ENGR 466 DESIGN REPORT 2

University of Victoria

DEPARTMENT OF MECHANICAL ENGINEERING

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1 Introduction

1.1 Current State of the Project

Currently, the mechanical components of the telecine device are being machined as Group 1 prepares for assembling the mechanical device. At the same time, the electrical circuits are being constructed with recently acquired electronic components. It is hoped that, testing of the entire assembled device can begin within 2 weeks time.

1.2 Objectives of this Report

This report gives an overview of the mechanical components of a telecine device meant to convert analog film into digital images. Each component of the design is described in terms of its purpose, dimensions, materials, overall assembly methods, and the characteristics of operation. For critical components, where stresses acting on the components are relatively high, some approximate calculations are performed to give an idea of the strength of the parts. Then a summary of the overall design is presented in the form of an assembly drawing indicating the way each component interfaces with the others. A brief introduction to the electrical system and programming control flow is found at the end of this report.

2 Final Design Description

The following section outlines the design of a telecine machine for converting analog 28 mm film to a digital format. The device is made up of a number of design modules which interface with one another to perform the task of cycling through the individual frames on a film reel.

The subsystems of this device are as follows:

- **Film gate**: This device flattens and aligns the film as it passes in front of a digital camera. The component itself is made of two aluminum plates which sandwich the film, forcing it flat. The aluminum plates have a narrow channel for the film to follow, lined with spring-loaded guides to align the film horizontally (preventing sideways drifting of the frames).
- **Film transport mechanism**: The film transport mechanism is what propells the film, pulling it through the film gate. A set of custom-made sprockets were machined to fit the dimensions of the 28 mm film. One of the sprockets is actuated by a stepper motor while the other is free-spinning. The sprockets pull the film by the sprocket holes in the film.

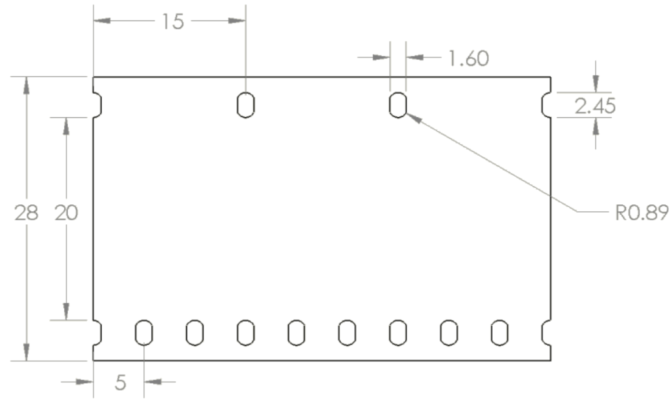

Figure 1 - 28mm Film Segment

The sprockets are fabricated from aluminium and are sandwiched by two aluminium disks for the film to rest on. The sprockets are spaced apart with a delrin spacer of much smaller diameter than the sprockets so the frame of the film is not resting on its surface. The coupler between the sprockets and the stepper motor is also fabricated from delrin.

- **Film Reel Actuation**: The reels of film need to rotate, both feeding film to the sprockets (avoiding unnecessary tension in the film), and spooling up film that has already been imaged on a take-up reel (avoiding a pile of tangled film at the end of the system).

  A set of custom-made steel shafts are designed to fit a 28 mm standard film reel. Each of the two shafts (one for out-take, one for up-take) are coupled to a DC motor via a set of aluminum pulleys. The pulley system serves two purposes. One, the ratio of the pulley diameters reduce the speed of rotation from the DC motors; a relatively fast-spinning DC motor can turn the film reels at a slower rate. The ratio of the pulley diameters is approximately 2:1. The other important role that the belted pulley system plays is to allow for slippage. If, for some reason, the film transport sprockets are not moving the film at the same rate as the film reels are rotating, the film will not be providing tension to stall the shaft of the DC motor driving the reel shaft, the belt driving the pulley will slip and provide relief.

  As mentioned above, the reel shafts are stainless steel and the pulleys are aluminium. The DC motors are mounted to a piece of 1/8” angle aluminium.

- **Passive Roller Array**: The film is guided from the reels to the sprockets by a set of four delrin rollers. The rollers are free spinning and machined to only contact the film on the edges, in order to prevent unnecessary friction forces on the film. The rollers spin on stainless steel shafts and are sandwiched by two delrin washers.

- **Film Tension Monitor**: Should the tension in the film become too high, a monitoring system will alert the actuators moving the film and act to remedy the problem. One of the passive rollers mentioned above is fixed to the end of an aluminum lever-arm which pivots about the knob of a potentiometer. As the tension in the film increases, the roller will deflect and rotate the knob of the potentiometer, creating an analog output which can be measured and translated into a digital quantity of the tension of the film. The lever-arm is attached to a spring so that, as the tension is reduced, the arm rotates back to the zero-displacement position.
- **LED Frame Illumination Device**: This provides the light source for the film. The array of LEDs was originally from a flashlight. The round shape of the aluminum casing makes it perfect for mounting using a cylindrical interference fit.
- **Camera Mount**: This holds the camera in place as it takes pictures. At this moment, the client has not yet provided the camera he wishes to use. Therefore general mounting plates were modeled but it is subject to change once the camera arrives.

In summary, the combined action of the above-described subsystems is as follows: The DC motor driving the out-take film reel feeds film through an array of passive rollers which guide the film to a set of sprockets, which rigidly fix and actuate the film through the film gate (positioned between the two sprockets). The film then passes through another set of rollers and is rolled onto an up-take reel driven by another DC motor. As each frame passes through the film gate, it is framed and illuminated by a light source and then captured by a digital camera mounted above the film gate. The tension in the line is monitored by a spring-loaded roller which deflects as the tension increases.

3 DETAILED MECHANICAL OVERVIEW

3.1 FILM GATE

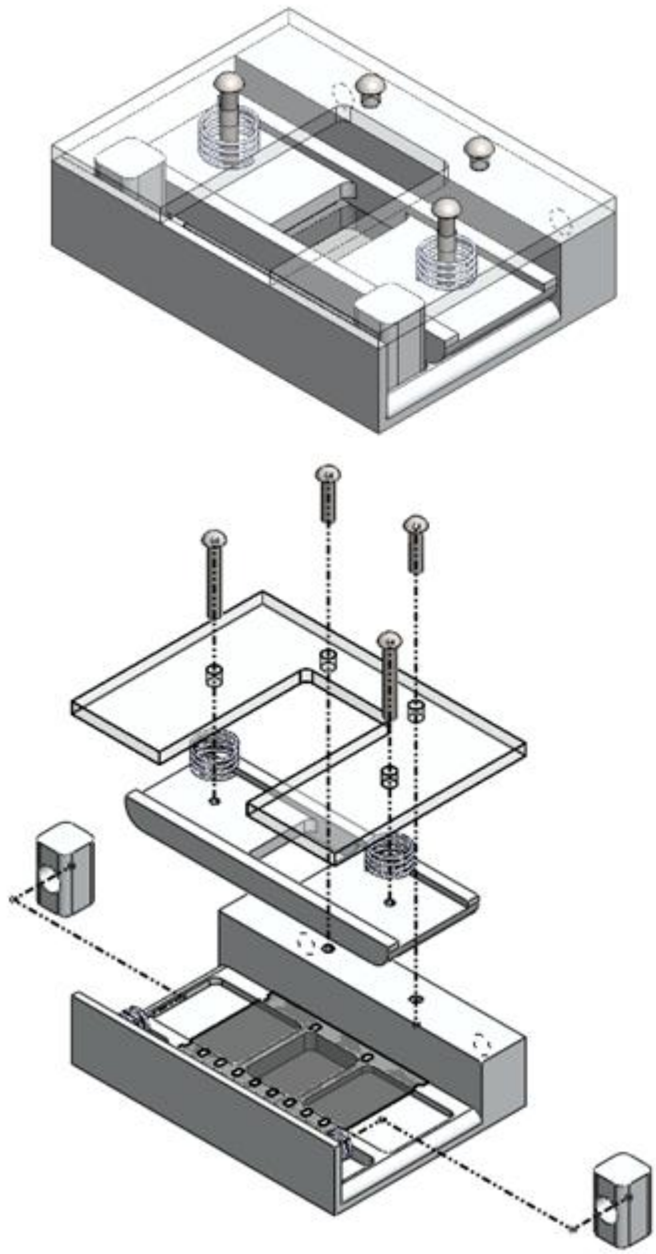

Figure 2: Film gate assembly exploded views

3.1.1 SPECIFICATIONS

The purpose of the film gate is to align and straighten the film as each frame passes by for capture by the camera. The main criteria of concern are to pass the film through this device with a margin of error less than 1/64 inches without causing damage the film.

3.1.1.1 COMPONENTS AND MATERIALS

This device will be mainly constructed out of aluminum. To prevent wear on the film it will be anodized by the client. Aluminum was chosen because the client requested this as his material of choice and that it would be more durable than using plastics. The springs used in this assembly are commercially available through capital iron and are chosen because they are cheap and abundant. Two types of screws were used, both of them are standard ANSI Inch sized which makes it easier for the machine shop to make threading and holes. The mounting frame for the pressure plate is made out of transparent plexi-glass so that the pressure plate can be exposed. This makes it easier to assemble the film gate and it acts as a visual verification of how well the film is passing through the device. The bill of materials is listed in the table below.

Table 1: Film gate assembly – Bill of Materials

ITEM NO.	PART NUMBER	MATERIAL	DESCRIPTION	QTY.
1	A002-B003_base	Aluminum	Base plate	1
2	virtualFilmModel^A002-003_assem	Aluminum	Film Representation	1
3	A002-B003_topTensioner	Aluminum	Pressure Plate	1
4	A002-B003_TensionMount	Plexi-glass	Pressure plate Mount	1
5	A002-B003_screw	Steel	#4-40 Screw Short	2
6	A002-B003_screw	Steel	#4-40 Screw Long	2
7	A002-B003_spring	Steel	Pressure Plate Springs	2
8	A002-B003_tensioner	Aluminum	Tension Blocks	2
9	A002-B003_spring-2	Steel	Tension Block Springs	2
10	A002-B003_Post	Aluminum	TBD	2

3.1.1.2 DRAWINGS AND MACHINED COMPONENTS

Besides minor modifications and adjustments, all the components of this film gate device have been machined and made. The drawings that were used to create these parts in the machine shop can be found in APPENDIX A. The assembled film gate can be seen in the figure below.

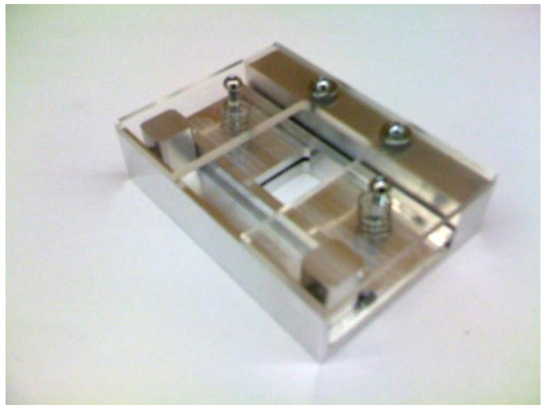

Figure 3: Actual film gate workpiece

3.1.2 Failure Modes

Since this component is not under any type of major strain or stress it is unlikely for the part to break especially since it is made out of aluminum. This device can align the film with an error of less than 1/64 of an inch thanks to the spring loaded mechanisms. However there is still major concern on the integrity of the film, especially on the pressure plate where pressure is added to straighten the incoming film. Several features were incorporated in the film gate to minimize this potential wearing on the film.

3.1.2.1 Filleted Film Entry and Exit

The entry and exit for the film gate are designed to be rounded so that the film can slip into and out of the film gate with ease. The cross section figure shown below illustrates this design.

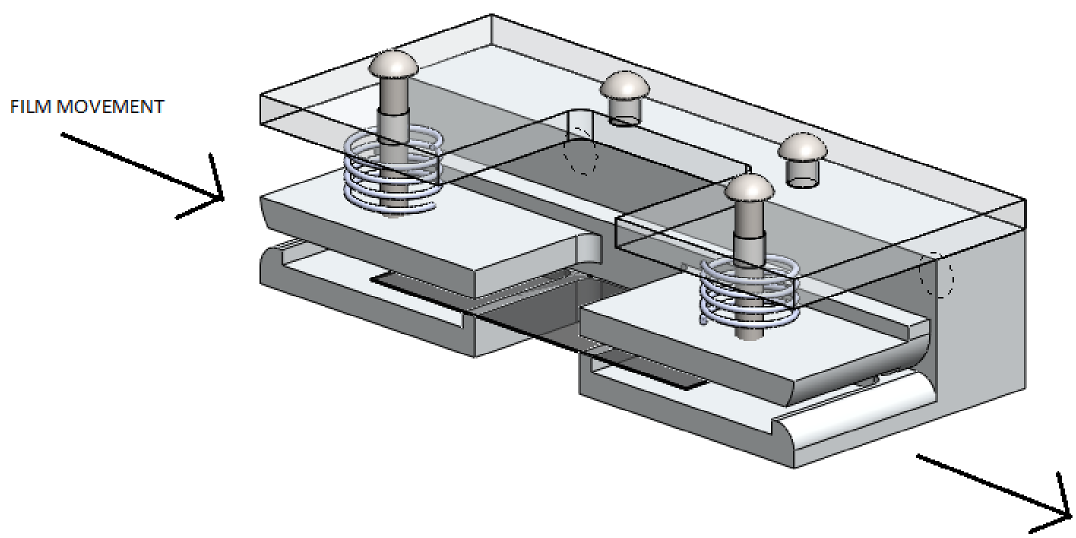

Figure 4: Film movement through the film gate

3.1.2.2 Spring Force and Spring Length

The amount of force the pressure plate adds to the film is important in terms of keeping the film in shape and aligned. However if too much force is added, the friction that results can tear the film apart during film advancement from the stepper motor. To simplify this problem, the forces acting on the film are analyzed as shown in the figure below.

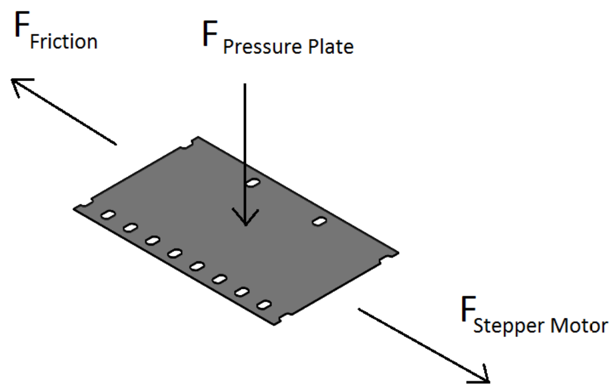

Figure 5: Simplified force analysis acting on the film

The force that caused friction will be equal to the amount of force the stepper motor will have to pull in order to advance the film. The force from the springs on the pressure plate will provide the normal force for the friction. The formulas for the calculations are shown below.

$$F_{friction} = \mu N = \mu F_{pressure\ Plate}$$

$$F_{pressure\ Plate} = k_{spring} x$$

Equation 1

$$\therefore x = \frac{F_{friction}}{\mu k_{spring}}$$

Using the equation above, the maximum amount of spring compression can be calculated. The spring constant was found by compressing the spring using a known amount of weight. The apparatus is shown below.

The spring constant was found by measuring the deflection of the spring that was caused by the 108g of weight. The equation used to calculate the spring constant is shown below. The deflection was measured to be 5mm. Therefore the spring constant for one spring is approximately 211.68 N/m. Keep in mind there are two springs so the total spring constant is double this value.

$$mg = k_{spring}x$$

Equation 2

$$k_{spring} = \frac{mg}{x}$$

Unfortunately, the coefficient of friction μ is not known. These values have to be found experimentally which is difficult to do. The closest estimate would be to take the coefficient of friction to be aluminum against aluminum which is 1.4[1]. From the force following calculations on the sprockets, the maximum amount of force that can be applied to the film before the holes tear was found to be 21 N. Using a safety factor of 3, the maximum amount of force should be no more that 7 N. Therefore the maximum amount of allowed spring deflection is approximately 11 mm. In the actual film gate device, the springs were cut so that the maximum deflection is 5 mm which is below the safety limit. However it not known if this is enough pressure to keep the film from bending too much. It will be up to experimentation and troubleshooting the film gate to find out.

3.1.3 Comments

The assembly and making of the film gate device was done very well and as expected. There are a few minor improvements that could be made to make the device more accessible to the user. For example, the two screws that secure the top mounting plate require screw drivers to remove. Every time a new roll of film is replaced, these screws will need to be undone. It would be better if they were thumb screws instead so the user can quickly setup the telecine system.

3.2 FILM TRANSPORT MECHANISM

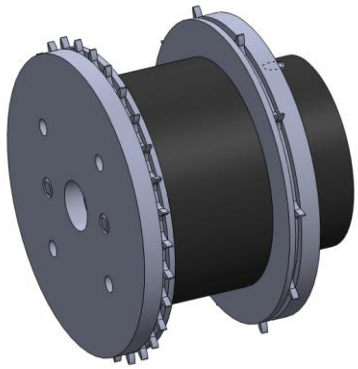

Figure 6: Transport Sprocket

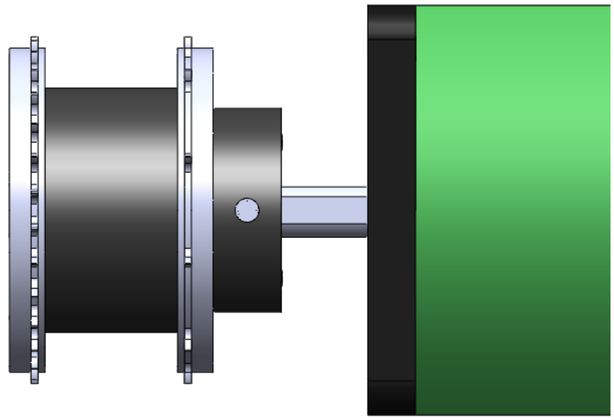

Figure 7: Transport Sprocket - Side View

The overall film transport mechanism is composed of two sprockets with sprocket teeth dimensions and spacing to mate with the sprocket holes of the 28 mm film (see **Error! Reference source not found.**). One of these sprockets is fixed directly to the shaft of a stepper motor as seen in Figure 7. The sprocket actuated by the stepper motor is responsible for pulling the film frame-by-frame through the device. Accuracy in frame-to-frame movements is achieved by actuating the stepper motor through a number of steps that will progress the film by a length equal to a single frame (15mm). The radius of the film sprocket -23.87 mm- results in system dimensions where 50 steps taken by the stepper motor –each step is 0.72 degrees- corresponds to the advancement of one frame in the film. The second sprocket composing this mechanism is free-spinning and is fixed to the frame through a Delrin bushing. The sprockets guide the film through the film gate where each frame is digitally captured. Figure 8 below shows the layout of the two sprockets; the gap between them is the designated location of the film gate.

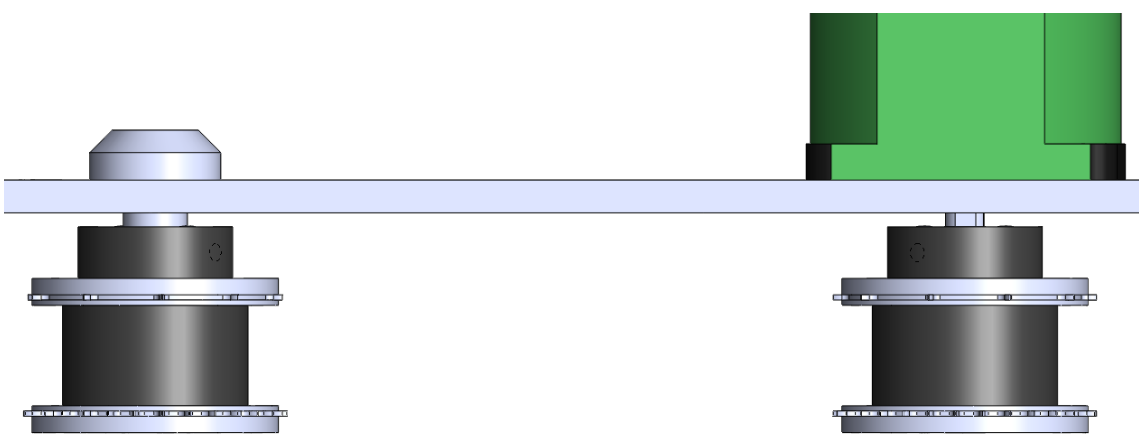

Figure 8: Film Transport Mechanism - Top View

3.2.1 Specifications

The sprocket is composed of a series of independently machined layers. The layers are held together by two 1/8” steel pins, which are press fit into holes perpendicular to the layers of the sprocket. Figure 9 below, is an exploded view with the major components of a film sprocket.

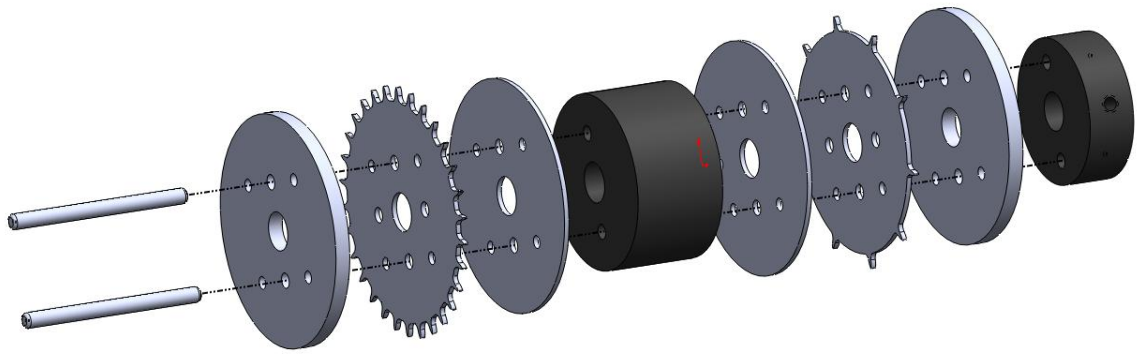

Figure 9: Film Transport Sprocket - Exploded View

Corresponding with the dimensions of the 28 mm film, there is a distinct sprocket positioned to engage with either side of the frame. One side of the film has three holes per frame while the other side has one. As seen in the figure above, these two distinct sprockets can be seen sandwiched between two aluminium disks. The sprockets themselves are fabricated from aluminum on a CNC mill. The aluminium sandwiches on either side act as a large and continuous surface for the film to rest on as it passes over the teeth of the sprocket. The aluminum sandwiches and the sprockets are only wide enough to support the edges of the film where there are only sprocket holes and no frame. Between these two sprockets is a Delrin spacer. This spacer has a smaller diameter than the aluminum sandwich disks; this eliminates contact of the frame of the film with the sprocket, preventing friction damage to the film. A Delrin coupler is attached to the sprocket set so that the assembly can be coupled to the stepper motor shaft, for the active sprocket, or a roller shaft, for the free-spinning sprocket. A 6-32 set screw is used to fix the coupler onto a shaft.

Table 2 is a bill of materials for the entire film transport device. The part numbers in this table correspond to a single drawing found in APPENDIX B. For more detailed dimensions of the device described in this section, please reference these drawings. The stepper motor and its controller which are used to actuate the device, are not listed in this table.

Table 2: Film Transport Mechanism - Bill of Materials

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Coupler	Coupler between the stepper motor and the sprocket	2
2	OuterSandwich	Thick shoulder for film to rest on	4

3	SprocketCoarse	Sprocket with 10 teeth	2
4	OuterSandwich_THIN	Thin shoulder for film to rest on	4
5	LongInnerSpacer		2
6	SprocketFine	Sprocket with 30 teeth	2
7	Sprocket_Pin	Pins to align components	4
8	6-32_Set_Screw		2
9	Delrin_Bushing		1

3.2.2 Failure Modes

This mechanism is operating at very low speeds. The materials making up the device have material properties far superior to what is necessary for the application. For example, the Vexta stepper motor used in this application has a stall torque of 1.372 Nm. In the absolute worst case scenario, a force applied to a single sprocket tooth would resist this entire torque. This force, acting at 23.87 mm from the motor shaft would need to be 57.5 N. If this sprocket tooth is further approximated to be a small, rectangular cantilever beam with length of 1.534 mm and cross sectional area of $(1.016\ \text{mm})^2$, an applied stress on the sprocket can be estimated.

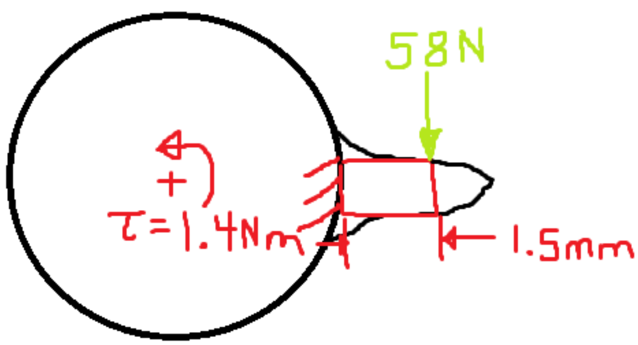

Figure 10: Point Load Applied to Single Tooth – Tooth approximated as a Cantilever Beam (in red)

The center of the sprocket is assumed to be grounded. A second moment of area for the 'cantilever tooth' is calculated to be $5.33e^{-13}$ m^4. Reducing the 57.5N force to a moment acting on the cantilever, an applied moment of 0.08763 Nm is calculated. Using the formula for the stress in a cantilever beam, a max stress in the tooth is calculated to b 83.5 MPa. The tensile strength of 7075 aluminium is 503 MPa [5]. A factor of safety of more than 6 is calculated for this, highly unlikely and conservative, loading approximation.

Materials with strength far greater than the demands of the application were chosen to give the device longevity of operation.

The film will fail long before the components of the transport mechanism. The film is made from non-flammable cellulose acetate [2, 3]. Modern day material properties of this material are used to estimate the yield strength of this material at 24 MPa [4]. This may be too high of a value when considering the film. Material science may have improved the mechanical properties of cellulose acetate since the time of 28 mm film production (around 1910). Moreover, the film is decomposing; almost certainly, it does not have the ideal mechanical properties listed for cellulose acetate. A factor of stafety of 3 is used to approximate a more conservative yield strength of 8MPa.

It is assumed that, in the worst case scenario, the entire 57.5 N load (calculated based on the stall torque of the motor acting 23.87 mm away from the motor shaft) is acting on a single sprocket hole. The film will fail due to shear stress acting on the film between two sprocket holes.

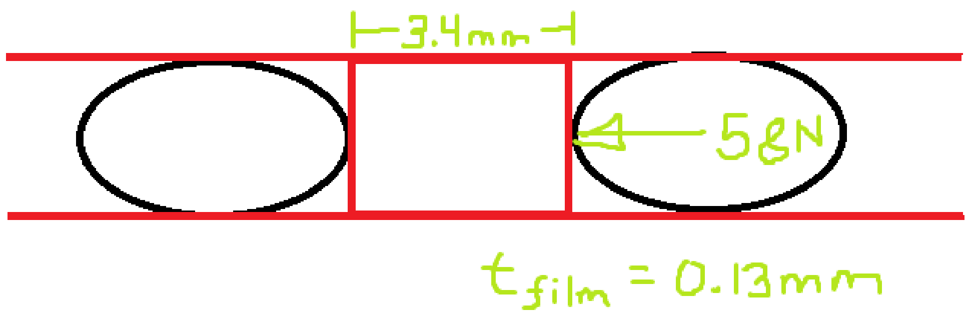

Figure 11: Approximation of Shear Load on Sprocket Holes

The 57.5 N load is approximately divided over two rectangular areas on each side of the sprocket hole. The area is equal to the distance between the sprocket holes (3.4 mm), multiplied by the thickness of the film (0.13 mm), and finally multiplied by 2. Under these loading conditions, a shear force of 65 MPa is calculated. This is far larger than the tensile strength of the film; moreover, the shear strength of the film is likely an even smaller value than the tensile strength.

Using the tensile strength value of 8 MPa assumed above, and further assuming that it is equal to the shear strength of the film material, a maximum force that can be applied to a single sprocket hole of the film is calculated to b 7.1 N

3.2.3 Comments

The diameter of the sprockets is relatively large. A larger sprocket is preferred because of the increased number of sprocket teeth and a higher sprocket hole to tooth contact ratio. Because the film is old and damaged in parts, more sprocket teeth are required to minimize possible slippage of the film.

The sprocket component is proving to be a challenge to design. The current dimensions of the sprocket, although carefully chosen, do not give ideal tooth engagement with the film. As this is the most critical component of the telecine device, another iteration of fabrication is required.

3.3 FILM REEL UP-TAKE AND OUT-TAKE

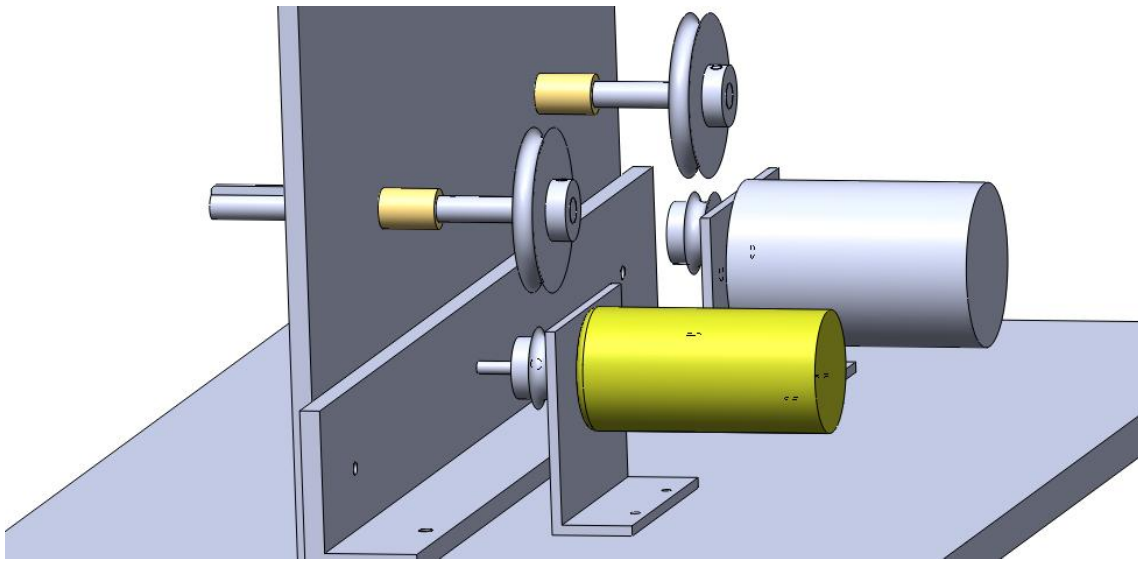

Figure 12: Reel Drive System (rubber belts for pulleys not shown)

The film reel drive system has two, keyed, stainless steel shafts that are driven through a set of aluminium pulleys by two DC motors. The shafts rotate inside brass bushings. Pulleys are used to drive the reels, as opposed to directly driving the shafts, to allow the film reels to slip if the film is put in excessive tension. The DC motors are supported by motor mounts made from 1/8” aluminium angle.

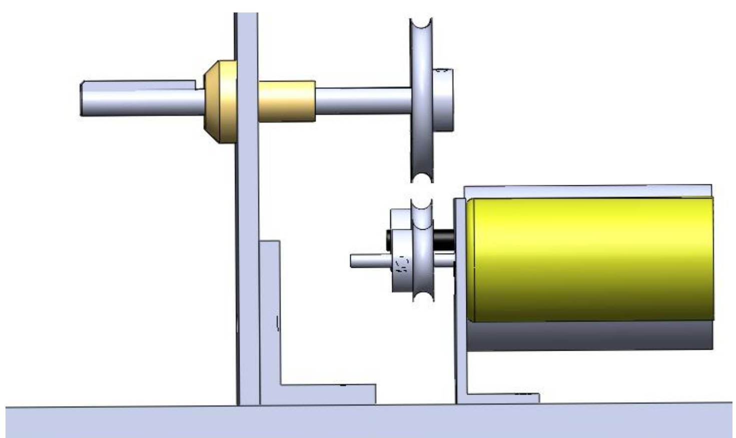

Figure 13: Reel Drive System - Side View

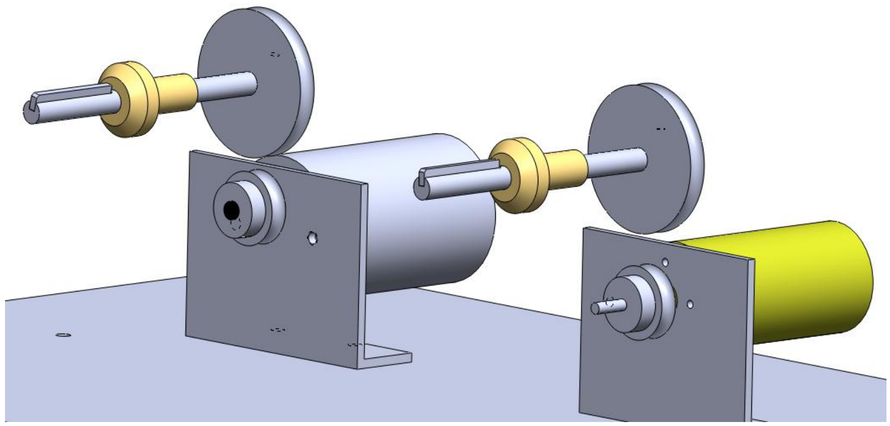

Figure 14: Reel Drive System (supporting system frame not shown)

3.3.1 SPECIFICATIONS

The pulleys are fixed to both the steel reel shafts and the DC motor shafts by 6-32 set screws. The key on the reel shaft is laser welded into the keyway.

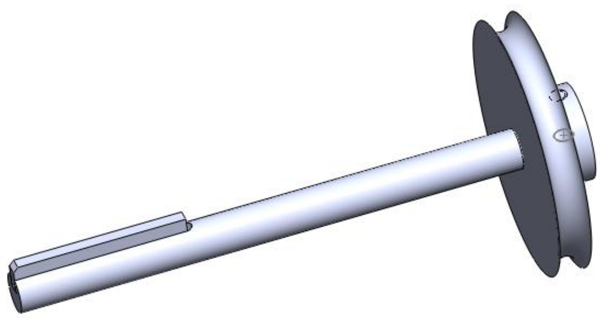

Figure 15: Keyed Shaft for Reel Drive

Figure 16: Small Pulley

Table 3 is a bill of materials for the film reel drive system. The part numbers in this table correspond to a single drawing found in APPENDIX C. For more detailed dimensions of the device described in this section, please reference these drawings. The DC motors and associated circuitry, which are used to actuate the reels, are not listed in this table.

Table 3: Film Reel Drive System - Bill of Materials

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ReelRod		2
2	ReelKey		2
3	LargePulleyRoller		2
4	6-32_Set_Screw		4
5	SmallPulleyRoller	Pulley for larger motor	1

6	SmallPulleyRoller_4mm	Pulley for smaller motor	1
7	Brass_Bushing		2
8	GE_restricted	Mount for larger motor	1
9	Wimpy_Faithful	Mount for smaller motor	1

The DC motors used to drive the reels have different sized shafts –both 8 mm diameter and 4 mm diameter. As a result, two different pulleys are to be coupled with each respective motor. Items 5 and 6 in the bill of materials, list the two pulleys with differing bore sizes. As the shafts driving the reels are identical, only one pulley design is required as seen in Figure 15.

3.3.2 Comments

The 28 mm film reels do not have consistent shapes at the center of the film reel. The size and shape of the key and shaft are chosen as an average of the sizes and shapes seen on the film reels available through the client.

3.4 Roller Array

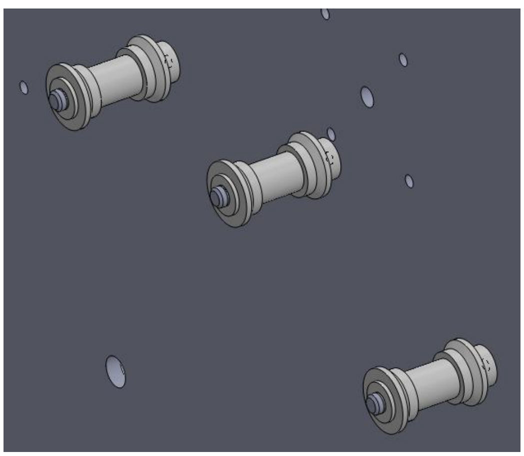

Figure 17: Film Roller Array

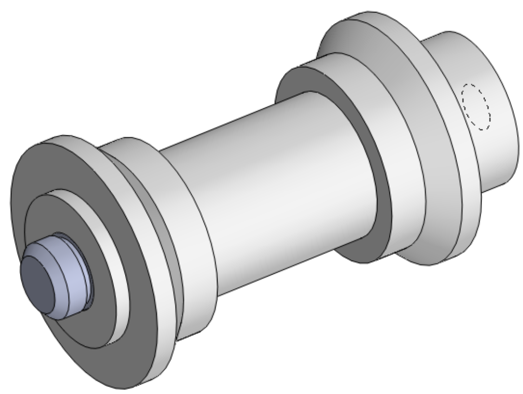

Figure 18: Delrin Film Roller

An array of Delrin rollers are used to guide the film between the reels and the sprockets. The rollers all spin freely on a stainless steel shaft which is fixed to the frame of the device.

3.4.1 Specifications

The roller itself is a single piece of Delrin. The profile of the roller, as seen in Figure 19, is shaped to minimize contact with the film and maintain alignment. The sloped sides (where the diameter drops from 1” to 0.8”) provide a valley for the film to rest in. The grove in the center with the flat shoulders on either side (where the diameter drops from 0.8” to 0.6”) give the film support on the edges while preventing the frames from contacting the surface.

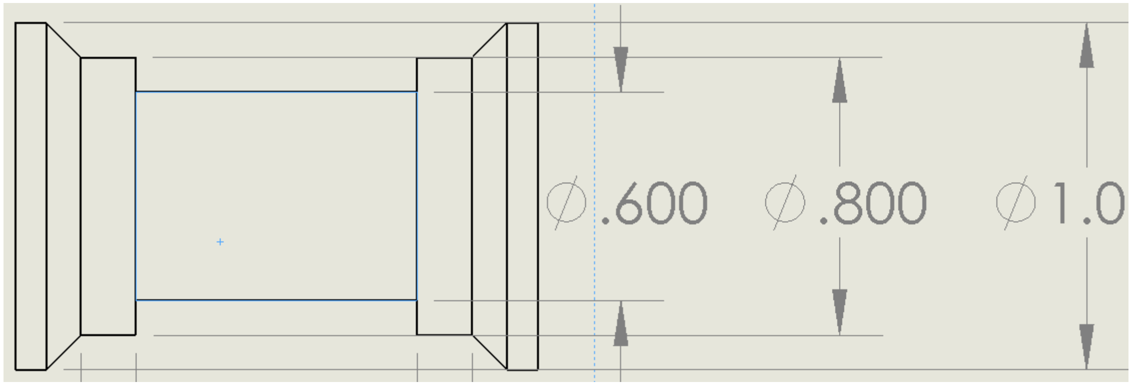

Figure 19: Film Roller Profile

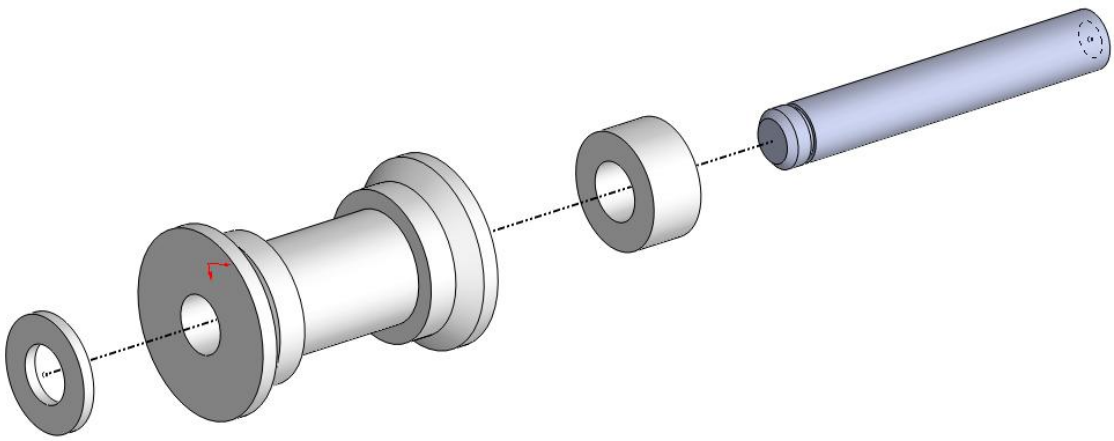

Figure 20: Film Roller Assembly - Exploded View

As seen in Figure 20, the film roller assembly is composed of the plastic roller itself, sandwiched between two Delrin spacers all of which spin freely on a stainless steel shaft. The shaft is fixed to the frame of the device with 10-32 screws. The roller and the washers are fixed axially with a 5/16" c-clip.

Table 4 is a bill of materials for all of the film rollers. The part numbers in this table correspond to a single drawing found in APPENDIX D (with the exception of the fasteners). For more detailed dimensions of the device described in this section, please reference these drawings.

Table 4: Film Roller Array - Bill of Materials

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RollerPin		4
2	DelrinSpacer		4
3	RollerPLASTICSECTION		4
4	DelrinWasher		4

5	5/16" C-Clip		4
6	10-32 Screw		4
7	10-32 Washer		4

3.4.2 Failure Modes

The film rollers are passive, have a low coefficient of friction and are subjected to minimal loads. They will not fail or wear out in this lifetime.

The coefficient of friction of Delrin is 0.06 [6]. This contact friction is far lower than that experienced as the film passes through the film gate. Moreover, the frames of the film are hanging over a smaller diameter of the roller, eliminating contact all together. The film will experience minimal wear from this system.

3.4.3 Comments

One of the film rollers, instead of being fixed to the stationary system frame, is mounted on the film tensioner device. This device is discussed in more detail in the following section.

3.5 Film Tension Monitor

The film tension monitoring device for the system translates a rotational deflection of a spring-loaded potentiometer into a digital value for the tension of the system. As seen in **Error! Reference source not found.**, one of the film rollers described above, is mounted to the end of a 5” aluminum bar as seen in Figure 22. The center of this bar is fixed to the rotation axis of a potentiometer. At the other end of the aluminum bar is a hole to attach a spring. The spring is fixed at the other end to a 6-32 screw on the system frame. This spring resists the rotation of the aluminum rod as the tension in the film pulls on the roller. As the tension changes in the film and the bar rotates, the value of the potentiometer changes and can be translated to a relative tension value.

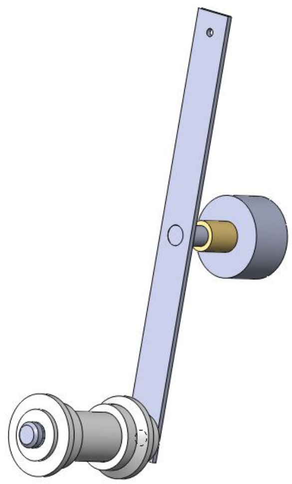

Figure 21: Film Tension Device

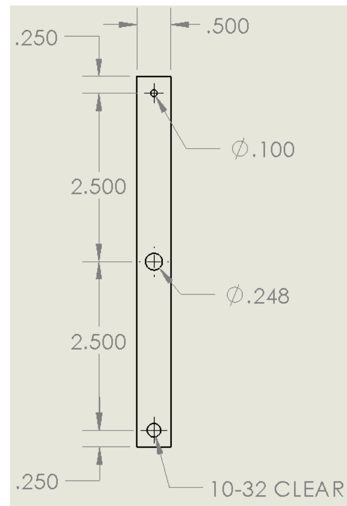

Figure 22: Tensioner Arm

3.5.1 Specifications

The tensioner arm is press fit onto the end of the potentiometer. The film roller assembly is fixed to the tension arm with a 10-32 screw. The linear spring used to provide rotational resistance is harvested from an old printer.

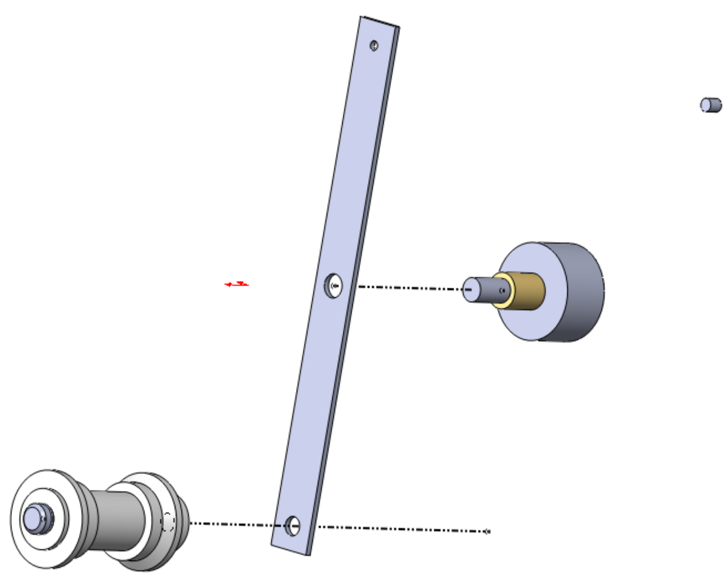

Figure 23: Film Tensioner Assembly - Exploded View

Table 5 is a bill of materials for all of the film tensioner. The part numbers in this table correspond to a single drawing found in APPENDIX E (with the exception of the fasteners). For more detailed dimensions of the device described in this section, please reference these drawings.

Table 5: Tensioner Device - Bill of Materials

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Potentiometer		1
2	TensionArm		1
3	RollerAssembly	An Instance of the Delrin Film Roller	1
4	6-32_Screw		2
5	Linear Spring		1

3.6 LED and Camera Mounts

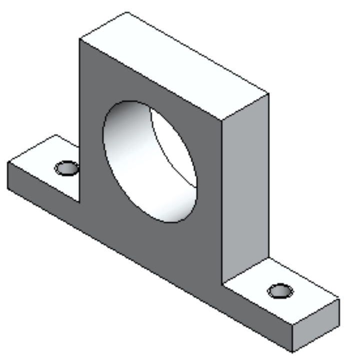

Figure 24: LED mount plate

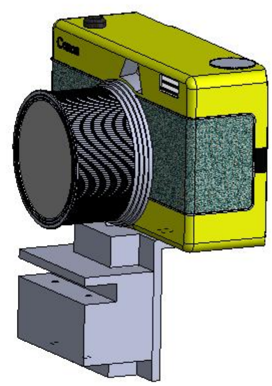

Figure 25: Camera Mount Plate

3.6.1 Specifications

The function of both these devices is to hold the electronic components. For the LEDs, the mounting plate is stationary and illuminates the film gate directly above it. The Camera mounting plate on the other hand is a bit different. In addition to keeping the camera stationary, the mounting plate must also have an adjustable XY stage so that the camera can aligned manually with the film gate.

3.6.1.1 Components and materials

In order to increase the durability, the mounts will be machined out of aluminum. The bill of materials for the two components is shown in the table below.

Table 6: LED and Camera Mount - Bill of Materials

ITEM NO.	PART NUMBER	MATERIAL	DESCRIPTION	QTY.

1	A004_LEDMounts	Aluminum	LED mount	1
2	A004_FrameLBracket	Aluminum	Camera bracket attached to the frame	1
3	A002-CameraLBracket	Aluminum	Camera bracket attached to the camera	1

3.6.1.2 EXPLODED VIEW

The camera mount provides XY stage alignment using two bracket parts. The first bracket slides along the frame, giving it the X alignment. The Y alignment is achieved by using the second camera bracket to slide in the perpendicular direction on the first bracket. The exploded view shown in the figure below illustrates the mechanism in action.

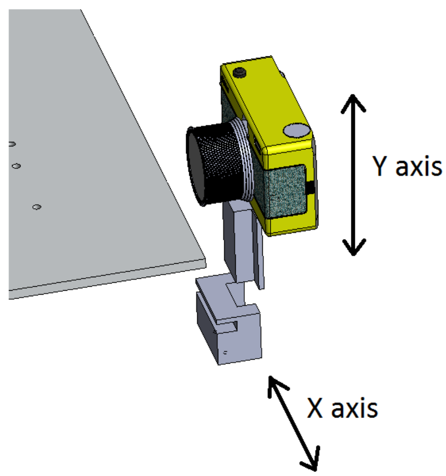

Figure 26: Exploded view for the camera mount

3.6.2 DRAWINGS

The drawings for the LED mount can be found in APPENDIX F. The models for the camera mounts are complete, but since the camera is not given, the drawings for the parts are not complete

4 DESIGN COMPONENT INTERFACING AND ASSEMBLY OVERVIEW

The interfacing between the mechanical parts is very important in order to keep the film aligned. Misalignment of the film can cause severe damage to the film and surrounding components. The holes and spacing of the frame that holds the parts together were determined in order to prevent the parts from interfering with each other and to keep parts aligned with one another. The full assembly overview of all the parts is shown in Figure 27. The detailed drawings for the frame, L bracket and base plate can be found in APPENDIX G.

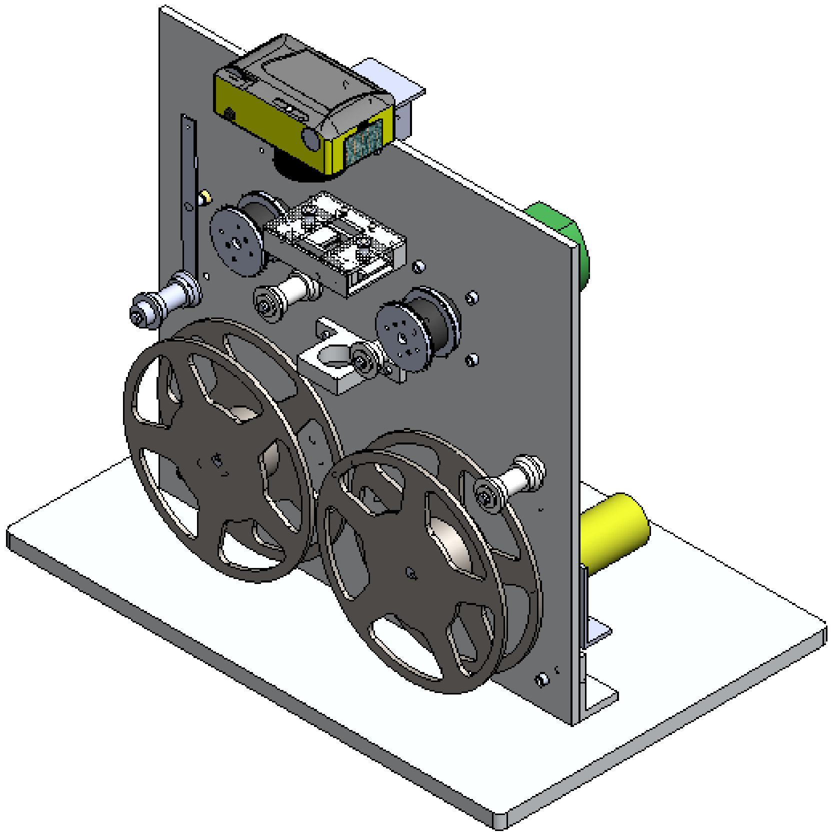

Figure 27: Full assembly of all the parts

The distance the film is away from the frame is very important in terms of film alignment. All the components are designed to be 0.5 inches away from the frame as illustrated by the side view of the assembly shown in Figure 28.

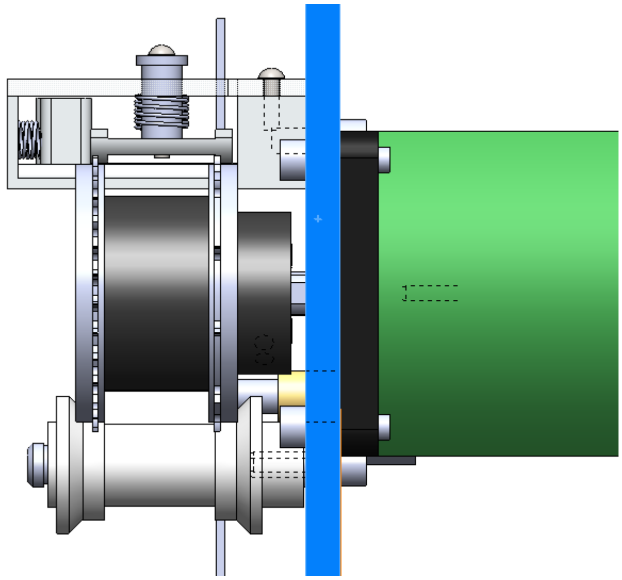

Figure 28: All components located 0.5 inches away from frame (highlighted in blue)

5 Electrical Design

The control system for the telecine machine will be controlled by an Adruino microcontroller as shown in the figure below. The client requests an interface system that will allow the user to reverse the film as well as adjusting the speed of film advancement.

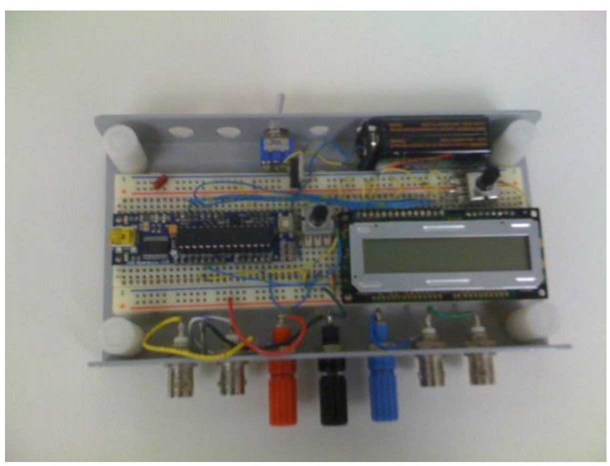

Figure 29: Adruino microcontroller with LCD screen

The electrical componets and its functionality is shown in Table 7. The full electronic schematic diagram can be found in APPENDIX H.

Table 7: Electronic Components

Component	Description
Adruino Microcontroller	Microcontroller used to control the motors, camera capture, sensor information, and user interface for the telecine setup.
LCD Screen	Displays information to the user. For example, frame counts, motor speed and motor direction.
Tension Sensor	The tension senor is a potentiometer attached to a lever so that a change in tension can be measured as a change in voltage.
DC motors (2 qty)	The DC motors uptake or releases the film for the stepper motor to advance. The speed of these motors is based on the values obtained from the Tension sensor.
IRFZ40 (2 qty)	MOSFET that allows the Adruino MC to control the DC motor speed and to turn on or stop the motor.
955 Power supply	5VDC power supply that is powered by a power outlet. This power source will supply 5VDC to the microcontroller, LCD and the DC motors.
VEXTA 5 phase Stepper Motor	Stepper motor to drive the film sprockets.
VEXTA Motor Controller	The motor controller for the 5 phase stepper motor. It is powered by an electric outlet.

6 Preliminary Software Design

The implementation of the software control system is aimed for simplicity and robustness. Since the main project objective is only focused on capturing film, most of the microcontroller's resources will execute the operations one at a time. The preliminary software design for this project is displayed in Figure 30 and Table 8.

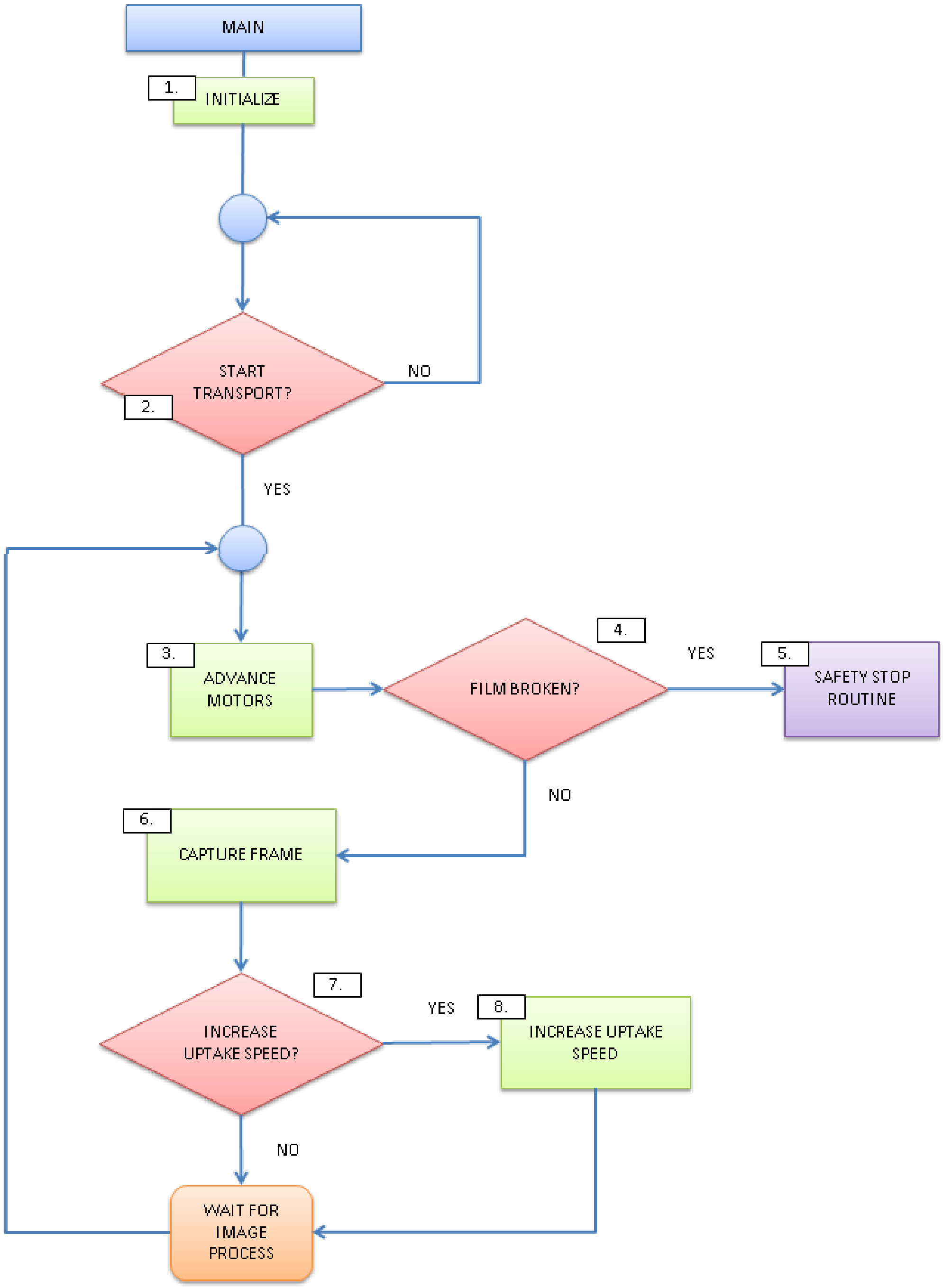

Figure 30: Software design flowchart

Table 8: Software design description

Ref	Description

1	Initialization for the control system. This is where the rotational speeds for the motors are first set, along with the manual adjustments so that the frame matches with the film gate hole.
2	This is a confirmation for the user to start the film transport operation. The trigger for this event will be a push button input of some sort. Otherwise, the program will wait until the user is ready.
3	The motors advance the film forward by one frame. This means the stepper motor and the driving film motors will all move.
4	This is where the optical sensors will try to detect a discontinuation in the film.
5	This routine is accessed if there is a discontinuation in the film. It could mean that the film has been broken or the film wheel has reached the end of the movie. Either way, the whole system must stop. The micro-controller will power down everything to conserve power.
6	If everything goes well in the film advancement, a signal will be sent to the camera to capture the frame on the film.
7	Optical sensors will check the thickness left in the film wheel and decide if the motors require a change in speed.
8	Changes in motor speed are requested so it will be adjusted accordingly. Afterwards it will wait for the camera to finish processing the image before repeating the entire film capturing process.

7 Conclusions

Even though the design of the telecine machine have been refined and drawn, there are still many challenges that still need to be resolved. Most of the issues so far are due to the amount of time it takes to produce the parts. This is caused by the lack of experience in the machine shop and the need to remake failed parts.

In the stress calculations on the parts described above, the effects of periodic loading of parts over time was not considered. Perhaps, for an estimation of the lifetime of this device, fatigue calculations should be performed.

The next major steps in the project are to setup the electronics and programming. Although the components have been tested individually, interfacing all the components will still remain a tough challenge. The goal is to begin assembly of parts next week and troubleshooting the issues early before the prototype presentation.

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8 APPENDICES

Apendix A: Film Gate Drawings

Apendix B: Transport Mechanism Drawings

Apendix C: Film Reel Drive System Drawings

Apendix D: Roller Array Drawings

Apendix E: Film Tensioner Drawings

Apendix F: LED Mount Drawings

Apendix G: Frame Drawings

Apendix H: Electronics Schematics