

COAVL: A Virtual Lab on Computer Organization and Architecture

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with

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COAVL Presentation
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Virtual lab objective and relevance

- COA is a core course in the curriculum of CSE, EE and ECE
- Laboratory experiments essential to understanding basics
- Most places used bread board based setup

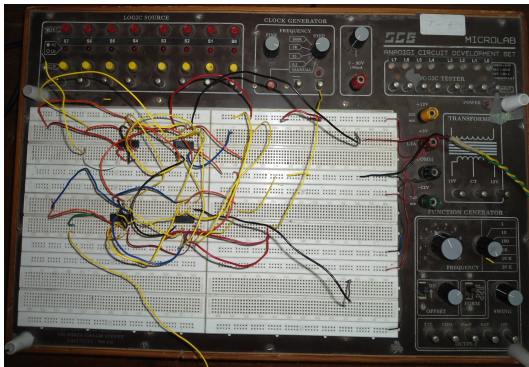
Drawbacks

- 1 Limits the size and extent of experiments
- 2 Time consuming



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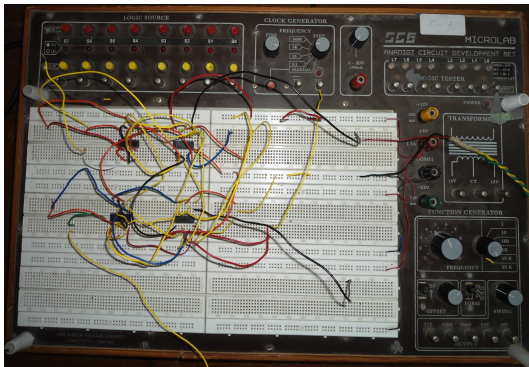


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Virtual lab objective and relevance contd..

- FPGA based lab to overcome this limitation
- Also has some limitations:
 - Learning curve with FPGAs somewhat high
 - Expensive
 - Logistics barrier of running lab
- Hence virtual lab, especially for most institutions



Experiments designed using concept hierarchy

Computer Arithmetic related

- Design of a Ripple Carry Adder
- Design of a Carry-Look-Ahead Adder
- Design of Wallace Tree Adder
- Synthesis of flip-flops
- Design of Registers and Counters
- Design of Combinational Multipliers
- Design of Booth's Multiplier
- Design of an ALU

Memory related

- Design of Memory elements
- Design of Associative cache without replacement policy
- Design of Direct Mapped cache without replacement policy

CPU design related

Design of single instruction CPU

Web interface of COLDVL

- Pedagogic considerations are reflected in web interface
- Web interface includes set of experiments, manual, others

Web interface of each experiment

- *Theory*
- *Objective*
 - *Guideline to check key behavior of the design*
 - *Test plan*
 - *Assignments*
- *Procedure*
- *Experimentation platform* (generic simulation platform) considered
- *Quizzes*
- *Further reading*



Features of the COAVL simulator

- The simulator supports 5-valued logic [True(T)(wire color: blue) False(F)(wire color: black) High impedance(Z)(wire color: green) Unknown(X)(wire color: maroon) Invalid(I)(wire color: orange)]
- Capable of simulating combinational circuits and synchronous sequential circuits
- Control signal generation from a user given ASM chart
- Bus based design with wired AND operation to CPU design
- Includes a single instruction CPU design with built-in controller
- Saving with Identification to check plagiarism
- Circuit analysis through different wire colors
- Minimal server dependency by having client side simulation



COAVL simulator interface

The simulator has the following:

Graphical editor

- A canvas to design the circuit
- Click and Drop method to add the components
- Different functional buttons like undo/redo, delete, zoom, save/open, print, showing timing diagram etc.

Palette

- Tools like connection, selection, clone
- All types of logic gates and flip-flops
- Inputs including free running clock
- Display units
- Adders, decoders, multiplexers, registers, counters etc.
- Arithmetic logic units, memory elements including cache memory
- Controller
- Other complex components like single instruction CPU, 4 bit address working memory etc.

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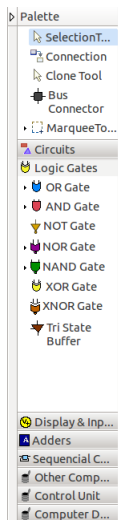
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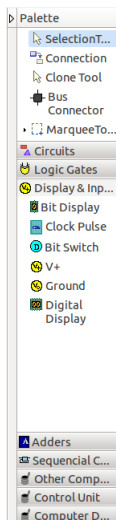
COAVL simulator interface

The screenshot displays the COAVL simulator interface. At the top is a toolbar with various icons for file operations, simulation control, and editing. The main workspace is a large grid. On the left side, there are several control panels: 'Dynamic Port Circuit' with 'In' and 'Out' checkboxes and a 'Set Port' button; 'Set Labels and Names' with input fields for 'Label' and 'Name'; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a large empty text area. Below these are 'Controller Current State', 'Component Name', and 'User Identification' sections, each with a large empty text area. On the right side, there is a 'Palette' containing a list of components: SelectionT..., Connection, Clone Tool, Bus Connector, MarqueeTo..., Circuits, Circuit, 16 terminal, Logic Gates (OR Gate, AND Gate), Display & Inp..., Bit Display, Clock Pulse, Adders (HalfAdder, FullAdder), Sequential C..., RS flipflop, D flipflop, Other Comp..., 2:4 Decoder, Control Unit, Controller, Computer D..., CPU, and Memory. A mouse cursor is visible in the center of the grid.

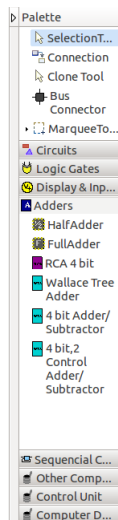
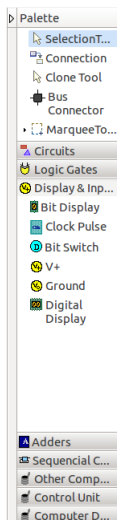
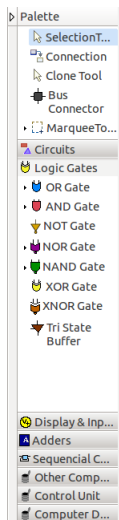
Component drawers in COAVL simulator



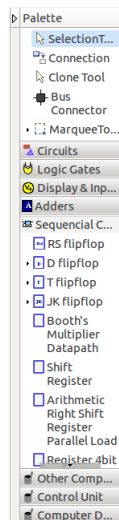
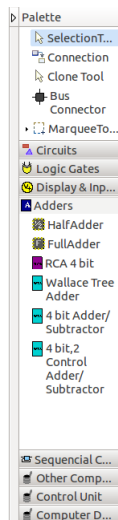
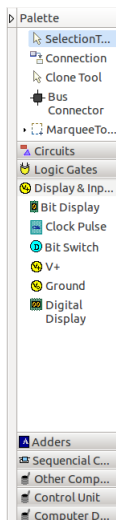
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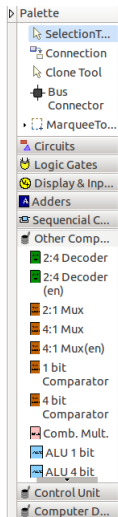
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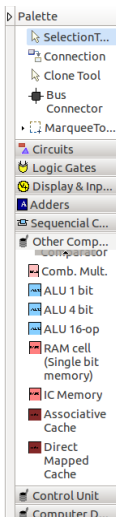
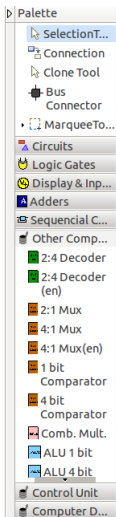
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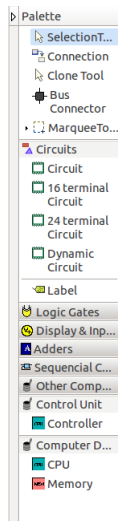
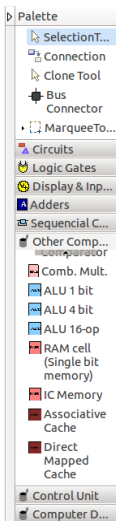
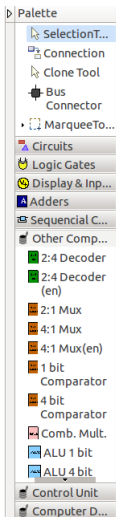
Component drawers contd..



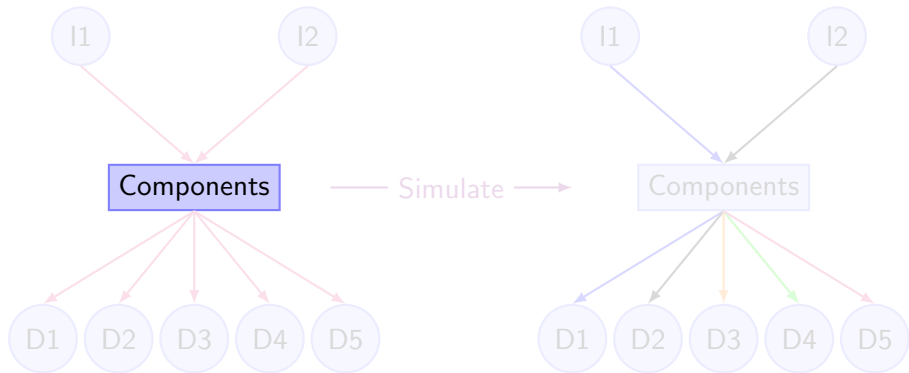
Component drawers contd..



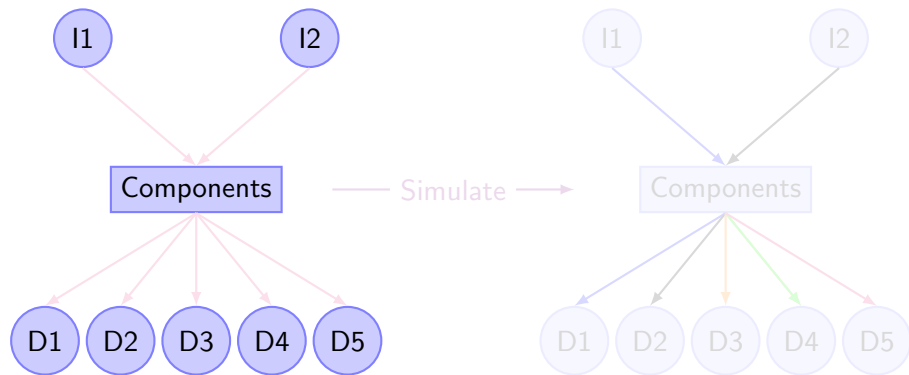
Component drawers contd..



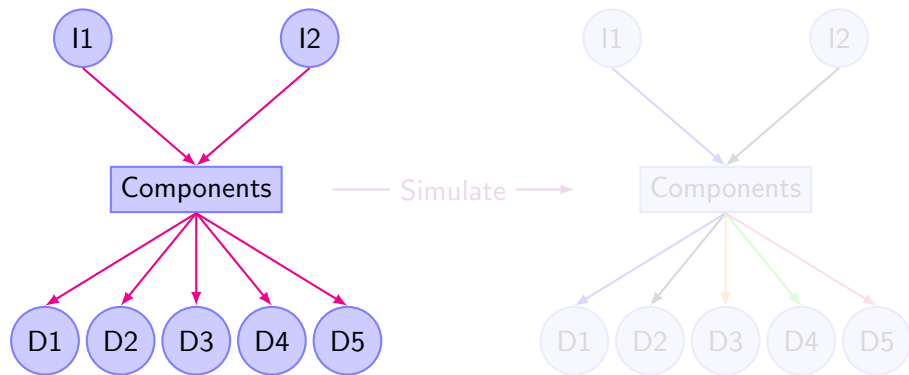
Building a circuit



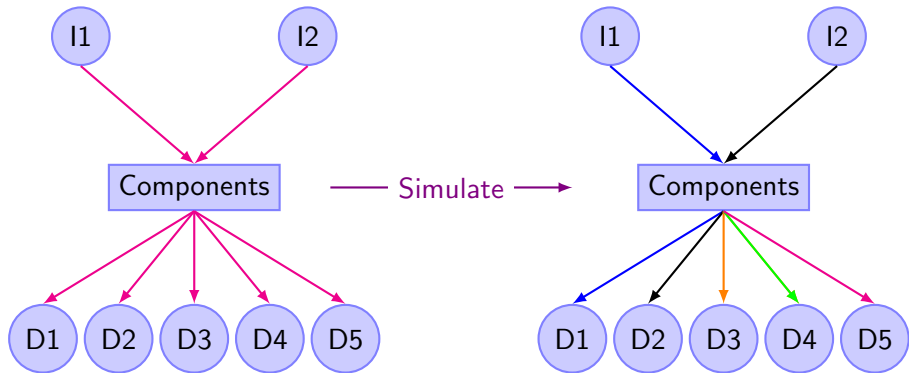
Building a circuit



Building a circuit

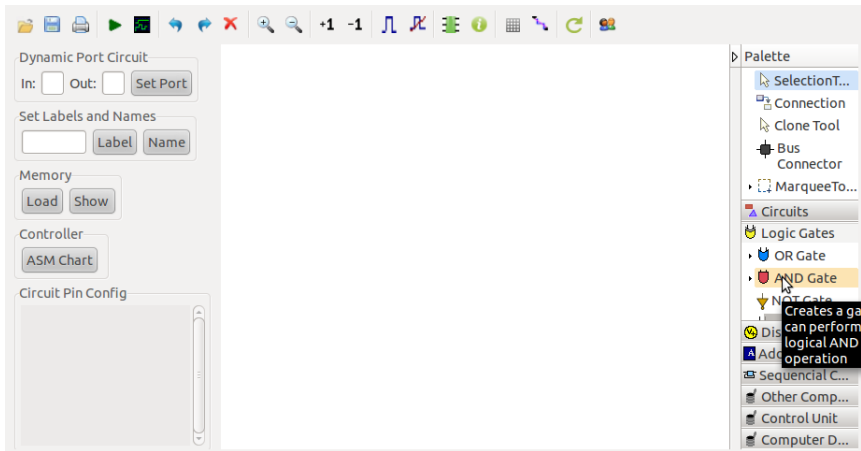


Building a circuit



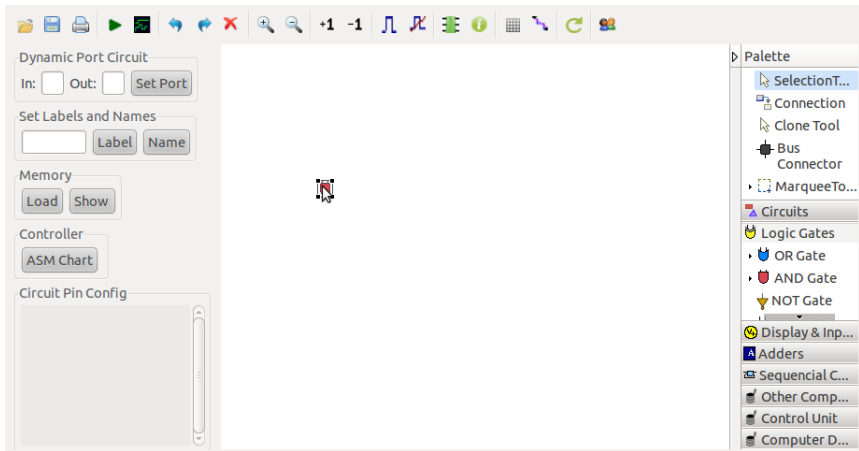
Building a half adder circuit

To instantiate a component left click on the component icon



Instantiating a component contd..

Drop the component at desired position



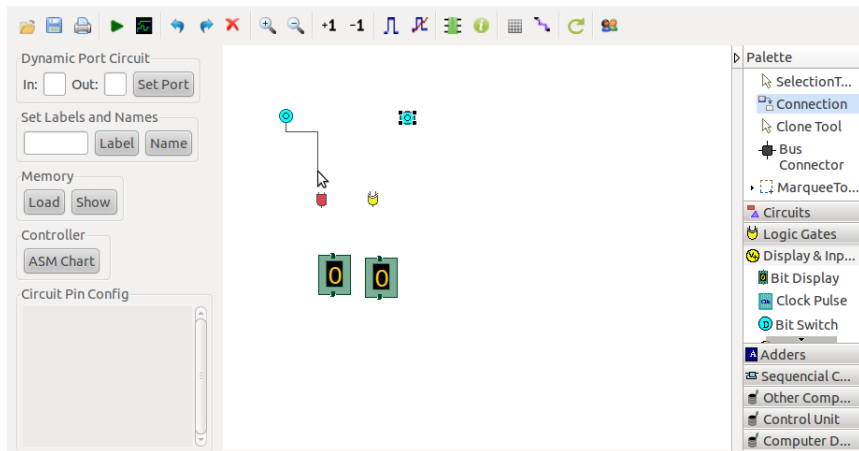
Connecting components

left click on the connection tool

The screenshot displays a digital logic design software interface. On the left, there are several control panels: 'Dynamic Port Circuit' with 'In:' and 'Out:' fields and a 'Set Port' button; 'Set Labels and Names' with a text input field and 'Label' and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a scrollable list area. The central workspace shows a circuit diagram with two blue circular components at the top, two red and yellow components in the middle, and two green rectangular components at the bottom. On the right, a 'Palette' window is open, listing various components. The 'Connection' tool is highlighted, and a tooltip indicates it can be used to connect various parts. The palette also includes categories like 'Circuits', 'Logic Gates', 'Display & Inp...', 'Bit Display', 'Clock Pulse', 'Bit Switch', 'Adders', 'Sequential C...', 'Other Comp...', 'Control Unit', and 'Computer D...'. At the bottom of the screen, there are navigation icons and a logo for IIT Kharagpur.

Connecting components contd..

left click on the output terminal, move the mouse to the desired input terminal



The screenshot displays a virtual lab environment with a central workspace containing a circuit diagram. The diagram includes a blue circular terminal on the left, a red terminal below it, a yellow terminal to the right, and two green rectangular components at the bottom. A mouse cursor is positioned over the red terminal. To the left of the workspace is a control panel with sections for 'Dynamic Port Circuit', 'Set Labels and Names', 'Memory', 'Controller', and 'Circuit Pin Config'. To the right is a 'Palette' menu with various tool options. The top of the interface features a toolbar with icons for file operations, simulation, zooming, and other functions.

Dynamic Port Circuit
In: Out: Set Port

Set Labels and Names
 Label Name

Memory
Load Show

Controller
ASM Chart

Circuit Pin Config

Palette

- SelectionT...
- Connection
- Clone Tool
- Bus Connector
- MarqueeTo...
- Circuits
- Logic Gates
- Display & Inp...
- Bit Display
- Clock Pulse
- Bit Switch
- Adders
- Sequencial C...
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- Control Unit
- Computer D...

Haff adder circuit

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In: Out: Set Port

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Palette

- SelectionT...
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- Logic Gates
- Display & Inp...
- Adders
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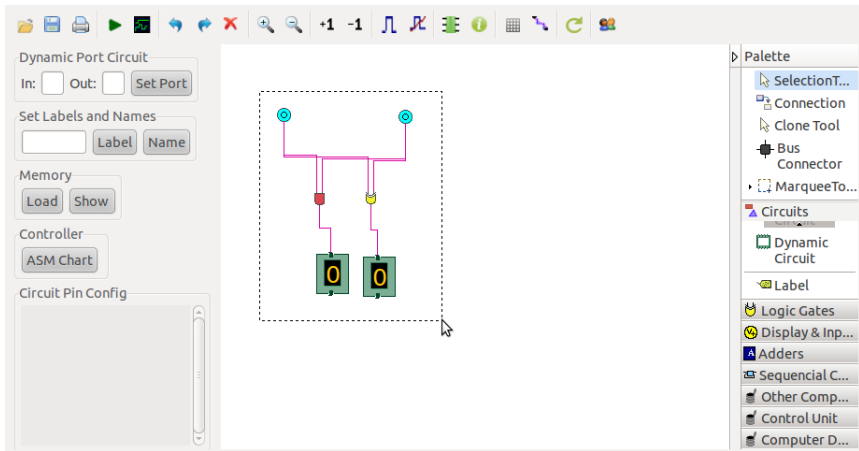
Cloning components

left click on the selection tool

The screenshot displays a circuit design software interface. On the left, there are several control panels: 'Dynamic Port Circuit' with 'In:' and 'Out:' fields and a 'Set Port' button; 'Set Labels and Names' with an input field and 'Label' and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a scrollable list. The central workspace shows a circuit diagram with two blue circular input ports at the top, connected by a horizontal pink line. From this line, two vertical pink lines lead to two green rectangular components, each containing a yellow '0'. A red square and a yellow circle are positioned on the pink lines between the top and the components. On the right, a 'Palette' menu is open, listing various tools and components. The 'SelectionTool' is highlighted with a mouse cursor, and a tooltip 'SelectionTool' is visible next to it. Other items in the palette include 'Connection', 'Clone Tool', 'Bus Connector', 'MarqueeTo...', 'Circuits', 'Dynamic Circuit', 'Label', 'Logic Gates', 'Display & Inp...', 'Adders', 'Sequential C...', 'Other Comp...', 'Control Unit', and 'Computer D...'. At the bottom right, there is a small logo of a university.

Cloning components contd..

Select the desired components to be cloned



The screenshot displays a circuit simulation software interface. On the left, there are several control panels: 'Dynamic Port Circuit' with 'In:' and 'Out:' fields and a 'Set Port' button; 'Set Labels and Names' with a text input field and 'Label' and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a scrollable list. The central workspace shows a circuit diagram with two logic gates (labeled '0') connected to a common bus. A dashed rectangular selection box is drawn around these two gates, and a mouse cursor is positioned at the bottom right corner of the box. On the right side, a 'Palette' panel lists various components: 'SelectionT...', 'Connection', 'Clone Tool', 'Bus Connector', 'MarqueeTo...', 'Circuits', 'Dynamic Circuit', 'Label', 'Logic Gates', 'Display & Inp...', 'Adders', 'Sequencial C...', 'Other Comp...', 'Control Unit', and 'Computer D...'. The 'Clone Tool' is highlighted in the palette.

Cloning components contd..

left click on the clone tool

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Cloning components contd..

Drag from any selected component

The screenshot displays a circuit design software interface. On the left, there is a control panel with several sections: 'Dynamic Port Circuit' with 'In:' and 'Out:' fields and a 'Set Port' button; 'Set Labels and Names' with a text input field and 'Label' and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a scrollable area. The top of the interface features a toolbar with various icons for file operations, execution, and editing. The main workspace shows two circuit diagrams. The left diagram has two blue square components at the top connected to two green rectangular components at the bottom. The right diagram is identical but with a mouse cursor hovering over one of the green components. On the right side, a 'Palette' menu is open, listing various components. The 'Clone Tool' is highlighted in blue. Other items in the palette include Selection..., Connection, Bus Connector, MarqueeTo..., Circuits, Dynamic Circuit, Label, Logic Gates, Display & Inp..., Adders, Sequential C..., Other Comp..., Control Unit, and Computer D...

Simulating circuits

Click on the *Simulate* button in the top toolbar

The screenshot displays a circuit simulation software interface. The top toolbar contains various icons, with the 'Simulate' button (represented by a green play icon) highlighted by a mouse cursor. Below the toolbar, there are several control panels: 'Dynamic Port Circuit' with 'In:' and 'Out:' fields and a 'Set Port' button; 'Set Labels and Names' with a text input field and 'Label' and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a scrollable area. The main workspace shows two circuit diagrams. The left diagram has a cyan input terminal on the left and a yellow output terminal on the right. The right diagram has yellow input terminals on both the left and right. Both diagrams feature a red bus connector and a yellow bus connector, with wires leading to two green display boxes labeled 'Carry' and 'Sum'. The 'Carry' display shows '0' and the 'Sum' display shows '1' in the left diagram, and '1' and '0' in the right diagram. On the right side, a 'Palette' panel lists various components like 'Selection...', 'Connection', 'Clone Tool', 'Bus Connector', 'MarqueeTo...', 'Circuits', 'Dynamic Circuit', 'Label', 'Logic Gates', 'Display & Inp...', 'Adders', 'Sequential C...', 'Other Comp...', 'Control Unit', and 'Computer D...'. A small logo is visible in the bottom right corner of the software window.

Clock waveform

- 1 Click the *Show waveform* button to see the waveform
- 2 Red arrow indicates the button to start the clock
- 3 Violet arrow indicates the button to see the component name

The screenshot displays a digital logic simulator interface. On the left, a control panel includes a 'Show waveform' button (indicated by a red arrow), 'Dynamic Port Circuit' settings, 'Set Labels and Names' fields, 'Memory' buttons, 'Controller' options, and 'Circuit Pin Config'. The central area shows a circuit diagram with three bit displays labeled '0', '1', and 'Z', and three input switches labeled 'D2', 'D1', and 'D0'. A red arrow points to the 'Show waveform' button, and a violet arrow points to the 'Show component name' button. On the right, a timing diagram window shows a clock signal and three data signals: 'Input : Clock input #0 Value=00', 'Input : Bit Switch #0 Value=01', and 'Input : Bit Switch #1 Value=01'. Below these are three output signals: 'Output : Bit Display #0 Value=02', 'Output : Bit Display #1 Value=01', and 'Output : Bit Display #2 Value=00'. The right sidebar shows a component palette with various logic elements like '4 Decoder', '1 Mux', and 'Comparator'.

Simulating sequential circuits

Red arrow indicates the button to see the pin configuration of a component

The screenshot displays a logic simulator interface with a central circuit diagram and several control panels. The circuit diagram features a central component labeled "Arsh Reg" (4-bit arithmetic right shift register). It is connected to a 4-bit data bus (F3, F2, F1, F0) and a 4-bit control bus (S1, S0, and two unlabeled control lines). A red arrow points to a button in the top toolbar, which is used to view the pin configuration of a component. The left panel contains controls for "Dynamic Port Circuit", "Set Labels and Names", "Memory", "Controller", and "Circuit Pin Config". The "Circuit Pin Config" panel shows the following configuration:

```
I/P: Clk:16, S1:15, S0:14
S1 S0: 00 for no change
S1 S0: 01 for arithmetic right shift
S1 S0: 10 for parallel load
S1 S0: 11 for clear
I0: 9, I1: 10, I2: 11, I3: 12
O/P: F0: 8, F1: 7, F2: 6, F3: 5
```

The right panel shows a "Palette" with various components like SelectionT..., Connection, Clone Tool, Bus Connector, MarqueeTo..., Circuits, Circuit, 16 terminal Circuit, 24 terminal, Logic Gates, Display & Inp..., Adders, Sequential C..., Other Comp..., Control Unit, and Computer D... The bottom status bar indicates "4-bit arithmetic right shift register is loaded".

Simulating sequential circuits contd..

Dynamic Port Circuit
In: Out: Set Port

Set Labels and Names
first clck Label Name

Memory
Load Show

Controller
ASM Chart

Circuit Pin Config
Anticlockwise
I/P: Clk:16, S1:15, S0:14
S1 S0: 00 for no change
S1 S0: 01 for arithmetic right shift
S1 S0: 10 for parallel load
S1 S0: 11 for clear
I/O: 9, I1: 10, I2: 11, I3: 12
O/P: F0: 8, F1: 7, F2: 6, F3: 5

Arsh Reg

S1 S0

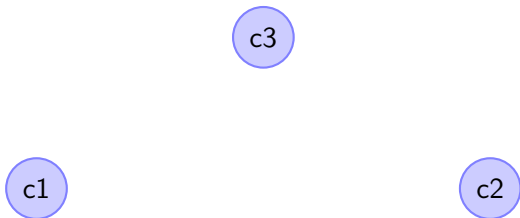
F3 F2 F1 F0

Arithmetic right shift after first clock

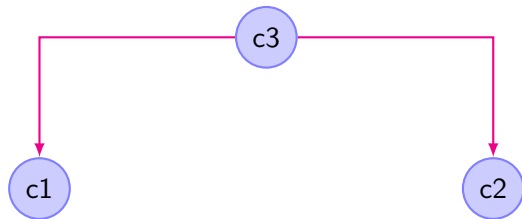
Palette
SelectionT...
Connection
Clone Tool
Bus Connector
MarqueeTo...
Circuits
Circuit
16 terminal Circuit
24 terminal
Logic Gates
Display & Inp...
Adders
Sequential C...
Other Comp...
Control Unit
Computer D...



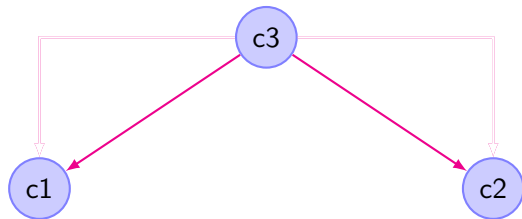
Change connection type



Change connection type



Change connection type



Generating control signals from a given ASM chart

Dynamic Port Circuit
In: Out:

Set Labels and Names

Memory

Controller

Circuit Pin Config

Enter State Chart

Number of States

Number of Inputs

Number of outputs



Generating control signals from a given ASM chart contd..

The screenshot shows a software application interface for generating control signals from an ASM chart. The interface includes a toolbar with icons for file operations, execution, and zooming. On the left, there are panels for 'Dynamic Port Circuit', 'Set Labels and Names', 'Memory', 'Controller', and 'Circuit Pin Config'. The 'Controller' panel has an 'ASM Chart' button. A central window titled 'SWT Application' is open, showing a dialog with input and output name fields.

Dynamic Port Circuit
In: Out: Set Port

Set Labels and Names
 Label Name

Memory
Load Show

Controller
ASM Chart

Circuit Pin Config

SWT Application
Enter the name of the inputs
input1 input2
Enter the name of the outputs
out1 out2

Generating control signals from a given ASM chart contd..

The screenshot shows a software interface for generating control signals from an ASM chart. The interface includes a toolbar at the top with various icons for file operations, execution, and editing. On the left, there are several configuration panels: 'Dynamic Port Circuit' with 'In' and 'Out' fields and a 'Set Port' button; 'Set Labels and Names' with a text input field and 'Label' and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a scrollable list. The main area is a grid where a dialog box titled 'Enter State Table' is open. This dialog box contains a table with columns for 'State', 'Inputs' (00, 01, 10, 11), and 'Outputs' (out1, out2). The table is populated with dropdown menus for each cell. The 'S0' state row has dropdowns for S1, S2, S0, S1, 0, and 1. The 'S1' state row has dropdowns for S1, S2, S2, S1, 1, and 0. The 'S2' state row has dropdowns for S2, S2, S2, S0, 0, and 1. An 'Enter' button is located at the bottom of the dialog box.

State	Inputs				Outputs	
	00	01	10	11	out1	out2
S0	S1	S2	S0	S1	0	1
S1	S1	S2	S2	S1	1	0
S2	S2	S2	S2	S0	0	1

Generating control signals from a given ASM chart contd..

Red arrow indicates the button to reset the controller

The screenshot displays a circuit simulation environment. On the left, there are several control panels: 'Dynamic Port Circuit' with 'In:' and 'Out:' fields and a 'Set Port' button; 'Set Labels and Names' with a text input and 'Label' and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a scrollable list. The main workspace shows a green CPU component with three input pins connected to logic gates (0, 1, 1) and two output pins connected to logic gates (1, 0). On the right, a 'Palette' lists various components like Circuits, Logic Gates, OR Gate, AND Gate, Display & I/O, Bit Display, Clock, Adders, HalfAdder, FullAdder, Sequential..., RS flipflop, D flipflop, Other Co..., 2:4 Decoder, Control Unit, Controller, Computer..., and CPU. A red arrow points to a circular refresh icon in the top toolbar.

Loading working memory to examine the behavior of the single instruction CPU component

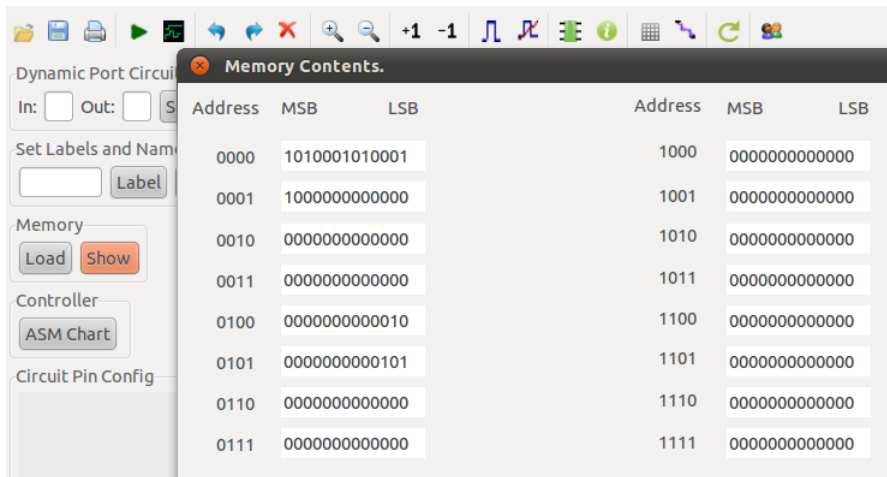
The screenshot shows a software interface for a virtual lab. On the left, there are several control panels: 'Dynamic Port Circuit' with 'In' and 'Out' fields and a 'Set Port' button; 'Set Labels and Names' with a text input, 'Label', and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; and 'Circuit Pin Config' with a scrollable area. The main window is titled 'Load Memory Contents' and contains a table with the following structure:

Address	MSB	LSB	Address	MSB	LSB
0000			1000		
0001			1001		
0010			1010		
0011			1011		
0100			1100		
0101			1101		
0110			1110		
0111			1111		

At the bottom of the dialog, there are three buttons: 'Load Memory', 'Reset Memory', and 'Load from file'.



Showing working memory content at any point of time



Dynamic Port Circuit
In: Out: S

Set Labels and Name
 Label

Memory
Load Show

Controller
ASM Chart

Circuit Pin Config

Memory Contents.

Address	MSB	LSB	Address	MSB	LSB
0000	1010001010001		1000	0000000000000	
0001	1000000000000		1001	0000000000000	
0010	0000000000000		1010	0000000000000	
0011	0000000000000		1011	0000000000000	
0100	0000000000010		1100	0000000000000	
0101	00000000000101		1101	0000000000000	
0110	0000000000000		1110	0000000000000	
0111	0000000000000		1111	0000000000000	



Connecting the CPU with working memory

The screenshot displays a virtual lab environment for connecting a CPU to working memory. The interface is divided into several sections:

- Dynamic Port Circuit:** Includes input and output fields and a "Set Port" button.
- Set Labels and Names:** Includes a text input field and "Label" and "Name" buttons.
- Memory:** Includes "Load" and "Show" buttons.
- Controller:** Includes an "ASM Chart" button.
- Circuit Pin Config:** A scrollable list of pin configurations:
 - interface
 - Pin Config:
 - input pin (upper):
 - 20-31 : data input (20:MSB),
 - 19: clock input
 - output pin(lower):
 - 1: memory enable
 - 2: R/W'

The central diagram shows a green "Memory" block and a green "CPU" block. A yellow square with a black "0" is connected to the CPU's input pin (pin 19). Pink lines represent the data bus connecting the CPU's input pins (20-31) to the Memory block's pins. A mouse cursor is positioned over the top of the Memory block.

Saving components with identification

Click the save button

The screenshot displays a digital logic simulator interface. On the left, a sidebar contains various toolbars and configuration options. The top toolbar includes icons for file operations (Save, Print), simulation (Run, Stop), and navigation (Home, Back, Forward). Below this, the 'Dynamic Circuit' section has 'In:' and 'Out:' fields and a 'Set Port' button. The 'Set Labels and Names' section has input fields for 'Label' and 'Name'. The 'Memory' section has 'Load' and 'Show' buttons. The 'Controller' section has an 'ASM Chart' button. The 'Circuit Pin Config' section provides details for a 2:4 Decoder, including terminal configurations and numbering. The 'Controller Current State' section has a status indicator. The 'Component Name' section shows 'AND Gate #1'. The 'User Identification' section is partially visible.

The main workspace shows a circuit diagram with two input terminals (blue and red), two output displays (green boxes with '0'), a 2:4 Decoder (green box labeled 'Dec'), and a Half Adder (green box labeled 'H/A').

A modal dialog box is overlaid on the right side of the workspace. It contains two input fields: 'Enter Your Name : gargi' and 'Enter Your Roll No. : 123'. Below the fields is an 'Enter' button.

Saving components with identification contd..

The image shows a logic simulator interface with a circuit diagram and a file save dialog. The circuit diagram features a 2:4 decoder connected to two 0 outputs and a half adder (H/A). The file save dialog is open, showing the file name 'MyCkt1logic' and the save location 'coa-vls'. The dialog also displays a list of files and folders in the 'coa-vls' directory.

Dynamic Port Circuit
In: Out:

Set Labels and Names

Memory

Controller

Circuit Pin Config
2:4 Decoder:
Upper Terminals:Inputs
Bottom Terminals:Outputs
Bottom Left Corner:
Circle Represents pin-1
Pin
Numbering:Anticlockwise
I/P: A0 : 5,A1 : 7
O/P: D0 : 4,D1 : 3.

Controller Current State

Component Name
AND Gate #1

User Identification

Name: MyCkt1logic

Save in folder: coa-vls

Browse for other folders

Places

- Search
- Recently Used
- coa-vls
- Desktop
- File System
- 186 GB File...
- 105 GB File...
- System Res...
- Documents
- Music
- Pictures
- Videos

Name	Size	Modified
ECLIPSE		Monday 01 August 2011
coa website backup		Tuesday 09 August 2011
cmake		Tuesday 09 August 2011
coa project		Thursday 29 September 2011
RegSlide		Tuesday 18 October 2011
NetBeansProjects		Thursday 31 May 2012
tmp		Monday 03 September 2012
ui-prevSit12sep		Wednesday 12 September 2012
public_html		Wednesday 12 September 2012
eclipse		Friday 28 September 2012
Videos		Thursday 01 November 2012
pdf		Friday 23 November 2012

Palette

- Selectio...
- Connecti...
- Clone Tool
- Bus Connector
- Marquee...
- Circuits
- Circuit
- Logic Gates
- NOT Gate
- NOR Gate
- Display & L...
- Digital Display
- Adders
- HalfAdder
- FullAdder
- Sequential...
- RS FlipFlop
- Other Co...
- 2:4 Decoder
- Control Unit
- Controller
- Computer ...
- CPU

Saving components with identification contd..

Click the *Show User Id* button to see identification in a saved file

The screenshot displays a digital logic simulator interface. On the left, there are several control panels: 'Dynamic Port Circuit' with 'In' and 'Out' fields and a 'Set Port' button; 'Set Labels and Names' with a text input and 'Label' and 'Name' buttons; 'Memory' with 'Load' and 'Show' buttons; 'Controller' with an 'ASM Chart' button; 'Circuit Pin Config' with a scrollable list of settings for a 2:4 Decoder; 'Controller Current State' with a scrollable list; 'Component Name' with 'AND Gate #1'; and 'User Identification' with 'gargi 123'. The top toolbar contains various icons, with the 'Show User Id' icon highlighted by a mouse cursor. The central workspace shows a circuit diagram with a 2:4 decoder, two 7-segment displays, and an H/A component. On the right, a component list is visible, including 'Selectio...', 'Connecti...', 'Clone Tool', 'Bus Connector', 'Marquee...', 'Circuits', 'Circuit', '16', 'Logic Gates', 'NOT Gate', 'NOR Gate', 'Display & I...', 'Digital Display', 'Adders', 'HalfAdder', 'FullAdder', 'Sequencial...', 'RS flipflop', 'D flipflop', 'Other Co...', '2:4 Decoder', 'Control Unit', 'Controller', 'Computer ...', and 'CPU'.

Thank you!

