Microfire LLC Mod-pH Datasheet

Release Information

Release History

Release	Date	Description
2.0.0	3/24/2023	Updates for version 2 of hardware.
1.1.0	8/13/2021	Added additional reflow procedures.
1.0.0	4/23/2021	Initial

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About the Mod-pH Module

A module for interfacing with pH probes. It has been designed to be flexible and simple to incorporate into new or existing electrical designs.

- pH range of 0.001 to 14.000 pH units
  - Accuracy ±0.005 pH units
  - Resolution 0.001 pH units
  - Temperature compensated
- I^2C with software definable address
  - Default address 0x0B
  - 10kHz, 100 kHz, 400 kHz, 1 MHz compatible
- 25 mm wide x 15 mm high x 0.8mm thick
  - Material type: FR-4 TG155
  - DIP and castellated edges
- Calibration options include:
  - Single point
  - Dual point
  - Triple point

Mechanical Specification

The Mod-pH module is a single-sided 25x15 mm 0.8 mm thick PCB with dual castellated/through-hole pins around the east and west edges. It is designed to be usable as a surface mount module as well as in Dual Inline Package (DIP) type format, with the 12 pins on a 2.54mm pitch grid with 0.9mm holes.

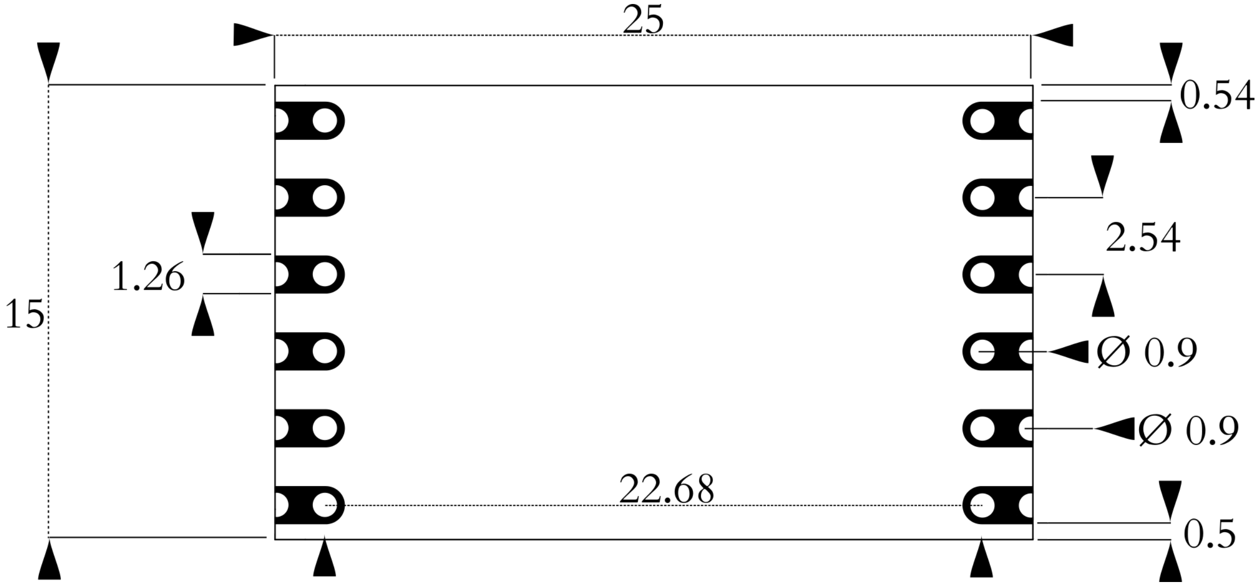


Figure 1. Physical dimensions of the module.

Pinout

The pinout of the module has been designed to provide as many interface options as possible.

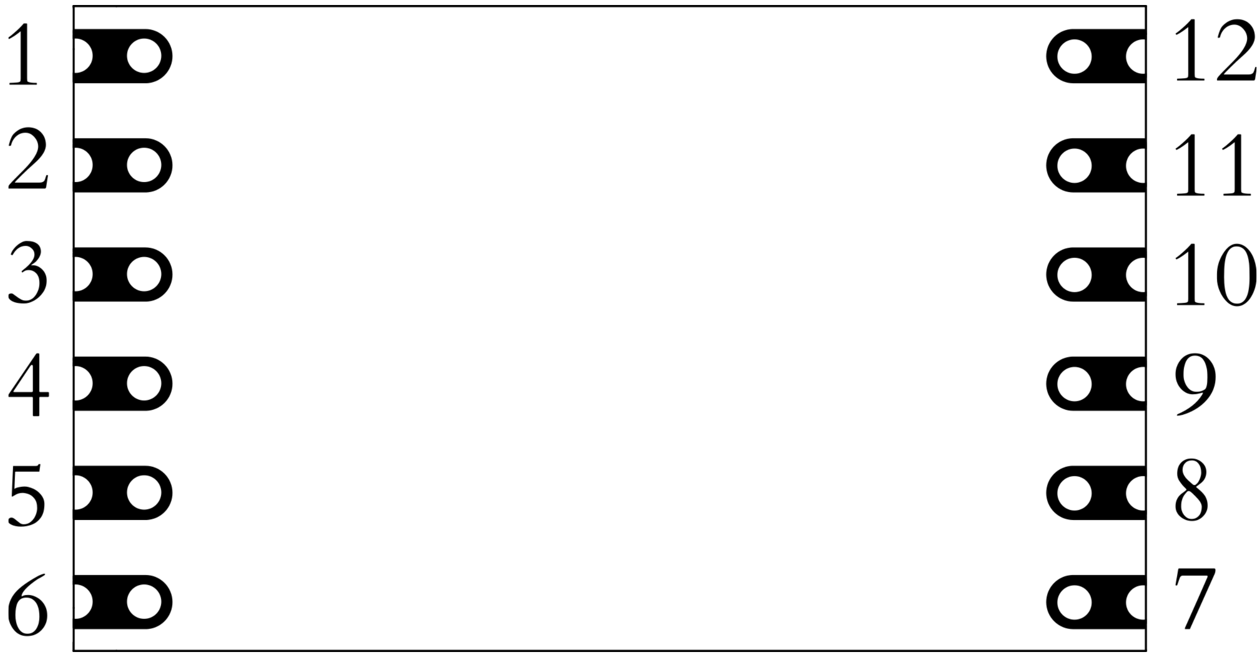
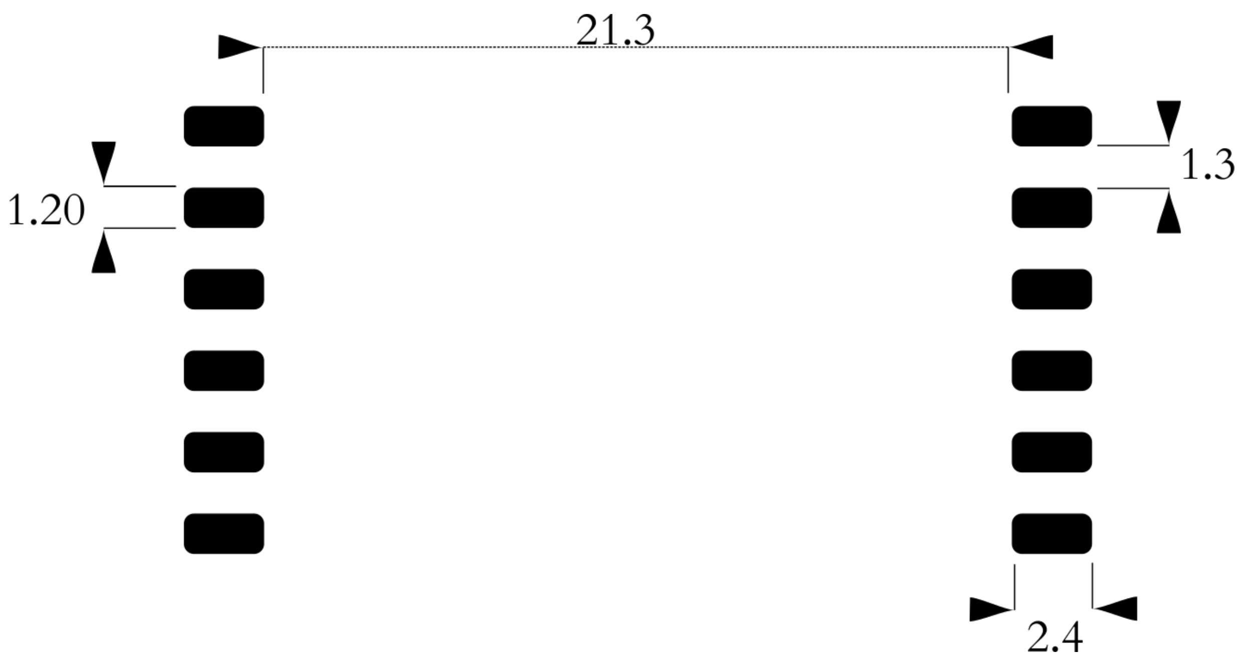


Figure 2. Pinout of the module.

Pin 1: Probe 1 input. Provides a connection to the sensing electrode of a pH probe.
Pin 2: Probe 2 input. Provides a connection to the reference electrode of a pH probe.
Pin 3: Not used in this module.
Pin 4: Not used in this module.
Pin 5: Not used in this module.
Pin 6: Not used in this module.
Pin 7: Not used in this module.
Pin 8: Not used in this module.
Pin 9: I^2C SCL. Clock line for I2C interface.
Pin 10: I^2C SDA. Data line for I2C interface.
Pin 11: VIN. 3.3-volt power supply.
Pin 12: Ground. Ground for the module.

Surface Mounting

The following figure shows the recommended footprint for mounting the module through reflow processes. It provides for a Class 1 connection (*IPC-A-610G § 8.3.4 Castellated Terminations*).



It is recommended that the stencil be 8 mils in thickness to ensure enough solder paste can flow into the castellations.

The module is assembled with Chip Quik SMD291SNL50T3 (Sn96.5/Ag3.0/Cu0.5) solder paste, a lead-free paste with a 249-degree Celsius peak reflow temperature. Reflowing the module multiple times can cause malfunction, to avoid the issue, if it is possible, use a lower melting-point temperature solder paste.

Operating Conditions

Temperature:

- **Absolute:**
  - **Maximum:** 85 C
  - **Minimum:** -40 C
- **Recommended:**
  - **Maximum:** 50 C
  - **Minimum:** 10 C

When approaching the absolute temperature ratings, it should be noted that the module's temperature will begin to affect measurements, the extent of which will need to be characterized to the specific environment the module will be deployed in.

Voltage:

- **Absolute Maximum:** 5.5 volts
- **Absolute Minimum:** 1.8 volts (3.3 volts is required for proper operation)

Electrical Specification

Power Supply

The module requires 3.3 volts for proper operation. It can be supplied with less and still communicate through the various peripheral interfaces, but this will not allow the analog circuitry to operate properly. Voltage should not exceed 5.5 volts.

There is no reverse polarity protection on the module.

Power Isolation

Due to the nature of electrochemical sensors, galvanic isolation between the probe from other parts of the circuit is needed to eliminate or reduce interference from external sources. The simplest way to achieve this is to use an isolated power supply and isolated peripheral coupler device. For example, if using I^2C, a device to supply isolated power, ground, SDA, and SCL lines will provide sufficient isolation.

Power Consumption

All modules are designed to be low-power. Power usage has been characterized at two points, idle and active sensor measurement.

- Current use is typically 0.15 mA

I²C Interface

The module supports speeds of 10kHz, 100 kHz, 400 kHz, and 1 MHz at 3.3 volts.

The I²C interface uses the following pins:

- **Pin 9 SCL**: serial clock
- **Pin 10 SDA**: data

Additional Circuitry

The module has no pullup resistors on the I²C bus. For reliable communication, appropriate resistors must be chosen for the SDA and SCL lines.

I²C Address

The default address is 0x0B by default. It can be changed through firmware.

I²C Write

Writing is done by sending a start condition followed by the module's address with the write bit set. The master device then sends data 8 bytes at a time. The first byte received is considered to be the register address. Successive writes will automatically increment the register address by one byte. Transmission is finished with a stop condition.

I²C Read

Reading is done by sending a start condition followed by the module's address with the read bit set. The master sets the register to read from, then requests data. The device then sends the appropriate number of bytes as determined by the register being read.

Design Incorporation

Adding the module is a straightforward process.

Power

A suitable power supply must be supplied. Ideal solutions will provide an isolated, low-ripple, low-EMI, 3.3-volt supply.

Ground

The module operates at the same ground potential as what **Pin 11**: Ground is connected to, so a low-impedance connection is needed.

Probe Connection

A pH probe that is compatible with the module consists of two wires. This is most commonly provided with a BNC, SMA, or U.FL connector.

Considerations

- **Pin 1**: Probe 1 input and **Pin 2**: Probe 2 input pins should be on their own island plane pour or otherwise isolated by no pour surrounding them.
- **Pin 1**: Probe 1 input and **Pin 2**: Probe 2 input pins should be as short as possible.
- If the PCB is 4 or more layers, consider routing **Pin 1 and Pin 2** traces on internal layers to protect the probe input signal from interference.
- Avoid routing other traces near **Pin 1** and **Pin 2**.
- Flux residue on **Pin 1, Pin 2,** and at the probe connection must be removed. This is ideally accomplished by using a “no-clean” solder paste and/or through mechanical means such as an ultrasonic bath.

Unused Pins

Any unused pins should be left unconnected to any other trace or net.

pH Measurements

pH Theory

A basic definition of pH is the inverse logarithm of the concentration of hydrogen ions in a solution.

One way hydrogen ions can be introduced is by the dissociation of water molecules. This process is called autoionization. In pure water, the concentration of hydrogen ions produced by dissociation is 1×10^{-7} M (moles per liter of water) which equals a pH of 7. A change in hydrogen ions can also be caused by introducing a substance to the water. If the substance increases hydrogen ions, it is considered an acid. If it decreases hydrogen ions, it is a base.

Hydrogen ion concentration is measured in pH units. Being logarithmic, a pH 5 liquid is 10 times more acidic than a liquid at pH 6.

As an aside, what pH stands for is debatable. Søren Peter Lauritz Sørensen, who first described and wrote about it, never explained where the `p` that he wrote came from. Others have assumed that it might be `power` or `potential` of Hydrogen, but this isn't reflected in any of Sørensen's work.

Considerations

Measuring pH is relatively straightforward, but it is important to keep some things in mind.

Response Time

pH probes are electrochemical devices. They don't react instantly as a purely electrical device would. The probes need some time to reach an equilibrium. This is especially true when calibrating since it moves the probe through a very wide range of values. To reach a stable measurement when moving from 4.0 pH to 7.0 pH or 7.0 pH to 10.0 pH, it may take several minutes.

Interference

A pH probe outputs a very weak signal in the millivolt range; the entire range is approximately -400 to 400 milli-Volts. This signal is then carried through the wire of the probe, where it is measured. This leaves a lot of opportunities for the signal to experience interference. Other probes, faulty electrical equipment, poor grounding, strong sources of EMI, and any number of other sources may contribute to a faulty reading. Isolation can help with some sources, but not all of them.

Temperature

The temperature of a solution affects the pH. For example, a solution at 25°C may measure 6.5 pH, and the same solution at 20°C may be 6.45 pH. Part of the difference is the actual change in pH of the solution and not an error. A much smaller part of the change is due to a change in the resistance of the probe and is accounted for with a temperature compensation formula.

The module uses several points of data for taking measurements and calibration. With all the points together, it applies a temperature compensation formula that adjusts the measured value to a compensated value. It is good practice to notate in some way that pH measurements have been temperature compensated for comparisons to other measurements. It is important to note that pH measurements from other devices may use different compensation formulas or no formula at all.

Calibration

Calibration is needed to obtain accurate measurements. Each module is very slightly different from the next, and each pH probe will have a slightly different response from another. For these reasons, neither modules nor probes are interchangeable without both being calibrated together. Also, pH probes gradually degrade, requiring recalibration to maintain accuracy.

Procedure

Following good lab procedures is important to obtain the best results while also staying safe. pH measurements typically involve calibration solutions which are generally all toxic or hazardous to some extent. Aside from safety considerations, the following is a step-by-step process calibration:

1. Collect all the materials needed: calibration solutions, clean water, towels, equipment, etc.
2. Rinse the probe in clean water. RO/DI, deionized, or distilled water is best. Tap off excess water drops trapped in the probe tip and blot dry.
3. Pour some calibration solution into a separate container. It should be enough to fully submerge the tip of the probe, then submerge the probe.
4. Continually take measurements, watching for the measurement to stabilize. Eventually, only the third decimal place will vary from measurement to measurement. When the reading stabilizes, have the module calibrate itself for the solution.
5. Safely dispose of the calibration solution and clean or dispose of the container.
6. Repeat steps 2 through 5 for each calibration point.

It is important to note that pH solutions change slightly with temperature. The internal calculations in the module account for this when given the solution's temperature. When calibrating, use the labeled pH value, not the temperature-adjusted value.

Calibration Types

The module supports three methods of calibration.

Single Point

Single point is the least useful and should generally not be used. It uses one point and is only accurate for a small range around that one point.

If this method is used, it should not be used at 7.0 pH. The reason is the pH scale is not a straight linear line all the way through the entire range. It is generally linear through 4.0 to 7.0 pH and separately linear through 7.0 to 10.0 pH. The differing slopes will skew readings near the 7.0 pH point.

Dual Point

Dual point calibration is used for measuring between two set points. For pH measurements, the two points are typically 10. pH to 7.0 pH, or 7.0 pH to 4.0 pH. This type of calibration will provide accurate measurements between the two points and less accurate results outside of the points.

Triple Point

With three points of calibration at 4.0, 7.0, and 10.0, nearly the entire pH range can be accurately measured. Towards the extremes of the pH scale, there is significant non-linearity, and they must be calibrated more closely to the expected range (10.0 to 14.0, for example).

Precedence

The module will select the best calibration type from the available calibrated points as follows:

1. If there are high, mid, and low points, it will use triple-point calibration to calculate the result.
2. If there are high and low points, it will use dual-point calibration to calculate the result.
3. If there is a single-point calibration data, it will use single-point calibration to calculate the results.
4. No calibration points used will result in an uncalibrated measurement.

I²C Interface

The module's I²C interface operates similarly to many common I²C sensors. Several registers hold values such as calibration, pH, temperature, or version information. The registers are used to pass information both to the module and the controlling device. Tasks are performed by writing a specified value to a certain register.

Registers

All registers are either 1 byte or a float which is 4 bytes formatted as an IEEE 754 32-bit floating point, little-endian. The firmware will allow the registers to be read and written.

Register Listing

Register Name	Value	Type	Description
HW_VERSION_REGISTER	0	byte	Hardware version
FW_VERSION_REGISTER	1	byte	Firmware version
TASK_REGISTER	2	byte	Task register
STATUS_REGISTER	3	byte	Status of measurement
PH_REGISTER	4	float	Measured pH
TEMP_C_REGISTER	8	float	Measured temperature in Celsius
MV_REGISTER	12	float	mV value from the probe
CALIBRATE_REFLOW_REGISTER	16	float	Reference-low calibration data
CALIBRATE_READLOW_REGISTER	20	float	Read-low calibration data
CALIBRATE_REFMID_REGISTER	24	float	Reference-mid calibration data
CALIBRATE_READMID_REGISTER	28	float	Read-mid calibration data
CALIBRATE_REFHIGH_REGISTER	32	float	Reference-high calibration data
CALIBRATE_READHIGH_REGISTER	36	float	Read-high calibration data
CALIBRATE_SINGLE_OFFSET_REGISTER	40	float	Single-offset calibration data

CALIBRATE_TEMPERATURE_REGISTER	44	float	Calibration temperature data

All the CALIBRATE_* registers are automatically saved when written.

Tasks

When a particular value is written to TASK_REGISTER, it starts an operation within the module.

For example, when MEASURE_PH_TASK is written to the TASK_REGISTER register, a pH measurement is performed. To read the resulting measurement, you would read the PH_REGISTER register.

Task Listing

Task Name	Duration	Value	Description
MEASURE_PH_TASK	750 ms	80	pH measurement
CALIBRATE_LOW_TASK	750 ms	20	Low-point calibration
CALIBRATE_MID_TASK	750 ms	10	Mid-point calibration
CALIBRATE_HIGH_TASK	750 ms	8	High-point calibration
CALIBRATE_SINGLE_TASK	750 ms	4	Single-point calibration
I2C_TASK	1 ms	2	I²C address change

MEASURE_PH_TASK - pH Measurement

Starts a pH measurement.

Request Registers

Register	Description
TEMP_C_REGISTER	The solution-under-test's temperature in Celsius. If the temperature is unknown, pass 25.0

Response Registers

Register	Description
PH_REGISTER	Value of pH measurement
STATUS_REGISTER	An error code for the measurement. Can be one of the following: **0**: no error **1**: outside lower range **2**: outside upper range **3**: system error

CALIBRATE_LOW_TASK - Low Point Calibration

Performs a low-point calibration.

Note: When passing the calibration solution's value, use the temperature-compensated value.

Required Registers

Register	Description
PH_REGISTER	The pH of the calibration solution.
TEMP_C_REGISTER	The calibration solution's temperature in Celsius. If the temperature is unknown, pass 25.0

Response Registers

Register	Description
CALIBRATE_REFLOW_REGISTER	Reference-low calibration data
CALIBRATE_READLOW_REGISTER	Read-low calibration data
STATUS_REGISTER	An error code for the measurement. Can be one of the following: **0**: no error **1**: outside lower range **2**: outside upper range **3**: system error

CALIBRATE_MID_TASK - Middle Point Calibration

Performs a mid-point calibration.

Note: When passing the calibration solution's value, use the temperature-compensated value.

Required Registers

Register	Description
PH_REGISTER	The pH of the calibration solution.
TEMP_C_REGISTER	The calibration solution's temperature in Celsius. If the temperature is unknown, pass 25.0

Response Registers

Register	Description
CALIBRATE_REFMID_REGISTER	Reference-mid calibration data
CALIBRATE_READMID_REGISTER	Read-mid calibration data
STATUS_REGISTER	An error code for the measurement. Can be one of the following: **0:** no error **1:** outside lower range **2:** outside upper range **3:** system error

CALIBRATE_HIGH_TASK - Middle Point Calibration

Performs a high-point calibration.

Note: When passing the calibration solution's value, use the temperature-compensated value.

Required Registers

Register	Description
PH_REGISTER	The pH of the calibration solution.
TEMP_C_REGISTER	The calibration solution's temperature in Celsius. If the temperature is unknown, pass 25.0

Response Registers

Register	Description
CALIBRATE_REFHIGH_REGISTER	Reference-high calibration data
CALIBRATE_READHIGH_REGISTER	Read-high calibration data
STATUS_REGISTER	An error code for the measurement. Can be one of the following: **0**: no error **1**: outside lower range **2**: outside upper range **3**: system error

CALIBRATE_SINGLE_TASK - Single Point Calibration

Performs a single-point calibration.

Note: When passing the calibration solution's value, use the temperature-compensated value.

Required Registers

Register	Description
PH_REGISTER	The pH of the calibration solution.
TEMP_C_REGISTER	The calibration solution's temperature in Celsius. If the temperature is unknown, pass 25.0

Response Registers

Register	Description
CALIBRATE_SINGLE_OFFSET_REGISTER	Single-offset calibration data
STATUS_REGISTER	An error code for the measurement. Can be one of the following: **0:** no error **1:** outside lower range **2:** outside upper range **3:** system error

I2C_TASK – I²C address change

Changes the device's I²C address.

Required Registers

Register	Description
PH_REGISTER	Used to store the new I²C address temporarily.

Response Registers

Register	Description
None	

Microfire LLC

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Modules

Mod-EC
Mod-pH
Mod-ORP
Mod-ISO
Mod-NTC

Development Boards

Isolated Dev Board
Mod-EVAL
Mod-EVAL_ISO

Probes

Industrial pH Probe
Industrial EC Probe
Industrial ORP Probe
Lab pH Probe
Lab EC Probe
Lab ORP Probe

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