



# Digital Circuit Design

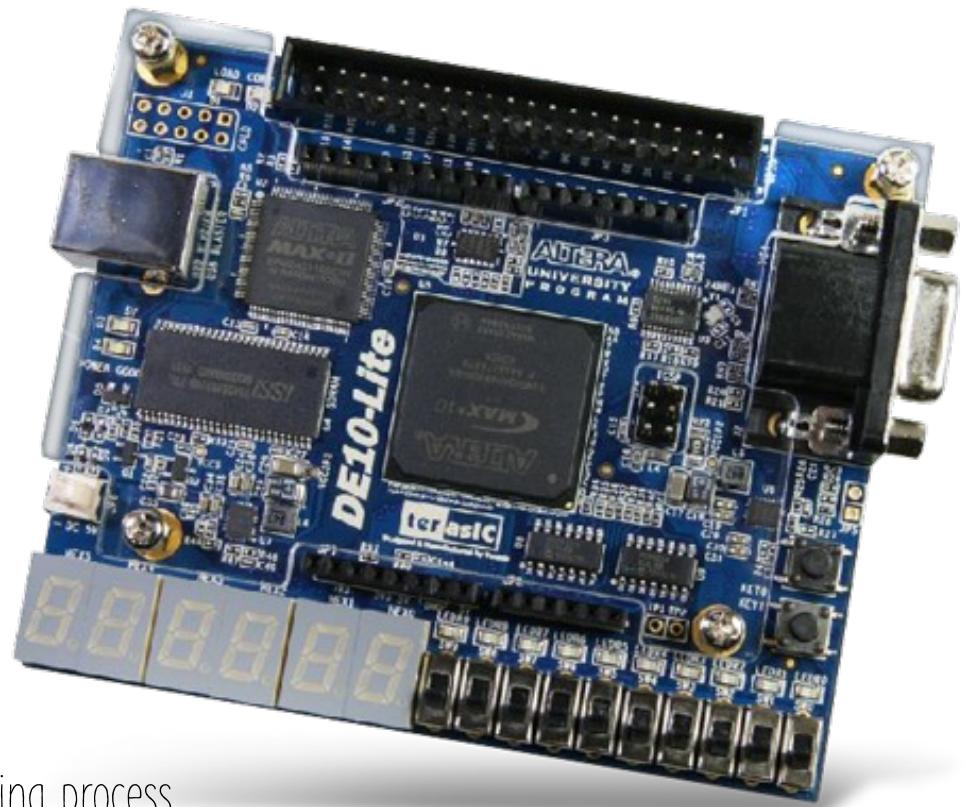
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Li Bai

# What we will cover...

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- 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

---

aws academy student login 1

All Perspectives Images Videos News More Tools

About 15,400,000 results (0.19 seconds)

 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 ...

 Instructure  
<https://awsacademy.instructure.com> · [Translate this page](#) ::

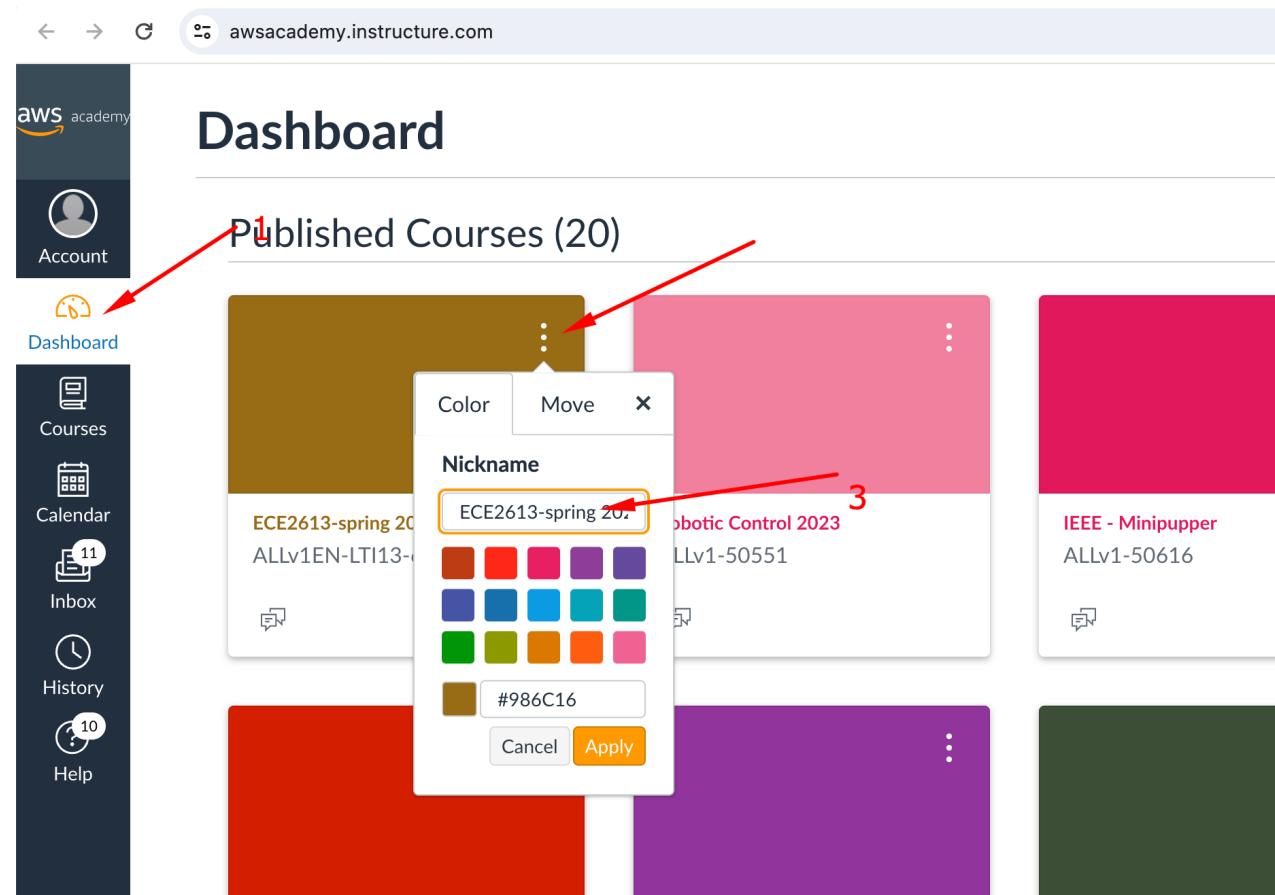
**Untitled** 2  
学生の方はこちらからログインしてください。已注册课程的学生请在这里登录. Educator Login. (For educators who have access to the AWS Academy Portal).

 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

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# Access Learner's Lab

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The screenshot shows a web browser window with the URL `awsacademy.instructure.com/courses/67880/modules`. The page title is `ALLv1EN-LTI13-67880 > Modules`. On the left, a sidebar menu includes `Home`, `Modules` (which is highlighted with a red arrow labeled **1**), `Discussions`, and `Grades`. The main content area displays course modules:

- `Course Welcome and Overview`
- `AWS Academy Learner Lab Compliance and Security`
- `AWS Academy Learner Lab` (with a red arrow labeled **2** pointing to the `Launch AWS Academy Learner Lab` button)
- `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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I Agree

# Start lab

---

awsacademy.instructure.com/courses/67880/modules/items/6035341

ALLv1EN-LTI... > Modules > AWS Acade... > Launch AWS Academy Learner Lab

AWS

Start Lab

End Lab

AWS Details

Readme

Reset

EN-US

Learner Lab

Environment Overview

Environment Navigation

Access the AWS Management Console

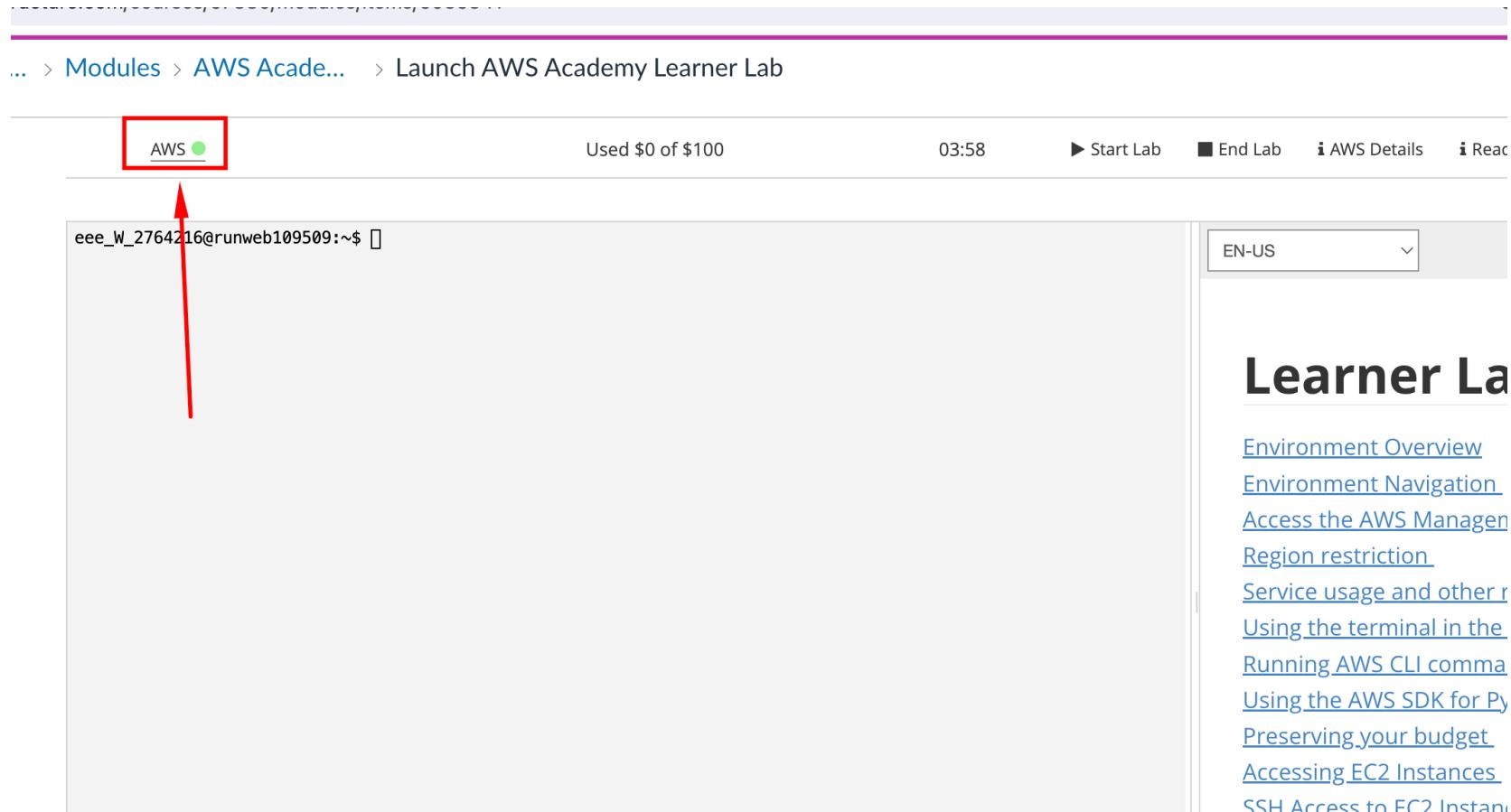
Region restriction

Service usage and other restrictions

A red box highlights the 'Start Lab' button, and a red arrow points to it from below.

# AWS green -> go to console

---



... > Modules > AWS Acade... > Launch AWS Academy Learner Lab

AWS green

Used \$0 of \$100 03:58

▶ Start Lab ■ End Lab AWS Details Read

eee\_W\_2764216@runweb109509:~\$

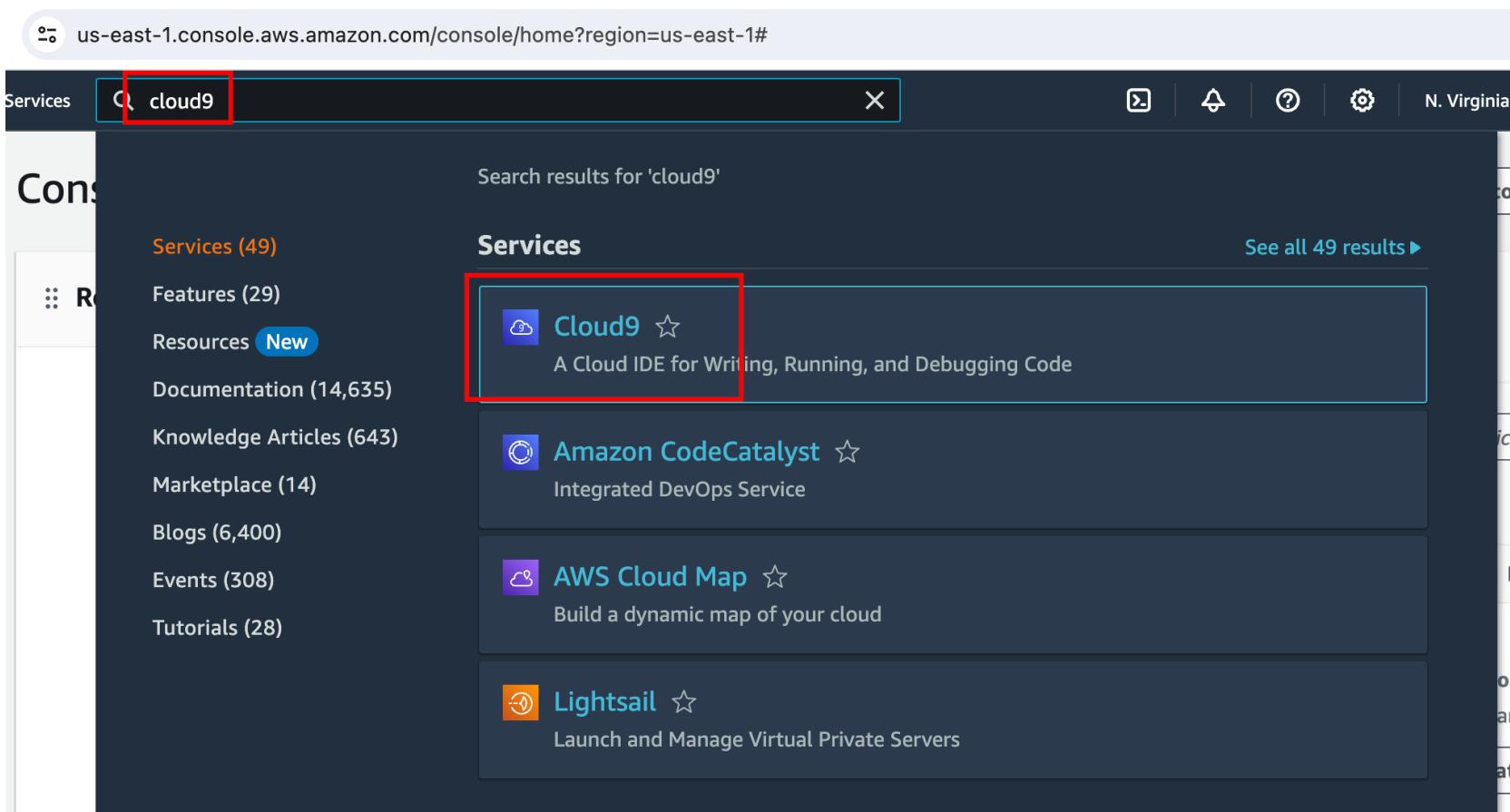
EN-US

**Learner La**

- [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](#)
- [SSH Access to EC2 Instances](#)

# Find cloud9

---



The screenshot shows the AWS Management Console search results for 'cloud9'. The search bar at the top contains the query 'cloud9'. The results are displayed under the 'Services' category, with a total of 49 results. The first result, 'Cloud9', is highlighted with a red box. The description for Cloud9 is: 'A Cloud IDE for Writing, Running, and Debugging Code'. Other results listed are 'Amazon CodeCatalyst', 'AWS Cloud Map', and 'Lightsail'.

us-east-1.console.aws.amazon.com/console/home?region=us-east-1#

Services  X

Search results for 'cloud9'

Services (49) [See all 49 results ▾](#)

Cloud9 ☆  
A Cloud IDE for Writing, Running, and Debugging Code

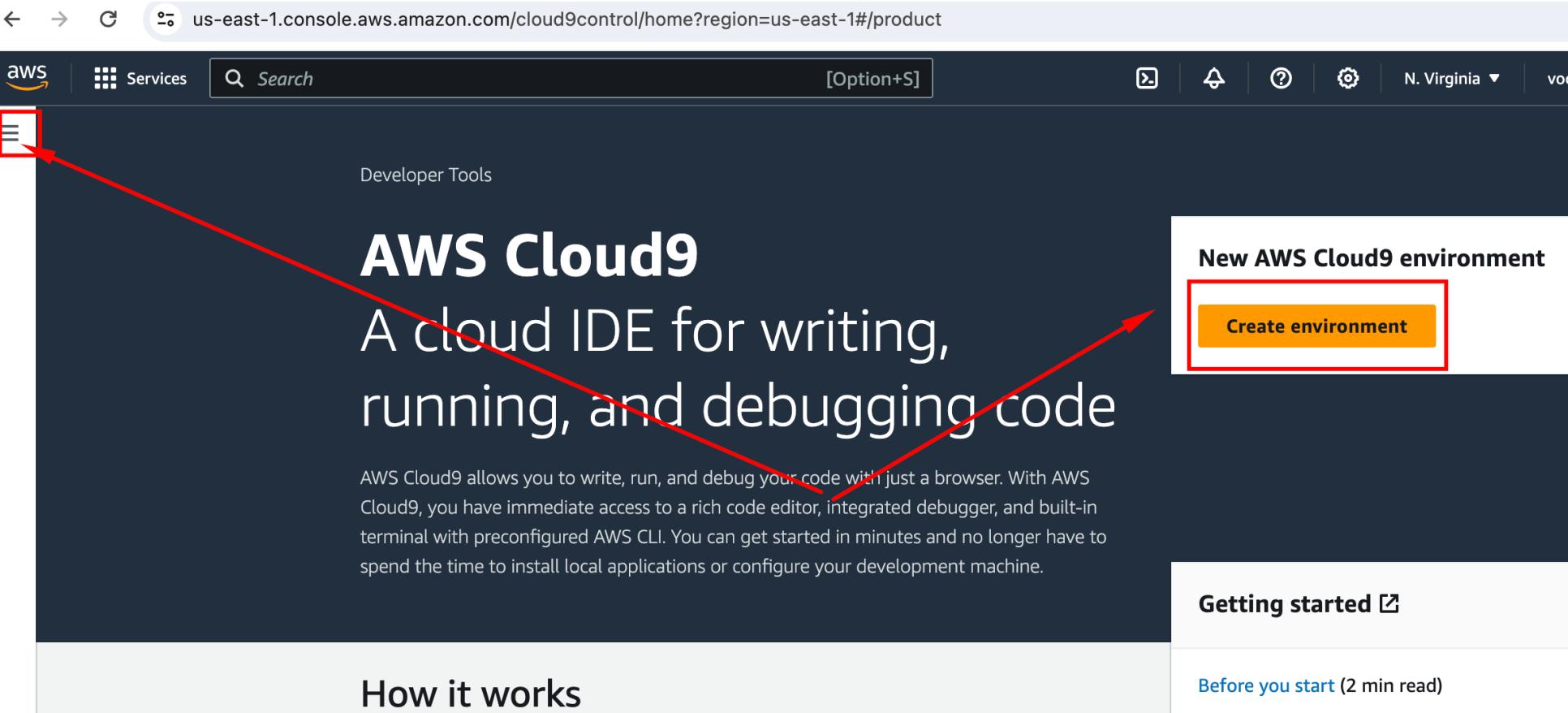
Amazon CodeCatalyst ☆  
Integrated DevOps Service

AWS Cloud Map ☆  
Build a dynamic map of your cloud

Lightsail ☆  
Launch and Manage Virtual Private Servers

# Create environment

---



The screenshot shows the AWS Cloud9 control console interface. At the top, there is a navigation bar with the AWS logo, a 'Services' dropdown, a search bar, and various icons. Below the navigation bar, the main content area has a dark background. On the left, the text 'Developer Tools' is visible. In the center, the heading 'AWS Cloud9' is displayed in large white text, followed by the subtext 'A cloud IDE for writing, running, and debugging code'. Below this, a paragraph of text describes the features of AWS Cloud9. On the right side, there is a white callout box with a black border and a red border around the 'Create environment' button. The callout box contains the text 'New AWS Cloud9 environment' and the button 'Create environment'. At the bottom of the main content area, there are two buttons: 'How it works' and 'Before you start (2 min read)'. The 'Create environment' button is the primary focus, indicated by the red highlighting.

# Ubuntu server cloud9 setup

aws Services Search [Option+S]

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** 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**

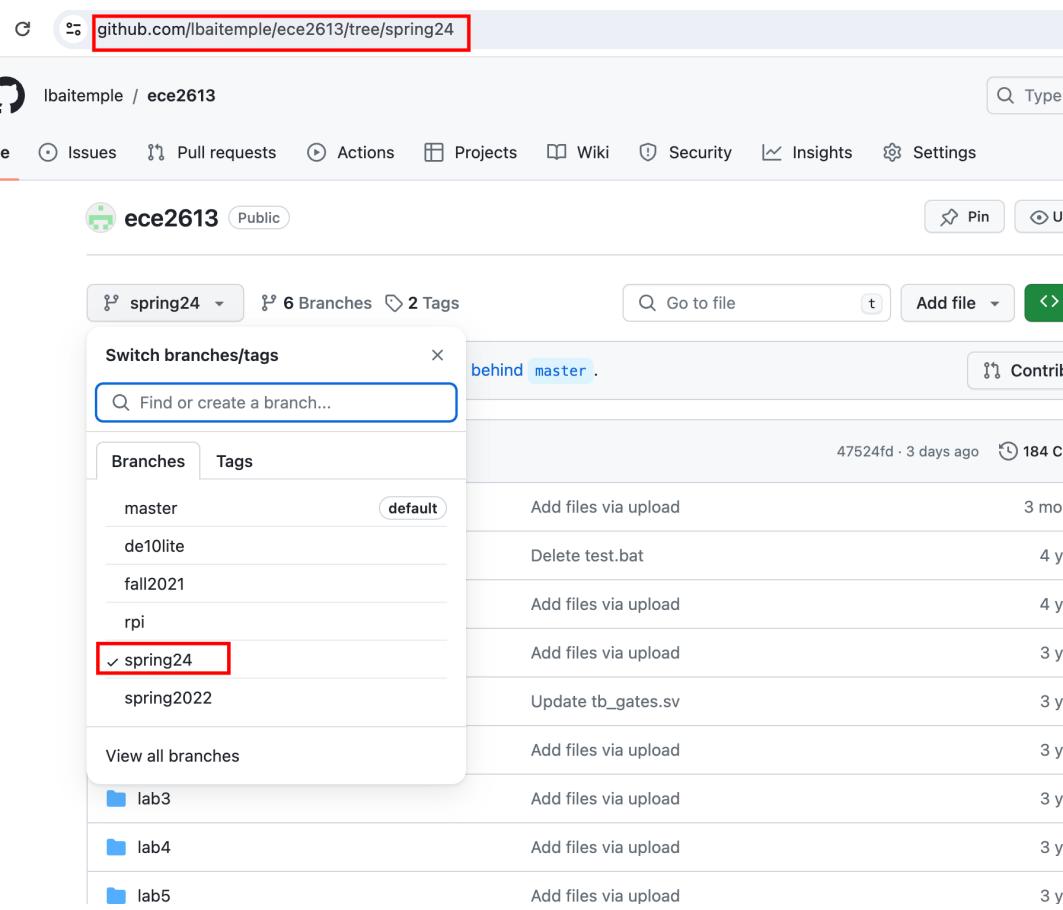
- **AWSServiceRoleForAWSCloud9** - AWS Cloud9 creates a service-linked role for you. This allows AWS Cloud9 to call other AWS services on your behalf.  
You can delete the role from the AWS IAM console once you no longer have any AWS Cloud9 environments. [Learn more](#) 

[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

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...

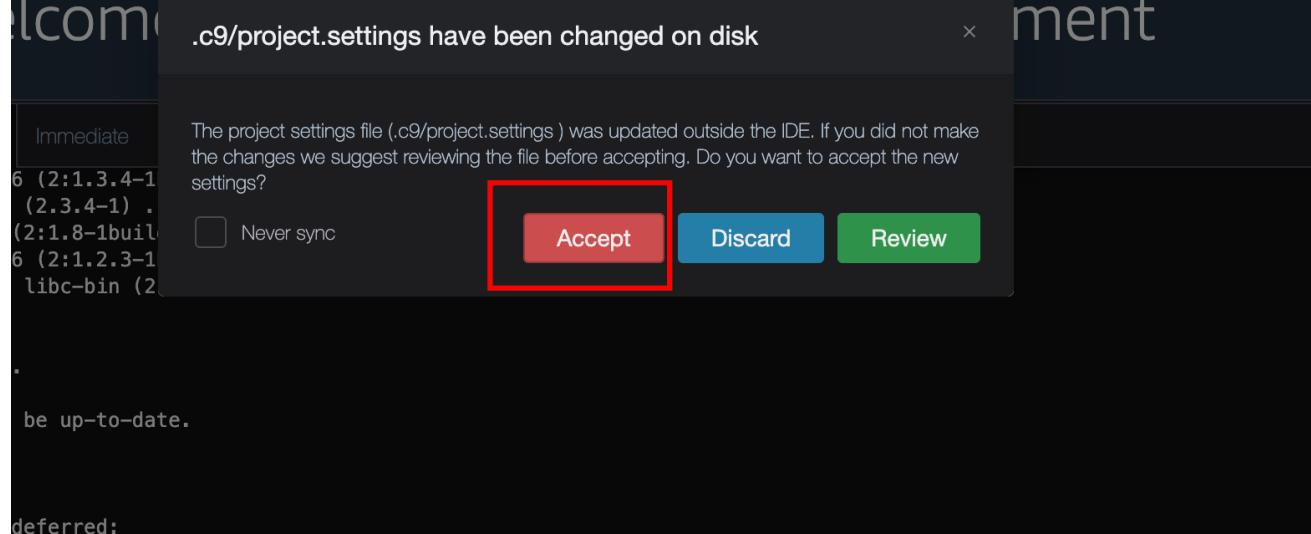
---

sudo reboot

# Reboot the system

VS Cloud9

Welcome



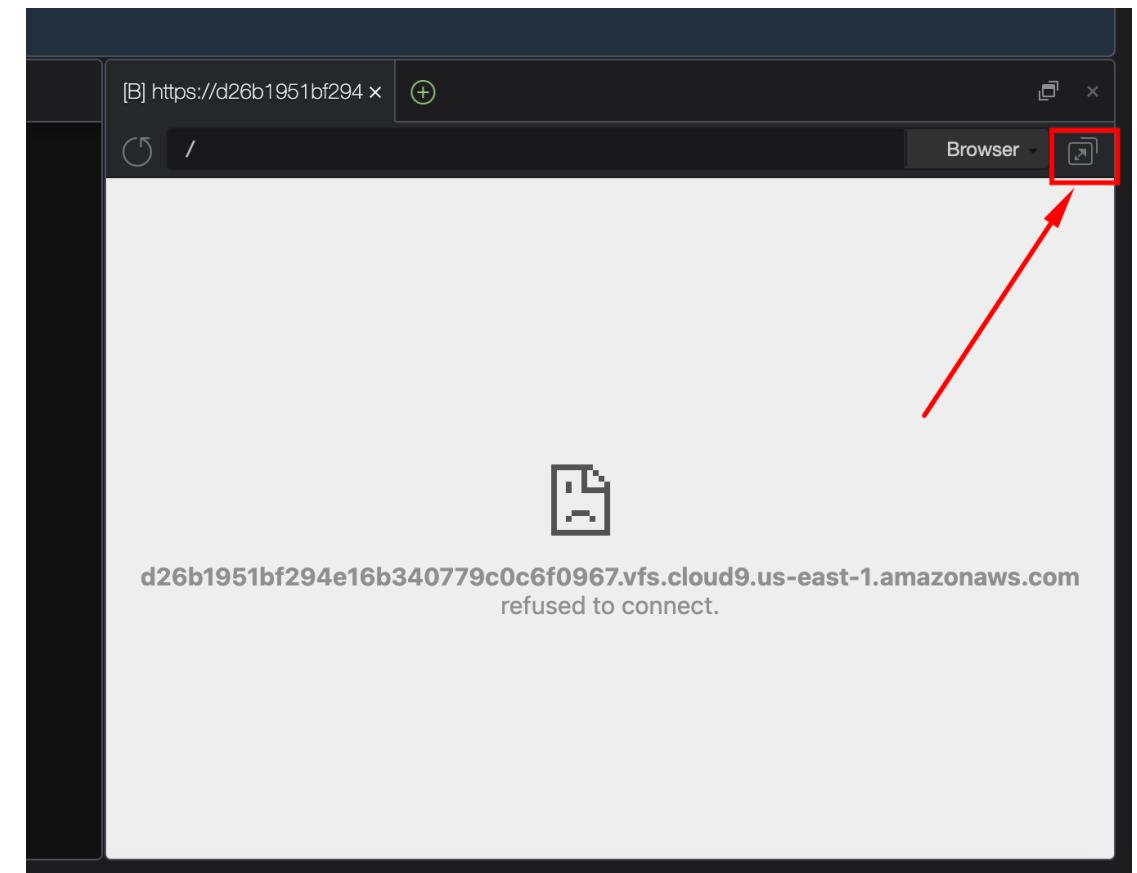
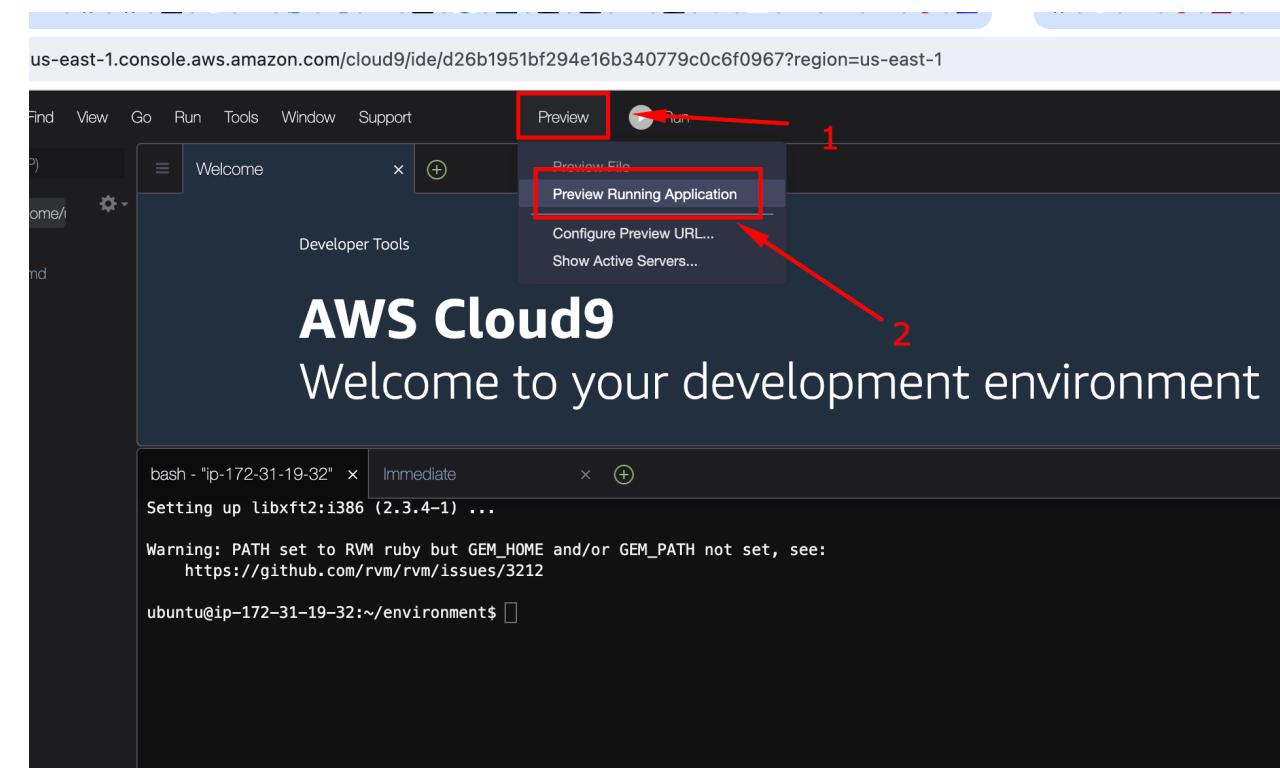
AWS Cloud9

Welcome to your development

```
bash - "ip-172-31-19-32" x Immediate x +  
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
```

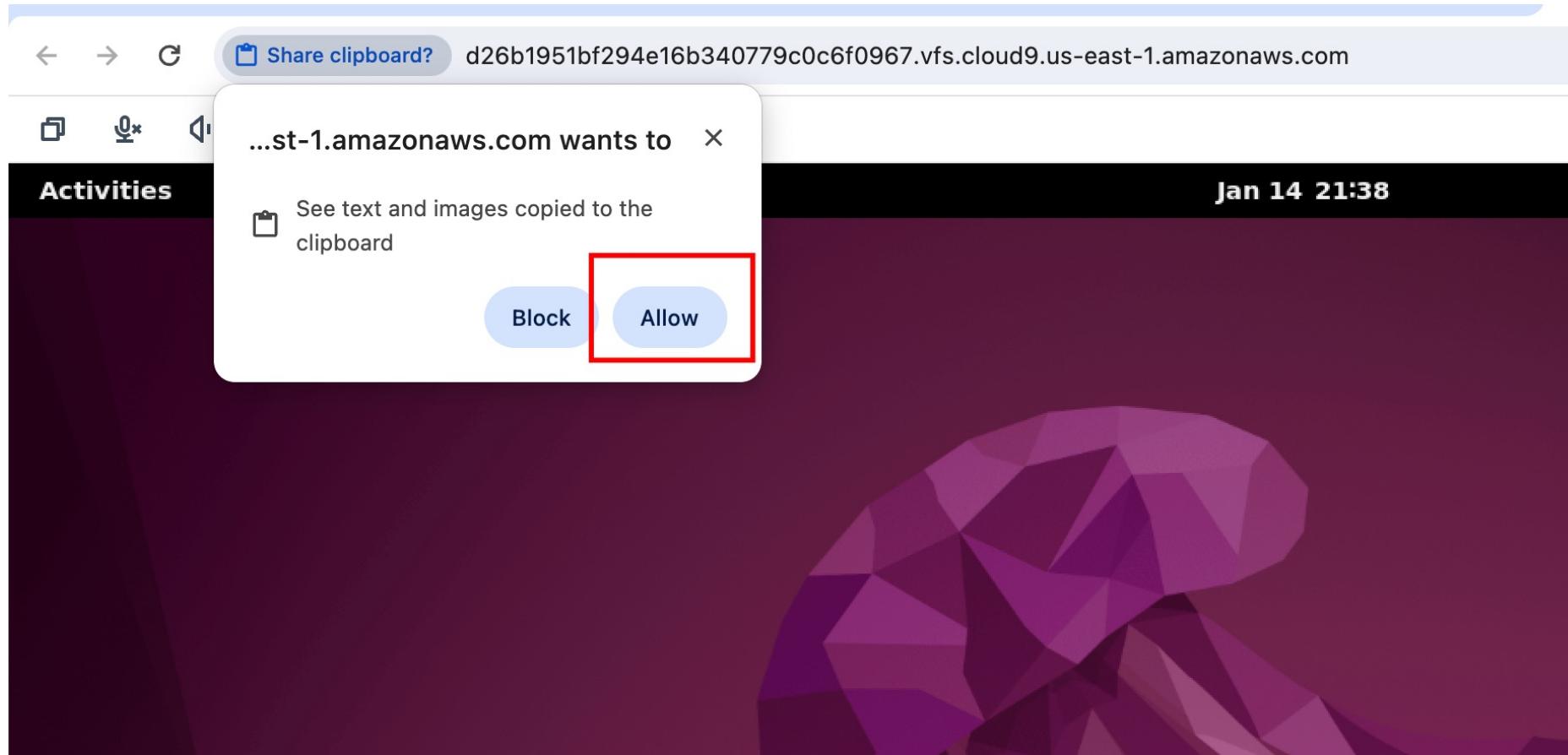
# Xwindow access

---



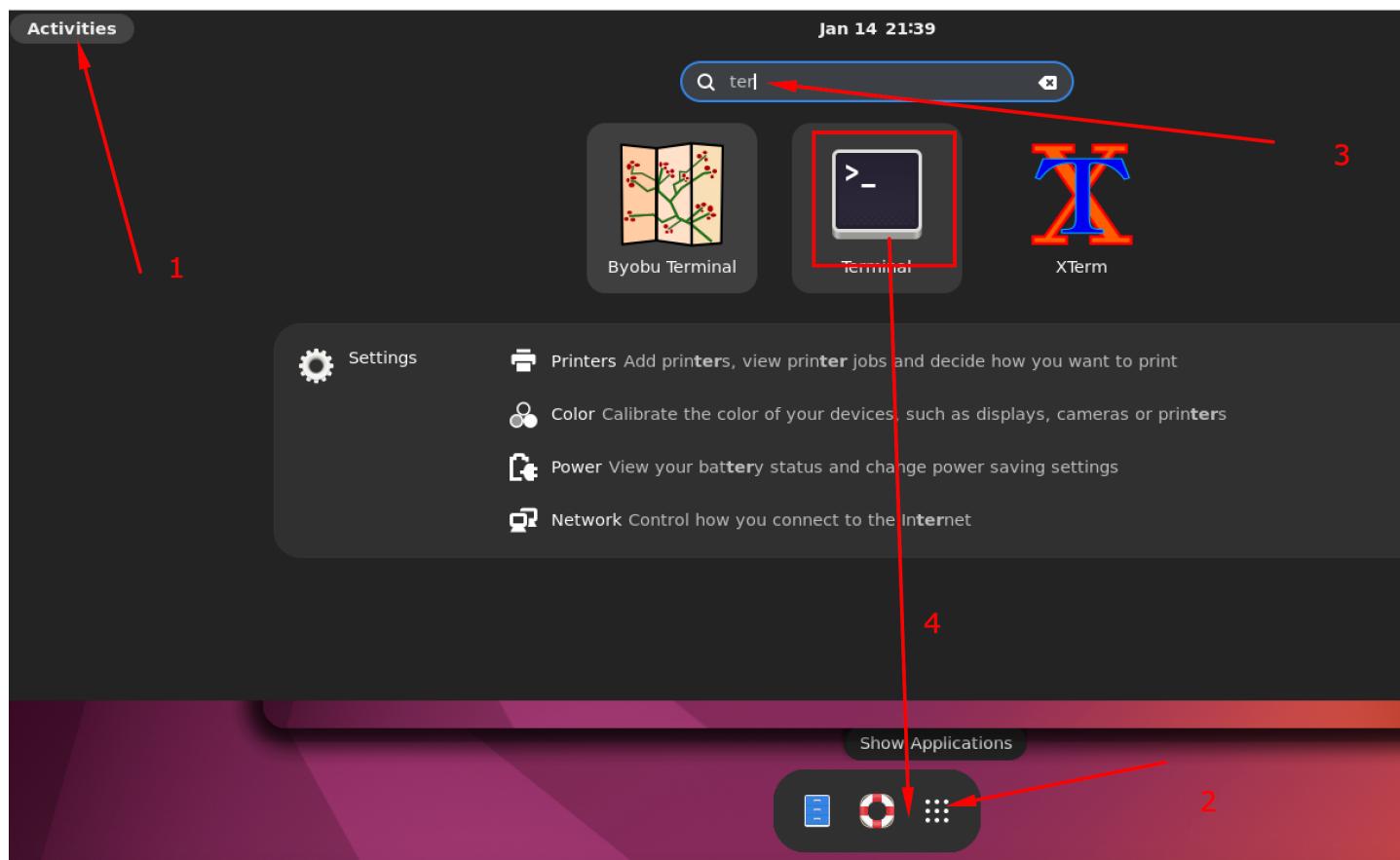
# Allow xwindow

---



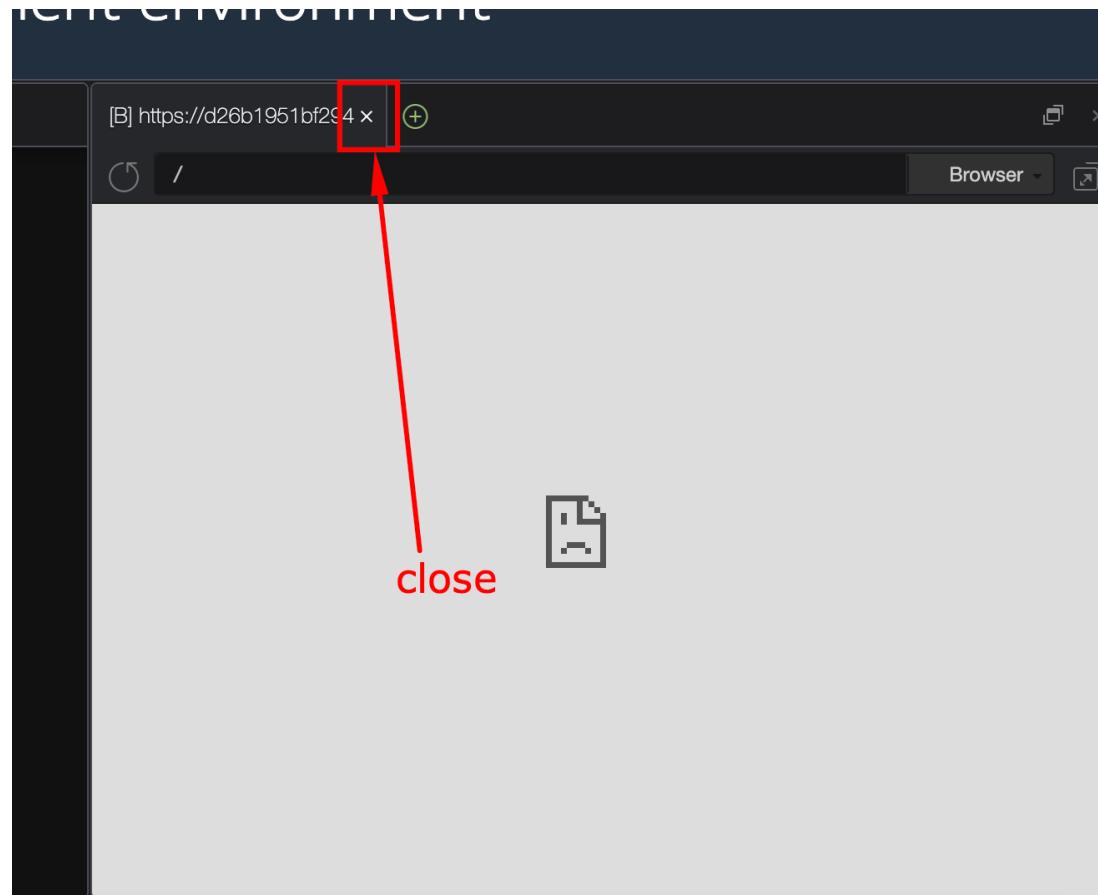
# Place terminal in task bar

---



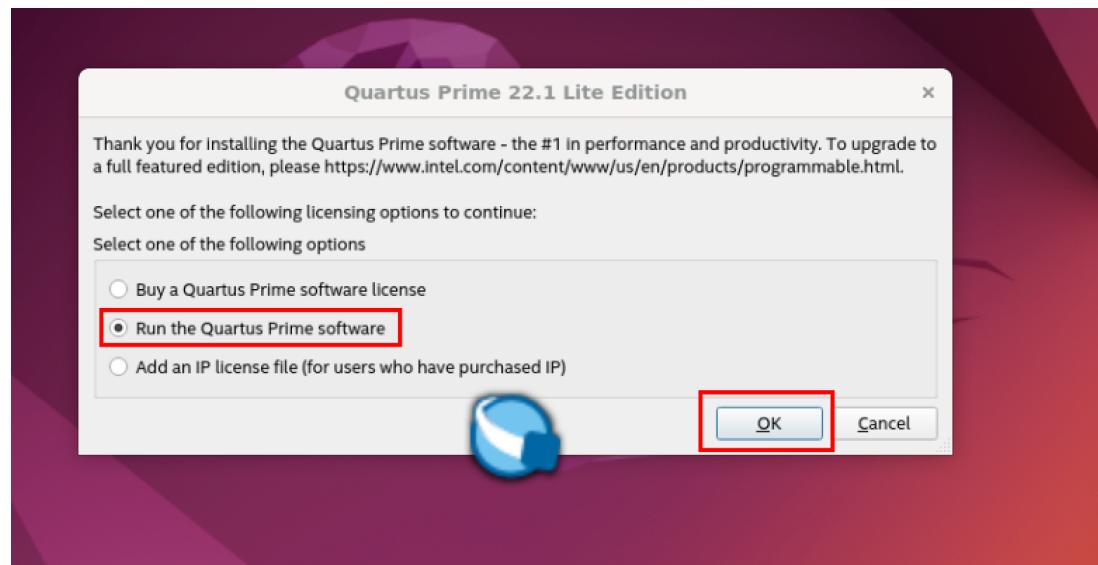
# Close access to xwindow

---



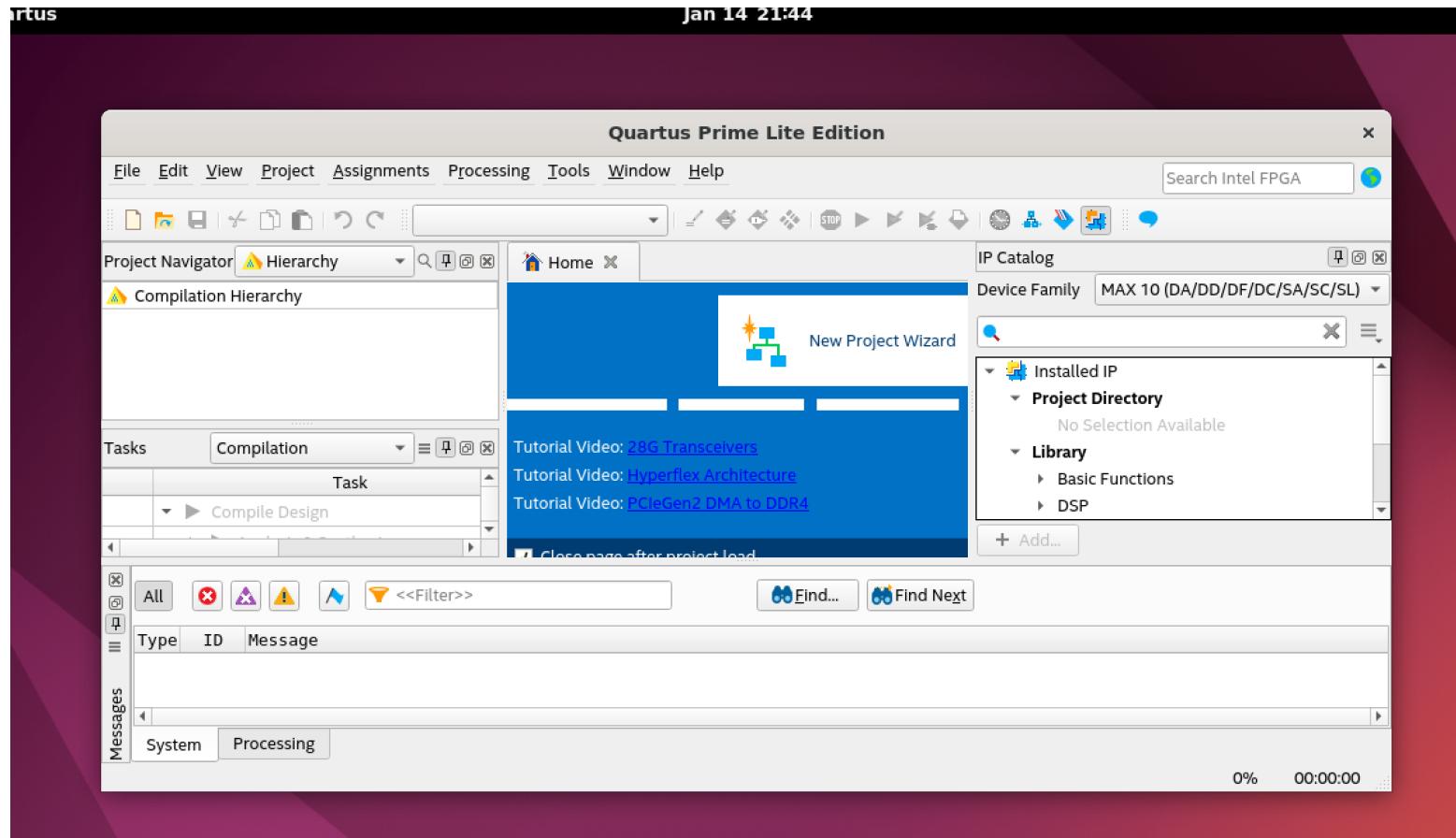
# Open quartus in cloud 9 terminal

```
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 &
```

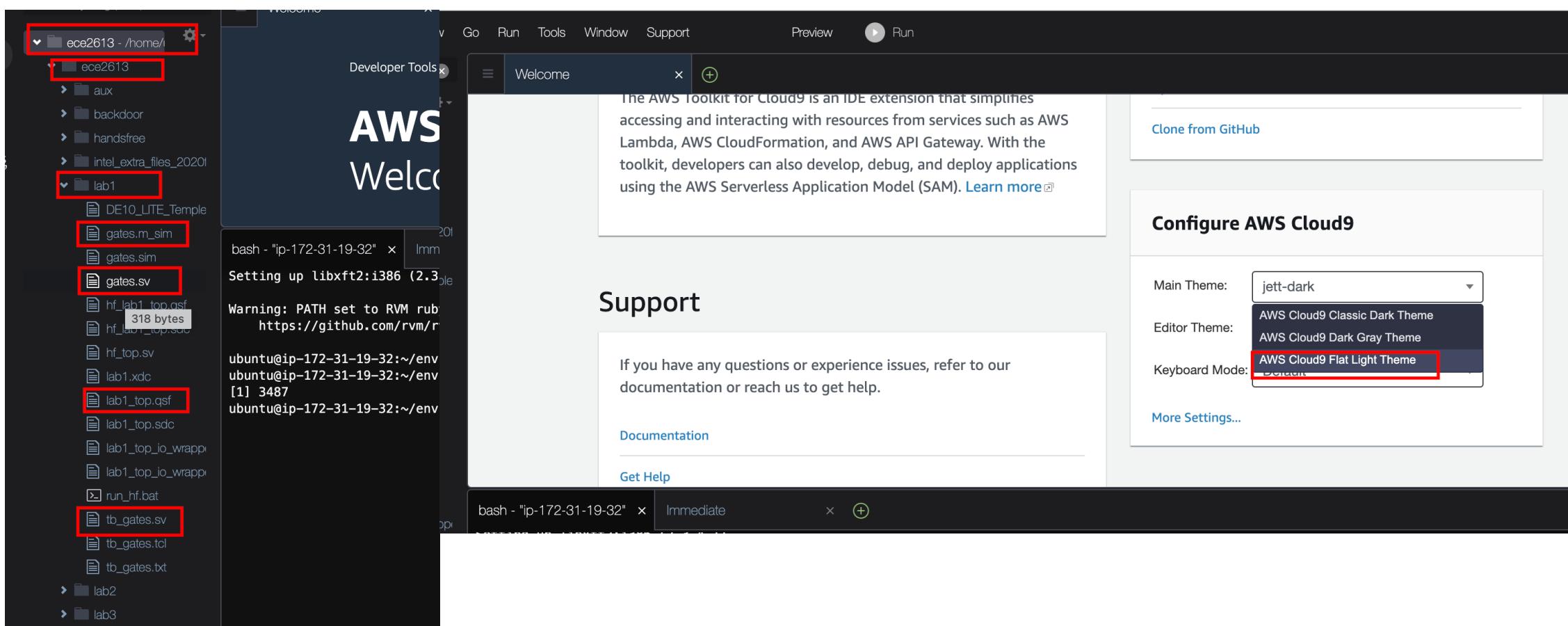


# Quartus in xwindow

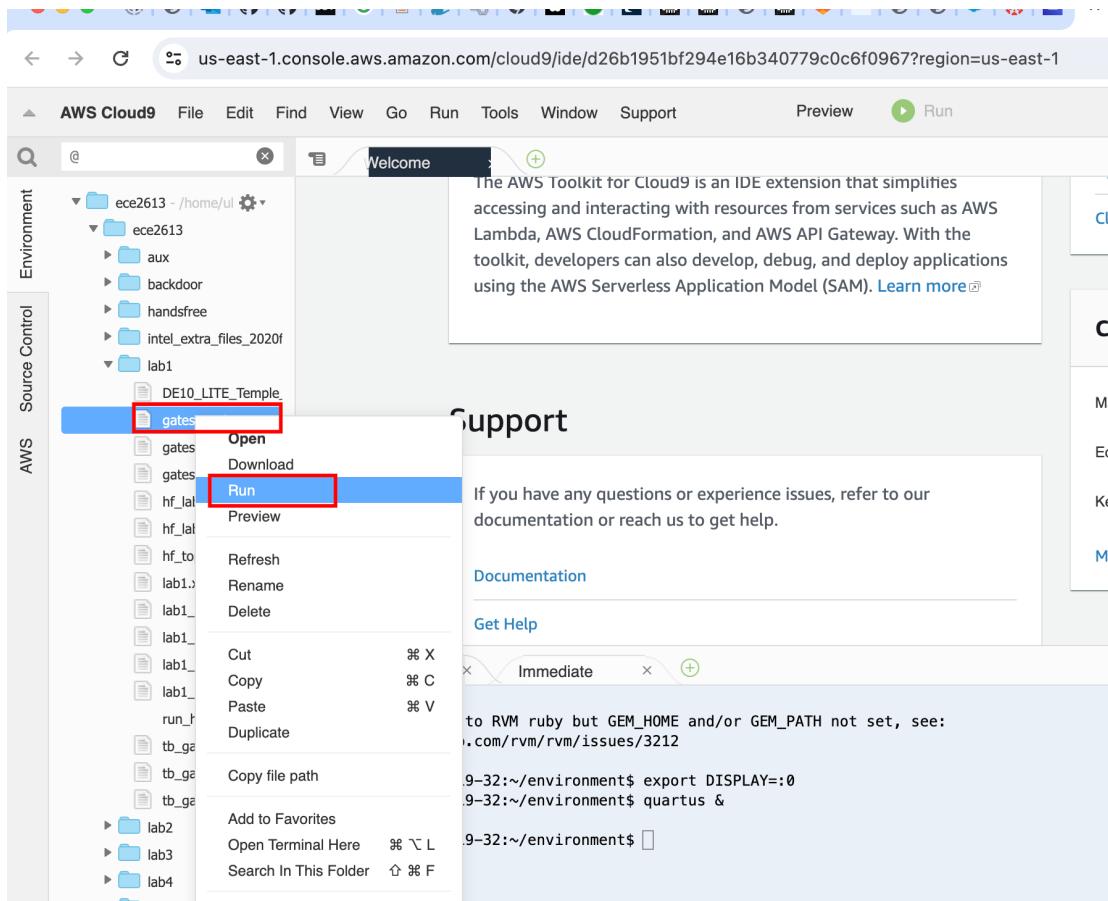
---



# Cloud 9 file listing



# Check m\_sim file



```
# Loading work.gates
# do gates.m_sim
# Mismatch--loop index i:
# Mismatch--loop index i:
# Mismatch--loop index i:
# Mismatch--loop index i:
# 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 ...

accessing and interacting with Lambda, AWS CloudFormation, and AWS CloudWatch Metrics. Developers can use the AWS Serverless Application Model (SAM) toolkit to build and deploy serverless applications.

**Support**

If you have any questions or need help, please refer to our documentation or reach out to our support team.

**Documentation**

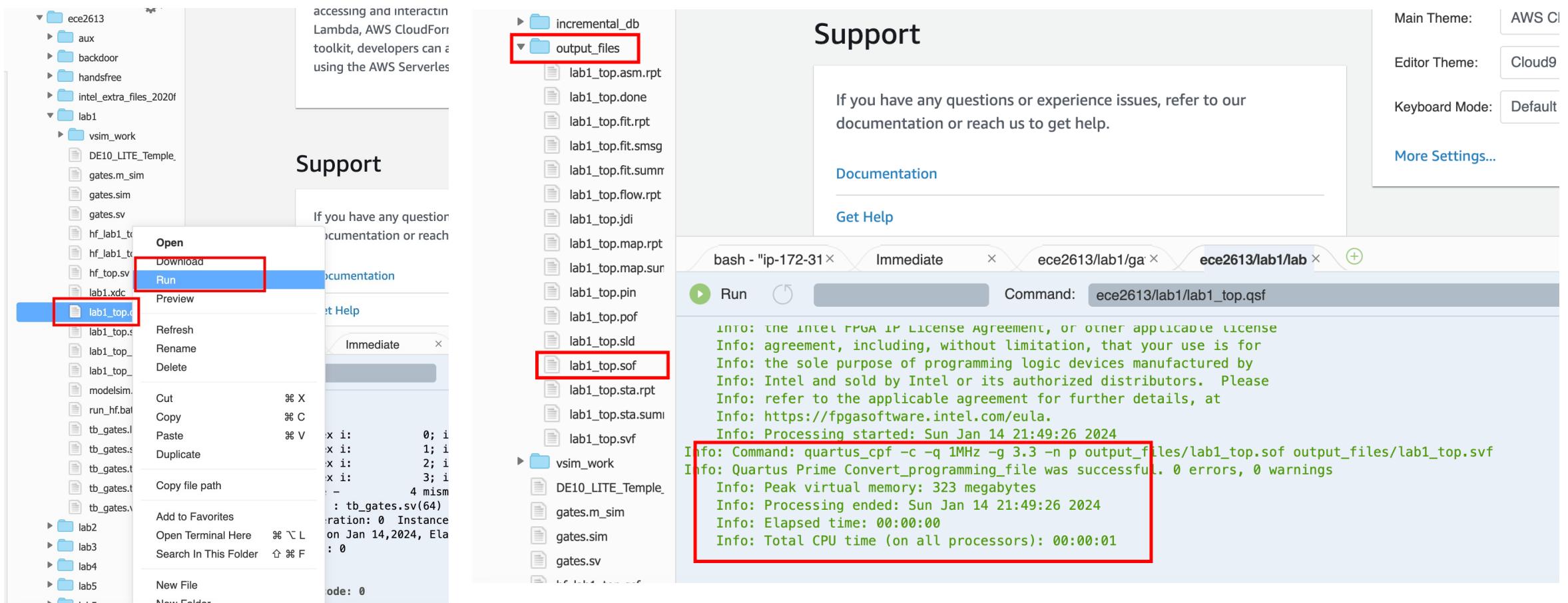
**Get Help**

**Main Theme:** AWS Cloud9

**Editor Theme:** Cloud9

**Keyboard Mode:** Default

**More Settings...**



File Explorer:

- ece2613
- aux
- backdoor
- handsfree
- intel\_extra\_files\_2020f
- lab1
  - vsim\_work
    - DE10\_LITE\_Temple
    - gates.m\_sim
    - gates.sim
    - gates.sv
    - hf\_lab1\_tb
    - hf\_lab1\_tb.sv
    - hf\_top.sv
    - lab1.xdc
- lab2
- lab3
- lab4
- lab5

Context Menu (highlighted with red boxes):

- Open
- Download
- Run
- Preview
- Refresh
- Rename
- Delete
- Cut
- Copy
- Paste
- Duplicate
- Copy file path
- Add to Favorites
- Open Terminal Here
- Search In This Folder
- New File
- Show Folder

File List:

- incremental\_db
- output\_files
  - lab1\_top.asm.rpt
  - lab1\_top.done
  - lab1\_top.fit.rpt
  - lab1\_top.fit.smsg
  - lab1\_top.fit.sumr
  - lab1\_top.flow.rpt
  - lab1\_top.jdi
  - lab1\_top.map.rpt
  - lab1\_top.map.sumr
  - lab1\_top.pin
  - lab1\_top.pof
  - lab1\_top.sld
  - lab1\_top.sof
  - lab1\_top\_sta.rpt
  - lab1\_top\_sta.sumr
  - lab1\_top.svf
- vsim\_work
  - DE10\_LITE\_Temple
  - gates.m\_sim
  - gates.sim
  - gates.sv

Support:

If you have any questions or experience issues, refer to our documentation or reach us to get help.

Documentation

Get Help

bash - "ip-172-31-1-1" \* ece2613/lab1/ga \* ece2613/lab1/lab \*

Run 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
```

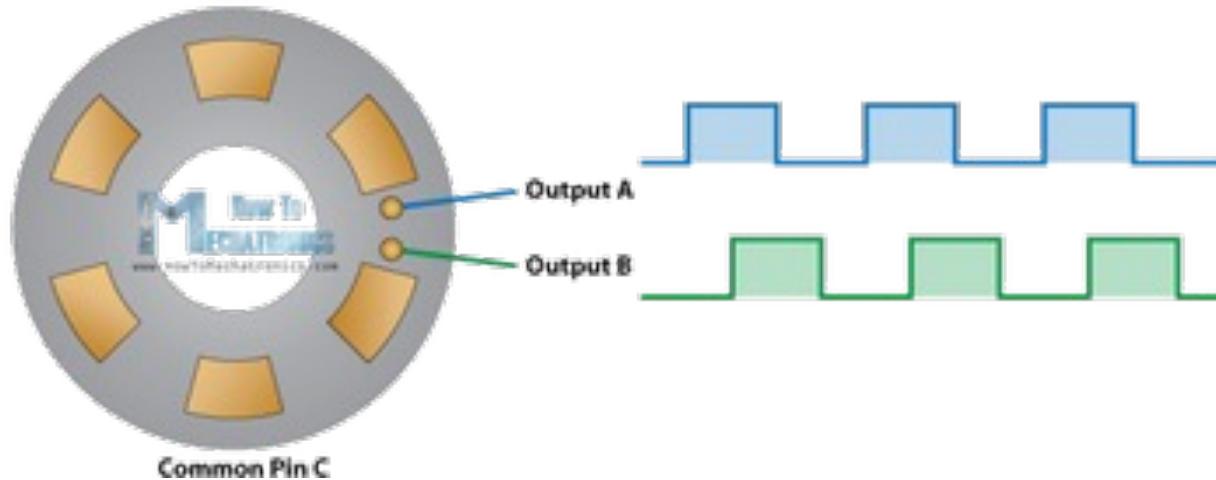
# For the next class...

---

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

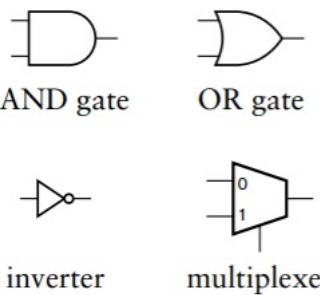
# Rotatory encoder – example for FPGA

---



# Gate symbols

---



A	B	AND	OR	XOR	Inverter (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  $25^{\circ}\text{C}$  and  $30^{\circ}\text{C}$ . Each vat has two temperature sensors indicating whether the temperature is above  $25^{\circ}\text{C}$  and above  $30^{\circ}\text{C}$ , 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 and the following examples

# Solution

---

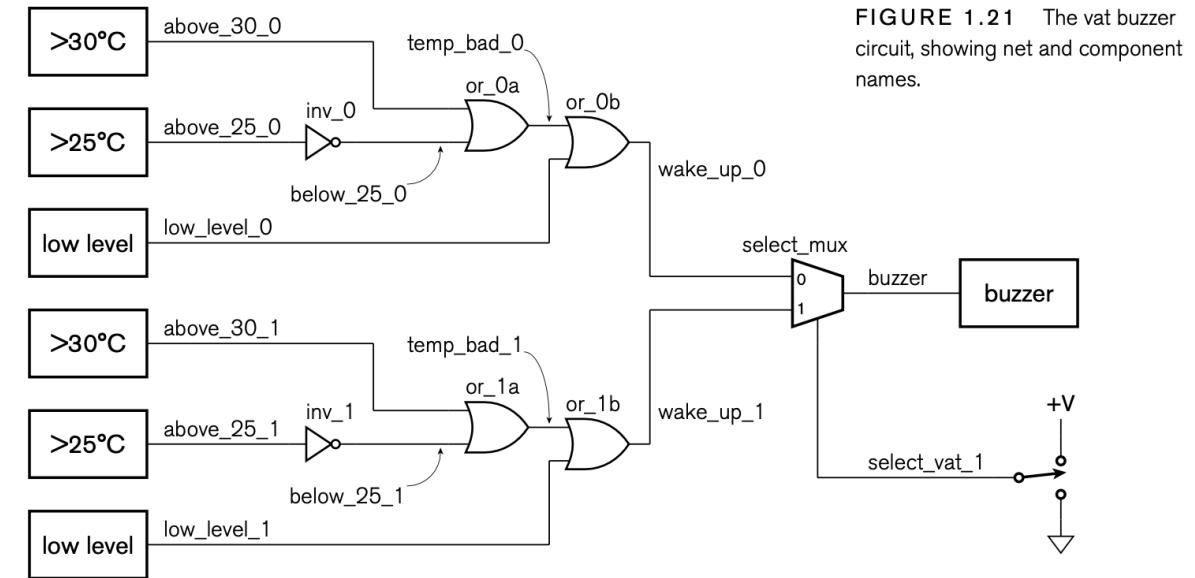
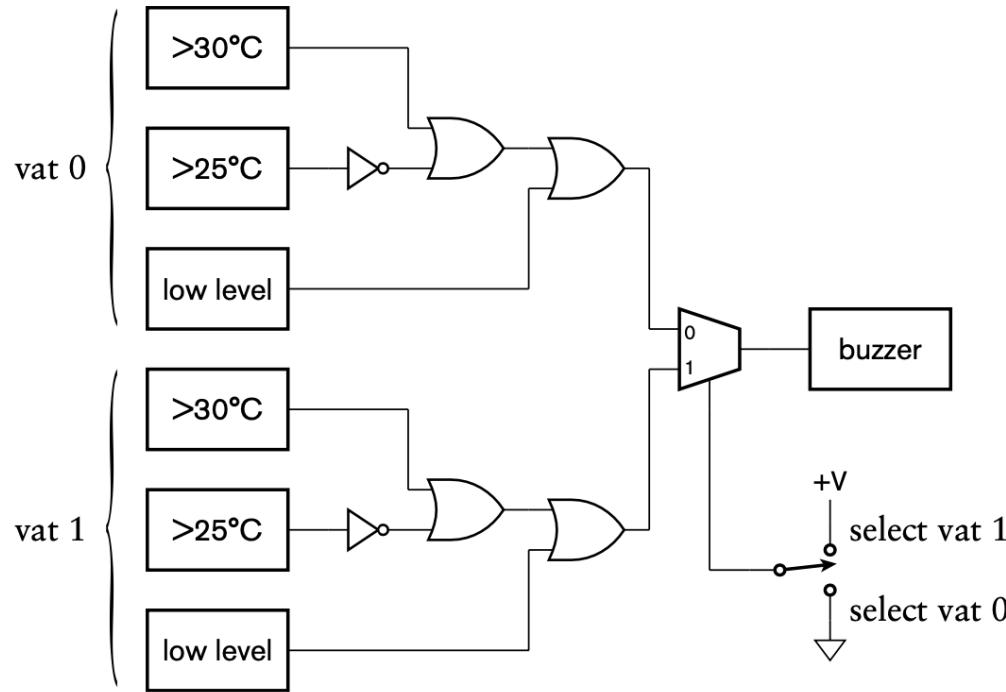


FIGURE 1.21 The vat buzzer circuit, showing net and component names.

# Verilog

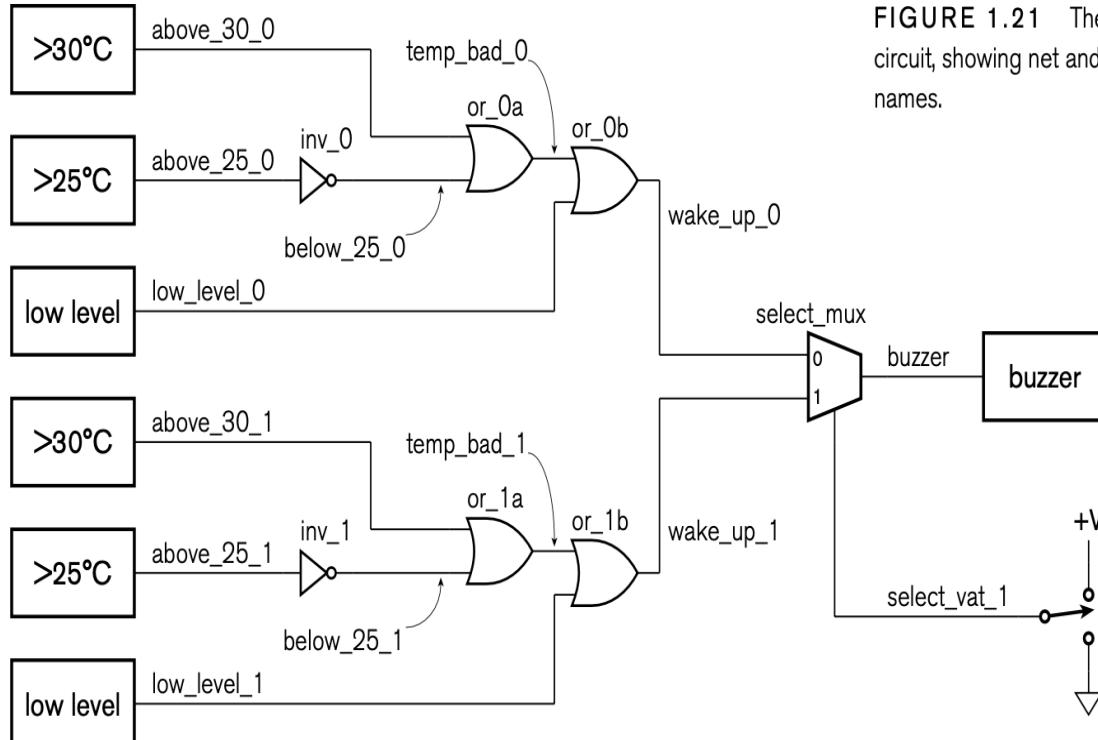


FIGURE 1.21 The vat buzzer circuit, showing net and component names.

```
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);

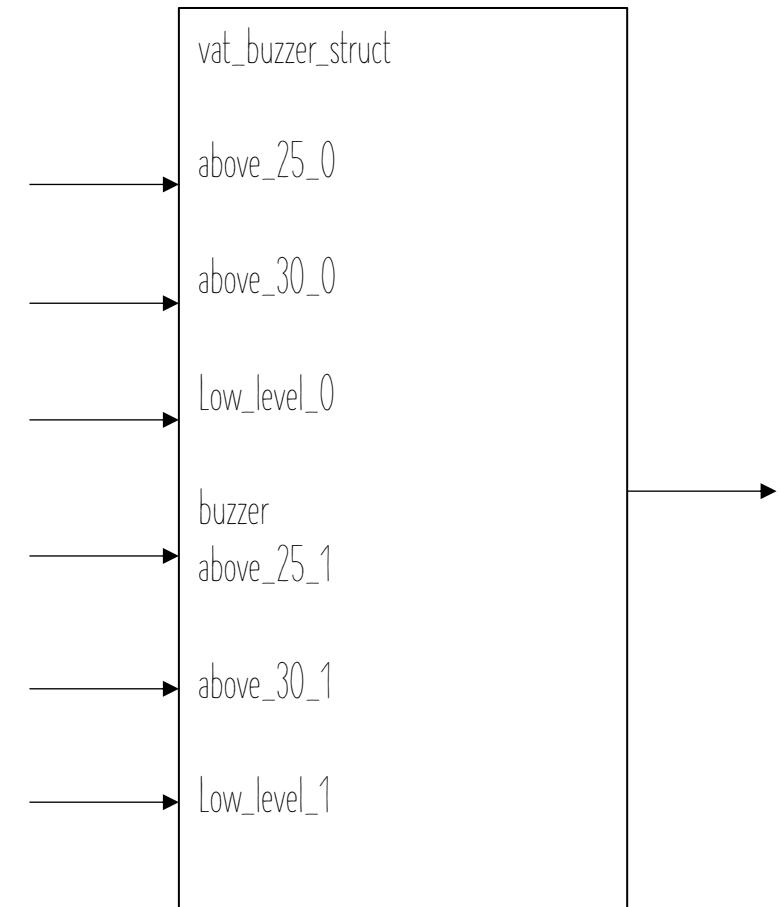
endmodule
```

```
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

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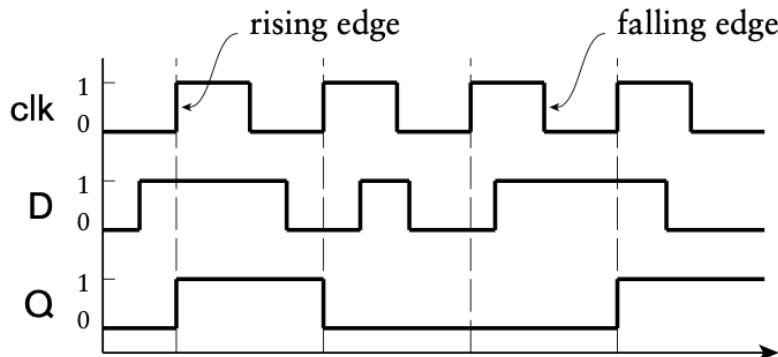


FIGURE 1.7 Timing diagram for a D flip-flop.

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

