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AUTOMATED MICRODENSITOMETER

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ABSTRACT

An interface to a Carl Zeiss microdensitometer and the HCL'S micro-computer MICRO 2200 has been built to digitize, log, and process the analog variable density information on photographic plates.

The automated process eliminates the tedious and time consuming reduction procedures of analog records on charts and helps a direct evaluation of intensity from the photographic plates and films for the quantitative analysis of spectrograms.

Key words microdensitometer—interface

Introduction

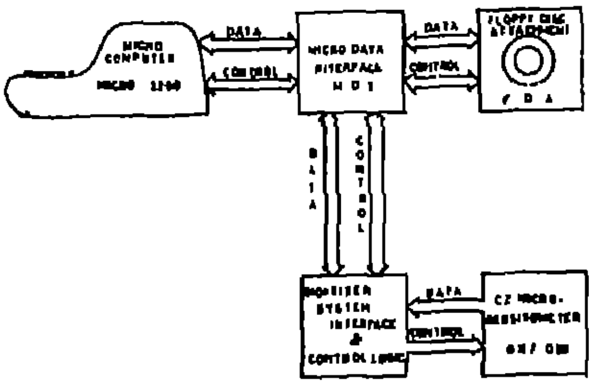
In quantitative interpretation of spectrograms of astronomical objects, the use of microdensitometer for measurements of photographic plates and films is common. The advantage of recording a vast amount of information on photographic plates is largely offset by the difficulty in reducing it to a useable form.

Large computing systems have been generally used for reducing the density information stored on photographs (Lynga and Arinder, 1972) ; (Vasilevskis and Popov, 1971). Some smaller systems have also been developed, but with different interface hardware. A need is often felt for an inexpensive and simple device for digitization and data handling capable of being interfaced with a microcomputer.

In the conventional instruments the density is recorded as deflections on strip charts and then manually digitized and fed into the computer for further analysis. The manual method of digitization is always tedious, time-consuming and error-prone. This paper describes a system built to eliminate the manual method of scaling and computation by automating the process of digitization, logging and computation of the analog variable. The automated system is aimed to increase the speed and efficiency in the reduction of spectrophotometric data from photographic plates and films.

Description of the system

The automated system (Fig. 1) is built around a microdensitometer manufactured by Messrs. Carl Zeiss, Jena. The basic system consists of hardware, the electronic interface circuitry and software application programmes. The hardware consists of a position sensor, a digitizer, a system interface and the control logic, Micro 2200, desk top computer with Microdata Interface (MDI) and floppy disk attachment (FDA).



BLOCK DIAGRAM OF AUTOMATED MICRO DENSITOMETER

Fig. 1

The position sensor is an incremental shaft encoder (ROTASWITCH-826) which gives 500 pulses per revolution with quadrature output and is coupled to a gear directly attached to the table movement screw in the microdensitometer. This arrangement gives one pulse at every 8 microns linear displacement of photographic plate/film. This pulse is the basic clock for the system, and digitization and data transfer at each position is done only on arrival of this pulse.

The digitizer (Teledyne Philbrio 4111-10 A/D converter) is an analog to digital converter (A/D) of 3 digits with BCD output which digitizes the analog voltage from the micro photometer. The output is calibrated such that the zero and the maximum deflection on the chart recorder. Correspond to zero and 99.9 of the digitized output.

The system interface (Fig. 2) is an hand-shake logic that interfaces digitizer and the micro-computer Micro 2200. The interface consists of address latching and decoding circuit, data ready indicator, digits multiplexer and data over signal-generator (Appendix 1). The control logic controls the functions like release/hold of microdensitometer, depending upon the command from Micro 2200.

Operation

1. *Logging deflections to the disc :* The sequence of digitization and data reduction (flow charts 1, 2, and 3) is as follows :

Photographic plate or film is positioned on the micro-densitometer. The programme to log the deflections to disc (sample programme 1) is called from the disk to microcomputer memory and initiated for execution. The microcomputer then asks for the dark level, clear level, number of such levels to be averaged, and length of the plate in millimeters over which the data are to be digitised. Once this is given the micro-computer digitizes the deflections at every linear displacement of eight microns on the plate. As soon as the digitization is over for a given length of the plate, digitization and data logging are stopped and and this is indicated by printing the number "999"

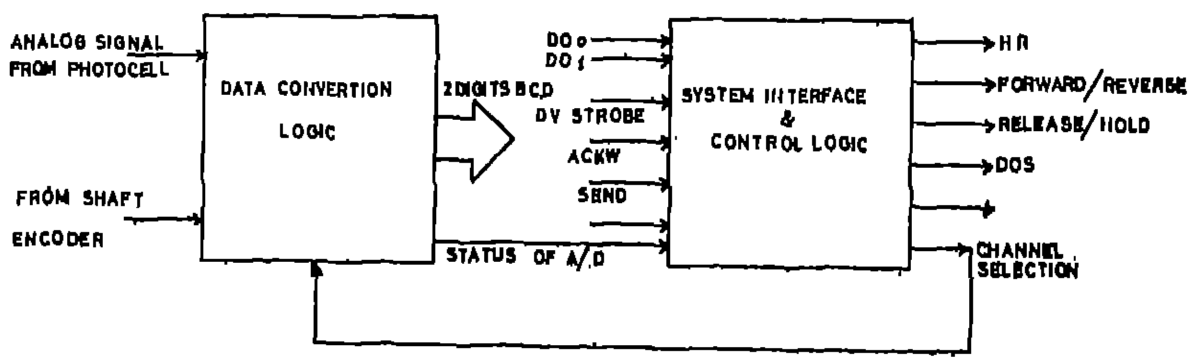


Fig 2

DIGITIZER & SYSTEM INTERFACE

Micro 2200 is a desk-top computer with 2000 programming steps and 200 data registers. MDI is a digital input/output port through which Micro 2200 can interact with the external world. FDA for Micro 2200 is a memory back up and has a capacity of 30,000 programming steps and 3000 data registers.

The software is a collection of application programmes written in BASIC language residing in the floppy disk. The various programmes are, logging deflection to disk, computing density/opacitance, logging calibration, computing intensities and printing out data from disk. These programmes which are kept in separate blocks of the disk, can be called to Micro 2200 for execution and can be linked to other programmes by entering the block number of a particular programme.

on the printer These deflections are stored in the disk.

2. *Computation of Density Opacitance :* For densitometric analysis a few standard parameters are commonly required to be calculated. Transmittance T of a point on the photographic plate is measured from the deflections of the microdensitometer scanning beam corresponding to the intensity transmitted by the region being sampled (I_t), compared to that transmitted by a clear portion of the plate (I_O).

$$T = \frac{I_t}{I_O} = \frac{\text{Deflection} - \text{dark}}{\text{Clear} - \text{dark}}$$

Density 'D' is defined as the logarithm of the reciprocal of transmittance T.

$$D = \text{Log}\left(\frac{1}{T}\right)$$

$$= -\text{Log}\,(T)$$

$$= \text{Log}\, I_0 - \text{Log}\, I_t$$

while the density is the most generally used parameter in the densitometric analysis, the opacitance and the Baker transformed density log ω have found wide-spread applications in astronomical photography (de Vaucouleurs 1968). Opacitance ω is defined as the reciprocal of transmittance minus unity.

$$\omega = \left[\left(\frac{1}{T}\right) - 1\right]$$

The Baker transformed density D_s is thus

$$D_s = \text{Log}\,\omega = \text{Log}\left[\left(\frac{1}{T}\right) - 1\right]$$

The major advantage of these transformations lies in the linearization of the characteristic curve over a large range, especially near the 'toe' at lower densities. The deflections in the disk are converted to density/opacitance by calling the programme "compute density/opacitance" (sample programme 2) For this step, it is necessary to enter the block number of the programme which computes density or opacitance. This programme is brought to the second page of memory, starting from location 1000, and the control is transferred to the programme. As the execution of the programme starts one page of data which is equal to 100 points is transferred from the disk to data memory of the microcomputer. These deflections are converted to density or opacitance as required and transferred back to the same block in the disk, where the deflections were initially stored, and an indication is made on the printer by printing the block number of the page for which computation is over. The computation and transfer to the disk continues for the given length of plate. As soon as this operation is completed for the entire length of the plate the number "888" is printed. This is an indication that the computations are over and the values of density/opacitance are stored in the disk.

3. Computation of intensity : The values of density/opacitance stored in the disk are converted to intensity by calling a programme to compute intensity. This calling is normally done by the programme to compute density/opacitance. For this step, it is again necessary to enter the block number of the programme which computes intensity. This programme is brought to the first page of memory and control is transferred to the programme. The conversion algorithm is based on a third degree polynominal equation, the coefficients A, B, C and D being obtained separately from calibrated plates. As the execution of programme commences, it asks for coefficients which are entered through the keyboard. Once these coefficients are entered and the programme is initiated for execution it will transfer a page of data which is equal to 100 points to data memory. These data which correspond to density/opacitance are now converted to intensity by the algorithm using the coefficients A, B, C and D. Once the intensities are computed for the 100 points the results are again transferred to the block of the disk from where the density/opacitance was brought and the block number for which the computations were done is printed at the printer. The process continues for the remaining length of the plate. As soon as the computation is over for the entire length of the plate it prints out the number '777'. This is an indication that the intensity computation is over and the results are stored in the disk.

4. Printing the data stored in the disk : The data in the disk, which correspond to deflection/density/opacitance/intensity can be printed out (sample programme 3) for any length of the plate by calling this programme. This programme can be called by earlier programmes by merely entering the block number of this programme. Once the programme is initiated for execution, it asks for the number of blocks of data to be printed out. After entering this number, it prints out the data and halts with an indication on the printer.

5. Flow Charts, sample programmes and a list of programmes : Flow charts showing the sequence of operations and sample programmes showing the programming steps used in logging and processing of data are given in Appendix II. Each programme consists of a block number, a calling format, the inputs needed during execution and an indication of the end of the programme steps. These programmes can be linked to other programmes for continuing the computations.

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APPENDIX-I

Micro-computer Interfacing

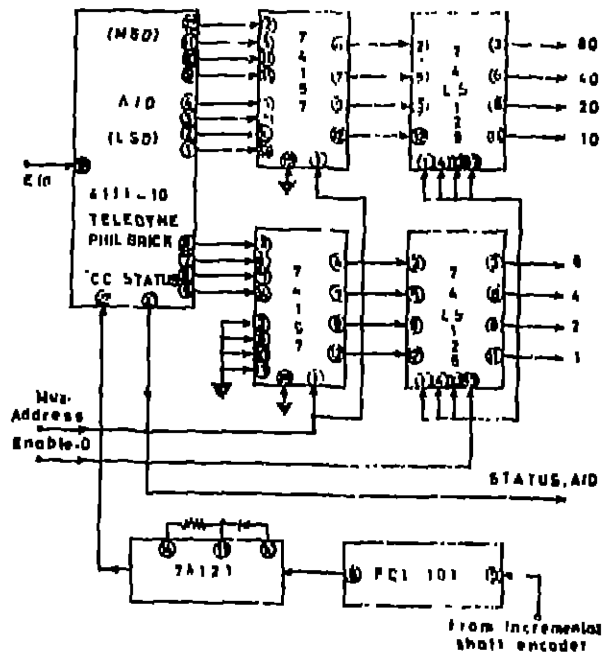
Microcomputer Micro 2200, communicates with peripherals through digital input/output port called as microdata interface (MDI). The peripherals used in this interface are analog to digital converter (A/D), latched output relays and floppy disk drive. When one or more peripherals are connected to MDI, an interface circuitry is required. This interface is necessary to convert the information being transferred, from the peripherals to the microcomputer into a compatible format, and during a reverse transfer to convert the information from the microcomputer into the peripheral format. The basic functions of an interface circuitry are buffering, address decoding or device selection, command decoding and timing and control. Micro-2200 has 8 input lines, 8 output lines, 2 input/output device address lines, 2 interrupt device address lines and 7 control lines. The interface circuitry is classified into two major groups, namely digitizer and system interface which are described with circuit/schematic diagrams

Digitizer

The digitizer is an analog to digital (A/D) converter. (Fig. 3), Teledyne-Philbric 4111-10 of integrating type with conversion time of 2 milliseconds for the fullscale of +10 volts. The analog signal from the photometer is presented to E_{in} of A/D. The sinusoidal signal corresponding to the linear displacement of the plate/film, coming from incremental shaft encoder, is shaped to a T.T.L. pulse by FCL-101, the Schmitt trigger, and is presented to the converting command of A/D through monostable 74121. The 3 digits output of A/D are multiplexed using two 74157, and is presented to data bus of Micro-2200 through two tristate buffers 74 LS 125.

System Interface

The system interface circuitry is described in the following groups, namely control and hand-shake logic, address latching and decoder and motor control circuits (Fig. 4-6). *Control and hand-shake logic* consists of status setting flip-flop (1/2 7473) whose output is "AND" ed (¼ 74 LS09), with output of monostable (74121), triggered from ACKW pulse of Micro-2200, to pull down hardware ready signal to low and synchronous BCD up/down counter to count the number of digits transferred to Micro-2200, and flip-flop (½ 7473) to latch the 'TAKE' signal from Micro-2200 for raising the hardware ready, when outputting data from Micro-2200.

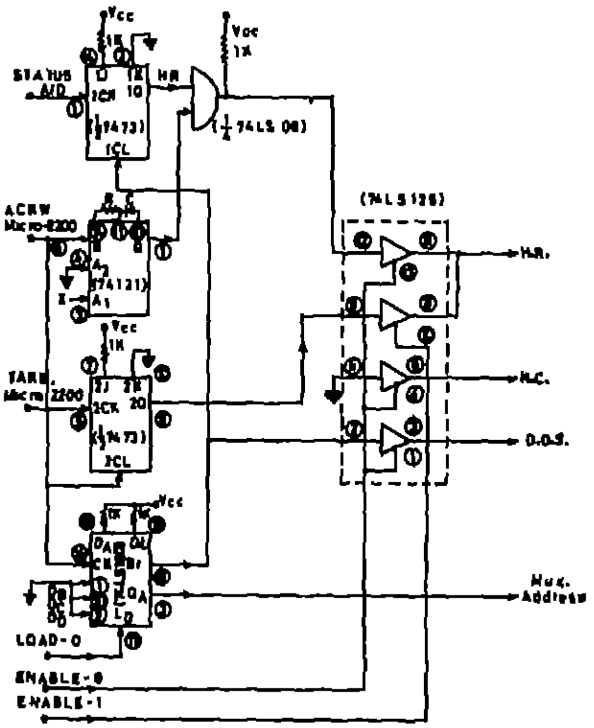


ANALOG TO DIGITAL CONVERTER & MULTIPLEXER

Fig. 3

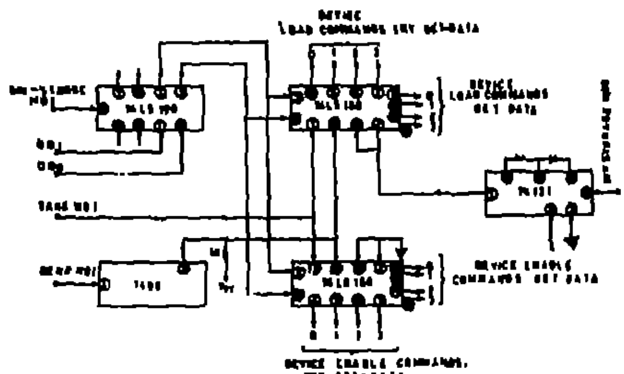
Address latching and decoder consists of 74 LS-190 to latch device address outputted from Micro-2200, one 74 LS 156 to decode two address lines to four device load commands to GET-DATA and four device load commands to INV-GET-DATA, one 74 LS 156 to decode 2 address to 4 device enable commands to GET-DATA and 4 device enable commands to INV-GET-DATA.

Motor control circuit consists of one 74 LS 193 to latch the command from Micro-2200 and 2 relay drivers to drive the relays of which one is used to hold/release motor and the other to forward/reverse the motor.



CONTROL& HAND SHAKE LOGIC

Fig. 4

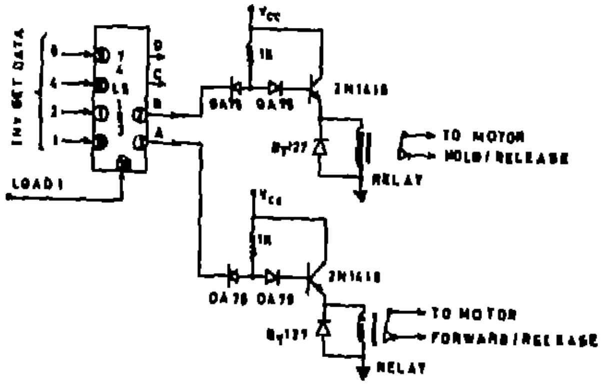


ADDRESS LATCHING & DECODER

Fig. 5

Data Logging

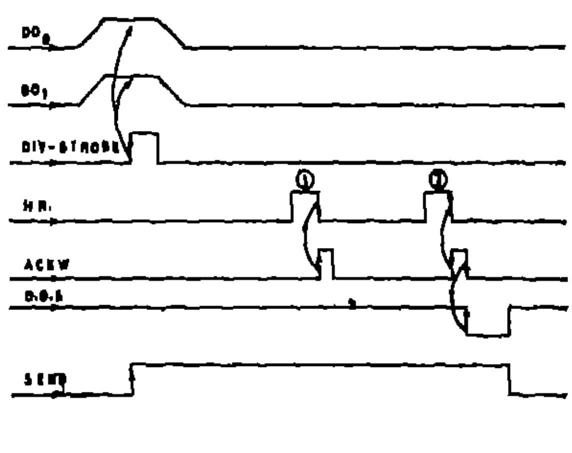
Data exchange between the microcomputer and the peripherals can be classified into the following types namely, programmed data transfers, interrupt data transfers and direct memory access transfers. Programmed data transfer is commonly used in almost all the microcomputer systems. The same is used in this case also.



MOTOR CONTROL CIRCUIT

Fig. 6

GET-DATA and INV-GET-DATA are input and output instructions of micro-2200. Before executing these instructions the address of the device number is to be entered into the "Y" register of micro-2200. As there are only two address lines, only four external devices can be addressed. When GET-DATA/INV-GET-DATA is executed Micro-2200 outputs the device address stored in "Y" register on the address lines DO_0 and DO_1 and the DIV-STROBE pulse on strobe line. Device address DO_0 and DO_1 are latched into 74 LS 190 at the raising edge of DIV-STROBE pulse (Timing diagram, Fig. 7). The latched address is decoded separately for input and output and "AND" ed with control signals "SEND" and "TAKE" to get 2 sets of device load commands strobed by DIV-STROBE pulse through monostable 74121, and 2 sets of device enable commands.



TIMING DIAGRAM, GET-DATA (Input)

Fig. 7

Data logging starts with the execution of the instruction GET-DATA with A/D address 00_{16}. The device enable command enables the 74 LS 125 at A/D and loads synchronous up/down counter 74 LS 190 with number 1_{10}, which corresponds to 2 sets of data (1 set = 2 digits BCD) to be transferred to Micro-2200. Micro-2200 now waits for the hard ware ready (HR) command, before it can read from the data bus. This HR is generated from the output of status flip-flop (½ 7473) "AND" ed (¼ 74 LS 09) with output (Q) of monostable (74121). The low going status signal which indicates the end of conversion (EOC) of A/D sets the flip-flop (½ 7473). This in turn raises HR to logical 1. Now Micro-2200 reads the data on the data bus and sends a pulse on 'ACKW' line. This is an indication that Micro-2200 has read 2 digits of data and has placed in its 'X' register. The ACKW pulse is used to lower HR to logical 0, through monostable 74121, and to down-count the synchronous up/down counter (74 LS 190) which switches the multiplexer to the first set of digits. After a delay of time "t" which is set in the monostable 74121 the HR again raises high (timing diagram). Micro-2200 now reads the second set of digits and places them in 'X' register after shifting to the left the digits which are read earlier and then sends a pulse on ACKW line. This pulse pulls down HR to low again and down-counts the synchronous up/down counter. This time "borrow" the low-going pulse from synchronous counter, goes to status flip-flop to clear it and to the data over signal (DOS) of Micro-2200 to indicate that the data coming from the external device are over. The data available on 'X' register of Micro-2200 is transferred to the first page of data memory. This sequence continues until 100 points of data are collected. As soon as the 100 points of data are stored in the data memory, Micro-2200 outputs a word on its INV-GET-DATA lines with relay address to hold the movement of the microdensitometer. The device load commands coming from the address latching and the decoder circuit loads the lower significant digit (LSD) of the word into 74 LS 193. Device enable command enables one gate of 74 LS 125 which is connected to HR "TAKE" signal from Micro-2200, and sets the flip-flop (½ 7473) which raises HR to high. The output (QB) is used to drive the electromechanical relay through the driver translator (2 N 1418) whose contacts are used to disconnect the power to the microdensitometer. Micro-2200 now transfers the 100 points of data stored in the first page of data memory to the specified block in the floppy disk. As soon as the transfer of data to the floppy disk is over, Micro-2200 outputs a word on its INV-GET-DATA lines which switches the relay off allowing the microdensitometer to move and to continue data logging. This completes one cycle of data logging for 100 points and transferring the same to the disk. This cycle can be repeated to log data for the remaining length of the plate/film.

References

de Vaucouleurs, G. 1968. *Applied Optics* 7, 1513.

Delcronix, A. Conception et Reausation D'un Photometre Pour La Lecture des spectres stouslres sur plaque photographique, *Bulletin de la societe Royale des sciences de liege*, Tome 11 (1960) fasc. 5 8, B5R6A6 49 (5-8) 219-280 (1980).

Lynge, G., and Arinder, G. The Computer controlled microphotometer at the Lund Observatory, *Reports from the Observatory of Lund*, No. 4. 1972.

Vasilevskis, S., and Popov., W.A. 1971, The Lick Gaertner Automatic Measuring System, *Lick Observatory Bulletin*, No. 598.

APPENDIX-II

SAMPLE PROGRAMMES

1. Logging Deflection to Disk

'DARK' Logging and Averaging

```
GOLD 4

2 EX 3
INV GET DATA
INV GET DATA
INV GET DATA          ; To hold
INV GET DATA            Microdensitometer
INV GET DATA
INV GET DATA

HLT
____________          ; To enter No. of points of
____________            dark to be logged and
STX 2                   averaged
SPACE
SPACE
SLV 8
GOLD 1
SLV 8                 ; Prints No points entered
SPACE
SPACE

2 EX
CE
INV GET DATA
INV GET DATA
INV GET DATA          ; To release Microdensito-
INV GET DATA            meter
INV GET DATA
INV GET DATA

GRP 1
GOLD 9
DL 11
0 EX
GET DATA
+ 1000
```

$\sum_{n}^{2}$

```
DEX 2
GOTO
L 11

SD, MEAN

EX
SLV 8
```

```
                    SLV 8
                    GOLD 1              ; Prints "DARK"
                    SLV 8                 averaged
                    SLV 8
                    STM 100
                    SPACE
                    SPACE
                    SPACE

                    2 EX 3
                    INV GET DATA
                    INV GET DATA        ; To hold
                    INV GET DATA          Microdensitometer
                    INV GET DATA
                    INV GET DATA
                    INV GET DATA

'CLEAR'             HALT
Logging and         ----------          ; To enter no. of points
Averaging           ----------            to be logged and
                    STX 2                 averaged
                    SPACE
                    SPACE
                    SLV 8
                    GOLD 1
                    SLV 8
                    SPACE
                    SPACE

                    2 EX
                    CE
                    INV GET DATA
                    INV GET DATA        ; To release
                    INV GET DATA          Microdensitometer
                    INV GET DATA
                    INV GET DATA
                    INV GET DATA

                    GRP 1
                    GOLD 9
                    DL 12
                    0 EX
                    GET DATA
                    + 1000
                    -
                    Σ 2
                      n
                    DEX 2
                    GOTO
                    L 12

                    SD, MEAN
```

```
                          EX
                          –
                          MEM 100
                          –
                          SLV 8
                          SLV 8
                          GOLD 1            ; Prints clear averaged
                          SLV 8
                          SLV 8
                          STM 110           ; Stores @ 110

                          2 EX CE
                          3
                          INV GET DATA      ; To hold
                          INV GET DATA        Microdensitometer
                          INV GET DATA
                          INV GET DATA
                          INV GET DATA
                          INV GET DATA

                          HLT
"DEFLECTION"              ________          ; To enter approximate
Logging Starts            ________            length of plate in MM
                          STM 120
                          SPACE
                          SPACE
                          SLV 8
                          GOLD 1            ; Prints length of plate
                          SLV 8               entered
                          SPACE
                          SPACE

                          –1
                          –
                          STX 8
                          0
                          STX 1

                          2 EX CE
                          INV GET DATA
                          INV GET DATA      ; To release
                          INV GET DATA        Microdensitometer
                          INV GET DATA
                          INV GET DATA
                          INV GET DATA

                          DL 13
                          99
                          STX 2
                          DL 14
                          0 EX
                          GET DATA
```

```
+ 1000
-
-
- MEM 100
-
STM
DP/IND 2
DEX 2
GO TO
L 14

2 EX CE
3
INV GET DATA
INV GET DATA          ; To hold
INV GET DATA            Microdensitometer
INV GET DATA
INV GET DATA

SLV 1                 ; To record on disk

INX 1
RCX 1
X 100
-
SLV 8
PRINT
SLV 88

2 EX CE
INV GET DATA
INV GET DATA          ; To release
INV GET DATA            Microdensitometer
INV GET DATA
INV GET DATA
INV GET DATA

DEX 8
GOTO
L 13

2 EX CE
3
INV GET DATA
INV GET DATA          ; To hold
INV GET DATA            Microdensitometer
INV GET DATA
INV GET DATA
INV GET DATA

SPACE
SPACE
SPACE
```

```
CE
999
SLV 8
GOLD 1          ; Indicates deflection
SLV 8             logging is over

CE
SPACE
SPACE

HLT
__________      ; Enter block No of
__________        programme
SLV 8
GOLD 1          ; Prints block No
SLV 8             entered

STX 8
SLV 6           ; Loads programme on
SPACE             page 1
SPACE
TL 1000         ; Control is transferred
HLT               to programme on
                  page 1
```

Programme is stored in Block 0
Call by 0 STX 8 SLV 4

2. Computation of Opacitance

Log ω

$= \log\left(\frac{\text{Clear}}{\text{DEF}}\right) - 1$

```
SPACE
SPACE
SLV 8
MEM 120
SLV 8
SLV 8
GOLD 1          ; Prints length of plate
SLV 8
SLV 8
HLT
__________      ; Enter length of plate
__________        if it is not correct
STM 120
SPACE
SPACE
 ·1
-
STX 8
SPACE
DL 15
SLV 8
```

```
RCX 8
PRINT
SLV 8
SLV 0              ; Loads a page from
                     disk
99
STX 5
DL 16
MEM 110
—
MEM
DP/IND 5
-
-1
-
INV 10x
STM
DP/IND 5
DEX 5
GOTO
L 16
SLV 1              ; Record a page of data
DEX 8
GOTO
L 15
CE
SLV 8
888
GOLD 1
SLV 8
SPACE
SPACE
CE
HLT
________           ; Enter block no of
________             programme
SLV 8
GOLD 4
SLV 8
STX 8
SLV 6              ; Load programme to
SPACE                location 1000
SPACE
TL 1000
HLT
```

Programme is stored in block No. 4

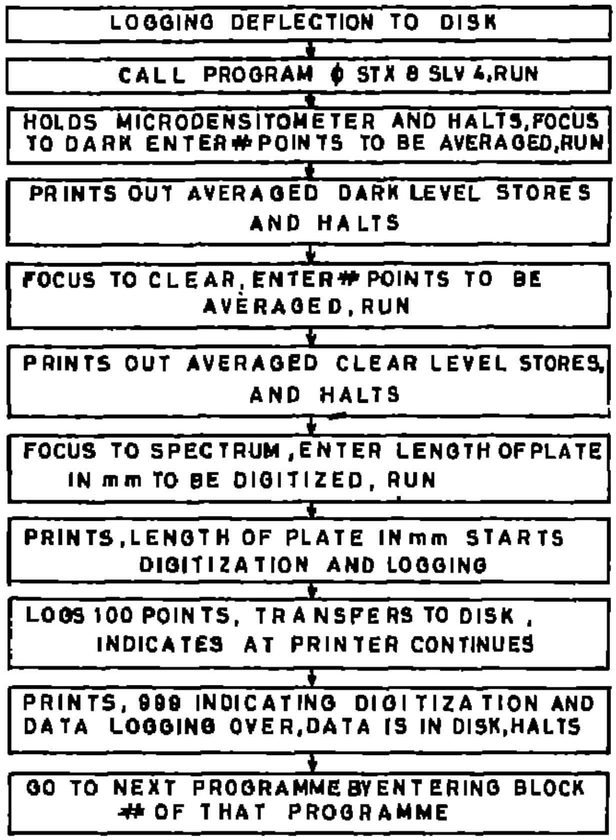
Call by 4 STX 8 SLV 6

3. Printing data from disk

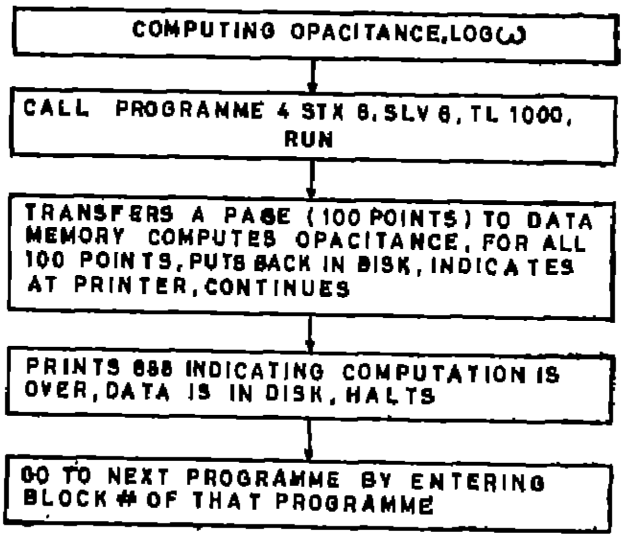
```
SPACE
SPACE
HLT
———————          ; Enter No. of pages to
———————            be printed
SLV 8
GOLD 1
SLV 8
−1
−
STX 8
SPACE
DL 14
SPACE
SPACE
SLV 0            ; Load a page of data
99
STX 5
DL 15
MEM
DP/IND
5
PRINT
DEX 5
GOTO
L 15
DEX 8
GOTO
L 14
SPACE
SPACE
CE
111
SLV 8
GOLD 1
SLV 8
SPACE
HLT
———————          ; Enter block No of
———————            programme
STX 8
SLV 6
SPACE
SPACE
TL 1000
HLT
```

Programme is stored in block 28
Call by 28 STX 8 SLX 6

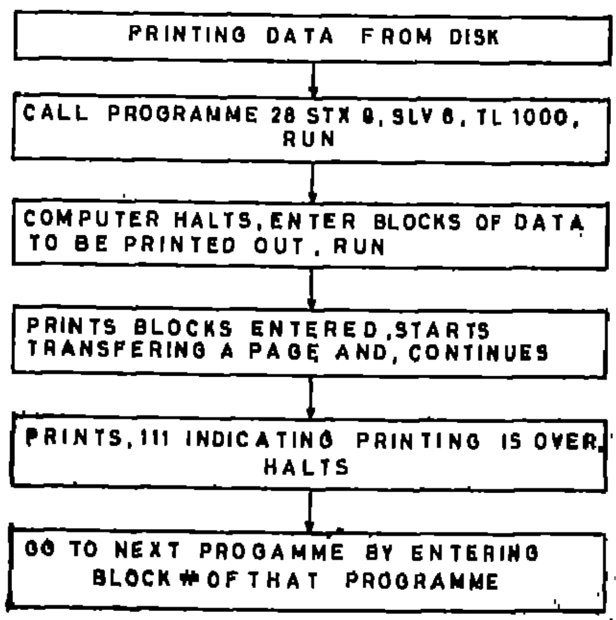
FLOW CHART-1



FLOW CHART-2



FLOW CHART-3



LIST OF PROGRAMS

Program Name	Block No. in disk	Calling format	Inputs needed	Action taken	End indication	Remarks
Logging deflection to disk	0	0 STX 8 SLV 4	Dark, Clear levels, length of plate in MM	Logs dark, Clear level, takes average prints, Stores, Logs spectrum	Prints "999"	Can be linked to following programme by entering block No.
Computing density $D = -\text{Log}\left(\frac{DEF}{CLR}\right)$	1	1 STX 8 SLV 4	Nil if linked	Computes density taking deflection halts from disk & puts back	Prints "888"	-do-
Computing Opacitance Log w $-\text{Log}\left(\frac{CLR}{DEF}-1\right)$	4	4 STX 8 SLV 4	-do-	-do-	-do-	-do-
Computing intensity $= A + BX + CX^2 + DX^3$	5	5 STX 8 SLV 4	Coefficients, A, B, C, D, No. of blocks of data	Computes intensity taking density/ opacitance from disk & puts back	Prints "777"	-do-
Printing data from disk	28	28 STX 8 SLV 6	No. of blocks of data	Prints out data	Prints "111"	-do-