

PRINT WITH BUFFERED PLOTTING

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ABSTRACT

Title: Print With Buffered Plotting

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Purpose/Description: Effects synchronous, yet completely buffered, CALCOMP plotter operation during IBM 1401 tape-to-print jobs. Data from one tape is printed at 600 lines per minute on the 1403 while data, expressed in rectangular coordinates, from an independent tape is simultaneously plotted at 1.7 inches per second (2.5 inches per second with the higher speed plotter). Under sense switch control, printing and plotting may operate together or singly. If plotting only, plotting speed is increased to the full 2.0 inches per second (3.0 inches per second with the higher speed plotter).

Method: All plotting takes place during the 85 millisecond interlock between successive print cycles; thus plotting is completely buffered and requires no additional time.

Restrictions/Range: Tape records can be variable length up to a maximum of 3996 characters for printing or 1200 characters (100 coordinate points) for plotting. Print tape records can be logically (* denotes end of line) de-blocked for printing or can be de-blocked in a fixed number of characters per line. Spacing is either single space or first character forms control. A least-mean-square-error line is incremented between successive plot points. Plot points are four digit integer values representing rectangular coordinate deflections expressed in hundredths of an inch. Eight different symbol alternatives are provided to mark each point.

Storage Requirements: 7556 core positions.

Equipment Specifications: IBM 1401 (8K core, print storage, high-low-equal compare, advanced programming, and sense switches); IBM 1403; IBM 1407; two IBM 729, CALCOMP Incremental Recorder(attachment via RPQ # W01372).

PRINT WITH BUFFERED PLOTTING

Purpose

With no increase in computer time required, mechanized plotting capabilities may be added to an IBM 1401 installation. This addition of a graphical display medium may be accomplished virtually without increased cost by taking advantage of the timing relations present in a 1401 with print storage. This program was written to effect completely buffered plotting while continuing to print 600 lines per minute from an unrelated tape. As many data processing installations employ at least one 1401 in primarily a tape-to-printer capacity, it is hoped the program offers a significant contribution to their libraries.

This program for an IBM 1401 Data Processing System with print storage and an on-line CALCOMP Incremental Recorder thus provides plotting capabilities without incurring additional time requirements. This is accomplished by plotting during the 85 milliseconds of process time available between successive print cycles. Input for printing is variable length blocked records of up to 3996 characters in length. Data for plotting consists of pairs of four digit integers (X,Y) coordinates representing rectangular coordinate deflections expressed in hundredths of an inch.

The program maintains the full 600 lines per minute printing capability of the IBM 1403 while simultaneously plotting data from an independent tape on an on-line

CALCOMP plotter. Plotting speed is at the rate of 1.7 inches per second while simultaneously printing or 2.0 inches per second if plotting only when using the 200 increments per second plotter.

PRINT WITH BUFFERED PLOTTING

Introduction

A printed listing of function values for various arguments is frequently the result of a computer-aided problem solution. In many instances, this information must be displayed graphically in order that the user may readily interpret results. Curve fitting, regression analysis, electrical and mechanical system responses, preparation of engineering drawings, transient studies, statistical presentations, and the solution of systems of differential equations constitute but a few such applications. An on-line plotter offers a fast, economical, and convenient means of mechanizing graphical output. One such system is the on-line attachment of a CALCOMP Incremental Recorder to an IBM 1401 Data Processing System.

The IBM 1401 computer provides high-speed input-output among its other attributes and consequently is frequently employed as an input-output satellite to a larger computer. In such an application, a major portion of its time is spent printing tape on the high speed 1403 printer (132 alpha-numeric characters/line, 600 lines/minute, forms movement up to 75 inches/second). The length of each print cycle is thus 100 milliseconds while printing at 600 lines per minute. With the print storage feature only 2 milliseconds are required to transfer data into print storage and the remaining 98ms are

then released for processing. Further, two additional logical instructions are provided: Branch Printer Busy and Branch Printer Carriage Busy.

The IBM 1401's internal speed (11.5 microsecond basic cycle time) is such that a tape record may be read and prepared for printing in approximately 10 to 15 milliseconds. Thus, one can, by employing the Branch Printer/Carriage Busy instructions, introduce a form of priority multi-programming in which a tape-to-print job maintains its maximum 600 lines per minute speed while another job is performed in between successive print cycles. The incremental cost of running the second job is then essentially zero since the 100 milliseconds between successive lines printed must transpire regardless of whether the second job is run or not. (One could consider an increment cost associated with the price of the print storage feature; however, the feature has other implications with respect to card reading and punching which will not be discussed here. Let it suffice to state that, in general, the feature will already exist in systems used primarily to support a larger computer or in larger scale 1401 installations in which the 1401 is the prime computer.)

The CALCOMP Incremental Recorder is a digital plotter capable of moving .01 inch in any one of eight directions (a relative 0, 45, or 90° in each of the four quadrants).

All movement is incremental relative to the pen's present position, that is, there is no fixed coordinate system inherent to the plotter. Two basic speeds presently exist for the plotter: 200 increments per second and 300 increments per second. The plotter is thus capable of moving .01 inch each 5 milliseconds ($3\frac{1}{3}$ milliseconds with the higher speed model). The pen can also be raised or lowered under program control; however, vertical pen movement interlocks the plotter for 100 milliseconds.

Physically, plotting takes place by moving a 120 foot roll of paper either forward or backward beneath the pen for +X incremental directions; +Y incremental directions are obtained by moving the pen laterally across the paper. Simultaneously incrementing both the pen and paper together results in a relative 45 degree increment. Symbols to mark a point are thus limited only by one's imagination since any sort of figure can be generated by combinations of the ten elementary commands. The 120 foot long paper roll, the ability to draw different symbols without pen change, rapidity of movement, and lack of axis restrictions afford the opportunity to batch process many different jobs without operator intervention or extensive pre-processing.

IBM 1401 Data Processing Systems may be had in many different configurations. A typical system can consist of a 1401 central processing unit, a 1402 card reader/punch, a 1403 chain printer, and up to 6 magnetic tape units,

(729II, 729IV, or 7330 in any mixture). A 1407 Console Inquiry Station can provide a direct and immediate means of communication between the operator and the system as well as well as being a de-bugging convenience. The 1407 can also serve as the interface through which a CALCOMP Incremental Recorder can be connected on-line to an IBM 1401 Data Processing System. Further, the plotter tie-in via the 1407 provides a single character buffer such that, when the plotter is pulsed with only a single control digit at a time, the 1401 will be released for processing immediately upon receipt of the control digit. Approximately 5 milliseconds (100 milliseconds for pen raising or lowering) of buffered time thus becomes available with the 200 increments per second model plotter. The control digit for the next incremental movement can be calculated or other processing done before the plotter can accept another command without interlocking the entire system.

The buffered interlock times, 98 milliseconds between successive print instructions, 5 milliseconds between successive plotter increments, and 100 milliseconds between successive vertical pen movements, provide a basis for multiplexing between a tape-to-print program and an independent tape-to-plotter program without loss of printer speed. If printing is the priority program, then printing will be maintained at 600 lines per minute while plotting proceeds at 1.7 to 1.8 inches per second (with the high speed plotter 2.5 inches per second).

PRINT WITH BUFFERED PLOTTING

Coding Information

The general logic of the program is to assemble a line for printing, then test to see if either printer or printer carriage is busy. If a busy status exists, control passes to the plotting program which increments a least-mean-square-error line between successive points, with the pen up or down per request, then draws any one of eight symbol alternatives to mark the point. Printer busy status is interrogated each .01 inch during plotting; as soon as a not busy status exists or a pen raising or lowering command is executed, control returns to the printing program. In this manner the time left after assembling a line for printing is fully utilized for plotting; frequent "busy" testing and the forcing of a print cycle following each pen up or down movement insure that printing is not delayed. Detailed program logic implementation is contained in the flow charts and the liberal annotation of pertinent sections in the source program listing. Only general remarks will, therefore, be considered here.

The print tape buffer is originated just past the print area in order that the absence of an expected record mark will not cause program information to be destroyed by the instruction "transmit record" to print area. Each logical record transmitted, as opposed to moved, to the print area is checked to insure that its length, including the

terminating record mark, is not more than 133 characters. The first 132 characters of an excessive length logical record are printed, then the physical tape record is re-read and printed in lines of 100 characters each. Printing of the next tape record reverts to sense switch control. If multiples of other than 100 characters per line are desired, change the B-field of source card number 68 (e.g. SBR MUL, 57 will dump tape in 57 character line multiples). In conjunction with first character forms control, location 201 must always contain a work mark.

A single end of file ejects a new page while two successive end of files on the print tape cause a programmed halt after outputting an operator message on the 1403.

The plot tape buffer can be expanded beyond 1200 characters simply by altering its area defining card.

Each pair of coordinate points is considered positive; for special applications in which negative numbers as well would be desirable, source card numbers 281 and 282 can be changed to pick up sign bits from characters 2 and 8 of the plot control word (e.g. MZ HOLDX-4, HOLDX ; MZ HOLDY-4, HOLDY).

The maximum X coordinate value allowed with any one axis set is determined by the constant from source card 325. Thirty-nine inches is nominally allowed; changing the constant to + 9599 will allow X values up to 95.99 inches to be plotted. Maximum Y values are similarly controlled by the constant from source card 326; if the wider model

is available, changing the constant to + 2900 will

allow plotting of values up to 290.00 inches.

plotter is available, changing the constant to + 2900 will allow full width plots. Points which exceed set limits are ignored and cause movement to the next point to be made with pen up regardless of pen request per plot control word.

Spacing between successive axis sets is controlled by the constant in source card 365. Positive and negative (X,Y) directions relative to the paper roll are determined by the control digits contained in source cards 442 through 449.

The use of "R" (restore) as a pen control request is to facilitate batching. Restore causes the following sequence to be executed:

- a) Raise pen from paper.
- b) Move to the point ($[X_{\text{max}} + 4.00"]$, 0); that is, to an X position four inches farther than the largest integral inch value encountered while plotting relative to the present axis set.
- c) Define a new axis set by zeroing present X position, present Y position, and maximum X value encountered.
- d) Move to (X,Y) coordinate requested in plot control word.
- e) Until the next restore request is encountered, subsequent plotting is with respect to this new axis set.

As the basic process time required to calculate successive plotter control digits and test printer busy status is approximately 1.6 milliseconds, the program is capable of taking full advantage of the higher speed (300 increments per second) plotter. Actual production plotting while printing jobs have yielded an overall average plotter

rate of 1.7 inches per second with the slower (200 increments per second) plotter; this figure includes tape reading as well as pen raising and lowering time. When plotting without printing and moving between successive points without having to raise or lower the pen, plotting speed is increased from 1.7 to 2.0 inches per second.

While all plotting is completely buffered, on-line 1407 messages are not. In order not to slow down printing, use of on-line 1407 messages should be used judiciously. Approximately 22 lines could have been printed during the time it takes to type each message.

A single end of file on the plot tape causes a programmed halt after first outputting an operator message on the 1407.

In summary, salient source cards are:

<u>Source Card</u>	<u>Meaning</u>
19	Assign print tape to unit #2
47	Assign plot tape to unit #5
55-58	Define print tape buffer
68	Define length of line for tape dumping
95	End of job halt
142	End of print tape halt
258	End of plot tape halt
281	Force positive X sign
282	Force positive Y sign
325	Upper limit for X
328	Upper limit for Y
365	Spacing between successive axis sets

<u>Source Card</u>	<u>Meaning</u>
442	Move 0 degrees control digit
443	Move 45 degrees control digit
444	Move 90 degrees control digit
445	Move 135 degrees control digit
446	Move 180 degrees control digit
447	Move 225 degrees control digit
448	Move 270 degrees control digit
449	Move 315 degrees control digit
465-487	Define symbol figures

PRINT WITH BUFFERED PLOTTING

Equipment Specifications

IBM 1401 Central Processing Unit (8K core minimum)
Print Storage Feature
High-Low-Equal Compare Feature
Advanced Programming Features
Sense Switch Feature

IBM 1402 Card Read-Punch (optional)

IBM 1403 Chain Printer

IBM 1407 Console Inquiry Station

IBM 729 Magnetic Tape Units (2 required, any model)

CALCOMP Incremental Recorder (attachment via RPQ W01372,
any model)

PRINT WITH BUFFERED PLOTTING

Printer Usage.

Print tape records can be variable length up to 3996 characters per record. A record mark separates print lines in blocked records. First character forms control per FORTRAN as well as all 1401 form control characters can be used.

Including the record mark, a logical record must contain not more than 133 characters. The record mark is not printed. If printing under first character forms control, the first character of each logical record is not printed.

Record marks are not used when printing with a fixed number (normally 100) of characters per line. The character count of the physical tape record is printed along with the last line when printing in this fixed format. Print lines within a tape record are single spaced; tape records are double spaced.

PRINT WITH BUFFERED PLOTTING

Plotter Usage:

Data points are two four digit integers representing rectangular coordinate deflections expressed in hundredths of an inch. The first point plotted relative to a new axis must have an R as its associated pen control character. Each pair of (X,Y) points are contained in a 12 character BCD plotter control word. Plot tape record lengths are variable, in multiples of 12 characters, up to 1200 characters (100 points) per record.

Plotter control word format is:

Character 1	Pen Control
blank	Leave pen as it was for previous point.
0	Lower pen to paper prior to going to (X,Y).
9	Raise pen from paper prior to going to (X,Y).
R	"Restore". Raise pen. Space to new axis. Go to (X,Y).
W	"Write". Write next 23 characters as an on-line 1407 message. Note that each write request adds approximately .25 seconds.
Character 2	Can be used for sign of X if special operating system allows; otherwise not used for plotting and positive X coordinate is always assumed.
Characters 3-6	X Coordinate ($0 \leq X \leq 3900$) Four digit integer representing rectangular coordinate deflection expressed in hundredths of an inch.

Character 7	Symbol Control	
	blank	no symbol 0 milliseconds
	+	dot 40 milliseconds
	=	double diamond 120 milliseconds
	⊘	circle 290 milliseconds
	-	diamond 350 milliseconds
	*	asterisk 370 milliseconds
	.	star 390 milliseconds
)	square 450 milliseconds

Character 8 Can be used for sign Y if special operating system allows; otherwise not used for plotting and positive Y coordinate is always assumed.

Characters 9-12 Y Coordinate ($0 \leq Y \leq 1000$)

Four digit integer representing rectangular coordinate deflection expressed in hundredths, of an inch.

A sample plot, together with its plot control words, is shown in Figure 1. The 1407 message may appear anywhere in the sequence. Blanks are treated as zeros. The different symbol markers are as shown; for symbol timing considerations see Character 7 above.

Axis layout is:

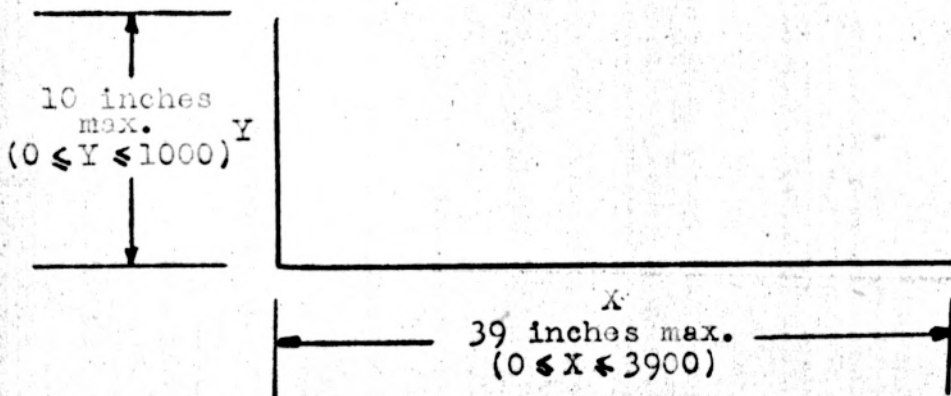
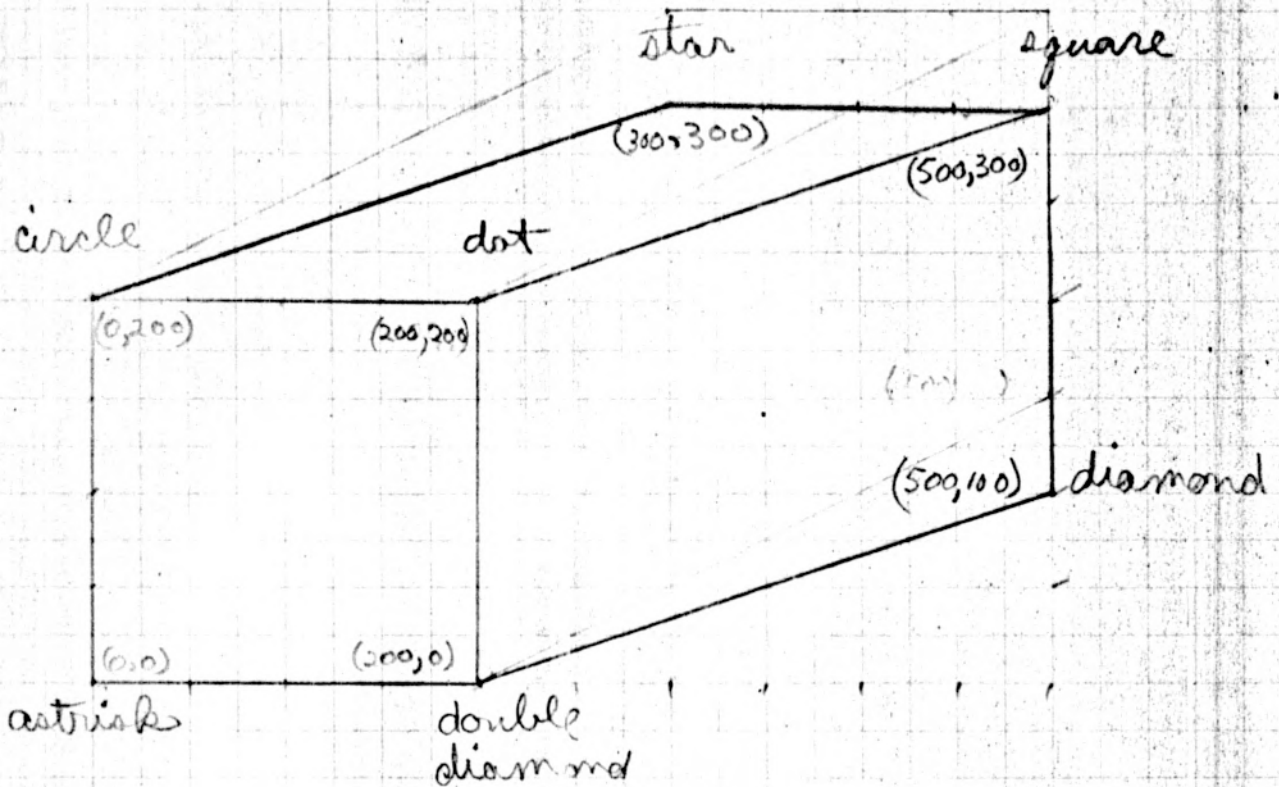


FIGURE 1



1 2 3 4 5 6 7 8 9 10 11 12 A

```

R 0 200 = 300
O 200 + 500
    $ 500
    0 * 300
    200 300
    0 500 - 400
    + 0 500 ) + 600
    300 • 600
    1 0 0 + 500
9 500 600
0 200 500
} W S A M P L E S Q U A
  R E W I T H S Y M B
    
```

Comments

```

Restore double diamond
Pen down dot
circle
astriks
blank
diamond
square
star
blank
blank
Pen up
Pen down
Message
    
```

PRINT WITH BUFFERED PLOTTING

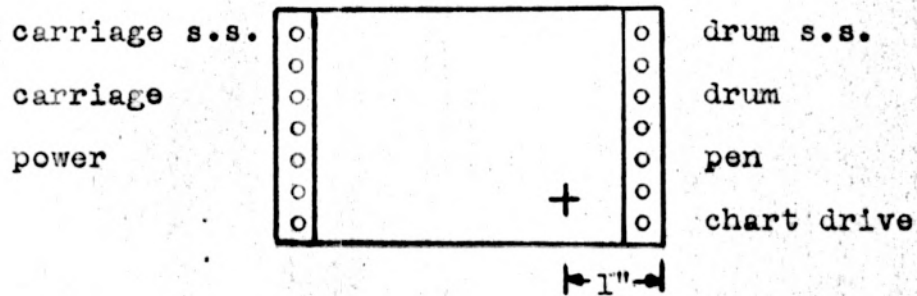
Operating Instructions

1. Purpose

Simultaneously print one tape at 600 lines per minute while plotting at 1.7 inches per second from an independent second tape. Print tape variable length records up to 3996 BCD characters and plot tape variable length records up to 1200 BCD characters can be used.

2. Set-Up

- a. Mount PRINT tape on unit #2. Mount PLOT tape on unit #5.
- b. Ready 1402, 1403, 1407, and plotter. When turning power ON or OFF, the 1401 mode switch should be in ALTER. Use cross-hair insert to initially position pen one inch from right-hand paper edge.



3. Operation

- a. Set mode switch to RUN; tape select switch to N; I/O check stop UP.
- b. Press CHECK RESET and START RESET on 1401 console.
- c. Select SENSE SWITCH combination for job per:

	A	UP-always
PLOT	B	UP-PLOT tape #5
	C	not used
TAPE ERROR	D	UP-accept tape redundancy after HALT DOWN- read redundant record 39 more times after HALT.

E UP-with G also UP, PRINT tape #2 in 100 character lines.

F UP-with G also UP, PRINT tape #2 single spaced
DOWN-with G also UP, PRINT tape #2 with first character forms control.

PRINT G UP-PRINT tape #2 per sense switch E or F.

d. Place program deck in 1402; press CHECK RESET, then LOAD on 1402 to initiate job.

e. Programmed HALTS are:

Storage Address

Description

4452

End of job, both "B" and "G" DOWN. Select sense switches per 3. c, then press START to initiate new job.

4538

Read redundancy tape unit #2. If "D" UP accept redundancy; if "D" DOWN re-read 39 more times. Press START to continue.

4643

Two successive end of files on tape unit #2. If finished printing turn "G" DOWN. Press START to continue.

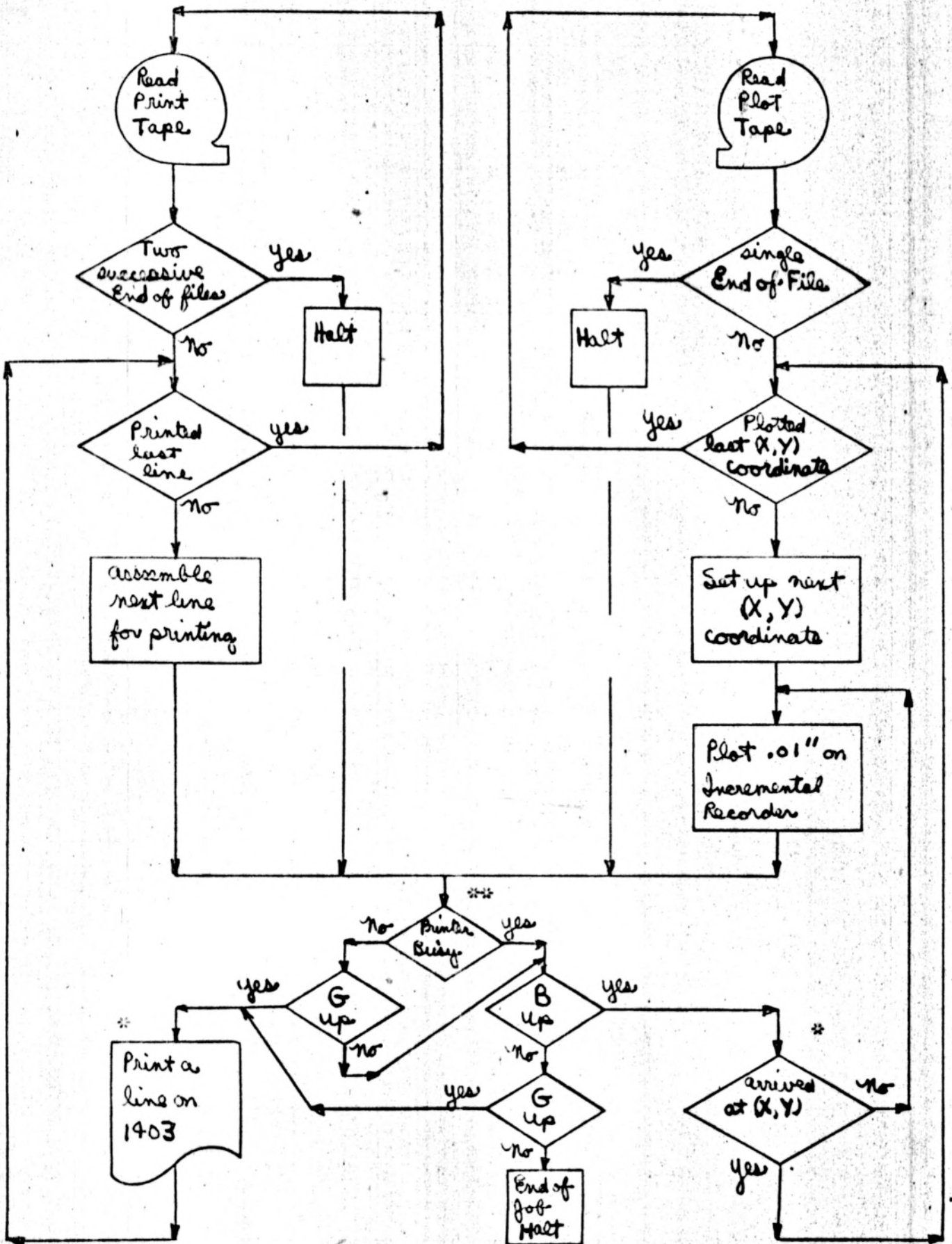
5169

Read redundancy tape unit #5. If "D" UP accept redundancy; if "D" DOWN re-read 39 more times. Press START to continue.

5224

Single end of file on tape unit #5. If finished plotting turn "B" DOWN. Press START to continue.

MACRO- FLOW CHART PRINT WITH BUFFERED PLOTTING



* This flow chart contains certain simplifications as an aid to clarity

** Between successive lines, the printer remains busy long enough to plot $\approx .17''$

PRINTING- PLOTTING MULTIPLEXING

START

Set PRINT linkage to FETCH

Set PLOT linkage to BLOCK

Set exceeded limit switch on

Set blank pen status

Initialize Print Area

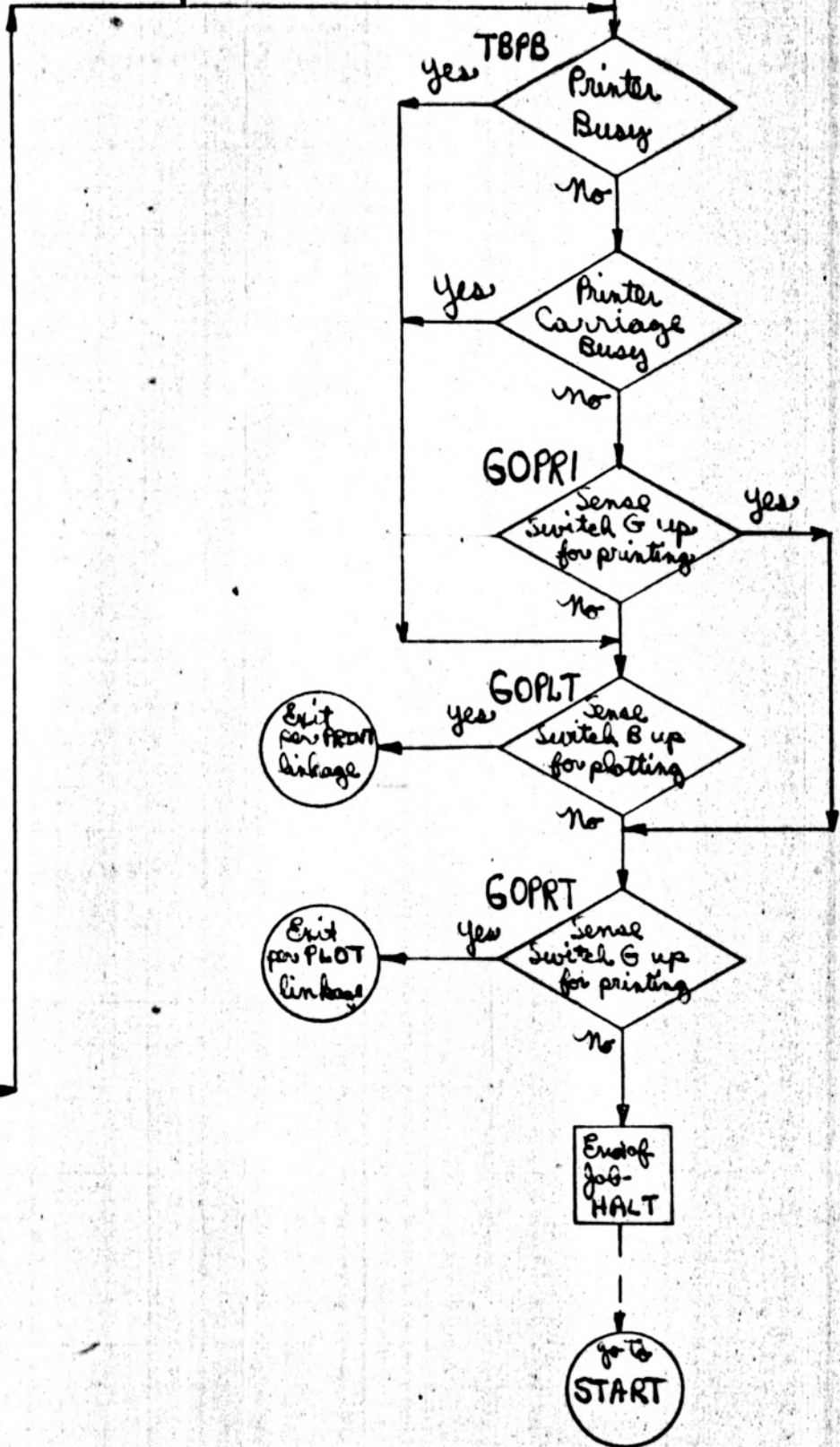
Set constant for "character multiple" printing

PLOT

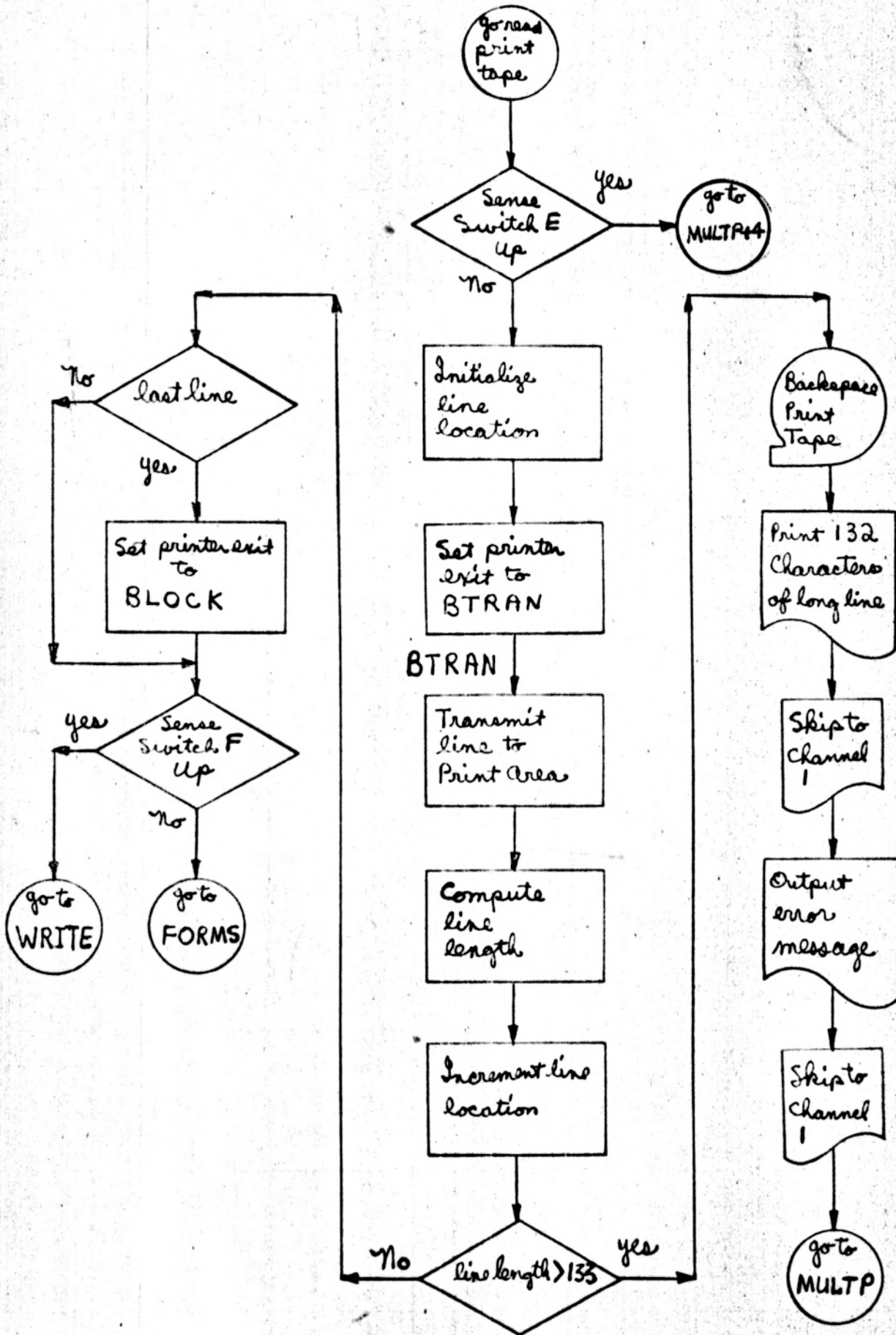
Save return linkage for exit GOPRT

PRINT

Save return linkage for exit GOPLT

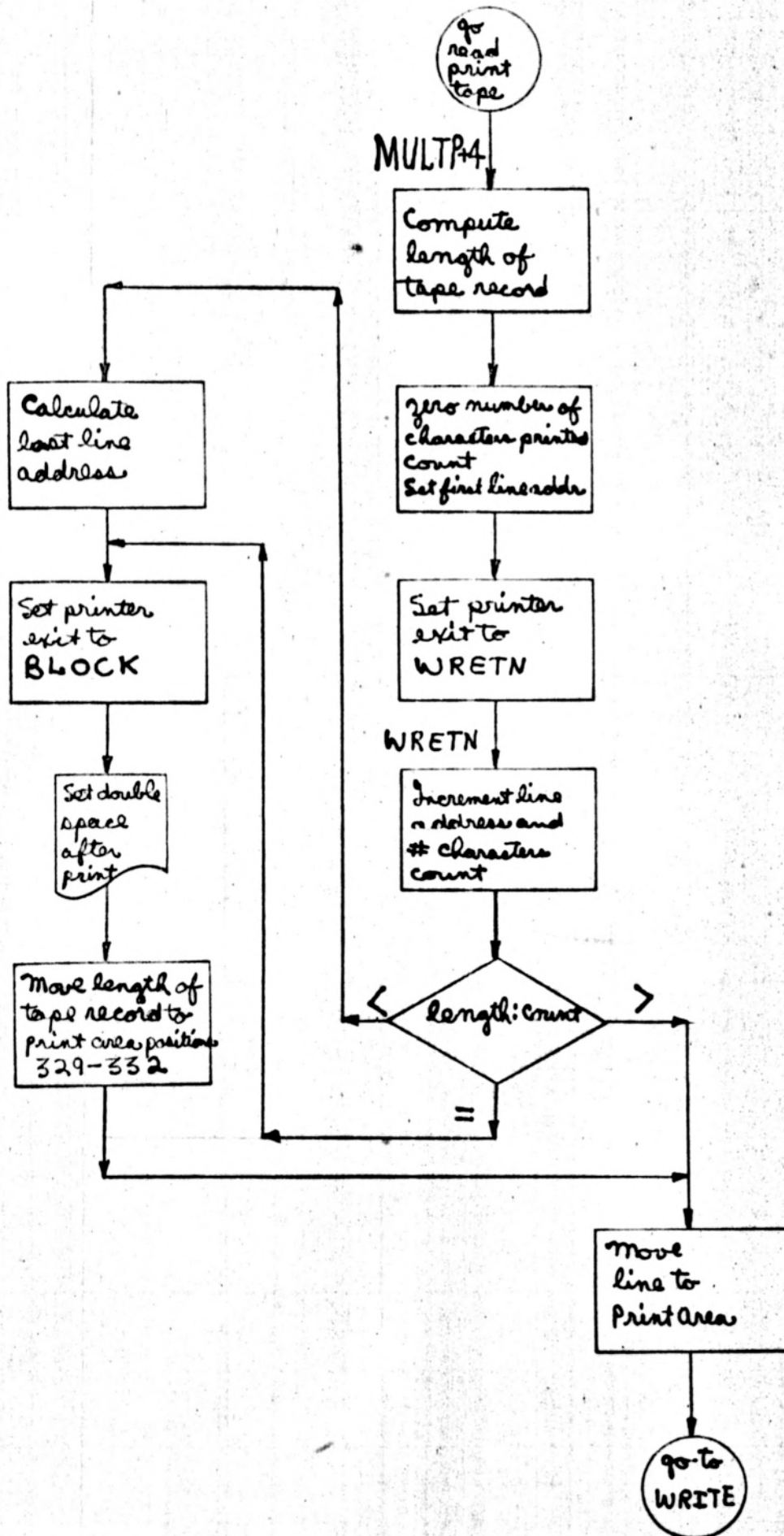


PRINT TAPE RECORD IN LOGICAL LINES
BLOCK

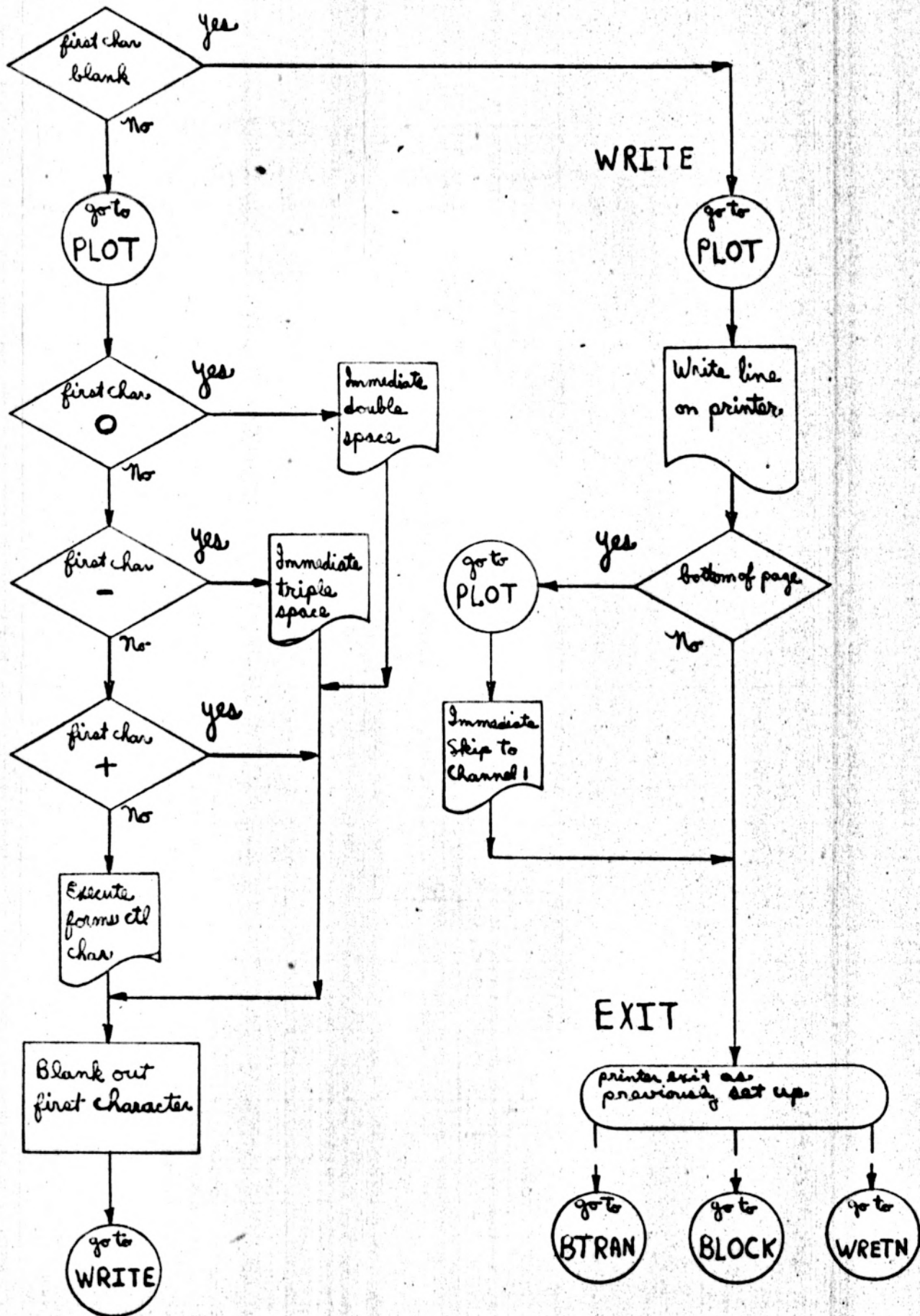


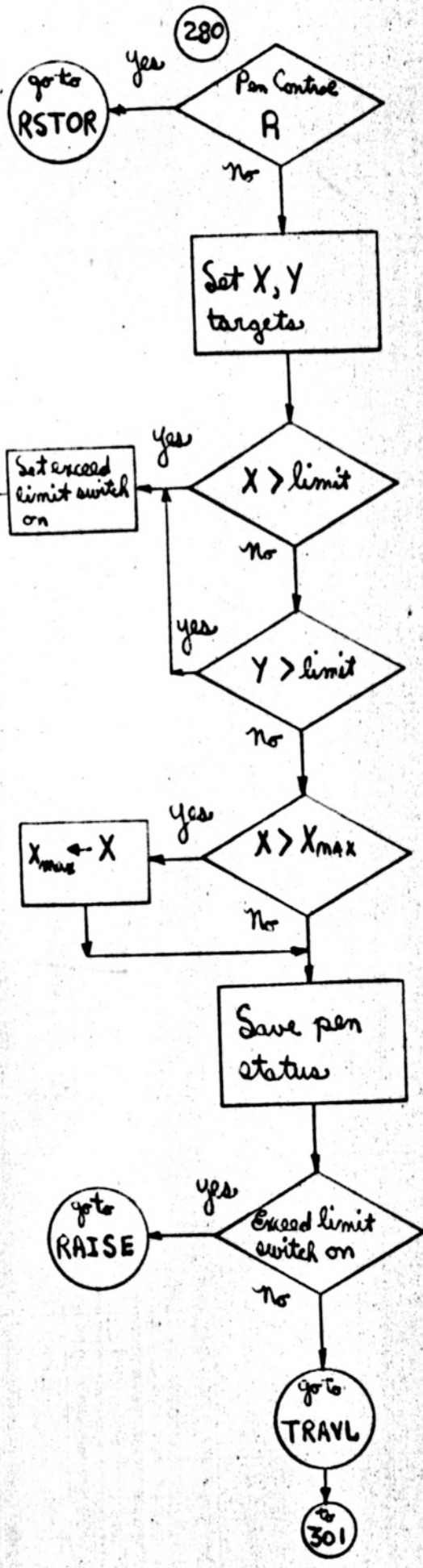
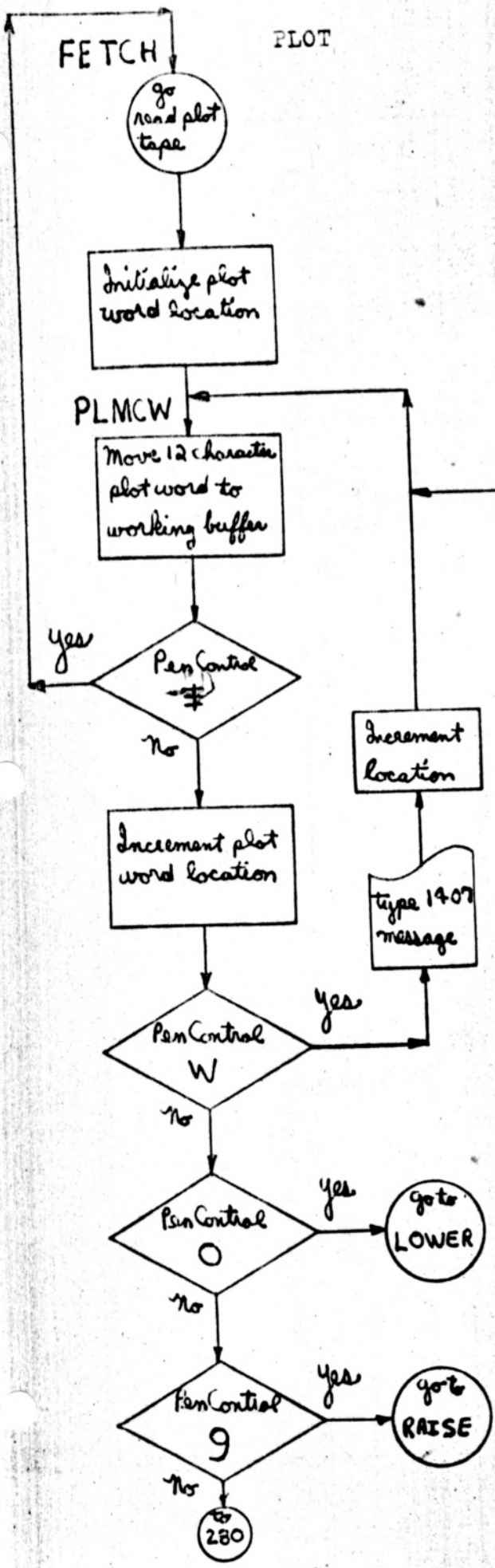
PRINT TAPE RECORD AS 100 CHARACTER LINES

MULTP



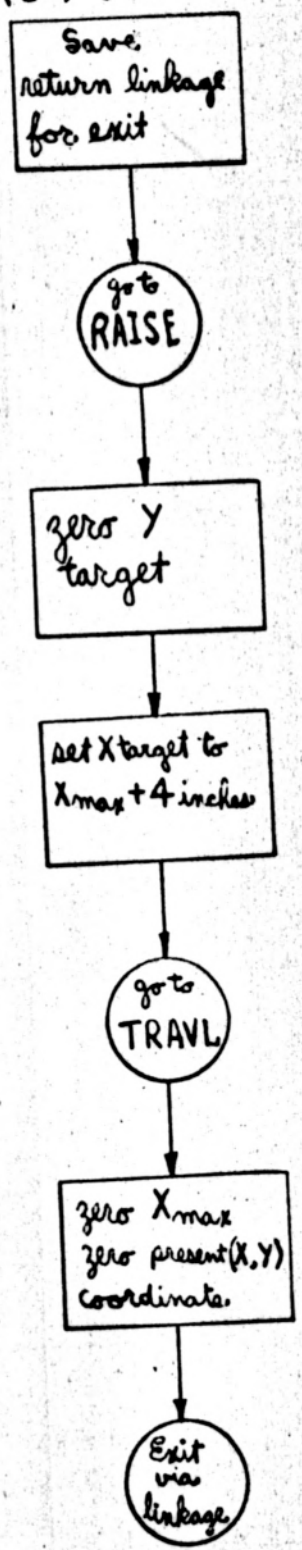
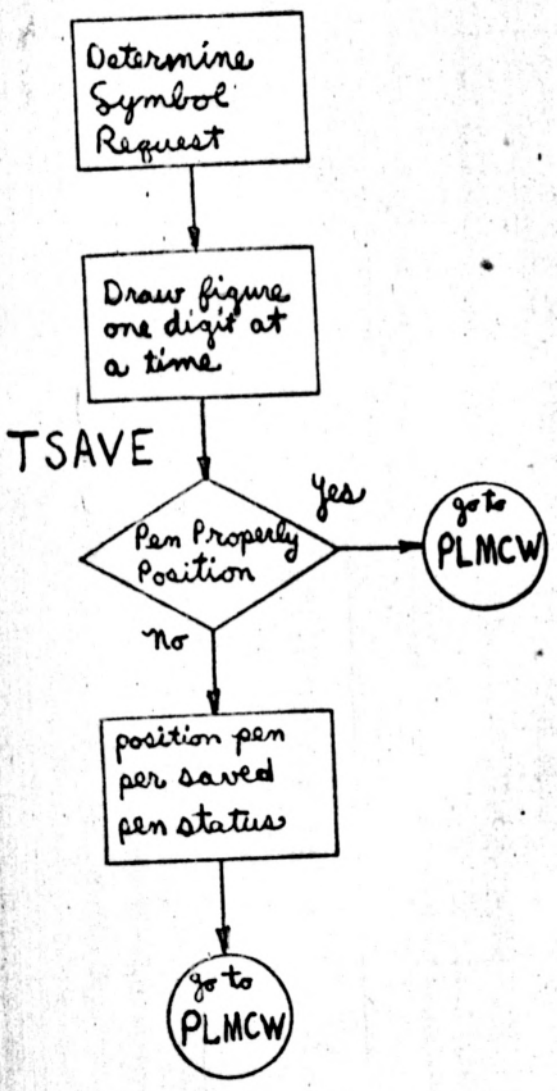
FORMS





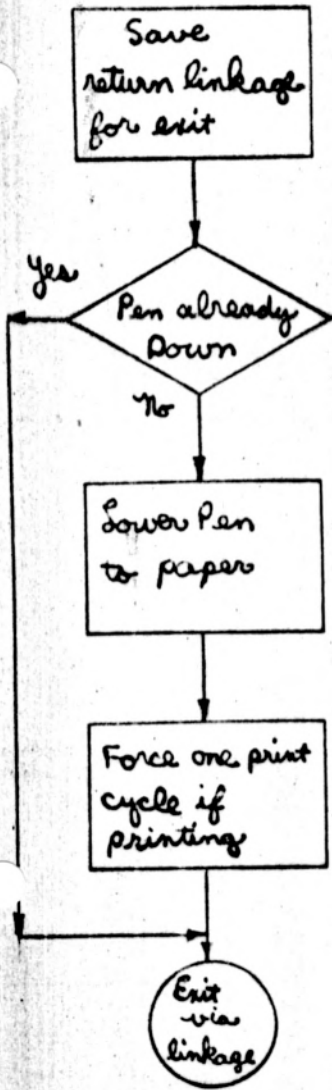
301

RSTOR

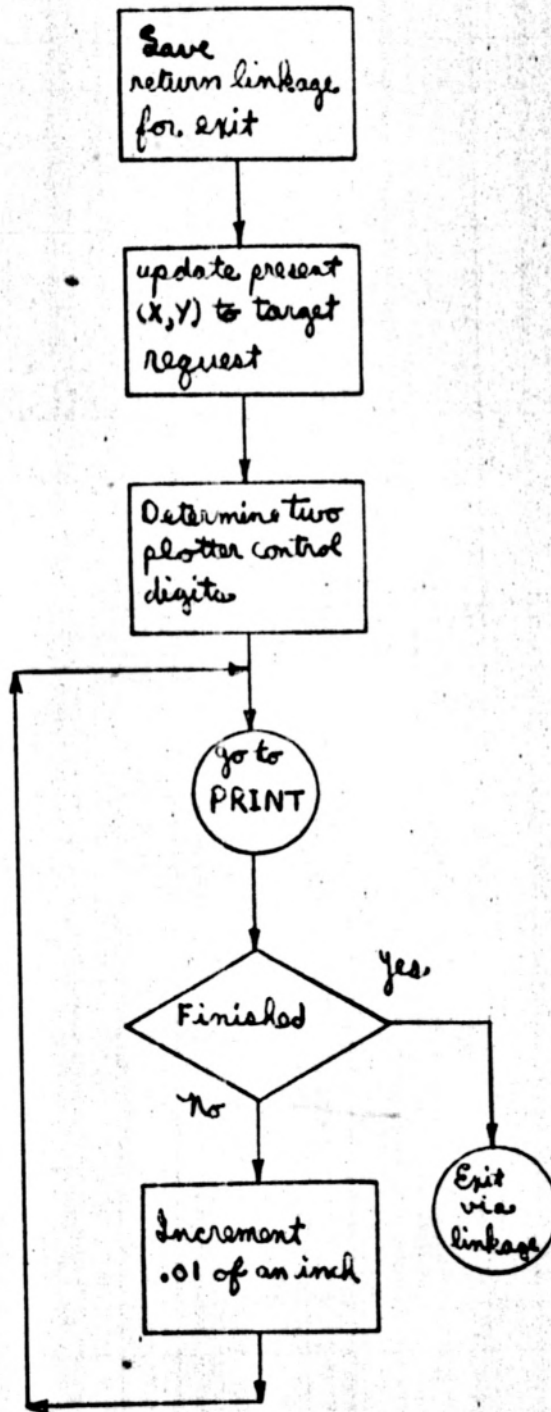


PEN CONTROL AND INCREMENT LINE

LOWER



TRAVL



RAISE

