Design and Use of a Computer Controlled Movie Camera Facility

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1. Introduction

The purpose of this report is to explain the motivation behind, design, and use of the movie production facilities available in the COINS Department at the University of Massachusetts. This document discusses the software available to the user as well as the hardware developed to aid in the implementation of the system. Figure 1.1 shows the camera, drive unit, and associated equipment as it appears in a special case. The purpose of such a system is to facilitate the production of high quality 16mm films from computer generated images. Animation will be used as a medium for effectively presenting simulation and graphical data. The hardware includes a motor driven movie camera and the interface between the camera and the computer. The software consists of control programs and special purpose subroutines designed to coordinate the displaying of images and the camera shutter control. Also, the MOVIE BYU interactive graphics system has been modified to include film making. The system as described in this report has been implemented on a VAX 11/780 computer with a Grinnell graphics processor and a high resolution color monitor.

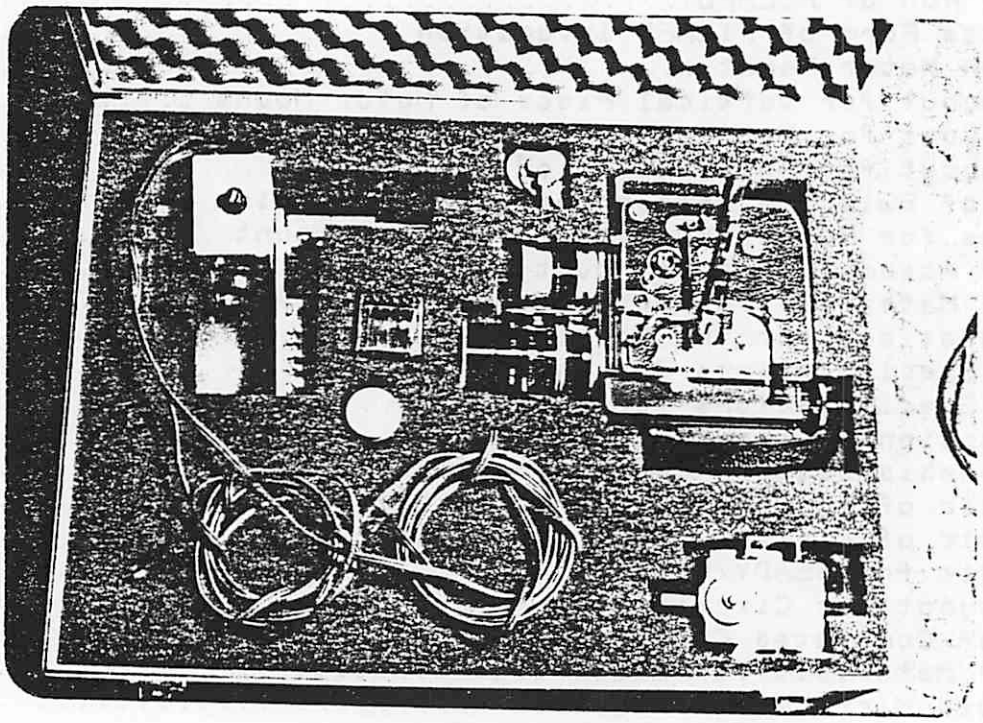

Figure 1.1
Camera and Drive Unit in Case

Camera:

After discussions with several animators at the 1979 SIGGRAPH conference and with the investigators providing the funds at UMass, it was determined that commercially available cameras suitable for

producing films from computer generated images were financially out of the reach of this department. This is due to the strict, rather uncommon photographic requirements imposed by display devices.

The display to be used refreshes the image at a rate of 30 times per second. Shutter speed tests have shown that an exposure duration of between 1/4 and 1/2 second is needed to eliminate the phenomenon of "banding". Also, the amount of light emitted by the displays requires the use of either a "long" (relative to normal photography) exposure duration or the use of inordinately high speed film. As a film is pushed in regard to its speed, the resolution decreases. It is therefore desirable to choose a long exposure duration as opposed to pushing the film.

The use of computer generated images imposes another constraint upon the equipment. An animation sequence is composed of a series of images produced by the machine. Any two consecutive images are similar enough to one another that, when viewed at a reasonable rate (16-24 f.p.s.), the illusion of pure motion is perceived. It is typically beyond the capability of graphics systems and those who use them to produce such sequences in real time. It therefore becomes necessary to produce a single image, photograph the image, advance the film, and then repeat the cycle. This technique, known as "single-framing", implies that the camera must be capable of exposing frames one at a time.

The large number of images involved in an animation sequence presents a third requirement. Animation is typically used to present data produced by simulations of models. In this case, the data and the images representing the data are produced by the computer with little intervention from humans. The best of all possible worlds would have the computer control the camera as well. Thus we see that the camera must fulfill three requirements:

1) It must be capable of consistently exposing frames for a duration of between 1/4 and 1/2 second.

2) It must be capable of exposing a single frame.

3) Actuation of the shutter must be electronically controllable by the computer.

Camera Control:

Readily available 16mm cameras, e.g. Bolex, Beaulieu, Eumig, etc., do allow single frame exposure. However, when in the stop frame mode of operation, one of two default conditions governs the shutter speed. In one case, the exposure duration defaults to a predetermined value, usually 1/40 second, which is too short for our usage by at least one order of magnitude. This results in severe banding in the film. Alternately, the exposure duration is governed solely by the mechanical depression and release of the shutter

actuator. In this case, accurate control of the exposure is impossible.

The solution proposed in this project involves modification of a readily available 16mm movie camera. The Bolex line is designed so that the shutter may be driven externally. The models recommended by animators using such a scheme include the "H16" and "Reflex" series. The reflex, or RX, models have the added ability of viewing the image as it will appear on the film without altering the configuration of the lens turret. Within this series are models 1 through 5. The top model, 5, has the capability of accepting a 400' film magazine and has predrilled and threaded motor mounting holes.

Control of the shutter and film advance is provided by a Superior Electric Slo-Syn synchronous motor. The motor to be used has a speed of 72 rpm when run on 120 VAC at 60 Hz. This, coupled with a shutter opening of 135 degrees, yields an exposure duration of 5/16 second, which is well within the requirement stated earlier. The motor is switched on with a digital relay triggered by the computer. A microswitch controlled by a cam affixed to the rotor shaft of the motor maintains the "ON" state until one revolution has been completed.

The following sections describe, in detail, the camera, software, drive unit, and available 16mm films.

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2. Camera

This section in intended to familiarize the user with the movie camera. All of the subsections should be understood prior to using the camera. They begin with a brief introduction to the various parts of the camera, continue with detailed discussions of its operation, and end with subsections concerning fault diagnosis and care of the camera.

The bulk of the written material and photographs contained within this section was taken from the Bolex H16 RX-5 instruction manual. The manual and photographs were supplied by Bolex USA whose cooperation and assistance the author wishes to gratefully acknowledge. The text has been amended in order to elucidate details relevant to the use of the camera for computer animation.

2.1 Explanation of Parts

This section provides the user with a brief understanding of the parts of the camera and lens system. The camera is a Bolex model H16 RX-5 equipped with a three lens turret holding Switar lenses with focal lengths of 10, 26, and 75mm. For general purpose photography a wide choice of lenses is desired. However, only one is needed when photographing from a monitor. There are several criteria for choosing a lens, and these are discussed in greater detail in Section 2.7. Briefly, the greater the focal length of a lens, the farther from the object the camera must be placed. Also, a long focal length tends to introduce less distortion along the periphery of the image. Figures 2.1, 2.2, and 2.3 show various views of the camera with the parts labelled as per the captions.

2.2 Viewfinder

The optical system of the H16 RX-5 camera allows through-the-lens viewing during filming as well as when the camera is not running. The picture formed on the ground glass of the reflex prism is completely free from flicker. The reflex viewfinder (part #4 in Figure 2.1) enables framing and accurate focusing. In addition, it enables one to estimate the depth-of-field, to check on the filter being used, and to evaluate the illumination of the scene.

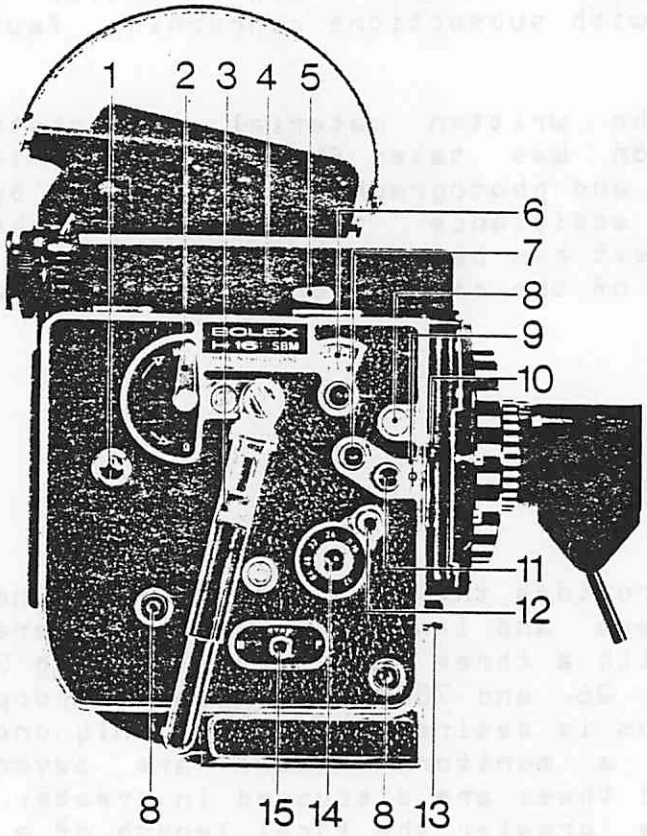


Figure 2.1
Right Side of Camera Body

1. Footage counter
2. Lever for disengaging spring drive
3. Spring drive winding handle -- spring run: 28 sec. @ 24 f.p.s.
4. Reflex viewfinder
5. Viewfinder closing lever
6. Frame counter
7. Shaft for rewind crank
8. Threaded mounting holes for accessories
9. Film plane guide mark
10. Variable shutter dial and control lever
11. Drive shaft for special drive unit
12. Exposure control knob: (I) for Instantaneous or (T) for Time Exposure
13. Front release for normal running
14. Film speed selection knob
15. side release for normal running: continuous (M), single frame exposure (P)

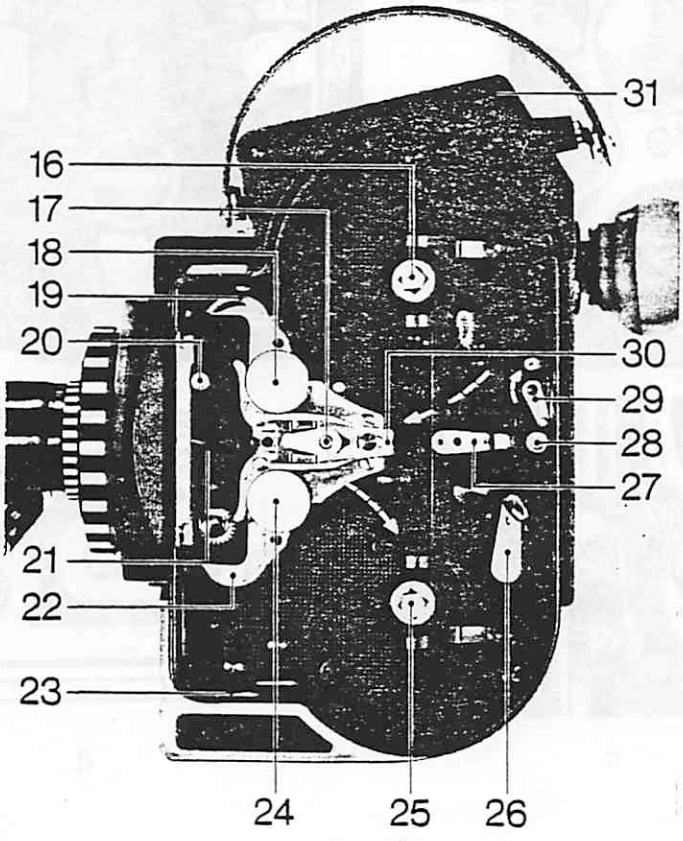


Figure 2.2
Left Side of Camera Body with Cover Removed

16. Upper spool shaft for feed spool
17. Loop former locking lever and opening knob
18. Upper sprocket
19. Upper loop former
20. Pressure pad locking pin
21. Pressure pad
22. Lower loop former
23. Film knife
24. Lower sprocket
25. Lower spool shaft for take-up spool
26. Retaining arm
27. Spool ejector
28. Feet setting on footage counter
29. Lever for suppressing audible signal
30. Knob for opening loop formers
31. Saddle for 400' film magazine

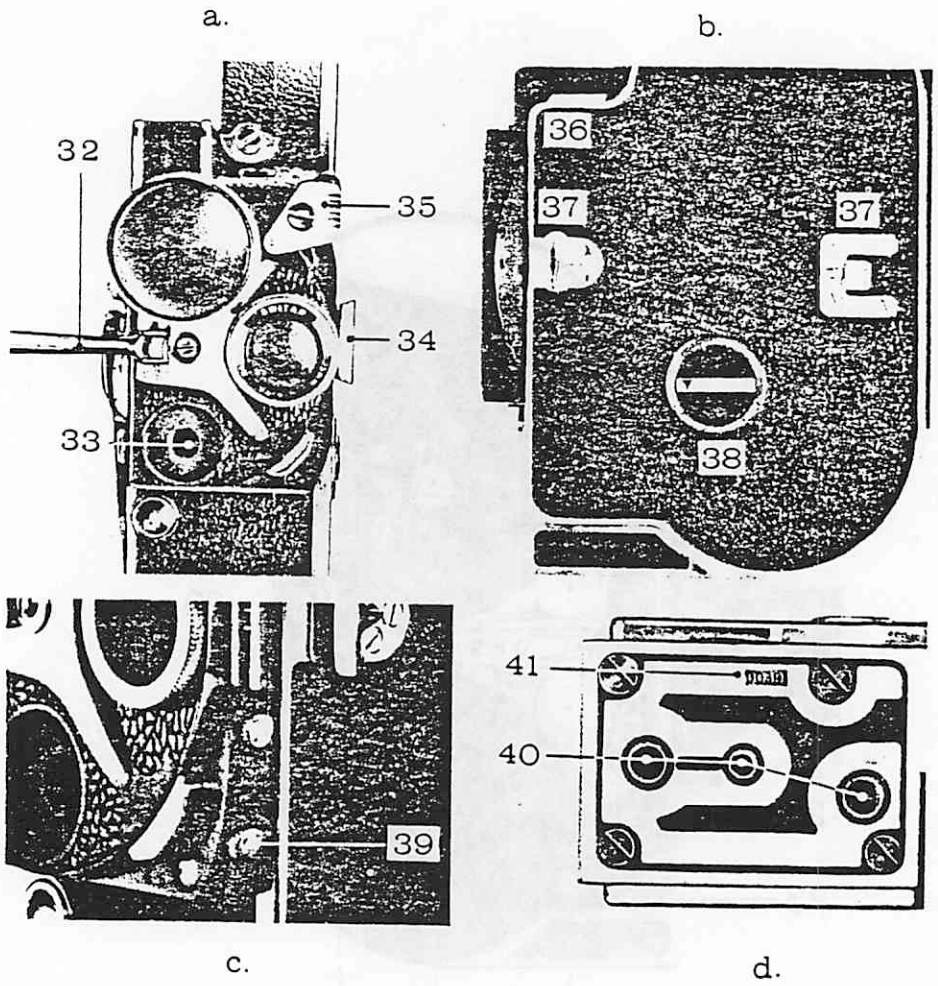


Figure 2.3
Camera body: a. front, b. cover, c. turret, d. bottom

32. Turret lever
33. Hole for turret locking plug
34. Gelatin filter-holder
35. Turret locking clamp
36. Exposure meter shoe
37. Auxiliary multifocal viewfinder attachment
38. Cover opening knob
39. Cover for clapstick lamp
40. 1/4 and 3/8" thread for mounting camera
41. Serial number

The reflex prism (see Figure 2.14) reflects an average of 25% of the light passing through the lens into the viewfinder. This factor has been taken into account in the table of exposures given in Section 2.8.

The viewfinder has been designed in such a manner that the eye piece may be adjusted to the vision of the user. This adjustment adapts the viewfinder to the operator's eyesight, whether or not glasses are being worn, and remains the same for all lenses used on the camera. It is advisable to check this adjustment from time to time. The steps required to adjust the eyepiece are as follows:

1) Rotate the turret until the prism is uncovered.

2) Loosen the milled eyepiece locking ring.

3) Point the camera at a well lighted subject (sky, white wall, etc.)

4) Turn the adjusting ring of the eyepiece until the grain of the ground glass appears perfectly sharp.

5) Tighten the locking ring.

When this adjustment is correct, a subject at infinity should appear perfectly sharp at full aperture, with the distance setting ring on the lens set to infinity.

If the reflex viewfinder is not used during filming, close it by moving the small lever (part #5 in Figure 2.1) into a vertical position. If it is left open, there is a risk of sunlight or artificial light from behind the camera entering the viewfinder eyepiece and fogging the film.

Focusing the camera is extremely simple since the viewfinder allows the user to see exactly what will appear on the film. To properly focus the camera, open the diaphragm on the lens to its widest position, smallest f-stop number, and then turn the distance setting ring until the image is in sharp focus on the ground glass. Close the diaphragm to the proper setting prior to exposing any film.

2.3 Winding and Film Speed

The Bolex camera uses a spring to operate both the shutter and film transport mechanisms. When using the special motor drive unit, the spring must be disengaged. This section discusses the spring driven operation in the event that the camera should be used in its normal mode of operation. Use of the special motor drive is discussed in Section 4.5. In order to wind the spring, the side release (part #15 in Figure 2.1) must be moved to the STOP position and the spring disengaging lever (part #2 in Figure 2.1) to MOT. Lift the spring winding handle (part #3 in Figure 2.1) which

automatically engages with the spindle, and turn counterclockwise. Wind the spring fully but without forcing it, then lower the handle and secure it on the catch labelled "a" in Figure 2.4. Otherwise, there is a risk that the handle will turn during filming.

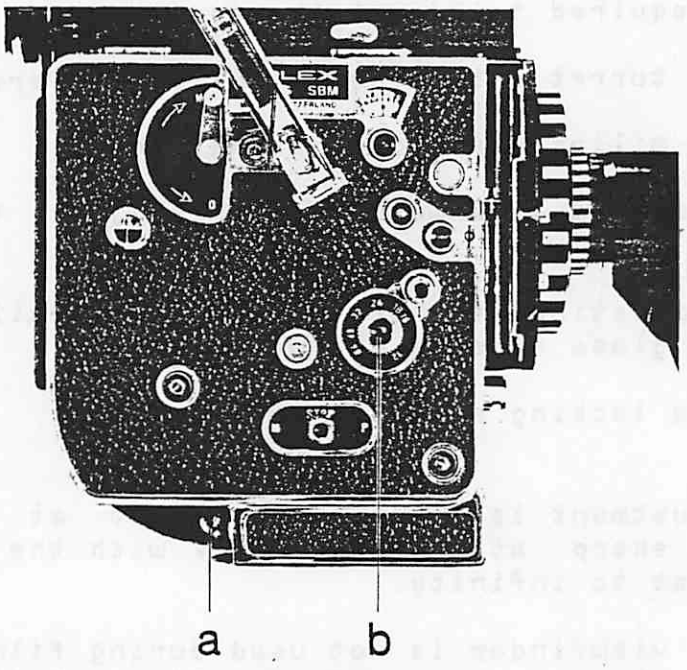


Figure 2.4
Winding

When fully wound, the spring drives nearly 18 feet of film, i.e. 28 seconds of filming at a speed of 24 f.p.s. Make a habit of winding after each take, regardless of how much power is still in reserve.

The camera has seven continuous filming speeds: 12, 16, 18, 24, 32, 48, and 64 frames per second. To select the desired speed, turn the control knob "b" until the corresponding figure is opposite the red dot. When the film is projected at normal speed, 18 or 24 f.p.s., a lower filming speed will produce an accelerated motion effect while a higher filming speed will give a slow motion effect. When changing filming speeds, do not forget to alter the f-stop setting. When changing from 24 to 32 f.p.s., the diaphragm should be opened half a stop, from 24 to 48 f.p.s. by a whole stop, and from 24 to 64 f.p.s. by 1 1/2 stops (see Figure 2.12a).

IMPORTANT!!: When the camera is not loaded, it must not be run at speeds over 24 f.p.s. since this could damage the mechanism.

The camera can be used for normal, continuous, or single-frame filming. These different operations are controlled by the side release (part #15 in Figure 2.1). Normal filming is suitable for

most general shots. The camera runs as long as the operator depresses the front release button (part #13 in Figure 2.1) or pushes the side release toward M. For maximum stability when the camera is mounted on a tripod, it is advisable to use a cable release which attaches, by means of an adapter, onto the side release knob. Single-frame operation may be accomplished in two ways. First, pushing the side release button to P and then releasing it causes exactly one frame to be exposed. Turning the exposure control knob (part #12 in Figure 2.1) to the position marked I causes the exposure to be instantaneous (see Figure 2.12a for the precise duration). With the control knob in the position marked T, the shutter remains open as long as the button is depressed. Alternately, the special motor drive unit may be used. Here, a single frame may be triggered by either the computer or by depressing the shutter release button on the top of the circuit box. This results in consistent exposures of a duration longer than provided by the 1 setting above. The table in figure 2.12a contains the exact duration. Further discussion of the special motor drive is reserved for Section 4.

The mechanism of the H16 RX-5 camera can operate in reverse as well as forward by means of either a small auxiliary crank or the special motor drive. The spool can thus be fully rewound and a partially exposed film removed from the camera. This is particularly useful for special effects, such as lap dissolves, double exposures, and trick effects. The steps involved for rewinding the film are given below. The references are to Figure 2.5. It is very important that steps 1, 2, and 3 be followed exactly when using the motor drive. Elimination of either steps 1 or 2 when driving the camera with the motor may result in serious damage to the camera.

1) Disengage the spring by moving lever (1) to O. If you feel a slight resistance towards the end, <u>do not force</u> the lever but press the front release while continuing to move the lever.

2) Move the side release lever to M, continuous filming.

3) Close the variable shutter, see section 2.8, by lowering lever (3) so as to prevent fogging of the film.

4) Turn the hand crank (4) in the direction of the engraved arrow but do not try to rewind the film faster than allowed by the governor. When using the motor drive, move the direction switch on the circuit box to REVERSE and depress the button on the top of the circuit box once for each frame rewound.

To resume normal spring driven operation, move the side release to STOP and the disengaging lever to MOT. When using the special motor drive unit, simply move the direction switch on the side of the circuit box to FORWARD.

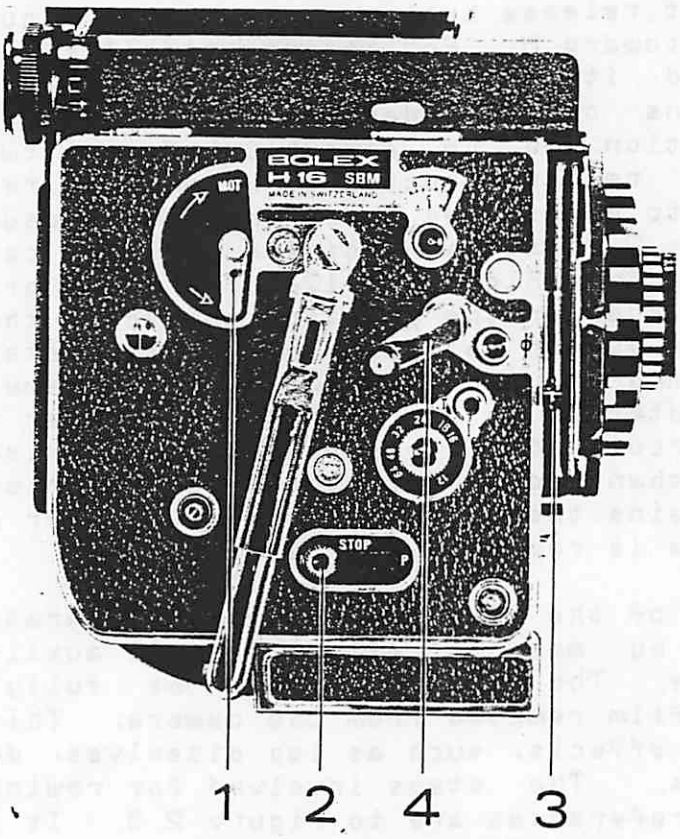


Figure 2.5
Rewinding

2.4 Film Handling Capabilities

The H16 RX-5 camera takes 50 or 100 foot spools of single or double perforated 16mm film. When the camera is equipped with a 400' film magazine, it will accept 200' films on spool or 400' films on core. Films with a single row of perforations are used when a magnetic track is to be added to the original film.

At each extremity of the film there is usually a leader, approximately 6 feet at the beginning and 3 feet at the end, to prevent the sensitive film from being exposed to light during loading or unloading. These leaders are usually removed by the processing laboratories.

Black-and-white and color films come in various sensitivities,

which are expressed in ASA or DIN degrees and indicated on the instruction leaflet accompanying each film. The date before which the film should be exposed is normally stamped on the film pack. The life of the film may be extended to some degree by refrigerating the film when not being used. Unprocessed 16mm film is available with a magnetic strip for sound recording. It is advised, however, that this film be avoided since the magnetic layer can cause premature wear on the parts which come into contact with it, particularly the pressure pad, and metal particles may find their way into the camera mechanism. More complete information regarding available films, packaging, and storage is given in Section 5.

The projection times for various lengths of film run at different speeds is given in Figure 2.6. More complete information may be found in publication (1.) given in Appendix B. Normal 16mm film contains 40 frames per foot.

f.p.s.	12	18	24	32	48	64
1m (~3ft)	0:10.9min	0:07.3	0:05.5	0:04.1	0:02.7	0:02
15m (~50ft)	2:44	1:49	1:22	1:01	0:41	0:30
30m (~100ft)	5:28	3:38	2:44	2:03	1:22	1:01

Figure 2.6
Film Running Times: Film Length vs. Speed

2.5 Loading and Unloading

Now that the basic features and operation of the camera have been explained, the next step is to outline the procedure employed for loading and unloading the film. To avoid exposing the edges and ends of the film, the camera should be loaded in subdued light. Before loading the camera, follow steps given below.

1) Move the side release (part #15 in Figure 2.1) to STOP.

2) Move the disengaging lever (part #2 in Figure 2.1) to MOT.

3) Turn the film speed selection knob (part #14 in Figure 2.1) until the number corresponding to the desired film speed faces the red dot.

4) Wind the camera (see Section 2.3).

Begin loading the film by turning the lid opening knob (part #38 in Figure 2.3) in the direction indicated by the arrow O. The inside of the camera appears in Figure 2.7.

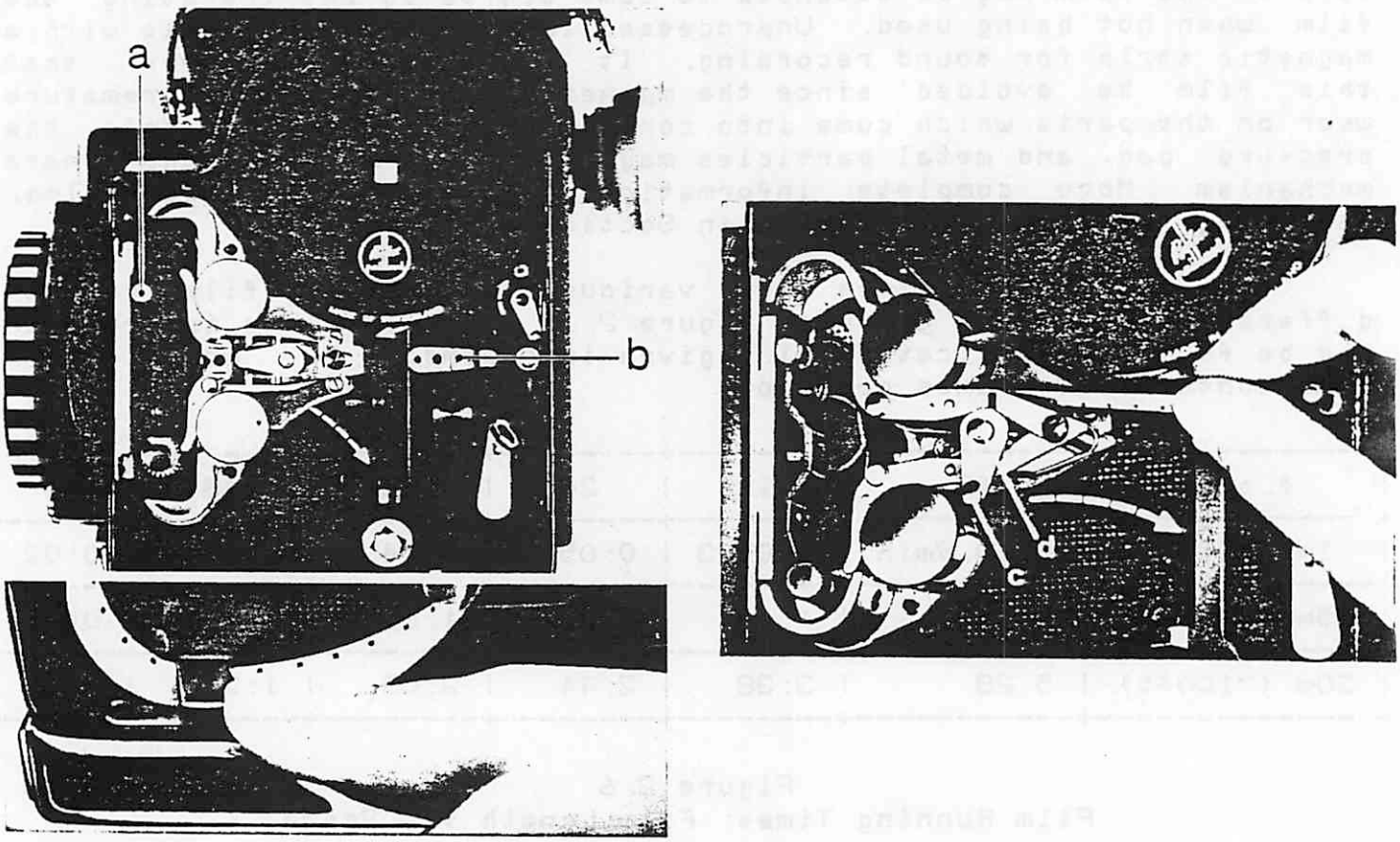


Figure 2.7
Film Loading

Prepare to load the film as follows:

1) Check that the pressure pad pin (a) is locked and that the pressure pad cannot open.

2) Remove the empty spool from its spindle by pressing ejector (b), and place the spool holding the film on the upper spool shaft. The film should run in the direction indicated by the engraved arrow. In the film gate, the dark, shiny side of the film (the backing) should face toward the back of the camera and the light matt side (sensitized) toward the lens.

3) Using the film knife (see Figure 2.7b) cut off the end of the film diagonally between two perforations, as shown in the figure. Remember to remove the piece which has been cut off.

4) Close the loop formers by rotating the control lever (c) until it is parallel to the pressure pad.

5) Press the release while simultaneously pushing the film against the sprocket (see Figure 2.7c). The film is automatically threaded into the camera.

6) Continue to depress the release until 10" to 12" of film have passed through the drive mechanism.

7) Open the loop formers by pressing knob (d). If left closed, the formers will automatically open as the camera lid is replaced.

8) Insert the end of the film into the slot in the core of the take-up spool. Rotate the spool until about three turns of film have been taken up, and place the spool on the lower spool shaft.

9) Turn the take-up spool by hand, clockwise, to take up all remaining slack.

Press the release and run the camera for several seconds to assure that the film is advancing normally and the loops at either end of the film gate are forming correctly. Replace the lid and lock it by turning the knob in the direction indicated by the arrow F. If it does not lock, do not force the ring! The spools or the pressure pad may be incorrectly positioned. Finally, press the release until the film leader has been taken up. The camera is now ready for use.

The footage counter shows the length of film that has been exposed and appears is Figure 2.8a.

a. b.

Figure 2.8
Counters: a. footage counter, b. frame Counter

Once the camera has been loaded, the counter reads "ft." Run the camera until the figure 0 arrives opposite the white line in the

center of the red mask. This indicates that the film leader has been taken up and filming may begin. The counter automatically returns to ft. when the camera lid is removed for loading or unloading film. The footage counter is sufficiently accurate for ordinary filming. For special effects that require absolute precision, the frame counter should be used.

By indicating the exact number of frames exposed, the frame counter is invaluable for scientific studies, as well as various effects, such as lap dissolves and double exposures. It is also very useful for single framing animation. Figure 2.8b shows the frame counter. The upper dial adds the frames in forward run and subtracts them in reverse run, from 0-50 frames. The lower dial totals, in units of 50, the frames in forward run and subtracts them in reverse run, up to 1000 frames. Beyond this figure, the cycle starts again and the figures shown on both dials should be added to the 1000 frames already totaled. Take no notice of the relative positions of the dials but only of their readings. It is easy to determine whether the figures shown on the frame counter refer to the first or second cycle by looking at the footage counter, since 1000 frames of 16mm film correspond to 25 feet. To set the frame counter to zero, use knob (a) in Figure 2.8c which controls the upper dial and knob (b) which controls the lower dial.

When the footage counter shows that the film is entirely exposed, run the camera for about 10 seconds to wind the end leader onto the take-up spool. Before opening the camera, make sure that there is no film left in the gate. This is accomplished by moving the guide mark of the exposure knob (part #12 in Figure 2.1) to position T and rotating the turret to reveal the aperture. Push the side release to open the shutter. If any film remains, it will be seen as an ivory colored rectangle in the aperture. This procedure will cause at most one frame to be lost. Do not open the camera in bright light or the edges of the film may be fogged. Slight pressure on the spool ejector (part #27 in Figure 2.2) will free both spools.

2.6 Shutter

This camera is equipped with a shutter whose aperture can be varied both when the camera is running and when it is stopped. This enables the exposure time to be reduced without changing the filming speed. In dazzling light, such as snow and water scenes, the variable shutter can be used to reduce the exposure, thereby often eliminating the need for a neutral density filter.

The shutter can be locked in each of its four positions by pushing the lever inwards. The 1/4 and 1/2 closed positions are marked on the face of the lever by the figures 1/2 and 1. The

position marked 1/2 indicates that the shutter has been closed to three-fourths of its normal size. The diaphragm should be opened half a stop to compensate for the decreased exposure time. When the lever is in the position marked by 1, the shutter opening has been reduced to one-half of its original size, and the diaphragm should be opened one full stop. These settings are illustrated in Figure 2.9.

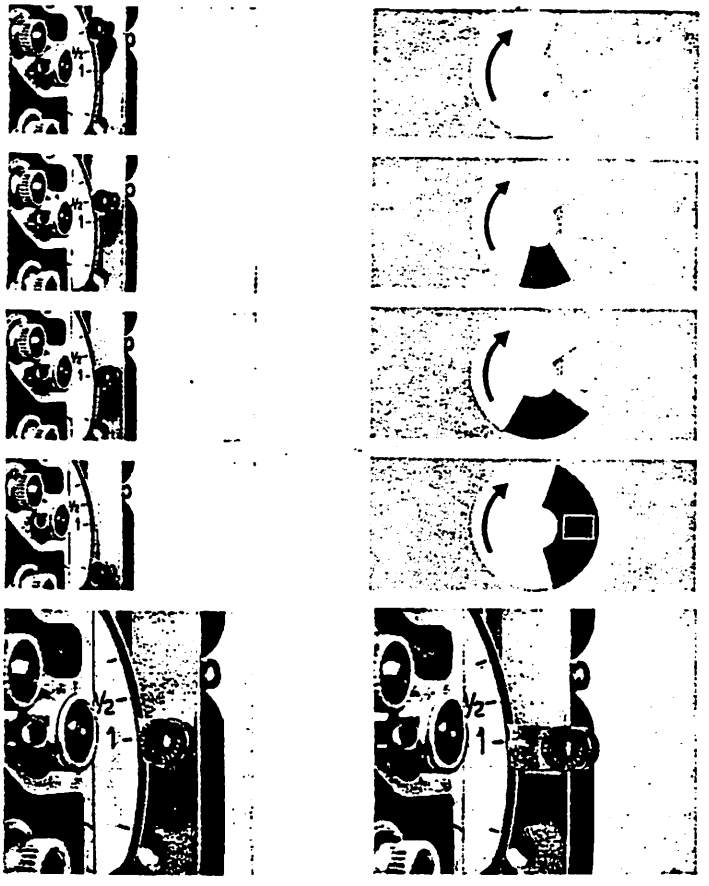


Figure 2.9
Shutter Settings

A warning triangle appears in the reflex viewfinder when the variable shutter is not fully opened.

The use of the variable shutter allows one to obtain various effects without the use of special equipment. Some of these effects are described in the following paragraphs.

Fade-in. A film beginning abruptly with a title or a brilliantly lit scene may dazzle the eyes of an audience in a darkened room. The eye needs only between one-half second and two seconds to become adapted to the brightest scene image, if the transition is gradual. In such cases, it is a good idea to introduce the opening scene with a fade-in, using the variable shutter, as follows:

1) Close the variable shutter without locking the control lever.

2) Start the camera and simultaneously open the shutter with the lever. To ensure a smooth movement, press the middle finger against the edge of the turret and, holding the small black lever knob firmly between thumb and index finger, move the lever gently upward. Before beginning to film, practice making this movement smoothly and, particularly, making it last the desired time.

3) Continue filming until the end of the first sequence.

4) For safety's sake, lock the lever in the "open" position before filming further sequences.

Fade-out. A gradual darkening at the end of the last scene avoids an abrupt finish. The fade-out can be slower than the fade-in and is achieved in the same manner, only in the reverse order.

Transitional fade. If it is not possible to avoid linking two scenes with an appreciable difference in light, the transition will be smoother if the first scene is ended with a fade-out and the second initiated with a fade-in. To avoid a break in continuity, these two fades should not last longer than two or three seconds.

Lap dissolves. A lap dissolve is made by superimposing a fade-out on a fade-in so that one picture gradually disappears as the next gradually appears. This makes for a very smooth transition during which the brightness of the picture scarcely varies. The procedure for producing a lap dissolve is given below.

1) Close the sequence with a fade-out, without interrupting filming and without regard to the frame counter.

2) Lock the shutter in the "closed" position.

3) Set the two dials of the frame counter to zero.

4) Disengage the motor and wind the film in reverse until the frame counter indicates the figures corresponding to the duration of the fade-out.

5) Move the side release to STOP and the motor disengaging lever to MOT.

6) Frame the second sequence and release the shutter lever.

7) Press the release and simultaneously make a fade-in of the same length as the previous fade-out.

8) Continue filming.

Double exposure. In order to enhance the artistic effect of a sequence, the professional cameraperson sometimes uses double exposures, i.e. the superimposing of two different scenes on the same length of film. This procedure is outlined below.

1) Set the f-stop according to the lightmeter reading.

2) Half close the variable shutter by locking the lever in position "1".

3) Set the frame counter to zero.

4) Film the first scene.

5) Note the reading of the frame counter.

6) Fully close the variable shutter and lock the lever in that postion.

7) Disengage the motor and wind the film back until the frame counter again reads zero.

8) Engage the motor.

9) Free the variable shutter lever and lock it in position "1".

10) Film the second sequence until the frame counter reaches the figure noted under step 5.

11) Open the variable shutter and lock its lever in that position.

Choosing a more favorable f-stop. As a rule, very small diaphragm apertures, high f-stop settings, should be avoided, as there is a risk of diffraction affecting picture quality. Moreover, with some film sensitivities and lighting conditions, even the smallest aperture opening cannot prevent over-exposure. As the variable shutter permits reduced exposure time without changing the filming speed, both of these risks are greatly minimized and a neutral density filter is unnecessary.

Increased picture definition. Closing the variable shutter reduces exposure time and thereby increases the sharpness of moving subjects. However, if the filming speed is not increased, this procedure can result in jerkiness on the screen.

In special cases, where picture sharpness is more important than steadiness, e.g. frame-by-frame analysis of scientific phenomena, sporting events, and motion studies, it is an advantage to be able to reduce exposure time, without changing filming speed, as this diminishes the blur caused by a moving subject. Increased picture

sharpness is especially useful when the film is to be projected on wide screens. To safegaurd against the risk of jerkiness, due to the shutter's being partially closed, the filming speed should be increased.

2.7 Turret and Lenses

The lenses on the H16 RX-5 camera are mounted on a turret. Simply by turning the turret, one can rapidly change from one focal length to another, from a medium long view to a long view or a close-up. To turn the turret, use the fold-away lever (part #32 in Figure 2.3) as shown in Figure 2.10a. In this way, there is no risk of accidentally moving the diaphragm and focusing rings. Three click stops ensure that the lenses are correctly positioned in front of the filming aperture. When using heavy lenses, such as zooms or telephotos with very long focal lengths, the turret should be locked with the special clamp (part #35 in Figure 2.3). This configuration is shown in Figure 2.10b. The locking plate assumes the position labelled Pos. 1 when not in use and position Pos. 2 when the turret is locked.

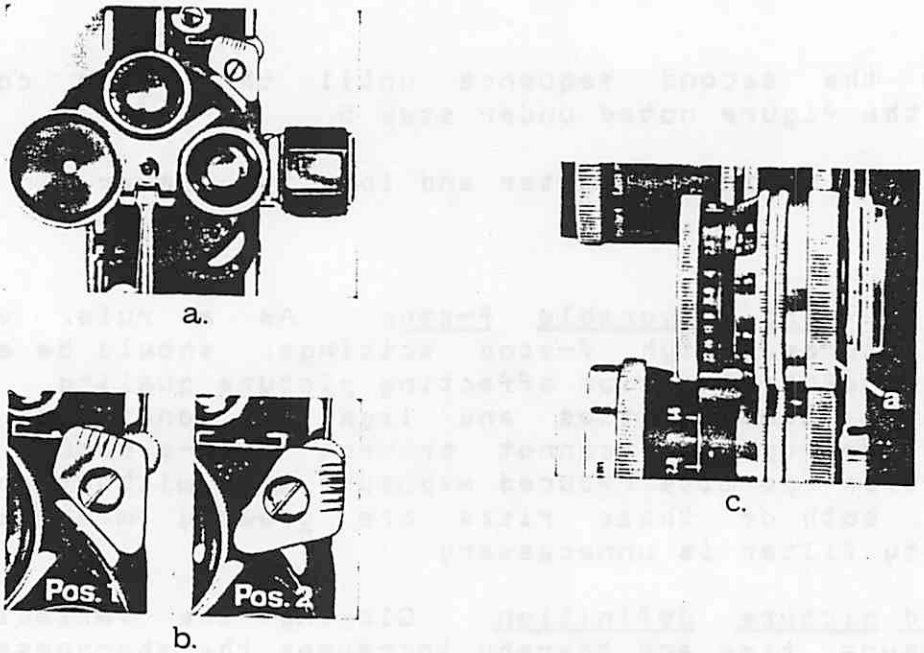


Figure 2.10
Lens Turret: a. turret, b. turret lock, c. lens rear ring

Due to the varied focal lengths of the lenses, care must be taken when positioning them on the turret. Keep the lenses

positioned so that there is a reasonable distance between the wide-angle lens (10mm) and the long focal length lens (75mm). In order to keep the field of view clear, it is recommended that lenses with focal lengths greater than 75mm be unscrewed from the turret prior to using shorter focal length lenses. Lenses should be held by their rear rings when being screwed into or out of the turret. This ring is labelled "a" in Figure 2.10c. As stated earlier, the camera is equipped with three Switar lenses with focal lengths of 10, 26, and 75mm. The specifications for these lenses are given in the table in Figure 2.11.

	Switar 10mm f/1.6	Switar 26mm f/1.1	Switar 75mm f/1.9
Hor. Field ∠	52 deg. = 965 0/00	21deg. = 371 0/00	7deg. = 129 0/00
Rel. Mag.	0.4x	1x	3x
Focusing Range	8"- infinity	(7 1/2")20"- inf.	(2'6")5'- inf.
Diaphragm Preselection	yes	yes	yes

Figure 2.11
Lens Specifications

The field of view covered by a lens depends upon its focal length. Standard lenses with a normal focal length of 26mm cover a medium field of view and are suitable for ordinary use. This lens will generally be the appropriate choice for use in photographing images displayed on a color monitor. Wide-angle lenses with focal lengths of 10mm cover a wide field and are used for general views, or when it is not possible to get sufficiently far away from a scene. They heighten the effect of perspective. Telephoto lenses with long focal lengths of 75 to 150mm cover a limited field and are used for filming at great distances and for close-ups of sporting events, etc.

The reflex viewfinder of the H16 RX-5 camera allows the operator to view the picture exactly as it will appear on the film, with its sharp and blurred areas faithfully reproduced. Thus, it is simple to focus accurately and, at the same time, to estimate the depth-of-field.

The depth-of-field is the area within which the picture is in focus. It varies according to the focal length of the lens, the diaphragm opening, and the filming distance. The depth-of-field is made shallower by lengthening the focal length, shortening the distance between the lens and the subject, or widening the diaphram opening. Focusing must, therefore, be especially accurate. Conversely, the depth-of-field is made greater by shortening the

focal length of the lens, icreasing the filming distance, or closing the diaphram opening. Each of the lenses has a depth-of-field scale which indicates the distances within which the picture will be in focus. The depth-of-field is read from the scale at the points indicated by the pair of orange dots which have the greatest separation. The distances are calculated from the film plane in the camera (part #9 in Figure 2.1). Experimentation has shown that either the 26mm lens or the 75mm lens is quite well suited to taking pictures from a graphics display. The 26mm lens has become the standard choice since it allows placement of the camera closer to the screen.

2.8 F-stop Adjustment

The lens diaphragm controls the amount of light allowed to reach the film and is adjusted according to the lighting conditions, film sensitivity, filming speed, and position of the variable shutter. The size of the diaphragm opening is indicated by a scale on the lens. The points along the scale are called "stops" and the settings are termed "f-stops". The amount of light admitted by the lens is doubled at each successive f-stop, starting from the highest value and moving toward the smallest value. For instance, moving the diaphragm from f/11 to f/8 doubles the amount of light passing through the lens.

The table appearing in Figure 2.12a gives the actual exposure duration for the various filming speeds available. The column labelled "Light Meter" contains the equivalent exposure durations after accounting for the fact that the viewfinder removes approximately 25% of the light entering the lens. The last entry in the table contains the data relevant for filming with the camera when the shutter is being controlled by the special drive motor, see section 4.

Experiments have been performed with various color films to determine the optimum f-stop for accurate exposure of images displayed on the color monitor. Light meter readings taken from the color monitor are misleading because the meters average the intensity both over time and across the entire display. Since the image is being rewritten at a rate of 30 times per second, the light meters are inaccurate. Figure 2.12b lists the films tested and the resulting suggested f-stop settings.

Filming Speed	Shutter Open Lever UP		Shutter 1/4 cl. Lever on 1/2		Shutter 1/2 cl. Lever on 1	
	Real	Meter	Real	Meter	Real	Meter
12 f.p.s.	1/33	1/40	1/45	1/55	1/75	1/94
16 f.p.s.	1/45	1/55	1/60	1/75	1/100	1/125
18 f.p.s	1/50	1/60	1/70	1/07	1/110	1/137
24 f.p.s	1/65	1/80	1/90	1/112	1/150	1/188
32 f.p.s.	1/90	1/110	1/120	1/150	1/200	1/225
48 f.p.s.	1/130	1/160	1/180	1/225	1/300	1/375
64 f.p.s.	1/180	1/220	1/240	1/300	1/400	1/500
speed 18-64 f.p.s.	single-frame exposure (selector in position I) 1/30 1/40					
Drive Unit	5/16	1/4				

a.

Film	Experimentally determined f-stop (*)
7239	~4.0
7240	5.6 - 8.0
7247	2.8 - 4.0
(*) These values are a guide only	

b.

Figure 2.12
Exposure Times

2.9 Filters

The camera is provided with a slot between the turret and the reflex prism into which the filters fit. The filters, therefore, remain in place regardless of which lens is being used. When filming without a filter, an empty filter holder should be left in the slot to prevent light infiltration which would fog the film. See that the holder is located firmly in the slot. Filters are mounted in the following manner with all references being to Figure 2.13.

1) Remove the fastening clamp (a) from the filter mount.

2) Open the spring blades (b) and (c).

3) Insert the cut-out-filter (d) between the blades.

4) Press the spring blades (b) and (c) together between thumb and index finger.

5) Replace the fastening clamp (a).

Once this process has been completed, store the filters in the case provided in order to protect them from dust and fingerprints.

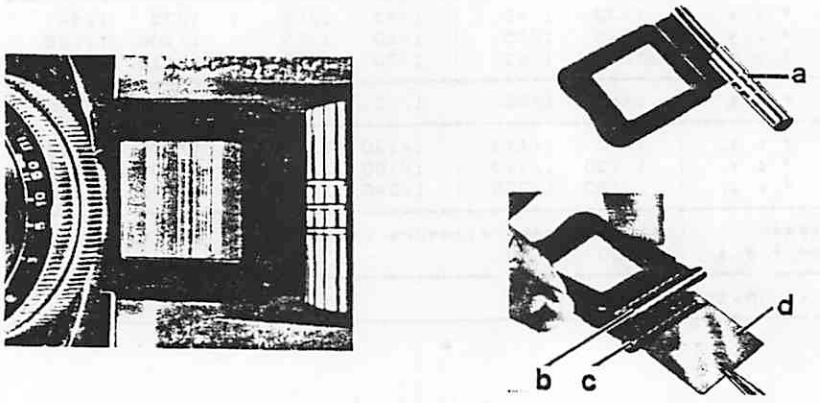


Figure 2.13
Filter Holder

A set of four gelatin filters is provided with the camera. The 1A Skylight filter for color films tones down excessive blue and improves color reproduction for pictures taken in the shade or overcast weather, for distance shots, or in snow or at high altitudes. This filter requires no diaphragm correction. The 85 Daylight filter for color film is a conversion filter. It is used for filming in daylight with Kodachrome II Type A artificial light film. When setting the f-stop, remember that color film for artificial light, used with the 85 Daylight filter, has the same sensitivity as a daylight color film used without a filter. It is recommended that the diaphragm be opened two-thirds stop when using this filter. The Yellow 8 filter is used for increasing contrast in black-and-white films. The diaphragm should be opened one stop when using this filter. The 96 Neutral Density ND 0.060 filter can be used with both black-and-white and color films and in no way affects color reproduction. As the ASA sensitivity is reduced four times, the diaphragm should be opened two stops. This filter should be used when the lighting conditions and the film sensitivity require an aperture lower than the smallest stop on the lens or when it is desirable to reduce the depth-of-field in order to achieve special effects, e.g. a sharp foreground against a blurred background. More complete information may be found in the publications listed in Appendix B.

2.10 Fault Diagnosis

The following is a list of problems found in films and their probable causes.

Film all black	<-->	Variable shutter left closed
Film under-exposed, pictures reversed, orange tint	<-->	Film incorrectly loaded with dark side toward lens
Pitures too dark and flat	<-->	Under-exposed
Pictures too bright and washed out	<-->	Over-exposed
Blurred pictures	<-->	Inaccurate distance setting
"Jumpy" pictures	<-->	Camera unsteadiness
Unnatural coloring	<-->	Used filters designed for black-and-white film while shooting color. Too long a delay between exposure and development. Films poorly stored before and after use.
Dominant red-orange tint	<-->	Filming done too early in the morning or too late in the evening. Used a tungsten lamp with daylight film or an underpowered lamp with tungsten film.
Dominant blue tint	<-->	Filmed distant subjects at high altitudes or on water without the appropriate filter. Water scenes with strong reflections filmed without a polarizing filter.
Partly obscured picture	<-->	An object, such as finger or a long telephoto lens, in front of the taking lens.
Parallel scratches on the edge of the film	<-->	Dust or particles of emulsion in the film gate. Camera badly loaded.
Fogged film	<-->	Direct light entered through the reflex viewfinder.
Out-of-focus or distorted picture	<-->	Pressure pad incorrectly locked

2.11 Care

The interior of the camera which houses the film drive mechanism must be kept spotless. Gelatin deposits and dust sometimes accumulate in the gate and on the pressure pad when unexposed film is run through the camera and should be removed by the following procedure, which refers to Figure 2.14.

1) Open the pressure pad by lifting its pins.
2) Unscrew the shaft and remove the pressure pad by pulling it directly away from the camera body.
3) Gently clean the gate and pressure pad, paying special attention to the aperture, using a clean cloth wound around the end of a small stick. If the gelatin deposit is hard to remove, dampen the cloth and thoroughly dry the part after cleaning.
4) Replace the pressure pad.

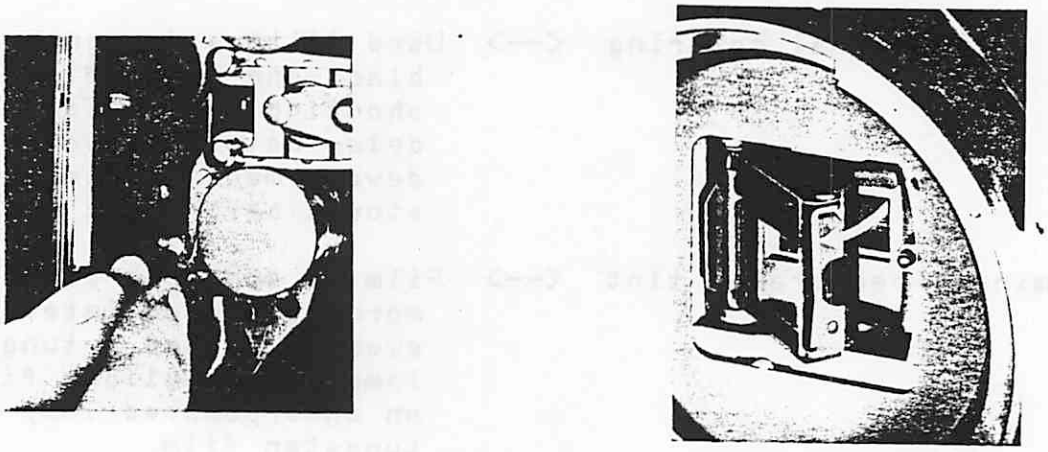


Figure 2.14
Pressure Pad and Reflex Prism

The reflex prism can be reached by rotating the lens turret until it is uncovered (see Figure 2.14). Since the prism is mounted on hinges, it can be swung out in order to clean the back and the ground glass. Use a soft, dry brush or special paper for cleaning these parts. The prism can be cleaned while the camera is loaded. The reflex viewfinder, however, must not be dismantled.

Keep the outer surfaces of the lenses absolutely clean with the special lens paper sold in camera stores. Avoid rubbing the lens more than necessary since this could damage the coating. Screw on the lens cap between takes and avoid fingerprints and dust.

Further information may be found in publications (3. and 4.) given in Appendix B.

3. User Interface

The purpose of this facility is to allow a user to easily create 16mm movie films from graphical data. The camera may be activated either manually or while under computer control. The software developed for this purpose may be broken into five levels. Films may be made from an existing sequence of files containing images ready for display, from a sequence of data files and a user provided display creation program, by user developed FORTRAN programs, from within the Movie BYU interactive graphics system, and finally, through manual operation of the camera.

This section will detail each of the modes of operation and will include a discussion of the conventions employed for the file structure of the data and image sequences. In all of the following discussions and examples, prompts issued by the system appear underlined.

This system has been implemented on a VAX 11/780 computer, thus the details in the following sections pertain to this machine. For users employing a different machine, this section provides a framework for the type of software that could be developed. The specific details, such as the file structure conventions, must be determined by the user as dictated by the available computer.

The first two modes of operation allow the user to create films from sequence of data or image files. The code for these command procedures and the special FORTRAN programs used by the procedures is included in Appendix D.

3.1 File Structure Convention

Both of the modes of operation employing files are implemented on a VAX 11/780 and, therefore, the design of the file structures was dictated by the capabilities of the system. The two modes of operation requiring a sequence of files assumes that each file contains the data for exactly one image. The data may be in the form of saved Grinnell images in one case, or may be the data required by some display creation program.

The naming convention for files is completely specified in Section 2.1 of the VAX/VMS Command Language User's Guide. Only a brief review of the conventions is given here. Identification of a file contains five parts, two of which are optional and default to predetermineed values when left unspecified. The identification has the form:

device:[directory]filename.extension:version

The parts have the following definitions.

Device -- This parameter indicates the device on which the file is to be found, e.g. dra0 indicates disk drive 0. If this value is left unspecified, the device on which the user is currently running is used.

Directory -- This indicates the directory / subdirectory on which the file is to be found. The current directory is used when this value is left unspecified.

Filename -- This is the name given to the file. It may contain 1 to 8 letters or numbers and must be included in order to ensure correct reference.

Extension -- This is usually used to indicate the type of information contained within the file. It may be 0 to 3 letters or numbers.

Version -- This is a number used to differentiate between copies of the same file. The VAX/VMS system allows only approximately 63 versions of any particular file / extension combination to exist at any one time even though the version numbers have a range of 1 to 32000 (roughly). If 63 versions exist, say 1 through 63, and a new one is added, version 64, then the lowest version is automatically deleted.

The display of simulation data in the form of a movie may be divided into three parts. The first section consists of displaying the initial image for a length of time long enough for the viewer to become familiar with the display. The middle part is the actual movie and consists of showing frames at a rate high enough to cause the perception of pure motion. This section consists of one or two frames on the 16mm film for each of the displays. Ideally there should be small, smooth changes between consecutive images. The last section consists of holding the last image on the screen long enough for the viewer to investigate the details.

For the modes of operation utilizing user created sequences of files, certain additional conventions have been adopted. The following is a list of these conventions and an example file structure.

1) All files containing data or images to be used in one film must have the same device, directory/ subdirectory, and file name.

2) The data or display file for the initial image must have the extension "AAA" and a version number higher than any other version number in the sequence.

3) The remainder of the files may have any extension normally allowed by the operating system but the version

numbers must be in increasing order starting with the data or display to be viewed immediately after the initial image.

4) The version numbers of these files must be incremented by a fixed constant, e.g. 1.

5) The final image will be that image produced from the file with the highest version number.

Figure 3.1 contains an example of the file structure. The file named FRAMES contains the images to be used to make a film. There is to be a total of 200 images in the film. According to the above conventions, the first image is found in file FRAMES.AAA.400. The sequence of files would assume the following appearance:

```
FRAMES.AAA.400
FRAMES.EX1.1
FRAMES.EX1.2
      .
      .
      .
FRAMES.EX1.50
FRAMES.EX2.51
      .
      .
      .
FRAMES.EX2.100
FRAMES.EX3.101
      .
      .
      .
FRAMES.EX3.150
FRAMES.EX4.151
      .
      .
      .
FRAMES.EX4.199
```

Figure 3.1
Example File Structure

In the above figure, versions 1 through 198 are used for the actual motion part of the film. That is, only one or possibly two frames on the movie film are used for each image. Version 199, the 200th image, is held and photographed enough times so that the viewer can carefully scan the image.

The next two sections describe the procedures available which allow the user to create films from sequences of data or image files

stored under the above conventions. A discussion of the required parameters as well as the action performed is included.

3.2 Film From Image Files

This command procedure allows the user to create a film for an existing sequence of image files. The user must supply the image files in a structure as defined in the earlier section entitled "File Structure Convention". The images will be copied to the Grinnel and photographed one at a time. Any error encountered by the procedure will cause the process to be terminated and the graphics display freed for use by other users. The procedure is invoked with the following call:

$ @FILMFI P1 P2 P3 P4 P5 P6 P7

The values of the parameters may be eliminated from the above command, in which case the procedure will issue prompts. Note: if any of the values are to be eliminated from the command, then all should be eliminated so that there is no chance of associating the wrong value with a parameter. The parameters have the following definitions:

P1 --> Name of the file containing the images. It is assumed that each image is located in a different version under this file name.

P2 --> Number of frames (pictures) to be taken of the initial image. The initial image, typically iteration 0 of a simulation run, is assumed to be located in file "P1" under extension AAA. This parameter allows the user to hold the first image longer than the rest.

P3 --> Starting iteration number. This is the version number of the first frame after the initial image. It is assumed the image will be found in file "P1", version "P3".

P4 --> Ending iteration number. As above, except that this parameter indicates the number of the last image.

P5 --> Iteration increment. This parameter allows the user to skip iterations while making the movie. P5 must be > 0. The system will take pictures of every "P5"th image

starting with "P3".

P6 --> Number of shots per iteration. This parameter indicates the number of pictures to be taken for every image. Remember that normal movie projectors run at a rate of 18 frames per second.

P7 --> Number of shots to be taken of the last frame. This allows the user to hold the final frame longer than the others.

Example

Assume that the user has the sequence of files given in the example in the section above entitled "File Structure Convention" (see page 29). For this example, let the files contain images produced from simulation data at some previous time. The images are ready to be copied directly to the display. The interaction shown in Figure 3.2 will produce a movie of the displays with the initial and final images displayed for 5 and 10 seconds respectively.

```
$ @FILMFI
Enter the file name: frames
Enter number of shots of initial image: 90
Enter starting iteration: 1
Enter ending iteration: 199
Enter iteration (version) increment: 1
Enter number of pictures per iteration (version): 1
Enter number of pictures of final image: 180
FORTRAN STOP
      .
      .
      .
FORTRAN STOP
$
```

Figure 3.2
Example Run of FILMFI

Alternately, the command procedure could have been invoked by the sequence shown in Figure 3.3 in which values for all of the parameters were specified at the time of the original call.

```
$ @FILMFI frames 90 1 199 1 1 180
FORTRAN STOP
      .
      .
      .
FORTRAN STOP
$
```

Figure 3.3
Alternate Form of FILMFI Invocation

3.3 Film From Data Files

This command procedure allows the user to create a film for an existing sequence of data files. The user must supply the data files in a structure as defined in the earlier section entitled "File Structure Convention". Also, the command procedure must be provided with the name of a program which will create and display an image from the data. This program will be applied by the command procedure to each of the data files, and the resulting image will be photographed. Any errors encountered by the procedure will cause the process to be terminated and the graphics display freed for use by other users. The code involved with these command procedures may be found in Appendix C. The procedure is invoked with the following call:

$ @FILMFD P1 P2 P3 P4 P5 P6 P7 P8

The values of the parameters may be eliminated from the above command, in which case the procedure will issue prompts. Note: if any of the values are to be eliminated from the command, then all should be eliminated so that there is no chance of associating the wrong value with a parameter. The parameters have the following definitions:

P1 --> Name of the files containing the data. It is assumed that each image is located in a different version under this file name.

P2 --> Number of frames (pictures) to be taken of the initial image. The initial image, typically iteration 0 of a simulation run, is assumed to be located in file "P1" under extension AAA. This parameter allows the user to hold the first image longer than the rest.

P3 --> Starting iteration number. This is the version number of the first frame after the initial image. It is assumed the image will be found in file "P1", version "P3".

P4 --> Ending iteration number. As above, except that this parameter indicates the number of the last image.

P5 --> Iteration increment. This parameter allows the user to skip iterations while making the movie. P5 must be > 0. The system will take pictures of every "P5"th image starting with "P3".

P6 --> Number of shots per iteration. This parameter indicates the number of pictures to be taken for every image. Remember that normal movie projectors run at a rate of 18 frames per second.

P7 --> Number of shots to be taken of the last frame. This

allows the user to hold the final frame longer than the others.

P8 --> Name of the self-contained image creation program. It must obtain the data from file FOR099.DAT.

Example

Assume that the user has the sequence of files given in the example in the section above entitled "File Structure Convention" (see page 29). In this case, let each file contain data from a simulation. The program named DISPLAY takes data from unit 99, file FOR099.DAT and produces a graphical display. Further, let the executable code for DISPLAY be located on another device and directory, e.g. usera:[sim.code] The interaction detailed in Figure 3.4 will produce a movie of the displays with the initial and final images displayed for 5 and 10 seconds respectively.

```
$ @FILMFD
Enter the file name: frames
Enter number of shots of initial image: 90
Enter starting iteration: 1
Enter ending iteration: 199
Enter iteration (version) increment: 1
Enter number of pictures per iteration (version): 1
Enter number of pictures of final image: 180
Enter name of display producing program: usera:[sim.code]DISPLAY
FORTRAN STOP

.
.
.

FORTRAN STOP
$
```

Figure 3.4
Example Run of FILMFD

Alternately, the command procedure could have been invoked by the sequence shown in Figure 3.5 in which values for all of the parameters were specified at the time of the original call.

```
$ @FILMFD frames 90 1 199 1 1 180 dra1:[sim.code]DISPLAY
FORTRAN STOP

.
.
.

FORTRAN STOP
$
```

Figure 3.5
Alternate Form of FILMFD Invocation

3.3 FORTRAN Compatibility

This section describes the subprograms for controlling the camera which are available to users working within FORTRAN. The set of subprograms contains four subroutines and three functions which allow the user to load new film into the camera, take pictures, examine and clear the exposed frames and footage counters, check the status of the picture-taking cycle, and suspend the program execution until the camera is ready. All of the routines are written in FORTRAN IV-PLUS and are available in the same library as the other Grinnell routines, user1:[movie]grlib1/lib. The FORTRAN code for all of the subprograms appears in Appendix D. Since the routines were specifically written for use with the Grinnell, standard initialization and configuration of the device is required. The function, invocation format, and argument list conventions are given below.

Users with systems comprised of equipment other than a Grinnell and VAX should use these routines as a guide for constructing a set which is compatible with the available equipment.

GR-TAKE-PICTURE

This subroutine allows the user to take pictures of the image being displayed at the time of the call. The routine will take the number of pictures indicated by its one argument. The form of the call is as follows:

```
call GR_TAKE_PICTURE(num_shots)
```

where "num_shots" is an integer scalar whose value indicates the number of pictures to be taken. A call with num_shots=0 will result in an immediate return from the routine and thus no action. With num_shots>0, "num_shot" pictures will be taken, and the routine will return when the camera is completely finished with the final picture. This is the normal mode of operation. With num_shots<0, " |num_shots| " pictures will be taken, and the routine will return to the calling program immediately after <u>initiating</u> the picture taking cycle for the last picture. Since the initiation of the picture-taking process requires roughly only 10 microseconds, but the entire cycle is close to .9 seconds, this mode allows the calling program to utilize the difference for further computation. Note that if the image is erased immediately upon returning from GR_TAKE_PICTURE after being called with a negative argument, the last picture will <u>not</u> contain the desired image.

GR-GET-FRAMES

This routine is written in the form of a function and allows the user to determine the number of frames which have been exposed. GR_GET_FRAMES may be invoked as either a subroutine or a function. In the latter case, the name of the function must be declared as type INTEGER*4. The counter is set to zero by a call to GR_ZERO_COUNTER

or to GR_NEW_FILM (see below). This routine is invoked by a call in either of the following forms:

```
call GR_GET_FRAMES(nframes)

OR

nframes = GR_GET_FRAMES(i)
```

where "nframes" and "i" are four byte integer variables which will contain the number of exposed frames upon returning from the subroutine. In the second form, the variable "i" will also contain the number of exposed frames.

GR-GET-FOOTAGE

This function is similar to GR_GET_FRAMES except that the value returned is the number of exposed feet of film. The counter is set to zero by a call to GR_ZERO_COUNTER or to GR_NEW_FILM (see below). This subprogram may be invoked as either a subroutine or a function. In the latter case, the name of the function must be declared as type REAL*4 by the calling routine. The routine is invoked by a call in either of the following forms:

```
call GR_GET_FOOTAGE(footage)

OR

footage = GR_GET_FOOTAGE(x)
```

where "footage" and "x" are four byte, real variables which will contain the number of exposed feet upon return from the routine. When the second form is used, the variable "x" will also contain the returned value.

GR-NEW-FILM

This routine is designed to aid the user in loading new film into the camera. When called, this routine advances 5 ft. of film, 200 frames, through the camera. This amount allows the skipping of any film which may have been exposed accidentally while the film was being threaded onto the takeup spool. Also, the routine sets both the exposed footage and frame counters to zero. The call to this routine appears as follows:

```
call GR_NEW_FILM
```

GR-CAMERA-READY

This subprogram is intended to be used with GR_TAKE_PICTURE when the latter is called with a negative argument. This routine

determines whether or not the camera is ready to take a picture. That is, whether or not it is safe to alter the image of which a picture is being taken without disturbing the picture. This routine may be referenced as either a subroutine or a function. When used as a function, the name must be declared as type LOGICAL. The logical value upon return from the routine indicates the state of the picture-taking cycle. This subprogram may be invoked by calls of either of the following two forms:

```
call GR_CAMERA_READY(flag)

                OR

flag = GR_CAMERA_READY(t)
```

where "flag" and "t" are logical variables. After returning from GR_CAMERA_READY, the logical value of "flag" will indicate the state of the cycle as follows: if flag is .TRUE. then the camera is ready to take another picture while if flag is .FALSE. the camera is still in the process of taking a picture. When the latter form is used, the value of "t" will be identical to that of "flag".

GR-CAMERA-WAIT

This routine allows the user to wait until the camera is ready to take another picture without using any CPU time. Execution of the calling program is suspended until the camera is ready. The routine is invoked through the following call:

```
call GR_CAMERA_WAIT
```

GR-ZERO-COUNTER

This routine is designed to allow the user to zero both the footage and frame counters. This routine and GR_NEW_FILM are the only routines which reset these counters; GR_INITIALIZE does not affect them. This subroutine is invoked by the following command:

```
call GR_ZERO_COUNTER
```

Example Program

The following program makes use of the above procedures to make a film of a red square on a light blue background which appears to proceed toward the viewer. The three parts of the film are created in the three sections of the program. Five seconds of film are taken

of both the initial and final images of the square.

```
      program DEMO
      integer*4 nframes
      real*4 footage
c
c This program makes a film of a red square on a light blue
c background.  The square appears to move toward the viewer.
c
c initialize and configure the system
      call GR_INITIALIZE(0,'  ')          ! initialize the Grinnell
      call GR_CONFIG565                   ! 5 bits red, 6 green, 5 blue
c
c clear the screen
      call GR_CLEAR
      call GR_FLUSH
c
c
c ready the camera
      write(6,100)                              ! query the user
100   format(' Enter any number after the film has been threaded: ',$)
      read *,i
      call GR_NEW_FILM                    ! zero counters, load film
c
c
c display the first image
      call GR_RECT(0,0,512,512,0,255,255)         ! blue background
      call GR_RECT(250,250,10,10,255,0,0)         ! red square 10x10
c
c take 5 seconds of the first image @ 18 f.p.s projection speed
      call GR_TAKE_PICTURE(90)          ! 18 f.p.s.. 5 sec. = 90
c
c
c
c loop while making the square larger, take one picture
c of each image
       do 1 k=6,200                              ! k is 1/2 side length
            call GR_RECT(255-k,255-k,2*k,2*k,255,0,0)
            call GR_TAKE_PICTURE(1)
1       continue
c
c finish the film with 5 seconds (@ 18 f.p.s) of the last image displayed
      call GR_TAKE_PICTURE(89)          ! 89 - 1 from above loop
c
c output the number of frames and exposed footage used
      call GR_GET_FRAMES(nframes)           ! exposed frames
      call GR_GET_FOOTAGE(footage)          ! exposed footage
      write(6,101) nframes,footage
101   format(' ',i6,' frames _',f6.2,' feet wer used.')
c
      stop
      end
```

3.4 From Within Movie BYU

The Movie BYU graphics system allows a user to create, manipulate and display models of three-dimensional objects. The ability to trigger the movie camera has been incorporated into this system at two levels. This section deals only with the details of the Movie BYU system which are relevant to the use of the film-making functions. For a complete discussion of the capabilities and usage procedure, the reader is referred to the complete documentation manual.

At the level of the DRAW and VIEW commands, a routine has been added which allows the user to take pictures of the display as it appears at the time of the invocation of the call. The user command has the form:

>> PICS

Issuing this command will cause the program to ask for the number of pictures (frames of film) to be shot. This prompt appears as:

<Enter number of pictures [0-18000]>

A value of zero, 0, will cause no pictures to be taken. For any value less than zero, the absolute value of the argument is used. The picture-taking process requires roughly .9 seconds per frame, during which time program execution will be suspended. Control will be returned to the user only after all of the pictures have been taken.

The second appearance of the film-making capability appears within the MOVIE command. After the other parameters have been entered, the system will ask the user if a film is to be made from the images. This prompt will appear as:

<Film making (Y or N)?>

If the answer given by the user is affirmative, the system will then issue a prompt for the number of frames to be exposed for each of the images. The prompt for this datum appears as:

<Enter number of pictures per image (0-180)>

The action associated with the value is as described for the PICS command. This action has no relation to the "<Pause after each frame?>" command which allows the user to insert a short delay between frames for ease of viewing. However, it is affected by the "<Pictures?>" command. A negative response to this query causes the system to forego the displaying of any of the images, and thus no pictures will be taken within MOVIE.

The three parts of a film correspond to calls to PICS, MOVIE

with film-making, and then PICS again. The first call to PICS allows the user to present the initial image for an extended time. The call to MOVIE with film-making creates the middle section of the film, which includes the animation, and the second call to PICS allows the user to hold the final image for an extended time.

3.5 Manual Operation

In some cases, the most convenient method for taking pictures is manual control. The special motor drive designed to adapt the camera to making films from computer generated images includes this capability. By depressing the shutter release button on the top of the circuit box (see Figures 4.17 and 4.21), one frame on the film is exposed. The direction of movement of the film is determined, as in all other modes of operation, by the setting of the power/direction switch. This switch is located on the side of the circuit box. The settings are, from back to front: REVERSE, OFF, and FORWARD.

4. Motor Drive Unit

This section details the design, assembly, and use of the motor drive unit. The drive allows the camera to be triggered by the computer and provides an exposure duration of roughly 5/16 of a second. This section includes the designs for the electrical circuits as well as the hardware.

4.1 Motor

The motor chosen for the drive unit is a Slo-Syn synchronous motor marketed by the Superior Electric company. This motor was selected because it is designed to run at a fixed rate dependent upon the input line frequency. The model chosen operates at 72 revolutions per minute when run on 120VAC at 60 Hz. This rate translates to .833 seconds per revolution. Coupling this with a shutter opening of 135 degrees produces an exposure duration of 5/16 of a second. The Superior Electric model number is SS50E which stands for Slo-Syn, 50 ounce-inches of torque, and the "E" indicates that the motor has a double ended shaft. The rear end of the shaft is not utilized in the present implementation and may, therefore, be deleted. It was intended that this single motor could be used to run the take-up spool on a 400' film magazine through the rear shaft. Figure 4.1 shows the motor as it is mounted on the vertical plate of the motor mount, see below.

4.2 Motor Mount

The purpose of the motor mount is twofold. First, it must provide a solid support for the motor drive and the associated circuitry. Secondly, the mount must be so designed that it both fixes the position of the motor relative to the camera body and absorbs as much of the vibration caused by the motor as possible. This section contains a discussion of the requirements and design of the mount. Layout plans for the various pieces are also included as well as a list of the required materials. The motor must be held in such a way that the rotor shaft and coupling assembly are collinear with the driving shaft of the camera. Also, a totally rigid mount would transmit the motor vibrations to the camera which would, in turn, cause the image on the film to appear blurred.

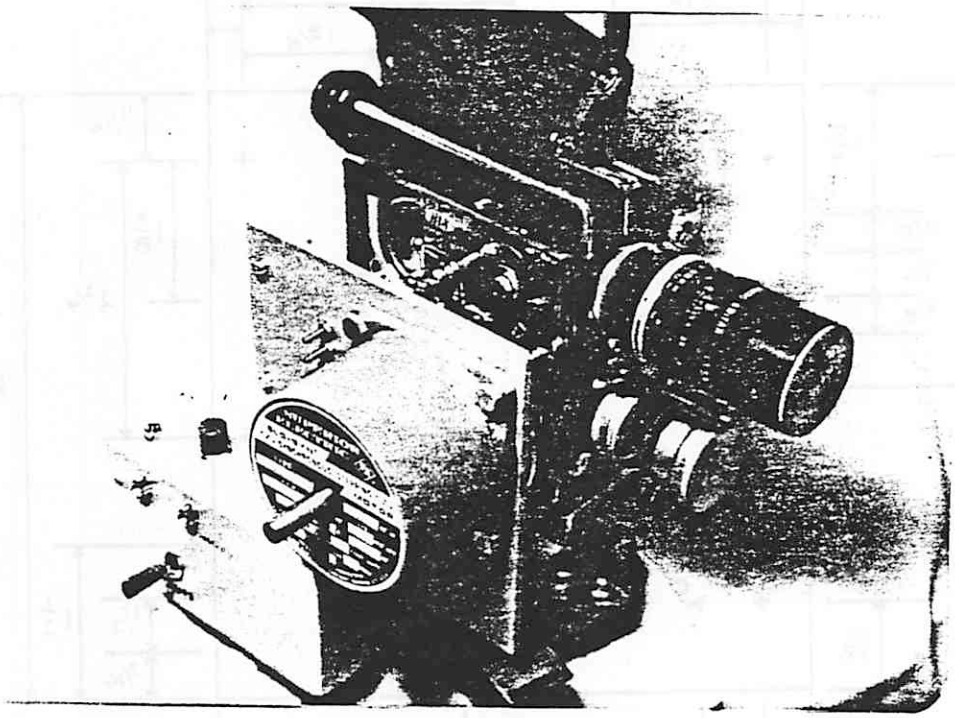


Figure 4.1
Motor on Motor Mount

The design incorporated consists of three separate pieces which are bolted together to form an "L"-shaped assembly. The camera is affixed to the bottom, horizontal, section of the support through the use of two thumb screws. The vertical piece is used to support the motor and circuit box.

It is recommended that both of the flat pieces be machined from 3/16 inch thick aluminum plate. The vertical section is a square, 6 inches on a side, drilled and tapped as indicated in Figure 4.2. The plate to which the camera body is attached is a 4 3/4 by 3 1/2 inch rectangular plate drilled and tapped as shown in Figure 4.3.

The joint between the two pieces should be machined from 1 1/4 inch steel angle stock. The piece should be cut to the same length as the width of the base of the "L", i.e. 3 1/2 inches, and have the edges finished. The pattern for the bolt holes is given in Figure 4.4.

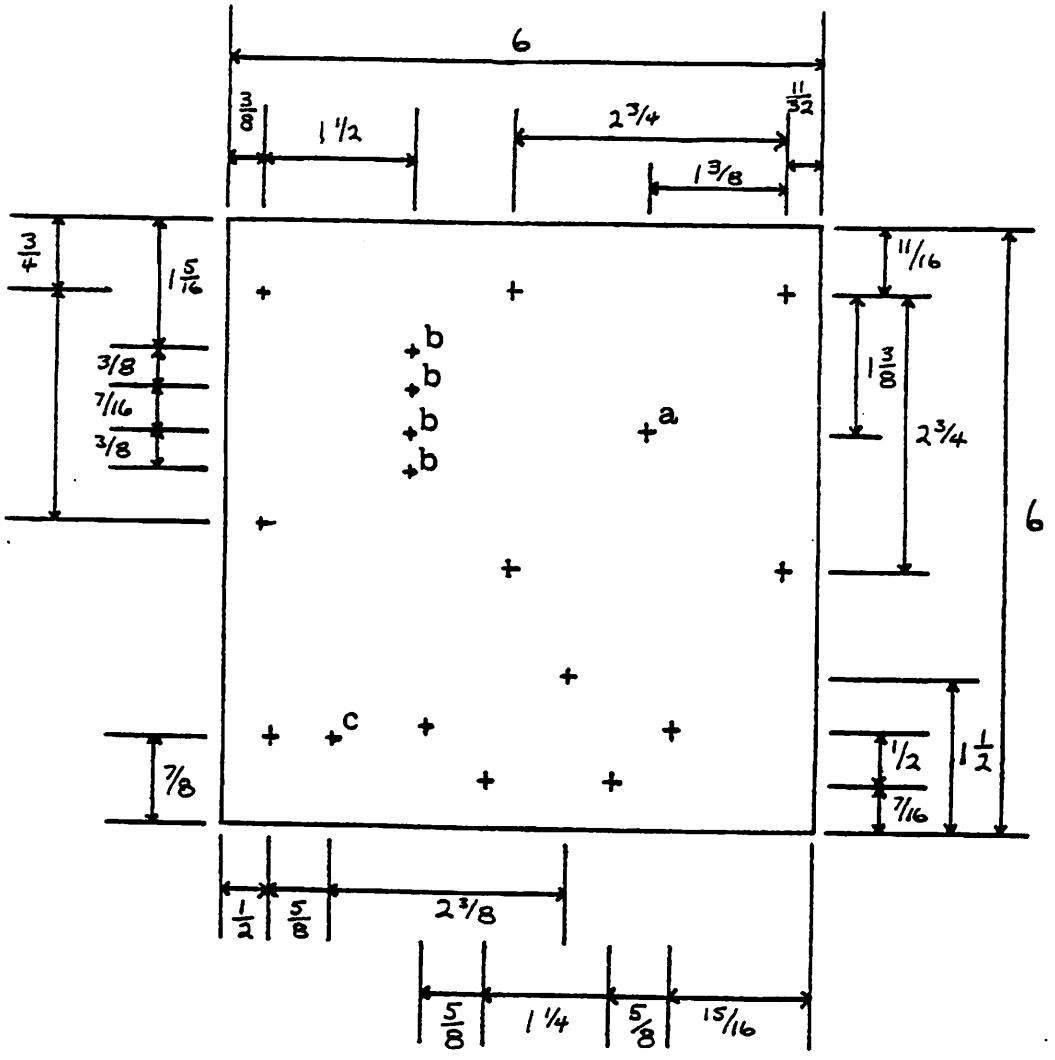


Figure 4.?
Hole Layout for Vertical Piece of Motor Mount
Hole sizes: a - 5/8", b - 3/16", c - 1/4", all others - drill and tap to 1/4 - 20 thread.

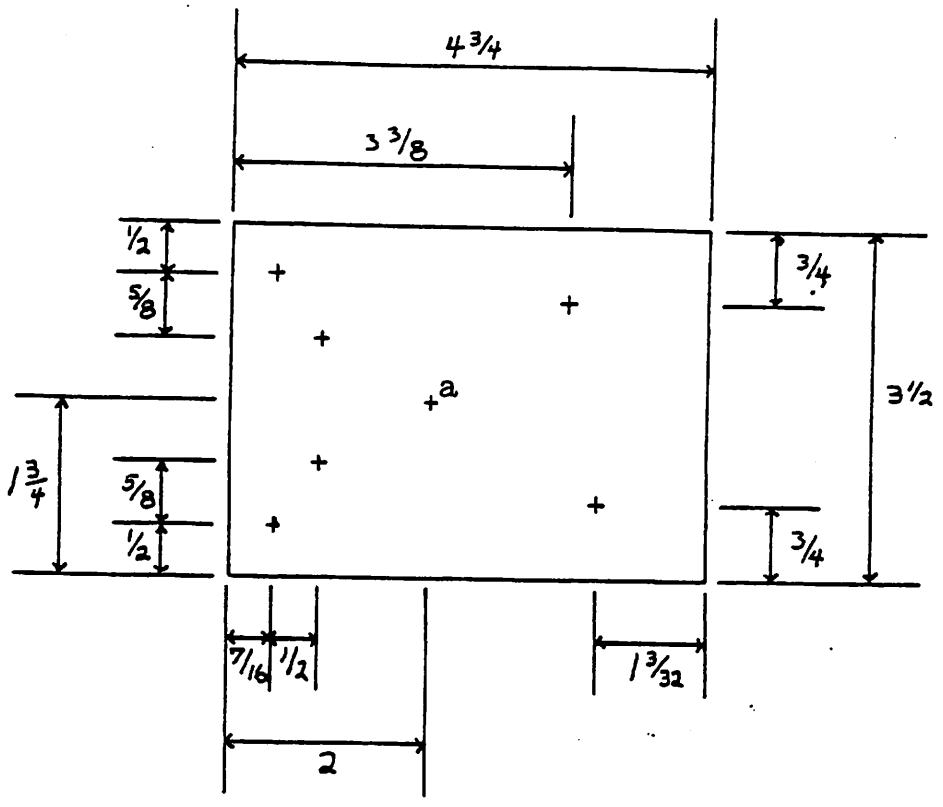


Figure 4.3
Hole Layout for Horizontal Piece of Motor Mount
Hole sizes: a - drill and tap to 1/4 - 20 thread, all others - drill 1/4".

The cam driven microswitch used to control the motor requires an addition to the above mount. To begin with, the accurate initial placement and adjustment of the switch is difficult. Also, as the motor is used, the microswitch may slowly slide away from the cam. This causes it to go out of adjustment and, after prolonged use, the switch may cease to function entirely. The solution to this problem is in the form of a combination adjuster / lock mechanism. The mechanism consists of an "L"-shaped aluminum bracket bolted directly to the vertical plate with four long adjusting screws mounted in the section of the bracket which is perpendicular to the plate. The screws are held in position by a washer, lockwasher, and nut on either side of the bracket. They are inserted through the angle bracket far enough to make contact with the sides of the microswitches opposite the cam. By adjusting the position of the screws, the positions of both of the microswitches can be accurately set. Tightening of the nuts on the screws maintains the adjustment. The design and hole layout for the adjustment / locking mechanism appears in Figure 4.5.

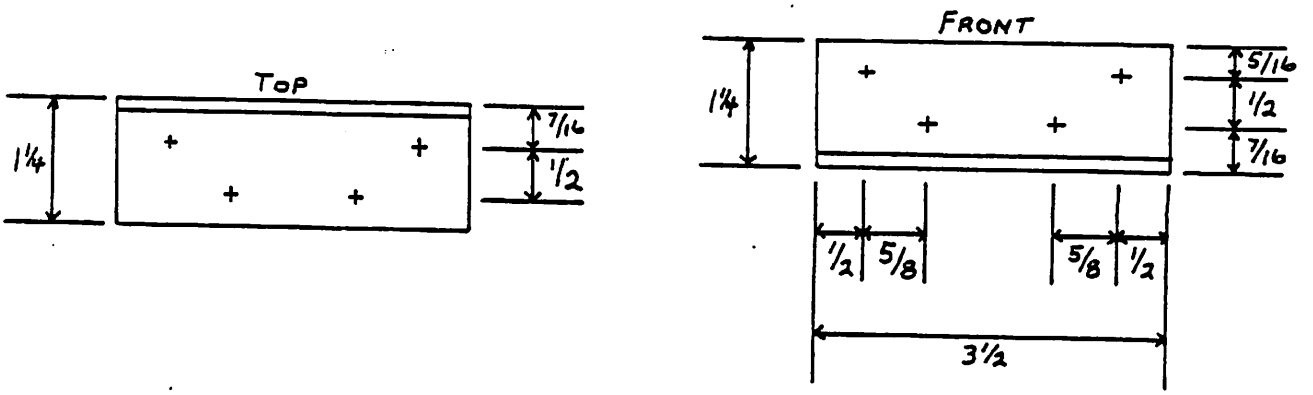


Figure 4.4
Hole Layout for Angle Piece
Drill all holes to 1/4".

The vibration damping characteristic of the mount is incorporated in the form of rubber bushings placed between the contact points of the sections of the mount. A bushing is also placed between the mount and the camera body. The bushings are cut from 1/16 inch rubber gasket material and are inserted between the angle and the vertical and horizontal pieces upon assembly. The larger of the bushings is placed between the horizontal section of the "L" and the camera body. The camera body is further cushioned from vibrations by placing large, relatively soft rubber washers between the thumb screws and the bottom of the mount. The motor, switches, and circuit bow are bolted directly to the vertical plate. Patterns for the rubber bushings appear in Figure 4.6. The pattern in Figure 4.5a is used for the pieces to be bolted between the angle bracket and the flat plates. Two bushings made from this pattern are required.

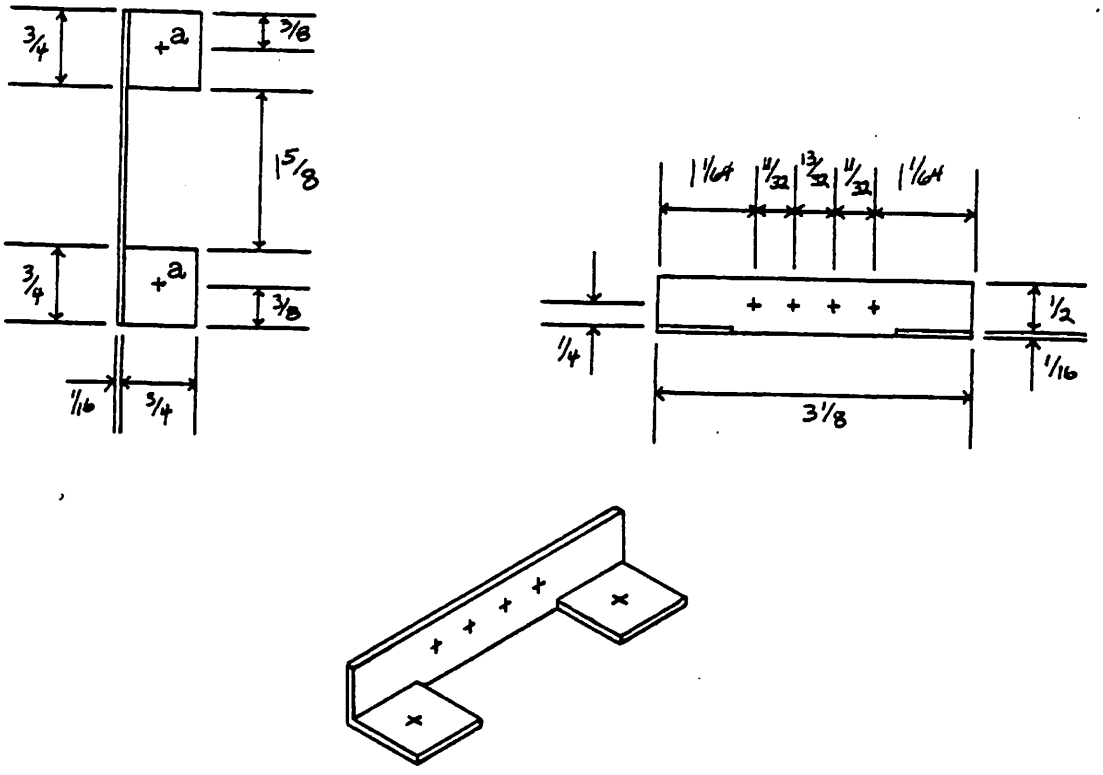


Figure 4.5
Design of Switch Adjustment and Lock Mechanism
Hole sizes: a - drill 1/4", all others - drill #5.

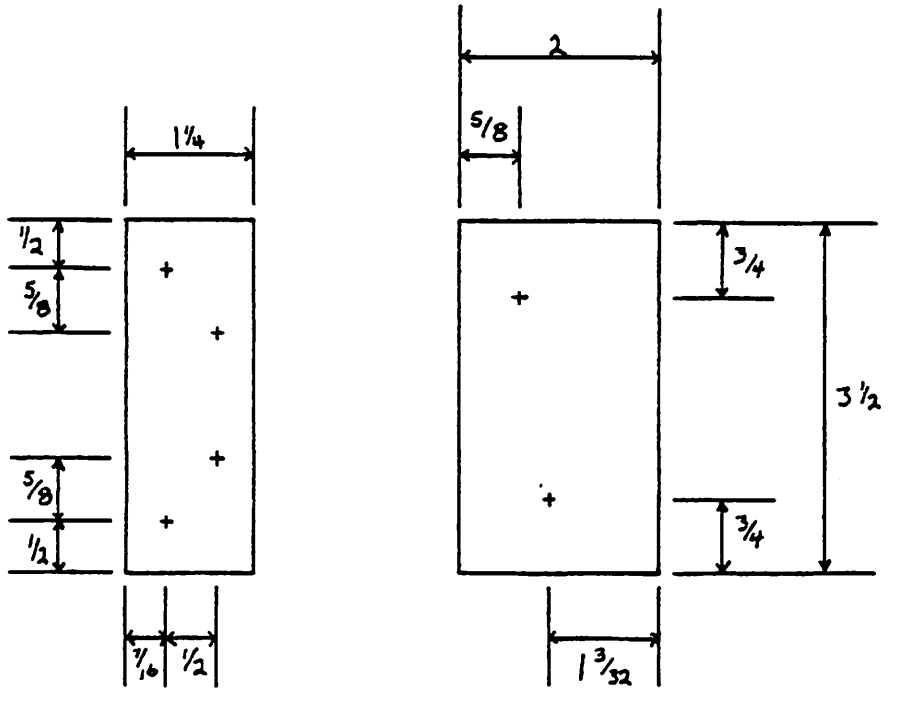


Figure 4.6
Patterns for Rubber Bushings
a. between angle and plates, b. under camera body.

Figure 4.7 contains an illustration of the assembled motor mount less the motor and camera. A complete list of the materials required for construction of the motor mount appears in Figure 4.8.

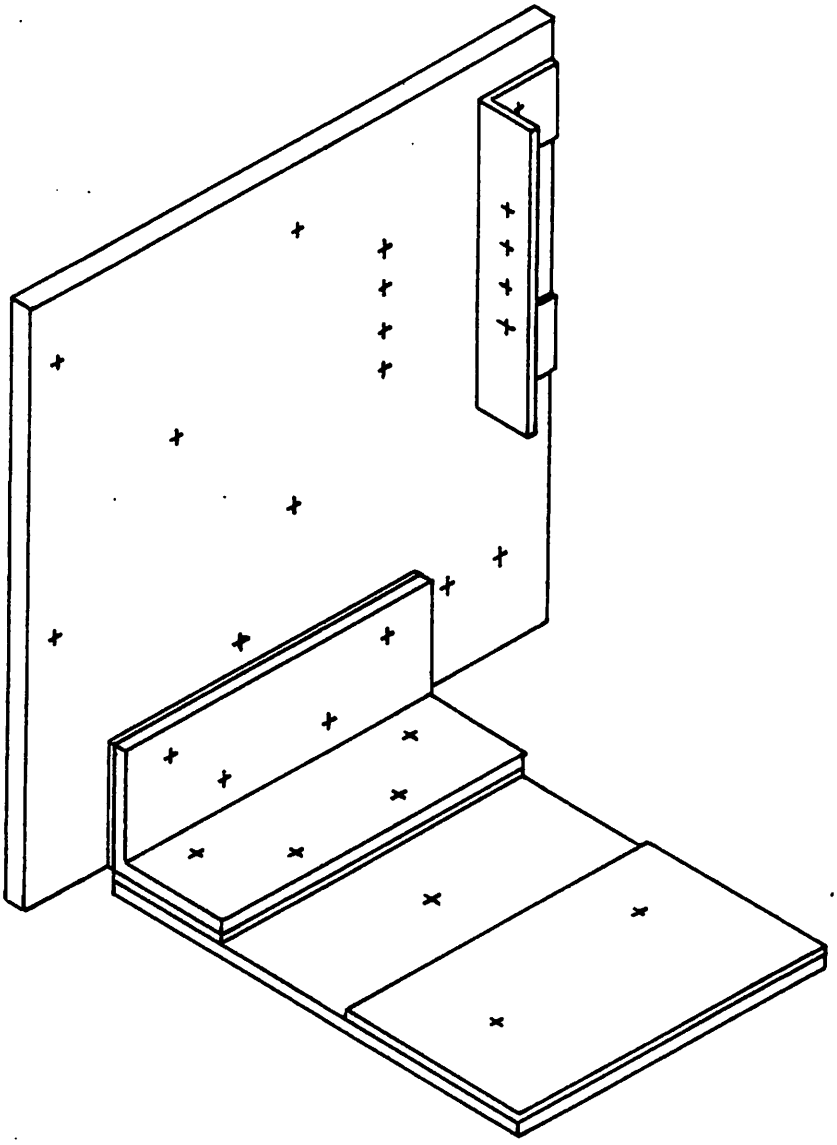


Figure 4.7
View of Assembled Motor Mount

Quan.	Description
1	6" x 6" x 3/16" aluminum plate
1	4 3/4" x 3 1/2" x 3/16" aluminum plate
1	1 1/4" x 1 1/4" x 3 1/2" long angle iron
1	1/16" rubber bushings
14	1/4-20 x 7/16" machine screws
14	7/16" lock washers
4	4-40 x 2" machine screws
8	4-40 nuts
4	#4 lock washers
2	3/8-16 x 3/4" wingnuts
2	7/8" flat washers
2	1 3/8" sponge rubber washers
2	1 3/8" flat washers

Figure 4.8
List of Materials for Motor Mount

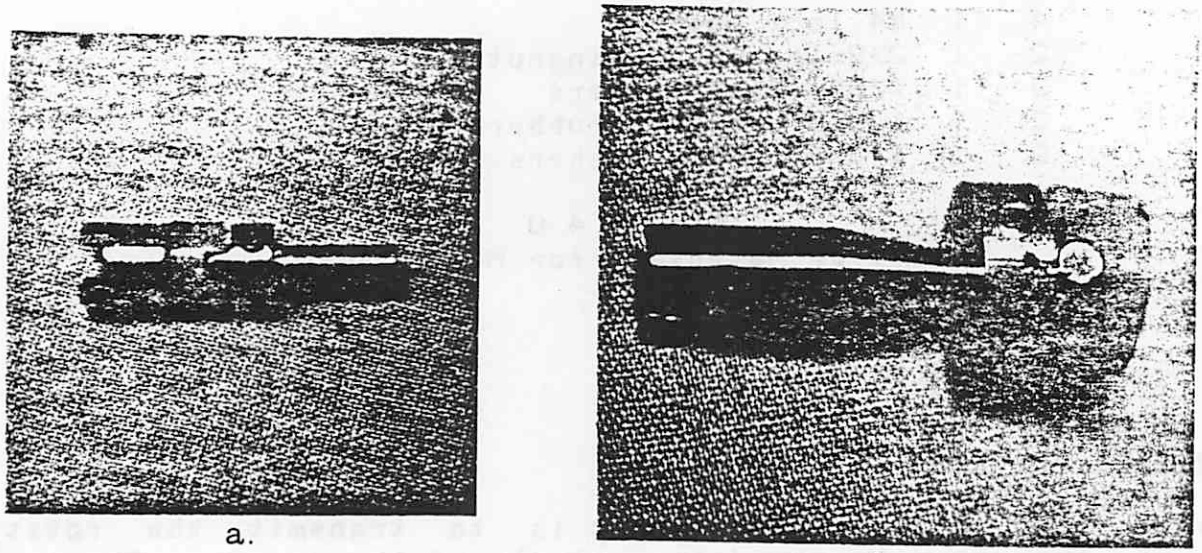
4.3 Coupling and Cam

The purpose of the coupling unit is to transmit the rotational motion of the motor to the drive spindle of the camera. The coupling must also be capable of absorbing the instantaneous startup shock produced by the motor, as well as slight lateral and angular misalignment. The style of coupling chosen consists of three sections. One end section rigidly attaches to the end of the rotor. The other end section fits over the drive spindle of the camera. The middle section consists of a cylindrical nylon bushing with a slot in each end. Raised projections on the end sections mate with the slots in the center section, thus transmitting the force from one end of the coupling to the other. This type of coupling is marketed by the Renbrandt Company of Boston, see Appendix A for the address. The author wishes to express his appreciation to the Renbrandt company for its assistance in producing a coupling. Figure 4.9 shows two configurations for the coupling.

The difference between the styles lies in the method of attachment of each to the camera. Both couplings employ a Tinymite coupler on the rotor of the motor. This appears in Figure 4.9b on the right end. The Tinymite coupling has a 3/8" bore on one end and a 1/8" bore on the other. The basic piece for this part is available from Renbrandt as part #A-201-35, which attaches to the shaft through the use of two 4-40 set screws per hub. This piece must have one of the ends bored to 3/8". There are two possible configurations for the camera end of the coupling.

The coupling in Figure 4.9a is a specially modified Minimite

coupling, also supplied by the Renbrandt Company. A Minimite, part #A-201-36, with one extra long end is the basic piece. This coupling attaches with two 2-56 spline socket, cup point set screws per hub. The extra long end must be bored to a diameter of 4mm and then slotted. The slot should have the same dimensions as the slot in the solid piece discussed below. The short end of this assembly is locked onto a 1/2" brass pin which, in turn, is locked into the end of the Tinymite coupler. The resulting assembly actually consists of two complete couplers joined by a brass pin.



a. b.

Figure 4.9
Configurations for the Coupling

In the coupling in Figure 4.9b, the Minimite assembly has been replaced by a single piece, thereby reducing the number of parts which can be lost. The design of the piece was taken directly from the assembly which it replaces and appears in Figure 4.10. This single piece should be machined from stainless steel to avoid the possibility of sheering off the two blades. The end with the smaller diameter is locked into the corresponding end of the Minimite coupling. The coupling in Figure 4.9b shows the assembled unit minus the end section of the Tinymite coupling which is locked to the rotor shaft.

The purpose of the cam is to provide the motor control circuitry with information as to the position of the rotor. The cam consists of a machined disk rigidly attached to the rotor. A notch in the edge of the disk provides a marker. A single 6-36 set screw is used to attach the cam to the rotor. Since the roller must follow the contour of the cam, the edges of the notch should be somewhat rounded. The design of the cam is given in Figure 4.11.

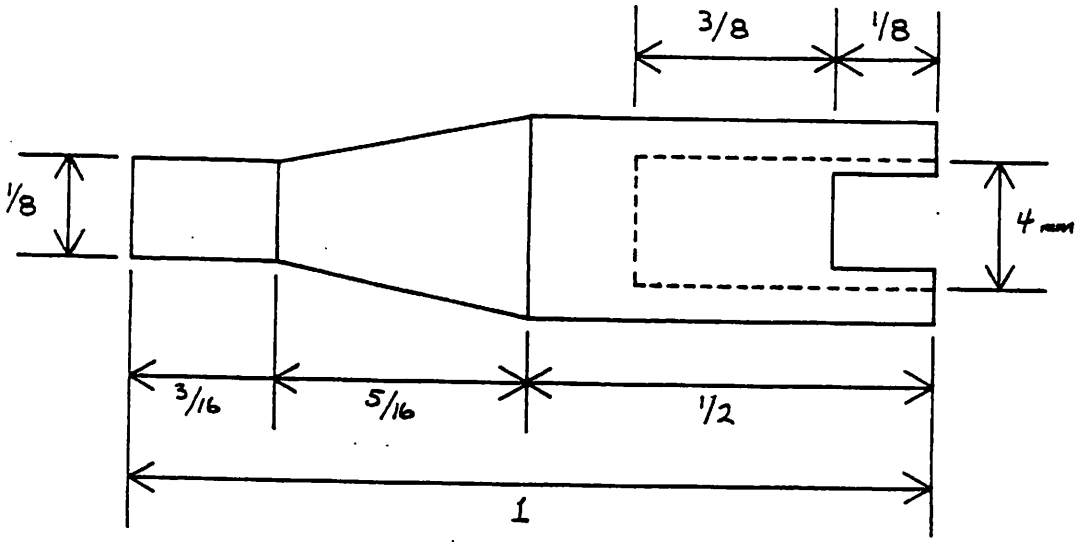
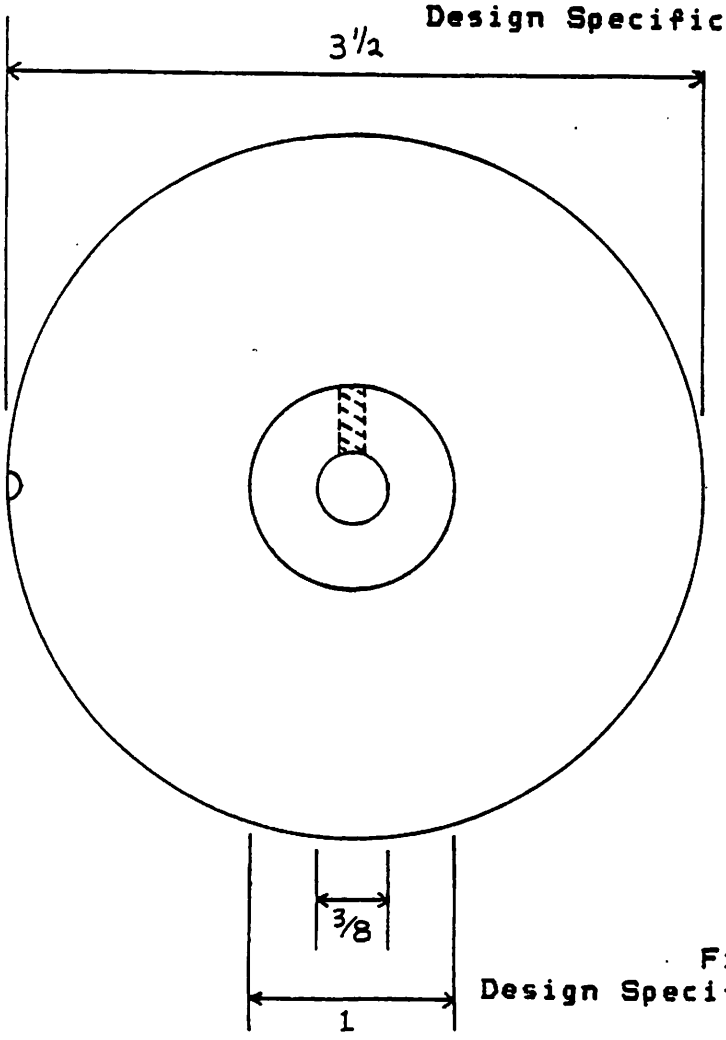


Figure 4.10
Design Specifications for the Coupling



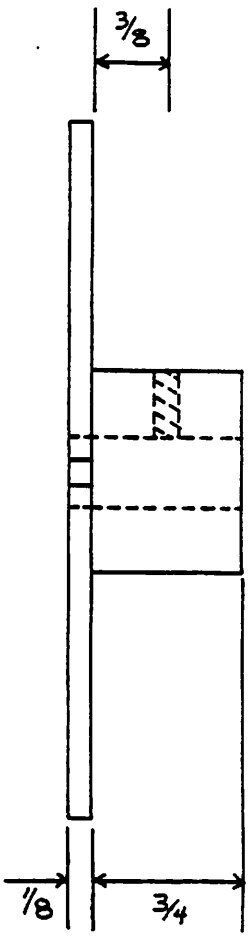


Figure 4.11
Design Specifications for the Cam

The roller of one of the microswitches rides along the outer edge of the cam. The switch is positioned so that when the roller is in the notch on the cam, the circuit through the switch is open. However, when the roller is riding out of the notch, the circuit is closed. A

detailed discussion of the use of the microswitches is reserved for Section 4.3, concerning the motor control circuitry. Figure 4.12 shows the position of the cam on the rotor shaft while Figure 4.13 illustrates the positioning of the microswitches relative to the notch in the cam.

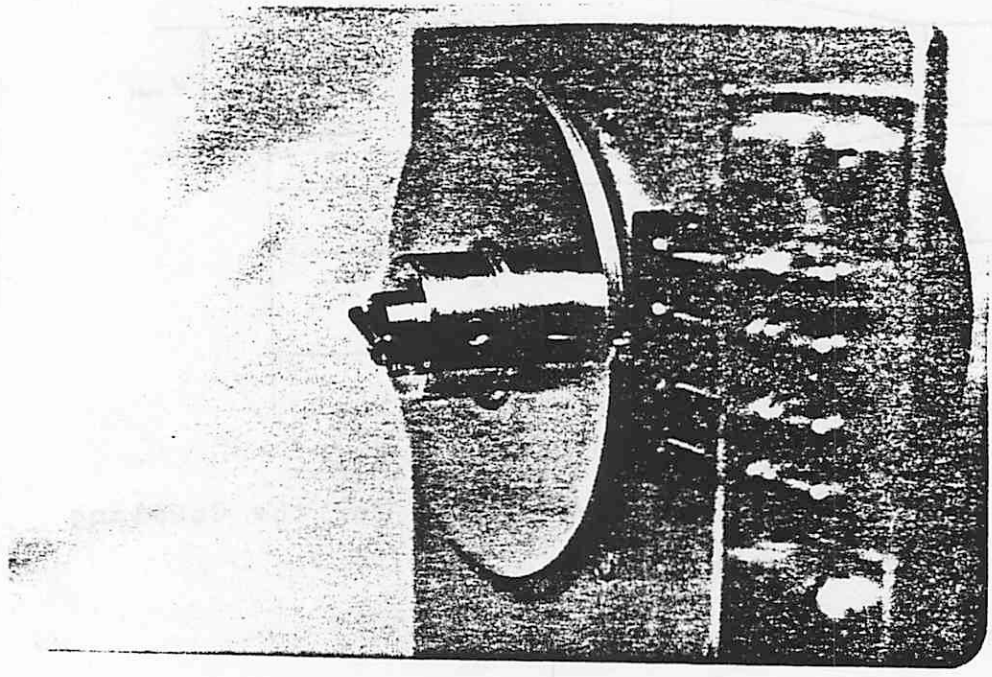
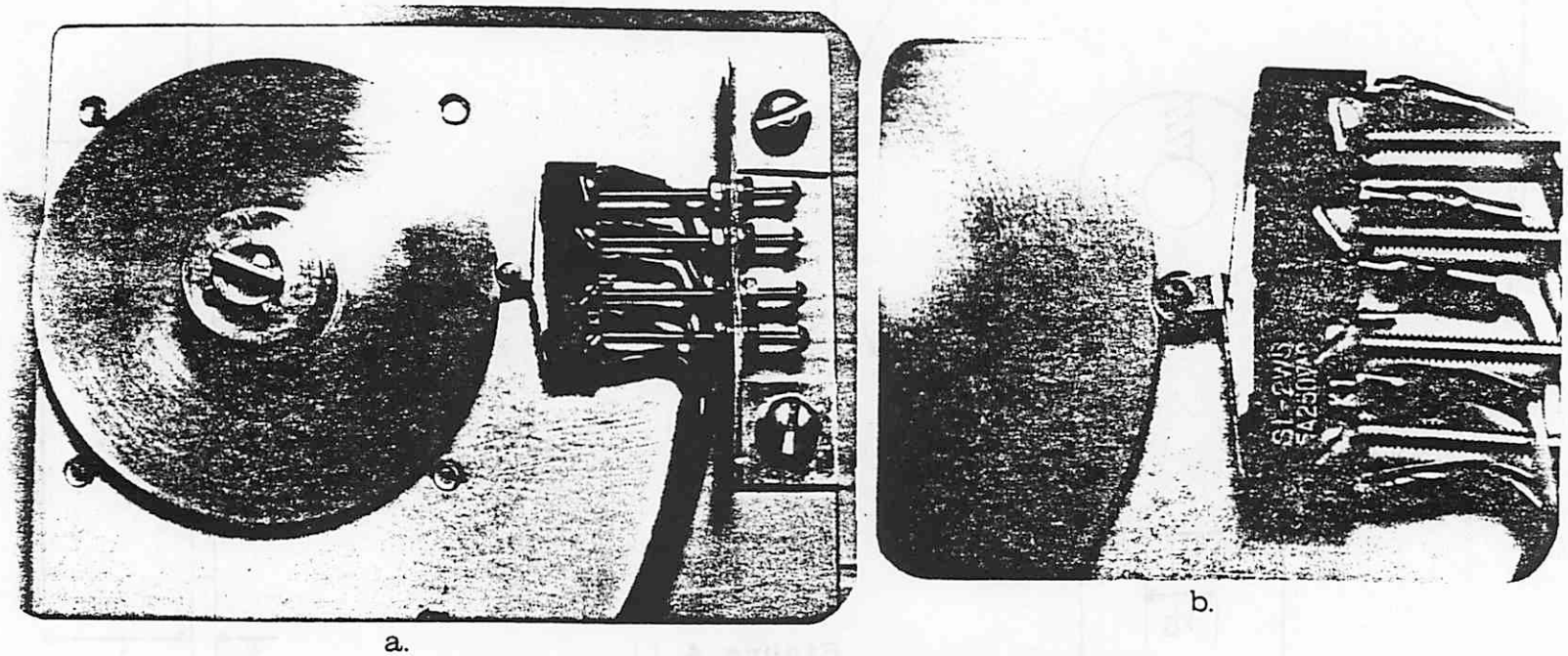


Figure 4.12
Cam Position on the Rotor



a. b.

Figure 4.13
Relationship Between the Microswitches and the Cam

4.4 Motor Control Circuitry

The camera drive shaft rotation is linked in a 1:1 ratio with the shutter and film advance mechanism, i.e. one rotation of the shaft exposes and advances exactly one frame of film. Therefore, the motor rotor must make exactly one complete revolution for each frame. The purpose of the motor control circuitry is to cause the rotor to complete exactly one revolution after being triggered. The cycle may be triggered either by the computer or by the user through a pushbutton mounted on the circuit box.

The control is accomplished by a blend of electronic and mechanical means. The basic circuit schematic is shown in Figure 4.14. The motor requires two 120 VAC, 60 Hz, inputs whose phases differ by 90 degrees. If the leading signal is applied to terminal 1 of the motor, while the lagging input is applied to terminal 3, the motor will turn in a clockwise direction. Reversing the inputs results in counterclockwise rotation. The phase shifting network is contained within the box labelled "A". Switch S1 is used to set the direction of rotation of the motor while lights L1 and L2 provide the user with an indication of the direction.

The outlined area labelled "B" contains the actual ON/OFF control of the motor. Switches S2, PB1, and relay RL are connected in parallel so that the motor will turn whenever at least one of the switches is closed. The relay is located on the circuit board containing the digital circuit, see below. It is connected to the AC circuit by a twin lead cord. To allow the drive unit to be portable, the cord is cut into two sections and joined with a plug and socket connector. The female, panel mount connector (CN2 in Figure 4.15), is used on the cord attached to the relay and the male connector (CN1 in Figure 4.14) on the cord from the circuit box. PB1 is a manual pushbutton mounted on the circuit box and is intended to allow the user to manually initiate a picture-taking cycle. When the pushbutton is closed (depressed), the motor begins to turn. The pushbutton may then be released as the motor is under the control of the switch S2.

S2 is a lever, with roller, actuated microswitch which is controlled by the cam affixed to the rotor shaft of the motor. When the motor is "OFF", the roller of the switch is located in the notch in the edge of the cam. Since S2 is used in a normally open configuration, the switch is open. Once the rotor and cam begin to turn, the roller moves out of the notch, thus forcing the switch into a closed configuration. The rotor and cam will continue rotating until the roller of the switch drops back into the notch in the cam. If neither S2 nor RL are closed at this point, the motor will turn off. Initiation of one rotation of the motor is caused by closing either S2

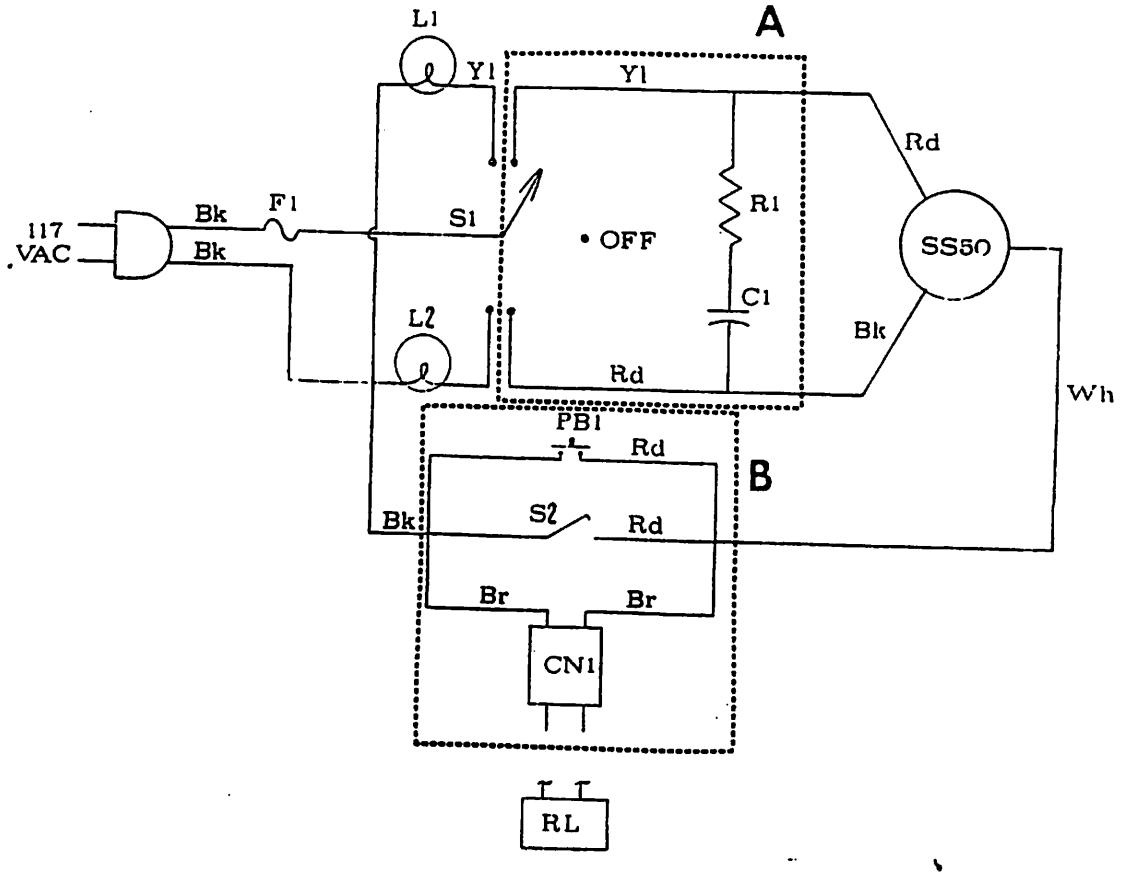


Figure 4.14
Schematic of AC Motor Control Circuit

Components:

C1 - 2.25 mfd capacitor
CN1 - 2 prong male connector
F1 - 1/2 Amp slow blow fuse
L1 - 120 V amber lamp
L2 - 120 V red lamp
PB1 - SPST pushbutton, NO
R1 - 400 ohm resistor
RL - 120 V, 5 Amp relay
S1 - DPDT switch
S2 - SPST microswitch
SS50 - motor

Color code:

Bk - black
Br - brown
Rd - red
Wh - white
Yl - yellow

or RL. The action will continue, regardless of the behavior of S2 or RL, due to the cam control of S2, until the cam has finished exactly one complete revolution and is in its original position, thus opening S2. The use of the mechanical control for switch S2 assures that the rotor completes exactly one revolution.

RL provides both the second path for initiation of a cycle and the connection with the computer. RL is a digitally controlled relay, i.e. a switch controlled by TTL signals, which can handle 120VAC at 4 amps. The relay is controlled by the computer through the circuit shown in Figure 4.15.

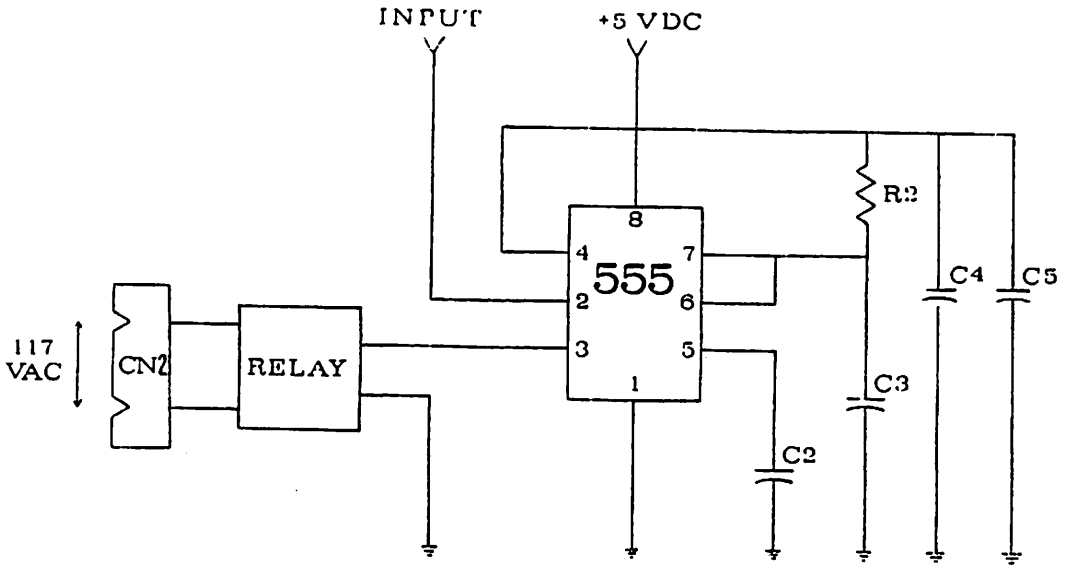


Figure 4.15
Schematic of Digital Control Circuit

Components:

555 - Signetics 55 Timer
C2 -..01 mfd cap.
C3 - .01 mfd cap.
C4 - 1000 mfd electrolytic cap.
C5 - 2.2 mfd tantalum cap.
R2 - 100 meg ohm resistor
Relay - 120 V, 5 Amp

The purpose of this circuit is to receive, invert, and latch a pulse from the computer. The integrated circuit used is a Signetics 555 Timer. When triggered by a negative-going pulse, the output of the timer will remain "ON", high, for a time determined by the time constant of the resistor / capacitor network composed of R1 and C2. In this circuit the timer is set to remain on for .1 seconds. The input to the timer is normally high, and the output is triggered when the input makes a transition from high to low. Capacitors C3 and C4 provide a degree of noise filtering. The complete specifications for the Signetics 555 Timer appear in Appendix E.

The primary use of this equipment is in conjunction with the the COINS Department VAX 11/780 computer and Grinnell color graphics processor. The input to the timer is provided by setting and resetting bit zero of the Peripheral Device Enable Register in the Grinnell. The Grinnell uses a "high" state to indicate a reset, logical 0, condition and a "low" state to indicate a set, logical 1, condition. Consecutively setting and resetting the bit results in a 2 microseconds long input pulse to the timer. All of the software discussed in Section 3, entitled "User Interface", makes this procedure transparent to the user.

The system is also applicable in cases where the camera is to be controlled through a device other than a Grinnell. All that is required of the system is that the software be capable of setting and resetting at least one bit which is accessible from the outside of the

machine. The circuit in Figure 4.15 has been designed to work with inverted logic, i.e. the "set" condition is indicated by a low (0 volts) state. By placing an inverter between the INPUT in Figure 4.15 and pin 2 of the 555 timer, the circuit will function properly with normal logic, i.e. the "set" condition is indicated by a high (+5 volts) state.

In summary, switches S2 and relay RL are used to initiate a picture-taking cycle. One of these must be closed long enough to cause the cam to rotate far enough to close the microswitch S3. This switch remains closed until the cam completes exactly one revolution and the microswitch then turns off.

A secondary circuit is used to control lights indicating the state of the motor. When the motor is in the process of taking a picture, i.e. ON, the WAIT light (L3) is turned on. Alternately, when the motor is ready to take a picture, i.e. OFF, the READY light (L4) is turned on. This circuit appears in Figure 4.16. Notice that the input and fuse are shared with the circuit in Figure 4.14.

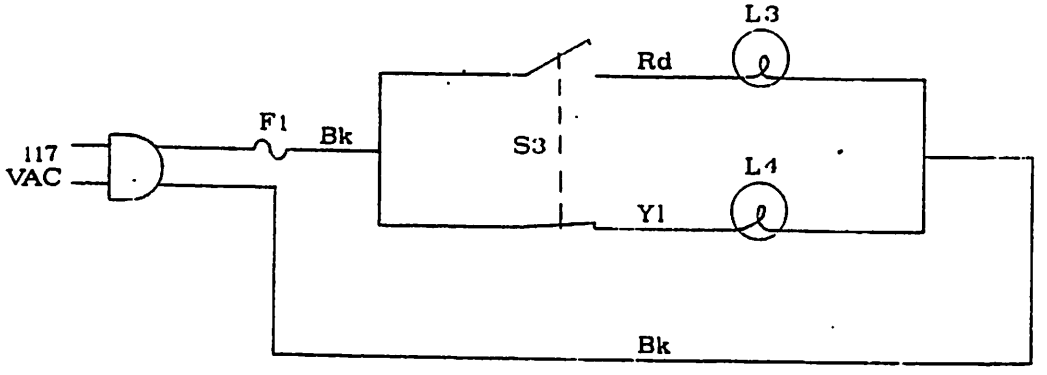


Figure 4.16
Schematic for READY/WAIT Circuit

Components:

F1 - 120 volt, 1/2 amp fuse (Slow-Blow)
L3 - red -WAIT- lamp
L4 - amber -READY- lamp
S3 - SPST microswitch

Color code as in Figure 4.14.

The circuits used to control the motor and the ready and wait light are housed in a circuit box which is mounted on the same plate as the motor. The hole layout for the box appears in Figure 4.17. The microswitches are mounted directly to the motor mounting plate except on the same side as the cam, i.e. toward the camera. The capacitor and resistor in the circuit shown in Figure 4.14 should be mounted on a piece of circuit board and placed in the back of the circiut box. Figure 4.18 contains two views of the completed circuit box. This figure also indicates the locations on the box of the various lamps and switches. The timer circuit should be assembled on a separate circuit board and located in or near the device supplying the input signal.

A complete list of the components used in the construction of the motor control circuitry appears in Figure 4.19.

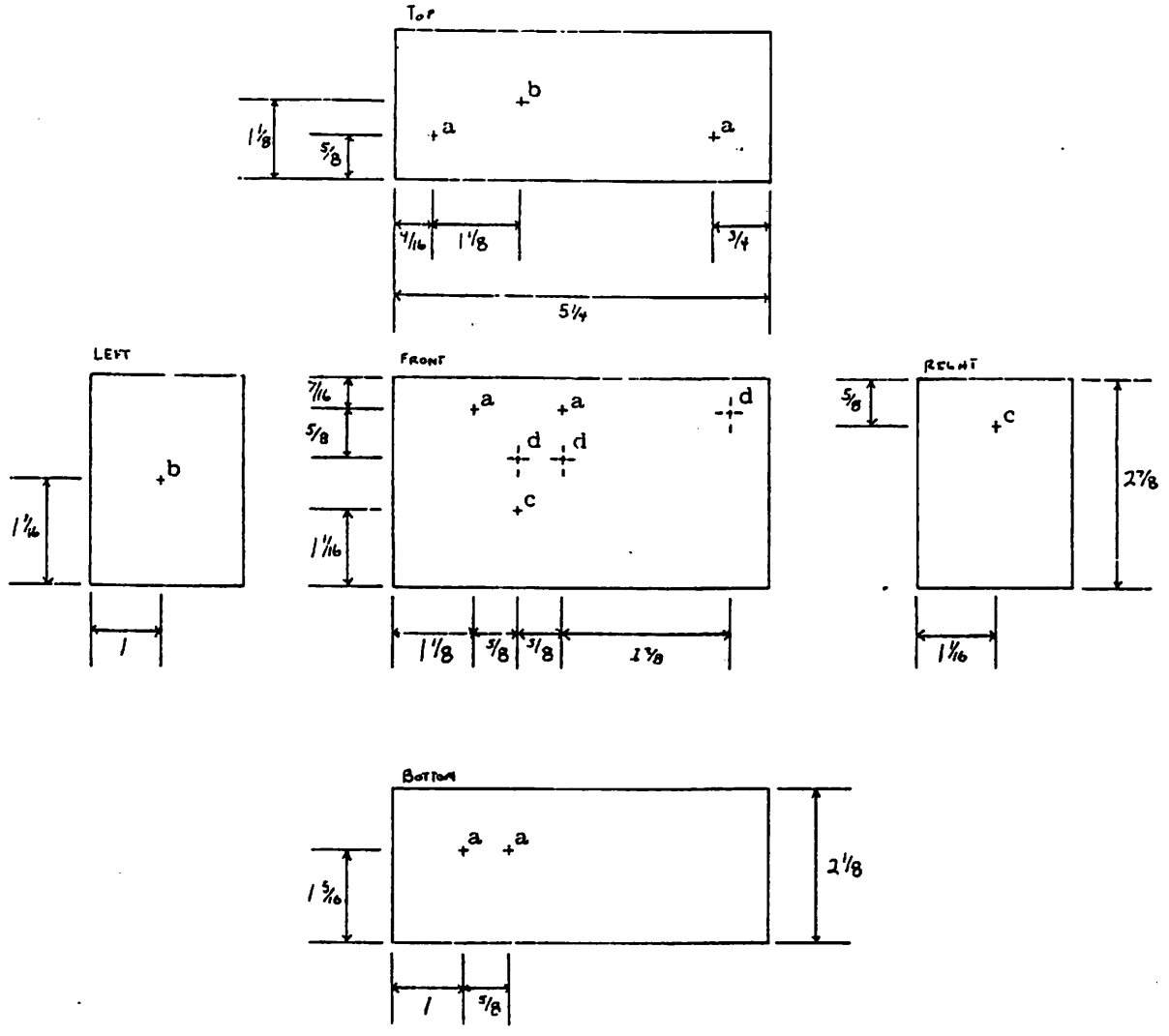
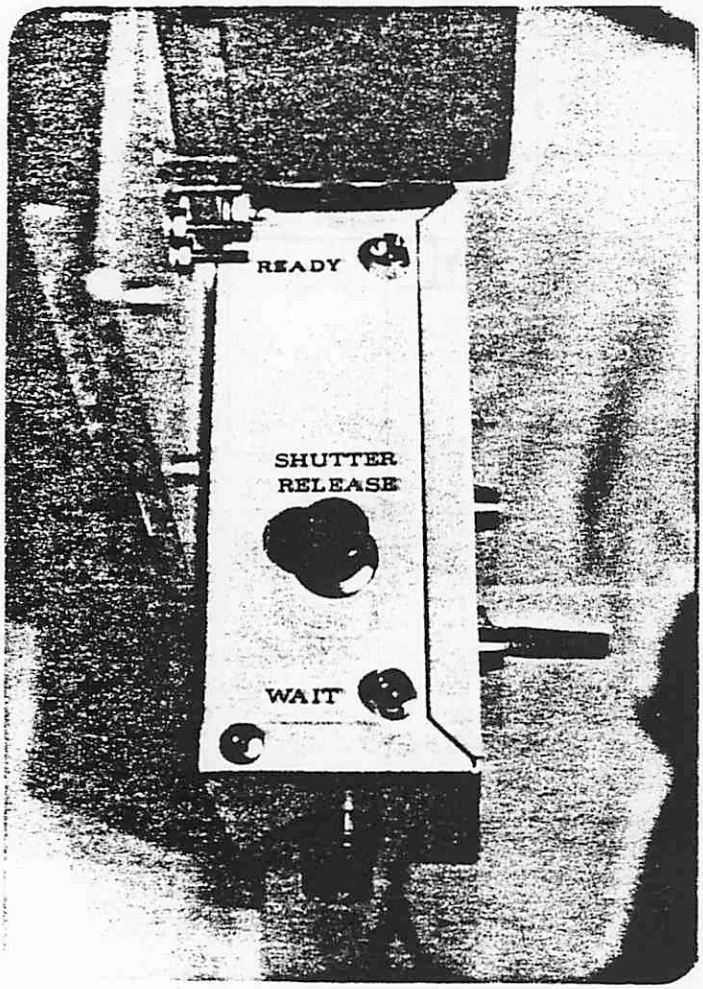


Figure 4.17
Hole Layout for Circuit Box
Hole sizes: a - 5/16", b - 1/2", c - 7/16", d - 1/4" (in back).



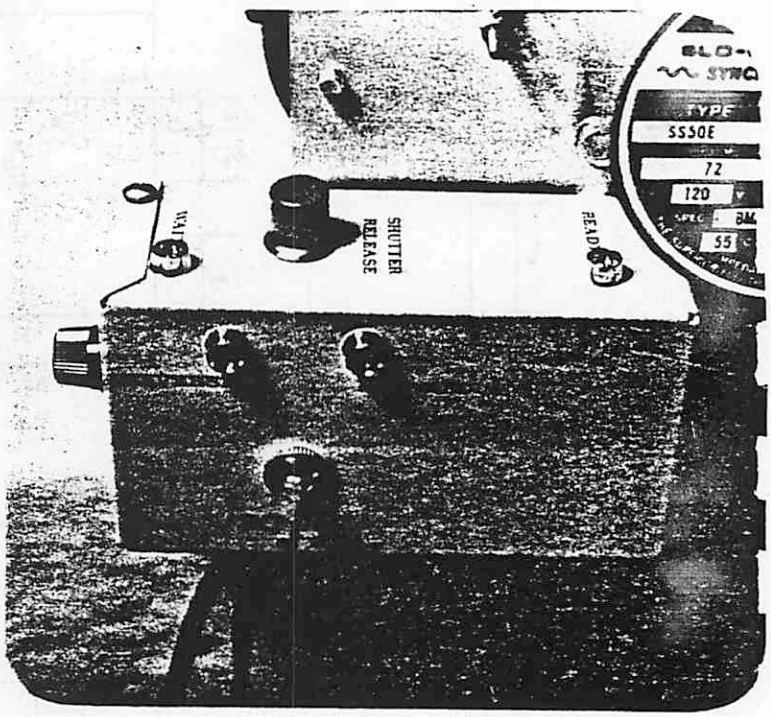


Figure 4.18
Views of Completed Circuit Box

Electronic Components:

Label in Figure	Description	Supplier Code	Part #
C1	2.25 mfd., 330 VAC capacitor	SE.	C-SS50
C2, C3	.01 mfd. disc capacitor	RS.	272-135
C4	1000 mfd. electrolytic cap.	RS.	272-958
C5	2.2 mfd. tant. capacitor	RS.	272-1407
CN1	2 prong male connector, 7.5A	RS.	274-201
CN2	2 prong female ", chassis mt.	RS.	278-1636
F1	1/2A Slow-Blow fuse	RS.	270-1282
F1	Panel-mount fuse holder	RS.	270-364
L1, L3	120 volt neon lamp, amber	RS.	272-703
L2, L4	120 volt neon lamp, red	RS.	"
PB1	SPST pushbutton, 3 amp, NO	RS.	275-609
R1	400 ohm, 25 watt resistor	SE.	R-SS50
R2	100 Meg Ohm resistor	ES.	---
RL	Solid-state Relay 5A 250V	GE.	GSR 10AU50DA
S1	DPDT 6A. neutral ctr. switch	RS.	275-653
S2	Microswitch lever/roller 5A	RS.	275-017
	or	RS.	275-236
S3	microswitch, lever 5A	RS.	275-016
SS50	Slo-Syn Synchronous Motor	SE.	SS50E
555	Signetics 555 Timer IC	SIG.	555

Miscellaneous Parts:

Quan.	Description	Supplier	Part #
4	6-36 x 1" machine screws	HD.	---
4	6-36 nuts	HD.	---
4	#6 lockwashers	HD.	---
---	paint for circuit box	HD.	---
6'	line cord	RS.	278-1255
---	20 guage stranded wire assorted colors	RS.	278-1304
30'	20 guage zip cord	RS.	278-1265
3	strain reliefs	RS.	278-1636
1	assorted shrink tubing	RS.	278-1627
1	4 1/2" x 6" IC perfboard	RS.	276-1394
1	5 1/4" x 3 x 2 1/8" chas. box	RS.	270-238
2	1/4-20 x 7/16" machine screws	HD.	---
2	7/16" lock washers	HD.	---
2	3/4" flat washers	HD.	---

Supplier Codes:

SIG. -- Signetics Corporation
SE. -- Superior Electric Company
RS. -- Radio Shack
GE. -- General Electric Company
HD. -- Hardware Store
ES. -- Electronics Store

Figure 4.19
List of Materials for Control Circuit

4.5 Assembly of Drive Unit

This section describes the procedures employed to assemble the drive unit and associated circuitry. All of the electrical connections should be soldered using multicore solder to ensure conductivity. The assembly procedures may be divided into four groups. The figures appearing in sections 4.1 through 4.4 should be used to clarify the procedures outlined in this section. The first two include the assembly of the motor mount and the control circuitry. The third step involves attaching the motor, circuit box, and switches to the mount, and the fourth consists of the adjustment of the microswitches and motor coupling.

Motor Mount

Assembly of the motor mount is straightforward. The vertical piece is bolted to the angle bracket using four of the 14 1/4-20 x 7/16" machine screws indicated in the list of materials (see Figure 4.8). Each of the machine screws should have a lock washer placed between the screw head and the angle piece. Also, one of the rubber bushings (see Figure 4.6a) should be placed between the two pieces. The four holes in the vertical side of the angle piece match a set of four holes near the bottom of the vertical section. The angle should be bolted on the side opposite that shown in Figure 4.2. Addition of the horizontal piece is similar.

The horizontal piece should be bolted to the bottom of the angle in the same fashion as was the vertical piece. Again, lock washers should be used between the screw heads and the angle, and one of the rubber bushings should be placed between the parts. The final piece to be added is the microswitch adjuster.

The microswitch adjuster mechanism should be bolted in the upper left hand corner of the vertical plate. This bracket is bolted on the same side as was the angle bracket. The section of the adjuster bracket which is perpendicular to the vertical plate must be between the mounting holes for the bracket and the row of four 3/16" holes. This row of holes will be used for mounting the microswitches. The resulting assembly should resemble Figure 4.7.

Addition of the four 4-40 x 2" machine screws to the microswitch adjuster completes this section of the assembly. All of the screws are inserted in the same manner. A 4-40 nut should be threaded onto the screw, followed by a lock washer and a flat washer. Each screw is then inserted from the side opposite the row of holes in the motor mounting plate into one of the holes in the adjuster and secured by a second flat washer and nut, in that order. Figure 4.20 shows the completed microswitch adjuster. By changing the position of the pair of nuts, the length of the screw protruding through the adjuster bracket may be

changed. When the microswitches are in place, the screws will touch the the backs of the switches. Therefore, by changing the position of the pair of nuts, the position of the switch is changed.

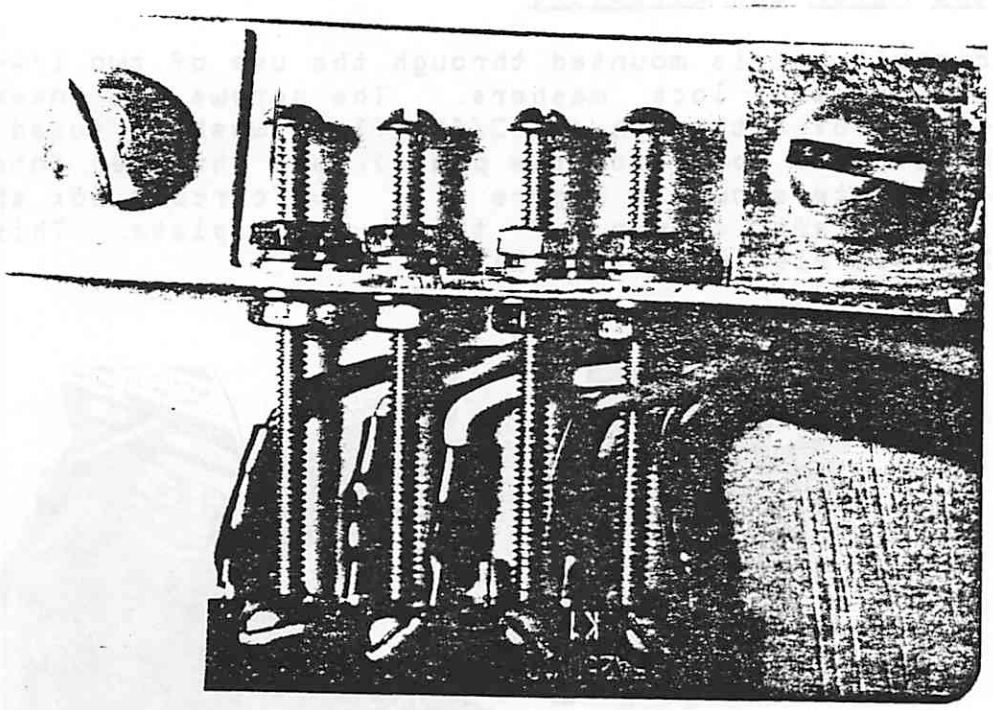


Figure 4.20
Completed Microswitch Adjuster

Circuitry

The second phase of assembly involves construction of the circuitry. The digital circuit (shown in Figure 4.15) should be constructed on its own circuit board. This board is then mounted in the cabinet housing the processor which is to provide the triggering pulse. In this implementation, the circuit board is mounted in the Grinnell cabinet in the section housing the power supply. This provides easy access to +5VDC and ground connections. The female connector on the leads from the relay should be mounted in the cabinet so as to allow easy access from the outside.

The AC motor control circuit should be placed on a circuit board cut to fit into the circuit box. The wires from the motor should be covered by a piece of shrink tubing and inserted through the hole in the right end of the box as viewed in Figure 4.17. A strain relief should be used to lock the position of the wires as they enter the box. Roughly four inches of wire should be left outside of the box to ensure that the motor and circuit box can be easily positioned on the mounting plate. The AC line cord and the cord used to connect the control circuitry and the digital circuitry should be inserted in the two holes in the bottom of the circuit box. Again, strain reliefs should be used to lock the cord in position. The leads for the microswitches should be soldered to the switches and then bundled and encased in shrink

tubing. However, the wires must be passed through the mounting plate from the side with the adjuster and through the appropriate hole in the back of the circuit box before they are tied into the circuit. The wires should pass through the unthreaded 1/4" hole which appears in Figure 4.2 to the left of the set of holes used to mount the angle piece.

Mounting the Motor and Circuitry

The circuit box is mounted through the use of two 1/4-20 x 7/16" machine screws and lock washers. The screws are inserted from the inside of the box, through a 3/4" flat washer (used to provide separation of the box from the plate), and threaded into the side of the mounting plate shown in Figure 4.2. The circuit box should end up on the lower left corner of the mounting plate. This is shown in Figure 4.21 (see also Figure 4.18).

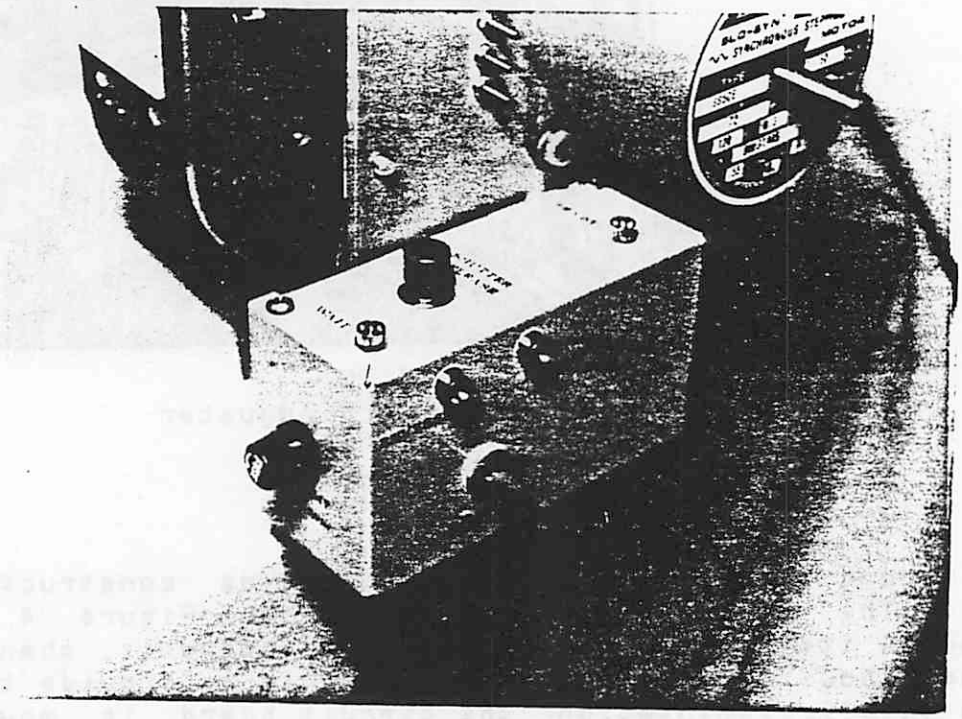


Figure 4.21
Completed Circuit Box

The motor is mounted on the side of the plate shown in Figure 4.2 with the rotor shaft passing through the 5/8" hole in the upper right corner. The motor is held by four 1/4-20 x 7/16" machine screws and lock washers. Finally, the microswitches are attached to the side of the plate opposite that shown in Figure 4.2 with the four 6-36 screws. The screws should be inserted from the switch side and locked with a lock washer, flat washer, and nut on the same side as the circuit box. The microswitch without the roller on the lever should be positioned so that its lever contacts the lever of the other microswitch directly behind the roller. The position of the microswitches is shown in Figure 4.13.

The cam should be pushed onto the rotor shaft so that the flange is next to the plate. Adjust the position of the cam so that the roller of the microswitch rides along the center of the flange. The cam should be locked in this position with the set screw in its base. The coupling hub with the 3/8" bore is mounted on the end of the rotor shaft and locked in place with its pair of set screws. This configuration is shown in Figure 4.12.

Adjustment

Two adjustments must be made in order for the unit to function properly. The positions of the microswitches relative to the cam must be set and locked. Also, the orientation of the coupling relative to the camera drive shaft must be established.

The first adjustment to be carried out is that of the microswitches. When the roller of the microswitch controlling the motor is in the notch in the cam (as shown in Figure 4.13b) the switch must be open. However, when the cam is rotated so that the roller is out of the notch, the switch must be closed. The transition between open and closed is indicated by a "click". The second microswitch should be adjusted so that its action matches that of the first. These adjustments are accomplished through the use of the adjuster mechanism (see Figure 4.20).

Loosen the screws used to anchor the switches to the plate and adjust the positions of the switches with the screws which push against their backs. When correctly positioned, momentary depression of the shutter release button on the circuit box should cause the cam to rotate once and stop when the roller reaches the notch. Also, the READY light should turn off and the WAIT light on as the cam begins to turn. As the cam completes one cycle and stops, the WAIT light should go out and the READY light should come on. Once the positions have been determined, lock each of the adjusting screws using the two opposing nuts.

The coupling requires adjustment in two dimensions. First, the length of the entire assembly must be set. To accomplish this, the parts of the coupling should be loosly fitted together and mated with the hub attached to the rotor shaft. Insert the driving end of the coupling into the housing surrounding the drive shaft spindle (part 11 in Figure 2.1) so that the slot meshes with the locking pin, and bolt the body to the mount, see Section 4.6. This configuration is shown in Figure 4.22. During the process, the motor disengaging lever should be positioned at the MOT setting and the side release at STOP.

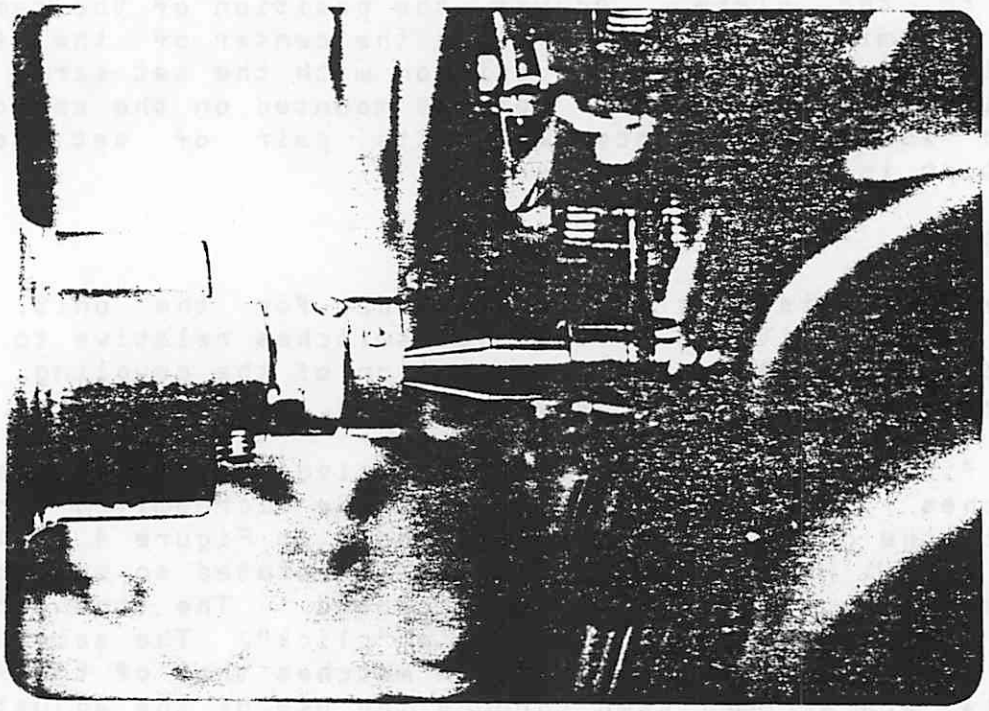


Figure 4.22
Cam-Coupling-Camera Connection

The length of the coupling should be set so that the parts cannot be separated while the camera body is in position. The design of the coupling allows for slight misalignment and nonlinearity of the rotor shaft and the camera drive shaft so there is no adjustment for these parameters.

The second adjustment involves the relationship between the position of the cam and the slot in the driving end of the coupling. This adjustment must be performed with the camera and drive unit assembled, as during the above length adjustment. With the cam rotated so that the notch is roughly 100 degrees counterclockwise from the microswitch roller (when viewed from the cam side of the vertical plate), lock the positions of all of the set screws in the coupling. This is to allow centering of the shutter opening in the motor rotation cycle. In order to test the setting, the spring disengaging lever MUST be set to O and the side release to M. If this is not done and the drive motor is activated, serious damage to the camera could result. Rotate the lens turret and open the reflex prism to expose the shutter (see Figure 2.14). When the motor is in the READY state, roller in the notch, the shutter should completely obscure the aperture. As the motor cycles, the shutter should rotate exactly once, exposing the aperture, and stop with the aperture again completely obscured. This completes the assembly and adjustment of the drive unit.

4.6 Using the Drive Unit

This section describes the procedure for using the motor drive and camera. Since the exposure duration is considerably longer than is normally incorporated, a tripod or other solid mount should be employed to hold the drive unit and camera steady.

The drive unit should first be mounted on the tripod. The hole in the center of the horizontal plate (see Figure 4.3) has been threaded to match the mounting screw on most tripods. Once the drive unit has been firmly locked in place, the horizontal piece must be adjusted so that the camera will be level. Finally, plug the 117 VAC power cord into an available outlet and the cord connecting the AC Motor Control Circuitry and the DC digital control circuitry into the appropriate socket. Make sure that the roller is in the notch in the cam. Test the drive without the camera by moving the POWER switch on the circuit box to either FORWARD or REVERSE and depressing the shutter release button on the top of the circuit box. The cam should make exactly one revolution and stop with the roller of the microswitch in the notch in the cam. If the the cam either fails to complete a full revolution or does not stop, turn the power off and refer to Section 4.5 and readjust the microswitches.

After the drive has been tested, turn the power off and place the coupling on the hub mounted on the end of the rotor shaft. Before the camera body is mounted, the spring disengaging lever MUST be set to O and the side release set to M. Again, if this is not carried out and the drive is engaged, serious damage to the camera may result. Place the camera on the horizontal section of the mount so that the driving end of the coupling engages the camera drive shaft. The camera body is held to the mount through the use of the two 3/8-16 x 3/4" wingnuts. The large flat washers and sponge rubber washers are used at this point as an additional means of insulating the camera from vibration. A 7/8" flat washer, 1 7/16" flat washer, and a 1 7/16 sponge rubber washer should be placed on each of the wingnuts. The wingnuts are then inserted through the horizontal mounting plate from the bottom and into the appropriate holes in the bottom of the camera (see Figure 2.3). The wingnuts should be tightened finger tight only so as to avoid damage to the camera.

Before beginning to film, the alignment of the shutter and cam must be checked. To accomplish this, first rotate the lens turret until the reflex prism has been uncovered. Open the prism so as to uncover the shutter disk. With the roller of the microswitch in the notch in the cam, the shutter disk should completely obscure the aperture. Move the POWER switch to either FORWARD or REVERSE and depress the shutter release button once. The shutter should rotate exactly once, exposing the aperture, and stopping in the same position as before moving, with the aperture fully obscured. If the aperture is not completely covered both before and after the shutter rotates, refer to Section 4.5 and readjust the relative positions of the coupling and the cam. When this procedure has been completed, the camera and drive unit are now ready for use and should appear as in Figure 4.1.

5. Film

This section presents information regarding the types of 16mm film currently available. The author wishes the thank the Eastman Kodak Company for providing the information for this section through their publication entitled the Cinematographer's Field Guide. The sections include a table of film specifications for quick reference, a detailed discussion of each of the films in the table, and sections dealing with the packaging and storage of film.

5.1 Quick Reference Table

Film Name	Code No.	Type	Exposure Day	Index Tung	More Info.
Eastman Double-X Neg.	7222	B & W Neg.	250	200	pg66
Eastman 4-X Neg.	7224	B & W Neg.	500	400	67
Eastman Plus-X Neg.	7231	B & W Neg.	80	64	68
Eastman Ektachrome Video News Film (day)	7239	Color Rev.	160	40 KWF 80A	69
Eastman Ektachrome Video News Film (tung)	7240	Color Rev.	80 KWF 85B	125	71
Kodak Ektachrome EF (daylight)	7241	Color Rev.	160	40 KWF 80A	73
Kodak Ektachrome EF (tungsten)	7242	Color Rev.	80 KWF 85B	125	75
Eastman Color Neg. II	7247	Color Neg.	64 KWF 85	100	77
Eastman Ektachrome Video News Film High Speed (tungsten)	7250	Color Rev.	250 KWF 85B	400	79
Eastman Ektachrome Commercial	7252	Color Rev.	16 KWF 85	25	81
Kodak Ektachrome MS	7256	Color Rev.	64	16 KWF 80A	83
Kodak Plus-X Reversal	7276	B & W Rev.	50	40	85
Kodak 4-X Reversal	7277	B & W Rev.	400	320	87
Kodak Tri-X Reversal	7278	B & W Rev.	200	160	89

KEY: Neg. - negative, Rev. - reversal, KWF - Kodak Wratten Filter
day - daylight, tung - tungsten, B & W - black-and-white

5.2 Technical Data

This section contains the technical data pertaining to the films described in the chart in the previous section. Only information regarding 16mm films is included. More complete information is available in the Cinematographer's Field Guide.

--7222--
Eastman Double-X Negative Film

<Exposure Indexes>
Daylight - 250 Tungsten - 200

<Process>
Black and white with D-96 developer at commercial laboratories. The film may be pushed 1 stop (or more) with some loss in quality - check your processing laboratory.

<Use>
This black-and-white negative camera film is designed for general production use and in photography under adverse lighting conditions. It is useful where greater depth of field is needed without increasing the illumination level.

<General Properties>
Eastman Double-X Negative Film 7222 is a high-speed, panchromatic material that has good image-structure characteristics and excellent sharpness.

<Reciprocity Characteristics (EI-250)>
No exposure or filter compensation is required for exposure times between 1/10000 and 1 second.

<Handling>
Total Darkness.

<Rolls Available> 7222 (16mm)

CAT. No.	Iden No.	Description	Perf Type
197 1654	DXN449	100'; camera spool	2R-2994
197 1662	DXN455	100'; camera spool - winding B	1R-2994
148 4625	DXN430	100'; camera spool high speed	2R-3000
173 7527	DXN451	400'; on core	2R-2994
173 7543	DXN457	400'; on core - winding B	1R-2994
173 7600	DXN597	400'; on core - magnetic strip winding B	1R-2994
197 1191	DXN434	400'; camera spool high speed	2R-3000

--7224--

Eastman 4-X Negative Film

<Exposure Index>

Daylight - 500 Tungsten 400

<Process>

Black and white with D-96 developer at commercial laboratories. This film may be pushed 1 stop (or more) with some loss in quality - check with your processing laboratory.

<Use>

This black-and-white negative camera film is suitable for all general photography under adverse lighting conditions. It is useful in situations where great depth of field is desired without an increase in illumination.

<General Properties>

Eastman 4-X Negative Film 7224 is an extremely high-speed, panchromatic material having medium resolving power and excellent tonal rendition.

<Reciprocity Characteristics (EL-500)>

No exposure of filter compensation is required except for exposures of 1 second where the exposure should be increased by 1/2 stop.

<Handling>

Total darkness.

<Rolls Available> 7224 (16mm)

CAT. No.	Iden No.	Description	Perf Type
147 4444	4XN449	100'; camera spool	2R-2994
147 4428	4XN430	100'; camera spool high speed	2R-3000
173 9341	4XN451	400'; on core	2R-2994
184 2863	4XN434	400'; camera spool high speed	2R-3000

--7231--

Eastman Plus-X Negative Film

<Exposure Index>
Daylight - 80 Tungsten - 64

<Process>
Black and white with D-96 developer at commercial laboratory. The film may be force processed 1 stop (or more) with some loss in quality - check with your local laboratory.

<Use>
The speed and grain characteristics of Eastman Plus-X Negative Film make it well suited for general motion picture production. These film characteristics provide an excellent balance between the maximum desirable speed for general production work and the finest grain negative offered by Kodak at that speed.

<General Properties>
The medium speed of this panchromatic film permits the use of relatively small apertures in daylight (thus allowing good depth of field). The film is widely used for making composite projection background scenes.

<Reciprocity Characteristics (EI-80)>
No exposure on filter compensation is required except for exposures of 1 second where the exposure should be increased 1/2 stop.

<Handling>
Total darkness.

<Rolls Available> 7231 (16mm)

CAT. No.	Iden No.	Description	Perf Type
191 3490	PXN449	100'; camera spool	2R-2994
191 3508	PXN455	100'; camera spool - winding B	1R-2994
173 9721	PXN451	400'; on core	2R-2994
173 9747	PXN457	400'; on core - winding B	1R-2994
173 9762	PXN597	400'; on core - magnetic stripe winding B	1R-2994
178 4115	PXN434	400'; camera spool high speed	2R-3000

--7239--
Eastman Ektachrome Video News Film (Daylight)

<Exposure Indexes>
Daylight - 160 Tungsten - 40, (filter 80A)

<Process>
VNF-1 or RVNP at commercial labs. This film may be force processed 1 stop with little loss in quality and up to 3 stops with some quality loss.

<Use>
This high-speed color reversal film is intended for photography under low-level daylight illumination. Among its many applications are news photography, sporting events, and high-speed photography. It is a companion film to Eastman Ektachrome Video News Film 7240 (Tungsten). The processed original camera film is ready for projection and, because it is balanced for projection at 5400K, it is suitable for television broadcasting.

<General Properties>
Eastman Ektachrome Video News Film 7239 (Daylight) can be exposed at effective film speeds ranging from 1/2 to 2 times the normal exposure indexes without loss in quality. The processed camera original is meant for direct projection; however, color duplicates can be made on Eastman VN Print Film 7399 (Process VNF-1) or on Eastman Ektachrome R Print Film 7389 (Process ME-4) using recommended shortened first developer times.

<Reciprocity Characteristics (EI-160)>
For exposure times ranging from 1/10000 to 1 second, no compensation is needed for either exposure level of for color balance.

<Handling>
Total darkness.

<Rolls Available> 7239 (16mm)

CAT. No.	Iden No.	Description	Perf Type
121 8163	VND449	100'; camera spool	2R-2994
121 8205	VND455	100'; camera spool - winding B	1R-2994
121 8106	VND430	100'; camera spool high speed	2R-3000
121 8585	VND595	100'; camera spool - mag stripe winding B	1R-2994
121 8262	VND432	200'; camera spool high speed	2R-3000
121 8304	VND450	200'; camera spool	2R-2994
121 8668	VND601	360'; camera spool mag stripe winding B	1R-2994
121 8403	VND433	400'; on core high speed	2R-3000
121 8361	VND451	400'; on core	2R-2994
121 8460	VND457	400'; on core - winding B	1R-2994
121 8445	VND434	400'; camera spool high speed	2R-3000
121 8486	VND578	400'; camera spool	2R-2994
121 8627	VND597	400'; on core magnetic stripe winding B	1R-2994
121 8502	VND452	1200'; on core	2R-2994
121 8569	VND458	1200'; on core - winding B	1R-2994

--7240--

Eastman Ektachrome Video News Film (Tungsten)

<Exposure Indexes>

Daylight - 80, (filter 85B) Tungsten - 125

<Process>

VNF-1 or RVNP at commercial labs. This film may be force processed 1 stop with little loss in quality and up to 3 stops with some quality loss.

<Use>

This is a high-speed camera film intended for use in tungsten light and in daylight with an appropriate filter. It can be used equally well for color news photography, nightime sporting events, industrial photography with existing light, and for high-speed photography. The processed original camera film is ready for projection and, because it is balanced for projection at 5400 K, is suitable for television broadcast.

<General Properties>

Eastman Ektachrome Video News Film 7240 (Tungsten) can be exposed at effective speeds ranging from 1/2 to 2 times the normal exposure indexes with little loss in quality. The processed camera original is intended for direct projection; however, duplicates can be made on Eastman Ektachrome VN Print Film 7399 (Process VNF-1) or on Eastman Ektachrome R Print Film 7389 (Process ME-4) using the recommended shortened first developer times.

<Reciprocity Characteristics (EI-125)>

For exposure times ranging from 1/10000 to 1 second, no compensation is needed for either exposure level or color balance.

<Handling>

Total darkness.

<Rolls Available> 7240 (16mm)

CAT. No.	Iden No.	Description	Perf Type
127 9967	VNF447	50'; magazine	2R-2994
162 7603	VNF595	100'; camera spool mag stripe winding B	1R-2994
162 5318	VNF449	100'; camera spool	2R-2994
162 6282	VNF455	100'; camera spool - winding B	1R-2994
162 6969	VNF450	200'; camera spool	2R-2994
162 6548	VNF456	200'; camera spool - winding B	1R-2994
162 7744	VNF596	200'; camera spool mag stripe winding B	1R-2994
195 4791	VNF601	360'; camera spool mag stripe winding B	1R-2994
162 7009	VNF451	400'; on core	2R-2994
162 7264	VNF457	400'; on core	1R-2994
162 7942	VNF597	400'; on core magnetic stripe winding B	1R-2994
162 7108	VNF578	400'; camera spool	2R-2994
162 7389	VNF452	1200'; on core	2R-2994
162 7421	VNF458	1200'; on core - winding B	1R-2994
162 7967	VNF598	1200'; on core magnetic stripe winding B	1R-2994

--7241--

Kodak Ektachrome EF Film (Daylight)

<Exposure Indexes>
Daylight - 160 Tungsten - 40, (Filter 80A)

<Process>
ME-4 at commercial labs or at Kodak. This film may be force processed 1 stop with little loss in quality and up to 3 stops with some quality loss.

<Use>
This is a high-speed camera film balanced for daylight, and is intended for situations in which illumination level is low, or for high-speed photography. It is a companion film to Kodak Ektachrome EF 7242 Film (Tungsten). The processed original camera film is ready for projection and, because it is balanced for projection at 5400K, it is suitable for television broadcast.

<General Properties>
Kodak Ektachrome EF Film 7241 can be exposed at 1/2 to 2 times the exposure indexes with little loss in quality. The processed camera original is intended for direct projection. Color duplicates can be made, however, on Eastman Ektachrome R Print Film 7389 (Process ME-4) or on Eastman Ektachrome VN Print Film 7399 (process VNF-1) using recommended shortened first developer times.

<Reciprocity Characteristics (EI-160)>
For exposure times from 1/10000 to 1 second, no exposure or filter compensation is required.

<Handling>
Total darkness.

<Rolls Available> 7241 (16mm)

CAT. No.	Iden No.	Description	Perf Type
154 9609	EF595	100'; camera spool mag stripe winding B	1R-2994
147 1739	EF449	100'; camera spool	2R-2994
147 1713	EF455	100'; camera spool - winding B	1R-2994
147 1754	EF430	100'; camera spool high speed	2R-3000
147 1986	EF450	200'; camera spool	2R-2994
147 1796	EF432	200'; camera spool high speed	2R-3000
153 9683	EF601	360'; camera spool	1R-2994
147 1945	EF451	400'; on core	2R-2994
153 4296	EF457	400'; on core - winding B	1R-2994
153 8594	EF597	400'; on core magnetic stripe winding B	1R-2994
156 9813	EF578	400'; camera spool	2R-2994
147 1838	EF434	400'; camera spool high speed	2R-3000
147 1929	EF452	1200'; on core	2R-2994
154 2851	EF458	1200'; on core - winding B	1R-2994

--7242--

Kodak Ektachrome EF Film (Tungsten)

<Exposure Indexes>

Daylight - 80, (Filter 85B) Tungsten - 125

<Process>

ME-4 at commercial labs or at Kodak. This film may be force processed 1 stop with little loss in quality and up to 3 stops with some quality loss.

<Use>

This is a high-speed camera film intended for use under difficult lighting conditions where sufficient exposure cannot be obtained with color reversal films of slower speed. Its many applications include color newsfilm work, various nighttime sporting events, industrial photography using existing light, and high-speed photography by both daylight and artificial light. The processed film is balanced for projection at 5400 K and is suitable for television broadcast.

<General Properties>

Kodak Ektachrome EF Film 7242 can be exposed at effective speeds ranging from 1/2 to 2 times the normal exposure indexes with little loss in quality. the processed color original is designed primarily for direct projection; however, color duplicates can be made on Eastman Ektachrome R Print Film 7389 (Process ME-4) or on Eastman Ektachrome VN Print Film 7399 (Process VNF-1) using recommended shortened first developer times.

<Reciprocity Characteristics (EI-125)>

For exposure times ranging from 1/10000 to 1 second, no exposure or filter compensation is required.

<Handling>

Total darkness.

<Rolls Available> 7242 (16mm)

CAT. No.	Iden Number	Description	Mag. stripe	NO stripe	Perf Type
164 8138	EFB447	50'; magazine			2R-2994
147 2059	EFB449	100'; camera spool			2R-2994
147 2018	EFB450	200'; camera spool			2R-2994
147 2984	EFB451	400'; on core			2R-2994
154 4220	EFB578	400'; camera spool			2R-2994
147 2968	EFB452	1200'; on core			2R-2994
147 2034	EFB455	100'; camera spool		B-wind	1R-2994
154 9724	EFB595	100'; camera spool	B-wind		1R-2994
153 6333	EFB456	200'; camera spool		B-wind	1R-2994
153 4437	EFB596	200'; camera spool	B-wind		1R-2994
153 4452	EFB601	360'; camera spool	B-wind		1R-2994
147 2943	EFB457	400'; on core		B-wind	1R-2994
153 4478	EFB597	400'; on core	B-wind		1R-2994
153 4270	EFB458	1200'; on core		B-wind	1R-2994
153 4494	EFB598	1200'; on core	B-wind		1R-2994
147 1994	EFB430	100'; camera spool		H. SPD.	2R-3000
147 1010	EFB432	200'; camera spool		H. SPD.	2R-3000
147 1036	EFB433	400'; on core		H. SPD.	2R-3000
147 1051	EFB434	400'; camera spool		H. SPD.	2R-3000

--7247--

Eastman Color Negative II Film

<Exposure Indexes>
Daylight - 64, (Filter 85) Tungsten - 100

<Process>
ECN-2 at commercial labs. This film may be force processed 1 or 2 stops. Check with your local lab for their recommendations before exposing the film.

<Use>
Eastman Color Negative Film II 7247 is a camera film intended for general motion picture production. The wide exposure latitude of this high-speed film makes it especially suitable for both indoor and outdoor photography under a wide variety of conditions.

<General Properties>
Color Negative II Film is balanced for use in tungsten light, and in daylight with appropriate filters. The emulsion contains a colored-coupler mask to achieve good color reproduction in release prints. This film is characterized by a high degree of sharpness, fine grain, and excellent color rendition.

<Reciprocity Characteristics (EI-100)>

Exposure Time	1/10000	1/1000	1/100	1/10	1	10
Exp. Increase	none	none	none	none	1/2 stop	1 stop

<Handling>
Total Darkness.

<Rolls Available> 7247 (16mm)

CAT. No.	Iden No.	Description	Perf Type
165 5109	ECN449	100'; camera spool	2R-2994
165 4987	ECN455	100'; camera spool - winding B	1R-2994
170 6654	ECN450	200'; camera spool	2R-2994
170 6670	ECN456	200'; camera spool - winding B	1R-2994
165 5661	ECN451	400'; on core	2R-2994
165 5687	ECN457	400'; on core - winding B	1R-2994
165 5703	ECN452	1200'; on core	2R-2994
170 7983	ECN458	1200'; on core - winding B	1R-2994

--7250-- Eastman Ektachrome Video News Film High Speed (Tungsten)>

<Exposure Indexes>
Daylight - 250, (Filter 85B) Tungsten - 400

<Process>
VNF-1 or RVNP at commercial labs. This film may be force processed 1 stop with little loss in quality and up to 3 stops with some loss in quality.

<Use>
The very high speed of this color reversal camera film makes photography possible with very low-level illumination. It can be used for color news photography, nighttime sporting events, and high-speed photography by both daylight and artificial light. The processed original camera film is balanced for projection at 5400K and is suitable for television broadcasting.

<General Properties>
Eastman Ektachrome Video News Film High Speed 7250 (Tungsten) can be exposed at effective speeds ranging from 1/2 to 2 times the normal exposure indexes with little loss in quality. The processed camera original is meant for direct projection; however, color duplicates can be made on Eastman Ektachrome VN Print Film 7399 (Process VNF-1) or on Eastman Ektachrome R Print Film 7389 (Process ME-4) using recommended shortened first developer times.

<Reciprocity Characteristics (EI-400)>
For exposure times ranging from 1/10000 to 1 second, no compensation is needed for either exposure level or color balance.

<Handling>
Total darkness.

<Rolls Available> 7250 (16mm)

CAT. No.	Iden No.	Description	Perf Type
121 8700	VNX449	100'; camera spool	2R-2994
121 8783	VNX450	200'; camera spool	2R-2994
121 8908	VNX578	400'; camera spool	2R-2994
121 8866	VNX451	400'; on core	2R-2994
121 8924	VNX452	1200'; on core	2R-2994
121 8726	VNX455	100'; camera spool - winding B	1R-2994
121 8882	VNX457	400'; on core - winding B	1R-2994
121 8981	VNX595	100'; camera spool mag. stripe winding B	1R-2994
121 8015	VNX596	200'; camera spool mag. stripe winding B	1R-2994
121 8031	VNX601	360'; camera spool mag. stripe	1R-2994
121 8056	VNX597	400'; on core mag. stripe winding B	1R-2994
121 8684	VNX430	100'; camera spool high speed	2R-3000
121 8767	VNX432	200'; camera spool high speed	2R-3000
121 8841	VNX434	400'; camera spool high speed	2R-3000

--7252--

Eastman Ektachrome Commercial Film

<Exposure Indexes>
Daylight - 16, (Filter 85) Tungsten - 25

<Process>
ECO-3 at commercial labs or at Kodak. This film may be force processed 1 stop with some loss in quality.

<Use>
This color reversal camera film is designed to provide a low-contrast original from which a color release print of good projection quality can be made.

<General Properties>
Eastman Ektachrome Commercial Film 7252 can be printed directly onto Eastman Ektachrome Print 7390 or Eastman Reversal Color Print Film 7387, or their equivalents. Alternatively, it can be printed directly onto a film such as Eastman Color Internagative Film 7271, from which prints can be made on Eastman Color Print Film 7381 or on Eastman Color SP Print Film 7383. Direct printing onto Eastman Ektachrome R Print Film 7389 is also possible, but somewhat lower contrast will result.

<Reciprocity Characteristics (EI-25)>

Exposure Time	1/10000	1/1000	1/100	1/10	1/2	1
Exp. Increase	1/3 stop	1/3 stop	none	none	1/2 stop	1/2 stop

<Handling>
Total darkness.

<Rolls Available> 7252 (16mm)

CAT. No.	Iden No.	Description	Perf Type
174 1180	EC0449	100'; camera spool	2R-2994
145 3265	EC0455	100'; camera spool - winding B	1R-2994
174 1149	EC0430	100'; camera spool high speed	2R-3000
145 3281	EC0450	200'; camera spool	2R-2994
173 8103	EC0451	400'; on core	2R-2994
173 8145	EC0457	400'; on core - winding B	1R-2994
174 1289	EC0433	400'; on core high speed	2R-3000
174 1305	EC0434	400'; camera spool high speed	2R-3000
173 8244	EC0452	1200'; on core	2R-2994
173 8285	EC0458	1200'; on core - winding B	1R-2994

--7256--

Kodak Ektachrome MS Film

<Exposure Indexes>

Daylight - 64 Tungsten - 16, (80A Filter)

<Process>

ME-4 at commercial labs or at Kodak. This film may be force processed 1 stop with little loss in quality and up to 3 stops with some quality loss.

<Use>

Combining the qualities of medium speed, sharpness, and excellent color rendition, this film finds useful applications in such diverse fields as industrial motion pictures, instrument recording, high-speed camera use, and sports photography under conditions of low daylight illumination.

<General Properties>

Kodak Ektachrome MS Film 7256 is a color reversal film balanced for daylight. The processed camera originals are intended for direct projection; however, color duplicates can be made on Eastman Ektachrome R Print Film 7389 (Process ME-4) or on Eastman Ektachrome VN Print Film 7399 (Process VNF-1) using recommended shortened first developer times.

<Reciprocity Characteristics (EI-64)>

Exposure Time	1/10000	1/1000	1/100	1/10	1
Exp. Increase	none	none	none	none	1 stop

<Handling>

Total darkness.

<Rolls Available> 7256 (16mm)

CAT. No.	Iden Number	Description	Mag. stripe	NO stripe	Perf Type
141 4846	EMS449	100'; camera spool			2R-2994
141 4861	EMS455	100'; camera spool		wind-B	1R-2994
141 4887	EMS430	100'; camera spool high speed			2R-3000
141 4960	EMS450	200'; camera spool			2R-2994
141 5025	EMS451	400'; on core			2R-2994
166 7625	EMS457	400'; on core		wind-B	1R-2994
141 5249	EMS434	400'; camera spool high speed			2R-3000
177 3464	EMS458	1200'; on core		wind-B	1R-2994

--7276--

Kodak Plus-X Reversal Film

<Exposure Indexes>

Daylight - 50 Tungsten - 40

<Process>

Kodak Liquid Reverse Chemicals at commercial labs. This film may be force processed 1 or more stops with some loss in quality - check with your local processing lab.

<Use>

This black-and-white film is used widely for general exterior photography, and for indoor photography where there is ample artificial illumination. It is useful, also, for television news coverage, documentary production, and kinescope recordings. It is also available with magnetic stripe for single-system sound recording applications.

<General Properties>

Kodak Plus-X Reversal Film is a medium-speed, panchromatic, reversal motion picture film. It is characterized by a high degree of sharpness, good contrast, high resolving power, and excellent tonal gradation. When processed as a reversal film, the resulting positive can be used for projection or for duplication; processed as a negative material by conventional methods, the film will yield satisfactory results, although with some loss in speed and an increase in granularity.

<Reciprocity Characteristics (EI-50)>

Exposure Time	1/10000	1/1000	1/100	1/10	1
Exp. Increase	1/2 stop	none	none	none	none

<Handling>

Total darkness.

<Rolls Available> 7276 (16mm)

CAT. No.	Iden No.	Description	Perf Type
153 2803	PXR449	100'; camera spool	2R-2994
153 2829	PXR450	200'; camera spool	2R-2994
153 2845	PXR451	400'; on core	2R-2994
183 9687	PXR578	400'; camera spool	2R-2994
162 5326	PXR452	1200'; on core	2R-2994
153 2811	PXR455	100'; camera spool - winding B	1R-2994
153 2837	PXR456	200'; camera spool - winding B	1R-2994
153 2852	PXR457	400'; on core - winding B	1R-2994
158 9621	PXR437	400'; camera spool - winding B	1R-2994
162 5409	PXR458	1200'; on core - winding B	1R-2994
147 4022	PXR595	100'; camera spool mag. stripe winding B	1R-2994
178 3711	PXR597	400'; on core mag. stripe winding B	1R-2994
153 0187	PXR580	100'; camera spool	2R-1667

--7277--

Kodak 4-X Reversal Film

<Exposure Indexes>
Daylight - 400 Tungsten - 320

<Process>
Kodak Liquid Reversal Chemicals at commercial labs. This film may be force processed 1 or more stops with some loss in quality - check with your local processing lab.

<Use>
The very high speed of this black-and-white film makes photography possible even with limited illumination. With Kodak 4-X Reversal Film, the sports photographer can film nighttime sporting events in poorly lighted stadiums and the reporter can get that "impossible-light" shot. It also finds application in industry for making analytical studies using available light. It is also available with a magnetic stripe for single-system sound recording applications.

<General Properties>
Kodak 4-X Reversal Film 7277 is characterized by high resolving power and good contrast. An antihalation layer is incorporated in the film structure. The recommended exposure indexes can be doubled if first developer time is extended; in this case, there will be a slight loss in image quality. The emulsion is hardened to permit rapid processing at a high temperature.

<Reciprocity Characteristics (EI-400)>
For exposure times between 1/10000 and 1 second, no compensation in required.

<Handling>
Total darkness.

<Rolls Available> 7277 (16mm)

CAT. No.	Iden No.	Description	Perf Type
154 3495	4XR449	100'; camera spool	2R-2994
174 1974	4XR450	200'; camera spool	2R-2994
154 3453	4XR451	400'; on core	2R-2994
174 2188	4XR578	400'; camera spool	2R-2994
174 2501	4XR452	1200'; on core	2R-2994
154 3479	4XR455	100'; camera spool - winding B	1R-2994
154 3511	4XR457	400'; on core - winding B	1R-2994
174 2089	4XR597	400'; on core mag. stripe winding B	1R-2994
174 1818	4XR430	100'; camera spool	2R-3000
174 2121	4XR434	400'; camera spool	2R-3000
152 4081	4XR580	100'; camera spool	2R-1667

--7278--

Kodak Tri-X Reversal Film

<Exposure Indexes>
Daylight - 200 Tungsten - 160

<Process>
Kodak Liquid Reversal Chemicals at commercial labs. This film may be force processed 1 or more stops with some loss in quality - check with your local processing lab.

<Use>
The high speed of this black-and-white panchromatic film with antihalation undercoat makes it suitable for general interior photography with artificial light. It can be used in daylight, also, and is particularly useful for sports pictures taken at regular speed or slow motion in weak light (overcast sky or late in the day). It is also available with a magnetic stripe for single-system sound recording applications.

<General Properties>
Kodak Tri-X Reversal Film 7278 is characterized by high speed, excellent tonal gradation, and high resolving power. When processed as a reversal film, the resulting positive can be used for projection or for duplication. Processed as a negative material by conventional methods, the film will yield satisfactory results, although with some loss in speed.

<Reciprocity Characteristics (EI-200)>

Exposure Time	1/10000	1/1000	1/100	1/10	1
Exp. Increase	none	none	none	none	1/2 stop

<Handling>
Total darkness.

<Rolls Available> 7278 (16mm)

CAT. No.	Iden Number	Description	Mag. stripe	NO stripe	Perf Type
147 2133	TXR449	100'; camera spool			2R-2994
147 2141	TXR455	100'; camera spool		wind-B	1R-2994
147 4147	TXR595	100'; camera spool	wind-B		1R-2994
147 2158	TXR430	100'; camera spool high speed			2R-3000
147 2166	TXR450	200'; camera spool			2R-2994
147 2174	TXR456	200'; camera spool		wind-B	1R-2994
147 2182	TXR451	400'; on core			2R-2994
147 2190	TXR457	400'; on core		wind-B	1R-2994
164 3253	TXR578	400'; camera spool			2R-2994
178 3778	TXR597	400'; on core	wind-B		1R-2994
160 5161	TXR434	400'; camera spool high speed			2R-3000
162 5748	TXR452	1200'; on core			2R-2994
162 5763	TXR458	1200'; on core		wind-B	1R-2994
178 3794	TXR598	1200'; on core	wind-B		1R-2994

5.3 Packaging

This short section provides information regarding the lengths of film available, types of cores and spools, windings, and perforation types. 16mm film is available in lengths of 100, 200, 400, and 1200 feet. The film is furnished on several types of cores and spools depending upon the equipment in which the film is to be exposed.

Cores and Spools

Type T Core. This is a plastic core with a 2-inch (51mm) outside diameter and containing a 1-inch (24.4mm) center hole with a keyway and a film slot. This core is normally used with 16mm films up to 400' (122m) in length, except 100 (30.5m) and 200' (61m) lengths of camera negative and reversal materials. These two lengths are generally furnished on camera spools with integral leaders and trailers, suitable for loading in subdued light.

Type Z Core. This plastic core has an outside diameter of 3" (76mm) and an inside diameter of 1" (25.4mm). It contains both a keyway and a film slot in the hole. This core is used with camera and print films in rolls longer than 400' (122m).

R-90 Spool. This is a metal camera spool with a 3.615 (92mm) flange diameter and 1 1/4" (32mm) core diameter. There is a square hole with a single keyway in both flanges. The center hole configuration is aligned on both flanges. The standard sales lengths for this spool are 100' (30.5m) of acetate base film, 125' (38.1m) of 4-mil ESTAR Base film, and 200' (61m) of 2 1/2-mil ESTAR Thin Base film.

R-190 Spool. This is a metal camera spool with a 4.940" (125mm) flange diameter and a 1 1/4" (32mm) core diameter. It has a square hole with a single keyway, two offset round drive holes, and one elliptical hole in both flanges. It also has Side 1 and Side 2 markings. This spool will accept 200' (61m) of acetate base film, 250' (76m) of 4-mil ESTAR Base film, and 400' (122m) of 2 1/2-mil ESTAR Thin Base film.

Winding Designations

A plastic core is normally used with all 16mm films in lengths over 200'. Camera spools are normally supplied with films in lengths of 100 and 200'. Film supplied on 100 and 200' camera spools includes an integral leader and trailer, for loading in subdued light.

Film is usually wound on spools and cores so that the emulsion side of the film faces toward the center of the roll. When the roll is held so that the outside or leader end of the film leaves the roll at the top and toward the right, Winding A has the perforations along the edge of the film toward the observer and Winding B has the perforations along the edge away from the observer.

Perforation Types

1) 2R-2994 - 16mm film perforated two edges with a perforation pitch

of 0.2994" (short pitch) (ANSI PH22.110-1965)

2) 2R-3000 - 16mm film perforated two edges with a perforation pitch of 0.3000" (long pitch) (ANSI PH22.5-1964)

3) 1R-2994 - same as number 1 except perforated one edge (ANSI PH22.109-1965)

4) 3R-2994 - 35mm film perforated 16mm with a perforation pitch of 0.2994" (short pitch) (ANSI PH22.17-1965)

5) 1R-3000 - same as number 2 except perforated one edge (ANSI PH22.12-1964)

6) 3R-3000 - same as number 4 except with a perforation pitch of 0.3000" (long pitch) (ANSI PH22.170-1968)

5.4 Care and Storage

Although Kodak and Eastman motion picture camera films are manufactured to very high-quality standards, a certain amount of care in storage of unexposed, exposed unprocessed, and processed films should be exercised. Given the care outlined in Figure 5.1, film and film images will last longer, stay cleaner, and will not be adversely affected by extremes of temperature and humidity.

	Short Term (less than 6 months)		Long Term (more than 6 months)	
	Temp.	% Rel. Hum.	Temp.	% Rel. Hum.
Raw Stock in original cans	13C (55F)	below 70	-18 to -23C (0 to -10F)	(1)
Exposed Unprocessed	-18 to -23C (0 to -10F)	(1) (2)	Not Recommended	
Processed B & W	24C (75F)	60	(3)	(3)
Color	21C (70F)	40 to 50	18C (0F)	15 to 50

Figure 5.1
Recommended Film Storage Temperatures

Notes:
1) Keep sealed (in original cans) until the temperature is above the dew point of the outside air. Allow 1 full hour for 16mm film to warm up 14 degrees C (25 degrees F) and 1 1/2 hours for a rise of 55 degrees C (100 degrees F).

2) Exposed film should be processed as soon as possible after exposure.
3) There are several methods employed for long-term storage of color film images. Although these methods are too detailed to be covered adequately here, information concerning this subject can be found in the the following article: Adlestein, P.Z., Graham, C.L., and West, L.E., "Preservation of Motion Picture Color Films Having Permanent Value," Journal of the SMPTE, 79:1011-18, November, 1970.
4) For infrequent use and when maximum useful life is the primary concern.

Raw Stock and Relative Humidity

The quantity of moisture held by a photographic film at equilibrium is determined by its chemical properties and the relative humidity of the air.

Motion picture raw stock is packaged in taped cans that are essentially water-vapor tight and, therefore,, does not require storage in an area having carefully controlled humidity as long as the original seal remains unbroken. Raw stock should be kept in its original taped can up to the time the film is to be exposed. Avoid storage at relative humidities of 70 percent or higher because of possible damage that can occur to labels and cartons from moisture and mold, and to cans from rust.

Temperature

Storage of stock at temperatures between -18 and -23 degrees C (0 and -10 degrees F) will not prevent sensitometric deterioration completely, but will reduce it to a minimum. After a package of raw stock has been removed from cold storage, it should be allowed to warm up until its temperature is above the dew point of the outside air. Allow 1 hour for film which needs to warm 14 degrees C (25 degrees F) and 1 1/2 hours for warming 55 degrees C (100 degrees F). Damage from moisture condensation occurs when the can is removed from cold storage and is not allowed sufficient warm-up time before the seal is removed.

Protection from Physical Damage

Films should not be stored near heating pipes or in the line of sunlight coming through a window, even if the room is air-conditioned. Maintained room temperature should be as uniform as possible throughout the storage area by means of adequate air circulation. If the building is not fireproof, some fire extinguishing system should be available. Storage rooms for motion picture raw stock should be designed so that the film is stored at least 6" off the floor.

Unprocessed Film Before and After Exposure

Exposed film, particularly color, deteriorates more rapidly than unexposed film. Therefore, films should be exposed and processed as soon as possible after the package is opened. Also, do not keep film in the camera magazine longer than is necessary. Magazines that are loaded a long time ahead of use should be held in an airtight metal box until they are needed for the camera. Loaded cameras or magazines and carrying

cases containing film should be protected from direct sunlight and should not be left in closed spaces that can trap heat from the sun or other sources such as closed automobiles, airplanes, or the hold of ships. Immediately after exposure, the film should be returned to its can and retaped to help prevent any increase in moisture content over that picked up during filming.

Processed Film

The following suggestions apply to the storage of color films but also apply to black-and-white films in many instances.

1) Each film should be adequately washed to remove residual chemicals and to make sure that the residual hypo level does not exceed the recommended maximum.

2) Film should be treated in the recommended stabalization bath for the amount of time required to provide optimum stabilization of the dye images.

3) Wetting agents for the prevention of water spots, and detergents for cleaning processed film should be selected with great care. Antimold compounds in some wetting agents may also be harmful to the dyes. KODAK Movie Film Cleaner (with Lubricant) has proved to be a satisfactory cleaning material for these purposes.

4) If alkaline or detergent solutions are used for cleaning, the film should be rewashed and relubricated if it is to be used again.

5) Film should not be stored in an atmosphere containing acid vapors or fumes of sulfur dioxide, peroxide, or hydrogen sulfide.

6) Films intended for either short- or long-term storage should be wound in an emulsion-in orientation prior to such storage.

Further information may be found in publications (5., 6., 7., and 8.) given in Appendix B.

Appendix A

This appendix contains the addresses of suppliers of various components and services.

Motor:

Superior Electric Company
6 Abbott Road
Wellesley Hills, Ma. 02181
(617) 237-0750

Headquarters:
383 Middle Street
Bristol, Conn. 06011
(203) 582-9561

Sales Agent:
Electro Sales Company, Inc.
100 Fellsway West
Somerville, Ma. 02145
(617) 666-0500

Electronic Components:

Signetics Corporation
P.O. Box 9052
Sunnyvale, Ca. 94086
(468) 739 7700

Radio Shack, Regional Office
Box 445
10 Mazzeo Drive
Randolf, Ma. 02368
(617) 963-8000

Radio Shack Headquarters
500 One Tandy Center
Fort Worth, Tx. 76102
(817) 390-3011

General Electric Company
street
town, state zip
phone

Couplings:

Renbrandt, Inc.
659 Massachusetts Avenue
Boston, Ma 02118
(617) 445-8910

Film:

Fran-Tek Corporation
71 Lamb Street
South Hadley, Ma 01075
(617) 445-9910

Eastman Kodak Company

(Technical Information)
Sales and Engineering Representitives
500 12th Street S.W.
Washington, D.C. 20024
(202) 554-9300

(Film Orders)
Customer Relations Representitives
1187 Ridge Road West
Rochester, NY 14650
(716) 254-1300

(Processing)
16-31 Route 208
Fair Lawn, NJ 07410
(201) 797-0600

Camera:

Bolex U.S.A. Inc.
250 Community Drive
Great Neck, NY 11020
(516) 446-8222

Appendix B

This appendix contains a list of the titles of publications, mostly by Eastman Kodak, which pertain to film-making. If a code number is given, the publication is from Kodak and may be ordered either directly from Eastman Kodak or through a local camera shop.

1. A Comparison of Running Times - 8 mm, Super 8, 16 mm, and 35 mm Motion Picture Films >> CODE S-42

2. Kodak Filters for Scientific and Technical Uses; Describes physical, optical, and transmission characteristics of the complete line of Kodak Filters. >> CODE B-3

3. Maintaining Your Still and Movie Camera and Projector >> CODE AA-1

4. Sources of Motion Picture Services and Equipment- 16 mm, 8 mm, and super 8 >> CODE AD-20

5. Handling and Storage of Kodak and Eastman Motion Picture Films >> CODE D-23

6. Storage and Care of Kodak Color Films >> CODE E-30

7. VIDEOfilm NOTES - Care and Handling of Television Film >> CODE H-40-9

8. Film Notes for the REEL PEOPLE - Film Handling >> CODE H-50-2

9. A Glossary of Photographic Terms >> CODE AA-9

10. Photographing Television Images >> CODE AC-10

11. Filming a Television Program in Super 8 >> CODE S-67

12. Better Movies in Minutes; Shows how to make sharp, colorful, and interesting movies, both indoors and out. Includes a chapter on making movies outdoors at night and indoors without movie lights. >> CODE AD-4

13. Reciprocity Data; Kodak Color Films >> CODE E-1

14. Kodak Color & B/W Films for Still and Movie Cameras (Information Sheet) >> CODE F-4

15. Understanding Graininess and Granularity >> CODE F-20

16. Proceedings of the INTERFACE '73 Microelectronics Seminar >> CODE G-35

17. Proceedings of the Kodak Microelectronics Seminar, INTERFACE '74 >> CODE G-41

18. High Speed Photography; Describes the cameras, films, and techniques used in high-speed photography. Includes information on film bases, sensitometry, processing, selection of films, and camera manufacturers. >> CODE G-44

19. Proceedings of the Kodak Microelectronics Seminar INTERFACE '75; Contains the complete papers presented by 15 speakers at the INTERFACE '75 Microelectronics Seminar sponsored by Eastman Kodak Company and held in Monterey, California, Oct. 19-21, 1975. >> CODE G-45

20. Proceedings of the Kodak Microelectronics Seminar INTERFACE '76; Contains the complete text and illustrations of 15 technical papers presented at the INTERFACE '76 Microelectronics Seminar, sponsored by Eastman Kodak Company and held in Monterey, California, Oct. 3-5, 1976. >> CODE G-47

21. Proceedings of INTERFACE '77 Microelectronics Seminar; A collection of papers given at the 1977 Kodak Microelectronics Seminar, INTERFACE '77. The papers are presented by members of various companies in the microelectronics field. >> CODE G-48

22. Selection and Use of Kodak and Eastman Motion Picture Films (Business- Industry- Entertainment- Medicine- Television- Education- Government); Helps those engaged in motion picture production to choose the film best suited to a particular application and obtain best results from films selected. >> CODE H-1

23. Cinematographer's Field Guide - Motion Picture Camera Films;

Comprehensive descriptions of B&W and color camera films. Includes light sources and filters for use. Tips on storage, care, shooting for TV, tools, etc. Explanations of film can label info, and how to order stock. Names, addresses, and phone numbers of Kodak (motion picture) facilities worldwide are given. >> CODE H-2

24. A Guide for Processing Black-and-White Reversal Motion Picture Films >> CODE H-7

25. Motion Picture Prints from Color Originals >> CODE H-25

26. VIDEOfilm NOTES - Television Film Editing and Splicing Techniques >> CODE H-40-8

27. VIDEOfilm NOTES - Using Films for Television >> CODE H-40-11

28. Film Notes for the REEL PEOPLE - Splicing for the Professional >> CODE H-50-1

29. Film Notes for the REEL PEOPLE - Projection Practices and Techniques >> CODE H-50-3

30. Film Notes for the REEL PEOPLE - The Case for Test Films >> CODE H-50-7

31. Basic Film-maker's Packet; Covers all of the important technical, aesthetic, and financial considerations a film-maker should know. It also covers information on the selection and use of film, production techniques, magnetic sound recording, animation, single-concept films, and effective control of finances. >> CDOE H-100

32. Film in Television Packet; A select group of data books, pamphlets, and periodicals that offers necessary and creative information on film applications for television. >> CODE H-200

33. Basic Scientific Photography; Introduces the student and advanced amateur to the applications of photography illustrating and documenting the natural sciences, archaeology, and biomedicine. >> CODE N-9

34. Kodak Photographic Products Catalog (latest edition) >> CODE

P2-1

35. Basic Production Techniques for Motion Pictures; "How-to" information for business, industry, television, education, and government on the making of films, primarily 16 mm. >> CODE P-18

36. Kodak 16 mm, 35 mm, and 70 mm Films >> CODE P-29

37. Kodak Films for Cathode-Ray Tube Recording; A guide to selecting the film best suited to specific applications of cathode-ray tube photography. >> CODE P-37

38. Kodak Image Test Chart; A film-test object (approximately 4x5 inches) and instructions are provided to test and check lens resolution and image formation in microphotography and the graphic arts. >> CODE P-301

39. Kodak Image Test Chart (Large); This 20x24 inch version of the Kodak Image Test Chart is provided to measure performance of cameras, lenses, films, and plates in single- or multiple-reduction microphotographic systems. >> CODE P-303

40. 1979 Publications Index - Motion Picture and Audiovisual Markets Division; A catalog of 250 publications in the areas of professional motion picture, television, and audiovisual communications. >> CODE S-4

41. A Guide to Motion Picture and AV publications >> CODE S-10

42. Materials for Visual Presentations - Planning and Preparation >> CODE S-13

43. The World of Animation - A new book that tells all about animation, including its historical beginnings, with major emphasis on the here's-how-you-do-it end. It discusses several techniques such as photographic, cel, 3-dimensional, slide, and computer. In addition, plans are included for construction of an animation stand. It also includes a section concerning how animation is used and what employment opportunities are available. >> CODE S-35

44. Splicing Motion Picture Film with Kodak Film Cements >> CODE S-38

Appendix C

Command Procedures and Associated Programs

```
$!
$! * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
$! * This command procedure allows the user to create a film                   *
$! * from an existing set of image files.  The procedure uses                 *
$! * files FOR099.DAT while processing and deletes all files with             *
$! * this name during processing.  The  parameters  are as                    *
$! * follows:                                                                 *
$! *                                                                          *
$! *        P1 --> Name of the file containing the images.  It is             *
$! *               assumed that each image is located in a different          *
$! *               version under this file name.                              *
$! *                                                                          *
$! *        P2 --> Number of frames (pictures) to be taken of                 *
$! *               the initial image.  The initial image, typically           *
$! *               iteration 0 of a simulation run, is assumed to be          *
$! *           located in file "P1" under extension AAA.  This                *
$! *               parameter allows the user to hold display the first        *
$! *               image longer than the rest.                                *
$! *                                                                          *
$! *        P3 --> Starting iteration number.  This is the version            *
$! *               number of the first frame after the initial image.         *
$! *               It is assumed the the image will be found in file          *
$! *               "P1", version "P3".                                        *
$! *                                                                          *
$! *        P4 --> Ending iteration number.  As above except that this        *
$! *               parameter indicates the number of the last image.          *
$! *                                                                          *
$! *        P5 --> Iteration increment.  This parameter allows the user       *
$! *               to skip iterations while making the movie.  P5 must        *
$! *               be > 0.  The system will take pictures of every            *
$! *               "P5"th image starting with "P3".                           *
$! *                                                                          *
$! *        P6 --> Number of shots per iteration.  This parameter             *
$! *               dicates the number of pictures to be taken for every       *
$! *               image.                                                     *
$! *               Remember that normal movie projectors run at a rate        *
$! *               of 18 frames per second.                                   *
$! *                                                                          *
$! *        P7 --> Number of shots to be taken of the last frame.  This       *
$! *               allows the user to hold the final frame longer than        *
$! *               the others.                                                *
$! * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
$!
$! Enable the error trapping routine, branch on CTRLY or fatal errors
$!
$ On CONTROLY Then goto erxt
$ On ERROR  Then goto erxt
```

```
$!
$! Ask the user for values of null parameters.
$!
$ If P1 .EQS. ""  Then
$   INQUIRE P1 "Enter the file name"
$!
$ If P2 .EQS. ""  Then
$   INQUIRE P2 "Enter number of shots of initial image"
$!
$ If P3 .EQS. ""  Then
$   INQUIRE P3 "Enter starting iteration (version) number"
$!
$ If P4 .EQS. ""  Then
$   INQUIRE P4 "Enter ending iteration (version) number"
$!
$ back:
$ If P5 .EQS. ""  Then
$   INQUIRE P5 "Enter iteration (version) increment (>0)"
$ If 'P5 .LE. 0  Then goto back
$!
$ If P6 .EQS. ""  Then
$   INQUIRE P6 "Enter number of pictures per iteration (version)"
$!
$ If P7 .EQS. ""  Then
$   INQUIRE P7 "Enter number of pictures of final image"
$!
$!
$!
$! Allocated the Grinnell
$ ALLOCATE GRA0:
$!
$!
$! Process initial image
$ COPY 'P1.AAA  FOR099.DAT
$ RUN coptogrz
$ count = 0
$ loops:
$ if count .GE. 'P2  Then goto loop2
$ count = count + 1
$ RUN shootz
$ goto loops
$!
$!
$! loop through images
$ loop2:
$ if 'P3 .GT. 'P4  Then goto end
$ DELETE for099.dat.*
$ COPY 'P1.*.'P3  for099.dat
$ RUN coptogrz
$ P3 = 'P3 + 'P5
$ count = 0
$ loop1:
$ if count .GE. 'P6  Then goto loop2
$ count = count + 1
$ RUN shootz
```

```
$ goto loop1
$!
$!
$! Process the final image
$ end:
$ P7 = 'P7 -'P6
$ count = 0
$ loop3:
$ if count .GE. 'P7  Then goto loop4
$ count = count + 1
$ RUN shootz
$ goto loop3
$!
$!
$! clean up and terminate
$ loop4:
$ DELETE for099.dat.*
$ DEALLOCATE GRAO:
$ EXIT
$!
$!
$! Error handling
$ erxt:
$ DEALLOCATE GRAO:
$ WRITE sys$output "  "
$ WRITE sys$output "  "
$ WRITE sys$output "* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 * * * *"
$ WRITE sys$output "  "
$ WRITE sys$output "Abnormal termination from CTRLY or program FATAL
 ERROR. . ."
$ WRITE sys$output "  "
$ WRITE sys$output "* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 * * * *"
$ EXIT



$!
$! * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
$! * This command procedure allows the user to create a film                  *
$! * from an existing set of data files.  The procedure uses                  *
$! * a user defined display creation program to produce the images             *
$! * from the given sequence of data files. The procedure also uses            *
$! * file FOR099.DAT while processing and deletes all files with               *
$! * this name during processing.  The  parameters  are as                     *
$! * follows:                                                                  *
$! *                                                                          *
$! *        P1 --> Name of the file containing the images.  It is             *
$! *               assumed that each image is located in a different          *
```

```
$! *                version under this file name.                          *
$! *                                                                       *
$! *        P2 --> Number of frames (pictures) to be taken of the          *
$! *               the initial image.  The initial image, typically        *
$! *               iteration 0 of a simulation run, is assumed to be       *
$! *           located in file "P1" under extension AAA.  This             *
$! *               parameter allows the user to hold display the first     *
$! *               image longer than the rest.                             *
$! *                                                                       *
$! *        P3 --> Starting iteration number.  This is the version         *
$! *               number of the first frame after the initial image.      *
$! *               It is assumed the the image will be found in file       *
$! *               "P1", version "P3".                                     *
$! *                                                                       *
$! *        P4 --> Ending iteration number.  As above except that this     *
$! *               parameter indicates the number of the last image.       *
$! *                                                                       *
$! *        P5 --> Iteration increment.  This parameter allows the user    *
$! *               to skip iterations while making the movie.  P5 must     *
$! *               be > 0.  The system will take pictures of every         *
$! *               "P5"th image starting with "P3".                        *
$! *                                                                       *
$! *        P6 --> Number of shots per iteration.  This parameter in       *
$! *               dicates the number of pictures to be taken for every    *
$! *               image.                                                  *
$! *               Remember that normal movie projectors run at a rate     *
$! *               of 18 frames per second.                                *
$! *                                                                       *
$! *        P7 --> Number of shots to be taken of the last frame.  This    *
$! *               allows the user to hold the final frame longer than     *
$! *               the others.                                             *
$! *                                                                       *
$! *        P8 --> Name of the self-contained image creation program.      *
$! *               It should obtain the data form file FOR099.DAT.         *
$! * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
$!
$! Enable the error trapping routine, branch on CTRLY or fatal errors
$!
$ On CONTROLY Then goto erxt
$ On ERROR  Then goto erxt
$!
$! Ask the user for values of null parameters.
$!
$ If P1 .EQS. ""  Then
$   INQUIRE P1 "Enter the file name"
$!
$ If P2 .EQS. ""  Then
$   INQUIRE P2 "Enter number of shots of initial image"
$!
$ If P3 .EQS. ""  Then
$   INQUIRE P3 "Enter starting iteration (version) number"
$!
$ If P4 .EQS. ""  Then
$   INQUIRE P4 "Enter ending iteration (version) number"
```

```
$!
$ back:
$ If P5 .EQS. ""  Then
$    INQUIRE P5 "Enter iteration (version) increment (>0)"
$ If 'P5 .LE. 0  Then goto back
$!
$ If P6 .EQS. ""  Then
$    INQUIRE P6 "Enter number of pictures per iteration (version)"
$!
$ If P7 .EQS. ""  Then
$    INQUIRE P7 "Enter number of pictures of final image"
$!
$ If P8 .EQS. ""  Then
$    INQUIRE P8 "Enter name of display producing program"
$!
$!
$!
$! Allocated the Grinnell
$ ALLOCATE GRA0:
$!
$!
$! Process initial image
$ COPY 'P1.AAA  FOR099.DAT
$! RUN 'P8
$ @putitup
$ count = 0
$ loops:
$ if count .GE. 'P2  Then goto loop2
$ count = count + 1
$ RUN shootz
$ goto loops
$!
$!
$! loop through images
$ loop2:
$ if 'P3 .GT. 'P4  Then goto end
$ DELETE for099.dat.*
$ COPY 'P1.*.'P3  for099.dat
$! RUN 'P8
$ @putitup
$ P3 = 'P3 + 'P5
$ count = 0
$ loop1:
$ if count .GE. 'P6  Then goto loop2
$ count = count + 1
$ RUN shootz
$ goto loop1
$!
$!
$! Process the final image
$ end:
$ P7 = 'P7 -'P6
$ count = 0
$ loop3:
$ if count .GE. 'P7  Then goto loop4
```

```
$ count = count + 1
$ RUN shootz
$ goto loop3
$!
$!
$! clean up and terminate
$ loop4:
$ DELETE for099.dat.*
$ DEALLOCATE GRA0:
$ EXIT
$!
$!
$! Error handling
$ erxt:
$ DEALLOCATE GRA0:
$ WRITE sys$output "  "
$ WRITE sys$output "  "
$ WRITE sys$output "* * * * * * * * * * * * * * * * * * * * * * * * *
 * * * *"
$ WRITE sys$output "  "
$ WRITE sys$output "Abnormal termination from CTRLY or program FATAL
 ERROR..."
$ WRITE sys$output "  "
$ WRITE sys$output "* * * * * * * * * * * * * * * * * * * * * * * * *
 * * * *"
$ EXIT
```

```
      program shootpic
c
c This program is used in by command proceedure "filmfi" to
c trigger the camera shutter once.
c
      call GR_INITIALIZE(0,'  ')
      call GR_TAKE_PICTURE(1)
      stop
      end
```

```
C
      IMPLICIT INTEGER*2 (A-Z)
C
      PARAMETER BUFLEN=4096
C
      BYTE BUF(BUFLEN)
      INTEGER LENGTH
C
      CALL GR_INITIALIZE(0,' ')
C
C
      OPEN(UNIT=10,TYPE='OLD',FORM='UNFORMATTED',NAME='for099.dat',
     1         READONLY,ERR=100)
C
```

```
1     READ(10,END=2) LEN , (BUF(I),I=1,LEN)
      LENGTH=LEN/2
      CALL GR_SEND_BUF(BUF,LENGTH)
      CALL GR_FLUSH
C     CALL GR_WRITE(BUF,LENGTH)
C     CALL GR_WAIT
C
      GO TO 1
2     CALL GR_FLUSH
100   stop
      END
```

Appendix D

FORTAN Code for Subroutines

```
      subroutine GR_TAKE_PICTURE (num_shots)
      integer*4 gr_old_time(2),current_time(2),delta_t(2)
      integer*4 gr_exp_frames,count
      integer*4 DIFFERENCE_XXX
      real*4 gr_exp_footage
      common /gr_camera/gr_old_time,gr_exp_frames,gr_exp_footage
      include 'dr1:[movie]grdefs.for'
      parameter C1='FFFFFFFF'x
      parameter C2=10000000
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c *                                                               *
c *  This routine triggers the camera "num_shots" times.          *
c * The sign of num_shots indicates the return status of the      *
c * routine.  With num_shots > 0, the routine waits for the       *
c * exposure cycle to be completed prior to returning.  With      *
c * num_shots < 0, the routine will return immediately after      *
c * initiating the camera action for the last of the "num_-       *
c * shots" frames.  With num_shots = 0, the routine returns       *
c * without performing any action.                                *
c *                                                               *
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      if(num_shots.EQ. 0) return      ! if 0 was passed, return
c
      delta_t(2)=C1
       do 1 count=1,IABS(num_shots)             ! loop for each pic
              call SYS$GETTIM(current_time)     ! get real clock time
              delta_t(1)=DIFFERENCE_XXX(current_time(1),gr_old_time(1))
              if(delta_t(1) .LT. C2) then
                                delta_t(1)=-(C2-delta_t(1))
                                call SYS$SCHDWK(,,delta_t,)
                                call SYS$HIBER
                               endif
              call GR_SEND(SPD .OR. 1)          ! trigger the camera
              call GR_SEND(SPD)
              call GR_FLUSH
              gr_exp_frames = gr_exp_frames + 1        ! update frame cnt
              gr_exp_footage = gr_exp_footage + .025   ! update footage
              call SYS$GETTIM(gr_old_time)
1      continue
c test for return condition
      if(num_shots .GE. 0) then                 ! if >0, wait
              call SYS$GETTIM(current_time)     ! get real clock time
              delta_t(1)=DIFFERENCE_XXX(current_time(1),gr_old_time(1))
              if(delta_t(1) .LT. C2) then
                                delta_t(1)=-(C2-delta_t(1))
                                call SYS$SCHDWK(,,delta_t,)
                                call SYS$HIBER
                               endif
                          endif
      return
      end
```

```
      integer*4 function GR_GET_FRAMES(num)
      integer*4 gr_old_time(2),gr_exp_frames,num
      real*4 gr_exp_footage
      common /gr_camera/gr_old_time,gr_exp_frames,gr_exp_footage
c
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c *                                                                   *
c *  This function returns the number of frames which have            *
c * been exposed on the current roll of film.  (That is, since       *
c * the last call to GR_NEW_FILM.) The value is a 4 byte integer.     *
c *  Standard 16mm film contains 40 frames / foot.                    *
c *                                                                   *
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c
c The global variable "gr_exp_frames" contains the number of frames
c exposed to the current time.
      num = gr_exp_frames
      GR_GET_FRAMES = gr_exp_frames
c
c
      return
      end


      real*4 function GR_GET_FOOTAGE(len)
      integer*4 gr_old_time(2),gr_exp_frames
      real*4 gr_exp_footage,len
      common /gr_camera/gr_old_time,gr_exp_frames,gr_exp_footage
c
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c *                                                                   *
c *  This function returns the number of feet of film which           *
c * have been exposed on this roll of film.  (That is, since         *
c * the last call to GR_NEW_FILM.)  The value of the function        *
c * is a 4 byte, real number.                                         *
c *  Standard 16mm film contains 40 frames / foot.                    *
c *                                                                   *
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c
c The global variable "gr_exp_footage" contains the footage exposed
c to the current time.
      len = gr_exp_footage
      GR_GET_FOOTAGE = gr_exp_footage
c
c
      return
      end
```

```
      subroutine GR_NEW_FILM
      integer*4 gr_old_time(2),gr_exp_frames
      real*4 gr_exp_footage
      common /gr_camera/gr_old_time,gr_exp_frames,gr_exp_footage
c
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c *                                                                   *
c *  This subroutine is used to aid in loading a new roll            *
c * of film. When called it immediately advances 5 feet of film      *
c * through the camera.  Also, it clears the exposed frame and       *
c * footage counters.                                                 *
c *                                                                   *
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c
c Advance 5 feet, 200 frames.
      call GR_TAKE_PICTURE(200)
c
c Zero both the exposed frame counter and the exposed footage counter.
      gr_exp_frames = 0
      gr_exp_footage = 0.0
c
c
      return
      end



      logical function GR_CAMERA_READY(switch)
      integer*4 gr_old_time(2),current_time(2),delta_t
      integer*4 gr_exp_frames,count
      integer*4 DIFFERENCE_XXX
      real*4 gr_exp_footage
      logical switch
      common /gr_camera/gr_old_time,gr_exp_frames,gr_exp_footage
      parameter C1=10000000
c
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c *                                                                   *
c *  This function allows the user to determine the state of          *
c * the camera.  A logical value of "FALSE" is returned when the      *
c * camera is still in the process of exposing the film.  A value     *
c * of "TRUE" is returned when the camera is ready to take a          *
c * picture.  The purpose of this routine is to allow a program       *
c * to make effective use of the subroutine GR_TAKE_PICTURE when      *
c * called with a negative argument.  (In such a case, GR_TAKE-       *
c * _PICTURE returns immediately after initiating the final           *
c * picture, without waiting for the camera to finish its cycle.)     *
c *                                                                   *
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c
c Obtain the current real clock time.
      call SYS$GETTIM(current_time)
c
c Calculate the length of time since the last picture was initiated.
      delta_t=DIFFERENCE_XXX(current_time(1),gr_old_time(1))
```

```
c
c If the difference is too small, i.e. <.85 sec, return FALSE.
      if(delta_t .LT. C1) then
                                  switch = .FALSE.
                                  GR_CAMERA_READY = .FALSE.
                               else
                                  switch = .TRUE.
                                  GR_CAMERA_READY = .TRUE.
                               endif
c
c
      return
      end


      subroutine GR_CAMERA_WAIT
      integer*4 gr_old_time(2),current_time(2),delta_t(2)
      integer*4 gr_exp_frames,count
      integer*4 DIFFERENCE_XXX
      real*4 gr_exp_footage
      common /gr_camera/gr_old_time,gr_exp_frames,gr_exp_footage
      parameter C1='FFFFFFFF'x
      parameter C2=10000000
c
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c *                                                                   *
c *  This routine causes the program to hibernate until               *
c * the camera is ready to take the next picture.  It is              *
c * designed to be used in conjunction with the GR_TAKE_PIC-          *
c * TURE / GR_CAMERA_READY sequence.  If the host program             *
c * has finished its processing and is ready to take a picture,       *
c * but GR_CAMERA_READY returned a value of FALSE, then this          *
c * routine may be called so that the program can wait without        *
c * using CPU time.                                                   *
c *                                                                   *
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c
c Load time constant in machine representation.
      delta_t(2)=C1
c
c Obtain the current real time.
      call SYS$GETTIM(current_time)
c
c Calculate the length of time since the last picture was initiated.
      delta_t(1)=DIFFERENCE_XXX(current_time(1),gr_old_time(1))
c
c If the lenght of time is less than .85 sec, hibernate!
      if(delta_t(1) .LT. C2) then
                                  delta_t(1)=-(C2-delta_t(1))
                                  call SYS$SCHDWK(,,delta_t,)
                                  call SYS$HIBER
                               endif
c
      return
      end
```

```
      subroutine GR_ZERO_COUNTERS
      integer*4 gr_old_time(2),gr_exp_frames
      real*4 gr_exp_footage
      common /gr_camera/gr_old_time,gr_exp_frames,gr_exp_footage
c
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c *                                                                     *
c *  This routine allows the user to zero both the footage              *
c * and frame counters.                                                 *
c *                                                                     *
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c
      gr_exp_footage = 0.0
      gr_exp_frames = 0
c
      return
      end


      integer*4 function DIFFERENCE_XXX (n1,n2)
      integer*4 n1,n2,q1,q2
c
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c *                                                                     *
c *     This routine returns the difference between n1 and n2.          *
c * Both n1 and n2 are 32 bit positive integers. The difference         *
c * between the values is found for the 31 low order bits. If          *
c * this is zero, then the 32nd bits are compared. When the             *
c * difference is in the 32nd bit, a value of 7FFFFFFF hex is           *
c * returned.                                                           *
c *                                                                     *
c * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c
      parameter C1='7FFFFFFF'x
      parameter C2='80000000'x
c
c
      q1 = n1 .AND. C1                  ! strip off the high
      q2 = n2 .AND. C1                  !         bit
c
c
      if(q1 .EQ. q2) then               ! if = compare bit 32
                     if((n1.AND.C2) .EQ.(n2.AND.C2)) then
                      DIFFERENCE_XXX = 0
                     else
                      DIFFERENCE_XXX = C1
                     endif
                     elseif(q1 .GT. q2) then
                      DIFFERENCE_XXX = q1-q2
                     else
                      DIFFERENCE_XXX = q1 + (C1-q2)
                     endif
      return
      end
```

Appendix I:

Specifications for the Signetics 555 Timer

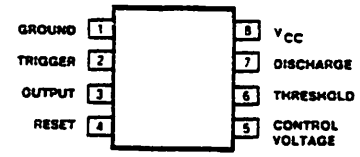
SE555F,H,N,N-14 • SE555C,F,H,N,N-14 • NE555F,H,N,N-14

FEATURES

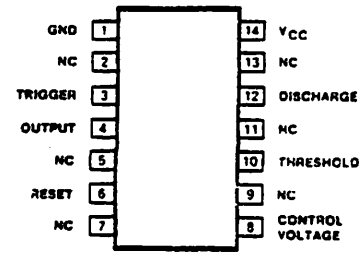
- Turn off time less than 2μs
- Maximum operating frequency greater than 500kHz
- Timing from microseconds to hours
- Operates in both astable and monostable modes
- High output current
- Adjustable duty cycle
- TTL compatible
- Temperature stability of 0.005% per °C
- SE555 Mil std 883A,B,C available M38510 (JAN) approved, M38510 processing available.

PIN CONFIGURATIONS

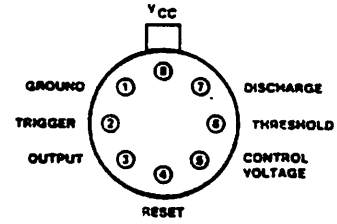
N PACKAGE



F,N-14 PACKAGE



H PACKAGE



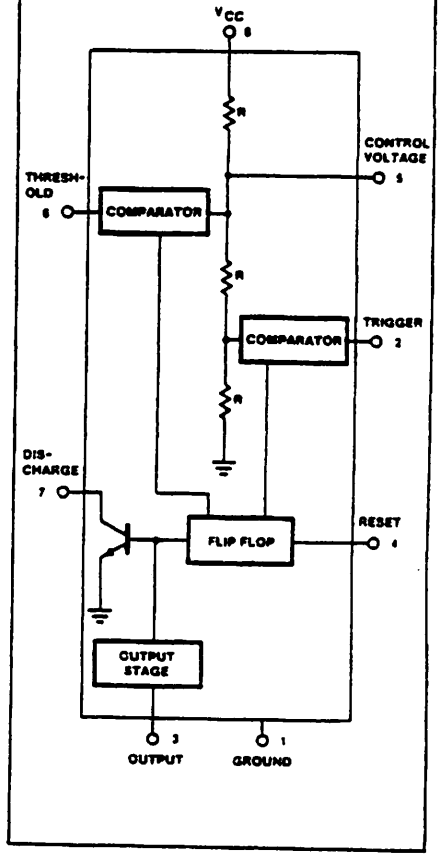
APPLICATIONS

- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Missing pulse detector

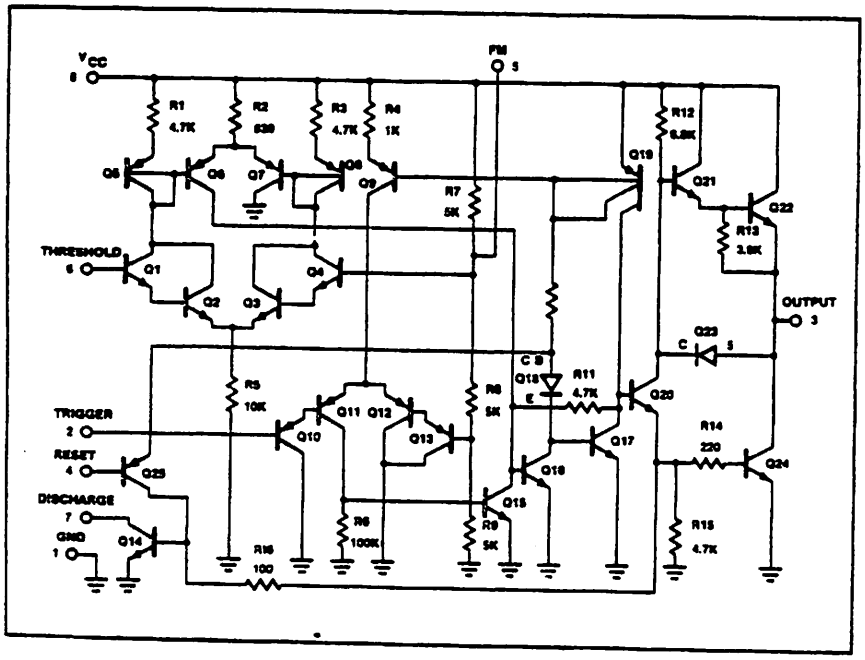
ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING	UNIT
Supply voltage		
SE555	+18	V
NE555, SE555C,	+16	V
Power dissipation	600	mW
Operating temperature range		
NE555	0 to +70	°C
SE555, SE555C	-55 to +125	°C
Storage temperature range	-65 to +150	°C
Load temperature (soldering, 60sec)	300	°C

BLOCK DIAGRAM



EQUIVALENT SCHEMATIC



DC ELECTRICAL CHARACTERISTICS T_A = 25°C, V_{CC} = +5V to +15 unless otherwise specified.

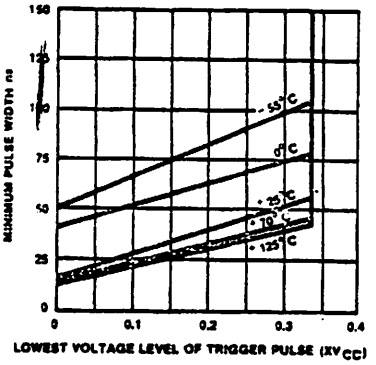
PARAMETER	TEST CONDITIONS	SE555			NE555/SE555C			UNIT
		Min	Typ	Max	Min	Typ	Max	
Supply voltage		4.5		18	4.5		16	V
Supply current (low state)[1]	V_{CC} = 5V R_L = ∞		3	5		3	6	mA
	V_{CC} = 15V R_L = ∞		10	12		10	15	mA
Timing error (monostable)	R_A = 2KΩ to 100KΩ							
Initial accuracy[2]	C = 0.1μF		0.5	2.0		1.0	3.0	%
Drift with temperature			30	100		50		ppm/°C
Drift with supply voltage			0.05	0.2		0.1	0.5	%/V
Timing error (astable)	R_A, R_B = 1kΩ to 100kΩ							
Initial accuracy[2]	C = 0.1μF		1.5			2.25		%
Drift with temperature	V_{CC} = 15V		90			150		ppm/°C
Drift with supply voltage			0.15			0.3		%/V
Control voltage level	V_{CC} = 15V	9.6	10.0	10.4	9.0	10.0	11.0	V
	V_{CC} = 5V	2.9	3.33	3.8	2.6	3.33	4.0	V
Threshold voltage	V_{CC} = 15V	9.4	10.0	10.6	8.8	10.0	11.2	V
	V_{CC} = 5V	2.7	3.33	4.0	2.4	3.33	4.2	V
Threshold current[3]			0.1	0.25		0.1	0.25	μA
Trigger voltage	V_{CC} = 15V	4.8	5.0	5.2	4.5	5.0	5.6	V
	V_{CC} = 5V	1.45	1.67	1.9	1.1	1.67	2.2	V
Trigger current	V_{TRIG} = 0V		0.5	0.9		0.5	2.0	μA
Reset voltage[4]		0.4	0.7	1.0	0.4	0.7	1.0	V
Reset current			0.1	0.4		0.1	0.4	mA
Reset current	V_{RESET} = 0V		0.4	1.0		0.4	1.5	mA
Output voltage (low)	V_{CC} = 15V							
	I_{SINK} = 10mA		0.1	0.15		0.1	0.25	V
	I_{SINK} = 50mA		0.4	0.5		0.4	0.75	V
	I_{SINK} = 100mA		2.0	2.2		2.0	2.5	V
	I_{SINK} = 200mA		2.5			2.5		V
	V_{CC} = 5V							
	I_{SINK} = 8mA		0.1	0.25		0.3	0.4	V
	I_{SINK} = 5mA		0.05	0.2		0.25	0.35	V
Output voltage (high)	V_{CC} = 15V							
	I_{SOURCE} = 200mA		12.5			12.5		V
	I_{SOURCE} = 100mA	13.0	13.3		12.75	13.3		V
	V_{CC} = 5V							
	I_{SOURCE} = 100mA	3.0	3.3		2.75	3.3		V
Turn off time[5]	V_{RESET} = V_{CC}		0.5	2.0		0.5		μs
Rise time of output			100	200		100	300	ns
Fall time of output			100	200		100	300	ns
Discharge leakage current			20	100		20	100	na

NOTES

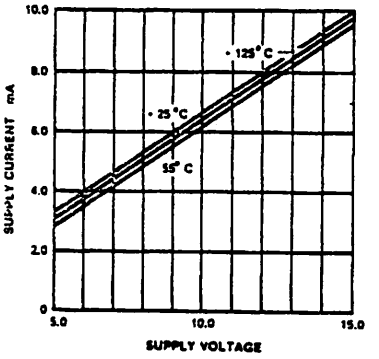
1. Supply current when output high typically 1mA less.
2. Tested at V_{CC} = 5V and V_{CC} = 15V.
3. This will determine the maximum value of R_A + R_B, for 15V operation, the max total R = 10 megohm, and for 5V operation, the max total R = 3.4 megohm.
4. Specified with trigger input high.
5. Time measured from a positive going input pulse from 0 to 0.8xV_{CC} into the threshold to the drop from high to low of the output. Trigger is tied to threshold.

TYPICAL PERFORMANCE CHARACTERISTICS

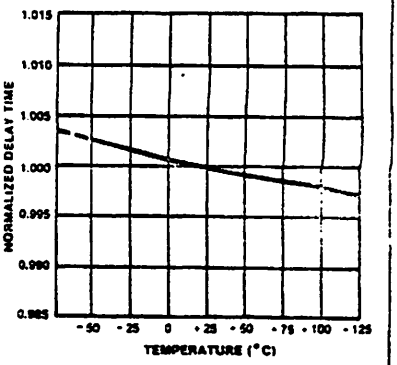
MINIMUM PULSE WIDTH REQUIRED FOR TRIGGERING



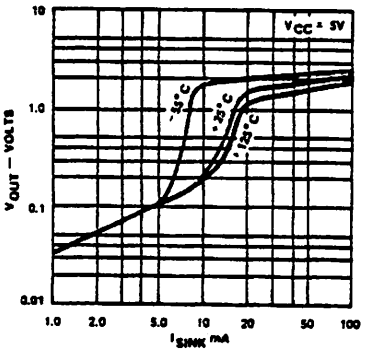
SUPPLY CURRENT vs SUPPLY VOLTAGE



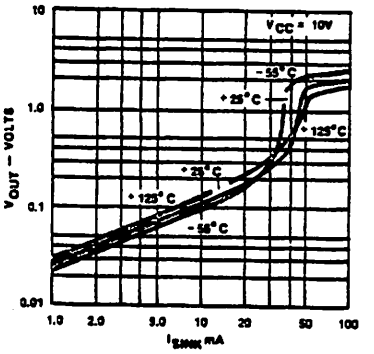
DELAY TIME vs TEMPERATURE



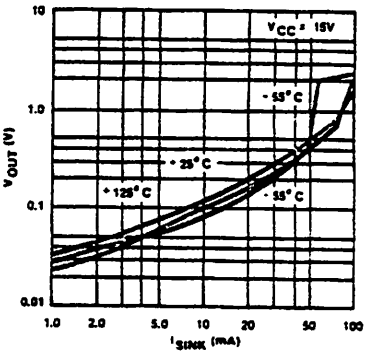
LOW OUTPUT VOLTAGE vs OUTPUT SINK CURRENT



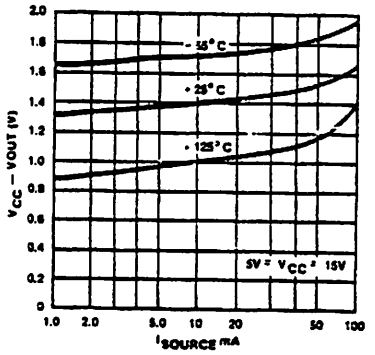
LOW OUTPUT VOLTAGE vs OUTPUT SINK CURRENT



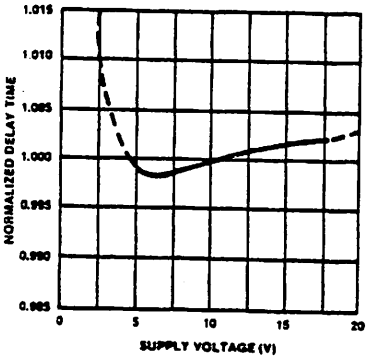
LOW OUTPUT VOLTAGE vs OUTPUT SINK CURRENT



HIGH OUTPUT VOLTAGE DROP vs OUTPUT SOURCE CURRENT



DELAY TIME vs SUPPLY VOLTAGE



PROPAGATION DELAY vs VOLTAGE LEVEL OF TRIGGER PULSE