A DATA RECORDING SYSTEM FOR DEEP SEA LOGGING

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Summary A data recording-reproducing system has been developed in conjunction with an oceanographic in situ multi-sensor probe for measuring chemical properties. The recording unit is built around a deck of a single channel, entertainment-type miniature magnetic tape recorder. The tape speed was reduced to 0.125 ips by slightly modifying the original speed control, which results in four hours' continuous recording. The recording unit incorporates a frequency counter to convert the input frequency signal to a serial, four digits, BCD code. The code is recorded twice per frame by chopping the bits with a 250 Hz signal. The frame lasts 5 seconds after which a command is sent to the main unit advancing the multiplexer one step ahead.

The reading unit consists of a second small tape recorder and a decoding circuit. The tape is played back 15 times faster than the recording speed. Synchronization and bits identification are based on counting the (original) 250 Hz chopping signal. This eliminates the problem due to wow flutter and non constancy of tape speeds. The serial BCD code is converted to a parallel code to facilitate printing or tape-to-tape transfer, for computer compatibility.

The use of non-expensive tape decks as well as integrated circuit modules reduces markedly the price of the system without compromising on accuracy or reliability.

Introduction Most present day oceanographic chemical and ecological analyses are performed in vitro after sampling the ocean. However, it may be speculated safely that this classical method will gradually give way to in situ methods by which the required parameters will be measured by a remote probe so that only the information will be handled. A research program has been initiated, therefore, at UCLA, Department of Geology, to study and develop new oceanographic in situ chemical sensors as well as the required telemetering systems.

The first sensor to be developed was a high pressure pH electrode (1) which is now being operated with a specially designed telemetering unit (2). The unit can accept up to ten different sensors and employs analog to frequency conversion and time multiplexing to transmit the information to the water surface via a two conductor cable. The same cable carried also an “advance” command from the surface to the probe which steps the multiplexer one step forward. This type of operation is suitable for shallow water work, but becomes cumbersome for deep sea research due to the required long electrical cable which has to be specially installed on board ship. Also, long electrical cables are highly vulnerable and have relatively short lives. It was felt, therefore, that deep sea studies require in situ recording which will eliminate the long electrical cable.

It has been emphasized many times in the past, that oceanographic instrumentation should be as simple and as inexpensive as possible. The vulnerability of oceanographic work excludes, practically, the use of very sophisticated and hence expensive instrumentation. This is particularly true for scientific projects which operate on limited budgets. Our research and design were aimed, therefore, at developing a system that is compatible with the above requirement but accurate and reliable enough for high precision studies. This goal was achieved, in the case of the recording unit, by using a single channel entertainment-type magnetic tape recorder, which records the information digitally.

In this paper I shall describe the design of the recording and read-out units. First, a general description of the system will be given, followed by a somewhat more detailed discussion on some key points, especially those pertinent to the successful use of an entertainment-type tape recorder.

General Description Figure 1 is a simplified block diagram of the recording unit. The frequency of the input signal is measured and converted to a BCD number which is recorded serially on the single channel magnetic tape recorder. The miniature magnetic recorder (TELMAR 100T, distributed by MARTEL, Los Angeles, California) is 19.5 x 8.5 x 5 cm and has a capstan-drive mechanism which is governed by a feedback speed control. The actual speed is measured by a tiny tachometer and compared to the desired value, and the error signal is fed to a motor-driver amplifier.

The tape recorder was slightly modified in three respects: we have bypassed the amplifying circuitry by feeding our signal directly to the magnetic head, a tape-spool securing lock was incorporated to hold the spools firmly and thirdly, the tape speed was slowed down. The latter was achieved by adding an extra resistor to the speed control circuit. The speed was reduced from 15/16 ips to 0.125 ips resulting in four hours of continuous recording (one side) for a 1-3/4" spool loaded with a 0. 8 mil tape. At this low speed, the magnetic head is capable of recording directly (no bias) the frequency band 200-300 Hz. All our data are, therefore, modulated with a 250 Hz signal before being fed to the magnetic head. The unit also provides at regular intervals an “advance” command which is fed to the interconnecting cable to advance the multiplexer in the probe.

The recording unit is built into a 10.2 cm ID x 53 cm L stainless steel high pressure housing (EG & G type 270) which is rated to 10,000 psi. Figure 2 is a photograph of the disassembled recording unit. The unit is built in three sections: the lower electronics compartment, the tape recorder and the battery pack. The electronics section is protected by a plastic shield to prevent damage when handling the unit. Two high pressure electrical connectors, at the upper cap of the unit, provide the required electrical connection.

The recording unit was designed to operate continuously during an ocean log. It is mounted on a standard hydrographic cable adjacent to the chemical probe and connected to it by a two conductor cable through oceanographic connectors. The maximum recording time (four hours) is sufficient for a complete logging of any depth in the ocean.

The read-out assembly - which is to be located on board ship or on shore - includes another entertainment-type tape recorder (CRAIG 212, distributed by CRAIG PANORAMA, INC., Los Angeles, California), an electronic read-out processor and a suitable output device. Figure 3 is a simplified diagram of the read-out assembly when connected to a digital printer. It is planned, however, to record the output of the read-out unit on a computer compatible tape format. This secondary tape will then be sent to a computer facility for data reduction and evaluation.

The tape is played back at a speed of 1-7/8 ips, namely 15 times faster than the recording speed. The read-out unit converts the serial BCD to a parallel BCD number and generates a “print” command whenever the complete BCD number is ready to be transferred to the recorder.

Most of the circuitry of both the recording and read-out units was realized by IC digital TTL logic. Some of the gates and amplifiers” however, were built from discrete components. The choice of TTL logic was dictated by the fact that complex IC units (such as decade counters and shift registers) are mainly available in this logic. Discrete components were, therefore, incorporated whenever practical, to reduce the total power consumption as the TTL logic has a relatively large power drain (approximately 40 mw. per gate). This consideration is clearly highly important for the recording unit, which has to include its own battery source.

Recording Unit A somewhat more detailed block diagram of the recording unit is depicted in figure 4. All the timing signals as well as the 250 Hz modulating signals are derived from a 100 KHz master oscillator. The oscillator’s frequency is divided by a series of decade counters (BCD) down to a frequency of 0.2 Hz. Various outputs of dividers are gated by the logic section which is producing the “advance” command, gating the signal frequency-counter, driving the parallel to series converter and controlling the “editor”.

A better insight to the inner organization of the unit may be gained by inspecting the detailed block diagram of figure 5 and the circuit of figure 6. It should be noted that the outputs of the oscillator's frequency dividers (DECA 1 to DECA 6) are being used as inputs to the various gates. For example, the output of DECA 5 is feeding a BCD-to-decimal decoder which is controlling, with B_6 and B_6, the parallel to series converter of figure 6. The 16 gates of this section are connected to the BCD outputs of the signal frequency-counter and are opened in sequence resulting in a serial 4 digits BCD code.

While the decade counters are IC complex TTL units (TI SN7490N), the NOR gates are built from discrete components resulting in 5 mw power consumption per gate. The recording unit is powered by a 4 cell rechargeable NiCd battery rated at 3.5 Amper-Hour. The total current consumption of the unit (electronics plus tape recorder) is approximately 350 ma. No voltage regulators are employed since the NiCd battery has a relatively constant voltage output (5.4v - 4.5v) which is within the specified limits of the logic circuitry.

An additional 22.5 volts small carbon-zinc battery is also incorporated to provide a high voltage (at least 18 volts) “advance” commands, as required by the probe.

Recording Format The recording unit was designed to operate continuously in five second cycles (refer to figure 7). Each cycle starts with a reset pulse which clears the signal frequency-counter. This is followed by a 1 second count of the input frequency during which (excluding the last 0.1 second), a sync pulse is recorded on the tape to identify the leading end of the frame. This sync signal is a continuous 250 Hz sine-wave which is formed by chopping a DC pulse with a 250 Hz square-wave and filtering the resultant to produce a relatively clean 250 Hz sine-wave. The last 0.1 second of the counting period is left blank on the tape after which the 16-bits are serially recorded. Each bit is recorded within 0.1 second of which the first part identifies the bit (zero or one) according to the length of the 250 Hz sine-wave signal. For a “one” bit, the 250 Hz signal lasts for 80% of the bit time but lasts only 20% of the time for a “zero” bit. The first string of the 16 bits is followed by a second (shorter) sync signal after which the name 16 bits are recorded again.

The length of the frame period (5 seconds) was dictated by the settling time of the probe. Immediately after the 1 second counting period an “advance” command is sent to the probe which advances the multiplexer one step ahead. The probe is then allowed 4 seconds to stabilize before its output frequency is counted. As 4 seconds are available for recording it was decided to record the information twice in order to increase the system's reliability. It should be emphasized that in case of ambiguity one will always be able to decide which of the two recordings is correct by comparing them to the adjacent recording of the same parameter.

All the logic operations which are required for producing the sync pulses, spaces and bits, are performed by the “editor” which is a discrete logic circuitry. These logic operations are summarized on the bottom of figure 7. Note that all the necessary inputs are derived from the oscillator’ s frequency divider or from the BCD to digital converter (Z_1 to Z_{10}) which is driven by one frequency divider decade (DECA 5).

Synchronization and Bit Identification The use of an entertainment-type tape recorder with its relatively poor performance dictated a careful design to ensure reliable read-out. The main problems that had to be overcome were inconstancy of the original tape speed, wow and flutter. Our approach was aimed, therefore, at developing a sync and bit identification method that will be practically independent of tape instantaneous speed and will allow a large tolerance to the average tape speed. Another restriction that had to be met, was the available recording frequency band which is only 100 Hz wide (200 Hz-300 Hz).

We have overcome these restrictions by basing the bits and sync identification on the number of cycles (the original 250 Hz modulating signals) which are contained in them. Originally, the sync, the “zero” bit and the “one” bit differ in length. The “zero” bit is 0.02 seconds long, the “one” bit is 0.08 seconds long and the sync is at least 0.3 seconds long. On the tape, however, these pulses are recorded as an interrupted 250 Hz sinewave signal and will contain, therefore, different numbers of cycles. The “zero” bit contains, 5 cycles, the “one” bit contains 20 cycles and the sync contains at least 75 cycles. Hence, one can identify the various pulses by counting the number of cycles within them. This method is completely independent of the recording or playback speeds as long as the read-out unit is capable of counting the (original) 250 Hz cycles,

Read-Out Unit The block diagram of the read-out unit is depicted in figure 8 and will be discussed in conjunction with the timing diagram of figure 9. The tape is played back on a CRAIG 212 magnetic tape recorder and its “monitor” output terminals (these terminals are merely disconnecting and replacing the speaker) are fed to the read-out unit. The signal is first conditioned by AMP I which is a combination of a threshold device, a hard amplifier and a limiter. The output of this circuit is a square-wave signal as shown in figure 9. This signal is fed to a rectifier circuit which is followed by a Schmitt trigger and a pulse amplifier (NOR 1). The output of the latter is a DC pulse which is high whenever the input signal is low and vice versa.

The purpose of the rectifier unit is to reduce the erroneous readings due to noise spikes. Since bit identification is based on counting and since the counting logic is relatively fast any noise spike might be counted and may result in an error. We have overcome this problem by introducing the rectifier circuit which includes an RC integrator. The Schmitt trigger will fire only if the input signal will persist a sufficient length of time which will be enough to raise the rectifier’s output above the firing level. Hence, a short spike or a number of short spikes would have no effect on the Schmitt trigger. The output of NOR 2, therefore, will be a squarewave which will be present only when a real input signal is received. Clearly, one or two cycles of the input signal are lost during the integration process which should be taken into account.

Each leading edge of NOR 1 output pulse clears the binary counter (BC) and the two flip-flops (FF). The trailing edge of NOR 1 is used as a clock pulse (CP) for the shift register.

The BC counts the incoming signal which is identified according to the number of the counted pulses. If this number is less than 16 the input is identified as a “zero” bit and if the number is between 16 and 64 it is identified as a “one” bit. In the latter case FF1 is switched and a “one” enters the shift register when the CP arrives. If the number of counts is larger than 64 a sync is identified, NOR 4 is locked to inhibit the CP from shifting the shift register and a print command is produced by AMP 5. The shift register is read out, therefore, whenever a sync pulse is identified since the shift register should contain, at that instance, the preceding 16 bits BCD number.

All the read-out circuitry is realized by TTL logic excluding the amplifiers and the rectifier circuits which are built from discrete components.

Performance The signal to noise ratio (S/N) at the output terminals of the play-bacTtape recorder is a function of the recording level, tape noise and noise figure of the play-back amplifier. By properly erasing the tape one can obtain a low background noise which is approximately 30 db below an average recording signal. This S/N is sufficient to overcome the problem of dropouts which may cause, otherwise, erroneous decoding. During read-out, the volume control of the play-back recorder is turned to its maximum position so that the output amplitude is high enough - even during a dropout - to trigger the read-out unit.

It was observed that sharp noise spikes may appear, superimposed on the signal, if heavy loads are switched in the vicinity of the play-back tape recorder. The decoding method, however, proved to be able to overcome these spikes.

The electronic circuitry of the recording unit was designed to operate in the expected temperature range of 0°C-35°C and neither the electronics nor the tape recorder showed any sign of performance deterioration when exposed to this temperature range. The average tape speed was found to change slightly (3%) over this temperature range, but this had no effect on the overall performance.

The system’s field performance is presently being evaluated by exposing it to actual ocean measurements.

Conclusion In this paper, we have attempted to describe the successful employment of an entertainment-type magnetic tape recorder for the application of digital recording. It was shown that a simple, inexpensive tape deck can be employed in conjunction with high reliability and accuracy data recording. Although our system was tailored to meet the particular application of oceanographic logging, it is clear that the basic method can be employed for similar applications in which the use of a non-precision tape deck is permissible.

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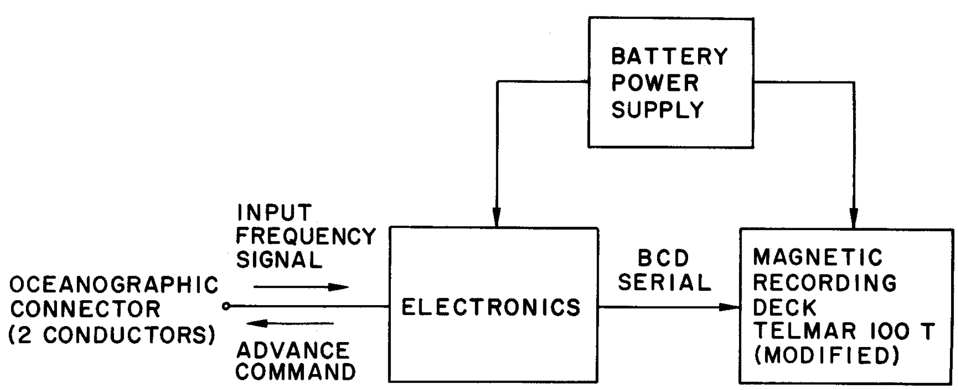


Fig. 1 - Simplified Block Diagram of the Recording Unit.

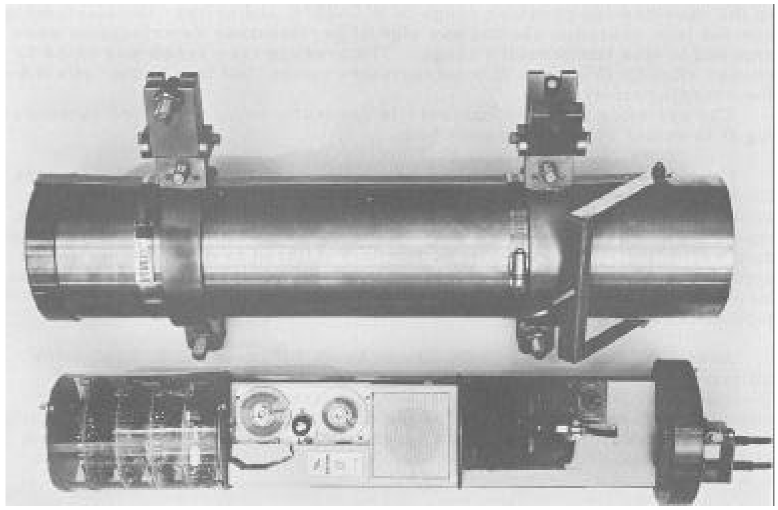


Fig. 2 - The Recording Unit.

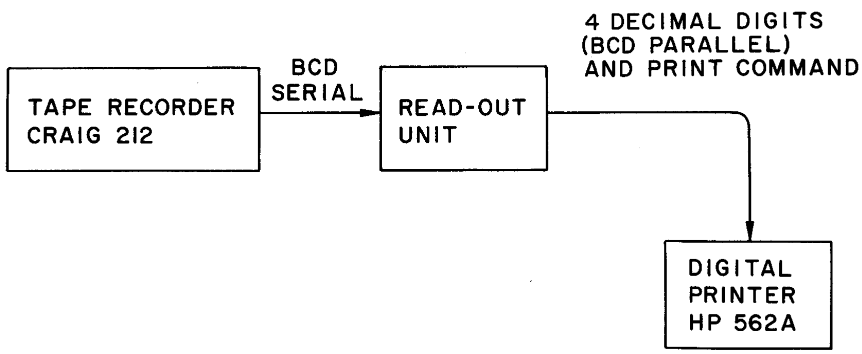


Fig. 3 - Simplified Block Diagram of the Read-Out Unit.

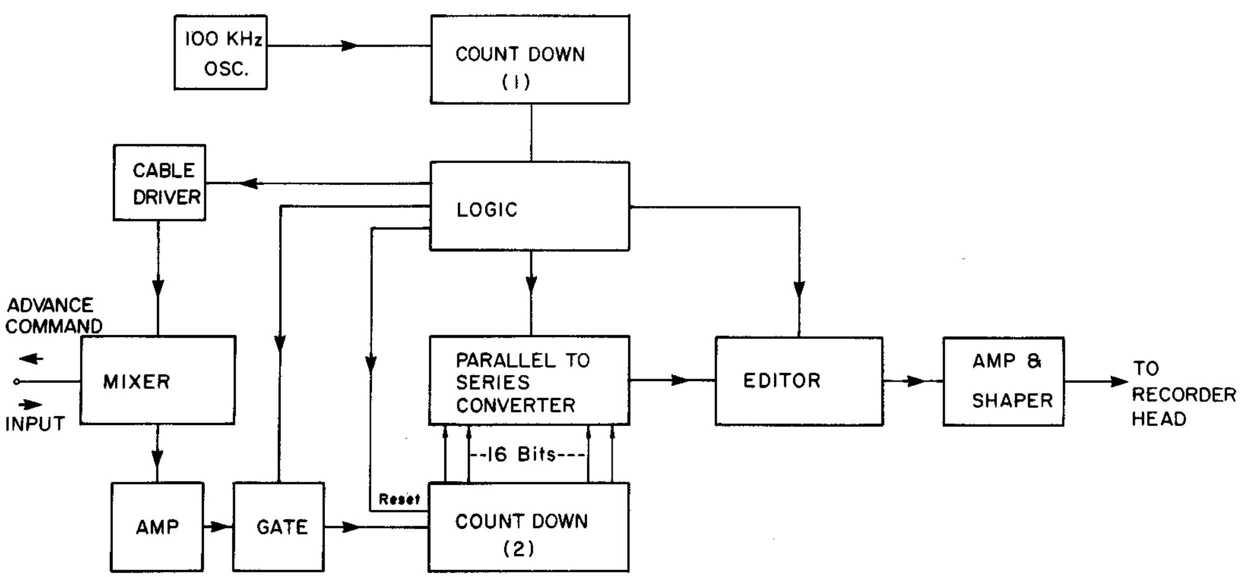


Fig. 4 - Block Diagram of the Recording Unit.

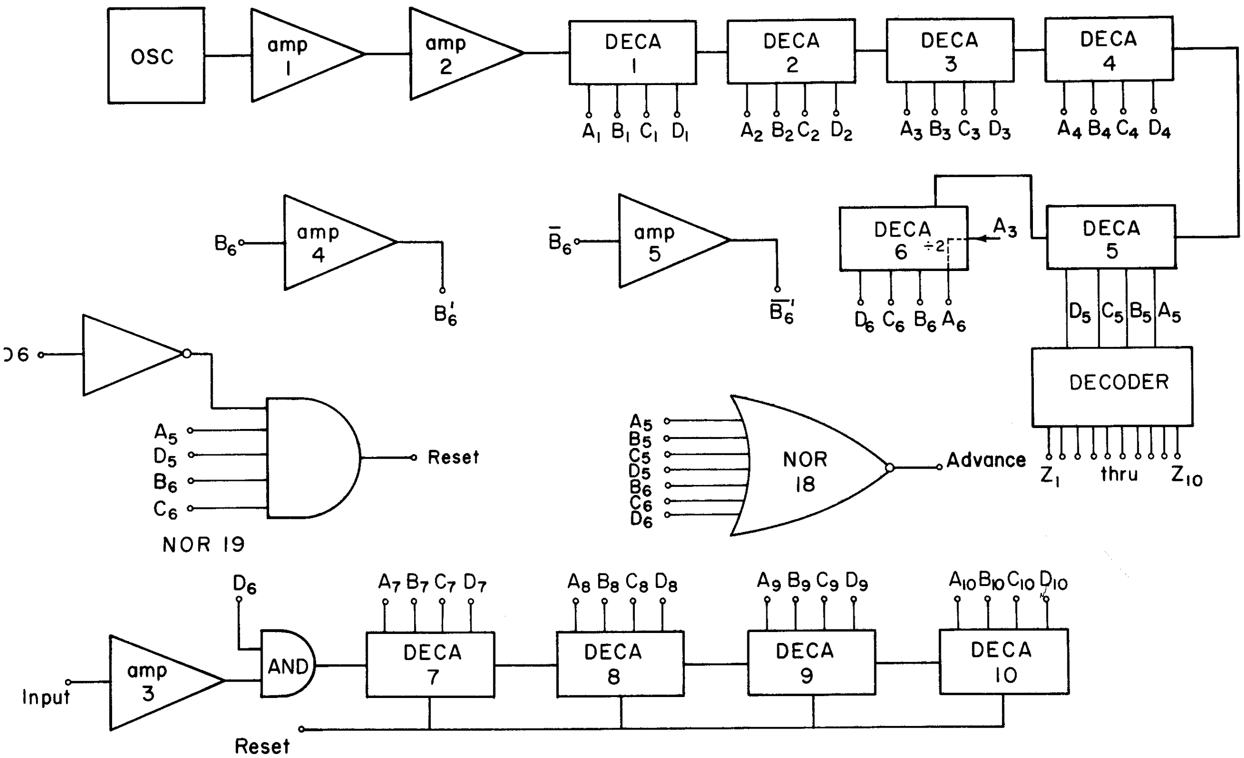
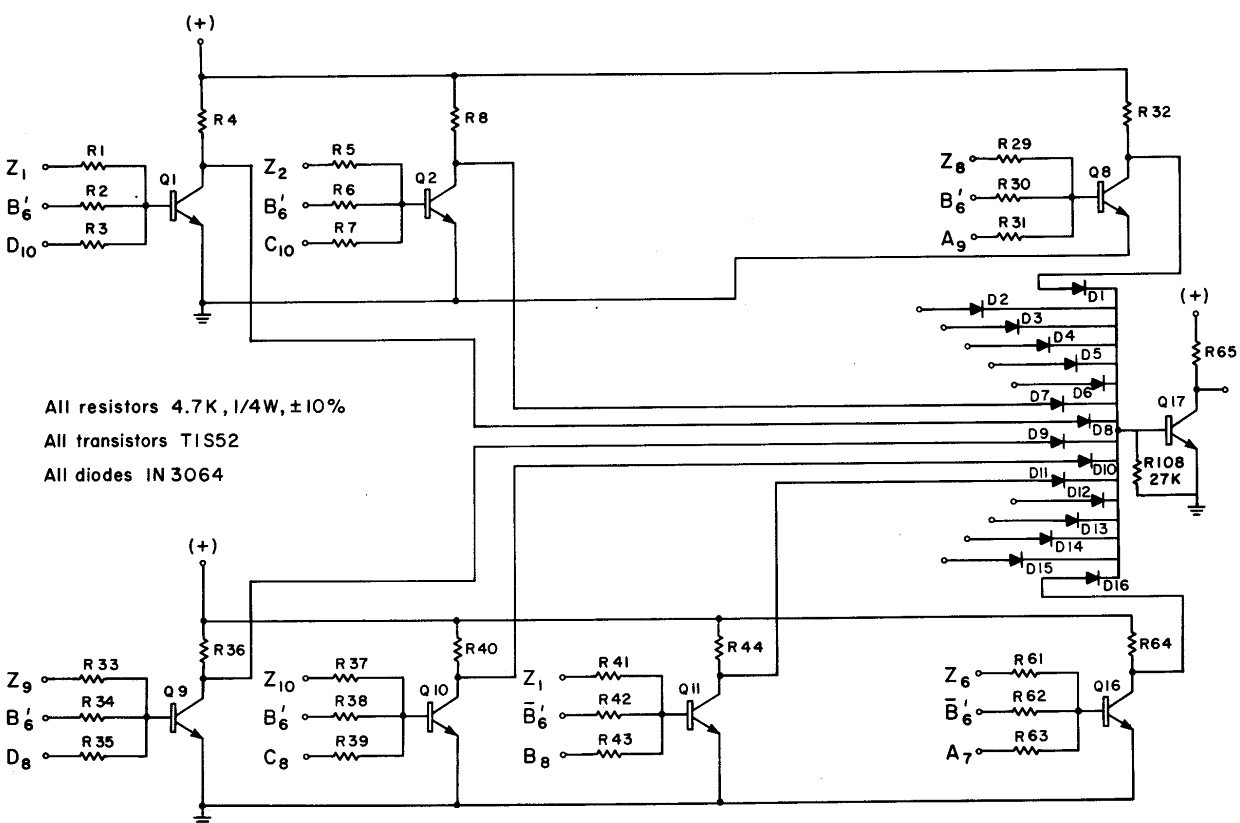
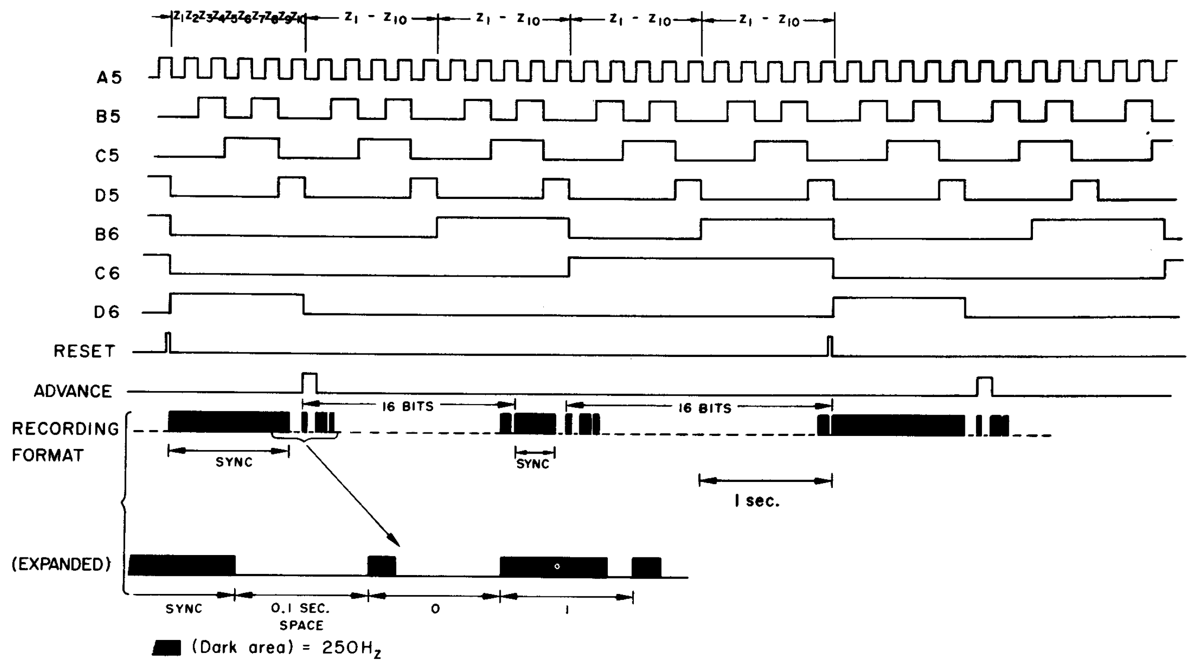


Fig. 5 - Frequency Dividers and Main Gates of the Recording Unit.



Fib. 6 - Parallel to Series Converter.



RESET:	$\overline{D6}\cdot C6\cdot B6\cdot D5\cdot A5\cdot C4$
ADVANCE:	$\overline{D6}\cdot\overline{C6}\cdot\overline{B6}\cdot\overline{D5}\cdot\overline{C5}\cdot\overline{C5}\cdot\overline{B5}\cdot\overline{A5}$
COUNT:	D6
SYNC:	$D6\cdot\overline{Z10} + Z7\cdot Z8\cdot Z9\cdot B6\cdot\overline{C6}$
SPACE:	$D6\cdot Z10 + Z10\cdot B6\cdot\overline{C6}$
BIT PULSE:	$\overline{D4}\cdot(\overline{B4}\cdot\overline{C4}\cdot\overline{M_n} + M_n)\cdot A6$

Fig. 7 - Timing Diagram of the Recording Unit.

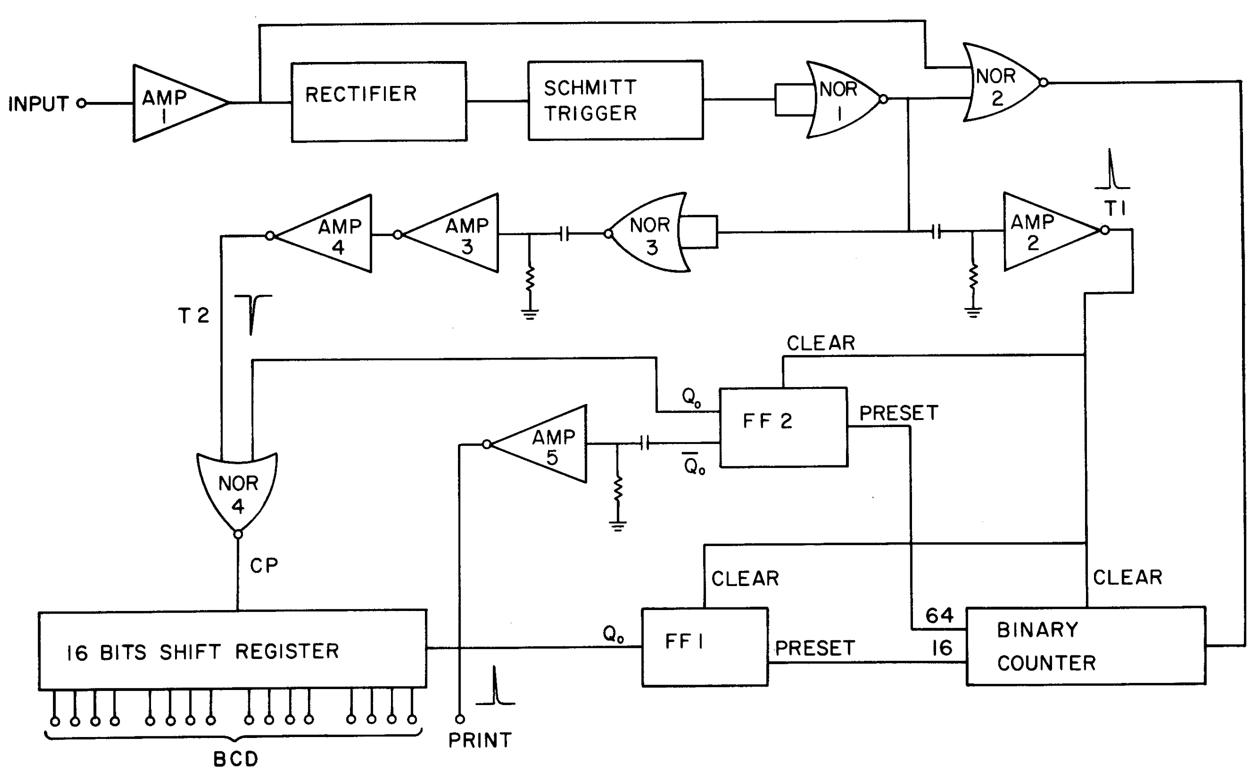


Fig . 8 - Block Diagram of the Read-Out Unit

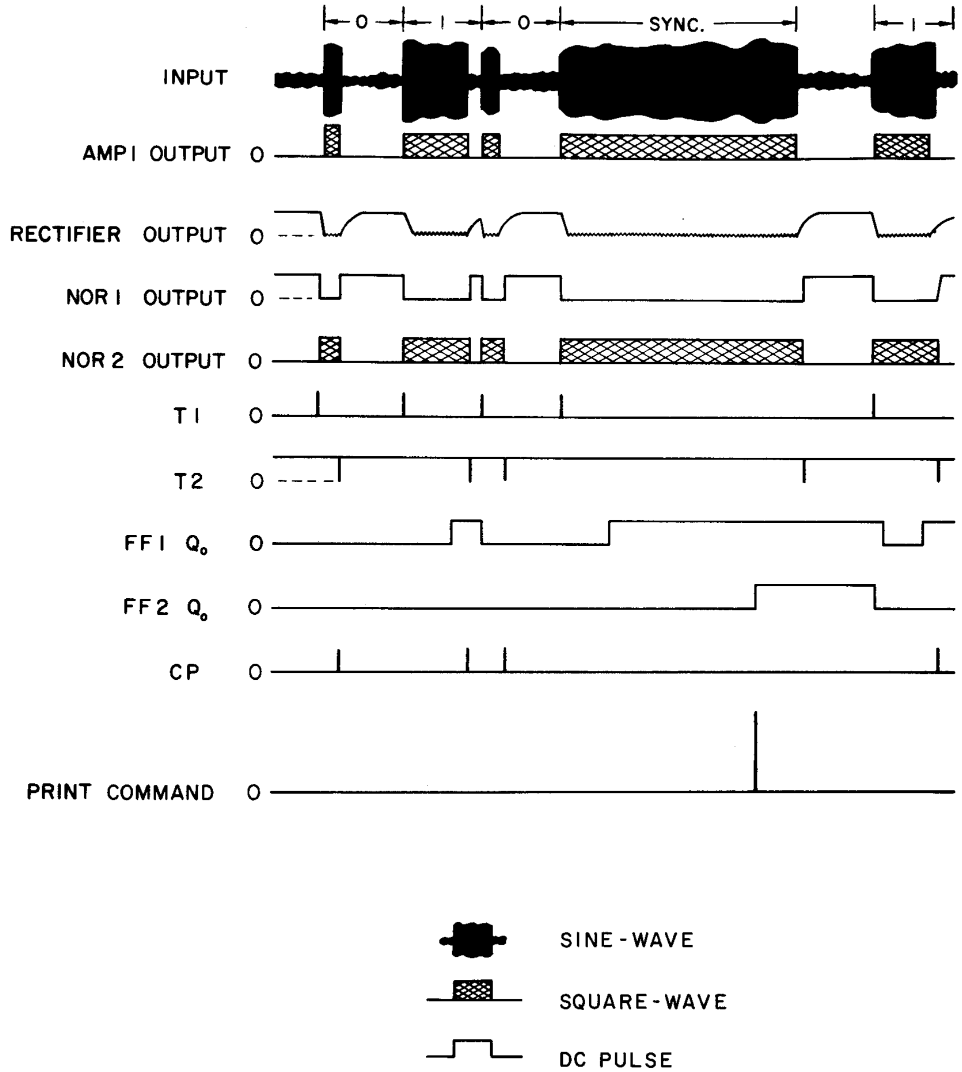


Fig. 9 - Timing Diagram of the Read-Out Unit.