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Title:

The BBC Microcomputer as a Laboratory Tool

Author: Chris Adie

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Synopsis

The purpose of this User Note is to explain the facilities available on the BBC microcomputer and the support that the ERCC can provide for it. It is not intended as a real time computing tutorial.

Keywords

BBC microcomputer, real time application

Edinburgh Regional Computing Centre

James Clerk Maxwell Building, The King's Buildings, Mayfield Road, Edinburgh, EH9 3JZ. Telephone 031-667 1081

1 Introduction

The BBC microcomputer is a low-cost machine which is eminently suitable for a variety of real time tasks. It has a wide selection of built-in interfaces, and an even greater variety can be bought as add-on units. The ERCC recommends and supports this microcomputer for "low-end" real time applications. The term "BBC microcomputer" in this User Note should be taken as including the BBC B, BBC Plus, BBC Plus 128 and Master 128 variants: the Master Compact is not covered.

The purpose of this User Note is to explain the facilities available on the BBC microcomputer and the support that the ERCC can provide for it. It is not intended as a real time computing tutorial. The BBC microcomputer is now widely used for real time tasks within the community served by the ERCC. It is clearly not suitable for all real time tasks; very fast sampling for extended periods is not possible, nor is it sensible to use the machine where heavy computation is required. Nevertheless, there is a large range of "low-end" real time applications where the BBC microcomputer is the most suitable tool:

* Moderate to slow speed analog data sampling and display, up to 100 samples a second. A typical application is automated gas chromatography data capture and analysis.

* Burst-mode analog data acquisition: sampling at, for example, 10 kHz for short time. Typical applications are "stimulus and response" biological experiments.

* Event counting and timing to 10 ms resolution. A typical application is ECG interval analysis.

* Control and feedback situations, where the computer forms part of a feedback loop. Typical applications occur in Engineering and Physics laboratories.

* Simple data logging; acquiring data (possibly already in digital form), displaying and storing it for later analysis.

* Teaching applications: interfacing computers to student experiments.

The support offered by the ERCC for the BBC microcomputer in real-time applications falls into four categories as follows:

(1) Advice and Guidance

The ERCC is able to offer guidance on whether the BBC microcomputer is suitable for a particular real time application, and advice on how to use the facilities available on the microcomputer to solve the problem in hand. The advice is based both on extensive experience in solving real time problems, and on a knowledge of what other departments in the University are doing in similar situations. The advice offered will be impartial - the ERCC will not attempt to push the BBC microcomputer where another machine would be more appropriate; for instance where an existing application using, say, an Apple is to be duplicated, or where a turnkey system would solve the problem. However, it should be understood that no support can necessarily be offered by the ERCC in such cases. The ERCC hopes to evaluate future products for the BBC microcomputer, and will be able to advise on their relevance for real time applications.

(2) Information

The ERCC has already built up a considerable library of information on the BBC microcomputer hardware and software and on interfaces for it. We also have information on real time applications in the University, and can try to prevent duplication of effort. Specific information which is available is listed in Section IV.

(3) Communications and Other Utilities

The ERCC provides X-Talk communications software for file transfer to and from EMAS. This is available as a ROM, and it can transfer EMAS files to and from the BBC's discs, cassette tape, or memory. X-Talk also gives the BBC terminal emulation capability. User Note 74 describes X-Talk in detail. There is alternative file transfer ROM called Kermit, which is also available through the ERCC. See Appendix 2 for details of how to connect to the network.

Where there is a common requirement for hardware or software for real time applications on the BBC microcomputer, the ERCC may be able to identify or provide such utilities. Section V lists currently available utility software.

(4) Central Facilities

It is hoped to provide central facilities such as PROM programming, tape and disc format interchange, academic software distribution, and demonstration/evaluation facilities. The specific facilities currently on offer are listed in Section V.

The onus is on the user to provide resources for software and/or hardware development, and this should be borne in mind when costing a project. The ERCC may be able to implement particular projects on a paid consultancy basis.

Note also that it is not intended that ERCC should provide any measure of support whatsoever for privately owned BBC microcomputers.

II Configurations

The BBC microcomputer can use either standard cassette tapes or 5.25" floppy disc as bulk storage media. The former is cheaper but relatively slow, and the latter is faster and more expensive. Both configurations are supported by ERCC. There is also a choice between colour and monochrome video monitors.

The ERCC has identified a range of peripherals with which we have had experience and which we recommend for connection to the BBC microcomputer. While great care has been taken to ensure that these peripherals are serviceable and reliable, no guarantee can be given that they are the "best" in any particular sense. They will, however, all function with the BBC microcomputer (given the appropriate connecting cable).

The recommended items for a new BBC microcomputer system are listed below. The latest prices are available from ERCC. Please consult ERCC before ordering any equipment, in order that a configuration best suited to your needs can be identified.

* BBC Master 128

* Microvitec 14" low, medium, or high resolution colour monitor

* Zenith ZVM-123-EZ monochrome (green or amber screen) monitor

* Dixons TR30 tape recorder

* CS8005 dual 80/40 track switchable disc drive.

* Epson compatible printer

* Acorn IEEE488 interface

* Acorn Turbo Upgrade

If you wish to purchase a colour monitor, please contact the ERCC to make sure you understand the implications in terms of screen resolution.

Suppliers: Orders for these items should be placed through Mr Robertson, ERCC, the King's Buildings (031-667 1081 ext. 2613) in order to take advantage of University discounts which he has negotiated with the suppliers on some items. Note that all computer equipment purchased from UGC funds should be approved by the Computer Equipment Panel.

Maintenance: The above items are covered by warranties of varying duration. Post warranty maintenance may be arranged through the ERCC Service Support Unit at the King's Buildings (031-667 1081 ext. 2622).

III Interfaces

The following interfaces are standard on the BBC microcomputer:

(1) A-D converter

The BBC has a 4 channel 10-bit analog to digital converter built in, which is suitable for moderate to slow speed data acquisition. The conversion time is roughly 10ms per channel, and the default mode of operation is that the processor cycles round the four channels every 40ms, retaining for access by BASIC the last value read from each channel. The machine can be caused to sample from fewer channels (e.g. 1 channel every 10ms) by using the *FX 16 command. Conversion can be synchronized (in software) to an external event by using *FX 17. The analog input range is 0 to 1.8 V, and analog signals are connected to the machine through a 15-pin D-type female connector at the back. Appendix 1 gives details of some problems which may arise, and how to cure them.

(2) RS423 Serial Interface

The serial interface is compatible with the RS232C specification (sometimes known as V24). The port can be used for driving the BBC microcomputer from a VDU, or for a serial printer, and is used when the BBC microcomputer is in terminal emulation mode. The default mode of operation is for the serial port to operate under control of the operating system. Hardware flow control signals are used, called CTS and RTS (clear to send and ready to send). If the equipment you wish to interface to this port does not have these signals, then CTS must be connected directly to RTS to allow the port to function. An alternative method of flow control (used by the terminal emulator) is XON/XOFF. This is implemented in software, and bypasses the operating

system. If you wish to use this protocol, please see User Note 74. The connector for the serial port is a 5-pin "domino" DIN type. If you wish to connect to the ERCC network, please see Appendix 2.

(3) Parallel Printer Port

An 8-bit parallel (Centronics-compatible) printer port is provided underneath the machine. A suitable connector should be purchased with your printer. This port is normally handled by the operating system: it is the 'A' half of a 6522 VIA chip. The port can only be used as an output; one handshake line (CA1) and a strobe line (from CA2) are provided. Advice should be sought from ERCC on how to use this port other than for a printer.

(4) User I/O port

This 8-bit parallel I/O port is the B half of the 6522 VIA chip used for the printer. Each of the 8 bits is independently configurable as an input or an output. Three handshaking lines (CA2, CB1 & CB2) are provided. All I/O through the port is done by the user's software. A suitable connector is available from Radiospares. The ERCC may be able to make up connectors (for an appropriate charge) if users do not have the necessary mass termination tools.

(5) 1 MHz bus

The 1 MHz bus is an 8-bit parallel digital interface, with the capability of driving up to 512 8-bit I/O ports. It is essentially an extension of the 6502 CPU bus, with 8 data lines, 8 address lines an extra 'page' line, handshaking and interrupt lines. Any device on the bus is mapped into the system memory between &FC00 and &FE00. Almost any type of hardware can be interfaced to the 1 MHz bus - examples are specialized data gathering units, IEEE488 interface, Cambridge Ring interface, high-speed A to D and D to A interfaces, and expanded (paged) memory. (Some of these devices are already available; others are not.) If you wish to interface your own equipment to the bus, the ERCC has information and experience on doing this.

(6) Tube

The Tube is a specialized interface to allow other processors to be fitted to the BBC microcomputer. The real time user is unlikely to be concerned with how the tube works, or how to interface to it.

(7) Econet

Econet is a local area network of the 'Ethernet' genus. It is a 4-wire system, and the connection to the BBC microcomputer is via a DIN plug at the back of the BBC microcomputer. This connector is only present if the machine has an Econet interface fitted internally. Facilities available through the Econet include file server, print server, and facilities suitable for teaching applications. Contact ERCC for further information, but note that the Econet is not supported by the ERCC in any way.

(8) Video outputs

Three video output connectors are provided on the back of the BBC microcomputer. They provide RGB (red-green-blue) and synchronization signals for a colour monitor (DIN connector); composite video output for a monochrome monitor (BNC connector); and UHF Modulated output for a TV set (phono connector). The display defaults to interlaced mode, which may cause flickering on some monitors. The interlace can be turned off in all but one of the display modes if required.

(9) Audio I/O

The internal speaker in the BBC microcomputer is wired through a push-on connector to the main printed circuit board. If external use is to be made of the audio signal, the user can plug his own equipment onto this internal connector. Three signal sources feed the audio output: the sound generator chip (which has four independent channels), the (optional) speech processor, and an external source from a pin on the 1 MHz bus connector.

(10) Light Pen

A light pen input is provided on the analog input connector. The input is connected directly to the video controller chip, which determines the light pen position on the screen. This can be read under software control.

(11) Disc interface

The disc interface is fitted internally, and is required if the BBC microcomputer is to be used with discs. A suitable connecting cable should be purchased with your disc drive.

Other interfaces are available for connection to the BBC microcomputer. Some of these are described briefly below: you should contact the ERCC for further information and for advice on which interfaces are most suitable for your application. Note that because new interfaces are continually being brought out, this list makes no pretence at completeness.

(12) Control Universal
A Eurocard backplane connecting to the 1MHz bus and accepting cards from the CU range, including a variety of interface cards.

(13) Digithurst
Image processing hardware and software, vision systems. (Connects to user port.)

(14) Geophysical Systems
Audio frequency signal display and analysis system. Fourier transform spectral analysis. (Connects to 1MHz bus.)

(15) Unilab
Fast A/D and D/A unit, programmable gain amplifier, trigger facility, relay switching port. (Connects to 1MHz bus.)

(16) Excet Systems
Unit measuring voltage, current, power, resistance, light intensity, times, temperature. (Connects to A/D port.)

(17) Grafitek Electronics
High speed A/D interface with storage capability. (Connects to user port.)

(18) Philip Harris
Fast A/D interface: Ohms and Volts, variable gain. (Connects to user port.)

(19) Educational Electronics
VELA interface unit - a multipurpose interface with its own built-in microprocessor. (Connects to user port.)

(20) Cambridge Computer Consultants
IEEE488 interface unit with software in BASIC. (Connects to 1MHz bus.)

(21) Cambridge Systems Technology
IEEE488 interface unit with software in ROM. (Connects to 1 MHz bus.)

(22) Northern Technical and Chemical Services
Pressure and linear movement transducers. (Connects to A/D port.)

(23) Ramamp Computers
Control unit offering mains switching and 200v ADC isolation. (Connects to user port.)

(24) Oasis
High performance 16-channel 12-bit ADC. (Connects to 1 MHz bus.)

(25) Solidisk Technology
RAM disc using "sideways RAM". (Fitted internally.)

(26) Commotion
Servo motors and interface unit. (Connects to user port.)

(27) Cambridge Electronic Design
Intelligent interface type 1401. Advanced interface featuring multiple channel ADCs, DACs and digital I/O. Has a built-in 6502 microprocessor with 64k of memory. Software also available.

(28) Minor Miracles
Variety of opto-isolated digital I/O interfaces.

(29) DCP Microdevelopments
Low cost "Interbeeb" digital I/O and ADC interface unit.

(30) Freddy Systems
Backplane system for 1 MHz bus.

(31) Acorn
IEEE488 interface with software in ROM. (Connects to 1 MHz bus.)

(32) ERCC
Multifunction interface unit. Connecting to the 1 MHz bus, this unit has been developed by the ERCC to provide several commonly required functions, including a 12 bit ADC with 8 input channels incorporating signal conditioning and amplification, two DACs, and digital I/O capability. Contact ERCC for further details.

IV Information

The information listed in this section is held by ERCC. You are welcome to make an appointment to look at this information, some of which is available for borrowing under special circumstances.

Note that the BBC Microcomputer Advanced User Guide is particularly useful when writing machine code programs.

(1) Manuals

BBC microcomputer users manual (as distributed with each machine).
BBC microcomputer service manual and circuit diagram.
BBC microcomputer disc filing system manual.
BBC microcomputer MOS manual.

BBC microcomputer Advanced User Guide.
BBC Master Welcome Guide.
BBC Master Reference Manual parts 1 & 2.
Econet manual.
Wordwise manual.
View manual.
Viewsheet manual.
Viewstore manual.
Acorn IEEE interface unit manual.
Cambridge Computer Consultants IEEE488 interface unit manual.
Logo II manual.
BBC microcomputer X-Talk user guide: User Note 74.
ATP Prom Programmer manual.
ATPL Sidewise User Manual.
EXMON User manual.
DISC DOCTOR User manual.
TOOLKIT User manual.
Advanced Basic ROM Users Guide.
6502 Second Processor Users Guide.
ADE User Manual.
Multi-Basic User Manual.
Acornsoft ISO Pascal User Manual.
Acornsoft Printdriver Generator manual.
Oxford Pascal User Manual.
Termulator manual.
Disk Filing System User Guide
PROPAK User Guide.

(2) Books

Birnbaum	Assembly language programming on the BBC microcomputer.
Davis	Using floppy discs with the BBC microcomputer.
Foster	Real Time Programming - Neglected Topics.
Rushton	The BBC microcomputer revealed.
Smith	Interfacing Projects for the BBC Microcomputer.
Beverley	The Complete Wordwise Plus Handbook.

(3) Data Sheets

6502	CPU
6845	CRTC
6522	VIA
6850	ACIA
8271	FDC
7002	ADC
1770	FDC

(4) Periodicals

Beebug	all issues to date
Acorn User	all issues from August 1982

(5) Acorn

1MHz bus application note.
Sideways ROM application note.
Econet summary note.
Acorn publicity leaflets.
Design for video synchronizer for BBC microcomputer.

(6) Miscellaneous

Information on most of the interfaces detailed in Section III.
Some hints and tips from magazine articles.
List of software packages for the BBC microcomputer.
Library of contributed software.

The last two items can be VIEWed on EMAS by typing VIEW MICROS.MICROBASE.

There is a BBC User Group for BBC Microcomputer users in the community served by the ERCC, which meets once a term. The secretary is Mrs A.Kelly, ERCC, 59 George Square (October 1986).

V Facilities

This section lists specific facilities currently available from the ERCC (other than general advice, guidance and information).

(1) Demonstration and Evaluation

The ERCC can demonstrate the BBC Microcomputer to interested users. If you are interested in specific add-ons or software, the ERCC can offer demonstrations of the following products:

ATPL Eprom programmer
ATPL Sidewise ROM board
EXMON machine code monitor
DISC DOCTOR utility
WORDWISE text processor
TOOLKIT ROM
Acornsoft Termulator (terminal emulator)
Acorn 6502 second processor
Acorn IEEE488 interface unit
ERCC Multifunction interface unit
ADE Assembler and screen editor ROM
View Word Processor ROM
Viewstore database
Viewsheet spreadsheet
Acornsoft ISO Pascal
Multi-Basic (a multi-tasking Basic)

(2) Communications

Software is available for file transfer using the X-Talk or Kermit protocols between the BBC microcomputer and EMAS. "Native mode" terminal emulation is also provided in X-Talk. See Appendix 2.

(3) Screen Dump

Software to provide hard copy of the screen display using an Epson compatible printer is available. Modes 0 to 6 are supported, and mode detection is automatic.

(4) Eprom Programming

ERCC has the appropriate hardware (an ATPL Prom Programmer) to program EPROMS for installing in sideways ROM sockets for special applications. We are able to produce sideways ROM containing programs supplied by users.

(5) Media Interchange

File copying facilities between 40 and 80 track discs and cassette tape are available.

(6) Terminal Emulation

Acornsoft Termulator is the recommended terminal emulator ROM for the BBC. It is a development of the Sussex Workstation which was previously recommended, but includes several new features, including VT100 emulation as well as VT52 and Tektronix 4010.

(7) A to D Conversion Software.

Demonstration software illustrating use of BBC's internal ADC, simple digital filtering, peak detection algorithm, and two point calibration. Automatic axis scaling is used.

(8) SDL Software

Software for logging from the RS423 serial port onto disc is available.

(9) Digital Filter Design Software

A software package for the design of non-recursive digital filters is available for the BBC Microcomputer. Smoothing and differentiating filters are supported.

Please note that all the lists of services, information held, and interfaces available, are being continually added to.

Appendix 1

(1) Reference voltage variation

The ADC chip in the BBC microcomputer is a µPD7002, which has four multiplexed input channels and an effective resolution of up to approximately 10 bits.
The value returned to BASIC by the ADVAL call is:

$$ADVAL(n) = 65520\ Vn/Vref$$

where Vn is the voltage on input channel n, and Vref is the reference voltage. Vref is roughly 1.8V, and Vn must always be between 0 and Vref.

Vref is derived externally to the ADC, with a resistor and three forward biased general purpose silicon diodes in series (see page 505 of the BBC microcomputer handbook, and figure 1 overleaf). This arrangement is perfectly satisfactory for low precision applications, but where high precision is required, the temperature dependence of Vref may become a problem.

Experiments were carried out to determine the variation of Vref with temperature. Comparison with a temperature and supply independent voltage reference diode showed that over the course of a day, Vref could vary by as much as 3%. After switch-on, Vref fell over about 3 hours by 2.5% as the ambient temperature inside the microcomputer rose from room temperature to 39 degrees centigrade. Sun shining on the microcomputer case resulted in a further fall of about 0.5%. Removing the top cover of the microcomputer resulted in a swift drop in temperature accompanied by a rise of Vref to nearly its switch-on value. Forced convection was also found to alter Vref.

Further experiments demonstrated that the problem lay with the method of generating the reference voltage rather than the ADC chip itself. A better method of generating Vref is shown in figure 2. A reverse biased band-gap voltage reference diode type ZN423 (obtainable from Radiospares) provides a Vref of approximately 1.26V, and takes about 5mA from the power supply. The diode, plus its dropping resistor, can be mounted externally to the computer, perhaps in the headshell of the 15-way D-type connector used to connect the computer to the source of the analog signals. No internal modification to the computer is necessary. This circuit reduces Vref from 1.8V to 1.26V, and therefore it should be ensured that the signal to be measured remains below the latter value.

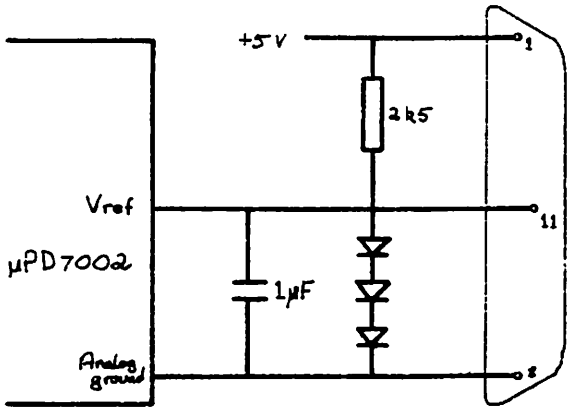

FIGURE 1

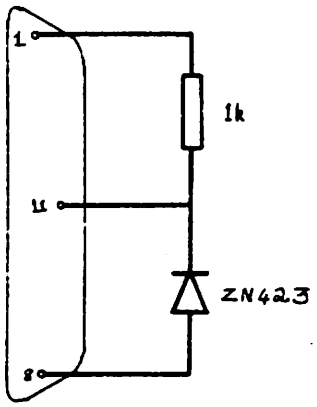

FIGURE 2

The uPD7002 chip is in fact supposed to work with a Vref of 2.5V. Using 1.26V may reduce the accuracy of the conversion (see Section 2 below). If this is thought to be a problem, the circuit of figure 3 could be used. Two reference diodes in series are used to produce 2.52V. This method requires an internal modification to the BBC microcomputer. The silicon diode chain must be open-circuited. This is best done by clipping one lead on one diode and bending it back slightly so that contact is broken. This modification may possibly invalidate Acorn's warranty. Note that if this is done, the two ZN423 diodes must be in circuit whenever any A to D conversion is required. A single ZN458 diode could be used instead of the two ZN423s.

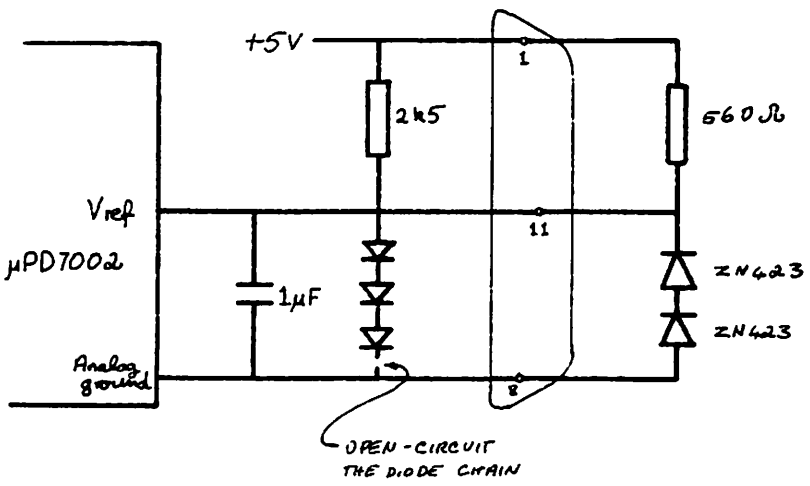

FIGURE 3

(2) Accuracy

Perhaps the most important problem is the accuracy of the built-in ADC. If you divide down a potential from Vref and feed it to one of the inputs, you will find that the number returned by ADVAL will fluctuate about a mean value. This effect can be demonstrated by writing a program to plot a histogram of the ADC output. Dividing the ADVAL result by 16 to give a reading in the range 0 to 4095, and calculating the standard deviation of the resulting distribution, we obtain roughly 2.0 (using the built-in reference source). What is the effective resolution of the ADC taking this noise into account? Taking 95% confidence limits of this distribution we obtain that the effective resolution is 9 bits. This means that 95% of our readings will be within 0.5 parts in 2^9 of the true value. If we insist on every single reading being within 0.5 parts in 2^n, then n=8.5.

By using a 2.5V Zener diode as described above for the reference voltage, the situation is improved, and the noise standard deviation reduces to 1.55. This corresponds to a 95% confidence level at 9.5 bits. NEC, the chip manufacturers, now claim only a 10 bit accuracy (rather than 12 bits).

Investigation shows that the noise sd (measured in parts in 4096) in inversely proportional to Vref. This implies that the noise voltage is constant at about 1mV (SD) or 4 mV (pk-pk).

Beverly, in Acorn User (March 1984) showed how to trade off sampling time against ADC accuracy by averaging a number of readings. If you take the average of N readings and plot a histogram of the resulting distribution, you find that the standard deviation falls by a factor SQRT(N). This procedure is effectively a digital smoothing filter, and better filters can be designed to reduce the noise even further.

A useful article on ways of reducing noise on the ADC was published in ACORN USER magazine, March 1984.

(3) Input Protection

The 7002 chip will be destroyed if voltages greater than 5 V or less than -0.3 V are applied to its inputs. It is suggested that protection circuitry be used as shown in figure 4. This should lessen the risk of damage to the chip. But remember that the best way to protect the chip is to stay within the specified range. Note that the circuit of figure 4 should not be used if the input is derived from Vref by means of a potentiometer, or if high precision measurements are required. It is really intended for use during development or training activities. ERCC has information on a more elaborate protection circuit.

A further point to note is that if one ADC input goes even slightly negative, the readings of the other inputs may be disturbed. This may be prevented by using a type CA3130 amplifier, referenced to ground, to buffer the input, preventing a negative voltage reaching the ADC.

(4) Timing

It is important to realize is that the conversion rate of the ADC is not 10ms, but varies between 11 and 12 ms. Moreover, the way the ADC operates means that the sampling rate is not related to the 'ticks' of the real time clock used by the Basic variable TIME. The following program fragment therefore will not do quite what you may think it should do:

```
290 *FX 16,1
300 DIM BUFFER(100)
310 FOR I=1 TO 100
320 T%=TIME : REPEAT UNTIL T%+1=TIME
330 BUFFER(I)=ADVAL(1)
340 NEXT I
```

You may think you are reading channel 1 at the quoted 10ms sampling rate, but you will find that every 10 samples or so, there will be two consecutive identical samples because the ADC has not had time to finish a conversion since the last ADVAL(1) command. This effect will only be a problem if you need to sample fast.

One way to get round it is to increase the conversion speed of the chip. Pin 2 is the clock input to the ADC, which is clocked at 1MHz. The chip is supposed to be able to run with a 3MHz clock, so by bending pin 2 out of its socket and connecting it via a 2" insulated wire to IC34 pin 11 (which is a 2MHz clock line) it is possible to increase the speed of conversion to about 1 sample every 6 ms. This will invalidate your warranty! There will still be a time error of up to 6 ms in the values read using the above program fragment.

If you are sampling slowly, but nevertheless wish to minimize the error in sampling time, you can use TIME as your main clock, and initiate conversion with *FX 17 when TIME reaches an appropriate value. Wait for two TIME ticks (assuming you have not speeded up the ADC as described above) before issuing ADVAL.

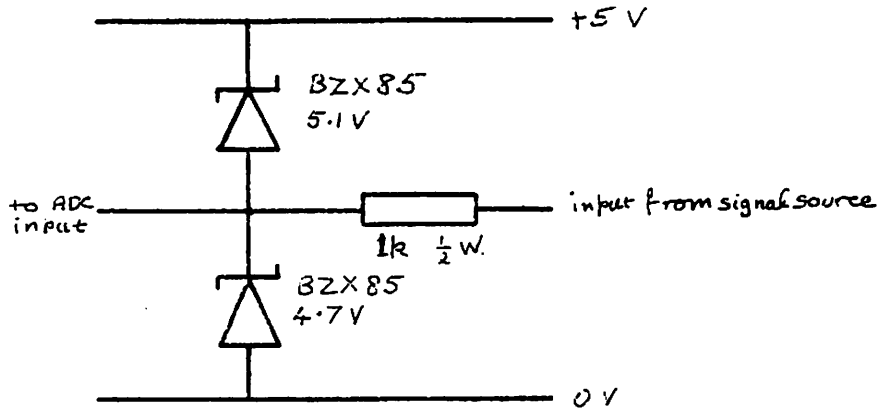

FIGURE 4

Appendix 2

If the BBC microcomputer is to be connected to the ERCC network, three things are required:

(1) A connection to a PAD, as for an ordinary terminal. If you do not already have this, please contact (The Service Support Unit, ERCC, the King's Buildings (031-667 1081 ext. 2641) who will advise on the cost involved.

(2) A suitable connecting lead. Available from Engineering Support Group, ERCC, the King's Buildings.

(3) Software. Suitable software on ROM (Kermit or X-Talk) may be ordered from ERCC Administration, the King's Buildings, (031-667 1081 ext. 2679)