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A Low-Cost Optical Data Acquisition System for Vibration Measurement

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SUMMARY

A low-cost optical data acquisition system was designed to measure deflection of vibrating rotor blade tips. The basic principle of the new design is to record raw data, which is a set of blade arrival times, in memory and to perform all processing by software following a run. This approach yields a simple and inexpensive system with the least possible hardware.

Functional elements of the system were breadboarded and operated satisfactorily during rotor simulations on the bench, and during a data collection run with a two-bladed rotor in the Lewis Research Center Spin Rig.

Software was written to demonstrate the sorting and processing of data stored in the system control computer, after retrieval from the data acquisition system. The demonstration produced an accurate graphical display of deflection versus time.

INTRODUCTION

An optical data acquisition system of the type described in reference 1 can simultaneously measure the vibration deflections of all the blades on a spinning rotor, and can provide a complete vibration record for each rotor blade. Unlike a strain gauge measurement system with its slip-ring capacity limitations, the optical system can measure the response at several positions of every blade on a multi-bladed rotor. The optical system measures vibration deflection directly, without the calibration problems inherent to a strain gauge measurement system. Signal processing and analysis is facilitated in the optical system because data is taken in digital form.

A major disadvantage of this optical system is that its relative complexity makes it costly and difficult to maintain or repair. The results of an in-house effort to simplify the system and produce a low-cost version are presented in this report. This effort was prompted by the need for additional optical data acquisition capability at the Lewis Research Center to cover independent operation of another Spin Rig (ref. 2), and an advanced version of a Rotating System Dynamics Rig.

REVIEW OF THE ORIGINAL SYSTEM

The original optical data acquisition system, as reported in reference 1, comprises a set of fixed optical probes which sense blade passage, a microcomputer system which receives and processes data from the probes, and a control computer which sorts the data into a usable form after each data collection run (fig. 1).

Three optical probes are located at each of every other viewing port of 32 ports that are equally spaced around the perimeter of the spin rig case (fig. 2). One probe monitors the position of the leading edge of the blade tip, another monitors the tip midchord, and the third monitors the blade tip trailing edge. In this manner bending, torsion, and camber vibration modes can be identified. A single additional probe senses the start of each revolution with the passage of a timing mark on the rotor shaft.

Each probe contains a high-resolution optical reflective sensor and associated support electronics (ref. 2). The sensor is a focused LED emitter and matched protodetector in a single package. A visible light beam emitted by the LED is focused at the blade tips. As a blade edge passes by the probe at high speed the event is detected, converted to a TTL compatible logic signal, and sent to the microcomputer system.

The microcomputer system contains data acquisition boards, one for each optical probe, which record the "time" that reflected signals from each blade are detected. Two high-speed frequency synthesizers included in the system serve as the system reference clocks during alternate revolutions of the rotor. Two are used since one does not program rapidly enough to maintain a constant number of clock pulses per revolution.

A counter associated with the synthesizers counts clock pulses during each revolution of the rotor, and is reset to zero at the start of each revolution to begin each measurement timing period. This count represents the time corresponding to any angular position of the rotor during each revolution, and the total number of counts per revolution can range from 6400 to 78 592, as chosen by the experimenter. This information is stored on each board in a 4 K x 8-bit memory.

At the start of a data collection run, the frequency of the synthesizers is initially set by software to give the clock counts per revolution necessary for the desired deflection resolution, and during the run is software compensated for any minor variations in rotor speed. The maximum allowable deflection (from either direction of center or zero) is related to deflection resolution by a factor of 128 because of the 8-bit memory word size.

To deal with missing and/or extraneous blade signals, a "time window" for data acceptance from each port is provided on the data acquisition boards. Only one blade pulse is accepted during each window sampling period. An artificial pulse is inserted if a blade signal is not present during the window time.

Blade arrival times are stored in memory on each board. During a data collection run, the blade arrival times obtained during a "normalization run" without excitation are subtracted from those measured with vibration applied. This removes the tares due to nonuniform spacing of ports or blades. This processing is controlled by a microprocessor on each board which converts the difference in blade arrival times to blade deflection. At the conclusion of a data collection run, all deflection data are transmitted to a Hewlett-Packard HP-1000 system control computer, which sorts and processes the data to give a complete (though discrete) vibration versus time history for each rotor blade.

OBJECTIVE AND CONCEPTS OF NEW DESIGN

The design objective was to simplify the original system without compromising those characteristics which are basic to the overall performance. Performance benchmarks of special concern (which are covered in more detail elsewhere in this report) were the maximum allowable deflection, deflection resolution, maximum (unaliased) frequency, and frequency resolution.

Several new design concepts result in a much simpler system and reduce its cost. The basic principle is to record the raw data, which is a set of blade arrival times, in memory and to perform all processing by software following a run. As with the original system, a "normalization run" without excitation precedes a data collection run with vibration applied; however, with the new system all processing of blade arrival times and the conversion to blade deflection is done by software, in the system control computer after completion of a run. This trades off hardware for software, reducing the complexity and cost of data acquisition boards. The frequency synthesizers are eliminated by "time stamping" the blade arrival times, measured from the start of a run rather than from the start of each revolution.

A decrease in the number of boards required further reduces cost and leads to a more reliable system because of a lower component count. The requirement for built-in self-test features for board diagnostics was waived (which will be seen to be reasonable because of the sharply reduced board complexity and component count), yielding additional simplification and component reduction. A system with fewer boards and lower component count is easier and cheaper to adapt to future improvements in integrated circuits.

A further significant cost reduction can be expected if the control computer is a personal computer instead of a minicomputer (Hewlett-Packard HP-1000). However, this concept was not implemented before this report was completed.

DESIGN OF THE NEW SYSTEM

Data Acquisition Boards

A system with fewer data acquisition boards and fewer components can be designed if each board accepts data from more than one optical probe. This is possible because the pulses from any probe are relatively widely spaced in time, compared to the temporal variation of any pulse due to blade vibration. The signals from one or more other probes can be interspersed if a known ordering of the pulses is maintained. This approach does not reduce the total memory size but saves substantial duplication of other components, such a counters and latches. (It also eases the problem of clock counter wrap-around that is discussed later.) In the extreme case, all 16 probes monitoring a common blade tip region could be connected to a single board; however, it can be shown that for a 56-bladed rotor the maximum allowable blade deflection that would not cause scrambled signals would be only 35 mils. This could be an acceptable value for some rotors, but it does not compare favorably with the 102 mil swing allowable from the original system, for an identical deflection resolution of 0.8 mils. Reducing the probe inputs per board by a factor of two will increase the maximum allowable deflection by a factor of 2 to 70 mils. A board configuration having four optical probe inputs was chosen because it allows a maximum allowable deflection of 140 mils, which exceeds the performance of the original system in this area. A typical input circuit having this configuration is shown in figure 3.

One pair of probes (ports 0 and 2) is separated from the other pair (ports 4 and 6) by input gates G1 and G2. This allows optional delay to be added to signals from one probe pair. The signals from both probe pairs are combined at output gate G3, and appear at the output of this gate as a composite train of interspersed blade detection pulses. These pulses latch the count from a high-speed wrap-around clock counter, and initiate writing the count into the current address of memory (fig. 4). As a result, a time corresponding to each blade passage is stamped into memory.

Depending on the rotor configuration, delay may be required to separate probe signals which are coincident or overlap in time. For example, probe signals for a nonvibrating 56-bladed rotor are coincident at ports 0 and 4, as well as at ports 2 and 6 (fig. 5). The optimum delay shifts the signal from the probe at port 4 to a position midway between signals from ports 0 and 2, thereby maximizing the allowable blade deflection, as shown in figure 5. This also positions the signal from the probe at port 6 to midway between between probe signals from ports 2 and 0. No delay is required for rotor configurations where time coincidence or overlap is not a problem, as shown in figure 6 for the nonvibrating 2-bladed rotor case, for two possible ways of connecting probes to boards.

The optimum delay for a data board with four optical probe inputs from consecutive even numbered ports can be shown to be

$$t = \frac{15}{sn} \qquad (1)$$

where

t optimum delay time in seconds
s rotor speed in rpm
n number of rotor blades.

Delay can be optimized, prior to each series of data collection runs, by setting switch-selectable comparator lines in the delay circuit to give the required number of clock counts. The clock count required is given by

$$\text{clock count} = tf \qquad (2)$$

where

t optimum delay time in seconds
f clock frequency in hertz.

Because four optical probes share a single memory, the memory address size on each board must be increased from 4 to 16 K to obtain the same number of data points per probe as in the original system. However, the total memory address size of the system remains unchanged.

A penalty paid for the simplicity of the new system is that the size of a memory word must increase. The 8-bit memory word size of the original system is not adequate where a high-speed wrap-around clock counter is used to measure time. Though counter wrap-around can be handled by software, the counter must not wrap-around before the next blade arrives to obtain meaningful, nonscrambled timing records. A 16-bit word size satisfies this racing limitation, with clock speeds as high as 20 MHz, for the worst case condition of a two-bladed rotor operating at 3000 rpm. This conclusion is derived from the following time relationships, which are based on the connection scheme given in table I:

$$t_b = F \times \frac{60}{s} = \frac{1}{8} \times \frac{60}{s} = \frac{7.5}{s} \tag{3}$$

where

t_b time in seconds between blade signals arriving at a board, for a two-bladed rotor
F fraction of a revolution between adjacent viewing ports connected to a board
s rotor speed in rpm.

$$T = \frac{2^n}{f} \tag{4}$$

where

T time in seconds before a counter wrap-around
n number of bits in a memory word
F clock frequency in hertz.

$$\frac{T}{t_b} = \frac{2^n s}{7.5f} = 1.31$$

for $n = 16$, $s = 3000$ rpm, $f = 20$ MHz.

Additional measures were taken to further simplify the design of the data acquisition boards and reduce the component count. The hardware "time window" used in the original system to correct for missing and/or extraneous blade signals was eliminated, since it can be replaced by an equivalent software-generated window. A software window also has the advantage of greater flexibility if future modifications are required. Since the new board design significantly reduces the number of components used and their complexity (as shown later in this report), improved reliability as well as easier maintenance and trouble-shooting can be expected. Therefore the requirement for on-board diagnostics was waived, though this capability was deemed essential in the original system.

Control Board

The master clock and wrap-around clock counter are located on a separate control board which also has control circuits for interfacing with an external computer (fig. 7). During the acquisition, storage, and retrieval phases of a data collection run the control circuits enable or disable control lines to the data acquisition boards as called upon by software. A section of the control board (1/Rev Data Section) records the time when each rotor revolution begins, as monitored by a separate optical probe. This information is used in the measurement of rotor speed. Except for clock frequency and memory address size, the 1/Rev Data Section of the control board is similar in design to a typical data acquisition board.

Wrap-around of the clock counter can be taken into account by software, but it must not occur in less than one revolution to obtain useful timing records. A clock frequency of 1.25 MHz overcomes this limitation at rotor speeds as low as 1500 rpm, and is readily available by using the 16 most significant bits from the 20-bit clock counter. The following time relationships support this conclusion:

$$t_r = \frac{60}{s} \tag{6}$$

where

t_r time in seconds for a rotor revolution
s rotor speed in rpm.

$$\frac{T}{t_r} = \frac{2^n s}{60f} = 1.31 \tag{7}$$

for $n = 16$, $s = 1500$ rpm, $f = 1.25$ MHz.

A 2 K address size was chosen so that the memory fill time for the control board would be the same as for the data acquisition boards when operating with a two-bladed rotor. For other rotor configurations, the 16 K data board memories fill before the control board memory and terminate the data collection run. The time to fill the 2 or 16 K memory is defined by

$$t = \frac{60M}{sN}$$

where

t time in seconds to fill memory
M memory address size
s rotor speed in rpm
N data points per revolution.

COMPARISON OF NEW SYSTEM WITH ORIGINAL SYSTEM

The deflection resolution and maximum allowable deflection of the new system are compared in table II with values given by the original system, for a test rotor diameter of 20 in. A clock frequency of 20 MHz is required to give the same resolution at 15 000 rpm as given by the original system. At high speed (15 000 rpm) the new system allows a greater blade tip deflection for the same spatial resolution. At low speed, the resolution of the new system is better (e.g., by a factor of 5 at 3000 rpm) because the clock always runs at full speed. (The clock speed in the original system is proportional to rotor speed to keep a constant number of clock counts per revolution.) The allowable blade tip deflection for the new system increases as the number of blades decreases, unlike the case with the original system where it is independent of rotor blade configuration. For the two systems, resolution and maximum allowable deflection are given as follows:

Original System

$$\text{Res} = \frac{\pi d}{c} \tag{9}$$

where

Res	deflection resolution in inches
d	rotor diameter in inches
c	clock count per revolution.

$$\text{MAD} = \frac{128\pi d}{c} = 128 \times \text{Res} \tag{10}$$

where

MAD	maximum allowable deflection in inches
d	rotor diameter in inches
c	clock count per revolution

New System

$$\text{Res} = \frac{\pi d s}{60f} \tag{11}$$

where

Res	deflection resolution in inches
d	rotor diameter in inches
s	rotor speed in rpm
f	clock frequency in hertz.

If only one port is connected to a board, the maximum allowable deflection (before scrambled signals occur) is half the circumferential spacing between blade tips. With all four ports connected, and chosen so that the signal train is evenly interspersed (under idealized nonvibrating conditions), the allowable deflection is reduced by a factor of four in all cases except for 32- and 64-bladed rotors. In this case, the allowable deflection is reduced by a factor of 2. These relationships are summarized as follows:

$$\text{MAD}\left(\frac{t_s}{2}\right) \times \frac{1}{2} = \frac{\pi d}{4n} \quad \text{(for 32 or 64 blades)} \tag{12}$$

where

MAD	maximum allowable deflection in inches
t_s	circumferential blade tip spacing in inches
d	rotor diameter in inches
n	number of rotor blades

$$\mathrm{MAD} = \left(\frac{t_s}{2}\right) \times \frac{1}{4} = \frac{\pi d}{8n} \quad \text{(for all other rotors)} \qquad (13)$$

Additional system characteristics are compared in table III. The new system is equivalent in all areas while having the advantage of reducing, by a factor of 4, the number of data acquisition boards required to monitor a common blade tip region (leading edge, midchord, or trailing edge). Hardware requirements listed in table IV are sharply reduced in the new system. Note the complete absence in the new system of the more complex chip types, such as microprocessors and fifo, eprom, and dram memories. Note that the bulk of the data in the original system is stored in dram, whereas this is done in sram in the new system. The reduced component count should give higher reliability and substantially lower power requirements. Costly frequency synthesizers are not required in the new system because of the use of "time stamping" with a wraparound counter. Midchord probes and their associated data acquisition boards are not included in either system for this comparison. The 56- and 2-bladed rotors that have been tested show limited camber mode activity due to blade stiffness, making midchord probes of limited use.

A disadvantage of the new system, and a minor inconvenience if the rotor configuration is changed frequently, is that the rotor configuration determines the manner in which the data acquisition boards are connected to their respective viewing ports. This is illustrated in table I for a set of four data acquisition boards numbered 1 to 4. Six possible connection schemes are listed for rotor configurations of from 2 to 64 blades. Board-to-port connections are arranged to give the best maximum deflection value for each case.

Except for rotor case 6, optical probes from four ports are connected to each board. For rotor case 6, signal separation becomes a problem since the probe signals from a 32- or 64-bladed rotor are time coincident at all 32 ports; however, if only two probes are connected to each board, and one signal is delayed with respect to the other by use of the on-board delay, they can be separated (with a 2:1 reduction in maximum frequency). Doubling the number of data boards would restore the maximum frequency and the system would still be a fraction of the size of the original system. This doubling was not considered warranted, however, for the limited application to 32- or 64-bladed rotors.

SYSTEM TESTS

The simplified optical data acquisition system was breadboarded to evaluate the new design and demonstrate satisfactory data capture, storage, and retrieval. The breadboard contained control board electronics and circuitry for a single data acquisition board. Bench tests were conducted for simulated rotor blade configuration and rotor speed conditions. Inputs from the four optical probes were simulated by pulse generators, and a logic pattern generator was used to manually control command lines which are normally controlled by the HP-1000 computer.

After completion of a simulated data collection run, the logic pattern generator was used to manually scan data stored in selected areas of both the data board and control board memories. For a given rotor blade configuration and rotor speed, the incremental clock count (difference in the clock count stored at adjacent memory locations) is predictable and repetitive if the system is operating satisfactorily. This increment is 357 counts on the data board and 5000 counts on the control board for a 56-bladed rotor at 15 000 rpm, and is 16 384 counts on both boards for a 2-bladed rotor at 4577 rpm. These counts were verified during breadboard tests.

The breadboard was then tested in the spin rig with a 2-bladed test rotor operating at 4577 rpm. No external excitation was applied to the rotor. Optical probes from four adjacent ports were connected to the data acquisition board. Again an increment of 16 384 counts was expected; however, minor variations in rotor speed, and imperfections in rotor geometry and positioning of the optical probes can influence this count. Their effects though small were observed in the test data, indicating that the system is responsive to these variations.

SOFTWARE PROGRAM

A software program was written in Fortran to sort and process the blade arrival times and rotor revolution timing information obtained during a data collection run. These records are converted by the software to blade deflections, rotor speed, and a graphical display of deflection versus time for each blade of a 2 to 64-bladed rotor. Acceptable limits for the blade arrival times are set by a software window which determines any missing and/or extraneous blade signals.

Because the system control computer was not linked to the new data acquisition system, test data from an actual data collection run was not available. Since the program assumes that test data from a run has already been transferred from the control board and data acquisition boards to the system control computer, and are ready for processing, simulated test data was used to demonstrate that the software program produces satisfactory blade vibration records. A subroutine was added to generate the required data table for this simulation. For a 2-bladed rotor with a sawtooth-like blade motion, an accurate graphical display of deflection versus time was produced for each blade.

CONCLUDING REMARKS

The new optical data acquisition system has met all specified design objectives. New concepts incorporated into its design have significantly reduced the hardware requirements for this type of measurement system, without compromising basic performance characteristics. Performance was improved for most operating conditions.

Most system modifications can be made in software. However, a change in test rotors may require a modification in the external input connections to the data acquisition boards, since rotor configuration determines the manner in which the boards are tied to their respective viewing ports.

Though tests were confined to a breadboard containing only basic functional elements of the new system, the principles of "time stamping" with a wrap-around counter and of interspersing data from several probes in a single memory were successfully demonstrated by these tests.

An operational software program was written which demonstrated that an amplitude versus time history for each rotor blade can be reconstructed by the control computer, after data retrieval at the end of a data collection run.

No provision was made, before this report was completed, for linking with the system control computer or for handshaking during the data retrieval phase, since this may be dependent upon the computer type chosen. If feasible, the use of a personal computer in this application can lead to a significant cost reduction.

REFERENCES

1. Lawrence, Charles, and Meyn, Erwin H.: The Use of an Optical Data Acquisition System for Bladed Disk Vibration Analysis. NASA TM-86891, 1984.

2. Brown, Gerald V., et al.: Lewis Research Center Spin Rig and Its Use in Vibration Analysis of Rotating Systems. NASA TP-2304, 1984.

TABLE I. - BOARD-TO-PORT CONNECTION LIST

Port number	Data acquisition board number					
	Case 1[a]	Case 2[a]	Case 3[a]	Case 4	Case 5	Case 6[b]
0	1	1	1	1	1	1
1					1	
2	2	2	1	1	1	
3					1	
4	3	1	1	1		1
5						
6	4	2	1	1		
7						
8	1	1	2	2	2	2
9					2	
10	2	2	2	2	2	
11					2	
12	3	1	2	2		2
13						
14	4	2	2	2		
15						
16	1	3	3	3	3	3
17					3	
18	2	4	3	3	3	
19					3	
20	3	3	3	3		3
21						
22	4	4	3	3		
23						
24	1	3	4	4	4	4
25					4	
26	2	4	4	4	4	
27					4	
28	3	3	4	4		4
29						
30	4	4	4	4		
31						

[a] No delay required.
[b] Frequency resolution is improved by a factor of 2, but maximum frequency is reduced by a factor of 2.

ROTOR CONFIGURATION

Case 1: n = odd (n = 1, 3, 5, 7, ... 57, 59, 61, 63)
Case 2: n = even, n/2 = odd (n = 2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62)
Case 3: n & n/2 = even, n/4 = odd (n = 4, 12, 20, 28, 36, 44, 52, 60)
Case 4: n & n/2 & n/4 = even, n/8 = odd (n = 8, 24, 40, 56)
Case 5: n & n/2 & n/4 & n/8 = even, n/16 = odd (n = 16, 48)
Case 6: n & n/2 & n/4 & n/8 & n/16 = even (n = 32, 64)

where n = number of rotor blades.

TABLE II. - DEFLECTION RESOLUTION AND MAXIMUM ALLOWABLE DEFLECTION

[Rotor diameter = 20 in.]

System	Number of rotor blades	RPM	Maximum allowable deflection, ± mil	Deflection resolution, mil
Original	Any number	15 000	[a]102 to 1257	[a]0.8 to 9.8
		3 000	[a]102 to 1257	[a]0.8 to 9.8
New	56	15 000	140	0.8
		3 000	140	.16
	2	15 000	3927	.8
		3 000	3927	.16

[a] Can be set over this range by software change of synthesizer frequency.

TABLE III. - SYSTEM CHARACTERISTICS

[56 Blades, 15 000 rpm.]

System characteristics	System	
	Original	New
Memory size per board	4096 8-bit words	16 384 16-bit words
No. of data boards	16	4
Sample time and sample rate (Time for blade n to get from port N to port (N+2)	t = 250 μS f = 4000 Hz	t = 250 μS f = 4000 Hz
Memory per blade $\frac{\text{(Memory size x No. of boards)}}{\text{No. of blades}}$	1170 words	1170 words
Time to fill memory $\frac{\text{(Memory per blade)}}{\text{Sample rate}}$	T = 0.292 sec	T = 0.292 sec
Frequency resolution (1/T)	3.42 Hz	3.42 Hz
Maximum unaliased frequency (f/2)	2000 Hz	2000 Hz

TABLE IV. - HARDWARE REQUIREMENTS

Item	System	
	Original	New
Data acquisition boards		
Total number of boards $\left(\frac{\text{Ports x Probes/Port}}{\text{Probes/Board}}\right)$	$\frac{16 \times 2 = 32}{1}$	$\frac{16 \times 2 = 8}{4}$
IC's per board	68	30
Total IC's	2178	240
CPU	32 x 1 = 32	0
Fifo	32 x 1 = 32	0
Eprom	32 x 2 = 64	0
Dram	[a]32 x 8 = 256	0
Sram	32 x 2 = 64	[b]8 x 4 = 32
Control Board		
Number of boards	2	1
IC's per board	Board 1 = 97 Board 2 = 44	43
Total IC's	141	43
Frequency synthesizer	2	None

[a] Total memory = 1 Mbits.

[b] Total memory = 2 Mbits.

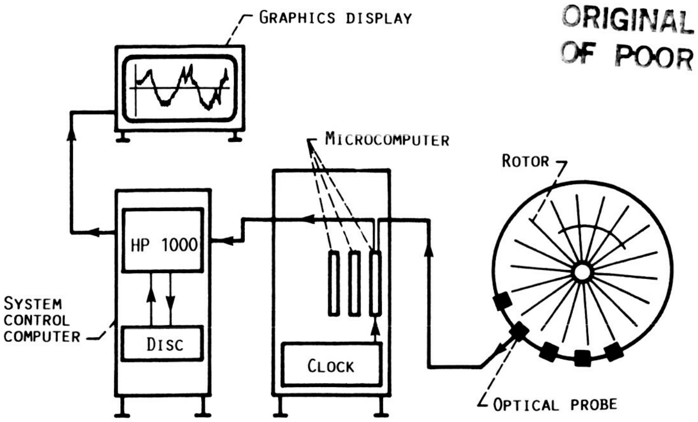


FIGURE 1. - DATA ACQUISITION SYSTEM.

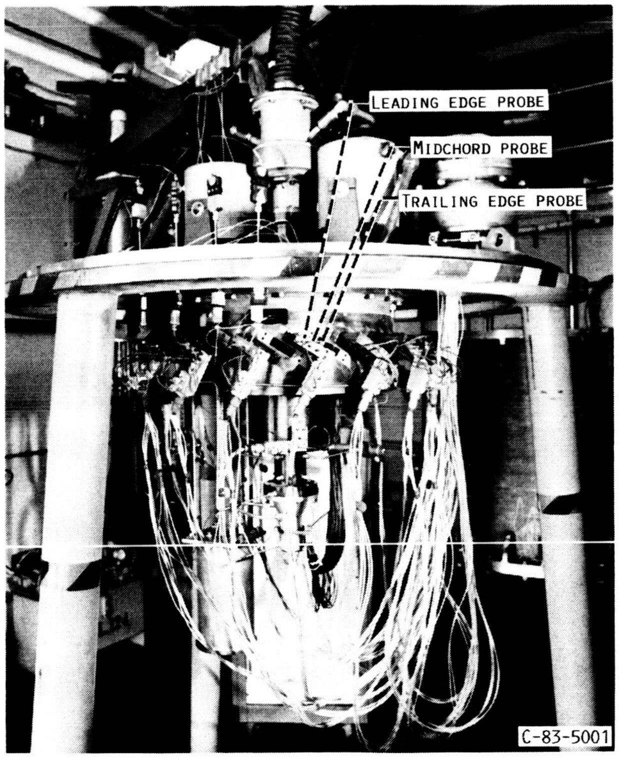


FIGURE 2. - OPTICAL DATA AQUISITION SYSTEM.

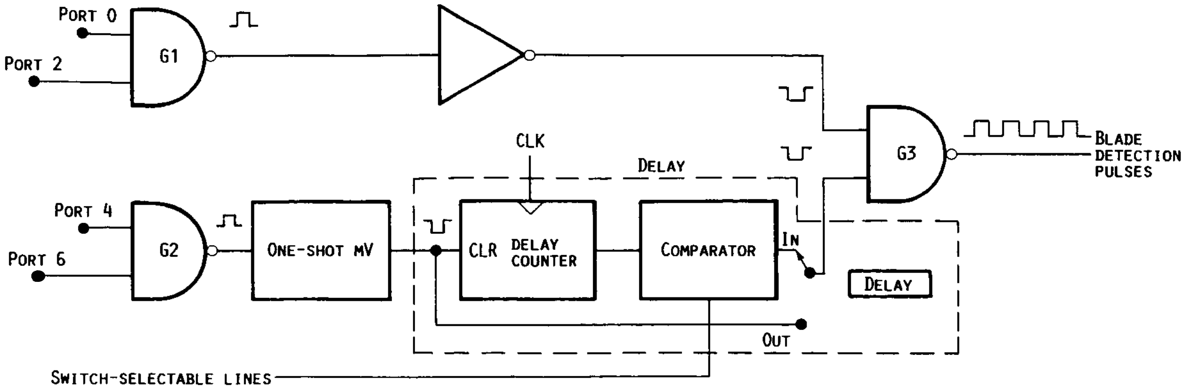


FIGURE 3. - TYPICAL 4-PROBE INPUT CIRCUIT.

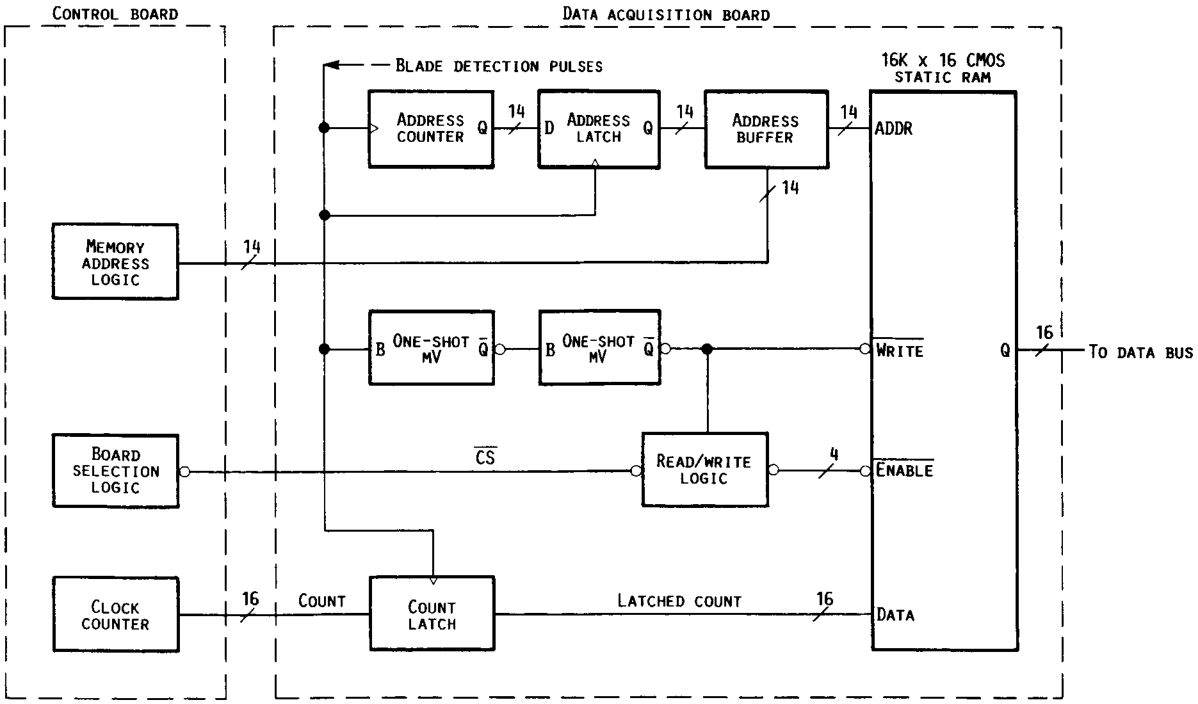
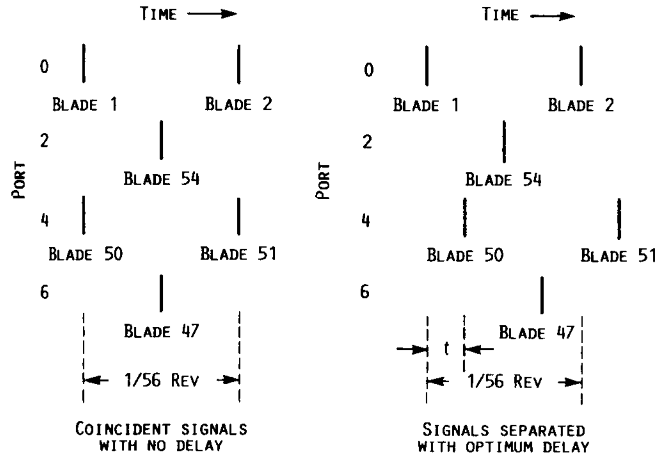


FIGURE 4. - SIMPLIFIED BLOCK DIAGRAM OF MEMORY LOGIC FOR NEW DATA ACQUISITION BOARD.



COINCIDENT SIGNALS WITH NO DELAY

SIGNALS SEPARATED WITH OPTIMUM DELAY

$$4t = 1/56 \text{ Rev} = \frac{60}{56 \text{xRPM}}$$

$$\text{Delay} = t = \frac{15}{56 \text{xRPM}} = \frac{15}{56 \text{x} 15000} = 17.86 \ \mu\text{s}$$

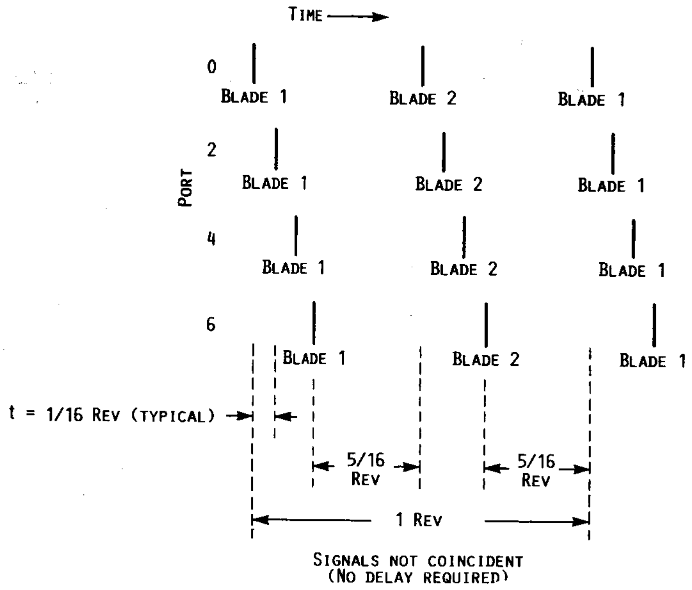
$$t = 357 \text{ Counts at } 20 \text{ MHz}$$

$$t = \frac{1}{224} \text{ Rev}$$

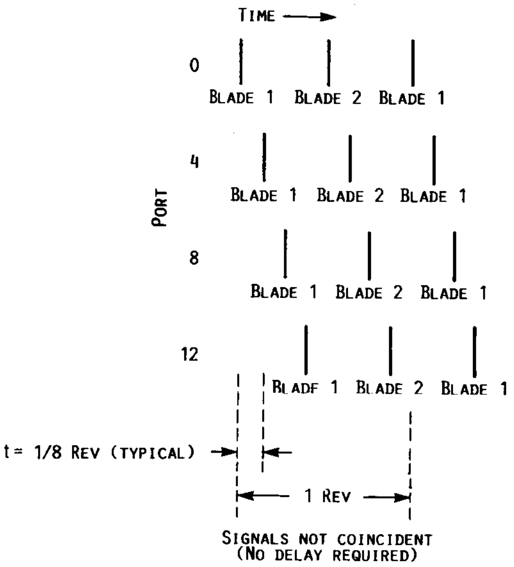
$$\text{Maximum allowable blade deflection} = \pm \frac{t}{2}$$

$$= \pm \frac{1}{448} \text{ Rev}$$

Figure 5. - Probe signals for a 56-bladed rotor.

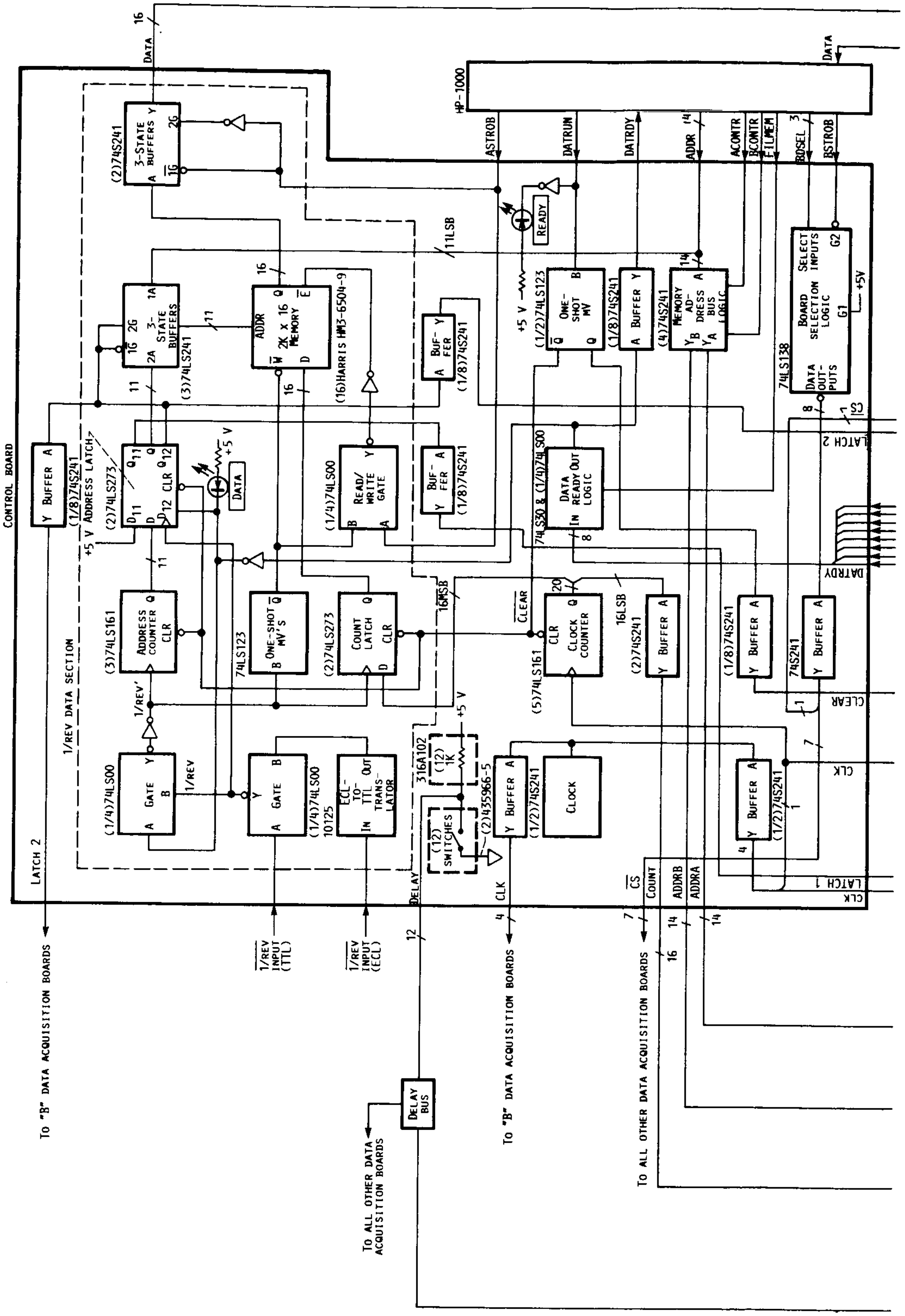


MAXIMUM ALLOWABLE BLADE DEFLECTION = $\pm \frac{t}{2} = \pm \frac{1}{32}$ REV



MAXIMUM ALLOWABLE BLADE DEFLECTION = $\pm \frac{t}{2} = \pm \frac{1}{16}$ REV

FIGURE 6. - PROBE SIGNALS FOR A 2-BLADED ROTOR.



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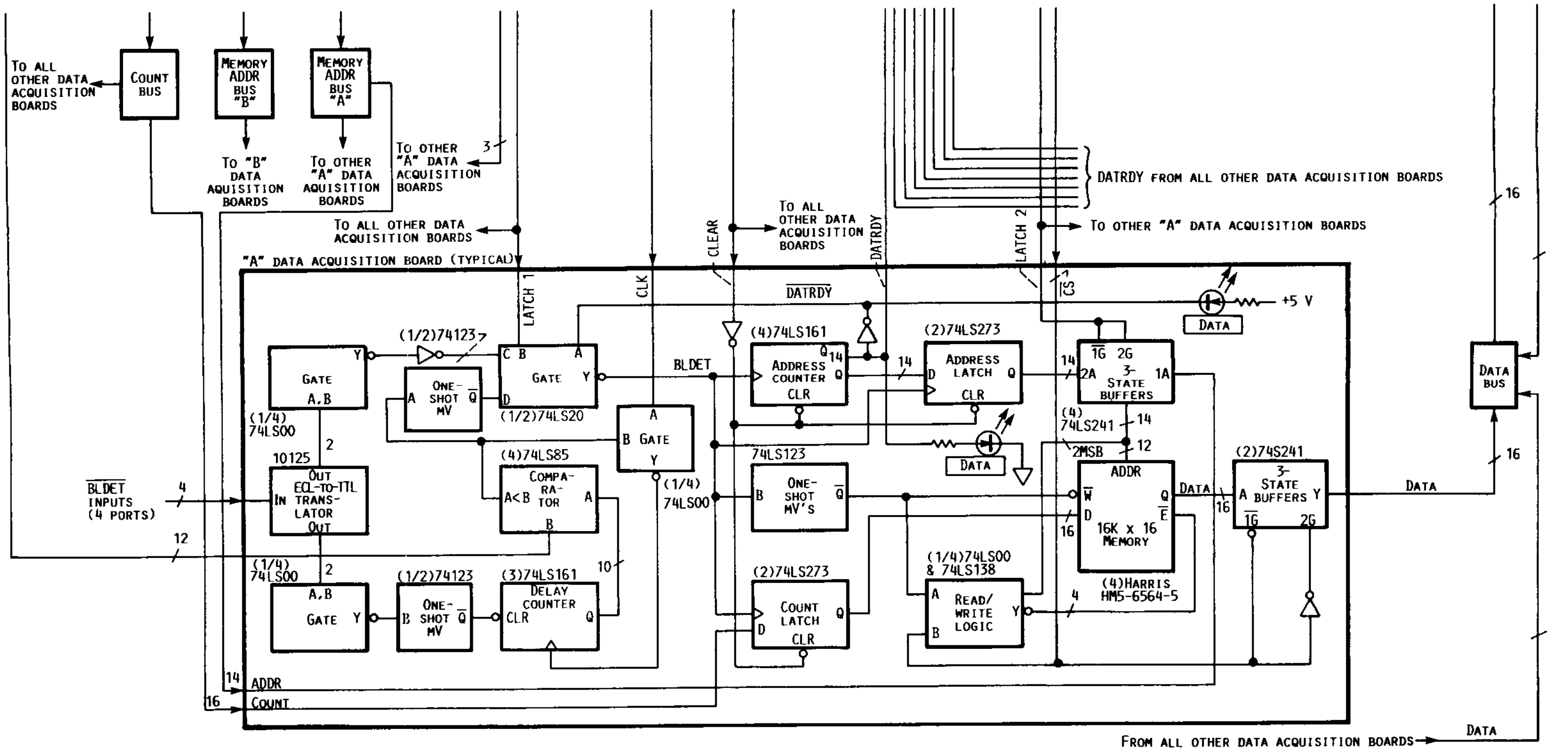

"A", blade leading edge probes

"B", blade trailing edge probes

Figure 7. - Block diagram of new optical data acquisition system.

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16. Abstract

A low-cost optical data acquisition system was designed to measure deflection of vibrating rotor blade tips. The basic principle of the new design is to record raw data, which is a set of blade arrival times, in memory and to perform all processing by software following a run. This approach yields a simple and inexpensive system with the least possible hardware. Functional elements of the system were breadboarded and operated satisfactorily during rotor simulations on the bench, and during a data collection run with a two-bladed rotor in the Lewis Research Center Spin Rig. Software was written to demonstrate the sorting and processing of data stored in the system control computer, after retrieval from the data acquisition system. The demonstration produced an accurate graphical display of deflection versus time.

17. Key Words (Suggested by Author(s))
Turbomachinery vibration; Bladed-disk vibration; Vibration measurement; Data acquisition; Optical sensor

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