Phase Detector

General Description

Phase detector device is intended to detect presence of mains power voltage on 6 Line wires against 3 Neutral wires (1 Neutral is shared with 2 Lines). Earth wire is not used. Power line side is galvanically isolated from the rest of device. Presence of power voltage is evaluated by means of AC zero crossing events counting and relative time measurement.
This device targets to monitoring and verification testing of power switching devices, such as general-purpose relays, triacs, heating systems etc.

6-Phase Detector

Functions and Benefits

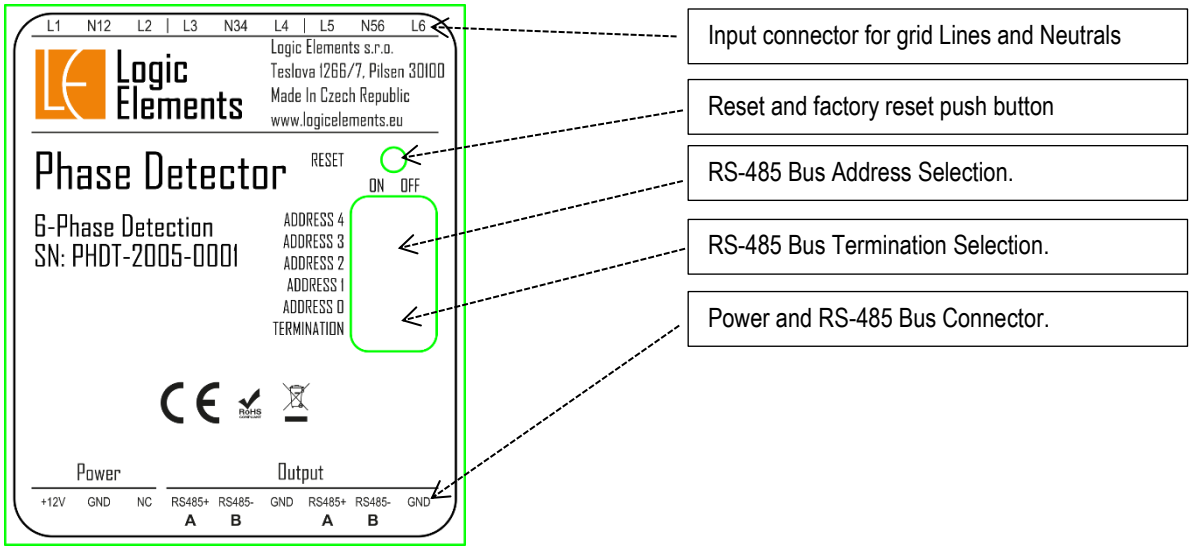
- 6 Lines evaluated at the time
- Count zero-crossing events over time
- ON and OFF state time measurement
- Tolerance parameter allows for sparse missing periods and relay debouncing
- Current state time measurement
- 1 Digital output Modbus RTU with address switch
- Remote firmware update over Modbus

Parameters

Parameter	Value		
	Minimum	Typical	Maximum
Mounting	35/7.5 (DIN 46277, EN 50022)		
Width	3 modules		
Number of inputs	6		
Number of outputs	1		
Ambient temperature	-40 °C		85 °C
Power supply voltage	4.5 V	12 V	25 V
Power supply consumption @ 12 V	20 mA	30 mA	40 mA
Mains grid Line load	2 x 100 kOhm		
Mains grid counter frequency	2 x grid frequency		
Modbus communication	19200 baud/s, 8 data bits, Even parity, 1 stop bit		
Modbus address	64 + 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
L1	Line 1	Grid power Line 1 referred to Neutral 12
N12	Neutral for Line 1 and 2	Neutral wire common for Line 1 and Line 2
L2	Line 2	Grid power Line 2 referred to Neutral 12
L3	Line 3	Grid power Line 3 referred to Neutral 34
N34	Neutral for Line 3 and 4	Neutral wire common for Line 3 and Line 4
L4	Line 4	Grid power Line 4 referred to Neutral 34
L5	Line 5	Grid power Line 5 referred to Neutral 56
N56	Neutral for Line 5 and 6	Neutral wire common for Line 5 and Line 6
L6	Line 6	Grid power Line 6 referred to Neutral 56
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 64**. 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) + **64** = **95**.

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: 4000. Maximum: 28000.* Unit: mV.
6, 7	Status register	BIN	Binary map of different status flags Meaning of respective bits: Bit 0 - Generic error - Any error flag. 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: 983041.*
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	Tick	INT	Internal millisecond tick Unit: ms.
11, 12	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.*
13, 14	Product number	INT	Product family identification. Constant value 2050 for all instances. *Minimum: 2050. Maximum: 2050.*
15, 16	Hardware version	INT	Hardware revision of the device defined as 0xAAAABBBB: AAAA - major part BBBB - minor part *Minimum: 65537. Maximum: 327695.*
17, 18	Bootloader version	INT	Firmware revision of the bootloader as number 0xAAAABBBB: AAAA - major version BBBB - minor version *Minimum: 262145. Maximum: 327695.*
19, 20	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.*
21, 22	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.*

23, 24	CRC checksum	INT	CRC checksum of the current application
25, 26	Firmware size	INT	Firmware size of the current application in bytes *Minimum: 10000. Maximum: 28000.*
27, 28	Configuration writes	INT	Number of writes into internal configuration flash. Assuming flash size 4kB, entry size 128 B, minimal total endurance is 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	Writing 1111 stores the current calibration into one-time programmable memory
9	Reserved	INT	Reserved for future use
100	Enable detection	ENUM	Enable phase detection and measuring. Allowed values: Value 0 - Disable - Phase detector does not evaluate state of Lines. Value 1 - Enable - Phase detector detects all Line wires and evaluate zero crossing and time measurement. **Default: 1.** *Minimum: 0. Maximum: 1.*
101	Clear all counters	ENUM	Clear all counters and measured times at once. Allowed values:

			Value 0 - None - Do nothing with counters. Value 1 - Clear all - Clear all counters. **Default: 0.** *Minimum: 0. Maximum: 1.*
102	Current state of Lines	BIN	State of phase detection on respective power Lines Meaning of respective bits: Bit 0 - Line 1 - L1 is live. Bit 1 - Line 2 - L2 is live. Bit 2 - Line 3 - L3 is live. Bit 3 - Line 4 - L4 is live. Bit 4 - Line 5 - L5 is live. Bit 5 - Line 6 - L6 is live. **Default: 0.** *Minimum: 0. Maximum: 63.*
103	Tolerance	INT	Tolerance of ON and OFF state duration measurement. This tolerance does not affect Counters 1-6 **Default: 5.** *Minimum: 2. Maximum: 65535.* Unit: ms.
104, 105	Counter L1	INT	Count of zero-crossing events detected at Line 1
106, 107	Counter L2	INT	Count of zero-crossing events detected at Line 2
108, 109	Counter L3	INT	Count of zero-crossing events detected at Line 3
110, 111	Counter L4	INT	Count of zero-crossing events detected at Line 4
112, 113	Counter L5	INT	Count of zero-crossing events detected at Line 5
114, 115	Counter L6	INT	Count of zero-crossing events detected at Line 6
116, 117	Duration on L1	INT	Time duration of current detected state at Line 1 Unit: ms.
118, 119	Duration on L2	INT	Time duration of current detected state at Line 2 Unit: ms.
120, 121	Duration on L3	INT	Time duration of current detected state at Line 3 Unit: ms.
122, 123	Duration on L4	INT	Time duration of current detected state at Line 4 Unit: ms.
124, 125	Duration on L5	INT	Time duration of current detected state at Line 5 Unit: ms.
126, 127	Duration on L6	INT	Time duration of current detected state at Line 6 Unit: ms.
128, 129	Last ON time L1	INT	Time duration of the most recent ON state at Line 1 Unit: ms.
130, 131	Last ON time L2	INT	Time duration of the most recent ON state at Line 2 Unit: ms.
132, 133	Last ON time L3	INT	Time duration of the most recent ON state at Line 3 Unit: ms.
134, 135	Last ON time L4	INT	Time duration of the most recent ON state at Line 4 Unit: ms.
136, 137	Last ON time L5	INT	Time duration of the most recent ON state at Line 5 Unit: ms.
138, 139	Last ON time L6	INT	Time duration of the most recent ON state at Line 6 Unit: ms.
140, 141	Last OFF time L1	INT	Time duration of the most recent OFF state at Line 1 Unit: ms.
142, 143	Last OFF time L2	INT	Time duration of the most recent OFF state at Line 2 Unit: ms.
144, 145	Last OFF time L3	INT	Time duration of the most recent OFF state at Line 3 Unit: ms.
146, 147	Last OFF time L4	INT	Time duration of the most recent OFF state at Line 4 Unit: ms.
148, 149	Last OFF time L5	INT	Time duration of the most recent OFF state at Line 5 Unit: ms.

150, 151	Last OFF time L6	INT	Time duration of the most recent OFF state at Line 6 Unit: ms.

Register Notes

- Registers spanning more than one modbus register are little endian (least significant portion are located at lower address).
- Registers use one from the following number formats:
  - INT – Integer value (signedness may differ among registers depending on the usage)
  - BIN – Integer unsigned value where each bit has dedicated meaning
  - ENUM – Enumerated value from given list
  - FLOAT – Simplified floating point number represented as 10 times the original number
  - FLOAT32 – Single precision floating point number in IEEE-754 format.
- The content of registers denoted as **Non-volatile** is stored in the internal non-volatile Flash memory, so the most recently written value is used after device power up. The values of these registers should not change more than 320000 times according to minimal endurance of the memory. Number of write operations can be obtained from input register "Configuration writes"
- **Default** value is used out-of-box or when user resets the configuration by pressing push button for more than 5 seconds. If default value is not mentioned, holding register will be set to 0. Holding registers may have some factory default value that is not stated in the table (e.g., identification such as serial number, firmware revision etc.).
- **One-time prog.** stands for registers that are written during manufacturing process. It can be temporarily changed by write command, though the value will be lost at power down.

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 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.

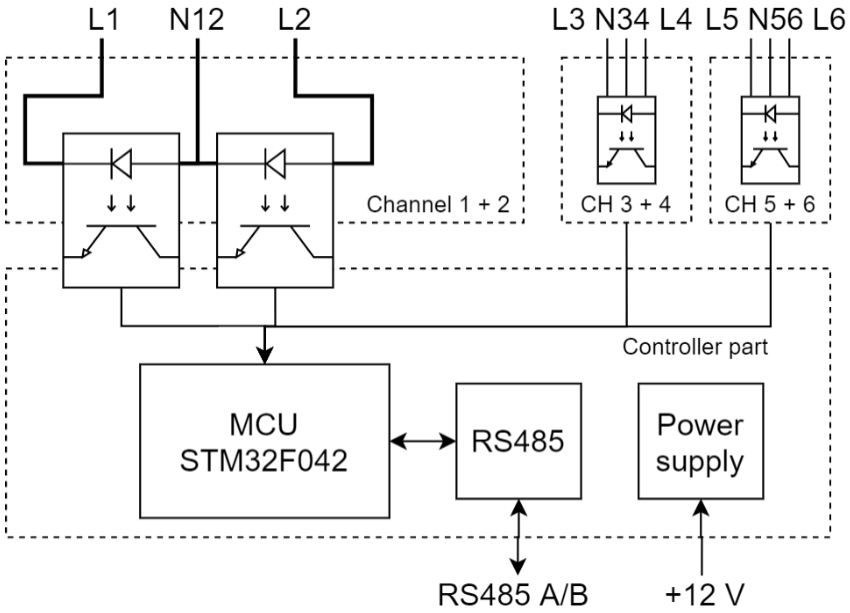
Push Button

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

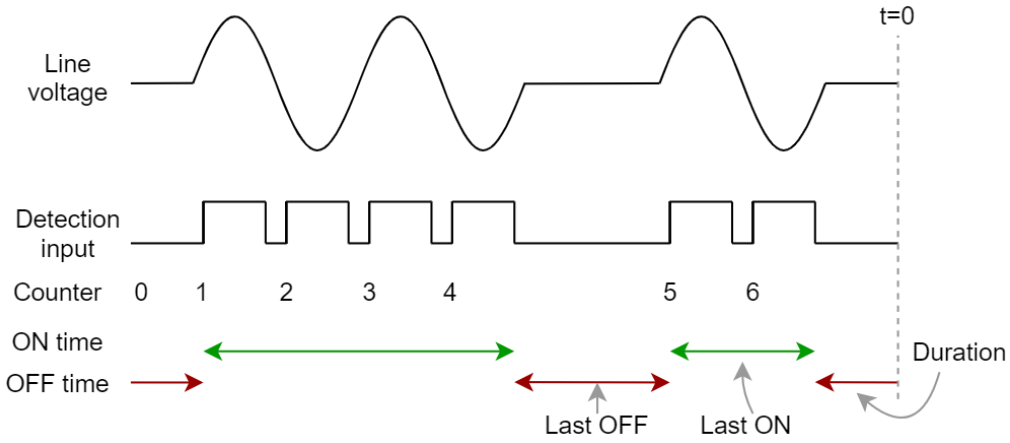
Push time [s]	Action
Less than 0.5 s	Nothing (debouncing and false push prevention feature)
Between 0.5 s and 5 s	Device restart
More than 5 s	Reset to factory default settings. Device will restart as well.

Functional description

The device is composed of two galvanically isolated parts. The Controller part contains RS485 transceiver, power supply stabilizer and microcontroller. The Phase detection part contains 3 groups of 2 Line power detectors with common Neutral wire. Line detection is done by bidirectional optocoupler, the output of which is evaluated by controller.



The output of optocoupler distinguishes among 2 states of Line voltage, either near-zero or above-zero voltage. When Line voltage is above threshold voltage, the detection signal is active. When Line voltage comes below the threshold, the detection switches to zero as well. This causes short pulses between half-periods of continuously turned-on Line. These pulses are counted by Counter 1-6 registers. The counter frequency is twice the power line frequency because it evaluates both zero-crossing events within a single period.



The ON and OFF time is evaluated by following the detection pulse run and the value of Tolerance register. As long as the detection low state is shorter than Tolerance value, it is considered as uninterrupted ON state. Longer low state implies beginning of OFF state.
At any given time (see “t=0” in the figure above), the time of current Line state is stored in Duration register, as well as duration of the most recent ON and OFF states.

Wiring and power up

Recommended powering-up sequence is as follows:

1. Make sure that Line wires are not powered and can be safely manipulated, e.g., turn off the circuit breaker
2. Connect desired Line and Neutral wires to the phase detector
3. Power up the phase detector
4. Connect phase detector to RS485 bus
5. Turn on the circuit breaker

Line State Detection Use Case

The common use case of Phase Detector is to detect current state of Line wires, for instance when testing power line switching elements, e.g., relays, triacs.
Recommended sequence is as follows:

1. Read register “Current state of Lines” to get whether Line is ON or OFF
2. Optionally read register “Duration on Lx” to get duration of current detected state (e.g., if state L1 is ON, Duration L1 of 20 s means L1 is ON for 20 s so far and counting).

Averaged ON Time Use Case

Another common use case is to measure averaged ON time of Line wire over given time. This can be used in applications where power is delivered in discontinuous random-distributed pulses in multiples of half power cycles. Such applications include heating or cooling systems.
Recommended sequence is as follows:

1. Write value 1 to “Clear all counters” to start measurement
2. Wait some averaging time
3. Read values of “Counter Lx”
4. Averaged ON time is given as “Counter Lx” / averaging time in percent.

PWM Measurement Use Case

Another common use case is to measure Pulse-Width Modulated power line where proportional power is delivered by short ON and OFF times in a periodical manner (expecting whole half cycles). Then single measurement of ON and OFF time gives us information about PWM power.
Recommended sequence is as follows:

1. Read “Last ON time Lx” to the most recent continuous ON period
2. Read “Last OFF time Lx” to the most recent continuous OFF period (to get the most precise reading, it is advised to read all registers in a single transaction).
3. Measured PWM power is given as “Last ON time Lx” / (“Last ON time Lx” + “Last OFF time Lx”) x 100 in percent.
4. If boundary values of 0 and 100 % are allowed, we must read also “Current state of Lines” and “Duration on Lx” and add condition that if “Duration on Lx” is greater than expected period, the “Current state of Lines” implies 0 or 100 % PWM.

Device Limitations

Common Neutral

There is common Neutral wire for every 2 Line wires due to space limitation.

Heat-up

Live power lines cause detection circuitry to heat up by up to 30 °C in time. The used parts should however withstand such temperatures over the whole recommended ambient temperature range.

Norm Compliance

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

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

Document revisions

Revision number	Date	Remarks
Rev 01.0	08/2020	Document release
Rev 01.1	11/2020	Changed default modbus speed to 19200 8-E-1, extended power supply range.