ECE 274 - Digital Logic

Lecture 14

- Lecture 14 – RTL Design
  - Four Step RTL Design Method

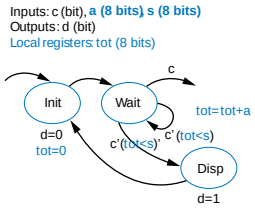
RTL Design Method

TABLE 5.1 RTL design method.

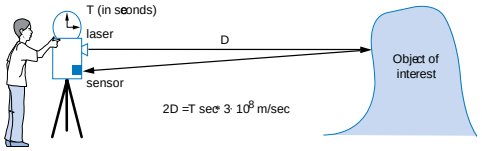
	Step	Description
Step 1	*Capture a high-level state machine*	Describe the system's desired behavior as a high-level state machine. The state machine consists of states and transitions. The state machine is "high-level" because the transition conditions and the state actions are more than just Boolean operations on bit inputs and outputs.
Step 2	*Create a datapath*	Create a datapath to carry out the data operations of the high-level state machine.
Step 3	*Connect the datapath to a controller*	Connect the datapath to a controller block. Connect external Boolean inputs and outputs to the controller block.
Step 4	*Derive the controller's FSM*	Convert the high-level state machine to a finite-state machine (FSM) for the controller, by replacing data operations with setting and reading of control signals to and from the datapath.

Step 1: Create a High-Level State Machine

- Let's consider each step of the RTL design process in more detail
- Step 1
  - Soda dispenser example
  - Not an FSM because:
    - Multi-bit (data) inputs *a* and *s*
    - Local register *tot*
    - Data operations *tot=0, tot<s, tot=tot+a.*
  - Useful high-level state machine:
    - Data types beyond just bits
    - Local registers
    - Arithmetic equations/expressions



Step 1 Example: Laser-Based Distance Measurer

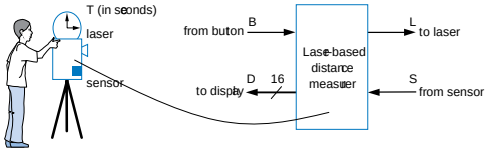


- Example of how to create a high-level state machine to describe desired processor behavior
- Laser-based distance measurement – pulse laser, measure time T to sense reflection
  - Laser light travels at speed of light, $3*10^8$ m/sec
  - Distance is thus D = T sec * $3*10^8$ m/sec / 2

Step 1 Example: Laser-Based Distance Measurer

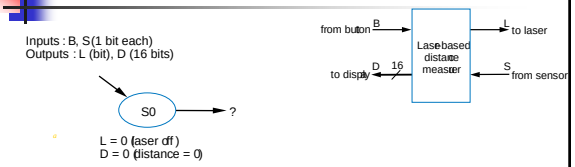
- Laser-based Distance Measurer
  - Used in adaptive cruise control systems for automobiles
  - Maintain particular "safe" distance between car in front
    - May need to decrease cruise speed
    - Need to measure the distance to the car in front

Step 1 Example: Laser-Based Distance Measurer



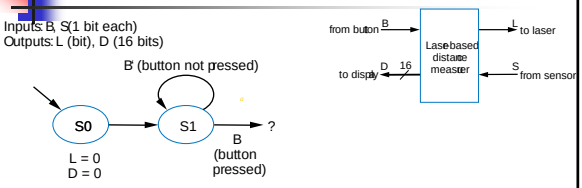
- Inputs/outputs
  - B: bit input, from button to begin measurement
  - L: bit output, activates laser
  - S: bit input, senses laser reflection
  - L: 16-bit output, displays computed distance

Step 1 Example: Laser-Based Distance Measurer



- Step 1: Create high-level state machine
- Begin by declaring inputs and outputs
- Create initial state, name it S0
  - Initialize laser to off (L=0)
  - Initialize displayed distance to 0 (D=0)

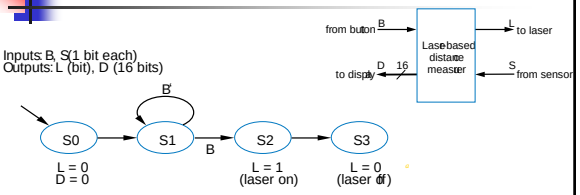
Step 1 Example: Laser-Based Distance Measurer



- Add another state, call S1, that waits for a button press
  - B' – stay in S1, keep waiting
  - B – go to a new state S2

Q: What should S2 do? A: Turn on the laser

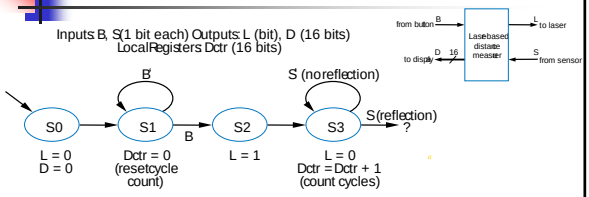
Step 1 Example: Laser-Based Distance Measurer



- Add a state S2 that turns on the laser (L=1)
- Then turn off laser (L=0) in a state S3

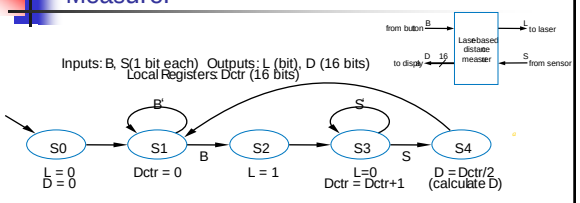
Q: What do next? A: Start timer, wait to sense reflection

Step 1 Example: Laser-Based Distance Measurer



- Stay in S3 until sense reflection (S)
- To measure time, count cycles for which we are in S3
  - To count, declare local register Dctr
  - Increment Dctr each cycle in S3
  - Initialize Dctr to 0 in S1. S2 would have been O.K. too

Step 1 Example: Laser-Based Distance Measurer



- Once reflection detected (S), go to new state S4
  - Calculate distance
  - Assuming clock frequency is $3x10^8$, Dctr holds number of meters, so D=Dctr/2
- After S4, go back to S1 to wait for button again

Step 2: Create a Datapath

- Datapath must
  - Implement data storage
  - Implement data computations
- Look at high-level state machine, do three substeps
  - (a) Make data inputs/outputs be datapath inputs/outputs
  - (b) Instantiate declared registers into the datapath (also instantiate a register for each data output)
  - (c) Examine every state and transition, and instantiate datapath components and connections to implement any data computations

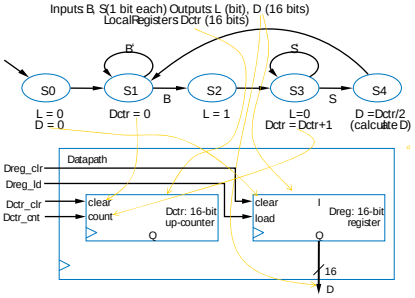
Instantiate: to introduce a new component into a design.

Step 2 Example: Laser-Based Distance Measurer

(a) Make data inputs/outputs be datapath inputs/outputs

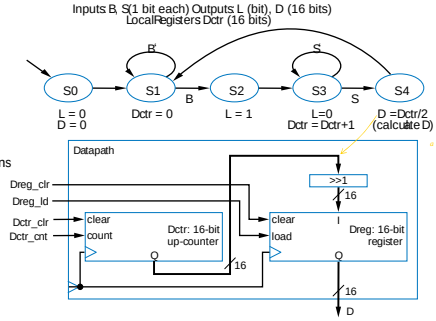
(b) Instantiate declared registers into the datapath (also instantiate a register for each data output)

(c) Examine every state and transition, and instantiate datapath components and connections to implement any data computations

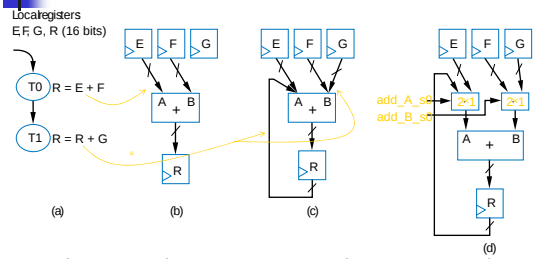


Step 2 Example: Laser-Based Distance Measurer

(c) (continued) Examine every state and transition, and instantiate datapath components and connections to implement any data computations

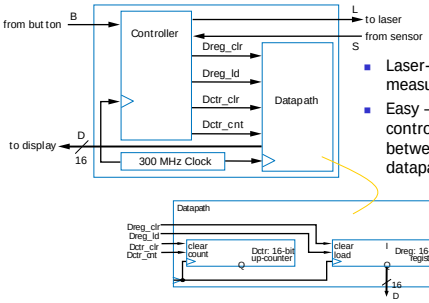


Step 2 Example Showing Mux Use



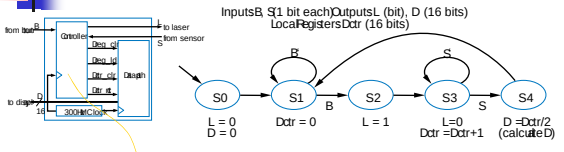
- Introduce mux when one component input can come from more than one source

Step 3: Connecting the Datapath to a Controller

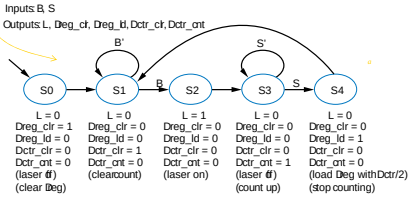


- Laser-based distance measurer example
- Easy – just connect all control signals between controller and datapath

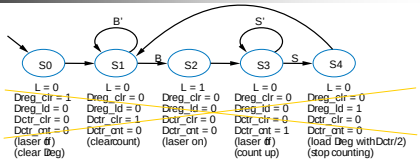
Step 4: Deriving the Controller's FSM



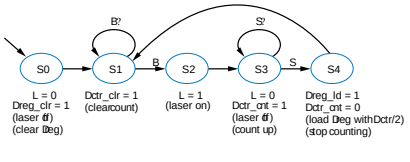
- FSM has same structure as high-level state machine
  - Inputs/outputs all bits now
  - Replace data operations by bit operations using datapath



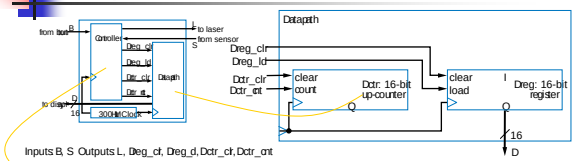
Step 4: Deriving the Controller's FSM



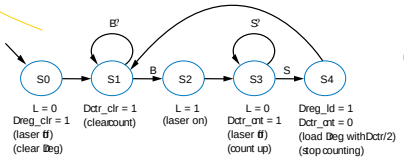
- Using shorthand of outputs not assigned implicitly assigned 0



Step 4



Inputs B, S Outputs L, Dreg_clr, Dreg_ld, Dctr_clr, Dctr_cnt



- Implement FSM as state register and logic (Ch3) to complete the design

Design Challenge

- Design Challenge
  - Design a 4-bit up-counter using the RTL design process.
    - Design a high-level state machine for a 4-bit up-counter with count control input *cnt*, count clear input *clr*, and a terminal count output *tc*.
    - Use the RTL design method to convert the high-level state machine to a controller and a datapath.
    - Use a register and adder in the datapath, not a counter itself.
    - Design the datapath and controller to structure.
  - Due:
    - Next Lecture (Monday, October 17)
  - Extra Credit *(Homework)*
    - 2 points