California Polytechnic State University Pomona

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

Dgtl Circuit Dsgn Verilog Lab

ECE 3300L Section E01

Report # 5

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Presented to

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DESIGN OVERVIEW:

We built a tiny digital odometer that goes from 00 to 99, can run forwards or backwards, and lets us choose the speed with five slide-switches. The board gives us a 100 MHz crystal clock, way too fast to watch. So we built a clock divider which turns that into a 32-bit binary counter that's basically counting nanoseconds. Then we built a 32x1 mux which grabs one bit from that counter to control speed. In the top module we detect the rising edge of that bit and call it a tick. Every tick means "advance the ones digit by one." We have two counters doing the math and the seg7_scan.v flicks the right hand two digits of the seven-segment display on and off really fast so our eyes think both are lit at the same time.

MODULE HIERARCHY:

- bcd_updown_top.v
    - tick_generator
    - bcd_digit
    - Dual_bcd_ counter
    - sevenseg_driver

Top Module:

Explanation:

This is the master coordinator that stitches everything together and connects to the board pins named in the .xdc file.

- BTN0 (active-low) resets the whole thing to 00.
- A tiny edge detector flips the dir flag each time you press BTN1.
- Instantiates tick_generator so SW[4:0] pick the speed.
- Feeds the tick and dir into dual_bcd_counter to get units and tens.
- Pipes those digits into sevenseg_driver; only the two right-most 7-seg digits are used, the others stay dark.
- Mirrors the units nibble on LED3-0, tens on LED7-4, and shows the raw switch setting on LED12-8 so you can see the speed tap you chose.

Tick_generator Module:

Explanation:
This module is our speed control. It keeps a 32-bit counter that races along at the board's 100 MHz clock. Because each bit in a binary counter flips at half the rate of the bit to its right, we can pick any bit to get a slower rhythm. The five slide-switches (SW[4:0]) decide which bit we tap: switch = 0 chooses the slowest bit (bit 31), switch = 31 grabs the fastest bit (bit 0). We then watch that chosen bit and spit out a one clock cycle "tick" pulse every time it rises, that tick drives the rest of the design.

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bcd_digit Module:

Explanation:
It stores a single decimal digit (0-9). When the enable input goes high for one clock, the wheel moves exactly one step. If dir is 1 we count up; if dir is 0 we count down. When we wrap from 9→0 (going up) or 0→9 (going down), the module raises rollout for one cycle. Reset (rst_n) instantly forces the number to 0. Internally the code just checks the state and decides what the next value and rollout should be.

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dual_bcd_counter Module:

Explanation:
This is simply two bcd_digit's put together for direction purposes.

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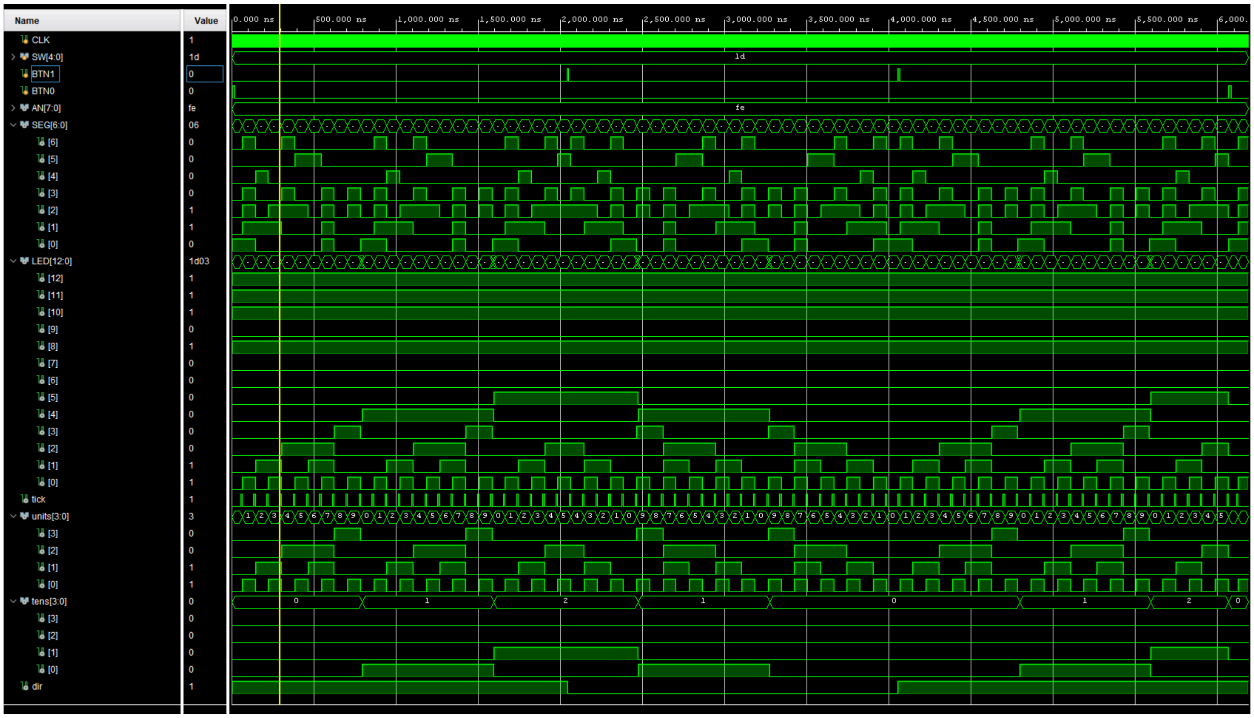
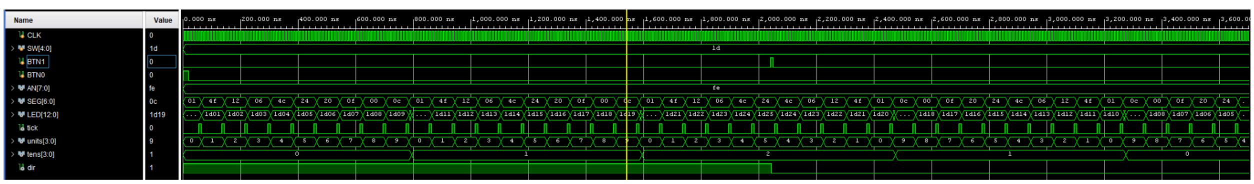
sevenseg_driver Module:

Explanation:
FPGAs save pins by time-sharing the 7-segment display. This driver flicks between the units and tens digits so quickly your eyes blend them together. A tiny 16-bit prescaler inside produces a toggle around 1.5 kHz per digit. On one phase we light the right-hand digit with the units pattern; on the other phase we light the left-hand digit with the tens pattern. A case lookup (the seg_lut function) converts each 4-bit BCD nibble into the seven LED segments, and we remember the Nexys A7 segments are active-low (0 means "on").

XDC Snippet:

TEST BENCH:





```
Starting bcd_updown_top_tb...
Time=0 | BTN0=1, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 0 | LED=1d00
Time=20000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 0 | LED=1d00

Counting up...
Time=55000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 0 | LED=1d00
Time=65000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 1 | LED=1d01
Time=135000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 1 | LED=1d01
Time=145000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 2 | LED=1d02
Time=215000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 2 | LED=1d02
Time=225000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 3 | LED=1d03
Time=295000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 3 | LED=1d03
Time=305000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 4 | LED=1d04
Time=375000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 4 | LED=1d04
Time=385000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 5 | LED=1d05
Time=455000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 5 | LED=1d05
Time=465000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 6 | LED=1d06
Time=535000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 6 | LED=1d06
Time=545000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 7 | LED=1d07
Time=615000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 7 | LED=1d07
Time=625000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 8 | LED=1d08
Time=695000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 8 | LED=1d08
Time=705000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 9 | LED=1d09
Time=775000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 0, units= 9 | LED=1d09
Time=785000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 0, units= 0 | LED=1d00
Time=795000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 0 | LED=1d10
Time=855000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 0 | LED=1d10
Time=865000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 1 | LED=1d11
Time=935000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 1 | LED=1d11
Time=945000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 2 | LED=1d12
Time=1015000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 2 | LED=1d12
Time=1025000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 3 | LED=1d13
Time=1095000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 3 | LED=1d13
Time=1105000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 4 | LED=1d14
Time=1175000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 4 | LED=1d14
Time=1185000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 5 | LED=1d15
Time=1255000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 5 | LED=1d15
Time=1265000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 6 | LED=1d16
Time=1335000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 6 | LED=1d16
Time=1345000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 7 | LED=1d17
Time=1415000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 7 | LED=1d17
Time=1425000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 8 | LED=1d18
Time=1495000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 8 | LED=1d18
Time=1505000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 9 | LED=1d19
Time=1575000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 1, units= 9 | LED=1d19
Time=1585000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 1, units= 0 | LED=1d10
Time=1595000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 2, units= 0 | LED=1d20
Time=1655000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 2, units= 0 | LED=1d20
Time=1665000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 2, units= 1 | LED=1d21
Time=1735000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 2, units= 1 | LED=1d21
Time=1745000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 2, units= 2 | LED=1d22
Time=1815000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 2, units= 2 | LED=1d22
Time=1825000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 2, units= 3 | LED=1d23
Time=1895000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 2, units= 3 | LED=1d23
Time=1905000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 2, units= 4 | LED=1d24
Time=1975000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=1 | tens= 2, units= 4 | LED=1d24
Time=1985000 | BTN0=0, BTN1=0, SW=29 | dir=1, tick=0 | tens= 2, units= 5 | LED=1d25
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Changing direction to count down...
Time=2040000 | BTN0=0, BTN1=1, SW=29 | dir=1, tick=0 | tens= 2, units= 5 | LED=1d25
Time=2045000 | BTN0=0, BTN1=1, SW=29 | dir=0, tick=0 | tens= 2, units= 5 | LED=1d25
Time=2050000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 2, units= 5 | LED=1d25
Time=2055000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 2, units= 5 | LED=1d25
Time=2065000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 2, units= 4 | LED=1d24
Time=2135000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 2, units= 4 | LED=1d24
Time=2145000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 2, units= 3 | LED=1d23
Time=2215000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 2, units= 3 | LED=1d23
Time=2225000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 2, units= 2 | LED=1d22
Time=2295000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 2, units= 2 | LED=1d22
Time=2305000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 2, units= 1 | LED=1d21
Time=2375000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 2, units= 1 | LED=1d21
Time=2385000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 2, units= 0 | LED=1d20
Time=2455000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 2, units= 0 | LED=1d20
Time=2465000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 2, units= 9 | LED=1d29
Time=2475000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 9 | LED=1d19
Time=2535000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 9 | LED=1d19
Time=2545000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 8 | LED=1d18
Time=2615000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 8 | LED=1d18
Time=2625000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 7 | LED=1d17
Time=2695000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 7 | LED=1d17
Time=2705000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 6 | LED=1d16
Time=2775000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 6 | LED=1d16
Time=2785000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 5 | LED=1d15
Time=2855000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 5 | LED=1d15
Time=2865000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 4 | LED=1d14
Time=2935000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 4 | LED=1d14
Time=2945000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 3 | LED=1d13
Time=3015000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 3 | LED=1d13
Time=3025000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 2 | LED=1d12
Time=3095000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 2 | LED=1d12
Time=3105000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 1 | LED=1d11
Time=3175000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 1 | LED=1d11
Time=3185000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 0 | LED=1d10
Time=3255000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 1, units= 0 | LED=1d10
Time=3265000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 1, units= 9 | LED=1d19
Time=3275000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 9 | LED=1d09
Time=3335000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 9 | LED=1d09
Time=3345000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 8 | LED=1d08
Time=3415000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 8 | LED=1d08
Time=3425000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 7 | LED=1d07
Time=3495000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 7 | LED=1d07
Time=3505000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 6 | LED=1d06
Time=3575000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 6 | LED=1d06
Time=3585000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 5 | LED=1d05
Time=3655000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 5 | LED=1d05
Time=3665000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 4 | LED=1d04
Time=3735000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 4 | LED=1d04
Time=3745000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 3 | LED=1d03
Time=3815000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 3 | LED=1d03
Time=3825000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 2 | LED=1d02
Time=3895000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 2 | LED=1d02
Time=3905000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 1 | LED=1d01
Time=3975000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=1 | tens= 0, units= 1 | LED=1d01
Time=3985000 | BTN0=0, BTN1=0, SW=29 | dir=0, tick=0 | tens= 0, units= 0 | LED=1d00
```
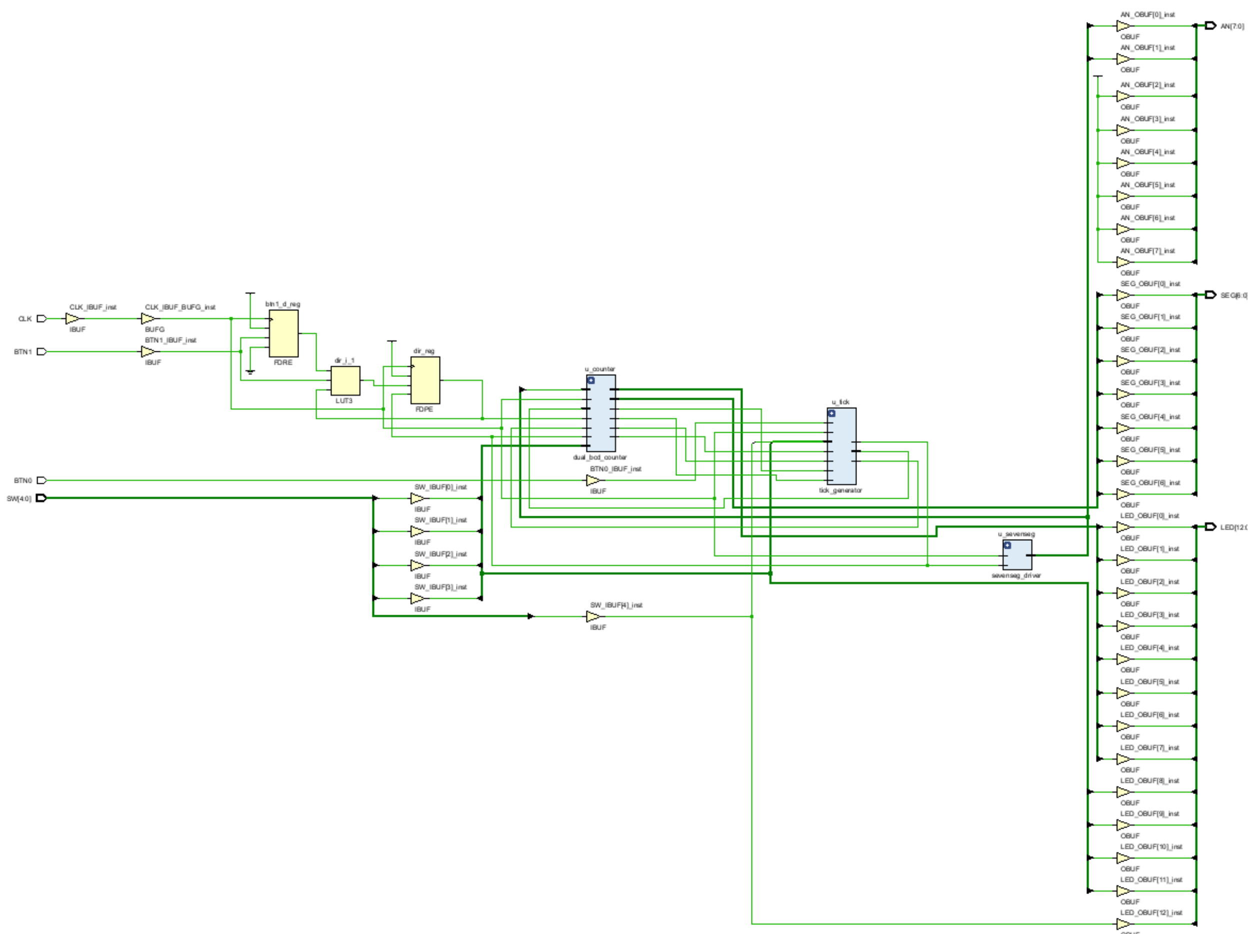
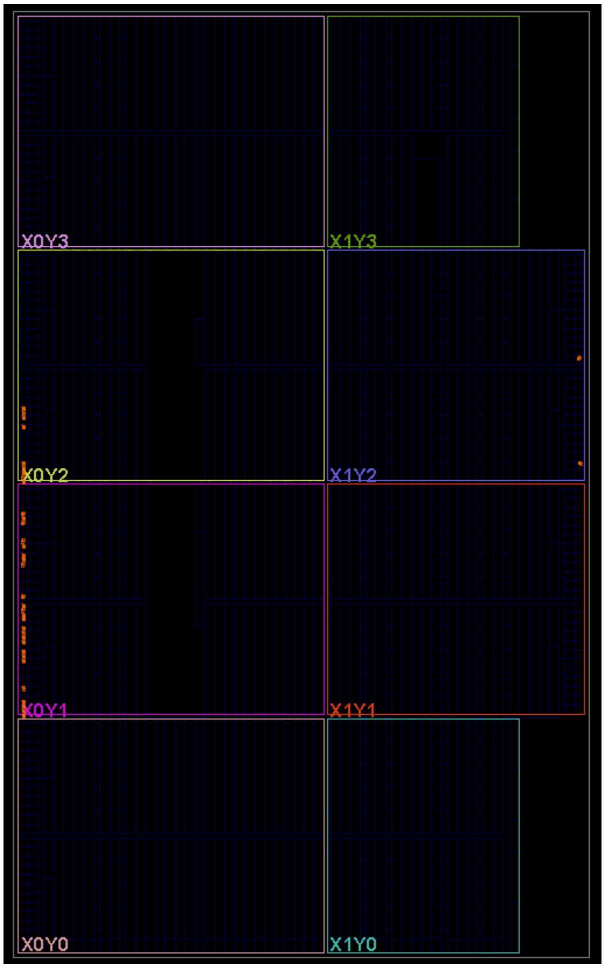

Explanation:

The bcd_updown_top_tb testbench is designed to simulate a user interacting with the BCD counter. It begins by generating a 100 MHz clock and then starts a sequence of timed events to test the module's functionality. First, it triggers a system wide reset by activating BTN0, ensuring the counter starts in a known state (zero, set to count up). After releasing the reset, the simulation allows the counter to increment for a period. It then tests the direction-change logic by simulating a press of BTN1, which causes the dir signal to flip and the counter to begin decrementing. After another delay, it simulates a second press of BTN1 to verify that the counter can switch back to counting up. Finally, it asserts the reset again to confirm that the circuit can be returned to its initial state at any time.

SCHEMATIC:



SYNTHESIS SCHEMATIC:



RESOURCE UTILIZATION:

Site Type	Used	Fixed	Prohibited	Available	Util%
Slice LUTs*	35	0	0	63400	0.06
LUT as Logic	35	0	0	63400	0.06
LUT as Memory	0	0	0	19000	0.00
Slice Registers	60	0	0	126800	0.05
Register as Flip Flop	60	0	0	126800	0.05
Register as Latch	0	0	0	126800	0.00
F7 Muxes	1	0	0	31700	<0.01
F8 Muxes	0	0	0	15850	0.00

CONTRIBUTIONS:

Arvin Ghaloosian (50%)

- Wrote and verified simulation code
- Handled on-board testing and debugging
- Implemented LED mirroring and switch logic

Vittorio Huizar (50%)

- Designed and verified tick_generator
- Edited constraint file for correct pin mapping
- Verified and edited up/down logic

REFLECTION:

Splitting the job into tiny files (divider, mux, digit, scanner) made each one easy to write and unit-test before wiring them together. We also never realised you can make a clean 1 cycle pulse just by remembering the previous state of a signal which was super handy for tick generation. Picking the prescaler bit felt like guessing at first, now we understand that every left shift doubles the period. One thing we could have implemented to make the design better is button debouncing to ensure the direction change doesn't press multiple times.

Link to demo video:

https://youtube.com/watch?v=_J6T0dxOkh8
