

Gold



Gold Venue



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Silver



Swag

OFFERZEN



# Allan Pead

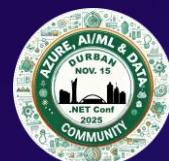
## Tiny Devices, Big Potential: .NET & C# IoT

CTO, developer, lecturer, Microsoft Internet of Things MVP, Microsoft Dev Technologies MVP, Microsoft Azure MVP

Allan Pead is a CTO, architect and software developer with more than 20 years commercial experience.

[linkedin.com/in/adpead/](https://www.linkedin.com/in/adpead/)

@adpead

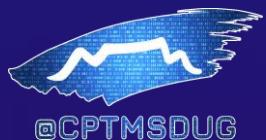
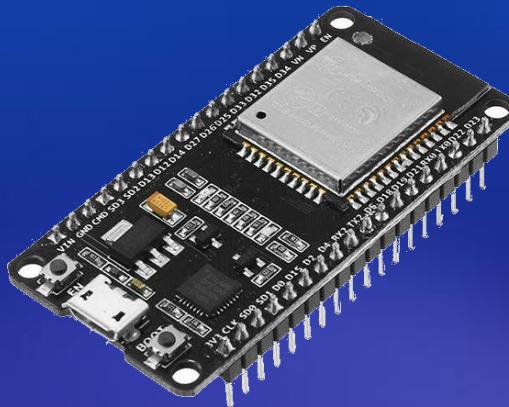


# Joburg



# #dotnetconfsa.

# Tiny Devices, Big Potential: .NET & C# IoT



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- Twitter: [@adpead](https://twitter.com/adpead)
- About.me: [https://about.me/allan\\_pead](https://about.me/allan_pead)
- Linkedin: <https://www.linkedin.com/in/adpead/>
- Blog: <https://explorationspace.co.za>
- Raspberry Pi South Africa
- <https://www.facebook.com/groups/1493503984198019>
- Cape Town MS Developer User Group
- <https://www.meetup.com/Cape-Town-Ms-Dev-User-Group/>



Microsoft Internet of Things Most Valuable Professional  
Microsoft Developer Technologies Most Valuable Professional

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# What is this talk about?



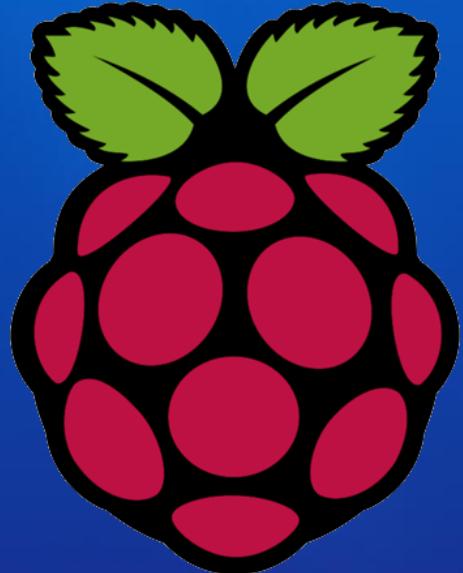
- Using .NET and .NET Nanoframework on Microcontrollers for custom implementations of IoT solutions.
- Adding intelligence via MCPs to Microcontrollers
- Connecting to the “I” thing.



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# Microcomputers (SBCs)

- “Low(ish)-Cost” Computer
- Linux, Android, Windows 10 IoT
- Interact with hardware and electronics
  - GPIO, I2C, SPI
  - HATs
- IoT Device (Internet of Things!)



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# Microcontrollers

- Extremely low cost
- Long battery life
- Solutions run on the metal
- Interact with hardware and electronics
  - GPIO, I2C, SPI
  - HATs
- IoT Device (Internet of Things!)

The REAL IoT □

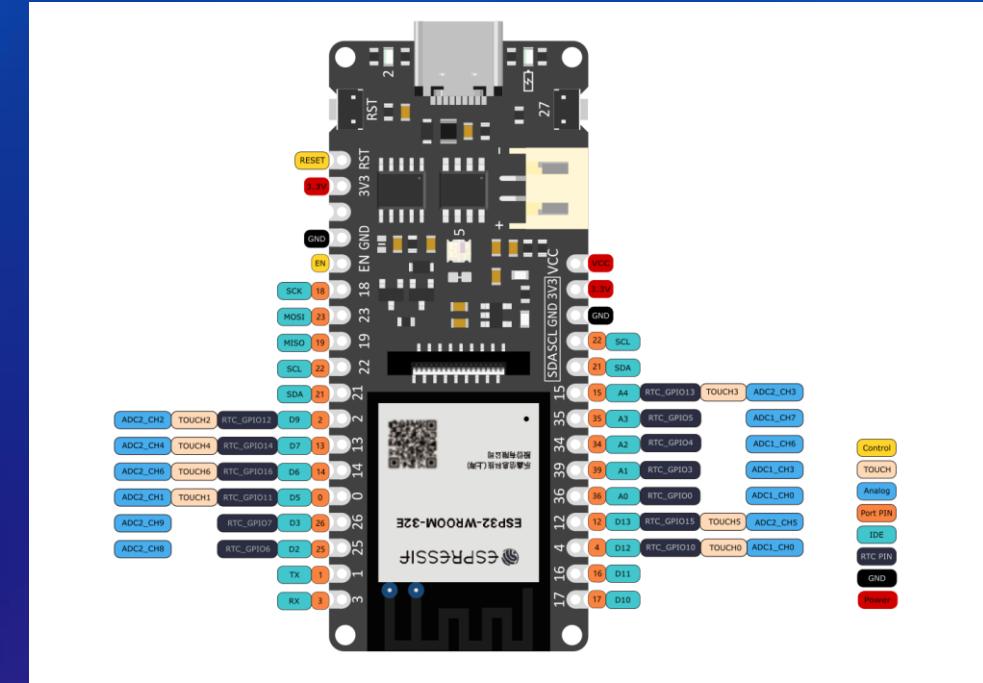


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# Hardware Interfacing



Alternate Function	
I2C1 SDA	3.3V PWR
I2C1 SCL	GPIO 2
	3.3V PWR
	GPIO 3
	5
	GND
	GPIO 4
	7
	GND
	9
	GPIO 17
	11
	GPIO 27
	13
	GPIO 22
	15
	3.3V PWR
	17
SPI0 MOSI	GPIO 10
SPI0 MISO	GPIO 9
SPI0 SCLK	GPIO 11
	19
	21
	23
	GND
	25
Reserved	27
	29
	GPIO 5
	31
	GPIO 6
	33
	GPIO 13
	35
SPI1 MISO	GPIO 19
	35
	GPIO 26
	37
	GND
	39
	36
	GPIO 16
	SPI1 CS0
	38
	GPIO 20
	SPI1 MOSI
	40
	GPIO 21
	SPI1 SCLK

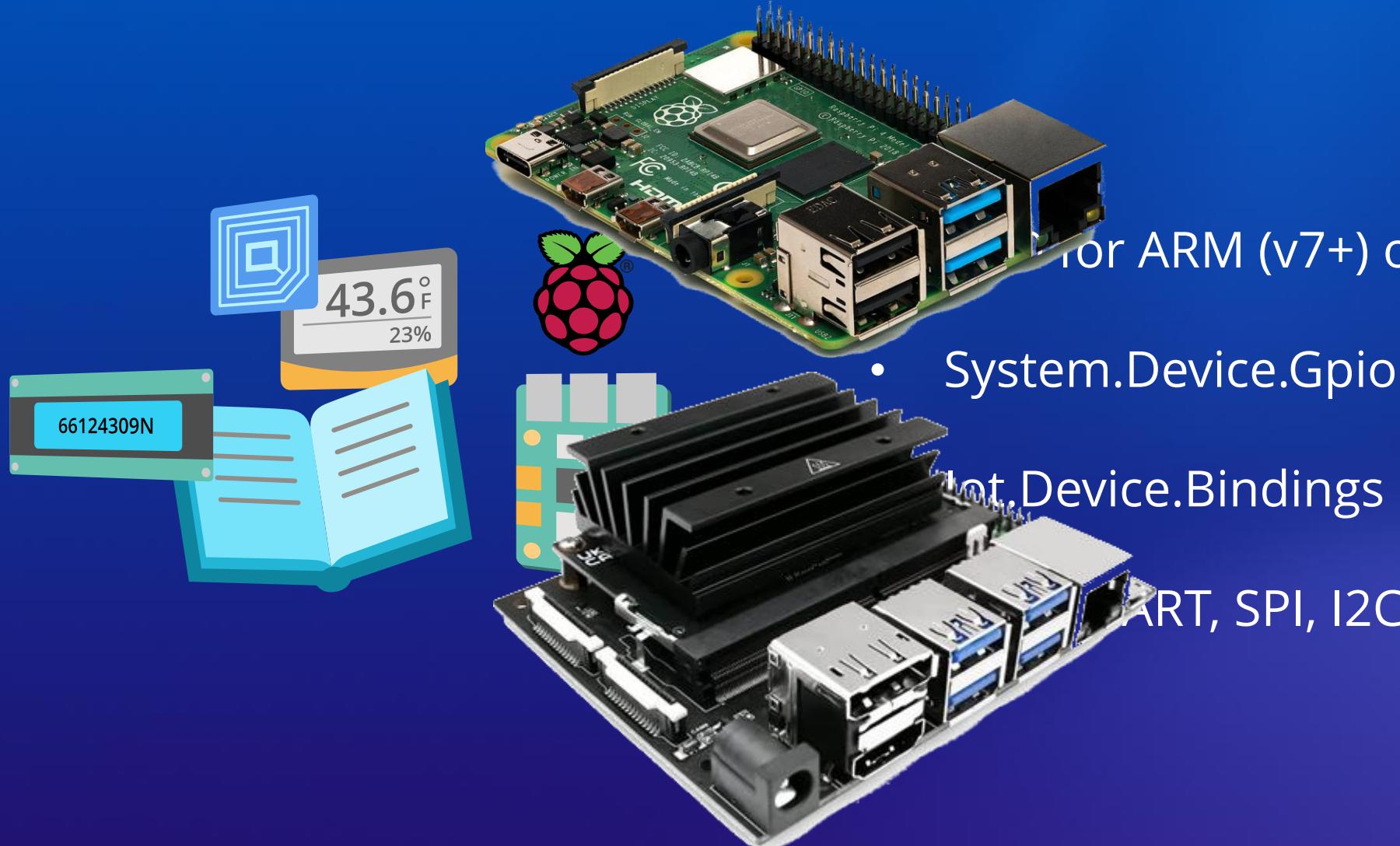


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# Build any app with the tools and libraries you love



# .NET for IoT



for ARM (v7+) or ARM64

- System.Device.Gpio

IoT.Device.Bindings

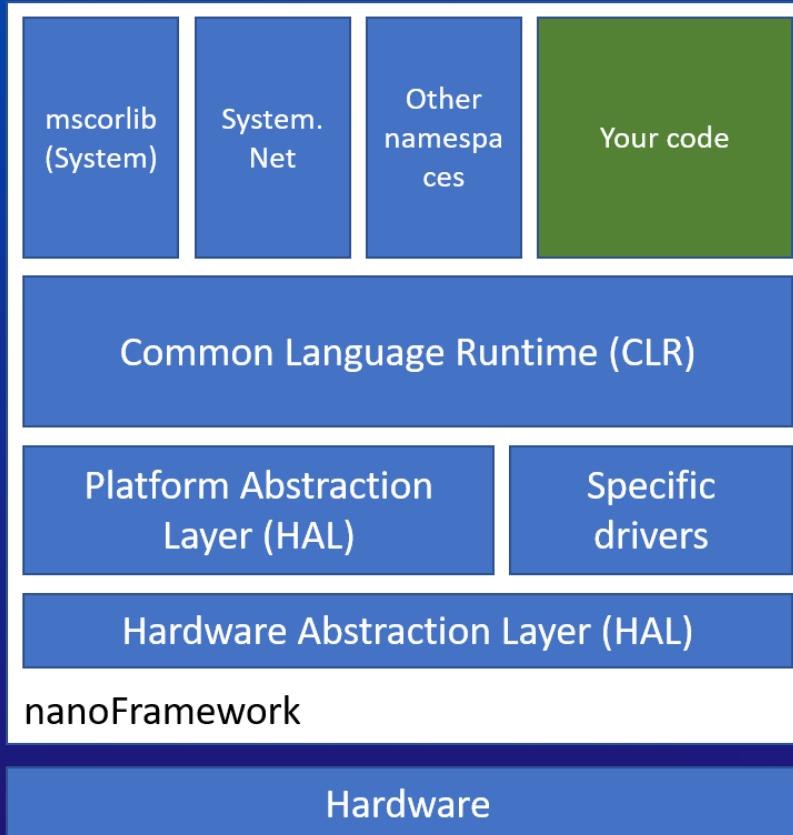
SPI, I2C

<https://dotnet.microsoft.com/apps/iot>

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# .NET Nanoframework



Reduced version of the .NET Common Language Runtime (CLR)

Subset of the .NET base class libraries

Resource-constrained devices with as low as 256kB of flash and 64kB of RAM  
Runs directly on bare metal

GPIO, UART, SPI, I2C

Espressif ESP32  
OrgPal  
STMicroelectronics  
TI SimpleLink  
NXP boards  
Netduino boards



<https://docs.nanoframework.net/>

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# Demo - IoT

- A lap around
- **Visual Studio 2026** and **.NET Nanoframework**



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# .NET Nanoframework ❤ Electronics



GPIO → GpioController

ADC → AdcController

I2C → I2cDevice

SPI → SpiDevice

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# .NET Nanoframework ❤ Electronics

The screenshot shows the official documentation for .NET Nanoframework devices. The top navigation bar includes links for API Reference, IoT.Device, Contributing, GitHub, and Discord, along with a search bar. The main content area is titled "Devices / List and category of devices". A sidebar on the left contains a search bar and a navigation tree under the "Devices" category, listing various sensor components such as A4988, AD5328, Ads1115, Adxl345, Adxl357, Ags01db, Ahtxx, Ak8963, Am2320, Amg88xx, Apa102, At24C128C, AtomQrCode, Axp192, Bh1745, Bh1750fvi, Bmm150, Bmp180, Bmxx80, Bno055, Button, Buzzer, and Card.

**Sonars**

- [NuGet v1.2.159](#) HC-SR04 - Ultrasonic Ranging Module
- [NuGet v1.2.159](#) HC-SR04 - Ultrasonic Ranging Module for ESP32 with RMT

**Distance sensors**

- [NuGet v1.2.159](#) HC-SR04 - Ultrasonic Ranging Module
- [NuGet v1.2.159](#) HC-SR04 - Ultrasonic Ranging Module for ESP32 with RMT
- [NuGet v1.2.159](#) LidarLiteV3 - LIDAR Time of Flight Sensor
- [NuGet v1.2.159](#) VL53L0X - distance sensor

**Passive InfraRed (motion) sensors**

- [NuGet v1.2.159](#) HC-SR501 - PIR Motion Sensor

**Motion sensors**

- [NuGet v1.2.159](#) HC-SR501 - PIR Motion Sensor

**Displays**

- [NuGet v1.2.159](#) APA102 - Double line transmission integrated control LED
- [NuGet v1.1.82](#) Character LCD (Liquid Crystal Display)
- [NuGet v1.0.3](#) ePaper drivers for .NET nanoFramework
- [NuGet v1.1.159](#) LCD library for SparkFun RGB Serial Open LCD display (sizes 20x4 or 16x2) with I2C connection
- [NuGet v1.2.153](#) Max7219 (LED Matrix driver)
- [NuGet v1.0.88](#) PCD8544 - 48 × 84 pixels matrix LCD; famous Nokia 5110 screen

**IN THIS ARTICLE**

- Infrared sensors
- Gyrosopes
- Compasses
- Motor controllers/drivers
- Inertial Measurement Units
- Magnetometers
- Hygrometers

**Clocks**

- Sonars
- Distance sensors
- Passive InfraRed (motion) sensors
- Motion sensors
- Displays
- GPIO Expanders
- CAN BUS libraries/modules
- Proximity sensors

<https://docs.nanoframework.net/devicesdetails/README.html>

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# .NET Nanoframework Reference Boards

**Espressif ESP32 series**



**OrgPal boards**

**STMicroelectronics boards**



**TI SimpleLink boards**

**NXP boards**

# .NET Nanoframework ❤️ Community

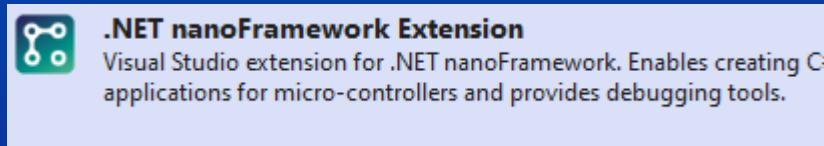
## Available community boards

Target name	Firmware Images	MCU	Frequency	FLASH	RAM
MBN_QUAIL	<a href="#">doudsmith 1.8.0.254</a>	STM32F427VG	180 MHz	1024 kB	256 kB
GHI FEZ CERB40-I	<a href="#">doudsmith 1.8.0.254</a>	STM32F405RG	168 MHz	1024 kB	192 kB
IngenuityMicro Electron	<a href="#">doudsmith 1.8.0.254</a>	STM32F411CE	100 MHz	512 kB	128 kB
IngenuityMicro Oxygen	<a href="#">doudsmith 1.8.0.254</a>	STM32F411CE	100 MHz	512 kB	128 kB
WeAct F411CE	<a href="#">doudsmith 1.8.0.254</a>	STM32F411CE	100 MHz	512 kB	128 kB
ST Nucleo64 F401RE	<a href="#">doudsmith 1.8.0.254</a>	STM32F401RE	84 MHz	512 kB	96 kB
ST Nucleo64 F411RE	<a href="#">doudsmith 1.8.0.254</a>	STM32F411RE	100 MHz	512 kB	128 kB
ST_STM32F411_DISCOVERY	<a href="#">doudsmith 1.8.0.254</a>	STM32F411VE	100MHz	512kB	128kB
ST Nucleo144 F412ZG	<a href="#">doudsmith 1.8.0.254</a>	STM32F412ZG	100 MHz	1024 kB	256 kB
ST Nucleo144 F746ZG	<a href="#">doudsmith 1.8.0.254</a>	STM32F746ZG	216 MHz	1024 kB	320 kB
ST STM32F4DISCO	<a href="#">doudsmith 1.8.0.254</a>	STM32F407VGT6	168 MHz	1024 kB	192 kB
ST Nucleo144 F439ZI	<a href="#">doudsmith 1.8.0.254</a>	STM32F439ZI	180 MHz	2048 kB	256 kB
TI_CC1352P1_LAUNCHXL_868	<a href="#">doudsmith 1.8.0.254</a>	TI CC1352	48MHz	352kB	80kB
TI_CC1352P1_LAUNCHXL	<a href="#">doudsmith 1.8.0.254</a>	TI CC1352	48MHz	352kB	80kB
PybStick Std 26	<a href="#">doudsmith 1.8.0.254</a>	STM32F411RE	100 MHz	512 kB	128 kB
NETDUINO3_WIFI	<a href="#">doudsmith 1.8.0.254</a>	STM32F427VI	168 MHz	1408kB	164kB
BrainPad2	<a href="#">doudsmith 1.8.0.254</a>	STM32F401RE	84 MHz	512 kB	96 kB
Lilygo TWatch 2020	<a href="#">doudsmith 1.8.0.143</a>	Esp32 V3	240 MHz	16MB	8MB
Lilygo TWatch 2021	<a href="#">doudsmith 1.8.0.21</a>	Esp32 V3	240 MHz	16MB	8MB

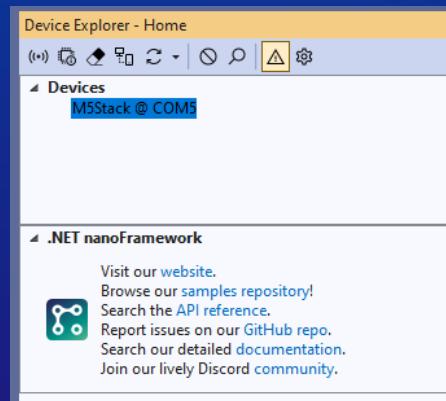
<https://github.com/nanoframework/nf-Community-Targets>

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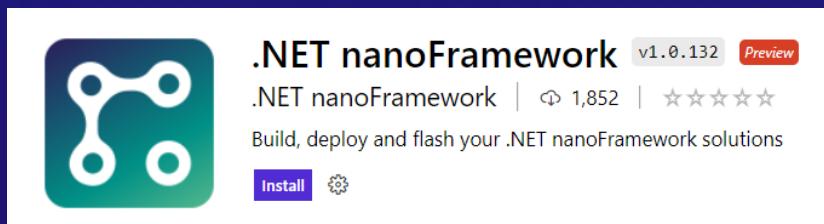
# .NET Nanoframework – Getting Started



Visual Studio 2022 / 2026 Debug Experience



Visual Studio Code Extension



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# .NET Nanoframework - nanoff

```
dotnet tool install -g nanoff
```

```
nanoff --update --target  
ESP32_PSRAM_REV0 --serialport  
COM31
```

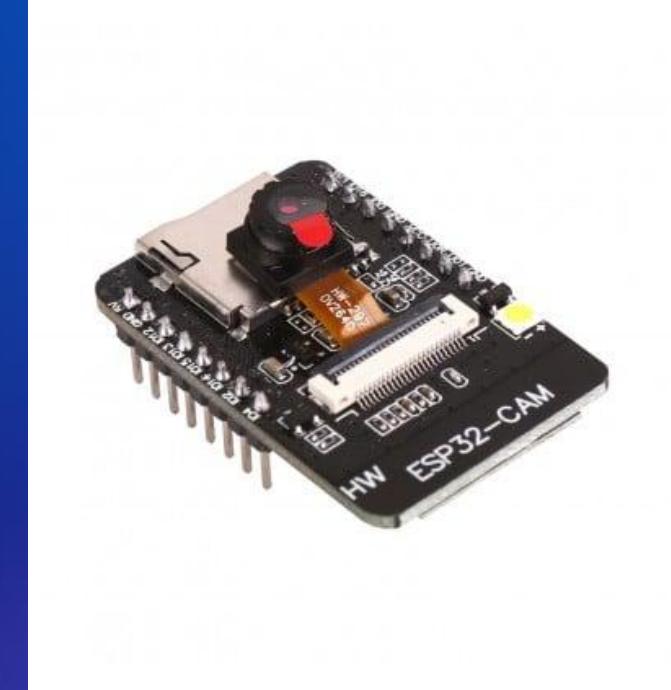
**Easily flash with .NET Global tool**

<https://github.com/nanoframework/nanoFirmwareFlasher>

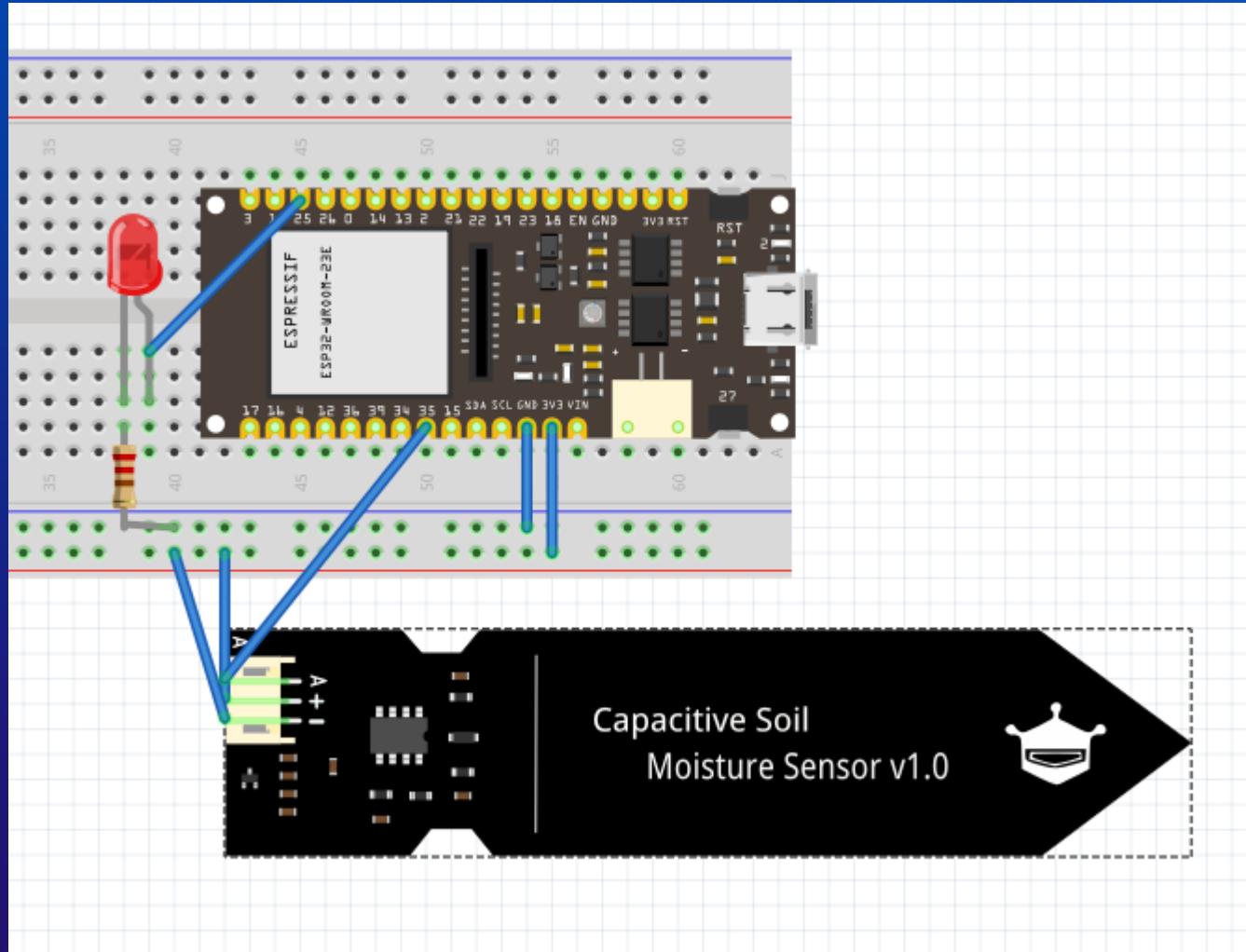
#dotnetconfsa.

# Native Camera Support

- Hardware Acceleration
- OV2640, OV3660, OV5640, OV7670, OV7725, NT99141, GC032A, GC0308, GC2145, BF3005, BF20A6, SC101IOT, SC030IOT, SC031GS, HM0360, HM1055
- Support Native IDF AI Inference
  - Face Detection
  - People Detection
  - Cat Detection.



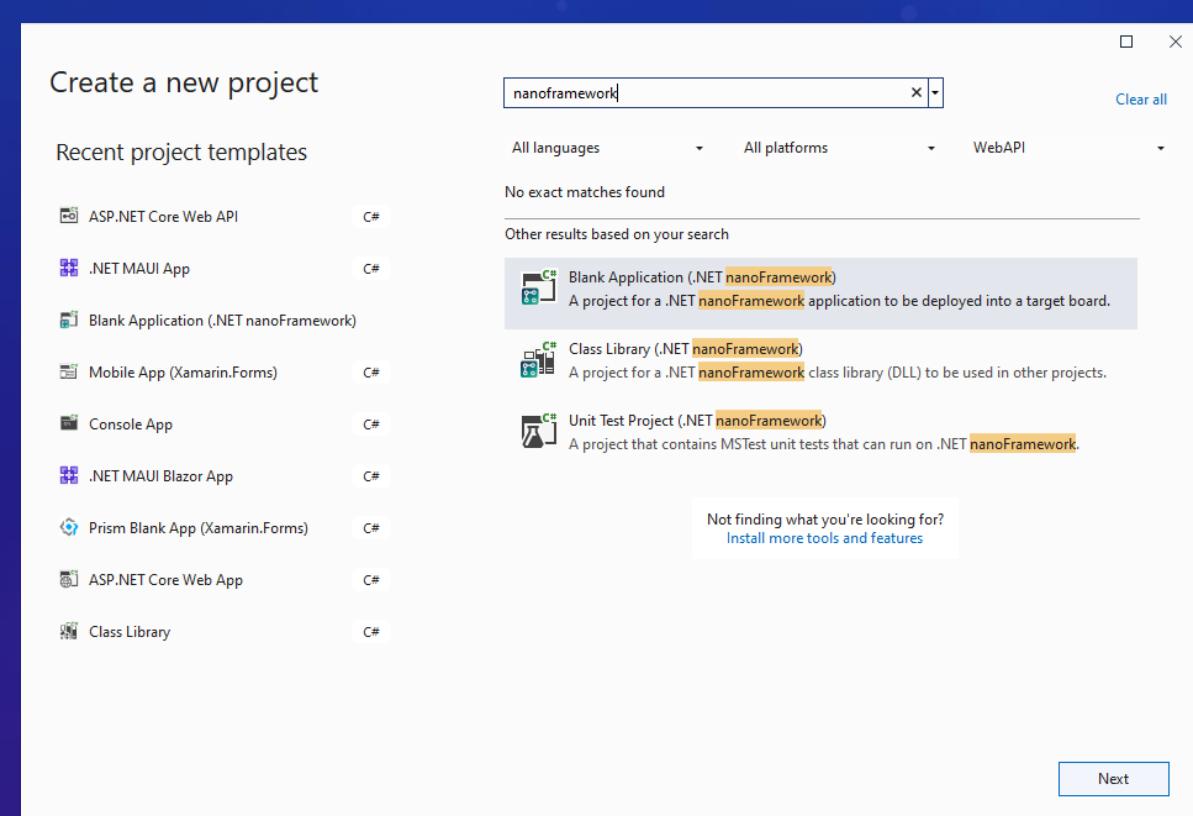
# Walkthrough – Intelligent Connected Agriculture with Nanoframework



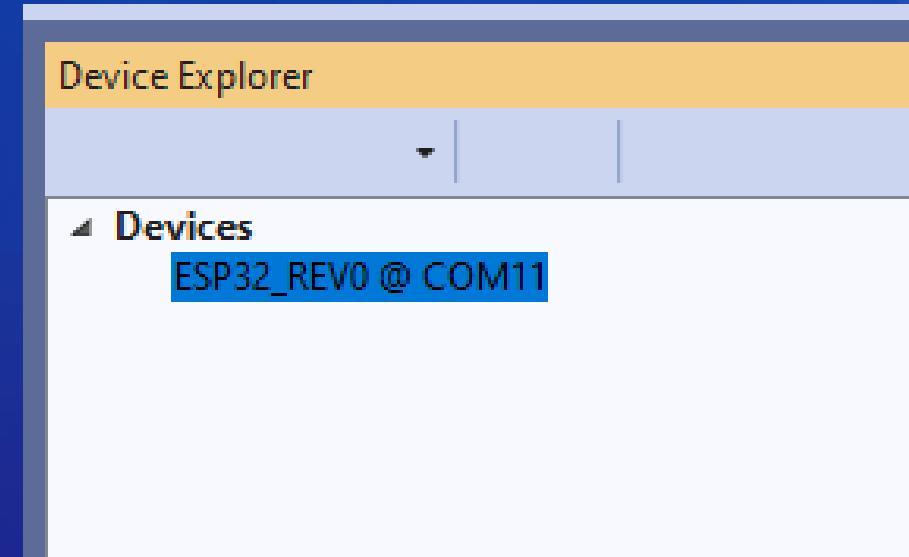
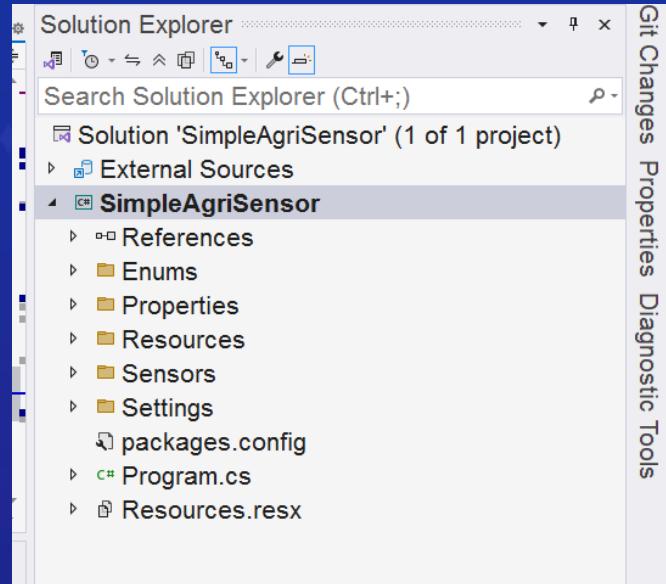
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# Nanoframework & .NET

```
using nanoFramework.Json;
using nanoFramework.M2Mqtt;
using nanoFramework.M2Mqtt.Messages;
using nanoFramework.M5Stack;
using nanoFramework.Networking;
using nanoFramework.Presentation.Media;
using System;
using System.Device.Adc;
using System.Device.Gpio;
using System.Diagnostics;
using System.Text;
using System.Threading;
```



# Nanoframework & .NET



```
1 reference
static void TelemetryLoop()
{
    while (true)
    {
        var reading = _moistureSensor.GetMoisturePercentage();
        string moistureData = $"{{\"soil_moisture\" : {reading}}}";

        client.Publish("demo/telemetry", Encoding.UTF8.GetBytes(moistureData), null, null, MqttQoSLevel.AtMostOnce, false);
        Debug.WriteLine("Message sent: " + moistureData);

        Thread.Sleep(3000);
    }
}
```

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# Reading a Moisture Sensor in C#

```
// Initialize Analog to Digital Converter
AdcController adc = new AdcController();

// Open Analog Channel
AdcChannel moistureAnalog = adc.OpenChannel(7);

// Read Value from Pin
moistureAnalog.ReadValue();
```

# Switching on a Relay (Pump)

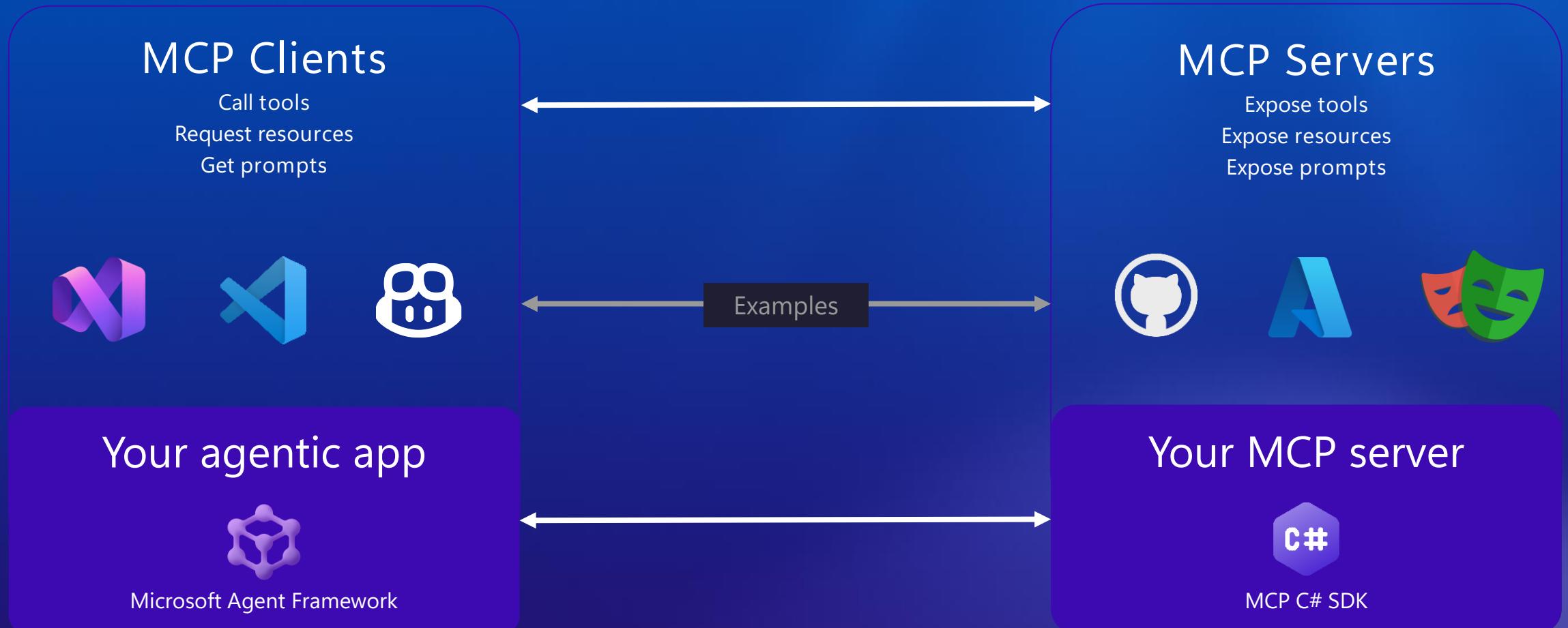
```
// Initialize Gpio Controller
GpioController gpioController = new GpioController();

// Open Digital Pin Channel
GpioPin pin = gpioController.OpenPin(2);

// Set Mode for Digital Pin (Input or Output)
gpioController.SetPinMode(2, PinMode.Output);

// Switch relay on
pin.Write(PinValue.High);
```

# Model Context Protocol (MCP)



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# Devices as MCPs

## Expose Tools to

Lan  
Mo

```
[McpServerTool("get_moisture", "Get the moisture reading from the sensor. Check the location of the sensor and make sure it is connected correctly. If you are using a digital sensor, make sure it is properly configured and connected to the MCP pin. You can also check the MCP configuration file for more information about the sensor settings.")]
0 references
public static string GetMoisture()
{
    if (_moistureSensor == null)
    {
        Initialize();
    }
    return _moistureSensor.ReadMoisture();
}

// Step 1: Discover and register MCP tools
McpToolRegistry.DiscoverTools(new Type[] { typeof(Light), typeof(Moisture) });
Debug.WriteLine("MCP Tools discovered and registered.");

// Step 2: Start WebServer with MCP controller
// You can add more types if you also want to use it as a Web Server
// Note: HTTPS and certs are also supported, see the previous sections
using (var server = new WebServer(80, HttpProtocol.Http, new Type[] { typeof(McpServerController) }))
{
    // Optional: Customize MCP server information and instructions
    // This will override the default server name "nanoFramework" and version "1.0.0"
    server.AddTool("get_moisture", GetMoisture);
}
```

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# MCP Clients

## Expose Tools to

Lan  
Mo

```
[McpServerTool("get_moisture", "Get the moisture reading from the sensor. Check the location of the sensor to make sure it's pointing at the soil." )]  
0 references  
public static string GetMoisture()  
{  
    if (_moistureSensor == null)  
    {  
        Initialize();  
    }  
    return _moistureSensor.Moisture;  
}  
  
// Step 1: Discover and register MCP tools  
McpToolRegistry.DiscoverTools(new Type[] { typeof(Light), typeof(Moisture) });  
Debug.WriteLine("MCP Tools discovered and registered.");  
  
// Step 2: Start WebServer with MCP controller  
// You can add more types if you also want to use it as a Web Server  
// Note: HTTPS and certs are also supported, see the previous sections  
using (var server = new WebServer(80, HttpProtocol.Http, new Type[] { typeof(McpServerController) }))  
{  
    // Optional: Customize MCP server information and instructions  
    // This will override the default server name "nanoFramework" and version "1.0.0"  
    server.AddTool("get_moisture", GetMoisture);  
    server.AddTool("get_light", GetLight);  
    server.AddTool("set_light", SetLight);  
    server.AddTool("get_temp", GetTemperature);  
    server.AddTool("set_temp", SetTemperature);  
    server.AddTool("get_humid", GetHumidity);  
    server.AddTool("set_humid", SetHumidity);  
    server.AddTool("get_moisture", GetMoisture);  
    server.AddTool("get_light", GetLight);  
    server.AddTool("set_light", SetLight);  
    server.AddTool("get_temp", GetTemperature);  
    server.AddTool("set_temp", SetTemperature);  
    server.AddTool("get_humid", GetHumidity);  
    server.AddTool("set_humid", SetHumidity);  
}
```

# Demo - MCP

- ESP32 as a MCP Server

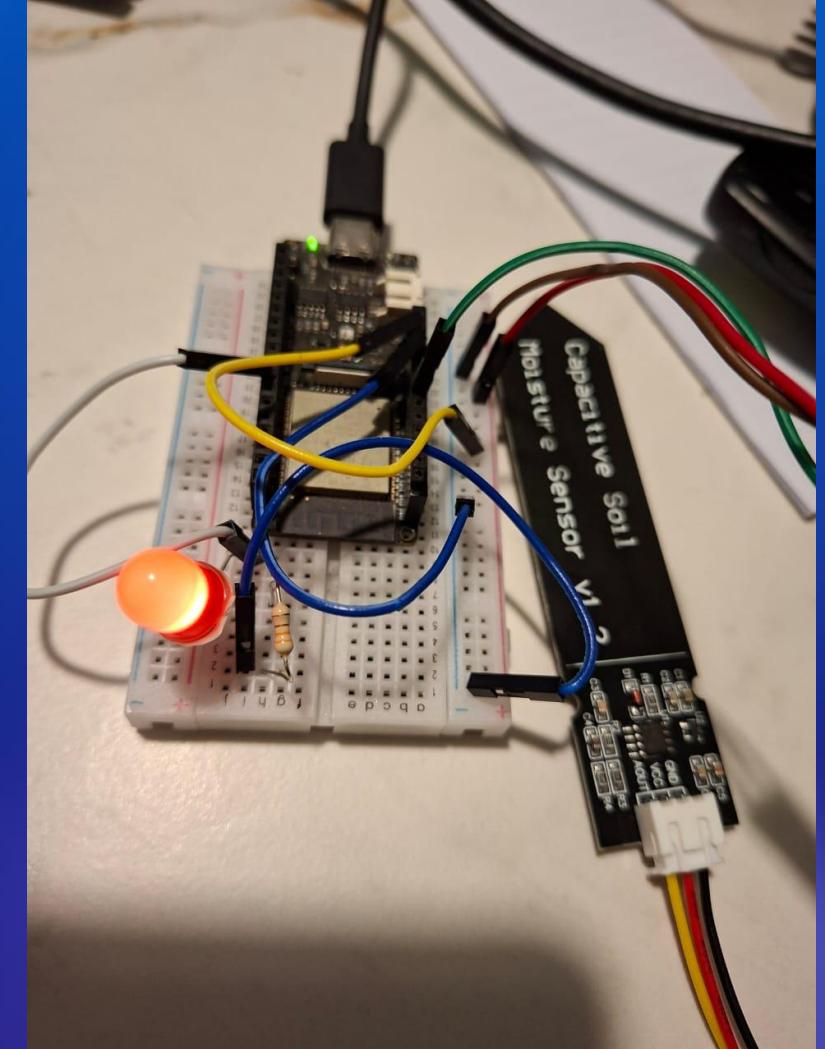
t. Do you want me to do anything (water, log this reading, set an alert)?

User > if the moisture is less than 50% turn off the light

Assistant > I checked the moisture at "dot net conf joburg" – it's 21%, which is below 50%, so I turned the light off.

User > if the moisture is more than 50% turn on the light

Assistant > I checked the moisture at "dot net conf joburg" – it's 100%, which is above 50%, so I turned the light on.



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.NET

# Cloud Telemetry

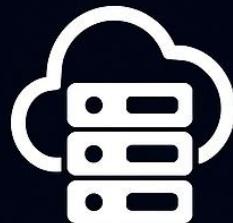
Insights    Actions



AWS



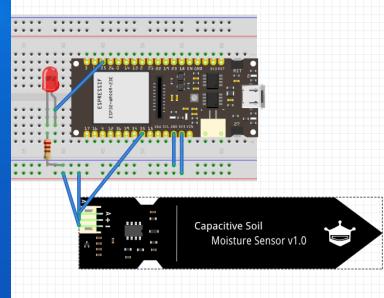
Azure



ON-PREMISES

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# AWS IoT - MQTT



```
1 reference
1 reference
static void TelemetryLoop()
{
    while (true)
    {
        var reading = _moistureSensor.GetMoisturePercentage();

        string moistureData = JsonConvert.SerializeObject(new { soil_moisture = reading, timestamp = DateTime.UtcNow.ToString("o") });

        client.Publish("demo/telemetry", Encoding.UTF8.GetBytes(moistureData), null, null, MqttQoSLevel.AtMostOnce, false);

        Debug.WriteLine("Message sent: " + moistureData);

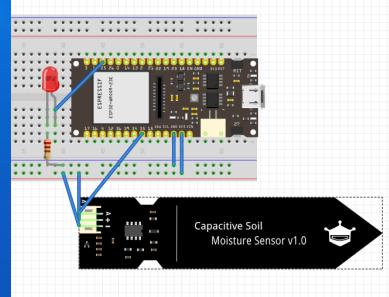
        _relay.ToggleRelay();

        Thread.Sleep(3000);
    }
}

Thread telemetryThread = new Thread(new ThreadStart(TelemetryLoop));
telemetryThread.Start();
}
```

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# Azure Devices SDK – Azure IoT Hub



```
DeviceClient azureIoT = new(IotHubAddress, DeviceID, SasKey, azureCert: new X509Certificate(Resource.GetString(Resource.StringResources.AzureRootCerts)));
azureIoT.Open();

// Gets the twin
var twin = azureIoT.GetTwin(new CancellationTokenSource(5000).Token);
if ((twin != null) && (twin.Properties.Desired.Contains("TimeToSleep")))
{
    minutesToGoToSleep = (int)twin.Properties.Desired["TimeToSleep"];
}

// Report the twins
TwinCollection reported = new();
reported.Add("TimeToSleep", minutesToGoToSleep);
reported.Add("Firmware", "nanoFramework");
azureIoT.UpdateReportedProperties(reported, new CancellationTokenSource(5000).Token);

var reading = _moistureSensor.GetMoisturePercentage();

string moistureData = JsonConvert.SerializeObject(new { soil_moisture = reading, timestamp = DateTime.UtcNow.ToString("o") });

if (moistureData != null)
{
    //Publish telemetry data if we have a measure
    azureIoT.SendMessage(moistureData);
}
```

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# Home Farm



IoT Device and Power Unit



Sensor



Pump

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# Demo Farm - Telemetry

## • Device Information

- **Device ID**: A unique identifier for the sensor device, used to track and manage individual sensors within the network.
- **Zone**: Describes the specific geographical area and field where the sensor is located, helping to organize and analyze data based on location.

## • Timestamp

- **Date and Time**: The exact moment when the sensor data was recorded, crucial for time-series analysis and tracking environmental changes over time.

## • Sensor Readings

- **Temperature** (Celsius): Measures the ambient temperature, important for monitoring climate conditions that affect crop growth.
- **Humidity** (Percent): Indicates the moisture content in the air, which can influence plant transpiration and growth.
- **Soil Moisture** (Percent): Reflects the water content in the soil, essential for irrigation management and ensuring optimal growing conditions.
- **Light Intensity** (Lux): Represents the amount of light the area receives, which is critical for photosynthesis and plant development.
- **pH** Level: Shows the acidity or alkalinity of the soil, important for nutrient availability and overall soil health.

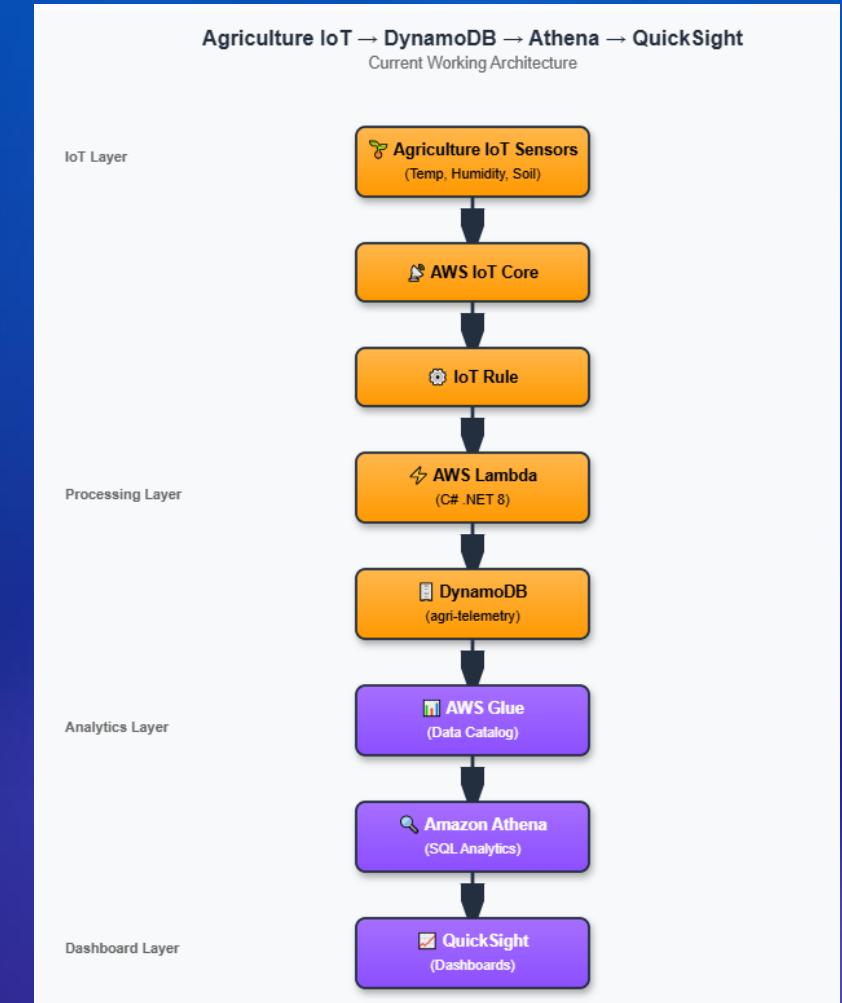
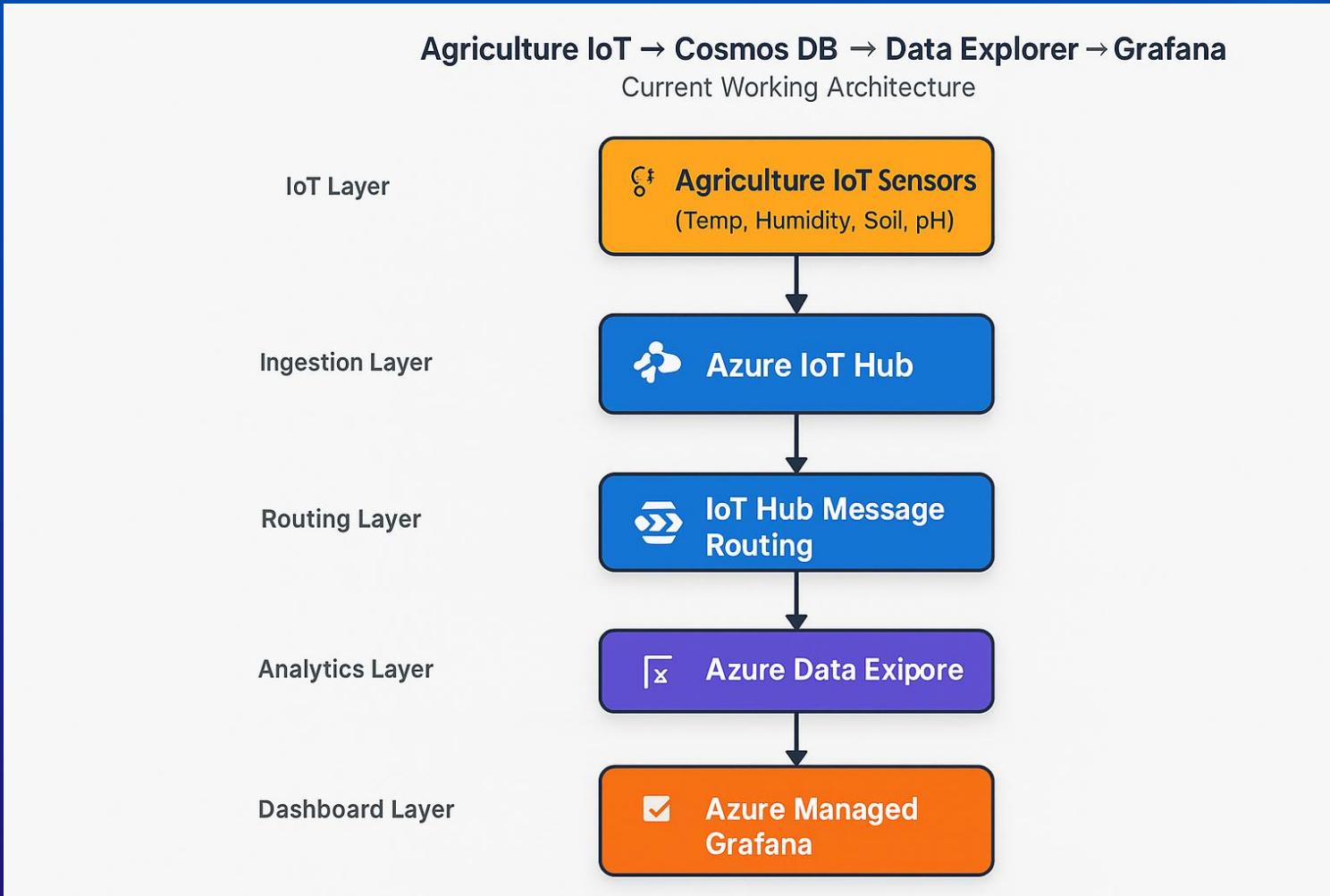
## • Metadata

- **Crop Type**: Specifies the type of crops being monitored, aiding in the analysis of data specific to different plant species.

```
agri_data.json > [ ] data > {} 1 > () sensors
  13   "data": [
  14     {
  18       "sensors": {
  22         "light_intensity_lux": 681.0,
  23         "ph": 6.66
  24       },
  25       "metadata": {
  26         "crop_type": "vegetables",
  27         "location": {
  28           "zone": "Zone A",
  29           "field": "North Field (Vegetables)"
  30         }
  31       }
  32     },
  33   {
  34     "device_id": "AGRI-SENSOR-001",
  35     "zone": "Zone A - North Field (Vegetables)",
  36     "timestamp": "2025-09-09T14:58:50.588128",
  37     "sensors": [
  38       "temperature_celsius": 27.2,
  39       "humidity_percent": 67.8,
  40       "soil_moisture_percent": 61.1,
  41       "light_intensity_lux": 649.0,
  42       "ph": 6.9
  43     ],
  44     "metadata": {
  45       "crop_type": "vegetables",
  46       "location": {
  47         "zone": "Zone A",
  48         "field": "North Field (Vegetables)"
  49       }
  50     }
  51   },
  52   {
  53     "device_id": "AGRI-SENSOR-001",
  54     "zone": "Zone A - North Field (Vegetables)",
  55     "timestamp": "2025-09-09T15:28:50.588128",
  56     "sensors": [
  57       "temperature_celsius": 27.1,
  58       "humidity_percent": 60.6,
  59       "soil_moisture_percent": 60.5,
  60       "light_intensity_lux": 470.0,
  61     ],
  62     "metadata": {
  63       "crop_type": "vegetables",
  64       "location": {
  65         "zone": "Zone A",
  66         "field": "North Field (Vegetables)"
  67       }
  68     }
  69   }
  70 }
```

# Azure

# AWS



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# Telemetry

Table: agri-telemetry - Items returned (50)

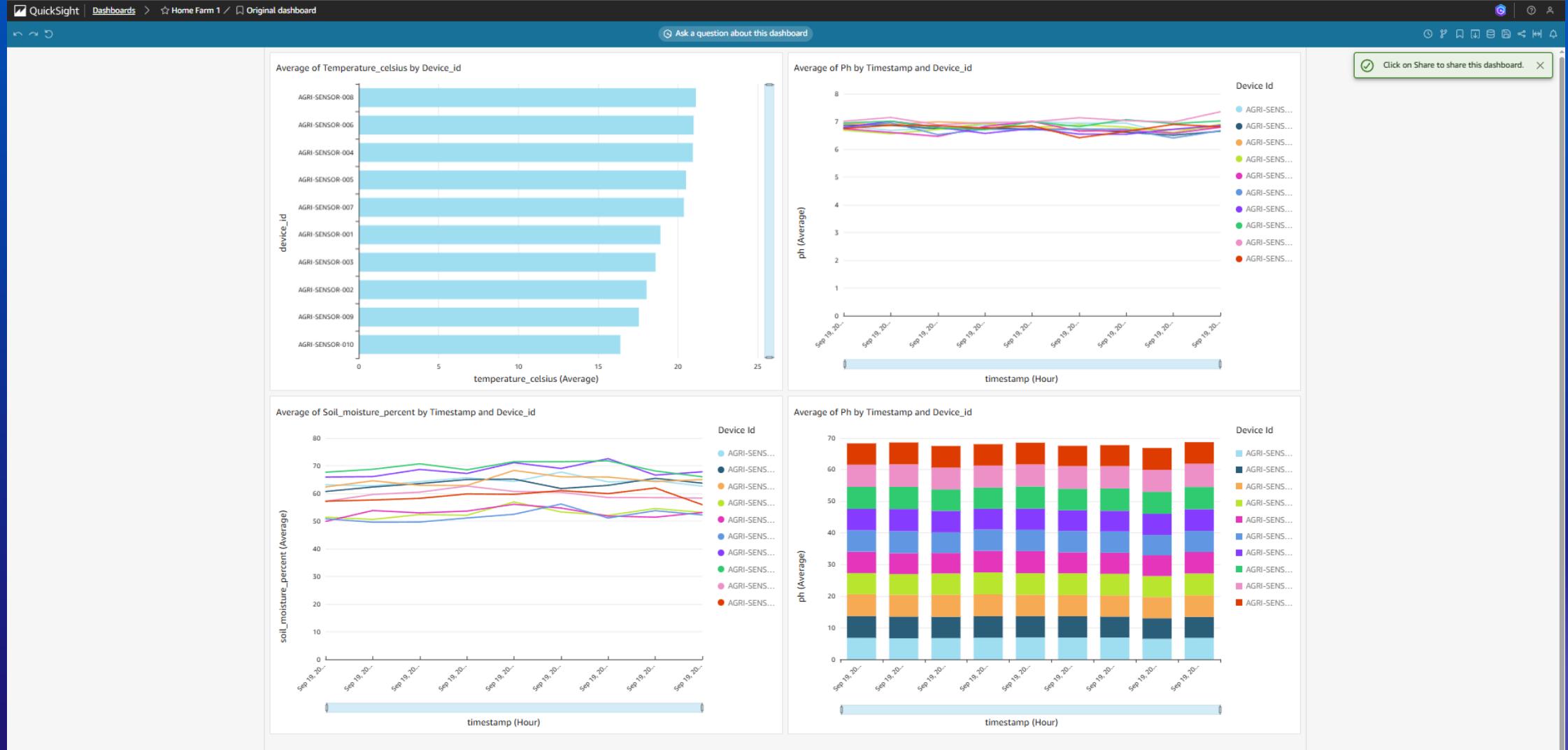
Scan started on September 20, 2025, 04:27:16

Actions ▾ Create item

	device_id (String)	timestamp (Number)	crop_type	expires_at (TTL)	humidity_percent	iso_time	light_intensity_lux	location_field
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-001</a>	1758276088196	vegetables	<a href="#">1773828089</a>	57.8	2025-09-1...	521	North Field (Vege...
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-001</a>	1758276089100	vegetables	<a href="#">1773828089</a>	58.7	2025-09-1...	458	North Field (Vege...
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-001</a>	1758276089827	vegetables	<a href="#">1773828089</a>	64.7	2025-09-1...	317	North Field (Vege...
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-001</a>	1758276090596	vegetables	<a href="#">1773828090</a>	58.1	2025-09-1...	364	North Field (Vege...
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-001</a>	1758276189885	vegetables	<a href="#">1773828190</a>	65.6	2025-09-1...	262	North Field (Vege...
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-001</a>	1758276190529	vegetables	<a href="#">1773828190</a>	71.6	2025-09-1...	72	North Field (Vege...
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-001</a>	1758276191074	vegetables	<a href="#">1773828191</a>	62.6	2025-09-1...	0	North Field (Vege...
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276088198	fruits	<a href="#">1773828088</a>	61.2	2025-09-1...	539	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276089101	fruits	<a href="#">1773828090</a>	53.8	2025-09-1...	464	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276089828	fruits	<a href="#">1773828089</a>	59	2025-09-1...	487	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276090597	fruits	<a href="#">1773828090</a>	59.5	2025-09-1...	229	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276189886	fruits	<a href="#">1773828190</a>	64.1	2025-09-1...	194	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276190530	fruits	<a href="#">1773828190</a>	68.6	2025-09-1...	159	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276191075	fruits	<a href="#">1773828191</a>	64.9	2025-09-1...	47	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276191654	fruits	<a href="#">1773828191</a>	69.3	2025-09-1...	6	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276192276	fruits	<a href="#">1773828192</a>	69.3	2025-09-1...	2	East Field (Fruits)
<input type="checkbox"/>	<a href="#">AGRI-SENSOR-008</a>	1758276599072	fruits	<a href="#">1773828599</a>	66.3	2025-09-1...	5	East Field (Fruits)

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# Home Farm



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Silver



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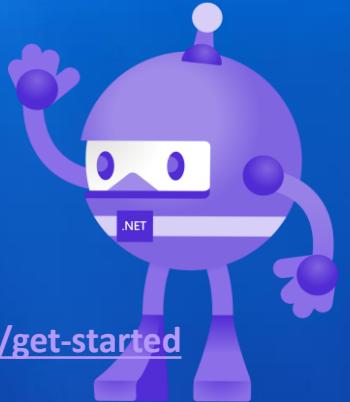
Joburg

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## Resources



### Getting Started with .NET

<https://learn.microsoft.com/en-us/dotnet/standard/get-started>

### Getting Started with .NET Nanoframework

<https://docs.nanoframework.net/content/getting-started-guides/getting-started-managed.html>

### Getting Started with AWS IoT

<https://docs.aws.amazon.com/iot/latest/developerguide/iot-gs.html>

### Getting Started with Azure IoT

<https://learn.microsoft.com/en-us/azure/iot/>



# Thank you!!

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