Computerized Pavement Condition Survey Unit

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16. Abstract

A computerized field pavement condition survey unit and an IBM PC/XT computer base office reader and analysis system were developed for use in the pavement management program used by WSDOT.

The pavement condition recording and computing device is a microprocessor controlled, data acquisition and reduction system which uses a combination of manual inputs and odometer readings to develop pavement condition reports. These reports are printed on the system printer and written to a standard compact magnetic tape cartridge along with the raw data for later inclusion in the Washington State Department of Transportation's pavement management data base.

The device, including all of its attendant equipment, is fully portable so that it may be used in any motor vehicle that has an odometer pulse generator (preferably producing approximately 4,000 TTL level counts per mile) and 12 Vdc power source.

The office system consists of an IBM PC/XT or AT microcomputer with a printer and a 20 megabyte cartridge tape drive. It also has the software needed to read preview, analyze and convert the data for direct entry into WSDOT's pavement management system.

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COMPUTERIZED PAVEMENT CONDITION SURVEY UNIT

by
Derald Christensen
Danny R. Haase
Senaka C.B. Ratnayake
Donald J. Hacherl

Washington State Transportation Center
Department of Civil Engineering
University of Washington
Seattle, WA

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Abstract

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The device, including all of its attendant equipment, is fully portable so that it may be used in any motor vehicle that has an odometer pulse generator (preferably producing approximately 4,000 TTL level counts per mile) and 12 Vdc power source.

The office system consists of an IBM PC/XT microcomputer with a printer and a 20 Megabyte cartridge tape drive. It also has the software needed to read, preview, analyze and convert the data for direct entry into WSDOT's pavement management system.

The overall system performed as designed. The time required to collect the surface condition data took longer than initially

expected but time and user familiarity appears to improve on this. However, it was still faster than the original manual technique. The office system proved to be the best time saver and also greatly improved data access and accuracy.

Introduction

The time allotted for obtaining pavement condition ratings and to integrate these into a prioritized rehabilitation program for a given road system can be substantially reduced through improved data collection techniques. To gather, record, and process the field data more efficiently, it was necessary to develop a system that would speed up the field data collection process and eliminate the handwritten field coding and office hand entry of the data and allow direct input of the data into the main computer.

To accomplish this, the University of Washington developed and built a portable pavement rating device and provided WSDOT with the prototype. Correlation and operational tests of the prototype were conducted by WSDOT personnel to check operator usability and computer compatibility. These tests were performed by completing actual pavement condition surveys using the current method and the new method of survey. A high degree of correlation was found. The raters became proficient with the new technique of rating rather quickly. Computer compatibility was tested with the application of real data to the main computer and checking the usability of the data within the pavement management system computer programs.

Summary

The original objective was to develop a computerized field and office pavement condition survey system that would both increase data collection speeds and accuracy, and enhance the data analysis and transfer phases. This goal was accomplished with minimal technical problems.

The major benefits associated with the development of this hardware are the increase in speed or time savings in collecting the field data, the improved accuracy and resolution of the data and the enhancement to the office system as related to increased turn around, and data access.

Conclusions

The development of the prototype system was successful and was accomplished with virtually no conceptual or initial design related difficulties. Both the initial time and fund allotments were under estimated, however.

The unit performed well in the field, but the overall time savings in collecting the pavement condition data, even though improved, fell below expectations. Also, the data collected, in general appears to predict a more severe or worse condition than conventional methods. These results are to be expected, do mainly to the fact that a much more detailed survey with a higher degree of accuracy is being taken.

The office system showed the most improvement in overall system performance as related to previous methods of handling the data. The new office system also allowed a much more detailed look at the data and at exactly where in the road each defect or other flagged item was located. This can be an extremely useful tool in setting exact project limits or for assigning repair crew efforts.

Recommendations

A larger hard disk drive maybe required to handle the large amounts of data that are to be collected. Either a single drive with one hundred plus megabytes or a dual 20 megabyte removable hard disk drive is recommended.

Two additional accessories, which are relatively inexpensive but are necessary for doing extensive data analysis are a BASIC complier and an 8087 math co-processor. These two items will increase the computers performance and will decrease the time required to read and analyze the data.

In the development of this system there were approximately 3500 lines of computer code developed. Over 2700 of these were in the field survey unit and were written in assembly code. The accepted industry figure for estimating programming costs is 8 lines of debugged and documented computer code per day. This works out to be just under 20 man months of program software development for this project alone. In future research efforts of this type, this fact should be taken into consideration.

Pavement Survey Hardware System

Field Survey System

General

The field survey system consists of a microprocessor control unit, a 20 Megabyte cartridge tape drive, a printer, hand terminal and a data entry keyboard. These items are tied together into a single integrated data collection system. (See Figure 2,3,4 & 5).

The operation of the field unit is controlled through the hand terminal and a series of menu items. The hand terminal is limited to four lines of sixteen characters each and thus leads to some nesting of the different menu lists and items (See Figure 1). However, the hand terminal is only required during initial set up procedures under most circumstances and thus lends itself well to this type of control.

Alphanumeric data can also be entered into the unit during or between runs. This is a little cumbersome with this type of terminal but is still practical. Any type of ASCII terminal or portable microcomputer unit could be adapted for use with the field unit if large amounts of alphanumeric data are required. Each interval (usually 0.1 miles) can contain up to 300 bytes (ASCII characters) of alphanumeric information, in addition to the surface condition data. This is about 19 lines of text on the hand terminal.

The operation of the field pavement survey unit is as follows. The power is turned on once all leads have been

installed. The control is automatically switched to the hand terminal and the initial menu is displayed on the LCD screen (See Figure 1). The set up data is entered and the system is initiated by pressing the START and ENTER keys. The unit will begin collecting data when the vehicle reaches the BEGIN MILE or immediately if the BEGIN MILE and the ODOMETER are set to the same value. The BEGIN MILE, END MILE and the ODOMETER readings will be displayed continuously on the hand terminal once the system is initiated.

The system is connected directly to the vehicles odometer output, which is its primary control signal. Once the unit begins to collect data a red LED will flash on the face of the keyboard (See Figure 2). The unit will automatically sample all of the keys on the keyboard (except the five left most CONTROL KEYS) and store the status of each key on tape at the rate or spacing specified during the set up procedure (samples per interval, See Figure 1).

The data sequence is defined as the distance between the BEGIN and END MILE marks. The begin mile - end mile sequence is then divided into intervals, which are usually selected to be one tenth of a mile. Associated with each interval is a 300 byte alphanumeric data storage area on the tape. Up to the 300 bytes of data can be entered at the beginning of each sequence or at any one of the intervals within the sequence. To enter alphanumeric data at an interval break, the vehicle must be stopped and the PAUSE and ENTER keys must be pressed on the

CONTROL KEYS section of the keyboard. A menu will appear instructing the operator to press F1 to enter the information. When completed the menu will direct the operator to push the F2 key to begin normal operation again(See Figure 1).

The vehicle speed that can be obtained while still collecting valid data is dependent on the number of samples per interval and the interval length as selected in the initial parameter set up. Under normal or default operations there is no real limitation, that is, the maximum speed is in excess of 50 mph.

The use of the printer at present requires that the vehicle come to a stop at the end of each interval to eliminate any or all data loss. The system still functions properly if not stopped, however, a number of samples will be lost at the beginning of each interval. Future modifications will eliminate this by putting a buffer on the printer.

Microcomputer Control Unit

This is the main component and consists of a microprocessor-based control unit with power supply, input digital signal capability and input/output communication ports. A control rating panel (CRP), a hand terminal, remote transcrack unit, a tape drive and a printer are all connected into this unit. This complete system is housed inside a water resistant Zero case and is completely portable.

Control Rating Panel - Keyboard

The rating portion of the CRP regulates the monitoring of the pavement defect data. The CRP maintains a running evaluation of the pavement condition. The microprocessor control unit then samples (scans) these inputs at a fixed distance interval (approximately 4,000 scans per mile maximum or any even integer division thereof) and records this raw information along with the accumulations and any desired alphanumeric text on the magnetic tape cartridge. The terminal also displays the BEGIN MILE, END MILE and the ODOMETER READING, while data is being collected.

Control Keys

The starting sequence will allow the automatic initiation of a test run. The odometer must be set to a known milepost prior to the start of the test run. When the odometer is incremented or decremented to the starting mile value, data collection automatically begins. The BEGIN MILE is always numerically less than the END MILE. In the decrementing direction, the value keyed in as END MILE will start the data collection. Auto start cannot be modified while collecting data, but it can be deactivated by pressing the STOP plus the ENTER key on the CRP.

A plus or minus sign in front of the interval value will select whether the odometer will increment with distance or decrement. When in the decrement mode, the END MILE value is considered the start of the measuring sequence and the BEGIN MILE the finish. BEGIN MILE must always be numerically less than END

MILE.

The BST/ACP key (push-on-push-off) records the pavement type as ACP when not activated (light off) and BST when activated (light on).

The STOP key followed by the ENTER key (momentary contact) will halt data collection, terminate the run, and print out and record the accumulated data.

The PAV'T EXEMPT key (push-on-push-off) halts data collection while activated (light on) and resumes data collection when deactivated (light off). The odometer continues working through this phase and results in a normal run with fewer samples for that particular interval. This is used to exclude unwanted roadway sections such as bridge decks. The PAV EXMT and the BST/ACP keys are both turned off either by pressing the key again or when the computer resets the CRP at start up.

The END OF FILE key places an end of file mark (EOF) on the tape each time this key and the ENTER key is pushed. This is used for tape control. If problems occur a double EOF on the tape will allow the repositioning of the tape back to this position.

The PAUSE key will return the menu control back to the operator and allow for parameter modification, updating, report generation, addition of comments to that tape interval and system restart.

The STOP, PAUSE, and START keys are tied together so that

only one of these keys will be on at a time. The only way to turn off any one of these keys is to press one of the others or when the computer resets the CRP. When any of these keys are pressed the ENTER key will light up to remind the operator to press ENTER. This must be done before the actual function is performed by the microprocessor unit.

The EOF (End of File) key is a push-on-push-off key which will also light the ENTER key. The ENTER key is to get the computers attention so that if the EOF, STOP, PAUSE, or START keys were pressed by accident, the operator could change the situation before the computer reacted. If the EOF was pressed by accident, pressing it again will turn it off, the ENTER key will stay on but pressing it will only turn the light off. After the computer has recognized the ENTER key and the key which turned it on, the computer will toggle the Ent. STRB line which will turn off the ENTER key light and the EOF if it was pressed. The computer will not turn the STOP, PAUSE, or START lights off, however, so that the operator will know which mode the system is in at all times. The PAV EXMT. and the BST/ACP keys will not affect the ENTER key.

Special Function Keys

The special function keys are user definable keys and can be used for anything the operator wishes. To use these keys the operator simply defines what they are to be used for in the comment section and proceeds as defined. The first two keys (F1 & F2) are push-on-push-off keys, that is, their status is

recorded to tape continuously whether on or off.The last Three (F3, F4, & F5) are momentary-on keys and are used for counting items such as pot holes or for flagging purposes.

The F3, F4, and F5 keys will stay on until the computer reads them, after which the computer will toggle the M STRB line which will turn them off. This assures the operator that the data has been read. If the vehicle stops in the middle of a sequence and one of these three keys are pressed, they will stay on until the vehicle moves forward enough for the system to take another sample of the keyboard. When the vehicle is moving at reasonable speed, this interaction between the keys and the computer will be such that the keys will appear to be momentary switches. The transcrack keys function in the same manner.

Control Rating Keys

The rating portion of the CRP is divided into four distinct, visually separated, rating categories. The categories are laid out from left to right as follows: Alligator cracking, longitudinal cracking, transverse cracking, patching, and raveling or flushing.

The four "CLR" buttons are used to clear or deactivate any defect keys that are in the active status, but will not erase any of the accumulated data in the memory registers. All keys have LED lights in them to indicate active status ("on"). The CLR key will light if an invalid selection has been made in that category.

The CRP is scanned and data stored to tape and accumulated in memory at up to the odometer factor rate per mile. This depends on the input variables, samples per interval and interval length. The BEGIN MILE - END MILE sequence is separated into intervals of any desired length.

The keyboard (CRP) contains three printed circuit boards (PCB's), a housing and a front panel with keys (See Figures 2, 6 - 9 & 12 - 15). The top PCB supports only the switches (keys) and the LEDs (Light Emitting Diodes) for the individual keys. The second board consists of two parts. The main part is the circuitry which handles the switch debounce for the data switches and the LED drivers. The second part is the circuitry for the control switches. This includes the logic circuitry for these switches. The third board consists of the logic circuitry for the data switches and the buffers for the signals going to and coming from the microprocessor control unit.

Each key has its own set of logic circuitry consisting of a flip-flop and a delay buffer (see figures 15 and 16). Through jumpers on the board the switch can be made to function as a momentary push-on, a momentary push-on with computer reset, or a push-on-push-off type switch. Each switch can be set or reset by the computer (all keys at once) and can be cleared by any selected clear key or the pressing of another data key in the section.

A hand held rating device is included for the counting of transverse cracks by the driver. The device is identical to the

"TRANS CRACK" section on the keyboard and is connected to the main panel through a front panel connector and a six foot long expandable cord.

Control Rating Panel Defect Categories

The ALLIGATOR CRACKING and the LONGITUDINAL CRACKING categories each have five keys. At least one key must be activated in either category to indicate a defect. Two keys can be activated at the same time under alligator or longitudinal cracking to indicate defects in each wheel path. Under longitudinal cracking, any combination of these keys can occur because of multiple cracks. If the "+1" key is pushed, it will duplicate the greatest severity that is active in that category. Activating the "+1" key under alligator cracking indicates two simultaneous defects at the same severity as the key activated in the left hand column. Each time the computer scans the panel, it records the active condition shown on the panel; one count per activity. If the "+1" is active, then the most severe condition indicated gets two counts.

All these keys are push-on-push-off keys (except for the CLR keys). When the CLR key is pressed, all the keys in its category will turn off. If the +1 is pressed by itself or if the HL, >1/4, and the SP are all on at the same time, the CLR key will light up to indicate that this is an invalid situation. Pressing the unwanted key again or the CLR key will remedy the situation.

The severity (S), extent (E) and deduct value (D) are calculated as follows:

Alligator Cracking Formulas

$$S_{AC} = \frac{C_1 + 2C_2 + 3C_3}{C_1 + C_2 + C_3}$$ (Round to nearest 10th)

$$E_{AC} = \frac{2(C_1 + C_2 + C_3) + 1}{N_s}$$ (rounded to nearest 10th after checking E for limits)

$$D_{AC} = 15(S_{AC}-1) + 10(E_{AC}-1) + 10 \quad \text{(Deduct)}$$

$$= 5(3S_{AC} + 2E_{AC}-3)$$

C_1 = counts of "HL" (hairline) severity in each wheel path

C_2 = counts of ">1/4" (over 1/4") severity in each wheel path

C_3 = counts of "SP" (spalling) severity in each wheel path

N_s = Number of times panel scanned in rated length

If $C_1 + C_2 + C = 0$, then print "(0.0, 0.0)"

If $E<1.03$, then print "(0.0, 0.0)"

If $E>4.0$, then $E = 4.0$

Longitudinal Cracking

$$S_{LC} = \frac{C_1 + 2C_2 + 3C_3}{C_1 + C_2 + C_3}$$ (Round to nearest 10th)

$$E_{LC} = \frac{C_1 + C_2 + C_3 + 1}{N_s}$$ (round to nearest 10th after checking $E<1.10$)

$$D_{LC} = 10[(S_{LC}-1)+(E_{LC}-1)] + 5$$

$$= 10(S_{LC} + E_{LC}) - 15$$

C_1 = Counts of "HL" severity along 1 or more cracks

C_2 = Counts of ">1/4" severity along 1 or more cracks

C_3 = Counts of "SP" severity along 1 or more cracks

N_s = Number of times panel scanned in rated length

If $C_1 + C_2 + C_3 = 0$, then print "(0.0, 0.0)"

If $E<1.01$, then print "(0.0, 0.0)"

Each crack is counted separately.

The TRANSVERSE CRACKING category has three keys. Each push of a key will count one in the computer at that particular severity. The computer will only scan this category for severity and the data is sent directly to the computer as it is counted.

All these keys are push-on-stay-on keys with computer reset. They are tied together so that only one can be on at a time and it will stay on until the computer reads it and shuts it off. They are, therefore, used to count individual cracks.

The severity (S_{TC}), extent (E_{TC}) and deduct value (D) are calculated as follows:

$$S_{TC} = \frac{N_1 + 2N_2 + 3N_3}{N_1 + N_2 + N_3} \quad \text{(round to nearest 10th)}$$

22N (round to nearest 10th after checking

$$E_{TC} = 0.78 + \frac{\quad}{L} \quad \text{for } E<1.00)$$

$$D_{TC} = 5[(S_{TC}-1) + (E_{TC}-1) + 1] \quad \text{(Deduct)}$$

$$= 5(S_{TC} + E_{TC} - 1)$$

$N = N_1 + N_2 + N_3$

N_1 = Number of "HL" cracks

N_2 = Number of ">1/4" cracks

N_3 = Number of "SP" cracks

If E>3.0, then make E = 3.0

If E<1.00, then print "(0.0, 0.0)"

L = length of section in <u>feet.</u>

The PATCHING category has seven keys. The left column is used to measure extent when combined with distance and the right column is for severity. In each column, not more than one key can be active at one time. If another key is pushed when one is already active, the new one will then become active and cancel the other.

At present the F1 key is being used to indicate full depth patching and operates independently from the other keys in this category (This will be changed in future units). If a key is pressed in one column but not pressed in the other, the CLR key will light up to indicate that this is an invalid situation. Pressing a key in the other column or the CLR key will remedy this situation.

The severity (S_{PA}), extent (E_{PA}) and deduct value (D) are

calculated as follows:

$$S_{PA} = \frac{B + 2A + 3A'}{B + A + A'} \quad \text{(round to nearest 10th)}$$

$$E_{PA} = 0.92 + \frac{2.08\ (B + A)}{N_s} \quad \text{(round to nearest 10th after checking for } E<1.00\text{)}$$

$$D_{PA} = 10[(S_{PA}-1) + (E_{PA}-1) + 1] \quad \text{(deduct)}$$

$$= 10(S_{PA} + E_{PA} - 1)$$

$B = C_{B1/4} + 2C_{B1/2} + 3C_{B3/4} + 4C_{BF}$

$A = C_{A1/4} + 2C_{A1/2} + 3C_{A3/4} + 4C_{AF}$

$A' = C_{A'1/4} + 2C_{A'1/2} + 3C_{A'3/4} + 4C_{A'F}$

$C_{B1/4}$ = Counts for 1/4 la1/4 lane BST patching

C_X = counts if activated button when scanned N_s times

N_s = Numbers of times scanned in

B = BST, A = ACP, A'= ACP(full depth), F = Full width

y = portion of lane width

C = Accumulated counts

If E>3.0, then make E = 3.0

If E<1.00, then print "(0.0, 0.0)"

If B+A = 0, then print "(0.0, 0.0)"

The RAVELING or FLUSHING category has nine keys. The left column defines the defect, the middle the severity, and the right the extent. In each column, not more than one key can be active

at any one time. If another key is pushed when one is already active, the new one will then become active and cancel the other. If there is a key pressed in one or two columns but not all three, the CLR key will light to show that this is an invalid condition. Pressing a key in each column or pressing the CLR key well remedy this situation.

The severity (S), and extent (E) are calculated as follows:

$$S_{RA} = \frac{SR_1 + 2SR_2 + 3SR_3}{N_s} \quad \text{(round to nearest 10th)}$$

$$S_{FL} = \frac{SF_1 + 2SF_2 + 3SF_3}{N_s}$$

$$E_{RA} = \frac{ER_1 + 2ER_2 + 3ER_3}{N_s} \quad \text{(round to nearest 10th)}$$

$$E_{FL} = \frac{EF_1 + 2EF_2 + 3EF_3}{N_s}$$

$SF_1 = SR_1$ = Accumulated counts at "slight" severity

$SF_2 = SR_2$ = Accumulated counts at "moderate" severity

$SF_3 = SR_3$ = Accumulated counts at severe" severity

N_s = Number of times scanned in rated length

$EF_1 = ER_1$ = Accumulated counts at "localized" extent

$EF_2 = ER_2$ = Accumulated counts at "wheel path" extent

$EF_3 = ER_3$ = Accumulated counts at "entire lane" extent

Hand Terminal

The hand terminal is a full ASCII terminal (regular computer terminal) except it is limited to four lines of sixteen characters each. It also has four programable special function keys, which are used extensively for program control. The acronym above each key or the F1, F2, F3, or F4 specification in the menu text defines there individual functions.

Menu Variables

The control portion of the system allows input of project data as well ata as well as controlling the sequencing of a test. This control function is performed by using the hand held terminal with menu driven data input and the control key functions on the CRP.

The following is a description of the individual variables that are entered from the hand terminal (See Figure 1).

1. SYSTEM CD/REC:

   This is a user definable input and is meant for sequence identification purposes.

2. TEAM INITIALS:

   Two sets of two alpha-values are provided for entering two raters intials.

3. DATE: Month-day-year (00-00-00).

4. CURRENT TIME: - 24 Hour clock

5. DISTRICT/SIGN ROUTE/FUNCTIONAL CLASS:

   District = one digit, sign route = up to three digits, functional class = one digit (0-000-0).

6. CONTROL SECTION/CONTROL SECTION SEQUENCE:

   Control section = four digits, control section sequence = three digits (0000- 000).

7. LANE: Both = 1, right = 2, left = 3 (0).

8. ODOMETER FACTOR:

   This is the number of counts per mile generated by the odometer.

9. ODOMETER READING:

   The current odometer reading is displayed on the hand terminal while data is being collected and is entered manually.

10. BEGIN MILE:

    Normal operation will trigger data collection at this preset mileage if the direction is incrementing; data collection will end at this mileage if the direction is decrementing.

11. END MILE:

    Data collection will automatically end at this preset mileage and record the data to tape. If the printer option is active a report is generated. Normal operation will trigger data collection at this preset mileage if the

direction is decrementing.

12. INTERVAL:

A preset distance interval at which the system will automatically terminate the accumulations and record the accumulated information to tape. If the print option is on a summary report is generated. Also a plus or minus sign in front of this variable controls whether the counting is incremented of decremented.

13. SAMPLES/INTERVAL:

This defines the resolution between samples.

14. PRINTER ON/OFF:

Activates or deactivates the printer option.

All of the above items are held in the memory after entry. The memory items are held until erased or modified. This part of the memory is non-volatile and will not be altered by unplugging or turning the unit off and on.

Tape Cartridge Drive

Most of cartridge tape control is handled automatically by the system software. The tape cartridge is rewound upon insertion (if the power is on) and positioned at the beginning of tape and on track one or it can be allowed to continue from the current tape position (the operator must be aware of which track he is on and set the system to the proper track if necessary). Also the tape can be positioned at a double end of file mark which is

automatically placed at the end of a tape if and when a data collection sequence has been completed or the system has been shut down. Also, the operator can place a double end of file on the tape using the keyboard. This is used for limited tape control. This will also allow for more efficient use of individual tapes. A software tape reset feature is also provided to reinitialize a new tape when first starting a sequence of measurements. The filling of a tape with data or the removal of a tape sounds an audible alarm and initiates a menu sequence on the hand terminal. This allows for efficient tape management and control.

The tape drive is used for storing both the raw data and information which is important for keeping track of the data. When the system is first turned on the computer will set up the tape control card (See Figure 5) for proper parity and bit count. Then the system will check the tape drive for its present status to verify that proper communications have been set up. If a status byte is not received the system will send the message "PLEASE TOGGLE THE POWER" to the hand terminal. After the parameters have been entered and the tape has been positioned to where the operator wishes, and the START button has been pushed, the system will write a 512 byte record at the beginning ot the tape called the Sequence Header. This information is used to identify one sequence from another and is in the following format:

STARTING BYTE #	NO.of BYTES	DESCRIPTION
0	8	ASCII word "HEADER ". Used for locating the Sequence Header when reading the tape.
8	2	Zeros
10	1	The calculated number of records needed for one interval.
11	5	Zeros
16	4	ASCII System Code and Record
20	4	ASCII Team Letters
24	6	ASCII Date (Month/Day/Year)
30	6	ASCII Time (Hours/Minutes/Seconds)
36	1	ASCII District
37	3	ASCII State Route
40	1	ASCII Functional Class
41	4	ASCII Control Section
45	3	ASCII Control sequence
48	1	ASCII Lane
49	4	Odometer Reading *
53	5	Length of interval, the first byte is going to be either an ASCII "+" or "-". *
58	4	Odometer Factor *
62	4	Begin Mile *
66	4	End Mile *
70	40	Zeros
110	2	Number of samples per interval
112	4	Zeros
116	8	ASCII word "COMMENT "
124	300	Comment Buffer
424	88	Accumulations

* A hexadecimal number represented as hh.hh . Where hh is a two byte hex number representing either the integer number or the decimal number in 10 thousandths. Ex 10.20 would represent the decimal number 256.512 .

As the system collects data it writes it to the tape drive in 512 byte records. At the end of every interval (defined by the operator) the system will fill the remaining part of the current record with zeros. If there are less records than the calculated number of records per interval, the system will write blank records to the tape until there are enough records. This condition would result from extensive use of the pavement exempt key.

The system is now ready to write the Interval Summary record. The format is very similar to the Sequence Header and is as follows:

STARTING BYTE #	NO.of BYTES	DESCRIPTION
0	8	ASCII word "SUMMARY ".
8	2	Interval Sequence Number
10	1	The calculated number of records needed for one interval.
11	5	Zeros
16	4	ASCII System Code and Record
20	4	ASCII Team Letters
24	6	ASCII Date (Month/Day/Year)
30	6	ASCII Time (Hours/Minutes/Seconds)
36	1	ASCII District
37	3	ASCII State Route
40	1	ASCII Functional Class
41	4	ASCII Control Section
45	3	ASCII Control Sequence
48	1	ASCII Lane
49	4	Odometer Reading *
53	5	Length of interval, the first byte is going to be either an ASCII "+" or "-". *
58	4	Odometer Factor *
62	4	Begin Mile *
66	4	End Mile *
70	2	Alligator Crack Severity **
72	2	Alligator Crack Extent **
74	2	Longitudinal Crack Severity **
76	2	Longitudinal Crack Extent **
78	4	Zeros
82	2	Patching Severity **
84	2	Patching Extent **
86	2	Ravelling Severity **
88	2	Ravelling Extent **
90	2	Flushing Severity **
92	2	Flushing Extent **
94	2	Flag Button #1
96	2	Flag Button #2
98	2	Flag Button #3
100	2	Flag Button #4
102	2	Flag Button #5
104	2	Transverse Crack HL
106	2	Transverse Crack >1/4
108	2	Transverse Crack SP
110	2	Number of samples per interval
112	4	Zeros
116	8	ASCII word "COMMENT "
124	300	Comment Buffer
424	88	Accumulations

* A hexadecimal number represented as hh.hh . Where hh is a two byte hex number representing either the integer number or the decimal number in 10 thousandths. Ex 10.20 would represent the decimal number 256.0512.

** A hexadecimal number represented as h.h . Where h is a one byte hex number representing either the integer number or the decimal number in tenths.

When the END MILE is reached or the STOP key is pressed (followed by the ENTER key) the system will write the last summary to tape followed by a file mark to indicate the end of the sequence.

Printer

The printer is a twenty column serial printer and is driven directly by the microprocessor control unit. It is turned on in the setup menu and is used to print a summary report of the accumulated data associated with each defect category.

Odometer Circuitry

An odometer which is an automotive industry standard unit, giving approximately 4,000 TTL level positive transitions per mile is required. The actual number of pulses can be anything. The greater the number the more accurate the distance measurements and the greater the number of samples per interval that are possible (within limits). This device must be mounted on the vehicle and can be calibrated by the mocroprocessor control unit.

Office Data Reduction and Analysis System

IBM PC/XT Computer System

The IBM PC/XT computer system is an integral part of the

overall pavement survey system. It is used to read, edit and display the data from the tapes that are recorded in the field. It also has the software required to do the initial data averaging and file development required to get the data into the interpreting program used by the State in their overall pavement management system.

This system consists of an IBM PC/XT with a printer and a Digi-Data Corporation model 6450 cartridge tape drive. Also, software has been developed to control the tape drive, to read, edit and analyze the data and to put the data in a form that can be entered directly into the State's pavement management system.

Software

The computer system uses PC DOS, IBM BASIC, dBASE III and Microsoft's Fortran compiler. The software packages developed for this system consist of the tape control and data access program (TDRIV), the database management software and the MSFortran version of the State's INTERP program from their main frame pavement management system.

Tape Control and Data Access

The tape drive control and reading software package is called TDRIV. This package was written in IBM BASIC to take advantage of the built in capabilities for access and control of the IBM RS-232C serial data port. This port is used to interface to the Digi-Data tape drive. At present the software is being used with the standard IBM interpretive BASIC, a BASIC compiler

would improve the performance of this package considerably. Also if this package was reprogrammed in a more sophisticated language such as Fortran or C it would increase its speed and decrease it size over that of a compiled BASIC.

Users Guide For Pavement Survey Unit Software

TDRIV is a program designed to read data tapes from the field pavement survey unit. In addition to displaying the sequence and interval summaries, TDRIV can display individual samples or compute severity, extent and deduct values for the different intervals and averages these values over a given sequence.

Running TDRIV

All of the functions in TDRIV are accessed from a main menu, (the one that comes up when the program is first started). The following sections will cover each option in detail.

1) Set Track

The cartridge tapes are formatted such that there are four logical tracks per tape. The set track function changes the track that the tape drive looks at and hence provides an easy way to skip a quarter of the tape at a time. One word of warning though, the tracks are arranged on the tape in a serpentine format so that the end of track one is at the beginning of track two, etc. This means that if you are at the beginning of track

one and switch to track two, you will be at the very end of track two and doing any sort of read operation will push you over onto track three.

2) Rewind Tape

This will move to the beginning of track one and read the first sequence header, positioning you at sequence one, interval one.

3) Search for Summary

This will search through the tape sequentially from the current position looking for either the next interval summary record or a specific summary, if you gave it an interval number. This is a handy way to move long distances forward in a sequence.

4) Read Current Header

This will read the current sequence header. If the tape is currently positioned in the first sequence then this command behaves exactly like (2) and rewind the tape. Its main use occurs when the tape is positioned on some sequence other than the first. It can then be used either to recover from a "tape position lost" error without losing track of what sequence it was on or as a fast way to back up.

5) Dump Interval to Disk

This will dump all the data for a single interval to a disk file of the users choice, one sample per line.

6) Display Individual Samples

This option allows you to see which keys were depressed for each sample during an interval. The samples are displayed 20 at a time, with blanks representing no data, question marks representing invalid or default data and various mnemonic symbols (such as Sp for spalling, etc., See Appendix A) for representing valid data. After each screen of data you may enter either a carriage return to see the next 20 samples, a specific sample number to see 20 samples starting with that number, or a minus one (-1) to return to the main menu. You will be returned to the main menu automatically when all samples in an interval have been displayed. This in essence gives the operator a detailed map of the complete road system.

7) Space Forward Interval

8) Reverse Space Interval

The forward/reverse space interval function will reposition the tape to the end of the following/preceding interval and then display the interval summary. Should the end/beginning of a sequence be encountered, the sequence header will be read and displayed.

9) Compute Summary Statistics

This will compute the severity, extent and deduct values for the current interval, and then display them to the screen

following the interval summary. This operation entails a large amount of data manipulation an number crunching. The speed of these operations can be increased substantially by the use of a BASIC compiler and an 8087 math co-processor. Also, the amount of data being collected may become a consideration. An IBM PC/AT would also greatly improve performance. There are also co-processor type boards for the XT which can greatly improve its performance for a relatively low cost.

A new option is also available but the software modification have yet to be added. That is, at present the field system computes and stores the accumulated data associated with the severity, extent and deduct calculations. This mode will use these values directly and will be added to the IBM software by late spring and will substantially enhance the overall performance of the IBM system.

10) Forward Space Sequence (file)

11) Reverse Space Sequence

The forward/reverse space sequence function moves to the beginning of the following/preceding sequence and reads and displays the sequence header.

12) Retension Tape

Spins the tape cartridge from one end to the other to even out the tape tension. This can sometimes cure intermittent tape errors, if the tape has been sitting for a while or has undergone a great deal of stop and start motion.

13) Autosummary of Current Sequence

This function computes severities, extents and deduct values for all intervals in the current sequence and writes the data into two files. The two file are referred to as the header and the data files.

<type><state_route><dir><beg_mile>.DAT

where <type> is either H or D for header and data files respectively, <state_route> is the state route number, <dir> is the direction of travel (either P or M for increasing or decreasing mile number) and <beg_mile> is the beginning milepost number. These two files are the two required for input to the dBase programs for later manipulation.

14) Stop

Stops the program and returns you to the basic command level.

Database Software

This package is used to manipulate and display the database once it has been generated by TDRIV. It also computes the average severity, extent and deduct values for each begin mile-end mile sequence. This data is used as input to INTERP, the first of a series of Fortran programs used by WSDOT in their pavement management system.

Applications

The application of this research and development effort is in the implementation by WSDOT of this hardware and software into their current pavement management system and practices. This equipment will decrease the number of man hours involved and enhance the accuracy and data accessibility. It will also lend itself to future enhancements and developments to further improve the existing system.

The cost to develop this peace of hardware was $68,200.00 and the estimated cost for the construction of future units, given that a minimum of six units are built and the same design is used, will be approximately $12,000.00 each. The estimated cost savings to the state resulting from the implementation of these units into their existing PMS would be mainly in the added efficiency of handling the data and in the increased accuracy and resolution afforded by this unit. The savings in keypuching will be about $1500.00 per survey, while the savings due to the increased quaility of the data is impossible to put a value on. There should be an eventual time reduction in the actual data collection, however, current experience with the prototype unit has not been extensive enough to resolve this.

APPENDIX A

FIGURES

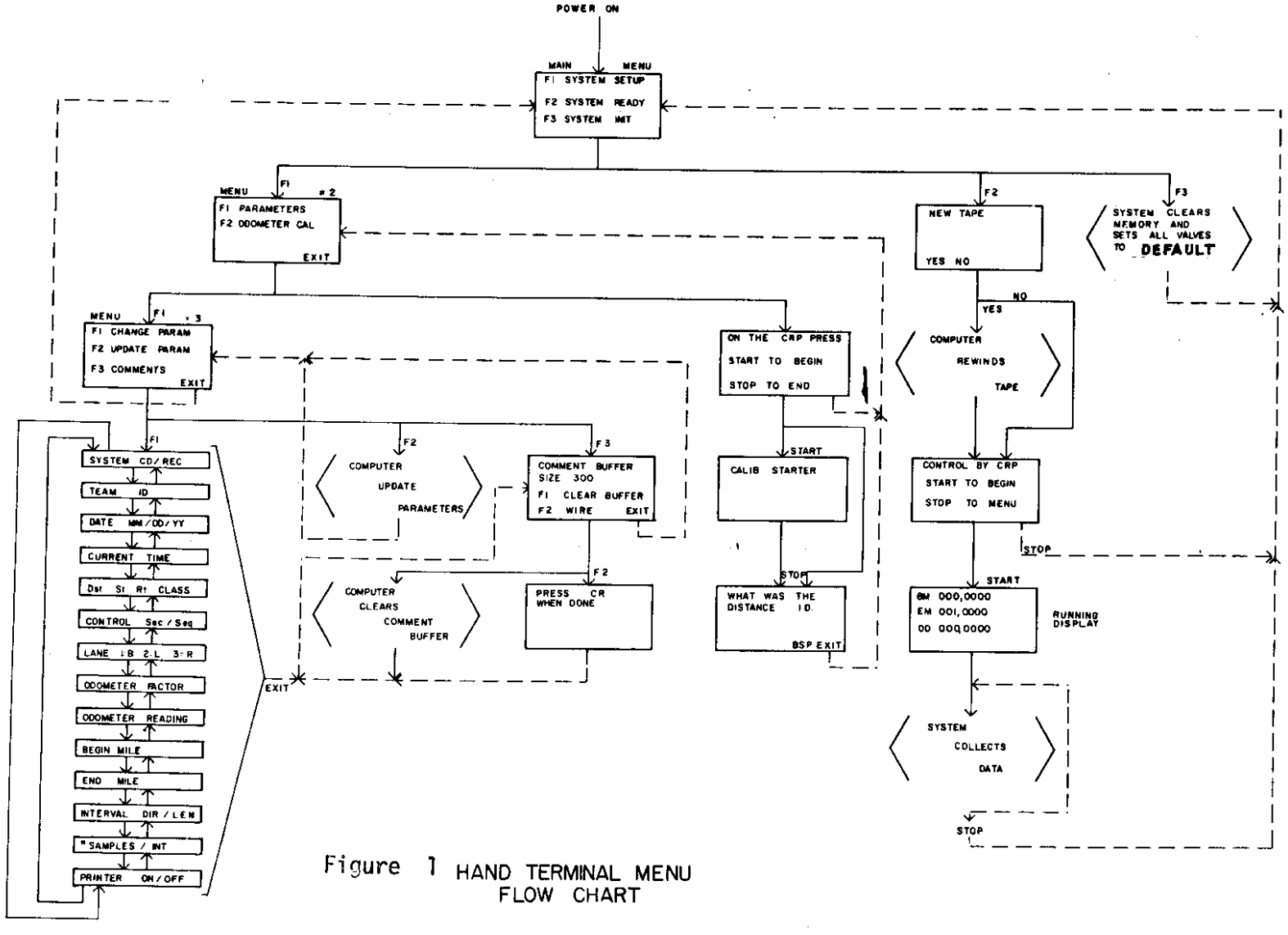


Figure 1 HAND TERMINAL MENU FLOW CHART

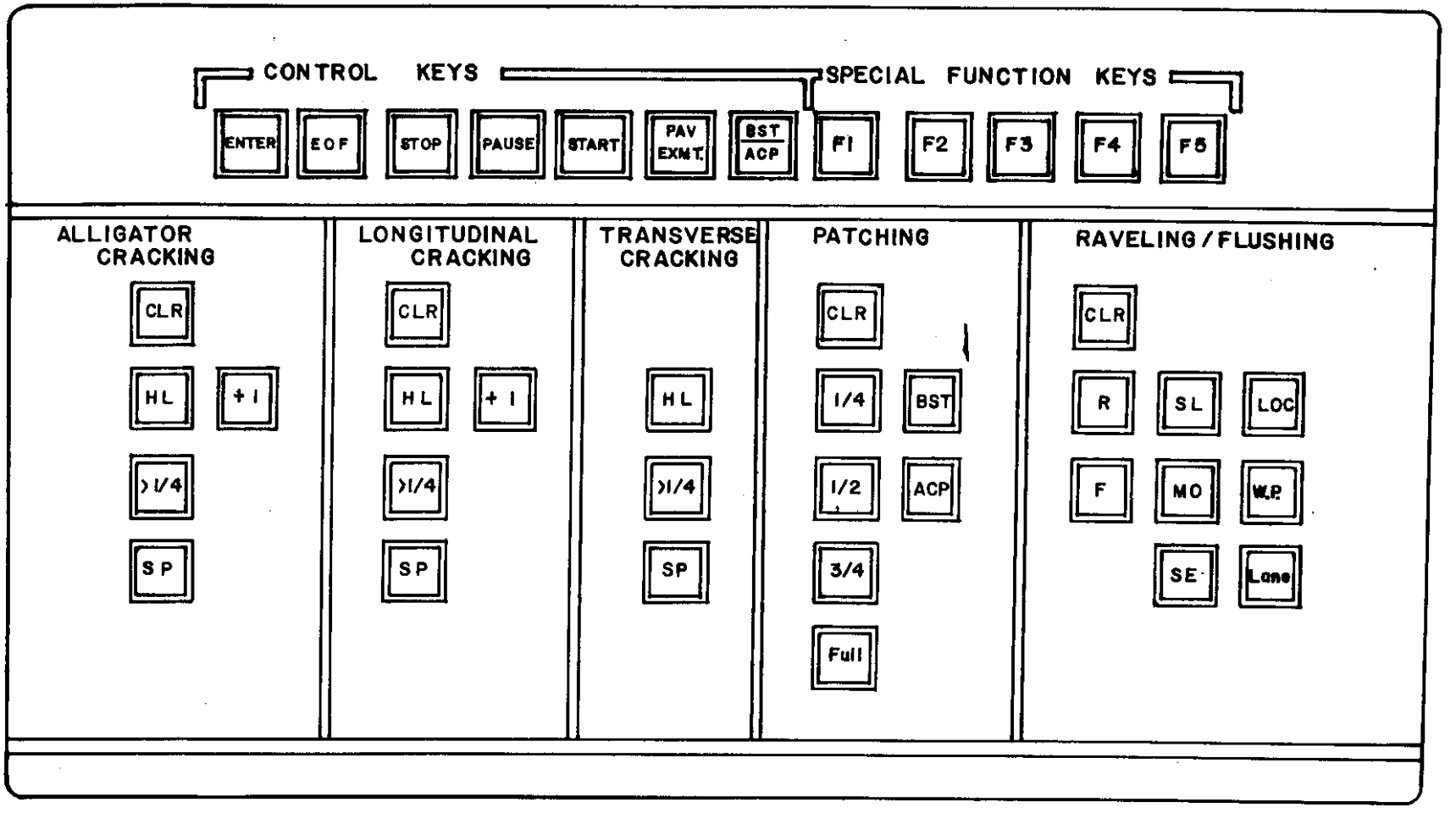


Figure 2 Crp Keyboard Layout

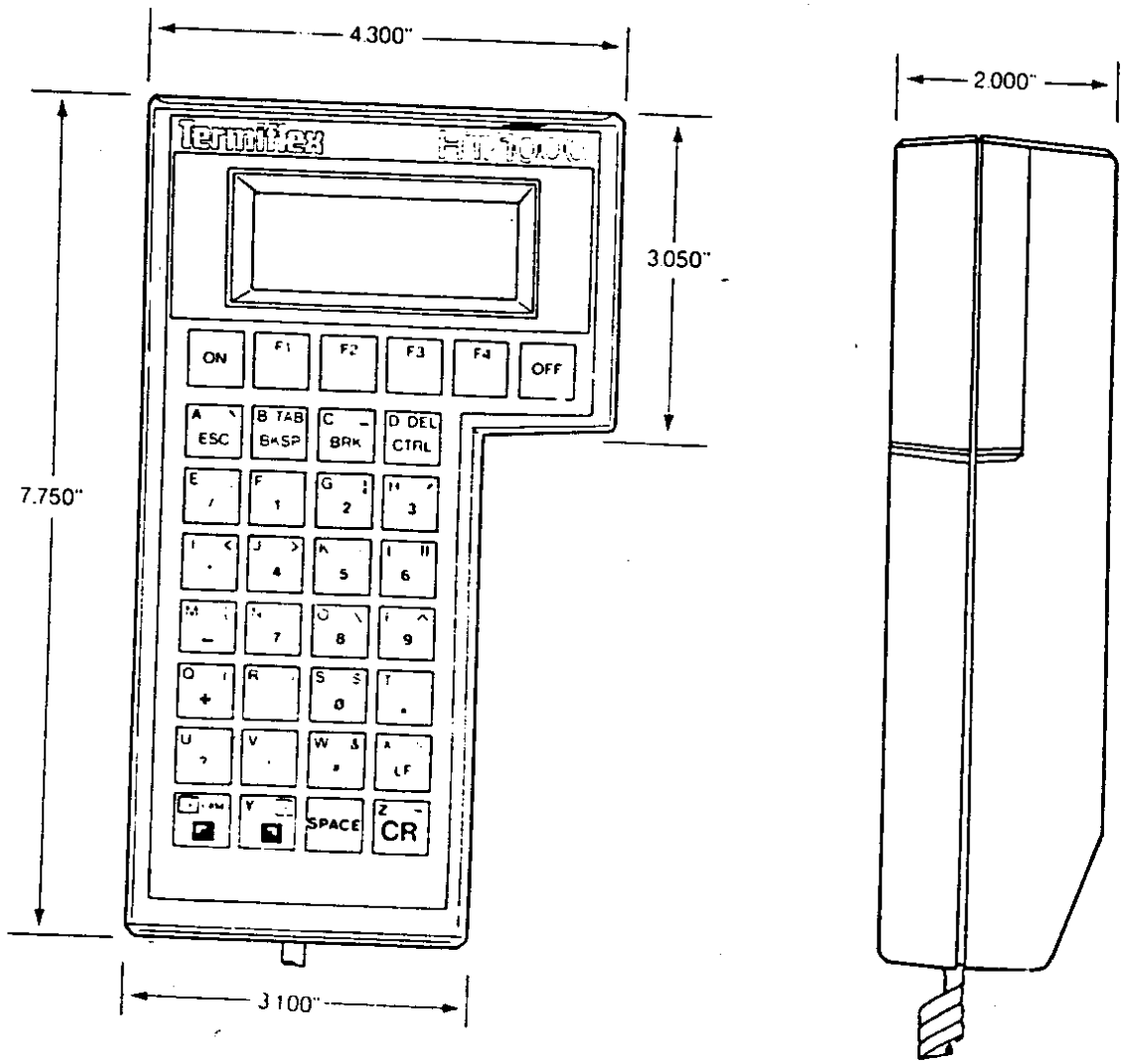


Figure 3 Hand Terminal Layout

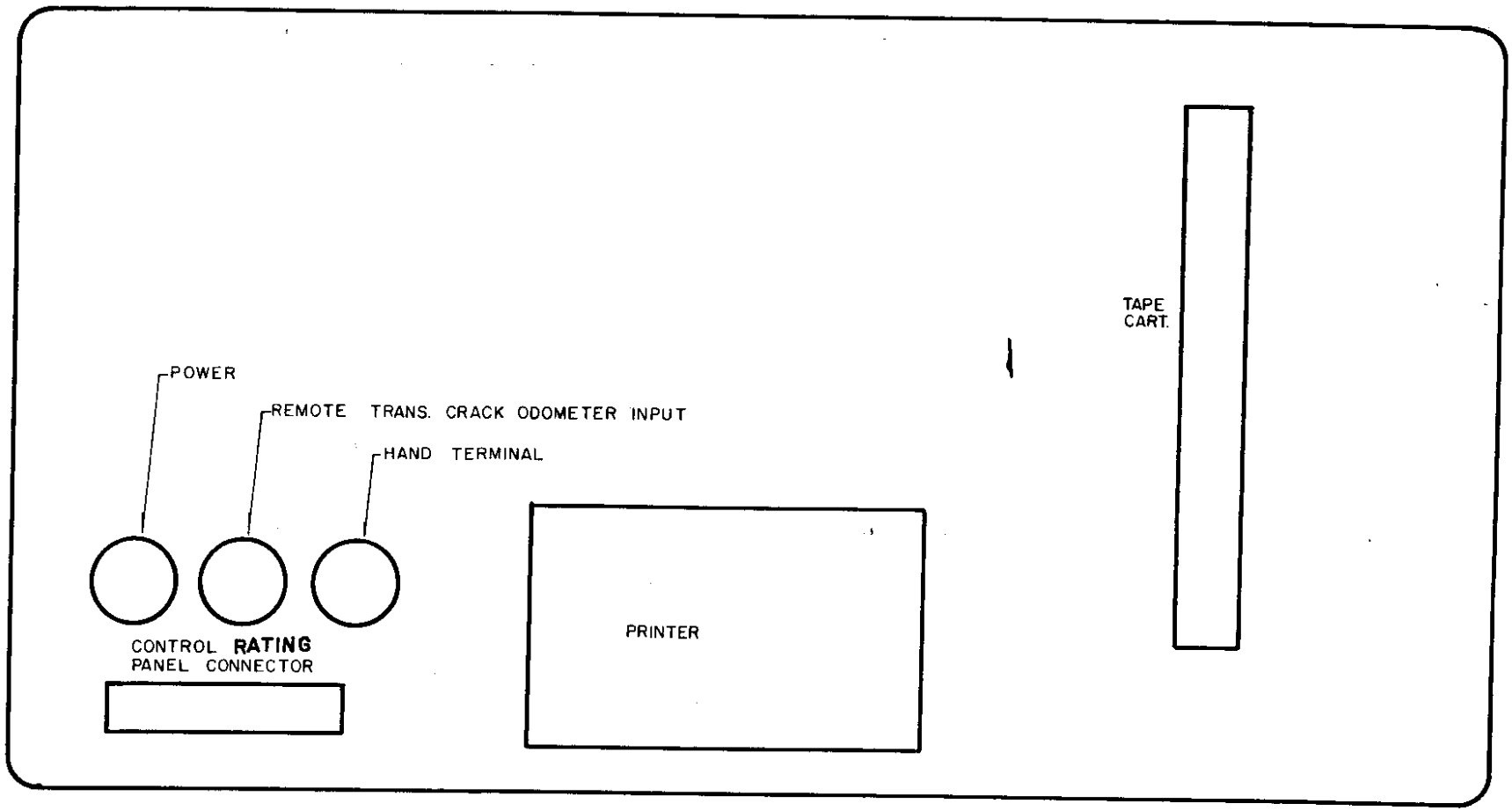
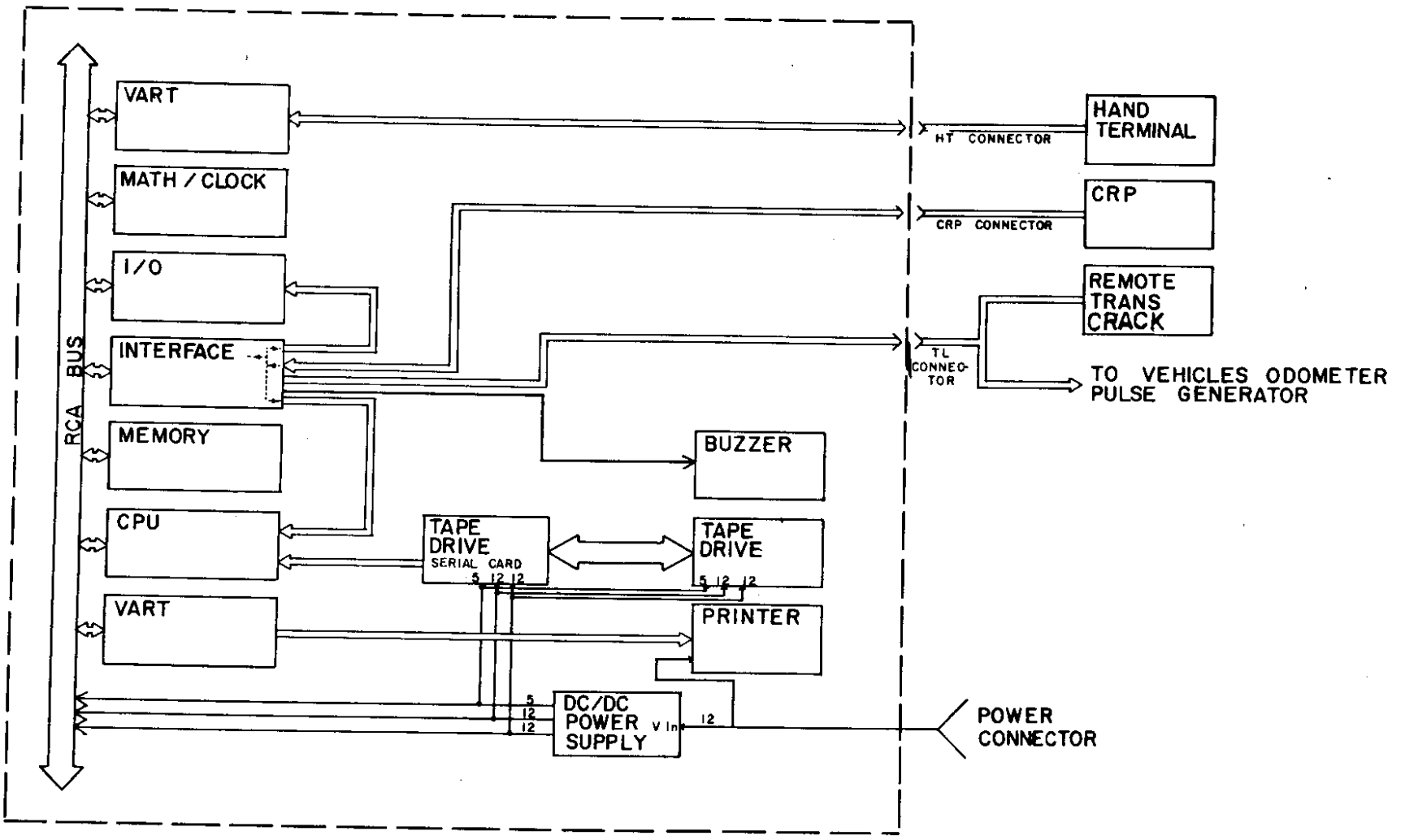
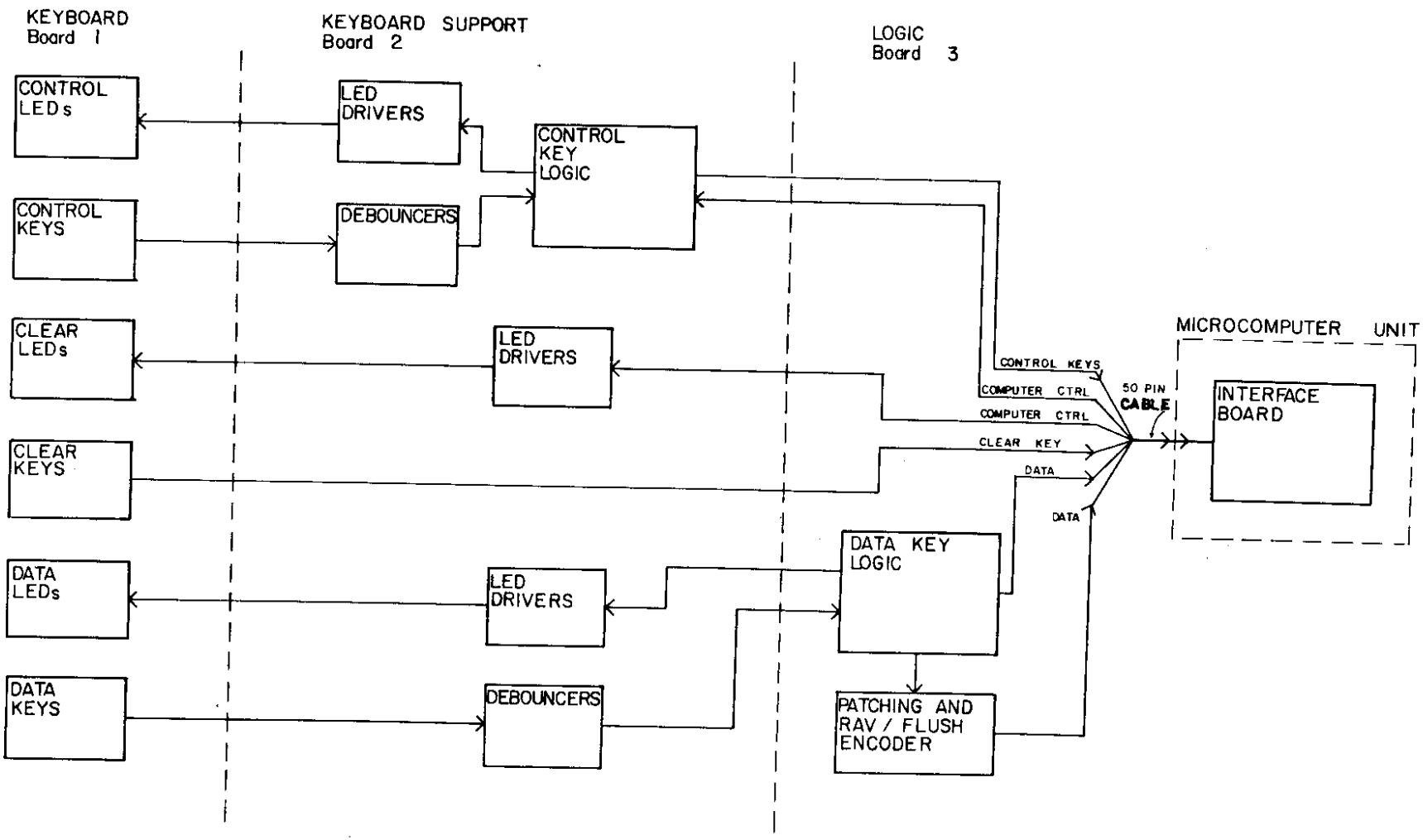


Figure 4 Microcomputer Control Unit Panel Layout



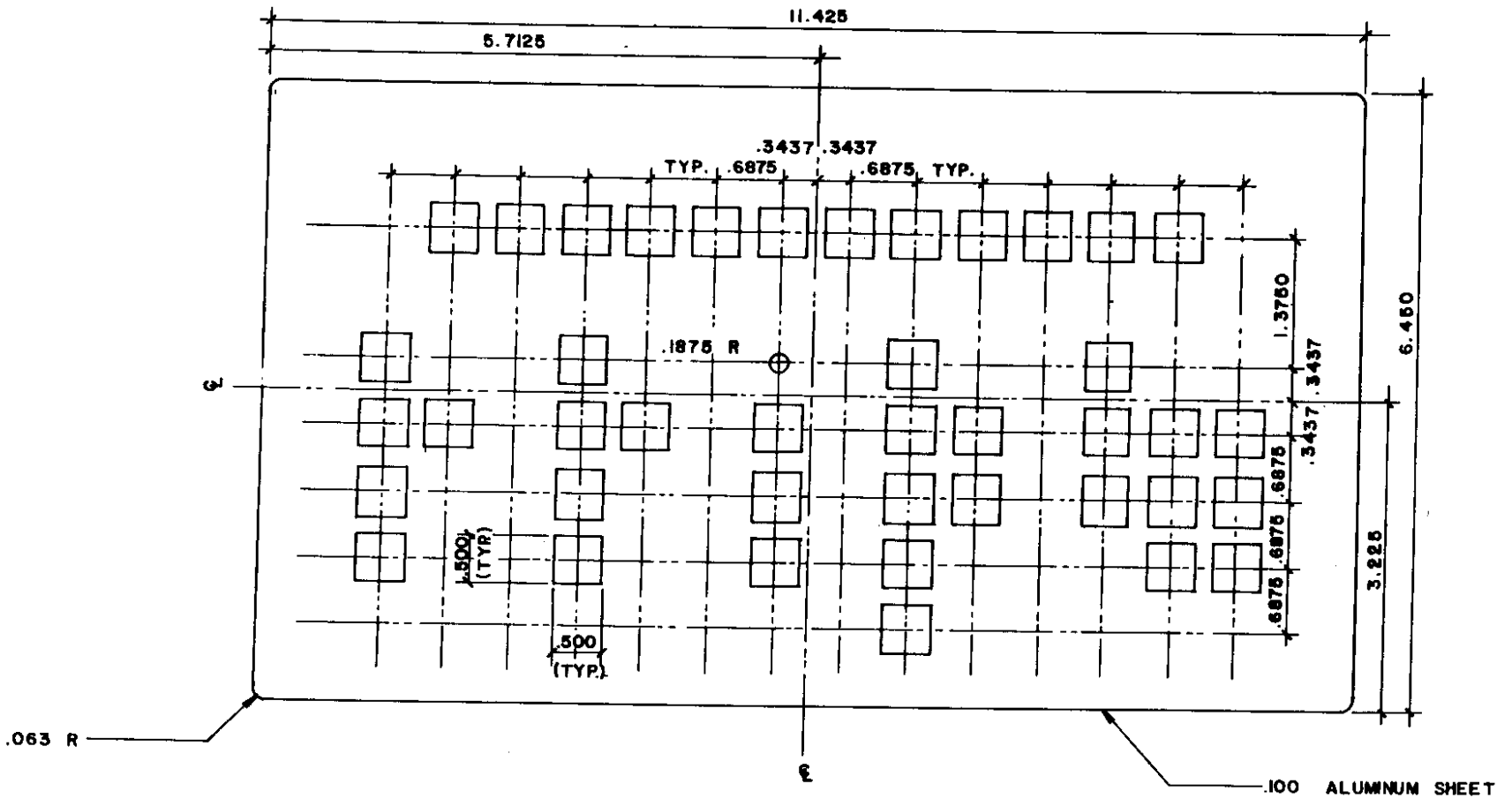
PAVEMENT SURVEY SYSTEM BLOCK DIAGRAM

Figure 5 Pavement Survey System Block Diagram



CRP BLOCK DIAGRAM

Figure 6 CRP Block Diagram



TOP PLATE

NOTE: ALL DIMENSIONS ARE IN INCHES

Figure 7 CRP Keyboard Top Plate Construction Detail

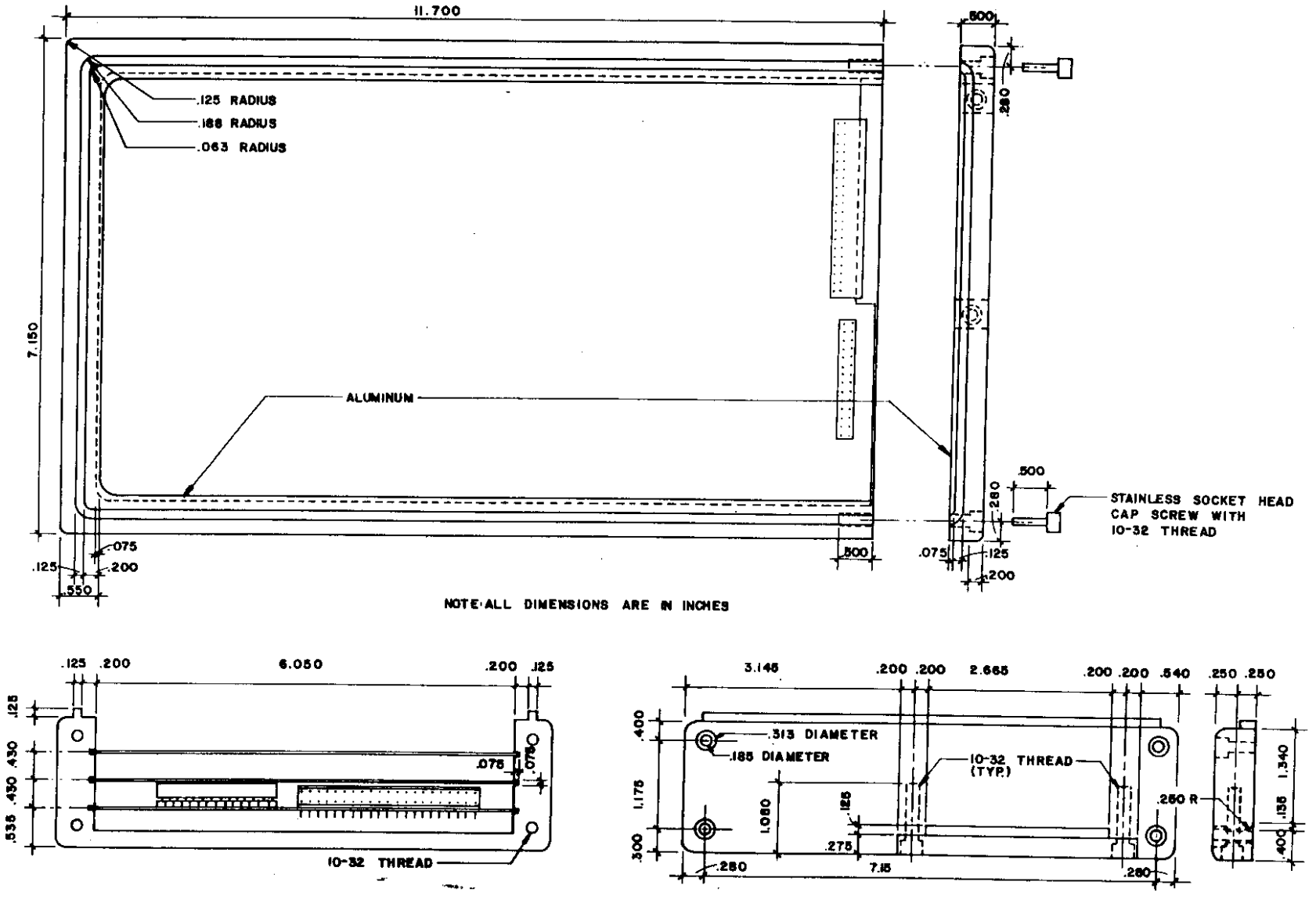


Figure 8 CRP Housing - Construction Detail

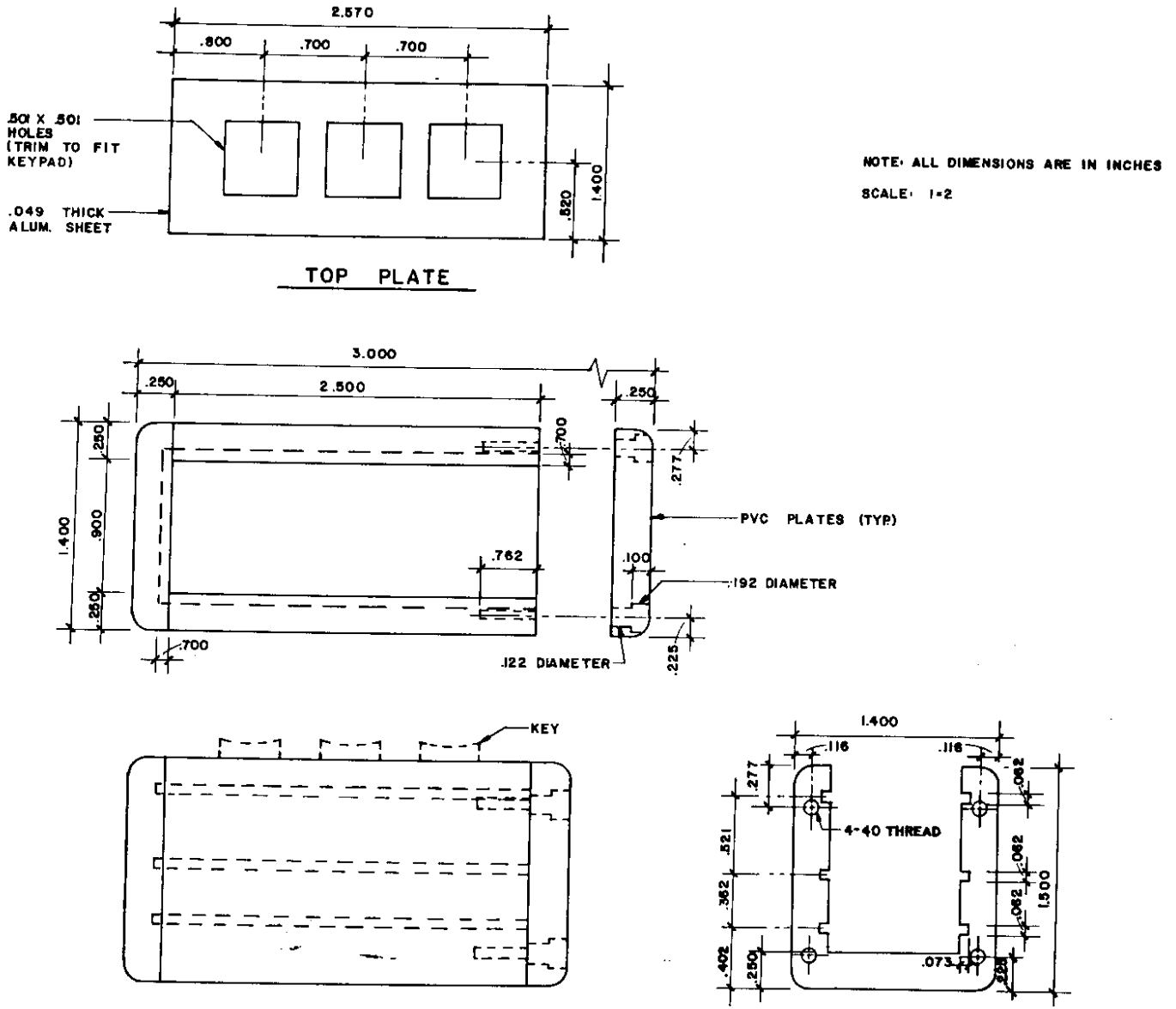


Figure 9 CRP Remote Construction Detail

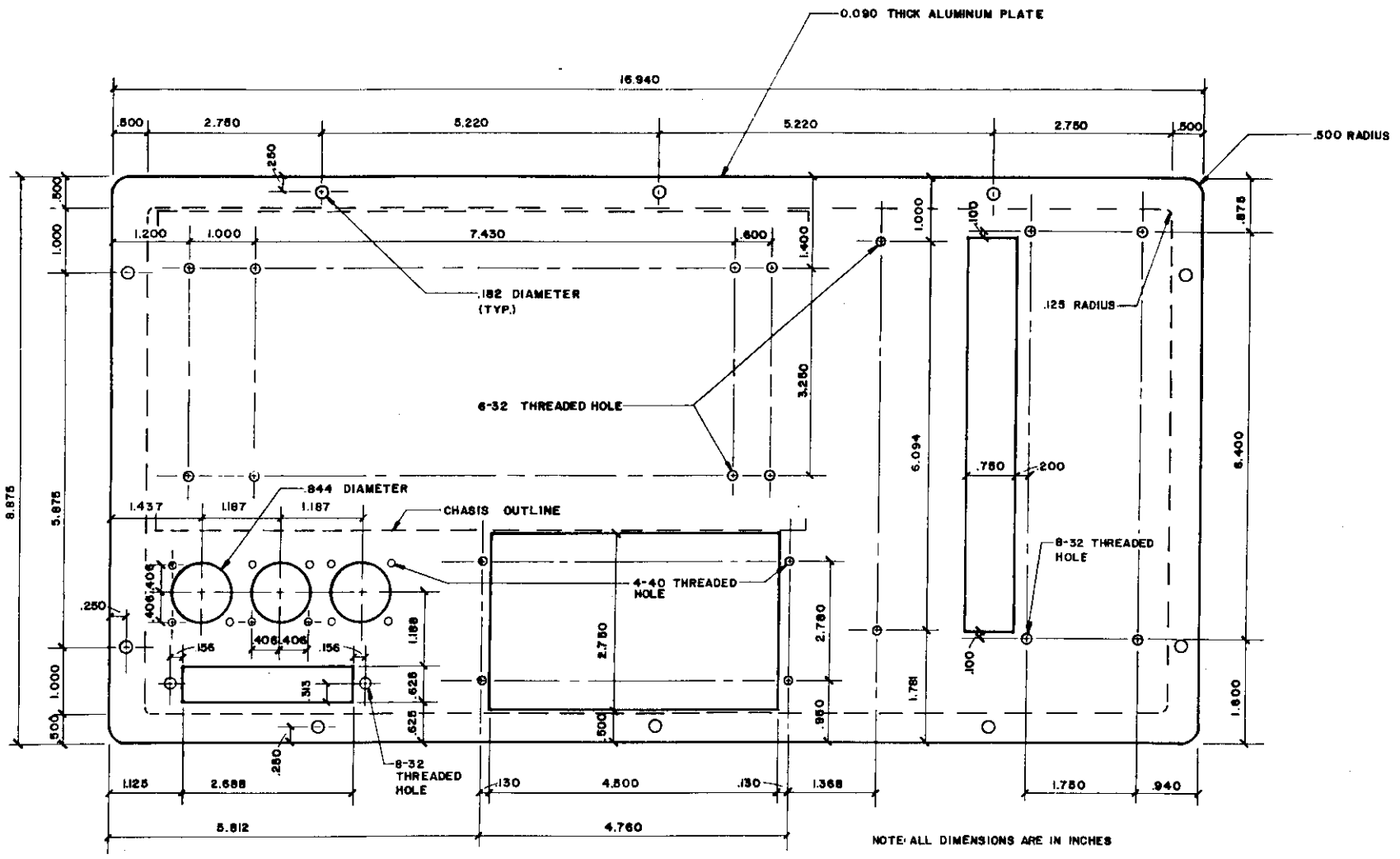


Figure 10 Control Panel Construction Detail

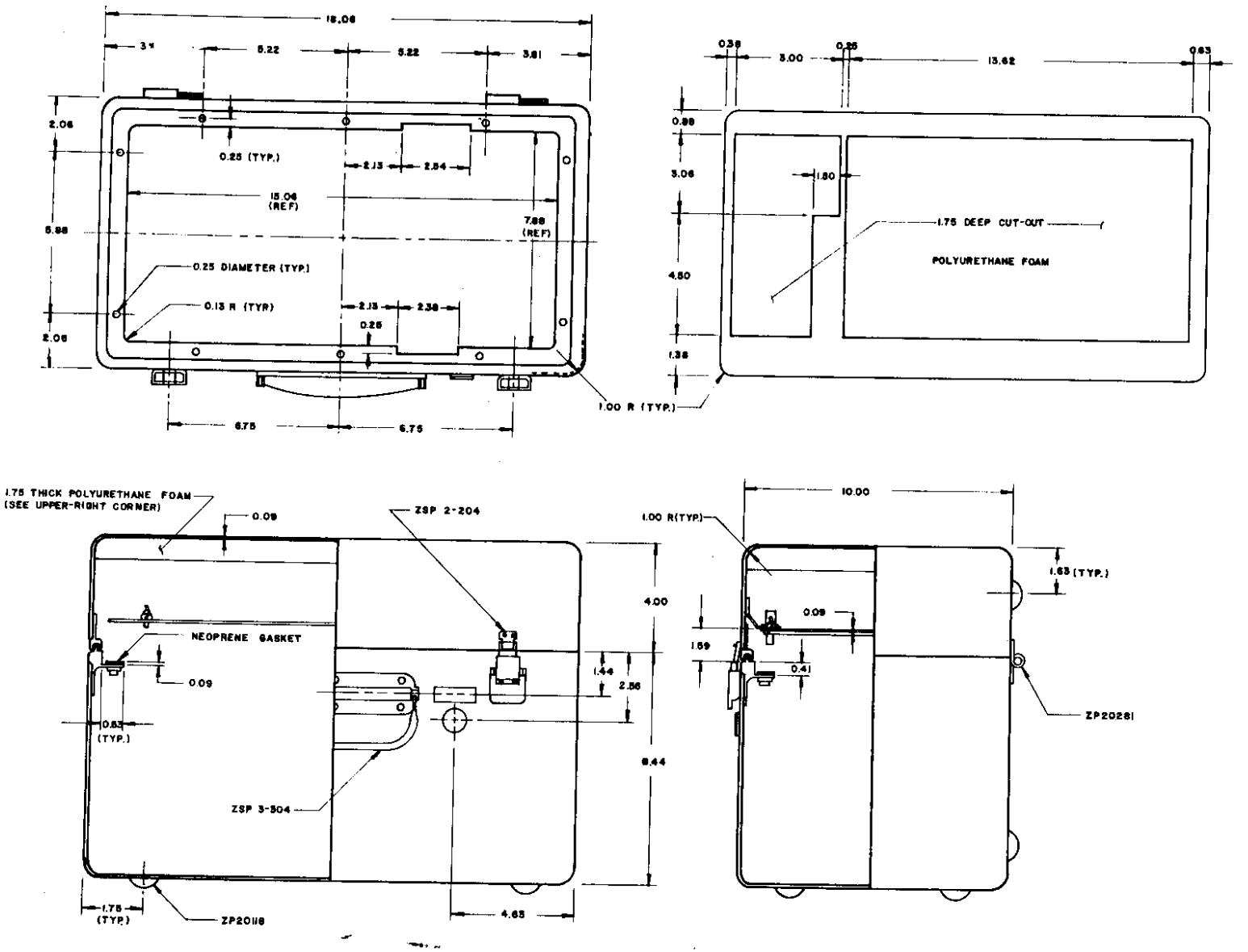


Figure 11 System Enclosure - Construction Detail

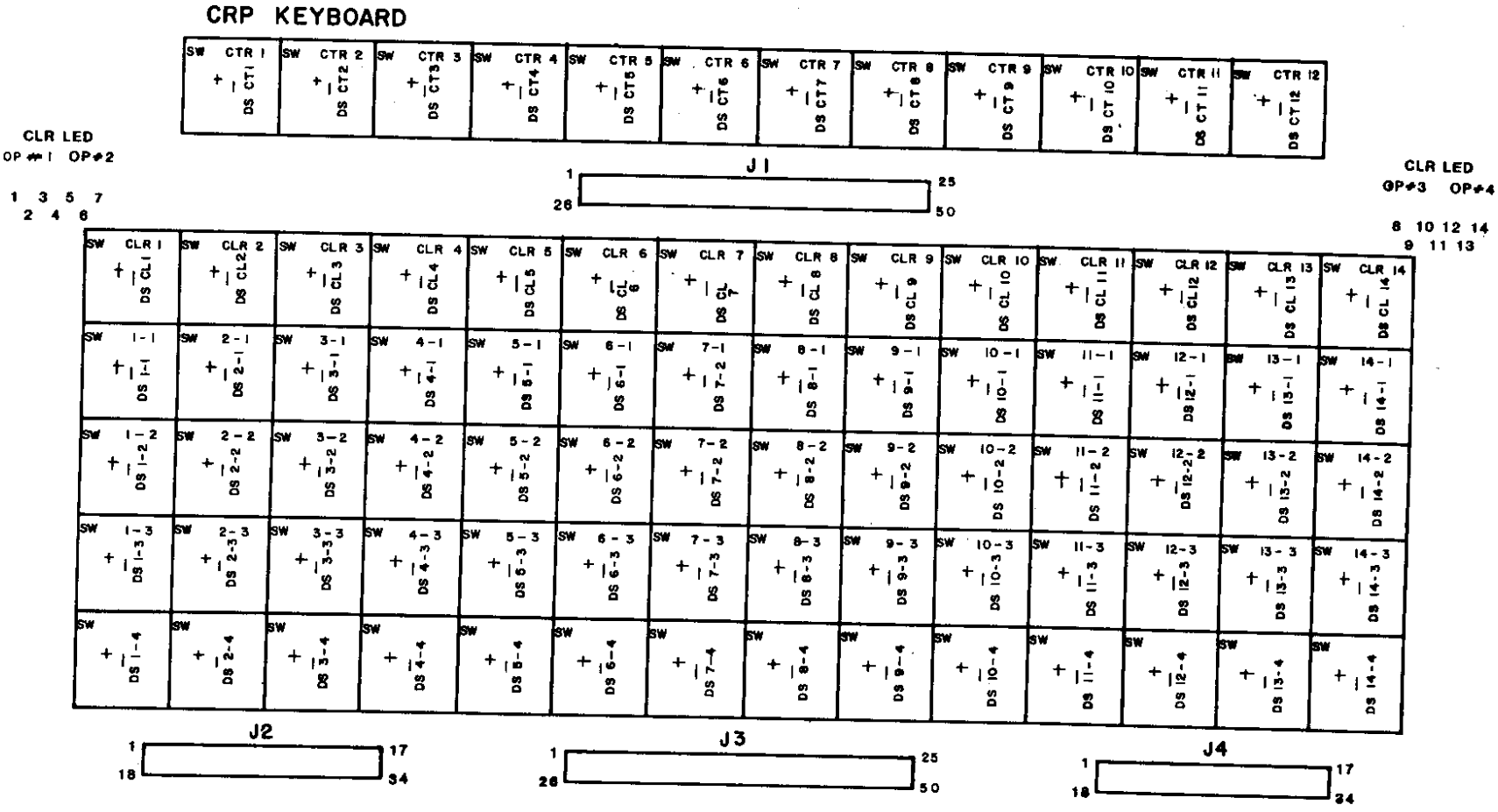


Figure 12 CRP Keyboard PCB Layout - Keyboard

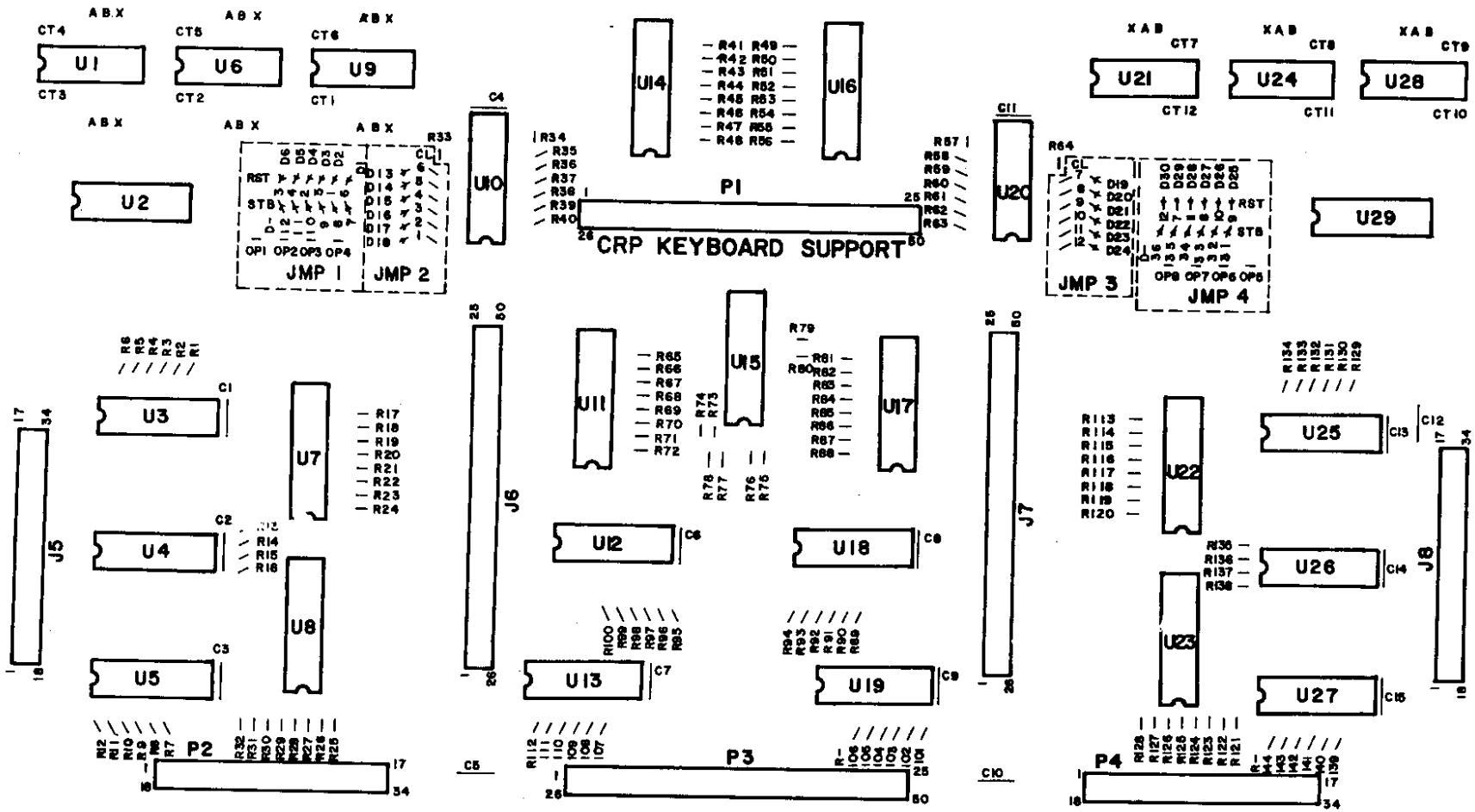


Figure 13 CRP Keyboard PCB Layout - Keyboard Support

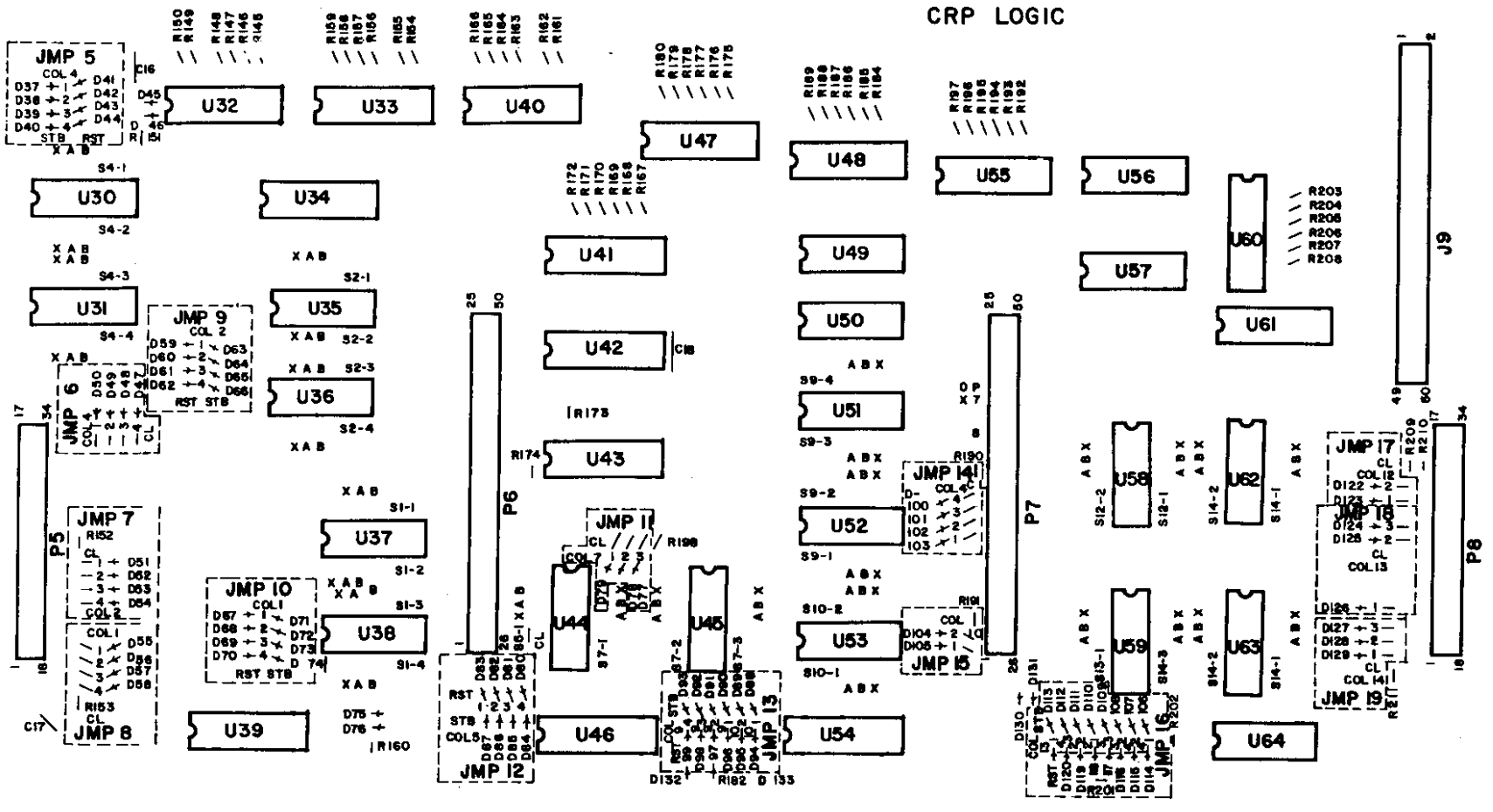


Figure 14 CRP Keyboard PCB Layout - control Logic

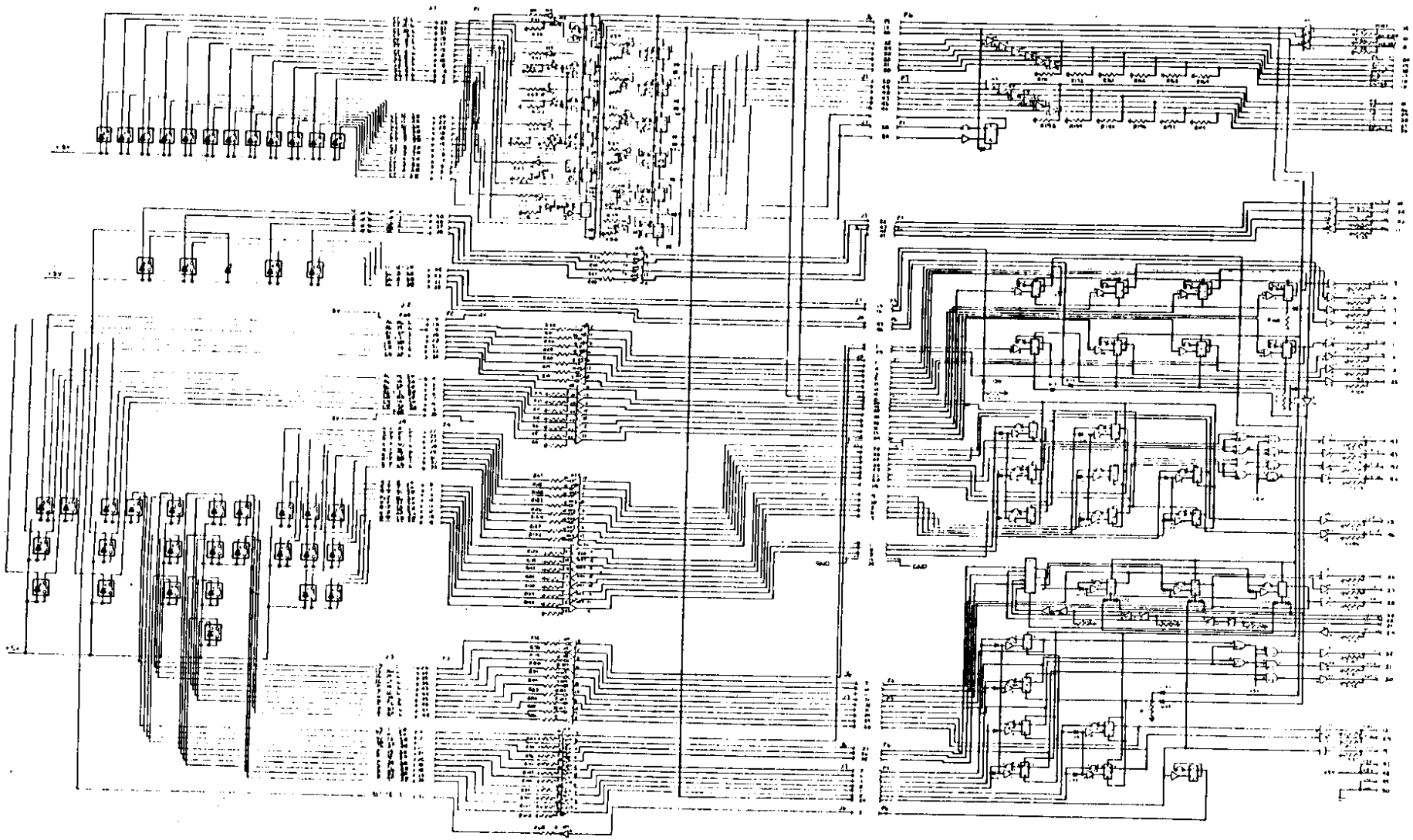


Figure 15 CRP Keyboard - Electronics Schematic

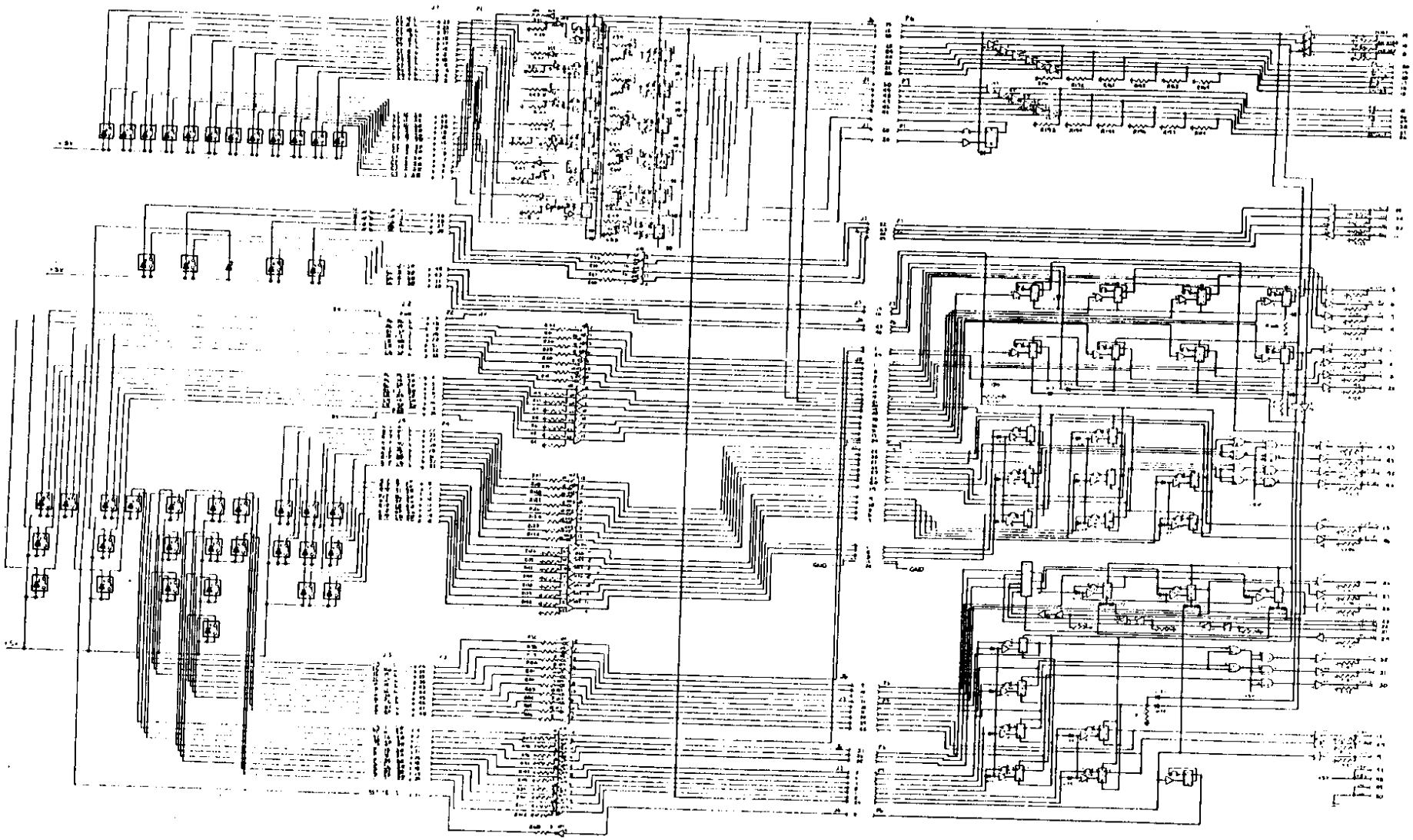


Figure 15 CRP Keyboard - Electronics Schematic

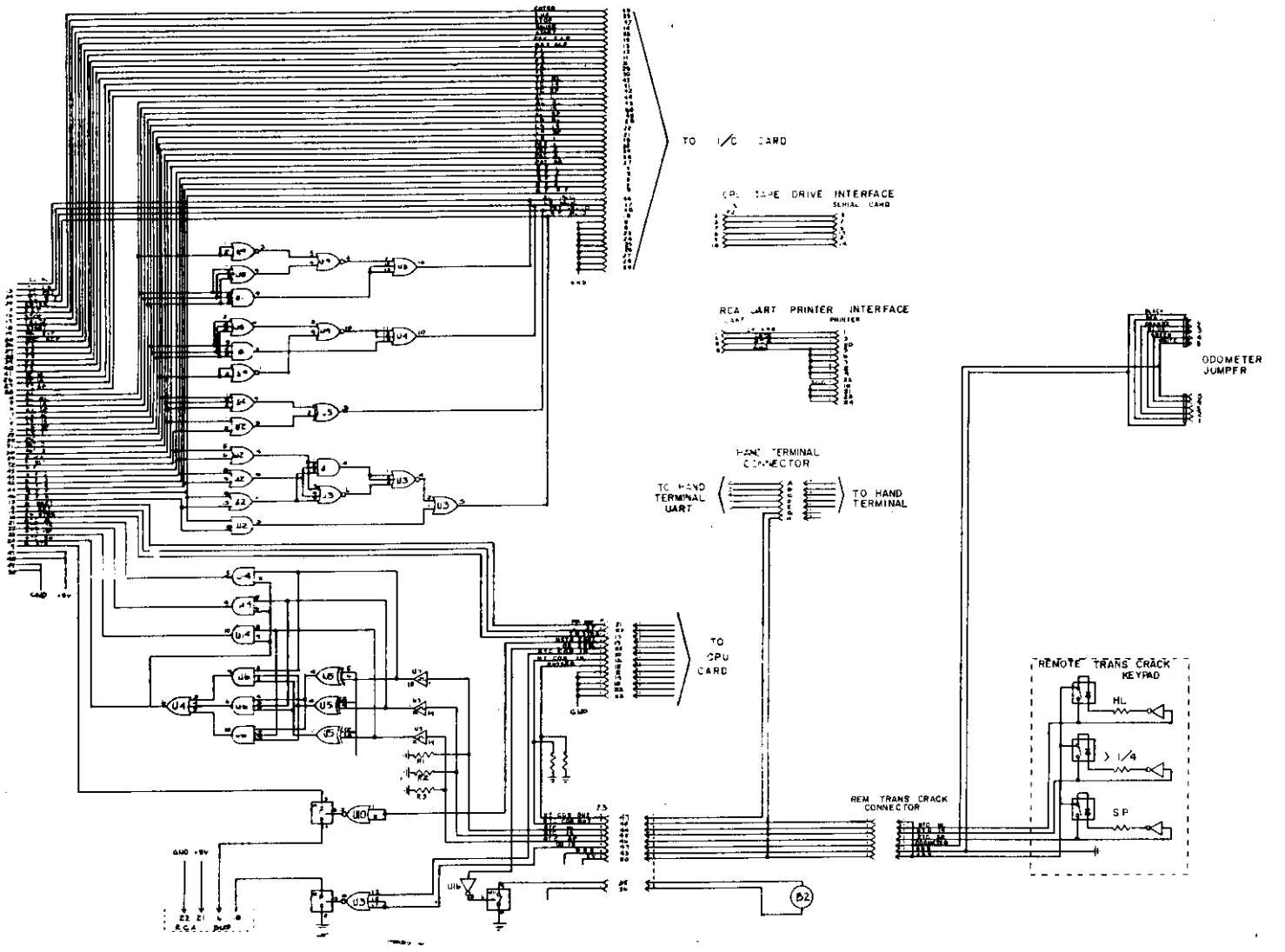


Figure 16 Custom Interface Board and Connector Detail

APPENDIX B

GLOSSARY AND ABBREVIATIONS

AL - Alligator Crack

ACP - Asphalt Concrete Pavement

BM - Beginning mile post.

BST - Bituminous Surface Treatment

CLASS A,B,C - There are three classes of parameters; A) Those parameters which must have a value for the system to run a sequence and are loaded with a default value when the system is initialized; B) Those parameters which are not needed for a successful run of a sequence, but are still loaded with a default value when the system is initialized, and C) those parameters which are used only for information.

CLR - Clear all keys in this section of CRP

CRP - Control-Rating Panel

The hand held keyboard used for entering road fault conditions and controlling basic program execution. Also referred to as the Keyboard.

EM - Ending milepost.

Enter - Used to enter control command on CRP

EOF - End of File

F - Flushing

FULL - Full depth

HL - Hairline

HT - Hand Terminal

F1-F2 - Special Function keys - push-on push-off operation. These keys are counted for each sample until they are released

F3-F4 - Special Function keys - momentary on operation. Reset by the computer each time they are sampled.

Header - Refers to the information put on the tape preceding the actual data record.

Internal Summary - This is the accumulated data summary of the individual surface condition data which is

stored internally on the magnetic tape.

Keyboard - The data entry panel used to enter the surface condition data.

Lane - The actual traffic lane being surveyed.

LOC - Location

LN - Longitudinal Crack

MCU - Microcomputer Control Unit

The main instrument package which houses the computer system, printer, tape drive, and front connectors.

MO - Moderate

PAUSE - Returns control of MCU back to the HT during data sampling.

PAV EXMT - Pavement Exempt

R - Raveling

Record - A 512 byte block of information on the tape which could either be default data, a sequence header, or an interval summary.

RTC - Remote Transverse Crack

The hand held unit containing three push-buttons used for entering transverse crack information remote from the CRP.

R/F - Raveling/Flushing

Sequence

An operator defined section of data on tape which is all the road default data accumulated between the Begin Mile and either the End Mile or the point where the operator pushed the STOP button.

A sequence is always preceded by a 512 byte information header and ended with a file mark on the tape.

STOP - Stops data sampling.

START - Start data sampling.

SE - Severe

SL - Slight

SP - Spalling

TC - Transverse Crack