TV Remote Controller Decoder

The TV Remote Controller Decoder kit is available, free to schools, to use in their Wireless Technology Curriculum. Former ARRL Education & Technology Program Coordinator, Mark Spencer, WA8SME, created the TV Remote Control Decoder kit and is available by sending your request, on school letterhead to the ARRL Education Services Department. Please continue reading to find out how the kit can enhance your curriculum and how you can obtain a kit for your school.

Introduction

Have you ever wondered what makes your remote control work? The messages travel via electromagnetic waves just above radio in frequency--the infrared.

The TV Remote Control Decoder Kit features a photo-sensitive detector, programmed PIC chip and a visual display in the form of four LEDs. [all photos by Mark Spencer, WA8SME]

The ARRL Education and Technology Program has cooked up a project that detects and decodes the infrared messages from a TV remote. You probably have a number of them around the house. In fact, remote controls have become so important that when they are misplaced there is a sense of panic.

These days you can't buy a TV, DVD player, VCR, stereo system and many other appliances without having to control the appliance by remote control. But do you know how they work? Are there things you wish you could control with the remote?

How a TV Remote Control Works

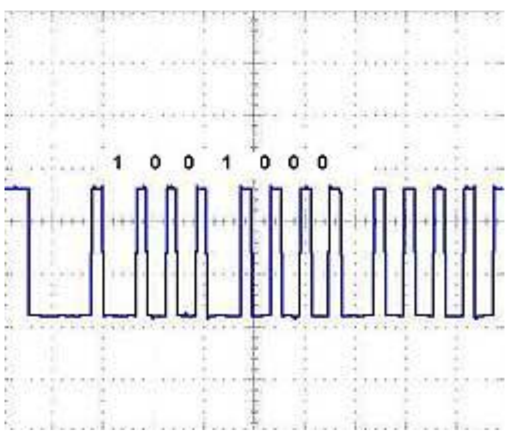
If you take a close look at the working end of the typical TV remote, you will see lurking behind a translucent protective window, or maybe right out in plain sight, the bulb of a light emitting diode (LED). Alternatively if you look at the receiving end, somewhere on the front of the appliance operated by remote control, you will see an opening (also

probably covered by a translucent or decorative window) and another LED-like bulb. The LED in the remote control is an infrared transmitter, the LED-like bulb in the appliance is an infrared receiver. The typical TV remote control uses infrared light as the medium over which commands are sent between you and the appliance.
While you are in a darkened room, look into the remote LED while you press one of the keys. You'll see the LED dimly flash. That is a command being sent by infrared light in serial format. We cannot generally see infrared light with just our eyes, but you can detect some other light (spurious radiation) being emitted by the LED at the same time it is emitting infrared light.

The light used in a standard remote control to carry the commands from the user to the appliance is the near-infrared range frequency of approximately 980 nanometers, the edge of visibility. A nanometer is one-billionth of a meter.

To illustrate, the radio portion of the electromagnetic spectrum sports wavelengths of 30,000 km to 1 mm (14.230 MHz is in the 20 meter band), followed by infrared from 1 mm to 800 nm and up to visible light (800 to 400 nm--"green" can be defined as 565 nm), ultraviolet light and X-rays.

Back at our remote controlled appliance (TV, VCR or whatever), the LED receiver is specially designed to respond to infrared light at a frequency of 980 nm. It also has some very sharp filters that eliminate as much background light outside of the 980 nm frequency range as possible. These filters prevent bright sunlight from overwhelming the receiver (receiver front end overload), but the filters are not perfect. That is why sometimes when there is bright sunlight shining directly on the appliance you may have difficulty controlling it with the remote.



The Sony remote uses a mark-and-space binary code similar to RTTY's Baudot code.

When you press a button on the remote, the LED sends a special code assigned to that key as a beam of infrared light pulses. The infrared receiver on the appliance in turn receives that beam of infrared light pulses and converts it into electrical impulses that correspond to the key code, and sends those impulses to a computer that controls the appliance.

Modulation to the Rescue!
Using light to transmit information from the remote to an appliance sounds like a good idea, but there is a problem. Can you think of a problem that must be overcome before this system will work properly? (Hint: We touched on the cause in the preceding paragraph.) The problem is that the sun sends infrared light along with all the other colors of the light spectrum, including light at 980 nm. There has to be a way for the appliance infrared receiver to differentiate between infrared light sent by the remote control and the infrared light coming from the sun.

The appliance infrared receiver is designed to respond not only to infrared light at a frequency of 980 nm but also to light that is modulated at a frequency of approximately 38,500 Hz. This concept is not new to hams; the same technique is commonly used in FM repeaters to prevent retransmissions of unintentional signals, called a subaudible tone. If the PL tone is not present, the repeater disregards the signal. The same thing happens with the remote controlled devices: unless the infrared light beam is modulated at 38,500 hertz, the signal is ignored.

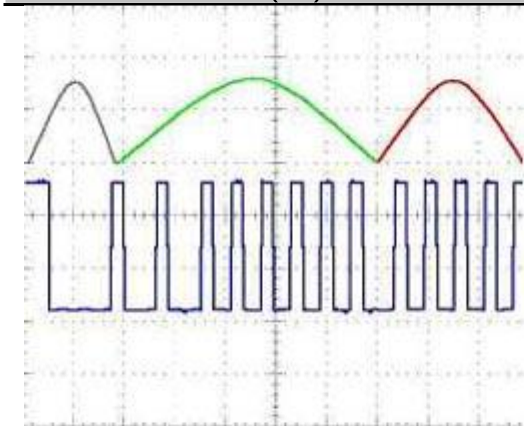
Infrared light from the sun is not modulated; the sun sends light as a continuous wave (CW)--but, of course, only when it is above the horizon! House lights also emit infrared light at 980 nm, but that light is turned on and off at a rate of 120 hertz, the harmonic frequency of household ac current. So the infrared receiver disregards 980 nm light that is constant and also the light that is modulated at 120 hertz, and will only respond to infrared light modulated at 38,500 hertz, which pretty much eliminates everything but the light beam from the remote control.

Hmmm...Tastes a Little Like RTTY!
Now that we have covered how the signal goes from the remote control to the TV, the next topic is how the appliance recognizes the individual keys (power-on, channel selection, volume control, etc). Each equipment manufacturer has a unique system for transmitting commands to their appliances. This allows you to select the specific appliance you want to control. This project uses the Sony TV code identified as 0000. This code was chosen because it is the simplest to understand and decode. A sampling of the 7 bit binary key codes used in the Sony protocol follows:

SONY Control-S Protocol for TV

Remote Key	Digital Code Sent (decimal) binary
1	(0) 000 0000
2	(1) 000 0001
3	(2) 000 0010
4	(3) 000 0011
5	(4) 000 0100
6	(5) 000 0101
7	(6) 000 0110
8	(7) 000 0111

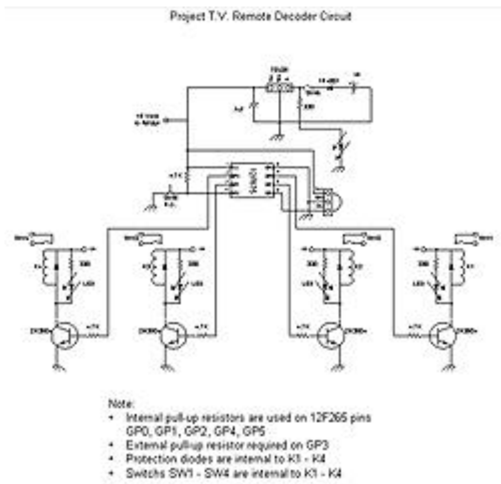
9	(8)	000 1000
0	(9)	000 1001
Enter	(11)	000 1011
Channel up	(16)	001 0000
Channel down	(17)	001 0001
Volume up	(18)	001 0010
Volume down	(19)	001 0011
Power on	(21)	001 0101
Power off	(47)	010 1111
Mute	(20)	001 0100



The picture at left illustrates the serial stream sent when a key is pressed on a remote control that is programmed to operate a Sony TV. The gray line is the start bit, green covers the seven data bits, and red is the device code (SONY 0000).

You may already be familiar with this type serial code; it is similar to RTTY's Baudot code. There are two signal levels: a high voltage that represents the "mark" state, and the low voltage that represents the "space" state. The no signal state is "mark." The information stream begins with a start bit, then the bits for the key are transmitted, and finally, the device identifier code bits are sent. These final bits allow the appliance to verify that the received command is intended for it; if not, the controlling computer ignores the command.

There is a slight problem with sending on and off pulses of light to represent the binary bits of 1's and 0's--how can the receiver tell if no signal represents a 0 or just that the remote control is done sending? The Sony protocol solution is to make a 0 bit a "space" that is .8 milliseconds long, a 1 bit is a "space" that is 1.2 ms long, and a start bit is a "space" that is 2.4 ms long. There is a pause of 0.68 ms between bits. So when the infrared pulses are being received, a 2.4 ms space pulse is recognized as a start pulse, a 1.2 ms space pulse is recognized as the 1, and a 0.8 ms space pulse is recognized as a 0. This is what makes the coding of a remote controller different from RTTY. The picture at right illustrates the serial stream sent when key 0 is pressed. Overlaid on the oscilloscope pattern are labels for the individual bits.



How it Works
The two basic blocks of this circuit are the infrared receiver and the PIC microcontroller that is programmed to detect and interpret a key press and activate the associated relay. The architecture of the circuit is very open, allowing the user to adapt the interface to their own specific needs. When a key is pressed, the appropriate PIC pin goes high, which turns on the attached 2N3904-switching transistor. The transistors can handle up to around 200 mA, so they should be rugged enough to handle relays designed to switch high voltage and current.

In this particular circuit, a 9 V battery powers the board. The 9 V source is stepped down to 5 V by the 78M05 5V/500 mA voltage regulator to supply voltages for the infrared receiver, PIC, the relays and associated indicator LEDs.

The PIC is pre-programmed to recognize remote keys 0 through 5. Keys 1 through 4 toggle the associated relay when pressed. Key 5 will turn on all four relays; key 0 will turn off all four relays. Only the PIC device chosen and the programming limit the number of relays and the key sequences allowed. If additional relays are required, the builder could easily modify the circuit and code for the 16F676 14-pin device. The open source code for this project is well documented so that the builder can follow the programming logic and make changes, if desired.

The program is specifically written to decode the Sony 0000 protocol. Therefore, the remote control will need to be programmed to that protocol. Most remote controls, both brand specific and universal, can be programmed to control most brands of appliances. The instruction manual that came with the remote should be consulted to program the Sony 0000 or Sony TV protocol.

Final Thoughts
It only takes a little imagination to think of ways you can use a TV remote to control something around your shack. However, the first application that came to my mind was adaptive technology--applying technology to mitigate some of the challenges faced by the disabled. Consider a TV remote conveniently located on a wheelchair that would allow the user to control difficult, if not impossible, to reach lights and appliances. The decoder could easily be interfaced to common home appliances to turn them on and off without having to physically touch the appliance controls.

I originally designed the TV remote decoder to be used by teachers presenting wireless technology in their classrooms. The wireless technology topics that can be illustrated by this little device are limited only by the imagination and ingenuity of the teacher. After I completed the prototype of the TV remote decoder, I realized the utility of the device in everyday life is limited only by the imagination and ingenuity of any user. I hope that you will give the project a try to see how you can improve your life experience through this adaptive technology, or better yet, improve the life of someone else.

The TV Remote Control Decoder kit is available to interested and qualified schools through generous donations to the Education and Technology Program Fund. To qualify for one of these kits, interested schools need to write the ARRL Education Services Department on school letterhead and verify that:

> (1) the lead teacher has reviewed the lesson material above and,
> (2) the lesson material and the kit fit into the school's curriculum and the school intends to use the kit as an instructional activity, and
> (3) the school has the capability to build the kit (preferably, students will do the actual construction).

Send requests to ARRL Education Services Department, 225 Main St, Newington, CT 06111.

For more information about the ARRL Education and Technology Program, contact the ARRL Education Services Department, etp@arrl.org.

To learn more about how to support the ARRL Education and Technology Program, contact ARRL Chief Development Officer Mary Hobart, K1MMH, 860-594-0397; mhobart@arrl.org