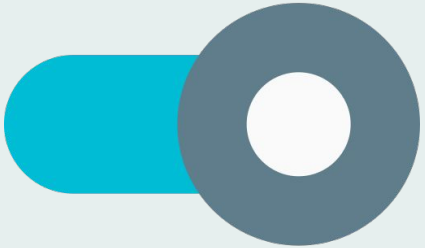
TinyML Fundamentals

Part II



How do we enable TinyML?

What Makes TinyML?

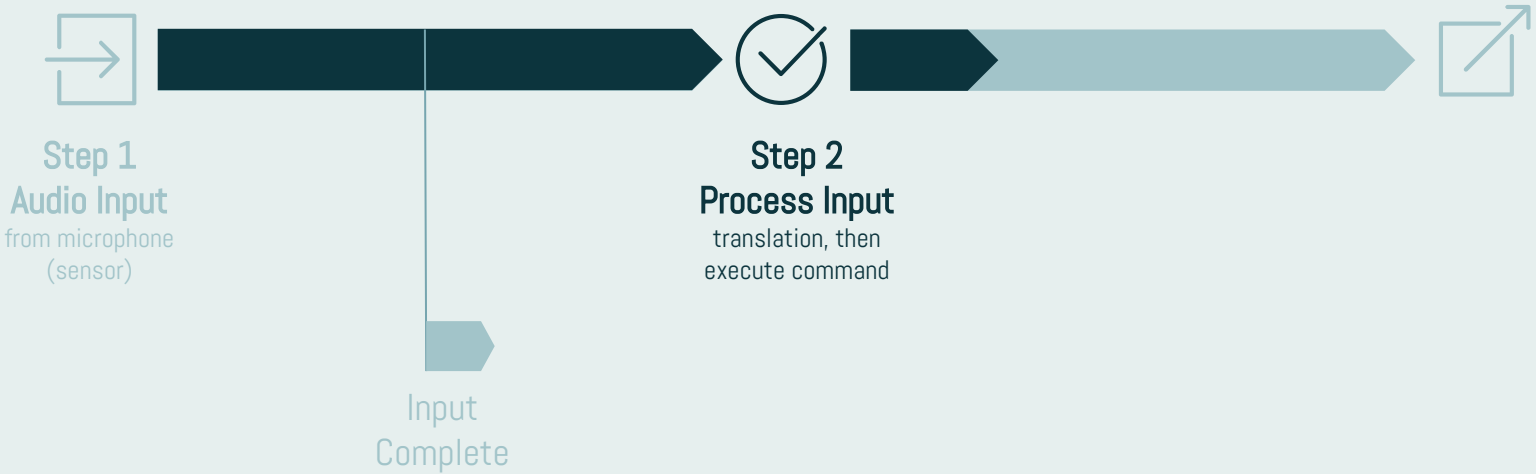
Embedded Systems

Machine Learning

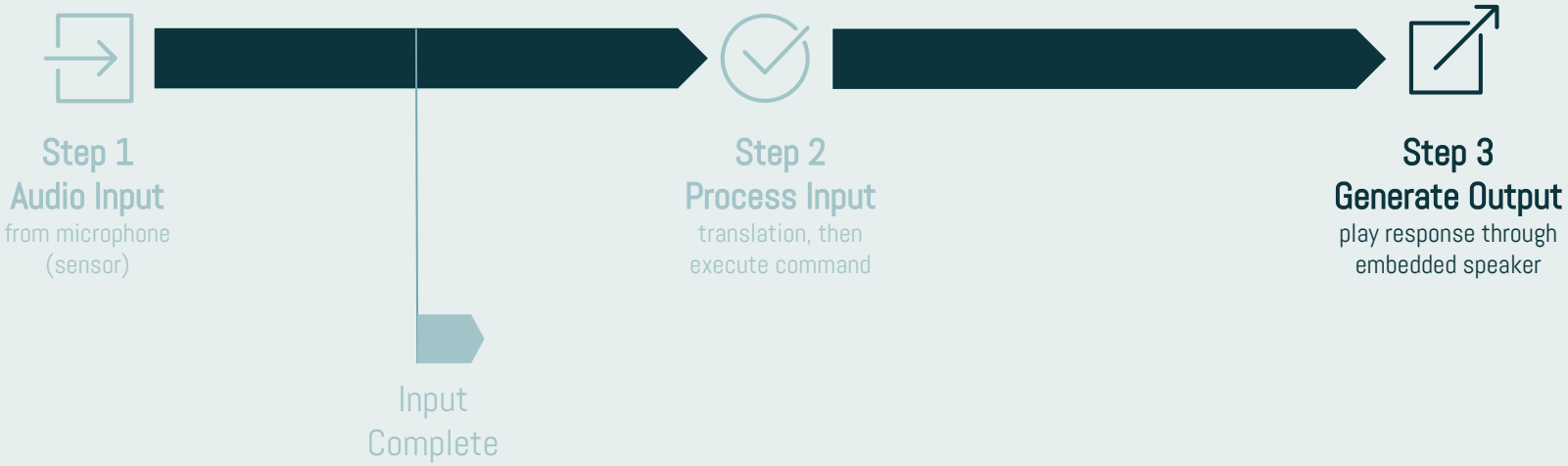
The Three Basic Steps

The Three Basic Steps

The Three Basic Steps

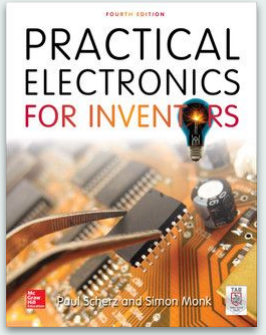


The Three Basic Steps



Input

Endpoints Have Sensors, Tons of Sensors



Motion Sensors, Gyroscope, Magnetometer, Radar, Accelerator

Acoustic Sensors, Ultrasonic, Microphones, Geophones, Vibrometers

Environment Sensors, Temperature, Humidity Pressure, IR, etc

Touchscreen Sensors, Capacitive, IR

Image Sensors, Thermal, Image

Biometric Sensors, Fingerprint, Heart Rate

Force Sensors, Pressure, Strain

Rotation Sensors, Encoders

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Force Sensors, Pressure, Strain

Rotation Sensors, Encoders

Biometric Sensors

Non-invasive Glucose Monitoring

Fingerprint + Photoplethysmography (PPG)

Source: Jacobs School of Engineering/UC San Diego

Endpoints Have Sensors, Tons of Sensors

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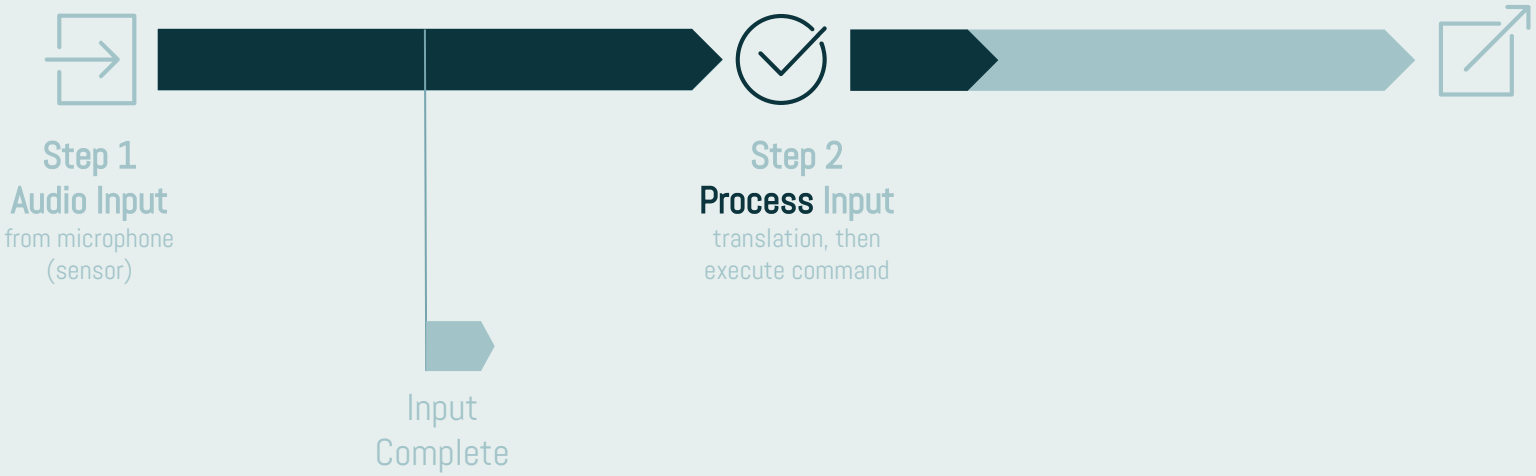
TINY MACHINE
LEARNING KIT
ARDUINO
edX
TensorFlow

Processing


Step 1
Audio Input
from microphone
(sensor)
Input
Complete
Step 2
Process Input
translation, then
execute command

Thinking Big

BIG

GPU/CPU

610 mm^2

Thinking Small

BIG

GPU/CPU

610 mm^2

Mobile SoC

107mm^2

Thinking Tiny

BIG

GPU/CPU

610 mm^2

SMALL

Mobile SoC

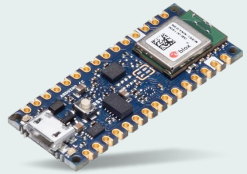
107mm^2

Tiny

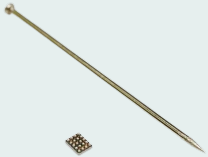
Apple 0778

30mm^2

Thinking Record-Breaking



nRF52840 SoC
49mm^2



World's smallest ARM-Powered MCU
48MHz, 32kB flash, 20-pin

BIG
GPU/CPU
610 mm^2

SMALL
Mobile SoC
107mm^2

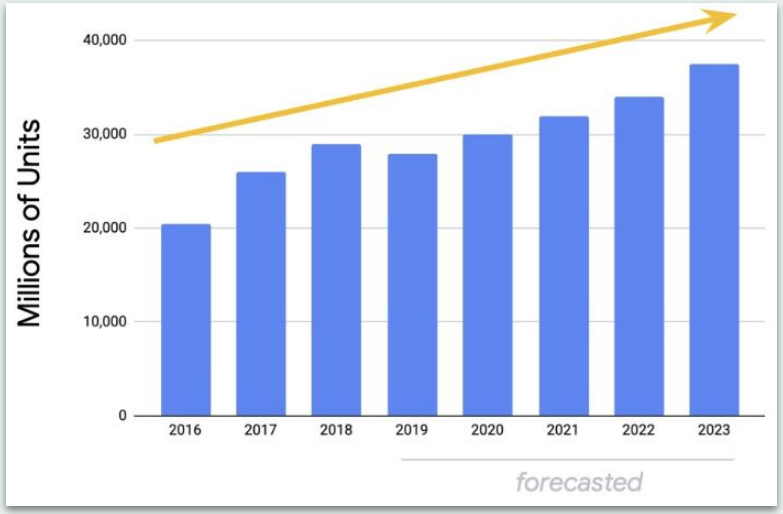
Tiny
Apple 0778
30mm^2

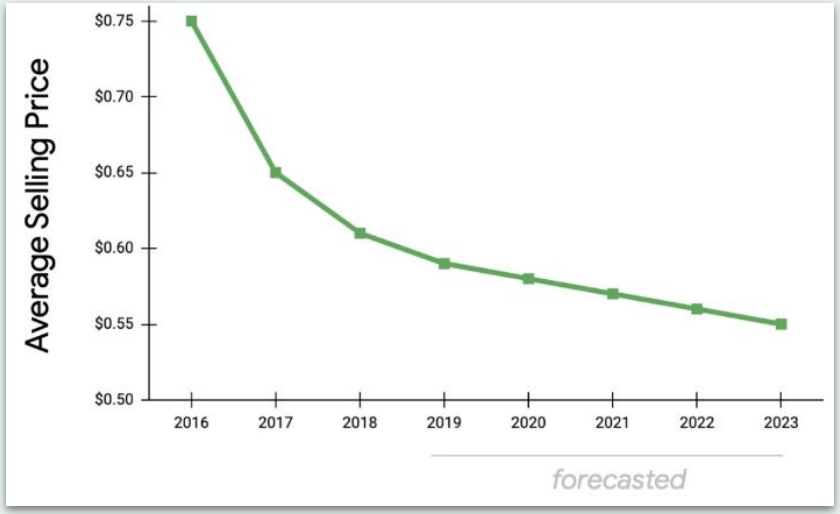
Kinetis KL03
3.2mm^2


2.0 mm
1.6 mm

+250 Billion MCU Today

MCU Demand and Pricing Forecast





Source: IC Insights

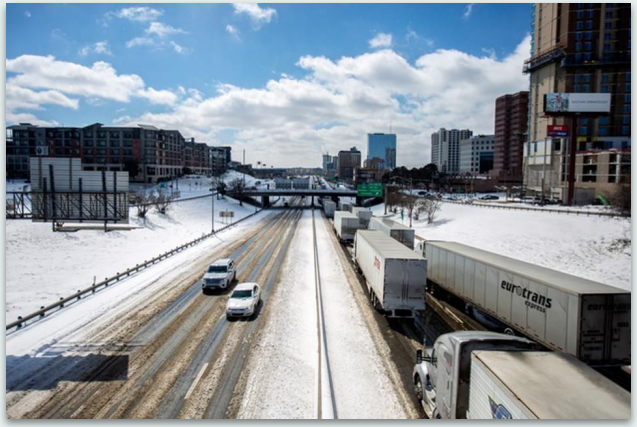
https://www.imf.org/-/media/Files/Publications/WP/2022/English/wpiea2022031-print-pdf.ashx

Semiconductor Crisis

A fire in a Japanese semiconductor factory in March 2021

Floods at Chinese ports in August 2021

Drought conditions in Taiwan since 2020

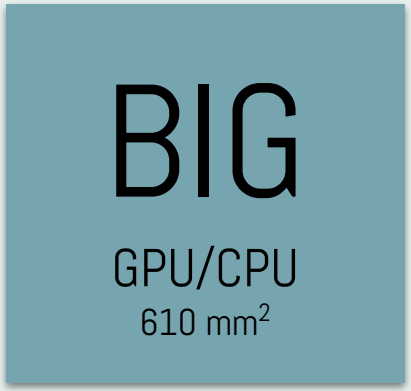


Extreme winter weather in Texas (2021) impacted many supply chains

7nm Tech Race

https://www.scmp.com/tech/big-tech/article/3190590/chinas-top-chip-maker-smic-achieves-7-nm-tech-breakthrough-par-intel

Comparing Power



300W
NVIDIA Tesla P100

6.9W*
Apple A15

Neural Decision Processor
Always-on deep learning
speech/audio recognition
Ultra low power, 128KB SRAM
12-pin, 2.52mm^2

140 µW
Syntian NDP100

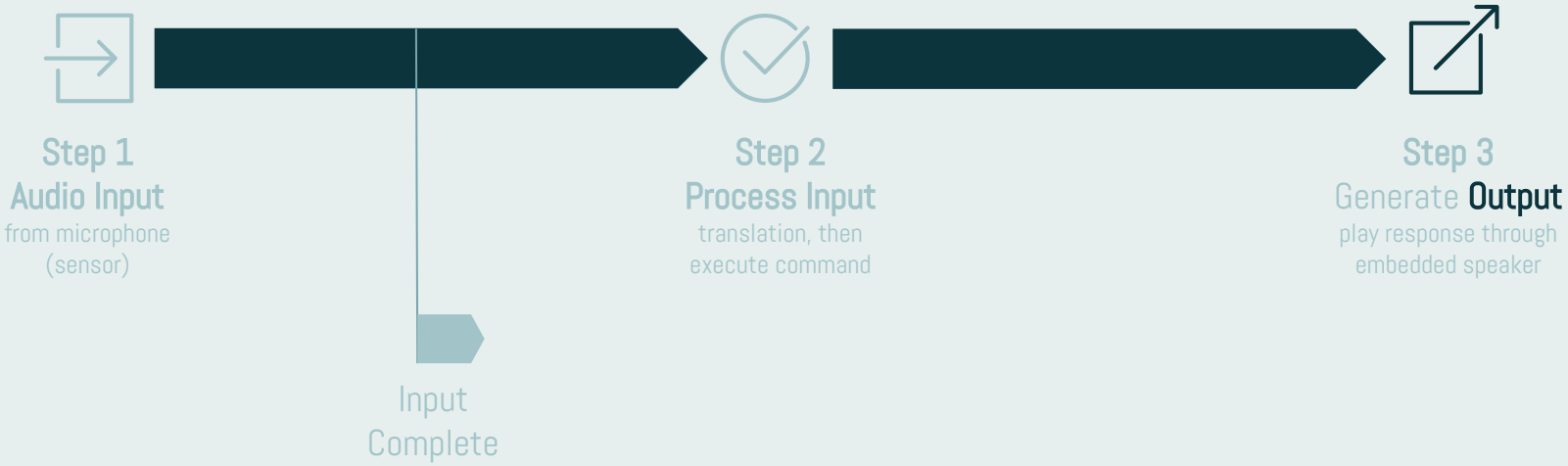
Comparing Power

Neural Decision Processor
Always-on deep learning
speech/audio recognition
Ultra low power, 128KB SRAM
12-pin, 2.52mm^2

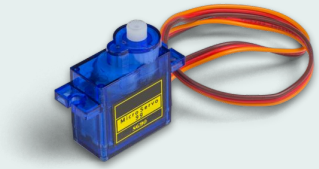
140 µW
Syntian NDP100

Use case: button cell battery

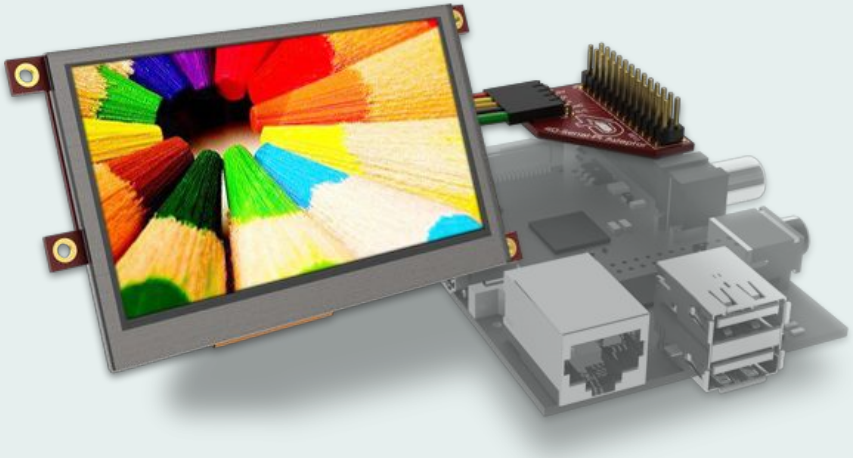
Output


Step 1
Audio Input
from microphone
(sensor)
Input
Complete
Step 2
Process Input
translation, then
execute command
Step 3
Generate Output
play response through
embedded speaker

Output

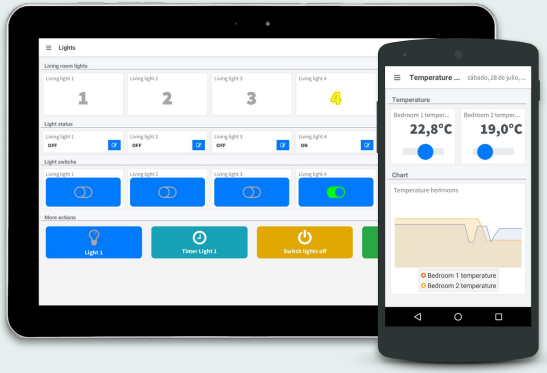


Servos



Displays

Speakers



MCUs enable **TinyML**

SIZE

LOW POWER

LOW COST

MCUs enable **TinyML**

SIZE

LOW POWER

LOW COST

< 140 µW

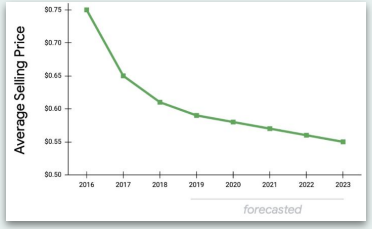
Syntian NDP100

MCUs enable **TinyML**

SIZE

LOW POWER

LOW COST



What Makes **TinyML**?

1. MCU is the building block of **TinyML** devices.
2. Theses devices are going to be pervasive or ubiquitous
3. Are they capable of running ML models?