CHAPTER 3
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Redesign of ERGYS Exercise Equipment Stim-Wear

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INTRODUCTION:

Spinal cord injury (SCI) individuals suffer from drastic changes in their lifes tyle. The lack of exercise of paralyzed muscles brings many health problems. There are indications that some of these changes may be reversed by exercise and fitness training. Computerized functional electrical stimulation (FES) allows active exercise of limbs paralyzed by upper motor neuron lesions.

The FES leg cycle ergometer has been investigated to study its safety and other effects. As a built-in safety feature, the computerized FES requires all of its 18 leads to be connected to electrodes in order for it to operate. Unfortunately, individuals with incomplete SCI do not use all the 18 leads due to sensation in the skin overlying some of the muscle groups.

The purpose of this project is to enable persons with incomplete SCI to use the ERGYS FES leg cycle ergometer exercise equipment. A resistor box was developed to receive the impulses sent by the computer and present an impedance that would indicate that all of its 18 leads were connected to the computer's internal impedance monitor. The 18 leads are divided into six sets of three. There are three sets of three leads on each side. Each set of leads is colored red, blue and yellow, which are connected to the quadriceps, hamstrings, and gluteus muscles respectively (See Figure 4.1). The box would consist of "dummy" loads to which the pulse would be sent. The load would consist of a 1K resistor connected to each set of leads. There will be a total of six 1K-resistor loads in the box (See Figure 4.2).

SUMMARY OF IMPACT

This device will allow people with partial SCI to use the FES leg cycle ergometer machine. FES is used to provide exercise of limbs to those with spinal cord injuries. Physical activity in paralyzed muscles has been suggested to reduce health problems that are consequence of inactivity due to SCI. Those individuals with partial SCI will be able to exercise the paralyzed muscles without feeling pain in those muscles that have sensation.

TECHNICAL DESCRIPTION

The box was designed to stay attached to the front end of the chair of the ergometer machine. After analyzing the structure of the ergometer chair and the lead cables, it was found that the length of the cables was sufficient to reach the front end of the ergometer chair and the muscles to be stimulated. The box is divided into two symmetrical halves, each containing three sets of three lead connectors. One half contains the right side lead connectors and the other contains the left side lead connectors. Each set of three connectors is soldered to a 1K-resistor load and to a grounding point (See Figure 4.2). The box is attached to the chair by means of a piece of Velcro fabric.

ALTERNATIVES CONSIDERED

The option of building individual 1K resistor load boxes and connect them to each set of leads was considered, however, this option seemed impractical since the boxes would simply lie around when not in use because of their small size and they could get easily lost.

Another option was to put a box with several loads at the end of the existing leads (one on each side of the chair). This was deemed as impractical as the individual boxes, since they would be easily be misplaced.

Placing a box on each side of the chair between the connectors of the computer and the lead cables was also considered. The box would be designed to stay attached to the side of the ergometer chair. Each box would consist of a pair of connectors, one for input and the other for output leads. There would be a switch inside the box that would route the pulse to either the muscle or to the 1K resistor load. This option seemed very practical, but the structure of the chair did not allow for its implementation. The lead cables when not in use could be caught in the pedals. In addition, the cables to and from the box were being caught in the pedal gears. This alternative was more costly than our choice because the special connectors that would have to be used were expensive. The cost was under $20.

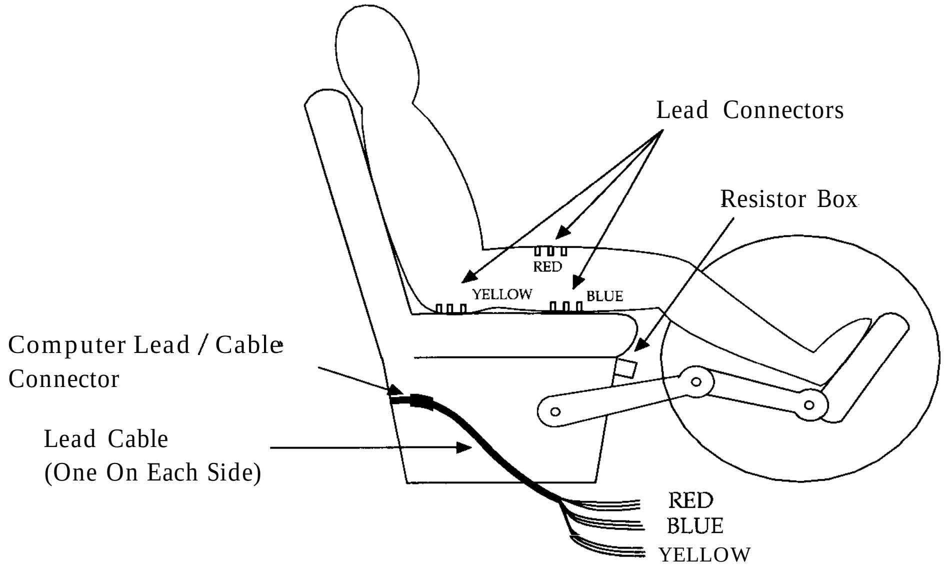

Figure 3.1. Diagram illustrating placement of box and details of box.

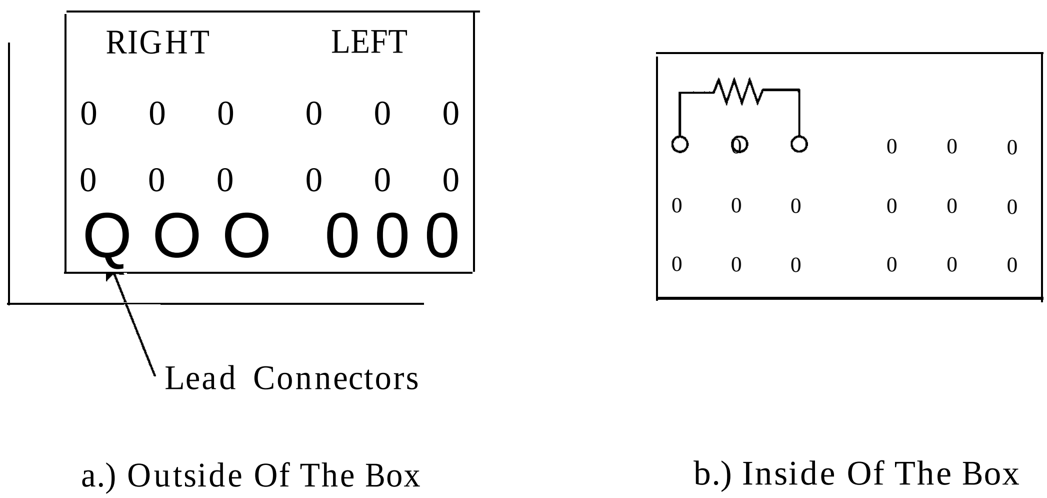

Figure 3.2. Diagram illustrating the resistor box.

Hands-Free Phone System

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INTRODUCTION

A telephone system was designed for persons with little or no control of his/her limbs, to function with the DuoFone 600 telephone, with voice recognition capability, manufactured by Tandy Corporation.

The system provides several special features. First, the standard procedure of lifting the handset of the telephone was replaced by lightly blowing on a plastic air tube. Then, the process of dialing a number by pressing individual buttons (digits) on the phone's keypad was performed by verbalizing each digit until all telephone number's digits have been "dialed". The telephone provides a handful of pre-stored "voice names" to provide automatic dialing of their corresponding telephone numbers. The telephone system was equipped with a nearby speaker and a microphone so that use of the handset is optional. Finally, terminating a telephone call typically performed by placing the handset back into its resting position on the phone was accomplished by once again blowing on the plastic air tube.

SUMMARY OF IMPACT

Many individuals suffer from spinal cord injury and disease that may limit their physical abilities to perform tasks which persons without spinal cord damage would perform quite simply. Despite the physical limitations, loss of most arm and leg movement, quadriplegic individuals typically have fully developed cognitive capabilities.

In order to provide a severely physically disabled person an extra degree of freedom, a project was undertaken to create a phone system which provides a high-level quadriplegic the ability to conveniently communicate with others by phone without assistance. The phone system is tailored to a person who has no control of his/her limbs yet possesses a moderate level of speech clarity and loudness.

TECHNICAL DESCRIPTION

The Hands-Free telephone system consists of Tandy's DuoFone 600 in conjunction with external control interface box.

The external circuitry used to perform most of the special functions described above consists of three main parts. First, the "Sip & Puff" circuitry allows typical "picking up" and "hanging up" of the handset. Next, circuitry is required to prompt the telephone to receive each spoken digit of a dialing number, providing the 1+(Area Code) when necessary. Finally, a speaker and microphone are necessary to allow communication without a handset.

The "Sip & Puff" circuit consists of an air tube connected to a pressure sensor switch that is then fed to a 555 RC de-bouncing circuit. A D flip-flop is initially set when the system is turned on for the first time. Then, each time a puff is sensed, the flip-flop changes state. Hence, the first puff will be defined as that to "pick up" the telephone and the following puff will signify "hanging up" the telephone. When the flip flop is in the ON state, it will enable two relays which make two connections between wires attached to the DuoFone 600. (Note: These are wires labeled HookA, HookA, HookB, HookB).

The manufacture's intended use of the voice recognition function is to act as a form of speed dialing. For example, when the handset is lifted to place a call, the telephone would prompt the entire seven or eleven digit number to be dialed. Our main goal was to store only a single digit as a recognizable "name". Hence, we are interested in having the telephone recognize seven or eleven "names", which are digits zero through nine.

The function of prompting the Duofone 600's voice recognition circuitry to accept individual verbalized digits is controlled by a state machine located on the system circuit board. Connecting two wires attached to the phone, both labeled "voice", causes a signal to be generated prompting the voice recognition circuitry to attempt to match the proceeding speech to its pre-stored memory. Thus, a state machine, described in Figure 3.3, was created to determine exactly when to generate this prompting signal.

Eight states have been defined: S8: Wait for phone to be in use; S1: Wait for DataValid (signal generated when DTMF signal is detected and decoded); S2: Load counter to 7; S3: Load counter to 11; S4: Wait for not DataValid; S5: Decrement counter, GT & generate prompting signal; S6: Wait for not DataValid; S7: Wait for phone use to be terminated.

Thus, the system should rest in state 8 when not in use. When phone use begins, the machine moves to state 1 where it waits for a digit to be dialed. When the first digit is dialed, a counter is set. If this first digit is a one, indicating a call outside the user's area code is being placed, then state 3 loads the counter to eleven. Otherwise, a "non-one" causes state 2 to load the counter only to seven. Regardless which state was chosen, two or three, the state machine automatically proceeds to state four where it waits for the termination of the DTMF signal. (This is a safety measure to prevent one DTMF signal to account for all the digits intended to be dialed.) If all seven or eleven digits have not been dialed, then the machine proceeds from state four to state five where the counter monitoring the number of digits dialed is decremented, a GT signal is produced resetting a Motorola DTMF receiver circuit, and the prompting signal is generated for the DuoFone 600's voice recognition circuitry to activate. The state machine proceeds to state six where it awaits another DataValid signal detecting a digit being dialed. Upon receiving this DataValid signal, the machine moves to state four where it waits for the DTMF signal to terminate again. The machine will again proceed to state five if the counter is not zero. But, if the counter's value is zero, all the digits have been dialed, and the state machine activates state seven where it waits for the phone use to end. When this termination occurs, the state machine once again rests in state eight.

The third part of this phone system, the speaker and microphone circuit, will be added in a subsequent student project.

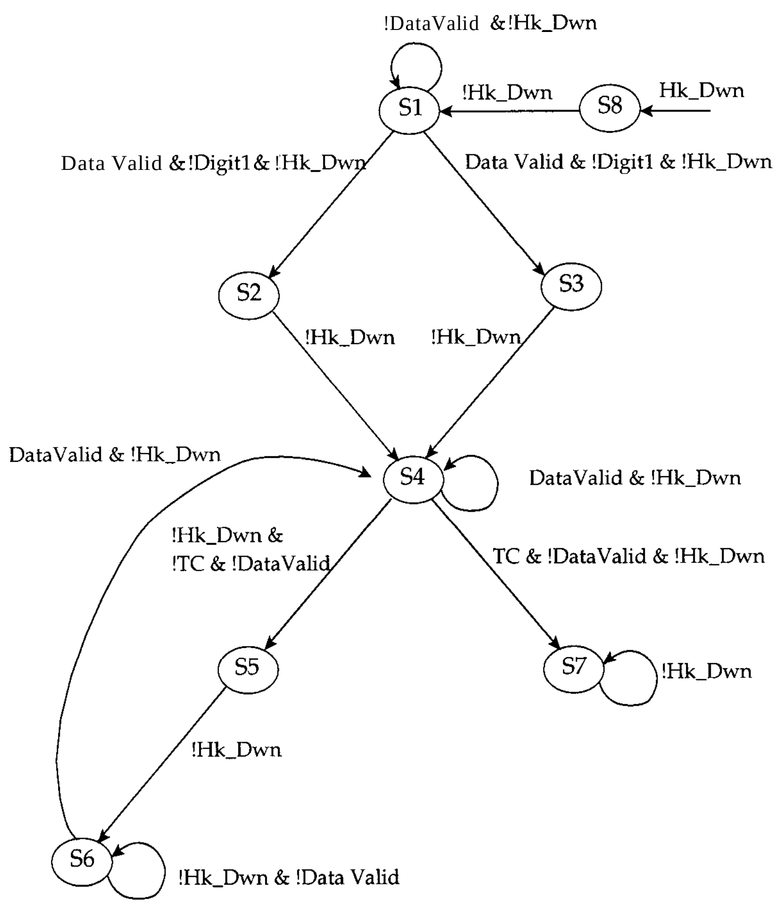

Figure 3.3. Diagram of State Machine

Pressure Relief Training Device

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INTRODUCTION

The pressure relief training device was developed specifically for individuals confined to wheelchairs as a result of an injury to their spinal cord. One of the most common, as well as serious, complications experienced by these individuals are pressure sores or decubiti. Decubiti can be defined as an ulceration of the skin and the underlying tissue caused by pressure that limits the flow of blood to the affected area, mainly the posterior femoral cutaneous nerves located in the lower limbs. The interference with normal blood flow is caused by the prolonged pressure of the body upon the cushion of the wheelchair. The prevention of decubiti is best accomplished by frequent changes of position. It is therefore recommended that individuals confined to wheelchairs perform a one minute duration push-up about four times an hour (Agris, J. and M. Spira. "Pressure Ulcer: Prevention and Treatment." Ciba Clinical Symposia. Vol. 31, No 5, 1979.)

SUMMARY OF IMPACT

The pressure relief-training device will help the individuals confined to the wheelchair form the psychological habit of doing regular push-ups. It will also help the physical therapist in monitoring the patients for appropriate compliance with the prescribed push-up regimen with its built in alarm system (Malament, I.B., M.E. Dunn, and R. Davis. "Pressure Sores: An Operant Conditioning Approach to Prevention." Archives of Physical Medicine and Rehabilitation. 56:161-165, 1975.) When the patients have done a successful push-up, it permits the flow of blood to the posterior femoral cutaneous nerves which therefore reduces the incidence of decubiti.

TECHNICAL DESCRIPTION

Previous attempts at solving this problem have relied on sensing when pressure is removed from the seat. Since the pressure relief training device detects the shifting of the body weight onto the arms of the wheelchair, a unique modification of the design of an armrest is crucial. It was installed in place of the original wheelchair armrest. The strain gauge transducer is mounted at the center on the underside of the aluminum cross-member so that the fine wires from which the gauge are made undergo resistance changes. Since the pressure sensor functions as a bridge, the output of the bridge is delivered to the precision instrumentation of amplifier (AD 524). It was then amplified, and sent to the comparator with a variable threshold set by the physical therapist in conjunction with the individuals' body weight. A 4-bit up-down counter with the decoder / demultiplexers counts up to N times and recycles. By adding the divide-by-120 counter, one can adjust the timing between 15 to 50 minutes. A pulse is provided when the counter reached the setup time to set a flip-flop to drive a buzzer. Whenever the comparator detects a successful push-up has been completed, the counter is reset and the alarm is terminated. If the comparator did not detected the 10 seconds duration push-up, the alarm will be activated and the counter will also reset after one minute. A block diagram of the device is shown below. The cost was approximately $120.

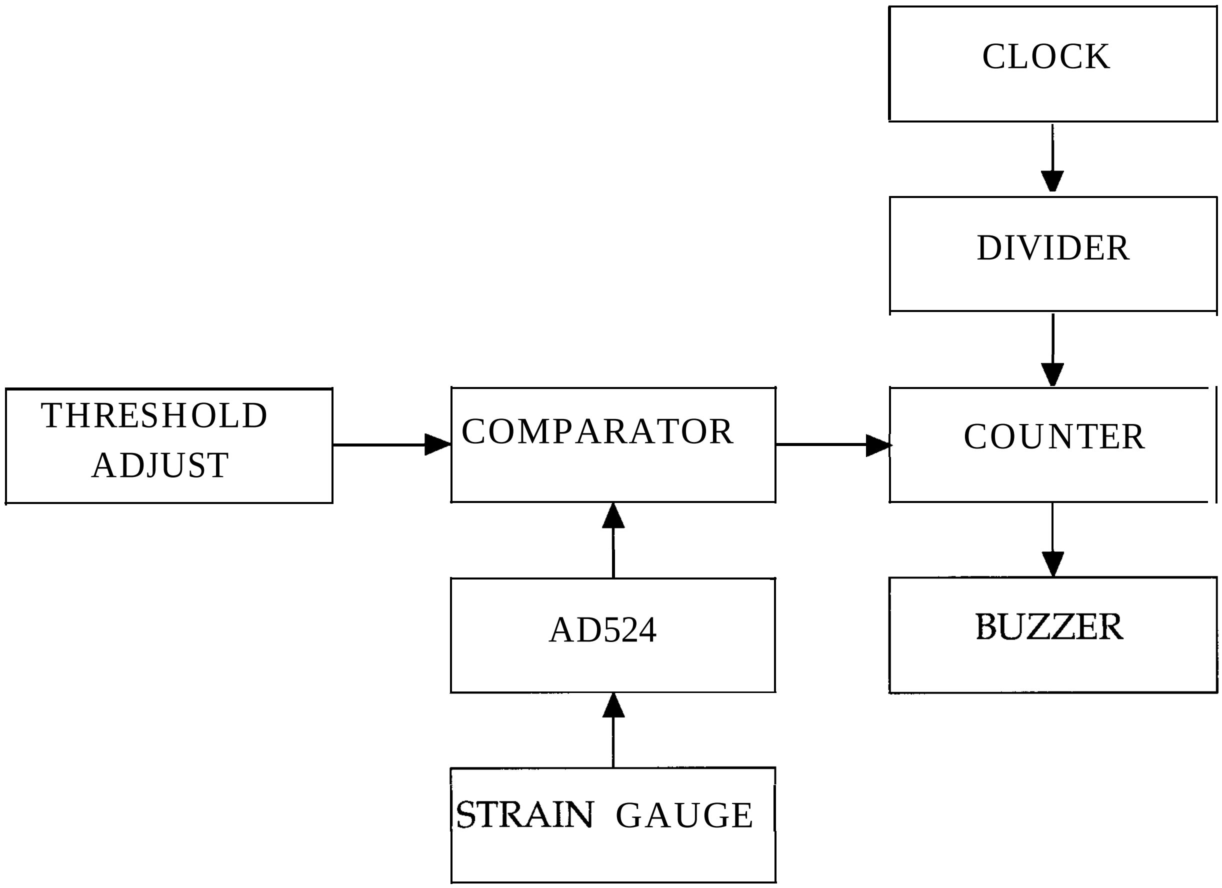

Figure 3.4. Block Diagram of Device.