**Introduction**

The goal of this project is to construct a portable tuned radio frequency receiver that will pick up the WWV radio signal broadcasted by the National Institute of Standards and Technology in Fort Collins, CO. The broadcast information includes time announcements, standard time intervals, standard frequencies, time corrections, a binary coded decimal (BCD) time code, geophysical alerts, marine storm warnings, and Global Positioning System status reports. The times are given in coordinated universal time (UTC). The receiver I will be constructing will not only output the audio transmissions, but it will also decode the BCD time code and display the information on a LCD screen.

The proposed project has numerous applications ranging from making sure that your alarm clock is set correctly to tuning a piano (the station broadcasts a standard 440 Hz tone every hour). The device would also be extremely valuable for devices that require high accuracy time synchronization such as seismograph equipment. When an earthquake occurs, various instruments in different locations record the magnitude of the quake. The clocks of these devices must be synchronized with each other in order to accurately compare the data collected from the different areas.

**Description**

A functional block diagram of the receiver is shown in Figure 1. The WWV station transmits on 2.5, 5, 10, 15, and 20 MHz. The receiver will be battery powered and tuned to the 10 MHz broadcast since it is the frequency that is least affected by the time of day. The project will be divided into two modules. The first module will be the tuned radio frequency (TRF) receiver and the second module will be the decoding circuitry needed to decode and display the BCD time code. For this application, a microcontroller
will be used to provide the decoding circuitry and display operation. When the signal is received, it will be filtered and amplified through numerous tuned amplifiers. The first output of the TRF receiver will go to a speaker so that the user may listen to the vocal announcements and audio tones of the radio broadcast. To generate the second output, the receiver will send the broadcast signal through a low pass filter so that the BCD time code can be extracted and then sent to the microcontroller for decoding and display.

**Figure 1: Functional Block Diagram**

The BCD time code is transmitted on a 100 Hz subcarrier. The time code provides information on the current minute, hour and day of year (including information on time correction, leap second indication, and daylight savings time). Data is transferred in serial fashion at a rate of 1 bit per second. The entire data stream is comprised of 60 bits, which means a full minute of the time code is required to decode all of the information. A 200 ms 100 Hz pulse is used to represent a 0 bit while a 500 ms pulse is used to represent a 1 bit. The LCD screen will display the current coordinated universal time and day of year.
The software will also display “DST” if daylight savings time is in affect. A sketch of the final product is shown in Figure 2.

**Figure 2: Sketch of Final Product**

![Diagram of Final Product]

**Benefits**

As far as general purposes are concerned, the project may be used as a highly accurate radio controlled clock. Since the information is provided by the National Institute of Standards, the user can be ensured that he or she is receiving the most accurate time reading available in the United States.

The device would probably be most beneficial for more sophisticated applications such as high accuracy time synchronization of devices or frequency calibrations. For example, electrical power companies require accurate time synchronization for power grid management. That way power can be transferred to the parts of the grid where it is needed most during certain times of the day. Since the receiver will also allow the user to listen to the audio broadcast, any of the transmitted tones can be used to calibrate the
frequencies of various devices such as an oscillator or tuning a musical instrument.

**Comparisons to Similar Products**

Currently, there are no commercial WWV receivers that both output the audio broadcasts and display the decoded BCD signal. Casio offers an assortment of “atomic” watches that calibrate themselves to the WWV signal once a day (through radio reception) with prices ranging from $39.95 to $150. Atomic Time also sells a wide variety of higher end “atomic” watches and wall clocks with price ranges of $199.99-$249.99 and $29.95-$64.95 respectively. While all of these products display or at least calibrate themselves to the coordinated universal time, none of them allow the user to listen to the broadcasted audio tones or time announcements.

There are also various amateur WWV receivers available on the market. Hobbytron offers an assembled WWV receiver kit for $62.90, while Hamtronics Inc. sells a more robust receiver for $149. Even though these receivers allow the user to have access to the broadcasted audio tones and time announcements, none of them provide a means of displaying the decoded BCD signal.

A number of larger electronic device manufacturers such as Fluke also sell time and frequency standards, but these devices are not readily available to the average consumer since they typically cost several thousands of dollars. A detailed list of manufacturers of time and frequency receivers is available at [http://www.boulder.nist.gov/timefreq/stations/wwv.html](http://www.boulder.nist.gov/timefreq/stations/wwv.html).

**Development**

The development of the receiver will begin with the construction of the TRF receiver itself. The receiver will be comprised of multiple tuned radio frequency (RF)
amplifier stages, an audio amplifier stage for driving the speaker, and an active low pass filter for the extraction and amplification of the BCD time code signal. The tuned RF amplifier stages will first be tested individually with the use of a function generator with a 10 MHz output signal to ensure that each stage is providing the necessary amplification for the desired frequency. The AM detector will be tested with the use of an amplitude modulated test signal also provided by a function generator. The audio amplifier and low pass filter sections will be tested with a similar method as the tuned RF amplifier stages. The only exception is that the low pass filter section will be designed so that the frequency of interest is 100 Hz. The testing of the filter will be conducted by using a recording of the WWV broadcast as the input. The output of the filter will be examined to ensure that the amplitude of the 100 Hz pulses is adequate for use with the microcontroller and that there are no undesired frequencies present on the output waveform. Once the operation of each stage is verified, they will be connected together in their corresponding places of the overall circuit. An adequate portable power supply will then be designed and tested to power this portion of the receiver. An antenna will then be attached to the circuit and the receiver will be taken outdoors for reception testing. By attaching the antenna, the center frequency of the first RF amplifier stage will most likely change since the antenna has a small amount of capacitance associated with it. Therefore certain component values will need to be changed in this stage to compensate for this shift in frequency.

Since WWV is a shortwave radio signal, its reception is dependent on several factors including atmospheric conditions, solar flares, sunspot activity, and the construction of the building that the user is trying to receive the signal in. Since it is
nearly impossible for me to receive the signal in the laboratory (due to the construction of the building), the development of the decoding software and the demonstration of the project will be done through the use of an audio recording of the broadcast. This will ensure that I always have a stable signal to work with when I begin writing and debugging my software.