

Modbus on Sunrise SE-11

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1. Modbus

Modbus is a simple, open protocol for both PLC and sensors[1][2]. Details on Modbus can be found in the website www.modbus.org.

1.1. Modbus settings

Senseair Sunrise supports 9600 baud rate only.

Other Modbus settings are as follows:

Slave address: 104 (default)

Baud rate: 9600 bps

Parity: NONE

DataBits: 8

StopBits: 1

1.2. Modbus registers on sensor

The Modbus registers are mapped in memory, mapping is interpreted by the sensor at command reception.

Maps of registers (all registers are 16-bit words) are summarised in Table 1 and Table 2. Associated number is Modbus register number, register address is calculated as (register number - 1)

Table 1 : Input Registers

| IR# | Addr. | Name | Description (read only registers) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----|----------|----------------------------|--|---|--|------------------|---|--------------------|---|---|--|--|---|---|---|---|---|---|---|-------------------------------|---|---|---|---|---|---|---|---|--|--|---|----------|--|---|----------|--|----|----------|--|----|----------|--|----|----------|--|----|----------|--|----|----------|--|----|----------|--|
| IR1 | 0x00 | ErrorStatus0 | <table border="1"> <thead> <tr> <th>Bit</th> <th>Error description</th> <th>Suggested action</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>Fatal error</td> <td>Try to restart sensor by power on/off. Contact local distributor.</td> </tr> <tr> <td>1</td> <td>I2C communication error I2C error.</td> <td>Try to restart sensor by power on/off. Check wires, connectors and I2C protocol implementation. Contact local distributor.</td> </tr> <tr> <td>2</td> <td>Internal I2C operation error Indicates instable communication on sensors local I2C bus.</td> <td>Try to restart sensor by power on/off. Contact local distributor.</td> </tr> <tr> <td>3</td> <td>Calibration error Indicate that calibration failed (ABC, zero, background or target calibration).</td> <td>Try to repeat calibration, ensure environment is stable during calibration.</td> </tr> <tr> <td>4</td> <td>Self diagnostics error</td> <td>Try to restart sensor by power on/off. Contact local distributor.</td> </tr> <tr> <td>5</td> <td>Out of range Indicate that measured concentration is not within sensors measurement range</td> <td>Perform suitable CO₂ calibration (zero, background or target calibration). Contact local distributor.</td> </tr> <tr> <td>6</td> <td>Memory error Error during memory operations</td> <td>Try to restart sensor by power on/off. Contact local distributor.</td> </tr> <tr> <td>7</td> <td>External I2C error I2C error</td> <td>Try to restart sensor by power on/off. Check wires, connectors and I2C protocol implementation. (see TDE5531) Contact local distributor.</td> </tr> <tr> <td>8</td> <td>Reserved</td> <td></td> </tr> <tr> <td>9</td> <td>Reserved</td> <td></td> </tr> <tr> <td>10</td> <td>Reserved</td> <td></td> </tr> <tr> <td>11</td> <td>Reserved</td> <td></td> </tr> <tr> <td>12</td> <td>Reserved</td> <td></td> </tr> <tr> <td>13</td> <td>Reserved</td> <td></td> </tr> <tr> <td>14</td> <td>Reserved</td> <td></td> </tr> <tr> <td>15</td> <td>Reserved</td> <td></td> </tr> </tbody> </table> | Bit | Error description | Suggested action | 0 | Fatal error | Try to restart sensor by power on/off. Contact local distributor. | 1 | I2C communication error I2C error. | Try to restart sensor by power on/off. Check wires, connectors and I2C protocol implementation. Contact local distributor. | 2 | Internal I2C operation error Indicates instable communication on sensors local I2C bus. | Try to restart sensor by power on/off. Contact local distributor. | 3 | Calibration error Indicate that calibration failed (ABC, zero, background or target calibration). | Try to repeat calibration, ensure environment is stable during calibration. | 4 | Self diagnostics error | Try to restart sensor by power on/off. Contact local distributor. | 5 | Out of range Indicate that measured concentration is not within sensors measurement range | Perform suitable CO ₂ calibration (zero, background or target calibration). Contact local distributor. | 6 | Memory error Error during memory operations | Try to restart sensor by power on/off. Contact local distributor. | 7 | External I2C error I2C error | Try to restart sensor by power on/off. Check wires, connectors and I2C protocol implementation. (see TDE5531) Contact local distributor. | 8 | Reserved | | 9 | Reserved | | 10 | Reserved | | 11 | Reserved | | 12 | Reserved | | 13 | Reserved | | 14 | Reserved | | 15 | Reserved | |
| | | | Bit | Error description | Suggested action | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 0 | Fatal error | Try to restart sensor by power on/off. Contact local distributor. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1 | I2C communication error I2C error. | Try to restart sensor by power on/off. Check wires, connectors and I2C protocol implementation. Contact local distributor. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2 | Internal I2C operation error Indicates instable communication on sensors local I2C bus. | Try to restart sensor by power on/off. Contact local distributor. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 3 | Calibration error Indicate that calibration failed (ABC, zero, background or target calibration). | Try to repeat calibration, ensure environment is stable during calibration. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 4 | Self diagnostics error | Try to restart sensor by power on/off. Contact local distributor. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 5 | Out of range Indicate that measured concentration is not within sensors measurement range | Perform suitable CO ₂ calibration (zero, background or target calibration). Contact local distributor. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6 | Memory error Error during memory operations | Try to restart sensor by power on/off. Contact local distributor. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 7 | External I2C error I2C error | Try to restart sensor by power on/off. Check wires, connectors and I2C protocol implementation. (see TDE5531) Contact local distributor. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 8 | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9 | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10 | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 11 | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 12 | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 13 | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| IR2 | 0x01 | | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| IR3 | 0x02 | | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| IR4 | 0x03 | Filtered CO ₂ | CO ₂ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| IR5 | 0x04 | Unfiltered CO ₂ | Unfiltered CO ₂ value | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| IR6 | 0x05 | | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| IR7 | 0x06 | | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| IR8 | 0x07 | | Reserved | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 2: Holding Registers

| HR# | Addr. | Name | Description (read/write registers) |
|------|-------|--------------------------------|--|
| HR1 | 0x00 | ABC Status | 0x0008: ABC calibration; 0x0004: Other types of calibration |
| HR2 | 0x01 | SCR | Special Command Register SCR=0x00FF: System reset SCR=0x7C05: Target calibration SCR=0x7C06: Background calibration SCR=0x7C07: Zero calibration |
| HR3 | 0x02 | Calc Target | Calibration target value |
| HR4 | 0x03 | CO ₂ Value Override | Override CO ₂ value |
| HR5 | 0x04 | ABC Time | Time passed in hours for ABC calibration |
| HR6 | 0x05 | Calc Para0 | Calibration parameter0 |
| HR7 | 0x06 | Calc Para1 | Calibration Parameter1 |
| HR8 | 0x07 | Calc Para2 | Calibration Parameter2 |
| HR9 | 0x08 | Calc Para3 | Calibration Parameter3 |
| HR10 | 0x09 | Start Meas | Start to measure when 1 is written to the register in single measurement mode |
| HR11 | 0x0A | Meas Mode | Measurement mode (0: continuous mode, 1: single measurement mode) (System reset required after changing measurement mode) |
| HR12 | 0x0B | Meas Period ¹ | Measurement period in seconds (ranged from 2 to 65535) |
| HR13 | 0x0C | Meas Num ² | Number of measurements: recommended to be less than four times of measurement period (ranged from 1 to 32767) |
| HR14 | 0x0D | ABC period | Time in hours to perform ABC calibration (System reset required after changing configuration) |
| HR15 | 0x0E | Clear ErrorStatus 0 | Write any number to this register to clear ErrorStatus 0 |
| HR16 | 0x0F | | Reserved |
| HR17 | 0x10 | | Reserved |

Note: In single measurement mode, backup HR5 to HR9 to the host before shutting down the sensor and write HR5 to HR9 back to the sensor after turning it on. This is for proper background calibration. In addition, ABC Time must be supplied to the sensor correctly by the host in single measure mode.

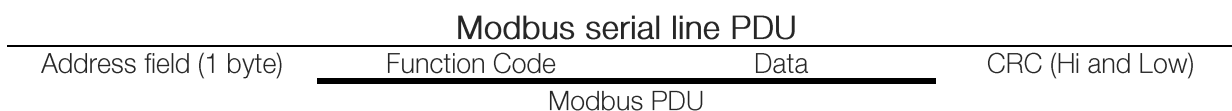
¹ When measurement period is set to be smaller than the time elapsed for the current measurement, current CO₂ output will not be updated and the next measurement will start.

² When the Number of Measurements (NOM) is set to be smaller than the current NOM, the current CO₂ output will be calculated immediately if the new NOM has been reached, and the actual NOM for the average is undefined, which is between the old NOM and the new NOM.

1.3. Serial line frame and addressing

Serial line frame

Modbus over serial line specification [2] distinguishes Modbus Protocol PDU and Modbus serial line PDU in the following way:



Addressing rules

Addressing rules are summarised in the table:

| Address | Modbus over serial line V1.0 | Senseair Sunrise Sensor |
|-----------------|------------------------------|---|
| 0 | Broadcast address | No broadcast commands currently implemented |
| From 1 to 247 | Slave individual address | Slave individual address |
| From 248 to 253 | Reserved | Nothing ¹⁾ |
| 254 | Reserved | "Any sensor" ²⁾ |
| 255 | Reserved | Nothing ¹⁾ |

Notes:

1. "Nothing" means that sensor doesn't recognise Modbus serial line PDUs with this address as addressed to the sensor. Sensor does not respond.
2. "Any sensor" means that any sensor with any slave individual address will recognise serial line PDUs with address 254 as addressed to them. They will respond. So that this address is for production / test purposes only. It must not be used in the installed network. This is a violation against the Modbus specification [1].

1.4. Bus timing

| Parameter | Min | Typ | Max | Units |
|-------------------|-----|-----|-----|-------|
| Response time-out | | | 180 | msec |
| | | | | |
| | | | | |

"Response time-out" is defined to prevent master (host system) from staying in "Waiting for reply" state indefinitely. Refer to page 9 of MODBUS over serial line specification [2].

For slave device "Response time-out" represents maximum time allowed to take by "processing of required action", "formatting normal reply" and "normal reply sent" alternatively by "formatting error reply" and "error reply sent", refer to the slave state diagram on page 10 of the document mentioned above.

Function codes descriptions (PUBLIC)

Description of exception responses

If the PDU of the received command has wrong format:

No Response PDU, (sensor doesn't respond)

If Function Code isn't equal to any implemented function code:

Exception Response PDU.

| | | |
|--|--------|----------------------|
| Function code | 1 byte | Function Code + 0x80 |
| Exception code = <i>Illegal Function</i> | 1 byte | 0x01 |

If one or more of addressed Registers is not assigned (register is reserved or Quantity of registers is larger than maximum number of supported registers):

Exception Response PDU.

| | | |
|--|--------|----------------------|
| Function code | 1 byte | Function Code + 0x80 |
| Exception code = <i>Illegal Data Address</i> | 1 byte | 0x02 |

01 (0x01) Read Coils (one bit read / write registers)

Not implemented.

02 (0x02) Read Discrete Inputs (one bit read only registers)

Not implemented.

03 (0x03) Read Holding Registers (16 bits read / write registers)

Refer to Modbus specification [1].

Request PDU

| | | |
|--------------------------|--------|-------------|
| Function code | 1 byte | 0x03 |
| Starting Address Hi | 1 byte | Address Hi |
| Starting Address Lo | 1 byte | Address Lo |
| Quantity of Registers Hi | 1 byte | Quantity Hi |
| Quantity of Registers Lo | 1 byte | Quantity Lo |

Response PDU

| | | |
|----------------|--------------|--------|
| Function code | 1 byte | 0x03 |
| Byte Count | 1 byte | 2 x N* |
| Register Value | N* x 2 bytes | |

* N = Quantity of Registers

If Address is out of range:

Exception Response PDU,

| | | |
|--|--------|------|
| Function code | 1 byte | 0x83 |
| Exception code = <i>Illegal Data Address</i> | 1 byte | 0x02 |

If Quantity=0 or Quantity>Number of Registers:

Exception Response PDU,

| | | |
|--|--------|------|
| Function code | 1 byte | 0x83 |
| Exception code = <i>Illegal Data Value</i> | 1 byte | 0x03 |

04 (0x04) Read Input Registers (16 bits read only registers)

Refer to Modbus specification [1].

Quantity of Registers is limited to 32.

Request PDU

| | | |
|--------------------------|--------|-------------|
| Function code | 1 byte | 0x04 |
| Starting Address Hi | 1 byte | Address Hi |
| Starting Address Lo | 1 byte | Address Lo |
| Quantity of Registers Hi | 1 byte | Quantity Hi |
| Quantity of Registers Lo | 1 byte | Quantity Lo |

Response PDU

| | | |
|----------------|--------------|-------------|
| Function code | 1 byte | 0x04 |
| Byte Count | 1 byte | 2 x N* |
| Register Value | N* x 2 bytes | |

* N = Quantity of Registers

If Address is out of range:

Exception Response PDU,

| | | |
|--|--------|-------------|
| Function code | 1 byte | 0x84 |
| Exception code = <i>Illegal Data Address</i> | 1 byte | 0x02 |

If Quantity=0 or Quantity>Number of registers:

Exception Response PDU,

| | | |
|--|--------|-------------|
| Function code | 1 byte | 0x84 |
| Exception code = <i>Illegal Data Value</i> | 1 byte | 0x03 |

05 (0x05) Write Single Coil (one bit read / write register)

Not implemented.

06 (0x06) Write Single Register (16 bits read / write register)

Not implemented.

15 (0x0F) Write Multiple Coils (one bit read / write registers)

Not implemented.

16 (0x10) Write Multiple Registers (16 bits read / write register)

Refer to Modbus specification [1].

Address of Modbus Holding Registers for 1-command reading/writing is limited in range 0x0000..0x001F.

Request PDU

| | | |
|--------------------------|--------------|----------------|
| Function code | 1 byte | 0x10 |
| Starting Address Hi | 1 byte | Address Hi |
| Starting Address Lo | 1 byte | Address Lo |
| Number of Register Hi | 1 byte | Value Hi |
| Number of Register Lo | 1 byte | Value Lo |
| The Number of Data Bytes | 1 byte | 2 x N* |
| Register value to write | 2 x N* bytes | Value to write |

* N = Quantity of Registers

Response PDU (is an echo of the Request)

| | | |
|-------------------------------|--------|------------|
| Function code | 1 byte | 0x10 |
| Starting Address Hi | 1 byte | Address Hi |
| Starting Address Lo | 1 byte | Address Lo |
| Number of Register written Hi | 1 byte | Value Hi |
| Number of Register written Lo | 1 byte | Value Lo |

If Address is out of range:

Exception Response PDU,

| | | |
|--|--------|------|
| Function code | 1 byte | 0x90 |
| Exception code = <i>Illegal Data Address</i> | 1 byte | 0x02 |

20 (0x14) Read File record

Not implemented.

21 (0x15) Write File record

Not implemented.

22 (0x16) Mask Write Register (16 bits read / write register)

Not implemented.

23 (0x17) Read / Write Multiple Registers (16 bits read / write register)

Not implemented.

2. References

- [1] MODBUS Application Protocol Specification V1.1b
- [2] MODBUS over serial line specification and implementation guide V1.02

3. Examples

Set measurement mode to continuous mode:

Write 0 to holding register 10. Note that after measurement mode has been written to the sensor it has to be restarted before it will change to the new measurement mode.

Request:

0x68 0x10 0x00 0x0A 0x00 0x01 0x02 0x00 0x00 0x64 0xA8

Response:

0x68 0x10 0x00 0x0A 0x00 0x01 0x28 0xF2

Set measurement mode to single measurement mode:

Write 1 to holding register 10. Note that after measurement mode has been written to the sensor it has to be restarted before it will change to the new measurement mode.

Request:

0x68 0x10 0x00 0x0A 0x00 0x01 0x02 0x00 0x01 0xA5 0x68

Response:

0x68 0x10 0x00 0x0A 0x00 0x01 0x28 0xF2

Single measurement sequence

1. Drive EN pin high
2. Wait for 35ms (or longer) for sensor start-up and stabilisation
3. Write stored sensor state data from previous measurement cycle to HR5-HR9

Request:

0x68 0x10 0x00 0x04 0x00 0x05 0x0A 0x00 0x00 0x7B 0x2C 0xFE 0x7E 0x0D 0x14 0x00
0x06 0xAE 0x5B

Response:

0x68 0x10 0x00 0x04 0x00 0x05 0x48 0xF2

State data written to the sensor in request above is just an example, it is very important that correct state data is written to the sensor.

4. Write 1 to HR10 to start measurement

Request:

0x68 0x10 0x00 0x09 0x00 0x01 0x02 0x00 0x01 0xA5 0x5B

Response:

0x68 0x10 0x00 0x09 0x00 0x01 0xD8 0xF2

5. Wait until ready pin goes low or 6s (for default configuration)

6. Read CO2 value, in example CO2 value is 0x0D53 = 3411d ppm

Request:

0x68 0x04 0x00 0x03 0x01 0xC8 0xF3

Response:

0x68 0x04 0x02 0x0D 0x53 0xA1 0x94

7. Read sensor state data from HR5-HR9 and save it for next measurement

Request:

0x68 0x03 0x00 0x04 0x00 0x05 0xCD 0x31

Response:

0x68 0x03 0x0A 0x00 0x00 0x7B 0x2C 0xFE 0x7E 0x0D 0x14 0x00 0x06 0xEC 0xF4

8. Drive EN pin low

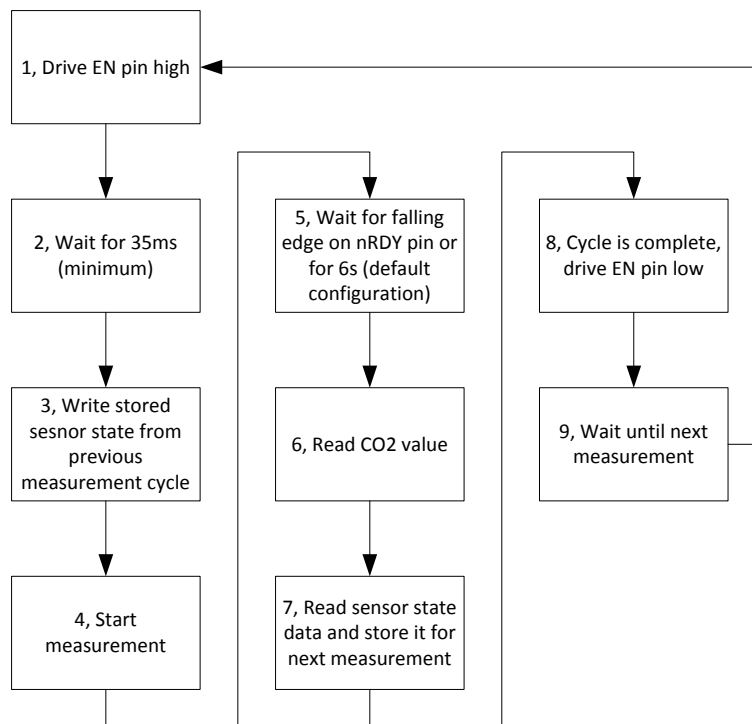


Figure 1, Communication sequence for single measurement mode

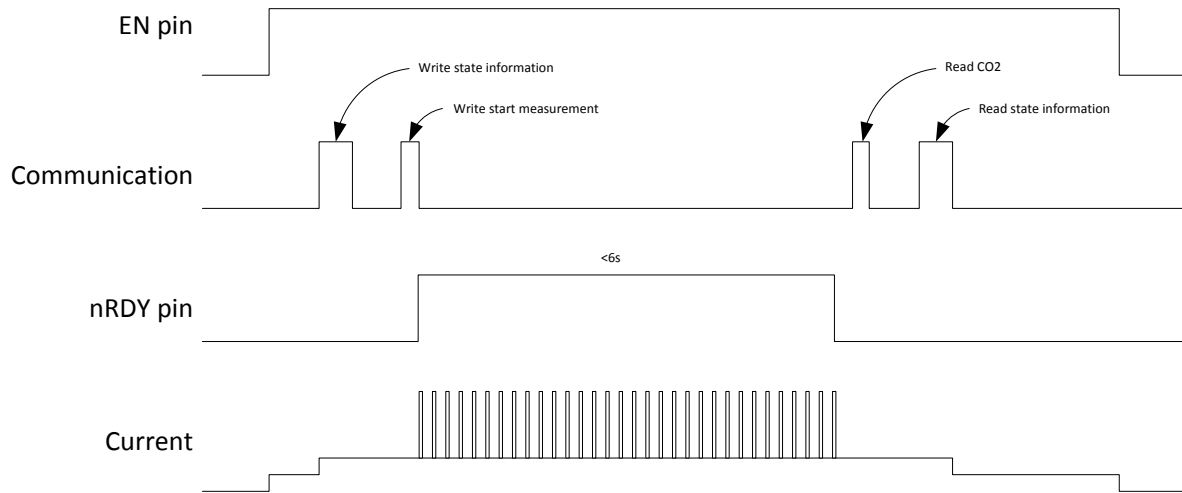


Figure 2, Timing diagram for single measurement mode

CO2Meter, Inc

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