پروژه طراحی سیستم دیجیتال

مزدک تیموریان

۴۰۱۱۰۱۴۹۵

دانشکده مهندسی کامپیوتر

دانشگاه صنعتی شریف

تیر ۱۴۰۳

طراحی مدار برای مدیریت پارکینگ (سؤال ۸ میانترم)

آ) ابتدا ماژولی طراحی میکنیم که نقش ساعت را داشته باشد.

```
module Clock (
    input start,
    input clk,
    output reg [11:0] clock_time
);
    reg [12:0] counter;
    always @(posedge clk) begin
        if (~start) begin
            clock_time <= 0;
            counter <= 0;
        end
        else begin
            if (counter >= 60) begin
                clock_time <= clock_time + 1;
                counter <= 0;
            end
            if (clock_time >= 23) begin
                clock_time <= 0;
            end
            else begin
                counter <= counter + 30;
            end
        end
    end

endmodule
```

همانطور که در شکل بالا مشاهده میکنید این ماژول با ورودی گرفتن سیگنال clk و start شروع به شمارش کرده و به ازای هر ۶۰ چرخه مقدار clock_time را یکی زیاد میکند که نماینده ساعت است و همچنین ساعت بعد از گذر از ۲۳ دوباره ۰ میشود. (روز بعد)
حال از این ماژول در ماژول اصلی استفاده میکنیم.

```
always @(car_entered or car_exited or start or clock_time) begin
    if (clock_time < 8) begin
        MAX_CAP_UNI = 0;
        MAX_CAP_GENERAL = 0;
    end
    else if (clock_time < 13) begin
        MAX_CAP_UNI = 500;
        MAX_CAP_GENERAL = 200;
    end
    else if (clock_time < 14) begin
        MAX_CAP_UNI = 450;
        MAX_CAP_GENERAL = 250;
    end
    else if (clock_time < 15) begin
        MAX_CAP_UNI = 400;
        MAX_CAP_GENERAL = 300;
    end
    else if (clock_time < 16) begin
        MAX_CAP_UNI = 350;
        MAX_CAP_GENERAL = 350;
    end
    else begin
        MAX_CAP_UNI = 200;
        MAX_CAP_GENERAL = 500;
    end
    if (~start) begin
        uni_car_parked <= 0;
        parked_care <= 0;
        uni_vacated_space <= MAX_CAP_UNI;
        vacated_space <= MAX_CAP_GENERAL;
        uni_is_vacated_space <= 1'b1;
```

```
module Parking(
    input start,
    input clk,
    input car_entered,
    input is_uni_car_entered,
    input car_exited,
    input is_uni_car_exited,
    output reg [15:0] uni_car_parked,
    output reg [15:0] parked_care,
    output reg [15:0] uni_vacated_space,
    output reg [15:0] vacated_space,
    output reg uni_is_vacated_space,
    output reg is_vacated_space,
    output wire [11:0] clock_time
);
    integer MAX_CAP_PARKING = 700;
    integer MAX_CAP_UNI;
    integer MAX_CAP_GENERAL;

    Clock clock (
        .clk(clk),
        .start(start),
        .clock_time(clock_time)
    );
```

نحوه کار پارکینگ با توجه به ساعت بصورت زیر است

- از ساعت ۰ تا ۸ هیچ ماشینی نمیتواند وارد شود و صرفاً ماشین‌هایی که از قبل داخل پارکینگ بودند میتوانند خارج شوند.
- از ساعت ۸ تا ۱۳ ظرفیت دانشگاه برابر با ۵۰۰ و ظرفیت آزاد ۲۰۰ ماشین است.
- از ساعت ۱۳ تا ۱۴ ظرفیت دانشگاه و آزاد به ترتیب برابر با ۴۵۰ و ۲۵۰ است.
- از ساعت ۱۴ تا ۱۵ ظرفیت دانشگاه و آزاد به ترتیب برابر با ۴۰۰ و ۳۰۰ است.
- از ساعت ۱۵ تا ۱۶ ظرفیت دانشگاه و آزاد به ترتیب برابر با ۳۵۰ و ۳۵۰ است.
- از ساعت ۱۶ تا ۲۴ ظرفیت دانشگاه و آزاد به ترتیب برابر با ۲۰۰ و ۵۰۰ است.

توجه کنید در صورتی که بعد از تغییر ساعت تعداد ماشین‌های یک گروه بیشتر از ظرفیت آنها درون پارکینگ شوند این مقدار بیش از ظرفیت با عددی منفی نمایش داده شده و تنها درصورتی ماشین جدید از آن گروه میتواند وارد پارکینگ شود که تمامی ماشین‌های مضاف بر ظرفیت از پارکینگ خارج شوند.

حال در ادامه منطق ورود و خروج پیاده‌سازی شده است.

```
            uni_vacated_space <= MAX_CAP_UNI;
            vacated_space <= MAX_CAP_GENERAL;
            uni_is_vacated_space <= 1'b1;
            is_vacated_space <= 1'b1;
        end
        else if (start) begin
            vacated_space = MAX_CAP_GENERAL - parked_care;
            uni_vacated_space = MAX_CAP_UNI - uni_car_parked;
            if (car_entered) begin                                          //check if car entered
                if (parked_care + uni_car_parked < MAX_CAP_PARKING) begin
                    if (is_uni_car_entered) begin                           //check if it is uni car
                        if (uni_is_vacated_space && $signed(uni_vacated_space) >= 1) begin  //check if there is any empty space
                            uni_car_parked = uni_car_parked + 1;
                            uni_vacated_space = MAX_CAP_UNI - uni_car_parked;
                            if (uni_car_parked >= MAX_CAP_UNI) begin        //check if the uni cap is full
                                uni_is_vacated_space = 1'b0;
                            end
                        end
                    end
                    else begin
                        if (is_vacated_space && $signed(vacated_space) >= 1) begin          //check for general cars
                            parked_care = parked_care + 1;
                            vacated_space = MAX_CAP_GENERAL - parked_care;
                            if (parked_care >= MAX_CAP_GENERAL) begin
                                is_vacated_space = 1'b0;
                            end
                        end
                    end
                end
```

```
                end
            end
            else if (car_exited) begin                                      //check if car exited
                if (is_uni_car_exited) begin                                //check if it is uni car
                    if (uni_car_parked > 0) begin
                        uni_car_parked = uni_car_parked - 1;
                        uni_vacated_space <= MAX_CAP_UNI - uni_car_parked;
                        if (!uni_is_vacated_space) begin                    //check if the uni cap is full
                            uni_is_vacated_space = 1'b1;
                        end
                    end
                end
                else begin                                                  //check for general cars
                    if (parked_care > 0) begin
                        parked_care = parked_care - 1;
                        vacated_space <= MAX_CAP_GENERAL - parked_care;
                        if (!is_vacated_space) begin
                            is_vacated_space = 1'b1;
                        end
                    end
                end
            end
        end
    end

endmodule
```

ماژول تست طراحی شده برای ماژول بالا نیز بصورت زیر است.

```
    #1;
    car_entered = 0;
    #20;
    car_exited <= 1;
    is_uni_car_exited = 0;
    #1;
    car_exited = 0;
    #20;
    car_entered <= 1;
    is_uni_car_entered = 1;
    #1;
    car_entered = 0;
    #20;
    car_entered <= 1;
    is_uni_car_entered = 1;
    #1;
    car_entered = 0;
    #20;
    car_entered <= 1;
    is_uni_car_entered = 0;
    #1;
    car_entered = 0;
    #20;
    car_entered <= 1;
    is_uni_car_entered = 0;
    #1;
    car_entered = 0;
    #20;
    car_exited <= 1;
    is_uni_car_exited = 0;
```

```
initial begin
    clk <= 0;
    start <= 0;
    car_entered <= 0;
    car_exited <= 0;
    is_uni_car_entered <= 0;
    is_uni_car_exited <= 0;
end

always begin
    #5 clk <= ~clk;
end

initial begin
    #12;
    start = 1;
    #20;
    car_exited <= 1;
    is_uni_car_exited = 0;
    #1;
    car_exited = 0;
    #80;
    car_entered <= 1;
    is_uni_car_entered = 0;
    #1;
    car_entered = 0;
    #20;
    car_entered <= 1;
    is_uni_car_entered = 1;
    #1;
```

```
        #1;
        car_exited = 0;
        #20;
        car_entered <= 1;
        is_uni_car_entered = 0;
        #1;
        car_entered = 0;
        #20;
        car_exited <= 1;
        is_uni_car_exited = 1;
        #1;
        car_exited = 0;
        #300;
        $stop();
    end

    initial begin
        $monitor("clock time: ", clock_time ," car entered: ", car_entered, " car exited: ", car_exited,
        " uni car parked: ", $signed(uni_car_parked), " parked care: ", $signed(parked_care),
         " uni vacated space: ", $signed(uni_vacated_space), " vacated space: ", $signed(vacated_space));
    end
endmodule
```

نحوه عملکرد ماژول تست را میتوانید در شکل‌های زیر مشاهده کنید. (توجه کنید که برای آزمایش پر شدن پارکینگ تعداد ورود و خروج ماشین‌ها ۱۰۰ تایی گذاشته شده‌اند.)

```
# clock time:    x car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:    200 vacated space:    500
# clock time:    0 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    0 car entered: 0 car exited: 1 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    0 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    1 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    2 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    3 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    4 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    5 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    6 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    7 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:      0 vacated space:      0
# clock time:    8 car entered: 0 car exited: 0 uni car parked:      0 parked care:      0 uni vacated space:    500 vacated space:    200
# clock time:    8 car entered: 1 car exited: 0 uni car parked:      0 parked care:    100 uni vacated space:    500 vacated space:    100
# clock time:    8 car entered: 0 car exited: 0 uni car parked:      0 parked care:    100 uni vacated space:    500 vacated space:    100
# clock time:    9 car entered: 0 car exited: 0 uni car parked:      0 parked care:    100 uni vacated space:    500 vacated space:    100
# clock time:   10 car entered: 0 car exited: 0 uni car parked:      0 parked care:    100 uni vacated space:    500 vacated space:    100
# clock time:   10 car entered: 1 car exited: 0 uni car parked:    100 parked care:    100 uni vacated space:    400 vacated space:    100
# clock time:   11 car entered: 0 car exited: 0 uni car parked:    100 parked care:    100 uni vacated space:    400 vacated space:    100
# clock time:   12 car entered: 0 car exited: 0 uni car parked:    100 parked care:    100 uni vacated space:    400 vacated space:    100
# clock time:   13 car entered: 0 car exited: 1 uni car parked:    100 parked care:      0 uni vacated space:    350 vacated space:    250
# clock time:   13 car entered: 0 car exited: 0 uni car parked:    100 parked care:      0 uni vacated space:    350 vacated space:    250
# clock time:   14 car entered: 0 car exited: 0 uni car parked:    100 parked care:      0 uni vacated space:    300 vacated space:    300
# clock time:   15 car entered: 0 car exited: 0 uni car parked:    100 parked care:      0 uni vacated space:    250 vacated space:    350
# clock time:   15 car entered: 1 car exited: 0 uni car parked:    200 parked care:      0 uni vacated space:    150 vacated space:    350
# clock time:   15 car entered: 0 car exited: 0 uni car parked:    200 parked care:      0 uni vacated space:    150 vacated space:    350
# clock time:   16 car entered: 0 car exited: 0 uni car parked:    200 parked care:      0 uni vacated space:      0 vacated space:    500
# clock time:   17 car entered: 0 car exited: 0 uni car parked:    200 parked care:      0 uni vacated space:      0 vacated space:    500
# clock time:   17 car entered: 1 car exited: 0 uni car parked:    200 parked care:      0 uni vacated space:      0 vacated space:    500
# clock time:   17 car entered: 0 car exited: 0 uni car parked:    200 parked care:      0 uni vacated space:      0 vacated space:    500
# clock time:   18 car entered: 0 car exited: 0 uni car parked:    200 parked care:      0 uni vacated space:      0 vacated space:    500
# clock time:   19 car entered: 0 car exited: 0 uni car parked:    200 parked care:      0 uni vacated space:      0 vacated space:    500
# clock time:   19 car entered: 1 car exited: 0 uni car parked:    200 parked care:    100 uni vacated space:      0 vacated space:    400
# clock time:   19 car entered: 0 car exited: 0 uni car parked:    200 parked care:    100 uni vacated space:      0 vacated space:    400
# clock time:   20 car entered: 0 car exited: 0 uni car parked:    200 parked care:    100 uni vacated space:      0 vacated space:    400
```

```
# clock time:   19 car entered: 0 car exited: 0 uni car parked:   200 parked care:     0 uni vacated space:     0 vacated space:   500
# clock time:   19 car entered: 1 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:     0 vacated space:   400
# clock time:   19 car entered: 0 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:     0 vacated space:   400
# clock time:   20 car entered: 0 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:     0 vacated space:   400
# clock time:   21 car entered: 0 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:     0 vacated space:   400
# clock time:   21 car entered: 1 car exited: 0 uni car parked:   200 parked care:   200 uni vacated space:     0 vacated space:   300
# clock time:   21 car entered: 0 car exited: 0 uni car parked:   200 parked care:   200 uni vacated space:     0 vacated space:   300
# clock time:   22 car entered: 0 car exited: 0 uni car parked:   200 parked care:   200 uni vacated space:     0 vacated space:   300
# clock time:   23 car entered: 0 car exited: 0 uni car parked:   200 parked care:   200 uni vacated space:     0 vacated space:   300
# clock time:   23 car entered: 0 car exited: 1 uni car parked:   200 parked care:   100 uni vacated space:     0 vacated space:   400
# clock time:   23 car entered: 0 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:     0 vacated space:   400
# clock time:    0 car entered: 0 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:  -200 vacated space:  -100
# clock time:    0 car entered: 1 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:  -200 vacated space:  -100
# clock time:    0 car entered: 0 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:  -200 vacated space:  -100
# clock time:    1 car entered: 0 car exited: 0 uni car parked:   200 parked care:   100 uni vacated space:  -200 vacated space:  -100
# clock time:    1 car entered: 0 car exited: 1 uni car parked:   100 parked care:   100 uni vacated space:  -100 vacated space:  -100
# clock time:    1 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:  -100 vacated space:  -100
# clock time:    2 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:  -100 vacated space:  -100
# clock time:    3 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:  -100 vacated space:  -100
# clock time:    4 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:  -100 vacated space:  -100
# clock time:    5 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:  -100 vacated space:  -100
# clock time:    6 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:  -100 vacated space:  -100
# clock time:    7 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:  -100 vacated space:  -100
# clock time:    8 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:   400 vacated space:   100
# clock time:    9 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:   400 vacated space:   100
# clock time:   10 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:   400 vacated space:   100
# clock time:   11 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:   400 vacated space:   100
# clock time:   12 car entered: 0 car exited: 0 uni car parked:   100 parked care:   100 uni vacated space:   400 vacated space:   100
```

در شکل زیر نیز نحوه عملکرد ماژول در حالت معمولی را میتوانید مشاهده کنید.

```
# clock time:    x car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:   200 vacated space:   500
# clock time:    0 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    0 car entered: 0 car exited: 1 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    0 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    1 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    2 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    3 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    4 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    5 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    6 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    7 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:     0 vacated space:     0
# clock time:    8 car entered: 0 car exited: 0 uni car parked:     0 parked care:     0 uni vacated space:   500 vacated space:   200
# clock time:    8 car entered: 1 car exited: 0 uni car parked:     0 parked care:     1 uni vacated space:   500 vacated space:   199
# clock time:    8 car entered: 0 car exited: 0 uni car parked:     0 parked care:     1 uni vacated space:   500 vacated space:   199
# clock time:    9 car entered: 0 car exited: 0 uni car parked:     0 parked care:     1 uni vacated space:   500 vacated space:   199
# clock time:   10 car entered: 0 car exited: 0 uni car parked:     0 parked care:     1 uni vacated space:   500 vacated space:   199
# clock time:   10 car entered: 1 car exited: 0 uni car parked:     1 parked care:     1 uni vacated space:   499 vacated space:   199
# clock time:   11 car entered: 0 car exited: 0 uni car parked:     1 parked care:     1 uni vacated space:   499 vacated space:   199
# clock time:   12 car entered: 0 car exited: 0 uni car parked:     1 parked care:     1 uni vacated space:   499 vacated space:   199
# clock time:   13 car entered: 0 car exited: 1 uni car parked:     1 parked care:     0 uni vacated space:   449 vacated space:   250
# clock time:   13 car entered: 0 car exited: 0 uni car parked:     1 parked care:     0 uni vacated space:   449 vacated space:   250
# clock time:   14 car entered: 0 car exited: 0 uni car parked:     1 parked care:     0 uni vacated space:   399 vacated space:   300
# clock time:   15 car entered: 0 car exited: 0 uni car parked:     1 parked care:     0 uni vacated space:   349 vacated space:   350
# clock time:   15 car entered: 1 car exited: 0 uni car parked:     2 parked care:     0 uni vacated space:   348 vacated space:   350
# clock time:   15 car entered: 0 car exited: 0 uni car parked:     2 parked care:     0 uni vacated space:   348 vacated space:   350
# clock time:   16 car entered: 0 car exited: 0 uni car parked:     2 parked care:     0 uni vacated space:   198 vacated space:   500
# clock time:   17 car entered: 0 car exited: 0 uni car parked:     2 parked care:     0 uni vacated space:   198 vacated space:   500
# clock time:   17 car entered: 1 car exited: 0 uni car parked:     3 parked care:     0 uni vacated space:   197 vacated space:   500
# clock time:   17 car entered: 0 car exited: 0 uni car parked:     3 parked care:     0 uni vacated space:   197 vacated space:   500
# clock time:   18 car entered: 0 car exited: 0 uni car parked:     3 parked care:     0 uni vacated space:   197 vacated space:   500
# clock time:   19 car entered: 0 car exited: 0 uni car parked:     3 parked care:     0 uni vacated space:   197 vacated space:   500
# clock time:   19 car entered: 1 car exited: 0 uni car parked:     3 parked care:     1 uni vacated space:   197 vacated space:   499
# clock time:   19 car entered: 0 car exited: 0 uni car parked:     3 parked care:     1 uni vacated space:   197 vacated space:   499
# clock time:   20 car entered: 0 car exited: 0 uni car parked:     3 parked care:     1 uni vacated space:   197 vacated space:   499
```

ب) در این قسمت با استفاده از نرم‌افزار Quartus مدار را سنتز میکنیم. که نتایج آن در شکل‌های زیر قابل مشاهده است.

	Fmax	Restricted Fmax	Clock Name	Note
1	91.39 MHz	91.39 MHz	car_entered	
2	387.45 MHz	260.01 MHz	clk	limit due to minimum period restriction (max I/O toggle rate)

در شکل بالا بیشترین مقدار فرکانس مدار قابل مشاهده است ($387.45M_{Hz}$ در حالت بدون محدودیت I/O و $260.01M_{Hz}$ با محدودیت I/O)

عامل محدود کننده فرکانس تأخیر مسیر بحرانی است.

-1.581	Clock:clock|clock_time[9]	Clock:clock|counter[3]	clk	clk	1.000	-0.600	1.894
-1.581	Clock:clock|clock_time[9]	Clock:clock|counter[4]	clk	clk	1.000	-0.600	1.894
-1.581	Clock:clock|clock_time[9]	Clock:clock|counter[5]	clk	clk	1.000	-0.600	1.894
-1.581	Clock:clock|clock_time[9]	Clock:clock|counter[8]	clk	clk	1.000	-0.600	1.894
-1.473	Clock:clock|clock_time[9]	Clock:clock|counter[3]	clk	clk	1.000	-0.600	1.786
-1.473	Clock:clock|clock_time[9]	Clock:clock|counter[4]	clk	clk	1.000	-0.600	1.786
-1.473	Clock:clock|clock_time[9]	Clock:clock|counter[5]	clk	clk	1.000	-0.600	1.786
-1.473	Clock:clock|clock_time[9]	Clock:clock|counter[8]	clk	clk	1.000	-0.600	1.786
-1.468	Clock:clock|clock_time[8]	Clock:clock|counter[3]	clk	clk	1.000	-0.600	1.781
-1.468	Clock:clock|clock_time[8]	Clock:clock|counter[4]	clk	clk	1.000	-0.600	1.781
-1.468	Clock:clock|clock_time[8]	Clock:clock|counter[5]	clk	clk	1.000	-0.600	1.781
-1.468	Clock:clock|clock_time[8]	Clock:clock|counter[8]	clk	clk	1.000	-0.600	1.781
-1.454	Clock:clock|clock_time[9]	Clock:clock|counter[11]	clk	clk	1.000	-0.473	1.894
-1.454	Clock:clock|clock_time[9]	Clock:clock|counter[1]	clk	clk	1.000	-0.473	1.894
-1.454	Clock:clock|clock_time[9]	Clock:clock|counter[6]	clk	clk	1.000	-0.473	1.894
-1.454	Clock:clock|clock_time[9]	Clock:clock|counter[7]	clk	clk	1.000	-0.473	1.894
-1.454	Clock:clock|clock_time[9]	Clock:clock|counter[9]	clk	clk	1.000	-0.473	1.894
-1.454	Clock:clock|clock_time[9]	Clock:clock|counter[10]	clk	clk	1.000	-0.473	1.894
-1.454	Clock:clock|clock_time[9]	Clock:clock|counter[2]	clk	clk	1.000	-0.473	1.894
-1.454	Clock:clock|clock_time[9]	Clock:clock|counter[12]	clk	clk	1.000	-0.473	1.894
-1.434	Clock:clock|clock_time[9]	Clock:clock|clock_time[3]	clk	clk	1.000	-0.151	2.196
-1.433	Clock:clock|clock_time[2]	Clock:clock|counter[3]	clk	clk	1.000	-0.600	1.746
-1.433	Clock:clock|clock_time[2]	Clock:clock|counter[4]	clk	clk	1.000	-0.600	1.746
-1.433	Clock:clock|clock_time[2]	Clock:clock|counter[5]	clk	clk	1.000	-0.600	1.746
-1.433	Clock:clock|clock_time[2]	Clock:clock|counter[8]	clk	clk	1.000	-0.600	1.746
-1.420	Clock:clock|clock_time[2]	Clock:clock|counter[3]	clk	clk	1.000	-0.600	1.733
-1.420	Clock:clock|clock_time[2]	Clock:clock|counter[4]	clk	clk	1.000	-0.600	1.733
-1.420	Clock:clock|clock_time[2]	Clock:clock|counter[5]	clk	clk	1.000	-0.600	1.733
-1.420	Clock:clock|clock_time[2]	Clock:clock|counter[8]	clk	clk	1.000	-0.600	1.733
-1.393	Clock:clock|clock_time[9]	Clock:clock|clock_time[3]	clk	clk	1.000	-0.151	2.155
-1.375	Clock:clock|clock_time[7]	Clock:clock|counter[3]	clk	clk	1.000	-0.600	1.688
-1.375	Clock:clock|clock_time[7]	Clock:clock|counter[4]	clk	clk	1.000	-0.600	1.688
-1.375	Clock:clock|clock_time[7]	Clock:clock|counter[5]	clk	clk	1.000	-0.600	1.688
-1.375	Clock:clock|clock_time[7]	Clock:clock|counter[8]	clk	clk	1.000	-0.600	1.688
-1.355	Clock:clock|clock_time[4]	Clock:clock|counter[3]	clk	clk	1.000	-0.600	1.668
-1.355	Clock:clock|clock_time[4]	Clock:clock|counter[4]	clk	clk	1.000	-0.600	1.668
-1.355	Clock:clock|clock_time[4]	Clock:clock|counter[5]	clk	clk	1.000	-0.600	1.668
-1.355	Clock:clock|clock_time[4]	Clock:clock|counter[8]	clk	clk	1.000	-0.600	1.668

شکل بالا نیز که نشان دهنده مسیرهای با بیشترین تأخیر است با معکوس کردن بیشترین تأخیر آن با تقریب خوبی به فرکانس نشان داده شده میرسیم.

$$1.894 + 0.473 = 2.367 = T \Rightarrow \frac{1}{T} \approx 0.422 \approx 0.38745 \pm 0.050$$