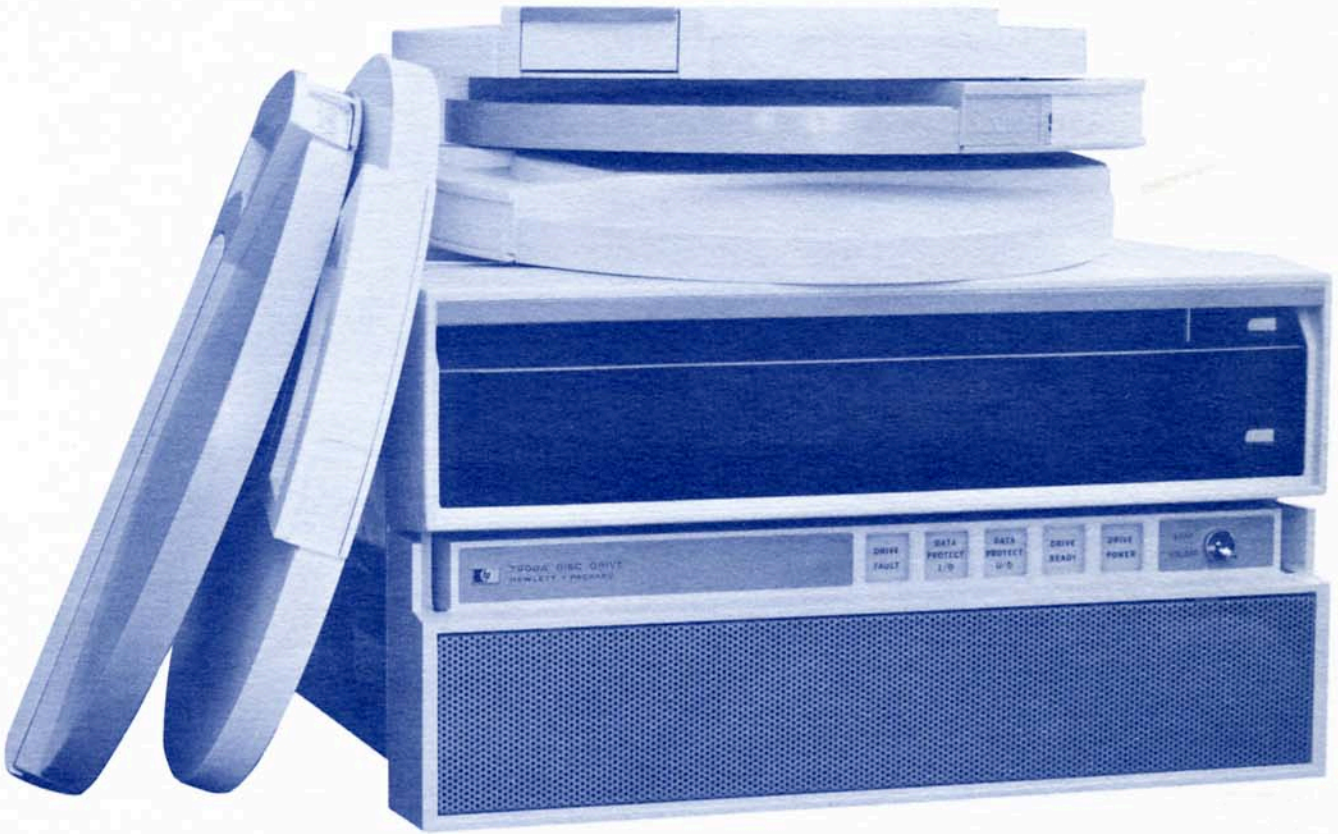
APPLICATION NOTE 167-8
DATA DOMAIN MEASUREMENT SERIES

Stable displays of disc system waveforms synchronized to record address.



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APPLICATION NOTE 167-7

STABLE DISPLAYS OF DISC SYSTEM WAVEFORMS SYNCHRONIZED TO RECORD ADDRESS

By Ralph Reiser

INTRODUCTION

A high-performance disc memory system is capable of storing millions of information bits on the surface of one of its platters. These information bits are written onto, or read from the platters by analog signals which are driving (or being driven by) read/write recording heads. Adjustment of these signals is extremely critical to accommodate interchangeability of platters, magnetic surface quality variation, head-to-track alignment, and other factors.

Examination of the parameters of these analog signals with an oscilloscope is frequently complicated by display jitter causing difficulty in interpreting the waveform. Display jitter is introduced when the oscilloscope trigger is not fully synchronous with data under investigation. This application note discusses how stable analog signals can be achieved and displayed easily and with full confidence when the oscilloscope is triggered from an HP Model 1620A Pattern Analyzer.

1620A PATTERN ANALYZER

The Pattern Analyzer generates a Pattern Trigger Output (PTO) pulse when it recognizes, in the data flow, the same serial data-bit that has been selected by the settings on its Trigger Word Switches (TWS). This trigger word can be recognized in a digital disc system operating at speeds up to 20 MHz. In addition, a digital delay feature can generate a digital Delayed Trigger Output (DTO). The DTO display may be delayed any number of clock pulses (up to 999 999) past trigger word recognition. As a result, two display trigger pulses occur with each pattern recognition enabling the operator to view activities associated with the selected PTO both at the time of recognition (PTO) and at some pre-determined time after pattern recognition (DTO).

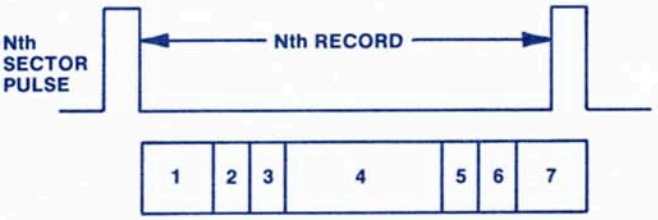
DISC SYSTEMS

Some disc systems are designed in such a way that data on the platter is synchronous with the index pulse or the sector pulse, or with both. Stable oscilloscope displays are relatively easy to obtain in these types of systems. Oscilloscopes with a delayed sweep, especially a digital delay, enhance the stable display capability when examining analog signals at the read/write head.

Other disc systems are designed so that data on the platter is not necessarily synchronous with index or sector pulses. Instead, data is phase-locked to the clock pulses in such a way that the analog waveform on the platter contains both clock and data information. This design method permits higher disc system performance characterized by increased density of data on the platter and a higher rate of data transfer. Higher rates of data transfer are made possible by faster clocking synchronous with data information.Systems of this type generate index pulses and sector pulses mechanically and usually cause unstable display of read/write head analog signals when used to trigger an oscilloscope.

THE HP 7900A DISC SYSTEM

The high performance 7900A is a moving head, phase-lock loop, two-platter disc system which operates at 2400 RPM. Each side of each platter (4 sides) has 200 +3 tracks with 24 sectors per track. Data in each sector is positioned and has a format as shown in figure 1.



1.	PREAMBLE	APPROX 192 ZEROS	PHASE-LOCK LOOP
2.	SYNC WORD	1 BIT PLUS 15 ZEROS	PHASE-LOCK LOOP
3.	ADDRESS WORD	16 BITS	CYLINDER, HEAD, RECORD ADDRESS
4.	DATA FIELD	2048 BITS	128 16-BIT WORDS
5.	CYCLIC CHECKWORD	16 BITS	
6.	POSTAMBLE	32 ZEROS	
7.	INTER-RECORD GAP	UNDETERMINED BIT LENGTH	

Figure 1. Sector Data Position and Format

Figure 2 illustrates the manner in which data pulses and clock pulses are combined for entry onto the data track with data bits inserted between clock pulses. Because the clock pulse rate is 2.5 MHz, a string of one's

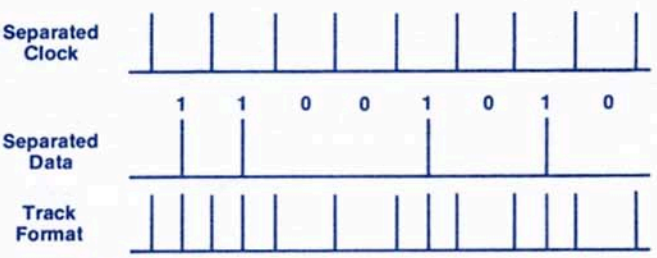


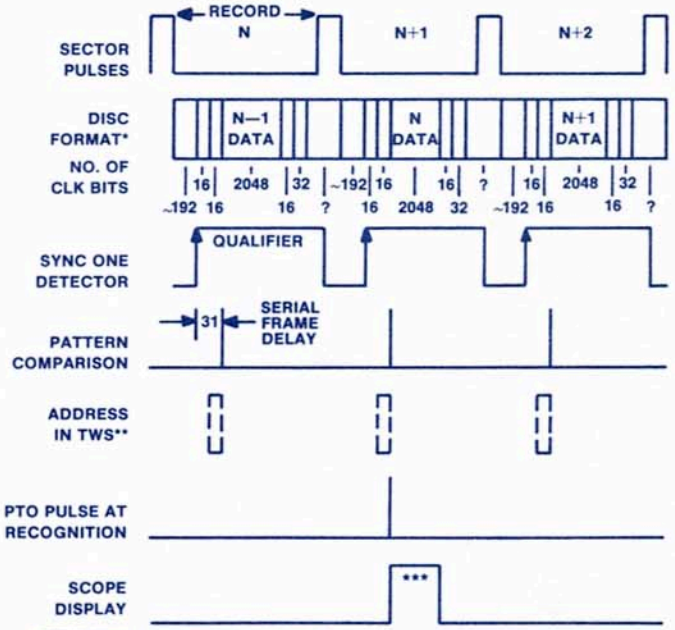
Figure 2. Track Format of Data and Clock Pulses

in the data stream present the equivalent of a 5 MHz pulse rate in the track format while a string of zero's in the data stream present the 2.5 MHz pulse rate in the track format. When reading the disc head information track, the read head, synchronized with the clock pulses, separates the clock pulses from the data bits. The write head, on the other hand, transfers clock and data pulses to the disc head in the track format. Figure 2 illustrates how the separated clock is combined with, or separated from, the data 11001010 into the track format.

SYNCHRONIZING TO DISC DATA

Clock pulses and data are synchronized within each loop only from the start of the sync word to the beginning of the inter-record gap as shown in figure 1. An oscilloscope trigger-point derived from a point outside this region will almost certainly result in a jittery display. Within this region however, is an address word containing cylinder, head, and sector coding. The address word defines a unique sector among some 19 000 sectors. Using qualifier, frame delay, digital delay, and pattern recognition features, the 1620A can be set up to recognize any desired unique address word within that sector. On recognition, the 1620A generates a reliable PTO pulse and displays a stable waveform on an oscilloscope. Figure 3 illustrates this concept.

Three adjacent and active records at the disc read head are shown in figure 3. Separated data (detailed in figure 2) is clocked continuously through the trigger word shift register in the pattern analyzer. Output of the "sync one" detector from the disc interface board goes high with the "1" bit in the sync word of each active record (see figure 1). The "sync one" signal remains high during the synchronized area of the record, then goes low during the inter-record gap. The sixteen-bit address word ends 32 clock pulses after the "sync one" signal goes high. Therefore, with the pattern analyzer serial frame delay set for 31, and



*SEE FIGURE 1 FOR RECORD FORMAT
**TWS MEANS TRIGGER WORD SWITCHES ON THE ANALYZER
***TIME DEPENDS ON SWEEP SPEED

Figure 3. Disc System Data and Control Signal Format and Pattern Analyzer Function Relationship

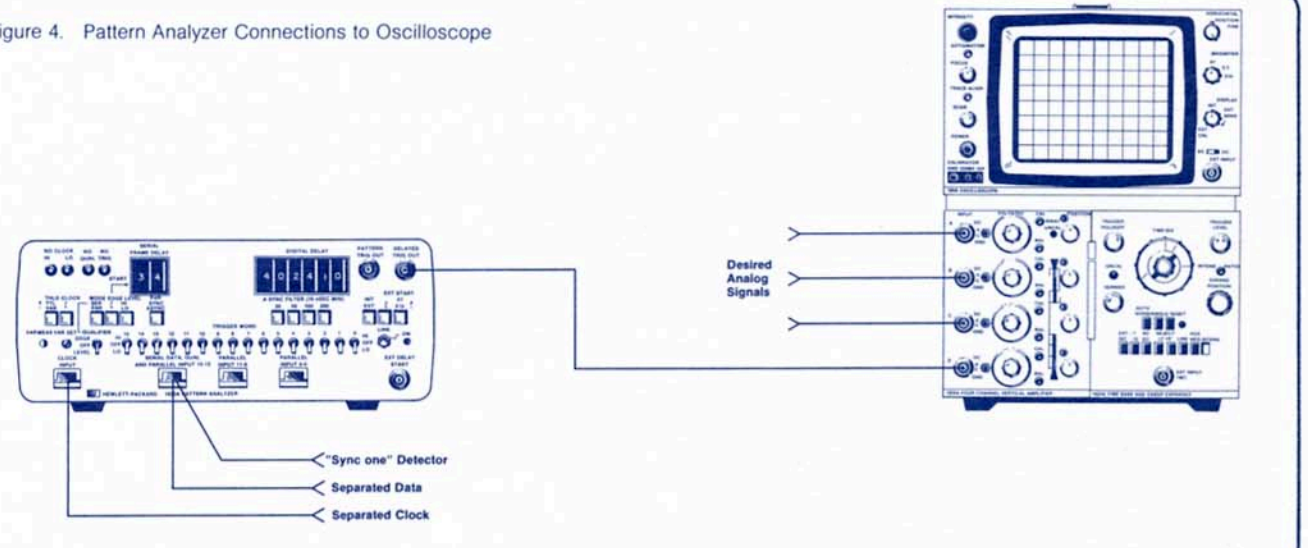
qualified from the positive edge of the "sync one" output, we are assured that address pattern recognition occurs only when the address in the TWS shift register matches the address pattern of the desired record.

SYNCHRONIZING THE SCOPE DISPLAY

Upon address pattern recognition, a PTO is generated for synchronizing an oscilloscope. Stable display of head analog signals, separated data, separated clock pulses, and other waveforms in the sector can be achieved using the DTO and appropriate digital delay.

Without changing any of the connections shown in figure 4, the operator is able to sync the oscilloscope display from any sector of the disc system memory simply by positioning the TWS to recognize and capture the address of the sector of interest.

Figure 4. Pattern Analyzer Connections to Oscilloscope



With monitor oscilloscope probes connected to appropriate locations on the system interface board, channels A, B, and C will display index, sector, and data waveforms respectively as shown in figure 5.

The monitor oscilloscope is synchronized on cylinder 50, head 1, and sector 4 with data being read from sectors 4 and 8, as determined by the unique address pattern format recognition.

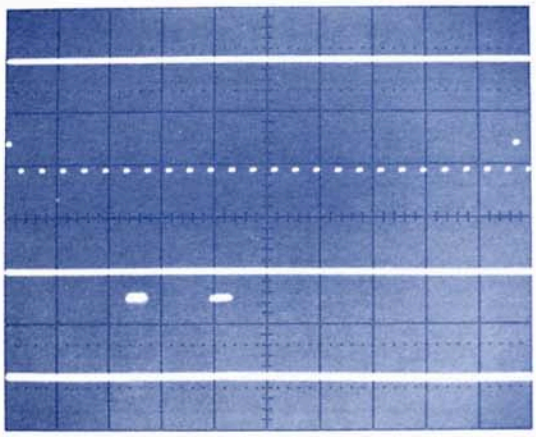


Figure 5. Oscilloscope Display of Index and Sector Pulses, with Two Active Records

TWS SETTING TO SECTOR ADDRESS

How is this unique pattern recognized by the Pattern Analyzer, and how do we know the address pattern to use for the sector of interest? Every disc system Handbook shows the address format for the sectors in a manner similar to figure 6. The HP 7900A system, for example, uses the address pattern shown in figure 6 to indicate cylinder 97, head 1, sector 5, unprotected. However, note that this format is generated serially starting with the least significant bit (LSB) of the

Bit No.	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Code	1	0	0	0	0	1	1	0	0	1	0	0	1	0	1	0
Address For:	lsb CYLINDER								lsb HEAD		lsb SECTOR					PRO-TECT

Figure 6. Address Coding for Locating a Desired Sector

cylinder coding and continuing for the next 15 address bits. Because the serial (address) word is shifted into the Pattern Analyzer TWS SR from its most significant bit, the Pattern Analyzer TWS must be set to reflect the mirror image of the address format, or:

0101001001100001.

To further confuse the issue, most disc systems (HP 7900A, for example) are so designed that when the sector pulse for sector (N+1) occurs, the data for sector (N) appears. Therefore, the oscilloscope display achieved through the settings in figure 6 would be of data written in sector 4 to be read by head 1 from cylinder 97.

READ HEAD ANALOG SIGNAL DISPLAY

A frequently-encountered problem that contributes to disc reading errors is analog signal quality from the READ head. Poor quality analog signals can be caused by head-to-track alignment, quality and uniformity of the magnetic oxide coating, and disc surface velocity. Figure 7A, B, C, and D show read-head analog signals from sectors 4 and 8 of cylinders 50 and 200 respectively. Note how the signals vary in amplitude

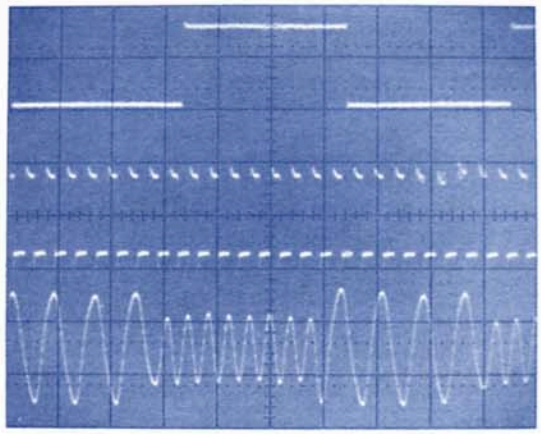


Figure 7A. Oscilloscope Display of Outer Disc Track Read Head Analog Signal with Strings of 1's and 0's

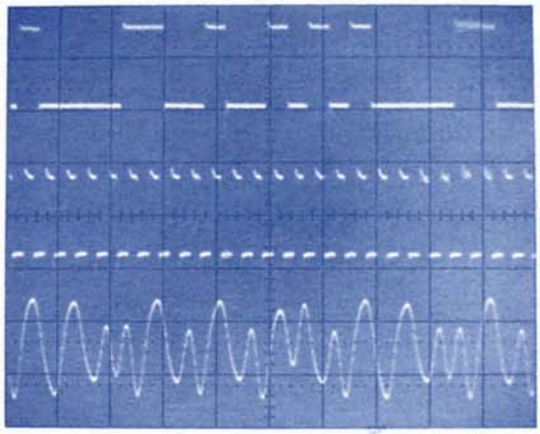


Figure 7B. Oscilloscope Display of Outer Disc Track Read Head Analog Signal with Mixture of 1's and 0's

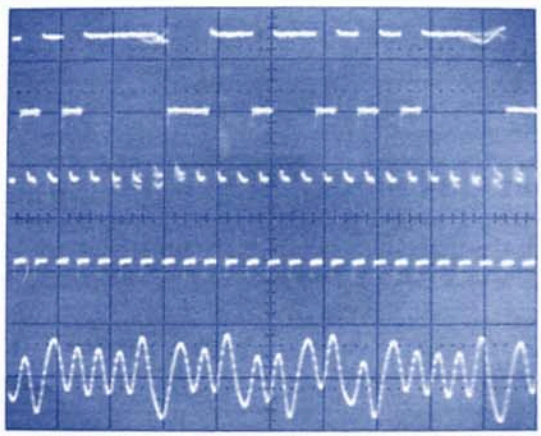


Figure 7C. Oscilloscope Display of Inner Disc Track Read Head Analog Signal with Mixed 1's and 0's

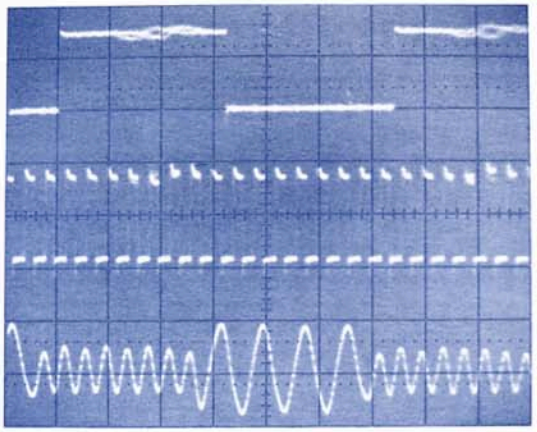


Figure 7D. Oscilloscope Display of Inner Disc Track Read Head Analog Signal with Strings of 1's and 0's

as the head moves from outside to inside tracks of a disc; the double frequency when the data is a string of zeros; and phase reversal when data is a mixture of ones and zeros.

Figure 8 illustrates timing relationships between four signals with oscilloscope time base set for a sweep speed of 0.5 μs/div. From bottom to top, these signals are: read head analog signal from test point 2 on the disc; output of read head decoder on the interface board

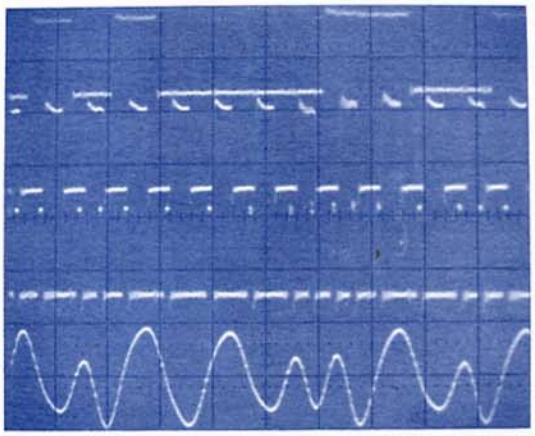


Figure 8. Timing Relationships of Analog and Digital Waveforms

converting analog signal to TTL compatible levels; separated clock data from the interface board; separated data from the interface board. Timing resolution may be increased by setting a higher sweep speed on the oscilloscope time base.

DISPLAYING CONTROL WAVEFORMS

Other points of interest are easily viewed using the digital delay feature of the Pattern Analyzer. Indexing the digital delay by incrementing appropriate thumbwheel switches enables the operator to clock-delay the display window while monitoring the read head analog signal for possible disc surface problems.

To display the end word pulse (refer to figure 3), simply set digital delay to 128 x 16 = 2048. To position the end word pulse near mid screen, as shown in figure 9, the digital delay was set to 2000. Notice, too, the stable display of the 16-bit check word that occurs after the end word pulse.

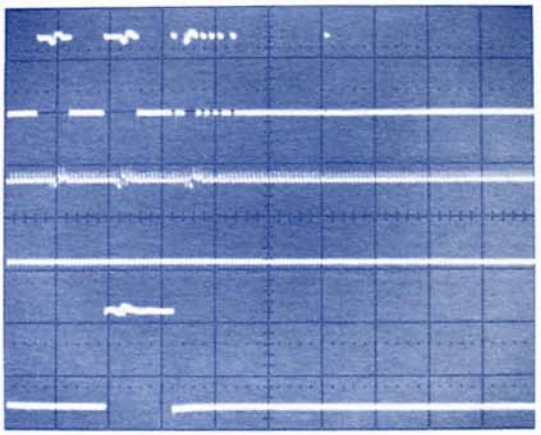


Figure 9. End Word Pulse Positioned at Mid Screen

Figure 10 shows the time interval from the end of data in one sector to the start of information in the next sector.

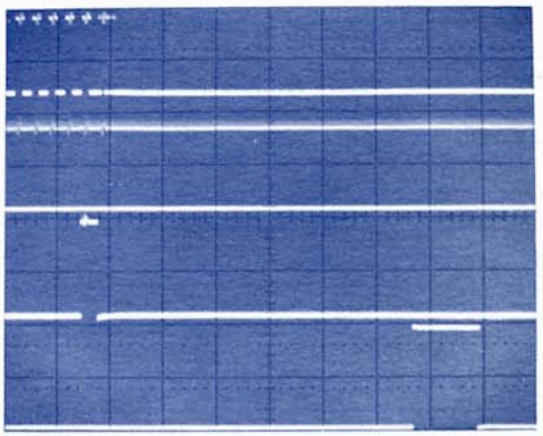


Figure 10. Time Interval from End Word to Start of Subsequent Sector

Digital delay range (999 999 clock pulses) enables the operator to sync reliably in one sector and view signals in subsequent sectors. Figure 11 illustrates

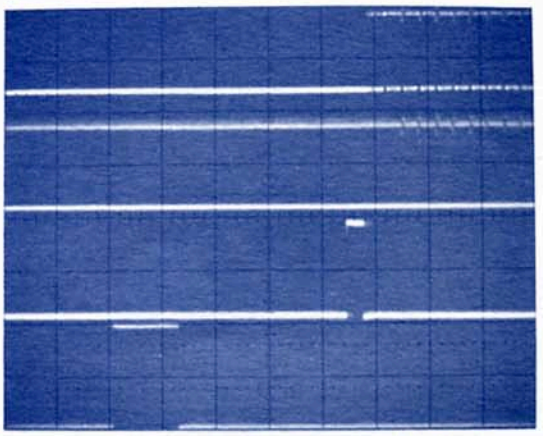


Figure 11. Sync Word Count Pulse and 16-Bit Address Word of Subsequent Sector

the sync word count (254) pulse and the 16-bit address word of a subsequent sector. Figure 12, on the other hand, shows the TTL compatible signal of a subsequent sector. Notice that the sync word is not present in the separated data of figure 12, but is clearly shown in the TTL compatible signal derived from the disc read head analog signal.

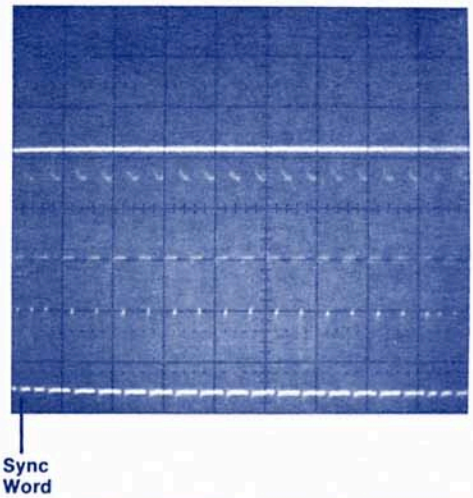


Figure 12. TTL Compatible Signal of Subsequent Sector

Figure 1 shows the sector sync word to be a byte of sixteen bits consisting of a logic 1 followed by fifteen logic 0's. Note that this logic 1 is positioned between two adjacent clock pulses in figure 12. This sync word logic 1 is located immediately to the right of the fourth vertical graticule line in figure 12. Also note that the fifteen logic 0 bits of the sync word are represented by the absence of logic 1's during the next 15 bit cells.

CONCLUSION

Using only one instrument set up (see figure 4), the operator needs only to set up the Pattern Analyzer TWS to the logic pattern of the desired address plus digital delay to the desired clock pulse to be able to generate a stable, reliable sync signal at a predetermined point of interest anywhere on the disc. Regardless of whether the computer is writing on (or reading from) the disc, or how many sectors are active, or in the presence of data rate fluctuations, the Pattern Analyzer will select that specific sector address from among more than 19 000 sector addresses. As soon as pattern recognition occurs, the Pattern Analyzer generates a reliable sync point to provide a stable display of one or more of the 48 x 10^6 bits in the Model 7900A system. All this selectivity in the Pattern Analyzer is designed so the operator can easily make functional and electrical measurements which determine disc waveform quality as a function of system performance.

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