OptoRadio Project

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Introduction:

This paper presents a low cost digitally modulated optical carrier transceiver for voice. The radio presented is not a finished design but is a first step in this direction.

At the June VHF QSO Party in 2008 I first saw the operation of a laser communicator. Simply built from a handful of components and off the shelf components it is capable of communicating CW mode. When 'keyed down' a 555 timer modulates the power to the laser pointer at a rate of about 800 Hz. The transmitted laser light is received by a solar cell which acts a detector producing a voltage following the modulation envelope. A Radio Shack amplifier with speaker provides an audible tone. The design goes back to an article *Get on 488 THz for Less Than $100*, QST Feb 1997 pgs 96-97.

These units gave me an idea to digitize voice and use the data bits to pulse modulate the output of an IR LED. A photo-detector receives the signal and the received data bits are used to reconstruct the audio signal. The distance possible with an IR LED is not as good as a laser pointer but with digital signal processing it is hoped that the distance can be improved. Also, the pointing angle of an LED is not as critical as for a laser pointer and there is no eye safety concern. This project's objective is to provide the physical building blocks of an OptoRadio and a basic signaling system. My goals are;

1. a transceiver that improves upon what exists
2. an open architecture design that can be easily understood and used by others
3. work on batteries
4. a low cost transceiver, and
5. ease of use.

Future efforts will improve on distance and add selectable compatibility with existing laser communicators.

Concept:

Figure 1 shows the basic block diagram for one half of the radio. The other half is the same but flows in the opposite direction.

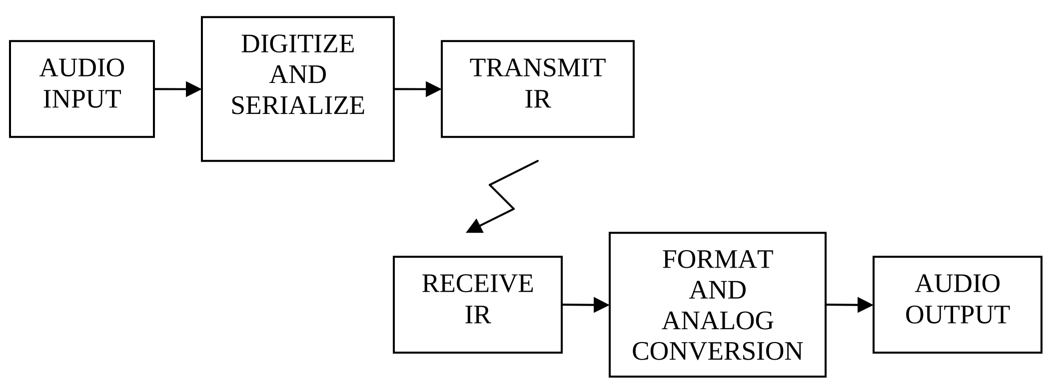

Figure 1 OptoRadio Block Diagram

In the Audio Input the operator's voice is converted to an audio frequency signal by a microphone. The audio signal is filtered and amplified. The signal needs to be amplified to a level that makes the best use of the following analog-to-digital (A/D) converter input range. The audio filter allows just what is intended to be digitized, anything else just shows up at the A/D as noise and reduces the signal-to-noise ratio (S/N). Using an electret microphone, the audio signal maximum will be about 0dBm or 0.223V peak-to-peak. The maximum A/D input level is 1.2V peak-to-peak but a slightly lower value, 1V peak-to-peak, will be used to avoid the noise due to input saturation. The voltage gain needed is in the range of 5 to 6. The development model will use a variable gain design but a final design would have automatic gain control (AGC).

The signal digitized and formatted for serial transmission. An A/D converter produces a fixed length binary number representative of the amplitude at an instance of time called the sampling period. The data may be transmitted as this binary value or be encoded for error detection at the receiver. There are also encoding schemes for error correction.

Initially the data will be sent in un-encoded binary format. Characters are added before and after the binary data to frame the data so that the receiver can discern when it has the correct start and end of data. Data and formatting characters are output at time periods consistent with the optimum transmission rate. The optimum rate is dependant on the data sizes to be transmitted, the maximum rate the transmitter can be modulated and the maximum rate the receiver can accept data.

A high speed IR LED provides the light transmission carrier. Power to the LED is turned on and off as dictated by the data to be transmitted. This is pulse code modulation (PCM). The transmitter needs a driver that provides the LED voltage and current quick enough for the transmission rate.

A high speed photodiode receives the IR signal. The photodiode is mounted on the inside end of a blackened tube to block out as much as possible other sources of IR. It is followed by an amplifier with a threshold detector.

In Format and Analog Conversion the resulting 1 and 0's are collected by the receiving end of the UART and binary data stripped of framing characters is reproduced. The binary data is output to a digital to analog (D/A) converter. If encoding is used errors are detected and handled. If only error detection is used then the analog value of the previous sampling period is output. If error correction is used then the processed value is output.

At the Audio Output the digitally reconstructed is low pass filtered to remove high frequency components due to the D/A process. An amplifier then produces a signal capable of driving a speaker.

It will be easy to add compatibility with the CW laser transceiver. A connection would be added for a key and when the key closes the microcontroller will create a tone in digital form to be transmitted. I believe the frequency range of the solar cell includes the 870 nanometer IR frequency although it would have to be tested. The frequency range of the red laser pointer is not in the specified range of the IR photodiode and so a separate solar cell would have to be added. The solar cell detected output would be directed to the audio output.

In Figure 2 a complete radio is shown with the capability of being a full duplex system but a push to talk will be used to reduce power consumption.

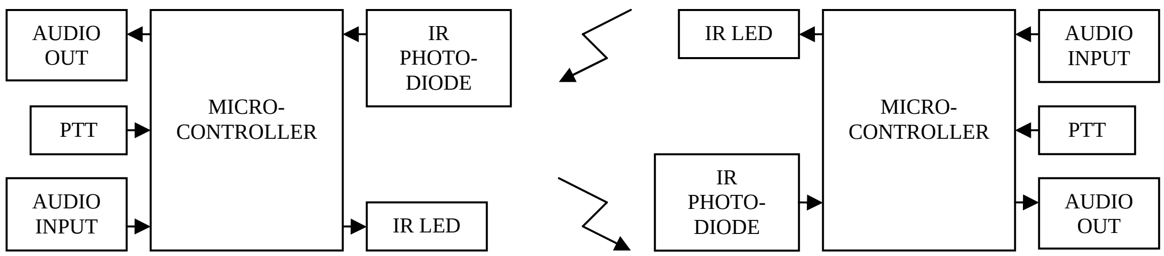

Figure 2 Complete radio

Design Considerations:

The voice needs to be digitized at a rate fast enough that it can be reconstructed at the other end. An audio band width of 3.5 kHz is chosen. Digitizing of the audio signal exceed the Nyquist rate (*Communications Systems*, McGraw-Hill 1975, A. Bruce Carlson, page 298) to prevent aliasing or more than twice the audio band width. The target sampling rate will be 8 kHz. Audio will be digitized to eight bits which is convenient to use within a microcontroller. The UART function will add a 1.5 bit period start character and a 1 bit period stop character. Two bit periods will separate framed bytes. The total number of serial transmission bit periods per digital sample is 12.5. To keep a continuous stream of data flowing the serial transmission rate needs to be equal to or greater than 12.5 time 8 kHz or 100 kHz. A standard UART baud rate is 115 kHz. A digital communication channel band width should be ten times the maximum signally rate. Thus the transmitting and receiving components must be capable of 1 Mhz.
Some of these design constraints may be modified as necessary. To accommodate error detection and correction code data lengths that are longer than the original data lengths there are two options; reduce the digitized data bits from 8 to a lesser number or increase the size of the transmitted data word. The first option may be able to continue to use the built in microcontroller UART. The second option will require the coding of a UART function with a longer data word. Increasing the data length requires an increase of modulation rate or a reduction in the sampling rate. Reducing the sampling rate reduces the audio band width.

Major Components:

This radio becomes possible because of the availability of new low power high capability components that don't cost a lot. Although some of the components are available in dual-in-line (DIP) format others are only available as surface mount. This becomes a challenge for the home brewer.

Microcontroller.

A microcontroller from Silicon Laboratories performs many of the functions at a very low cost. The C8051F330 microcontroller as a DIP sells for less than 3 dollars and includes;

1. an 8051 core processor
2. 24.5 MHz oscillator

3. 10-bit A/D with 200kHz sampling rate
4. 10-bit D/A with a 20kHz bandwidth
5. 8k bytes of flash ROM
6. 256 bytes of SRAM and 512 bytes of XRAM, and
7. UART.

The development system costs less than $70 and includes a development board that connects to a PC via USB, a C compiler and an Assembler.

IR LED.

The TSFF5210 IR LED from Vishay is optimized for 870 nanometer (345 terahertz). Digikey sells at $1.08. Specifications are;

Beam width	20º
Forward max current	100 ma
Forward voltage typical	1.5 V
Radiant power	50 mW
Pulse Frequency modulation max	24 MHz

IR PHOTODIODE.

The receiving photodiode is a BPW83 also from Vishay. It has a Beam width of 130º and a daylight blocking filter, 870 to 950 nm. The maximum data rate that the photodiode can sustain is about 3 MHz. Digikey sells at $1.01.

LED DRIVER.

The IR LED will be driven by a ULN2003 high current Darlington-pair array from Texas Instruments. It is capable of operating at up to 30 MHz. Digikey sells at $0.55.

POWER MANAGEMENT.

A buck-boost DC-to-DC converter from Analog Devices, ADP2504ACPZ-3.3-R7, will supply 3.3 VDC for battery input voltage from 2.3 to 5.5 volts. The maximum current is 1 amp. Digikey sells at $3.15.

State of Project:

I have procured the major components for a prototype transceiver. I am in the process of designing the various stages of the transmitter and receiver. I have written a strawman program in Assembly language for the microcontroller. I am relearning PCB123 to make a circuit card.