UNIVERSITY CARLOS III OF MADRID

VHDL Practice Manual

Integrated Circuits and Microelectronics

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1. OUTLINE

2. INTRODUCTION

This practice consists in designing a synchronous circuit by using synthesizable VHDL code. The practice is proposed as a simple project where the specifications of the circuit are defined and fixed and the student can make decisions about how to develop it.

The evaluation of this work will take into account the following aspects:

- Correct operation of the circuit.
- The circuit is synchronous, synthesizable and does not generate latches.
- Sensitivity lists are correct.
- Code is legible; it should contain enough comments for its comprehension.
- Simulations: should test enough functionality of the circuit.
- Documentation, which must include the following points:
  - Circuit block diagram
  - Description (textual) of every block, including all the explanations about their functionality, inputs and outputs.
  - Description (textual) of the performed simulations and captures of their corresponding waveforms. Simulation for the complete circuit must be included, as well as other blocks that are deemed appropriate. Simulations can be performed by using the simulator Modelsim. A student version can be downloaded from the web site model.com.
- Synthesis results using Quartus II and the EP2S15F672I4 device from the Stratix-II family: number of flip-flops and combinational functions. Copy-paste of the Quartus generated file is not accepted, please take the time to describe the results and document them with your own tables. A free version of Quartus (web edition) is available in www.altera.com.

3. CIRCUIT FUNCTIONALITY

The proposed problem is the design of the control circuit of an espresso coffee machine. The coffee machine has two programmable buttons (“espresso” and “lungo”) to prepare short or long coffees, and an additional power-on switch (“power_on”).

The coffee machine control circuit will use the two programmable buttons and the power-on switch as inputs, and will generate an output “pump”. When this output is active, the pressure pump of the coffee machine will be on, and it will be off otherwise.

By default, the programmed times of these buttons are predefined as 10 seconds for “espresso” and 20 seconds for “lungo”. The maximum allowed programmable time for a button is 60 seconds, and the minimum is 1 second.

3.1. System start

After powering on, the coffee machine needs to be preheated before operation, and it needs a minimum preheating time of 75 seconds. During this time the coffee machine will omit any petition of coffee preparation or button programming, and the pump will be off.

The programming buttons have internal leds (“espresso_led” and “lungo_led”). While the coffee machine is preheating, both buttons will blink with a frequency of one blink per second (500ms on, 500ms off). Once the coffee machine is ready, both buttons will remain on.

3.2. Operation

There are two operation modes, manual and automatic. When pushing one of the buttons with a short press, less than 1 second duration, the coffee machine starts making coffee. After that, if that button is not pressed again, it will continue preparing coffee until the programmed time is reached (automatic stop). On the other hand, if after pressing it the same button is pressed again before the programmed time is over, the coffee machine will stop in that moment, independently of the programmed time (manual stop).

The programming button that was pressed will blink while the coffee is been prepared, once per second (500ms on, 500ms off), while the other button which is not been used will remain off.

Once a button has been pressed, the machine will omit presses of the other button until the coffee preparation o programming of the other button is finished.

3.3. Timings programming

The timings programming is made with a long press of the button. If the button press lasts more than one second, then the programming starts. The time value that will be memorized will be the one that corresponds to the duration of the button press, with a maximum value of 60 seconds. During this time the coffee machine will be activating the pressure pump (so that the user can estimate the amount of prepared coffee while pressing the button).

Example:

1- The “espresso” button is pressed during 25 seconds → Then 25 seconds are programmed associated to this button (and the pressure pump is activated during this time).
2- The “lungo” button is pressed during 30 seconds → Then 30 seconds are programmed associated to this other button (and the pressure pump is also activated during this time).
3- The “espresso” button is pressed briefly (less than 1s.) and it is pressed again after 20 seconds → the coffee preparation starts and stops after 20 seconds
4- The “espresso” button is pressed briefly (less than 1s.) and it is not pressed again → the coffee preparation starts and stops after 25 segundos, because this is the time programmed for this button.
5- The “lungo” button is pressed during 40 seconds → Time is reprogrammed for this button; the pressure pump is active during this time.
6- The “lungo” button is pressed briefly and is not pressed again → Coffee is been prepared for 40 seconds.

3.4. Possible improvements

1- Add an additional switch, so that when it is enabled it is possible to program the timings without activating the pump.
2- Add an additional LED that is on when the programmed timing for button “lungo” is less than the one for button “espresso”.
3- Add a visualization system with four 7-segment displays, to represent in them the current programmed times for each button (two displays each). During button programming the display should show the time transcurred in seconds. During coffee preparation it should show the remaining time.
4- Add anti-rebound functionality for the buttons, as button presses could have rebounds and be detected as multiple presses.

3.5. Recommendations

The system must be synchronous, so it must include clock and reset signals. The clock frequency that is going to be used in the coffee machine is 1MHz.

Try to optimize the design, using for instance the minimum possible number of counters.