Lab 5 Preparation

Lab 5 Components

- Part I: Create a counter
  - Use the synchronized counter circuit described in lectures.
- Part II: Slow down the clock
  - Use the counter and the on-board clock to create a slower clock.
- Part III: Morse code decoder
  - Decode incoming Morse Code signals!
  - Uses code from Part II ☺

Design Guidelines

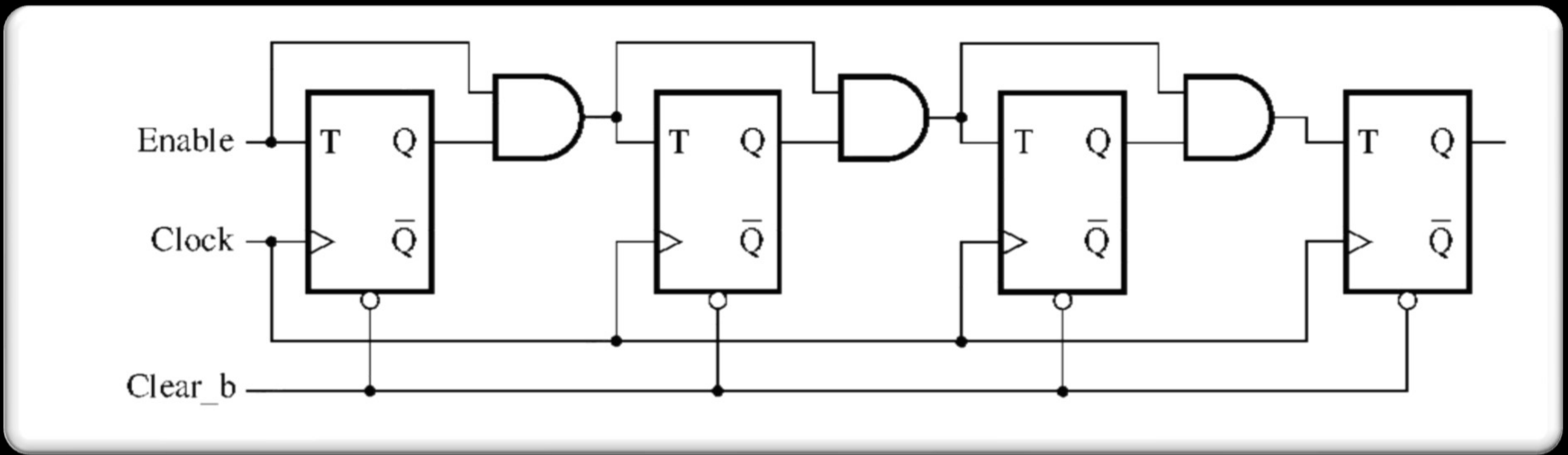
- A note on `always` blocks:
  - Combinational Circuits use blocking assignment statements (the = operator)
  - Sequential Circuits use non-blocking assignment statements (the <= operator)

```
always @(*) begin
  q = d;
end
```

```
always @(posedge clock) begin
  q <= d;
end
```

- Do NOT mix assignment types in the same always block!

Part I – 4-bit Counter



- Diagram shows a 4-bit synchronous counter, made with T-flip-flops
  - The T flip-flops here have an active-low asynchronous reset (`Clear_b`).
- Need to use hierarchical design to make an 8-bit counter.

Part I (continued)

- Prelab parts:
  - Draw and label 8-bit counter schematic.
  - Write Verilog code for flip-flop and counter
    - Don’t use “`tff`” as a module name.
  - Simulate your counter to confirm correctness.
  - Augment Verilog code with input/output layer.
  - Analyze your design!
    - Logic Utilization (in ALMs)
    - Maximum Frequency (F_{max})
    - Netlist Viewer

Tools in Quartus

Part II: More Counters

- Main goal:
  - Display incrementing digits on a hex display at different speeds (e.g., once per second, twice per second, etc)
- How do we do this?
  1. Need access to a clock signal.
  2. Need to adjust this clock signal to the right speed.
  3. Need to increment a counter at this adjusted clock speed.

Part II (continued)

- Step #1: Finding a clock signal
  - DE1-SoC has a 50MHz clock
    - Pin `CLOCK_50`
  - Hertz (Hz) => number of cycles per second
    - 50MHz => How many clock cycles per second?
    - Would you be able to see that?

Part II (continued)

- Step #2: Slowing down the clock.
  - Load a counter with a countdown value (through a parallel load) and produce an enable signal when the countdown reaches zero.

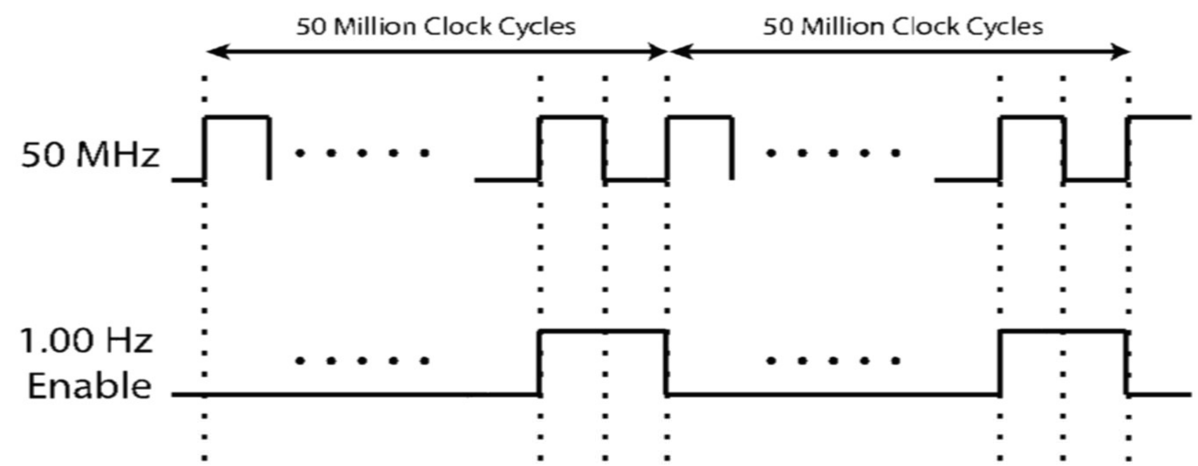


Figure 3: Timing diagram for a 1 Hz enable signal

- Another module will use this enable signal to determine whether it will change on the next clock pulse or not.

Part II: An Aside

- Here is an alternate implementation of counters:

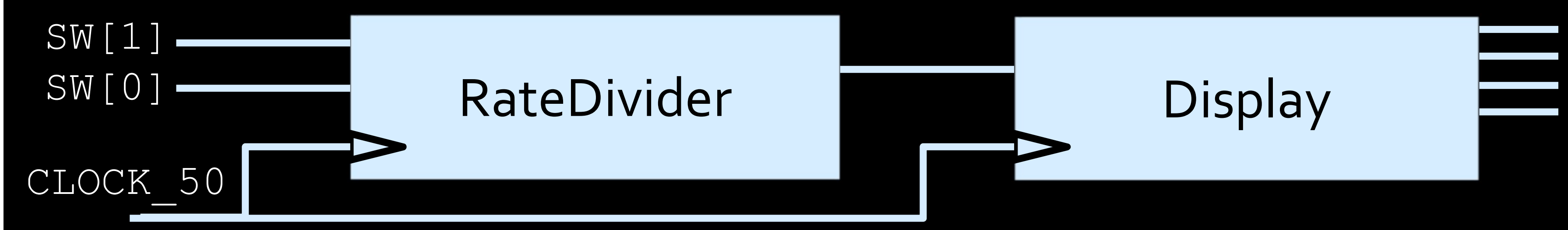
```
reg [3:0] q;

always @(posedge clock)
begin
   if (Clear_b == 1'b0)
      q <= 0;
  else
      q <= q + 1;
end
```

- Things to note:
  - Non-blocking assignment (sequential circuit)
    - Means that assignments are implemented in parallel, not series.
  - Synchronous active-low `Clear` signal

Part II (cont'd)

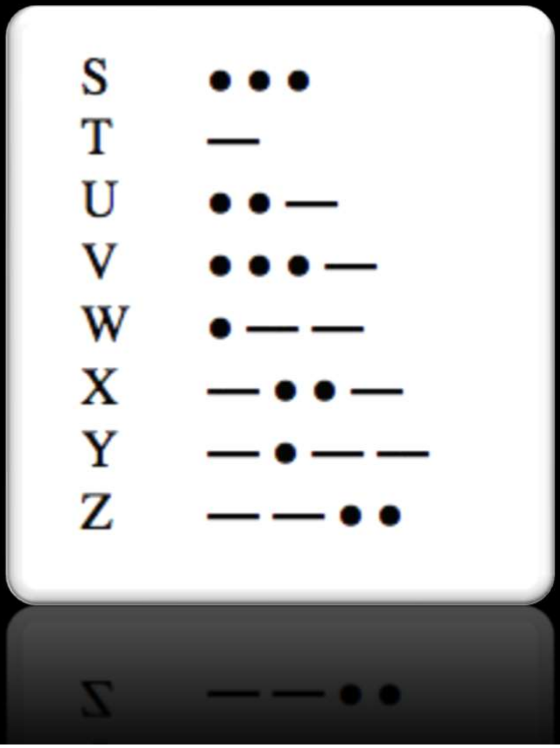
- Step #3: Updating the display counter.
  - You will need 2 counters for this:
    - A `RateDivider` counter (from previous step)
    - A `Display` counter (that feeds to the 7-segment decoder)
    - Both will be synchronized to the same 50MHz clock.



  - Recall the purpose of an `Enable` signal in a counter.
    - How often do you want the `Display` counter to increment?
    - `SW[1]` and `SW[0]` will control that rate.

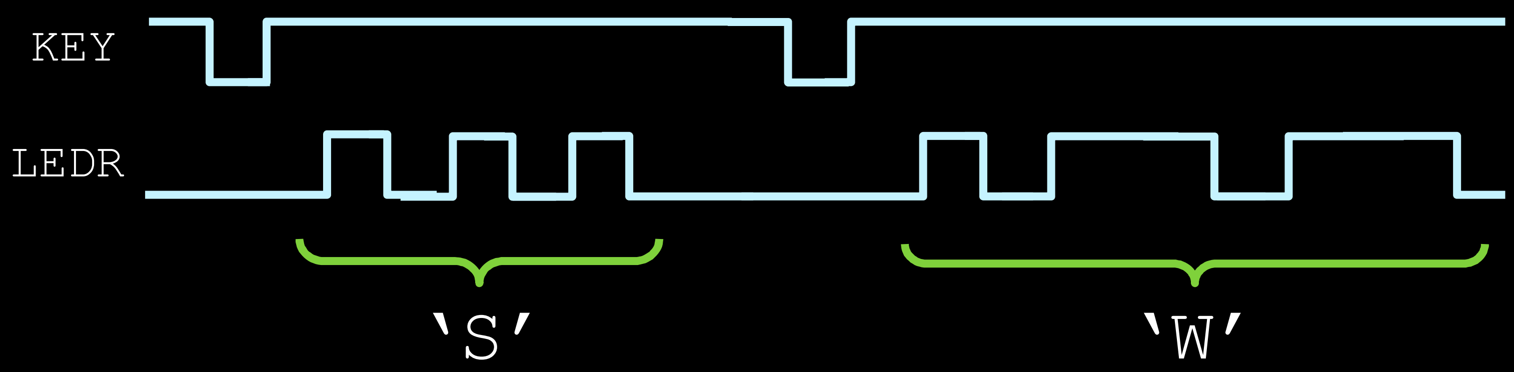
Part III – Morse Code

- Morse Code: “A method of transmitting text information as a series of on-off tones, lights, or clicks that can be directly understood by a skilled listener or observer without special equipment. “



Part III (continued)

- You will be transmitting individual letters using a single red LED
  - Dot => 0.5 seconds LED on
  - Dash => 3 * 0.5 seconds LED on
  - Pause (between symbols or in the end of transmission) => 0.5 seconds LED off



Part III (continued)

- How do you do this?
  - Step #1: Create a Lookup Table (LUT)
    - Switch values as input, binary representation of the corresponding Morse code letter to transmit as output.
  - Step #2: Create a shift register
    - When the `KEY` input sends a signal, load a shift register with the current value from the lookup table.
    - Shift out a bit on each clock cycle and send it to the LED.

Part III (continued)

- How to decide on the binary representation in the LUT
  - Each bit corresponds to 0.5 seconds of light (`1`) or no light (`0`).
  - <u>Example:</u> • – ("dot dash")
    - Multiple ways this could be represented:
      - `101110`
      - `10001110`
      - `10111000`
      - `1001110000000`
  - All of these look like "dot dash" in the end, so it's up to you (or up to the longest letter you encode)
- How do you make the shift register move bits out every half a second?
  - Rate divider from Part II ☺