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A VCA-BASED PROGRAMMABLE CONTROLLER UNIT

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INTRODUCTION

A low cost real and deferred time programmable controller unit based on the BBC B micro-computer and voltage controlled amplifiers (VCAs) has been developed primarily for the precise and detailed spatialisation of recorded sound in the concert hall or other performing environment. It also provides additional amplitude based functions (extremely accurate and rapid panning and envelope shaping), as well as an inexpensive digitally controlled mixing facility.

INITIAL DESIGN CONSIDERATIONS

Composers of electro-acoustic music have long been aware of the medium's vast creative potential for sonic spatialisation effects ("location modulation"), and much time and effort has been expended in the development of systems and techniques to control the perceptual movement of sound and in understanding more fully the psycho-acoustic principles which govern it. In particular, those of us working with recorded sound in a two-channel stereo format enhanced by playback utilising multi-speaker configurations - eight to fourteen is typical - have devised fairly sophisticated (albeit essentially manual) techniques for locational control in the concert hall environment. However, even these have serious limitations as far as precise and highly detailed manipulation of sound objects is concerned; there are necessarily constraints on what is physically possible using only fader movements and pan controls on a standard mixing desk, and it seemed to us that some form of microprocessor control of these functions was the obvious way forward.

The following design brief was prepared and executed in the electro-acoustic studios of the University of Newcastle upon Tyne. The research and development work was carried out by Douglas Doherty and Robin Terry.

INITIAL DESIGN BRIEF

1. The audio elements of the device should be of a fully professional standard.
2. The device should be relatively cheap (£1000-£1500)
3. Sampling of faders should be available at varying rates up to at least 50Hz per fader.
4. Within the above constraint there should be as many channels available as possible.
5. The unit should be compact, robust and easily portable.
6. Recording of fader movements should be in real time.

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INITIAL DESIGN DECISIONS

Working from this simple design brief a number of decisions were made at the outset:

1. To keep costs down there would be no digitisation of the audio signal. The quality of many digital systems is unsatisfactory, and for simple level control functions high quality analogue devices are often superior and more reliable than any but the best (and most expensive) of digital devices. A corollary of this was that all analogue audio components would have to be of the highest quality.
2. We would design our circuitry to maintain as far as possible total separation between its analogue and digital elements. We would also use tried and tested components known for their reliability and high performance; we had neither the time nor the resources to enter the field of electronic design innovation.
3. For the audio signal path we chose the following:
   A. DBX 215x series VCAs which are industry standard presenting high quality, low noise performance over a 100dB range.
   B. 5534 op-amps which are again an industry standard.
   C. Reed-relay rather than transistor switches.
4. The system should be controlled from an external micro-computer rather than a dedicated internal micro-processor. The BBC B was chosen for a number of reasons, not least because of its interface capabilities and the ease of assembly language programming.
5. For the digital interface we chose the following:
   A. The 6522 versatile interface adapter.
   B. One 10-bit ADC multiplexed between up to 8 channels.
   C. One 14-bit DAC multiplexed between up to 8 channels.
   D. High quality 100mm throw faders for ADCs to read.
   E. 1MHz bus output from BBC micro.
6. The design would be expandable allowing future software expansion within the pre-existing hardware. The analogue audio hardware has only one simple function and that is to vary attenuation of audio signals passed through the VCAs. Within this simple area of activity a number of facilities previously available only in very expensive systems could be provided. The basis for this provision would be software rather than hardware.
7. Given the limitations of a relatively small micro-computer, the maximum number of channels giving sufficiently high resolution was deemed to be eight.

The main real time operations (FADERS mode and PAN mode) are interrupt driven, sampling faders and joysticks respectively at a maximum rate of 100Hz and a minimum rate of 1Hz for each of 8 faders and at correspondingly faster rates for fewer faders.

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The PCU software was developed after making certain decisions about its nature.

1. The sound projectionist, engineer and studio composer are more interested in the sonic result than any visual aspects of the process. We therefore conceived a system that did not rely on sophisticated graphics (consuming large amounts of memory) but one which was command based.
2. The memory of the BBC B is relatively small anyway, so the software would have to be written in machine language on sideways RAM.
3. The software would eventually be transferred to EPROM.

FURTHER IDEAS

By this stage in the design process, it was apparent that what was originally conceived as a fader/real time input device could easily be extended to include other user interface possibilities such as joystick and keyboard (ASCII not piano) input.

Real Time Application

The joystick input could be used to emulate a quadrapan and sequences of movements could be recorded.

Deferred Time Applications

These were a natural extension of the field of operation of the device and include keyboard entry of pan and envelope type functions. Studio based usage began to assume a new importance due to the possibilities that these functions provided. Normally such facilities are only available on fully digital systems running on mainframe computers, for example MUSIC11.

THE PROGRAMMABLE CONTROLLER UNIT

The PCU operates in a number of modes. These and their operation are listed below.

FADERS Mode

In this mode the DC voltage across up to 8 faders is sampled in order at the specified RATE (see below). The 10 bit value provided by the ADC is converted to 14 bits, stored and output to the DAC. This is done via a logic multiplexing system which scans the number of channels specified by the CHAN command (see below).

The data is stored in 4 byte words 1 a new data word is created every time the relevant fader moves. This technique is used to economise on memory usage.

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RECORD and PLAY (see below) are triggered via a variable level audio trigger which can be assigned to any input channel or an external source thus ensuring that playback of the sequence of fader movements begins at the same time as the recording process did.

Commands in FADERS mode

FADERS	Enters mode
STATUS	Gives present mode, memory used, RATE and CHAN values
RATE	Sampling rate from 100 to 1
CHAN	Number of channels scanned from 1 to 8
RECORD	On receiving trigger pulse changes in fader position are stored
PLAY	On receiving trigger pulse stored values are output to DAC

PAN Mode

In this mode double joysticks connected to the "analogue in" port of the BBC B are used to pan up to two stereo inputs between left and right (obeying the equal power law) as well as allowing the vertical axis to control volume.

Commands in PAN mode

PAN	Enters mode
STATUS	Gives present mode, memory used, RATE and CHAN values
RATE	Sampling rate from 100 to 1
CHAN	Number of input channels panned from 1 to 4
RECORD	On receiving pulse changes in joystick position are stored
PLAY	On receiving pulse stored values are output to DAC
PRECISION	Changes joystick precision between 10 and 14-bit resolution
EDIT	Allows programming of deferred time panning sequences. These sequences may be programmed to a time resolution of 10ms between 255 pan positions. On compiling interpolation takes place between these values at the specified resolution.
COMPILE	Compiles information entered on EDIT mode into a format ready to PLAY.

ENVELOPE Mode

This mode functions in deferred time allowing the user to program a series of amplitude values in either standard synthesiser ADSR type envelopes or more sophisticated sequences of level variations. 4 independent sequences assigned to each pair of VCAs (i.e. channels 1 & 2, 3 & 4, 5 & 6 and 7 & 8) can be created. It will be possible to superimpose a sequence of PAN movements on an ENVELOPE producing "panned envelopes".

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Commands in ENVELOPE Mode

STATUS	Gives present mode, memory used, and CHAN values
CHAN	Selects which envelopes are active
PLAY	On receiving pulse stored values are output to DAC
EDIT	Allows programming of envelope sequences. These sequences may be programmed to a time resolution of 10ms and 1024 steps giving amplitude resolution of .1dB. Compilation will interpolate values to 14-bit resolution.
COMPILE	Compiles information entered in EDIT mode into a format ready to PLAY

PROGRAM facility

This allows a sequence of operating commands to be stored, edited, then executed in a manner of a computer program. A sample program could for instance select a mode, selete RATE and CHAN values, load in a sequence from disk and PLAY it. A feature also incorporated into this facility is the ability to repeat a sequence of commands as many times as desired, or indefinitely within a FOR...NEXT loop. Programs do not take up memory used for the storage of sequences - they are stored in separate areas of memory.

Commands in PROGRAM facility

PROGRAM	Enters the PROGRAM facility
LIST	Lists the program currently in memory
RUN	Executes the program currently in memory
FOR...NEXT	Allows a sequence of commands to be repeated (see above)
NEW	Erases the current program from memory

FUTURE EXPANSION

Other Modes

A number of other modes are planned including:

1. GATE mode which will allow the PCU to act as a noise gate.
2. DIFFUSE mode in which the joystick will act as an octopan.

Additional Facilities

1. EDIT in FADERS mode which will allow the creation of detailed sequences of fader movements over up to 8 faders in deferred time.
2. Close in an out

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Interface

It is hoped that with the addition of a small box to convert an output from the Atari ST series to a 1MHz bus output the PCU will be controllable from this much more powerful machine with no modification. This should be possible since the 6522 versatile interface adapter chip is a 6800 processor peripheral and the 68000 processor in the Atari ST is designed to be compatable with 6800 peripherals. The advantages of a much faster machine with uo to 300 times the memory would be felt in every mode of operation.