COEN-4720 Embedded Systems

Lecture 8
Block Diagrams, Data Flow Diagrams, Flowcharts, Algorithmic State Machines

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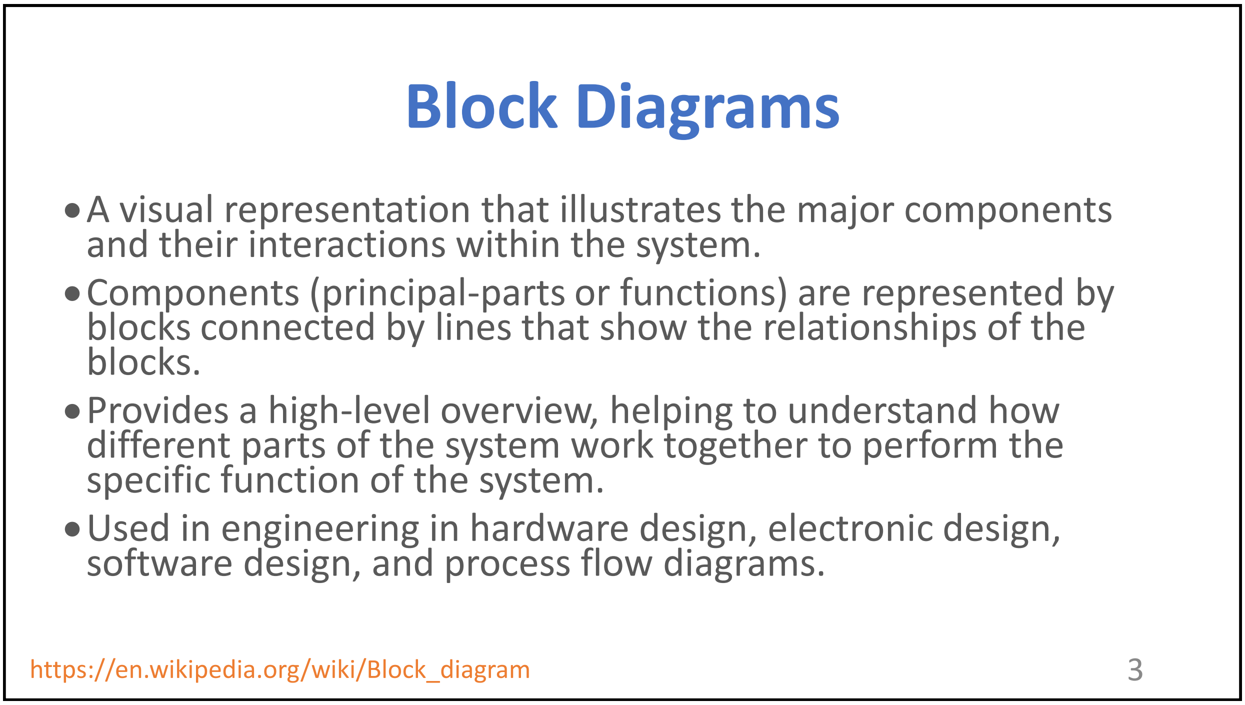
BE THE DIFFERENCE.

Outline

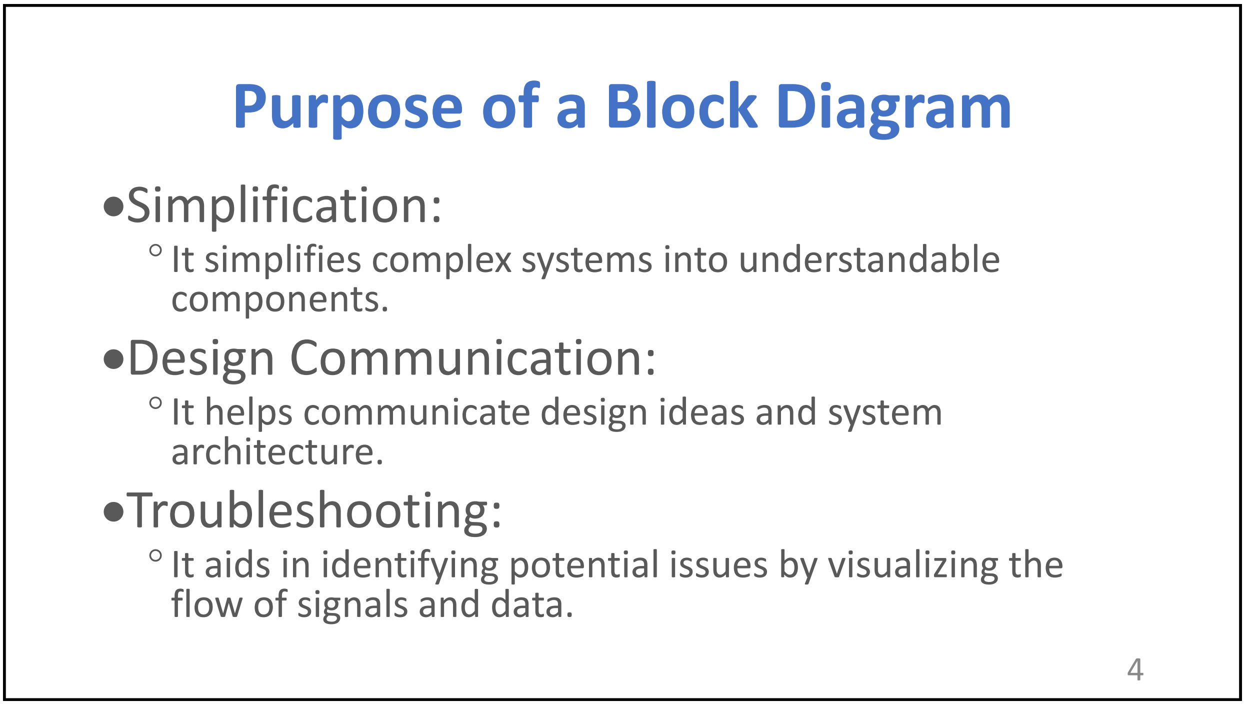
- Block Diagrams
- Data Flow Diagrams
- Flowcharts
- Algorithmic State Machines



Block Diagrams

- A visual representation that illustrates the major components and their interactions within the system.
- Components (principal-parts or functions) are represented by blocks connected by lines that show the relationships of the blocks.
- Provides a high-level overview, helping to understand how different parts of the system work together to perform the specific function of the system.
- Used in engineering in hardware design, electronic design, software design, and process flow diagrams.

https://en.wikipedia.org/wiki/Block_diagram



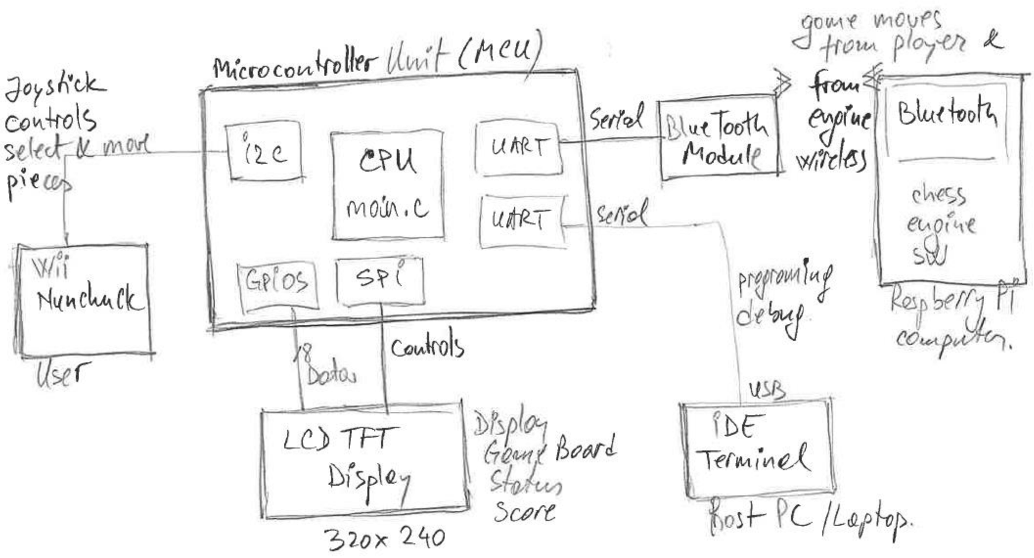
Purpose of a Block Diagram

- Simplification:
  - It simplifies complex systems into understandable components.
- Design Communication:
  - It helps communicate design ideas and system architecture.
- Troubleshooting:
  - It aids in identifying potential issues by visualizing the flow of signals and data.

Key Components

- Microcontrollers Units (MCUs)
  - Their processors execute main algorithms and process data.
- Memories
  - RAM: Temporary storage for data being processed.
  - ROM/Flash: Non-volatile storage for firmware and system software.
- Input/Output Interfaces
  - Sensors: Devices that gather data from the environment (e.g., temperature sensors, motion detectors).
  - Actuators: Devices that perform actions based on commands from MCU (e.g., motors, LEDs).
  - Communication Interfaces: Protocols for data exchange (e.g., UART, SPI, I2C).
- Power Supply
  - Source of power for the embedded system (may include voltage regulators and battery management).
- Additional
  - Signal Conditioning: Circuits that prepare sensor signals for processing.
  - User Interface: Displays, buttons, or touchscreens for user interaction.
  - Communication Modules: For wireless communication (e.g., BlueTooth, Wi-Fi, etc.).

Example: Chess Game System



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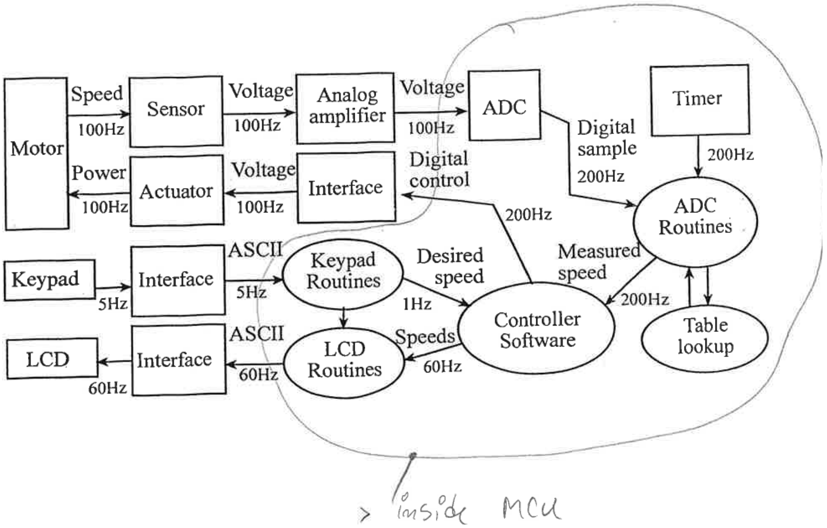
Data Flow Diagrams

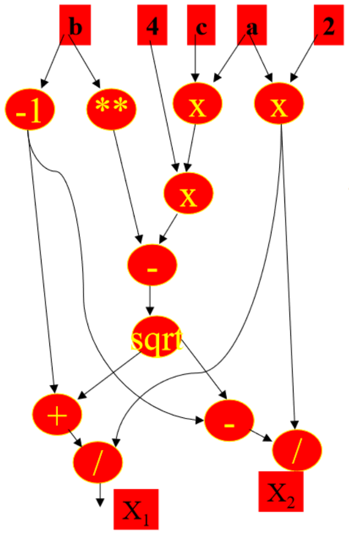
- A block diagram of the system showing the flow of information
- Rectangles – represent Hardware components
- Ovals – represent Software modules
- Arrows connecting components and modules are labeled with data types and bandwidth

Example of Data Flow Diagram: Motor Controller System



A Note… on Diagrams vs. Graphs

- What we call here Data Flow Diagrams, some people/references call them Data-Flow Graphs (DFG).
- However, that introduces confusion because:
  - A Data Flow Graph (DFGs) is a popular type of "computational model", which is a directed graph that shows the *data dependencies* between a number of functions. See example to the right.



$$x_1 = \frac{-b+\sqrt{b^2-4ac}}{2a}$$

$$x_2 = \frac{-b-\sqrt{b^2-4ac}}{2a}$$

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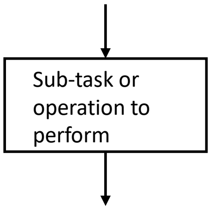
Flowcharts

- 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.

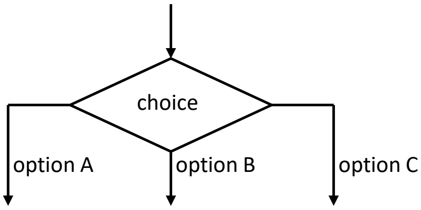
1. Operation Box

- 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.



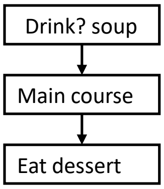
2. Decision Box

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



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.



Drink? soup

Main course

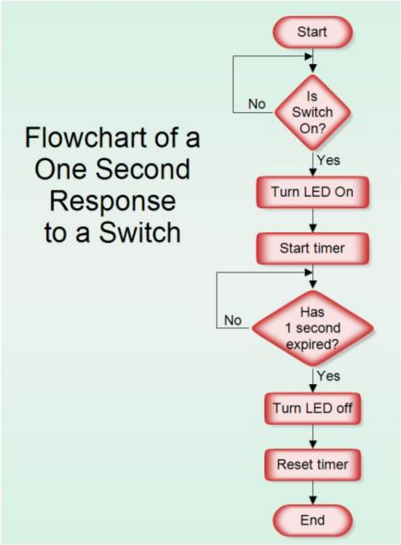
Eat dessert

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.

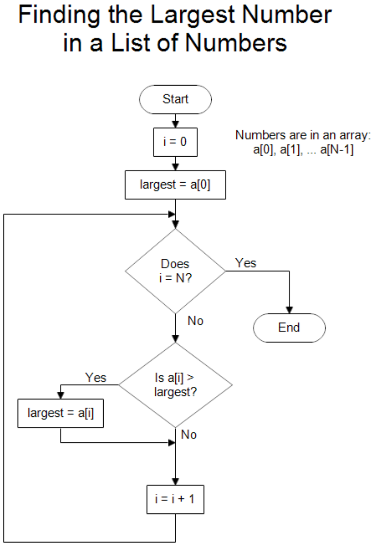
Flowchart Example: LED on for 1 second

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



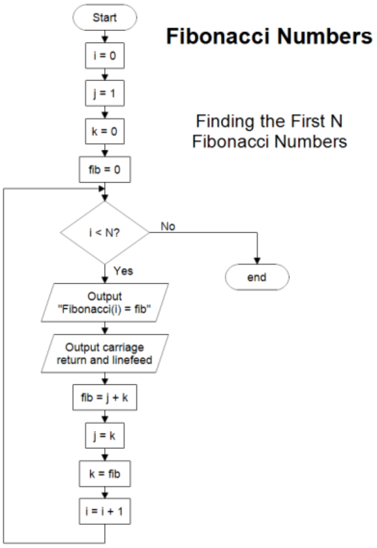
Flowchart Example: Find Largest Number

- Sometimes Start and End are included inside ovals too.

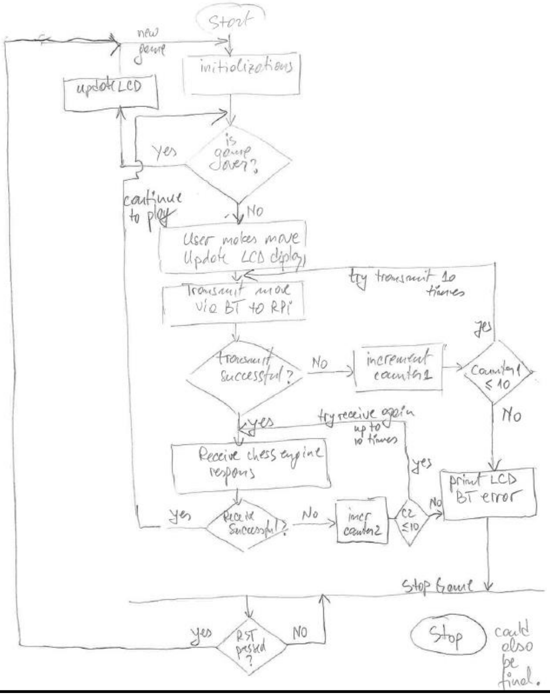

Finding the Largest Number in a List of Numbers
Start
i = 0
Numbers are in an array: a[0], a[1], ... a[N-1]
largest = a[0]
Does i = N?
Yes
End
No
Is a[i] > largest?
Yes
largest = a[i]
No
i = i + 1

Flowchart Example: Fibonacci Numbers

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

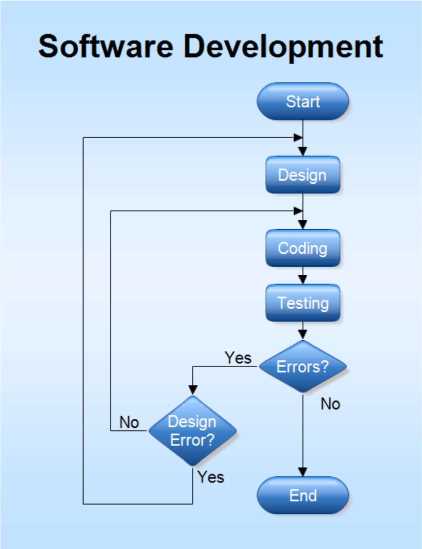

Fibonacci Numbers
Finding the First N Fibonacci Numbers
Start
i = 0
j = 1
k = 0
fib = 0
i < N?
No
end
Yes
Output "Fibonacci(i) = fib"
Output carriage return and linefeed
fib = j + k
j = k
k = fib
i = i + 1

Flowchart Example: Chess Game



Flowcharts – Last Note

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



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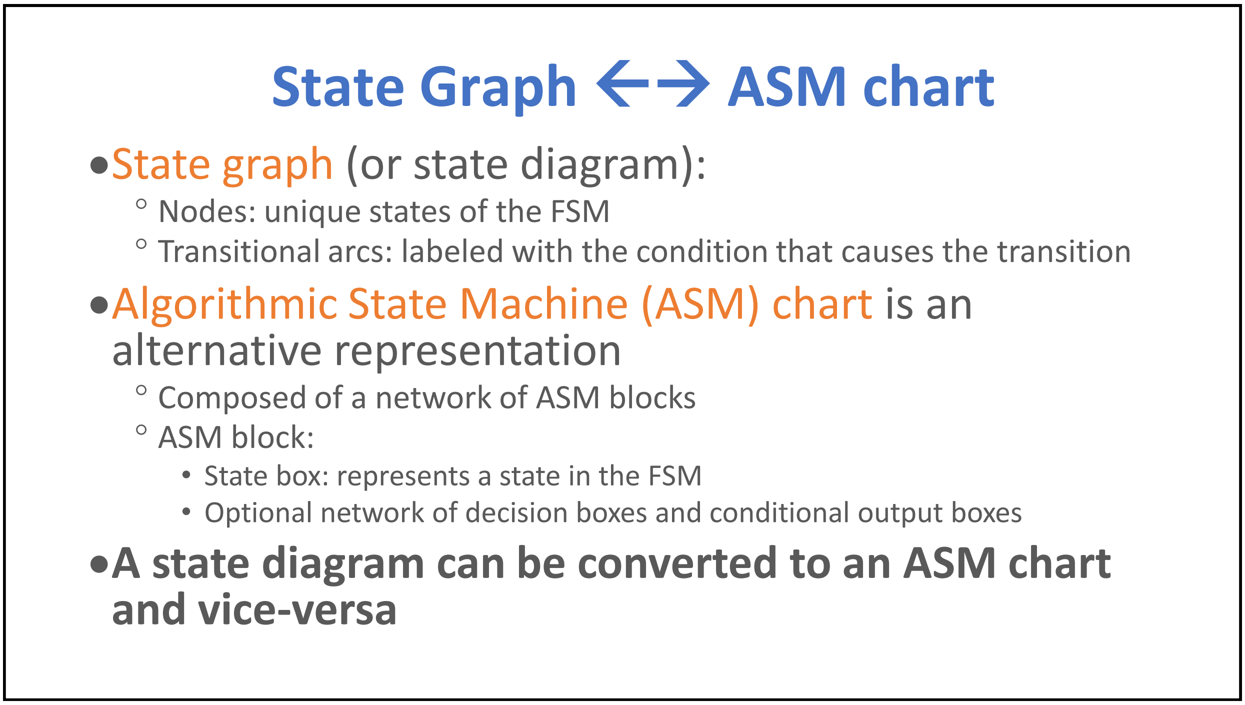

State Graph ←→ ASM chart

- 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**

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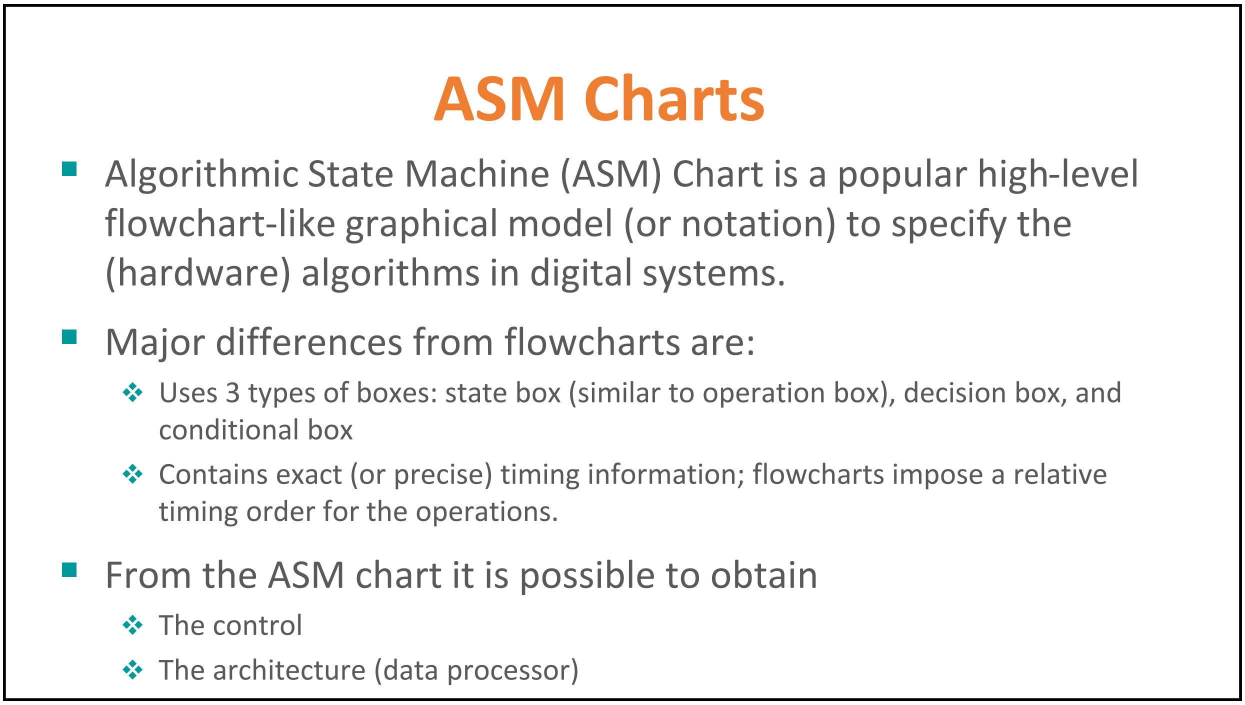

ASM Charts

- 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)

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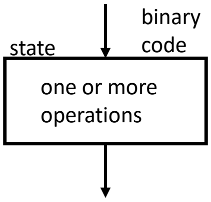
Components of ASM Charts

- 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**.



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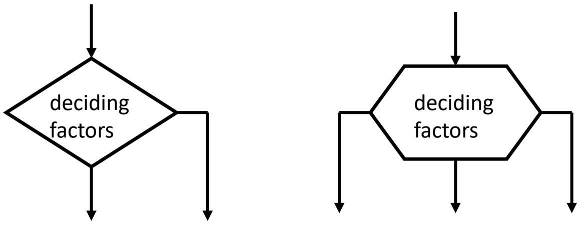
Components of ASM Charts

- 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.



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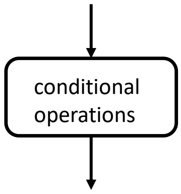
Components of ASM Charts

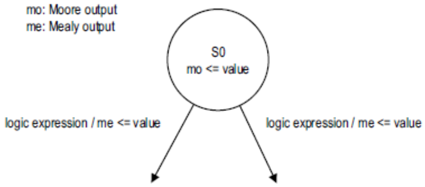
- The conditional box is represented by a rectangle with rounded corners. It always follows a decision box and contains one or more *conditional operations* that are only invoked when the path containing the conditional box is selected by the decision box.



conditional operations

State Graph ←→ ASM chart

State of State Graph



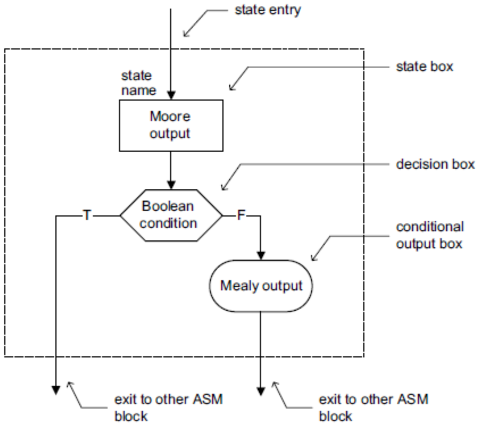
mo: Moore output
me: Mealy output

S0
mo <= value

logic expression / me <= value

logic expression / me <= value

ASM Block



state entry

state name

state box

Moore output

decision box

Boolean condition

T

F

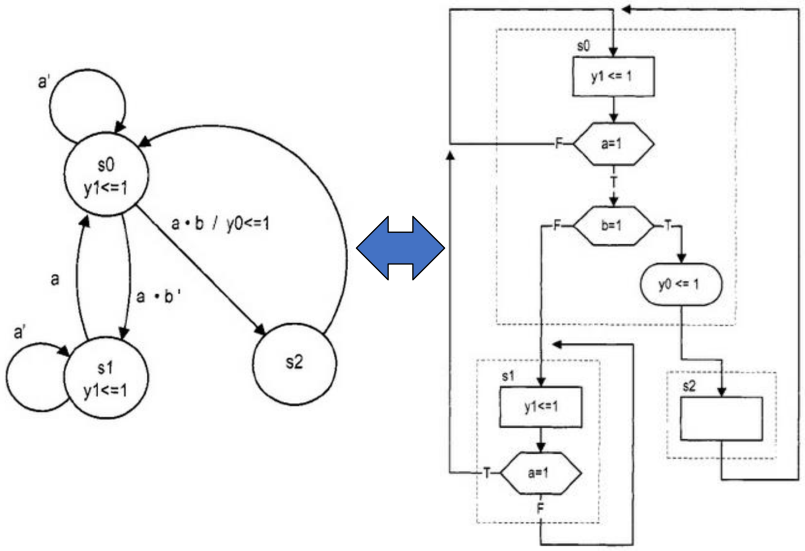
conditional output box

Mealy output

exit to other ASM block

exit to other ASM block

Example



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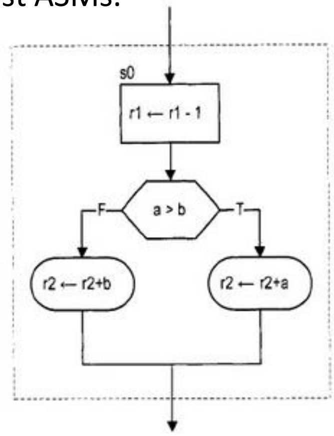
  - Algorithmic State Machine with Datapath (ASMD)

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



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 ← r – 1 means:
  - r_next <= r_reg – 1;
  - r_reg <= r_next at the rising edge of the clock (when machine exits current block)

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.

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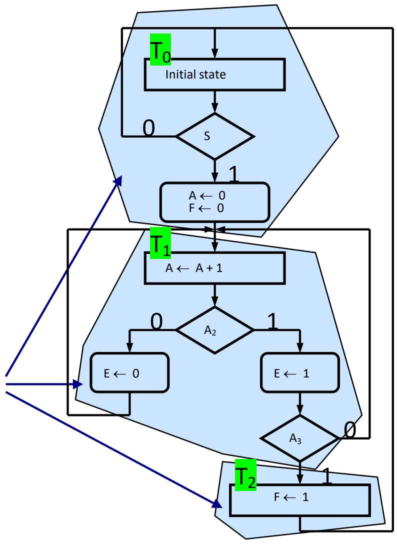
Timing in ASM Charts



3 ASM blocks

3 clock cycles

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Example: Fibonacci Numbers Generator

- Fibonacci number generator: generate the first **n** Fibonacci numbers.
- A sequence of integers
- fib(i) =

  0, if i = 0

  1 if i = 1

  fib(i-1) + fib(i-2), if i > 1

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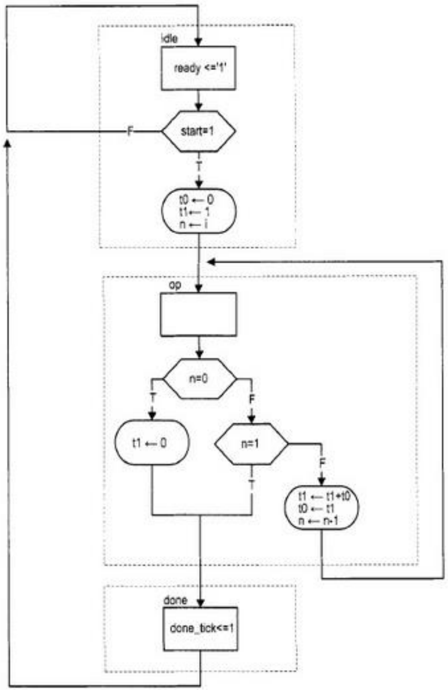
ASMD chart



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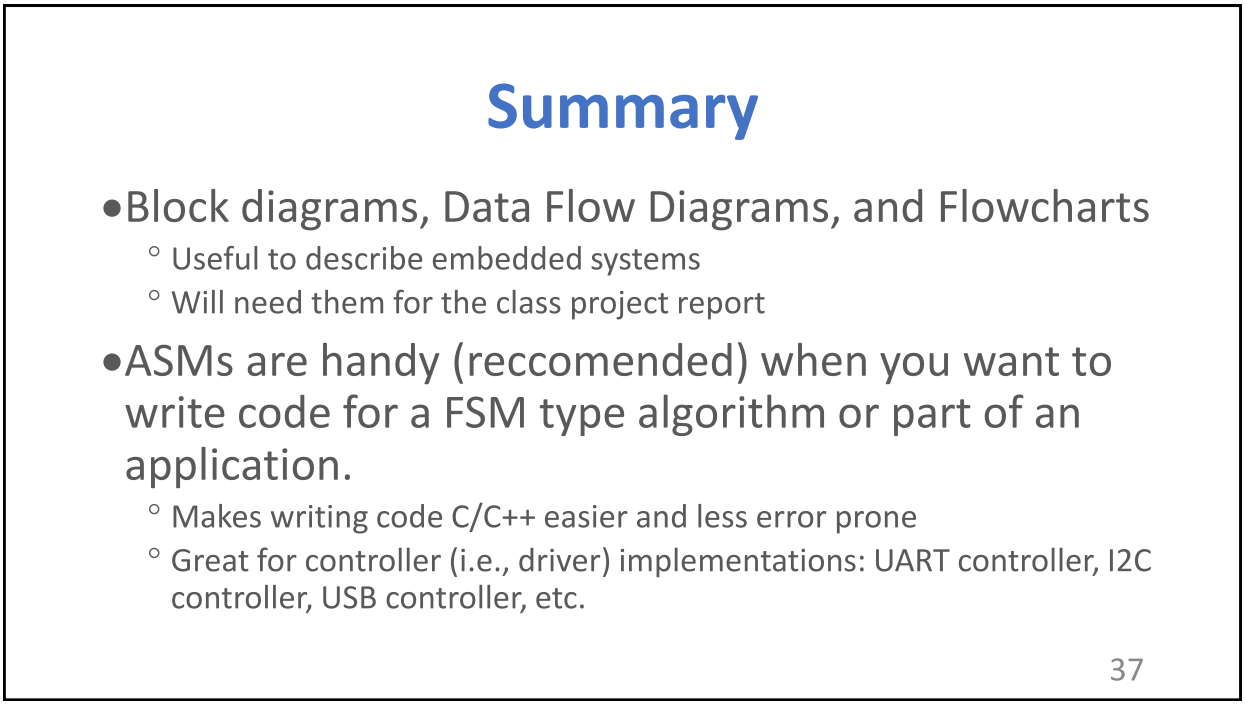

Summary

- Block diagrams, Data Flow Diagrams, and Flowcharts
  - Useful to describe embedded systems
  - Will need them for the class project report
- ASMs are handy (reccomended) when you want to write code for a FSM type algorithm or part of an application.
  - Makes writing code C/C++ easier and less error prone
  - Great for controller (i.e., driver) implementations: UART controller, I2C controller, USB controller, etc.