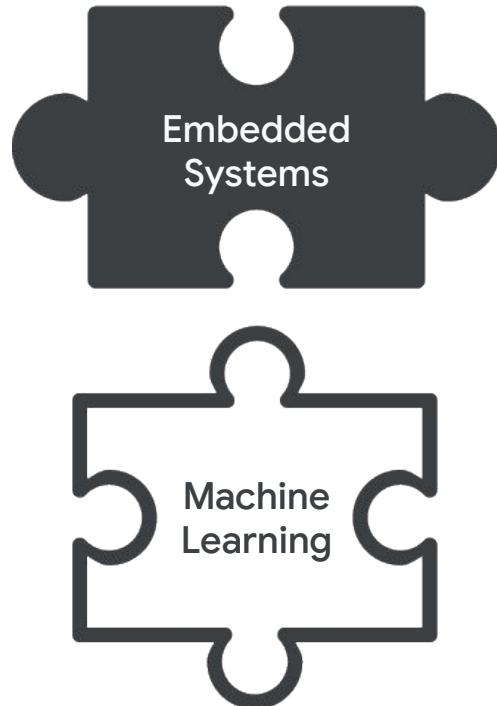


How Do We Enable TinyML?

What Makes **TinyML**?



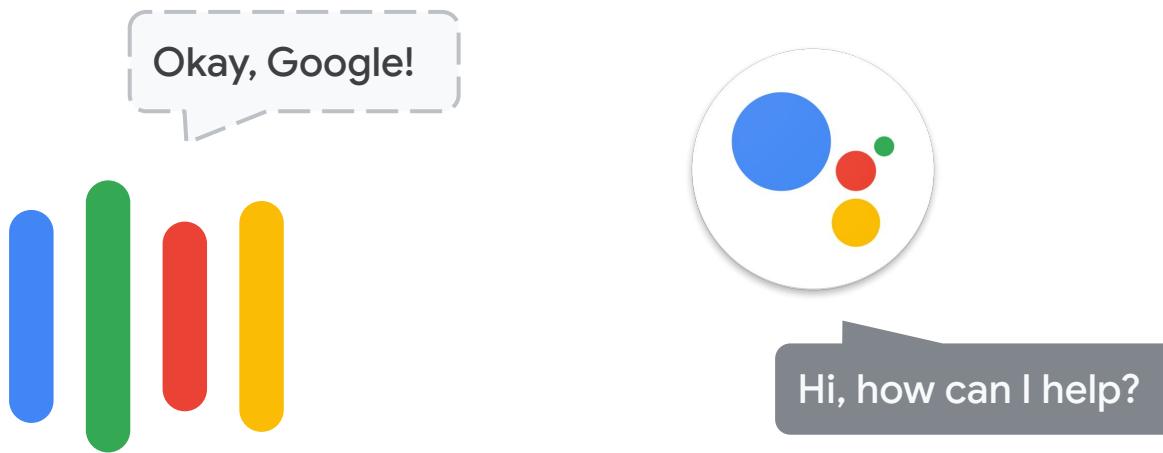
TinyML

Let's Take an Example

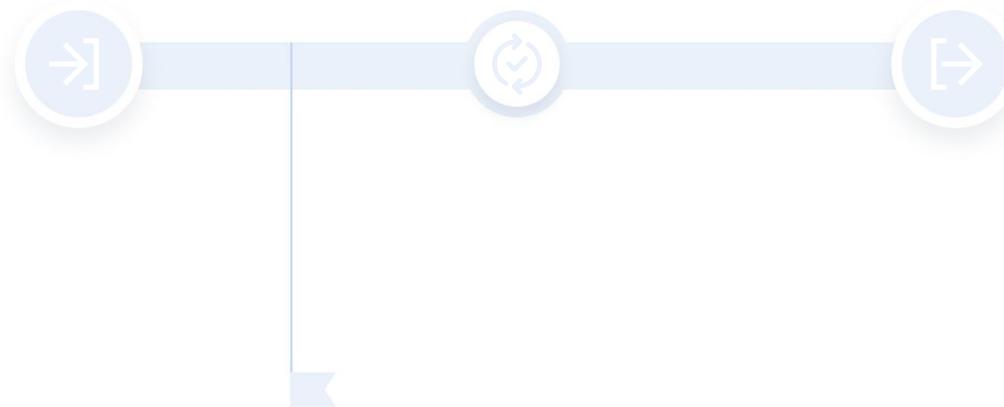


Google Assistant

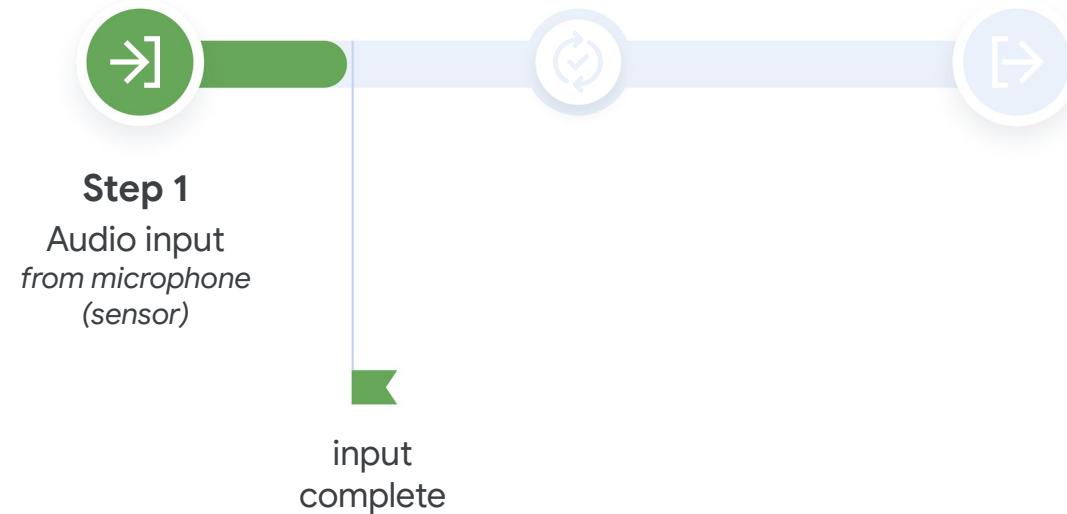
Let's Take an Example



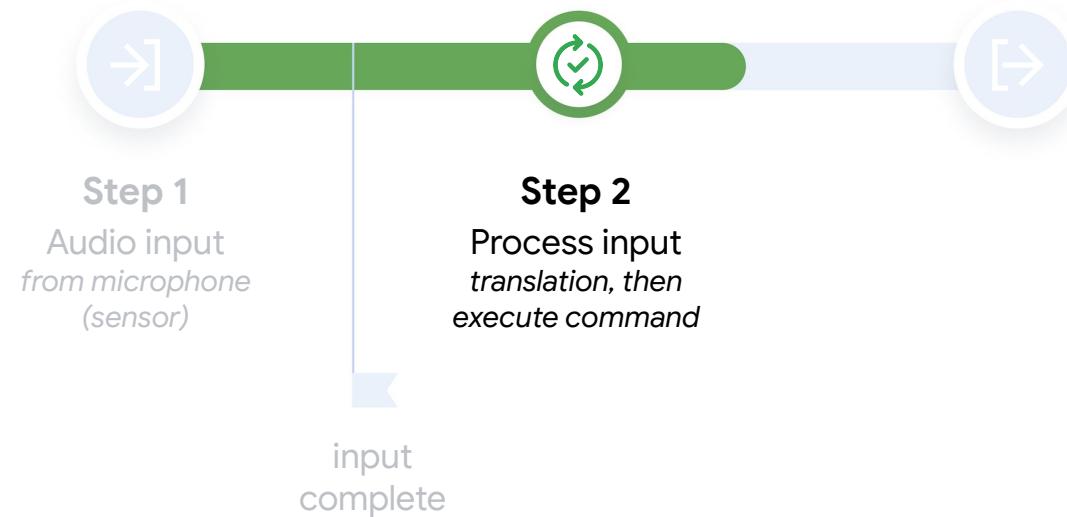
The Three Basic Steps



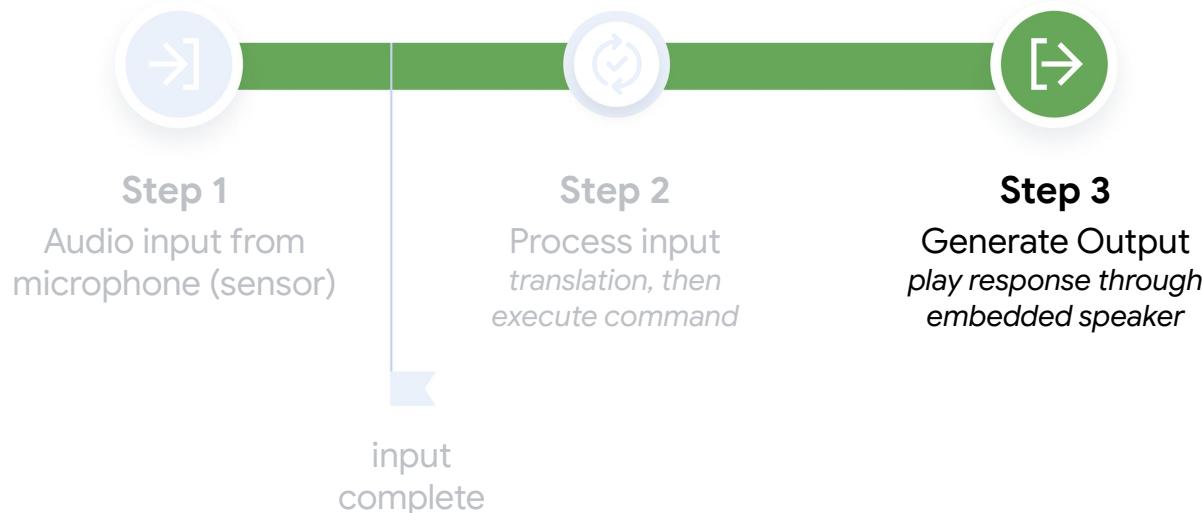
The Three Basic Steps



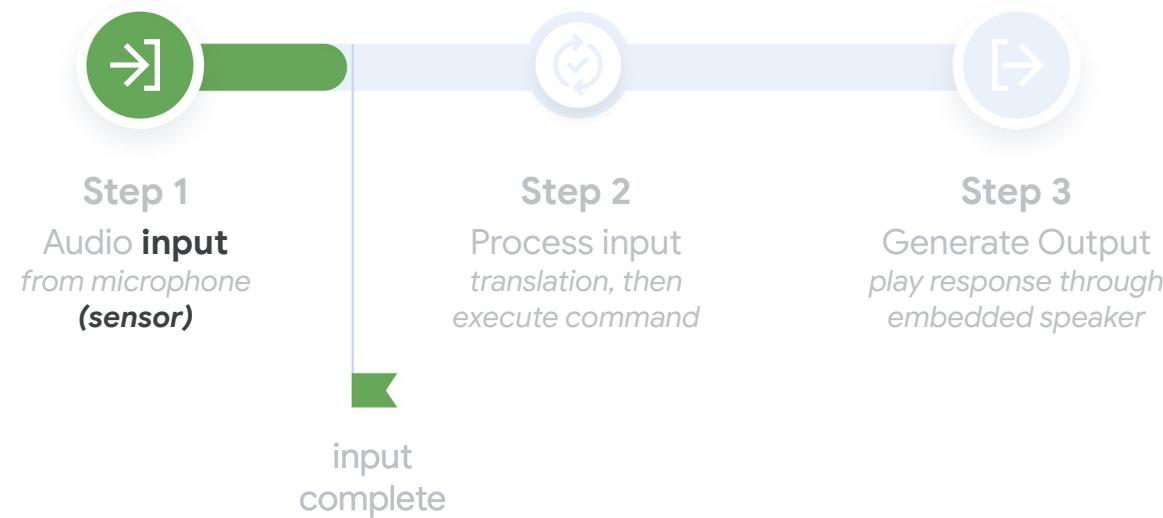
The Three Basic Steps



The Three Basic Steps



Input



Endpoints Have Sensors, Tons of Sensors

Motion Sensors

Gyroscope, radar,
magnetometer, accelerator

Acoustic Sensors

Ultrasonic, Microphones,
Geophones, Vibrometers

Environmental Sensors

Temperature, Humidity,
Pressure, IR, etc.

Touchscreen Sensors

Capacitive, IR

Image Sensors

Thermal, Image

Biometric Sensors

Fingerprint, Heart rate, etc.

Force Sensors

Pressure, Strain

Rotation Sensors

Encoders

Endpoints Have Sensors, Tons of Sensors

Motion Sensors

Gyroscope, radar,
magnetometer, accelerator

Acoustic Sensors

Ultrasonic, Microphones,
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Touchscreen Sensors

Capacitive, IR

Image Sensors

Thermal, Image

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Pressure, Strain

Rotation Sensors

Encoders

Biometric Sensors



Non-invasive Glucose Monitoring



Fingerprint + Photoplethysmography (PPG)

Endpoints Have Sensors, Tons of Sensors

Motion Sensors

Gyroscope, radar,
magnetometer, accelerator

Acoustic Sensors

Ultrasonic, Microphones,
Geophones, Vibrometers

Environmental Sensors

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Fingerprint, Heart rate, etc.

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Pressure, Strain

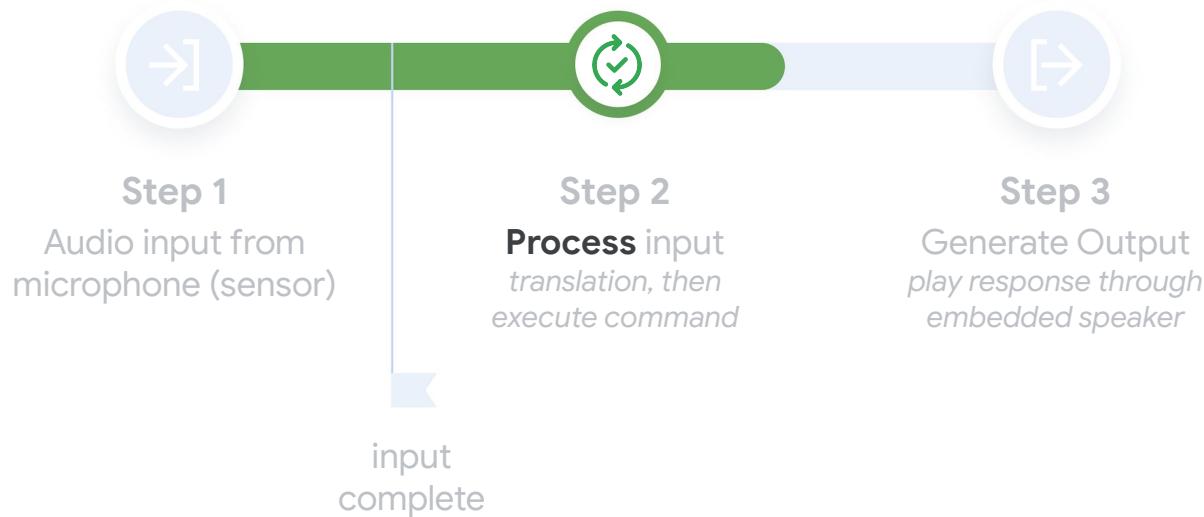
Rotation Sensors

Encoders

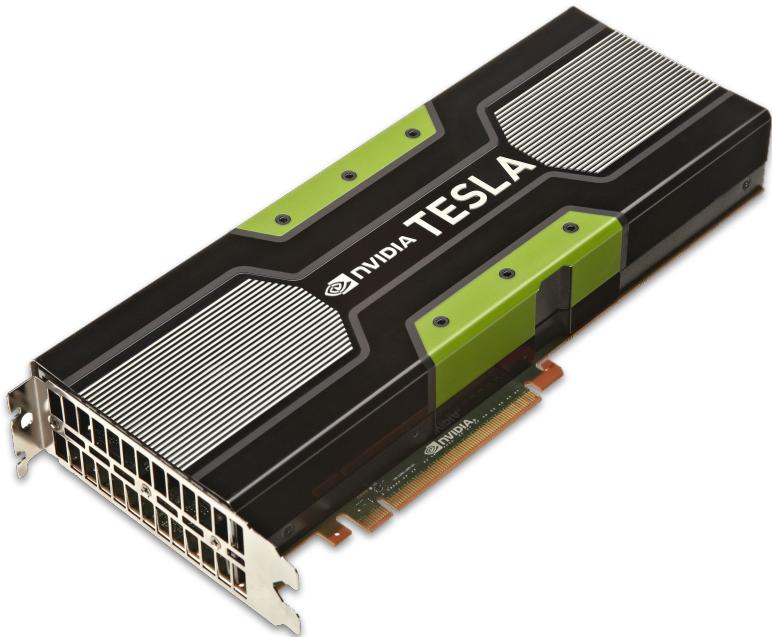
Endpoints Have Sensors, Tons of Sensors



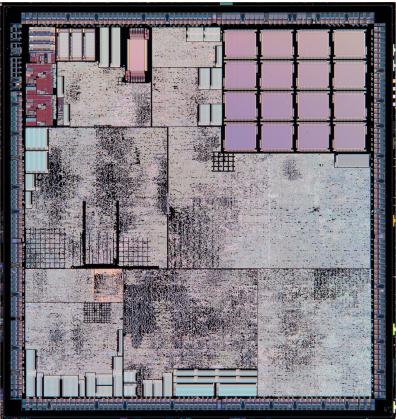
Processing



Thinking Big



Thinking Big



Thinking Big

BIG
GPU / CPU
 $561mm^2$

Thinking Small

BIG
GPU / CPU
 $561mm^2$



Thinking Small

BIG
GPU / CPU
561mm²



Thinking Small

BIG
GPU / CPU
 $561mm^2$

SMALL

Mobile SoC
 $83mm^2$

Thinking Tiny

BIG
GPU / CPU
 $561mm^2$

SMALL

Mobile SoC
 $83mm^2$



Thinking Tiny

BIG
GPU / CPU
 $561mm^2$

SMALL

Mobile SoC
 $83mm^2$



Thinking Tiny

BIG
GPU / CPU
 $561mm^2$

SMALL

Mobile SoC
 $83mm^2$



Thinking Tiny

BIG
GPU / CPU
 $561mm^2$

SMALL

Mobile SoC
 $83mm^2$

TINY

Apple 0778
 $30mm^2$



We're just getting started.

Thinking Record-breaking

BIG
GPU / CPU
 561mm^2

SMALL

Mobile SoC
 83mm^2

TINY

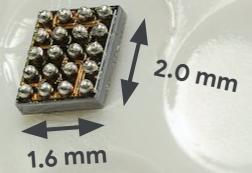
Apple 0778
 30mm^2

**world's smallest
ARM-Powered MCU**

48MHz, 32KB flash, 20-pin



Kinetis KL03
 3.2mm^2

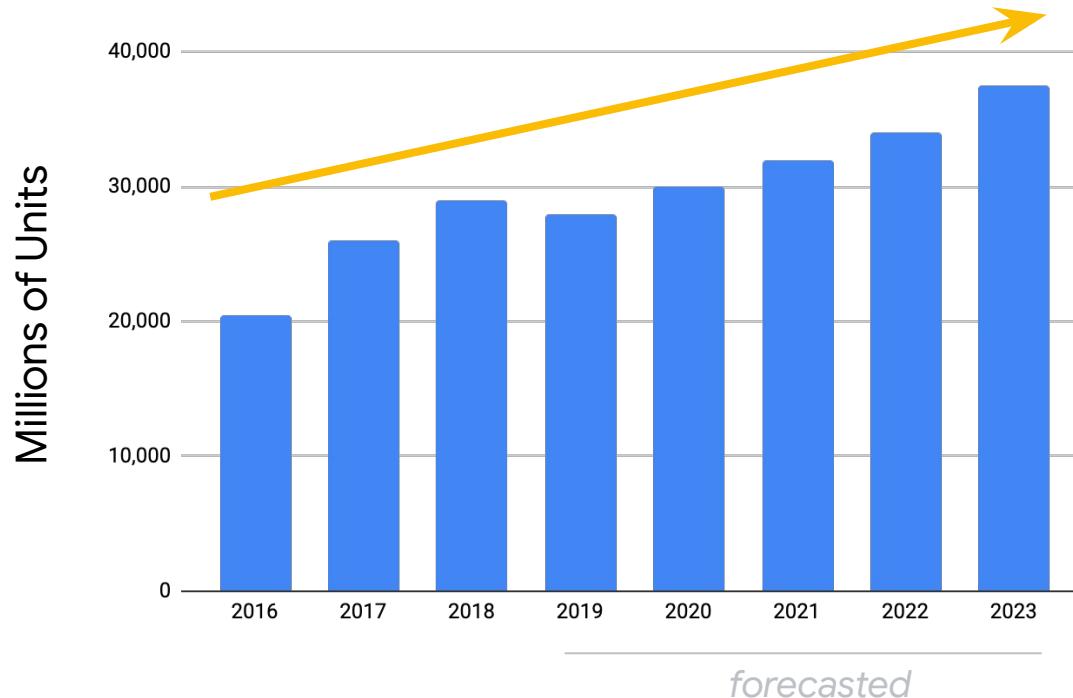


2.0 mm

1.6 mm

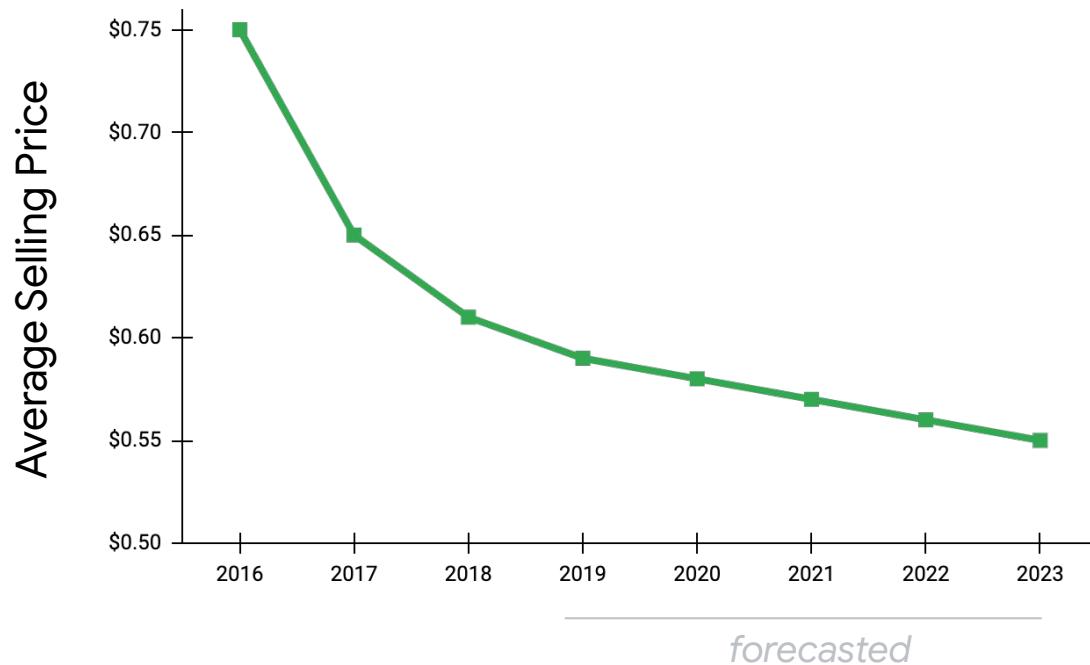
250 Billion
MCUs today

MCU Demand Forecast



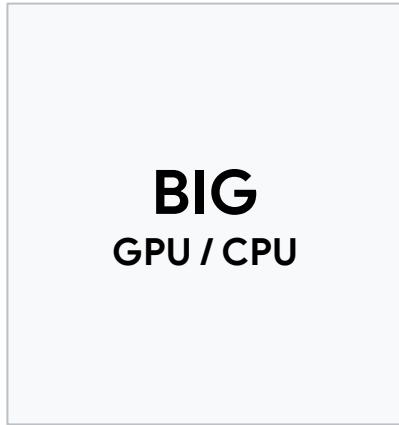
Source: IC Insights

MCU Pricing Forecast



Source: IC Insights

Comparing Power



BIG
GPU / CPU

300W
NVIDIA Tesla K80



3.64W
Apple A12

Neural Decision Processor

*Always-on deep learning
speech/audio recognition*

Ultra low power, 128KB SRAM,
12-pin, 2.52mm²



140 µW
Syntiant NDP100

Comparing Power



Use case: button cell battery

Neural Decision Processor

*Always-on deep learning
speech/audio recognition*

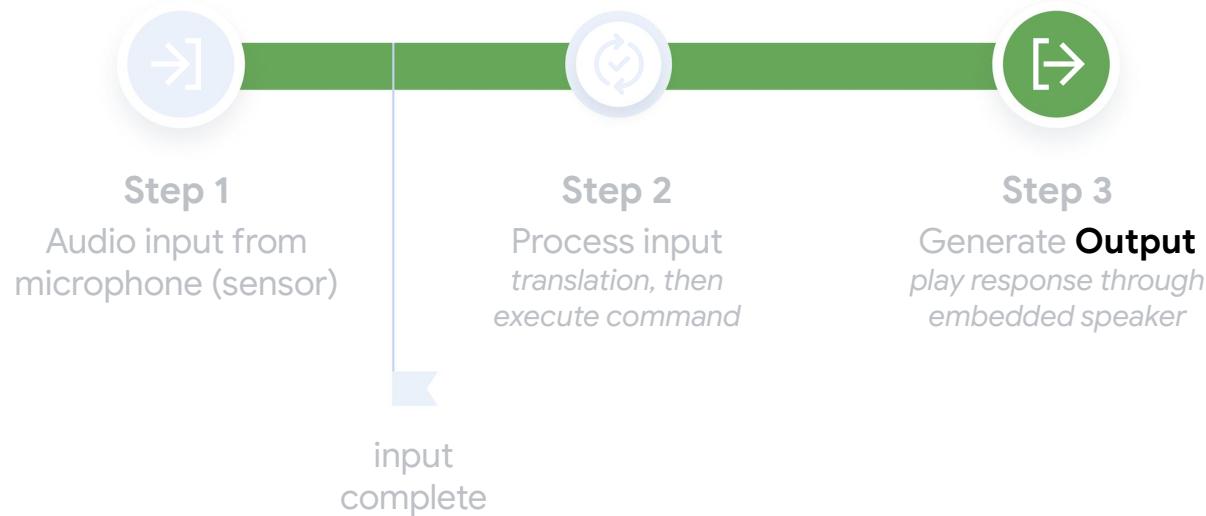
Ultra low power, 128KB SRAM,
12-pin, 2.52mm²



140 µW

Syntiant NDP100

Output



Output

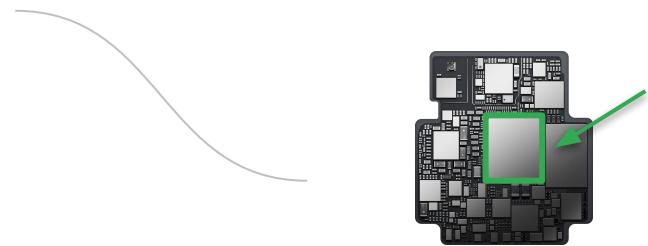


MCUs enable **TinyML**

SIZE

LOW
POWER

LOW
COST

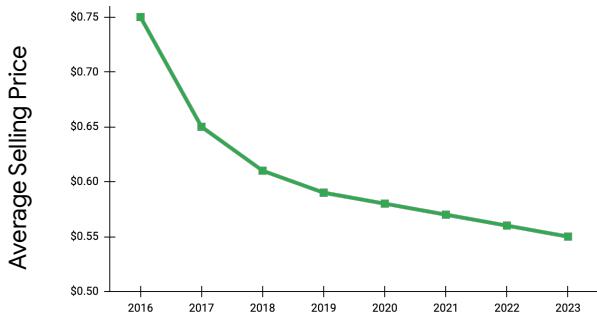


MCUs enable **TinyML**



< 140 μ W
Syntiant NDP100

MCUs enable **TinyML**



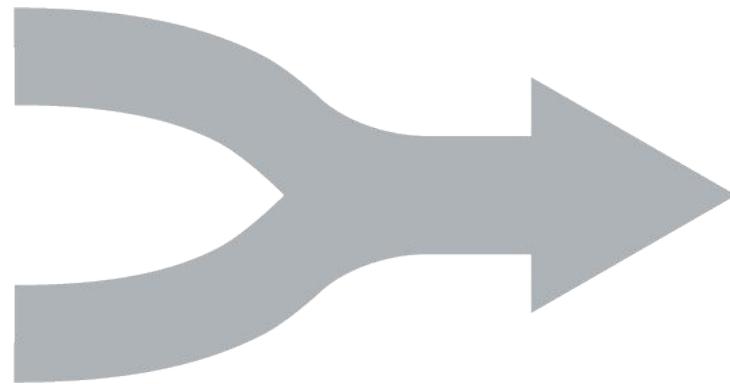
MCUs enable **TinyML**



What Makes **TinyML**?

Embedded
Systems

Machine
Learning



TinyML