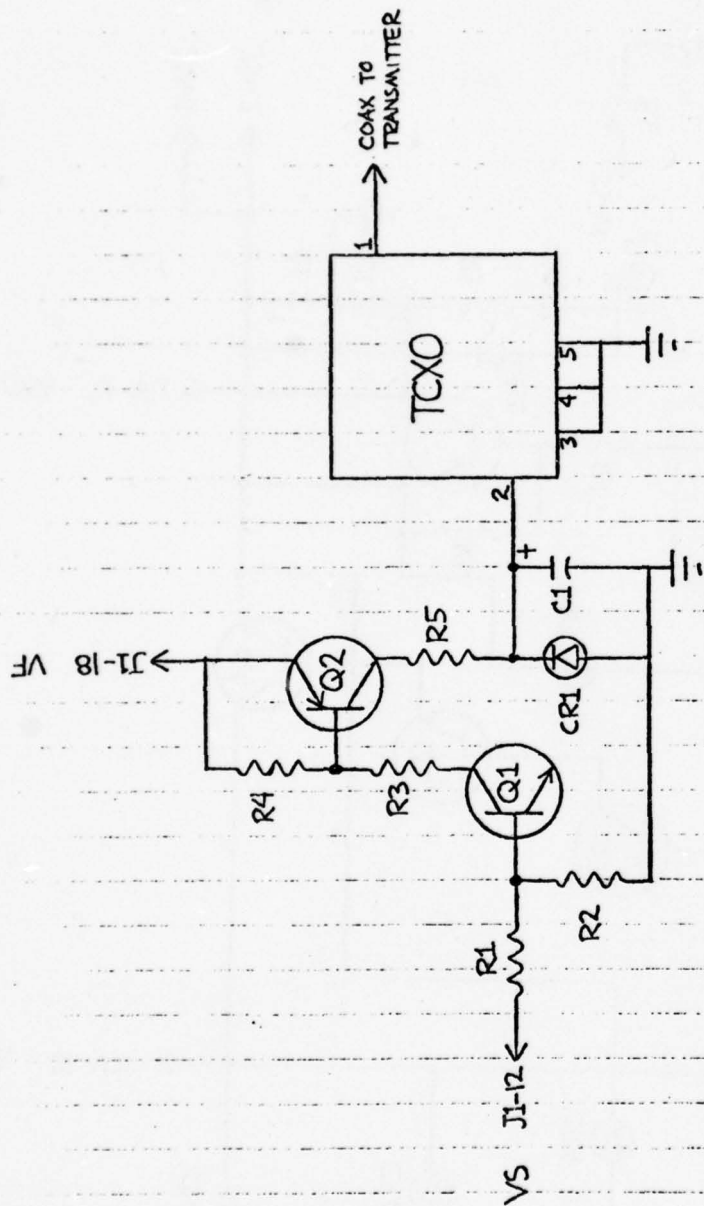


Figure D.7. TCXO POWER

DC:P1-5 12/76

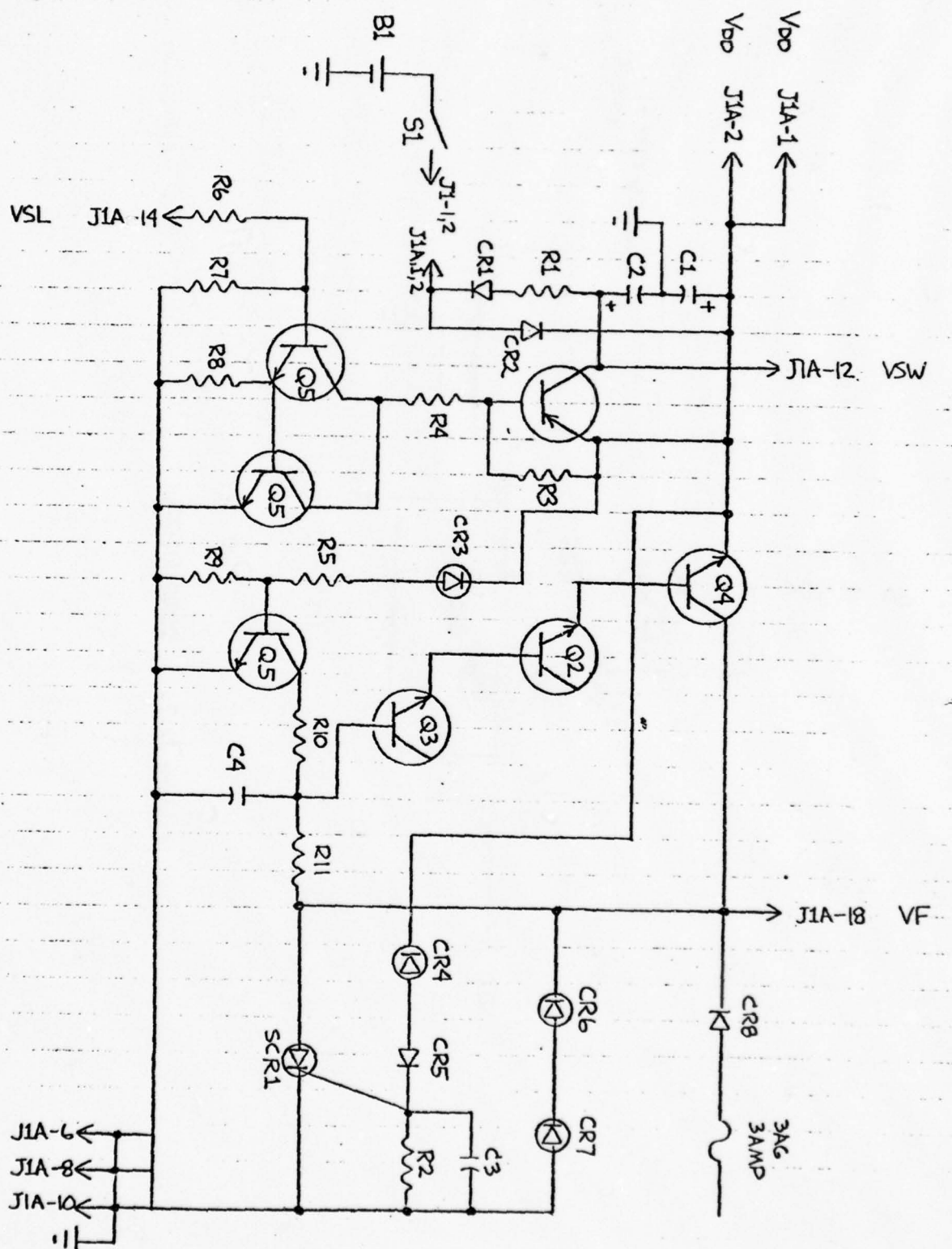


Figure D.8. POWER SUPPLY

FL	LOC	COSMAC CODE	LNNO	SOURCE LINE
			00001	..DCP EXECUTIVE PROGRAM
			00002	..
			00003	..
			00004	..REGISTER ASSIGNMENTS
	#0003		00005	PC=R3
	#0004		00006	CALL=R4
	#0005		00007	RETN=R5
			00008	..SUBROUTINE ADDRESSES
	#03F2		00009	CALC=#03F2
	#0393		00010	CALCSR=#0393
	#03B1		00011	CALCPR=#03B1
	#0302		00012	ENCODE=#0302
	#0200		00013	GXMIT=#0200
	#0431		00014	LDELY1=#0431
	#0435		00015	LDELY2=#0435
	#0461		00016	MEASR= #0461 0465
	#02EC		00017	RND= #02EC
	#034D		00018	UPDATE=#034D
	#C249		00019	LOADOP=#C249
	#C257		00020	STOROP=#C257
	#C25B		00021	STORE=#C25B
	#C24D		00022	LOAD =#C24D
	#C00D		00023	SDCON=#C00D
			00024	..RAM LOCATIONS
	#8C3C		00025	CON1 =#8C3C
	#8C3E		00026	CON2 =#8C3E
	#8C50		00027	FLAG1 =#8C50
	#8C51		00028	FLAG2=#8C51
	#8C52		00029	FLAG3=#8C52
	#8C53		00030	FLAG4=#8C53
	#8C54		00031	FLAG5=#8C54
	#8C22		00032	FMIN=#8C22
	#8C26		00033	FPRECP=#8C26
	#8C24		00034	FSTAGE=#8C24
	#8C5A		00035	PAD=#8C5A
	#8C2A		00036	PMIN=#8C2A
	#8C32		00037	PRECP1=#8C32
	#8C34		00038	PRECP2=#8C34
	#8C44		00039	RAND=#8C44
	#8C4A		00040	RATE1=#8C4A
	#8C4D		00041	RATES=#8C4D
	#8C4E		00042	RATEP=#8C4E
	#8C28		00043	SMIN=#8C28
	#8C2C		00044	STAGE1=#8C2C

#8C2E	00045	STAGE2=#8C2E
#8C30	00046	STAGE3=#8C30
#8C66	00047	TDATA=#8C66
	00048	
	00049	..INITIALIZATION
	00050	
0000	00051	ORG #00
0000 C08108	00052	LBR #8108 ..BRANCH TO ENTRY OF MICRO
0005	00053	ORG #05
0005 F88CB8	00054	LDI #8C; PHI R8 ..8C INTO R8.1 TERM R0
0008 F800A7	00055	LDI #00; PLO R7 ..00 INTO R7.0
000B F80007 FF B7	00056	LDI #FF; PHI R7 ..TRANSMIT AFTER 2 CYCLE
000E F850	00057	LDI A.0(FLAG1)
0010 A8	00058	PLO R8
0011 F801	00059	LDI #01
0013 58	00060	STR R8 ..1 INTO FLAG1
0014 18	00061	INC R8
0015 F800	00062	LDI #00
0017 58	00063	STR R8 ..0 INTO FLAG 2
0018 F844	00064	LDI A.0(RAND)
001A A8	00065	PLO R8
001B F800	00066	LDI #00 ..SET UP RAND TO 0005
001D 58	00067	STR R8
001E 18	00068	INC R8
001F F805	00069	LDI #05
0021 58	00070	STR R8
0022 F84A	00071	LDI A.0(RATE1) ..SET UP RATE1,2,3 WITH FF
0024 A8	00072	PLO R8
0025 F8FF58	00073	LDI #FF; STR R8 ..FF INTO RATE1
0028 1858	00074	INC R8; STR R8 ..FF INTO RATE 2
002A 1858	00075	INC R8; STR R8 ..FF INTO RATE3
002C F868	00076	LDI A.0(TDATA)+#02
002E A8	00077	PLO R8 ..POINT R8 TO BUCKET ACCUM
002F F80058	00078	LDI #00; STR R8 ..0 OUT THE BUCKET
0032 1858	00079	INC R8; STR R8
0034 3050	00080	BR #50
	00081	
	00082	..EXECUTIVE PROGRAM
0050	00083	ORG #50
	00084	..IS IT TIME TO COLLECT NEW DATA?
0050 F851	00085	EXEC1: LDI A.0(FLAG2) ..POINT TO FLIP-FLOP
0052 A8	00086	PLO R8
0053 08	00087	LDN R8 ..TEST FLAG
0054 3AD4	00088	BNZ EXEC2 ..DON'T COLLECT DATA IF FLAG IS
0056 F801	00089	LDI #01 ..SET FLIP FLOP TO 1 SET

0058 58	00090	STR R8
0059 D4	00091	..MAKE ROOM FOR NEW DATA
005A C249	00092	SEP CALL
005C 8C2E	00093	,A(LOADOP) ..GET STAGE 2
005E D4	00094	,A(STAGE2)
005F C25B	00095	SEP CALL
0061 D4	00096	,A(STORE) ..STORE IN STAGE 3
0062 C24D	00097	SEP CALL
0064 D4	00098	,A(LOAD) ..GET PRECIP1
0065 C25B	00099	SEP CALL
0067 D4	00100	,A(STORE) ..STORE IN PRECIP 2
0068 C249	00101	SEP CALL
006A 8C2C	00102	,A(LOADOP) ..GET STAGE 1
006C D4	00103	,A(STAGE1)
006D C25B	00104	SEP CALL
	00105	,A(STORE) ..STORE IN STAGE 2
	00106	..COLLECT NEW DATA
006F D4	00107	SEP CALL ..MEASURE DATA
0070 E3 0465	00108	,A(MEASR)
0072 E3	00109	SEX PC
0073 65	00110	OUT 5 ..TURN OFF FAST CLOCK AND HIGH
0074 00	00111	,#00 ..VOLTAGE
	00112	..PERFORM CONVERSIONS
0075 D4	00113	SEP CALL
0076 03F2	00114	,A(CALC) ..CONVERT FSTAGE TO FEET
0078 24	00115	,A.0(FSTAGE)
0079 22	00116	,A.0(FMIN)
007A 0FA0	00117	,4000 ..40 FT FULL SCALE
007C 66	00118	,A.0(TDATA) ..STORE INTERMED RESULT
007D 28	00119	,A.0(SMIN)
007E 2C	00120	,A.0(STAGE1) ..FINAL STAGE VALUE
007F F852	00121	LDI A.0(FLAG3) ..DO WE CONVERT PRECIP ALDO
0081 A808	00122	PLD R8 ; LDN R8
0083 3A91	00123	BNZ EA1 ..BYPASS CONVERSION IN FLAG3=1
0085 D4	00124	SEP CALL
0086 03F2	00125	,A(CALC) ..CONVERT PRECIP TO INCHES
0088 26	00126	,A.0(FPRECIP)
0089 22	00127	,A.0(FMIN)
008A 03E8	00128	,1000 ..10 INCHES FULL SCALE
008C 68	00129	,A.0(TDATA)+#02
008D 2A	00130	,A.0(PMIN)
008E 32	00131	,A.0(PRECIP1)
008F 30A5 9B	00132	BR EA2
0091 D4	00133	EA1: SEP CALL ..USING BUCKET, NO CONVERSION
0092 C249	00134	,A(LOADOP) ..NECESSARY
0094 8C68	00135	,A(TDATA)+#02

0096 D4	00136	SEP CALL	..COPY BUCKET INTO PRECP1
0097 C257	00137	,A(STOROP)	
0099 8C32	00138	,A(PRECP1)	
	00139	..RETURN IMMEDIATELY??	
009B F854	00140	EA2: LDI A.0(FLAG5)	..GET FLAG5
009D A8	00141	PL0 R8	
009E 08	00142	LDN R8	
009F 32A5	00143	BZ EA2	..IF FLAG5=0, DON'T RETURN
00A1 F800	00144	LDI #00	
00A3 58	00145	STR R8	
00A4 D5	00146	SEP RETN	..RETURN TO CALL PROGRAM
00A5 F850	00147	EA2: LDI A.0(FLAG1)	..IS THIS THE FIRST LOOP
00A7 A8	00148	PL0 R8	
00A8 08	00149	LDN R8	..GET THE FLAG
00A9 32C1	00150	BZ EB2	..IF ZERO NOT FIRST LOOP
00AB F800	00151	LDI #00	..FIRST LOOP, CLEAR FLAG
00AD 58	00152	STR R8	
00AE D4	00153	SEP CALL	..GET STAGE 1
00AF C249	00154	,A(LUADUP)	
00B1 8C2C	00155	,A(STAGE1)	
00B3 D4	00156	SEP CALL	..PUT IN STAGE 2
00B4 C25B	00157	,A(STORE)	
00B6 D4	00158	SEP CALL	..PUT IN STAGE 3
00B7 C25B	00159	,A(STORE)	
00B9 D4	00160	SEP CALL	
00BA C249	00161	,A(LOADOP)	
00BC 8C32	00162	,A(PRECP1)	..GET PRECIP 1
00BE D4	00163	SEP CALL	
00BF C25B	00164	,A(STORE)	..PUT IN PRECIP 2
	00165	..RATE CALCULATIONS	
	00166	..CALCULATE STAGE RATE	
00C1 D4	00167	EB2: SEP CALL	..CALCULATE A+B*(C-D)
00C2 0393	00168	,A(CALCSR)	..A IS RBASE
00C4 2C	00169	,A.0(STAGE1)	
00C5 30	00170	,A.0(STAGE3)	..D
00C6 3C	00171	,A.0(CON1)	..B
00C7 4D	00172	,A.0(RATES)	..RAM STORAGE FOR RESULT
	00173	..CALCULATE PRECIP RATE	
00C8 D4	00174	SEP CALL	
00C9 03B1	00175	,A(CALCPR)	..A IS RBASE
00CB 32	00176	,A.0(PRECP1)	..C
00CC 34	00177	,A.0(PRECP2)	..D
00CD 3E	00178	,A.0(CON2)	..B
00CE 4E	00179	,A.0(RATEP)	..RAM STORAGE FOR RESULT
	00180	..UPDATE THE RATES	
00CF D4	00181	SEP CALL	
00D0 034D	00182	,A(UPDATE)	
00D2 30DC	00183	BR EXEC3	

	00184	..
	00185	..NO DATA HAS BEEN COLLECTED
	00186	..DELAY TO MAKE UP FOR IT
00D4 F800	00187	EXEC2: LDI #00 ..SET FLIP FLOP TO ZERO
00D6 58	00188	STR R8
00D7 D4	00189	SEP CALL
00D8 0431	00190	,A(LDELY1)
00DA FFFF	00191	,#FFF 0100
	00192	..
	00193	..ALL PATHS MEET HERE
	00194	..IS IT TIME TO TRANSMIT
00DC E8	00195	EXEC3: SEX R8
00DD F84A	00196	LDI A.0(RATE1) ..POINT TO CURRENT RATE
00DF A8	00197	FLO R8
00E0 97	00198	GHI R7 ..GET CYCLE COUNTER
00E1 FC01	00199	ADI #01 ..ADD ONE TO IT
00E3 B7	00200	PHI R7 ..STORE IT
00E4 F7	00201	SM ..R7.1-RATE1
00E5 CB0139	00202	LBNF EXEC4
00E8 F800	00203	LDI #00 ..OH BOY, WE GET TO TRANSMIT
00EA B7	00204	PHI R7
00EB 17	00205	INC R7
00EC D4	00206	SEP CALL
00ED 02EC	00207	,A(RND) ..GENERATE RANDOM #
00EF 9F	00208	GHI RF ..CHOP IT DOWN TO 12 BITS
00F0 FA0F	00209	ANI #0F
00F2 BF	00210	PHI RF
00F3 D4	00211	SEP CALL ..DELAY FOR A WHILE
00F4 0435	00212	,A(LDELY2)
	00213	..ALL DONE WITH DELAY...MEASURE DATA AGAIN
00F6 D4	00214	SEP CALL
00F7 0461 0465	00215	,A(MEASR) ..TURNS ON FAST CLOCK ALSO
	00216	..CALCULATE AGAIN
00F9 D4	00217	SEP CALL
00FA 03F2	00218	,A(CALC)
00FC 24	00219	,A.0(FSTAGE)
00FD 22	00220	,A.0(FMIN)
00FE 0FA0	00221	,4000
0100 66	00222	,A.0(TDATA)
0101 28	00223	,A.0(SMIN)
0102 5A	00224	,A.0(PAD) ..THROW THIS AWAY
0103 F852	00225	LDI A.0(FLAG3)
0105 A8	00226	FLO R8
0106 08	00227	LIN R8
0107 CA0114	00228	LBNZ EC1 ..NO CALC NEC. IF FLAG3=1
010A D4	00229	SEP CALL

010B 03F2	00230	,A(CALC)	
010D 26	00231	,A.0(FPRECP)	
010E 22	00232	,A.0(FMIN)	
010F 03EB	00233	,1000	
0111 68	00234	,A.0(TDATA)+#02	
0112 2A	00235	,A.0(PMIN)	
0113 5A	00236	,A.0(PAD)	..THROW THIS AWAY
	00237	..ENCODE DATA	
0114 D4	00238	EC1: SEP CALL	
0115 0302	00239	,A(ENCODE)	
	00240	..TRANSMIT DATA	
0117 D4	00241	SEP CALL	
0118 0200	00242	,A(GXMIT)	
011A 20	00243	,#20	..32*8 CLOCK
011B 04	00244	,#04	..4 BYTES TO TRANSMIT
011C F853	00245	LDI A.0(FLAG4)	
011E A8	00246	PLO R8	
011F 08	00247	LDN R8	..GET FLAG 4
0120 3226	00248	BZ EC3	
0122 F800	00249	LDI #00	..IF SET, CLEAR IT AND RETURN
0124 58	00250	STR R8	
0125 D5	00251	SEP RETN	..RETURN TO CALL PROGRAM
	00252	..NOW COMPENSATE FOR RANDOM DELAY	
0126 D4	00253	EC3: SEP CALL	
0127 C249	00254	,A(LOADOP)	..GET OLD DELAY COUNTER
0129 8C44	00255	,A(RAND)	
012B 9F	00256	GHI RF	..CHOP DOWN TO 12 BITS
012C FA0F	00257	ANI #0F	
012E BF	00258	PHI RF	
012F D4	00259	SEP CALL	
0130 C00D	00260	,A(SDCON)	..CALC.REMAINING DELAY
0132 0FFF	00261	,#0FFF	
	00262	..DELAY TO EVEN UP TIME	
0134 D4	00263	SEP CALL	
0135 0435	00264	,A(LDELY2)	
0137 303E	00265	BR EXEC5	
	00266	..DELAY WHEN NO TRANSMISSION HAS BEEN MADE	
0139 D4	00267	EXEC4: SEP CALL	
013A 0431	00268	,A(LDELY1)	
013C FFFF 10D4	00269	,#FFFF	6555
	00270	..DELAY TO CREATE A 4 MINUTE CYCLE TIME	
013E D4	00271	EXEC5: SEP CALL	
013F 0431	00272	,A(LDELY1)	
0141 FFFF	00273	,#FFFF	1000
0143 C00050	00274	LBR EXEC1	..GO TO BEGINNING
	00275	END	

Symbol table

CALC	03F2	CALCPR	03B1	CALCSR	0393	CALL	0004
CON1	8C3C	CON2	8C3E	EA1	0091	EA2	00A5
EB2	00C1	EC1	0114	EC3	0126	ENCODE	0302
EXEC1	0050	EXEC2	00D4	EXEC3	00DC	EXEC4	0139
EXEC5	013E	FLAG1	8C50	FLAG2	8C51	FLAG3	8C52
FLAG4	8C53	FLAG5	8C54	FMIN	8C22	FPRECP	8C26
FSTAGE	8C24	GXMIT	0200	LDLY1	0431	LDLY2	0435
LOAD	C24D	LOADOP	C249	MEASR	0461	PAD	8C5A
PC	0003	PMIN	8C2A	PRECP1	8C32	PRECP2	8C34
RAND	8C44	RATE1	8C4A	RATEP	8C4E	RATES	8C4D
RETN	0005	RND	02EC	SDCON	C00D	SMIN	8C28
STAGE1	8C2C	STAGE2	8C2E	STAGE3	8C30	STORE	C25B
STOROP	C257	TDATA	8C66	UPDATE	034D		

LOC COSMAC CODE LNNO SOURCE LINE

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00001      ..TRANSMITTER ROUTINE
00002      ..THIS ROUTINE CONTROLS THE TRANSMITTER
00003      ..TO SEND MANCHESTER ENCODED DATA AT 100 HZ.
00004      ..
0200 00005      ORG #200
00006      ..TRANSMITTER CONSTANTS
00007      ..BIT 3 (FAST CLOCK) AND
00008      ..BIT 7 (HIGH VOLTAGE) SHOULD ALWAYS BE SET.
      #0094 00009      CPO=#94 ..POWER ON CONSTANT BIT 4
      #00B4 00010      CTO=#B4 ..TRANSMITTER ON CON BIT 5
      #00F4 00011      CCO=#F4 ..CARRIER ON CONSTANT BIT 6
      #0022 00012      SYNC1=#22 ..FIRST SYNC WORD (CONTAINS TWO
00013      ..CLOCK BITS ALSO
      #00EB 00014      SYNC2=#EB ..SECOND SYNC WORD
00015      ..CHARACTER CONSTANTS
      #0004 00016      EOT=#04
00017      ..RAM LOCATIONS
      #0062 00018      ADDR=#62
      #006A 00019      TBUF=#6A
00020      ..REGISTER ASSIGNMENTS
      #0003 00021      PC=R3
      #0004 00022      CALL=R4
      #0005 00023      RETURN=R5
00024      ..
00025      ..SEQUENCE TO TURN ON AND INITIALIZE TRANSMI
0200 E3 00026      GXMIT: SEX PC
0201 65 00027      OUT 5 ..TURN POWER ON
0202 94 88 00028      , 88 T000000000
0203 D4 00029      SEP CALL ..DELAY FOR WARM UP OF 1 SEC
0204 02AF 00030      ,A(DELAY) Delay 1/4 sec.
0206 512C 192D 00031      , 1515E
00032      ..
0208 E3 00033      SEX PC
0209 65 a 00034      SEX PC OUT 5 ..TURN TRANSMITTER ON
020A B4 D8 00035      OUT 5 , ETO
020B E3 C4 00036      #96 SEX PC
020C 65 C4 00037      NOP OUT 5 ..TURN CARRIER ON
020D FA C4 00038      NOP , CCO
020E 51 F68C 00039      LDI SC SEP CALL LDI SC ..CARRIER LASTS FOR 4 SEC
020F 000F B8 00040      PHI R8 ,A(DELAY) #128
0211 000F C4 C4 00041      NOP , #CB66
0213 D4 00042      SEP CALL SEP CALL
0214 02AF 3245 00043      A(DELAY) ,A(DELAY)
0216 000F 500F 00044      , #3245 , #CB66

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	00045	..	..PREPARE TO TRANSMIT CLOCK
0218 7A	00046	NOP	REQ ..RESET Q---Q IS THE SERIAL OUTPUT L
0219 E4	00047	NOP	SEX PC
021A 341A	00048	NOP	B1 * ..WAIT FOR EF1=0
021C 3C1C	00049	NOP	BNI * ..WAIT FOR SIGNAL, EF1=1
021E 3E1E	00050	NOP	OUT J ..TURN OFF CARRIER
021F 3E1F	00051	NOP	OUT J ..TURN OFF CARRIER
	00052	..	..BIT TO BE SENT
0220 D4	00053	NOP	SEP CALL ..DELAY TO AVOID OVERLAP
0221 02AF	00054	NOP	,A(DELAY)
0223 0001	00055	B1+	,#0001
0225 3C25	00056		BNI * ..WAIT FOR SIGNAL
0227 7B	00057		SEQ ..TRANSMIT SECOND HALF OF FIRST BIT
	00058		..TRANSMIT CLOCK BITS
0228 46	00059	XCLOCK:	LDA R6 ..SET UP LOOP COUNTER
0229 AD	00060		PLO RD
022A F808	00061		LDI #08 ..INITIALIZE BIPHS BIT COUNTER TO 8
022C AC	00062		PLO RC
022D F8AA	00063	XC1:	LDI #AA ..SET UP CLOCK BYTE
022F AF	00064		PLO RF
0230 D4	00065		SEP CALL ..TRANSMIT BYTE
0231 0278	00066		,A(BIP)
0233 00	00067		,#00
0234 2D	00068		DEC RD ..DECREMENT COUNTER
0235 8D	00069		GLO RD ..TEST COUNTER
0236 3A2D	00070		BNZ XC1 ..DONE WHEN COUNTER IS ZERO
	00071		..DONE WITH CLOCK
	00072		..
	00073		..PREPARE TO TRANSMIT SYNC
0238 F822	00074		LDI SYNC1 ..SET UP TRANSMIT BYTE
023A AF	00075		PLO RF
023B D4	00076		SEP CALL ..TRANSMIT BYTE
023C 0278	00077		,A(BIP)
023E 00	00078		,#00
023F F8EB	00079		LDI SYNC2 ..SET UP NEXT TRANSMIT BYTE
0241 AF	00080		PLO RF
0242 D4	00081		SEP CALL ..TRANSMIT BYTE
0243 0278	00082		,A(BIP)
	00083		..ALL DONE WITH SYNC TRANSMISSION
0245 00	00084		,#00
	00085		..
	00086		..PREPARE TO TRANSMIT ADDRESS
0246 F861	00087		LDI A.0(ADDR)-#01
0248 AB	00088		PLO R8
0249 F803	00089		LDI #03 ..SET UP LOOP COUNTER
024B AD	00090		PLO RD

024C 18	00091	XA1:	INC R8	
024D D4	00092		SEP CALL	.. TRANSMIT WORD
024E 0276	00093		,A(BIPHS)	
0250 01	00094		,#01	.. FROM LEFT TO RIGHT
0251 2D	00095		DEC RD	.. DECREMENT COUNTER
0252 8D	00096		GLO RD	.. TEST IT
0253 3A4C	00097		BNZ XA1	.. GO FOR MORE?
0255 18	00098		INC R8	.. POINT TO LAST 7 BITS
0256 F807	00099		LDI #07	
0258 AC	00100		PLO RC	
0259 D4	00101		SEP CALL	.. TRANSMIT LAST 7 BITS
025A 0276	00102		,A(BIPHS)	
025C 01	00103		,#01	.. FROM LEFT TO RIGHT
	00104			.. ALL DONE WITH ADDRESS
	00105			.. PREPARE TO TRANSMIT DATA
025D F869	00106	XDATA:	LDI TBUF-1	.. SET UP POINTER TO ADDRESS :
025F A8	00107		PLO R8	
0260 46	00108		LDA R6	.. SET UP LOOP COUNTER
0261 AD	00109		PLO RD	
0262 18	00110	XD1:	INC R8	.. POINT TO BYTE
0263 D4	00111		SEP CALL	.. TRANSMIT IT
0264 0276	00112		,A(BIPHS)	
0266 00	00113		,#00	
0267 2D	00114		DEC RD	.. DECREMENT COUNTER
0268 8D	00115		GLO RD	.. TEST COUNTER
0269 3A62	00116		BNZ XD1	.. DONE WHEN COUNTER IS ZERO
	00117			.. DONE WITH DATA TRANSMISSION
	00118			..
	00119			.. PREPARE TO TRANSMIT EOT CHARACTER
026B F804	00120	XEOT:	LDI EOT	.. SET UP TRANSMIT BYTE
026D AF	00121		PLO RF	
026E D4	00122		SEP CALL	.. TRANSMIT IT
026F 0278	00123		,A(BIP)	
0271 00	00124		,#00	
	00125			.. ALL DONE
0272 E3	00126		SEX PC	.. TURN OFF TRANSMITTER
0273 65	00127		OUT 5	
0274 00	00128		,#00	
0275 D5	00129		SEP RETURN	.. RETURN TO CALLING PROGRAM
	00130			.. BIPHS ROUTINE
	00131			.. THIS ROUTINE CONTROLS THE SERIAL I/O
	00132			.. OF DATA TO THE TRANSMITTER
0276 08	00133	BIPHS:	LDN R8	.. ENTRY POINT TO LOAD BYTE
0277 AF	00134		PLO RF	.. FROM MEMORY FOR TRANSMISSION
0278 E6	00135	BIP:	SEX R6	.. POINT TO PARAMETER
0279 F800	00136		LDI #00	.. LOAD A 0
027B F1	00137		OR	.. OR IT WITH PARAMETER

027C 3282	00138		BZ *+06	.. IF ZERO BRANCH
027E 8F	00139		GLO RF	.. NOT ZERO
027F FE	00140		SHL	.. SHIFT BITS OUT TO LEFT
0280 3084	00141		BR *+04	
0282 8F	00142		GLO RF	
0283 F6	00143		SHR	.. SHIFT BITS OUT TO RIGHT
0284 AF	00144		PLO RF	.. STORE MODIFIED BYTE
0285 3B94	00145		BNF XB1	.. BRANCH IF BIT IS ZERO
0287 3C87	00146		BN1 *	.. WAIT FOR SIGNAL
0289 7A	00147		REQ	.. CLEAR Q
028A D4	00148		SEP CALL	.. DELAY TO AVOID OVERLAP
028B 02AF	00149		,A(DELAY)	
028D 0001	00150		,#0001	
028F 3C8F	00151		BN1 *	.. WAIT FOR SIGNAL
0291 7B	00152		SEQ	
0292 309F	00153		BR XB2	
0294 3C94	00154	XB1:	BN1 *	.. WAIT FOR SIGNAL
0296 7B	00155		SEQ	.. SET Q
0297 D4	00156		SEP CALL	.. DELAY TO AVOID OVERLAP
0298 02AF	00157		,A(DELAY)	
029A 0001	00158		,#0001	
029C 3C9C	00159		BN1 *	
029E 7A	00160		REQ	.. CLEAR Q
029F 2C	00161	XB2:	DEC RC	.. DECREMENT BIT COUNTER
02A0 8C	00162		GLO RC	.. TEST COUNTER
02A1 3AA8	00163		BNZ XB3	.. BRANCH IN NOT ZERO
02A3 F808	00164		LDI #08	.. RESET BIT COUNTER TO 8
02A5 AC	00165		PLO RC	
02A6 16	00166		INC R6	.. INCREMENT BY PARAMETER
02A7 D5	00167		SEP RETURN	
02A8 D4	00168	XB3:	SEP CALL	
02A9 02AF	00169		,A(DELAY)	
02AB 0001	00170		,#0001	
02AD 3078	00171		BR BIP	.. LOOP AGAIN
	00172		.. DELAY ROUTINE	
	00173		.. THIS ROUTINE DELAYS	
	00174		.. PROGRAM EXECUTION FOR	
	00175		.. (PLACE EQUATION HEWE) SEC	
	00176		..	
02AF 46	00177	DELAY:	LDA R6-	.. GET HI BYTE OF DELAY
02B0 BE	00178		PHI RE	
02B1 46	00179		LDA R6	.. GET LO BYTE OF DELAY
02B2 AE	00180		PLO RE	
02B3 2E	00181	D1:	DEC RE	.. DECREMENT COUNTER
02B4 9E	00182		GHI RE	.. TEST HI BYTE
02B5 3ABC	00183		BNZ D2	.. BRANCH IF NOT ZERO

02B7 8E	00184	GLO RE	.. TEST LO BYTE
02B8 32C0	00185	BZ (D3)	.. ALL DONE IF ZERO
02BA 30B3	00186	BR D1	.. LOOP AGAIN
02BC 8E	00187	D2:	GLO RE
02BD 8E	00188		.. KILL SOME TIME
02BE 30B3	00189	GLO RE	.. KILL SOME TIME
02C0 D5	00190	BR D1	.. LOOP AGAIN
		SEP	RETURN

00191
00192

.. ALL DONE WITH DELAY ROUTINE
END

CA1802 Boston Systems Office Version 1B(15)
GXMIT.OBJ, GXMIT.LST=GXMIT.SRC

Symbol table

ADDR	0062	BIP	0278	BIPHS	0276	CALL	0004
CCO	00F4	CPO	0094	CTO	00B4	D1	02B3
D2	02BC	D3	02C0	DELAY	02AF	EOT	0004
GXMIT	0200	PC	0003	RETURN	0005	SYNC1	0022
SYNC2	00EB	TBUF	006A	XA1	024C	XB1	0294
XB2	029F	XB3	02A8	XC1	022D	XCLOCK	0228
XD1	0262	XDATA	025D	XEOT	026B		

FL	LOC	COSMAC	LNNO	SOURCE LINE
	CODE	00001		..FDC SUBROUTINE
		00002		..FREQUENCY TO DIGITAL CONVERSION
		00003		..MAXIMUM SAMPLING FREQUENCY 5
		00004		..REGISTER ASSIGNMENTS
	#000F	00005		CNT=#0F ..COUNT OF 0-1 TRANSITIONS
	#000D	00006		REF=#0D ..#SAMPLES IN ONE SECOND
	#000E	00007		MEM=#0E ..MEMORY OF PREVIOUS SAMPLE
	#0005	00008		RETN=#05 ..RETURN ROUTINE
	#0008	00009		PRAM=#08
02C1		00010		ORG #2C1 ..PROGRAM STARTS HERE
		00011		..SELECT DEVICE
02C1	E6	00012	FDC: SEX R6	..TAKE DEVICE # FROM
02C2	65	00013	OUT 5	..PARAMETER LIST
		00014		..INITIALIZE REGISTERS
02C3	46	00015	LDA R6	..POINT PRAM TO
02C4	A8	00016	PLO PRAM	..DATA STORAGE AREA
02C5	F800	00017	LDI #00	..ZERO COUNTER
02C7	AF	00018	PLO CNT	
02C8	BF	00019	PHI CNT	
02C9	AE	00020	PLO MEM	..ZERO SAMPLE MEMORY
02CA	F84C	00021	LDI #4C	..SET #4C8F INTO LOOP
02CC	BD	00022	PHI REF	..COUNTER. THERE ARE 4B8F
02CD	F88F	00023	LDI #8F	..LOOPS IN ONE SECOND AT
02CF	AD	00024	PLO REF	..2 MHZ CLOCK.
		00025		..THIS LOOP SAMPLES EF2 AT 19343 HZ
		00026		..FOR CLOCK OF 2.476 MHZ
02D0	3DE0	00027	LOOP: BNZ F1	..IF SAMPLE IS ZERO, BRANCH
02D2	8E	00028	GLO MEM	..GET PREVIOUS SAMPLE
02D3	3ADD	00029	BNZ F2	..BRANCH IF NO 0-1 TRANSITION
02D5	1F	00030	INC CNT	..TRANSITION, INCREMENT COUNTER
02D6	1E	00031	F3: INC MEM	..SET A 1 IN SAMPLE MEMORY
02D7	2D	00032	F4: DEC REF	..ONE LESS CYCLE TO GO
02D8	9D	00033	GHI REF	..TEST REFERENCE, HIGH BYTE
02D9	3AD0	00034	BNZ LOOP	..COLLECT ANOTHER SAMPLE
02DB	30E6	00035	BR F6	..REF = 0 ALL DONE
02DD	8E	00036	F2: GLO MEM	..A NOP STATEMENT
02DE	30D7	00037	BR F4	
02E0	F800	00038	F1: LDI #00	..SAMPLE IS ZERO
02E2	AE	00039	PLO MEM	..ZERO SAMPLE MEMORY
02E3	AE	00040	PLO MEM	
02E4	30D7	00041	BR F4	
02E6	9F	00042	F6: GHI CNT	..STORE FREQUENCY IN RAM
02E7	58	00043	STR PRAM	..LOW BYTE FIRST
02E8	18	00044	INC PRAM	..POINT TO NEXT LOCATION
02E9	8F	00045	GLO CNT	..GET HIGH BYTE
02EA	58	00046	STR PRAM	
02EB	D5	00047	SEP RETN	..RETURN TO CALLING PROGRAM
		00048	END	

FL	LOC	COSMAC CODE	LNNO	SOURCE LINE
			00001	..RANDOM NUMBER GENERATOR
			00002	..LEAVES A RANDOM NUMBER IN R(F)
		#0004	00003	CALL=R4
		#0005	00004	RETN=R5
		#C249	00005	LOADOP=#C249
		#8C44	00006	RAND=#8C44✓
		#C04F	00007	MPYOP=#C04F
		#C257	00008	STOROP=#C257
02EC			00009	ORG #2EC
02EC	D4		00010	SEP CALL
02ED	C249		00011	,A(LOADOP)
02EF	8C44		00012	,A(RAND)
02F1	D4		00013	SEP CALL ..MULTIPLY BY #0C35
02F2	C04F		00014	,A(MPYOP)
02F4	0300		00015	,A(MULT)
02F6	9F		00016	GHI RF ..CHOP OFF MSB
02F7	FA7F		00017	ANI #7F
02F9	BF		00018	PHI RF ..STOPE IT
02FA	D4		00019	SEP CALL ..STORE NEW RANDOM NUMBER
02FB	C257		00020	,A(STOROP)
02FD	8C44		00021	,A(RAND)
02FF	D5		00022	SEP RETN ..RETURN TO CALL PROGRAM
0300	0C35		00023	MULT: ,#0C35 ..MULTIPLIER
			00024	END

FL LOC	COSMAC CODE	LNNO	SOURCE LINE
		00001	.. DEFINITIONS
	#0004	00002	CALL=R4
	#0005	00003	RETURN=R5
	#006A	00004	TBUF=#6A ✓
	#0066	00005	TDATA=#66 ✓
0302		00006	ORG #302
0302 98		00007	ENCODE: GHI R8
0303 B9		00008	PHI R9
0304 F86A		00009	LDI A.0(TBUF)
0306 A9		00010	PLO R9
0307 F86A		00011	LDI A.0(TDATA)+4
0309 A8		00012	PLO R8
030A F802		00013	LDI #2
030C AD		00014	PLO RD
030D 28		00015	E1: DEC R8
030E 08		00016	LDN R8
030F FA3F		00017	ANI #3F
0311 BF		00018	PHI RF
0312 D4		00019	SEP CALL
0313 032A		00020	, A(PARITY)
0315 08		00021	LDN R8
0316 7E		00022	SHLC
0317 7E		00023	SHLC
0318 7E		00024	SHLC
0319 FA03		00025	ANI #3
031B 52		00026	STR R2
031C 28		00027	DEC R8
031D 08		00028	LDN R8
031E FE		00029	SHL
031F FE		00030	SHL
0320 F1		00031	OR
0321 BF		00032	PHI RF
0322 D4		00033	SEP CALL
0323 032A		00034	, A(PARITY)
0325 2D		00035	DEC RD
0326 8D		00036	GLO RD
0327 3A0D		00037	BNZ E1
0329 D5		00038	SEP RETURN
		00039	.. NOW COMES THE PARITY ROUTINE
032A F800		00040	PARITY: LDI #0
032C AF		00041	PLO RF
032D F806		00042	LDI #6
032F AC		00043	PLO RC
0330 9F		00044	GHT RF

0331 59	00045		STR R9
0332 9F	00046	P1:	GHI RF
0333 F6	00047		SHR
0334 3B37	00048		BNF P2
0336 1F	00049		INC RF
0337 BF	00050	P2:	PHI RF
0338 2C	00051		DEC RC
0339 8C	00052		GLO RC
033A 3A32	00053		BNZ P1
033C BF	00054		GLO RF
033D F6	00055		SHR
033E 3345	00056		BDF P3
0340 09	00057		LDN R9
0341 F940	00058		ORI #40
0343 3048	00059		BR P4
0345 09	00060	P3:	LDN R9
0346 F9C0	00061		ORI #C0
0348 59	00062	P4:	STR R9
0349 19	00063		INC R9
034A D5	00064		SEP RETURN
	00065		END

FL	LOC	COSMAC CODE	LNNO	SOURCE LINE
			00001	..UPDATE RATE SUBROUTINE
		#000F	00002	AC=RF
		#8C4D	00003	RATES=#8C4D
		#8C4B	00004	RATE2=#8C4B
		#8C4A	00005	RATE1=#8C4A
		#0005	00006	RETN=R5
034D			00007	ORG #34D
034D	E8		00008	UPDATE: SEX R8
034E	87		00009	GLO R7
034F	FF04		00010	SMI #04
0351	3B60		00011	BNF U1
0353	F84B		00012	LDI A.0(RATE2)
0355	A8		00013	PLO R8
0356	72		00014	LDXA
0357	AF		00015	PLO AC
0358	F0		00016	LDX
0359	28		00017	DEC R8
035A	73		00018	STXD
035B	8F		00019	GLO AC
035C	73		00020	STXD
035D	F800		00021	LDI #00
035F	A7		00022	PLO R7
0360	F84D		00023	U1: LDI A.0(RATES)
0362	A8		00024	PLO R8
0363	72		00025	LDXA
0364	BF		00026	PHI AC
0365	F7		00027	SM
0366	336C		00028	BDF U2
0368	F0		00029	LDX
0369	AF		00030	PLO AC
036A	3070		00031	BR U3
036C	9F		00032	U2: GHI AC
036D	AF		00033	PLO AC
036E	F0		00034	LDX
036F	BF		00035	PHI AC
0370	F84A		00036	U3: LDI A.0(RATE1)
0372	A8		00037	PLO R8
0373	9F		00038	GHI AC
0374	F7		00039	SM
0375	337F		00040	BDF U5
0377	9F		00041	GHI AC
0378	58		00042	STR R8
0379	F800		00043	LDI #00
037B	A7		00044	PLO R7

R7.0-4
branchif R7.0<4

037C 18
037D 3086
037F 9F
0380 18
0381 F7
0382 3386
0384 9F
0385 58
0386 8F
0387 F7
0388 338C
038A 8F
038B 58
038C 18
038D 9F
038E 58
038F E2
0390 D5

00045 INC R8
00046 BR U6
00047 U5: GHI RF
00048 INC R8
00049 SM
00050 BDF U6
00051 GHI RF
00052 STR R8
00053 U6: GLO RF
00054 SM
00055 BDF U7
00056 GLO RF
00057 STR R8
00058 U7: INC R8
00059 GHI RF
00060 STR R8
00061 SEX R2
00062 SEP RETN
00063 END

LOC	COSMAC	LNNO	SOURCE	LINE
	CODE			
		00001	..RATE CALCULATION ROUTINE	
		00002	..ENTRY POINTS AT CALCSR OR CALCPR	
		00003	..REGISTER ASSIGNMENTS	
	#0004	00004	CALL=R4	
	#0005	00005	RETN=R5	
	#000D	00006	MA=RD	
		00007	..SUBROUTINE ADDRESSES	
	#C249	00008	LOADOP=#C249	
	#C262	00009	COMPOP=#C262	
	#C24D	00010	LOAD=#C24D	
	#C031	00011	SMEM=#C031	
	#C053	00012	MPY=#C053	
	#C1D5	00013	ADD1=#C1D5	
	#C257	00014	STOROP=#C257	
	#C252	00015	LODCON=#C252	
	#C0A1	00016	DIVOP=#C0A1	
		00017	..VARIABLE ADDRESSES	
	#8C2C	00018	STAGE1=#8C2C	
	#8C40	00019	ALERT=#8C40	
	#8C38	00020	SRALRT=#8C38	
	#8C42	00021	FLOOD=#8C42	
	#8C3A	00022	SRFLD=#8C3A	
	#8C36	00023	RBASE=#8C36	
	#8C5A	00024	PAD=#8C5A	
		00025	..	
		00026	..ENTRY TO CALCULATE THE STAGE RATE	
0393		00027	ORG #393	
0393	F836	00028	CALCSR: LDI A.0(RBASE)	
0395	A8	00029	PLO R8	
0396	D4	00030	SEP CALL	
0397	C249	00031	,A(LOADOP)	..LOAD STAGE
0399	8C2C	00032	,A(STAGE1)	
039B	D4	00033	SEP CALL	
039C	C262	00034	,A(COMPOP)	..IS IT GREATER THAN ALERT LEVEL
039E	8C40	00035	,A(ALERT)	
03A0	3BB4	00036	BNF CA1	..BRANCH IF NO
03A2	F838	00037	LDI A.0(SRALRT)	
03A4	A8	00038	PLO R8	
03A5	D4	00039	SEP CALL	
03A6	C262	00040	,A(COMPOP)	..IS IT > FLOOD LEVEL
03A8	8C42	00041	,A(FLOOD)	
03AA	3BB4	00042	BNF CA1	..BRANCH IF NO
03AC	F83A	00043	LDI A.0(SRFLD)	
03AE	A8	00044	PLO R8	..POINT R8 TO FLOOD RATE

03AF 30B4	00045	BR CA1	..SKIP OVER OTHER ENTRY POINT
	00046		
	00047		..ENTRY TO CALCULATE THE PRECIP RATE
03B1 F836	00048	CALCPR: LDI A.0(RBASE)	
03B3 A8	00049	PLO R8	..POINT R8 TO BASE RATE
03B4 98	00050	CA1: GHI R8	
03B5 20 BD	00051	GHI MA PHI MA	
03B6 46	00052	LDA R6	..POINT MA TO C
03B7 AD	00053	PLO MA	
03B8 D4	00054	SEP CALL	..LOAD C
03B9 C24D	00055	,A(LOAD)	
03BB 46	00056	LDA R6	..POINT MA TO D
03BC AD	00057	PLO MA	
03BD D4	00058	SEP CALL	..SUBTRACT D FROM C
03BE C031	00059	,A(SMEM)	
03C0 D4	00060	SEP CALL	
03C1 03E1	00061	,A(ABS)	..TAKE ABSOLUTE VALUE
03C3 46	00062	LDA R6	..POINT MA TO B
03C4 AD	00063	PLO MA	
03C5 D4	00064	SEP CALL	..MULT B*(C-D)
03C6 C053	00065	,A(MPY)	
03C8 88	00066	GLO R8	..POINT MA TO A
03C9 AD	00067	PLO MA	
03CA D4	00068	SEP CALL	
03CB C1D5	00069	,A(ADD1)	..ADD A
03CD D4	00070	SEP CALL	
03CE C257	00071	,A(STOROP)	..STORE IN PAD
03D0 8C5A	00072	,A(PAD)	
03D2 D4	00073	SEP CALL	
03D3 C252	00074	,A(LOADCON)	..LOAD 1500
03D5 05DC	00075	,1500	..A DECIMAL MUMVVER
03D7 D4	00076	SEP CALL	
03D8 C0A1	00077	,A(DIVOP)	..DIVIDE
03DA 8C5A	00078	,A(PAD)	
03DC 46	00079	LDA R6	..POINT TO STORAGE
03DD AD	00080	PLO MA	
03DE 8F	00081	GLO RF	..STORE LOW BYTE ONLY
03DF 5D	00082	STR RD	
03E0 D5	00083	SEP RETN	..RETURN TO CALL PROGRAM
	00084		..ABSOLUTE VALUE PROGRAM
	00085		..REGISTER ASSIGNMENTS
	00086		
03E1 9F	00087	ABS: GHI RF	
03E2 FE	00088	SHL	
03E3 3BEE	00089	BNF DONE	
03E5 9F	00090	GHI RF	
03E6 FBFF	00091	XRI #FF	
03E8 BF	00092	PHI RF	
03E9 8F	00093	GLO RF	
03EA FBFF	00094	XRI #FF	
03EC AF	00095	PLO RF	
03ED 1F	00096	INC RF	
03EE D5	00097	DONE: SEP R5	
	00098	END	

FL LOC	COSMAC CODE	LNNO	SOURCE LINE
		00001	.. GENERAL CALCULATION ROUTINE
		00002	.. COMPUTES $G=A/(B-C)*(D-E)+F$
		00003	.. REGISTER ASSIGNMENTS
#0004		00004	CALL=R4
#0005		00005	RETN=R5
#000D		00006	MA=RD
#000F		00007	AC=RF
		00008	.. SUBROUTINE ADDRESSES
#C249		00009	LOADOP=#C249
#C02D		00010	SMOP=#C02D
#C257		00011	STOROP=#C257
#C24D		00012	LOAD=#C24D
#C031		00013	SMEM=#C031
#C04F		00014	MPYOP=#C04F
#C0B7		00015	DIV=#C0B7
#C1D5		00016	ADD1=#C1D5
#C25B		00017	STORE=#C25B
		00018	.. VARIABLE ADDRESSES
#8C20		00019	FMAX=#8C20
#8C22		00020	FMIN=#8C22
#8C5A		00021	PAD=#8C5A
		00022	..
03F2		00023	ORG #03F2
03F2 D4		00024	CALC: SEP CALL
03F3 C249		00025	,A(LOADOP) .. LOAD B
03F5 8C20		00026	,A(FMAX).
03F7 D4		00027	SEP CALL.
03F8 C02D		00028	,A(SMOP) .. COMPUTE B-C
03FA 8C22		00029	,A(FMIN).
03FC D4		00030	SEP CALL.
03FD C257		00031	,A(STOROP) .. STORE RESULT
03FF 8C5C		00032	,A(PAD)+#02.
0401 46		00033	LDA R6. .. POINT RD TO D
0402 AD		00034	PLO MA.
0403 D4		00035	SEP CALL.
0404 C24D		00036	,A(LOAD) .. LOAD D
0406 46		00037	LDA R6. .. POINT RD TO E
0407 AD		00038	PLO MA.
0408 D4		00039	SEP CALL.
0409 C031		00040	,A(SMEM) .. COMPUTE D-E
040B D4		00041	SEP CALL.
040C C257		00042	,A(STOROP) .. STORE RESULT
040E 8C5A		00043	,A(PAD).

0410	46	00044	LDA R6.	
0411	BF	00045	PHI AC.	..LOAD A INTO AC
0412	46	00046	LDA R6.	
0413	AF	00047	PLD AC.	
0414	D4	00048	SEP CALL.	
0415	C04F	00049	,A(MPYOP).	..COMPUTE A*(D-E)
0417	8C5A	00050	,A(PAD).	
0419	F85C	00051	LDI A.0(PAD)+#02.	
041B	AD	00052	PLD MA.	
041C	D4	00053	SEP CALL.	
041D	C0B7	00054	,A(DIV)	..DIVIDE BY (B-C)
041F	46	00055	LDA R6.	
0420	AD	00056	PLD MA.	
0421	D4	00057	SEP CALL.	..STORE INTERMEDIATE
0422	C25B	00058	,A(STORE).	
0424	46	00059	LDA R6.	..POINT MA TO F
0425	AD	00060	PLD MA.	
0426	D4	00061	SEP CALL.	
0427	C1D5	00062	,A(ADD1).	..ADD F
0429	46	00063	LDA R6.	..POINT MA TO STORAGE AREA
042A	AD	00064	PLD MA.	
042B	D4	00065	SEP CALL.	
042C	C25B	00066	,A(STORE).	..STORE RESULT
042E	D5	00067	SEP RETN.	..RETURN TO CALL PROGRAM
		00068	END	

LOC	COSMAC	LNND	SOURCE LINE
	CODE		
		00001	..LONG DELAY ROUTINE
		00002	..REGISTER ASSIGNMENTS
	#0004	00003	CALL=R4
	#0005	00004	RETN=R5
		00005	..SUBROUTINE ASSINMENTS
	#02AF	00006	DELAY=#02AF
		00007	..
0431		00008	ORG=#0431
0431	46	00009	LD1: LDA R6.
0432	BF	00010	PHI RF.
0433	46	00011	LDA R6.
0434	AF	00012	PLD RF.
0435	D4	00013	LD1: SEP CALL.
0436	02AF	00014	,A(DELAY)
0438	0007	00015	,#0007.
043A	2F	00016	DEC RF.
043B	9F	00017	GHI RF.
043C	3A42	00018	BNZ LD1.
043E	8F	00019	GLO RF.
043F	3A35	00020	BNZ LD1: LD1: LD1.
0441	D5	00021	SEP RETN.
0442	9F	00022	LD1: GHI RF.
0443	3A35	00023	BNZ LD1: LD1: LD1.
		00024	END

.. Tipping Bucket
 .. with limiter incase it fails a sdupurang.

445
 445 D4
 446,7 C249
 448,9 8C68
 44A D4
 448,C CIEB
 44D,E 0100
 44F,0 F8FF
 451 AD
 452 E0
 453,4 3F5D
 455 61

456 2F
 457 8D
 458,9 325D
 45A 2D
 45B,C 3053
 45D 62

45E D4
 45F,0 C257
 461,2 8C68
 463 D5

BUCKET:

BUCKET2:

BUCKET1

ORG 445
 SEP CALL
 ,A(LOADOP)
 ,A(TDATA)+#02
 SEP CALL
 ,A(ADDCON)
 ,256
 LDI#FF
 PLO RD
 SEXRB
 BN4 BUCK1
 OUT1

DECLAC
 GLO RD
 BZ BUCK1
 DEC RD
 BR BUCK2
 OUT2

SEP CALL
 ,A(STORCP)
 ,A(TDATA)+#02
 SEP RETN
 END.

Reg
 .. any address will do.
 0 → 255 255-0
 1 → 256 255-0

15 Aug
MEASUR.SRC.

#0004	00004	CALL=R4
#0005	00005	RETN=R5
	00006	.. ADDRESSES
#02AF	00007	DELAY=#02AF
#02C1	00008	FDC=#02C1
#8C22	00009	FMIN=#8C22
#8C20	00010	FMAX=#8C20
#8C24	00011	FSTAGE=#8C24
#8C52	00012	FLAG3=#8C52
#8C26	00013	FPRECP=#8C26
#0447	00014	BUCKET=#0445
650461	00015	ORG #0461 0465
650461 E3	00016	MEASR: SEX PC
660462 65	00017	OUT 5
670463 88 28	00018	,#88 ..TURN ON HIGH V,FAST CLOCK
680464 D4	00019	SEP CALL ..DELAY FOR WARM UP
690465 02AF	00020	,A(DELAY)
6A0467 415E 192C	00021	,#415C
6B0469 D4	00022	SEP CALL
6E046A 02C1	00023	,A(FDC) ..MEASURE COMMON
70046C 88 28	00024	,#88
71046D 22	00025	,A.0(FMIN) ..PLACE RESULT AT FMIN
72046E D4	00026	SEP CALL
73046F 02C1	00027	,A(FDC) ..MEASURE V-SYSTEM
750471 89 29	00028	,#89
760472 20	00029	,A.0(FMAX) ..PLACE RESULT AT FMAX
770473 D4	00030	SEP CALL
780474 02C1	00031	,A(FDC) ..MEASURE STAGE
7A0476 8A 2A	00032	,#8A
7B0477 24	00033	,A.0(FSTAGE) ..STORE RESULT AT FSTAGE
7C0478 F852	00034	LDI A.0(FLAG3) ..POINT TO FLAG3
7E047A A8	00035	PLO R8
7F047B 08	00036	LIN R8 ..GET FLAG3
80047C 3A8569	00037	BNZ MEAS1 ..USR BUCKET IF FLAG3=1
82047E D4	00038	SEP CALL
83047F 02C1	00039	,A(FDC) ..MEASURE PRECIP
850481 88 28	00040	,#88
860482 26	00041	,A.0(FPRECP) ..STORE RESULT AT FPRECP
870483 30888C	00042	BR MEAS2 ..BRANCH OVER BUCKET
890485 D4	00043	MEAS1: SEP CALL
8A0486 0445	00044	,A(BUCKET) ..MEASURE PRECIP WITH BUCKET
8C0488 D5	00045	MEAS2: SEP RETN ..RETURN TO CALL PROGRAM
	00046	END

Symbol table

BUCKET	0447 ✓	CALL	0004 ✓	DELAY	02AF ✓	FDC	02C1
FLAG3	8C52 ✓	FMAX	8C20 ✓	FMIN	8C22 ✓	FPRECP	8C26

UTILITY ROUTINES: SOFTWARE.

160	F804 B3 F8FE A3 D3	ORG#160 ^{IN/OSP} LDI A,1(0444) PHI R3 LDI A,0(0444) PLO R3 SEP R3	INPUT/DISPLAY DECIMAL NUMBERS A3 BRANCH TO 04FE 34 35 30
160	F804 B3 F8D6 A3 D3	ORG#168 LDI A,1(CALIBS) PHI R3 LDI A,0(CALIBS) PLO R3 SEP R3.	CALIBRATE STAGE BRANCH TO 04D6
170	F801 B3 F9C0 A3 D3	ORG#170 LDI A,1(CALIBP) PHI R3 LDI A,0(CALIBP) PLO R3 SEP R3.	CALIBRATE PRECIP BRANCH TO 01C0
170	F804 B3 F9C3 A3 D3.	ORG#178 LDI A,1(CMEASR) PHI R3 LDI A,0(CMEASR) PLO R3 SEP R3.	MEASURE DATA BRANCH 04C3

UTILITY ROUTINES CON'D

TEST
TRANSMITTER

0	F801		ORG #180	
	B3		LDI A1(CGXMIT)	
	F889		PHI R3	
	A3		LDI A10(CGXMIT)	
	D3 FF		PL0 R3	
3	F98C	CGXMIT	SEP R3	
	B3		LDI #8C	
	F853		PHI R8	
	A8		LDI A10(FLAG4)	
	F801		PL0 R8	
	58		LDI #01	
	D4		STR R8	
	0114		SEPCALL	
	D4		#0114	CO 04FE
	0965		SEP CALL	
	D4		,A(MEASUR2)	" measure Vcc, Vss.
	02C1		SEP CALL	" measure RF out.
	86 (BE)		,A(FDC)	
	2E		,#86	
	D4		,#2E	
	02C1		SEP CALL	" measure RF reflected.
	87 (BF)		,A(FDC)	
	30		,#87	
	D4		,#30	
	03F2		SEP CALL	" calculate RF out.
	2E		,A(CALC)	
	22		,A10(RFOUT)	
	03E8		,A10(FMIN)	
	46		,1000	
	5F		,A10(RFOUT)	
	5F		,A10(PAD)16	
			,A10(PAD)16	

CGXMIT CON'D

D4	SEL CALL	... (CALL) REFLECTED
03F2	,A(CALL)	
30	,A.O(FRFIN)	
22	,A.O(FMIN)	
03E3	,1000	
43	,A.O(FRFE)	
5F	,A.O(PAD)+6	
5F	,A.O(PAD)+6	
F846	LDI A.O(RFOU1)	negat display program
AS	PLO 23	
E1 6500	← E3 65 00	TURN OFF Vm
CO04FE	LBIZ C503	

CAUBP CON'D

IE'S	D1	SEP CALL
E4	03F7	JA(CALLC)
56	72	JAIO(FMIN)
57	26	JAIO(FPRECIP)
E8	03E8	JAIO(FPRECIP)
EA	66	JAIO(FDATA)
E8	32	JAIO(PRECIP)
EC	2A	JAIO(DMIN)
ED	F82A	LDI AIO(FMIN)
EF	A8	PLC RS
IF0	C00503	LBZ LOUP1
IF3		—

		ORG #04C3
4C3	F88C	CMEASR: LDI #5C
CS	B8	PLC RS
C6	F859	LDI AIO(FLAGS)
C8	A8	PLC RS
C9	F801	LDI #01
CB	58	STR RS
CC	D4	SEP CALL
CD	006F	#006F
CF	F820	LDI AIO(FMAX)
DL	A8	PLC RS
D2	C00503	LBZ LOUP1
D5		—

4D6 D4
 D5 0465
 D7 D4
 D6 03F2
 DA 22
 DS 24
 DC 0FA0
 DE 66
 DF 2C
 EO 28
 E1 F828
 E3 A3
 E4 C00503
 E7

ORG # 0106
 CALIBS: SEP CALL
 ,A(MEASR)
 SEP CALL
 ,A(CALL)
 ,AIO(EMINI)
 ,AIO(ESTAGE)
 ,#0FA0
 ,AIO(TDATA)
 ,AIO(STAGE)
 ,AIO(SMIN)
 LDI AIO(EMINI)
 PLO RB
 LBR LOOP1

31C0 F852
 C2 AS
 C3 F88C
 C5 B8
 C6 08
 C7 32E0
 C9 F861
 CB AF
 CC 98
 CD 6E
 CE EF
 CF F801
 D1 73
 E2 F880
 D4 73 73 73 73 73 73 5F
 FB D4
 DC 816C
 DE 30D8
 EO D4
 E1 0461

ORG # 01C0
 CALIBP LDI AIO(FLAG3)
 PLO RB
 LDI # 8C
 PHI RB
 LON RB
 BZ
 LDI AIO(PAD)+7
 PLO RF
 PHI RB
 PHI RF
 SEX RF
 LDI #01
 STXD
 LDI #50
 STXD, STXD, STXD, STXD, STXD, STXD, STXD, STXD
 DISPLAY: SEP CALL
 ,A(LEDD)
 BR DISPLAY
 SEP CALL
 ,A(MEASR)

no calibration necessary.
 display message

INSERT / DISPLAY.

B3*

3LFE

(F8BCB3BF)

F800A8

1F

F861

AF

88

FA0F F910

73

88

F6 F6 F6 F6

F9 10

73

F8 0C 73

F8 08 73

F8 80 73 13 73

F8 0A 5F

F8 5A

AF

D4

81 6C

F

F8 01

8A

D4

04 91

F8 61

AF

9A

32 20

F6

32 33

8A

F8 12

32 53

0F

2F

5F

START: LDI #8C; PHI R8; PHI RF

LDI #00; PLO R8

LOOP1 SEX RF

LDI A.0(PAD)+#07

PLO RF

GLO R8

ANI #0F; ORI #10

STXD

GLO R8

SHR, SHR, SHR, SHR

ORI #10

STXD

LDI #0C; STXD

LDI #08; STXD

LDI #80; STXD; STXD; STXD

LDI #0A; STIR RF

LDI A.0(PAD)

PLO RF

SEP CALL

,A(LEDD)

~~AS UNLOCK~~

LDI #01

PHI RA

SEP CALL

,A(READ)

LDI A.0(PAD)+#07

PLO RF

GHI RA

BZ KEYSN

SHR

BZ NOKEY

GLO RA

XRI #12

BZ ENCODE

LDN RF

DEL RF

STIR RF

.. point to RAM

.. 8C00

.. use RF as stack pointer

.. and set up display

.. buffer.

.. get unique address

.. and set decimal point

.. set up other display

.. point RF to Buffer.

.. wait for key to be released

.. ENTER KEY PRESSED?

.. TEST IT, BRANCH IF YES.

.. SHIFT NEW DIGIT INTO

.. DISPLAY BUFFER.

.. FIRST MAKE ROOM

4	1F		INC RF	.. THEN BRING IT IN
5	8A		GLO RA	
6	F910		ORI #10	.. Remember to set point
8	5F		STR RF	
9	F85A		LDI A.0(PAD)	.. point to display buffer.
B	AF		PLORF	
C	D4	WAIT	SEP CALL	
D	81 6C		LEDD	
F	8B <u>4C</u>		, A(DISPLAY)	
1	30 27		B3 WAIT	.. IF KEY NOT RELEASED YET, WAIT
3	2F		BR NOKEY.	.. GO AGAIN. FOR MORE DATA.
4	4F	ENCODE:	LDA RF	.. ENCODE THE SELECTED
5	FE FE FE FE		SHL;SHL;SHL;SHL	.. ADDRESS INTO ONE
4	52		STR R2	.. BYTE OF DATA AND
6	0F		LDR RF	.. STORE IT IN R8.0
6	FA 0F		ANI #0F	.. R8.0 POINTS TO USER
D	F1		OR	.. SELECTED ADDRESS
E	AS		PLOR8	
F	36 5F		B3 *	
1				

USES R8
 RF
 LEDD SUBROUTINE
 READ SUBROUTINE.

1	FB 00 A7	LOOPB: LDI #00, RLO R1	.. Read flip flop
4	88 AD	GLO R8; RLO R2	.. prepare to load
6	98 RD	GHI R8; PHI RD	.. binary number
8	D4	SEP CALL	..
7	C2 4D	,A(LOAD)	.. Load it,
9	D4	SEP CALL	.. and convert it
C	C3 0A	,A(CBD)	.. to a decimal
E	8C 5C	,A(PAD)+#02	.. store decimal in
10	06	,#06	.. display buffer
11	D4	SEP CALL	.. reformed
12	C2 52	,A(LOADCON)	.. display buffer
14	8C 5C	,A(PAD)+#02	.. decimal format.
16	0F	LDN R2	
17	52	STR R2	
18	FB 80	LDI #80	
1A	5F	STIR R2	
1B	2F	DEC R2	
1C	5F	STIR R2	
1D	2F	DEC R2	
1E	02	LDN R2	
1F	5F	STIR R2	
80	D4	SEP CALL	.. DISPLAY CONTENT
81	81 6C	,A(LEDD)	.. OF DISPLAY BUFFER.
83	FB 01	LDI #01	
85	BA	PHI RA	
86	D4	SEP CALL	.. scan the keys
87	04 91	,A(READ)	
89	9A	GHI RA	
8A	32 83	BZ KEYSN	.. bad read, try again
8C	F6	SHR	
8D	32 80	BZ DISPLAY.	.. no key pressed, branch
8F	8A	GLO RA	
90	FB 12	XRI #12	
92	32 03	BZ INSERT	.. "INC" WAS PRESSED, BRANCH

5D1 F65A
 5D2 AF
 5D4 D4
 5D5 81 6C
 5D7 36 D9
 5D9 30 80

F6: LDI A.0 (PAD)
 PLO RF
 WAIT: SEP CALL
 ,A(LEDD)
 B3 WAIT
 BR DISCY

5D8 F65A
 5D9 AF
 5DE 0F
 5DF 1F
 5E0 1F
 5E1 5F
 5E2 D4
 5E3 C2 9F
 5E5 8C 5C
 5E7 06
 5E8 98 8D
 5EA 88 AD
 5EC D4
 5ED C2 5B
 5EF 18
 5F0 18
 5F1 36 E1
 5F3 30 03

INSERT LDI A.0 (PAD)
 PLO RF
 LDN RF
 INC RF
 INC RF
 STR RF
 SEP CALL
 ,A(CDB)
 ,A(PAD)+#02
 ,#06
 GHI R8; PHIR0
 GLO R8; PLO R0
 SEP CALL
 ,A(STORE)
 INC R8
 INC R8
 B3 *
 BR LOOP1

.. reformatted during buffer
 .. to BCD format

.. convert decimal to
 .. binary

.. store result in desired
 .. address
 .. take next address

.. wait for key to be released
 .. start over again

04AD F661
 04AF AF
 04B0 EF
 04B1 F616
 04B2 73 73 73 73
 04B3 F6 80
 04BA 73 73
 04BC F6 03
 04BE 73
 04BF 00 05D1

CLEAR: LDI A.0(PAD)+#07
 PLO RF
 SEX RF
 LDI #10
 STXD, STXD, STXD, STXD, STXD
 LDI #80
 STXD, STXD
 LDI #0B
 STXD
 LBR F6