

# Morse Code Application for Wireless Environmental Control Systems for Severely Disabled Individuals

Cheng-Hong Yang, Li-Yeh Chuang, Cheng-Huei Yang, and Ching-Hsing Luo

**Abstract**—Some physically-disabled people with neuromuscular diseases such as amyotrophic lateral sclerosis, multiple sclerosis, muscular dystrophy, or other conditions that hinder their ability to write, type, and speak, require an assistive tool for purposes of augmentative and alternative communication in their daily lives. In this paper, we designed and implemented a wireless environmental control system using Morse code as an adapted access communication tool. The proposed system includes four parts: input-control module; recognition module; wireless-control module; and electronic-equipment-control module. The signals are transmitted using adopted radio frequencies, which permits long distance transmission without space limitation. Experimental results revealed that three participants with physical handicaps were able to gain access to electronic facilities after two months' practice with the new system.

**Index Terms**—Adaptive signal processing, assistive technology, environmental control, Morse code.

## I. INTRODUCTION

ACCOMPANIED by the rapid growth of information technology engineering, computers are now used widely in a variety of fields. Applications of computers and various software in training, teaching, learning, and computer-assisted instruction are a major future trend. However, most products are designed for general persons, and are inaccessible to people living with disabilities, unless extra adaptive tools and interfaces were designed for them. Consequently, a current trend in high technology production is to develop adaptive tools for handicapped people to assist them with self-learning and personal development, and lead more independent lives. Among the various technological adaptive tools available, many are based on the adaptation of computer hardware and software. The areas of application for computers and these tools include training, teaching, learning, rehabilitation, communication, and adaptive design [1]–[4].

Many computer-assisted key-in systems are designed to allow people living with disabilities the use of computers; these include the head mouse, mini-keyboard, king-keyboard, trackball,

joystick, alternative keyboard, and keyguard [5]. These communication interfaces are based on traditional line-controlled technique, or new techniques like infrared-control, ultrasonics, or radio waves. The mouse emulators, hand-mouse, joystick mice, trackballs, and touch screens are used by speech impaired users and users with moderate cerebral palsy; the mouse-driven keyboard is used by the individuals with disabilities who are unable to use a keyboard effectively but can use a mouse [3], [6]. All of these researches try to provide an unhindered computer environment for people living with disabilities, no matter whether they suffer from a spinal cord injury, or are nonvocal quadriplegics, visually handicapped, or hearing impaired. Usually people living with disabilities will face problems, like high equipment cost, an accurate recognition, expansibility, portability, and availability [7]–[9]. A person with severely handicapped hand coordination and dexterity has great difficulties handling environmental control devices due to the lack of a suitable adaptive communication device and computer input interface. Morse code, as an adapted computer-access method via special software programs, hardware devices, and switches has been shown to be valuable in assistive technology (AT), augmentative and alternative communication (AAC), rehabilitation, and education [10]–[20]. Over 30 manufactures/developers of Morse code input hardware or software for use in AAC and AT have been identified to date [6].

In this study, Morse code, with an easy-to-operate single switch input system, was selected as a communication adaptive device for people living with disabilities, an easily operated interface provided and an elicit recognition method implemented. The handicapped may be able to access electronic facilities by using the proposed communication interface system. Experimental results revealed that three handicapped participants were able to gain access to resources in electronic facilities after two months' practice with the proposed system. This paper is organized as follows. In Section II, the system design of the proposed system is presented. Section III details the experimental result and discussion with concluding remarks made in Section IV.

## II. SYSTEM DESIGN

Morse code is a simple, fast, and low-cost communication method composed of a series of dots, dashes, and intervals in which each character entered can be translated into a predefined sequence of dots and dashes (the elements of Morse code). A dot is represented as a period (“.”), while a dash is represented as a hyphen or minus sign (“-”). Each element, dot or dash, is transmitted by sending a signal for a standard length of time.

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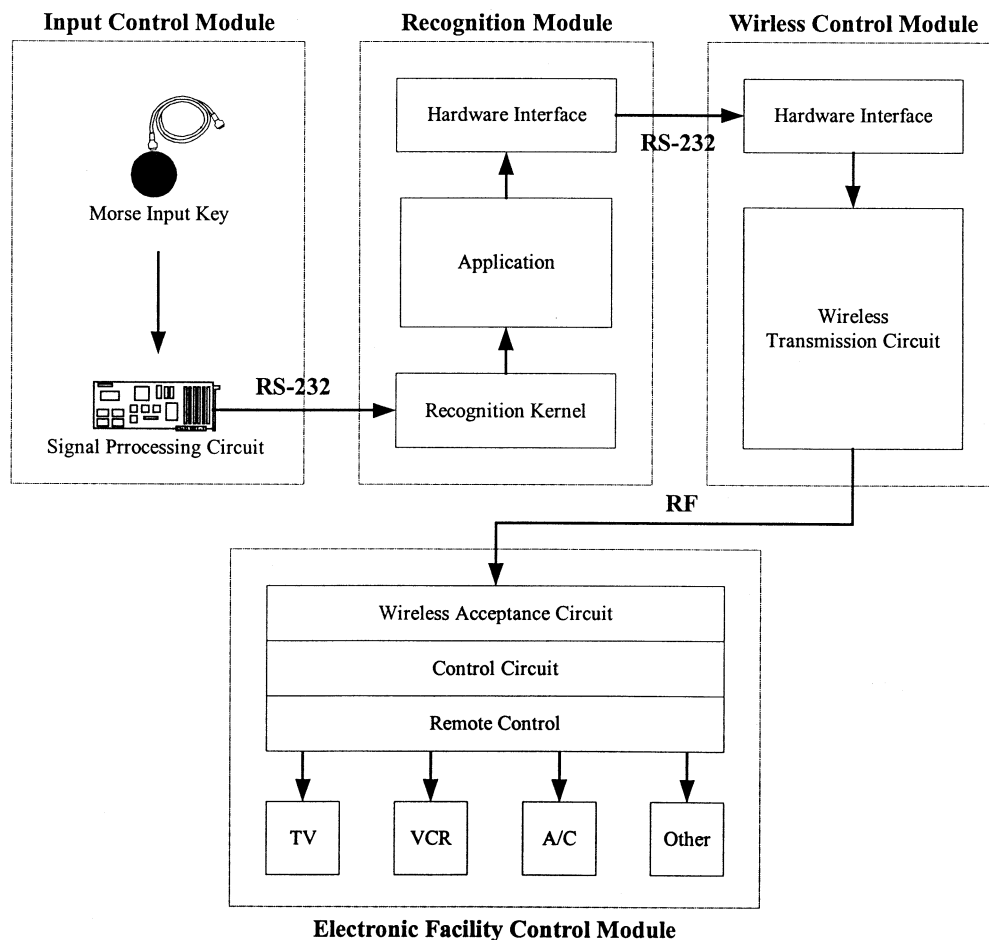


Fig. 1. Block diagram of the wireless environmental control system.

According to the definition of Morse code, the tone ratio for dot to dash must be 1 : 3. That means that if the duration of a dot is taken to be one unit, then that of a dash must be three units. In addition, the silent ratio for dot-dash space to character-space also has to be 1 : 3. In other words, the space between the elements of one character is one unit while the space between characters is three units [21].

Some people with impaired hand coordination and dexterity need family members or trained nursing staff to assist them in their daily lives. Morse code has been shown to be an excellent candidate for a communication adaptive device [6]. In our previous study, we present an interactive Morse code emulation system to help beginners or people living with disabilities to become acquainted with Morse code and to communicate with a computer by implementing a multimedia package [21]. A stable typing rate is strictly required in order to recognize Morse code correctly. It is not easy to control typing speed due to long time typing cause of tired and resulted in error generated. This restriction is a major hindrance for people living with disabilities to have Morse code as a useful tool. Therefore, several adaptive recognition methods were developed to increase recognition rate [22]–[24]. An easy-to-operate input interface especially for physically handicapped users to facilitate access to the Internet also designed [25]. In this paper, we selected Morse code as an input method to handle environmental control devices for

the person with disabilities. The proposed system help the persons with physically disabilities to operate all electronic system, for example, a TV, air-conditioner, video, and so on, by using a single switch. To allow people with disabilities easy control of all electronic facilities without space limitation, we selected wireless transmission instead of wire transmission.

The wireless environmental control system proposed in this paper is divided into four modules: an input-control module; a recognition module; a wireless-control module; and an electronic-equipment-control module. A block diagram of the proposed system frame is shown in Fig. 1. Initially, the signals, which are generated by a user pressing a single switch, go through an input-control module. The data transfer of the single chip and computer is based on a universal asynchronous receiver transmitter (UART), which uses an RS-232 port. The input signal are recognized as either dot or dash or dot-dash space to character-space in the recognition module. The dot-dash space and character space represent the space that exists within a character and between characters, respectively. After the input data stream has been recognized, these digital signals are sent to the wireless control module to be transferred using a radio frequency (RF). Next, in the electronic facility control module, the RF signal is then received by the wireless acceptance circuit and transformed into digital signal by a single chip 8051. We can then control the single-switch relay

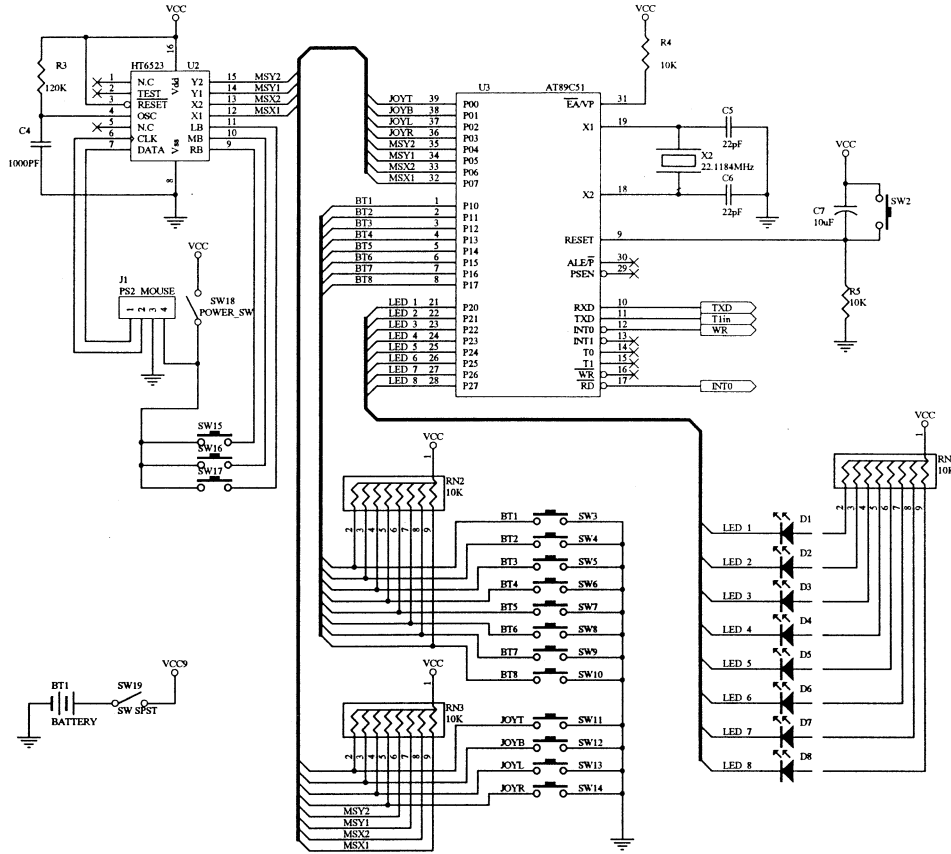


Fig. 2. Input control circuit.

and use a remote controller to operate electric appliances. A detailed explanation of how each module operates is presented in the following section.

#### A. Input-Control Module

The input-control module consists of a set of highly sensitive switch circuits, a single chip, and a coding/encoding circuit. The signals, which are generated by a user pressing a single switch, go through a signal processing circuit and are then sent to a personal computer (PC) via the RS232 port. After the data is transferred, the signal is sent to the recognition module to be recognized. An 8051 single chip is adopted to handle communication between the press-button processing and the personal computer. The input control module circuit is shown in Fig. 2.

#### B. Recognition Module

The recognition kernel here is divided into four parts (see Fig. 3) [25]: space recognition; tone recognition; adaptive processing; and character recognition. A Morse code character  $x_i$  is represented as follows:

$$e_1(x_i), b_1(x_i), \dots, e_j(x_i), b_j(x_i), \dots, e_n(x_i), b_n(x_i)$$

where

- $e_j(x_i)$   $j$ th tone duration in the character  $x_i$ ;
- $b_j(x_i)$   $j$ th silent duration in the character  $x_i$ ;
- $n$  the total number of Morse code elements in the character  $x_i$ ;

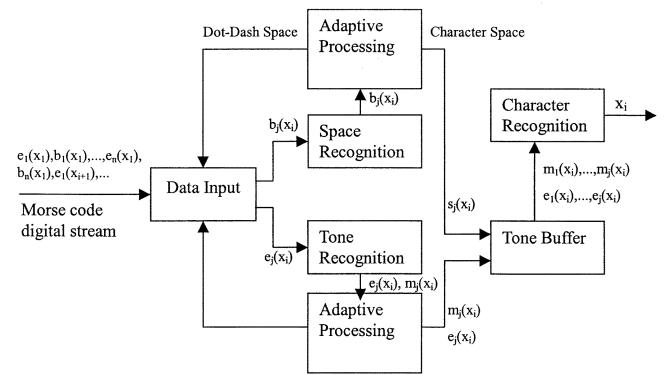


Fig. 3. Block diagram of the Morse code recognition system.

$m_j(x_i)$  the  $i$ th Morse code element of the input character  $x_i$ ;

$s_j(x_i)$  the  $i$ th character space of the input character  $x_i$ .

A block diagram of the Morse code recognition process is shown in Fig. 3. Initially, the input data stream is sent individually to either tone recognition or space recognition depending on the switch-down time (tone element) or switch-up time (space element). In tone recognition, the tone element value is first recognized as either a dot or a dash, and then sent to the adaptive process, which is used to recalculate weights. Simultaneously, in the tone buffer section, the recognized tone element (dot or dash) and each successive tone element are saved in a dot-dash buffer and a tone element buffer. Next, in the space recognition

Morse Code Map (EN)

Special Keys	Edit Keys	Number Keys
Shift	Insert	1
Ctrl	Delete	2
Alt	Home	3
Caps Lock	End	4
Tab	PageUp	5
Enter	PageDown	6
	Back	7
		8
		9
		0

Normal Keys		
A	N	Space
B	O	
C	P	
D	Q	
E	R	
F	S	
G	T	
H	U	Left
I	V	Top
J	W	Right
K	X	Bottom
L	Y	
M	Z	

Fig. 4. Input character match table.

stage, the space element value is recognized as being either a dot-dash space or a character space. If a character space is obtained, then the value(s) in the tone buffer is (are) sent to character recognition. To account for a variable switch-down and switch-up speed, both, the space element value and tone element value, have to be adjusted. If the space element value is recognized as a character space, it is divided by a constant (3.0) before being fed into the adaptive processing stage. Otherwise, the space element value feeds directly into the adaptive processing stage. The tone element value is sent into the tone base adjustment. Once this occurs, the character can be identified in the character recognition [25].

The software for the application part provided in the operation interface includes five functions: coding format; input match table; recognition methods; function selection; and help.

- 1) *Coding format.* The control mode is used to control each electronic facility.
- 2) *Input match table.* Shows each character, number, and control key of the Morse code as well as the function of the each electronic facility (Figs. 4 and 5).
- 3) *Recognition methods.* Three different recognition methods, Luo and Shih (LS) [22], Shih and Luo (SL) [23], and Yang [24], are incorporated. Method 1, the LS method, proposes a system that can recognize varying typing speeds using an adaptive technique, the least-mean-square (LMS) algorithm. This system can adjust its characteristics to successfully recognize a message under unstable typing conditions, but the typing speed variation is limited to a range between 0.67 and two times the current speed. To satisfy this limitation, a handicapped person has to be well trained; otherwise, the system will not successfully recognize the Morse code message. However, this restriction can not always

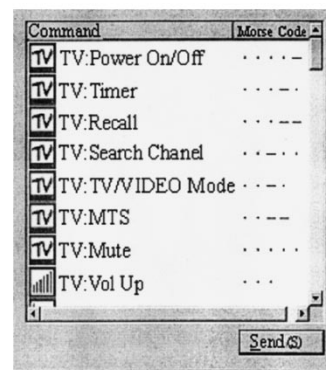


Fig. 5. Some functional commands in Morse code.

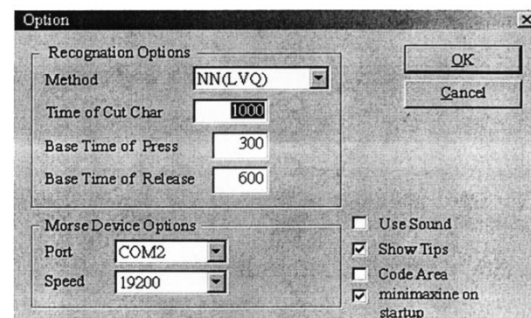


Fig. 6. Function selection.

be complied with by a beginner or by someone with serious disabilities. Therefore, this method cannot be effectively used. Subsequently, method 2, the SL method is an improved method that combines the LMS algorithm with a character-by-character matching technique to overcome the typing speed limitation. Method 3, Yang [24], is a method in which the collected predecessors of tone values and silent values are used to determine the critical tone element value or silent element value, respectively. The determined critical tone element is then used to distinguish the next incoming element as a dot or dash. The same procedure is used to discriminate the silent element.

- 4) *Function selection.* The user can select the word retrieval time, press and release of base time, serial port, hint display, and sound (Fig. 6).
- 5) *Help.* Introduce the each function of the proposed system.

### C. Wireless-Control Module

In this module, the signal is translated into an instruction to control facilities with a RF signal. When the characters are identified, they are sent to a wireless control module via the hardware interface, RS232 port. The digital data is put into a mixer and local oscillator together. Then, a modulating wave is generated and amplified by a power amplifier and sent out by an antenna. An 8051 chip is used to save and decode the incoming signal. Then, the control signal instruction RF is transmitted to the electronic facility (video, TV, recorder, air conditioner, etc.). The wireless-control module circuit is integrated with the input control circuit, and is shown in Fig. 7.

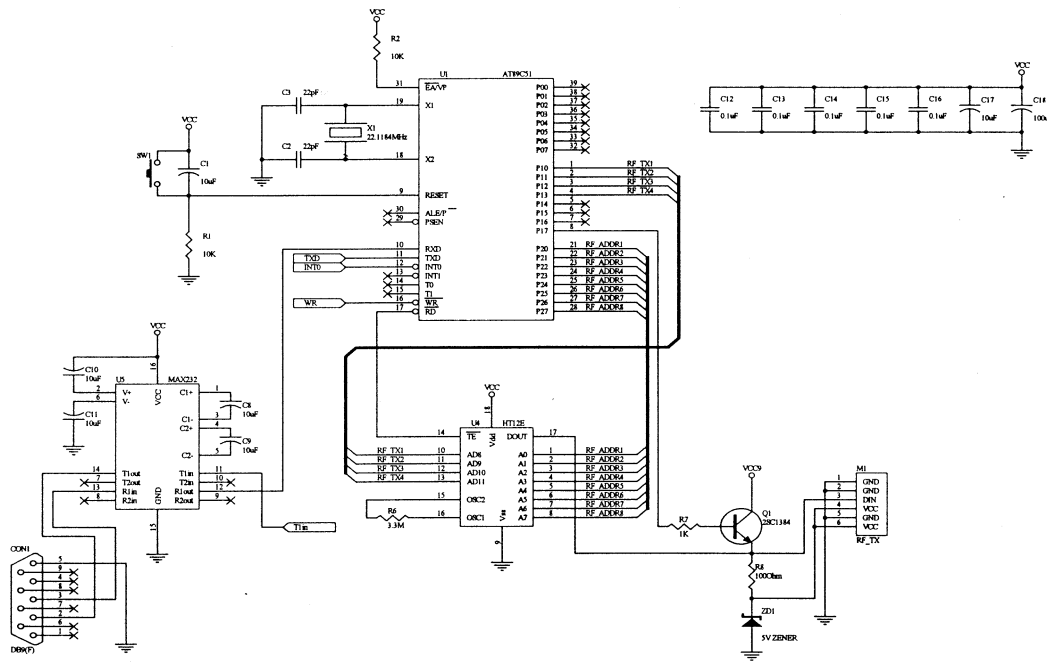


Fig. 7. Wireless-control circuit.

#### D. Electronic-Facility-Control Module

The main function of the module is to operate the electronic facilities. The signal is accepted by an antenna of the wireless accepting circuit and amplified by an amplifier. The frequency difference between the local oscillator and the mixer is in a low to medium frequency range and, therefore, has to be boosted running it through a middle frequency signal amplifier and filter. Next, the signal is filtered for comparison via an amplitude-limited and data filter, and transformed into a digital signal. The output of the Boolean numbers “0” or “1” are sent to the single chip to be interpreted. Finally, the control signal is transmitted by a remote controlled single chip to operate the device controllers. They can be used to operate peripheral devices. The electronic facility control circuit is shown as Fig. 8.

A summary gives an example of how the system works. Let us assume that the handicapped user wants to turn on a TV. Initially, s/he needs to input the TV Morse code form into input-control module. In this example, the user inputs the Morse code “...-” after the input signal is recognized by the recognition module. Then, the Morse code signals are sent to the wireless control module. The signals are interpreted by the single-chip 8051 which emits a control signal to the electronic-facility-control module. In the electronic-facility-control module, the RF signal drives the single-switch relay to turn the TV power on.

The characteristic of the proposed system can be summarized as follows.

- 1) The operation is easy because it is wireless.
- 2) Due to a board integration of operations on a single board, a disabled can easily control an electronic facility.
- 3) The RF transfer control used is able to avoid the infrared (IR) transfer control problem in which the control has to meet the right direction of the receptor to operate the electronic facility.
- 4) The system is easily controlled and can be extended.

### III. RESULTS AND DISCUSSIONS

Many individuals with motoric and/or sensory disabilities are using newly developed adapted-access software programs, hardware peripherals, and learning methods. These technologies allow them to use microprocessor devices via Morse code input systems from switches external to the computer. Even with limited movement or sensory capabilities, are successfully operating computers and other devices via adapted switching mechanisms and Morse code emulation of keyboard input functions [6]. Research and clinical experience are indicating that the fast input rate and low level of physical exertion inherent in a Morse code input system could make it a viable and competitive method of microprocessor control for many people living with disabilities. This alternative computer access method gives handicapped people the ability of speech output, typing, dialing, drawing, and other modes of expression<sup>1</sup> [20].

Even with simple actions such as turning on the light, TV, or air conditioner, etc., people living with disabilities have to overcome considerable difficulties in their home life. Therefore, an environment that allows people with limited hand coordination and dexterity due to muscle atrophy, cerebral palsy, and severe handicap easy operation of every day devices is needed. Although people living with disabilities are able to use infrared light to control electric equipment at home, the users must shout the signal in right direction and the assistance of a receptor is limited due to its range. Moreover, we need to have every equipment monitor control that causes the user inconvenience.

In this system, a handicapped person can use a Morse code input controller to handle the electronic facility. Initially, the signals are serially sent to the computer by means of a serial port after input of the number which represents the electronic facility. An adaptive Morse code recognition was selected to identify

<sup>1</sup><http://www.uwec.edu/ce/Morse2000.htm>.

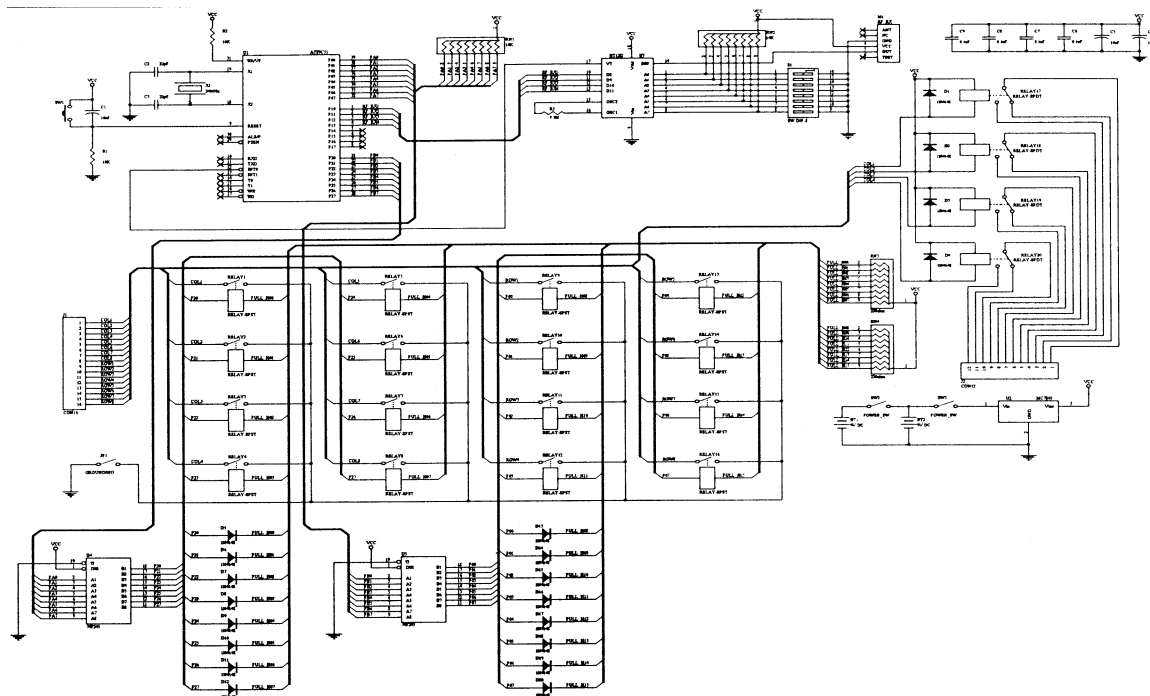


Fig. 8. Wireless accepting/control circuit diagram of electronic facility.

the incoming Morse code signal. After the dot or dash signal of the Morse code was recognized, the computer sent a message to the assigned electronic facility. Maintaining precise intervals is a difficult task even for abled persons, not to mention people living with disabilities. Subsequently, an unstable typing speed or rate may generate space recognition errors. Since the handicapped user is unable to achieve a stable typing speed, the transmission uses an adaptive algorithm which adjusts the criteria which identify a dot or a dash gradually. At last, the control signal is sent to the electronic facility via high-frequency wireless communication and allows people living with disabilities to take care of his daily life. The system presented can be installed in Windows 95/98 and Windows NT environments.

Commonly, IR technology is selected to handle the electronic facility. However, the transmission distance is short for IR radiation and easily blocked by several obstacles. It is not easy to move for severe disabilities. Therefore, high-frequency wireless communication is selected as communication media. The system allows frequency errors of the emitter and a wide temperature range, but affects the reliability of receiver. To increase reliability, a medium frequency is first used to identify the appropriate frequency, then a filter is used to decrease the frequency of range.

Three participants were chosen as test participants to investigate the efficiency of the proposed system after practicing on this system for two months. Participant 1 (P1) was a 14-year-old male adolescent who has been diagnosed with cerebral palsy. His voluntary movements are accessible, but an initial delay is evident before movement is initiated. The involuntary movement partially disrupts the volitional movement, making it uncoordinated. An intelligent quotient (IQ) test showed his intelligence to be normal. Although his hearing and cognition abilities are normal, he exhibited marked speech difficulties. Participant 2 (P2) was a 14-year-old female adolescent with cerebral palsy, athetoid type, who experiences involuntary movements of all her limbs. The involuntary motion is increased when she is excited. Her intelligence is relatively high, but dysarthria is noted, resulting in difficulty of verbal communication. Participant 3 (P3) was a 40-year-old adult male, with a spinal-cord injury and incomplete quadriplegia due to an accident. His right wrist is limited in its functions and his individual finger movement is also limited, which results in dysfunctional hand movement. The sensation in both of his upper extremities is well preserved, and his intellect and ability to verbally communicate are as good as before the accident.

During the training, we provided training on the code set that the participants will ultimately use and they were given text to type. Then, they practiced this system to control electronic facilities. For example, the command "POWER ON" using Morse code, can be constructed using a single switch. To produce "...—", the participants pressed and released the switch, and "POWER ON" appears on the screen. The TV is then turned on automatically. After the tests, the three participants stated that the functionality of the device would improve daily life routines considerably for them. According to the participants, one minor problem with this training is that the end result is limited typing speed and the participants must remember all the Morse code sets of commands.

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#### IV. CONCLUSION

In this study, we have designed and implemented a human-interface for the environmental control device under a windows environment for handicapped persons whose hand coordination and dexterity are impaired by such ailments as amyotrophic lateral sclerosis, multiple sclerosis, muscular dystrophy, and other

severe handicap. Morse code was selected as the adaptive communication device. This system provides an easy-to-operate environment and allows a handicapped user to access an electronic facility by Morse code. This system unites every kind of house electric equipment in a wireless environment; people living with disabilities can use Morse code to key-in a control command for any kind of electric equipment. By using a wireless RF signal transport, the equipment can be activated. Thus, people living with disabilities can be more independent and their dependence on relatives or friends is limited, which decreases social cost. Experimental results revealed that three handicapped participants were able to gain access to electronic facilities after two months' practice with the new system.

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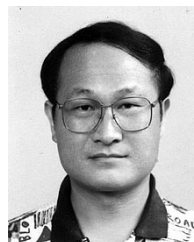
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