Microcomputer Interfacing

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Preface

Computer science courses have in the past tended to concentrate on the use of computers for numerical and data processing and have ignored the rapidly growing use of small microprocessor-based systems for an ever wider range of communications, data logging and control applications. With the continuing fall in the price of hardware and the widespread use of more effective software tools, the use of microcomputers in these areas can only increase still further. This book is intended for first and second-year undergraduate computer scientists taking courses in these areas. It will also be of use to engineers and others taking diplomas and masters degrees which include a substantial computing element.

It is not the object of this book to provide an in-depth study of any individual area as this is covered by other, more specialised courses, but it is intended that it should cover the fields likely to be of importance over the next ten years. For this reason, chapters on speech output and robotics have been included, as well as the more traditional material on data logging and motor control.

The material discussed is supported by working example programs which can be transferred to any suitable microcomputer system. Except for the very simple applications, the hardware required can be purchased very cheaply either in kit form or complete. A list of possible suppliers is provided in Appendix E.

This book is intended to be strongly practical in approach and to this end only one microcomputer system has been used. The BBC microcomputer has been chosen because of its wide distribution in schools, colleges and universities. It has proved to be most suitable for courses involving data acquisition and control because of the large number of useful interfaces already provided and it was very easy to extend these facilities through either the user port or the 1 MHz bus (see Chapter 3).

In many experiments the excellent graphics facilities available on the BBC micro are an additional benefit. This is particularly true when it is necessary to display a large number of data items in a clear, concise form. Graphical input can be provided with joysticks, a digitiser or a light pen.

The programs described in the text are printed with the aid of a special text formatter that assists in illustrating the underlying logical structure. When typing them into a microcomputer, care must be taken to follow the normal BASIC rules. In particular where program lines are broken up over several text lines the complete program line must be typed before pressing 'return'. Blank lines and spaces at the start of individual lines are to aid readability and should be ignored when typing the program. The complete text of the formatting program is given in Appendix B, together with an example of a BASIC program before and after formatting.

In addition to these advantages, the use of a fully developed microcomputer system means that all the facilities required for program development are readily available. Programs can be stored on either cassette or disk and reloaded at will. Most common printers can be connected simply by obtaining the appropriate connecting lead.

Since this book is aimed primarily at computer scientists, the emphasis is strongly on programming. The hardware needed to perform the experiments can either be constructed very simply using just a few commonly available-components, or can be purchased from well-known suppliers. Students are not expected to have any knowledge of electronics. For this reason it is not intended that they will need any specialist circuits, unless their supervisors think that these are desirable.

At the end of each chapter there are problems which take the form of programming suggestions for the student to work through himself. The object is to ensure that the student considers first the final user's view of the system and then how this may be implemented. No computer is of any use without software. This is as true of microcomputer systems used in control applications as it is for large mainframes used for data processing. Attempts have been made to design languages specifically for control applications but unfortunately these often lack many of the facilities to which the programmer is accustomed in the more common general-purpose languages.

All too often the programmer provides a facility which is difficult or cumbersome to use because he has not considered the user's requirements fully. Hence one of the aims throughout this book is to show the programmer how a simple and easily-understood package can be produced by approaching the user's requirements in the right way.

WARNING

Neither computers nor humans like being connected to high-voltage electricity, so it is very important that experiments involving the sensing or switching of high voltages or currents are performed only with equipment which is specifically designed for the purpose, and that proper safety precautions are taken.

All the experiments in this book are designed to use low-voltage (usually 5 V) power supplies. If a 5 V regulated power supply is not available, a fresh 6 V battery is a suitable substitute.

When motors are to be controlled, a model mains controller of the appropriate voltage is a cheap and effective power source.

Under no circumstances should mains voltages be connected directly to the microcomputer as they will almost certainly cause permanent damage to the microcomputer's electronics or serious personal injury.

ACKNOWLEDGEMENTS

The program formatter given in Appendix C was developed from a program written by Jim Notan and published in the July 1983 issue of Micro User. It is included here with the publisher's permission.

I would like to acknowledge the help given by a number of students who performed many of the experiments described in this book. In many cases they suggested improvements or alternative methods, and these have been incorporated as appropriate.

I would particularly like to thank Ted Walsh and David Owen Hughes for their help and encouragement throughout the project; David Cox for his help with the access routines described in Chapter 3 and the monitor program in Appendix B; Eric Stancliffe and David Martin for their help with the interfaces for the model railway project; Paul Raby for his assistance in interfacing to the 1 MHz bus; and Gillian Armitt for turning my original manuscript into a readable book.

Contents

1 Microcomputers in Control Applications

1.1 INTRODUCTION

The continuing rapid fall in the cost of microcomputer systems means that computers may now be considered for applications which even a year or two ago would have proved too expensive. Computers have become a mass-market commodity which is now freely available in the high street stores as well as through specialist suppliers. Where once computers could only be used for complex scientific or business computing, they are now becoming a common feature of the office or home. Tasks such as word processing or financial modelling, which were not previously considered economic, may now be performed on almost every computer.

A new generation is developing which sees the computer to be as much a part of daily life as the calculator or the television. The computer is no longer something to be feared or locked up in special air-conditioned rooms. In addition, the use of microcomputers for data collection and control has increased very rapidly. Considerable flexibility in the controller's functions is obtained by altering the software rather than by having to redesign the hardware completely. This revision process is very much quicker if the programs are written in a high-level language rather than machine code or assembler. Any microcomputer, even the cheapest, is suitable for use as a microcomputer controller. Expensive development systems and other test equipment are no longer absolutely necessary to develop the programs. This means that there has been an explosion in the range of control and robotics applications areas. One can now consider applications areas, which formerly would only be contemplated in defence and other similar high expenditure areas, for development in the classroom or at home.

Computer science in general has not responded to this development and the challenge it represents. Design and programming errors which would cause incorrect results in the traditional data processing or scientific areas, cause chaos when the computer is attempting to control something. This illustrates the need for effective analysis of the problem and good program design.

This book is intended as an introduction to the writing of control programs by computer scientists. It is anticipated that most readers will not have extensive electronics knowledge and so only the most basic circuits are described. No construction details are given since the circuits can be constructed by soldering on to stripboard or built up on one of the commercially-available prototyping or plugboard systems. It is assumed that the more complex experiments will be purchased or acquired in kit form from one of the many companies which produces suitable products.

Since this book is principally concerned with *software*, the choice of microcomputer is very important. Any microcomputer which allows connection of additional equipment to the processor bus may be used. However, it is much easier if the microcomputer designer has allowed for this expansion and has provided the necessary power and driving capability. Since very similar functions are required for many of the programs, a programming language which allows the independent development of subprograms is very useful. The BBC microcomputer manufactured by Acorn has been chosen because it posesses these qualities. It has a wide range of hardware interfaces already provided and, in addition, both the operating system and the BBC dialect of BASIC allow the interfaces to be used with maximum effect.

1.2 THE ANATOMY OF A MICROCOMPUTER SYSTEM

Any computer system collects information from a number of sources, processes it, and possibly stores it for future use before outputting the results in some usable form (figure 1.1).

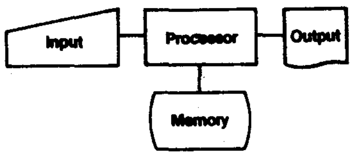

Figure 1.1 A typical microcomputer system

The form which this information takes depends on the task that the computer is expected to perform. A home computer used mainly for playing games will require a keyboard to enter programs and instructions to the games, a joystick or some other similar device as an additional means of input, a television screen on which to display instructions and information on how the game is progressing, and some storage device on which to save programs between sessions. The storage is likely to be an audio tape recorder since these are cheap and readily available, and the slow transfer rate is only evident at the start of a session. (see figure 1.2.)

If the computer is to be used mainly for word processing, it will look very different (figure 1.3). The principal input device would now be a much more sophisticated keyboard. The largest possible online memory would be provided so that as much text as possible can be accessed immediately. Cassette tape is considered far too slow for the storage of large amounts of textual information so floppy disks or even small fixed "winchester" hard disks, keyboards, screens and printers must be controlled by the microcomputer. Indeed, it is quite likely that a major part

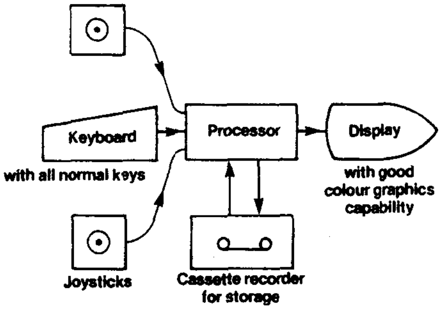

Figure 1.2 A typical home microcomputer used mainly for games playing

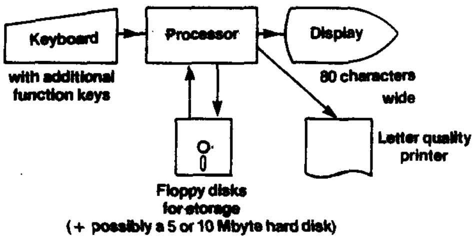

Figure 1.3 A typical word processing system

of the processing power is taken up with these tasks. All the hardware facilities and the software needed to integrate them into a usable system are provided by the hardware manufacturer.

1.3 THE INTERFACES AVAILABLE

The BBC microcomputer is well endowed with interfaces of different kinds. Some are essential for the proper running of the microcomputer while others allow the connection of specific additional options. Yet further connections are provided so that any useful device can be connected. The different connectors can be categorised in several different ways, such as their position on the case, their function and whether they can be used for input, output or both. Before attempting to make a connection to a particular port it is important to ensure both that the port can transfer information in the required direction and that the electrical characteristics are compatible.

The most commonly used connectors are located at the rear of the case (see figure 1.4).

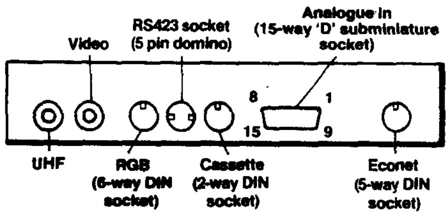

Figure 1.4 The connections on the back of the BBC microcomputer

To the left may be seen a variety of connectors for different types of video output. These include ports not only for a normal television and a monochrome video monitor, but also for a high-quality (RBG) colour monitor. The output for all these connectors is generated by a special video controller integrated circuit within the BBC microcomputer.

The serial port is located between the sockets for the colour monitor and the cassette recorder. It is used for bit-by-bit transfers to peripherals such as modems and serial printers. It can also be used for communication with other computers. The RS423 standard, to which the BBC serial port complies, is very similar to the older RS232 standard. Although the two standards differ in some details, the serial port can usually be connected successfully to equipment complying with the older standard.

On the other side of the microcomputer is the "ECONET" network socket. This is the interface with Acorn's own local area network. Space is provided on the main printed circuit board in the microprocessor case for both the hardware and software necessary to connect the BBC microcomputer to the "ECONET" network. These may be purchased at the same time as the machine or may be installed later. To determine whether a particular machine has the "ECONET" option fitted, press the "N" and "BREAK" keys together and the following message will appear if the "ECONET" option is fitted.

Econet Station <nnn>

The three digit number <nnn> is the station number coded for that particular machine. This can be changed by reconfiguring a set of links inside the BBC microcomputer. If the option is fitted, but the microcomputer is not connected to a network, or the network is not functioning correctly, the additional message

No Clock

will appear beside the first.

In addition to the connections at the back of the BBC, there are another five ribbon cable connections underneath the case (figure 1.5). These connectors are attached directly to the printed circuit board. As well as connections for the disk unit, the printer and the user port, there are two sockets for connecting additions to the microcomputer. The 1 MHz bus connector allows special hardware to be connected to the internal 6502 microprocessor bus in an orderly manner. The data lines are directly accessible through this socket, and special address lines provide partial decoding to assist in the design of

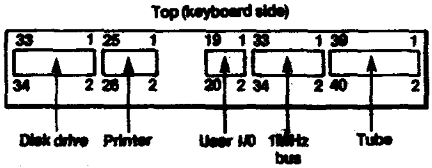

Figure 1.5 The connections on the underside of the BBC microcomputer

additional hardware. The machine operating system provides routines to read and write to these locations. These routines should always be used as they will work for all configurations of the machine. The "TUBE" interface is provided specifically for the connection of additional processors and should only be used for that purpose.

Both the printer and user ports are connected to a special integrated circuit within the microcomputer called a Versatile Interface Adaptor (VIA). This integrated circuit provides a wide range of facilities, including two parallel ports, two timers and its own serial port. One of the parallel ports is used to drive a parallel printer to the printer port, and the other is connected to the user port. Apart from the printer port, all the other facilities can be accessed directly by the user.

1.4 USING MICROCOMPUTERS FOR CONTROL

Traditionally, control applications have been developed on expensive microcomputer development systems (figure 1.6). These are specialised microcomputers specifically designed to allow programs to be developed which will eventually be run on processors which do not have enough memory and peripherals to write programs. In many cases the development system can sit in the prototype hardware, in