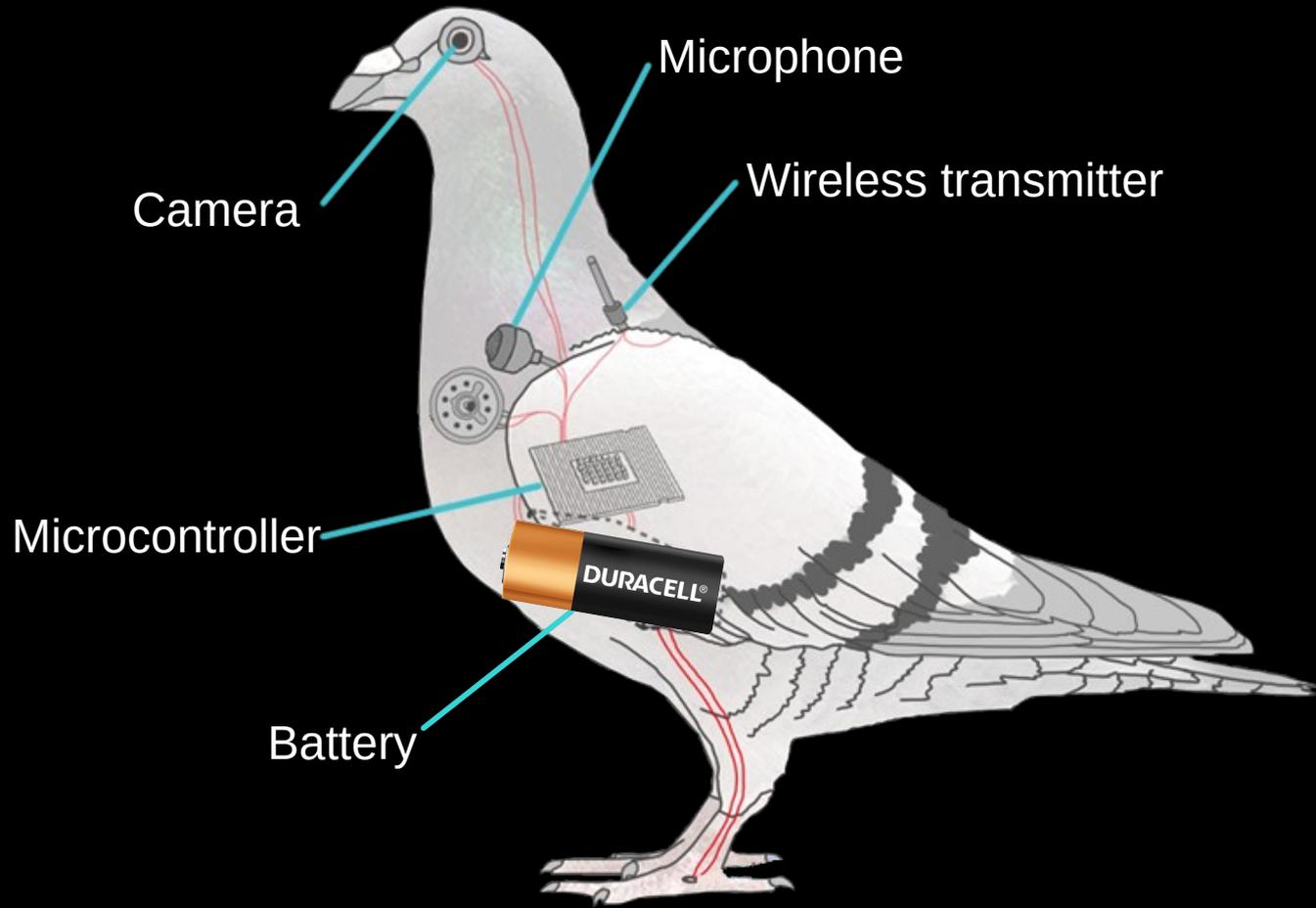


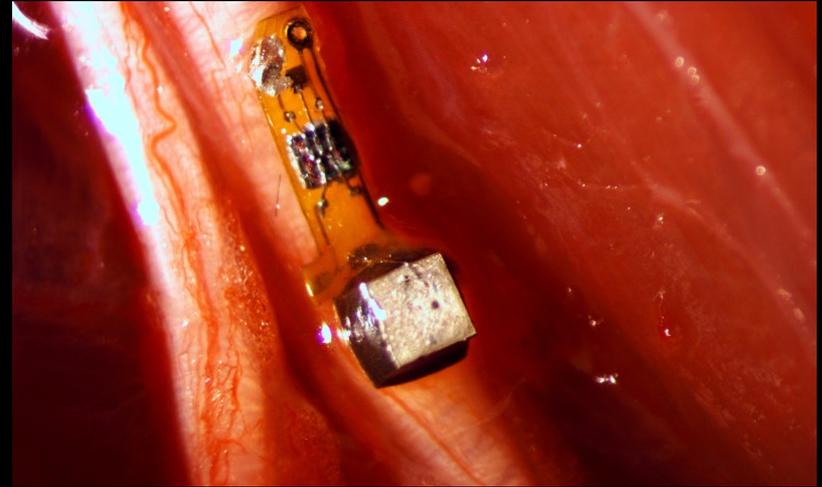
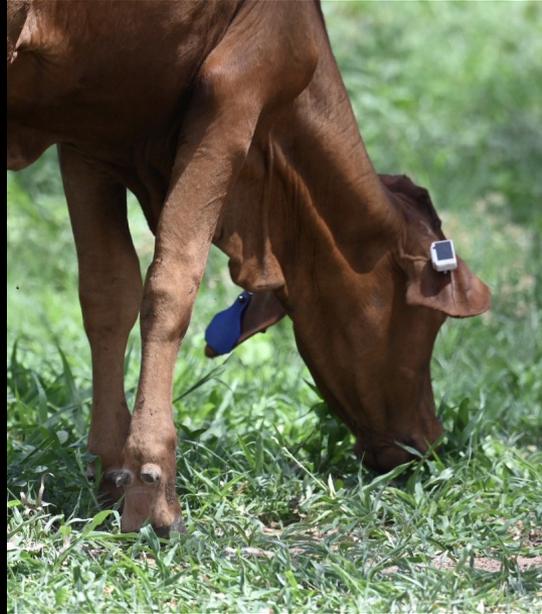
TECHNISCHE  
UNIVERSITÄT  
DRESDEN

# Riotee: An Open-source Hardware and Software Platform for the Battery-free Internet of Things

RIOT Summit



# Cyber-physical Systems



# Batteries

# Batteries



Up to **\$500** per battery replacement

# Batteries



Up to **\$500** per battery replacement



**180,000t** waste per year in the US

# Batteries



Up to **\$500** per battery replacement

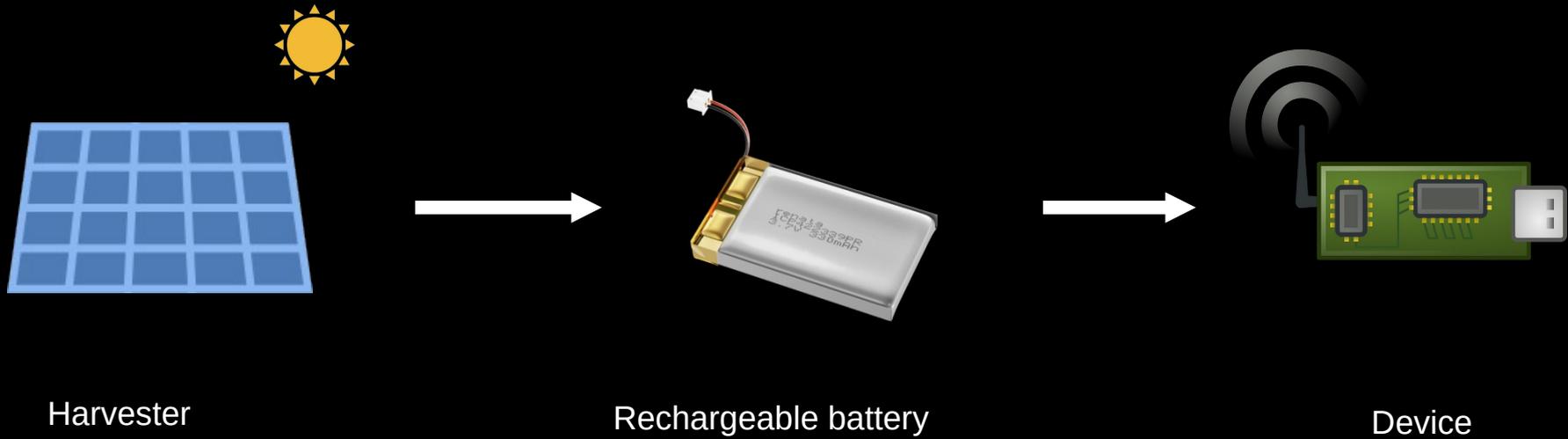


**180,000t** waste per year in the US



Replacement **impossible**

# Energy Harvesting



# Rechargeable Batteries

# Rechargeable Batteries



# Rechargeable Batteries



# Rechargeable Batteries



# Going Battery-free



# Going Battery-free



Lifetime

1-5 years

>20 years

# Going Battery-free



Lifetime

1-5 years

>20 years

Materials

Lithium, Cobalt, ...

Baryte

# Going Battery-free



Lifetime

1-5 years

>20 years

Materials

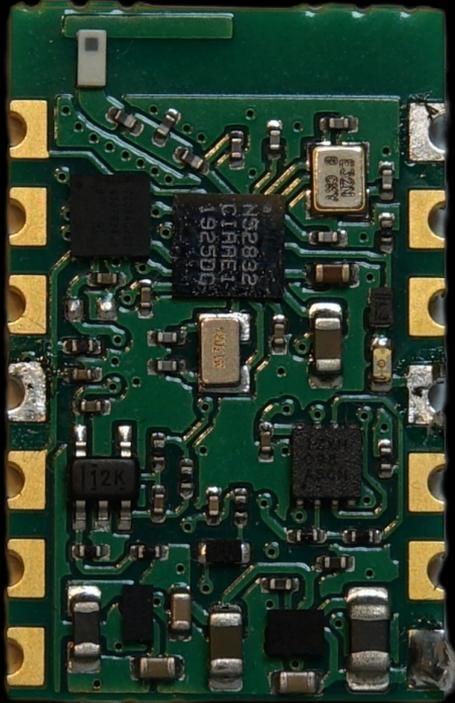
Lithium, Cobalt, ...

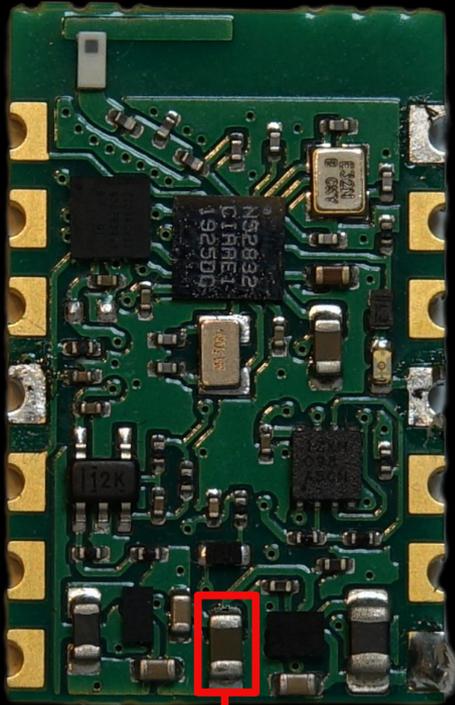
Baryte

Leakage

10000nA

1nA





22 $\mu$ F ceramic capacitor

# Challenges

# Challenges



Forward progress

# Challenges



Forward progress



Time-keeping

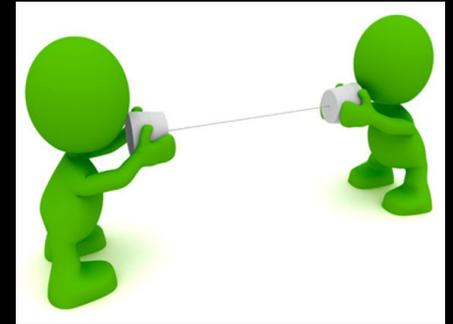
# Challenges



Forward progress



Time-keeping



Communication

# Developer Workflow

# Developer Workflow



Idea

# Developer Workflow



Idea

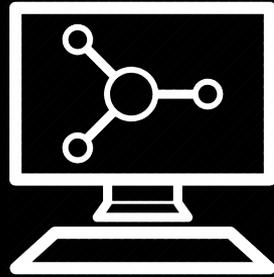


Simulation

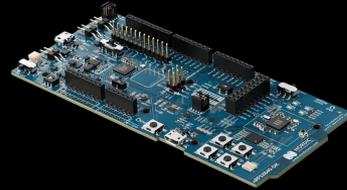
# Developer Workflow



Idea



Simulation

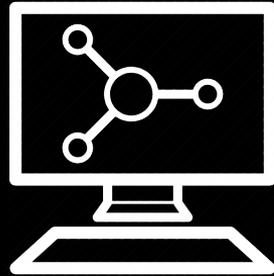


Implementation

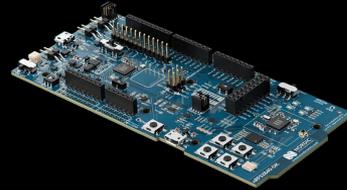
# Developer Workflow



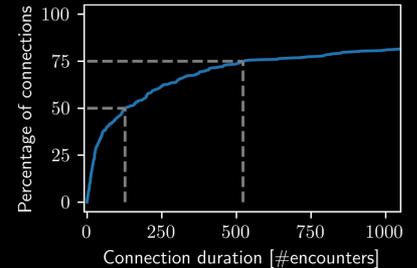
Idea



Simulation



Implementation



Evaluation



All  Part # / Keyword 

In Stock  RoHS

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- Use fewer or different keywords
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- Apply 1 filter at a time

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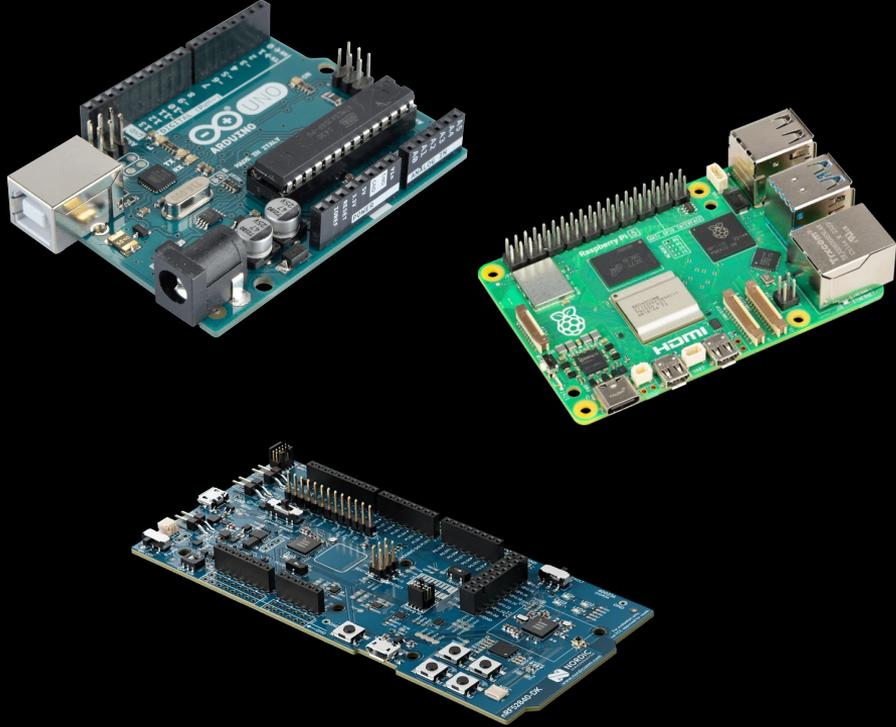
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	OPEN SOURCE	GENERAL PURPOSE	DOCUMENTATION
WISP (2008)			
DEBS (2016)			
Flicker (2017)			
Capbara (2018)			
<a href="#">PiBLE</a> (2018)			
<a href="#">Bfree</a> (2020)			
<a href="#">Botoks</a> (2020)			
Empire (2020)			
<a href="#">Flync</a> (2020)			
<a href="#">SuperSensor</a> (2023)			

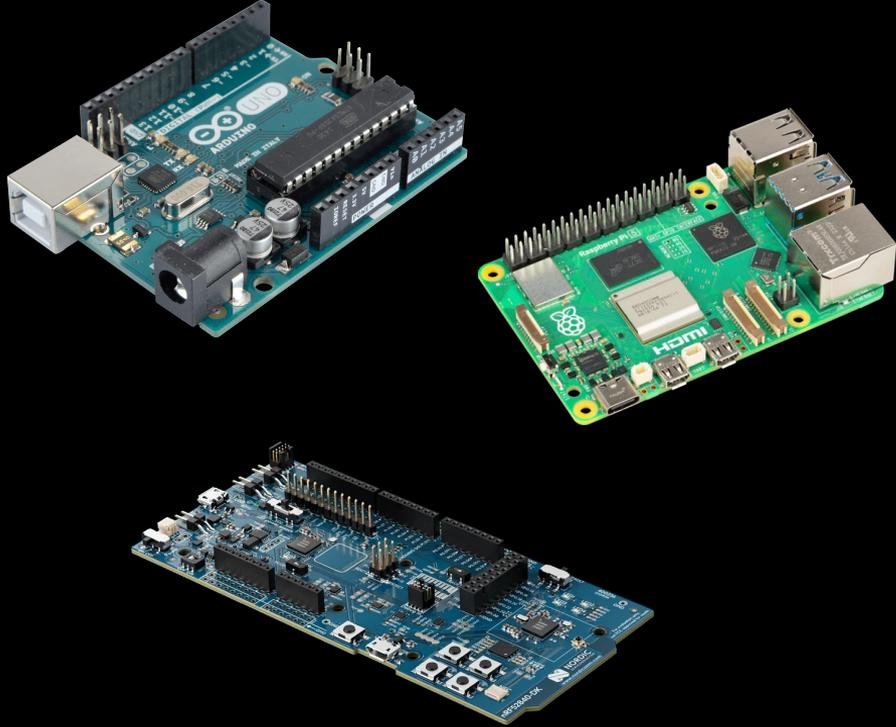
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WISP (2008)	✓		
DEBS (2016)	✗		
Flicker (2017)	✓		
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<a href="#">PiBLE</a> (2018)	✓	✓	
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<a href="#">Botoks</a> (2020)	✓	✗	
Empire (2020)	✗	✗	
<a href="#">Flync</a> (2020)	✓	✗	
<a href="#">SuperSensor</a> (2023)	✓	✓	

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PiBLE (2018)	✓	✓	✗
Bfree (2020)	✓	✗	✗
Botoks (2020)	✓	✗	✓
Empire (2020)	✗	✗	✗
Flync (2020)	✓	✗	✗
SuperSensor (2023)	✓	✓	✗



Battery-powered



Battery-powered



Battery-free

Riotee is the first **general-purpose** development platform for battery-free devices that is both open-source and **commercially available**.

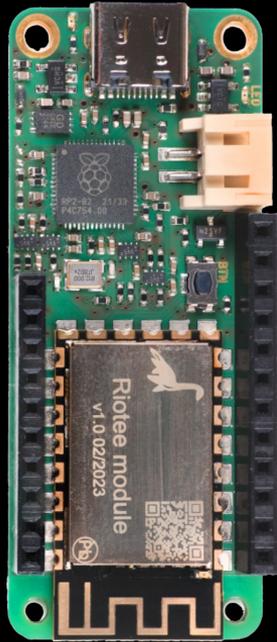
# Riotee Hardware

# Riotee Hardware

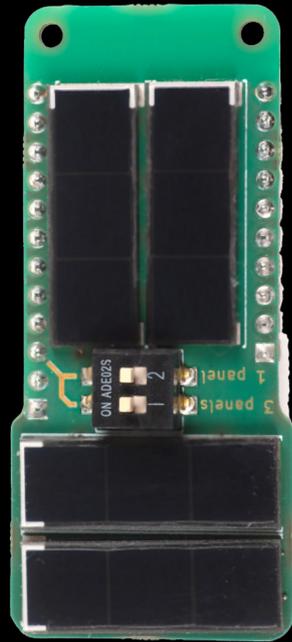


Riotee Board

# Riotee Hardware

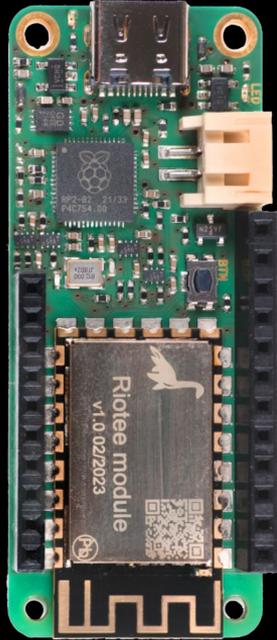


Riotee Board

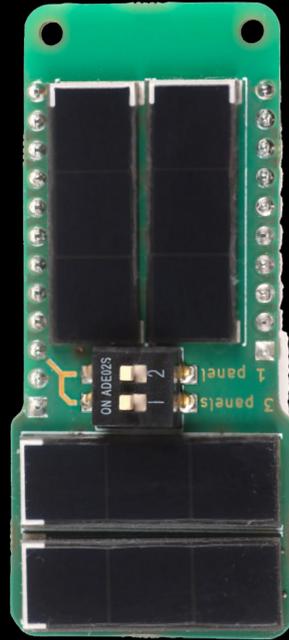


Solar Shield

# Riotee Hardware



Riotee Board

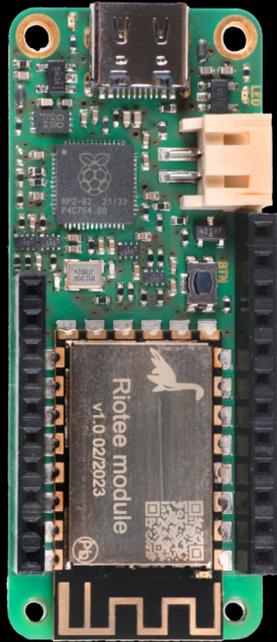


Solar Shield

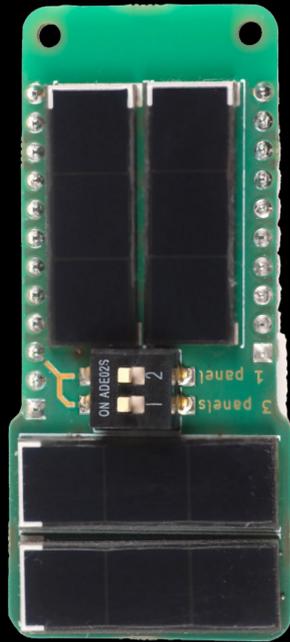


Capacitor Shield

# Riotee Hardware



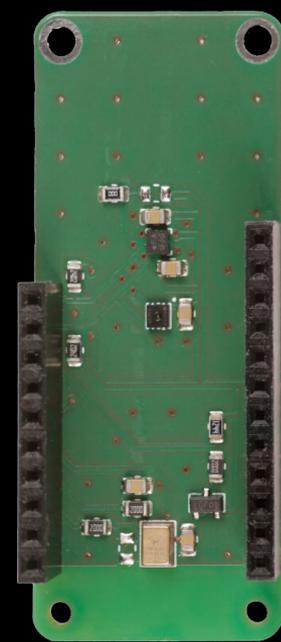
Riotee Board



Solar Shield



Capacitor Shield

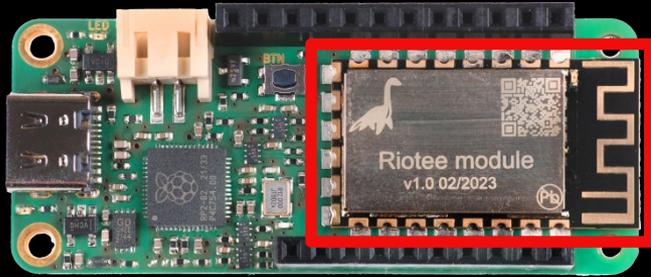


Sensor Shield

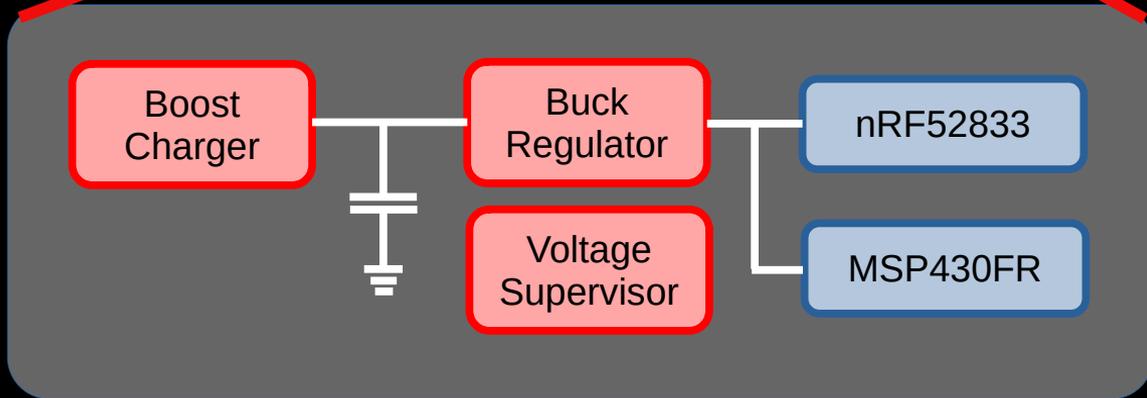
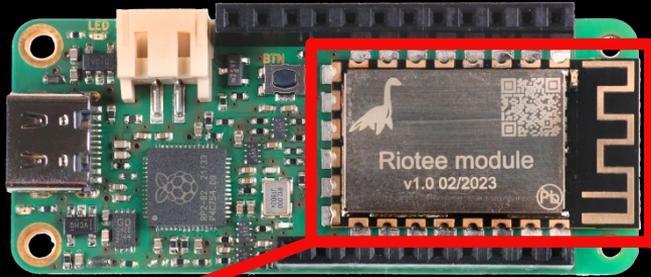
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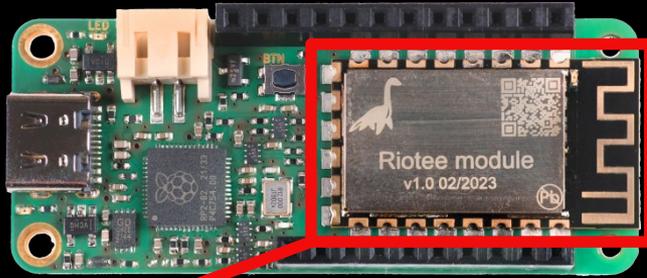
# Riotee Module



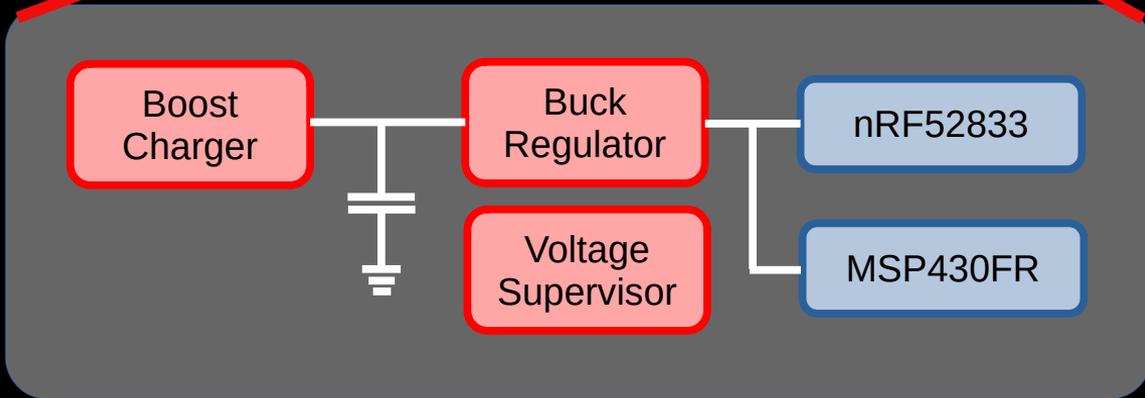
# Riotee Module



# Riotee Module



Riotee Probe



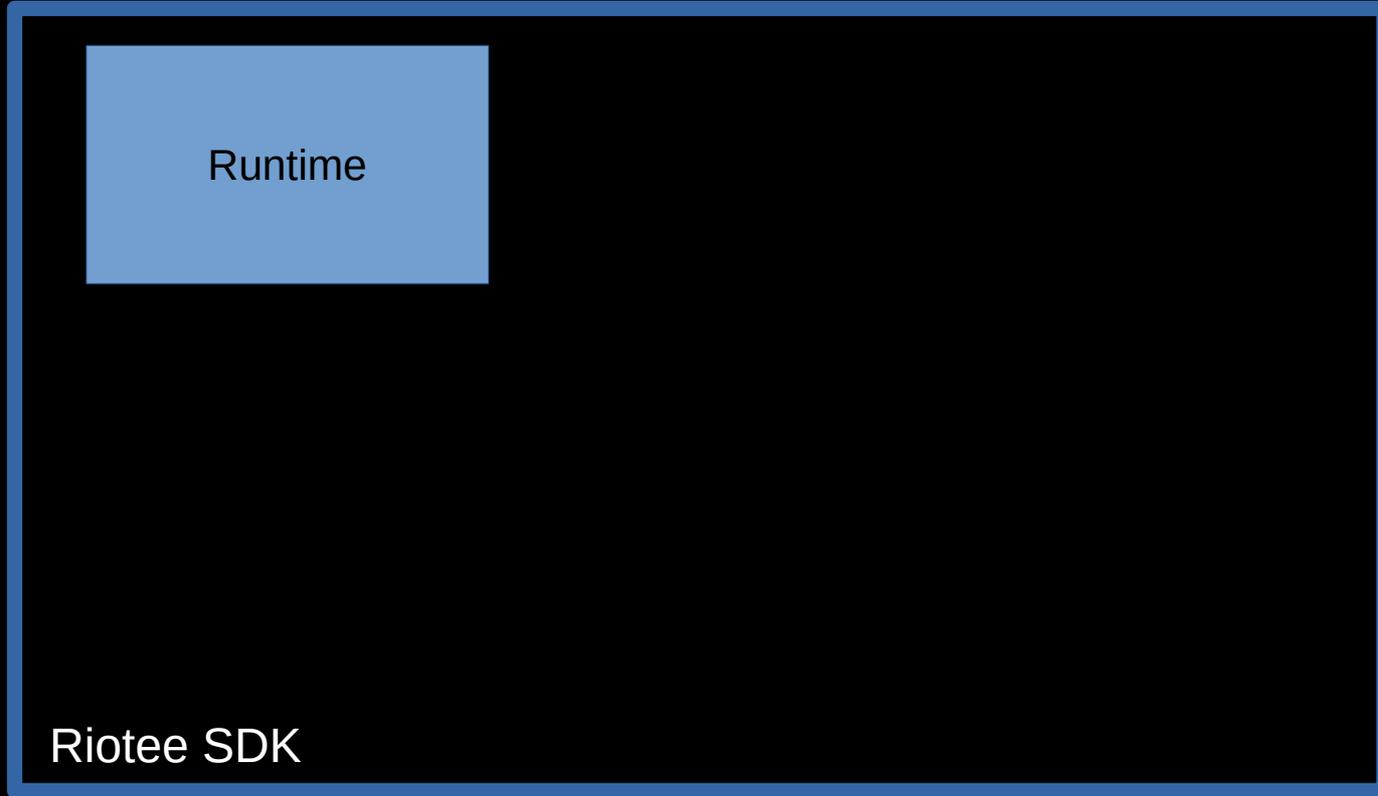
# Software

# Software

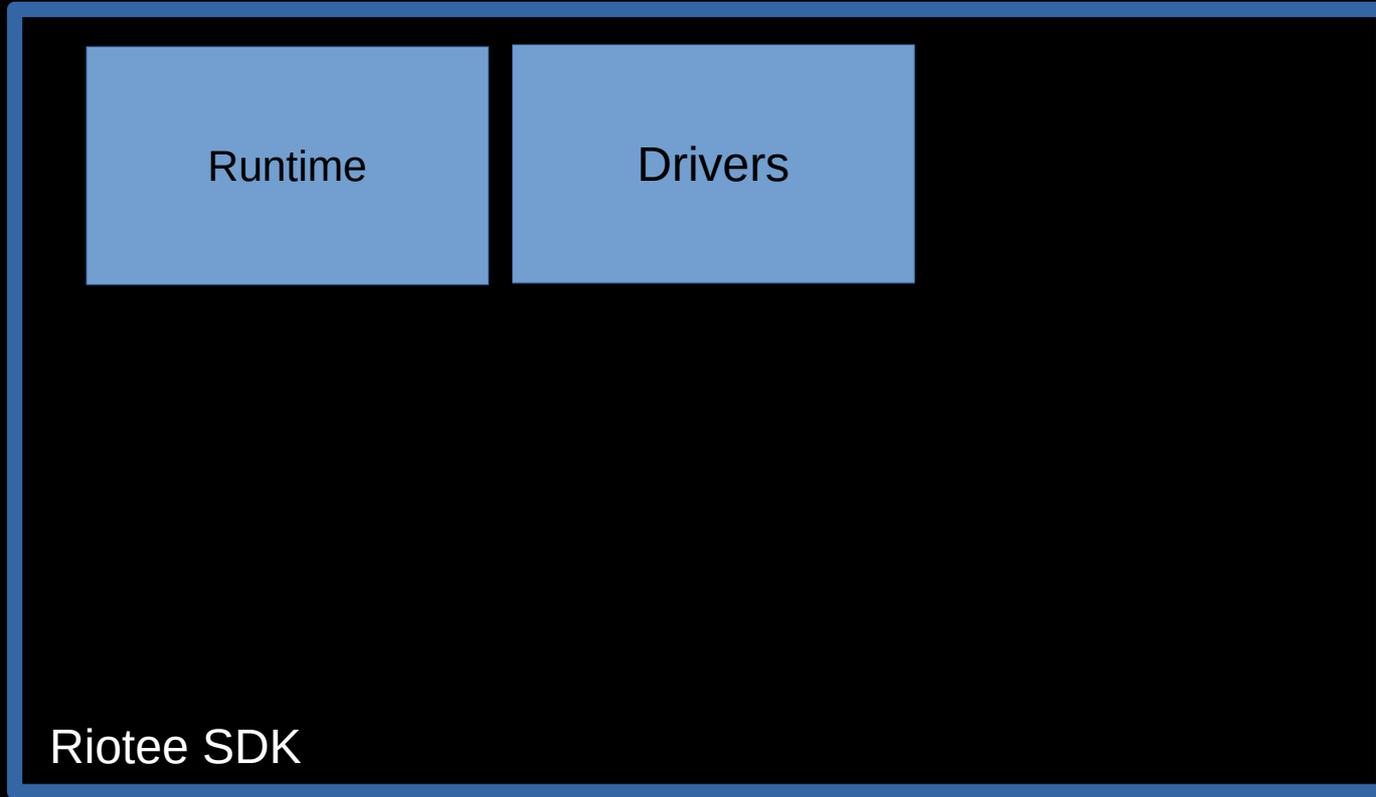


Riotee SDK

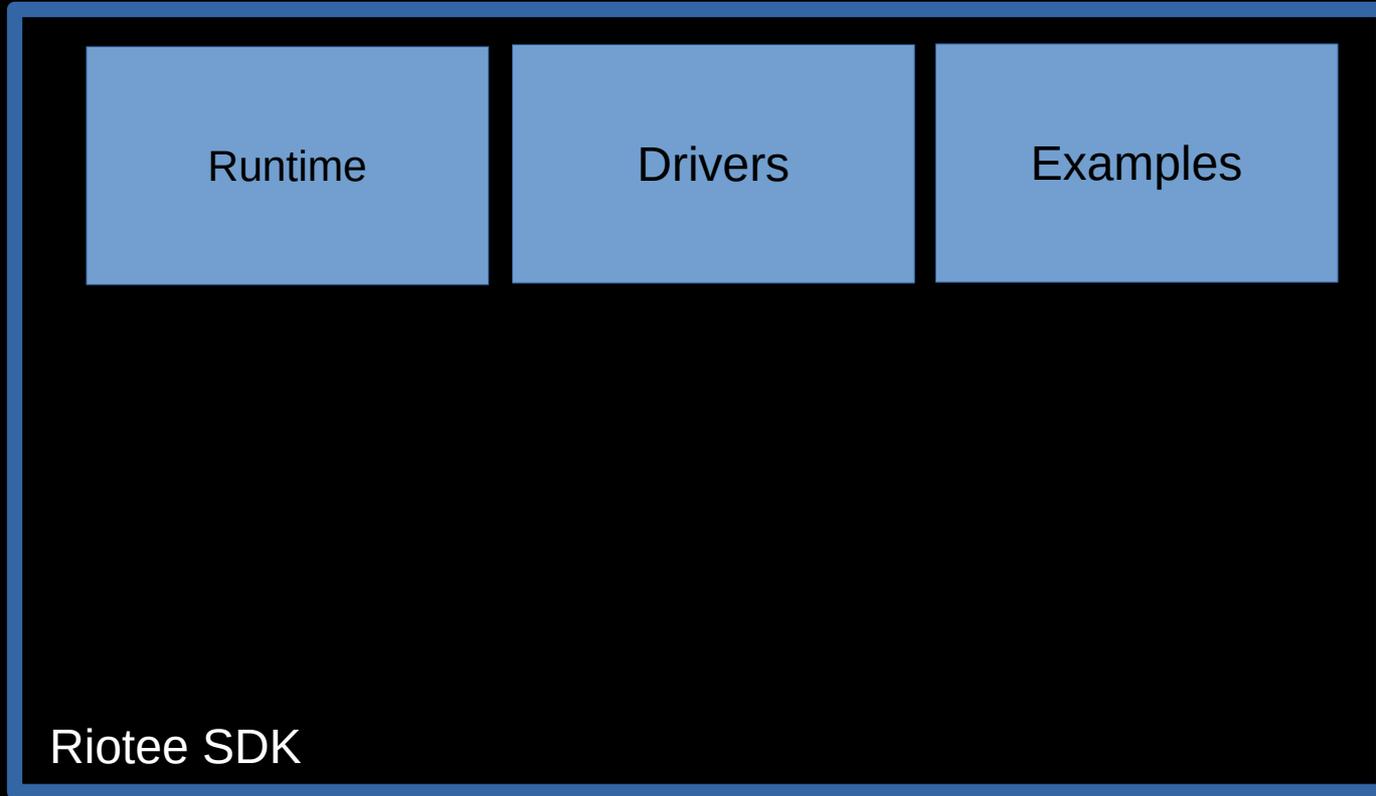
# Software



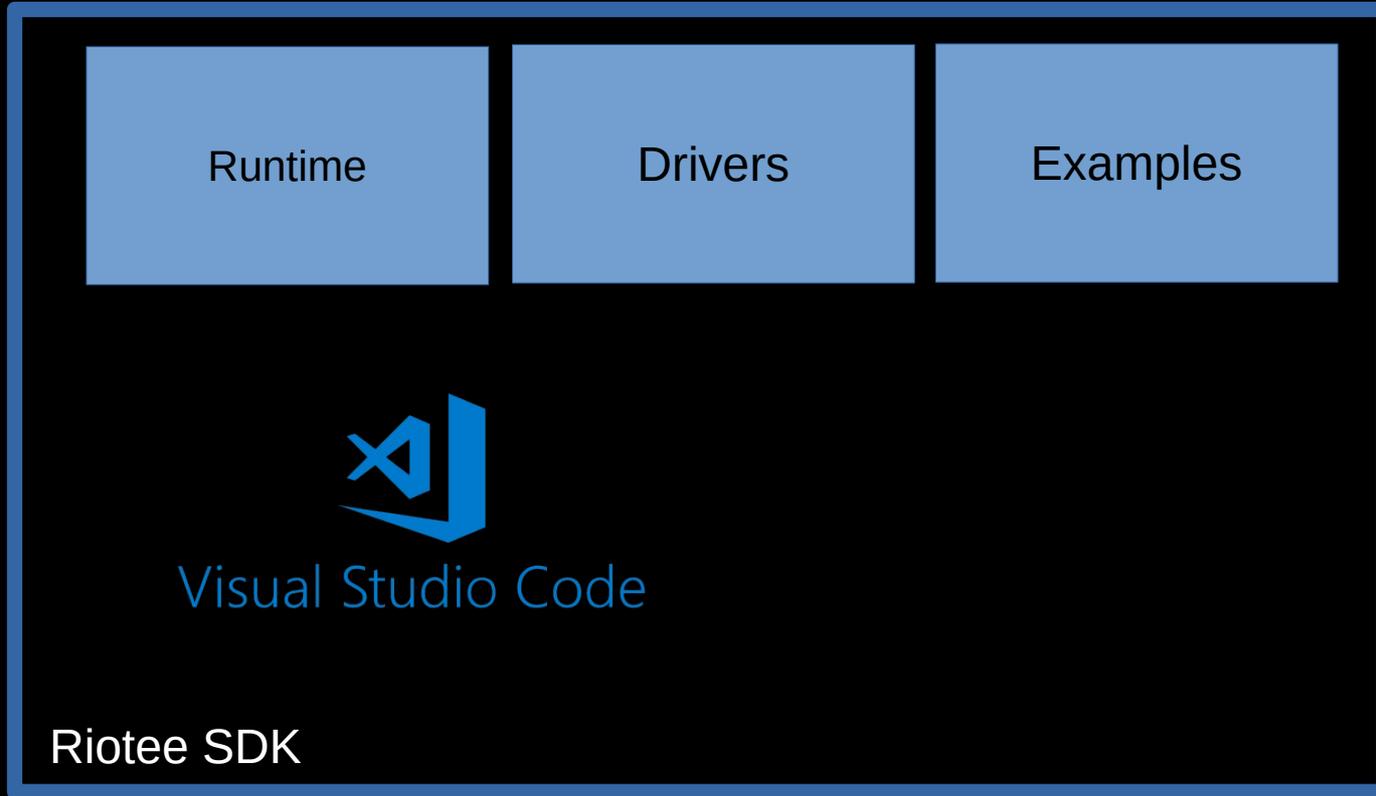
# Software



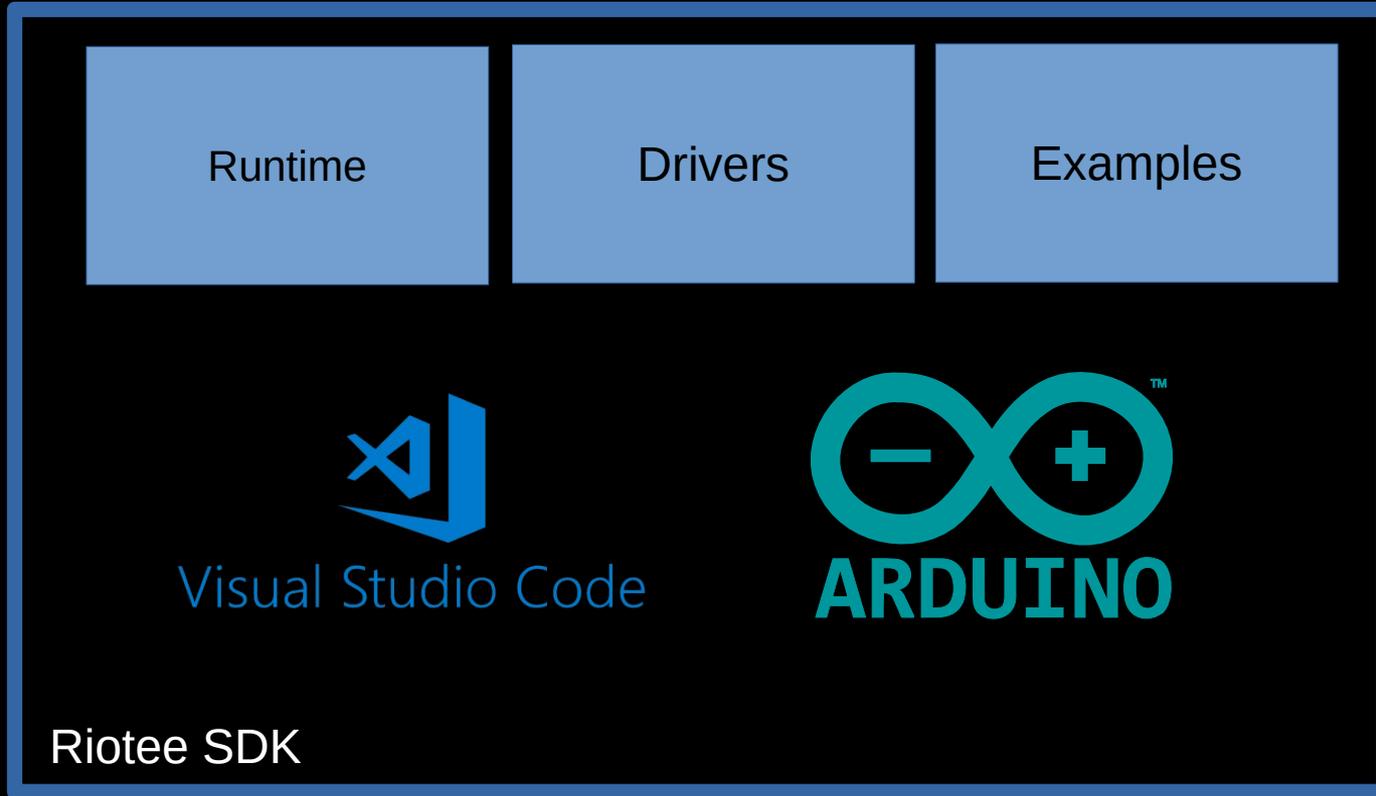
# Software



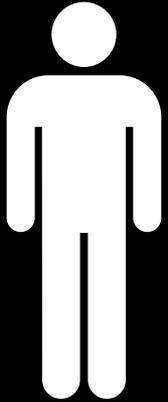
# Software



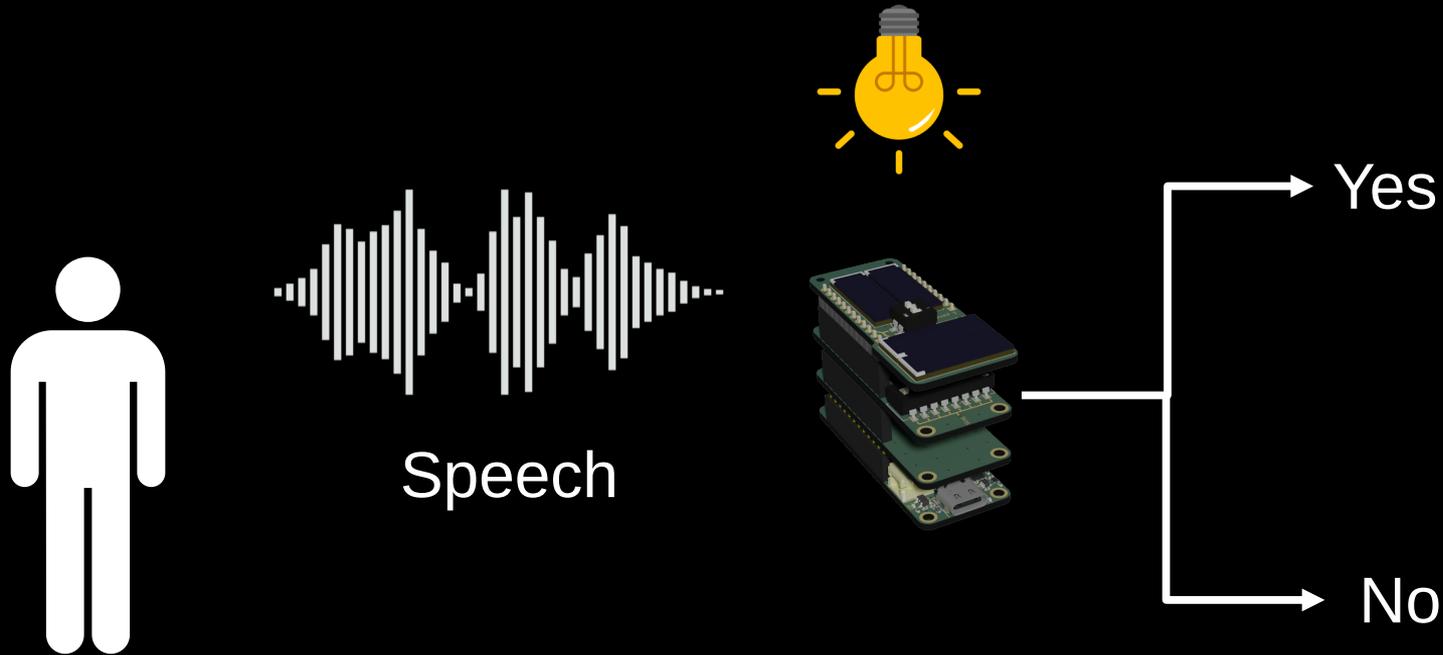
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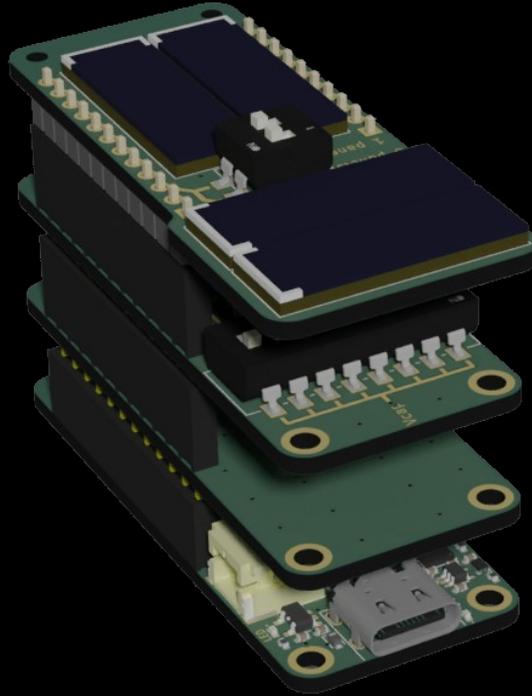
# Application Example



# Application Example



# Hardware



# Application Code

# Application Code

```
wait_for_sound();
```

# Application Code

```
wait_for_sound();
```

```
sample_microphone(&samples, 16384, 16384);
```

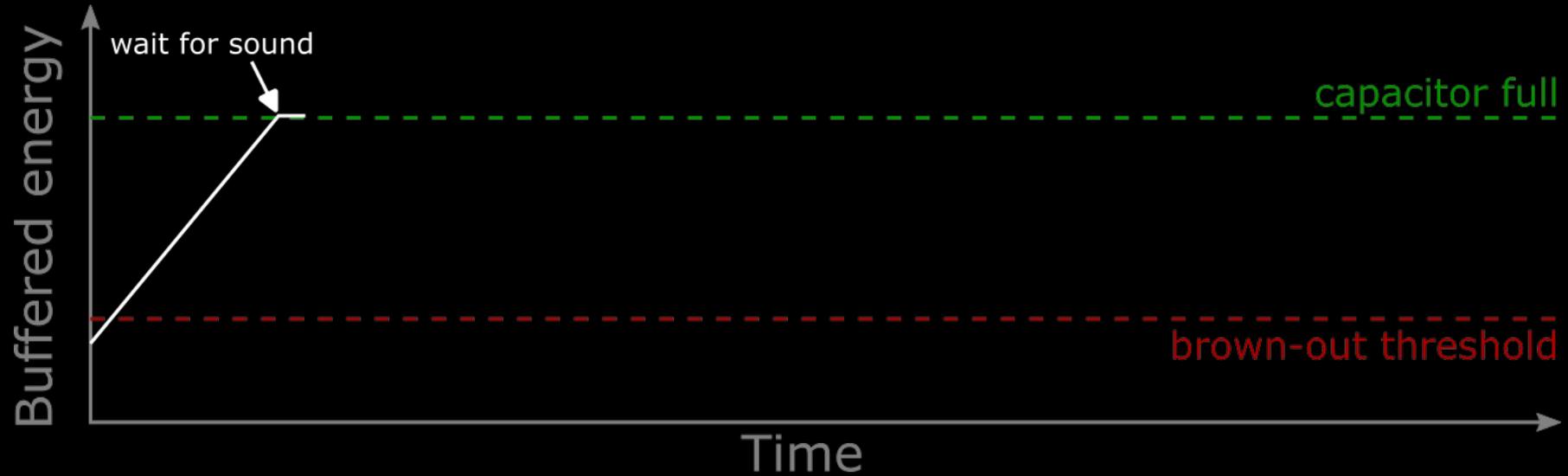
# Application Code

```
wait_for_sound();  
sample_microphone(&samples, 16384, 16384);  
run_inference(&result, &samples);
```

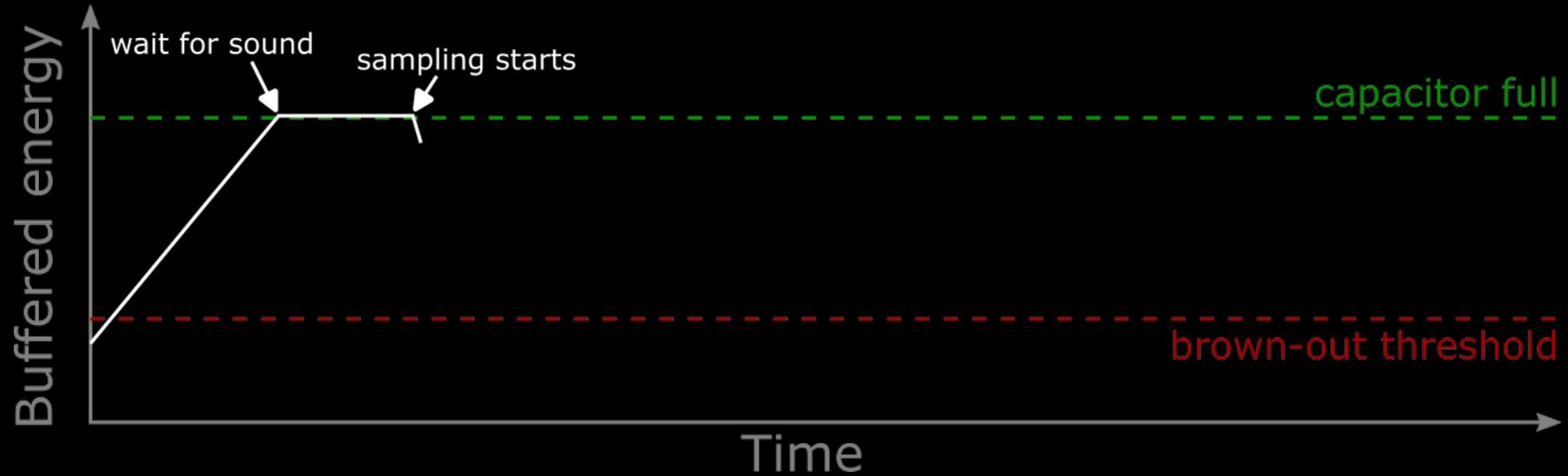
# Application Code

```
wait_for_sound();  
sample_microphone(&samples, 16384, 16384);  
run_inference(&result, &samples);  
transmit_result(&result);
```

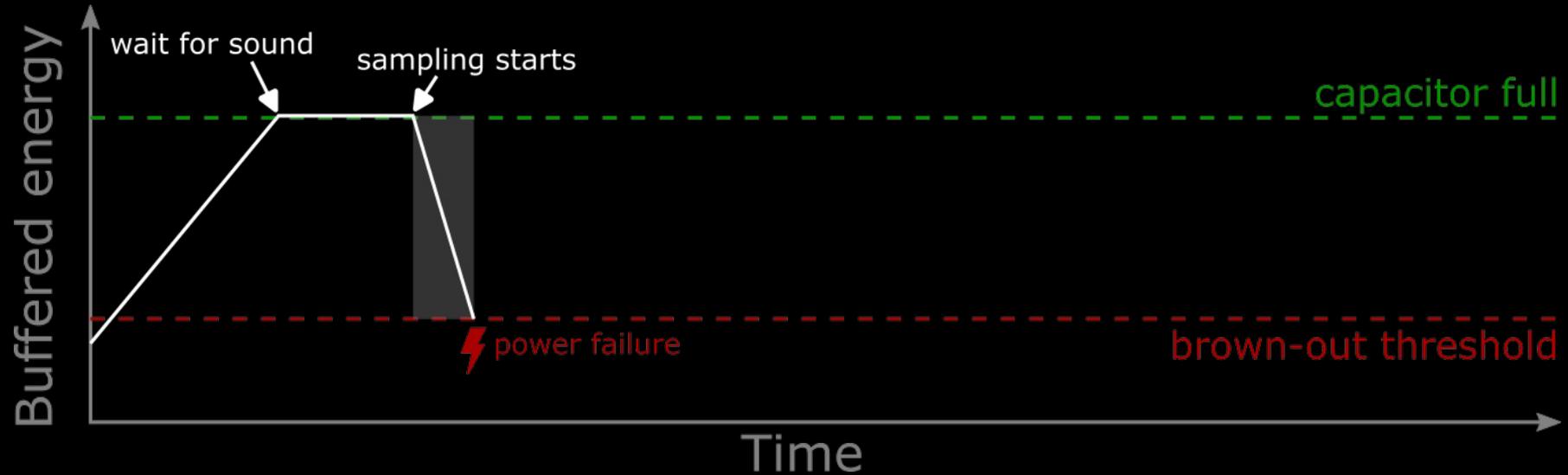
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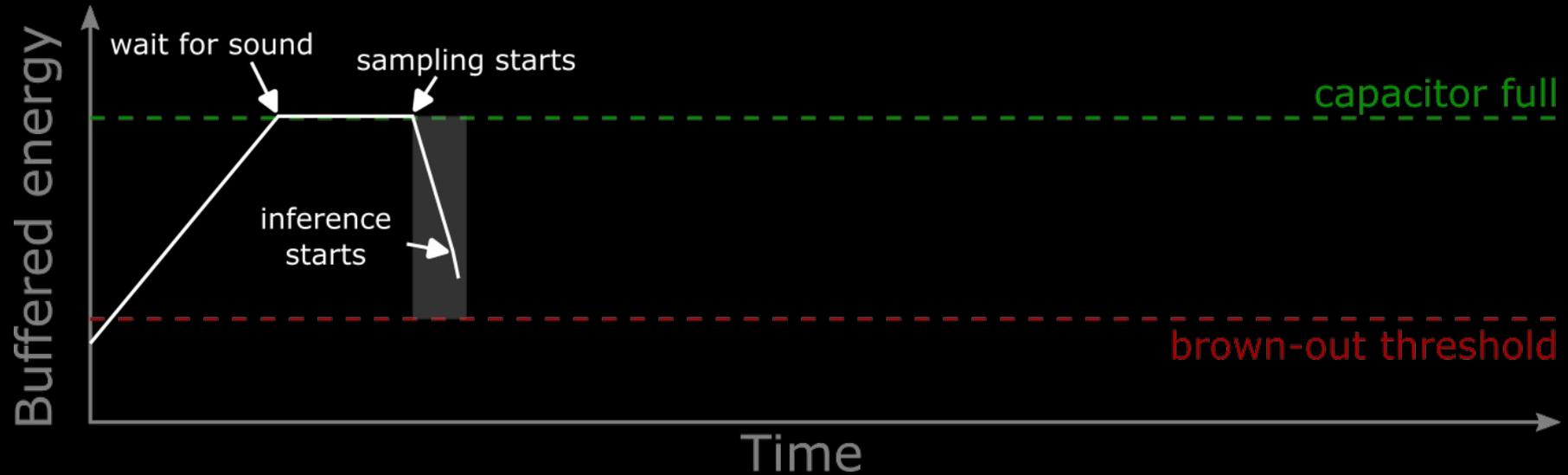
# Intermittent Execution



# Intermittent Execution

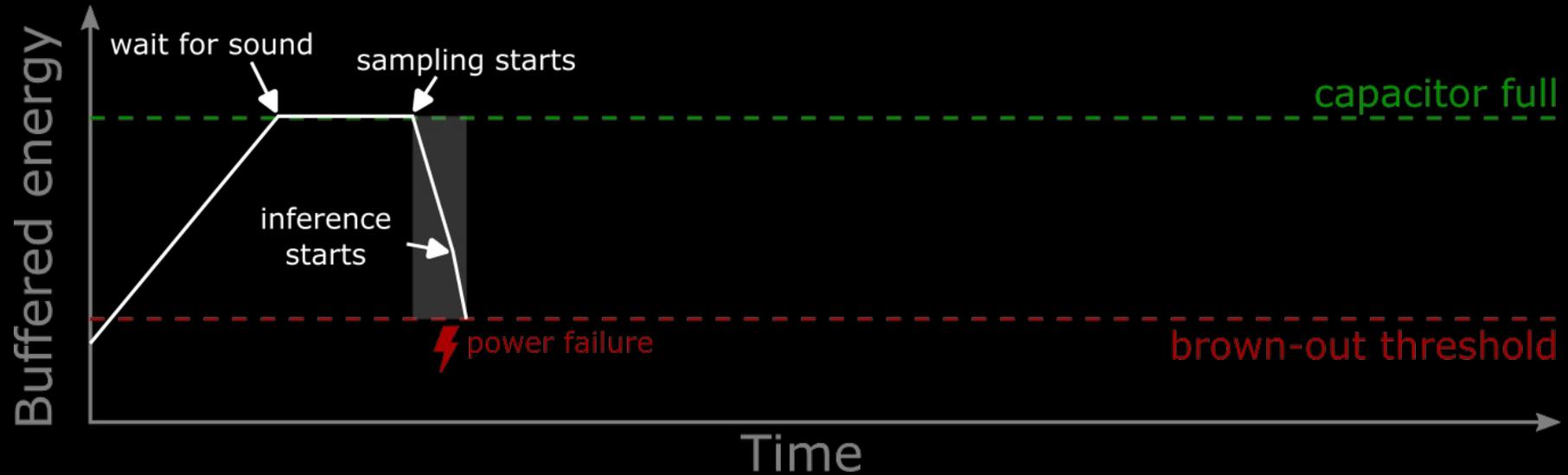


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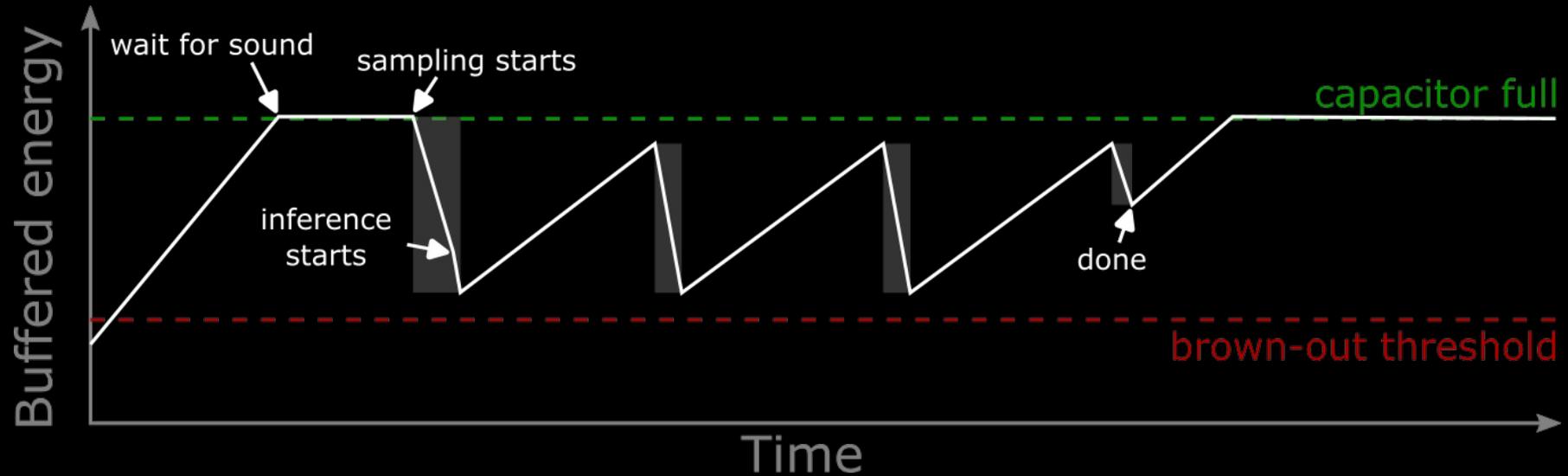


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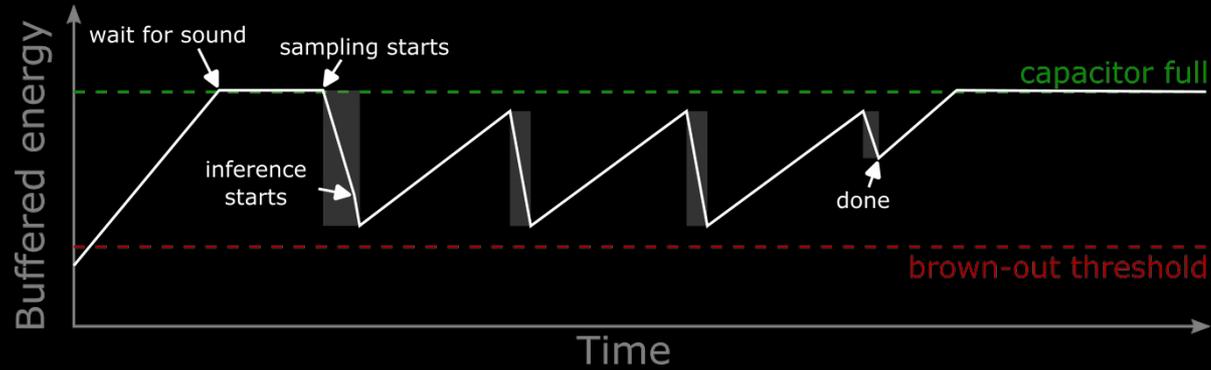
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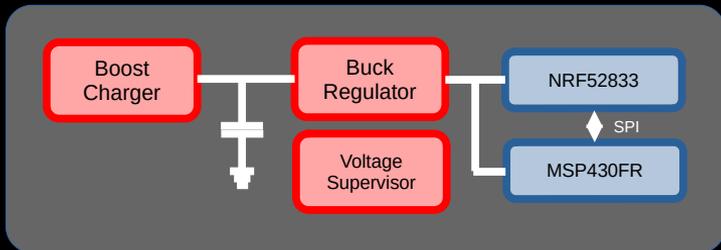
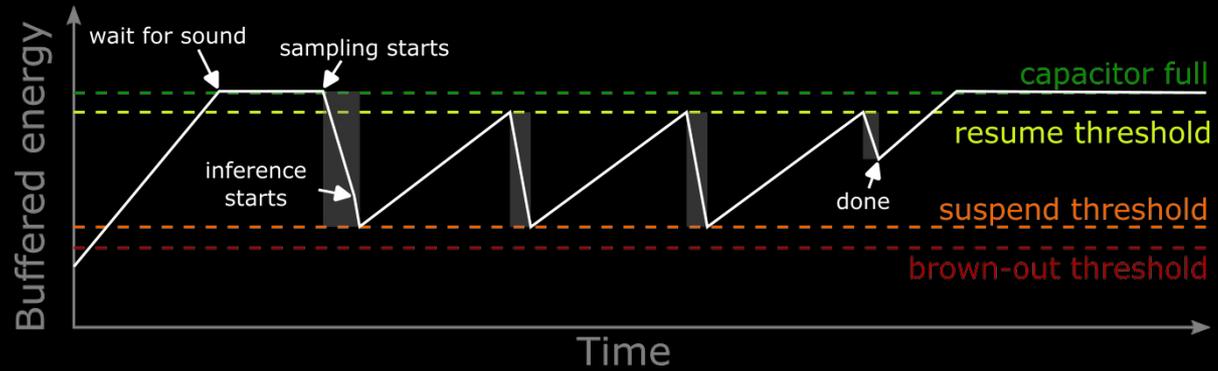
# Intermittent Execution



# Intermittent Execution

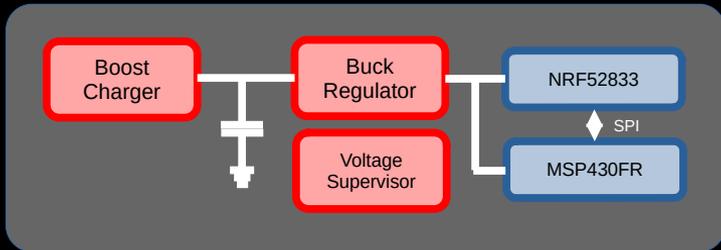
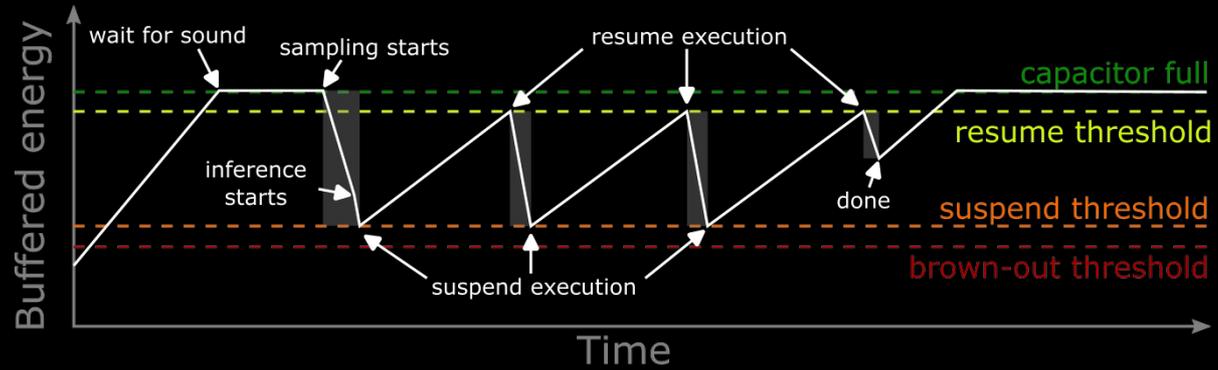


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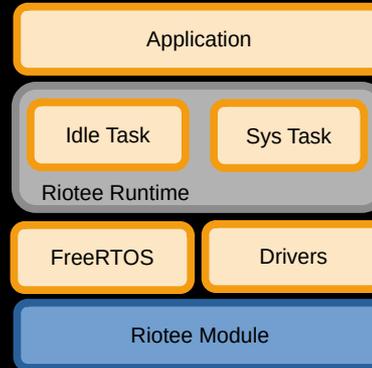


Voltage Supervisor

# Intermittent Execution



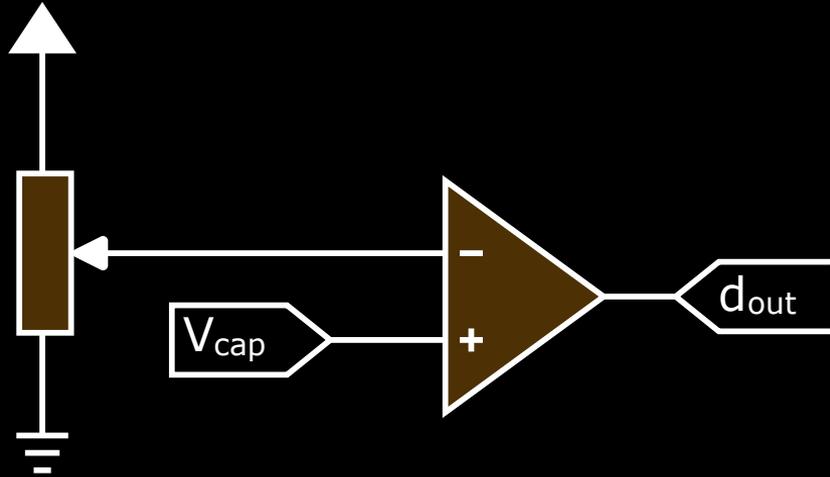
Voltage Supervisor



Intermittent Runtime

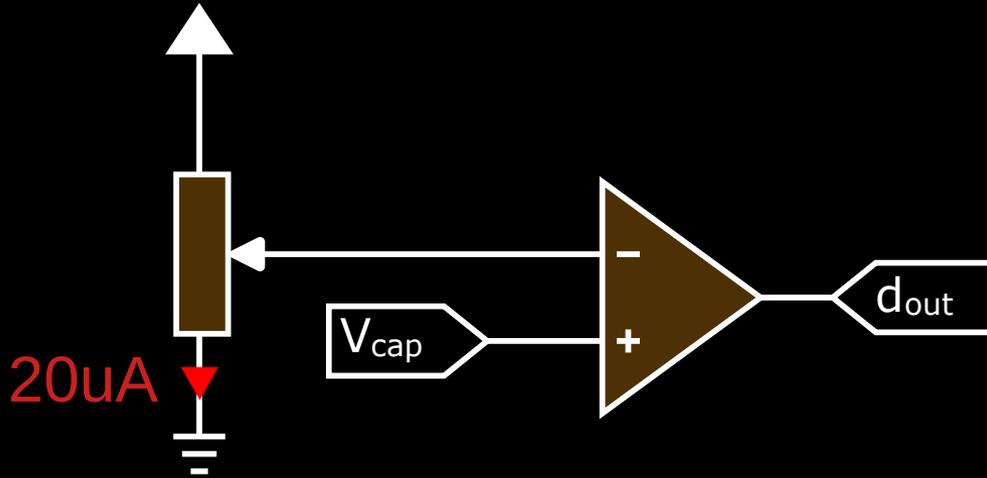
# Voltage Supervisor

# Voltage Supervisor



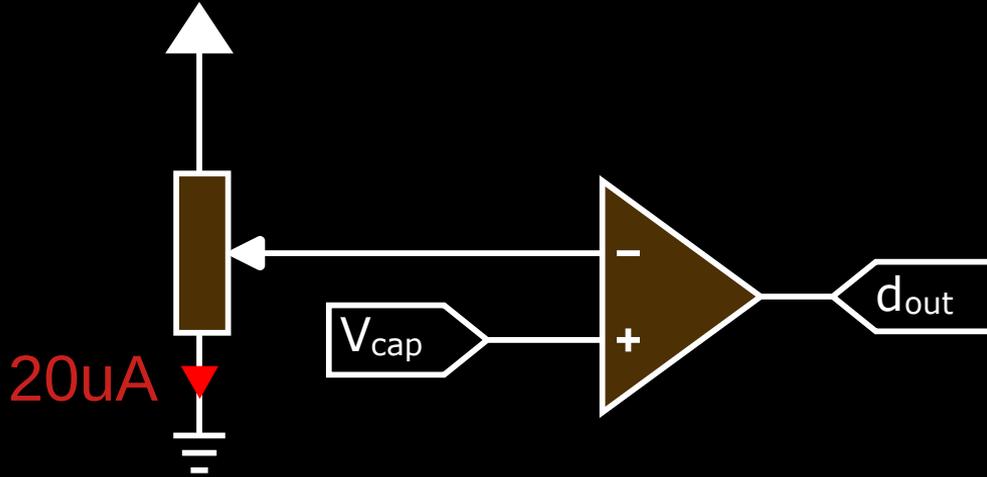
Potentiometer-based

# Voltage Supervisor

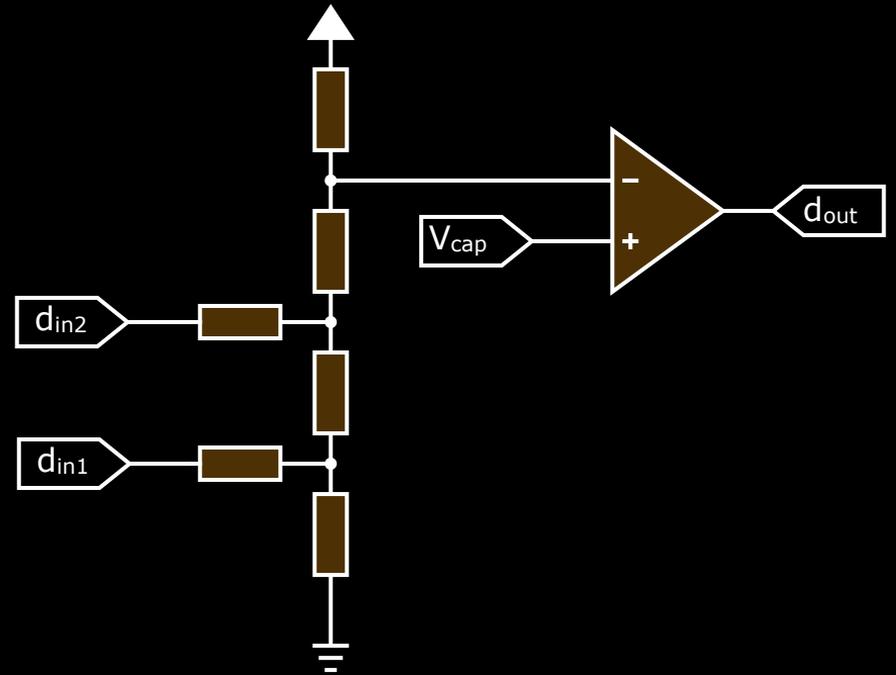


Potentiometer-based

# Voltage Supervisor

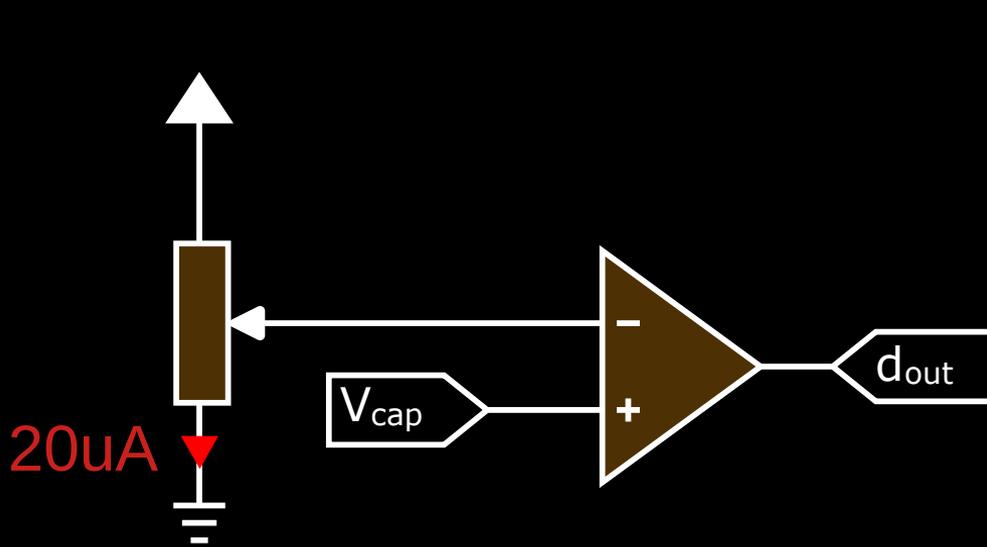


Potentiometer-based

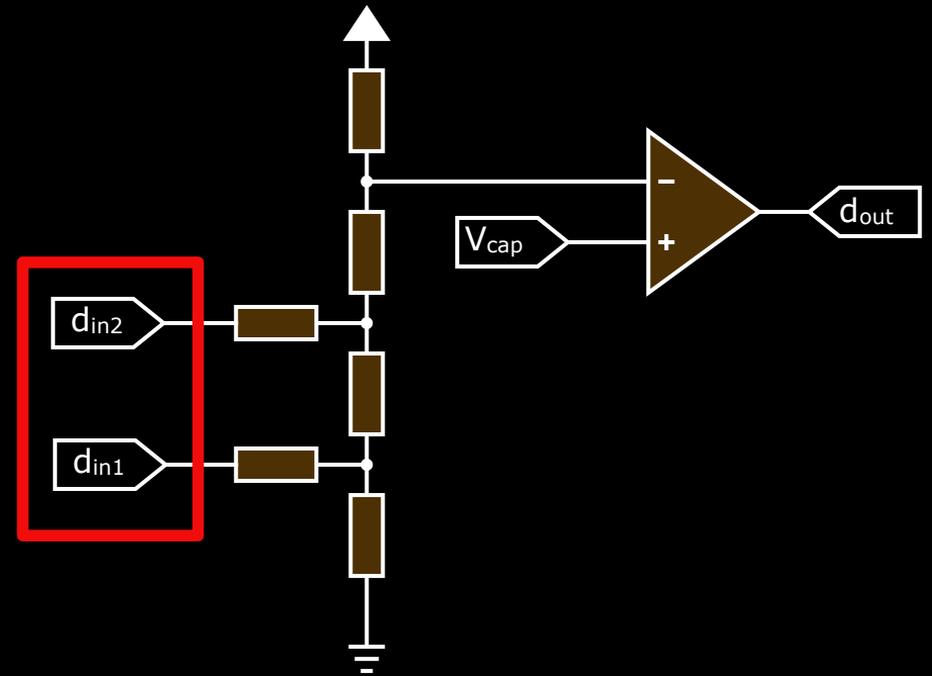


Riotee

# Voltage Supervisor

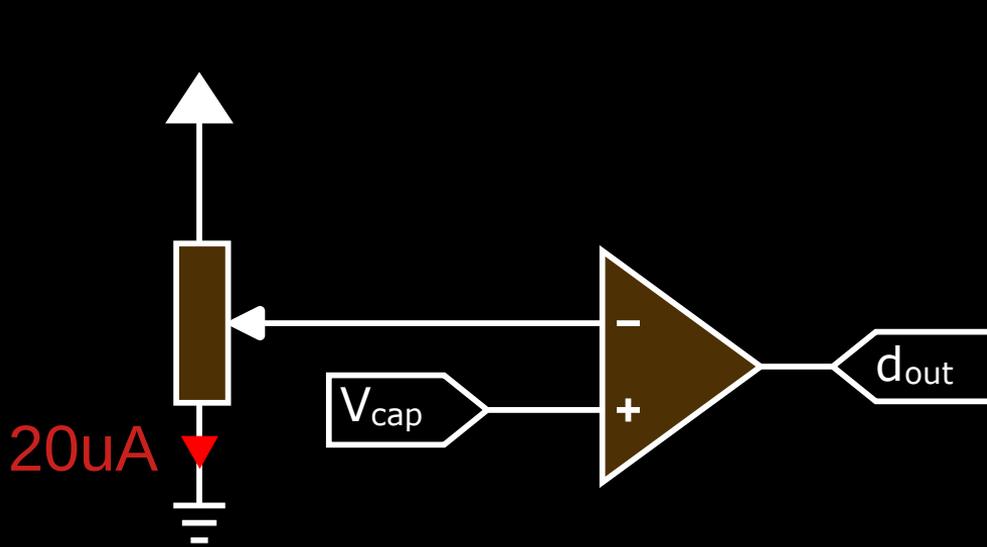


Potentiometer-based

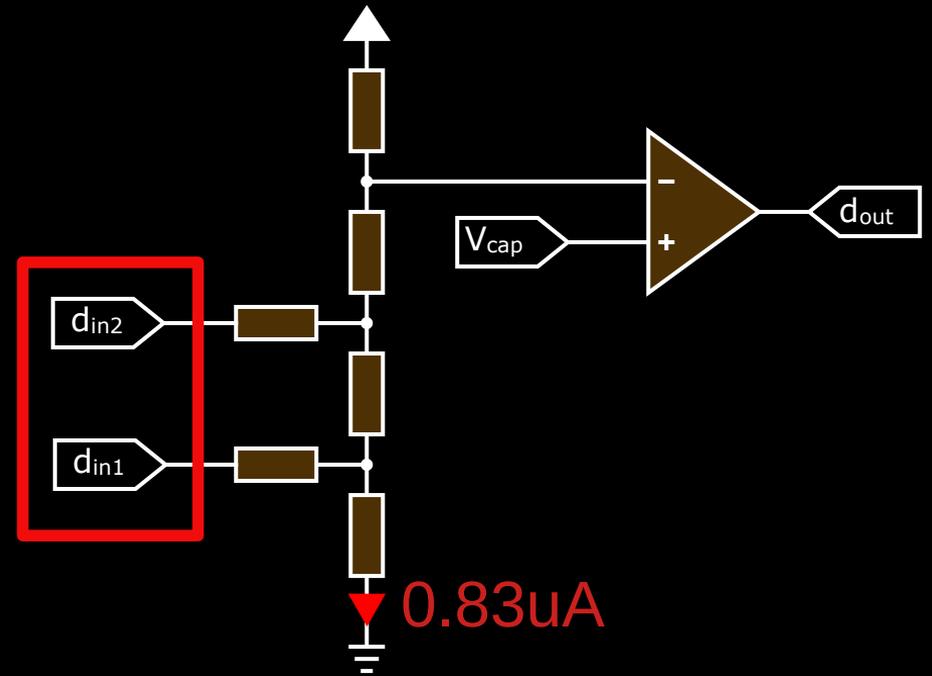


Riotee

# Voltage Supervisor



Potentiometer-based

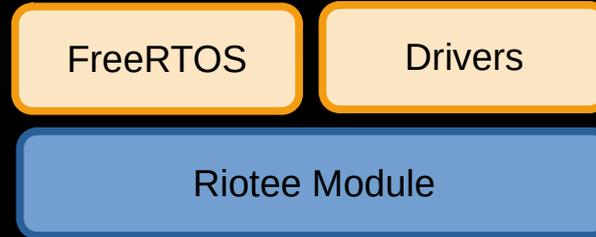


Riotee

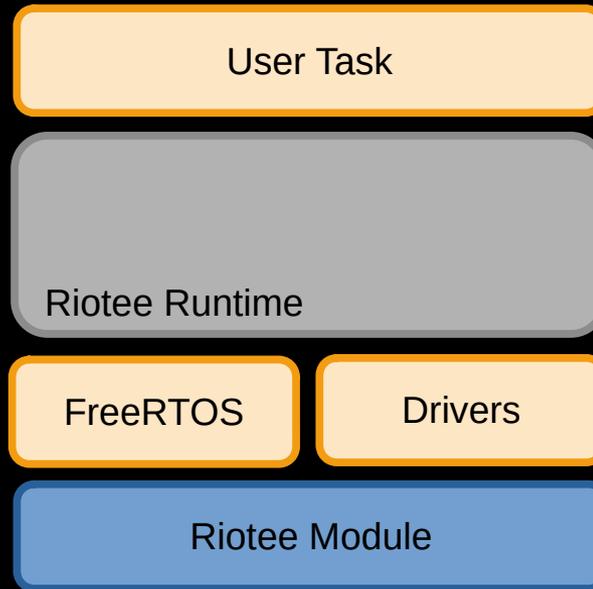
# Intermittent Runtime



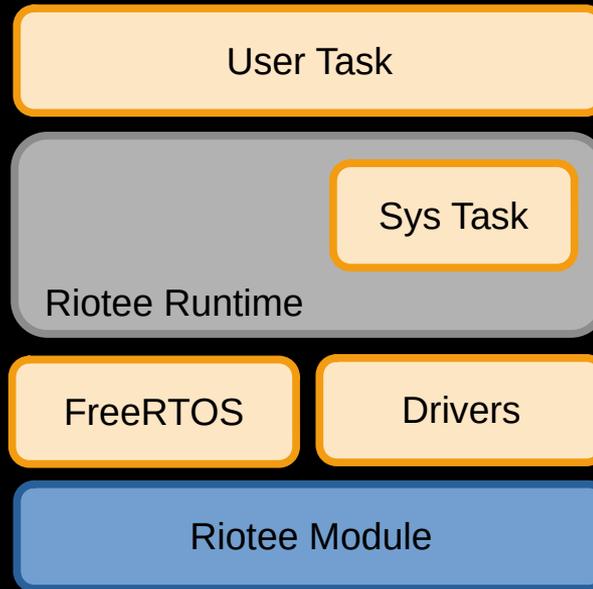
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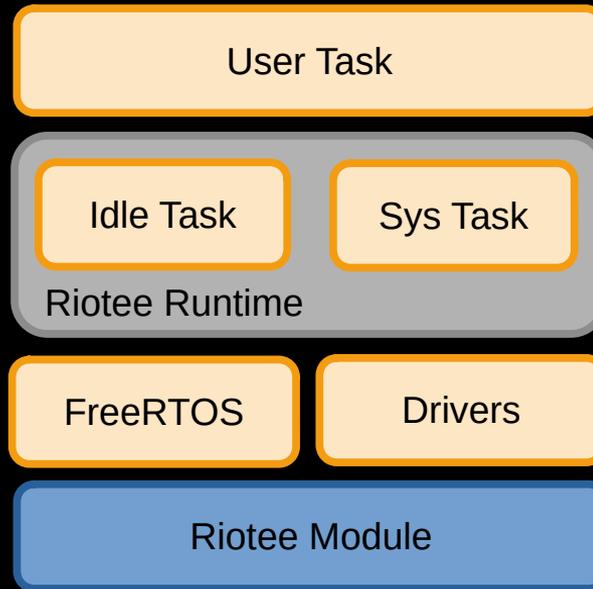
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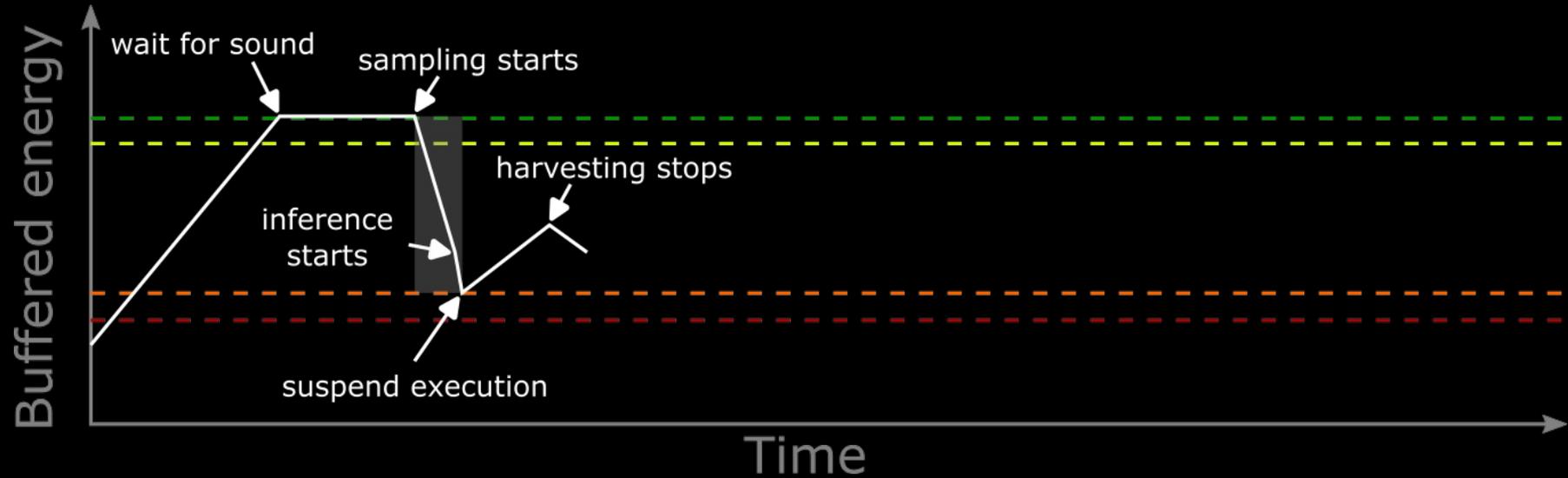
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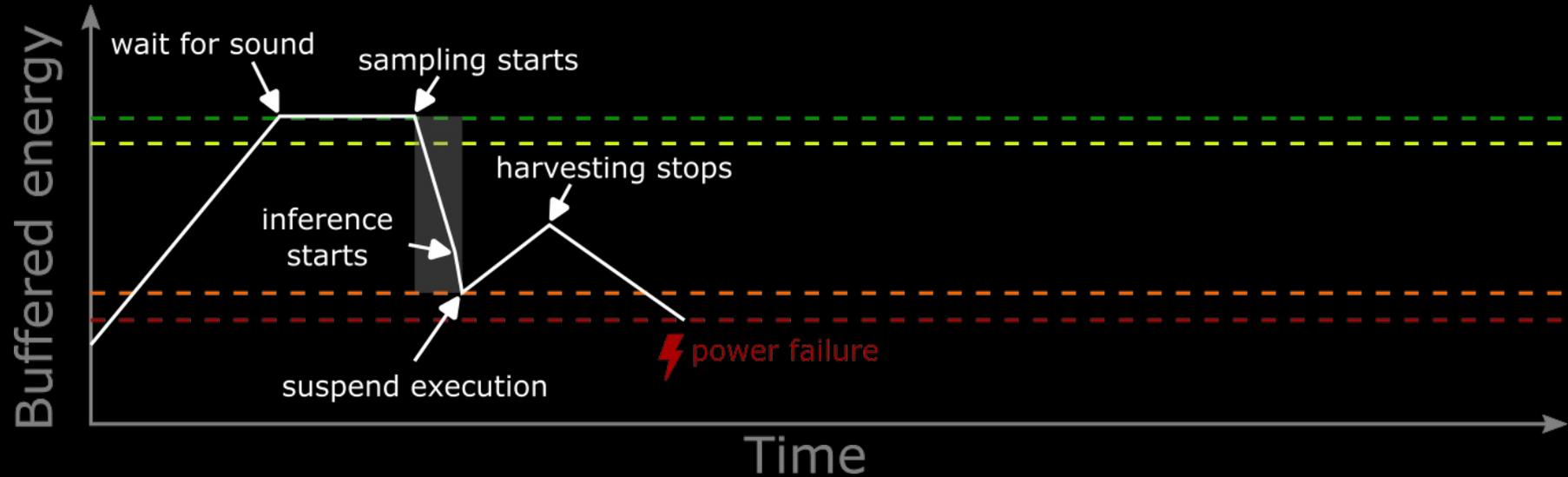
# Intermittent Runtime



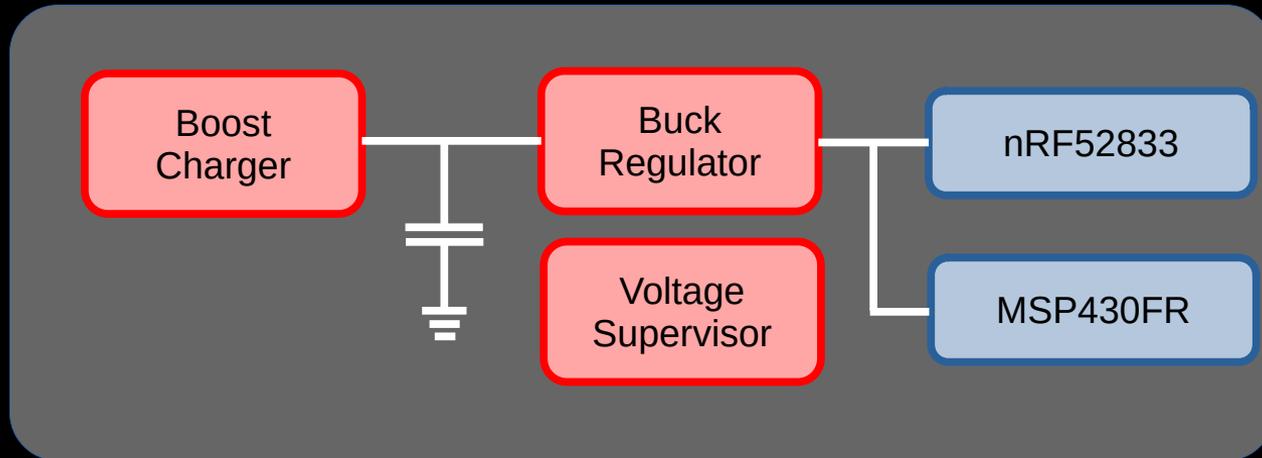
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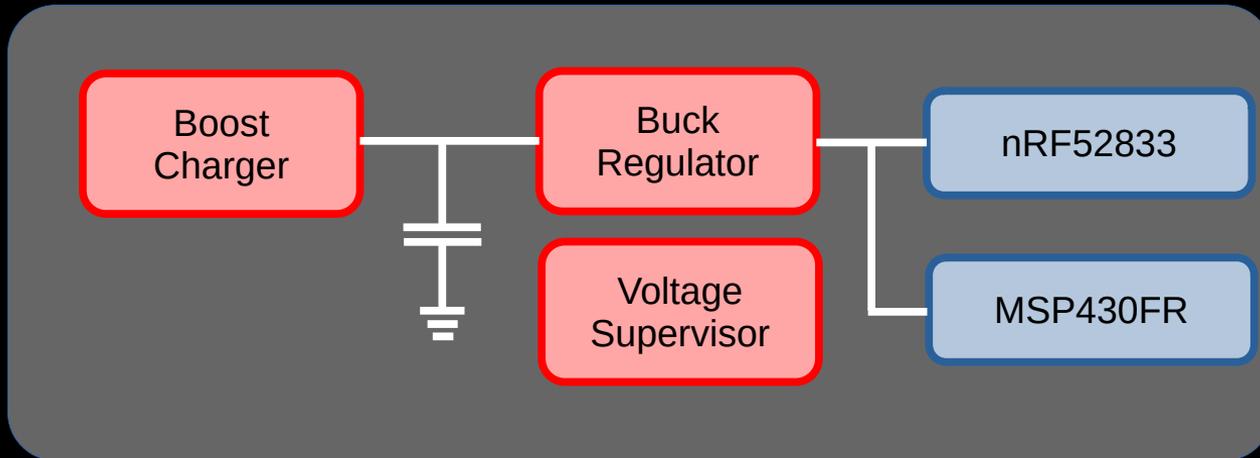
# Checkpointing



# Dual SoC

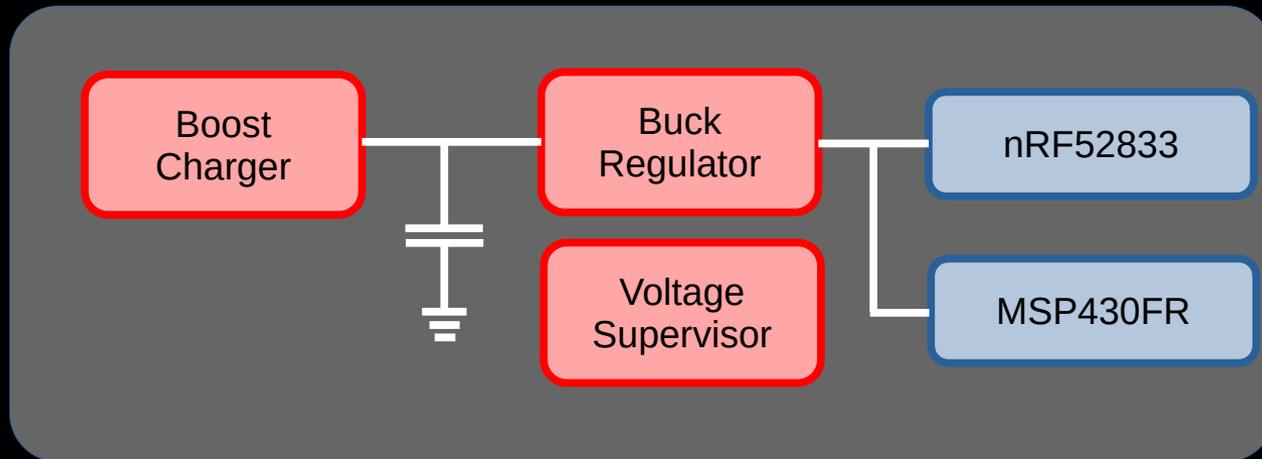


# Dual SoC



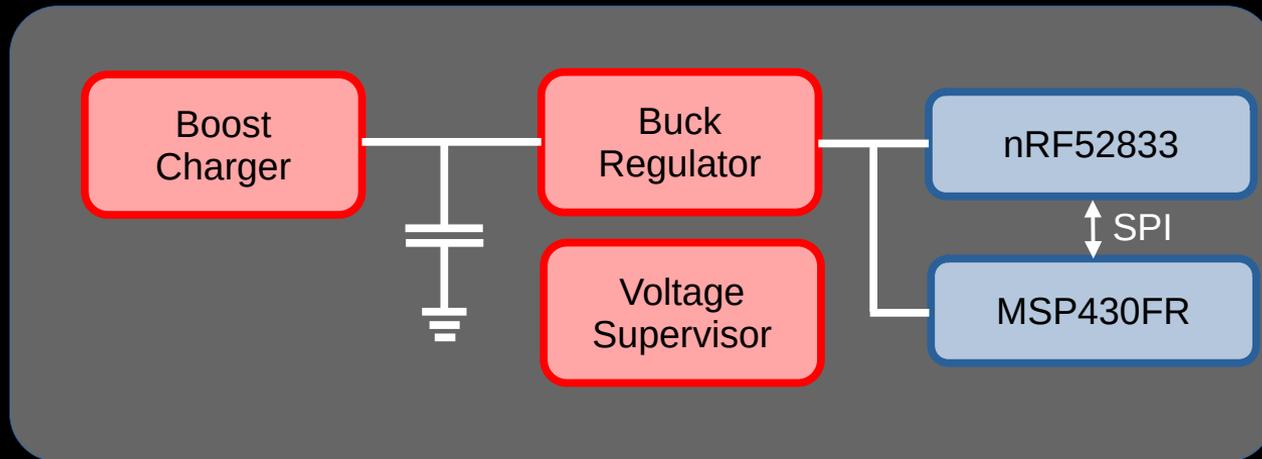
- ▶ 64 MHz Cortex-M4F
- ▶ 2.4 GHz wireless radio

# Dual SoC



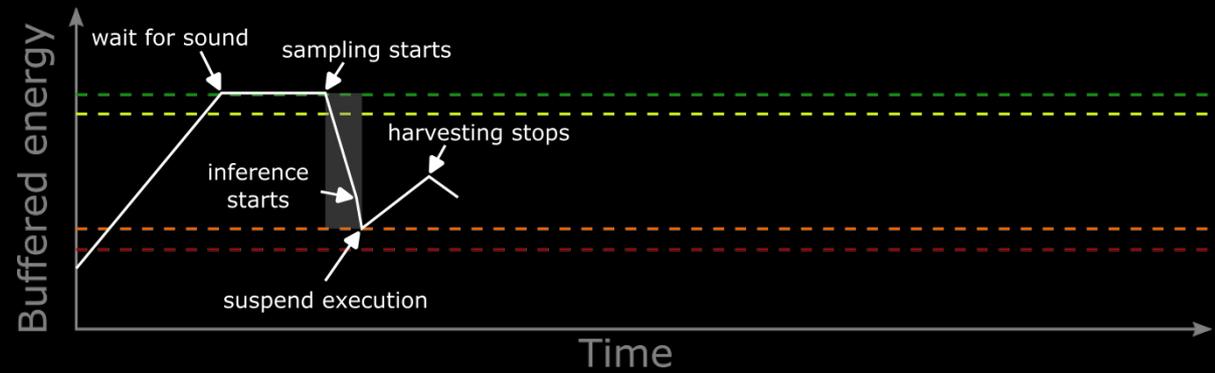
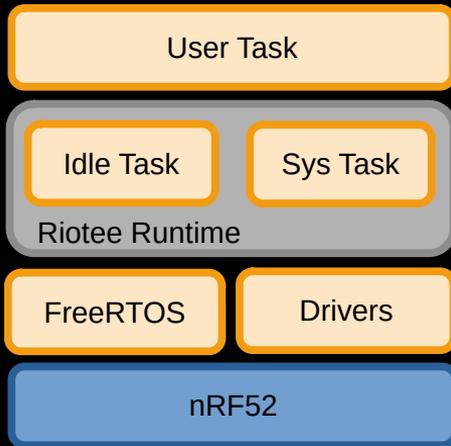
- ▶ 64 MHz Cortex-M4F
- ▶ 2.4 GHz wireless radio
- ▶ 16-MHz CPU
- ▶ 128kB FRAM

# Dual SoC

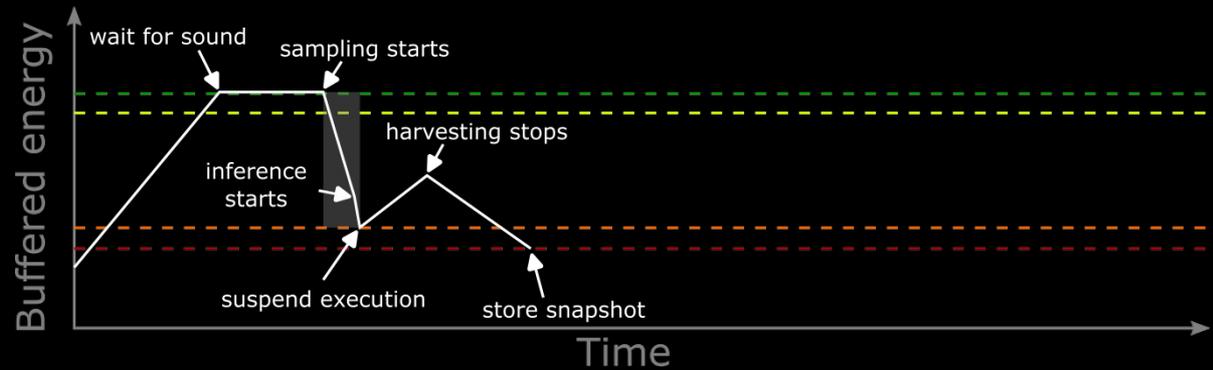
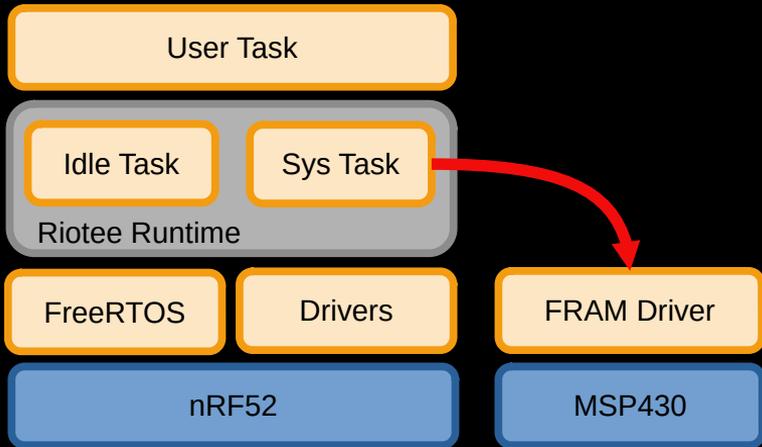


- ▶ 64 MHz Cortex-M4F
- ▶ 2.4 GHz wireless radio
- ▶ 16-MHz CPU
- ▶ 128kB FRAM

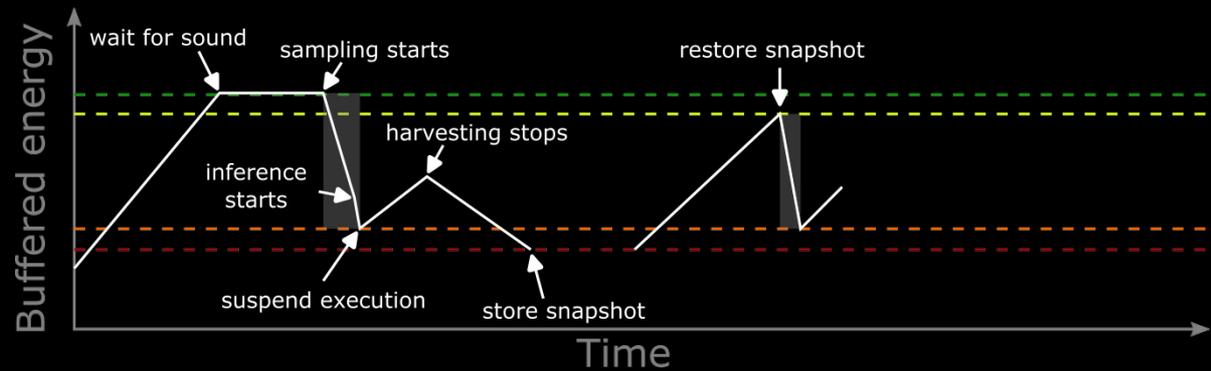
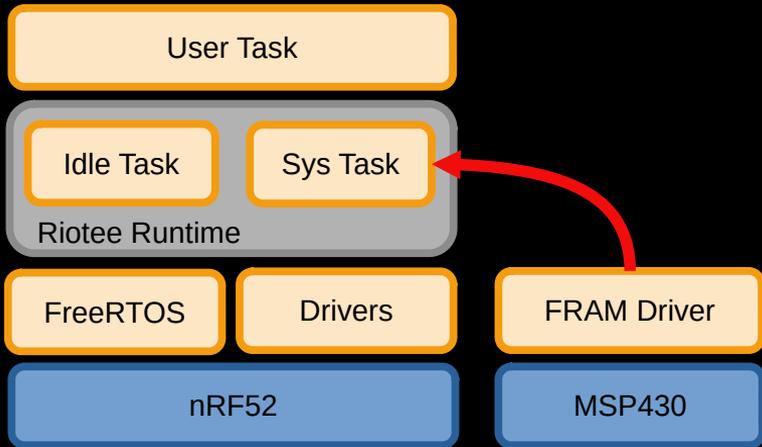
# Checkpointing



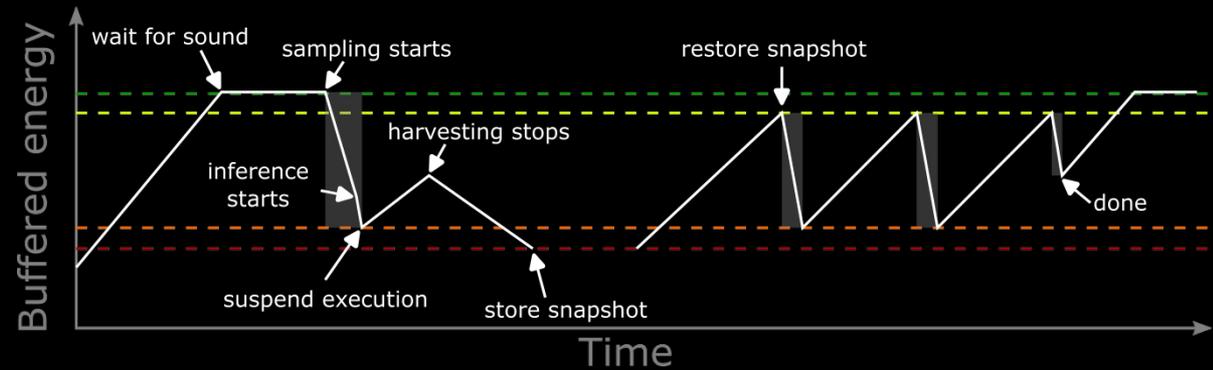
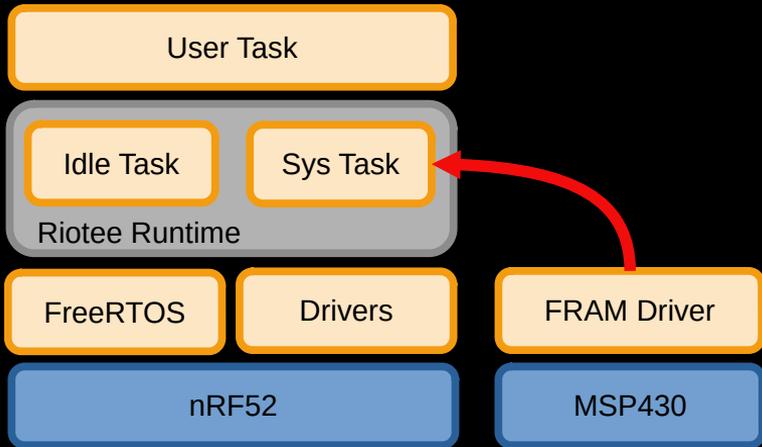
# Checkpointing



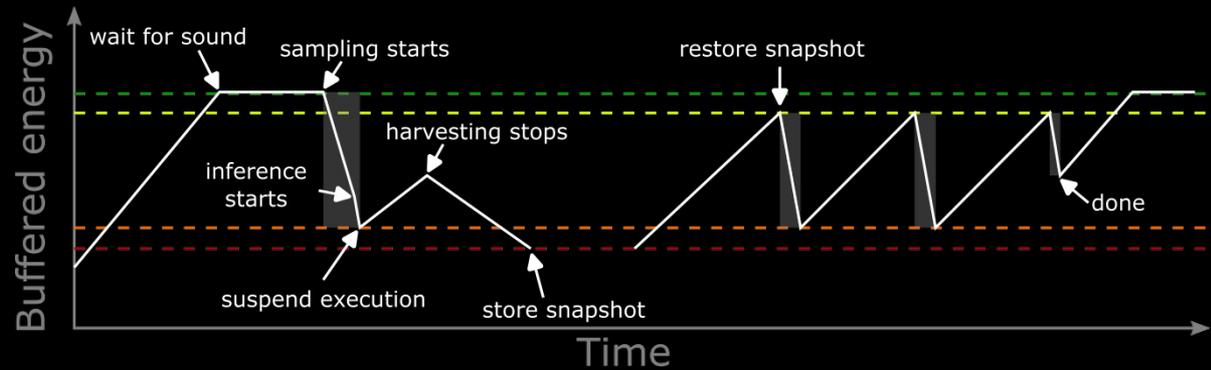
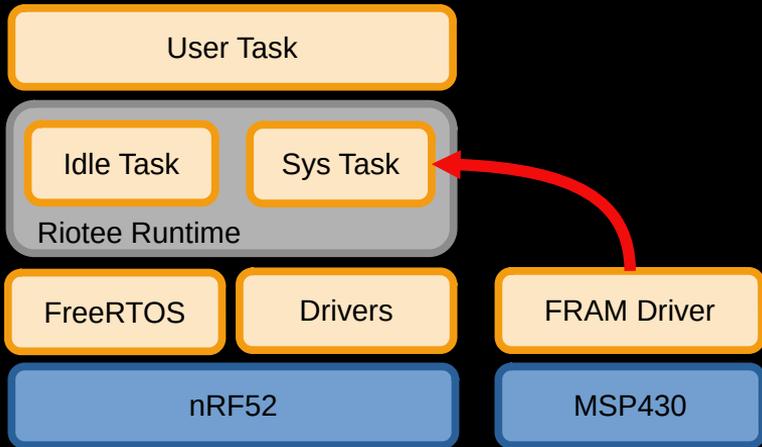
# Checkpointing



# Checkpointing

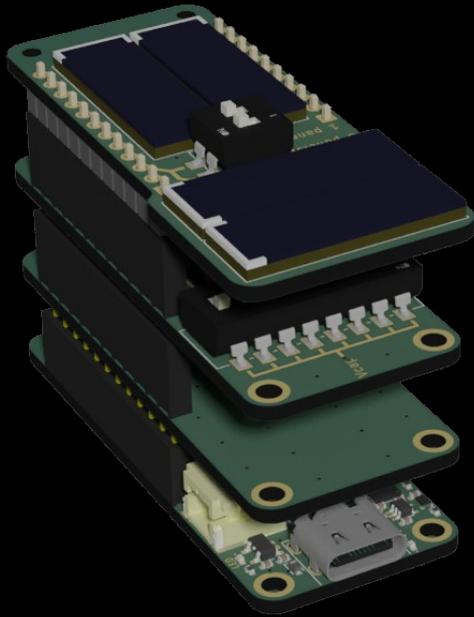


# Checkpointing

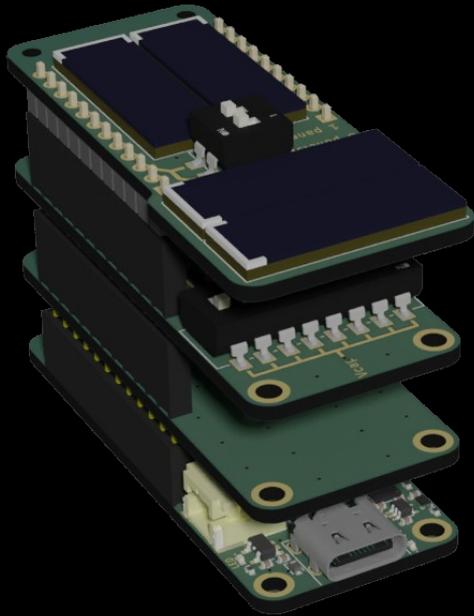


Hotword detection example available in the SDK

# Wrap-up

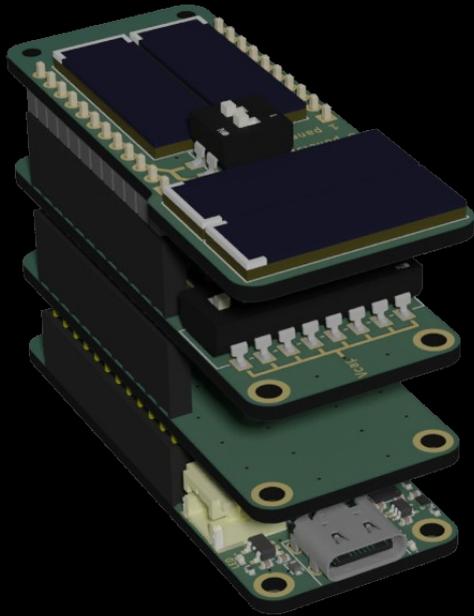


# Wrap-up



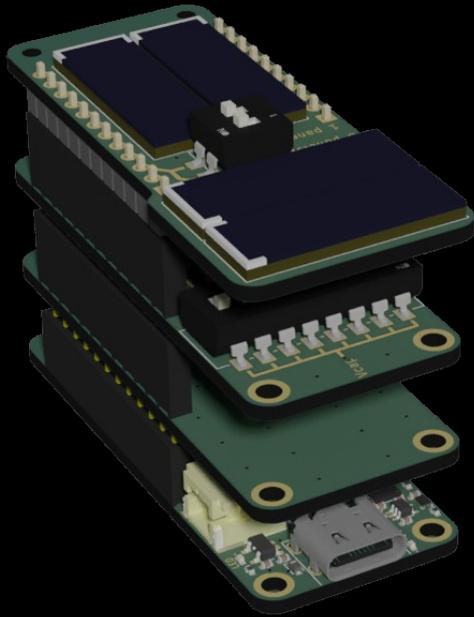
- ▶ “Batteries included”

# Wrap-up



- ▶ “Batteries included”
- ▶ Flexible and hackable

# Wrap-up



- ▶ “Batteries included”
- ▶ Flexible and hackable
- ▶ Powered mode available



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## RIOTEE\_BOARD\_10



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