Internet of Things (IoT) Platforms & Devices

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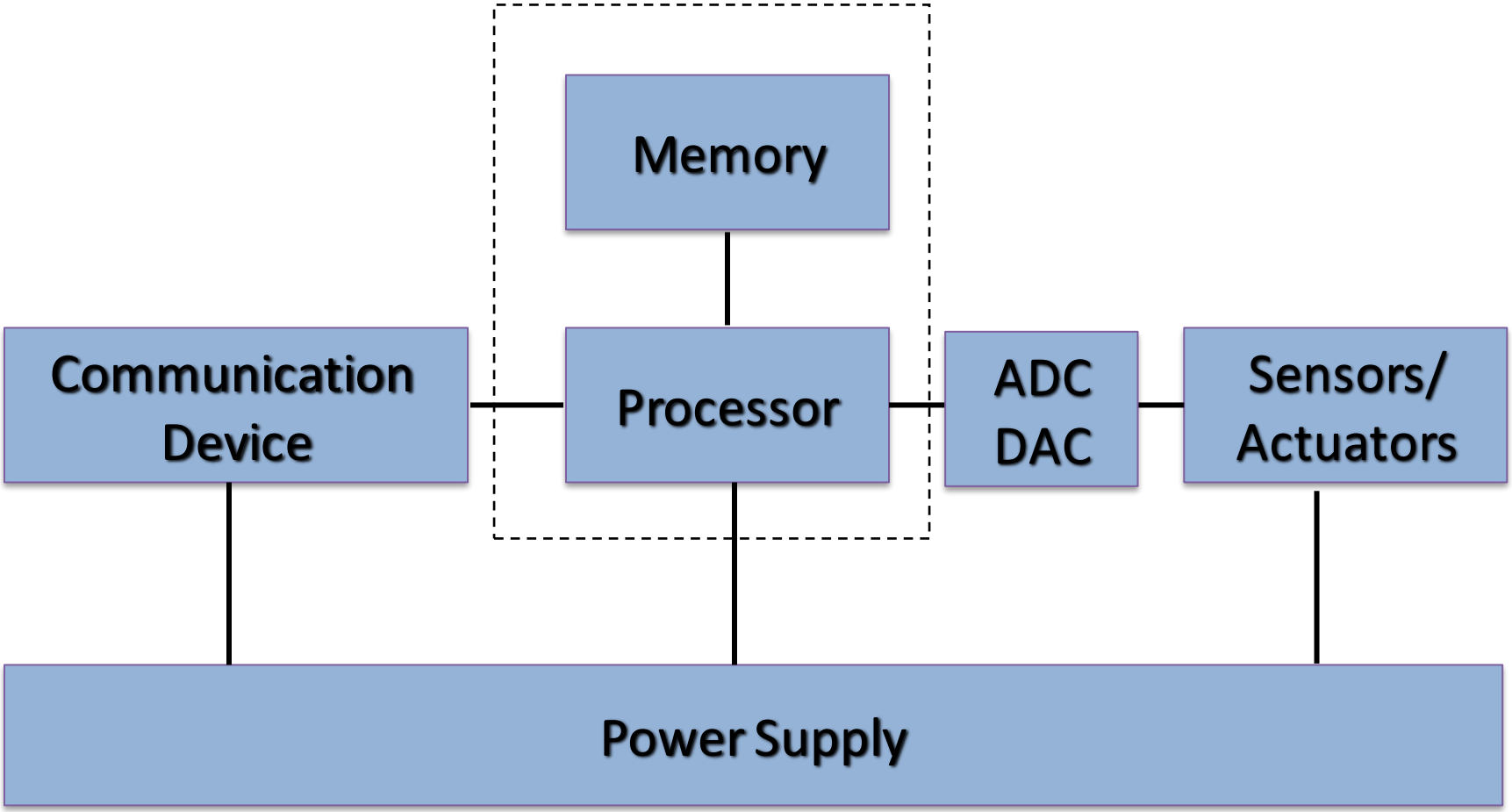
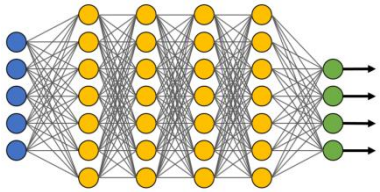
School of Computing
Newcastle University

Main components

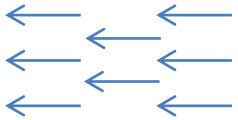


IoT Miniaturization (AI use case)

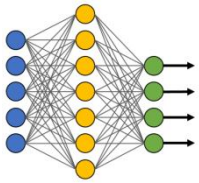


LargeNN

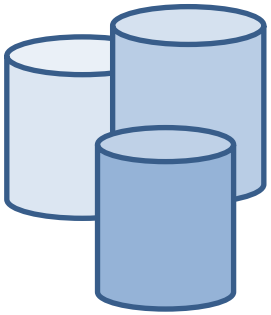
Cloud computing



Data in-motion



Optimized models



Terabytes of datasets

AI **EdgeAI**

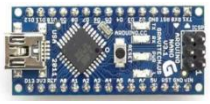
Silicon limitations

Video

Image

Audio

Sensor data



Low-End MCU

MCU

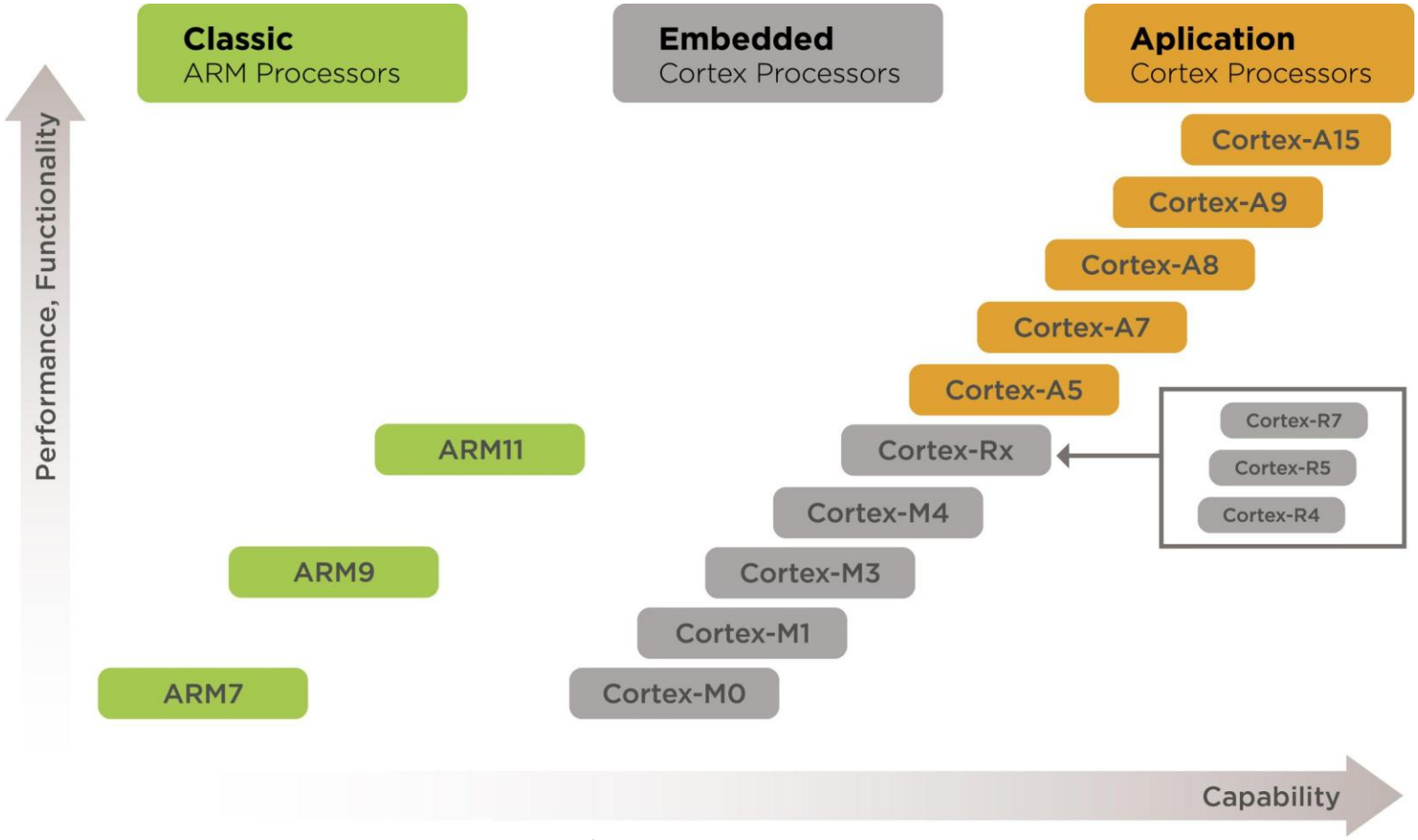
MCU + FPU

CPU

CPU + GPU

arm

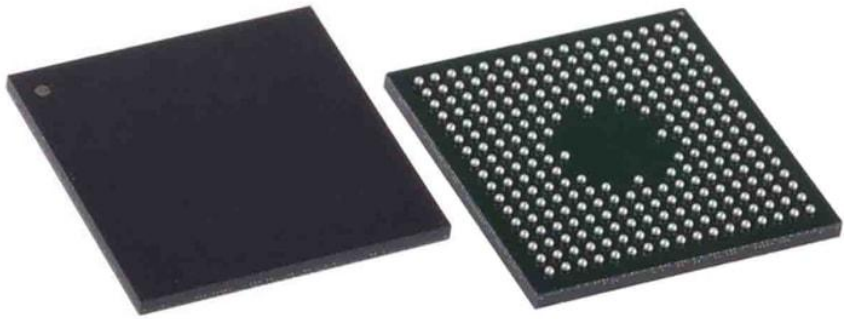
ARM Processors



British semiconductor and software design company based in Cambridge, England.

ARM Cortex A

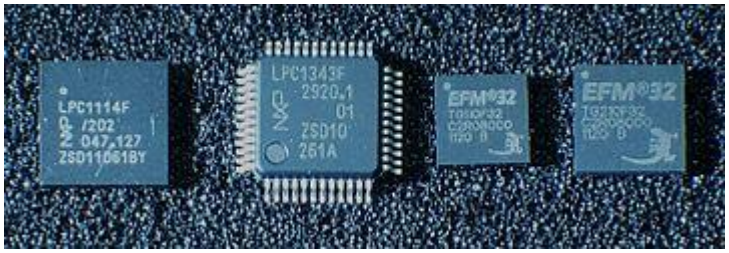
- Characteristics
  - High frequency up to 2GHz
  - Multi-core capabilities
  - Advanced memory management
  - Linux operating system
- Applications
  - Smartphones
  - Digital TV
  - Home gateways



Source: STMicroelectronics

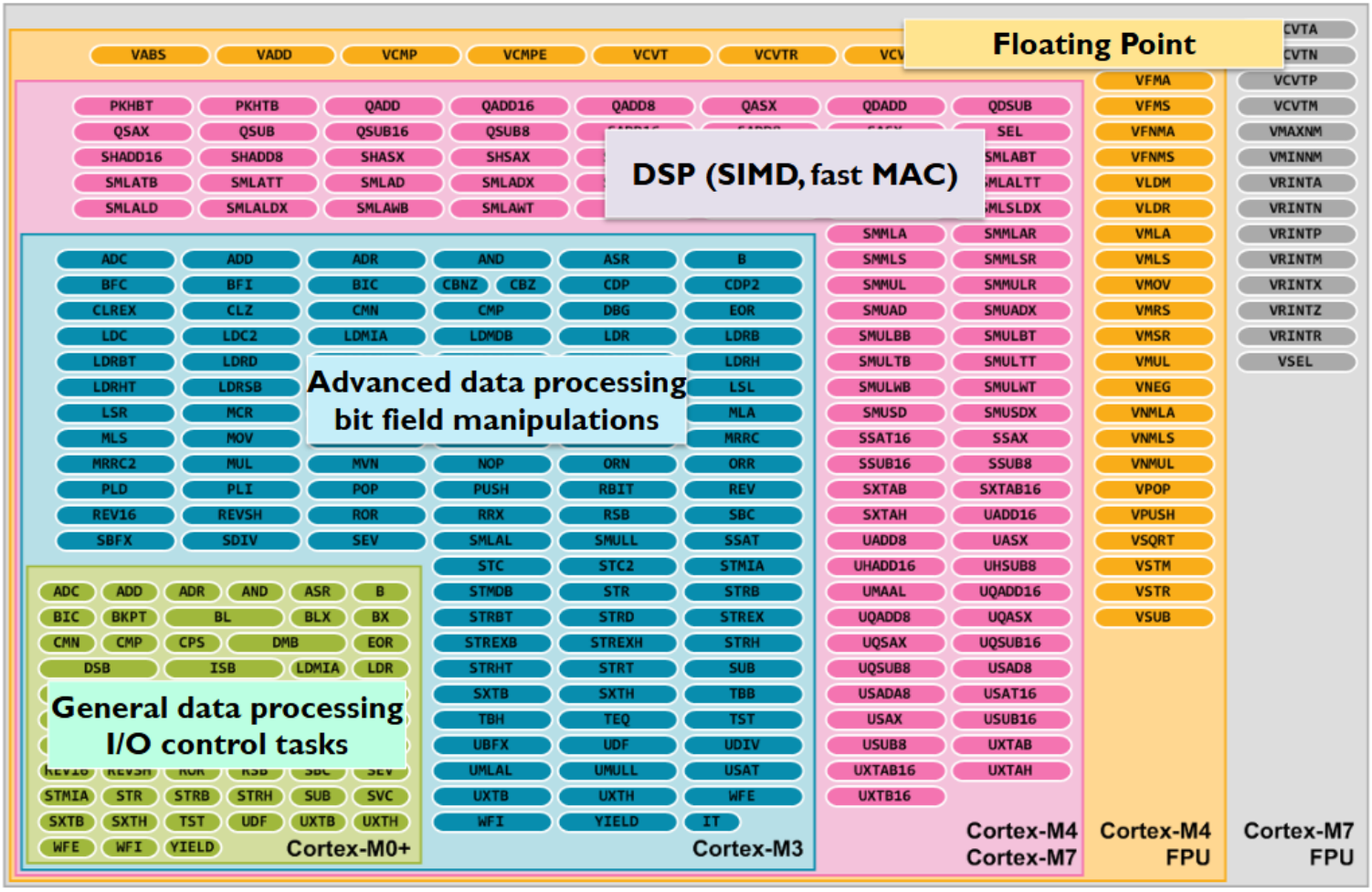
ARM Cortex M

- Characteristics
  - Cost-sensitive solutions for microcontroller applications
  - Low power consumption
  - Interrupt management
  - Low memory
- Applications
  - Microcontrollers
  - Mixed signal processing
  - Smart sensors
  - Internet of Things



source: https://en.wikipedia.org/wiki/ARM_Cortex-M

ARM Cortex M


Floating Point
VABS VADD VCMP VCMPE VCVT VCVTR
VFMA VFMS VFNMA VFNMS VLDM VLDR VMLA VMLS VMOV VMRS VMSR VMUL VNEG VNMLA VNMLS VNMUL VPOP VPUSH VSQRT VSTM VSTR VSUB
VCVTA VCVTN VCVTP VCVTM VMAXNM VMINNM VRINTA VRINTN VRINTP VRINTM VRINTX VRINTZ VRINTR VSEL
DSP (SIMD, fast MAC)
PKHBT PKHTB QADD QADD16 QADD8 QASX QDADD QDSUB
QSAX QSUB QSUB16 QSUB8 SEL
SHADD16 SHADD8 SHASX SHSAX SMLABT
SMLALD SMLALDX SMLAWB SMLAWT SMLSLDX
SMMLA SMMLAR SMMLS SMMLSR SMMUL SMMULR SMUAD SMUADX SMULBB SMULBT SMULTB SMULTT SMULWB SMULWT SMUSD SMUSDX SSAT16 SSAX SSUB16 SSUB8 SXTAB SXTAB16 SXTAH UADD16 UADD8 UASX UHADD16 UHSUB8 UMAAL UQADD16 UQADD8 UQASX UQSAX UQSUB16 UQSUB8 USAD8 USADA8 USAT16 USAX USUB16 USUB8 UXTAB UXTAB16 UXTAH UXTB16
Cortex-M4 Cortex-M7
Cortex-M4 FPU
Cortex-M7 FPU
ADC ADD ADR AND ASR B
BFC BFI BIC CBNZ CBZ CDP CDP2
CLREX CLZ CMN CMP DBG EOR
LDC LDC2 LDMIA LDMDB LDR LDRB
LDRBT LDRD LDRH
LDRHT LDRSB LSL
LSR MCR MLA
MLS MOV MRRC
MRRC2 MUL MVN NOP ORN ORR
PLD PLI POP PUSH RBIT REV
REV16 REVSH ROR RRX RSB SBC
SBFX SDIV SEV SMLAL SMULL SSAT
STC STC2 STMIA
STMDB STR STRB
STRBT STRD STREX
STREXB STREXH STRH
STRHT STRT SUB
SXTB SXTH TBB
TBH TEQ TST
UBFX UDF UDIV
UMLAL UMULL USAT
UXTB UXTH WFE
WFI YIELD IT
Advanced data processing
bit field manipulations
Cortex-M3
ADC ADD ADR AND ASR B
BIC BKPT BL BLX BX
CMN CMP CPS DMB EOR
DSB ISB LDMIA LDR
STMIA STR STRB STRH SUB SVC
SXTB SXTH TST UDF UXTB UXTH
WFE WFI YIELD
General data processing
I/O control tasks
Cortex-M0+

Operating Systems for IoT

- Real-Time Operating Systems
  - FreeRTOS
  - Zephyr OS
  - Mbed
- Low memory footprint (kB vs MB)
- Support for lightweight communication protocols
  - IPv4/IPv6
  - CoAP/LwM2M
  - MQTT
  - 802.15.4/Thread
  - Bluetooth Low Energy
  - CAN

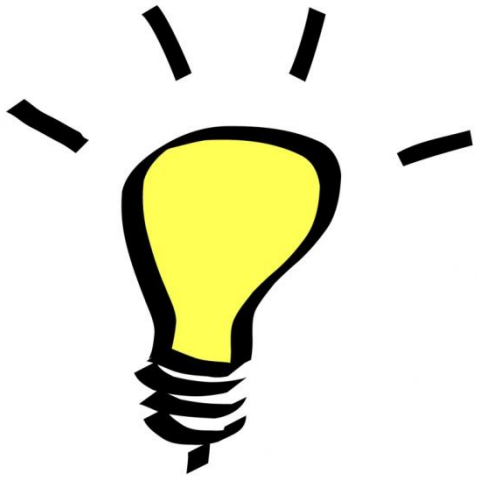
Zephyr®

PROTOTYPING BOARDS

DIY

Communication protocols
- MQTT
- LwM2M
- XMPP
- HTTP
- CoAP
- …

Cloud platforms
- Amazon
- Google Brillo
- Apple HomeKit
- ARM mbed
- CoAP
- …



Devices
- Raspberry Pi
- Arduino
- Intel Edison
- Proton Particle
- …

Software
- Eclipse Kura
- TensorFlow
- NodeRED
- Apach Spark
- Eclipse Edgent
- …

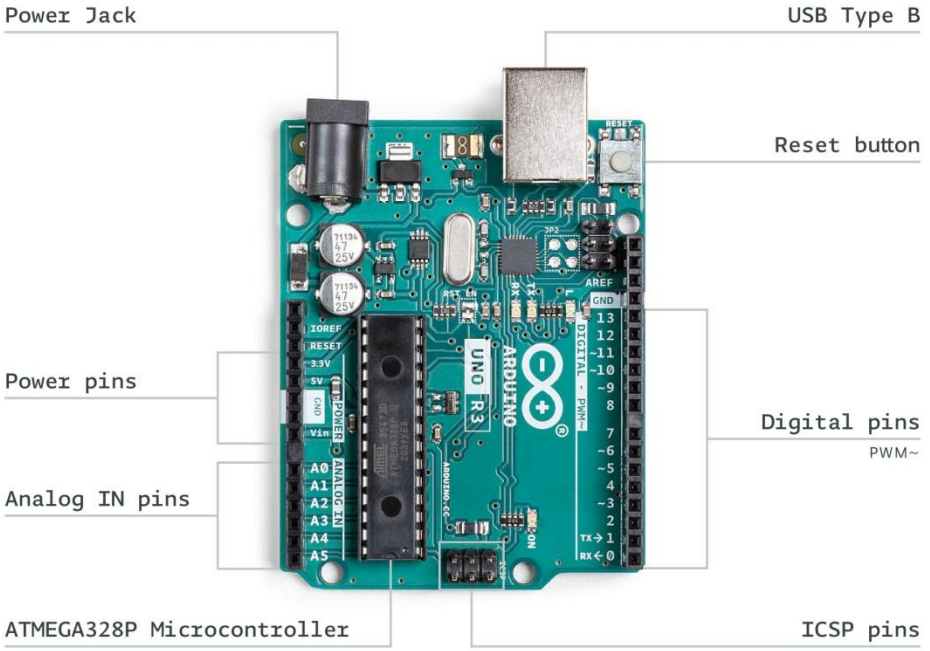
Communication technologies
- Ethernet
- 2G/LTE/5G
- LoRA
- NB-IoT
- WiFi
- Bluetooth LE
- …

Arduino

- Open source hardware
  - Processor ATmega328
  - Clock Speed 16 MHz
  - Digital I/O Pins 14
  - Analog Input Pins 6
  - Flash Memory 32 KB
  - SRAM 2 KB
  - EEPROM 1 KB

  - Bare-metal coding

2005

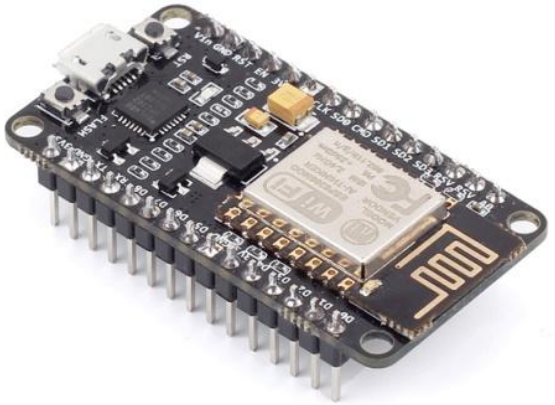


Raspberry Pi Pico

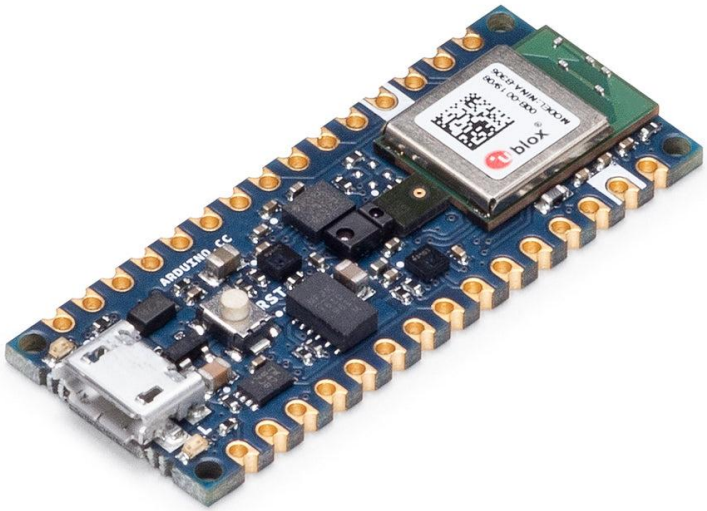
- 21 mm × 51 mm form factor
- RP2040 microcontroller chip designed by Raspberry Pi in the UK
- Dual-core Arm Cortex-M0+ processor
- flexible clock running up to 133 MHz
- 264KB on-chip SRAM
- 2MB on-board QSPI Flash
- 26 multifunction GPIO pins
  - 3 analogue inputs
  - UART, SPI, I2C, PWM, USB

ESP32

- Processor
  - Xtensa dual-core 32-bit
  - 160 or 240 MHz
- Memory
  - 520 KiB RAM
  - 448 KiB ROM
- Wireless connectivity
  - Wi-Fi 802.11 b/g/n
  - Bluetooth BLE
- 34 × programmable GPIO

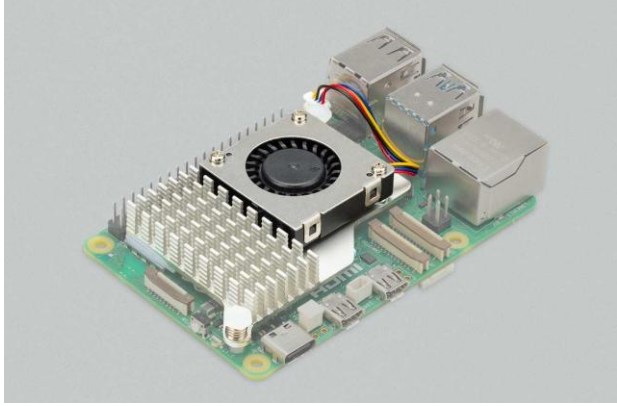


Arduino BLE Sense 33



- Processor
  - 64 MHz Arm® Cortex-M4F (with FPU)
- 1 MB Flash + 256 KB RAM
- Connectivity
  - Bluetooth® 5 multiprotocol radio
  - 802.15.4 transceiver
- Sensors
  - LSM9DS1 (9 axis IMU)
  - LPS22HB (Barometer and temperature sensor)
  - HTS221 (relative humidity sensor)
  - APDS-9960 (Digital proximity, Ambient light, RGB and Gesture Sensor)
  - MP34DT05 (Digital Microphone)
  - ATECC608A (Crypto Chip)

Raspberry Pi



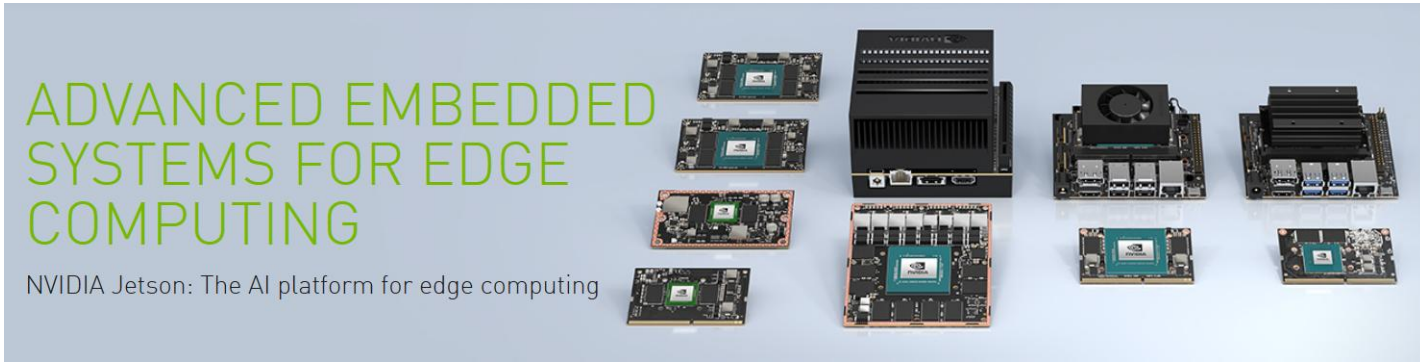
- Processor (Pi 5)
  - Broadcom BCM2712 @2.4GHz
  - quad-core 64-bit Arm Cortex-A76
- Memory
  - RAM 4/8GB
  - microSD card slot
- Connectivity
  - Gigabit Ethernet
  - Dual-band 802.11ac Wi-Fi
  - Bluetooth 5.0 / Bluetooth Low Energy (BLE)

Nvidia Jetson Nano

- GPU cores as in the datacenter
- NVIDIA Jetson is the most popular edge computing platform

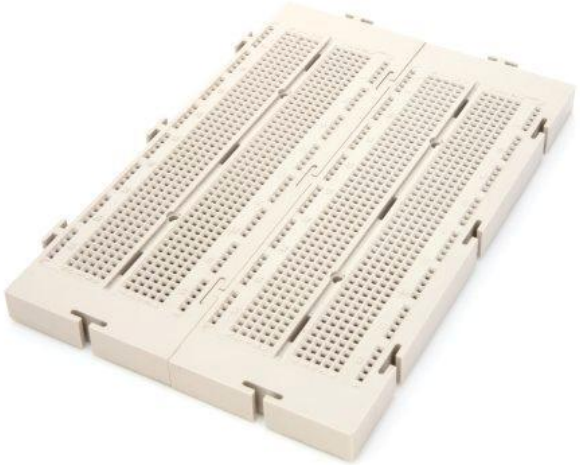
TECHNICAL SPECIFICATIONS

GPU	NVIDIA Maxwell architecture with 128 NVIDIA CUDA® cores
CPU	Quad-core ARM Cortex-A57 MPCore processor
Memory	4 GB 64-bit LPDDR4, 1600MHz 25.6 GB/s
Storage	16 GB eMMC 5.1
Video Encode	250MP/sec 1x 4K @ 30 (HEVC) 2x 1080p @ 60 (HEVC) 4x 1080p @ 30 (HEVC) 4x 720p @ 60 (HEVC) 9x 720p @ 30 (HEVC)
Video Decode	500MP/sec 1x 4K @ 60 (HEVC) 2x 4K @ 30 (HEVC) 4x 1080p @ 60 (HEVC) 8x 1080p @ 30 (HEVC) 9x 720p @ 60 (HEVC)

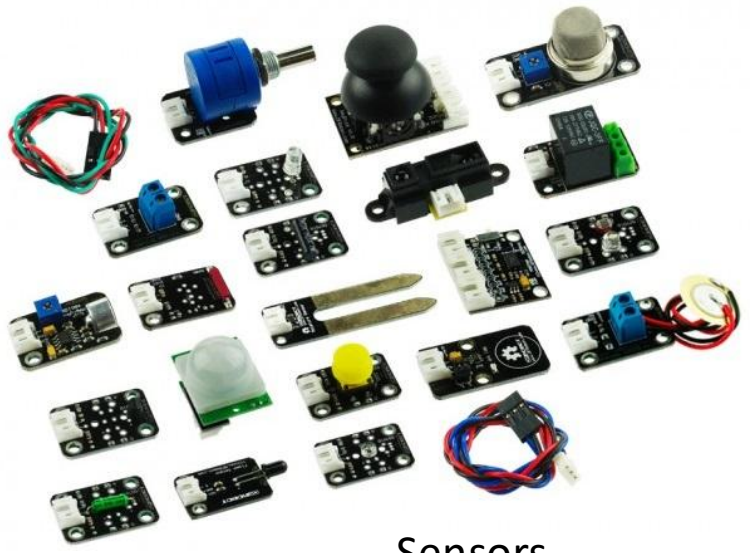


SENSORS

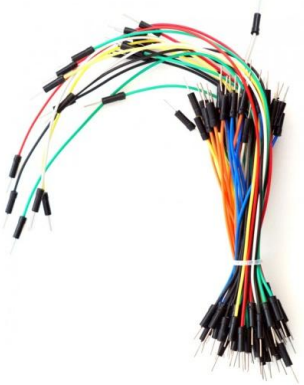
Generic Sensors



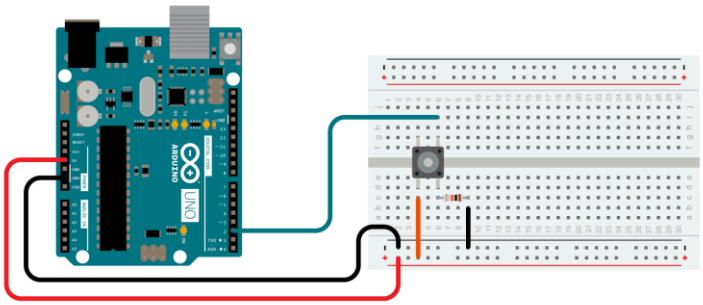
Breadboard



Sensors



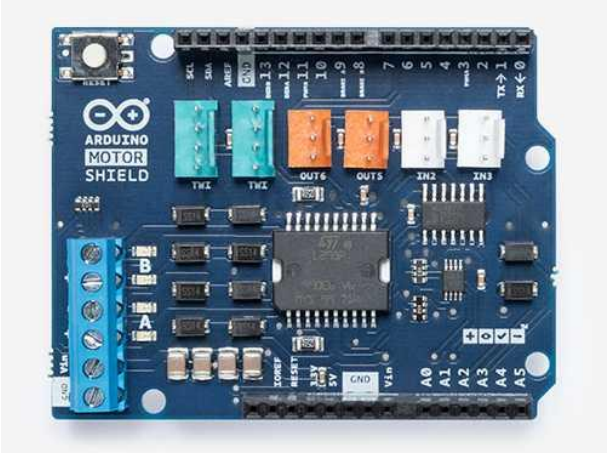
Wires



Wiring

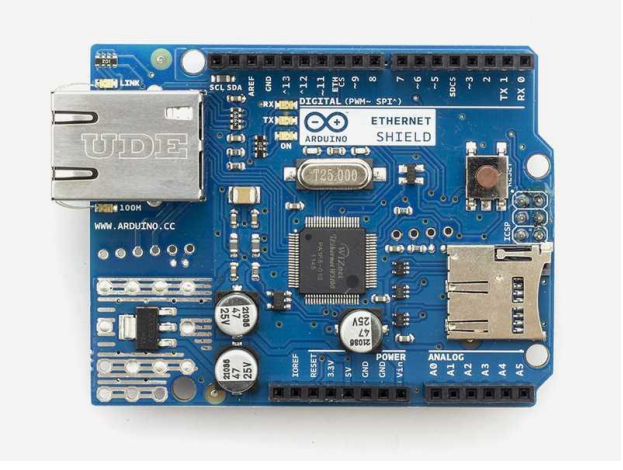
Arduino Shields

Motor Shield



Relay Shield

Ethernet Shield

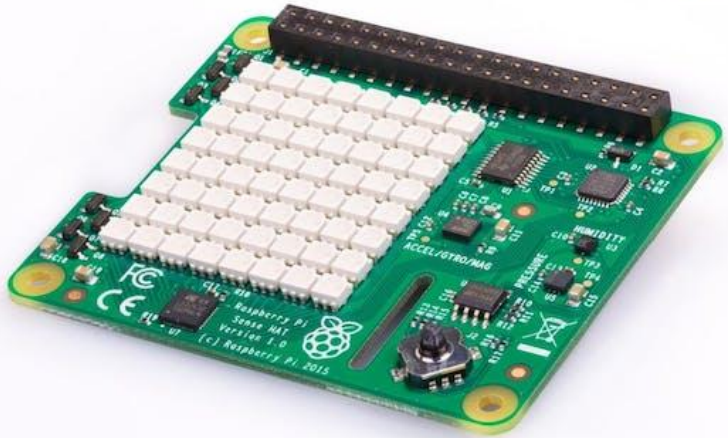


RPI HATs

PoE Hat

Lora Hat

Sense HAT



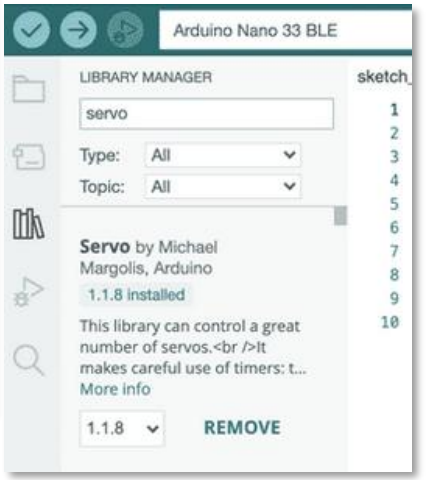
LEGO Build HAT

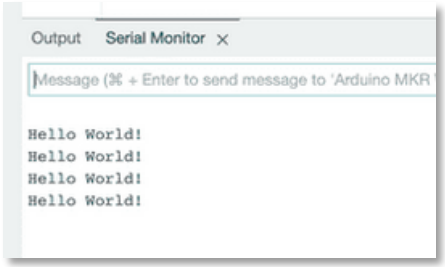
PLATFORMS

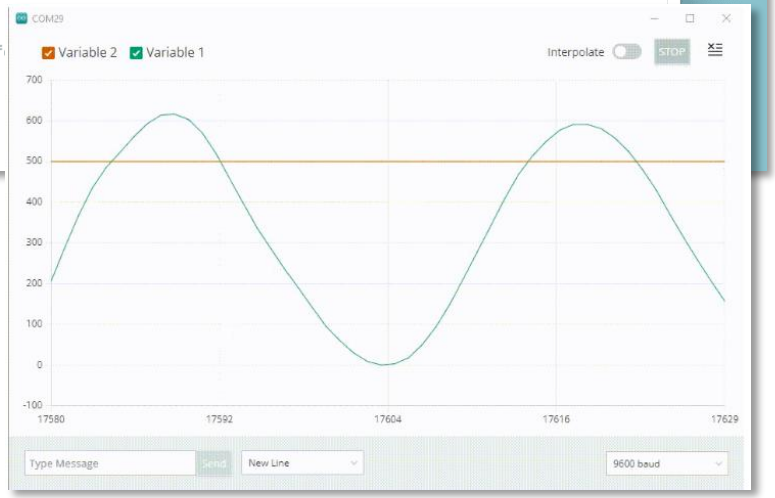
Arduino IDE


VERIFY/UPLOAD
SELECT BOARD & PORT
OPEN SERIAL MONITOR
AnalogReadSerial | Arduino IDE 2.0.0-rc9
Arduino MKR WiFi 1010
SKETCHBOOK
OPEN SERIAL PLOTTER
BOARD MANAGER
LIBRARY MANAGER
DEBUGGER
SEARCH
/*
AnalogReadSerial
Reads an analog input on pin 0, prints the result to the Serial Monitor.
Graphical representation is available using Serial Plotter (Tools > Serial Plotter menu).
in of a potentiometer to pin A0, and the outside pins to +5V and ground.
This example code is in the public domain.
https://www.arduino.cc/en/Tutorial/BuiltInExamples/AnalogReadSerial
*/
// the setup routine runs once when you press reset:
void setup() {
// initialize serial communication at 9600 bits per second:
Serial.begin(9600);
}
// the loop routine runs over and over again f
void loop() {
// read the input on analog pin 0:
int sensorValue = analogRead(A0);
// print out the value you read:

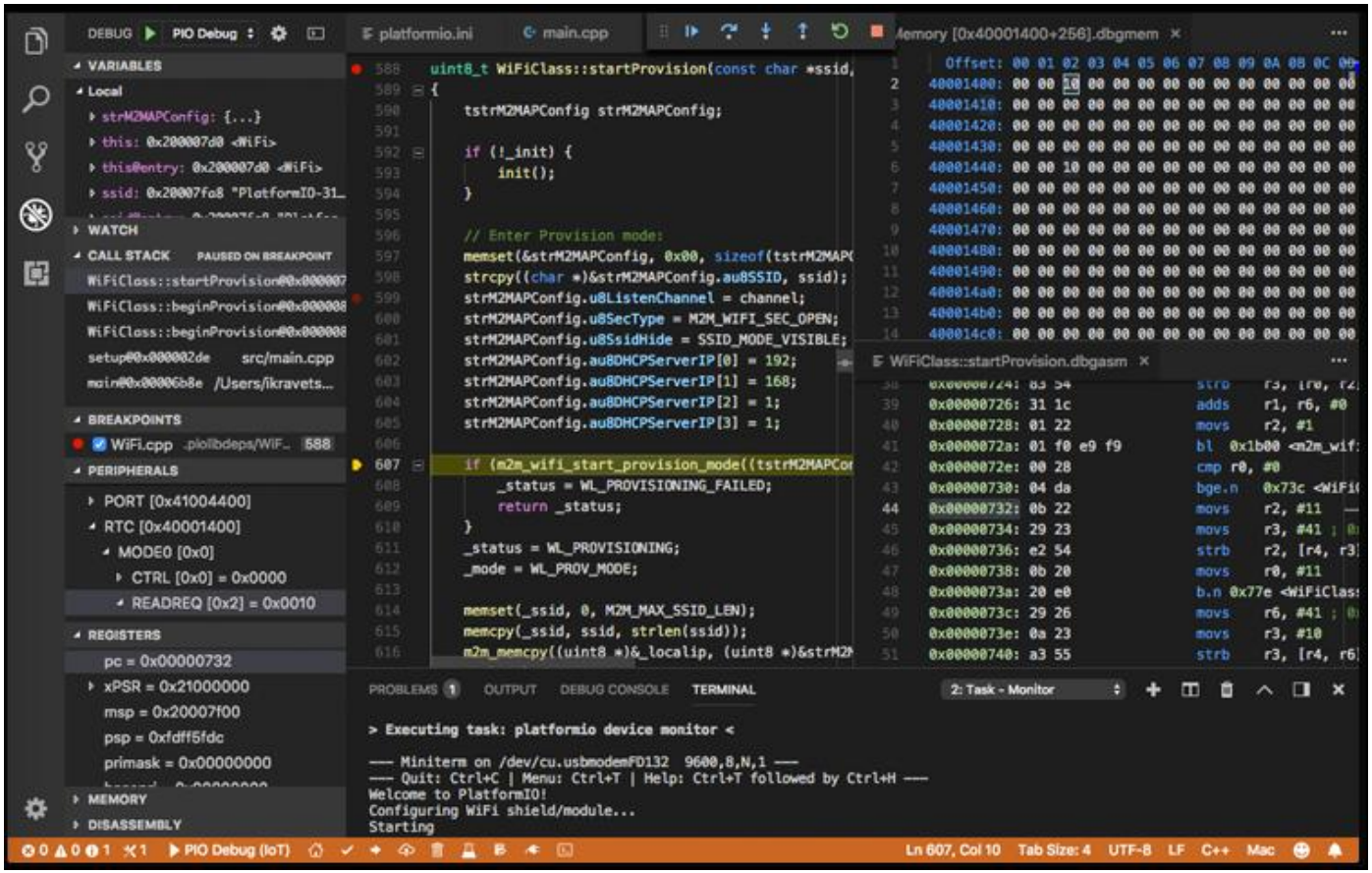

Arduino MKR WiFi 1010
BOARDS MANAGER
MKR WiFi 1010
Arduino SAMD Boards (32-bits ARM Cortex-M0+) by Arduino
Version 1.8.13
INSTALLED
Boards included in this package:
Arduino M0 Pro (Native USB Port), Arduino MKR GSM 1400, Arduino MKR NB 1500, Arduino M0, Arduino MKR1000, Arduino MKR WiFi 1010, Arduino MKR WAN 1310, Arduino MKR Vidor 4000, Adafruit Circuit Playground Express, Arduino


Arduino Nano 33 BLE
LIBRARY MANAGER
servo
Type: All
Topic: All
Servo by Michael Margolis, Arduino
1.1.8 installed
This library can control a great number of servos.
It makes careful use of timers: t...
More info
1.1.8
REMOVE


Output
Serial Monitor
Message (⌘ + Enter to send message to 'Arduino MKR
Hello World!
Hello World!
Hello World!
Hello World!


COM29
Variable 2
Variable 1
Interpolate
STOP
700
600
500
400
300
200
100
0
-100
17580
17592
17604
17616
17629
Type Message
Send
New Line
9600 baud

PlatformIO

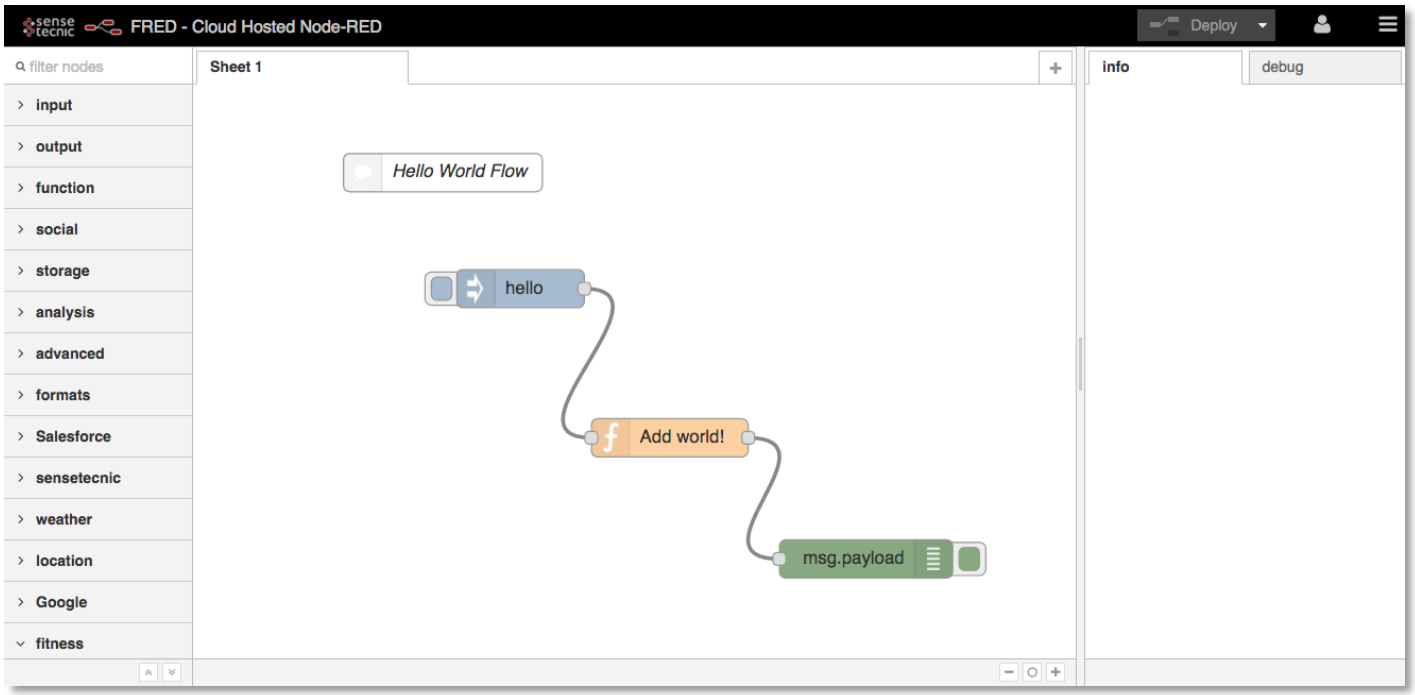


Frameworks

- Arduino
- CMSIS
- Energia
- ESP8266 Non-OS SDK
- ESP8266 RTOS SDK
- Espressif IoT Development Framework
- Freedom E SDK
- FreeRTOS
- Renesas Flexible Software Package
- libopencm3
- Mbed OS
- PULP OS
- PULP Runtime Environment
- PULP SDK
- Shakti SDK
- Standard Peripheral Library
- STM32Cube
- WD-Firmware
- WiringPi
- Zephyr

- Built on top of Microsoft's Visual Studio Code

NodeRED



- Messages

```
msg = {
  payload:"message payload",
  topic:"error",
  location:"somewhere"
};
```

- Nodes
  - Input Nodes (e.g. inject)
  - Output Nodes (e.g. debug)
  - Processing Nodes (e.g. function)