ECSE 323 – Winter 2014

Digital System Design

System Integration of the Mars Clock System

Group 09

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Presented to:
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Contents

Introduction

Our objective for this lab is to develop a hardware application using the DE1 Altera Board by scripting in VHDL which can display time on both Mars and Earth by taking into account various factors such as daylight saving and various time zones. Having already worked on related VHDL codes in the previous four labs, our aim is to build a complete Mars Clock System which can do complex calculations such as synchronization of Earth and Mars Clock systems.

It is important to have a basic understanding of time zones and daylight savings in order to implement this system. There are 24 time zones on both Earth and Mars, however, Martian time zones are equally spaced at 15 degree intervals unlike on Earth. On Earth, there are 40 time zones ranging from -12 to +11. Coordinated Universal Time (UTC) is the primary time standard and corresponds to the time zone 0. For example, the time zone for New York is -5. Also, daylight saving on Earth is imposed by the Daylight Saving Time (DST) which shifts the display time by one hour. This shift occurs when DST is enabled.

In the end, in order to integrate all the functions and display it on the Altera Board, we will be designing a user interface which allows the user to move between operation modes and take inputs through the buttons.

Functions of the Mars Clock System

The Mars Clock System must be able to do the following tasks on the DE1 Altera Board:

- Display time on Mars

  The LED display on DE1 Altera Board must show the time on Mars in a selected time zone.

- Display time on Earth

  This feature would show the time on Earth along with the function of Daylight saving time (whether it's enabled or not).

- Display date on Earth

  This feature would show the date, month and year on Earth.

- Setting Mars and Earth Time Zones

  This feature would enable users to choose time zones on the Earth and Mars.

- Include Daylight Saving feature

  This feature enables users to manually indicate whether Daylight savings time is in use or not.

- Synchronization of Earth and Mars times

  This feature would automatically sync the time on Mars given the current time on Earth by simply pressing a button.

- Design friendly User Interface

  The UI would enable users to easily provide inputs on the DE1 Altera Board and display all the above functions.

Final Block Diagram

After taking into account all the circuits from previous labs, we implemented these modules and compiled them. After compilation, we created a final module named g09_User_Interface. The pin out diagram, with inputs of clock, reset, push, synch, load, switch and set_value and outputs of LED_1, LED_2, LED_3 and LED_4 can be seen below:

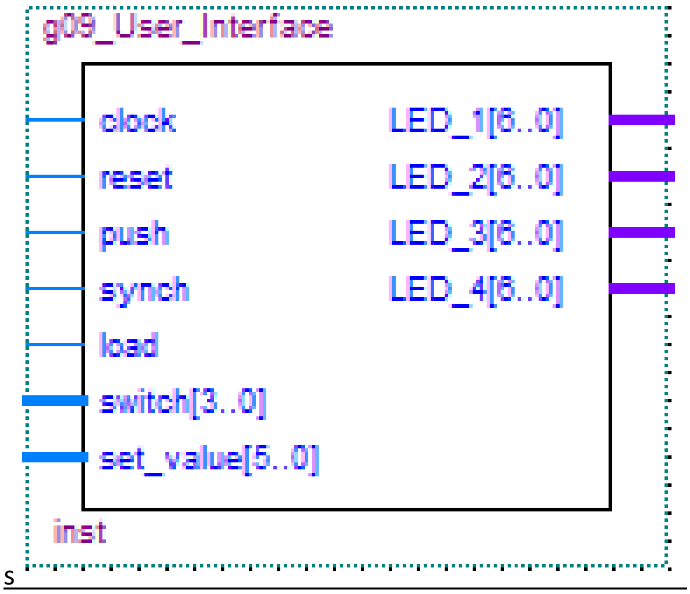


Figure 1: User Interface Block Diagram

The switch (4 bit) input is used to determine the state, the set_value (6 bit) input is used for taking inputs such as seconds, minutes, hours, etc. and reset, push, synch and load were used as functions (described in the User Guidelines). Basic timer was used to generate pulse second for Mars and Earth, which were synced to their HMS counters. YMD Counter was further used to keep track of days, months and years on Earth. Along with daylight saving and time zones, UTC was taken into account. Whereas for Mars, it's HMS counter along with its time zones was taken into account for MTC.

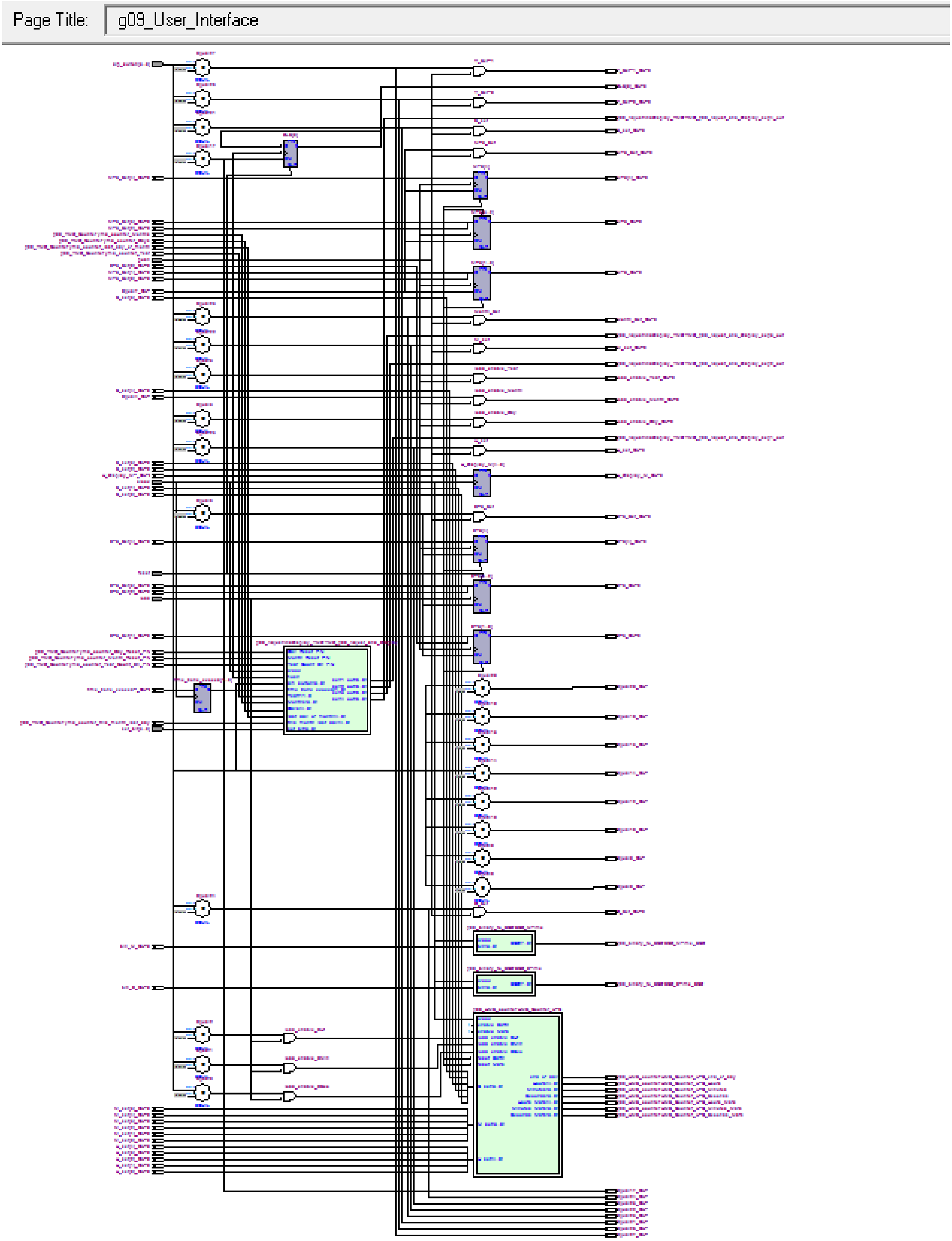


Figure 2: RTL Diagram

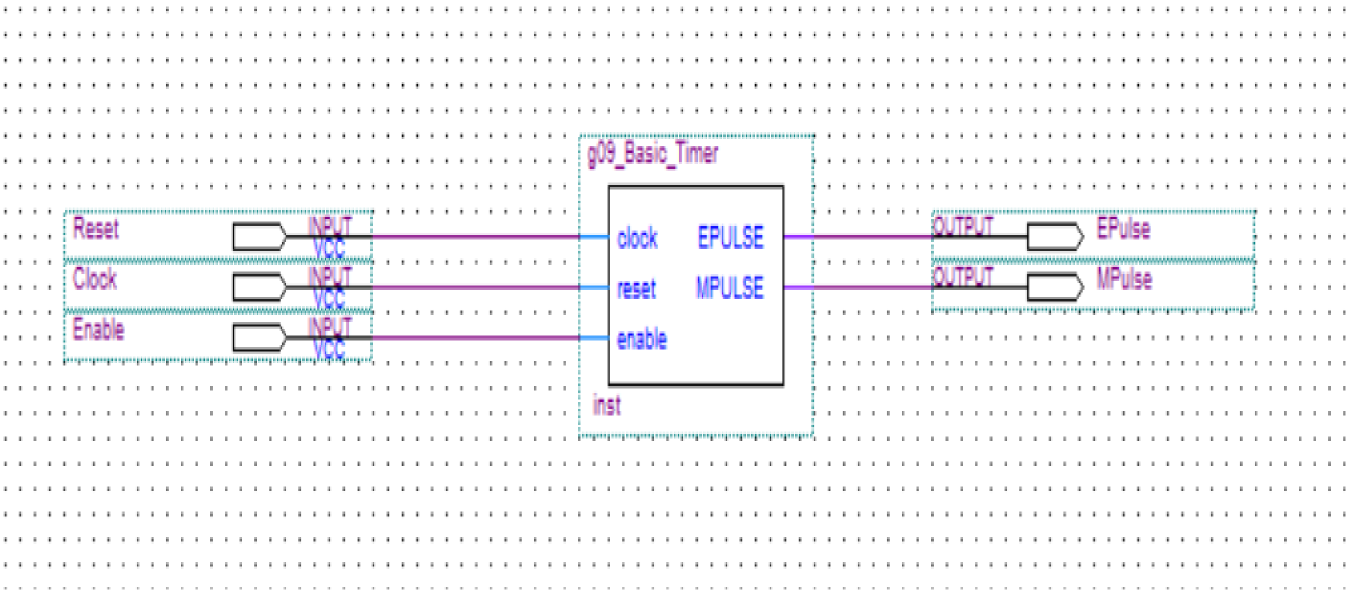
Description of Previous Components

Prior to lab 5, there have been four labs in which we built various VHDL codes related to the calculations for the functions of the Earth and Mars Clock systems. In this section, we will be describing the important components that we used for lab 5.

Basic Timer

One of the most important components used for lab 5 is the Basic Timer circuit. Built in lab 3, the main function of this circuit is to generate one pulse for each second. Since the DE1 Altera Board generates a frequency of 50MHz, which is approximately a period of 20ns, a frequency divider circuit was implemented in order to generate a time pulse which is much slower than Altera Board's clock.

When LPM counter, which counts down to 0, reaches 0, the pulse output goes high for one clock period. It also generates a pulse for the Mars clock, where 1 Martian second is 1.027 seconds on Earth. The following figure depicts the Pinout diagram for the basic timer. The inputs are reset, clock and enable and the outputs are EPulse and MPulse.



Pinout Diagram

Figure 3: Basic Timer

After performing the timing simulation, it can be seen that the propagation delay for EPULSE and MPULSE is 18.7ns and 19.5ns. The following figure shows the timing simulation:

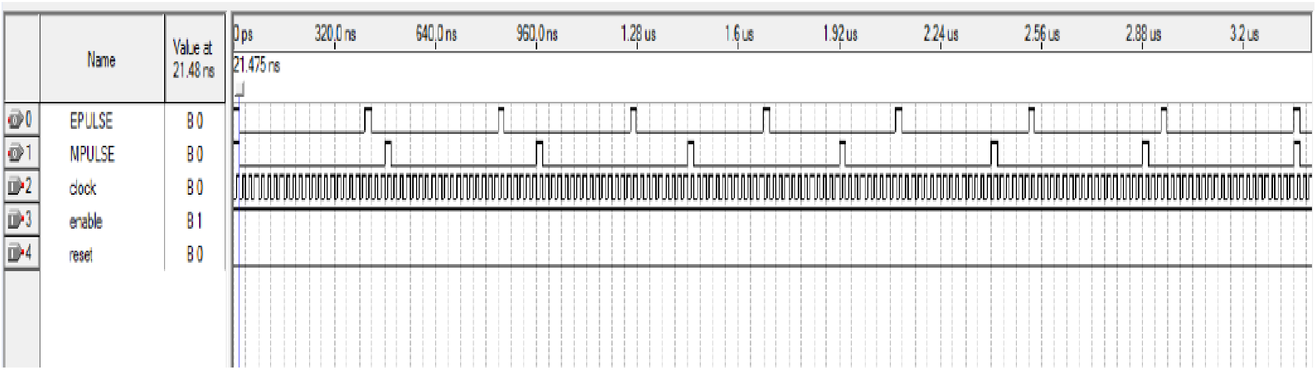


Figure 4: Simulation of Basic Timer

HMS Counter

sThe next component used for lab 5 is the HMS counter which was built in lab 3. The pulse generated from the basic timer circuit will trigger each second at a time which would increment the value of second that ranges from 0-59. Once the second counter reaches 59, it would reset to 0 and increment minute counter by 1 which ranges from 0-59. After the minute counter reaches 59, it would reset to 0 and increment the hours counter by 1 which ranges from 0-23. The figure below is the block diagram of the HMS Counter with inputs of clock, reset, sec_clock, count_enable, load_enable, H_Set, M_Set, S_Set and outputs of Hours, Minutes, Seconds, end_of_day and Test_Pulse.

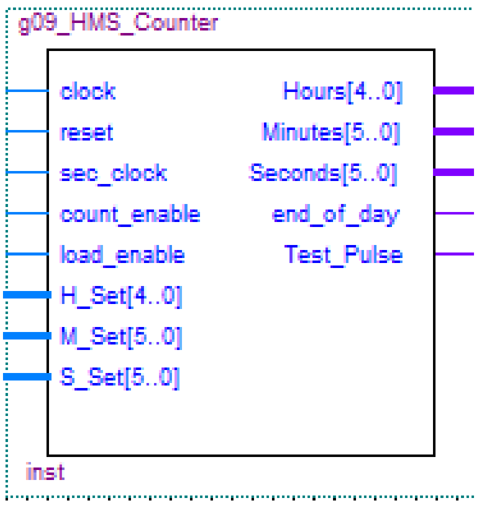


Figure 5: HMS Counter

YMD Counter

YMD Counter was built in lab 4 using a process block that keeps track of the days, months and years on Earth. The day counter ranges from 0-31 (depends on the type of Month: if February, it's 28/29 depending on leap year, if March, it's 31 and if it's April, it's 30).This would trigger the month counter which ranges from 1 to 12 which eventually triggers the year counter which ranges from 0 to 4000. The figure below is the symbol diagram of the YMD counter, with inputs of clock, reset, day_count_en, load_enable, Y_Set, M_Set and D_set and outputs of Years, Months and Days.

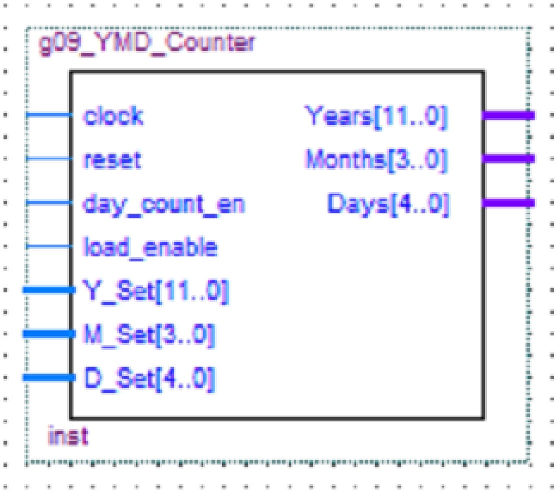


Figure 6: YMD Counter

A figure of the functional simulation can be seen below. For the year 1001 (which is a non-leap year), in the month of January there are 31 days and in the month of February there are 28 days.

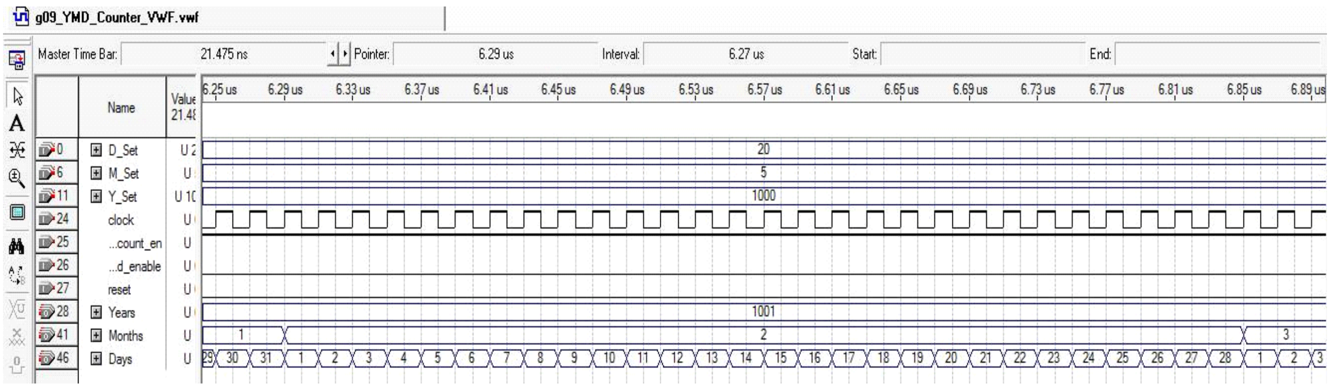


Figure 7: YMD Counter Simulation

UTC to MTCs

UTC to MTC circuit was built in lab 4 to take in the Earth time and date as input which is expressed in the format Y:M:D:H:M:S and eventually calculates and generates the Mars time of day for the Mars clock (MTC time; Mars Coordinated Time) which is expressed in the format H:M:S.

Below is a symbol diagram for this circuit:

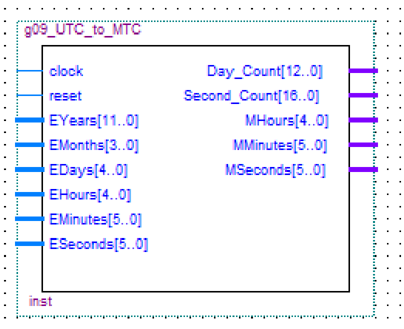


Figure 8: UTC to MTC

Binary to BCD/7 segment decoder

We also used the 7 segment decoder and binary to BCD circuits from lab 2 to get the number displays on the LEDs on the DE1 Altera Board.

The following flow chart summarizes all the functions of the previously built circuits and how these were implemented in our final block diagram:

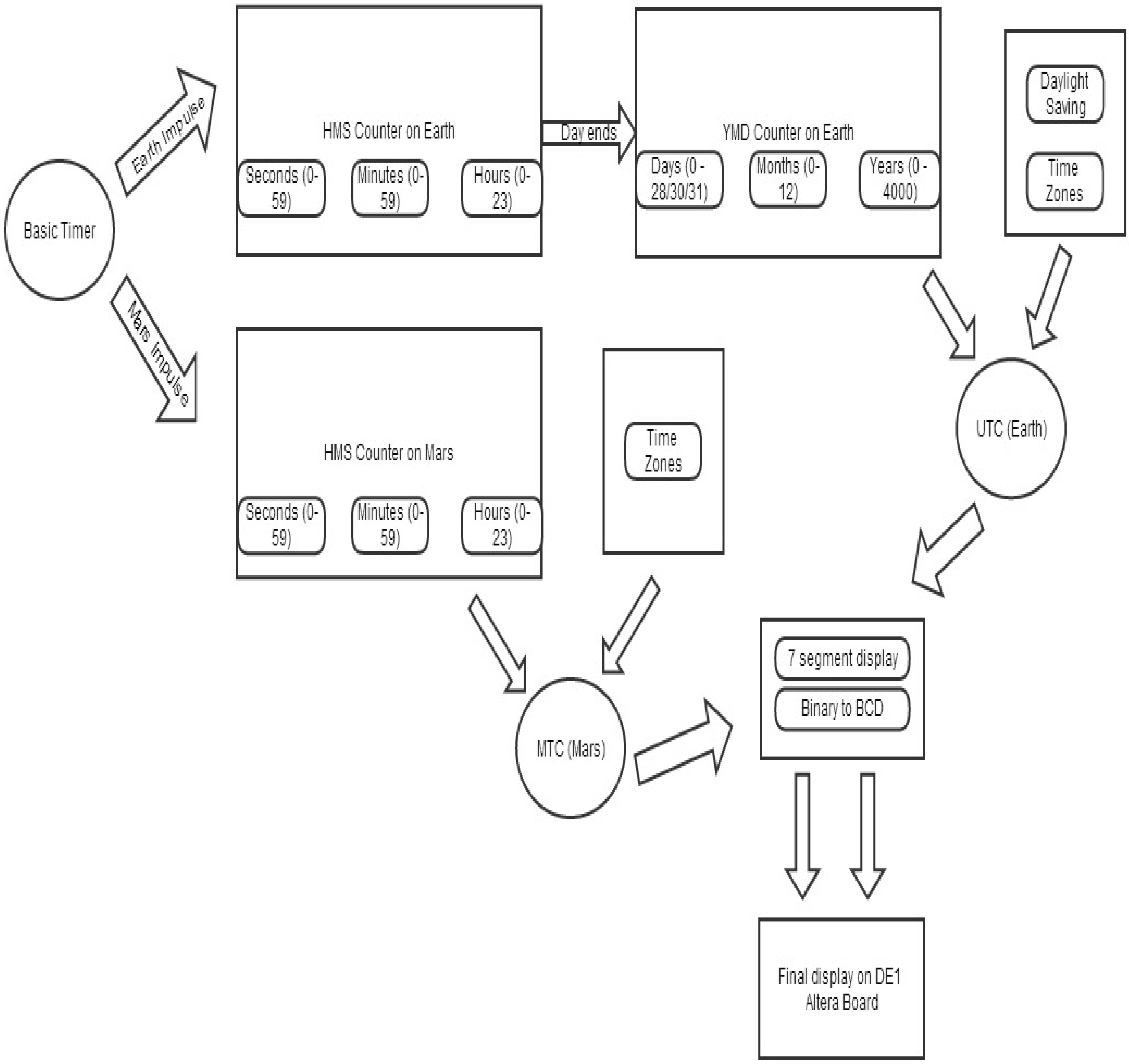


Figure 9: Flow Chart for the entire system

User Guidelines

There are two kinds of switches available on the DE1 Altera Board: 10 toggle and 4 push buttons. In our UI, we decided to use the first 4 toggle switches for selecting the state and the remaining 6 toggle switches for setting the values. Also, the 4 push buttons for determining functions:

Toggle Switches

SW[3]	SW[2]	SW[1]	SW[0]	Function
0	0	0	0	Seconds on Earth
0	0	0	1	Minutes on Earth
0	0	1	0	Hours on Earth
0	0	1	1	Seconds on Mars
0	1	0	0	Minutes on Mars
0	1	0	1	Hours on Mars
0	1	1	0	Days on Earth
0	1	1	1	Months on Earths
1	0	0	0	Years on Earth (lower 6 bits)
1	0	0	1	Years on Earth (upper 6 bits)
1	0	1	0	Enable daylight saving
1	0	1	1	Set time-zone

Push Buttons

- **KEY[0] - Reset**

  This is used to reset the system. It resets the value of time on Mars and Earth to 0. Years is also set to 0 whereas the day and month on Earth is set to 1.

- **KEY[1] – Load**

  When we set the value for different components such as seconds, minutes, hours, etc. the load button can be pressed to load them to the register.

- **KEY[2] - Push**

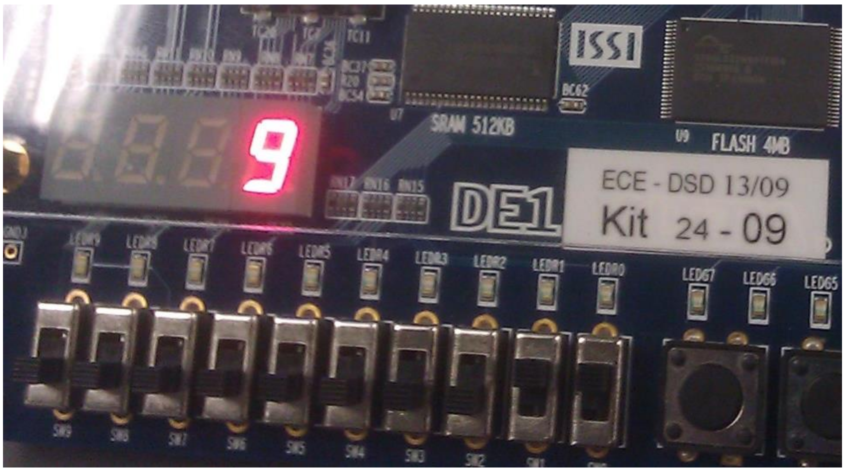
  After setting the values using the 6 toggle switches, we press the push button to set those values before they can be loaded onto the DE1 Altera Board.

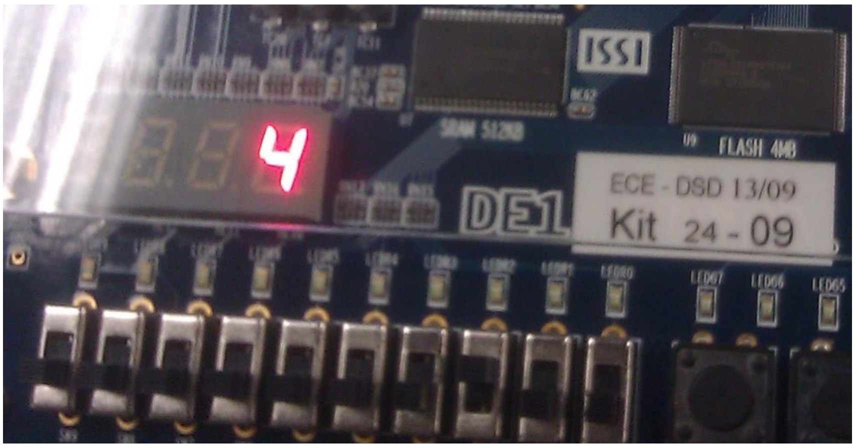
- **KEY[3] - Synchronization**

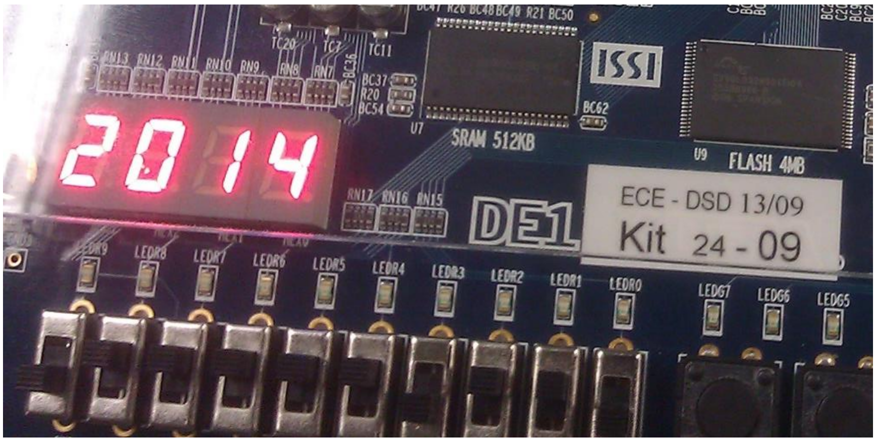
  This button is used to synchronize the Earth and Mars Clock systems and to obtain the time on Mars after setting the time on Earth.

Testing

Test Case 1: For our first test, we just tried setting the date and checking if it was stored properly. We tried 9th April, 2014 (9-4-2014) on the Altera board at the time of demo. As seen in the screenshots below, the date was set and displayed correctly.

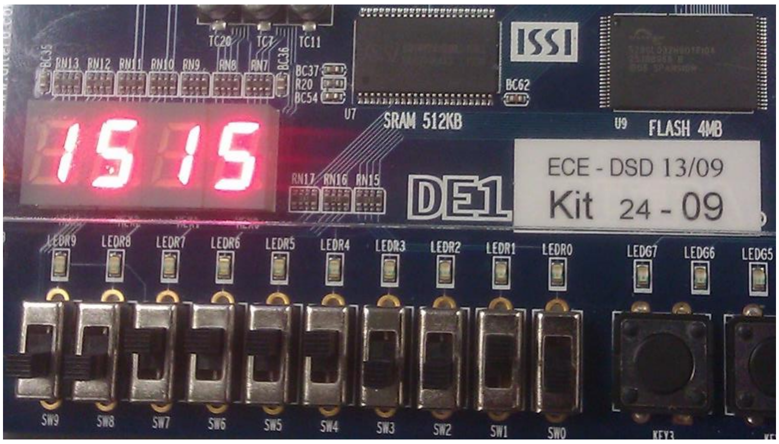


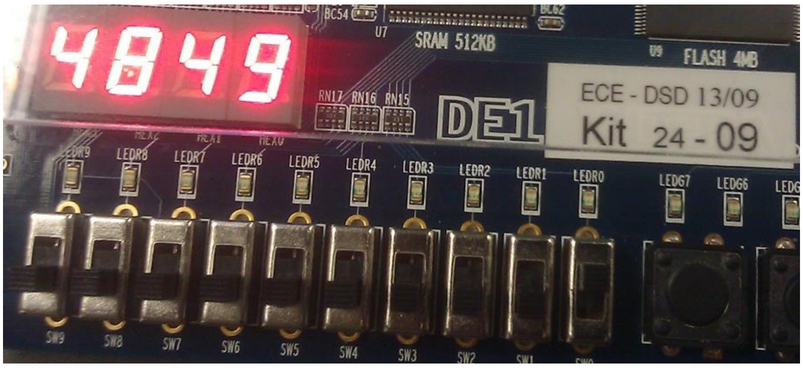


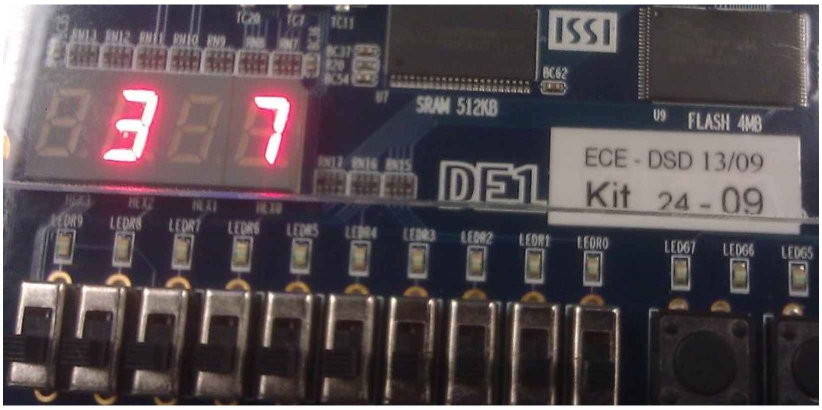


Test Case 2: We tested the accuracy of our system for loading the time on earth and setting it for different time zones. We had designed the system to display the time on Earth and Mars simultaneously. The right-two LEDs displayed the time on Earth , while the left-two LEDs displayed the time on Mars. We even tested if the Day Light Saving function was working properly.

For testing our system, we first set the time at GMT (19:49:00). We then set the time zone to UTC -05:00, which is the time zone of Montreal. We also switched on the Day Light Saving to check if the time changed to the local time. As can be seen in the screenshots below, the time accurately changed to the local time (15:48:07).







Test Case 3: For this test, we tried to synchronize the Earth and the Mars Clock. We wanted to obtain the time on Mars by setting the time on Earth. Unfortunately, this wasn't very accurate. The Mars clock didn't synchronize properly and the Mars time was a bit off.

This was surprising because the Mars clock worked properly in the Functional simulation. The UTC_to_MTC function, which was used to convert the Earth time into Mars time, also worked properly while testing for Lab 4.

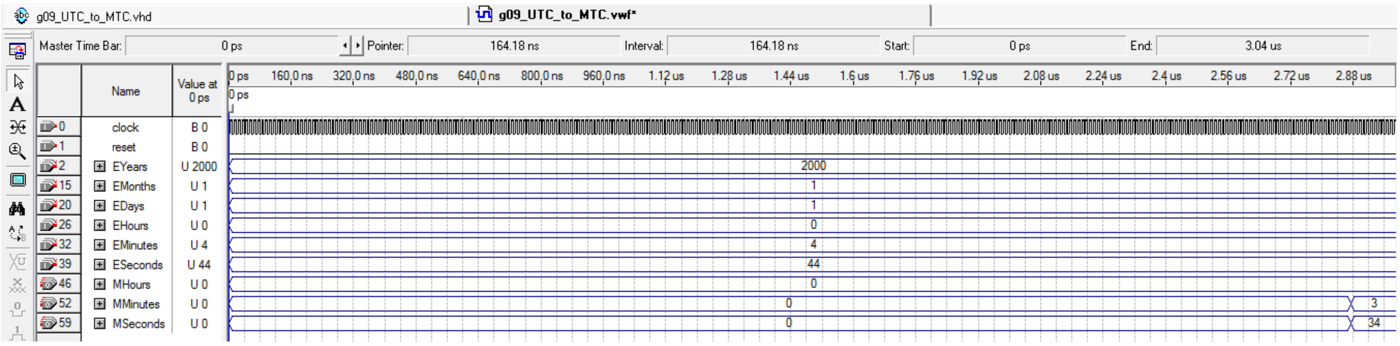


Figure 10: UTC to MTC simulation

The UTC-MTC simulation above shows that the function accurately converts the Earth time into Mars time. It didn't work properly when we called it in the final interface. We weren't left with sufficient time for the final lab to debug the problem and obtain a perfectly-working circuit.

Summary of FPGA Resource Utilization

Flow Status	Successful - Thu Apr 10 17:35:18 2014
Quartus II 64-Bit Version	9.1 Build 350 03/24/2010 SP 2 SJ Full Version
Revision Name	g09_Lab_Five
Top-level Entity Name	g09_User_Interface
Family	Cyclone II
Device	EP2C20F484C7
Timing Models	Final
Met timing requirements	Yes
Total logic elements	1,169 / 18,752 (6 %)
Total combinational functions	1,169 / 18,752 (6 %)
Dedicated logic registers	157 / 18,752 (< 1 %)
Total registers	157
Total pins	43 / 315 (14 %)
Total virtual pins	0
Total memory bits	2,496 / 239,616 (1 %)
Embedded Multiplier 9-bit elements	0 / 52 (0 %)
Total PLLs	0 / 4 (0 %)

Figure 11: FPGA Resource Utilization

Conclusion

The entire process of designing a Fully-Integrated Mars Clock System was highly challenging, but very rewarding. We were successful in getting most of the system working, with some exceptions in the Earth-Mars synchronization.

The main issue that arose in designing the final system was getting the synchronization working properly. The UTC_to_MTC function was working accurately, when designed during Lab 4. When we tried to test the final system after setting the earth and the Mars time zone, the clocks didn't synchronize accurately.

Some other issues that arose were due to limitation of the hardware. We initially assigned 3 toggle switches to select the state but we couldn't assign all the states and had to rely on a push button, which didn't work properly. As a result, we decided to use 4 toggle switches to decide the states. We only used 12 states so there were 4 inputs that were left unused. Since there were 6 toggle switches to set the values, the year had to be set in 2 parts, which is confusing for the user. Another issue was due to limited LEDs which allowed us to have only 4 outputs. As a result, the user couldn't see the day, month, year or hours, minutes, seconds together.

As mentioned above, we had 4 state inputs unused that can be used to add more functionality. As for possible enhancements, the obvious one is to add the day (Mon, Tues, Wed, etc.) of the week. This can be easily added as it is not tough to find out the day, once the date is known. We can also create a stop watch for both the Earth and Mars Clock.

Questions

1. Determine the time on Olympus Mons on Mars for Montreal at midnight April 11, 2014, 2pm April 23rd, 2014 and 5pm April 23, 2014?

   For midnight April 11, 2014: 9hrs, 21 minutes
   For 2pm April 23rd, 2014: 15 hrs, 54s minutes
   For 5pm April 23, 2014: 18 hrs, 49 minutes

2. How many Martian hours would the DSD final exam take?

   1 Martian second = (24*3600+39*60+35.244) / (24*3600) = 1.02749 Earth seconds

   DSD final = 3 Earth hours

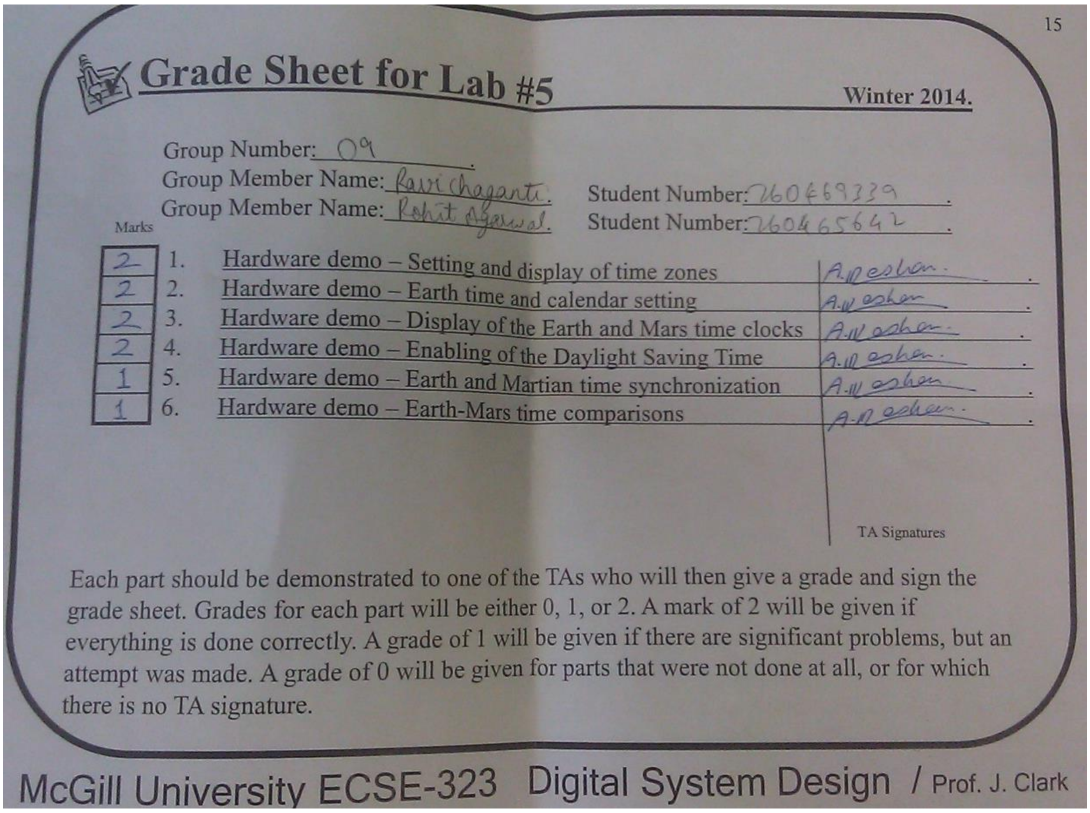
   1 Earth second = 1/1.02749 = 0.9732 Mars seconds

   The DSD final would take = 2.9196 Martian Hours

References

1. J. J. Clark,"lab_1_14w", Winter 2014, Digital System Design, ECSE 323, McGill University
2. J. J. Clark,"lab_2_14w", Winter 2014, Digital System Design, ECSE 323, McGill University
3. J. J. Clark,"lab_3_14w", Winter 2014, Digital System Design, ECSE 323, McGill University
4. J. J. Clark,"lab_4_14w", Winter 2014, Digital System Design, ECSE 323, McGill University
5. J. J. Clark,"lab_5_14w", Winter 2014, Digital System Design, ECSE 323, McGill University

Lab Demo Sheet



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Grade Sheet for Lab #5 Winter 2014.

Group Number: 09

Group Member Name: Ravi Chaganti. Student Number: 260469339

Group Member Name: Rohit Agarwal. Student Number: 260465642

Marks		
2	1. Hardware demo – Setting and display of time zones	
2	2. Hardware demo – Earth time and calendar setting	
2	3. Hardware demo – Display of the Earth and Mars time clocks	
2	4. Hardware demo – Enabling of the Daylight Saving Time	
1	5. Hardware demo – Earth and Martian time synchronization	
1	6. Hardware demo – Earth-Mars time comparisons	

TA Signatures

Each part should be demonstrated to one of the TAs who will then give a grade and sign the grade sheet. Grades for each part will be either 0, 1, or 2. A mark of 2 will be given if everything is done correctly. A grade of 1 will be given if there are significant problems, but an attempt was made. A grade of 0 will be given for parts that were not done at all, or for which there is no TA signature.

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Figure 11: Lab Demo Sheet