A Motorized Blade Adjustment for a Table Saw

by

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Abstract

A table saw is a manual tool that works on the principle of a continuously spinning circular blade. The table saw performs multiple cuts to various materials, mainly wood, at angles up to 45 degrees. The height and angle of the blade on a table saw is adjusted by means of two separate hand cranks. The problem with the hand crank method of blade adjustment is it requires both time and user torque. A motorized blade adjustment system has been developed which integrates DC gearmotors into the existing adjustment system of a portable table saw therefore decreasing the time and user torque required to adjust the height and angle of the blade.

Needs analysis techniques were utilized to find the customer requirements of less time and less user torque for the blade adjustment. Overall weight of the saw was also a customer requirement due to the relationship between weight and portability. Customer requirements led to the conception of design alternatives of which the gearmotor alternative was selected. Components were designed, manufactured and integrated into the existing system along with electronic components such as a motor controller, power supply, switches, etc. The electronic components allow the user to interface with the gearmotors therefore controlling the speed and direction of the gearmotors. Once fabrication and assembly were complete, testing was performed on the motorized blade adjustment to make sure it would meet or exceed the customer requirements.

The table saw originally required 12 lb-in of torque and 20 seconds to fully adjust the height of the blade. The table saw also required 5 lb-in of torque and 15 seconds to fully adjust the angle of the blade. The motorized blade adjustment requires approximately 0 lb-in of torque and 19 seconds to fully adjust the height of the blade. The motorized blade adjustment requires approximately 0 lb-in of torque and 10.25 seconds to fully adjust the angle of the blade. The weight of the table saw was to be equal to or less than 100 pounds. The weight of the table saw with integrated components is 93 pounds.

Future revisions to the motorized blade adjustment might include lessening the weight of the table saw by using lighter weight components, and simplifying the operation by using a different type of motor controller therefore eliminating one user interface switch.

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1. Introduction

A table saw works on this principle of a continuously spinning circular blade. The table saw is a very versatile tool because it allows its operator to produce a multitude of cuts to many materials, mainly wide sheets of plywood and narrow pieces of lumber, with only a few adjustments to the blade. Among home woodshop owners the table saw is the most popular large power tool (1).

1.1 Problem Definition

Table saws are very useful tools in the world of woodworking but with their usefulness exists a problem. The problem with table saws is the user must physically rotate a pair of hand cranks to position the blade in both height and angle. These actions take a certain amount of time and user torque, especially when multiple angles need to be cut into a piece of material.

The prototype detailed in this report uses a motorized blade adjustment method that will do most of the work of the user, therefore requiring less time and less torque by the user than the hand crank method. Special consideration is given to the weight of the table saw as well since the prototype is a portable table saw and weight can affect portability.

1.2 Background

Table saws have been a lifesaver for many wood workers who need their material cut fast and accurately. Due to the wide array of uses, table saws can come in all shapes and sizes but table saws all serve the same basic purpose; making long, straight rip cuts (with the wood grain) and repeated crosscuts (across the wood grain) much more quickly and accurately than ordinary circular saws (2).

In its makeup a table saw is just what it sounds like: a circular saw blade set inside a broad, flat table. Blades are always removable in order to replace or to switch with a different blade since different materials and types of cuts require different types of blades. Both the cabinet and contractor table saws generally use a belt drive system for driving the blade, which helps to protect the motor in case the blade jams. Benchtop table saws use a direct drive system where the blade is directly connected to the motor. This makes for a less complex and more compact system than the larger, stationary table saws. The blade and motor are mounted to the saw frame by a trunnion which is a fancy term for a table saw's motor mount. A moveable "fence" or rail at one side of the table acts as a guide for boards or sheets of plywood as they are pushed through the blade as to keep them parallel to the blade and at a constant distance from the blade. A miter gauge sits on top of the table as well. The miter gauge runs through a slot in the table, running parallel to the blade, allowing material to be run through the blade at a constant angle (4). The height of the blade from tabletop to blade top can be adjusted by the rotation of a hand crank by the user. In addition, the angle of the blade can be adjusted by means of a hand crank. As with most products on the market, table saws come in low-end, mid-range and high-end models.

Three types of table saws exist in today's market: high-end ($1500+) cabinet and arbor-style models, mid-range contractor models and low-priced benchtop models. The cabinet and arbor-style table saws are permanently placed models because of their large size. Cabinet and arbor-style table saws are made for 10"–12" blades however the larger the blade is, the more expensive it will be. A premium 14 inch saw blade can cost as much as twice the price of the same blade in a 10 inch size. Contractor model table saws are smaller than the cabinet and arbor styles and generally use a 10 inch blade. Contractor saws could be transported from place to place but would require some extra hands to do so since they are still relatively large. Benchtop table saws perform many of the functions of larger stationary table saws but have a decided advantage in their mobility. High mobility makes benchtop table saws the perfect choice for framing and deck building. Benchtop table saws are also a good choice for small shops with limited space due to the use of a 10″ blade and weight between 60 and 100 pounds (2,3). Two common benchtop table saws can be found below in Figures 1 and 2.

Figure 1. 10″ Benchtop Table Saw by DeWalt

Figure 2. 10″ Benchtop Table Saw by Delta

1.3 Scope of Report

The remainder of this report introduces certain problems existing with today's table saws and discusses the details of a solution to these problems. The report will span from the early stages of design conception to the testing of a prototype adjustment system integrated into an existing benchtop table saw.

2. Pre-Design Criteria

A need for an alternate adjustment system had to be found which began a series of tasks known as pre-design criteria. A patent search was performed, which showed what adjusting methods existed for table saws (see patents in Appendix A). Information regarding how table saw users felt about the current blade adjustment methods was found through the distribution of a survey (See survey in Appendix B). Interpreting what was important to the customer in order to create possible design solutions was possible by feeding the results of the survey into a house of quality (See survey results in Table 5 in Appendix B). Once the most important aspects of the saw and adjustment method were known from the house of quality, measurable objectives were created which were claims saying what the finished product would do. Three possible design concepts were then conceived, which tried to fulfill the key characteristics that the potential table saw users wanted. One design concept would be chosen, through the use of a selection method, to be taken to the next stage of design.

In addition to the tasks mentioned above, a budget was constructed which accounts for all of the items required to complete the assembled prototype. The project was funded personally except for a few parts, which were furnished by OCAS. (See budget in Table 6 in Appendix D). A schedule was constructed as well, which would help the project run smoothly and on time throughout the year. (See schedule in Table 7 in Appendix D)

2.1 House of Quality

The house of quality was used to organize information from surveys, interviews and personal experience and interpret what was important to the customer. When surveyed, people were asked to rate the importance of certain characteristics of the current blade adjustment method. The highest rated characteristics were used as the customer requirements in the house of quality.

Engineering characteristics were arrived at as a way to satisfy the customer requirements. The engineering characteristic that stood above the rest in importance was to design an adjustment system that required less user torque to adjust the blade in height and angle. Two other important engineering characteristics were to lessen the time required to adjust the blade in height and angle and also to keep the weight of the saw as low as possible. The house of quality can be found below in Table 1.

Table 1. House of Quality

	Material Property	Yield Strength	Mass Density	Cost of Materials	**Manufacturing**	Part Tolerances	Cost of Manufacture	**Design**	Amount of Parts	Size of Parts	System Requiring Less User Torque	Customer Importance	Satisfaction With Hand Crank	Satisfaction With Locking Lever	Future Satisfaction	Improvement Ratio	Sales Point	Improvement Ratio	Relative Weight
Cost		3	3	9		9	9		9	1	9	3	4	4	4	1.0	1.0	3.0	0.04
Reliability		3	1			9	1		3		3	4	3	3	4	1.3	1.0	5.3	0.08
Durability		9	1						3		3	4	3	4	4	1.1	1.0	4.6	0.07
Ease of Use										3		3	3	3	5	1.7	1.5	7.5	0.11
Minimal Weight			9						9	9	3	4	4	4	3	0.8	1.5	4.5	0.07
Safety											9	3	4	3	5	1.4	1.0	4.3	0.06
Good Ergonomics										1		4	2	3	5	2.0	1.5	12.0	0.17
Time to Position Blade											9	4	2	4	5	1.7	1.5	10.0	0.15
Torque Required by User									3		9	4	2	4	5	1.7	1.5	10.0	0.15
Accuracy of Blade Position						3						4	4	4	5	1.3	1.5	7.5	0.11
Absolute Importance		0.96	0.86	0.39		1.42	0.47		1.85	1.14	4.20	11.30						68.7	1.00
Relative Importance		8.52	7.7	3.48		12.56	4.16		16.4	10.0	37.2								
Technical Difficulty		5	5	5		5	5		4	4	5								
Target Values		43000	0.283	10		0.005	0		4	Fit	Small								
Units		psi	lbm/in^3	$		in.	$		#		lbsf								

2.2 Measurable Objectives

Measurable objectives are claims stating what the finished product will do. The measurable objectives were created from results of both the House of Quality and the survey. The results were the weight of the saw, the torque required to position the blade and the time required to position the blade. For this project, three measurable objectives were developed. The measurable objectives are listed below in Table 2.

Table 2. Measurable Objectives

Measurable Objectives
Time required to fully adjust blade will be less than 20 seconds for height and less than 15 seconds for angle.
Torque required by user to adjust the blade will be less than 12 lb-in for the height and less than 5 lb-in for the angle.
Weight of saw will be 100 pounds or less with integrated components.

Values for the measurable objectives were not known at the time the measurable objectives were created but values were given after testing of the purchased saw was complete. Determining these values will be explained in Chapter 3. The measurable objectives became the proof of design, which states what the completed adjustment system will do and how it will be tested. (See Proof of Design Agreement in Appendix H).

2.3 Design Concepts

Three design concepts were created with the intention of satisfying the customer's requirements. The first design concept involved lever arms with locking mechanisms connected to the trunnion. One lever would adjust the height of the blade and one lever would adjust the angle of the blade. The user would simply push the lever arms while watching the blade's position. Once the desired position was obtained the user would lock the trunnion in its position. The second concept used electric linear actuators to act as the muscles of the operation. One actuator would adjust the height of the blade and one actuator would adjust the angle of the blade. Actuators would be connected to the trunnion and an input from the user through a switch or potentiometer would activate the actuators and therefore move the blade to the desired position. The third concept was based on the use of gearmotors. One gearmotor would adjust the height of the blade and one gearmotor would adjust the angle of the blade. The gearmotors would connect to the existing components of the saw and do the work that the user once did. The user would control the speed and direction of the gearmotors through the use of switches and a potentiometer. The gearmotors would rotate the crankshafts, via gears, and therefore move the blade into the desired position. (Design concepts can be seen in Figures 11, 12, 13 and 14 in Appendix C).

All three concepts had their advantages and disadvantages therefore a selection process had to be performed in order to choose the best design concept.

2.4 Selection of Preferred Design

Only one design alternative could be taken to the stage of design so the Pugh's selection method was performed. The criterion used were the same as the customer requirements used in the house of quality. The three design concepts were compared against the current adjustment method and rated as being either better, the same as, or worse than the current method. The gearmotor concept and the linear actuator concept ranked equally higher against the hand crank method than did the manual lever concept, therefore a decision had to be made as to which concept would be taken to the design stage. The gearmotor concept was chosen since the system could be overridden by the hand cranks in case of motor or electronic failure, whereas the linear actuator concept could not be overridden. The Pugh's selection matrix can be found below in Table 3.

Table 3. Pugh's Selection Matrix

Criterion	Linear Actuators	GearMotors	Manual Positioning Lever	Hand Crank
Cost	-	-	S	
Reliability	S	S	S	**D**
Durability	S	S	S	
Ease of Use	+	+	S	**A**
Weight	-	-	S	
Safety	S	S	S	**T**
Ergonomics	+	+	-	
Time to Position Blade	+	+	+	**U**
Accuracy of Blade Position	S	S	S	
User Torque Required	+	+	S	**M**
Σ+	4	4	1	
Σ-	2	2	1	
Total	2	2	0	

Now the pre-design criterion was complete. The motorized blade adjustment method had been selected and there was an idea of what characteristics the motorized blade adjustment should have. The next stage of the project was the design stage.

3. Design Solution

The motorized blade adjustment had to be designed and incorporated into an existing table saw, which currently uses a hand crank method for adjusting the saw blade. One design criterion was to have the gearmotors work in conjunction with the existing components of the saw, since this was why the gearmotor method was chosen over the linear actuator concept. The blade needed to be adjustable to the same degree of accuracy as with the standard adjustment method, which is currently accurate to the degree in the adjustment of the angle of the blade. The design also had to meet the three measurable objectives: 1. To fully adjust the height of the blade in less than 20 seconds and to fully adjust the angle of the blade in less than 15 seconds, 2. The user should use less than 12 lb-in to adjust the height of the blade and less than 5 lb-in to adjust the angle of the blade, 3. The saw will weigh 100 pounds or less with the integrated components.

The first step was to purchase a table saw. The Craftsman portable table saw model 137.228010 was purchased in January due to its adequate size for incorporating components but not so large as to become too expensive. Inside is a motor connected to a trunnion that could raise, lower and pivot. The saw uses a 10-inch blade and can accept a multitude of different 10-inch blades for cutting various materials and making different types of cuts. The angle of the blade is adjustable in 1-degree increments through the pivot motion of 90 degrees vertical to 45 degrees. The height is adjustable to 3 inches at 90 degrees and 2 inches at 45 degrees. After acquiring the saw, testing was performed to find the torque and speed required to adjust the blade in both its height and angle. This testing would allow for the selection of gearmotors that would perform the required blade adjustments.

3.1 Calculating Required Torque and Speed

Calculating the torque required to adjust the height and angle of the blade was performed in a crude yet effective manner. All that was needed was a ruler and a scale. A digital fish scale, accurate to the ounce, was used to measure the force required to overcome static friction and rotate the hand cranks. The scale was connected to the handle of the cranks and force was applied perpendicular to the cranks until the cranks started to move therefore giving a value of force required to overcome static friction. This task was performed several times for both the height and angle cranks. The force required to move the crank was determined to be 7 pounds for the height and 3 pounds for the angle of the blade. Once the forces were known, the radii of the cranks were measured and they were both found to be 1.625 inches. Through calculations the torque required for the height was 192 oz-in (12 lb-in) and for the angle, 80 oz-in (5 lb-in).

For determining the required speed of the motors the blade was adjusted for height and angle multiple times and the time to adjust was recorded. Sixty seconds was divided by the average time in seconds for full blade adjustment and this value was then multiplied by the number of revolutions needed for full blade adjustment. The calculated value would be the minimum number of rpm needed from the gearmotors to fulfill the time requirement of the measurable objectives. The values were found to be 110 RPM for the angle and 137 RPM for the height. (For more detail, see calculations in Appendix E). Gearmotors could now be selected since the required torque and speed were known.

3.2 Gearmotor Selection

Gearmotors were needed in order to position the blade in height and angle. The major question was whether to use AC or DC power. The benefit of AC motors would be that they do not require an external power supply since they are running off of the same power as the saw motor. The problem with AC motors is they are larger and do not produce as high a value of stall torque as DC motors of equivalent size. The choice then was to purchase DC gearmotors. Gearmotors were purchased yet the specifications of the gearmotors were not listed. The torque and speed of the gearmotors had to be found in order to know whether or not the gearmotors would meet the requirements of the measurable objectives. Testing was performed to find the maximum torque, speed and amperage draw of the gearmotors.

3.3 Gearmotor Testing

The maximum torque and speed produced by the gearmotors was found through equations relating motor speed, input current, back EMF and output torque. When motors are rotated they act as generators and produce a voltage known as Back EMF (Back Electro-Motive Force). Ke, a constant, is equal to milivolts of back EMF per rpm. Kt, another constant, is equal to oz-in of torque per Ampere of input. Kt is equal to 1.35 Ke (7). Now that the equations were known, a device was needed to test the gearmotors and find their specifications. The back EMF and rpm were needed to be able to make the calculations therefore a tachometer and a voltmeter were needed. A tachometer was found in the MET storage room and had the value of 1.9 Volts per 1000 rpm. The shaft of a gearmotor, without the gear head, was connected to the shaft of a tachometer with silicon tubing. The other gearmotor was connected to the opposite end of the existing gearmotor in the same manner. The setup can be seen below in Figure 3.

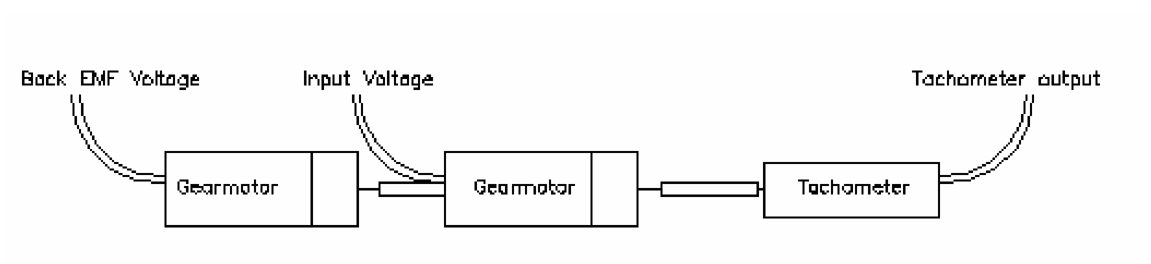


Figure 3. Motor Testing Setup

An input voltage of 15 Volts was given to the gearmotor in the center. The back EMF was recorded from the gearmotor on the left and the output voltage from the tachometer was recorded. Knowing that the tachometer produces 1.9 Volts/1000 rpm the rpm could be calculated. With the recorded back EMF value and the rpm, the constant Ke was now known which was found to be 4.085 mV/rpm. When multiplied by 1.35, Kt was given to be 5.520 oz-in/Ampere.

To find the torque of the motor with the gearhead, the gear ratio was needed. Output voltage of the motor without the gearhead was divided by the output voltage of the motor with the gearhead. This calculation gave a gear ratio of 30:1. With a maximum amperage pull of 2.286 Amperes for the gearmotors, the stall torque of the gearmotors was calculated to be 378.5 oz-in. Speed of the gearmotors was needed as well. The speed at 15 Volts was found using the output voltage from the tachometer. The speed was calculated to be 120.6 rpm, therefore at 24 Volts the speed would be 193 rpm.

The maximum torque needed was 192 oz-in and the maximum speed needed was 136.5 rpm. The gearmotors were found to deliver 378.5 oz-in of torque and 193 rpm therefore making them perfect candidates for the job. (For all calculations, see Appendix E).

3.4 Bracket Design

It was now known that the gearmotors would fit the application therefore brackets were designed to allow the gearmotors to be integrated into the existing system. The existing components of the table saw are shown on the following page in Figures 4 and 5.

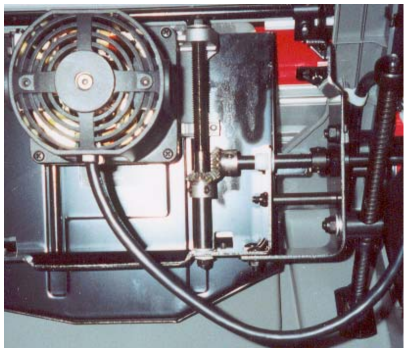


Figure 4. Height Adjustment Components

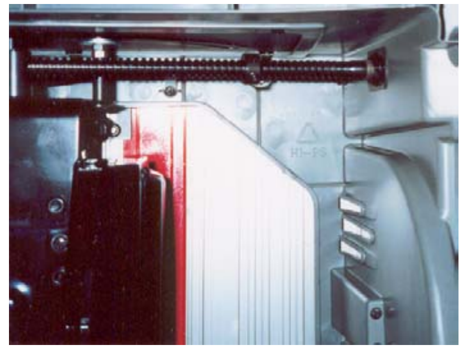


Figure 5. Angle Adjustment Components

The current height adjustment consists of an input shaft from the hand crank connected to a lead screw via gears. The lead screw is connected to the motor/blade assembly, which slides up and down on a set of runners. When the user rotates the hand crank the lead screw is rotated therefore raising or lowering the motor and blade. The brackets containing the existing input shaft were chosen as the mounting spot for a gearmotor bracket.

The current angle adjustment consists of a lead screw, which is connected to a hand crank and the motor trunnion. When the user rotates the hand crank the trunnion swivels on its contact points on the underneath of the table. Since the trunnion houses the motor/blade assembly the blade changes its angle along with the trunnion from 90 degrees vertical to 45 degrees. The plastic frame of the saw was chosen as the mounting place for the bracket housing the gearmotor for adjusting the blade angle.

Design of the brackets was accomplished with the use of Mechanical Desktop 6.0, a micrometer and an engineer's scale. The existing components of the saw were measured and modeled in Mechanical Desktop 6.0 to allow for the design and proper integration of the gearmotor brackets. The brackets were designed with .1 inch thick steel plate, the same material and thickness used for the existing brackets. (For part drawings, see Appendix F).

Now that the brackets for the gearmotors were designed, a system to allow the user to easily control the gearmotors in both speed and direction had to be designed.

3.5 Control/Electrical System Design

The user of the table saw must have a way to interface with the gearmotors in order to adjust the blade's angle and height. The chosen method for interfacing with the gearmotors was through the use of PWM (pulse width modulation). A motor controller circuit converts a DC voltage into a series of pulses therefore making the pulse duration directly proportional to the DC voltage. The advantage of this system is the speed of the gearmotors can be controlled with virtually no power loss in the control circuit (8). The motor controller can be seen below in Figure 6.

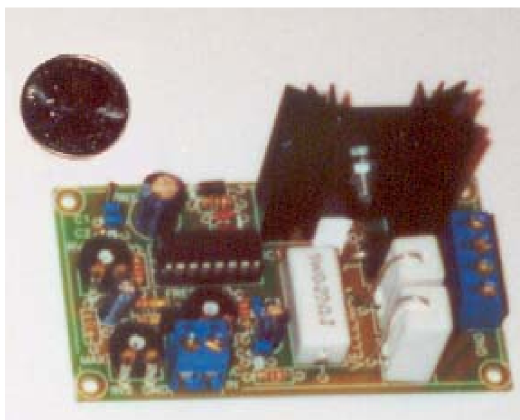


Figure 6. DC to Pulse Width Modulator

The user will interface with the adjustment system by means of two switches and a potentiometer. First, the user will select whether he/she wants to adjust the angle or the height. This selection is made on a double pole/double throw (DP/DT) switch. The next selection is to make the blade height or angle move in a positive or negative direction. Positive direction for the blade height would be raising the blade, negative would be lowering the blade. Positive direction for the blade angle would be increasing the blade angle, negative would be decreasing the blade angle. This selection is made on a DP/DT switch with a center off position, allowing the user to break the circuit between the motor and motor controller. The third step in interfacing with the adjustment system is by means of a potentiometer. The potentiometer is a variable resistor, which connects into the motor controller allowing the user to regulate the rate at which the blade adjusts.

Power for the gearmotors needed to come from a 24 Volt power supply, which would have to be powered from a 110 Volt outlet. For safety reasons and convenience, it was decided that a set of receptacles would be connected to the saw, which could be turned off via a kill switch. The receptacles would power both the saw motor and the 24 Volt power supply. (For a complete wiring diagram, see Appendix F).

3.6 Gearmotor Integration

Design and layout of all the components was now complete and the integration of these components into the saw had to be performed so that testing could take place.

Integrating the gearmotors into the saw started with manufacturing the gearmotor brackets. The material used for the brackets was .1 inch steel plate, the same material and thickness used for the existing brackets. A plate was cut into a 3.0 inch x 6.6 inch rectangle for the height adjustment bracket and a 3.0 inch x 6.2 inch rectangle for the angle adjustment bracket. Holes for mounting the brackets to the existing components and holes for mounting the gearmotors were drilled on a mill, as was a hole in one of the existing brackets for the height adjustment bracket. The plates were then bent on the hydraulic bender to 90 degrees. For the height adjustment, a gearmotor was mounted to the bracket and then the gearmotor/bracket assembly was mounted to the existing bracket of the saw with two bolts. One bolt was placed through the newly drilled hole and the other bolt through an existing hole. The assembled height components are on the following page in Figure 7.

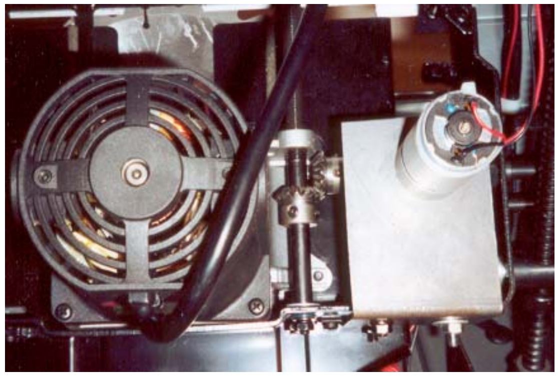


Figure 7. Integrated Height Adjustment

To transmit torque from the gearmotor to the existing input shaft, gears were needed. Four gears, identical to the existing gears in the saw, were purchased. Two gears would be used for the height adjustment and two gears would be used for the angle adjustment. In order to connect gears to the gearmotors an adapter was needed since the bore on the gear was .42 inches and the gearmotor shaft had a diameter of .25 inches. An aluminum bar was drilled on a lathe for an inside diameter of .25 inches. The outside of the bar was turned on a lathe until it reached the diameter of .42 inches. The bars, now tubes, were cut into two .8 inch sections and two holes, .2 inches in diameter, were drilled through the side of each tube to accommodate set screws. Gears could now be placed on the gearmotors. One gear was placed on the input shaft of the table saw and one gear, along with a gear adapter, was placed on the gearmotor. The setscrews were tightened and torque could now be transmitted from the gearmotor to the input shaft. Now that the height adjustment bracket had been mounted, the angle adjustment bracket had to be mounted to the table saw.

Before mounting the angle adjustment bracket, the lead screw for changing the angle was removed from the table saw and turned down on a lathe from .50 inches to .42 inches in order to accommodate the gear. The gear was placed on the lead screw and the lead screw was then mounted back into the table saw. Next, the gearmotor was mounted to the angle adjustment bracket and the gearadapter and gear were mounted to the gearmotor. The gearmotor/bracket assembly was then placed on the frame of the table saw in its approximate mounting position, the holes for the bolts were marked on the frame of the table saw and then the holes were drilled through the plastic frame with a hand drill and a 1/4th inch drill bit. Then bracket was placed back onto the frame and bolted down. The assembled angle components are below in Figure 8. (For complete assembly drawings, see Appendix F).

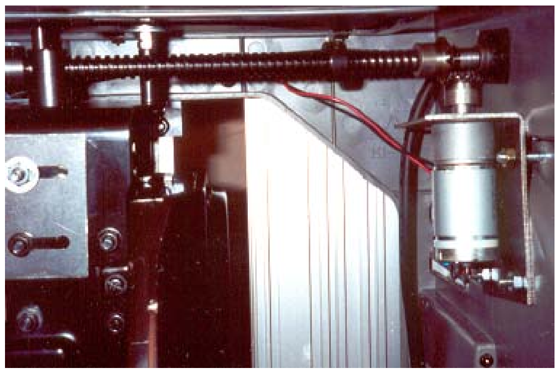


Figure 8. Integrated Angle Adjustment

The gearmotors were now mounted to the table saw but they could not produce any results without a control system. The next step was to integrate the control system into the table saw which would enable the user to easily control the gearmotors in both speed and direction.

3.7 Control/Electrical System Integration

Integration of the electrical components into the table saw would complete the design stage of the motorized adjustment system and would allow for testing of the system to begin. Many items were purchased in order to complete the integration of the electrical components. These items included a 24 Volt, 6.5 Ampere power supply for powering the gearmotors, a Velleman K8004 DC to Pulse Width Modulator for use as a motor controller, two user interface switches and the potentiometer along with a soldering iron, solder, 16 AWG wire and a motor controller box and additional accessories such as an AC receptacle, wire connectors etc.

Four holes were drilled in the table saw stand for mounting the power supply. The power supply was then mounted to the stand using ¼ inch bolts. A hand drill was used for drilling three holes on the face of the table saw to accommodate the user interface switches and the potentiometer. The switches and potentiometer were then mounted in the holes. The receptacle and kill switch were mounted to an inside wall of the table saw's frame with bolts. A plug was connected to a 9 foot wire, which was connected to the switch. The kill switch was wired to the receptacle, which would allow the user to cut power to the table saw and control system. The motor controller was assembled through soldering and was then wired to the user interface switches and the potentiometer. A plug was connected to the power input of the motor controller to allow for disconnection of the power supply if need be. The motor controller was then mounted to an inside wall of the table saw's frame and enclosed in a box to protect it from the environment. The final step was to connect the gearmotors to the angle/height selection switch. The integrated electronics can be seen below in Figures 9 and 10.

Figure 9. Integrated Electronics

Figure 10. Integrated User Controls

The design stage of the project gave an exact target to shoot for with the measurable objectives. Design, fabrication and assembly of the motorized blade adjustment was completed in the design stage as well. Testing of the motorized adjustment system could now take place to make sure all of the measurable objectives assigned earlier were met.

4. Testing

Testing was performed on April 26, 2002. The objective of testing was to see if the table saw would meet the measurable objectives created earlier in the year. The measurable objectives were as follows:

1. The time required to fully adjust the blade will be less than 20 seconds for the height and less than 15 seconds for the angle.
2. The torque required by the user to adjust the blade will be less than 12 lb-in for the height and less than 5 lb-in for the angle.
3. The weight of the saw will be 100 lbs or less with integrated components.

The blade was adjusted in both height and angle to full adjustment and the time required for these actions was found using a stopwatch. The weight of the saw was found by using a bathroom scale. The torques required for the height and angle adjustments were assumed to be zero since a potentiometer was now used for the adjustment instead of hand cranks. The results of the testing are below in Table 4.

Table 4. Testing Results

	Required	Measured
• Adjustment time:		
Angle	< 15 sec.	10.25 sec.
Height	< 20 sec.	19 sec.
• User torque:		
Angle	< 5 lb-in	≈ 0 lb-in
Height	< 12 lb-in	≈ 0 lb-in
• Saw weight:	≤ 100 lbs.	93 lbs.

The measured time to adjust the height and angle of the blade was less than the required time for adjustment. The torque required for adjustment was assumed to be approximately zero as explained earlier. The weight of the saw with the integrated adjustment system was 93 pounds, lighter than the required weight.

The saw passed the critical point of the project criteria by meeting and exceeding the measurable objectives.

5. Conclusion

This project focused on the development of a motorized blade adjustment that would exceed the hand crank adjustment method in the areas of time and user torque required for adjustment of the blade. The requirements of table saw users were found through various needs analysis techniques, which led to the conception of three design alternatives. One design alternative was selected and taken through the stages of design, fabrication and testing.

Time for full adjustment of the height of the blade dropped from 20 seconds to 19 seconds. Time for full adjustment of the angle of the blade dropped from 15 seconds to 10.25 seconds. The torque required to adjust the height and angle of the blade was virtually eliminated since gearmotors replaced the job that the user once had. With the integrated components the table saw weighed 93 pounds, 7 pounds under the weight limit of 100 pounds.

Future development on this prototype might include simplifying the user controls by using a microprocessor with the motor controller. This would eliminate the need for the user to select whether to increase or decrease the height or angle of the blade. Another recommendation would be to lessen the weight of the saw by using lighter weight components such as lighter weight gearmotors and a smaller power supply.

Appendix A

Existing Patents

US6,244,149 claimed a method where the cutting tool height is adjusted by way of a crank and a threaded rod, upon which a rod follower is movably threaded. The follower is connected to a height-adjusting lever for slidably moving the gear case and thus the motor, arbor and cutting tool upwardly and downwardly depending upon the direction in which the crank is rotated. The cutting tool angular position is adjusted by pivotably moving the support plate to change the angle of the blade. The angular position of the support plate is locked in position by a locking bar, which extends through a slot in the front of the cutting tool base across the support plate and through a similar slot in a bracket attached to the rear of the cutting tool base. A cam lever mechanism is positioned outward of the front of the cutting tool base such that when the cam lever is pivoted to its locked position, the locking bar is pulled forwardly compressing and frictionally locking the support plate between the bracket and the front of the cutting tool base.

US5,875,698 claims a method where the elevating mechanism includes a threaded rod and a nut which engages a pivoting link. The pivoting link also engages the cutting tool. Rotation of the threaded rod pivots the link, which in turn raises and lowers the cutting tool. A spring biases the cutting tool towards its lower position to remove play between the components. The angulating mechanism includes a lever, two cams and a locking rod. Rotation of the lever moves the locking rod longitudinally due to the action between the two cams. The longitudinal movement of the rod compresses the support plate and frictionally engages the support plate against a worktable bracket to maintain the position of the support plate with respect to the worktable.

US5,875,698 makes a claim for just the angular adjustment on a table saw. It claims a saw blade position setting apparatus of a working table such as a table saw which is mounted on a support frame and to which a blade assembly is mounted with a handle assembly including a handle and a handle shaft held by the support frame to be rotatable and operatively connected to the blade assembly. The blade assembly is supported by a support member connected to the handle shaft. A clutch mechanism is selectively transmitting rotation of the handle to a blade assembly elevating mechanism and a blade assembly inclining mechanism. The elevational position and the inclination of the blade assembly are adjusted in accordance with the rotation of the handle assembly. A rack is secured to the support frame and the handle assembly is moved along the rack to a predetermined angle position. A lock lever is disposed in operative association with the handle assembly and operatively connected to the clutch mechanism. The lock lever serves to lock the support member to the predetermined angle position and is provided with a cam mechanism through which operation of the clutch mechanism is changed (5).

Appendix B

Survey/Results

Survey for Table Saws

1. Do you ever work on small projects that require the use of cutting material (i.e. wood, metal, plastic etc.)?

   YES NO

2. Would a small portable table saw be useful in these situations?

   YES NO

3. Have you ever used a benchtop table saw? (Compact, portable table saw using a 10" blade)?

   Yes No

4. What did or didn't you like about the benchtop table saw over conventional table saws?

   ____
   ____
   ____
   ____

5. Rate the hand crank method for blade adjustment.
   (Unsatisfied = 1, Satisfied = 5)

Reliability	1	2	3	4	5
Durability	1	2	3	4	5
Ease of Use	1	2	3	4	5
Ergonomics	1	2	3	4	5
Time to position	1	2	3	4	5
Accuracy	1	2	3	4	5

6. Put a check by the blade adjustment method you would rather have (some exist, some do not).

- ☐ Rotating hand crank
- ☐ Lever for manually positioning (Moment arm)
- ☐ Electronic positioning

7. How much would the chosen method from above be a factor in your buying decision for a table saw?

A little						A lot
1	2	3	4	5	6	7

8. Rate the importance of each aspect of a newly designed table saw. (Unimportant = 1, Important = 5)

1. Cost over existing models	1	2	3	4	5
2. Reliability	1	2	3	4	5
3. Durability	1	2	3	4	5
4. Ease of Use	1	2	3	4	5
5. Minimal Weight	1	2	3	4	5
6. Safety	1	2	3	4	5
7. Good Ergonomics	1	2	3	4	5
8. Time to Position Blade	1	2	3	4	5
9. Accuracy of Blade Position	1	2	3	4	5
10. Cosmetics	1	2	3	4	5
11. Torque required to adjust blade	1	2	3	4	5

Table 5. Survey Results

Question 5 (Satisfaction with Hand Crank)	Customer Response					Avg. Satisfaction
1=Unsatisfied 7=satisfied	**1**	**2**	**3**	**4**	**5**	
Reliability	1	4	11	9	5	3.43
Durability	2	4	12	8	4	3.27
Ease of Use	3	15	6	4	2	2.57
Ergonomics	6	10	12	2		2.33
Time to position	4	12	10	4		2.47
Accuracy			10	18	2	3.73

Question 6 (Preferable Blade Adjustment Method)	
Rotating hand crank	4
Lever for manually positioning (Moment arm)	2
Electronic positioning	22

Question 8 (Characteristic Importance)	Customer Response					Avg. Importance
Unimportant=1 Important=5	**1**	**2**	**3**	**4**	**5**	
Cost over existing models	1	7	6	12	4	3.37
Reliability			3	19	8	4.17
Durability			3	20	7	4.13
Ease of use	5	6	8	8	3	2.93
Minimal weight		1	8	10	11	4.03
Safety	2	5	6	16	1	3.30
Good ergonomics		2	9	12	7	3.80
Time to position blade			1	18	11	4.33
Accuracy of blade position				25	5	4.17
Cosmetics	5	17	5	3		2.20
Torque required to adjust blade			6	12	12	4.20

Appendix C

Design Concepts

The first design concept involved lever arms with locking mechanisms connected to the trunnion. One lever would adjust the height of the blade and one lever would adjust the angle of the blade. The user would simply push the lever arms while watching the blade's position. Once the desired position was obtained the user would lock the trunnion in its position.

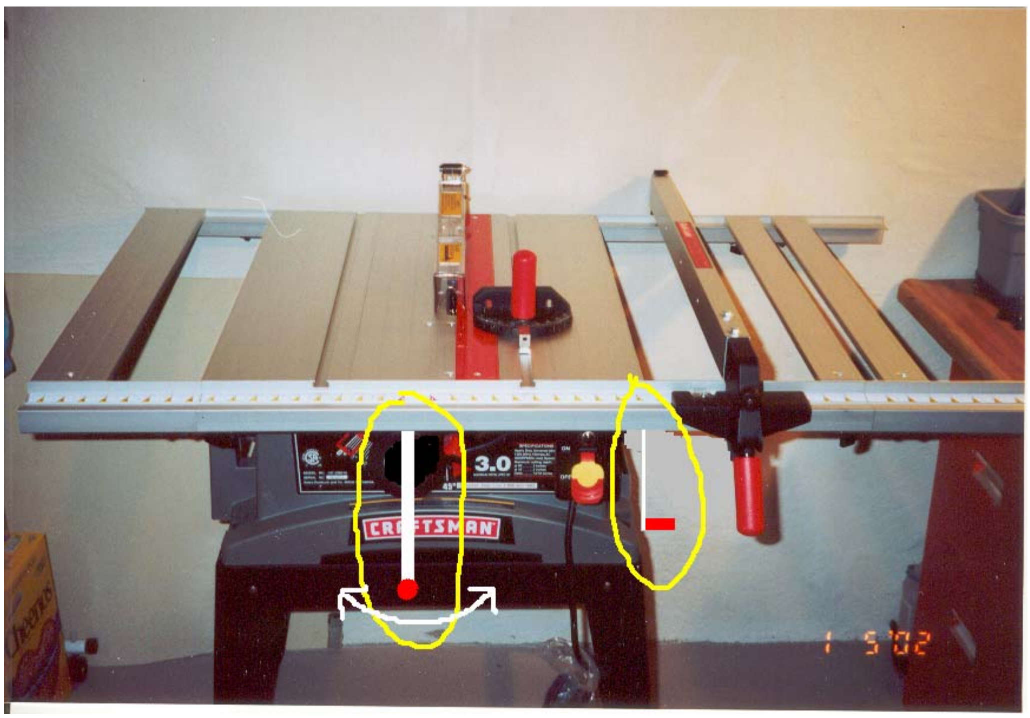


Figure 11. Manual Lever Concept

The second concept used electric linear actuators to act as the muscles of the operation. One actuator would adjust the height of the blade and one actuator would adjust the angle of the blade. Actuators would be connected to the trunnion and an input from the user through a switch or potentiometer would activate the actuators and therefore move the blade to the desired position.

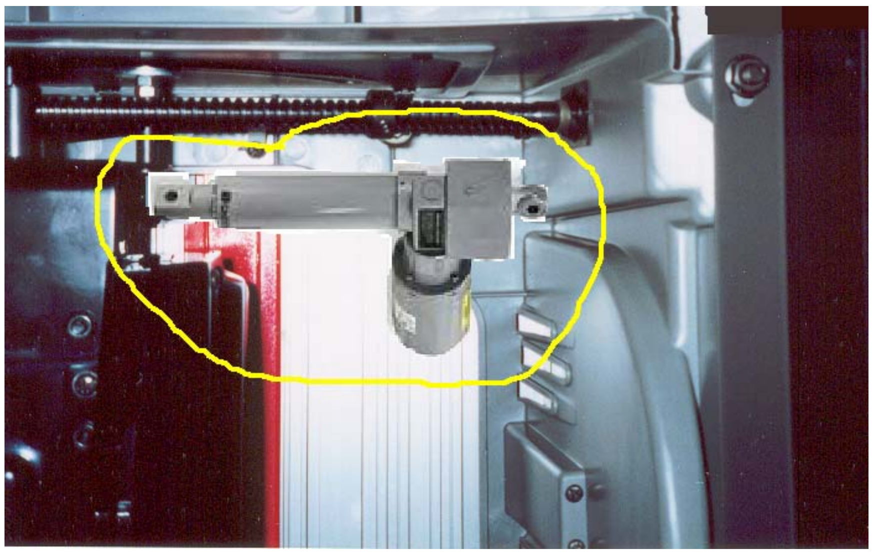


Figure 12. Linear Actuator Angle Adjustment Concept

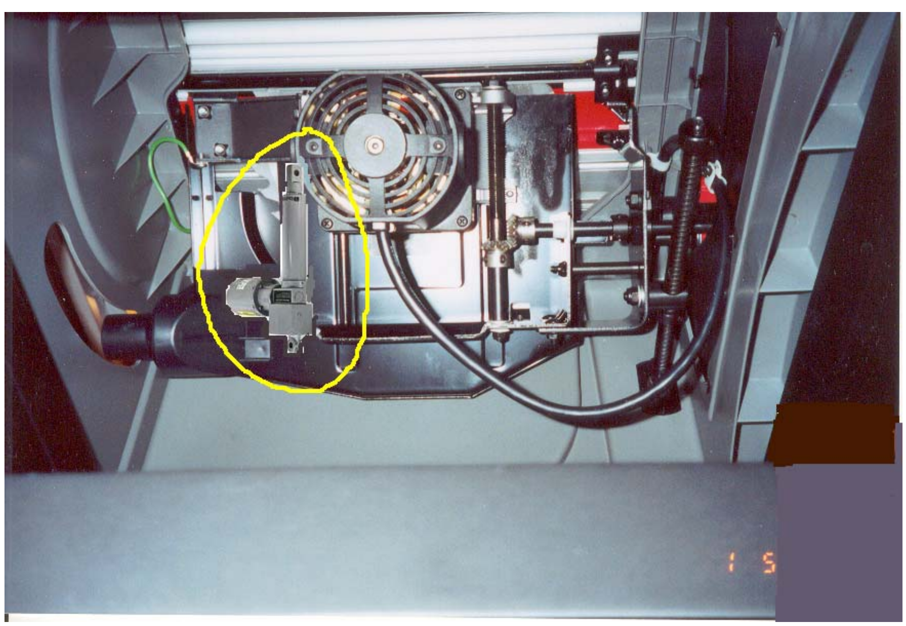


Figure 13. Linear Actuator Height Adjustment Concept

The third concept was based on the use of gearmotors. One gearmotor would adjust the height of the blade and one gearmotor would adjust the angle of the blade. The gearmotors would connect to the existing components of the saw and do the work that the user once did. The user would control the speed and direction of the gearmotors through the use of switches and a potentiometer. The gearmotors would rotate the crankshafts, via gears, therefore moving the blade into the desired position.

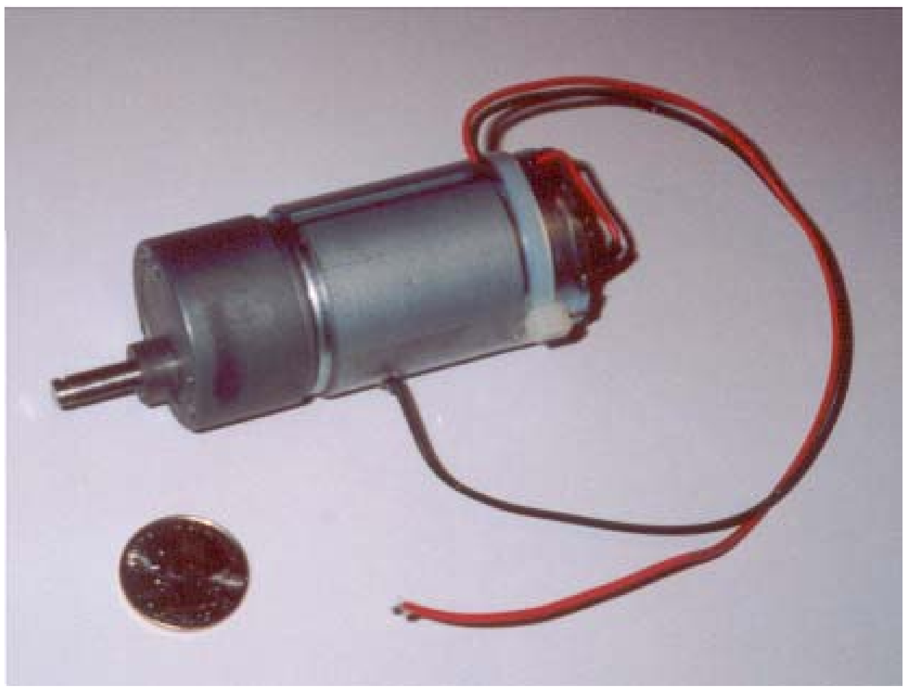


Figure 14. Gearmotor Concept

Appendix D

Management

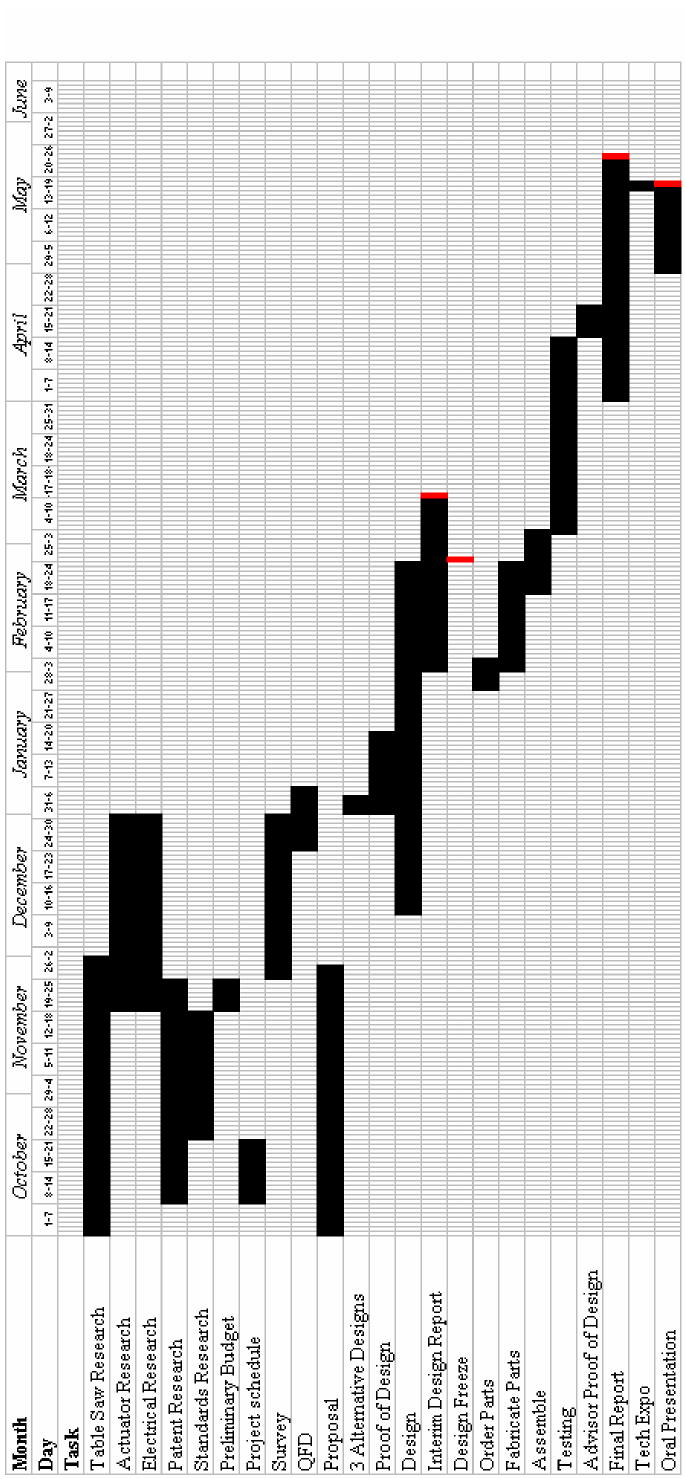
A budget was made, which accounts for all of the items required to complete the assembled prototype. Some of the items were furnished by OCAS yet most items were purchased. The project was funded personally.

Table 6. Budget

Item	Method to obtain	Quantity	Total Price ($)
Benchtop table saw	Purchase	1	296.79
Gearmotors	Purchase	2	21.2
Motor Controller	Purchase	1	22.95
Power Supply	Purchase	2	37.28
Electrical Accessories	Purchase	1	65.39
Gearmotor mounting brackets	School resources	2	N/A
Gear Adapters	School resources	2	N/A
Gears	Purchase	4	13.39
Bolts/Fasteners	Purchase	?	10
Total			467.00

A schedule was constructed as well, which would help the project run smoothly and on time throughout the year.

Table 7. Schedule



Appendix E

Calculations

Finding Required Torque

Height Adjustment

Force = 6 lb 15 oz ≈ 7 lb

Radius = 1 .625″

7 lb * 1.625″ = 11.38 lb-in ≈ 12.0 lb-in = 192 oz-in

Angle Adjustment

Force = 2 lb 14 oz ≈ 3 lb

Radius = 1 .625″

3 lb * 1.625″ = 4.875 lb-in ≈ 5.0 lb-in = 80 oz-in

Finding Required Speed

Average angle adjustment = 15 seconds.

Revolutions for maximum angle adjustment = 27.5

(60 seconds/15 seconds) * 27.5 = 110 rpm

Average height adjustment = 20 seconds.

Revolutions for maximum angle adjustment = 45.5

(60 seconds/20 seconds) * 45.5 = 136.5 rpm

Motor Equations

Kt = 1.35 Ke

Kt = oz-in/Ampere

Ke = mV/rpm

V=IR

Tachometer = 1.9 Volts/1000 rpm

Finding Torque of Motors Per Ampere of Input

1.77968 Volts was measured so:

(1.780/1.9) * 1000 = 937 rpm

Ke = 3828 mV/937 rpm = 4.085 mV/rpm

Kt = 4.087 * 1.350 = <u>5.520 oz-in/Ampere</u>

Maximum Output of Motors

V=IR

Resistance of motors was measured at 10.5 Ω, therefore:

24 Volts = I * 10.5Ω

I = 2.286 amperes

5.520 oz-in/Ampere * 2.286 Amperes = 12.617oz-in

Gear head is 30:1

12.617 * 30 = <u>378.5 oz-in</u>

At 15 Volts input to the motor, the tachometer's output voltage from the gearhead was used to find out speed.

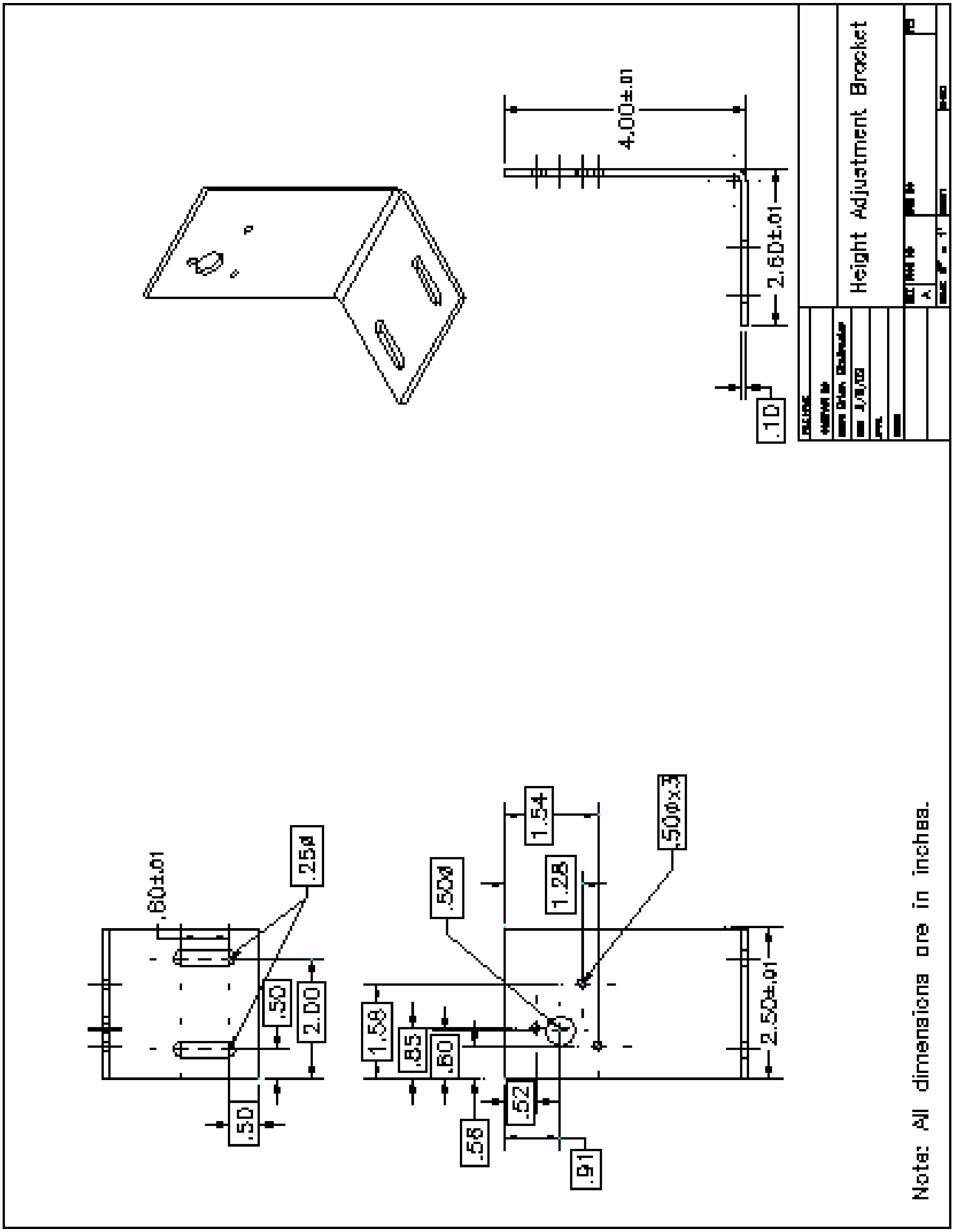
Average tachometer output = .2293 Volts

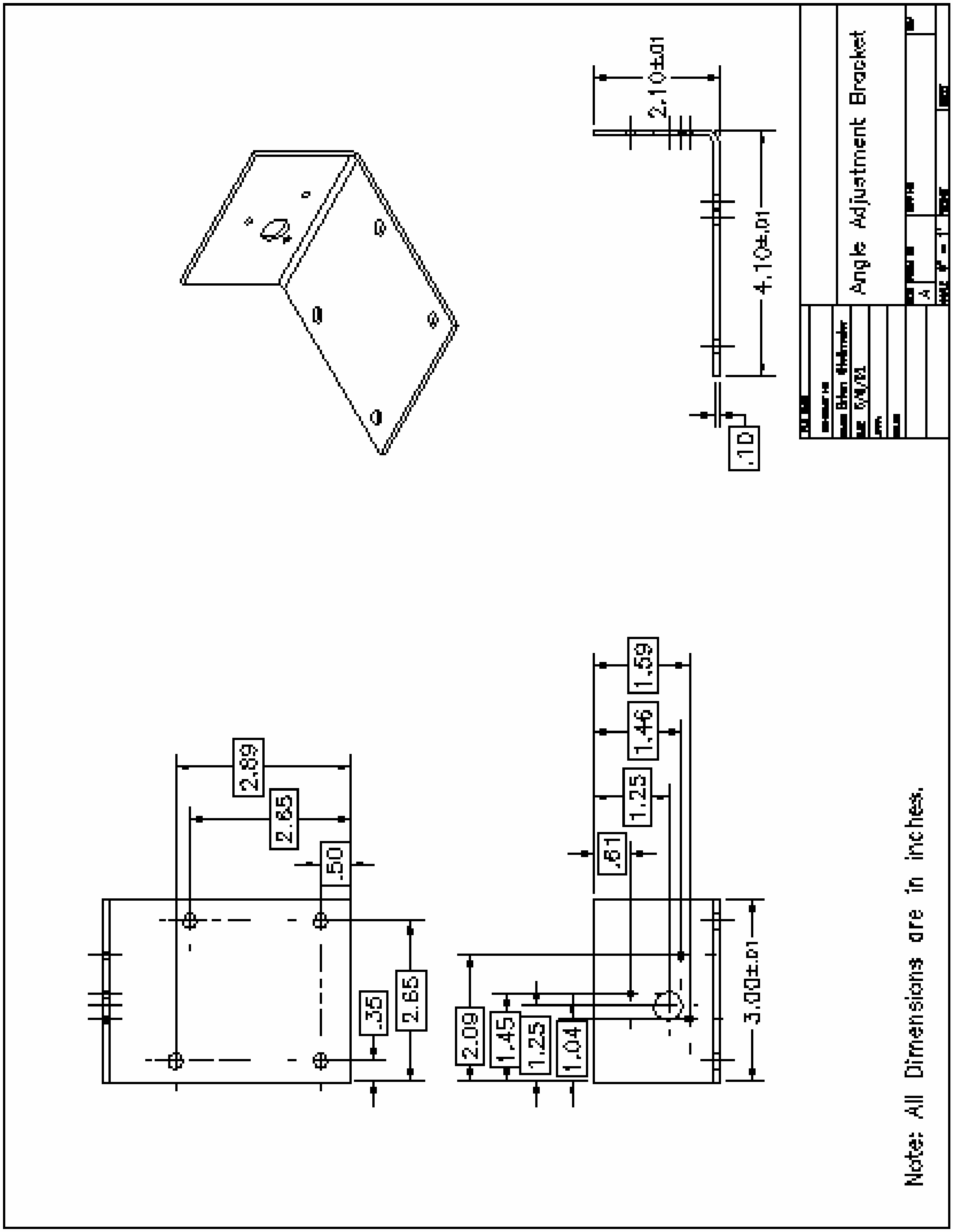
.2293 Volts / (1.9 Volts/1000 rpm) = 120.6 rpm

(24 Volts/15 Volts) * 120.6 rpm = <u>193 rpm</u>

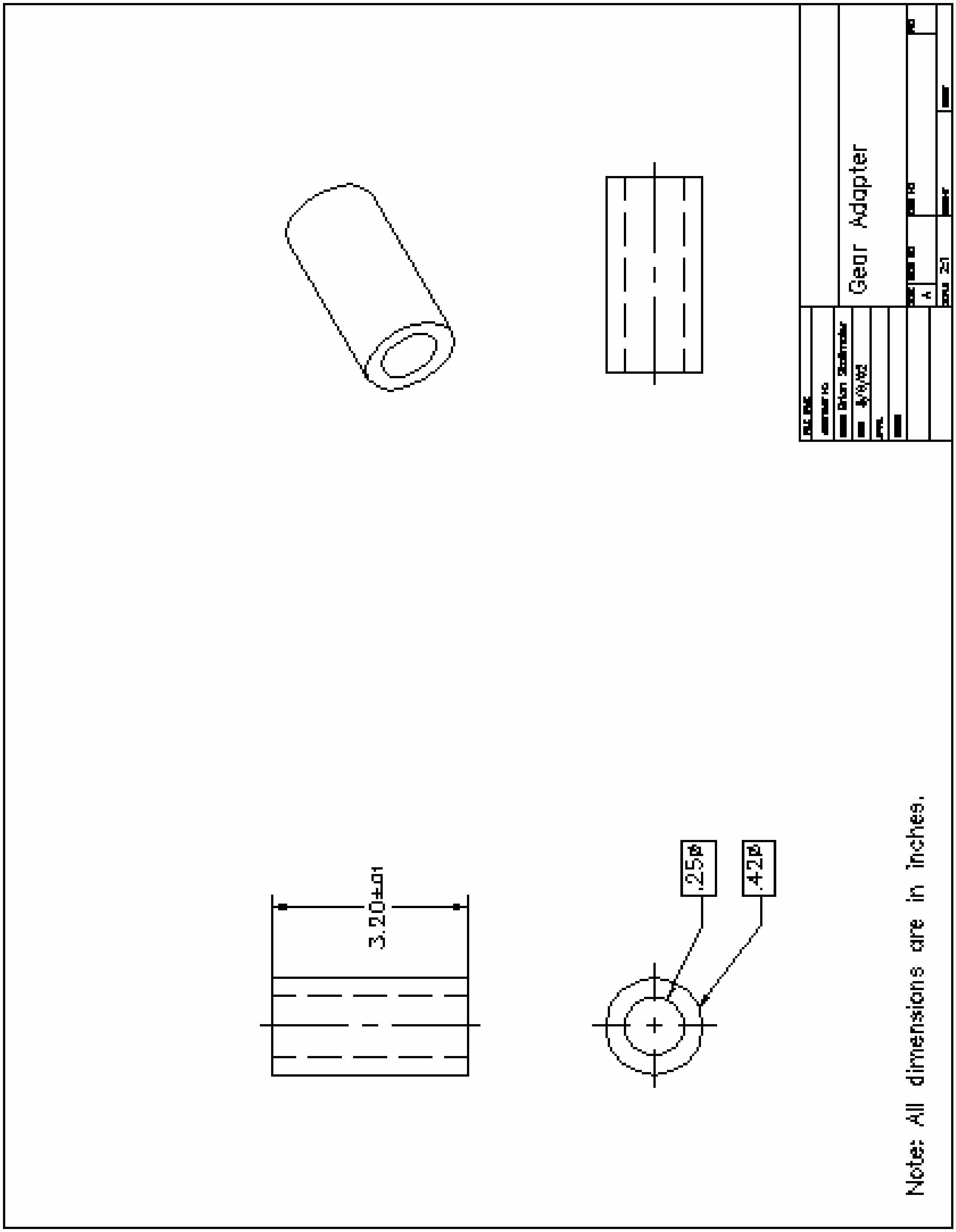
Appendix F

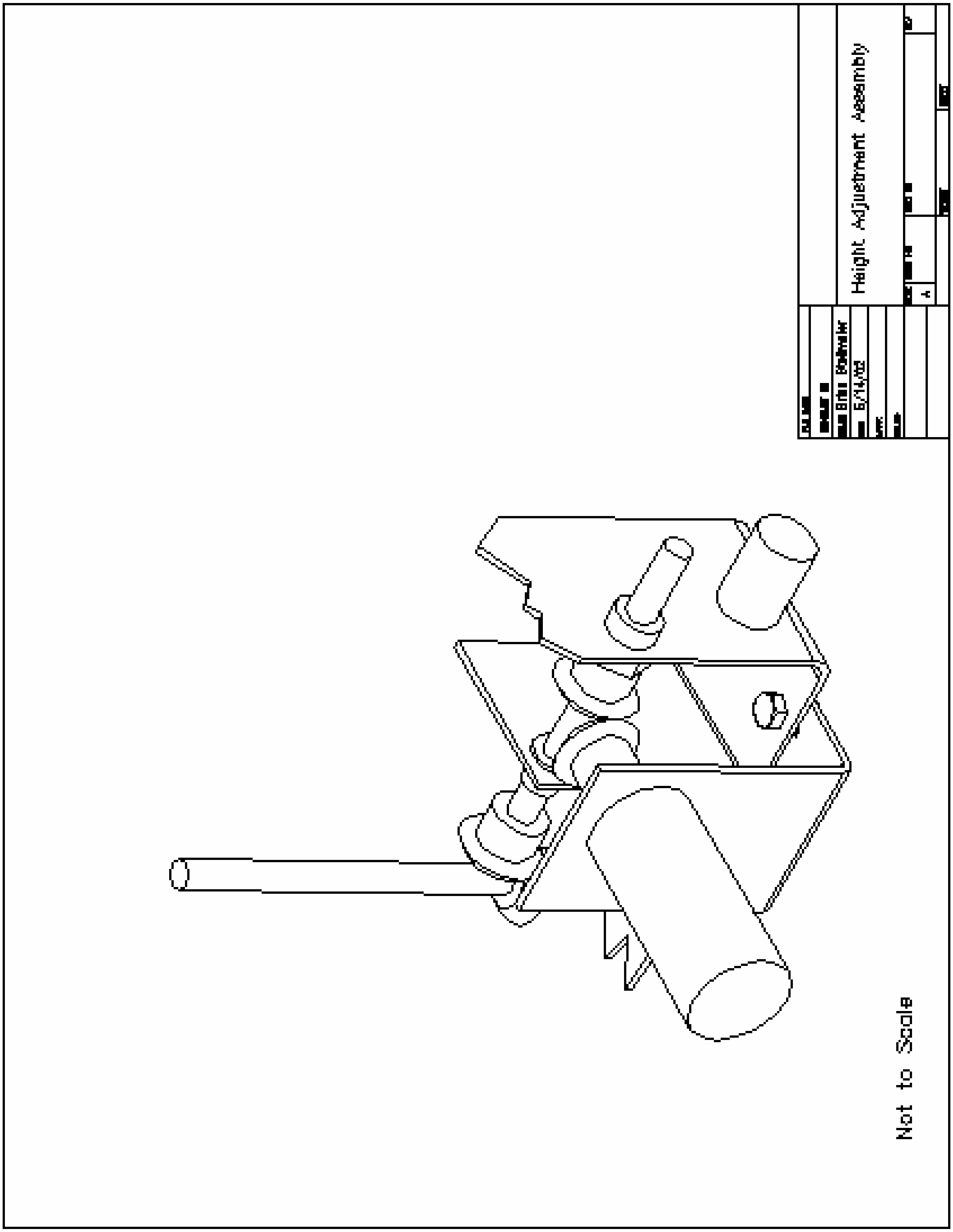
Drawings

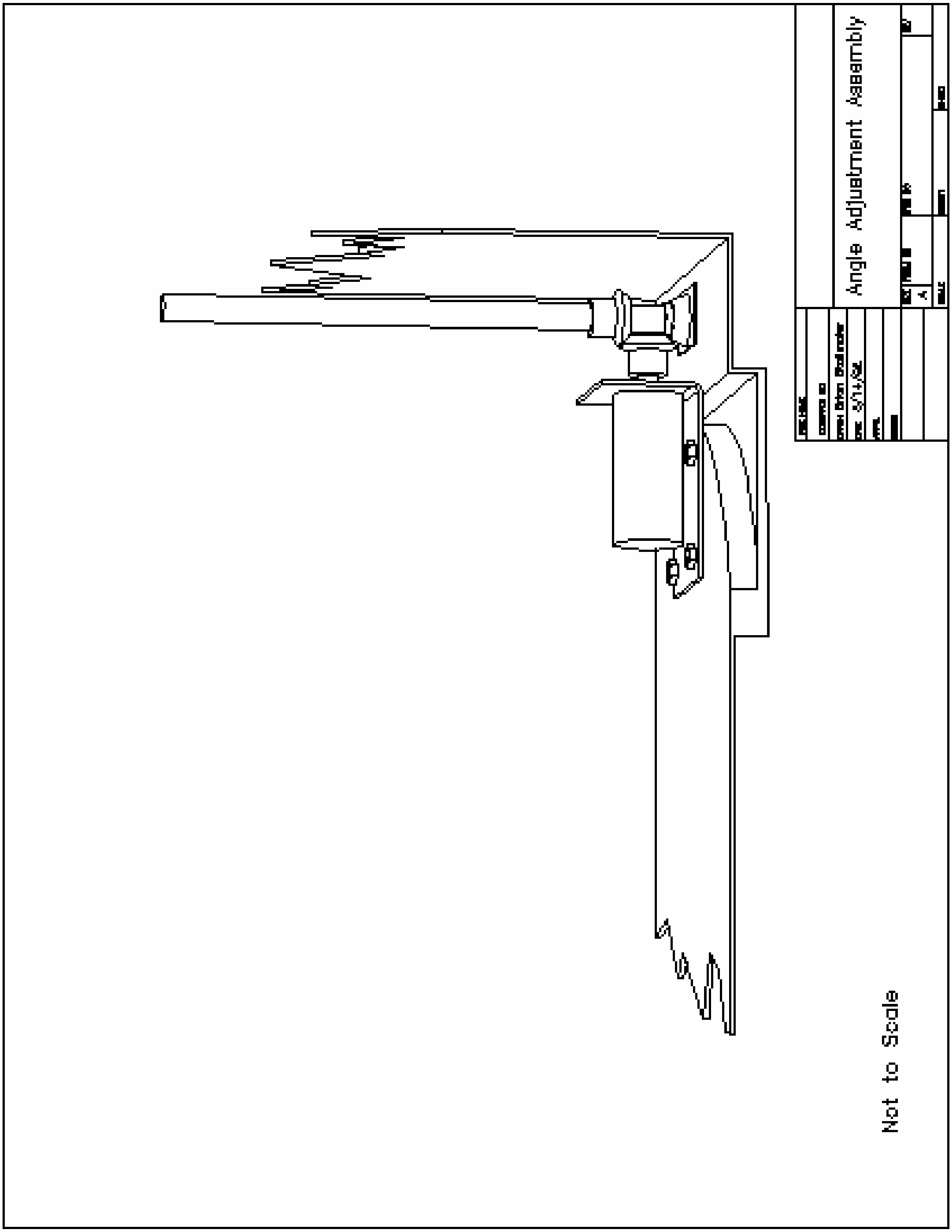

Height Adjustment Bracket
4.00±.01
2.60±.01
.10
.80±.01
.25⌀
.50
2.00
.50
1.58
.85
.60
.58
.52
.91
.50⌀
1.54
1.28
.50⌀x3
2.50±.01
Note: All dimensions are in inches.

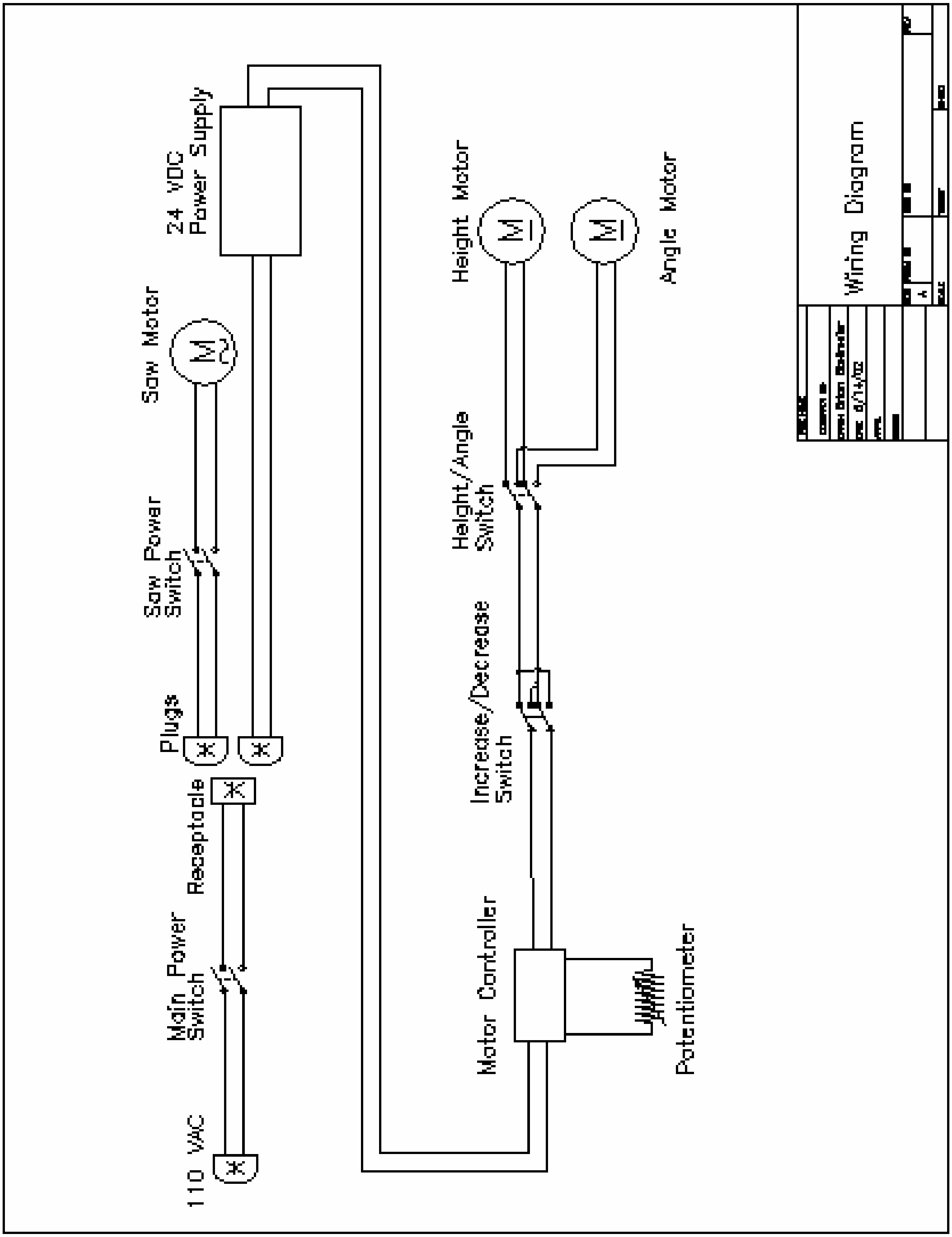


Angle Adjustment Bracket
2.10±.01
4.10±.01
.10
2.89
2.65
.50
.35
2.65
1.59
1.46
1.25
.61
2.09
1.45
1.25
1.04
3.00±.01
Note: All Dimensions are in inches.


Gear Adapter
3.20±.01
.25ø
.42ø
Note: All dimensions are in inches.


Height Adjustment Assembly
6/14/02
Not to Scale


Angle Adjustment Assembly
Not to Scale



110 VAC
Main Power Switch
Receptacle
Plugs
Saw Power Switch
Saw Motor
24 VDC Power Supply
Motor Controller
Potentiometer
Increase/Decrease Switch
Height/Angle Switch
Height Motor
Angle Motor
Wiring Diagram

Appendix G

References

References

1. "Benchtop Bonanza," Nov. 2, 2001 http://www.popularmechanics.com/home_improvements/tools/2001/10/benchtop_bonanza/index6.phtml

2. "Buying guide for table saws," Nov 20, 2001 http://170.224.4.200/lkn?action=howTo&p=BuyGuide/chstablesaw.html&topic=howToLibrary

3. "Table Saws," Nov 20, 2001 http://www.toolseeker.com/basepages/toolpages/tablesawinfo.htm

4. "Cut projects down to size," Oct 25, 2001 http://www.consumerreview.com/guides/homeandgarden/powersaws_guide.asp

5. "US Patent & Trademark Office," Nov 6, 2001 http://patents.uspto.gov

4. "OSHA search page," Oct 26, 2001 http://www.osha-slc.gov/html/dbsearch.html

5. "Faulhaber MicroMo Electronics, Inc," Dec 4, 2001 http://www.micromo.com/03application_notes/appnote2.asp

6. <u>DC to Pulse Width Modulator</u>. Velleman-Kit K8004 Manual. Belgium

Appendix H

Proof of Design Agreement

Proof Of Design Agreement

1. Time required to fully adjust blade height will be less than 20 seconds and the time required to fully adjust blade angle will be less than 15 seconds.
   a. This will be tested by activating the gearmotors and, with a stopwatch, measuring the time required to perform the said tasks.

2. The torque required by the user will be less than 12 in-lb to adjust the height of the blade and less than 5 in-lb to adjust the angle of the blade.
   a. The torque required to activate the gearmotors will be measured through the use of a fish scale or equivalent means.

3. The weight of the saw will be 100 pounds or less with integrated components.
   a. The weight of the saw will be measured by means of a bathroom scale.

[signature]	6/03/02	[signature]	6/3/02
Dr. Robert Wynn	Date	Brian Stollmaier	Date