SYSTEM DESIGN OF PROFESSIONAL DIGITAL MASTERING SYSTEM

PREPRINT NO 1959 (E4)

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**Presented at
the 73rd Convention
1983 March 15-18
Eindhoven, The Netherlands**

AUDIO
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AN AUDIO ENGINEERING SOCIETY PREPRINT

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1. Abstract

We have already presented reports on the development of a professional 2-channel Digital Audio Mastering System using 3/4-inch U-type video cassette recorders. 1) 2)
This system consists of a Digital Audio Processor, an Electronic Editor and a Preview Unit; it makes possible all operations required for record production from recording and editing to the cutting of disks.
Although this system already has several advantages over analog recording systems, improving its capabilities and future system expansion are important if it is to be developed further.
This paper, taking this into consideration, deals with the development of a digital audio mastering system with a multi-microprocessor structure using a 16-bit microprocessor.

2. Introduction

Professional equipment is required to be highly reliable, to have good operability and have high quality; the already presented system was designed and developed taking these points into consideration.
A code with low redundancy and powerful error correctability was developed to protect data against tape dropout, etc. and the Electronic Editor was designed to search for editing points with high accuracy using memory so that editing can be done in a way similar to editing using an analog recorder.
However, for the creation of a total digital audio mastering system, it is necessary to provide a wide range of peripherals such as a digital mixer and equalizer, a way to interface with the video system and further improved operability.
In that case, a digital system offers the possibility of the effective systems construction by making full use of its excellent characteristics and advanced features.
In this paper, we will describe the system design concept and the system we actually developed.

3. Design Concept

The system was designed to meet the following conditions so that it would have a performance meeting professional requirements.

1) Flexibility so that it could meet multi-function requirements

2) Good compatibility for system expansion

3) High reliability

4) Good operability

5) Easy serviceability

These conditions could only be fulfilled by developing our Digital Audio Mastering System using an effective design method.
The structured design method is an effective method in which the functions of the system are arranged hierarchically from the overall design concept to the details and operations are also developed logically from the top level to down. Software design using this method allows tasks to be assigned to hierarchical modules so that programming can be separated resulting in a reduced development time. Task modules are controlled by a real time operating system described later.
In hardware design, the required function can be divided into the convenient blocks with full expandability so that it is also possible to adopt the most appropriate design to these blocks.
In this system, these blocks are formed using a multi-microprocessor structure likned by computer bus and microprogramming technique. This has improved integration and, as a result, the system's reliability.
A self-diagnostic functions has been incorporated to improve serviceability and the fact the system is programmed is expected to make a major contribution to the modification and expansion of the system in the future.

4. New Digital Mastering System

4-1. Functions

The functions required to be provided by the new system are:

1) As far as the man-machine interface is concerned, operability should be improved by centralizing all control functions and displays.

2) The changing of the work flow should be possible through operation of the controls and should not require reconnecting cables or resetting switches.

3) Automatic control of the VTR functions by time codes should be expanded to enable four-channel recording using two processors, auto-location, synchronized operation with another system, etc.

4) It should be able to record and reproduce user's information other than digital audio data. (The BP format employed in this system has a user's data area with a size of 6.72 kbps.)

5) The possibility of connection to a digital mixer/equalizer should be considered from the beginning of the design stage.

To meet these requirements, an entirely new System Controller is provided and this acts as the center controller of the total system. This System Controller makes system expansion in stages possible.
Fig. 1-a shows the basic recording/playback system using a Digital Processor and VTR while Fig. 1-b is the system improved by the addition of the System Controller.
As shown in Fig. 1-c, an Electronic Editor can be formed by adding Editing Boards to the main unit of the System Controller and an Edit Controller (AE CTL).
Fig. 1-d shows a system using a Digital Mixer/Equalizer which makes signal processing (tone control, echo processing, etc.) possible. In this example, the Digital Mixer has an independent Main Unit and Controller. The digital data and CPU control data are interfaced between this Main Unit and the System Controller; this makes it possible to use all the functions of the System Controller and control the Mixer from the System Controller. In this way, the system has the flexibility to meet the increasingly complicated requirements of music producers.
Fig. 2 shows the principal functions of the System Controller.

4-2. System Configuration

Fig. 3 shows the block diagram of the system which can be divided into five basic blocks.

1) Block 1: Man-Machine Interface

   The CRT display terminal makes it possible to input and output characters. The SC CTL (System Controller) has a key section which consists of VTR control keys, Function control keys, Hexadecimal keys, etc., with Display sections such as level meter, time-code indicator and user's data indicator.
   The AE CTL (Edit Controller) controls the Electronic Editor and has a search dial, fader control and the various control keys required for editing. Each of these contollers incorporates an 8-bit microprocessor for decentralized processing.

2) Block 2: System Controller/Electronic Editor Main Frame

   This block is housed in an independent chassis and performs the control and processing required by the System Controller and Electronic Editor.
   All the processors and VCRs are connected to this block so that centralized control of the signals is possible in the various operation modes.

This eliminates complex procedures such as the reconnection of cables and helps makes working more efficient by preventing mistakes. The connection cables of the various devices are connected to this main frame using one connector for each device.

3) Block 3: VCR section

Up to three VCRs can be connected. For editing, for example, it is possible to use two VCRs for playback and the third for recording.

4) Block 4: Processor section

Up to two Digital Processors can be connected so that four-channel recording is possible as well as mixing down from four to two channels using a Digital Mixer.

5) Block 5: Expander block

I/O ports are provided for the connection of future newly developed devices such as the Digital Mixer.
The I/O ports include an I/O interface for a CPU bus conforming to RS-232-C as well as an I/O interface for digital audio data. A composite sync input terminal and SMPTE time code input/output terminals are also provided for compatibility with video systems.

As described above, it is possible to construct an editor from this system by adding editor boards to the System Controller section and by connecting the AE CTL. In this way, the Main Frame (Block 2) is divided into an SC section and an AE section.
Fig. 4 is a block diagram of the SC/AE Main Frame which consists of a total of seven circuit boards, each of which has a different function. The SC section consists of four boards, the SC CPU, SC DCK, SC DPR and SC SMP.

SC CPU: Based on a 16-bit microprocessor (MC68K) controlled by RMS (described later). Executes communications with the CRT display terminal and SC CTL; controls VCR operations, time codes, the Electronic Editor and Expander section.

SC DCK: Consists of VCR control ports, video signal multiplexer, etc.

SC DPR: Provided with I/O ports for the input/output of digital audio data, time codes, user's data and mode change flags to/from the Digital Processors. Data flow can be switched according to the job. A PLL circuit is also provided for sync operation with a video system.

SC SMP: Generates/reads SMPTE time codes.

These boards are connected by a CPU bus (Standard VERSAbus*) and are controlled by an 16-bit microprocessor.

The AE CPU, AE DIO and MEMORY boards provide the editing functions.

AE CPU: Incorporates an 8-bit microprocessor (MC6800) to control editing operations. This CPU communicates with the AE CTL and the 16-bit CPU of the SC CPU.
The single-chip signal processor performs various digital signal processing such as PCM signal filtering for memory search, DPCM processing, attenuation, etc. 2)

AE DIO: Consists of parallel/serial conversion ports for PCM signals and expander ports.

MEMORY: Used for storage when searching editing points, for cross-fade processing when editing, etc.

The boards are connected with a data bus and are controlled by the 8-bit CPU of AE CPU. This CPU communicates with the 16-bit CPU of the SC CPU via the CPU bus; it performs decentralized MEMORY and level control processing.

5. Task Management

The task modules are given priorities in system design; they are linked with other task modules and run when necessary. Since real-time control is required for this system, it uses a Real Time Multitask Operating System (RMS) with a 16-bit microprocessor (MC68K) for system control with software as described previously. With RMS incorporated in the System Controller, it is possible to simplify software and improve reliability and serviceability.

5-1. Outline of RMS

The control multiple tasks in real-time, the RMS performs the following functions:

1) Running of tasks according to their priorities

2) Multi-processing of tasks

3) Makes tasks operation dynamic

4) Synchronization of and communications between tasks

5) Message transfer between tasks

6) Control of input/output devices

7) Control of software timer based on hardware timer

8) On-line debugging

RMS is a high-performance supervisor for process control and processes the above functions in real-time.
The program configuration of the RMS program is shown in Fig. 5

5-2. Task configuration

Fig. 6 is a diagram of tasks linked by RMS and the exception processing program section of the System Controller.
IRQ indicates interrupt generation due to hardware or interrupt handling by RMS. TASKS are task sections (modules) that perform the various functions of the system under the control of RMS. Arrows indicate the activation of Tasks by RMS and the relationship between tasks.
System Task, activated by an interrupt from the Terminal, has top priority, making possible various monitor functions when debugging the system and in self-diagnosis.
The IRQ Analyze Task determines the causes of interrupts from the System Controller and Editor CPU; if the interrupt is from the System Controller, the Task to be activated is selected according to the contents of the data sent in a packet.
The Controller Control Task forms packets, designating data to be displayed by the SC CTL.
The Deck Control Task generates VCR control commands.
The Mode Control Task controls the VCRs by time code and performs such operations as auto location, synchronization, etc.
The Function Control Task controls the VCR and Digital Audio Processor mode depending on the purpose of the operation.
The IRQ.V.SYNC. interrupts with specific periods to activate V. SYNC Task. This Task has a high priority and its principal operations are time code processing singal switching in editing, etc.

5-3. System memory map

This sytem uses a Standard VERSAbus* as its CPU bus and RMS, TASKs and WORK AREAs are located in the 16M byte linear space according to hardware specifications. In the memory map, software occupies about 96 k bytes as is shown in Fig. 7.

6. Conclusion

This paper concerning the development of a professional two-channel Digital Audio Mastering System has emphasized the multiplicity of functions and expandability; we have introduced the top-down structured design method as the most efficient method of system design.
The system configuration uses a multi-microprocessor structure while decentralized processing contributes to improving the reliability of the system and its serviceability. In software, various Tasks are controlled by the Real-time Multitask System which also improves reliability and expandability.
We realize that, to create a total digital mastering system, we have to continue our efforts in the development of peripherals.

(References)

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The 66th AES preprint, 1980.

2) T. Mori, et al.: "ELECTRONIC EDITING IN THE PCM RECORDING USING U-TYPE VTR".

The 68th AES preprint, 1981.

* "VERSAbus" is a trademark of Motorola Inc.

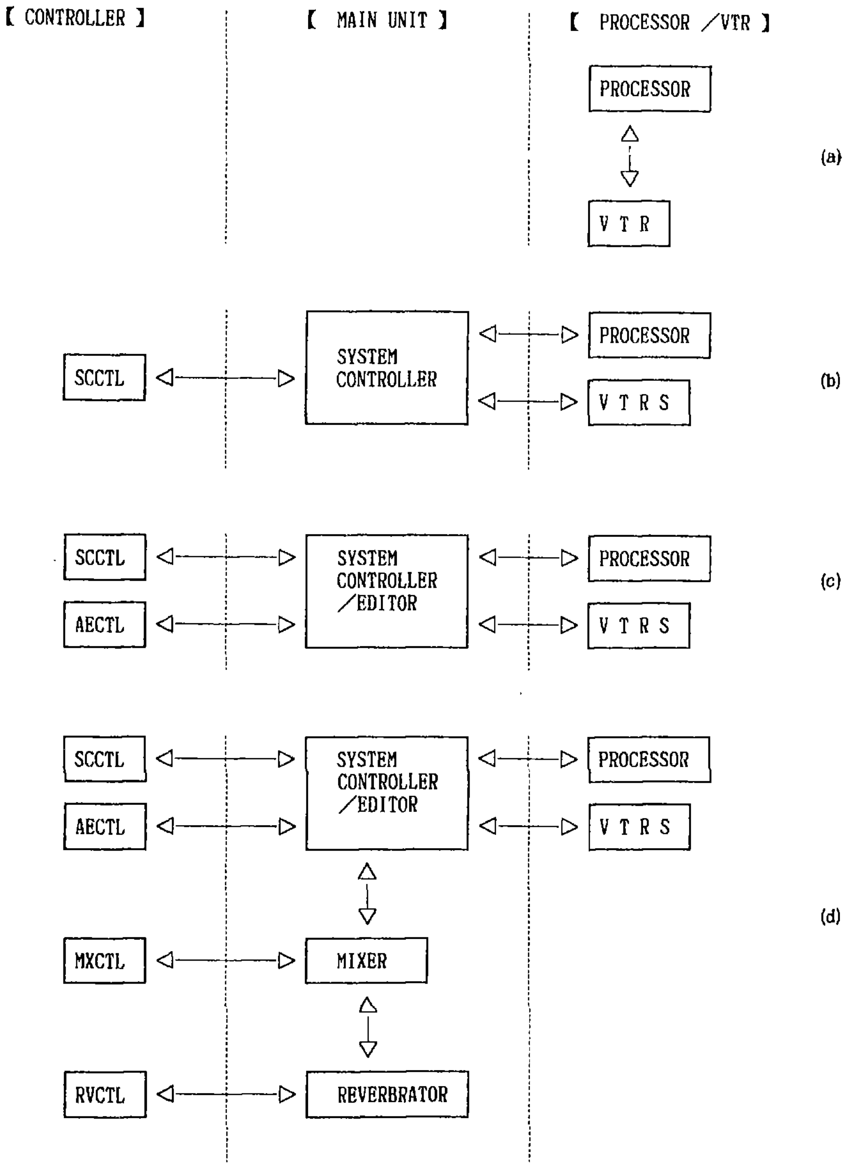

FIG. 1 CONCEPT OF SYSTEMATIZATION

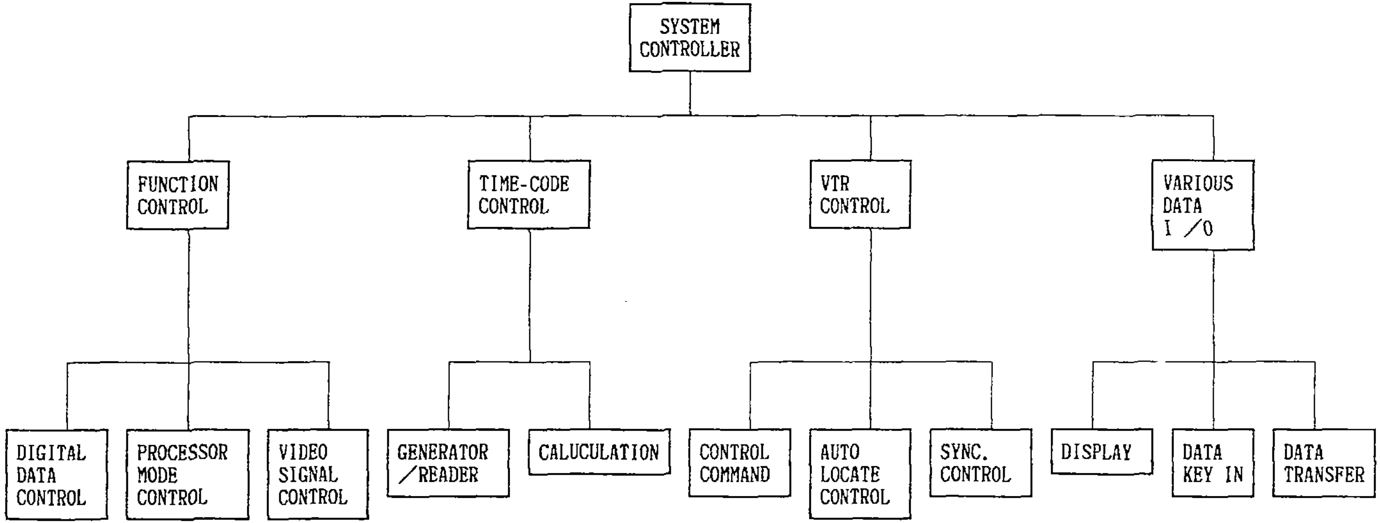

FIG . 2 FUNCION DIAGRAM OF SYSTEM CONTROLLER

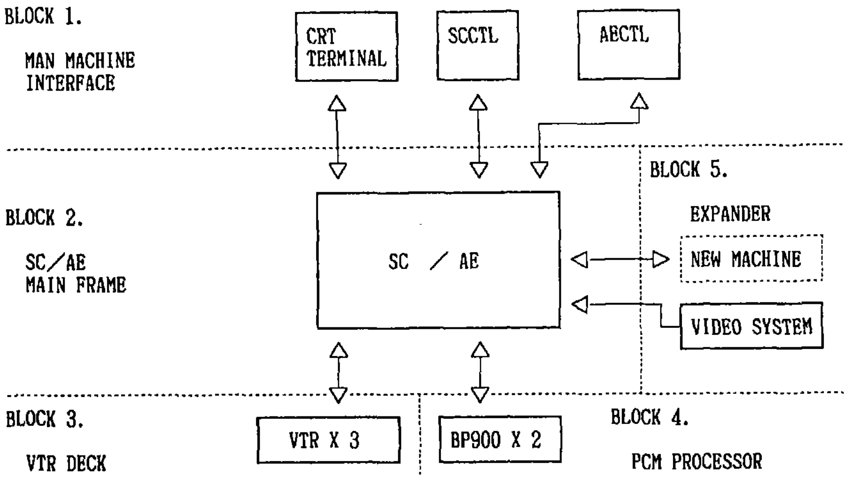

FIG. 3 SYSTEM DIAGRAM

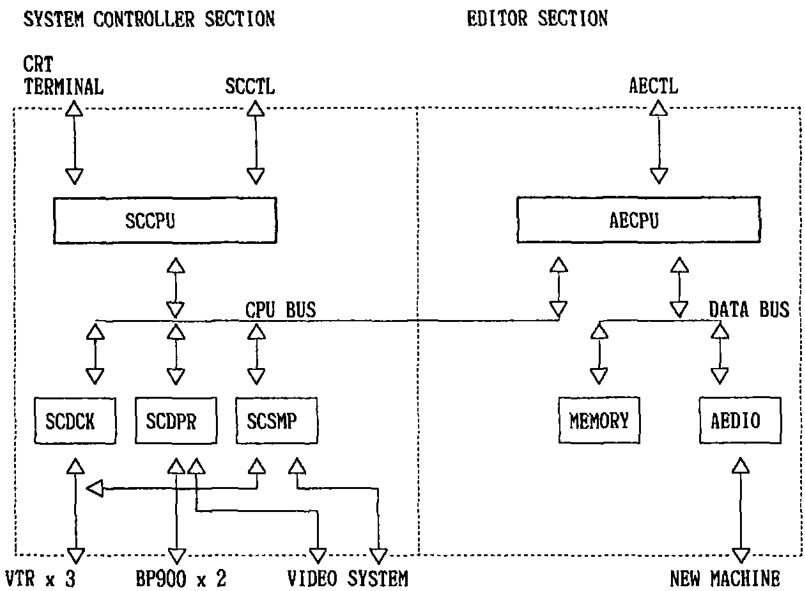

FIG. 4 BLOCK DIAGRAM OF SC ／AE MAIN FRAME

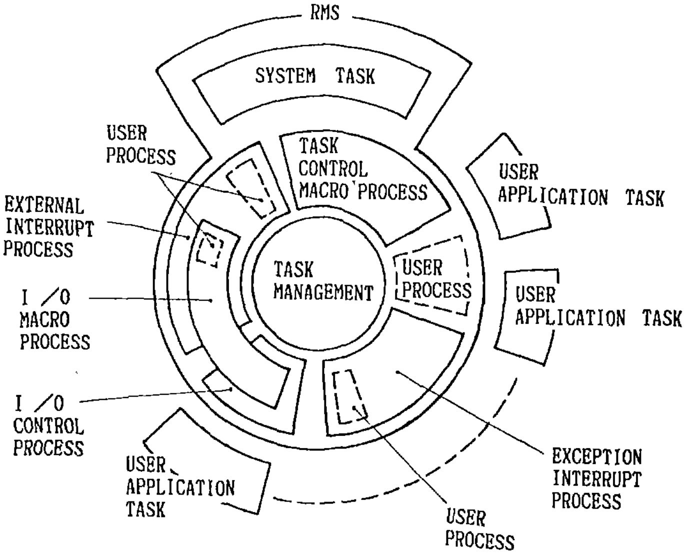

FIG. 5 CONFIGURATION OF RMS PROGRAM

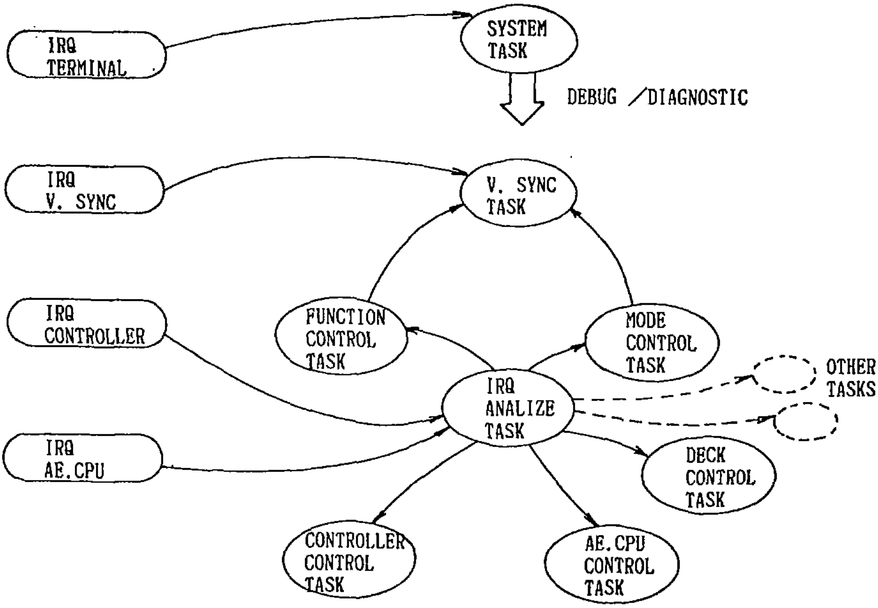

FIG. 6 TASK TRANSITION IN SYSTEM CONTROLLER

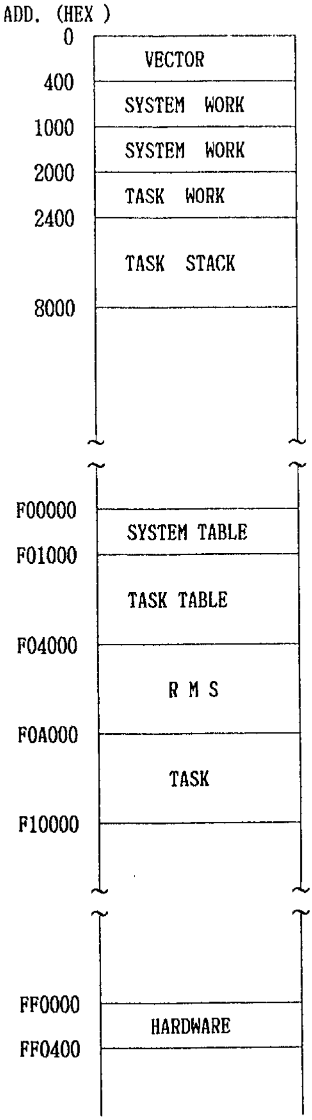

FIG. 7 SYSTEM MEMORY MAP