Cambridge Series I/O Processor

USER GUIDE

Input/Output Processor Guide

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Contents

1. Introduction

1.1 This Guide

Function of this guide

This guide describes the uses of the facilities provided by the I/O processor in the Acorn Cambridge Workstation. Most of it also applies to the BBC Microcomputer (Models B, B+ or Master 128) in a system with an Acorn Cambridge Co-Processor.

The guide provides the Workstation (or the Co-Processor) user with information otherwise found in the *BBC Microcomputer System User Guide* (for the model B+) and the other manuals listed in the *Guide to Documentation* section of the *ACW Welcome Guide*. Specialist users may need to refer to these publications, but this guide covers the vast majority of situations.

See also the *Guide to Documentation* in this publication.

Conventions observed in this guide

(1) The Acorn Cambridge Workstation is usually abbreviated to 'ACW'. It contains one floppy disc drive and one Winchester drive.

(2) The term *I/O Processor* refers both to the I/O Processor built-in to the ACW and to the BBC Microcomputer in a system built around a Cambridge Co-Processor.

(3) [BREAK] [RETURN] [ESCAPE] [SHIFT] and [CTRL] signify the corresponding keyboard keys rather than the actual words.

(4) In examples where commands have to be typed in response to a prompt (e.g. the Panos prompt '->'), both the command and the prompt are shown, for example:

```
-> cat -help
```

It is assumed that command lines are terminated by [RETURN].

(5) Non-decimal numbers are prefixed by their base. For example 16_1A is decimal 26; and -2_1010 is equivalent to -10 in decimal.

1.2 The System Architecture

Figure 1 shows the main functional units of the ACW (or the Cambridge Co-Processor). All peripheral devices are handled by the 6502 I/O (Input/Output) processor, which communicates with the main 32016 processor via the TUBE interface.

1.3 Communicating with the I/O Processor

The peripherals are handled by firmware controlled by the I/O processor. This consists of the Machine Operating System (MOS) and the various ROM-based filing systems: ADFS, DFS, and NFS.

The means of communicating with the I/O processor depends on the current environment, as outlined below:

1.3.1 Single Processor Mode

In this mode, the I/O processor operates independently of the 32016 processor, and all the facilities described in the *BBC Microcomputer System User Guide* for BASIC and assembly language programs are available.

Examples

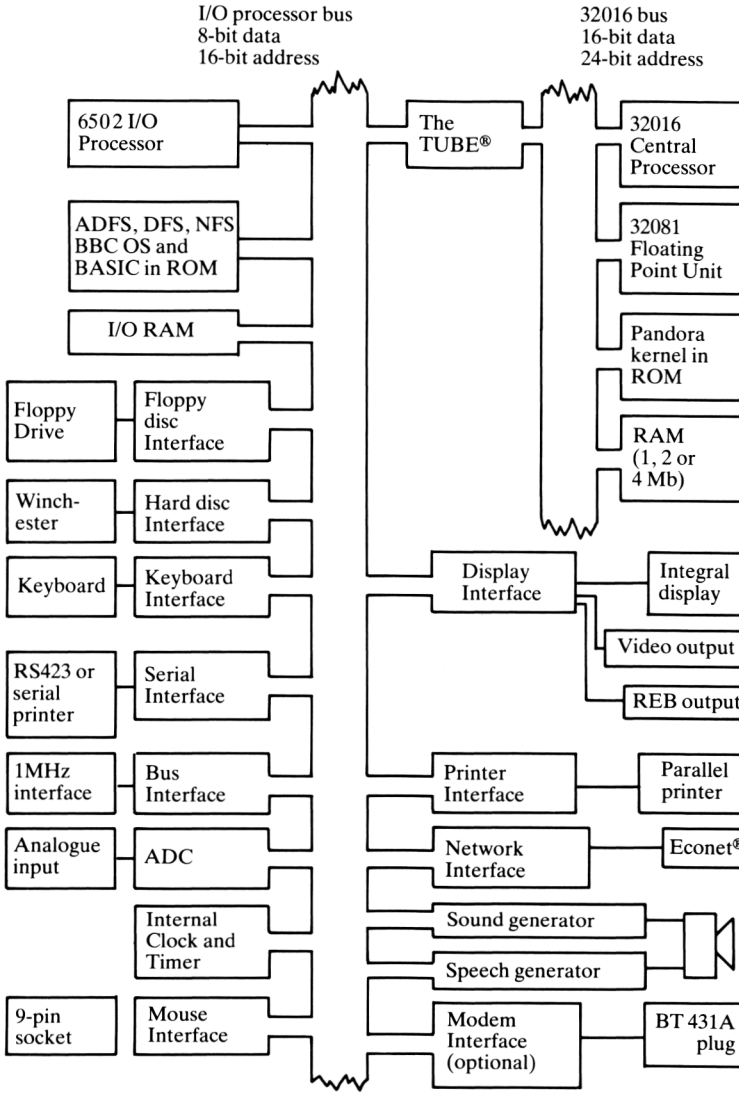
```
>*FREE
>*CAT
>RUN
```

1.3.2 Pandora Command Mode

The 'star' commands described in the BBC Microcomputer user guides are handed to the MOS of the I/O processor for direct execution.

Examples

```
*FREE
*CAT
*DIR :0
*PANOS
```



Note: BBC Micro configurations will be a subset of the above

Figure 1: ACW System Architecture

1.3.3 32000 BASIC

32000 BASIC is BASIC version IV which is based on an earlier version, BASIC I, the language supplied with BBC Microcomputers. Unlike most of the systems software provided with the equipment, 32000 BASIC runs directly from Pandora, the firmware kernel, instead of from Panos, the disc-based operating system for the Cambridge Series computers.

32000 BASIC contains several improvements on BASIC I: a built-in screen editor and faster execution (especially in real arithmetic), new statements are provided, and much greater memory is available. For some users, the most significant difference between the two versions of BASIC will be the fact that 6502 assembly language cannot be incorporated into 32000 BASIC programs. However, object files prepared with the 32000 Assembler may be loaded and called by BBC BASIC programs, and useful MOS routines may still be accessed with the CALL statement. The enhancements and differences between the implementations are detailed in the *BBC BASIC Reference Manual* supplied.

Examples

```
>*FREE
>*CAT
>RUN
```

1.3.4 Panos Command Mode

Various Panos utilities are available for handling filing systems and other functions. In addition, the *star* utility can be used to transmit commands to the I/O processor's MOS.

1.3.5 Programs Running under Panos

All the languages have built-in features for handling the keyboard, display and files; sometimes as part of a library. Additionally, a library of operating system procedures (similar to system calls) is accessible from most languages. These are described in the *Panos Programmer's Reference Manual*. They include facilities for input, output and file handling, setting and reading the internal clock and handling asynchronous events (interrupts). In addition, functions are available which simulate the BBC *OSByte*, *OSWord* and *OSFile* functions.

A Panos environment is assumed in the following sections; reference is made to *star*, *OSByte*, and *OSWord* commands only when no Panos alternative is available.

Examples

```
-> copy a -to b
-> star free
-> star fx 238,128
```

2. The Filing Systems

2.1 Introduction

The following systems are available to the I/O processor:

ADFS: The Advanced Disc Filing System. This controls the Winchester disc and floppy discs with double density format. These 'MFM' (Modified Frequency Modulation) floppy discs are currently not available on Co-Processor configurations.

DFS: This uses floppy discs with single density format. A major purpose of the DFS is to maintain compatibility with earlier systems. Distribution software for the ACW and Co-Processor is supplied in this format (except for the ADFS utilities disc, which is supplied in ADFS format).

NFS: The Network Filing System. This enables a number of stations to share a filing system operated by a special station (the 'file server'), using the Econet network.

ADFS, NFS and DFS are supported by Panos. The following additional filing systems are also available, but normally only via *star* commands:

*IEEE	The IEEE488 filing system
*TAPE or *TAPE12	The 1200 Baud cassette filing system
*TAPE3	The 300 Baud cassette filing system
*TELESOFT	The Teletext filing system
*ROM	The sideways ROM cartridge system

The various filing systems are described in the sections which follow.

2.2 ADFS and NFS Structure and Concepts

The ADFS and NFS use a tree-structured filing system. The root directory of the filing system contains the names of files and sub-directories. Each sub-directory may contain further files and sub-directories. The full name of a file consists of the name of the filing system in which it is stored, followed by the names of the sub-directories along the route from the tree-root to the file, followed by the file name itself. The component items are separated by full stops. The full name of the file is its 'pathname'.

Figure 2 shows an example directory structure in a filing system.

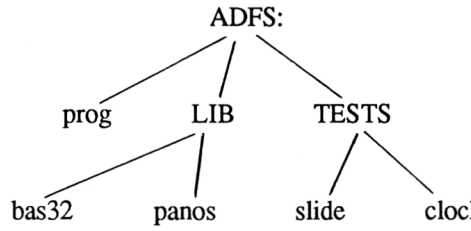


Figure 2: Example NFS/ADFS Directory

ADFS: (including the colon) is the Panos name of the filing system. *LIB* and *TESTS* are sub-directories; *prog, bas32, panos, slide* and *clock* are files.

The full name of the file *clock* is therefore:

```
ADFS:$.TESTS.clock
```

where the dollar symbol ('$') indicates the root directory. Econet users need to distinguish between this root directory ('$') and the 'start-up' directory belonging to the fileserver, where the user is placed after entering Panos (even though they are often identical). For this reason, the ampersand symbol ('&') is used to refer to the start-up directory.

In order to avoid having to give the full name of a file, a current working directory is assumed and is automatically prefixed to any file names. On power up, this directory is set to 'ADFS:$'.

To change the current working directory within Panos, the *set* utility is used. For example:

```
-> set dir tests
```

will change the current working directory to ADFS:$.tests if it was previously set to ADFS:$.

A more complete discussion of AD/NFS directories, in the Panos context, is given in *Panos Filing System Conventions*, in the section on the *'ACW Filing System'* of the *Cambridge Workstation Welcome Guide*. This material is also covered in section 3.6 of the *Cambridge Co-Processor User Guide – 'About the AD/NFS directories'*.

2.3 Advanced Filing System (ADFS)

In ADFS, the different disc drives are referred to by numbers preceded by a colon, as follows:

:0	the Winchester disc, when fitted.
:4	the first floppy disc drive.
:5	the second floppy disc drive, if fitted.

ADFS Floppy Disc Drives (:4 and :5) are currently not available in Co-Processor configurations.

Other numbers are reserved for future expansion. The directories and files on each drive form a self contained tree. The drive unit number appears in the pathname immediately after the filing system name. The default option is ':0', so it need not appear in the pathname. If the files and directories in the example above had been on drive :4 the full Panos pathname would be:

```
ADFS::4.$.TESTS.clock
```

These extended pathnames are only available in Panos.

The following sections describe the ADFS from within a Panos environment. Users of other environments should consult the *Winchester Disc Filing System User Guide*.

2.3.1 Low-level Access

Users who wish to gain direct access to the Winchester disc without using the filing system procedures may use the OSWORD 70 to OSWORD 73 set of calls. Their use is described in the *Winchester Disc Filing System User Guide*.

2.3.2 Directory Information

Each directory can contain up to 47 entries. Each entry refers to an object, which may be a file or a sub-directory, and contains the following information:

- Name of object
- Access permission
- Creation date and time (or load and execution addresses)[1]
- Start address and length of object on the disc

2.3.3 Object Names

In Panos, the name of a directory or file can be from one to ten characters in length. Any of the following characters are valid within file names:

`A ... Z, a ... z, 0 ... 9, _, /` and `!`

The '_' character, however, can only be used as the second or later character.

The name of the file – the 'leafname' – should in addition have an extension separated by a hyphen, '-'. An extension can be from zero to four characters long. These extensions are described in the *Panos Guide to Operations*.

2.3.4 Access Permission

The following file attributes may be set and unset by the Panos *Access* utility, and examined by the Panos *Catalogue* utility, using the *-full* keyword.

L - Lock. If the L attribute is set, the object file or directory cannot be deleted or overwritten.

---

1 Only *files* have creation dates and times; directories have the word 'directory' in this position, and they contain other systems information.

R - Read access. This must be set for a file to be read; only files may be restricted in this way.

W - Write access. This must be set to allow writing operations on the file (i.e. updating and deletion).

In the case of NFS objects there are two sets of user's access attributes, one set for the owner and one set for other users.

To display the access attributes, the cat -full Panos utility and keyword may be used. The attributes are shown in the following format:

```
rw-l/rw-l
```

Absent attributes are replaced by the hyphen character. The third attribute is at present not implemented.

To set attributes within Panos, the *access* command is followed by the file name and the list of required attributes. For example:

```
-> access fourier-f77 rw
```

In the case of NFS files the owner's and other user's attributes are separated by a stroke, with the owner's attributes placed first:

```
-> access legendre-pas lrw/r
```

This example allows the owner to read or write the file, but not to delete it or write to it. Other users may read the disc, but not write to it (that is, they cannot delete or rename). A locked file can be unlocked by giving it a new set of attributes which exclude the 'l' attribute.

The default attributes for files are 'rw/rw'.

The default attribute for a *directory* is 'l' (that is, r–l/r–l). The 'r' and 'w' attributes have no meaning for a directory and are ignored when altering directories. The locked attribute prevents a directory from being deleted, but does not prevent entries being made in it.

Under Panos, both ADFS and NFS files are given two sets of attributes, but the second set have no significance for ADFS at present.

The ADFS 'E' (execute only) attribute is not supported by Panos. Files which have the 'E' attribute set (which can be carried out using a *star* command) cannot have their attributes altered by the Panos *access* utility.

2.3.5 Creation Date and Time

This information is automatically added to the directory by Panos when the file is created. When a file is stored by the editor, the file is recreated so that the *current* date and time is stored. The creation date and time information is not stored for directories. For machine code programs running on the I/O processor, this part of the directory contains the load and execute address.

When using the *copy* utility for these files, the *-exact* option must be used if you wish to preserve the original date and time information rather than replace it with the current date and time. The *-exact* option in effect preserves the load and execute addresses, (see above), and thus must be used for machine code programs that run on the I/O processor.

2.3.6 Start Address and Length of Object on the Disc

This information is computed automatically by the filing system firmware. Files are stored as contiguous blocks in ADFS. The space left by deleted files is filled by new files if possible. See also *Compacting Winchester Disc Files.*

2.4 Network Filing System (NFS)

The Econet system allows a number of users to share a filing system operated by a large capacity storage device connected to the network (the 'file server'). The day-to-day running of the system is the responsibility of the network manager, whose duties are described in the *Econet Level 2 File Server Manager's Guide.*

The following sections describe the NFS from within a Panos environment. Users of other environments should consult the *Econet Level 2 File Server User Guide.*

Many of the concepts such as object names, creation time and date are in common with ADFS (q.v.).

2.4.1 The User Identifier

Each network user is given a user identifier by the network manager. The manager creates a directory on the file server with this name. When the user 'logs on' to the system, this will become the current working directory, and may be referred to simply by the symbol '&'. The root directory of the file server has the symbol '$'.

The identification name is also put onto a list. This list of names is checked against the passwords provided by users as they attempt to log on.

2.4.2 The Password

A password of up to six characters may be used to control access to the system. A new user may choose a password and inform the system of it. Once this action has been taken, this same password must be given each time the user logs on.

To set a password after having logged on, a Panos *star* command is issued; for example:

```
-> star pass "" acorn
```

Users may change their passwords at any time. For example, to change the password from 'acorn' to 'oak', the user simply types:

```
-> star pass acorn oak
```

2.4.3 The Station Number

Each Econet station has a different number. The network manager will establish the station numbers by various methods (such as setting links on the printed circuit board), depending on the model.

The numbers are used by the system, but users do not normally need to be aware of their own station number. However, it may be necessary to know the number of the station acting as the file server.

2.4.4 Logging-on from Panos

This is the means by which users identify themselves to the network system.

If the station is already running Panos, then the *logon* utility may be used. The arguments to the logon command are as follows: the optional keyword *-as* is followed by the optional station number of the file server which the user wishes to access. This is followed by the user identifier and the

corresponding password (if previously set).

The default file server station number is 254, so the user only needs to quote an explicit file server if a different file server needs to be accessed. As an alternative to giving the password in the logging-on command line, the *-pass* keyword may be given. This allows the user to enter an un-echoed password on the following, prompted line. Three examples of logging-on are given below:

```
-> logon ambrose
-> logon -as eustace
-> logon 237 clarence -pass
: password
```

2.4.5 Logging-on from Pandora

If the station is running at the Pandora prompt level and you wish to load Panos from a networked file server, there is a different procedure for logging-on. Ensure that the Network Filing System is set as the current filing system by typing:

```
*NET
```

and logon by entering:

```
*I AM <identifier> <password>
```

or,

```
*I AM <identifier> :
```

and then type in your password (un-echoed) on the next line. Substitute your own identifier and password, where indicated. Once logged-on, you can load and run Panos by typing:

```
*PANOS
```

2.4.6 Printing

The Panos device *printer:* or *lp:*, as described in the *Printer Interface* section of this guide, may be used as a destination device to effect printing. The device will be interpreted as either the printer at the user's station, or, in a suitably configured network, as the network printer. This interpretation is established by the Panos *configure* utility.

2.4.7 Logging-out

Network users can end a session by typing:

```
*BYE
```

2.5 Disc Filing System (DFS)

In DFS the surfaces of the discs are referred to individually as follows:

1st drive:	upper surface	:0
	lower surface	:2
2nd drive:	upper surface	:1
(when fitted)	lower surface	:3

Acorn's DFS uses a single-level directory structure; there are no sub-directories. The directory name is a single character. Under Panos the full name of a *DFS* file has the following form:

```
DFS::2.A.MYPROG
```

where,

DFS:	is the filing system name
:2	is the surface number
A	is the directory character
MYPROG	is the filename

The full stops are delimiters. The normal, default surface number is '0' and the default directory character is '$'.

The DFS is fully described in the *Disc Filing System User Guide.*

2.6 Filing System Operations

These are described from a Panos environment. A summary of '*' commands for users working in other environments (e.g. Pandora or Basic) is given in *Appendix B* of this guide. Full details are may be found in the *Winchester Disc Filing System User Guide* or the *Econet Level 2 File Server Users Guide.*

The following Panos utilities are relevant to operating with files:

Access	Changes the access permission of files
Catalogue	(abbreviation: *cat*) displays information about files

Copy	This copies files and directories and can be used to send data to devices. For example:
	`-> copy -from file1 -to file2`
	`-> copy file1 -to vdu:`
	(The second example will display the contents of file1 on the screen. Depress SHIFT and CTRL to halt the scrolling text, or set vdu -paged true from Panos for the same effect.)

Create	Creates files or directories.
Delete	Deletes files or directories.
Rename	Renames files or directories.

Files are created automatically by the editor and by the language compilers; they do not need to be created explicitly beforehand.

2.7 Housekeeping Operations

2.7.1 Formatting

All new discs, whether Winchester or floppy discs, must be formatted before they can be used for storing files. The Winchester discs supplied by Acorn have been formatted for you, but floppy discs are not.

Formatting consists of creating the root directory, and of recording on the disc information to define the tracks and sectors. This recorded information is also read back in order to check the disc for defects: in the case of the Winchester disc, the locations for any defects are noted and a defect list is stored on the disc. Sectors containing defects are avoided for subsequent operations. Floppy discs with defects should be rejected, though it is usual to accept a limited number of defects on a Winchester disc. These are usually supplied already formatted, together with a document containing the defect list. A user will only need to reformat the Winchester disc should all the information on it need to be cleared, or if an extreme failure in another part of the system has caused the information on it to be corrupted.

2.7.2 Filing System Utilities

Utilities, often running under Basic, are provided for a variety of housekeeping operations including formatting both Winchester and floppy discs and making backup copies. On the ACW, ADFS utilities are supplied on an ADFS format disc, see *ACW ADFS Utilities*. DFS utilities are in ROM (see the next section). ADFS and DFS utilities for the Co-Processor are provided with the Winchester disc, Welcome disc, and/or in ROM depending on the models and configurations used. See *Appendix B* or the appropriate User Guide.

2.7.3 DFS Utilities

To format FM floppy discs (these are loosely referred to as 'single density discs'), use the DFS utility program **FORM80*. This program is in ROM on the B+ and Master computers and on disc for the model B Microcomputer. Refer to *Appendix B* of this Guide, or Chapter 7 of the *Disc Filing System User Guide* for further information.

2.7.4 ACW ADFS Utilities

The utilities are divided into three categories:

ADFS Floppy utilities
ADFS Winchester utilities
ADFS General utilities

One of these groups may be selected from the first menu. Subsequent menus allow the selection of a particular utility and give detailed information about each one, if required. A brief description of each utility is given below.

Using the Utilities

The utilities are written in BBC BASIC and run on the 6502 I/O processor. They make use of 6502 assembler routines and will not run under 32000 BASIC. The programs may be used directly from the floppy disc, or they may be installed onto the Winchester disc.

To *run* the utilities from the *floppy* disc, select the single processor mode by moving the 'TUBE' rocker switch to the left whilst keeping the CTRL key depressed. Insert the utilities disc into the floppy drive and type:

```
>*ADFS
>*DIR :4
>*AUTILS
```

A menu will then appear on the screen. Under both Pandora and Panos, the floppy disc drive is designated ':4'; the Winchester disc drive as ':0'.

To *install* the utilities onto the *Winchester* disc, it is convenient to use Panos. Enter Panos and type:

```
-> copy :4.$...* -to :0.$...* -exact
```

Copy this exactly, i.e. including the dots. This carries out a 'tree copy' of all the files in the utilities directory on the floppy disc, transferring them to the Winchester.

To *run* a utility program installed on the *Winchester* disc, enter single-processor mode and type:

```
>*ADFS
>*DIR :0.$
>*AUTILS
```

ADFS Floppy Utilities

Aform — Formats single- or double-sided, 40– or 80–track discs to the ADFS (double density) format.

Backup — Makes an identical copy of an ADFS floppy disc.

Verify — Checks that there are no errors on an ADFS floppy disc.

ADFS Winchester Utilities

Wform — Formats a Winchester disc. This operation erases the entire contents of a hard disc and is completely irreversible; there is no way that files lost by re-formatting can be retrieved – you have been warned! (But, see under *Backup Files*, below.)

Because of the large capacity of the Winchester disc, formatting takes some time to carry out. The ACW is supplied with its Winchester disc pre-formatted, so *Wform* will not need to be used for some time.

Verify Checks a Winchester disc for errors.

ADFS General Utilities

Catall Lists the contents of all the directories on a disc (floppy or Winchester).

Copyfiles Copies files from one filing system to another.

Dircopy Duplicates part or all of an ADFS directory structure in another part of the ADFS directory, possibly on another disc.

Exall Lists the contents of all the directories on a disc. (Similar to *Catall*).

Harderror Removes a sector of a floppy disc containing a hard error from the free-space map.

Recover Enables accidentally deleted files to be recovered.

Weditor Enables the data in any sector of the Winchester disc to be displayed and, if necessary, changed.

2.7.5 Backup Files

In everyday use, files quickly proliferate. Many of these files will have a short-lived usefulness and should be disposed of by deletion. Some files, however, will have a more permanent usefulness and should be preserved carefully outside the machine on a floppy disc. Backup copies of important files should be made as a part of regular disc 'housekeeping' sessions.

The Panos *copy* utility provides a convenient means of making independent copies of important files. For instance, if a user wishes to make archive copies of all the files kept in a directory on the Winchester disc called *usdir*, the command:

```
-> copy usdir.* -to :4 -confirm
```

could be used. In the above example, the user is prompted for each file to be copied to the floppy disc. A powerful feature of Panos allows selective backups to be made. For instance:

```
-> copy $...* -to :4 -after 28-May-86
```

will copy all files on the Winchester changed since that date.

Alternatively, you could define a variable *<date>* which holds a string version of the date of the last backup session, then:

```
-> copy * -to :4 -after <date>
```

will transfer all the files created or modified in the current directory after the last backup disc was made; however, in both examples, make sure that there is enough room on the disc before proceeding.

Network users should consult their network manager about arrangements for backing up their files.

2.7.6 Compacting Winchester Disc Files

In typical use and over a period of time, a large capacity Winchester disc will provide for the creation, reorganisation and deletion of a great many files. It is recommended that the user compacts the disc periodically, as part of normal 'housekeeping' duties. This serves to consolidate the files, gathering the free space on the disc into larger contiguous sections.

Compacting is carried out by the ADFS *COMPACT* command.

The recommended routine for disc file maintenance is regularly to:

- Check directories
- Delete unnecessary files
- Backup important files on removable discs
- Compact the Winchester disc.

To see the effect of compacting a hard disc, first use the **MAP* command. This lists the free space on the disc in two columns: the disc address, followed by the length of free space (in units of 256 byte sectors). The *MAP* command may be followed by the **FREE* command, which displays the amount of both free and used space left on the disc. For example:

```
*MAP
*FREE
*COMPACT 30 50
```

The two numbers after the *COMPACT* command are the recommended values of the start page (30 Hex) and the length, in pages (50 Hex), of the screen memory used as a work area.

Note that compacting the hard disc may take several minutes, and that during the process the disc access light will flash on and off. Do not be alarmed when random patterns appear on the screen. These occur if screen memory is used as a buffer, providing extra memory space for the process. When compaction is complete, the star prompt will reappear (although it may be difficult to see if the screen display is particularly mixed up).

Type the *MAP* command again,

```
*MAP
```

and notice that the list of free spaces on disc is now shorter and that the first free space on the disc has been moved to a higher address. It may be worth entering the *COMPACT* command again, to further reduce the fragmentation of free space.

```
*COMPACT 30 50
*MAP
*FREE
```

The list of free spaces may be shorter still this time, but the marginal benefits of further compacting the free space may not be worth the time spent carrying out the process.

These commands may be carried out under Panos, e.g.:

```
-> star free
```

2.7.7 Care of the Winchester Disc and Parking Heads

To avoid damage or data loss from the Winchester disc, *do not move the disc unit whilst it is running*. Never rotate the disc unit quickly, nor subject it to sudden, jerky movements. The Winchester Disc of the Acorn Cambridge Workstation, for instance, is mounted inside the main unit and should not be tilted beyond the limits of the tilt/swivel base (i.e. about 30° from the horizontal plane).

Extra care should be taken if you are trying to re-pack or transport an Acorn product equipped with a Winchester Disc. Keep the unit upright, and fit the expanded polystyrene packing pieces around each side of the machine. With the machine still upright, gently lift the unit into the box in which it was supplied. Pack the box with any extra packing material suplied, and transport in an upright and shock-free way.

Take care that Acorn equipment does not overheat whilst running (for instance, by blocking ventilation slots or by leaving the machine near a window in sunlight).

It is important that the read/write heads of the Winchester Disc are moved to the 'parking zone' before switching off the mains power. The exact command to park the heads will depend on which program is in control. For instance:

From BASIC (either 32000 BASIC or 6502 BASIC), type:

```
>*BYE
```

From Pandora, type:

```
*bye
```

the '*' is supplied by Pandora

From Panos, type:

```
-> .quit
*bye
```

to return to Pandora before typing:

2.7.8 Error Recovery

Although it us unlikely, errors do sometimes occur in data stored on discs. If an error should occur in a directory, large amounts of data may be rendered inaccessible to the filing system. It may be possible to recover such data by overriding the normal filing system routes to the data and using lower-level access to the disc.

However, this method should only be considered as a method of last resort. The best plan is to make regular backup copies of significant files.

The *WEDITOR* utility is available as an 'ACW General Utility' menu on the ADFS utilities disc supplied with the ACW. The program itself is described in Chapter 9 of the *Winchester Disc Filing System User Guide*. It can be used to display, and if necessary change, a single byte of data in any sector of the disc (a sector is 256 bytes). Hexadecimal, character and string searches are supported, as well as movement directly to disc addresses. *Use of this program is only recommended for suitably qualified or experienced users.*

In addition, the ADFS utilities disc contains programs (*Harderror* and *Recover*) which can be used to rescue data on ADFS floppy discs.

3. Display Interface

3.1 Introduction

This chapter describes the text and graphics facilities of the Cambridge Series I/O Processor, and how these facilities may be controlled.

3.2 Character Set

Data are sent to the display as a sequence of characters represented by 8-bit bytes. The printable characters conform to the American Standard Code for Information Interchange (ASCII) character set, except for character 96 which is replaced by the pound sterling symbol '£'. Tables 1 and 2 (and *Appendices C* and *D*) show the printable characters within the ASCII character set.

3.3 Access to the Display

In Panos, the display is represented by the devices *vdu:* and *rawvdu:*. The difference between these two devices resides in the way in which the 'non-printable' characters are interpreted, as indicated below:

For *vdu:* (the default device under Panos)

Code	Interpretation
9	tabulates to pre-set stops
10	newline, i.e. line feed and carriage return
13	carriage return
32 to 126	prints as ASCII characters

All other characters between 0–31, and >127 are represented as their hexadecimal value enclosed in square brackets.

Dec	Hex	ASCII	Dec	Hex	ASCII
32	20	SPACE	80	50	P
33	21	!	81	51	Q
34	22	"	82	52	R
35	23	#	83	53	S
36	24	$	84	54	T
37	25	%	85	55	U
38	26	&	86	56	V
39	27	'	87	57	W
40	28	(	88	58	X
41	29	)	89	59	Y
42	2A	*	90	5A	Z
43	2B	+	91	5B	[
44	2C	,	92	5C	\
45	2D	-	93	5D	]
46	2E	.	94	5E	^
47	2F	/	95	5F	_
48	30	0	96	60	£
49	31	1	97	61	a
50	32	2	98	62	b
51	33	3	99	63	c
52	34	4	100	64	d
53	35	5	101	65	e
54	36	6	102	66	f
55	37	7	103	67	g
56	38	8	104	68	h
57	39	9	105	69	i
58	3A	:	106	6A	j
59	3B	;	107	6B	k
60	3C	<	108	6C	l
61	3D	=	109	6D	m
62	3E	>	110	6E	n
63	3F	?	111	6F	o

Table 1: Printable Characters

Dec	Hex	ASCII	Dec	Hex	ASCII
64	40	@	112	70	p
65	41	A	113	71	q
66	42	B	114	72	r
67	43	C	115	73	s
68	44	D	116	74	t
69	45	E	117	75	u
70	46	F	118	76	v
71	47	G	119	77	w
72	48	H	120	78	x
73	49	I	121	79	y
74	4A	J	122	7A	z
75	4B	K	123	7B	{
76	4C	L	124	7C	|
77	4D	M	125	7D	}
78	4E	N	126	7E	~
79	4F	O			

Table 2: Printable Characters (continued)

For the device *rawvdu:*

Code	Interpretation
0 to 31,127	control graphics & text display; see *Control Codes* in Table 3.
32 to 126	prints as ASCII characters
128 to 255	codes are available for redefinition by the user. See *Changing the Character Set*, below.

In BASIC the output behaves like *rawvdu:*

3.4 Controlling the Display Facilities

There are various possibilities:

(1) Certain facilities can be controlled by the Panos *configure* utility and by the *set* utility using the *vdu* attribute.

(2) BBC BASIC and Cambridge LISP have built-in commands for display control.

(3) Most of the facilities may be software controlled by sending a sequence of characters (the *control code*), to the Panos device *rawvdu:*. These codes are described and listed in the following section.

(4) A small number of facilities can only be accessed by the OSBYTE and OSWORD functions. These are described in the *Panos Programmers Reference Manual.*

(5) In addition, certain graphics libraries are provided for the languages supplied with the ACW and Co-Processor system. The Welcome disc has simple libraries, *PlotLib* for Fortran-77 and *GLib* for Pascal. The *graphics library* referred to in the following sections is a hypothetical non-language specific one.

(6) Another technique is to write application-specific code to run on the 6502 host processor and communicate with it by means of 'user OSWord' calls or 'reserved VDU codes'.

Reference is made to these means of control, if available, with each facility described in this chapter.

Further details of the Panos, BASIC and LISP commands are given in their reference manuals.

VDU and **FX* codes from BBC BASIC are not given since they are identical to the control codes and OSBYTE calls respectively.

The graphics libraries are described at the end of this chapter. A uniform structure is used where possible but there are differences in the mnemonics used in particular graphics libraries for the various programming languages.

3.4.1 Control Codes

These consist of a sequence of from 1 to 10 bytes which are sent to the device *rawvdu:*. The first byte is in the range 0 to 31 or is 127 (as with ASCII control characters). The following bytes may have any value in the

Dec value	Hex value	Extra bytes	Meaning
0	0	0	does nothing
1	1	1	send next character to printer only
2	2	0	enable printer
3	3	0	disable printer
4	4	0	write text at text cursor
5	5	0	write text at graphic cursor
6	6	0	enable VDU drivers
7	7	0	make a short beep
8	8	0	backspace cursor one character
9	9	0	forwardspace cursor one character
10	A	0	move cursor down one line
11	B	0	move cursor up one line
12	C	0	clear text area
13	D	0	move cursor to start of current line
14	E	0	page mode on
15	F	0	page mode off
16	10	0	clear graphics area
17	11	1	define text colour
18	12	2	define graphics colour
19	13	5	define logical colour
20	14	0	restore default logical colours
21	15	0	disable VDU drivers
22	16	1	select screen mode
23	17	9	re-program displayed character
24	18	8	define graphics window
25	19	5	various graphics functions
26	1A	0	restore default windows
27	1B	0	does nothing
28	1C	4	define text window
29	1D	4	define graphics origin
30	1E	0	home text cursor to top left
31	1F	2	move text cursor to x, y
127	7F	0	backspace and delete

Table 3: I/O Processor Control Codes (VDU Codes)

range 0 to 255.

The numerical values of these bytes are given in the following sections. Where a parameter with a range greater than 255 is to be sent, two bytes are used to transmit its value; the least significant byte is sent first. In this case, the prefixes 'l' and 'h' are used to distingush the low byte and high byte respectively.

A summary of the codes is given in Table 3; examples of their use are given in sections below.

3.4.2 Enabling and Disabling the Display

It is possible to disable the display, that is, to prevent text or graphics being written to the screen: this is useful when preventing a password typed at the keyboard from being echoed to the screen. For example.

To disable the display:	Control Code 21
To enable the display:	Control Code 6

3.5 Screen Mode

The ACW and Co-Processor computers can display text and graphics in a variety of modes. There is a trade-off between screen resolution and the number of colours which can be displayed simultaneously, referred to as the palette of colours. The characteristics of the 8 modes are shown in Table 4. The graphics column indicates the number of pixels in the horizontal and vertical directions. The text column shows the number of characters per line by the number of lines on the screen.

Mode 7 is described separately in the 'Teletext' section.

The Cambridge Series computers normally operate in mode 3 with white text on a black background.

3.5.1 Mode Selection

Control Code	22,n
Panos	set vdu -mode n (or use the *configure utility*)
BASIC	MODE n
LISP	(mode n)
Graphics Library	mode(n)

Mode	Graphics	Colours	Text
0	640 × 256	2 colour display	80 × 32
1	320 × 256	4 colour display	40 × 32
2	160 × 256	16 colour display	20 × 32
3	n/a	2 colour text only	80 × 25
4	320 × 256	2 colour display	40 × 32
5	160 × 256	4 colour display	20 × 32
6	n/a	2 colour text only	40 × 25
7	n/a	Teletext display	40 × 25

Table 4: Screen Modes

In Table 4, 'n' is the number of the mode: note that changing modes clears the screen. The currently selected screen mode may be obtained by calling OSBYTE 135, the mode number will be returned in *Result2*.

3.6 Colour

Text foreground, text background, graphics foreground and graphics background colours can be separately selected from the 'palette' of colours. These selections determine in what colours subsequent text and graphics will be drawn. The colours in the palette are referred to by 'logical colour numbers' since each may be defined to be any of the available 'actual' colours.

The 'actual' colours are numbered as shown in Table 5. For colours 8 to 15, the flashing rate may be set as follows:

OSBYTE 9 sets the duration of the first colour
OSBYTE 10 sets the duration of the second colour.

0	black
1	red
2	green
3	yellow
4	blue
5	magenta (blue-red)
6	cyan (blue-green)
7	white
8	flashing black-white
9	flashing red-cyan
10	flashing green-magenta
11	flashing yellow-blue
12	flashing blue-yellow
13	flashing magenta-green
14	flashing cyan-red
15	flashing white-black

Table 5: The Palette of Colours

The duration is given in centiseconds, using *Param1*. Values between 0 and 255 may be used, with a default setting of 25 centiseconds: a value of 0 gives infinite duration. The previous setting is available in *Result1* and *Result2*.

3.6.1 Selecting the Palette

The default palette in the two-colour modes (0,3,4 and 6) is as follows:

logical colour	**colour**
0	black
1	white

The default palette in the four-colour modes (1 and 5) is as follows:

logical colour	colour
0	black
1	red
2	yellow
3	white

The default palette in mode 2 is the set of actual colours. To re-define a logical colour in the palette the following may be used:

For Panos, see below.

Graphics Library	PALETTE (l,a)
Control Code	19,l,a,0,0,0

where:

'l' is the logical colour number
'a' is the actual colour number

To restore the palette to the default logical colours:

Control Code	20

To read the palette, use OSWORD 11. A parameter block of 5 bytes should be established. On entry, the first byte should be set to the logical colour number. On exit, the following four bytes will contain the same four numbers used to assign the actual colour by control code 19.

3.6.2 Selecting Colours from the Palette

The default selections are such that, with a default palette, text and graphics foreground is white while text and graphics background is set to black.

With colour selections from Panos and LISP, the commands shown in Figure 3 are available to select colours from the palette. (Note that 'n' is the selected logical colour number).

In the graphics functions, the 'style' parameter, 's', in the graphics functions defines how the plotted colour is combined with the colour already present in the following way:

Text foreground colour:

Control Code	17 n
BASIC	COLOUR n
Graphics Library	TFORE (n)

Text background colour:

Control Code	17 n + 128
BASIC	COLOUR n + 128
Graphics Library	TBACK (n)

Graphics foreground colour:

Control Code	18 s n
BASIC	GCOL s,n
LISP	(ink n)
Graphics Library	GFORE (s,n)

Graphics background colour:

Control Code	18 s n + 128
BASIC	GCOL s,n + 128
LISP	(paper n)
Graphics Library	GBACK (s,n)

Figure 3: Selecting Colours from the Palette

0 plot the colour specified

1 OR the specified colour with the colour already present

2 AND the specified colour with the colour already present

3 Exclusive-OR the specified colour with the colour already present.

4 Invert the colour already present

These operations mean that the logical function is applied bitwise to the binary logical colour numbers of the colours concerned.

To restore the default foreground and background selections, as well as to restore the default palette, use:

Control Code 20

3.6.3 Panos Colour Selection

Vdu text, foreground and background colours may be selected from the group of actual colours by using the Panos *set* utility. These are referred to by name, using the keywords *-COL, -FORE* and *-BACK* respectively. For example:

```
-> set vdu -col magenta
```

3.7 Screen Co-ordinates

Position on the screen is described by co-ordinates. Text and graphics co-ordinates differ:

3.7.1 Text Co-ordinates

The origin is at the top left of the screen. The position is given in 'text units', which correspond to the character size in the selected mode, as in the following table:

mode	horizontal range	vertical range
0	0 to 79	0 to 31
1	0 to 39	0 to 31
2	0 to 19	0 to 31
3	0 to 79	0 to 24
4	0 to 39	0 to 31
5	0 to 19	0 to 31
6	0 to 39	0 to 24
7	0 to 39	0 to 24

Figure 4 shows the ranges for mode 0

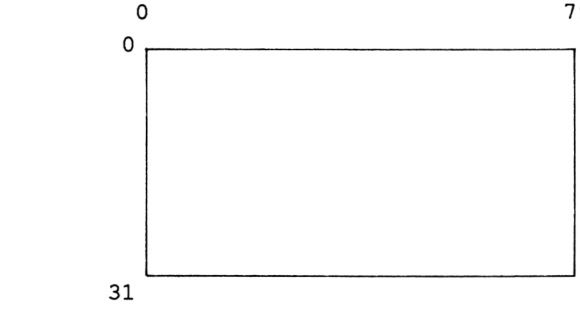


Figure 4: Text Co-ordinates for MODE 0

3.7.2 Graphics Co-ordinates

The position is given in 'graphics units' measured from the origin, which is by default at the bottom left of the screen (except for Cambridge LISP). The 'graphics unit' ranges (with the origin at bottom left) are:

horizontal	0 to 1279
vertical	0 to 1023

as shown in Figure 5. These ranges are independent of the screen mode.

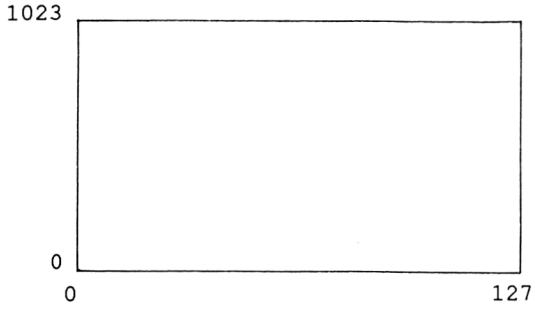


Figure 5: Graphics Co-ordinates

3.8 Windows

Separate text and graphics windows may be defined. When windows have been set up, text will appear only in the text window and graphics will appear only in the graphics window. In the default case, text and graphics windows cover the entire screen area.

3.8.1 Setting up windows

Windows are defined by the co-ordinates of their edges, x0, y0, x1, y1, as in Figures 6 and 7.

Control Code	28 x0 y0 x1 y1
Graphics Library	twind (x0,y0,x1,y1)

The order of the parameters should be noted; these consist of the x and y coordinates of the bottom left corner of the window, followed by those of the top right corner. 'Corner' means the corner cell *within* the window.

To clear the text window to its background colour:

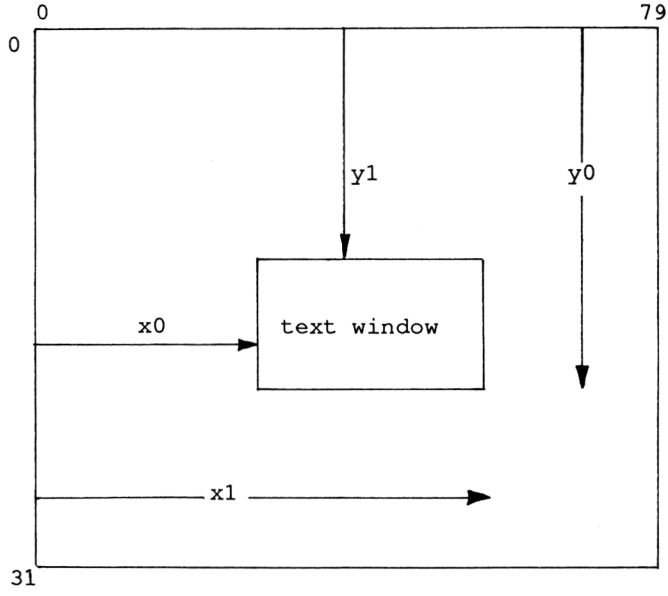


Figure 6: Setting a Text Window

Control Code	12
BASIC	CLS
Graphics Library	tclear

These commands reset the text cursor to the top left of the window.

Graphics Library	gwind (x0,y0,x1,y1)
Control Code	24 lx0 hx0 ly0 hy0 lx1 hx1 ly1 hy1

As in the case of text windows, the parameters consist of the x and y co-ordinates of the bottom left corner of the window, followed by those of the top right corner.

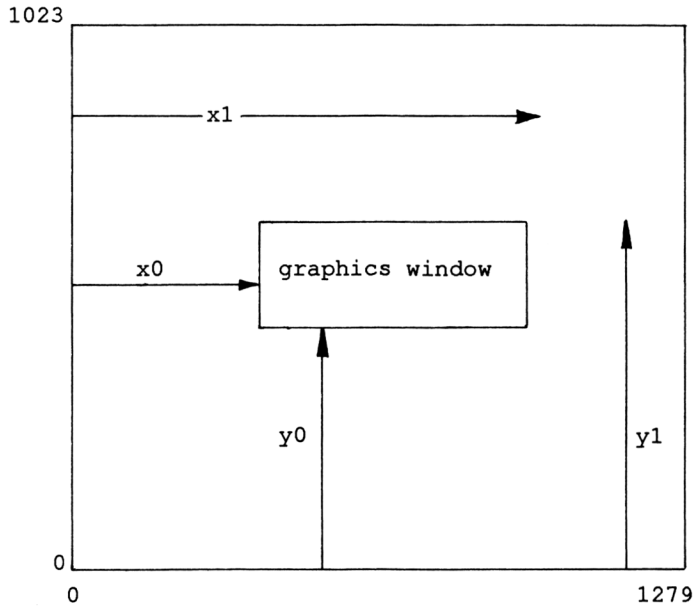


Figure 7: Setting a Graphics Window

To clear the graphics window to its background colour:

Control Code	16
BASIC	CLG
LISP	(clg)
Graphics Library	gclear

These commands do not affect the graphics cursor.

3.8.2 Restoring Default Windows

To restore the default windows for text and graphics (where the windows occupy the whole screen):

Control Code	26

This code re-positions the text cursor at the top left of the screen and moves the graphics cursor to the graphics origin at the bottom left of the screen.

3.9 Writing Text to the Screen

Text is normally written to the screen at the text cursor position. The 'home' position of the text cursor is at the top left of the text window. It is placed there by the 'clear text window' and 'restore default windows' commands and by:

Graphics Library	home
Control Code	30

The text cursor may be moved around the screen as follows:

Control Code	Action
8	Left one character (without deleting it)
9	Right one character
10	Down one line
11	Up one line
13	Move to start of current line
127	Backspace and delete

The text cursor may be moved to the position given by co-ordinates (x,y) relative to the top left corner of the text window.

Control Code	31 x y
BASIC	TAB(X,Y)

The BASIC TAB(X) command will move the text cursor to column X of the text window, or if it is already beyond column X of that line, the cursor will move to column X on the next line.

The tabulate character, code 9, when sent to the device *rawvdu:* will move the text cursor one position to the right. When sent to the device *vdu:*, however, it causes the text cursor to move at least one space and stop at the next preset position. The preset stops are set by the Panos *set* utility:

```
-> set tabs [-at position] [-then increment].
```

Any printable characters sent to the screen (either *vdu:* or *rawvdu:*) will be written at the text cursor position.

To read the horizontal and vertical co-ordinates of the text cursor, relative to the current text window:

BASIC	*POS* returns the horizontal position *VPOS* returns the vertical position
OSBYTE 134	*Result1* returns the horizontal position, *Result2* returns the vertical position.

To read the character at the cursor position, use OSBYTE 135. *Result1* will contain the code of the character. If the character cannot be recognised, then zero will be returned. *Result2* will contain the current display mode.

Text can also be written at the graphics cursor position by control code 5. Subsequent characters will be written at the graphics cursor position, and in the graphics colours.

Text sent to the screen in this way will overwrite whatever is currently displayed, in accordance with the current 'style' parameter, so that characters can be superimposed. Text written in this way can only be written in the graphics window. Text scrolling will be supressed. The text cursor is unaffected and will remain where it was left (unless moved in the manner described above).

To revert to writing at the text cursor position, use control code 4.

3.9.1 Scrolling and Paged Mode

Text normally scrolls upwards when it reaches the bottom of the screen. An alternative to this is the 'paged mode', where output halts when it reaches the bottom of the screen. Depressing the [SHIFT] key causes the whole screen, less seven lines, to be scrolled up.

To set paged mode:

Control Code	14
Panos	set vdu -page true

To set scrolling mode:

Control Code	15
Panos	set vdu -page false

3.9.2 Changing the Character set

Control code 23 may be used to redefine displayed characters.

The pre-defined characters occupy ASCII codes 32 to 126. Codes 128 to 255 are left undefined for the users who wish to define their own characters or shapes.[1] In fact *any* displayable character may be re-defined.

For example, to redefine code 240 as a small 'dog', (see Figure 8), use the following statement:

Control Code	23	240	17,225,34,60,60,66,129,129

where

- The '23' means 'redefine'
- The '240' is the character to be redefined
- The eight numbers give the binary sum of each row of pixels (white=1, black=0) making up the desired character, see Figure 8.

Note that characters cannot be defined in Mode 7.

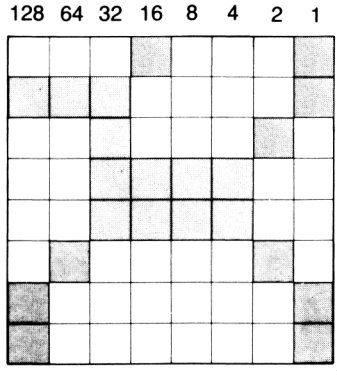
OSWORD 10 allows the definition of a character to be read. A parameter block of 9 bytes should be set up. On entry, the first byte is set to the code of the character whose definition is sought. On exit, the following 8 bytes will contain the definition of the character, in the same format as above.

To turn the cursor on and off, use:

Control Code	23 1 0 0 0 0 0 0 0 0	will turn the cursor off
Control Code	23 1 1 0 0 0 0 0 0 0	will turn the cursor on

---

1 Note, however, that the proposed ISO standard for 8-bit characters will define codes 128–255.



16+1 = 17
128+64+32+1 = 225
32+2 = 34
32+16+8+4 = 60
32+16+8+4 = 60
64+2 = 66
128+1 = 129
128+1 = 129

Figure 8: Defining a Character

4. Graphics

4.1 Introduction

4.1.1 Graphics Functions

A variety of facilities are available for drawing lines and curves, and filling in areas, by using various systems of co-ordinates. These are described in the following sub-sections.

An extended set is available to Master 128 (with the Co-Processor) or Graphics Extension ROM users.

4.1.2 The Graphics Origin

The default origin is at the bottom left corner of the screen (except for Cambridge LISP where it is at the screen centre). The origin may be moved to the position (x,y) by:

Control Code	29 lx hx ly hy
Graphics Library	ORIGIN(x,y)

This code does not affect the position of the graphics cursor.

4.2 Control Code Graphics Functions

Various functions are provided by:

Control Code	25 k lx hx ly hy

The parameter k determines the action as follows:

0 move relative to last point

1 draw line relative in the current graphics foreground colour

2 draw line relative in the logical inverse colour

3 draw line relative in current graphics background colour

4 move to absolute position

5 draw line absolute in the current graphics foreground colour

6 draw line absolute in logical inverse colour

7 draw line absolute in current graphics background colour

Lines are drawn from the previous cursor position unless otherwise stated.

Higher values of 'k' have other effects which are related to the effects given by the values 0 to 7.

8–15 as 0–7 but with the last point in the line omitted

16–23 as 0–7 but with a dotted line

24–31 as 0–7 but with a dotted line and without the last point on the line

32–63 are reserved for the Graphics Extension ROM

64–71 as 0–7 but only a single point is plotted

72–79 as 0–7 but draw a horizontal line to the left and right of the point until a colour other than the current background colour is needed.

80–87 as 0–7 but plot and fill a triangle. When filling solid triangles with colour the computer fills the triangle between the coordinates given and the last TWO points visited.

88–95 as 0–7 but draw a horizontal line to the right until reaching the current background colour.

96–255 reserved for future expansions.

To read the status of a graphics point, use OSWORD 9. A parameter block of 5 bytes should be set up. On entry, the first four bytes contain the x and y co-ordinates of the point. On exit, the fifth byte contains the logical colour of the point (or 255 if the point is off screen).

OSWORD 13 may be used to read the last two graphics cursor positions (refer to the *Advanced User Guide for the BBC Micro*).

4.2.1 BASIC Graphics Functions

MOVE x,y	move cursor to x,y without drawing a line
DRAW x,y	draw a line from the last cursor position to x,y

PLOT k,x,y	identical to Control Code 25, above.

4.2.2 LISP Graphics Functions

Acorn Cambridge LISP provides a set of graphics routines. In order to use them, a graphics screen mode must be selected by calling (mode n) with n = 0,1 or 2. The co-ordinate system for the screen can be reset by (scale h), but by default the screen has height 1024. After a call to (scale h), the top of the screen has y co-ordinate h. The width of the screen is always 5/4 times its height. (cls) clears the screen, and (home) moves a notional graphics cursor to the centre of the screen. Two styles of graphics are supported:

simple Cartesian graphics

```
(moveto x y), (drawto x y)
```

turtle graphics

```
(turn n), (turnto n)
(move l), (draw l)
```

If a closed convex figure is drawn on the screen between calls (fill t) and (fill nil), the area will be filled in. (circle r) and (circleat x r y) draw circles, and with (fill t) set, they draw filled in circles.

The effect of ink depends upon the screen mode; small arguments will lead to solid colours, and larger values will give a variety of shaded effects.

(circle r)	draw circle at current position
(circleat x y r)	draw circle at position x,y
(fill <flag>)	set/clear area - fill mode
(ink n)	establish colour
(mode n)	set screen mode
(move l)	Turtle graphics
(draw l)	Turtle graphics
(drawto x y)	Cartesian graphics
(moveto x y)	Cartesian graphics
(cls)	clear screen
(home)	go to mid-screen
(scale h)	set logical screen height
(paper n)	establish colour
(turnto n)	turns through a specified angle:
(turnto 0)	points to 12 o'clock, and positive angles turn clockwise.

4.3 VDU Status Byte

An OSBYTE 117 call returns a single byte of VDU status flags in *Param1*, as below:

bit	value	
0	1	bit set if control code has been sent (printer on)
2	4	bit set if paged mode is on
3	8	bit set if software scrolling, unset if scrolling is by hardware (i.e. whole screen)
4	16	bit set if shadow display mode is selected
5	32	bit set if cursors are joined by control code
7	128	bit set if VDU is disabled by control code

4.4 Interlace and Screen Vertical Shift

These may be set by the Panos *configure* utility. The default setting is interlace off and zero vertical shift.

An interlaced scan (that is, with alternate lines being drawn on the cathode ray tube) makes the individual lines of the raster less noticeable, though under some circumstances, it can produce a flickering effect. The vertical shift moves the active area of the display up or down on the physical screen.

5. Teletext (Mode 7)

In Teletext mode, 25 lines of 40 characters can be displayed. In addition to text characters, 64 'mosaic' graphics characters are available. The text and graphics characters may be displayed in 8 colours (which may have the additional attribute of 'flashing'). Separate text and graphics windows are not available.

5.1 Text Characters

Some characters are displayed differently in Teletext mode; these different characters are shown in the table below.

Code	Modes 0 to 6	Mode 7
91	[	←
92	\	1/2
93	]	→
94	^	↑
123	{	1/4
124	|	‖
125	}	3/4
126	~	÷

Table 6: Mode 7 Character Variations

For a table of the complete mode 7 character set, see *Appendix D*

5.2 Graphics Characters

These consist of six cells on a 2 pixel wide by 3 pixel high grid, thus giving a screen resolution of 80 pixels horizontally and 75 pixels vertically. The

full set of graphics characters is shown in *Appendix D*. The code for a required shape may be found by adding up the weights for the cells, as shown in Figure 9, and adding the result to 160. Figure 9 also shows an example.

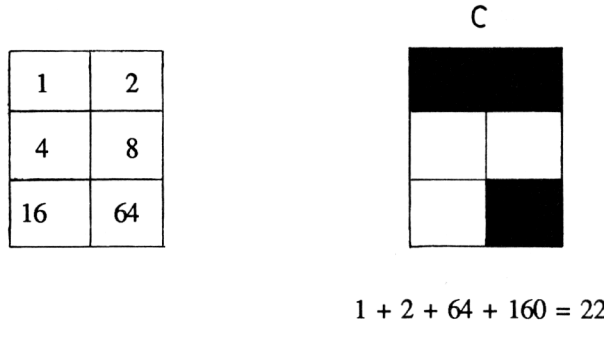


Figure 9: Teletext Graphics Characters

5.3 Control of the Display

The display is controlled on a line by line basis by sending control codes. These act on all subsequent characters on the line. The display returns to the default settings for the next line. The control codes are shown in Appendix C; the default settings are shown by asterisks. A detailed description of the codes follows.

Codes 0 to 31 and 127
These have the same effects as those described in the 'control codes' section, except for codes concerned with effects which are not available in this mode and which therefore have no effect.

Codes 128,138,139,142,144,145 and 155
These have no effect.

Codes 129 to 135
These select the text character set for subsequent characters on the line, and define the colour. Code (128 + N) selects the actual colour number, N, as given in the table in the 'colour' section. The code itself will display as a space.

Codes 136 and 137
Code 136 will cause subsequent characters on the line to flash, that is, to alternate between the selected colour and black. Code 137 will prevent subsequent characters from flashing. OSBYTE 9 and OSBYTE 10 do not control the flashing rate in this mode.

Codes 140 and 141
Code 141 causes double-height text to be displayed. Everything on the line after this code has its top half doubled in height, and displayed. The line below must also include code 141 with the same text following, in order to display the bottom half of the double-height text. Code 140 cancels this effect.

Codes 145 to 151
These select the graphics character set for subsequent characters on the line, and define the colour. Code (144 + N) selects the actual colour number, N, as given in the table in the 'colour' section. The code itself will display as a space.

Code 152
This causes following characters on the line to be concealed, i.e. displayed as blanks in the current background colour. This effect is cancelled by a following code in the range 129–135 (and certain others). Any character 'concealed' in this way will become visible if the 'conceal' code is replaced by another code (typically a space). This code is normally used by Teletext services in implementing the 'Press REVEAL to Display' facility.

Codes 153 and 154
These select the mode of display for graphics characters: code 153 gives solid colour; code 154 displays the individual cells separated from each other.

Codes 156 and 157
These control the background colour: code 156 causes subsequent characters to have a black background; code 157 causes the previously selected character colour to become the background for subsequent characters. The background colour will not flash.

Codes 158 and 159
Code 158 holds; code 159 releases graphics.

6. Sound

6.1 Introduction

6.1.1 Capabilities

The I/O processor can generate sounds on four channnels simultaneously; these are numbered 0 to 3. Channel 0 gives various noise effects, channels 1 to 3 produce single notes over a range of over five octaves.

6.1.2 Control of Sound Generation

Two commands are used: *SOUND* and *ENVELOPE*. The system-functions OSWORD 7 (for *SOUND*) and OSWORD 8 (for *ENVELOPE*) can also be used to access these commands. In other languages (FORTRAN, C, Pascal) they could be accessed using library functions.

6.2 The SOUND Command

This command is buffered; for each channel there is a separate buffer which can hold up to four *SOUND* commands awaiting execution. Each buffer may be flushed by the 'F' parameter of the *SOUND* command as described below. The buffers may be examined by using the *ADVAL* request (or OSBYTE 128).

The *SOUND* command takes seven parameters:

```
SOUND(H,S,F,C,A,P,D)
```

(In BASIC the first four parameters are combined into one 16-bit integer consisting of four hexadecimal digits.)

The functions of the parameters are as follows:

H Continuation control
This parameter may be 0 or 1. If H = 0 then the other parameters are interpreted normally; if H = 1, however, instead of playing a new note on the selected channel, the previous note is allowed to continue. In this case the other parameters of SOUND are ignored and allows the 'release' phase of the previous note to continue. Normally a note will be played as soon as the previous note reaches the end of its 'sustain'

phase. (The phases are described under the ENVELOPE command.)

S Synchronization control
This parameter is used to synchronize the playing of a number of notes. If S = 0 then the note is played as soon as the previous note on the selected channel has ended, or, in the case of notes using the ENVELOPE function, has reached the end of the sustain phase. To play a group of N notes, with these commencing together, each note should be selected with its S parameter set to N-1. The group will start to play when the last command has been issued and when all previously selected notes in the group of channels have ceased.

F Flush control
This parameter may be 0 or 1. Commands with F = 0 are stored in the channel buffer. If a command with F = 1 is issued, then the buffer for the selected channel is flushed, and any note sounding on the channel is terminated. The note defined in the command is then played.

C The channel number
C = 0 selects the noise effects channel.
C = 1 to 3 selects one of the three tone channels.

A The amplitude control parameter
The amplitude can be controlled directly by values of A from 0 (off) to -15 (maximum). More complex control of amplitude, and also pitch, may be obtained by selecting one of 16 envelopes by A = 1 to A = 16. The envelope is defined by the ENVELOPE command using the corresponding envelope number.

P The pitch control parameter
For channels 1 to 3, the pitch may be varied in logarithmic steps of one eighth of a tone by values between 0 and 255. P = 89 gives 440 Hz, corresponding to the note A above middle C. Other values are shown in Figure 10.

For channel 0, the parameter P controls the effect as follows:

P	**Effect**
0	High frequency periodic noise.
1	Medium frequency periodic noise.

	Octave number						
Note	**1**	**2**	**3**	**4**	**5**	**6**	**7**
B	1	49	97	145	193	241	
A #	0	45	93	141	189	237	
A		41	89	137	185	233	
G #		37	85	133	181	229	
G		33	81	129	177	225	
F #		29	77	125	173	221	
F		25	73	121	169	217	
E		21	69	117	165	213	
D #		17	65	113	161	209	
D		13	61	109	157	205	253
C #		9	57	105	153	201	249
C		5	53	101	149	197	245

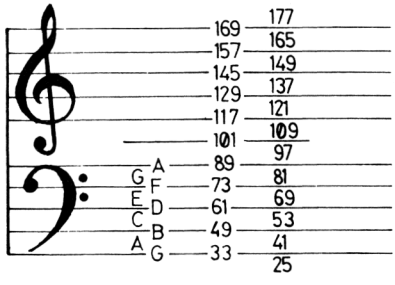


Figure 10: The Pitch Control

2 Low frequency periodic noise.

3 Periodic noise of frequency determined by the pitch setting of channel 1.

4 High frequency 'white' noise.

5 Medium frequeny 'white' noise.

6 Low frequency 'white' noise.

7 'white' noise of frequency determined by the pitch setting of channel 1.

D The duration parameter
This parameter determines the total duration of sounds whose amplitude is determined explicitly by a negative, or zero value, of the 'A' parameter. The duration is given in twentieths of a second. If an envelope has been selected by a positive value of 'A', the duration 'D' will determine the total of the attack, decay and sustain periods, but not of the release phase.

6.3 The ENVELOPE Command

This command allows the amplitude and pitch of a sound to vary in a controlled manner whilst it is playing. The ENVELOPE command takes 14 parameters:

```
ENVELOPE (N, T, PI1, PI2, PI3, PN1, PN2, PN3,
          AA, AD, AS, AR, ALA, ALD)
```

Table 7 gives a summary of the functions of the parameters; they are described in more detail below.

N The envelope number
This is in the range 1 to 16. Up to 16 different envelopes may be stored by ENVELOPE commands and subsequently selected by the 'A' parameter of a SOUND command.

T The step time
This is in the range 1 to 255 centiseconds. Its value (modulo 128) determines the length in centi-seconds of each step of the pitch and amplitude envelopes. If its value is 128 or more (bit 7 is set) then auto-repetition of the pitch envelope is suppressed.

Parameter	Range	Function
N	1 to 16	Envelope number
T bits 0-6	0 to 127	Length of step in centiseconds
T bit 7	0 or 1	0 = auto-repeat the pitch envelope 1 = no auto-repeat of pitch envelope
PI1	-128 to 127	Change of pitch per step in section 1
PI2	-128 to 127	Change of pitch per step in section 2
PI3	-128 to 127	Change of pitch per step in section 3
PN1	0 to 255	Number of steps in section 1
PN2	0 to 255	Number of steps in section 2
PN3	0 to 255	Number of steps in section 3
AA	-127 to 127	Change of amplitude per step in attack phase
AD	-127 to 127	Change of amplitude per step in decay phase
AS	-127 to 127	Change of amplitude per step in sustain phase
AR	-127 to 127	Change of amplitude per step in release phase
ALA	0 to 126	Target amplitude at end of attack phase
ALD	0 to 126	Target amplitude at end of decay phase

Table 7: ENVELOPE Command

PI1,PI2,PI3,PN1,PN2,PN3

These define the pitch envelope which consists of three sections; each section is specified by two parameters: the increment per step – *PI* – and the number of steps in the section – *PN*. The pitch envelope automatically repeats for the duration of the note, unless supressed by the 'T' parameter. Figure 11 shows a typical pitch envelope.

AA,AD,AS,AR,ALA,ALD

These parameters define the amplitude envelope, which itself consists of four sections: the attack, decay, sustain and release phases, as seen in Figure 11, of a typical amplitude envelope. The amplitude starts at zero and then climbs at a rate set by *AA* (the attack rate) until it reaches the level set by *ALA*. It then climbs or falls at the rate set by *AD* (the decay rate) until it reaches the level set by *ALD*. However, if *AD* is zero the amplitude will stay at the level set by *ALA* for the

duration of the sound.

The envelope then enters the sustain phase, which lasts for the remaining duration 'D' of the sound. The duration, 'D', is set by the SOUND command. During the sustain phase the amplitude will remain the same, or fall at the rate set by *AS*.

At the end of the sustain phase the note will be terminated if there is another note waiting to be played on the selected channel. If no note is waiting, the amplitude will decay at a rate set by AR until it reaches zero. If AR is zero, the note will continue indefinitely.

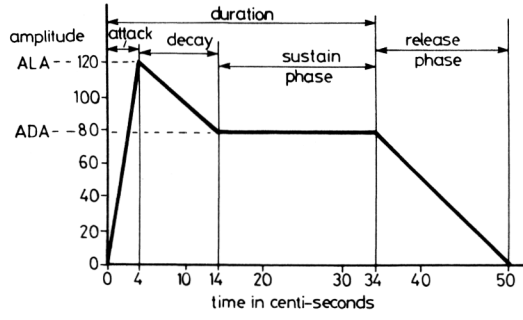


Figure 11: A Pitch Envelope

7. Keyboard Interface

7.1 Introduction

The keyboards of the Acorn Cambridge Workstation and the BBC Microcomputer are functionally identical, differing only in layout, although the ACW and Master 128 additionally have numeric keypads. The features of the keyboards are outlined in the introductory manuals. This section gives some additional information.

7.1.1 Auto-Repetition

Most keys auto-repeat; the exceptions are [ESCAPE], [CTRL], [SHIFT], [CAPS LOCK], [SHIFT LOCK] and the function keys. The auto-repeat rate and the delay before auto-repetition can be set by the Panos *Configure* utility.

7.1.2 Caps Lock

The state of [CAPS LOCK] on entering Panos can be set by the *configure* utility.

7.1.3 The BREAK Button or Key

This will force a return to the Pandora operating system kernel. The [BREAK] button is useful if a program gets stuck in a loop that cannot be left by pressing the [ESCAPE] key.

Pressing the [BREAK] button alone gives a 'soft reset' which neither clears the definitions of the user-defined keys, nor resets the system clock. Pressing [CTRL]-[BREAK] gives a 'hard reset' which clears these.

7.2 Function Keys

By default these have no effect, but the function keys may be programmed to produce either a string of characters, or a single code. For some functions, the [BREAK] key, the [COPY] key and the cursor movement keys can be considered 'soft' keys. In this case, these keys may be treated as function keys numbered from 10 to 15, as follows:

BREAK	f10
COPY	f11
←	f12
→	f13
↓	f14
↑	f15

7.2.1 Assigning Character Strings to the Keys

For BASIC, the **KEY* function may be used. Within Panos, the *set* utility is used, with the *key* attribute. A 'newline' character can be inserted into a string by means of the two character combination '|M'. For example:

```
-> set key 3 "edit myprogram|m"
```

Key numbers can take the values 0 to 15. The [BREAK] key (or button) continues to have its normal function; it will return control to Pandora, but any string assigned to the [BREAK] key will then be issued. [CTRL]-[BREAK] will remove all assignments of strings to function keys.

The cursor editing keys will not produce the strings assigned to them unless this has been previously enabled by an *FX 4,2, i.e. (OSBYTE 4,2).

OSBYTE 4,0	resets the normal line editing functions
OSBYTE 4,1	disables the line editing function and assigns the single byte codes shown in Tables 8 and 9.
OSBYTE 4,2	disables editing and permits the keys to have character strings assigned to them as if they were numbered 'f11' to 'f15'.

Where the keys are pressed with [SHIFT] or [CTRL] , single codes are produced, as listed in Tables 8 and 9.

To allow the function keys to produce a single code, use:

OSBYTE 225,n

where n is the 'base number'; if n=240, then the codes shown in Tables 8 and 9 will be produced (but will be ignored by the Panos device *kb:*).

OSBYTE 225,1	returns the function keys to their normal function of generating strings

OSBYTE 225,0 renders the keys inoperative

Codes may also be produced by the function keys used in conjunction with [SHIFT], [CTRL], and both [SHIFT] and [CTRL] together.

OSBYTE 226,n sets the base number for [SHIFT]-[key n].

The default value for n is 128, as shown in Tables 8 and 9.

OSBYTE 227,n sets the base number for [CTRL]-[key n].

The default value for n is 144, as shown in Tables 8 and 9.

OSBYTE 228,n sets the base number for [SHIFT]-[CTRL]-[key n].

The default is for these key combinations to have no effect. The values for n=160 are shown in Tables 8 and 9.

The Panos *show* utility may be used to examine the strings assigned to the function keys. The keys may be reset to clear the string assignments by sending the OSBYTE 18 command.

7.3 Character Set

Characters are read from the keyboard as 8-bit bytes. The codes for the printable characters correspond to the ASCII character set, except that '£' replaces the character assigned to code 16_60.

The hexadecimal codes produced by the keys, either alone or in combination with [SHIFT] and [CTRL] keys, are shown in Tables 8 and 9.

7.4 Keyboard Access

From BASIC:

Use *INPUT, INKEY, INKEY$, GET, GET$*

From Panos:

the keyboard is accessible to programs as the devices *kb:* (the default) and *rawkb:*. The characteristics of these devices are described below. When entering commands to Panos, the keyboard behaves like *kb:*

key		alone	shift	ctrl
0		30	30	30
!	1	31	21	31
"	2	32	22	32
#	3	33	23	33
$	4	34	24	34
%	5	35	25	35
&	6	36	26	36
'	7	37	27	37
(	8	38	28	38
)	9	39	29	39
*	:	3A	2A	3A
+	;	3B	2B	3B
<	,	2C	3C	2C
=	-	2D	3D	2D
>	.	2E	3E	2E
?	/	2F	3F	2F
@		40	40	00
A	a	61	41	01
B	b	62	42	02
C	c	63	43	03
D	d	64	44	04
E	e	65	45	05
F	f	66	46	06
G	g	67	47	07
H	h	68	48	08
I	i	69	49	09
J	j	6A	4A	0A
K	k	6B	4B	0B
L	l	6C	4C	0C
M	m	6D	4D	0D
N	n	6E	4E	0E
O	o	6F	4F	0F
P	p	70	50	10
Q	q	71	51	11
R	r	72	52	12

Table 8: Hexadecimal Codes Given by Keys

key		**alone**	**shift**	**ctrl**	
S	s	73	53	13	
T	t	74	54	14	
U	u	75	55	15	
V	v	76	56	16	
W	w	77	57	17	
X	x	78	58	18	
Y	y	79	59	19	
Z	z	7A	5A	1A	
{	[	5B	7B	1B	
|	\	5C	7C	1C	
}	]	5D	7D	1D	
~	^	5E	7E	1E	**Shift**
£	_	5F	60	1F	**ctrl**
f0		80	80	90	A0
f1		81	81	91	A1
f2		82	82	92	A2
f3		83	83	93	A3
f4		84	84	94	A4
f5		85	85	95	A5
f6		86	86	96	A6
f7		87	87	97	A7
f8		88	88	98	A8
f9		89	89	99	A9
TAB		09	09	09	
COPY		87	8B	9B	
←		88	8C	9C	
→		89	8C	9D	
↓		8A	8D	9E	
↑		8B	8E	9F	
RETURN		OD	0D	0D	
ESCAPE		1B	1B	1B	
DELETE		7F	7F	7F	
SPACE		20	20	20	

Table 9: Hexadecimal Codes Given by Keys (cont)

Other means of accessing the keyboard are described in the *Detecting Keystrokes* section.

7.4.1 The Device kb:

The printable characters give the codes indicated in Tables 8 and 9. Carriage return and line feed (CTRL J) are both read as code 10 (16_0A).

By default, the characters are echoed to the display, and auto-repeat is enabled.

The tabulate key, [TAB] , causes the text cursor (see *display interface*) to move to predefined positions which are set by the Panos *set* utility. The tabulate key is read as code 16_9, and this is treated as a delimiter equivalent to a space. The translation of this code to cursor movement occurs on output, in the display or printer interface.

The function keys have no effect by default, but the Panos *set* utility will assign any string of characters to them.

The [ESCAPE] key causes an asynchronous event (explained in the *Panos Guide to Operations*).

Keyboard input is 'buffered': if a sequence of keys is depressed before a program is ready to read them, the characters are saved and handed to the program when it requests input from the keyboard; they are not echoed until this point.

7.4.2 The Device Rawkb:

The key codes are read directly. All codes are available as shown in the table. The characters are not echoed to the display; auto-repeat is enabled, line editing is disabled and the input is buffered.

7.5 Detecting Keystrokes

Accessing the keyboard in the manner described above will cause programs to wait until the [RETURN] key is depressed (the [ESCAPE] key excepted). An alternative method is to enable the keyboard to cause an asynchronous event by means of the Panos library functions:

Event2	is caused by any key, if enabled
Event6	is caused by [ESCAPE] if enabled

The function OSBYTE 129 may be used to give an effect similar to the BASIC *INKEY* function.

7.6 ACW Keypad

The ACW (and the Master 128) have a separate numeric keypad forming part of the keyboard. Normally these keys return the same codes as the equivalent keys on the main keyboard. However, it is possible to map the codes onto different values.

Executing *FX 238,n from within Basic or at Panos command level, or OSBYTE 238,n from within a Panos program resets the base number for the keypad. The default setting for the base, i.e. the character '0', is 48, which generates the normal values. Other characters have the following offsets from the base:

RETURN	-35
#	-13
*	-6
+	-5
,	-4
–	-3
.	-2
/	-1
0–9	+0 – +9
DELETE	+79

Thus, for example, after:

```
-> star fx 238,49
```

the key [2] will return the normal code (and echo as) '3', (although this example is hardly a useful one).

8. Printer Interface

The ACW and the BBC Microcomputer provide connections for both parallel (Centronics compatible) and serial (RS423, RS232C, V24) printers.

8.1 External Connections

8.1.1 Parallel Printer Port

On the ACW, a 24-way 'Delta' or IEEE 488 style connector is provided, see *Appendix A*. The connections are shown in Table 10 together with those of the standard 36-way connector with which printers are usually provided.

	connector pin		
Signal	**26–way**	**24–way**	**36–way**
strobe	1	1	1
Data 0	3	2	2
Data 1	5	3	3
Data 2	7	4	4
Data 3	9	5	5
Data 4	11	6	6
Data 5	13	7	7
Data 6	15	8	8
Data 7	17	9	9
Acknowledge	19	10	10
No connection	21,23,25,26	11,12	11 to 17
Ground	2,4,6...,24	13 to 24	18 to 29

Table 10: Connections for ACW Parallel Printer Port

The connections are arranged so that insulation displacement connectors may be used to make a connecting cable; in this case it is recommended that 'flat

and twisted' cable be used. With conventional solderable connectors a twisted pair should be used for each signal, with a ground connection at both ends.

For the BBC Micro connections, see the *BBC Micro User Guide* or equivalent.

8.1.2 Serial Port

This is described in the *RS423 interface* section, as is the standard 25-way D-type connector with which serial printers are usually fitted. For driving printers the connections shown in Table 11 should be made:

RS423 connector		**printer 25-way connector**		
function	*pin*		*function*	*pin*
data out	B	to	Receive data	3
CTS	D	to	data terminal ready	20
		or to	request to send	4
ground	C	to	signal ground	7

Table 11: Serial Printer Connections

8.2 Software Interface

The Panos *configure* utility may be used to select the parallel or the serial port, and to set the baud rate and other parameters for the serial port.

Note that unless *configure* is run when Panos is installed, or re-installed, attempts to print to other than a parallel printer will fail.

The network printer, or a 'user supplied' printer interface, may also be selected. The procedure for using a printer which does not conform to the standard parallel or serial interface is described in Section 10.6 of the *Advanced User Guide for the BBC Micro* (the user print vector).

8.2.1 Access

From Panos, the printer is accessible as the device *printer:* or *lp:*; the names are synonymous. The printer may also be accessed by certain of the 'Control Codes' described in the display interface section.

8.2.2 Character Translation

The following translations occur:

Carriage return (code 16_0D) is inserted after each *newline* (code 16_0A).

Tabulate (code 16_9) is translated to a number (at least one) of space (code hex 20) characters according to the current setting of the tabulate stops (see the Panos *set* utility).

A selected character may be suppressed. For example some printers automatically insert a *newline* character after each *carriage return*; this would result in double spacing unless the *newline* character were suppressed.

To suppress the character with code C (decimal):

BASIC	*FX 6,C
Panos	Use the *configure* utility
Other languages	OSBYTE 6 C

8.2.3 Control Codes

The following are not applicable under Panos but only in BASIC.

Control Code 1 a will send a single character with code a to the printer. The suppressed character may be sent in this way.

Control Code 2 will cause any subsequent output to the display to be sent to the printer as well.

Control Code 3 will prevent further display output from being sent to the printer.

9. RS423 Interface

9.1 External Connections

Table 12 shows how the ACW (or BBC Micro) should be connected to the 25-way D-type connector with which most serial interfaces are provided.

ACW 5-pin Domino Din			**Canon 25-way connector**	
Function	*pin*		*Function*	*pin*
Data in	A/1	connect to	Transmitted data	2
Data out	B/2	connect to	Received data	3
CTS	D/4	connect to	Request to send	4
RTS	E/5	connect to	Clear to send	5
GND (0V)	C/2	connect to	Signal ground	7

Table 12: Connections for RS423

The signal levels conform to the specifications of the Electronic Industries Association standard RS422A and RS423A. The protocol used by the ACW is as follows:

- The I/O Processor will transmit while CTS is asserted.
- The I/O Processor will assert RTS when it is ready to receive.

9.2 Software Interface

The RS423 port is accessible from Panos as the device *RS423:*. No filtering or translation of characters is applied for input or output.

The Baud rates for transmission and reception and other parameters may be set up by the Panos *configure* utility.

10. 1 MHz Bus Interface

This is an extension of the bus signals of the 6512 Input/Output processor.

10.1 External Connections

Devices connected to the bus are accessed by the I/O processor as part of its memory space, that is, they are 'memory mapped'. The bus contains the least significant 8-bits of the address bus and two signals decoded from the high order 8-bits of the address. These are labelled NFC and NFD, and are 'active low'. These signals are decoded from high address bytes 16_FC and 16_FD.

The bus connections are shown in Table 13. For a detailed description of the signals, reference should be made to the 6512 microprocessor handbook. See also the *Advanced User Guide, Chapter 27* On the ACW a 37-way 'D' type connector is used.

The signals are buffered by LSTTL devices.

10.2 Software Interface

The bus may be accessed by OSBYTE calls, as in the table below:

	Read	**Write**
Assert 16_FC	OSBYTE 146	OSBYTE 147
Assert 16_FD	OSBYTE 148	OSBYTE 149

Param1 holds the address offset. For reading, *Result1* is the data byte taken from the bus; for writing, *Param2* is the data byte to be written.

Some system peripherals are connected to the 1 MHz bus, and are assigned parts of the address space as shown in Table 14.

37-way	IDC	function	37-way	IDC	function
1	1	0V	20	2	R/NW
2	3	0V	21	4	1MHzE
3	5	0V	22	6	NNMI
4	7	0V	23	8	NIRQ
5	9	0V	24	10	NPGFC
6	11	0V	25	12	NPGFD
7	13	0V	26	14	NRST
8	15	0V	27	16	Analog Input
9	17	0V	28	18	D0
10	19	D1	29	20	D2
11	21	D3	30	22	D4
12	23	D5	31	24	D6
13	25	D7	32	26	0V
14	27	A0	33	28	A1
15	29	A2	34	30	A3
16	31	A4	35	32	A5
17	33	A6	36	34	A7
18	35	N/C	37	36	N/C
19	37	N/C			

N/C = No connection

Table 13: Connections for 1 MHz Bus

16_FC00 to 16_FC0F	Test hardware
16_FC1D to 16_FC13	Teletext interface
16_FC14 to 16_FC1F	Prestel interface
16_FC20 to 16_FC27	IEEE 488 interface
16_FC28 to 16_FC2F	Reserved for use by Acorn
16_FC30 to 16_FC3F	Cambridge ring interface
16_FC40 to 16_FC47	Winchester disc interface
16_FC48 to 16_FC7F	Reserved for use by Acorn
16_FC80 to 16_FC8F	Test hardware
16_FC90 to 16_FCBF	Reserved for use by Acorn
16_FCC0 to 16_FCFE	Available for user applications
16_FCFF	Paging register for memory expansion
16_FD00 to 16_FD7F	Reserved for use by Acorn
16_FD80 to 16_FDFF	Available for user applications.

Table 14: 1MHz Bus Address Assignments

11. Analogue Interface

The ACW (and the BBC Microcomputer) is provided with a four-channel 12-bit analogue to digital converter (ADC). Two digital inputs are also provided on the input connector.

11.1 External Connections

The connections are shown in Table 15. See the technical description and circuit diagram in the appropriate user guide or service manual.

pin	function	pin	function
1	+5v	9	~LPSTB
2	0V	10	PBI
3	0V	11	VREF
4	CH3	12	CH2
5	Analogue Gnd	13	PBO
6	0V	14	VREF
7	CH1	15	CHO
8	Analogue Gnd		

Table 15: Connections for Analogue Port

Note that the input voltages should be within the range 0V to +1.8V; voltages outside this range may cause damage to the ADC. Although an internal reference voltage is provided, for the greatest accuracy an external temperature compensated reference should be used. If the full 12-bit accuracy is required, great care must be taken with screening the leads and securing analogue ground connections. For further details of the ADC, refer to the manufacturer's data sheet.

Transduction factor

The digital output varies from 0 to 65520 in steps of 16, to correspond to voltages between 0V and +1.8V.

Conversion time:

10 milliseconds per channel.

Associated digital inputs:

The digital inputs may be used to interface to a switch, to ground, or to a TTL signal.

11.2 Software Interface

BASIC:

the *ADVAL* ('analogue to digital conversion value') function is provided.

Panos Library:

OSBYTE 16 selects the number of active channels.

Param1=0 will disable all channels
Param1=1 will enable channel 1 only
Param1=2 will enable channels 1 and 2
Param1=3 will enable channels 1,2 and 3
Param1=4 will enable all four channels

The converter repeatedly cycles through the selected channels, converting each in turn. It stores the last value obtained from each channel.

OSBYTE 17 will override this free-running mode, forcing the ADC to start a conversion on the channel indicated by the value in *Param1*.

OSBYTE 128 can be used to read a particular ADC channel, or to discover which channel last completed a conversion operation. It also reads the digital inputs. *Param1* selects the number of the channel to be read. The value is returned in two bytes: the most significant is in *Result1*, the least significant is in *Result2*.

If *Param1* is zero then *Result2* will contain the number of the last channel to have had a conversion completed. If no channels have completed a conversion since an OSBYTE 16 or OSBYTE 17 call, then zero will be

returned. The two least significant bits of *Result1* record the status of the digital inputs.

Completion of conversion can be notified by causing an interrupt (asynchronous event number 3). The Panos library procedures may be used both to enable and to handle this event.

12. Internal Clock and Timer

The ACW (and BBC Microcomputer) contains both an internal clock and an internal timer which measures time in units of 0.01 seconds (centi-seconds). The clock and timer run continuously while the ACW is powered on; a hard reset, i.e. CTRL - BREAK , or mains power switch will reset the clock and times to zero. Both the clock and the timer values are held as binary numbers in five consecutive bytes, giving a range of approximately 1012.

The clock may be accessed as follows:

Panos: *set* and *show* utilities are used to set and read the clock. After a hard reset, the clock is in an unset state. Programs running under Panos may use various Panos library functions.

BASIC: TIME is a pseudo-variable which sets or reads the lower four bytes of the internal clock.

LISP: The function (timeofday) returns a string giving the time of day; (date) returns a string giving the date.

The timer may accessed by programs running under Panos as follows:

OSWORD 4 sets the timer to the value in the five byte parameter block. The timer counts upwards and can initiate an interrupt (i.e., asynchronous event 5) when it reaches zero. Programs running under Panos can respond to this event. For BASIC, *FX14,5 and *FX13,5 enable and disable this event respectively.

13. User Port

This is a digital interface which may be used for input or for output, or for both input and output.

The connector pins go directly to a 6522 Versatile Interface Adaptor (VIA). The VIA contains two fully programmable bi-directional 8-bit I/O ports.

The ACW uses a 25-way 'D-type' connector, see Table 16 for the connections. Also shown in the table is the pin-out of the IDC connector on the I/O Processor board (and thus available to the BBC Microcomputer user) which connects to the connector on the back of the ACW.

25-way	IDC	function	25-way	IDC	function
1	1	+5V	14	2	CB1
2	3	+5V	15	4	CB2
3	5	0V	16	6	PB0
4	7	0V	17	8	PB1
5	9	0V	18	10	PB2
6	11	0V	19	12	PB3
7	13	0V	20	14	PB4
8	15	0V	21	16	PB5
9	17	0V	22	18	PB6
10	19	0V	23	20	PB7
11	21	N/C	24	22	N/C
12	23	N/C	25	24	N/C
13		N/C			

Table 16: Connector Pin Assignments - User Port

The VIA is memory mapped at locations 16_FE40 to 16_FE6F. The method of programming the function of the VIA is described in the 6522 Data Sheet; this information is reproduced in Chapter 22 of the *Advanced User Guide for the BBC Micro*.

Appendix A. ACW Connector Pins

This appendix shows connector pin assignments for the ACW. Those for the BBC Microcomputer are similar – refer to the User Guide supplied.

Note that pinouts are viewed from the *rear* of the unit (ACW) as shown in Figure 12.

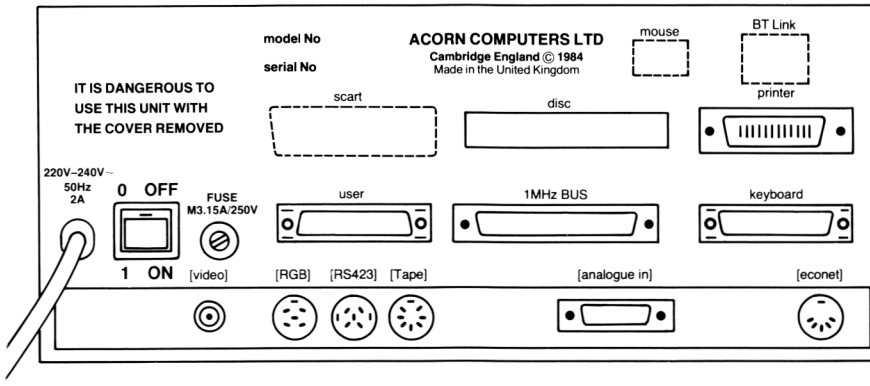


Figure 12: Sketch Showing Rear Panel of ACW Main Unit

Printer

see Chapter 8, Table 10

RGB

1	Red
2	Green
3	Blue
4	Sync
5	0V
6	5V

RS423

see Chapter 9, Table 12

Tape (Cassette)

1	Output
2	0V
3	Input
4	Output (parallel with 1)
5	No connection
6,7	Motor control

Analogue In

see Chapter 11, Table 15

Econet

1	Data
2	0V
3	Clock
4	Data
5	Clock

User Port

see Chapter 13, Table 16

1MHz Bus

see Chapter 10, Table 13

Appendix B. '*' Command Summary

Filing System Commands

The table is a summary of the more important filing system '*' commands.

Function	DFS	ADFS	NFS
select filing system	*DISC	*ADFS	*NFS
lock or unlock a file	*ACCESS	*ACCESS	*ACCESS
select previous directory	-	*BACK	-
create text file from keyboard	*BUILD	-	-
close all files and park heads or log off	-	*BYE	*BYE
display a disc or directory catalogue	*CAT	*CAT	*CAT
create a new directory	-	*CDIR	*CDIR
re-organise physical storage on disc	*COMPACT	*COMPACT	-
copy files from a drive/directory to another	*COPY	*COPY	-
remove a single named file	*DELETE	*DELETE	*DELETE
remove specified files	*DESTROY	*DESTROY	*DESTROY
select current drive/directory	*DIR	*DIR	*DIR
select current drive	*DRIVE	-	-
execute list of '*' commands in file	*EXEC	*EXEC	*EXEC
display amount of free space on disc	-	*FREE	*FREE
display list of commands	*HELP	*HELP	*HELP
select current library	*LIB	*LIB	*LIB
load file into memory (e.g. machine code)	*LOAD	*LOAD	*LOAD
specify auto-start option	*OPT 4	*OPT 4	*OPT 4
change a file name	*RENAME	*RENAME	*RENAME
execute a machine code program	*RUN	*RUN	*RUN
save memory image into a file	*SAVE	*SAVE	*SAVE
specify disc or directory title	*TITLE	*TITLE	-
display text file on screen	*TYPE	-	-
remove specified files with confirmation	*WIPE	-	-

For a full list of filing system commands applicable to the particular model of 'I/O Processor' in use, type

```
*help DFS
*help ADFS
*help NFS
```

or consult the appropriate User Guide.

Most commands can be abbreviated, but a full stop must be appended to the abbreviation, e.g.

```
*h.
```

means *Help.

Appendix C. Printable Characters

Dec	Hex	ASCII	Dec	Hex	ASCII
32	20	SPACE	80	50	P
33	21	!	81	51	Q
34	22	"	82	52	R
35	23	#	83	53	S
36	24	$	84	54	T
37	25	%	85	55	U
38	26	&	86	56	V
39	27	'	87	57	W
40	28	(	88	58	X
41	29	)	89	59	Y
42	2A	*	90	5A	Z
43	2B	+	91	5B	[
44	2C	,	92	5C	\
45	2D	-	93	5D	]
46	2E	.	94	5E	^
47	2F	/	95	5F	_
48	30	0	96	60	£
49	31	1	97	61	a
50	32	2	98	62	b
51	33	3	99	63	c
52	34	4	100	64	d
53	35	5	101	65	e
54	36	6	102	66	f
55	37	7	103	67	g
56	38	8	104	68	h
57	39	9	105	69	i
58	3A	:	106	6A	j
59	3B	;	107	6B	k
60	3C	<	108	6C	l
61	3D	=	109	6D	m
62	3E	>	110	6E	n
63	3F	?	111	6F	o
64	40	@	112	70	p

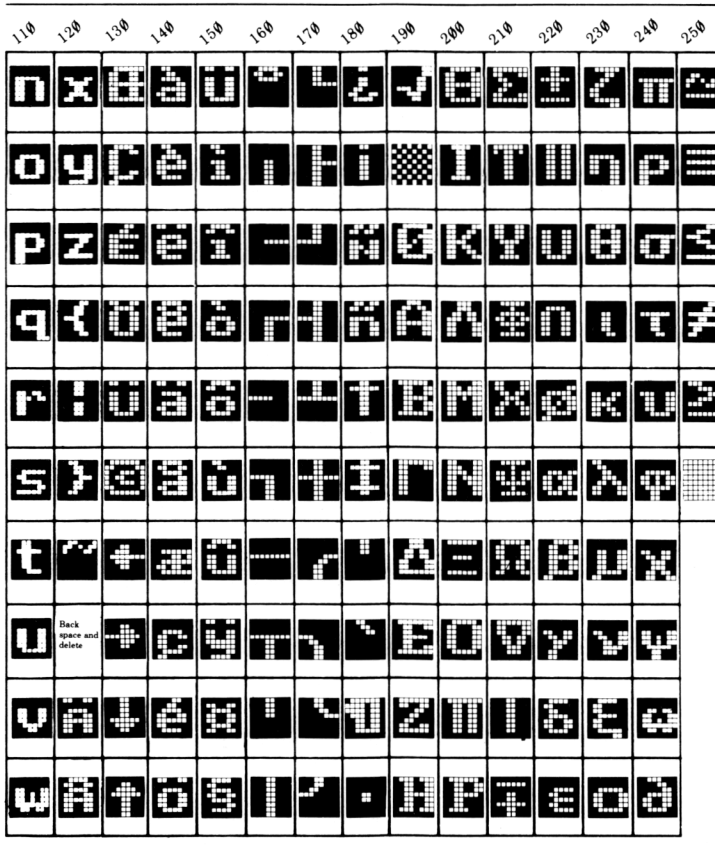
65	41	A	113	71	q
66	42	B	114	72	r
67	43	C	115	73	s
68	44	D	116	74	t
69	45	E	117	75	u
70	46	F	118	76	v
71	47	G	119	77	w
72	48	H	120	78	x
73	49	I	121	79	y
74	4A	J	122	7A	z
75	4B	K	123	7B	{
76	4C	L	124	7C	|
77	4D	M	125	7D	}
78	4E	N	126	7E	~
79	4F	O			

Appendix D. Character Sets

ASCII Character Set

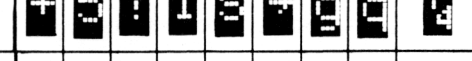
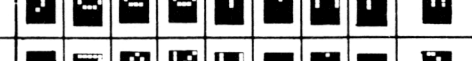
applies to Modes 0 to 6 (and 128 to 134).

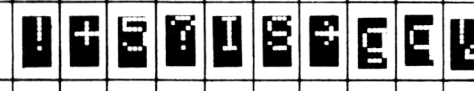
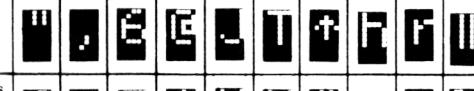
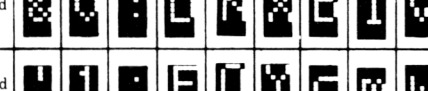
	Ø	1Ø	2Ø	3Ø	4Ø	5Ø	6Ø	7Ø	8Ø	9Ø	1ØØ
Ø	Nothing	Down	Default logical colors	Move text cursor to ØØ	(	2	<	F	P	Z	d
1	Next to printer	Up	Disable VDU	Move text cursor	)	3	=	G	Q	[	e
2	Start printer	Clear text	Select mode		*	4	>	H	R	\	f
3	Stop printer	Start of line	Reprogram characters	!	+	5	?	I	S	]	g
4	Separate cursors	Paged mode	Define graphics area	"	,	6	@	J	T	^	h
5	Join cursors	Scroll mode	Plot	#	-	7	A	K	U	_	i
6	Enable VDU	Clear graphics	Default text/ graphics areas	$	.	8	B	L	V	£	j
7	Beep	Define text color	Nothing	%	/	9	C	M	W	a	k
8	Back	Define graphics color	Define text area	&	Ø	:	D	N	X	b	l
9	Forward	Define logical colors	Define graphics origin	'	1	;	E	O	Y	c	m


110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
Back space and delete

Teletext Alphanumeric Character Set

applies to Mode 7.

	Ø	1Ø	2Ø	3Ø	4Ø	5Ø	6Ø	7Ø	8Ø	9Ø	1ØØ	11Ø	12Ø
Ø	Nothing	Down	Nothing	Move cursor to ØØ									
1	Next to printer	Up	Disable VDU	Move cursor									
2	Start printer	Clear screen	Select mode										
3	Stop printer	Start of line	Reprogram characters										
4	Nothing	Paged mode	Nothing										
5	Nothing	Scroll mode	Nothing										
6	Enable VDU	Nothing	Nothing										
7	Beep	Nothing	Nothing										Back space and delete
8	Back	Nothing	Nothing										Nothing
9	Forward	Nothing	Nothing										Alpha red

130	140	150	160	170	180	190	200	210	220	230	240	250
Alpha green	Normal * height	Graphic cyan										
Alpha yellow	Double height	Graphic white										
Alpha blue	Nothing	Conceal display										
Alpha magenta	Nothing	Contiguous graphics *										
Alpha cyan	Nothing	Separated graphics										
Alpha * white	Graphic red	Nothing										
Flash	Graphic green	Black * background										
Steady *	Graphic yellow	New background										
Nothing	Graphic blue	Hold graphics										
Nothing	Graphic magenta	Release * graphics										

* every line starts with these options

Teletext Graphics Character Set

applies to Mode 7.

	0	10	20	30	40	50	60	70	80	90	100	110	120
0	Nothing	Down	Nothing	Move cursor to 00									
1	Next to printer	Up	Disable VDU	Move cursor									
2	Start printer	Clear screen	Select mode										
3	Stop printer	Start of line	Reprogram characters										
4	Nothing	Paged mode	Nothing										
5	Nothing	Scroll mode	Nothing										
6	Enable VDU	Nothing	Nothing										
7	Beep	Nothing	Nothing										Back space and delete
8	Back	Nothing	Nothing										Nothing
9	Forward	Nothing	Nothing										Alpha red

130	140	150	160	170	180	190	200	210	220	230	240	250
Alpha green	Normal * height	Graphic cyan										
Alpha yellow	Double height	Graphic white										
Alpha blue	Nothing	Conceal display										
Alpha magenta	Nothing	Contiguous graphics *										
Alpha cyan	Nothing	Separated graphics										
Alpha * white	Graphic red	Nothing										
Flash	Graphic green	Black * background										
Steady *	Graphic yellow	New background										
Nothing	Graphic blue	Hold graphics										
Nothing	Graphic magenta	Release graphics *										

* every line starts with these options

Guide To Documentation

The publications referred to in this Guide are listed below. See the *ACW Welcome Guide* for an extended list of all related documentation.

Panos Guide to Operations:
This gives a comprehensive description of the Panos operating system, both for the user and for the high-level language programmer.

Panos Programmers Reference Manual:
Of interest to users who wish to write programs which interface with Panos at a low level.

Cambridge Workstation Technical Description and Service Manual
Acorn Computers Ltd.,
Part Number 0418,100
to be published – describes the hardware

Cambridge Co-Processor Technical Description and Service Manual
Acorn Computers Ltd.,
Part Number 0410,000
to be published – describes the hardware

Language Manuals

32000 Assembler Reference Manual
32000 BBC BASIC Reference Manual
FORTRAN 77 Reference Manual
ISO Pascal Reference Manual
C Reference Manual
Cambridge LISP Reference Manual

The language manuals describe the implementation dependent features of the languages, the compilation control parameters, and diagnostic facilities. The guides are not intended to serve as reference manuals to the standard features of the languages.

BBC Microcomputer Related Documentation

This guide to the Cambridge series I/O processor does not claim to be exhaustive, it is simply a collection of material which is thought to be relevant and useful to 'typical' ACW users. Expert or specialist users may need access to particular manuals written for the BBC Microcomputer.

BBC Microcomputer System User Guide
Part Number 0433 000
Issue 1, October 1984

Disc Filing System User Guide
Part Number 0403 700
Issue 2, 1983

Winchester Disc Filing System User Guide
Part Number 0427 000
Issue 1, 1984

Econet Level 2 File Server User Guide
Part Number 0412 018
Issue 1, 1983

Econet Level 2 File Server Manager's Guide
Part Number 0412 017
Issue 1, 1983

There is a set of manuals specifically written for the BBC Microcomputer Master Series. This includes:

Master Series Welcome Guide
Part Number 0443,000
Issue 1, 1986

Master Series Reference Manual Part One
Part Number 0443,001
Issue 1, 1986

Master Series Reference Manual Part Two
Part Number 0443,002
Issue 1, 1986

In addition, the following items of 'third party' documentation may prove useful:

6512A Microprocessor Handbook
7002 (ADC) Data Sheet
6522 (VIA) Data Sheet
6845 Video Controller Data Sheet
6850 (ACIA) Data Sheet

The Advanced User Guide for the BBC Micro
Bray, Dickens and Holmes.
Cambridge Microcomputer Centre, 1983.

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