Super 8 mm film digitizer

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Christopher Stewart

April 2018

Thesis Advisor:

Professor Moise Cummings

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The digital age killed film as a medium of recording images. As the devices to record such formats become less accessible, so do the methods to view them. There still exist a large quantity of super 8mm film reels from the days when film was the preferred way to capture home movies and save memories. Even as the digital age continues to press forward and bring new technology into our lives, some people are finding the desire to use older analog formats. Vinyl, polaroid and super 8mm film are seeing a resurgence in usage. As one of these people who shot some super 8 film, I found the methods to view it very limiting. Finding a projector or digitizing it. The current services offering digitization don’t satisfy the needs of a casual hobby user; they are either too expensive or don’t provide sufficient resolution quality that is needed when working with film.

The goal of this design is to create a device that can digitize super 8mm film. This device should at least meet all the specs of the professional models, and exceed the consumer models. Resolution, scan speed, reel size acceptance, flexible camera settings, weight and ease of use. Price will be the final determining factor in the product success if it meets all these criteria.

The design of the device functions as follows; A motor gear turns a driven gear attached to a hub with an offset pin. The distance is the length of 1 frame of super 8mm film. Sitting on the offset pin is a metal claw that reaches horizontal and has 2 super 8mm film sprocket sized claws in it. A plastic piece fits the metal claw to the gear and down to the lower hub. There is a similar hub at the bottom that rotates the same speed and orientation as the main hub, similar pin hooked to the claw- this keeps it rotating as vertical linkage. The film is fed through a channel with a slot cut that accepts the claw as its rotational motion is constrained linearly. Once per turn, the claw enters the film and hooks the sprockets, bring it down and letting go as the claw rotates back to the top. As the claw pulls away, the metal piece hits a metal contact that completes a circuit, taking a picture. The camera is below the claw slot with a cutout window exposing the film to the lens. An LED light is shining from the other side to illuminate the film for the camera. Film exits the channel and is fed out of the machine.

The concept was successful at indexing the film, frame by frame, past the camera and triggering a photo at the proper moment. The 5-watt LED was bright enough and the camera was able to focus. During the first prolonged test the LED was lacking a heatsink and generated enough heat to warp the film guide. This caused the film to feed past the camera at an increased distance from what the camera was focused at, leaving each frame blurry and out of focus.

Preventing this issue from happening again will involve using a lower power LED, utilizing an aluminum heatsink and increasing the amount of material around the film guide to reinforce in case of mishandling the device, replacing plastic pins with metal dowels and using a programmable camera. These changes will solve all the major issues I have noticed with the operation of the device. The integrated camera will allow me write my own program to reach the all camera related product objectives. The metal dowels will prevent any frame skipping that could occur in the future as 3d printed parts wear down. Reinforcing the film guide will prevent warping due to mishandling of the device, i.e. drops, falls, exc. Lowering the LED power will decrease the heat, so the camera stays in focus and prevents warping of plastic parts

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The current method for digitizing Super 8 mm film formats isn't suitable for anyone without a major budget or resources.

BACKGROUND

There is something to be said about the feel of an older movie. The time before everything was shot with digital cameras. The way bright light bleeds onto other colors in the frame, casting a warm glow across the image. Shadows seeming darker, hiding details in them, adding intrigue to the borders of a picture. The scratches, artifacts, and grain that give each picture its own birthmark. To shoot on film isn't just to capture a moment that looks like your favorite filter. It's about a chemical process that takes place, the light throwing itself through your lens and onto the film strip, burning its image into the small square frame forever. A sense of permanence that is missing from todays' fire and forget media creation. Shooting on film requires a slower, more deliberate pacing. A method to madness. It's taking the time to plan things out, to put importance on a few things instead of no importance on everything.

Everyone capable, has a cell phone and every cell phone has camera in it. People are so used to recording everything that goes in their lives, all the important moments get lost. When Kodak first revealed Super 8mm film in 1965 (1) it immediately gained popularity as the standard for home movie format. Super 8 film launched as a full line of products, the film, the camera, the developing, the editors, and the projectors for viewing finished film. In order to begin shooting, all you needed to do was place the preloaded plastic cartridge into your camera and pull the trigger. When you were done, take the film to a local lab for developing. Cutting and splicing the processed film to create the desired video length and finally inviting the whole family over to view the finished product on the projector (2). A projector was the primary way of viewing movie film before digital format gained popularity. The main way of consuming content now is through digital format like YouTube or Netflix. Even movie theaters use digital projection now (3).

With some of the past few years biggest Hollywood movies being shot on film (4) (5), there is definitely an analog renaissance taking place. The idea of creating things on a physical format is becoming more popular. People are recording on tapes, shooting polaroid's and even using Super 8 again. The issue is, that with every new technology advancement-viewing older formats becomes hard. If you wanted to shoot something new on Super 8 or even view an older family home movie, your options for this are limited. You could send it out to a few of the specialty labs that will digitize it for you- but the cost is often far too high for anyone looking to create more than 5 minutes of footage. The process takes weeks and although they are professionals who take care in their work, you lose control of the image and how it is digitized (6). There are home machines, but at ~300 dollars you can't even capture a high enough resolution to be acceptable by any of todays' video standards (7). There are in between products that are either too expensive, give you control and good quality or cheap but don't output adjustable, usable footage (8)

RESEARCH

SCOPE OF THE PROBLEM

Although Super 8 is a very old method of creating video content, there are still quite a few groups of people that enjoy doing so still, or would like to get into the craft. Independent film makers, those without major budgets or resources who want to get a feel for shooting on film before moving onto larger formats. Artists who enjoy the specific look Super 8 film gives to a piece are lured by the low entry price but expensive processing fees making it impossible to use any substantial amount of film in a project. If anyone had home movies from the 70s that were shot on Super 8 looking to revive those old memories and share with a larger audience- or even share to the rest of the family over social media, the cost would be too much.

CURRENT STATE OF THE ART

There are currently 4 methods to digitize Super 8 film. (8) (9) (6) (7)

Table 1: State of the art

Method	Average cost	Pros	Cons
Semi-pro film scanner	$1299	• Durable • 1080p quality	• Software buggy • Expensive • No color control • Slow 2 -FPS
Consumer basic film scanner	$300~$500	• Quick- .5FPS • Cheap • Easy to use	• Quality 720p • Frame rate • No color control • Internal software
Send away to labs	$1+ per foot	• Quality 1080p to 4k • Professional color grading	• Room for error under mail/lab technician control • Cost for larger projects • Slow -Weeks to get back
Retrofit 70s projector	$100~$300	• Quality high as needed • Complete control over image • Cheapest	• Non-repeatable/all custom parts • No guarantee of success in repair/conversion

The combination of features that the market misses is giving the user the most amount of control over the final image as possible while allowing usable quality. While some of these features might be locked down to allow for the most simplistic way of operation and transferring film, the customer who is deciding to transfer Super 8 film isn't concerned with stripping the process down to the bare bones or else they would just have shot digitally to begin with. They want to get the most of the film they shot, and that means leaving certain features open ended enough for camera upgrades or fine tuning of the capture process. Every reel of Super 8 film is shot differently and it requires a tailored approach to achieve a look that is faithful to the format.

END USER

The end user is one of two types of people. The first being someone who has a large archive of older Super 8 film footage from home movies or otherwise footage they would like to save and share. This person is most likely older than 30, having had family who shot these movies in the height of the format. The footage has been stored away for a while and the user wants to digitize it so it can exist in a viewable format for many years to come. The nature of almost spontaneously finding these films doesn't speak for our user to have a lot of money to put toward the project. The second user is a younger sub 30 hobbyist, independent filmmaker, or artist who has discovered Super 8 format. They are looking to film in this format for a short film, part of a larger movie, or possible art project.
Seeing as the first user doesn't care much for the "artistic control" over the image and likely won't want to stray from the easiest options preferring a more fire and forget technique, the most likely user is our second case.

CONCLUSIONS AND SUMMARY OF RESEARCH

From the research, it seems like the biggest issue with the current market for Super 8 mm film digital converters, is the price. The second most mentioned issues consumers have is the lack of control over the image being output. Either the auto exposure of the image is wrong and makes it too dark, or the color correction doesn't find the proper channel (7). With the lack of control also comes issues with the software being supplied with the device as they all depend on internal stitching software to convert each frame into the video (8). Each consumer device also has a max of 50ft reel transfers at a time and when dealing with archive 400foot footage that poses a problem. The solution should offer at least 2k video transfer, control over exposure for each sequence, ideally cost less than $400, not required additional software for operation and be able to transfer film reels larger than 50ft.

CUSTOMER FEATURES

An examination of my research required me to poll target consumers to determine the degree of accuracy to the conclusions made about customer features.

The survey was constructed to gauge important features against one another. It was offered to members of various internet forums that focus on either independent or super 8 filmmaking. (10)

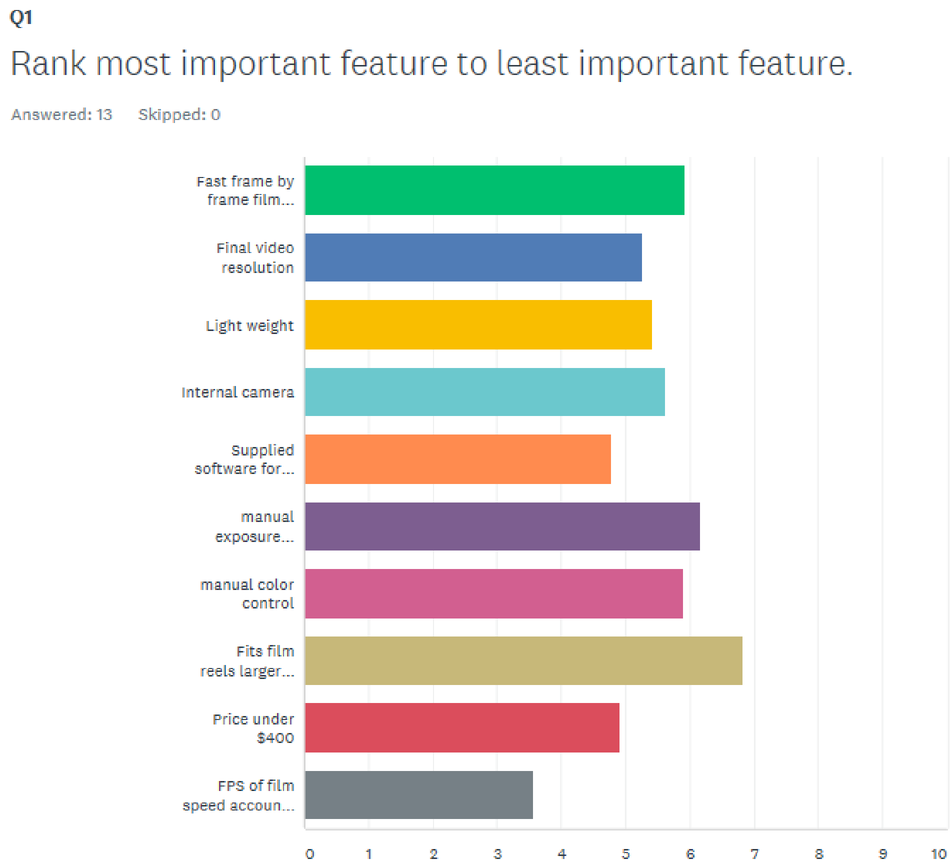


Figure 1: Consumer survey

The survey doesn't offer any definitive decisions for priority of features, however it doesn't counter any of the previous suggestions for feature importance. Taking the experience, I've had with solving this problem personally, research into other solutions, as well as the current market features and customer feedback; the customer requirements and their importance boil down to this list.

1. High image quality
2. Cheap
3. Adjustable image
4. Easy to use
5. Quick process speed
6. Light weight
7. Adaptable to reel size

PRODUCT OBJECTIVES

When looking at the current market solutions to the problem of digitizing super 8 film they seem to match image quality with price. The higher cost gets you a better resolution. This makes sense in a traditional manner but with the rapid expanse of 4k video creation and consumption, the cost for a comparable still image camera with acceptable resolution is plummeting. The manufacturers of these digitizing devices and labs are holding resolution hostage. 4k video resolution is 3840x2160 pixels, that equates to 8294400 pixels total. Still image camera resolution is measured in megapixels, MP. 4k has an 8.3MP resolution possible. On a quick search for digital cameras, I found a 16MP camera for $29.99 from Target (11). A majority of customer features can be met by utilizing a type of still image camera for the digitizing process. This will yield a high resolution, as well as exposing the camera settings for individual control, and will reduce cost of the overall machine. The device will feature less operating steps for ease of use and utilize adjustable reel arms to allow all ranges of reel size. The part that advances the film will be synced with the image capturing to allow for a high frame by frame process speed.

QUALITY FUNCTION DEPLOYMENT

			Engineering Requirements (units)														**Customer Satisfaction Rating** (0.00 - 1.00)			
		Importance wt.	Resolution of Video (pixels)	Acceptable Reel size (ft)	Frame scan per second (FPS)	Camera settings exposed (Y/N)	Steps to setup (#ofsteps)	weight (lbs)	cost ($)											
	Customer Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14	A	B	C	D
1	High image quality	0.30	9			3											0.9	0.7	0.5	1
2	Adaptable to reel size	0.05		9													0.3	0.3	0.3	1
3	Quick process speed	0.10			9		1										0.8	0.6	1	0.1
4	Adjustable Image	0.15	1		1	9											1	0.4	0.2	0.7
5	easy to use	0.10					9	3									0.1	0.5	0.7	0.3
6	Light weight	0.05						9									0.3	0.5	0.9	1
7	Cheap	0.25							9								0.7	0.3	0.8	0.1
8																				
9																				
10																				
	Total Importance	1.00	2.85	0.45	1.05	2.25	1	0.75	2.25											
	Engineering requirement importance																			
Performance	Retrofit 70s projector		2k	50	1	Y	10	12	250											
	Semipro film scanner		1080	50	2	N	7	8.8	1300											
	Basic consumer film scanner		720	50	0.5	N	6	3	400											
	Send away to lab		4k	All	hours	Y	4	0	1 per ft											
	New Product Targets		4k	200	1	Y	4	5	300											

Figure 2: Quality Function Deployment

Interaction Matrix															
	Engineering Requirements	Resolution of Video (pixels)	Acceptable Reel size (ft)	Frame scan per second (FPS)	Camera settings exposed (Y/N	Steps to setup (#ofsteps)	weight (lbs)	cost ($)	0	0	0	0	0	0	0
Engineering Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Resolution of Video (pixels)	1			3	9			3							
Acceptable Reel size (ft)	2					1									
Frame scan per second (FPS)	3				3										
Camera settings exposed (Y/N)	4							3							
Steps to setup (#ofsteps)	5														
weight (lbs)	6							1							
cost ($)	7														
0	8														
0	9														
0	10														
0	11														
0	12														
0	13														
0	14														

Figure 3: Interaction Matrix

From the quality function deployment, the key design features are:

1. High image quality (4k)
2. Cost (<$400)
3. Image control (exposed camera settings)

These features are the concepts that revealed themselves through the research, lacked representation in current market solutions, oriented in customer feature analysis, and demonstrated importance during the Quality function deployment.

DESIGN

CONCEPTS

The concept of this project will revolve around moving film 1 frame at a time and taking a picture each time it stops at a defined spot. The use of a servo motor could be implemented to index each from but would require programming to obtain the proper start and stop motion. In the effort of keeping things a simple as possible, I've opted for a purely mechanical system to drive the motor and film. This will keep things in sync and not require programming a motor. The hurdle in this design will be providing continuous motor function while only engaging the film once per cycle so the camera has time to take a still photo of the film frame.

Concepts developed based on the criteria of:

- Continuous motor will drive the mechanism
- Allowing the part to engage the film 1 per cycle

- Needs to translate rotation to translation

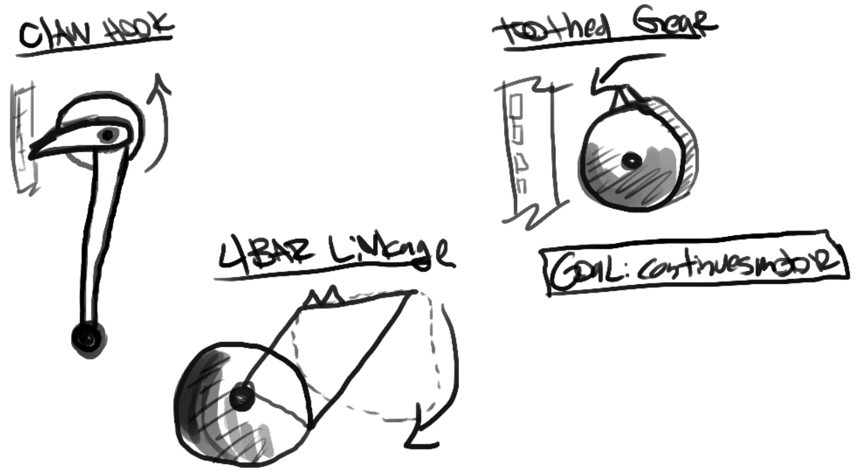


Figure 4: Concept Drawings

Table 2: Decision matrix

Type of engagement	Claw hook	4 Bar linkage	Toothed Gear
Ease of Design	2	1	3
Reliability	3	2	1
Ease of implementation	3	1	3
Total	**8**	4	7

From the decision matrix, the best design concept will be the claw hook. This will give me the most reliable motion which is the most important trait as this will have to engage the film over 3000 times per 50 feet of footage.

Since this was the major piece that involved design decisions, the majority of the design work was measuring and building brackets to hold everything in place. The camera, gears, motor, led and metal hook were outside components bought for their specifications within this project.

Camera: **Needs** a photo resolution of at least 8mp. Size to be less than 100mm to keep the footprint down. Usb connection. **Found** Logictech c920, resolution of 15mp, size 47mm when disassembled. Usb connection.

Gears: **Needs** sizes from 1” to 3” with small format teeth. Durable but lightweight material. **Found** gears used for RC cars, sizes ranging .75”-2”, material made of ABS molded plastic. Pd= 48

Motor: **Needs** anything that can run lower than 1500 rpm. Small footprint. **Found:** 12vDC 40rpm motor by Buhler, 1-7/8” X 1-5/8” footprint.

LED: **Needs** to be small, draw no more power than 12volts. Provide ample light for film. White color temperature. **Found:** 5watt Chanzon LEDS, require 6volts, 6500k color temp, 7.26mm diameter.

Hook: **Needs** metal construction, prongs small enough to fit inside film sprockets. **Found:**

film engager from disassembled super 8 projector. Metal with dual film sprocket prongs.

DRAWINGS

The final design was adjusted for stability, as the 1 connection point for the claw was rotating when the hub turned. A system designed after a railroad train wheel linkage was implemented to keep the claw rigid and offer a more predictable motion.

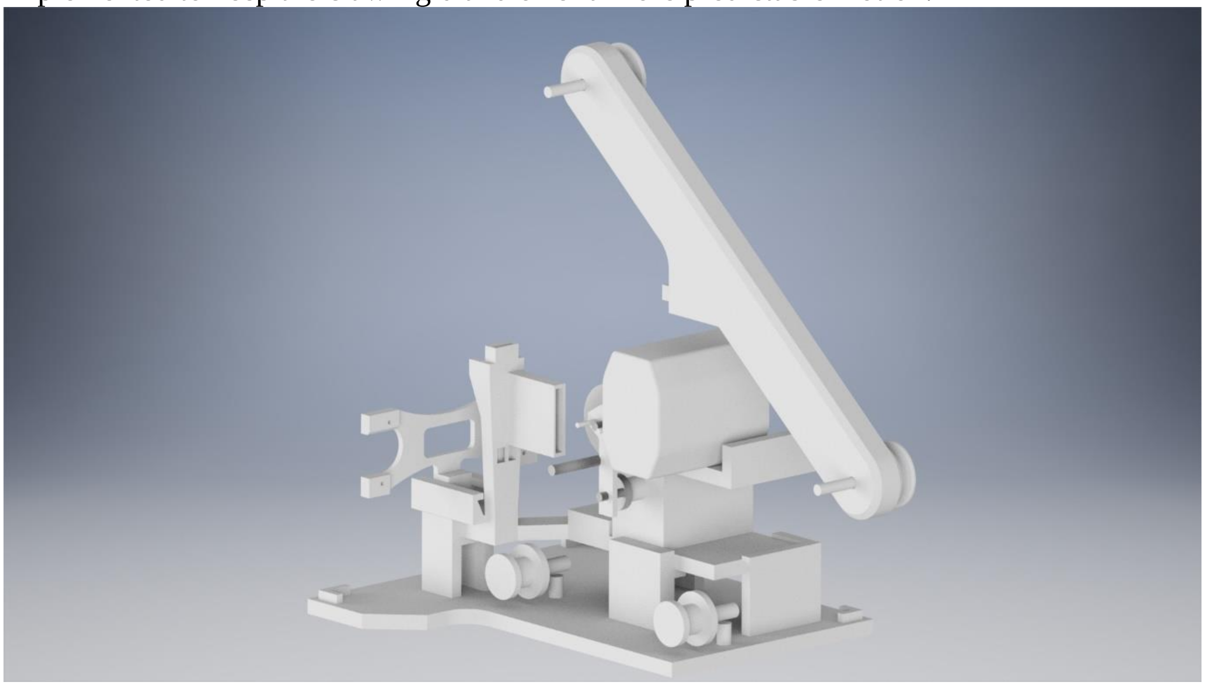


Figure 5: X-ray assembly view

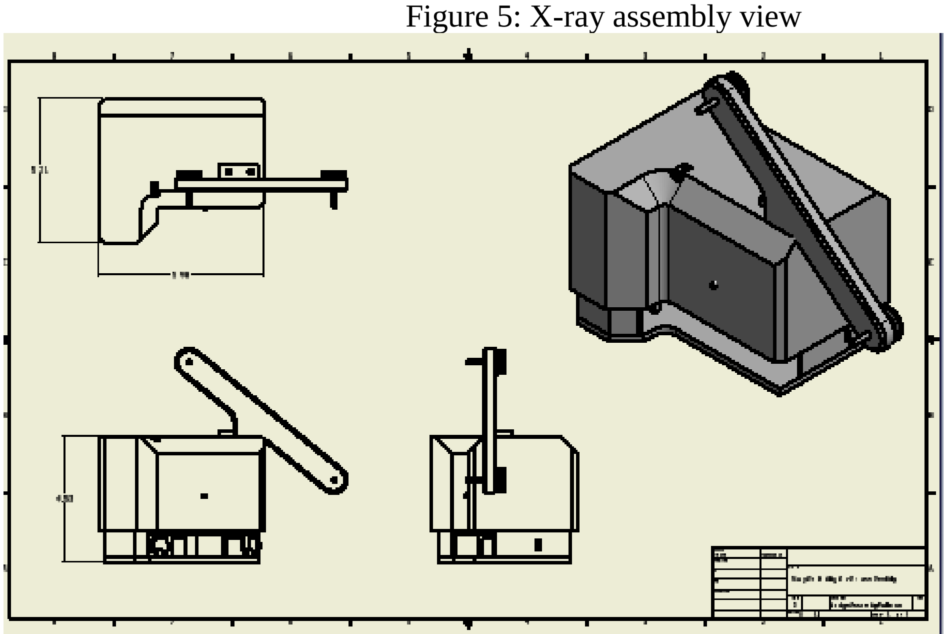


Figure 6: Overall dimension assembly

LOADING CONDITIONS

The final loading conditions had to be readjusted from the original work, previous calculations were assuming initial motor speed and gear sizes. This was used to gain a

minimum and maximum set of values for RPM, Pitch diameter as well as gear ratio.
Summary of calculations:

$$Final\ goal\ of\ hub\ speed = 120rpm, motor\ @250\ rpm$$
$$\frac{250rpm}{120rpm} = 2.08 \sim 2\ gear\ ratio$$
$$smallest\ gear\ found\ with\ 30\ teeth$$
$$ratio = 2;\ Ng = 60$$

<u>Center distance</u>

$$c = 9375in$$

Horsepower of drive motor and loading conditions

$$V = 12volts, A = 25mp, eff\% = 90$$
$$hp = 000362\ hp$$
$$Wt = .1824lbs$$

Stress calculations

$$Si = 49.86psi$$

Adjusted stress

$$Safety\ Factor = 2.0$$
$$Si_{adj} = 199.44psi$$

DESIGN ANALYSIS

Design analysis consisted of running critical components through finite element analysis to check for failures due to stress.

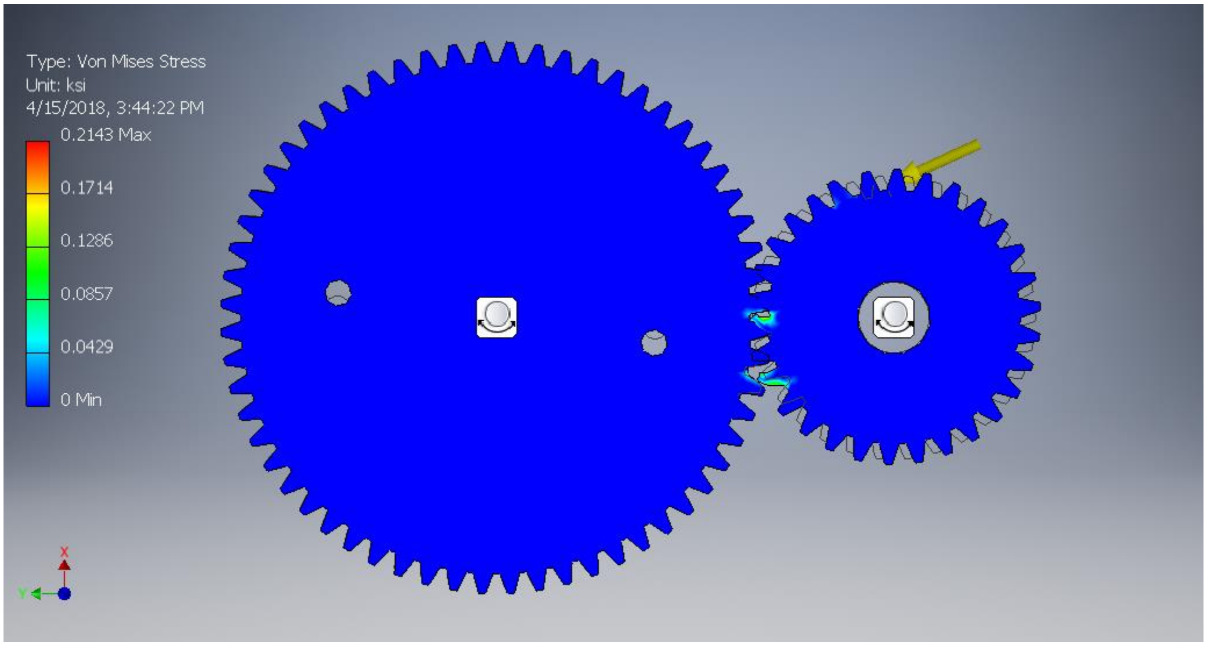


Figure 7: Fea of gears

Assembly of the whole design was put through motion simulation to verify clearance and functionality of the claw hook design. This makes sure the motor is able to move the claw hook around translating it into linear movement to engage the film.

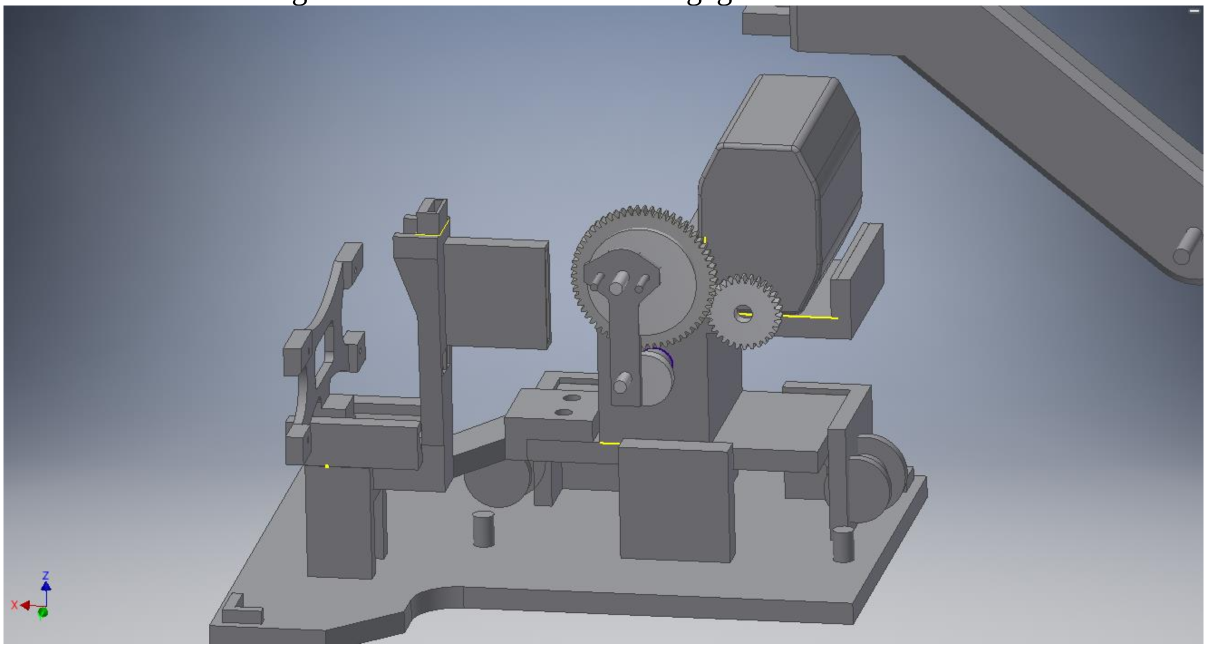


Figure 8: Working model of Design

BILL OF MATERIAL

The design was based off of standard components that fit my design criteria as well as custom printed brackets that would be too expensive to make out of anything but 3d printing so after verifying the design will work, my component selection consisted of purchasing those speculative products and gaining access to a 3d printer. Bill of materials details all 3d printed geometry in the final assembly.

Table 3: Bill of Material

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	motor_gearbracket	Bracket to hold motor and gear shafts
2	1	Camera mount	Mount that screws into camera
3	1	Camera rail	Rail allowing camera to slide for focus adjustment
4	1	clawdrawdown	Linkage that attaches to metal claw
5	1	clawhub	Hub that attaches gear and claw together, provides rotation offset
6	1	clawhub_Lower	Connect to the linkage keeping it rotating vertically
7	1	clawhub_idler	Changes direction of back gears to all hubs rotate same direction
8	1	fimguide	Feeds film in front of the claw grab zone and past the camera
9	1	12v motor	Provides power
10	2	Film bead	guides the film once it exits machine
11	1	Casebottom	Bottom that all components sit on
12	1	caseUpper	Outer case that holds film, power switch and air vents
13	1	Reel arm	Holds spools
14	2	Reelbelt hub	Connects to the back of sprockets to hold in place
15	1	Spur Gear1	Driver gear
16	1	Spur Gear2	Driven gear
Purchased components			
17	1	Logitech c920 webcam	USB webcam
18	1	5 Watt LED	Provides light
19	1	600ma constant current driver	Regulates power to LED
20	1	Usb computer mouse	Allows computer to receive photo capture input
23	1	thermal paste for LED	Attaches LED to heatsink
24	1	LED aluminum heatsink	Absorbs LED heat and prolongs life and reduces damage
25	1	Electrical wire	Connect power to components
26	1	3d PLA spool 1.75mm	Material most parts were made of
27	1	120v to 12v adapter	Regulates power to Motor

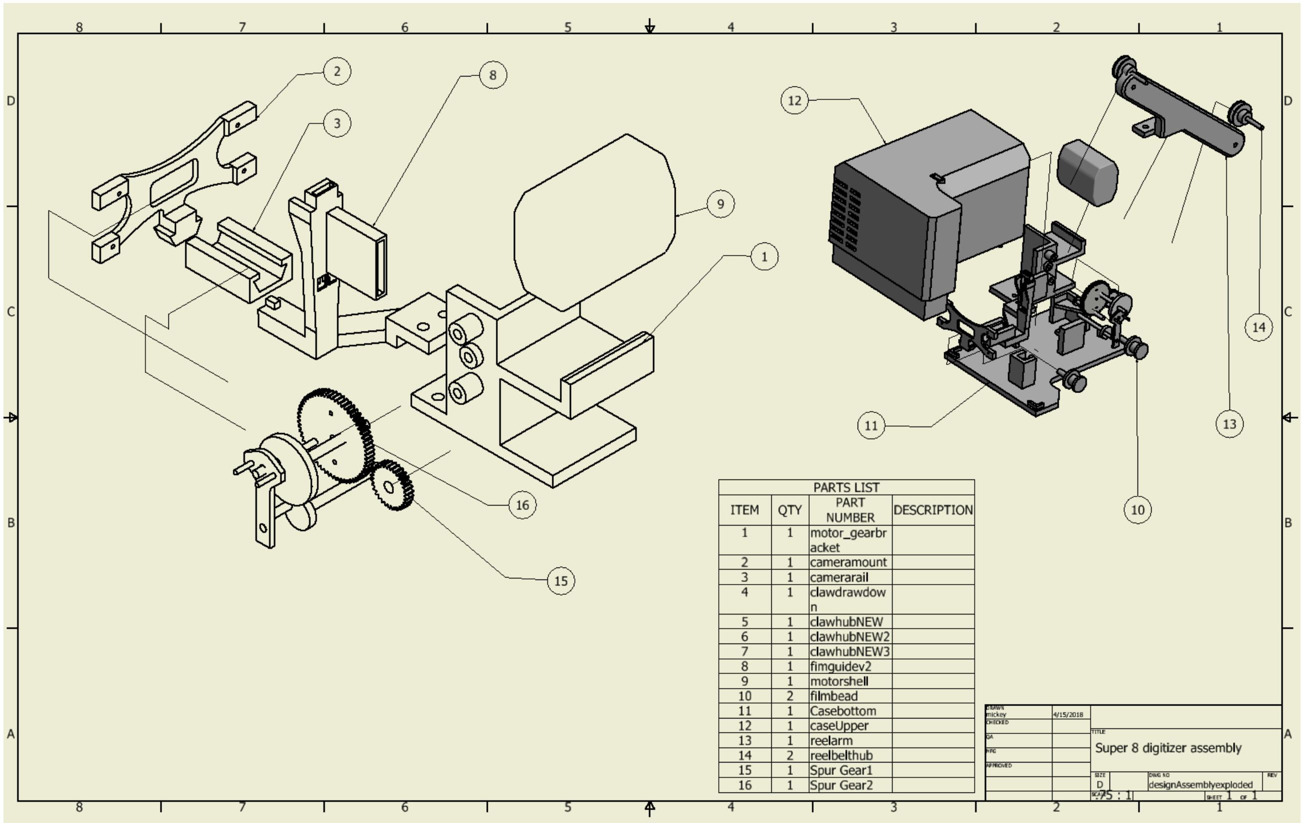


Figure 9: Exploded view

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Table 4: Proposed Budget

Component	Price USD
Existing tech (for concept generation)	50
Camera	100
Film for testing	50
Misc electronics (motor, monitor, controls)	100
Materials (3d filament, metal for body, bearings, ..exc)	75
Total	375

Table 5: Actual Budget

Component	Price USD	Already own
Logitech c920 webcam	50	
5 Watt LED	11	
600ma constant current driver	8	
Usb computer mouse	5	
Gears	8	yes
12v 40rpm motor	16	yes
thermal paste for LED	15	
LED aluminum heatsink	5	
Electrical wire	5	yes
3d PLA spool 1.75mm	25	yes
120v to 12v adapter	25	yes
Total	173	
Adjusted actual price		94

SCHEDULE, PROPOSED /ACTUAL (DESIGN)

Table 6: Proposed Schedule (Design)

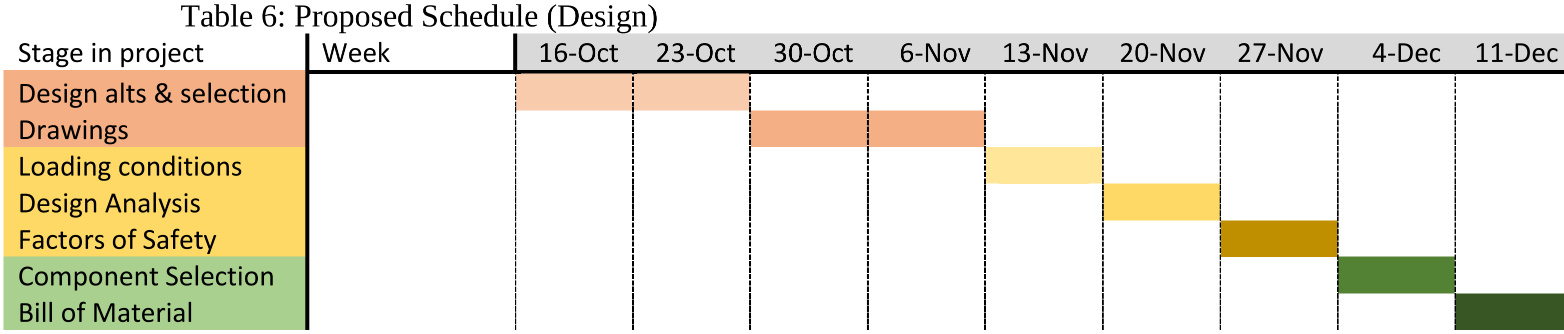


Table 7: Actual Schedule (Design)

Stage in project	Week	16-Oct	23-Oct	30-Oct	6-Nov	13-Nov	20-Nov	27-Nov	4-Dec	11-Dec
Design alts & selection										
Drawings										
Loading conditions										
Design Analysis										
Factors of Safety										
Component Selection										
Bill of Material										

SCHEDULE, PROPOSED /ACTUAL (MANUFACTURING)

Table 8: Proposed Schedule (Manufacturing)

Stage in project	Week	15-Jan	29-Jan	12-Feb	19-Feb	26-Feb	12-Mar	19-Mar	26-Mar	2-Apr	5-Apr
Design II presentation											
Source parts											
Source 3D printer											
Fabricate parts											
Assembly											
Testing											
Refinement											
Tech Expo											

Table 9: Actual Schedule (Manufacturing)

Stage in project	Week	15-Jan	29-Jan	12-Feb	19-Feb	26-Feb	12-Mar	19-Mar	26-Mar	2-Apr	5-Apr
Design II presentation											
Source parts											
Source 3D printer											
Fabricate parts											
Assembly											
Testing											
Refinement											
Tech Expo											

The differences in the proposed/actual schedules for manufacturing are because I couldn't gain access to a 3d printer as quick as I hoped. The device has 3 main systems to it, the camera/led/capture system, the film index/motor system, and the brackets/case that hold it all together. Since the brackets and film index system were to be 3d printed I didn't start on those fabrications until the week of march 19^{th} once I got my 3d printer. The other components I sourced quicker and was able to setup them up for a small proof of concept test. This involved running a very prototyped cardboard version of the claw hook system along with the camera and lights to test the film travel and capture concepts.

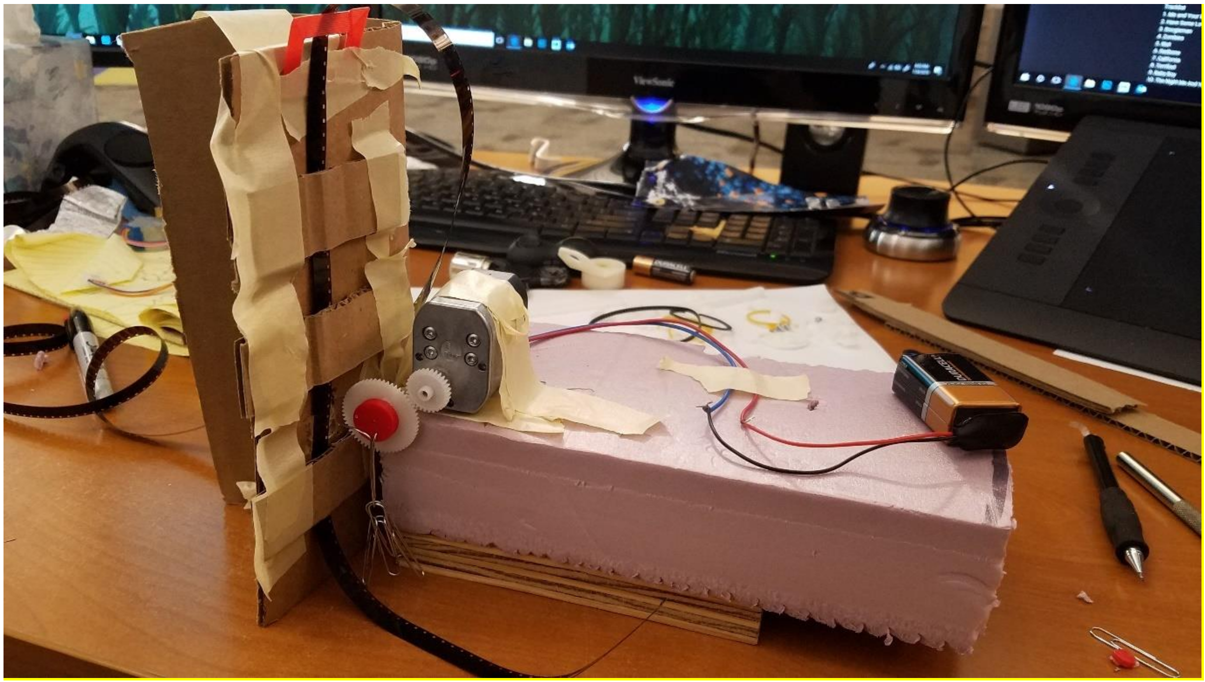


Figure 10: Early concept prototype

FABRICATION AND ASSEMBLY

PROCESSES AND TOOLING

After the verifying my design, purchasing my components and designing my models; the next step was to 3d print the remaining components. Having never built functioning parts from a 3d printer, only statues and small toys, there was a lot I needed to learn about fabrication with 3d printed parts. This stage took the longest in the entire project timeline as each part could run a build time of 2 hours on average. Some parts were 12 hour prints. The turnaround time is much faster and cheaper than traditional methods of rapid prototyping but the prints still produce a lot of lead time in between iterations. As a result of my inexperience, most parts had to be printed multiple times. The *film guide* in particular was close to 8 prints to get it correct.

Getting a successful part to come off the printer requires:

- Correct orientation and printer settings
- Proper geometry and modeling within limitations

As I wasn't aware of these settings and limitations in practice, it took several bad prints before I realized I needed a redesign to prevent errors. Most commonly, the parts I designed initially had too much overhang. This is where the printer cant print a floating portion so it must create support material, this can sometime be hard to remove or impossible to print in the case of intersecting geometry and other overhangs. These pieces had to be broken up into 2 components with several locating holes added so they could be fixed back together with pins.

Figure 11: Printed componants

As far as orientation, 3d printed parts are not the same strength in all directions. Due to the layering type of build, they are much weaker along the build layer path. This requires attention put into the rotation of the part inside the printer zone so that the stress points are placed against the grain and will prevent breakage.

Each part that was 3d printed required sanding and some post processing to get into the working dimensions.

ASSEMBLY AND TOOLING

As most of the functional pieces were not 3d printed and I had to be careful about damaging them, I did not use screws and tapped holes in the assembly. The way I assembled all my components together was a 3d printed rivet system. The PLA to PLA parts were designed with male and female pins in them so they press fitted together. This allowed for me to test a part without damaging and pull it back off in case there were modifications needed. The other parts that interfaced with PLA had pin holes drilled into non critical parts. The PLA parts then had pins printed into them that lined up with the drilled holes, once they were pushed through- a soldering iron was used to melt the ends closed and create a flange that held everything in place.

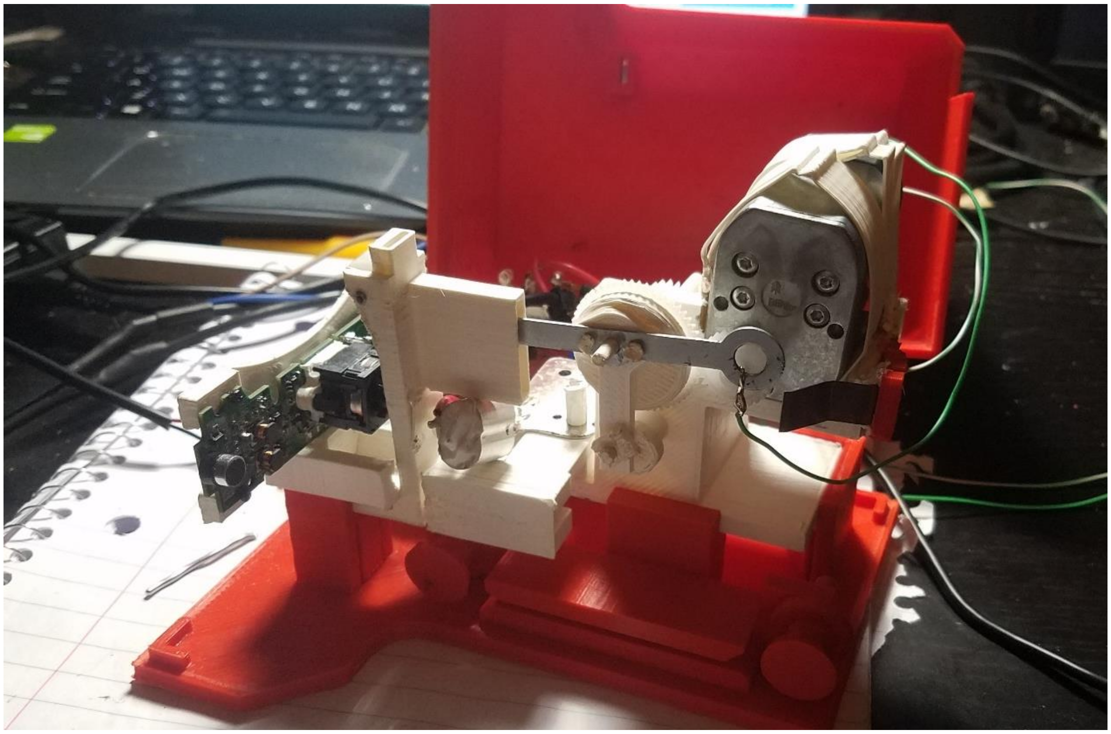


Figure 12: Assembled view

Figure 13: Product view

FULL SCALE PRODUCTION ASSESSMENT

This method of fabrication is suitable for a small batch of parts in a prototype stage but not for production or any number of devices that will be sold and shipped. There is too much sanding and processing time for each PLA part. The device would need to be redesigned so the base and top cover stay PLA 3d printed as well as the 3 non-moving brackets. The rest of the pieces that move should be made of blanked metal. This would cut back on process time

as well as provide more rigidity. The 3d pins that allow rotational freedom between the claw hook hub and the linkage would need to be metal dowel pins so they wouldn't be a danger of wearing them out.
Using metal pieces would increase material cost but also decrease life cycle time for each product. Since the post processing of 3d printed parts requires personal, and the blanking could be done automatically, after the initial tooling cost this would probably not increase the product price much if at all. I would put each unit cost somewhere around $90 to manufacture. Most of that cost in the external components.

TESTING AND PROOF OF DESIGN

TESTING METHODS

The methods for testing involve running the device through what would be a standard use case scenario and comparing it to the results of the professionally digitized footage.
A 50ft reel of Super 8 footage will be feed through the machine and scanned 1 frame at a time. This will be done overnight as it will take several hours and the machine requires an automatic, hands off run cycle.
A successful test will contain these criteria:

- All 3600 frames were indexed
- The frames are in focus
- The frames are exposed properly

I am already aware of a pending issue with the device, as I am using an external webcam to record my frames- it uses webcam software plugged to my laptop to take the pictures. The issue being, out of the 2 programs I have and the many that I tried, I cannot meet both the resolution and speed requirements simultaneously. The Logitech program allows for the 15mp scans but doesn't allow quick enough shutter speed between shots to meet the 2 frames per second target. The Yawcam software does have a quick enough shutter speed to meet the goal, but will only capture 1080p resolution. As a result, speed and resolution will not be used as a measurement of successful testing in this case.

TESTING RESULTS

During the first test ran, there was no heatsink installed on the 5 watt LED. My inexperience with high power LEDs led me to believe they don't generate heat, which was one of the main reasons for their selection in this project. These were false assumptions as the LED generated enough heat during the test to warp the 3d printed film guide. This part is crucial to the function of the device as it feeds the film into a slot, lines it up with claw hook, feeds it past the camera, and flows out of the bottom of the device. The consequence of the warping has caused the camera to go out of focus, so the footage obtained is not of the quality needed for a successful test.
Below are 2 frames for comparison. On the top is the footage received from a professional scanning service, on the bottom is the result of my device scanning the same footage.

Figure 14: Film scan comparison

RECOMMENDATIONS

Recommendations for version 2 of this design:

- Lower LED bulb to 1 watt
- Use metal dowels for the hub-claw hook pins.
- Build more material around the film guide aiding to its rigidity
- Replace camera with a programable camera (raspberry pi).
- Use programmable camera and write a program to hand the capture and image processing

These changes will solve all the major issues I have noticed with the operation of the device. The integrated camera will allow me to write my own program to reach the 2 product objectives of 4k transfer and 2fps transfer speed simultaneously. The metal dowels will prevent any frame skipping that could occur in the future as 3d printed parts wear down. Reinforcing the film guide will prevent warping due to mishandling of the device, i.e. drops, falls, exc. Lowering the LED power will decrease the heat as well as prevent light leaks from inside the device into the camera.

FUTURE IMPROVEMENTS

After all previous improvements are made, the device is designed in a way that will allow scalability into larger film formats. The hub distances and film guide clearances will need to match the target film, but it could be done to accommodate 16mm, super 16mm and even 35mm film; needing only minor adjustments to ensure the film fits inside the machine properly.

.

WORKS CITED

1. **Kodak.** Super 8 mm film History. *Kodak.com.* [Online] Eastman Kodak Company, 2017. [Cited: 9 13, 2017.] http://www.kodak.com/motion/products/production/spotlight_on_super_8/super_8mm_history/index.htm.
2. **Melina, Remy.** What happened to Super 8 film, and Why Was It So Great? *LiveScience.* [Online] 6 8, 2011. [Cited: 9 15, 2017.] https://www.livescience.com/33332-why-super-8-great.html.
3. **Brenneman, Jackie.** Cinema Technologies. *National Association of Theatre Owners.* [Online] 2017. [Cited: 9 15, 2017.] http://www.natoonline.org/initiatives/cinema-technologies/.
4. **Internet Movie Database.** The Force Awakens: Technical Specifications. *Internet Movie Database.* [Online] IMDB, 2015. [Cited: 9 15, 2017.] http://www.imdb.com/title/tt2488496/technical?ref_=tt_dt_spec.
5. —. The Hateful Eight: Technical Specifications. *Internet Movie Database.* [Online] IMDB, 2015. [Cited: 9 15, 2017.] http://www.imdb.com/title/tt3460252/technical?ref_=tt_dt_spec.
6. **LightPress.** Light Press Super 8 mm. *Light Press.* [Online] [Cited: 8 16, 2017.] http://lightpress.tv/super-8mm/.
7. **Wolverine Data.** Wolverine 8mm and Super 8 mm Movie Reels to Digital MovieMaker. *Wolverine Data.* [Online] 2017. [Cited: 9 15, 2017.] http://secure.mm5server.com/merchant.mvc?Screen=PROD&Store_Code=WD&Product_Code=F2DMM100&Attributes=Yes&Quantity=1.
8. **B&H Photo Video.** B&H Photo Video Pro Audio. *Reflecta Super 8 Scanner.* [Online] B&H, 2017. [Cited: 9 15, 2017.] https://www.bhphotovideo.com/c/product/1108887-REG/reflecta_super_8_scanner.html.
9. **Gladstone, Josh.** DIY Film Scanner (with Samples). *Cinematography.* [Online] 7 25, 2013. [Cited: 9 15, 2017.] http://www.cinematography.com/index.php?showtopic=60402.
10. **Stewart, Christopher.** *Super 8mm film digitizing.* [Survey] 9 15, 2017.
11. **Target.** Polaroid 16MP Digital Camera - Black. *Target.* [Online] 2017. [Cited: 10 1, 2017.] https://www.target.com/p/polaroid-16mp-digital-camera-black-is126-blk/-/A-52125676?ref=tgt_adv_XS000000&AFID=google_pla_df&CPNG=PLA_Electronics+Shopping&adgroup=SC_Electronics&LID=700000001170770pgs&network=g&device=c&location=9015712&gclid=Cj0KCQjwpMLOBR.

APPENDIX A: CALCULATIONS

Calculations for the gear ratio, gear construction, loading conditions:

$$Final\ goal\ of\ hub = 120rpm, motor\ @250\ rpm$$

$$\frac{250rpm}{120rpm} = 2.08 \sim 2\ gear\ ratio$$

$$pd = 48$$

$$addendum = a = \frac{1}{pd} = .0208$$

$$dedendum = b = \frac{1.25}{pd} = .0261$$

$$clearance = c = \frac{.25}{pd} = .0052$$

$$smallest\ gear\ found\ with\ 30\ teeth$$

$$ratio = \frac{Ng}{Np}; \frac{Ng}{30} = 2;\ Ng = 60$$

<u>Pitch diameter</u>

$$Dp = \frac{Np}{pd}; \frac{30}{48} = .625in$$

$$Dg = \frac{Ng}{pd}; \frac{60}{48} = 1.25in$$

<u>Circular Pitch</u>

$$p = \frac{\pi}{pd} = .06544in$$

<u>Outside diameter</u>

$$DoP = \frac{Np + 2}{pd} = .667in$$

$$Dog = \frac{Ng + 2}{pd} = 1.29in$$

<u>Root diameter</u>

$$DrP = Dp - 2b = (.625 - 2 * .0208) = .5834in$$

$$Drg = Dg - 2b = (1.29 - 2 * .0261) = 1.2378in$$

<u>Whole depth</u>

$$\underline{hf = a + b = .0208 + .0261 = .0469in}$$

<u>Working depth</u>

$$\underline{hk = 2 * a = 2 * .0208 = .0416in}$$

<u>Tooth thickness</u>

$$t = \frac{\pi}{2 * pd} = .0327in$$

<u>Center distance</u>

$$c = \frac{ng + Np}{2 * pd} = \frac{30 + 60}{2 * 48} = .9375in$$

Base circle diameter

$$DbP = DpCos\theta = .625cos20 = .587in$$
$$DbG = DGCos\theta = 1.25cos20 = 1.1746in$$

The gear construction has been calculated, the loading conditions and stress follow

Horsepower of drive motor

$$V = 12volts, A = 25mp, eff\% = 90$$
$$hp = \frac{V * A * eff}{746} = .000362\ hp$$

$$Wt = \frac{126000 * P}{Nd} = \frac{126000 * .000362}{250} = .1824lbs$$

Radial force

$$Wr = Wt(tan\theta) = .1824tan20 = .06638\ lbs$$

Normal force

$$Wn = \frac{Wt}{cos\theta} = .1824cos20 = .1941 \text{ lbs}$$

Stress calculations

$$Si = \frac{Wt * pd}{F * J}(KoKsKmKbKv)$$
$$F = 1.5in; Ks = 1; Jp + Jg = .21; Ko = 1\ (uniform\ shock);$$
$$km = 1 + cpf + cma = 1 + .12 + .26 = 1.38$$
$$Kb = 1\ (solid\ plastic); Kv = 1.3\ (non\ accurate\ gear); Qv = 5$$
$$Si = \frac{.1824 * 48}{1.5 * .21}(1.3 * 1.38) = 49.86psi$$

Adjusted stress

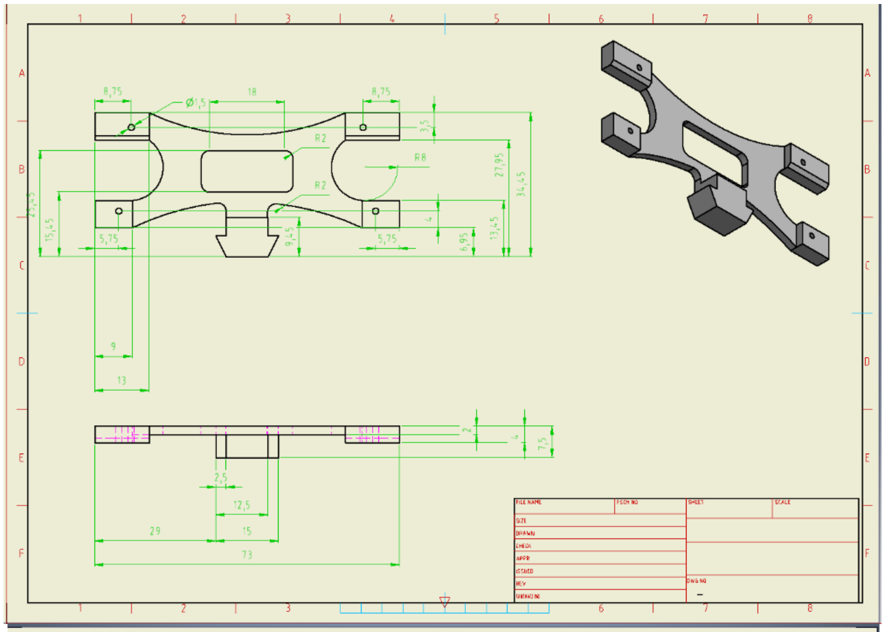
$$Si_{adj} = Si * \left(\frac{Yn}{SF * Kr}\right)$$
$$number\ of\ cycles = Nc = 60 * life * n * q = 60 * 20000 * 250 * 1 = .3x10^{9}cycles$$
$$Yn = .8750$$
$$Kr = 1.25; not\ deadly\ if\ failure$$
$$Safety\ Factor = SF = 2.0$$
$$\left(\frac{1.75 * 2}{.8750}\right)49.86 = 199.44psi$$

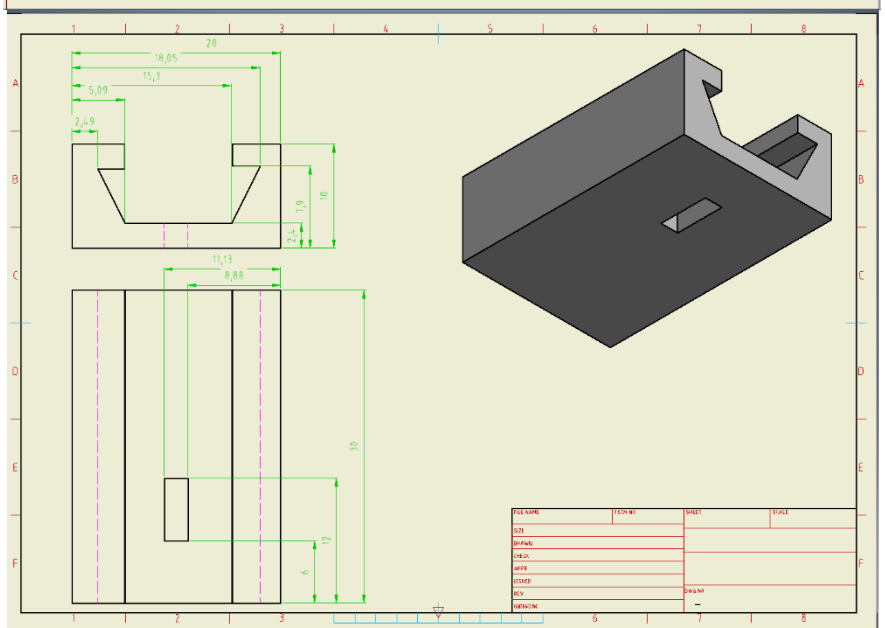
Safety Factor

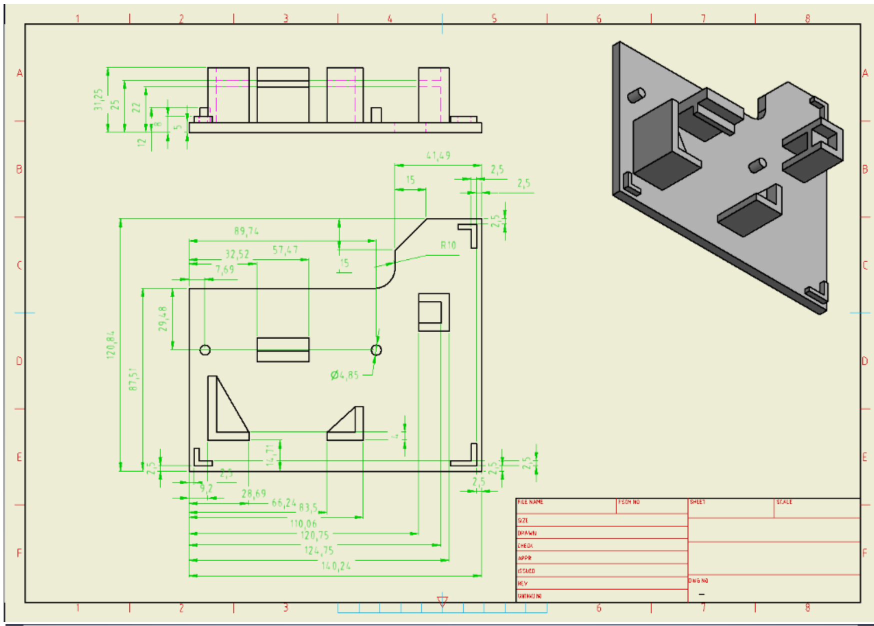
$$Safety\ Factor = SF = 2.0$$

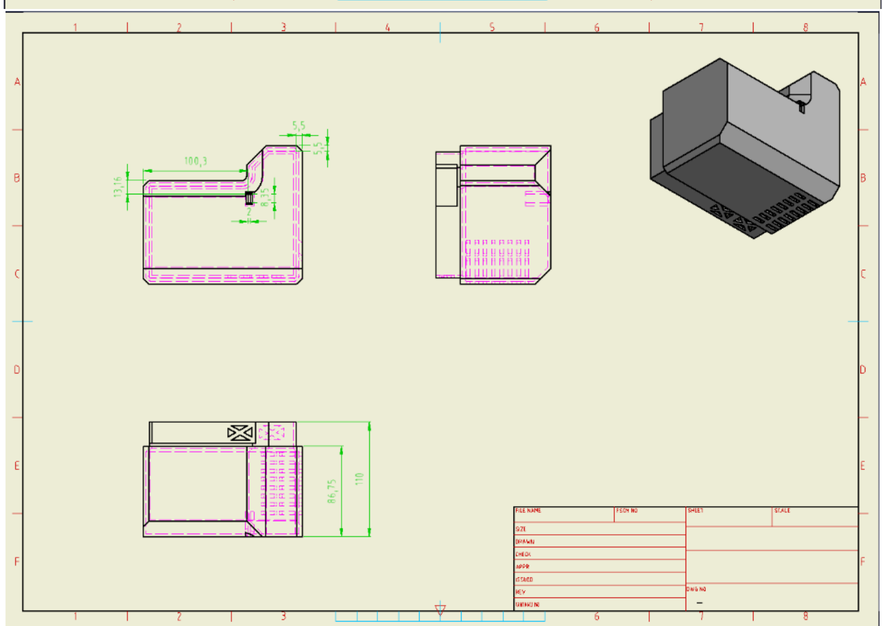
This factor of safety was chosen because of the low risk of injury in the event of a failure, the cost to replace materials isn't very expensive as well as rating it against common safety factors. Bridges start at 4, I didn't believe this required a SF that high. It is higher than 1 however; this is because the film running through the machine is fragile and non-replaceable.

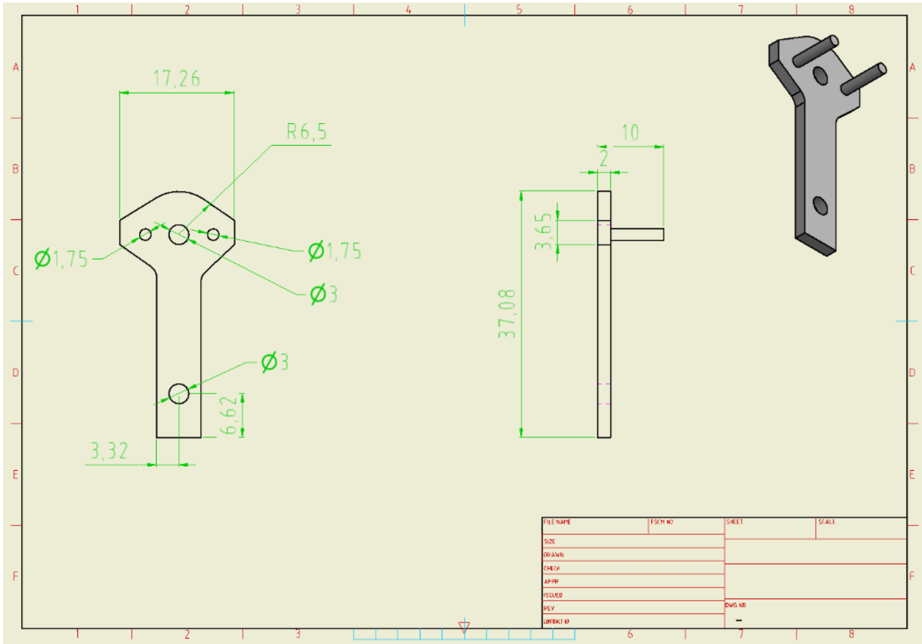
APPENDIX B : PART DRAWINGS

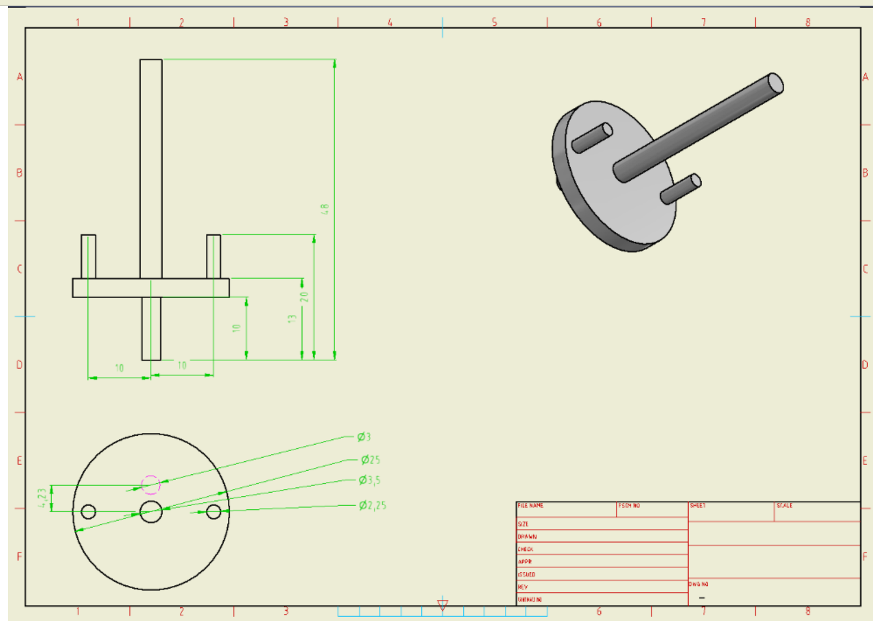


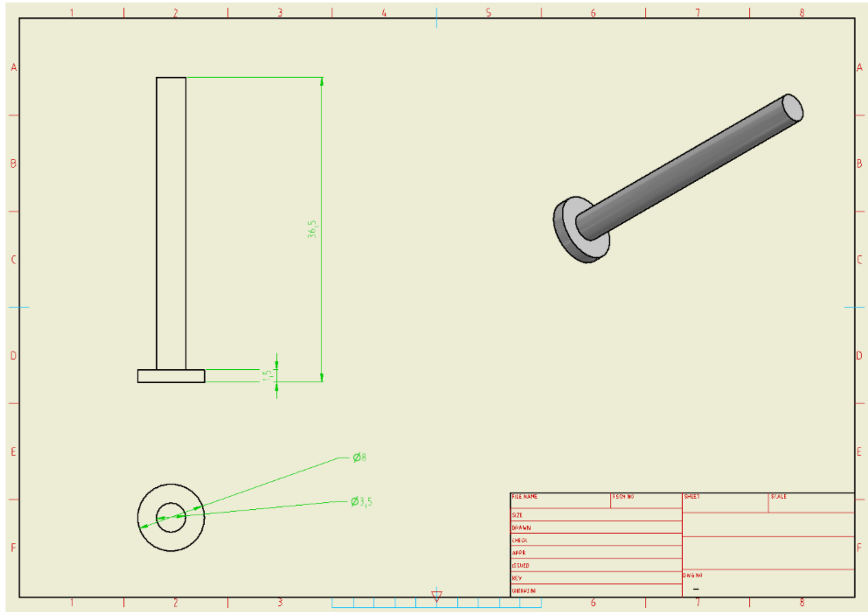


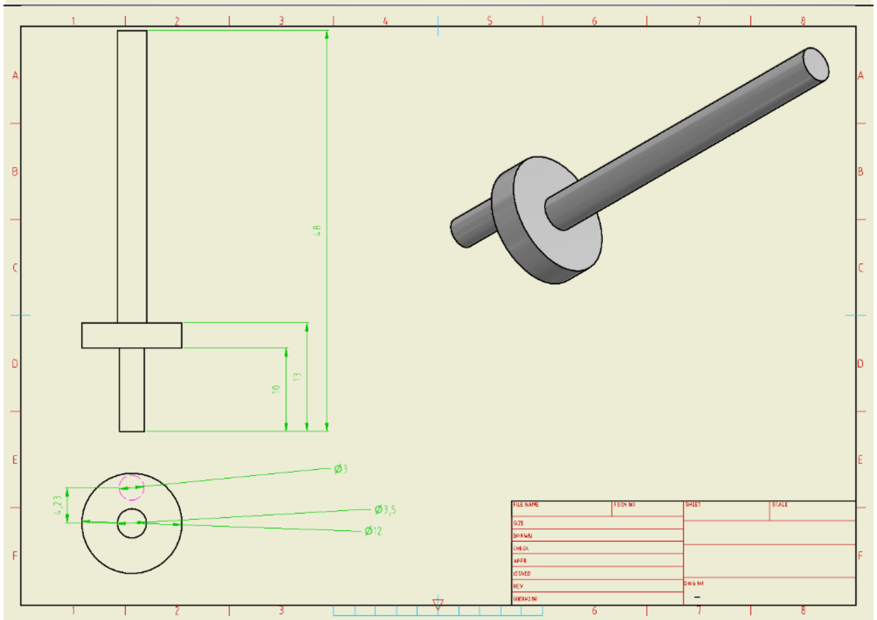


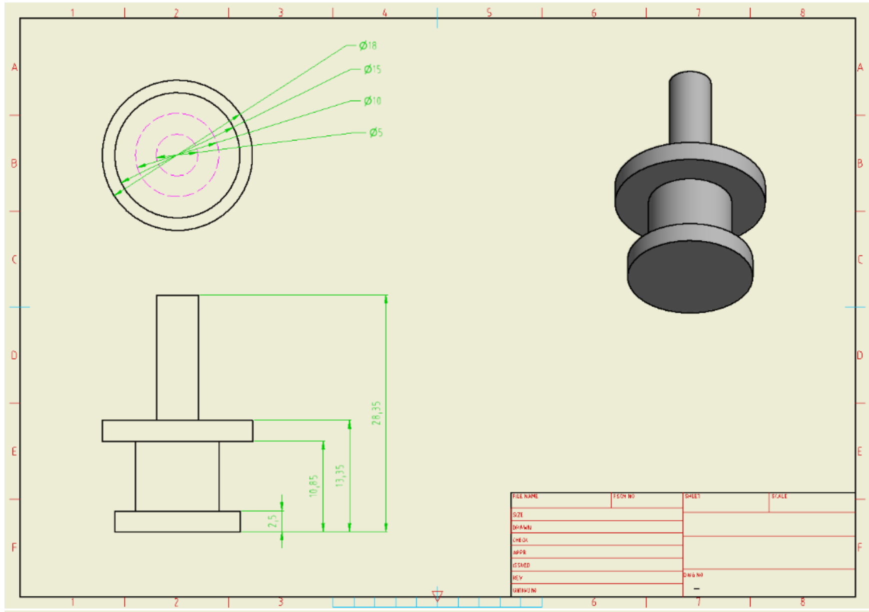


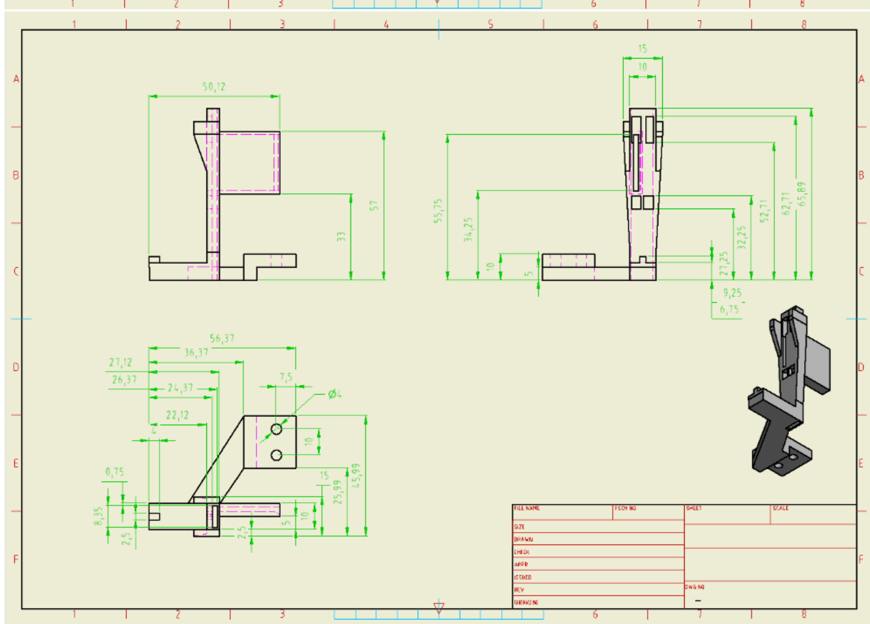

17,26
R6,5
10
2
Ø1,75
Ø1,75
Ø3
3,65
37,08
Ø3
6,62
3,32

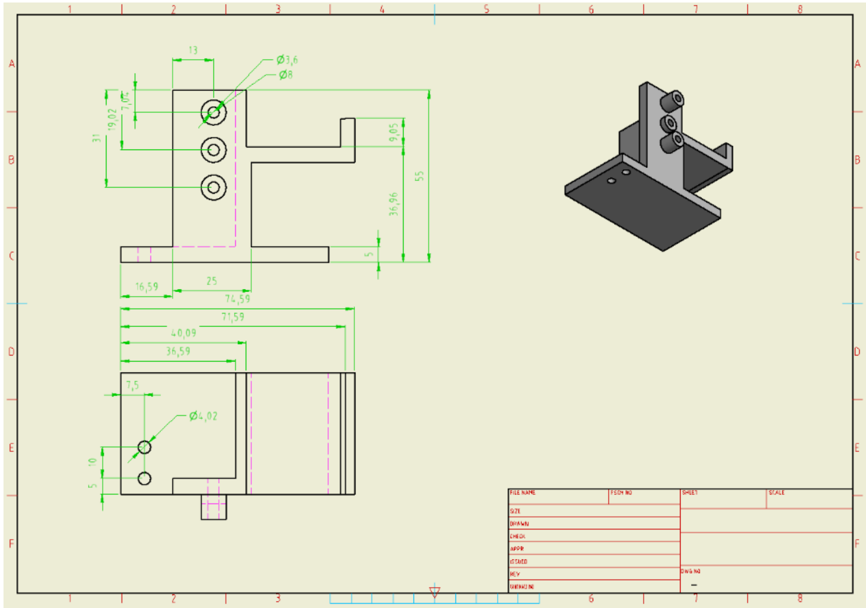

48
20
13
10
10
10
Ø3
Ø25
Ø3,5
Ø2,25
4,23

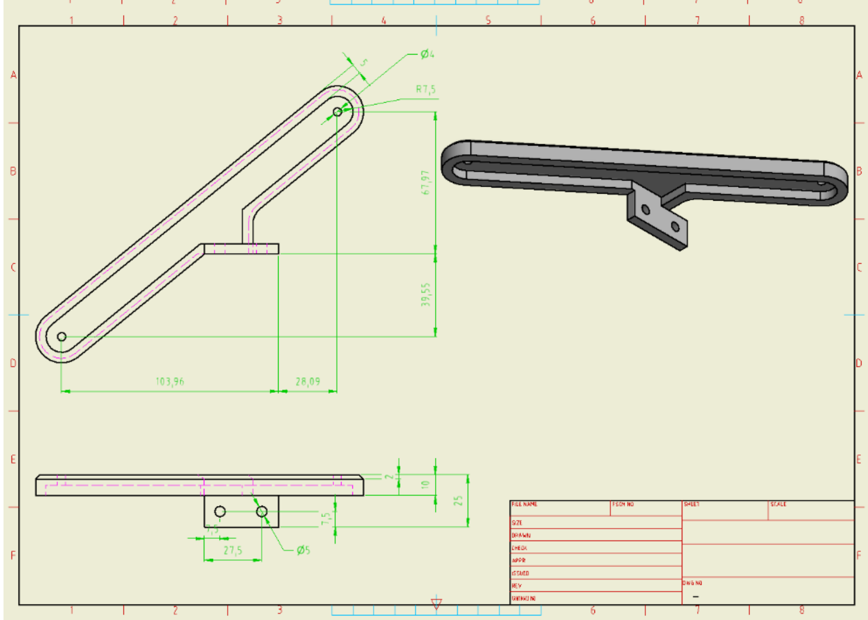

36,5
1,5
Ø8
Ø3,5

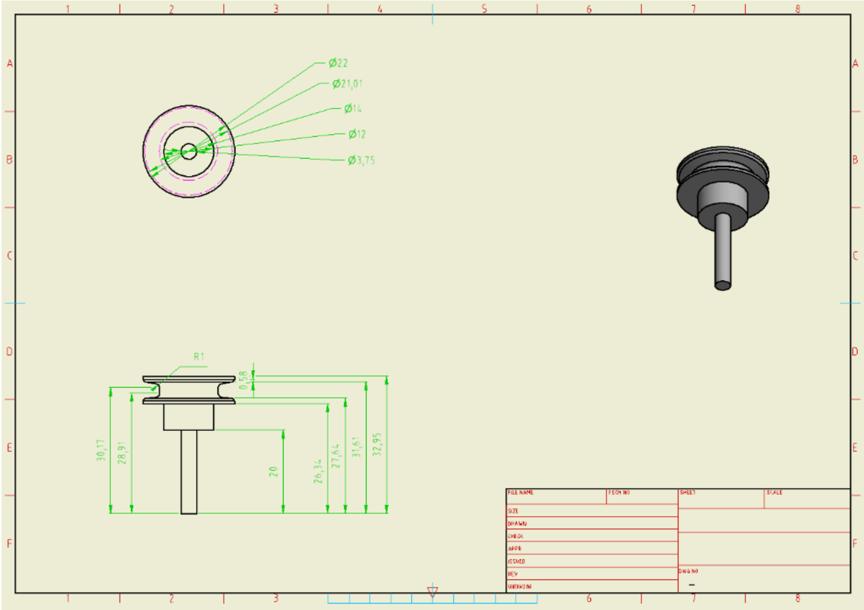

48
13
10
Ø3
Ø3,5
Ø12
4,23


Ø18
Ø15
Ø10
Ø5
28,35
13,35
10,85
2,5


50,12
57
33
15
10
55,75
34,25
10
5
65,89
62,71
52,71
32,25
27,25
9,25
6,75
56,37
36,37
27,12
26,37
24,37
22,12
7,5
Ø4
10
15
25,99
45,99
0,75
8,35
2,5
2,5
5
10


13
Ø3,6
Ø8
19,02
31
9,05
55
36,96
5
16,59
25
74,59
71,59
40,09
36,59
7,5
Ø4,02
10
5


Ø4
R7,5
67,97
39,55
103,96
28,09
2
10
25
7,5
27,5
Ø5



Ø22
Ø21,01
Ø14
Ø12
Ø3,75
R1
0,58
30,17
28,91
20
26,34
27,64
31,61
32,95
FILE NAME
SHEET
SCALE
SIZE
DRAWN
CHECK
APPR
ISSUED
REV
DWG NO