

**MAKER
&CODER**
EXPLORE, INNOVATE, EXCEL

MC4.0 CONTROLLER

**COMPLETE PRODUCT & ECOSYSTEM
DOCUMENTATION**



ESP32 Core

Touchscreen

30+ Modules

95+ Sensors

Ages 7+

MAKER & CODER GLOBAL

MULTI-CODING PLATFORM | AI | ROBOTICS | IOT | AUTOMATION | STEAM EDUCATION

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1. Product Overview

The MC 4.0 Controller is a flagship touchscreen microcontroller platform developed by Maker and Coder Global. It is engineered as the ultimate all-in-one device for AI, Robotics, IoT, and STEM/STEAM education — suitable for learners from age 7 through to professional engineers and university researchers. Designed to eliminate the need for multiple different platforms at different learning stages, the MC 4.0 is a single device that scales with its user from the first line of code to industry-grade project deployment.



The MC 4.0 is powered by the ESP32 — a high-performance, dual-core 32-bit microprocessor running at up to 240 MHz with integrated Wi-Fi and Bluetooth. This processor is manufactured by Espressif Systems and is one of the most capable and widely adopted chips in the global embedded systems and IoT industry. Its combination of processing power, wireless connectivity, rich peripheral support, and low power consumption makes it the ideal engine for a platform like the MC 4.0 that must handle everything from simple LED control to real-time AI inference, wireless networking, and multi-motor robotics.

At the front of the MC 4.0 sits a vibrant 320×240 pixel full-colour touchscreen display with a fully customisable GUI. Users can design their own interfaces — dashboards, menus, game screens, data panels — entirely in code, making the touchscreen a genuine output and input device rather than a fixed display. Three dedicated capacitive touch buttons below the screen provide quick programmable inputs for any application.

The MC 4.0 is built around a modular stacking architecture. Additional hardware modules connect directly onto the controller via a physical stacking interface — no wiring and no soldering required. Over 30 stackable modules are available, covering everything from long-range LoRaWAN and cellular networking to industrial relay control, GPS, stepper motors, and CNC motion. Combined with support for 95+ Grove-compatible sensors, the MC 4.0 is a platform without limits.

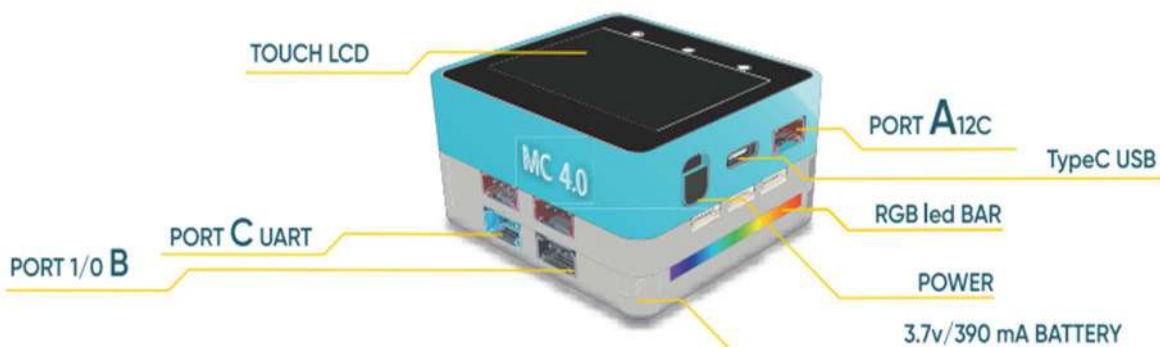
Programming is handled through the dedicated MCLab platform — which supports Scratch block coding, Python, and connects via Wi-Fi, Bluetooth, or USB — as well as the Arduino IDE with C++, Visual Studio Code with PlatformIO, MATLAB & Simulink, and ROS 2. This breadth of platform support ensures the MC 4.0 is at home in a primary school classroom, a university engineering lab, or a professional product development environment.



Why MC 4.0?

- ◆ One platform from age 7 to professional engineer — no hardware upgrade needed
- ◆ Industry-grade ESP32 processor with built-in Wi-Fi and Bluetooth
- ◆ Fully customisable 320×240 touchscreen GUI — design your own interface in code
- ◆ 30+ plug-and-play stackable modules — expand instantly, no soldering
- ◆ 95+ compatible sensors — every project covered in one ecosystem
- ◆ Multi-platform: MCLab, Arduino IDE, VS Code, MATLAB, ROS 2
- ◆ STEM/STEAM, higher education, research, competitions — all in one device

2. Core Hardware Specifications



2.1 Processor & Wireless

The MC 4.0 is driven by the ESP32 — a dual-core Xtensa LX6 processor manufactured by Espressif Systems, running at up to 240 MHz. This is one of the most powerful and widely used processors in the embedded systems and IoT industry. It provides the processing headroom required for real-time sensor fusion, touchscreen GUI rendering, wireless communication, and even on-device AI inference — all simultaneously. The integrated Wi-Fi (802.11 b/g/n) and dual-mode Bluetooth (Classic + BLE) make the MC 4.0 natively connected without requiring any additional modules for standard wireless use cases.

Specification	Details
Processor	ESP32 — Dual-Core Xtensa LX6, up to 240 MHz (Espressif Systems)
Memory	520 KB SRAM + 4 MB Flash + PSRAM for GUI and AI workloads
Wi-Fi	802.11 b/g/n — HTTP, HTTPS, MQTT, WebSocket, OTA updates, web server
Bluetooth	Dual-mode: Classic Bluetooth + BLE 4.2 — smartphone control, peer devices
ADC	18 × 12-bit SAR ADC channels
PWM	16 × independent PWM channels — motor control, servo, LED dimming
SPI / I2C / UART	Multiple hardware SPI, I2C, and UART buses
USB Interface	USB Type-C — programming, firmware flash, serial monitor

2.2 Display & Touch Interface

The MC 4.0 features a 320×240 pixel full-colour LCD touchscreen as its primary user interface. The display is not a fixed output — it is a fully programmable canvas where users design and render their own graphical interfaces entirely through code. From simple text and sensor dashboards to animated graphics, custom menus, and interactive game screens, the display adapts to whatever the application demands. Three capacitive touch buttons positioned below the screen add physical input options that can be mapped to any function in a program.

Specification	Details
Resolution	320 × 240 pixels (QVGA) — full colour
Display Type	Colour LCD — bright, sharp, readable in indoor and outdoor light
Touch	Full capacitive touchscreen — tap, drag, multi-touch GUI support
GUI Customisation	Fully programmable — design any interface in Scratch, Python, or C++
Touch Buttons	3 × dedicated capacitive touch buttons below the display
Libraries	LovyanGFX / TFT_eSPI for Arduino; native MCLab GUI blocks for Scratch/Python
Use Cases	Sensor dashboards, control panels, game UIs, data displays, custom menus

2.3 Built-in Sensors & Peripherals

Component	Description & Function
IMU — 6-Axis	Accelerometer + Gyroscope — measures motion, tilt, orientation, vibration, and gestures in three axes
RTC — Real-Time Clock	Maintains accurate date and time without internet connectivity; enables timestamped data logging and scheduled automation
Microphone (MEMS)	Built-in digital microphone for audio capture, voice command recognition, sound level detection, and audio AI projects
Speaker	Built-in speaker with onboard amplifier — audio output, text-to-speech synthesis, alarm tones, music, and audio feedback
Vibration Motor	Built-in haptic feedback motor — tactile alerts, notifications, and physical interaction responses
RGB LED	Programmable full-colour RGB LED — visual status indication, animated lighting effects, and alert signalling
LED Indicator	Dedicated status LED for power, data transfer, and operational state
Reset Button	Hardware reset — restarts the controller cleanly without disconnecting power
Power Button	Dedicated on/off power control button

2.4 I/O Ports & Connectivity

Port	Protocol / Function
USB Type-C	Programming port — firmware upload, serial monitor, data transfer; also powers the device from any USB-C source
Grove Port A	I2C — connect I2C sensors, displays, and environmental modules; supports multiple devices on the same bus via I2C addressing
Grove Port B	GPIO / ADC — digital and analogue sensor connections, servo control, relay modules, digital actuators
Grove Port C	UART — GPS modules, serial sensors, serial communication with external devices and modules
MicroSD Card Slot	File storage, data logging, audio and image asset storage, offline program data management
Stacking Interface	Modular physical and electrical connector for all 30+ expansion modules — plug-in, no cables or soldering

3. Power & Motor Stack Modules

The MC 4.0's stacking architecture allows two critical hardware modules to be connected directly beneath the controller, transforming it from a desktop programming device into a fully portable, autonomous robotics platform. These modules are the Battery Stack and the 4-Encoder DC Motor Driver Stack.

3.1 Battery Stack Module

The Battery Stack attaches directly to the MC 4.0 via the stacking interface to provide completely wireless, portable operation. It is an essential component for any mobile, field-deployed, or competition robotics project where a USB or mains power connection is not practical.

Specification	Details
Battery	7.4V, 500mAh LiPo (Lithium Polymer) — rechargeable, high energy density
BMS	Integrated Battery Management System — overcharge protection, over-discharge protection, short-circuit protection, and cell balancing
RGB	Dual-side RGB LEDs Strip — independently controllable on left and right sides, or synchronized for unified lighting effects; supports dynamic patterns and status indication
Stack Connection	Direct plug-in via stacking interface — no cables or soldering; physically and electrically secure

3.2 4-Encoder DC Motor Driver Stack

The 4-Encoder DC Motor Driver is a dedicated robotics power module that stacks directly onto the MC 4.0 (typically below the battery stack). It provides four-channel closed-loop motor control, enabling precise, programmable movement for wheeled robots, conveyor systems, and any multi-motor mechanism.

Specification	Details
Motor Channels	4 independent channels — drive up to 4 motors simultaneously, each independently controlled
Compatible Motors	BO (Battery operated) DC Metal Gear Encoder Motors — robust, widely available, metal gear for torque and durability
Grove Motor Ports	4 × dedicated Grove connectors — plug motors directly, no terminal screws or soldering
Encoder Feedback	Rotary encoder signal per channel — measures actual motor rotation for closed-loop speed and position control
Precision Movement	Program exact travel distances, rotation angles, and target speeds using encoder tick counts
PID Control	Encoder feedback enables PID loop implementation for smooth, accurate motion control
On/Off Switch	Dedicated power switch on the motor driver module
5V / Vin Switch	Power rail selector for motor supply voltage

External Charging Port	Dedicated charging port on the battery stack — allows independent charging of the internal LiPo battery using an external 8.4V adapter. Supports simultaneous operation with USB-C programming. Also enables connection of an external battery for extended power supply.
Stack Connection	Direct plug-in stacking connector — physically and electrically connects to MC 4.0 or battery stack

4. Stackable Expansion Modules

The MC 4.0 supports a comprehensive ecosystem of 30+ stackable expansion modules. Every module connects to the MC 4.0 via the physical stacking interface — no wiring harnesses, no soldering, and no separate power connections. Modules can be stacked in sequence to build multi-function systems, and the MC 4.0 automatically communicates with them through the stacking bus. This plug-and-expand architecture is one of the most powerful features of the MC 4.0 platform, enabling rapid hardware configuration changes for different projects without any rework.

WIRELESS & NETWORK COMMUNICATION MODULES

1	LoRaWAN Module	Long-range wireless networking module. Supports full LoRaWAN protocol stack for IoT sensor networks, smart agriculture, smart city, and industrial remote monitoring deployments.
1.1	LoRaWAN 470 MHz	470 MHz frequency variant — standard band for China and Asia-Pacific region LoRaWAN networks
1.2	LoRaWAN 915 MHz	915 MHz frequency variant — standard band for US, Canada, Australia, and Latin America LoRaWAN deployments
1.3	LoRa P2P	Direct peer-to-peer LoRa communication without requiring a LoRaWAN gateway — for direct long-range device-to-device links
2	LoRa 433 MHz	Long-range LoRa communication at 433 MHz — P2P and mesh networking; widely used in Asia and Europe for sub-GHz IoT applications
3	LoRa 868 MHz	LoRa module for the 868 MHz band — primary LoRa frequency for Europe and global P2P deployments under ISM band regulations
3.1	Cellular Module	Multi-protocol cellular communication stack supporting LTE, NB-IoT, CAT-1, GSM, and Zigbee — available as sub-variant modules:
3.2	LTE (4G)	4G LTE high-speed data — for real-time cloud connectivity, video streaming IoT, and high-bandwidth applications

3.3	NB-IoT	Narrowband IoT — ultra-low power, deep penetration; ideal for battery-operated sensors deployed in basements, manholes, or remote fields
3.4	CAT-1	LTE Category 1 — mid-speed cellular for IoT applications requiring reliable 4G coverage without full LTE data rates
3.5	GSM (2G)	2G GSM voice and data — the widest global network coverage; ideal for remote area deployments where only 2G is available
3.6	Zigbee	IEEE 802.15.4 Zigbee mesh networking — smart home automation, building management, and industrial sensor mesh networks
4	COMX Module	Universal swappable communication module with multiple sub-variants. A single hardware slot accepts different COMX cards for different cellular/wireless protocols — maximum flexibility with minimum hardware changes.
4.1	COMX LoRaWAN 470	COMX card for LoRaWAN 470 MHz Asia-region operation
4.2	COMX LoRaWAN 915	COMX card for LoRaWAN 915 MHz US/Australia-region operation
4.3	COMX LTE	COMX card for 4G LTE cellular data
4.4	COMX NB-IoT	COMX card for NB-IoT low-power cellular operation
4.5	COMX CAT-1	COMX card for LTE CAT-1 operation
4.6	COMX GSM	COMX card for 2G GSM cellular voice and data
4.7	COMX Zigbee	COMX card for Zigbee mesh network operation

MOTOR & MOTION CONTROL MODULES

5	Stepper Motor Module	Full stepper motor driver stack — bipolar stepper motor control with configurable micro-stepping for precision position control in 3D printing, CNC machines, camera sliders, and linear actuators
6	Stepper Motor Driver	Standalone stepper driver — independent bipolar and unipolar stepper motor driver module with step/direction interface and adjustable current
7	Servo Module	Multi-channel PWM servo controller — drive multiple RC servo motors simultaneously for robotic arms, pan-tilt camera mounts, and articulated mechanisms

8	Servo 2 Module	Extended servo module with additional channels — for complex multi-joint robots, hexapod legs, and advanced servo-driven mechanisms requiring more than the primary servo module provides
9	GoPlus2 Module	Compound robotics expansion — integrates motor driver, servo controller, and digital I/O in a single stackable module; the go-to module for complex educational robotics builds
10	GRBL Module	CNC motion control module implementing the GRBL open-source firmware — accepts G-code commands for multi-axis CNC machining, laser engraving, pen plotters, and precision XY stages
11	4 Encoder Motor	4-channel closed-loop encoder motor driver as a standalone stackable module — same functionality as the integrated motor stack, packaged for flexible stacking configurations

INDUSTRIAL AUTOMATION & I/O MODULES

12	Base X Module	Universal expansion base — additional I/O pins, power distribution rails, and breakout access for complex builds requiring more connection points than the Grove ports provide
13	Timer Module	Precision hardware timer — time-critical control loops, task scheduling, frequency generation, and real-time automation timing independent of the main processor
14	4in 8out Module	PLC-style digital I/O — 4 optocoupled digital inputs and 8 digital transistor outputs for industrial automation, machine control, and relay/solenoid driving
15	4 Relay Module	4-channel mechanical relay module — switch AC or DC high-voltage/high-current loads; ideal for smart home appliances, industrial machine switching, and building automation
16	PPS Module	Pulse Per Second precision timing module — generates a highly accurate 1 PPS signal for GPS time synchronisation, industrial clock systems, and precision time-stamping

WIRED NETWORKING & CONNECTIVITY MODULES

17	LAN Base Module	Wired Ethernet base — adds 10/100 Mbps RJ45 Ethernet connectivity for applications requiring a stable, fixed-line network connection instead of or alongside Wi-Fi
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18	USB Module	USB host and device expansion — connect USB peripherals (keyboards, barcode scanners, USB drives) or operate as a USB device to a host computer
19	Base PoE Module	Power over Ethernet base — receives both network data and DC power supply over a single Ethernet cable; eliminates separate power wiring for wall-mounted or ceiling-deployed nodes
20	COMMU Module	Industrial serial communication bus expansion — adds RS232, RS485, and CAN bus interfaces for integration with industrial PLCs, variable frequency drives, and fieldbus equipment
21	LAN Module	Compact Ethernet module for wired network connectivity in size-constrained stacked builds where a full LAN Base would be too large
22	IoT Base NB	NB-IoT integrated IoT base — combines an NB-IoT cellular modem with direct IoT cloud platform integration for deployments in areas with NB-IoT coverage
23	IoT Base CatM	LTE Cat-M1 integrated IoT base — optimised for mobile or moving IoT assets, smart meters, and tracking applications using the LTE-M (eMTC) network

POSITIONING & LOCATION MODULES

24	GPS Module	GNSS/GPS satellite receiver — provides latitude, longitude, altitude, speed, heading, and UTC time fix; ideal for vehicle tracking, asset monitoring, and outdoor navigation projects
25	GNSS Module	Advanced multi-constellation GNSS receiver — simultaneously tracks GPS (US), GLONASS (Russia), BeiDou (China), and Galileo (EU) satellites for higher positional accuracy and faster signal acquisition than single-constellation GPS

DISPLAY, METERING & MEASUREMENT MODULES

26	Dual Meter Module	Dual-channel precision analogue meter display — visualises two live electrical readings (voltage and current) simultaneously with a needle-style graphical display
27	DMX Module	DMX512 professional stage and architectural lighting control — output DMX universes to control LED stage lights, moving heads, and DMX-enabled theatrical fixtures
28	HMI Module	Dedicated secondary Human-Machine Interface display — provides an additional operator screen for control panels, machine status

		dashboards, and process visualisation independent of the main MC 4.0 display
29	RS232 Module	RS232 serial interface — enables communication with legacy industrial and commercial equipment including POS terminals, barcode scanners, lab instruments, and legacy PLCs
30	4-20mA Module	Industrial 4–20 mA current loop interface — the standard analogue signal format for industrial process sensors including pressure transmitters, flow meters, level sensors, and temperature transmitters

5. Complete Module Reference Table

No	Module Name	Category	Primary Use Case
1	LoRaWAN Module	Wireless	Long-range IoT network — P2P and LoRaWAN infrastructure
1.1	LoRaWAN 470 MHz	Wireless	Asia region 470 MHz LoRaWAN
1.2	LoRaWAN 915 MHz	Wireless	US/Australia 915 MHz LoRaWAN
2	Stepper Motor	Motion	Precise stepper motor position control
3	Servo Module	Motion	Multi-channel RC servo control
4	Servo 2	Motion	Extended servo channels for complex robotics
5	Cellular	Wireless	LTE / NB-IoT / CAT-1 / GSM / Zigbee cellular
6	Base X	I/O	Universal I/O and power expansion base
6.1	Timer	Control	Precision hardware timing and scheduling
7	GoPlus2	Robotics	Motor + servo + I/O combined expansion
8	GPS	Location	GNSS/GPS position tracking and navigation
9	GRBL	CNC	G-code CNC / laser engraving motion control
10	COMX	Wireless	Universal swappable cellular communication module
10a	COMX LoRaWAN 470	Wireless	COMX 470 MHz LoRaWAN card
10b	COMX LoRaWAN 915	Wireless	COMX 915 MHz LoRaWAN card
10c	COMX LTE	Wireless	COMX 4G LTE card
10d	COMX NB-IoT	Wireless	COMX NB-IoT low-power card
10e	COMX CAT-1	Wireless	COMX LTE CAT-1 card
10f	COMX GSM	Wireless	COMX 2G GSM cellular card
10g	COMX Zigbee	Wireless	COMX Zigbee mesh networking card
11	Stepper Driver	Motion	Standalone bipolar/unipolar stepper driver
12	LoRa 433 MHz	Wireless	433 MHz LoRa long-range P2P
13	LoRa 868 MHz	Wireless	868 MHz LoRa — Europe / global P2P

14	IoT Base NB	IoT	NB-IoT integrated IoT cloud base
15	IoT Base CatM	IoT	LTE Cat-M1 integrated IoT cloud base
16	LAN Base	Network	Wired 10/100 Mbps Ethernet base
17	USB Module	Interface	USB host/device peripheral expansion
18	Base PoE	Network	Power over Ethernet — data + power over one cable
19	4in 8out	Industrial	4 digital inputs + 8 digital outputs — PLC-style I/O
20	COMMU	Serial	RS232 / RS485 / CAN industrial serial bus
21	Dual Meter	Display	Dual analogue meter — live voltage and current display
22	DMX	Lighting	DMX512 professional stage lighting control
23	HMI	Display	Secondary HMI operator display module
24	RS232	Serial	RS232 legacy industrial equipment interface
25	4-20mA	Industrial	4–20 mA current loop for industrial process sensors
26	4 Relay	Control	4-channel relay for AC/DC high-voltage switching
27	GNSS Module	Location	Multi-constellation GNSS — GPS + GLONASS + BeiDou + Galileo
28	LAN Module	Network	Compact wired Ethernet for stacked builds
29	4 Encoder Motor	Robotics	4-channel closed-loop encoder motor driver
30	PPS Module	Timing	Precision pulse-per-second timing synchronisation

6. Sensor Expander Module

The MC 4.0 ecosystem includes a dedicated Sensor Expander Module that multiplies the available Grove I/O ports, enabling multiple sensors and peripheral units to be connected and read simultaneously from a single MC 4.0 controller. Without the expander, complex multi-sensor projects may be limited by the number of available Grove ports. With the expander, this constraint is removed entirely — making it possible to build sophisticated sensor arrays, environmental monitoring stations, and multi-input robotics systems from a single MC 4.0 unit.

Sensor Expander — Key Capabilities

- Expands Grove I/O — multiple sensors connected and operating simultaneously
- Supports I2C, GPIO/ADC, and UART Grove modules on the expanded ports
- Power-distributed — each expanded port receives stable, regulated power from the host controller
- Plug-and-play — sensors are automatically detected by MCLab; no configuration required
- Compatible with all 95+ supported sensors and Grove units in the MC 4.0 ecosystem
- Ideal for: weather stations, competition robots with multiple sensors, lab data loggers, smart environment monitors

7. Compatible Sensors & Units (95+ Supported)

The MC 4.0 supports over 95 individual sensors, units, and peripheral modules through its Grove ports. All sensors are compatible with both MCLab (Scratch blocks and Python) and the Arduino IDE. They connect via standardised Grove connectors to Grove Port A (I2C), Grove Port B (GPIO/ADC), or Grove Port C (UART) as appropriate for their protocol. The following is the complete categorised catalogue.

7.1 Environmental & Atmospheric Sensors

Sensor	Protocol	Measures
Temperature & Humidity (DHT11/22)	GPIO	Ambient temperature, relative humidity
ENV Unit (SHT30 + BMP280)	I2C	Temperature, humidity, atmospheric pressure
ENV Pro Unit	I2C	Temperature, humidity, pressure, altitude — high precision
ENV III Unit	I2C	Temperature, humidity, pressure — compact form factor
CO2 Unit (SCD40)	I2C	CO2 concentration ppm, temperature, humidity
TVOC / eCO2 Unit (SGP30)	I2C	Total volatile organic compounds, estimated CO2
Dust Sensor Unit	GPIO	PM2.5 and PM10 particulate matter concentration
Gas Sensor Unit	ADC	Flammable gas, smoke, and CO detection
Formaldehyde Sensor	UART	HCHO (formaldehyde) indoor air quality
UV Sensor Unit	I2C	UV light intensity and UV index (UVA/UVB)
Light Sensor Unit	I2C	Visible ambient light in lux
Thermal Camera (MLX90640)	I2C	32×24 pixel thermal infrared heat imaging

7.2 Motion, Position & IMU Sensors

Sensor	Protocol	Measures
IMU Unit (MPU6886)	I2C	6-axis accelerometer + gyroscope (also built-in on MC 4.0)
9-DOF IMU (MPU9250)	I2C	9-axis accelerometer + gyroscope + magnetometer
Accelerometer (ADXL345)	I2C	High-g shock and vibration acceleration
Magnetometer / Compass	I2C	Magnetic field heading and compass bearing
Joystick Unit	I2C	2-axis analogue joystick with push-click button

Encoder Unit	I2C	Rotary encoder for position and speed feedback
Angle Unit (Potentiometer)	ADC	Rotational angle 0–360°
Vibration Sensor	GPIO	Vibration and mechanical shock detection
Tilt Sensor	GPIO	Tilt angle and incline detection
Hall Effect Sensor	GPIO	Magnetic field proximity detection

7.3 Distance, Proximity & Object Detection

Sensor	Protocol	Measures
Ultrasonic Distance Unit	GPIO	Distance 2 cm – 400 cm via ultrasonic echo
RGB Ultrasonic Unit (I2C)	I2C	Distance 2–400 cm + programmable RGB LED status indicator
ToF Distance Unit (VL53L0X)	I2C	Laser time-of-flight distance 0–2 m
ToF 4M Distance Unit (VL53L1X)	I2C	Laser time-of-flight distance 0–4 m, extended range
IR Distance Unit	ADC	Short-range infrared proximity and edge detection
PIR Motion Sensor	GPIO	Passive infrared human motion detection
Radar Unit (24 GHz mmWave)	UART	Human presence detection through non-metallic walls
Laser Distance Sensor	UART	Long-range precision laser distance measurement

7.4 Colour, Light & Image Sensing

Sensor	Protocol	Measures
Colour Sensor (TCS34725)	I2C	Red, Green, Blue, and clear light intensity values
Colour Unit (TCS3472)	I2C	Precise RGBC colour detection and lux measurement
Ambient Light Sensor	I2C	Visible light lux and infrared light level
Camera Unit (OV2640)	I2C + GPIO	2MP image and video capture, QR code scanning, face detection
QR Code / Barcode Scanner	UART	1D and 2D barcode and QR code reading
RFID Unit (RC522)	I2C / SPI	13.56 MHz RFID and NFC tag read and write
Fingerprint Sensor	UART	Fingerprint template enrolment and matching

7.5 Line Following & Grayscale Sensors

The MC 4.0 ecosystem includes two dedicated I2C grayscale line-following sensors specifically engineered for robotics competition and autonomous navigation projects. By using I2C communication, these sensors reduce wiring complexity to a single Grove cable while delivering multi-channel reflectance readings that enable precise line detection and tracking algorithms.

Sensor	Specification & Details
5-Way Grayscale Line Follower (I2C)	5-channel reflectance sensor array; I2C interface via Grove Port A; detects black-white line transitions across 5 sensing points simultaneously; address configurable; compact PCB form factor; ideal for standard-width competition tracks
6-Way Grayscale Line Follower (I2C)	6-channel reflectance sensor array; I2C interface via Grove Port A; wider sensing field for better coverage on wider tracks; supports weighted centroid calculation for smooth, accurate line-position estimation; preferred for high-speed and curved-track line following
Output Per Channel	0–255 grayscale reflectance value per channel — higher value = more reflected light (white surface)
Use Cases	Line-following robots, track racing, maze solving, edge detection, position sensing on marked surfaces
MCLab Support	Native block and Python API — read all channels in a single function call
Arduino Support	Direct I2C library access — all channels readable in one I2C transaction

The 5-way sensor is suited to standard competition track widths, while the 6-way sensor provides greater positional resolution for faster robots and more complex track geometries. Both sensors support PID-based line tracking algorithms when combined with the MC 4.0's encoder motor driver stack — enabling competition-grade line-following performance.

7.6 RGB Ultrasonic I2C Sensor

The RGB Ultrasonic Unit combines distance measurement with integrated visual feedback in a single compact Grove-compatible module. Unlike standard ultrasonic sensors that provide only a distance value, this sensor adds programmable RGB LEDs around the transducer face — allowing colour-coded distance alerts to be set directly in the sensor hardware.

Specification	Details
Distance Range	2 cm – 400 cm via ultrasonic time-of-flight
Protocol	I2C — Grove Port A; plug-and-play, no pin configuration needed
RGB LEDs	Programmable RGB LEDs integrated around the ultrasonic transducer face
Visual Feedback	LED colour changes based on measured distance — programmable colour thresholds
Use Cases	Obstacle avoidance with visual alert, proximity-triggered lighting, interactive distance displays, robot status indicators
MCLab Support	Block and Python — read distance value and set LED colour in a single command

Arduino Support	Grove I2C library — set LED colours and read distance via I2C register map
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This sensor is particularly effective in classroom and competition settings because the integrated RGB feedback makes sensor behaviour immediately visible without needing to look at a screen — the robot itself shows what it is detecting through its colour.

7.7 Input, Output & Display Units

Unit	Protocol	Function
Button Unit	GPIO	Single debounced push button
Dual Button Unit	GPIO	Two independent debounced push buttons
CardKB Mini Keyboard	I2C	Full QWERTY miniature keyboard for text input
Encoder Knob	I2C	Rotary encoder + push click + RGB LED indicator
Joystick Unit	I2C	2-axis analogue joystick with click button
Vibration Motor Unit	GPIO	External haptic feedback actuator
RGB LED Strip	GPIO	Addressable WS2812B colour LED strips
LED Bar Unit	I2C	10-segment programmable LED bar graph
7-Segment Display	I2C	4-digit 7-segment numerical display
OLED Display (0.96")	I2C	128×64 px monochrome OLED — text and vector graphics
LCD Display (1.14")	SPI	135×240 colour LCD — rich GUI secondary display
E-Ink Display	SPI	Low-power e-paper display — image persists with zero power
Servo Driver Unit	I2C	16-channel PWM servo controller (PCA9685)
Relay Unit	GPIO	Single-channel relay for load switching

7.8 Communication & Interface Units

Unit	Protocol	Function
RS485 Unit	UART	Industrial RS485 half-duplex serial bus
CAN Unit	SPI	CAN bus for automotive and industrial networks
1-Wire Unit	GPIO	DS18B20 and 1-Wire sensor chain interface
I2C Hub / Expander	I2C	Expand one I2C port to multiple simultaneous devices
GPS Unit	UART	GPS/GNSS standalone positioning module

4G LTE Unit	UART	4G cellular data communication module
Bluetooth SPP Unit	UART	Bluetooth serial passthrough for wireless terminal
Wi-Fi Camera Unit	Wi-Fi	Live video streaming camera over local Wi-Fi
Ethernet Unit (W5500)	SPI	Wired Ethernet via SPI hardware controller
NFC Unit	I2C	13.56 MHz NFC tag read and write

7.9 Power, Energy & Analogue Units

Unit	Protocol	Function
Voltmeter Unit	I2C	DC voltage measurement 0–36 V
Ammeter Unit	I2C	DC current measurement via precision shunt
Power Meter Unit	I2C	Simultaneous voltage, current, and power measurement
DAC Unit (MCP4725)	I2C	12-bit Digital-to-Analogue output 0–3.3 V
ADC Unit (ADS1115)	I2C	16-bit precision 4-channel Analogue-to-Digital converter
Weight / Load Cell	I2C	HX711 load cell amplifier — digital scale and force measurement
AC Power Meter	UART	AC mains voltage, current, power factor, and energy metering

7.10 Specialty & Advanced Units

Unit	Protocol	Function
Thermal Camera (MLX90640)	I2C	32×24 thermal IR heat mapping camera
CO2 + TVOC (SCD40+SGP30)	I2C	Dual air quality — CO2 concentration and VOC levels
Laser Unit	GPIO	Visible laser pointer / beam module
Servo Gripper	GPIO	Servo-actuated gripper claw for pick-and-place robotics
Mini Fan Unit	GPIO	Small brushless fan for airflow and cooling control
Pump Unit	GPIO	Peristaltic pump for liquid transfer and dispensing
Solenoid Valve Unit	GPIO	Water and gas flow control solenoid valve
Motor Driver (Single)	I2C	Single-channel brushed DC motor driver with PWM speed control
Microphone Unit (I2S)	I2S	High-quality digital I2S microphone for audio AI applications

Speaker / Buzzer Unit	GPIO	External speaker or piezo buzzer output
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8. Programming Languages & Platforms

One of the defining strengths of the MC 4.0 Controller is its extraordinary breadth of programming platform support. From visual drag-and-drop block coding for children through to professional embedded C++ development, ROS 2 robotics middleware, and MATLAB engineering tools — the MC 4.0 is compatible with every major development environment used across education, research, and industry. No other controller in its class offers this range.

8.1 MCLab — Official Platform

MCLab is the dedicated cloud-based development and learning platform for the MC 4.0, built by Maker and Coder Global. It requires no software installation and runs in any modern browser. MCLab supports three connection modes — Wi-Fi, Bluetooth, and USB — and offers two complete programming environments within the same platform.

Feature	Block Mode (Scratch)	Text Mode (Python)
Target Users	Ages 7–14, beginners, visual learners	Ages 12+, intermediate and advanced
Programming Style	Drag-and-drop visual blocks — no typing	Full Python syntax in a browser IDE
Hardware Access	All MC 4.0 features accessible via blocks	All MC 4.0 features via Python API
Sensor Support	All 95+ sensors via dedicated blocks	All 95+ sensors via Python library calls
Module Support	All 30+ sensors via dedicated blocks	All 30+ sensors via Python library calls
AI Projects	Face, voice, object, qr & bar reader, colour, gesture AI blocks	Full ML/AI Python APIs with model import
IoT Projects	MC Cloud, AWS, Azure, MQTT, HTTP, cloud dashboard blocks	Complete IoT Python networking libraries
Connection	Wi-Fi / Bluetooth / USB	Wi-Fi / Bluetooth / USB

8.2 Arduino IDE

The MC 4.0 is fully supported in the Arduino IDE through the M5Core2 library published by Maker and Coder Global. This library provides complete hardware abstraction for every on-board component — the 320×240 touchscreen, capacitive touch buttons, IMU, RTC, speaker, microphone, RGB LED, vibration motor, and all Grove ports — as clean, well-documented API calls. The full power of C++ and the entire Arduino third-party library ecosystem is available, making the Arduino IDE the preferred workflow for secondary and higher education students and professional developers who need maximum hardware control and performance.

8.3 Visual Studio Code

Visual Studio Code is fully supported as a development environment for the MC 4.0. Through the PlatformIO IDE extension, VS Code becomes a complete professional embedded development environment — with IntelliSense auto-completion, advanced JTAG and serial debugging, automatic dependency management, and one-click firmware upload. For MicroPython projects, extensions such as Pymakr provide direct file synchronisation and REPL terminal access from within the editor. VS Code with PlatformIO represents the most powerful and industry-relevant development workflow available for the MC 4.0, and is the recommended choice for professional developers and advanced university-level students.

8.4 Platform IO

PlatformIO is a professional open-source embedded development platform that runs as an extension within Visual Studio Code and is fully supported by the MC 4.0. It serves as a more capable alternative to the standard Arduino IDE, offering automatic library management, multi-environment build configuration, and a built-in unit testing framework. All board settings, library dependencies, and upload parameters are defined in a single platformio.ini configuration file — making projects fully reproducible and easy to share across development teams. PlatformIO's integrated serial monitor, logic analyser support, and remote debugging capabilities make it the preferred choice for professional developers and advanced students building production-ready firmware on the MC 4.0.

8.5 MATLAB & Simulink

MATLAB and Simulink, the flagship engineering tools from MathWorks, are fully supported by the MC 4.0 through serial communication and the MATLAB Support Package for Arduino Hardware. Engineers and university students can stream live sensor data directly into MATLAB for real-time analysis, signal processing, and control system design. In Simulink, control algorithms — such as PID controllers, Kalman filters, and state machines — can be designed as visual block diagrams and deployed directly onto the MC 4.0, or used for hardware-in-the-loop (HIL) simulation. This makes the MC 4.0 an excellent physical testbed for control engineering, mechatronics, and signal processing courses, where theoretical models can be experimentally validated against real hardware.

8.6 ROS (Robot Operating System)

ROS is an open-source robotics middleware framework that has become the industry standard for professional and research-grade robotic systems. The MC 4.0 fully supports ROS integration through its serial and Wi-Fi communication interfaces. Through the micro-ROS library, the MC 4.0 can become a direct participant in a ROS 2 network — publishing and subscribing to topics, calling services, and participating in the ROS computation graph. This makes it suitable for university-level robotics research, autonomous navigation stacks such as Nav2, and multi-robot coordination systems. Real sensor data from the IMU, encoders, and ultrasonic units can be fed directly into ROS topics and visualised in tools such as RViz.

Platform	Language / Tool
MCLab	Scratch (Block) + Python — cloud-based, browser, no install
Arduino IDE	C++ — full hardware library, third-party ecosystem
Visual Studio Code + PlatformIO	C++ / MicroPython — professional IDE, advanced debug
MATLAB & Simulink	MATLAB / Simulink — engineering analysis, HIL simulation, control design
ROS 2 (micro-ROS)	C++ / Python — robotics middleware, topic pub/sub, Nav2, RViz

9. Educational Applications & Use Cases

The MC 4.0 Controller is designed from the ground up as an educational platform. Its unique combination of an accessible entry point (Scratch block coding, ages 7+), rich built-in hardware, and professional-grade ceiling (C++, ROS, MATLAB) means it is genuinely the only hardware platform a learner needs from their first programming lesson through to university-level engineering projects.

9.1 STEM & STEAM Education

Domain	MC 4.0 Components	Curriculum Topics
Science	IMU, ENV sensor, CO2, UV, RTC, microphone	Motion physics, atmospheric science, environmental monitoring, sound, chronometry
Technology	ESP32, Wi-Fi, Bluetooth, MCLab, USB	Microprocessors, networking, IoT, cloud computing, cybersystems
Engineering	Motor driver, encoders, Grove I/O, stacking modules	Mechatronics, control systems, closed-loop feedback, system integration
Arts	320×240 touchscreen GUI, RGB LED, speaker, vibration	UI/UX design, digital media, computational art, interactive installations
Mathematics	Encoder counts, sensor data, PID control	Algebra, coordinate geometry, data analysis, statistics, control theory

9.2 Curriculum Levels

- Primary School (Ages 7–11): Block coding on MCLab, basic LED and display projects, first sensor readings, simple automation sequences
- Lower Secondary (Ages 11–14): Introduction to Python on MCLab, IoT sensor dashboards, multi-sensor data collection, basic wheeled robotics
- Upper Secondary (Ages 14–18): Advanced Python, AI projects (face, voice, object), autonomous line-following robots, competition project builds
- Higher Education: Arduino C++, embedded systems design, control engineering with MATLAB/Simulink, ROS 2 robotics research, final-year engineering projects
- Professional / Research: PlatformIO firmware development, industrial IoT prototyping, multi-module system integration, custom hardware-software development

9.3 Competition & Project Events

- Line-following robot competitions — 5-way / 6-way I2C grayscale sensors + 4 encoder motors + PID speed control
- Obstacle avoidance challenges — RGB Ultrasonic I2C + ToF sensors + motor driver stack + autonomous navigation
- STEM fairs and science olympiads — multi-sensor environmental monitoring projects, AI demonstrations
- IoT hackathons — Wi-Fi + cellular modules + MCLab cloud dashboards + real-time data visualisation
- Robotics and innovation competitions — any combination of 30+ modules and 95+ sensors
- University project exhibitions — ROS 2 integration, MATLAB HIL simulation, computer vision with camera units.

10. Complete Technical Specification Summary

Specification	Details
Core Processor	ESP32 — Dual-Core Xtensa LX6, 240 MHz — Espressif Systems
Memory	520 KB SRAM + 4 MB Flash + PSRAM
Display	320 × 240 px Full Colour LCD — fully customisable GUI
Touch Interface	Full capacitive touchscreen + 3 × capacitive touch buttons
Wi-Fi	802.11 b/g/n — HTTP, MQTT, WebSocket, OTA, web server
Bluetooth	Dual-mode: Classic Bluetooth + BLE 4.2
IMU	6-axis — accelerometer + gyroscope (built-in)
RTC	Real-Time Clock — date and time without internet
Microphone	Built-in MEMS digital microphone
Speaker	Built-in speaker with amplifier
Vibration Motor	Built-in haptic vibration motor
RGB LED	Programmable full-colour RGB LED
SD Card	MicroSD slot — data logging and file storage
USB	Type-C — programming, firmware flash, serial monitor
Grove Ports	Port A (I2C) + Port B (GPIO/ADC) + Port C (UART)
Stacking Interface	Modular physical and electrical expansion connector
Battery Stack	7.4 V, 500 mAh LiPo + BMS + external charging port + power switches
Motor Driver Stack	4-channel encoder DC motor driver + 4 Grove motor ports
Stackable Modules	30+ expansion modules — wireless, motion, industrial, networking, display
Sensor Expander	Multi-port Grove expander for simultaneous sensor connections
Compatible Sensors	95+ sensors and units — full ecosystem catalogue
Line Follower Sensors	5-way I2C grayscale + 6-way I2C grayscale
RGB Ultrasonic	I2C ultrasonic distance + programmable RGB LED combined unit
Programming Languages	Scratch (block), Python, Arduino (C++), MicroPython
Platforms Supported	MCLab, Arduino IDE, VS Code + PlatformIO, MATLAB & Simulink, ROS 2
Arduino Library	M5Core2 — Maker and Coder Global
Connection Methods	Wi-Fi, Bluetooth, USB
Target Age	7 years and above
Education Levels	Primary, Secondary, Higher Education, Professional, Research

11. Summary

The MC 4.0 Controller from Maker and Coder Global is far more than a microcontroller — it is a complete, end-to-end hardware and software ecosystem built for the full spectrum of learning and making. From its high-performance ESP32 dual-core processor and fully customisable 320×240 touchscreen GUI, to its rich built-in sensor and audio hardware, 30+ stackable expansion modules, and 95+ compatible Grove sensors, every aspect of the MC 4.0 has been designed to remove barriers between an idea and a working system.

The modular stacking architecture means capabilities are added instantly — snap on a battery stack for portability, a motor driver stack for robotics, a LoRaWAN module for long-range IoT, or a cellular module for global connectivity. The sensor expander module ensures that complex multi-sensor projects are never limited by port count. The dedicated I2C 5-way and 6-way grayscale line follower sensors and RGB Ultrasonic I2C sensor bring competition-ready performance to robotics projects without complex wiring.

The MC 4.0's programming platform support is unmatched in its class — MCLab for Scratch and Python, Arduino IDE with C++, Visual Studio Code with PlatformIO, MATLAB and Simulink for engineering control design, and ROS 2 for professional robotics research. This means the MC 4.0 is genuinely appropriate for a 7-year-old's first LED project, a secondary school competition robot, a university mechatronics lab, and a professional IoT product prototype — all on identical hardware.

For STEM and STEAM educators, the MC 4.0 delivers a single, coherent platform that covers every domain and every curriculum level. For competition teams, it is a proven, feature-complete robotics controller. For engineers and researchers, it is a rapid prototyping platform with the wireless, industrial, and precision motion capabilities that real projects demand. The MC 4.0 Controller is the definitive all-in-one platform for anyone who builds with technology.