AN INTERFACE DESIGN FOR A FLEXOWRITER AND THE D17B "MINUTEMAN" COMPUTER

A Thesis

Presented to

the Faculty of the Department of Electrical Engineering

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Curtis Burke Herbert, Jr.

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ABSTRACT

This thesis presents the design of an interface between a Friden Flexowriter and a D17B "Minuteman" computer. Standard TTL logic modules were employed to construct a device that would allow the Flexowriter to load octal and alphanumeric data into the computer via the keyboard or the paper tape reader, and to allow the computer to drive, through appropriate software, the typewriter and the paper tape punch of the Flexowriter.

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CHAPTER I

INTRODUCTION

D17B Computer

The D17B airborne digital computer is a general purpose computer that was designed as an inertial guidance and control system for the "Minuteman" Intercontinental Ballistic Missile. It is a synchronous, serial computer with a rotating magnetic disc as the main memory unit. Diode logic is used throughout the computer and the flip-flops are designed with discrete components.

Friden Flexowriter

The Friden Flexowriter is comprised of an electric typewriter, a paper tape punch and a punched paper tape reader. The Flexowriter utilizes a 6 level code to transmit all characters of a standard typewriter character set. The Flexowriter is capable of transmitting 10 characters per second, maximum, from the keyboard or the paper tape reader and also receiving, at the same rate, at either the paper tape punch or the typewriter.

Interface

The logic unit designed to interface the Flexowriter to the D17B computer provides complete conversion from the 6 level code of the Flexowriter keyboard or paper tape reader to the 3 level code of the D17B computer. All necessary commands are assigned to single keys on the Flexowriter and are interpreted by the interface for transmission to the

computer. The interface unit also receives characters from the computer and transfers them to the Flexowriter typewriter or paper tape punch. Provision is made for necessary voltage level conversion between the computer and the Flexowriter.

CHAPTER II

D17B COMPUTER DESCRIPTION

D17B Characteristics

Pertinent characteristics of the computer are as follows:

1. 27 bit word length, 24 of which are sign and magnitude
2. 2's complement binary arithmetic
3. 2985 words of storage organized as:
   a. 21 channels of 128 words or sectors each
   b. 4 rapid access loops of 1, 4, 8 and 16 words respectively
   c. 4 single word arithmetic registers designated as the accumulator (A), the lower accumulator (L), the instruction register (I), and the number register (N)
   d. Power consumption of 350 watts, utilizing a total of 19 different AC and DC voltage sources

Input-Output Structure

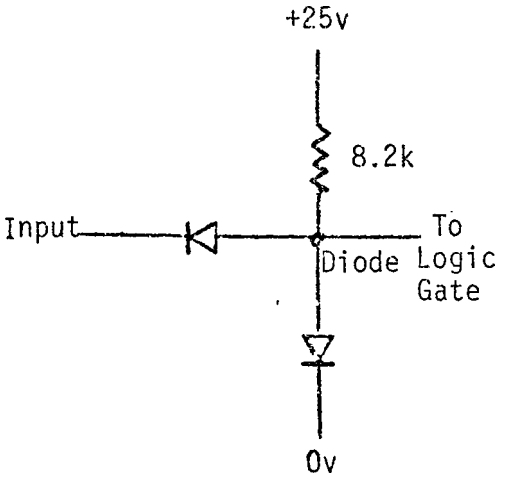
The D17B has a character input feature that will allow a 5 bit code to be entered into the magnetic disc memory at the rate of 800 characters per second from an external device. This is the input that is utilized to enter data from the Flexowriter keyboard or the punched paper tape reader. The 5 bit code is composed of 3 bits of data and 2 control bits. Data is entered as a string of 8 octal characters per word followed by a control character that signifies the end of the word. Other control codes are utilized to set the location register and to set the various modes of the computer. A complete listing of the codes is contained in Appendix C.

There are several methods of outputting data and/or control information from the D17B. The output selected for use with the Flexowriter is an 8 bit wide output originally intended for use as a digital to analog converter output; however, the digital register is available within the computer and provides a ready means of outputting up to 8 bits per output character.

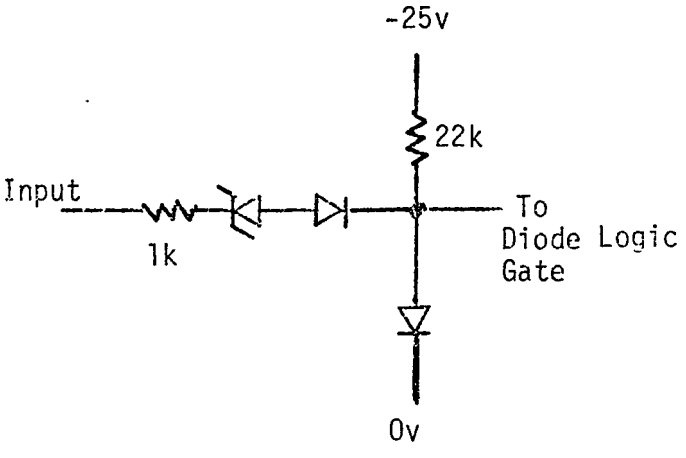
Input-Output Circuits

The structure of the input circuitry of the D17B is shown in Figure 1. The input lines for both codes and timing must swing between 0 volts and minus 12 volts, with minus 12 volts being the "1" or true logic state, at the input to the diode logic gates. The input circuitry of the D17B requires that the character lines swing between 0 volts and approximately minus 13 volts; however, the timing pulse lines must swing between 0 volts and approximately plus 12 volts.

The flip-flops that comprise the "A" voltage output register are loaded from the 8 most significant bits of either the right or left split word of the computer upon execution of the "VOA" command. The output driver circuits of the flip-flops are shown in Figure 2. The 8 bits are transferred to the interface unit and are output to the Flexowriter by a discrete output signal. The discrete output signal is generated by a "DOA" command and is output via a single line from the circuit shown in Figure 3. Other discrete output lines are used to set the interface unit to either the octal data mode or the alphanumeric character mode. These lines are output from the computer via another circuit identical to the one shown in Figure 3.



Character Input Lines



Timing Input Circuit

FIGURE 1

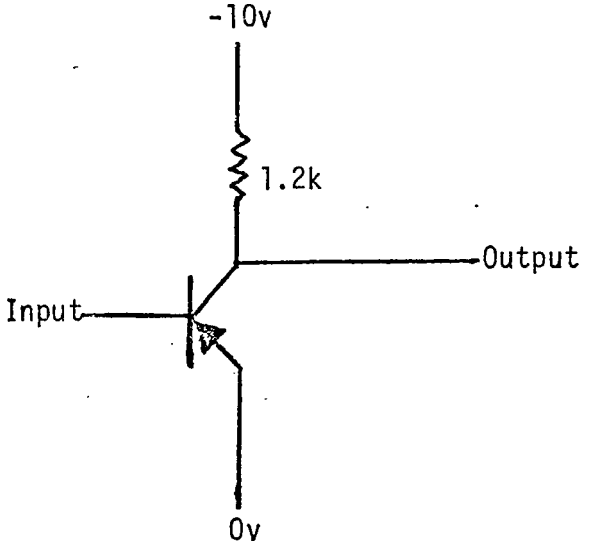


FIGURE 2

CHAPTER III

FLEXOWRITER DESCRIPTION

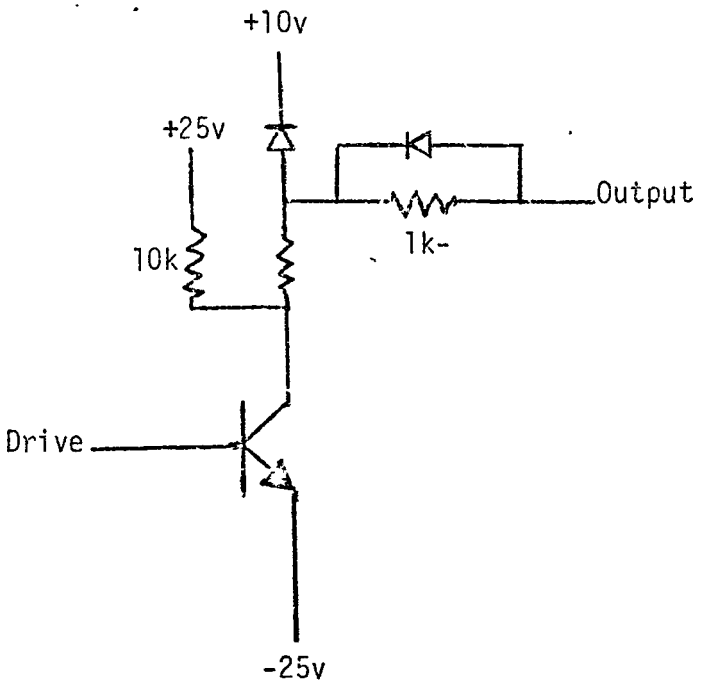
Flexowriter Characteristics

Pertinent characteristics of the Friden Flexowriter are as follows:

1. 6 level code to represent the 26 characters of the alphabet, 10 numerals, 7 special characters and 7 control characters for a total of 50 codes.
2. Both upper and lower case type fonts for all alphanumeric and special character codes.
3. Punched paper tape reader, 10 character per second transmission rate.
4. Paper tape punch, 10 characters per second transmission rate. Paper tape may be punched from computer or keyboard.
5. Regeneration feature for duplicating punched tapes.
6. Single 48 volt power supply internal to Flexowriter.

Input-Output Structure

The Flexowriter outputs data from the keyboard via a set of 6 cam operated switch contacts. The switches are normally open and are closed for a "true" condition in the code. A seventh switch is used for timing and is closed after the character switches have had sufficient time to close and the contact bounce has terminated. The paper tape reader outputs are derived from a similar set of contact closures. The timing relationships of the contacts for the keyboard and the reader are shown in Figure 4. Full switch circuit diagrams are shown in Appendix A.



Discrete Output Lines

FIGURE 3

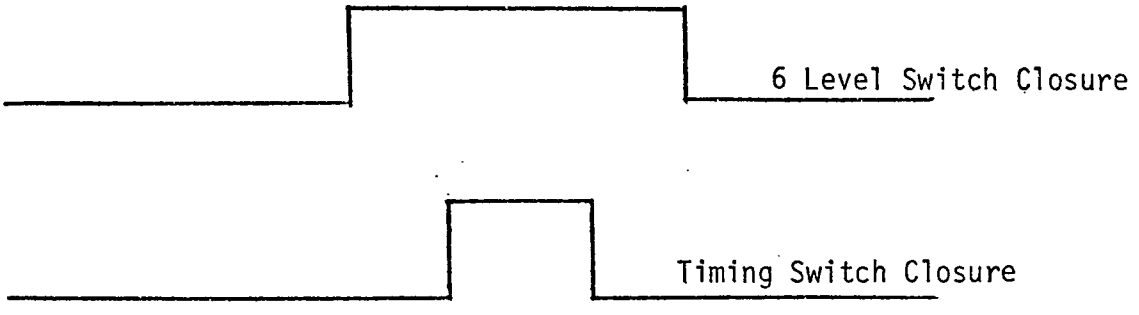


FIGURE 4

The input circuitry for the Flexowriter typewriter is shown in Figure 5. The type solenoids or translators require plus 48 volts for actuation which is furnished by the plus 48 volt supply of the Flexowriter via a set of relay contacts in the interface unit. The 6 level code solenoids are energized first, and after a short period of time, the type clutch magnet is energized allowing the clutch to engage, cycle the translator, and type the character. The punch functions in much the same manner; however, in this instance, the punch is not driven directly from the interface but rather the typewriter is driven and when the punch is turned on it is driven via the typewriter switches internal to the Flexowriter. Control codes, such as carriage return, tab, etc, are interpreted by the Flexowriter and executed accordingly. Adequate time must be allowed for execution of these codes, e.g., if the carriage has advanced 60 spaces and a carriage return is executed, then sufficient time must be allowed for the carriage to return to its starting position before another code is transferred to the Flexowriter.

CHAPTER IV

INTERFACE LOGIC UNIT

General

The logic unit that interfaces the D17B computer to the Flexowriter is designed with standard 7400 series transistor-transistor logic (TTL) modules and is constructed on a plug-in, wire wrapped assembly. Power for the logic unit is furnished by an external 5 volt supply, and an external 28 volt supply is used to power the relays that interface to the Flexowriter type solenoids and to the type/reader contacts. Level conversions from 5 volt logic levels to the D17B logic levels are accomplished by discrete component level translators using plus 25 volts and minus 25 volts from the computer. Conversions from 10 volt logic levels in the D17B are made by clamping the D17B signals to 0 and 5 volts in the interface.

Since the D17B utilizes negative voltages for true logic signals, the interface was set up at 0 and minus 5 volts, with 0 volts being common to the interface and the D17B, and minus 5 volts as logic common. The Flexowriter is completely isolated by relays for noise suppression and has no common connection to the interface or computer.

Interface to the Flexowriter

The Flexowriter is interfaced to the logic unit by electro-mechanical relays. Level conversion and complete isolation is provided between the Flexowriter and the interface as shown in Figure 6. The output circuits to the Flexowriter also provide level conversion and isolation via relays in a similar manner.

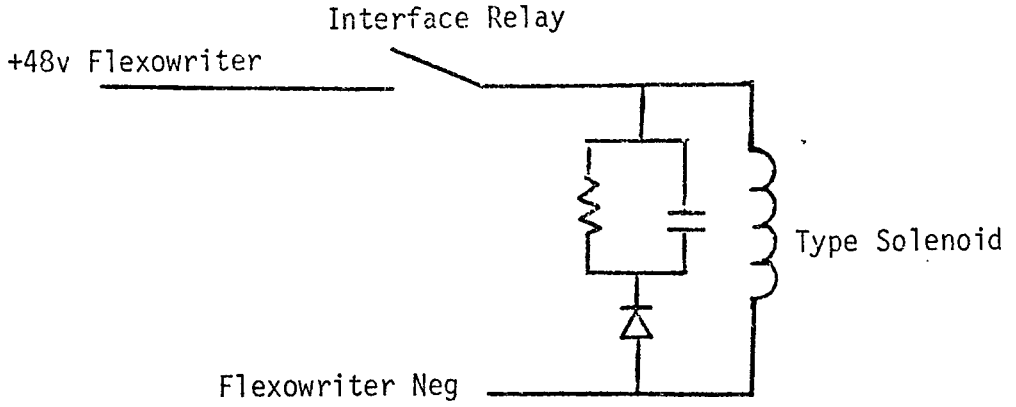


FIGURE 5

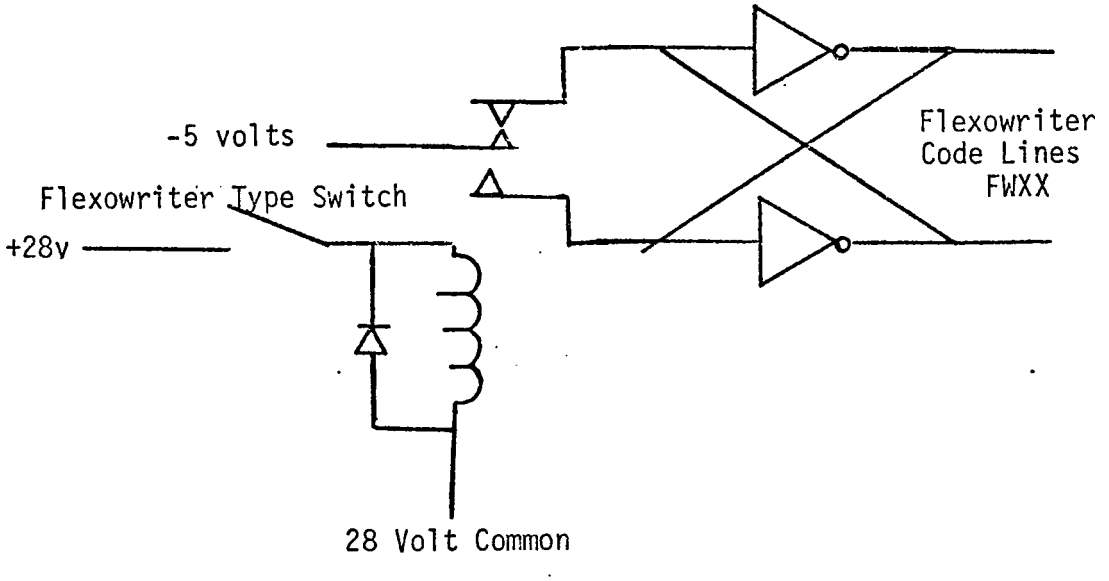


FIGURE 6

Interface to the D17B

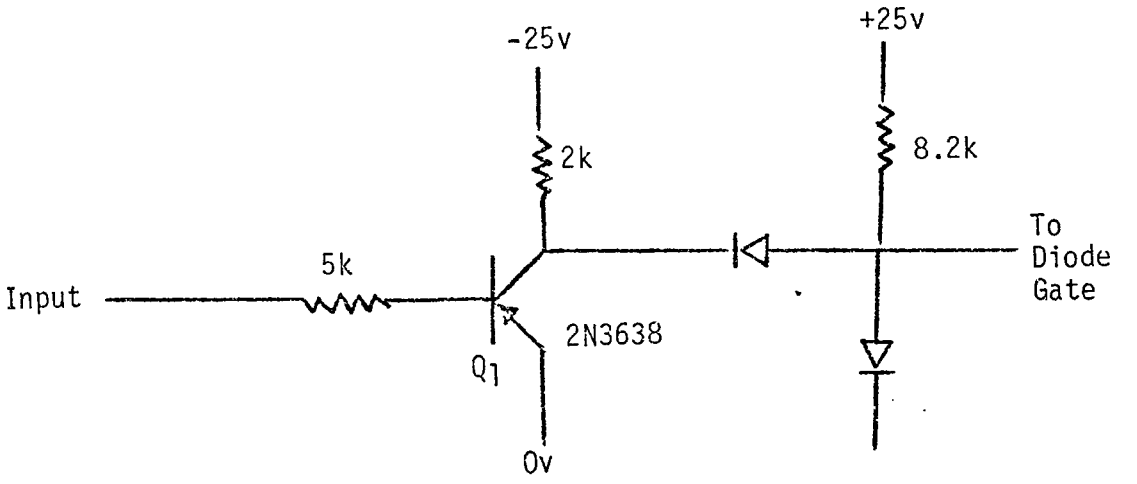
The necessary logic levels for the D17B were provided by using discrete component level converters as shown in Figures 7a and 7b. A 0 volt level at the logic drive input will bias the character line driver transistor Q_1 into an off state. The collector will swing to approximately minus 13 volts as determined by the voltage divider of 2K and 8.2K (Figure 7a) between minus 25 and plus 25 volts. At an input level of minus 5 volts the transistor is conducting and shunts the input to the D17B to 0 volts. The timing line input must swing between 0 volts and a positive voltage in order to drive the diode gate inputs (Figure 7b) between minus 12 volts and 0 volts. At a logic input of 0 volts, Q_2 is turned on and shunts the input to the D17B to 0 volts. At a logic level of minus 5 volts, Q_2 is turned off allowing the collector to rise toward the plus 25 volt supply. A positive voltage greater than approximately 7 volts at the timing line inputs will drive the inputs to the diode gates from a negative value to approximately 0.3 volts.

Inputs from the D17B are clamped to the logic levels of 0 and minus 5 volts as shown in Figures 8a and 8b.

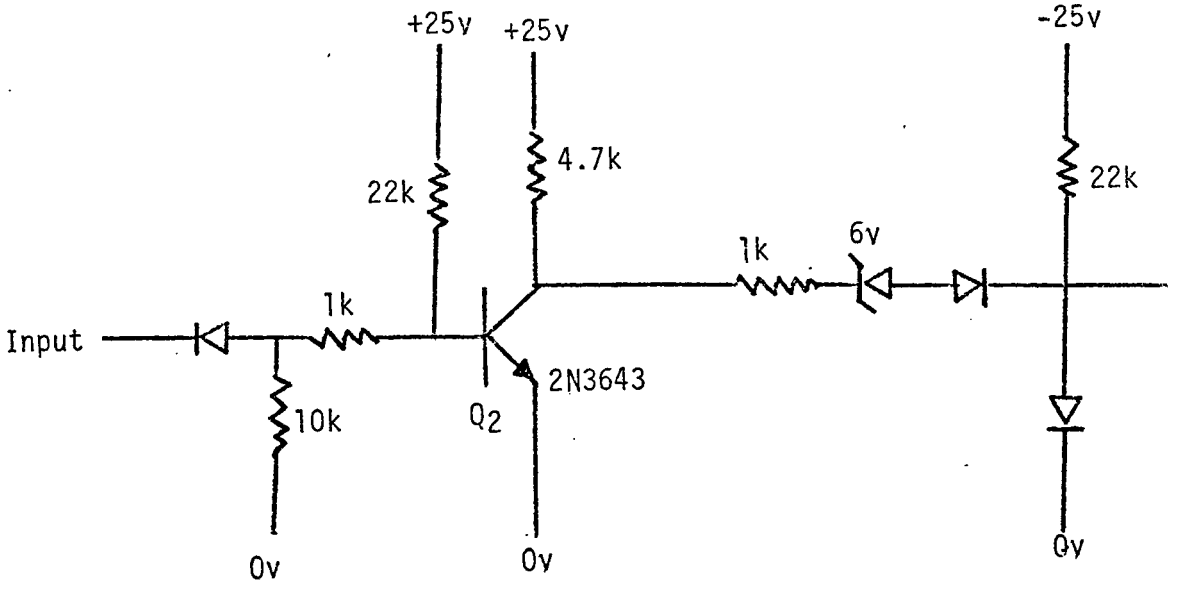
Logic Unit Functional Description

Input to Computer

The interface unit is designed to accept 6 bit codes from the Flexowriter and convert these codes into 5 bit codes for the D17B computer. As shown in Appendix C, there are 2 types of codes for the D17B, command codes and octal data codes, being differentiated by bit b_4.

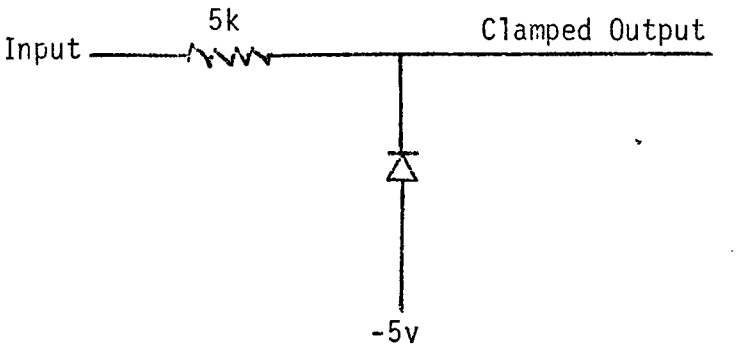

-25v
+25v
2k
8.2k
To
Diode
Gate
Input
5k
2N3638
Q_1
0v

(a)

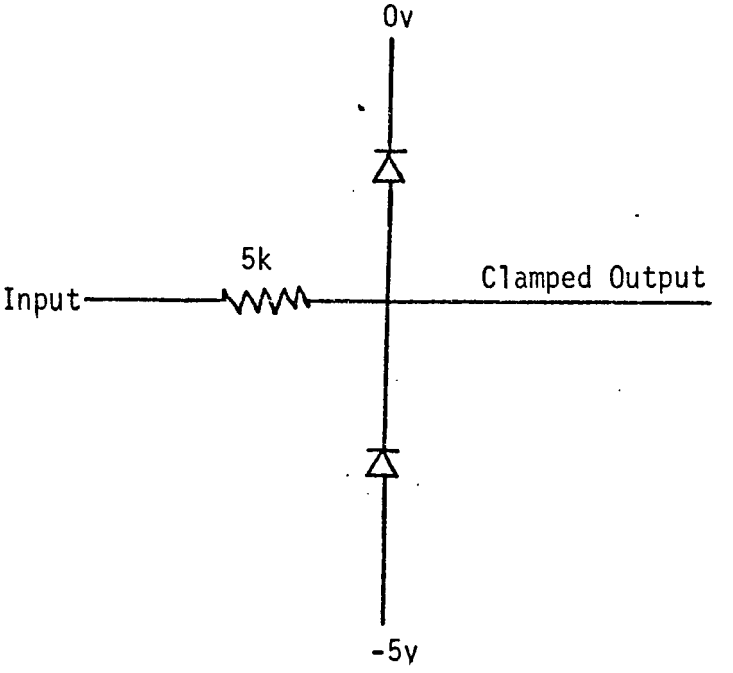

+25v
+25v
-25v
22k
4.7k
22k
1k
6v
Input
1k
2N3643
10k
Q_2
0v
0v
0v

(b)

FIGURE 7



(a)



(b)

FIGURE 8

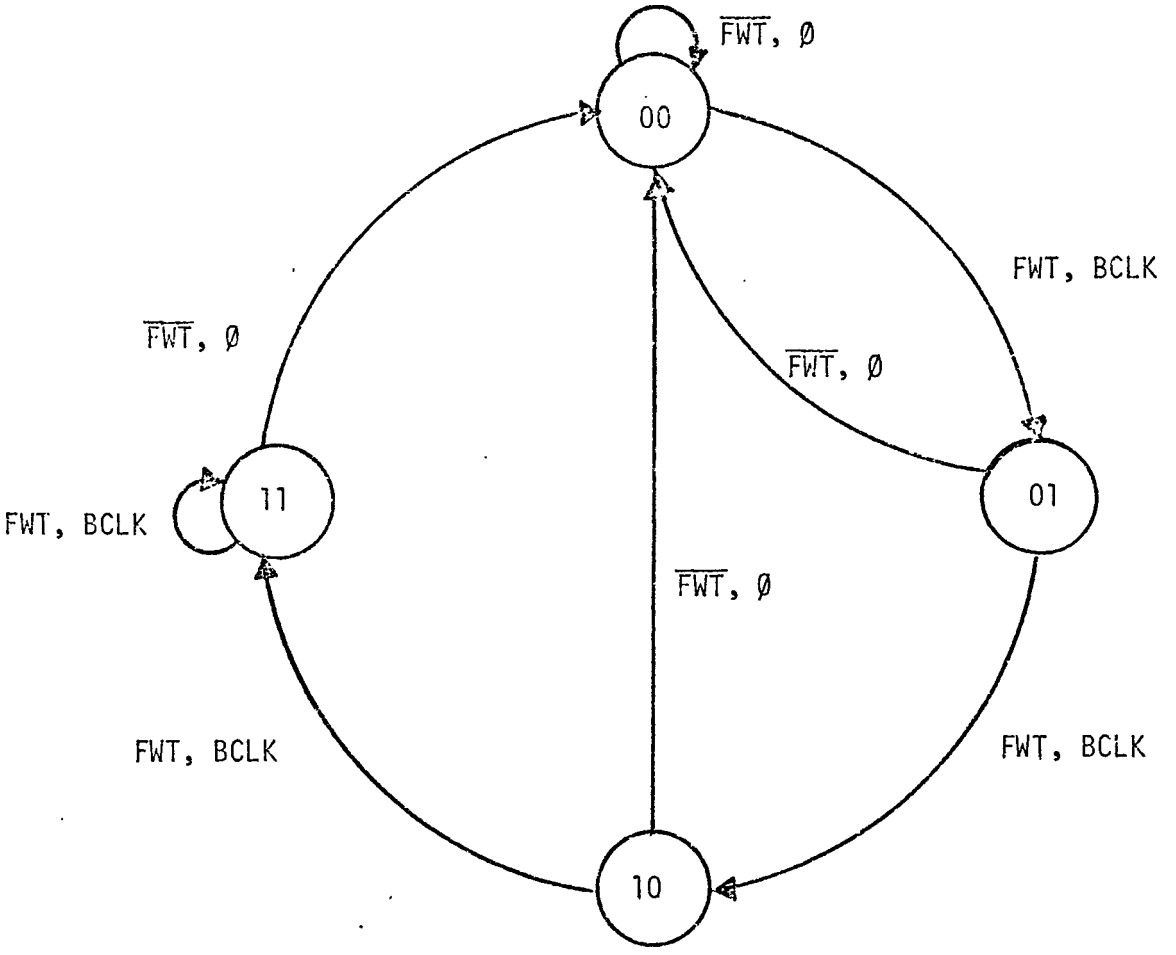
The interface decodes the special character keys on the Flexowriter, designated as command keys, and passes the appropriate command to the D17B. Octal data from keys 0 through 7 is passed as such, provided the mode is set to "Data" by the breakpoint switch. Alphanumeric data from the remainder of the keys is passed as two 5 bit codes for each character, provided the "Alphanumeric" mode s selected by the breakpoint switch.

As an illustration of the logic functions of the interface unit, let us consider an example of entering octal data from keys 0 through 7 into the D17B memory unit. 0 volts is designated as logic 1. Figures 1 and 2, Appendix A, show the logic for the following discussion. Appendix E contains the timing diagrams. The breakpoint switch on the Flexowriter is depressed, energizing relay K15 and causing the signal BRKPT to become true. This conditions the logic such that only 1 octal character will be passed to the D17B.

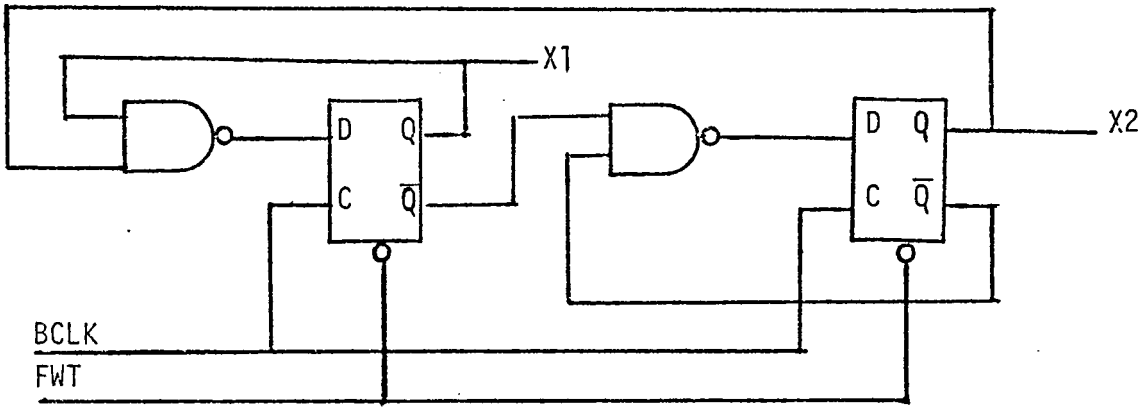
The entry of data into the D17B is timed by a 2 phase clock signal, the phases of which are designated ACLK and BCLK. BCLK is the clock signal for the sequential machine shown in Figure 9. Inputs to the machine are FWT and BCLK. The machine resides at state 00 until FWT becomes true. It then progresses with each BCLK until it reaches state 11 where it remains until FWT becomes false.

The states are decoded as $\overline{X1}.\overline{X2}$, $X1.\overline{X2}$, $\overline{X1}.X2$ and $X1.X2$. The interface generates a timing pulse coincident with ACLK during state $X1.\overline{X2}$ when transferring octal data. The timing pulse, TC, is true when:

$$TC = (ACLK)(\overline{COM})(\overline{X1})(X2)(BRKPT)$$


$\overline{FWT}$, Ø
00
FWT, BCLK
$\overline{FWT}$, Ø
$\overline{FWT}$, Ø
11
01
FWT, BCLK
$\overline{FWT}$, Ø
FWT, BCLK
FWT, BCLK
10

(a)


X1
D
Q
C
$\overline{Q}$
D
Q
C
$\overline{Q}$
X2
BCLK
FWT

(b)

FIGURE 9

If BRKPT is false, the interface is set to transfer alphanumeric data. The 6 level code is transferred as two 5 bit characters similar to above except the second timing pulse is generated during state $\overline{X1}.X2$. The TC pulse is now true for data transfer whenever:

$$TC = (ACLK)(\overline{COM})(\overline{X1})(X2)(\overline{BRKPT})+(ACLK)(\overline{COM})(X1)(\overline{X2})(\overline{BRKPT})$$

If a command key is struck then TC is generated one time as:

$$TC = (ACLK)(COM)(X1)(X2)$$

COM is derived from the decoding of a given 6 bit command code as shown in the 7430 gates 10A through 18A. Note on the timing diagram that the signals FW1-FW6 are valid well ahead of FWT, hence ample time is allowed for the command decoding.

The signal CHAR1, generated during the state $X1.\overline{X2}$ and when BRKPT is true, i.e. octal data transfer mode, selects FW1 as bit 1, FW2 as bit 2 and FW3 as bit 3. These are the 3 octal data bits transferred to the computer. The fourth bit transferred is COM, which is false during octal data transfer and the fifth bit, bit 5, is an odd parity bit for the 5 bit transfer and is given by:

$$BIT5 = \overline{(BIT1+BIT2) + (BIT3+COM)}$$

For alphanumeric data transfer, CHAR2 is generated prior to CHAR1 since the last 3 bits of the character must be entered before the first 3 bits. This is necessary because the data is entered into the low order bits of the accumulator and then precesses left by three bits into the next higher order three bits of the accumulator.

CHAR2 is generated during the state $X1.\overline{X2}$ when BRKPT is false, i.e. alphanumeric mode, and is used to select FW4 as BIT1, FW5 as BIT2, and FW6 as BIT3. The fourth and fifth bits of the word are as previously

described. After these 3 bits are entered, CHAR1 becomes true during state $\overline{X1}.X2$ and selects FW1, FW2 and FW3 as bits 1, 2 and 3, respectively. The timing pulse for both word entries is generated coincident with ACLK.

When the timing signal FWT becomes false, the state counter is reset to $\overline{X1}.\overline{X2}$ and awaits another data entry. The D17B must be set to the "Non-Compute" mode prior to data entry and once in this mode may be set to "Fill" from the Flexowriter and data entered. The data word of either 8 octal characters of 3 bits each, or 4 alphanumeric characters of 6 bits each, is transferred from the accumulator to the memory upon receipt of the "Enter" command from the interface. This command is generated by striking the carriage return key of the Flexowriter. Note that only the last 8 octal characters, or the last 4 alphanumeric characters, entered are transferred to the memory. Preceding entries are shifted out of the accumulator as new data is entered. The 5 bit lines are converted to appropriate levels for entry to the D17B as described earlier.

Output from Computer

The data is output from the computer via the 8 bit register of the voltage output "A" function. Upon execution of the VOA command in the computer, the 8 most significant bits of the designated split word, are entered into the output register and remain in the register until another VOA command changes them. The D17B logic levels are clamped to the 0, minus 5 volt level required for the TTL logic, entered through buffers and designated as COMP1-COMP8. The output portion of the interface is set to either the data mode or the alphanumeric mode by the discrete

output lines as shown in Figure 2, Appendix A.

COMP1, COMP2 and COMP3 are always transferred to the Flexowriter type solenoid drive lines FWCH1, FWCH2 and FWCH4, respectively, via the relays K1, K2 and K3. If the interface is set to the "Data" mode, then FWCH8 is always false. FWCHA is derived from the parity bit which is an odd parity bit for the first 4 Flexowriter channels. One exception is if an octal data value of zero is transferred, then this bit is set false and the next bit, FWCHB, is set true. These conditions may be seen from the expression for the signal BASE5 and BASE6 for the relay transistor drivers.

$$BASE5 = (FWTIME)(PARBIT)(\overline{ZRO})(DATA)$$

$$BASE6 = (FWTIME)(ZRO)(DATA)$$

The term FWTIME is the output strobe for the Flexowriter and is generated by the number 1 discrete output line whenever the DOA-1 command is executed. All timing for the output of data to the Flexowriter is under program control and is accomplished by maintaining the number 1 discrete output line in the true state for approximately 55 milliseconds.

For transfer of alphanumeric data, the full 6 level code is transferred as contained in the voltage output register. The VOA8 line is derived from the most significant bit of the designated split word. Execution of a VOA instruction loads all 8 bits of the register, hence for octal data output the accumulator must be shifted by 3 bits between output cycles and by 6 bits between output cycles of alphanumeric data.

The Flexowriter may be completely controlled by generating the appropriate codes from the computer, e.g. upper or lower case may be set, carriage return or tab executed, etc.

CHAPTER V

PROGRAMMING CONSIDERATIONS

The D17B has an adequate set of instructions for general purpose programming. These are covered in other publications and will not be detailed here.

As mentioned previously, all of the timing for the Flexowriter output cycle is controlled by the computer program. Execution of a DOA-1 instruction, octal code 40XX2601, begins the output cycle, and execution of any other DOA instruction terminates the cycle. Approximately 55 milliseconds should be allowed for the initiation of the output cycle and approximately 45 milliseconds allowed before a second character is transferred to the Flexowriter. A suggested program sequence to accomplish this is described in Appendix C.

A utility program is given in Appendix C. This program allows the user to output a specified number of memory locations to the typewriter, or the paper tape punch. For the typewriter output, the format is set for 8 words per line and for the paper tape punch a single word, followed by a carriage return character. This allows the user to create a paper tape suitable for later entry into the computer. An example of the format is shown in Appendix C. The typewriter format example is a complete listing of the utility program.

Programming is relatively straightforward with the exception of the "Store" command. Here the store address must be specified as the true address plus 2 locations. This is necessary since the addressing scheme is synchronized with the read heads on the drum and these heads lead the write heads by 2 word locations.

The entry of data into the D17B is hardware controlled. Data may be entered only when the computer is in the "Fill" load. A detailed procedure for loading the D17B is given in Appendix C.

CHAPTER VI

SUMMARY

The project to interface a Friden Flexowriter and a "Minuteman" D17B computer was successfully accomplished. The addition of the Flexowriter furnishes an easy means of entering data, programming the D17B, and obtaining a hard copy of any required output data. The design could be improved by the replacement of the relays with optical couplers that are readily available at a reasonable price. This would enhance the reliability and eliminate the 28 volt relay power supply.

Further devices that would provide flexibility in the use of the computer are octal read-outs for the accumulator, the lower accumulator and the instruction register, and the addition of a small switch unit on the Flexowriter for the master reset and single step functions. Additional output devices could be added on the remaining 2 voltage output registers and the remaining discrete output lines could be used for control functions.

BIBLIOGRAPHY

1. U.S. Air Force Technical Manual, T.O. 11G2-10-5-3-5, "General Purpose Digital Computer (Model D17B)".

2. Project Office Memorandum No. 71, "Preliminary Maintenance Manual of the Minuteman D17A Computer and Associated Test Equipment", Autonetics Company, January 1960.

3. EM2065, "Minuteman Computer Logical Description, Guidance and Control Equipment for the Minuteman", Autonetics Company, January 14, 1960, revised June 15, 1961.

4. "Minuteman D17 Computer Training Data", June 8, 1970, Autonetics Company.

5. U.S. Air Force Technical Manual, T.O. 11G2-10-5-3-10, "Overhaul (Repair)", October 15, 1962 with change 12.

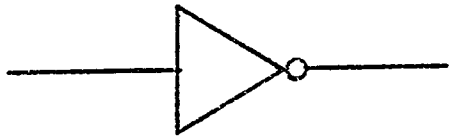
6. "The TTL Data Book for Design Engineers", Texas Instruments Inc., 1973.

APPENDIX A

Logic Diagrams

LOGIC SYMBOLS

The logic symbols, in general, conform to MIL STD 806. All logic elements used are standard TTL logic elements. Symbols used are as follows.

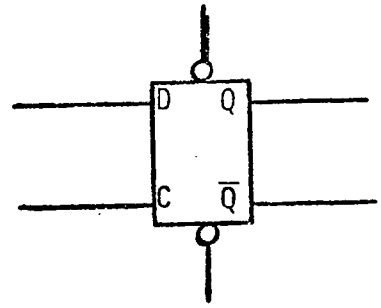


Inverting Driver
SN 7404

Nand Gate
SN 7400

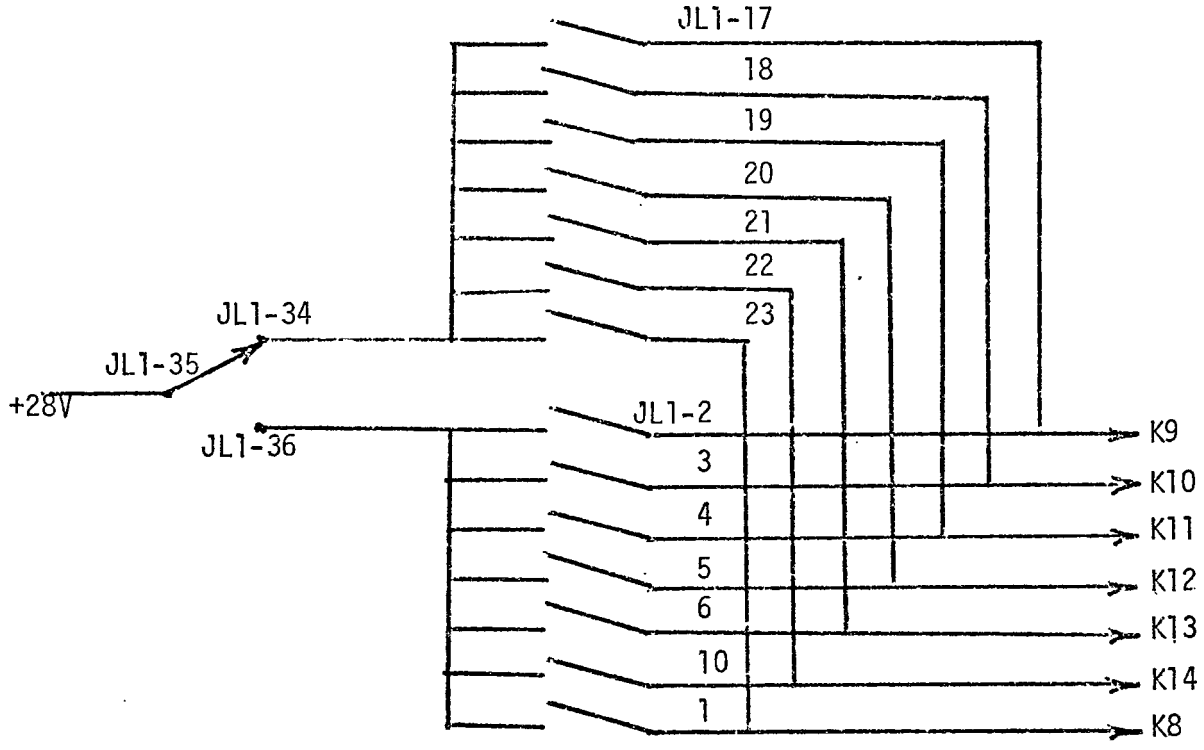
Exclusive or Gate
SN 7486

Nor Gate
SN 7402

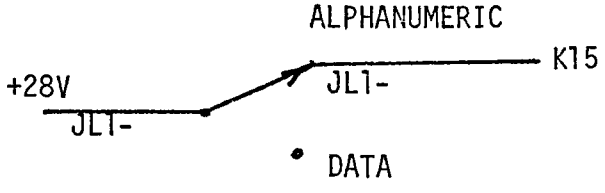


D Type Flip Flop
SN 7474

TYPE



READER



BREAKPOINT SWITCH

FLEXOWRITER SWITCH CIRCUITS

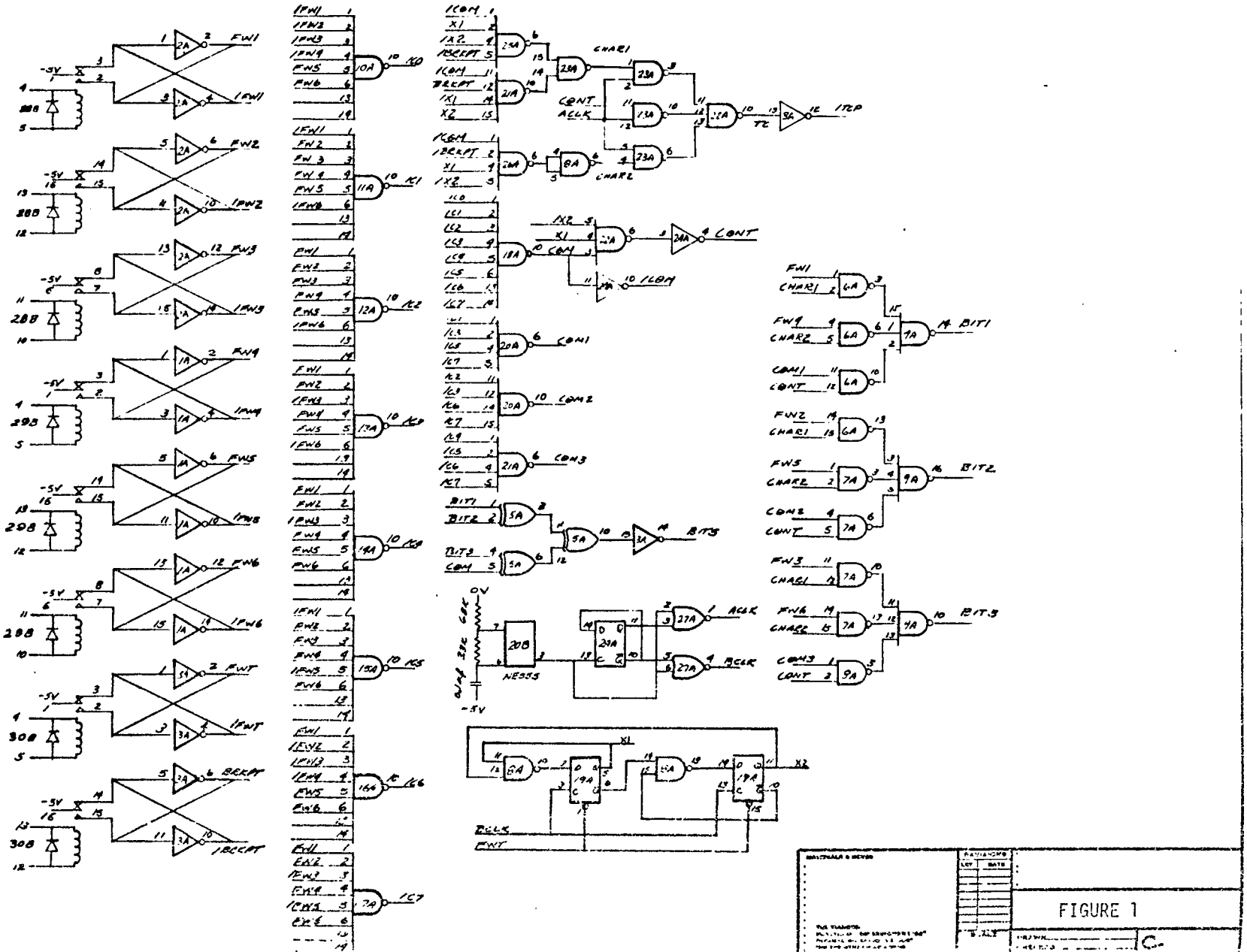


FIGURE 1

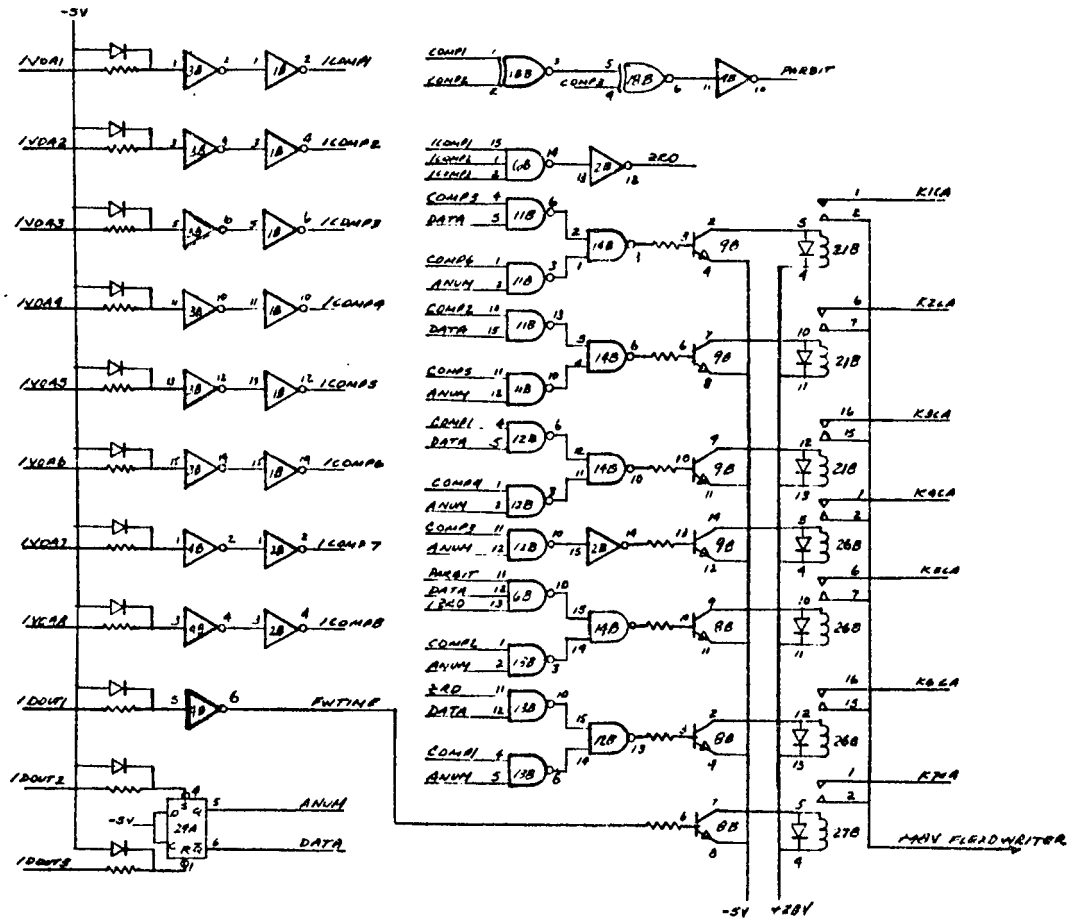
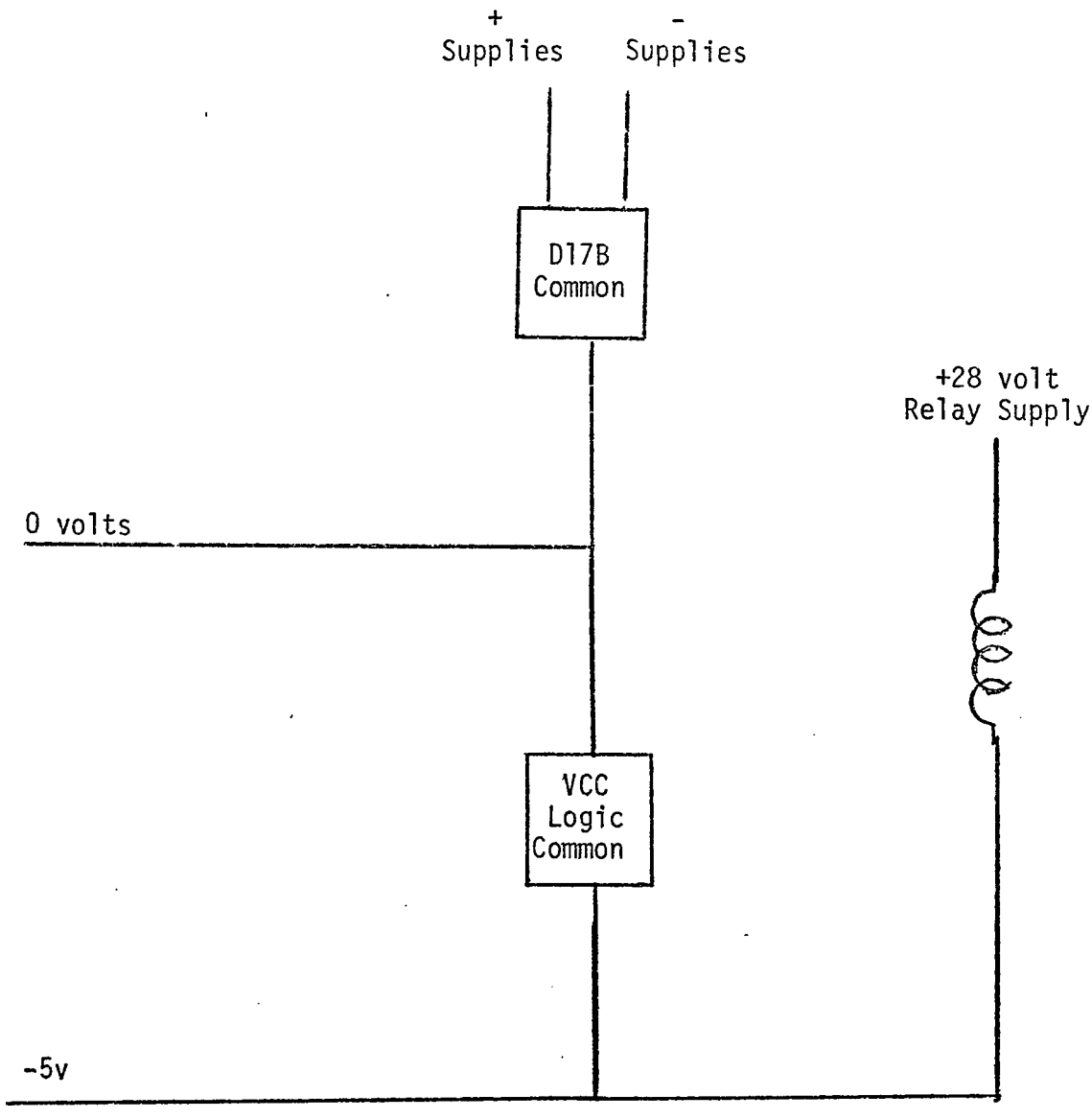

-5V
/VDA1
/VDA2
/VDA3
/VDA4
/VDA5
/VDA6
/VDA7
/VDA8
/DOUT1
/DOUT2
/DOUT3
/CAMIN
/COMPB
/COMPB
/COMPB
/COMPB
/COMPB
/COMPB
/COMPB
/COMPB
FWTINB
ANUM
DATA
COMP1
COMP2
PARBIT
/CMD1
/CMD2
/CMD3
2CO
COMP3
DATA
COMP4
ANUM
COMP2
DATA
COMP3
ANUM
COMP1
DATA
COMP4
ANUM
COMP2
ANUM
PARBIT
DATA
/2CO
COMP1
ANUM
2RD
DATA
COMP1
ANUM
K1CA
K2CA
K3CA
K4CA
K5CA
K6CA
K7CA
K8CA
MAIN FIELDWRITER
-5V
+28V

FIGURE 2



POWER SUPPLY CONFIGURATION

APPENDIX B

Program Listings

APPENDIX B

DUMP PROGRAM D17B

Memory Location	Instruction	Comments
10 PUNCH	CLA, INST6	
11	STO, LOC124	Set LOC124 to skip space character for punch
12	CLA, TDCR2	
13	STO, TDCR1	Shorten carriage return TD for punch operation
14	CLA, INST7	
15	STO, LOC152, JMP46	Set LOC152 to skip word count logic
16 ANUM	CLA, INST1	
17	STO, 152	Set LOC152 to restore word count logic
20	CLA, INST8	
21	STO, LOC102	Set LOC102 to set output mode to alphanumerics
22	CLA, INST9	
23	STO, LOC105	Set LOC105 to shift accumulator left 6 places
24	CLA, INST6	
25	STO, 124	SET LOC124 to skip space character for alphanumerics
26	CLA, '4'	
27	STO, LOC161	Set character count equal 4
30	STO, LOC126	Set character count work location
31	CLA, '21'	

Memory Location	Instruction	Comments
32	STO, LOC162	Set word count to oct 21
33	STO, LOC163	Initiate word count work location
34	CLA, '40'	
35	STO, 75, JMP57	Reset long time delay for carriage retu.n
36		
37 DATA	CLA, INST1	
40	STO, LOC152	Set LOC152 to include word count logic
41	INST1 = STO, DMP CNT	
42	CLA, INST2	
43	STO, LOC124	Set LOC124 to restore space character
44	CLA, '40'	
45	STO, LOC75	Reset long time delay for carriage return
46	CLA, INST3	
47	STO, LOC102	Set LOC102 to set output mode to data
50	CLA, '7'	
51	STO, LOC161	Set character count equal 7
52	STO, LOC126	Set character count work location
53	STO, LOC162	Set word count equal 7
54	STO, LOC163	Set word count work location
55	CLA, INST4	
56	STO, LOC105	Set LOC105 to shift accumulator left 3 places
57	CLA, START ADD	

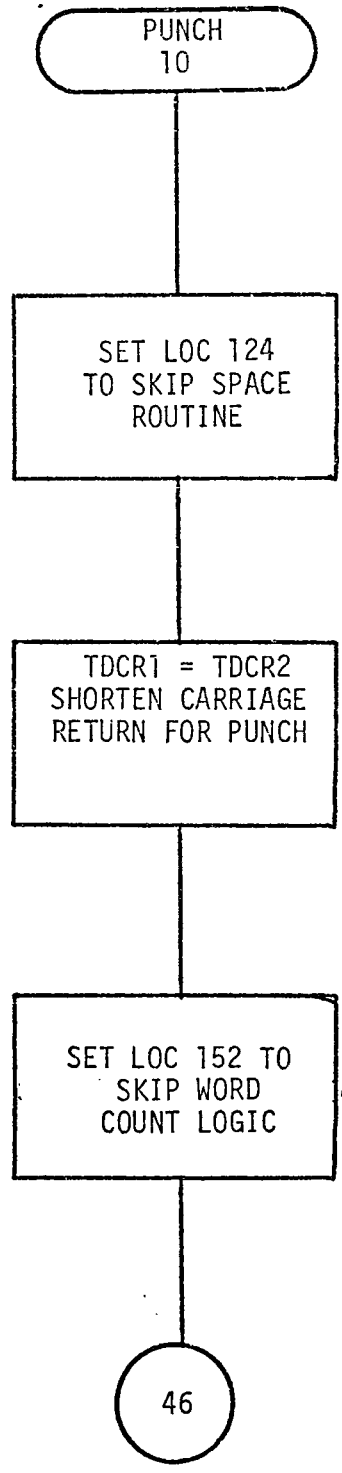
Memory Location		Instruction	Comments
60		ADD, INST5	Form data fetch instruction
61		STO, LOC100	
62	CR	CLA, CRCODE	Load carriage return code
63		DOA, 2	Set to anum mode
64		VOA	Output to register
65		DOA, 1	Start output cycle
66		CLA, TDCR1	Delay for carriage return
67		SUB, 1	
70		SKM, 71, 67	
71		DOA, 3	Turn off cycle; set to data
72		CLA, TDCR2	Delay before next character
73		SUB, 1	
74		SKM, 100, 73	
75		TDCR1	Constant time delay for carriage return
76		TDCR2	Constant time delay for carriage return
77		INST5 = CLA, LOC00	
100	LD	CLA, ADD	Load data word
101		STO, TEMP	Store data in TEMP
102	OUTPUT	DOA3	Set to data mode
103		CLA, TEMP	Load data from TEMP
104		VOA	Output to register
105		ALS, 3	Shift data character
106		STO, TEMP	Store data in TEMP

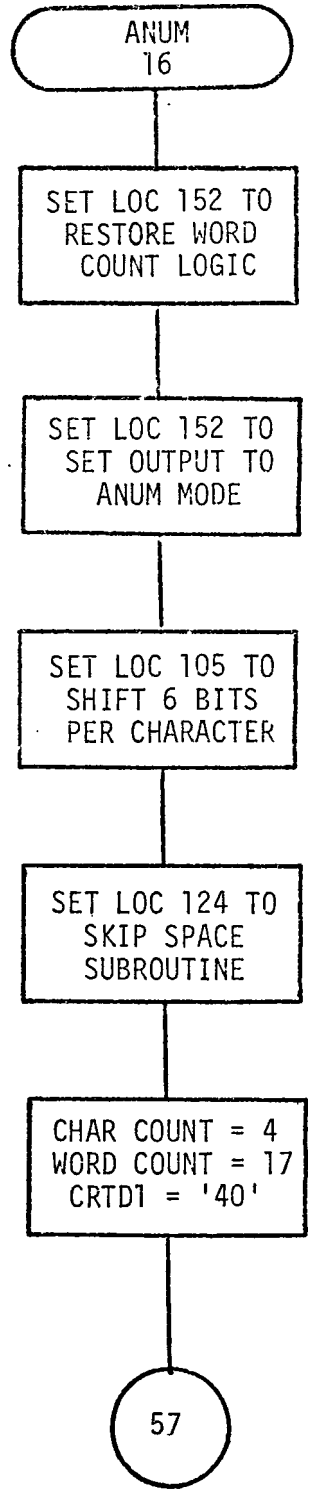
Memory Location		Instruction	Comments
107		DOA, 1	Start out cycle
110		CLA, TD1	Time delay for output cycle
111		TD1=2	
112		SUB, 1	
113		VALUE = 1	
114		TMI, 115, 112	
115		DOA, 3	Stop cycle, set to data
116		CLA, TD1	Time delay between characters
117		SUB '1'	
120		VALUE = 1	
121		TMI, 122, 117	
122		CLA, CHAR CNT WORK LOC	
123		SUB '1'	Decrement character count
124		TMI, 130, 125	Transfer to LOC130 if all characters output
125		STO CHAR CNT WORK LOC, JMP102	Save current character count
126		CHAR CNT WORK	Character count work location
127		TEMP	TEMP work location
130	SPACE	DOA, 2	Set to anum
131		CLA, SPACE CODE	Load space character code
132		VOA	Output space character
133		DOA	Start output cycle
134		CLA, TD1	
135		SUB '1'	

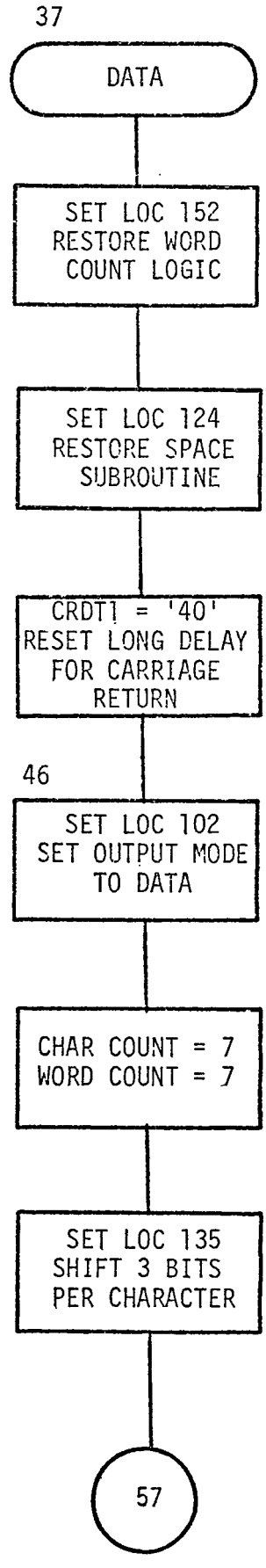
Memory Location	Instruction	Comments
136	VALUE = 1	
137	TMI, 140, 135	
140	DOA3	Stop out cycle. Set to data
141	SPACE CODE	Constant space character code
142	CLA, CHAR CNT SAVE	Restore character count
143	STO, CHAR CNT WORK	
144	CLA, INST100	Increment data address in LOC100
145	ADD '1'	
146	STO, INST100	
147	CLA, DMPCNT	
150	SUB '1'	Decrement dump counter
151	TMI, 177, 152	Go to END if completed
152	STO, DMPCNT	
153	CLA, WORD CNT WORK	
154	SUB, 1	Decrement word count
155	TMI, 157, 156	
156	STO, WD CNT WORK, JMP to 100	Line not complete go to DATA
157	CLA, WD CNT	
160	STO, WD CNT WORK, JMP to 62	Line complete. Restore WD CNT, go to carriage return (CR)
161	CHARCNT SAVE AREA	
162	WD CNT SAVE AREA	
163	WD CNT WORK AREA	
164	INST6 = TMI 142, 125	

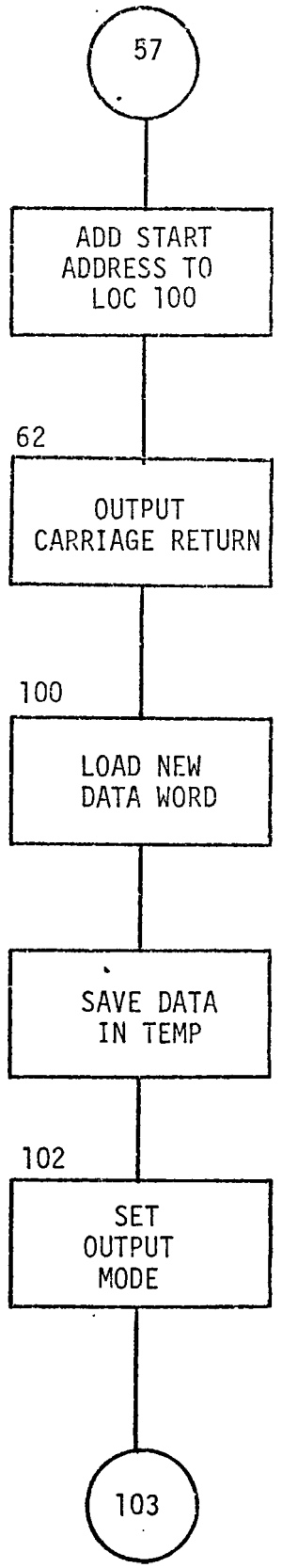
Memory Location	Instruction	Comments
165	CRCODE	
166	INST3 = DOA3	
167	INST4 = ALS3	
170	INST2 = TMI, 130, 125	
171	VALUE = 7	
172	VALUE = 40	
173	INST8 = DOA, 2	
174	INST9 = ALS6	
175	VALUE = 4	
176	VALUE = 21	
177 END	HALT	

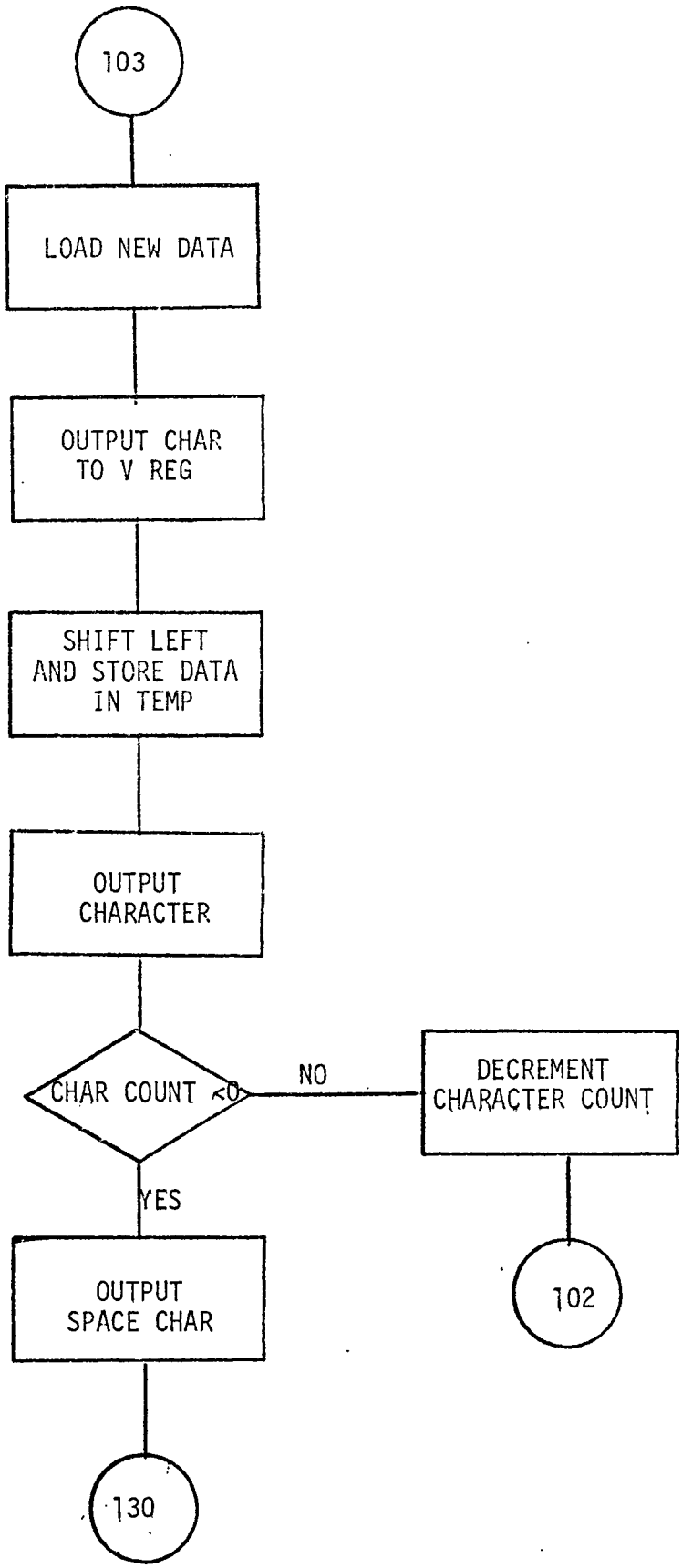
NOTE: All numbers in octal

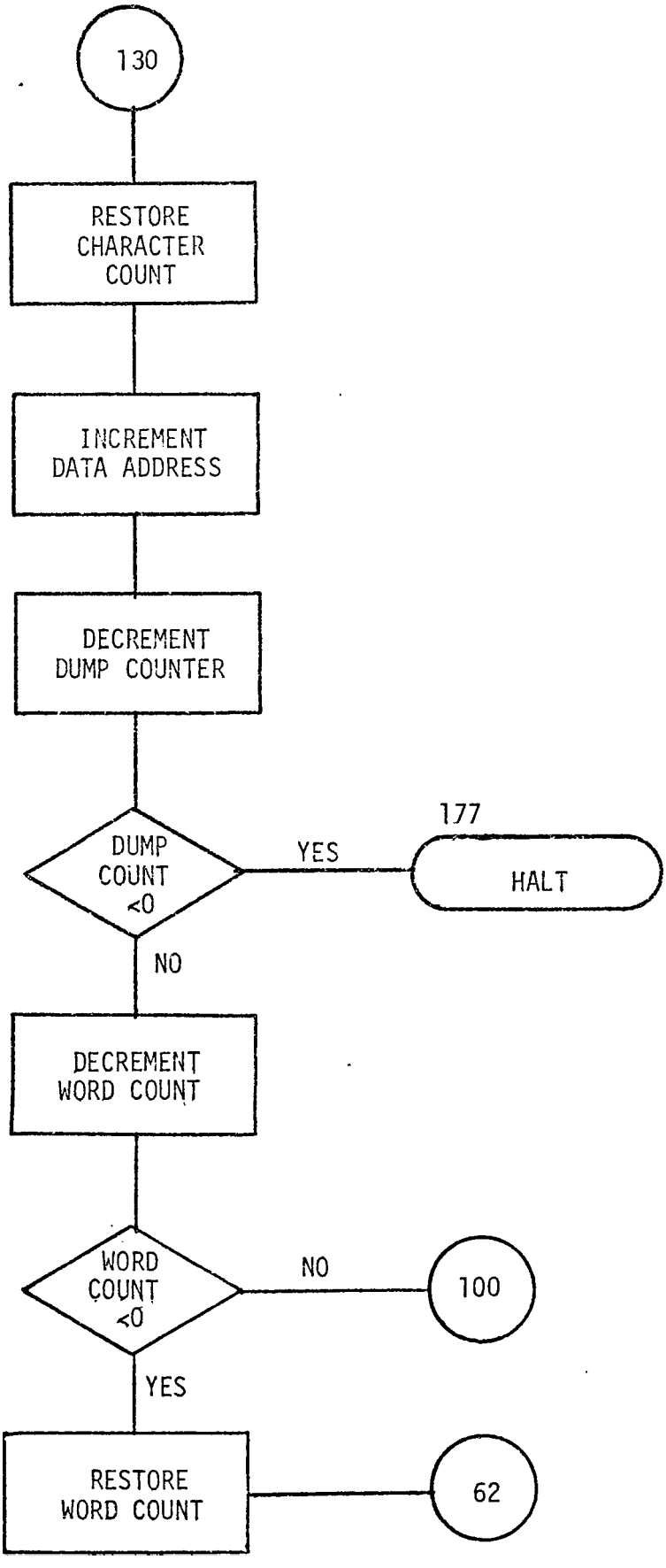

PUNCH
10
SET LOC 124
TO SKIP SPACE
ROUTINE
TDCR1 = TDCR2
SHORTEN CARRIAGE
RETURN FOR PUNCH
SET LOC 152 TO
SKIP WORD
COUNT LOGIC
46


ANUM
16
SET LOC 152 TO
RESTORE WORD
COUNT LOGIC
SET LOC 152 TO
SET OUTPUT TO
ANUM MODE
SET LOC 105 TO
SHIFT 6 BITS
PER CHARACTER
SET LOC 124 TO
SKIP SPACE
SUBROUTINE
CHAR COUNT = 4
WORD COUNT = 17
CRTD1 = '40'
57


37
DATA
SET LOC 152
RESTORE WORD
COUNT LOGIC
SET LOC 124
RESTORE SPACE
SUBROUTINE
CRDT1 = '40'
RESET LONG DELAY
FOR CARRIAGE
RETURN
46
SET LOC 102
SET OUTPUT MODE
TO DATA
CHAR COUNT = 7
WORD COUNT = 7
SET LOC 135
SHIFT 3 BITS
PER CHARACTER
57


57
ADD START ADDRESS TO LOC 100
62
OUTPUT CARRIAGE RETURN
100
LOAD NEW DATA WORD
SAVE DATA IN TEMP
102
SET OUTPUT MODE
103


103
LOAD NEW DATA
OUTPUT CHAR TO V REG
SHIFT LEFT AND STORE DATA IN TEMP
OUTPUT CHARACTER
CHAR COUNT <0
NO
DECREMENT CHARACTER COUNT
102
YES
OUTPUT SPACE CHAR
130


130
RESTORE CHARACTER COUNT
INCREMENT DATA ADDRESS
DECREMENT DUMP COUNTER
DUMP COUNT <0
YES
177
HALT
NO
DECREMENT WORD COUNT
WORD COUNT <0
NO
100
YES
RESTORE WORD COUNT
62

APPENDIX C

Operating Instructions & Codes

APPENDIX C

FLEXOWRITER OPERATING INSTRUCTIONS

Data Entry

To enter data into the D17B from the Flexowriter keyboard:

1. Place D17B in halt, non-compute mode.
2. Press master reset.
3. Depress "Enable" switch on Flexowriter.
4. Depress "Breakpoint" switch on Flexowriter.
5. Set fill mode by typing a minus (-).
6. Set location into D17B instruction register by sequentially typing eight octal numbers followed by plus (+).

   Example: To set the D17B to channel 1, sector 20; type

   00000120+
7. Enter data into channel 1, sector 20, by sequentially typing eight octal characters followed by a carriage return.

   Example: 45010101 CR

   (The instruction register is incremented by each carriage return.)
8. Continue to enter data into sequential memory locations by typing eight octal characters, each followed by a carriage return.
9. Upon completion of data entry, enter a transfer instruction into the instruction register, and then set the computer to the compute mode by typing a comma.

   Example: To execute a program beginning at memory location

00000100, enter a transfer to that location into the instruction register by typing 50000100+. Next set the D17B to the compute mode by typing a comma (,).

10. Set the D17B switch to run and the program will be executed.

Example: To enter a program at memory location 00000100, set D17B switch to halt, non-compute and type

-00000100+45010000 CR

55020131 CR

45030001 CR

550400132 CR

40002200 CR

50000100+, switch to run

To create a punched paper tape the computer need not be turned on. The following procedure is used.

1. Turn on the Flexowriter and punch.
2. Run some leader by depressing the tape feed switch.
3. Raise the "Enable" switch to disable the keyboard if the computer is on and in the "Load" mode.
4. Punch the tape.

The program may be entered on the paper tape and the tape loaded into the D17B as follows:

1. Depress "Breakpoint" switch for octal data.
2. Put D17B in halt, non-compute mode and press master reset.
3. Set instruction register to load address.
4. Raise "Enable" switch to enable reader.

5. Place tape in reader.
6. Turn on tape reader.
7. After tape is loaded, depress "Enable" switch, set transfer instruction in instruction register, set to compute and put D17B into run mode.

Limitations on Entry

1. Alphanumeric and octal data may not be mixed on a single paper tape.
2. Eight octal characters per input word.
3. Four alphanumeric characters per input word.

Data Output

To output data from the D17B, three instructions are used:

40XX2601 DOA1 Starts the output pulse

40XX2602 DOA2 Sets the Flexowriter to the alphanumeric mode

40XX2603 DOA3 Sets the Flexowriter to the octal data mode

The data is always output from the most significant bits of the accumulator. For octal data, the 3 most significant bits are output; for alphanumeric data, the 6 most significant bits are output. The output timing cycle is controlled by the program. The data is transferred to the output register of the D17B by a VOA instruction. The Flexowriter cycle is initiated by a DOA1 command. Approximately 55 milliseconds of delay are necessary for the Flexowriter to accept the command. The output cycle is then terminated and another 45 millisecond delay is necessary before another character is transferred. A suggested program sequence to

output a single character from the accumulator is:

Label	Instruction	Remarks
START	DOA3	Set octal data mode
	CLA, LOCA01	Load accumulator from memory location 01
	VOA	Output data to register
	DOA1	Start output cycle
	CLA, TIME1	Load delay time
	TIME1	Value = 00000002
SUB1	SUB, ONE	Decrement accumulator
	ONE	Value = 00000001
	TMI, $+1	Transfer on minus to next instruction, otherwise jump to SUB1
	DOA 3	Terminate output cycle and set to octal data mode
	CLA, TIME	Load delay time
SUB2	SUB, ONE	Decrement accumulator
	ONE	Value = 00000001
	TMI, $+1	Continue on minus, otherwise jump to SUB2

D17B Computer Input Codes

Description	Character b_5	b_4	b_3	b_2	b_1	Flexowriter Key
0	1	0	0	0	0	0
1	0	0	0	0	1	1
2	0	0	0	1	0	2
3	0	0	0	1	1	3
4	0	0	1	0	0	4
5	0	0	1	0	1	5
6	0	0	1	1	0	6
7	0	0	1	1	1	7
Halt	0	0	0	0	0	;
Location	1	1	0	0	1	+
Fill	1	1	0	1	0	-
Verify	0	1	0	1	1	'
Compute	1	1	1	0	0	,
Enter	0	1	1	0	1	CR
Clear	0	1	1	1	0	$
Delete	1	1	1	1	1	.

Flexowriter Commands from Computer

Instruction	Octal Code	Remarks
DOA,1	40XX2601	Start output cycle (reset by any other DOA)
DOA,2	40XX2602	Set alphanumeric mode
DOA,3	40XX2603	Set data output mode
VOA	40XX3000	Output 6 most significant bits

Flexowriter Controls

Enable Switch - Depress for keyboard, raise for reader.

Breakpoint - Depress for octal data, raise for alphanumeric.

Punch Switch - Turn on to punch.

Tape Feed - Depress to run paper tape.

Regen - Load paper tape into reader, turn on punch and depress Regen to duplicate punched paper tape.

Start Read - Depress to start reader.

Stop Read - Depress to stop reader.

00000000 00000000 00000175 50000016 40552601 44560064 74570113 54620004
44110164 54120126 44130076 54140077 44150007 54460154 44170041 54200154
44210173 54220104 44230174 54240107 44250164 54260126 44270175 54300163
54310130 44320176 54330164 54340165 44350172 54570077 00000000 44400041
54420154 55530004 44430170 54440128 44450172 54460077 44470166 54500104
44510171 54520163 54530130 54540164 54550165 44560167 54570107 44600001
64610077 54720102 44630165 40642602 40653000 40662601 44670075 74700113
10670071 40722603 44730076 74740113 10730100 00000040 00000014 45010000
45010100 55020131 41032603 45040127 41053000 01062203 55070131 41102601
45120111 00000002 75140113 00000001 11120115 41162603 45170111 75210113
00000001 11170122 45230126 75240113 11250130 55020130 00000007 00000000
41312602 45320141 41333000 41342601 45350111 75370136 00000001 11350140
41422603 20000000 45430161 55440130 45450100 65460113 55470102 45500002
75510113 11520177 55530004 45540163 75550113 11560157 55000165 45600162
54620165 00000007 00000007 00000004 11250142 56000000 41032603 01062203
11250130 00000007 00000040 41032602 01062206 00000004 00000021 40002200

APPENDIX D

Mnemonic Listing

APPENDIX D

MNEMONIC LISTING

ACLK — Clock signal, nominal 2KHz rate, with BCLK comprises a 2 phase CLK.

ANUM — Flip-flop output that indicates the alphanumeric mode on output to the Flexowriter. Set by DOA #2 command from D17B.

BASEXX — Signal that drives the output transistors.

BCLK — Clock signal, nominal 2KHz rate, with ACLK comprises a 2 phase clock.

BITXX — Output signals to the D17B character input lines. 5 signals total (BIT4 = COM).

BRKPT — Level generated by the breakpoint switch closure. Indicative of data mode on input from Flexowriter to D17B.

CHAR1 — Signal used to strobe the DATA character from the Flexowriter lines (FWXX) to the D17B input lines (BITXX), or to strobe the 3 most significant bits of the ALPHANUMERIC character to the D17B.

CHAR2 — Signal that strobes the 3 least significant bits of the ALPHANUMERIC character from the Flexowriter lines (FWXX) to the D17B input lines (BITXX).

CLK — CLK signal used to generate ACLK and BCLK, nominal 4KHz.

COILKXX Signal that drives the various relay coils used to isolate the Flexowriter and D17B.

COM Command indicator bit to the D17B (BIT4). Indicates a command code from Flexowriter.

COMPXX Output signals (buffered and clamped) from D17B.

COMXX Signals that indicate presence of a command code from the Flexowriter.

CONT Signal that strobes the command code from the Flexowriter to the D17B.

CXX Signals that indicate a command code from the D17B.

DATA Flip-flop output that indicates the DATA mode on output to the Flexowriter. Set by DOA #1 command from D17B.

DOUTXXCL DOUT signal, clamped to 0 and minus 5 volts.

DOUTXXIN Signal from D17B on DOUTX command.

FWCHXX Signals to Flexowriter type solenoids.

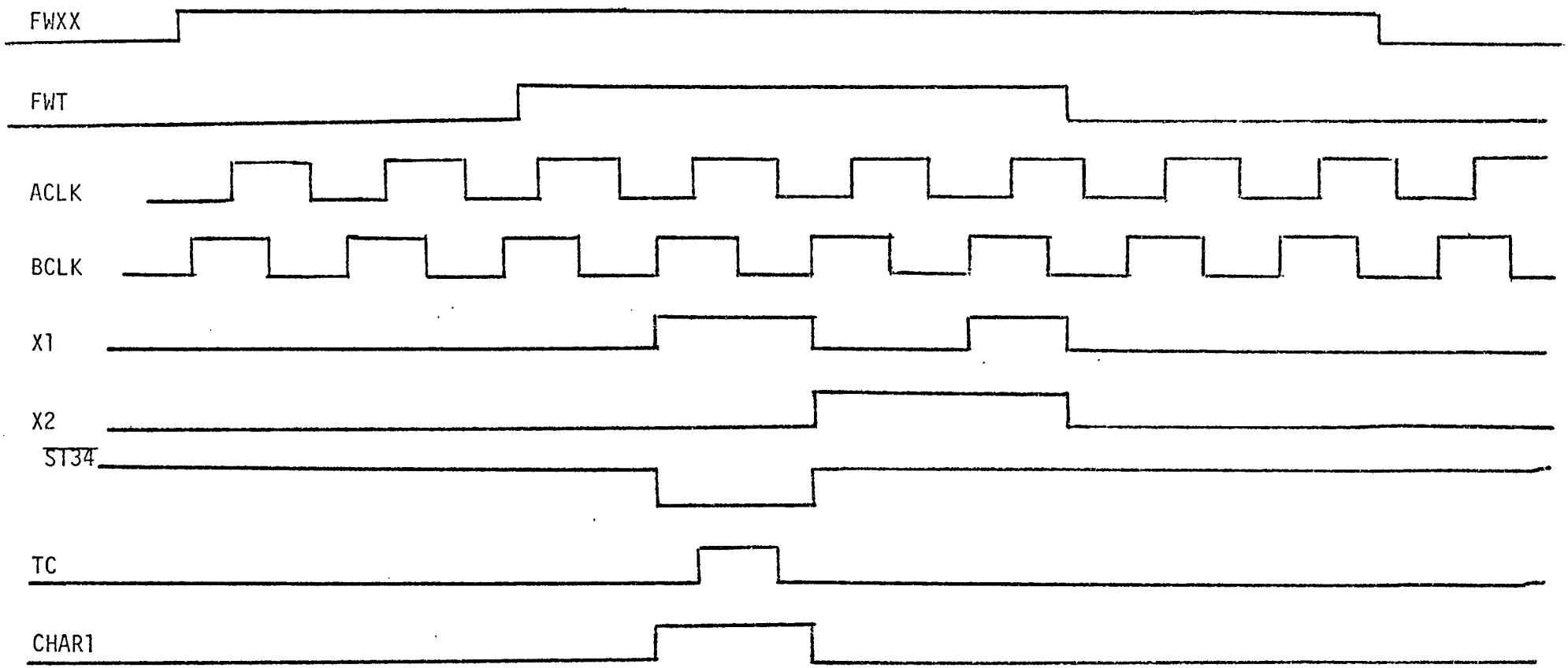
FWT Flexowriter timing pulse. Generated by switch closure in Flexowriter.

FWXX Flexowriter input lines. Generated by type keys and/or reader switches.

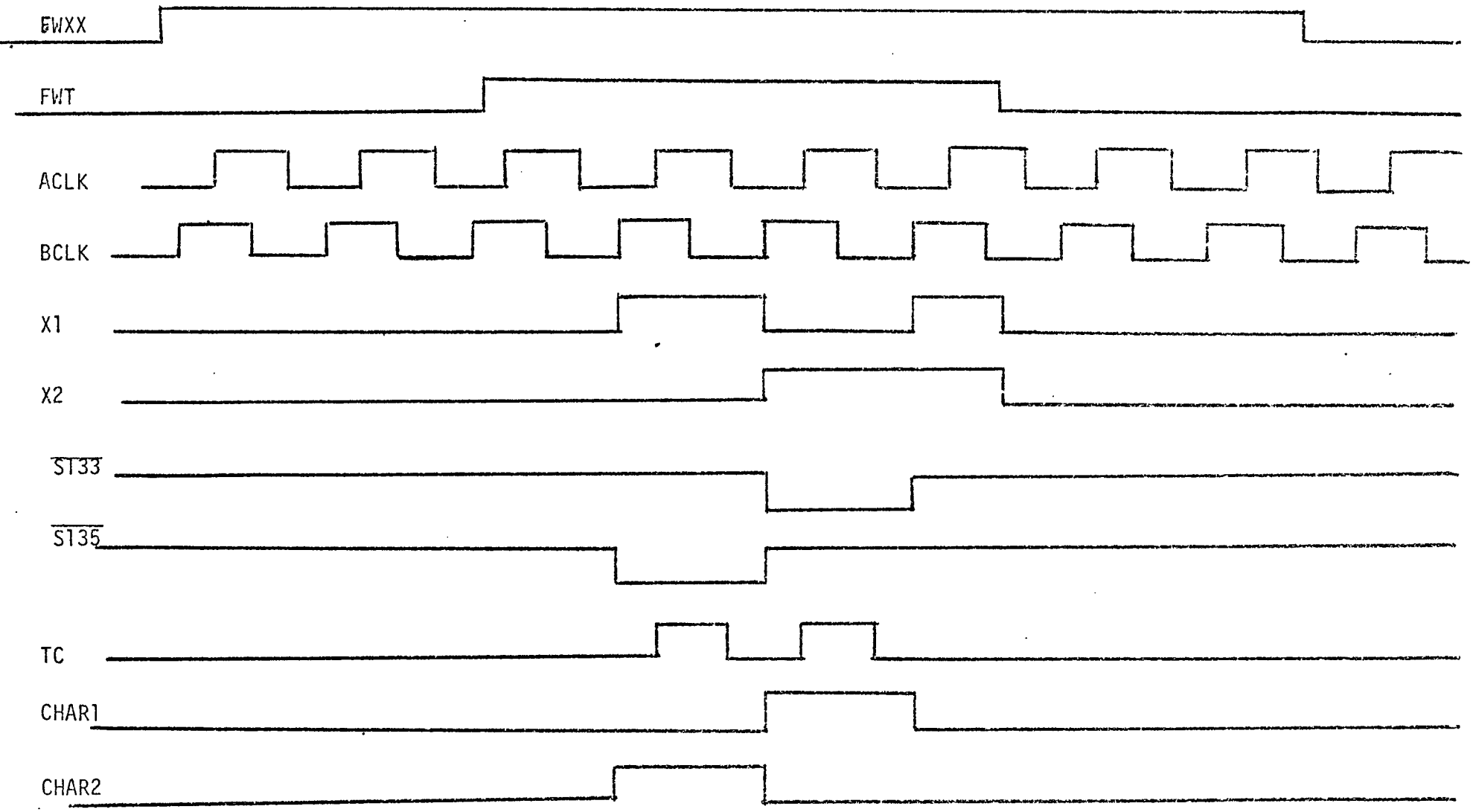
GPXX	Ground pin on logic modules, minus 5 volts.
KXXNO	Normally open contacts of relays.
LOGCOM	Logic common, minus 5 volts, not common to D17B.
PARBIT	Parity bit for output to Flexowriter.
TC	Timing pulse generated to strobe data to the D17B.
TCP	Output timing pulse to D17B (inverse of TC).
VOAXX	Output of D17B voltage output 'A' register.
VOAXXCL	VOAXX signal, clamped to 0 and minus 5 volts.
VPXX	Voltage pins of logic modules 0 volts.
V5NEG	Negative 5 volt logic supply. Logic common not common to D17B.
X1,X2	Output of timing generator, used to enable strobe for data input to D17B.
ZERO V	0 volts, logic supply, common to D17B and interface.
ZRO	Signal indicative of a code for zero code output to the Flexowriter. Note odd bit for zero code for Flexowriter.

APPENDIX E

Timing Diagrams



COMMAND OR OCTAL DATA TIMING



ALPHANUMERIC DATA TIMING