503
COMPUTER
MANUAL

VOL. 1

A

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MANUAL

INTRODUCTION

The Technical Manual of the 503 computer is intended to give members of an installation using the computer knowledge of the machine, the ways in which it can be used, and the engineering details.

The Manual is issued by Scientific Computing Division, Elliott Bros. (London) Ltd., Elstree Way, Borehamwood, Herts. The Manual consists of four volumes, as follows:–

VOLUME	SUBJECT
1	Functional Specification
2	Programming Information
3	Operating Information
4	Engineering Maintenance

All enquiries should be addressed to the 503 Librarian.

The Manual is divided into Volumes, Parts, Sections (of the manual) and Chapters. Individual chapters in some cases have sections and sub–sections, but the coding on the top of each page consists of at most 4 numbers separated by fullstops, sections and sub–sections of chapters being ignored. Each section of the Manual is an independent unit; the page numbering, therefore does not run on from section to section.

Each volume has its own contents list.

Circulation is based on the principle that each 503 installation will be provided with three copies of Volumes 1, 2 and 3 and one copy of Volume 4 to the engineer responsible for maintaining the installation.

Each Volume is divided into binders for convenience. There are about 150 pages to each binder and these are marked A, B, C etc. The indexing system does not take binders into account, as it is assumed that all binders of a given volume are always required and material is shifted to the next binder if the number of pages of the sections originally included becomes too large.

The normal charge for each binder is ten guineas, including updating.

UPDATING

The updating system provides for issue of additions and amendments. Each set of these is accompanied by a serially numbered amendment list to be filed for future reference. The amended sheets are marked "Issue 2" etc. and there is a bold line in the margin indicating the amended parts.

Elliott Bros. (London) Ltd., accept no responsibility for the loss of amendments in transit where this is due to incorrect or incomplete addressing instructions, including details of any special markings needed to ensure rapid Customs or Censorship clearance.

A check list is circulated to all manual holders giving details of updating, so that they can check whether their own copies are up to date; a form of request for any amendments needed is provided.

Replacement is on a page by page basis rather than by complete chapters or sections.

503 TECHNICAL MANUAL

VOLUME 1 503 FUNCTIONAL SPECIFICATION

CONTENTS LIST

PART 1 GENERAL DESCRIPTION

CONTENTS

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
A digital plotter
A high speed character printer

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 similar to the 803, so the existing 803 library of programs can be run on the 503 (see 2.2.2 (Appendix I) and 2.2.3.1) 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 (see 2.2.1.). To allow for closer control of program coding, an advanced Symbolic Assembly Program is provided (see 2.1.2.). Programs for the 503 may also be written in ALGOL, the modern international programming language (see 2.1.3.).

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

a) Central Processor. This contains the arithmetic and control logic and a core store. The store contains 8192 words and has a cycle time of 3.6 μ sec The arithmetic unit provides for fixed point and floating point operations. A display panel for engineering purposes is also provided.

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 paper tape punches. The control console houses the directly connected input/output control 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 appropriate logic boards, to form a larger installation:

1. Core backing store.
2. 503 Line printer

3. Card Reader/Punch.
4. 503 Magnetic Tape handlers (up to 8).
5. Elliott Card Reader.
6. Digital Incremental Plotter.
7. High Speed Character Printer.

In general these peripheral devices communicate with the computer through peripheral controllers. The autonomous transfer system provides for parallel working of the central processor and the peripheral devices.

As operation times depend on environmental conditions, the ones quoted throughout this Volume are approximate.

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.

(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 magnetic tape controller occupies half a cabinet module.

(3) The controller for the card reader/punch occupies one cabinet module.

(4) The 503 line printer is integral with a control pedestal which contains the controller and power supplies.

(5) The controller for the card reader is housed in the control station.

(6) The controller for the digital plotter is housed in the control station.

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 sufficient power for the basic computer. In addition it can supply power for four modules of backing store, the card reader and digital plotter controllers. The modules containing the backing store need not be combined with the central processor modules into a single cabinet suite. Where other peripheral devices are added a peripheral services cabinet, which may form a second cabinet suite (see 1.1.3a) is required. Larger systems require a second power cabinet module in which case a second cabinet suite is required.

The individual cabinet suites are connected by cable, and individual peripheral devices are connected via their controllers.

The length of cable permitted between a controller and its peripheral equipment depends on the peripheral equipment concerned. In the case of tape handlers the distance is 40 feet but in the case of Reader/Punch it is 20 feet.

All connections between cabinets containing peripheral controllers are made at the cabinet modules containing the power supplies. The various cabinets are connected so as to form a single string without branches. The order of units on this string must be:–

(1) Line printer or printers

1. 1. 2a
5. 1. 3

(2) Control console

(3) Central processor

(4) Other units in any order.

The cable connecting any two units may not exceed 25 feet in length, nor may the total length of all such cables exceed 125 feet.

Overall dimensions are approximately:–

Item	Height cm	Height in	Width cm	Width in	Depth cm	Depth in	Doors cm	Doors in
Cabinet Module	199	78¼	97	38	61	24	48	19
Two Module Cabinet Suite	199	78¼	190	75	61	24	48	19
Three Module Cabinet Suite	199	78¼	284	112	61	24	48	19
Four Module Cabinet Suite	199	78¼	378	149	61	24	48	19
Reader Console	89	35*	79	31	85	33¼		
Punch Console	89	35*	79	31	85	33¼		
Control Console	89	35*	126	50	85	33¼		
Card Reader	126	49¾	105	41¼	57	22½		
Card Reader/Punch	150	59	70	27½	120	47¼		
Line Printer Pedestal	140	55¼	147	58	77	30½		
Magnetic Tape Handler	196	77	58	23	61	24	48	19
Cold Air Unit	122	48	69	27	185	73		
Digital Plotter	25	9¾	46	18	38	14¾		
Display Panel	55	21¾	94	37⅛	13	5		
Display Panel with Stand	126	49¾	102	40¼	61	24		
Character Printer	116¾	46	86¼	34	66	26		

* to working surface

Floor Loading

For a table of weights of the units see 1.1.3a

Environmental Control

The central processor cabinet together with the peripheral controller cabinets, if any, are temperature controlled by a closed circuit system of ventilation. The air is cooled by a refrigeration unit, capable of extracting up to 10Kw of heat, and circulated via under–floor ducting to the computer cabinets. This air is then returned to the cold air unit, carrying the heat dissipated by the cabinets, where it is cooled once more and recirculated.

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 control console is illuminated.

The control station, and all peripheral handlers (but not controllers installed in cabinet modules) are cooled by open circuit ventilation with the room air. This air must be maintained within the limits.

Temperature	21°C ± 2°C
Relative Humidity	40% to 60%
Filtration	95% to 5 microns

If magnetic tape is not used then the filtration requirements may be relaxed to 10 microns.

For this purpose, air conditioning units are required. Normally several self–contained units are used. 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. (See 1.1.3a).

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). The central processor itself requires only a single phase, but the cold air unit, and certain peripheral equipment (e.g. Card reader/punch) requires 3–phases.

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 5 msec, i.e. one quarter cycle. If the supplies are still outside tolerance at the end of this period, a controlled shut–down will be automatically initiated.

The computer complies with the British Standards Specification Number 800, 1954 edition, for electrical radiation.

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. Auxiliary supplies are however still on until the mains isolaters are switched off. Peripheral devices are in general switched on and off locally.

The power module of the central processor has sufficient spare capacity to supply four modules of backing store, and also the control console and logic mounted therein.

Any system employing peripheral controllers requires additional power supplies for them. A single module contains the power supplies for the controllers mounted in the peripheral controller cabinet. The Line Printer controller is mounted in the printer pedestal, and has an individual power supply. The controllers for the Digital Plotter and the Elliott Card Reader are mounted in the control console and draw power from the central processor.

For a table of the power requirements and heat produced by the various elements of the 503 system see 1.1.3a.

1. 1. 2a

5. 1. 3

Controlled Shutdown

Power off, causes the following sequence of events to occur:

(1) Bit 37 of the interrupt location is present (see 1.2.5.), which causes the content of the usual registers to be stored.

(2) All peripheral devices are reset.

(3) The store is shut down in such a way that its content is undisturbed.

(4) The D.C. power supply is turned off except for certain auxiliary supplies.

Note that any record in process of being written on a peripheral will inevitably be corrupt. However, no other data will be corrupt.

Power on does not affect the store, and resets the computer. The inhibit flip–flop will be reset, so allowing interrupt, but the mask register will be clear.

In the case of an integral D.C. power failure controlled shut–down is impossible.

PART 1: GENERAL DESCRIPTION

SECTION 3: INSTALLATION INFORMATION

This section provides information that will be found helpful in the choice of computer room. The provision of false floors, power supplies and environmental control of dust, humidity and temperature is the responsibility of the customer. Elliott Brothers will be glad, at all times, to put customers in touch with organisations who can advise on and provide these facilities.

It is essential that preparatory work on the layout of the computer room be commenced some months before installation, and site surveys should be carried out by the suppliers of the false floor, environmental control and power supply equipments to assess the individual requirements and layout of each installation. Computer Maintenance Division of Elliott Brothers (London) Ltd. should be kept informed of the situation and they will be glad to advise on technical aspects of the computer requirements. The power supplies, floors and environmental control should be installed before delivery of the computer.

LAYOUT

The general layout of all possible items in a 503 system and the mains power requirements are shown in the drawings following.

The various items for any system should be installed in the positions shown, using standard cable-form lengths for interconnection purposes. (Exceptionally 6.08 metres (20 ft.) cable-forms can be used instead of the standard type).

The information in this section is given for general information. For a particular installation it is recommended that the customer should consult the Installation Section of our Maintenance Division.

A false floor is normally essential, for the installation of the computer, to carry interconnecting cables. A list of approved suppliers is available and the cost per foot laid (in Great Britain) varies between £1-£2 per square foot, depending on the supplier and the type of floor.

In laying out the computer room in the case of magnetic tape installations, facilities should be provided for storage of magnetic tape within the controlled environment of the computer room.

The cabinet suites are supported on the base floor by means of a rigid cradle to which they are bolted.

The approximate weights of the various cabinets are as follows:

Logic cabinet	470 kg. (1,045 lbs.)
Main store cabinet	410 kg. (895 lbs.)
Power cabinet	630 kg. (1,395 lbs.)
Backing store cabinet (16,384 words)	290 kg. (645 lbs.)
Backing store cabinet (32,768 words)	500 kg. (1,095 lbs.)
Additional backing store cabinets (32,768 words)	380 kg. (845 lbs.)
Peripheral services cabinet	560 kg. (1,245 lbs.)
Full controller cabinet	470 kg. (1,045 lbs.)
Half full controller cabinet	360 kg. (795 lbs.)
*Control console	390 kg. (850 lbs.)
*Punch console	110 kg. (250 lbs.)
*Reader console	110 kg. (250 lbs.)
*Magnetic tape deck	340 kg. (750 lbs.)
*Card reader/punch	430 kg. (950 lbs.)
*Elliott card reader	140 kg. (300 lbs.)
Digital plotter	15 kg. (33 lbs.)
*Digital plotter with stand	27 kg. (60 lbs.)
*Line printer	860 kg. (1,900 lbs.)
*Display panel	34 kg. (75 lbs.)
Display panel with stand	50 kg. (110 lbs.)
Interface matching unit	360 kg. (792 lbs.)
*Character printer	186 kg. (400 lbs.)
*803B film controller	114 kg. (250 lbs.)
*803B film handler	295 kg. (650 lbs.)

*Completely supported by the false floor in all cases.

The minimum recommended height (from the base floor) for the computer room is 2.75 metres (9 ft.). The overall loading averages less than 1,250 kg./m.^{2} (250 lbs./sq. ft.).

GENERAL SPECIFICATION FOR FALSE FLOOR

The false floor is to be fixed so that its surface is 0.15 metres (6.0 inches) above the base floor, with a minimum clearance of 0.08 metres (3 inches).

There should be no restrictions caused by false floor support members immediately below the cable entries of the cabinets, which would interfere with the bend of the cables.

The false floor should be capable of being adjusted to accommodate such level variations as are found on concrete screed floors, to normal building standard.

The false floor should be of modular construction, the panels being easily removable to give access to cables, etc., running beneath. The panels should be in sections to allow the cut-outs, shown in the drawings following, without impairing the load carrying qualities.

COOLING OF THE COMPUTER AND COMPUTER ROOM

The method of cooling makes use of the one air conditioning system to cool both the computer and the room. The room air is drawn through the computer by a series of fans to extract any heat dissipated.

ENVIRONMENTAL CONTROL OF COMPUTER ROOM

The ambient air in the computer room must be controlled to 21° $\pm$ 2°C.

In assessing the total cooling capacity required it is necessary to calculate the heat arising from:

(a) People in the room.

(b) Heat flow through the walls and ceiling.

(c) The computer equipment.

The various computer units requiring cooling are listed below with their dissipations:

	Units	*Maximum heat dissipation (kW)*
(a)	Central processor	6.4
(b)	Peripheral services cabinet serving one controller cabinet	0.8
(c)	Peripheral services cabinet serving more than one cabinet	1.0
(d)	Card reader/punch controller cabinet	0.7
(e)	Magnetic tape controller ($\frac{1}{2}$ cabinet)	0.3
(f)	Backing store 1st cabinet (32,768 words)	0.7
(g)	Each additional cabinet (32,768 words)	0.35
(h)	Control console	1.36
(j)	Magnetic tape handler	1.3
(k)	Line printer	1.5
(l)	Card reader/punch	2.0
(m)	Digital plotter	0.11
(n)	Elliott card reader	0.22
(o)	Interface matching unit	0.3
(p)	Character printer	0.45
(q)	803B film matching unit	0.26
(r)	803B film controller	0.24
(s)	803B film handler	0.48

REQUIREMENTS FOR AIR CONDITIONING

A typical installation, consisting of a, b, d, e, j × 2, f, h, n, as listed above would have a maximum dissipation of about 13 kW or 44,400 B.Th.U. per hour.

It is essential that a site survey is carried out by the suppliers of the air-conditioning equipment to assess the capacity needed for the particular installation and to advise on the correct placing of the Units.

FILTRATION REQUIREMENTS

Because of the importance of providing filtered air for the magnetic tape units, a source of such air should be placed within 3.05 metres (10 feet) of the tape units. The air drift should be away from the area of the tape units and under no circumstances should contaminated air from the line printer, card reader, tape punch, open doors or windows or any other dust source be allowed to flow in the direction of the magnetic tape units.

The degree of filtration required is:

90% down to 10 microns normally, and
90% down to 15 microns if magnetic tape is not used.

An anti-dust mat should be provided and smoking should be prohibited.

Special advice should be sought for exceptionally bad atmospheres.

Details of computer room maintenance are given in Appendix A.

HUMIDITY CONTROL

Humidity should be kept between 40 and 60 per cent relative humidity for installations with magnetic tape and punched cards; if these are not used, it is sufficient to limit to 60 per cent R.H. by normal de-humidifying.

For small installations with only one or a few air conditioners, the equipment should be within 3.05 metres (10 feet) of the relevant units.

RECOMMENDED AIR CONDITIONING SYSTEMS

There are two basic types of air conditioning systems.

1. A number of air-conditioning units disposed at various points ('window units'). This gives the following advantages:

   (a) No ducting is required to distribute the air conditioning capacity.

   (b) Failure of any one unit does not put the installation out of commission.

Note that humidity control must be provided for magnetic tape and card units by an additional unit as 'window units' do not add water to the atmosphere. With low ambient temperatures the relative humidity inside the computer room will be about 15% but the minimum requirement is 40% for such systems.

2. Central System. This system should be of modular construction so that there are a number of separate units and the breakdown of one does not affect the performance of the others.

The advantages of this system are:

   (a) Humidity control and high efficiency filtration may be provided as part of the unit.

   (b) The areas which are influenced by the unit can be governed, by the run of the ducting, to suit the installation (with 'window units' it may be necessary to specify more units than required to ensure that all parts of the room are conditioned.)

If magnetic tape is present, all units must be fitted with high efficiency filters. The circle of influence is 3.05 metres (10 ft.) for the magnetic tape units. One or more humidifiers with appropriate control may be required. These should be within 3.05 metres (10 ft.) of the magnetic tape and punched card equipment.

Computer Maintenance Division can advise on both these types of equipment.

503 POWER DISSIPATION AND MAINS CONSUMPTION

	Power consumption (kW)	*Mains input power (kV A)*
Logic cabinet	2.53	
Store cabinet	1.78	
Power cabinet	2.68	9.08
Control console	1.44	1.32
Basic system	8.43	10.4
Power cabinet (additional power when using peripheral controllers)	0.5	0.6
Core backing store		
(1st cabinet) (32,768 words)	1.04	
(2nd, 3rd and 4th cabinets) (32,768 words)	0.49 each	
(16,384 words only)	0.35	
Peripheral services cabinet	1.1	1.4
Card reader/punch controller cabinet	0.8	1.02
Magnetic tape controller (½ cabinet)	0.37	0.47
Elliott card reader	0.22	0.23
Digital plotter	0.11	0.11
Card reader/punch	2.0	2.5
Magnetic tape handler	1.3	1.6
Line printer	1.5	1.9
Interface matching unit	0.36	0.45
Character printer	0.57	0.72
803B film matching unit	0.33	0.41
803B film controller	0.24	0.27
803B film handler	0.48	0.53

These figures are only to be used for heat loading (power consumption) and mains capacity (mains power input). Note that they include the power required for the open circuit cooling fans.

PACKAGING TRANSPORT AND INSTALLATION

This section is intended as general information. The Installation Section of our Maintenance Division should be consulted for a particular installation.

On Site Work

Each site is surveyed prior to delivery when a standard form (Installation Questionnaire and Information Sheet) is completed with the aid of the customer. The Installation Section of our Maintenance Division will advise on the amount of on site work required before installation of the system can commence.

Transport

For U.K. and Europe, packing and delivery are normally undertaken by Elliott Brothers (London) Ltd. Outside Europe, transport is normally by sea to the nearest convenient dock and special arrangements are made for final delivery.

General

The customer is expected to supply the labour to assist in off-loading and moving the equipment into the computer room under Elliott's supervision (usually 6-8 men are required).

Special handling equipment is required for the installation, in addition to a crane or fork lift and recommendations on handling equipment can be obtained from Computer Maintenance Division. For installation in U.K. or Europe, where a company vehicle is normally used, special handling equipment is carried, but a local fork lift or crane is usually required.

The ideal place for the 503 computer is an easily approachable ground floor site. This should be borne in mind if a new site is being selected.

SUMMARY OF THE QUESTIONNAIRE AND INFORMATION SHEET

Specification of computer.
Customer's name and adress.
Site address and name of site representative.

THE COMPUTER ROOM

Which floor is it to be located on?
Dimensions of room?
Please provide a plan of the access route and the computer room.
Maximum permissible floor loading?
Type of false floor and effective height between the true and false floor?

CONSTRUCTION OF WALLS

The following must be stated for each wall: —

(a) Internal or external?
(b) Single or double structure?
(c) Type and thickness of material?
(d) Area of windows, single or double glazing?

Material and thickness of floor. Surface covering and its thickness?
No. of floors above the computer room?

POWER SUPPLIES

For a single phase and three phase supply quote: volts, frequency and current, also the tolerance on the voltage and frequency.
Is earth connection provided? If so, what resistance?
Any existing power points with number pins.

ACCESS

Width of corridors (if any).
Steps to be negotiated and ramps if available (etc.).
Lift (if any) and its particulars.
Hours during which the installation can be carried out.
Is a local labour force available, if so, how many men?
Is a mechanical hoist available? If so, lifting capacity, etc.
Is there a service road?
Are there any restrictions on waiting time? (details).
Is Police permission required before unloading can take place?
Any obstacles to be encountered between the vehicle and the building? (If so, details).
Are there any restrictions on the use of Elliott labour on site?
Any further information.

APPENDIX A

MAINTENANCE OF COMPUTER ROOMS

The cleaning and maintenance of the computer room must be adequately supervised to ensure that the following instructions are rigidly adhered to.

GENERAL

Mops and Dusters

Impregnated mops and dusters, and **no** other type, must be used in the computer room. These should be changed at frequent intervals.

Wood Block Flooring

The wood block flooring should be swept using either impregnated mops or dusters and should be maintained in a clean, polished but not slippery state.

Anti-Dust Mats

The Anti-dust mats, situated in the air locks and viewing rooms, should be changed regularly.

Refuse

Paper bins must be emptied outside the computer room. Waste paper sacks must **never** be used in the computer room.

Polishes

Care should be taken when using spirit polishes as these have a high content of white spirit and are therefore inflammable. Care should also be taken in the disposal of the rags, etc., used for polishing.

DAILY MAINTENANCE

Furniture

The furniture and any trolleys, etc., housed in the computer room, should be dusted daily with impregnated mops or dusters and should be kept clean and brightly polished. If the furniture is dirty it should be washed with a warm detergent solution before any polish is applied. The minimum amount of water should be used for this operation.

Dusting the Computer Cabinets

The control console, the computer cabinets and any peripheral devices should be dusted daily using impregnated dusters. Only the plain surfaces of the equipment should be dusted, i.e., the tops, sides and backs. Under **no** circumstances should cleaners dust the switch area of the control console or any peripheral device.

Inaccessible Areas

Skirtings, or areas where cabinets or other equipment stand and any other areas not accessible for sweeping should have any dust removed daily using a vacuum cleaner. When the floor is polished the polisher should be fitted with a suction device.

MONTHLY MAINTENANCE

The Walls

All the walls should be dusted down, using impregnated dusters or mops, at least once each month.

Glass.

The windows and the glass in the partitions and doors should be washed once every month.

The Ceiling

The ceiling should be dusted, monthly, by vacuum brushing, care being taken not to disturb any light fittings on the ceiling.

PART 2 BASIC 503 SYSTEM

CONTENTS

PART 2: BASIC 503 SYSTEM

SECTION 1: CENTRAL PROCESSOR

The Main Store

The main store contains 8192 words (addressed from 0 to 8191) 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 are fixed instructions by means of which a simple tape code may be read and are as follows:—

Previous Instruction	Address	F1	N1	B	F2	N2	Notes
ENTRY	0	26	4	:	06	0	Protected storage
3	1	22	4	/	16	3	
3	2	55	7	:	71	0	
	3	43	1	:	40	2	
	4						Used for count

These fixed instructions may be modified by depression of the MODE switch associated with tape reader 1, to read 5 channel tape (see 1.2.2.). 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 8165 are used for the Reserved Area Program (see 2.2.1.), 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 button 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 a 73 order or any order from groups 1, 2 or 3 (see pages 3, and 5) having a location in the reserved area as its address (see 1.3.1.) will cause an error interrupt. 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 1.3.1.).

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 core store boxes are kept at a temperature of $40 \pm 2{\cdot}5°C$ by a local control system. This system is connected directly to the main power input and is normally in operation even when the main computer is turned off at the control station. Provided the mains are switched on this obviates the need to wait for the store boxes to warm up when the main computer is turned on.

The Registers

There are seven 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 Register of 1 bit. (O.F.R.).

An Interrupt Memory Register of 11 bits.

An Interrupt Permit Register of 1 bit.

An Interrupt Mask Register of 8 bits.

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

Number Representation within the Computer

The fixed-point number representation within the computer is such that numbers are held in the range $-1 \leqslant x < +1$. The 'two's complement' notation is used for negative numbers i.e. they are represented by words beginning with 1, on the basis that the negative number $(-x)$ is represented by $(2-|x|)$ thus:

1 0101 1000 0000 0000 0000 0000 0000 0000 0000 00

this is $1+\frac{1}{4}+\frac{1}{16}+\frac{1}{32}=1\frac{11}{32}$

which is $(2-\frac{21}{32})$ so the word represents $-\frac{21}{32}$

The largest possible number is $1-2^{-38}$

The standard floating-point form is $x=a.2^b$ such that $-1 \leqslant a < -\frac{1}{2}$ or $a=0$ or $\frac{1}{2} \leqslant a < 1$ and $-256 \leqslant b \leqslant 255$. The mantissa (a) of the number is represented by bits 10 to 39 inclusive of the word and the exponent (b) is represented by bits 1 to 9 inclusive (see below).

Floating point round-off is obtained by forcing the last of the 30 digits, representing the mantissa, to be 1 in all cases except where the number is exactly representable in 30 bits of signed binary. This means that a floating point number can be represented to an accuracy of 8 significant figures.

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. e.g. 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 following tables give the basic instruction code of the 503. For a fuller description of the functions see 2.1.1.1.

For the instructions for the peripheral devices see 1.4.

Unless otherwise stated the N digits of an instruction specify the address of a location.

The contents of the accumulator and specified location are denoted by a and n. a′ and n′ indicate these contents after the function has been performed. AR is the auxiliary register. 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 with an asterisk.

The approximate operation times are given in μ secs. The actual times of executing any instruction vary with the environmental conditions but will normally lie within $\pm 10\%$ of the figures quoted. If the environmental conditions of the computer exceed those recommended, larger variations in speed must be expected.

$\left[\frac{N+1}{2}\right]$ is the integral part of $\frac{N+1}{2}$ i.e. $\frac{N}{2}$ for n even and $\frac{N+1}{2}$ for n odd.

	Function	*Operation*	*Result* a′	*Result* n′	*Time* (*in* μ *sec*)
Group 0	00	Do nothing	a	n	7·2
	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	0	n	
	07	Negate and add	n − a	n	
Group 1	10	Exchange	n	a	8·4
	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	0	a	
	17	Write, negate and add	n − a	a	
Group 2	20	Write	a	a	8·4
	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	0	
	27	Subtract from store	a	n − a	
Group 3	30	Replace	n	n	8·7
	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	0	
	37	Replace and subtract from store	n	n − a	
Group 4	40	44 Transfer control unconditionally			4·5
	41	45 Transfer control if C(A) is negative			
	42	46 Transfer control if C(A) is zero			
	43	47 Transfer control if overflow indicator is set and clear it (fixed point)			
	(40 to 43	Transfer to the first instruction of a pair and			
	44 to 47	Transfer to the second instruction)			

Group 5

The instructions in group 5 require a fuller explanation, and are as follows:—

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. The digits of the double-length number are shifted N places to the right, the N right-hand digits being lost. If the original number is positive or zero, N zeros are inserted at the left-hand end: if it is negative N ones are inserted. Hence the sign of the number is maintained. The effect is division by 2^{N}.	$6{\cdot}6+1{\cdot}2\left[\frac{N+1}{2}\right]$
51 N	Right shift a N times. Clear A.R. The digits in the accumulator are shifted N places to the right, the N right-hand digits being lost, and N zeros are inserted at the left. The A.R. is not used in the process and is cleared as a separate operation.	$6{\cdot}6+\ {\cdot}9\left[\frac{N+1}{2}\right]$
52 N	Multiply a by n giving double-length product. The existing C(A) is multiplied by C(N). C(A) and the existing content of the A.R. (which is *not* used in the function) are deleted and replaced by the double-length product. Since the multiplier and the multiplicand are both of single length the result is always exact.	34·8 to 46·8 (average 37·2)
53 N	Multiply a by n giving single-length rounded product. Clear A.R. The existing C(A) is multiplied by C(N). C(A) is deleted and the double-length product is formed, the quantity 2^{-39} is artificially added and the left-hand 39 digits of the result are placed in the Acc. The A.R., whose original content is not used in the function, is cleared.	36·3 to 48·3 (average 38·7)
54 N	Double, [C(A)+C(AR)], N times. The digits of the double-length number are moved N places to the left. N zeros are inserted at the right-hand end, and the N left-hand digits are lost. Unless overflow takes place the effect is multiplication by 2^{N}. If N≥38, the A.R. is clear after this function.	$6{\cdot}6+1{\cdot}2\left[\frac{N+1}{2}\right]$
55 N	Clear A.R. Double C(A) N times. The digits in the acc. are moved N places to the left, N zeros are inserted at the right-hand end, and the N left-hand digits are lost. Unless overflow takes place the effect is multiplication by 2^{N}. The A.R. has no part in this process and is cleared as a separate operation.	$6{\cdot}6+\ {\cdot}9\left[\frac{N+1}{2}\right]$
56 N	Divide double-length dividend, single length quotient. Clear A.R. The function consists of the division of a double-length number by C(N). C(A) is deleted and replaced by the single-length, unrounded quotient. The A.R. is cleared by the process.	68·7
57 0	Read A.R. The existing C(A) is deleted, and replaced by a word comprising a zero in the sign digit position and a copy of the 38 digits of the A.R. in the remaining positions. The A.R. is not affected.	4·8

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.	13·2 to 30·3 (average 18)
	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.	31·5 to 41·1 (average 33·8)
	64	N	Divide a by n, clear A.R.	60·9 to 61·8
	65	4096	Standardise, i.e. convert the 39-bit integer in Acc. to standard floating-point form, clear A.R. e.g. if C(A)=5×2^{-38}, the result would be $\frac{5}{8}\times2^{3}$ and the time 7·8+·9 (18) μ secs.	$7\cdot8+\cdot9\left[\frac{n+1}{2}\right]$ (where n is the number of shifts required).
*	66	N	Load registers and transfer control. This instruction is used to exit from an interrupt program (see 1.2.4.).	19·5
*	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.	7·2

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 1.4.). The 73 instruction is used in entering subroutines.

	Function		*Operation*	*Time (in μ sec)*
	70		Read from the Word Generator to the Accumulator.	18
*	71	N	Read one character from a specified input device to the Accumulator.	18‡
*	72	N	Transfer a single word from the Accumulator to a specified peripheral device.	18·9‡
	73	N	Write the address of this instruction, i.e. store S.C.R.	7·8
*	74	N	Output one character on a specified output device.	18·9‡
*	75	N	Transfer a single word from a specified peripheral device to the Accumulator.	18‡
*	76	N	Output N to peripheral controllers.	22·2†
			Input a number of control bits from a specified peripheral device to the Accumulator. Prepare for autonomous transfer.	
*	77	N	Execute the operation specified by the last 76 instruction. If a transfer was specified use locations N onwards in the store (see 1.3.1).	
			Transfer M words—set up tag	38·7+3·6M
			—transfer each word.	9·6

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

†No standard device is busy to 76 order.

Notes

(a) The computer time required to perform an interrupt is 27·9 μ secs.

(b) If either C(Acc) or C(N) is zero when any of the following orders are obeyed then in most cases the operation takes less than the normal time.

Function	C(Acc)	C(N)	Result	Fixed Point Overflow Set	Time in μ secs.
52, 53	x	0	0	No	8·7
52, 53	0	x	0	No	8·7
†56	x	0	0	Yes	8·7
56	0	0	0	Yes	8·7
56	0	+x	0	No	68·7
56	0	-x	-2^{-38}	No	68·7
63	x	0	0	No	8·7
63	0	x	0	No	8·7
64	x	0	error interrupt	No	8·7+error interrupt
64	0	x	0	No	8·7

† The dividend in a 56 instruction is a double length, held in both the Acc. and the A.R.

(c) Any shift order with zero address takes 5·4 μ secs.

B-modification

A B-line does not increase the operational time if the instruction preceding the B-line is in groups 0–3. If the instruction is in groups 4 to 7 then its time is increased by 3·6 μ secs. as a result of the presence of the B-line.

If the B-line is present between the two instructions of a pair then the 19 least significant bits of the content of the location specified in the address part of the first instruction are 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-line is associated with the first instruction of the pair and is sensed as this instruction is being obeyed. When the B-line is present a marker MOD is set. When this marker MOD is set, the contents of the address of the first instruction are stored in a special register B as the first instruction is completed. MOD is then checked before any further instruction is obeyed and if it is set, the contents of the B register are added to the second instruction of the pair and MOD is cleared. If the first instruction of a pair is a 77 instruction then the presence of a B-line between the two instructions does not cause modification.

A B-line can only appear between two instructions held in the same word. The instruction 67 N can be placed anywhere and can therefore be used to modify either the first or second instruction in a word. The action of the instruction 67 N is to set MOD and load the B register so that its effect is similar to 00 N followed by a B-line.

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

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

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

(3) The instruction 67 N followed by a B-line is obeyed as if only one of these were present (see below).

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

The following table shows comparisons of times taken for B-line and 67 instructions.

Instruction	*Time Taken*
67 N:20 5	15·6 μ secs
00 N/20 5	15·6 μ secs
67 N/20 5	19·2 μ secs

8-channel Paper Tape

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 below 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 bits with binary values ranging from 0 to 127.

8-channel Paper Tape Code

00000.000	0	R	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		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	H	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		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	10	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	V	10111.110	94	~	11101.110	126	U
00111.111	31	.	01101.111	63		10101.111	95	%	11101.111	127	E

For notes see below.

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

(2) Abbreviations:

B	Backspace (optional)
E	Erase
F	Flexowriter Programmatic Codes (optional) (see 1.5.1.).
H	Stop Code (Halt)
L	New Line
P	Paper Throw
R	Run out
S	Space
T	Tabulate
U	Underline
V	Vertical Bar

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

(4) Code 126 (underline) and code 62 (vertical bar) are non-escaping, 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 8, 7, 6, 5, 4, 3, 2, 1 respectively; with the sprocket hole appearing between channels 3 and 4. The parity channel is channel 5. When a code is input to the computer the number of 'ones' is checked for even parity, the parity bit is then removed and the remaining 7-bits are mixed with the Accumulator. Similarly, 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.

(6) The codes for Paper Throw, Backspace, Halt and Flexowriter Programmatic Codes do not exist on the control typewriter.

5-channel Paper Tape

A 5 channel tape which is $\frac{11}{16}$" wide can also be used on the 503. This is used in conjunction with the 5-channel paper tape code (as used on the 803).

Channels are identified by serial numbers 1 to 5, and a sprocket hole track is placed between channels 3 and 4.

Binary values allocated to the channels are:—

channel	5	4	.	3	2	1
binary	16	8	.	4	2	1

The table of codes shown on the next page includes the 5-channel code together with its decimal values and its representation on a Teleprinter.

To enable a Teleprinter to distinguish between the two meanings of a character, two special characters are provided. These are 'letter shift' and 'figure shift' (ls and fs). One of these precedes each group of other characters on a tape, to indicate whether they are to be read as letters or as figures and symbols.

The character 'line feed' (lf) is interpreted by a Teleprinter as an instruction to print the next letters, figures or symbols on a new line, while 'carriage return' (cr) causes printing to start or restart at the left hand margin. 'Space' (sp) characters are inserted on a tape whenever required, to cause the Teleprinter to space out the letters, figures and symbols. 'Blank' (bl) has no meaning, and the Teleprinter will ignore it; several inches of blanks are punched at each end of the tape to simplify handling.

5-Channel Paper Tape Code

Binary Code and Tape Representation	*Decimal Value*	*Character Indicated*	
		Figure Shift	*Letter Shift*
00.000	0	Blank	
00.001	1	1	A
00.010	2	2	B
00.011	3	*	C
00.100	4	4	D
00.101	5	$ or &	E
00.110	6	=	F
00.111	7	7	G
01.000	8	8	H
01.001	9	'	I
01.010	10	,	J
01.011	11	+	K
01.100	12	:	L
01.101	13	–	M
01.110	14	.	N
01.111	15	%	O
10.000	16	0	P
10.001	17	(	Q
10.010	18	)	R
10.011	19	3	S
10.100	20	?	T
10.101	21	5	U
10.110	22	6	V
10.111	23	/	W
11.000	24	@	X
11.001	25	9	Y
11.010	26	£	Z
11.011	27	Figure Shift	
11.100	28	Space	
11.101	29	Carriage Return	
11.110	30	Line Feed	
11.111	31	Letter Shift	

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 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 1,000 characters/second.

(b) Control buttons and lamps for the readers.

(c) Two paper tape dispensers and two reception bins for use with the readers.

(d) A paper tape winder.

(e) Drawers for the storage of reels of paper tape and for programming manuals, etc.

Included in the punch console are:—

(a) Two paper tape punches, operating at a nominal 100 characters/second, in sound proof boxes.

(b) Control buttons and lamps for the punches.

(c) Two paper tape reception bins.

(d) A paper tape winder.

(e) Drawers for the storage of reels of paper tape and/or programming manuals, etc.

(f) An 8-hole Uni-Punch.

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.

Tape Readers

The Elliott tape reader has a nominal speed of 1,000 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 referred to as readers 1 and 2. The instruction code is (see also 2.1.1.):—

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 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. 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 disclosed 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. Operation of this button causes the READER lamp, which is housed in the LOAD button, to be lit, since the passage of tape without corresponding 71 orders is treated as an error. The buffer is accordingly placed in the busy state.

(3) *Brake release bar.* This is depressed in order to place tape under the reader. Carrying this out puts the buffer into the busy state, and the READER lamp is lit. The READER lamp is housed in the LOAD button. Pressing this button causes the character currently to the right of 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.
A check is made to ensure that not more than one leading edge of a sprocket hole is sensed since the last read instruction for this buffer. Failure causes the READER lamp to be lit.
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 button which when depressed exchanges the roles of reader 1 and reader 2. A lamp housed within the button is lit when the readers are in the exchanged state. The LOAD and MODE buttons and lamps are always associated with the same physical readers.

(2) MANUAL. This is a push-push button and contains a lamp which is lit whilst the button 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 button marked MODE. This is a push-push button and contains a lamp which is lit whilst the button 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 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 the 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 and the bits in positions 6, 7 and 8 will be zero.

The MODE button 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. The options include input of up to 8 bits arranged in any order of significance with even, odd or no parity check. A single board is substituted for the standard one in respect of each reader, and may be designed to provide any two modes of operation for that reader. The Elliott reader may be set to handle 5, 6, 7 or 8 hole tape by sliding the brake release bar.

The initial instructions normally deal with 8 channel tape but the depression of the MODE button 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 button which causes the initial instructions to deal with 5 channel tape.

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

Tape Punches

The paper tape punch has a nominal speed of 100 characters per second. Each punch on the operating station is connected to two one-character buffers situated within the operating station.

The two punches operate independently and are referred to as punch 1 and punch 2. The instruction code is (see also 2.1.1.):—

74 N Output a set of bits of the address (N) to a tape punch

For $0 \leqslant N \leqslant 2047$ output is via punch 1

For $2048 \leqslant N \leqslant 4095$ output is via punch 2.

The first 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 first 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. As soon as the punch is ready the character is transferred into the second buffer together with a parity bit, if required, and the first buffer is placed in the ready state. The character in the second buffer controls the setting of the punch magnets, and is punched onto the tape.

After the first buffer has been placed in the ready state, at least 9 milliseconds must elapse before the punch will again be ready to accept a new character. Consequently the punch will continue at full speed as long as an appropriate output order is given within this interval.

The body of the 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. If either punch has been switched off,

the manual condition must be set before the punch is switched on. If output instructions to the punch switched off have occurred while it was off, one character can be lost, if the manual condition is set while switching on; but if the manual condition for the punches is not set, several characters may be lost as the punch motor speeds up. The punch motors are switched off by the control electronics when the punch is idle. The motors are switched off when no character has been received for approximately 30 seconds. If a new character is now output, it is delayed for about 1 second to allow the punch to reach its operating speed again.

(2) *Tape feed lever.* Depression of this lever causes blank tape to be run out so long as the punch motor is running. This lever is not normally used.

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 and MODE buttons and lamps are always associated with the same physical punches.

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

(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 button marked MODE. This is a push-push button containing 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 the one normally used for standard 8-channel tape. When a 74 instruction is obeyed, bits 1 to 8 of its address are sent to the punch control unit. In the normal mode, bits 1 to 7 are placed in the buffer and an even parity check bit generated. 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 options provided by the MODE switch may be varied, at extra cost, for the punches in the same way as for the readers, by the provision of a single special board in place of a standard one for each punch. The punch is immediately adjustable to deal with 5, 6, 7 or 8 channel tape.

Each punch has associated with it a push button marked RUNOUT. Pressure on the button causes the punch to run out blank tape. 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 state. To remove the busy state after reloading or otherwise dealing with the tape, the punch must be switched from manual to non-manual.

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 the diagram on page 10.

The output writer is an 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 paper used in the output writer cannot be wider than $10\frac{7}{8}$ inches ($27\frac{1}{2}$ cms.) giving a maximum of 124 characters across a page excluding margins.

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.

Either of these instructions will be held up if the output writer is busy. The TYPEHOLD lamp on the main control panel will be illuminated during this holdup.

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 ▲ to be typed. An indicator lamp on the keyboard, marked DEMAND, is lit when a 71 4096 instruction is held up on a busy signal from the one character buffer associated with the input typewriter. Depression of any key causes the buffer to be loaded and the DEMAND lamp to be extinguished. A 71 4096 instruction may also be held up if the output writer is busy. In this case a character cannot be accepted from the input keyboard until the output writer ceases to be busy, although the DEMAND lamp will be lit.

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.

The MESSAGE button described under 'Manual Control' is also mounted on the input keyboard. It contains a lamp which is lit when the interrupt inhibit flip-flop is set. (See Manual Control and 1.2.3.).

Busy, Interrupt and Manual

In order to allow time shared operation of the paper tape equipment two interrupt channels are provided.

Tape Readers

The Tape Readers use Normal Interrupt Channel 2 which is associated with bit 7 of the permit register and location 8172 (see 1.2.3.). Interrupt occurs on this channel whenever either reader becomes available for use i.e. ceases to be busy. Thus while the reader or control console MANUAL button is depressed, a parity error exists or a reader is unloaded, no interrupt will occur and the busy bit remains set to 1. The tape reader will continue to run at full speed if an input order is received within 80 μsecs. of the interrupt occurring. The MANUAL button has the effect of making the readers appear to be busy and consequently causes interrupt on release provided the readers are correctly loaded.

Tape Punches

The Tape Punches use Normal Interrupt Channel 3. which is associated with bit 6 of the permit register and location 8171 (see 1.2.3.). Interrupt occurs on this channel whenever either punch or the digital plotter becomes available for use i.e. ceases to be busy. Thus while the punch or control console MANUAL button is depressed, RUNOUT contact is closed, no interrupt will occur and the busy bit remains set to 1. Again the MANUAL button causes interrupt on release, provided the device is not being held busy by other causes.

The Instruction 75 7168 causes a control word to be placed in the accumulator. The significance of the bits of this word is as follows:—

bit 39 (sign bit)	is 1 when reader 1 busy
bit 38	is 1 when reader 2 busy
bit 37	is 1 when punch 1 busy
bit 36	is 1 when punch 2 busy
bit 35	is 1 when output writer busy
bit 34	is 1 when digital plotter busy

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.

	Name	Colour	Type	If with lamp	Location
Reader Console	Reader 1 ON/OFF		Toggle		Reader body
	Reader 1 RUNOUT		Push		Reader body
	Reader 1 BRAKE RELEASE		Bar		Reader body
	Reader 1 LOAD	Red	Push	Lamp	Reader control panel
	Reader 1 MODE	Green	Push-push	Lamp	Reader control panel
	Reader 2 ON/OFF		Toggle		Reader body
	Reader 2 RUNOUT		Push		Reader body
	Reader 2 BRAKE RELEASE		Bar		Reader body
	Reader 2 LOAD	Red	Push	Lamp	Reader control panel
	Reader 2 MODE	Green	Push-push	Lamp	Reader control panel
	Reader SELECT	Amber	Push-push	Lamp	Reader control panel
	Readers MANUAL	Red	Push-push	Lamp	Reader control panel
	Readers HOLDUP	Amber	—	Lamp	Reader control panel
Punch Console	Punch 1 ON/OFF		Toggle		Punch body
	Punch 1 FEED		Lever		Punch body
	Punch 1 RUNOUT	Red	Push	Lamp	Punch control panel
	Punch 1 MODE	Green	Push-push	Lamp	Punch control panel
	Punch 2 ON/OFF		Toggle		Punch body
	Punch 2 FEED		Lever		Punch body
	Punch 2 RUNOUT	Red	Push	Lamp	Punch control panel
	Punch 2 MODE	Green	Push-push	Lamp	Punch control panel
	Punches SELECT	Amber	Push-push	Lamp	Punch control panel
	Punches MANUAL	Red	Push-push	Lamp	Punch control panel
	Punches HOLDUP	Amber	—	Lamp	Punch control panel
Input Keyboard	Typewriter LOWER CASE	Green	—	Lamp	Input keyboard
	Typewriter DEMAND	Amber	—	Lamp	Input keyboard
	MESSAGE	Red	Push	Lamp	Input keyboard

Control Console

The main control panel is an array of push buttons and lamps, arranged mainly in two rows.

The top row comprises, from left to right:—

(a) OFF. (Push+Lamp). Red.
This switches the whole system off.

(b) ON. (Push+Lamp). Green.
This switches power on to the computer and peripheral controllers. The lamp is lit when the computer is on.

(c) BUSY. (Lamp). Amber.
This is lit when the computer is waiting for a busy signal to go down.

(d) INITIAL INSTRUCTIONS. (Push). Grey.
This initiates a control interrupt to the initial instructions.

(e) NO PROTN. (Push-push+Lamp) Red.
This switches the reserved area protection on or off. The lamp is lit when the reserved area is unprotected.

(f) CLEAR. (Push). Grey.
This has effect only when the reserved area is unprotected. Pressure on the button then causes the store to be cleared and also has the same effect as depressing RESET. When the button is released the computer stops in an interruptable wait. The lamp in the RESET button will be lit at this time.

The lower row comprises, from left to right:—

(g) AIR CONDITION. (Lamp). Red.
This is lit if the computer shuts down due to an overheat condition. If a cold air unit is fitted the lamp will also light when the mains are first switched on, when the OFF button is depressed and if the cold air unit fails.

(h) ERROR. (Lamp). Red.
This is lit when an error condition is detected, and extinguished when error interrupt occurs. It is also lit when the machine is on margins, or the parity key is in the override or stop position.

(i) TAG. (Lamp). Amber.
This is lit when the computer is waiting for a tag bit to disappear.

(j) TYPEHOLD. (Lamp). Amber.
This is lit when the computer is waiting for the typewriter busy to clear.

(k) MANUAL. (Push-push+Lamp). Red.
When depressed this renders all paper tape equipment, the control typewriter and the digital plotter busy.

(l) RESET. (Push+Lamp). Green.

(1) clears the overflow indicator.

(2) resets all error states.

(3) clears the interrupt permit register i.e. prevents any normal interrupt.

(4) clears the interrupt memory register.

(5) resets the interrupt inhibit flip-flop i.e. allows manual interrupt.

(6) clears all tags and sets correct parity in all store locations.

(7) stops on an interruptable wait.

The lamp is lit during the interruptable wait, i.e. from the time the RESET or CLEAR button is operated until the next interrupt occurs.

There is one additional lamp placed between the two rows. This is the TRANSFER lamp. The BUSY, TRANSFER and TAG lamps form a vertical column.

(m) TRANSFER. (Lamp). Green.
This is lit whenever one or more autonomous data transfers are in progress.

To the left of this array of buttons and lamps is the 39-key word generator.

To the right of the main control panel is the peripheral control panel. The DIGITAL PLOTTER button is situated adjacent to the CLEAR button and the BACKING STORE lamp is adjacent to the RESET button, below the PLOTTER lamp.

(n) DIGITAL PLOTTER MANUAL. (Push-push). Red.
When depressed this renders the digital plotter busy.

(o) BACKING STORE PARITY. (Lamp). Red.
This is lit whenever there is a backing store parity error.

These two are fitted whether or not the devices are present.

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 2.2.1.).

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.	Causes the computer to read a specially prepared, relocatable binary tape.
IN; N.	Reads a special binary tape whose position in the store is optional. The integer N specified where the program is to be placed.
NAME.	Transfers control to the program called NAME.
N.	Transfers to the first instruction in location N.
N; S.	Transfers to the second instruction in location N.
CONT.	Continues a program from the point at which it was left to obey a Manual Interrupt.
CONT; ERRINT.	Continues a program from the point at which it was left to obey an Error Interrupt.
LIST.	Prints out in 'chronological' order the names of the programs in the store beginning with the last to be stored. If a checkable program is incorrectly stored its name is followed by an asterisk. The size of the available store is printed after each list.
CANCEL.	Removes the last program stored.
CANCEL; NAME.	Beginning with the last program stored, removes all programs as far back as and including the named program by changing the RAP pointers.
RESET.	Clears the main store and resets the RAP pointers.
FREE STORE.	Prints the size of the available store on the output writer.

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.
*	If this appears after a listed program name then that program is corrupt.

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.
UNCHEK	The program is not sum-checkable.
END	The running of a program has been successfully completed and control has returned to the RAP.

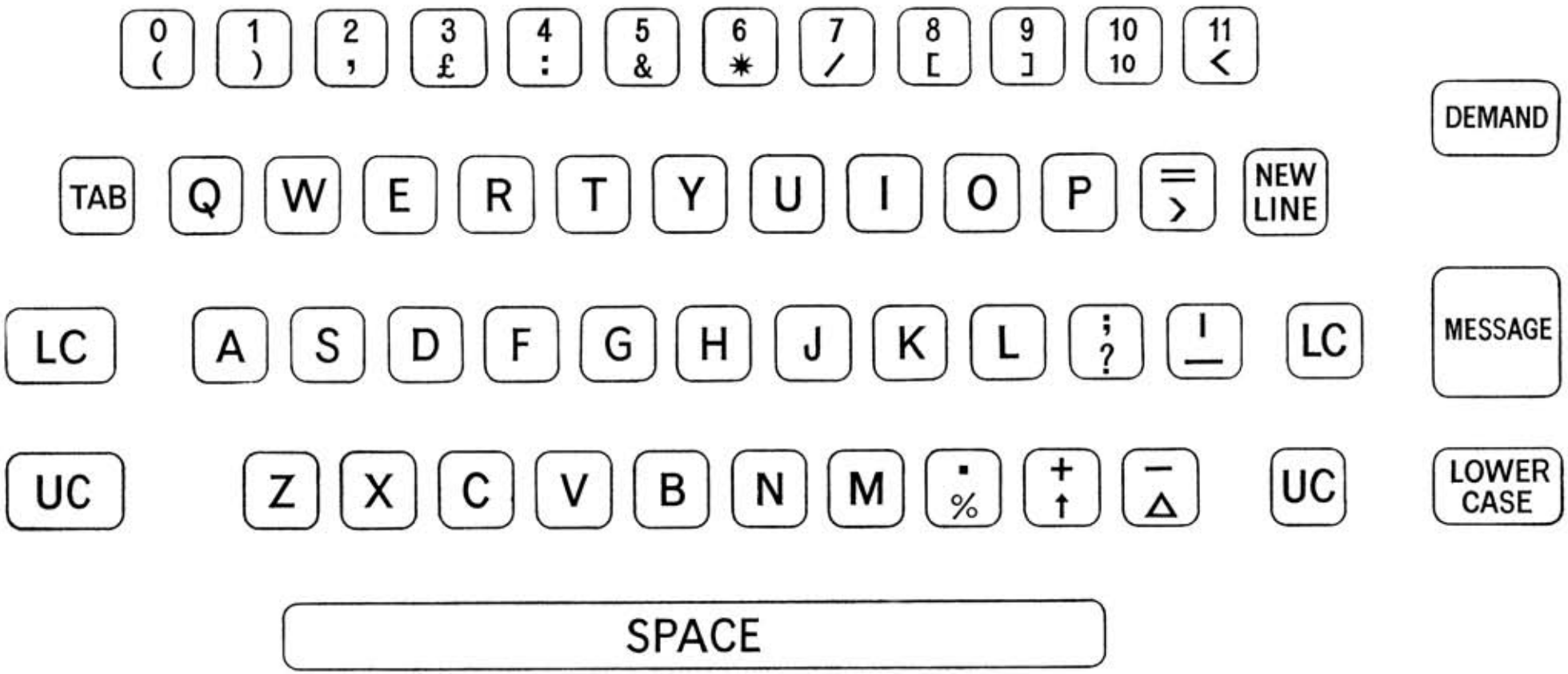
When the machine detects an error condition an error interrupt takes place. Control is immediately transferred to the basic Error Interrupt routine held in the RAP and ERRINT will be output followed by an indication of which error digits are present.

The significance of the ERRINT message is as follows:—

ERRINT 1	bit 38 of the error location is present, i.e. Floating point overflow.
ERRINT 2	bit 37 of the error location is set when the power is turned off, and present when power is turned on.
ERRINT 3	bit 36 of the error location is present, i.e. parity error in the main store.
ERRINT 4	bit 35 of the error location is present, i.e. attempted use of unavailable peripheral device.
ERRINT 5	bit 34 of the error location is present, i.e. impermissible reference to the reserved area.

(For a more explicit explanation of the error bits see 1.2.5. and 2.2.1.).

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.



KEYBOARD OF CONTROL TYPEWRITER

PART 2 BASIC 503 SYSTEM

SECTION 3 INTERRUPT FACILITIES

GENERAL INTRODUCTION

There are two types of interrupt which take place on the 503. These are known as Control Interrupts and Normal Interrupts (see 1.2.4.).

The three Control Interrupts are:-

(a) Error Interrupt

(b) Initial Instructions Interrupt

(c) Manual Interrupt

and they occur either due to machine or programming errors or due to the action of the operator.

Normal Interrupts only occur in response to a signal from a device which has been busy and is now free to perform a further operation. e.g. When a line printer has printed a line it indicates that it is now free to print another line if required.

There are three registers associated with the interrupt system:-

An Interrupt Memory Register of 11 bits

An Interrupt Permit Register of 1 bit

An Interrupt Mask Register of 8 bits

Three bits of the Interrupt Memory Register are associated with Control Interrupts, and these are set to 1 whenever a Control Interrupt is requested. The other eight bits are associated with Normal Interrupts and are set to 1 whenever a peripheral device indicates that it is free to accept further instructions. This register cannot be set by program.

The Interrupt Mask Register is set by program to indicate which normal interrupts are to be allowed and in what order of priority they should be executed. When a bit of the register is set to one, an interrupt request can be accepted, subject to the state of the Interrupt Permit Register. Diagrams showing how the registers function and are set by program appear at the end of 1.2.4.

When the Interrupt Permit Register is set to zero no interrupts other than I.I. or Error are accepted although the requests are registered in the Interrupt Memory Register.

Thus for an actual interrupt to take place there must be a 1 bit in the Interrupt Memory Register, the Mask Register and the Permit Register simultaneously.

The Interrupt Permit Register can be set by program and is automatically set to zero when an interruption takes place, except in the case of an Initial Instructions Interrupt.

Up to eleven separate interrupt channels are available. Three of these are known as Control Interrupt channels and are provided in the basic computer. The remaining eight are known as Normal Interrupt channels (see 1.2.4.). Of these eight channels those of second and third highest priority are provided as standard (see 1.2.2.), that of fourth highest priority is provided with any peripheral equipment purchased and the other five are available as optional extras.

With the exception of the Initial Instructions Interrupt, each channel has associated with it a single location in the reserved area of the store containing information relating to the course to be taken when the interrupt occurs. This is called the Interrupt Location and must contain:-

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

(b) In digit positions 21 to 33 the address (J) 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 of the pair. Thus digit positions 20 to 33 contain the value to which the 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 1.2.1). Locations 8174 and 8175 are associated with two of the three control interrupts, Manual Interrupt and Error Interrupt. The remainder are associated with normal interrupts. The higher address is that of the interrupt with the higher priority (see 1.2.4.).

An interrupt may only occur when an instruction is about to be obeyed. This means that interrupt may take place during a hold-up caused by a busy peripheral device, since when an instruction refers to a busy peripheral device the S.C.R. is decreased and the instruction repeated from the beginning. An interrupt cannot take place while tagging is in process.

The system is so arranged that interrupt may take place when a B-modified instruction is about to be obeyed (see 1.2.4.).

CONTROL INTERRUPTS

The control interrupts are:-

(a) ERROR INTERRUPT

This takes place automatically when certain error conditions are detected (see 1.2.5.). It takes place even if the permit bit is zero (otherwise the permit bit is cleared). Its priority is highest and its interrupt location is 8175.

(b) INITIAL INSTRUCTION INTERRUPT

This takes place when the ' INITIAL INSTRUCTIONS' button, on the control console, is depressed. It takes place even if the permit bit is zero, but does not clear the permit bit. Initial instructions interrupt is not associated with an interrupt location in the reserved area. Instead it uses location 0 as an interrupt location. (For this purpose the content of location 0

may be regarded as zero). As a result of the special properties of locations 0 to 3, pressure on the 'INITIAL INSTRUCTIONS' button results in a transfer of control to location 0 without any actual storage of registers.

(c) MANUAL INTERRUPT

This takes place when the 'MESSAGE' button, on the control console, is depressed. It cannot occur if the permit bit is clear (when it does occur the permit bit is cleared as usual). Its priority is third, and its interrupt location is 8174.

SUMMARY TABLE

The following table gives details of the eleven interrupt channels, in sequence of decreasing priority.

Interrupt	Interrupt Locations	Mask bit	Controlled by permit bit	Clears permit bit
Error	8175	none	no	yes
Initital Instructions	0	none	no	no
Manual	8174	none	yes	yes
Normal 1	8173	8		
Normal 2(a)	8172	7		
Normal 3(b)	8171	6		
Normal 4(c)	8170	5		
Normal 5	8169	4	yes	yes
Normal 6	8168	3		
Normal 7	8167	2		
Normal 8	8166	1		

(a) allocated to the paper tape readers

(b) allocated to the paper tape punches and the digital plotter

(c) allocated to peripheral equipment.

Channel 2 and 3 are supplied as standard on basic machines. In addition, Channel 4 is supplied with any peripheral devices capable of performing on A.D.T.

PART 2 BASIC 503 SYSTEM

SECTION 4 OPERATION OF INTERRUPTS

The eight channels which are provided by the interrupt control unit are known as Normal interrupt channels (see 1. 2. 2. and 1. 2. 3.). These Normal interrupt channels may be connected to external devices for on-line applications (see 1. 4. 5.) or alternatively to peripheral devices to facilitate time-shared programming (see 1. 3. 1.). Lines 2, 3 and 4 are provided to the paper tape readers, the paper tape punches and the digital plotter, and the peripheral equipment respectively.

An interrupt may occur only when an instruction is about to be obeyed. This means that interrupt may take place during a hold-up caused by a busy peripheral device, (see 1. 3. 1. The 77 Instruction), since when an instruction refers to a busy device the S. C. R. is decreased and the instruction repeated from the beginning. 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, other than Initial Instructions and Error, are inhibited by clearing the permit bit described below.

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. (see 1. 2. 3.).

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

e) The content of the A.R. is stored in digit positions 1 to 38 of location L + 2. Digit 139 of this location is made zero.

f) The content of the 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 the OFR register is stored in position 39 of location L + 3, and the five bits used for error indication are stored in positions 34 to 38. Digit 39 is made 1 if OFR is set, and the error indication is the presence of a 1 in one or more of the positions 34 to 38 (see 1. 2. 5.).

g) The S.C.R. is set to the value contained in digit positions 20 to 33 of the interrupt location (J) (see 1. 2. 3.), i.e. control is transferred to the required instruction.

The instruction 66 L is used for restoring the computer to its state at the time of interrupt (see 1. 2. 5.). The effect of the instruction 66 L is as follows:-

a) Set the modifier register from location L and set the modifier indicator.

b) Restore Acc. from location L + 1.

c) Restore A.R. from digit positions 1 to 38 of location L + 2.
Digit 39 of this location is made zero.

d) Restore OFR from position 39 of location L + 3, i.e. if digit 39 of location L + 3 is 1 set OFR.

e) Set S.C.R. to the value contained in positions 1 to 14 of location L + 3 (i.e. cause a transfer of control) and remove the inhibition on interrupts by setting the permit bit to 1.

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 channel 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 memory. Once set, the memory will remain set until it is cleared as in (d) below. The eight memories for normal interrupt together with the three for control interrupt form an 11-bit Interrupt Memory Register (see 1. 2. 3.).

c) Interrupts are further controlled by means of a one-bit memory called the 'permit bit' and an eight-bit 'mask register'. The contents of these may be jointly altered by program.

d) Normal interrupts occur at the earliest opportunity whenever a bit in the interrupt memory register, the corresponding bit in the mask register and the permit bit are all ones. At this time the bit in the interrupt memory register and the permit bit are made zero.

e) In the event that more than one corresponding pair of bits is present, then only the most significant pair is effective. That is, subject to the mask register, there is a priority sequence for interrupts, the highest priority being associated with the most significant bit in the interrupt memory register. Only one bit from the interrupt memory register is cleared on any one occasion.

f) The instruction 72 N, where N is less than 512, is used to set the mask register and permit bit. If N is less than 256 then the permit bit is made zero and N placed in the mask register. Otherwise the permit bit is made one, and (N-256) is placed in the mask register. For example, 72 320 sets the permit bit as 1 and places 64 in the mask register i.e. places a 1 in mask bit 7 (Channel 2).

g) Additionally, the permit bit is made one whenever a 66 order is obeyed.

h) The interrupt memory register and mask register are automatically cleared when the machine is switched on, while the permit bit is one. This situation is also obtained whenever the 'RESET' button is pressed.

Further information on the Control of Interrupts under RAP can be found in the relevant chapter in 2. 2. 1.

The diagrams below give examples of how the Interrupt Registers function.

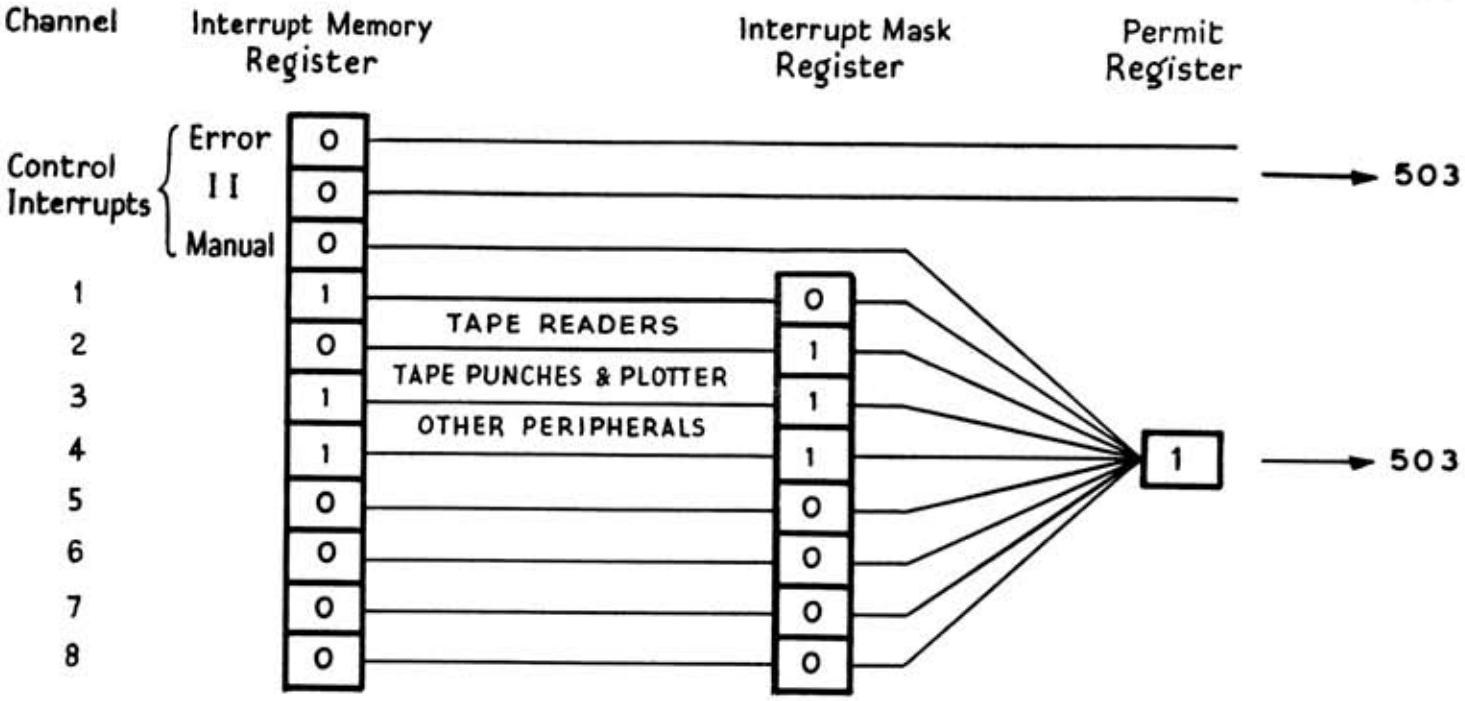


FIG.1 The devices associated with Channels 1, 3 and 4 have indicated in the Memory Register that they wish to interrupt. The Mask Register is set to allow interrupts on Channels 2, 3 and 4 (72 368 would set it as above); interrupts are therefore possible on Channels 3 and 4, but since Channel 3 has higher priority, this is the interrupt which is accepted.

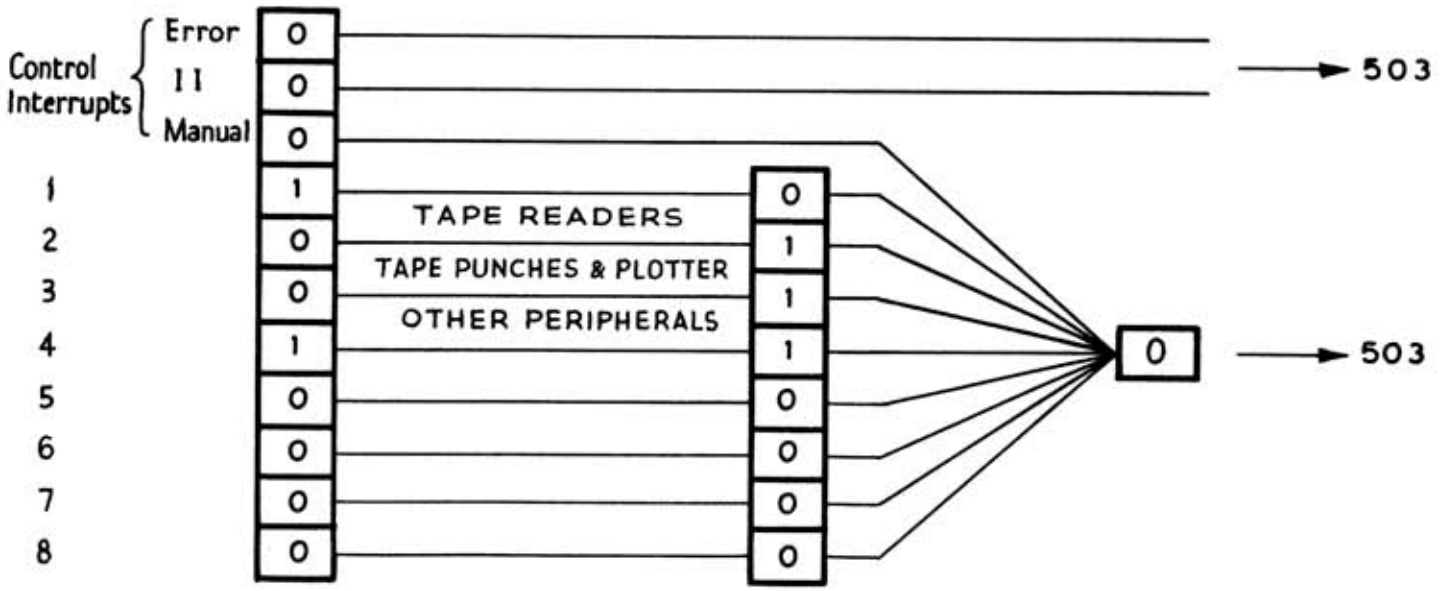


FIG.2 The interrupt on Channel 3 has been accepted. The corresponding bit in the Interrupt Memory Register is automatically set to 0, and the Permit Register automatically cleared to inhibit any further interrupts. The interrupt on Channel 4 is still waiting to be accepted.

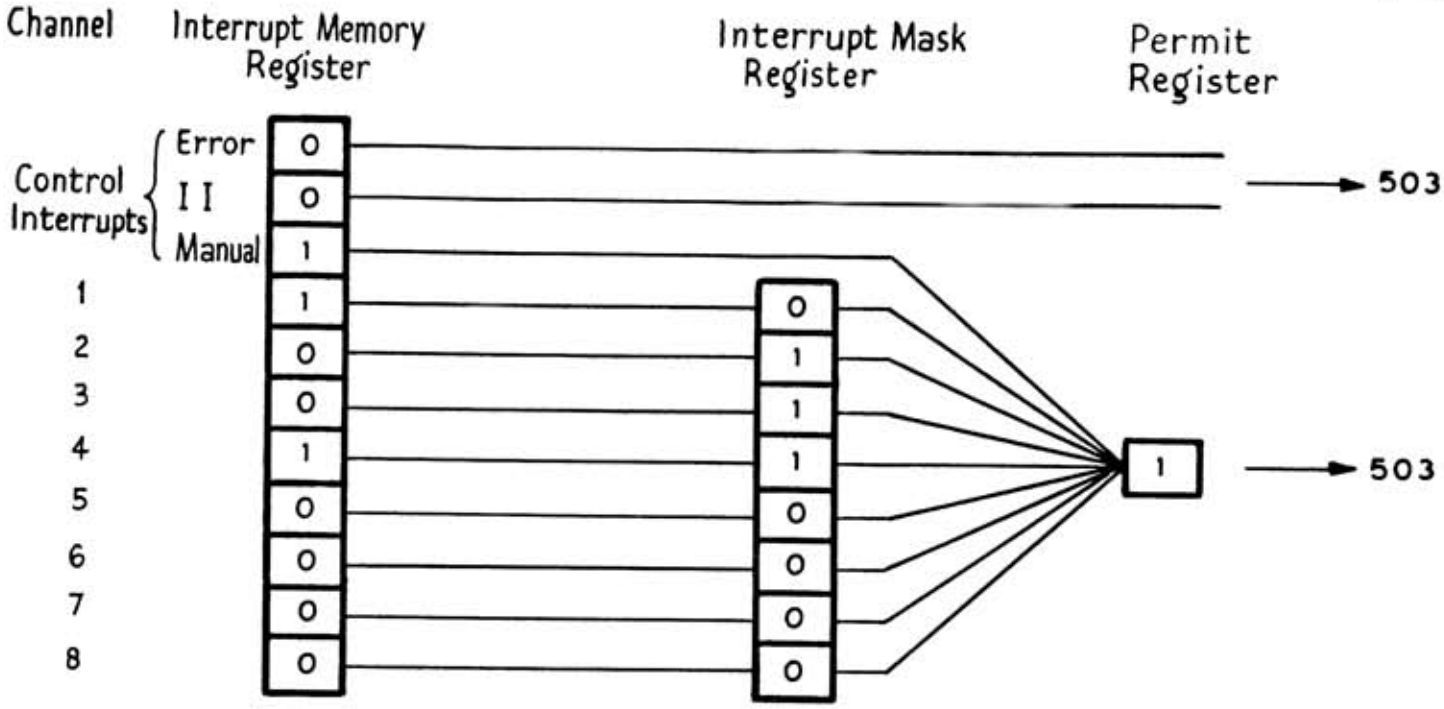


FIG.3 Although the Interrupt on Channel 4 is still awaiting acceptance, the Message button on the control console has been pressed and since the Control Channels have higher priority, the Manual Interrupt is the one accepted. If the instruction 72 352 is subsequently given, the effect will be as in Fig.4 below.

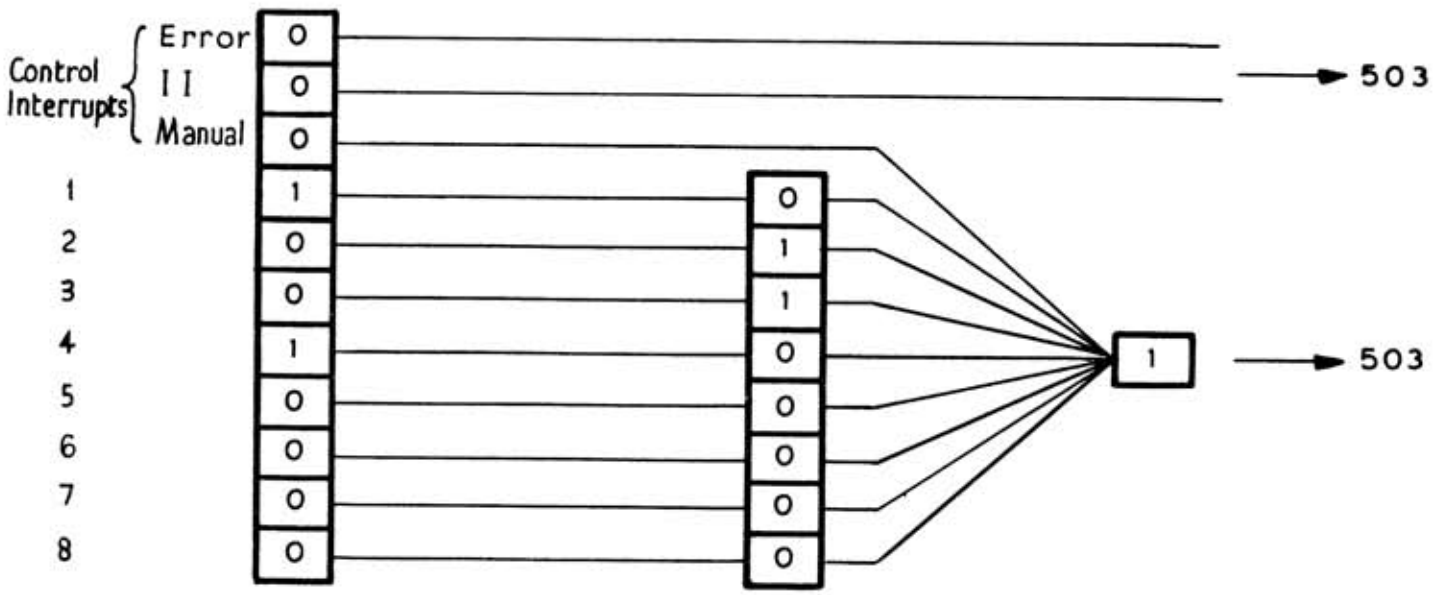


FIG.4 Note that although the Mask Register has been set to O on Channel 4, this does not affect the corresponding Channel of the Interrupt Memory Register which is still indicating an interrupt request.

PART 2 BASIC 503 SYSTEM

SECTION 5 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 1. 2. 3.).

The errors causing the interrupt fall into five classes. Each class has an associated bit in location L + 3 (see 1. 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 due to an unavailable peripheral device (see below). The instruction causing the interrupt is not obeyed.

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. It is, however, set to 1 whenever the power is turned off.

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

Advance warning of an error interrupt by a peripheral may be obtained by examining the control word of the device with a 76 instruction. It is at the option of the programmer to make use of this warning i.e. either to take action to avoid the interrupt, or to ignore it. 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 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. This state will be indicated in the control word of the 76 instruction. 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.

From the above description it will be seen that error interrupts associated with peripheral devices can only occur when 72, 77 and some 75 instructions are 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 and some 75 instructions.

The three states mentioned above may refer to peripheral devices or their controllers depending on circumstances. Whenever 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 8176 until cleared by a subsequent 77 instruction, it is possible to read the former when an interrupt occurs just before the latter.

PART 3 PERIPHERAL CONTROL

CONTENTS

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:—

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

The instruction 77N (execute) initiates the transfer first tagging 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, adjusts its record of the number of locations and the address of the first location involved and then resumes the program.

Provision is made for autonomous transfers from more than one device to take place concurrently.

Locations 8176 to 8191 are reserved for logical use by 76N and 77N according to the class number C given below; e.g. Core Backing Store corresponds to location 8186, i.e. 8176 +C.

The 15 classes of peripheral device are allocated a fixed priority order as shown below. At the 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 (83.4 μ secs. for 127 place shift) plus the time required to deal with any higher priority transfers that may be demanded. An ADT may take place between the tagging of two consecutive words.

The 76 Instruction

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

(1) Place the 76 address code in location 8176 to scale 2^{-38}.

(2) Input 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) The N digits of the 76 instruction specify the device and the type of transfer required:—

m.s.

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

l.s.

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-existent (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 × 2 + 1) means prepare to write on magnetic tape in format 1, odd parity, through controller channel 1 (4096) and tape handler 3 (see 1.4.2. Instruction Code).

Classes are allocated thus:—

	C	512*C*	*Priority*
Elliott Card Reader	1	512	7
Spare	2	1024	5
Spare	3	1536	6
Card { Reader	4	2048	10
Card { Punch	5	2560	9
Line Printer	6	3072	11
Spare	7	3584	8
Magnetic Tape (Controller channel 1)	8	4096	1
(Controller channel 2)	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 associated counting location is 8176 + C.

The 77 Instruction

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

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

(2) Set in the location associated with the peripheral controller (this will be one of the locations 8177 to 8191) a pair of counts i.e. 77 8192–T : 77 N–1.

(3) Clear location 8176 after having stored its contents internally.

(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) When tagging is complete, signal to the peripheral device that transfers may commence. The A.R. is used in this process and is not clear on exit.

After step 5 the program starts to obey the next instruction. The peripheral device has been activated by 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 the counts, set in step 2 above, are incremented by 1 and a word is transferred to or from the location specified by the lower count. At the same time the tag bit is cleared.

(8) The upper count is tested. If the count is zero 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 discovers that the non-existent controller of class 0 has been selected.

(b) The value of T is wired into the peripheral transfer control unit for 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 operation other than an ADT attempts to use a tagged location then the operation 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) When the reserved area is protected locations 8176 to 8191 cannot be altered except through the mechanism of a 76 or 77 instruction. When the protection is removed they can be altered by any normal means other than by tagging. These locations may be read by any instruction at any time.

(f) Interrupt cannot occur during steps 2 to 4 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 line then the B line is ignored.

(j) If an attempt is made to tag a location in the reserved area when it is protected the following will occur:—

(i) The 77 instruction will be completed normally but no reserved area location will in fact be tagged. The peripheral device will be activated as usual.

(ii) Error interrupt will occur when the next instruction is about to be obeyed.

(iii) The peripheral device will proceed to transfer words to or from the computer, as in steps 6 to 8. Any attempt to place a word in a reserved location will be suppressed, the incoming word being lost. Output of words from the reserved area to the peripheral will occur normally.

For an example of an autonomous transfer see 1.4.1. 'Block Transfer'.

Signals Involved in Transfers

The 76 instruction causes a PREP 76 signal to be sent out on a busbar together with the address N 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 code. When the central processor has received an AVAILABLE signal from the controller 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 control word over the data input busbars. The central processor receives this word and terminates the ACT 76 signal. PREP and ACT are of a fixed length.

The 77N 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 an ADT MASK signal on a line going direct to the controller involved. This signal remains until the central processor decides that a block transfer has been completed.

Once the ADT 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 ADT signal to the central processor. This signal

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

The DEMAND ADT and SELECT ADT 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" busbar. This signal is sent by the controller concerned to the central processer as soon as the SELECT signal appears.

The 72 and 75 instructions make use of PREP, AVAILABLE, BUSY and ACT signals in a way similar to that used by the 76 instruction. Separate busbars 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.

(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, as specified under 'The 76 Instruction' on page 1. 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, 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 except in emergency.

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

PART 4 PERIPHERAL DEVICES

CONTENTS

PART 4: PERIPHERAL DEVICES

SECTION 1: CORE BACKING STORE

Core backing store is supplied in units of 16,384 words. A maximum of eight units may be connected to the 503 via a single controller. The units form a single continuous store of up to 131,072 words, addressed from 0 to 131,071. Two units may be housed in a single 503 cabinet module; the controller is housed in the same module as the first two units.

Addresses are interpreted modulo 131,072, and attempts to read from non–existent locations yield zero.

Words may be transferred between the main store of the machine and the backing store by means of autonomous data transfers, or single words may be transferred between the accumulator and the backing store.

Block Transfer

The program maintains in a location of the main 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 of this block from the backing store to the 503 store (i.e. to read it), the following instructions are given:–

```
76    5120    (to write the block over to backing store,
               the instruction is 76    5121)

.
.
.
place content of S in Accumulator
77    N
.
.
.
```

The first instruction prepares the Core Backing Store for a read operation, the second transfers the pseudo–instruction pair to the accumulator and the third gives the read instruction. This 77 N causes locations N to N + T – 1 in the main store to be tagged, and initiates the transfer.

As the backing store obtains each word ready for transfer to the 503, the program hesitates at the end of an instruction, the word is transferred to the appropriate location in the main store, and the location tag is removed.

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

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 transferred between that address and the single word backing store register. This register can in turn be read into, or copied from, the accumulator.

To read the content of location A to the Acc., the following instructions are required:–

(1) Place $A.2^{-38}$ in Acc.

(2) 72 5120

.

.

.

(3) 75 5122

Between instructions (2) and (3) the central processor is free to continue computation.

The corresponding write instructions are:–

(1) 72 5122

.

.

.

(2) Place $A.2^{-38}$ in Acc.

(3) 72 5121

Between instructions (1) and (2) the central processor is free to continue computation.

The Backing Store Register

In either type of transfer all words transferred pass through a single word register called the backing store register. In the case of autonomous transfer this is entirely automatic. In the case of single words, the transfer between accumulator and backing store register and the transfer between register and backing store are treated as separate operations. Transfers from the backing store register do not disturb its contents, so that the same word may be transferred from it several times if desired.

The backing store register contains 40 bits, i.e. one word plus a parity bit. When a word is transferred from the central processor the parity bit is sent with it. In due course the entire 40 bits are placed in the backing store No checking takes place in this direction. When a word is transferred from the backing store to the backing store register, the parity checking process is initiated as soon as the word reaches the register. If an error is detected then the backing store is placed in the error state. When a word is transferred from the backing store register to the central processor, only 39 bits are transmitted, and the central processor generates and attaches a new parity bit.

When the backing store is in the error state any further instruction which refers to it, except 76 instructions and the reset error instruction 75 5120, will cause an error interrupt just before the instruction is obeyed. The 76 instructions and 75 5120 instruction can only cause interrupt if the controller is not connected.

Time Taken

All transfers take place via the backing store register. Operations, once initiated, take place independently of the central processor arithmetic unit. The total time for a backing store operation is, in general, made up of two parts; the time taken to execute the instruction within the central processor (called the program time) and the time taken to complete the backing store operation. The table gives the program time and the additional time that must elapse before a subsequent backing store instruction can be obeyed. The times quoted assume that the backing store is ready to obey the instruction immediately.

The time taken to complete the transfer of a block of data by ADT is dependent not only on the inherent speed of the Core Backing Store but on the length of instructions in the program which is being obeyed while the transfer is taking place, and on other peripheral devices of higher priority which may also be demanding the attention of the central processor. The maximum rate of transfer is in the region of 20,000 transfers per second. As each transfer is made, the program hesitates for 10 μ secs.

9.6

The Instruction Code for the core backing store is as follows:—

Function	*Operation*	*Program Time* (in μ secs.)	*Additional Time* (in μ secs.)
	Autonomous Data Transfers		
† 76 5120	Prepare to read from the backing store by autonomous transfer and read control word to Acc.	22·2	0
† 76 5121	Prepare to write to the backing store by autonomous transfer and read control word to Acc.	22·2	0
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 the Acc. $T.2^{-18}+A.2^{-38}$	38·7+3·6 T (set up tag) +9·6 T (transfer the words).	50 T minimum
	Single Word Transfers		
72 5120	Load backing store register from location A of the backing store, where A is specified by the content of the Acc. as $A.2^{-38}$	18·9	55 (but 75 5122 may follow after only 35 of these)
72 5121	Copy content of backing store register to location A of the backing store, where A is specified by the content of the Acc. as $A.2^{-38}$	18·9	55
72 5122	Copy content of Acc. to backing store register.	18·9	0
75 5122	Copy content of backing store register to Acc.	18	0
	Acknowledge error		
† 75 5120	Read control word to accumulator. Cancel the backing store error state if this is set.	18	0

The significance of the control word bits is:—

bit 4 set to one when the store is busy on an ADT.
bit 5 set to one when there is a parity error.

Busy and Interrupt System

The backing store is appropriately safeguarded by busy lines, etc. so that correct operation is ensured. A busy interrupt signal is sent at the end of all ADT's, but not after single word transfers.

If a 72 5120 is closely followed by an inspection of the control word, this inspection may be too soon to detect a parity error if one has occurred. However, if an error has occurred the error indication will be set by the time the store becomes unbusy, so any attempt to use the erroneous data will cause an erorr interrupt, and the error cannot pass undetected. It is recommended that no attempt be made to inspect the control word after orders involved in single word transfers, since the time taken by the inspection is long compared to the operation time, and since errors are in any case unlikely.

There is a red lamp inscribed PARITY mounted on the Control Station on the peripheral control panel. It is lit when the backing store parity error condition is set.

† *These instructions are not held up by a backing store busy, i.e. they may be given at any time. They may also be given when bit 5 is set to 1 without causing an interrupt.*

PART 4: PERIPHERAL DEVICES
SECTION 2: MAGNETIC TAPE

MAGNETIC TAPE FACILITIES

A dual channel controller is used in the system, and operates a maximum of eight handlers. Instructions can be issued to any handler via either channel of the controller. Two autonomous data transfers, 2 reading or 2 writing or one of each, may take place on any two handlers simultaneously provided that they are monitored through different channels of the controller. At the same time, operations which do not require autonomous data transfer may take place on any number of the remaining handlers.

The tape 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. The tape handler is also compatible with the IBM 729 V and VI handlers at a packing density of 800 bits/inch. A handler normally has alternative packing densities of 556 or 800 bits/inch. However, it is possible for a handler to have densities of 200 or 556 bits/inch. There is a switch for changing between the two densities available on any one handler.

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

The handler is fitted with a dual-stack head, and all writing on to tape is accompanied by automatic reading and parity checking.

503 Tape System

The system uses ½-inch 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. A row of 7 bits across the tape is known as a character and the six information bits are here referred to as a set. If a block is read using different parity than was employed when it was written, then a parity fault will be indicated. When even parity is used, a set of six zeros cannot be written on to the tape, as a character consisting entirely of zeros cannot be detected. This character is used for a special purpose, described on page 14.

There are two formats for storing a computer word on tape. It is essential that a block be read using the same format as was employed when it was written.

The two formats 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 sets. The most significant six bits form the first set.

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

Format 2. Writing: The first set on the tape contain 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 sets.

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

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

The length of a block is determined by a program write

instruction. In order that there should be no confusion between very short blocks and irregularities of the tape surface, the minimum block length permitted is three words. At the end of a block there is a short gap (approximately three characters long) followed by a longitudinal check character which causes the parity of all seven of the tracks in the block to be even. This is followed by a gap of at least $\frac{11}{16}$ inches (1.75 cms), before the beginning of the next block. It is possible for the longitudinal check character to consist entirely of zeros, since this character does not itself have a parity check.

During reading, the longitudinal 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 block 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. Longitudinal 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 block or an erase operation, at such a time that there remains at least 2.5 milliseconds before the tape begins to stop.

When the handler has ceased to be busy it is possible for it to obey further 77 or 72 instructions. If such an instruction requiring the same direction of tape motion is

received during the first 1.5 milliseconds of the 2.5 milliseconds mentioned above, 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.

If an ADT is involved, the controller channel and handler normally cease to be busy at the same time. In the case of a long block (i.e. a block longer than specified), the controller channel 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 block (i.e. a block shorter than specified), the controller channel only will continue to be busy after the check character has been read, and it will in fact remain busy until the remaining tags have been cleared.

Writing on Magnetic Tape

All reels of tape are provided with a small plastic ring known as a write permit ring. This must be inserted before writing can take place on that reel and thus prevents any accidental overwriting on tape. When the ring is not present, the file protect lamp is lit.

Before starting to write at the beginning of a tape one must issue either two erase instructions or none at all. A single erase instruction should not be issued at the beginning of a tape.

In order to ensure that no spurious characters are read and no wanted block becomes corrupt, certain precautions must be

observed:-

(i) If the power is turned off for any reason during the process of writing a tape, then on turning the power on again the last block written must be overwritten before attempting to write subsequent blocks.

(ii) Selective overwriting is forbidden, i.e. the overwriting of one or more blocks at the beginning or in the middle of a tape, except with the special precautions given on page 12. More exactly, if a block B is written on a tape to follow a block A written on an earlier occasion, then none of the blocks which previously followed A can be read correctly, unless the precautions are observed.

(iii) Noise blocks, generated by switching the write head currents on or off, may appear in the interblock gaps. When the interblock gap is of the nominal length of $\frac{3}{4}$ inch any noise blocks which occur in it will not be read. However, if the interblock gap is increased by means of one or more erases then these noise blocks may be read as genuine blocks. For this reason special care should be taken to allow for the presence of noise blocks when advancing, retreating or reading over erased portions of the tape. It is strongly recommended, in view of this limitation, that block addressing should be used to differentiate

between genuine blocks and noise blocks.

When the retreat one block instruction is obeyed, the tape stops in a position determined by the leading character of the block which has been traversed. If now a new block is written, this block may not start in exactly the same place as the block which was traversed. The timing is so arranged that the block will start slightly late. This ensures that a repeated cycle of retreat one block, write one block, cannot shorten an inter-block gap.

note Pg

TAPE CONTROL

A set of routines is included in the 503 Peripheral Control Program (PCP) which provides all the normal facilities required when using the 503 magnetic tape system. The remainder of this section describes in detail the hardware features of the magnetic tape system. Normal programs, using the PCP, need not be concerned with the precise details of the instruction code and hardware features, since these are automatically catered for in the tape system program.

The logic associated with each particular handler occupies nine boards of the controller which occupies half a 503 cabinet. The appropriate boards are omitted if the full complement of eight handlers is not present. These boards carry the logic to deal with 72 instructions, i.e. advance one block, retreat one block, rewind and erase.

Magnetic Tape Instruction Code

The instruction code is:-

76 4096+8(P-1) Prepare to read, format 1, odd parity, using controller channel 1

76 4097+8(P-1) Prepare to write, format 1, odd parity, using controller channel 1

76 4100+8(P-1) Prepare to read, format 1, even parity, using controller channel 1

76 4101+8(P-1) Prepare to write, format 1, even parity, using controller channel 1

76 4352+8(P-1) Prepare to read, format 2, odd parity, using controller channel 1

76 4353+8(P-1) Prepare to write, format 2, odd parity, using controller channel 1

76 4356+8(P-1) Prepare to read, format 2, even parity, using controller channel 1

76 4357+8(P-1) Prepare to write, format 2, even parity, using controller channel 1

76 4608+8(P-1) Prepare to read, format 1, odd parity, using controller channel 2

76 4609+8(P-1) Prepare to write, format 1, odd parity, using controller channel 2

76 4612+8(P-1) Prepare to read, format 1, even parity, using controller channel 2

76 4613+8(P-1) Prepare to write, format 1, even parity, using controller channel 2

76 4864+8(P-1) Prepare to read, format 2, odd parity, using controller channel 2

76 4865+8(P-1) Prepare to write, format 2, odd parity, using controller channel 2

76 4868+8(P-1) Prepare to read, format 2, even parity, using controller channel 2

76 4869+8(P-1) Prepare to write, format 2, even parity, using controller channel 2

In the 76 instructions, P is the handler number. $1 \leq P \leq 8$.

The control word indicating the state of the controller and handler is read to the least significant eleven digits of the accumulator (see page 11).

77 N.Read or write as specified by the last 76 instruction starting at location N of the main store.
Transfer T words where $T.2^{-18}$ is the contents of the accumulator. $1 \leq T \leq 7932$.

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 block, T words only are transferred, but the tape motion continues to the end of the block (long block). If the value of T is greater than the number of words in the block (short block), the tape motion stops when the end of the block is reached; the remaining tagged words in the main store associated with the transfer are then cleared.

Note that if 0 < T < 3 this instruction is invalid; the instruction will behave as an erase instruction, no data will be transferred to tape, and a SHORT BLOCK error will be indicated.

72 4096+8(P-1) or 72 4100+8(P-1)	Advance one block on handler P
72 4097+8(P-1) or 72 4101+8(P-1)	Retreat one block on handler P
72 4098+8(P-1) or 72 4102+8(P-1)	Erase approx. four inches (10.15 cms) on handler P
72 4099+8(P-1) or 72 4103+8(P-1)	Rewind tape on handler P.

If at the beginning of the first block an instruction to retreat one block is given, then the tape motion is stopped when the beginning of reel marker is reached, and the beginning of reel bit (bit 8) is set in the control word. If when bit 8 is set, a retreat or rewind instruction is given, it is treated as an order to do nothing, and no interrupt occurs. If the beginning of reel marker is encountered during the execution of any instruction, then that instruction is terminated and the control word is set appropriately. This will only happen if the tape has been incorrectly loaded. The tape will stop unconditionally at the beginning of reel marker.

When the end of reel marker is reached, no action is taken except to record this fact in the control word. This is because one may wish to write trailing blocks after the warning marker has been passed. A block which straddles the end of tape marker is read normally. The amount of usable tape remaining after the reflective marker is 10 feet (3.05 metres) less than the full length of leader tape. The

standard for the length of leader tape used is 25 feet (7.625 metres), so that the amount of tape normally available is 15 feet (4.475 metres).

75 4096+8(P-1) Read control word on handler P to accumulator and cancel error states (bits 5, 10 and 11) on handler P.

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

The significance of the control word bits is:-

bit 1 Set to one when the handler is not available.
bit 2 Spare.
bit 3 Set to one when writing is permitted.
bit 4 Set to one when the handler is busy.
bit 5 Set to one when there is a parity error on the handler.
bit 6 Set to one when controller channel 1 is busy.
bit 7 Set to one when controller channel 2 is busy.
bit 8 Set to one at the beginning of the tape.
bit 9 Set to one at the end of the tape.
bit 10 Long block. Set to one when the last block contained more characters than specified by the contents of the accumulator at the time of the 77 instruction, and zero otherwise.
bit 11 Short block. Set to one when the last block contained fewer characters than specified by the contents of the accumulator at the time of the 77 instruction, and zero otherwise.

Bit 3 is set to 1 provided a write permit ring is present in the reel of tape. If bit 3 is zero then any instruction to write or erase on the handler will cause an error interrupt.

Bits 5, 10 and 11, the error state bits, return to zero when the handler is put into the MANUAL state.

Bit 8 is set to 1 when the tape is loaded, and returns to 0 when the tape is first moved. It is set to 1 whenever the tape is returned to its initial position.

Bit 9 is set to 1 when the physical end of reel marker is reached or passed in the forward direction, and is set to 0 when a rewind instruction is given. (N.B. retreat instructions over the end of reel marker will not reset bit 9 to zero). It is 0 when the handler is put into the MANUAL state.

Each of bits 1 to 7 (excluding 2) is 1 when the appropriate condition is satisfied and 0 otherwise.

A 77 or a 72 instruction, relating to a handler which is in the error state or not available, will cause an error interrupt; any tape instruction causes an error interrupt if the controller is not present in the system (see 1.2.3. and 1.2.5.).

Special Effects

(1) 'Selective over-writing', i.e. the over-writing of one or more blocks at the beginning or in the middle of a

tape, is allowed only if special precautions are observed; otherwise there is no guarantee that the blocks following these over-written will be accurately preserved.

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

(i) The block must be followed by approximately 8 inches (20.3 cms.) of blank tape, obtained by using two 'erase' orders (72 4098, etc.).

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

(iii) Because of engineering tolerances, the block should not normally be longer than 400 words. If it is longer, this will mean that there is less likelihood of the block being overwritten successfully.

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

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

(ii) It must be followed by 4 inches (10.15 cms.) of blank tape, i.e. a single 'erase' order.

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

(2) Blocks of a non-integral number of words may arise in connection with IBM compatibility. Reading such a block is always possible; the final word will be completed as though the block had a sufficient number of additional zero characters to form an exact number of words. Such a block will always give rise to either the short or long block indication in the control word, as appropriate.

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

If the first character of a block to be written in even parity is zero, then the instruction is equivalent to an erase instruction, and the short block indication will be set in the control word.

(3) Although it is not normally possible to write less than three words, this can be done on even parity by initiating a three word transfer and filling the unwanted character positions with zeros. When the first all zero character is reached, the block will end and the short block indication will be set in the control word.

This is how IBM tape marks are written but it is not recommended as a general practice.

Note that there is no restriction on reading less than three words.

Switches and Lamps

The following table shows the switches and lamps situated at the top of the tape handlers.

Name	Colour	Type	If with Lamp
POWER	Green/Red	Push-push	Lamp
REWIND TO LOAD POINT	Amber	Push	-
(REMOTE)	Green	Push	Lamp
Manual (LOCAL)	Red	Push	Lamp
HIGH DENSITY	Green	Push	Lamp
FORWARD TO LOAD POINT	Amber	Push	-
STOP	Red	Push	-
REVERSE	Amber	Push	-
LOW DENSITY	Amber	Push	Lamp
HANDLER NUMBER SELECTOR	-	ROTARY SELECTOR	Lamp
file protect	Amber	-	Lamp
ready	Green	-	Lamp
beginning of tape	Green	-	Lamp
error	Red	-	Lamp

The POWER indicator is divided into two - the upper half green and the lower red. The green half is illuminated when the power switch on has occurred normally. The red half is illuminated when the power has not been successfully switched on to all units. If this condition occurs the power should be switched off and the switch on attempted again after a pause of 2 minutes.

The FORWARD TO LOAD POINT, REVERSE and REWIND buttons have no effect unless LOCAL is depressed.

If the handler number selector is moved when the handler is not in the LOCAL state, the handler will at once enter the LOCAL state. The handler may be restored to the REMOTE state by pressing the REMOTE button, provided that the number now selected is not already in use.

Only one handler may be set to a particular number and be in the REMOTE state. If another handler is set to the same number it will not be possible to cause that handler to transfer to the REMOTE state. Before a handler is switched to POWER OFF, its rotary selection switch should be moved to the spare position (beyond 8). If it is not, then it could interfere with another handler which is in use and switched to the same number.

Busy, Interrupt and Manual

Interrupt occurs when and only when a handler goes NOT BUSY (including after advances, retreats, erases and rewinds). The tape will continue to move at full speed if

another order for a move in the same direction is given within 1.5 milliseconds of the interrupt.

When a handler is on LOCAL it is in the NOT AVAILABLE state and not the BUSY state. Thus there is no interrupt when the handler comes out of the LOCAL state.

Summary of handler characteristics

Tape length	not greater than 2,400 feet.
Tape width	0.5 inches.
Tape speed	75 inches/sec. $\pm$ 10%.
Rewind time	$3\frac{1}{2}$ mins. max. ($3\frac{1}{4}$ mins. typical).

Packing density	556 bits/inch	800 bits/inch
	=92.6 words/inch in format 1	=133.3 words/inch in format 1
	=79.4 words/inch in format 2	=114.3 words/inch in format 2
Character transfer rate	41,700 characters/sec	60,000 characters/sec
Word transfer rate, format 1	6,950 words/sec (144 μsecs per word)	10,000 words/sec (100 μsecs per word)
format 2	5,957 words/sec (168 μsecs per word)	8,571 words/sec (117 μsecs per word)

Inter-block gap length	0.75 inches nominal
Inter-block gap times	
(a) at full speed	10 millisec.
(b) with stop and immediate restart	not greater than 18 millisec.

For the type of tape recommended see 3.1.1.

Nominal tape capacity for 2,400 feet reel at 556 bits/inch.

Format 1

Average block length, words	32	128	512
Length (inches)	.35	1.4	5.5
Gap	.75	.75	.75
No. of blocks	26,000	13,500	4,500
No. of words	840,000	1,730,000	2,350,000
Time/(block + gap) at full speed (secs)	.015	.03	.08
Blocks/sec. Max.	68	35	12
Effective words/sec. Max.	2,200	4,500	6,100

Format 2

Average block length, words	32	128	512
Length (inches)	.40	1.6	6.5
Gap	.75	.75	.75
No. of blocks	25,000	12,000	4,000
No. of words	800,000	1,500,000	2,000,000
Time/(block + gap) at full speed (secs)	.015	.03	.10
Blocks/sec. Max.	65	32	10
Effective words/sec. Max.	2,100	4,100	5,300

Nominal tape capacity for 2,400 feet reel at 800 bits/inch.

Format 1

Average block length, words	32	128	512
Length (inches)	0.24	0.96	3.84
Gap	0.75	0.75	0.75
No. of blocks	28,800	16,800	6,270
No. of words	922,000	2,150,000	3,170,000
Time/(block + gap) at full speed (secs)	0.013	0.023	0.061
Blocks/sec. Max.	75	44	16
Effective words/sec. Max.	2,400	5,600	8,200

Format 2

Average block length, words	32	128	512
Length (inches)	0.28	1.12	4.48
Gap	0.75	0.75	0.75
No. of blocks	28,000	15,400	5,500
No. of words	896,000	1,970,000	2,820,000
Time/(block + gap) at full speed (secs)	0.014	0.025	0.07
Blocks/sec. Max.	73	40	14.5
Effective words/sec. Max.	2,340	5,120	7,400

USE OF MAGNETIC TAPE ON THE 503

All Instructions

Before any attempt is made to move tape in any way, check bit 1, i.e. handler NOT AVAILABLE. If this is present, any operation on this handler will give rise to an error interrupt.

It is usual for the controlling program to refer to bit 6 and bit 7 and use whichever controller channel is not busy.

Rewind and Initial Positioning

When rewind is complete, the beginning of reel marker, bit 8, will be set, and further rewinds will not affect the position of the tape. When a handler is at the beginning of tape, the appropriate lamp on its control panel is lit.

First Block on Tape

Before writing the first block on a tape, check that bit 8 is present.

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

A further retreat one block order will cause the handler to stop at the beginning of reel marker.

WRITE AND MOVE BACK DELETED - NO LONGER APPLICABLE

End of Tape

It is permitted to write beyond the end of the reel marker but a note should be kept of tape used in this way so as to avoid going more than the normal (see page 10) fifteen feet (4,575 metres) beyond the marker.

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

Errors, etc.

These are indicated by the parity marker, bit 5, and long and short block markers, bits 10 and 11 respectively. An error is also indicated on the control panel of the handler. These errors 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.

If an error occurs on reading, then retreat one block and read again. It is unlikely that the error will occur a second time. If an error occurs on writing, then retreat one block and write again. If still unsuccessful, retreat one block, erase four inches of tape, and write again. On even parity, the short block indicator may be set on writing. This probably indicates that an all-zero character has terminated the block and probably implies a programming error.

Do not attempt to read any blocks beyond the one most recently written on the tape without obeying the special precautions described on page 13. Errors will almost certainly result if this is attempted.

PART 4: PERIPHERAL DEVICES

SECTION 3: LINE PRINTER

Note. This issue describes the current models (Series 5) of the line printer and does not refer to the earlier model (Series 4) which was described in previous issues.

The contents of this section are generally applicable to both models of the line printer. Specific details of each model are given in the table at the end.

Printing takes place, a line at a time, on continuous stationery with marginally punched sprocket holes. Each line may contain up to 120 characters from a 64 character repertoire. Control of vertical paper format is provided by means of a continuous band of punched tape which advances one character for each line that passes under the printing head. The line printer code is given on Page 4. See 3.1.1 for details of the paper to be used on the line printer.

The line printer is connected to the 503 via a single controller. The transfer of characters to the line printer takes place using autonomous data transfers (A.D.T.'s) in order to minimise the hold-up time (i.e. after initiating the transfer, the central processor can continue and run concurrently with the transfer of data to the line printer). Full details of A.D.T.s are given in 1.3.1. Characters are output to the line printer in blocks (buffers) of 121 characters, each 7 bits long, from the 7 least significant positions of a set of 121 consecutive locations in the 503 main store. The first character determines the vertical paper format, the remainder form one line of print.

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 line printer buffer is filled by an A.D.T. and the characters are then printed from the buffer. The maximum rate of transfer to the buffer during the A.D.T. is 30,000 words/sec.

The Control Word.

The control word provides information on the condition of the line printer. Thus by testing this word the programmer can determine the state of the line printer, in particular whether it is available for printing. Each of 5 bits in the control word has a certain significance as follows:

bit 1 Printer not available. Set to one when the printer is in MANUAL.
2 Error type 1. Set to one when the paper is nearly out.
3 Spare. Always zero.
4 Printer busy. Set to one when the printer is engaged in a paper feed or print operation or while an A.D.T. is in progress.
5 Error type 2. Set to one when:—
(a) paper is exhausted.
(b) paper is broken or jammed in the feed mechanism.
(c) paper runs away.
(d) hammer driver fuse is blown.
(e) yoke is open.

When bit 5 is set the device goes into MANUAL and so bit 1 is also set.

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 bit positions 1 to 7 of the word N, specifies the vertical format. The least significant 6 bits of this character are used to determine the action to be taken, as indicated overleaf—

	Binary Value	Action
1.	$0 \leqslant p \leqslant 30$	Move p+1 lines and print.
2.	p=31 or 32	Overprint i.e. no line feed.
3.	p+32 ($1 \leqslant p \leqslant 30$)	Search for configuration p on control loop and print.
4.	p=63	(a) If there is no control loop: error type 2 (c) occurs.
		(b) If there is a control loop: find punching in top of form channel (1).

The last two of the above operations are effected by the vertical format control loop; this is a closed loop of 12-hole tape of which only 6 channels are used. The loop is read by a tape reader situated in a recess at the left side of the printer. On receiving the instruction to find the next printing position, tape and paper move together until the configuration (punched in channels 2 to 6) is found on tape corresponding to the binary representation of p; the line is then printed in that position.

Channels 7 to 12 of the tape loop are not active.

Channel 1 is the top of form channel; this is controlled both by the TOP OF FORM button on the console and also by the programmer setting p=63. When the paper has been loaded, this button is depressed with the effect that

(a) if there is no control loop, paper feed occurs for a specified period,

or (b) if there is a control loop, it is searched for a punching in channel 1 and when it is found the paper is aligned accordingly.

If a character is called for which cannot be found on the control loop, line feeds are given until a time delay cut out occurs. Bit 5 of the control word is then set and the printer goes into the manual state.

In practice a standard control loop will probably be found to satisfy most requirements. As a guide, a standard control loop could consist of a one page loop (number of sprocket holes in loop = no. of lines on page with a punching in the top of form channel (1) at the third sprocket position. This would cause printing to start 3 lines down from the top of the page. If a special format is required, it is the programmer's responsibility to make his own loop to correspond with the program instructions. Details of how to make the loop can be found in the manufacturer's handbook.

Printing Speeds

The characters are arranged on the print wheel in order of binary value (see page 4), a complete set of characters for each of the 120 positions in a line. The normal speed of printing is achieved with any selection from the range of characters.

However, the speed can be raised (so that it becomes equal to the revolutions/minute of the print wheel) when a line contains characters which occupy not more than 48 consecutive positions on the print wheel and the lines are printed with single spacing. For example, lines which are either wholly numeric or wholly alphabetic are printed at the maximum rate.

If a line contains a character not included in the line printer code, then the effective print rate drops to approximately one-third of the maximum rate.

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

Name	*Colour*	*Type*	*Lamp lit when*	*Pushing button causes*
POWER ON	Green	bl	System power connected.	Power to be connected.
POWER OFF	Red	bl	System power available but not connected.	Power to be disconnected.
MANUAL	Red	bl	In the MANUAL state.	A change of state.
TOP OF FORM	Yellow	bl	Permanently lit.	Hole in 'top of form' channel to be positioned under reader.
TEST PRINT	Yellow	bl	Depressed.	Causes full lines of the characters set on the engineer's switches to be printed.
TRACTOR INDEX	Yellow	bl	Permanently lit.	Causes tractors to advance 1 pitch ≡ 3 lines.
PRINTER READY	Green	l	Printer ready for operation.	
ERROR 1	Red	l	Error state type 1.	
ERROR 2	Red	l	Error state type 2.	
YOKE OPEN	Red	l	Yoke (cover door) is open.	
NO PAPER	Red	l	Paper is broken or exhausted.	
PAPER LOW ALERT	Red	l	Paper almost exhausted.	
ALARM STATUS	Red	l	Engineering fault.	

Controls are also provided for the adjustment of:

Form position
Penetration
Paper tension.

There are also yoke switches so that the yoke may be opened for easy loading of paper.

The TOP OF FORM, TEST PRINT and TRACTOR INDEX buttons are only operative when the device is in the MANUAL state.

Power can only be switched on by pressing the local ON button. It may, however, be switched off by either the local or the control console OFF button.

When the power is first switched on the system is in the manual state, with the PRINTER READY light out for about 2 secs. until it is ready for operation. Pressure on the MANUAL button causes the ON-LINE state to be engaged, making the printer available to the 503.

When an error type 2 occurs, the line printer automatically goes into the MANUAL state. When the next 77 order referring to the line printer is given, an Error Interrupt occurs. The error must be corrected by operator intervention and then the device should be returned to its on-line state.

Full details of how to operate the line printer are given in 3.1.6.

Busy, Interrupt and Manual

Interrupt occurs when the printer goes unbusy. Manual places the printer in the non-available state.

Line Printer Code

0000000	0	S	0011101	29	+	0110011	51	S
0001000	8	(	0011110	30	—	0110100	52	T
0001001	9	)	0011111	31	.	0110101	53	U
0001010	10	,	0100000	32	;	0110110	54	V
0001011	11	£	0100001	33	A	0110111	55	W
0001100	12	:	0100010	34	B	0111000	56	X
0001101	13	&	0100011	35	C	0111001	57	Y
0001110	14	*	0100100	36	D	0111010	58	Z
0001111	15	/	0100101	37	E	0111110	62	V
0010000	16	0	0100110	38	F	1000000	64	S
0010001	17	1	0100111	39	G	1011000	88	[
0010010	18	2	0101000	40	H	1011001	89	]
0010011	19	3	0101001	41	I	1011010	90	10
0010100	20	4	0101010	42	J	1011011	91	<
0010101	21	5	0101011	43	K	1011100	92	>
0010110	22	6	0101100	44	L	1011101	93	↑
0010111	23	7	0101101	45	M	1011110	94	△
0011000	24	8	0101110	46	N	1011111	95	%
0011001	25	9	0101111	47	O	1100000	96	?
0011010	26	10	0110000	48	P	1111000	120	@
0011011	27	11	0110001	49	Q	1111001	121	'
0011100	28	=	0110010	50	R	1111110	126	U

All other characters appear as △.

Abbreviations

S Space
U Underline
V Vertical Bar.

Tabular Summary of Models Available

Maximum rate of printing	1,250 lines per minute	333 lines per minute
Normal rate of printing	1,000 l.p.m.	300 l.p.m.
Minimum rate (when line contains unspecified character)	400 l.p.m.	110 l.p.m.
Speed of paper throw	27½ inches/sec. minimum	18 inches/sec. minimum

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 850 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.

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 on page 14 .

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, one location corresponding to each column of the corresponding card, where an unpunched position is represented by 0 and a punched position by 1. Column 1 is read to the first location and column 80 to the last. Position 39 corresponds to the 12 (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 on page 13
The corner cut on the card is the corner corresponding to column 1 and the 12(Y) row (see page 15 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.

Loading of the read buffer 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

Principles of Operation (continued)

word to be loaded to the check register.

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

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.

The Instruction Code for the Bull card reader/punch (continued)

Function	Operation
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.
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 ER and EP lamps 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:

The Instruction Code (continued)

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 significance of the control word bits is:-

bit 1 Reader/punch not available. Set to one when 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. Set to one from the time the PROG button is depressed until the first read instruction pair is obeyed.

bit 3 End. Set to one 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. Set to one whilst the reader/punch is busy moving cards.

bit 5 Read error. Set to one from the time a read error is detected until a reset instruction is obeyed.

bit 6 Punch error. Set to one from the time a punch error is detected until a reset instruction is obeyed.

bit 7 Read mode. Set to one whilst the device is in the read mode.

bit 8 Punch mode. Set to one whilst the device is in the punch mode.

bit 9 R.P. & S mode. Set to one whilst the device is in the R.P. & S mode.

bit 10 R.P. mode. Set to one 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.
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.

Manual Control (continued)

Control	Full Name	Type	Lamp is lit when	Pressure on button causes
CL.M	Clear Main Track	b		Main track to be cleared of cards.
CL.S	Clear 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	
IM	Incident on Main track	l	Incident has occurred	
IS	Incident on Subsidiary Track	l	Incident has occurred	
IE	Incident on Ejection Track	l	Incident has occurred	

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.

Manual Control (continued)

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.

When the power is first switched on, the machine is in the manual state and the lamp in the START 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.
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, the 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' instruction.

Manual Control (continued)

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

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 tis previous auto state.

d) Emptying of the main hopper when the reader/punch is in the Read, Punch, 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 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.

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.

Manual Control (continued)

a) "

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 abondoned.

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 auto state for approximately 200 m.sec after depression of the START button. At all other times it causes the reader/punch to remain in the manual state. It is not expected that the facilities provided by this button will be of great value to the programmer and some care must be exercised in its use.

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

Errors and Incidents (continued)

a)

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.

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.

Errors and Incidents (continued)

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 cause 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.

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. Th 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.

Bull Card codes with corresponding Friden Flexowriter Codes.

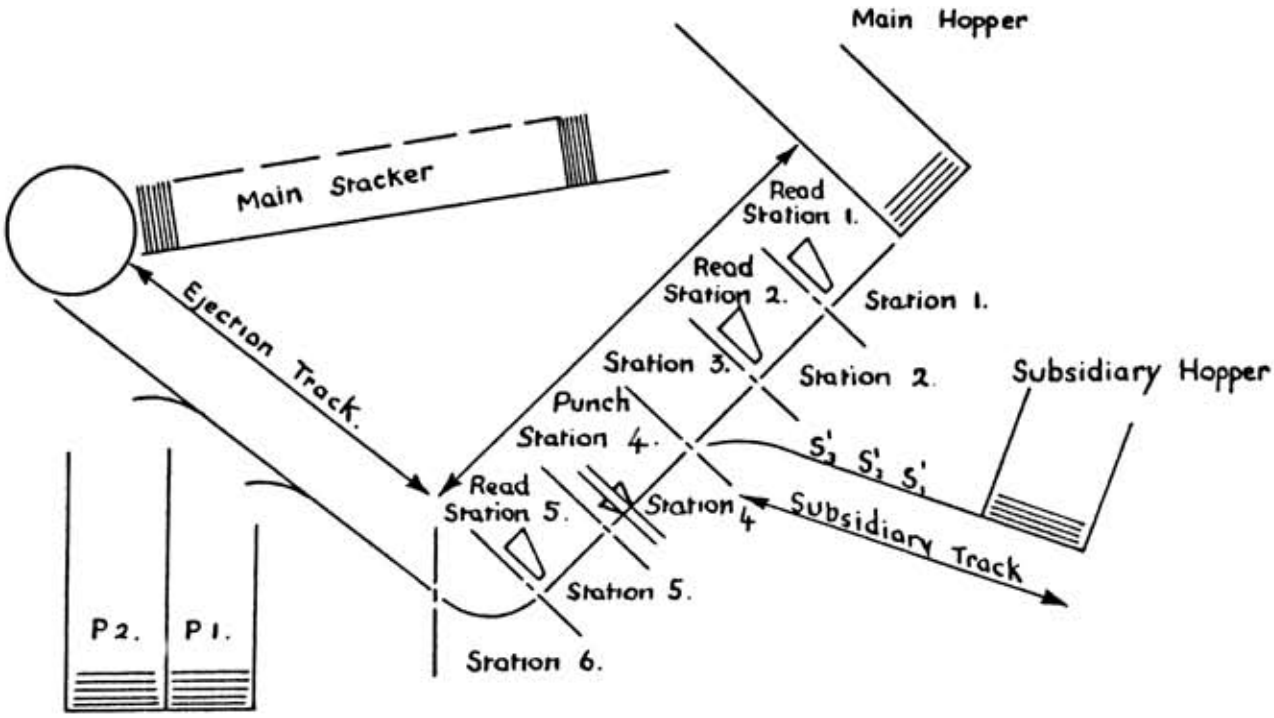
Bull code	Bull char	Friden char	Friden val	Friden code
0	0	0	16	0010000
1	1	1	17	0010001
2	2	2	18	0010010
3	3	3	19	0010011
4	4	4	20	0010100
5	5	5	21	0010101
6	6	6	22	0010110
7	7	7	23	0010111
8	8	8	24	0011000
9	9	9	25	0011001
11	10	10	26	0011010
12	11	11	27	0011011
7.11	A	A	33	0100001
7.0	B	B	34	0100010
7.1	C	C	35	0100011
7.2	D	D	36	0100100
7.3	E	E	37	0100101
7.4	F	F	38	0100110
7.5	G	G	39	0100111
7.6	H	H	40	0101000
8.12	I	I	41	0101001
8.11	J	J	42	0101010
8.0	K	K	43	0101011
8.1	L	L	44	0101100
8.2	M	M	45	0101101
8.3	N	N	46	0101110
7.12	O	O	47	0101111
8.4	P	P	48	0110000
8.5	Q	Q	49	0110001
8.6	R	R	50	0110010
9.11	S	S	51	0110011
9.0	T	T	52	0110100
9.1	U	U	53	0110101
9.2	V	V	54	0110110
9.3	W	W	55	0110111
9.4	X	X	56	0111000
9.5	Y	Y	57	0111001
9.6	Z	Z	58	0111010
blank col.	sp	sp	64	1000000
9.12	.	.	31	0011111
9.7.12	/	/	15	0001111
9.7.11	,	,	10	0001010
9.7.0	;	;	32	0100000
9.7.1	%	%	95	1011111
9.7.2	$	ω	90	1011010
9.7.3	£	£	11	0001011
9.7.4	◇	[	88	1011000
9.7.5	□	]	89	1011001
9.7.6	Δ	?	96	1100000
9.7	*	*	14	0001110
9.8.12	+	+	29	0011101
9.8.11	=	=	28	0011100
9.8.0	(	(	8	0001000
9.8.1	)	)	9	0001001
9.8.2	x	&	13	0001101
9.8.3	:	:	12	0001100
9.8.4	<	<	91	1011011
9.8.5	>	>	92	1011100
9.8.6	≠	↑	93	1011101
9.8.	—	—	30	0011110
All other punchings		Δ	94	1011110

Notes.

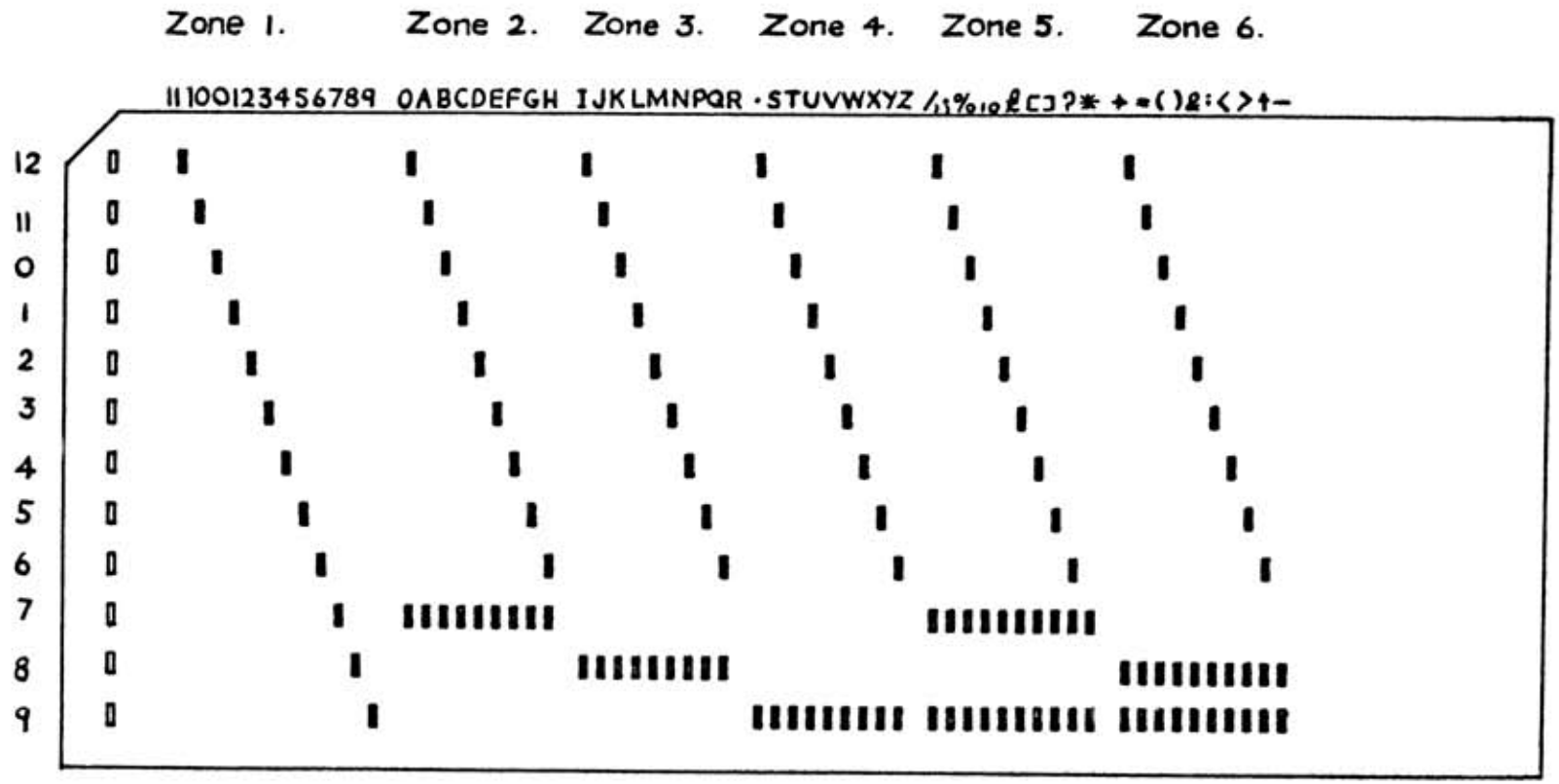
1. Any combination of holes which does not constitute a recognised character is decoded on reading as the Flexowriter character Δ (or ~)
2. Any unrecognised character is coded on punching as a blank column.

1.4.4.

A DIAGRAM OF THE TRACK LAYOUT OF THE BULL READER / PUNCH



BULL CARD CODE (For series 300 machines).



A blank column is sp (i.e. 64), and all other Bull Codes are decoded as △ (i.e. 94).

The code symbols along the top edge of the card show the Friden characters corresponding to the Bull codes.

PART 4: PERIPHERAL DEVICES

SECTION 5: DIRECT OUTPUT AND INPUT

This section outlines the general method of peripheral communication of the 503. The information given is for general interest only: detailed descriptions will be found in the appropriate parts of Volume 4. A user requiring a special device to be connected can make use of the Interface Matching Unit (see 1.4.8.) which has been specially designed to simplify the connection of these devices.

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. e.g. PREP and ACT are communal signals.

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 N1 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 1.3.1. '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 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 72N for output to a peripheral device or 75N 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 1.3.1.

For 'Program Interrupts' see 1.2.4.

PART 4: PERIPHERAL DEVICES

SECTION 6: ELLIOTT CARD READER

The card reader is mounted in a cabinet which also contains the immediate control logic. The logic for the interface between the central processor and the card reader is contained within the control desk. On the cabinet are mounted an operator's control panel and a stacking device for loading cards into a card storage tray. The input magazine has a working capacity of 1500 cards and card receiver trays have a working capacity of 1800 cards. The maximum rate of reading is 340 cards per minute.

Cards are read column by column as they move past a single read station consisting of twelve phototransistors. The correct times of reading for the first five columns are determined by the instants at which the trailing edge of the card passes one of five phototransistors. The last of these five phototransistors also initiates a count which is advanced by pulses from a magnetic timing wheel attached to one of the card drive rollers. The count is further corrected by the action of a phototransistor at the time when column 43 is to be read.

Sixteen pulses per column are given by the magnetic timing wheel. Each of columns 6 to 80 are read at a time eight pulses after the leading edge of a hole in the column has been sensed. If a column is unpunched then the reading time is determined by the main count.

Reading makes use of the autonomous transfer system. Read instructions result in a card being read to any 80 consecutive locations in the store, one location corresponding to each column in the card. Each location contains in bit positions 39 to 28 an image of the corresponding card column, where an unpunched position is represented by 0 and a punched position by 1. Position 39 corresponds to the 12 (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. Bits 8 to 27 of each location are always zero. Any unrecognised punching is decoded as a specific 'Wrong' character. A standard code (shown on page 3) is provided but other codes, to customer specification, may be provided at extra cost. The change of code is achieved by substitution of a few logic boards in the controller.

The instruction code is:—

76 512 Read control word to Acc. and prepare to read a card.
77 N Read a card to locations N to N+79 of the main store.

The significance of the control word bits is:—

bit 1 Reader not available. Set to one when the reader is not available (see below).
bits 2 and 3 Spare (always zero).
bit 4 Busy. Set to one when the reader is in the busy state. In this case a further 77 instruction is held up until the busy state disappears.
bit 5 Read error. Set to one when the card last read was read incorrectly (see below).

Bit 5 is set to 1 when the previous card appeared to have either too many or too few columns (i.e. the count system has failed). The following are examples of this:—

(a) The device was switched off while the last read instruction was being executed. This also causes bit 4 to be set to one.
(b) There was a card jam whilst the previous card was being read.

The following reasons for unavailability cause bit 1 to be set to one.

(a) Device not switched on. Bit 4 is also set to one.
(b) Reader in manual state.
(c) No card on sensing platform.
(d) Stacker door open.
(e) Stacker full.
(f) Engineers' switches incorrectly set. see P7

Bit 5 must only be cleared by switching to MANUAL, correcting the error and switching back to AUTO.
Bit 1 is cleared by switching to MANUAL, rectifying the condition causing the error and switching back again to AUTO.

The following buttons and lamps are provided on the operator's control panel:—

(a) OFF (Push+Lamp) Red.
The lamp is lit when power is available and the device is switched off.

(b) ON (Push+Lamp) Green.
The lamp is lit when the device has power on.

(c) MANUAL (Push-push+Lamp) Yellow.
The lamp is lit whenever the button is depressed. Depression of the button causes the reader to be placed in the manual state. Raising the button causes the reader to be placed in the auto state provided none of the other conditions exist which would cause it to be unavailable.

(d) ERROR (Lamp)Red.
The lamp is lit when the reader is unavailable and bit one is set to one.
After the necessary correction of the condition the reader remains in the unavailable state until the MANUAL button is released. Thus the operator must depress the MANUAL button, correct the error condition and then release the MANUAL button.

(e) RESET (Push) Red.
This resets the internal electronics and sets the reader ready to work as soon as it goes into the available state.
This button should be pressed:—
(a) after first switching on the Card Reader,
and (b) after clearing a card crash and before releasing the MANUAL button.

(f) SINGLE SHOT (Push) White.
This button is only operable when the reader is in the manual state.
Pressure on the button causes one card feed and this occurs even though there may be no card on the sensing platform.

There is also a switch, mounted on the reader mechanism, which controls the supply of power to the motor. This switch should only be used in an emergency i.e. when there is a card jam.

The card reader can be switched ON or OFF by means of its own ON and OFF buttons when it is in either the MANUAL or the AUTO state. It can also be turned OFF by the control console OFF button when in either state. It is recommended that the card-reader be put into the MANUAL state before it is switched OFF.

The controller of the card reader is so arranged that once a transfer has been initiated there will always be 80 words transferred even though the reader may have gone into the unavailable state during the course of the transfer. In such an event some of the information arriving in the store may be wrong. If the reader is placed in the manual state whilst a transfer is in progress then the transfer will be properly completed.

Busy Interrupt and Manual

Interrupt occurs when the card reader goes unbusy. Manual places the reader in the non-available state. If the device is in the Auto state when it is switched on then interrupt will probably occur. No interrupts will occur when the device is in the Manual state.

503 ELLIOTT CARD READER CODE

Column Punching 12- bit	7-bit Binary Value	Decimal Value	Significance of Character
0	0010000	16	0
1	0010001	17	1
2	0010010	18	2
3	0010011	19	3
4	0010100	20	4
5	0010101	21	5
6	0010110	22	6
7	0010111	23	7
8	0011000	24	8
9	0011001	25	9
Y–1	0100001	33	A
Y–2	0100010	34	B
Y–3	0100011	35	C
Y–4	0100100	36	D
Y–5	0100101	37	E
Y–6	0100110	38	F
Y–7	0100111	39	G
Y–8	0101000	40	H
Y–9	0101001	41	I
X–1	0101010	42	J
X–2	0101011	43	K
X–3	0101100	44	L
X–4	0101101	45	M
X–5	0101110	46	N
X–6	0101111	47	O
X–7	0110000	48	P
X–8	0110001	49	Q
X–9	0110010	50	R
0–2	0110011	51	S
0–3	0110100	52	T
0–4	0110101	53	U
0–5	0110110	54	V
0–6	0110111	55	W
0–7	0111000	56	X
0–8	0111001	57	Y
0–9	0111010	58	Z
Blank	1000000	64	Space
Y	0011101	29	+
X	0011110	30	—
0–1	0001111	15	/
3–8	0011100	28	=
Y–3–8	0011111	31	.
X–3–8	0001011	11	£
0–3–8	0001010	10	,
Y–4–8	0001001	9	)
X–4–8	0001110	14	*
0–4–8	0001000	8	(
any other 12-bit character	1011110	94	Wrong

PART 4: PERIPHERAL DEVICES

SECTION 7: DIGITAL INCREMENTAL PLOTTER

The controller for the digital plotter is housed in the control station (see 1.1.2.) and it shares an interrupt channel with the tape punches (see 1.2.3.).

Several models of the Digital Plotter are available; the details peculiar to each are summarised at the end of this section. The following information applies to all models.

The Device

The plotter will draw continuous two dimensional plots as a sequence of linear incremental movements of a pen over paper. Basic movements of pen relative to paper can be made along three mutually perpendicular axes. Movement of a drum, holding the paper beneath the pen, and movement of the pen carriage along tracks parallel to the drum axis give the two dimensional plot, while the pen can be raised from or lowered onto the paper to move from one trace to another.

Drum and carriage are controlled by geared stepping motors which may be stepped in either direction. The drum and carriage steps may be called for either separately or together, so that from any one point it is possible to move to one of eight others by a single move.

The pen is raised or lowered by a solenoid mechanism in the pen housing.

The paper used with the plotter may be in the form of single sheets or continuous rolls. The single sheets may be unpunched or marginally punched to fit the sprockets on the drum and should be taped to the drum of the plotter with masking tape. Continuous rolls should be 12 inches wide, marginally punched to fit the sprockets on the drum. The main drive to the paper is through the drum but a take-up drive is also connected to the feed and take-up rollers. The take-up roller on the front of the plotter can be replaced by a clear plastic shield containing a slit with serrated edge. The paper is threaded through this in action and can then easily be torn off.

When rolls are used, moving the pen along the length of the roll and back the same number of steps results in a position discrepancy of less than one step length.

The pen units for the plotter are easily interchanged and are supplied in several colours. Instead of the pen unit an eyepiece with cross-hairs may be fitted. The manual controls can then be used to position the pen exactly, where preprinted paper is in use.

A limit switch is positioned at each end of the pen carriage tracks. If the pen is given 'move left' or 'move right' pulses repeatedly the pen will stop when either switch is reached, without damaging effects, and further pulses cause no further movement in the respective directions. This fact may be used to roughly position the pen, but the cut-out is not invariably at the same place on the track so that further such use of the switch may not give the same position.

Instruction Code

The action of the plotter is governed by the least significant six bits of the address of the output instruction. These six bits are treated as a set of three adjacent pairs of bits, each pair controlling a possible direction of movement of pen relative to paper. To facilitate description of the output orders we use map conventions so that a line upwards on the drum is North, one to the right is East and pen movements are UP and DOWN relative to the paper.

With this convention	bit 1	gives an eastward movement
	bit 2	gives a westward movement
	bits 3, 4	control N–S movement
	bits 5, 6	control UP-DOWN movement.

The ten standard instructions are listed, together with their effect and the associated 6 bit character, below.

Instruction	*Character*	*Action*
72 7169	00 00 01	E
72 7170	00 00 10	W
72 7172	00 01 00	N
72 7176	00 10 00	S
72 7173	00 01 01	NE
72 7174	00 01 10	NW
72 7177	00 10 01	SE
72 7178	00 10 10	SW
72 7184	01 00 00	UP
72 7200	10 00 00	DOWN

After a 72 instruction has been issued the main processor is free to carry on as long as no further such 72 instructions occur before the plotter is free. To detect whether the plotter is free a further instruction 75 7168 can be used to fetch a control word to the accumulator; bit 34 of this is set to one while the plotter is busy.

The time taken before the 'busy' bit is cleared is determined by two electronic timers in the control logic – one for drum and carriage movements and the other for pen raising and lowering.

Non-Standard Instructions

The effect on the plotter of a self contradictory bit pair (11) for one of the basic modes is indeterminate. There will usually be some motion of the pen, depending on the state of the circuits involved at the time. Any result is carried out in a normal fashion as far as the main 503 is concerned, and no harm will result to the plotter except that the pen may not be in the anticipated position at the conclusion of the instruction.

As each pair of bits for a basic mode of motion is treated independently any incorrect bit pairs will have no effect on the other pairs, and, moreover, it is possible to specify a pen movement up or down at the same time as a drum and/or carriage movement. The motions will be executed correctly and take the time of the longest basic mode called for.

When a pen raise or lower is called for at the same time as another movement it is likely that the carriage and/or drum movements will be nearly complete by the time the raise/lower movement begins to have effect on the trace, but this should not be relied on.

Manual Controls

The following controls are fitted on the body of the plotter. Rotary two or three way switches are used with the functions clearly marked on them.

Power on/off controls the supply of main power to the plotter. A neon indicator below the switch is lit when the power is ON.

If the device is turned off and then on during a plot it will continue to function but may be one step out in any direction. The device is designed for continuous running.

Carriage Fast Run. This three position switch allows the carriage to be stepped E or W.

Carriage Single Step allows the carriage to be single-stepped to E or W. Each switching gives rise to a single pulse to the stepping motor.

Drum Fast Run allows drum control similar to those of 'carriage fast run' giving N or S steps.

Drum Single Step allows the drum to be single-stepped.

Pen Up/Down. This three position switch can issue pulses to the pen circuits similar to those given by pen raise and lower orders. If the pen remains down when the switch is turned to UP due to some discontinuity in action (e.g. changing pens or switching on) the switch should be turned to DOWN and then to UP again to raise the pen. This sequence of actions performs the necessary internal resetting for correct pen control and should be gone through, after the plotter has been switched on, to ensure that computer instructions can be obeyed.

Chart drive on/off. This switch, controlling the take-up drive to the feed and take-up rolls, is switched **on** when rolls are in use and **off** when single sheets of paper are being used and during chart replacement.

The controls so far mentioned all have some effect on the plotter even when the plotter is under computer control. Thus they should not be used unless the plotter is first placed in the MANUAL condition relative to the computer. To do this the MANUAL button associated with the plotter, and positioned on the main control console to the right of the main array of buttons and lamps, should be depressed. This button is a red, push-push button containing a lamp which is lit when the button is depressed. The depression of this MANUAL button makes the plotter 'busy' so that no instructions can be issued from the computer to the plotter.

The plotter is also made 'busy' when the control console MANUAL button is depressed (see 1.2.2.).

If the power on/off switch on the plotter is turned to 'off' when a plotter instruction is issued the plotter is detected as being in the non-available state. When this happens an error interrupt to a standard location is forced so that appropriate corrective measures can be taken.

An incorrect reference to the digital plotter causes a peripheral device error interrupt.

If there is no digital plotter controller on the 503 then the bit in the control word of the paper tape station corresponding to the digital plotter is permanently set to busy (i.e. bit 34 is set to 1).

Summary of Models

The physical characteristics of the available models of the Digital Plotter and their essential differences are detailed below. The standard model is the 565 plotter.

Model number	*Weight kg (lbs)*	*Step Size cm (in)*	*Width cm (in)*	*Chart Width cm (in)*	*Plotting Width cm (in)*
506	24 (53)	0.01	100 (39.4)	78.8 (31)	75 (29.5)
507	15 (33)	0.01	45.8 (18)	30.5 (12)	28 (11)
564	24 (53)	(0.005)	100 (39.4)	78.8 (31)	75 (29.5)
565	15 (33)	(0.01)	45.8 (18)	30.5 (12)	28 (11)
566	15 (33)	(0.005)	45.8 (18)	30.5 (12)	28 (11)

On all models the maximum width for unpunched single sheets of paper will be 0.5 inches less than the width of a marginally punched single sheet or continuous roll (i.e. Chart width).

The models specified in the above table have the following times for plotter operations:

Drum/carriage steps : 300 steps/sec.

Raise/Lower pen : 0.1 sec.

Drum/carriage fast run : 100 steps/sec.

The timer in the control logic gives a delay of 3.3 ms for carriage and drum operations and 100 ms for pen raise and lower operations.

PART 4: PERIPHERAL DEVICES
SECTION 8: INTERFACE MATCHING UNIT

INTRODUCTION

The Interface Matching Unit (IMU) is a general purpose peripheral controller, designed to minimize the special design needed for attaching a special peripheral device on to the 503. The interface between the IMU and the peripheral device is simpler than that presented by the 503 to a standard peripheral controller (1.4.5.) in that the noise rejection levels, the rise times and general response rates demanded of the IMU are less stringent. In addition the interface matching unit ensures that the chance of signals issued erroneously by the handler interfering with the operation of the computer or other peripheral devices is virtually zero.

The IMU is normally used when an existing piece of electronic equipment has to be connected to a standard 503 system. A certain amount of special electronic design may still be required to produce the signals required by the IMU. It should be noted that it is possible to use the IMU in a large number of different ways and hence it is not possible to give a complete description. For a particular use of this unit the Engineering Dept. of Scientific Computing Division, Elliott Bros. (London) Ltd., should be consulted.

The input or output rate which can be achieved is the same as that available by direct connection to the 503, viz. up to 10,000 words/sec. normally or up to 100,000 words/sec. if special programming restrictions and/or other arrangements are made.

FACILITIES

The IMU is designed to enable information to be transmitted between the 503 and the external device in any of the following ways:—

(a) Repetitive input to the 503 via an ADT using 76, 77 instructions.

(b) Repetitive output from the 503 via an ADT using 76, 77 instructions.

(c) Single word input to the 503 using 75 instructions.

(d) Single word output from the 503 using 72 instructions.

The class number (see 1.3.1.) of the IMU may be any of the class numbers not otherwise allocated. The most significant four bits of instructions referring to the IMU are then prescribed by the class number so selected. Digits 1 and 3–9 of the address of any 72, 75, 76 instruction referring to the IMU are made available to the peripheral device for use in any way desired.

SIGNAL LEVELS

The special equipment must provide and accept signals at the prescribed levels. The logic signal levels are nominally 0V and +10V for logic 1 (true) and logic 0 (false) respectively. Signals are output via Minilog F2 elements and all the drive from these elements is available to the device. (For further information regarding Minilog F2 elements apply to the Technical Information Section of Scientific Computing Division). The actual levels are:—

From device	**false level**	+6V to +10V, input impedance 6·8 KΩ to earth
	true level	−2V to +0·1V, input impedance greater than 100KΩ
To device	**false level**	+10V ±1V
	true level	+0·3V ±0·3V output impedance less than 400Ω

Note that the significance of signals on *data* lines can be reversed easily by program so that inverters here are not normally necessary.

CONSTRUCTION

The IMU including individual power stabilisers and the necessary transmitter/receivers is normally held in half a 503 peripheral controller cabinet.

The power supplies of the central processor power unit are sufficient for the IMU provided not more than two modules of Core Backing Store are included in the system. In these circumstances, therefore, a peripheral services cabinet is not required.

DETAILS OF OPERATION

76 orders may arrive at any time. They result in a control word being passed to the computer from the controller. No other action occurs on a 76 order, and no signal is passed to the device itself.

The control word contains a 'not available' and a 'busy' bit (bits 1 and 4 respectively) both generated by the controller. It may additionally contain up to four other bits, which reflect the current logic true or false states of corresponding D.C. inputs from the device to the controller.

The Control word can be increased to 10 or 16 bits provided the IMU has a 26 or 39 bit input respectively.

The 'not available' bit is controlled by an additional D.C. input from the device, which acts as a signal to the controller that the device is turned on and operational. If this signal fails, any ADT in progress is completed by the controller, so as to remove tags properly from the 503 main store.

(a) When a 72 or 77 order for the general purpose controller arrives, the controller returns busy until any operation in progress is complete. One 75 order is used for error correction and never returns busy; details of operation for other 75 orders, are given under the 75 Instructions (see below).

(b) Bits 1 and 3–9 of the relevant address are staticised – i.e. in the case of 72 and 75 orders, the address of that order, in the case of 77 orders the address of the associated 76 order. Additionally one of three staticisors is set to indicate a 72, 75 or 77 order. The content of these 11 staticisors is available to the device. They are referred to as the I staticisors. The setting of the 72, 75 or 77 staticisor indicates to the device that action is required. The device now examines the I staticisors, and subsequent action depends on the particluar instruction given.

In the case of a 77 instruction the presence of I1 (i.e. the fact that the first I staticisor has been set to 1) indicates ADT output required (i.e. odd address) and the absence of I1 indicates ADT input required (i.e. even address).

ADT Input

In the case of an ADT input instruction:—

(a) A staticisor called READY is set.

(b) The device may now place information on the INFORMATION lines. There may be 13, 26 or 39 of these.

(c) The device energises a TRIGGER line; Trigger being a pulse between 10 μs and 2 ms.

(d) READY is reset, at the beginning of TRIGGER.

(e) The data on the information lines is passed to the computer.

(f) READY is set again, and the cycle repeats. The device must change the data on the INFORMATION lines only if READY is set.

(g) When sufficient words have been read, the 77 staticisor will be reset, followed by the I staticisors. This will occur while READY is not set.

(h) The device may now turn off the final INFORMATION signals.

ADT Output

In the case of ADT output instructions:—

(a) The first word is obtained from the computer and staticised on 13, 26 or 40 DATA staticisors.

(b) READY is set.

(c) The device accepts the data and then energises TRIGGER.

(d) READY is reset at the beginning of TRIGGER.

(e) The next word is obtained and the cycle repeats.

(f) When sufficient words have been output, the 77 staticisor is turned off, followed by I the staticisors as before.

Error

If in the case of an ADT insufficient transfers are caused by the device, this being detected by a gap of 0·5 seconds or more between READY being set and the receipt of the next TRIGGER, then the controller takes the following action:—

(a) Sets an error staticisor which makes the controller unavailable.

(b) Causes artificial transfers to take place so as to remove the tags from the computer store.

The error staticisor is reset either by system reset or by a special 75 instruction (see below).

72 Instructions

In the case of 72 instructions:—

(a) The word from the computer is staticised as DATA on 13, 26 or 40 lines, and also the I staticisors are set.

(b) READY is set.

(c) The device accepts the data and then energises TRIGGER.

(d) At the beginning of TRIGGER, READY is reset, together with the 72 staticisor and the I staticisors.

75 Instructions

There are two kinds of 75 instructions.

In the case of a 75 instruction with the I staticisors 1 and 3–9 all being set to zero the following occurs:—

The Controller is always available and not busy, the control word is sent to the computer after which the error staticisor is reset and a 10 μs error reset waveform is made available to the device.

In the case of a 75 instruction with at least one of the significant I lines at 1 the following occurs:—

(a) It is expected that the device is waiting, with a word available on the information lines.

(b) When the 75 occurs, the information is sent to the computer on 13, 26 or 39 lines, READY is set, and the IMU goes busy.

(c) The device may make the IMU not busy by sending TRIGGER, and READY will be reset at the end of the trigger as usual.

There are two ways of using these 75 facilities:—

(1) In the case of a device which normally expects a stream of 75 orders, e.g. a tape reader, the next word is placed on the information lines by the device before it sends TRIGGER as in (c) above.
Thus the IMU remains busy until the word is available.
The IMU is normally not busy when first switched on, so that it may be necessary to have some initiation process, either manually or as in (2) below.

(2) Alternatively, it may be desirable to select one of a number of channels by a 72 order, and then read the channel by a 75 order. In this case, the device will make the IMU not busy as in (c) above without changing the word on the information lines, or possibly clearing the word. Thus a further 75 order would receive either the same or meaningless information.
When the 72 order arrives, the word from the computer is probably meaningless, though available if required. Usually the I staticisors specify what word is to be input on the following

75 order. This word is then placed on the information lines before the TRIGGER is energised. Thus, as soon as the IMU becomes not busy, the word is there, ready for the subsequent 75 order, so that 72, 75 pairs may be written without too much concern over the 'busy' situation.

It is suggested that if 75 orders are to be used in either of the two ways outlined, one of the four control bits available for the device should be used to indicate whether a 75 order, if issued, would receive valid information or not – i.e. whether the device is 'expecting' a 75 order.

SPECIAL FACILITIES

Control Busy

When this line is made true by the external device, the computer is prevented from carrying out any non ADT instruction for the duration of any ADT controlled by the IMU. This enables an ADT rate of up to 50,000 words/sec.

Hold Demand

When this line is made true by the external device, an ADT once commenced, will take place at a rate determined by the computer at approximately 100,000 word/sec. In this case the external device must be synchronized with the computer – i.e. the device must be capable of sending TRIGGER on receipt of READY.

PART 4: PERIPHERAL DEVICES
SECTION 9: HIGH SPEED CHARACTER PRINTER

The character printer is a serial printer operating at a nominal speed of 100 char/sec. Each character is made up from a set of dots arranged within a 5 x 5 array.

The equipment is arranged to plug into a socket of the paper tape punch and to operate in the place of that punch; in addition the punch itself is connected to the computer via a special control box. The equipment can be installed in the field, to 503 control stations. The movement of a manual switch will route the information sent from the computer either to (a) the high-speed printer or (b) the paper tape punch. When the switch is in position (b) the printer can be used for off-line printing of paper tape via its own tape reader.

The printer includes horizontal and vertical tabulate facilities.

The equipment comprises:—

(a) Printer and Console
(b) Tape reader and Pedestal
(c) Electronic change-over box

The box plugs into either punch socket on the output console and provides a socket into which the punch may in turn be plugged. The box is situated on the output console. The printer must be within 15 feet of this box and the tape reader within 6 feet of the printer. The tape reader is a 200 char/sec. reader which is used to drive the printer when off-line.

DIMENSIONS AND WEIGHT

	Width (ins)	Depth (ins)	Height (ins)	Weight (lbs)
Printer and Console	34	26	46	400
Tape Reader and Pedestal	18	18	30	
Electronics Box	5½	8½	4½	

POWER SUPPLY

3 phase, 50 cycles supply provided on 4 lines, 220-240 volts plus or minus 10% line to neutral is required. Current requirements do not exceed 6 amps per phase for starting and one amp per phase when running.

CHARACTER SPECIFICATION

Characters are printed at a spacing of 10 to the inch; the line spacing is six lines per inch. Each character is approximately .1 inch high by .08 inches wide and is formed by selecting any number of points from a total of 25 points arranged in a 5 x 5 array.

The line length can vary between 0 and 150 characters printed on standard sprocket-fed stationery of width 6 inch minimum to 17$\frac{55}{32}$ inch maximum. Up to four carbon copies can be obtained.

Two standard character repertoires are provided:—

1. The 503 8-channel code with the exception of lower case letters. (See Appendix I).
2 The standard Elliott 5-channel code.

An attempt to print lower case letters will cause the corresponding upper case letter to be printed. The character repertoire is controlled by a plug-in box.

Line feed time is 40 msecs. Carriage return time is 300 msecs. maximum.

A right-hand adjustable margin stop is provided and an attempt to print beyond this will cause overprinting of the last character.

TABULATION

Horizontal tabulation facilities are provided by means of inserting pins in any of 150 positions in a panel. On receiving the tabulate character the printer spaces at a normal speed of 100 char/sec. until it reaches the specified pin. The pins may be as near to the left-hand margin as desired, but a pin will not be found if it occupies the next character position to that of the current position of the print head, the nearest position being two characters from the head. It is not possible to place pins in adjacent character positions. An attempt to tabulate beyond the last pin position will place the printer in Busy and require manual intervention (a series of additional pins should therefore be inserted at the extreme right-hand end to overcome this).

Vertical tabulation facilities are provided by inserting pins in a disc that rotates once per standard 66-line sheet of paper. The rate of tabulation is 100 lines per second. Vertical tabulation stops as soon as any pin is encountered.

On the 5-channel version, no Vertical Tabulate control character has been allocated.

OPERATION

An on-line/off-line switch is provided. When on-line the printer gives a direct print up of the information that would normally be sent to the punch with the following differences:—

(a) The rate for horizontal tabulation is 100 char/sec.
(b) The rate for vertical tabulation is 100 lines per second.
(c) Line feed takes up to 40 msecs.
(d) New line takes up to 300 msecs.
(e) An attempt to print a line longer than set may cause overprinting. (See CHARACTER SPECIFICATION.)
(f) Tabulate may cause a hold-up condition (see TABULATION).
(g) The codes differ from the flexowriter code in the following respects:—
    (i) Codes 62 (vertical Bar) and 126 (underline) are escaping.
    (ii) Lower case alphabet is printed in upper case.
    (iii) All unallocated codes cause Δ to be printed.
    (iv) Stop and Blank are ignored.

The printer motor switches off automatically approximately 30 seconds after the most recent print instruction and subsequently takes about 1½ seconds to turn on automatically on receipt of the next instruction.

MANUAL CONTROLS

The following controls are provided on the console.

1. **Off/Manual/Auto**

   Three position rotary switch. When switched to the OFF position only the printer motor will be off, so that it is quite safe to change paper, etc.

The following controls are only effective when the printer is switched to manual.

2. **On-line/Off-line**

   Non-locking, push-button switch containing two lamps. The top half is illuminated green when the printer is ON-LINE, and the bottom half is illuminated yellow when OFF-LINE. This switch is only effective when the printer is switched to manual. It may be necessary to wait up to 30 seconds after the last output order was obeyed before the change can be effected. This is because the motor remains energised for approximately 30 seconds after the last print order as the best compromise between excessive switching on and off and remaining on continuously.

3. **Spaces**
   Non-locking, push button switch. The printer will space at 100 characters per second whilst depressed.
4. **Line Feeds**
   Non-locking, push-button switch. The printer will line-feed at a minimum speed of 25 lines per second whilst depressed.
5. **Space,** single shot
   Non-locking, push-button switch. The printer will space one character position each time it is pressed.
6. **Tabulate**
   Non-locking, push-button switch. The printer will start one tabulation operation when pressed.
7. **Print-head Return**
   Non-locking, push-button switch. The printer will return the print head to the beginning of the line from any position when pressed.
8. **Line-feed,** single shot
   Non-locking, push-button switch. The printer will feed one line each time it is pressed.
9. **Vertical Tabulate**
   Non-locking, push-button switch. The printer will initiate a vertical tabulate which will continue at 100 lines per second until the next stop is reached. The maximum throw is 12 inches.

INDICATOR LAMPS

There are indicator lights to show each of the following conditions:—

Printer in AUTO (Yellow)

Paper Supply low (Red)

Note: This lamp is incorporated in a switch which enables an operator to override this error condition by first going into MANUAL and then pressing the switch.

Oil pressure low (Red)

Parity (Red)

Note: This lamp is incorporated in a switch which enables the operator to reset after first going into MANUAL. The lamp is lit if a parity error is discovered.

OFF-LINE OPERATION

When off-line the printer reads from paper tape via its own reader. It is completely disconnected from the computer and its motor is permanently switched on. The manual controls are still effective so long as the rotary switch is in the MANUAL position.

BUSY-INTERRUPT

An attempt to output to the printer when on-line will be held up on Busy in the following cases:—

Printer in Manual

Low Oil Pressure indicated

No paper in printer

Parity error

These conditions are indicated by corresponding lamps on the console. The Busy state of the printer can be detected in the same way as the corresponding punch by giving a 75 7168 instruction and an interrupt is given when the printer goes unbusy.

APPENDIX 1

8-CHANNEL PAPER TAPE CODE

00000.000	0	N	01010.000	32	;	10010.000	64	S	11000.000	96	?
00010.001	1		01000.001	33	A	10000.001	65		11010.001	97	A
00010.010	2	L	01000.010	34	B	10000.010	66		11010.010	98	B
00000.011	3	P	01010.011	35	C	10010.011	67		11000.011	99	C
00010.100	4	T	01000.100	36	D	10000.100	68		11010.100	100	D
00000.101	5		01010.101	37	E	10010.101	69		11000.101	101	E
00000.110	6		01010.110	38	F	10010.110	70		11000.110	102	F
00010.111	7		01000.111	39	G	10000.111	71		11010.111	103	G
00011.000	8	(	01001.000	40	H	10001.000	72		11011.000	104	H
00001.001	9	)	01011.001	41	I	10011.001	73		11001.001	105	I
00001.010	10	,	01011.010	42	J	10011.010	74		11001.010	106	J
00011.011	11	£	01001.011	43	K	10001.011	75		11011.011	107	K
00001.100	12	:	01011.100	44	L	10011.100	76	N	11001.100	108	L
00011.101	13	&	01001.101	45	M	10001.101	77		11011.101	109	M
00011.110	14	*	01001.110	46	N	10001.110	78		11011.110	110	N
00001.111	15	/	01011.111	47	O	10011.111	79		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	

Abbreviations

N No effect S Space P Paper Throw (Vertical Tabulate)

L New line T Tabulate

All unallocated codes generate the symbol Δ Codes 62 (|) and 126 (—) are escaping.

APPENDIX 2

5-CHANNEL PAPER TAPE CODE FOR HIGH SPEED CHARACTER PRINTER

		Character	
Binary	*Decimal*	*Figure Shift*	*Letter Shift*
00.000	0	bl	bl
00.001	1	1	A
00.010	2	2	B
00.011	3	*	C
00.100	4	4	D
00.101	5	&	E
00.110	6	=	F
00.111	7	7	G
01.000	8	8	H
01.001	9	'	I
01.010	10	,	J
01.011	11	+	K
01.100	12	:	L
01.101	13	—	M
01.110	14	.	N
01.111	15	%	O
10.000	16	0	P
10.001	17	(	Q
10.010	18	)	R
10.011	19	3	S
10.100	20	?	T
10.101	21	5	U
10.110	22	6	V
10.111	23	/	W
11.000	24	@	X
11.001	25	9	Y
11.010	26	£	Z
11.011	27	fs	fs
11.100	28	sp	sp
11.101	29	cr	cr
11.110	30	lf	lf
11.111	31	ls	ls

Abbreviations

bl	blank—no effect	cr	carriage return
fs	Figure shift	lf	line feed (**without** carriage return)
sp	space	ls	letter shift

PART 4 : PERIPHERAL DEVICES

SECTION 10 : MAGNETIC FILM

1. GENERAL DESCRIPTION

1.1. Facilities for using magnetic film on the 503 are provided by attaching an 803 controller and film handlers to the 503 via an 803/503 film matching unit. A standard film store consists of a controller unit and from 1 to 5 film handlers. The maximum number of handlers which can be used in any single program is 4, but it is often convenient to have a spare. Handlers are numbered 1, 2, 3, 4, S (where S means spare) and no more than one handler must be switched to the same number at the same time. Spare handlers cannot be accessed by program.

Each handler holds one spool of 35 mm. magnetic film and films are interchangeable between handlers.

1.2. The matching unit accepts instructions from the 503, processes them and then sends them to the 803 film controller. Thus the matching unit appears as a peripheral to the 503 but as an 803 central processor to the film controller. The film controller cabinet connects the film handlers to the film matching unit and controls their operation.

1.3. A film is 1,000 ft. long and is divided into 4096 permanently addressed blocks of equal length. Alternate blocks are numbered sequentially. They are interleaved so that blocks N and 4095—N are physically adjacent to each other. Blocks 0 to 2047 are read in one direction and blocks 2048 to 4095 are read in the opposite direction. The order of blocks on the film is:

4095, 0, 4094, 1, 4093, 2, ...

..... 2050, 2045, 2049, 2046, 2048, 2047.

The direction of the film is automatically reversed when block 2047 or block 4095 is passed so that block 2048 appears to immediately follow block 2047 and block 0 to follow block 4095.

1.4. Each block has a fixed capacity of 64 words. Since data is recorded on the film in rows on 7 parallel information tracks, the 39 bit computer words are split up into 6 film characters of 7 bits each. The block address is recorded on a separate track known as the block address track, in which the address is positioned at the start of the data block. This track on the film can be read but cannot be changed or destroyed by program.

There is a further 9th track which is inaccessible to the programmer, known as the clock track. This is used for timing. It is written when each data character is written on film and is used when reading to indicate to the equipment the exact moment when the film character is under the reading heads.

(Recording is by a 'non-return to zero' method having a basic character time of 240 μ sec.).

Once a film block is properly recorded it will retain the correct information almost indefinitely.

1.5. To provide a check on information held on magnetic film a parity bit is included in each word of data and in each block address. Odd parity is maintained throughout. The parity bit for each word is held in the 40th bit position, after the 39 bits of the computer word. The remaining 2 bits (41, 42) of the 6th film character of each word are spare.

1.6. The state of the film matching unit is held in a special control word. Only 2 bits of the 5 bit control word are used, the other 3 bits are always zero. A control word is also maintained for each handler and this indicates the state of the handler at any instant, i.e. whether it is under manual control, searching, etc. These control words give information to the programmer which can be used to prevent a hold up occurring in the Central Processor. For further details see Paragraph 4 of this Section.

1.7. Programs written for the 803B using magnetic film will work, unaltered on the 503 provided that the last 30 locations of store are not used.

Magnetic film is included in the device list for the Peripheral Control Program which uses the interrupt facilities of the 503 to arrange maximum utilisation of the peripherals. In addition, programs not using PCP, may contain instructions for use of magnetic film in the 503 interrupt system, providing certain programming restrictions are adhered to (see Paragraph 6 of this Section).

2. OPERATIONS

2.1. Three types of operation are provided to allow the film to be used as extra store: reading a block of words from film into store, writing a block on to film and searching for a film block. Only complete blocks of 64 words can be transferred at a time. When reading, the 64 words of the film block are transferred to 64 consecutive locations of the main store and when writing 64 consecutive words from the main store are transferred to the required film block.

2.2. Two types of instruction are needed to perform each of these operations—a prepare instruction, and an execute instruction, similar in operation to the prepare and execute instructions required on other 503 peripherals. The prepare instruction also brings into the accumulator the control word for the specified handler.

The 76 (prepare) instruction places the handler control word in the 5 least significant bits of the accumulator, the remaining bits being set to zero. The parity bits in the control word for that handler are then set to zero.

If a 76 instruction is sent to the matching unit when the film controller is not busy then:

1. The matching unit starts the 803 controller working.
2. The matching unit sends a busy signal to the 503.
3. The matching unit remains busy while the 503 cycles on the 76 instruction until a copy of the handler control word is placed in the accumulator and the handler control word then reset (thus clearing any error states that existed).

Any number of 76 instructions may be given but every 77 (execute) instruction must be preceded by a 76 instruction, although they need not be consecutive to each other. Attempting to obey a 77 instruction without previously obeying a 76 instruction causes an error interrupt.

2.3. The instruction code (the same as for the 803) is as follows:

to read

76 1024 + 8(H − 1)	places handler H control word in the accumulator, clears any error states and prepares to read from handler H. (H can take values from 1 to 4)
77 N	reads the next block into locations N to N + 63 of main store.

to write

76 1025 + 8(H − 1)	places handler H control word in the accumulator, clears any error states and prepares to write on Handler H.
77 N	writes the next block from locations N to N + 63 of main store.

Reading and writing use the ADT facilities of the 503. Thus when a 77 instruction is given, the store is tagged and the central processor is then free to carry out other instructions. However in order to be compatible with the 803, any film instruction (applying to any handler), which is given when a read/write instruction is being performed causes the central processor to be held up i.e. unlike any other device the film 76 instruction can be held up on busy, to correspond with the effect produced on the 803.

2.4.

to search

76 1026 + 8(H − 1) places handler H control word in the accumulator clears any error states and prepares to search on handler H.

77 N searches for block N (so that it may subsequently be read or written).

A search is made by the shortest route. The current position of the film on the specified handler is determined, first, by reading the next block number. A direction reversal occurs if necessary and the film block numbers are continually read until the required block is found. No search operation is required if consecutively numbered blocks are used e.g. numbered N, N + 1, N + 2, ...

Only one search may be executed at any one time regardless of the number of handlers attached to the machine. All other film instructions on other handlers may be carried out while a search is in progress; but if a read/write instruction is given to the handler engaged on a search the operation is held up until the search is complete. E.g. if a search is taking place on handler 2 then the effect of other film instructions is as follows:

Function	*Action*	*Central Processor*	*Matching Unit*
Read/Write on H1	takes place immediately	free	busy
Search on H1	accepted by film for later	free	busy
Read/Write on H2	accepted by film for later	free	busy
Search on H2	accepted by film for later	free	busy

The matching unit busy means that any further 76 will cause the central processor to be held up.

2.5. An additional instruction, also present in the 803 instruction code is:

75 1027 which transfers to the accumulator the address of the last block read or written from the last handler to be operated on. The address is written into the 13 least significant bits of the accumulator, the rest being set to zero.

2.6. Two further 75 instructions are provided for use of magnetic film in the 503 interrupt system, and these are described in Paragraph 6.

The functions 75 and 76 take 576 μ secs. to perform although the central processor is only occupied for approximately 300 μ secs. If a further film instruction is given the central processor is held up in a busy state until the original 75 or 76 instruction is completed.

3. MANUAL CONTROLS AND LAMPS

The manual controls are situated across the top of the handler cabinet and are shown in Figure 1.

3.1. Switches

HANDLER NUMBER (5 position switch) This switch may be turned to any of five positions to determine whether the handler is to be used as handler number 1, 2, 3, 4 or S for a particular program to be run. S indicates spare. Only one handler should be set to a particular number at any one time. If two or more handlers are set to the same number, the red error light beside the switch lights on all handlers and the 2^{-38} bit in the control word for each handler is set to 1.

Any number of handlers may be switched to 'spare' at the same time. *This switch should not be moved when any part of the film unit is under computer control.*

OFF (push switch)

switches off power in the handler except the incoming mains supply and −24V for the controls: when the power is off the red light is on. Its use should be avoided when any part of the film system unit is under program control.

ON (push switch)

This is only operative when the power is on at the computer and the handler is switched to MANUAL (OFF and MANUAL lamps on). When the supply is on, the button lights green.

MANUAL (push-push switch)

When pressed and the button lights yellow, the handler is no longer under computer control.

If a read or write operation is in progress when the button is pressed the operation is completed before the handler is released from computer control. If a search operation is in progress, the search stops at the end of the next block and can be resumed by releasing the MANUAL button.

When pressed and the light goes out, the handler is in the 'auto' state and capable of control by the 503.

The MANUAL switch has no effect on the action of the HANDLER NUMBER, OFF and PARITY OVERRIDE switches but *all others are only operative when the handler is in the manual condition.*

LOAD (push switch)

When pushed this button will cause the film to be tensioned correctly and after about 5 secs. when the motors are working normally the sprockets drive the film left until either a beginning of block mark or beginning of film mark is encountered. The light comes on when the button is pressed and goes out when the operation is complete. The MANUAL button may now be pressed to return the equipment to the 'auto' condition, (MANUAL lamp out).

N.B. A film must be 'loaded' before the handler can be put in the 'auto' condition.

UNLOAD (push switch)

When a spool of film is to be removed from the handler, control is put to manual and the UNLOAD button is pressed. The lamp lights blue and the film is moved to the right until the end is free of the left-hand spool when the motors stop.

MOVE LEFT (push-push switch)

When either is pressed the film moves in the appropriate direction until the button is pressed again or the end of film marker is reached.

MOVE RIGHT (push-push switch)

The film stops in a position to read the next block.

If the MOVE RIGHT button is pressed while the film is obeying the MOVE LEFT button, nothing happens until the MOVE LEFT button is pressed for the second time, when the film will move to the right until the MOVE RIGHT button is pressed again (and vice versa).

WRITE PERMIT (push-push switch)

Permits or prohibits writing on the film when handler is in 'auto' condition. (Writing is always prohibited in the manual condition.)

Changing the setting of the switch when the handler is in 'auto' has no effect. The amber light is on when writing is permitted.

PARITY OVER-RIDE (push-push switch) — When on, it is lit red and *all* handlers ignore any parity errors that arise; the system continues if one occurs, but does not write on any block in which a block address parity error has occurred although it will appear to do so. It remains effective until the button is released.

RESET (push switch) — This cancels any search in progress and clears the control word parity error digits.

Pressing the reset button on any handler resets all handlers.

3.2. Lamps

HANDLER NUMBER ERROR LAMP — The ERROR lamp lights when more than one handler is set to the same number. No harm is done when the film unit is at rest and not under program control but at any other time trouble may result.

DATA PARITY ERROR LAMP / ADDRESS PARITY — When a film parity error is detected on a handler, the corresponding lamp lights on that handler.

SEARCH LAMP — This lights while a handler is searching. A search can be stopped by pressing the RESET button.

4. CONTROL WORDS

4.1. The control word for each handler consists of 5 bits which are allocated as follows:

bit 1 The handler is not capable of being controlled by the 503 i.e. it is disconnected, switched off, in manual, or two handlers are switched to the same number. (The latter affects *all* handler control words as well as those belonging to the handlers in error.)

bit 2 Block address parity error has been detected in the block address.

bit 3 Writing is permitted on this handler.

bit 4 This handler is busy on a search instruction.

bit 5 Data parity error has been detected during reading.

A one in any of these positions indicates that the respective condition is true; a zero indicates a false condition.

Examples: (1) If a handler is set to 'auto' and a block address parity error has been detected, the control word is 00010, i.e. the integer + 2.

(2) If, in addition writing is permitted on this handler the control word is 00110, i.e. the integer + 6.

(3) If a handler is in the manual state the control word is 00001, i.e. the integer + 1.

When a 76 instruction is obeyed a copy of the handler control word for the named handler is placed in the accumulator and the parity bits in positions 2 and 5 are reset to zero.

4.2. The 5 bits of the matching unit control word are allocated as follows:

bits 1-3 Always zero.

bit 4 Matching unit busy.

bit 5 The film did not send back a 'transfer' within 1 second of the issue of a Read/Write instruction; or the time between word transfers is greater than 1 second during the operation of a Read/Write instruction, and indicates a failure to transfer the complete number of words.

5. ERROR CONDITIONS

5.1. Programming and operating errors

An error interrupt will occur as a result of any of the following errors:

1. Attempting to obey a 77 instruction without previously obeying a 76 instruction.
2. Attempting to obey a 77 instruction with the film handler on MANUAL or with the power turned off, etc. i.e. when bit 1 is set in the handler control word.
3. Attempting to obey a 77 instruction with the power turned off at the controller.

Attempting to obey a 75 or 76 instruction with an impossible address may cause the matching unit to become permanently busy, and must be cleared by pressing the RESET button on the 503 console.

Errors may be caused if the handler is switched on when it is not in the manual condition.

5.2. Hardware errors

Data parity errors can occur on both read and write operations but they are only detected during a read operation. Thus a block can be written on film incorrectly, such that a wrong parity word is present on the film. This can only be detected by trying to read back the same block. If this fails several times on data parity, the error can be assumed to be a write, rather than a read error. A data parity error occurrence during reading does not cause a word with wrong parity to be written into the main store.

Block address parity errors are detected on read and write operations. The appropriate bit in the control word is set to one immediately a parity error is detected and the associated lamp on the film handler is lit. The 503 stops when the film operation, in which the parity error was detected, is complete, unless the PARITY OVER-RIDE switch is on. *In the case of a block address parity error occurring during a write operation, writing on the film is inhibited.*

When a block address parity error occurs during a read or write operation, it may mean that the wrong block is operated on and it is for this reason that the write operation is made ineffective.

Since the block address track is only recorded once, before a new film is delivered a persistent parity error on the block address track is indicative of a fault in the reading equipment or alternatively of a deterioration of the film itself, and unless the error is isolated the cause should be investigated as soon as convenient.

If a search is begun and due to an error on the block address track, the correct block cannot be found, the search may go on indefinitely. If this should occur, any film RESET button should be pressed to stop the search.

The effect of the PARITY OVER-RIDE button is as follows:

On: If this is *on* on *any* handler, film parity errors cause the corresponding bit to be set in the handler control word but the film does not stop.

Off: film parity errors cause the Matching unit to remain busy after transferring the 64th word (i.e. the last word) of the block being operated on, if this switch is *off* on *all* handlers.

If a main store parity error occurs during a film write operation, the operation is completed before the 503 stops on error interrupt. The wrong parity is transferred to the film and will not be detected until that block is read.

6. RECOMMENDED USAGE

6.1. When using film in the 503 interrupt system, a means of checking the matching unit control word and correcting any errors that may have occurred is essential, in order to prevent a hold up

occurring in the central processor or the matching unit becoming permanently busy (until reset by the RESET button on the 503 console). The instructions provided for this purpose are described below.

75 1152 places in the accumulator a copy of the matching unit control word

75 1280 causes the store locations associated with an unfinished transfer to be detagged and when complete resets bit 5 of the matching unit control word

The matching unit is never busy to these instructions.

Bit 4 is set in the matching unit control word when the matching unit is busy and any further 76 instruction will cause the central processor to be held up. In order to prevent this occurring the programmer should give a 75 1152 instruction before each 76 instruction so that he can examine the matching unit control word thus obtained and take the required action, i.e. if bit 4 is set, then no film 76 instruction should be given until it is cleared.

When a data transfer takes place, in certain error conditions the controller may fail to demand its full number of word transfers. This results in the 503 having store locations tagged for transfers to film and causes the matching unit to remain permanently busy. The matching unit detects this state, setting bit 5 in the matching unit control word if a word transfer does not take place within 1 second of the start of a 77 instruction or if there is more than 1 second between word transfers.

If on examining the matching unit control word the programmer discovers bit 5 is set he should give a 75 1280 instruction. This is accepted immediately by the matching unit, which demands data word transfers from the 503 until all the tagged store locations associated with the matching unit are detagged. The 77 instruction is thus completed, but incorrectly. Bit 5 is reset in the matching unit control word. Then the programmer should repeat the transfer operation in which the error occurred.

Bit 5 of the matching unit control word may also be set if the following programming restriction is not adhered to. A read/write instruction must never be given to a handler which is busy on a search. If this is not observed, the instruction is accepted by the film for later and since a word transfer does not take place within one second, bit 5 of the matching unit control word is set (in addition to bit 4), and a final program stop may be caused. This can be avoided by examining the handler control word before giving any 77 instruction and taking the necessary action.

While the 503 is waiting for the film controller to provide a block address during a 75 instruction or a control word during a 76 instruction, ADT's and interrupts are allowed to take place. If an interrupt (e.g. error or manual) occurs when the 503 is cycling on the 76 instruction it may result in restart of a program which causes a different 76 instruction to be sent to the matching unit. Therefore, if a 76 instruction is not repeated within 45 to 60 μ secs. the instruction is cancelled. Another 76 instruction then issued by the 503 to the matching unit is treated as a new instruction.

The chances of this occurring are very slight but if it does occur the error states in the control word may be lost when the 76 instruction is cancelled so that parity error may not be detected.

6.2. In general programs are run with the PARITY OVER-RIDE switch on to allow the programmer to check the handler control words for parity errors.

It is important that programs should include instructions to test the handler control words in order to prevent time being wasted by operating and programming errors which can be avoided, and also to check for parity errors. In the event of an error which has caused a wrongly performed operation the program should initiate a repeat or display a message to the operator. If more than three repeats still prove unsuccessful then probably there is a fault in the handler or the film. However, a small proportion of parity errors may be expected in any extended film program and only a significant increase in the frequency of parity faults should be taken to indicate a fault in the equipment.

The parity checking mode i.e. PARITY OVER-RIDE off, is generally only used in special circumstances such as maintenance or program debugging, since considerable time may be taken in restarting.

The Peripheral Control Program may be used for input/output from/to magnetic film, thus eliminating the need for detailed checking by the programmer, while ensuring maximum utilisation of the 503 peripherals. There is also a set of 803 library programs which simplify the use of film and provide various additional facilities.

6.3. Every block of a new film should be written with the PARITY OVER-RIDE on before any reading operation is attempted since the method of checking a film is such that information with wrong parity may be left on the film.

It is recommended that the operator should keep records of the use to which each film is put including full details of the occurrence of errors or suspected errors.

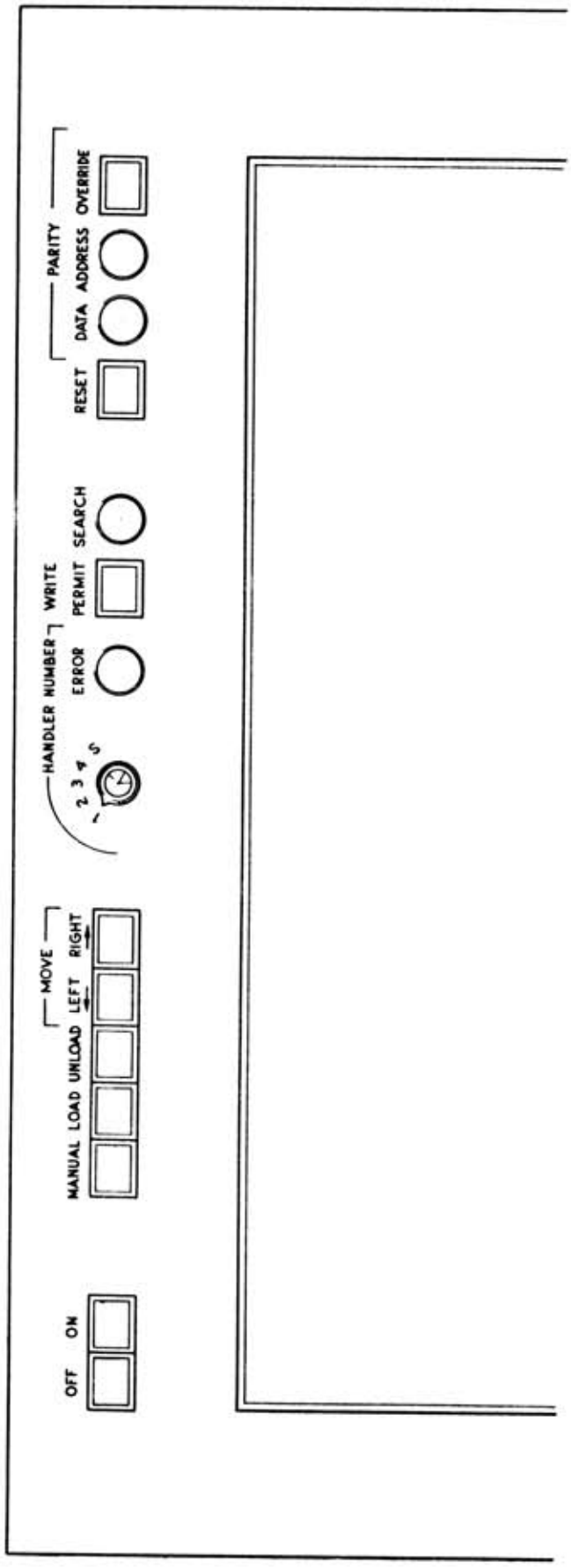
7. STORAGE AND MAINTENANCE OF FILMS

A high standard of cleanliness is required when handling films. They should be stored in dustproof boxes which are preferably non-inflammable. The part of the film between the end of film marks must be free from dents, creases or joins as this may damage the read/write head.

The handler doors must never be left open longer than necessary, nor should they be opened when the air is dusty. For further notes on general operation and maintenance of film equipment see T.I.S. 68.2.8.64.

8. SUMMARY TABLE

Type of film	35-mm. magnetic oxide coated polyester base.
Film length	1,000 ft. per spool.
Film capacity	4096 blocks or 262144 words.
Block length	2.55 in. (average including gaps = 2.8 in.).
Start distance from rest	1.69 in. approx.
Stop distance	1.12 in. approx.
Film speed	27.5 in./sec. approx.
Rate of block transfers	Slightly under 5 blocks/sec.
Rate of character transfers	4.17 kc.
Block traversal time at full speed	102 ms. (including one interblock gap).
Operation of:	
75 instruction	576 μ sec.
76 instruction	576 μ sec.



HANDLER CONTROL PANEL

Figure 1 (cont'd)

PART 4: PERIPHERAL DEVICES

SECTION 11: ON-LINE CLOCK

INTRODUCTION

This device is designed to give, if it is desired, an accurate measure of program running time and is housed in the control console.

The clock is basically a binary serial counter of 14 bits whose count is increased by 1 every $\frac{1}{8}$ second (timed by a crystal controlled oscillator). The count is the value of the counter, regarded as a binary number, and it increases until it reaches its maximum value, $2^{14} - 1$, with all 14 bits set to 1. The counter then overflows with the next increment so that all the bits are reset to 0 and the count continues through another cycle. A complete cycle of the on-line clock is achieved every $2^{14} \times \frac{1}{8}$ seconds i.e. every 34 minutes 8 seconds.

The on-line clock shares the normal interrupt channel 3 with the paper tape punches and digital incremental plotter.

It can be examined by a program at any time. When a program requires access to the on-line clock it uses the instruction 75 7169 which reads the state of the clock counter, i.e. the control word, into the main accumulator.

No manual controls are provided and it is not affected by any reset, clear store, or other controls but runs whenever the machine is on.

CONTROL WORD

The control word gives the necessary information about the condition of the on-line clock. Bits 8 to 21 represent the state of the clock in the following way:-

bit 8 switches (i.e. changes from 1 to 0 or 0 to 1) every $\frac{1}{8}$ second
bit 9 switches every $\frac{1}{4}$ second
bit 10 switches every $\frac{1}{2}$ second

and so on until

bit 21 switches every 17 minutes 4 seconds.

The timing system uses a crystal controlled oscillator whose accuracy is $\pm$ .01% i.e. $\pm$ 1 second in $2\frac{3}{4}$ hours.

The initial value of the count when switching on is not defined but is purely random.

Bits 34 to 39 of the control word are the six busy bits associated with the control system (see 1.2.2.).

Unlike most peripherals, the clock can go busy of its own accord without a central processor instruction (while the count is being increased every $\frac{1}{8}$ second) but the time it is busy is so short that it is unnecessary to have a busy bit in the control word.

PERIPHERAL CONTROL PROGRAM (PCP) AND INTERRUPTS

A device routine for the digital clock will be included in PCP. This will enable the program to take readings from the clock at the beginning and end of the program run and, if the clock overflows, it takes this into account.

The on-line clock shares the normal interrupt channel 3 (see section 2.5.3 of this manual) and PCP examines its state as soon as possible after the INTERRUPT is given. The INTERRUPT occurs when the 16th bit of the control word switches from 0 to 1, which is every 1 minute 4 seconds. There are, therefore, 32 INTERRUPTS per clock cycle.

INSTRUCTION CODE

75 7169 is the instruction for determining the state of the on-line clock. This transmits to the main accumulator the six busy bits (34 to 39) of the control word associated with the control station (just as with the instruction 75 7168 - see 1.2.2.) in addition to the fourteen bits (8 to 21) which give the state of the clock.

The instruction may be held up in the central processor for about 20 microseconds by a signal line, PERIPHERAL BUSY, from the clock controller if the counter is about to be, or is being, increased. This prevents any attempt to transfer to the main accumulator a copy of the control word while some of its bits are switching (and are, therefore, undefined). It is arranged that the PERIPHERAL BUSY signal is given well in advance of the switching so that the copying of the control word is always completed before the next increment to the counter can occur.

PART 5 OFF-LINE EQUIPMENT

CONTENTS

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. It is a recorder–reproducer, and 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 1. 2. 1.

Keyboard layout. See diagram on page 5.

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.

Carriage. The standard carriage is the 12–inch but as optional extras, a 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.

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 is copied, including those which are not associated with a keyboard key (See Switch 6).

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 a 'Non–Print' switch and enables tapes to be copied from reader to punch without printing taking place.

Switch 6. This switch is an "OVERRIDE STOP" switch and when depressed 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 the 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 "Programatic" functions. These functions are mainly associated with the control of the auxiliary reader and punch, when fitted.

Switch 10. Punches the "run out" character (00000000) 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 5) (Throw). This key punches the "throw" character (00000011). If the electric line finder is fitted a paper throw is caused.

Key 42. (See Page 5) (Vertical bar and Underline). This key is non-escaping, i.e. the carriage does not move when the character is typed.

Stop Code. The Stop or Halt Code (10011100) will, when read by the reader cause the Flexowriter to halt unless override stop (switch 6, see above) is depressed.

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) Flexofeed 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).

(6) Addition of an auxillary 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 auxillary tape punch, for systems use.

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