Remote Control of Microcontrollers with a Telephone

Chong Chen and Jack Crotty
Department of Engineering Technology and Industrial Studies
Middle Tennessee State University
Murfreesboro, TN 37132

Abstract

Computer network technology has developed rapidly in recent years. A person may contact another person in any part of the world through a computer network. A person may also control the operations of a computer at a remote location through a computer network. Each of these requires access to a computer linked to a computer network.

This paper presents a low cost, simple system to control a microcontroller over a phone line. Any touch-tone phone can be used for sending commands to the microcontroller. A computer and computer network access are not needed for this remote control. The system allows one to operate a microcontroller and control other equipment connected to the microcontroller from any touch-tone telephone.

This remote control system includes an answering machine, a signal detecting and decoding circuit, and a Motorola 68HC812 microcontroller. The answering machine works like a regular answering machine, which answers calls and records messages. The control commands are entered by pressing a telephone keypad. The password, start command, and other control commands are comprised of different predetermined keypad signal sequences. The detecting and decoding circuit monitors the incoming phone signals and sends the decoded keypad signals to the microcontroller. When a start command is detected, the microcontroller takes over the phone line and signals the answering machine to drop off the line. Then, after detecting a correct password, the microcontroller accepts the incoming commands from the phone line. Following these commands, the microcontroller may send signals to operate other connected equipment, such as air conditioning, or security system of a building. It may also send requests to other computers.

Introduction

With the development of local area networks, wide area networks, and the Internet, people can easily operate remote computer systems. The distance between the computer and the operator is no longer measured in feet, and could be hundred or thousand miles. To communicate with a computer network, the operator usually needs another computer linked to the network. Figure 1 shows a computer network [1]. Any computer in the network may send information to, or receive information from, any other computer in the network.

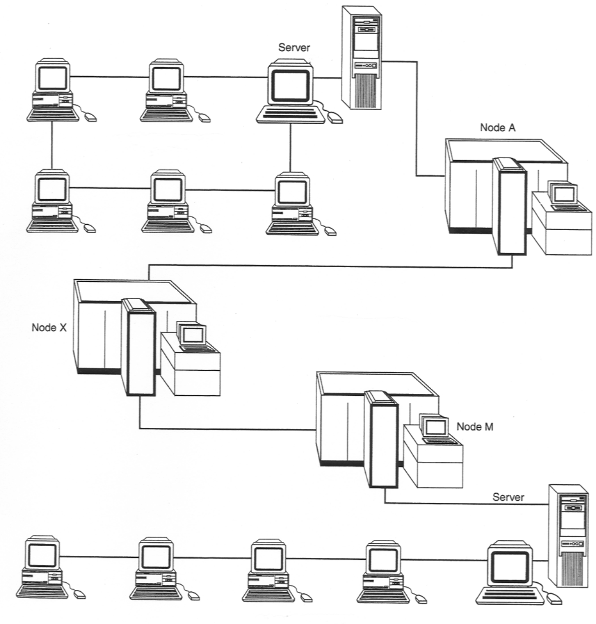

Figure 1. A Computer network

Computer networks, especially the Internet, provide convenience and accessibility to computer users. A person on a trip may read email and check other information on his/her office computer, or search and get information stored in other computers through Web pages, as long as the computer is properly connected to the Internet.

For people on the road, in a shopping mall, or at many other locations, it is often impossible to have access to a computer linked to a network. However, public telephones are available almost everywhere. With cellular telephones becoming more affordable, operating a computer or a microcontroller through the telephone system allows one to enter predetermined commands from almost any location. These commands could comprise simple or more complicated instructions.

Fiber optic materials are used widely in telecommunications. It provides high quality information transmission. Today's telephone systems offer baud rates higher than 45 K to most households. This fast, reliable communication has allowed the use of the telephone network for more than mere communication of voice. Fiber optic telephone lines and the use of touch-tone telephones enable the telephone system to transmit many diverse types of information. Touch-tone phones allow different types of systems to communicate. They also allow faster transmission of keystrokes.

The remote control system presented uses a microcontroller to accept commands entered from the keypad on a touch-tone telephone. A microcontroller is a single-chip-controller integrated with a microprocessor and its peripherals. A microcontroller consists of four basic parts: central processing units (CPU), registers, internal memory, and an input/output (I/O) subsystem. These parts are connected internally by an internal bus. Figure 2 shows the structure of a microcontroller [2]. The internal memory and I/O subsystem, which are not available in a microprocessor, make a microcontroller more advanced than a microprocessor. The internal memory stores the program to be executed and data that are to be operated on by the program. Examples of the memory include RAM, ROM, PROM, and EPROM. The I/O subsystem allows the microcontroller to exchange information with the outside world. The I/O subsystem is grouped into units called I/O ports. Each I/O port has I/O lines to transfer information between the external devices and the ports. These lines can be input only, output only, or programmable to be either. Each port also has its own control, status, and data registers. A microcontroller may also have an analog-to-digital converter and/or a digital-to-analog converter.

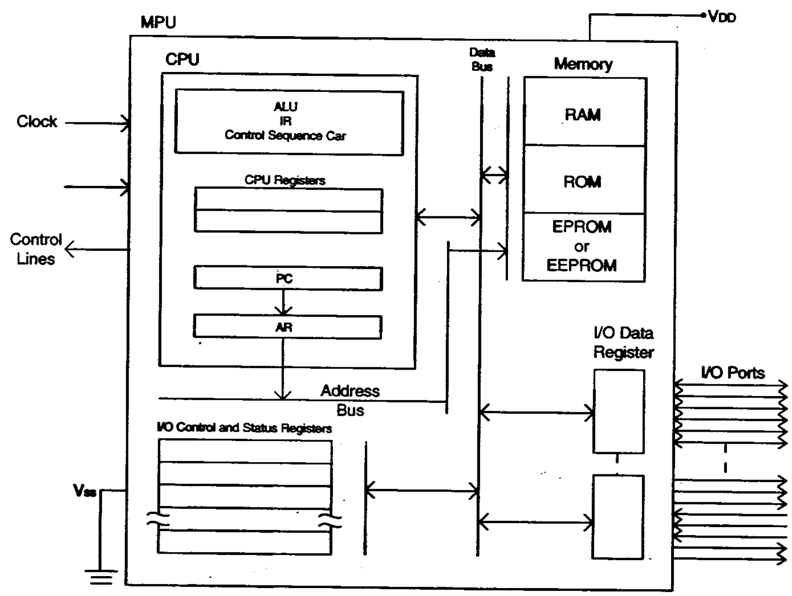

Figure 2. Block diagram of a microcontroller

The remote control system is connected to phone line through an answering machine. The answering machine answers all incoming phone calls. The microcontroller 'listens' on the line for a start command. When a start command is detected, the system connects a 600-Ohm load, which is the same amount of resistance of a picked up phone, to the phone line. This makes the answering machine automatically disconnect from the line. The microcontroller takes over the phone line, and awaits password and control commands.

Operation of a touch-tone phone

The heart of a touch-tone telephone system is Dual Tone Multiple Frequency (DTMF) encoding. With DTMF encoding, two distinct frequencies are sent out over the phone line [3]. Eight different frequencies are used in the DTMF encoding system. These frequencies are shown in Figure 3. Each digit or key produces a combination of two of these frequencies. Four of the eight frequencies are attached to the four rows of the keypad, and the remaining four are attached to the four columns of the keypad. With four rows and four columns, the DTMF encoding supports 16 distinct keys. A touch-tone keypad has four rows, three columns, and twelve buttons, the numbers 0 through 9, plus “*” and “#”. However, the frequency for a fourth column is available for encoding in the system. To use the additional four keys, defined as A, B, C, and D by the telephone system standard, all that would be needed are four additional buttons and contacts connecting the four rows to the additional column.

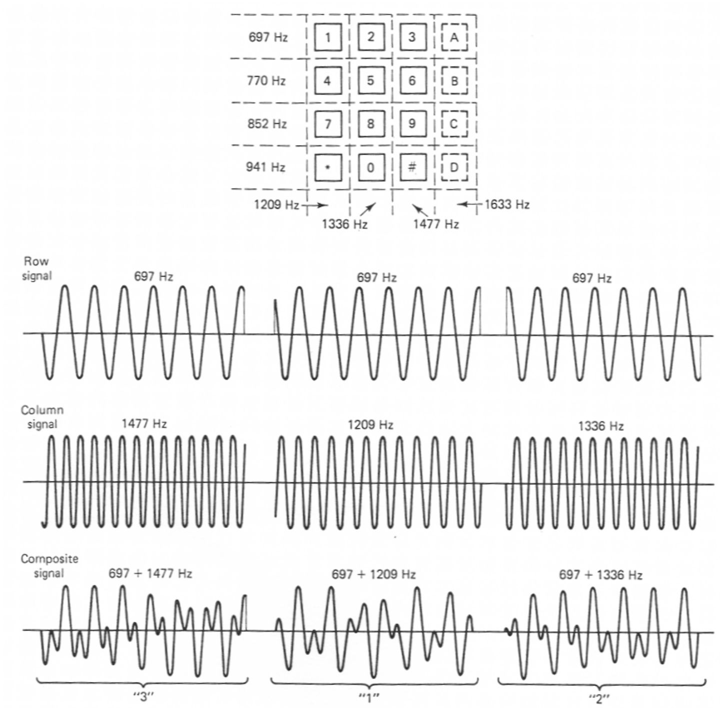

Figure 3. DTMF dial

Standard touch-tone telephone keypads have two contacts per button. For example, when button 1 is pushed, one contact turns on the 697-Hz oscillator, and the other one turns on the 1209-Hz oscillator. The buttons on the top row of a telephone keypad are numbers 1, 2, and 3. All of them are connected to a row wire that runs horizontally beneath them to the 697-Hz oscillator. Figure 3 shows how the frequencies are combined when the number “312” is dialed on a DTMF dial. The frequency combinations for all keys of a touch-tone phone are listed in Table 1.

Table 1. Touch-tone telephone key frequency combinations

Key	1	2	3	4	5	6	7	8	9	0	*	#
Row frequency (Hz)	697	697	697	770	770	770	852	852	852	941	941	941
Column frequency (Hz)	1209	1336	1477	1209	1336	1477	1209	1336	1477	1336	1209	1477

Control System

The remote control system presented in this paper is a low cost, simple system to control a microcontroller over telephone lines. This control system includes a telephone answering machine, a detecting and decoding circuit, and a Motorola 68HC812 microcontroller. The answering machine can be any standard unit found in most households, which usually answers calls and records messages. The microcontroller accepts commands sent from a standard touch-tone phone at any location. The microcontroller may also control additional systems or processes at its own location. This approach does not require complicated network connections. It provides remote control of the system from any location having access to a telephone, either hardwired or cellular.

Figure 4 is the schematic diagram of the control system. This system can be used with any phone line jack having an assigned phone number. A metal oxide varistor (MOV) is used to protect the circuit from any high voltage spikes that may enter through the telephone line. A telephone system considers a 600-Ohm load connected to the line as a correct load or a picked up phone. When the pickup relay contact is open, the 10-kOhm resistor and the primary of the transformer are in parallel with the answering machine. A 10-kOhm resistance is much higher than what the phone system recognizes as a picked up phone. Therefore, the circuit is not noticed by the telephone system. This concept is important because it allows an answering machine to be connected and the control circuit to monitor the signals. As soon as a phone call comes, the answering machine greets the call. That allows the caller to leave a message or send control commands. When the answering machine is working, the HT9170 decoding circuit decodes all the incoming keypad signals and sends them to the microcontroller. The start command of this control system is the “#” key. That could be reprogrammed to a more complicated one for different applications. When the microcontroller detects the start command, it acknowledges the signal by closing the pick up relay. This causes the 10-kOhm resistor to be bypassed and the control circuit to be connected to the telephone line through the 600-Ohm resistor. Now, the answering machine recognizes a signal that a “phone” has been picked up. Therefore, it drops off the line.

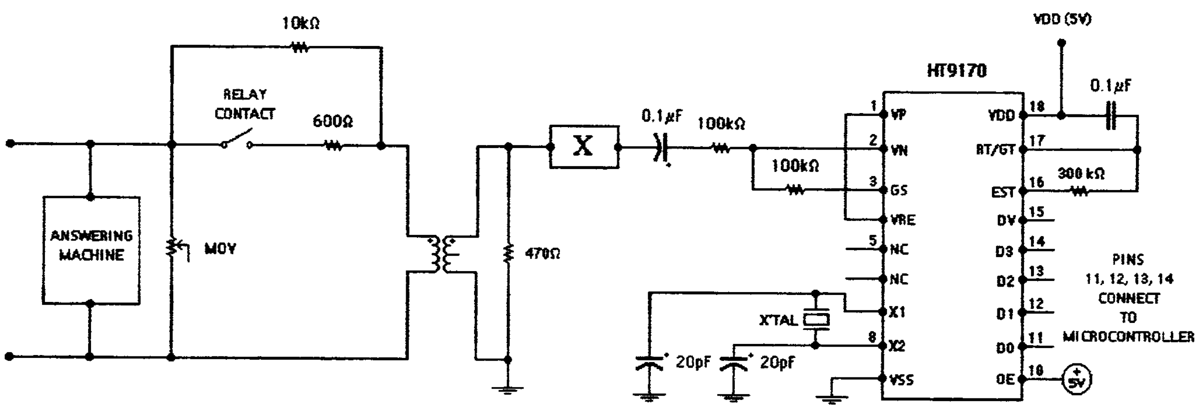

Figure 4. Control circuit between telephone line and microprocessor

In the control system, the transformer is used to isolate the decoding and microcontroller circuit from the phone line circuit. Block “X” in Figure 4 is an amplifier circuit. Its details are shown in Figure 5. This amplifier circuit amplifies and limits the signal levels to the decoding IC chip. The voltage gain of the amplifier is 100/1.5. When the signal voltage on the phone line is

0.15 volt, the output voltage of the amplifier would be 10 volts, if there were no clipping from the op-amp. However, since the op-amp uses a positive and negative 5-volt power supply, the output of the amplifier is approximately limited to a range between positive and negative 4.2 volts.

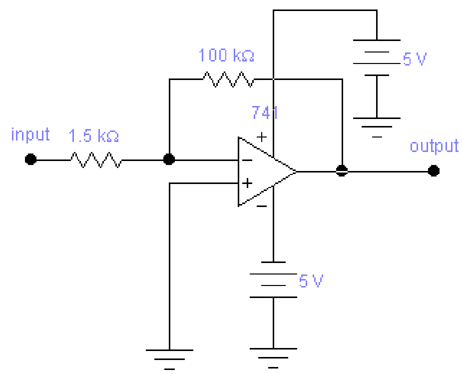

Figure 5. Amplifier circuit for shaping and limiting telephone signals

The HOLTEK HT9170 is a Dual Tone Multi Frequency (DTMF) receiver integrated with a digital decoder and a band-split filter function [4]. This chip uses digital counting techniques to detect and decode all of the 16 DTMF tone pairs, mentioned in the above section, into 4-bit binary outputs. Table 2 shows the HT9170 input/output relation. The data outputs (D0 - D3) are tristate outputs. When Output Enable (OE) input is low, the data outputs are high impedance. When the OE input is high, the data outputs represent the decoded input frequencies.

Table 2. HT9170 data output table

Row Frequency (Hz)	olumn Frequency (Hz)	Dight	OE	D3	D2	D1	D0
697	1209	1	H	L	L	L	H
697	1336	2	H	L	L	H	L
697	1477	3	H	L	L	H	H
770	1209	4	H	L	H	L	L
770	1336	5	H	L	H	L	H
770	1477	6	H	L	H	H	L
852	1209	7	H	L	H	H	H
852	1336	8	H	H	L	L	L
852	1477	9	H	H	L	L	H
941	1209	0	H	H	L	H	L
941	1336	*	H	H	L	H	H
941	1477	#	H	H	H	L	L
697	1633	A	H	H	H	L	H
770	1633	B	H	H	H	H	L
852	1633	C	H	H	H	H	H
941	1633	D	H	L	L	L	L
Any	Any	Any	L	Z	Z	Z	Z

A standard 3.5795 MHz crystal connected between the X1 and X2 pins of HT9170 is required to implement the oscillator function. Resistors R1, R2, and R3, and capacitors C1, C2, C3, and C4 are recommended for use in a HT9170 circuit by its manufacturer.

Microcontroller

The microcontroller used is a Motorola 68HC812 programmed with C language. The MC68HC812 microcontroller unit (MCU) is a 16-bit device composed of standard on-chip peripheral modules connected by an inter-module bus [5]. Modules include a 16-bit central processing unit (CPU12), a Lite integration module (LIM), two asynchronous serial peripheral interfaces (SCI0 and SCI1), a serial peripheral interface (SPI), a timer and pulse accumulation module, an 8-bit analog-to-digital converter (ATD), 1-kbyte RAM, and memory expansion logic with chip selects, key wakeup ports, and a phase-locked loop (PLL).

In this control system, the microcontroller receives the decoded information from the HT9170. After detecting the start command, the microcontroller energizes the pick up relay to connect the 600-Ohm resistor to the phone line. Then, it is ready to receive the password and more commands sent in through the phone line.

Applications

Based on the commands received, the microcontroller may perform various control functions. Applications include controlling the household environment (heating, air conditioning, security system, etc.) recording system status, and providing further communication to other linked computers.

One of the projects that have been worked on is to control the temperature, humidity, and a security system in a house. A microcontroller is used to receive the signals from sensors and to activate/deactivate alarms, lights, air conditioning, heat pump, and dehumidifier. This microcontroller is the same one used in the remote control system. It allows the operator of the control system to modify the control program or change the set ups, such as the temperature or humidity levels, at another location.

Conclusions

This paper presents a control system for remotely operating a microcontroller over the phone line. The system is low in cost, easy to build, and easy to install. Based on the commands received, the microcontroller will control other equipment or contact a computer linked to the microcontroller. The entire system has been built and tested in the laboratory. It performed all the functions expected.

Bibliography

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Biography

Dr. Chong Chen is an associate professor in the Department of Engineering Technology and Industrial Studies, Middle Tennessee State University. He received his B.S. degree from Hebei Institute of Technology in China, M.S. degree from Tianjin University in China, and Ph.D. degree from the University of Kentucky, all in Electrical Engineering. Dr. Chen teaches electric circuits, electronics, controls, and industrial electricity. His research areas include controls, power electronics, electric machines, and electromagnetic fields. Dr. Chen is a Professional Engineer registered in the State of Tennessee.

Mr. Jack Crotty received his M.S. degree in Industrial Studies from Middle Tennessee State University. Mr. Crotty has many years of industrial experience in instrumentation, controls, and computer programming. Currently, he is a control engineer at the Trane Co. in Clarksville, Tennessee.