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DIGITAL TAPE TRANSFER CONSOLE

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Abstract

With the arrival of compact discs the increased audio quality possible could only be maximised if the signal chain from source to master tape was totally digital.

Although commercial digital recording consoles were being built to provide a digital path from source to digital master tape there were no plans for a digital audio transfer console which would complete the digital chain.

Thus work on a digital transfer unit went ahead with customer liaison. (1) Signal processing and control experience gained on large digital consoles was applied to produce a two channel unit, which was to interface to a SONY 1610 and editor.

This paper therefore briefly describes such a transfer unit, which has been in commercial use for over one year now, and although performing admirably, experience and further discussions with future customers, has resulted in development of the original "one off" prototype into a commercial Digital Transfer Console. The production consoles interface to both Sony 1610 and AES standards with two digital and one analogue stereo input all under independant control. Snapshot memory and switchable sampling rate is also included. It is these developments which are detailed in the second half of this paper.

1. Prototype Digital Transfer Unit (DTU)

A two channel unit was conceived to provide a stereo path with signal conditioning for compact disc applications, taking into account special requirements of the application (2) (3). In order to operate within an existing environment of PCM 1610 and editor, the following extra facilities were required above those developed for a digital multitrack recording console.

1. Serial Interface to Sony PCM 1610 providing two input ports.
2. Serial Interface to Sony PCM 1610 providing two output ports.
3. Synchronisation of DTU sample rate clock to Sony PCM 1610 wordsync at 44.1KHz.
4. Pre-emphasis and De-emphasis filters.

These extra facilities were developed and used in conjunction with standard processing functions of filtering, equalisation, dynamic range control, and fading. Figure 1 shows the Sony editor with the DTU.

1.1 Description of Processing Facilities

Those provided are:

1. Pre and De-emphasis filters
2. 4 Band Semi-Parametric equaliser having
   a) Low Frequency Shelf (LFS)
   b) Low-mid Frequency Peaking (LMP)
   c) High-mid Frequency Peaking (HMP)
   d) High Frequency Shelf (HFS)
3. Second order High and Low Pass Filters
4. Dynamic Range Control including
   a) Limiter
   b) Compressor
   c) Expander
   d) Noise Gate
5. Level Control - Fader

These functions in large systems may be configured in any order under operator control, however in this application only the function of Equalisation (EQ) and Dynamic Range Control (DRC) may be re-ordered, thereby reducing complexity. The processing chain is shown in Figure 2 where De-emphasis and Pre-emphasis (if selected) are at the start and end of the processing chain respectively with the final control being gain.

1.2 Processing Rack Implementation

To reduce system cost and size the starting point for development was an Audio Processing Rack used in other developed products. The 19" 11U high rack is self contained having an integral power supply and fan tray for cooling. Normally up to 16 Audio Processors are fitted along with Routing, Fader, Delay, and Control processing forming a sub-system to a large digital console.

It was therefore decided to remove all but two Audio Processors and the Controller, which would provide two channels of processing functions required, the command interface to the DTU control surface, and communication to the Audio Processors via the rack backplane.

The controller, based on an NEC BP-0186 single board computer, was now not being fully utilised and hence it was decided to incorporate the necessary control software required for console module and system control.

Although increasing software development this approach alleviated the need to use further 8086 based processors in the console with associated interfacing and actually simplified the software task.

Thus all console and processing control is performed by the one single board computer.

Further to reduce cost the console/processing interface is via an RS422 balanced parallel cable thereby avoiding the more costly fibre optice solution which is uneconomic for such a small system. A limit of 30 metres is placed on the length of the RS422 interface cable.

The audio processors used are of bit slice design using micro-coded software algorithms to perform the required processing operations. This allows new facilities to be incorporated merely by changing the microcode which incorporates the new developments of:-

1. Pre-emphasis and De-emphasis filters

2. Fader operating in microcode, rather than hardware based, with ramped coefficients to avoid zipper noise.

1.2.1 Interface Hardware Requirements

In order to provide audio routing, timing signals, and addressing for the audio processing cards, along with the interfacing requirements for the Sony PCM 1610, an Interface Board was developed.

A Phase Lock Loop is used to lock the DTU master clock to the Sony PCM 1610 word sync output, and internal timing generated from this generates the necessary clocks and timings required for the Input and Output ports to meet Sony specifications. An LED indicates a locked condition.

Further to this rack routing is provided by the provision of address sequences, data latches and clocks allowing data to be passed through the audio processors and to facilitate the stereo cross coupling of dynamic range control voltages.

The input interface receives Sony PCM 1610 format serial data at TTL levels, which is converted to a floating point format of 16 bits plus a 4 bit exponent before entering the processing. The interface detects the absence or presence of the input sync pattern thereby knowing whether an input is connected or not, when the system is locked to word sync.

Output data in floating point format is converted to 16 bits 2's Complement before being serialised for transmission, in Sony PCM 1610 format, via the output ports.

A Control Interface from the Interface Card exists to the processing rack controller, which allows knowledge of the following status.

1. Synchronisation of word clock to Sony PCM 1610
2. Connection of Inputs to Sony PCM 1610
3. Pre or De-emphasis applied to Sony PCM 1610

System operating level adjustment is provided for on this card and allows an exponent value to be attributed to the 16 bit data received from the Sony PCM 1610. Currently an input exponent of 2^{-4} gives a maximum of +24dB input and output levels, with head room of +24dB for equaliser adjustments. This can of course be easily altered to meet future requirements.

1.3 Console Implementation

As the requirements for control are minimal requiring only the use of three existing modules, namely equalisation and filters, Dynamic Range Control, and Fader, the console may be physically small.

Each module (to be outlined later) has a single 8048 microcontroller which communicates with a 22 bit parallel bus known as the Console Interface Bus (CIB). Each 8048 is responsible for detection of key states, rotary control movements, and

maintenance of LED and alpha-muneric displays. Also they receive display information and send control adjustments over the 22 bit CIB.

It is this CIB which is buffered to RS422 and interfaces directly to the processing rack 8086 micro controller, thereby providing the control interface.

2. Development into Digital Transfer Console

After some months in operation it became apparent that although the basic DTU worked reliably and with good audio quality, it was lacking certain features, which would provide increased control flexibility and applications for a commercial product.

Also at this time a small two channel console with several stereo inputs (analogue and digital) and with recall storage facilities was being considered. Over a period of about a year, the following enhancements to the DTU were collated and a product defined to suit any mono, two channel or stereo application requiring digital and/or analogue inputs and outputs (4).

1. Increased I/O ports analogue and digital
2. Digital Input mix
3. Digital Interface to AES/EBU and Sony 1610 formats
4. Input gain trim and balance
5. Metering
6. Non-volatile desk storage, for all desk settings
7. Store execution by external trigger
8. Shelving filters to be switchable to peaking
9. Switchable sample rate from 48KHz to 44.1KHz

These enhancements pointed to substantial modifications of hardware and software, but on an existing basis of a known working system. The concept of a small console and remote processing rack was preserved.

2.1 Console

The console is in the style of a desk top mixer which provides for the increased control surface requirements of extra modules above those used by the DTU. As previously, only one set of modules are supplied operating on both channels, except for the faders which may be assigned to provide gain level control on each channel independently. High resolution NEVE 200 segment bargraph meters are used displaying absolute peak level with an overlaid brighter display of VU

characteristics thereby giving constant display of both modes.

The I/O ports have been increased to give two stereo digital inputs and one analogue, with one digital and analogue stereo output. The digital input format is selectable from the console to conform to AES/EBU or Sony PCM 1610 formats with both output formats driven at all times. Analogue line outputs are also provided for headphones on the console, and processing rack.

A non-volatile memory is provided allowing up to 200 console snapshot memories for which preview is provided. Memory operations are controlled from the ancillary control module, and may be sequentially recalled by an external event controller for automation purposes. An RS232 serial port when connected to a printer to obtain hard copy of desk settings or store contents.

The audio processing requirements have been increased by the obvious requirement for more faders, and by the new function of a stereo three into one mix, provided after the input faders, prior to the two channels of Equalisation, Filters and Dynamic Range Control. The mixing function and the extra faders are performed in mocrocode operating in audio processors as in the DTU. Also, the shelving filters can be selected to be shelve or peaking, thereby increasing the equaliser flexibility.

2.2 Console Modules

The console contains the previously used equaliser and filter, dynamic range controller, and fader modules plus a new ancillary control, meter and three more fader modules all with 8048 controllers interfacing to the CIB and hence processing rack.

Each module will be detailed giving an appreciation of facilities and specification.

2.2.1 Filter and Equaliser module

The panel may be used to control the operation of the four band equaliser and the high and low pass filters, and is shown in Figure 4.

2.2.1.1 Four band equaliser

The four EQ sections are:-

Low frequency switchable shelving/peaking
Lower midrange Peaking
Upper midrange Peaking
High frequency switchable shelving/peaking

The equaliser consists of four second order sections which may be selected/de-selected en bloc using the 'EQ' key. When the equaliser is in use, the Light Emitting Diode (LED) integral in the 'EQ' key will be lit. Similarly individual sections of the equaliser may be switched on or off. Corner frequencies (+/- 0.25dB) for the shelving sections and centre frequencies for the peaking sections are adjustable by individual Incremental rotary control (IRC's) having an associated 4 character display. The Low and High frequency sections are selectable to a shelving or peaking characteristic. Boost/cut and Q settings are adjustable by increment/decrement keys.

2.2.1.2 High and Low pass filters

The filter section consists of two second order maximally flat (Butterworth) filters which may be selected/de-selected en bloc using the 'FILTER' key. When the filter is in use, the LED integral in the 'FILTER' key will be illuminated.

The high and low pass sections of the filter may be switched off by adjusting control settings to flat.

Corner frequencies (-3dB) for the filters are adjustable by individual IRC's.

2.2.2 DRC module

The DRC is a fully comprehensive stereo dynamics control system of exceptional range and versatility which incorporates the following, and is detailed in Figure 5:-

Limiter
Compressor
Expander
Noise gate

Each of these may be selected/de-selected by an 'ON' key and the parameters associated with each function may be displayed on the panel using the 'DISPLAY' key for the required function. Each function has the following parameters associated with it:-

Attack	(ms)
Release	(ms)
Threshold	(dB)
Ratio	

Of these four parameters, the Attack & Release times are common to all of the four DRC functions. IRC's are provided for these four parameters. The controls are assignable to each of the four DRC functions and assignment is by means of a 'DISPLAY' key associated with the 'ON' key for each function.

DRC functions are based on peak signal levels unless the 'AUTO' key is selected, in which case a temporal average is compared with peak to determine whether to employ fast or slow recovery times in the sidechain. Auto operation requires the setting of Slow Mean or Fast Peak capture times also using IRC's. A 'DELAY' key is provided to insert a 200us delay in the signal path. This enables the sidechain signal to be processed and applied to the DRC gain cell in time to avoid overshoot in fast limiting. External control of the DRC gain cell is possible, and this is selected using the 'EXTRN' key. When operating in this mode the LED integral in the key will be lit. The signal input for this function is the left channel (CH1) of the analogue input, which may not be used as a program input while this mode is maintained.

2.2.3 Ancillary Control module

The ancillary controls module provides control of the Snap-shot memories, configuration and pre- and de-emphasis filters. A 'PRINT' key is provided which may be used to dump the currently displayed control settings (which may be preview or program) to the printer port. Figure 6 shows the panel layout.

2.2.3.1 Memory controls

One of the 200 available non-volatile stores may be selected using the IRC labelled 'STORE SELECT'. Alternatively, stores may be stepped through using the 'INCR' and 'DECR' keys. The store may either be previewed and modified if required by operating the 'PREVIEW' key or recalled and implemented by the processing using the 'RECALL' key. Preview is a latching control and after selection the LED integral in the key will remain lit until the key is operated again and the preview mode cancelled. When preview is released the state of the controls is stored, enabling adjustments to store settings without affecting program settings. Alternatively, if not in preview mode, the current state of the console controls may be written into the selected store using the 'STORE' key. If external sequencing of stores is required, then the 'SEQ' key should be depressed. This will alow an external event controller to step the console through the 200 stores repeatedly until the 'SEQ' key is operated again. The LED integral in the 'SEQ' key is illuminated during sequenced operation.

New stores may be inserted into the list at any point using the 'INSERT' key, which moves the currently selected store and all those above it up 1 place. The store previously at 200 is lost. The new store thus created contains the current console control settings.

Store may be deleted from the list using the 'DELETE' key, which simply deletes the currently selected store and moves all those above it down 1 place.

Groups of stores may be copied or moved within the list using the 'COPY BLOCK' or 'MOVE BLOCK' keys in conjunction with the 3 IRC's labelled 'STORE SELECT', 'BLOCK START' and 'BLOCK END'. The block is first defined and then the 'COPY BLOCK' or 'MOVE BLOCK' key used to complete the operation. In the case of a copy the original block is preserved, but in the case of a move it is deleted.

2.2.4 Configuration control module

The configuration module provides controls for sample rate selection, input format selection, metering modes, emphasis and processing configuration, and is shown in Figure 7.

2.2.4.1 Configuration control

The system is capable of being reconfigured at the touch of a button. No re-wiring is required to configure any one of three processing configurations, which allow DRC to be configured either pre- or post-EQ, or with Equalisation in the sidechain (S/C). The 'DRC S/C EQ' key configures the equaliser in the DRC sidechain and in this condition the LED integral in the key is lit. If sidechain equalisation is not selected, the 'DRC POST EQ' key may be used to switch the order of the DRC and EQ processing blocks. If the DRC post EQ state is selected then the LED integral in the key will be lit (the configuration of an external control voltage input is controlled using a key on the DRC panel). The Processing organisation is shown in Figure 3.

2.2.4.2 Pre-emphasis & De-emphasis filters

The input De-emphasis filter is selected automatically if either the Pre-emphasis bit is set on the incoming 1610 format data stream or the 15/50us emphasis code is set on the incoming AES/EBU format data stream, and its operation is indicated by the illumination of the LED integral in the 'DE-EMPH' key. The key is not used. The output Pre-emphasis filter is selected using the 'PRE-EMPH' key and when the filter is active, the LED integral in the key will be lit.

2.2.4.3 Meter controls

The Neve Bargraph meters may be selected to Hold peak signal or to provide peak reading with a long decay time, by the use of the 'PEAK HOLD' key. Peak hold mode is indicated by the led integral in the 'PEAK HOLD' key. The adjacent 'RESET' key may be used to reset the display when in this mode. If held down while peak hold is selected, then the normal long decay mode results. VU level is continuously displayed as a bar of greater brightness than the peak level on the same bargraph.

2.2.4.4 Format controls

Input data format for each channel is individually selected by one of two keys, 'AES/EBU' or 'PCM 1610'. The system sampling frequency is selectable by a single key, '44.1 KHz' or '48.0 KHz'.

2.2.5 Faders

Faders and gain trims are all of the same type offering both level and balance control and their operation is identical. The motorised assignable Stereo Fader is to be adopted as the standard item for this purpose. Figure 8 details the Fader.

2.2.5.1 Stereo Input Faders

Each input to the DTC has an associated stereo fader which allows comprehensive level and balance control for the stereo input. The scale plate has labelling showing increasing level away from the operator.

2.2.5.2 Stereo Input Fader Operation

Each Stereo Input Fader effectively controls four faders, two in each channel. The first in each channel is operated as an individual fader having a Mute facility and a gain

ranging from 'off' to +10dB. These may be selected for adjustment by means of the channel assignment buttons CH1 (left) and CH2 (right). The second fader in each channel is ganged to its partner in the complementary half of the stereo pair. Both of these are adjusted together when the channel assignment button 'MAIN' is selected. The range of adjustment in this mode is from 'off' to 0dB. This results in a maximum gain of +10dB at the inputs. For each assignment the gain setting in dBs is displayed in the four character display on the fader, to allow accurate gain adjustments and easy duplication of previous setups. 0dB line-up buttons are provided for a) the currently selected fader(s) of the four ('0dB SEL') and for b) all four faders ('0dB ALL). These cause the motor in the fader to move the control to the 0dB position. Each line-up button includes an indicator LED which illuminates as long as the respective line-up is maintained. If faders are manually set to 0dB, the appropriate indicator(s) will also illuminate. A Mute control is provided with a pair of LED indicators showing the mute status for each channel. If the Left side of the Mute rocker switch is depressed the, left channel (ch1) is muted. A subsequent operation of the switch unmutes the channel. Muting for the right channel is similarly controlled with the Right side of the Mute switch.

2.2.5.3 Stereo Output Fader

One Stereo Fader is provided to implement level control on the outputs of the DTC. Operation of this fader is similar to that of the input faders.

2.3 Interfaces

2.3.1 Digital I/O

The Unit interfaces with the SONY PCM 1610 format and AES/EBU format at both inputs and outputs. Both output formats are provided for each digital I/O port. Both output formats will be driven when operating at 44.1 KHz but only the AES/EBU format output will be driven when operating at 48.0 KHz. Input format will be selectable for each of the two stereo digital inputs via front panel switches.

Synchronisation is to the master SONY 1610 unit WORDSYNC, or if not interfacing to SONY equipment the DTC will generate its own 44.1 KHz or 48.0 KHz WORDSYNC. A WORDSYNC output will be provided,

which will either be a buffered PCM 1610 input WORD-SYNC or the internally generated wordclock.

The Event controller input accepts TTL logic levels and will cause the next console store to be accessed and implemented on detection of a high to low logic level transition. A contact closure would be adequate for this purpose.

All interface connections to and from the PCM 1610 are by means of 75 ohm co-axial cable carrying standard TTL voltage levels.

The RS232C printer port on the console is implemented on a 25 way female 'D' connector.

2.3.2 Analogue I/O

A stereo headphone output jack is provided on the console. Maximum level is +24dBu into 600 Ohms. In addition, a line output at the same level is provided in the IEC standard XLR configuration on both the console and the processing unit. Analogue inputs are provided on the processing rack for DRC control and Stereo audio.

2.3.3 Interface List

1. INPUT 1 - 1610 CH 1 serial input
2. INPUT 1 - 1610 CH 2 serial input
3. INPUT 2 - 1610 CH 1 serial input
4. INPUT 2 - 1610 CH 2 serial input

5. INPUT 1 - AES/EBU CH 1 serial input
6. INPUT 1 - AES/EBU CH 2 serial input
7. INPUT 2 - AES/EBU CH 1 serial input
8. INPUT 2 - AES/EBU CH 2 serial input

9. INPUT 3 - CH 1 analogue input
10. INPUT 3 - CH 2 analogue input

11. 1610 CH 1 serial output
12. 1610 CH 2 serial output

13. AES/EBU CH 1 serial output
14. AES/EBU CH 2 serial output

15. CH 1 headphone output
16. CH 2 headphone output
17. CH 1 analogue line output
18. CH 2 analogue line output

19. Word Sync input
20. Word Sync output

21. Event controller input
22. RS 232C Serial Printer Port

2.4 Conclusions

With the increasing use of Digital Recording and growth of the compact disc, the development of the DTC has progressed in parallel with the needs of the market. Already three systems are under construction for - Sterling Sound New York, Masterdisk New York and Disc Mastering Nashville. Experience in design and operation of the first transfer console has led to a practical, and currently unique product, ideally suited to the needs of Analogue or Digital Disc Mastering Studios.

2.5 Acknowledgements

I wish to express my thanks for the help and enthusiasm of G. Boswell who developed the requirements for the Digital Transfer Console from the original DTU prototype. Also thanks to A.H. Langley, (Vice President Sales, Rupert Neve Inc) for his constructive ideas and customer liaison.

2.6 References

1. Tape One Studios, London

2. Foster. B CD Mastering How it should happen Studio Sound October 1984

3. Spencer-Allen, K. Digital Equipment Studio Sound, September 1984

4. Digital Tape Transfer Console, DTC-1, Neve Specification May 1985

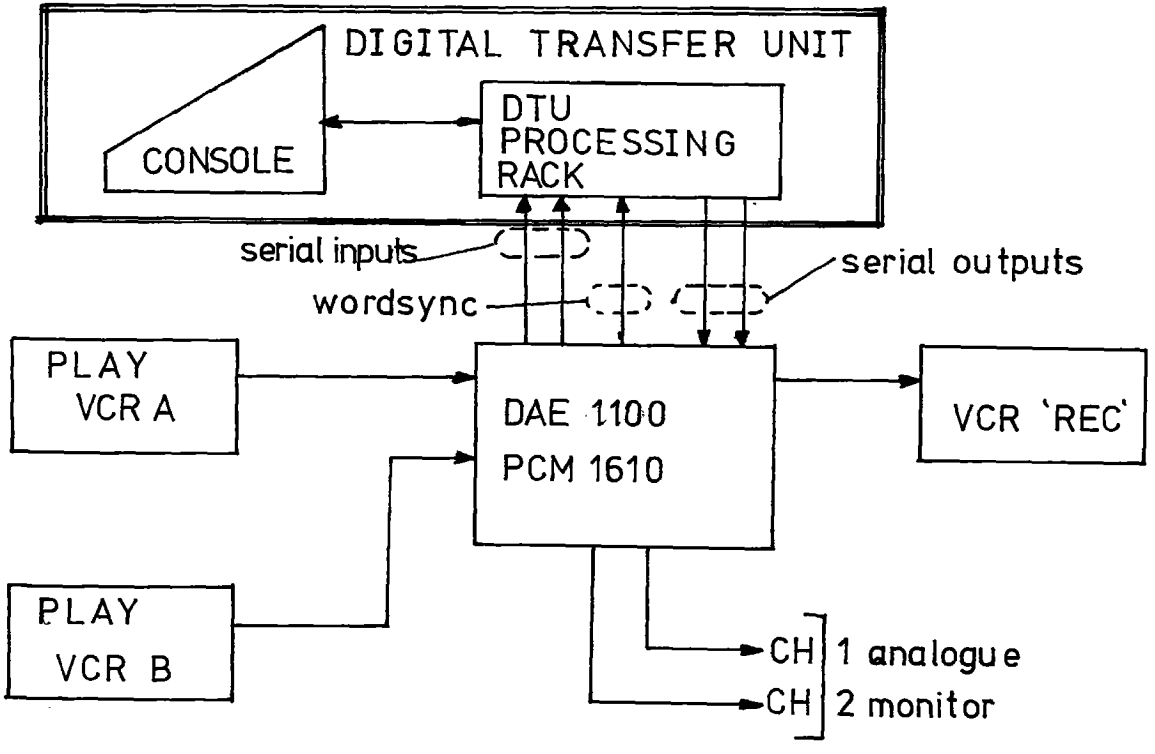

Figure 1 DTU with Sony Editor

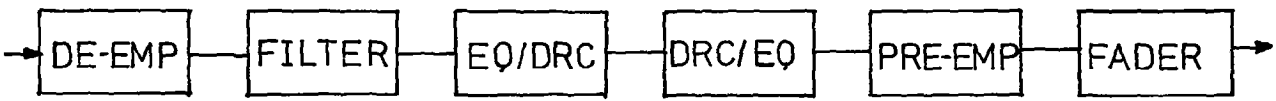

Figure 2 Processing Path

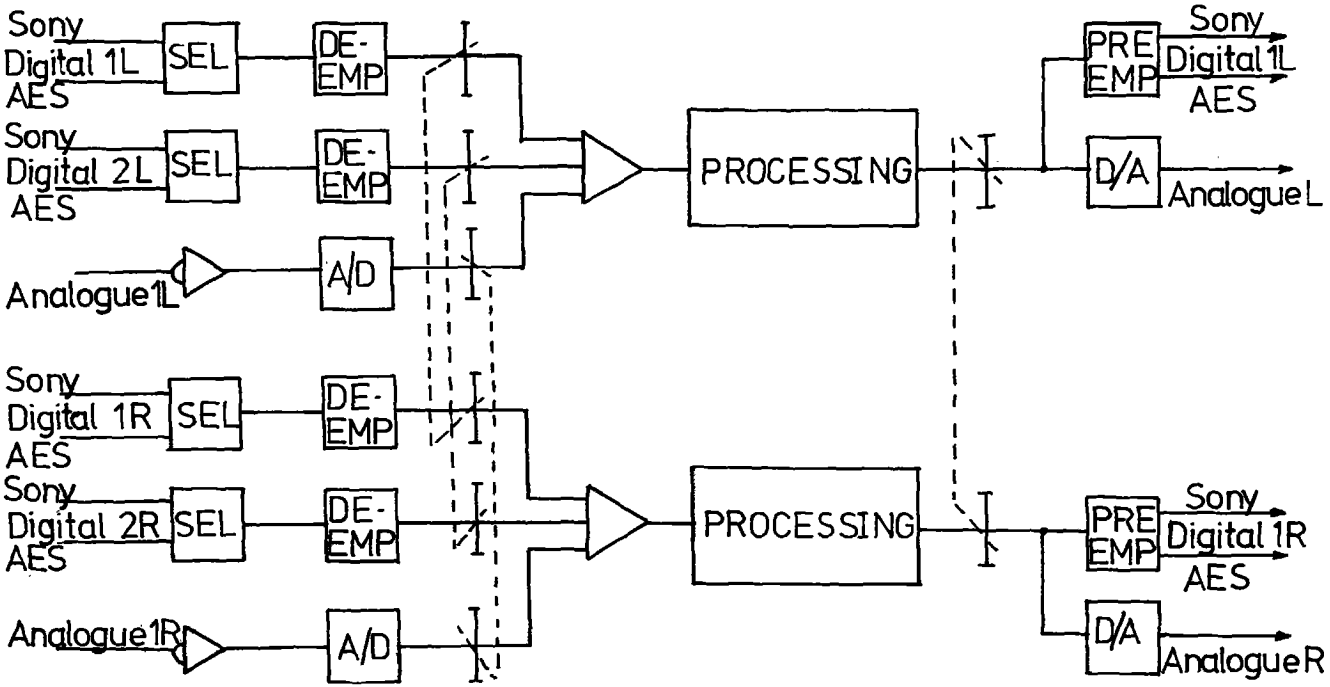

Figure 3 DTC Block Diagram

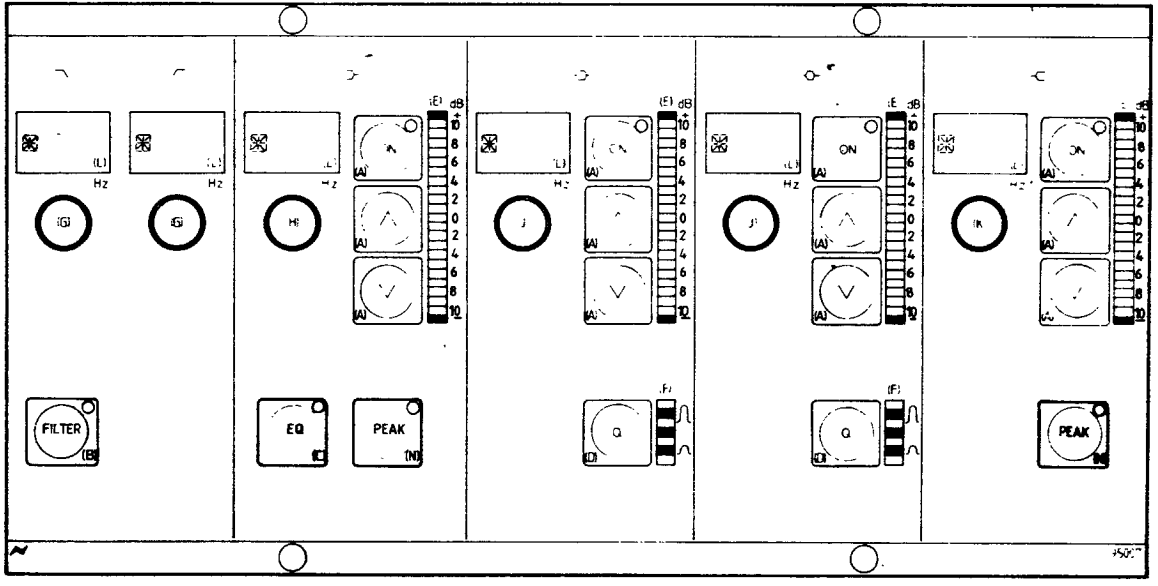

Figure 4 Filter and Equaliser Module

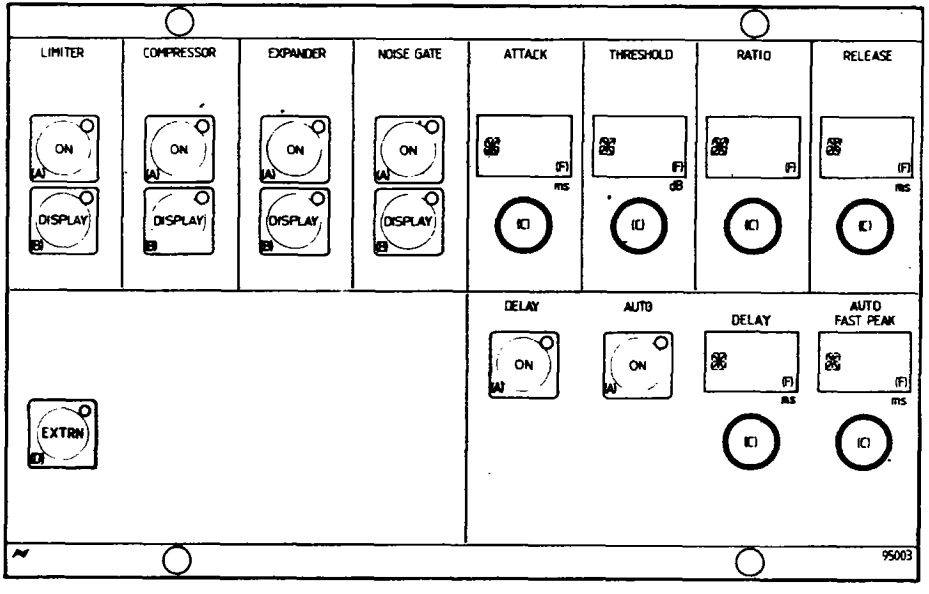

Figure 5 DRC Module

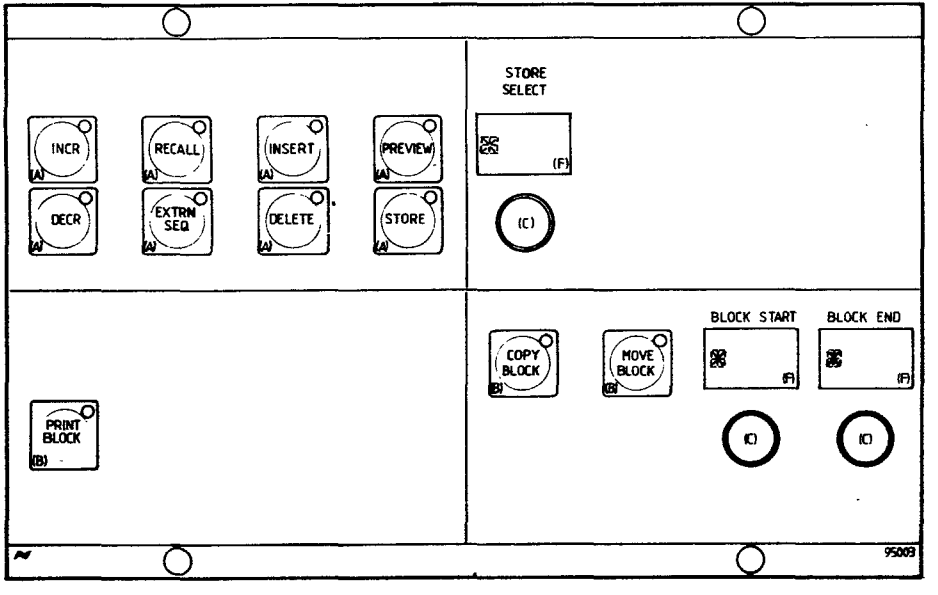

Figure 6 Ancillary Module

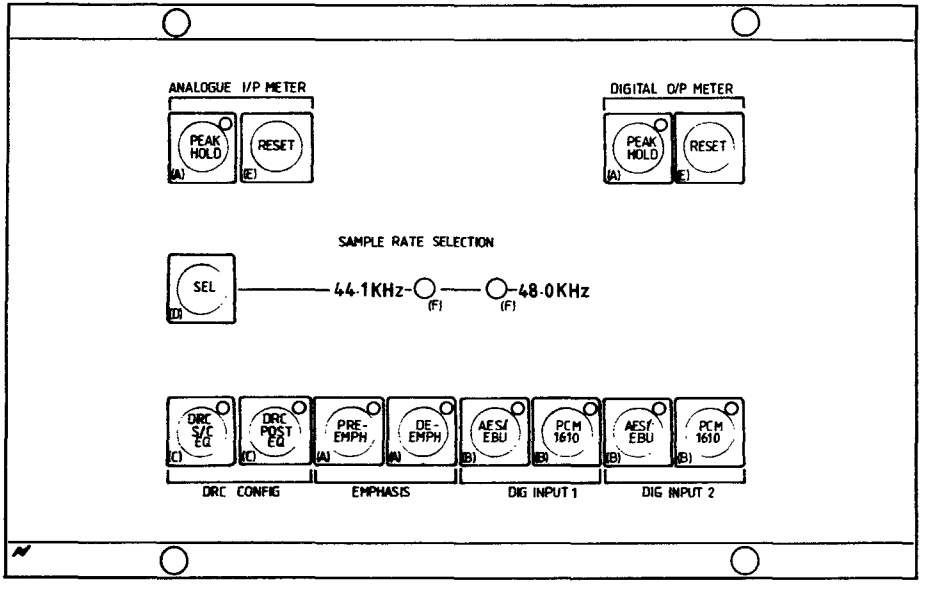

Figure 7 Configuration Control Module

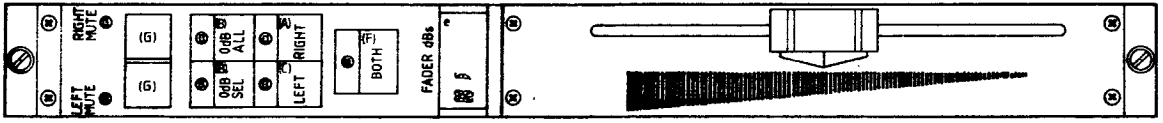

Figure 8 Fader Module