

طراحی سیستم‌های دیجیتال

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مقدمه

این پروژه بخشی از درس طراحی سیستم دیجیتال تحت نظارت دکتر فصحتی است. هدف آن طراحی و اجرای یک سیستم قوی مدیریت پارکینگ دانشگاهی است که نظارت بهینه و به صورت زمان واقعی بر فضاهای پارکینگ را فراهم می کند. این سیستم بین وسایل نقلیه مرتبط با دانشگاه و وسایل نقلیه غیر دانشگاهی تفاوت قائل شده و از استفاده بهینه از ظرفیت پارکینگ موجود اطمینان حاصل می کند. این پروژه با استفاده از Verilog توسعه یافته و بر روی یک FPGA پیاده سازی شده است تا از عملکرد و قابلیت اطمینان بالای آن در مدیریت مدارهای دیجیتال بهره برد.

طراحی

فاز طراحی

کد وریلاگ مازول را می توانید در زیر مشاهده کنید. توضیحات لازم در قالب کامنت در کد گنجانده شده است.

```
module parking_management_system (  
    input wire clk,  
    input wire reset,  
    input wire car_entered,  
    input wire car_exited,  
    input wire is_uni_car_entered,  
    input wire is_uni_car_exited,  
    output reg [9:0] uni_parked_car, // Number of university cars currently parked  
    output reg [9:0] parked_car, // Number of non-university cars currently parked  
    output reg [9:0] uni_vacated_space, // Number of vacated spaces reserved for university  
cars  
    output reg [9:0] vacated_space, // Number of vacated spaces for non-university cars  
    output reg uni_is_vacated_space, // indicates if there is a vacated space for university  
cars  
    output reg is_vacated_space // Indicates if there is a vacated space for non-university  
cars  
);  
  
parameter MAX_PARKING_SPACE = 700; // Total maximum parking spaces available  
parameter MAX_UNI_SPACE = 500; // Maximum parking spaces reserved for university cars  
parameter CLK_FREQ = 100_000_000; // Frequency of the clock signal (in Hz)  
parameter NON_UNI_BASE_SPACE = 200; // Initial base space reserved for non-university  
cars
```

```

// these regs are used to adjust the non_uni_space
reg [31:0] elapsed_time_cycles;
reg [9:0] non_uni_space;
reg [3:0] time_threshold;

task update_space_availability;
    input [9:0] uni_parked_car, parked_car;
    output reg uni_is_vacated_space, is_vacated_space;
begin
    if (uni_parked_car < MAX_UNI_SPACE && uni_parked_car + parked_car <
MAX_PARKING_SPACE) begin
        uni_is_vacated_space = 1;
    end else begin
        uni_is_vacated_space = 0;
    end

    if (parked_car < non_uni_space && uni_parked_car + parked_car < MAX_PARKING_SPACE)
begin
        is_vacated_space = 1;
    end else begin
        is_vacated_space = 0;
    end
end
endtask

always @(posedge clk or posedge reset) begin
    if (reset) begin
        elapsed_time_cycles <= 0;
        time_threshold <= 0;
        uni_parked_car <= 0;
        parked_car <= 0;
        uni_vacated_space <= MAX_UNI_SPACE;
        vacated_space <= NON_UNI_BASE_SPACE;
        non_uni_space <= NON_UNI_BASE_SPACE;
        uni_is_vacated_space <= 1;
        is_vacated_space <= 1;
    end else begin
        elapsed_time_cycles <= elapsed_time_cycles + 1;

        // Update time threshold based on elapsed time
        case (elapsed_time_cycles)
            CLK_FREQ * 300 * 60: time_threshold <= 4;
            CLK_FREQ * 240 * 60: time_threshold <= 3;
            CLK_FREQ * 180 * 60: time_threshold <= 2;
            CLK_FREQ * 120 * 60: time_threshold <= 1;
            default: time_threshold <= 0;
        endcase

        // Adjust non-uni space allocation based on time threshold

```

```

    case (time_threshold)
        0: non_uni_space <= NON_UNI_BASE_SPACE;
        1: non_uni_space <= 250;
        2: non_uni_space <= 300;
        3: non_uni_space <= 350;
        4: non_uni_space <= MAX_UNI_SPACE;
    endcase

    // Handle university car entered
    if (car_entered && is_uni_car_entered) begin
        if (uni_parked_car < MAX_UNI_SPACE && uni_parked_car + parked_car <
MAX_PARKING_SPACE) begin
            uni_parked_car <= uni_parked_car + 1;
            uni_vacated_space <= uni_vacated_space - 1;
        end
        update_space_availability(uni_parked_car, parked_car, uni_is_vacated_space,
is_vacated_space);
    // Handle university car exited
    end else if (car_exited && is_uni_car_exited) begin
        if (uni_parked_car > 0) begin
            uni_parked_car <= uni_parked_car - 1;
            uni_vacated_space <= uni_vacated_space + 1;
            uni_is_vacated_space <= 1;
        end
    // Handle non-university car entered
    end else if (car_entered && !is_uni_car_entered) begin
        if (parked_car + uni_parked_car < MAX_PARKING_SPACE && parked_car <
non_uni_space) begin
            parked_car <= parked_car + 1;
            vacated_space <= vacated_space - 1;
            update_space_availability(uni_parked_car, parked_car,
uni_is_vacated_space, is_vacated_space);
        end
    // Handle non-university car exited
    end else if (car_exited && !is_uni_car_exited) begin
        if (parked_car > 0) begin
            parked_car <= parked_car - 1;
            vacated_space <= vacated_space + 1;
            is_vacated_space <= 1;
        end
    end
end
end
end
endmodule

```

فاز تست

می‌توانید کد ماژول تست بنچ را در زیر مشاهده کنید:

```
module TB_parking_management_system;
```

```

reg clk;
reg reset;
reg car_entered;
reg car_exited;
reg is_uni_car_entered;
reg is_uni_car_exited;
wire [9:0] uni_parked_car;
wire [9:0] parked_car;
wire [9:0] uni_vacated_space;
wire [9:0] vacated_space;
wire uni_is_vacated_space;
wire is_vacated_space;

integer outfile;

parking_management_system uut (
    .clk(clk),
    .reset(reset),
    .car_entered(car_entered),
    .car_exited(car_exited),
    .is_uni_car_entered(is_uni_car_entered),
    .is_uni_car_exited(is_uni_car_exited),
    .uni_parked_car(uni_parked_car),
    .parked_car(parked_car),
    .uni_vacated_space(uni_vacated_space),
    .vacated_space(vacated_space),
    .uni_is_vacated_space(uni_is_vacated_space),
    .is_vacated_space(is_vacated_space)
);

parameter CLK_PERIOD = 10;
parameter DELAY = 10;

always begin
    # (CLK_PERIOD / 2) clk = ~clk;
end

task display_state;
    begin
        $fwrite(outfile, "Time: %0t\nNumber of university cars currently parked:
%d\nNumber of non-university cars currently parked: %d\nNumber of vacated spaces reserved for
university cars: %d\nNumber of vacated spaces for non-university cars: %d\nIs there a vacated
space for university cars? %s\nIs there a vacated space for non-university cars? %s\n",
            $time, uni_parked_car, parked_car, uni_vacated_space, vacated_space,
            uni_is_vacated_space ? "yes" : "no",
            is_vacated_space ? "yes" : "no");
    end
endtask

task car_enter(

```

```

    input is_uni
);
    begin
        car_entered = 1;
        is_uni_car_entered = is_uni;
        #DELAY;
        car_entered = 0;
        is_uni_car_entered = 0;
        display_state();
    end
endtask

task car_exit(
    input is_uni
);
    begin
        car_exited = 1;
        is_uni_car_exited = is_uni;
        #DELAY;
        car_exited = 0;
        is_uni_car_exited = 0;
        display_state();
    end
endtask

initial begin
    outfile = $fopen("output_results.txt", "w");

    clk = 0;
    reset = 0;
    car_entered = 0;
    car_exited = 0;
    is_uni_car_entered = 0;
    is_uni_car_exited = 0;

    $fwrite(outfile, "Resetting the system...\n");
    reset = 1;
    #DELAY;
    reset = 0;
    #DELAY;

    // Test normal operations
    $fwrite(outfile, "Event 1: Uni Car Enters");
    car_enter(1);

    $fwrite(outfile, "Event 2: Another Uni Car Enters");
    car_enter(1);

    $fwrite(outfile, "Event 3: Non-Uni Car Enters");
    car_enter(0);

```

```
$fwrite(outfile, "Event 4: Non-Uni Car Exits");
car_exit(0);

$fwrite(outfile, "Event 5: Uni Car Exits");
car_exit(1);

$fwrite(outfile, "Event 6: Non-Uni Car Enters Again");
car_enter(0);

#6000000;
$fwrite(outfile, "Event 7: Non-Uni Car Enters After Long Delay");
car_enter(0);

// Test edge cases
$fwrite(outfile, "Event 8: Fill up university parking spaces");
repeat (500) begin
    car_enter(1);
end

$fwrite(outfile, "Event 9: Fill up non-university parking spaces");
repeat (200) begin
    car_enter(0);
end

$fwrite(outfile, "Event 10: Attempt to park another university car (should fail)");
car_enter(1);

$fwrite(outfile, "Event 11: Attempt to park another non-university car (should
fail)");
car_enter(0);

$fwrite(outfile, "Event 12: Exit a university car");
car_exit(1);

$fwrite(outfile, "Event 13: Exit a non-university car");
car_exit(0);

$fwrite(outfile, "Event 14: Park a university car after space is vacated");
car_enter(1);

$fwrite(outfile, "Event 15: Park a non-university car after space is vacated");
car_enter(0);

$fclose(outfile);

$finish;
end

endmodule
```

همانطور که می بینید ۱۵ حالت مختلف در این تست بنچ بررسی شده است. می توانید نتیجه ها را در فایل output_results.txt ببینید. نتیجه ۴۹۹۳ خط شده است به همین دلیل دیگه در این داکيومنت آورده نشده است.

سنتز

فایل وریلاگ را در کوارتوس باز می کنیم. از لیست دیوایس ها Cydone IV GX را انتخاب کرده ایم. کامپایل می کنیم.

The screenshot displays the Quartus II 64-Bit software interface. The top menu bar includes File, Edit, View, Project, Assignments, Processing, Tools, Window, and Help. The main workspace is divided into several panes:

- Project Navigator:** Shows the project hierarchy with 'parking_management_system' selected.
- Table of Contents:** Lists various report sections like Flow Summary, Flow Settings, and Analysis & Synthesis.
- Flow Summary:** Provides a detailed overview of the compilation process, including flow status, version information, and resource usage statistics.
- Messages:** Displays a list of messages generated during the compilation, including warnings and errors.

The Flow Summary pane shows the following details:

- Flow Status: In progress - Wed Jun 26 15:54:22 2024
- Quartus II 64-Bit Version: 13.1.0 Build 162 10/23/2013 53 Web Edition
- Revision Name: Parking
- Top-level Entity Name: parking_management_system
- Family: Cydone IV GX
- Total logic elements: 150 / 21,280 (< 1 %)
- Total combinational functions: 146 / 21,280 (< 1 %)
- Dedicated logic registers: 86 / 21,280 (< 1 %)
- Total registers: 86
- Total pins: 48 / 167 (29 %)
- Total virtual pins: 0
- Total memory bits: 0 / 774,144 (0 %)
- Embedded Multiplier 9-bit elements: 0 / 80 (0 %)
- Total GXB Receiver Channel PCS: 0 / 4 (0 %)
- Total GXB Receiver Channel PMA: 0 / 4 (0 %)
- Total GXB Transmitter Channel PCS: 0 / 4 (0 %)
- Total GXB Transmitter Channel PMA: 0 / 4 (0 %)
- Total PLLs: 0 / 4 (0 %)
- Device: EP4CGX22CF19C6
- Timing Models: Final

The Messages pane shows the following messages:

- 334004 Delay annotation completed successfully
- 334003 Started post-fitting delay annotation
- 334004 Delay annotation completed successfully
- 11218 Fitter post-fit operations ending: elapsed time is 00:00:02
- 169177 2 pins must meet Altera requirements for 3.3-, 3.0-, and 2.5-V interfaces. For more information, refer to AN 447: Interfacing Cyclone IV GX Devices with 3.3/3.0/2.5-V LVTTTL/L
- 144001 Generated suppressed messages file C:/altera/13.1/output_files/Parking.fit.smsg
- Quartus II 64-Bit Fitter was successful. 0 errors, 6 warnings
- Running Quartus II 64-Bit Assembler
- Command: quartus_asm --read_settings_files=off --write_settings_files=off Parking -c Parking

حال ابزار Time Quest Analyzer را باز می کنیم.

TimeQuest Timing Analyzer - C:/altera/13.1/Parking - Parking

File View Netlist Constraints Repgrts Script Tools Window Help

Report

Report not available

Getting Started

Welcome to the TimeQuest Timing Analyzer

The TimeQuest Timing Analyzer is a powerful ASIC-style timing analysis tool that validates the timing performance of all logic in the design using industry standard constraint, analysis, and reporting methodology. You can use the TimeQuest analyzer to constrain, run, and view results for all timing paths in your design. The TimeQuest Timing Analyzer offers the following graphical user interface features:

Report Pane
Lists generated report panels.

Tasks Pane
Lists common tasks you can perform. You can double-click a command to start a process in the flow.

View Pane
Displays selected report panels. You can split the View pane into sub-panels by dragging the splitter control in the upper right corner of the pane.

Console
Displays SDC and Tcl commands executed by the GUI or command-line.

command.
- Type "exit" to exit.
- Type "help" to view a list of Quartus II Tcl packages.
- Type "help <package name>" to view a list of Tcl commands available for the specified Quartus II Tcl package.
- Type "help -tcl" to get an overview on Quartus II Tcl usages.

tcl> project_open -force "C:/altera/13.1/Parking.qpf" -revision Parking
tcl>

Console / History /

0% 00:00:00 Ready

سپس در مرحله بعدی Create Timing Netlist:

TimeQuest Timing Analyzer - C:/altera/13.1/Parking - Parking

File View Netlist Constraints Repgrts Script Tools Window Help

Report

TimeQuest Timing Analyzer Summary

- Advanced I/O Timing
- Board Trace Model Assignments
- Input Transition Times
- Signal Integrity Metrics

Tasks

- Open Project...
- Netlist Setup
- Create Timing Netlist
- Read SDC File
- Update Timing Netlist
- Reset Design
- Set Operating Conditions...
- Reports
- Slack
- Report Setup Summary
- Report Hold Summary
- Report Recovery Summary
- Report Removal Summary
- Report Minimum Pulse Width Summary
- Report Max Skew Summary

Board Trace Model Assignments

| | Pin | I/O Standard | Near Time Length | Near Time L per Length | Near Time C per Length | Near Series R | Near Differential R | Near Pull-up R | Near Pull-down R | Near C | Far Tls |
|----|----------------------|--------------|------------------|------------------------|------------------------|---------------|---------------------|----------------|------------------|--------|---------|
| 1 | uni_parked_car[0] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 2 | uni_parked_car[1] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 3 | uni_parked_car[2] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 4 | uni_parked_car[3] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 5 | uni_parked_car[4] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 6 | uni_parked_car[5] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 7 | uni_parked_car[6] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 8 | uni_parked_car[7] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 9 | uni_parked_car[8] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 10 | uni_parked_car[9] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 11 | parked_car[0] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 12 | parked_car[1] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 13 | parked_car[2] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 14 | parked_car[3] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 15 | parked_car[4] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 16 | parked_car[5] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 17 | parked_car[6] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 18 | parked_car[7] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 19 | parked_car[8] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 20 | parked_car[9] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 21 | uni_vacated_space[0] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 22 | uni_vacated_space[1] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 23 | uni_vacated_space[2] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 24 | uni_vacated_space[3] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 25 | uni_vacated_space[4] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 26 | uni_vacated_space[5] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 27 | uni_vacated_space[6] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 28 | uni_vacated_space[7] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 29 | uni_vacated_space[8] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 30 | uni_vacated_space[9] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 31 | vacated_space[0] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 32 | vacated_space[1] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 33 | vacated_space[2] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 34 | vacated_space[3] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 35 | vacated_space[4] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 36 | vacated_space[5] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 37 | vacated_space[6] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 38 | vacated_space[7] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 39 | vacated_space[8] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |
| 40 | vacated_space[9] | 2.5 V | 0 in | 0 H/in | 0 F/in | short | - | open | open | open | 0 in |

available for the specified Quartus II Tcl package.
- Type "help -tcl" to get an overview on Quartus II Tcl usages.

tcl> project_open -force "C:/altera/13.1/Parking.qpf" -revision Parking
tcl> create_timing_netlist -model slow
Parallel compilation is not licensed and has been disabled
High junction temperature operating condition is not set. Assuming a default value of '85'.
Low junction temperature operating condition is not set. Assuming a default value of '0'.
tcl>

Console / History /

0% 00:00:00 Ready

و سپس Read STC File و بعد از آن Update Timing Netlist را انتخاب می‌کنیم. سپس از بین گزارش‌های آماده شده Report Fmax Summary را انتخاب می‌کنیم. حال فرکانس ماکس را در اینجا می‌توانیم مشاهده کنیم:

| Fmax Summary | | | | |
|--------------|-----------|-----------------|------------|------|
| | Fmax | Restricted Fmax | Clock Name | Note |
| 1 | 190.8 MHz | 190.8 MHz | clk | |