RTD Emulator

General Description

Resistor Temperature Detectors (RTD) are sensors used to measure temperature. The detector is based on material with accurate relationship between resistance and temperature as resistance is easy to measure.
This device is intended to serve as emulator of RTDs by allowing to set desired resistance or temperature on each port. Such a device is very useful for testing of systems that measure temperature using RTD, for instance heating systems. Programmable and possibly very high temperature slew rate of this device allows for automatic boundary-condition and fault testing, emulation of which is otherwise very cumbersome.

RTD Emulator

Functions and Benefits

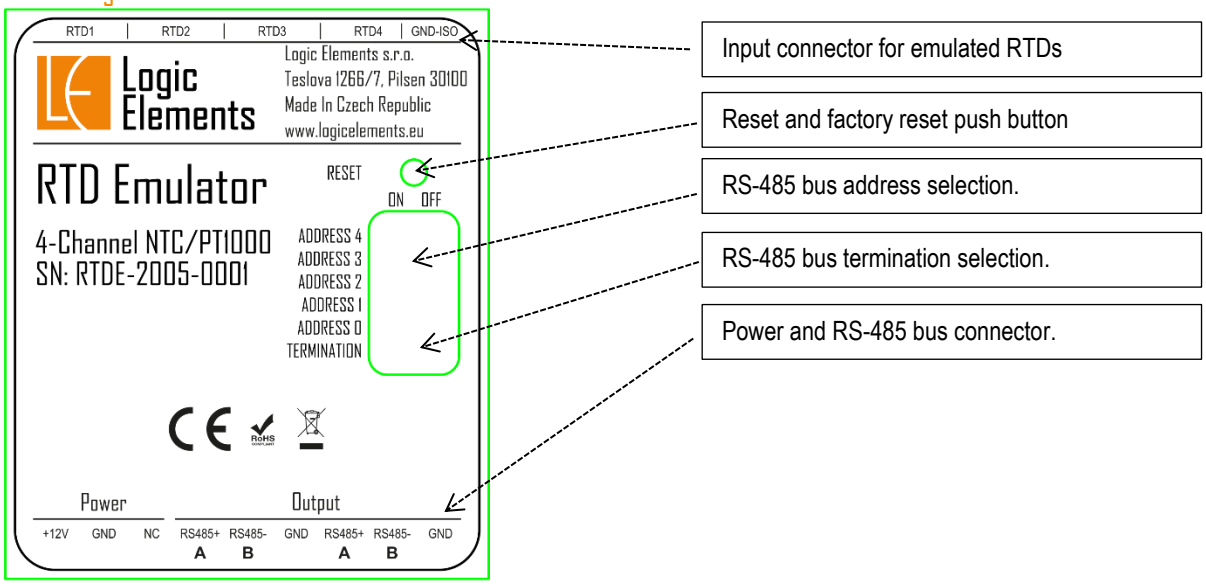
- 4 channels isolated from power and RS-485
- Direct resistance settings
- Emulate NTC using coefficients and temperature
- Platinum sensors are supported (low absolute accuracy, can be used for dynamic response testing)
- Programmable temperature slew rate
- 1 Digital output Modbus RTU with address switch
- Remote firmware update over Modbus

Parameters

Parameter	Value		
	Minimum	Typical	Maximum
Mounting	35/7.5 (DIN 46277, EN 50022)		
Width	3 modules		
Number of inputs	1 RS-485 bus		
Number of outputs	4 RTD channels		
Ambient temperature	-20 °C		60 °C
Power supply voltage	6 V	12 V	25 V
Power supply consumption @ 12 V	22 mA	28 mA	35 mA
Nominal resistance of RTD port	120 Ohm		100225 Ohm
Resistance step (LSB)	1.953 Ohm		
Temperature accuracy (NTC 10k B3977) @ 25 °C	+- 0.25 °C		
Accuracy vs ambient temperature	-1 °C @ 60 °C		+1 °C @ -20 °C
RTDx pins voltage to GND-ISO	0 V		3.3 V
Current through RTDx port	-10 mA		10 mA
Modbus communication	19200 baud/s, 8 data bits, Even parity, 1 stop bit		
Modbus address	32 + DIP value		

Pin Description

Pin Placing



Pinout Table

PIN	Type	Description
+12V	Power supply pin	Power supply pin for external power supply
GND	Power supply pin	Power pin for supply ground
NC	Not connected	Not internally connected
RS485+ A	RS-485 bus output	Positive RS-485 bus differential output
RS485- B	RS-485 bus output	Negative RS-485 bus differential output
RTD1	RTD port 1	Port for RTD emulation 1. Both pins are interchangeable. Voltage at either pin must not exceed working range 0 – 3.3 V
RTD2	RTD port 2	Port for RTD emulation 2.
RTD3	RTD port 3	Port for RTD emulation 3.
RTD4	RTD port 4	Port for RTD emulation 4.
GND-ISO	Ground of isolated RTDs	Ground of isolated part of RTD emulator. This ground must be tied to the ground of measuring device.
Termination	Switch	Turn on termination resistor 150 R on RS-485 bus in case the device is placed in the end of RS-485 bus.
ADDRESS 0 – ADDRESS 4	Switch	Set Modbus RTU protocol address that will be added to **base value 32**. Individual address switches represent numerical values: ADDRESS 0: 1 ADDRESS 1: 2 ADDRESS 2: 4 ADDRESS 3: 8 ADDRESS 4: 16 If given switch is turned on, related numerical value is effective. RS-485 Modbus protocol address is determined as sum of all numerical values enabled by switches. If all switches are ON, address is equal to 31 (1 + 2 + 4 + 8 + 16) + **32** = **63**.

Modbus RTU Protocol

The device implements Modbus RTU slave supporting the following function codes 3, 4, 16.

Modbus Registers Mapping – Input Registers

Address	Name	Format	Description
0, 1	Uptime	INT	Number of seconds since device power up Unit: s.
2, 3	Register map version	INT	Version of register map in format 0xAAAABBBB: AAAA - major part BBBB - minor part *Minimum: 65537. Maximum: 5242960.*
4	Analog supply	INT	Measured analog reference voltage *Minimum: 2500. Maximum: 3500.* Unit: mV.
5	Power voltage	INT	Measured power supply voltage *Minimum: 5000. Maximum: 25000.* Unit: mV.
6, 7	Status register	BIN	Binary map of different status flags Meaning of respective bits: Bit 0 - Generic error - Global error flag. Bit 4 - RTD 1 out-of-range - Computed resistance from given temperature is out of range at RTD1. Bit 5 - RTD 2 out-of-range - Computed resistance from given temperature is out of range at RTD2. Bit 6 - RTD 3 out-of-range - Computed resistance from given temperature is out of range at RTD3. Bit 7 - RTD 4 out-of-range - Computed resistance from given temperature is out of range at RTD4. Bit 16 - Configuration flash error - Error when working with configuration memory. Bit 17 - Low voltage - Detected low power supply voltage. Bit 18 - Modbus timeout - No modbus communication for timeout period. Bit 19 - Testing mode - Testing mode is enabled. *Minimum: 0. Maximum: 4095.*
8	Input signals	INT	Set of input signals. Bits 0-4 - Modbus address offset Bits 5-8 - Bootstrap Bit 9 - Pushbutton *Minimum: 0. Maximum: 1023.*
9, 10	Serial number	INT	Serial number of product with common device ID in format XXYYZZZZ. XX - year of production YY - month of production ZZZZ - serial incremental number of the product *Minimum: 20050001. Maximum: 20080099.*
11, 12	Product number	INT	Product family identification. Constant value 2051 for all instances. *Minimum: 2051. Maximum: 2051.*
13, 14	Hardware version	INT	Hardware revision of the device defined as 0xAAAABBBB: AAAA - major part BBBB - minor part *Minimum: 65537. Maximum: 327695.*
15, 16	Bootloader version	INT	Firmware revision of the bootloader as number 0xAAAABBBB: AAAA - major version BBBB - minor version *Minimum: 262145. Maximum: 327695.*
17, 18	Firmware version	INT	Firmware revision of the current application image as an incremental number. See list of FW revision or release notes for respective features.

			Minimum: 1. Maximum: 150.
19, 20	Assembly date	INT	Assembly information of the current application in format XXXXYYZZ: XXXX - year of FW build YY - month of FW build ZZ - day of FW build *Minimum: 20200413. Maximum: 20221231.*
21, 22	CRC checksum	INT	CRC checksum of the current application
23, 24	Firmware size	INT	Firmware size of the current application in bytes *Minimum: 10000. Maximum: 28000.*
25, 26	Configuration writes	INT	Number of writes into internal configuration flash memory (size 4kB, entry 128 B, total endurance 10000 * 4096 / 128 = 320000) *Minimum: 0. Maximum: 1000000.* Unit: writes.

Modbus Registers Mapping – Holding Registers

The table below contains a description of all Holding registers and its function description.

Address	Name	Format	Description
0, 1	Test register	INT	Internal testing purpose
2	Command	INT	Following commands are supported: Value 9901 - Reset Value 8801 - Factory reset Value 7701 - Testing mode Value 66xx - Invoke error Value 5501 - Invoke watchdog reset **Default: 0.** *Minimum: 0. Maximum: 9901.*
3	Modbus baud rate	ENUM	Modbus RTU serial port baud rate Allowed values: Value 0 - 9600 - 9600 baud/s. Value 1 - 19200 - 19200 baud/s. Value 2 - 38400 - 38400 baud/s. Value 3 - 57600 - 57600 baud/s. Value 4 - 115200 - 115200 baud/s. **Non-volatile, default: 1.** *Minimum: 0. Maximum: 4.*
4	Modbus parity	ENUM	Modbus RTU serial port parity Allowed values: Value 0 - NONE - NONE parity. Value 1 - EVEN - EVEN parity. Value 2 - ODD - ODD parity. **Non-volatile, default: 1.** *Minimum: 0. Maximum: 2.*
5	Modbus stop bits	ENUM	Modbus RTU serial port - number of stop bits Allowed values: Value 0 - 1 stop bit - 1 stop bit. Value 1 - 2 stop bits - 2 stop bits. **Non-volatile, default: 0.** *Minimum: 0. Maximum: 1.*
6	Apply modbus parameters	INT	Apply new modbus communication parameters. Value 1 - Apply new settings **Default: 0.** *Minimum: 0. Maximum: 1.*
7	Modbus timeout	INT	Longer silent period implies connection lost. Zero value disables timeout indication. **Non-volatile, default: 10.** *Minimum: 0. Maximum: 7200.* Unit: s.
8	Calibration mode	INT	Set calibration resistance values to all channels. Value 0 - calibration disabled Value 1 - 8 - 100k low values 0 - 7 Value 9 - 16 - 100k FS values 31, 63, … 255 Value 17 - 24 - 2 x 1k FS values 31, 63, … 255

			Default: 0. *Minimum: 0. Maximum: 24.*
9	Reserved	INT	Reserved for future use
10, 11	PT temperature correction	FLOAT32	Temperature correction that is added to requested temperature when emulating PT sensors **Non-volatile, default: -10.** *Minimum: -50. Maximum: 50.* Unit: °C.
12, 13	Resistance correction	FLOAT32	Resistance correction that is added to requested resistance in all emulation modes **Non-volatile, default: 0.** *Minimum: -500. Maximum: 500.* Unit: Ohm.
100	Emulation mode	ENUM	Mode of RTD emulation. Selected mode is common for all 4 channels Allowed values: Value 0 - Direct resistance - Set resistance is directly applied to RTD ports. Value 1 - NTC thermistor - Set temperature is used for NTC resistance computation. Value 2 - Platinum RTD - Set temperature is used for PT1000 resistance computation. **Default: 0.** *Minimum: 0. Maximum: 2.*
101	Reserved	INT	Reserved for future use
102	NTC beta	INT	NTC beta coefficient for computation **Default: 3977.** *Minimum: 3000. Maximum: 5500.*
103	NTC stock resistance	INT	NTC stock resistance at 25 °C (10000 for common 10k NTC) **Default: 10000.** *Minimum: 1000. Maximum: 10000.* Unit: Ohm.
104	Platinum stock resistance	INT	Platinum stock resistance at 0 °C Value 100 - PT100 Value 500 - PT500 Value 1000 - PT1000 **Default: 1000.** *Minimum: 100. Maximum: 1000.* Unit: Ohm.
105, 106	Set resistance 1	FLOAT32	Resistance that should be set at RTD port 1 **Default: 10000.** *Minimum: 120. Maximum: 100225.* Unit: Ohm.
107, 108	Set resistance 2	FLOAT32	Resistance that should be set at RTD port 2 **Default: 10000.** *Minimum: 120. Maximum: 100225.* Unit: Ohm.
109, 110	Set resistance 3	FLOAT32	Resistance that should be set at RTD port 3 **Default: 10000.** *Minimum: 120. Maximum: 100225.* Unit: Ohm.
111, 112	Set resistance 4	FLOAT32	Resistance that should be set at RTD port 4 **Default: 10000.** *Minimum: 120. Maximum: 100225.* Unit: Ohm.
113, 114	Temperature 1	FLOAT32	Set temperature for RTD port 1 **Default: 25.** *Minimum: -200. Maximum: 600.* Unit: °C.
115, 116	Temperature 2	FLOAT32	Set temperature for RTD port 2 **Default: 25.** *Minimum: -200. Maximum: 600.* Unit: °C.
117, 118	Temperature 3	FLOAT32	Set temperature for RTD port 3 **Default: 25.** *Minimum: -200. Maximum: 600.* Unit: °C.
119, 120	Temperature 4	FLOAT32	Set temperature for RTD port 4 **Default: 25.** *Minimum: -200. Maximum: 600.* Unit: °C.
121, 122	Temperature slew rate	FLOAT32	Slew rate of temperature change in temperature emulation mode. Temperature is modified proportionally to eliminate large steps. Zero value disables this feature and temperature changes immediately in a single step. **Default: 0.** *Minimum: 0. Maximum: 100.* Unit: °C/s.

RS-485 Communication Settings

RS-485 settings can be changed through Modbus Holding registers. The new settings are applied **only** after writing the "Apply modbus parameters" register. The default configuration is as follows.

Parameter	Value
Baud rate	19200 Baud/s
Word length	8 bits
Parity	Even
Stop bits	1

Led Indication

For simple behavior indication, the device is equipped with Red and Green LED diode inside the housing next to the Termination DIP switch.

LED state	Meaning
Green – blinking	Operational state with active communication.
Red – solid	Malfunction, device is not operating.
Red – blinking	Warning state. Some internal error, requested resistance is out of range or undervoltage.
Red + Green concurrent blinking	Modbus communication timeout.
Red + Green alternate blinking	Bootloader is working. Either at power on or after remote firmware upgrade.

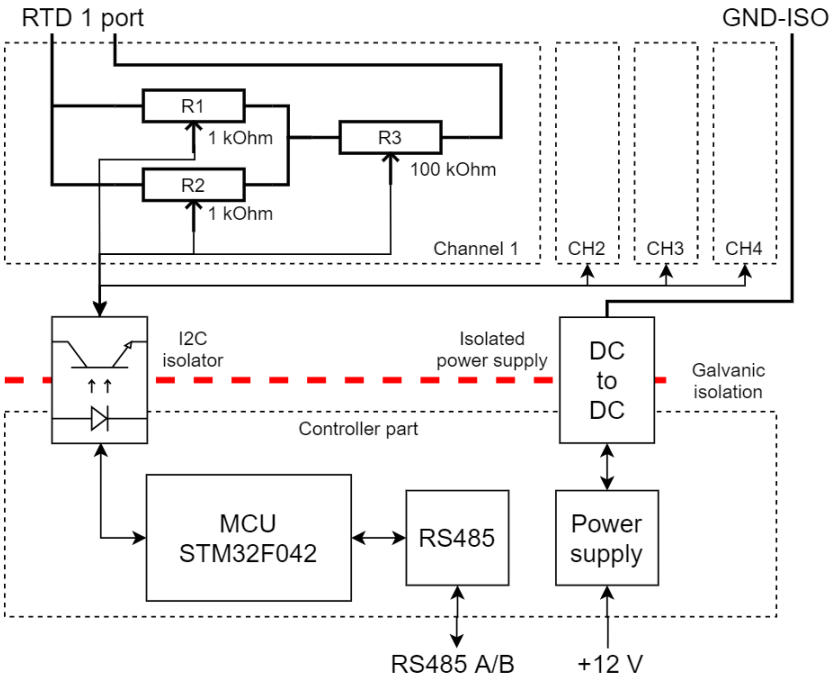
Push Button

Push button can be used to restart device and to reset it to the factory default settings

Push time [s]	Action
Less than 0.5 s	Nothing (debouncing and false push prevention feature)
Between 0.5 s and 5 s	Device restart
More than 5 s	Reset to factory default settings. Device will restart as well.

Functional Description

The RTD Emulator is composed of two galvanically isolated parts. The Controller part contains RS485 transceiver, power supply stabilizer and microcontroller. The RTD part containing 4 channels is isolated by I2C isolator and DC-to-DC power supply. All 4 channels are galvanically referenced to common isolated ground (GND-ISO). In most applications, this GND-ISO must be connected to the ground of device that measures the emulated resistance.
Each RTD channel is composed of 3 digitally controlled resistors (trimpots), 2 (R1 and R2) with nominal full-scale value of 1 kOhm and 1 (R3) trimpot of 100 kOhm. The final resistance value between RTD ports is given by parallel combination of R1 and R2 plus value of R3.



Temperature Slew Rate

The RTD Emulator supports smooth temperature change with programmable slew rate via "Temperature slew rate" register. The slew rate defines the temperature change with respect to time (units centigrade per second °C/s). If this register has non-zero value, the current temperature is internally incremented (decremented) by small steps every 50 ms to emulate continuous temperature change. The requested temperature is reached in time given by temperature difference over slew rate.

Factory Calibration

Each input channel is factory calibrated at room temperature 25 °C at these points:

- 100k trimpot for codes 0, 1, 2, 3, 4, 5, 6, 7 (in order to precise PT1000 absolute tolerance)
- 100k trimpot for codes 31, 63, 95, 127, 159, 191, 223, 255 (decrease large scale non-linearity)
- Both 1k trimpots in parallel for codes 31, 63, 95, 127, 159, 191, 223, 255 (decrease small scale non-linearity)

Resistance computation uses linear interpolation between these points.

Wiring and Power Up

Recommended powering-up sequence is as follows:

1. Power up RTD emulator
2. Connect RTD emulator to RS485 bus
3. Connect GND-ISO to measuring device
4. Connect all used RTD ports. Note that both pins of each RTD port are interchangeable.

NTC Emulation Use Case

Typical application of RTD emulator is emulation of multiple NTC sensors of a single regulation device (heating system, boiler, circulation pump, etc.). One should proceed in the following steps:

1. Write "Value 1 - NTC thermistor" to register "Emulation mode"
2. Write "Temperature slew rate" register if needed
3. Write "NTC stock resistance" constant as expected by the measuring device
4. Write "NTC beta" constants as expected by the measuring device
5. Write desired temperature to registers "Temperature 1-4" whenever this value should change.

PT1000 Emulation Use Case

In order to emulate PT1000 with acceptable accuracy, few extra steps are recommended to set proper correction constants with the first usage in new measuring device:

1. Keep the same polarity of injected current for all channels (this helps to keep the same common voltage)
2. Write “Value 2 - Platinum RTD” to register “Emulation mode”
3. Write value 1000 to register “Platinum stock resistance”
4. Write mid-range temperature to registers “Temperature 1-4”
5. Read measured temperatures from your measuring device
6. Modify value of correction register “PT temperature correction” to get correct temperature. Note that device come pre-calibrated for constant current measuring device, such as VMS-1502.
7. The new value should be valid until the measuring device changes

Device Limitations

Common GND-ISO

All 4 channels must be referenced to the common ground (GND-ISO). This ground should be connected to ground of measuring system that evaluates resistance of emulator.

RTD Ports Common Voltage

Voltage at any RTD port to GND-ISO must be within supply boundaries of trimpots, i.e., below 3.3 V. Violation of this boundary may damage the device.

Resistance Resolution

Trimpots support only 256 values over the nominal range. So LSB of R3 is approx. 100k / 256 = 390.625, LSB of R1 is 3.906 Ohm.

Minimal Resistance Value

Wiper of each trimpot has inevitable wiper resistance of approx. 75 to 200 Ohm. Minimal possible set resistance is than 1.5 * 75 = 112.5 Ohm. This resistance is also dependent on applied voltage, thus low-boundary resistance values may differ with common voltage. This effect should be compensated when PT1000 is emulated.

Low Accuracy

Even though each trimpot channel contains factory multi-point resistance calibration, trimpots have generally high tolerance, including high differential and integral nonlinearity, and ambient temperature dependency. Therefore, this device is not intended to be used as a source of precise resistance or RTD values for calibration.

Norm Compliance

This product was developed and manufactured with the compliance of following European norms (EN):

- EN 61000-4
- EN 55032
- EN 50581:2013

CE

Document revisions

Revision number	Date	Remarks
Rev 01.0	09/2020	Document release
Rev 01.1	11/2020	Changed default modbus speed to 19200 8-E-1, extended power supply range.