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MICRODENSITOMETER
DIGITIZATION

by

BRUCE W. BINNS

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in the School of
Photographic Arts and Sciences in the
College of Graphic Arts and Photography
of the Rochester Institute of Technology

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Signature of the

Author Bruce W. Binns ....

Photographic Science
and Instrumentation

Certified

by John F. Carson ....

Thesis Advisor

Accepted

by Ronald Francis ....

Coordinator, Graduate
Program

School of Photographic Arts and Sciences
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Rochester, New York

CERTIFICATE OF APPROVAL

MASTER'S DEGREE

This is to certify that the Master's Thesis of Bruce W. Binns has been examined and approved by the thesis committee as satisfactory for the thesis requirement for the Master of Science degree

John F. Carson

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19 August 1981

Date

MICRODENSITOMETER DIGITIZATION

by

Bruce W. Binns

Submitted to the Photographic Science and
Instrumentation Division in partial fulfillment
of the requirements for the Master of Science
degree at the Rochester Institute of Technology

ABSTRACT

The importance of performing extensive calculations on microdensitometer data makes entry of the data into a computer mandatory for many types of investigative situations. The previously available facilities in the Photographic Science department have supported only manual data entry techniques. Such techniques are slow and prone to error, greatly limiting use usefulness of the Ansco Model 4 microdensitometer available for student use. This thesis has involved the designated implementation of a low cost digitizatio technique that allows convient gathering, storage, and machine read input of data into the RIT timesharing computer facilities. A conservative increase of two orders of magnitude has been noted with the system compared with manual data entry techniques.

ACKNOWLEDGEMENTS

I would like to thank Dr. Gerhard Schumann whose initial interest helped get this project started, and my advisor, professor John F. Carson, whose guidance and advice was most appreciated. A grant from the CIA aided the financing of this work and is also appreciated.

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CHAPTER I

INTRODUCTION

INTRODUCTION

The first question that should be asked concerning the digitization of microdensitometer output is why should one bother to digitize at all. The answer lies in investigating the reasons for gathering microdensitometer data in the first place. In some situations, there is only interest in gathering qualitative date. Increasingly however, there is both desire and need to use the microdensitometer as a quantitative measuring tool as well. While a chart recorder output provides an excellent means of gathering and evaluating qualitative data, quanitative determinations must be made on a point by point basis. Where the number of points of interest is large, as in power spectrum analysis, for example, much time may be spent making quantitative determinations from the chart recorder output. As manipulation of quantitative data can be facilitated quite easily by computer, it is often desired to get the data from the microdensitometer to the computer in the most expedient manner.

The previous method of getting microdensitometer data into the RIT computer involved looking at the data on the chart recorder output, interpreting the output as a numerical quantity on a point by point basis, and getting the data input to the computer by either keypunching the data onto punch cards or by typing the data directly into the computer via teletype. Even if a data point were read off the chart recorder output, interpreted and typed into the computer every ten seconds, a 1000 data point trace for a power spectrum analysis would take almost three hours to get into the computer. It must be remembered that 1000 data points may be somewhat minimal for some applications. To input 10,000 data points at one every ten seconds, would take in excess of 27 hours. It must also be kept in mind that reading one data point every ten seconds and typing it into the computer is actually an extremely fast rate for a single person. In addition, the chance of error goes up when working faster, as well as when operator fatigue sets in. A single error in data entry in an RMS granularity determination may significantly affect the result.

Obviously, is can be seen that there is a crying need to improve upon the tedium and error prone nature Typical use involving the microdensitometer digitizer that has been constructed allows entry of microdensitometer data into the computer at the rate of ten data points every second. Thus, a 1000 point microdensitometer trace may be loaded into the computer in under two mimutes, as compared with almost three hours using manual data entry techniques. And just as significantly, the chance of human error during data entry is eliminated.

The capability resulting from an increase of two orders of magnitude in the speed of microdensitometer data entry into the computer and the elimination of the chance of human error during data entry, is one that has both obvious and subtle implications. On the surface, the digitizer apperars to be another handy gadget that will save students' time, resulting less chance of errors spoiling good data, and generally improve the level of sophistication and professionalism possible for students working with the microdenstiometer. While these are all worthy goals, and indeed are the primary impetus behind construction of the digitizer, there are more subtle implications to this increase in capability. Rather than concentrate exclusively on how to use a new tehcnology for conventional ways of doing things, it is also important to consider what kinds of changes in the way of doing things a new technology allows. Even more important is consideration of what new kinds of things are now possible with this new technology, that were previously out of the question.

The capability of getting microdensitometer data into the computer in an expedient, accurate manner, suggests two different areas where this capability might be put to use, in addition to aiding areas that previously have resulted in manual data entry, out of necessity. One area is the more routine use of the microdenstiometer to make measurements of MTF and power spectrum, where these measurements are of secondary, although interesting importance, but could not previously have been justified due to the time requriements of the manual data entry method. On the other end of the spectrum from making simple, routine measurements, is using the digitizer to make previously impossible projects a reality. To be sure, even with the help of the digitizer, digitization of a small two dimensional area of film by repeated scans in a raster mode might well be a monumental task. Despite the work involved however, there are very interesting investigations that could be be made with modest size two dimensional arrays of digitized image data, that would be all but impossible using manual data entry methods from the resulting multitude of chart recorder traces.

Thus, it can be seen how the capability to dramatically increase the throughput on getting data from the Ansco Model 4 microdensitometer to the RIT computer is both a significant advance over previous manual data entry methods, as well as having profound implications in expanding the usefulness of the microdensitometer as a data gathering tool for both small and large investigations.

CHAPTER II

BASIC DESIGN CONSIDERATIONS

DATA GATHERING AND STORAGE

In getting microdensitometer data into the computer, is becomes necessary to either transmit the data real time to the computer, or to have some form of local storage of the digital information. Real time transmission of data directly to the computer would require the expense of additional phone lines, communications equipment leases, and additional computer port charges. Such a system, as well as being potentially expensive, would also be restricted to gathering data only at those times when computer timesharing service is available. The high cost and inconvenience of the real time data gathering approach suggests using some form of local data storage that would allow digitization of microdensitometer traces at any time, even if the computer was unavailable. Transmission of the data to the computer would then occur at some point in time when timesharing service was available.

To retain the capability of machine reading of the locally stored data, it becomes necessary to interface with the computer via computer mag tape, punch cards, paper tape, or telephone line. Both computer mag tape and punch cards have the disadvantage of being prohibitively expensive with costs in excess of one thousand dollars.

The use of telephoe communication of data to the computer would still require some form of associated local data storage such as RAM or magnetics if data were to be gathered without computer timesharing available, and would also result in an extremely expensive system.

The use of paper tape for local data storage offers several specific advantages. First, if reasonable care is taken paper tape offers the user a permanent, virtually unalterable copy of the original data. This copy may be retained by the user, and entered into the computer via the paper tape reader built into the most widely used computer terminal at RIT, the KSR 33. Should the data require further analysis after the data is no longer on the computer system, it becomes a simple matter to read the data on again. Indeed, this feature might also be of use should the computer dispose of the data before the user is finished with it. The paper tape record of smaller traces with one to two hundred data points would even be short enough (ten to twenty inches, with ten data points per inch) to allow careful folding and permanent storage in the user's laboratory notebook.

There was an additional cost advantage in the final selection of paper tape as the method of choice with the existance of a salvageable paper tape punch that would be committed to the project. eliminating the need to purchase the single most expensive part of the digitizer.

QUANTIZATION REQUIREMENTS

The decision of what degree of quantization, expressed for instance in bits, suggests some type of compromise between accuracy and freedom from noise on the one hand, and physical demands for fast and easy data acquisition, local storage, and transmission on the other hand. In practive, both of these factors must be tempered with the realities concerning characteristics of both the data handling hardware, and the microdensitometer signal being digitized. Fortunately no real tradeoff or compromise is necessary, and the selection of the quantization level is straightforward. As the paper tape system stores and transmits data in eight bit bytes, use of any quantization level up to eight bits, such as six, seven, or eight bits, results in no increase in the time to punch the data onto paper tape, or the amount of paper tape needed to digitize a given number of data points. The microdensitometer signal, with a calibration accuracy of .020 density units, as well as drift and signal noise may be well specified by an eight bit system with a plus-or-minum-one-half least-significant-bit (+/- 0.5 LSB) quantization error of .008 density units when digitizing the entire microdensitometer range of zero to four density units. If even this small quantization interval is too large, it is often possible to reduce the range of density values digitized, producing a +/- 0.5 LSB quantization error of .002 density units when a range of 1.0 density units is digitized for example. There exists a line voltage induced noise intrinsic with the microdenstiometer signal of less than plus of minus 0.01 density units. For most purposes, this may be ignored. In the event it is believed that such a signal might affect results, the problem may be easily eliminated by either selection of an appropriate sampling rate, or by simple digital filtering in software (for more information of either technique, see RECOMMENDATIONS in Chapter IV).

SAMPLING INTERVAL REQUIREMENTS

A primary requirement of a machine designed for student use is that the controls and operation of the machine are clear and easy to use. In selecting the type of sample intervals to use, the choice is simplified if sample intervals of 1, 2, 5 micrometers, etc., are used instead of arbitrary intervals that are strictly hardware dictated such as 3.479 micrometers, etc. Beyond the desire for sampling intervals that are numerically easy to use and remember, there is also a need for sampling intervals that will comer a wide range in spatial frequency. Operations such as power spectrum analysis and investigation of high resolution systems often require sampling intervals approaching the one micrometer region, while digitization at low frequency for purposed of performing step wedge calibration or investigations involving low frequency information such as uneven development or illumination falloff in an optical system, may require sampling intervals approaching one milimeter. Fortunately none of these requirements were difficult to meet, and with the combination of selection of Ansco stage speed and one of four possible digitizer digitizing rates, spatial sampling frequency can range from 20,000 samples per millimeter, to one sample every eight millimeters. In addition, one of the digitization rates was chosen such that one sample is taken every small division of the chart recorder paper, with twenty divisions per inch, and two inches per minute paper speed. Use of the digitizer with this sample rate will allow simultaneous production of a chart recorder trace plotting the data, with a paper tape record of the data produced facilitating easy entry of the data into the computer.

CHAPTER III

DIGITIZER DESIGN AS IMPLEMENTED

BASIC CHARACTERISTICS

The digitizer is housed in a rack mounting cabinet with the paper tape punch mounted in a chassis below the punch, and the main power supplies mounted below the chassis in the bottom of the cabinet. Controls to operate the digitizer are located on the front panel of the electronics chassis. Basic operations of the digitizer as used to digitize a typical microdensitomer trace with the Ansco Model 4 microdenstometer is found in the operator's manual, included as appendix B. Also covered in this manual is an explanation of the front panel controls.

The digitizer circuitry is implemented almost entirely in CMOS digital integrated circuits, with the exception of a number of analog devices used for data scaling and analog to digital conversion, and a number of discrete semiconductor devices used for interface to the paper tape punch. The CMOS circuitry offers advantages of low power consumption and high noise immunity.

CIRCUIT DESCRIPTION

The circuitry of the digitizer is constructed primarily on four, forty-four pin edge connected prototyping cards, using wire wrap construction for the integrated circuit components. The analog signal comes in from the microdensitometer via J501 located on the cabinet, past terminal strip D, and onto the prescale/A/D board. Op amp U102A and associated components R101 to 104 form a differential amplifier that will reject any noise that lies between the digitizer chassis and the Ansco chassis, as any common mode input will be greatly attenuated. Inverting amplifier U102B with a virtual ground at pin 6 allows setting the offset desired via the front panel control R501, and front panel control R502 allows setting the desired gain. Amplifier U106A inverts the signal for proper polarity as well as rolling off high frequency noise via C115, while U106B provides active lowpass filtration with its associated component for frequencies in excess of approximately 15 Hz. R121 converts the voltage output of U106B into a current input for the 8700CJ CMOS integrating analog to digital converter. U105 is a monolithic temperature stabilized voltage reference, that contains an on-chip heater and temperature sensing circuit that maintains the reference zener at approximatly 90 degrees C. The zener itself is actually an active circuit, and provides buffering to obtain a low dynamic impedence. The reference voltage is converted into a reference current via R118, and the A/D converter performs a conversion with the convert pin, pin 21 is brought to a logic one level (+5 volts). If the convert pin is held high, as is the case in standby operation, the converter will convert continiously at a rate of approximately 800 Hz. U103 provides a regulated +/- 15 volts to power the op amps, and U104 A and B derive a +/- 5 volts by voltage dividers R112 to R115 and voltage follower buffering to power the A/D converter and the digital logic.

As the stage drive of the microdensitometer is performed with synchronous motors, the clock to determine the digitizer sampling rate is line derived as well. As it was necessary to use non-integer division of the line frequency in order to get sampling intervals in even micrometer intervals, phase locked loop frequency multiplications was used. A reference 60 Hz signal from T502 is clipped and smoothed up with components R201 to R203, CR201 and CR202, and capacitors C201 and C202, and converted into a square wave by Schmitt trigger U202. The free running frequency of phase locked loop U201 is set at approximately 600 Hz, and the signal is divided down by U203 to provide a 60 Hz signal that may be phased locked on the 60 Hz line-derived reference from U202 pin 8. The 600 Hz signal is then divided down to 66.6 Hz by U204 wired as a modulo nine counter, and the resulting signal sent to binary counter U205, and switch SW507 to select between the two lock rates possible with sample rate C. The two highest sampling rates A and B are 8.3 and 4.16 Hz respectively, and are the result of division of the 66.6 Hz input to U205 by 8 and 16, respectively, Sample rate C is the slow speed sampling rate and allows two possible sampling rates. The input to U206 is selected from either the same 66.6 Hz signal that is fed into U205, or from the output of U205 that has divided the signal by four to 16.6 Hz. U206 is wired as a modulo 100 counter, providing either .66 or .16 Hz when sample rate C is selected. Power is supplied via an on-board voltage regulator, and it may be noted that the auto mode control signal from the control bvoard makes use of left-over gates on the hex Schmitt trigger chip U202.

The control board accepts signals from the clock board and the front panel controls, and controls the operation of the A/D converter and the paper tape interface board. The mode select switch on the front panel, SW503, selects between a logic zero state forcing the digitizer into a standby mode, a logic one state forcing the digititzer into the data gathering mode, or the automatic mode where the digitizer state is determined by the presence or lack of presence of line voltage on the ac auto input. If line voltage is present, the auto signal will go to a logic one, and if the signal is absent, a logic zero. This is accomplished by driving optoisolater U301 with the ac signal that has been rectified by CR301 and dropped in voltage by R301. The output of U301 is lowpass filtered and sent to the Schmitt trigger U202 for conditioning. When the digitizer is in the standby mode the advance button is activated via U303 and the A/D converter is given a logic one signal from U302. When the mode signal goes to logic one, the advance button is deactivated as is the single sample one shot U305B. At the same time, clock pulses at the selected frequencies are gated through U302A into the convert one shot U304A which causes the A/D converter to be given a pulse and start conversion, as well as triggers one shot U305A which supplies the punch enable pulse to the punch interface board. The punch interface board will pulse those punch magnets that correspond to a logical one signal from the A/D converter when the punch enable is pulsed by U305A. At the same time, the advance magnet is also pulsed, being pulsed simultaneously with the data bits (if any) that are logic one from the A/D converterand are being punched onto paper tape. In the standby mode. is is possible for the advance input to the punch interface board to go to a logic one, which will cause the advance magnet to be energized continuously and the paper tape punch to advance at the maximum rate of about twenty cycles per second, as long as the advance buton on the front panel remains expressed. Under these conditions, only the advancing hole will be puched onto the paper tape, and none of the data holes will be punched. The punch magnets are driven by a CMOS buffer and emitter follower stage consisting of U404 and half of U405, and small signal transistors Q401 to Q409, with current limiting resistors R401 to R409 saturating the high voltage switching transitors Q410 to Q418 that actually drive the punch magnets themselves. The high voltage switching transistors are protected from inductive transients at the end of the punch pulse by clamping diodes within the punch itself. The punch interface card also acts as the display interface, and the front panel LED's are driven directly by CMOS buffer chips U405 and U406 with current limiting resistors R410 to R417. The front panel LED's therefore display the output of the A/D converter continuously.

TROUBLESHOOTING SUGGESTIONS

In the event that it is suspected that there is some type of problem with the digitizer, the following procedure is recommended. First, ensure that the problem is actually with the digitizer, and that the digitizer is supplied with ac power and a signal from the microdensitometer. Next, it is suggested to check the fuses, as all are accessible on the rear of the chassis with the rack cover removed. If a problem persists after making these simple checks, is is suggested to attempt to isolate the problem as much as possible before proceeding. If the front panel LED's indicate the A/D converter is functioning correctly, but no paper tape is punched, this would suggest the problem would lie with the control board, the clock board, or the punch interface board, a well as being a problem potentially in the paper tape punch, its connecting cable, or power supply, If the single sample button will cause the punch to punch a data point onto paper tap this would narrow things down to the control board or the clock board, If even further investigation shows that the problem exists for some, but not all of the available clock freqencies as selected by the sampling rate selector, this would indicate that problem is with the clock generator or selector switch. If it appears that the problem involves the paper tape punch, it would be wise to consult the Friden manual for the punch. It would also be advisable in the case of apparent punch trouble to do what ever is possible to make sure that the punch is getting line voltage and magnet driver voltage before disassembling the digitizer itself. Factors such as a loose connector could be the only problem.

If the above mentioned do not uncover the difficulty, its most likely the easiest to trace the signal through the offending area by removing the digitizer chassis. This may be done in the following steps: 1) remove line cord, 2) disconnect the Cannon connector from the digitizer chassis as accessed from the floor of the punch compartment, 3) remove the rear panel, 4) remove the line cord and connections to the neutral (lower) terminal of terminal strip A that goes to the power supplies down below, and the chaff blower above, 5) remove the shielded lead that connects to terminal strip D, 6) remove the ac auto in connections (if made) and the switched power connections to the chaff blower on terminal strip B, 7) remove the power supply connections to terminal strip C, 8) remove the screws that secure the chassis to the rack on the front panel.

The chassis may now be withdrawn from the front and the top cover removed to gain access to the electronics. At ths point it would be wise to visually inspect the circuit boards visible. This procedure may be particularly helpful if previous investigations have narrowed down the possible plasce the problem is likely to be in. In the event that the problem has still not been located, it is possible to jumber the connections to the digitizer, and plug the paper tape punch back into the digitizer. If the problem has appeared to be an analog one, a signal may be introduced in the input, and traced through the prescale system stage by stage. If the problem is thought to be a digital one, then the digitial signals may be readily traced through the system, begining with the 60 Hz reference input to the clock circuit, through the phase locked loop multiplication up to 600 Hz, and division back down again to form the various sample frequencies. From that point, the timing signals would be traced through the train of one shots to the A/D converter and the punch interface card. At this point it would be easy to check for proper operation of the mode control and advance button. The collector voltages on the drive transistors may also be scoped, to ensure that power is being delivered to the punch magnets.

In any trouble shooting effort is will be helpful to reference the circuit description section, as well as the schematics and interconnect information is appendix A, and the basic timing diagrams in appendix B.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

In conclusion, an electronic interface has been designed and constructed to digitize the density output of the Ansco Model 4 microdensitometer in use in the Photographic Science and Instrumentation department at the Rochester Institute of Technology. The digitizer that has been constructed allows the storage and later machine reading of microdensitometer data on punched paper tape. This method, although low in cost, allows easy data acquisition by students, provides a permanent record of the data gathered, and reduces by two orders of magnitude the present manual method of entry of microdensitometer data into the RIT Xerox Sigma 9 computer. The digitizer has met the objectives of adequate digitization accuracy with an eight bit binary data representation format, and the need for flexible data gathering within a range of 20,000 samples per millimeter down to 0.125 samples per millimeter should the need arise.

RECOMMENDATIONS

With the hardware capability of digitized microdensitometer traces a reality, it may be suggested that this is just really the beginning of what might be done. If this resource is to be used most wisely however, it suggested that careful thought and planning go into the efforts in software endeavors that others are surely to follow with. Certainly without exception, the field of software stands alone for the number of times the wheel has been reinvented. This is not to say that there is no educational value in reinventing the wheel, but rather, to look at the other side of the coin, who can say what great discoveries are being passed by? It is hoped that this project will do more than allow old style thinking to be carried out in a more abrupt fashion. It is hope that the capability to digitize microdensitometer data more easily will act as a catalyst toward both greater understanding and use of the capability. Increasingly, the most useful tool for the scientist and engineer is software, and with these thoughts in mind, I would like to present some simple challanges to the advanced or curious student.

PROBLEM 1: Ansco Microdensitomer Noise

As mentioned earlier, there exists a +/- 0.01 density unit noise in the signal coming out of the Ansco microdensitometer itself. The noise is at line frequency and hence is not a problem when data is gathered with the chart recorder. The digitizer can digitize data quickly enough to see this noise under some circumstances. The 60 Hz noise may be completely eliminated by sampling at either of the two slower sample rates, C-1 and C-2. This is because both of these sampling rates are at integer numbers of line cycles. Although the density range of the noise is small, it is possible it might affect calculations such as power spectrum determinations. But perhaps there is salvation after all. The noise is synchronized with the sampling rate (both are tied to line frequency), and repeats with a frequency of every five samples. If the microdensitometer stage is stationary, and a reference sample of the noise is taken, it might be possible to then start the microdensitometter, and take the effect of the noise out for a long trace. As a check, the stage would be stopped before the digitizer, to see if 'phase lock' has been maintained. It might also be possible to ignore the effect of the noise on the data until the data is in the frequency domain. and take the noise out at that time. Either method would allow data gathering over ten times the rate of the slower sampling rate, and would be quite a time saver. Also of interest would be to determine under what circumstance could the amount of noise present be tolerated, or not even show up at all, for various types of measurements, such as edge analysis MTF, granularity, etc.

PROBLEM 2: Interactive Image Analysis Software Package

A far different kind of problem exists when writing a computer program that is fully idiotized, does the most often desired image analysis problems, yet is small enough to fit in a 20Kword (32K?) computer account. This is basically a task that involves knowing as much about what to leave out, as it does about what to include. The most difficult part of the task however, is to approach the student in a manner somewhat akin to a programmed learning environment, where the students are encouraged to go further on their own, rather that being frustrated and confused by too many bells and whistles, or hampered by a relatively rigid approach to data analysis. The proper approach would help the student learn as much as possible from the data gathered on the microdensitometer, by going through the analytic procedures with the student, rather than for the student.

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BIBLIOGRAPHY

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4. Friden Inc.: Paper Tape Punch Service Manual

APPENDICES

APPENDIX A

SCHEMATICS AND INTERCONNECT INFORMATION

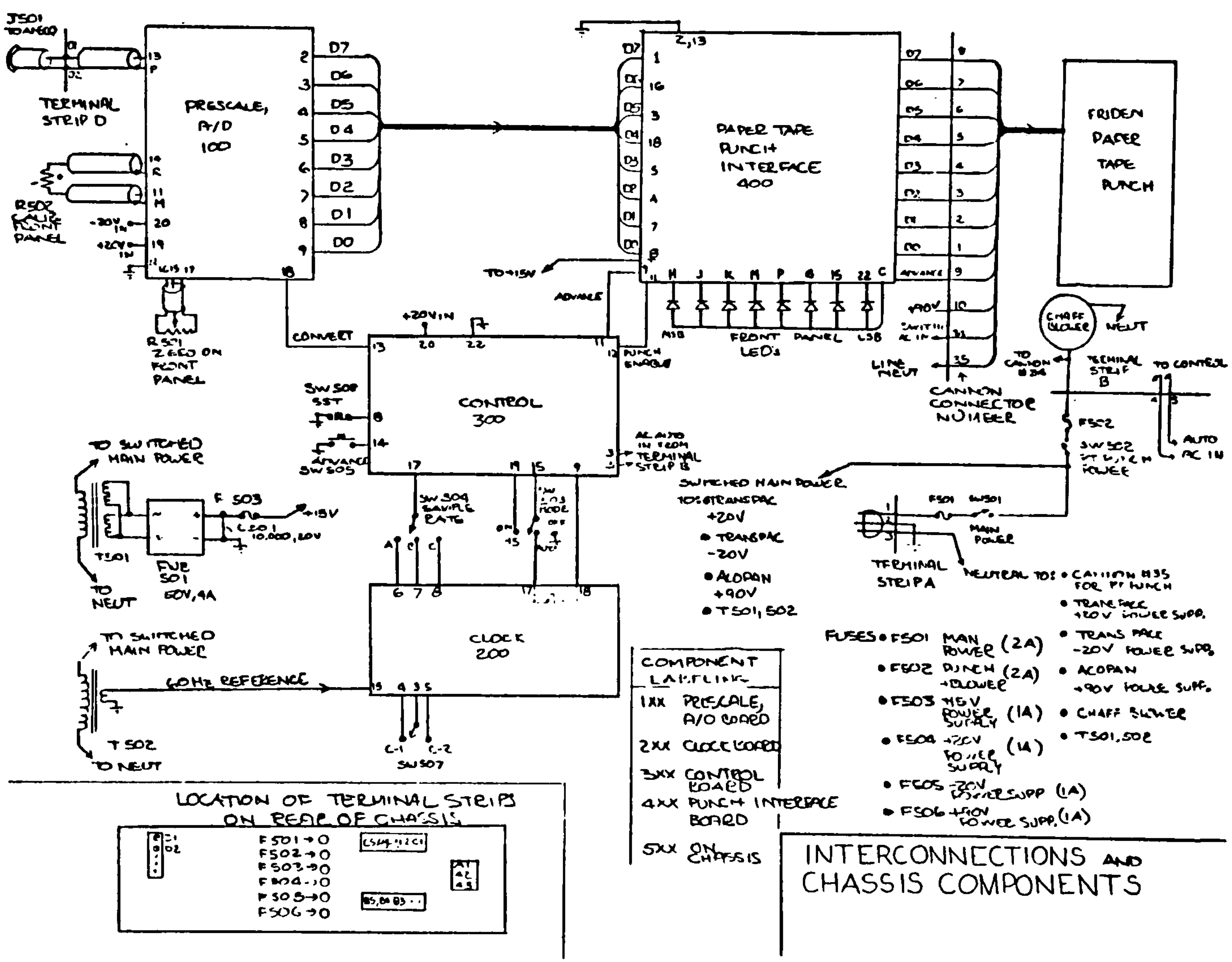


FIGURE 1 Interconnections and Chassis Components

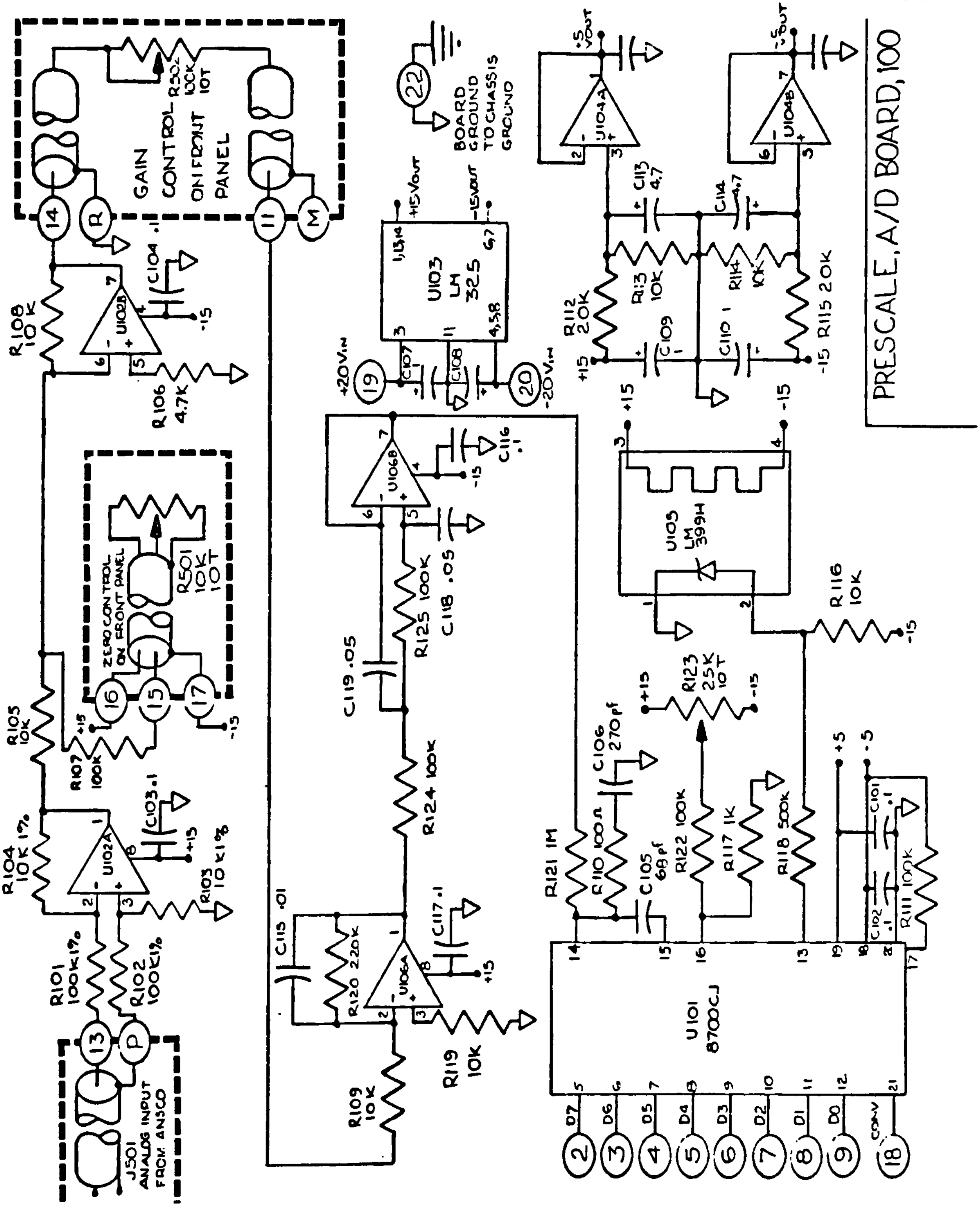


FIGURE 2 Prescale, A/D Board Schematic

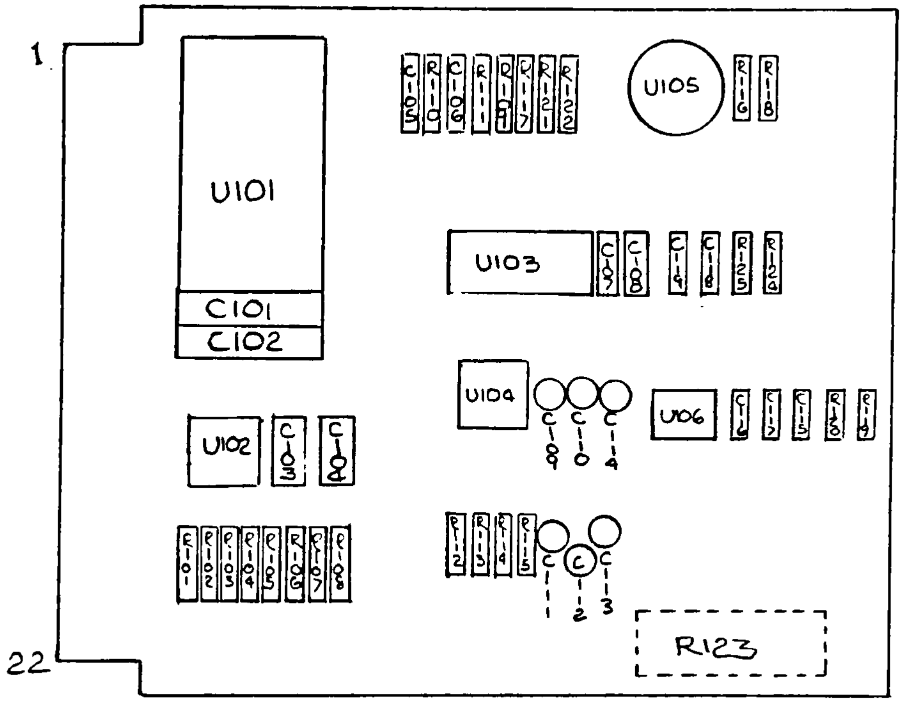


FIGURE 3 Prescale, A/D Components Location

PRESCALE, A/D BOARD

EDGE CONNECTIONS

A		1	
B		2	D7 out to (4/1)
C		3	D6 out to (4/16)
D		4	D5 out to (4/3)
E		5	D4 out to (4/18)
F		6	D3 out to (4/5)
H		7	D2 out to (4/A)
J		8	D1 out to (4/7)
K		9	D0 out to (4/8)
L	KEY	10	KEY
M	ground(shield for 11)	11	analog in from R502, gain cntl
N		12	
P	analog input, coax shld	13	analog signal in from Ansco
R	ground(shield for 14)	14	analog output to R502
S		15	zero input from R501
T		16	+15v out to R501
U		17	-15v out to R501
V		18	convert input from (3/13)
W		19	+20v in
X		20	-20v in
Y		21	
Z		22	ground in

TABLE 1 Prescale, A/D Board Edge Connections

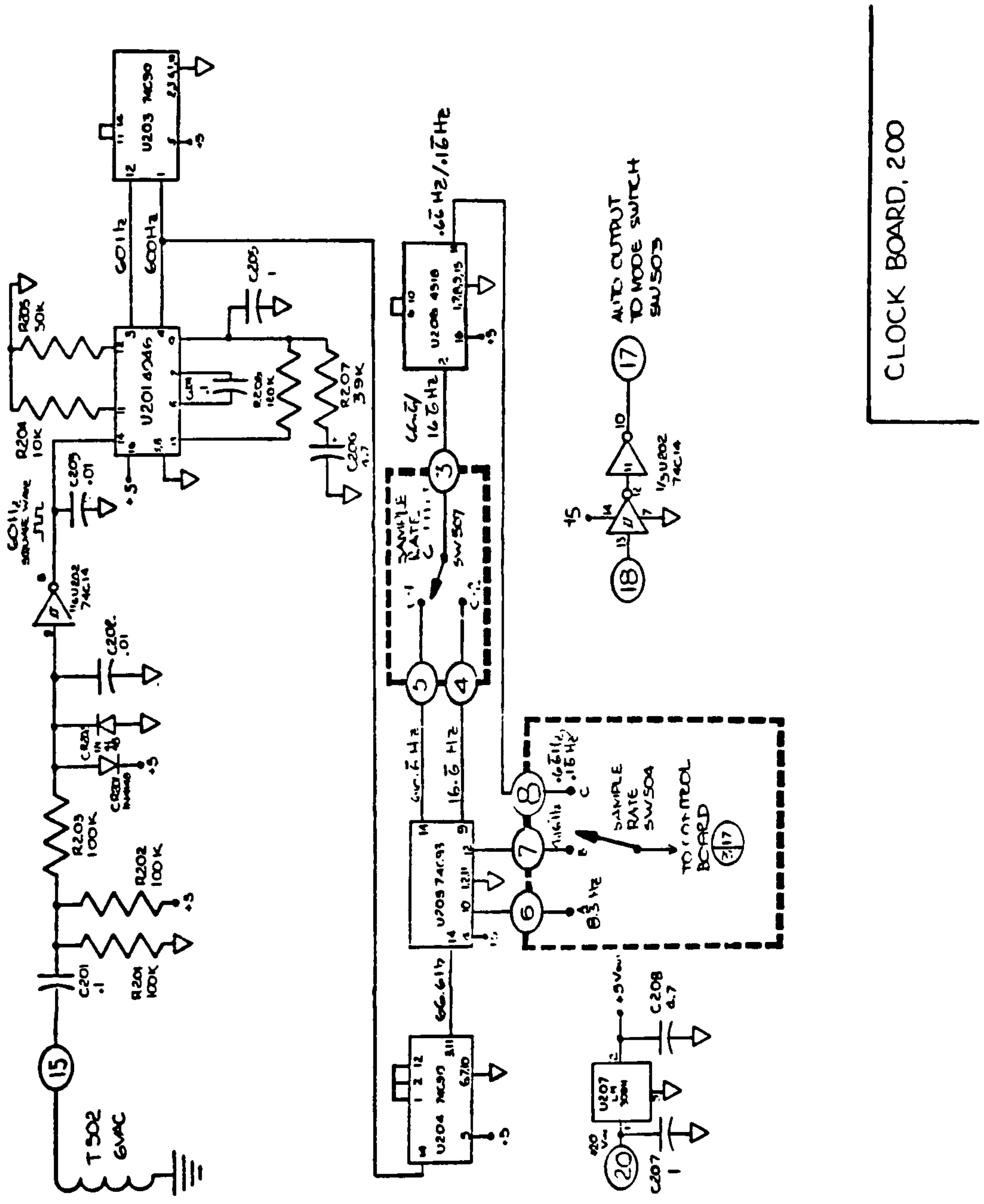


FIGURE 5 Clock Board Schematic

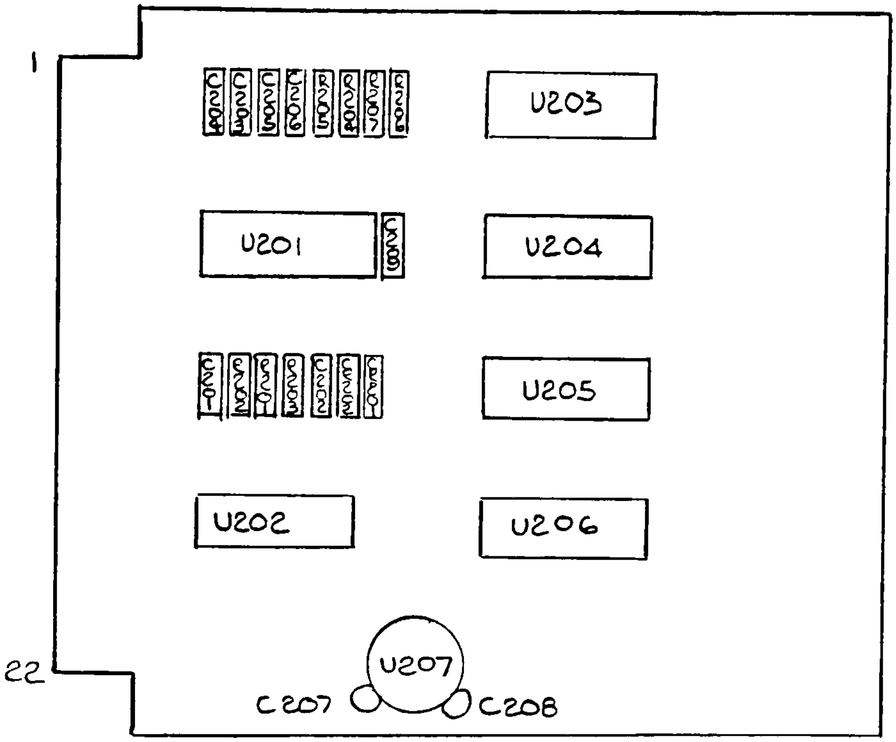


FIGURE 5 Clock Board Components Location

CLOCK BOARD

EDGE CONNECTIONS

1	
2	
3	clock in from SW507
4	66.6 Hz out to SW507
5	16.6 Hz out to SW507
6	clock A out, 8.33 Hz to SW504
7	clock B out, 4.16 Hz to SW504
8	clock C out, 0.66, 0.16 Hz to SW504
9	
10	
11	
12	
13	KEY
14	
15	60 Hz input from T502
16	
17	auto output to SW503
18	auto input from (3/9)
19	+5 volt out
20	+20 volt in
21	
22	ground in

TABLE 2 Clock Board Edge Connections

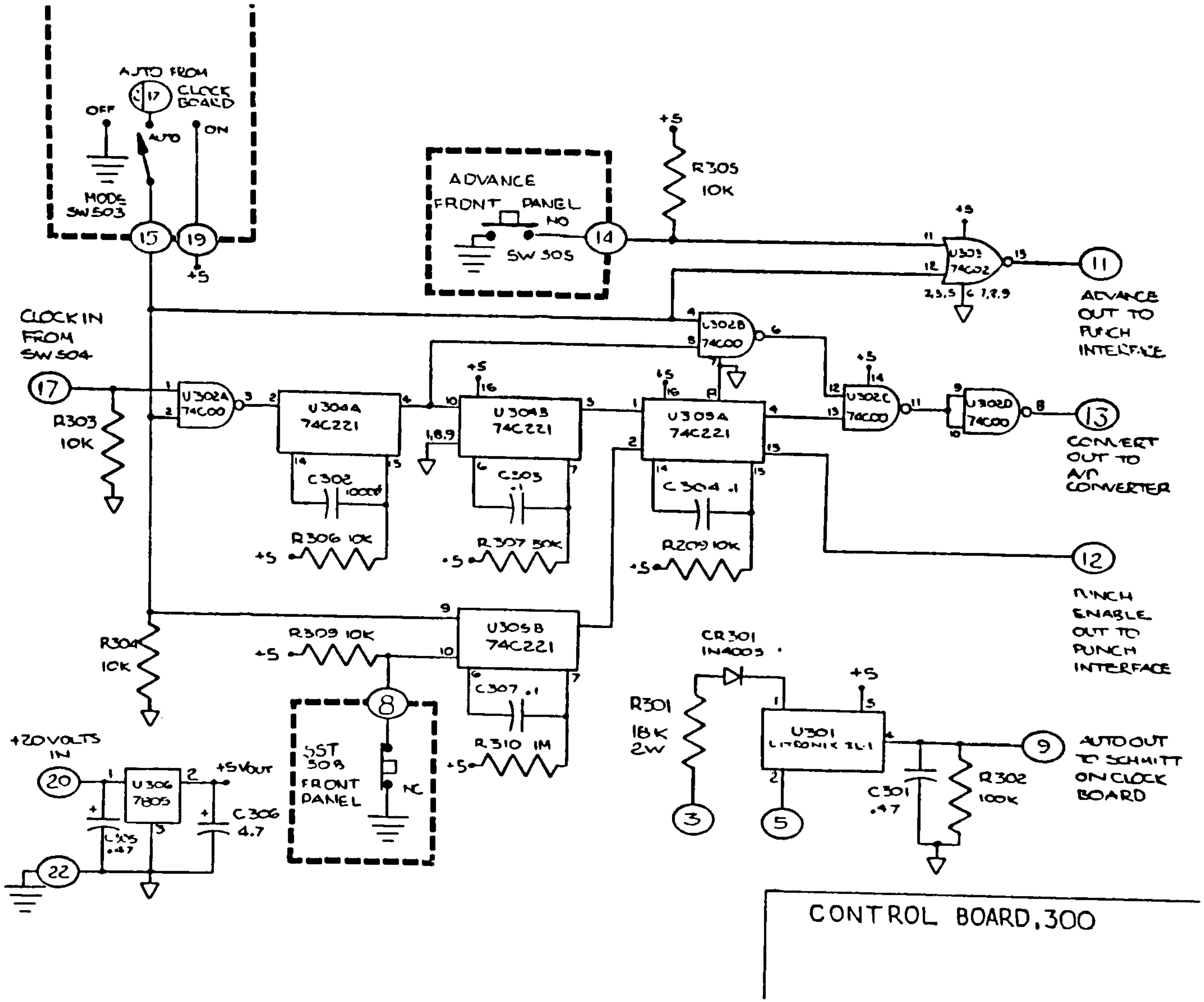


FIGURE 6 Control Board Schematic

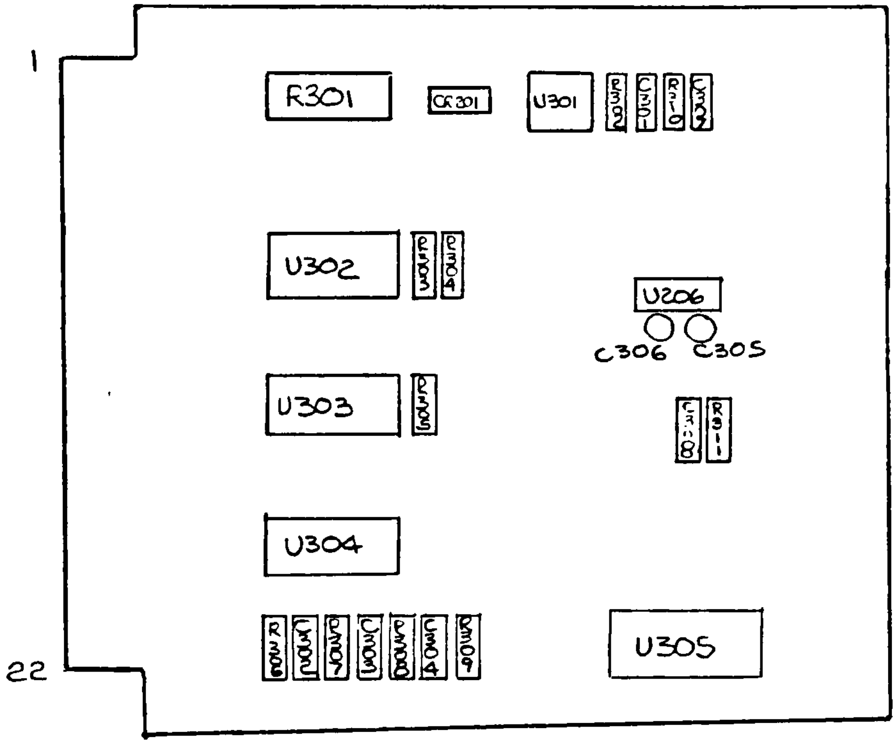


FIGURE 7 Control Board Components Layout

CONTROL BOARD

EDGE CONNECTIONS

1	
2	
3	AC in (auto mode function)
4	
5	AC in (auto mode function)
6	
7	KEY
8	single step in from SW508
9	auto out to (2/18)
10	
11	advance out to (4/9)
12	punch enable out to (4/11)
13	convert out to (1/18)
14	advance in from SW505
15	mode in from SW503
16	
17	clock in from SW504
18	
19	+5 volts out to mode switch SW503
20	+20 volts in
21	
22	ground in

TABLE 3 Control Board Edge Connections

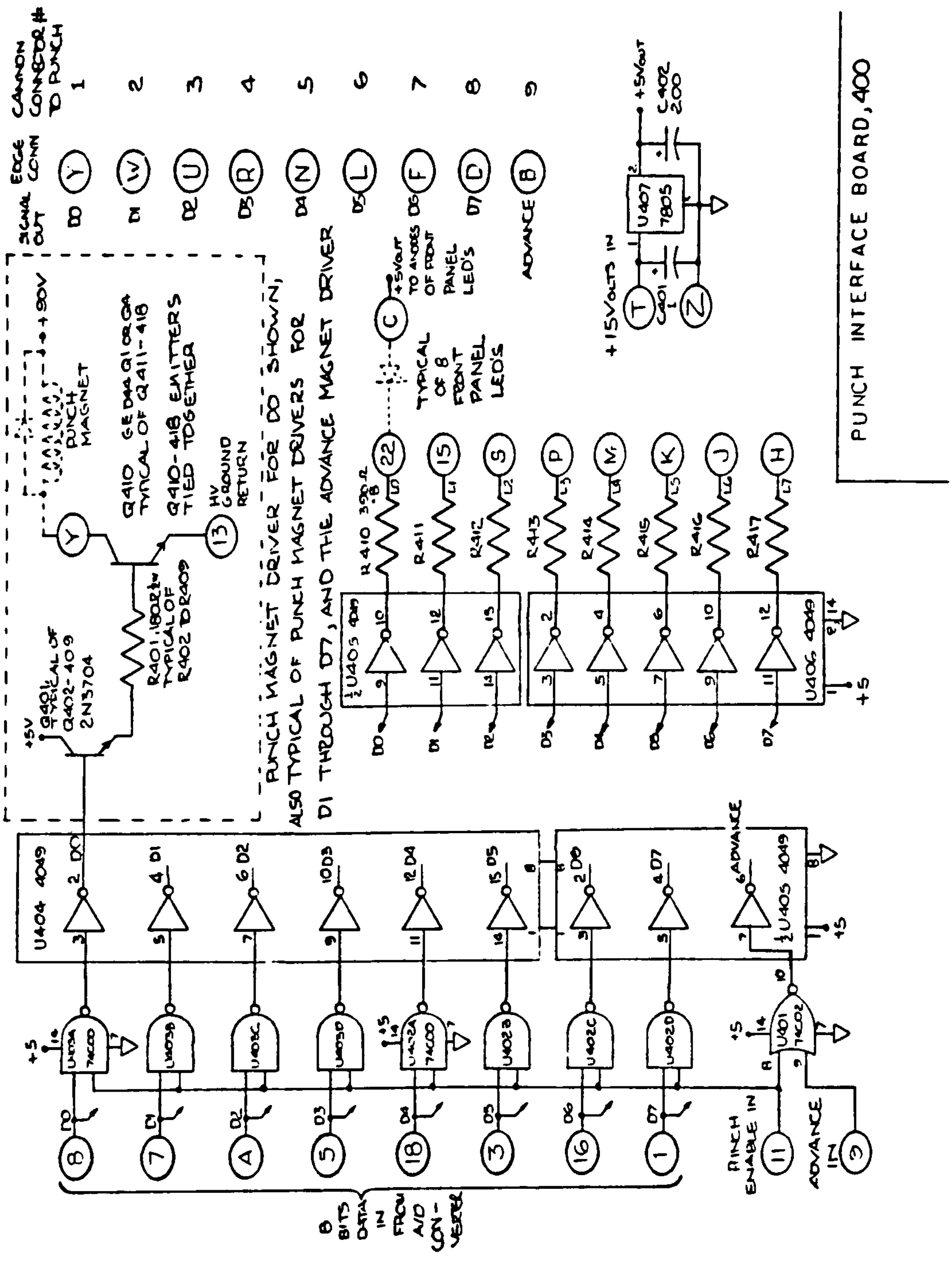


FIGURE 8 Punch Interface Board Schematic

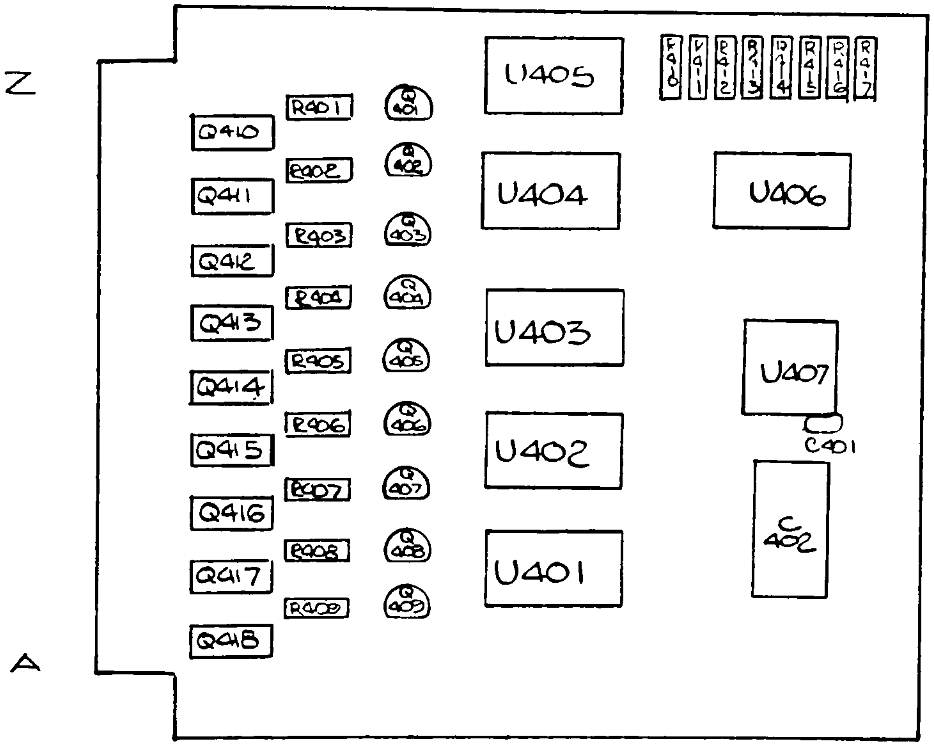


FIGURE 9 Punch Interface Board Components Location

PUNCH INTERFACE BOARD

EDGE CONNECTIONS

A	D2 in	1	D7 in
B	Advance out to CANNON #9	2	
C	+5 volt out	3	D5 in
D	D7 out to CANNON #8	4	
E		5	D3 in
F	D6 out to CANNON #7	6	
H	L7 to FRONT PANEL LED	7	Dl in
J	L6	8	D0 in
K	L5	9	Advance in from (3/11)
L	D5 out to CANNON #6	10	
M	L4	11	Punch enable from (3/12)
N	D4 out to CANNON #5	12	
P	L3	13	H V ground return
R	D3 out to CANNON #4	14	
S	L2	15	Ll
T	+15 volt in	16	D6 in
U	D2 out to CANNON #3	17	
V		18	D4 in
W	Dl out to CANNON #2	19	
X	KEY	20	KEY
Y	D0 out to CANNON #1	21	
Z	Logic ground out	22	L0

TABLE 4 Punch Interface Board Edge Connections

APPENDIX B

TIMING DIAGRAMS

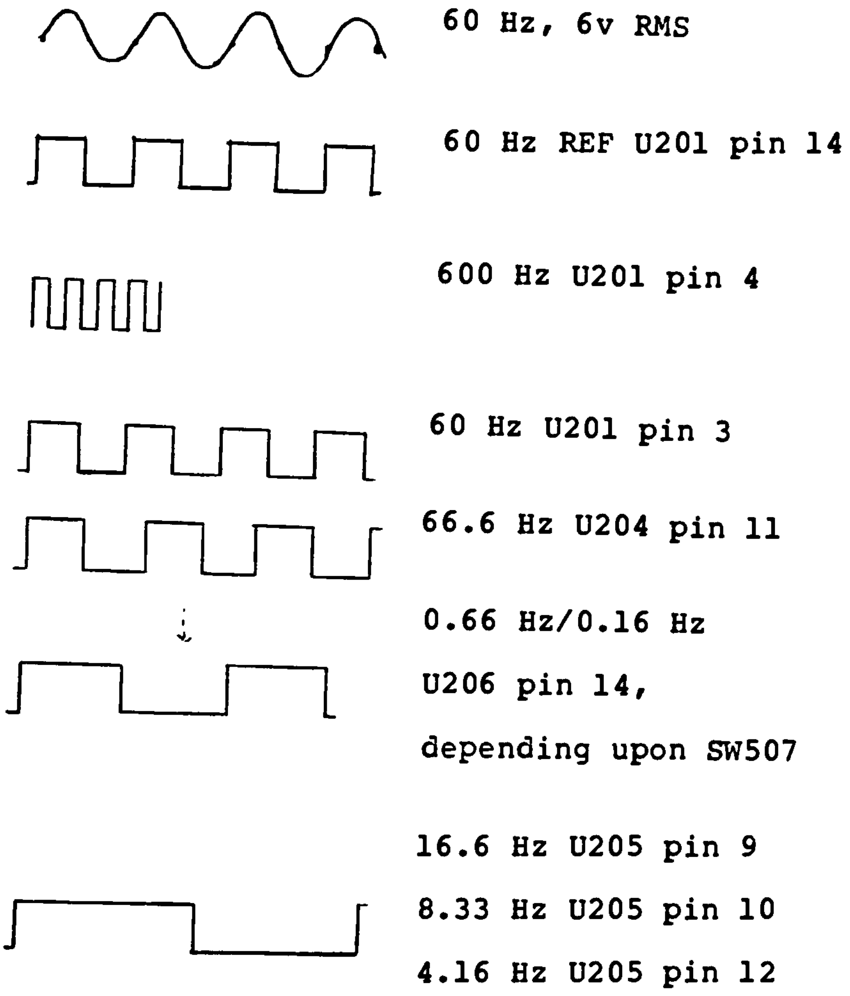


FIGURE 10 Clock Circuit Timing Diagrams

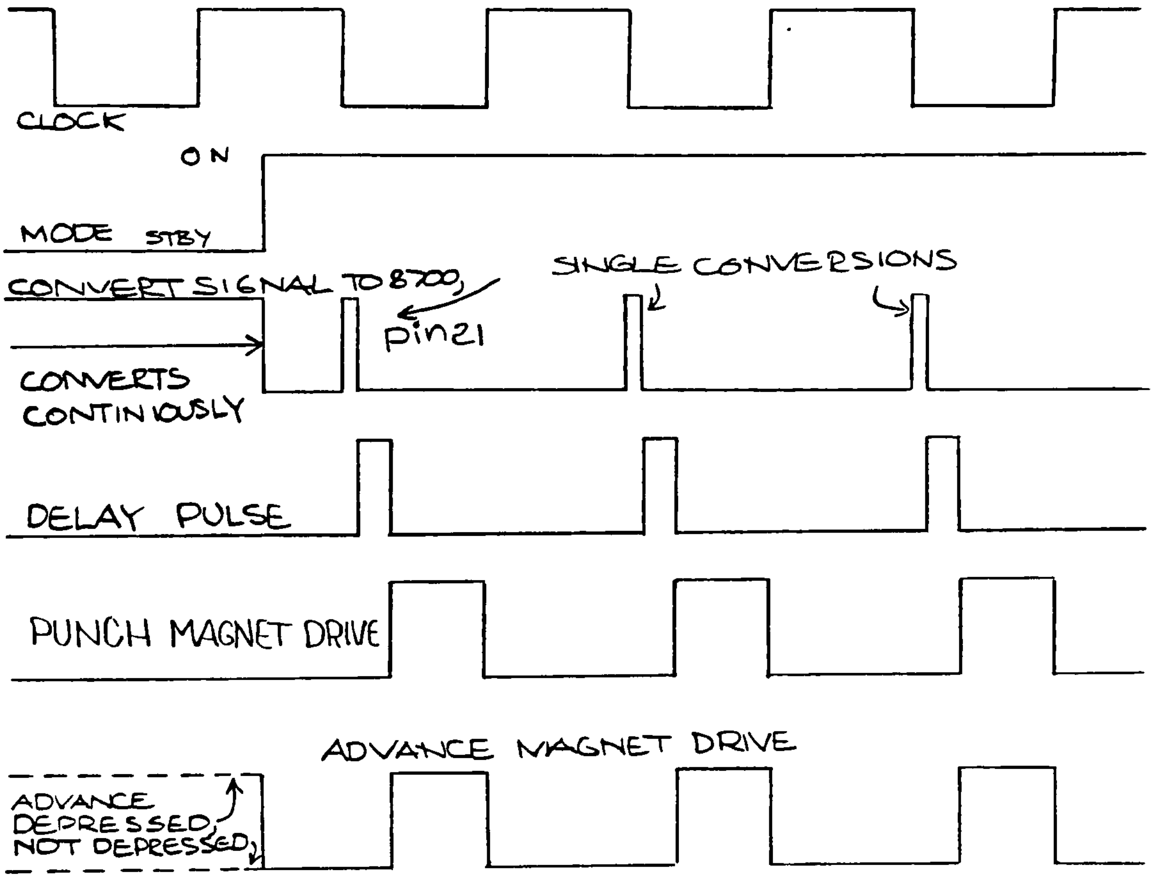
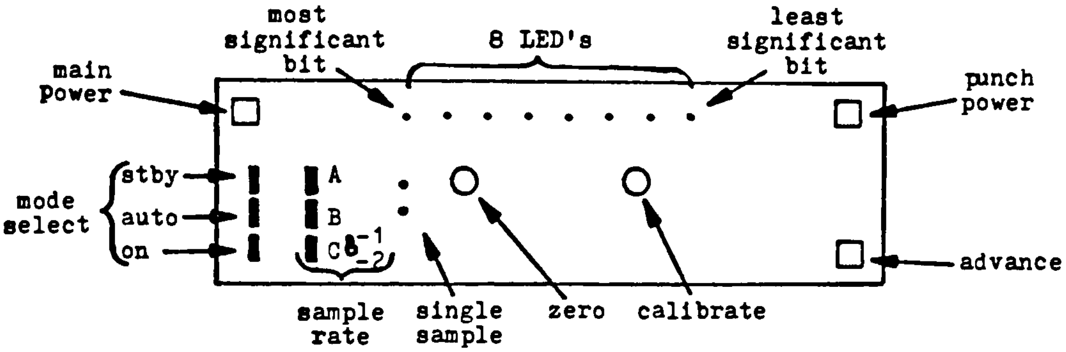


FIGURE 11 Control Circuit Timing Diagrams

APPENDIX C

OPERATORS MANUAL

FRONT PANEL EXPLANATION



MAIN POWER - removes all power from the digitizer when turned off

PUNCH POWER- allows turning off punch power with electronics still on

MODE SELECT- selects one of three modes:

1) standby
2) auto- digitizes and punches paper tape automatically as long as the microdensitometer stage is in motion
3) on - digitizes and punches paper tape independently of microdensitometer stage status

SAMPLE RATE

The three pushbuttons and toggle switch select the number of times per second the digitizer samples the microdensitometer density, and punches that density onto paper tape. sample rates A and B, the two top pushbuttons, are used for higher speed digitizing; sample rate C is used for slow sped digitizing, when the toggle switch next to C is in the up position, a sample will be taken once every small division on chart paper with 20 div/in, and 2 in/min of chart drive speed. When the toggle switch is in the down position, a very slow sample rate of once every 6 seconds is selected, for step table digitizing, etc.; the position of the toggle switch does not affect sample rates A or B.

EIGHT LEDs

The LEDs display the output of the A/D converter continuously, and functions as a 'binary digital densitometer'. It will thus appear to read density continuously. During either 'auto' or 'on' sampling modes, the LEDs will be updated with a new binary density value only once per sample actually punched onto paper tape.

ZERO and CALIBRATE

The zero and calibrate knobs are used to determine the desired maximum densitty and the desired minimum density that the digizer will digitize. The maximum density will be recorded as a binary 11111111, making all the LEDs light, and punching eight data holes on the paper tape. The minimum density will be recorded as a binary 00000000, making all the LEDs go out, and punching no data holes in the paper tape. (note: a ninth hole, used to advance the paper tape, is always punched. It is smaller in diameter than the data holes).

SINGLE SAMPLE

The single sample button causes the current output of the A/D converter to be punched onto paper tape. The single sample feature should be used only when the data is not changing with the digitizer in the standby mode.

ADVANCE

When the digitizer is not sampling and punching data (anytime in the standby mode, or when paused in the auto mode), depressing the advance button will cause the paper tape punch to advance producing a leader with no data holes punched (the same as the lowest density value digitizable).

How to Pick the Digitizer Clock Rate You Want. (How the different clock rates differ)

Clock Rates A and B

Clock rates A and B are used when high speed sampling is desired. The chart recorder may be used to monitor progress of the trace, or not used at all.

Clock Rate C-1

Clock Rate C-1 is used to provide a sampling rate of one sample per small division of chart recorder paper,(20 divisions/ in paper, 2in/min chart recorder speed).

Clock Rate C-2

Clock Rate C-2 is used for slow speed samplng, eg, to digitize a step wedge.

EXAMPLE OF HOW TO DIGITIZE A MICRODENSITOMETER TRACE

I How to turn digitizer on

1. Set mode select pushbutton to 'stby' (uppermost pushbutton of left row of buttons).
2. Turn 'main power' switch on (illuminated pushbutton in upper left corner).
3. Turn 'punch power' switch on if it is not already on (illuminated pushbutton in upper right corner).

NOTE: It is not possible to harm digitizer by using a different sequence of turning on switches, the above sequence is merely suggested to avoid the confusion of the paper tape beginning to punch as soon as power is applied.

II How to zero and calibrate digitizer

Supose we want the digitizer to digitize densities from 0 (lowest density) to 4 (highest density).

1. Adjust sample position and/or lamp voltage so that the Ansco chart recorder reads 0.00 density units.
2. Adjust the digitizer 'zero' knob, until all the LED's on the digitizer front panel just go out.
3. Adjust sample position and/or voltage so that the Ansco chart recorder reads 4.00 density units.
4. Adjust the digitizer 'calib' knob until all the LED's

just light up.

III How to select a sample rate

Suppose we want to sample at a rate where one sample is taken every small division of the chart recorder paper. For this purpose we will then limit ourselves to those sampling rates obtainable with digitizer clock rate C-1.

1. Select digitizer clock rate C-1, by depressing clock rate pudhbutton C, (the bottom button of the right hand row of pushbuttons) and by positioning the toggle switch next to button C, in the '-1' position. (up)

NOTE: The position of the toggle switch does not affect clockrates A and B.

2. The Ansco stage speed we select will now determine how many samples per millimeter will be digitized and punched onto paper tape. By consulting the table inside the front cover, we decide on an Ansco stage speed of .1mm/min providing 400 samples per millimeter, as being adequate for our purposes.

lV Digitizing the Trace

1. Depress the 'advance' button, to put a leader on the paper tape.

2. Start the digitizer digitizing, by selecting the 'on'mode (the middle pushbutton of the left hand row of pushbutons).

3. Start making the trace with the Ansco as would normally be done if the digitizer were not being used.

4. When the trace is finished, stop the digitizer by returning the mode switch to the 'stby' position. (upper button of left hand row of pushbuttons).

5. Depress the 'advance' button again to put a leader on the other end of the paper tape.

6. It is suggested to identify the paper tape at this time by making notations on leader. This will help avoid confusion later.

```
     ∇ READIN;CHARLIST;CHAR;NUMBER
[1]    S∆READIN←1 2⍴DONE,100
[2]    CHARLIST←2∓0,⍳255
[3]    ⍎')SET ⍞ IN UC;BIN;DRC;SIZE=1'
[4]    'OUTPUT FILE'
[5]    ⍎')SET ⎕ OUT DC/',⍞,';BCD;NODRC'
[6]    READ:CHAR←⍞
[7]    NUMBER←¯1+CHARLIST⍳CHAR
[8]    ⎕←'I3'∆FMT(NUMBER)
[9]    →READ
[10]   DONE:'ALL DONE'
     ∇
```

Above is a listing of the APL function Readin, that accepts data from the paper tape in the binary direct mode, and places it in a data file named by the user. In the example below, the characters typed by the computer are underlined. Shown below, the workspace named READ.

```
!APL
APL DO4
Clear WS
       )LOAD READ
READ    SAVED    22:15 AUG 15,'78
       READIN
OUTPUT FILE:  EDGE 1
ALL DONE
       )OFF HOLD
!
```

Shown above, the workspace READ is loaded once in APL, and the function READIN in that workpace is executed by typing the function's name. When the function is executed, it prompts the user for the data file name that the data from the paper tape will be placed in. After the file name has been typed in, followed by a carriage return, the paper tape may be read in by pushing the control lever on the paper tape reader to start, and halted by moving the control lever to stop. After the data is read in, the function execution is terminated by depressing the break key followed by any ASCll key (for example ';'), and the computer responds by typing 'ALL DONE'. It is then possible to get back to the executive system by typing)OFF HOLD. The present version of the CP-V operating system is not completely transparent to the number 190 in decimal, representing the lost data command in EBCDIC. Thus, until this bug in the operating system is fixed, it is suggested to scale the data so as not to include this value.

Available Sampling Rates

Ansco Stage Speed in mm/min	Digitizer Clock Rate	Sample Rate in samples/mm	Sample Period in mm
.025	A	20,000	.05
.025	B	10,000	.1
.1	A	5000	.2
.1	B	2500	.4
.25	A	2000	.5
.025	C-1	1600	.125
.25	B	1000	1
1	A	500	2
.1	C-1	400	2.5
1	B	250	4
.25	C-1	160	6.25
4	A	125	8
.1	C-2	100	10
4	B	62.5	16
10	A	50	20
1	C-1	40	25
.25	C-2	40	25
10	B	25	40
4	C-1	10	100
1	C-2	10	100
80	A	6.25	160
10	C-1	4	250
80	B	3.125	320
4	C-2	2.5	400
10	C-2	1	1000
80	C-1	.5	2000
80	C-2	.125	8000

APPENDIX D

QUANTIZATION EFFECTS

QUANTIZATION EFFECTS

The digitization of the microdensitometer results in the introduction of quantization error that is related to the number of bits used in the digitization. Ideally, one would like to use a large number of bits in the digitization, and make the noise contribution from quantization approach zero. Practical considerations suggests that more than a reasonable number of bits will not make a significant contribution to the accuracy with which microdensitometer traces may be digitized, but may result in a system that offers significantly lower performance in terms of the rate of data gathering, the storage efficiency, and the rate at which communications with the computer take place.

The contribution of quantization noise may be evaluated in terms of its RMS value. An ideally quantized signal is shown in Figure 12-a. The straight line represents the results if no quantization error were present. The staircase is the transfer function of the quantizing system. If no additional loss of accuracy is involved in the digitization, the maximum deviation of the quantized signal from the true signal is plus or minus one

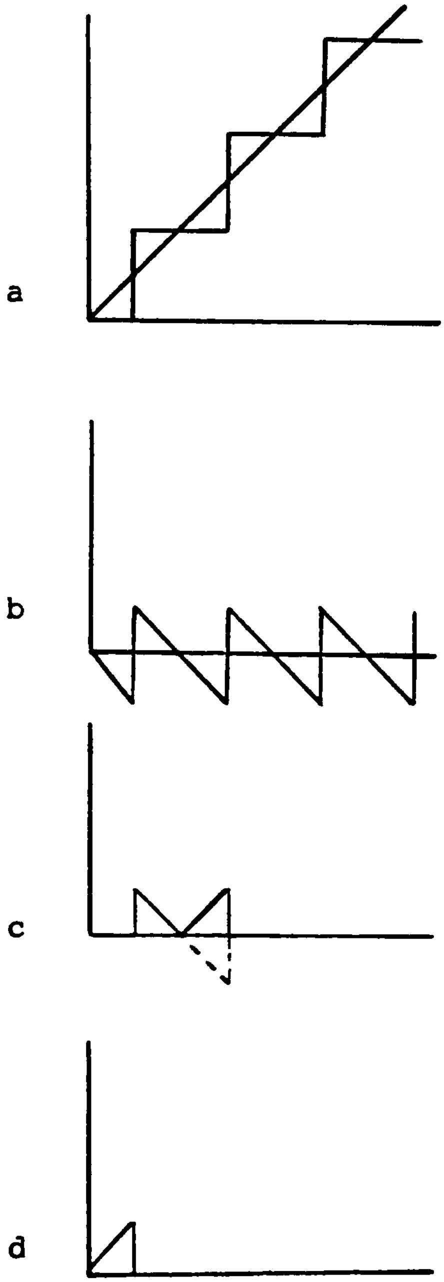


Figure 12 Quantization Effects

half of the quantization level, or plus or minus one half of the level of the least significant bit. If the distribution of voltages that are to be digitized is randomly distributed, then the occurrence of voltages that produce the maximum quantization error is not very large. The difference from the desired signal is shown in Figure 12-b. The RMS value of this waveshape is independant of sign, and is constant over an integer number of cycles, and can therefore be redrawn as shown in Figure 12-c. As both halves of the waveshape are equivalent the evaluation of the second half only, as shown in Figure 12-d is allowable. The RMS value of a function is determined by taking the square root of the mean of the square of the function. The function in Figure 12-d is:

$$Y=X$$

squared:

$$Y=X^2$$

the RMS value of a function is determined by taking the square root of the mean value of the square of the function

$$RMS = \sqrt{(1/L) \int_0^L f^2(X)\, dX}$$

for the function $Y=X^2$:

$$\mathrm{RMS} = \sqrt{(1/0.5) \int_{0}^{0.5} X^2 dX}$$

$$= \sqrt{2 \left[(1/3)\ X^3 \right]_{0}^{0.5}}$$

$$= \sqrt{(2/3)(0.5)^3}$$

$$= 0.289$$

Thus, the RMS value of the noise introduced by quantization is 0.289 times the quantization level. The use of an eight bit word for each data point digitized is very convenient, so the amount of RMS noise introduced by eight bit digitization is of interest. An eight bit system will have two to the eighth, or 256 levels. If a density range of zero to 4.0 is digitized, then the quantization level is 4/256 = 0.0156 density units. The RMS noise associated with quantization is 0.0156 x 0.289 = 0.0045 density units. The Ansco Model 4 microdensitometer has a specified accuracy of +/- 0.02 density units, and has an observed noise of approximately +/- 0.01 density units on the lower end of the scale, towards a density of zero, and a noise of approximately +/- 0.05 density units on the upper end of the scale toward a density of 4.0. The total noise when the quantization noise is added is determined as the square root of the sum of the squares of the two noise sources:

$$\text{net noise} = \sqrt{(\text{micro D noise})^2 + (\text{quantization noise})^2}$$

$$= \sqrt{(0.0156)^2 + (0.0045)^2}$$

$$= 0.0162 \text{ density units}$$

This results in an increase of only about four percent, and may generally be considered negligible. The noise at the upper range of the microdensitometer is much larger, and it is unusual to require the entire density range from zero to four to be digitized. If a smaller range of densities is digitized, then the noise introduced is even less. The use of an eight bit system for digitization of the Ansco Model 4 microdensitometer signal therefore does not excessively degrade the signal with quantization noise.