A photographic recorder for experimental parachute test data

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A Photographic Recorder for Experimental Parachute Test Data

by

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Thesis adviser: Professor John Carson
ACKNOWLEDGMENTS

My deepest and most sincere thanks go to Mr. Richard Norman, Rochester Institute of Technology, and Mr. Michael Piekarski, Sperry-Univac Corporation.

Without the guidance, assistance, patience, and hundreds of hours of their personal time, this project would not have been possible. Fortunate indeed is the student who has the help of not only one but two people of such noble character.

I am grateful to my wife and Ms. Sharon Perry for help in preparing this and previous reports.

Prof. John Carson, my advisor, helped to smooth the road on several occasions when things started getting rough.

Mr. Louis Hampshire, Technical Photographic Branch, Wright-Patterson Air Force Base, arranged for my visit to the base so that preliminary research could be started.

Mr. Ralph Speelman, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, supplied the application and invaluable information and material support.

Mr. Thomas Pratuch, my research room-mate, was responsible for several innovations that improved the quality of the prototype recorder.

The Central Intelligence Agency provided financial support.
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ABSTRACT

Improvement in the ability to record and retrieve experimental data in general enhances the degree of utilization of information. Recent advances in electronic logic circuits, and the advent of the light emitting diode, make possible the utilization of photography as an initial recording medium. This improves the retrieval time for data, since it can be reduced and coded prior to recording with modern solid state circuits.

A feasibility study, and construction of a prototype recorder was done for application to experimental parachute test data. The recorder monitors strain gage response at a sample rate of 20 per second, converts the input to eight bit binary, and records each sample on 16 mm film. It is designed to operate normally in a 10 g environment, and to survive much higher accelerations with minimal damage.

Evaluation of the completed prototype indicated that there is an improvement in the utilization of test data available, under certain field conditions, through the use of a photographic/electronic interface.
INTRODUCTION

Improvement in the ability to record and retrieve experimental data in general enhances the degree of utilization of information. Current improvements have been mainly due to solid state electronics.

Recently, there have been advances in electronic logic circuits that have opened new horizons of data acquisition and reduction due to the lowering of cost and size barriers.

Also, the light emitting diode (LED), has emerged from the laboratory to take an ever increasing role in the data handling industry.

The interface of solid state electronics and photography for the initial storage of reduced data is a relatively unexplored concept.

Photography has taken a second seat to some of its more recent counterparts in the realm of data storage. Magnetic tape, cores, and drums have, in general, assumed the bulk of data storage chores in information handling. This is an excellent choice for most applications, since magnetic mediums can be played back instantly, erased, and re-recorded.

There are applications where magnetic recorders do not
perform adequately for the intended purpose. For example, in certain types of field testing it is useful to have reduced data available as soon as possible so that immediate remedial action can be taken before termination of the days experimentation.

Because of the inability of older electronic technology to do little more than record raw data without the use of relatively large amounts of costly support equipment, magnetic tape was, in general, an adequate medium for initial storage. The tape then, as a rule, had to be processed in some manner so that the test personnel could utilize the information.

Now, small and relatively inexpensive data processing packages are available so that the possibility of near real time data utilization is a reality.

Since real time reduction and storage of data is now available, a better form of storage retrieval would increase the utilization of the data in question.

Photography is the logical answer to the above problem. If the storage of the reduced data is done on film, in the proper manner, no sophisticated readout equipment is required. Therefore, the data can be utilized at any time or place, independent of intricate equipment. In addition to the above, advantages such as lower cost and increased
reliability are realized.

This thesis is designed to demonstrate the increased efficiency of data utilization possible through the use of an interface between solid state electronics and photography, with regard to experimental parachute test data.
BACKGROUND INFORMATION

The Flight Dynamics Laboratory (FDL) at Wright-Patterson A.F.B. is charged with the design and testing of parachute recovery techniques. The scope of testing ranges from small survival equipment parachutes to huge cargo airdrop systems.

In the event of a total failure of an experimental parachute recovery system, there can be associated a relatively large loss of data, working capital and equipment.

FDL is interested in reducing the danger to expensive test recording equipment from drop damage, as well as optimizing the data obtained per dollar

Currently there are two levels of recovery system testing. One is inexpensive with respect to inflight recording equipment, and the other is comparatively costly, ranging in cost from $5,000 to $100,000 per test for the recording equipment.

The test engineer feels that the inexpensive method of data recording is unsatisfactory for the following reasons: the data obtained is in the form of an aluminum plate, approximately 1 x 2 inches in size, upon which a stylus, that has a weight attached, has etched its path
of travel; the motive force for the stylus is acceleration of the test package that is attached to the experimental parachute (see Figure 1); the relative cost of the information obtained is still high when the total test cost is considered. Cinetheodolites, at least two still photographers and one cinematographer, a cargo aircraft and crew as well as the test engineer are present at all tests\(^3\), regardless of the inflight instrumentation utilized.

The expensive system is capable of recording several response variables. Typical of these are resistances from stress links that connect the camera clevis to the upper risers and center line of the parachute (see Figure 2). A magnetic recorder is used for this type of test. This, and its supporting input equipment, except for the actual stress links, is responsible for the bulk of the cost of the test package\(^4\).

The mean effective sample rate of the above method, although analog, averages one tenth of a second per sample\(^5\) (see Data Sheets 1 and 2), with four parameters (including time) being recorded. The sample rate is per parameter, i.e. the recorder is using parallel channels.

There is one difficulty common to both of the test methods described above. Correlation of data recorded
inflight and by the cinetheodolites with respect to time has been less than completely satisfactory. The principle problem rests in the difficulty of correlating the start of the test (time zero).
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DATA SHEET 2
CONCEPT ONLY

Figure #1

Base Plate

Direction of Acceleration

PLATE TRAVEL

DRIVE GEAR

STYLI

WEIGHT
CONCEPT AND APPLICATION

The use of a photographic emulsion for the storage of coded information has been used extensively in the data processing industry. Depending on the context of the word coded, information storage on film may range from microfilm aperture cards of engineering drawings to optical sound tracks, to optically indexed microfilm files, to the ultra compact storage of input/output data for certain N.A.S.A. space applications.

As implied above, there has been only limited use of photographic systems for the initial storage of experimentally acquired coded information. One reason is that there are other methods that are more highly developed toward field applications, such as magnetic tape recording. Another reason may be that there is a confidence barrier associated with the "fact" that photographic emulsions are subject to "not coming out" when developed. Much to my surprise, the latter reason has been stated several times to me by competent engineers and technicians, when the alternative of film was suggested.

The inherent high information capacity of film as well as the ability of the emulsion to record an image (in the pictorial sense), are in general, the reasons for
the selection of the medium.

The above are not necessarily the only reasons why a photographic system should be considered when selecting a recording medium. In fact, the above may even be considered trivial compared with other properties of the photographic system, when seen in light of a particular application.

In the case of experimental parachute testing, film has six distinct advantages over magnetic tape. It requires much less hardware to write on. There is no mechanical degradation of the writing equipment with hard use, such as with the writing head in a tape recorder. The record is many times easier to protect from drop damage, (see Appendix p.67 for armored film cassette). A photographic recording system of the same size can store many times as much information, i.e. a photographic recorder can be made smaller, and therefore stronger, to accomplish the same mission. An equivalent photographic system as compared with the magnetic system currently used in the parachute test, will be at least one, and possibly two orders of magnitude less expensive if put into limited production. Being of much simpler mechanical construction, and solid state electronic design, reliability is increased proportionally. When photography is interfaced with some.
of the latest advances in electronic logic circuits, nearly immediate access to processed data is available to the test engineer. The above makes possible better utilization of valuable man hours and equipment by allowing meaningful and immediate field modifications to test parachutes, while the test crews are standing by. This implies a general speed-up of development programs, provided that the full advantages of such a recording system are utilized.
PROTOTYPE DESCRIPTION

The prototype recorder is best described in five sections: 1) Casing, 2) Optics, 3) Mechanics, 4) Cassette, 5) Electronics.

**Casing:** The casing is composed of .550 inch polyvinylchloride (PVC) material that is secured with 10x24x1" hex head bolts, (see Appendix p. 60, and Photograph p. 71).

PVC was selected because of its ability to take large amounts of shock without permanent deformation, as well as its excellent machining characteristics. Also, PVC may be welded at room temperature by the use of tetrahydrofuran as a solvent. This proved useful in the fabrication of the LED array holder, (see Appendix p. 68). If it had been fabricated out of another material, such as aluminum, the cost would have been excessive, since one piece construction would have been required.

All components of the casing were machined on a mill to a tolerance of ± .005 inches.

The casing finish consisted of four coats of engineering white Rust-O-Lium and two coats of Test Orange by the same manufacturer. The interior is unfinished except for optical areas, which are sprayed flat black with Rust-O-Lium.
Assembly of the casing, including required modifications for optics and electronics, required approximately one hundred and fifty man/machine hours. This time includes layout, remake, and instruction on machine operation.

Optics: The optical system selected consisted of one Edmund Scientific 25mm plano-convex coated lens, stock no. 94,021, with a .125 inch aperture, (see Appendix pp. 69-70). The aperture was set 6mm in front of the plano surface, between the lens and the LED array, so that astigmatism would be minimized. The LED array was machined so that the individual LED's were orientated radially with the origin of the radii positioned at the surface of the plano side of the lens.

The LED's have an equivalent point source location one centimeter in front of the end of the lamps, (see Appendix p.47). Design of the array mount took the above into account so that the most intense spot would be imaged sharply on the film plane.

There are no baffles to the system with the exception of the entrance plate of the cassette.

Approximately ten man hours were required for the above.

Mechanics: The drive for the cassette consists of a
motor mount, (page 66), motor, main drive assembly, (page 65), and take-up drive assembly, (page 64). An Edmund Scientific 12vDC reversible, self-starting, 7rpm motor that gives 12 in.-oz. of torque drives the cassette, (Stock No. 41,862). The take-up and main drives are attached to the motor/motor mount assembly, and are coupled by two number 12 rubberbands that have been impregnated with graphite.

Required time for the above, including design, layout, fabrication, and adjustment, was approximately fifty man hours.

Cassette: The cassette and related film transport components are made of aluminum except for the followers, which are epoxy impregnated fiber, and the follower retainer caps, which are steel, (see Appendix p. 63).

The cassette was designed to withstand all impact stresses that would occur if the test package were to hit the ground at non-deployed terminal velocity. The design assumed that the casing as well as the instrumentation box may be destroyed but that the cassette must withstand all residual impact forces.

The exposure slit as shown on page 67 provides the only baffle in the optical path.

The drive sprocket is a stock item from LaVezzi Machine
Works, No. 216BF31B. The drive shaft for the drive sprocket is designed in a fashion similar to the shafts for both the supply and take-up spools.

**Electronics:** All electronic design, major assembly and checkout was done by Mr. Michael Piekarski, (Sperry-Univac Corp.). Approximately one hundred man hours were absorbed in this phase of assembly.

The technical manual for the electronic package is included in the Appendix, pages 23-46.
PROTOTYPE PARAMETERS AND PERFORMANCE

As in the preceding section, five separate prototype sections will be discussed: 1) Casing, 2) Optics, 3) Mechanics, 4) Cassette, 5) Electronics.

Casing: The casing was designed to withstand heavy impact to protect its contents from shock and foreign particle damage. It also provides a highly contrasting image should it become separated from the parachute test package upon impact.

It was not required that the casing withstand all impact forces that it may be subjected to, but only that it would display a good survival probability under heavy stress.

Drop tests of the empty casing from a height of twenty feet were unable to show any flaws in design or workmanship.

Optics: The system resolution required no more than two lines per millimeter, since the image consisted of dots .5mm in diameter, with a separation of 1mm. The lens selected was not tested for resolution since it was obvious that the capabilities it possessed were well beyond those required of it.

Astigmatism was held to a minimum by the careful
selection of the aperture location and by the bending of the lens.

The aperture was set at f/7.808, since fabrication of the retainer, which acts as the aperture, was made simpler by the use of a .125 inch drill instead of the lathe work that would have been required to make an aperture of f/8.

The FLV-104 LED's have an equivalent point source location approximately one centimeter in front of its built-in lens, (see Appendix p. 47). The LED array mount was designed with the above in mind so that the maximum image intensity would result when the system was focused correctly.

Exposure, although not really part of the optics, is related closely enough to warrant discussion in this section.

The exposure is controlled in two ways. Primary control is by LED operation time, i.e. the command pulse to the LED control transistor is limited in duration. This method allows the exposure to be controlled by factors of ten, i.e. $10^{-1} , 10^{-2} , \ldots , 10^{-5}$ seconds. With the selected film, (Kodak Linagraph Shellburst Film (Estar Base)), $10^{-4}$ seconds has been found to be the best gross exposure level. The extended red sensitivity of Shellburst film was required, since the spectral output
of the LED's ranges from 660nm to 680nm.

Secondary control of exposure is accomplished by the use of neutral density gelatin filters that are taped over each LED. Individual filtering permits adjustments for non-uniformity in LED alignment and manufacture.

The exposures of LED bits five, six, seven, and eight were intentionally made slightly different from each other so that data readback by the user would be easier, (see Appendix p. 58 - recorder output sample).

Performance of the optical system is well beyond the requirements for unaided read out of data by the user, as is best illustrated by the recorder output sample, (see Appendix p. 58).

Mechanics: The cassette drive was designed to advance the film at .47 in./sec*. The actual performance averages out to .44 in./sec., with a speed variation of ± 3.7%. As is clearly shown by the recorder output sample, (see Appendix p. 58) no serious degradation of readability has resulted. The discrepancy between design and actual film speed is attributed to insufficient motor torque.

The cassette drive assembly is engaged by pushing the mount into the casing until it stops, locking into position with the motor lock screw, and then turning on the 24v supply for a maximum of five seconds. This operation allows the drive sleeves, which are spring loaded, to rotate past

see page 26 for calculations
the drive slots in the bottom of the cassette enough times to assure positive engagement, as well as moving two to three inches of film past the entrance slit of the cassette so that unexposed film will be in position when the recorder is restarted.

The above operation has been proven simple and reliable enough, so that fellow students were able to perform the operation successfully after about thirty seconds instruction. There have been no film transport failures attributed to the drive system.

Cassette: Other than the ability to survive a total recovery system failure, as described previously, the cassette must perform two other functions flawlessly. The first is film supply and take-up, and the second is protection of the recorded information from scattered light that gets past the light baffle at the front of the cassette.

Film supply and take-up was unreliable until a retaining pin was installed between the supply spool and the drive sprocket, so that the film was prevented from forming an excessively large coil on the supply spool when loading tension was released. This modification was done very late in the development of the project, and is not shown in the engineering drawings.

Although there are no light traps as such in the cassette,
stray light coming through the baffle has been shown to be minimal. There is so little stray light getting into the cassette that it can be handled in bright room light without a cap over the slit.

The cassette was tested for shock survivability by throwing it against a cement wall. This was done once, since the machining is very costly in man hours. However, there was no evidence of damage from the above test.

Electronics: Input for the recorder was set at a maximum potential of 10vDC by specification. Sensor response to its stimulus, in the case of parachute testing the test variable is force, is changed in potential to a value between 0 and 10vDC.

The electronic package was designed to meet the following specifications:

1) Convert an analog input signal to an output that can be photographically recorded.
2) The output signal must be easily read by the user.
3) Sample rate must equal or exceed 20 per second.
4) Input resolution must be at least .005 of full scale deflection.
5) Operate from an external 24vDC supply.
6) Correlate the recorded data with event time.
7) Have the possibility for multiple channel recording.

8) Have the possibility for synchronization of internal event time correlation with external clocks.

9) Recording must be initiated by the closing of a single circuit.

10) Must operate normally under accelerations in excess of 10 g's.

The assembled electronic package meets or exceeds all specifications:

1) The analog input signal is converted to eight bit binary and displayed by LED's.

2) As demonstrated by the recorder output sample, a user can easily read the signal, provided that he or she is familiar with Binary Coded Data (BCD).

3) The analog to digital converter (ADC) is capable of 1000 conversions per second, but is programed to convert only 20 times per second.

4) Input resolution is one part in 256, or .0039 of full scale deflection.

5) The supply voltage required for the prototype configuration is 24vDC.

6) A separate channel is reserved on the film for a
time correlation marker, which gives one second interval marks. The time mark consists of ten dots spaced .05 seconds apart, then the remainder of the second channel is blank.

7) Multiplexing (multiple channel recording) is easily done with the addition of a MPX-8A multiplexer, which is made by the same manufacturer. With a series of four multiplexers, it is possible to record as many as 64 channels of input. Only the sample rate of the ADC and the drive motor speed would need to be changed to accommodate this.

8) The crystal oscillator is easily synchronized with other clocks. This is common practice in many industrial and scientific applications.

9) The recorder is activated by the closing of an 'enable' circuit.

10) The recorder has operated normally while being repeatedly dropped on the floor from a height of three to four feet. This is shock well above normal parachute opening values.

System Evaluation: In addition to the test described above, final calibration and evaluation tests were run as follow:
1) To check the system for calibration, known voltages were applied to the recorder, and plotted against response. The system response was nearly linear over the entire input range, but averaged .0625 vDC high. This amounts to a consistently high response of .00625%. The degree of non-linearity is equal to ± 1/2 of the value for the least significant bit, or ± .0195% of full scale deflection.

2) To check the system response to changing input, a resistor-capacitor circuit was attached to the recorder in place of the intended sensor (a stress link as supplied by FDL) and charged. The output curve of the above plotted smoothly, indicating that the recorder is capable of resolving very small $\frac{dv}{dt}$ data (see Appendix p. 57 for results).

3) Ease of use was tested by asking several volunteers to operate the recorder, and to then read the output. Total instruction time, including that used to explain BCD, averaged ten minutes. Every volunteer was able to demonstrate operational and read out proficiency on the first trial. All volunteers were seniors or graduates of the photographic science program, so it is likely
that a technician may need slightly more instruction before he can use the recorder.

\[ \text{CALCULATIONS} \]
\[ \text{Drive sprocket diameter} = 1.513 \text{ in}, \]
\[ \text{Sample rate} = 20/\text{sec.} \]
\[ \text{Image diameter/channel} = .5 \text{mm.} \]
\[ \text{Image separation/sample} = .1 \text{mm.} \]

\[ \text{Circum.}(C) \text{ of sprocket} = \pi d = \pi(1.513) = 4.76 \text{ in.} = 120 \text{ mm.} \]

\[ ( .5 \text{ mm.} + .1 \text{ mm.} ) \times (20 \text{ samples/sec.}) \times (60 \text{ sec./min.}) = 720 \text{ mm/min.} \]

\[ 720 \text{ mm/min. of sampling} = 5.9 \text{ RPM} \]
\[ C = 120 \text{ mm of sprocket} \]

Selection of a stock 7 rpm motor allows a 16% drop in rpm due to drag.
SUMMARY AND CONCLUSION

The project was designed to demonstrate the feasibility of using photography as an initial recording medium for coded experimental data.

It was noted that other recording mediums performed very well under most circumstances, but that there were areas in experimental data acquisition where immediate access to reduced data was difficult or impossible due to the usual need for support equipment that is not designed for field use.

A specific application for the photographic recording concept was sought and found at Wright-Patterson Air Force Base in the Recovery and Crew Station Branch of the Air Force Flight Dynamics Laboratory (FDL).

The application was in parachute riser force data recording. All parameters for the prototype recorder were designed to meet the requirements of the above application. This was to demonstrate the flexibility of the concept as well as to assure the continued support of FDL.

The prototype was constructed between November '73 and May '74 with the aid of Mr. Michael Piekarski of Sperry-Univac Corporation, and Mr. Richard Norman of the Rochester Institute of Technology staff.
Subsequent tests of the system were conducted to demonstrate its conformance to specifications prior to flight testing.

Actual flight tests were not conducted due to unavoidable delays in the program schedule.

Inflight testing was not necessary to demonstrate feasibility of the concept, although it would have added the finishing touch to the project.

Laboratory tests demonstrated that the recorder performed at or above all requirements.
RECOMMENDATIONS

Future development of the recording concept is recommended in the following areas:

1) Study of the usefulness of a photographic recorder/magnetic recorder hybrid. One system would supply immediate reduced data, while the other supplied a computer compatible record of raw data.

2) Feasibility study for an automatic optical reader for recorder output.

3) Feasibility study for recorder output/computer interface.

4) Feasibility study for the use of different colored LED's and color film for easier readout.

5) Survey of current data collection practices to determine where significant time, money or data may be saved by application of the recorder concept.
FOOTNOTES


2 Ibid.

3 Mr. Lou Hampshire (4950\textsuperscript{th}/ENPI), Technical Photographic Branch, WPAFB, conversation, 1973.


5 Ibid.


7 Ibid.
REFERENCES:


WPAFB, "Motion Picture Film of Parachute Test" WP73-58, 57, 60 and 61, 1973.


ILLUSTRATIONS AND PARTS LISTS:

1. Assembly Block Diagram
2. List of Parts, Assembly One
3. Component Location Chart, Assembly One (Al)
4. List of Parts, Assembly Two
5. Component Location Chart, Assembly Two
6. Timing Chart for 4017A chips (Systems Operating Sequence)
7. COS/MOS CD4000A Series Integrated Circuits Ref.
8. Crystal Oscillator Schematic
9. Circuit Chart, Al Board
10. Analog to Digital Converter/Sample and Hold Amplifier Interface, (ADC and SHA) Assembly Two
11. Assembly Two Logic
12. Typical Exposure Logic
LIST OF PARTS, ASSEMBLY ONE

1-5 Decade Counter/Divider, (CD4017A)
6 Presettable Divide-By-N Counter, (4018A),
   set to divide by 5
7 Quad 2-Input NAND Gate, (CD4011A)
8 Hex Buffer/Converter, inverting, (CD4009A)
9 Quad 2-Input NOR, (CD4001A)
SW-1 Test switch, N.O.
SW-2 Osc. power on, N.C.
See corresponding numbers on List of Parts p. 35
LIST OF PARTS, ASSEMBLY TWO

1-4  Triple 3-Input NAND, (CD4023A)
5-6  Hex Buffer/Converter, inverting, (CD4009A)
7-8  Driver Transistor Array, (3081)
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ILLUSTRATION #11
• Very high axial intensity
• Narrow (4°) beamwidth
• Detectable at 30 feet
• Fast (ns) risetime
• Ideally suited for use in any photoelectric application where the modulation or interruption of a narrow beam light is required, such as in a control or information transmission system
• Applications include: Film annotation, fiber optic source, traffic monitor, short range data link, shaft angle encoder, pollution monitor source, photoelectric source and medical monitoring source.

NARROW BEAM SHAPE

- 50% of Axial Intensity
- Maximum Irradiance & Smallest Spot Size
- Equivalent Point Source Location
- Near Field
- Distant Field

GENERAL DESCRIPTION
The FLV 104 visible emitting narrow beam L.E.D. is a high intensity source specifically intended for excitation of photodetectors, especially photodiodes and transistors when the separation distances are measured from mm to several meters.

The FLV 104 is the visible beam companion device to the FPE 104 narrow beam infrared emitter. Both devices have identical optics and therefore identical radiation patterns.

ABSOLUTE MAXIMUM RATINGS

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<td>$\text{V}_F$</td>
<td>Forward Voltage</td>
<td>-</td>
<td>2.0</td>
<td>2.5</td>
<td>Volts</td>
<td>$I_F = 100 \text{ mA}$</td>
</tr>
<tr>
<td>$\text{B}_V$</td>
<td>Reverse Breakdown</td>
<td>3.0</td>
<td>8.0</td>
<td>-</td>
<td>Volts</td>
<td>$I_R = 10 \mu\text{A}$</td>
</tr>
</tbody>
</table>

ELECTRICAL CHARACTERISTICS (25°C Ambient)
## OPTO-ELECTRONIC CHARACTERISTICS @ $I_F = 100$ mA, 25°C Ambient

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETERS</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_L$</td>
<td>Axial Luminous Intensity</td>
<td>0.50</td>
<td>150</td>
<td></td>
<td>mcd</td>
</tr>
<tr>
<td>$I$</td>
<td>Axial Radiometric Intensity</td>
<td></td>
<td>4.0</td>
<td></td>
<td>mW/sr</td>
</tr>
<tr>
<td>$L$</td>
<td>Average Effective Luminance</td>
<td></td>
<td>5.0</td>
<td></td>
<td>cd/cm²</td>
</tr>
<tr>
<td>$N$</td>
<td>Average Effective Radiance (Axial)</td>
<td></td>
<td>140</td>
<td></td>
<td>mW/sr/cm²</td>
</tr>
<tr>
<td>$A_s$</td>
<td>Effective Emitting Source Area (Axial)</td>
<td></td>
<td>0.028</td>
<td></td>
<td>cm²</td>
</tr>
<tr>
<td>$\Delta I/\Delta T$</td>
<td>Temperature Coefficient of Intensity (Note 1)</td>
<td></td>
<td>0.5</td>
<td></td>
<td>%/°C</td>
</tr>
<tr>
<td>$\Delta I/\Delta F$</td>
<td>Excitation Coefficient of Intensity (Note 1)</td>
<td></td>
<td>1.0</td>
<td></td>
<td>%/°C</td>
</tr>
<tr>
<td>$\lambda pk$</td>
<td>Peak Spectral Wavelength</td>
<td></td>
<td>670</td>
<td></td>
<td>nm</td>
</tr>
<tr>
<td>$\Delta \lambda$</td>
<td>Spectral Bandwidth</td>
<td></td>
<td>20</td>
<td></td>
<td>nm</td>
</tr>
<tr>
<td>$\Delta \lambda pk/\Delta T$</td>
<td>Temperature Spectral Shift Coefficient (Note 2)</td>
<td></td>
<td>0.17</td>
<td></td>
<td>nm/°C</td>
</tr>
<tr>
<td>$\Delta \lambda pk/\Delta T_F$</td>
<td>Excitation Spectral Shift Coefficient (Note 2)</td>
<td></td>
<td>0.1</td>
<td></td>
<td>nm/mA</td>
</tr>
<tr>
<td>$\theta_{50}$</td>
<td>Beam Angle at 50% Axial Intensity</td>
<td></td>
<td>4.3</td>
<td></td>
<td>Degrees</td>
</tr>
<tr>
<td>$\Delta \theta_A$</td>
<td>Beam Axis to Mechanical Axis</td>
<td></td>
<td>1.5</td>
<td></td>
<td>Degrees</td>
</tr>
<tr>
<td>$t_r$ and $t_f$</td>
<td>Light Output Rise and Fall Time (Note 3)</td>
<td></td>
<td>10</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$c_0$</td>
<td>Capacitance (V=0, f=1.0 MHz)</td>
<td></td>
<td>100</td>
<td></td>
<td>pf</td>
</tr>
</tbody>
</table>

---

**FIGURE 1. BEAM PATTERN OF INTENSITY**

**FIGURE 2. SPOT DIAMETER VERSUS SEPARATION DISTANCE (NEAR FIELD)**

**FIGURE 3. SPOT DIAMETER VERSUS SEPARATION DISTANCE (FAR FIELD)**

**FIGURE 4. FORWARD V-I CHARACTERISTICS**
FIGURE 5. AVERAGE AXIAL IRRADIANCE, H

FIGURE 6. EMISSION SPECTRUM VISIBLE (GaAsP LED)

FIGURE 7. RELATIVE RADIOMETRIC OUTPUT (%) VERSUS EXCITATION CURRENT (SEE NOTE 4)

NOTES:
1. ΔI/ΔT and ΔI/ΔP are the percentage derating factors for all radiometric output characteristics referenced to their typical value at 25°C ambient and I_p = 100 mA.
2. Δλpk/ΔT and Δλpk/ΔP are the derating factors for all wavelength characteristics referenced to their typical value at 25°C ambient and I_p = 100 mA.
3. Time for a 10%–90% change in light intensity with a step change in current.
4. Normalization: LED Intensity = 4 mw/sr (measured using sensor 1 mm² area).
5. Projected source point is the distance, S_p, from which LED inverse square LAW characteristics may be computed for S > 5 cm.

\[
H = \frac{1.0 \text{ mw}}{\text{cm}^2} \times \frac{S_p^2}{(S-S_p)^2} \quad 1 < S_p < 2 \text{ cm}
\]

6. E (illumination in mW/cm²) = \( H \) (irradiance in mw/cm²) \( \times S \times e_L \) (luminous efficacy) for GaAsP LED's EL ~ 40 lm/w.
7. H (irradiance) normalized to 1.5 mw/cm² typical @ S = 1 cm or E (illumination) normalized to 60 ml/cm² typical @ S = 1 cm.
8. Luminous intensity curve coincides with radiant intensity curve for pulse excitation (for average currents of 20 mA or less.)
KODAK LINAGRAPH SHELLBURST FILMS
PHOTOGRAPHIC AND PHYSICAL PROPERTIES

KODAK LINAGRAPH SHELLBURST Films are designed especially for cinetheodolite photography—motion-picture photography of aerial objects from the ground. They have excellent acutance and produce maximum contrast in pictures of distant aircraft, missiles, and other targets against sky backgrounds having various degrees of atmospheric haze and low-contrast conditions. These products are also used in spark-chamber photography, bubble-chamber photography, and other applications where high resolution is of prime importance.

Although these films are presently produced in three forms (as listed in the table at the right), it is expected that KODAK LINAGRAPH SHELLBURST Film (ESTAR-AH Base) will eventually replace the other two films.

Exposure Information
Photorecording Sensitivity: 200 (KODAK Developer D-19 for 8 minutes at 68 F)

Relative CRT Speeds: P11—650 P15—80

Speed (for airborne objects): The numbers given in the table below are based on a USA Standard and are for use with exposure meters marked in “ASA” speeds. They are also based on development in KODAK Developer D-19 for 8 minutes at 68 F (20 C) with continuous agitation.

<table>
<thead>
<tr>
<th>KODAK WRATTEN Filter</th>
<th>Blue Sky</th>
<th>White Sky</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>400</td>
<td>320</td>
</tr>
<tr>
<td>No. 25</td>
<td>50</td>
<td>64</td>
</tr>
<tr>
<td>No. 29</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>No. 8N5</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>No. 39</td>
<td>160</td>
<td>64</td>
</tr>
</tbody>
</table>

As with most special-purpose films, best results will be obtained with KODAK LINAGRAPH SHELLBURST Films if exposure information is determined for the actual conditions under which the film is to be used. Exposure-meter readings should be correlated with camera exposures that are known by trial to be correct. Once this correlation has been established for the particular equipment in use and the type of subject to be photographed, it can be used in conjunction with exposure-meter readings to determine the correct exposure for various lighting conditions.

Filters: A wide variety of color filters can be used with these films; the choice is not restricted to those mentioned above. In photographing very bright portions of the sky, a filter may be useful simply as a means of preventing overexposure. In many cases, satisfactory results can also be obtained without the use of a filter. The following chart may be of use in selecting the proper filter.

<table>
<thead>
<tr>
<th>KODAK WRATTEN Filter</th>
<th>Subject</th>
<th>Background (Sky)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 25 (red)*</td>
<td>Bright (white, yellow, orange, etc.)</td>
<td>Blue</td>
</tr>
<tr>
<td>No. 39 (blue)</td>
<td>Dark</td>
<td>Blue</td>
</tr>
</tbody>
</table>

*No. 29 (deep red) filter or a No. 8N5 (dark yellow) filter can be used in place of a No. 25 Filter if the latter is unavailable. These filters give results which differ only slightly in contrast. They are also useful in photographing portions of the sky which are so close to the sun that a dark filter is needed to prevent overexposure.

With a white sky background, the color of the filter is not critical. A red filter, however, is generally preferred.

Night Exposures: Do not use a filter. Shoot with the lens wide open, at 12 to 16 frames per second.

Color Sensitivity
Panchromatic with extended red sensitivity
Darkroom Handling
KODAK LINAGRAPH SHELLBURST Films must be handled in total darkness. However, a KODAK Safelight Filter No. 3 (dark green), in a suitable safelight lamp with a 15-watt bulb can be used for a few seconds at a distance of not less than 4 feet from the film after development is 50 percent completed.

Image-Structure Characteristics
This information is based on development in KODAK Developer D-19 for 8 minutes at 68 F with continuous agitation.

Resolving Power

<table>
<thead>
<tr>
<th>Test-Object Contrast</th>
<th>Value†</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000:1</td>
<td>125 lines/mm</td>
<td>High</td>
</tr>
<tr>
<td>1.6:1</td>
<td>50 lines/mm</td>
<td>–</td>
</tr>
</tbody>
</table>

RMS Granularity (net density of 1.0)

<table>
<thead>
<tr>
<th>Value‡</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Medium</td>
</tr>
</tbody>
</table>

† This value was determined as described in "A Simple Camera for the Measurement of Photographic Resolving Power," by J. H. Altman, Photographic Science and Engineering, V. 5 No. 1 (January-February 1961), 17-20.
‡ This value represents 1,000 times the standard deviation in density produced by the granular structure of the material when a uniformly exposed and developed sample is scanned by a densitometer having an optical system aperture of f/2.0 and a circular scanning aperture of 48 in diameter. The value is proportional to the sensation of graininess which would be perceived if the sample were viewed at a magnification of 12x.

The sensation of graininess will increase or decrease with the viewing magnification; e.g., if the viewing magnification is doubled, the value is about doubled.

The graininess of a print is also affected by the printing operation. Grainularity is changed roughly in proportion to the contrast of the print material; e.g., if a negative of granularity value 10 is printed onto a material of contrast 2.0, the granularity of the print will be about 20 [see "Wiener-Spectrum Analysis of Photographic Granularity," by E.C. Doerner, Journal of the Optical Society of America, LII (June 1962), 669.]

It appears (from our limited data) that a difference of about 6 percent in the effective value of rms granularity corresponds to a just noticeable difference in the visual impression of graininess.
DESCRIPTION
Model ADC–8S is a low-cost, 8-bit Analog-to-Digital Converter employing a "staircase" conversion technique. Packaged in the industry's smallest A/D module (2" x 3" x 0.4"), the ADC–8S adjustment-free performance includes monotonicity over 0°C to +70°C, 1/2 LSB differential linearity and input impedance over 100MΩ. Parallel data output is standard. Both status and its complement signals are provided for synchronization with external components such as the SHA series of sample and hold amplifiers. In brief, the ADC–8S is a definitive answer to the "Make vs Buy" question.

DESIGN
Besides using standard 74 series TTL IC logic, the ADC–8S includes the monolithic "μDAC" components developed by Analog Devices. These μDAC components capitalize on the superb-matching and tracking qualities inherent in monolithic processing to yield high performance. Pin layout is such that Analog, Digital and Power connections are separated for ease of use.

OPERATION
The timing diagram and block diagram for the ADC–8S is shown in Figure 1. The leading edge of the convert command pulse resets the ADC–8S to the zero state. The trailing edge starts the 8-bit binary counter and D/A converter from zero, and the D/A converter generates an output which increases until it is equal to the analog input. At this time, the comparator's output changes state, inhibiting the counter and holding the final digital result in the register.

Fig. 1 ADC–8S Timing and Block Diagrams

USER FLEXIBILITY
The ADC–8S includes a built-in precision reference and can be externally wired to accept unipolar or bipolar analog inputs. Various coding options, including BCD, are available. The gain of the ADC–8S may also be arbitrarily changed with an external resistance connected between the Buffer Output (pin 3) and the Comparator Input (pin 6). The gain change will be based on approximately 5000Ω/volt.

APPLICATIONS
The high input impedance of the ADC–8S makes it ideally suitable for use with linear or rotary resistance transducers and other transducers with high output impedance.

A low cost 0-99 display using the ADC–8S is shown in Figure 2. A typical use for this display would be as a percentage-meter measuring device reading in % of full scale.

The low sell price of the ADC–8S allows the OEM purchaser to use an A/D per channel in multi-channel systems which simplifies the data acquisition system design, improving performance and reliability with overall lower systems cost and increased system flexibility.

FEATURES
Low Cost — $49. (100+)
High Performance
8-Bit Resolution
Monotonic – 0°C to +70°C
High Input Impedance – 100MΩ
Programmable Input Ranges
Adjustment Free
Smallest Size – 2" x 3" x 0.4"

REPRESENTED BY

ANALOG DEVICES INC
ROUTE ONE INDUSTRIAL PARK
P.O. BOX 280 NORWOOD, MASS. 02062
TEL: 617/329-4700 TWX: 710/394-6577
ADC-8S Analog to Digital Converter

**Specifications**: 8-Bit or 2 digit BCD

**Accuracy**
- Relative
- Quantizing
- Monotonicity
- Long Term Stability

**Differential Linearity**

**Temperature Coefficient**
- Gain (of reading)
- Zero (of F.S.)

**Conversion Time**
- 1ms
- ±5V, ±10V, 0 to +10V, or 0 to +5V
- Refer to Programming Chart

**Input Impedance**
- With Buffer
- Bypassing Buffer

**Input Trigger**
- (Convert Command)
- (See Fig. 1)

**Output Signals**
- Unipolar
- Bipolar

**Output Code**
- Unipolar
- Bipolar

**Status**
- (See Fig. 1)

**Status (see Fig. 1)**

**Power Supply Requirements**
- (Grounds Internally Connected)

**Power Supply Sensitivity**
- Gain (of reading)
- Zero (of F.S.)

**Temperature Range**
- Operating
- Storage

**Prices**
- (1–9)
- (10–24)
- (25–99)
- (100+)

**INTEGRAL RANGE PROGRAMMING**

<table>
<thead>
<tr>
<th>Analog Input Range</th>
<th>WITH BUFFER</th>
<th>BYPASSING BUFFER</th>
</tr>
</thead>
<tbody>
<tr>
<td>±5V</td>
<td>1</td>
<td>3 to 5, 4 to 6</td>
</tr>
<tr>
<td>±10V</td>
<td>1</td>
<td>3 to 5</td>
</tr>
<tr>
<td>±5V</td>
<td>1</td>
<td>3 to 5, 6 to 7</td>
</tr>
<tr>
<td>±10V</td>
<td>1</td>
<td>3 to 4, 6 to 7</td>
</tr>
</tbody>
</table>

**Notes:**
1. When ordering BCD specify ADC-8S/BCD.
2. Soldiered to 125°C nominal output voltage, internal.

**Actual Label**

**Outline Dimensions**

**Figure 2** 0–99 Display Using ADC-8S/BCD
PRELIMINARY TECHNICAL DATA

FEATURES
Low Tracking Error: 0.01% at Low Frequency
Low Drift: 20µV/°C
Low Droop Rate: 5µV/ms
Short Aperture: 40ns
High Input Impedance in Sample Mode:
   4 x 10⁶ ohms
DTL/TTL Compatible
Compact Module: 11/8” x 2” x 0.4”

APPLICATIONS
Data Acquisition
Data Distribution
Peak and Valley Measurement
Simultaneous Sample and Hold

GENERAL DESCRIPTION
The SHA-5 is a low cost, general purpose sample and hold amplifier built in a very compact module package. When DTL or TTL logic "1" is applied at the control input, the operating mode is “Sample”, and the output tracks the input at unity gain, without polarity inversion. When logic “0” is applied, the operating mode is “Hold”, and the output remains at the value just prior to the opening of the switch. See Figure 1.

TRACKING LOOP
Charge proportional to the instantaneous value of input signal voltage is stored in the hold capacitor (see Figure 1). Since this capacitor is connected in a high gain feedback loop, its charging current is provided by an amplifier. Thus, the SHA-5 is relatively easy to apply, since capacitor charging current does not have to be supplied by the signal source.

DYNAMIC PERFORMANCE
Of prime importance in selecting sample and hold amplifiers is the transition characteristic when the module is commanded into “Hold” by the application of a logic “0” to the control input. A finite delay occurs between the application of the hold command and the response of the internal switching circuit. In the SHA-5, this “aperture delay” time is 40ns. The aperture jitter, or the cycle to cycle repeatability of aperture delay, is approximately 4ns. In most systems and for most applications, the jitter specification is the limiting factor on overall system speed for a given accuracy, since the essentially fixed aperture delay can be compensated by adjusting the system timing.

The SHA-5 settles to 0.01% in 15µs or less after a 20 volt step input. When switched to “Hold”, the switching transient settles to ±1mV within 2µs. Since aperture jitter is approximately 4ns, an input signal slewing at a rate of 12.5mV/µs will be acquired to appreciably better than one LSB uncertainty for a 12 bit A/D converter. The holding droop rate of 5µV/ms is appropriate for practically all data acquisition and distribution applications.

APPLICATIONS
In the design of sample and hold amplifiers, the major tradeoff is usually in connection with speed of acquisition and droop in “Hold”. As the size of the storage capacitor is increased, the droop rate improves and the acquisition time lengthens. The SHA-5, conceived as a general purpose product, has been designed with droop rate appropriate for use with almost all successive approximation A/D converters; it is also well suited for use in data distribution systems using D/A converters with up to 12 bit resolution, where the data update rate is not slower than approximately 10 per second. The 15µs settling time makes the SHA-5 appropriate for use with all but the fastest A/D converters.
### SPECIFICATIONS

(typical @ +25°C and nominal supply voltages, unless otherwise specified)

<table>
<thead>
<tr>
<th>MODEL</th>
<th>SHA-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACCUcRACY</strong></td>
<td></td>
</tr>
<tr>
<td>Gain</td>
<td>+1</td>
</tr>
<tr>
<td>Gain Error</td>
<td>±0.01%</td>
</tr>
<tr>
<td>Gain Tempco</td>
<td>±0.3ppm/°C</td>
</tr>
<tr>
<td><strong>SAMPLE MODE DYNAMICS</strong></td>
<td></td>
</tr>
<tr>
<td>Small Signal Frequency Response (-3dB)</td>
<td>1.4MHz</td>
</tr>
<tr>
<td>Full Power Bandwidth</td>
<td>30kHz</td>
</tr>
<tr>
<td>Settling Time to 0.01% (20V input step)</td>
<td>15µs</td>
</tr>
<tr>
<td>Overload Recovery</td>
<td>10µs</td>
</tr>
<tr>
<td><strong>SAMPLE TO HOLD SWITCHING</strong></td>
<td></td>
</tr>
<tr>
<td>Aperture Delay Time</td>
<td>40ns</td>
</tr>
<tr>
<td>Aperture Jitter</td>
<td>~4ns</td>
</tr>
<tr>
<td>Switching Transient Settling Time (to ±1mV)</td>
<td>2µs</td>
</tr>
<tr>
<td>Sample-to-Hold Offset</td>
<td>5mV</td>
</tr>
<tr>
<td><strong>HOLDING CHARACTERISTICS</strong></td>
<td></td>
</tr>
<tr>
<td>Droop Rate</td>
<td>5µV/ms</td>
</tr>
<tr>
<td>Feedthrough (20V p-p @ 1kHz in)</td>
<td>1mV p-p</td>
</tr>
<tr>
<td><strong>INPUT CHARACTERISTICS</strong></td>
<td></td>
</tr>
<tr>
<td>Resistance (Sample Mode)</td>
<td>4 x 10^9 ohms</td>
</tr>
<tr>
<td>Bias Current (Sample Mode)</td>
<td>25mA</td>
</tr>
<tr>
<td>Offset, Initial</td>
<td>±1mV</td>
</tr>
<tr>
<td>Offset vs Temp</td>
<td>±20µV/°C</td>
</tr>
<tr>
<td>Offset vs Supply</td>
<td>±10µV/%</td>
</tr>
<tr>
<td>Input Voltage Range</td>
<td>±10V</td>
</tr>
<tr>
<td><strong>OUTPUT CHARACTERISTICS</strong></td>
<td></td>
</tr>
<tr>
<td>Output Voltage</td>
<td>±10V @ 5mA</td>
</tr>
<tr>
<td>Capacitance Load</td>
<td>1000pF</td>
</tr>
<tr>
<td><strong>DIGITAL CONTROL LOGIC LEVELS</strong></td>
<td></td>
</tr>
<tr>
<td>(DTL/TTL Compatible)</td>
<td></td>
</tr>
<tr>
<td>(&quot;1&quot;) Sample</td>
<td>+2 to +5.5V @ 15mA</td>
</tr>
<tr>
<td>(&quot;0&quot;) Hold</td>
<td>-0.5 to -0.8V @ 50µA</td>
</tr>
<tr>
<td><strong>POWER REQUIREMENTS</strong></td>
<td></td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>±15V</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>25mA</td>
</tr>
<tr>
<td><strong>TEMPERATURE RANGE</strong></td>
<td></td>
</tr>
<tr>
<td>Operating</td>
<td>0°C to +70°C</td>
</tr>
<tr>
<td>Storage</td>
<td>-55°C to +85°C</td>
</tr>
<tr>
<td><strong>PACKAGE</strong></td>
<td>Module</td>
</tr>
<tr>
<td><strong>DIMENSIONS</strong></td>
<td>1.12&quot; x 2&quot; x 0.4&quot; (28.5mmx50.8mmx10mm)</td>
</tr>
</tbody>
</table>

Specifications subject to change without notice.

---

**OUTLINE DIMENSIONS and PIN CONNECTIONS**

(Dimensions in Inches)

```
0.41 MAX

0.25 MIN

1.15 MAX

1.80

2.03 MAX

0.1 GRID
```

**NOTES:**

1. Pins: 0.019 ±0.001 dia. rodar, gold plated per MIL-G-45204B, Class I, Type II.
2. Grid and markings next to pins are for reference only, and do not appear on unit.
3. Mating socket AC-3100 or pin sockets P/N 2-330808-8 (7 required.

**PIN DESIGNATIONS**

1. ANALOG GROUND
2. -15V
3. +15V
4. N.C.
5. N.C.
6. SIGNAL IN
7. CONTROL IN
8. LOGIC GROUND
9. N.C.
10. N.C.
11. N.C.
12. ANALOG OUTPUT
13. NO PIN
14. N.C.

---

**Figure 1. Simplified Block Diagram, SHA-5**
RC CIRCUIT CHARGING
C = 5000 μF
R<sub>ext</sub> = 10 kΩ
R<sub>int</sub> = 1 MΩ
23 May 94
P. Vredenburg
The dashed channel that overlays the perforations is the time correlation marker.

The most significant bit (MSB), is approx. 1mm in from the opposing perforations.

Bit 8, (LSB), is the dark channel nearest the time correlation mark. It is separated by two channel widths from the other bits.

Note the density change between bits 5, 6, and 7. This aids user readout.

<table>
<thead>
<tr>
<th>BIT</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>128</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

Response = \left( \text{sum of bits} + 1 \right) / 256.

This sample is a record of the potential across a capacitor that is charging.
Sprockets for use with 16mm sound film, perforated on one side only, .300 pitch perforations, per American Standard PH22.12-1964. The film diameters “B” are concentric with the shaft hole “A” within .002 T.I.R. The screw hole has no angular relationship to the sprocket teeth. Material is non-magnetic #303 stainless steel on all except 208B25F and 210B37A.

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>TEETH</th>
<th>&quot;A&quot;</th>
<th>&quot;B&quot;</th>
<th>&quot;C&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>208B25D</td>
<td>8</td>
<td>.2500</td>
<td>.753</td>
<td>9/16</td>
</tr>
<tr>
<td>208B25F*</td>
<td>8</td>
<td>.2500</td>
<td>.753</td>
<td>9/16</td>
</tr>
<tr>
<td>208B31D</td>
<td>8</td>
<td>.3125</td>
<td>.753</td>
<td>9/16</td>
</tr>
<tr>
<td>210B25D</td>
<td>10</td>
<td>.2500</td>
<td>.941</td>
<td>3/4</td>
</tr>
<tr>
<td>210B31D</td>
<td>10</td>
<td>.3125</td>
<td>.941</td>
<td>3/4</td>
</tr>
<tr>
<td>210B37A**</td>
<td>10</td>
<td>.3750</td>
<td>.945</td>
<td>51/64</td>
</tr>
<tr>
<td>210B37D</td>
<td>10</td>
<td>.3750</td>
<td>.941</td>
<td>3/4</td>
</tr>
<tr>
<td>216B31D</td>
<td>16</td>
<td>.3125</td>
<td>1.514-1.21/64</td>
<td></td>
</tr>
<tr>
<td>216B37D</td>
<td>16</td>
<td>.3750</td>
<td>1.514-1.21/64</td>
<td></td>
</tr>
<tr>
<td>216B50D</td>
<td>16</td>
<td>.5000</td>
<td>1.514-1.21/64</td>
<td></td>
</tr>
<tr>
<td>220B31D</td>
<td>20</td>
<td>.3125</td>
<td>1.897-1.45/64</td>
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<tr>
<td>220B37D</td>
<td>20</td>
<td>.3750</td>
<td>1.897-1.45/64</td>
<td></td>
</tr>
<tr>
<td>220B50D</td>
<td>20</td>
<td>.5000</td>
<td>1.897-1.45/64</td>
<td></td>
</tr>
</tbody>
</table>

*Part 208B25F is made from type #416 stainless steel, and has two set screws at 90°.
**Part 210B37A is made from B-1113 C.R.S.

The center drawing on this page describes a group of sprockets for use with 16mm silent film, perforated on both sides, .300 pitch perforations, per American Standard PH22.5-1964.

PART No. 216BF31B
This is a 16-tooth sprocket for 16mm sound film, suitable for use on many types of projectors and other equipment. It is case hardened for best wear life, finished in black oxide prior to grinding of the film diameters for good appearance, and relieved in cross section for light weight. The sprocket is equipped with a special decorative aluminum plug to conceal the end of the sprocket shaft.
MATERIAL: PVC

LENS MOUNT BOARD

P. VREDEBURG · R. NORMAN 8 APRIL 74

DRILL UNDER 3/4
REAM TO FIT LENS BARREL.