

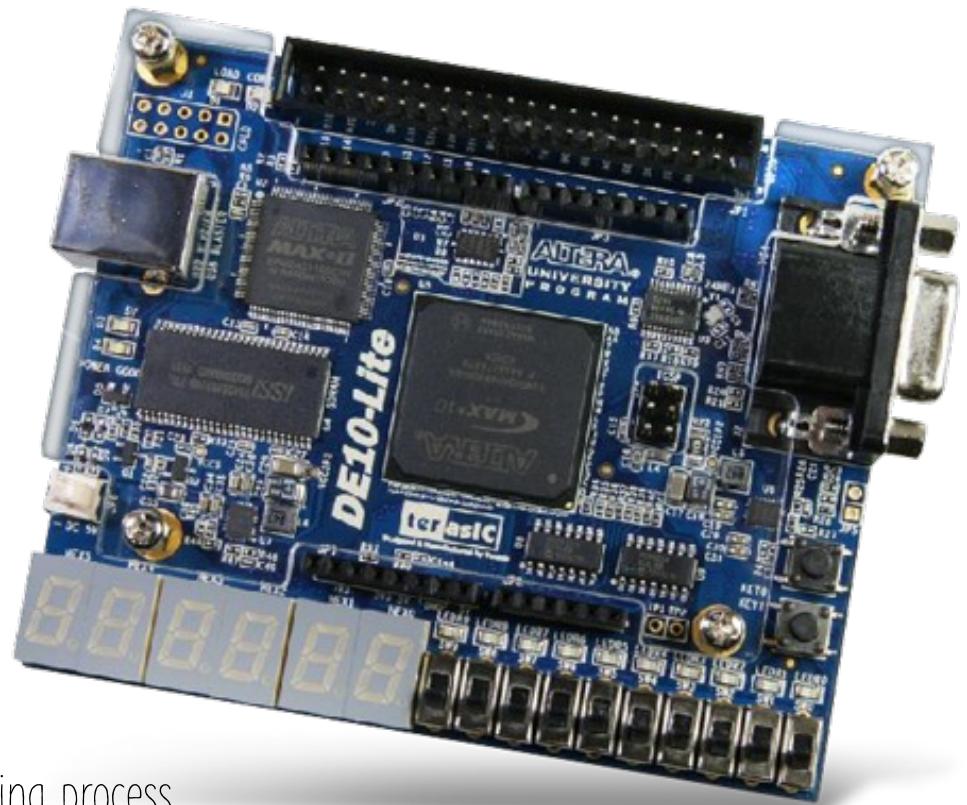


Digital Circuit Design

Li Bai

What we will cover...

- Digital (we will need to learn everything about the binary ...)
- We will need to design a process based on input/state to move into different output
- Difference between Arduino and DE10-Lite
 - Advantage of FPGA -> check out [here](#)
- Quartus and EDA Playground
 - Quartus will be on AWS Academy
 - <https://edaplayground.com/>
- Learn combinatory logic, sequential logic, flip-flop, block diagram, timing diagram, making process



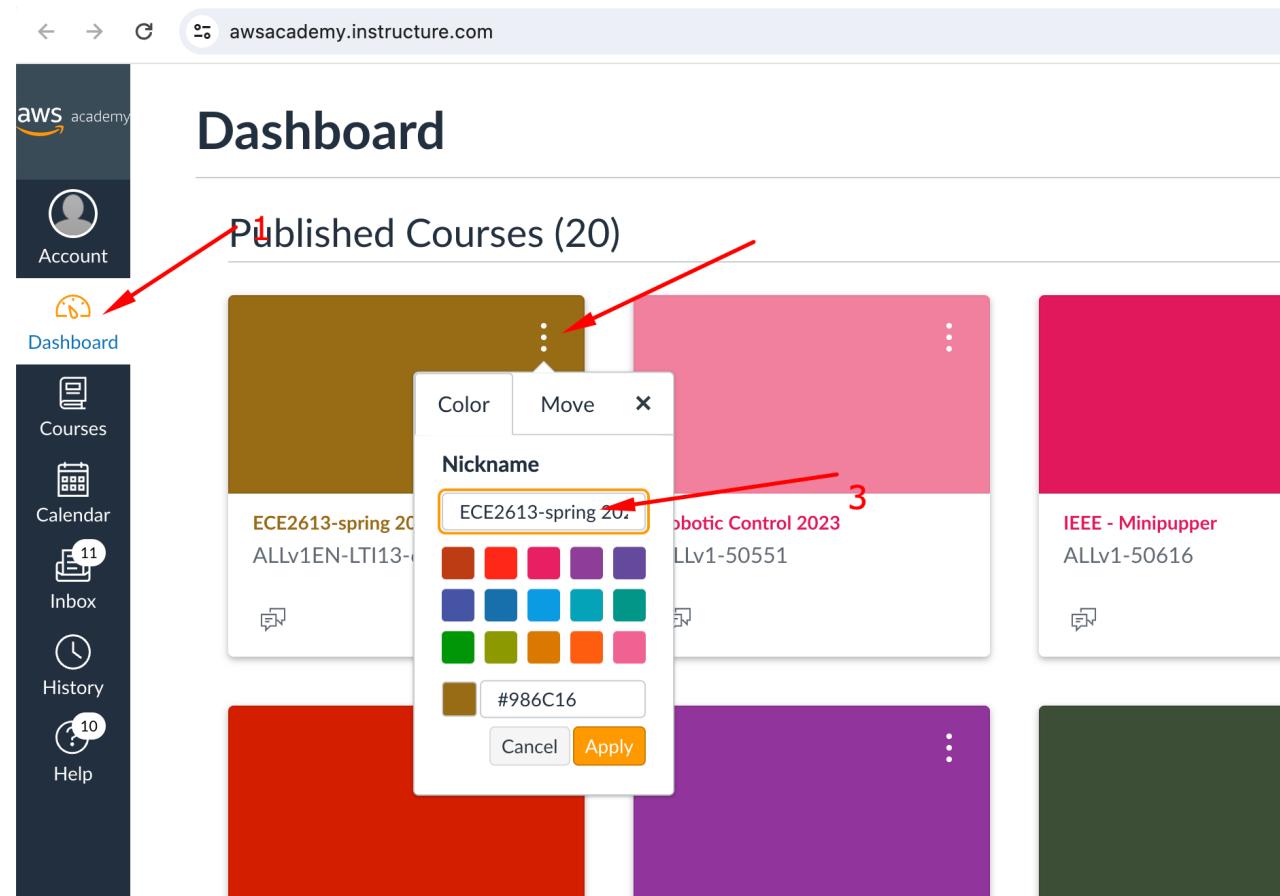
AWS Academy Student login

The screenshot shows a Google search results page with the query "aws academy student login" in the search bar. The results are filtered by "All". There are approximately 15,400,000 results.

1 AWS Academy Portal
AWS Academy Portal
<https://www.awsacademy.com> ::
AWS Academy Portal
We have launched a new **login** experience for all **AWS Academy** users. Please re ... Forgot your Password? Are you a **student**? information. close image. If you are ...

2 Untitled
Instructure
<https://awsacademy.instructure.com> · Translate this page ::
学生の方はこちらからログインしてください。已注册课程的学生请在这里登录. Educator Login. (For educators who have access to the **AWS Academy Portal**).
Instructure
<https://awsacademy.instructure.com/login/canvas> ::
Canvas - Amazon AWS Academy Login - Instructure
Canvas by Instructure. **Log In**. Forgot Password? Enter your Email and we'll send you a link to

AWS Academy Canvas



Access Learner's Lab

The screenshot shows a course navigation menu from awsacademy.instructure.com. The menu items are Home, Modules (which is highlighted with a red arrow labeled '1'), Discussions, and Grades. Below the menu, there are three main sections: Course Welcome and Overview, AWS Academy Learner Lab Compliance and Security, and AWS Academy Learner Lab. The AWS Academy Learner Lab section is expanded, showing a 'Launch AWS Academy Learner Lab' button (pointed to by a red arrow labeled '2') and a 'AWS Academy Learner Lab Resources' section.

awsacademy.instructure.com/courses/67880/modules

ALLv1EN-LTI13-67880 > Modules

Home

Modules

Discussions

Grades

Course Welcome and Overview

AWS Academy Learner Lab Compliance and Security

AWS Academy Learner Lab

Launch AWS Academy Learner Lab

AWS Academy Learner Lab Resources

Accept terms and conditions

-LTI... > Modules > AWS Academ... > Launch AWS Academy Learner Lab



Please read the terms and conditions shown below and click on the "I agree" button at the bottom of this page to continue.

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Start lab

The screenshot shows a web browser window for the AWS Academy Learner Lab. The URL in the address bar is `awsacademy.instructure.com/courses/67880/modules/items/6035341`. The page title is "ALLv1EN-LTI... > Modules > AWS Acade... > Launch AWS Academy Learner Lab". The main content area has a terminal-like interface with the prompt `eee_W_2764216@runweb109510:~$`. On the right side, there is a sidebar titled "Learner Lab" containing links for "Environment Overview", "Environment Navigation", "Access the AWS Management Console", "Region restriction", and "Service usage and other restrictions". At the top right of the main content area, there are several buttons: "Start Lab" (highlighted with a red box and arrow), "End Lab", "AWS Details", "Readme", "Reset", and a close button. The "AWS" tab is selected in the top navigation bar.

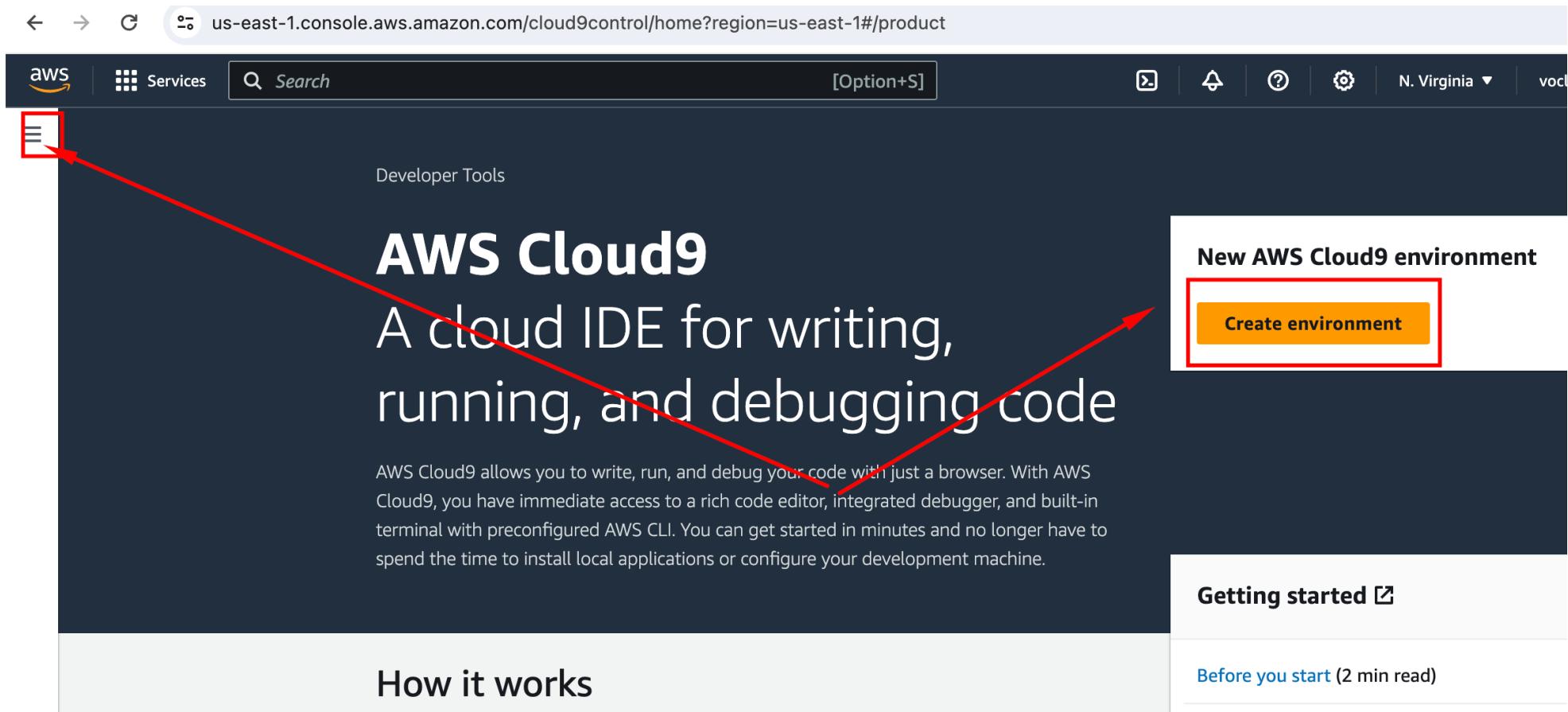
AWS green -> go to console

The screenshot shows the AWS Academy Learner Lab interface. At the top, there's a navigation bar with the path: ... > Modules > AWS Acade... > Launch AWS Academy Learner Lab. Below the navigation bar is a header with the AWS logo (highlighted with a red box and arrow), usage information (Used \$0 of \$100), time (03:58), and buttons for Start Lab, End Lab, AWS Details, and Readme. The main area features a terminal window with the command "eee_W_2764216@runweb109509:~\$". To the right of the terminal is a sidebar titled "Learner La" containing links to various resources: Environment Overview, Environment Navigation, Access the AWS Manager, Region restriction, Service usage and other r, Using the terminal in the, Running AWS CLI comma, Using the AWS SDK for Py, Preserving your budget, Accessing EC2 Instances, and SSH Access to EC2 Instanti.

Find cloud9

The screenshot shows the AWS CloudSearch interface. In the top navigation bar, the URL is `us-east-1.console.aws.amazon.com/console/home?region=us-east-1#`. The search bar contains the query `cloud9`, which is highlighted with a red box. The search results are displayed under the heading `Search results for 'cloud9'`. The results are categorized under `Services` (49). The first result, `Cloud9`, is highlighted with a red box and described as "A Cloud IDE for Writing, Running, and Debugging Code". Other results listed include `Amazon CodeCatalyst` (Integrated DevOps Service), `AWS Cloud Map` (Build a dynamic map of your cloud), and `Lightsail` (Launch and Manage Virtual Private Servers). A link to "See all 49 results" is also present.

Create environment



Ubuntu server cloud9 setup

AWS Cloud9 > Environments > Create environment

Create environment Info

Details

Name Limit of 60 characters, alphanumeric, and unique per user.

Description - optional

Limit 200 characters.

Environment type Info New EC2 instance Existing compute

Determines what the Cloud9 IDE will run on.

New EC2 instance

Cloud9 creates an EC2 instance in your account. The configuration of your EC2 instance cannot be changed by Cloud9 after creation.

Existing compute

You have an existing instance or server that you'd like to use.

New EC2 instance

Services Search [Option+S] 

New EC2 instance

Instance type Info

The memory and CPU of the EC2 instance that will be created for Cloud9 to run on.

t2.micro (1 GiB RAM + 1 vCPU)
Free-tier eligible. Ideal for educational users and exploration.

t3.small (2 GiB RAM + 2 vCPU)
Recommended for small web projects.

m5.large (8 GiB RAM + 2 vCPU)
Recommended for production and most general-purpose development.

Additional instance types
Explore additional instances to fit your need.

Additional instance types

Platform Info

This will be installed on your EC2 instance. We recommend Amazon Linux 2023.

Timeout

How long Cloud9 can be inactive (no user input) before auto-hibernating. This helps prevent unnecessary charges.

Network settings Info

Finalize your cloud9 environment

Network settings Info

Connection
How your environment is accessed.

AWS Systems Manager (SSM)
Accesses environment via SSM without opening inbound ports (no ingress).

Secure Shell (SSH)
Accesses environment directly via SSH, opens inbound ports.

► **VPC settings Info**

► **Tags - optional Info**
A tag is a label that you assign to an AWS resource. Each tag consists of a key and an optional value. You can use tags to search and filter your resources or track your AWS costs.

The following IAM resources will be created in your account

- **AWSServiceRoleForAWSCloud9** - AWS Cloud9 creates a service-linked role for you. This allows AWS Cloud9 to call other AWS services on your behalf.
You can delete the role from the AWS IAM console once you no longer have any AWS Cloud9 environments. [Learn more](#) 

[Cancel](#) **Create**

- c4.xlarge
- Ubuntu22.04
- ssh

Instruction on github

github.com/lbaitemple/ece2613/tree/spring24

lbaitemple / ece2613

Issues Pull requests Actions Projects Wiki Security Insights Settings

ece2613 Public

spring24 6 Branches 2 Tags

Switch branches/tags Find or create a branch...

Branches Tags

master default

de10lite

fall2021

rpi

✓ spring24

spring2022

View all branches

lab3

lab4

lab5

behind master

47524fd · 3 days ago 184 Commits

Add files via upload 3 months ago

Delete test.bat 4 years ago

Add files via upload 4 years ago

Add files via upload 3 years ago

Update tb_gates.sv 3 years ago

Add files via upload 3 years ago

Add files via upload 3 years ago

git clone -b spring24 https://github.com/lbaitemple/ece2613
cd ece2613
bash ./setup.bash
sudo reboot

2613_2024s

Instruction is provided at <https://sites.google.com/a/temple.edu/ece2612/home/cloud9-setup>

after you select the instance for cloud9, in the terminal

```
git clone -b spring24 https://github.com/lbaitemple/ece2613  
cd ece2613  
bash ./setup.bash  
sudo reboot
```

Test the code

- right click on m_sim (extension file) and run
- right click on qsf (extension file) and run

Resize cloud9 terminal windows

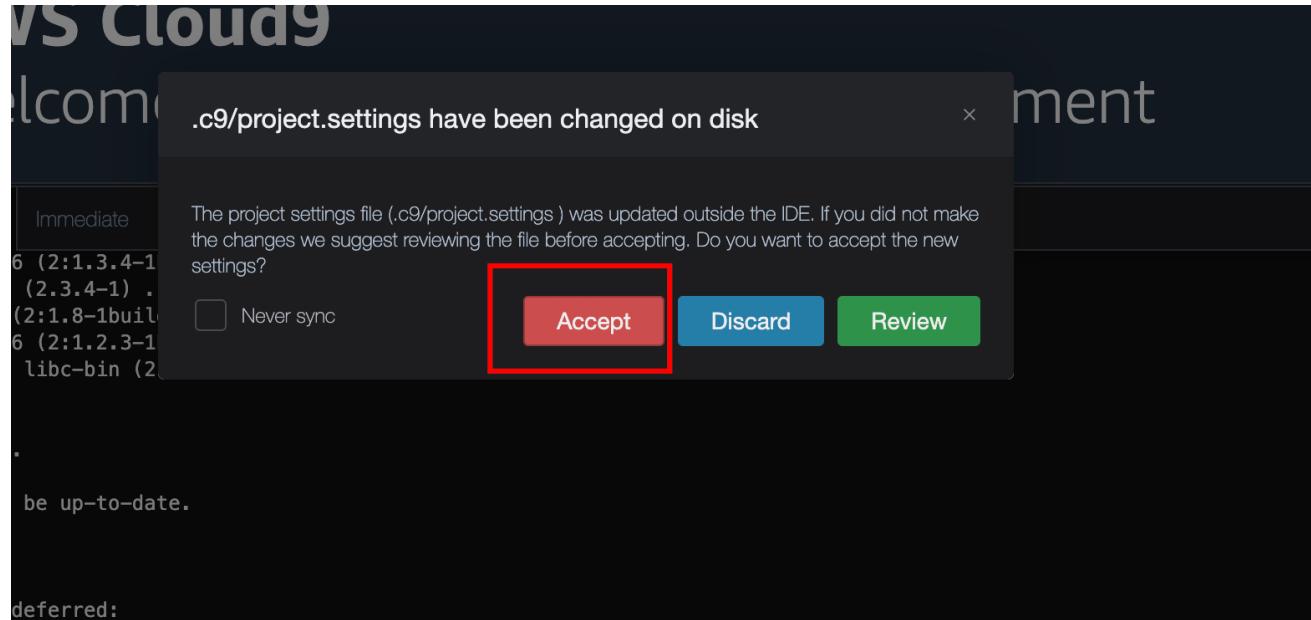
AWS Cloud9
Welcome to your development environment

```
bash - "ip-172-31-19-32" x Immediate x +  
Get:17 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy/multiverse amd64 c-n-f Metadata [8372 B]  
Get:18 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/main amd64 Packages [1277 kB]  
Get:19 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/main Translation-en [261 kB]  
Get:20 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/main amd64 c-n-f Metadata [16.1 kB]  
Get:21 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/restricted amd64 Packages [1272 kB]  
Get:22 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/restricted Translation-en [207 kB]  
Get:23 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/restricted amd64 c-n-f Metadata [520 B]  
Get:24 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/universe amd64 Packages [1023 kB]  
Get:25 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/universe Translation-en [228 kB]  
Get:26 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/universe amd64 c-n-f Metadata [22.1 kB]  
Get:27 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/multiverse amd64 Packages [42.1 kB]  
Get:28 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/multiverse Translation-en [10.1 kB]  
Get:29 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-updates/multiverse amd64 c-n-f Metadata [472 B]  
Get:30 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-backports/main amd64 Packages [41.7 kB]  
Get:31 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-backports/main Translation-en [10.5 kB]  
Get:32 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-backports/main amd64 c-n-f Metadata [388 B]  
Get:33 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-backports/restricted amd64 c-n-f Metadata [116 B]  
Get:34 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-backports/universe amd64 Packages [24.3 kB]  
Get:35 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-backports/universe Translation-en [16.5 kB]  
Get:36 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-backports/universe amd64 c-n-f Metadata [644 B]  
Get:37 http://us-east-1.ec2.archive.ubuntu.com/ubuntu jammy-backports/multiverse amd64 c-n-f Metadata [116 B]  
Get:38 http://security.ubuntu.com/ubuntu jammy-security/main amd64 Packages [1062 kB]  
Get:39 http://security.ubuntu.com/ubuntu jammy-security/main Translation-en [201 kB]  
Get:40 http://security.ubuntu.com/ubuntu jammy-security/restricted amd64 Packages [1244 kB]  
Get:41 http://security.ubuntu.com/ubuntu jammy-security/restricted Translation-en [203 kB]  
Get:42 http://security.ubuntu.com/ubuntu jammy-security/universe amd64 Packages [826 kB]  
Get:43 http://security.ubuntu.com/ubuntu jammy-security/universe Translation-en [156 kB]  
93% [14 Commands-amd64 store 0 B]
```

After about 15-20 minutes...

sudo reboot

Reboot the system

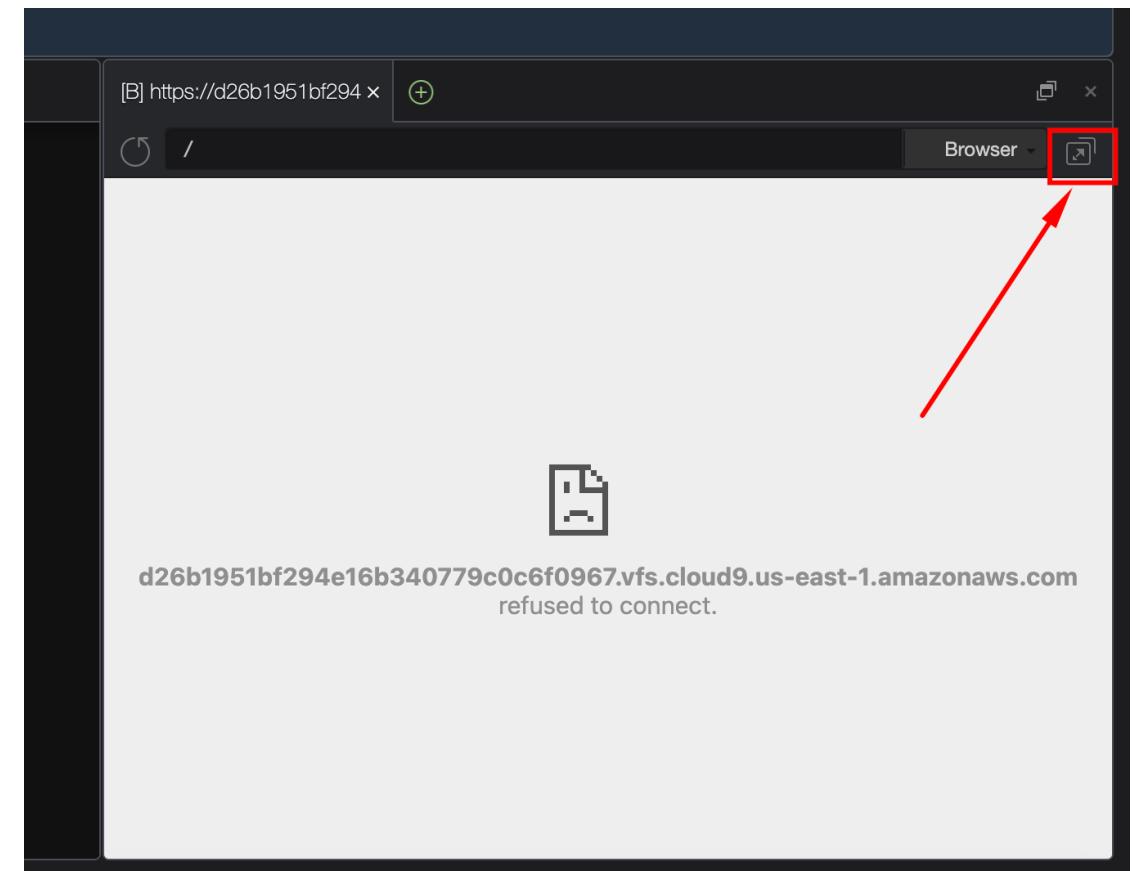
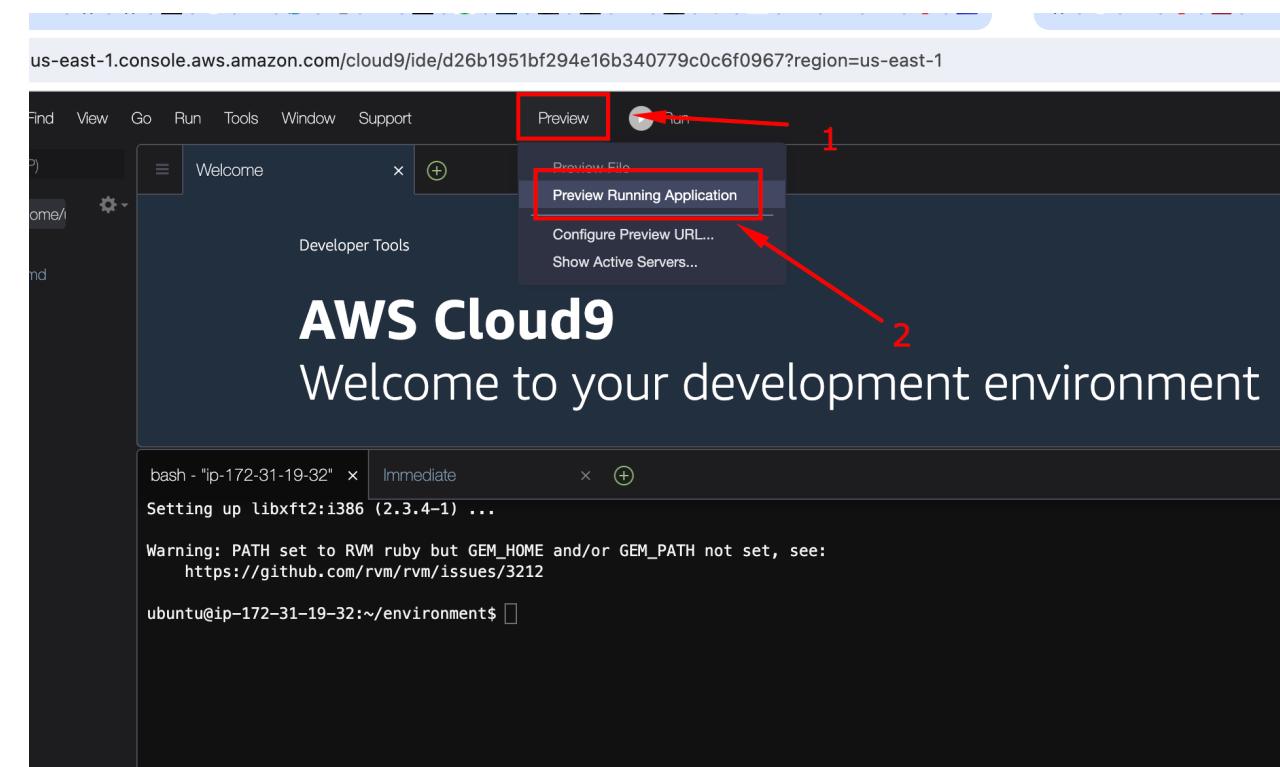


AWS Cloud9

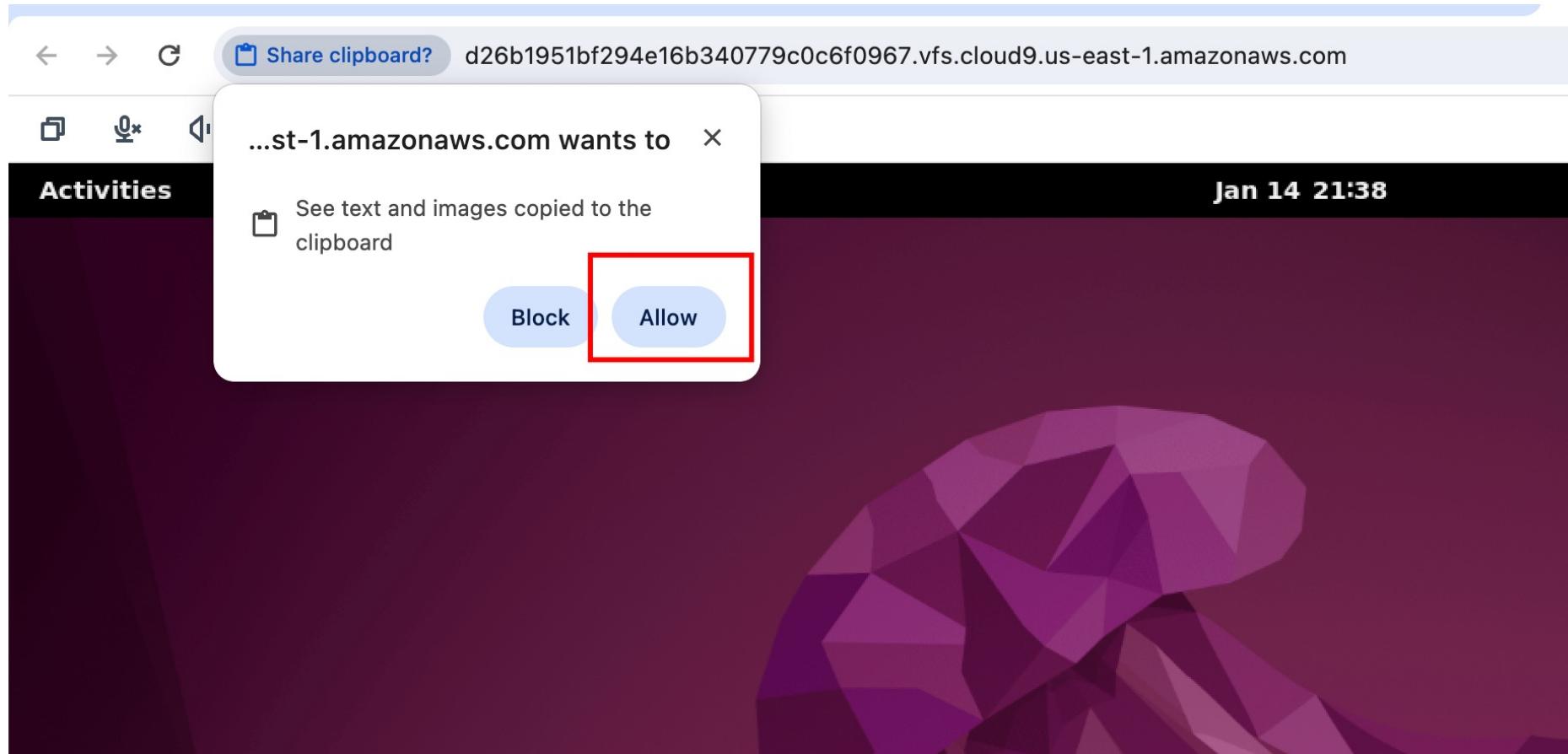
Welcome to your development environment

```
bash - "ip-172-31-19-32" ✘ Immediate ✘ +  
Setting up libxext6:i386 (2:1.3.4-1build1) ...  
Setting up libxft2:i386 (2.3.4-1) ...  
Setting up libxi6:i386 (2:1.8-1build1) ...  
Setting up libxtst6:i386 (2:1.2.3-1build4) ...  
Processing triggers for libc-bin (2.35-0ubuntu3.6) ...  
Scanning processes...  
Scanning candidates...  
Scanning linux images...  
  
Running kernel seems to be up-to-date.  
  
Restarting services...  
  
Service restarts being deferred:  
/etc/needrestart/restart.d/dbus.service  
systemctl restart docker.service  
systemctl restart getty@tty1.service  
systemctl restart networkd-dispatcher.service  
systemctl restart systemd-logind.service  
systemctl restart unattended-upgrades.service  
systemctl restart user@1000.service  
  
No containers need to be restarted.  
  
No user sessions are running outdated binaries.  
  
No VM guests are running outdated hypervisor (qemu) binaries on this host.  
voclabs:~/environment/ece2613 $ sudo reboot
```

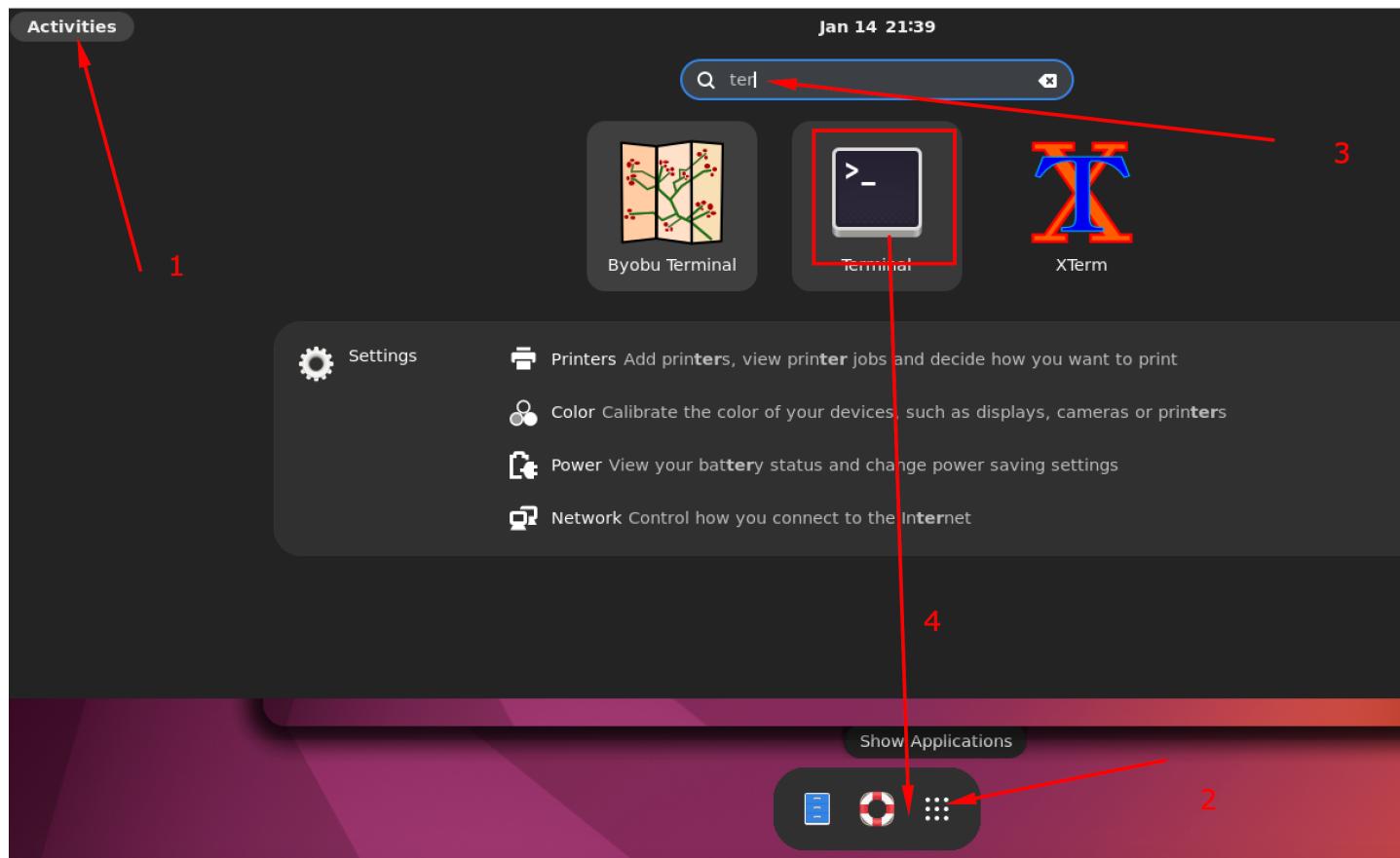
Xwindow access



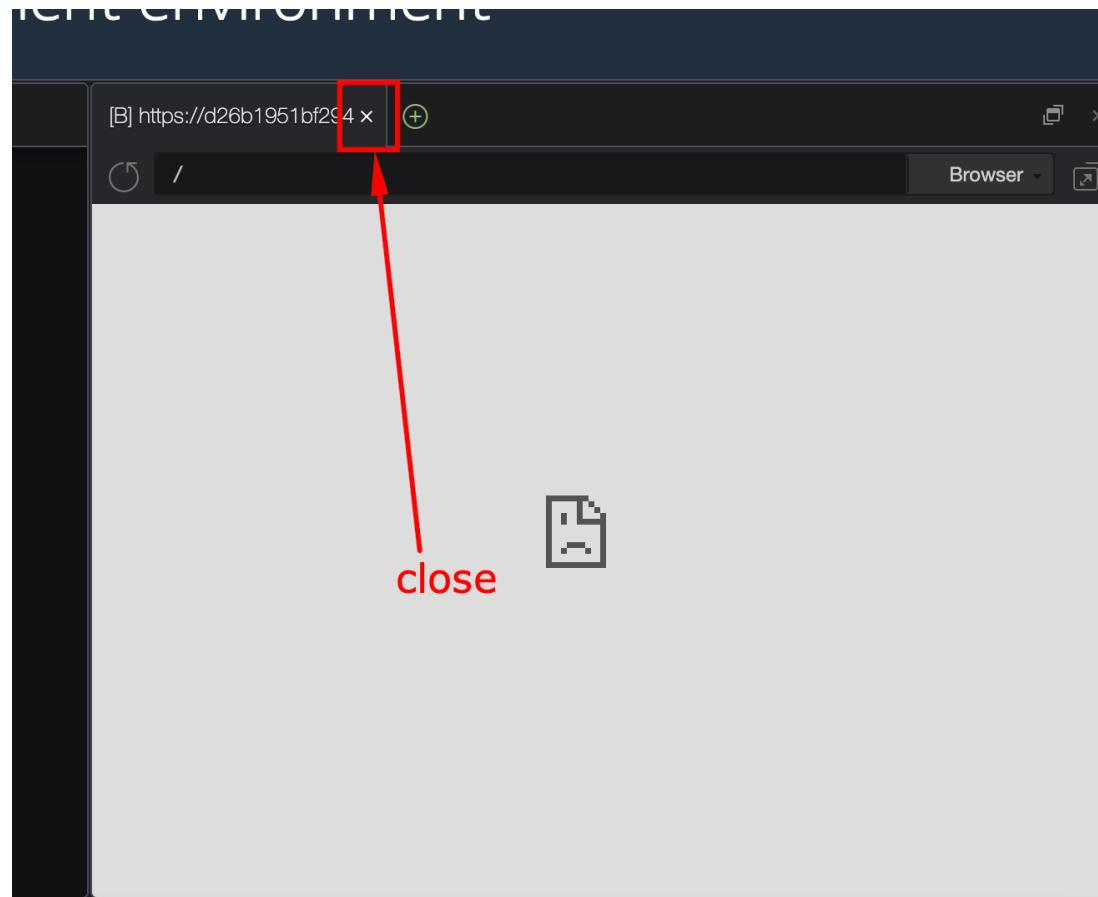
Allow xwindow



Place terminal in task bar

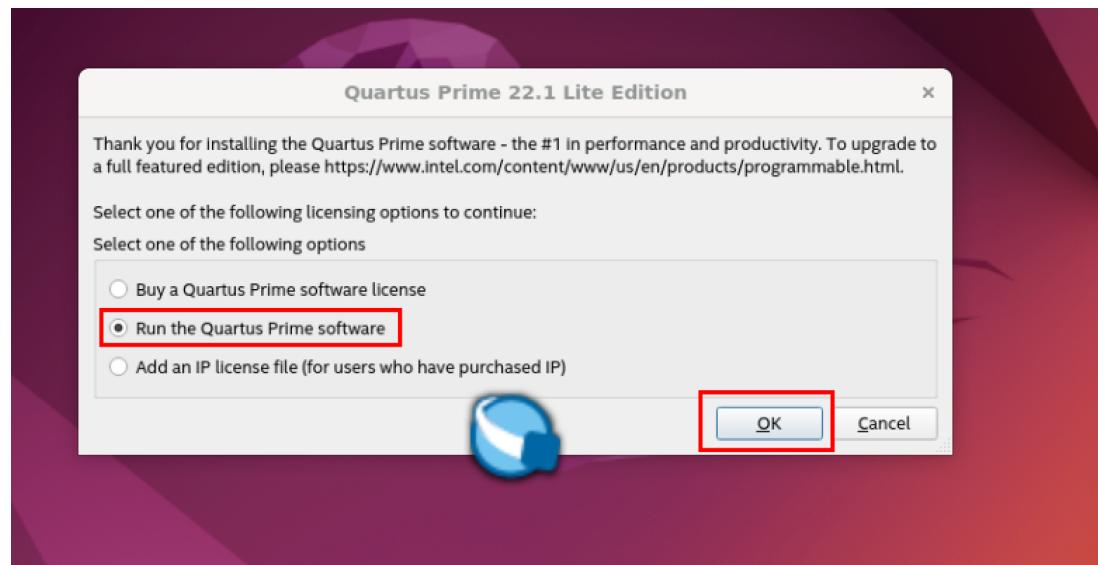


Close access to xwindow

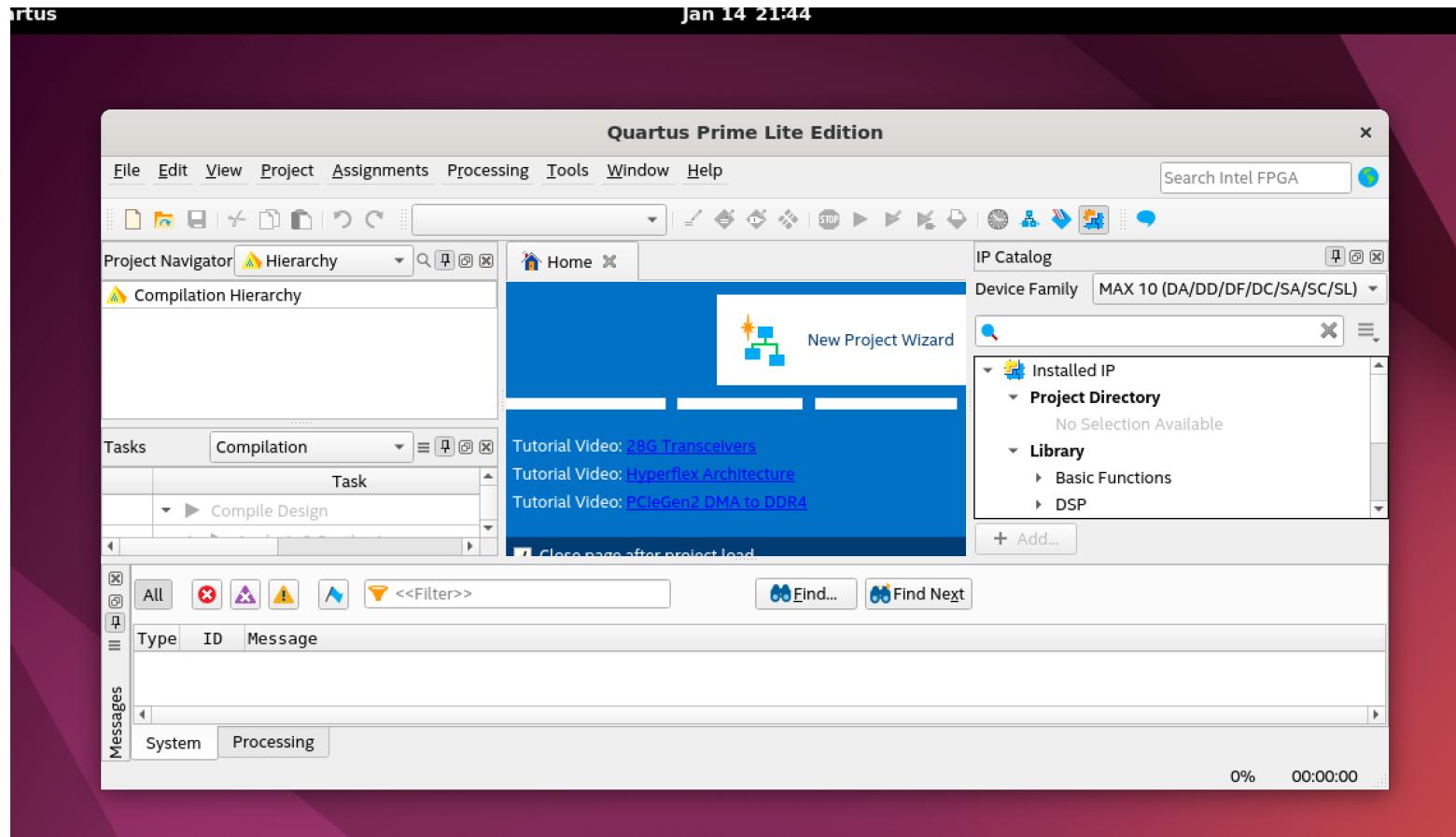


Open quartus in cloud 9 terminal

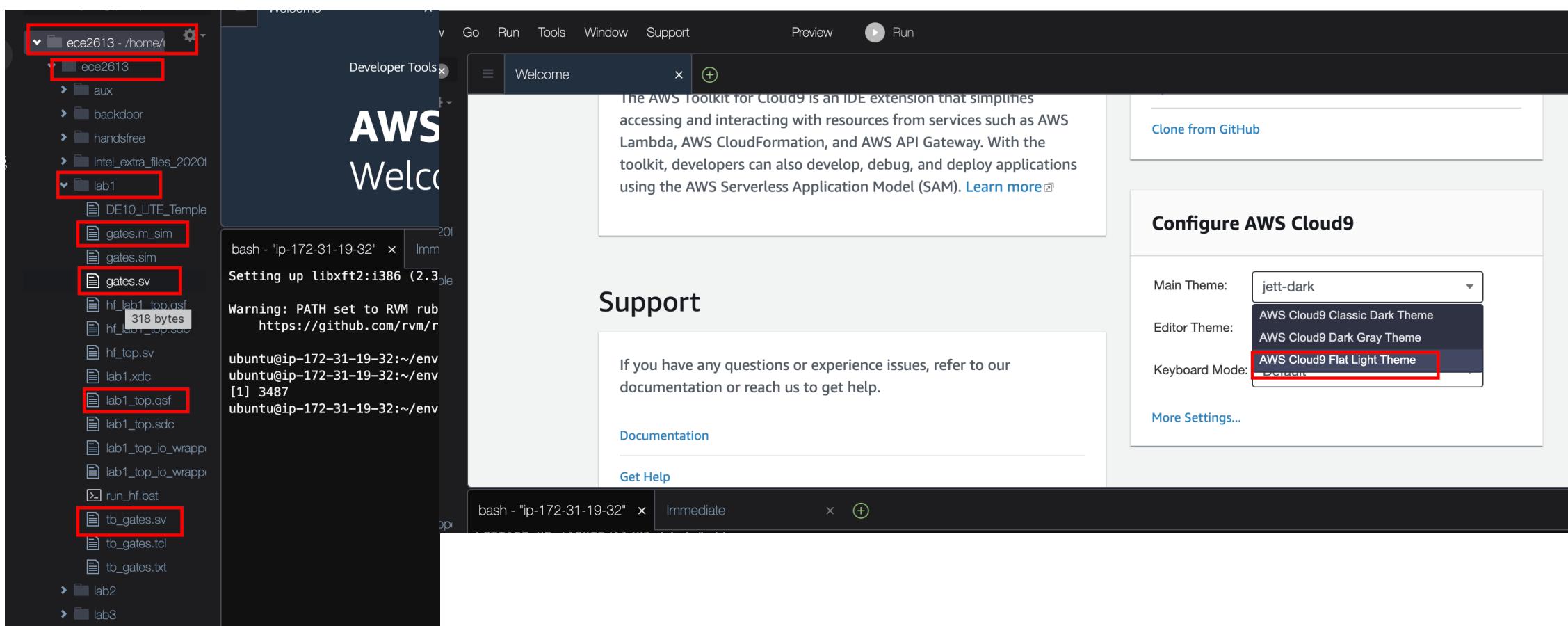
```
bash ip-172-31-19-32 ~ immediate
Setting up libxft2:i386 (2.3.4-1) ...
Warning: PATH set to RVM ruby but GEM_HOME and/or GEM_PATH not set, see:
https://github.com/rvm/rvm/issues/3212
ubuntu@ip-172-31-19-32:~/environment$ export DISPLAY=:0
ubuntu@ip-172-31-19-32:~/environment$ quartus &
```



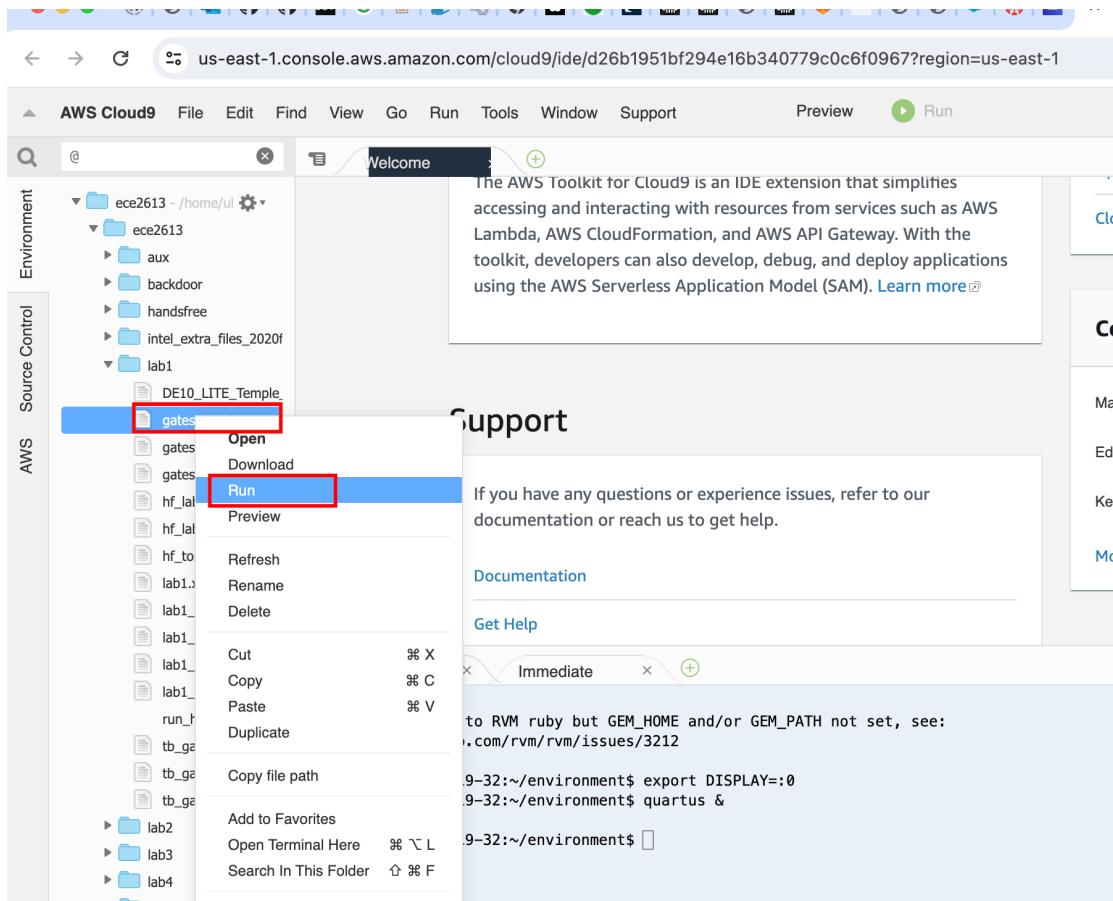
Quartus in xwindow



Cloud 9 file listing



Check m_sim file



```
# Loading work.gates
# do gates.m_sim
# Mismatch--loop index i: 0; input: 00, expected: 1000, received: xxxx
# Mismatch--loop index i: 1; input: 01, expected: 1110, received: xxxx
# Mismatch--loop index i: 2; input: 10, expected: 1110, received: xxxx
# Mismatch--loop index i: 3; input: 11, expected: 0011, received: xxxx
# Simulation complete - 4 mismatches!!!
# ** Note: $finish : tb_gates.sv(64)
#   Time: 80 ns Iteration: 0 Instance: /tb_gates
# End time: 21:48:13 on Jan 14, 2024, Elapsed time: 0:00:00
# Errors: 0, Warnings: 0
```

Process exited with code: 0

Check qsf file ...

The screenshot shows a terminal window with the following command and its output:

```
bash - "ip-172-31" * Immediate * ece2613/lab1/ga * ece2613/lab1/lab *
```

Command: ece2613/lab1/lab1_top.qsf

```
INFO: The Intel FPGA IP License Agreement, or other applicable license
Info: agreement, including, without limitation, that your use is for
Info: the sole purpose of programming logic devices manufactured by
Info: Intel and sold by Intel or its authorized distributors. Please
Info: refer to the applicable agreement for further details, at
Info: https://fpgasoftware.intel.com/eula.
Info: Processing started: Sun Jan 14 21:49:26 2024
Info: Command: quartus_cpf -c -q 1MHz -g 3.3 -n p output_files/lab1_top.sof output_files/lab1_top.svf
Info: Quartus Prime Convert_programming_file was successful. 0 errors, 0 warnings
Info: Peak virtual memory: 323 megabytes
Info: Processing ended: Sun Jan 14 21:49:26 2024
Info: Elapsed time: 00:00:00
Info: Total CPU time (on all processors): 00:00:01
```

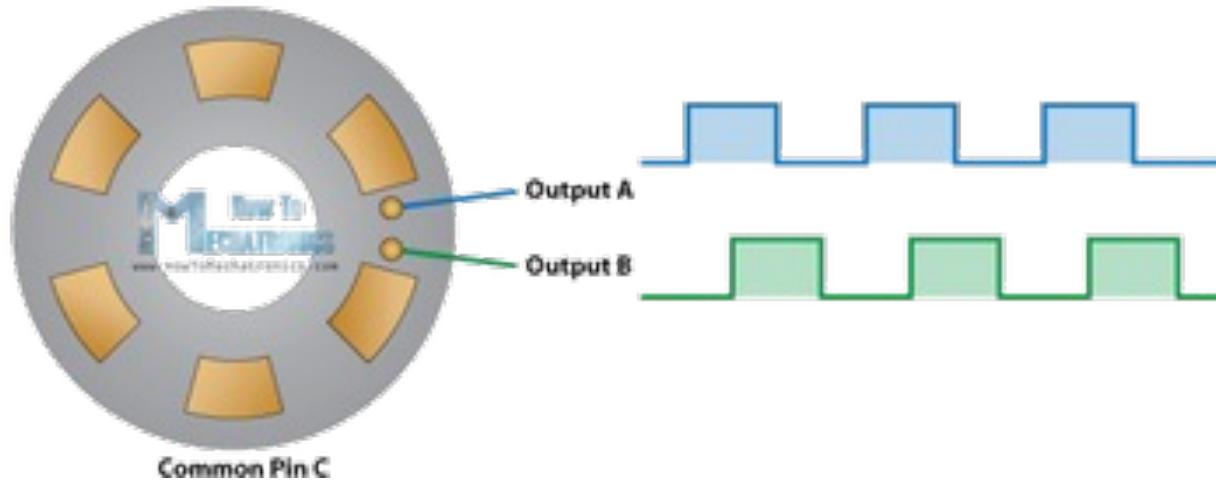
The terminal window is part of a larger interface with the following components:

- Left Panel:** A file browser showing a directory structure under "ece2613". A context menu is open over the file "lab1_top.qsf", with options: Open, Download, Run, Refresh, Rename, Delete, Cut, Copy, Paste, Duplicate, Copy file path, Add to Favorites, Open Terminal Here, Search In This Folder, New File, and Show Folders.
- Middle Panel:** A "Support" section with a "Documentation" link and a "Get Help" link.
- Right Panel:** A "Support" section with a "Main Theme: AWS Cloud9", "Editor Theme: Cloud9", "Keyboard Mode: Default", and a "More Settings..." button.
- Bottom Panel:** A "Support" section with a "Documentation" link and a "Get Help" link.

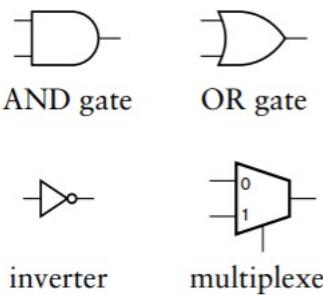
For the next class...

- Think about how you would design a vendor machine with instruction...

Rotatory encoder – example for FPGA



Gate symbols



A	B	AND	OR	XOR	Inverter (\bar{A})
0	0	0	0	0	1
0	1	0	1	1	1
1	0	0	1	1	0
1	1	1	1	0	0

Vat example

EXAMPLE 1.1 Suppose a factory has two vats, only one of which is used at a time. The liquid in the vat in use needs to be at the right temperature, between 25°C and 30°C . Each vat has two temperature sensors indicating whether the temperature is above 25°C and above 30°C , respectively. The vats also have low-level sensors. The supervisor needs to be woken up by a buzzer when the temperature is too high or too low or the vat level is too low. He has a switch to select which vat is in use. Design a circuit of gates to activate the buzzer as required.

SOLUTION Example 1.1 uses the basic logic functions:

Solution

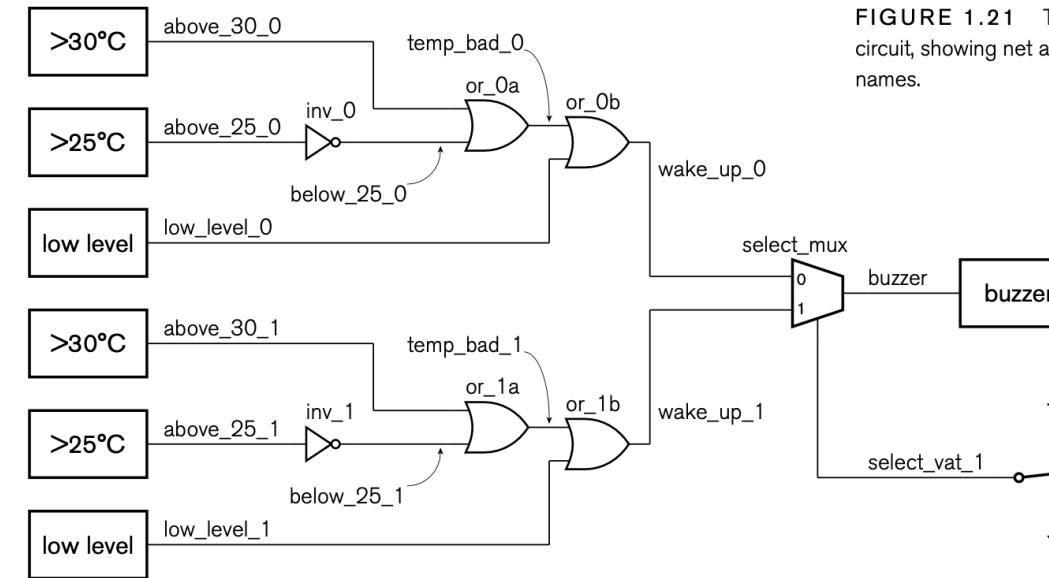
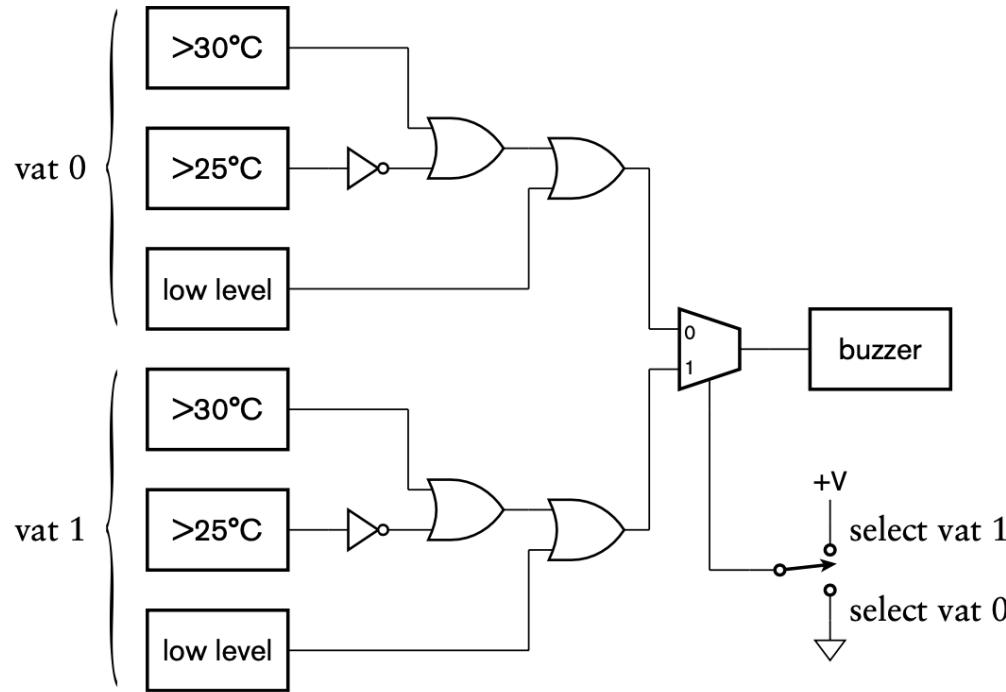


FIGURE 1.21 The vat buzzer circuit, showing net and component names.

Verilog

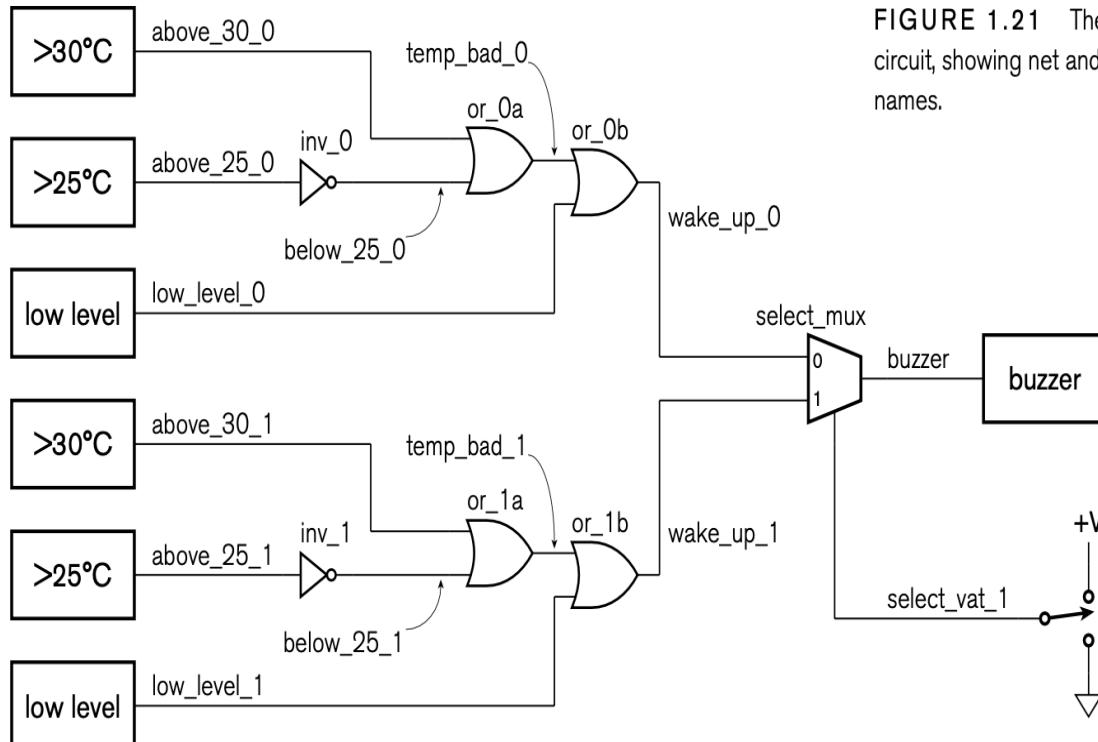


FIGURE 1.21 The vat buzzer circuit, showing net and component names.

```
module vat_buzzer_struct
( output buzzer,
  input above_25_0, above_30_0, low_level_0,
  input above_25_1, above_30_1, low_level_1,
  input select_vat_1 );

  wire below_25_0, temp_bad_0, wake_up_0;
  wire below_25_1, temp_bad_1, wake_up_1;

  // components for vat 0
  not inv_0 (below_25_0, above_25_0);
  or  or_0a (temp_bad_0, above_30_0, below_25_0);
  or  or_0b (wake_up_0, temp_bad_0, low_level_0);

  // components for vat 1
  not inv_1 (below_25_1, above_25_1);
  or  or_1a (temp_bad_1, above_30_1, below_25_1);
  or  or_1b (wake_up_1, temp_bad_1, low_level_1);

  mux2 select_mux (buzzer, select_vat_1, wake_up_0, wake_up_1);

endmodule
```

Block diagram and Verilog code

```
module vat_buzzer_struct
( output buzzer,
  input above_25_0, above_30_0, low_level_0,
  input above_25_1, above_30_1, low_level_1,
  input select_vat_1 );

  wire below_25_0, temp_bad_0, wake_up_0;
  wire below_25_1, temp_bad_1, wake_up_1;

  // components for vat 0
  not inv_0 (below_25_0, above_25_0);
  or or_0a (temp_bad_0, above_30_0, below_25_0);
  or or_0b (wake_up_0, temp_bad_0, low_level_0);

  // components for vat 1
  not inv_1 (below_25_1, above_25_1);
  or or_1a (temp_bad_1, above_30_1, below_25_1);
  or or_1b (wake_up_1, temp_bad_1, low_level_1);

  mux2 select_mux (buzzer, select_vat_1, wake_up_0, wake_up_1);

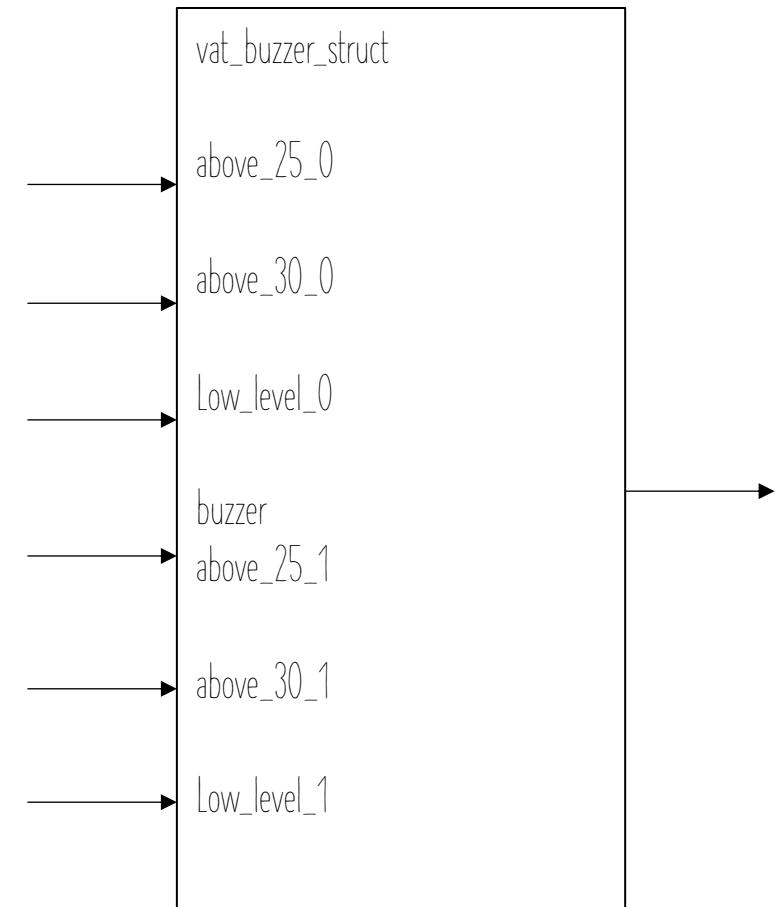
endmodule
```

```
module vat_buzzer_behavior
( output buzzer,
  input above_25_0, above_30_0, low_level_0,
  input above_25_1, above_30_1, low_level_1,
  input select_vat_1 );

  assign buzzer =
    select_vat_1 ? low_level_1 | (above_30_1 | ~above_25_1)
                 : low_level_0 | (above_30_0 | ~above_25_0);

endmodule
```

use gate primitive



use logic behavior

Soda vending machine

- Suppose a soda vending machine has two choices of soda, only one of which is dispensed at a time. The soda in the chosen slot needs to have the right cost, between \$2 and \$3. Each slot has two cost sensors indicating whether the cost is above \$3 and above \$20, respectively. The slots also have zero-level sensors. The supervisor needs to be notified by a dispenser when the cost is too high or too low, or the soda level is too low. They have a switch to select which soda slot is in use. Design a circuit of gates to activate the dispenser as required.

Timing Diagram

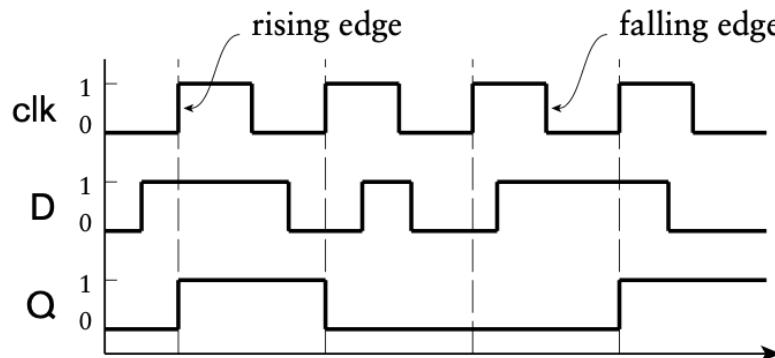


FIGURE 1.7 Timing diagram
for a D flip-flop.

EXERCISE 1.6 Complete the timing diagram in Figure 1.25, showing the operation of a rising-edge-triggered D flip-flop.

