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PCM TAPE RECORDING SYSTEM FOR SEISMOLOGICAL USE CONSTRUCTED OF C-MOS INTEGRATED CIRCUITS

by

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Abstract

A low-power 12-bit PCM (pulse code modulation) recording system has been developed. BCD (binary coded decimal) time and six information channels are recorded on one track of 1/4 inch magnetic tape. The input power of the recording unit is less than 1 Watt. The system was designed in 1974 for seismic field work and to gather information from several telerecording stations in digital form.

1. *Introduction*

Until recently, frequency modulation has been the usual technique when an analogue signal is to be recorded on magnetic tape. Now the pulse code modulation technique offers a new possibility for obtaining significantly higher accuracies and versatility. In addition, PCM data are readily amenable to processing with digital devices, especially digital computors.

Developed from C-MOS large-scale integrated (LSI) circuits, the system requires an input power of only 0.7 Watts which can be obtained from small batteries. The same system, if constructed from the commonly used TTL logic, would need an input of about 90 Watts.

The bit rate is 9.6 kbits/s at a sampling rate of 100 samples per channel per second. With a four-track tape recorder at a tape speed of 7 1/2 inch per second, the sampling rate can reach 400 samples per second; the bandwidth of each channel is then 120 Hz (–3 dB) and the bit rate 38.4 kbits/s.

2. *Description of the system*

Recording section

The input voltages of six analogue channels are amplified 2500 times and filtered through active low-pass 24 dB per octave filters (aliasing filters) (Fig. 1). The filters can easily be changed for different sampling rates. The frequency of the filters (–3 dB) is 0.3 x sampling rate.

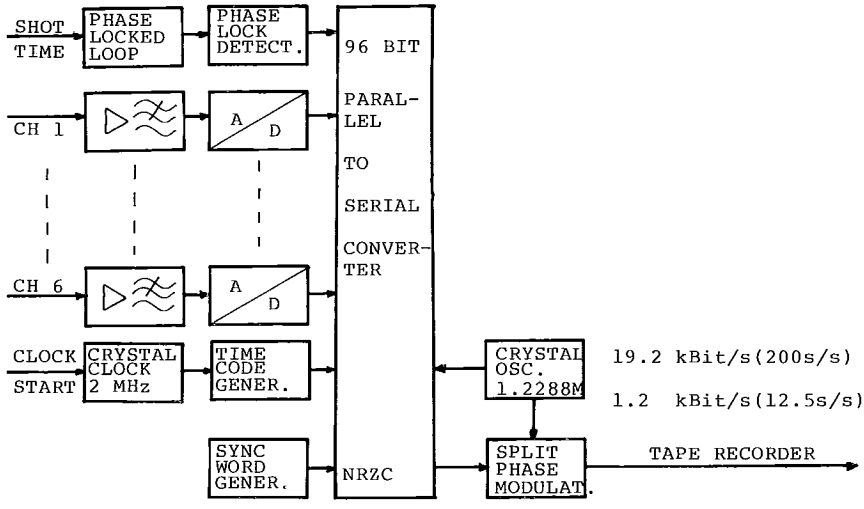

Fig. 1. 12-bit PCM recording section model SN-174.

The amplified and filtered voltage is then sampled and kept constant during the digitizing process. Each channel has an analogue-to-digital converter, because a counter ramp C-MOS converter needs about 2 ms to convert a 12-bit word, and to sample 400 times per second per channel with one converter demands a sampling time of less than 0.3 ms. Commercially made fast analogue-to-digital converters are not used for this purpose, as low-power 12-bit converters are much more expensive than six counter-ramp-converters.

Digitized words are read to the parallel memory with BCD time information, a shot time bit, a second pulse bit and a synchronous word (Fig. 2). The 96-bit word is converted into serial form and coded into a split-phase form for recording on magnetic tape (Fig. 3).

CHANNEL 1 12BIT+PARITY	CHANNEL 2 12BIT+PARITY	CHANNEL 3 12BIT+PARITY	BCD MIN.	SEC. PULSE	SYNC BIT
13 BIT +	13 BIT +	13 BIT +	7BIT +	1BIT +	1BIT

CHANNEL 4 12BIT+PARITY	CHANNEL 5 12BIT+PARITY	CHANNEL 6 12BIT+PARITY	BCD HOUR	SHOT TIME	SYNC BIT
13 BIT +	13 BIT +	13 BIT +	6BIT +	1BIT +	2BIT

Fig. 2. 96-bit (48 + 48) PCM data frame.

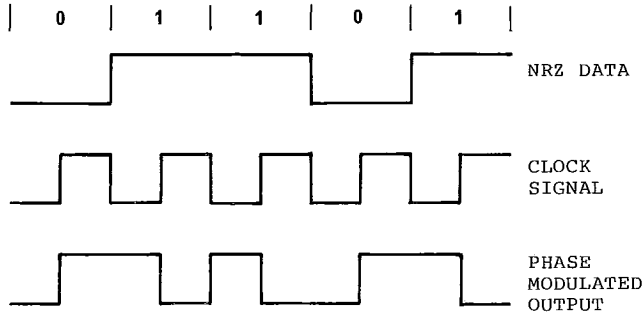

Fig. 3. Split-phase coding.

Reproducing section

The split-phase coded data is decoded and synchronized by a phase-locked loop (PLL) (Fig. 4). The decoded data are led to a serial-to-parallel converter with a synchronized clock. The parallel 96-bit word is at first analyzed all the time until the right parity bits and synchronizing word are found. The synchronized word is then read to a digital memory and converted to analogue form by a digital-to-analogue converter. BCD time information is decoded and led to a display unit. Next time the synchronous word and parity checks take place after a 96-bit interval. If the right synchronous word or parity bits are not found, everything starts again from the beginning and the incoming word is analyzed bit by bit until the system is again synchronized.

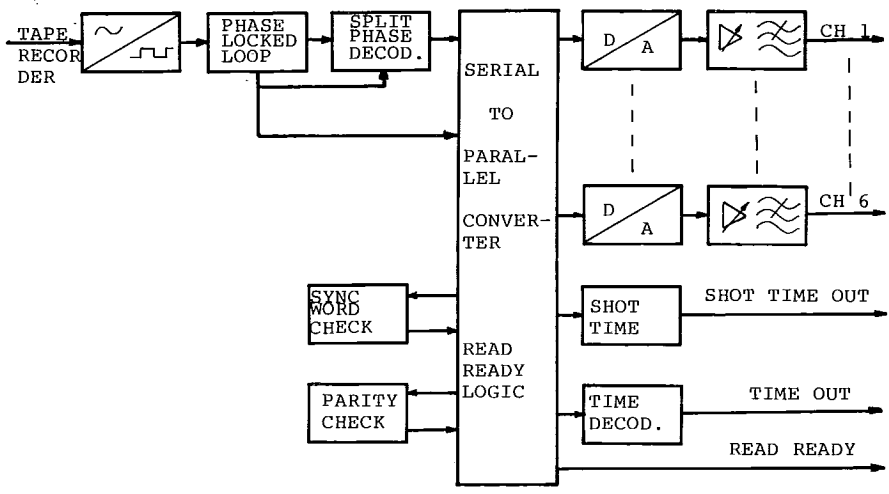

Fig. 4. 12-bit PCM decoding section model SN-274.

Crystal clock

The recording unit has an internal crystal-controlled clock. The crystal frequency is 2.097152 MHz and is accurate to within 10 ms per day. The time information is parallel BCD for hours, minutes and seconds. Negative pulses are for 24 hours, hours, minutes, seconds and 1/4 seconds. The clock can be synchronized by a radio time pulse.

As the time of day is coded on the magnetic tape it is easy to retrieve information.

3. *Discussion*

In the field it is only necessary to switch the power on, as the geophones and the tape recorder have been connected to the recording unit. The high dynamic range (72 dB) makes it unnecessary to adjust the input voltage levels.

To measure very strong motions every channel has a 60 dB attenuation switch. A digital detector gives a 3-second alarm if any of the channels exceeds the low or high-level limit (below 16 and over 4080).

Input voltage levels are from 1 μV to 4 mV and from 1 mV to 4 V. Instrumental noise voltage is 0.3 μV_{p-p} with the input resistance of 7 kΩ. The operating temperature ranges from -30 to $+80$°C. As the split-phase data are decoded by a phase-locked loop, it is possible to take data from the tape at any rate at which the tape

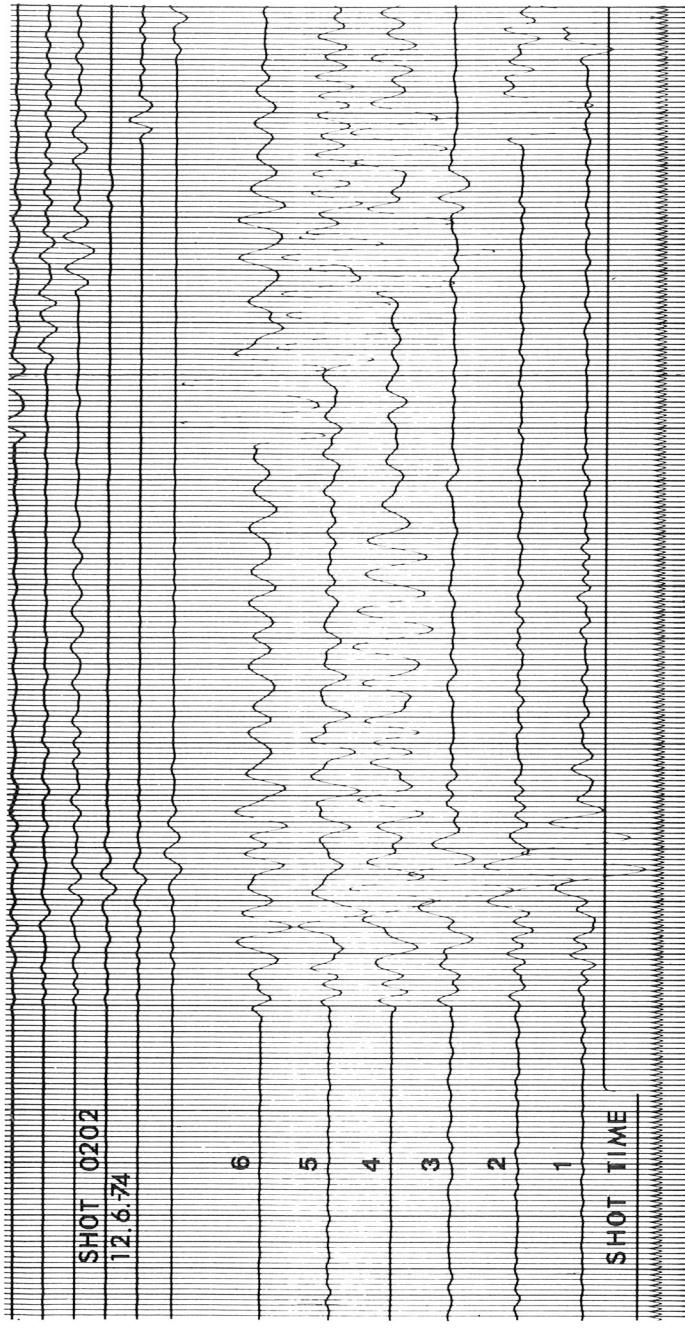

Fig. 5. An example of a seismic recording.

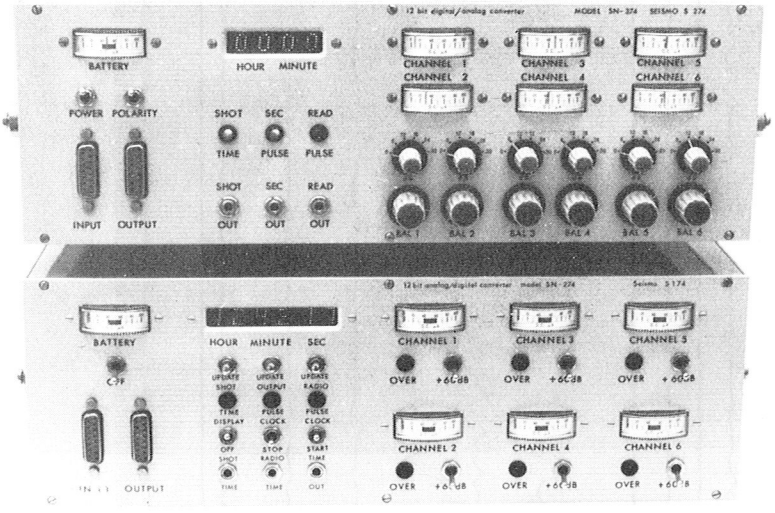

Fig. 6. 12-bit six-channel PCM recording and reproducing system model SN174/274.

recorder can operate. We have punched paper-tape for our computer terminal, increasing the access time 60 times. One second is then converted into one minute. Similarly, the events can be taken from the tape faster than they were recorded. For example, a 10-hour recording can be reproduced in less than an hour.

Acknowledgements: The writer wishes to thank Prof. E. VESANEN for encouragement and suggestions during the work, and others at the Institute of Seismology for many helpful discussions.