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A LOW-DRIFT INSTRUMENT LANDING SYSTEM (ILS) MONITOR

by

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INTRODUCTION

PURPOSE.

The purpose of this activity was to design, build, and install a prototype model of a low-drift Instrument Landing System (ILS) monitor. This work was performed as part of the ILS monitoring investigation for Test Functional Module (TFM) development under Task 9 of 9550-AF-501-78-002.

BACKGROUND.

As part of Task 9 of 9550-AF-501-78-002, the FAA Technical Center was tasked to design and develop several TFM's for various navigational aides. In the analysis of ILS TFM requirements, the problem of signal drift in the presently used monitors was encountered. This drift can cause erroneous alarms and system shut-downs which decrease system reliability and increase maintenance costs. It was decided to build a monitor that would minimize drift. This drift could be reduced by designing a monitor with the smallest possible number of components subject to drift. With such a monitor, both downtime of the system and maintenance costs would be reduced. This reduction should result in a more reliable and efficient system.

A typical Texas Instrument Far Field Monitor (FFM) contains three system monitors along with majority voting logic, to provide a higher degree of confidence in the detection and reporting of ILS faults. The purpose of these monitors is to constantly monitor input signals that represent the performance of the ILS, and provide alarm signals when tolerance limits are exceeded. The monitored signals are the outputs of detectors located within the ILS RF transmission path. This composite detected signal is used as an input to the analog section of the monitor and has three components:

1. A 90Hz sine wave,
2. A 150Hz sine wave, and
3. A DC component proportional to the transmitted RF signal strength.

The composite input signal is filtered into these three components. The two sine waves are full-wave rectified and converted to DC levels. These two DC signals are input to summing and differencing circuits to generate the sum-of-depth of modulation (SDM) and difference-of-depth of modulation (DDM) signals. The RF, SDM, and DDM signals are then input to alarm limit circuitry to detect out-of-tolerance conditions. The circuitry uses operational amplifiers with potentiometers used to control amplifier gain and offsets, and to set the tolerance limits.

A major cause of signal drift is the extensive use of analog circuits, with each monitor containing up to 30 op-amps and 200 passive components (resistors and capacitors). In the present monitor design, the op-amps used require external components for stability compensation. With time and temperature variations, the op-amps and external components degrade to the point where internal offset voltages and currents become large in comparison

to the input signals. Since the output of one op-amp is the input to another, even small errors due to drift in the first stage can become large in the final stage. In the alarm limit circuitry, analog comparison circuits are used with potentiometers providing reference and offset voltages. Again, component drift or degradation can produce unwanted error indications.

In the low-drift monitor a minimum amount of analog circuitry is used. The composite detected signal is separated into its three components. These components are then digitized by an A/D converter. From this point on, all processing is performed digitally.

DISCUSSION

SYSTEM OVERVIEW.

A block diagram of the low-drift ILS monitor is shown in figure 1. The main sections of this monitor are the analog input circuits, the microcomputer board, the analog-to-digital converter, and the serial communications circuits. The monitor can communicate with any RS-232C compatible device and is currently connected to a cathode-ray tube (CRT) terminal and a digital tape storage unit.

The input signal to the low-drift monitor is the same as to the present monitor, namely the detected RF signal. The analog input circuits filter the input signal into its three basic components (RF, 90Hz, and 150Hz). These signals are input to the analog-to-digital converter, and the converted digital values are stored in the memory of the microcomputer. The data can be sent to the remote terminal and/or stored on the cassette tape by command from the CRT terminal. Alarm limits for the data generated can also be changed via the terminal. In addition to its monitoring functions, the low-drift monitor has the capability of processing additional analog signals from outside sources. Thus long-term data collection can be performed concurrently on both the low-drift monitor and an existing monitor to provide a comparison of long term drift of the two systems.

HARDWARE DESCRIPTION.

The low-drift ILS monitor consists of three circuit boards housed in a single card cage. Two of the boards are commercially available from Zilog, while the other is a wire-wrap board designed and built at the FAA Technical Center.

The Zilog boards are the microcomputer board (MCB) and the analog input board (AIB). The MCB contains the Z-80 microprocessor, erasable programmable read only memory (EPROM), random access memory (RAM), an RS-232C serial interface, a clock/timer circuit (CTC), and the necessary logic and buffering to allow data transfer to and from the CPU. The AIB contains a 12-bit A/D converter and will accept 16 differential or 32 single-ended analog input signals. It is controlled by the MCB.

The wire-wrap board (WWB) contains all the analog circuitry needed to interface to the ILS equipment. This analog circuitry consists of buffer circuits (to provide isolation between the ILS and the low-drift monitor) and filter circuits to extract the three components of the ILS signal. All circuits used are commercially available integrated circuits.

The Z-80 microprocessor is the system CPU which controls all operations. The program to control the monitor is stored in EPROM. All variable data used and collected are stored in RAM. A crystal oscillator supplies the system clock to the CPU and peripheral devices. The CTC, which contains four independent timers, generates the baud rate clock to drive the serial communications line and also provides a 1-per-second internal interrupt to the CPU which is used to update system time. The serial communications line is driven by a universal asynchronous receiver/transmitter (UART). The UART receives parallel data from the CPU and outputs data in serial form. Data are received from the external devices in serial form and transferred to the CPU in parallel. Line drivers and receivers are provided to convert the TTL levels used in the CPU to RS-232C levels ($\pm$12V) required by the terminal and recorder. All data transfers are under program control.

The AIB is a 16-channel differential (or 32 channel single-ended) analog-to-digital converter board which is controlled by the MCB. The analog signals are brought onto the board via an edge connector. The program selects the channel to be converted, outputs a start-of-conversion signal, and waits for an end-of-conversion signal. When this signal is received, the digital data value is input from the AIB to the MCB and stored in RAM.

The wire-wrap board contains all the analog circuitry to interface to the present ILS monitor. The detected RF signal is input to a differential amplifier with unity gain for system protection. The output of this amplifier is then applied to the three filter circuits. The RF filter circuit is a 4-pole low-pass filter with a 3-dB point of 5Hz and a roll-off of 80dB/decade. This filter extracts the DC component of the signal. The 90Hz and 150Hz filters are band-pass filters with 3-dB points of $\pm$5Hz of center frequency. All three filters are integrated circuit filters and have a final amplifier stage with gain and offset potentiometers provided for calibration purposes. The 90Hz and 150Hz signals are rectified and all three outputs are then input to the AIB. Additional inputs to the WWB are the RF, 90Hz, 150Hz, SDM, and DDM signals generated by the present monitor. These signals are input to buffer amplifiers and the outputs are then input to the AIB. All passive components used on the WWB have a tolerance of 2% or better.

SOFTWARE DESCRIPTION.

The low-drift monitor is a hardware system under software control. The software consists of an initialization routine, a data input and formatting routine, an error checking and flagging routine, a serial communications routine, and a real-time clock update routine. All routines are written in either Zilog assembly language or PLZ, Zilog's high-level language. Approximately 4000 bytes of EPROM and 256 bytes of RAM are used.

When a power-on or manual reset pulse is received by the CPU, the initialization routine begins execution at location 0000. Initialization commands are sent to the CTC, UART, and AIB. This enables the real-time clock interrupt and serial communications at 1200 baud. Software flags, counters, and input signal high and low level limits are set to their initial values. The header message with the keyboard menu is output to the remote terminal. Control is then passed to the main routine.

The main routine is a loop which continually executes several smaller routines. First, the data is input from the AIB and the limit checking routine is executed. Each input data value is compared against stored high and low limits. If the value is outside either limit, a bit is set in an error flag. Each parameter has its own bit. The SDM and DDM values for the low-drift monitor are derived from the following equations:

SDM = 90Hz value + 150Hz value - offset
DDM = 90Hz value - 150Hz value

The offset is used in the SDM so that both the SDM and DDM will read as close to 0 as possible in normal operation. If the difference between the present and previous low-drift DDM is above a preset value, a status byte 'TRESP' is set to a 'T'. This byte will have an effect later on in the execution of the main routine. The analog signals from the existing monitor (dc voltages equivalent to RF, 90Hz, 150Hz, SDM and DDM) are also input to the AIB and digitized for long-term data collection.

After the limit checks are complete, the data conversion routine begins. This routine converts the binary data to ASCII format for output to the remote terminal. Three table look-ups are executed, one for each 4-bit nibble of the input data. The look-up values are added together to form the voltage level in binary form. For example, a voltage level of +2.793 volts will be input from the AIB as 0476 hex. Using the table look-up routine, the value returned will be 0AE9 hex. This value, converted to BCD format, will be 2793. The formatting inserts a decimal point and a plus or minus sign. The value output to the terminal will be +2.793.

When all the data has been converted, the remote terminal service routine begins. First, the flag byte 'TFG' is tested. If 'TFG' is a logical zero, then the DDM has not exceeded the present tolerance limits and the data will not be transmitted at this time. If 'TFG' is a logical one, then either an out of tolerance condition has been detected or the automatic transmit timeout has occurred. In this case, the data will be transmitted to the remote terminal. If 'TFG' is a logical zero, the routine inputs the status of the UART. If there has been no character transmitted from the terminal, 'TRESP' is set to 'N'. If there has been a character received, certain routines are executed. The received characters and routines are as follows:

D - Output data to remote terminal
T - Output data to cassette recorder
I - Initialize time and date
L - Display and change alarm limits
H - Print menu

Any other character will cause an error message to be printed. After the appropriate routine has been executed, 'TRESP' is reset to 'N' and 'TFG' is reset to a logical zero. The main routine repeats, beginning with the data input routine.

The CTC provides a 1-per-second interrupt to the CPU. This interrupt causes control to be transferred to the real-time clock update routine. In this routine, the word 'XMITT' is decremented. An 'XMITT' value of zero indicates the automatic transmit timeout has occurred. This will set 'TRESP' to a 'T' and set 'TFG' to a logical one. 'XMITT' is variable and can be changed from the remote terminal.

The limit display and change routine enables the user to change the input data limit values. Each limit can be changed from the keyboard, including the DDM difference value and automatic timeout interval. This change capacity has been included so the monitor can be adapted for different ILS monitor sites with no change in the hardware.

A flow chart of the program is provided in appendix A. A listing of the program is available from the Technical Center.

INSTALLATION AND CALIBRATION.

The low-drift monitor was installed at the Atlantic City Airport at the FFM at the end of runway 13/31 in April, 1982. A cable was run from the low-drift monitor to one of the three ILS system monitors and all required signals were connected. After the connection was made, a calibration of the low-drift monitor analog circuits was performed so that the output voltages between the two monitors were identical. This was done so that a long-term comparison could be made of the accuracy and reliability of the two monitors.

After calibration, the low-drift monitor was connected to the remote terminal/recorder located in the Technical Building via a Modem-Telco-Modem hook-up (see figure 1). From the terminal, all routines outlined in the software description were executed and tested. Long-term tests will be conducted for a six-month period to collect data on the performance of this monitor, and the results reported in a later report.

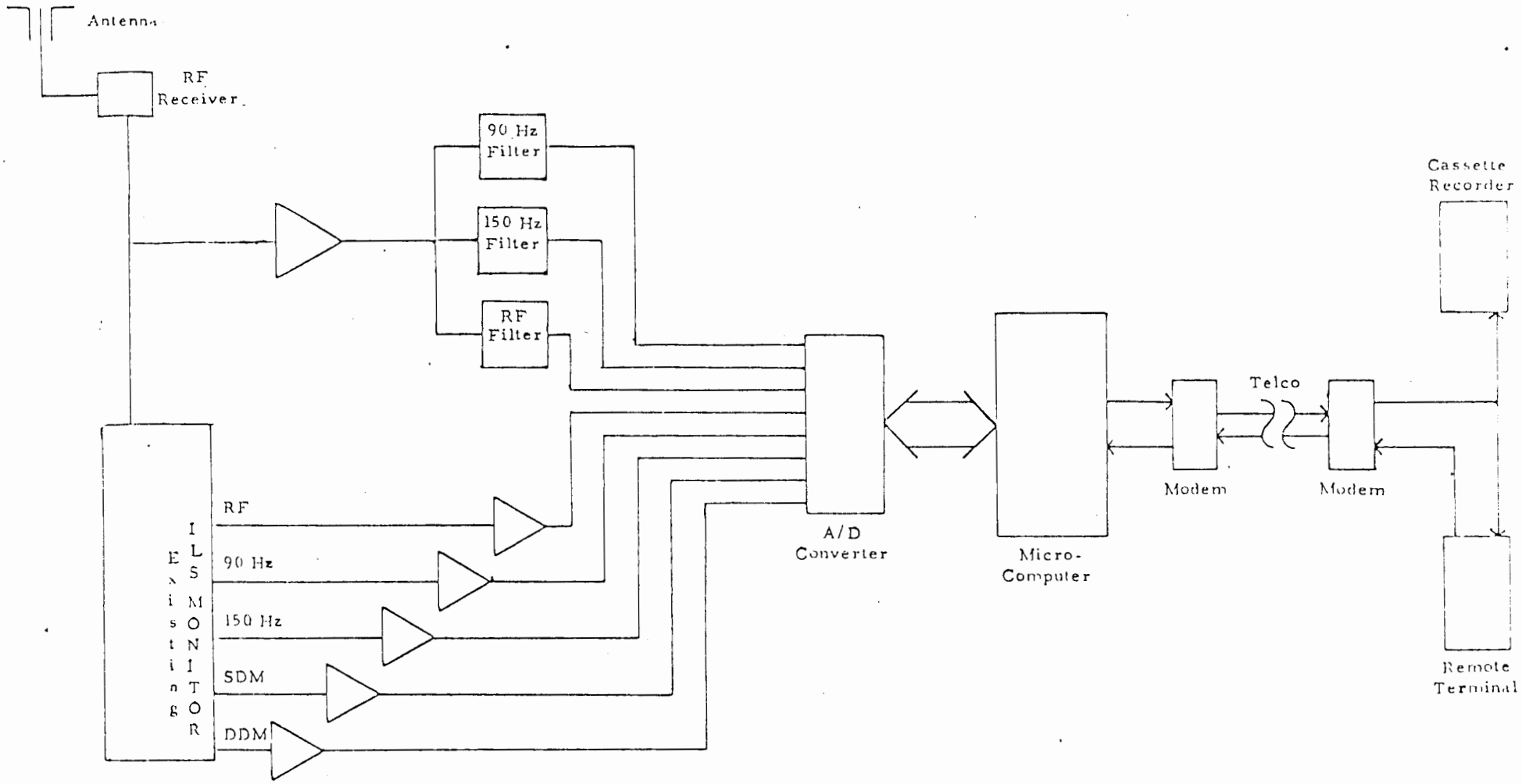
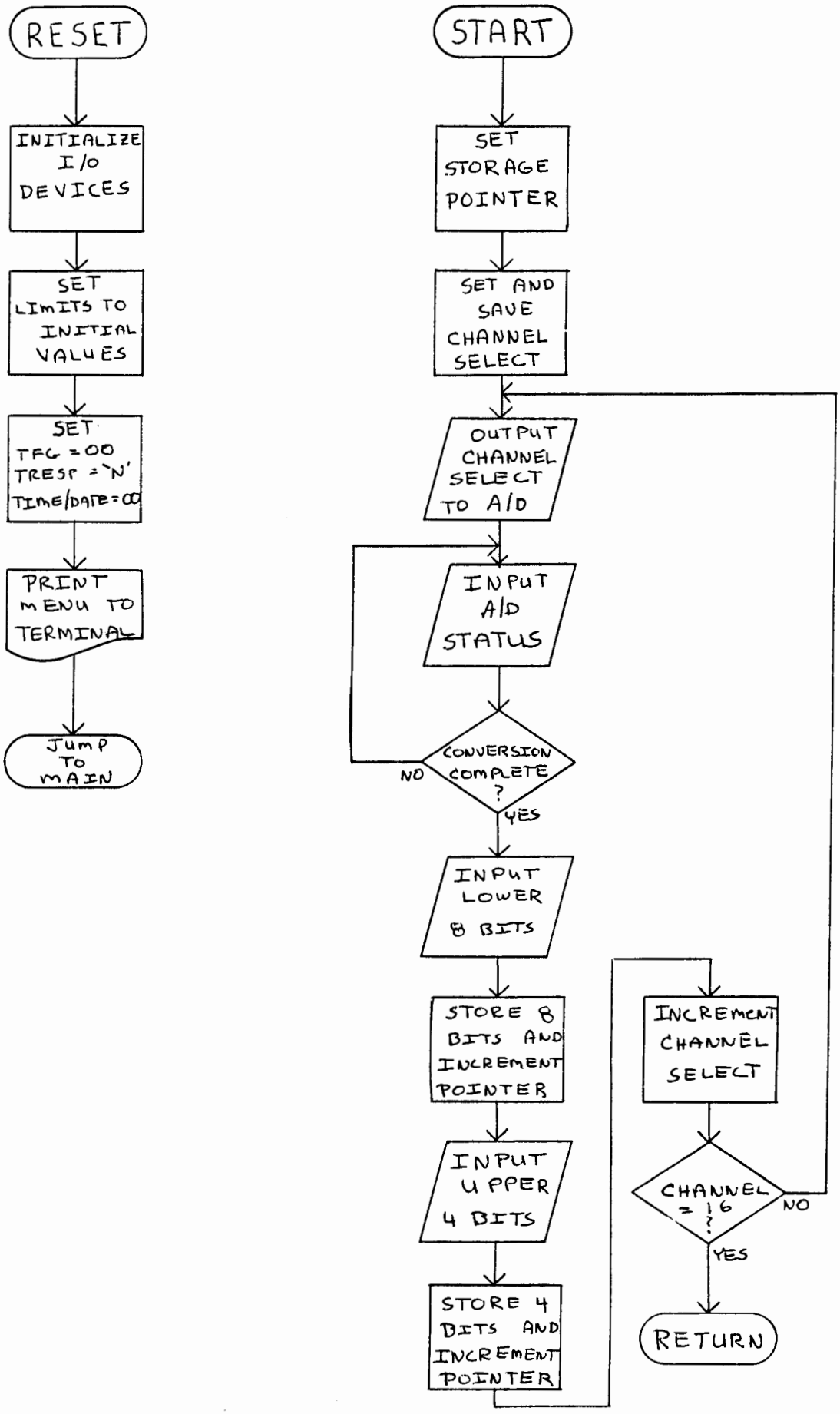
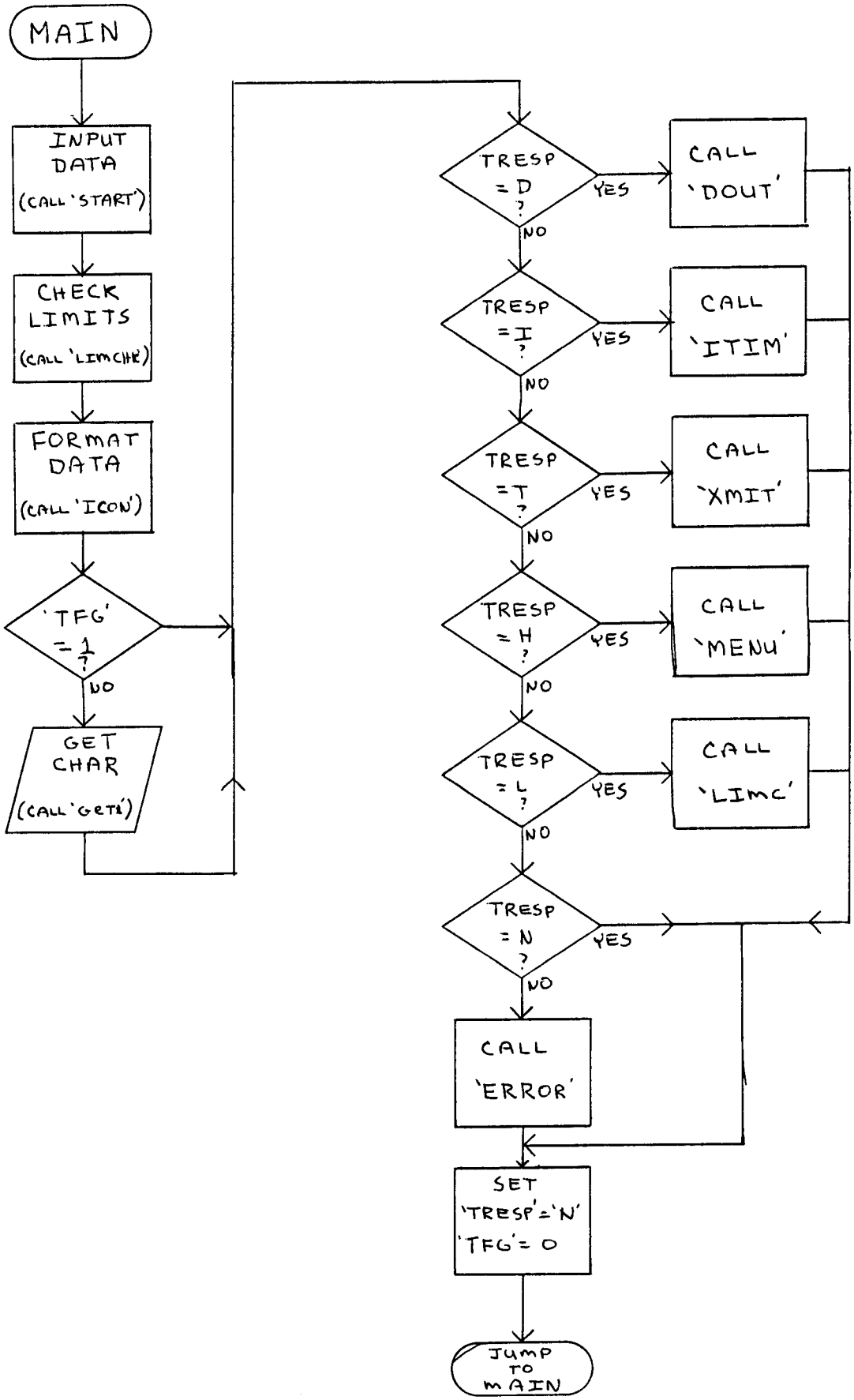
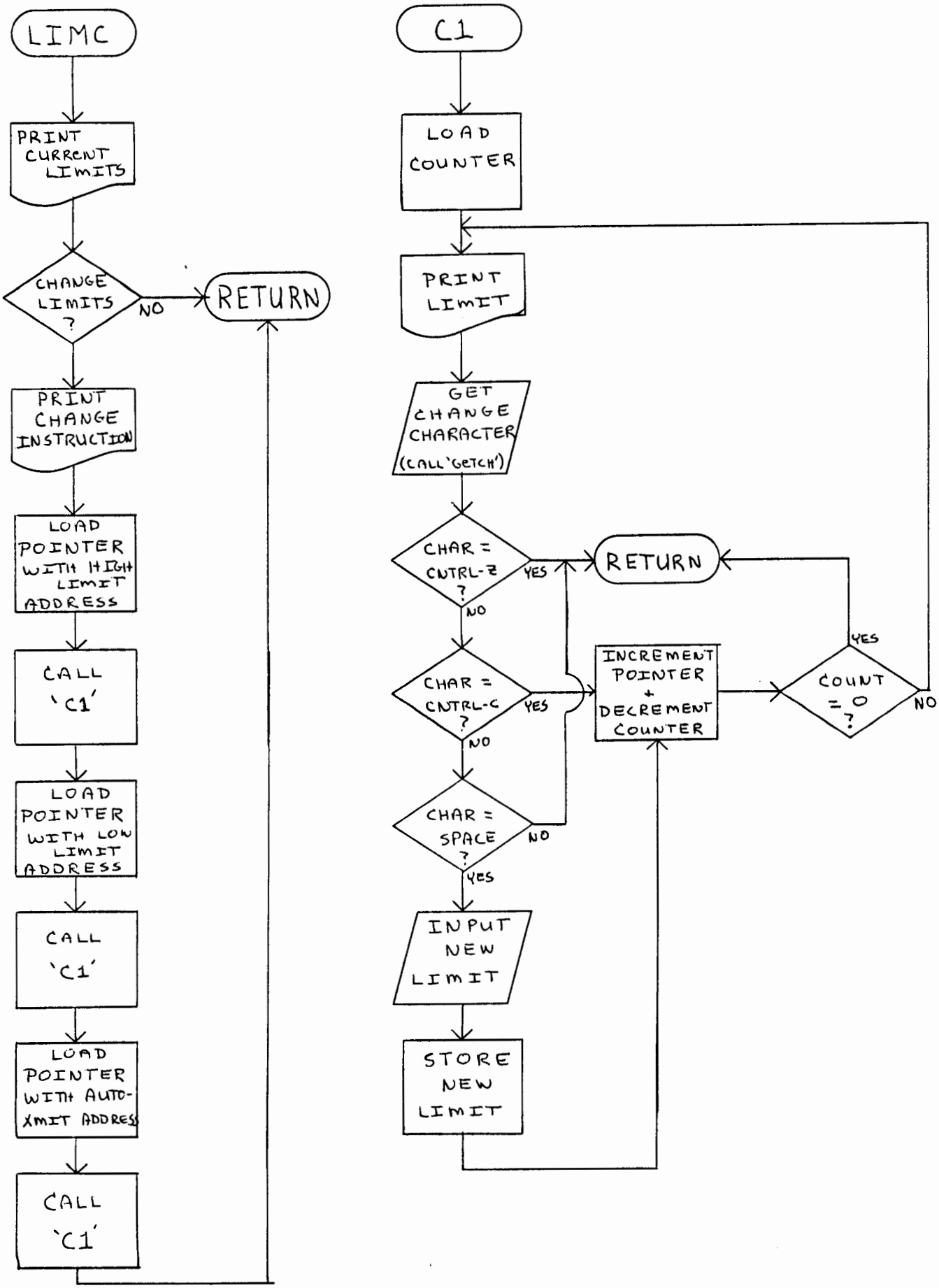
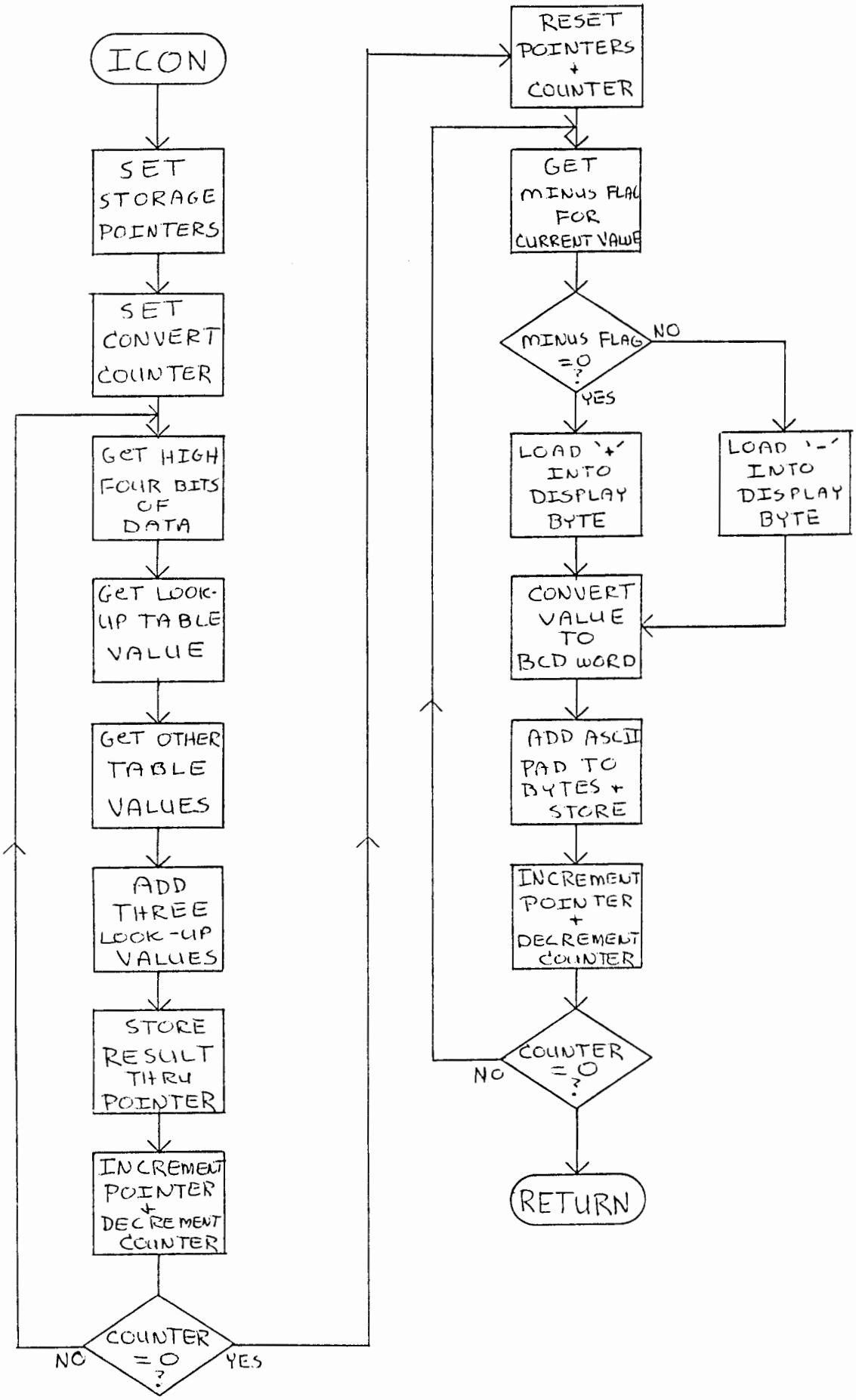


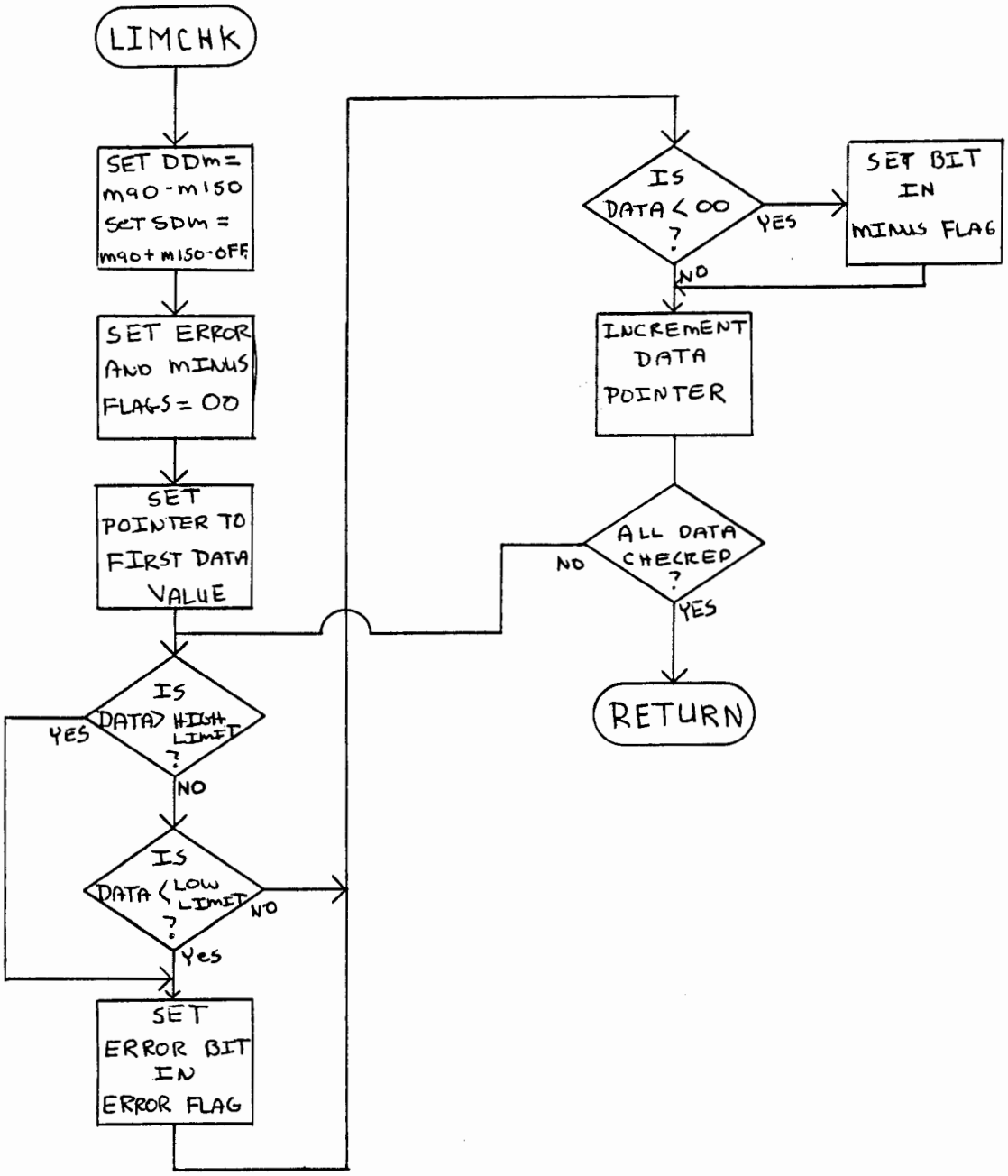
Figure #1. Block Diagram of Low-Drift ILS Monitor

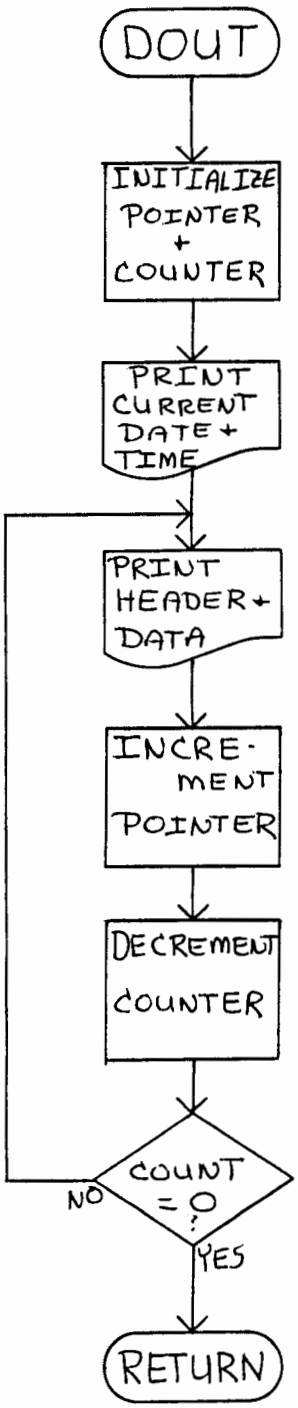

RESET
INITIALIZE I/O DEVICES
SET LIMITS TO INITIAL VALUES
SET TFG = 00 TRESP = 'N' TIME/DATE = 00
PRINT MENU TO TERMINAL
JUMP TO MAIN
START
SET STORAGE POINTER
SET AND SAVE CHANNEL SELECT
OUTPUT CHANNEL SELECT TO A/D
INPUT A/D STATUS
CONVERSION COMPLETE ?
NO
YES
INPUT LOWER 8 BITS
STORE 8 BITS AND INCREMENT POINTER
INPUT UPPER 4 BITS
STORE 4 BITS AND INCREMENT POINTER
INCREMENT CHANNEL SELECT
CHANNEL = 16 ?
NO
YES
RETURN

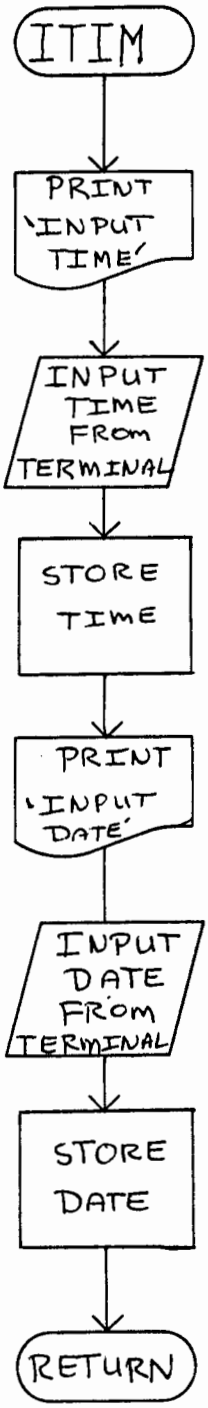

MAIN
INPUT DATA (CALL 'START')
CHECK LIMITS (CALL 'LIMCHK')
FORMAT DATA (CALL 'ICON')
'TFG' = 1 ?
NO
GET CHAR (CALL 'GETC')
TRESP = D ?
YES
CALL 'DOUT'
NO
TRESP = I ?
YES
CALL 'ITIM'
NO
TRESP = T ?
YES
CALL 'XMIT'
NO
TRESP = H ?
YES
CALL 'MENU'
NO
TRESP = L ?
YES
CALL 'LIMC'
NO
TRESP = N ?
YES
NO
CALL 'ERROR'
SET 'TRESP' = 'N' 'TFG' = 0
JUMP TO MAIN

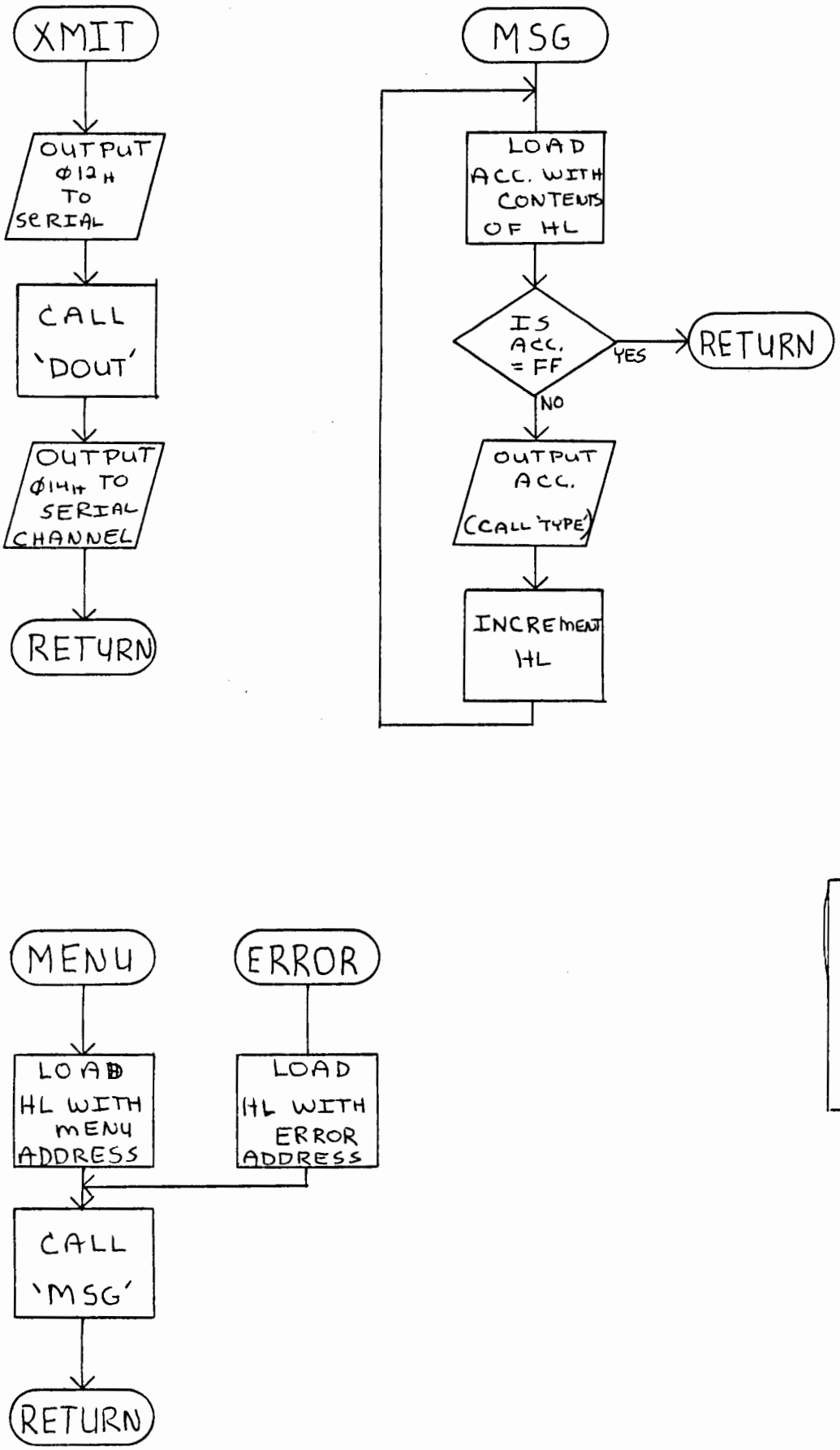

LIMC
PRINT CURRENT LIMITS
CHANGE LIMITS ?
NO
RETURN
PRINT CHANGE INSTRUCTION
LOAD POINTER WITH HIGH LIMIT ADDRESS
CALL 'C1'
LOAD POINTER WITH LOW LIMIT ADDRESS
CALL 'C1'
LOAD POINTER WITH AUTO-XMIT ADDRESS
CALL 'C1'
C1
LOAD COUNTER
PRINT LIMIT
GET CHANGE CHARACTER (CALL 'GETCH')
CHAR = CNTRL-Z ?
YES
RETURN
NO
CHAR = CNTRL-C ?
YES
NO
CHAR = SPACE ?
NO
YES
INPUT NEW LIMIT
STORE NEW LIMIT
INCREMENT POINTER + DECREMENT COUNTER
COUNT = 0 ?
YES
NO

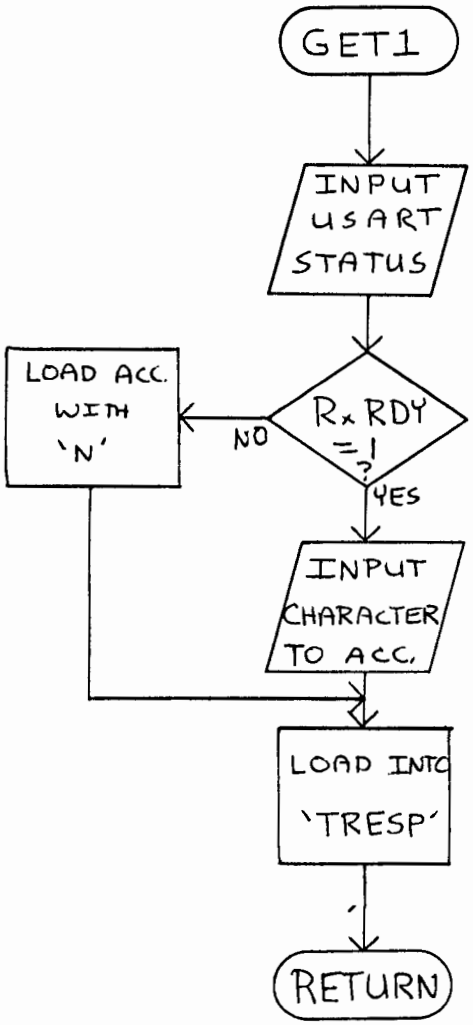

ICON
SET STORAGE POINTERS
SET CONVERT COUNTER
GET HIGH FOUR BITS OF DATA
GET LOOK-UP TABLE VALUE
GET OTHER TABLE VALUES
ADD THREE LOOK-UP VALUES
STORE RESULT THRU POINTER
INCREMENT POINTER + DECREMENT COUNTER
COUNTER = 0 ?
NO
YES
RESET POINTERS + COUNTER
GET MINUS FLAG FOR CURRENT VALUE
MINUS FLAG = 0 ?
NO
YES
LOAD '+' INTO DISPLAY BYTE
LOAD '-' INTO DISPLAY BYTE
CONVERT VALUE TO BCD WORD
ADD ASCII PAD TO BYTES + STORE
INCREMENT POINTER + DECREMENT COUNTER
COUNTER = 0 ?
NO
RETURN

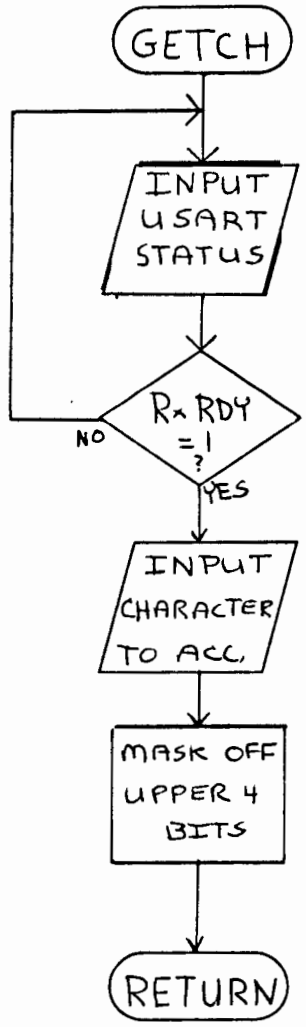

LIMCHK
SET DDm = m90 - m150
SET SDm = m90 + m150 - OFF
SET ERROR AND MINUS FLAGS = 00
SET POINTER TO FIRST DATA VALUE
IS DATA > HIGH LIMIT ?
YES
NO
IS DATA < LOW LIMIT ?
NO
Yes
SET ERROR BIT IN ERROR FLAG
IS DATA < 00 ?
YES
SET BIT IN MINUS FLAG
NO
INCREMENT DATA POINTER
ALL DATA CHECKED ?
NO
YES
RETURN


DOUT
INITIALIZE POINTER + COUNTER
PRINT CURRENT DATE + TIME
PRINT HEADER + DATA
INCRE-MENT POINTER
DECREMENT COUNTER
COUNT = 0 ?
NO
YES
RETURN


ITIM
PRINT 'INPUT TIME'
INPUT TIME FROM TERMINAL
STORE TIME
PRINT 'INPUT DATE'
INPUT DATE FROM TERMINAL
STORE DATE
RETURN


XMIT
OUTPUT Ø12H TO SERIAL
CALL 'DOUT'
OUTPUT Ø14H TO SERIAL CHANNEL
RETURN
MSG
LOAD ACC. WITH CONTENTS OF HL
IS ACC. = FF
YES
RETURN
NO
OUTPUT ACC. (CALL 'TYPE')
INCREMENT HL
TYPE
SAVE ACC.
INPUT USART STATUS
Tx RDY = 1 ?
NO
YES
RESTORE + OUTPUT ACC.
RETURN
MENU
LOAD HL WITH MENU ADDRESS
ERROR
LOAD HL WITH ERROR ADDRESS
CALL 'MSG'
RETURN


GET1
INPUT USART STATUS
Rx RDY =1 ?
NO
YES
LOAD ACC. WITH 'N'
INPUT CHARACTER TO ACC.
LOAD INTO 'TRESP'
RETURN


GETCH
INPUT USART STATUS
Rx RDY =1 ?
NO
YES
INPUT CHARACTER TO ACC.
MASK OFF UPPER 4 BITS
RETURN