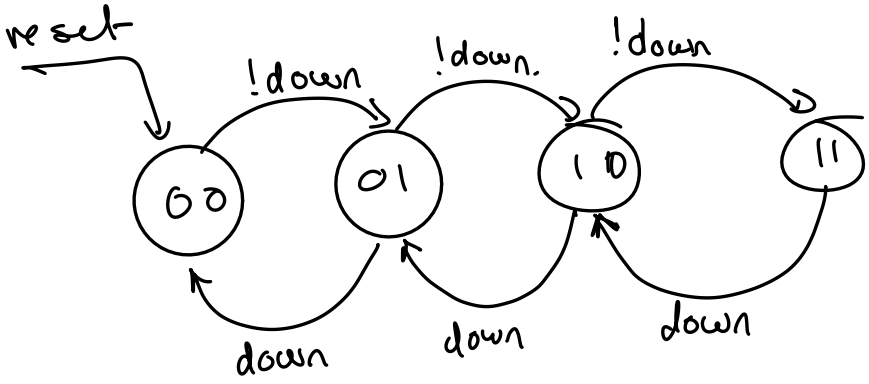
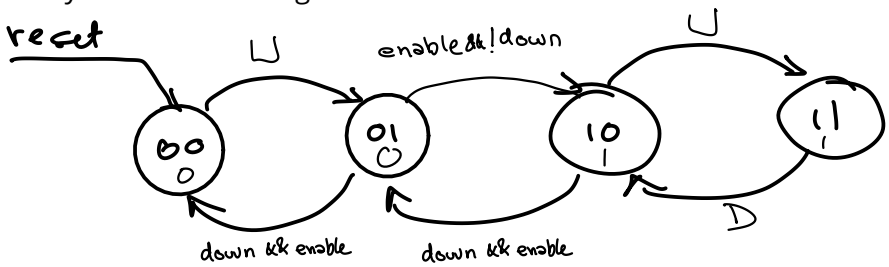
State Machines

Exercise 1: Modify the diagram so the state machine counts to 11 and stops. Add a "down" input that cause the values to count down.



Exercise 2: Show the state transition diagram and table for a 2-bit counter with reset, enable, and down inputs. Reset should have priority. Write the Verilog.

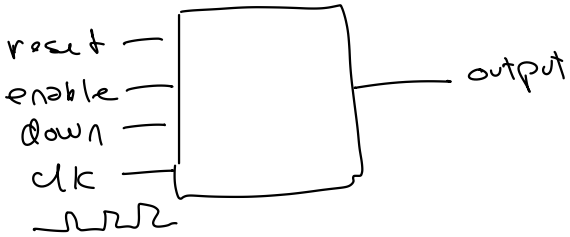


D ≡ down && enable

U ≡ !down && enable

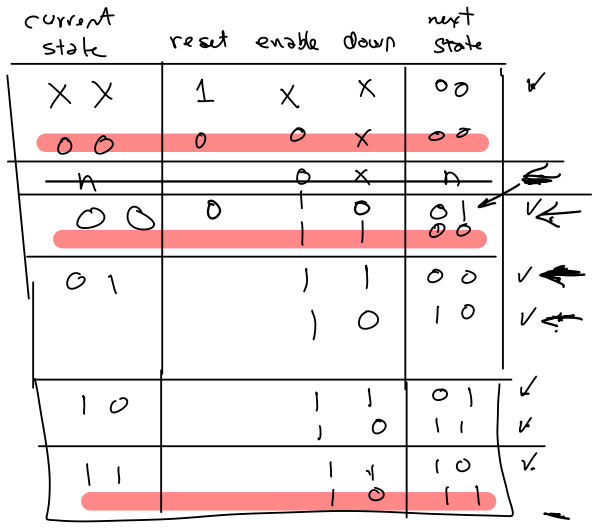
current state	reset	enable	down	next state	
X X	1	X	X	00	✓
0 0	0	0	X	00	
n		0	X	n	
0 0		1		01	✓
		1	1	00	
0 1		1	1	00	✓
		1	0	10	✓
1 0		1	1	01	✓
		1	0	11	✓
1 1		1	1	10	✓
		1	0	11	

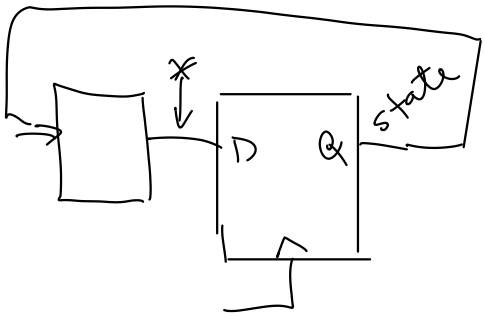
state	output
0 0	0
0 1	0
1 0	1
1 1	1



always_ff @(posedge clk)

state <= reset ?





always_ff @(...)
state <= *;

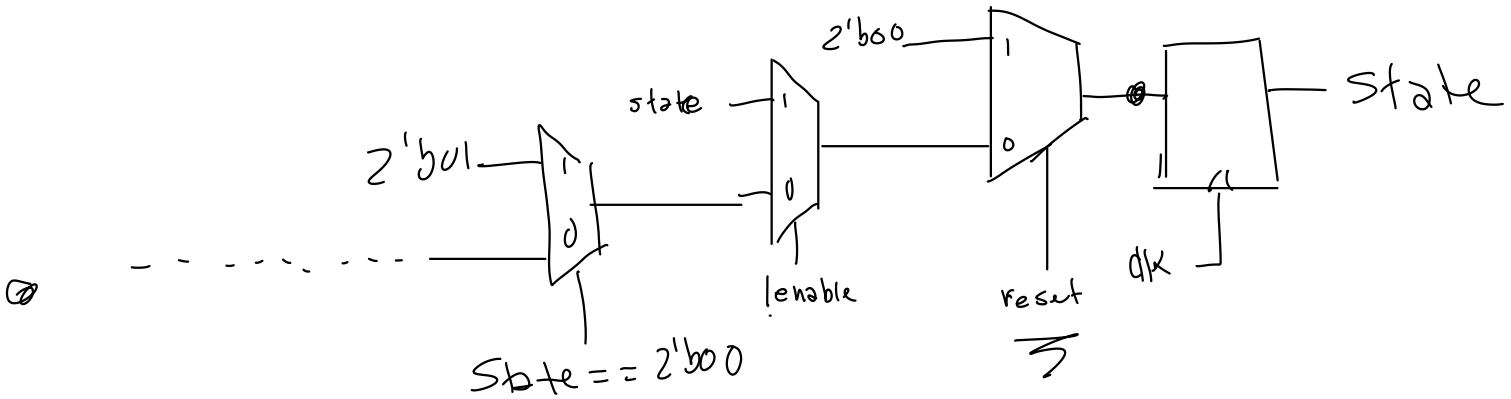
always_ff @(posedge clk)
state <= reset ? 2'b00 :
!enable ? state :
state == 2'b00 && !down ? 2'b01 :
state == 2'b01 && down ? 2'b00 :
state == 2'b01 && !down ? 2'b10 :
state == 2'b10 && down ? 2'b01 :
state == 2'b10 && !down ? 2'b11 :
state == 2'b11 && down ? 2'b10 :
state;

could combine

assign output = state == 2'b10 || state == 2'b11 ? 1'b1 : 1'b0;

clk = state == 2'b10 || state == 2'b11;

Exercise 2b (3): Draw the schematic:



Exercise 3: What value of N would result in a 20 ms delay if the clock frequency is 50 MHz? How many bits are needed for this timer's register?

$N = ?$ $\quad NT = 20 \times 10^{-3}$ $\quad f = 50 \times 10^6$

$$T = \frac{1}{f} = \frac{1}{50 \times 10^6} = \frac{1}{.05 \times 10^9} = 20 \times 10^{-9} = 20\text{ns}.$$

$$N = \frac{NT}{T} = \frac{20 \times 10^{-3}}{20 \times 10^{-9}} = 1 \times 10^6$$

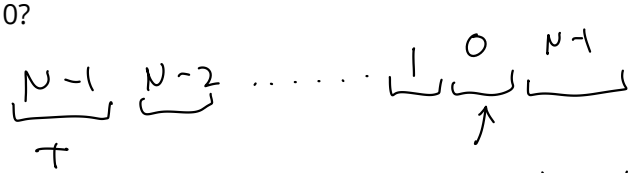
$$2^{2 \times 10} = 1024 \cdot 1024 = 2^{20} \approx 10^6$$

$$\log_2 2^n \geq \log_2 10^6$$

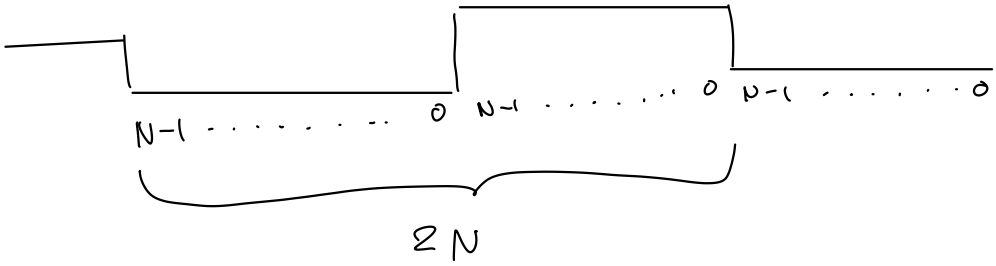
$$n \geq 19.9\ldots$$

use 20 bits

Exercise 4: Assume the timer above is reset to $N-1$ each time it reaches 0. For how long is the register value 0? What are the period and frequency of a signal that is inverted each time the count reaches 0?

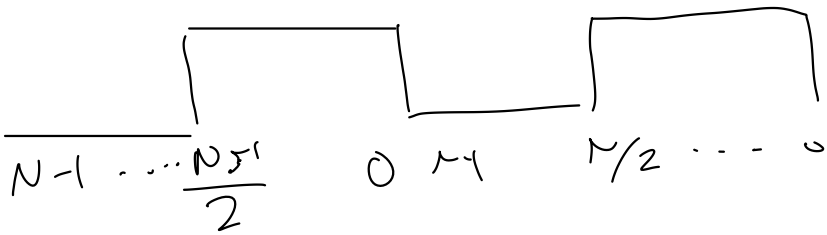


has any value for 1 clock period (T).

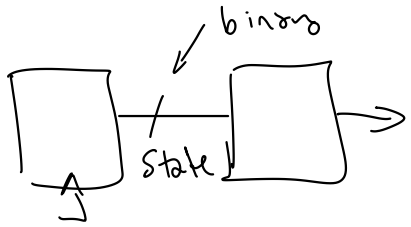


period = $2NT$ freq = $\frac{1}{2NT}$

period = NT $f = \frac{1}{NT}$



Exercise 5: How many bits are need to be to detect a state when a binary encoding is used? With a one-hot encoding?



— binary encoding: need all bits
— one-hot: only one bit.

Exercise 6: If we used 8-bits of state information, how many states could be represented? What if we used 8 bits of state but used a "one-hot" encoding?

w/ binary encoding we can have $0 \ldots 2^8 = 0 \ldots 255$
256 different states.

w/ one-hot 1000 0000, 0100 0000, ... 0000 0001