NORTHEAST RADIO OBSERVATORY CORPORATION
HAYSTACK OBSERVATORY

18 April 1984

TO: VLBA Acquisition Group

FROM: Alan E. E. Rogers

SUBJECT: Sony High-Density Digital Recorder

Sony has developed a high-density Digital recording system - see report attached. Comments:

1) At 5.95 Mbits/sq. inch, 24 12-inch reels weighing about 130 lbs (assuming standard 3M5198 tape) would be generated per station per day at 100 Mbits/sec. A density improvement of a factor of 2.6 is needed to meet the VLBA requirement of 50 lbs/day.

2) If limited to 12-inch reels and 5.95 Mbits/sq. inch, 24 machines would be needed at each station to be able to record for 24 hours unattended.

Sony engineers have recently demonstrated 14 Mb/sq. inch by narrowing the track width by a factor of 2 and eliminating the large error correction overhead. The machines would have to be modified to accept larger reels to reduce the number of machines needed at the stations and it is not yet known if this is possible.

Attachment

SONY HIGH-SPEED DIGITAL DATA RECORDER

VDR-2000

[first draft]

January 1984

Communication System Engineering Department
Communication Products Group

Broadcast Products Marketing Division
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Rev. C

Log of Revisions

revision symbol	description	date	approval
A	Fully revised all pages.	Jan.31,'84	K. Yamamoto
B	1.Revised following pages for clarification. pages 3, 10, 15, 16 (4 pages) 2.Added "log of revisions" page.	Feb. 2,'84	K. Yamamoto
C	Fully revised.	Feb.13.'84	K. Yamamoto

Introduction

The recent great increase in research activities has lead to an enormous increase in physical measurement data which can analysed by computer.

Digital data-recording equipment is preferable because the data can be reproduced repeatedly in the same form. A large digital memory system is needed particulary by researchers in the area of medical image processing because multiple copies must be sent to laboratories all over the whole country for coordinated study of medical images.

A newly developed high-density digital recorder with a rotary-head scanner, VDR-2000, can handle not only physical measurement data but also images. The digital recorder allows facilities to communicate with computer system, but it can be used as stand-alone equipment.

I. Features

1. The digital recorder has a rotary-head and uses 1-inch magnetic tape as the recording medium. Its tape transport mechanism is the same as SONY's BVH-2000 broadcast-use video tape recorder. This data recording system assures stable operation while achieving a high recording rate of 118 Mbps with a high recording density of 5.95 Mbits/sq. inch.

2. The equipment's main unit consists of the tape-transport mechanism and a digital processor. 8-bit parallel high-speed input and output ports are provided for high-speed digital data recording and reproducing. Continuous recording and reproducing for 1 hour is possible using a 12-inch reel of magnetic tape. The total recording capacity is 53 GByte in this case. An external interface unit is used to interface with other forms of data.

3. Asynchronous read & write buffer memories with large capacity (1MByte) are built into both the input and output interfaces of the digital processor, so the recording system can accept data in any clock rate.

4. Two built-in microcomputers (Z80 & MC68000) control operations of the recording system. The following DMA interfaces (optional) for computers are also provided.
   - GPIB interface unit
   - UNIBUS interface unit
   - CAMAC interface unit

5. A powerful error-correcting function is provided. With this function, the resultant bit error rate will be lower than 10^{-8} when properly stored magnetic tapes are used.

II. Examples of system configuration

Figure 1 shows a stand-alone type recording system. The block within the broken lines is the main unit. Manual operation of the system is possible for basic operations such as recording and reproducing when an external input and output interface is used. (An optional buffer memory may be included.)

When dealing with the data using the external input and output interface unit, the data handling mode can vary to suit the type of data. An optional interface controller with a MC68000 CPU is a convenient tool in this case. The controller can control the VDR-2000 through the GPIB bus.

Figure 2 shows how a data recording system consisting of a main unit and an external input and output interface unit can be combined with a host computer. The figure shows DEC's VAX-11 as the host computer. A GPIB interface card (IEC-11) and a UNIBUS DMA controller (DRU-11) are connected to the UNIBUS line. The GPIB bus is used by the computer to control the measuring instruments and the recording system.

"Tag" information specified by the user may be recorded on the specified tracks on the magnetic tape to enable easy tape access by computer. Maximum access time is 3 minutes with a 12" reel of magnetic tape.

1 MByte buffer memories are built into both input and output interfaces in the processor, so the following operations can be realized in combination with the computer-interface.

- Recording the data generated by a computer on the specified tape address after transferring them from the computer to the input interface memory.
- Reproducing the data on the specified tape address before saving them in the output interface memory and before transferring them to the computer for data processing.

These functions make the recording system suitable for generating computer art.

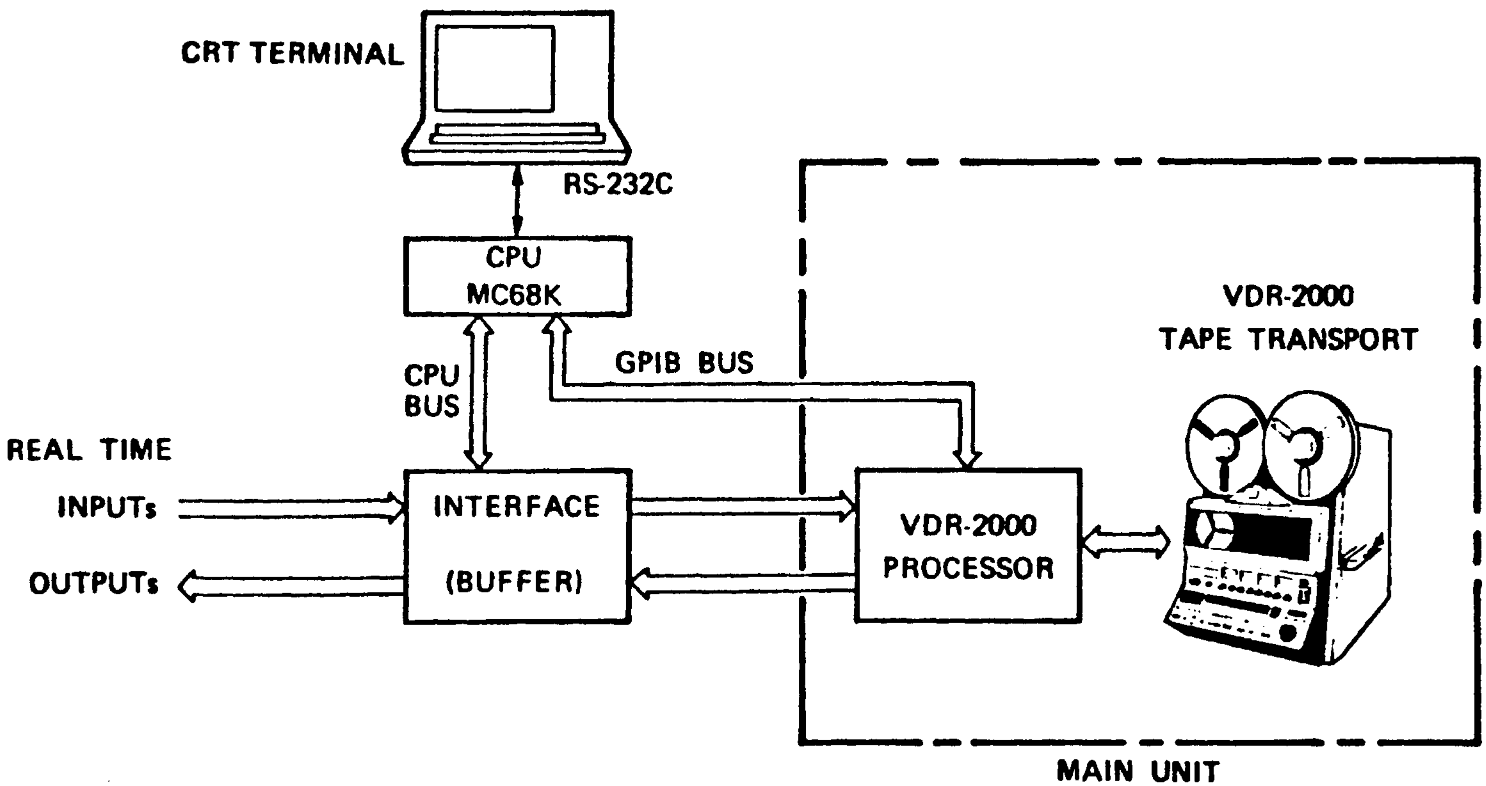


Fig. 1 STAND ALONE RECORDING SYSTEM

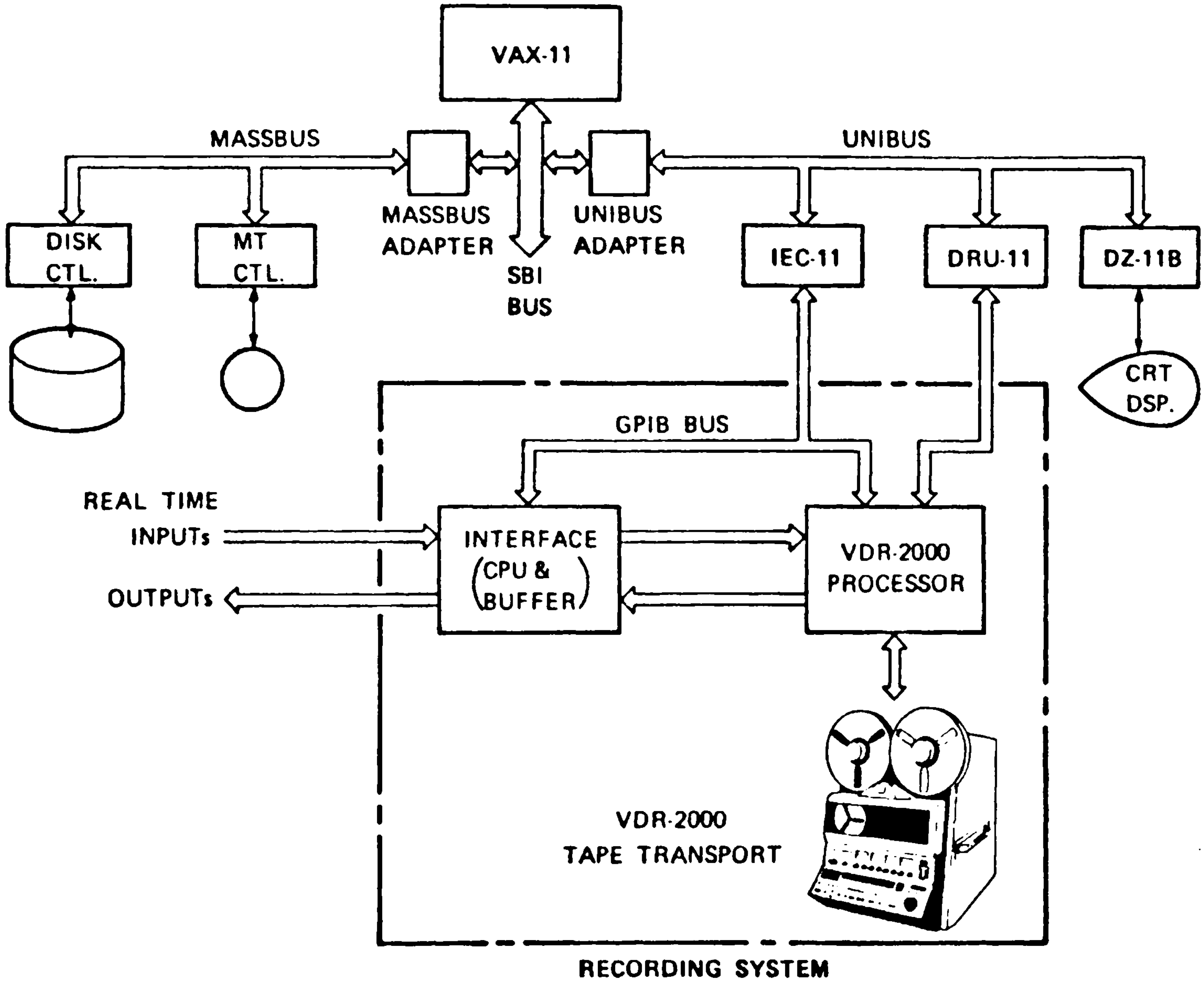
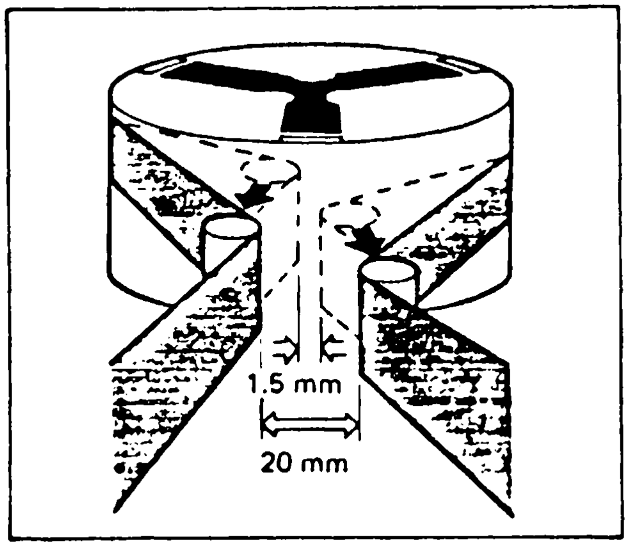


Fig. 2 COMPUTER AUTOMATED DATA ACQUISITION SYSTEM

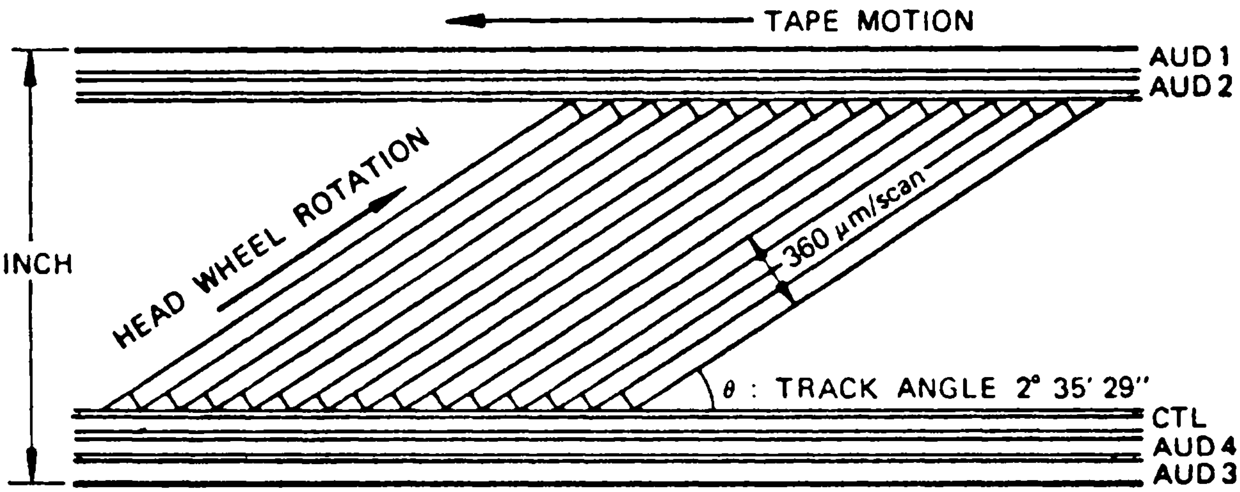
III. Recording format

Figure 3a shows the head wheel drum. Magnetic tape is wrapped around the head drum in a form of the Greek letter omega. When the tape is unloaded, the guide posts pull back to make tape loading easier.

Figure 3b shows the recording format. (This diagram is drawn with some exaggeration for easy understanding.) In the center of the tape there are helical-scan tracks recorded by the rotary-head scanner. Four tracks are simultaneously made on every revolution of the rotary-head scanner, because four recording heads are installed very close together around the circumference of the scanner. The CTL track and AUD tracks 1 to 4 are located on the edges of the tape, as can be seen in the figure. The system uses the CTL track for controlling the tape speed and the AUD 3 track for recording tape marks and addresses to allow high-speed tape access. AUD tracks 1, 2 and 4 are available for recording analog audio signals or the low-speed digital data which occasionaly accompany high-speed data.



a) HEAD WHEEL DRUM



b) RECORDING FORMAT

Fig. 3 HEAD WHEEL DRUM & RECORDING FORMAT.

IV. Block diagram

Figure 4 shows the block diagram of the recording system. A processor and a tape transport are in the right half of the diagram and an external interface unit is in the left. Now let's look closer at the function of each unit in the system.

1. Function of the units of the processor

IFW: (Input interface). Includes an asynchronous read/write buffer memory (1 MByte).

RCG: (Redundancy code generator). Generates error-correcting codes. This unit also cuts the data stream into blocks and adds error-correcting codes to each block.

SFL: (Shuffler). Shuffles the original data stream in time sequence every scanning period according to a preassigned format.

ENC: (Encoder). Divides the data stream by four before encoding it with a DC-free 8-9 NRZI code, after which the data stream is bit-serialized. This code is designed for use with high-density data recording with a rotary head scanner.

DR: (Data recovery). Picks up clock and block sync signals from the reproduced bit serial data, after which the data is transformed from bit serial into parallel form. Finally, 8-9 reversal transformation (decoding) is performed on the bit parallel data.

DSFL: (De-shuffler). Reconverts the shuffled data stream to the original stream. Burst errors caused by dropouts in the reproducing process become dotted errors in the resultant sequence.

ECC: (Error check & correction). Provides functions of error detection and correction.

IFR: (Output interface). Includes an asynchronous read/write buffer memory (1 MByte).

CSG: (Control signal generator). Generates system clock and other control signals. The Z80 CPU in this unit coodinates the operation of the processor and the tape transport as dictated by the system program.

CPU: (CPU). Includes the MC68000 CPU. The CPU controls input and output interface buffer memories and computer communication.

CIF: (Computer interface). Controls DMA operation between the host computer and the VDR-2000.

2. Function of units of the external interface

IF1: (Input interface). This unit can generate a trigger signal and headers to be added to the input data stream, detecting whether an input signal is present or not. An A/D converter may be included.

BUFF: (Buffer). The buffer memory is very effective in lowering and flattening the data rate when high-speed burst data is being handled.

FMT: (Formatter). Converts the input data stream into the byte-serial form which suits the VDR-2000.

DFMT: (De-formatter). Receives byte-serial data from the VDR-2000 and converts them to the original data stream by referring to headers in the serial data.

IF2: (Output interface). Outputs data at the command of the external system. A D/A converter may be included.

Each unit except the BUFF can be designed to meet any specific specifications.

Several standard units for image signal are prepared as external interfaces.

3. Function of units of the interface controller

CPU: (CPU). The same as the CPU unit in the processor. An MC68000 is installed in this unit.

EXT: (EXTENDER). Extends the CPU bus outside through bus driver and receiver.

Through the GPIB bus, the interface controller can control VDR-2000 and other equipment. The program-control function of the overall system can be expanded by attaching a micro floppy disk drive to the internal CPU bus.

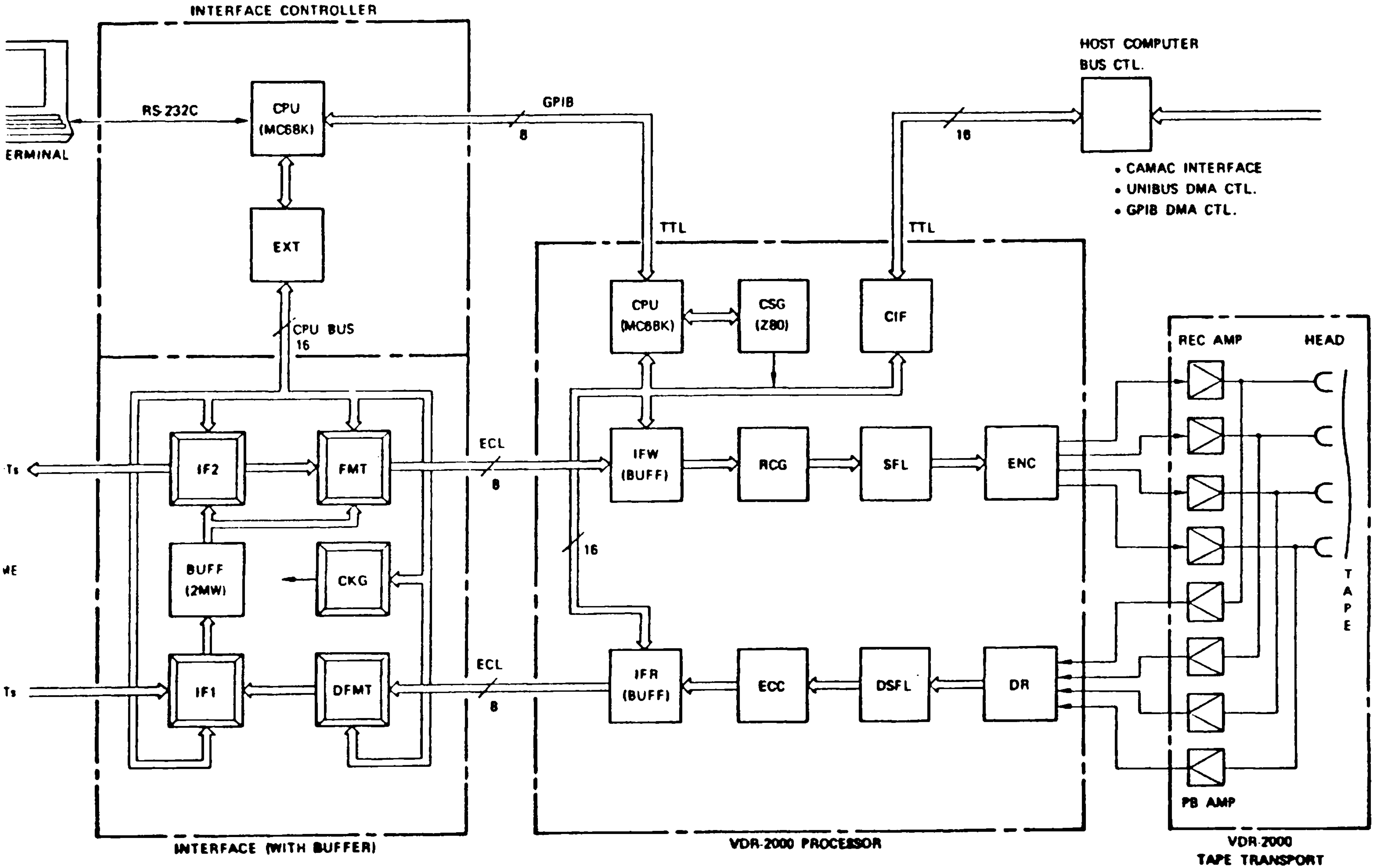


Fig. 4 BLOCK DIAGRAM OF RECORDING SYSTEM

V. Computer control

A macro command set is provided to easy control of the VDR-2000 by an external system. The following table shows typical examples of the macro commands.

COMMAND	ABBREVIATION	ARGUMENT	OPERATION
LOAD			
RECORD			
PLAYBACK	To be determined by this April, 1984.		
STOP			
STANDBY			
REWIND			

TABLE I

Codes and formats of the COMMAND system for computer control through the GPIB bus are defined as per the recommendations of the IEEE 488 Committee.

Before transferring the reproduced data to the host computer, pre-processing, such as averaging data between tracks, is possible using the MC68000 CPU in the processor. This will greatly reduce the load on the host computer. Figures 5 and 6 are overall views of the systems diagramed in Figures 1 and 2. All units can be mounted in a 19-inch EIA standard rack. Various configurations can be realized to suit various applications.

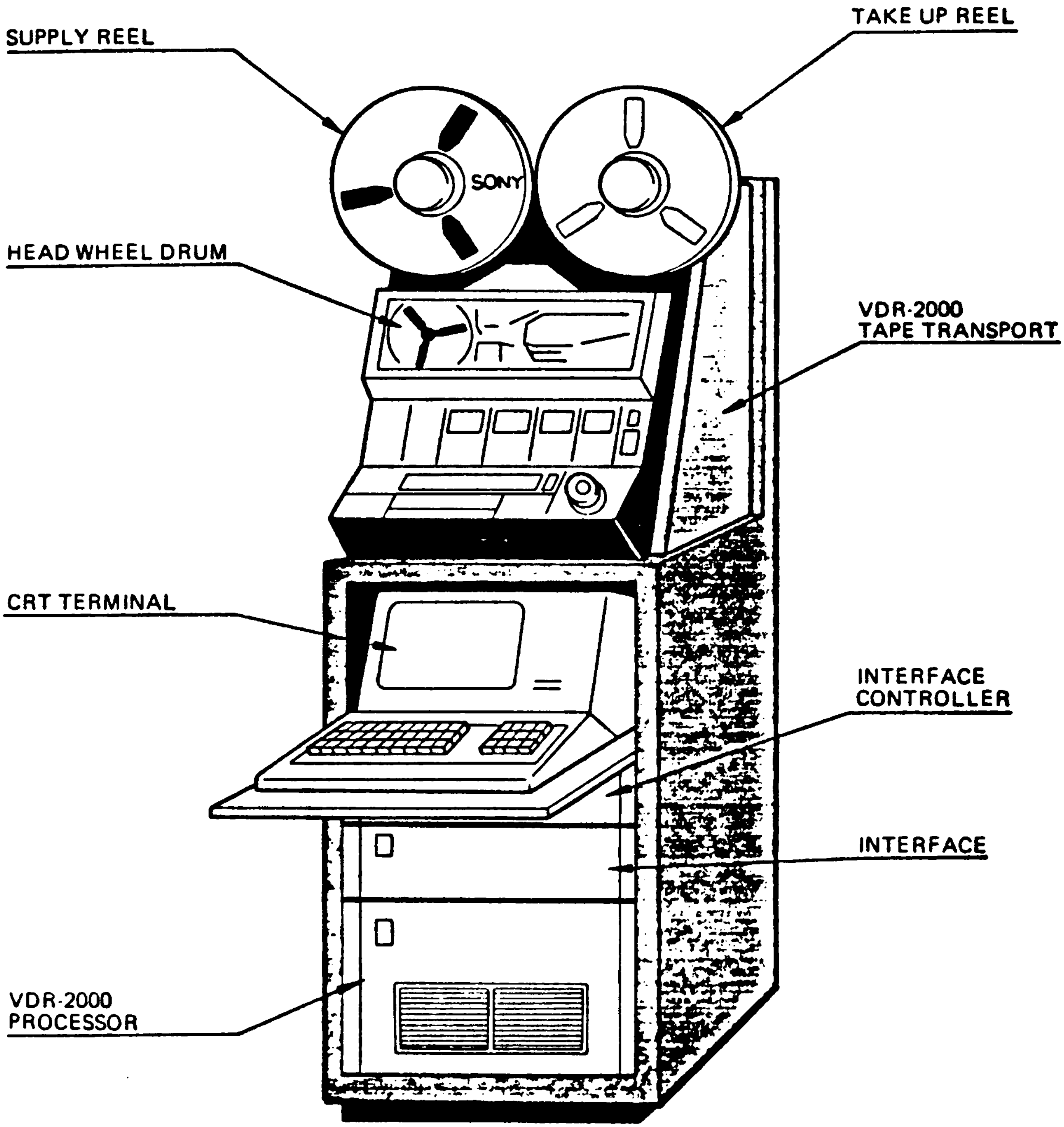


Fig. 5 STAND ALONE RECORDING SYSTEM

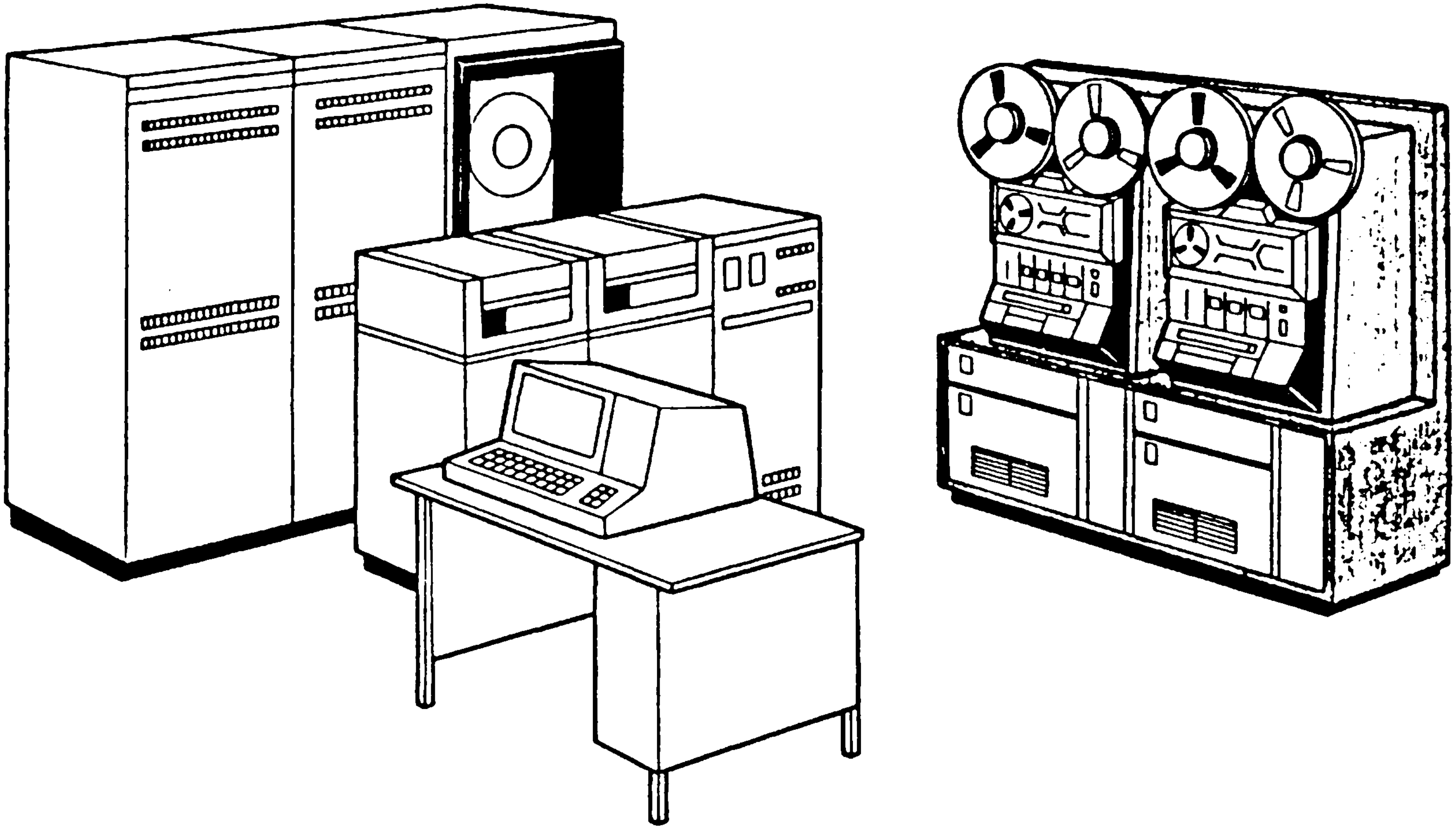


Fig. 6 COMPUTER AUTOMATED DATA ACQUISITION SYSTEM

VI. Major specifications

1. Tape transport

Tape width	25.4 mm
Tape speed	48.8 cm/sec
Revolution of drum	3,600 r.p.m.
Tape vs. head relative speed	25.83 m/sec 1016 IPS
Scanning type	Helical scan
Scan pitch	360 um
Build-up time	5 sec. max.

TABLE II

2. Recording system

Recording data rate	118 Mbps
Total capacity of record	53 GByte
Recording density	
Linear density	43,500 tpi (see note 1)
Area density	5.95 Mbits/inch^2
Maximum recording duration	1 hour
Channel code	DC-free 8-9 NRZI
Error-correcting code	Reed Solomon product code
Bit error rate	10^{-8} (in worst case)
Tape access time	3 minutes (max.)
Power requirement	100 to 115V AC, 50/60 Hz
Power consumption	2 kW (max.)
Total weight	150 kg (max.)

Note 1: transition per inch (FLUX CHANGE PER INCH)

TABLE III

3. Input word lengths and clock rates

Tables IV and V show the relation between input word length and maximum clock rate depending on the number of channels in the input interface. Table IV shows the relation when there is an error-correcting function and Table V shows the relation without an error-correcting function.

Word length	Maximum clock rate (MHz)			
	1ch.	7ch.	14ch.	28ch.
16 bit	9.37	1.0	0.52	0.26
12	9.83	1.4	0.7	0.5
8	14.75	2.1	1.0	0.5
4	29.5	4.2	2.1	1.0
1	118*	16.8	8.4	4.2

TABLE IV

Word length	Maximum clock rate (MHz)			
	1ch.	7ch.	14ch.	28ch.
16 bit	8.81	1.25	0.62	0.31
12	11.75	1.67	0.83	0.41
8	17.62	2.51	1.25	0.62
4	35.25	5.03	2.51	1.25
1	141*	20.1	10.0	5.0

TABLE V

Compare the starred values above. Higher recording rate is attained without error-correcting function, because additional data can be recorded in spaces assigned to parity codes.

4. Computer interface

Table VI shows the data transfer rate with various computer interfaces.

Computer interface	Data transfer rate
GPIB	400 kBps (8 bits/B)
CAMAC	1 Mwps (16 bits/w)
UNI-BUS	500 kwps (16 bits/w)

TABLE VI

The CAMAC interface is a high-speed, general purpose computer interface standardized by IEEE. It occupies a position one rank higher than the GPIB interface. The CAMAC interface is suitable for directly interfacing a main frame computer with both a recording system and measuring instruments.

(These specifications are subject to change in order to improve the system.)