University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

ECE 120: Introduction to Computing

Machine Models

FSM Outputs May or May Not Depend Directly on Inputs

As mentioned previously, for our class,
FSM outputs depend only on state,
not on FSM inputs.

Historically, such an FSM was called
a **Moore** machine.

The more general model,
- in which outputs may also depend on inputs,
- was called a **Mealy** machine.

More General Model Always Used in Practice

In practice,
- designers always use Mealy machines,
- so **FSM outputs may depend directly on inputs**.

If a designer wants
- an output to be independent of inputs,
- the designer simply designs the FSM to meet that requirement.

So the names are just of historical interest.

Inputs May Allow Us to Design a Smaller FSM

Why use the general model?

Inputs carry information.

We can sometimes build a smaller FSM
if we make use of that information.

More General Model Can Introduce Timing Issues

Why do we use the simpler model in ECE120?

If outputs depend directly on inputs,

output timing also depends on input timing,

so we lose the benefit of treating time as a discrete value (an integer).

An Example Illustrates the Tradeoffs

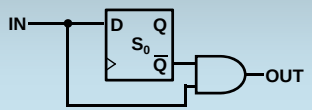
Let's use an example to illustrate these tradeoffs.

Say that we want to recognize the sequence **01** in a serial input **B**.

Whenever **B** is **0** in one cycle and **1** in the next cycle, we set the output **Z** equal to **1**.

Mealy Machine for 01 Sequence Recognizer

Consider the design to the right.



What is the next-state equation ($S_0^+ = ?$)?

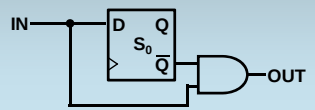
$S_0^+ = IN$ — Current IN is 1.

And the output equation?

$OUT = IN \cdot S_0'$ — Last IN was 0.

Transition Diagrams Look Different for Mealy Machines

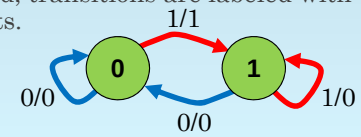
Now let's draw the state diagram.



We have two states.

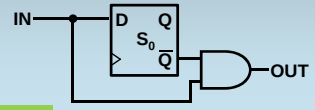
Outputs depend on inputs, so

- states cannot be labeled with outputs.
- Instead, transitions are labeled with outputs.

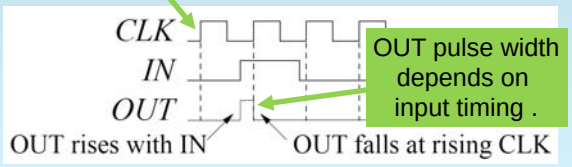


A Timing Diagram Reveals the Timing Issues

Recall that
OUT = IN · S_0'



S_0 is 0 after this edge.



We Can Usually Ignore the Narrow Output Problem

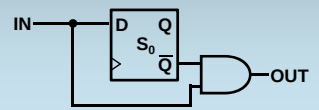
Usually, narrow output pulses don't matter.

If inputs
- come from flip-flops on the same clock,
- changes arrive early enough (but may limit clock speed).

We may have problems **if inputs are external or if outputs are used externally** (not on the same clock).

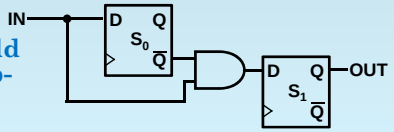
How Can We Fix the Narrow Pulse Problem?

What if we need a wider output pulse?



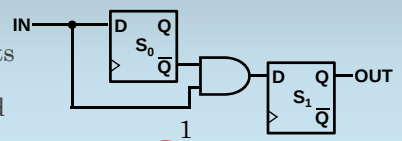
Do we have to redesign the system entirely? (as a Moore machine)

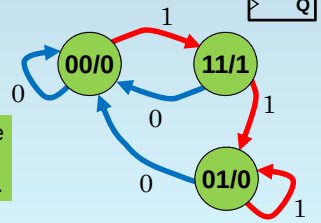
No! Just add another flip-flop.



The New Flip-Flop Splits One State into Two

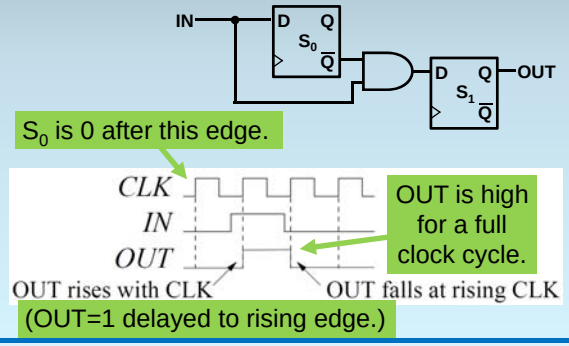
The new flip-flop splits the "1" state into "11" and "01" states.





Note: the 01 state is not reachable from other states.

OUT is Delayed but High for a Full Cycle with Moore



Summary of the Two Models

Moore: outputs depend only on state, not on inputs

Mealy: outputs can also depend on inputs

Mealy is used in practice.
- Can reduce size of design, but
- may create thin output pulses.

Solving these problems is easy:
add flip-flops to make a Moore design.

