Super Swingin' Radio Clock

Senior Project Description

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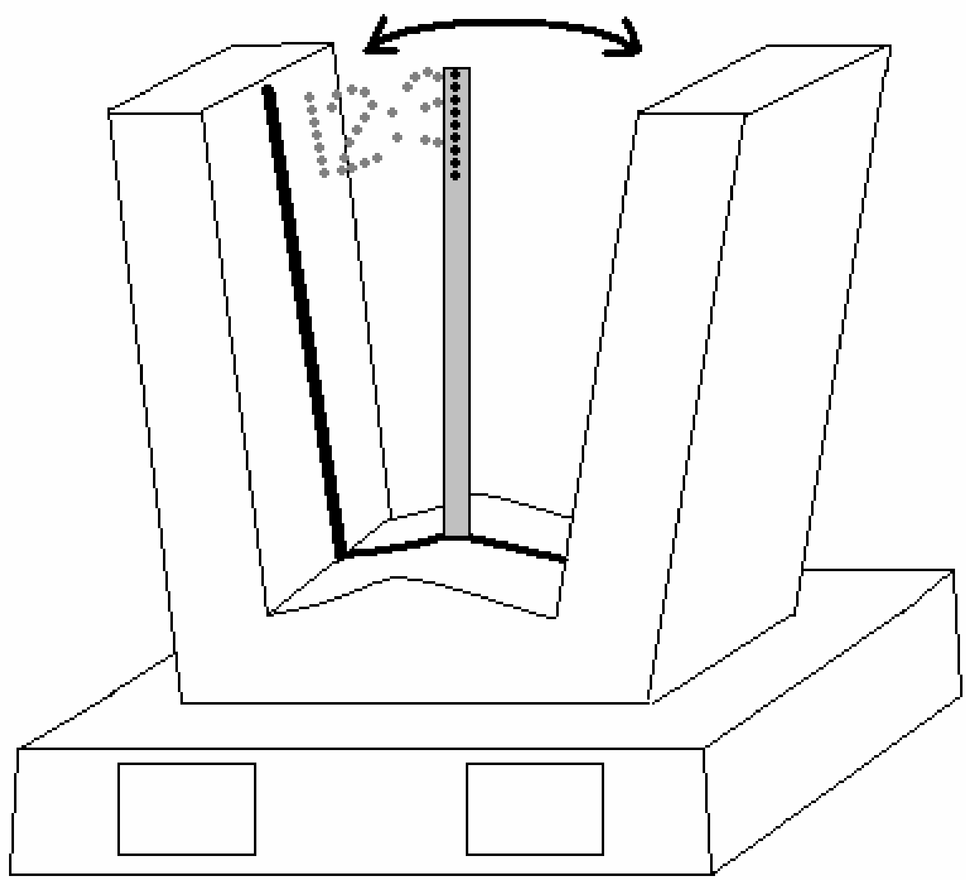
December 08, 2004
ETEC 471
Professor Todd Morton

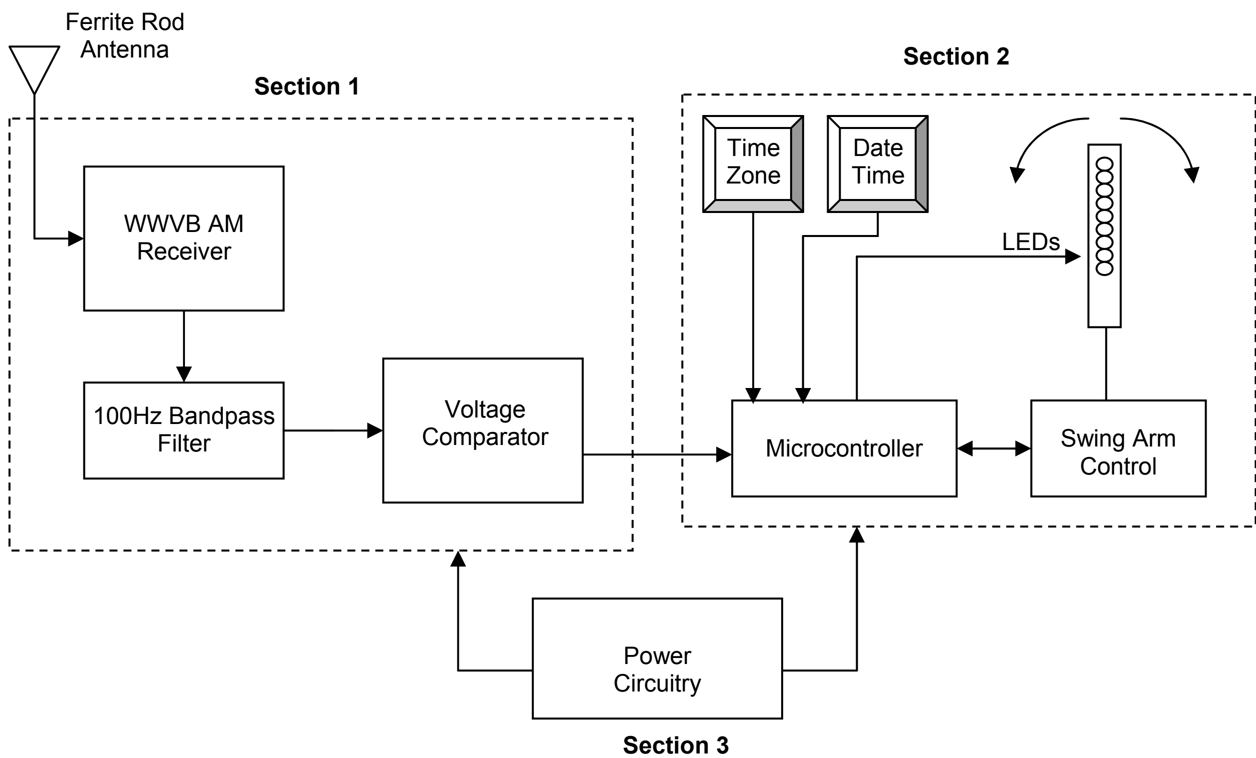


Introduction: For thousands of years people have been fascinated with time. Ancient cultures from around the world developed unique systems to track the cycles that govern Earth's seasons. From ancient Egyptian sundials to the high precision of today's Cesium atomic clock, we have developed into a society that depends on the accurate measure of time. The goal of this project is to satisfy this dependency by designing a clock that will be intriguing, stylish and extremely accurate.

The Super Swingin' Radio Clock (S^2RC) receives the WWVB signal broadcast by the National Institute of Standards and Technology (NIST) out of Fort Collins, Colorado. The broadcast information includes a data stream containing the current date and time given in Universal Coordinated Time (UTC). The S^2RC uses this data to set itself to within microseconds of the national time standard. In addition, the S^2RC has a unique way of displaying time. A vertical bar of light emitting diodes (LEDs) will swing back and forth rapidly. As the LEDs swing, they will turn on and off with precise timing to give the appearance of a fixed display floating in air.

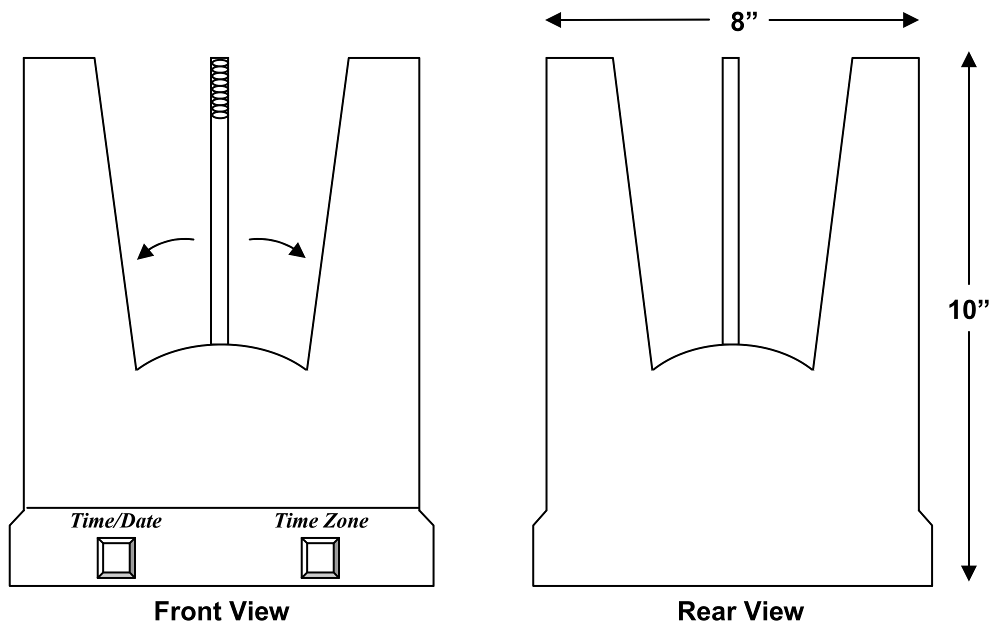
Functional Description: A basic block diagram of this project is shown in Figure 1. The project will be divided into three main sections. The first section will contain an AM receiver, an active bandpass filter and a voltage comparator. The second section will handle the decoding of the WWVB bit stream and the timing of the display mechanism. The second section will also include two buttons. The first button will change the display based on the user's time zone, and the second will toggle the display between the date and the time. A microcontroller will provide all of the timing and decoding necessary for this section. Finally, the third section will include power supply circuitry designed to provide adequate power to the system.

Figure 1: Basic System Block Diagram



The aesthetics of this project are important. An aesthetically pleasing design will catch peoples' attention and, consequently, sell more products. Great consideration is being taken in the design of an appealing case. Figure 2 shows one example of a possible case design. Although this design may change slightly, the final dimensions and layout should be similar to those shown in Figure 2.

Figure 2: Possible Design of the Finished Clock



Detailed Functional Description:

AM Receiver: The relatively low frequency of the WWVB signal lends itself nicely to a simple, low cost tuned radio frequency (TRF) receiver. As is the case with TRF receivers, the signal amplification will occur at the carrier. This practice causes stability problems at higher frequencies, but should not hinder this circuit. The signal will be received on a wound ferrite rod antenna.

Signal Conditioning: After the receiver has acquired the 60 kHz signal and amplified it to a useable level, the signal will be fed into an active 100 Hz bandpass filter to single out the Binary Coded Decimal (BCD) time code. The BCD signal will then be fed into a voltage comparator that will output clean pulses to the microprocessor. The voltage comparator allows for a useable signal to be extrapolated even when the incoming signal is weak or noisy. This comparator will incorporate hysteresis into its response to provide further stability to the final output.

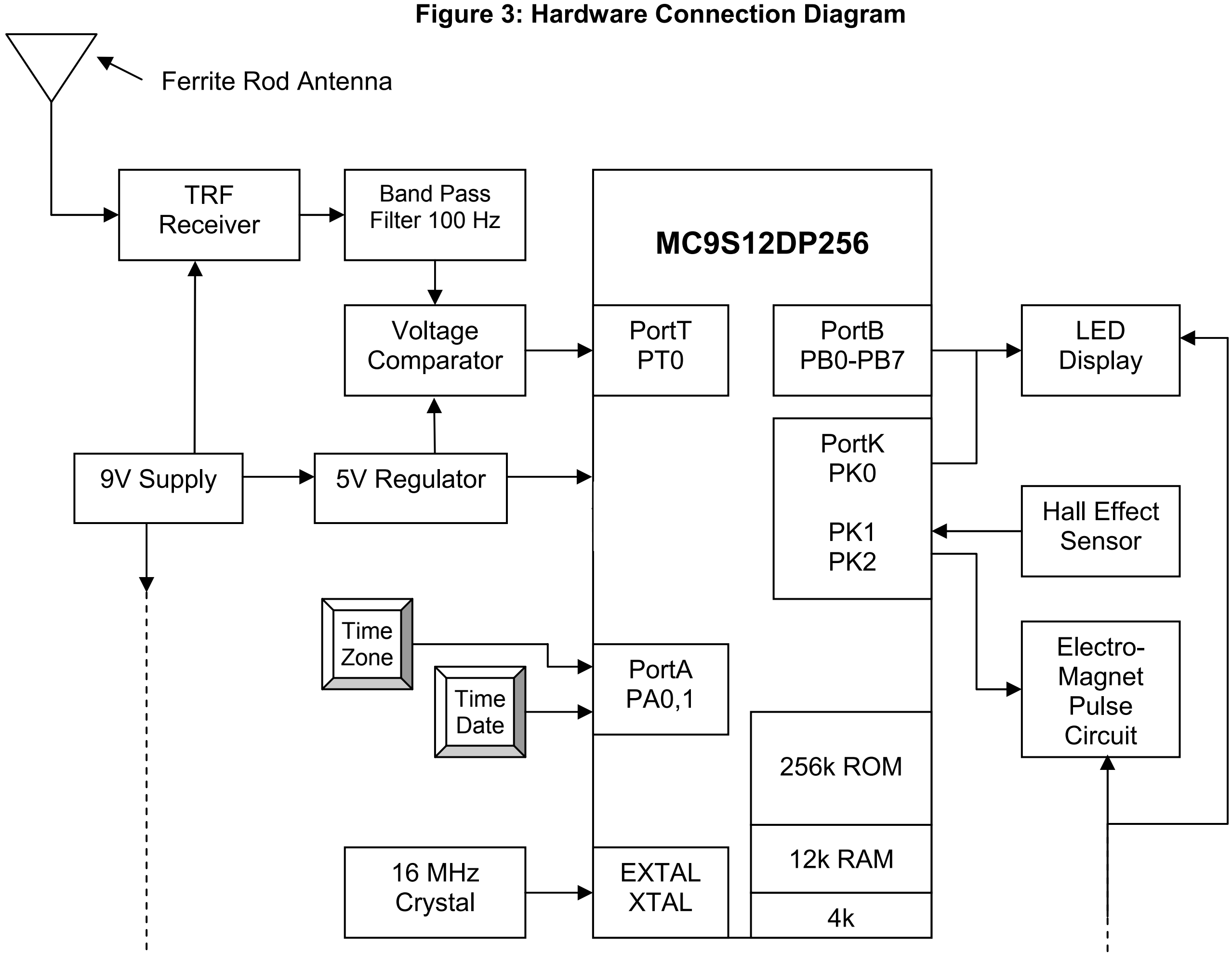
Swing Arm Control: The swing arm control circuitry will undoubtedly cause the most problems when designing this project. The idea is simple, but the implementation relies on the mechanical design of parts rather than the use of preexisting components. A small yet powerful magnet will be mounted at the bottom end of the swing arm. This magnet will serve to balance the weight of the LEDs and to provide acceleration to the swing arm. An electromagnet will be placed in the opposing magnetic field of this magnet, and when pulsed with an electric current, will set the swing arm in motion. A rotary spring mounted at the pivot point of the swing arm will cause it to rebound back towards its original position. When the arm has nearly reached its original position a Hall Effect sensor will trigger the next pulse on the electromagnet, thus causing repetitive oscillations of the swing arm.

The Microcontroller: A microcontroller will be used to satisfy the requirements of the second stage. Because extremely precise timing is required both to decode the incoming data as well as to light the swinging LED display, a microcontroller seemed to be the logical choice. This project requires a single timer channel, 9 Input/Output (I/O) pins for the LEDs, 2 I/O pins for the push buttons, and 2 I/O pins to sense the position of the swing arm and trigger another swing when necessary. All together, a total of 1 timer channel and 13 I/O pins are needed. Based on this information and its popularity and ease of use, the Motorola 68HC908AB32 microprocessor would work nicely for this project. It meets the requirements for I/O and has 1k of RAM, 32k of flash memory and

512 bytes of EEPROM available. The 68HC908AB32 has enough memory for the required software and should allow some space for future upgrades or unforeseen development problems.

This project will originally be developed on a Wytec MiniDragon evaluation board containing a Motorola MC9S12DP256 microcontroller. The development process will be expedited by using the Wytec board because of its debugging capabilities. The software written for the Wytec board will be easy to port to the Motorola 68HC908AB32 microprocessor for final development. Figure 3 shows a block diagram of how the external hardware will interface with the microcontroller.

Figure 3: Hardware Connection Diagram



The Power Circuitry: The power to run this project will come from a standard wall transformer delivering 0.5 amperes of current at 9V. A 5V voltage regulator will provide power to the microcontroller and voltage comparator, while 9V will be used on the AM receiver and the swing arm control. Preliminary worst case power requirements have been calculated to be about 300mA so the wall transformer selected should provide plenty of current without being overloaded. Because this clock is designed to set itself, there is no need for battery backup in case of power failure. Also, rather than implementing a power switch, this clock will simply turn on when it is plugged in.

Software Requirements: This project will be programmed in a modular format using the C programming language and the µC/OS-II operating system. The software will not be microprocessor specific, which should allow for an easy transition from the prototype to the final product. Table 1 shows the modules that this program will use, along with a brief description of each module.

It may be necessary to write other software modules for development and debugging purposes only. These modules would not be included in the final product. An example would be a module that displays the decoded date and time on a standard liquid crystal display to allow for debugging of the receiver and/or the decoder without having to worry about what the swinging display is doing.

Table 1: Software Modules Used

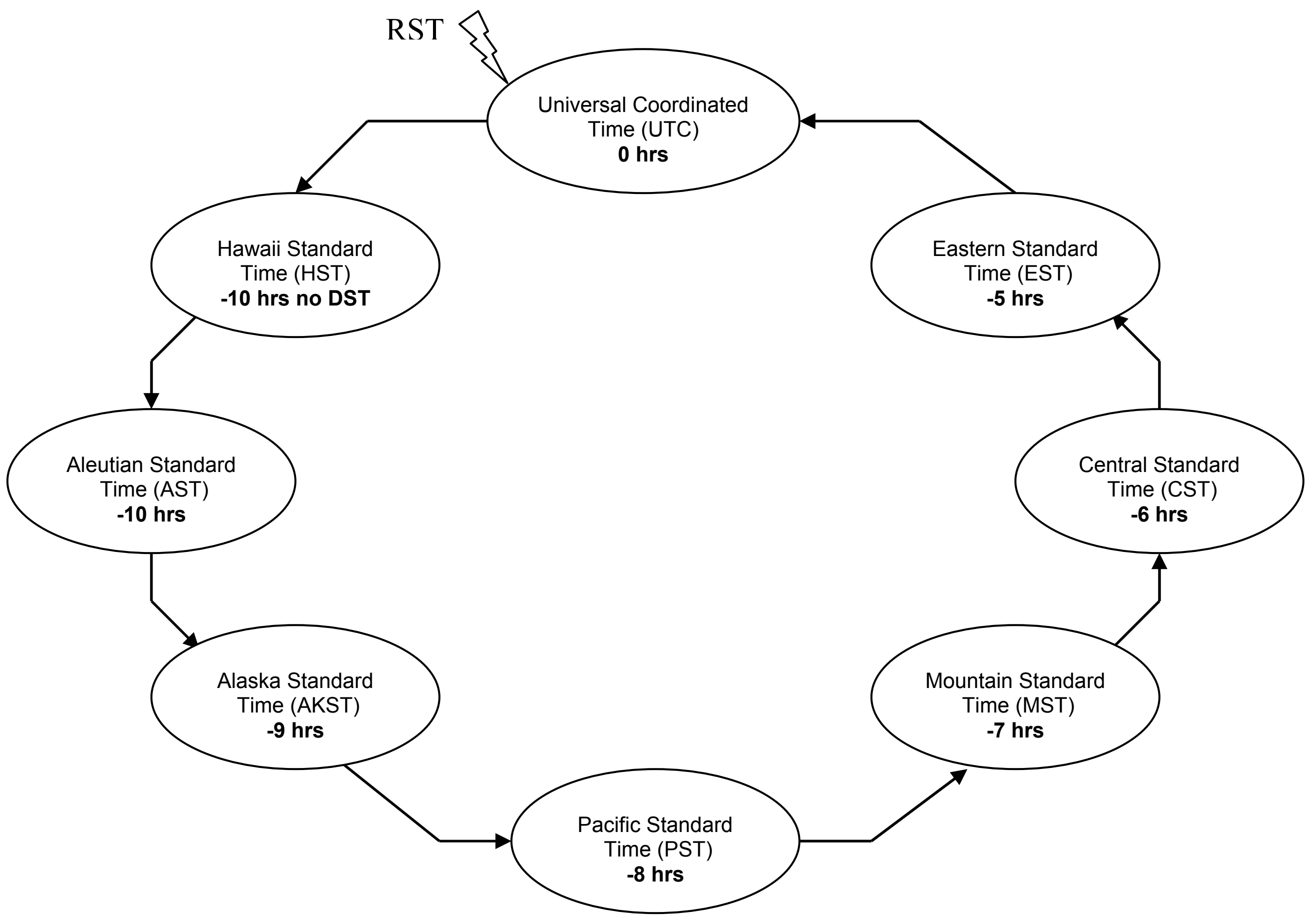
Module	Description
Kernel	The kernel will be the µC/OS-II pre-emptive kernel. If the timing constraints of this project turn out to be too tight, a simple time slice scheduler may be used.
Debounce	This is a preexisting module that will debounce the two push button switches in this project.
WWVDecode	This module will validate and decode the data received from WWVB into the current date and time.
Display	This module will handle the timing and display of the decoded data on the swinging display.
Main	This module will incorporate what's left and tie everything together.

User Interface: The user interface of the S^2RC is simple. There will be one pushbutton to toggle between time zones and one pushbutton to toggle the display between the time and the date. When the clock powers up, the time will be displayed in UTC. Each time the *Time Zone* button is pressed the display will briefly show the name of the new time zone and then the time will be displayed. Figure 4 shows an example of what the display will look like shortly after toggling to Hawaii Standard Time.

Figure 4: Display after switching to HST

The S^2RC will only display UTC and the time zones where the signal is most prevalent. These include: Hawaii Standard Time (HST), Aleutian Standard Time (AST), Alaska Standard Time (AKST), Pacific Standard Time (PST), Mountain Standard Time (MST), Central Standard Time (CST), and Eastern Standard Time (EST). Figure 5 shows the progression through the time zones each time the *Time Zone* button is pressed.

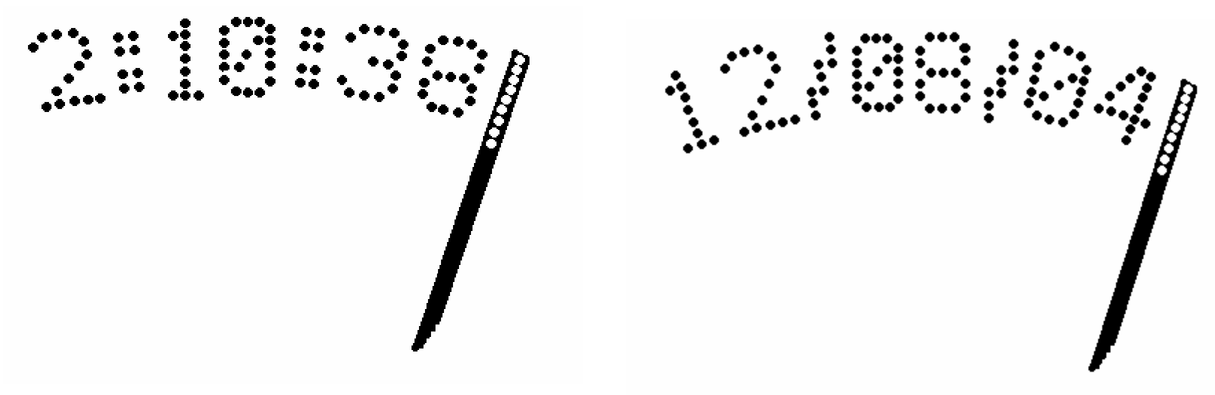
Figure 5: Time Zone Flow



After a short delay, the time zone display will automatically change to display the current time. The time will be displayed in the 12-hour time format. The second button, *Time*

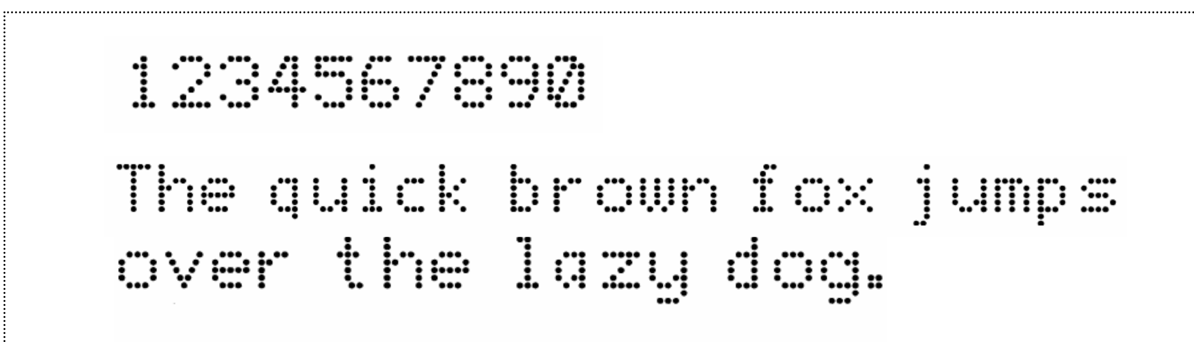
Date, will toggle the swinging display between the time and the date. The date will be displayed in the format of MM/DD/YY. Figure 6 shows an example of what the display will look like while in *Time* mode, and then in *Date* mode.

Figure 6: Display while in *Time* and *Date* mode



As seen in the figures above, the clock will use a standard 9x5 dot matrix font. A more complete example of this font is shown in Figure 7 below.

Figure 7: Standard 9x5 Dot Matrix Font



Development Plan: Although one never expects any major issues when a well designed plan is in place, some issues will undoubtedly arise. Nevertheless, a time table has been laid out to aid in the on time delivery of this product. Table 2 shows the planned implementation of the S^2RC on a week-by-week basis beginning at the start of Winter Quarter 2005.

The ability to receive and decode the WWVB signal is crucial to this project. Consequently, the majority of the time available for hardware design has been set aside for the construction and testing of Section 1 (refer to Figure 1). The low frequency of the WWVB signal coupled with its incredibly powerful transmission should allow for moderate to strong reception even here in Washington State. The first area of concern, however, is the hostile RF environment in the Ross Engineering Technology building at Western Washington University. It is possible to receive the WWVB signal inside the building by using an extended antenna, but it is not yet clear if a simple ferrite rod antenna will allow for adequate reception. If a ferrite rod antenna will not provide adequate reception, the line antenna in ET338 will be used during testing and demonstration. A well designed breadboard layout will be crucial to reduce noise and stray capacitance.

A second area of concern is the design and construction of the swing arm and electromagnet assembly. Again, a large amount of time has been slated for this segment of the project.

The hardware development portion of this project will take place almost exclusively in the main electronics lab at Western Washington University (ET340). An abundance of standard lab equipment is available including mixed signal oscilloscopes for digital logic analysis. The majority of the software development will also be carried out in this lab using the Metrowerks Code Warrior Integrated Development Environment (IDE). The lab is equipped with Noral debugging PODs which will be used for debugging during the software development stage.

The majority of the swing arm assembly will take place at my home where the tools necessary to build a functional prototype are available. The prototype will likely be constructed of wood and plastic.

Table 2: Weekly Schedule through Spring Quarter 2005

Winter Quarter 2005	
Week 01: 01/03/2005 – 01/09/2005	TRF receiver construction and testing
Week 02: 01/10/2005 – 01/16/2005	TRF receiver construction and testing
Week 03: 01/17/2005 – 01/23/2005	Band pass Filter and Voltage comparator setup
Week 04: 01/24/2005 – 01/30/2005	Band pass Filter and Voltage comparator testing
Week 05: 01/31/2005 – 02/06/2005	Band pass Filter and Voltage comparator testing
Week 06: 02/07/2005 – 02/13/2005	Testing of Section 1 together / signal conditioning if required
Week 07: 02/14/2005 – 02/20/2005	Testing continued and Final breadboard layout of Section 1
Week 08: 02/21/2005 – 02/27/2005 **Week 09:** 02/28/2005 – 03/06/2005	Assembly and testing of swing arm and electromagnet Testing will require some initial software design
Week 10: 03/07/2005 – 03/13/2005	Testing of swing arm assembly continued – Max speed test
Week 11: 03/14/2005 – 03/20/2005	Final Exams – Begin development of Decode Module
Week 12: 03/21/2005 – 03/27/2005	Spring Break – Continue on Decode Module

Spring Quarter 2005	
Week 01: 03/28/2005 – 04/03/2005	Finalize Decode Module – Begin Main and Display Modules
Week 02: 04/04/2005 – 04/10/2005	Continue Display Module
Week 03: 04/11/2005 – 04/17/2005	Continue Display Module – **Hardware Reviews**
Week 04: 04/18/2005 – 04/24/2005	Finish Main and Display
Week 05: 04/25/2005 – 05/01/2005	Tie all modules together with Kernel
Week 06: 05/02/2005 – 05/08/2005	Tie all modules together with Kernel
Week 07: 05/09/2005 – 05/15/2005	Debug and revise as needed
Week 08: 05/16/2005 – 05/22/2005	Debug and revise as needed
Week 09: 05/23/2005 – 05/29/2005	Debug and revise as needed – **Code Reviews**
Week 10: 05/30/2005 – 06/05/2005	Last minute bug fixes – Stress test
Week 11: 06/06/2005 – 06/10/2005	Final Presentations – Graduation!!!!!!!

Prototype Demonstration: The prototype of this design will consist of the TRF receiver, band pass filter, and voltage comparator all neatly implemented on a breadboard. The output will be fed into the microcontroller on a Wytec MiniDragon evaluation board. A separate module containing the swing arm assembly and the push buttons will be constructed and linked to the microcontroller. If time allows, the separate parts will be joined in an oversized project enclosure.

Project Specifications:

Displayed Clock Format............... 12-hours HH:MM:SS

Displayed Clock Resolution..........1 second

Displayed Date Format................MM/DD/YY

Receiver……………………………Follows WWVB Standard

Swing Rate……………………….. 16 – 24 Hz

Clock Accuracy w/Reception....... ±0.1 seconds

Clock Accuracy w/o Reception.... ±1 second per day

Characters Displayed……......... 10

PCB Dimensions .... 6in x 4in

Operating Temperature................ 0° to 50° C

Electrical Specifications:

Power Supply............................... UL cert. 120VAC to 9VDC @ 0.5A wall transformer

Max current draw..........................Approx. 300mA

Preliminary Parts List:

Part	Quantity	Distributor	Lead Time	Price	Max Current
LED Blue 3mm 5000mcd	9 (Max 7 on)	UBidItNow	Have	$2.25	210mA
Resistors 1%	20	Digi-Key	Have	$0.35	5mA
Capacitors 5%	10	Digi-Key	Have	$1.35	0mA
MC9S12DP256B	1	Freescale	Have	$14.87	65mA
Push Buttons	2	All Electronics	7 Days	$5.20	n/a
Cylindrical Magnet	1	Industrial Magnetics	Have	$0.38	n/a
16 MHz Crystal	1	Mouser	Have	$0.41	0.02mA
5V Voltage Regulator	1	Mouser	Have	$0.56	10mA
Ferrite Rod	1	Mouser	Have	$0.85	n/a
JFET Transistor	1	Mouser	Have	$0.15	1mA
LM324 Quad OpAmp	1	National	5 Days	$0.05	0.7mA
Hall Effect Sensor	1	Mouser	5 Days	$0.25	4mA
LM393	1	Mouser	5 Days	$0.12	2.5mA

Total Cost: $26.79 *Max Current:* 298.22mA