

# A Realtime Pin-Registered TeleScanner

By Edmund M. DiGiulio and James M. Bartell

*From the very earliest days of television, the industry has employed telecine machines to transfer program material from film into the video realm. In recent years we have seen the emergence of film scanners intended to serve a slightly different purpose. This paper describes a TeleScanner with the high-precision pin registration of a film scanner that operates at telecine machine speeds.*

Telecine machines are always used to transfer film into a standard television format, be it NTSC, PAL, or high-definition television (HDTV). The machines operate in realtime. The film transport is continuously moving, and recording is accomplished either by means of a flying spot scanner or a line array charge-coupled device (CCD). An important feature of these machines is their ability to move the film in fast-forward or reverse mode at slow speeds up to 10 times the normal frame rate.

Image steadiness on telecine machines is good for normal transfers, but unacceptable when critical superimposition matting has to be done. To overcome this difficulty, after-market suppliers have come up with pin-registered transport mechanisms that can be mounted on the telecine machines. These devices provide adequate registration accuracy for video effects applications, but require that the machine become an intermittent rather than continuous motion device. In this mode the transfer rate capability is reduced to ~2 frames/sec.

Film scanners are intended for scanning film into the high-resolution digital realm. They generally employ an intermittent film transport mechanism with pin registration. Images are captured by a full-frame CCD chip or a line array CCD that moves slowly across the frame. In either case the image capture rate is usually no

greater than several seconds per frame. The transfer rate is a function of the degree of resolution desired. The rate at which the data can be processed becomes the limiting speed factor. Because of the purely mechanical intermittent transport mechanisms employed, these devices are not capable of fast slew modes. The digital output from the scanner can then be manipulated for all types of post-production requirements and can also be downconverted to any of the standard television formats for normal television distribution.

In place of the conventional pin-registered mechanical camera-type movement that other scanners typically use, which are limited in speed to not much more than cine rate, the present device uses a low-inertia, high-torque DC motor, electronically controlled to advance the film (Fig. 1). This same technology was used by Cinema Products to manufacture one hundred 70mm projectors for the Showscan Film Corp.

The application is unique because precise pin registration has been added and operation of the register pins is not in mechanical linkage to the pull-down mechanism. Instead, it is, controlled electromechanically using an exotic but highly reliable actuating technology (Fig. 2). This approach provides all the advantages of high-precision pin registration for precise film scanning and still has the complete flexibility offered by a continuous motion telecine, because the device is capable of fast-forward and reverse slew modes at extremely high speed. For this reason we have categorized it as a TeleScanner. Pulldown and registration take <8 msec, allow-

ing adequate time for full image capture. Intermittent operation is from stop-motion to 60 frames/sec, forward or reverse.

It should be noted that precise pin registration is of critical importance when capturing images in the digital realm. Subsequent processing of the digital data will inevitably involve compression at some stage. A key feature of the MPEG-2 algorithm used for this process permits the amount of data being transmitted to be dramatically reduced by taking advantage of the fact that imagery in subsequent frames that does not change need not be redundantly transmitted. It is clear, therefore, that any frame-to-frame image variation caused by imprecise registration of those frames during scanning will work against the ability to compress data as much as desired and result in image degradation or lower compression ratios at the output.

There have been a multitude of sins committed in the name of "pin registration." The original Mitchell concept, which has been adopted as an industry standard, provided for a full fitting pin to be installed in the camera at the first perforation preceding the frame in the aperture on the inboard side. The outboard pin is full fitting in the vertical direction, but undersized in the horizontal direction to allow for film shrinkage.

There have been occasions where sound cameras have reduced the "full fitting" dimensions ever so slightly to make the cameras quieter. Telecines or scanners will often engage the correct register pin holes, except that they are full frame displaced from the aperture to allow adequate optical clearance.

The present machine's full fitting pins engage the correct perforations for precise registration accuracy,  $\pm 0.0002$  in. They are programmed to penetrate to two different depths, the first step for negative-type perforations that are 0.073 in. high and the second for print-style perfs that are 0.078 in. high.

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## A REALTIME PIN-REGISTERED TELESCANNER

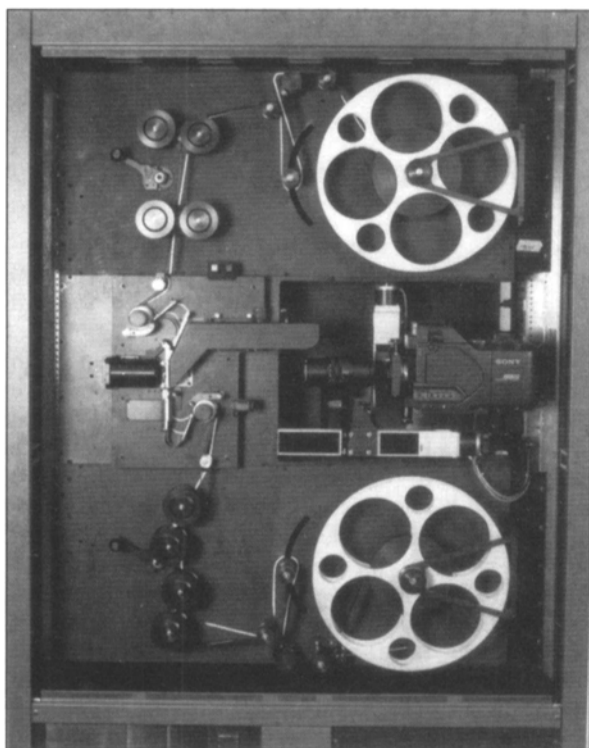


Figure 1. Overall view of TeleScanner with covers removed.

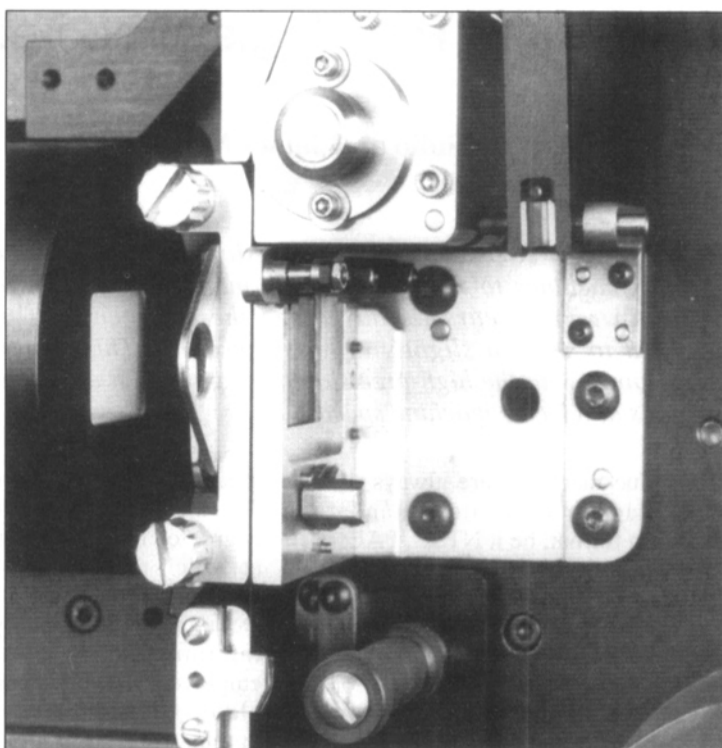


Figure 2. Gate assembly showing pulldown sprocket housing above register pins and pin actuator arm to the right.

### Modes of Operation

The film transport is capable of operating in several modes: high-speed slew, variable speed intermittent (cine), and pin-registered intermittent. High-speed slew is for fast-forward/rewind operations and runs at 150 frames/sec. The transport is capable of reversing from 150 frames/sec forward to 150 frames/sec reverse in <10 sec.

In intermittent mode, the transport can operate at fixed speeds of 24, 25, or 30 frames/sec and variable (jog or shuttle) from 1 to 60 frames/sec, forward or reverse. This allows the unit to function as a transfer machine (at a constant speed), or an editing table or color timing station (in jog or shuttle).

Pin-registered intermittent mode is available in forward mode only at any of the three fixed speeds. Transition between modes may be made directly without having to stop and restart. For instance, when running at a fixed forward speed, the register pins may be turned on or off instantaneously at the touch of a button.

From intermittent mode, the unit may go directly into high-speed slew and back into intermittent mode. The only delay encountered would be the few seconds necessary for acceleration

or deceleration of the take-up and supply reels. When moving at variable frame rates (shuttling), the transport will automatically switch from cine to slew mode once the maximum cine speed has been exceeded, and back to cine once the frame rate has been reduced.

Pulldown is accomplished via a sprocket attached to a high-torque, low-inertia motor. In cine mode operation, the pulldown motor moves with a trapezoidal velocity profile, accelerating from a stopped position very quickly and then decelerating to a stop after 90° of movement in < 7 msec. This pulldown time remains constant regardless of frame rate, which allows the dwell time to increase substantially at lower frame rates versus a purely mechanical mechanism. In slew mode, the motor moves continuously in a manner similar to a normal servo motor.

### Control System

The film transport control system is a distributed system consisting of three major subsystems: motor control, communication, and register pin drive (Fig. 3). The motor control subsystem is similar to an electronic pro-

jector control system with substantial control modifications to allow greater flexibility in operating modes. The communication subsystem allows for a multiplicity of high-speed communication protocols to be supported without burdening the motor control system processor. The register pin drive is a simple timing/voltage control system capable of driving the pins to two different depths depending on which perforation size is desired.

The advantages of the electronic projector approach are numerous. They include great variability in operating modes as well as a proven record of use in the field. By coupling the supply, take-up, constant velocity, and pulldown motors electronically instead of mechanically, many different modes of operation are possible. For instance, the pulldown motor is operated intermittently in cine mode for transfer, and continuously in slew mode for fast-forward or rewind.

A microprocessor controller, coupled with a combination of analog and digital control loops, is used to implement the various control subsystems (Fig. 4). This approach allows new modes of operation to be added by changing software without necessitat-

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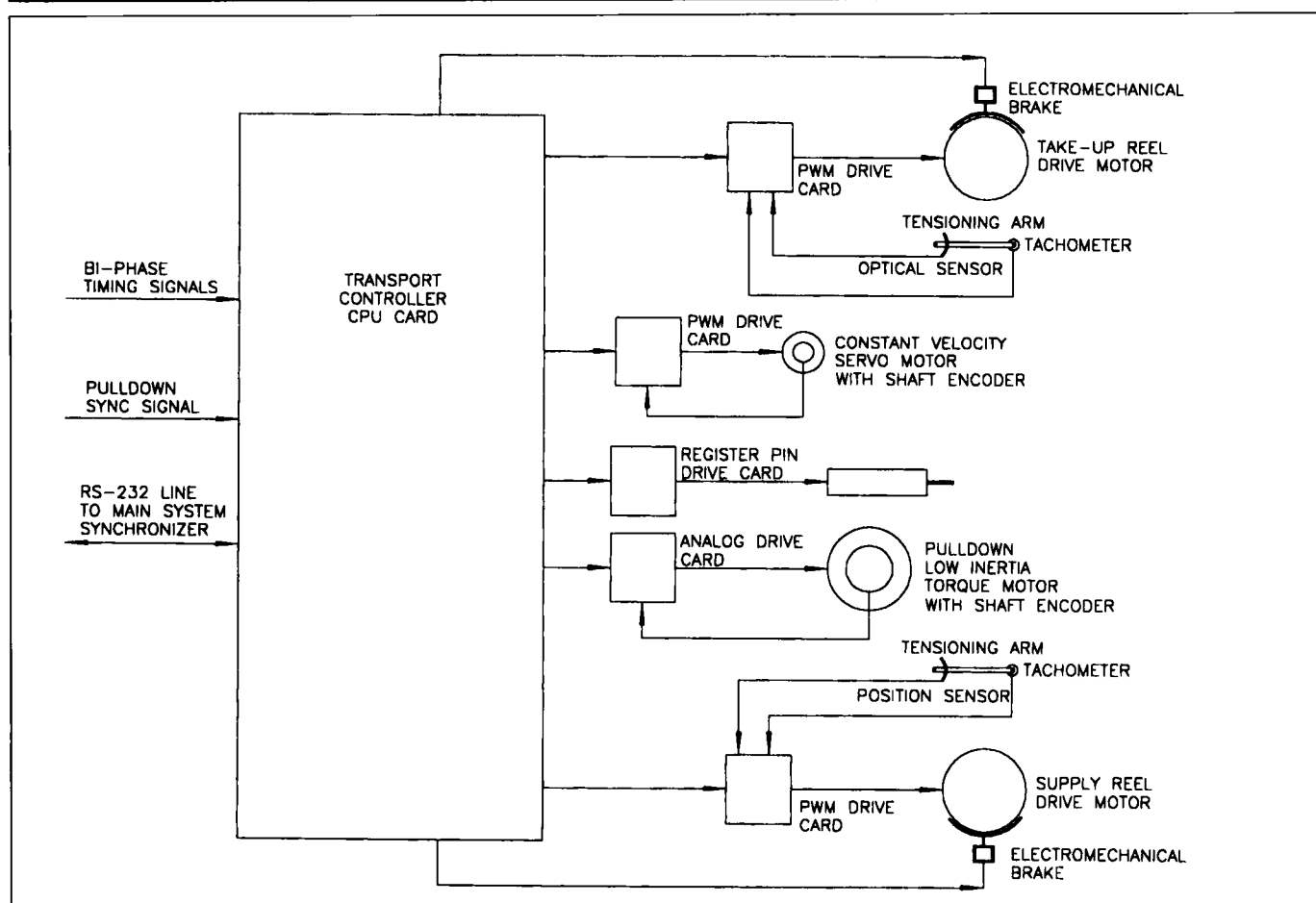


Figure 3. Transport control system block diagram.

ing a hardware redesign. This permits us to tailor the unit's operation to the customers exact requirements, while taking advantage of proven designs for precise motion control.

A variety of sensing techniques is used for each subsystem according to the specific requirements. The supply and take-up servo motors are controlled via analog tachometers as well as tension arm position sensors, providing speed and tension control. The constant velocity and pulldown motors use optical tachometers specifically designed to allow precise and controllable motion in both continuous and intermittent modes of operation. The pulldown motor uses a more sophisticated analog driver to provide more precise position control. Although the control loops in and of themselves are relatively simple, controlling them via a microprocessor allows each to be

independently operated according to the desired operation. For instance, the supply and take-up motors operate in a speed control mode during slew operations and in position control mode during frame-by-frame modes.

The communication subsystem handles all communication between the motor control subsystem, the register pin drive system, and the external world. Removing the burden for these tasks from the motor control system allows it to concentrate on the realtime motor control operations, while permitting high-speed, realtime communication with external controllers. Also, a multiplicity of communication protocols can be supported without fear of burdening the motor controllers.

Integration of other subsystems, such as lens and camera position control, are handled through this system. By isolating all internal and external communications through this one system, expansion and modification of the systems capabilities can be per-

formed without affecting the operation of other subsystems.

The register pin drive consists of a voltage waveform generator capable of generating two different waveforms, depending on which section of the tapered register pin is being used, as required by the different perforations. The different sections of the pin are engaged by driving the pins to two different depths. The different waveforms are generated by a combination of variable timing and variable voltage levels. This allows the same engagement and retraction times to be achieved for both drive operations. Solid-state relays and remotely programmable power supplies are used to provide the fast switching times and variable voltages necessary. The pins can be extended in <math><1.5\text{ msec}</math> and retracted in the same amount of time.

### Multi-axis Stages

Both the lens and high-definition video camera are mounted on 3-axis stages to allow for varying focus,

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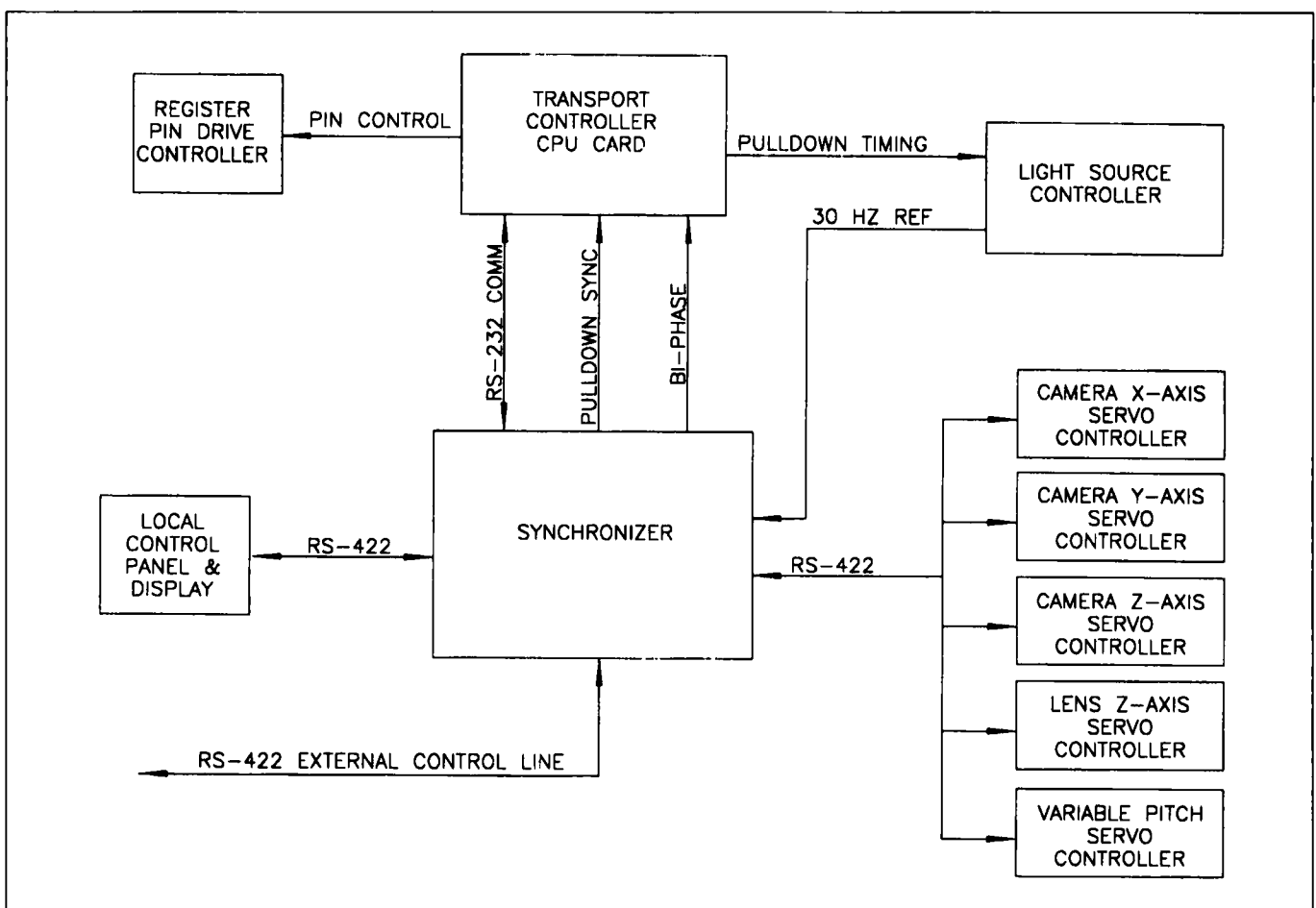


Figure 4. Main control system block diagram.

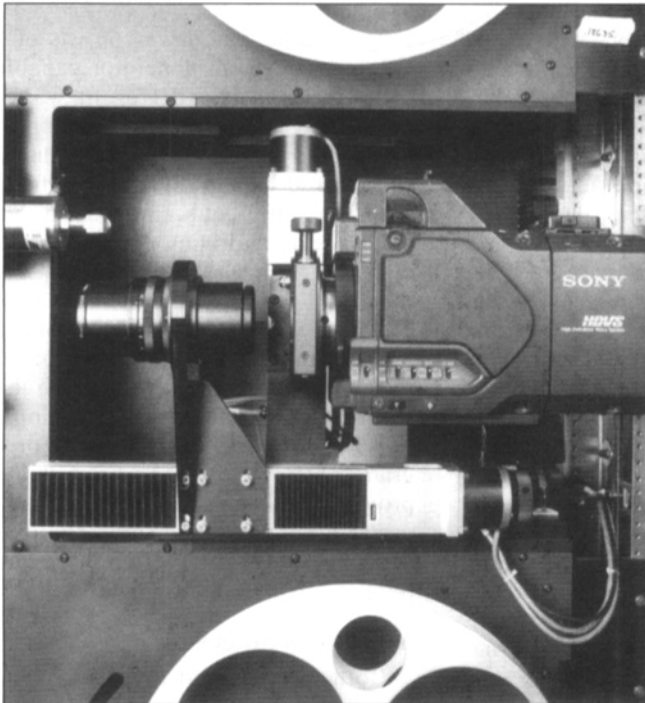


Figure 5. Lens and camera mounted on 3-axis actuator stages.

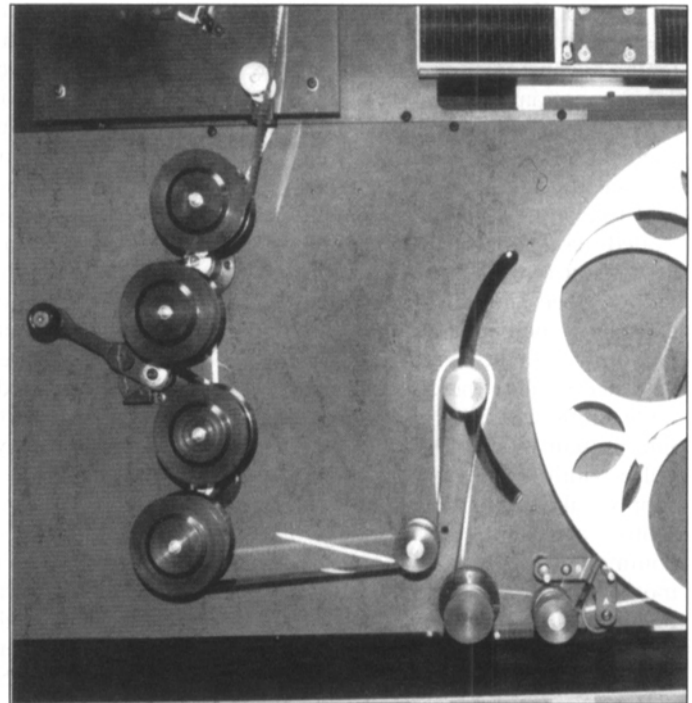


Figure 6. Supply side particle transfer rollers.

magnification, and centering, according to the format being transferred (Fig. 5). The stages are directed by a series of independent controllers, one for each axis, that are controlled by commands from the communication subsystem over an RS-422 serial data link. Each stage section has optical limit switches and homing sensors, providing a resolution and repeatability of 0.0002 in.

### Variable Pitch Mechanism

To compensate for the variation in pitch encountered in film stock of varying age, which can range from +0.0002 to -0.0006 in. from standard, a variable pitch mechanism has been provided. This mechanism consists of a linear actuator, which varies the position of the optical detector on the pulldown motor to control where the motor comes to a stop. This variation in stopping position is used to align the perforations with the register pin position before pin insertion. The pitch for each roll of film is determined by premeasuring a 100-perforation long section of each roll of film before threading.

### Particle Rollers

Dust particles have a tendency to cling to film, especially on the emulsion side. If these particles are allowed to build up on the stationary portions of the film gate structure that come into contact with the film, they can, if hard enough, cause scratches. To reduce the risk of scratching, a series of eight particle transfer rollers, four before the gate and four after, have been provided to remove dust particles (Fig. 6).

To make threading easy while providing at least 180° of wrap on each roller, the rollers rotate 90°, in pairs, to provide a straight-through threading path. The rollers are then rotated, via a lever, to provide a serpentine path maximizing contact between the rollers and the film.

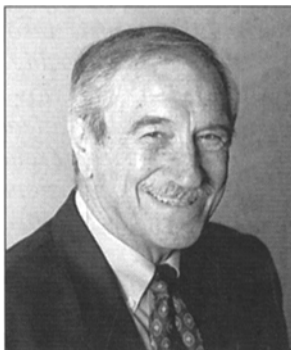
### Image Capture and Light Source

For the initial development of this machine, the video image capture device used is a Sony HDC-500 color high-definition video camera, with a provision to replace it with an HDC-

750 camera at a later date. The light source is a proprietary, electronically shuttered additive light source developed by Sony Pictures High Definition Center. The light source shutter is synchronized to the video

camera as is the pulldown of the film transport. A clean 24/30 frame transfer is accomplished by having the dwell time for the 2-field capture be shorter than the dwell time for the subsequent 3-field capture.

## THE AUTHORS



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**Edmund DiGiulio** is founder, vice-chairman, and director of research and development of Cinema Products Corp. He earned a BSEE from Columbia University in 1950 and an MS degree from UCLA in 1966.

DiGiulio spent the first decade of his career in the computer and aerospace industries, and in 1960, he applied his inventive talent to the development of the Craig Reader teaching machine. This project involved him in film and optics research and led him to the motion picture industry.

He joined Mitchell Camera, where he became vice-president of engineering and from there founded Cinema Products Corp. in 1968. Cinema Products has received several Academy Awards for scientific and technical achievement in professional motion picture camera design and engineering.

DiGiulio is the author of several scientific papers and is a well-known lecturer, having appeared frequently at technical conferences and symposiums in the U.S. and overseas. He holds numerous patents in computer and cinema technology.

DiGiulio is a Fellow of SMPTE. He

has served as Governor for the Hollywood region; Director of Engineering, Motion Pictures; and Chairman of the Sustaining Membership Committee.

He is also a Fellow of the BKSTS and an associate member of the ASC. In addition, DiGiulio is a member of AMPAS and currently serves as chairman of its Scientific and Technical Awards Committee.

**James Bartell** received a BSEE from the University of Michigan in Ann Arbor in 1979. After working for various firms, in aerospace and manufacturing, he joined Cinema Products Corp. in 1990 as director of electrical engineering. While there, he worked on the design of several Steadicams, wireless lens control systems, bar code readers, high-resolution videotaps, and intelligent batteries and chargers. He was project engineer for the development of the High Definition TeleScanner.

In 1997 he left Cinema Products and established BarTech Engineering, a manufacturing and consulting firm specializing in providing custom electronics for the film and television industries.