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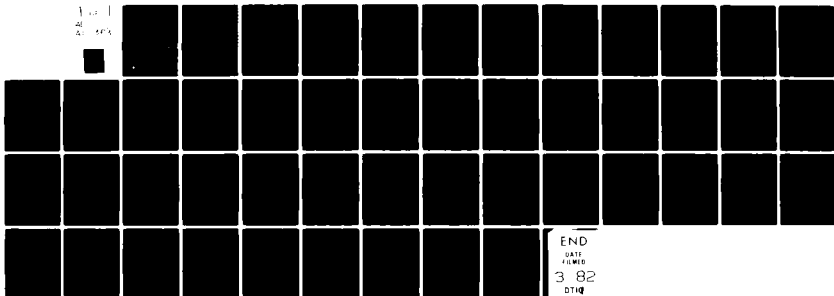
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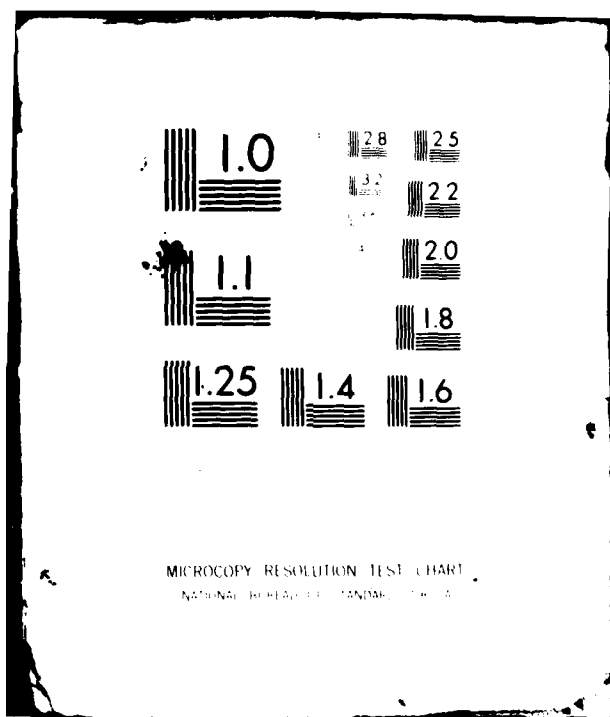
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A VIDEO PULSE RADAR SYSTEM FOR TUNNEL DETECTION

C. W. Davis, III and R. D. Gaglianella

ADA111363

The Ohio State University
ElectroScience Laboratory

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Columbus, Ohio 43212

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A video pulse radar system using a microcomputer-controlled data acquisition system is described which allows remote site recording of video pulse radar waveforms. Proper setup of the digital and analog hardware is presented and the functions provided by the firmware program are explained. The operation of the system is detailed along with recommendations concerning data collecting techniques.		

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I. INTRODUCTION

A video pulse radar system using a microcomputer controlled data acquisition system is described in this report. This portable system converts video pulse radar returns into a numerical representation which is stored on a digital tape recorder. The use of a microcomputer provides capability for limited preprocessing of the data in the field. In the present implementation, ensemble waveform averaging is the extent of the digital preprocessing. The bulk of the waveform analysis is intended to be performed on a more powerful remote computer, which obtains the waveforms by reading the microcomputer generated magnetic tapes.

The first two sections present the setup of the analog portion of the system and provide recommendations for a meaningful data collecting procedure. The next three sections detail the required interconnections between analog and digital systems, outline the capabilities of the microcomputer firmware, and describe the digital tape recorder. Finally, a sample waveform recording sequence as might be performed in the field is included.

II. SETUP OF THE ANALOG SYSTEM

The analog portion of the data collection system can be set up, checked out, and utilized independently from the microcomputer system.

The following discussion pertains to the use of a sampling oscilloscope with the HFW systems (Terrascan, BANT, and LBANT^{1,2}) and the 6 ns pulser. The use of the LBFA antenna with the Hewlett Packard pulse generator, is detailed in another report³.

The sampling oscilloscope performs the scaling of broadband time domain radar echoes (up to 1 GHz for this system) into low frequency (audio range) sampled replicas. This low frequency waveform is displayed on the oscilloscope screen. In the current application, the replica is also digitized by conventional analog to digital converters which are part of a microcomputer system.

The equipment associated with the sampling oscilloscope includes a 7844 dual beam mainframe, a 7S12 sampling system plug-in, a 7A22 differential amplifier plug-in, and a 7B50A timebase. Accessories of the 7S12 include

An S5 sampling head (rise time = 1 nsec),

An S-53 trigger recognizer, and an S-52 step generator.

To prepare the oscilloscope for use as a sampling receiver, the oscilloscope controls should be set as follows:

Beam Controls

Beam 1: Vertical mode - Left
Horizontal mode - B

Beam 2: Vertical mode - Right
Horizontal mode - A

B trigger source: Left

7A22 Differential Amplifier

Volts/Div: 1 Volt

HF - 3 dB Point: 1 MHz

LF - 3 dB Point: DC

+input port: DC
-input port: GND

7S12 Sampling Unit

Volts/Div: 100 mV with mV button depressed

Time-Distance: x1
Time/Div: 50 ns

Scan Knob: midrange
Scan Mode: REP

Use a 50 ohm termination unit on the input of the S-5 sampling head.

S-5 Coupling Switch: DC
S-53 Slope Switch: (+)

7B50A Timebase

Time/Div: 1 msec
Magnifier: x1

Triggering Controls:

Slope: (-)
Mode: Auto or Norm
Coupling: AC LF REJ
Source: INT

To make use of the waveform sampling capability, antennas and pulser are connected as shown in Figure 1. The Microlab FXR HZ-10N capacitive trigger pickoff unit is connected in series with the transmitting signal line from the Terrascan package pulse tube. The capacitive pickoff

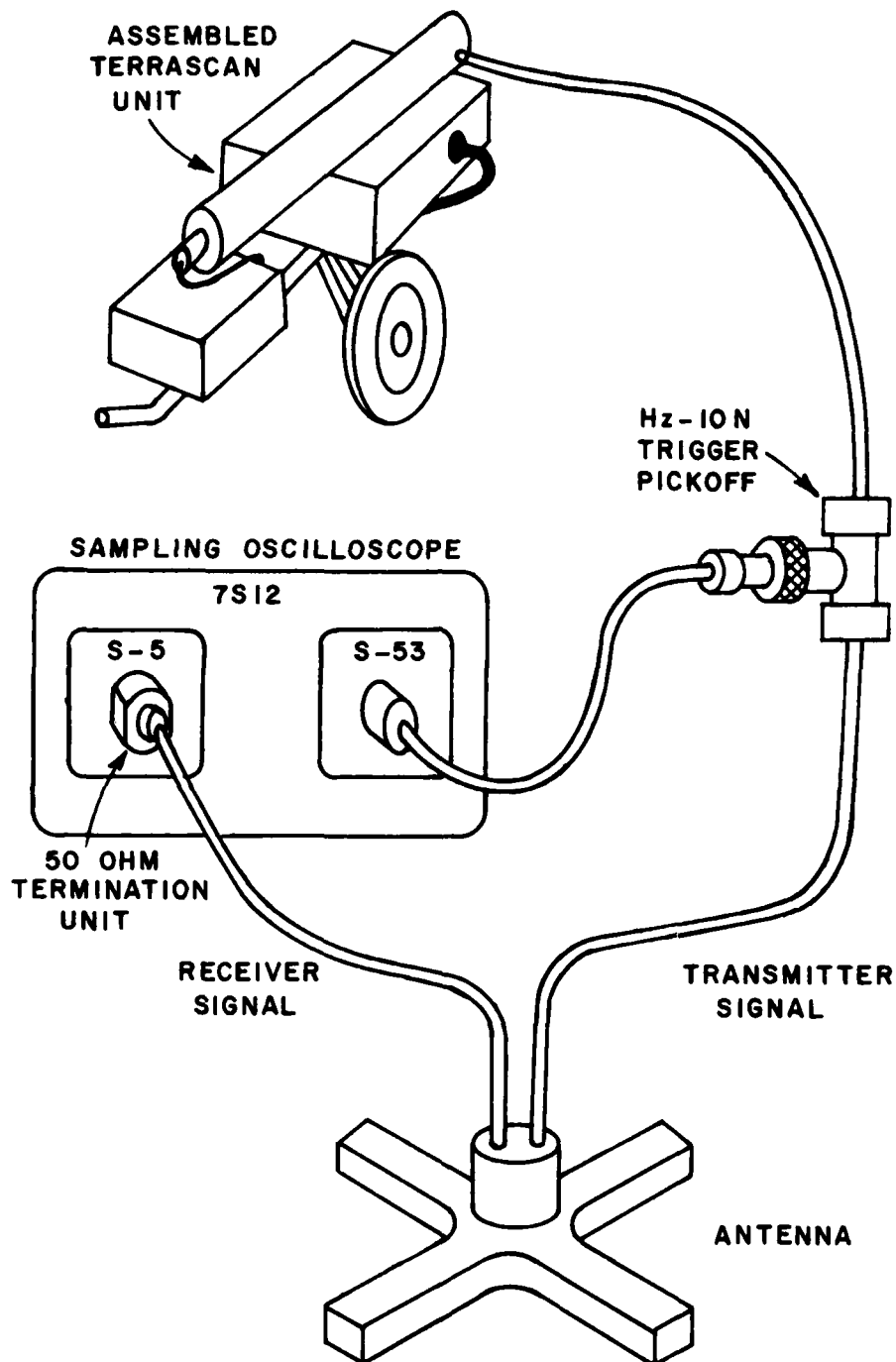


Figure 1. Antenna and pulser interconnections for use with the analog sampling system.

is generally placed as near to the pulse source as is possible, which in this case is directly on the end of the coaxial cable emerging from the Terrascan pulse tube. A TNC male to N male adapter will be necessary. The variable depth capacitive probe should initially be set about midway in its range of positions.

A short length of cable is then used to connect the capacitively coupled trigger to the S-53 trigger recognizer.

The transmitter pulse, after passing through the capacitive pick-off, is routed to the transmitting antenna using RG-9/U cable. Physically the two dipoles in each crossed pair are identical and either may be selected as the transmitting antenna. The receiving antenna is then connected via RG-9/U cable through a 50 ohm termination unit and into the S-5 sampling head. Because of internal delays in the oscilloscope, the minimum length of cable which can be used between the trigger pickoff and the S-5 sampling head is approximately 40 feet.

Care should be taken to guide the cables which are connected at the antenna upwards, perpendicular to the ground, for several feet. They should then be lead away in such a manner that they do not drape back down to the ground until they are several feet beyond the antenna tips. This is necessary to preserve symmetry (and consequently transmit/receive isolation) in the antenna region. When using the Terrascan antenna, this is nicely accomplished by the metal handle which is included with the antenna. For other antennas a wooden tripod, such as that used by a surveyor's transit, has been employed for this purpose. Once it has been verified that the system is set up as described above, the pulse generator may be powered up by turning on the Terrascan unit. The level and stability controls on the S-53 trigger recognizer are now adjusted to provide a stable picture of the received waveform on the oscilloscope screen (Beam 2). If the trace is free-running (not triggering) it will appear as a solid line. When proper triggering is occurring, the trace will appear

as a dotted line. Readjusting the capacitive pickoff may be deemed necessary. The capacitive pickoff should be pushed in only as far as is needed to provide a stable oscilloscope trace. Pushing the pickoff in all the way has the potential for burning out the S-53 unit. When the system has been set up properly and the intended equipment settings obtained, the control of the oscilloscope sweep may be turned over to the data acquisition microcomputer, as detailed in a later section.

III. DATA COLLECTION TECHNIQUES

A common problem encountered in remote data collecting occurs when the waveforms are finally being examined and it is found that a certain important equipment setting was not recorded or a definitive experiment was overlooked. It is taken for granted that the equipment settings, cables, antenna, and pulser used will be recorded in some way for each waveform. The discussions which follow are intended to detail methods which may be used to alleviate certain of the more basic oversights.

One of the most important pieces of information to be obtained from a recorded waveform is the relative time delay to a feature of interest (target echo). This relative delay corresponds to a signal path from the transmitting antenna to the target and back to the receiving antenna. The time at which the transmitter energy reaches the antenna feedpoint marks 'time zero' (t_0), corresponding to the surface of the ground. A cross-coupled pulse usually appears at this time. Time delays of subterranean echoes should be measured from this 'time zero' to allow accurate determination of depth. Since this time reference is so important it is often useful to set the oscilloscope range window to include the initial coupled pulse at t_0 , even though targets near the surface may not be of interest.

Certain antenna and pulser combinations may not provide a noticeable pulse at t_0 . To aid in identifying this time, a wire several feet long may be placed bisecting the feed region of the crossed dipoles. This should give rise to a strong ringing signal which will begin at t_0 . It is usually convenient to position t_0 one division from the left edge of the oscilloscope screen.

Even if the desired time window for recording does not include t_0 , a recording should be taken which does include it. It is felt that if precise delay measurements are needed, there is too much backlash in the oscilloscope mechanical delay control to rely solely on its readings. If this is the case, after recording the t_0 waveform the oscilloscope delay knob may be cranked out so that the last few centimeters (right hand side) of the first recording have now become the first few centimeters (left hand side) on the oscilloscope screen. This display should now be recorded and the process repeated until the desired time window is reached. The overlapping preliminary recordings may later be pieced together, allowing a precise determination to be made of the actual delay to any feature appearing in the waveform set which was recorded in the desired time window.

Another common problem encountered in data collection occurs when clutter is present in an early portion of the waveform which is much stronger than the expected signal echo (which occurs in a later part of the waveform). The dilemma is that when the oscilloscope gain is adjusted to provide an unclipped view of the clutter, very poor resolution is obtained for the weak target echo. The resolution limit is related to the quantization level of the 8 bit A/D converter of the recording system. On the other hand, if the oscilloscope gain is set to provide a reasonable presentation of a target echo, the clutter filled early portion of the waveform will be driven off screen, clipping the recorded waveform. This clipping may be acceptable in some instances, but for many types of data

processing the clipping causes erroneous results. Spectral analysis, filtering, and analysis in the complex frequency plane all may provide misleading information if clipped waveforms are used.

The present solution to this problem is to record the waveform twice, once on each gain setting. Then the two waveforms may be combined using a computer with more numerical precision. This allows the weak target echo to be represented with the same precision as the strong clutter signal. A more satisfying solution would be to incorporate a tapered gain function in the oscilloscope amplifiers, automatically increasing the front-end amplification as the later time portions of the waveform are being sampled. Unfortunately such a function has not been included in the present system.

IV. SETUP OF MICROCOMPUTER SYSTEM

The Microcomputer Data Acquisition System (MIDAS) allows controlling of the sampling process and converts the sampled radar signals into a digital format. This eliminates the need for bulky and expensive multi-channel analog recorders. The microcomputer consists of an Intel SDK-80 computer board, an 8 K byte memory board, and a board containing keypad, display and analog I/O. The heart of the computer is an Intel 8080 microprocessor.

The equipment associated with the data acquisition computer includes the microcomputer box, the microcomputer power unit, and a Tektronix 4923 Digital Cartridge tape recorder. These items are assembled as shown in Figure 2. Be certain that Pin 1 on each 'harmonic' connector on the recorder cable matches with the designated Pin 1 on the microcomputer box. Improper connection may damage the recorder.

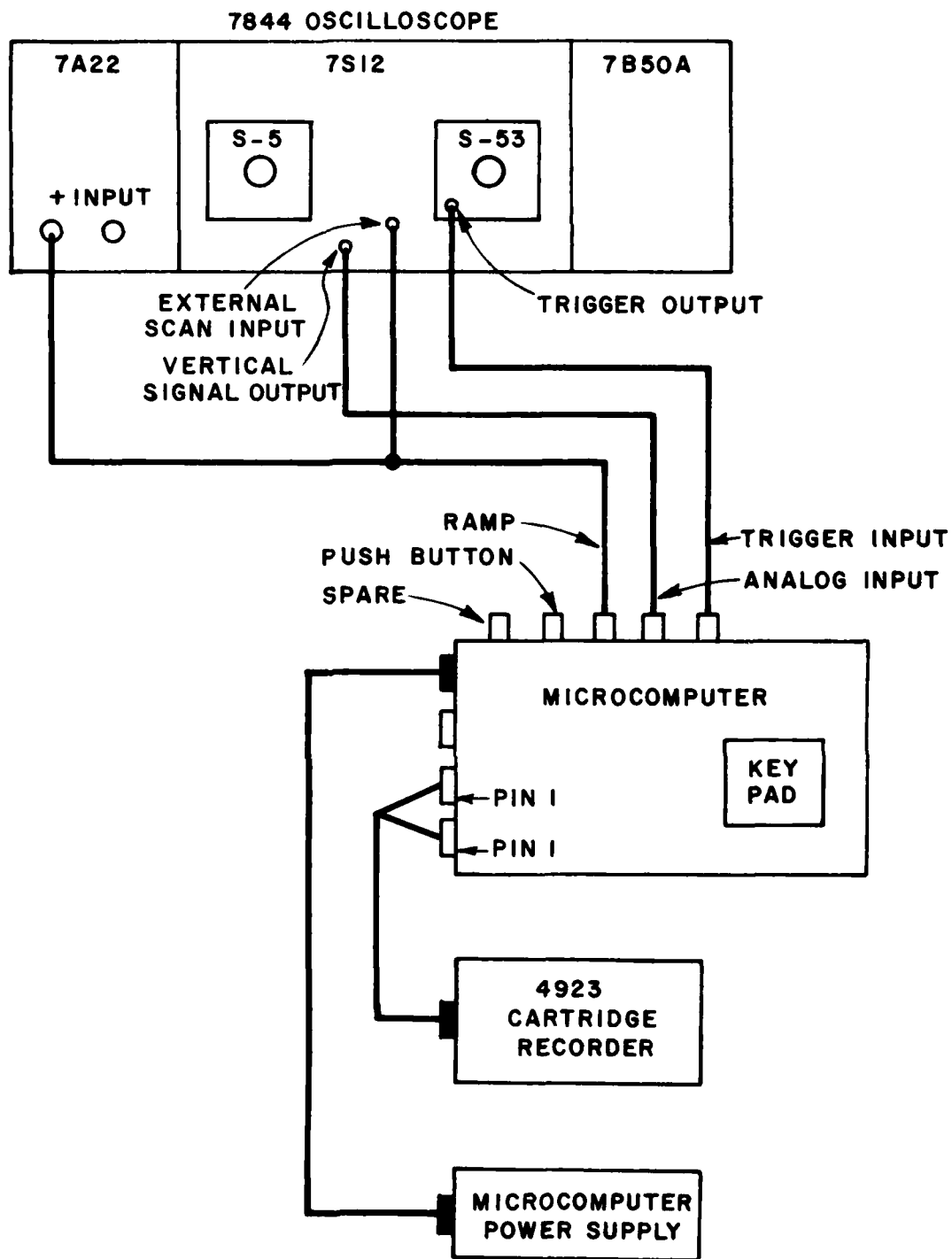


Figure 2. Interconnection of the sampling oscilloscope and the microcomputer system.

The connections which must be made between the microcomputer unit and the 7844 oscilloscope are illustrated in Figure 2. A specific description of each interconnection follows.

1. A coaxial cable with a BNC male fitting at one end and a BSM connector at the other is used to connect the 'trigger out' signal of the S-53 trigger recognizer to the trigger jack (Port F) on the microcomputer box. This signal provides the computer with interrupts, which synchronize certain computer functions with the firing of the pulse generator.
2. A coaxial cable with a BNC male plug at one end and pin plugs at the other is used to connect the vertical signal out of the 7S12 to the signal in jack (Port G) of the microcomputer box. The signal wire is the red wire. The black wire (ground) should be fastened to the grounding terminal on the 7A22 plug-in. This signal is the sampled waveform which is to be digitized by the A/D converter.
3. A coaxial cable with a BNC male plug at one end and pin plugs at the other is used to connect the ramp (Port H) from the computer box to the input ramp pin jack of the 7S12. The red wire is the signal wire. Connect the black (ground) pin plug to the pin jack of the grounded wire from step 2. This signal is used to drive the horizontal amplifiers of the oscilloscope which also determines the time delay of the sampling point. To utilize this signal properly, the external input push button on the 7S12 should be depressed and the scan vernier knob turned fully clockwise.
4. A coaxial cable with a BNC male plug at one end and pin plugs at the other is used to connect the (+) input of the 7A22 differential amplifier plug-in to the ramp signal of step 3. This

is done by piggybacking this red pin plug into the red pin plug which is in the 'input ramp' pin jack on the 7S12. When the computer is in the waveform display mode the ramp line is used to send an analog waveform to the oscilloscope on Beam 1. The volts/div switch of the 7A22 should be set at 1 v and the 7B50A time base should be set for 1 ms/div.

Upon powering up the microcomputer system an audible 'beep' will be heard and the Light Emitting Diode (LED) display will read all zeroes indicating that the computer program is idling in the command loop. The digital recorder power should be turned on after the computer itself. If analog and digital systems have been interconnected as previously described, the computer keypad may be now used to control the data acquisition and associated processes.

V. COMPUTER FIRMWARE FUNCTIONS

A summary of the keypress functions is given below. Their use is described in the following paragraphs.

- 0....Record a waveform from the sampling oscilloscope into the computer memory.
- 1.... Initiate remote pushbutton waveform recording sequence.
- 2....Enter two digit sequence number for next waveform.
- 3....No control function.
- 4....Select number of points desired per waveform (16,32,64,128, or 256).
- 5....No control function.

6....Select number of averages to be taken for each data point (0, 2, 4, 8, 16, or 32).

7....Enter tuneup mode which sweeps oscilloscope and displays on the LED's, the average value, peak value, and peak position of the digitized waveform.

8....Enable a program branch to a user supplied PROM.

A....Display a selected waveform from the computer memory on the oscilloscope.

B....Dump waveform data from computer memory to digital cartridge recorder.

C....No control function. Used to return to command loop from certain functions.

D....Read and verify waveform data from digital cartridge recorder against computer memory.

E....Turn off alarm which results when computer memory is full of waveforms or when a read/verify tape error has occurred.

F....Restart and re-initialize program.

The operation of these functions is now explained in detail.

(Ø) Record a waveform

Pressing key Ø while in the command loop initiates the recording of a waveform from the sampling oscilloscope. The center two LED's

display the sequence number for the waveform being recorded. The waveform is stored in the next available memory area and pertinent pointers are advanced. The memory is checked before recording commences and if the memory is full an alarm is set off (see keypress E). Otherwise the program returns to the command loop.

(1) Initiate remote pushbutton recording sequence

Pressing key 1 while in the command loop allows recording of successive waveforms to be controlled remotely, via a pushbutton. Each pressing of the pushbutton causes one waveform to be recorded into the computer memory (see keypress 0). To return to the program command loop press key C. This is an optional feature for user convenience and the pushbutton hardware has not been included with this system. The pushbutton cable is to be connected to BNC jack I on the computer chassis. When depressed, the button should short the cable center conductor to the shield (ground).

(2) Enter sequence number.

Stored with each waveform is a two digit sequence number which is to be used with written records to identify each waveform. Upon startup or reset, the sequence number is initialized to 00. As each waveform is recorded this sequence number is incremented up to FF (hexadecimal) after which it starts over at 00 again. The sequence number for the next waveform may be changed at any time by the user by pressing key 2 while in the command loop. At this point a 2 is displayed in the leftmost LED and the next two keypresses will select the new sequence number. The program is then returned to the command loop, but the new number is not displayed until the next recording operation.

(4) Select number of points per waveform.

Upon startup or reset the number of data points per recorded waveform is initialized to be 256. This may be changed by pressing key 4

while in the command loop. At this point a 4 is displayed in the left most LED and the next keypress will select the number of data points to be recorded as follows:

Key press	Selects
0	16 points
1	32 points
2	64 points
3	128 points
4	256 points

Keypresses other than 0 through 4 are ignored and the program waits for a valid entry. After a valid keypress the program returns to the command loop.

This feature was included for added flexibility.

Important note: If the number of data points per waveform is to be changed in the middle of a recording session, dump any waveforms remaining in memory onto the digital cartridge recorder (see keypress B). Having waveforms of differing lengths in memory may cause the waveform display feature (keypress A) to malfunction.

(6) Select number of waveform averages.

Upon startup or reset the number of averages taken per data point is initialized to 4. During data recording, each of the horizontal positions of the waveform (time positions) is sampled 4 consecutive times and the computed average value is stored in the proper cell of the memory area. The number of averages to be taken may be changed at any time by pressing key 6 while in the command loop. At this point a 6 is displayed

in the leftmost LED and the next keypress will select the number of averages to be taken per data point as follows:

Keypress	Selects
0	no averaging
1	2 averages
2	4 averages
3	8 averages
4	16 averages
5	32 averages

Key presses other than 0 through 5 are ignored and the program waits for a valid entry. After a valid keypress the program returns to the command loop.

(5) Enter tuneup mode

Pressing key 7 while in the command loop transfers program control into a 'tuneup' mode which allows computer controlled sweeping of the oscilloscope without recording a waveform and also verifies proper operation of the A/D and D/A converters. When in the tuneup mode the oscilloscope is swept continuously, employing the number of points per waveform and the number of averages per data point which have been selected. The incoming radar return should appear on the oscilloscope screen. The two leftmost LED's display the peak signal amplitude as a two digit hexadecimal number. The A/D converter output ranges from 0 below the bottom of the oscilloscope screen to FF above the top of the screen. The amplitude value which is displayed is that of the waveform element which is farthest from midscale (midscale=40 Hex) either above or below. The center two LED's display the time position of this peak as a two digit hexadecimal number. This number corresponds to the element number of the peak which ranges from 00 at the left edge of the oscilloscope screen

to FF at the right edge of the screen. The rightmost two LED's display the computed average value of the waveform as a two digit hexadecimal number. As with the peak amplitude, this value may range from 00 to FF.

To exit the tuneup mode, press key C.

(8) Branch to user ROM

User defined functions may be added to the computer without modifying the main program. These functions may be programmed into 2708 Erasable Programmable Read Only Memories (EPROM's) for use in hardware slots 'ROM 2' and 'ROM 3'.

To cause a jump from the main program to a user routine Key 8 is pressed while in the command loop. At this point an 8 is displayed in the leftmost LED and the next keypress will select the ROM position to which program control is transferred. Pressing Key 2 or 3 transfers control to ROM 2 (address 800 Hex) or ROM 3 (address C00 Hex). Pressing Key 0 selects the main program (ROM 0) and is equivalent to a software reset (see keypress F). If any key other than 0, 2, or 3 is pressed the program returns to the command loop.

(A) Display a stored waveform.

To display a previously stored waveform on the oscilloscope, key A is pressed while in the command loop. At this point an A is displayed in the leftmost LED and the next two keypresses select the sequence number (see Key 2) of the stored waveform to be displayed. If no waveform is found with the given sequence number, the program returns to the command loop. If a waveform is found, the sequence number is displayed in the leftmost two LED's. The waveform data is now being continuously cycled out of the D/A port to the oscilloscope. Turn down the intensity of beam 2 and turn up the intensity of Beam 1 on the 7844 oscilloscope. Now the

timebase and triggering controls of the 7B50A plug-in should be adjusted to provide a stable picture on the oscilloscope screen. (A plus to minus full scale pulse is inserted at the beginning of each cycle of the waveform data to provide a convenient trigger signal for the oscilloscope.)

To terminate the waveform display press Key C and the program will return to the command loop. To prepare for further waveform recording, turn down Beam 1 and turn up Beam 2 on the oscilloscope.

(B) Dump waveform data to cartridge recorder.

When the digital cartridge recorder is set in its write mode (see section on the cartridge recorder) and the computer is in the command loop, pressing Key B causes the waveforms stored in computer memory to be copied to the digital recorder. This waveform dumping process may be performed whether the memory is full or only partially full of waveforms; only the portion of memory containing waveform data is dumped. When the dump is completed, program control is returned to the command loop. At this point the STOP button on the recorder should be pressed in order to make each tape dump a complete logical file, as defined by the recorder. This is done to make waveform recovery from the tape more convenient. This is also required if the read/verify function of the computer (Key D) is to be used. If the indicator light over the recorder STOP button is lighted before you press the STOP button, this means the tape has no more room. This dump is probably incomplete (use Key D to check) and memory should be redumped on a fresh tape.

Waveform dumping of a given memory content may be performed any number of times (to provide redundant recordings if desired) until a new waveform is recorded via Key Ø or Key 1. When the first new waveform is recorded after dumping the memory, the software data pointers are reset and reference to the previous waveforms is lost. The sequence number is not reset, and continues in sequence.

(C) Return to command loop

Pressing Key C causes program control to return to the command loop when in the following operations

- 1) push button recording mode (Key 1)
- 2) Tuneup mode (Key 7)
- 3) Waveform display mode (Key A)

Key C may also be used as a convenient invalid character to abort the 'jump to user PROM' routine (Key 8). Control is returned to the command loop (see Key 8).

(D) Read and verify cartridge tape

After pressing Key B to copy the memory to tape it may be desirable to verify that the recording is accurate. This may be done if the memory dump constituted a complete tape file (as recommended in the Key B section). If the last dump was structured as only part of a file, the Key D read verify routine will not work properly. If the dump does constitute a complete file, the tape should then be rewound to the beginning of this file by a momentary press of the recorder's REVERSE button, and prepared for the read by pressing the RUN button. Pressing Key D on the computer while in the command loop will initiate a byte by byte comparison of the tape contents with the memory contents. If an error is encountered the alarm is set off. Pressing Key E will silence the alarm and return program control to the command loop, from where another tape write operation (Key B) may be tried. The STOP and then the REVERSE button on the recorder should be pressed to position the tape for another write attempt. If the tape data is valid, program control is returned

to the command loop. To prepare the recorder for further data recording press the STOP and then the FORWARD button on the recorder.

(E) Silence Alarm

Key E is pressed to silence the alarm which occurs when the computer memory is full of waveforms (in recording modes, Keys 0 or 1) or when a read/verify tape error is encountered (in tape check mode, Key D). Control is returned to the command loop.

(F) Software reset

Pressing Key F while in the command loop causes a branch to the beginning of the computer program. This resets all pointers and reinitializes all default values. This is equivalent to pressing the reset button on the SDK-80 computer card.

VI. THE DIGITAL CARTRIDGE TAPE RECORDER

This section briefly describes the digital recorder functions which are necessary to operate the recorder with the microcomputer data acquisition system. A more complete description of the recorder features may be found in the Tektronix 4923 Digital Cartridge Tape Recorder Users' Manual.

To insure that the internal circuitry of the 4923 recorder is properly initialized, the recorder should only be turned on after the main microcomputer data system has been powered up. (The microcomputer system provides the clock necessary for operation of the 4923 recorder.) Next, verify that the Test/Operate switch on the back of the recorder is in the operate position and the BINARY button on the front panel is depressed.

Read Operations

When the digital cartridge is inserted and the recorder is in a stopped condition, the Read Mode may be entered by a momentary press of the RUN button. The READ indicator (above the RUN button) will become lit. The microcomputer may then read data a byte (eight bits) at a time from the recorder's tape buffer. When a File Read Operation is complete, the STOP and then the FORWARD button should be pressed to position the tape for a read or write on the next file.

Write Operations

A Write Operation is used to write data onto the tape from the microcomputer. To enter Write Mode, press in and hold the WRITE button and simultaneously press the RUN button. The WRITE indicator (above the WRITE button) will illuminate.

Once the Write Mode has been entered, the Write Operation continues until the STOP button is pressed. Between the time when Write Mode begins and the time when the STOP button is pressed, all data from the microcomputer is written onto the tape. It is written from the data lines into a buffer that holds 128 eight-bit bytes (characters). When the buffer is full, the 128 data bytes are written onto the tape, constituting one data record. Records are written sequentially onto the tape in this manner to form tape files of data. When the STOP button is pressed, any unused character positions within the buffer are filled with NUL characters, and the last record of the file is written onto the tape followed by an End-of-File mark.

Skip Forward Operations

Skip Forward allows the 4923 to skip over one data file in the forward direction without transferring data. The operation may be ended earlier by pressing the STOP button. Skip Forward is implemented by a single momentary push of the FORWARD button. (Note that a momentary push is all that is required for the Skip Forward Operation. If the FORWARD button is held down, Fast Forward mode will begin, as described in the following paragraph.)

Fast Forward Operations

Fast Forward mode begins when the FORWARD button is pressed and held for about one second. When this occurs, the tape winds in the forward direction at 90 inches per second. This continues until the STOP button is pressed, or until the end of the usable tape area is reached, whichever occurs first.

Skip Reverse Operations

Skip Reverse allows the 4923 to back over one data file each time the REVERSE button is momentarily pressed. No data is transferred. The operation may be ended earlier by pressing the STOP button. (Note that a momentary push of the REVERSE button is all that is required for a Skip Reverse Operation. If the button is held down, Fast Reverse mode will begin, as described in the following paragraph.)

Fast Reverse (Rewind) Operations

Fast Reverse begins when the REVERSE button is pressed and held for about one second. When this occurs, the tape rewinds at 90 inches per second. Rewinding continues until the STOP button is pressed, or until the tape has rewound to the beginning of the usable tape area, whichever occurs first.

VII. EXAMPLE RECORDING SESSION

The following paragraphs describe a sample waveform recording session, using the various features of the microcomputer system.

First the oscilloscope, pulser, and antenna should be assembled and interconnected as dictated by the desired experiment and in accordance with Section II. The proper oscilloscope settings for the radar data can be determined while using the repetitive scan mode of the 7S12 sampling plug-in. After the computer connections are made as outlined in Section IV, the scan mode on the 7S12 should be set to external and the scan rate knob turned fully clockwise. When the computer is powered up the LED displays should read all zeroes indicating that the computer is ready and in the command loop. This may be further verified by pressing Key C on the key pad a number of times. The letter C should be displayed in the leftmost LED and an audible 'beep' should sound at each keypress.

If the number of averages to be taken is desired to be two instead of the default value of four, the key sequence 6-1 should be entered.

Pressing Key 7 then initiates sweeping of the oscilloscope in the tuneup mode. The radar waveform appears on the oscilloscope screen as it will be recorded and the numerics on the LED's indicate proper operation of the A/D converter. When ready to record a preliminary waveform press Key C to terminate tuneup mode and then Key Ø to record.

The sequence number of ØØ should be displayed in the center two LEDs. It is useful at this point to view the recorded waveform. This is done by entering Key sequence A-Ø-Ø, lowering the intensity of Beam 2 on the oscilloscope, and raising the beam 1 intensity. By viewing the waveform in this fashion the operator can decide if enough averages are being taken or if the high resolution (smoothing) feature of the 7S12 is needed.

After the appropriate measures have been taken and the preceeding sequence has been repeated, the memory may be cleared of these test waveforms by pressing Key B (memory dump) without enabling the cartridge tape recorder. The sequence number should then be reset (usually to zero) by entering key sequence 2-0-0.

The first two waveforms which should be recorded for any given trial are the top full scale and bottom full scale readings of the oscilloscope screen. These are used to calibrate the subsequent recorded waveforms in relation to the oscilloscope deflection factor. These straight line waveforms can be obtained by disconnecting the received signal cable from the S-5 plug-in and turning down the vertical sensitivity of the 7S12 to reduce noise. The 7S12 offset control is then used to position the trace to be recorded first at the top full scale line and then at the bottom full scale line.

After this detail has been taken care of, recording of waveforms can proceed by pressing key 0 for each recording. (See also Section III concerning data gathering techniques.) In between recordings the incoming received waveform may be viewed by pressing Key 7 (tuneup) or by switching the 7S12 unit to repetitive scan. If the repetitive scan feature is used it is essential that the 7S12 is returned to the external scan mode and the scan knob turned fully clockwise before another recording is made.

Once the desired number of waveforms have been obtained or the alarm goes off signifying full memory, the waveforms may be copied to the cartridge recorder. (Key E is used to silence the alarm.) The digital recorder may be put into the write mode by pressing in and holding in the WRITE button and momentarily pressing the RUN button. (Be sure that the BINARY button is depressed.) Pressing Key B on the microcomputer then causes the memory dump to occur. After this operation is complete, the STOP button on the recorder should be pressed. This causes an End-of-File mark to be written and advances the tape to the next position for writing.

An optional Read/Verify check may be made at this point. To do this press Key D on the microcomputer. Then press the REVERSE button momentarily on the recorder. When the tape stops press the RUN button. If the tape data is valid program control returns to the command loop and an audible beep is generated. Press the STOP button and then the FORWARD button on the recorder to position the tape for the next write. If the tape data is not valid, a continuous alarm is set off which can only be silenced by pressing Key E on the microcomputer. This done, back-up the tape to the beginning of this bad file by pressing STOP then REVERSE and try the Read Verify again (Key D) or repeat the memory dump procedure (Key B).

This process of recording and dumping waveforms may continue until all experiments are done or until there is no room on the tape. If after a memory dump (Key B) the indicator light over the tape recorder STOP button is lighted before you press the STOP button, the tape is out of room. This dump should be repeated on a fresh tape.

APPENDIX I
WAVEFORM RECORD FORMAT AND MICROCOMPUTER PROGRAM LISTING

Each waveform as recorded on the digital tape cartridge contains five preamble bytes, a variable number of data points (specified in the preamble) and three postamble bytes. For the general case of 256 data points, the waveform record size is 264 bytes. The significance of these bytes in the order read from the tape is charted below.

- Byte 1: Header, always = 99 Hex
- Byte 2: Header, always = 88 Hex
- Byte 3: Number of waveform data bytes in record. Coded as follows.
 - 10 Hex 16 data bytes
 - 20 Hex 32 data bytes
 - 40 Hex 64 data bytes
 - 80 Hex 128 data bytes
 - 00 Hex 256 data bytes
- Byte 4: Number of averages taken by system per data point. Coded as an eight bit integer.
- Byte 5: Sequence number, used to identify the waveform. Range 00 Hex to FF Hex.
- Byte 6: First waveform data byte. Coded as an unsigned eight bit integer. 00 Hex corresponds to the most 'negative' value and FF Hex to the most positive value.
- Byte N+5: Last waveform data byte.
- Byte N+6: Low order byte of the waveform data checksum. This 16 bit checksum is the negation of the sum of the N waveform data bytes.
- Byte N+7: High order byte of waveform data checksum. When the 16 bit sum of Bytes 6 through N+5 is added to the 16 bit integer of bytes N+6 and N+7, zero should be the result.
- Byte N+8: Trailer, always = FF Hex.

The following pages contain the program listing for the microcomputer data acquisition system. This program resides in 2708 Programmable Read Only Memories (PROM) in hardware slots ROM0 and ROM1 on the SDK-80 microcomputer board.

SOURCE STATEMENT

```

1 *****
2 THIS PROGRAM IS THE OSCILLISCOPE VERSION
3 OF THE SECRET POLICE STOPCOMPUTER SYSTEM.
4 IT IS USED FOR GENERAL PURPOSES RESEARCH AND
5 OUTPUTS ON TO TELETYP IV 4024 DIGITAL RECORDER.
6 *****
7 PC0 EQU 0
8 PC1 EQU 400H
9 PC2 EQU 800H
10 PC3 EQU 000H
11 PC4 EQU 1
12 *****
13 *** 270 ALPHABET/DISPLAY INTERFACE ***
14 AL0 EQU 000H
15 AL1 EQU 000H
16 AL2 EQU 000H
17 AL3 EQU 000H
18 AL4 EQU 000H
19 AL5 EQU 000H
20 AL6 EQU 000H
21 AL7 EQU 000H
22 AL8 EQU 000H
23 AL9 EQU 000H
24 ALA EQU 000H
25 ALB EQU 000H
26 ALC EQU 000H
27 ALD EQU 000H
28 ALE EQU 000H
29 ALF EQU 000H
30 ALG EQU 000H
31 ALH EQU 000H
32 ALI EQU 000H
33 ALJ EQU 000H
34 ALK EQU 000H
35 ALL EQU 000H
36 ALM EQU 000H
37 ALN EQU 000H
38 ALO EQU 000H
39 ALP EQU 000H
40 ALQ EQU 000H
41 ALR EQU 000H
42 ALS EQU 000H
43 ALT EQU 000H
44 ALU EQU 000H
45 ALV EQU 000H
46 ALW EQU 000H
47 ALX EQU 000H
48 ALY EQU 000H
49 ALZ EQU 000H
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67 ALOD EQU 000H
68 ALOE EQU 000H
69 ALOF EQU 000H
70 ALOG EQU 000H
71 ALOH EQU 000H
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73 ALOJ EQU 000H
74 ALOK EQU 000H
75 ALOL EQU 000H
76 ALOM EQU 000H
77 ALON EQU 000H
78 ALOO EQU 000H
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0004 50000 MVI A,04H
0005 50001 STA AVGS
0006 50002 XOR A
0007 50003 STA PMS
0008 50004 LDI 000
0009 50005 SHLO STPLG
0010 50006 *** INITIALIZE DATA BUFFER POINTERS
0011 50007 LDI 00000000H
0012 50008 SHLO STPLG ;STORE POINTER
0013 50009 *** INITIALIZE PARALLEL PORT AS ***
0014 50010 MVI A,001FH
0015 50011 OUT PAICPT ;DATA CONTROL PORT
0016 50012 *** INITIALIZE PARALLEL PORT AS ***
0017 50013 CALL WAIT
0018 50014 *** INITIALIZE SPANSE MEMORY TO 0 ***
0019 50015 LDI 0
0020 50016 STA SPAN
0021 50017 MVI A,00H ;INTERUPT VECTOR
0022 50018 OUT PAICPT ;SET BIT 004
0023 50019 *** INITIALIZE PMS & NAVG TO DEFAULT VALUES
0024 50020 LDI 0010000H ;264 PMS/RECORD
0025 50021 SHLO PMS
0026 50022 JMP AROUND
0027 50023 *****
0028 50024 *** INITIALIZE 50000H IS INTERRUPT LOCATION
0029 50025 *****
0030 50026 ORG 50000H
0031 50027 JMP TMTRPT ;INTERUPT VECTOR
0032 50028 *** INITIALIZE 50079 KEYBOARD & DISPLAY
0033 50029 AROUND: MVI A,02H ;2**2 AVGS
0034 50030 STA NAVG
0035 50031 MVI A,00000000H ;HRESCALE FOR CLOCK = 20
0036 50032 OUT KDCATR
0037 50033 MVI A,02H ;LEFT ENTRY-ENCLOED 1-KEY ROLLOVER
0038 50034 OUT KDCNTR
0039 50035 AROUND: MVI A,00000000H ;CLEAR ALL STATUS AND DISPLAY
0040 50036 OUT KDCNTR
0041 50037 IN KDCNTR ;WAIT FOR CLE/M TO FINISH
0042 50038 JNC
0043 50039 CALL CMDAND LOOP ***
0044 50040

```

0002 014514	12	CPOLP:	LVI	SP:SP00+START
0003 014515	13		CALL	DEEP
0004 014516	14		CALL	PR00
0005 014517	15		CALL	DISP1
0006 014518	16		CP1	PR
0007 014519	17		U2	START
0008 014520	18		CP1	000
0009 014521	19		U2	TP01P
0010 014522	20		CP1	000
0011 014523	21		U2	TPWRT
0012 014524	22		CP1	000
0013 014525	23		U2	WAV01T
0014 014526	24		CP1	0
0015 014527	25		U2	PR00P
0016 014528	26		CP1	7
0017 014529	27		U2	TUN01P
0018 014530	28		CP1	6
0019 014531	29		U2	WAV01P
0020 014532	30		CP1	0
0021 014533	31		U2	SIZ01P
0022 014534	32		CP1	2
0023 014535	33		U2	SE01ST
0024 014536	34		CP1	1
0025 014537	35		U2	OUT01W
0026 014538	36		CP1	0
0027 014539	37		U2	PR00
0028 014540	38		U2	PR00
0029 014541	39		U2	PR00
0030 014542	40		U2	PR00
0031 014543	41		U2	PR00
0032 014544	42		U2	PR00
0033 014545	43		U2	PR00
0034 014546	44		U2	PR00
0035 014547	45		U2	PR00
0036 014548	46		U2	PR00
0037 014549	47		U2	PR00
0038 014550	48		U2	PR00
0039 014551	49		U2	PR00
0040 014552	50		U2	PR00
0041 014553	51		U2	PR00
0042 014554	52		U2	PR00
0043 014555	53		U2	PR00
0044 014556	54		U2	PR00
0045 014557	55		U2	PR00
0046 014558	56		U2	PR00
0047 014559	57		U2	PR00
0048 014560	58		U2	PR00
0049 014561	59		U2	PR00
0050 014562	60		U2	PR00
0051 014563	61		U2	PR00
0052 014564	62		U2	PR00
0053 014565	63		U2	PR00
0054 014566	64		U2	PR00
0055 014567	65		U2	PR00
0056 014568	66		U2	PR00
0057 014569	67		U2	PR00
0058 014570	68		U2	PR00
0059 014571	69		U2	PR00
0060 014572	70		U2	PR00
0061 014573	71		U2	PR00
0062 014574	72		U2	PR00
0063 014575	73		U2	PR00
0064 014576	74		U2	PR00
0065 014577	75		U2	PR00
0066 014578	76		U2	PR00
0067 014579	77		U2	PR00
0068 014580	78		U2	PR00
0069 014581	79		U2	PR00
0070 014582	80		U2	PR00
0071 014583	81		U2	PR00
0072 014584	82		U2	PR00
0073 014585	83		U2	PR00
0074 014586	84		U2	PR00
0075 014587	85		U2	PR00
0076 014588	86		U2	PR00
0077 014589	87		U2	PR00
0078 014590	88		U2	PR00
0079 014591	89		U2	PR00
0080 014592	90		U2	PR00
0081 014593	91		U2	PR00
0082 014594	92		U2	PR00
0083 014595	93		U2	PR00
0084 014596	94		U2	PR00
0085 014597	95		U2	PR00
0086 014598	96		U2	PR00
0087 014599	97		U2	PR00
0088 014600	98		U2	PR00
0089 014601	99		U2	PR00
0090 014602	100		U2	PR00
0091 014603	101		U2	PR00
0092 014604	102		U2	PR00
0093 014605	103		U2	PR00
0094 014606	104		U2	PR00
0095 014607	105		U2	PR00
0096 014608	106		U2	PR00
0097 014609	107		U2	PR00
0098 014610	108		U2	PR00
0099 014611	109		U2	PR00
0100 014612	110		U2	PR00
0101 014613	111		U2	PR00
0102 014614	112		U2	PR00
0103 014615	113		U2	PR00
0104 014616	114		U2	PR00
0105 014617	115		U2	PR00
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0114 014626	124		U2	PR00
0115 014627	125		U2	PR00
0116 014628	126		U2	PR00
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0118 014630	128		U2	PR00
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0121 014633	131		U2	PR00
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0123 014635	133		U2	PR00
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0125 014637	135		U2	PR00
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0128 014640	138		U2	PR00
0129 014641	139		U2	PR00
0130 014642	140		U2	PR00
0131 014643	141		U2	PR00
0132 014644	142		U2	PR00
0133 014645	143		U2	PR00
0134 014646	144		U2	PR00
0135 014647	145		U2	PR00
0136 014648	146		U2	PR00
0137 014649	147		U2	PR00
0138 014650	148		U2	PR00
0139 014651	149		U2	PR00
0140 014652	150		U2	PR00

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ADDRESS	OPERATION	TIME	TIME	CALL	TEXT
0000	0000	145		CALL	TUNE
0001	0001	146		LDA	TPEAK
0002	0002	147		MOV	PMPSR
0003	0003	148		CALL	TIME
0004	0004	149		LDA	PMPSR
0005	0005	150		CALL	TAVE
0006	0006	151		LDA	PMPSR
0007	0007	152		CALL	TIME
0008	0008	153		LDA	PMPSR
0009	0009	154		CALL	TAVE
0010	0010	155		LDA	PMPSR
0011	0011	156		CALL	TIME
0012	0012	157		LDA	PMPSR
0013	0013	158		CALL	TAVE
0014	0014	159		LDA	PMPSR
0015	0015	160		CALL	TIME
0016	0016	161		LDA	PMPSR
0017	0017	162		CALL	TAVE
0018	0018	163		LDA	PMPSR
0019	0019	164		CALL	TIME
0020	0020	165		LDA	PMPSR
0021	0021	166		CALL	TAVE
0022	0022	167		LDA	PMPSR
0023	0023	168		CALL	TIME
0024	0024	169		LDA	PMPSR
0025	0025	170		CALL	TAVE
0026	0026	171		LDA	PMPSR
0027	0027	172		CALL	TIME
0028	0028	173		LDA	PMPSR
0029	0029	174		CALL	TAVE
0030	0030	175		LDA	PMPSR
0031	0031	176		CALL	TIME
0032	0032	177		LDA	PMPSR
0033	0033	178		CALL	TAVE
0034	0034	179		LDA	PMPSR
0035	0035	180		CALL	TIME
0036	0036	181		LDA	PMPSR
0037	0037	182		CALL	TAVE
0038	0038	183		LDA	PMPSR
0039	0039	184		CALL	TIME
0040	0040	185		LDA	PMPSR
0041	0041	186		CALL	TAVE
0042	0042	187		LDA	PMPSR
0043	0043	188		CALL	TIME
0044	0044	189		LDA	PMPSR
0045	0045	190		CALL	TAVE
0046	0046	191		LDA	PMPSR
0047	0047	192		CALL	TIME
0048	0048	193		LDA	PMPSR
0049	0049	194		CALL	TAVE
0050	0050	195		LDA	PMPSR
0051	0051	196		CALL	TIME
0052	0052	197		LDA	PMPSR
0053	0053	198		CALL	TAVE
0054	0054	199		LDA	PMPSR
0055	0055	200		CALL	TIME
0056	0056	201		LDA	PMPSR
0057	0057	202		CALL	TAVE
0058	0058	203		LDA	PMPSR
0059	0059	204		CALL	TIME
0060	0060	205		LDA	PMPSR
0061	0061	206		CALL	TAVE
0062	0062	207		LDA	PMPSR
0063	0063	208		CALL	TIME
0064	0064	209		LDA	PMPSR
0065	0065	210		CALL	TAVE
0066	0066	211		LDA	PMPSR
0067	0067	212		CALL	TIME
0068	0068	213		LDA	PMPSR
0069	0069	214		CALL	TAVE
0070	0070	215		LDA	PMPSR
0071	0071	216		CALL	TIME
0072	0072	217		LDA	PMPSR
0073	0073	218		CALL	TAVE
0074	0074	219		LDA	PMPSR
0075	0075	220		CALL	TIME
0076	0076	221		LDA	PMPSR
0077	0077	222		CALL	TAVE
0078	0078	223		LDA	PMPSR
0079	0079	224		CALL	TIME
0080	0080	225		LDA	PMPSR
0081	0081	226		CALL	TAVE
0082	0082	227		LDA	PMPSR
0083	0083	228		CALL	TIME
0084	0084	229		LDA	PMPSR
0085	0085	230		CALL	TAVE
0086	0086	231		LDA	PMPSR
0087	0087	232		CALL	TIME
0088	0088	233		LDA	PMPSR
0089	0089	234		CALL	TAVE
0090	0090	235		LDA	PMPSR
0091	0091	236		CALL	TIME
0092	0092	237		LDA	PMPSR
0093	0093	238		CALL	TAVE
0094	0094	239		LDA	PMPSR
0095	0095	240		CALL	TIME
0096	0096	241		LDA	PMPSR
0097	0097	242		CALL	TAVE
0098	0098	243		LDA	PMPSR
0099	0099	244		CALL	TIME

0110 521014	171	STA	TPEAK	!MULT DATA, SO UPDATE
0113 521014	172	LDA	REPSTR	
0116 521014	173	STA	TIME	!SAVE POSITION OF THE +PEAK
0119 521014	174	LDA	TPKNG	
0110 00	175	END	C	
0110 022001	176	UC	TAVEP	!JUMP IF NEW DATA FOR < TPKNG
0120 79	177	MOV	AOL	!NEW DATA IS SMALLER
0121 521014	178	STA	TPKNG	!THAT OLD TPKNG
0124 521014	179	LDA	REPSTR	
0127 521014	180	STA	TPKNG	!SAVE POS. OF THE -PEAK
0128 0001	181	END	C	!HC HAS DATA
0120 221014	182	LDA	TAVG	
0120 00	183	END	C	
0130 221014	184	SHLD	TAVG	!UPDATE SUM
0133 210113	185	LXI	REPSTR	
0136 54	186	LDA	NPIS	!INCREMENT KAMP COUNT
0137 521014	187	LDA	NPIS	!IF OF PIS/WAVEFORM
0138 00	188	END	C	!KAMP DONE ?
0139 021000	189	UC	TLOC	!IF NOT CONTINUE DATA TAKING
0130 521014	190	LDA	TPKNG	!IS (+) OF (-) PEAK LARGER
0141 44	191	MOV	C+4	
0142 521014	192	LDA	TPEAK	
0145 81	193	ADD	C	
0146 055001	194	UC	FIXAVG	!CARRY SFT IF IPEAK IS LARGER
0143 79	195	MOV	AOL	
0144 521014	196	STA	TPEAK	!SET TPKNG, TPKNG
0140 521014	197	LDA	TIME	!BE DISPLAYED
0150 521014	198	STA	TIME	
0153 521014	199	LDA	NPIS	!SET # OF PIS/WAVEFORM
0156 57	200	SIC	C+1	
0157 0644	201	END	C	
0159 00	202	SHFCH1	10K	
0156 1F	203	LDA	REP	
0158 025001	204	UC	CMFCBT	!SUM OF DATA VALUES
0150 221014	205	LDA	TAVG	!DIVIDE AOL BY
0151 003203	206	CALL	HLSHR	!IF OF PIS/WAVEFORM
0154 221014	207	SHLD	TAVG	
0157 00	208	END	C	
0159 521014	209	END	C	
0159 521014	210	END	C	
0159 521014	211	END	C	

*** RECORD A WAVEFORM

END

0163 000004	212	CALL	NRHML
0164 000005	213	ACMG	
0165 000006	214	LHLC	NRHML
0166 000007	215	LHLC	
0167 000008	216	IF OF PTS LEFT IN BUFFER	NRHML
0168 000009	217	ACMG	IF OF PTS LEFT IN BUFFER
0169 000010	218	LHLC	NRHML
0170 000011	219	LHLC	NRHML
0171 000012	220	LHLC	NRHML
0172 000013	221	IF OF PTS LEFT IN BUFFER	NRHML
0173 000014	222	ACMG	IF OF PTS LEFT IN BUFFER
0174 000015	223	LHLC	NRHML
0175 000016	224	LHLC	NRHML
0176 000017	225	LHLC	NRHML
0177 000018	226	LHLC	NRHML
0178 000019	227	LHLC	NRHML
0179 000020	228	LHLC	NRHML
0180 000021	229	LHLC	NRHML
0181 000022	230	LHLC	NRHML
0182 000023	231	LHLC	NRHML
0183 000024	232	LHLC	NRHML
0184 000025	233	LHLC	NRHML
0185 000026	234	LHLC	NRHML
0186 000027	235	LHLC	NRHML
0187 000028	236	LHLC	NRHML
0188 000029	237	LHLC	NRHML
0189 000030	238	LHLC	NRHML
0190 000031	239	LHLC	NRHML
0191 000032	240	LHLC	NRHML
0192 000033	241	LHLC	NRHML
0193 000034	242	LHLC	NRHML
0194 000035	243	LHLC	NRHML
0195 000036	244	LHLC	NRHML
0196 000037	245	LHLC	NRHML
0197 000038	246	LHLC	NRHML
0198 000039	247	LHLC	NRHML
0199 000040	248	LHLC	NRHML
0200 000041	249	LHLC	NRHML
0201 000042	250	LHLC	NRHML
0202 000043	251	LHLC	NRHML
0203 000044	252	LHLC	NRHML
0204 000045	253	LHLC	NRHML
0205 000046	254	LHLC	NRHML
0206 000047	255	LHLC	NRHML
0207 000048	256	LHLC	NRHML
0208 000049	257	LHLC	NRHML
0209 000050	258	LHLC	NRHML
0210 000051	259	LHLC	NRHML
0211 000052	260	LHLC	NRHML
0212 000053	261	LHLC	NRHML
0213 000054	262	LHLC	NRHML
0214 000055	263	LHLC	NRHML
0215 000056	264	LHLC	NRHML
0216 000057	265	LHLC	NRHML
0217 000058	266	LHLC	NRHML
0218 000059	267	LHLC	NRHML
0219 000060	268	LHLC	NRHML
0220 000061	269	LHLC	NRHML
0221 000062	270	LHLC	NRHML
0222 000063	271	LHLC	NRHML
0223 000064	272	LHLC	NRHML
0224 000065	273	LHLC	NRHML
0225 000066	274	LHLC	NRHML
0226 000067	275	LHLC	NRHML
0227 000068	276	LHLC	NRHML
0228 000069	277	LHLC	NRHML
0229 000070	278	LHLC	NRHML
0230 000071	279	LHLC	NRHML
0231 000072	280	LHLC	NRHML
0232 000073	281	LHLC	NRHML
0233 000074	282	LHLC	NRHML
0234 000075	283	LHLC	NRHML
0235 000076	284	LHLC	NRHML
0236 000077	285	LHLC	NRHML
0237 000078	286	LHLC	NRHML
0238 000079	287	LHLC	NRHML
0239 000080	288	LHLC	NRHML
0240 000081	289	LHLC	NRHML
0241 000082	290	LHLC	NRHML
0242 000083	291	LHLC	NRHML
0243 000084	292	LHLC	NRHML
0244 000085	293	LHLC	NRHML
0245 000086	294	LHLC	NRHML
0246 000087	295	LHLC	NRHML
0247 000088	296	LHLC	NRHML
0248 000089	297	LHLC	NRHML
0249 000090	298	LHLC	NRHML
0250 000091	299	LHLC	NRHML
0251 000092	300	LHLC	NRHML
0252 000093	301	LHLC	NRHML
0253 000094	302	LHLC	NRHML
0254 000095	303	LHLC	NRHML
0255 000096	304	LHLC	NRHML
0256 000097	305	LHLC	NRHML
0257 000098	306	LHLC	NRHML
0258 000099	307	LHLC	NRHML
0259 000100	308	LHLC	NRHML
0260 000101	309	LHLC	NRHML
0261 000102	310	LHLC	NRHML
0262 000103	311	LHLC	NRHML
0263 000104	312	LHLC	NRHML
0264 000105	313	LHLC	NRHML
0265 000106	314	LHLC	NRHML
0266 000107	315	LHLC	NRHML
0267 000108	316	LHLC	NRHML
0268 000109	317	LHLC	NRHML
0269 000110	318	LHLC	NRHML
0270 000111	319	LHLC	NRHML
0271 000112	320	LHLC	NRHML
0272 000113	321	LHLC	NRHML
0273 000114	322	LHLC	NRHML
0274 000115	323	LHLC	NRHML
0275 000116	324	LHLC	NRHML
0276 000117	325	LHLC	NRHML
0277 000118	326	LHLC	NRHML
0278 000119	327	LHLC	NRHML
0279 000120	328	LHLC	NRHML
0280 000121	329	LHLC	NRHML
0281 000122	330	LHLC	NRHML
0282 000123	331	LHLC	NRHML
0283 000124	332	LHLC	NRHML
0284 000125	333	LHLC	NRHML
0285 000126	334	LHLC	NRHML
0286 000127	335	LHLC	NRHML
0287 000128	336	LHLC	NRHML
0288 000129	337	LHLC	NRHML
0289 000130	338	LHLC	NRHML
0290 000131	339	LHLC	NRHML
0291 000132	340	LHLC	NRHML
0292 000133	341	LHLC	NRHML
0293 000134	342	LHLC	NRHML
0294 000135	343	LHLC	NRHML
0295 000136	344	LHLC	NRHML
0296 000137	345	LHLC	NRHML
0297 000138	346	LHLC	NRHML
0298 000139	347	LHLC	NRHML
0299 000140	348	LHLC	NRHML
0300 000141	349	LHLC	NRHML
0301 000142	350	LHLC	NRHML
0302 000143	351	LHLC	NRHML
0303 000144	352	LHLC	NRHML
0304 000145	353	LHLC	NRHML
0305 000146	354	LHLC	NRHML
0306 000147	355	LHLC	NRHML
0307 000148	356	LHLC	NRHML
0308 000149	357	LHLC	NRHML
0309 000150	358	LHLC	NRHML
0310 000151	359	LHLC	NRHML
0311 000152	360	LHLC	NRHML
0312 000153	361	LHLC	NRHML
0313 000154	362	LHLC	NRHML
0314 000155	363	LHLC	NRHML
0315 000156	364	LHLC	NRHML
0316 000157	365	LHLC	NRHML
0317 000158	366	LHLC	NRHML
0318 000159	367	LHLC	NRHML
0319 000160	368	LHLC	NRHML
0320 000161	369	LHLC	NRHML
0321 000162	370	LHLC	NRHML
0322 000163	371	LHLC	NRHML
0323 000164	372	LHLC	NRHML
0324 000165	373	LHLC	NRHML
0325 000166	374	LHLC	NRHML
0326 000167	375	LHLC	NRHML
0327 000168	376	LHLC	NRHML
0328 000169	377	LHLC	NRHML
0329 000170	378	LHLC	NRHML
0330 000171	379	LHLC	NRHML
0331 000172	380	LHLC	NRHML
0332 000173	381	LHLC	NRHML
0333 000174	382	LHLC	NRHML
0334 000175	383	LHLC	NRHML
0335 000176	384	LHLC	NRHML
0336 000177	385	LHLC	NRHML
0337 000178	386	LHLC	NRHML
0338 000179	387	LHLC	NRHML
0339 000180	388	LHLC	NRHML
0340 000181	389	LHLC	NRHML
0341 000182	390	LHLC	NRHML
0342 000183	391	LHLC	NRHML
0343 000184	392	LHLC	NRHML
0344 000185	393	LHLC	NRHML
0345 000186	394	LHLC	NRHML
0346 000187	395	LHLC	NRHML
0347 000188	396	LHLC	NRHML
0348 000189	397	LHLC	NRHML
0349 000190	398	LHLC	NRHML
0350 000191	399	LHLC	NRHML
0351 000192	400	LHLC	NRHML
0352 000193	401	LHLC	NRHML
0353 000194	402	LHLC	NRHML
0354 000195	403	LHLC	NRHML
0355 000196	404	LHLC	NRHML
0356 000197	405	LHLC	NRHML
0357 000198	406	LHLC	NRHML
0358 000199	407	LHLC	NRHML
0359 000200	408	LHLC	NRHML
0360 000201	409	LHLC	NRHML
0361 000202	410	LHLC	NRHML
0362 000203	411	LHLC	NRHML
0363 000204	412	LHLC	NRHML
0364 000205	413	LHLC	NRHML
0365 000206	414	LHLC	NRHML
0366 000207	415	LHLC	NRHML
0367 000208	416	LHLC	NRHML
0368 000209	417	LHLC	NRHML
0369 000210	418	LHLC	NRHML
0370 000211	419	LHLC	NRHML
0371 000212	420	LHLC	NRHML
0372 000213	421	LHLC	NRHML
0373 000214	422	LHLC	NRHML
0374 000215	423	LHLC	NRHML
0375 000216	424	LHLC	NRHML
0376 000217	425	LHLC	NRHML
0377 000218	426	LHLC	NRHML
0378 000219	427	LHLC	NRHML
0379 000220	428	LHLC	NRHML
0380 000221	429	LHLC	NRHML
0381 000222	430	LHLC	NRHML
0382 000223	431	LHLC	NRHML
0383 000224	432	LHLC	NRHML
0384 000225	433	LHLC	NRHML
0385 000226	434	LHLC	NRHML
0386 000227	435	LHLC	NRHML
0387 000228	436	LHLC	NRHML
0388 000229	437	LHLC	NRHML
0389 000230	438	LHLC	NRHML
0390 000231	439	LHLC	NRHML
0391 000232	440	LHLC	NRHML
0392 000233	441	LHLC	NRHML
0393 000234	442	LHLC	NRHML
0394 000235	443	LHLC	NRHML
0395 000236	444	LHLC	NRHML
0396 000237	445	LHLC	NRHML
0397 000238	446	LHLC	NRHML
0398 000239	447	LHLC	NRHML
0399 000240	448	LHLC	NRHML
0400 000241	449	LHLC	NRHML
0401 000242	450	LHLC	NRHML
0402 000243	451	LHLC	NRHML
0403 000244	452	LHLC	NRHML
0404 000245	453	LHLC	NRHML
0405 000246	454	LHLC	NRHML
0406 000247	455	LHLC	NRHML
0407 000248	456	LHLC	NRHML
0408 000249	457	LHLC	NRHML
0409 000250	458	LHLC	NRHML</


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0248 00      FOR      A
0249 40      MOV      C,A
0250 50      PVI      A,20H
0251 60      RLC
0252 70      LCP
0253 80      JNZ      A,10H
0254 90      STA      RAVGS
0255 A0      CCMPLT
0256 B0      *****
0257 C0      SET LENGTH OF WAVEFORM TO 256,128,64,32, OR 16
0258 D0      *****
0259 E0      CALL      KIN
0260 F0      CPI      5
0261 01      JNC      SIZE00
0262 10      INP      A
0263 20      MOV      C,A
0264 30      XRA      A
0265 40      MVI      RLC
0266 50      RLC
0267 60      USE
0268 70      CNZ
0269 80      ALV
0270 90      ANI      0FH
0271 A0      STA      RPL+1
0272 B0      MOV      A,C
0273 C0      INC      RPL
0274 D0      PUI
0275 E0      STA      RPL
0276 F0      ANI      0FH
0277 01      STA      RPLS
0278 10      JPD      CCMPLT
0279 20      *****
0280 30      INITIATE RECORDING WITH ANTENNA HANDLE PUSHBUTTON
0281 40      *****
0282 50      IN      RPLST
0283 60      ANI      0FH
0284 70      C7
0285 80      IC
0286 90      ANI      0FH
0287 A0      JZ
0288 B0      CALL
0289 C0      KIN
0290 D0      RPLST
0291 E0      RPLST
0292 F0      RPLST
0293 01      RPLST
0294 10      RPLST
0295 20      RPLST
0296 30      RPLST
0297 40      RPLST
0298 50      RPLST
0299 60      RPLST
0300 70      RPLST
0301 80      RPLST
0302 90      RPLST
0303 A0      RPLST
0304 B0      RPLST
0305 C0      RPLST
0306 D0      RPLST
0307 E0      RPLST
0308 F0      RPLST
0309 01      RPLST
0310 10      RPLST
0311 20      RPLST
0312 30      RPLST
0313 40      RPLST
0314 50      RPLST
0315 60      RPLST
0316 70      RPLST
0317 80      RPLST
0318 90      RPLST
0319 A0      RPLST
0320 B0      RPLST
0321 C0      RPLST
0322 D0      RPLST
0323 E0      RPLST
0324 F0      RPLST
0325 01      RPLST
0326 10      RPLST
0327 20      RPLST
0328 30      RPLST
0329 40      RPLST
0330 50      RPLST
0331 60      RPLST
0332 70      RPLST
0333 80      RPLST
0334 90      RPLST
0335 A0      RPLST
0336 B0      RPLST
0337 C0      RPLST
0338 D0      RPLST
0339 E0      RPLST
0340 F0      RPLST
0341 01      RPLST
0342 10      RPLST
0343 20      RPLST
0344 30      RPLST
0345 40      RPLST
0346 50      RPLST
0347 60      RPLST
0348 70      RPLST
0349 80      RPLST
0350 90      RPLST
0351 A0      RPLST
0352 B0      RPLST
0353 C0      RPLST
0354 D0      RPLST
0355 E0      RPLST
0356 F0      RPLST
0357 01      RPLST
0358 10      RPLST
0359 20      RPLST
0360 30      RPLST
0361 40      RPLST
0362 50      RPLST
0363 60      RPLST
0364 70      RPLST
0365 80      RPLST
0366 90      RPLST
0367 A0      RPLST
0368 B0      RPLST
0369 C0      RPLST
0370 D0      RPLST
0371 E0      RPLST
0372 F0      RPLST
0373 01      RPLST
0374 10      RPLST
0375 20      RPLST
0376 30      RPLST
0377 40      RPLST
0378 50      RPLST
0379 60      RPLST
0380 70      RPLST
0381 80      RPLST
0382 90      RPLST
0383 A0      RPLST
0384 B0      RPLST
0385 C0      RPLST
0386 D0      RPLST
0387 E0      RPLST
0388 F0      RPLST
0389 01      RPLST
0390 10      RPLST
0391 20      RPLST
0392 30      RPLST
0393 40      RPLST
0394 50      RPLST
0395 60      RPLST
0396 70      RPLST
0397 80      RPLST
0398 90      RPLST
0399 A0      RPLST
0400 B0      RPLST
0401 C0      RPLST
0402 D0      RPLST
0403 E0      RPLST
0404 F0      RPLST
0405 01      RPLST
0406 10      RPLST
0407 20      RPLST
0408 30      RPLST
0409 40      RPLST
0410 50      RPLST
0411 60      RPLST
0412 70      RPLST
0413 80      RPLST
0414 90      RPLST
0415 A0      RPLST
0416 B0      RPLST
0417 C0      RPLST
0418 D0      RPLST
0419 E0      RPLST
0420 F0      RPLST
0421 01      RPLST
0422 10      RPLST
0423 20      RPLST
0424 30      RPLST
0425 40      RPLST
0426 50      RPLST
0427 60      RPLST
0428 70      RPLST
0429 80      RPLST
0430 90      RPLST
0431 A0      RPLST
0432 B0      RPLST
0433 C0      RPLST
0434 D0      RPLST
0435 E0      RPLST
0436 F0      RPLST
0437 01      RPLST
0438 10      RPLST
0439 20      RPLST
0440 30      RPLST
0441 40      RPLST
0442 50      RPLST
0443 60      RPLST
0444 70      RPLST
0445 80      RPLST
0446 90      RPLST
0447 A0      RPLST
0448 B0      RPLST
0449 C0      RPLST
0450 D0      RPLST
0451 E0      RPLST
0452 F0      RPLST
0453 01      RPLST
0454 10      RPLST
0455 20      RPLST
0456 30      RPLST
0457 40      RPLST
0458 50      RPLST
0459 60      RPLST
0460 70      RPLST
0461 80      RPLST
0462 90      RPLST
0463 A0      RPLST
0464 B0      RPLST
0465 C0      RPLST
0466 D0      RPLST
0467 E0      RPLST
0468 F0      RPLST
0469 01      RPLST
0470 10      RPLST
0471 20      RPLST
0472 30      RPLST
0473 40      RPLST
0474 50      RPLST
0475 60      RPLST
0476 70      RPLST
0477 80      RPLST
0478 90      RPLST
0479 A0      RPLST
0480 B0      RPLST
0481 C0      RPLST
0482 D0      RPLST
0483 E0      RPLST
0484 F0      RPLST
0485 01      RPLST
0486 10      RPLST
0487 20      RPLST
0488 30      RPLST
0489 40      RPLST
0490 50      RPLST
0491 60      RPLST
0492 70      RPLST
0493 80      RPLST
0494 90      RPLST
0495 A0      RPLST
0496 B0      RPLST
0497 C0      RPLST
0498 D0      RPLST
0499 E0      RPLST
0500 F0      RPLST
0501 01      RPLST
0502 10      RPLST
0503 20      RPLST
0504 30      RPLST
0505 40      RPLST
0506 50      RPLST
0507 60      RPLST
0508 70      RPLST
0509 80      RPLST
0510 90      RPLST
0511 A0      RPLST
0512 B0      RPLST
0513 C0      RPLST
0514 D0      RPLST
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0999 20      RPLST

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0200 0000	435	ADJ	CFR	
0201 0001	440	OUT	DISPLY	:WRITE THE ORDER DIGIT
0202 0002	441	RET		
0203 0003	442			
0204 0004	443			
0205 0005	444			
0206 0006	445			
0207 0007	446			
0208 0008	447			
0209 0009	448			
0210 0010	449			
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0212 0012	451			
0213 0013	452			
0214 0014	453			
0215 0015	454			
0216 0016	455			
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0218 0018	457			
0219 0019	458			
0220 0020	459			
0221 0021	460			
0222 0022	461			
0223 0023	462			
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0225 0025	464			
0226 0026	465			
0227 0027	466			
0228 0028	467			
0229 0029	468			
0230 0030	469			
0231 0031	470			
0232 0032	471			
0233 0033	472			
0234 0034	473			
0235 0035	474			
0236 0036	475			
0237 0037	476			
0238 0038	477			
0239 0039	478			
0240 0040	479			
0241 0041	480			
0242 0042	481			
0243 0043	482			
0244 0044	483			
0245 0045	484			
0246 0046	485			
0247 0047	486			
0248 0048	487			
0249 0049	488			
0250 0050	489			
0251 0051	490			
0252 0052	491			
0253 0053	492			
0254 0054	493			
0255 0055	494			
0256 0056	495			
0257 0057	496			
0258 0058	497			
0259 0059	498			
0260 0060	499			
0261 0061	500			
0262 0062	501			
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0265 0065	504			
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0274 0074	513			
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0279 0079	518			
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0284 0084	523			
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0287 0087	526			
0288 0088	527			
0289 0089	528			
0290 0090	529			
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0293 0093	532			
0294 0094	533			
0295 0095	534			
0296 0096	535			
0297 0097	536			
0298 0098	537			
0299 0099	538			
0300 0100	539			
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0463 0263	702			
0464 0264	703			
0465 0265	704			
0466 0266	705			
0467 0267	706			

LINE	ADDRESS	INSTR	OPER	DATA	PC	PSW	STATUS	REMARKS
460	0000	RET						
461	0001	;						
462	0002	;						
463	0003	;						
464	0004	REFRAN:	MOV					
465	0005	CALL						
466	0006	REFRAN:	MOV					
467	0007	CALL						
468	0008	REFRAN:	MOV					
469	0009	CALL						
470	0010	REFRAN:	MOV					
471	0011	CALL						
472	0012	REFRAN:	MOV					
473	0013	CALL						
474	0014	REFRAN:	MOV					
475	0015	CALL						
476	0016	REFRAN:	MOV					
477	0017	CALL						
478	0018	REFRAN:	MOV					
479	0019	CALL						
480	0020	REFRAN:	MOV					
481	0021	CALL						
482	0022	REFRAN:	MOV					
483	0023	CALL						
484	0024	REFRAN:	MOV					
485	0025	CALL						
486	0026	REFRAN:	MOV					
487	0027	CALL						
488	0028	REFRAN:	MOV					
489	0029	CALL						
490	0030	REFRAN:	MOV					
491	0031	CALL						
492	0032	REFRAN:	MOV					
493	0033	CALL						
494	0034	REFRAN:	MOV					
495	0035	CALL						
496	0036	REFRAN:	MOV					
497	0037	CALL						
498	0038	REFRAN:	MOV					
499	0039	CALL						
500	0040	REFRAN:	MOV					
501	0041	CALL						

0335 07	MOV	H0A	
0336 70	MOV	A0L	
0337 10	MAP		
0338 0F	MOV	L0A	
0339 00	UCH	C	
033A 003200	UNZ	PLSHR	
033B 00	RET		
ROUTINE ADDS CONTENTS OF HL TO CHKSUM			
033C 07	ACRG		
033D 05	PUSH	H	
033E 2A0010	LPH	CHKSUM	
033F 10	JAN	C	
0340 220010	SHLN	CHKSUM	
0341 01	POP	H	
0342 00	ACRG		
0343 00	RET		
0344 00	NEGATE H0L REGISTER		
0345 70	MOV	A0H	
0346 2F	CPA		
0347 07	MOV	H0A	
0348 70	MOV	A0L	
0349 2F	CPA		
034A 0F	MOV	L0A	
034B 2A	INX	H	
034C 00	RET		
034D 00	MVI	A0CLR7	
034E 14EF	OUT	DAICNT	:SET OFF ALARM UNTIL :ALL 'E' IS PRESSED.
034F 000F	IN	WUNTR	:KEY PRESSED LATELY?
0350 1600	ANI	WUNTR	
0351 005000	JZ	TPUMP1	:IF TO CONTINUE ALARM.
0352 000000	CALL	WIN	
0353 000000	CPI	REN	
0354 000000	JNZ	TPUMP1	

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0427	200015	056		LMC	ENDITE	IF HAVE REACHED THE
0428	10	064		CAP	0	END OF THE DATA YET?
0429	E1	067		POP	0	
042C	060000	068		JC	TPCHRO	KEEP GOING IF NOT
042F	010000	070		LXI	H00000	
0432	220010	071		SHLO	STARTR	RESET STORAGE POINTER
0435	000000	072		UEP	CLDIP	
		073	:			
		074	:			
		075	:			
		076		ORG	1000F	REG. OF ONBOARD RAM
1500		077	STARTR: US	2		
1501		078	ORHIF: US	2		
1502		079	ENDIR: US	2		
1503		080	AVG: US	2		
1504		081	KRPSIN: US	1		
1505		082	NPTS: US	2		
1506		083	AVGS: US	1		
1507		084	SYSFLG: US	1		
1508		085	SGMU: US	1		
1509		086	CHKSUM: US	2		
1510		087	SEGMU: US	1		
1511		088	NPT: US	2		
1512		089	AVG: US	1		
1513		090	AVG: US	2		
1514		091	IFFAK: US	1		
1515		092	ITIME: US	1		
1516		093	TPKNEB: US	1		
1517		094	TIMEB: US	1		
		095	:	STACK AREA		
151A		096	SPN: US	STARTA		
		097	:	BEGINNING OF DATA BUFFER		
2000		098	ORG	2000F		
0000		099	ORUPU: START			
		700				

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