Microfire LLC Mod-ORP Datasheet

Release Information

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Release History

Release	Date	Description
1.1.0	8/13/2021	Added additional reflow procedures.
1.0.0	4/23/1021	Initial

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Justin Decker

About the Mod-ORP Module

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

- ORP range of -2.2 to 2.2 volts
  - Accuracy ±0.001 mV
  - Resolution 0.001 mV
- Multiple hardware interfaces operating at 3.3 volts
  - I²C with software definable address
    - Default address 0x0E
    - 10kHz, 100 kHz, 400 kHz, 1 MHz and 3.4 MHz compatible
  - UART
    - NMEA formatted output
  - USB Serial
    - Same as UART
  - 1-Wire interface for DS18B20 temperature sensor
- 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

Mechanical Specification

The Mod-ORP 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 Dual Inline Package (DIP) type format, with the 12 pins on a 2.54mm pitch grid with 0.8mm holes.

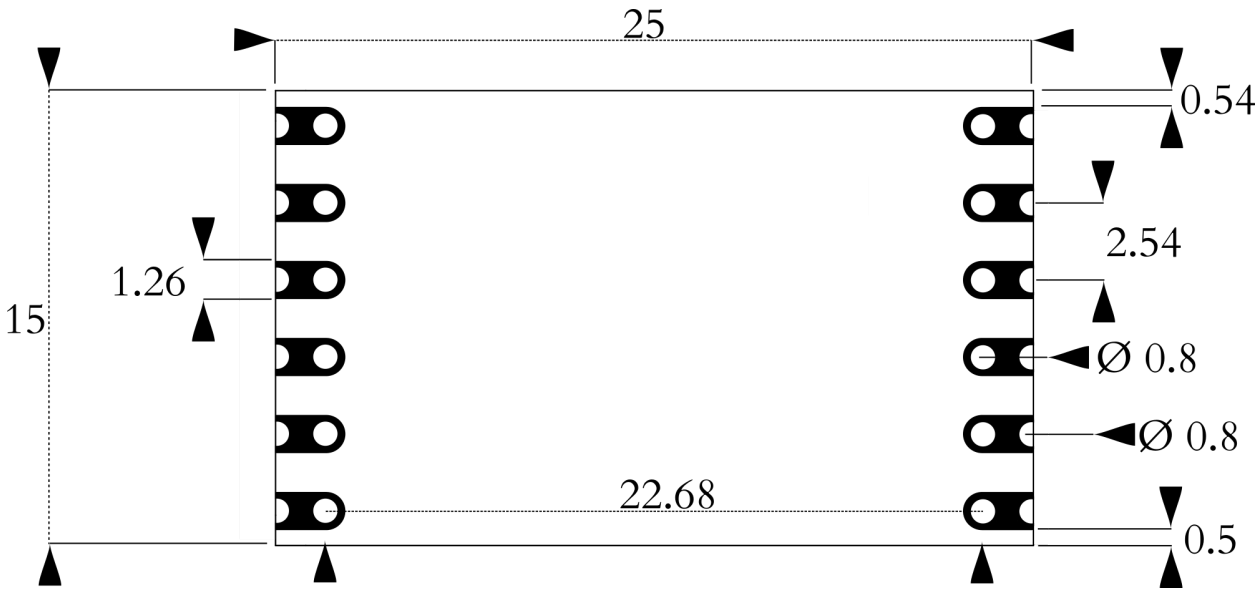


Figure 1. Physical dimensions of the module.

Pinout

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

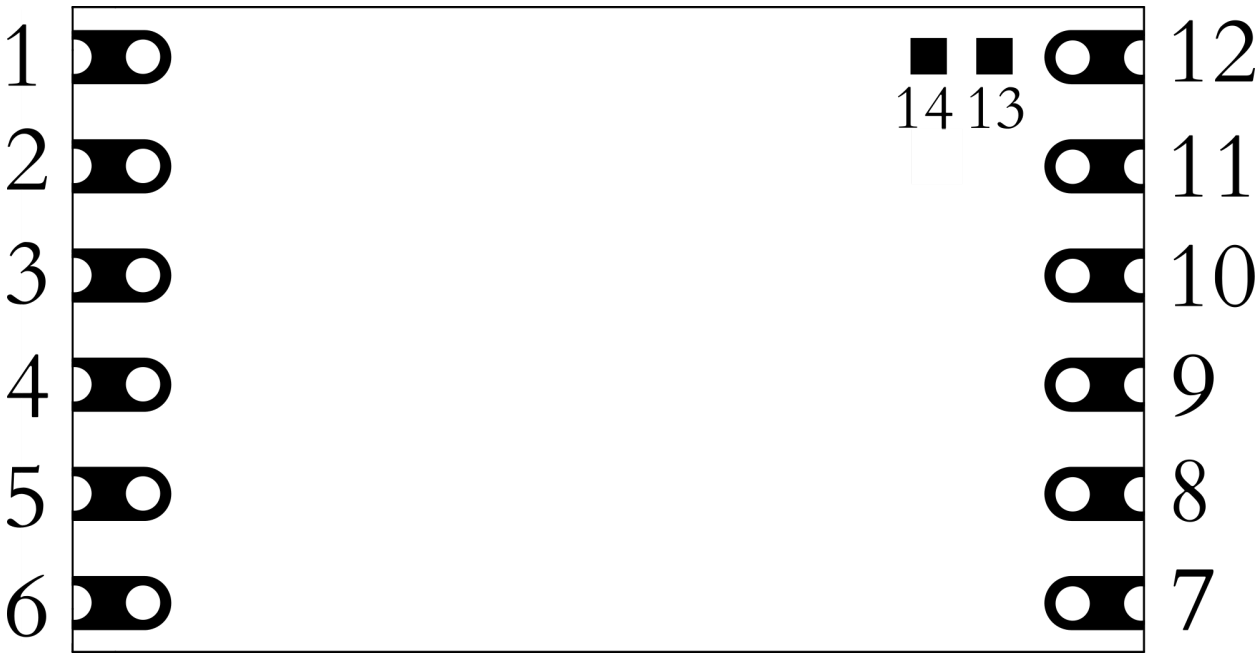
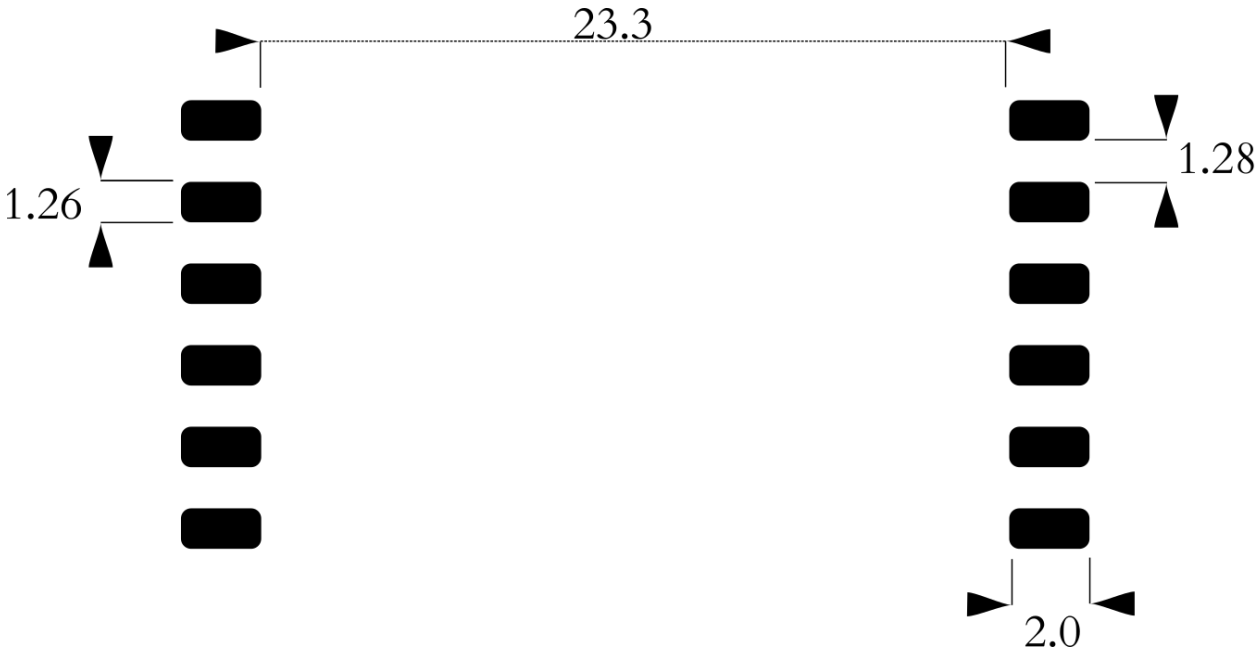


Figure 2. Pinout of the module.

Pin 1: Probe 1 input. Provides a connection to the sensing electrode of an ORP probe.
Pin 2: Probe 2 input. Provides a connection to the reference electrode of an ORP probe.
Pin 3: Probe 3 input. Not used in this module.
Pin 4: 1-Wire. Provides 1-Wire DS18B20 interface.
Pin 5: USB Data-. Differential data line -.
Pin 6: USB Data+. Differential data line +.
Pin 7: UART TX. transmit line for UART serial interface.
Pin 8: UART RX. receive line for UART serial interface.
Pin 9: I²C SCL. Clock line for I2C interface.
Pin 10: I²C SDA. Data line for I2C interface.
Pin 11: VIN. 3.3 volt power supply.
Pin 12: Ground. Ground for module.
Pin 13: SWD. Serial Wire Data pin. *Used to program the MCU.*
Pin 14: SWC. Serial Wire Clock pin. *Used to program the MCU.*

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 mil 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 to 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:

- **Absolue Maximum**: 3.63 volts
- **Absolute Minimum**: 1.62 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 properly operate. Voltage should not exceed 3.63 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 I²C, 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

Hardware Interfaces

The module provides I2C, UART, USB serial, and a limited-use 1-Wire interface. All interfaces are simultaneously available.

I²C

The module supports speeds of 10kHz, 100 kHz, 400 kHz, 1 MHz and 3.4 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 0x0E 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.

UART

The UART interface uses:

- **Baud**: 9600
- **Data bits**: 8
- **Parity**: None
- **Stop bits**: 1
- **Voltage**: 3.3 volt only

These parameters are not configurable.

The UART interface uses the following pins:

- **Pin 8 RX**: receive in
- **Pin 7 TX**: transmit out

Additional Circuitry

No additional components are required for operation.

USB Serial

- Compatible with the USB 2.1 specification
- Supports full (12Mbit/s) and low (1.5Mbit/s) speed communication

The USB interface uses the following pins:

- **Pin 5 D-**: differential pair -
- **Pin 6 D+**: differential pair +

VID/PID

The module can be identified with the following information:

- **VID**: 0x04D8
- **PID**: 0xE920

Additional Circuitry

If the module is to be powered through USB, the voltage must be converted from 5 volts to 3.3 volts. USB D- and D+ must be routed as a differential pair.

An example of a working combination of USB connector and power regulator would be:

Molex Micro USB Connector - 47346-0001
Analog Devices ADP150 - ADP150AUJZ-3.3-R7

1-Wire

The module provides a 1-Wire interface to connect a DS18B20 temperature sensor. The interface is limited to just the DS18B20 device.

The 1-Wire interface uses the following pin:

- **Pin 4 1-Wire**: 1-Wire

Additional Circuitry

The Pin 4 1-Wire line requires a pullup resistor for reliable communication. The resistance needed is determined, in part, by the length of the cable. For a 1 to 3 meter cable, a 4.7 kOhm resistor will work.

The DS18B20 can be operated using power, ground and 1-Wire connections, or in parasitic power mode.

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.

Communication

I²C, UART or USB all have particular hardware requirements that must be planned or provided for. Refer to their Hardware Interface sections for more details. (I²C Additional Circuitry, UART Additional Circuitry and USB Additional Circuitry). It is best to choose one communication method; having the UART connected but using I²C, for example, will introduce unneeded noise to the system.

1-Wire Temperature Sensor

This connection is optional. If it is not used, **Pin 4**: 1-Wire can be left unconnected. A connector and pullup resistor are needed to connect a DS18B20 temperature sensor. Refer to the Hardware Interface section for more details.

Probe Connection

An ORP probe that is compatible with the module consists of two wires. This is most commonly provided for with a BNC, SMA, or U.FL connector. While plain wires and pin terminations can be used, they may not perform as well as a properly insulated connection would.

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.

ORP Measurements

ORP Theory

Oxidation-Reduction Potential of a solution's electron transfer capability. A solution that is strongly reductive is weakly reductive and vice versa. The exact process varies by the specific chemical reaction that takes place, one species will undergo oxidation, losing electrons, while another species accepts those electrons and is reduced.

Because ORP doesn't measure a specific substance, rather it is a measure of activity, the unit of measure is simply the millivolt output of the ORP probe. The probe consists of an electrode made of platinum and a reference electrode. An electrical potential develops between the two electrodes in response to the solution it is immersed in.

The platinum will either donate or accept electrons, which will be indicated by the millivolt response. Tap water is typically around 300 mV and green tea, an antioxidant, is around -100 mV. A swimming pool may be around 600 mV.

It should be noted that pH and ORP are different measurements. However, in many reactions, a low or high pH may create conditions that change the ORP. In solutions where ORP and pH are dependent, the reference electrode of the ORP probe can be replaced with the sensing electrode of a pH probe. This is known as rH or pH compensated ORP.

Considerations

Measuring ORP can be complicated due to potentially complex chemical reactions, so it is important to keep some things in mind.

Response Time

ORP probes are electro-chemical devices. They don't react instantly like a purely electrical device would. The probes need some time to stabilize. Depending on the reaction taking place, this may be quick, on the order of seconds, or slow, on the order of hours.

Interference

An ORP probe outputs a weak signal in the millivolt range. 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 ORP reading. Due to ORP not being a measure of a specific substance, there is no temperature compensation.

Calibration

Calibration is needed to obtain accurate measurements. Each module is very slightly different from the next and each probe will have a slightly different response from another. For these reasons, neither modules or probes are interchangeable without both being calibrated together. Also, ORP probes gradually degrade, requiring recalibration to maintain accuracy.

Procedure

Following good lab procedures is important to obtain the best results while also staying safe. ORP 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, deionised, 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.

It is important to note that ORP solutions change slightly with temperature. The solution may provide temperature-compensated values, in this case the solution should be brought to one of those temperatures and that value used.

Calibration

Single Point

ORP is calibrated using a single point.

NMEA Interface

The NMEA interface provides a human-readable text interface for interacting with the device. It is also easily machine parsed for automating tasks. All functions and data can be accessed through this interface.

NMEA Physical Connection

The NMEA interface can be accessed by connecting to the UART interface using:

- **Baud**: 9600
- **Data bits**: 8
- **Parity**: None
- **Stop bits**: 1

It is also available on the USB serial output.
Note: *Output is sent to both UART and USB Serial interfaces, regardless of which interface the command was received from.*

Once connected, the module will wait for input with a maximum of 10 ms between characters. If characters are spaced more than 10 ms apart, the module will emit a parser error and the command will not be accepted.

NMEA Sentence Structure

The modules comply with the original NMEA standard closely. A sentence consists of the following elements:

ELEMENT	DESCRIPTION
$	Always begins a sentence
TYPE	Sentence type
,	Delimiter
ARGUMENT	Arguments of any type. Spaces are allowed
,	*Delimiter if another argument follows*
*****	Sentence end

00	A two digit checksum, represented in hexadecimal format.

Some examples of valid sentences;
$OMEA,21.663,0*28
$ECMEA,22.1,0.019,25.0,1.0*40

Invalid sentences:
PHMEA,25.0,0*78 - No starting **$**
$ECMEA 22.1,0.019,25.0,1.0*40 - Space between type and arguments

NMEA Checksum

By default, the module will accept invalid checksums. Rather than passing an NMEA sentence with the correct checksum, a 00 can be sent (*$TYPE**00). This behavior can be changed with OCRC, turning checking on or off. This setting is not saved through a power reset cycle.

The checksum is calculated for all characters between, and not including, the starting **$** and just before the ending *. It is calculated by XORing each character with the next.

An example function in C/C++:

```
int nmea_checksum(const char *s){
  int c = 0;
  while (*s)
  {
    c ^= *s++;
  }
  return c;
}
```

Source: Wikipedia

$OMEA - ORP Measurement

Starts an ORP measurement. It takes 750 ms to complete a measurement.

Request Parameters

Parameter	Description
None	

Response Parameters

Parameter	Description
mV	The solution-under-test's mV. Formatted as a floating point number with up to 3 decimal places. Represents the raw, unmodified mV value from the attached probe.
STATUS	An error code for the measurement. Can be one of the following: **0**: no error **1**: system error

Example Requests

$OMEA*06 - an ORP measurement.

Example Responses

$OMEA,14.468,0*27 - ORP value measured as 14.468 mV without error

$OERR - Parser Error

Unsolicited response to an NMEA parse error.

Response Parameters

Parameter	Description
ERROR	NMEA parse error. Can be one of the following: **1**: Unexpected character encountered **2**: Sentence buffer full **3**: Sentence type longer than 5 **4**: CRC error **5**: System error

Example Responses

$OERR,1*17 - An unexpected character was encountered.

$OCRC - CRC Error Checking

Turns NMEA sentence CRC checking on or off and retrieves the current status.

Request Parameters

Parameter	Description
0	Turns CRC checking off
1	Turns CRC checking on

Response Parameters

Parameter	Description
CRC	Returns: **0**: if CRC checking is turned off **1**: CRC checking is on

Example Requests

$OCRC*1D - Gets the status of CRC checking.
$OCRC,0*01 - Turns CRC checking off.
$OCRC,1*00 - Turns CRC checking on.

Example Responses

$OCRC,1*00 - CRC checking is on.
$OCRC,0*01 - CRC checking off.

$OTEM - 1-Wire Temperature

Starts a temperature measurement with the optionally attached DS18B20 sensor. The module provides a basic interface to the sensor. It is initialized with 12-bit precision and is not changeable. It takes 750 ms to complete a measurement.

Request Parameters

Parameter	Description
None	

Response Parameters

Parameter	Description
TEMP_C	Temperature in Celsius. Formatted as a floating point number with 3 decimal places.
TEMP_F	Temperature in Fahrenheit. Formatted as a floating point number with 3 decimal places.
STATUS	An error code for the measurement. Can be one of the following: **0**: No error **3**: System error

Example Requests

$OTEM*13 - Starts a temperature measurement.

Example Responses

$OTEM,25.688,78.238,0*08 - A temperature response without errors.
$OTEM,-127,-127,3*0C - A temperature response with no sensor connected.

$OINF - ORP Calibration Information

Requests or sets ORP calibration and other system information. To get information, the sentence can be called without parameters.

To set any parameter, either an actual value, or a default value of **-9999** can be used. If **-9999** is passed, the parameter is ignored. All parameters must be filled with an actual value or **-9999**.

To set the default value, pass `**nan**`. Internally, the module distinguishes between calibration data, which can be a large range of numbers, by using a *Not A Number* placeholder.

Request Parameters

Parameter	Description
SINGLE_POINT_OFFSET	Single point calibration data.
I2C_ADDRESS	The I²C address of the module. The default value for this is 0x0E (14 decimal).

Response Parameters

Parameter	Description
SINGLE_POINT_OFFSET	The calibration data of the single-point calibration.
I2C_ADDRESS	The I²C address of the module. The default value for this is 0x0E (14 decimal).
HARDWARE_VESION	The hardware version of the module.
FIRMWARE_VERSION	The firmware version on the module.

Example Requests

$OINF*0E - Retrieves ORP calibration and system information.
$OINF,25.0,-9999*3A - Sets low read and reference data only.
$OINF,nan,14*6A - Resets all values to system default.

Example Responses

$OINF,25.000,14,1,1*12 - Full listing of calibration and system information.

$OSIN - Single Point Calibration

Performs a single-point calibration. It takes 750 ms to complete a measurement.

Request Parameters

Parameter	Description
CALIBRATION_MV	The mV of the calibration solution.

Response Parameters

Parameter	Description
SINGLE_POINT_OFFSET	The calibration data of the single-point calibration.
STATUS	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

Example Requests

$OSIN,600.0*1F - performs single-point calibration at 600.0 mV.

Example Responses

$OSIN,-375.029,0*22 - the result of the calibration with no errors.

I²C Interface

The module's I²C interface operates similarly to many common I²C sensors. There are several registers which hold values such as calibration, ORP and 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	To initiate tasks
FW_VERSION_REGISTER	1	byte	Hardware version
TASK_REGISTER	2	byte	Firmware version
STATUS_REGISTER	3	byte	Status of measurement
MV_REGISTER	4	float	Measured mV
TEMP_C_REGISTER	8	float	Measured temperature in Celsius
CALIBRATE_SINGLE_OFFSET_REGISTER	12	float	Single-offset calibration 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_ORP_TASK is written to the TASK_REGISTER register, an ORP measurement is performed. To read the resulting measurement, you would read the MV_REGISTER register.

Task Listing

Task Name	Duration	Value	Description
MEASURE_ORP_TASK	800 ms	80	ORP measurement
MEASURE_TEMP_TASK	800 ms	40	Temperature measurement
CALIBRATE_SINGLE_TASK	800 ms	4	Single-point calibration
I2C_TASK	1 ms	2	I²C address change

MEASURE_ORP_TASK - ORP Measurement

Starts an ORP measurement.

Request Registers

Register	Description
None	

Response Registers

Register	Description
MV_REGISTER	Value of ORP measurement
STATUS_REGISTER	An error code for the measurement. Can be one of the following: **0**: no error **1**: system error

MEASURE_TEMP_TASK - 1-Wire Temperature

Starts a temperature measurement with the optionally attached DS18B20 sensor. The module provides a basic interface to the sensor. It is initialized with 12-bit precision and is not changeable. It takes 750 ms to complete a measurement.

Required Registers

Register	Description
None	

Response Registers

Register	Description
TEMP_C_REGISTER	Value of temperature measurement
STATUS_REGISTER	An error code for the measurement. Can be one of the following: **0**: no error **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
orp_REGISTER	The ORP 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
MV_REGISTER	Used to temporarily store the new I²C address.

Response Registers

Register	Description
None	

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Certificate of Compliance

RoHS 3 Directive 2015/863/EU

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Modules
Mod-EC
Mod-pH
Mod-ORP
Mod-ISO_I2C_UART
Mod-Temp

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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