



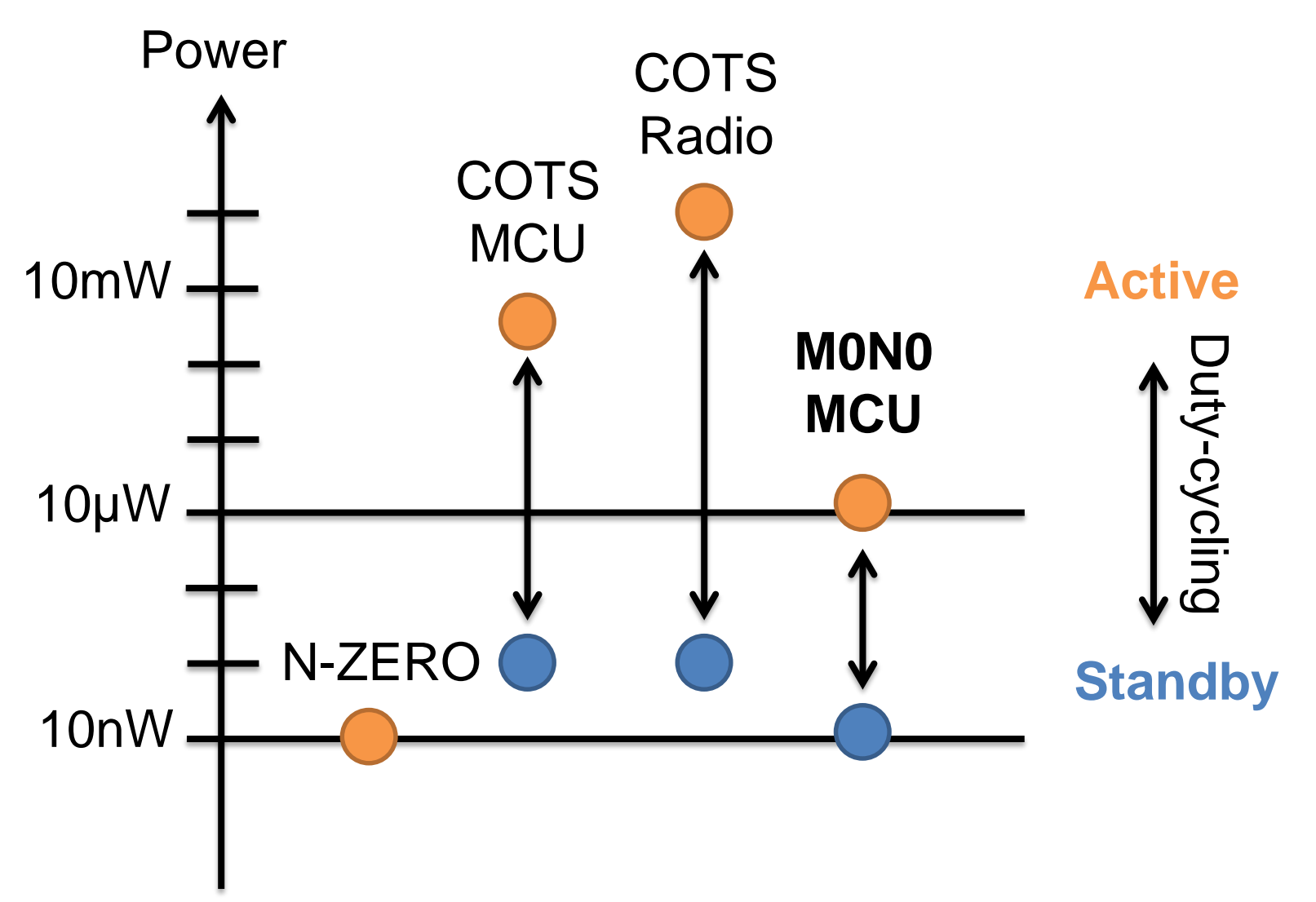
# MONO: an Ultra-low Power Microcontroller

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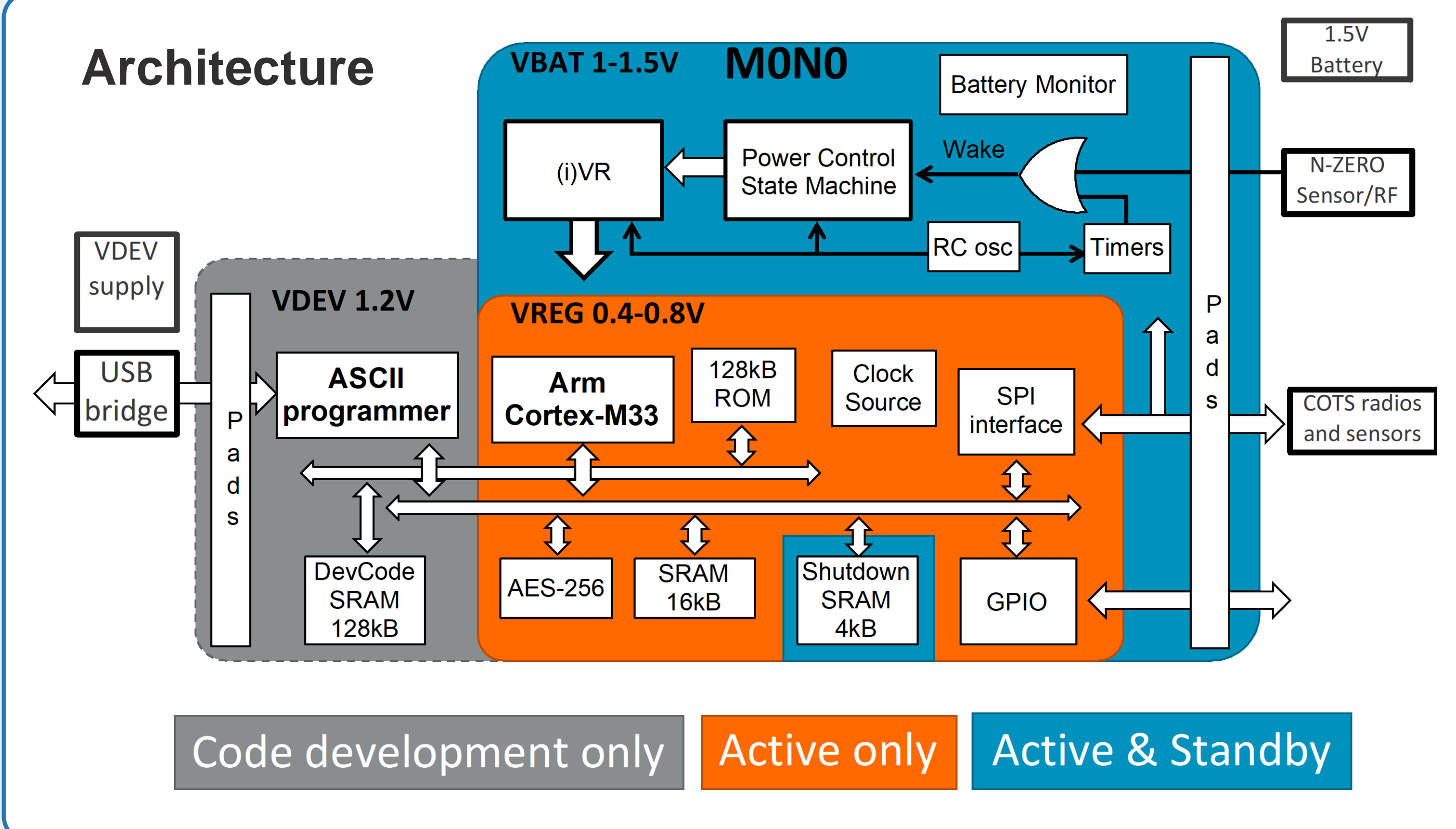
## Specialized Functions: Near Zero Power RF and Sensor Operations (N-ZERO)

### Motivation

- MONO is the first MCU to offer 10 nW shutdown power and 10 μW active power to fit naturally alongside 10 nW N-ZERO wakeup sensors
- Enabling smarter sensor nodes with >10x battery life

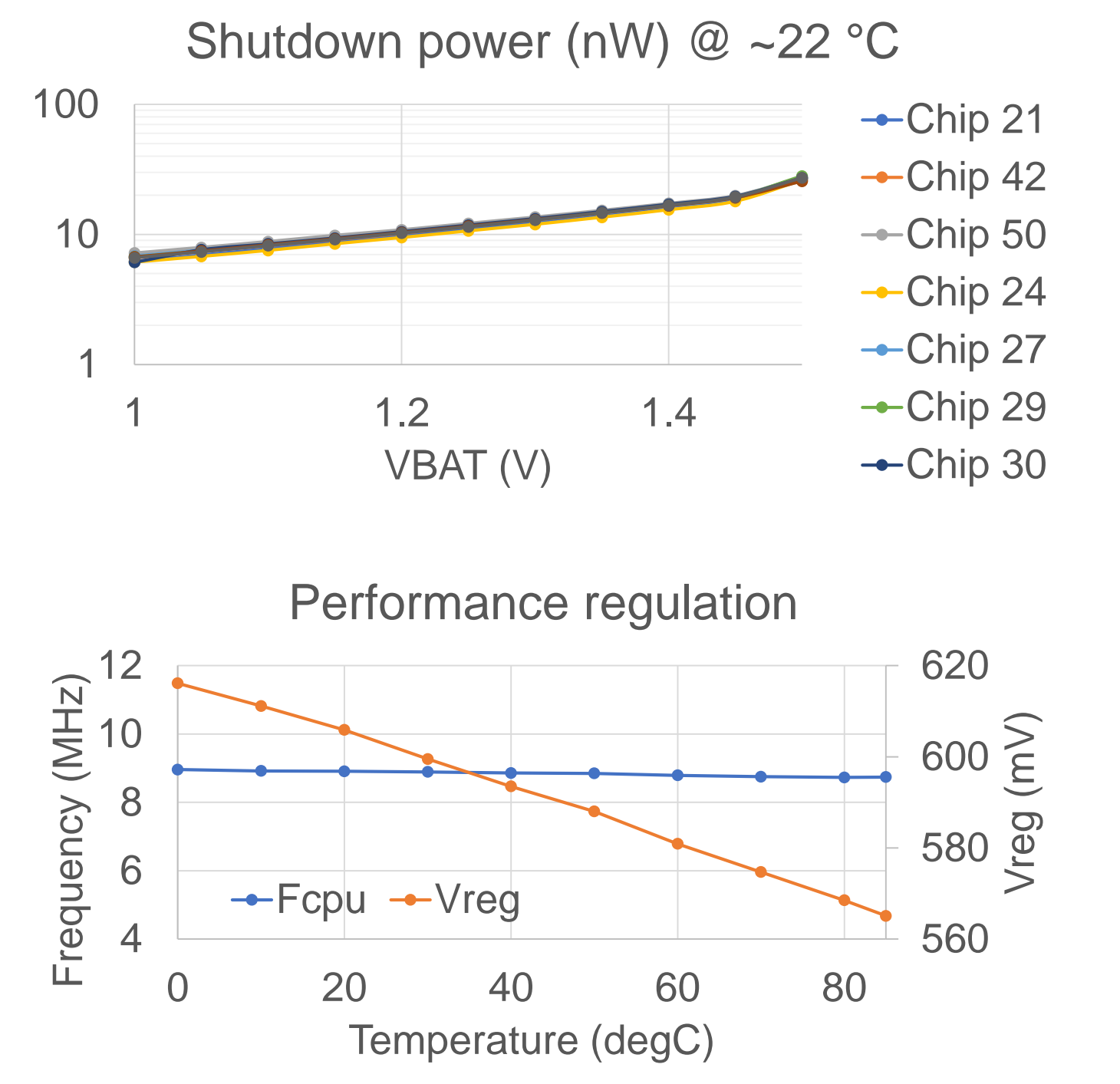


### Architecture



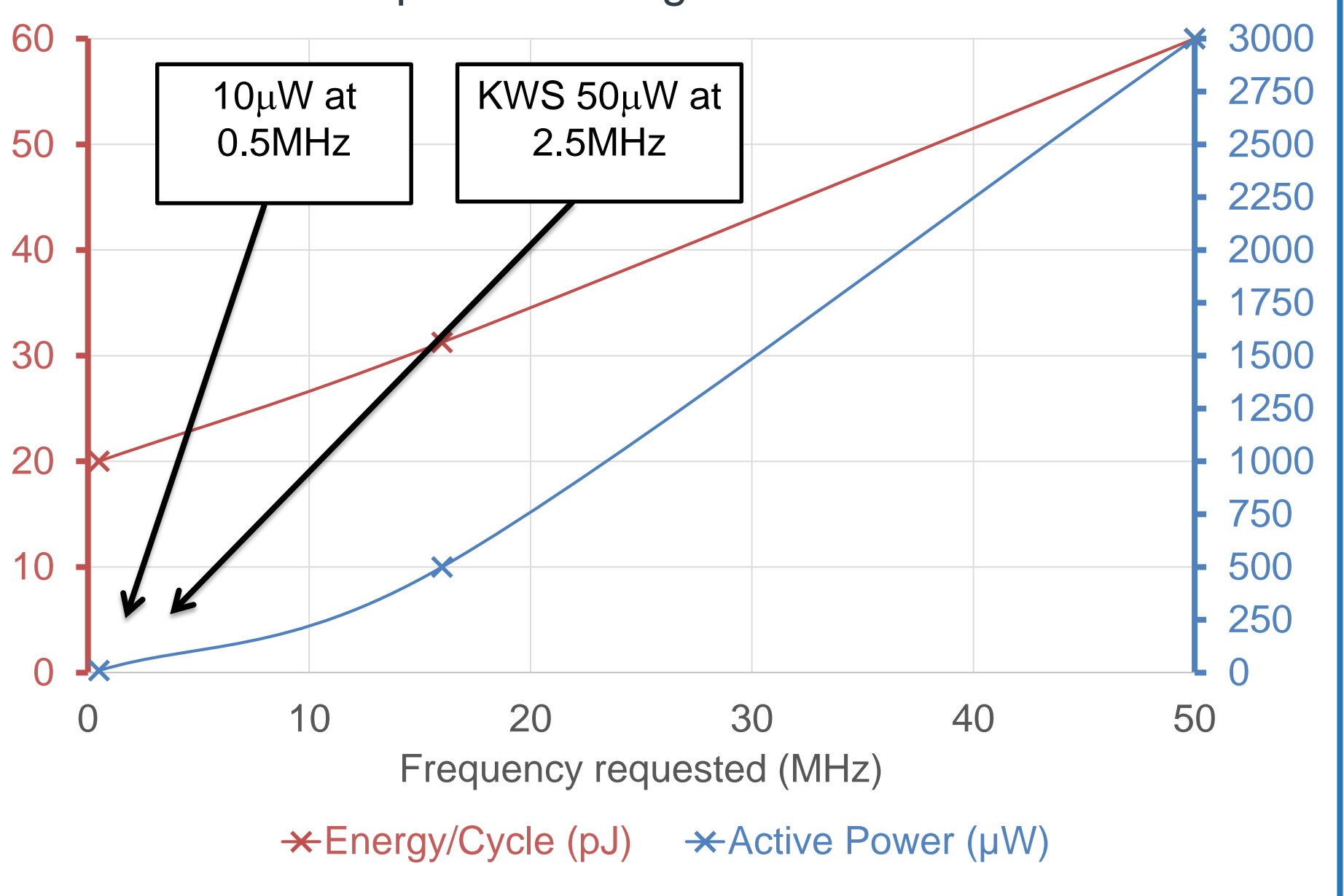
### Chip Measurement Highlights

- 10 nW full chip shutdown power
- 10 μW, 0.5 MHz active power
- Booting code within an hour of arrival: just insert battery & send a wakeup pulse
- Performance regulation working as expected
- DVFS functional across most of target range
- Timed-shutdown mode with internal RTC wakeup measured at 260 nW

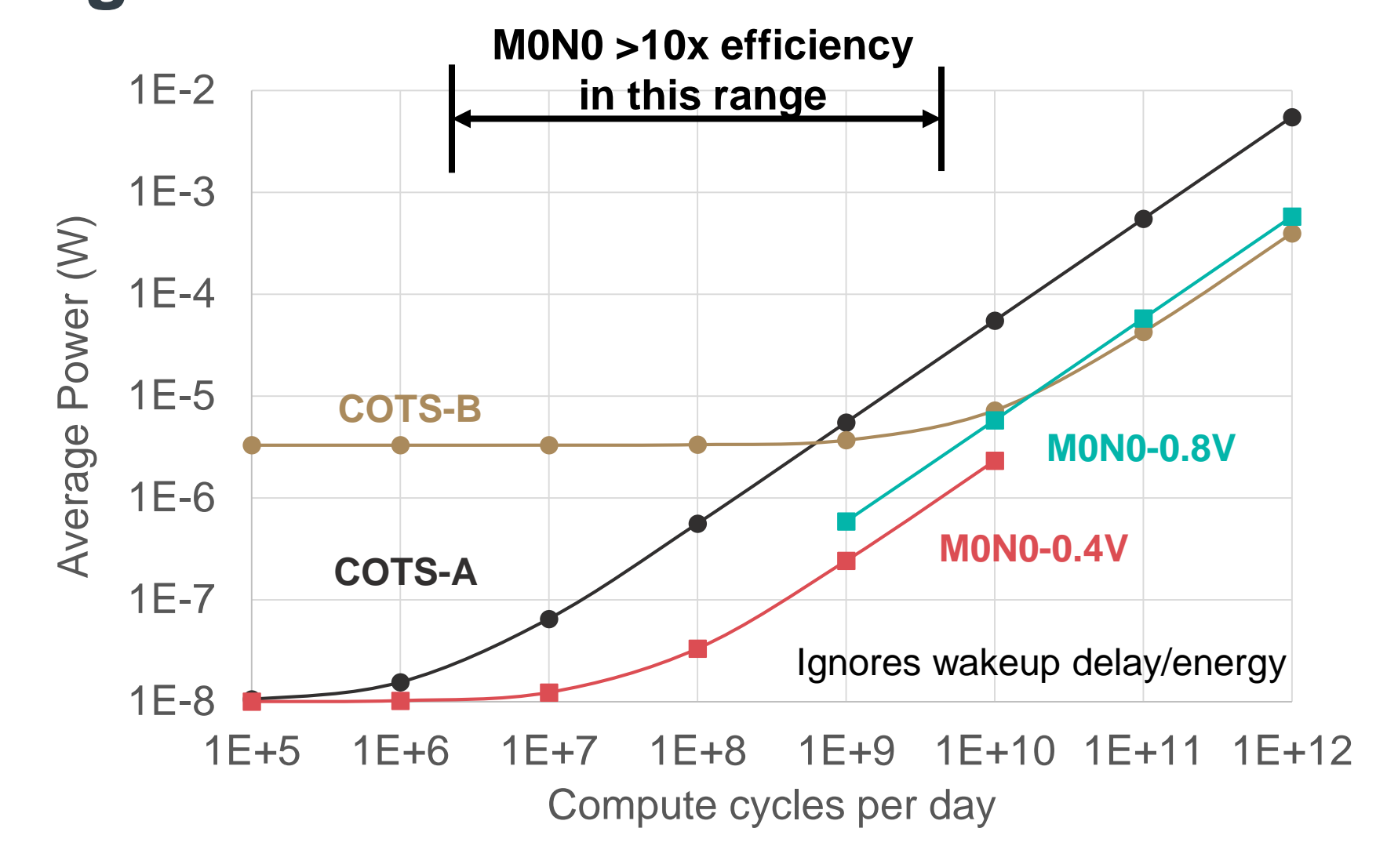
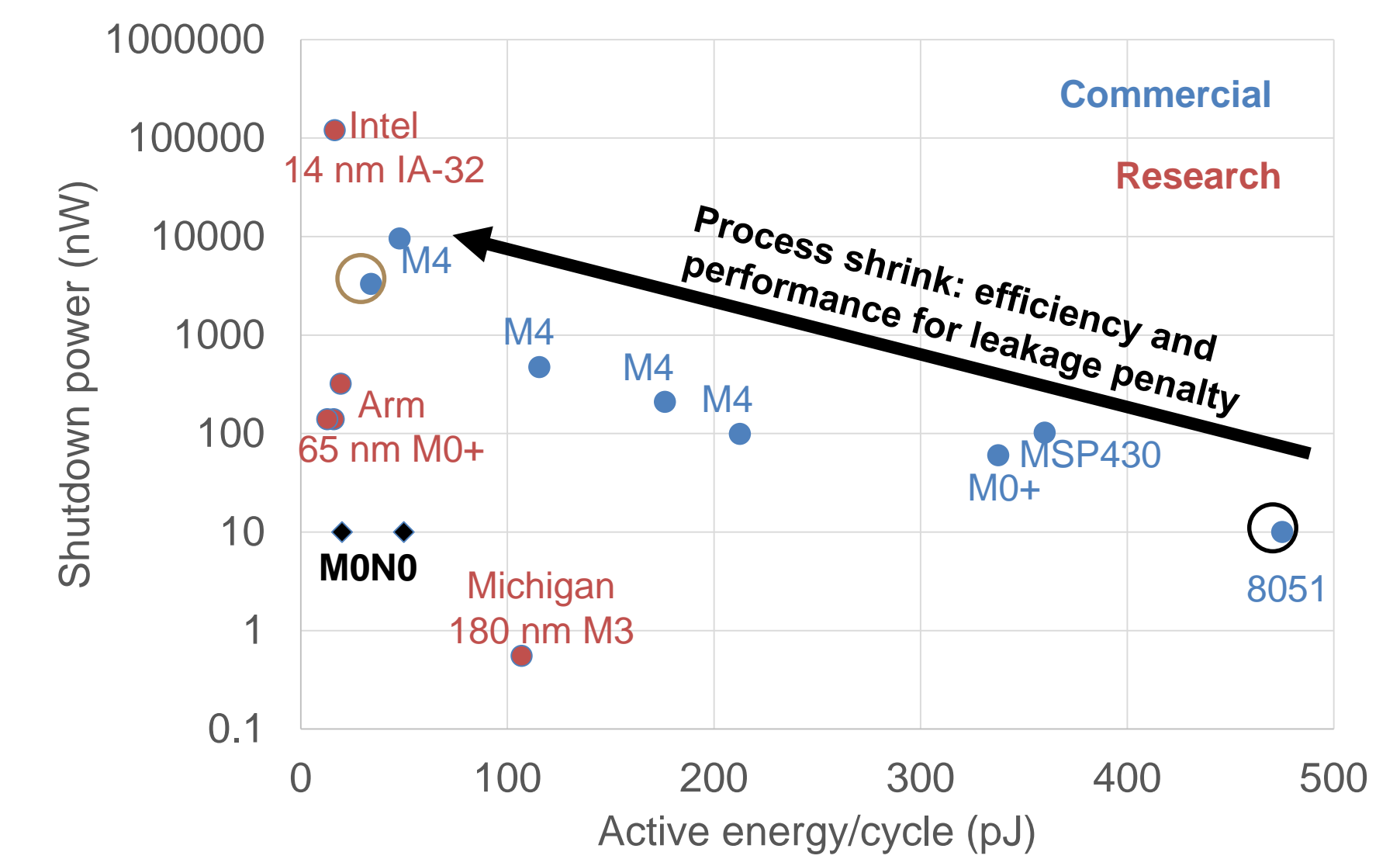


### MONO System Specifications

- CPU: Cortex-M33 with DSP/SIMD extensions (no FPU)
- Active Performance: 0.5-50 MHz @ 10 μW - 3 mW
- Shutdown power: 10 nW at 1.2 V 20 °C
- ROM: 128 kB via-programmed
- SRAM: 16 kB active + 4 kB shutdown
- Shutdown SRAM breakeven time: ~1 s for 4 kB transfer
- Functional temperature range: 0-85 °C



### Benchmarking

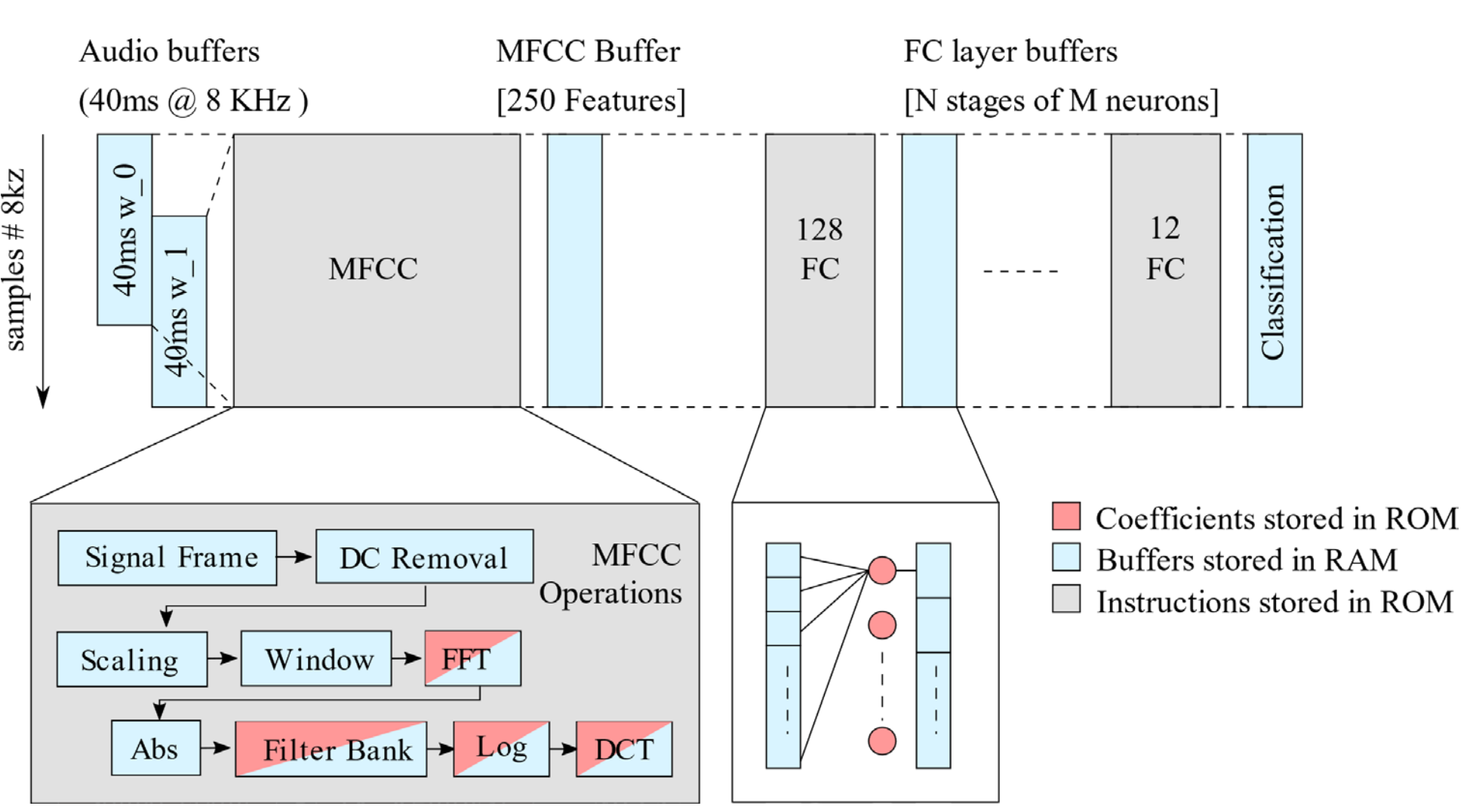


### Current Status

- Final testing starts in July
- Phase 3 will deliver:
  - KWS demo boards
  - SW development boards
  - ROM chip generator
- Please let us know if you are interested in using MONO or have an application!
- [james.myers@arm.com](mailto:james.myers@arm.com) & [ben.conrad@arm.com](mailto:ben.conrad@arm.com)

### Keyword Spotting Demo

- SW demo to prove capability
- Targets Google Speech Commands Dataset, detecting 10 keywords
- Most work is feature extraction rather than the neural network
- Optimized memory usage and buffer scheduling
- Runs at ~2.5 MHz for 50 μW



Percentage	Profile 1	Test set										
Lab\Pred	Silence	Unknown	Down	Go	Left	No	Off	On	Right	Stop	Up	Yes
Silence	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown	0.25	65.93	5.64	4.66	2.21	2.45	3.19	4.66	4.90	0.49	1.23	4.41
Down	0.00	5.25	84.96	1.67	0.00	0.48	6.44	0.24	0.00	0.24	0.00	0.72
Go	0.25	5.93	3.21	75.31	0.25	5.19	1.98	0.25	0.00	0.25	0.99	6.42
Left	0.94	2.82	0.24	0.24	76.47	1.65	0.71	0.94	1.18	7.53	5.88	1.41
No	0.00	7.88	1.97	10.84	0.49	71.43	0.25	0.74	0.49	0.00	0.49	5.42
Off	0.00	6.31	12.14	1.94	3.16	0.49	72.82	0.97	0.00	0.97	0.97	0.24
On	0.25	10.86	0.76	1.01	1.01	0.76	5.30	77.78	0.25	0.51	0.51	1.01
Right	0.00	7.58	0.00	0.00	3.54	1.52	0.00	1.01	81.57	4.29	0.25	0.25
Stop	0.25	4.23	0.50	0.00	18.16	0.75	0.75	0.75	4.98	63.68	4.48	1.49
Up	0.00	2.43	1.22	1.22	15.82	2.43	1.22	0.49	0.00	4.62	68.37	2.19
Yes	0.50	7.71	2.49	18.16	1.74	8.21	1.74	0.75	1.24	1.00	2.49	53.98

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DVFS = dynamic voltage and frequency scaling  
KWS = keyword spotting

