Timing Pulses

- Important element of laboratory electronics

- Pulses can control logical sequences with precise timing.
  - If your detector “sees” a charged particle or a photon, you might want to signal a clock to store the time at which it occurred.
  - You could use the event to generate a standard pulse so that your clock always responds in the same way.

- Alternatively, you might need to reset your electronics after the event
  - Clearly you want the reset pulse to arrive as soon as possible after the data has been processed
  - This requires a precision time delay generator
A simple type of delay generator…

1. A **D-type flip-flop** receives a clock edge and goes from low to high at the output
   - The output charges up an **RC circuit** after going high.
   - The charged capacitor also serves as the **clear input** to the D flip-flop.

4. **So, that after a fixed time (roughly RC)** the flip-flop resets back to its initial state.

5. The net result is a single pulse that has a duration (or **pulse width**) determined by the combination of the resistor & capacitor

This is called a **monostable multivibrator** or **one-shot**.
One-shot: D-type flip-flop

**Diagram:**
- D-clock
- Q-output
- S or PRE
- R or CLR
- Input
- +5V
- Pulse Input

**Function Table:**

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE</td>
<td>CLR</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
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<tr>
<td>L</td>
<td>L</td>
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<td>H</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

[Texas Instruments 74LS74 flip-flop datasheet]
One-shot: D-type flip-flop

- **D** - clock
- **Q** - output
- **Q** - output
- **Input**
- **S or PRE**
- **R or CLR**
- **Pulse Input**

**FUNCTION TABLE**

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<td>L</td>
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<td>H</td>
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<tr>
<td>H</td>
<td>H</td>
</tr>
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</table>

[Texas Instruments 74LS74 flip-flop datasheet]
One-shot: D-type flip-flop

- **Input**: S or PRE
- **Output**: Q, \(\overline{Q}\)
- **Clock**: R or CLR
- **Pulse Input**

**Function Table**

<table>
<thead>
<tr>
<th>PRE</th>
<th>CLR</th>
<th>CLK</th>
<th>D</th>
<th>Q</th>
<th>(\overline{Q})</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>(\uparrow)</td>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>(\uparrow)</td>
<td>L</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
<td>X</td>
<td>L</td>
<td>(Q_0)</td>
<td>(\overline{Q_0})</td>
</tr>
</tbody>
</table>

[Texas Instruments 74LS74 flip-flop datasheet]
One-shot: 74LS123

Characteristics:

- 2 clock inputs triggered by either a rising edge or a falling edge.
- 2 outputs (Q & \overline{Q}).
- A reset or clear input, instantly sets the output to a standard condition regardless of the current state or clock level.
- Can be confused a little by pulses in quick succession.

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
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<tbody>
<tr>
<td>CLEAR</td>
<td>A</td>
</tr>
<tr>
<td>L</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>H</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>↓</td>
</tr>
<tr>
<td>↑</td>
<td>L</td>
</tr>
</tbody>
</table>

\[ P_{in} \]

\[ P_{out} \]

\[ t_W \]

\[ RETRIGGER \]
One-shot: 74LS123

Characteristics:

- 2 clock inputs triggered by either a rising edge or a falling edge.
- 2 outputs ($Q$ & $\bar{Q}$).
- A reset or clear input, instantly sets the output to a standard condition regardless of the current state or clock level.
- Can be confused a little by pulses in quick succession.

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<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLEAR</td>
<td>A B</td>
</tr>
<tr>
<td>L</td>
<td>X X</td>
</tr>
<tr>
<td>X</td>
<td>H X</td>
</tr>
<tr>
<td>X</td>
<td>X L</td>
</tr>
<tr>
<td>H</td>
<td>L ↑</td>
</tr>
<tr>
<td>H</td>
<td>↓ H</td>
</tr>
<tr>
<td>↑</td>
<td>L H</td>
</tr>
</tbody>
</table>
A single one-shot will produce a variable delay pulse.

2 one-shots can be combined to produce a pulse of variable duration/width produced at variable delay after a trigger.

→ Pulse Delay Generator ... very useful in a research lab.
A single one-shot will produce a variable delay pulse.

2 one-shots can be combined to produce a pulse of variable duration/width produced at variable delay after a trigger.

Pulse Delay Generator … very useful in a research lab.
Setting the Pulse Width

\[ t_W = K R_{\text{ext}} C_{\text{ext}} \]

with

- \( R_{\text{ext}} = 260 \, \text{k}\Omega \)
- \( R_{\text{ext}} = 160 \, \text{k}\Omega \)
- \( R_{\text{ext}} = 80 \, \text{k}\Omega \)
- \( R_{\text{ext}} = 40 \, \text{k}\Omega \)
- \( R_{\text{ext}} = 20 \, \text{k}\Omega \)
- \( R_{\text{ext}} = 10 \, \text{k}\Omega \)
- \( R_{\text{ext}} = 5 \, \text{k}\Omega \)

(K IS INDEPENDENT OF R)
The Problem with One-Shots

1. One-shots are very useful in a research laboratory as pulse delay generators.

2. **One-shots should be avoided in regular circuitry, because**
   
   → They are useful in asynchronous circuits for avoiding glitches and signal races ...

   → It's very easy to put them all over your asynchronous circuit with all the pulse timing set just right. It is very hard to figure out how the circuit works just by looking at it (or even a circuit diagram).

   → The pulse width depends on temperature (R, C, and chip).

   → The pulse width depends on supply voltage.
Pulse Width vs. Temperature

VARIATION IN OUTPUT PULSE DURATION
VS
FREE-AIR TEMPERATURE

Δtw(out) – Variation in Output Pulse Duration

VCC = 5 V
C_{ext} = 60 \text{ pF}
R_{T} = 10 \text{ K ohms}

'LS122

\text{See Note 14}

\text{tw(out)} \approx 370 \text{ ns at } T_A = 25^\circ \text{C}

T_A – FREE-AIR TEMPERATURE – ^\circ \text{C}
Pulse Width vs. Supply Voltage

VARIATION IN OUTPUT PULSE DURATION
vs
SUPPLY VOLTAGE

$C_{ext} = 60 \text{ pF}$
$R_{ext} = 10 \text{ K ohms}$
$T_A = 25^\circ \text{ C}$

$\Delta t_{w(out)}$ Variation in Output Pulse Duration

$t_{w(out)} \approx 370 \text{ ns}$
at $V_{CC} = 5 \text{ V}$

$V_{CC} - \text{ Supply Voltage} - V$

$4.5 \quad 4.75 \quad 5 \quad 5.25 \quad 5.5$
• Frequency dividers.

2. Counters in Verilog.

3. Ripple counter (next week).

4. Synchronous counter (next week).
JK-type flip-flops are used in counters.
T-type flip-flops are used in counters.

**JK Logic table**

<table>
<thead>
<tr>
<th>J</th>
<th>K</th>
<th>$Q_{n+1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>$Q_n$</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>$\overline{Q}_n$</td>
</tr>
</tbody>
</table>

**T Logic table** (clock falling edge)

<table>
<thead>
<tr>
<th>T</th>
<th>$Q_{n+1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$Q_n$</td>
</tr>
<tr>
<td>1</td>
<td>$\overline{Q}_n$</td>
</tr>
</tbody>
</table>
Counters in Verilog are easy → just use always (synchronous).

→ and a self-referential “add 1” assignment.

```verilog
module counter_v3(input1, output1);    // module for an 8-bit synchronous counter
    input input1;                      // 1-bit input
    output reg [7:0] output1;         // 8-bit output register
    always@(posedge input1)          // synchronous loop, clocked on input1 rising edge
        begin
            output1 <= output1 + 1;    // self-referential add+1 assignment.
            // output1 = output1 + 8'b00000001; could have used this instruction line instead.
        end
endmodule
```
module counter_v3(input1,output1); // module for an 8-bit synchronous counter
   input input1; // 1-bit input
   output reg [7:0] output1; // 8-bit output register
   initial // this block initializes the output register
      begin // to zero.
         output1 = 8'b00000000;
      end
   always@ (posedge input1) // synchronous loop, clocked on input1 rising edge
      begin
         output1 <= output1 + 1; // self-referential add+1 assignment.
         // output1 = output1 + 8'b00000001; could have used this instruction line instead.
      end
endmodule
Initializing a register

This section initializes the register to zero. ("initial" is only for simulation!)

```verilog
module counter_v3(input1, output1);
  input input1;
  output reg [7:0] output1;

  initial
    begin
      output1 = 8'b00000000;
    end

  always@(posedge input1)
    begin
      output1 <= output1 + 1;
    // output1 = output1 + 8'b00000001; could have used this instruction line instead.
    end
endmodule
```
module counter_v3(input1, output1, output2); // module for an 8-bit synchronous counter
input input1; // 1-bit input
output reg [7:0] output1; // 8-bit output register
output reg [2:0] output2; // 3-bit output register

initial // this block initializes the output registers
begin // to zero.
output1 = 8'b00000000;
output2 = 3'b000;
end

always @(posedge input1) // synchronous loop, clocked on input1 rising edge
begin
  output1 <= output1 + 1; // self-referential add+1 assignment.
  // output1 = output1 + 8'b00000001; could have used this instruction line instead.

  if (output1 <= 8'b11100111)
    begin
      output2 = 3'b000; // output2 stays at zero for output1 <= 231.
    end
  else
    begin
      output2 = output2 + 1; // output2 starts counting for output1 > 231.
    end
end
endmodule
module counter_v3(input1, output1, output2); // module for an 8-bit synchronous counter
    input input1; // 1-bit input
    output reg [7:0] output1; // 8-bit output register
    output reg [2:0] output2; // 3-bit output register
    reg [1:0] temp; // "temp" variable 2-bit register.

initial // this block initializes the output registers
    begin
    output1 = 8'b00000000; // to zero.
    output2 = 3'b000;
    temp = 2'b00;
    end

always@(posedge input1) // synchronous loop, clocked on input1 rising edge
    begin
    output1 <= output1 + 1; // self-referential add+1 assignment.
    temp <= temp + 1; // temp is used as counter.
    end
if (output1 <= 8'b11100111)
    begin
    output2 = 3'b000 + temp; // output2 counts continuously to 2 for output1 <= 231.
    end
else
    begin
    output2 = output2 + 1; // output2 starts counting for output1 > 231.
    end
endmodule

Recommendation: check the Technology Map Viewer after compiling.
module Input_to_Output_converter(input_register1, input_register2, input_register3, output_register1, output_register2, output_register3);

input [1:0] input_register1;
input [1:0] input_register2;
input [1:0] input_register3;
output reg [7:0] output_register1;
output reg [7:0] output_register2;
output reg [7:0] output_register3;

always

begin

    // 1st output
    output_register1 = output_8bit(input_register1);

    // 2nd output
    output_register2 = output_8bit(input_register2);

    // 3rd output
    output_register3 = output_8bit(input_register3);

end
// This function defines the output codes given a 2-bit input
function [7:0] output_8bit;
    input [1:0] input_number_2bit;
    begin
        output_8bit = 7'd1111111;
        if (input_number_2bit == 4'b00)
            output_8bit = 7'd1111111;
        if (input_number_2bit == 4'b01)
            output_8bit = 7'd1001011;
        if (input_number_2bit == 4'b10)
            output_8bit = 7'd1000000;
        if (input_number_2bit == 4'b11)
            output_8bit = 7'd0000000;
    end
endfunction
endmodule