MODULE 20

WIRELESS

PREREQUISITES: MODULE 4: OP-AMPS II; MODULE 11: MICROCONTROLLERS III; MODULE 13: SENSORS & TRANSDUCERS; MODULE 14: DISCRETE COMPONENTS.

OUTLINE OF MODULE 20:

What you will learn about in this Module:
- Infra Red (IR) data communication circuits
- Radio Frequency (RF) integrated circuits for data transmission

What you will build in the lab:
- An infra-red universal remote with scrambler function
- A radio-frequency data link

INTRODUCTION:

Wireless communications are shaping the future of consumer electronics. Connectivity between devices without wires has been around for quite a while, but recently the trend toward fewer external cables and wires has sharply increased. It is important to realize that the electro-magnetic spectrum has several regions that are used for communications, and that many of these regions are federally regulated because the demand for bandwidth is fierce and growing worse. If you really want to use radio frequencies to transmit data, you should get an amateur radio operators license (HAM radio license), at least at the "Technician" level, which does not require knowledge of Morse Code. The use of optical wavelengths (light) to transmit data is, to the best of my knowledge, unregulated.

There are several other ways to transmit data without wires. One of my favorites is acoustic (sound). The very first wireless TV remote controls were primitive mechanical "chimes" in a hand-held box, with a button-actuated, spring-loaded hammer that would strike one of three aluminum rods, each cut to length to resonate at a different frequency. Every time you pressed one of the buttons on the remote it sounded like someone had dropped a piece of silverware. A tone decoder at the TV set would detect which of the three chimes had been struck, and would execute one of three functions (volume UP, volume DOWN, or advance channel…in the days of 13 channels, going in both directions was not too important). Sound primitive? (pun intended). Well, one advantage was that the batteries never died in those old devices. They were 100% mechanical at the user-end…not a single electronic component in them.

Each mode of wireless communication has advantages and disadvantages which limit its usefulness. For example, radio waves can travel very long distances, often going through or around objects, whereas visible light is easily obstructed and can usually only transmit data directly along the "line of sight". Sound waves, like waves in the electromagnetic spectrum, are also useful over certain regions of the spectrum for certain applications. For example, most wavelengths of light do not penetrate sea water very well, but sound waves can penetrate very deeply. In fact, it is sound, not light, that makes the ocean transparent to humans and many marine creatures.

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Some people confuse acoustic waves with electro-magnetic waves, but the difference should be obvious to anyone who has had a term or two of physics. Sound waves are pressure waves traveling through a physical medium, such as a gas, liquid or solid. This is why sound can not be transmitted through empty space. Light, however (and other forms of electro-magnetic waves) readily travel through empty space because the waves propagate via interactions between electric and magnetic fields, as described by Maxwell's Equations.

READINGS FROM HOROWITZ AND HILL (H&H): *ART OF ELECTRONICS*

5.18

Browse Chapter 13, paying attention to the following sections:

- 13.09 (transmission lines)
- 13.11 (tuned amplifiers)
- 13.12 (RF circuit elements)
- 13.13 (measuring amplitude or power)
- 13.14-13.15 (AM)
- 13.16 (superheterodune)
- 13.17 (single sideband)
- 13.18 (FM)
- 13.19-13.20 (RTTY, Pulse Modulation)
- Radio Frequency Circuit Tricks (pg 902)
- 13.21 (special construction techniques)

ADDITIONAL READINGS & INTERNET RESEARCH:

Find an old physics book, or search the Internet to find a detailed treatment of the electro-magnetic spectrum. You should investigate to find which regions of the spectrum are generally used for communications, such as RF (radio frequency), microwaves, optical (IR – UV light), etc.

Then, see if you can find a "standard" for optical communications, such as how an infra-red remote controller works for a modern television set. How is data usually encoded (how do they transmit and decode 1's and 0's using optical signals)?

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SELF QUIZ

1: What range of frequencies or wavelengths constitute the RF (radio frequency) range of the electro-magnetic spectrum?

2: What range of frequencies or wavelengths constitute the microwave range of the electromagnetic spectrum?

3: What range of wavelengths constitute the visible spectrum for light?

4: What range of wavelengths constitute the IR (infra-red) range in the electro-magnetic spectrum?

5: If you transmitted sounds at increasing frequencies, would the sound eventually become "visible" when it reached the frequency of visible light?

PLEASE ANSWER THE ABOVE QUESTIONS AND E-MAIL TO THE INSTRUCTOR
"I have neither given nor received aid on this examination, nor have I concealed any violation of the Honor Code"

X____

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LABORATORY PROJECTS

Choose at least one of the following projects for your laboratory exercise:

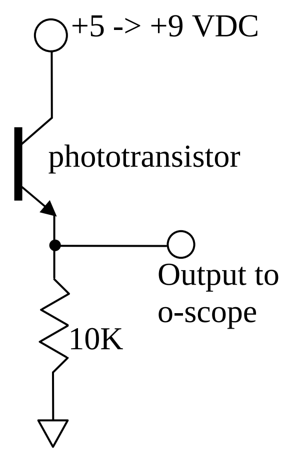
1- RF Communication: Contact the instructor to check out the pre-built wireless RF data communication kit. The module is constructed using commonly-available wireless RF communication ICs that are available, for example, from DigiKey. Look at the wireless chips, get the IC part number, search the DigiKey web page, and locate the manufacturer's data sheet for the chipset. Read over the data sheet and download the circuit schematic from the web page for this course. Then, simply program the microcontroller to transmit a series of known 8-nit numbers from the transmitter to the receiver.

2- IR Communication: There are many simple and useful applications for IR communication. Infra-red light travels well through short distances of soft tissue, so it is possible to use IR to establish bi-directional communication with implantable biomedical devices. IR signals are often used for event detection as well, such as proximity detectors in industrial applications (the automatic flushing urinals and toilets in some buildings often use IR proximity detectors to detect when the person walks away), and in the form of "light beam interrupters" that can detect when someone walks through a doorway. Generally, IR is excellent for low power, line-of-sight, short distance wireless data communication, such as IR printers, PDAs, and, of course, the ubiquitous and all-important TV/VCR remote control. One great advantage of optical communication is that it is almost entirely immune to environmental noise, unlike RF. It is also generally highly secure; the transmitter and the receiver need to be pointed at one another, since the signal does not tend to spread out and work its way around intervening objects as RF signals do.

For this exercise, you will build a TV/VCR remote controller using a PIC16F84A microcontroller. Only your controller will be far more dastardly than most TV/VCR remote controls, since it will also incorporate a signal jammer that will automatically block anyone else from controlling the TV/VCR while your system is operating.

Here is what you will need to do for this laboratory:

A- Build yourself a simple photodetector circuit as shown to the right. Scrounge an IR phototransistor (NOT a photodiode!) or borrow one from the instructor.



B- Borrow or steal a TV/VCR remote control unit that functions with a TV set (not a broken one).

C- Apply power (+5 → +9 VDC) to your circuit as shown. Use an oscilloscope to read the voltage across the resistor as shown. You may need to set up your circuit so that it does not pick up too much ambient room light. Most photodetectors are very directionally sensitive, so just turning the detector away from the sources of light will usually reduce most of the unwanted background signal.

D- Point your TV/VCR remote controller head-on at the phototransistor, and press one of the buttons. Watch what happens on the oscilloscope. You will probably need to twiddle the adjustments to see the full signal. It should be a short series of short and long pulses in some fixed order. You may also need to use the oscilloscope in "single shot" mode, which allows you to set a trigger, then capture a single trace when the signal voltage crosses a threshold. You will need to experiment with this a bit. This will allow you to freeze and study the signal waveform.

E- Carefully record the waveform, especially the pulse widths and the time between pulses. Be sure to get all pulses in the signal. Do this for at least the following 4 buttons: volume UP, volume DOWN, channel +1, channel -1. You will probably note that the signal is encoded as short and long pulses. Why doesn't the device just use ON and OFF to represent 1's and 0's? This is because optical data links are typically *asynchronous*, meaning that the receiver is not clocked (synchronized) with the transmitter. So, zero signal is not 0, it is really just no signal at all. Then, when the receiver sees the beginning of a pulse, it times each pulse; Long pulses = 1 or 0, short pulses mean the opposite (0 or 1). It expects a certain number of pulses.

F- Now, using ExpressSCH, design a very simple circuit using a PIC16F84A microcontroller to turn ON and OFF a single IR photodiode EMITTER. This is just like an LED, but the light it produces is not visible to the human eye. You can also scrounge around for one of these, or borrow one from the instructor. You may also wish to include a +5 VDC regulator, so that you can power your circuit using a 9 Volt battery (so it is mobile).

G- Note that the PIC16F84A can only output ~10 mA from each pin. To get a strong IR optical signal you may need to boost the current output capability of your circuit by using an additional transistor, as you may recall from Module-14: Discrete Components. H&H also describe how this can be easily done. I suggest that you use a single, logic level HexFET. If you choose to do this, you will need to put a resistor in series with the IR Emitter, as a simple way to limit the current through the emitter. Just find out the maximum current allowed through the IR Emitter, and add a resistor that will limit the current to this value. Use the +5V supply for the PIC16F84A microcontroller, and use Ohm's law to calculate the resistor value at the desired current. If you assume no voltage drop across the IR Emitter, this will very conservatively limit your current through the device.

H- Add 4 push-button switches to your circuit, one for each of the TV/VCR remote functions. These switches can go to any of the PIC16F84A input pins.

I- Program the PIC16F84A to detect switch closure of each of the 4 switches. When switch closure is detected, the microcontroller should output the corresponding series of pulses to the IR Emitter. This is done by programming in the four known pulse sequences that you determined from steps D and E above. Every time you press one of the buttons, the corresponding pulse sequence should come out in the form of light pulses from the IR Emitter, with a short delay (say ~½ second), then if you continue to hold down the switch, the pattern should repeat.

J- Check your output pulses by using the simple detector circuit you built earlier. They should match the pulses from your TV/VCR remote control unit.

K- Now, go and find the TV that works with the TV/VCR remote controller that you originally used. You should be able to control it remotely with your circuit. If not, go back and check the original signal pulse patterns, and verify that your circuit is generating the same pulse patterns as the TV/VCR remote.

L- If your remote controller works, you can do some very interesting things to enhance its performance. For example, you could integrate the simple detector circuit into your remote control unit. You would need to make sure the resistor was set correctly so that you would get a pulse pattern with very nearly 0 to 5 V pulse amplitudes. You would also need to add a slide or toggle switch to put your device into "learn" mode. Then, when you press one of the function buttons, your device can be programmed to *learn* each pulse pattern. You would need to do a fair amount of extra programming, but devices like this are pretty nifty, and they already exist on the market (you can sometimes find them in gadget stores or catalogs). The bad news is that your device will "forget" everything the moment you turn OFF the power, unless you also include some NV RAM (non-volatile RAM) to store the pulse train data, even when the device is powered down. The other cool thing you can do is….

M- Assuming your controller works, you will now add a sinister jamming feature that will allow you to assert total control of the TV/VCR. Your friends will find this annoying, but as you are probably an engineer your friends almost certainly already find you annoying. Doing this will only reinforce their current opinions. Anyway, here is what you can do: The TV/VCR will only respond if it can interpret the incoming IR signal as a unique command. That means if there is an extra pulse or two in there, the TV/VCR will almost certainly ignore the command, assuming that it is an error. So, you should also include a "jam" mode on your device. You will need to do a bit of experimenting to determine what works best. Generally, a continuous series of either short or long pulses will do the trick.

N- Test to be sure the pattern you have selected will not cause the TV/VCR to do anything sketchy, like turn ON or OFF, switch channels, emit smoke, etc. Then, when you put your device into JAM mode, you should program it to continuously put out this jamming signal EXCEPT when you are pressing one of the buttons on your device. When you press one of the buttons on your device, the jamming signal should stop for a short period, at least twice as long as the longest pulse train, or you could guess and say ~ ½ second, then your device should send out the signal, then after another short delay the jamming should start again (unless the button is still being pressed).

O- Draw out a logical flow chart or write pseudo-code for the program, including the jamming feature. This will definitely help you to do the programming.

P- As fun as the jamming feature can be, it will consume a lot of battery power since you are continuously outputting a signal through the IR Emitter. Can you think of strategies to extend the battery life of your jamming circuit?

FEEDBACK

Was this Module useful and informative?

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Is there a topic that should get more or better coverage?

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In what way can this Module be improved:

Content: ____

Depth of Coverage: ____

Style: ____

Any additional comments that will help us to improve this course:

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If you prefer, you may e-mail comments directly to Bob Dennis: yoda@umich.edu