Operator's Manual

Backpack Lever Arm System

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Backpack Lever Arm System
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**Important Safety Instruction**

⚠ Avoid operating lever arm system in a confined space.

⚠ Avoid operating lever arm system when people or objects are directly behind or to the right of the wheelchair.

⚠ Avoid rain and moisture and harsh conditions.

⚠ Do not put more than 10lb load on the lever arm system.

⚠ Only use professional technicians to perform any repairs to the device.

⚠ When replacing the battery, only use a 6V battery.

⚠ Do not block the lever arm’s path.

⚠ Make sure the switch is “OFF” when the lever arm system is not in use or when battery is disconnected.
Parts and Accessories

Three Limbs:

Hinges:
Top view:
Size view:

Motor 1 (HSR-5995TG):

External Potentiometer
Motor 2 (HS-785HBB):

Attachment to the back of the wheelchair:

Crossover Clamp:
Attachment of the backpack to the lever arm via the clipper:

**Features**

This device features a single switch mechanism (electrical) is used to conveniently position the device at user’s lower thoracic/upper abdominal level for optimal comfort. It will bring an object from the back of the wheelchair to the front as close to user’s midline as possible to allow users have easy access to their belongings.

In a position of non-use, the limbs fold into a compact position at the rear of the client’s wheelchair. A simple ‘ON/OFF’ switch will control the movement of the limbs, which will sequentially unfold to obtain the position desired. The first Limb is securely fastened to the back of the wheelchair. Limbs 2 and 3 rotate (in that order) in a counterclockwise fashion upon client stimulus to bring the backpack into the position desired. The rotating motions are driven by two servo motors that are controlled by a PIC microcontroller.
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1. Introduction

1.1 General Overview

The device is an electrically operated lever arm, capable of moving the client’s belongings to an accessible position. It is designed to operate on the right side of the client with the push of a switch also controlled from the right side.

![Control Box for the Lever Arm System](image)

Figure 1. Control Box for the Lever Arm System

The device is to be attached to the back of a wheelchair with the specific function of carrying a backpack, to the front of the client, precisely to position of the client’s mid-body line. The manner in which this task will be carried out is through a switch that operates the lever arm, composed of three limbs rotating about two hinges, which rotates to carry the backpack secured by a clipper from the back of the wheelchair to the front. Operating this switch again will reverse the motion of the lever arm folding up the limbs to the back of the wheelchair. The rotational motions are driven by two servo motors, Motor 1 (the HSR-5995TG) and Motor 2 (the HS-785HHB), attached at the two hinges.
Specifically, the level arm goes through a sequence of motion to accomplish the goal of bringing the backpack from the back of the wheelchair to the front as close to client’s midline as possible. The following flow chart describes this sequence.

**Figure 2.** Enclosed motors

**Figure 3.** Flow chart of device operation
Figure 4. Closed position

Figure 5. 90 degrees rotation
Due to the fact that this device is designed to be transportable and adaptable to any wheelchair, a quick installation is required. To secure the lever arm system to the back of the wheelchair, the clamps on limb 1 must grip the vertical support beams on the back of the wheelchair. First choose a height that is not only appropriate for the client, but also appropriate to the wheelchair to allow an unobstructed path for the lever arm. Then open the clamps with a Philip head screwdriver and clamp around the support beam. When ready, screw the clamp tightly closed around the beam.
1.2 How to Use

1. Make sure the switch is on “OFF” position.
2. Open the crossover clamp.
3. Place the open part of the crossover clamp around the two vertical bars at the back of the wheelchair at about 6 inches above the arm-rests.

4. Push the two screws on either side of the crossover clamp through the pre-drilled holes on Limb One (there are two sets of holes, please choose the one that are appropriate for the wheelchair)

5. Tighten the two screws on the crossover clamps as much as possible.

6. Place the backpack or bag on the clipper located on limb 1. (limit of 10 lbs)
7. Turn the switch on the top of the control box to “Forward”

8. Push the switch to the “ON” position to bring the backpack from behind the wheelchair to the front.

9. To close the lever arm switch the switch on top of the control box to “reverse” and push the switch again back to the “OFF” position, but only
when the lever arm is fully open (limb 3 should be in front of the wheelchair and the lever arm’s movement is at a halt).
2. Maintenance

**Electrical:**

**Battery:**

When the lever arm system’s ability to effectively carry a backpack diminishes (slow arm movement or signs of excess strain on arm even within the weight limit), it is likely that the battery needs to be replacement. To do so, please buy a new 12V battery pack similar to the one used for the device and remove the old battery pack to plug in the new one.

**Mechanical:**

**Hinges:**

Grease the hinges of the lever arm system periodically to maintain the device’s peak performance. Use only metal-safe lubricant oil to apply to the two hinges located between limbs 1 and 2 and between limbs 2 and 3.

![Figure 7. two hinges](image)
Screws:
Periodically check the lever arm system for any loose screws. Screws are located on each hinge and the crossover clamps connecting limb 1 to the wheelchair. A Philips head screw driver is required. If there are any missing screws, discontinue the operation of the lever arm and disconnect the power supply. Any load that the lever arm system is carrying should be removed promptly. Please refer to the BLANK section for replacing the missing screw with the correct screw.

Cleaning:
Although the lever arm system is resistant to rust, never use any cleaning solutions. Only use a damp cloth to wipe the limbs and avoid any excessive force.
3. Technical Description

The purpose of the Backpack Lever Arm System is to move the client’s belongings from the rear of his wheelchair to the front (at the mid-line position). The unique forward/reverse motion of the device will allow it to return to the collapsed position, allowing convenient storage. The system consists of 3 limbs; 2 of them are moved by Servo Motors Arms (using Pulse-Width Modulation) for the desired motion.

Figure 8. Lever Arm at its closed position
Complete motion of the lever arm system is 270 degree rotation of Motor 1 (the HSR-5995TG) and 90 degree rotation of Motor 2 (the HS-785HHB).

The following section will provide a description of the lever arm system’s mechanical design. As defined here, Limb 1 is fixed to the back of the client’s wheelchair using movable cross-over clamps. This feature enables customization, based on the width of different wheelchairs.
Figure 9. Crossover Clamps

All three limbs are made out of sturdy 80/20 T-slotted profiles that are made from Aluminum. Aluminum is a great material for this device because it is remarkable for its ability to resist corrosion. A thin surface layer of aluminum oxide forms when the metal is exposed to air which prevents further oxidation. This ensures that the lever arm will be able to operate in any weather condition. It is also very light in weight, which is very critical for this project because we want to add as little extra weight to the wheelchair as possible. The addition of the device should not affect the balance of the wheelchair.

The 80/20’s aluminum T-slotted profiles is very easy to work with because it requires no welding, priming or painting. There are also many different accessories provided by 80/20 that makes building the project very convenient. One of the accessories that we used the most was the T-nuts that are placed into the grooves of the T-slots to fasten attachments to the lever arm.

In terms of the Length dimensions, Limb 1 is 22 inches in Length, Limb 2 is 20 inches and Limb 3 is 10 inches. The cross-section of each limb is 1 inch x 1 inch square shaped; the 80/20 material has grooves running along the entire limb. Teflon T-shaped pieces (1 inch x ½ inch) with
threaded 8-32 sized holes are placed inside these grooves, and connected to the motors arms to allow for rotation.

Each hinge is made up of two L-shaped aluminum pieces, a solid aluminum block, a bearing, brass sleeve, two Teflon washers, and a single ¼-20 hexagonal head screw.

**Figure 10.** Side view of the hinges

**Figure 11.** Top View of the hinges
The L-shaped aluminum pieces that rest on the top surface/bottom surfaces are shown below. These provide maximum support in terms of sustaining the load and holding the hinge in place. Each piece is ¼ inches in thickness. The two ¼-20 clearance holes in line of each other have hexagonal head bolts running through the 80/20 material and are secured at the bottom by a nut.

**Figure 12. L-shaped Bars**
Figure 13. L-Shaped Bars

The rectangular-shaped aluminum block is placed in between the two L-shaped pieces on each limb. This is secured to the 80/20 material by two, ¼-20 hexagonal head bolts. These are tightened in place by hexagonal shaped nuts. The dimensions of this piece are 2.75’’ (length) x 1’’ (width) x .5’’ (thickness).

Bearings have been placed within the rectangular block pieces to allow for smooth rotation. Specifically, the bearings are .625’’ (outer diameter) and .250 (inner diameter). Teflon washers rest above and below the bearing. In addition, there is a brass sleeve, 1/3 inches in diameter than is inserted within the aluminum block. The ¼-20 hexagonal head screw runs through this sleeve to ensure that there is a tight fit. This way, negligible movement of parts within the hinge occurs when there is rotation.
The arms of the motors are also made out of aluminum. The design of the arms involves a .6” diameter center hole at the proximal end; this will be connected directly to the top of the motor. In addition, there are four threaded 5-40 holes surrounding this center hole to secure fasten the arm. At the distal end of the arm, there is an 8-32 hole through which a screw will be placed and connected to a Teflon T-shaped piece along the groove of a Limb. When motor rotation occurs, this T-shaped piece will run in either direction depending on the direction of movement.
The motors that are used for this device are servo motors. They were chosen based on the fact that servos move to an absolute angle. Unlike steppers there is no timing that is necessary for the signal. The servos are controlled by pulse with modulation (PWM). By varying the duty cycle of the pulse sent to the motor different angles can be established.

The first motor that was ordered was the SPG 785 gearbox assembly. This setup is based around the HS-785 servo motor. The motor produces 183oz-inches of torque and rotates 3.5 full revolutions. The gear assembly has 4:1 gear ratio bumping torque up to 732oz-inches but cutting the rotation down to 315°. This motor was originally planned for use on the 270° degree rotation of limb 2 around limb 1. However as the project progress we realized that this would not be enough torques for used with the weight of the backpack. Therefore the motor was utilized for the rotation of limb 3 around limb 2.
The second motor ordered was that SPG 5995 Power Servo. This is based around the HSR-5995TG, which produces 258oz-inches and rotates 180°. The gearbox on this assembly is a 5:1 ratio, which boosts torque to 1290oz-inches. However, unlike the SPG 785 this has an external potentiometer, which still allows for full 180° rotation. This unfortunately is still not enough for the rotation of limb 2. So, once the motor was received it was modified by adding two 3.3 KOhm resistors to the leads off of the potentiometer in this way the internal chip receives a lower resistance with the same rotation. This make the motor rotate further with the same duty cycle. The new maximum rotation was roughly 255°. This is enough for our setup to work properly.
In terms of mounting the motors, they have been attached to the L-shaped aluminum pieces and 80/20 material by two 8-32 screws and housed by two plastic boxes to avoid potential injuries to the client.

**Figure 18.** Two Servo Motors Enclos
Finally, the backpack is connected to Limb 3 by a clipper Quickdraw.

**Figure 19.** Backpack Attached to the Lever Arm
The following section will describe the electric circuit design of the backpack lever arm system. Controlling the systematic movements of the device involved programming a PIC microcontroller and designing an optimal electrical circuit to run two servo motors. The device is user-controlled, through the use of 2 switches, one for the forward/reverse motion and the other to turn the device on/off. The forward motion results in Motor 1 rotating 270 degrees in a clockwise direction and Motor 2 rotating 90 degrees in a counterclockwise direction; the reverse motion causes the opposite sequence to occur, bringing the device back into a collapsible position at the back of the wheelchair.

Details of the electrical components will be helpful in case of any debugging issues. In terms of the circuitry and the manner in which the PIC is connected to various important components, pins 32 and 11 are VDD pins, which connect to the 5 V power supply. This is controlled by a voltage regulator. Pins 31 and 12 are VSS, and connected to ground. Pin 33 connects the forward/reverse switch and the LED to make sure that the PIC is powered and has a program on it. The MCLR pin (Pin 1) connects to a switch, which will be used to turn the entire device on or off. Pins 13 and 14 are the oscillators; externally, these are connected by a 4 MHz crystal. Finally, Pins 16 and 17 (RC0 and RC1) are connected to the signal input parts of the motors. In addition, the motors individually must have connections to the power supply and ground.

The following is a list of components that the team used to build the circuit:
- Resistors: 47k, 10k, 470
- Capacitors: 470μF, 100μF, 1μF, .1μF, 22pF
- Oscillator: 4 MHz Crystal
- Switch: SPST
- Microcontroller: PIC16F877

The schematic below shows steady-state voltages when the circuit is powered.
## 4. Troubleshooting

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<th>Problem</th>
<th>Possible Cause</th>
<th>Solution</th>
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</thead>
<tbody>
<tr>
<td>Device does not turn on as indicated by LED not illuminating.</td>
<td>Dead Batteries</td>
<td>Change batteries for full charged ones. Use only 6V batteries.</td>
</tr>
<tr>
<td>Device will not switch from open to close position.</td>
<td>Bad hardware/software.</td>
<td>Check connection between batteries. Turn device on and off to ensure that it is no a software glitch. If this does not resolve the problem return the device to the manufacturer for repair of the position switch.</td>
</tr>
<tr>
<td>Device swings out slower than usual or makes excessive noise.</td>
<td>- Low voltage from low battery power</td>
<td>Try replacing the battery first. If problem persists then loosen the exposed hexagonal bolt. If this does not fix the problem check for clearance between the protective cases and the motor arm.</td>
</tr>
<tr>
<td></td>
<td>- Bad Hinge connection.</td>
<td></td>
</tr>
<tr>
<td><strong>Limb swings out and then immediately swing back.</strong></td>
<td>Obstruction in movement.</td>
<td>Check that there is nothing blocking the motion of the limb as it rotates out. This can include the protective casing, debris in the hinges, blockage from the wheelchair, etc.</td>
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<tr>
<td><strong>Device does not rotate to full open position.</strong></td>
<td>Bad Software</td>
<td>Turn the device off and wait at least 10 seconds before turning it back on. If this does not solve the issue return the device to the manufacturer for software reprogramming.</td>
</tr>
<tr>
<td><strong>One limb rotates but the other does not.</strong></td>
<td>Hardware/Batteries</td>
<td>Change batteries for full charged ones. Remove protective cases and ensure the gears are not excessively worn. Ensure that there is clearance between the case and the motor arm. If problem persists return the device</td>
</tr>
</tbody>
</table>
| **Limbs begin to droop as the device rotates.** | Over weight restriction | to the manufacturer for motor replacement.  
Ensure that the weight guideline is followed for the backpack. (10 lb weight limit)  
Check clamp connection to backpack. |