High-Speed Intermittent Camera Using Multiple Shuttering of Each Frame

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A new application of an old principle will allow a precision, pin-registration, intermittent camera to record at a rate of 9600 pictures/sec for 2 min. The short exposure times normally associated with high frame rates can be obtained by the intermittent camera at lower frame rates with many impressive advantages. Consideration is given to current design objectives, and to the resultant increases in efficiency and present capabilities. Various applications to engineering problems are discussed. They were also illustrated at the Congress with motion pictures.

With the advent of commercially available high-speed motion-picture cameras, the instrumentation engineer has been given a tool which extends his ability to resolve small intervals of time. As higher frame rates and shorter exposure times provide the means of solving more problems of research and development, the engineer is depending more on photographic instrumentation as a means of observation and measurement.

Detailed analysis of individual frames is often required. It is of prime importance that these frames contain high-definition images with a minimum of motion during exposure.

Usually, higher frame rates are achieved at the expense of a high-definition image. Picture instability, which depends on mechanical and optical synchronization, is a difficult factor to eliminate.

Many times the question should not be, "how many frames/sec can you obtain?" but "how useful are the frames which are available?" Often a few, well-defined frames are more useful than many inferior ones.

Once the acceptable degree of image motion during exposure has been determined, the exposure time required can be simply assessed.

Pin-Registration Cameras

Since motion stopping is a function of exposure time, it should be considered separately and apart from its relationship to high frame rates. In the intermittent camera very short exposure times can be obtained without excessively high frame rates by decreasing the size of the open sector of the rotary disc shutter.

Use of the intermittent-film-transport system in high-frame-rate applications has been limited, owing to physical stresses imposed on moving parts. Traditionally, this type of movement utilized reciprocating actions which would impose high loads and eventually cause fatigue failure in those parts. Vibration was always high when frame rates were increased.

Efficient, accurate data reduction requires that the picture be precisely stabilized. This is possible only by using a pin-registration system to hold the film stationary and precisely located during exposure. This often introduces another reciprocating motion. However, the latest designs utilize balanced rotary or circular motions instead of reciprocating motions and consequently minimize the fatigue problem. Thus a higher frame rate can be attained with greater freedom from vibration, without losing the advantages of precision pin-registration. High-precision pin-registration cameras are currently available which operate at 400 frames/sec and have a film capacity of 1200 ft. There are many instrumentation problems which are better performed by this relatively slow but high-definition recording tool. A few recent uses of pin-registration cameras are given below.

(1) A record was made of a baseball player's race into home base on a close play.

(2) The Chrysler Corp. utilized pin-registration cameras during an evaluation program on a TV reconnaissance capsule. This capsule was installed in the warhead of a Redstone missile and ejected at an altitude of 50 miles. The ejection mechanism was observed at 400 frames/sec.

(3) MacDonnell Aircraft Corp. has used pin-registered intermittent cameras on many flight test programs; for example, to study the operation of a tail hook in an arresting gear hookup.

(4) A requirement for a higher frame rate plus extended observation time exists in studying nose cone ablation under plasma jet forces.

(5) The B-70 escape capsule is undergoing stability studies by North American Aircraft, Inc. High over Edwards Air Force Base, the capsule is ejected from a B-47 aircraft. Cameras studying the action of the mechanism and its flight characteristics require maximum picture stability and definition for extended times at −89 F and under high vibration. Compactness and reliability are essential. Tumbling occurring early in the trials was studied and later corrected.

(6) Detailed surveillance is required of the mechanisms which support and release the Atlas missile during its launch phase at Vandenberg Air Force Base. The rugged environments of shock, vibration, flying particles and heat are all present. Yet the pin-registration intermittent cameras provide high-definition observation for an extended time at elevated frame rates.

Multiple Shuttering

Many subjects lend themselves to other specialized techniques for increasing the sampling rate in the intermittent system.

Subjects which are of well-defined contrast, preferably a light-colored subject against a dark background, are most suitable for use of the "incremental shutter" techniques. Explosions, fragmentation, projectiles and well-defined shock-wave formations can be recorded at rates as high at 9600 exposures/sec.

This "incremental shutter" is a new application of an

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old principle and consists of a rotary shutter containing a series of sectors which will expose a series of images on each frame. This method increases the sampling rate by a factor equal to the number of sectors/cycle.

For example, a local sampling rate of 9600/sec can be obtained by using a shutter having 12 open sectors of 3° separated by opaque segments of 12°, rotating at 400 cps. Film transport in this system requires 180°. This means that 400 series of 12 samples/sec will be taken. There will also be 400 blank periods/sec. If two cameras equipped identically were driven at the same speed and were 180° out of phase, they would record 9600 samples/sec continuously for 2 min.

This is an adaptation of the old principle of multiple exposure upon a single piece of film. Displacements can be accurately plotted against the known time increments without appreciable loss of the intermittent camera's characteristically high-definition image.

The same net result could be obtained with subjects which could be illuminated by a high-frequency repeating strobe source, which also would place multiple images on the same frame.

The modern, precision intermittent camera provides an efficient means of high-speed recording of a high resolution of information. It is apparent that certain advantages are to be realized with this method:

(1) Observation time can be extended to 2 min at 400 frames/sec through the use of external 1200-ft-capacity film magazines.

(2) Motion stopping capability is high since short exposure times can be attained by decreasing the size of the open shutter sector, without relying on high frame rates which involve high film consumption.

(3) The definition of small detail is enhanced by the use of precision camera objectives, unencumbered with image-motion compensation prisms or imperfectly synchronized opto-mechanical elements.

(4) Image-placement accuracy and stability are excellent, owing to precision pin-registration which assures the exact location and securing of the film during exposure. Accurate data readout is greatly simplified by this facility.

(5) Synchronization equipment requirements are greatly simplified by shorter acceleration times, straightforward power requirements and longer run times.

(6) Economical operation is the net result of combining the foregoing elements. Setup and reload times are minimized by large film capacity and simplicity of operation; materials consumed are smaller; processing is less costly; engineering time for analysis and data readout is less; and the photographic record itself is one of accuracy and high definition.

When a requirement exists for superior resolution, engineers will repeatedly rely on that efficient "work horse" of the profession, the precision, intermittent camera with pin-registration accuracy.