CHAPTER 10
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An Extended Bilateral Balance Platform

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INTRODUCTION

Gait training for many children with Cerebral palsy includes the need to learn to provide equal force with each foot during the gait cycle. To facilitate this training it was desired to have a system that would provide visual and/or audible feedback to the child that was keyed to the application, during walking, of a predetermined force with each foot. The requirements were that the user should be free from wearing any device and that it should be functional over several steps. The solution arrived at is the extended bilateral balance platform (Figure 10.1). This system provides vertical force indication for each foot over a walking distance of six feet. The therapist is provided with a direct analog reading of the applied with each step. The therapist can also set predetermined force levels as goals for each foot. When the predetermined force is reached the system provides dual relay closures so that any external feedback device can be triggered.

The system designed is a variation on force plate technology, with specific features appropriate to this application. Modem force plates typically provide three axes of force measurement and, in some cases, moments. These force plates are generally of a size that accommodates only one step by one foot. Several force plates would therefore be required to obtain multiple steps of each foot. This would be cost prohibitive since such force plates are very expensive. Another related technology is bilateral balance measuring systems. These systems give dual foot readings but are designed for use by a standing rather than walking subject.

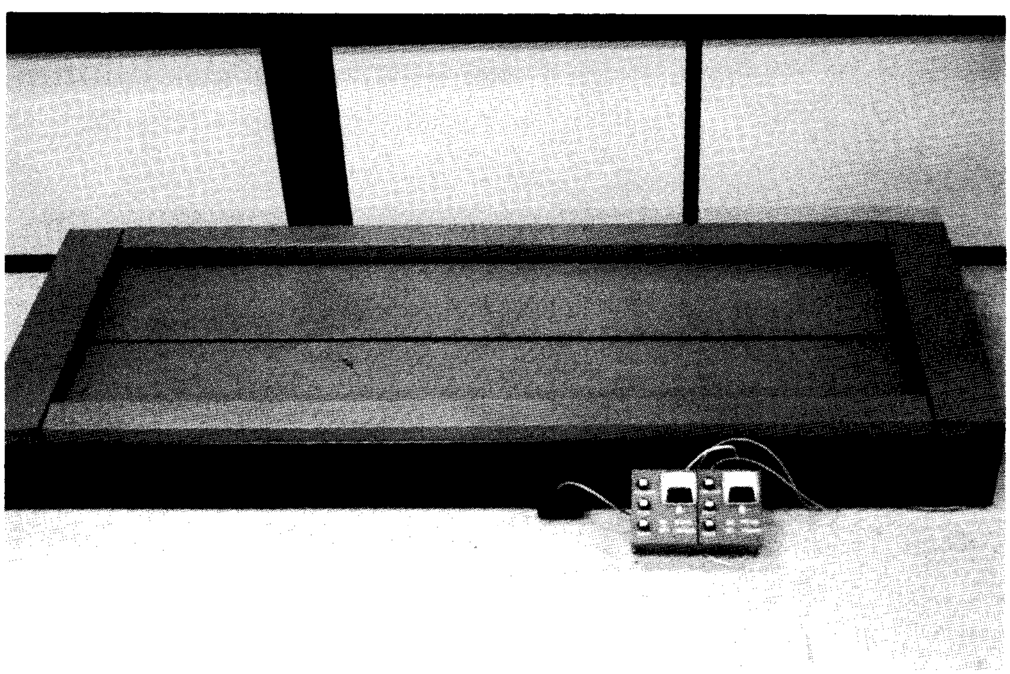

Fig.1 0.1. Photograph of complete system

SUMMARY OF IMPACT

The development of a physiologically and psychologically effective gait is a major goal for children with Cerebral palsy and other neurological and orthopedic challenges. It has been found through other work in physical and occupational therapy that the provision of attractive and stimulating feedback during a therapy task can significantly improve the subjects active participation and performance. Moreover, the ability to measure the activity "on line", rather than rely only on visual observation, provides the therapist with improved tools for quantifying performance and progress. The system described here is currently in use in the physical therapy department at UCP of Greater Houston. Initial use of the system has confirmed its utility in adding a new dimension to gait training.

TECHNICAL DESCRIPTION

The technical specifications developed for this project are listed below.

- Only vertical force is required.
- O-75 pound operating range.
- 300 pound overload capacity is required.
- The device must be easy to calibrate, have instantaneous readout, and have an adjustable threshold with standard jack outputs.
- The device must be bilateral, with reasonable accuracy and repeatability, and acceptable cost.

Force Sensing: The first issue pursued was force sensing components and the configuration of the system such that vertical force could be measured over a six foot length. The latter issue was resolved by constructing a stiff six foot by one foot beam for each foot from 2 x 12 lumber with 2 x 4 stiffeners attached to the bottom. Vertical force sensors at each end of the beam would then be summed to give the applied vertical force independent of the position of the foot along the walkway. Available commercial load cells were investigated, but were found to be prohibitively expensive, especially considering the number needed for the entire design equals a minimum of four, and possibly as many as eight if mounting limitations would have required support at the four corners of each beam. Without the use of commercial load cells, it was decided to build uniaxial force sensors using strain gages attached to "dog bone" shaped aluminum hangers located at each comer of each beam. The dimensions of the hangers were determined to maximize sensitivity in the O-75 pound range while also providing the required overload protection. Further details of the design and testing of the hangers are given in Figures 10.6 and 10.7.

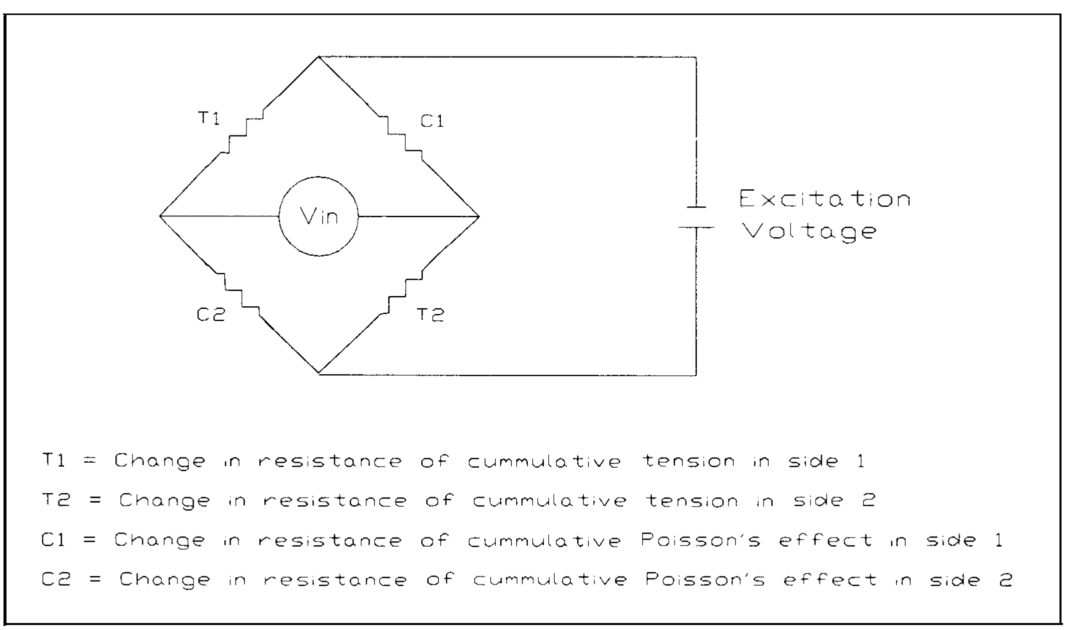

Fig. 10.2. Wheatstone Bridge Circuit for each Hanger.

The strain gages selected were CEA-13-125 UT 120's from Measurement Group, Inc. These gages are specifically manufactured for aluminum. Each unit consists of two gages in a T configuration. Two units (four gages) were used for each hanger, one on each side. Theses four gages were arranged in a Wheatstone bridge as shown in Figure 10.2. This design provides magnification of the desired axial tension, and cancellation of pure bending around a horizontal axis parallel to the plane of the hangers. The hangers are extremely stiff with respect to bending about a horizontal axis perpendicular to the plane of the hanger, and therefore strains associated with this direction of bending were not significant. Two potentiometers, for coarse and fine adjustments respectively, were provided across one leg of each bridge for initial and occasional balancing. In operation the imbalance of each bridge is proportional to the vertical force on that corner of the beam. The signal from each of the four bridges for each beam are summed to represent the total vertical force.

Electronics: In principle the bridge circuits are quite simple. A constant input voltage is supplied and the current or voltage difference that results from the bridge becoming unbalanced is obtained. The additional circuit features required included display of the total imbalance (force) on each beam, comparison of this force to a user selected target force, triggering of an external display when the target force is exceeded, and user operated zero and calibration controls. While straight forward in principle, several iterations were required before a system of adequate performance was obtained. The first design used DC to excite the bridges, with subsequent gain stages and comparator circuits. This approach was abandoned because of excessive DC drift. The second design used AC excitation and a three op-amp instrumentation amplifier and comparator. This design was plagued by a low Common Mode Rejection Ration and excessive noise. The final design (Figures 10.3 and 10.4) used high quality chips to improve the performance of the amplifier (AD624 Instrumentation Amplifier with variable gain) and the power supply (AD736 RMS to DC converter). A gain of 1000 was found to produce a suitable signal and a CMRR of 120 dB was realized. The converter was followed by a 1 Hz passive low pass filter and a voltage follower to isolate this part of the system. A summer amp was used to provide variable gain and the ability to manually zero the bridges to account for the weight

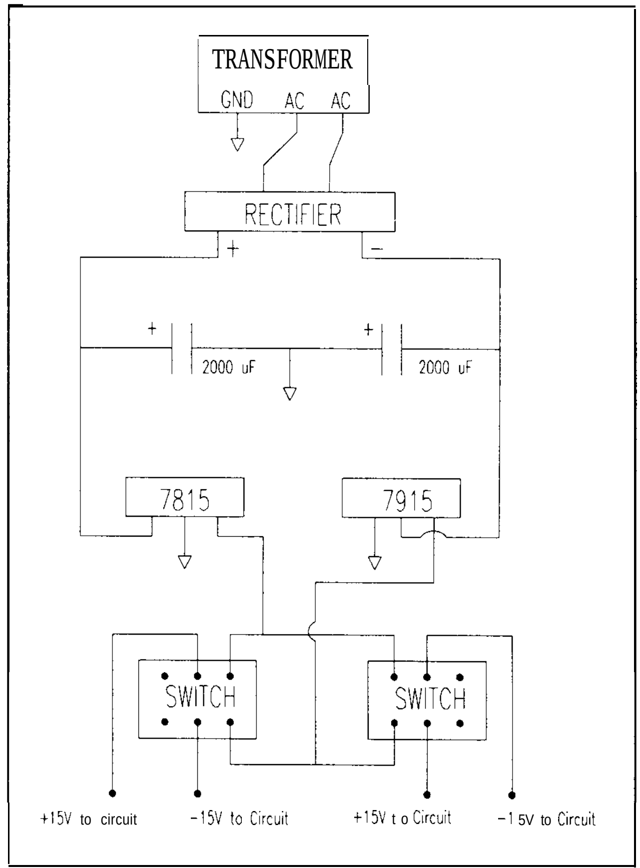

Fig. 10.3. System Power Supply.

of the beams. The variable gain was provided by a 250K, one turn potentiometer across the amplifier, allowing a 0 to 25 gain. Zeroing was provided by a potentiometer in a voltage divider configuration as one of the inputs to the summer amplifier. This provided the requiring offset voltage.

The comparator section of the system compares the output of the summer amplifier to the output from a voltage divider manually controlled by a potentiometer. When the system is set to the trigger adjust mode the voltage being selected is displayed on the same analog meter as that used to display actual forces. This provides the user with an easy to understand visualization of the target force. The comparator employed a 15 volt source to run the open collector with a 1KΩ resistor to sink the voltage. A buffer between the open collector and the following relays prevented any loading problems. Two 5 volt relays were connected in series to provide independent outputs for controlling reward/feedback systems. Monitoring of the signals from a voltmeter was created from an op-amp shunted in series such that the full scale deflection was equal to 10 volts. The inputs to the meter were the output from the summer amplifier or the trigger level potentiometer. The user control box contains the meters, zero, calibration gain, trigger level controls, and output jacks for each side of the system.

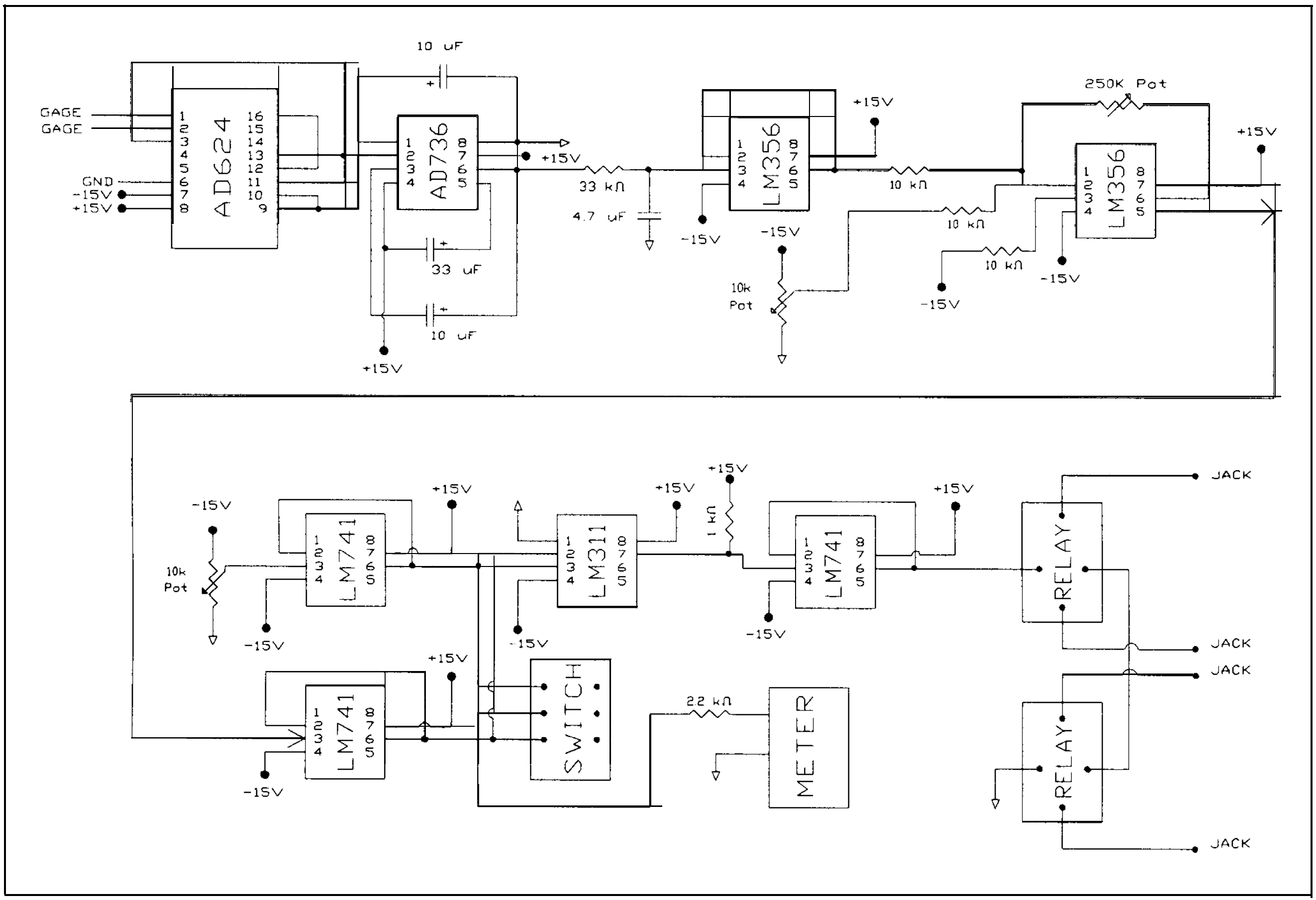

Fig. 10.4. Circuit Diagram.

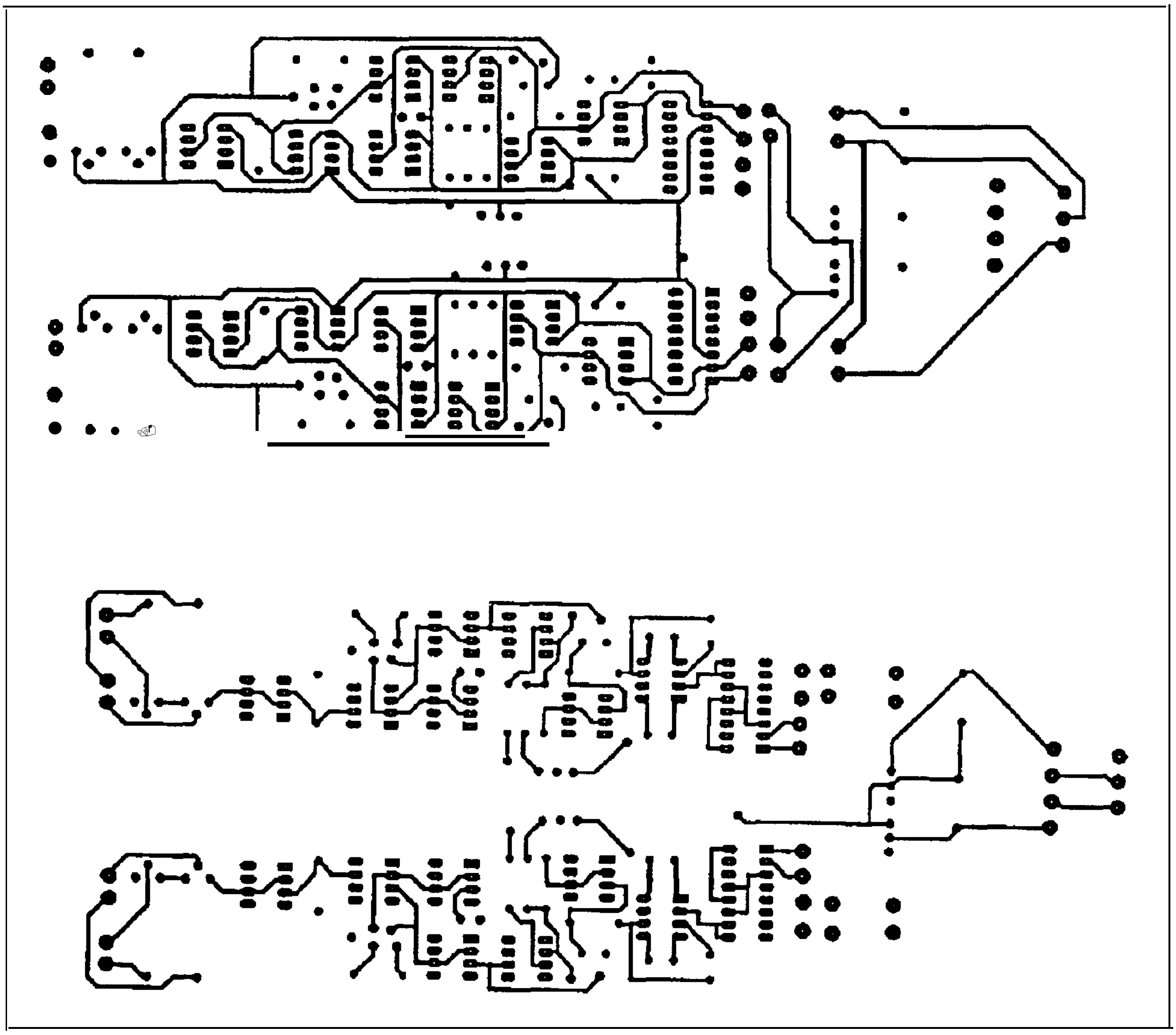

Fig. 10.5. Circuit Board Layout.

Overall power to the system was provided by an off-the- shelf 24 volt transformer. This provided the AC necessary to excite the bridges. In addition the transformer output was full wave rectified, filtered and regulated to provide stable +/- 15 volts for the rest of the electronics. To simplify assembly and improve reliability printed circuit boards were laid out (Figure 10.5) and manufactured through a service facility provided by the Electrical Engineering Department.

Mechanical Design: The key features of the mechanical design were the configuration and support of the hangers, the beams, and the surrounding structure. Preliminary designs for the hangers included analytical analysis of the required dimensions for sensitivity and strength, followed by testing in an Instron Series 4505. The resultant dimensions of the narrow part of the dog bone was 0.50 inches using material 0.125 inch thick. See Figure 10.6 for complete dimensions. Additional hanger support hardware was made from angle iron as shown in the detail drawing of Figure 10.7. The outer frame of the dual beam walkway was constructed from 2 x 8 lumber reinforced with 2 x 4 bracing. The spaces along the sides and ends of the beams were covered by an awning extending 4 inches from the sides of the frame and 6 inches from the ends. These structures are strong enough to stand on.

Cost: The overall cost of this final version of this product was $36 for lumber, $26 for mechanical fasteners, $61 for aluminum and angle iron including machining in a University service facility, $150 for the CEA 13 125 UT 120 strain gages, and a total cost of $156 for electronics. The key components of the electronics were the AD624 amplifier ($30) and the AD736 converters ($20).

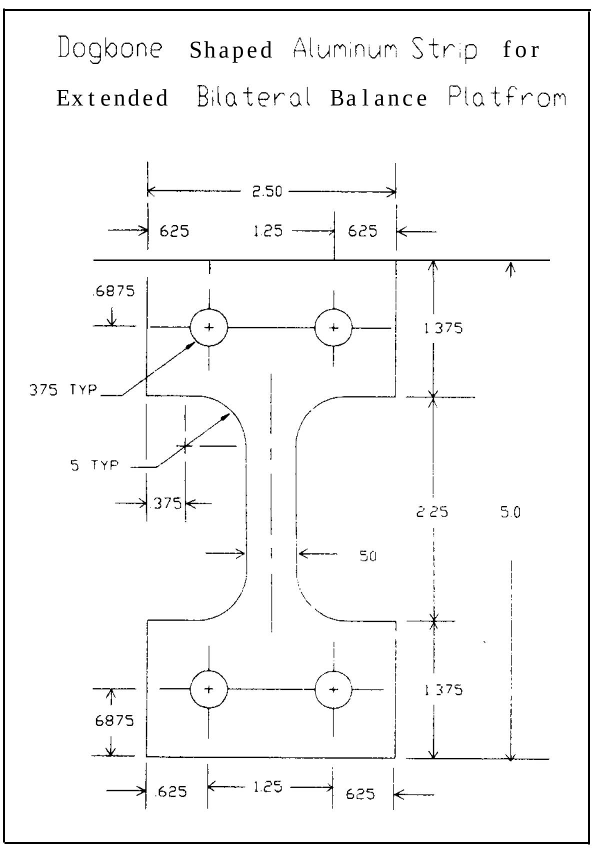

Fig. 10.6. Hanger Dimensions.

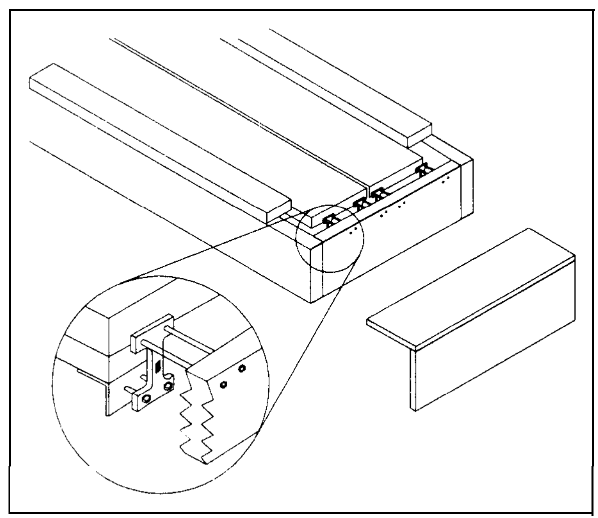

Fig. 10.7. Hanger Support.

Wheeled Toys and Trainers for Children

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INTRODUCTION

Young children with mobility impairments require a variety of wheeled devices for transportation, exercise and play, and pre-wheelchair training. Four designs which meet such needs are described here. The first is a custom wheelchair whose principle feature is that it is very low, allowing the user to propel herself by foot contact with the ground (Figure 10.8). The major objective of this design was independent mobility. While this user could be accommodated in a standard small wheelchair, this would be at the expense of independence since she would not be able to propel herself in a manual chair. While a power chair could be used, it would sacrifice other aspects of mobility at great expense.

The second design (Figure 10.9) features a platform type of surface for use in a sitting with legs extended position. This vehicle is propelled by working the wheels directly with the hands. The principle intent of this design was as a training tool for allowing children to become accustomed to manual wheelchair propulsion while using a device that is less threatening and more fun. In fact the fun aspect has made this device a favorite recreational item.

The third design (Figure 10.10) has been dubbed the "whizwheel." It is an enlarged version of a toy intended for a smaller child than the intended user of this design. This device is propelled by independently hand cranking each wheel. This allows a high degree of mobility and considerable entertainment in its use. The intended use of this device is in therapeutic exercise and play.

The fourth design (not illustrated) was a modification of a common prone scooter board. The modification adds musical sound when the board is propelled.

SUMMARY OF IMPACT

Each of these designs has proven to be very effective in their area of use. The low wheelchair met a very specific need for a user who wanted mobility independence while at school. The whizwheel contributes to the exercise and development of children who are restricted from participating in other physical activities. In addition it represents an example of adaptive equipment which is attractive to the normal child as well as serving the needs of individuals with handicaps. This helps eliminate social barriers to integrating handicapped and normal play in the school setting as the devices for those with handicaps become more desirable than those available for the normal child. The platform wheeled chair would also meet this goal if it were reproduced in a setting that was generally shared by normal children and those with handicaps. While this is generally not the case at the UCP center, siblings of clients are sometimes in attendance and have found this device to be a most enjoyable plaything. More importantly, it has met the center's goal of having a pre-wheelchair trainer that is attractive, fun, and not intimidating. The scooter board is also used at this location and adds an extra motivation to this form of therapeutic play.

TECHNICAL DESCRIPTION

Each of the projects described here demanded more in the way of imagination and fabrication skills than they did in detailed structural analysis. However careful attention was paid to strength requirements including consideration of both the intended and unintended user. In addition careful attention was paid to durable construction and safety analysis. The latter focused on stability and the risk of inserting fingers into the spokes of the wheels, and related pinch point hazards.

Low wheelchair: The principle components of the low wheelchair are a stadium seat, two bicycle wheels, two dolly wheels, and wood. The stadium seat proved to be a very useful starting point in that it was pre-made, the back folded, and in the folded position the entire chair can be carried just as a stadium seat would be.

Platform chair: The platform chair features lawn mower wheels for direct hand propulsion. There is also a dolly wheel at each end of the platform for stability. The seat and knee rest are adjustable along the length of the platform to accommodate different size users and various arm positions. The independently operated central drive wheels provide an exciting degree of maneuverability.

Whizwheel: The whizwheel required the most extensive construction of these projects in that, with the exception of the wheels, it was made from scratch. The structural members were bent from steel bars while the seat, seat back, and foot rest are of wood. The wheels are from a big wheel lawn mower with added handles and spoke covers. They are supported from the outer frame by the triangular steel components shown. The inner end of the axle is capped to reduce the opportunity for mechanical injury.

Musical scooter board: The scooter board is carpet covered plywood mounted on four dolly wheels. The active portion of a push-along musical baby toy was adapted to fit under the scooter board such that it turns against the floor when the scooter board is moved. This produces the desired musical output that accompanies use of the board.

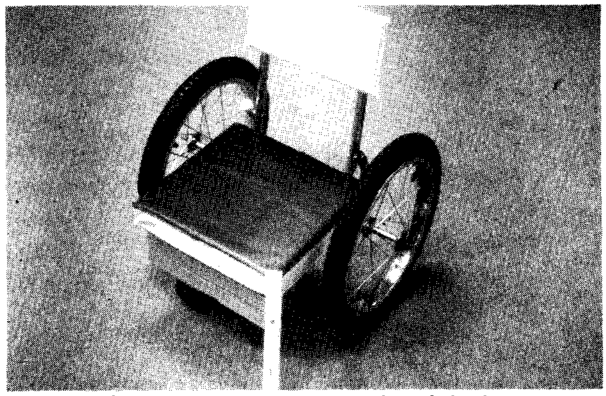

Fig. 10.8. Custom Wheelchair.

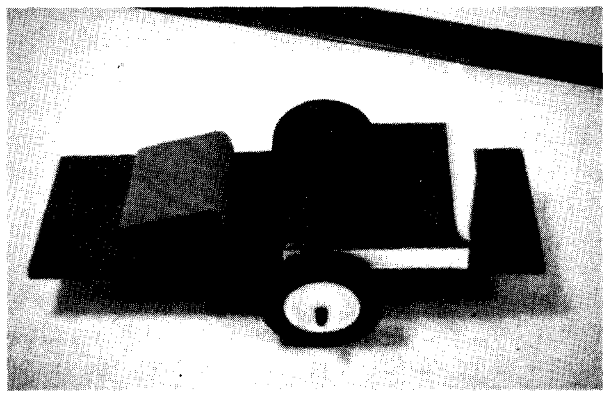

Fig. 10.9. Rolling Platform.

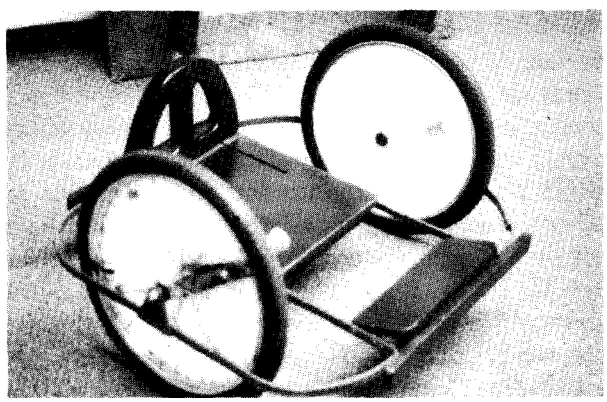

Fig. 10.10. Whizwheel.

Laser Pointer and Sensor/Controllers

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INTRODUCTION

Nonverbal individuals with limited limb function can communicate and even control their environment with head motion operated devices. However, the use of head position switch closure can often be limited for those individuals with spastic motion or with limited range of motion. The use of stick type head pointers can be cumbersome to use and are often wavy in their motion. Optical head pointers using incandescent bulbs have limited range and may be impractical in some ambient light conditions.

The use of laser pointers allows communication with lap tray based communication systems as well as for long range communication with remotely situated signs or displays. In addition, the development of light activated sensor allows such individuals to control external devices including environmental and communication aids.

SUMMARY OF IMPACT

The use of laser emitters worn on either eyeglass frames or on alternate head mounts provides a concise, long range light beam that is relatively unaffected by ambient light. This system allows a far greater range of communication and control of assistive devices than is possible with standard head pointers or incandescent optical pointers. Disabled users have shown a greater willingness to communicate and accept therapies and augmentative devices when using the laser pointer. The use of light sensors specifically tailored for laser energy allow such individuals the freedom of independent control of remote devices.

TECHNICAL DESCRIPTION

Laser emitter: This system employs a Midwest Laser Products Solid State DM1 Laser Module, priced at $130.00. The laser emits a 1 milliwatt output power at a wavelength of 670 nanometers. The output power is relatively safe for use in this setting provided that the beam is not projected continuously into an eye for an extended period of time. The laser requires 3.9-4.5 volts DC to operate. A power and control circuit were built to accommodate the laser as seen in Figure 10.11. The cost of the circuit components is $10. The laser produces a 0.6 inch spot at 40 feet. The laser module is only 1.6 inches long and 0.625 inches in diameter.

Laser sensors: Both an AC and a DC controller/sensor were developed such that both DC and AC devices could be controlled in a remote setting. The AC controller consists of a solar cell, an amplifier, a voltage follower and buffer amplifier (to prevent overloads), and a voltage comparator. The output of the comparator is sent to a timer to limit accidental tripping of the switch continually if there is spastic head movement. The timer is connected to a J-K flip flop that controls a relay to control an AC powered device. The entire circuit is powered through line voltage via a standard 110 volt wall plug. The line voltage enters a transformer, a full wave rectifier, and voltage regulator to produce 5 volts DC to power the circuit. This system is shown in Figure 10.12.

A DC controller was designed with a similar solar cell, an operational amplifier, voltage comparator, timer, flip flop, and relay operating in a fashion similar to the AC design. This system employs batteries as the power source. The DC controller is shown in Figure 10.13. The total cost of the AC controller is $62.95 which includes $22 for Plexiglas and project boxes to mount the sensor and circuit as well as $20 for an AC cord and plug. The DC controller cost was $44.95 and was similarly configured except for not needing the AC cord/plug. Instead, a battery case and batteries were needed.

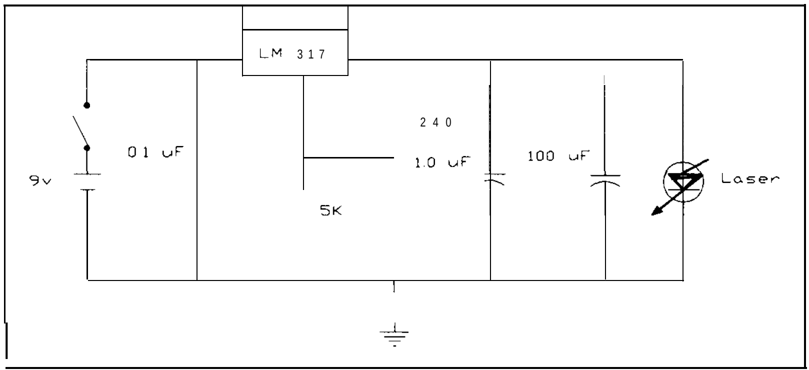

Fig. 10.11. Laser Emitter.

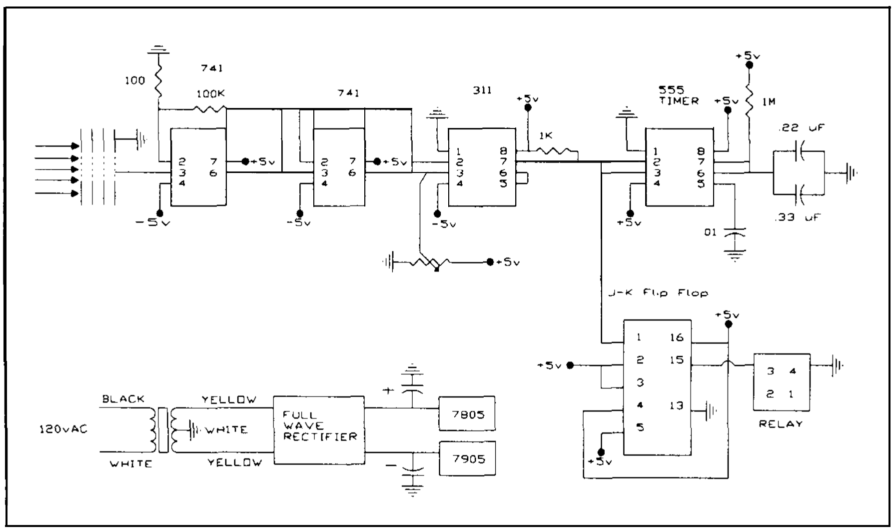

Fig. 10.12. Laser AC Controller.

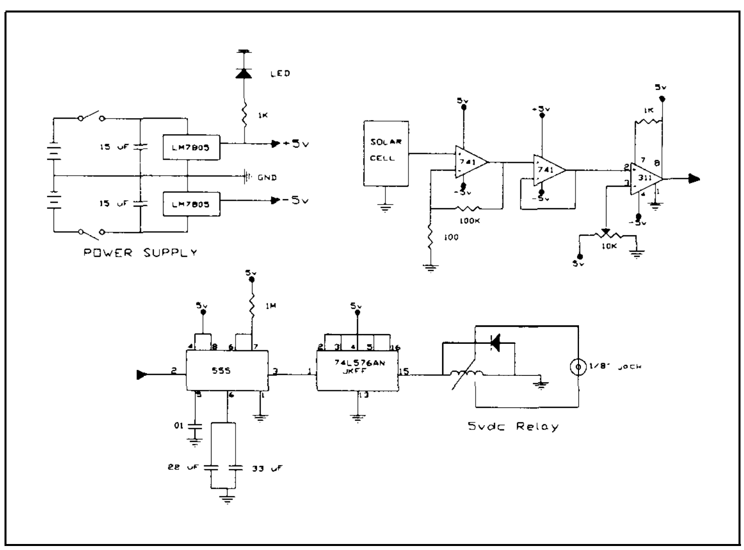

Fig. 10.13. Laser DC Controller.

Foot Operated Switch and Slide Projector Control

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INTRODUCTION

Nonverbal individuals with severe physical disabilities resulting from such conditions as Cerebral palsy have difficulty in performing simple everyday tasks. Yet such individuals often have the cognitive ability to understand the tasks and have the desire to complete the task, but simply lack the necessary motor control. Such individuals have an important need to gain a measure of independent living, including control of their environment, improvement of communication, and development of educational programs. Often, the development of such systems depends upon providing a means of control that is tailored to the limited physical abilities of the intended user.

A switch was developed for such an individual who has limited control of one foot. This motor control is limited to a swivel action such that the foot is rotated from a diagonal position (the foot is resting on edge) to a flat position (the foot is in the normal "down" position). The rotation action is slow, but is willfully controlled. The switch was then utilized to provide control to a variety of output devices including a radio, a tape player, or a number of communication devices.

An additional requirement was to allow such an individual to control a standard slide projector with the aid of the foot operated switch. However, the standard slide projector control provides continuous slide selection/removal as long as the control switch is depressed. Since the disabled individual who would be using the projector cannot quickly manipulate the foot switch, then an interface circuit was designed to allow the slide projector to change slides only when the switch was released, rather than continual slide changeout as long as the switch is depressed.

SUMMARY OF IMPACT

The foot switch allows a disabled individual with limited motor function to control a variety of output devices, thus providing an important means of quasi-independent control. This has proven to be a significant boost to the mental outlook and ego of such an individual and also provides encouragement to participate in other related therapies and control systems. The slide projector switch provides a means of self education, entertainment, and communication that was not previously available.

TECHNICAL DESCRIPTION

The foot operated switch consists of a hinged plate that depresses a standard single pole/double throw switch imbedded in a thin box. A spring provides a means of the plate returning to a diagonal position when not depressed. The switch box contains a 1/8 inch jack output to interface to any compatible output device by means of a suitable stereo 1/8 inch jack. The foot switch is shown in Figure 10.14.

The slide projector control system contains a modified slide projector switch, controlling circuitry to limit the slide selection process to one slide per switch opening, and a 1/8 inch stereo plug for connection to the foot switch (see Figures 10.15 and **10.6).** The control circuit consists of a CMOS monostable and relay. Batteries produce six volts which enter one pole of the foot switch, such that the circuit will receive six volts when the switch is closed (pedal depressed). When the pedal is released, the input signal will drop to the ground voltage. As the monostable detects this falling edge, it will output a pulse of 0.5 seconds duration. This is long enough to trigger the projector, but short enough to prevent more than one slide from advancing. This pulse duration is specified by the RC pair in Figure 10.16. The output pulse from the monostable enters a relay. For the duration of the pulse, the relay connects two wires that advance the projector. The entire circuit fits in a small project box that is equipped with an on/off toggle switch serving as a master power switch, a 1/8 inch stereo jack, and the cord that connects to the projector with its standard multi-pin plug.

Cost: The foot switch and slide projector control were quite inexpensive. In fact, the major cost was the slide projector remote control that had to be incorporated into the control box. The slide projector remote was $22.95, the switch and control circuitry were $18, and the project boxes were $6. The total project cost was **$47**.

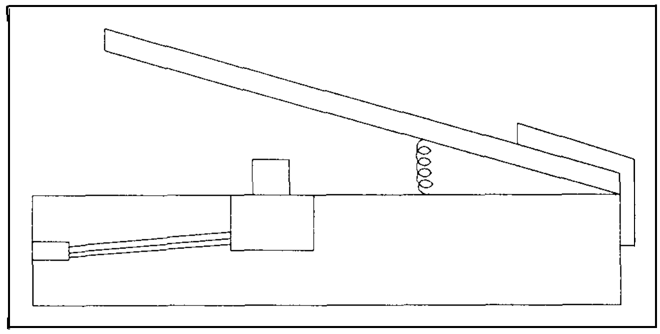

Fig. 10.14. Foot Switch.

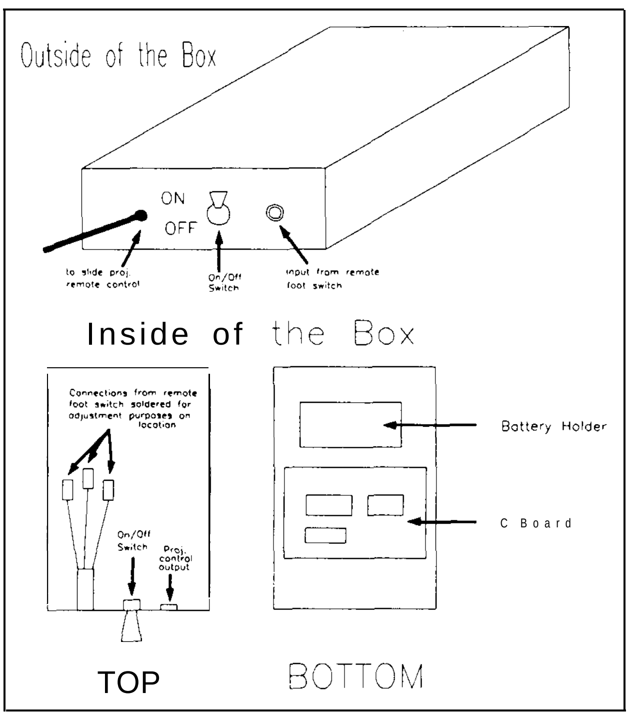

Fig. 10.15. Slide Projector Control Box.

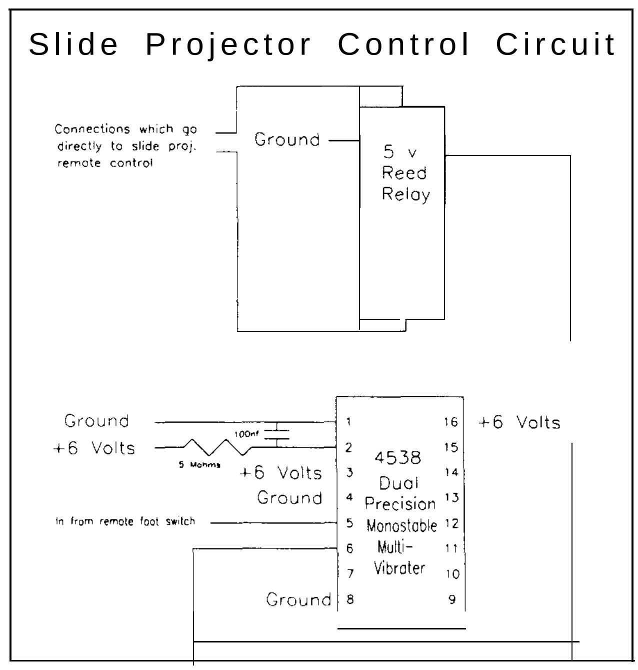

Fig. 10.16. Slide Projector Control Circuit.

A Pronation-Supination Exercise Device

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INTRODUCTION

Supination is the act of turning the hand so that the palm faces up. Exercise to achieve and develop this motion is regularly used in occupational therapy at UCP as a precursor to other hand, finger, and arm dexterity development. The goal of this project was to develop a controlled supination motion which could be easily demonstrated to the child, which was repeatable and measurable, and which provided a visual and/or audible reward for reaching a predetermined degree of supination (range of motion). The resultant device (Figure 10.17) meets these goals by providing a clear tube that can be pronated and supinated simultaneously by the child from one side, and by the therapist from the other side. It also provides a consistent motion, a scale to measure performance and progress, and an adjustable goal for triggering reward signals. An interesting additional feature that is popular at the UCP is a therapist's prompt button that can be used to trigger the feedback as a reward for effort, even if the goal is not fully reached.

SUMMARY OF IMPACT

The therapists at the UCP have an ongoing challenge in working with pre-school children with respect to obtaining consistent compliance with the desired therapeutic activity, and in motivating the child through the provision of appropriate rewards for effort and performance. The consistent measurement of performance and progress is also required. This design addresses these goals for the particular activity of supinating and pronating the hand and arm. The device is currently in use at UCP and has proven to be very useful in this particular exercise. One interesting, although inadvertent, feature of the design is that the use of the clear tube provided the ability of the child to see their hand during setup and use of the device. This eliminated the potential fear of inserting the hand into an opaque enclosure.

TECHNICAL DESCRIPTION

This design required the development of integrated mechanical and electrical systems. The mechanical system is used to control the intended motion of the hand and arm by both the child and the therapist. The electrical system is used to measure the degree of rotation from baseline, set a degree of rotation goal, and provide a visual and audible feedback when goal is reached, or at the option of the therapist. The mechanical system consists of a clear plastic tube supported on rollers so that it can be rotated freely in either direction. Mechanical stops are used to set the baseline. Clockwise or counter clockwise rotation is accommodated by using one side of the system for each direction of rotation from the baseline. The rotation of the tube is mechanically coupled to a potentiometer that provides a voltage proportional to the degree of rotation of the tube. A second potentiometer is used by the therapist to set the degree of rotation goal. A comparator is used to compare the voltages that represent current position and desired position. When the tube voltage reaches or exceeds the preset voltage the reward system is triggered. A reversing switch is used to accommodate changing the rotation from clockwise to counterclockwise since it is necessary to switch the inputs to the comparator for reversed rotation. The therapist prompt switch sets the tube voltage high which triggers the comparator. The circuit diagram is shown in Figure 10.18. This design has a distinct advantage over a mechanical switch set at the goal position in that it is easy to adjust and durable. In addition it provides a reward for all angles greater than the goal. This would be more difficult to achieve with a mechanical switch. The on board reward consists of a clown's face with incandescent bulb eyes and an LED array for the nose. When the reward is triggered the eyes become brighter and the nose lights. The eye display function is controlled by an op-amp and transistor circuit. This allows the lights to be on but not bright, until the goal is reached. The LEDs are also switched on by the transistor circuit triggered by the comparator. In addition to the self contained reward system the device provides an output jack so that external reward systems can also be used. The power supply to the system is a 9 volt battery and 8 AA 1.5 volt batteries.

The cost of this device was $130. The largest single component cost was the tube at $42.

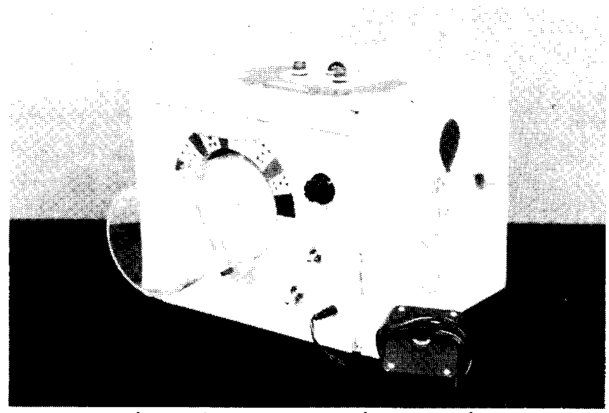

Fig. 10.17. Pronation Device.

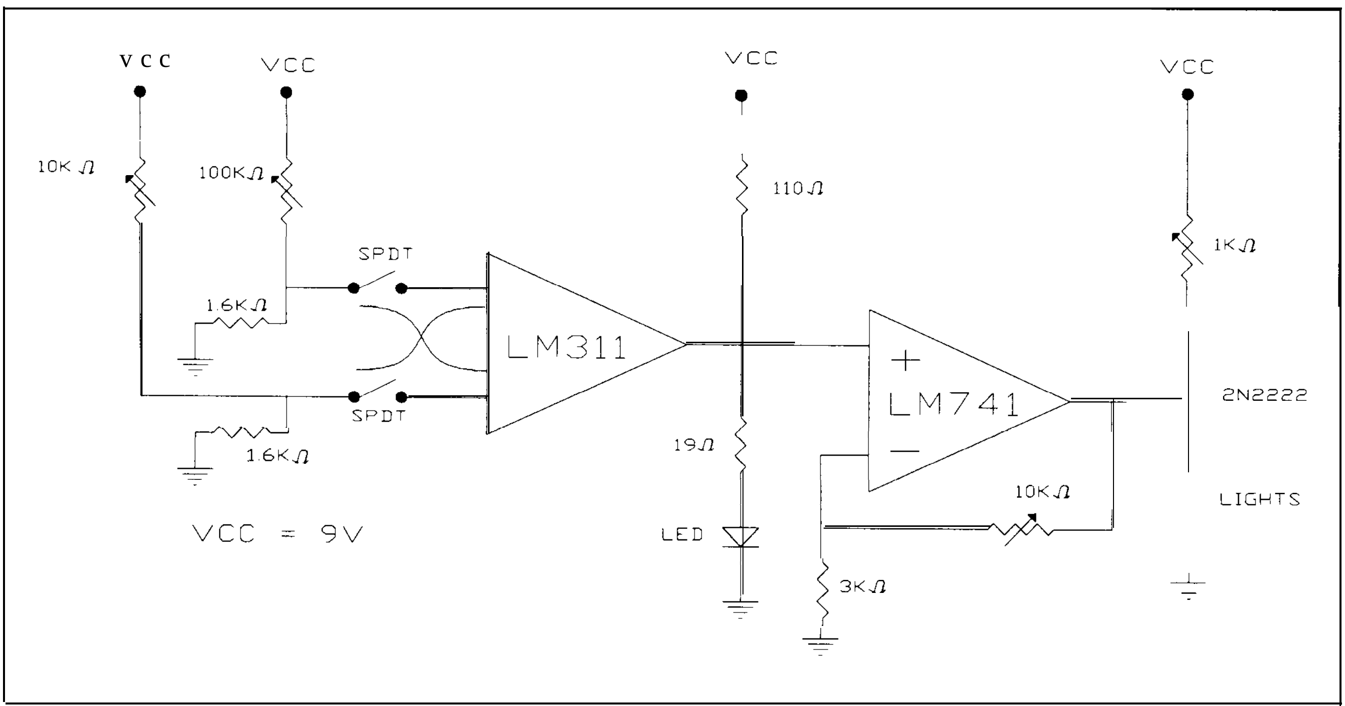

Fig. 10.18. Pronation Device Circuit.

Voice Controlled Computer Mouse

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INTRODUCTION

Individuals who are either quadriplegic or suffer from motor disabilities may have sufficient cognitive skills to operate computers and similar equipment both in the workplace and in a home environment. However, standard computer input devices, such as a keyboard, mouse, trackball, etc., require manual manipulation and control. These are obviously not designed to a severely disabled user.

A circuit was developed to allow voice input to control computer cursor movement, in much the same way as is accomplished through manual manipulation of a computer mouse. The system was designed to accept any voice, but can be fine tuned to a given voice through a brief training and adjustment period. Ease of operation and limited cost were important factors in the design.

SUMMARY OF IMPACT

The use of a voice activated computer mouse allows a disabled user to control computer software without the need for standard manual input devices. This allows a disabled individual to access employment scenarios that use computers, and also to control computers in a home environment. By using appropriate software, it is possible to type on screen by using a keyboard emulator, or to control environmental devices by means of a digital to analog conversion system. Such software and hardware are readily available in the marketplace. However, the utilization of such systems requires that the user be able to access and operate the computer, thus the need for the voice activated input.

TECHNICAL DESCRIPTION

Two separate designs were developed. One was based on a Radio Shack VCP200 speaker independent word recognizer chip, while the other was developed through the use of bandpass filters and timers in a customized design.

VCP200 Design: This speaker independent chip provides two modes of operation. In one mode, the chip recognizes either on/off or yes/no. In the other mode, it recognizes words such as go, turn right, reverse, stop, and turn left. The latter mode was more relevant to use in a computer mouse controller, where a need for left, right, up, and down commands are important to move the screen cursor. This chip outputs zero volts on the designated pin when one of five commands is recognized. The outputs of the chip are linked to a four input NAND gate. The NAND gate output is a logic high only when a command is recognized by the VCP200. The output of the NAND gate is linked to the reset of a 556 timer, which is configured as an astable circuit. The timer will continually output a pulse wave as long as the timer reset pin is "high." The output of this timer is then inverted and connected to the input of a second timer within the same 556 chip. This second timer is configured as a monostable circuit or one shot timer. The output of the timers are sent to a decoder circuit which then is connected to the 9 pin socket which is part of a Logitech bus mouse card, which fits into an expansion slot in a PC compatible computer. The system recognizes up, down, left and right commands. The "stop" command is used as an alternative to the button click on a computer mouse. One stop command acts as the left button click, while two stop commands in sequence acts as a right button click.

The system is shown in Figure 10.19. The cost of this system $10.00 for the VCP200, $48.00 for circuit components, and $15.00 for the 9 pin mouse connector. The system was developed for a computer with a bus mouse card already inserted.

Bandpass Filter Design: This system was developed as a speaker independent system which would allow fine tuning to individual speech variations, which was beyond the ability of the VCP200 system. This system employed bandpass filters set at 200, 350, 500, 1000, 1600, and 4000 Hz. Spoken words were then split into component bands, where the output of each band was amplified for subsequent processing. Timers were added to each band to allow adjustment of word lengths and to improve word recognition by eliminating turbulent sounds associated with the end stages of a spoken word. The outputs of each band were connected to RMS to DC converters and then on to compactors and shift registers. Comparison of the energy level in different bands could be used to correlate to specific spoken words. This system is shown in Figure 10.20. The output of this system is also connected to a 9 pin socket for a bus mouse.

The total cost for this system is $126.78 for system circuit components and a project box for mounting purposes.

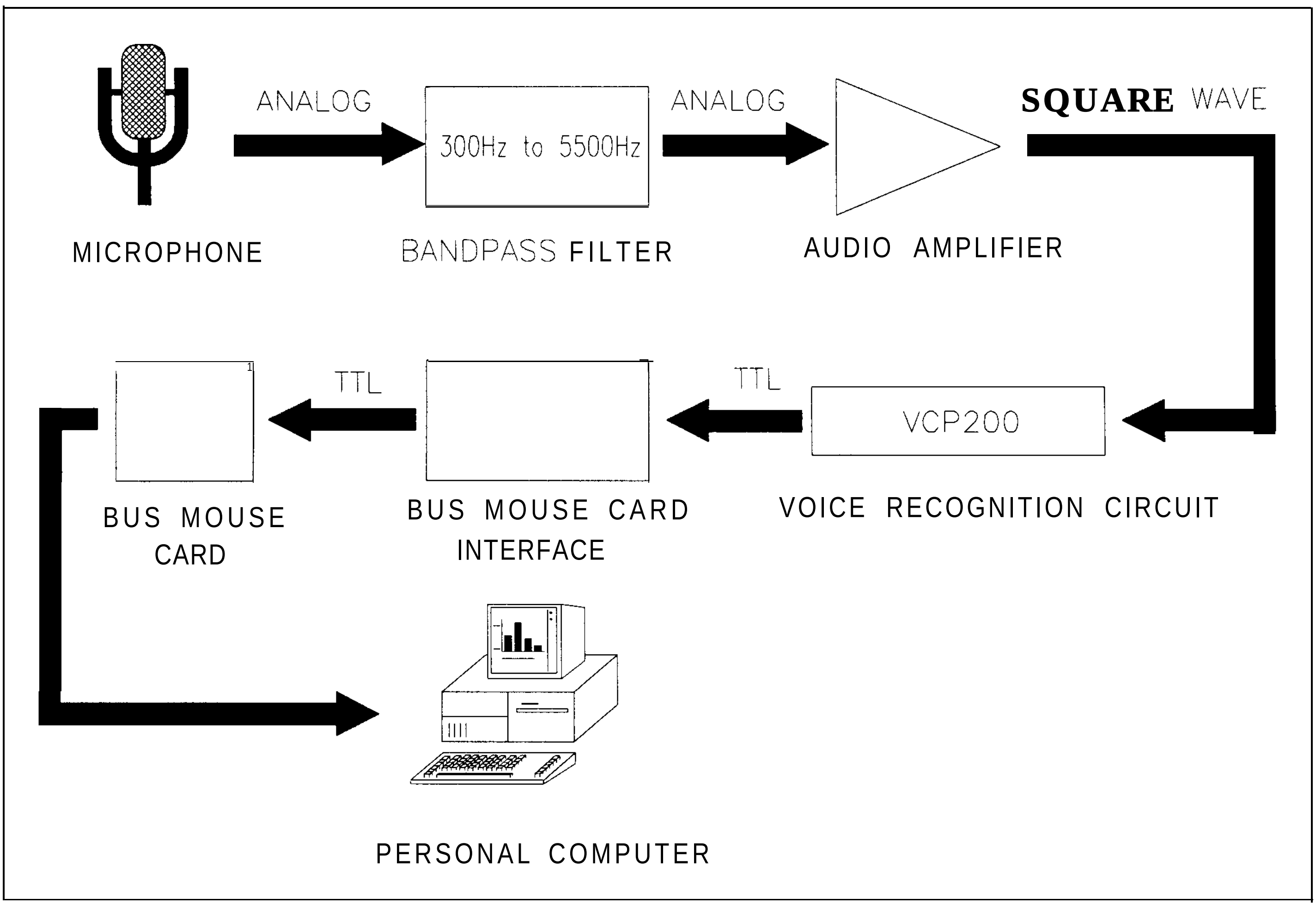

Fig. 10.19. VCP200 Design.

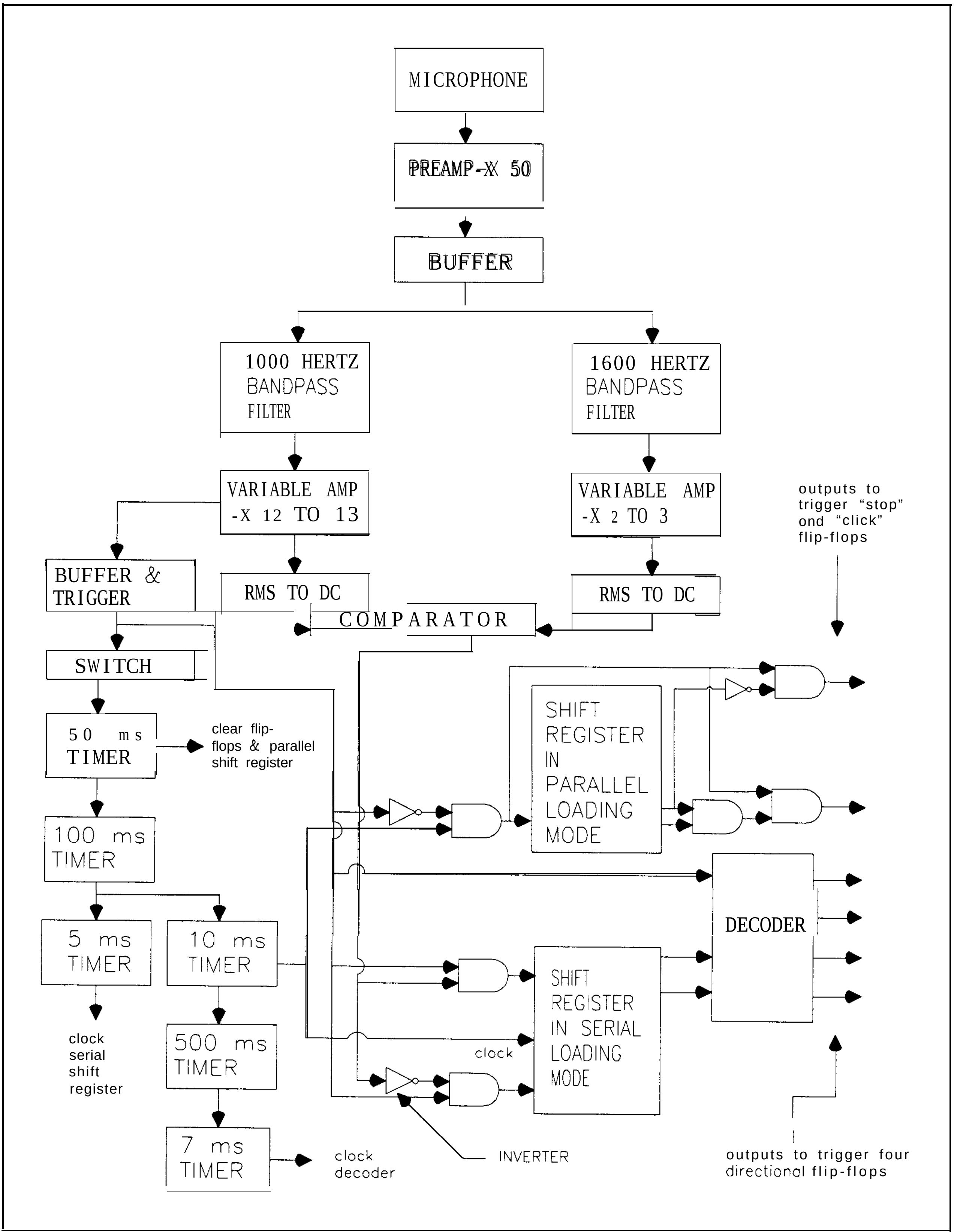

Fig. 10.20. Filter Design.