AQ-101S

Arc flash protection unit

Instruction manual

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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.

2 Abbreviations

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

QD – quenching device

RF – radio frequency

Rx – receiver

SAS – standard arc scheme

SF – system failure

Tx – transceiver

µP - microprocessor

3 General

The AQ-101S point sensor device is a sophisticated microprocessor-based arc flash protection unit that includes complete self-supervision. The device is designed to minimize the damage caused by an arcing fault (arc flash) by tripping the circuit breaker which supplies current to the fault. The complete system self-supervision functionality of AQ-101S provides the highest level of dependability as it continuously monitors all internal system functions as well as all external connections.

The AQ-101S device 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.

3.1 Unit features

AQ-101S is a multipurpose arc flash protection unit and 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 unit, or it can be a part of a more complex arc protection system through a binary bus.

The following list presents the main features of the unit:

- 92…265 V AC/DC auxiliary power supply or 18…72 V DC auxiliary power supply (optional)
- four (4) arc point sensor channels
- six (6) binary inputs with nominal operation voltage of 24, 110, or 220 V DC
- two (2) normally open trip relay outputs
- one (1) normally open trip relay output or one (1) normally closed trip relay output (electronic lock-out)
- three (3) binary output (24 V DC)
- one (1) system failure output
- seventeen (17) indication LEDs
- one (1) push button.

Figure. 3.1 - 1. Arc protection unit AQ-101S.

3.2 Dimensions and installation

AQ-101S can be either door-mounted or panel-mounted in a standard 19 inch rack. The unit's dimensions (without cards) are as follows:

- Height: 157 mm (6.18 in)
- Width: 50 mm (1.97 in)
- Depth: 160 mm (6.30 in).

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

Figure. 3.2 - 2. Dimensions of the device.
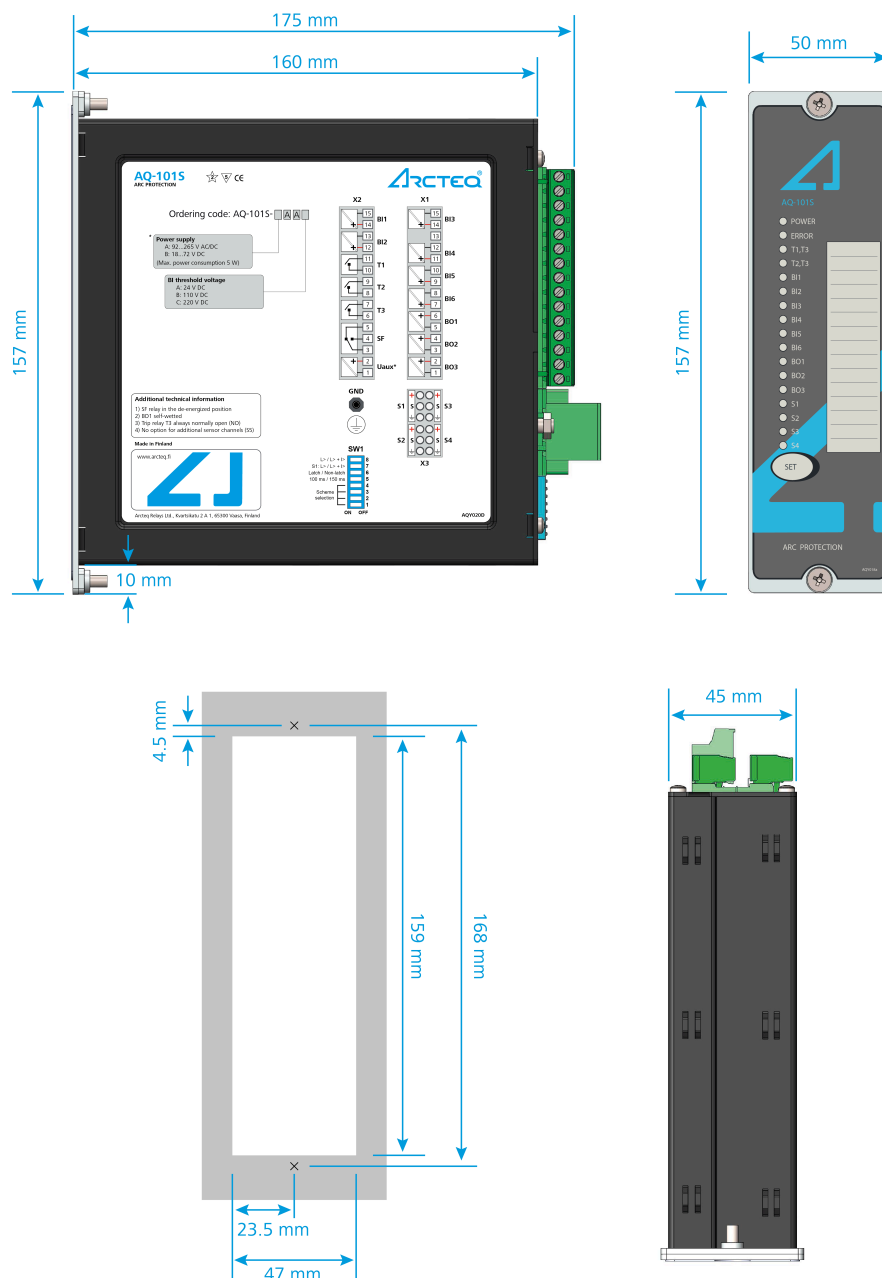
The following image illustrates how a unit is installed into a cut-out. Please note that as AQ-101S is narrower than the unit in the image, it is connected to the cut-out panel by a single screw on both the top and the bottom of the front panel instead of the two depicted below.

Figure. 3.2 - 3. Installing a unit into a cut-out.

3.3 Simplified block diagram

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

Figure. 3.3 - 4. Simplified block diagram of AQ-101S.
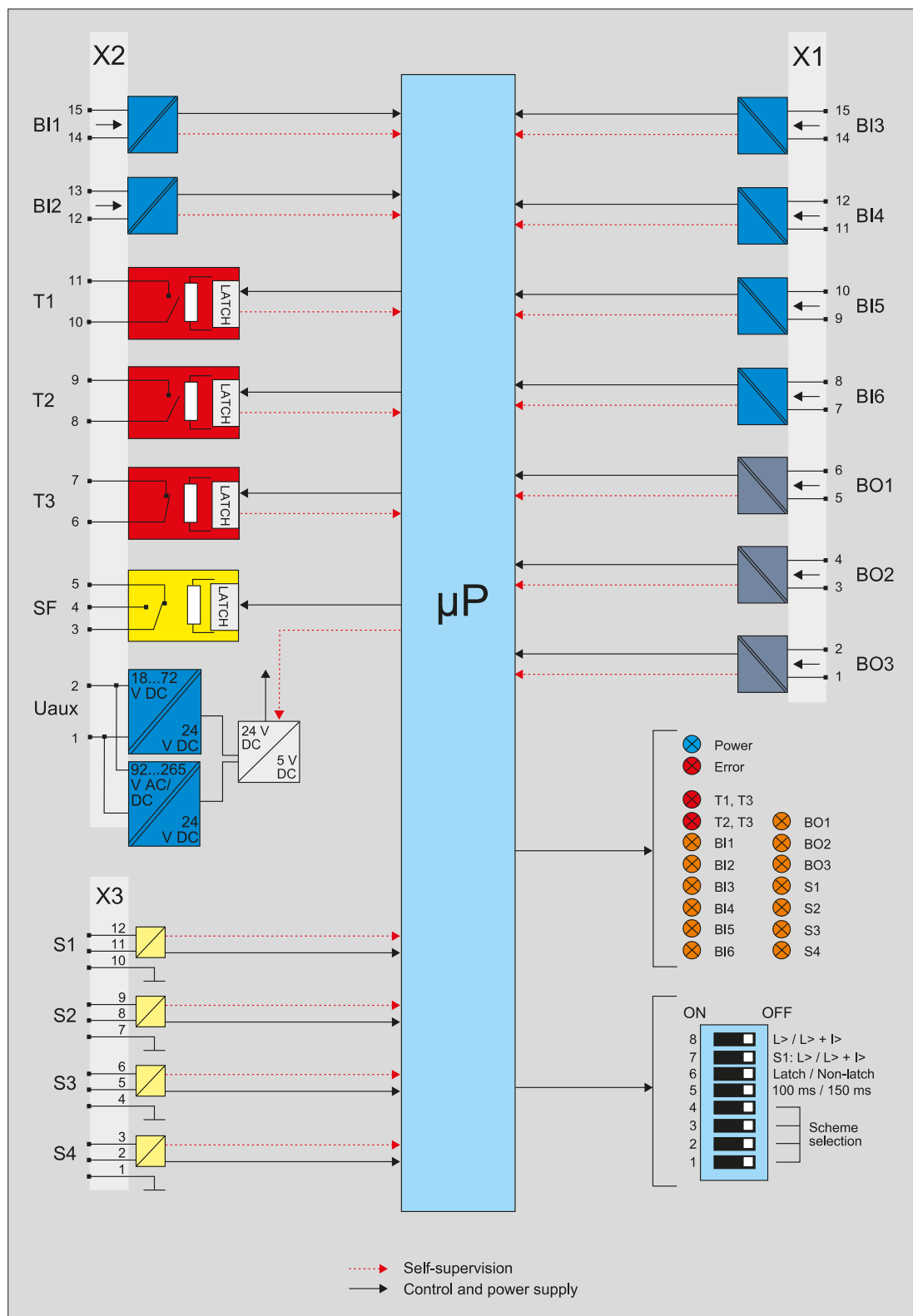
NOTE!

Please note that the latching (or non-latching) of trip relays T1 and T2 is determined with the DIP switch (SW1:6). The trip relay T3 is always latched.

The binary output BO1 is always non-latched!

3.4 Wiring

Figure. 3.4 - 5. Wiring diagram for AQ-101S.
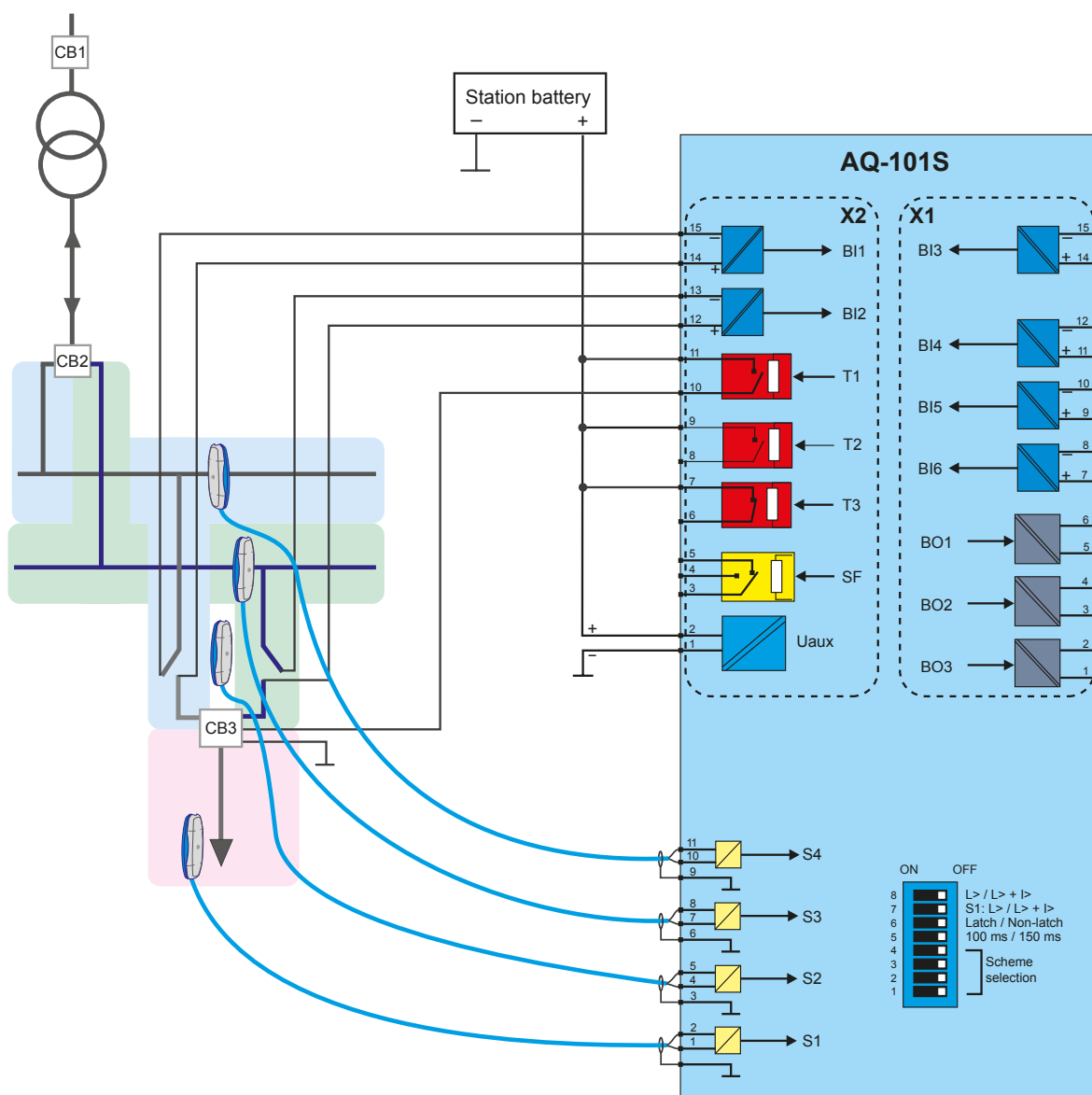
4 Operation and configuration

4.1 LED indicator functions

The AQ-101S unit has seventeen (17) indication LEDs. 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. The LEDs are on the unit's front panel to allow for a clear view without a separate need to open doors.

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

The LEDs of inactive sensors are off. If an arc sensor is activated for longer than 1.5 ms, its corresponding LED turns on. The activation function of the sensor LEDs is latched when the LED's light is not blinking.

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 for longer than 1.5 ms, the corresponding LED turns on (that is, they become latched). This also happens when a trip situation occurs. The trip outputs are controlled with DIP switch settings. All activation 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 if auxiliary power is lost. When the unit 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.

4.2 LED operations guide

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

Table. 4.2 - 3. 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.
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; <u>or</u>, pressure information has activated the sensor channel (when using an AQ-02 point sensor). | Check the sensor wire connection or perform a system setup (see the "System setup" chapter); <u>or</u>, check what activated the sensor. |

4.3 Push button (SET)

The unit contains one push button, SET, and it can be used for all operational functions. The push button is used for setting up the system (also known as auto-configuration), for resetting the indicator LEDs and the latched output relays, as well as for checking the input connection.

Figure. 4.3 - 6. The "SET" push button on the device's front panel.
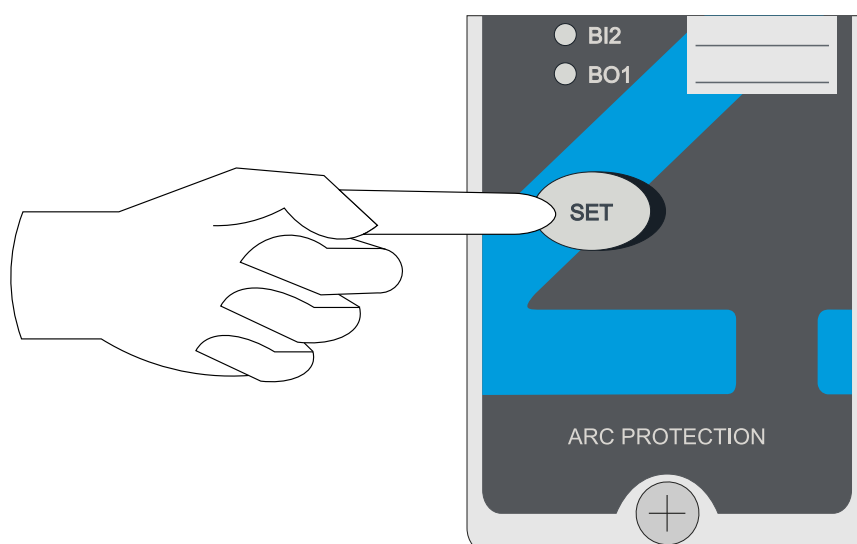
4.3.1 System setup (auto-configuration)

After all sensors and binary lines 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 LEDs to start blinking. The unit scans these inputs to see if they are connected; when an input is detected, the corresponding LED lights up to mark 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 during this sequence.

All sensor inputs remain operational even when they have not been auto-configured. System setup is only used for self-supervision purposes.

Please note that to reconfigure a unit with fewer connections (BI/BO or 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. After this, you must wait one minute before you begin the new auto-configuration sequence.

You can reconfigure a unit with more connections at any time without the wait and without having to move one of the DIP switches.

4.3.2 Reset

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

Unless the button is pressed, the latched trip relays remain active until the auxiliary power is disconnected. All LED indications also remain active even when the auxiliary power supply is disconnected unless the button is pressed. Please refer to the "Non-volatile memory" chapter for more information.

4.3.3 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 and binary input channels start blinking while the "Power" LED is already blinking. The LEDs blink as many times as there are connected sensors and binary output channels from other units.

4.4 DIP switch settings

The DIP switches are used to configure the unit's tripping logic and other functionalities. The various trip schemes can be programmed easily by selecting the appropriate DIP switch positions, which allows for more flexibility when changing the settings depending on the application. However, the most convenient way to set the unit or a more complex arc protection system is to use Standard Arc Schemes (SAS).

Tripping can be based on arc light only, or on both arc light and current thresholds, or on other tripping criteria (such as undervoltage, etc.). Current threshold and other tripping criteria can also be applied to BI1 to block tripping caused by natural light sources. The CBFP (circuit breaker failure protection) scheme can also be enabled with the DIP switches. The DIP switch's pins 1…4 are used for selecting schemes, and their numbering is based on binary arithmetic.

The DIP switches are located at the back of the unit for easy access. The figure below presents the DIP switch numbering, and the table below that gives a detailed description of the settings.
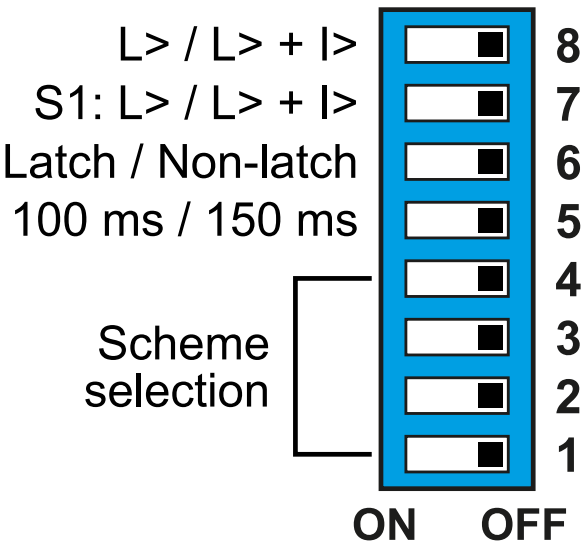
Figure. 4.4 - 7. DIP switch diagram.

Table. 4.4 - 4. DIP switch settings.

Pin number (name)	Function selection	ON (left position)	OFF (right position)
8 (L> or L> + I>)	The tripping criterion for the S2, S3, S4 (sensor) and S5 (fiber) channels.	Tripping on light only (L>).	Tripping on light and overcurrent (L> + I>), both of which are required to occur simultaneously to trigger tripping.
7 (S1: L> or L> + I>)	The tripping criterion for the S1 sensor channel.	Tripping on light only (L>).	Tripping on light and overcurrent (L> + I>), both of which are required to occur simultaneously to trigger tripping.
6 (Latch or Non-latch)	Latching or non-latching for the T1 and T2 trip relays.	T1 and T2 operate as latched.	T1 and T2 operate as non-latched.
5 (100 ms or 150 ms)	The setting for the CBFP time.	The CBFP time is set to 100 ms.	The CBFP time is set to 150 ms.
4 (scheme select)	Scheme selection.	Please refer to the "Scheme selection" and "Application examples" chapters.	Please refer to the "Scheme selection" and "Application examples" chapters.
3 (scheme select)	Scheme selection.	Please refer to the "Scheme selection" and "Application examples" chapters.	Please refer to the "Scheme selection" and "Application examples" chapters.
2 (scheme select)	Scheme selection.	Please refer to the "Scheme selection" and "Application examples" chapters.	Please refer to the "Scheme selection" and "Application examples" chapters.
1 (scheme select)	Scheme selection.	Please refer to the "Scheme selection" and "Application examples" chapters.	Please refer to the "Scheme selection" and "Application examples" chapters.

NOTE!

The T3 trip relays is always latched. The BO1 binary output function is always non-latched.

4.4.1 Scheme selection

This chapter describes the schemes that are available to this unit. The schemes are configured using the DIP switches numbered 1…4 ("Scheme selection"). Most of the schemes are designed for double busbar arc protection. For detailed instructions on each of the available schemes please refer to the AQ-SAS™ booklet (can be found at arcteq.fi/downloads/). Please note that there are four booklets: two are for schemes based on IEC standards (MV and LV versions) and the other two for schemes based on ANSI standards (MV and LV versions).

4.4.2 Available logic schemes

The schemes described below are the most important ones for this unit. However, additional schemes are also available; please contact your nearest Arcteq representative for more information on those schemes.

SS:1

The logic scheme SS:1 is used for selective arc protection solutions. The point sensor S1 monitors the outgoing feeder cable compartment. The point sensor S2 monitors the corresponding feeder breaker compartment. The point sensors 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-110P unit. The binary output BO1 sends light information to the incoming feeder of a connected AQ-110P unit when AQ-101S detects any arc fault.

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

Figure. 4.4.2 - 8. The logic diagram of SS:1.
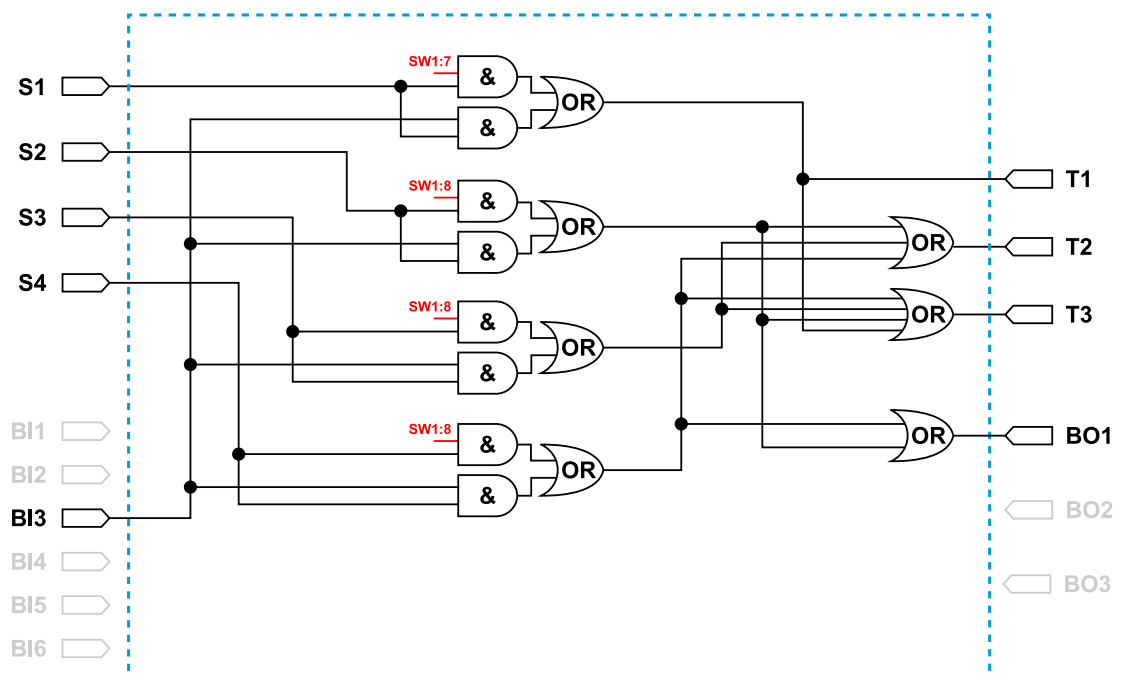
Figure. 4.4.2 - 9. The DIP switch settings of SS:1.
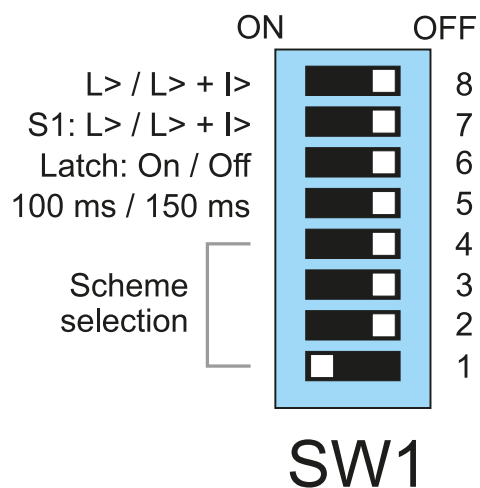
Figure. 4.4.2 - 10. The trip logic matrix of SS:1.

SS:1		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1	x		x			
	S2		x	x	x		
	S3		x	x			
	S4		x	x	x		

SS:2

The logic scheme SS:2 is used for selective arc protection solutions. The point sensor S2 monitors the incoming feeder breaker compartment. The point sensor S3 monitors the reserve busbar, while the point sensor 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-110P unit. 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 units and the intermediate units.

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

Figure. 4.4.2 - 11. The logic diagram of SS:2.

Figure. 4.4.2 - 12. The DIP switch settings for SS:2.
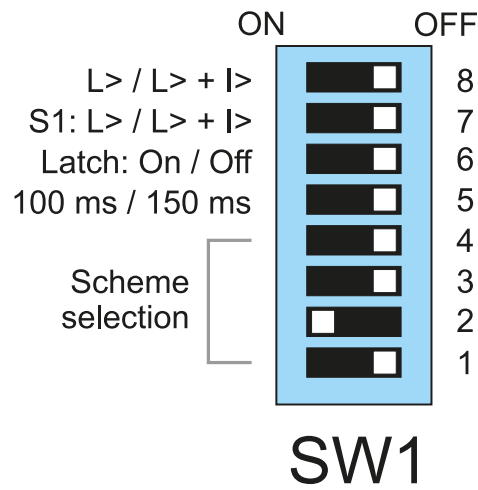
Figure. 4.4.2 - 13. The trip logic matric of SS:2.

SS:2		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1						
	S2	x	x	x	x	x	x
	S3		x	x	x	x	
	S4	x	x	x	x		x

SS:3

The logic scheme SS:3 is very similar to the previous scheme (SS:2). The point sensor S2 monitors the incoming feeder compartment. The point sensor S3 monitors the reserve busbar, while the point sensor 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-110P unit. 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 units and the intermediate units.

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

Figure. 4.4.2 - 14. The logic diagram of SS:3.
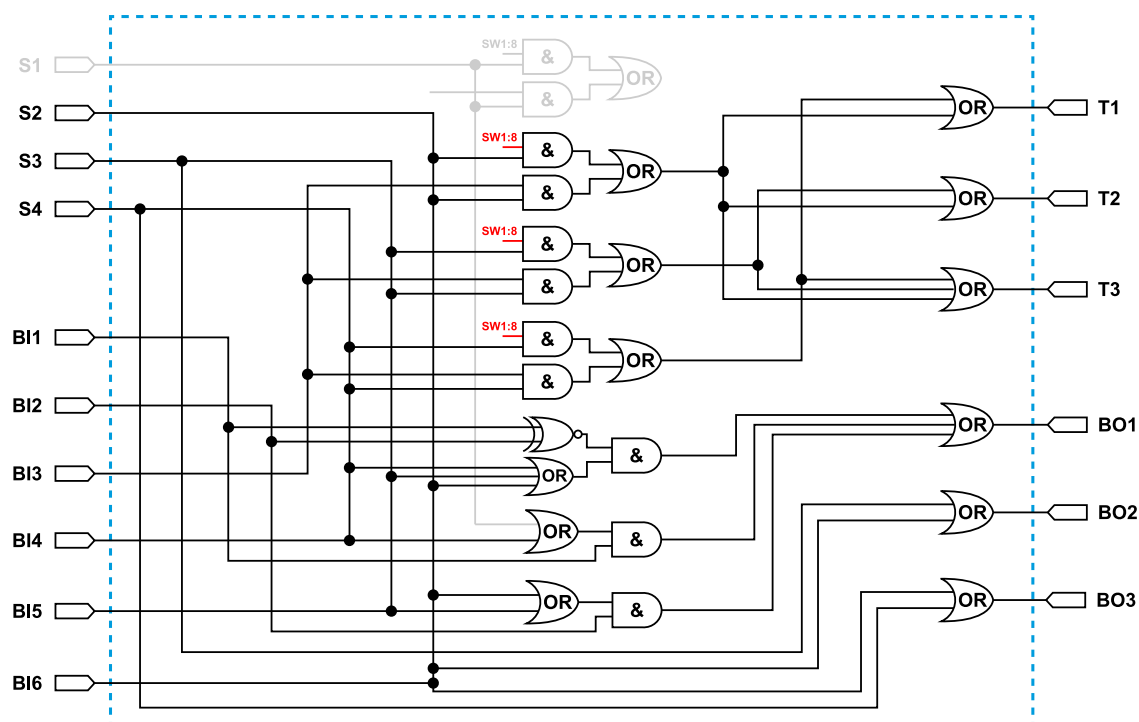

Figure. 4.4.2 - 15. The DIP switch settings for SS:3.

SW1

Figure. 4.4.2 - 16. The trip logic matric of SS:3.

SS:3		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1						
	S2	x	x	x	x	x	x
	S3		x	x	x	x	
	S4	x		x	x		x

SS:4

The logic scheme SS:4 is used as an intermediate unit. 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.

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

Figure. 4.4.2 - 17. The logic diagram of SS:4.
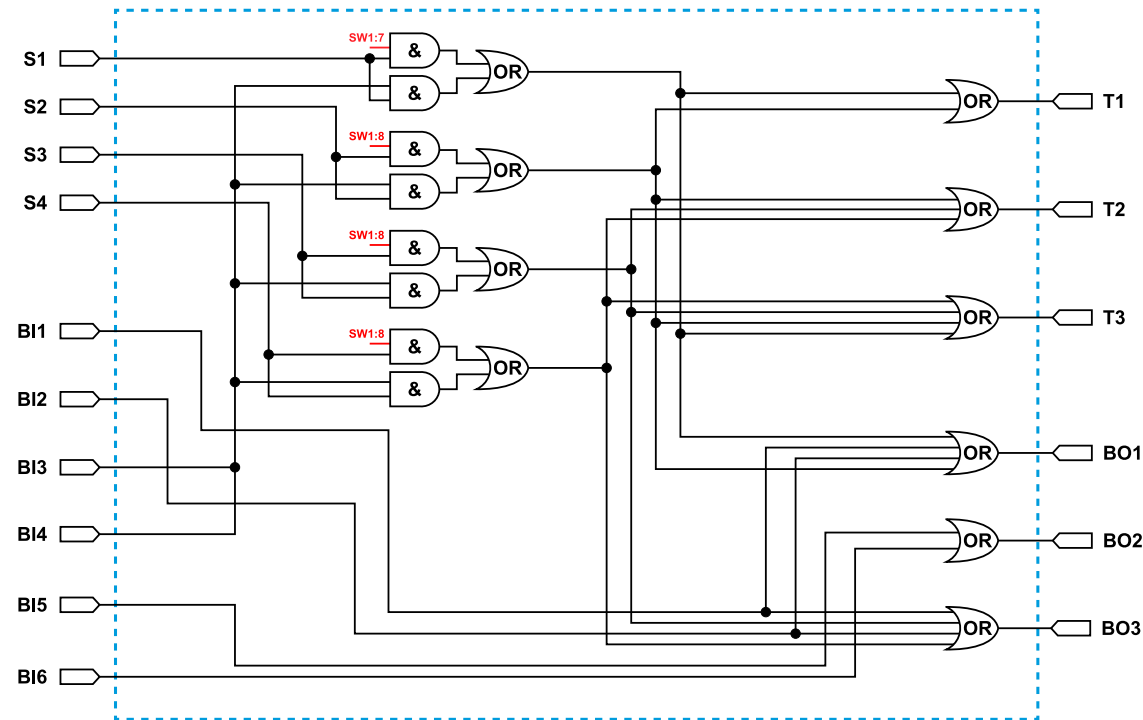
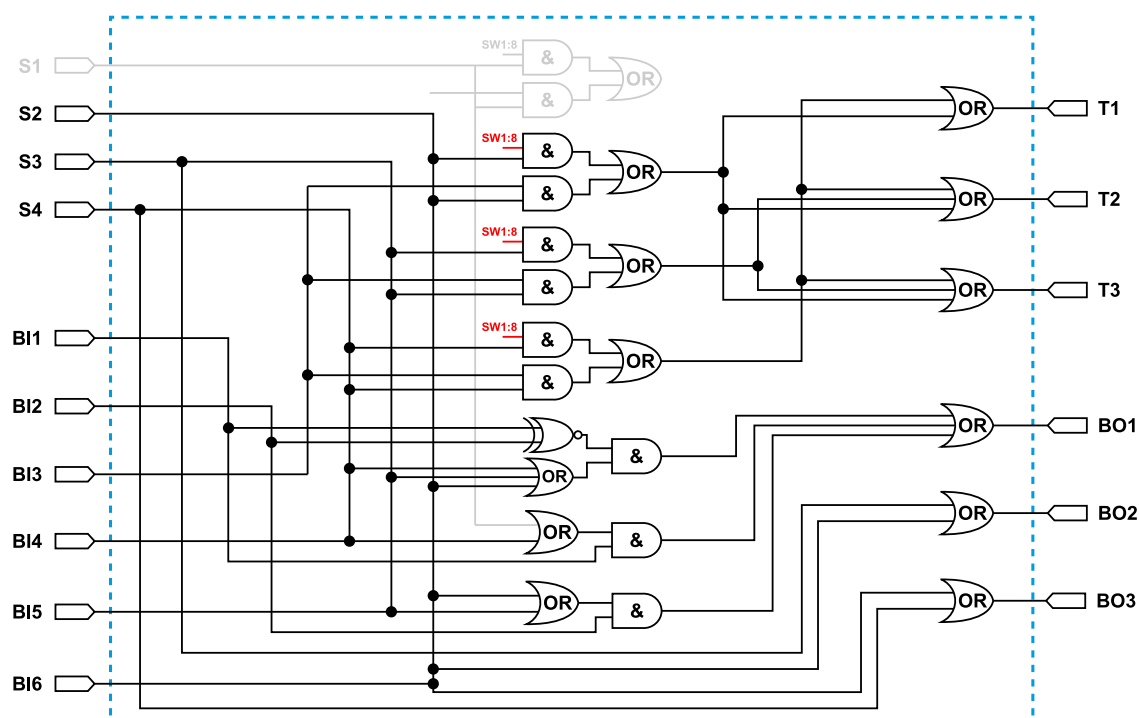Figure. 4.4.2 - 18. The DIP switch settings for SS:4.
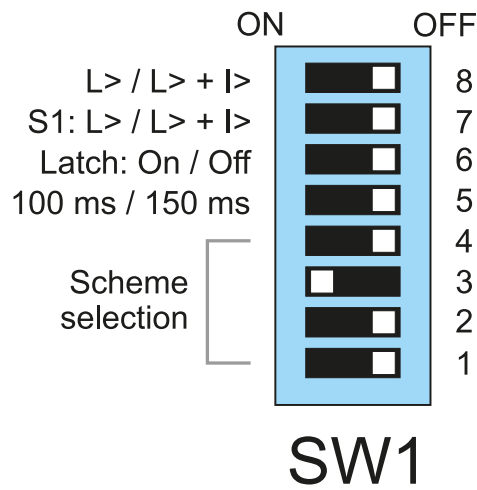
Figure. 4.4.2 - 19. The trip logic matric of SS:4.

SS:4		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1	x		x	x		
	S2	x	x	x	x		x
	S3		x	x			x
	S4		x	x			x

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 AQ-110P units. The binary inputs BI3 and BI4 receive overcurrent information from both of the incoming AQ-110P units. 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 AQ-110P units.

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

Figure. 4.4.2 - 20. The logic diagram of SS:5.
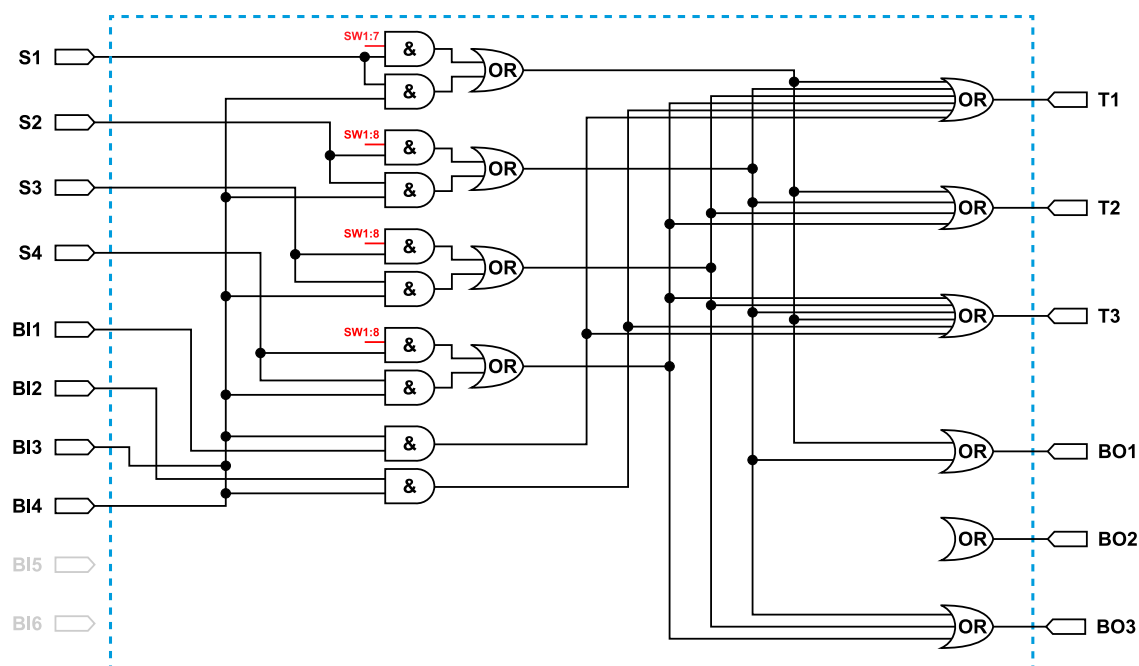
Figure. 4.4.2 - 21. The DIP switch settings for SS:5.
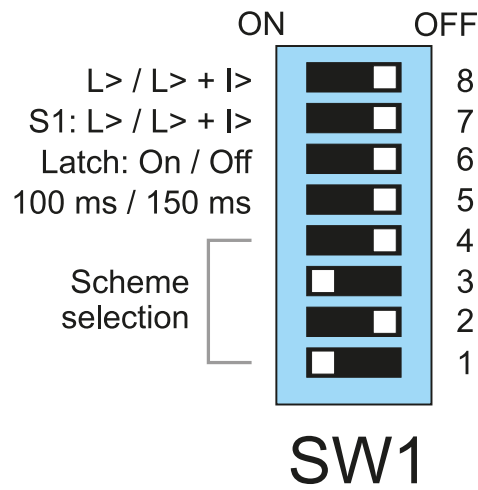
Figure. 4.4.2 - 22. The trip logic matric of SS:5.

SS:5		OUTPUTS					
		T1	T2	T3	BO1	BO2	BO3
INPUTS	S1	x	x	x	x		
	S2	x	x	x	x		x
	S3	x	x	x			x
	S4	x	x	x			x

4.5 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 unit 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.

5 Arc sensors

The AQ-100 series provides different types of arc sensors to be used with different units and different switchgear types according to specific application requirements. There are two types of sensors: arc light point sensors and arc light fiber optic loop sensors.

Arc light point sensors are typically installed in metal-clad compartments, and they provide a quick and accurate location of the faulted 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.

5.1 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. Only one sensor should be used per one closed metal-clad compartment. 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, the default threshold can also be set to 25,000 lux or 50,000 lux. An arc light sensor does not require further settings by the user. Its detection radius is 180 degrees.

Figure. 5.1 - 23. The AQ-01 light sensor.

An AQ-01 is installed either on the compartment wall or through the wall. When wall-mounting, the unit is placed on the wall (with the gray side against the wall) and then fixed to the wall with two screws from the back of the sensor. Through-the-wall mounting is similar: the unit is placed on the wall (with the blue side against the wall and the eye is pushed into the drilled compartment hole for protection) 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. 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.

i	NOTE! The AQ-01 point sensor does <u>not</u> come with a connection cable!

5.2 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. 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. Only one sensor should be used per one closed metal-clad compartment. The AQ-02 sensors <u>cannot</u> 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, the default threshold can also be set to 25,000 lux or 50,000 lux. An arc light sensor does not require further settings by the user. Its detection radius is 180 degrees. The pressure threshold is fixed at 0.2 bar above ambient pressure.

Figure. 5.2 - 24. AQ-02 arc light and pressure point sensor.

An AQ-02 can only be installed on the compartment wall as not to block pressure detection located next to "the eye". The unit placed on the wall (with the gray 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. 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.

5.3 Sensor—unit dependencies

Different sensor types can be used with different arc flash protection units of the AQ-100 series. The table below describes those dependencies.

Table. 5.3 - 5. Sensor—unit dependencies.

	AQ-01	AQ-02	AQ-06	AQ-07	AQ-08
AQ-101	Yes	Yes	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)
AQ-101D	Yes	Yes	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)
AQ-101S	Yes	Yes	No	No	No
AQ-102	No	No	Yes	Yes	Yes
AQ-103	Yes	Yes	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)

AQ-110P	Yes	Yes	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)
AQ-110F	No	No	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)	Yes (when the unit is equipped with the fiber option)

5.4 Connecting sensors

How to connect point sensors

1. Open the sensor covers and detach the connectors.
2. Attach the cable to the connector and to the unit.
3. Reattach the connectors to the sensor.
4. Run the auto-configuration procedure.
5. Once the auto-configuration has been successfully completed, put the sensor covers back in place.

For more detailed instructions, please refer to the "Connecting sensors" chapter in the AQ-0x instruction booklet (arcteq.fi/downloads).

6 System self-supervision

All AQ-101 and AQ-102 variants (that is, both LV and MV) have an extensive self-supervision feature, including both internal functions and external connections. The self-supervision module monitors the power supply, hardware and software malfunctions, as well as problems with the binary input connection(s) and sensor(s). Additionally, the module supervises the DIP switch settings by comparing actual values with the data stored in the non-volatile memory.

When the unit's condition is healthy, 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.

If a sensor failure occurs, the unit 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 unit is still in the protection mode, although the faulty sensor channel is blocked. If the error is resolved, the unit automatically clears the system failure status, energizing the SF relay and turning off the "Error" LED. If one or more of the sensors are disconnected, the healthy sensors remain in use and the unit remains operational accordingly. However, the unit remains in Error mode until the disconnected sensors are repaired.

The unit goes into SF alarm 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 unit is still operational.

7 Application examples

This unit 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.

7.1 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 unit, activating the trip relay in 7 ms. 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 unit.

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

Figure. 7.1 - 25. Connections of the double busbar application for AQ-101S.
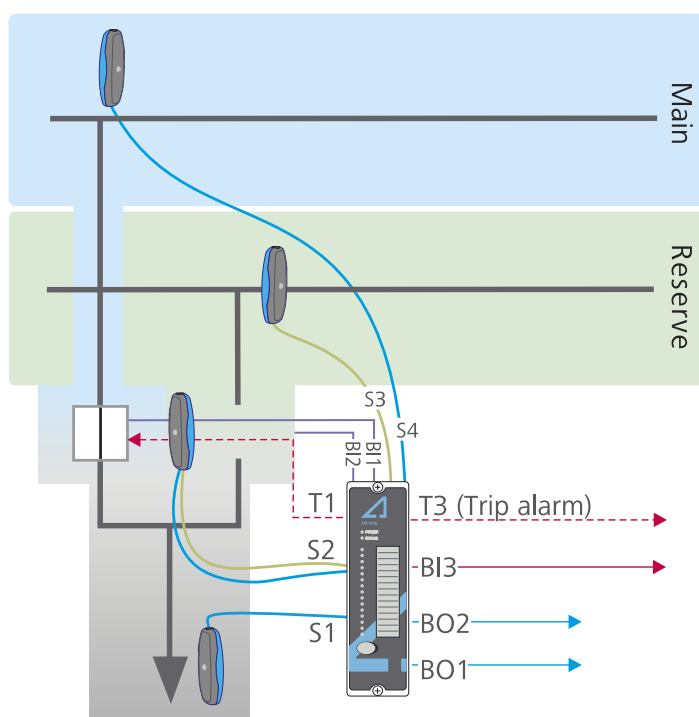
7.2 Circuit breaker failure protection

All AQ-101 variants include a selective circuit breaker failure (CBFP) function, which can be enabled through the DIP switch settings (please refer to the "DIP switch settings" chapter for more information). When enabled, the CBFP function activates when the tripped breaker fails to operate, or if the unit detects the presence of light after a set operating time. Please note that if the unit 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 (again, please refer to the "DIP switch settings" chapter for more information).

8 Connections

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

Figure. 8 - 26. Rear terminals of AQ-101S.
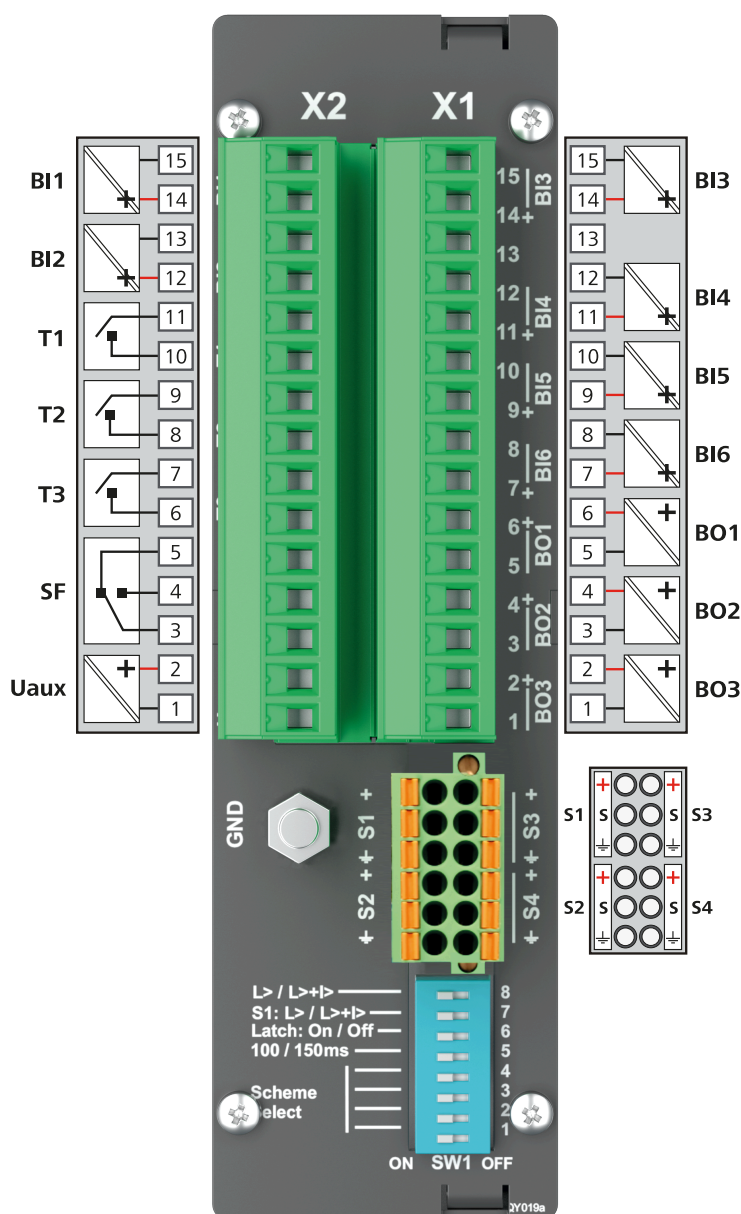
8.1 Outputs

8.1.1 Trip relays

This unit has two (2) integrated trip relays for tripping circuit breakers, namely T1 and T2. Their type is normally open (NO).

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.

8.1.2 Binary outputs

AQ-101S has three (3) binary outputs: BO1, BO2 and BO3 (+24 VDC). 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.

Please note that the binary ouputs are polarity-sensitive (see the "Wiring" chapter for more information).

8.1.3 System failure relay

The system failure (SF) relay is of the change-over type (NO/NC) and it is energized when the unit is in a healthy condition. Whenever the unit detects a system error or a disconnection between the auxiliary power supply and the contacts, the SF relay changes its state. The state stays this way until the unit returns to a healthy condition and the SF relay is energized again.

8.2 Inputs

8.2.1 Arc sensor channels

AQ-101S has four (4) arc point sensor channels: S1, S2, S3 and S4. You can connect a maximum of three (3) arc point sensors to each channel.

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/).

8.2.2 Binary inputs

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 information from an AQ-110P unit. 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 in this manual.

Please note that when AQ-101S receives an overcurrent signal from a non-Arcteq device, the actual operating time depends on the operating time of the third-party device. Therefore, the total operating time cannot be specified nor guaranteed.

The binary inputs are activated when a connected DC signal exceeds the specified nominal threshold level of the corresponding input. There are three (3) different nominal threshold levels available: 24, 110, or 220 VDC. Please note that the threshold value must be chosen and specified when ordering the unit. Please note that the actual activation of the binary input occurs earlier than the specified nominal threshold value (for more information see Chapter 11.4, "Techical Data").

8.3 Auxiliary voltage

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.

9 Testing

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

Any high-quality camera with an interchangable lens works well to simulate arc light. 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.

9.1 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.

9.2 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 point sensor unit that is being tested, and the BI3 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 BI3 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 point sensor unit but <u>do not activate</u> 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 the BI2 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 15 for all sensors.

9.3 Testing the CBFP function

The circuit breaker failure protection (CBFP) function is tested by taking the light signal and the secondary trip criterion signal (if applicable) and leaving them active for longer than the set CBFP time (that is, 100 or 150 ms). The T2 trip relay and the BO1 binary output must be active after the set time delay has passed to confirm the CBFP function operates correctly.

9.4 Testing the unit 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 unit 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 unit'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 20 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.

9.5 Test plan example

Basic data	
Date:	
Substation:	
Switchgear:	
Serial number:	

AQ-101S

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:	

10 Troubleshooting

Table. 10 - 6. Troubleshooting guide for AQ-101 variants.

Problem	Possible solution(s)
The sensor does not activate during testing.	Check the sensor's cable wiring (see the "Arc sensors" chapter for more information). 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.	Check the DIP switch settings (see the "DIP switch settings" chapter for more information).

11 Technical data

11.1 Mounting and installation

Table. 11.1 - 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)

11.2 Operating times

Table. 11.2 - 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 unit and the arc light (L>) from this unit.

11.3 Auxiliary voltage

Table. 11.3 - 9. Technical data for the relay auxiliary voltage (Uaux).

Auxiliary power supply	92…265 V AC/DC 18…72 V DC (optional)
Maximum interruption	100 ms
Maximum power consumption	5 W, < 10 mΩ
Standby current	90 mA

11.4 Binary inputs

Table. 11.4 - 10. Technical data for the relay binary inputs (BI1, BI2, BI3, BI4, BI5, BI6).

Nominal threshold voltage	24 V DC or 110 V DC or 220 V DC
Threshold: - pick-up - drip-off	$\geq$ 16 V DC or 88 V DC or 178 V DC $\leq$ 15 V DC or 75 V DC or 155 V DC
Rated current	3 mA
Number of inputs	6

11.5 Trip relays

Table. 11.5 - 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.

11.6 Binary output(s)

Table. 11.6 - 12. Technical data for the relay binary outputs (BO1, BO2, BO3).

Number of ourputs	3
Rated voltage	+24 V DC
Rated current (max.)	20 mA

11.7 System failure relay

Table. 11.7 - 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.

11.8 Sensors

AQ-01 point sensor

Table. 11.8 - 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. 11.8 - 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

11.9 Disturbance tests

Table. 11.9 - 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

11.10 Voltage tests

Table. 11.10 - 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

11.11 Mechanical tests

Table. 11.11 - 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.

11.12 Environmental conditions

Table. 11.12 - 19. Technical data for the environmental conditions.

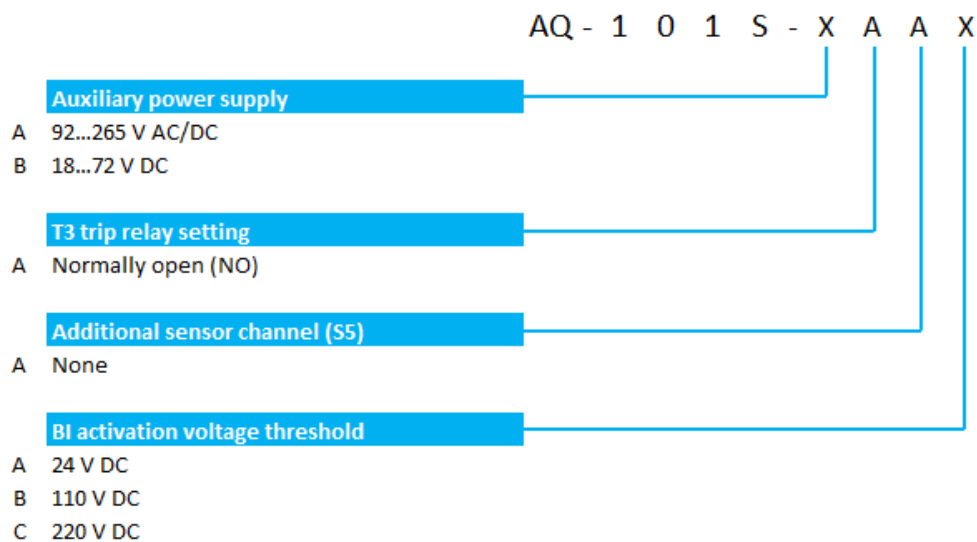| Specified ambient service temperature	–35…+70 ºC
Transportation and storage temperature	–40…+70 ºC
Relative humidity	Up to 97 %
Altitude	Up to 2,000 m above sea level

11.13 Casing
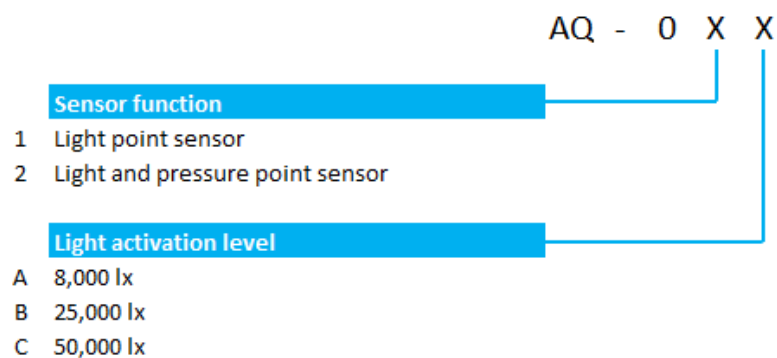
Table. 11.13 - 20. Technical data for the device casing.

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

12 Ordering information

AQ-101S point sensor unit

```
AQ - 1  0  1  S - X  A  A  X
```

Auxiliary power supply
A   92...265 V AC/DC
B   18...72 V DC

T3 trip relay setting
A   Normally open (NO)

Additional sensor channel (S5)
A   None

BI activation voltage threshold
A   24 V DC
B   110 V DC
C   220 V DC

AQ-0x point sensors

```
AQ - 0  X  X
```

Sensor function
1   Light point sensor
2   Light and pressure point sensor

Light activation level
A   8,000 lx
B   25,000 lx
C   50,000 lx

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 units (MV and LV).	Arcteq Ltd.

13 Contact and reference information

Manufacturer

Arcteq Relays Ltd.

Visiting and postal address

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65300 Vaasa, Finland

Contacts

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Technical support:	https://arcteq.fi/support-landing/
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