

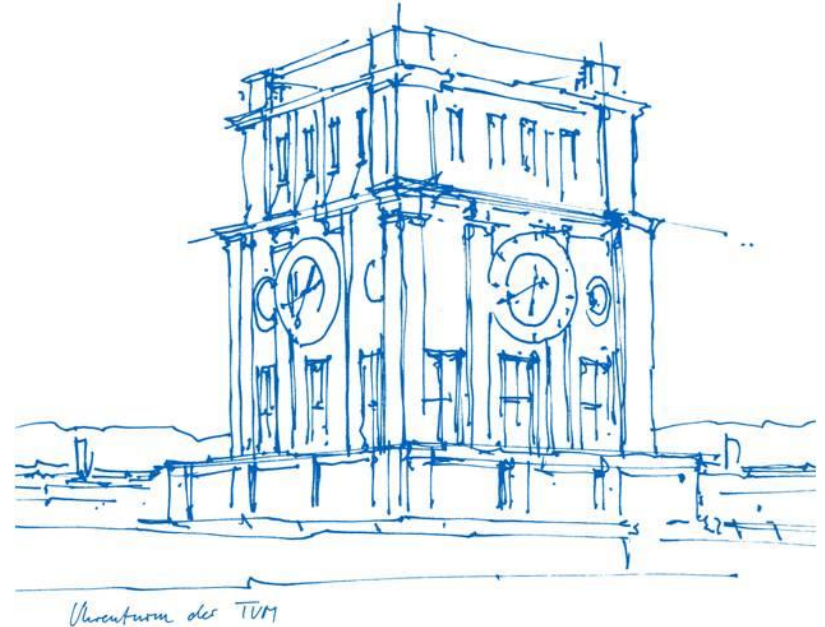
Sprint 4

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Edge Computing and the Internet of Things

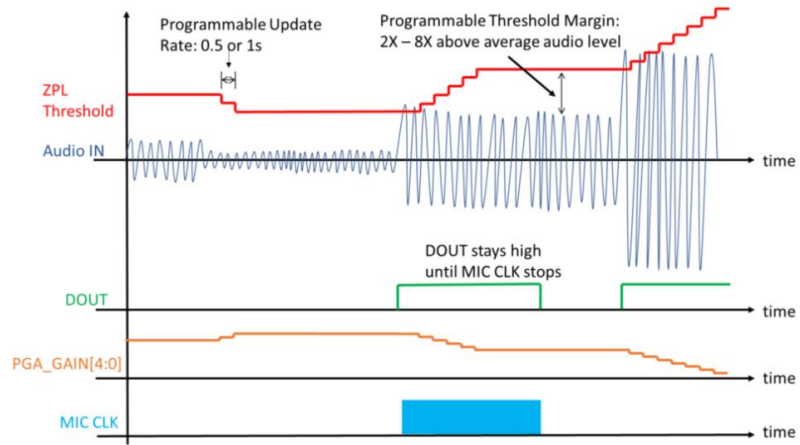
Technische Universität München

München, 26.01.2024



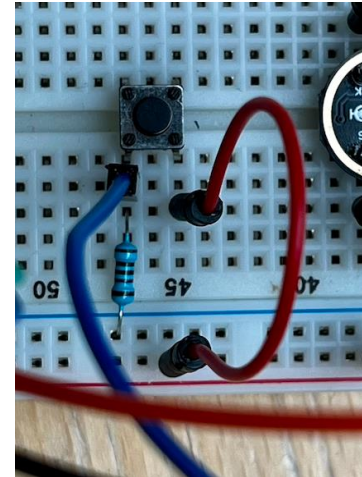
Deep sleep

Reality



[<https://vespermems.com/products/vm3011/>]

Solution

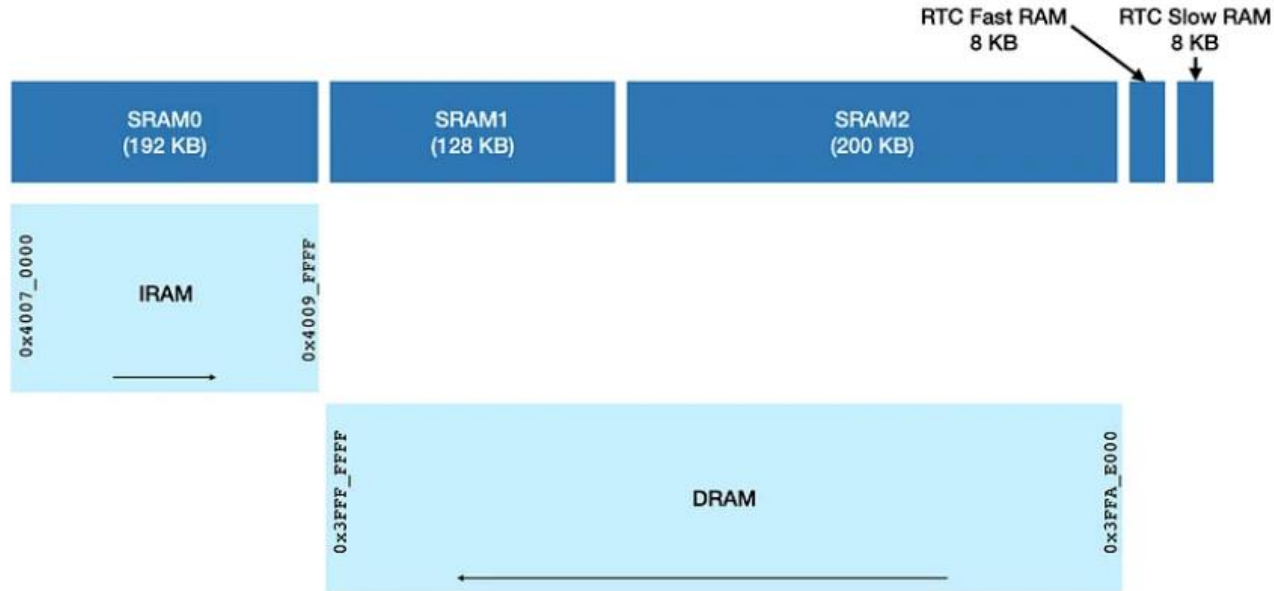


Post-training quantization

int16	floating-point	fixed-point
Training	$\approx 88\%$	$\approx 85\%$
Testing	$\approx 88\%$	$\approx 80\%$

int8	floating-point	fixed-point
Training	$\approx 88\%$	$\approx 88\%$
Testing	$\approx 88\%$	$\approx 88\%$

[ESP32] 512 kB SRAM ↯ heap

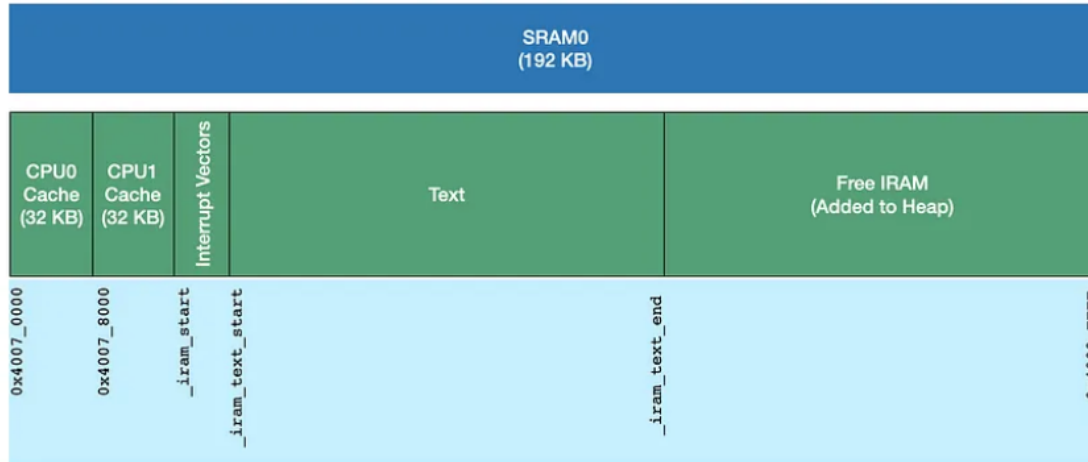


Programmers' Memory Map

[<https://blog.espressif.com/esp32-programmers-memory-model-259444d89387>]

[ESP32] 512 kB SRAM ↯ heap

IRAM Organisation

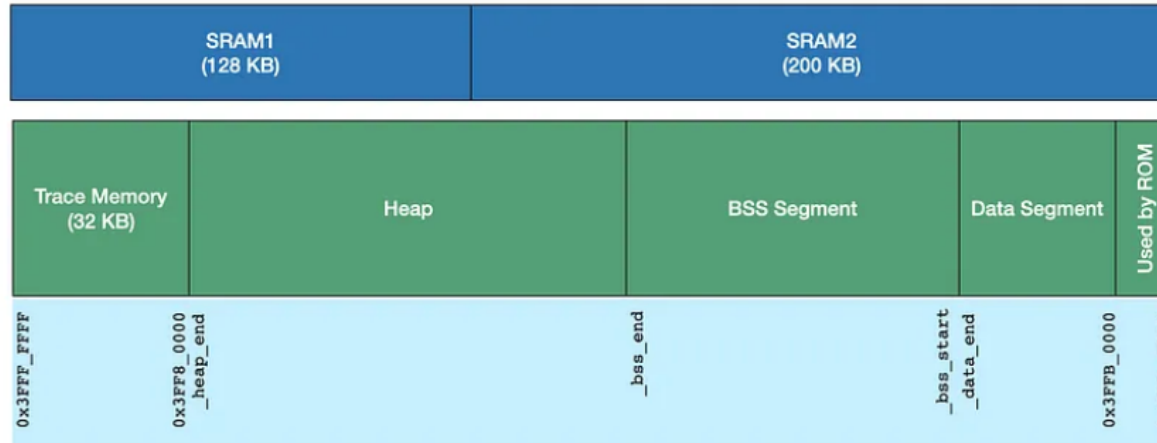


IRAM layout in dual core mode

[<https://blog.espressif.com/esp32-programmers-memory-model-259444d89387>]

[ESP32] 512 kB SRAM ↯ heap

DRAM Organisation with Trace Memory



DRAM Layout with Tracing Enabled

[<https://blog.espressif.com/esp32-programmers-memory-model-259444d89387>]

Memory inference



Example: 5s, 16kHz, MFCC: 308x32, quantization int8

Free \approx 350kB

Memory inference

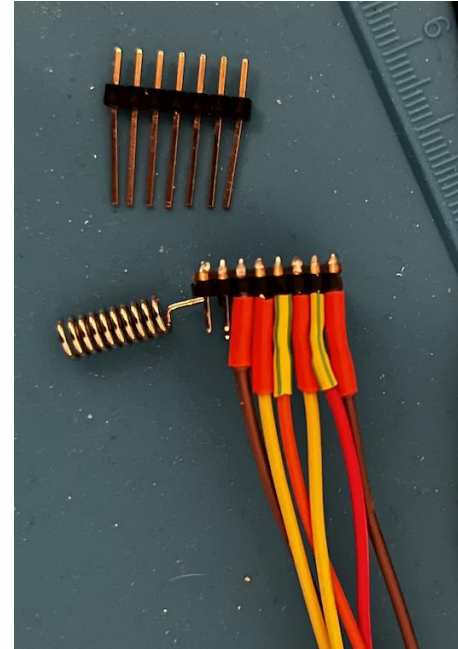
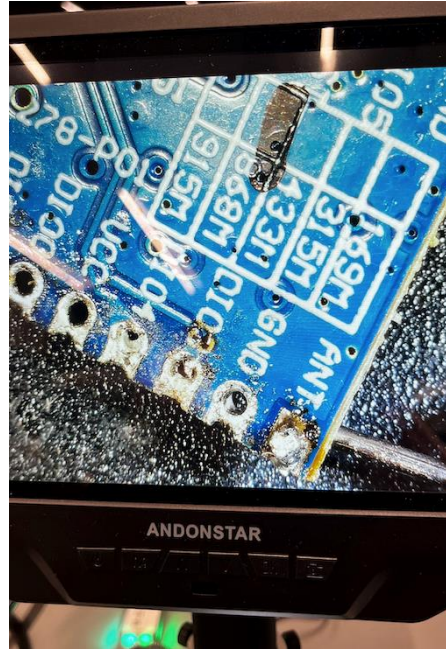
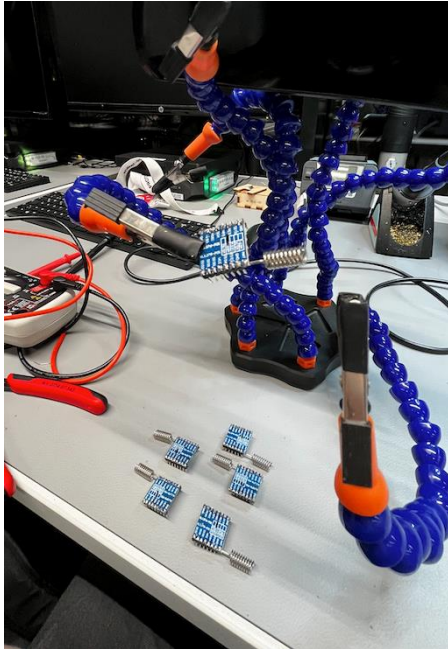
Example: 5s, 16kHz, MFCC: 308x32, quantization int8

Free $\approx 350\text{kB}$

Used $\approx 65\text{kB}$

mfcc input	conv1 weights	conv1 output	pool1 output	conv2 weights	conv2 output	pool2 output	conv3 weights	conv3 output	pool3 output	fc1 weights	fc1 output	fc2 weights	fc2 output	Σ
9.85 kB	256 B	48.96 kB	16.32 kB	2.32 kB	14.34 kB	3.58 kB	1.16 kB	1.34 kB	336 B	21.56 kB	64 B	260 B	4 B	
×	×	×												59.07 kB
		×	×		×									65.28 kB
			×	×	×									32.98 kB
					×	×								17.92 kB
						×	×							6.08 kB
							×	×						1.68 kB
								×	×					21.96 kB
										×	×			0.32 kB
											×	×	×	

LoRa pitch

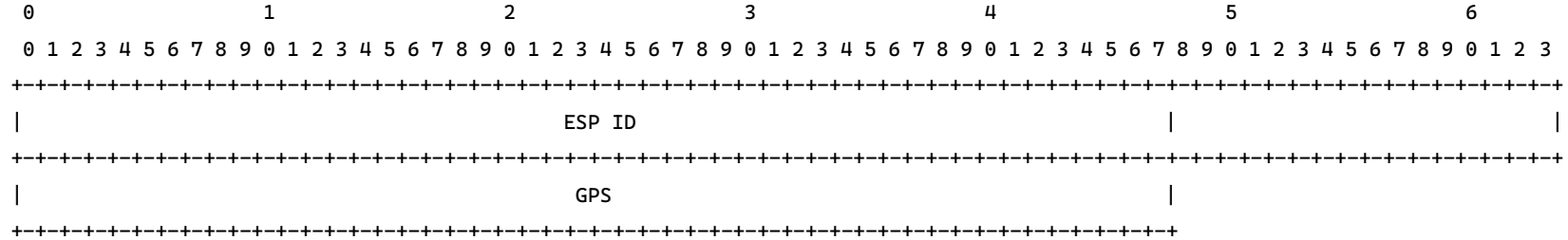


LoRa logic

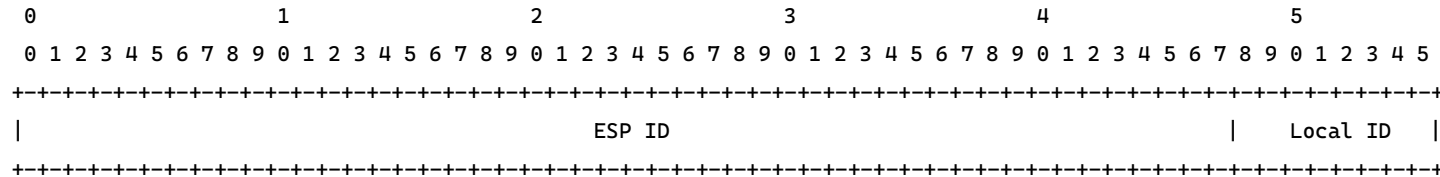
- **Initialization protocol:**
 - ESP -> RPi. MAC Address and GPS info
 - RPi -> ESP. ACK and local_id information (8 bits)
- **Classification protocol:**
 - ESP -> RPi. Local id and classification status of each bird.
 - RPi -> ESP. ACK.
- The initialization protocol is established every 24 hours. (max. 3 retries per cycle)
- The classification protocol is established every 15 min. (max. 3 retries per cycle)

LoRa initialization payload packages

1. LoRa initialization package:



2. LoRa initialization package ACK:



LoRa information payload packages

3. LoRa NN output package:

```
0                               1
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8
+-+-+
|   Local ID   |   Counter   |NN o.|
+-+-+
|   Local ID   |   Counter   |NN o.|
+-+-+
```

Example: 00000000 00000100 110 means:

- ID: 0.
- Counter: 4.
- NN classification: true for class 1, true for class 2, false for class 3.

4. LoRa NN output package ACK:

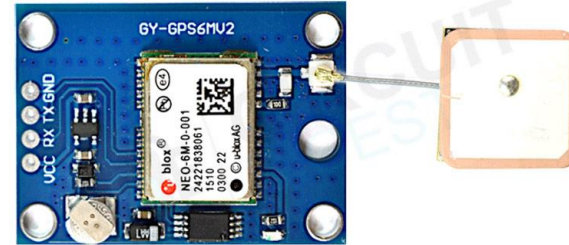
```
0                               1
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+
|   Local ID   |   Counter   |
+-+-+
```

LoRa duty cycle

- Time on Air:
 - LoRa initialization package (112 bits) -> 105.1 ms / package
 - LoRa initialization ACK package (56 bits) -> 64.1 ms / package
 - LoRa information package (19 bits) -> 36 ms / package
 - LoRa information ACK package (16 bits) -> 33.4 ms / package
- In the worst case (every connection fails), the Time on Air is 7.17 s / 24 h.
- Time on Air is less than the fair use limit (30 s / 24 h).
- Time on Air is far less than legal limitations for LoRa (864 s / 24 h).

GPS Module

- Using the GY-GPS6MV2
- Using UART to send data to the ESP
- Cold start in ideal conditions is ~2 mins
- Cold start in non-ideal conditions is ~10-20 mins
- Timeout is set to 30 mins
- 2.5m accuracy in ideal conditions



DEMO