ELLIOTT

COMPUTING DIVISION

CS 126

ELLIOTT 503 COMPUTER

TECHNICAL SPECIFICATION

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Computing Division
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Elliott 503 Specification

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1. The Computer

1.1. Description of the Computer

The 503 is a fast low-priced computer designed for the scientific market. It is completely transistorised, compact and of low power consumption. 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, magnetic film units, punch card equipment, a line printer, a core backing store.

1.2. Components of the Computer

The computer consists of some or all of the following components:-

(a) Central Processor comprising a core store of 8192 words with cycle time of 3.5 microsecs. arithmetic registers, control registers, and allied logical units.

(b) Paper Tape Station Type 3. This comprises two Elliott tape readers and two Teletype 100 tape punches with associated control keys and circuitry. The station is capable of dealing with various types of tape, (e.g. 5 and 8 channel) according to the setting of hand switches.

(c) Control Desk comprising directly connected input/output typewriter and control keys.

(d) Floating Point Unit for the provision of automatic floating point arithmetic.

(e) Peripheral Transfer Control Unit, allowing one or more autonomous peripheral transfers.

(f) Interrupt Control Unit to facilitate the programming for time-shared systems or for systems responding to random external stimuli.

(g) Peripheral Units:-

Elliott magnetic film units as used on 803.
Decca 4000 $\frac{1}{2}$" magnetic tape units.
I.B.M. 528 card reader/punch.
600 lines per minute printer.
Core backing store
Elliott Card Reader
I.B.M. 523 card punch.

The basic computer consists of the Central Processor, the Paper Tape Station, the Control Desk, and the Floating-Point Unit.

1.3. Physical Description of the Computer

1.3.1. Dimensions

The Central Processor (including core store), Floating Point Unit, and the power supply unit are all housed in a central cabinet made up of 3 standard 502 cabinet-units.

Dimensions of the components are:-

	Height	Width	Depth	Doors
Processor	80"	102"	19"	19"
Paper Tape Station	30"	80"	29"	
Control Desk				
Peripheral Transfer Control	80"	38"	19"	19"
Magnetic Film Handler	56"	$26\frac{1}{2}$"	32"	
Magnetic Film Controller	80"	38"	19"	19"
Magnetic Tape Handler	66"	30"	24"	
Magnetic Tape Controller	80"	38"	19"	19"
Elliott Card Reader				
I.B.M. 523				
Controller for Line Printer	80"	38"	19"	19"
Controller for 523	80"	38"	19"	19"
Core Backing Store	80"	$37\frac{3}{4}$"	19"	19"

1.3.3. Power Supplies

Mains input to a 503 system is provided by a single cable supplying single phase and/or three phase current.

The power cabinet in the processor unit supplies d.c. and a.c. power to the processor, the control desk, the paper tape station and the Elliott Card Reader if this is included in the system. It also controls the distribution of the mains supply to any other power cabinets in the system.

The processor and controllers are normally switched on and off together by means of push buttons on the control desk. Electromechanical devices are normally switched on and off by means of their own locally situated controls but a master switch is provided on the control desk to remove power from the whole system in case of emergency.

The customer provides a 50 cycle supply, either single phase within the range 220 to 240 volts or three phase within the range 400 to 440 volts. The three phase supply is always required for the magnetic tape units and for systems exceeding certain power consumption depending on the site of the installation.

The tolerance on the voltage is $\pm$ 10% of the r.m.s. value. The power supply system is designed to withstand interference generated by other loads and the interruption of the supply for 20 msecs.

Each piece of on-line peripheral equipment has a manual button which prevents any intermediate state being possible while it is being switched on. Thus the equipment is automatically in the manual state after being switched on and can only be placed under computer control by operating the manual button.

Mean power requirements of the components are approximately:-

Central Processor Floating Point Unit Control Desk Elliott Card Reader	4 KVA
Core Backing Store	
Peripheral Transfer Control	
Magnetic Film Unit	1 KVA
Magnetic Tape Unit	1 KVA
Card Reader/Punch	
Paper Tape Station	

1.3.4. Environmental Control

Air conditioning units are provided to hold the room ambient at $70^{\circ}F \pm 2\frac{1}{2}^{\circ}F$. Humidity control must be added for installations of magnetic tape. It is preferable that tapes are stored in a controlled environment.

The air conditioning units are mounted in a wall of the room and dispel heat externally.

Each site has to be surveyed to assess the number of air conditioning units required.

The air conditioning units run from an independent power supply, and the controlling thermostat is sited at the air intake to the processor.

It is not possible to switch power on to the computer if the internal temperature lies outside the range 70° to $80^{\circ}F$ and a lamp on the control desk indicates a temperature outside this range.

2.1. The Main Store

Word length is 39 bits. An extra bit, not available to the programmer, is used for autonomous transfer tagging.

A second bit is used for parity checking, each word being checked for odd parity every time it is read from the store.

Store size is 8192 words. Locations 0 to 3 contain fixed orders by which a simple tape code may be read. Writing to these locations has no effect, reading from them yields zero. Locations 8176 to 8191 are reserved for use in autonomous transfers.

2.2. 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.

2.3. The Instruction Code

2.3.1. Compatibility with 803

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.

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

digit	39 to 34	33 to 21	20	19 to 14	13 to 1
	Function	Address	B	Function	Address
	First instruction			Second instruction	

Instructions in Groups 0 to 3 and in Group 5 operate on fixed point numbers. Each of these occupies a single word and is a fraction in the range $-1 \leq x < +1$. Digit 39 indicates the sign of the number, zero for positive numbers and one for negative numbers which are represented by the complement of their modulus with respect to two.

2.3.2. Instructions

The tables below show the effect of each 503 instruction. N is the number contained in the address position of the instruction and represents either:

(1) an address in the store
or (2) in some group 5 instructions, a number of places shifted
or (3) in some group 7 instructions, an address used to select one of a series of alternative operations.

a and n represent the initial contents of the accumulator and storage location respectively.

a' and n' represent the contents after the instruction has been obeyed. Abbreviations used in the tables include Acc. for accumulator, A.R. for auxiliary register, and S.C.R. for sequence control register. Those 503 instructions which differ in any respect from corresponding 803 instructions are marked *.

Group 0

Instruction	Description	a'	n'
00 N	Do nothing	a	n
01 N	Negate	-a	n
02 N	Replace and count	n+1	n
03 N	Collate	a & n	n
04 N	Add	a+n	n
05 N	Subtract	a-n	n
06 N	Clear	o	n
07 N	Negate and add	n-a	n

Group 1

Instruction	Description	a'	n'
10 N	Exchange	n	a
11 N	Exchange and negate	-n	a
12 N	Exchange and count	n+1	a
13 N	Write and collate	a & n	a
14 N	Write and add	a+n	a
15 N	Write and subtract	a-n	a
16 N	Write and clear	o	a
17 N	Write, negate and add	n-a	a

Group 2

Instruction	Description	a'	n'
20 N	Write	a	a
21 N	Write negatively	a	-a
22 N	Count in store	a	n+1
23 N	Collate in store	a	a & n
24 N	Add into store	a	a+n
25 N	Negate store and add to store	a	a-n
26 N	Clear store	a	o
27 N	Subtract from store	a	n-a

2.3.2.

Group 3

Instruction	Description	a'	n'
30 N	Replace	n	n
31 N	Replace and negate store	n	-n
32 N	Replace and count in store	n	n+1
33 N	Replace and collate in store	n	a & n
34 N	Replace and add into store	n	a+n
35 N	Replace, negate store and add	n	a-n
36 N	Replace and clear store	n	o
37 N	Replace and subtract from store	n	n-a

Group 4

In the appropriate circumstances instructions 40 to 43 transfer control to the first instruction of the pair contained in location N. In similar circumstances instructions 44 to 47 transfer control to the second instruction of the pair.

Instruction	Effect
40 N or 44 N	Transfer unconditionally
41 N or 45 N	Transfer if a is negative
42 N or 46 N	Transfer if a is zero
43 N or 47 N	Transfer if overflow indicator is set and clear it.

Group 5

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

Instruction	Effect
50 N	Halve N times double-length
51 N	Shift a N places to the right, clear A.R.
52 N	Multiply a by n giving double-length result
53 N	Multiply a by n giving single-length rounded result
54 N	Double N times double-length
55 N	Double a N times. clear A.R.
56 N	Divide double-length number by n giving single-length result, clear A.R.
57 N	Place contents of A.R. in positions 1-38 of Acc. and make sign digit of Acc. zero.

Group 6

Instructions 60 to 65 operate on floating-point numbers. Each of these occupies a single word. Digits 1 to 9 contain 256 + b where b represents an exponent in the range $-256 \leqslant b < 256$. Digits 10 to 39 represent a fixed-point number m with sign. The floating point number is $m.\ 2^{b}$ and is (apart from the number zero) always used in standardised form in which $\frac{1}{2} \leqslant m < 1$ or $-\frac{1}{2} \geqslant m > -1$. Floating-point zero is represented by 39 zeros. Results of floating-point operations are rounded so that the error is not more than 2^{-29} without bias. Results of instructions 60 to 65 appear in Acc.

Instruction	Effect
60 N	Add n to a, clear A.R.
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.
64 N	Divide a by n, clear A.R.
65 4096	Standardise, i.e. convert the 39-bit integer in Acc. to standard floating-point form, clear A.R.
66 N	Spare - acts like 00 N.
* 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 (see 2.3.3.).

Group 7

All instructions in group 7, apart from the 73 instruction, are concerned with input and output. The table shows the action taken by the computer as a result of obeying the instructions. Details of how the instructions are used will be found in the sections dealing with peripheral devices.

Instruction	Effect
70 N	Read number generator to Acc.
* 71 N	Output N to Paper Tape Station. Mix 8 bits from Paper Tape Station with bits 1 to 8 of Acc. (see 4.1.)
* 72 N	Output n to peripheral controllers. Transfer a single word between Acc. and a peripheral device (see 4.6).
* 73 N	Write digits 2 to 14 of S.C.R. to positions 1 to 13 of location N. Write digit 1 of S.C.R. to position 39 of location N. Clear remaining positions of location N.
* 74 N	Output N to Paper Tape Station for selection purposes, then output N to Paper Tape Station as information (see 4.1.)
* 75 N	Output N to peripheral controllers. Transfer a single word between Acc. and a peripheral device (see 4.2., 5.2).
* 76 N	Output N to peripheral controllers. Input a single word from a peripheral device to Acc. Prepare for autonomous transfer (see 3.1., 3.2., 4.2. to 4.6.)
* 77 N	Execute the operation specified by the last 76 instruction. If a transfer was specified use locations N onward in the store.

2.3.3. B-modification

If the digit is present between the two instructions of a pair then the second instruction is modified by the addition of the least significant 19 digits of n, where N is the address in the first instruction. 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 being obeyed. When the B digit is present a marker M is set. Before the first instruction is completed, and if the B digit is present, the least significant 19 digits of n are stored in a special register R. Before any instruction is obeyed M is checked. If M is set then the contents of R are added to the instruction and M is cleared.

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 caused by the situation in (1) above).

(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, e.g. the instructions:-

```
67  1500  :  67  0
30    60  :          where c(1500) = 162 & c(162) = 7100
```

have the effect of replacing the number in the accumulator by the number in location 7160.

2.3.4. Operation Times

Approximate operation times are:-

Order		Description	Time in microsec.
Group 0		Simple arithmetic and logical	7
Groups 1, 2.		Simple arithmetic and logical	$8\frac{1}{2}$
Group 3		Simple arithmetic and logical	9
Group 4		Transfer control	5
50		Halve double-length	7.7 + .7 n
51		Right shift	$7\frac{1}{2} + \frac{1}{2}$ n
52, 53		Multiply	40 to 58
54		Double double-length	7.7 + .7 n
55		Double	$7\frac{1}{2} + \frac{1}{2}$ n
56		Divide	80
57		Read AR	5
60, 61, 62	+	Floating-point simple arithmetic	20
63		Floating-point multiply	38 to 52
64		Floating-point divide	72
65		Floating-point standardise	$6 + \frac{1}{2}$ n
70		Read control keys	20
71		Mix tape reader to Acc.	20
73		S.C.R. to Store	$8\frac{1}{2}$
74		Output N to tape	20
76		Prepare peripheral transfer	20
77		Transfer M words - tagging	$30 + 3\frac{1}{2}$ M
		- transferring (shared)	11 M

+ This is based on the assumption that 6-bit standardisation is required. The time can, in fact, vary between 16 and 40 /usec.

3.1. Autonomous Transfers

3.1.1. Transfer Instructions

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

Locations 8176 and 8191 are reserved for logical use by these instructions.

3.1.2. The 76 Instruction

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

(1) Place the instruction itself in location 8191.

(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.

The N digits of the 76 instruction specify the device and the type of transfer required:-

m.s.

Digits 10 to 13	Digits 4 to 9	Digits 1 to 3
class of device	number of device	operation

l.s

Of the 8 possible operations, those which require the computer on line (q.v. para. 3.2.) have digits 2 and 3 zero. There are, thus, two possible computer-on-line operations, 0 being read and 1 write. All other operations are computer-off-line. If more than 8 operations are required then digit 4 may be incorporated with the operation digits. Operations 8 and 9 are then on-line and operations 10 to 15 off-line.

Each of the 16 possible classes is associated with a specific peripheral controller except for class 0 which is illegal. 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 512 C + 8 D + P.

Classes are allocated thus:-

	C	512C
Elliott Card Reader	1	512
Magnetic Film	2	1024
Magnetic Film	3	1536
I.B.M. Card Reader	4	2048
I.B.M. Card Punch	5	2560
Line Printer	6	3072
Spare	7	3584
Magnetic Tape	8	4096
Magnetic Tape	9	4608
Core Backing Store	10	5120
Spare	11	5632
Spare	12	6144
Spare	13	6656
Spare	14	7168
Spare	15	7680

3.1.3. The 77 Instruction

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

1. Read the 76 instruction from location 8191. If no 76 instruction present STOP.

2. 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.

3. Clear the auxiliary register.

4. Set in the location associated with the peripheral controller (this will be one of the locations 8176 to 8190) a pair of counts. The pair of counts consists of N - 1 in the lower half word and -T in the upper half.

5. Clear location 8191.

6. Determine whether transfer can be initiated, i.e. check if relevant busy lines are up. Carry on as soon as permissible.

7. Check if the upper count is non-negative. If so the instruction is complete. If not, increment both counts.

8. Transfer to or from the location specified by the lower count. At the same time clear the tag digit. Then return to 7.

Notes:

a. 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 Acc.

b. 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.

c. When the computer is waiting for a tag to disappear for the reason mentioned in step 2 or for that mentioned in note b, then a light on the control display is lit.

d. Locations 8176 to 8191 cannot be written into other than by 76 or 77 instructions. These locations may be read by any instruction.

e. Interrupt cannot occur during steps 1 to 6 of the 77 instruction.

f. Steps 2 and 6 imply that a holdup may occur whilst an earlier transfer is completed.

3.2. 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 and certain devices may be connected to more than one 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. find a block on film.

(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.

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. Arrangements are made for the inclusion of additional devices at chosen positions in the priority sequence.

3.3. Reset Keys

If a peripheral device breaks down during a transfer then some tagged words remain in the store. These words must be untagged so each device has a reset key. Depression of the reset key causes the current transfer to be concluded even though the information transferred may now be nonsensical.

4.1. Paper Tape and Typewriter

The standard tape for 503 is 8-channel. The Type 3 Paper Tape Station can be manually switched to select the type of tape dealt with. The Elliott Tape Reader speeded to 1000 c/s provides the input mechanism, and the 100 c/s Teletype punch is used for output.

The Type 3 station comprises two desks.

The first desk contains all the electronics for controlling two tape readers, two perforators, a typewriter input/output unit, and a number generator control unit. The tape readers and perforators stand on top of this desk.

The typewriter and control unit stand on the second desk which is connected by cables only to the first and not to the processor.

The control keys for the processor are either on the typewriter or on the second desk.

Since there is no electronics in the second desk the design of the electronics allows for the second desk to be up to 30 feet from the first.

The 503 computer normally reads eight-channel paper tape, checks the parity channel and mixes seven bits with the accumulator. Similarly, an output, seven bits are taken from the output instruction address, a parity bit is generated and eight bits are punched.

The computer is normally controlled by the Friden Flexowriter but a number generator is provided for compatibility with 803.

4.1.1. 503 Control

The following general principles are the basis for the 503 Control System.

1. The 503 should be as near as possible identical in operation to the 803. Because of the 16 words for Autonomous Data Transfer 503 can only obey 803 programmes written for a 8160 word store, or less, or full 803 programmes written for the basic machine.

2. Error conditions detected automatically by the 503, e.g. main store parity, errors in tagging and peripheral device errors, cause the 503 to HALT with illuminated display indicating source of error.

3. The operating control of the 503 is via a flexowriter decoded by a standard programme held in a reserved area of store of 256 words. This reduces the effective 503 store to 7936 words. The control programme is initiated by a manual interrupt key.

Facilities Provided

1. Because of point 1 a full 39-bit Number Generator is provided for input of data. Manual triggering of a programme from the N.G. is by interrupt programme and the equivalent of the 803 read key is not provided. Similarly the 803 Selected Stop is not provided. 803 programmes using less than 7936 words can operate on the 503 with the normal 503 flexowriter control; using simulated N.G. control 803 programmes using up to 8160 words may be used on the 503.

2. Manual Interrupt. Depression of manual interrupt has no effect if interrupt inhibit light is ON. If the light is OFF, the manual signal is stored and the computer jumps to location 8160 as soon as it is about to obey a non-B modified instruction and the manual inhibit light is then turned ON, thus prohibiting further manual interrupts. The inhibit light is also turned OFF by 75 0 instruction and general reset.

3. The 503 always exists in one of the following states:-

(a) RUN: i.e. instructions being obeyed normally, manual interrupt possible, A.D.T's. allowed.

(b) BUSY: in this state the 503 continually extracts and decodes the same instruction but is prevented from obeying the instruction through one of the following (possibly transitory) conditions:-

(i) Instruction tagged
(ii) Operand tagged
(iii) Group 1, 2, 3 instruction referring to reserved store
(iv) Peripheral instruction (other than 77) held up by busy

(c) WAIT: in this state the 503 is effectively stopped but A.D.T's. are permitted. It is caused through one of the following conditions:-

Peripheral reset key depressed
Main store parity error
Peripheral device signalling an error

(d) HOLD-UP: in this state the 503 has commenced an instruction and is prevented from concluding it. The only case of this is during a 77 instruction when:-

(i) preceded by no or inadmissible 76 instruction
(ii) during tagging a location already tagged is found
(iii) the peripheral device is busy

If a parity error is discovered the 77 instruction is concluded in the normal way and WAIT occurs after it is completed.

In all the states (a) - (d) A.D.T's. are permitted. HOLD-UP and BUSY are both normally transitory states cleared by A.D.T's. and the 503 then reverts to RUN.

Manual interrupt is only permitted in the RUN state.

4. Errors

Errors due to HOLD-UP and BUSY can be manually cleared by correcting the offending peripheral device, e.g. turning to MANUAL or pressing peripheral reset. In addition, there is an ERROR ACKNOWLEDGE button. If the 503 is in the RUN state this button has no effect. If the 503 is not in the RUN state depression of this button causes the 503 first to enter WAIT and then to perform an interrupt independent of whether the next instruction is B-modified; the depression also clears parity and cancels Manual Interrupt, if set. This error interrupt causes a special interrupt to a programme which can, for example, print "ERROR" but the programme cannot return to the interrupt point and allow the 503 to continue (since the instruction may have been B-modified).

Error interrupt only indicates that the operator decided that an error had been made; it provides no diagnosis of what form the error took; this can be done only by recording the state of the control lamp of the machine at the instant error is depressed.

The WAIT state indicates an error has definitely occurred and the 503 can only be removed from this state through error interrupt. A BUSY condition may be an error and the 503 can be removed from this state either by removing the busy condition or by error interrupt; this latter will, however, not remove the cause of error.

Note that errors can be caused through leaving peripheral devices in the manual state.

5. Control Keys for 503

(a) Computer ON; this also initiates key c.

(b) Computer OFF; this turns off all power in case of emergency.

(c) Clear store (including reserved store) thus setting main store parity and operating key d (push button).

(d) System Reset. Clear tags from whole store, clear overflow. Clear manual interrupt inhibit lamp, clear 76 instruction, reset peripheral controllers and handlers if possible, clear parity bit. (Push button).

(e) Reserved store. Remove protection from reserved store. (Push-push button with lamp).

(f) Yale key removable in either ON or OFF position which can make certain control keys inoperative.

(g) Initial instructions. (Push button). If 503 is in RUN depression of this button causes the 503 to transfer to initial instructions. If 503 is in BUSY, WAIT or HOLD-UP Error Interrupt must first be depressed. In normal conditions, a binary input routine forming part of the reserved store will be used for input of programme.

(h) Initial Instructions select (push-push button). This enables 5 or 7 bit input via Initial Instructions.

(i) Number Generator comprising 39 two position keys.

(j) Manual Data (push-push button) providing a manual busy on 70 instruction.

(k) Manual Interrupt (push button with single shot logic).

(l) Error Interrupt.

6. Indicator Lamps

(a) Computer ON

(b) Reserved store inhibit OFF - associated with button f.

(c) Busy on 71 4096 instruction, i.e. waiting for flexowriter key to be depressed - situated on flexowriter keyboard. The logic for this is situated in Paper Tape Station. 503 will be in BUSY state.

(d) HOLD-UP - 503 in HOLD-UP state.

(e) One or more peripheral transfers in operation.

(f) BUSY - 503 in BUSY state.

(g) WAIT - 503 in WAIT state.

(h) Main Store parity error

(i) Manual Interrupt inhibit. This lamp is associated with key k. It is turned OFF by key d and turned ON by acknowledge manual interrupt signal from computer. It is also controllable by programme via instruction 75. 75 0 turns lamp OFF and 75 1 turns lamp ON.

(j) Floating-point overflow.

(k) 503 waiting for tag to clear in BUSY or HOLD-UP state.

(l) Temperature nearly out of range - when lit computer cannot be turned ON. If temperature goes out of range during operation this lamp comes on as a warning that the 503 will turn itself off if the temperature continues to rise (or fall).

4.2. Magnetic Film

Standard 803B Magnetic Film Handlers are used. The instruction code is as for 803B:-

75	1027	Transfer to Acc. address of last block read or written.
76	1024 + 8H	Place control word in Acc., prepare to read from handler H.
76	1025 + 8H	Place control word in Acc., prepare to write on handler H.
76	1026 + 8H	Place control word in Acc., prepare to search on handler H.
77N		Read or write using locations N to N + 63, or search for block N.

Search is a controller-on-line operation, but the controller is capable of performing one search and one read/write operation at the same time.

Each magnetic film controller may control up to 4 handlers. The addresses in the 76 instruction for a second controller are 512 greater than those given above.

Significance of the control word bits is:-

bit 1	Handler not available.
2	Block address parity error.
3	Writing permitted.
4	Handler busy.
5	Parity error on reading.
6	Controller busy.

4.3. Magnetic Tape

4.3.1. Tape Layout

The Decca 4000 Handlers use $\frac{1}{2}$" tape with 8 tracks. 5 tracks are used for information giving one word and 1 check bit in 8 rows. The seventh track is a block-marker track and the eighth is a clock-track. The 6th track is a parity check on each character.

Tape speed is 150"/sec.
Packing density is 300 rows/inch.
Stop/start distance is .3 inches.
Interhead gap is .39 inches.
One word is read in 177.8 /usec.
One word occupies 0.027 inches
One block occupies 1.7 inches and the inter-block gap is 0.69 inches.

350,000 Words are recorded per 1000 feet of tape.

Words are written in blocks of 64 and the tape is premarked and addressed. Bad patches are sensed on the block-marking run and block-marks are so placed that all bad patches occur in the inter-block gaps.

4.3.2. Magnetic Tape Facilities

Information may be read or written in items of T words. The controller is so arranged that at the end of a block reading or writing is suspended until a new block begins. When all T words have been dealt with the controller is free and the handler carries on to find the end of the current block. During writing the words written after the controller becomes free contain a fixed number. Searching may be carried out as on magnetic film.

4.3.3. Magnetic Tape Order Code

The order code referring to handler P is:-

76	4096 + 8P	Control word to Acc., prepare to read
76	4097 + 8P	Control word to Acc., prepare to write
76	4098 + 8P	Control word to Acc., prepare to search
76	4098 + 8P	Control word to Acc., wind on tape
76	4100 + 8P	Control word to Acc., rewind tape
77	N	Execute operation specified by the last 76 order.

If read or write is specified start at address N of the main store and transfer T words where Acc. contains $T.2^{-18}$. If search is specified then search for the block whose number is held in location N of the main store.

Each tape controller may control up to eight handlers. The addresses in the 76 instruction for the second controller are 512 greater than those given above.

4.4. Punched Cards

4.4.1. Elliott Card Reader

The instruction code for the Elliott card reader is as for 803B:-

76	512	Control word to Acc., prepare to read
77	N	Read a card to locations N to N + 79.

The significance of the control word bits is:-

bit 1 Device not available
2 No card on sensing platform
3 Spare
4 Device and controller busy
5 Error in reading of last card

Words are fed to the store through a 12 to 7 bit converter. Each location receives a 12-bit image of a column in digits 28 to 39 and a 7 bit coded equivalent in digits 1 to 7. All other digits are zero. Digit 39 corresponds to the Y row on the card. The 7 bit code is that used on 8 hole tape.

4.4.2. I.B.M. 523 Card Punch

The instruction code for the 523 punch is:-

76 2561 Control word to Acc., prepare to punch

77 N Punch a card from locations N to N + 79.

The significance of the control bits is:-

bit 1 Device not available
2 No card in hopper
3 Spare
4 Device and controller busy
5 Error in punching last card

Each column of the card is taken from its corresponding store location and is punched as a 12 bit image or decoded from a 7 bit code according to the value of digit 27. When digit 27 is 0 then the image is punched, otherwise the decode is punched.

Error indication is given on blank column or double-punched column according to plugboard wiring.

4.5. Line Printer

The line printer has a nominal speed of 600 to 900 lines per minute. The speed is 900 lines per minute when printing numerical information and 600 l.p.m. when printing alpha-numeric information. Each line has 120 positions, and each position has a repertoire of 56 characters. The characters are set up by 6-bit signals. There is a 120-character buffer which is set up in less than 2 msec.

The instruction code is:-

76 3073 Control word to Acc., prepare to print a line
76 3074 Control word to Acc., prepare to throw N lines
76 3075 Control word to Acc., prepare to throw to the line labelled N.
77 N Print one character from each of the locations N to N + 119, or
throw N lines, or
throw to the line labelled N on the printer control tape.

Significance of the control word bits is:-

bit 1 Printer not available
2 Mechanism error
3 Spare
4 Printer busy
5 Echo check error

4.6. Core Backing Store

Core backing store is supplied in units of 16,384 words. Access is by autnomous transfer or by a single word transfer. Any number of units may be considered as a single backing store under a single controller.

Cycle time is 50 /usec. and access time 15 /usec. There is a parity check on every word.

The instruction code is:-

72 N Transfer a single word between Acc. and location A of the backing store. The address A and the mode of transfer are specified by the contents of main store location N as $M.2^{0} + A.2^{-38}$, where M is 0 for reading from the backing store and 1 for writing to the backing store.

76 5120 Prepare to read from backing store by autonomous transfer.

76 5121 Prepare to write to backing store by autonomous transfer.

77 N Perform type of transfer specified by last 76 instruction between locations N onward in the main store and locations A onward in the backing store. The number of words transferred T and the address A are specified by the contents of Acc. as $T.2^{-18} + A.2^{-38}$.

There is no control word for the backing store, and Acc. is cleared on each 76 instruction.

5.1. Control Interrupt

There is an interrupt line which causes transfer to a fixed location without disturbing SCR. This line is connected to a manual button on the control desk. Location 5 must contain the order pair 73A : 40B. The interrupt will then cause the old SCR to be placed in A and transfer to take place to B. The manual button controls the interrupt line through a mechanism which ensures that for some fixed time after depression of the button all subsequent depressions are ineffective.

5.2. Peripheral Interrupt

When a peripheral transfer control unit is supplied 8 extra interrupt lines are available. Each line transfers control to a fixed location. The locations are 8167 to 8174. In addition a 75 instruction may be used to set a mask of 8 digits. Interrupt only occurs if the corresponding mask digit is 1.

Normally the interrupt lines are connected so that each corresponds to a particular peripheral controller. On completion of a transfer the interrupt line comes up. In general the interrupt lines may be connected to any desired source.

5.3. Instant of Interrupt

Interrupt of any kind may only take place just before the first word of an order pair is to be obeyed. Thus a required interrupt may not occur because:-

(a) There is a dynamic stop in the second order of a pair.

(b) A 77 order is in progress.

(c) A 77 order is held up waiting for tagging or clearance of busy lines. If the busy line is up as a result of a failure then operation of a local reset key will lead to interrupt.

In order to cause the interrupt to take place when situation (a) prevails, a button is provided which decrements SCR by $\frac{1}{2}$. The control keys used to start a programme are so arranged that all interrupts are suppressed, otherwise an interruption might inadvertently take place at the start of a programme.