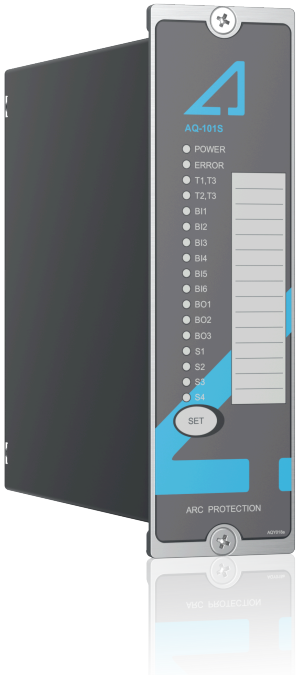
ARCTEQ®
PART OF ENSTO GROUP

AQ-101S

Arc flash protection device

Instruction manual



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Disclaimer

Please read these instructions carefully before using the equipment or taking any other actions with respect to the equipment. Only trained and qualified persons are allowed to perform installation, operation, service or maintenance of the equipment. Such qualified persons have the responsibility to take all appropriate measures, including e.g. use of authentication, encryption, anti-virus programs, safe switching programs etc. necessary to ensure a safe and secure environment and usability of the equipment. The warranty granted to the equipment remains in force only provided that the instructions contained in this document have been strictly complied with.

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1 Document information

Table. 1 - 1. History of Revision 1.

Revision	1.00
Date	April 2012
Changes	- The first revision of the manual.
Revision	**1.01**
Date	July 2012
Changes	- Scheme select DIP switch settings chapter updated. - System self-supervision chapter revised. - Ordering code for AQ-101S revised. - Point sensor max. wiring length updated to up to 200 meters.
Revision	**1.02**
Date	March 2014
Changes	- Scheme 6, 7, 9, 10, 11 internal logic segments added.

Table. 1 - 2. History of Revision 2.

Revision	2.00
Date	October 2020
Changes	- Content completely rewritten to improve grammar and readibility. - The "Available logic schemes" chapter updated. - The AQ-02 point sensor chapter added to the "Arc sensors" chapter, and AQ-02's technical data added to the "Technical data" chapter. - The sensor–unit type dependency list updated. - The "Connecting sensors" chapter added. - All technical data checked and updated where necessary. - Ordering information updated. - Images updated where necessary.
Revision	**2.01**
Date	November 2021
Changes	- Cut-out installation image added. - Dimension measurements updated in images and technical data. - Wiring diagram, simplified block diagram, DIP switch diagram & application image updated. - Push button image added. - Connections image updated. - The test plan example updated. - All table layouts unified in "Technical data". - The IP classification of point sensors updated. - The AWG value updated. - "Disturbance tests" table reformatted. - Order code images updated. - The number for Arcteq's technical support added to the reference information.

Revision	2.02
Date	January 2023
Changes	- Updated the Arcteq logo on the cover. - Updated the distance between the flash and the sensor in the "Testing the operation time" chapter. - Unified terminology used througout the manual (e.g. unit and device means the same thing. Now all AQ 100 series relays are called "devices"). - Improved many existing drawings. - Rearranged topics into a more logical order. - Added connection drawings to input and output descriptions under "Connections" chapter. - Added hyperlinks to chapters. (e.g. "See Device features chapter for more information") - Listed more features in Device features chapter. - Added information about binary output pulse messages. - Many tables have been simplified and made easier to read. - Scheme matrixes and simplified logic diagrams have been made more detailed in "Available schemes" chapter.
Revision	**2.03**
Date	April 2023
Changes	- Small changes to visual style. - Small improvements to descriptions.
Revision	**2.04**
Date	September 2024
Changes	- Updated the BI threshold voltage to only 24 V DC throughout the document. - Added point sensor dimensions.

2 Safety information

This document contains important instructions that should be saved for future use. Read the document carefully before installing, operating, servicing, or maintaining this equipment. Please read and follow all the instructions carefully to prevent accidents, injury and damage to property.

Additionally, this document may contain four (4) types of special messages to call the reader's attention to useful information as follows:

NOTICE!
"Notice" messages indicate relevant factors and conditions to the the concept discussed in the text, as well as to other relevant advice.

CAUTION!
"Caution" messages indicate a potentially hazardous situation which, if not avoided, **could** result in minor or moderate personal injury, in equipment/property damage, or software corruption.

WARNING!
"Warning" messages indicate a potentially hazardous situation which, if not avoided, **could** result in death or serious personal injury as well as serious damage to equipment/property.

DANGER!
"Danger" messages indicate an imminently hazardous situation which, if not avoided, **will** result in death or serious personal injury.

These symbols are added throughout the document to ensure all users' personal safety and to avoid unintentional damage to the equipment or connected devices.

Please note that although these warnings relate to direct damage to personnel and/or equipment, it should be understood that operating damaged equipment may also lead to further, indirect damage to personnel and/or equipment. Therefore, we expect any user to fully comply with these special messages.

3 Abbreviations

AQD – arc quenching device

BI – binary input

BO – binary output

CB – circuit breaker

CBFP – circuit breaker failure protection

CT – current transformer

EPROM – erasable, programmable read-only memory

HSO – high-speed output

LED – light emitting diode

LV – low-voltage

MV – medium-voltage

NC – normally closed

NO – normally open

PCB – printed circuit board

RF – radio frequency

Rx – receiver

SAS – standard arc scheme

SF – system failure

Tx – transceiver

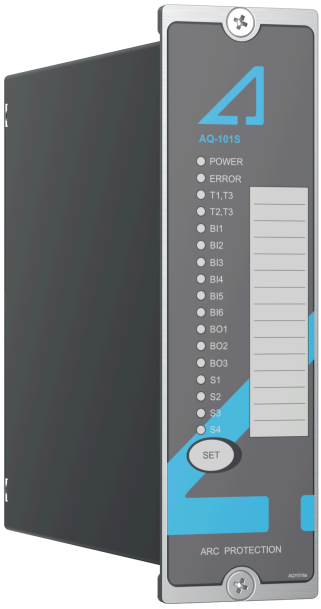
µP - microprocessor

4 General

The AQ-101S is a sophisticated microprocessor-based arc flash protection device with point sensor channels. The device is designed to minimize the damage caused by an arc fault. This is done by tripping the circuit breaker which supplies current to the fault when sensors detect arc light.

The device includes a complete system self-supervision functionality which provides the highest level of dependability as it continuously monitors all internal system functions as well as all external connections.

Figure. 4 - 1. Arc protection device AQ-101S.



The AQ-101S is designed according to the latest protection relay standards and is therefore suitable for installations in rough environments. These include utilities and power plants (both traditional and renewable), various heavy industry applications (off-shore, marine, oil, gas, mining, steel, etc.) as well as commercial and institutional electrical systems. AQ-101S is suitable for MV and LV switchgears as well as for motor control center applications in both new and retrofitted installations.

5 Device features

AQ-101S is an arc flash protection device which it can be applied to a variety of applications that require a large amount of data communication. It can be used on its own as a stand-alone device, or it can be a part of a more complex arc protection system by using binary inputs and outputs to connect multiple AQ 100 series devices together.

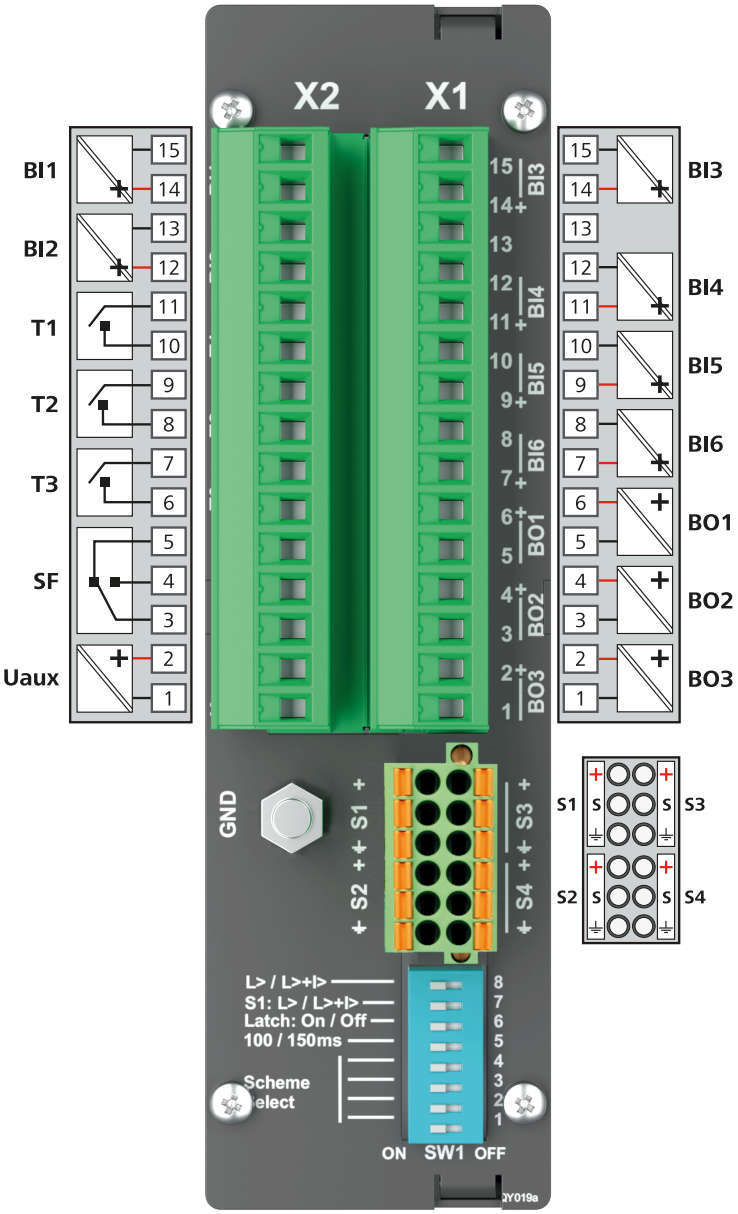
The following list presents the main features of the device:

- 92…265 V AC/DC auxiliary power supply or 18…72 V DC auxiliary power supply (optional)
- four (4) arc flash point sensor channels, max. three (3) point sensors per channel
- six (6) binary inputs with nominal operation voltage of 24 V DC
- three (3) trip relay outputs
- three (3) binary outputs (with internal 24 V DC power supply)
- one (1) system failure output (change-over)
- seventeen (17) indication LEDs
- eight (8) DIP switches for logic configuration
- one (1) push button.

6 Connections

The figure below depicts the connections of AQ-101S. Please note that the SF relay is in the de-energized position.

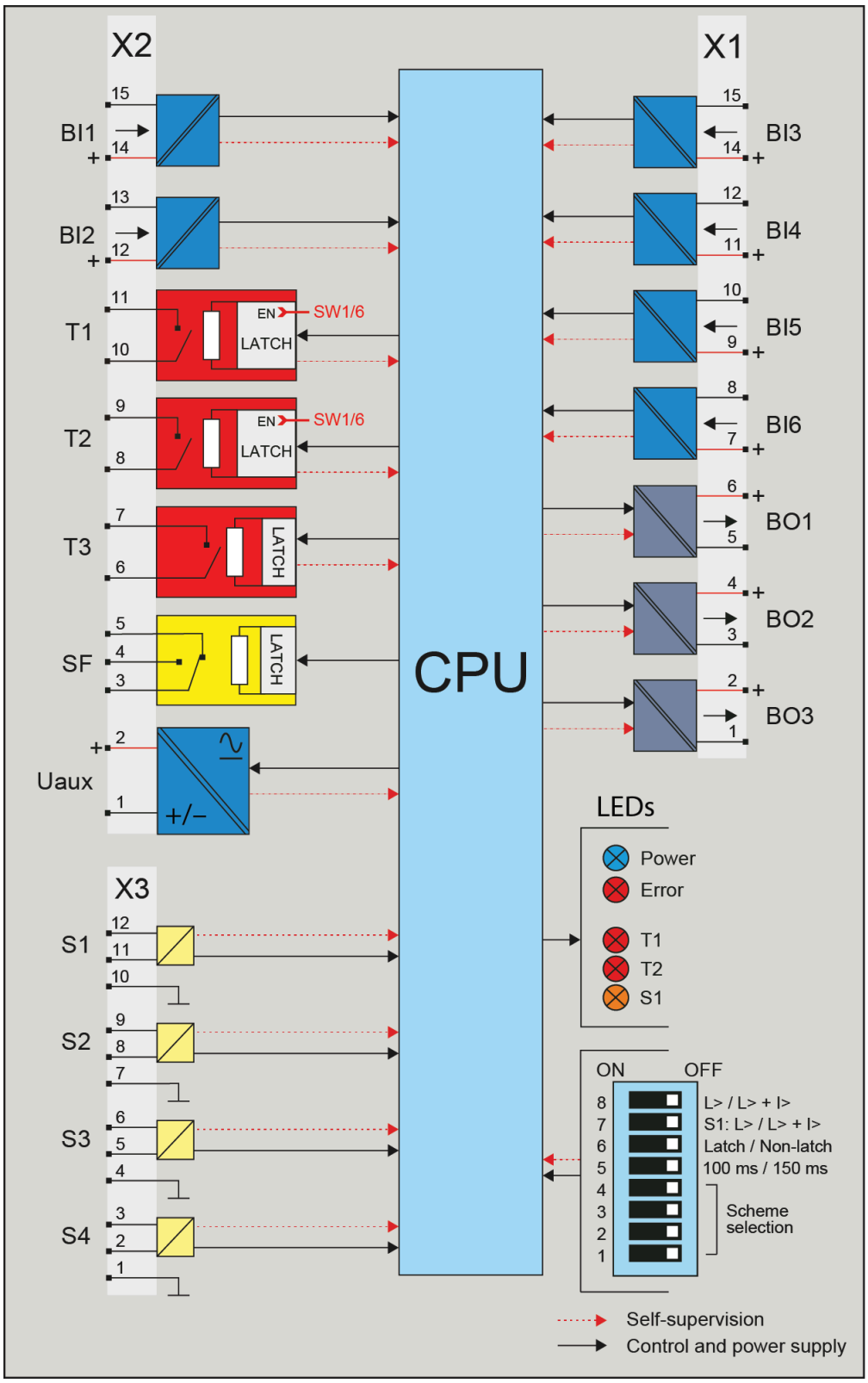
Figure. 6 - 2. Rear terminals of AQ-101S.



6.1 Simplified block diagram

The figure below presents the main components of the AQ-101S device.

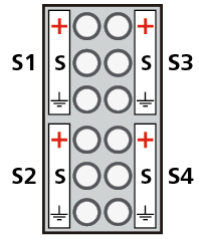
Figure. 6.1 - 3. Simplified block diagram of AQ-101S.



6.2 Inputs

6.2.1 Arc sensor channels

Figure. 6.2.1 - 4. Arc point sensor connections



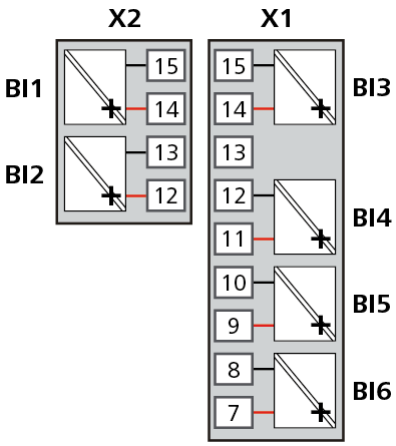
AQ-101S has four (4) arc point sensor channels: S1, S2, S3 and S4. Up to three (3) arc point sensors can be connected to each channel.

When the arc protection system has been set up, point sensor connections are constantly monitored. In case of sensor fault or disconnection, the device will go into Error mode. See System self-supervision chapter for more information.

For more information on sensors, please refer to the Arc sensors chapter as well as to the AQ-0x instruction booklet which can be found on Arcteq's website (https://www.arcteq.fi/downloads/).

6.2.2 Binary inputs

Figure. 6.2.2 - 5. Binary input connections



AQ-101S contains six (6) binary inputs.

Typically, BI1 and BI2 are reserved for the signal information concerning breaker position. In most applications BI3 is responsible for receiving overcurrent signal from an AQ-110 device. BI4, BI5 and BI6 can be used for receiving a trip signal or an arc light signal. For more information, please refer to the DIP switch settings chapter.

Please note that when AQ-101S receives an overcurrent signal from a non-AQ 100 series device, the actual operating time depends on the operating time of the that device. Therefore, the total operating time cannot be specified the technical data.

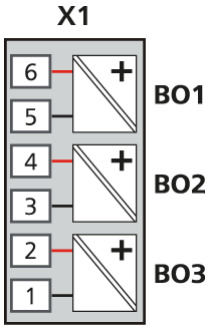
The binary inputs are activated when a connected DC signal reaches the specified nominal voltage level of the corresponding input. There are three (3) different nominal voltage levels available: 24, 110, or 220 VDC. The nominal voltage value must be chosen and specified when ordering the device. The actual activation of the binary input occurs at a lower voltage than the specified nominal voltage value (see Techical Datachapter).

AQ 100 series devices monitor health of wiring between binary inputs and binary outputs. If binary input loses connection to any of the configured binary outputs, the device will go into Error mode. See System self-supervision chapter for more information.

6.3 Outputs

6.3.1 Binary outputs

Figure. 6.3.1 - 6. Binary output connections



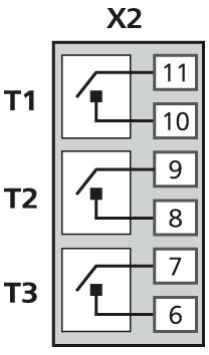
AQ-101S has three (3) binary outputs: BO1, BO2 and BO3. AQ 100 series binary outputs have an internal 24 VDC power supply. Binary outputs are used for sending overcurrent, light detection, master trip and other signals to other AQ 100 series devices in the same system. The binary output function can be configured with the DIP switches. For more information on the configuration, please refer to the DIP switch settings chapter.

AQ 100 series device's binary outputs send out sequences of pulses that are unique for each device. Binary inputs of the receiving AQ 100 series devices use these pulse messages to identify connected binary outputs. See System self-supervisionchapter for more information.

NOTICE!
Please note that the binary ouputs are polarity-sensitive.

6.3.2 Trip relays

Figure. 6.3.2 - 7. Trip relay connections

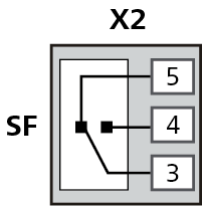


This device has three (3) normally open trip relay outputs. Trip relays T1 and T2 are used for tripping circuit breakers. T3 is a common trip relay that operates whenever T1 or T2 operates. It can be used either for tripping one additional disconnecting device, or as a trip alarm in a (local or remote) monitoring and alarming system.

T3 is always a latching relay. Trip relays T1 and T2 can be set as latching relays by setting DIP switch SW1:6 ("Latching / Non-latching") to "Latching" position.

6.3.3 System failure relay

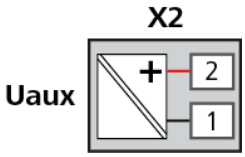
Figure. 6.3.3 - 8. System failure relay connection (de-energized position)



The system failure (SF) relay is of the change-over type (NO/NC) and it is energized when the device is in a healthy condition and powered on. Whenever the device detects a system error or the auxiliary power supply is disconnected, the SF relay changes its state. The state stays this way until the device returns to a healthy condition. See the System self-supervision chapter for more information.

6.4 Auxiliary voltage

Figure. 6.4 - 9. Auxiliary power supply connection



The auxiliary power supply voltage is 92….265 V AC/DC. Alternatively, the optional auxiliary power supply can be of 18…72 V DC. This choice must be specified when ordering.

7 Arc sensors

The AQ 100 series provides arc light point sensors and arc light fiber optic loop sensors. These sensors can be used with different devices and different switchgear types according to specific application requirements.

Arc light point sensors are typically installed in metal-clad compartments, and they provide a quick and accurate location of the fault area. Arc light fiber loop sensors typically cover a wider protected area with one fiber, when there is no need to pinpoint the exact location for a fault.

7.1 Arc light point sensor AQ-01

AQ-01 is an arc light point sensor with a light-sensitive photodiode element activated by arc light. The AQ-01 sensors should be mounted in the switchgear cubicles in such a way that the light-sensitive part covers the protected area as completely as possible. While multiple sensors can be installed, in most cases one sensor per closed metal-clad compartment is sufficient. In open spaces (such as a busbar section) the sensors should be mounted no more than two meters apart.

The default light intensity threshold for an AQ-01 sensor is 8,000 lux. Depending on the demand of the application, light point sensors can be ordered with 25,000 lux or 50,000 lux thresholds. Its detection radius is 180 degrees.

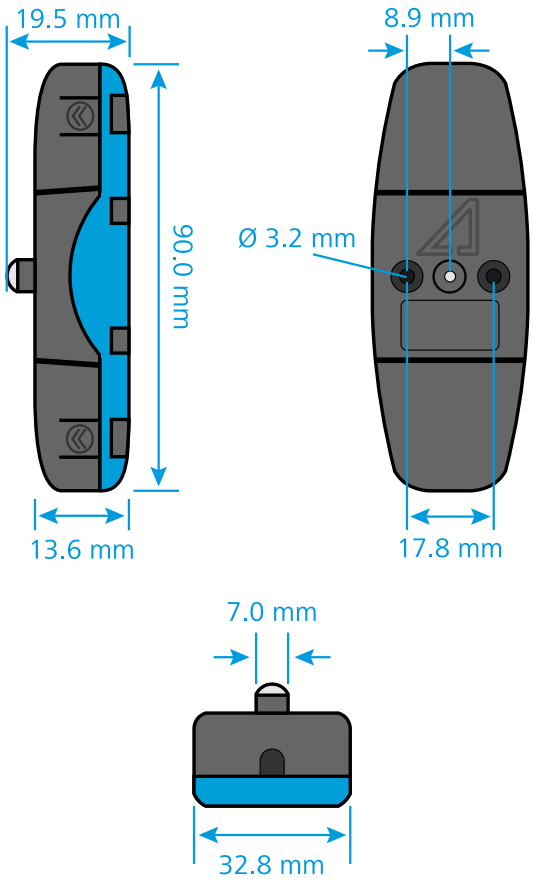
Figure. 7.1 - 10. The AQ-01 light sensor.

An AQ-01 is installed either inside or outside the compartment wall. When mounting inside the wall, the sensor is placed on the wall with the colored side against the wall and then fixed to the wall with two screws. When mounting outside the wall the sensor is placed on the wall with the grey side against the wall and the eye is pushed into the drilled compartment hole and then fixed to the wall with two screws from the back of the sensor. No external mounting plates are needed regardless of the mounting type; however, mounting brackets can be used if so desired.

Up to three (3) sensors can be connected in series (with the exception of AQ-103 which can take only one point sensor per channel). Installing a connection cable is simple as each end of the sensor has a detachable cover over the cable connectors. Please remember to reattach the cover once the wires have been installed.

NOTICE!
The AQ-01 point sensor does not come with a connection cable!

Figure. 7.1 - 11. Dimensions of arc flash sensors.



7.2 Arc light and pressure point sensor AQ-02

AQ-02 is an arc light and pressure point sensor that comes with arc light detection and ambient pressure detection. AQ-02 point sensor activates when both light and pressure are detected. The AQ-02 sensors should be mounted in the switchgear cubicles in such a way that the light-sensitive part covers the protected area as completely as possible. While multiple sensors can be installed, in most cases one sensor per closed metal-clad compartment is sufficient. The AQ-02 sensors cannot be installed in open spaces.

The default light intensity threshold for an AQ-02 sensor is 8,000 lux. Depending on the demand of the application, AQ-02 can also be ordered with 25,000 lux or 50,000 lux thresholds. Its detection radius is 180 degrees. The pressure threshold is fixed at 0.2 bar above ambient pressure.

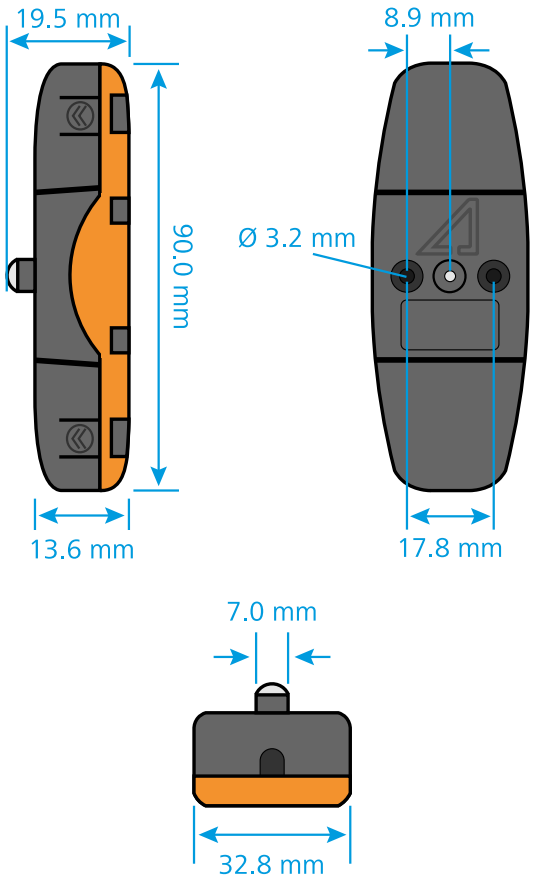
Figure. 7.2 - 12. AQ-02 arc light and pressure point sensor.

An AQ-02 can only be installed inside the compartment wall as not to block pressure detection located next to "the eye". The sensor is placed on the wall (with the colored side against the wall), and then fixed to the wall with two screws. No external mounting plates are needed regardless of the mounting type; however, mounting brackets can be used if so desired.

Up to three (3) sensors can be connected in series (with the exception of AQ-103 which can take only one point sensor per channel). Installing a connection cable is simple as each end of the sensor has a detachable cover over the cable connectors. Please remember to reattach the cover once the wires have been installed.

NOTICE!
The AQ-02 point sensor does not come with a connection cable!

Figure. 7.2 - 13. Dimensions of arc flash sensors.



7.3 Sensor dependencies

Compatibility of arc sensor types depend on the hardware available in the AQ 100 series device. The table below describes those dependencies.

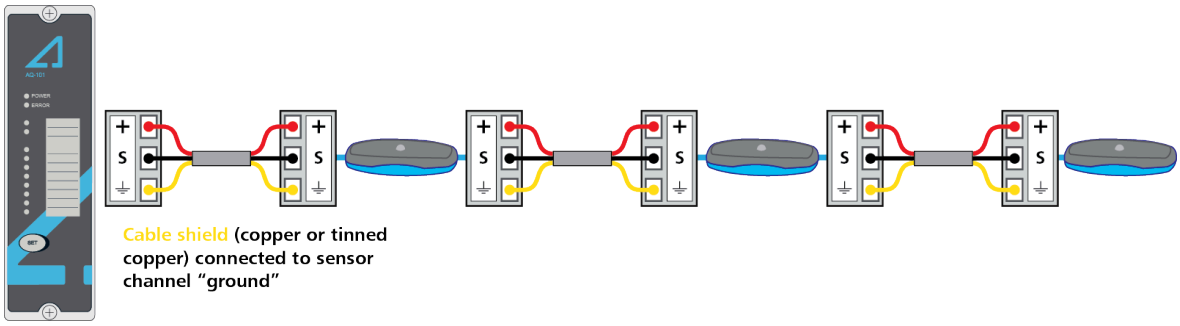
Table. 7.3 - 3. Sensor dependencies.

	Point sensors (AQ-01 & AQ-02)	Fiber loops (AQ-06, AQ-07 & AQ-08)
AQ-101	Yes	Order option
AQ-101D	Yes	Order option
AQ-101S	Yes	No
AQ-102	No	Yes
AQ-103	Yes	Order option
AQ-110P	Yes	Order option
AQ-110F	No	Yes

7.4 Wiring of point sensors

Point sensor connection with two-wire cable

Figure. 7.4 - 14. Point sensor connection with two wire cable.



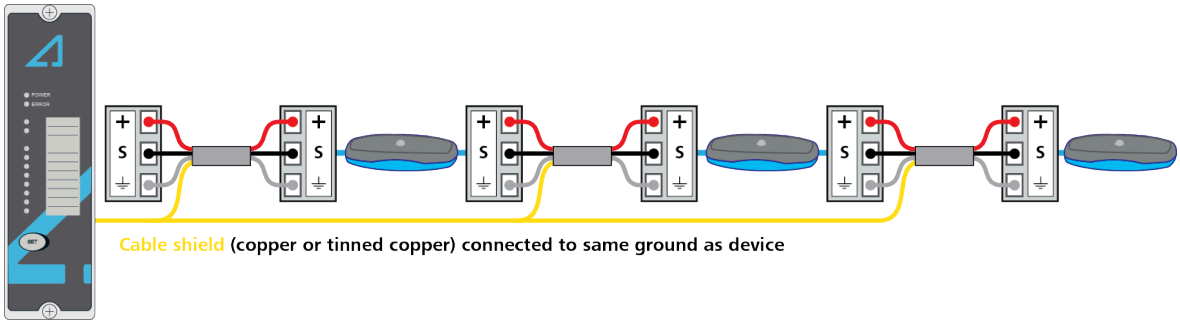
1. Open the sensor covers and detach the connectors.
2. Attach the cable to the connector and to the arc protection device.
3. Reattach the connectors to the sensor.
4. Run the auto-configuration procedure. See System setup for more details.

NOTICE!
Connect the cable shield to point sensor channel "ground" connector. Don't connect the cable shield to same ground as device.

NOTICE!
Shield of the cable must be either copper or tinned copper.

Point sensor connection with three-wire cable

Figure. 7.4 - 15. Point sensor connection with three wire cable.



1. Open the sensor covers and detach the connectors.
2. Attach the cable to the connector and to the arc protection device.
3. Reattach the connectors to the sensor.
4. Run the auto-configuration procedure. See System setup for more details.

NOTICE!
If the cable has a shield (copper or tinned copper), it is recommended to connect it to same ground as the device.

8 Operation and configuration

8.1 DIP switch settings

The DIP switches are used to easily configure various tripping logics and other functionalities for the device. The DIP switches are located at the back of the device. The figure below presents the DIP switch numbering, and the table below that gives a detailed description of the settings.

Protection logic can be defined by selecting a logic scheme with DIP switches 1 to 4. The scheme selection is based on binary arithmetic. Logic schemes are described in the next chapter.

Tripping can be set with DIP switches 7 and 8 to require either just arc light or both arc light and overcurrent simultaneously. Adding overcurrent criteria ensures the device trips when an arc fault occurs but not when a strong natural light source hits the light sensor (e.g. sunlight). Overcurrent signal comes from an external device (mainly AQ-110P or AQ-110F) and is connected to a binary input.

If the selected scheme uses CBFP (circuit breaker failure protection) its time delay (100 ms or 150 ms) can be set with DIP switch 5. CBFP logic depends on the chosen logic scheme. See Circuit breaker failure protection chapter for more information.

Figure. 8.1 - 16. DIP switch diagram.

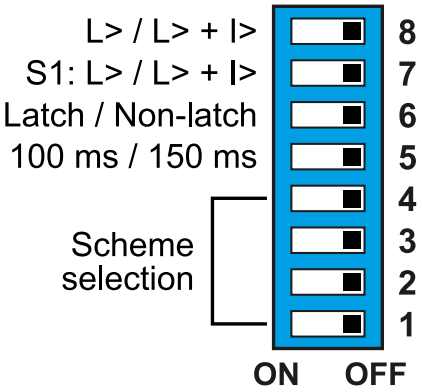


Table. 8.1 - 4. DIP switch settings.

Switch	Function selection	ON (left position)	OFF (right position)
8	The tripping criterion for the S2, S3, S4 (point sensors) and S5 (fiber loop) channels.	Tripping on light only (L>).	Light detection only trips if overcurrent is also detected at the same time (L> + I>).
7	The tripping criterion for the S1 point sensor channel.		
6	Enables or disables latching of T1 and T2 trip relays.	T1 and T2 operate as latching relays.	T1 and T2 latching is disabled.
5	The setting for the CBFP time.	The CBFP time is set to 100 ms.	The CBFP time is set to 150 ms.

Switch	Function selection	ON (left position)	OFF (right position)
4–1	Scheme selection. Please refer to the Available logic schemes chapter.	Switch 1: 1 Switch 2: 2 Switch 3: 4 Switch 4: 8	Switch 1: 0 Switch 2: 0 Switch 3: 0 Switch 4: 0

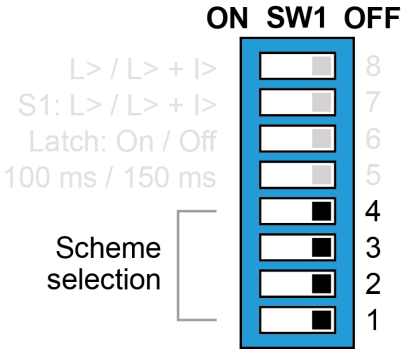
NOTICE!
The T3 trip relays is always latching. The BO1 binary output function is never latching.

8.2 Available logic schemes

The schemes described below are the most commonly used ones for AQ-101S devices. However, additional schemes are also available; please contact your nearest Arcteq representative for more information on those schemes. Most of the schemes are designed for double busbar arc protection. The schemes are configured using the DIP switches numbered 1…4 ("Scheme selection"). The scheme selection is based on binary arithmetic:

- Switch 1: 1
- Switch 2: 2
- Switch 3: 4
- Switch 4: 8

Figure. 8.2 - 17. DIP switches used for selecting the logic scheme.



AQ 100 series arc protection devices can be used as a stand-alone device or as a part of a more complex arc portection system with multiple AQ 100 series devices. The most convenient way to set the device to a more complex arc protection system is to use Standard Arc Schemes (SAS). For detailed instructions on each of the available Standard Arc Schemes please refer to the AQ-SAS™ booklet (can be found at arcteq.fi/downloads/).

8.2.1 SS:1

The logic scheme SS:1 is used for selective arc protection solutions. The point sensor channel S1 monitors the outgoing feeder cable compartment. The point sensor channel S2 monitors the corresponding outgoing feeder circuit breaker compartment. The point sensors channels S3 and S4 monitor the busbar compartment.

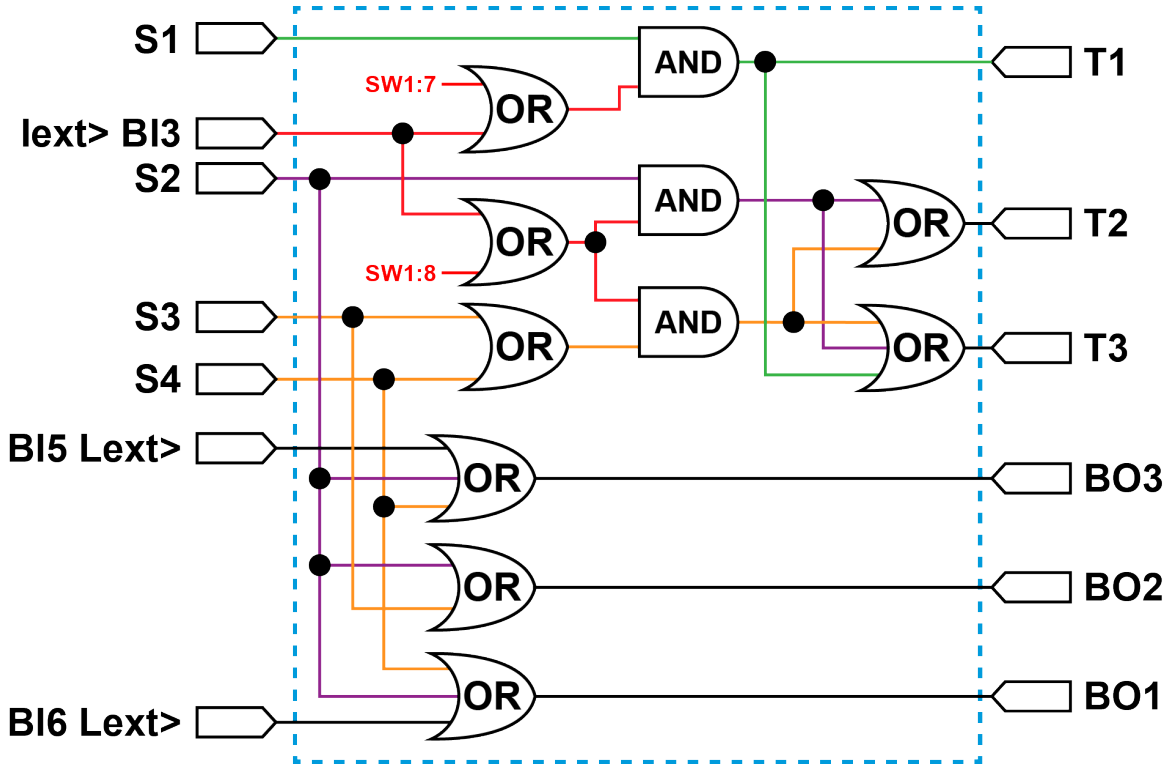
The trip contact T1 is responsible for tripping the circuit breaker of the outgoing feeder. The binary input BI3 receives overcurrent information from the incoming feeder of a connected AQ-110 device. The binary output BO1 sends light information to the incoming feeder of a connected AQ-110 device when AQ-101S detects any arc fault.

Figure. 8.2.1 - 18. Logic matrix of SS:1.

SS:1		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1	x[1]		x[1]			
	S2		x[1]	x[1]	x	x	x
	S3		x[1]	x[1]		x	
	S4		x[1]	x[1]	x		x
	BI1						
	BI2						
	BI3 I> from Main 1						
	BI4 I> from Main 2						
	BI5 Light from Main 1						x
	BI6 Light from Main 2				x		

1. Activates only if channel has been set to light only mode or overcurrent signal (BI3 or BI4) is ON.

Figure. 8.2.1 - 19. Simplified logic diagram of SS:1.



8.2.2 SS:2

The logic scheme SS:2 is used for selective arc protection solutions. The point sensor channel S2 monitors the incoming feeder circuit breaker compartment. The point sensor channel S3 monitors the reserve busbar, while the point sensor channel S4 monitors the main busbar compartment.

The trip contact T1 is responsible for tripping the section circuit breaker. The trip contact T2 is responsible for tripping the coupler circuit breaker.

The binary inputs BI1 and BI2 are responsible for recognizing the position of the incoming feeder circuit breaker. The binary input BI3 receives overcurrent information from the incoming feeder of a connected AQ-110 device. The binary inputs BI4, BI5 and BI6 are used for sending light information from the different locations of the busbar compartment.

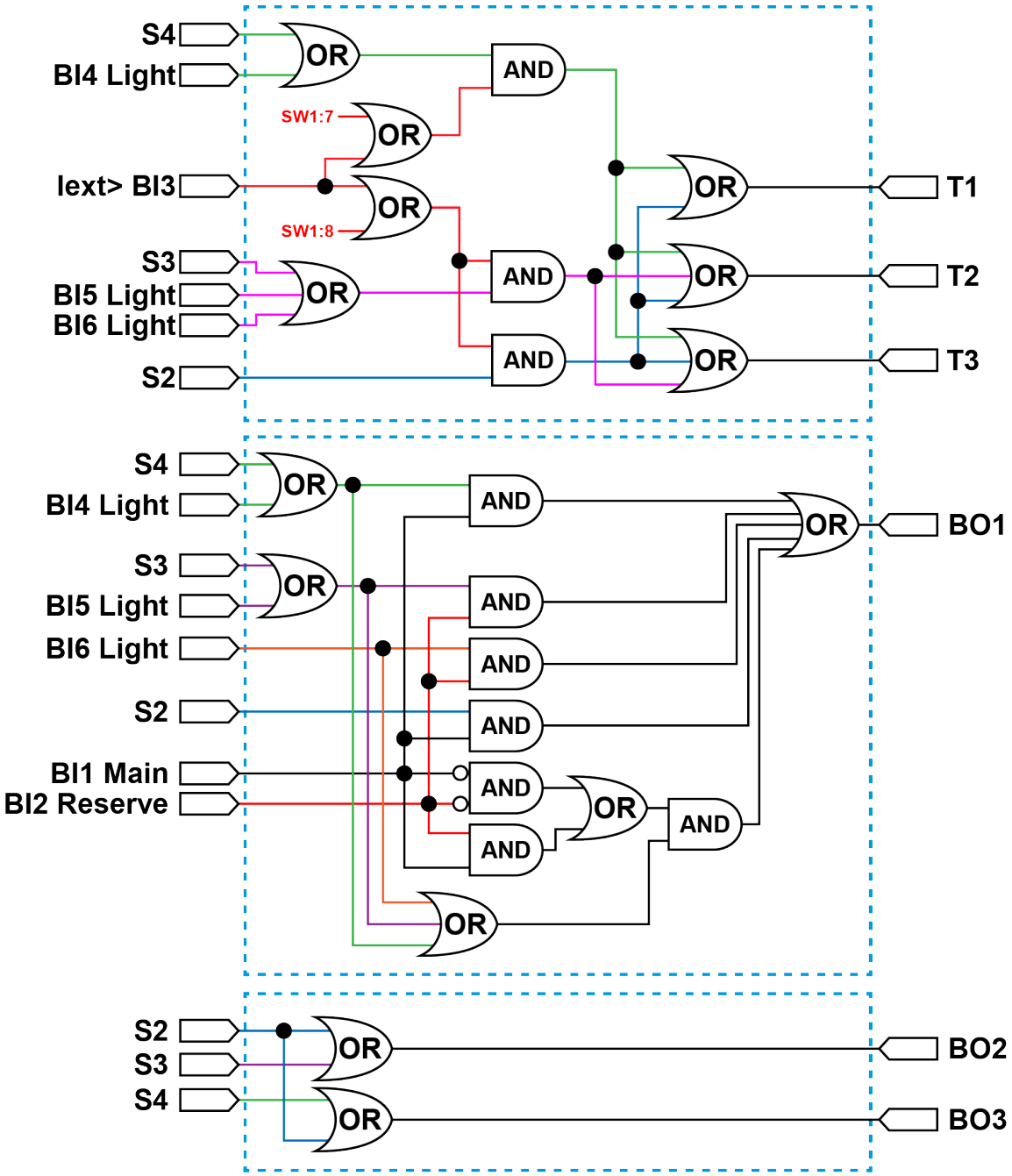
The binary outputs BO1, BO2 and BO3 send arc fault information to the incoming feeder devices and the intermediate devices.

Figure. 8.2.2 - 20. Logic matrix of SS:2.

SS:2		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1						
	S2	x[1]	x[1]	x[1]	x[2]	x	x
	S3		x[1]	x[1]	x[4]	x	
	S4	x[1]	x[1]	x[1]	x[3]		x
	BI1 Breaker to Main						
	BI2 Breaker to Reserve						
	BI3						
	BI4 Light Main	x[1]	x[1]	x[1]	x[3]		
	BI5 Light reserve (own)		x[1]	x[1]	x[4]		
	BI6 Light reserve (foreign)		x[1]	x[1]	x[4]		x

1. Activates only if channel has been set to light only mode or overcurrent signal (BI3) is ON.
2. Activates only if BI1 is ON.
3. Activates only if BI1 is ON or if both BI1 and BI2 are either ON or OFF.
4. Activates only if BI2 is ON or if both BI1 and BI2 are either ON or OFF.

Figure. 8.2.2 - 21. Simplified logic diagram of SS:2.



8.2.3 SS:3

The logic scheme SS:3 is very similar to the previous scheme (SS:2). The point sensor channel S2 monitors the incoming feeder compartment. The point sensor channel S3 monitors the reserve busbar, while the point sensor channel S4 monitors the main busbar compartment.

The trip contact T1 is responsible for tripping the section circuit breaker. The trip contact T2 is responsible for tripping the coupler circuit breaker.

The binary inputs BI1 and BI2 are responsible for recognizing the position of the incoming circuit breaker. The binary input BI3 receives overcurrent information from the incoming feeder of a connected AQ-110 device. The binary inputs BI4, BI5 and BI6 are used for sending light information from the different locations of the busbar compartment.

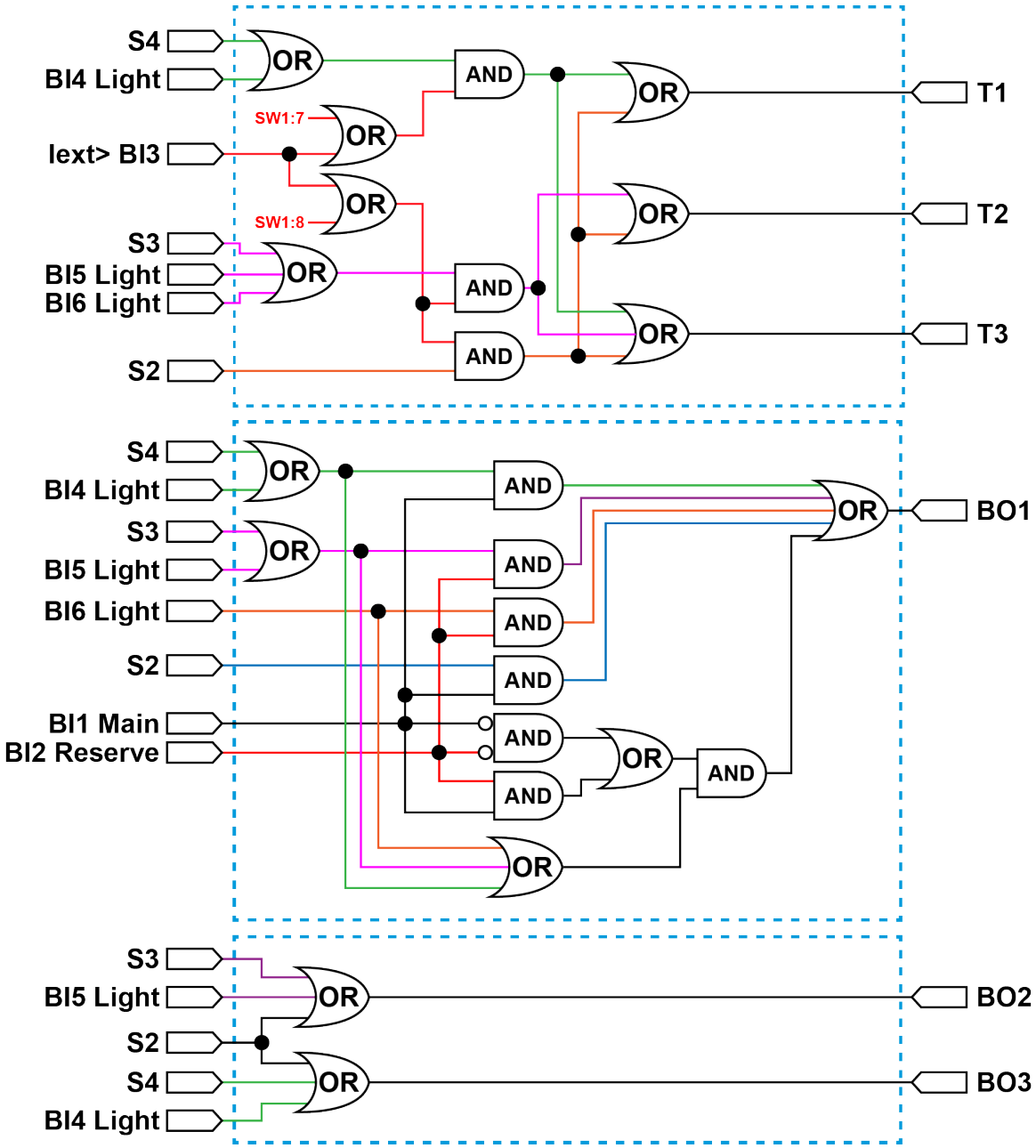
The binary outputs BO1, BO2 and BO3 send arc fault information to the incoming feeder devices and the intermediate devices.

Figure. 8.2.3 - 22. Logic matrix of SS:3.

SS:3		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1						
	S2	x[1]	x[1]	x[1]	x[2]	x	x
	S3		x[1]	x[1]	x[4]	x	
	S4	x[1]		x[1]	x[3]		x
	BI1 Breaker to Main						
	BI2 Breaker to Reserve						
	BI3						
	BI4 Light Main	x[1]		x[1]	x[3]		x
	BI5 Reserve (own)		x[1]	x[1]	x[4]	x	
	BI6 Reserve (foreign)		x[1]	x[1]	x[4]		

1. Activates only if channel has been set to light only mode or overcurrent signal (BI3) is ON.
2. Activates only if BI1 is ON.
3. Activates only if BI1 is ON or if both BI1 and BI2 are either ON or OFF.
4. Activates only if BI2 is ON or if both BI1 and BI2 are either ON or OFF.

Figure. 8.2.3 - 23. Simplified logic diagram of SS:3.



8.2.4 SS:4

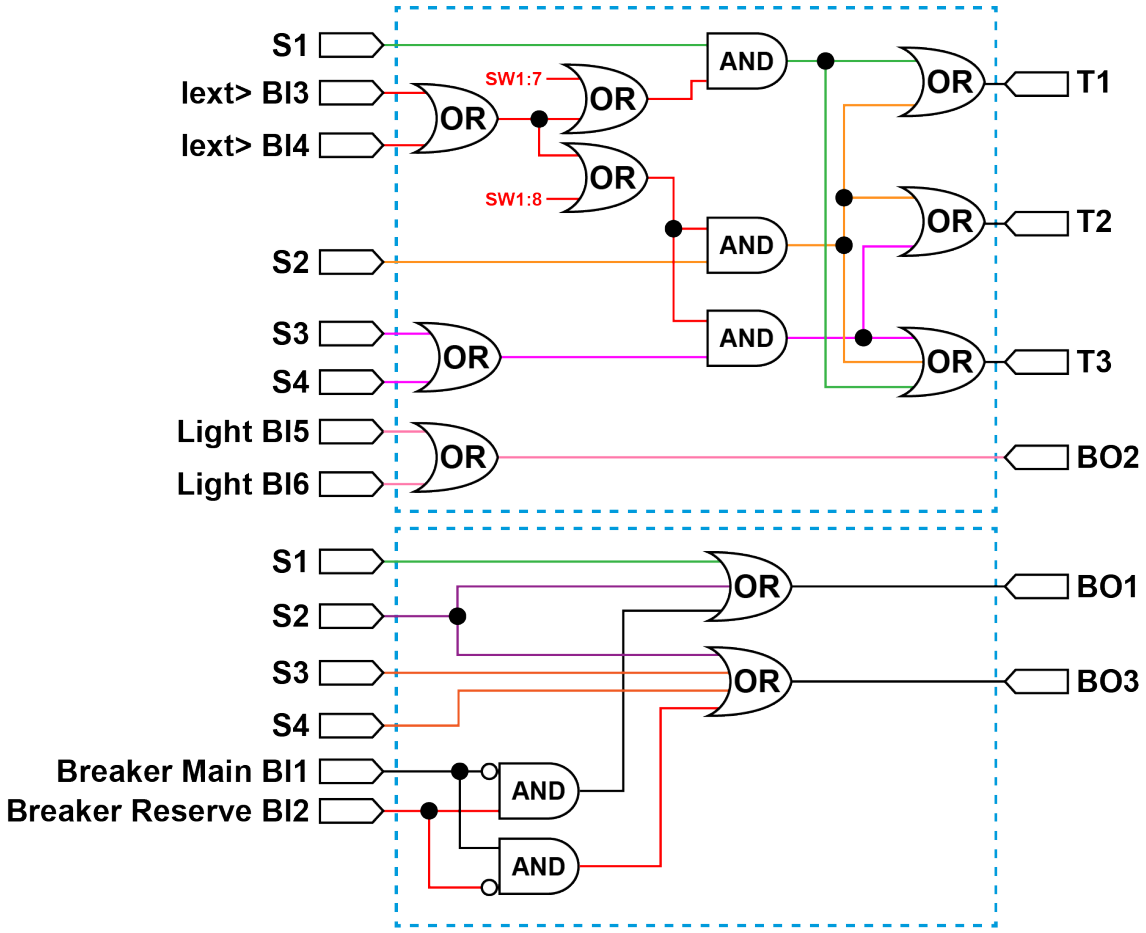
The logic scheme SS:4 is used as an intermediate device. The sensors monitor the section circuit breaker and the busbar within the section circuit breaker. The binary inputs BI3 and BI4 receive overcurrent information from two main busbar sections (BI3 from one of them, BI4 from the other). The binary outputs BO1 and BO3 represent the arc fault detected at both main busbar sections.

Figure. 8.2.4 - 24. Logic matrix of SS:4.

SS:4		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1	x[1]		x[1]	x		
	S2	x[1]	x[1]	x[1]	x		x
	S3		x[1]	x[1]			x
	S4		x[1]	x[1]			x
	BI1 Breaker to Main						
	BI2 Breaker to Reserve						
	BI3 I> from Main 1						
	BI4 I> from Main 2						
	BI5 Light from Main 1					x	x[3]
	BI6 Light from Main 2				x[2]	x	

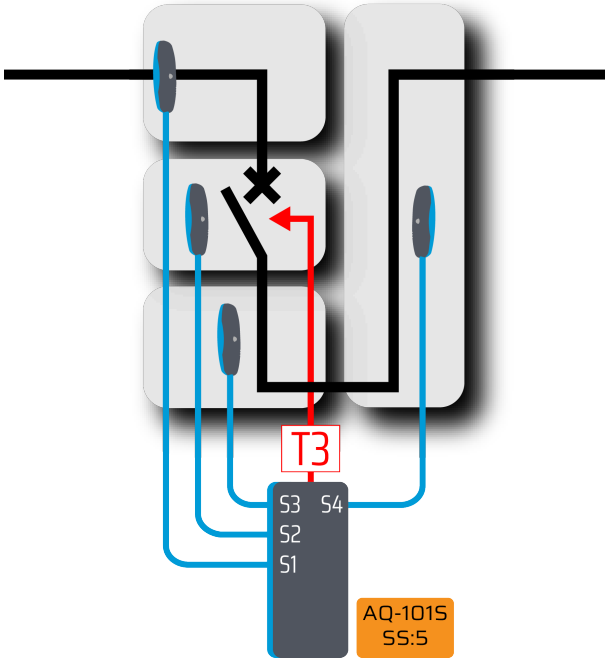
1. Activates only if channel has been set to light only mode or overcurrent signal (BI3 or BI4) is ON.
2. Activates only if BI1 is OFF.
3. Activates only if BI2 is OFF.

Figure. 8.2.4 - 25. Simplified logic diagram of SS:4.



8.2.5 SS:5

Figure. 8.2.5 - 26. Example connection for AQ-101S (SS:5).



The logic scheme SS:5 is used for arc protection solutions with a single busbar. The sensors monitor the section circuit breaker and the busbar within the section circuit breaker.

The binary inputs BI1 and BI2 receive the master trip (MT) signal from both of the incoming feeder AQ-110 devices. The binary inputs BI3 and BI4 receive overcurrent information from both of the incoming feeder AQ-110 devices.

The binary outputs BO1 and BO3 send any detected arc fault information from the busbar and the section circuit breaker to both of the incoming feeder AQ-110 devices.

You can find a more detailed description of this scheme in the AQ-SAS™ booklet.

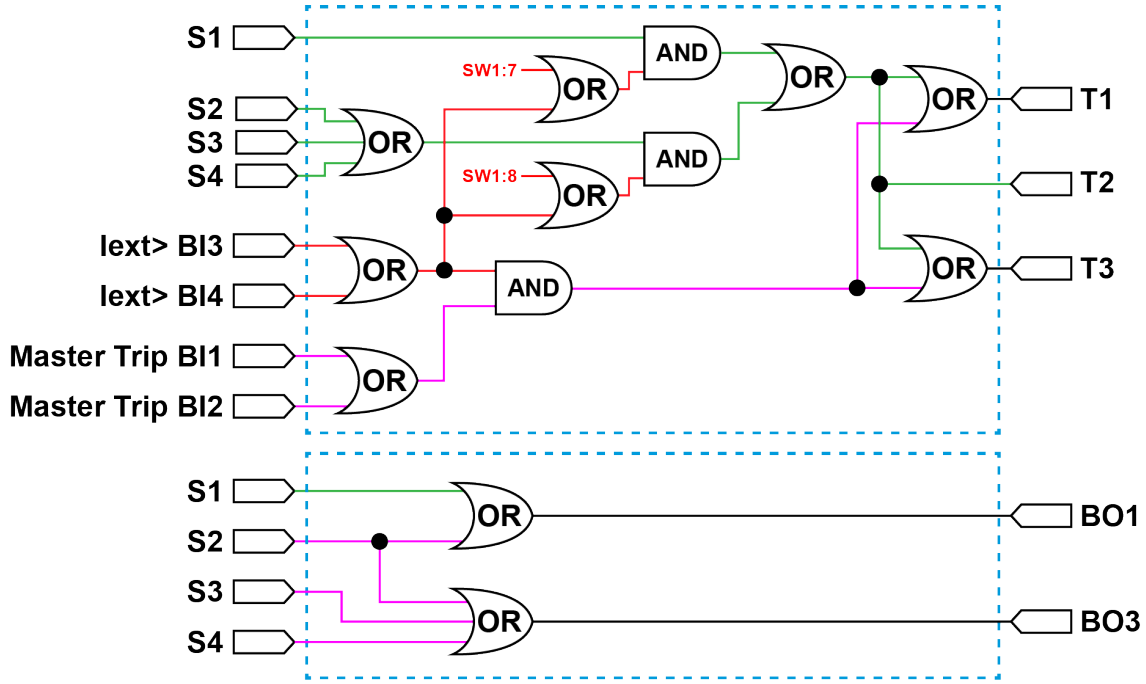
Figure. 8.2.5 - 27. Logic matrix of SS:5.

SS:5		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1	x[1]	x[1]	x[1]	x		
	S2	x[1]	x[1]	x[1]	x		x
	S3	x[1]	x[1]	x[1]			x
	S4	x[1]	x[1]	x[1]			x
	BI1 MT Incomer 1	x[2]		x[2]			
	BI2 MT Incomer 2	x[2]		x[2]			
	BI3 I> Incomer 1						
	BI4 I> Incomer 2						
	BI5						
	BI6						

1. Activates only if channel has been set to light only mode or overcurrent signal (BI3 or BI4) is ON.

2. Activates only if overcurrent signal (BI3 or BI4) is ON.

Figure. 8.2.5 - 28. Simplified logic diagram of SS:5.



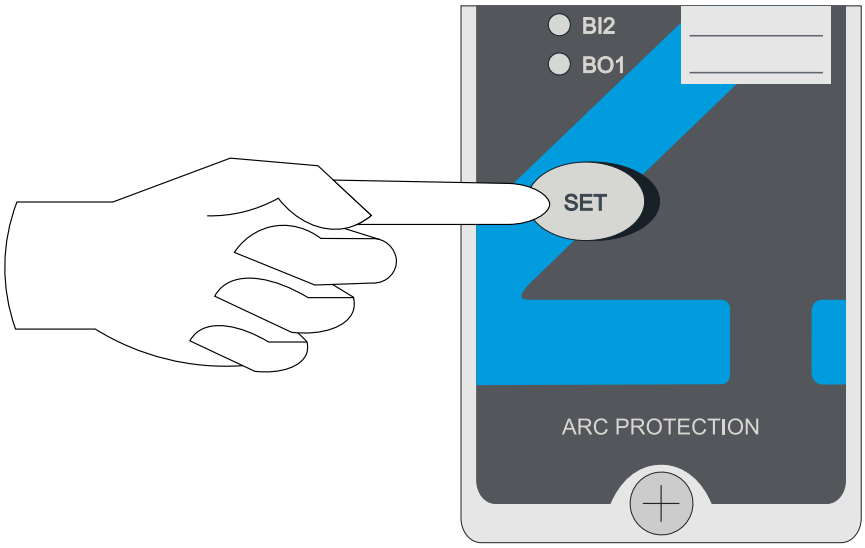
8.3 Push button (SET)

The device contains one push button, SET, and it can be used for all operational functions. The push button is used for:

1. Setting up the system (also known as auto-configuration)
2. Resetting the indicator LEDs
3. Resetting latched outputs
4. Checking the input connections

WARNING!
The SET button may require you to change the DIP switches before it works correctly. Do NOT use force when pushing the button, as this may cause the button to lodge deep inside the chassis!

Figure. 8.3 - 29. The "SET" push button on the device's front panel.



8.3.1 System setup (auto-configuration)

After DIP switches have been set to correct position and all sensors, binary inputs and binary outputs have been connected, a system setup procedure (also known as auto-configuration) must be performed. The sequence is initialized by pressing the SET push button for two seconds. This causes the sensor and binary I/O LEDs to start blinking. The device scans these inputs to see if they are connected; when an input is detected, the corresponding LED lights up to indicate that a connection was found. All inputs that are not connected continue to blink for three more seconds. Then, all LEDs are turned off. Additionally, the DIP switch setting are stored in the non-volatile memory after this sequence.

All arc sensors are operational even when they have not been auto-configured. System setup is only used for self-supervision purposes.

Please note that to reconfigure a device with fewer connections (BI/BO or arc sensors) than in the previously memorized setup, one of the DIP switches must be moved back and forth once before the system setup procedure is carried out. You can reconfigure a device with more connections at any time without having to move one of the DIP switches.

8.3.2 Reset

All LED indications and latched trip relays can be reset by pressing the SET push button.

8.3.3 Input connection check

After the system setup (auto-configuration) procedure is completed, you can verify the connectivity of all sensors and binary input channels by pressing the SET push button three (3) times within two (2) seconds. The LEDs of the corresponding sensors, binary input channels and the “Power” LED start blinking. The LEDs blink as many times as there are connected sensors and binary output channels from other devices.

8.4 Circuit breaker failure protection

The circuit breaker failure protection function is used for detecting a failure to open the circuit breaker when tripping command has been given by the arc protection relay. The CBFP function activates when the arc protection relay detects the presence of fault for a set duration (100 ms or 150 ms). In case of circuit breaker failure the arc protection relay will send a trip signal to the next available circuit breaker. Please note that if the device is set to operate on both arc light and overcurrent, both conditions must persist to activate the CBFP function. The CBFP function can be set to operate either on a 100-ms or a 150-ms delay (please refer to the DIP switch settings chapter for more information). The operation logic of CBFP function depends on the chosen logic scheme (see Scheme selection chapter for more information).

8.5 LED indicator functions

The AQ-101S device has seventeen (17) indication LEDs on the device's front panel.. Apart from the "Power" and "Error" LEDs, the user can write their own identifications for each of the remaining LEDs on the text insert located in the transparent pocket next to the LEDs.

When the device is powered up, it performs an LED test. All LEDs turn on for two (2) seconds and then turn off; only the blue "Power" LED stays on.

When the device operates normally, only the blue "Power" LED is lit.

If an arc sensor is activated, its corresponding LED turns on. Activated arc sensor LEDs will stay on until user has reset them with "SET" push button.

If there is a loose sensor wire or if the self-supervision function detects a configuration mismatch (that is, a new sensor has been attached but the auto-configuration system setup has not been run), the corresponding LED starts flashing and the "Error" LED activates.

The binary I/O LEDs indicate the status of the input and output lines. If any of the lines become active, the corresponding LED turns on. All light channel and trip indication LEDs are latched, even if the DIP switch settings are in the non-latched mode.

All LED indications are stored in the non-volatile memory (EPROM) to help identify the necessary trip information even after auxiliary power is lost. When the device is re-powered after a power supply loss, the front panel shows the status of all LEDs.

You can clear the LEDs by pushing the SET button.

8.6 LED operations guide

The table below describes the function of each indicator LED in detail.

Table. 8.6 - 5. LED operations of AQ-101S.

LED name (color)	Light off	Steady light	Blinking light	Action if abnormal
POWER (blue)	The auxiliary power supply is disconnected.	The auxiliary power supply is connected.	*(N/A)*	Check the power supply.

LED name (color)	Light off	Steady light	Blinking light	Action if abnormal
ERROR (red)	The system is healthy.	A system failure has occured.	A configuration mismatch has been detected. Protection is partially operational.	Verify the system condition (see the System self-supervision and Troubleshooting chapters)..
T1–T3 (red)	Normal status.	The trip relay has activated.	*(N/A)*	Check what caused the trip, clear the fault and reset the indicator LEDs with the push button.
BI1–BI6 (amber)	Normal status.	The binary input has been activated.	The binary input has a loose connection.	Check the binary input wiring.
BO1–BO3 (amber)	Normal status.	The binary output has been activated.	*(N/A)*	—
S1–S4 (amber)	Normal status.	Light information has activated the sensor channel.	There is a loose connection or a system setup has not been performed.	Check the sensor wire connection or perform a system setup (see the System setup chapter); or, check what activated the sensor.

8.7 Non-volatile memory

All critical system data (such as DIP switch settings and the system setup file) are stored in the non-volatile memory (EPROM) to ensure accurate operation and full self-supervision even if auxiliary power is lost temporarily.

Additionally, all LED indications are stored in the non-volatile memory to provide a quick recovery of the system status indication. This feature is especially important if tripping causes the device to lose its auxiliary power.

The non-volatile memory does not require a power supply to maintain the information and it retains the settings and the indications permanently without power.

9 System self-supervision

AQ 100 series devices have an extensive self-supervision function, including both internal functions and external connections. The self-supervision function monitors the following:

- power supply
- hardware
- software
- binary input connection(s)
- sensor connection(s)
- DIP switch settings

When the device's condition is healthy and is powered on, the "Power" LED is lit and the system failure (SF) relay is energized. If the self-supervision function detects a faulty condition or if the power supply fails, the SF relay is released and the "Error" LED becomes lit.

Point sensor connection monitoring

If a point sensor failure occurs, the device will go into Error mode. The "Error" LED turns on, the SF relay releases, and the LED of the corresponding faulty sensor channel starts blinking. In this situation the device is still operational, although the faulty sensor channel is blocked. If the error is resolved, the device automatically energizes the SF relay and turns off the "Error" LED and the blinking sensor channel LED. If one or more of the sensors are disconnected, the healthy sensors remain in use and the device remains operational accordingly. However, the device remains in Error mode until the sensors are connected again.

Binary input connection monitoring

During system setup (auto-configuration) AQ 100 series device checks how many AQ 100 device binary outputs or high-speed outputs have been connected to binary inputs. Each AQ 100 series device binary output and high-speed output constantly sends a short pulse every second which the receiving binary input uses to count the number of connected devices. If any of the outputs are disconnected after the system setup, the binary input will detect the mismatch and the device will go into Error mode and the binary input LED will blink. If the error is resolved, the device automatically clears the system failure status, energizing the SF relay and turning off the "Error" LED.

DIP switch setting monitoring

The device goes into Error mode, if a DIP switch setting is changed after the system setup procedure has been performed. However, the configured (stored) settings are still valid and the device is still operational.

10 Application examples

This device can be applied to a variety of power switchgear and controlgear layouts and technologies. This chapter describes some of the most typical applications. Please consult the AQ-SAS™ booklet (can be found at arcteq.fi/downloads/) or your nearest Arcteq representative for a solution to your particular application.

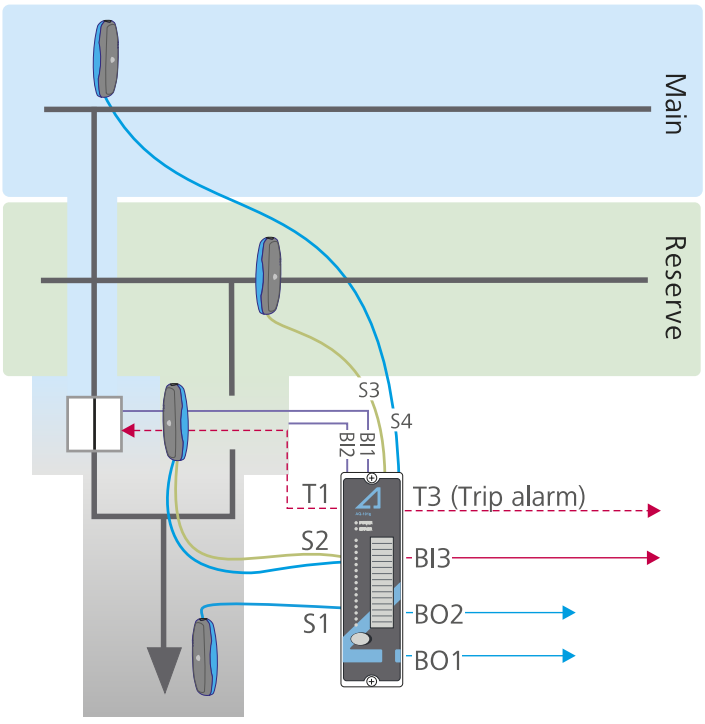
10.1 Double busbar application with overcurrent and arc light conditions (LV and MV)

AQ-101S can be used for applications that require tripping from both overcurrent (I>) and arc light (L>), where tripping is performed only when both conditions occur simultaneously. Typically, the overcurrent condition is obtained from an AQ-110 device. The I> condition can also be monitored by non-Arcteq products (such as a generic feeder protection relay); however, the total operating time depends on the device that feeds the I> signal to the AQ-101S device.

The figure below presents an example of a double busbar arc protection system (for both LV and MV) that applies both I> and L> for tripping. The S1 sensor channel typically monitors the outgoing cable compartment, while S2 monitors the circuit breaker compartment. S3 and S4 monitor the reserve busbar and the main busbar, respectively. The busbar arc light information is sent out through the BO1 (main busbar) and BO2 (reserve busbar) binary output channels.

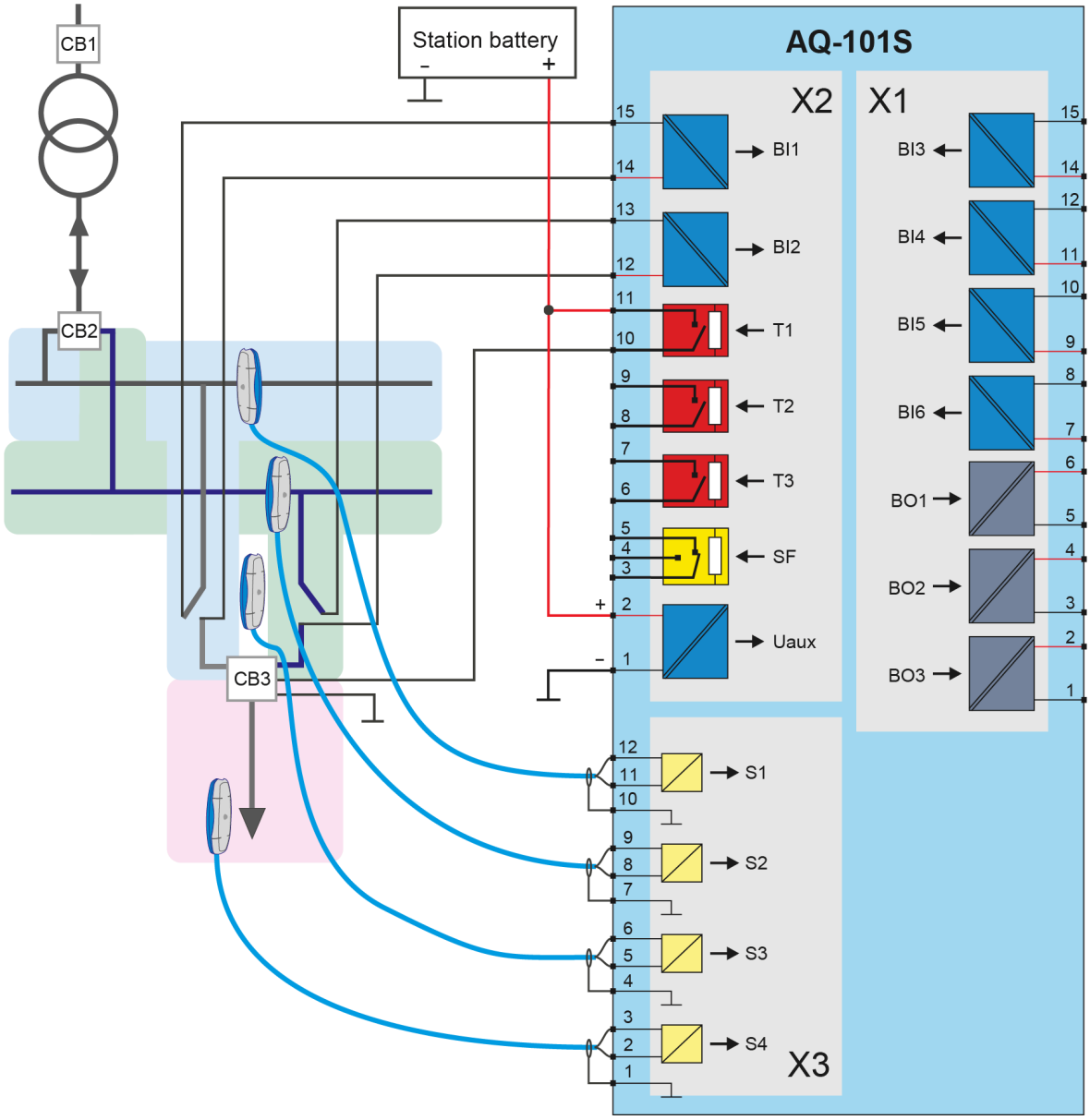
In this application, the current monitoring signal comes from an external overcurrent relay through the BI3 binary input channel. The position of the circuit breaker can be connected manually with either the main busbar or the reserve busbar. In order to indicate the circuit breaker's precise location, its position information is sent to the AQ-101S device via the BI1 (main busbar) or BI2 (reserve busbar) binary input channel. The T1 trip contact is responsible for tripping the circuit breaker. T3 gives synchronous information on the trip alarm. The connections of this example application are presented in the Wiring example chapter.

Figure. 10.1 - 30. Connections of the double busbar application for AQ-101S.



11 Wiring example

Figure. 11 - 31. Example wiring diagram for AQ-101S.



12 Dimensions and installation

The device can be either door-mounted or panel-mounted in a standard 19 inch rack. The device's dimensions (without connectors) are as follows:

- Height: 177 mm (6.97 in)
- Width: 51 mm (2.00 in)
- Depth: 168 mm (6.61 in).
-
-
-

The figure below presents the dimension of the device visually. It also shows the dimensions of the cut-out (bottom-left) required when mounting the device on a panel.

Figure. 12 - 32. Dimensions of the device and its cut-out panel.

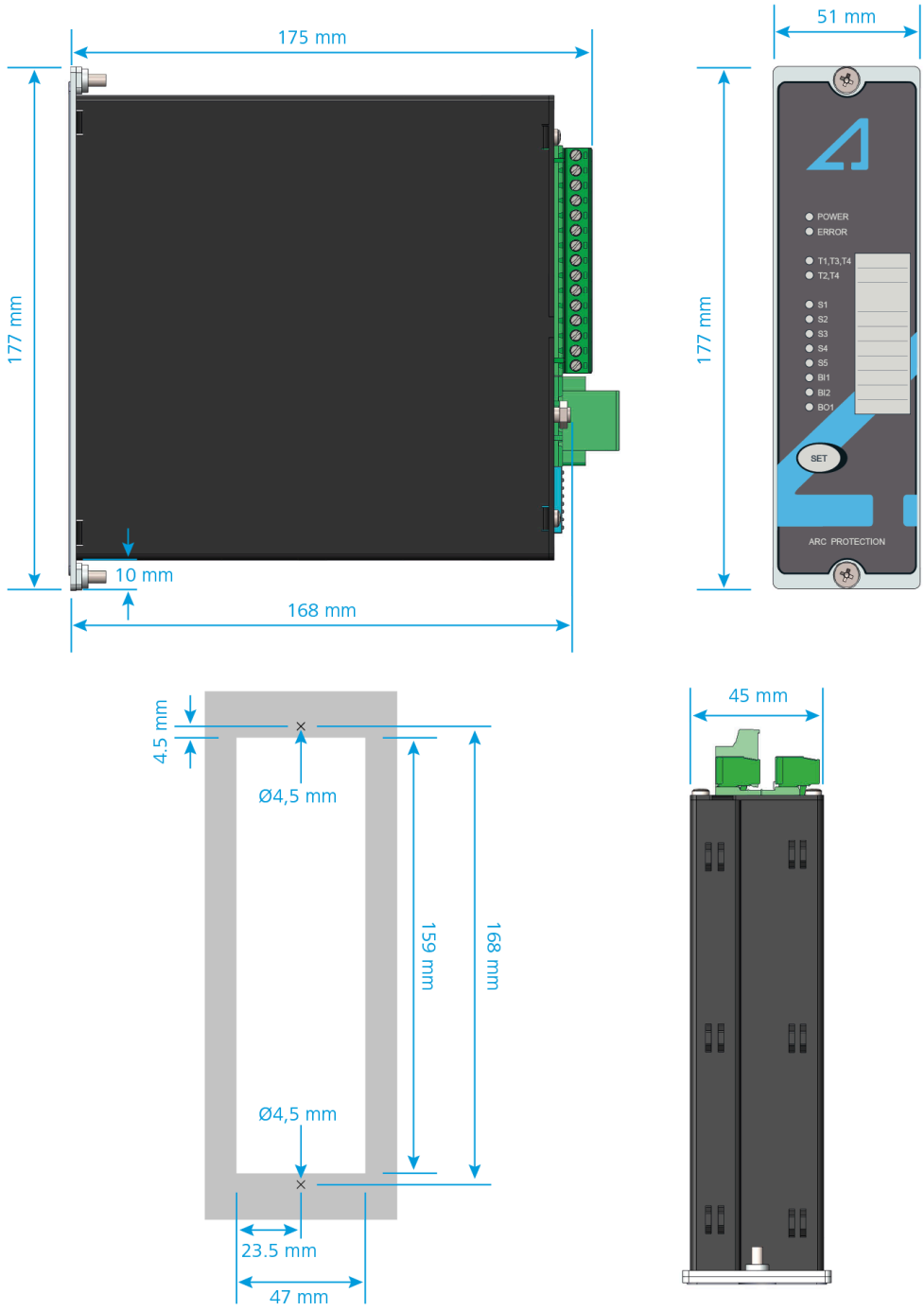
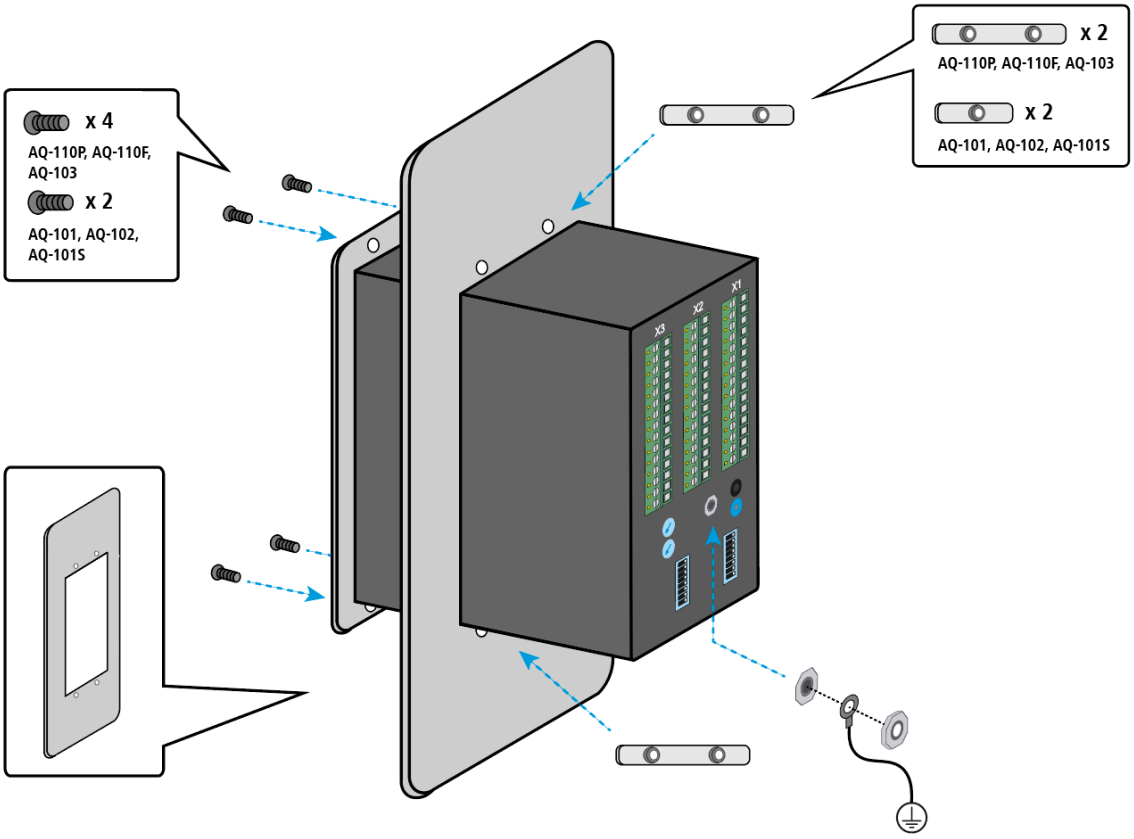


Figure. 12 - 33. Installing a AQ-100 series device to a door.



Point sensors

Figure. 12 - 34. Dimensions of arc flash sensors.

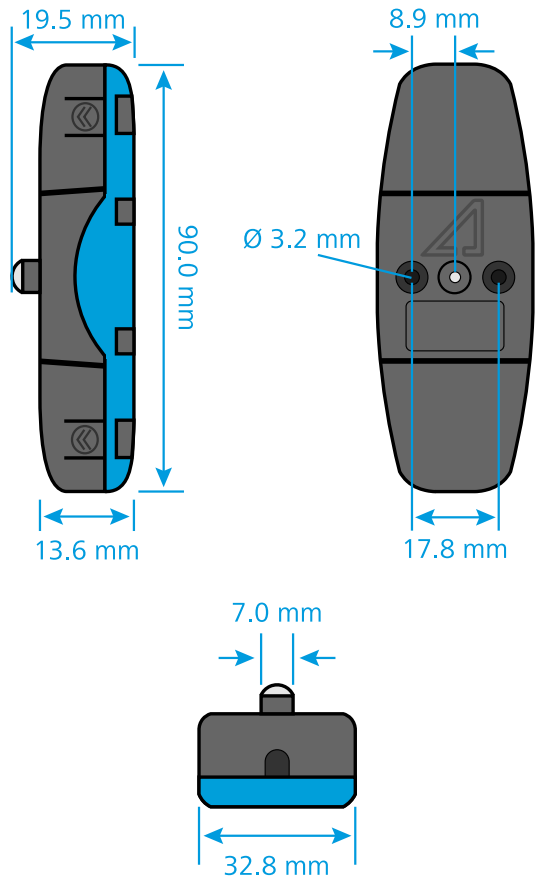
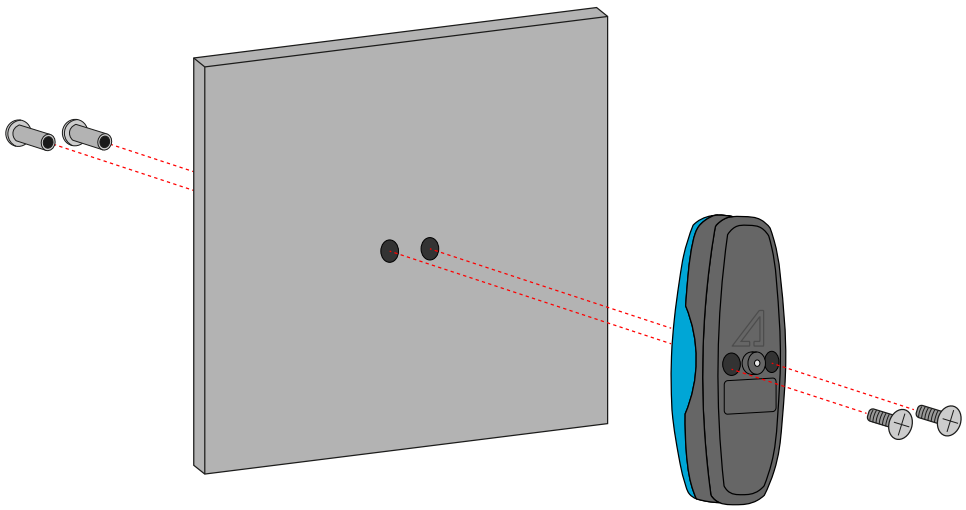


Figure. 12 - 35. Installing an arc flash sensor.



NOTICE!
Although the image above depicts the installation of an AQ-01 point sensor, please note that an AQ-02 pressure and point sensor is installed in the same way.

13 Testing

It is recommended that the device is tested prior to substation energizing. Testing is carried out by simulating an arc light for each sensor and verifying that the correct trip contact(s) tripped and that the correct indicator LED(s) turned on.

Any strong camera flash works well to simulate arc light. Please note that small LED lights like smartphone flashes are not strong enough to activate a point sensor or a fiber loop. Having a self-timer helps with the testing process because it can be connected to the test kit. Any strong flashlight works to test non-latched signals and the CBFP function. Before testing please check that the equipment used has a fully charged battery.

13.1 Testing the light-only mode

1. Check that the DIP switch settings are positioned according to your application.
2. Activate the camera flash within 30 cm (12 inches) of the sensor that is being tested.
3. Verify that the indicator LED of the corresponding sensor channel is lit.
4. Verify the activation(s) of the relay output(s) by checking the circuit breaker's status, or by monitoring the trip contact's status. The circuit breaker should open, or the contacts operate. Please note that you achieve the best test results when you operate the circuit breaker while testing.
5. Verify that the indicator LED(s) of the corresponding relay output(s) is lit.
6. If you are using any or all of the binary outputs (BO1, BO2, BO3), verify the signal activation(s) either through the status change of the relevant input, or by measuring the signal output voltage. Please note that binary outputs are of the non-latched type.
7. If you are using any or all of the binary outputs, also verify that each of the corresponding indicator LEDs are lit.
8. Press the SET push button to reset all indications and latches.
9. If you are using a binary input as the master trip, activate it and verify that the trip has occurred by repeating the steps 4 and 5.
10. Press the SET push button to reset all indications and latches.
11. Repeat the steps 1 through 10 for all sensors.

13.2 Testing the light and current mode

1. Check that the DIP switch settings are positioned according to your application.
2. Activate the following two things simultaneously: the camera flash within 30 cm (12 inches) of the sensor that is being tested, and the binary input used for the overcurrent condition (I>).
3. Verify that the indicator LED of the corresponding sensor channel is lit.
4. Verify that the indicator LED of the binary input is lit.
5. Verify the activation(s) of the relay output(s) by checking the circuit breaker's status, or by monitoring the trip contact's status. The circuit breaker should open, or the contacts operate. Please note that you achieve the best test results when you operate the circuit breaker while testing.
6. Verify that the indicator LED(s) of the corresponding relay output(s) is lit.
7. If you are using any or all of the binary outputs (BO1, BO2, BO3), verify the signal activation either through the status change of the relevant input, or by measuring the signal output voltage.
8. If you are using any or all of the binary outputs, also verify that the corresponding LEDs are lit.
9. If the DIP switches 7 and 8 are both set to the light-only mode, activate the camera flash within 20 cm (12 inches) from the sensor but do not activate the binary input used for the overcurrent condition (I>).
10. Verify that no trip has occured and only the indicator LED of the sensor activation is lit.

11. If you are using the binary output signal and have configured it to send light information, verify that it is activated.
12. Press the SET push button to reset all indications and latches.
13. If you are using a binary input as the master trip, activate it and verify that the trip has occurred by repeating the steps 5 and 6.
14. Press the SET push button to reset all indications and latches.
15. Repeat the steps 1 through 12 for all sensors.

13.3 Testing the CBFP function

The circuit breaker failure protection (CBFP) function is tested by taking the light signal and the additional trip criterion signal (if applicable) and leaving them active for longer than the set CBFP time (that is, 100 or 150 ms). Check that the correct outputs activated after the set delay time.

13.4 Testing the operation time

An operation time test is not required at commissioning as it is performed by the manufacturer both as a type test and as a routine production test. If you want to have more information of these tests, please refer to the routine test reports sent with the AQ-101S device and/or consult your nearest Arcteq representative for the type test reports.

However, if it is deemed necessary, you can conduct an on-site timing test with the following instructions.

1. Use a calibrated relay test set.
2. Connect one of the test set's outputs to a strong camera flash to initialize the flash and to configure the set's timer to start simultaneously with the flash.
3. Connect one of the AQ-101S device's trip outputs (T1, T2, T3) to a test set input and configure the input to stop the timer.
4. Place the camera flash within 30 cm (12 inches) of the sensor.
5. Initiate the flash and the timer by using the test set output.
6. Read the measured time between the simulated arc light and the operation of the trip contact.
7. Subtract the digital input delay of the test set from the final measured time (if applicable). For specific test instructions, please consult the manufacturer of the relay test set.

13.5 Test plan example

Basic data	
Date:	
Substation:	
Switchgear:	
Serial number:	

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Preconditions		Additional notes
Trip mode (channel 1):	___ L> ___ L> + I>	
Trip mode (channels 2, 3, 4):	___ L> ___ L> + I>	
CBFP in use:	___ Yes ___ No	
CBFP time setting:	___ 100 ms ___ 150 ms	

Object activated		LED active	T1, T2, T3 active	BO1 active	BO2 active	BO3 active	Additional notes
Sensor channel 1	S1						
	S2						
	S3						
Sensor channel 2	S1						
	S2						
	S3						
Sensor channel 3	S1						
	S2						
	S3						
Sensor channel 4	S1						
	S2						
	S3						
Binary inputs	BI1						
	BI2						
	BI3						
	BI4						
	BI5						
	BI6						

Involved personnel	
Tested by:	
Approved by:	

14 Troubleshooting

Table. 14 - 6. Troubleshooting guide for AQ-101 variants.

Problem	Possible solution(s)
The sensor does not activate during testing.	Check the sensor's cable wiring. or Check the testing equipment, especially the camera flash intensity (see the Testing chapter for more information).
The trip relay does not operate even when the sensor is activated.	Tripping might require overcurrent signal simultaneously with light signal. Check the DIP switch settings (see the DIP switch settings chapter for more information).

15 Technical data

15.1 Mounting and installation

Table. 15.1 - 7. Technical data for relay mounting and installation.

Panel: - material - thickness (min...max)	 metal 1.0...5.0 mm (0.04...0.20 in)
Panel mounting: - screw type - key size - tightening torque (min...max)	 ISO 14581 M4x12, galvanized Torx T20 1.5...2.0 N·m (13.3...17.7 lbf·in)
Grounding: - nut type - key size - tightening torque (min...max)	 DIN934-M5 galvanized 8 2.5...3.0 N·m (22.1...26.6 lbf·in)
Connectors X1 and X2: - connector type - wire cross section (min...max) - minimum stripping length - screw tightening torque (min...max)	 Phoenix Contact MSTB 2,5/15-ST-5,08 BD:1-15 0.2...2.5 mm^2 (24...13 AWG) 7 mm (0.28 in) 0.5...0.6 N·m (4.4...5.3 lbf·in)
Connector X3: - connector type - wire cross section (min...max) - minimum stripping length	 Phoenix Contact DFMC 1,5/6-STF-3,5 0.2...1.5 mm^2 (24...16 AWG) 10 mm (0.39 in)

15.2 Operating times

Table. 15.2 - 8. Technical data for relay operating times.

Trip time using mechanical trip relays	7 ms*
Reset time (arc light stage)	2 ms

*) The total trip time when using both the arc light (L>) or phase/residual overcurrent (I>) from an AQ-110 device and the arc light (L>) from this device.

15.3 Auxiliary voltage

Table. 15.3 - 9. Technical data for the relay auxiliary voltage (Uaux).

Auxiliary power supply	92…265 V AC/DC 18…72 V DC (optional)
Maximum power consumption	5 W, < 10 mΩ
Standby current	90 mA

Start-up inrush current	<150 ms (110 V DC) <600 ms (24 V DC)

15.4 Binary inputs

Table. 15.4 - 10. Technical data for the binary inputs (BI1, BI2, BI3, BI4, BI5, BI6).

Nominal threshold voltage	24 V DC
Threshold: - pick-up - drip-off	 Approximately 16 V DC or 88 V DC or 178 V DC Approximately 15 V DC or 75 V DC or 155 V DC
Rated current	3 mA
Number of inputs	6

15.5 Trip relays

Table. 15.5 - 11. Technical data for the trip relays (T1, T2, T3).

Number of trip relays	3 NO
Voltage withstand	250 V AC/DC
Carry: - continuous carry - make-and-carry for 3 s - make-and-carry for 0.5 s	 5 A 16 A 30 A
Breaking capacity DC*	40 W (0.36 A at 110 V DC)
Contact material	AgNi 90/10

*) When the time constant L/R = 40 ms.

15.6 Binary output(s)

Table. 15.6 - 12. Technical data for the binary outputs (BO1, BO2, BO3).

Number of outputs	3
Rated voltage	+24 V DC (internal power supply)
Rated current (max.)	20 mA

15.7 System failure relay

Table. 15.7 - 13. Technical data for the system failure relay (SF).

Number of SF relays	1

Rated voltage	250 V AC/DC
Carry: - continuous carry - make-and-carry for 3 s - make-and-carry for 0.5 s	 5 A 16 A 30 A
Breaking capacity DC*	40 W (0.36 A at 110 V DC)
Contact material	AgNi 90/10

*) When the time constant L/R = 40 ms.

15.8 Point sensors

AQ-01 point sensor

Table. 15.8 - 14. Technical data for the AQ-01 light point sensor.

Light intensity threshold	8,000 lux 25,000 lux 50,000 lux
Detection radius	180º
Mechanical protection	IP 20
Sensor cable specification	Shielded twisted pair 0.75 mm^2 (AWG: 18)
Maximum sensor cable length (per channel)	200 m
Operating temperature	–20…+85 ºC

AQ-02 point sensor

Table. 15.8 - 15. Technical data for the AQ-02 light and pressure point sensor.

Light intensity threshold	8,000 lux 25,000 lux 50,000 lux
Pressure threshold (fixed)	0.2 bar above ambient pressure
Pressure measuring accuracy	±1.8 % (of full scale)
Detection radius	180º
Mechanical protection	IP 20
Sensor cable specification	Shielded twisted pair 0.75 mm^2 (AWG: 18)
Maximum sensor cable length (per channel)	200 m
Operating temperature	–20…+85 ºC

15.9 Disturbance tests

Table. 15.9 - 16. Technical data for the disturbance tests.

Electromagnetic compatibility test	CE-approved and tested according to EN 50081-2 and EN 50082-2
Conducted emission (EN 55011, class A)	0.15…30.00 Hz
Radiated emission (EN 55011, class A)	30.00…1,000.00 MHz
Electrostatic discharge immunity (IEC 244-222 and EN 61000-4-2, level 4)	Air discharge: 15 kV Contact discharge: 8 kV
Electrical fast transients (EN 61000-4-4, class III & IEC 801-4, level 4)	Power supply input: 4 kV, 5/50 ns Other inputs and outputs: 4 kV, 5/50 ns
Surge immunity (EN 61000-4-5, level 4)	Between wires: 2 kV, 1.2/50 µs Between wire and earth: 4 kV, 1.2/50 µs
RF electromagnetic field (EN 61000-4-3, level 3)	f = 80…1,000 MHz, 10 V/m
Conducted RF field (EN 61000-4-6, level 3)	f = 150 kHz…80 MHz, 10 V/m

15.10 Voltage tests

Table. 15.10 - 17. Technical data for the voltage tests.

Insulation test voltage (IEC 60255-5)	2 kV, 50 Hz, 1 min
Impulse test voltage (IEC 60255-5)	5 kV, 1.2/50 µs, 0.5 J

15.11 Mechanical tests

Table. 15.11 - 18. Technical data for the mechanical tests.

Vibration test	2…13.2 Hz (± 3.5 mm) 13.2…100 Hz (±1.0 g)
Shock/bump test (IEC 60255-21-2)	20 g and 1,000 bumps/dir.

15.12 Environmental conditions

Table. 15.12 - 19. Technical data for the environmental conditions.

Specified ambient service temperature	–35…+70 ºC
Transportation and storage temperature	–40…+70 ºC

Relative humidity	Up to 97 %
Altitude	Up to 2,000 m above sea level

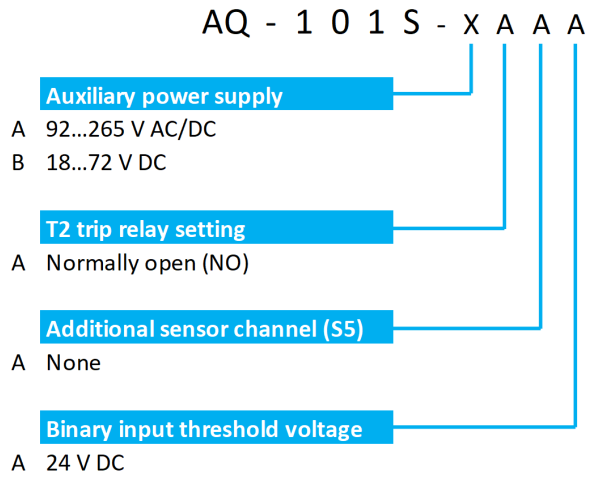
15.13 Casing

Table. 15.13 - 20. Technical data for the device casing.

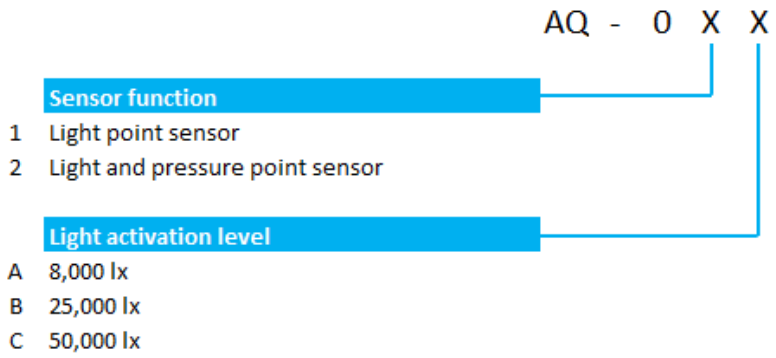
Protection: - front - back	 IP 50 IP 20
Device dimensions (W × H × D)	50 × 177 × 161 mm
Weight	0.7 kg

16 Ordering information

AQ-101S point sensor device



AQ-0x point sensors



Accessories

Order code	Description	Note	Manufacturer
AQX006	Wall mounting bracket	For AQ-103 and AQ-110x variants (MV and LV).	Arcteq Ltd.
AQX016	Wall mounting bracket	For AQ-101, AQ-101S and AQ-102 devices (MV and LV).	Arcteq Ltd.

17 Contact and reference information

Manufacturer

Arcteq Relays Ltd.

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