CHAPTER 15
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Design of a Leftside Handrail for the MTD Bus Company's Wheelchair Lifts

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INTRODUCTION

A Mass Transit District (MTD) in Illinois has received numerous complaints about wheelchair lifts that are installed on approximately half of their buses. MTD services the wheelchair-using community with over 12,000 bus rides per year. The wheelchair-using community complains that they are afraid to use the lift, because they feel unsafe while using it. They have good reason to feel anxious about the lift, for there have been documented cases in which wheelchair users have fallen off the lift when it was in operation. The lift has no left side handrail. Because of their anxiety, many potential MTD riders are staying off the buses. The wheelchair using community has requested that a left railing be placed on the lift to ease their anxiety and provide safer access. The left railing should act as a barrier to insure that people will not fall off the left side of the platform. In addition, the railing should act as a support for those desiring something to grip. Unable to arrive at a solution on how to modify their eight-year-old, obsolete wheelchair lift, MTD sought the help of the University of Illinois Rehabilitation Engineering division.

SUMMARY OF IMPACT

Mr. Patton remarks, "I want to thank you and especially Bill McGrath for your efforts in the design and development of a prototype grab rail addition to the District's EEC wheelchair lifts. As you are aware many handicapped riders have expressed anxiety with using the EEC model 120 wheelchair lift. One of their major concerns is that the EEC lift only offered one grab rail for getting on/off the lift and for stability while riding the lift. From **the** handicapped community's input, this grab rail modification project was implemented. With 50% of the District's wheelchair accessible fleet outfitted with the EEC model 120 lift and with the EEC model 120 lift and with the District carrying over 14,000 wheelchair riders annually, the impact of this grab rail modification could prove to be significant in relieving the anxieties that the wheelchair users have been experiencing. The District is hopeful that this modification will make the use of the MTD more comfortable, safe, and enjoyable for the wheelchair rider."

TECHNICAL DESCRIPTION

The Constraints

1. **The limited accessibility of patrons.** This railing will be used by people who have limited ability to control their limbs and/or torso. Consequently the railing must be easy to reach and maneuver around.

2. **Safety considerations.** Complementing the first constraint, this railing must be safe enough to insure that patrons with a limited ability to control their limbs will not hurt themselves when using this support railing. For example, the railing must have enough clearance from the door so as to assure that people cannot pinch their hand between the railing and the door. Thus, there must be adequate knuckle clearance between the outside door and the railing, or more precisely, room between the outside door and the patron's hand.

3. **Geometric constraints.** The original lift was not designed to have a left railing. The lift itself is a rather complex piece of machinery with many hydraulic tubes, pistons, and support beams running underneath the platform. The underside of the lift is unevenly plated

which added to the difficulty of determining a location for the railing.

4. **Difficulty of navigating a left turn into the body of the bus.** Because of the particular placement of the MTD cash box, wheelchairs are forced to roll over the left comer area of the top stair relative to when a person is walking into the bus. Thus, it would be difficult to mount the railing to this area and still have a railing that could be easily navigated around by a wheelchair.

5. **Minimal width of the lift platform. The** width of the lift is 34". In comparison to wheelchair lifts made today, this lift fails to give the desired width recommended by the National Workshop on Wheelchair Accessibility. In addition to not being wide enough, there already exists a right railing on the lift which narrows the entrance further by 2-1/2". There must exist enough space so as to allow a wheelchair user the area to maneuver through and around the railing. Positioning a left-hand railing that will preserve the remaining minimal width presents a considerable constraint.

6. **Weight considerations.** The platform lift capacity (design load) is six hundred pounds. Thus, the additional railing must be relatively light so as not to cause any significant fatigue to the equipment from additional repeated loadings over time.

7. **Vibration due to bus operation.** Some speeds and road conditions create a low enough frequency to put a base-mounted rail into a vibrating mode with excursions large enough to make fatigue loading a considered factor. A metal plate between the two uprights of the railing may be needed to change the frequency.

8. **Economic considerations.** A goal of this project is to safely solve the problem as inexpensively as possible. MTD is a non-profit organization and will have to modify the wheelchair lifts on approximately one half of their buses.

DESCRIPTION OF HOW THE WHEELCHAIR LIFT OPERATES

The wheelchair lift is hydraulic and is run by two hydraulic pumps that are connected to the oil reservoir of the bus. The platform has a lift capacity of 600 lb. When the wheelchair lift is stowed, it is in the form of steps. Able bodied passengers can then board and exit the bus. The steps unfold into a horizontal platform. The platform can then be lowered and raised to aid the handicapped in boarding and exiting the bus.

ALTERNATIVE LOCATIONS FOR THE LEFTSIDE HANDRAIL

1. **Folding bus door.** The idea of mounting a railing to the folding door was considered. This idea was definitively rejected by a wheelchair user when he tried to reach forward and grab hold of a model rail mounted on the door. The wheelchair user, who is comparatively strong and has excellent control of his torso, was unable to reach forward and support himself. He stated that most, if not all, wheelchair users would be unable to reach up and hold the stationary railing that would be mounted on the door to move along with the platform. It became obvious that the hand railing would have to move along with the platform as the lift was in operation. The railing must not be moving relative to the chair user. Realizing that the railing must be mounted upon the steps that fold out into a platform, efforts were redirected toward finding a mounting location on the steps.

2. **First step.** The first step relative to entering the bus (the lowest step) was considered and then later rejected. The door of the bus completely sweeps across the step when opening and closing. Therefore a railing in this location would impede the operation of the opening and closing of the door.

3. **Third step.** The third (top) step on the wheelchair lift looked to be a promising candidate. There existed a cast iron base (50,000 lb. tensile strength) that existed in the left comer of the step. The current right hand railing is attached to a similar cast iron base on the right side. However, this location **was** rejected, because due to the position of the MTD cash box, wheelchair users must roll over the left corner of the upper step. Two wheelchair users tried

numerous times to avoid this area, but were unsuccessful in all attempts. Unfortunately, this means rolling over the possible railing mounting area upon the iron base.

4. **Second step.** A railing on the second step offered the advantage of not being directly across from the right railing so one gained additional distance between the two railings. Also, **when** looking at the underside of the steps when the lift is in platform mode, one can see that the plating and support beams make it more favorable to mount the railing on the left side of the second step. This location for the railing was found to be approximately four inches from the left side. This allows space so a person does not get his/her hand pinched between the door and the railing, but it is not so far removed as to make maneuvering between the two railings difficult, if not impossible.

THE DESIGN

The reinforcing block: On the underside of the platform, there exists a channel 1" in width that is 2" from the left side of the second step. The channel is used as a web support structure to add support to the lift platform. The channel, like the entire rest of the support plating on the lift, is made of aluminum alloy 6061 T6 (45,000 psi tensile strength with good corrosion resistance). Apparently, nothing enters this channel at any point during the operation of the lift. A student engineer lined the channel with masking tape with the sticky end outward. If any mechanical part entered the channel and touched the tape, the tape would either stick to the entering mechanical mechanism, or the tape would show dirt spots where the machinery entered the channel. Throughout several tests, the tape stayed clean and untampered with in the channel. This led the student engineer to conclude that nothing entered the channel. The proposed design is to reinforce this channel by inserting a 6061 T6 aluminum support block into the channel. Figure 15.1 gives the dimensions of the reinforcing support. The support block should fit snugly against the bottom and walls of the channel. If there is not a snug fit, epoxy should be added to the channel around the edges of the support block.

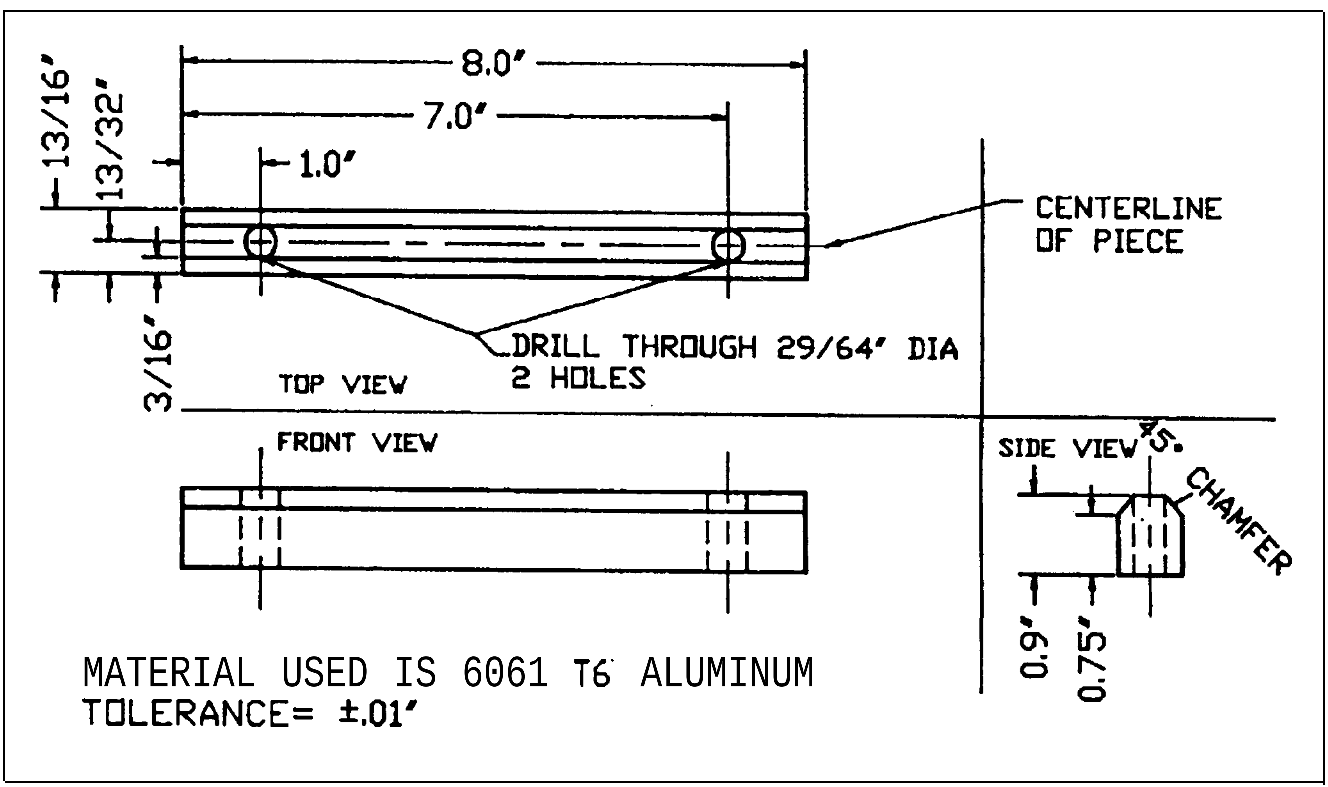

Fig. 15.1. Reinforcing Support.

The base plate: On top of the platform just above the channel and reinforcing block, a supporting plate is placed. Figure 15.2 provides the dimensions for machining the component that will be made out of stainless steel. The material, stainless steel, was chosen because the material provided the durability and corrosion resistance needed by the area. In addition, since the railing tube needed to be of stainless steel, the base was required to be stainless steel so that the railing could be welded to the base. A section of the blue rubber tread will be removed from the steps so as to allow the base plate to lie directly upon the platform aluminum plating. The base plating is 3/8" in height, which is the same as the rubber tread. Thus the base plate will be flush and not sticking up above the rubber tread. This will make the base plate less likely to be tripped over. The support plate provides a base for the railing.

Stainless steel: Type 304 stainless steel was chosen as the material to be used for the base plate, railing, and the foot guard. This is the most widely used of the stainless and heat resisting steels. It offers good corrosion resistance, and more than adequate strength. In addition, it is aesthetically pleasing, because it is a shiny silver and will match the right hand stainless steel railing. Type 304 has very good formability and can be readily welded by all common methods.

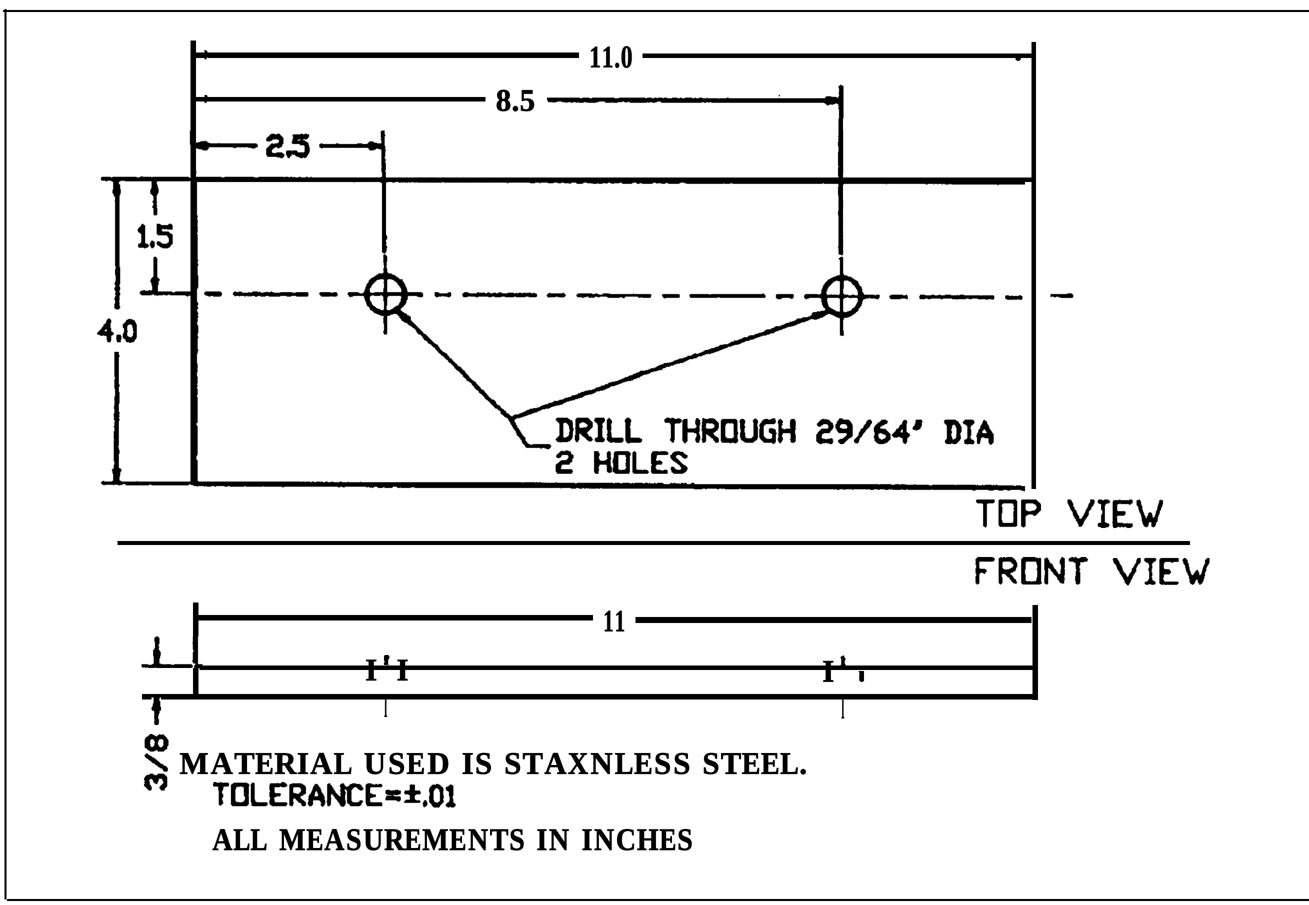

Fig. 15.2. Dimensions for Machining the Component.

The railing: The railing, Figure 15.3, is made from 1.25" diameter seamless stainless steel tubing with a wall thickness of .065". The height of the railing is 31.75". Both the diameter and the height of the rail fall within the specified dimensions recommended in the Guidelines Specifications for Passive Wheelchair Lifts by the National *Workshop on Wheelchair Accessibility.*

The railing has a bend in it to allow more flexibility of angles at which to grip the railing. This was determined by building a few models that experimented with different sizes and shapes. One simple rounded, long bend in the tube, allows for greater flexibility of angles at which to grab the railing but at a comparatively inexpensive cost at which to machine. In machining the railing, it may be easier to cut the railing into sections and then weld the sections together rather than bending the piece to the specified angle. The railing provides adequate (4") knuckle clearance between the railing and left wall and maneuverability space (29.5") between the railing as specified in the *General Specifications for Passive Wheelchair Lifts* by the National Workshop on Wheelchair Accessibility. The recommendation of a minimum clear width of 31" between the handrails at the height of 14" or more could not be met without putting another expensive bend in the tubing towards the left wall and outward relative to the lift, and so this recommendation was not clearly adhered to.

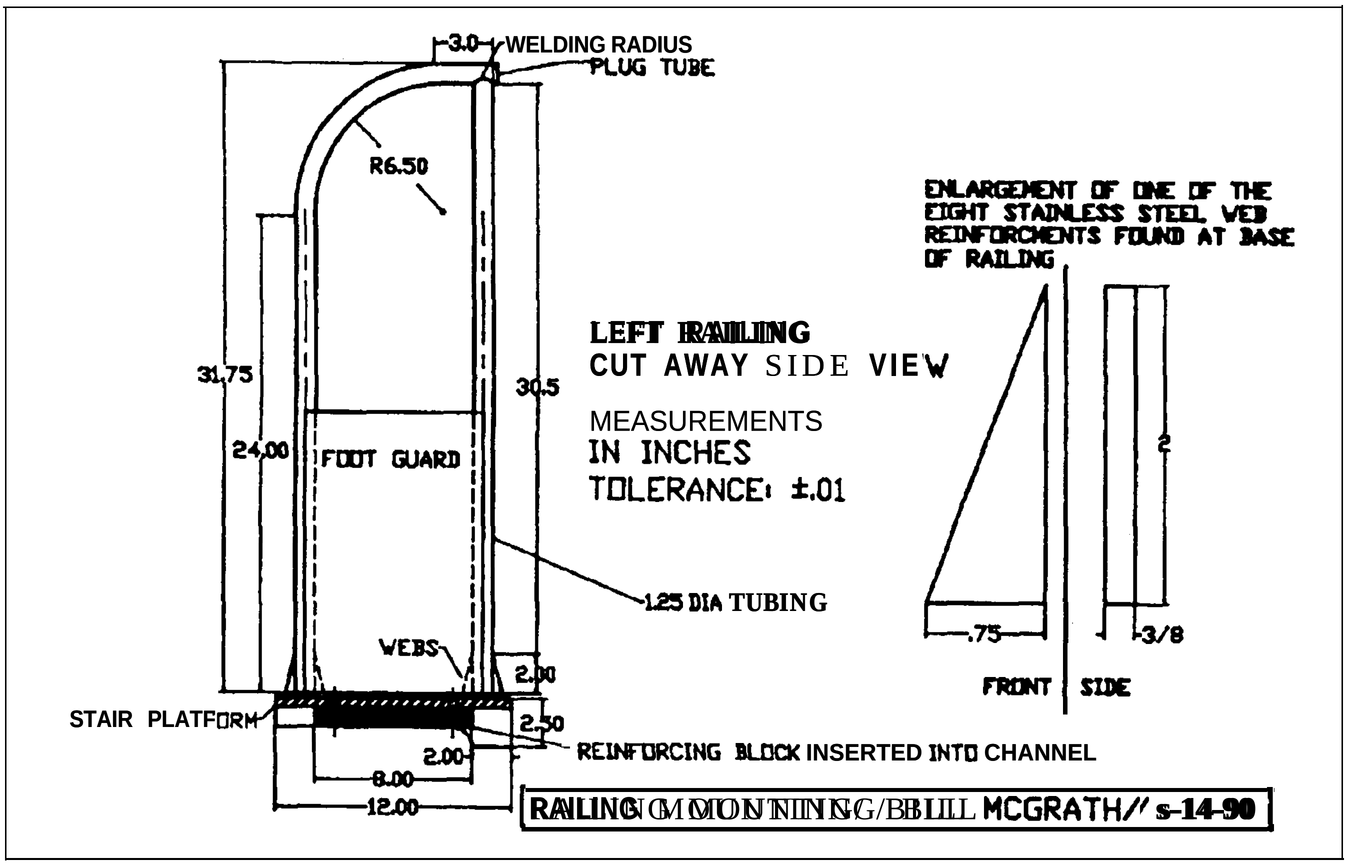

Fig. 15.3. The Railing.

The current left handle located on the door of the MTD bus must be removed. Initially, it was believed that the door handle could be maintained and a lower (26”) railing, designed to be used only by wheelchair users, could be installed to fit just under the current door handle. The lower railing would discourage non-disabled riders from using it, thus avoiding more than necessary wear upon the railing. The lower railing would also reduce the moment arm of the structure, and thus reduce the stresses and material requirements. This design, however, did not turn out as expected. The railing could not fit under the door handle but had to go next to the handle. The handle then acted as a hazard, creating an area of limited knuckle space on the door. As long as the handle remains on the door, there exists the potential problem of people getting their hands pinched between the door and the proposed left hand railing when the wheelchair lift is in operation. Since the door handle must be removed, the railing must be made taller and more sturdy so as to accommodate able-bodied bus riders who would normally use the handle on the door in addition to wheelchair riders.

Foot guard: The foot guard is a 9” x 14” piece of 20 gauge stainless steel sheet metal. The sheet metal is spot welded to the outer side of the railing. The sheet is attached to the side of the railing facing the right side of the lift. The foot guard plate is positioned on the railing to deter people from getting their feet snagged between the railing uprights and thus tripping.

The mounting of the components: The two railing uprights are welded together and then they are welded to the base plate. The minimum tensile strength for a stainless steel weld is 50,000 psi, which is more than adequate. It is recommended that stainless web support triangles are added and placed on the base plate around the railing uprights. A local welding company was consulted for the best welding procedure for stainless steel. The company suggested that pig welding would be best. Two holes are drilled into the wheelchair platform so that two 7/16" bolts may pass from the base plate on top of the platform through the support block that is positioned in the channel underneath the platform. The two 7/16" bolts should be zinc plated of grade 5 and have a length of 2.5”. These bolts offer great strength (74,000 psi) and corrosion resistance because of the zinc plating with the added advantage of being economical at a price of $.41 per bolt. Similarly, zinc plated nylock nuts (lock nuts) which resist vibration cost $.15 per nut. Stainless steel bolts can be substituted but at considerably more cost $3.22 per bolt.) External tooth lock washers should also be purchased to aid in resisting vibrations that may unfasten the nuts and bolts.

SOME BASIC CALCULATIONS

Calculation of the stresses in welds:

$$S = \frac{5.66M}{bD^2} = \frac{5.66 \times (32" \times 100\ lb.)}{\frac{1}{8}" \times 3.14159 \times (1.25")^2} = 29,517.97\ psi$$

S = stress in weld (in lbs/in^2)

M = bending moment of railing (in inch-lbs)

D = outer diameter of tubing (in inches)

b = fillet weld length (in inches)

Evaluation of calculated stresses: “The handrails should be capable of withstanding a horizontal force of 100 lb. concentrated at any point without permanent visible deformation” (section 2.2.7.3 of Guidelines Specifications for Passive Wheelchair Lifts by the *National Workshop on Wheelchair Accessibility).* This calculation estimates that the stress in one weld from the application of a 100 lb. force will result in a weld stress of 29,517.97 psi. Since there are two upright tubes in the proposed railing design and, thus, two welds, one at east of the tube bases, the calculated weld stress for each weld is actually half (14,759.0 psi) of the stress calculated, because the force is distributed between the two upright tubes. The minimum tensile strength for a stainless steel weld is 50,000 psi that provides adequate strength.

Safety factor = 50,000 psi/14,759 psi = 3.4

This seems to be a reasonable safety factor to maintain.

Finite element modeling. The locations and the magnitudes of the stresses upon the railing were determined using INERTIA, a finite element analysis software package. A 100 lb. load was applied from the right to the left upon the modeled railing.

The areas of tension and compression were in their expected places. The highest tension value was 2,166.28 psi and the highest compression value was of 2,571.47 psi.

COSTS

MATERIALS	COSTS
6' type 304 stainless steel seamless tubing with 1.25" outer diameter / .065" wall thickness	$177.00
4" x 11" x 3/8" plate of type 304 stainless steel	$57.50
1" x 1" x 9" piece of 6061 T6 aluminum	$34.80
14" x 12" sheet of gauge 20 type 304 stainless steel with a rough finish	$25.00
2-7/16" zinc plated grade 5 bolts with a length of 2.5"	$0.82
2 zinc plated 7/16" nuts	$0.28
2 external toothed lock washers	$0.50
Protyping Expenses	$200.00
TOTAL	$495.90

Fig. 15.4. Leftside Handrail for the MTD.

Design of an Upper Body Aerobic Unit for Nursing Home Residents

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INTRODUCTION

The Champaign County Nursing Home wanted to improve the fitness program available to their residents. The intent of this new piece of equipment was to maintain and increase the residents' arm strength and shoulder range of motion. In the therapists' opinion, the residents would benefit most if the exercise unit included an adjustable handle, varying resistance, and a feedback mechanism. The resulting design fulfilled all the requirements and is accessible from a wheelchair.

SUMMARY OF IMPACT

The device has many benefits that address:

- Eye-hand coordination
- Range of motion for the elbows, and shoulders
- Hand grip/strengthening
- Upper body/extremity endurance, and
- Trunk strengthening (for those who choose to lean forward away from the support of their wheelchair.)

TECHNICAL DESCRIPTION

The Constraints:

1. **Accessibility.** All users of this machine will be in wheelchairs. This requires consideration when designing for height and width of the unit.
2. **Self-servicing.** Although residents must pass an evaluation proving their maneuverability to use the exercise room, some residents' ability to perform detailed tasks is limited. The machine must therefore be simple to adjust and operate.
3. **State Regulations.** State regulations prohibit the use of electrical extension cords. With no outlet in close proximity to the space available for the machine, no electrical components could be utilized.
4. **Safety.** The design of the machine must be safe in order to minimize the chance of injury. One specific requirement was that the unit must be stationary when in use.
5. **Preferred options.** The following qualities were desired by the physical therapists in the final design of the unit.
   - **Feedback.** A feedback device should monitor performance and provide an indication of improvement. Any feedback mechanism would be unique in the exercise room and would increase the motivation to use the machine.
   - **Adjustable handle.** An important aspect of the unit is to improve shoulder range of motion. This can be accomplished by providing handles that can change the diameter of the path of rotation.
   - **Varying resistance.** A varying resistance would do two things. First, it would allow the unit to accommodate residents with different strength capacities. Second, it would provide an opportunity to increase arm strength.

Operation of the Exercise Unit

The exercise unit is operated by rotating the handles in a hand-bicycle fashion. The circular path of the handles can be altered to increase shoulder range of motion. The resistance is controlled by turning a knob located on the front panel. A timer is placed on top of the panel to provide timed feedback (see photograph).

Components of the Exercise Unit

Base. The base was designed to accommodate a wheelchair approaching from the front. The back legs are slanted to create ample room for leg extension. The base is constructed with ASTM A500-grade B cold-formed, welded 1" square steel tubing. This steel was selected for its high strength to weight ratio, low cost, and machineability. All the joints were assembled by welding. Four feet of the same material was added for stability and to allow the unit to be anchored.

Shaft and Wheel. Connecting the halves of the base is a 0.5” diameter aluminum rod 12” in length. This shaft is supported by pillow blocks that are bolted to the top of the base halves. At the center of the shaft, a 8” diameter wheel is fixed by a shaft collar so both rotate in unison. This wheel is where the resistance is applied.

Handles. The arm of the handle is 1” square aluminum tubing with a .125" wall and is attached to the shaft by a 10" x 32” x 1.25” bolt. The arm has 0.5” diameter holes drilled at distances of 2.5",3.5", and 5.5” from the shaft. This provides for three distinct handle locations. There is also a .25" slot connecting the holes which allows the handle to slide from one position to another. The handle itself is composed of a plastic housing around a .5" diameter steel stud. A second stud also incorporated in the handle design is a .25" x 20” x 2” threaded steel stud which is screwed into the end of the first stud. A .5" diameter circular steel retainer is threaded onto the end of the second stud to retain a spring and two washers. The first stud acts as a neck that fits into the holes of the arm. Once installed, the handle is adjusted by pulling it, sliding it to the desired location, and reinserting the handle. The spring is present to keep the handle within the arm and to allow the handle to be pulled out (but only to a certain point). To shield the hand from moving parts, a 3” diameter .25" thick PVC disc is press fitted onto the handle neck. A cotton belt is also fitted onto the neck to secure the hand while in motion (see photograph).

Resistance. To add resistance, a 2” diameter rubber roller is pressed against the rotating wheel. The roller is held in place by two 4.25” x 1” x 25” aluminum bars. At the other end of the connecting bars is a .5" diameter aluminum rod. Through this rod a plastic knob and a .25" x 20” x 2.25” threaded rod is screwed. The bars pivot about a fixed center .5" rod held in place by two .25" aluminum supports. When the knob is turned, the threads on the bolt force the top pin to move in one direction while the roller moves in the opposite direction.

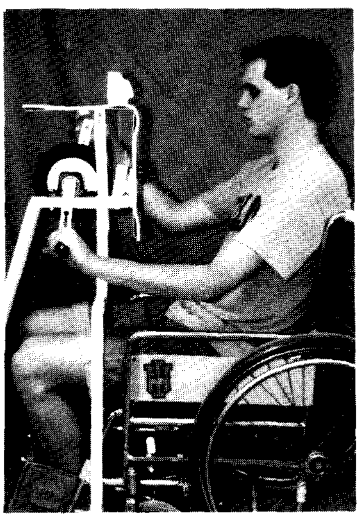

Fig. 15.5. Upper Body Aerobic Unit.

Feedback. The feedback implemented is a timer used to monitor endurance and improvement.

Panel and Supports. Encasing the shaft and wheel structure is a 1/16" thick sheet of aluminum. This acts as a shield against moving parts as well as a support for the resistance and timing mechanisms. The bottom of the panel is connected to the front of the base while the top is joined by supports stemming from the top of the base. To aid the panel in supporting the resistance mechanism, a 9.5” x 3" x .25" rectangular aluminum bar is fixed in front of the base and aligned with the triangle supports.

Calculations

Leg buckling: $$Pcr = \frac{\pi^2 EI}{Le^2}$$

Pcr = smallest critical load for the column (lbs)
E = modulus of elasticity psi)
I = moment of inertia (in^6)
Le = effective length (in)

The critical load is calculated using a steel modulus of elasticity (30 x 10^6psi). The effective length for a column fixed at the base and free at the upper end is 2L (53 in). The moment of inertia for a hollow box is equal to the difference between the moments of inertia of the two rectangles (.05697 in^4). With these values, the resulting critical load is 6005.0 lbs. Even in a maximum case of 200 lbs, the four legs will more than sufficiently accommodate. A similar calculation was performed on the aluminum panel support (6” x 1" x .25" rectangular bar). The smallest critical load for the supports is 892 lbs. With two supports being used, ample strength is achieved. Other factors considered were as follows:

- bending horizontal portion of base
- compression base and supports
- torsion shaft

Visual Fire Alarm for the Hearing Impaired

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Supervising Professor: Dr. Mark Strauss
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INTRODUCTION

In some rural schools, especially older ones, the fire alarm systems have audible, but in certain locations, no visual alarms. This clearly poses a risk to deaf students, but the cost to add visual alarms to an existing building can be prohibitively expensive. Thus a system was designed in which an existing alarm system could be supplemented with a radio frequency transmitter-receiver pair. The transmitter was stationary and activated by the fire alarm panel, and the receiver was to be worn by the deaf students. The receiver required certain modifications to emit either a flashing light or a vibration when the alarm sounded.

SUMMARY OF IMPACT

An obvious problem exists when a hearing impaired child attends a school that does not have a modem fire alarm system. A potential exists where the child could be at a location in the school, such as the library or rest room, where the child could not be prompted by others who have normal hearing and who could respond to the audible alarms. The design described in this report would have met the need of alerting a deaf child of the activation of the fire alarm system. Unfortunately, the alarm company refused to allow this device to be hooked into their system.

TECHNICAL DESCRIPTION

A Radio Shack car alarm transmitter and receiver pair was used on the basis of cost, availability, and effectiveness over the intended range. The transmitter was designed to be attached to the fire alarm using a relay supplied by the fire alarm company and a 12V supply (which powered the transmitter). The receiver portion emits a high-pitched pulsed audible alarm and pulses a small LED when activated; since neither was adequate by itself to alert a deaf person, the primary design focus was adapting the alarm to provide an effective means of alerting the student. The first alerting mechanism considered was a bright, flashing light. If successful, the student could see the alarm even if the unit was removed and placed on the desk or floor. A camera flash unit was obtained from a service shop and appropriate circuitry designed to drive it (Figure 15.6). The circuit was designed to flash once per second when the alarm went off.

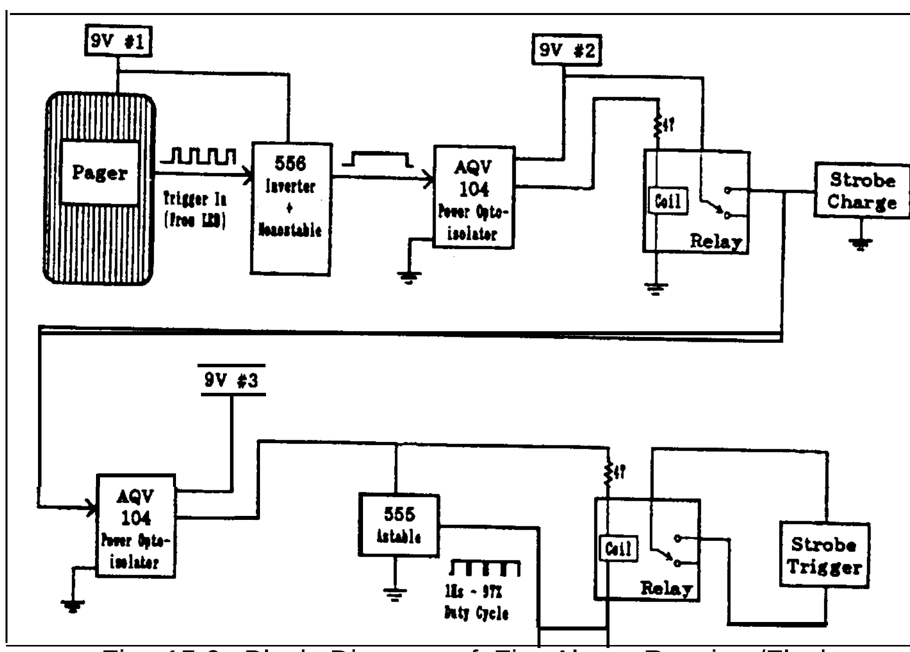

Fig. 15.6. Block Diagram of Fire-Alarm Receiver/Flash Circuit. Note that all relays are shown in the normally closed position; relays are 5VDC, 2A/125V; all resistors are 1/8 Watt; passive timing components for the two 555's are not shown.

The flash circuit consists of the camera flash, two optoisolators, an LM555 mono/astable oscillator, an LM556 (dual 555), two relays, and some external components for timing. The output of the receiver (obtained by tapping into the receiver circuit) was a normally-OV, pulsed 9V signal. This signal (Trigger) was fed into the LM556, which used one of its 555's as a simple inverter, providing a 9V default voltage and a negative-going trigger. The second half of the LM556 was set up as a one-shot and provided a 2-3 second constant pulse to drive the optoisolator. This activated the first relay, which activated the flash charging circuit; it also activated (through the second optoisolator) the LM555, which was set up to provide brief ON pulses every second (1 Hz). These pulses triggered the second relay, which provided the necessary switch closure to light the flash.

Although the circuit worked as designed, it had certain undesirable characteristics. First, it called for three separate 9V batteries: one for the receiver, one for the pulsing circuit, and one to charge the flash. These were necessary because the flash battery voltage fluctuated so greatly when charging that it was unreliable to use in the other stages, and the pulsing circuitry used considerable current and drove inductive loads (the relays), so it was undesirable to use the receiver battery for this purpose. The second undesirable characteristic was its size, owing to the three-circuit-board flash circuit, the flash capacitor, and the three batteries. Third, the flash charger drew so much current that even with an alkaline battery, simply testing the unit each day (4-5 flashes) would wear the charger battery down within a week. A number of alternatives were investigated, including a rechargeable battery system or switching to a vibrating element. For a number of reasons, foremost the simplicity, size reduction, and current reduction, it was decided to design a vibrating alert instead.

A call to Motorola, which makes vibrating pagers, revealed that a tiny (7/8" x 1/4" diameter), offset-weight motor was available for the vibrating element. This motor drew only 100mA at 1V and provided adequate vibration. Two circuits were designed to drive it. The first which used a second battery to drive the motor used a rectifying circuit to drive an optoisolator. When it was determined that the motor was a fairly clean load, the circuit was changed to one that used the receiver's 9V battery instead. This second circuit is shown in Figure 15.7.

The circuit of Figure 15.7 is a two-stage design. The first stage is a simple rectification/one-shot circuit, consisting of a diode (1N914), a resistor (1.5MΩ), and a capacitor (0.47μF). Each time the receiver pulses (that is, when it is activated), it charges the capacitor, which, combined with the 1.5MΩ resistor, has a time constant of about 0.75s. The voltage from the first stage is fed to the second, driver, stage. The second stage uses the capacitor voltage to drive the MOSFET (MTD6N08-1) gate through a 2.2K resistor, which in turn grounds the motor lead through 30 ohms current-limiting resistance. The input impedance of the MOSFET effectively isolates the motor from the rest of the circuitry. The advantage of this circuit is simplicity, size, extremely high input impedance (1MΩ), and low cost (no relays or optoisolators). The total parts cost for the visual fire alarm is $161.

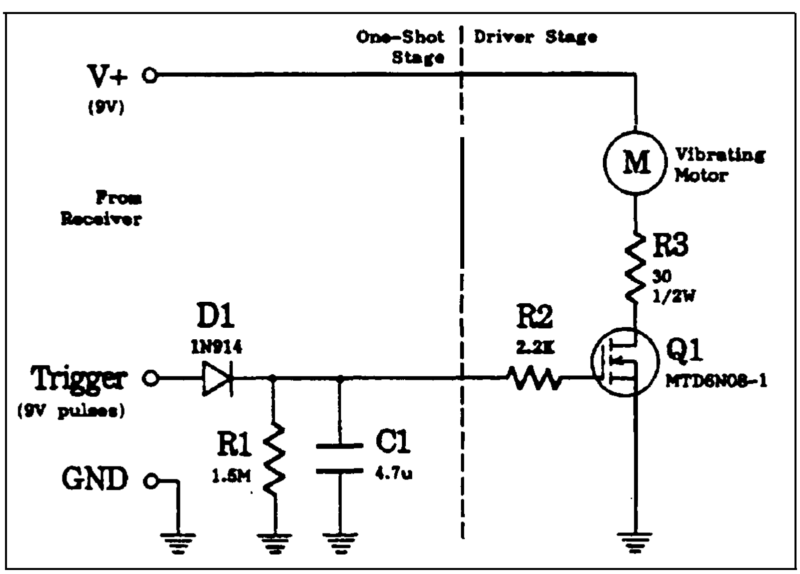

Fig. 15.7. Vibrator Driver Schematic.

A Remote Pager System for a Nurse-call Console

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INTRODUCTION

The Beckwith Living Center in Champaign, Illinois, offers specialized housing to students with disabilities. While preserving a "dormitory-like" atmosphere, Beckwith is able to provide food, maid, and nursing services to all of its students. Students may enlist the aid of a nurse at any time by simply pressing a conveniently located button in their room. This button activates a nurse-call console in the nurses' station that begins to sound a buzzer and flash a light corresponding to the room number of the student requesting assistance. However, a dangerous situation may present itself in which a student may desire aid at a time when the nurse on call may be reporting to another call (or may be away from the nurses' station for some other reason). Our solution to this problem was to interface a radio transmitter to the nurse-call console. This radio transmitter could then cause a remote pager to beep upon activation of the nurse-call console, serving as a signal to the nurse on call that another student is in need of help.

SUMMARY OF IMPACT

The addition of the remote pager system to the nurse-call console makes the system much more flexible. In addition, it allows the nurse on call to perform other functions. Furthermore, it eliminates the necessity of the nurse's presence in the nurses' station at all times while still allowing the nurse to constantly monitor the status of the students while he/she is doing his/her rounds, reporting to a call, or performing other tasks outside the nurses' station.

TECHNICAL DESCRIPTION

The interface circuit is triggered off the nurses' station console warning buzzer and toggles a 74LS74 D-type flip-flop into a high state. The high output of the D-type flip-flop is then used to activate a P-channel MOSFET (Motorola MTP2P50) which subsequently switches power to the transmitter. The transmitter has been hardwired into a constant transmit mode and upon receiving power will transmit the RF signal through a rubber whip antenna (Realistic Universal Top Mount Antenna #12-1331) which offers a safe and flexible mast while providing respectable transmission characteristics. The transmitted RF signal will activate the remote receiver at a maximum range of approximately 2.0 miles (terrain and condition dependent).

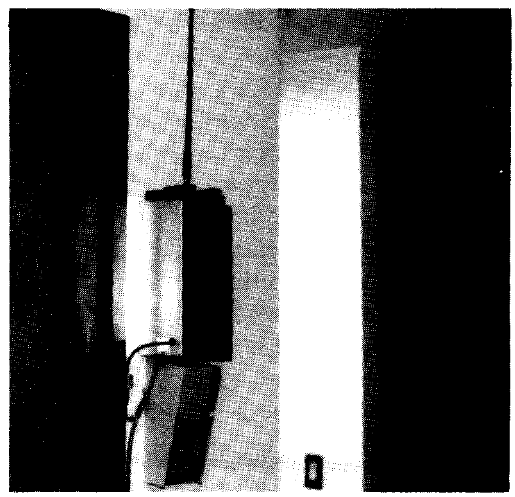
Fig. 15.8. Remote Pager System.

The first design protocol was to determine the appropriate interface input signal that could be utilized from the nurse-call console. Since the buzzer is always initiated for any call and its input wires were easily accessible, the nurse-call console's output to its buzzer was chosen as the activation signal for the nurse-call console interface. However, there were four inherent problems with this signal. First, the amplitude of the signal was approximately 9 V, and thus incompatible with standard TTL circuits. This was easily corrected by utilizing a National Semiconductor LM7805 5 V voltage regulator to effectively down scale the signal to appropriate TTL levels. Second, the buzzer output displayed a tendency to drop below 0 V (possibly caused by driving the reactive load presented by the buzzer coil) which could damage the TTL IC's. To avoid such a problem, a diode was used to clamp the output of the regulator to within approximately 0.7 V of ground. Third, the rise and fall times of the output signal were relatively slow. Unfortunately, the D-type flip-flop utilized in this circuit is edged-triggered and requires fast rising edges for reliable operation. Therefore it was necessary to use a logic element possessing a Schmitt trigger which could generate an output with a fast edge even with a slowly changing input signal. Since a debouncing circuit was also necessary for the reset switch, the National Semiconductor 74LS132 Quad two-input NAND Schmitt trigger IC was used. Two NAND gates were each set up in an inverter configuration and wired in series to provide a time delay. The output of the second NAND gate can then be fed directly to the clock input of the D-type flip-flop. Fourth, as one would expect, the buzzer output signal was extremely noisy. However, implementation of the Schmitt trigger NAND's also helped to reduce the noise problem because they possess better noise immunity than conventional gates.

After propagation through the voltage regulator and the NAND gates, the conditioned buzzer signal is fed into a D-type flip-flop. This flip-flop simply acts as a register that toggles high upon receiving the first rising edge of the conditioned buzzer signal and remains high until the flip-flop is reset manually. This toggle is easily implemented by tying the D input and the pre-set (active low) high through 10 KΩ pull-up resistors and feeding the conditioned buzzer signal into the clock input of the D-type flip-flop. Thus, any subsequent signal inputs after the initial rising edge will not alter the output of the flip-flop. The flip-flop remains in the "high state" until it receives an active-low clear signal that will cause it to return low (the initial pre-set). Since the clear signal overrides the clock inputs, it is advisable to debounce the clear/reset switch in order to avoid inadvertent clearing of another incoming buzzer signal. The debouncing circuit consists of the 2 remaining NAND gates from the 74LS132 connected in a standard latch configuration and wired to a SPDT push-button switch. The additional output current of a DSO026 MOS Clock Driver was used to interface the flip-flop to the P-MOSFET.

The P-channel MOSFET is simply used to switch the 12V power supply to the positive power terminal of the radio transmitter (Radio Shack #49-791). Although more expensive than an N-channel MOSFET, the P-channel MOSFET allows a simple power up configuration for the radio transmitter. The floating ground switchable to ground configuration utilizing an N-channel MOSFET could not be used because the ground return provided by the antenna ground will cause the output transistor of the radio transmitter to go into a "lock-up" mode and eventually become inoperable. The 12-volt power bus is supplied by a 12 V International Power Open Frame power supply and directly feeds the transmitter upon activation of the MOSFET. The TTL IC's power bus is supplied by another National Semiconductor LM7805 5 V voltage regulator that is powered by the 12 V power bus. Substantial decoupling in the form of a 220 μF Tantalex and a 0.1 μF Ceramic capacitor at each IC are provided in order to reduce noise present on the TTL power bus (See Figure 15.9). The cost of the project was $179.

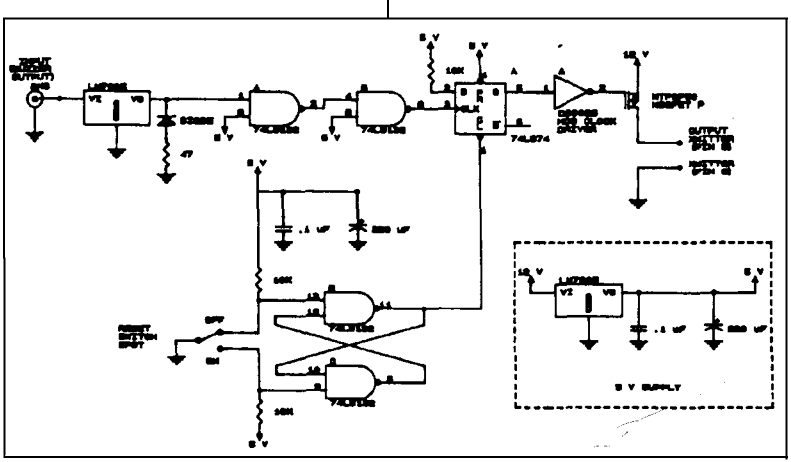

Fig. 15.9. Circuit Diagram for the Remote Pager System for a Nurse-Call Console.

Voice Amplifier

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INTRODUCTION

A voice amplifier and speaker are used by an individual with quadriplegia and damaged vocal cords to enhance his speaking voice, which is normally too quiet to easily hear. The speaker and amplifier are designed to mount onto and receive power from an electric wheelchair. A headset microphone is used to transmit his voice to the amplifier/speaker assembly. The only control required for this unit is a switch to select for ON or OFF. The main considerations in the design of the voice amplifier are good sound quality, aesthetics, and ease of operation/maintenance.

SUMMARY OF IMPACT

The voice amplifier, as shown in Figures 15.10 and 15.11, allows an individual with limited voice output to communicate with others. The sound quality, aesthetics and ease of operation are appropriate for it's intended use.

TECHNICAL DESCRIPTION

A 3.5" Realistic speaker ($15) is coupled with a National Semiconductor LM380L 2-watt audio amplifier to produce an amplified speaking voice for a speech impaired individual. This speaker is designed for automobile applications and thus has a number of desirable qualities. Namely, it is made with a plastic cone that is water resistant and more durable than the paper cones found in most loudspeakers. Also, since limited space is available for mounting the speaker, a small diameter but high sound quality unit is desirable. A handmade oak cabinet is used to contain both the speaker and amplifier; this is mounted underneath the right armrest of the wheelchair.

Fig. 15.10. Headset Microphone.

The selection of the amplifier was also dependent upon the size restrictions. The LM380 is packaged in a 14 pin DIP chip, which is quite small and easy to work with. LM380L 2-watt audio amplifier produces enough amplification for a loud talking voice. The 0.8 watt LM386 amplifier was rejected for this project because it was not powerful enough; while several higher wattage amplifier chips are also available from National Semiconductor, more power is not needed so these are not used either, but would be suitable as alternatives.

The ARM71 Headset Microphone ($149.00) was chosen for its excellent sound quality and attractive appearance. This model is often used on stage by vocal performers for the same reasons. Also, this headset is very comfortable for an individual to wear for extended periods of time, and has little problem with feedback because of its highly directional condenser microphone. A built-in miniature gooseneck allows the microphone to be easily positioned in space near the user's mouth.

A transformer is added to the output of the headset to boost the impedance from 50Ω to 250 KR. This provides a better impedance match to the 150 KΩ input resistance of the LM380 amplifier and thus a louder output volume.

The other components of this project consist of an LM317 voltage regulator, DPDT switch, and some miscellaneous electronic parts: resistors and capacitors ($6.00). The voltage regulator is used in order to provide the 1.5V needed by the headset, which replaces its 1.5V size AA battery. By using the voltage regulator, the headset can be powered from the wheelchair and not be dependent upon disposable batteries. A circuit diagram is shown below.

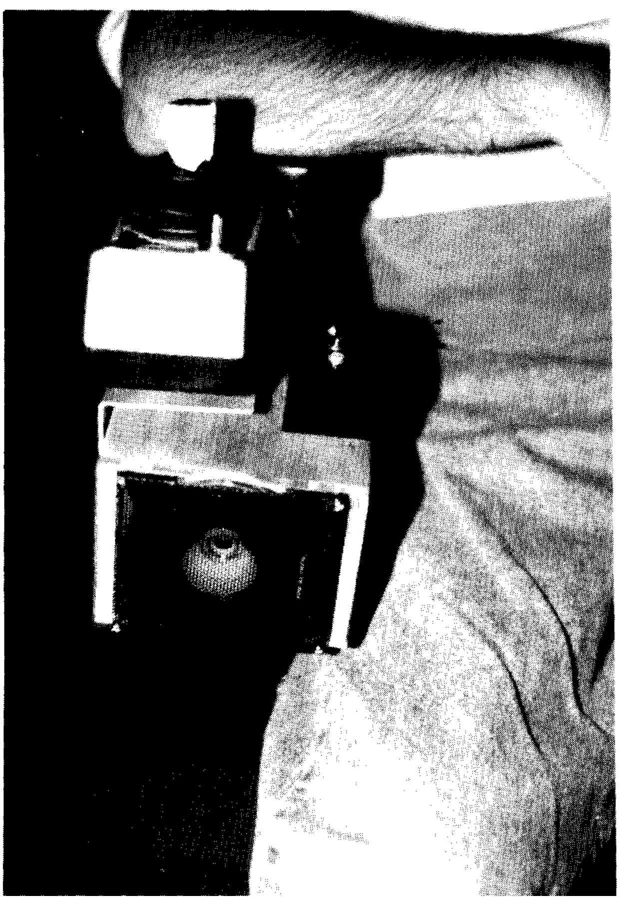

Fig. 15.11. Wheel Chair Components for the Voice Amplifer.

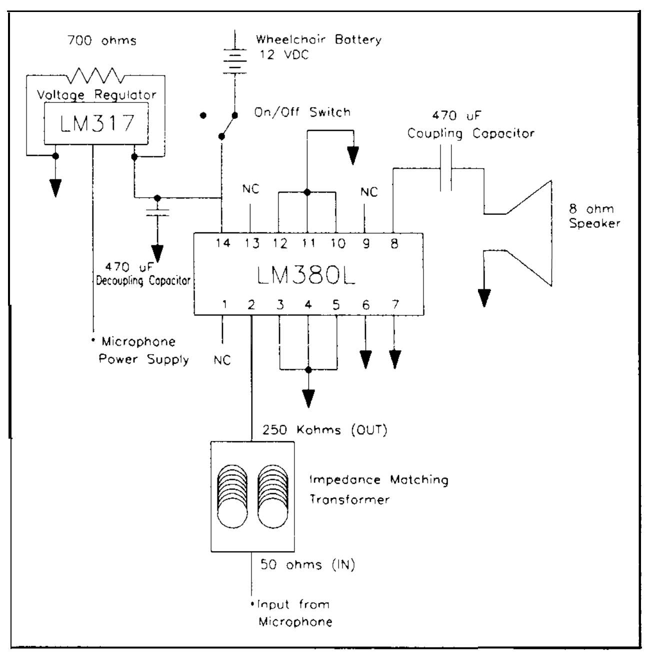

Fig. 15.12. Circuit Diagram for the Voice Amplifier