

# Lecture 7.5

## Flowcharts, Algorithmic State Machines

*Cris Ababei*

*Dept. of Electrical and Computer Engineering*



MARQUETTE  
UNIVERSITY

**BE THE DIFFERENCE.**

1

1

## Outline

- **Flowcharts**
- Algorithmic State Machines

2

2

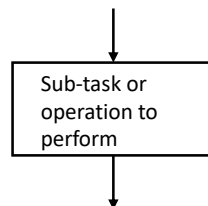
# Flowcharts

- **Flowcharts**: a tool for precise description of algorithms/procedures.
- Specify tasks to perform and their sequencing.
- Main symbols:
  1. **Operation box**: contains tasks/operations to perform.
  2. **Decision box**: alternative actions based on decisions to be taken.
  3. **Arrows**: indicate appropriate sequencing.

3

## 1. Operation Box

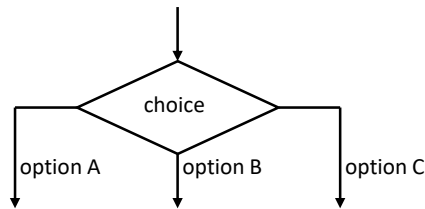
- An **operation box** is rectangular in shape
- Used to specify one or more subtasks to be performed. It has at most one entry point and one exit point.



4

## 2. Decision Box

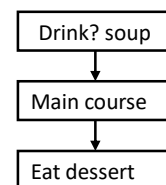
- A **decision box** is diamond-shaped. It has one entry point and multiple (but mutually exclusive) exit points.



5

## 3. Arrows

- **Sequential flow**: simplest type of sequencing; tasks are done in sequential order.
- An example: Eating a 3-course meal.
- Boxes are connected by lines with arrows. Lines without arrows are sometimes used. In the absence of **arrows**, the default flow direction is top-to-bottom and left-to-right.



6

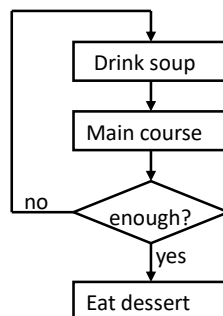
# Flowcharts

- **Iteration**: some tasks/operations may be repeatedly/iteratively done.
- This is achieved through the **loop-back** in the flowchart.
- Decision box is used to determine when to terminate the loop.

7

# Flowcharts

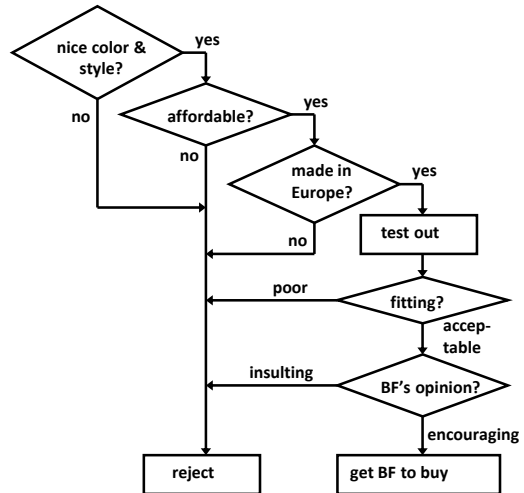
- An example: meal in a different (buffet?) style.



8

# Flowcharts

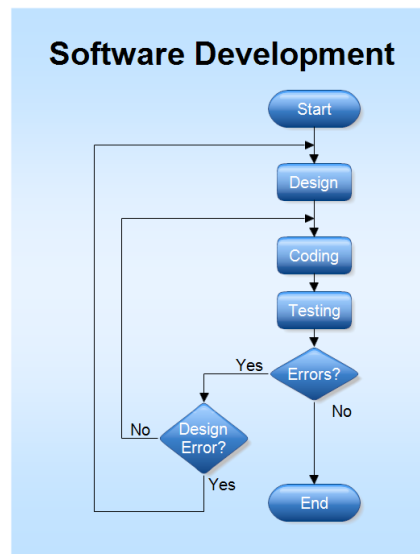
- Flowcharts can be used to implement complex decisions 😊.



9

# Flowcharts

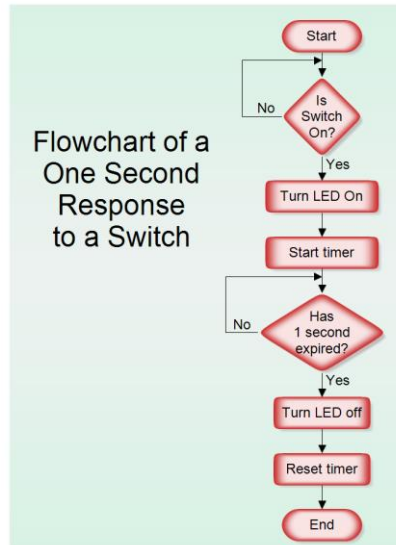
- You can use flowcharts even for the software development process itself!



10

## Flowcharts – more examples

- LED on for 1 second as response to a switch event.

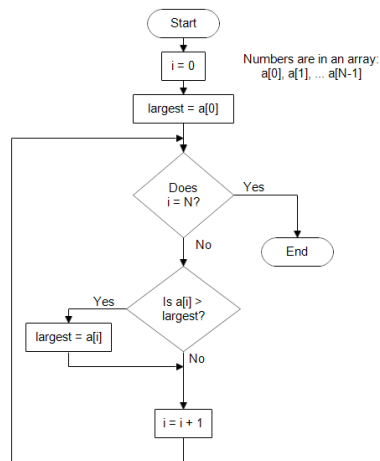


11

## Flowcharts – more examples

- Sometimes Start and End are included inside ovals too.

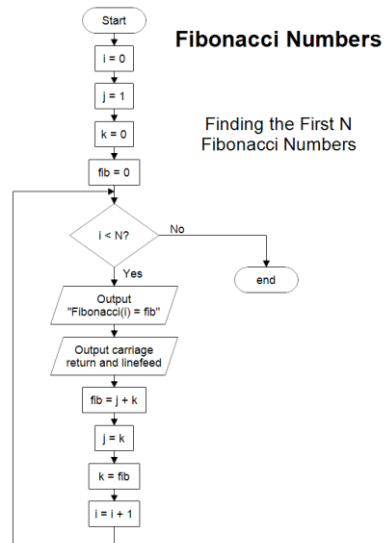
### Finding the Largest Number in a List of Numbers



12

## Flowcharts – more examples

- Additional blocks aside from rectangles, diamonds, and ovals.



13

## Outline

- Flowcharts
- Algorithmic State Machines

14

14

## State Graph $\leftrightarrow$ ASM chart

- **State graph** (or state diagram):
  - Nodes: unique states of the FSM
  - Transitional arcs: labeled with the condition that causes the transition
- **Algorithmic State Machine (ASM) chart** is an alternative representation
  - Composed of a network of ASM blocks
  - ASM block:
    - State box: represents a state in the FSM
    - Optional network of decision boxes and conditional output boxes
- **A state diagram can be converted to an ASM chart and vice-versa**

15

## ASM Charts

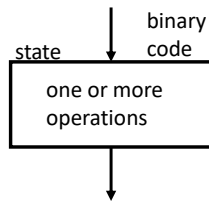
- Algorithmic State Machine (ASM) Chart is a popular high-level flowchart-like graphical model (or notation) to specify the (hardware) algorithms in digital systems.
- Major differences from flowcharts are:
  - ❖ Uses 3 types of boxes: state box (similar to operation box), decision box, and conditional box
  - ❖ Contains exact (or precise) timing information; flowcharts impose a relative timing order for the operations.
- From the ASM chart it is possible to obtain
  - ❖ The control
  - ❖ The architecture (data processor)

16



## Components of ASM Charts

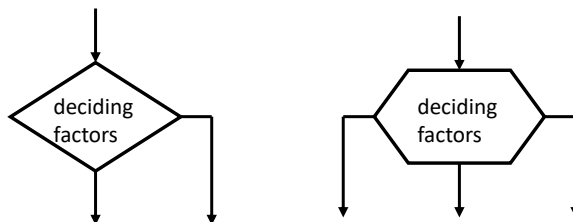
- The **state box** is rectangular in shape. It has at most one entry point and one exit point and is used to specify one or more operations which could be simultaneously completed in one **clock cycle**.



17

## Components of ASM Charts

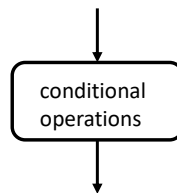
- The **decision box** is diamond in shape. It has one entry point but multiple exit points and is used to specify a number of alternative paths that can be followed.



18

## Components of ASM Charts

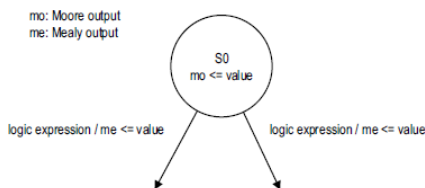
- The **conditional box** is represented by a rectangle with rounded corners. It always follows a decision box and contains one or more *conditional operations* that are only invoked when the path containing the conditional box is selected by the decision box.



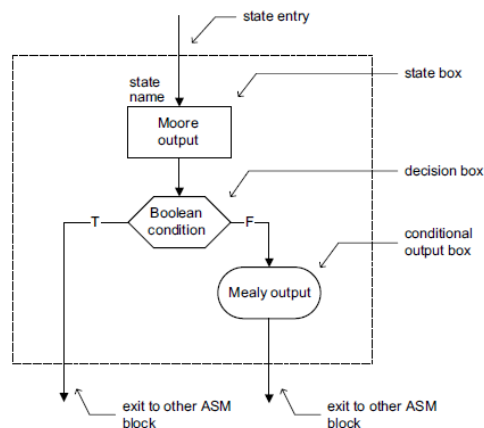
19

## State Graph $\leftrightarrow$ ASM chart

### State of State Graph

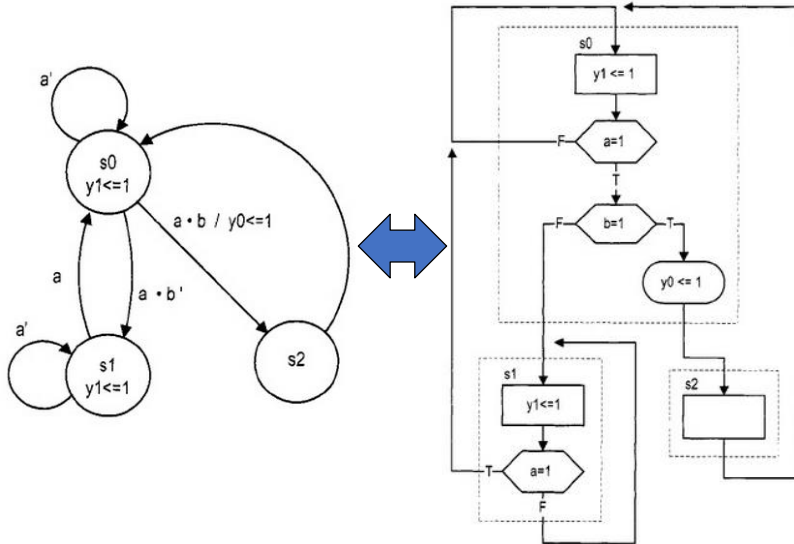


### ASM Block



20

## Example



21

## Outline

- Flowcharts
- Algorithmic State Machines
  - Algorithmic State Machine with Datapath (ASMD)

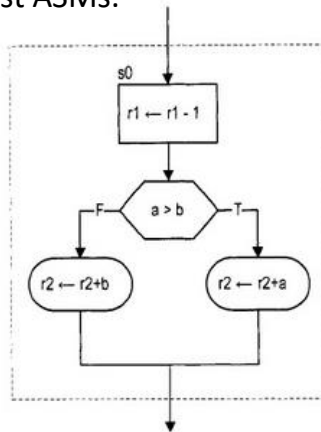
22

22

## Location of RT operation inside ASM block

- Extend ASM chart to incorporate RT operations and call it ASMD (ASM with data-path).
- Some people call them all just ASMs.

ASM block



23

## Decision box with a register

- RT operation in an ASMD chart is controlled by an embedded clock signal
- Destination register is updated when the machine exits the current ASMD block, but not within the block!
- Example:  $r \leftarrow r - 1$  means:
  - $r_{\text{next}} \leq r_{\text{reg}} - 1$ ;
  - $r_{\text{reg}} \leq r_{\text{next}}$  at the rising edge of the clock (when machine exits current block)

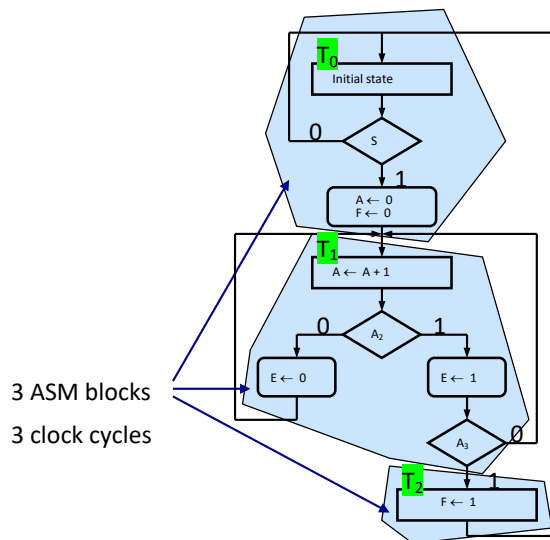
24

## Timing in ASM(D) Charts

- In the context of designing sequential digital circuits: precise timing is implicitly present in ASM/ASMD charts.
- Each state box, together with its immediately following decision and conditional boxes, **occurs within one clock cycle.**

25

## Timing in ASM Charts



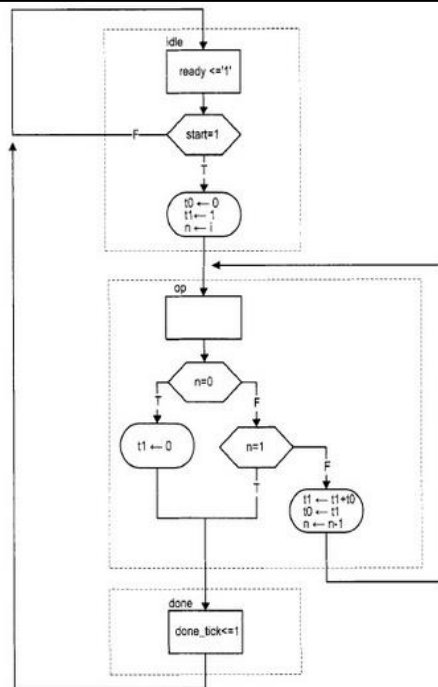
26

## Example: Fibonacci Numbers Generator

- Fibonacci number generator: generate the first  $n$  Fibonacci numbers.
- A sequence of integers
- $\text{fib}(i) =$ 
  - 0, if  $i = 0$
  - 1 if  $i = 1$
  - $\text{fib}(i-1) + \text{fib}(i-2)$ , if  $i > 1$

27

### ASMD chart



28

## Summary

- **Flowcharts** are useful all the time.
- **ASMs** are handy when you want to write code for a FSM type algorithm. They can make writing the code easier than when state-graphs are used.
- Use ASMs for portions of your application/program that you can specify as a FSM.
  - Great for controller (i.e., driver) implementation: UART controller, I2C controller, USB controller, etc.