

CHAPTER 16
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Feeding Mechanism

Designer: Brian Fay

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INTRODUCTION

A student at a local school for the mentally and physically disabled was limited by a disability that prevented him from feeding himself. A device allowing him to independently feed himself at his own pace was in great need. Unfortunately, past attempts to design such a device has resulted in products lacking proper safety, cost and durability. Often exposed linkages or robotic arms were used which posed a danger to the user at pinch points and especially to people who experience muscle spasms at times of excitement or fear. Previous de-

vices also commonly used an electronic control system to regulate the mechanism. This elegant engineering tends to come at such a high price that the device is not affordable to people and agencies with limited budgets who must also purchase other requisite items. Lastly, intricate mechanical designs often lack sufficient strength. Interference with exposed parts can cause damage to the mechanism and continual maintenance. A proper solution must take into consideration all of these factors. The device must be safe and allow the student to feed himself, while remaining cost efficient.

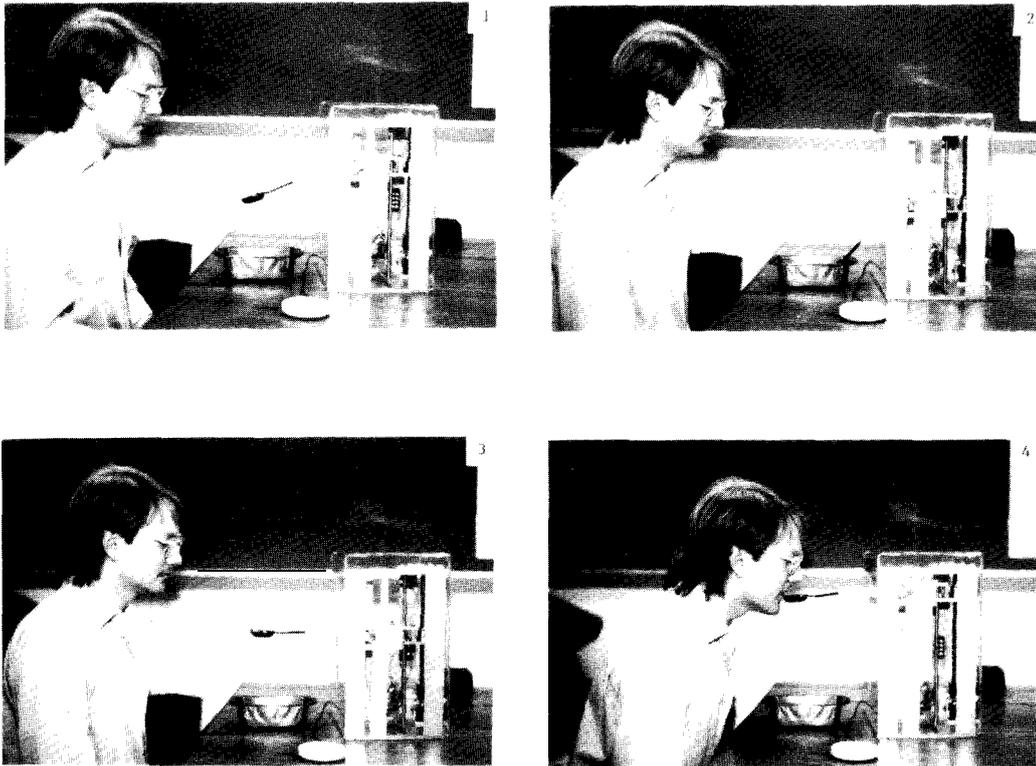


Figure 16.1. Picture of Feeding Mechanism.

PROJECT SOLUTION

A fresh start was required to prevent the problems of past designs from reoccurring. The solution uses neither a linkage nor a robotic arm. All parts are enclosed in a protective plastic casing with the exception of the utensil. This design constraint resulted in the design of the Compact Carriage Mechanism (CCM); a mechanism that uses the interaction of three shafts, three torsional springs, a rotational damper, and two cams to produce the optimum utensil motion. Also, the design uses no integrated circuitry; instead preferring a low voltage, low current system that can easily be adapted to differing user abilities. Safety served as a controlling principle in design decisions ranging from material selection to hypothetical accidents. A pictorial view of the designed feeder is shown in Fig. 16.2.

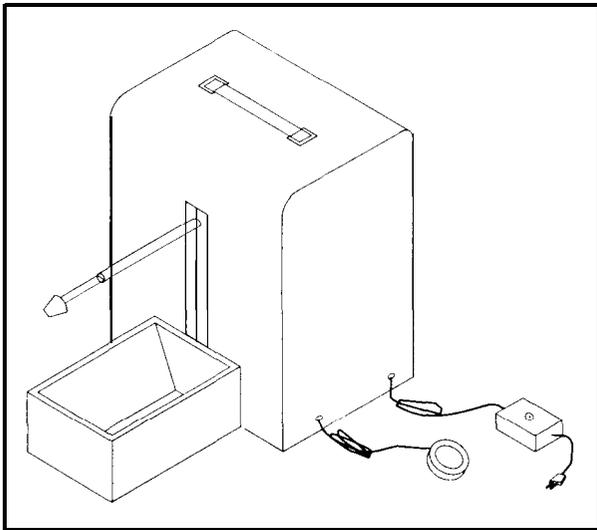


Figure 16.2. Feeding Mechanism.

TECHNICAL DESCRIPTION

The device consists of a mechanism enclosed within a PVC case, a spoon that is detachable for cleaning, a specially designed bowl, a “pad” switch for user input, and a 12V DC power supply that plugs into a wall outlet. During use, the case and bowl are positioned in front of the user such that the spoon is easily reached. The switch is positioned so the user can activate it with any body contact. The power supply is plugged into a wall outlet. When the switch is depressed, the spoon follows a motion similar to that shown in Fig. 16.3.

- 1) The spoon turns from a horizontal to a nearly vertical position and contacts the bowl
- 2) The spoon moves along the surface of the bowl slowly becoming nearly horizontal as it nears the bowl's end
- 3) The spoon rises from the bowl and retains its approximate horizontal orientation
- 4) After reaching the beginning height, the spoon stops and the food may be taken

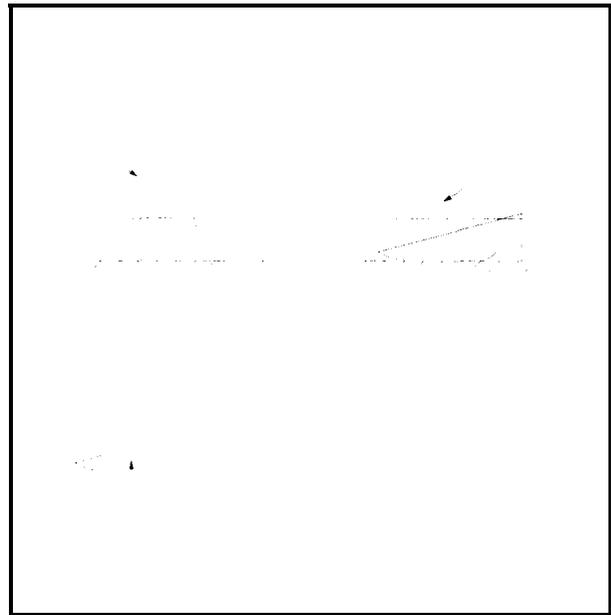


Figure 16.3. Motion of Spoon.

The cycle repeats when the user contacts the switch momentarily. The switch type may be varied depending on the disability of the user. Possible variations include a “Sip & Puff” switch for people possessing only movement of the torso, or a timer that would automatically initiate a cycle after a specified time lapse.

SPOON MOTION SYNTHESIS

The interaction of the linear actuator's vertical motion, and the Compact Carriage Mechanism's (CCM, see Fig. 16.4) rotational motion produces the spoon's external motion. The linear actuator is rotated by a 12V DC motor with an attached gearhead. The motor lies in a horizontal plane that is perpendicular to the actuator. Its rotation is transferred to the actua-

tor by a 90" gear box at a 1:1 speed ratio. The actuator is a special type in which the nut reverses its linear motion at the end of shaft threads. Thus, a relay to reverse motor rotation when the nut is at the end of its travel is not required.

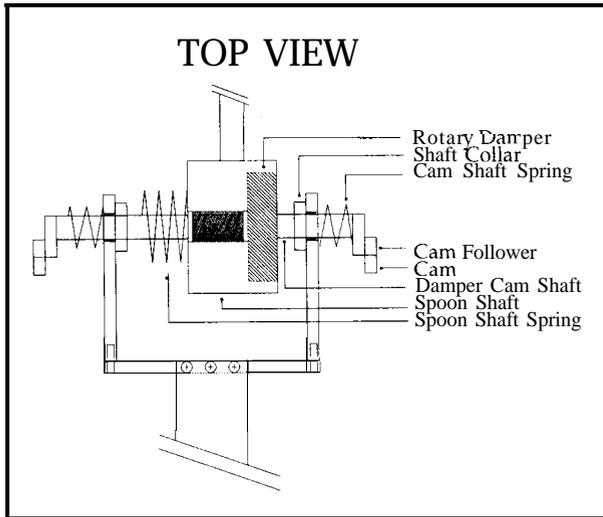


Figure 16.4. Top View of Compact Carriage Mechanism.

The CCM travels vertically along with the nut of the linear actuator. As shown in Fig. 16.4, the CCM is composed of three shafts that have the same center axes. The spoon is connected to the larger diameter shaft or "spoon shaft." The spoon shaft has two smaller shafts that lie in a bored hole at its center.

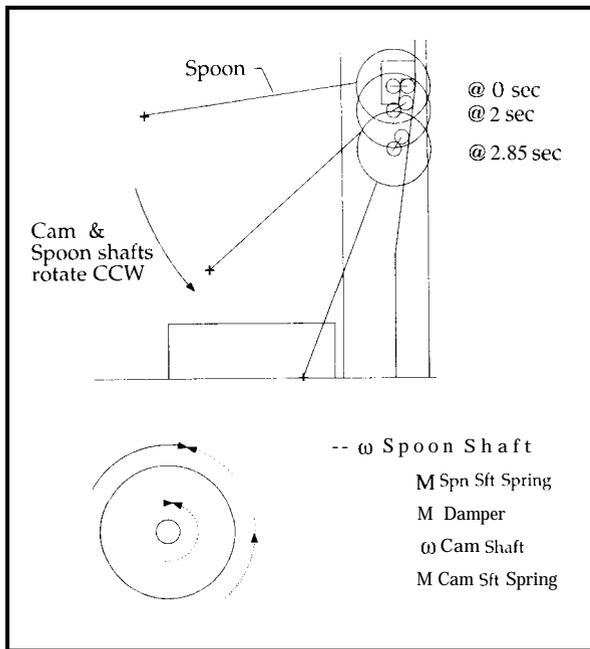


Figure 16.5. Rotation of the Cam Shaft.

Both of the smaller shafts extend outward from the spoon shaft through the plate of a bracket that transfers the vertical motion of the actuator to the CCM. Stainless steel torsional springs with identical dimensions are mounted to the outer surface of this plate and to the smaller shafts. A cam follower is attached at the end of each shaft. These follow the surface of two identical cams mounted at each side of the CCM. The two smaller shafts or "cam shafts" differ at the spoon shaft interface. The left cam shaft passes into the center bore of the spoon shaft where it would be free to rotate if it were not connected to the spoon shaft by a torsional spring. The cam shaft to the right is keyed into a rotational damper that is rigidly mounted to the spoon shaft.

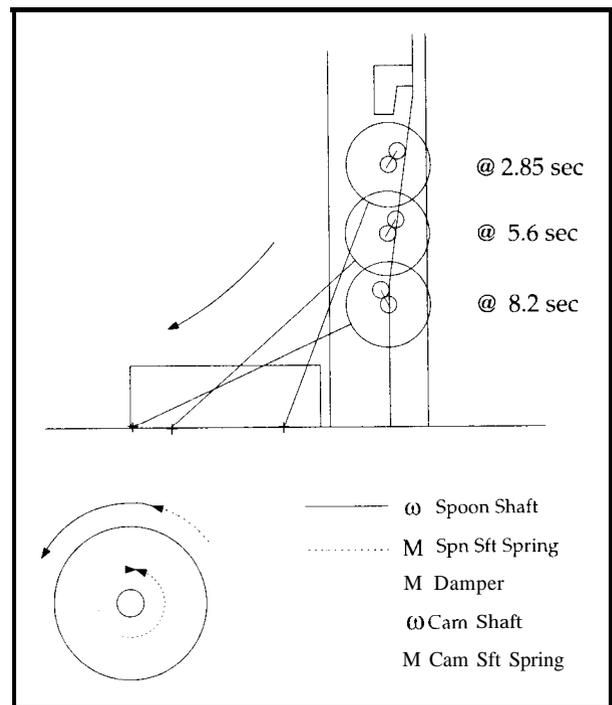


Figure 16.6. Rotation of Cam Shaft.

As shown in Fig. 16.5, rotation of the cam shafts is initiated by the descent of the linear actuator. As the CCM moves downward, the cam followers maintain contact with the surface of the cam that is linear and extends outward. This causes the cam shafts to experience a CCW rotation, and the outer springs become stressed. Since the cams and the outer torsional springs are identical, the cam shafts undergo equal rotation. Also, since the spoon shaft is connected to both cam shafts by components that will rotate only if an external movement is applied to the spoon shaft (a torsional spring and a rota-



COST ESTIMATE

Aluminum	\$115
Motor (Barber-Coleman #EYQE-73300-31)	45
Linear Actuator (Flennor #1627)	285
Gear Box (Berg #MX-14)	46
Rotary Damper (Vibratech #600,000)	35
Power Supply (Radio Shack #273-1653)	21
Misc. Vendor Parts	280
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Total	\$726

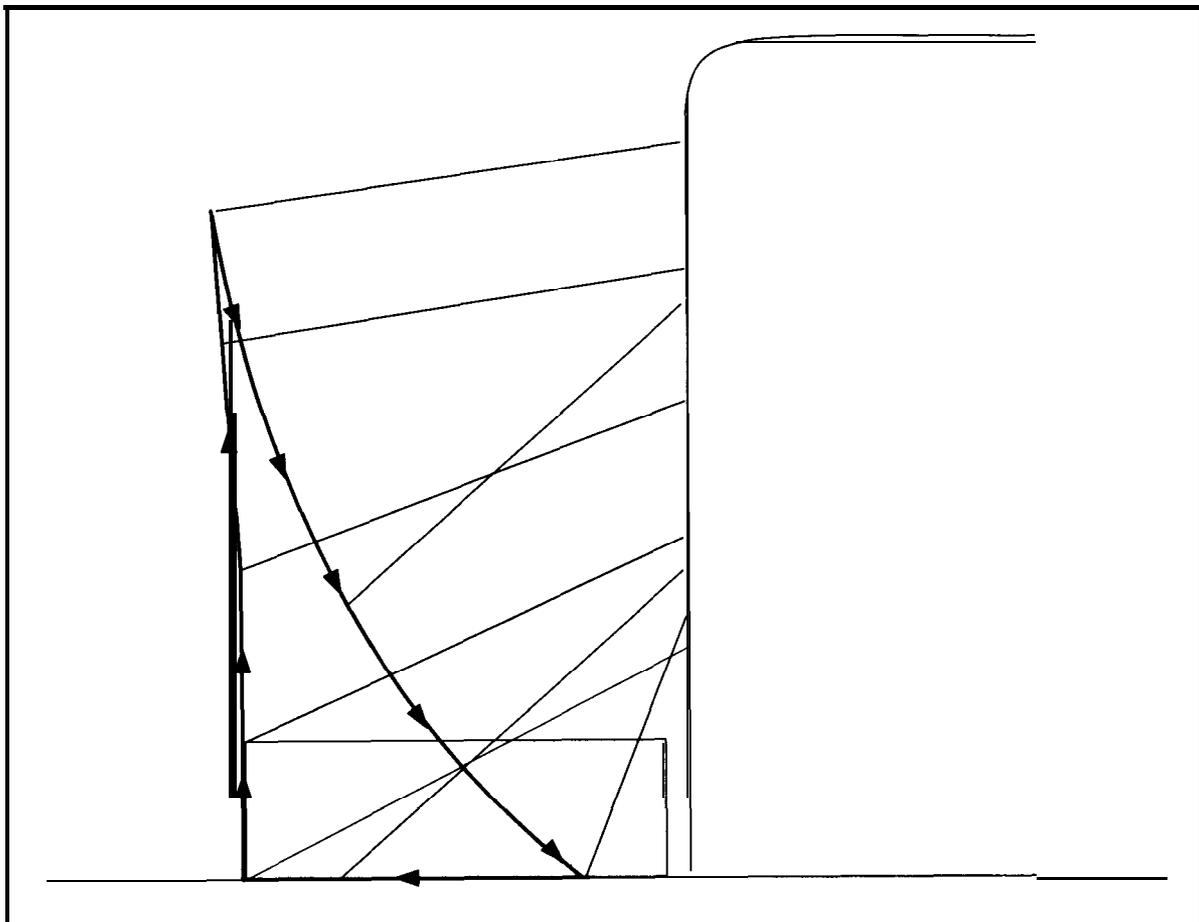


Figure 16.8. A Computer Simulation of the Spoon's Final Motion.

tional damper), the spoon shaft experiences the same rotation as the cam shaft until the spoon contacts the bowl surface. Once the spoon contacts the bowl, the continuing descent of the CCM causes the spoon shaft to experience a CW rotation (Fig. 16.6). This rotation is opposite the rotation of the cam shafts, and causes the internal spring to become stressed. A summation of moments about the shaft axes demonstrates it is of utmost importance that the outer springs maintain contact with the cam surface. Thus, the spring constant of the outer spring is much greater than the spring constant of the internal spring. As the actuator reaches the end of its threads, the CCM achieves its lowest position, and the spoon approaches the end of the bowl. At this time, the actuator reverses, and the CCM begins to move upward (Fig. 16.7). All component rotation reverses: the cam shafts rotate CW slowly relaxing the outer springs and the spoon shaft rotates CCW slowly relaxing the internal spring. If not restrained, the moment of the internal spring will force the spoon to follow the bowl surface along a path identical to the scooping motion. The rotational damper regulates the decay of the internal spring moment. Ideally, the damper will limit the rotation of the spoon and spoon shaft such that the spoon retains the nearly horizontal orientation found when the actuator and CCM reverse their

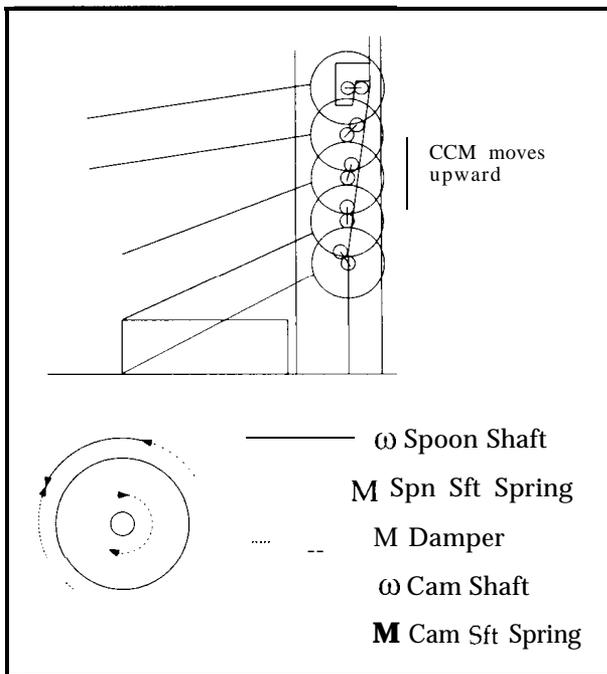


Figure 16.7. Rotation of Cam Shaft.

motion. The CCM moves upward and stops with the spoon at the beginning height and horizontal position.

TESTING AND REVISIONS

Upon receiving the rotational damper and vendor performance data, it was noted that an initial moment must be applied to the damper to initiate rotation. Thus, at the start of each cycle the internal torsional spring must be set at an initial moment slightly below the threshold required to rotate the damper. This is so the relative rotation between the spoon and cam shafts during bowl contact will fully decay. However, to initially stress the internal spring would cause the cam follower of the left cam shaft to lift off the cam until the internal and external springs were in equilibrium. In order to prevent this from occurring, two retainers were added at the top of the cams. These retainers allow the internal spring to be stressed, and the CCM to operate as described above. A computer simulation of the spoon's final motion using AutoCad™ is shown in Fig. 16.8.

ECONOMIC AND FUTURE CONSIDERATIONS

Although the present design is functional, certain changes are possible and justifiable should the device be mass produced. Foremost among these modifications is the design and production of a rotational damper. This would allow for a more advanced mechanism that was investigated during the design of the present mechanism, but was not pursued due to the high cost of initial production. Also, the cams used in the present design have a linear slope to reduce machining costs. A curved cam that was also investigated would be produced using an injection molded plastic.

The present design is a proper engineering solution to the project proposal. It possesses a simple design that achieves the desired task while also being relatively inexpensive to purchase and maintain.

Discussion Distribution System

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INTRODUCTION

In a mainstream classroom, hearing impaired students currently use an auditory trainer. This consists of a teacher-worn microphone and transmitter, and the student-worn receiver and hearing aid. As the teacher talks, the voice is picked up by the microphone, transmitted by radio waves from the transmitter to the student's receiver, where it is amplified and sent to the student's hearing aids. Although this is a very good system for the student to hear the teacher, it provides little to no assistance for the student to hear conversation from peers. The purpose of this project was to design a solution that would allow the hearing-impaired student to hear the other students in the class as well as the teacher, at the teacher's discretion. The design solution was the development of a device that was sensitive to pick up conversation in the room, as well as the teacher's transmitted signal, and re-broadcast both to the student's receiver.

TECHNICAL DESCRIPTION

An overview of the final system can be described as follows. Both transmitters and receivers used were provided by Telex Communications. The teacher wore a Telex microphone connected to a 70.025 MHz transmitter. This signal was picked up by a 70.025 receiver whose output was re-directed into a 70.325 MHz transmitter. Also input into this 70.325 MHz transmitter was the output signal from the signal processing board that will be described in the next paragraph. The output of the 70.325 MHz transmitter was received by a 70.325 receiver worn by the hearing-impaired student. The student then had control over the volume of the signal into his hearing aids.

Because the typical elementary school classroom is a large environment, typically on the order of 50' x 80', a major design task was to adequately sense conversation by the children within the seating area of this

room, and simultaneously attenuate noise generated from shuffling papers and dropping pencils. A thorough search for a quality microphone with high sensitivity yielded the Crown PZM-30R pressure zone microphone. This electret condenser microphone was chosen for several reasons. Pressure zone microphones are useful for picking up room conversations and they eliminate cone filtering in the audible frequency range and eliminate on-access peaking, which sometimes occurs on a pressure-type omni-directional microphone. Pressure zone microphones generally have better sensitivity over greater distances without necessarily narrowing the pickup angle. The frequency response of the microphone is 20 hertz to 20K hertz; a signal to noise ratio of 74 dB; and 7 millivolts per pascal of air pressure. The main feature that produces high sensitivity is the proximity of a miniature condenser microphone capsule to a sound reflecting plate. This allows the sound coming directly from the sound sources to combine in phase with the sound reflecting off the plate, thus increasing the incoming sound signal. The output of the microphone is double-ended and was converted to a single-ended output by using a phantom powering circuit. The signal from the single-ended output of the phantom power supply was amplified by a gain of 100 by a LM833 operational amplifier, chosen for its low quiescent noise (see Fig. 16.9). The output of the differential amplifier was shaped by a band pass filter with cutoff frequencies at 125 hertz and 6 kilohertz. The cutoff frequencies were chosen to pass the frequencies found in speech and reject frequencies due to noises outside this region. The output of the band pass filter was input to a comparator with a variable threshold reference signal. The output of the comparator flips between +15 and -15 volts but placing a diode on the output allows the input to vary between 0 and 15 volts. When speech exceeds the noise threshold in the classroom, the output from the comparator swings positive, and the positive current in the transistor's base causes current to flow

between the collector and the emitter and thus turning on a relay. The relay switches the microphone output signal into the 70.325 MHz transmitter. The purpose of the resistor and capacitor at the output of the comparator is to produce a 1 to 2 second delay in opening the relay contacts after the voice signal drops below the noise threshold. This would allow a person to catch his/her breath between sentences without the relay cycling off and back on again.

A Polytron 110V AC to $\pm 15V$ DC, 5V DC power supply was used to power the electronics. A printed circuit board was fabricated using Smartwork software. The power supply, printed circuit board, 70.025 MHz receiver and 70.325 MHz transmitter

were placed in a ABS plastic housing. The pressure plate microphone was mounted on the exterior of the box along with the transmitting and receiving antenna. The internal transmitter and receiver were powered by the power supply instead of rechargeable batteries. A power cord extended from the box to be plugged into a wall outlet in the classroom.

When the teacher decided that he should be the only one that the hearing impaired student listened to, the teacher simply turned off the power supply to the electronics within the box, and adjusted his belt-worn transmitter to transmit at 70.325 MHz directly to the student-worn receiver.

The cost of the supplies of this project was \$552, not including the donated transmitters and receivers.

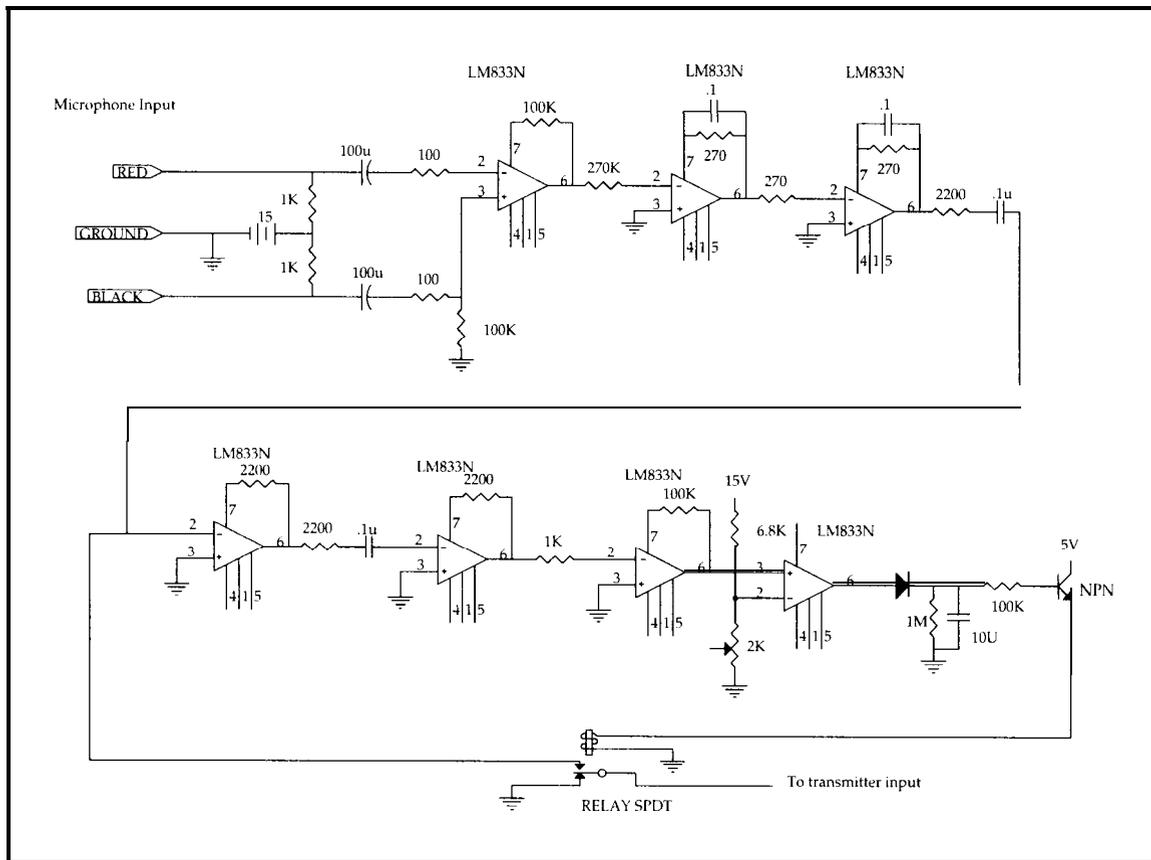


Figure 16.9. Discussion Distribution System.

Sensory Output Converter (SOC)

Designer: Manish Dubal

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INTRODUCTION

This project was carried out to design a modification to an instrument called the "Nervo-Scope" (manufactured by Electronic Development Labs, VA), so that it could be used independently by a blind chiropractic student. The "Nervo-Scope" is primarily used by chiropractors to carry out spinal analysis and diagnosis. It is a hand held instrument with two temperature probes and an analog display. The probes of the "Nervo-Scope" are slowly moved along the spine and temperature difference measured is displayed by the needle on the meter.

A need arose to modify the data output process of the "Nervo-Scope" for a blind chiropractic student. The modification, a sensory output converter (SOC), was designed so that the temperature difference displayed visually on the "Nervo-Scope" would also be heard audibly via a continuously varying tone. As the detected temperature difference changed, the pitch of the tone changed and the student could detect fluctuations. Since only the magnitude of the temperature difference was critical and not the absolute difference, the student could recognize large unusual differences in temperature by relating the change in the frequency of the tone to the temperature difference.

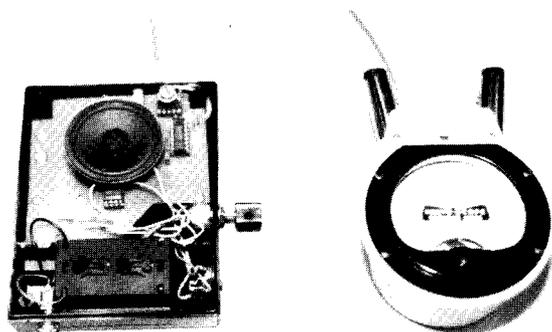


Figure 16.10. "Nervo-Scope."

SUMMARY OF IMPACT

The "Nervo-Scope" measures bilateral heat differences along the human spine. Your program designed an audible signal and corresponds to the swinging of the needle with the changing pitch of the tone. One of the big founders of chiropractic, whose invention this originally was and who claimed that you must use one of these in order to practice chiropractic, B. J. Palmer, if he were still alive, would be extremely pleased to know that you have adapted the unit for me. Thank you so much for your help.

TECHNICAL DESCRIPTION

The main design concept used was that of voltage-to-frequency conversion. The "Nervo-Scope" had an output signal going to its display which varied between +120mV and -12mV for full scale deflections of its display needle. This signal was used for the SOC. Due to the small magnitude of the output signal, it was amplified (gain = 401) using a Burr Brown INA101 instrumentation amplifier, (see Fig. 16.11). The INA101 has an extremely high input impedance (10t10 ohms) and very low noise, which is desirable to amplify very small signals. A Burr-Brown OPA27 op-amp (low noise, high open-loop gain, high CMR) was used to offset the amplified signal by 6 volts so that only a positive voltage was obtained. This was necessary since the voltage-to-frequency converter used accepted only positive or only negative values. The signal was then input to a Burr Brown VFC32 voltage-to-frequency converter which output square wave train. The VFC32 maintained extremely high linearity between the input voltage and the output frequency. This was critical for the SOC because the student had to audibly distinguish between different frequencies and relate them to a particular reading on the display. Appropriate values of resistors and capacitors were selected for the VFC32 so that the output frequency L(150 Hz to 1.85 kHz) was well within the acute audible range. The edges of the square wave train

were rounded to get a pleasant tone. This was done using a Burr Brown OPA627 op-amp (low noise, precise, high speed) which served as a passive low-pass filter (dB cutoff frequency of 3.3 kHz) and an audio amplifier. Provision was made so that the output could be heard on a 2" (0.12 watt) speaker or headphones. A 1 KΩ potentiometer was used to control the volume. All chips were powered by a 9V battery that was input to a National Semiconductor LM7805 5V regulator which in turn was input to a

Burr Brown HPR 105 (750/mW) power convertible to obtain +15V and -15V to power the chips. Estimated life of the components were packaged in a 4" x 6" plastic casing which could be connected to the "Nervo-Scope" via a telephone cable.

"Smartworks" software package was used to design a printed circuit board and "Kepru" printed circuit board supplies were used to fabricate it. The total cost to implement the project was \$734.18.

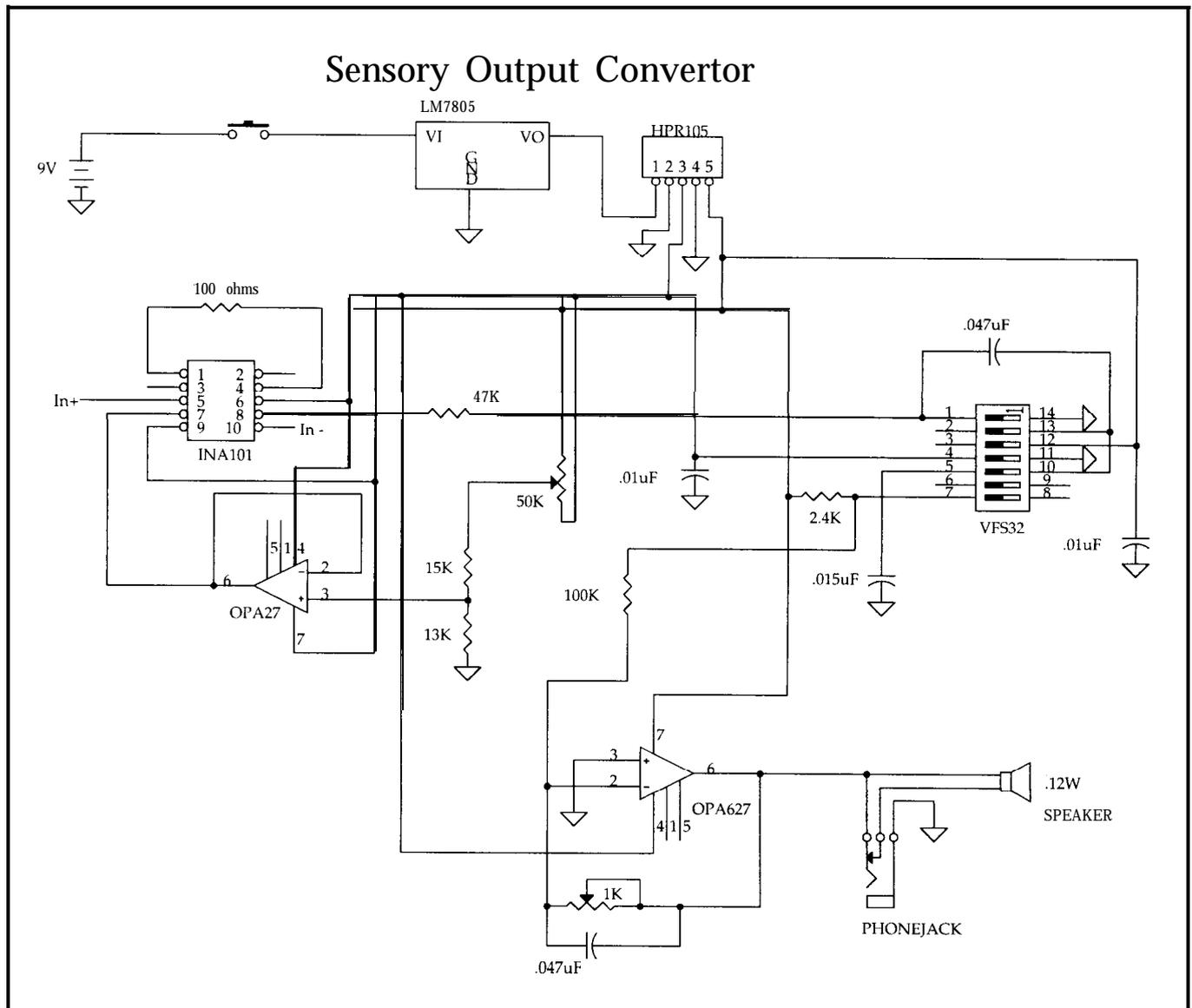


Figure 16.11. Sensory Output Converter.

Motorized Mount for a Light Talker

Designer: Chris Gianvecchio

Client Coordinator: Tim Dymond, SASSED, Roselle, IL

Supervising Professor: Dr. Mark Strauss

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INTRODUCTION

A device was designed for a high school student with cerebral palsy, in order to allow her to control the position of her Prentke Romich Light Talker. Her Light Talker enables her to communicate, since her cerebral palsy prevents her from speaking. Because she demonstrated little or no voluntary coordination of her arms and hands, she needed a device that she could use to rotate her Light Talker into its upright position when she wants to communicate and swing it down into its prone position when she wants to drive her wheelchair. Normally, the student needed the assistance of another person to prop-up her Light Talker on her wheelchair's lap tray when she wanted to speak and remove the Light Talker from the tray when she wanted to drive (since the Light Talker obstructs her vision). The Light Talker motorized mount will allow her to communicate and be mobile without the assistance of others.

TECHNICAL DESCRIPTION

The Light Talker is retained by an aluminum stand 8 inches tall, which is attached to an 8 mm stainless steel rod and centered between two vertical panels of $\frac{1}{4}$ " aluminum supports. The right end of the bar extends through the ball bearing in the right support and attaches to a motor's output shaft using a flexible shaft coupling. The motor is mounted to a cylindrical spacer which attaches the motor directly to the right support. The motor used is a Micro-Mo 12-volt DC model #HC519552 which has been geared-down 989:1, allowing a speed of approximately 5 rpm. The motor is powered by the wheelchair battery. When the motor is active, it rotates the stand and the Light Talker. Two microswitches

have been installed as limit switches at the extremes of the intended travel. When contacted by the rotating stand, the switches open the circuit to the motor thus stopping further rotation. These were added for safety reasons, and they also ensure that the Light Talker only moves through the necessary 90° angle.

The motorized wheelchair is operated by the student with the use of head switches and a DUFECO wheelchair interface system. The DUFECO system can be placed in an auxiliary mode, enabling the same controls that move the wheelchair to also rotate the Light Talker. When the DUFECO system is in the auxiliary mode, any signals that would normally command the wheelchair drive system will be sent to the DUFECO Switch Output Adapter Box. From there, the signal is sent via a four-wire cable to a small circuit mounted in the motor case. The circuit consists of two 12 VDC-10A single pole single-throw relays which work in conjunction with the limit switches. The circuit also contains a 1A fuse to provide safe failure.

The motor and circuit are enclosed in a light, but durable metal casing that protects the motor and circuit from physical as well as environmental damage. The 4-wire control cable is connected to the circuit by a 4-pin connector mounted in the box. This provides for quick disconnection and easy removal of the lap tray. The entire Light Talker Rotation Device is attached to the student's Plexiglas lap tray by 2 flat head screws.

The estimated cost of materials is \$280, which does not include the donated motor and gear box.

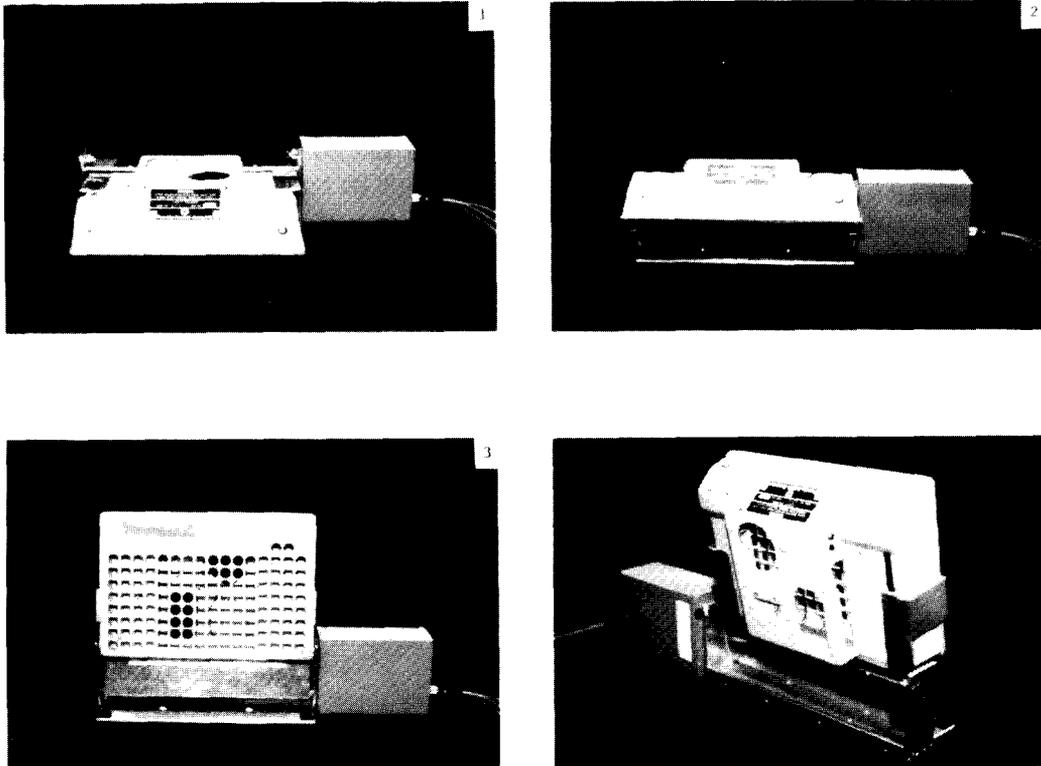


Figure 16.12. Picture of Motorized Mount for a Light Talker.

A Tactile Pacer

Designer: Brian Vicich

Supervising Professor: Dr. Mark Strauss

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INTRODUCTION

This project was designed to help a person who had a brain tumor. Her disability makes it difficult for her to stay on task. One solution to this problem, found by her therapist, is to have some type of auditory or tactile beat to which she can pace herself. A portable, tactile pace setting device was designed which uses a coil vibrator, which could be attached to the person's arm. The vibrator was designed to pulse at varying intervals by the user's discretion, from 1 to 2 beats per second. Both the on-off switch and the frequency adjustment are easily accessible and are partially external to the unit. The unit sits on a fabricated band and is attached with the use of Velcro. The blue and orange attractive band is worn on the child's wrist.

TECHNICAL DESCRIPTION

The Audiological Engineering Corporation uses small battery operated vibrators to convert auditory sounds into tactile stimuli. It was decided that one of these vibrators could be used to provide the tactile pacing stimulus that this individual needed. This vibrator is optimally powered by a 0-8 volt 225 hertz signal. The current draw varies between 40 and 100 mA. The main objective was to make a small system that would be easily adjusted so that the vibrator would vibrate from 1-2 vibrations per second. The 74S124N dual voltage controlled oscillator was ideally suited for this problem. This chip contains 2 oscillators that can each be independently set at different oscillations and the output of the first could enable the output of the second. The output of the second oscillator was set at 225 hertz. The frequency output of the first oscillator was controlled by a 10 K Ω single turn potentiometer. The full rotation of the potentiometer varied the output of the first oscillator between 1 and 2 hertz. The output of the first oscillator was used to enable the output of the second oscillator and the result was bursts of 225 hertz occurring at a frequency of between 1 and 2 hertz.

When the output of the second oscillator was not enabled, its output pin would be high. Since the vibrator would not like to see a DC voltage, a 2N3844 BJT inverter was used to convert the 8 volt DC output to 0 volts. Because the BJT inverter could not provide the current or the voltage to drive the vibrator directly, a T-MOS switch, MPF910 was used to switch the power directly from the battery to the vibrator. An LM7805 5-volt regulator was used to power the voltage controlled oscillators. A 9-volt rechargeable battery was used as the power supply.

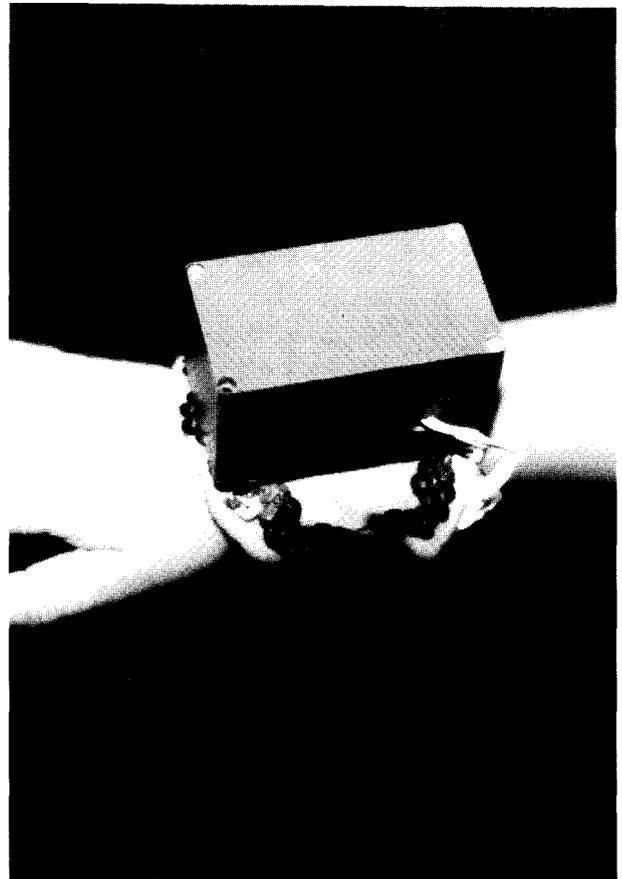


Figure 16.13. A Tactile Pacer.

