

Attention: Mrs. Lisa Huffman and Dr. Tom Hess

Subject : Transtibial Liner Donning

Enclosed is our report entitled "Transtibial Independent Liner Donning System". This report explains in detail the work completed by us as University of Idaho students in Biological and Agricultural Engineering and Mechanical Engineering during the Fall of 2013 and Spring of 2014, for the project you proposed. The report focuses on the design and implementation of the transtibial amputee liner donning system and includes specifics on testing the individual components within the system. The results display and describe the functionality of the system in a very intuitive manner. This is a final copy of the report. We appreciate the time you and Dr. Tom Hess have devoted to us. Please let us know if you have any questions or concerns.

Sincerely,

Matthew Guthrie
Jennifer Rainey
Jordan Simonson
Samantha Sutherland

TRANSTIBIAL APMUTEE: INDEPENDENT LINER DONNING SYSTEM REPORT

Senior Design Project Report

Submitted to:
Dr. Thomas Hess
Lisa Huffman

Names

Matthew Guthrie
Allyson Labrum
Jennifer Rainey
Jordan Simonson
Samantha Sutherland

Contact Info

Guth0637@vandals.uidaho.edu
Labr5159@vandals.uidaho.edu
Rain5140@vandals.uidaho.edu
Simo6466@vandals.uidaho.edu
Suth6834@vandals.uidaho.edu

Signatures

Matthew Guthrie
Allyson Labrum
Jennifer Rainey
Jordan Simonson
Samantha Sutherland

Project Sponsors:

Lisa Huffman
Dr. Tom Hess

Department of Biological and Agricultural Engineering

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Executive Summary

The aim of this project is to design a system that enables independent liner donning for transtibial amputees. The significance of such a system is applicable to the number of transtibial amputation performed each year in the United States-40,000. Liner donning requires a significant amount of effort. Because nearly 60% of amputations are caused from type II diabetes, these individuals may also experience other complications such as obesity, loss of sensation, poor hand strength and dexterity and even reduced vision. These circumstances significantly affect an amputee's ability to properly don their own. Enabling amputees to independently and properly don their liner is a new area of development. The purpose of this project is to design a system that ensures the amputee's liner is in the proper alignment for connection into the prosthetic limb, sits flush against the amputee's residual limb to eliminate the effect of pistoning, and limits the need for outside assistance. Thus, using the results of this design system, amputees could regain independence and assurance of proper liner donning. Accommodating the wide variance in users is the one limiting factor in our project.

Our design team has developed and manufactured a Transtibial Liner Donning System, TLDS. This system functions on a control loop, which controls two track and linear actuators. The system consists of three main components: an adjustable hydraulic stand, a pin guidance attachment, and the donning track with liner applicators. The adjustable stand accommodates chair heights that sit 1' to 3' off the ground. . The pin guidance attachment assists amputees primarily with aligning their liner, but also helps them invert the liner for donning. Lastly, while the donning tracks run from the distal end of the residual limb to the proximal end, the linear actuators move laterally and medially to accommodate the change in width of the limb. At the end of the linear actuators, are the liner applicator, which roll the liner onto the limb. The track system is programmed based on the amputees' individual requirements such as, limb length and width. . This data is used to calibrate the controls so that the correct speeds and stroke extensions are adjusted.

1.0 Introduction

Each prosthetic fitting is personalized to the amputee and many measures are taken to ensure all components align correctly. Given the complexity of the fitting process, it is equally important that all components connect properly when the amputee uses them. However, there are a significant number of amputees that have personal limitation that affect their ability to properly don their liner which in turn makes it extremely difficult to connect the liner and pin into the socket. Such limitations include, but are not limited to, reduced hand dexterity, minimal flexibility, and poor vision.

Given the limitation of many amputees and the complexity of the donning process there is sufficient need for the development of an assistant donning devices for amputees.

The project is aimed to design and manufacture a Transtibial Liner Donning System (TLDS) that accommodates all commercially available liners and all sizes. To accomplish this, a customizable calibration system or feedback control system is necessary. The approach in designing this donning system is by constructing several subsystems that mount together to create the TLDS.

1.1 Background

While the focus of this report and project is on the design and development of a TLDS, background on amputations and prosthetic fittings are important to understand the significance of the TLDS and its purpose. This section briefly explains what causes amputations, how amputees are fit for their prosthetic components, and the challenges they face when attempting to use their prosthetic.

1.1.1 Amputation

Amputation is the removal of a body part by trauma, constriction or surgery. In the US, it is most readily attributed to poor circulation seen in Type II diabetics; the second leading casus is from sever injury, but can also be attributed due to deformities, tumors, infections, and frostbit.

There are many types of amputations and are classified broadly as upper body and lower body, with the waist dividing the two. To narrow the discussion of amputation, only the lower body amputations will be focused upon, specifically transtibial. Transtibial amputations are classified as above the ankle, but below the knee. Full knee use is retained, but it is difficult for amputees to apply weight to their residual limb. Amongst the different types of amputations, transtibial and transfemoral are the most common with 40,000 performed each year in the United States.

1.1.2 Prosthetic Components

Once an amputation is performed, an extensive prosthetic fitting process begins. Regardless of the functional use of the device, the most important factors in the usefulness of the prosthetic is the fit of the socket and the alignment of the various components with respect to the body and to each other. Fitting affects alignment, alignment affects fittings; this balance between the two affects the comfort and function of the prosthetic. The socket is made of a plastic or carbon fiber material and is attached to an artificial foot by an aluminum tube called a "pylon." Most prosthesis for transtibial amputations consist of three major components: a socket, a shank, or shin and a foot. A socket encases the residual limb and usually contains a gel or elastomeric liner to provide a cushioning effect, but also aids in holding the prosthesis in place.

Reference: <http://www.oandp.com/resources/patientinfo/manuals/4.htm>

1.1.3 Fit of a Prosthetic Liner

The fitting process takes into account the individual's activity level and health, amputation level, and demands placed on the prosthesis daily. Alignment of the prosthesis can vary from one patient to the next, since posture and body size play a role. The most significant challenge for both the prosthesis fit and continual use for the patient is excess soft tissue around the residual limb. Being overweight or obese, inhibits the patients from being able to see the socket and properly lock in the pin. Additionally, the excess soft tissue inhibits the liner or makes it difficult to get the liner flush against the residual limb for donning purposes. Aside from weight challenges, amputee may also face other challenges as they age such as loss of vision and arthritis, which limits their hand dexterity. Loss of hand strength accompanied by poor vision, significantly reduces amputee's ability to pull their liners on in the correct orientation to lock into their prosthetic.

1.2 Problem Definition

The problem definition section will cover the specific design constraints and specifications while presenting the goals and final deliverables of the design process.

1.2.1 Design Goals

The overall goal was to design a device to aid lower limb amputees in donning their prosthetic liner. The device should ensure that the pin properly align into the prosthetic, that the liner sits flush against the limb, and that those with low hand dexterity, vision, or flexibility can independently don their liner.

From the beginning of the design process, the underlying goals of the design were to apply general engineering principles to ensure the TLDS would be a functioning device that patients with variable levels of ability and strength could use with ease and comfort.

We designed the TLDS with customizable components to ensure patients of different shapes and sizes would be able to use this device to aid with their personal donning process comfortably and safely while meeting all of the required specifications of the device.

1.2.2 Design Specifications and Constraints

Throughout the design process, the design team accumulated a set of specifications laid out by the client, our research, and other sources as shown in Table 1. These specifications and source for each specification provide a general outline of the requirements of the TLDS.

Table 1: TLDS Specifications

<u>Specification</u>	<u>Source</u>
Enable patients to align and don their liner with ease	Project Bid Outline
Align liner pin for donning	Project Bid Outline
Enable amputee independence	Project Bid Outline
Accommodate all liner sizes, brands and variations	Project Bid Outline
TLDS must accommodate liners with distal diameter from 2.5" to 12.0".	Client interview (10/3/2013)

TLDS must work with liners of proximal diameter from 3.1" to 11.7".	Client interview (10/3/2013)
TLDS must accommodate liners ranging in length from 12" to 16".	Client interview (10/3/2013)
TLDS must accommodate existing liner pin measurements: Diameter: 10mm Length: 1-2.25" Pitch: 1.5" metric	Client interview (10/3/2013)
Allow for use by patients with low hand dexterity	Project Bid Outline
Allow for use by patients with varying flexibility	Project Bid Outline
Ergonomic Design	Client interview (10/3/2013)
Be compatible with existing liner materials	Client interview (10/3/2013)

1.2.3 Deliverables

The TLDS is the final deliverable of this yearlong project. The final device has been tested on a plaster amputee mold and is ultimately designed for use with this mold. Further alterations, testing and validation is required for its future use on a human test subject.

Alongside the TLDS is the final wiki page site that has been maintained and updated all semester that includes valuable information about the TLDS, team members and background information about our project.

2.0 Methodology

Developing the TLDS was a year long process that began with researching, brainstorming and sketching ideas. Honing the ideas and drafts to meet the requirements outlined by the client resulted in the developments that supported proof of concept, prototypes, and the final TLDS.

Researching, brainstorming and deciding upon a design was the first steps in creating the TLDS. A number of design concepts were considered and researched. Each concept was considered and combined to create the TLDS.

Developing a project plan, schedule and dividing the tasks between team members was the next step required to get the project into the prototype stage. The TLDS will be described in extensive detail in the following sections.

2.1 Project Plan

The development of the TLDS was scheduled and tracked throughout the duration of the year. Each team member played a vital role in the development and ultimately the completion of the system. This section details the tasks and schedule of the progress as well as the responsibilities held by each team member.

2.1.1 Tasks

Fall semester the design team centered our efforts on prosthetic research and existing technologies as solutions for the defined problem. After a design solution was decided upon, the tasks were divided up among the team members and the device began to take shape.

The subsystems were defined and each member of the team was assigned responsibilities according to their interests and skill. An outline of the subsystems of the TLDS in combination with the work schedule and the responsibilities of each team member is summarized in Table 2 under the Team Responsibilities section.

2.1.2 Schedule

The initial schedule provided an outline of all project tasks and team member assignments. However, was optimistic and due to the learning curve and loss of team member, it was not an accurate representation of how the design progressed. The design team agreed that too much time was spent in the project-learning phase of the design. This caused a shortage of time for the development, implementation, and testing phase. Once the design team, client and mentors agreed upon the final design of the TLDS, the project schedule was updated weekly to account for team progress, lead times, and overall project status. A complete schedule of tasks is located in the appendix.

2.1.3 Team Responsibilities

Given that the TLDS was comprised of several subsystems, it was logical to assign team members to each system subsystem. Table 2, provides a general view of the subsystems and task assignments associated with the TLDS. Losing a team member, Allyson Labrum, halfway through the design process put extra stress on each of the remaining team members, as she was the lead on the programming and controls. After she withdrew, the controls portion was delegated to Jennifer; Jordan also assisted as it was major component of the design.

Table 2: Project Plan

<u>Task</u>	<u>Scheduled Completion Date</u>	<u>Actual Completion Date</u>	<u>Team Member</u>
CAD Prototype	1/15/2014	2/5/2013	Matt Guthrie
Stand (Specify/Order)	1/15/2014	4/1/2014	Jennifer Rainey
System Programming	1/15/2014	4/29/2014	Allyson Labrum/Jennifer Rainey
Linear Loader	1/30/2014	4/28/2014	Samantha Sutherland/Jordan Simonson
Liner Applicators	1/30/2014	4/28/2014	Matt Guthrie/Samantha Sutherland
Wiki Page	On-going	5/3/2014	Jordan Simonson

2.2 Design Alternatives and Selection

To fully understand the process that was followed while designing the TLDS, it is important to understand our methods for choosing the ideal design. It was decided that our device would consist of a general set of required components. The TLDS required a stand that would allow movement in the vertical direction, a device that would contact and apply the liner (the liner applicator), a liner loader that would hold the liner during the donning process, and finally a device that would change the position of the liner from the distal portion of the limb to the proximal. The following sections specify the subsystems and their possible solutions. The following sections describe the concepts that were considered for the final design of the TLDS.

2.2.1 Existing Devices

Throughout our research, a singular device was found to accomplish the goal of donning a prosthetic liner. This device was developed using vacuum technology to expand the liner until it was wide enough for the user to insert his limb. A similar product is shown in figure 1, below. This similar product is designed for latex glove donning. The device was simply scaled up to accommodate a liner.

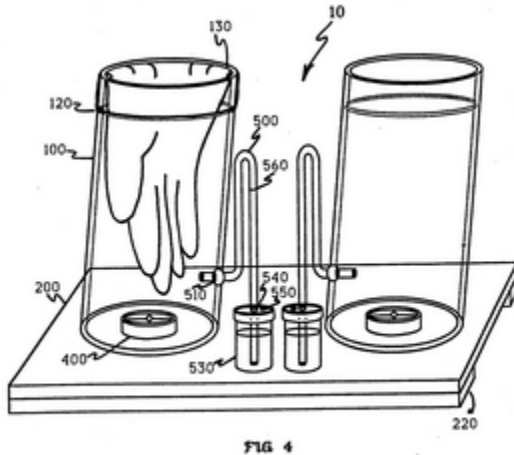


Figure 1: Latex Glove Donning Device

The design team considered basing the TLDS on this technology and altering it to fit the specifications of our device, however a number of specifications would not be met using this device. These reasons are discussed in detail in the “Concept Selection” section of this document.

2.2.2 Bases

The base of the TLDS is the foundation of the project. The base needed to support the weight of the device and the weight of the user’s limb, remain sturdy and ideally provide vertical movement or at minimum provide a permanent height adjustability setting. Each base in the following discussion was a viable option for the TLDS.

2.2.2.1 Tripod/Quad-pod Stand

The basic tripod or quad-pod stand, which is shown in figure 2, was the initial idea for the TLDS base. The tripod stand can be used for a number of uses and is relatively sturdy due to its wide base.

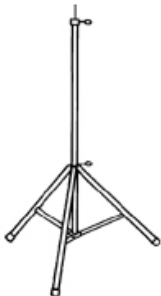


Figure 2: Tripod Stand

It was determined to be inexpensive, portable, easy to acquire or manufacture, and adjustable. If this base were used, a platform would have needed to be added to accommodate and support the other components of the system.

2.2.2.2 Adjustable Ramp

An adjustable ramp was another consideration for the base of the TLDS. This design is showed in a sketch in figure 3. It would have limited adjustability due to a fixed number of notches, and would have a downward slant for the user to have a relaxed posture for the donning process.

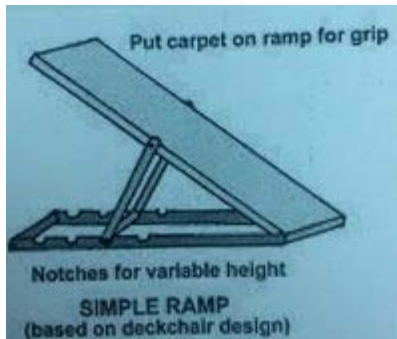


Figure 3: Adjustable Ramp

This base would have been easy to manufacture, sturdy and adjustable for the user.

2.2.2.3 Scissor Stand

A scissor stand base would have been the most stable option for the base of the system. A number of companies manufacture these devices, which would make one easy to purchase. The scissor stands available were expensive due to high weight capacities and extra capabilities that were not needed for the TLDS, however they provided the adjustability, and weight capacity, stability necessary for the system.

2.2.2.4 Hydraulic Table Stand

The final base design that the design team looked at was a hydraulic table stand commonly used in pet grooming. This design provided adjustability through a foot pump, stability and dimensions necessary for the TLDS. These tables typically supported much less weight than the scissor stands and were more cost effective.

This component was chosen for the final system. This stand met all of the requirements for the TLDS. It's physical dimensions of the platform were adequate at 24" by 48", it was rated at 200lb capacity, and was within our budget.

2.2.3 Liner Applicator

The liner applicator is the portion of the device that comes in contact with the prosthetic liner and physically applies it to the user's limb. This portion of the device would need to increase in diameter and remain in close contact with the limb despite its changing contours. A number of ideas were considered, they are outlined in the following sections based on their characteristics.

2.2.3.1 Internal or External Design

The design team was tasked with deciding the best method for liner application. The first concept that was considered was a garter design that would be placed between the liner fabric, contacting only the out fabric. A number of tests were conducted using a prototype with four end finials, shown in figure 4. This test gave us the initial impression that internal liner applicators would not be effective for the liner application so we were driven toward external applicators that would replicate the motion and

characteristics of the natural hand-application motion. The later was chosen for further development of this subsystem.



Figure 4: Liner Applicator Prototype

2.2.3.2 Static or Hinged Design

A number of designs were considered for the external liner applicator components, a hinged, mechanical design was initially considered due to the potential adjustability. This idea was rejected due to time and budget constraints; a static design was chosen. A number of prototypes were developed using anthropometric data. The radial curve of the applicator was initially based on the dimensions of the 99th percentile male thigh; this design would eliminate areas of high pressure on the limb. In a final rendition of the TLDS, this would be ideal; however for the prototype we designed the final liner applicator to accommodate the largest dimensions of the plaster limb mold.

2.2.4 Drive System

The drive system of the TLDS is the system that puts motion to the entire device. This subsystem required motion in lateral and longitudinal direction in order for the TLDS to function properly. Linear actuators and track actuators were chosen for this subsystem, they were purchased from Progressive Automations, their data sheets are found in the appendix. The challenge of this subsystem was to determine the most efficient, reliable orientation of these components.

2.2.4.1 Single Track or Double Track

As mentioned above, our drive system was purchased from Progressive Automations. Their engineers provided guidance to the design team during the process of determining the proper design and orientation of their parts. Their staff recommended a double track system due to the mounting brackets on the track to accommodate the linear actuators. The design team followed their recommendation of a double track-double actuator design for the TLDS. Figure 5, below, shows the single track concept which contrasts with the following image, figure 6, which shows the double track concept that was chosen for the TLDS.

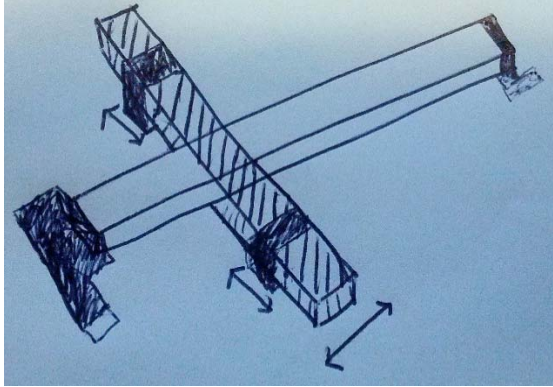


Figure 5: Single Track Custom Design Option



Figure 6: Double Track Design Option

3.0 Results & Discussion

This section is devoted to the final design and the results of project learning and prototyping efforts.

3.1 Final System Design

The plaster model limb, purchased parts, and the control system determined the final dimensions and functionality of the TLDS. This section covers the specifications, requirements, and development of each subsystem. Shown in figure 7 is an amputee using the TLDS.

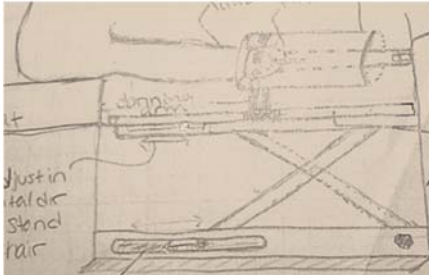


Figure 7: User Using the TLDS



Figure 8: TLDS Final Design

3.1.1 System Base

Based on the design goal, to limit the users need for hand use, we choose to implement track and liner actuators. Mounting the linear actuator to the sliding block of the track actuators provided the bidirectional, x and y axis movement we needed to accommodate. The average length and width of residual limb determined the needed platform dimension. The sketch shown in Figure 8 displays the top view of the system and shows the planned dimension of 24" by 36". The final dimension were 24" by 48", the extra length was need for mounting the plaster mold and mounting the control housing. The base also provided movement in the z axis allowing the eventual user to adjust the device for their personal needs.

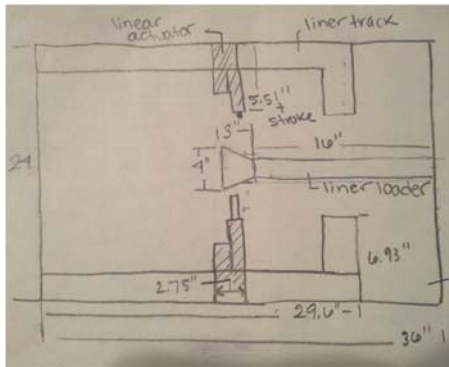


Figure 9: Top View of TLDS

3.1.2 Liner Loader

The liner loader was developed to address the users need to correctly align the liner pin each time the liner was donned. In order to meet this requirement we specified that it needed to be detachable, so that the user could hold it close in order to insert the liner in the correct alignment and assist with inverting the liner. The umbrella support cup at the end addresses the requirement to eliminate the air pocket formed between the liner and residual limb by supporting the umbrella at the end of the prosthetic liner. Providing support here, enables the user to fully draw back the liner and expose the umbrella, doing so, makes the surface of the liner nearly flat as to enable a flush contact with the residual limb.

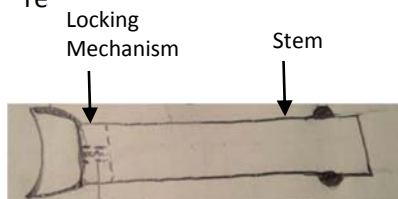


Figure 10: Sketch of the Liner Loader

3.1.3 Liner Applicators

The final design for the liner applicators was based on the plaster mold provided. This subsystem is composed of aluminum arcs of length 4.75" with a radius curvature of 2.6" and a thickness of 0.125". The radius was determined using the largest circumference on the molded limb, 16.4". The arc length of the applicators was determined using the smallest circumference, 10.5".

3.1.4 Drive System

The drive system is composed of track actuators that run on an input voltage of 12 volts DC and 5 amps at full load. During the donning process each track draws approximately 3 amps. The physical characteristics of the tracks provide the length necessary to accommodate for the longest prosthetic liner of 18", while providing an extra 4" for the track to calibrate for the actuation, with a total length of 22 inches of travel.

The linear actuators are mounted to the sliding block on the track actuators, the liner applicators are mounted to the end of these actuators. The stroke length of each actuator is four inches. These are used to accommodate a change in width of the limb from 2.5 to 5 inches in the prototype, but could accommodate the maximum change of 2.5 to 12.5 inches in a final design.

3.1.5 Controls

The track and linear actuators are controlled using an Arduino Uno microprocessor, speed controllers, and a simple code, which is located in the appendix of this document. The design team attempted to incorporate Infinion h-bridges into the design to reverse the direction of the track and linear actuator motors using the code, however after purchasing and testing the switches with the TLDS, they were found to be incompatible with the system, despite being rated to handle the high amperage draw of the actuators. The final prototype moves only in the donning direction and does not reverse to its reset-position. It is vital that the speed control potentiometers are not adjusted after initial calibration of the code or the device risks damage to itself or the plaster mold.

3.2 Budget

The first prototype of the TLDS was limited to \$3,000. The following section is a breakdown of the cost of each subsystem, which parallels section 3.1 Final System Design.

3.2.1 System Base

The base of the system was purchased from ebay.com for a price of \$212, which included shipping. No other costs are associated with this subsystem.

3.2.2 Liner Loader

The liner loader is a low-cost item. It is composed of PVC pipe, an umbrella cup which was printed on the 3-D printer, a machined piece of scrap aluminum and a pin locking mechanism donated by Lisa Huffman. Table 3 outlines the cost for this subsystem.

Table 3: Liner Loader Costs

Component	Cost for Prototype	Cost to Purchase
PVC Pipe	\$5	\$5
Umbrella cup	\$15	\$25
Scrap Aluminum	\$0	\$15
Pin Locking Mechanism	\$0	\$150
Total	\$20	\$195

3.2.3 Liner Applicators

The liner applicators were also low-cost for the design team to manufacture. Scrap pieces of aluminum were acquired from the shop; brackets were purchased for the connection to the actuators, and leather was purchased to line the applicators. Table 4 outlines the cost for this subsystem.

Table 4: Liner Applicator Costs

Component	Cost for Prototype	Cost to Purchase
Aluminum	\$0	\$15
Brackets	\$13	\$13
Leather	\$9	\$9
Total	\$23	\$37

3.2.4 Drive System

The drive system is where the majority of the finances went for the TLDS. The drive system is composed of two purchased track actuators and two purchased linear actuators. The costs for this subsystem are outlined in table 5.

Table 5: Drive System Costs

Component	Cost for Prototype	Cost to Purchase
Track Actuators (2)	\$278	\$278
Linear Actuators (2)	\$218	\$218
Power Supply	\$84	\$84
Total	\$580	\$580

3.2.5 Controls

The controls for the TLDS were also a significant portion of the TLDS. This price was higher than necessary due to failed components, user error, and incompatible products. The design team had no experience with the controls portion of this project, so costs could be reduced in this area. Table 6 outlines the costs for the controls portion of this project.

Table 6: Control System Costs

Component	Cost for Prototype	Cost to Purchase
Arduino Uno	\$50	\$20
Pressure Sensors	\$20	Unused
Breadboard	\$17	\$17
Jumper Kit	\$8	\$8
Infinion h-bridges	\$62	Unused
Speed Controllers (2)	\$60	\$60
Arduino Power Supply	\$10	\$10
Total	\$227	\$115

3.2.6 Miscellaneous Expenses

There were a number of miscellaneous expenses associated with this design. Prototype items, fastening items, and items to improve the aesthetics of the device are included in the following table, table 7.

Table 7: Miscellaneous Expenses

Component	Cost for Prototype	Cost to Purchase
Paint	\$10	\$25
JB Weld	\$8	\$8
Fasteners (Screws, nails, etc.)	\$0	\$10
Prototype Items <ul style="list-style-type: none">• Fineals• Threaded steel cylinders• Plywood• 2x4 boards	\$60	\$0
Power Strips	\$12	\$12
Total Cost	\$90	\$55

3.2.7 Total Expenses

The total expenses for this project are outlined as a combination of the subsystems. Table 8 outlines the total expenses for the design team as well as the total estimated cost assuming no mistakes, unneeded parts or prototyping costs.

Table 8: Total Cost

Component	Cost for Prototype	Cost to Purchase
Base	\$212	\$212
Liner Loader Assembly	\$20	\$195
Liner Applicator	\$23	\$37
Drive System Assembly	\$580	\$580
Control System Assembly	\$227	\$115
Miscellaneous Expenses	\$90	\$55
Total Cost	\$1152	\$1194

4.0 Conclusions & Recommendations

The following information is a culmination of recommendations for future work on the TLDS. It is the hope of the design team that this project is carried over for another senior design project.

4.1 Future Project Recommendations

The future work of this project will be divided into subsystem and specific recommendations will be given for future design teams to reference. The ultimate goal of the design team is to have a product that is suitable for use on amputees.

4.1.1 System Base

The design team has found a number of flaws with the base that was chosen for the TLDS. The hydraulic mechanism has a slow leak so the stand lowers slowly. Ideally this stand would be made in-house specifically for the TLDS. The length should be decreased for use on amputees instead of with the mold.

The ideal stand has all pinch points designed out or guarded out so amputees or those aiding the patient do not get injured by the base components pinching or catching clothing or extremities. Also the base

would be adjustable to various angles to allow for easy donning for the user, and eliminate the need for the residual limb to be straight at all times during the donning process.

4.1.2 Liner Loader

The liner loader is in the prototype phase. It is currently composed of PVC pipe and an umbrella cup that was 3-D printed. It would be ideal if the future work would include updating the device to a more permanent material selection that would include a removable attachment to the stand so the user can easily remove the liner loader for application of a liner.

4.1.3 Liner Applicators

The liner applicators are specifically designed for use with the plaster mold. For a final product, these would be adjustable for use by any user. Applying anthropometric data and adjustability to these items will be necessary. It could be possible to design multiple applicators that would range in sizes (potentially 3 to 5 sizes) to accommodate a variety of users. Along with this idea, the applicators would need to be easily replaceable and accessible to make swapping out applicators an easy task.

The addition, a feedback system would provide a safety feature for the design. Providing a method to prevent harm to the user will allow the amputee to use the TLDS without concern. Using resources on campus to learn about immediate feedback controls is recommended.

4.1.4 Drive System

The drive system is composed of two track actuators and two linear actuators. After application of the TLDS, we determined that a single track would provide a more symmetric donning process. This would require that a single track is eliminated and a specialized mount for the linear actuators is developed.

The current use of linear actuators is not completely compatible with the design or with the integration of sensor feedback. To fix this issue, the linear actuators should be upgraded to pneumatic cylinders that max out at a certain pressure that would be perfectly safe for all users. This way there is a pressure feedback, and harm to the user is eliminated.

The track actuators have moving parts that can potentially cause harm to the user or a bystander. It is the recommendation of the design team to provide a track case to guard out the pinch points created by the moving parts of the track.

4.1.5 Controls

The controls portion of the TLDS is very simple and rudimentary. For future renditions of the TLDS, it is recommended that the controls are completely renovated. Specific requirements of future controls include incorporating a mechanism to change the direction of the track and linear actuator motors, a more robust method of speed control, and incorporating a feedback mechanism.

Appendix

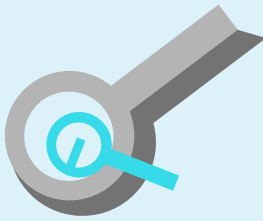
1. Complete Schedule of Tasks
2. Manufacturer data sheets:
 - 2.1 Track Actuator
 - 2.2 Linear Actuator
 - 2.3 Infineon TLE5205-2S H-Bridge
3. Arduino Code

0.1	CAD Prototype		1/16/14	1/30/14
0.1.1	CAD Liner Loader	Samantha Sutherland	1/16/14	1/30/14
0.1.2	CAD Liner Applicators	Matt Guthrie	1/16/14	1/30/14
0.1.3	CAD Drawings/ Dimensioning	Sam & Matt	1/16/14	1/30/14
0.2	Order Scissor Stand	Jennifer Rainey	1/16/14	2/4/14
0.3	System Programming	Allyson	1/16/14	1/22/14
0.3.1	Track/Control Box Connection	Sam & Allyson	1/16/14	2/5/14
0.3.2	Linear Accuator Selection		1/16/14	1/29/14
0.3.3	Linear Accuator Integration		1/16/14	1/16/14
0.4	Liner Loader		1/30/14	1/30/14
0.4.1	Pin Locking Mechanism		1/30/14	2/13/14
0.4.2	Stand Locking Connection		1/30/14	2/5/14
0.4.3	Manufacturing Material		1/30/14	2/12/14
0.4.4	Cup Attachment to Pylon		1/30/14	2/5/14
0.4.5	Umbrella Cup Design		1/30/14	2/12/14
0.4.6	Manufacturing Cup Material		1/30/14	2/12/14
0.5	Liner Applicators		1/30/14	2/12/14
0.5.1	Gripper Material		1/30/14	1/30/14
0.5.2	Grippers Connector Piece		1/30/14	2/5/14
0.5.3	Gear Mechanism/Spring		1/30/14	2/5/14
0.5.4	Connection to linear actuators		1/30/14	2/12/14
0.6	Limb Rest		2/1/14	2/14/14
0.6.1	Limb Rest Design		2/1/14	2/14/14
0.6.2	Limb Rest Material		2/1/14	2/7/14
0.6.3	Limb Rest Base Connection to Stand		2/1/14	2/7/14
0.7	Transtibial Liner Donning System		3/1/14	3/14/14
0.7.1	Connect Liner Applicators to Actuators		3/1/14	3/14/14
0.7.2	Mount Track Actuators to Stand		3/1/14	3/7/14
0.7.3	Mount Control Box to Stand		3/1/14	3/7/14
0.7.4	Connect Liner Loader		3/1/14	3/7/14
0.7.5	Mount Limb Rest		3/1/14	3/7/14
0.7.6	Connect Control Box		3/1/14	3/7/14
1	Validation and Testing		12/1/13	2/8/14
1.1	Validation test results		3/15/14	8/21/14
1.1.1	design FMEA		2/15/14	3/16/14
1.2	Schematics		12/1/13	12/1/13
1.3	Snapshot Day 2		12/6/13	12/11/13

	DUE: Portfolio, Wikipage, Logbook (w/review form) - to your lead instructor			
1.4		All team members	12/13/13	12/13/13
1.5	Test procedures		1/17/14	1/17/14
	DUE: Detailed Design Review (w/client & lead instructor)			
1.6			2/3/14	2/8/14
2	Reviews and document Retention	Jennifer Rainey	3/3/14	5/9/14
2.1	OASIS Abstract		1/15/14	5/9/14
2.1.1	Introduction		1/15/14	2/13/14
2.1.2	Product Design		1/15/14	1/15/14
2.1.3	Budget		1/15/14	1/15/14
2.1.4	Market Analysis		1/15/14	1/15/14
2.2	Design Report		12/12/13	12/12/13
2.2.1	Background		12/12/13	4/30/14
2.2.2	Problem Definition(Include Specs)		12/12/13	12/18/13
2.2.3	Plan(Tasks, Schedule)		12/12/13	12/18/13
2.2.4	Concept Exploration/Selection		12/12/13	3/11/14
2.2.5	System Design		12/12/13	3/11/14
2.2.6	Implementation/Testing		12/12/13	3/11/14
2.2.7	Budget Summary		1/3/14	4/2/14
2.2.8	Recommendations		3/1/14	5/29/14
	DUE: Logbook (w/review form) - by COB			
2.3			3/3/14	3/16/14
	DUE: Expo Registration and Information			
2.4			3/4/14	3/4/14
2.5	Snapshot Day 3		3/11/14	3/11/14
2.6	Poster Board Creation		3/15/14	3/15/14
2.7	Poster Board Printing		4/15/14	4/19/14
2.8	DESIGN EXPO		5/2/14	5/6/14
	DUE: Final Report, Website, Logbook (w/review form) - by COB			
2.9			5/9/14	5/9/14
2.10	Sub Task level 2		5/1/14	5/1/14

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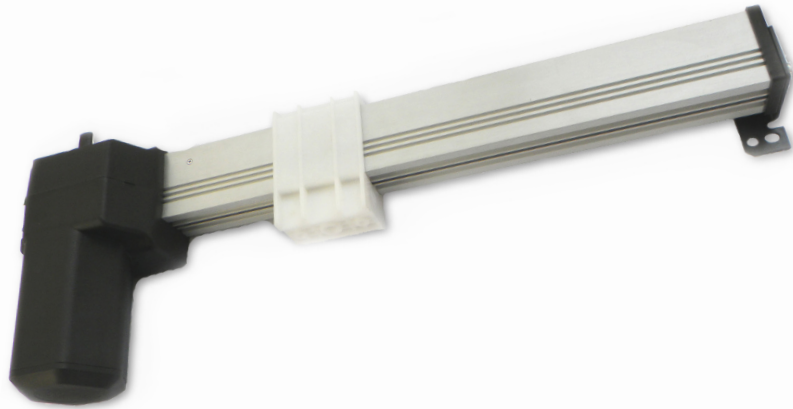
PA-19 LINEAR ACTUATOR

HOW TO ORDER

1.800.676.6123

SALES@PROGRESSIVEAUTOMATIONS.COM

WWW.PROGRESSIVEAUTOMATIONS.COM

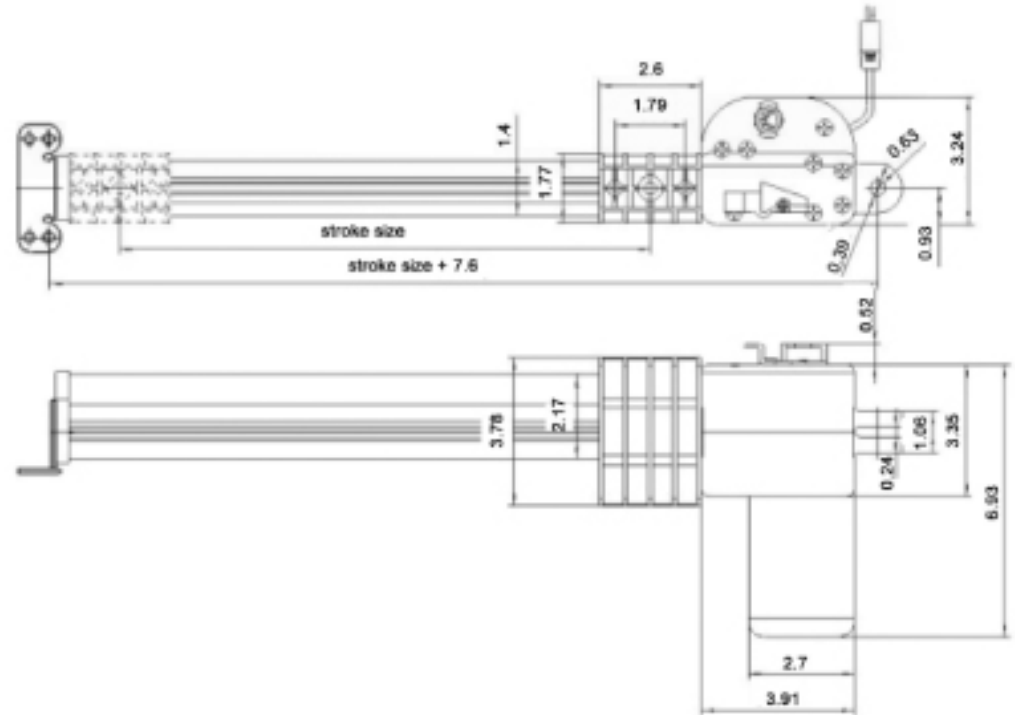


SPECIFICATIONS:

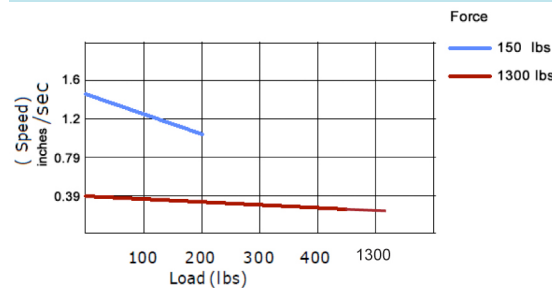
- Input Voltage: 12 VDC
- Current: 5A at full load
- Load Capacity: 150 lbs and 1,300 lbs push and pull
- Static Load: same as regular force
- Speed (no load): 1.30" per second and 0.24" per second
- Stroke length: 1" to 40"
- Min Installation Dimension: 7.60" + Stroke Size
- Screw Holes located on the sliding block.
The screws and pins are included with each order.
- Screw: ACME Screw
- Duty Cycle 10%
- Operational Temperature: -26°C~65°C (-15°F~150°F)
- Limit Switch: built-in non-adjustable
- IP Grade: IP54
- Low Noise Design: db<48 (A)
- Certification: CE and RoHS
- Made from aluminum alloy
- Gears: Polyformaldehyde
- Gear Ratio: 150 lbs - 38:1; 1300 lbs - 38:1
- Wire Length: 40"

For Custom Options See Page 3

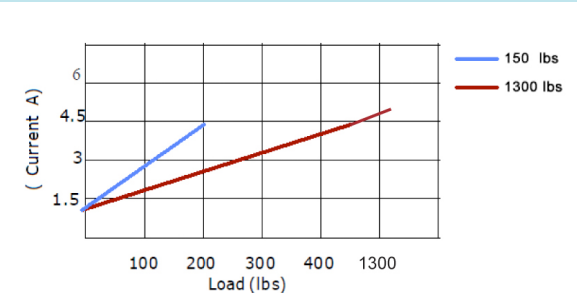
DIMENSIONS IN INCHES

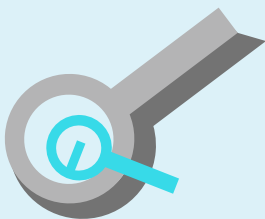


12 VDC SPEED VS LOAD



12 VDC CURRENT VS LOAD





3D MODEL (CLICK TO ACTIVATE)



HOLE TO HOLE DIMENSIONS

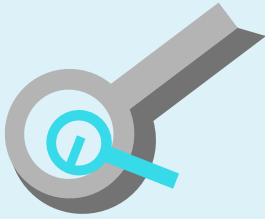
Stroke Sizes (in inches)	PA-19 Model Actuator	
	Fully Retracted (in inches)	Fully Extended (in inches)
0	7.6	7.6
1	8.6	8.6
2	9.6	9.6
3	10.6	10.6
4	11.6	11.6
6	13.6	13.6
8	15.6	15.6
9	16.6	16.6
10	17.6	17.6
12	19.6	19.6
14	21.6	21.6
16	23.6	23.6
18	25.6	25.6
20	27.6	27.6
22	29.6	29.6
24	31.6	31.6
30	37.6	67.6
40	47.6	87.6

PRODUCT ACCESSORIES:

- Will work with any PA's AC & DC controls boxes
- Mounting Brackets: BRK-19 set (for motor end mounting hole)
- Rocker Switches: any PA's Rocker Switches
- Longer Wires: AC-01
- Foot Controls: PDL-01, PDL-02 and PDL-03

SPEED IN INCHES PER SECOND

Forces (lbs)	No Load
150	1.30
1300	0.24



PA-19 LINEAR ACTUATOR

HOW TO ORDER

1.800.676.6123

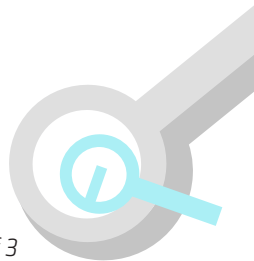
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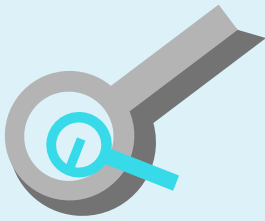
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CUSTOM OPTIONS:

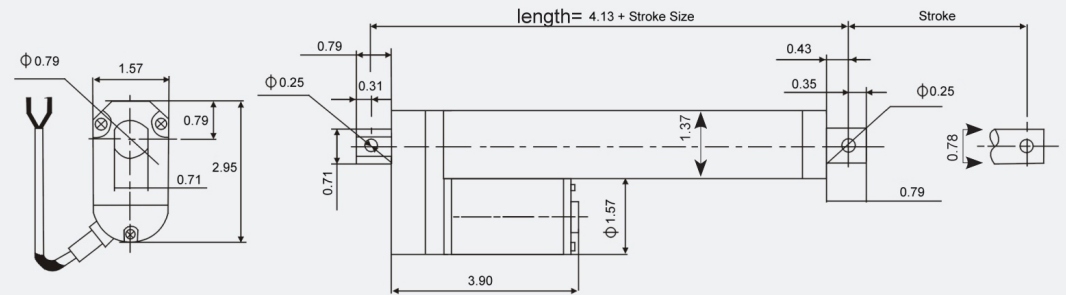
- Voltage: 24/36/48
- Wire length: Customizable
- Mounting Holes: Customizable size and Dimensions
- Connectors: Add your specific connector
- Gearing: Full Metal gears or plastic gears

ADDITIONAL OPTIONS ARE ALWAYS BEING ADDED, PLEASE GIVE US A CALL IF YOU NEED A CUSTOM OPTION YOU DO NOT SEE HERE 1-800-676-6123.





DIMENSIONS IN INCHES

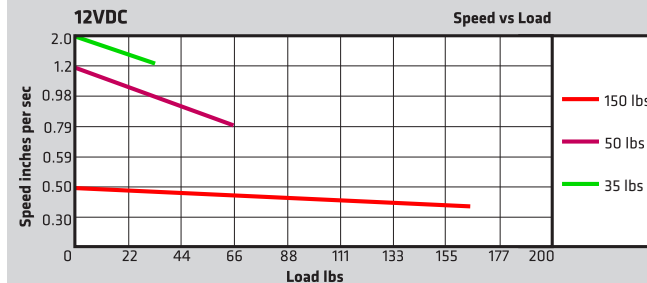


SPECIFICATIONS:

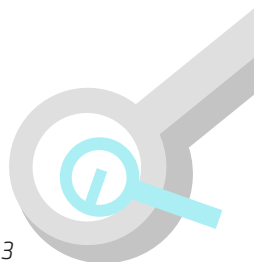
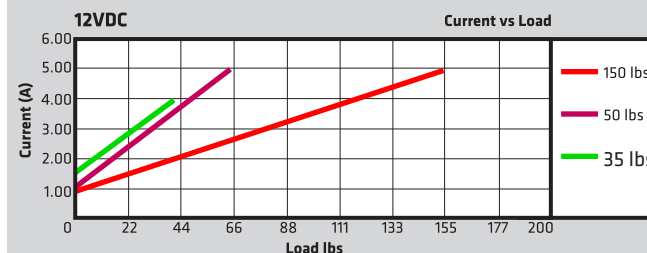
- Input Voltage 12VDC
- Current: 5A at full load
- Load Capacity: 35lbs, 50lbs, 150lbs
- Mounting Holes: 0.25" Diameter
- Static load: 2 x Force
- Stroke Length: 1" to 40"
- Screw: ACME Screw
- Duty Cycle 25%
- Operational Temperature: -25°C~+65°C
- Limit Switch: Built-in Non-Adjustable
- IP Grade: IP54
- Low Noise: db<45(A)
- Certifications: CE and ROHS
- Housing: 6062 Aluminum Alloy
- Powder Metal Gears
- Gear Ratio:
○ 150 lbs - 20:1 ○ 50 lbs - 20:1 ○ 35 lbs - 20:1
- Wire Length: 40"

For Custom Options See Page 3

12 VDC SPEED VS LOAD



12 VDC CURRENT VS LOAD





PA-14 MINI LINEAR ACTUATOR

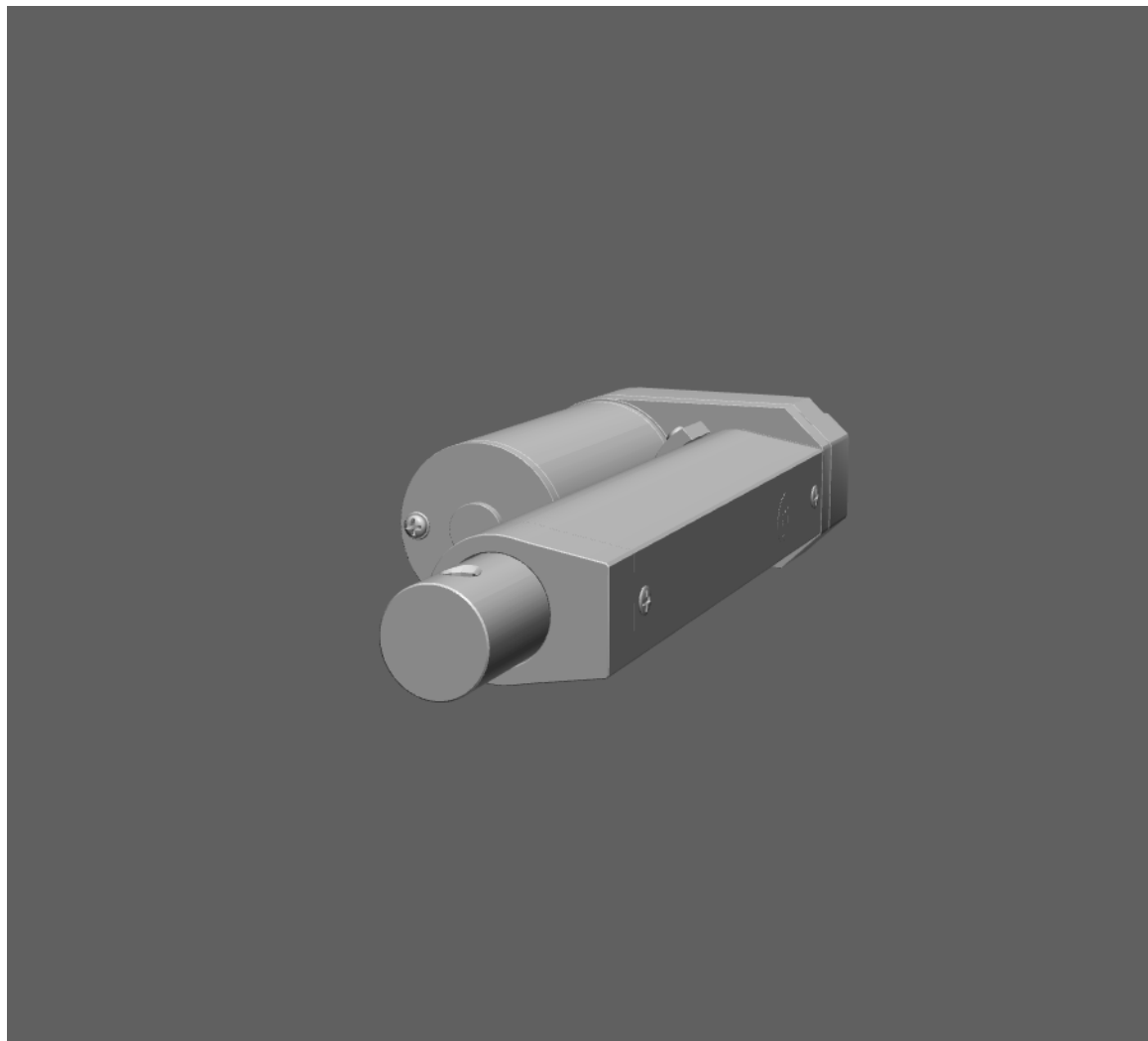
HOW TO ORDER

1.800.676.6123

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WWW.PROGRESSIVEAUTOMATIONS.COM

3D MODEL (CLICK TO ACTIVATE)



HOLE TO HOLE DIMENSIONS

Stroke Sizes (in inches)	PA-14 Model Actuator	
	Fully Retracted (in inches)	Fully Extended (in inches)
0	4.13	4.13
1	5.13	6.13
2	6.13	8.13
3	7.13	10.13
4	8.13	12.13
6	10.13	16.13
8	12.13	20.13
9	13.13	22.13
10	14.13	24.13
12	16.13	28.13
14	18.13	32.13
16	20.13	36.13
18	22.13	40.13
20	24.13	44.13
22	26.13	48.13
24	28.13	52.13
30	34.13	64.13
40	44.13	84.13

PRODUCT ACCESSORIES:

- Will work with any PA's AC & DC controls boxes
- Mounting Brackets: BRK-14 (for each end); BRK-03
- Rocker Switches: any PA's Rocker Switches
- Foot Controls: PDL-01, PDL-02 and PDL-03
- Rubber Boot: AC-05

SPEED IN INCHES PER SECOND

Forces (lbs)	No Load	Full Load
35	2.00	1.20
50	1.18	0.94
150	0.59	0.51



PA-14 MINI LINEAR ACTUATOR

HOW TO ORDER

1.800.676.6123

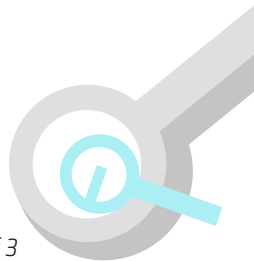
SALES@PROGRESSIVEAUTOMATIONS.COM

WWW.PROGRESSIVEAUTOMATIONS.COM

CUSTOM OPTIONS:

- Voltage: 24/36/48
- IP Grade: IP65
- Feedback: Potentiometer or Hall Effect Sensor (see PA-14P model)
- Wire length: Customizable
- Stroke Size: 1" – 40" in increments of 0.25"
- Mounting Holes: Customizable size and Dimensions
- Connectors: Add your specific connector
- Custom Dimensions: Change size and stroke of unit based on your requirement
- Gearing: Full Metal gears or plastic gears
- Customizable forces available up to 150lbs

ADDITIONAL OPTIONS ARE ALWAYS BEING ADDED, PLEASE GIVE US A CALL IF YOU NEED A CUSTOM OPTION YOU DO NOT SEE HERE 1-800-676-6123.



```
const int relayPinT = 2;
const int relayPinL = 4;

void setup()
{
  //calibration
  delay(5000);
  pinMode(relayPinT,OUTPUT);
  digitalWrite(relayPinT,HIGH);
  delay(15000);
  digitalWrite(relayPinT,LOW);
  pinMode(relayPinL,OUTPUT);
  digitalWrite(relayPinL,HIGH);
  delay(5000);
  digitalWrite(relayPinL,LOW);
  delay(15000);
  //switch polarity of linear actuators
  //end calibration
  //step one tracks
  pinMode(relayPinT,OUTPUT);
  digitalWrite(relayPinT,HIGH);
  delay(4000);
  digitalWrite(relayPinT,LOW);
  delay(1000);
  //step one linear
  pinMode(relayPinL,OUTPUT);
  digitalWrite(relayPinL,HIGH);
  delay(200);
  digitalWrite(relayPinL,LOW);
  delay(1000);
  //step two tracks
  pinMode(relayPinT,OUTPUT);
  digitalWrite(relayPinT,HIGH);
  delay(1500);
  digitalWrite(relayPinT,LOW);
  //step two linear
  pinMode(relayPinL,OUTPUT);
  digitalWrite(relayPinL,HIGH);
  delay(300);
  digitalWrite(relayPinL,LOW);
  delay(1000);
  //step three track
```

```
pinMode(relayPinT,OUTPUT);
digitalWrite(relayPinT,HIGH);
delay(2500);
digitalWrite(relayPinT,LOW);
//end
pinMode(relayPinL,OUTPUT);
digitalWrite(relayPinL,HIGH);
delay(12000);
digitalWrite(relayPinL,LOW);
delay(20000);
//Switch polarity of tracks and linear actuators
pinMode(relayPinT,OUTPUT);
digitalWrite(relayPinT,HIGH);
delay(22000);
digitalWrite(relayPinT,LOW);
delay(45000);
```

```
}
void loop()
{
```