503 TECHNICAL MANUAL

VOLUME I

FUNCTIONAL SPECIFICATION

The contents of this Volume are liable to alteration without notice.

503 TECHNICAL MANUAL

VOLUME 1: 503 FUNCTIONAL SPECIFICATION

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503 TECHNICAL MANUAL, VOLUME 1

Part 1. General Description.

Section 1. Description of components of the 503 System.

The Elliott 503 is a fast, low-priced, general purpose, digital computer designed for the scientific market. The logic elements use high-speed circuits based on high frequency transistors and diodes so that the 503 is completely transistorised and compact. The basic computer may be extended to form a medium-sized installation by the addition of some or all of the following:-

Magnetic tape units, punched card equipment, a line printer, a core backing store.

The 503 incorporates a fully autonomous facility for controlling the transfer of data between its central processor and its peripheral equipment.

The basic computer is functionally identical to the 803, so the existing 803 library of programs can be run on the 503 but at much greater speed. All existing programs in 803 Autocode may also be run on the 503 without alteration. The usual method of controlling the 503 is by means of the Reserved Area Program which makes provision for several programs to be in the computer store at the same time. To allow for closer control of program coding, an advanced Symbolic Assembly Program is provided. Programs for the 503 may also be written in ALGOL, the modern international programming language.

The basic 503 computer comprises items (a) and (b) below:-

a) Central Processor. This contains the arithmetic and control units and a core store. The store contains 8192 words and has a cycle time of 3.3 μ sec. The arithmetic unit provides for fixed point and floating point operations.

b) Control Station. This consists of a reader console, a punch console and a control console. The reader console includes two Elliott tape readers, and the punch console includes two Teletype 110 tape punches. The control console houses the directly connected input/output control

Description of components of the 503 System (continued)

typewriter together with all the manual controls required by any 503 system apart from those controls which are mounted on peripheral mechanisms.

The following peripheral units may be attached to the 503, in conjunction with the Peripheral Transfer Unit, to form a larger installation:

1. Core backing store.
2. Anelex line printer.
3. Bull card reader/punch Model LPM.
4. Ampex T.M.4. tape handlers (up to 8).

In general these peripheral devices communicate with the computer through peripheral controllers. The Peripheral Transfer Control Unit allows peripheral transfers to take place autonomously and provides for parallel working of the central processor and the peripheral devices.

An Interrupt Control Unit is also available and this provides 8 interrupt lines together with facilities for program control of their interaction. The lines may be connected to external devices for on-line applications or alternatively to peripheral devices to facilitate time-shared programming.

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Part 1. General Description.

Section 2. General Data.

Dimensions.

The standard 503 cabinet module can contain 7 shelves of standard printed circuit boards. The main store and power modules are, however, not laid out in this way. The central cabinet suite of the 503 is made up of 3 cabinet modules which contain respectively:-

1. Main 8192 word core store
2. The central processor logic including the peripheral transfer control unit and the interrupt control unit where these are provided.
3. Power supply equipment for the above items and also for the control station.

The control station comprises 3 free standing desk height consoles; the control console is normally situated between the reader and punch consoles.

Peripheral controllers are housed in extra cabinet suites of 1 to 4 cabinets each, as follows:-

1) Two 16,384 word units of core backing store are housed together with the backing store controller in one cabinet module. Further units of backing store are housed two to a cabinet module.

2) The Ampex magnetic tape controller occupies two shelf modules.

3) The controller for the Bull card reader/punch occupies three shelf modules.

4) The Anelex line printer is built into a control pedestal which contains the controller and power supplies.

Controllers always occupy a consecutive block of shelf modules but the disposition of controllers within one cabinet module will vary with each 503 as required by the specification.

The power cabinet module of the central cabinet provides

Dimensions (Continued)

sufficient power for the basic computer. In addition it can supply power for up to one cabinet module of peripheral controllers or backing store. Such systems are provided as a single 3 or 4 cabinet suite.

Larger systems require a second power cabinet module in which case a second cabinet suite is required. In no case are more than 4 cabinet modules connected together.

The individual cabinet suites are connected by cable, and individual peripheral devices are connected via their controllers. In no case may the length of a cable exceed 100 feet.

Overall dimensions are approximately:-

	Height		Width		Depth		Doors	
	cm	in	cm	in	cm	in	cm	in
Cabinet Module	203	80	96	37¾	48	19	48	19
Two Module Cabinet suite	203	80	190	75	48	19	48	19
Three Module Cabinet suite	203	80	284	112	48	19	48	19
Four Module Cabinet suite	203	80	378	149	48	19	48	19
Reader Console	112	44	57	22½	81	32		
Punch Console	112	44	57	22½	81	32		
Control Console	105	41½	124	49	81	32		
Magnetic Tape Handler	196	77	58	23	61	24	48	19
Line Printer Pedestal	140	55¼	147	58	77	30½		
Card Reader/Punch	150	59	70	27½	120	47¼		

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Power Supplies

The 503 system requires a 3 phase 4 wire power supply with a voltage within the range 220 to 240 Volts nominal line/neutral 50 c/s or 115 to 125 Volts nominal line/neutral 60 c/s. Tolerance on this supply is ± 10% of nominal on voltage and + 1% to - 2% on frequency. (The 115 to 125 Volts line/neutral supply will be used by connecting power cabinets from line/line i.e. 200 to 220 Volts).

Interference filters are fitted sufficient to remove the high frequency noise on the power supply in all except the most arduous industrial environments and the standard system will also withstand an interruption in the power supply of up to 20 msec i.e. one cycle. Longer interruptions in the power supply can be catered for by the provision of storage batteries if necessary.

The customer pays for the necessary power supply quoted above together with the isolators, fusegear and wiring to power cabinets, peripheral devices and cold air unit.

The customer will have to pay for an auto-transformer to bring the power supply voltage to within the quoted range if necessary. The central processor and the peripheral controllers are switched on and off together by means of common push buttons on the control console. The whole system can be switched off in an emergency by means of the "Off" button on the control console which is effective under all conditions.

The power cabinet module attached to the central processor cabinet suite has sufficient spare power available to provide for up to one extra cabinet module full of peripheral controllers. Larger systems will be provided with a second power cabinet module for the peripheral cabinet. Each power cabinet module is independent and individually controlled when switched to the "local" position but all cabinet modules can be controlled from the control station when switched to the "remote" position.

Power Supplies (Continued)

Power requirements are approximately :-

	Input K.V.A.	Dissipation K.W.
Logic Module		2.2
Store Module		1.3
Power Module	7.5	2.1
with extra peripheral module	8.5	2.8
Control Station including reader and punch logic power from power module	0.6	1.8
Bull reader/punch		
Ampex deck	0.5 to 0.9	

Environmental Control

For machines equipped with magnetic tape, it is important to install the computer in an air-conditioned, dust free environment.

The central processor cabinet together with the peripheral cabinet, if any, is temperature controlled by a closed circuit system of ventilation. A cold air unit, capable of extracting up to 10 K watts of heat, is situated in a separate room at a maximum distance of 50 ft. from the 503. This cold air unit is 4' high, 6' 1" deep and 2' 3" wide. The control knobs are situated near the top at the front of the unit and the circulating air inlet and outlet are situated side by side near the base. There are three alternative positions for the condenser air inlet, one in either side and one in the top of the unit. This enables the unit to be situated against a wall. The condenser air outlet is at the back of the unit and must have access to an outside wall, which should not be more than 10' distant. The cold air unit is connected to the computer through ducting which constitutes a closed air circulation path. The air leaves the unit at about 7°C and reaches the computer at about 10°C. When the air leaves the computer its temperature has risen to about 21°C and thus no heat exchangers are required in the 503 cabinets.

If the air supplied to the computer cabinets via the closed circuit system exceeds the normal intake temperature of 10°C by 10°C then the complete system is shut down automatically and a lamp on the console is illuminated.

The control station and all peripheral handlers (not peripheral controllers) are cooled by open circuit ventilation with the room air. To control the ambient temperature to 21°C ± 2°C, AIR KING conditioning units are required. The number of units required depends on the size of the installation, the size and shape of the room, and the atmospheric conditions outside the room. Each site must be surveyed to assess the number of air conditioning units required.

Environmental Control (Continued)

The air conditioning units are normally mounted in the walls of the room and dissipate heat to the external atmosphere. Where it is not possible to mount the units in the walls, a water system may be used as a heat sink if a source of water whose temperature does not exceed 24°C is available.

Part 2. Basic 503 System.

Section 1. Central Processor

The Main Store

The main store contains 8192 words, each of 41 bits. In each word 39 bits are available to the programmer. One of the remaining bits is used for parity checking of the store, and the other is used as a tag bit in autonomous data transfers.

Locations 0 to 3 of the store contain fixed instructions by means of which a simple tape code may be read. The fixed instructions may be set by a switch on the control console to read 5 or 8 channel tape. Writing to locations 0 to 3 has no effect, reading from them yields zero. Modification with one of the locations 0 to 3 results in a modifier of zero.

Locations 7936 to 8191 constitute the reserved area of the store. In the reserved area locations 8176 to 8191 are used in autonomous transfers, locations 8166 to 8175 are used for interrupts, and locations 7936 to 8166 are used for the Reserved Area Program (see Volume 2 Part 2), which contains basic control and monitoring routines. The reserved area is normally protected so that its contents cannot be altered by the operation of external instructions. A switch on the control console may be used to remove protection of the reserved area so that basic programs may be read to it.

When the reserved area is protected any attempt to write to it causes an error interrupt to take place (see 3.1). Similarly, any autonomous transfer referring to locations in the reserved area causes an error interrupt. The motions of performing such a transfer are gone through, but no writing into the reserved area takes place (see 3.1.).

When the reserved area is unprotected locations 7936 to 8175 are treated as ordinary store locations. Locations 8176 to 8191 can be used normally except that any autonomous transfer referring to them causes an error interrupt in the same way as it would for a protected reserved area.

The Main Store (Continued)

The main core store boxes are kept at a temperature of 40 ± 2.5°C by a local control system which is linked with the cooling system. Provided the cooling system has been operating for at least 10 minutes, there is no need to wait for warming up when the computer is turned on.

The Registers

There are four registers of interest to the programmer:-

An Accumulator of 39 bits
An Auxiliary Register of 38 bits. This is used with the Accumulator to form a double-length register.
A sequence Control Register of 14 bits
An Overflow Indicator of 1 bit.

Throughout this specification the digits in any register are numbered sequentially starting from the least significant digit which is numbered 1.

The Instruction Code

The instruction code of the 503 is, with a few exceptions, identical to that of an 803 equipped with a floating point unit. Where the instructions of the two machines differ the 503 version is more comprehensive than the 803 version and includes it as a special case. i.e. Additional features for the control of the peripheral devices.

As in the 803 there are two instructions and a position for the B-digit in each word:-

39 to 34	33 to 21	20	19 to 14	13 to 1
Function	Address	B	Function	Address

The Instruction Code (continued)

These tables give the basic instruction code of the 503. The instructions for the peripheral devices follow the descriptions of those devices.
Unless otherwise stated the N digits of an instruction specify the address of a location.
In the result columns a´ and n´ indicate "new contents" of the accumulator and location N. a and n likewise indicate "old contents". In groups 5 to 7, the address part of an instruction not requiring store access is used to further specify the function in which case the number is indicated by N. Those 503 instructions which differ in any respect from corresponding 803 instructions are marked *.

	Function	Operation	Result a´	Result n´	Time (in μ sec)
Group 0	00	Do nothing	a	n	7.5
	01	Negate	-a	n	
	02	Replace and count	n + 1	n	
	03	Collate	a & n	n	
	04	Add	a + n	n	
	05	Subtract	a - n	n	
	06	Clear	o	n	
	07	Negate	n- a	n	
Group 1	10	Exchange	n	a	8.5
	11	Exchange and negate	-n	a	
	12	Exchange and count	n + 1	a	
	13	Write and collate	a & n	a	
	14	Write and add	a + n	a	
	15	Write and subtract	a - n	a	
	16	Write and clear	o	a	
	17	Write, negate and add	n - a	a	

The Instruction Code (continued)

	Function	Operation	Result a	Result n	Time (in μ sec)
Group 2	20	Write	a	a	8.5
	21	Write negatively	a	-a	
	22	Count in store	a	n+1	
	23	Collate in store	a	a & n	
	24	Add into store	a	a + n	
	25	Negate store and add to store	a	a - n	
	26	Clear store	a	o	
	27	Subtract from store	a	n - a	
Group 3	30	Replace	n	n	9
	31	Replace and negate store	n	- n	
	32	Replace and count in store	n	n + 1	
	33	Replace and collate in store	n	a & n	
	34	Replace and add into store	n	a + n	
	35	Replace, negate store and add	n	a - n	
	36	Replace and clear store	n	o	
	37	Replace and subtract from store	n	n - a	

	Function		Operation	Time (in μ sec)
Group 4	40	44	Transfer control unconditionally	5
	41	45	Transfer control if a negative	
	42	46	Transfer control if a zero	
	43	47	Transfer control if overflow indicator is set and clear it	
	(40 to 43		transfer to the first instruction of a pair and	
	44 to 47		transfer to the second instruction)	

The Instruction Code (continued)

Group 5.

Some group 5 operations involve double-length numbers. These contain 77 bits of which the most significant 39 are held in the Acc., and the remaining 38 are held in the A.R. All single-length results of group 5 operations appear in the Acc.

Function	Operation	Time (in μ sec)
50 N	Halve, double-length, N times	7.7 + 0.7 N
51 N	Right shift a N times. Clear A.R.	7.5 + 0.5 N
52 N	Multiply a by n giving double length result	38 to 55
53 N	Multiply a by n giving single-length rounded result Clear A.R.	40 to 57
54 N	Double, double-length, N times	7.7 + 0.7 N
55 N	Double a N times. Clear A.R.	7.5 + 0.5 N
56 N	Divide double-length dividend, single-length quotient. Clear A.R.	81
57	Place contents of A.R. in positions 1-38 of Acc. and make sign digit of Acc. zero.	5

Group 6.

In functions 60 to 64 inclusive the computer treats both a and n as standard floating-point numbers and produces a standard floating point result, which replaces the old content of the accumulator.

Function	Operation	Time (in μ sec)
60 N	Add n to a, clear A.R.	14 to 36 (average 20)
61 N	Subtract n from a, clear A.R.	
62 N	Negate a and add n, clear A.R.	
63 N	Multiply a by n, clear A.R.	38 to 51
64 N	Divide a by n, clear A.R.	71
65 4096	Standardise, i.e. convert the 39-bit integer in Acc. to standard floating-point form clear A.R.	8 + 0.5 n

The Instruction Code (continued)

Group 6 (continued)

	Function		Operation	Time (in μ sec)
*	66	N	Load registers and transfer control. This instruction is used to exit from an interrupt program.	20
*	67	N	Modify the next instruction by adding to it the least significant 19 digits of n. The instruction is modified just before it is obeyed, and its stored form is unaltered.	7

Group 7

Instructions in group 7, apart from the 73 instruction, deal with the control of peripheral equipment. Details of how the instructions are used will be found in the sections dealing with the peripheral devices (see Section 4). The 73 instruction is used in entering subroutines.

	Function		Operation	Time in μ sec)	
	70		Read the Number Generator to Acc.	19	≠
*	71	N	Output N to Control Station, check parity and mix 7 bits into Acc.	19	≠
*	72	N	Output N to peripheral controllers. Output a single word from Acc. to peripheral device.	21	≠
	73	N	Write the address of the present instruction into the store location N.	7	
*	74	N	Output N to Control Station for selection purposes, then output N to Control Station as information.	19	≠
*	75	N	Output N to peripheral controllers. Input a single word to Acc. from a peripheral devise.	19	≠

The Instruction Code (continued)

Group 7 (continued)

	Function	Operation	Time (in μ secs)
*	76 N	Output N to peripheral controllers. Input a single word from a peripheral device to Acc. Prepare for autonomous transfer.	21 ‡
*	77 N	Execute the operation specified by the last 76 instruction. If a transfer was specified use locations N onwards in the store. (See 3.1.)	
		Transfer M words - set up tag	30 + 3.5 M.
		- transfer each word	10

‡ If the device is busy there will be a delay and the instruction will only be obeyed when the device becomes free.

N.B. If the denominator in a division is zero the result is zero and overflow is set. This takes 10 μ secs, but the division takes full time if the numerator is zero.

B - modification

Modification using a B-digit takes no extra time if the instruction preceding the B-digit is of groups 0-3. If the instruction is in groups 4 to 7 then its time is increased by 3.5 μ sec. as a result of the presence of the B-digit.

If the B digit is present between the two instructions of a pair then the content of the location specified in the address part of the first instruction is added to the second instruction. This modification takes place just before the second instruction is obeyed and its stored form is unaltered. Modification is accomplished as follows:

The B digit is associated with the first instruction of the pair and is sensed as this instruction is

B - modification (continued)

being obeyed. When the B digit is present a marker M is set. When this marker M is set, the contents of the address of the first instruction are stored in a special register R before the first instruction is completed. M is then checked before any further instruction is obeyed and if it is set, the contents of R are added to the second instruction of the pair and M is cleared.
If the first instruction of a pair is a 77 instruction then the presence of a B-digit between the two instructions has no effect.

Since a B digit can only appear between two instructions held in the same word it can only be used to modify instructions appearing in the less significant part of a word. The instruction 67 N can be placed anywhere and can therefore be used to modify the first instruction in a word. The action of the instruction 67 N is to set M and load R so that its effect is similar to 00 N followed by a B digit.

There are no exceptions to the action of modification so that :-

1) If a transfer control instruction is followed by a B digit the next instruction actually obeyed is modified.

2) If control is transferred to an instruction which is preceded by a B digit or by a 67 instruction then no modification will take place (unless the transfer instruction is followed by a B digit i.e. as in 1)).

3) The instruction 67 N followed by a B digit is obeyed as if only one of these were present.

4) Sequences of 67 instructions, possibly mixed with B digits, result in sequences of modifications.

Paper Tape Code

The standard tape used on the 503 is an 8-channel tape which is one inch wide. The Elliott 8-channel code is the standard tape code used on the 503. This code conforms closely with the B.S.I. code.

Channels are identified by serial numbers 1 to 8. Channel 5 is used to provide an even-parity check, and a sprocket hole track is placed between channels 3 and 4. Binary values allocated to the channels are:-

channel	8	7	6	5	4	.	3	2	1
binary	64	32	16		8	.	4	2	1

The table of codes shown on the next page includes the Elliott code together with its representation on a Flexowriter.

All input and output of 8-channel information to and from the 503 is performed through mechanisms which check for correct parity on input and insert correct parity on output. Representation within the 503 therefore consists of only seven bitswith binary values ranging from 0 to 127.

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8-Channel Paper Tape Code (Continued)

00000.000	0		01010.000	32	;	10010.000	64	S	11000.000	96	?
00010.001	1		01000.001	33	A	10000.001	65	F	11010.001	97	a
00010.010	2	L	01000.010	34	B	10000.010	66	F	11010.010	98	b
00000.011	3	P	01010.011	35	C	10010.011	67	F	11000.011	99	c
00010.100	4	T	01000.100	36	D	10000.100	68	F	11010.100	100	d
00000.101	5	B	01010.101	37	E	10010.101	69	F	11000.101	101	e
00000.110	6		01010.110	38	F	10010.110	70	F	11000.110	102	f
00010.111	7	R	01000.111	39	G	10000.111	71	F	11010.111	103	g
00011.000	8	(	01001.000	40	H	10001.000	72	F	11011.000	104	h
00001.001	9	)	01011.001	41	I	10011.001	73	F	11001.001	105	i
00001.010	10	,	01011.010	42	J	10011.010	74	F	11001.010	106	j
00011.011	11	£	01001.011	43	K	10001.011	75	F	11011.011	107	k
00001.100	12	:	01011.100	44	L	10011.100	76	F	11001.100	108	l
00011.101	13	&	01001.101	45	M	10001.101	77	F	11011.101	109	m
00011.110	14	*	01001.110	46	N	10001.110	78	F	11011.110	110	n
00001.111	15	/	01011.111	47	O	10011.111	79	F	11001.111	111	o
00110.000	16	0	01100.000	48	P	10100.000	80		11110.000	112	p
00100.001	17	1	01110.001	49	Q	10110.001	81		11100.001	113	q
00100.010	18	2	01110.010	50	R	10110.010	82		11100.010	114	r
00110.011	19	3	01100.011	51	S	10100.011	83		11110.011	115	s
00100.100	20	4	01110.100	52	T	10110.100	84		11100.100	116	t
00110.101	21	5	01100.101	53	U	10100.101	85		11110.101	117	u
00110.110	22	6	01100.110	54	V	10100.110	86		11110.110	118	v
00100.111	23	7	01110.111	55	W	10110.111	87		11100.111	119	w
00101.000	24	8	01111.000	56	X	10111.000	88	[	11101.000	120	x
00111.001	25	9	01101.001	57	Y	10101.001	89	]	11111.001	121	y
00111.010	26	10	01101.010	58	Z	10101.010	90	↑	11111.010	122	z
00101.011	27	11	01111.011	59		10111.011	91	<	11101.011	123	
00111.100	28	=	01101.100	60		10101.100	92	>	11111.100	124	
00101.101	29	+	01111.101	61		10111.101	93	↑	11101.101	125	
00101.110	30	-	01111.110	62			10111.110	94	~	11101.110	126	
00111.111	31	.	01101.111	63		10101.111	95	%	11111.111	127	E

For notes see next page.

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Paper Tape Code (continued)

1) The 8-bit code is shown in full on the preceding page with the position of the sprocket hole indicated by the decimal point (.).

2) Abbreviations :

B Backspace (optional)

E Erase

F Friden Programmatic Codes (optional)

H Stop Code (Halt)

L New Line

P Paper Throw

R Run out

S Space

T Tabulate

3) Code 94 is ~ on the model P flexowriter but Δ on the output typewriter. The non allocated codes will be ignored by the flexowriter but will all cause the code 94 character (Δ) to be printed on the direct output typewriter. All 128 codes can of course be generated by the paper tape output punches of the 503.

4) Code 126 (underline) and code 63 (vertical bar) are non excaping, i.e. the carriage does not move when the character is typed.

5) The 8-bit code is of even parity, the 8 channels are numbered 7, 6, 5, P, 4, 3, 2, 1 respectively; with the sprocket code appearing between channels 3 and 4. The parity channel is indicated by P. When a code is input to the computer the number of 'ones' is checked for even parity, the P bit is then removed and the remaining 7-bits are mixed with the Accumulator. Simarly, on output the program specifies seven bits and an 8th parity bit is automatically generated and inserted between bits 4 and 5. The resulting 8-bits are output to the selected device. Thus the instruction 74 91 will output binary 10111.011 on punch 1.

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Part 2. Basic 503 System.

Section 2. Control Station.

The control station is an assembly of all devices used by the computer operator on the basic system. The devices are arranged to form a compact unit so as to minimise the effort required on the part of the operator.

The control station consists of three free-standing units :-

1) The reader console.
2) The control console.
3) The punch console.

These units are normally arranged side by side in the order shown and with the reader console on the left.

Included in the reader console are :-

a) Two Elliott tape readers operating at up to 1000 characters/second.

b) Control buttons and lamps for the readers.

c) Paper tape dispensers and reception bins for use with the readers.

d) Facilities for the fixing of tape winders.

Included in the punch console are :-

a) Two Teletype 110 tape punches operating at 100 characters/second.

b) Control buttons and lamps for the punches.

c) Paper Tape reception bins.

d) Facilities for the fixing of tape winders.

Control Station (Continued)

Included in the control console are :-

a) A control typewriter.

b) Control buttons switches and lamps for the computer.

c) A working surface for the operator.

d) Drawers, subdivided to facilitate the storage of reels of paper tape and/or programming manuals, etc.

Tape Readers

The Elliott tape reader has a nominal speed of 1000 characters per second and stops on a character. Each reader on the operating station is connected to a one-character buffer. This arrangement ensures optimum operation without the necessity for the reader to stop centrally on a character.

The two readers operate independently and are marked with the identification numbers 1 and 2. The instruction code is (see also Volume 2 Part 1 Section 1) :-

71	0	Input an appropriate number of bits from tape reader 1 and mix 8 bits (some of which may always be zero) into accumulator.
71	2048	Input an appropriate number of bits from tape reader 2 and mix 8 bits (some of which may always be zero) into accumulator.

A buffer may at any time be in one of two states. These are 'busy' and 'ready'. The process by which

Tape Readers (Continued)

a character is read is as follows :-

A 71 0 or 71 2048 instruction causes 8 bits to be taken from the appropriate buffer and mixed into the accumulator, i.e. parity is checked and if correct the remaining 7 bits are mixed into the accumulator. This occurs only if the buffer is in the ready state. Otherwise the computer is held up until the buffer becomes ready. As the character is taken from the buffer the latter is put into the busy state. A character is then read by the tape reader and is loaded to the buffer. Certain checks are then performed. Provided the checks have discovered no error, the buffer is then put into the ready state again. Otherwise the buffer remains in the busy state and a lamp marked READER is lit to indicate the detection of an error.

The body of the Elliott reader is fitted with the following controls :-

1) On/Off switch. This controls the supply of power to the reader mechanism. When the reader is off the buffer cannot be loaded, and once the buffer is empty it remains in the busy state.

   This switch should always be left in the 'on' position but if for some reason it is required to switch off, the reader should previously be switched to manual.

2) Run out button. Pressure on the button causes tape to be passed through the reader at full speed without being read. Releasing the button stops the tape. The buffer is kept in the busy state as long as the button is depressed.

3) Brake release bar. This is depressed in order to place tape under the reader. So doing causes the buffer to be put in the busy state and the READER lamp to be lit. The READER lamp is

Tape Readers (Continued)

housed in the LOAD button. Pressing this button causes the character currently in the reading position to be read to the buffer. The buffer is then put in the ready state and the READER lamp is extinguished. The LOAD button is only effective after the brake release bar has been depressed.

On reading each character to the buffer, a check is performed before putting the buffer in the ready state. The check ensures that not more than one leading edge of a sprocket hole is sensed since the last read instruction for this buffer.

Tape must be loaded so that the sprocket hole of the first character to be read is just to the right of the light beam.

The following controls and indicators are common to both tape readers and are situated near them :-

1) SELECT. This is a push-push switch which exchanges the roles of reader 1 and reader 2 when depressed. A lamp housed within the switch is lit when the readers are in the exchanged state. The LOAD buttons and READER lamps are always associated with the same physical readers.

2) MANUAL. This is a push-push switch and contains a lamp which is lit whilst the switch is depressed. In this situation both tape readers are in the busy state.

3) HOLDUP. This is a lamp which is lit when the computer is held up as a result of either reader buffer being busy.

Each reader has associated with it a switch marked MODE. This is a push-push switch and contains a lamp which is lit whilst the switch is depressed. When the lamp is not lit the reader is in the normal mode. This is that generally used for reading 8-channel tape. In this mode the character is read to the buffer and checked for even

Tape Readers (Continued)

parity. If parity is odd the buffer remains busy and the READER lamp is lit. When a character is taken from the buffer the check bit is ignored and the remaining bits are routed so that of the 8 bits mixed into Acc., the bit in position 8 is always zero. When the mode lamp is lit the reader is in the special mode. This is normally used for reading 5-channel tape. In this mode the character is not checked for parity. The Elliott reader is set to handle 5, 6, 7, or 8 channel tape by sliding the brake release bar.

The MODE switch is provided to give the option of operating with even-parity 8-channel tape or unchecked tape with 5 channels. The layout of the electronics of the operating station is such that a single special board may be provided at extra cost for those installations which require other options. Substitution of the special board for the standard one alters the working of both modes of the readers as required. The options include input of up to 8 bits arranged in any order of significance with even, odd, or no parity check.

The initial instructions normally deal with 8 channel tape but the depression of the mode switch associated with reader 1 causes both the reader and the initial instructions to deal with 5 channel tape. When the reader select button is depressed the readers exchange identities and then it is the reader 2 mode switch which causes the initial instructions to deal with 5 channel tape.

Each reader also has associated with it a switch marked LOAD which contains the READER lamp. The switch operates in association with the brake release bar as described above.

Tape Punches

The Teletype 110 tape punch has a nominal speed of 100 characters per second. Each punch on the operating station is connected to a one character buffer situated within the operating station.

The two punches operate independently and are marked with the identification numbers 1 and 2. The instruction code is (see also Volume 2.1.1.) :-

74	N	Output an appropriate number of bits of the address N to tape punch 1.
74 N + 2048		Output an appropriate number of bits of the address N to tape punch 2.

A buffer may at any time be in one of the two states 'busy' or 'ready'. The process by which a character is punched is as follows:-

A punch instruction causes a character to be loaded to the buffer. This only occurs if the buffer is in the ready state. Otherwise the computer is held up until the buffer is ready. As the character is loaded to the buffer the latter is put into the busy state. A bit which makes parity even is then constructed in the buffer if required. As soon as the punch is ready to accept the character it is punched on to tape and the buffer is placed in the ready state.

The body of the Teletype punch is fitted with the following controls :-

1) On/Off switch. This controls the supply of power to the punch mechanism. When the punch is off the buffer cannot be unloaded, and once the buffer is full it remains in the busy state. This switch should always be left in the 'on' position, but if for some reason it is required to switch off, the punch should previously be switched to manual.

2) Tape feed. Depression of this lever causes blank tape to be run out. Since blank tape is not the B.S.I. standard code for runout, the tape feed control is not normally used. (see 5.1)

Tape Punches (continued)

The following controls and indications are common to both punches and are situated near them:-

1) SELECT. This operates in a similar manner to the reader SELECT button. The RUNOUT buttons and lamps are always associated with the same physical punches.

2) MANUAL. This operates in a similar manner to the reader MANUAL switch.

3) HOLDUP. This is a lamp which is lit when the computer is held up as the result of either punch buffer being busy.

Each punch has associated with it a switch marked MODE. This is a push-push button and contains a lamp which is lit when the button is depressed. When the lamp is not lit the punch is in the normal mode. This mode is that normally used for standard 8-channel tape. In the normal mode the 74 instruction causes bits 1 to 7 of its address to be placed in the buffer together with an even-parity check bit. When the character is punched the check bit appears in the channel 5 position on the tape. When the lamp is lit the punch is in the special mode. In this mode the 74 instruction causes bits 1 to 5 of its address to be placed in the buffer. When the character is punched a direct copy of the buffer content appears on tape. The special mode is normally used for 5-channel tape. The Teletype punch is immediately adjustable to deal with 8, 7, 6, or 5 channel tape.

Each punch has associated with it a push button switch marked RUNOUT. Pressure on the button causes the punch to runout on shift-in characters (value 7) if the MODE switch is in the normal position. In the special mode the runout is on blanks. Whilst the runout button is depressed the corresponding punch buffer is kept in the busy state. The RUNOUT button contains a lamp. This is lit when the punch is about to run out of tape. When the RUNOUT lamp is lit the buffer is put in the busy

Tape Punches (continued)

state. To remove the busy state after reloading or otherwise dealing with the tape, the punch must be switched from manual to non-manual.

The options provided by the MODE switch may be altered for punches in the same way as for readers by provision of another single special board at extra cost.

Control Typewriter

The control typewriter consists of two separate devices, the input keyboard and the output writer.

The input keyboard is situated at the front of the control console and is similar to the keyboard of an ordinary typewriter. Each typing key corresponds to one of two symbols according to case, and the symbol chosen is controlled by 'shift' keys. The input keyboard is shown in diagram on page 16.

The output writer is an IBM Model B electric typewriter whose keyboard is not used. This keyboard is not visible to the operator. The output writer types 12 characters per inch and has a 12 inch carriage fitted with a paper roll holder. It can type at a maximum speed of 10 characters/sec., and has a colour shift mechanism which is controlled by signals from the computer.

The instruction code for the control typewriter is:-

71 4096	Mix 7 bits from the input keyboard to positions 1 to 7 of Acc. Type the character so mixed in red on the output writer.
74 4096 + N	Type in black on the output writer the character corresponding to the least significant 7 bits of the address N.

Control Typewriter (continued)

Unless a 71 4096 instruction is waiting for a character from the input keyboard, depression of a key has no effect. The instruction is held up by a busy line until a key is depressed and the character actually accepted is then transmitted to the output writer. Any invalid code transmitted to the output writer causes the symbol Δ to be typed. An indicator lamp on the keyboard is lit when a 71 4096 instruction is held up by a busy signal. This lamp is marked DEMAND. A lamp marked LOWER CASE is provided to indicate case. This lamp is lit when the input keyboard is on lower case.

Instructions which refer simultaneously to the control typewriter and a reader or punch are interpreted as referring to the typewriter only. Thus the instruction 71 2048 + 4096, i.e. 71 6144, causes input from the keyboard only.

Switches and Lamps.

The following table shows all switches and lamps used in conjunction with paper tape and typewriter on the operating station. The table together with the list for the control console covers all switches and lamps on the operating station. In the table the 'type' column implies a switch unless worded as 'lamp'. R.C. means Reader Console, P.C. means Punch Console and I.K. means Input Keyboard.

Name	Type	If with lamp	Location
Reader 1 ON/OFF	Toggle		Body of reader
Reader 1 RUNOUT	Push		Body of reader
Reader 1 BRAKE RELEASE	Bar		Body of reader
LOAD 1	Push	Lamp	Near both readers
Reader 1 MODE and MACHINE MODE	Push-push	Lamp	Near both readers
Reader 2 ON/OFF	Toggle		Body of reader
Reader 2 RUNOUT	Push		Body of reader
Reader 2 BRAKE RELEASE	Bar		Body of reader
LOAD 2	Push	Lamp	Near both readers
Reader 2 MODE	Push-push	Lamp	Near both readers
Readers SELECT	Push-push	Lamp	Near both readers
Readers MANUAL	Push-push	Lamp	Near both readers
Readers HOLDUP	Lamp		Near both readers
Punch 1 RUNOUT	Push	Lamp	Near both punches
Punch 1 MODE	Push-push	Lamp	Near both punches
Punch 2 RUNOUT	Push	Lamp	Near both punches
Punch 2 MODE	Push-push	Lamp	Near both punches
Punches SELECT	Push-push	Lamp	Near both punches
Punches MANUAL	Push-push	Lamp	Near both punches
Punches HOLDUP	Lamp		Near both punches
Typewriter LOWER CASE	Lamp		Input keyboard
Typewriter DEMAND	Lamp		Input keyboard
MESSAGE	Push	Lamp	Input keyboard

Control Console

The following switches are provided on the control console :-

a) ON. This switches power on to the computer and peripheral controllers.

b) OFF. This switches the whole system off.

c) NO PROTN. This is a push-push button which switches the reserved area protection on or off.

d) CLEAR. This is a push button which only has an effect when the reserved area is unprotected. Pressure on the CLEAR button then causes the store to be cleared.

e) INITIAL INSTRUCTIONS. This is a push button which initiates a control interrupt to the initial instructions.

f) RESET. This is a push button which :

1) clears the overflow indicator.
2) resets all error states.
3) clears the interrupt permit register, i.e. prevents any normal interrupt.
4) resets the interrupt inhibit flip-flop, i.e. allows manual interrupt.
5) clears all tags and sets correct parity in all store locations.
6) stops on an interruptable wait.

g) MESSAGE. This is a push button which initiates a manual interrupt.

h) A 39-key number generator.

i) MANUAL. This is a push button. When it is depressed the control typewriter (including the keyboard) and all the control console is artificially kept in the busy state.

Control Console (continued)

The following lamps are provided on the control console :-

a) ON. This is lit when the computer is on.

b) AIR CONDITION. This is lit when the air conditioner is working and the computer temperature is within the required range.

c) NO PROTN. This is in the PROTN button and is lit when the reserved area is unprotected.

d) ERROR. This is lit when an error condition is detected and extinguished when error interrupt takes place. It will therefore only remain lit if the computer is in such a state as to lead to continued error interrupts.

e) TAG. This is lit whilst the computer is waiting for a tag to disappear.

f) BUSY. This is lit whilst the computer is waiting for a busy signal to go down.

g) INHIBIT. This is in the MESSAGE button and is lit whilst the interrupt inhibit flip-flop is set.

h) TRANSFER. This is lit whilst one or more autonomous transfers is in progress.

i) TYPE HOLDUP. This is lit when the computer is held up as a result of the output typewriter being busy.

j) RESET. This is in the RESET button and is lit whilst the computer is in the reset state.

(k) MANUAL. This is in the MANUAL button and is lit when the button is depressed.

Control Console (continued)

There is also a lamp on the Flexowriter which is lit under the control of the computer. This indicates that the computer is held up on a busy signal from the one character buffer associated with the Flexowriter. When the computer is held up in this way the lamp is lit. Depression of any key causes the buffer to be loaded and the lamp to be extinguished.

Manual Control

Normal running control of the 503 is by means of the 'MESSAGE' button and the Reserved Area Program (RAP) with communication through a directly coupled electric typewriter. Programs, each having a name and main entry point associated with them, are entered using the RAP, which provides a means of running the programs so held. (See Volume 2 Part 2).

Pressure on the message button causes entry to the RAP which then assumes a message will be input via the typewriter. The messages expected start with a control word which is followed by any necessary parameters.

The control words available are:-

IN.	This will cause the computer to read a specially prepared, relocatable binary tape.
GO TO; N. (GO TO; may be omitted if N is an identifier)	This transfers control to the program indicated by the parameter N, where N may be a program name or an absolute address.
CONTIN.	Continue the program from the point at which it was left to obey manual interrupt.
CONTINUE; ERRINT. CONTIN; ERRINT.	Continue the program from the point at which it was left to obey error interrupt.
LIST.	Print out in 'chronological' order the names of the programs in the store beginning with the last to be stored. If a program is incorrectly stored its name is followed by an asterisk.

Manual Control (continued)

CANCEL; N.	Effectively removes the programs, up to and including N, from the store beginning with the program most recently stored. If no parameter N is given only the most recent program is removed.
RESET.	Clears the main store and resets the RAP pointers.
FREE STORE.	Causes the size of the available store to be printed, on the output writer, as a four digit integer with no suppression of leading zeros.

The optional control words available are:-

COMMENT.	Copies to the output writer the message which follows until full stop. No action is taken.
READ.	Read a number of integers and identifiers to fixed locations so they may be used by the main program.

The messages printed on the output writer, when action from the operator is called for, are:-

NOPROG.	Named program is not available.
ERRSUM.	A sum-check error has been detected on attempting entry to a program
NOROOM.	There is not enough room in the store for the program being input.

The messages printed on the output writer to help the operator know the state of the computer are:-

?	This is printed on a new line to show that manual interrupt has been accepted.
>	Entry to a named program has taken place correctly, via the program head.
UNCHECK.	The program is not sum-checkable.

Manual Control (continued)

END. The running of a program has been successfully completed and control has returned to the RAP.

When the machine detects an error condition an error interrupt takes place. Control is immediately transferred to the basic Error Interrupt routine held in the RAP and 'ERRINT' will be output followed by an indication of which error digits are present (see 3.1.) The main store is then searched to see if a more comprehensive error diagnostic program is present. If so control is transferred to this program and if not NOPROG is output on the typewriter.

Part 2. Basic 503 System

Section 3 Interrupt Facilities

Up to eleven separate interrupt lines are available. Three of these are known as Control Interrupt lines and are provided in the basic computer. The remaining eight are known as Normal Interrupt lines (see 2.4.) and are available as an optional extra.

With the exception of one of the control interrupts, each line has associated with it a single location in the reserved area of the store. This is called the Interrupt Location. The interrupt location contains :

a) In digit positions 1 to 13 an address, L, which is the address of the first of a block of locations in which certain registers are stored when interrupt takes place.

b) In digit positions 21 to 33 the address to which control is to be transferred when interrupt takes place.

c) In digit position 20 a bit which indicates whether control is to be transferred to the first or second instruction in the specified pair. When the value of the bit is 0 control is transferred to the first instruction of the pair, when the value is 1 control is transferred to the second instruction in the pair. Thus digit positions 20 to 33 contain the value to which S.C.R. is to be set when interrupt occurs.

The interrupt locations are 8166 to 8175 and are in the reserved area of the store (see 2.1). Locations 8174 and 8175 are associated with two

Interrupt Facilities (continued)

of the three control interrupts. The remainder are associated with normal interrupts. The higher address is that of the interrupt with higher priority (see 2.4).

An interrupt may occur when any instruction is about to be obeyed and at no other time. The system is so arranged that interrupt may take place when a b-modified instruction is about to be obeyed (see 2.4).

Control Interrupts.

The control interrupts are :-

a) Error interrupt. This takes place automatically when an error condition is detected. It is like a normal interrupt (see 2.4) except that it has no associated permit bit and it cannot be inhibited (it does, however, set the inhibit flip-flop). Its priority is the highest and its interrupt location is 8175 (see 3.1. Error Detection).

b) Initial instructions interrupt. This takes place on depression of a button on the control console. Initial instructions interrupt is not associated with an interrupt location in the reserved area. Instead it uses location 0 as an interrupt location. It behaves like a normal interrupt except that it has no associated permit bit, cannot be inhibited, and does not set the inhibit flip-flop. As a result of the special properties of locations 0 to 3, pressure of the control button results in a transfer of control to location 0 without any actual storage of registers.

c) Manual interrupt. This takes place on pressure of the 'Message' button on the control console. It is like a normal interrupt except that it has no associated permit bit (it can, however, be inhibited

Control Interrupts (continued)

and does set the inhibit flip-flop). Its priority is third and its interrupt location is 8174.

Part 2. Basic 503 System.

Section 4. Operational interrupts.

The eight control lines which are provided by the interrupt control unit are known as Normal interrupt lines (see 2.3.). These Normal interrupt lines may be connected to external devices for on-line applications (see 4.5.) or alternatively to peripheral devices to facilitate time-shared programming (see 3.1.).

An interrupt may occur when an instruction is about to be obeyed and at no other time. When an instruction refers to a busy peripheral device the instruction is not obeyed. Instead the S.C.R. is decreased and the instruction is repeated from the beginning. Thus interrupt may take place during hold-up caused by a busy peripheral device (see 3.1. The 77 Instruction 1). The system is so arranged that interrupt may take place when a b-modified instruction is about to be obeyed.

When a normal interrupt is accepted by the computer the following takes place:-

a) Further interrupts of any kind are inhibited.

b) The associated interrupt location is read.

c) If the modifier indicator is set then the content of the modifier register is stored in location L. Otherwise location L is cleared.

d) The content of Acc. is stored in location L+1.

e) The content of A.R. is stored in digit positions 1 to 38 of location L+2. Digit 39 of this location is made zero.

Operational Interrupts (continued)

f) The content of S.C.R. is stored in digit positions 1 to 14 of location L+3. The value stored is that associated with the instruction about to be obeyed. The content of OVR is stored in position 39 of location L+3, and five bits used for error indication are stored in positions 34 to 38. Digit 39 is made 1 if OVR is set, and the error indication is the presence of a 1 in one or more of the positions 34 to 38 (see 3.1. Error Detection).

g) S.C.R. is set to the value contained in digit positions 20 to 33 of the interrupt location, i.e. control is transferred to the required instruction.

The instruction 66 N is used for restoring the computer to its state at the time of interrupt (see 3.1. Error Detection). The effect of the instruction 66 N is as follows:-

a) Remove the inhibition on interrupts.

b) Restore the modifier register from location N and set the modifier indicator.

c) Restore Acc. from location N+1.

d) Restore A.R. from digit positions 1 to 38 of location N+2.

e) Restore OVR from position 39 of location N+3, i.e. if digit 39 of location N+3 is 1 set OVR.

f) Set S.C.R. to the value contained in positions 1 to 14 of location N+3, i.e. cause a transfer of control.

Operational Interrupts (continued)

The following facilities are provided for dealing with sequences of interrupt signals and with sets of simultaneous interrupt signals:-

a) A prescribed rise in voltage on an interrupt line constitutes a signal. The voltage must return to its original level and rise again in order to yield a second signal.

b) Each interrupt signal is stored as a 1 in a one-bit register. The eight registers for normal interrupt together with the three for control interrupt form an 11-bit Interrupt Register (see 2.3.)

c) The bits of the interrupt register form a priority sequence with the control interrupt bits taking the three highest priority positions. Interrupt is always associated with the bit of highest priority present in the interrupt register.

d) When interrupt occurs the bit of highest priority present in the interrupt register is cleared.

e) Normal interrupts may be prevented from setting bits in the interrupt register according to the setting of bits 1 to 8 in a 9-bit Interrupt Permit Register. If the corresponding bit in the permit register is absent then the bit in the interrupt register cannot be set.

f) An Interrupt Inhibit flip-flop may prevent the passage of signals from the interrupt register to the computer. When the flip-flop is set all normal interrupts are inhibited.

g) The instruction 72 N ($N \leq 511$) sets N in the interrupt permit register.

Operational Interrupts (continued)

h) The ninth bit of the permit register is associated with the interrupt inhibit flip-flop. The flip-flop is reset when 1 is written in bit 9 of the permit register. This may be done by obeying the instruction 72 N where $256 \leqslant N \leqslant 511$, and is done automatically on obeying the instruction 66 N. The flip-flop cannot be set by a 72 instruction.

i) When any of the bits 1 to 8 of the permit register are set to 0 by a 72 instruction, the corresponding bits of the interrupt register are set to 0.

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Part 3. Peripheral Control

Section 1. Autonomous Transfers

Transfer Instructions

The autonomous data transfer system (ADT) provides for parallel working of the central processor and the peripheral devices in the following way:-

The instructions 76N (prepare) and 77N (execute) which initiate the transfer first tag the area of store to or from which words are to be transferred. This process involves making the tag bit of each location a 1. The instructions also record in locations 8176 to 8191 (which are set aside for this purpose) the number of locations and the address of the first location involved in the transfer. The normal sequence of the program then proceeds, but the tags prevent reference to a location involved in a transfer until the transfer to that location has been completed. As the program proceeds the peripheral device is operating. When the device is ready to transfer a word of information the computer completes its current instruction, transfers the word, clears the corresponding tag, and adjusts its record of the number of locations and address of the first location involved. Provision is made for autonomous transfers from more than one device to take place concurrently.

Instructions 76N (prepare) and 77N (execute) are used to specify an autonomous transfer.

Locations 8176 to 8191 are reserved for logical use by these instructions according to the class number C given below; e.g. Core Backing Store corresponds to location 8186.

The 15 classes of peripheral device are allocated a fixed priority order as shown below. At the

Transfer Instructions (continued)

completion of any instruction a number of words may be awaiting transfer to or from the central processor. In this case the word associated with the class of highest priority is dealt with first. If a word becomes available for transfer whilst other transfers are in progress then it will take its normal place in the priority sequence. At all times, when an ADT word transfer is about to take place that of highest priority at that moment of time is the transfer that actually occurs. Thus repeated demands from high priority devices may cause the exclusion of a low priority transfer until the former have been dealt with. The maximum delay between a word becoming available for transfer and the actual transfer is therefore the maximum instruction time (96.6 μsecs for 127 place shift) plus the time required to deal with any higher priority transfers that may be demanded.

The 76 Instruction

The effect of the instruction 76N is as follows :-

1) Place the instruction itself in location 8176 to scale 2^{-38}.

2) Send a control word from the specified device to Acc. The control word contains digits indicating the state of the device. The precise significance of the digits depends on the type of device. If the specified controller does not exist then cause an error interrupt.

3) Clear any error indication set up for the device. The N digits of the 76 instruction specify the

The 76 Instruction (continued)
device and the type of transfer required :-

m.s.	Digits 10 to 13	Digits 4 to 9	Digits 1 to 3	l.s.
	class of device	number of device	operation	

Of the 8 possible operations, those which require the computer on line have digit 2 zero. There are thus four possible computer-on-line operations. The other four operations are computer-off-line. If more than 8 operations are required then other available digits may be incorporated with the operation digits.

Each of the 16 possible classes is associated with a specific peripheral controller except for class 0 which is non-existant (see note a). Those classes for which digit 13 is 0 are associated with controllers which deal with fixed-length transfers. When digit 13 is 1, variable-length transfers are implied.

The value of N specifying device D of class C with operation P is normally 512C+ 8D + P.

e.g. 76 4113 (76 4096 + 8 x 2 + 1) means prepare to write on magnetic tape in format 1, odd parity, through controller 1 (4096) and tape handler 2 (see 4.2. Instruction Code).

The 76 Instruction (Continued)

Classes are allocated thus:-

	C	512C	Priority
Spare	1	512	7
Spare	2	1024	5
Spare	3	1536	6
Bull Card (Reader	4	2048	9
(Punch	5	2560	10
Line Printer	6	3072	11
Spare	7	3584	8
Magnetic Tape (Read	8	4096	1
(Write	9	4608	2
Core Backing Store	10	5120	12
Spare	11	5632	3
Spare	12	6144	4
Spare	13	6656	13
Spare	14	7168	14
Special operations (e.g. on-line)	15	7680	15

The 77 Instruction

The effect of the instruction 77N is as follows:-

1. Read the 76 instruction from location 8176. Use this instruction to select a device and test if it is busy. If the device is busy then re-read the 76 instruction and repeat the testing process. If a non-existent controller is selected then cause an error interrupt (see note a).

2. Clear location 8176 after having stored its contents internally.

3. Set in the location associated with the peripheral controller (this will be one of the locations 8177 to 8191) a pair of counts. The pair consists of N-1 in the lower half word and -T

The 77 Instruction (Continued)

in the upper half, where T words are to be transferred (see note b).

4. Tag the store area associated with the transfer, i.e. if T locations are involved tag locations N, N+1 .....N+T-1. If a location is found already tagged wait until the tag disappears (see note d).

5. Clear the auxiliary register.

After step 5 the program continues to obey the next instruction. The peripheral device has been activated by the completion of step 5 and when the device is ready to transfer a word the following operations take place:-

6. The central processor completes its current instruction.

7. Both counts are incremented and a word is transferred to or from the location specified by the lower count. At the same time the tag digit is cleared

8. The upper count is tested. If the count is non-negative then the transfer has been completed.

Notes:-

a. Specification of a non-existent controller causes an error interrupt when the 76 instruction is obeyed. The program should therefore not normally arrive at a 77 instruction referring to a non-existent controller. The interrupt mentioned in 1 is, however, useful if the error routine has not taken the 76 warning into account or if a program error has caused a 77 instruction to be obeyed in the absence of a preceding 76 instruction. In the latter case

The 77 Instruction (continued)

the 77 instruction discovers that the non-existent control 0 has been selected.

b. The value of T is wired into all controllers for which digit 13 of N in the 76 instruction is 0. When digit 13 is 1 then the value of T is taken from the Acc.

c. Tags are used to inhibit reference to locations associated with a transfer. If any instruction other than 77 attempts to use a tagged location then the instruction is held up until the tag disappears.

d. When the computer is waiting for a tag to disappear for the reason mentioned in step 4 or for that mentioned in note c, then a light on the control display is lit.

e. Locations 8176 to 8191 cannot be altered except through the mechanism of a 76 or 77 instruction when the reserved area is protected. When the protection is removed they can be altered by any normal means except by tagging. These locations may be read by any instruction at any time.

f. Interrupt cannot occur during steps 2 to 5 of the 77 instruction.

g. Steps 1 and 4 imply that a hold up may occur whilst an earlier transfer is completed.

h. The parity bit associated with a word in the main store is transmitted with the word to a peripheral device. A word coming from a peripheral device does not have the parity bit transmitted with it. Instead this bit is formed as the word is written to the main store.

i. If a 77 instruction is followed by a B digit then the B digit is ignored.

For an example of an autonomous transfer see 4.1. 'Block Transfer'.

Signals Involved in Transfers

The 76 N1 instruction causes a "Prep 76" signal to be sent out on a busbar together with the address N1 on the code lines (see 4.5 Interface Signals). The "Prep 76" signal is used to strobe the code lines, and the controller involved identifies itself by recognising the four most significantbits of the code. The controller then transmits an "Available" signal on a busbar to the central processor, provided that the controller is in a fit state to transmit this signal. When the central processor has received the "Available" signal it transmits an "Act 76" signal on a busbar. Using its identifying code together with the "Act 76" signal as a strobe, the controller transmits the 39-bit control word over the data input buses. The central processor receives this word and then removes the "Act 76" signal.

The 77 N2 instruction makes use of "Prep 77", "Available" and "Act 77" signals in a way similar to that used by the 76 instruction. In this case, however, a "Busy" signal may also be transmitted on its own busbar at the same time as the "Available" signal. The central processor ensures that an "Available" but no "Busy" signal is transmitted before it sends "Act 77". The "Act 77" signal is used by the peripheral controller to strobe the code lines so that it may be properly prepared for the transfer. The "Act 77" signal does not, however, actually initiate a transfer. When the central processor is ready to initiate a block transfer it sends a "Mask" signal on a line going direct to the controller involved. This signal remains until the central processor decides that the block transfer has been completed.

Once the "Mask" signal has been transmitted the 77 instruction is complete as far as the program is concerned, and other instructions are obeyed in their usual sequence. The peripheral device is now at work preparing to accept a word from, or transmit a word to, the central processor. When the device is ready to do so its controller sends a "Demand Transfer" signal to

Signals Involved in Transfers (continued)

the central processor. This signal is held until a reply is received from the central processor in the form of a "select" signal which signifies that information may be sent to the Data Input buses or that it may be taken from the Data Output buses.

The "Demand Transfer" and "Select" signals are sent over direct lines and do not use a busbar. Input and output transfers are distinguished by the presence or absence of a signal on an "ADT Input" bus. This signal is sent by the controller concerned to the central processor as soon as the "Select" signal appears.

The 72 and 75 instructions make use of "Prep", "Available" and "Act" signals in a way similar to that used by the 76 instruction. Separate buses are provided for the "Prep 72", "Prep 75", "Act 72" and "Act 75" signals.

Peripheral Controllers

All peripheral devices concerned with autonomous transfers communicate with the central processor via peripheral controllers. Many devices may be connected to a single controller.

There are three types of operation :-

a) Handler on-line: an instruction initiated via the controller is completed by the handler alone. The controller is free to deal with instructions concerning other handlers. An example of a handler-on-line operation is the rewinding of magnetic tape.

b) Controller-on-line: an instruction once initiated is completed by the controller and handler without further reference to the computer e.g. advance one record on magnetic tape.

Peripheral Controllers (continued)

c) Computer-on-line: an instruction which requires information to be passed between the computer and the controller throughout the time of execution. Any autonomous transfer is a computer-on-line operation.

An Instruction may be held up by a busy condition on a handler or a controller. Handler busy is set throughout operations of type a) b) and c). Controller busy is set throughout operations of type b) and c)

A 76 instruction is never held up by a busy condition, and may be executed at any time. A busy line is provided which at present is unused.

The peripheral transfer control unit ensures that devices which cannot wait (i.e. non-buffered devices) perform any necessary transfer before devices which can wait (i.e. buffered devices). Devices which are simultaneously ready to transfer a word are dealt with in a fixed priority sequence, specified under "The 76 Instruction". Arrangements are made for the inclusion of additional devices at chosen positions in the priority sequence.

There is a manual/auto switch associated with each peripheral device. In the manual state the device cannot communicate with the computer, and this situation is indicated by the presence of the 'device not available' bit of the control word. A peripheral device is always in the manual state when switched off, and remains in this state after being switched on until such a time as the manual/auto switch is set to auto. By this means the device cannot be used by the central processor whilst in a warming up or similar intermediate state.

In general, switches other than OFF are not operable unless in MANUAL. OFF itself must only be used when in MANUAL except in emergency. Because of this, the procedure for turn-on is as follows:-

Control Console ON puts power onto the basic machine,

Peripheral Controllers (Continued)

control station (including mechanisms) and all peripheral controllers. Local devices ON buttons must be used to turn the devices ON and these will then be in manual.

To turn the system OFF in an emergency only the control console OFF need be used, this has the same effect as pressing the local OFF buttons on each device. Normally, each device should be turned to MANUAL before pushing control console OFF. To summarize, devices in which sudden turning OFF could have adverse effects should not be turned OFF via the control console.

There is a Manual/Auto switch on both the Reader and Punch Consoles. It must be possible to replace Tape Readers and Punches by spares without switching off the 503, damaging the programme or endangering the operator.

Error Detection

Facilities are provided in the 503 for the detection of abnormal situations. These may arise as the result of

1) Malfunction of the central processor or of the peripheral devices.

2) Faults in programming.

3) Faults in manual setting-up or operation.

All these situations fall under the heading of errors.

Errors which arise in association with the working of the central processor lead to an immediate error interrupt. Those which arise in association with the working of peripheral devices may eventually lead to an error interrupt. In either case the interrupt is to a fixed location in the store whose address is that which has been preset in location 8175 (see 2.3.).

Error Detection (Continued)

The errors causing the interrupt fall into five classes. Each class has an associated bit in location L + 3 (see 2.4.); and this bit is set to 1 when the interrupt is caused by a member of the class. The bits of location L + 3 and the corresponding classes of error are:

bit 34 an attempted impermissible reference to the reserved area. The instruction containing the impermissible reference is not obeyed.

bit 35 error associated with a peripheral device (see below).

bit 36 a parity error in the main store. The instruction or autonomous transfer during which the error occurs is completed before error interrupt takes place.

bit 37 spare. This class is provided in case devices requiring immediate interrupt are connected to the 503 at some later date.

bit 38 Floating-point overflow. The instruction causing overflow is completed before error interrupt takes place.

Error interrupts caused by peripheral devices only take place after a warning has been given to the program that an interrupt is impending. This warning is given in the control word of the 76 instruction, and the control word also indicates the cause of the abnormal situation. The precise significance of the bits of the control word vary from device to device, although wherever possible similar indications occupy the same bits. At the instant at which an abnormal situation arises a peripheral device or its controller may be placed in one of three states:

1) "Error State". This state maintains itself

Error Detection (Continued)

until reset by the program. The reset is achieved by a 75 reset instruction which also reads the control word to the accumulator. When an instruction attempts to use a device which is in the error state, an error interrupt occurs just before the instruction is obeyed. For example, a parity error on magnetic tape will cause the device to be placed in the error state. This state will be indicated in the control word of the 76 instruction, and may be reset by a 75 instruction. If the program fails to take note of the error state and reset it, then an interrupt will occur just before a subsequent 77 instruction is obeyed.

2) "Unavailable State". This state maintains itself until reset by manual intervention. For example an empty hopper in a card punch will cause the punch to be in the unavailable state. A 77 instruction attempting to initiate the punching of a card will not then be obeyed, and an error interrupt will take place. In general, devices are in the unavailable state if they are

   a) not connected.

   b) not prepared for operation, e.g. not properly loaded, not in the auto state.

3) "Rejection State". This state maintains itself until removed by the normal course of events (either program or manual) or until the device goes into the unavailable state. When a device is in the rejection state it may reject certain instructions as invalid and cause an error interrupt before they are obeyed. For example, when the end of tape

Error Detection (Continued)

marker is under the photocell, a handler is in the rejection state with respect to read, write or move forward instructions, but not with respect to rewind or move back instructions.

From the above description it will be seen that error interrupts associated with peripheral devices can only occur when a 72, 75 or 77 instruction is about to be obeyed. In addition if a peripheral controller does not exist an interrupt will occur when an attempt is made to refer to such a controller by a 76 instruction as well as by a 72 or 75 instruction.

The three states mentioned above may refer to peripheral devices or their controllers depending on circumstances. Wherever possible the unavailable state is in fact the manual state so that manual intervention is completed by setting a device to auto.

Since a 76 instruction is stored in location 8191 until cleared by a subsequent 77 instruction, it is possible to read the former when an interrupt occurs just before the latter.

503 TECHNICAL MANUAL, VOLUME 1.

Part 4 Peripheral Devices.

Section 1 Backing Store.

Core backing store, (or magnetic core auxiliary store), is supplied in units of 16,384 words. Up to 8 units may be connected to the 503 through a single controller. These units form a single continuous store of up to 131,072 words. The units are housed two to a standard 503 cabinet module, and the controller is housed alongside the units in one of the modules.

Access to the backing store is in two modes: a block transfer between the backing and main store using the peripheral transfer unit facilities or a single word transfer between the accumulator and its backing store. Both take place through a special single-word register called the backing store register. An attempt to read from a non-existent register will yield zero.

Block Transfer.

The program maintains in a location of the working store (say S) a record of the number of words required (say T) and the first location in the backing store for each transfer required (say A). These quantities are held as the pseudo-instruction pair:

S) 00 T : 00 A

When it is required to initiate the transfer the instructions

76 5120* : 30 S

77 N : .....

are given. The machine then transfers the pseudo-instruction pair to the accumulator, prepares to read from the backing store, and gives the read instruction. This

* 76 5121 is the corresponding write instruction.

Block Transfers (continued)

causes locations N to N + T -1 to be tagged.

As the auxiliary store obtains each word ready for transfer to the 503, the program is interrupted, the word transferred to the appropriate location in the working store, and the location tag removed.

If another 77 N instruction concerning the backing store is given, the program is held up until the previous transfer is completed.

The time taken to obey the 77 N instruction is about 30 + 3·5T μsecs. At the end of this time tagging is complete and the program proceeds. As each word is subsequently transferred, the 503 is held up for approximately 10 μsecs. This occurs about every 50 μsecs.

Single Word Transfers.

Single word transfers to and from the backing store take place in two stages. The content of the specified address of the backing store may be read into, or written from, the single word backing store register. This register can in turn be read into, or copied from, the accumulator.

The cycle time of the store is 50 μsecs and the access time is 15 μsecs. Thus the on-line time for a single access is 15 μsecs, but there is a minimum time of 50 μsecs between successive accesses. If the required amount of time is not left between successive backing store instructions a delay will ensue.

To read the content of location N to the Acc, the following instructions are required:-

1) Place $N.2^{-38}$ in Acc.
2) 72 5120
3) 75 5122

} the corresponding write instructions are 72 5122, 72 5121

Single Word Transfers (continued)

but between instructions 2) and 3) a delay of approximately 15 μsecs. will occur. During this time the central processor is free to continue computation.

Information is received from the main store in words of 40 bits including the correct parity bit. Information read from the backing store is checked for parity, and, if parity is correct, 39 bits are transmitted to the main store. If parity is found to be wrong then no information is transmitted. Instead the parity bit is corrected and the word is rewritten in the backing store. The backing store is then placed in the error state and an error indicator lamp on the controller module is lit. The state of the controller is indicated to the program through the control word. As soon as possible after the occurrence of an error, an error interrupt takes place. The store remains in the error state until a reset button is pressed. An attempt to refer to a location in the backing store when it is already in the error state causes an error interrupt to occur.

The following controls are provided on the controller module:-

a) CLEAR STORE. This is a push button mounted in a guard ring. Pressure on the button causes the store to be cleared and correct parity to be written for each word. The store is set in the non-error state and the parity lamp is extinguished.

b) RESET. This is a push button and contains the ERROR lamp which is lit to indicate the error state resulting from a parity error. Pressure on the reset button causes the lamp to be extinguished and the error state to be removed.

The Instruction Code for the core backing is as follows:-

Function		Operation	Time (in μsecs)
76	5120	Prepare to read from the backing store by autonomous transfer and read control word to Acc.	21
76	5121	Prepare to write to the backing store by autonomous transfer and read control word to Acc.	21
77	N	Read or write as specified by the last 76 instruction between location N onwards in the main store and location A onwards in the backing store. The number of words transferred (T) and the address (A) are specified by the content of Acc as $T.2^{-18} + A.2^{-38}$	30 + 3.5T (set up tag) + 10T (transfer the words).
72	5120	Load backing store register from location A of the backing store, where A is specified by the content of the Acc. as $A.2^{-38}$.	21
72	5121	Write content of backing store register to location A of the backing store, where A is specified by the content of Acc. as $A.2^{-38}$.	21
72	5122	Write content of Acc. to backing store register	21
75	5122	Read content of backing store register to Acc.	19

The Instruction Code (continued)

The significance of the control word bits is:-

bit 1	spare
bit 2	spare
bit 3	spare
bit 4	store busy
bit 5	parity error.

503 TECHNICAL MANUAL, VOLUME 1

Part 4. Peripheral Devices.

Section 4. Magnetic Tape
Magnetic Tape Facilities

The standard tape handler used with the 503 is the Ampex TM4. Two controllers are used in the system, and these operate a total maximum of eight handlers. Instructions can be issued to any handler via either of the controllers. Two autonomous data transfers, either reading or writing or both, may take place on any two handlers simultaneously provided that they are monitored through different controllers.

The Ampex TM4 handler is equipped with an IBM-compatible read-write head, and may be used to read or write on all tapes dealt with by the IBM 729 II or IV handlers without alteration. For this purpose, there is a facility for changing the packing density on any Ampex TM4 handler from the standard 556 bits/inch to 200 bits/inch.

The standard 503 tape system is also compatible with the IBM tape system, and is based on the use of variable-length records. There are facilities for moving tape and rewinding it off-line. Any number of these operations may be carried out on any number of handlers simultaneously with a pair of data transfers.

The handler is fitted with a dual-stack head, and every write operation is accompanied by an immediate read for checking purposes.

503 Tape System

The system uses ½" tape with seven tracks. One track is used for parity checking, and the remaining six tracks for information. This lateral parity check may be even or odd under program control. It is essential that a record be read using the same parity as was employed when it was written. When even parity checking is used, a set of six zeros must be an impermissible character, as a character consisting entirely of zeros cannot be detected. This character is used for a special purpose, described on page 9.

There are two formats for storing a computer word on tape. These are as follows:

Format 1, Writing: Bits 37 to 39 of the word in the store are ignored. The remaining 36 bits are packed into six 6-bit characters. The most significant six bits form the first character.

Reading: Bits 37 to 39 of the word in the store are made zeros. The remaining 36 bits are composed of six characters, the first character occupying the most significant six bits.

Format 2, Writing: The first character on the tape contains zeros in the upper three positions. Bits 37, 38 and 39 of the word in the store are written into the remaining three bits, and the other 36 bits of the word are packed into the next six characters.

Reading: The upper three bits of the first character are ignored, and the remaining three bits together with the following six characters are packed into a word. Again the first character read occupies the most significant position.

Thus, in format 1, one computer word occupies six characters on tape, and in format 2, one computer word occupies seven characters on tape.

503 Tape System (continued)

Either format may be used with either parity. It is recommended that odd parity be normally employed. In particular, even parity with format 2 should be employed only in exceptional circumstances, taking care to avoid any zero characters.

The length of a record is determined by a programming instruction; at the end of a record there is a short gap (approximately three characters long) followed by a longditudinal check character which causes the parity of all seven of the tracks in the record to be even. This is followed by a $\frac{3}{4}$" gap before the beginning of the next record. It is possible for the longditudinal check character to consist entirely of zeros.

During reading, the longditudinal check character is identified in the following manner: the short gap which precedes the check character is detected, and this serves to indicate the end of the record to the controller. If no character is detected within a suitable length of time, the controller deduces that the check character consists entirely of zeros. Lateral parity is checked throughout the course of a read operation, and on the read-back of each character in a write operation. Longditudinal parity is checked at the end of these operations.

The following arrangements have been made to allow continuous running of the tape mechanisms. The handler will cease to be busy after a data transfer, advance or retreat one record or an erase operation, at such a time that there remains at least 3 milliseconds before the tape begins to stop. In fact this time is the time at which the check character is read in the data transfer and advance cases.

When the handler has ceased to be busy it is possible to obey further 77 or 72 instructions. If such an instruction, requiring the same direction of tape motion is received during the 3 milliseconds then the tape will not stop but will continue to run at full speed. If the instruction is received subsequently it will be accepted but the tape will nevertheless perform a complete stop-start cycle.

503 Tape System (continued)

If a controller is involved, that is in the data transfer case, the controller and handler normally cease to be busy at the same time. In the case of a long record, controller and handler will remain busy until the check character is read, i.e. even after the last required word has been transferred. In the case of a short record, however, the controller only will continue to be busy after the check character has been read, and will in fact remain busy until the remaining tags have been cleared.

In order to ensure that no spurious characters occur in inter-record gaps, and no wanted record becomes corrupt, certain restrictions must be observed.

The first of these is that if one writes a record and then moves the tape back, one cannot now arrange to write a successor to that record. More exactly, a record B may be written to follow a previously written record A only if

(i) The only operations performed on the tape since A was written have been zero or more erase operations

or if (ii) The operation on the tape which occurred next after A was written was an erase operation or a write operation.

The reason for this is that in any other circumstances A may be followed by only 3/8" of erased tape.

The second restriction forbids selective overwriting, i.e. the over-writing of one or more records at the beginning or in the middle of a tape, except with the special precautions given on page 9. More exactly, if a record B is written on a tape to follow a record A written on an earlier occasion, then none of the records which followed A will any longer be capable of being read correctly, unless the precautions are observed.

When the retreat one record instruction is obeyed, the tape stops in a position determined by the leading character

503 Tape System (continued)

of the record which has been traversed. If now a new record is written, this record may not start in exactly the same place as the record which was traversed. The timing is so arranged that the record will start slightly late. This ensures that a repeated cycle of retreat one record, write one record cannot shorten an inter-record gap.

The logic associated with a particular handler is arranged on boards so that these boards may be omitted if the full complement of eight handlers is not present. The circuitry on these boards includes the initiation of the off-line instructions, i.e. advance one record, retreat one record, rewind and erase.

Magnetic Tape Instruction Code

The instruction code is:-

76 4096 + 8P	Prepare	read,	format	1,	odd	parity,	using	controller 1
76 4097 + 8P	"	write	"	1,	odd	"	"	" 1
76 4098 + 8P	"	read	"	2	odd	"	"	" 1
76 4099 + 8P	"	write	"	2	odd	"	"	" 1
76 4100 + 8P	"	read	"	1	even	"	"	" 1
76 4101 + 8P	"	write	"	1	even	"	"	" 1
76 4102 + 8P	"	read	"	2	even	"	"	" 1
76 4103 + 8P	"	write	"	2	even	"	"	" 1
76 4608 + 8P	"	read	"	1	odd	"	"	" 2
76 4609 + 8P	"	write	"	1	odd	"	"	" 2
76 4610 + 8P	"	read	"	2	odd	"	"	" 2
76 4611 + 8P	"	write	"	2	odd	"	"	" 2
76 4612 + 8P	"	read	"	1	even	"	"	" 2
76 4613 + 8P	"	write	"	1	even	"	"	" 2
76 4614 + 8P	"	read	"	2	even	"	"	" 2
76 4615 + 8P	"	write	"	2	even	"	"	" 2

In the 76 instruction, P is the handler number. $0 \leq P \leq 7$. The control word indicating the state of the controller and handler is read to the least significant eleven digits of the accumulator.

Magnetic Tape Instruction Code (continued)

77 N Read or write as specified by the last 76 instruction, starting at location N of the main store. Transfer T words when $T.2^{-38}$ is the content of the accumulator. $1 \leqslant T \leqslant 7931$.

If the previous 76 instruction specified a "read" order and on the 77 instruction being obeyed the value of T is less than the number of words in the record, T words only are transferred, but the tape motion continues to the end of the record. If the value of T is greater than the number of words in the record, the tape motion stops when the end of the record is reached; the remaining tags in the main store associated with transfer continue to be cleared in the same manner as the previous tags.

Note that if T = 0 this instruction is invalid. The exact consequences of obeying the instruction in this case are not yet settled.

72 4096 + 8P Advance one record on handler P
72 4097 + 8P Retreat " " " " "
72 4098 + 8P Erase four inches " " "
72 4099 + 8P Rewind tape " " "

The ends of a reel of tape are indicated by reflective strips which are sensed by a photocell. In a rewind operation, the tape motion is stopped after the appropriate reflective strip is reached, and this situation is recorded in the control word. If the end or beginning of tape strip is encountered during the execution of any other instruction, then that instruction is fully executed and the control word is set appropriately.

In the case of the end of tape strip, no action is taken to prevent further instructions, which cause the tape to advance being obeyed. This is because one may wish to write trailer blocks after the warning strip has been passed. There are at least twelve feet of useable tape remaining after the reflective strip.

Magnetic Tape Instruction Code (continued)

In the case of the beginning of tape strip, a retreat one record instruction cannot be obeyed when the beginning of tape indicator is set, and any attempt to obey it will give an error interrupt.

75 4096 + 8P Read control word on handler P to accumulator and cancel error state on handler P.

This instruction may be executed while a data transfer is in process and/or simultaneously with the execution of any 72 instruction.

The significance of the bits of the control word is as follows:-

bit 1 Handler not available
bit 2 Spare
bit 3 Writing permitted
bit 4 Handler busy
bit 5 Parity error on handler
bit 6 Controller 1 busy
bit 7 Controller 2 busy
bit 8 Beginning of tape
bit 9 End of tape
bit 10 Long record. This bit is 1 if the last record read contained more characters than specified by the contents of the accumulator at the time of the 77 instruction, and zero otherwise.
bit 11 Short record. This bit is 1 if the last record read contained less characters than specified by the contents of the accumulator at the time of the 77 instruction, and zero otherwise.

Bits 5, 10 and 11 return to zero when the tape is loaded.

Bit 8 is set to 1 when the tape is loaded, and returns to 0 when the beginning of tape strip is passed in the forward direction. It is set to 1 when the strip is passed in the backward direction.

Magnetic Tape Instruction Code (continued)

Bit 9 is set to 1 when the end of tape strip is passed in the forward direction, and is set to 0 when the strip is passed in the backward direction. It is 0 when the tape is loaded.

Each of bits 1 to 7 inclusive is 1 when the appropriate condition is satisfied and 0 otherwise.

There is an error lamp associated with the controllers which is lit when any parity or timing error, or a detectable mechanical error, occurs on any handler. The error lamp is extinguished by the appropriate 75 instruction. A 77 or a 72 instruction relating to a handler which is in the error state causes an error interrupt: any of the above instructions causes an error interrupt if the controllers are not present in the system (see 2.3 and 3.1).

Special Effects

"Selective over-writing", i.e. the over-writing of one or more records at the beginning or in the middle of a tape, is allowed only if special precautions are observed, as otherwise there is no guarantee that the records following those over-written will be accurately preserved.

A record which is subsequently to be overwritten must fulfil the following conditions:

(i) The record must be followed by 8 inches of blank tape, obtained by using two "erase" orders (72 4098, etc.).

(ii) The record must be preceded by a "normal" record, which is not to be overwritten, and which is not followed by erased tape.

(iii) The record may not be longer than 400 words.

When this record is overwritten, the record which replaces it must fulfil the following conditions:

(i) It must be in the same format, and contain the same number of words, as the original record.

(ii) It must be followed by 4 inches of blank tape, i.e. a single "erase" order.

If this is done, the inserted record will operate correctly, and will itself be suitable for further selective over-writing if required.

Records of non-integer number of words may arise in connection with I.B.M. compatibility. Reading such a record is always possible, the final word will be completed as though the record had a sufficient number of additional zero characters to form an exact number of words. Such a record will always give rise to either the short or long record indication in the control word, as appropriate.

Special Effects (continued)

Arrangements have been made to allow such records to be written, though only on even parity. If an attempt is made to output an all zero character on even parity, the record will at once end. In this way a number of characters not representing an integer number of words will form the output record. The short record indication will be set in the control word.

Care must be taken if the first character of a record to be written is zero, since in this case the record written will be equivalent to a length of erased tape, actually about three quarters of an inch. Thus retreat one record will in this case retreat to the inter-record gap before the previous record.

Magnetic Tape Physical Specification

The following manual controls will be available on the Ampex TM4 handlers used in the 503 system.

i) Power
ii) Write Permit
iii) Manual
iv) Density high-low
v) Forward fast
vi) Forward drive
vii) Stop
viii) Reverse fast
ix) Reverse drive
x) Handler number selector

Of the above list, numbers i to ix inclusive are push-buttons, and x is a rotary selector. The "write permit" may, alternatively, be a guard ring attached to the tape reel. The push buttons have lights built into them. Numbers iv to ix inclusive have no effect, and their associated lights do not light up, unless iii is depressed.

If the handler number selector is moved when the handler is not in the manual state, the handler will at once enter the manual state. The handler may be restored to the auto state by operating and releasing the "manual" button (iii), provided that the number now selected is not already in use.

Magnetic Tape Physical Specification (continued)

Only one handler may be set to a particular number and be in the auto state. If another handler is set to the same number it will not be possible to cause that handler to transfer to the auto state.

Summary of handler characteristics

Tape length	2400 ft.
Tape width	0.5 in.
Tape speed	75 in./sec. ± 10%
Rewind time	3 mins. max. 2¼ mins. typical
Packing density (standard)*	556 characters/in. nominal = 92.6 words/in. in format 1. = 79.4 words/in. in format 2.
Character transfer rate	42,000 characters/sec.
Word transfer rate, format 1	7,000 words/sec.
format 2	6,000 words/sec.
Inter-record gap length	0.75 in. nominal
Inter-record gap times	
a) at full speed	10 millisec.
b) with stop and immediate restart	12.5 millisec.

* An alternative packing density of 200 characters/in. is available by setting the density switch on the handler to "low".

Tape capacity

Format 1

Average record length, words	32	128	512
length (inches)	.35	1.38	5.53
gap	.75	.75	.75
No. of records	26,200	13,500	4,600
No. of words	838,000	1,727,000	2,355,000
time/(record + gap) at full speed (millisecs)	.0147	.0284	.0835
Records/sec. Max.	68	35.2	12
Effective words/sec. Max.	2180	4500	6144

Format 2

Average record length, words	32	128	512
length (inches)	.40	1.61	6.45
gap	.75	.75	.75
No.of records	25,000	12,200	4,000
No.of words	800,000	1,540,000	2,050,000
time/(record + gap) at full speed (millisecs)	.0153	.0314	.0960
Records/sec. Max.	65.4	31.9	10.4
Effective words/sec. Max.	2090	4080	5330

Use of Magnetic Tape on the 503

Although the control of the 503 tape system is reasonably flexible, it is desirable that certain additional details be observed by the controlling program. No damage will result in the event that this is not done, nor, in general, will wrong data be read. However, it is possible that tape handlers may be unloaded, or faulty tapes written in certain circumstances. The necessary data is contained in the control word.

For the significance of the bits of the control word see page 7.

All Instructions

Before any attempt is made to move tape in any way, check bit 1, Handler not Available. If this is present, any operation on this handler will give rise to error interrupt.

Instructions Routed via Controllers

It is assumed that the controlling program will refer to bit 6 and bit 7 and use whichever controller is available. Note that it is probably better to wait until bit 4 clears before doing this, since bit 6 and bit 7 may also clear at that time.

Rewind and Initial Positioning

When rewind is complete, the beginning of tape marker, bit 8, will be set. If it is set, do <u>not</u> issue a further rewind order, as these will cause the handler to unload.

First Record on Tape

When writing the first record on a tape, first check that bit 8 is present and rewind if not, then issue two 'erase' instructions, thus erasing 8" of tape, and only then write the record.

First Record on Tape (continued)

Note that if subsequently an order is given to retreat over this record, the tape is now positioned before any record, but the beginning of tape marker is not yet set.

Do not issue a further retreat one record order, as this will cause the handler to unload.

Write and Move Back

The system is designed to allow continuous writing. If it is designed to write a record and then move back, with the intention of subsequently returning to write further records, it is necessary to erase at least a further 3/8in. of tape. Consequently, when rewind or retreat one record is required, if the previous operation was a 'write' operation, issue first an erase order, then the move back order. If desired, a dummy block may be written instead of using an erase order, in which case two 'retreat' orders are needed.

End of Tape

It is permitted to write beyond the end of tape marker. Note that a record should be kept of the tape used in this way so as to avoid going more than 12 feet beyond the marker.

Care should be taken not to attempt to read or advance one record at a point where the remainder of the tape is empty, as this will cause the handler to unload by running out of tape.

Selective Over-Writing

For selective over-writing see pages 7 and 8.

Errors etc.

These are indicated by the parity marker, bit 5. This may be cancelled by the use of a 75 order, and must be cancelled before issuing a 77 or 72 order or error interrupt will occur.

Errors etc. (continued)

If an error occurs on reading, then retreat one record and read again. Almost all errors should be overcome in this way. If an error occurs on writing, then retreat one record and write again. If still unsuccessful, retreat one record, erase four inches of tape, and write again. It is not necessary to erase before the move back in these error conditions. On even parity, the short record indicator may be set on writing. This indicates that an all-zero character has terminated the record, and probably implies a programming error.

Do not attempt to read any records beyond the record most recently written on the tape. Errors will almost certainly result if this is attempted.

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Part 4 Peripheral Devices

Section 3 Line Printer

The line printer may be connected to the 503 through a single controller. The printer has a nominal speed of 1000 or 667 lines a minute on marginally punched paper. The printer permits up to 120 characters per line using a 64 character repertoire. Vertical paper format control is provided by means of a continuous band of punched 8-hole tape which rotates once for each page that passes under the printing head.

Output to the line printer takes place by transferring 121 characters, each 7 bits long, from the 7 least significant positions of a set of 121 consecutive registers. The first character is used only for paper control.

The transfer of the characters to the line printer takes place using autonomous means to minimise hold up (see 3.1.).

The Instruction Code for the line printer is as follows:-

Function		Operation
76	3073	Prepare to print 1 line and read the control word from the line printer to the Accumulator.
77	N	Load printer buffer from locations N to N+120. Determine vertical throw from the first character (see Paper Control). Instigate the paper throw and print action.

When an instruction to print a line is given, the 503 is held up for less than 2 milliseconds while the line printer output unit buffer is being filled. The 503 is then allowed to proceed and printing commences.

The Control Word.

Significance of the digits of the control word:-

bit 1 Printer not available. A one is present if the printer is OFF or in MANUAL.

2 Spare. Always zero.

3 Recoverable error. A one is present if the paper is nearly out.

4 Printer busy. A one is present if the printer is engaged in a paper feed or print operation.

5 Non-recoverable error. A one is set if:

a) paper is exhausted.

b) paper is broken, or jammed in the feed mechanism.

c) paper runs away, i.e. non-existent character on control loop.

d) hammer driver fuse is blown.

e) throat (cover door) is open.

Paper Control.

Each 77 N instruction referring to the printer outputs 121 7 bit characters to the printer. The first of these, i.e. that taken from digit positions 1 to 7 of word N, specifies the vertical format. The last 6 bits are used to determine the action to be taken, as indicated below:-

Binary Value.	Action
$0 \leqslant p \leqslant 30$	Move p+1 lines and print.
p = 31 or 32	Overprint i.e. no line feed.
$33 \leqslant p \leqslant 62$	Look for configuration (p-32) on the paper tape control loop, and print
p = 63	Has the same effect as depressing the "top of form" button.

Paper Control (continued)

In the last case the paper tape control loop is a closed loop of punched 8-hole tape. A call for a particular configuration causes the paper feed to be actuated until the next time the character on the control loop being read is the same as that specified, i.e. the paper tape is read until a character is found with the same binary value as q. For each character on the tape which is read and rejected one line is thrown but as soon as the q configuration is found the line is printed. This is extremely useful if several pages are to be printed with the same page layout.

Two of the control buttons on the line printer are the "top of form" and "load" buttons. The 8th channel of the control loop is the "top of form" channel and when the "top of form" button is depressed the control loop is searched for a hole in channel 8. The 7th channel of the control loop is the "load" channel and when the load button is depressed the control loop is searched for a hole in channel 7.

If a non-existent character configuration is called for, paper feed occurs until the "top of form" character passes the reader for the second time or a time-delayed cut-out occurs.

Manual Control.

A tabular summary of the various controls and control lights found on the line printer is given below. The 'type' abbreviations used are:

b	button only
bl	button containing a lamp
l	lamp only

Manual Control (continued)

Name	Type	Lamp lit when	Pushing button causes
POWER ON	bl	System power connected	Power to be connected
POWER OFF	bl	System power available but not connected	Power to be disconnected
ON-LINE MANUAL	bl	in MANUAL state	Change of state
LOAD	b		Hole in 'load' channel of control loop to be positioned under reader
TOP OF FORM	b		Hole in 'top of form' channel to be positioned under reader
PRINTER READY	l	Printer ready for operation	
ERROR 1	l	Recoverable error state	
ERROR 2	l	Non-recoverable error state	
SPEED	HIGH-LOW positions select the two available speeds		

Also available on other parts of the line printer are variable controls affecting paper tension, relative position of line printed, density of printing, relative time of printing.

When the power is switched on first the system is in the manual state with the printer ready light out.

Manual Control (continued)

until it is ready for operation. Pressure on the ON-LINE-MANUAL button causes the ON-LINE state to be engaged, making the printer available to the 503.

When an error is signalled, engaging MANUAL will cause a hold up in any order involving the line printer until action has been taken, the error cancelled, and the printer returned to ON-LINE operation.

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Part 4. Peripheral Devices.

Section 4. Bull Reader Punch.

The Mechanism

The machine contains two tracks along which cards may move. These are called the main and subsidiary tracks. The maximum speed of operation is 300 card movements per minute.

The main track consists of:-

a) A feed hopper holding up to 3,450 cards.

b) An operative track.

c) Ejection tracks.

d) The normal reception stacker with 3,000 card capacity and two special pockets for the reception of cards. The latter are called P1 and P2 and can contain 750 and 50 cards respectively.

The operative track is divided into six card stations S1, S2, S3, S4, S5, and S6 which are separated from each other by a linear cycle. S1 and S2 are read stations each containing 80 operational brushes, S3 is a "blank" station at which no operations take place, S4 is a punch station containing 80 punches, S5 is a reread station of 80 brushes, and S6 is a selection station which directs cards to one of the three ejection tracks. One ejection track leads to the main stacker and the other two lead to special pockets, P1 and P2 respectively.

The main hopper and each card station on the main track has its own feed roller and clutch. The clutch at S6 always engages when a card moves into S6. Thus a card can never rest permanently at S6 and will always be forwarded to a stacker or pocket. From the operational point of view S6 is identical to the final destination of the card.

The Mechanism (continued)

A card is said to be "at Sn" when it is about to undergo the operation which takes place at Sn.

The subsidiary track consists of:-

a) A feed hopper holding up to 800 cards.

b) A track of three linear cycles which joins the main track just before S4.

The subsidiary track stations are named S1', S2' and S3', and all three are "blank" stations. The subsidiary track and hopper have a common clutch.

A diagram of the track layout is shown in Figure 1.

Principles of Operation

There are four possible modes of use:-

1) Reading only

2) Punching only

3) Reading and punching previously read cards.

4) Reading, punching previously read cards, and punching blank cards.

The most general mode of use is the last. The other modes differ only in the loading and unloading procedure and in the validity of certain operations.

Information relating to a card is transferred to and from the 503 by means of the autonomous transfer system. The transfers take place through a 12 x 80 bit read buffer or through a 12 x 80 bit punch buffer. The read buffer is loaded by card movement past the read stations, and the information it contains may be read to the 503 by means of a pair of instructions. These instructions result in the card being read to any 80 consecutive locations in the store,

Principles of Operation (continued)

one location corresponding to each column of the corresponding card column, where an unpunched position is represented by 0 and a punched position by 1. Position 39 corresponds to the Y row and position 28 to the 9 row. Each location also contains in positions 1 to 7 a 7-bit decode of the column punching. The code is shown in Figure 2. Any unrecognised combination of holes in a column is decoded as the value 94. The punch buffer may be loaded by a pair of instructions. Movement of a card past the punching station then causes the information in the punch buffer to be punched in the card. This process involves columns being punched from any 80 consecutive locations in the store. Bit 27 of each word determines whether the image stored in positions 39 to 28 or the decode of the character in positions 1 to 7 is to be punched. If bit 27 is 0 then the image is punched, and if it is 1 then the decode is punched. Any unrecognised 7-bit character is decoded as a blank column.

All card movements under program control involve simultaneous movement of cards which may be present at five stations. These are either the stations S1 to S5 or the stations S1' to S3' and S4 and S5.

Reading is accomplished as follows:-

A 12-bit check register is associated with S1, and a 12 x 80-bit read buffer is associated with S2. As a card is read at S1 a 12-bit row parity word is formed and stored in the check register. When the same card is read at S2 it is loaded to the read buffer and the row parity word is again formed. If the two row parity words for this card agree then it is ready to be read to the 503 by autonomous transfer. The next card movement past the read stations will cause:-

a) The card at S2 to be read and the information to be loaded to the read buffer and checked.

b) The card at S1 to be read for check purposes and its 12-bit check word to be loaded to the check register.

c) A card to be taken from the feed hopper and set into S1.

Principles of Operation (continued)

Punching is accomplished as follows:-

A 12 x 80 bit punch buffer is associated with S4. As a card moves from S4 to S5 the content of the buffer is punched in the card. At the same time a 12-bit check register associated with S5 is loaded. The word loaded to the check register must take into account any punching which may have existed on the card as well as the information currently punched. To this end there are 12-bit registers associated with S3 and S4. When a card has been read and checked at S2 its check word is placed in the register associated with S3. As the card moves to S4 its check word is moved to the register associated with S4. When the card is punched a 12-bit row parity word of the content of the punch buffer is formed. This is added bit by bit to the content of the register associated with S4, and the result is placed in the check register of S5. When the card is read at S5 its row parities are checked against the content of the check register.

Cards may be guided to the special pockets in three ways. All cards checked for punching at S5 and shown to contain an error are automatically guided to pocket 1 on entering S6.

'Preselect' instructions specify P1 or P2 in their address and there are 'preselect' instructions associated with S3 and with S4. A preselect instruction causes the card currently at the associated station to be deflected to the selected pocket when the card eventually enters S6. When there is a conflict between instructions, P1 takes priority over P2. Thus a card preselected at S3 for P2 which moves to S4 and is there preselected for P1 will go to P1.

The Instruction Code for the Bull card reader/punch is as follows:-

Function	Operation
76 2048	Prepare to read information from the read buffer and read control word to Acc. The read operation involves no movement of cards. If the read buffer has not been loaded by a previous card movement, then the information obtained is identical to that obtained from an unpunched card.
76 2561	Prepare to load the punch buffer and read control word to Acc. The load operation involves no movement of cards. If the punch buffer is already loaded then a bit-by-bit mix of information will take place.
77 N	Read from read buffer or load punch buffer as specified in the last 76 instruction.
72 2048	Move cards at all stations on the main track. The instruction is obeyed immediately providing no card movement is already in progress. If either buffer is busy on an autonomous data transfer then the movement takes place as soon as both buffers are free. The movement causes the read buffer to be loaded and a card to be punched from the content of the punch buffer.
72 2049	Move cards on the secondary track, i.e. at stations S1', S2', S3', S4 and S5. The instruction is obeyed immediately provided no card movement is already in progress. If either buffer is busy on an autonomous data transfer then the movement takes place as soon as both buffers are free. The movement causes a card to be punched from the content of the punch buffer.
72 2559+P	Preselect as S3. The card at present at S3 is predestined to go to special pocket P (P=1 or 2). When the card eventually enters S6 it is deflected to the selected pocket. If a card is simultaneously directed to P1 and P2 as a result of a series of select and preselect instructions then it will go to P1.

The Instruction Code (continued)

Function	Operation
72 2561+P	Preselect at S4. This is like the preselect at S3 instruction except that it refers to the card currently at S4.
72 2566	No stop. The reader/punch is set so that in the event of a read or punch error it remains available for normal use.
72 2567	Stop. The reader/punch is set so that in the event of a read or punch error it is placed in the manual state with the lamp in the START button extinguished. One or both of the lamps ER, EP are lit to indicate the type of error. Pressure on the START button causes the reader/punch to revert to its previous auto state with the lamps extinguished. The procedure using the CLM and INTR buttons may be used instead as described under Manual Control.
75 2048	Cancel. Cancel the error state, if set, and read control word to Acc.

A hold-up on busy may be caused by an attempt to obey a given instruction when the action initiated by another instruction is in progress. The 'preselect', 'cancel', 'stop' and 'no stop' instructions can not cause hold-up on a subsequent reader/punch instruction. The situation for other combinations is shown in the following table:

Operation Attempted	Read	Load	Operation in Progress: Move Main	Move Sub.
Read	B	A	B	A
Load	A	B	B	B
Move Main	AL	AL	B	B
Move Sub.	AL	AL	B	B
Preselect	A	A	B	B
Stop	A	A	B	B
No Stop	A	A	B	B

B = busy A = immediate action
AL = accepted for later action.

Move Main - Move cards on main track.
Move Sub. - Move cards on subsidiary track.

The Instruction Code (continued)

The significance of the bits of the control word is:-

bit 1 Reader/punch not available. The bit is 1 if the device is not available as a result of being in the manual state or switched off. When this bit is 0 the device is available to accept instructions.

bit 2 Program card. This bit is 1 from the time the PROG button is depressed until the first read instruction pair is obeyed.

bit 3 End. This bit is 1 when the last card has passed S2, i.e. when S1 and S2 are empty. It is reset to 0 either when the track is empty or whilst the reader/punch is unavailable.

bit 4 Busy. This bit is 1 whilst the reader/punch is busy moving cards.

bit 5 Read error. This bit is 1 from the time a read error is detected until a reset instruction is obeyed.

bit 6 Punch error. This bit is 1 from the time a punch error is detected until a reset instruction is obeyed.

bit 7 Read mode. This bit is 1 whilst the device is in the read mode.

bit 8 Punch mode. This bit is 1 whilst the device is in the punch mode.

bit 9 R.P. & S mode. This bit is 1 whilst the device is in the R.P. & S mode.

bit 10 R.P. mode. This bit is 1 whilst the device is in the R.P. mode.

Manual Control

The following table shows the control buttons and lamps provided on the card reader/punch. These are grouped on a control panel situated on top of the mechanism. In the table the entries in the "Control" column show the actual markings on the buttons and lamps. The "Type" column reads b for button only, l for lamp only, and bl for button containing a lamp. The Step by step button is of the latching type, and the buttons Read, Punch, R.P. and R.P. & S are interlocked so that only one is depressed at any instant.

Control	Full Name	Type	Lamp is lit when	Pressure on button causes
ON	Power on	bl	Power is connected	Power connected (see note 1)
OFF	Power off	bl	Power is available	Power disconnected
START	Start	bl	Machine in Auto state	Machine to go into auto state and possibly to load before doing so.
READ	Read	bl	Machine has been set for reading only	Machine to be set for reading only.
PUNCH	Punch	bl	Machine has been set for punching only.	Machine to be set for punching only.
R.P.	Read/Punch One Track	bl	Machine has been set for reading and punching using only the main track.	Machine to be set to read cards and punch in previously read cards.
R.P & S	Read/Punch Two Tracks	bl	Machine has been set for reading and punching using both tracks.	Machine set to read cards and punch in previously read cards or in blank cards.

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Manual Control (continued)

Control	Full Name	Type	Lamp is lit when	Pressure on button causes
S by-s	step by step	bl	Machine is set to operate step by step	Machine to operate step by step
STOP	Stop	b		Machine to go into manual state and lamp in start button to be extinguished.
CL.M	Clear Main Track	b		Main track to be cleared of cards.
CL.S	Empty Subsidiary track	b		Subsidiary track (and latter half of main track) to be cleared.
END	End of File	bl	Button has been depressed and the main track is not empty	Empty hopper to be ignored thus allowing last cards to be processed.
PROG	Program Card	b		Indication to programme that a special card is about to leave the hopper (normally 1st card of file). (see note 2).
INTR	Introduction	b		Cards to be fed up to S5. (see note 3).
ER	Error in reading	l	Error has occurred	
EP	Error in punching	l	Error has occurred	

Manual Control (continued)

Control	Full Name	Type	Lamp is lit when	Pressure on button causes
IM	Incident on Main Track	1	Incident has occurred	
IS	Incident on Subsidiary Track	1	Incident has occurred	
IE	Incident on Ejection Track	1	Incident has occurred	

When the power is first switched on, the machine is in the manual state and the lamp in the AUTO button is extinguished. Whenever the machine is in the manual state, cards which may have been left in the tracks may be cleared into the reception stackers or pockets by pressing the CL.M or CL.S buttons. These buttons have no effect if the machine is not in the manual state. Once the tracks have been cleared the machine is loaded by filling the appropriate hoppers, depressing one of the setting buttons Read, Punch, R.P. or R.P. & S. and then depressing START. Depending on the setting, one of four loading operations takes place:-

1) If Read had been depressed, cards are fed along the main track up to S3. The card at S3 has been read, checked, and loaded to the read buffer. The card at S2 has been read for checking purposes, and the card at S1 has not yet been read at all.

Note 1. The ON button must be depressed for a time sufficient for the switching action to take place. The lamp lights when the action is complete. Cards must be present in the hoppers corresponding to the machine state before the ON button will operate.

Note 2. The PROG button is only effective if depressed whilst the reader/punch is in the manual state.

Note 3. The INTR button is only effective when the reader/punch has stopped as the result of an error.

Manual Control (continued)

Provided no error in reading has taken place, the machine is now ready to receive 'read' and 'move main track' instructions, and is said to be in the Read state. In this state, instructions which involve the loading of the punch buffer or movement of cards on the subsidiary track are invalid. (See 'Errors and Incidents').
If a reading error is detected during the loading procedure then the reader/punch remains in the manual state and the ER lamp is lit. The main track may then be emptied by pressure on the CL.M button. The loading procedure may be tried again and the ER button will be extinguished when the START button is depressed.

2) If Punch had been depressed, cards are fed along the main track up to S4. The machine is now ready to receive 'load' and 'move main track' instructions and is said to be in the Punch state. In this state read instructions are invalid.

3) If R.P. had been depressed, the machine is loaded as in 1) above and the action in the case of a read error during loading is the same. However, the machine is now in the R.P. state and ready to receive 'read', 'load' and move main track' instructions. Only the instructions which cause movement on the subsidiary track are invalid.

4) If R.P & S. had been depressed, cards are fed along the main track up to S3 and along the subsidiary track up to S3'. A read error during loading is treated as in 1) above. The machine is said to be in the R.P & S state and is ready to receive all instructions.

In all four states the machine is always in a position to receive the 'preselect', 'cancel', 'stop' and 'no stop' instructions.

All error and incident lamps are extinguished when START is depressed, and the punch buffer is cleared if the track is empty.

Manual Control (continued)

A properly affected loading procedure causes the machine to be set into one of the four possible 'AUTO' states, Read, Punch, R.P. or R.P. & S. and the lamp in the auto button is then lit. If the loading procedure is not properly completed, e.g. because of a reading error or because a card hopper has not been loaded, then the machine remains in the manual state with any appropriate indicator lamp lit. No error interrupt can be caused as a result of a fault in a loading procedure.

Once the reader/punch is in one of the auto states it remains so unless one of a set of exceptional events causes it to go into the manual state or to switch off. These events are:-

a) Certain error events described under 'Errors and Incidents'.

b) Pressure on the STOP button. This allows operator intervention, and pressure on the START button then causes the reader/punch to return to its previous auto state.

c) Filling of a stacker or pocket. Once the offending stacker or pocket has been unloaded, pressure on the START button causes the reader/punch to return to its previous auto state.

d) Emptying of the main hopper when the reader/punch is in the Read, R.P. or R.P. & S. states and the END button is inoperative (see below). Once the hopper has been refilled, pressure on the START button causes the reader/punch to return to its previous auto state.

e) Emptying of the subsidiary hopper when the reader/punch is in the R.P. & S. state. Once the hopper has been refilled, the pressure on the START button causes the reader/punch to return to its previous auto state.

f) Emptying of the main track. This only occurs in very exceptional cases of end-of-file processing.

Events a) to e) cause the reader/punch to go into the manual state and event f) causes it to switch off.

Manual Control (continued)

The fact that the reader/punch is in the manual state is indicated in the control word of the 76 instruction by the 'not available' bit. An attempt to obey a 77 or 72 instruction when the reader/punch is in the manual state causes an error interrupt to occur before the instruction is obeyed.

End-of-file processing may be performed in three ways:-

a) Using 'dummy' cards placed at the end of the file. These prevent the hopper emptying until the complete file has been dealt with.

b) When the reader/punch has gone into the manual state as the result of an empty main hopper, pressure on the START button places the machine in the auto state and the remaining cards on the track may be processed as if the hopper contained three extra blank cards.

c) Before the main hopper becomes empty the END button may be depressed. This prevents the reader/punch going into the manual state as the result of an empty main hopper: the end of the file may then be processed as if the hopper contained three extra blank cards.

The INTR button is used when it is required to re-read a card which forms part of an ordered file. The occurrence of an error when the reader/punch has been set to stop causes the reader/punch to go into the manual state in such a way that subsequent pressure on the CL.M button causes all cards at S1 to S5 to be ejected to P1. These cards are replaced in the main stacker and pressure on the INTR button then causes the cards to be reloaded to their original positions. The cards at S2 and S3 are read as in a normal loading procedure, and the punch buffer and check registers at S4 and S5 retain the contents they had before the error stop instruction was issued. A throat jam occurring whilst cards are being reloaded under control of the INTR button may cause the records of parity to be destroyed. This jam must therefore be treated as if the reader/punch had switched off, i.e. the program must be abandoned.

Manual Control (continued)

The PROG button is used when it is required to treat a single card in some special way. Pressure on the PROG button causes a bit in the 76 control word to appear and remain until a read instruction pair has been obeyed.

The S by-s button causes the reader/punch to go into the manual state each time an instruction which causes card movement is obeyed. Whilst the S by-s button remains depressed, pressure on the AUTO button causes the reader/punch to go into the auto state until the next card movement.

Errors and Incidents

Faults and abnormal occurrencies fall into two classes:-

1) Errors.
2) Incidents.

Errors do not necessarily cause the reader/punch to change its state. Incidents cause the reader/punch to be switched to the Manual state or to be switched off.

The possible errors are:-

a) Read error. This causes the reader/punch to be placed in the error state. An attempt to operate the reader/punch by means of either a 77 instruction or a 72 move instruction will cause an error interrupt before the instruction is obeyed. An indication that a read error state exists is given in the control word of the 76 instruction.

b) Punch error. This is similar to the read error in effect except that a separate bit is used in the control word.

c) Program errors. These cause an immediate error interrupt and constitute attempts to use the reader/punch in an invalid way because it is not in the appropriate auto state.

Errors and Incidents (continued)

Incidents fall into the following classes:-

1) Incidents which cause the reader/punch to be switched off. They are:-

   a) Card jam on the main track.
   b) Card jam on the subsidiary track.
   c) Card jam on the ejection track.
   d) Blown fuse.
   e) Loss of synchronisation inside the reader/punch.

All these incidents cause the ON lamp to be extinguished. The card jams cause the associated incident lamp (IM, IS or IE) to be lit as well. Loss of synchronisation causes a lamp on the service panel to be lit.

2) Incidents which cause the reader/punch to be switched to the manual state. They are:-

   a) Card jam in the throat of the main track.
   b) Card jam in the throat of the subsidiary track.
   c) Card jam in the pocket selector mechanism.
   d) Empty main hopper.
   e) Empty subsidiary hopper when the reader/punch is in the R.P. & S mode.
   f) Full stacker or pockets.
   g) Occurrence of a read or punch error when the reader/punch has been set to stop.

All these incidents cause the lamp in the START button to be extinguished. The jams cause the associated incident lamp to be lit. An empty main hopper causes IM to be lit, and an empty subsidiary hopper causes IS to be lit. The occurrence of an error causes ER and/or EP to be lit according to which error has occurred.

Errors and Incidents (continued)

Normal operation is resumed and all lamps extinguished by pressure on the START button after corrective action has been taken. In the case of throat jams the offending card may be removed and placed in the bottom of the hopper. The gap in the sequence of cards will automatically be closed when it reaches S3 or S3' in the case of the Read, R.P. or R.P. & S. states or when it reaches S4 in the case of the punch state. The presence of this gap does not interfere with the normal operation of the reader/punch nor is it noticed by the program in any way.

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Part 4. Peripheral Devices

Section 5 Direct input and output

A user requiring to connect his own special device to the 503 may take one of two courses:-

a) Purchase a controller to which his device may be connected.

b) Integrate the functions of the controller into his own device and connect it direct to the 503.

The latter is "direct input and output" and will be described in this section.

Interface Signals

The central processor communicates with peripheral controllers through the following four sets of lines:-

a) Data Input Lines. These 39 lines transmit data from the controllers to the central processor.

b) Data Output Lines. These 40 lines transmit data from the central processor to the peripheral controllers.

c) Code Lines. These 13 lines transmit codes, set up by the program, from the central processor to the peripheral controllers.

d) Control Lines.

The data and code lines are connected in a busbar (i.e. 'ring main') system so that each line connects with the central processor and every peripheral controller. The control lines connect directly from the central processor to each controller, although some of these lines may be common to a number of controllers.

Transfer Systems.

There are two types of transfers which can take place between the 503 and its peripheral devices:-

a) Single-word transfers.

b) Block transfers using the Autonomous Data Transfer (A.D.T.) system Block transfers may be of fixed or variable length.

The A.D.T. system allows one or more transfers to take place in parallel with the normal running of the program. The variable length transfer is always used in conjunction with a special purpose device. This transfer is initiated by the instructions

76 N1

77 N2

separated, if so required, by other program instructions. The address N consists of 13 bits, the four most significant of which specify the controller, the next six the number of the device attached to this controller, and the next three the operation involved (see 3.1. "The 76 Instruction"). The special purpose device is always considered to be controller number 15 so that for this device the four most significant bits of N1 are ones. When the 76 instruction is obeyed a control word is loaded from the peripheral controller to the accumulator of the central processor. This word indicates the state of the special device to the program. The construction of the special purpose device may assign any desired meaning to each of the 39 bits of the control word.

The address N2 specifies the first location of the main store which is associated with the transfer. The number of words to be transferred is specified by the upper address position of the accumulator. The complete

Transfer Systems (continued)

content of the accumulator is transferred to the peripheral controller when the 77 instruction is obeyed. This word may be put to any desired use by the special purpose device.

Single word transfers are initiated by the instruction 72 N for output to a peripheral device or 75 N for input from a peripheral device.

The address N is split in the same way as the address N1 of the 76 instruction. When a 72 instruction is obeyed a single word is output from the accumulator to the peripheral device. When a 75 instruction is obeyed a single word is input to the accumulator from the specified device.

For "Operation of the A.D.T. system" and "Signals Involved in Transfers" see 3.1.

For "Program Interrupts" see 2.4.

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Part 5. Off-line Equipment

Section 1 Flexowriter

The eight hole off-line standard paper tape equipment for use with the 503 is called an Elliott Model P flexowriter. In Friden terms it is a recorder-reproducer, i.e. it comprises in one integral unit:-

(a) a tape reader
(b) a translator
(c) an electric typewriter with Keyboard
(d) a selector
(e) a tape punch.

The components of this are given in the following paragraphs.

Code. For eight channel code see Part 2 Section 1.

Keyboard layout. See diagram on page 6.

Stand. A simple frame stand is supplied. At extra cost, this frame can be replaced by a desk unit, with drawers sub-divided for tape storage.

Colour. The Flexowriter is grey with black keys.

Internal voltage. There is a rectifier attached to the stand which alters the external voltage from a 240 volt 50 cycle supply to give an internal voltage of 90 D.C.

Carriage. The standard carriage is the 12-inch but as optional extras, a Friden pin feed platen with retractable pins and/or a 16" or 20" carriage, can be fitted.

Label-holder. A holder to take continuous rolls of teleprinter stationary is fitted on top of the carriage.

Flexowriter (continued)

Tear-off strip. A perspex tear-off strip is fitted on the paper bail.

Platen. A friction-feed platen is fitted.

Typeface. The Elliott Model P Flexowriter has a diplomat style type face. This gives 12 characters per inch and a maximum of 114 character positions on a 12" carriage.

Line Spacing. A 66 tooth ratchet is fitted, giving 6, 4 or 3 lines to the inch under the control of a manual lever. A 33 tooth ratchet may be fitted as an optional variation at extra cost.

Colour Shift. The Flexowriter can type in either red or black. This colour shift is controlled by a manual lever.

Keyboard lock. The keyboard is locked while:-

a) the machine is switched off.
b) during carriage return and tabulate.
c) on malfunction of the punch.
d) after a parity error on punching. (See Parity Check).

Lamp. There is one lamp engraved "LOWER CASE" which is lit when the keyboard is in the lower case condition.

Switch 1. (On/Off). Switches the Flexowriter on and off.

Switch 2. (Punch On/Off). Switches the punch on and off. The reader is wired directly to the punch, so that when tape is being reproduced every character except erase and stop is copied, including those which are not associated with a keyboard key. (See Switch 6).

Flexowriter (continued)

Switch 3. (Start Reader). When this switch is depressed the reader starts reading the tape and producing a printed copy thereof.

Switch 4. (Stop Reader and Single Shot). If this switch is depressed, whilst tape is being read, it causes reading to stop. At each subsequent depression a single character is read by the reader.

Switch 5. This switch is not used on the standard Flexowriter. At extra cost it may be used as a 'Non-Print' switch. This enables tapes to be copied from reader to punch without printing taking place.

Switch 6. This switch is not used on the standard Flexowriter. At extra cost it may be used as an "OVERRIDE STOP" switch. When depressed this inhibits the stopping of the tape reader on reading the stop code and allows 'erase' to be copied and not ignored. With this switch depressed any of the 128 acceptable codes can be copied to the punch for production of binary tapes.

Switch 7. Punches the "Stop Code" character (10011100) but has no other action.

Switch 8. Punches the 'erase' character (11111111) and unlocks the keyboard after an error hold up. Erase is ignored by the reader except when Switch 6 is depressed.

Switch 9. This switch is not used on the standard Flexowriter but may be included at extra cost. This switch is called the "Aux" switch and it has the effect of suppressing the punching of the 32 hole of the letter concerned, and causing the 64 hole to be punched instead. The parity check hole is not affected. The "Aux" codes are punched by holding down switch 9, and depressing one of the upper case keys A to N. The allocation of these spare characters in the code range 65 to 78 cause Flexowriter "Programmatic" functions. These functions are mainly associated with the control of the auxiliary reader and punch, when fitted.

Flexowriter (continued)

Switch 10. Punches the "run out" character (00010111) continuously whilst depressed, but has no other action. On reading tape, "run out" is not printed but is copied to the punch.

Key W (See Page 6) (Throw). This key punches the "throw" character (00000011). If the electric line finder is fitted a paper throw is caused.

Key 42. (See page 6) (Vertical bar and Underline). This key is non-escaping, i.e. the carriage does not move when the character is typed.

Parity Check. The 8 channel code is of even parity and this is checked on the punch only. Therefore if the punch is switched off no parity check takes place. Facilities are provided whereby the punch may be left on without producing tape. When a parity error is detected the keyboard is locked and can only be released by means of switch 8.

Optional variations. The following are a list of variations, any of which may be specified, at extra cost. (These are in addition to those already mentioned).

(1) Lamson Formaliner paper feed attachment, (gives adjustable pin to pin dimension).

(2) Electric line finder.

(3) Edge card reader and/or punch. N.B. The edge card punch is not available with the 20" carriage.

(4) Backspace facility. This is operated when the code 00000101 is read by the reader. This code cannot be punched on tape by the Flexowriter from the keyboard but can be copied from input tape.

(5) Omission of tape reader, (and of switches 3 and 4) giving a tape-preparing-only unit (recorder).

Optional variations (continued)

(6) Addition of an auxiliary tape or edge card reader, for systems use.

(7) Omission of punch, (and of switches 2,7,8,9 and 10) giving an output printing-only unit (reproducer).

(8) Addition of an auxiliary tape punch, for systems use.

(9) Addition of a verifier reader, enabling keyboard verification of a previously punched tape.

Stop Code. The Stop or Halt Code (10011100) will, when read by the reader cause the flexowriter to halt unless override stop (switch 6) has been fitted and is depressed.