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MICROCOMPUTER INTERFACING FOR THE ACOUSTICS LABORATORY

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1. INTRODUCTION

Analogue instrumentation for the acquisition and processing of acoustic data is well developed and commonplace in acoustics laboratories. Increasingly, the availability of digital computing facilities has produced a shift from analogue data processing, but until recently instrumentation for digital acoustic data processing was expensive and the preserve of the larger laboratories.

The appearance during the past few years of inexpensive microcomputers, together with the accompanying developments in software, has resulted in the possibility of digital data processing and computer controlled instrumentation on a much wider scale. Already microcomputer based systems have been described for the control of experiments in acoustics (Heap and Oldham 1981), and in the important field of frequency analysis fast assembly language algorithms have been described for two popular microcomputers (McNeill and Burrows 1980; Davies and Craven 1980).

Specialised instrumentation designed to be compatible with microcomputers is becoming increasingly available for the acquisition of acoustic data. However in view of the extensive instrumentation which already exists in most laboratories it is of obvious interest to investigate means whereby this existing instrumentation can be coupled with microcomputers to create new systems.

This paper presents a description of an interfacing approach for the popular C.B.M. microcomputer which has been used successfully with a variety of standard acoustic instruments. The details of the interface are presented together with an account of complete systems which have been developed for research investigations.

2. GENERAL INTERFACING CONSIDERATIONS

The C.B.M. 3032 system provides two connection ports which are specifically intended for interfacing with external devices. These are the user port and I.E.E.E. port. The ports connect to the processor data and address lines via peripheral interface adapter (PIA) chips. Such chips are capable of providing sixteen data lines which may be configured under software control to act either as inputs or outputs or as a mixture of both. In addition, up to four additional lines are available from each chip to provide a variety of control functions. In the 3032 system, the interface chips which service the two connection ports are partially dedicated to other functions.

2.1 The I.E.E.E. port

This port has an 8 bit bi-directional data bus with the necessary control lines to conform to the I.E.E.E. standard 488, and is capable of supporting fifteen peripheral devices. The control lines form the management bus, conforming with standardised communication protocol between devices, and the transfer bus which supervises the transfer of data between devices in a handshaking mode. The instruments on the bus can be designated as a controller, of which there is only one (the 3032 in this case), a talker or a listener. Because some devices can be either a talker or a listener (i.e. can receive or send data respectively), the control lines need to be bi-directional, increasing the complexity of interface circuitry.

The I.E.E.E. port is used generally for communication between the 3032 and standard peripherals such as floppy disk drives or printers. It is designed to be user friendly, with commands incorporated into BASIC and data being transferred as ASCII character strings.

The data format used by this bus together with the complexity of the interface circuitry tend to be incompatible with the acquisition of acoustic data. This usually involves analog to digital conversion of signals from an input transducer and the subsequent transfer and processing of binary 8-bit data usually in volume. For such applications a machine code environment is required to provide simple and speedy data transfer rates and fast processing. In addition in systems in which the computer is required to control external equipment the operation of the bus is unnecessarily complex.

2.2 The user port

This is derived from the unused part of a MCS 6522 versatile interface adapter (VIA) and consists of an 8-bit data port plus two control lines. The eight lines forming the port can be individually programmed as inputs or outputs as can one of the control lines, the other being an input only.

The number of lines available limits the use of this port, and generally only one device at a time can be serviced through the user port. In situations in which the 3032 is to be used for data acquisition and instrument control on a fairly substantial scale, the limited input/output and control options provided by the two connection ports impose a serious restriction on what is possible. Fortunately these restrictions can be removed fairly readily by the provision of alternative PIA chips whose function is solely that of servicing external equipments.

2.3 The memory expansion port

In the systems described here, advantage is taken of the fact that memory locations from $9000 - $BFFF in the 3032 system are available for ROM expansion and constitute a vacant area in the memory map of the machine. Thus additional peripheral chips may be accessed directly from the memory expansion connector of the machine which gives access to all the necessary data, address and control lines. In order to accomplish this two steps are involved.

Input/output in the 3032 system via PIA chips makes use of the so-called memory mapped process in which the chips are accessed as a section of RAM. Clearly, therefore, it is necessary to modify the internal circuitry of the machine so that the region of the ROM expansion area in which the chips are to be located becomes accessible as RAM via the data lines on the memory expansion connector. An examination of the circuit diagrams for the 3032 (Hampshire 1980) shows that when addresses in the entire ROM area ($9000-$FFFF) are accessed, the memory expansion tristate data bus buffers are held in a write state and the data read directly onto the microprocessor data lines from whatever ROM chips may be in place. In order to open up the ROM expansion areas for access as RAM it is necessary to disable the process which deactivates the tristate data bus buffers when addresses in the range \$9000 - \$BFFF are selected. This is readily achieved by altering the links in jumper switches provided on the 3032 circuit board according to the connection options shown on the circuit diagrams. If this is done, the area \$C000 - \$FFFF is still a ROM protected area but \$9000 - \$BFFF becomes accessible as RAM, with the data bus buffers active. The area is no longer available for ROM expansion however, unless additional control circuitry is added to give partial protection.

Once the ROM area has been opened up in this way the second step involves the provision of external address decoding to provide appropriate signals for peripheral chip selection. The degree of decoding to be used depends upon the number of chips to be selected. In the system described here a general purpose interface unit has been constructed which contains 16 PIA chips.

2.3.1 Interfacing to the memory expansion port

The address space of the 3032 is sub-divided (internally) into 16 blocks of 4K by de-selecting the top four address lines (A12-A15) using a 1-out-of-16 demultiplexing integrated circuit. The same technique can be used externally to deselect the next four address lines (A8-A11). Connecting one of these deselected lines and a block select line to the chip select pins of a PIA enables up to sixteen devices to be located in a vacant block. The lower eight address lines (AØ to A7) are available for register selection on each PIA. This can lead to a large redundancy of memory space, for instance a MCS 6520 needs only two register select lines, but if necessary this situation can be readily improved by additional circuitry.

The provision of sixteen PIA chips in the interface unit makes it possible to access a variety of instruments and peripherals and extends considerably the usefulness of the 3032 as a controller and data acquisition device in acoustic experiments.

3. APPLICATIONS, DATA DISPLAYS

3.1 X-Y plotter

Figure 1 shows a block diagram of the system. Each data port of a MCS 6520 P.I.A. is connected to an eight bit digital to analog converter (D.A.C.), the outputs of which are connected to the X and Y inputs of a standard plotter. Data is presented sequentially to the port connected to the Y input, as the data on the other port is incremented in unit steps from zero to 255_{10}. A control line is used to control the pen-up/pen-down function.

Due to the slow action of most X-Y plotters a program written in BASIC using PEEK and POKE instructions to output data is fast enough, and additional programmed delays using FOR/NEXT loops may even be necessary to allow the plotter to respond correctly.

3.2 Level recorders or Y-T recorders

The technique described in 3.1 can be easily adapted for use with level recorders, where no X deflection is needed. Again control lines may be used to control pen-up/pen-down and paper drive.

3.3 Oscilloscope display

The same principle as in X-Y plotting applies here for fast displays on an oscilloscope capable of external X deflection. In this case BASIC is too slow to give a coherent trace, and so a machine code program is required. Unless a storage oscilloscope is available, it will be necessary to repeat the operation until interrupted by the user. This can readily be achieved by including in the loop a branch out of the program conditional on a specific key being pressed.

4. DATA ACQUISITION

4.1 Transient event recorders

These devices allow an analogue signal to be sampled in the time domain, digitised in an eight bit binary form and then stored in a R.A.M. of 2^N bytes, where N is typically between 10 and 12. Once the memory is full the digital data can be stored indefinitely. Cycling the data through a D.A.C. allows for X-Y plotting or display on an oscilloscope. In addition the digital data is available for output to a paper-tape punch or an on-line computer.

A typical commercial transient event recorder is the Datalab DL920 device. Although this equipment can be used as a stand-alone device using manual controls, most of the functions controlled by the front panel switches are also controllable by T.T.L. levels applied to a multi-way socket. This makes it ideal as a data acquisition module for a microcomputer.

Digital data is transferred in a bit parallel-byte serial manner using a handshaking system. An interface adapter, such as the MCS 6532, can be used to good effect by using one eight bit port to accept the digital data, leaving the second port to control the data capture and data transfer by individually programming each line of the port.

The DL920 has a dynamic R.A.M. and so there is a lower limit to the rate at which data can be taken by the computer. This means that the data generally has to be transferred as a block since any calculation on individual bytes would exceed the maximum time allowed. Consequently, a block of memory in the microcomputer must be saved specifically for the data from the DL920 and must be protected from corruption by the computer during its normal operation. This can be done by altering the two locations in zero-page memory which point to the limit of BASIC memory. For example, in the C.B.M.3032 this would normally be set at \$8ØØØ, but changing this to \$7ØØØ would allow for 4K of protected data storage.

4.2 Analogue memories

A similar device to that described in 4.1 is the Kemo Analogue Memory. This equipment can also be readily controlled by an on-line microcomputer and can have a maximum of four channels, each having four, eight or sixteen kilobytes of storage.

The main difference is that this device uses a static R.A.M. and so data can be transferred even at very slow rates. A handshaking procedure is not used, instead a clock pulse will latch a byte of data onto the data bus ready for collection by the computer. In this case a single byte can be taken by the computer and a calculation, e.g. an accumulation, can be carried out before the next byte is taken. Therefore the data can be reduced by the computer as it arrives, and so no areas of memory have to be reserved as in the previous case.

4.3 Direct data acquisition

A system has been developed (Davies, Kehayas and McNeill, 1981) using commercial eight bit A.D.C. combined with a multiplexer in the same hybrid package. An MCS 6520 peripheral interface adapter is used to strobe automatically the A.D.C. every time data is taken from the output of the device. A choice of from one to sixteen data channels is available (see figure 2). Data is taken from the 6520 directly into the R.A.M. of the microcomputer.

Using this technique, sample rates of 70 KHz for one data channel can be achieved, which is adequate to satisfy the Nyquist criterion for the audio range of frequencies.

5. A RESEARCH SYSTEM

A current research project at Liverpool Polytechnic is concerned with the effectiveness of noise barriers in outdoor conditions. It is necessary, therefore, to record acoustical data from two microphones (in order to calculate barrier attenuation), as well as meteorological data such as the speed, direction and turbulent intensity of the wind and air temperature.

The microcomputer, together with data acquisition equipment described in 4.1 and 4.2, has been interfaced to standard analogue acoustics and anemometer instrumentation (see figure 3). In addition temperature sensors and a wind-direction sensor have been developed.

5.1 The acoustical system

A source of octave filtered white noise is amplified to activate an exponential horn loudspeaker. This is received by a twin channel system, each comprising a half-inch microphone and a measuring amplifier plus octave filter set (all of which are standard Bruel and Kjaer equipment), and sampled by a Kemo analogue memory. In order to improve signal to noise ratio, each channel has the same centre frequency and bandwidth as the one used to produce the noise source.

The source filter has upper and lower cut-off frequencies set by the computer through a MCS 6532 P.I.A. This facility does not exist on the octave filter sets, but the filter can be moved from one octave to the next by an internal relay. A simple circuit can be made so that a T.T.L. level derived from the computer will drive this relay with a 24V DC supply. In this manner all filters can be set under computer control.

An automatic attenuator has also been incorporated in the noise generation system. This device allows the computer to ensure that the signal reaching the analogue memory is occupying the full range of the instrument without it being overloaded. In the same circuitry as the attenuator is an analogue switch which allows for tone burst generation.

5.2 Anemometry

A Disa battery operated constant temperature anemometer is used with a Datalab DL901 transient event recorder to obtain wind speed and turbulent intensity measurements. Calculations of the mean and root mean square of the output of the anemometer are required.

The wind direction sensor uses a revolving drum under a disc which is connected to a wind vane. A counter is set to zero when a specific point on the drum points due north. The device then gives out pulses, derived optically from black and white markings on the drum, until the same point is coincident with the wind vane. The pulses then stop. In this way the number of pulses given by the device measures how far away from due north is the direction indicated by the wind vane. Since the pulses are derived from the markings on the drum, variations in speed of the driving motor do not affect the result.

In order to count the pulses an MCS 6522 V.I.A. is used. This device will sense negative going pulses on a certain line of an input/output port. Each pulse will decrement a counter, and so by setting the original value in the counter and reading the counter on coincidence of the wind vane and the drum, the number of pulses is calculated.

5.3 Temperature sensors

A temperature dependent current source is used to measure air temperature. This semiconductor device is housed in TO52 package and gives an output of 1 μA/°K. This is converted into 0.1 V/°C using an operational amplifier circuit with appropriate resistive components.

This temperature dependent voltage is then applied to the input of a voltage to frequency converter (Teledyne 9400), which gives 3μs negative pulses at a frequency linearly dependent on the input voltage. Again a MCS 6522 V.I.A. is used to count these pulses in a given time. The system can be readily duplicated if temperature profile information is required and the use of a TTL data multiplexer permits several temperature sensors to be serviced by one V.I.A.

Software is currently being developed to allow for the complete system described in this section to operate automatically. This will allow large volumes of data to be analysed, reduced and stored on magnetic floppy disc for each outdoor experiment. This can be of value if suitable sites for experiments are a considerable distance away from the laboratory, or when the site and suitable vehicles are only available for a limited period of time.

6. CONCLUSION

The memory expansion port on the C.B.M. 3032 microcomputer permits the use of numerous peripheral interface adapters allowing the computer to control standard laboratory equipment, acquire data, and display and store results. In this way the computer can be adapted to individual needs whilst still retaining the screen editing facility and BASIC interpretation, which would otherwise require lengthy development. The memory expansion port allows equipment to be serviced and data to be processed speedily using machine code programmes.

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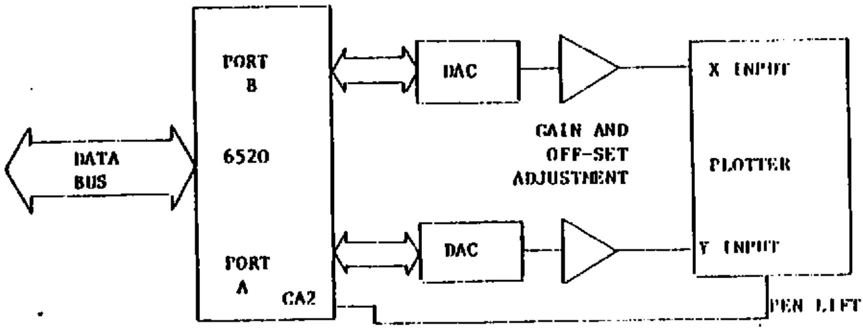

FIG. 1

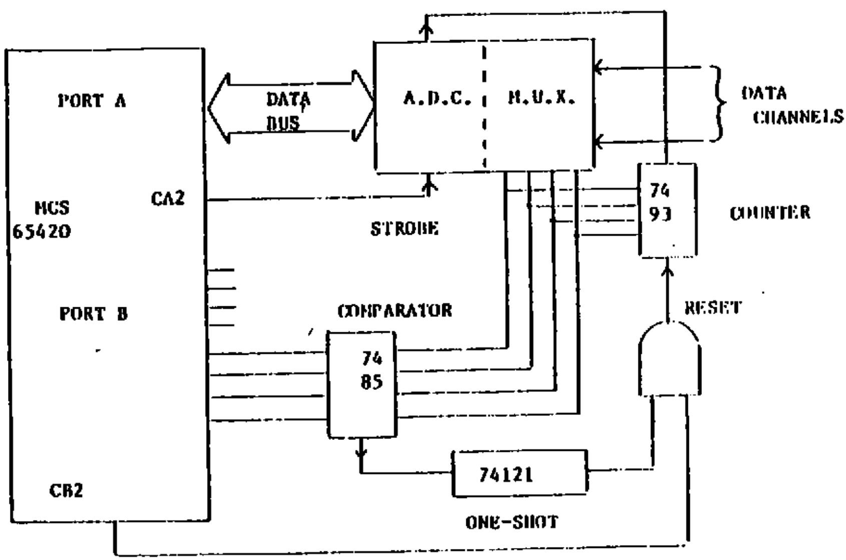

FIG 2

The counter is incremented after each conversion and selects the next data channel. The number of channels is set by Port B.

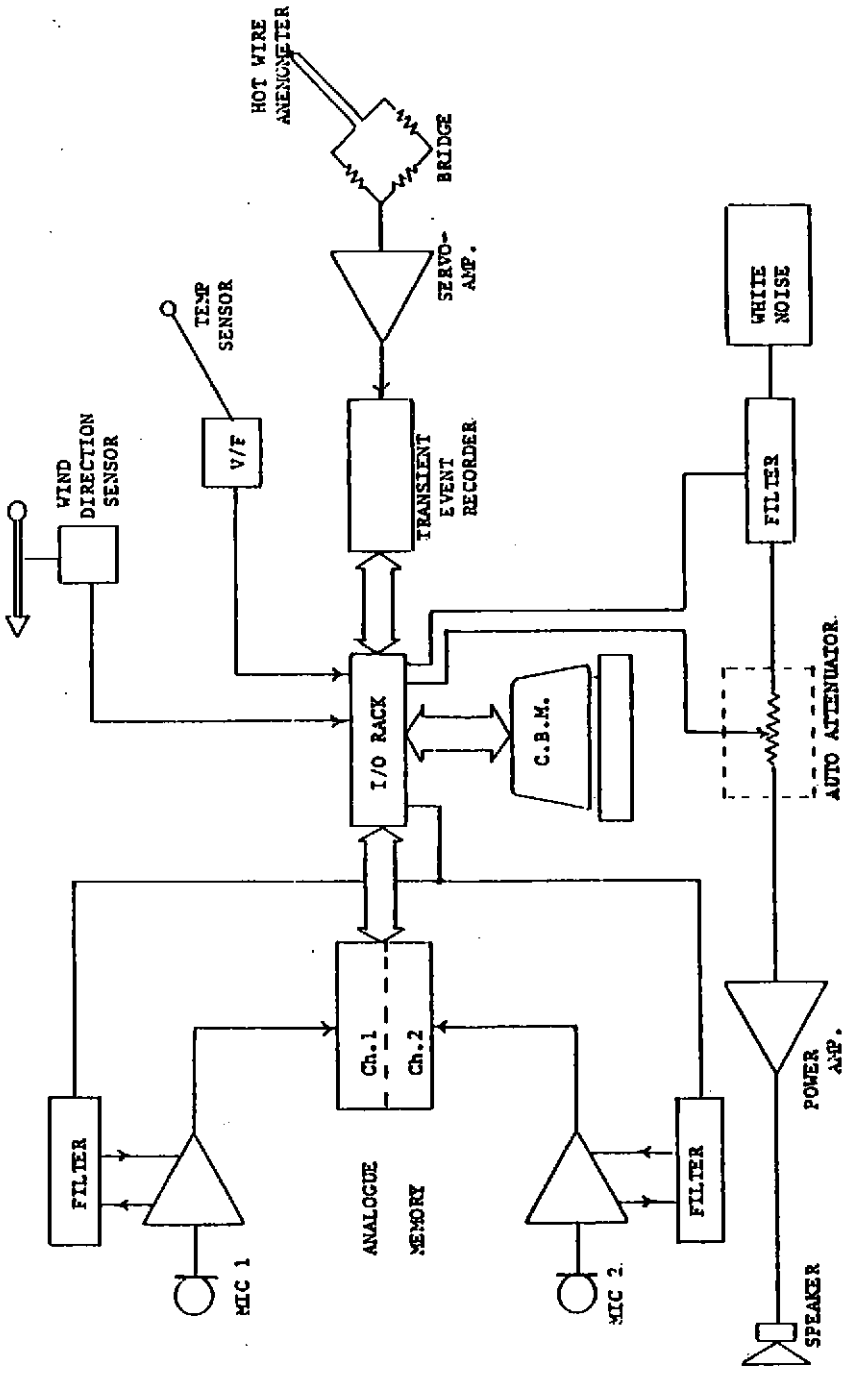
HOT WIRE
ANEMOMETER
BRIDGE
SERVO-
AMP.
TEMP
SENSOR
WHITE
NOISE
WIND
DIRECTION
SENSOR
V/F
TRANSIENT
EVENT
RECORDER
FILTER
I/O RACK
C.B.M.
AUTO ATTENUATOR
Ch.1
Ch.2
FILTER
ANALOGUE
MEMORY
FILTER
POWER
AMP.
MIC 1
MIC 2
SPEAKER

FIG.3