Operating Instructions

CONTROLLERS FOR BDN45F-A COMPRESSORS

SECOP

101N2720 Automotive · 9–34 V DC

Variable-Speed Efficiency

Premium Controllers

Mobile Applications

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INTRODUCTION

General Information

The 101N2720 Electronic Unit for BDN45F-A compressors is designed to be a universal, easy-to-use, and feature-rich compressor controller. Its main features are:

- → Drive for the BD Nano-Series compressors
- → Wide range DC voltage supply input
- → Wide range operating temperature envelope
- → Configurable battery protection
- → Fully integrated and configurable electronic thermostat functionality
- → Variable compressor speed control
- → Configurable speed blanking to prevent cabinet resonances
- → Easy to optimize parameters to ensure a sustainable cooling source

Application Information

The electronic unit can be operated in a wide range voltage supply between 9 V and 34 V DC, which makes it the ideal solution for OEM refrigeration in cars and trucks, i.e.:

- → Center console refrigerators for cars
- → Champagne coolers for car passengers
- → Refrigerators in trucks for driver convenience
- → Merchandise coolers for taxis and public transport
- → Portable refrigerators in cars for driver convenience.

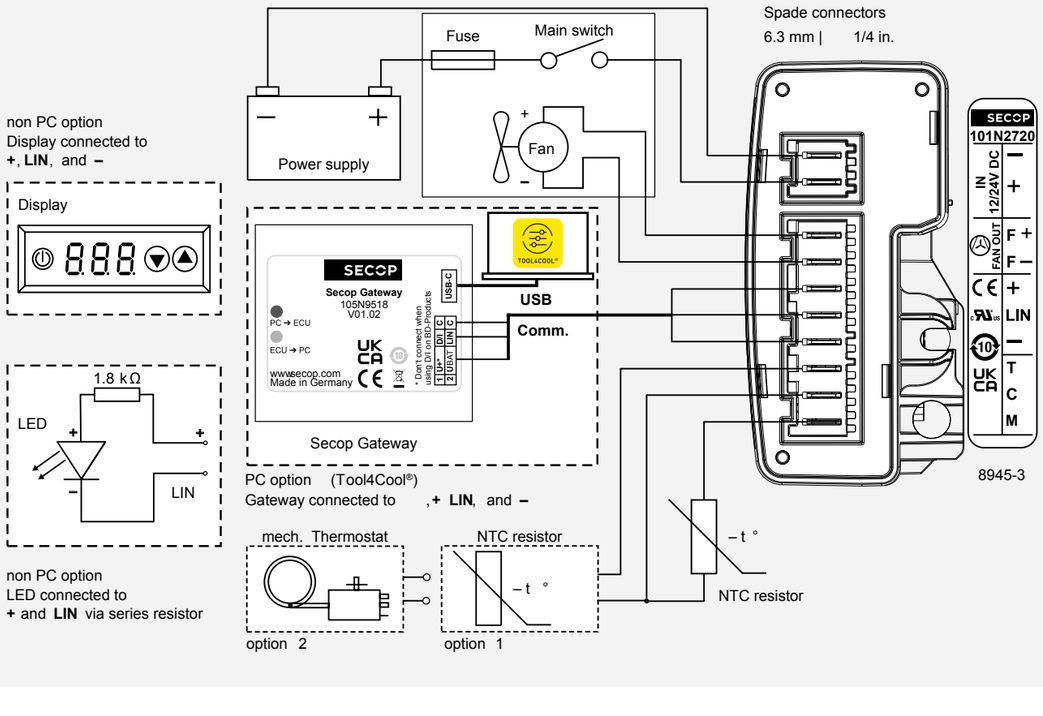
Note: This electronic unit is intended to be used in cars or trucks in OEM automotive solutions.

Benefits and Functions

The electronic unit can be configured and controlled via an easy-to-implement Modbus interface, using industry standard LIN hardware. Register description and design support for the Secop interface are available on request.

Secop offers the Tool4Cool® desktop software for testing and configuring the ECU. Tool4Cool® implements development shortcuts with its feature rich interface. It offers all configurable parameters clustered in a clean menu structure. In addition, it lets users save and recall configuration templates as well as log and plot register information, ie. to diagnose a thermostat. Tool4Cool® can also be used to program applications with a pre-defined parameter template at the factory. This makes it possible to configure each appliance in a production line by performing a single click of a mouse.

System Overview



SPECIFICATIONS

Absolute Maximum Ratings

	Minimum	Maximum
Supply voltage	9 V	34.0 V
Measurement tolerance		± 0,3 V
Current consumption	Depends on state, see datasheet	10 A
Machine compartment temperature (Operational)		
→ ECU	-40°C	85°C
→ Compressor	-10°C	55°C*
Compressor speed	2,300 rpm	4,500 rpm
Fan output power	N/A	5 W
LIN high signal voltage	9 V	34 V
T and P input voltage	C-pin voltage	C-pin plus 3.3 V
IP Rating	IP20	

* = Compressor operating envelope to be considered. Lower values might result depending on the evaporator and condenser design as well as refrigerant charge. To operate up to 55°C, Compressor Compartment Temperature protection must be enabled.

Please also see the ECU Datasheet for details on voltage levels.

Recommended Operating Conditions

Parameter	Value
Supply voltage	12 V or 24 V
Input fuse	15A
Operating temperature compressor compartment	25°C
LIN high signal voltage	Supply voltage, max. 27 V

Approvals

Approval	Certificate
UL	N/A*
CB	N/A*
VDE	N/A*

*The automotive series controllers are delivered without any 3rd party approval.

Reliability Tests

Test	Standard
Rapid temperature change	IEC 60068-2-14 Na
Vibration	ISO 16750-3-2012, 4.1.2.8 Test VIII
Thermal cycling with humidity	EN60068-2-35 test Db
High temperature storage	ISO 16750-4:2010 Section 5.1.2.2
IP Test (min. IP 20)	EN 60529 Edition 2.1 2001-02
Free fall	IEC 60068-2-32
Thermography	Internal Secop specification
Thermal performance	Internal Secop specification

Thermography Secop Standard

Via IR thermography, find the thermal hotspots of the PCB.

Operating conditions:
12 V/24 V, 40 W/80 W, 2,300 rpm/4,500 rpm

Thermal Performance Secop Standard

Attach temperature sensor to thermal hotspots of the PCB, run and record until thermal steady state is reached. Temperature may not exceed the max. specified temperature.

EMC and EMI

The automotive series of BD Nano controllers is tested according to following standards. EMI reports can be provided on request.

No	Tests	Standard*
1	Conducted emission-voltage method	CISPR 25:2016
2	Conducted emission-current probe method	
2.1	Conducted emission-current probe method	
3	Radiated emission ALSE method	
3.1	Radiated emission ALSE method	
3.2	Radiated emission ALSE method	
4	Radiated immunity antenna irradiation (ALSE test)	ISO 11452-2:2004
5	Radiated immunity antenna irradiation (ALSE test)	
6	BCI test	ISO 11452-4:2011
7	BCI test	
8	Load Dump (clamped)	ISO 16750-2:2012-11
8.1	Load Dump (clamped)	
9	Load Dump (unclamped)	
10	ESD	ISO 10605:2008
11	CI	ISO 7637-2:2011
12	Superimposed alternating voltage	ISO 16750-2:2012-11
13	Transient emission	ISO 7637-2:2011
14	Transient immunity	ISO 7637-3:2016
15	Slow decrease and increase of supply voltage	ISO 16750-2:2012-11
16	Momentary drop in supply voltage	
17	Reset behavior at voltage drop	
18	Reversed voltage	

* Compressor and ECU are tested on stand-alone level.
Operation in refrigeration appliance may influence/change the EMI performance.

Recommended Peripheries

Recommended Connector Types

Connector	Pins	Molex	CJT
Power supply	2	945 504 102	A7921HC-2P-0E
Fan	2	945 504 202	A7921HC-2P-1C
Display/Communication	3	932 504 023	A7921HC-3P-04
Thermostat/Program	3	932 504 003	A7921HC-3P-02

Recommended Crimp Inserts

Wire Gauge	Amount	Molex	CJT
0.5–1.0 mm	8	945 180 101	A7921-TP-A-L
1.0–2.5 mm	2	945 180 201	A7921-TP-A
4 mm			
6 mm			
10 mm			

Recommend NTC

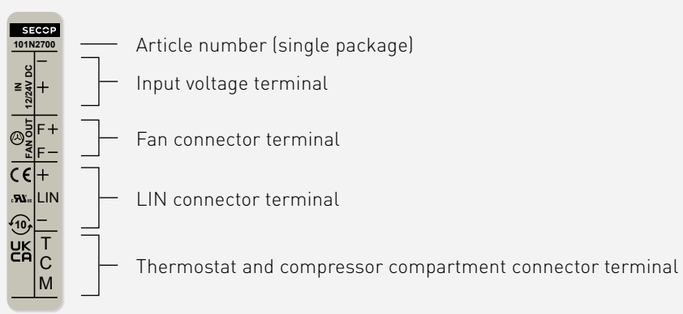
Article	Article Nb
Temperature sensor Epcos M800/5 1,500 mm, black	105N9617

Packaging Information

Article	Description	Article Nb.
Single Package	Individually packaged unit for resale	101N2700
Industrial Package	Bulk packaging with 40 units per box	101N2701
Single Package	Individually packaged unit for resale	101N2710
Industrial Package	Bulk packaging with 40 units per box	101N2711
Industrial Package	Bulk packaging with 40 units per box	101N2713
Single Package	Individually packaged unit for resale	101N2730
Industrial Package	Bulk packaging with 40 units per box	101N2731
Industrial Package	Bulk packaging with 40 units per box	101N2733

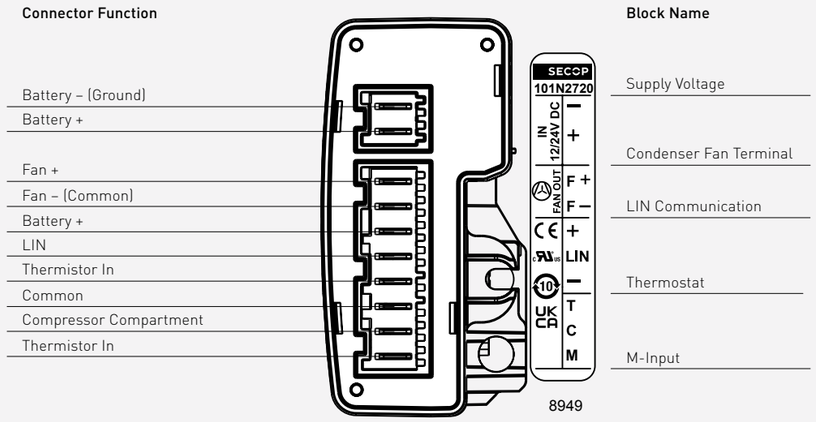
For more information about packaging see the chapter "Ordering Information"

Label Information



WIRING

Pinout Configuration



Pinout Description

Supply Voltage

Connect battery+ via a fuse directly to the battery+ pole. Please avoid any additional conjunctions between battery+ and the battery + pole, since they might introduce voltage drops in the cabling and interfere with the battery protection settings.

Connect battery- directly to the battery- pole and avoid any additional conjunction in the cabling.

Please make sure to use proper wires as described in the chapter "Recommended Cable Diameters" below.

Condenser Fan Terminal

Regardless of the systems main power source this output is regulated to max. 12V, therefore connect a 12V fan.

Connect fan+ to the fans plus pole, fan- to its minus or ground pole.

LIN Communication Interface

The 101N2700 is equipped with a LIN standard transceiver to enable communication with the device. The hardware is LIN, but the communication protocol used is Modbus. For details, see the chapter "Modbus Interface" and the "Modbus Register Description" available on request from Secop.

A self-developed master controller (e.g. display) or a standard Secop Gateway (105N9518) can be used to configure and control the unit via Tool4Cool® on a PC.

The DC out + connector within the LIN block is a direct connection to battery+ without any protection.

It is designed to supply displays or LEDs with energy. Do not use this input to supply voltage to the compressor controller since it can damage the output. Max current rating: 1A.

For usage of the Secop Gateway please refer to the chapter "Secop Gateway" below.

Thermostat

Connect either a mechanical thermostat (electrically a switch) or a NTC thermistor between T input and C-connector (common). Both components have no polarity. You can connect either contact to T or C.

The electronic unit will start the compressor if either the thermostat is closed (switched on) or the thermistors value represents a temperature above the cut-in value. The electronic unit will stop the compressor if either the thermostat is open (switched off) or the thermistors value is equivalent to a temperature below the cut-out temperature.

For cut-in and cut-out temperatures refer to the chapter "Accessible and Configurable Parameters – Thermostat" below.

Compressor Compartment Temperature Protection

To protect the compressor from out of envelope operation, a compressor compartment sensor must be attached to the M input. The sensor is a NTC of Type Epcos M500 (Secop: 105N9617). It must be placed in the hottest area in a compressor compartment inside the air flow.

Recommended Cable Diameters

To ensure a safe function of the compressor and to prohibit any damages, please refer always to the following cable diameters in your appliance. Additionally, the cross section ensures safe and stable operation of the battery protection. A voltage drop on the too thin cable might trigger the battery protection settings and therefore result in an unstable system.

Cable Size Cross section		**Max. Cable Length*** 12V operation		**Max. Cable Length*** 24V operation	
Metric	Imperial	Metric	Imperial	Metric	Imperial
1.0 mm²	18 awg	1.5 m	5 ft	3 m	10 ft
2.5 mm²	12 awg	2.5 m	8 ft	5 m	16 ft
4 mm²	12 awg	4 m	13 ft	8 m	26 ft
6 mm²	10 awg	6 m	20 ft	12 m	39 ft
10 mm²	8 awg	10 m	33 ft	20 m	66 ft

*Length between battery and electronic unit

We recommend keeping the cables as short as possible and not exceeding a supply cable length of 10 m (33 ft) at 12 V or 20 m (66 ft) at 24 V.

Input/Output FMEA

This tables offers help with troubleshooting improper connections.

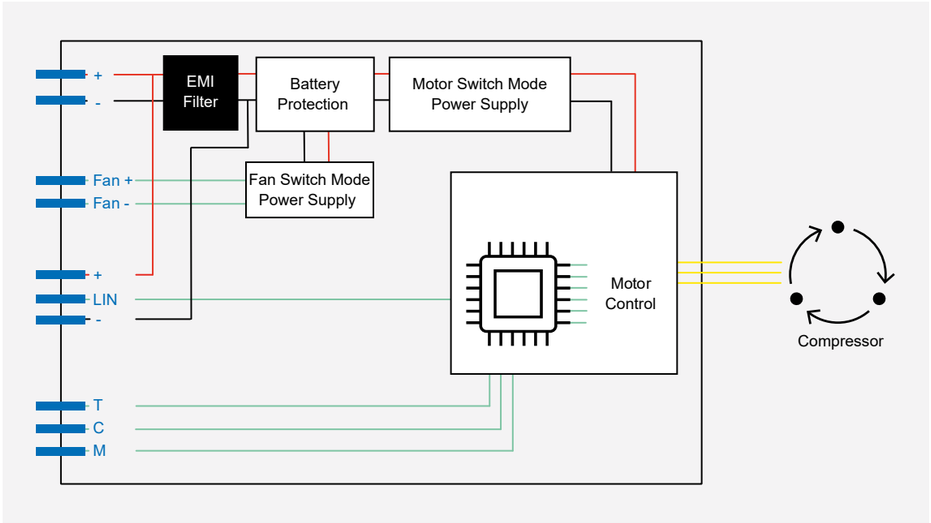
A "–" means no action at all, a green field is a temporary malfunction, which is no longer valid if the error is gone. Orange means possible auxiliary damaged, i.e., fuses or thermostats. Red means permanent damage to the controller.

Please note: None of these conditions should be met in a permanent application, nevertheless they are marked green here.

Pin	Connected to			
	Top neighbor	Bottom neighbor	Battery-	Battery+
Battery-	–	External fuse must trip	–	External fuse must trip
Battery+	External fuse must trip	Fan overvoltage, Fan out damaged	External fuse must trip	–
Fan+	Fan overvoltage, Fan out damaged	Fan short error	Fan out damaged	Fan overvoltage, Fan out damaged
Fan-	Fan short error	External fuse must trip	–	External fuse must trip
DC+	External fuse must trip	Communication impossible	External fuse must trip	- (connected internally)
LIN	Communication impossible	Communication impossible	Communication impossible	Communication impossible
Battery-	Communication impossible	Thermostat switches on	–	External fuse must trip
Thermostat	Thermostat switches on	Thermostat switches on	Thermostat switches on	Destroys the T input functionality
Common	Thermostat switches on	Triggers NTC error	–	External fuse must trip
M input	Triggers NTC error	–	Triggers NTC error	Destroys the M input functionality

APPLICATION

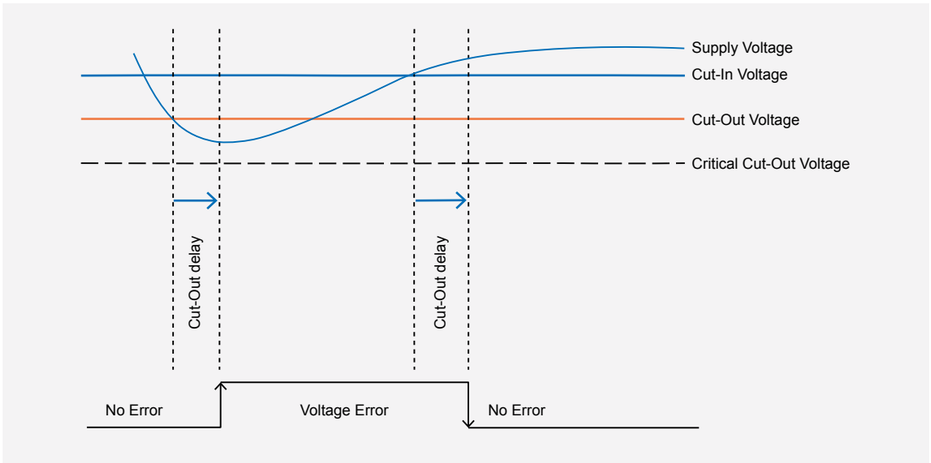
Functional Diagram



Detailed Function Description

Battery Protection

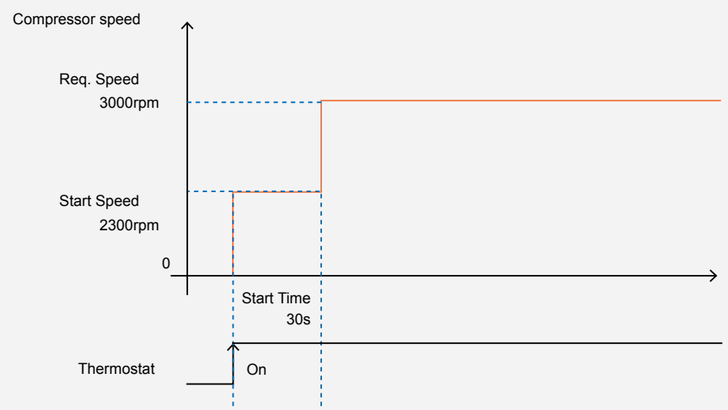
The battery protection prevents permanent damage to the battery by discharge. The setting range is 8.5–17 V DC for 12 V DC systems, and 19–34 V DC for 24 V DC systems. The cut-out values and cut in differences can be set individually for 12 V systems and 24 V systems. If the voltage remains below the cut-out voltage for the time specified in the parameter "Cut-out delay" (default 3 seconds), compressor and fan are stopped. Compressor and fan are stopped immediately, if the voltage drops below 8 V in 12 V systems and below 18 V in 24 V systems (critical stop).



The controller can be configured in a single range mode. In single range mode, it operates from the configurable cut-in voltage to absolute maximum voltage. The cut-out and cut-in voltages of 12 V registers apply to single range mode. In single range mode, the 12 V cut-out/cut-in register can be configured for any value of the full operating range. The critical stop voltages (8 V and 34 V) apply also in single range mode.

Motor Drives

The motor speed and thereby the capacity of the compressor is set using the "Requested speed" parameter. During start up, the compressor runs at a lower speed, called "Start speed" (configurable, default 2,300 rpm), then "Requested speed". The duration of the period running at "Start speed" is set using the "Start time" (default 30 seconds, adjustable) parameter.



If the compressor speed drops below the minimum or exceeds the maximum speed, the compressor will stop and an alarm for min. speed failure or max. speed failure will be recorded. The compressor will try to restart after the set "Restart time". The "Restart time" is 60 seconds by default and can be configured via software. The fan output is not affected from this behavior and runs independent.

A speed drop on high load conditions is expected and does not trigger the speed protection, i.e. in case the pull-down starts with a high heat load, the compressor might drop from 4,500 rpm to 4,300 rpm.

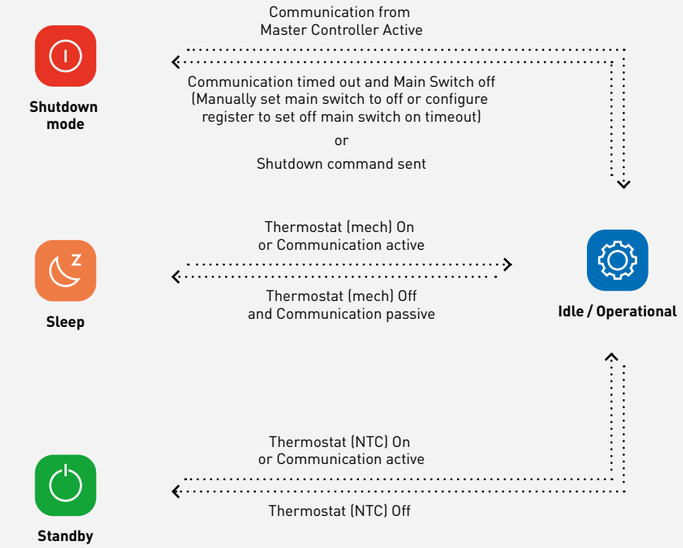
If the input voltage exceeds approx. 24 V at low load conditions, 2,300 rpm operation is not possible. The controller will adjust the minimum possible speed automatically.

Silent Stop Method

The BD Nano controller series features a new silent stop method for any motor stop except the "Main switch off" command. To achieve the most silent stop, the compressor reduces its rpm before stopping at a specific condition. Reaching that condition can take up to 10 seconds, delaying the switching off of the compressor for up to 30 seconds.

Sleep, Stop, and Operational States

The BD Nano automotive controller features several operation modes depending on configuration.



Modes and Current Consumption

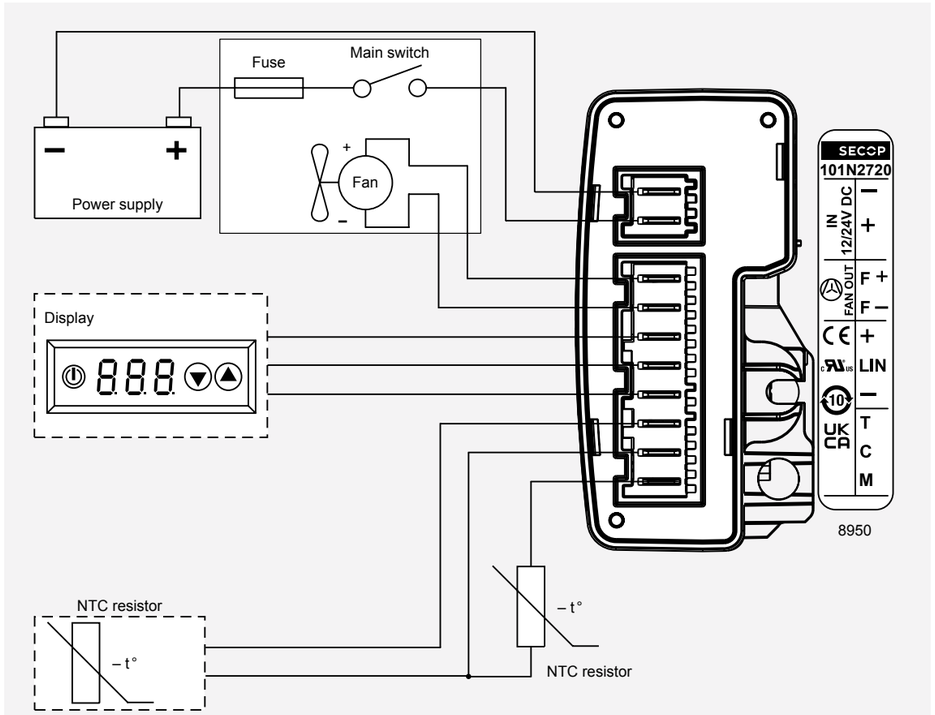
The BD Nano automotive controller features several operation modes depending on configuration.

Mode	Shutdown Mode	Sleep	Standby	Idle/Operational
Current	Lowest	Lower	High	Highest

Modes vs. Configuration

Configuration	Mode			
	Shutdown Mode	Sleep	Standby	Idle / Operational
With display	Possible	Not possible	Possible	Possible
With NTC	Not possible	Not possible	Possible	Possible
With mech. Thermostat	Not possible	Possible	Possible	Possible

Typical Application Circuit



Typical application with customer display

SECOP GATEWAY

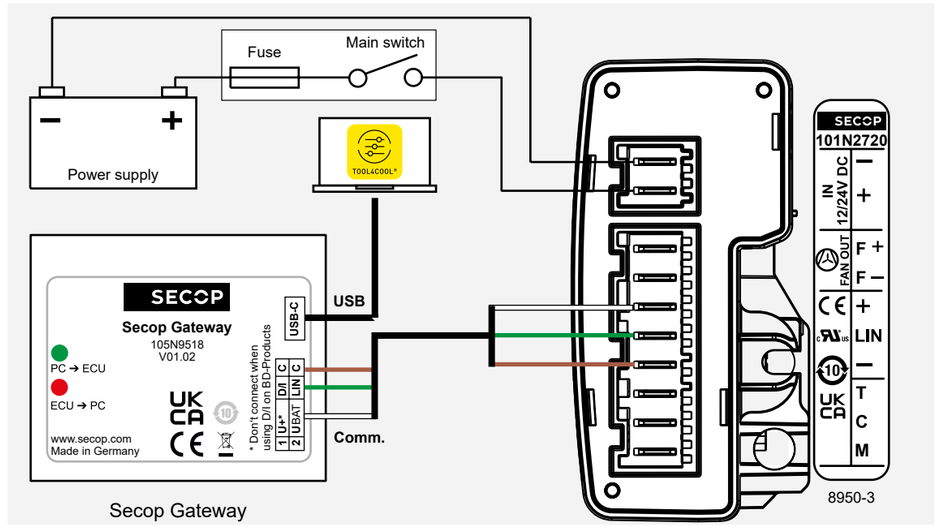
Product Information

The Secop Gateway is designed to help customers optimize their cooling circuits regarding software configurable parameters. Combined with Tool4Cool® it lets users debug the cooling appliance while development and define parameter sets, that can be applied in production lines. Using the LIN/One-Wire Gateway in production can save valuable time and components in a finished product.

It is possible to replace a programming and speed-resistor by applying the target values using the Gateway in production.

The Secop Gateway can also be a helpful tool for end of the line tests in production since all system relevant parameters can be obtained from Tool4Cool®.

Connecting the One-Wire/LIN Gateway



Ordering Information

Article Nb. 105N9518

Package contents:

1× LIN/One-Wire Gateway

1× USB-A to USB-C cable 2 m

1× Spade connector to LIN/One-Wire Gateway cable 2 m

Tool4Cool®

Installation and Configuration

Tool4Cool® is free of charge and available for downloads at secop.com/tool4cool

Please see the Tool4Cool® Handbook available on secop.com/tool4cool for a detailed description on how to install and set up Tool4Cool®.

Operation

For connecting, please refer to "Modbus – Establishing a Modbus Connection"

ACCESSIBLE AND CONFIGURABLE PARAMETERS

Configuration via Tool4Cool®

Please see the chapter "Changing Parameter Settings" in the Tool4Cool® operating manual, available at secop.com/tool4cool

All described parameters are available and editable via Modbus and Tool4Cool®.

Configuration via MODBUS

The protocol is designed according to the MODBUS Protocol Specification and MODBUS Serial Line Protocol and Implementation Guide, which are available at www.modbus.org.

Please note: Parameters stored in the devices EEPROM should not change their configuration too frequently, as the EEPROM can be damaged from excessive writing. To control the electronic unit via an external controller always use the RAM values, which are intended and designed to be written frequently.

Battery Protection

To protect the battery from deep discharging, the electronic unit constantly monitors the available voltage on its battery in pins and shuts off the cooling operation as soon as a voltage out of the configured envelope occurs.

It is possible to set a cut-out and cut-in level for both voltages 12 V and 24 V.

If the battery voltage drops below the cut-out voltage, the device stops fan and compressor. As soon as the battery voltage reaches above the cut-out voltage + cut-in voltage, the electronic unit continues with normal operation.

To ignore the 24 V cut-out and cut-in voltage and run in the full envelope, enable the solar mode.

To delay the cut out in situations where the supply voltage is expected to drop and return fast again (i.e. older system batteries, switching power supplies) a cut out delay can be applied. The actual cut-out will happen after the delay expired.

Single Range Mode

The Single Range Mode disables the battery protection and secondary voltage range, meaning no cut-out at 17 V happens.

Shutdown Command

To achieve the most energy saving state of the controller, it can be shut down via a command. If in Shutdown mode, the controller can only be woken by sending a Modbus request (i.e. read any register continuously until the controller answers).

The controller will enter Shutdown mode automatically if the communication timeout is configured to disable the main switch and the communication timeout has elapsed.

Compressor Operation

Compressor Start Delay

The compressor start delay applies after the thermostat signals cooling demand to the main controlling process. The compressor start delay is ideal for buffering a temperature spike, i.e. issued by opening the door of the cooling appliance.

Compressor Restart Time

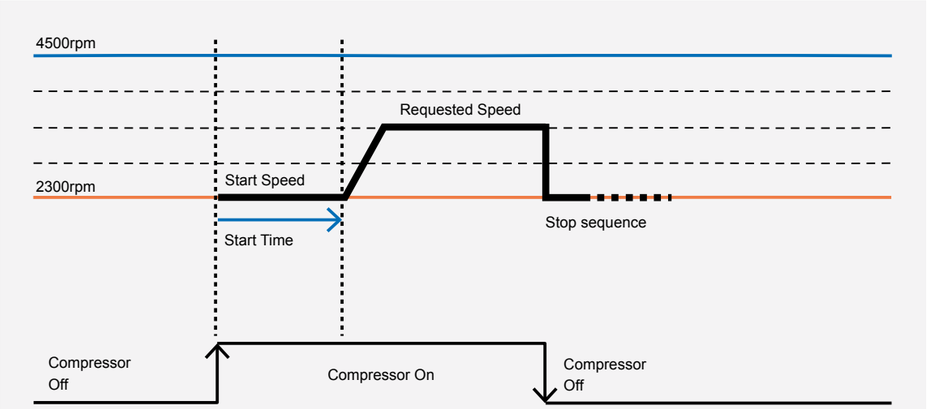
The compressor restart time applies after an error that has occurred while it was active. For example, if the controller tries to start the motor, but the motor is not able to run (i.e. high back pressure), the controller stops the motion and waits for the compressor restart time to retry the start attempt.

Compressor Start Speed

The compressor start speed applies after successful start of the compressor. For the specified compressor start time, the motors rpm is stays at the configurable compressor start speed.

Compressor Start Time

The compressor start time defines how long the compressor should stay in the start speed before accelerating/decelerating to the default requested speed.



Compressor Speed

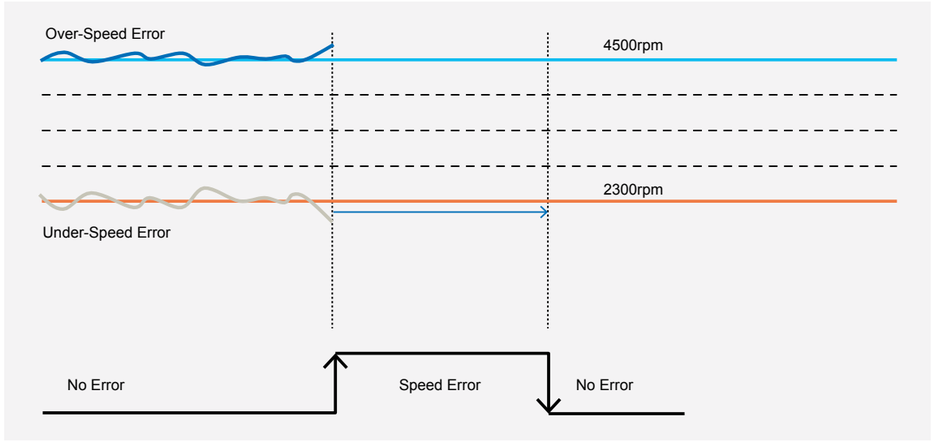
Requested Compressor Speed

The requested compressor speed value is designed to be adapted to the current cooling demand. After booting up the electronic unit, the register holds the value of the default requested compressor speed EEPROM address. To archive, i.e. faster pulldowns or more energy efficient cooling, the requested compressor speed can be changed via either an external controller (customer specific display) or a resistor on the P input.

Default Requested Compressor Speed

The default requested compressor speed is designed to be used in standalone applications that are one-time factory programmed with an optimized motor rpm. It can be applied using either Tool4Cool®, a customer specific display or a production line programmer. We recommend programing this cell only during an initialization. For frequent changes the RAM stored "requested compressor speed" is intended instead of the EEPROM stored "default requested speed".

Compressor Speed Protection

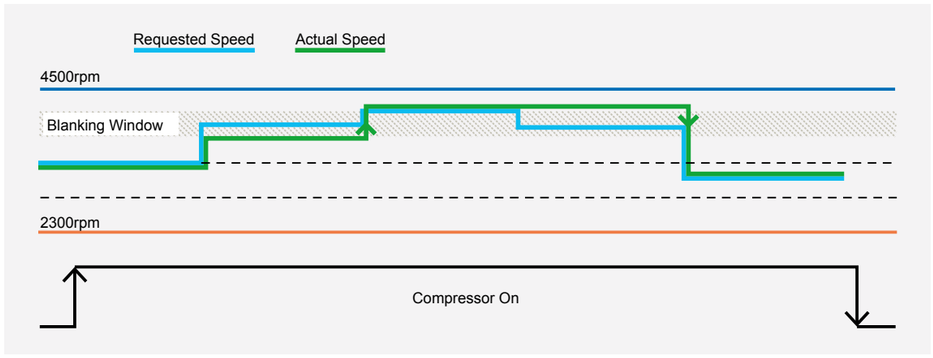


The compressor speed protection is a fixed algorithm that detects if the compressors motor is spinning either too fast or too slow. In case an out-of-range speed is detected, an error is reported, and the current cooling cycle is interrupted. The electronic controller will try to restart after the configured compressor restart time.

Compressor Speed Blanking Windows

Tubing and wiring in final applications have a certain resonance frequency. The compressor running vibration might trigger these application resonance frequencies, depending on the compressor speed. To prevent excessive noise from vibrating refrigeration loop components, it is possible to block sudden compressor rpm ranges. The controller will skip the programmed blanking windows when going through the rpm envelope to prevent audible noise from resonating refrigeration system parts.

If the rpm drops or increases by an out-of-control event (i.e. pressure changes in the refrigeration system, voltage increases or drops), the rpm might still run in the blanked windows.



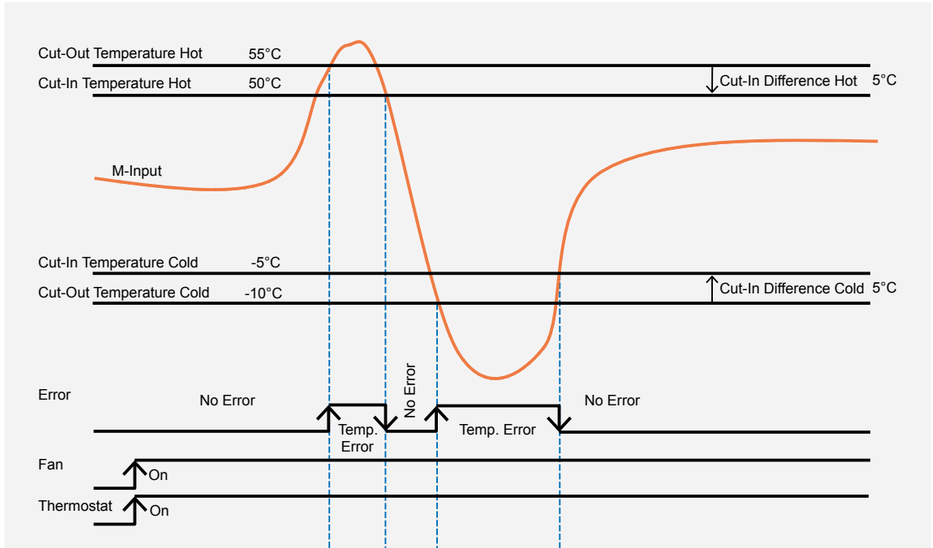
The registers of the controller will be pre-populated with known usual resonance windows to allow a head-start without intensive tuning. It is possible to configure the blanking windows to fit exactly to the application and refrigeration system.

Compressor Protection

Compressor Compartment Temperature Protection (M input)

To protect the compressor in high environmental temperatures in its compressor compartment, the new automotive controller features a secondary NTC input. The secondary NTC must be placed in direct proximity to the compressor to be able to measure the compressors environment temperature. It is mandatory to connect the secondary NTC to use the compressor in its extended operation range. The M input can be disabled for laboratory debugging of the appliance. We strongly recommend enabling the feature for any production appliance. If disabled, Secop reserves the right to decline any warranty claims.

Temperature cut-in/out for both cold and hot environment can be configured to be more restrictive.



Tilt Protection

The BD Nano Auto Controller series can be equipped with a tilt protection algorithm.

When available, the tilt protection will prohibit operation of the compressor out of the specified and configurable envelope. X and Y axis limits for both negative and positive tilt angle can be configured to trigger an error and thereby protect the compressor from tilting out of the released envelope.

The tilt protection protects the compressor from running dry in tilt angles above the maximum inclination level of the integrated oil pumps operating limits. By protecting the compressor from dry-run, its expected lifetime can be ensured.

Tilt protection is available for code numbers 101N2712 and 101N2700. Other code numbers do not include the feature.

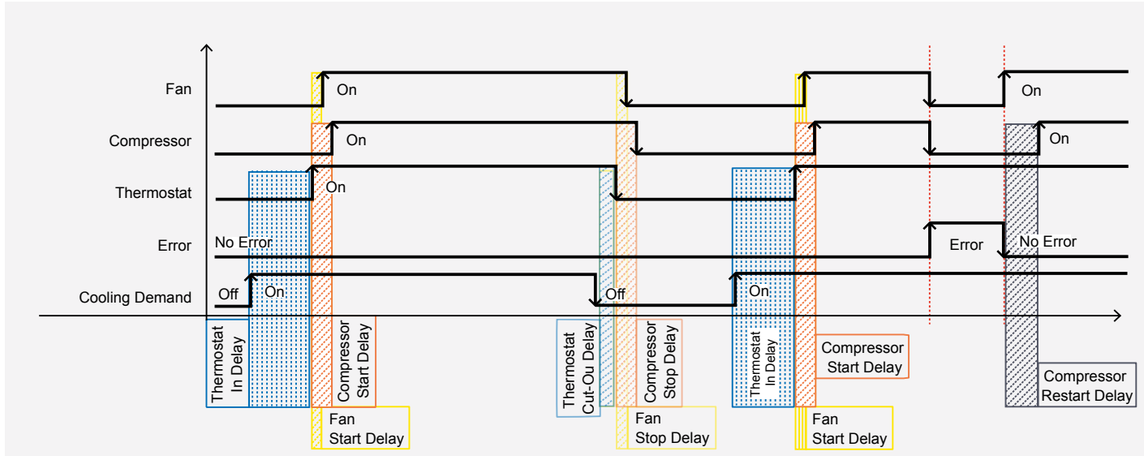
Delays

The BD Nano offers several options for delaying actions:

1. Compressor start delay
2. Compressor stop delay
3. Compressor restart delay
4. Fan start delay
5. Fan stop delay
6. Thermostat cut-in delay
7. Thermostat cut-out delay
8. Battery cut-out delay
9. Battery cut-in delay
10. Modbus response delay

In overall logic, delays add up, meaning, after an error stop, the compressor restarts after restart delay + compressor start delay, or after a mechanical thermostat switch on, both the thermostat cut-in delay and compressor start delay apply.

Compressor, fan, and thermostat delay are the delays influencing the cooling cycle. Independent of the source for cooling demand (thermistor input, thermostat input, Modbus register), the delays apply after the cooling demand is detected.

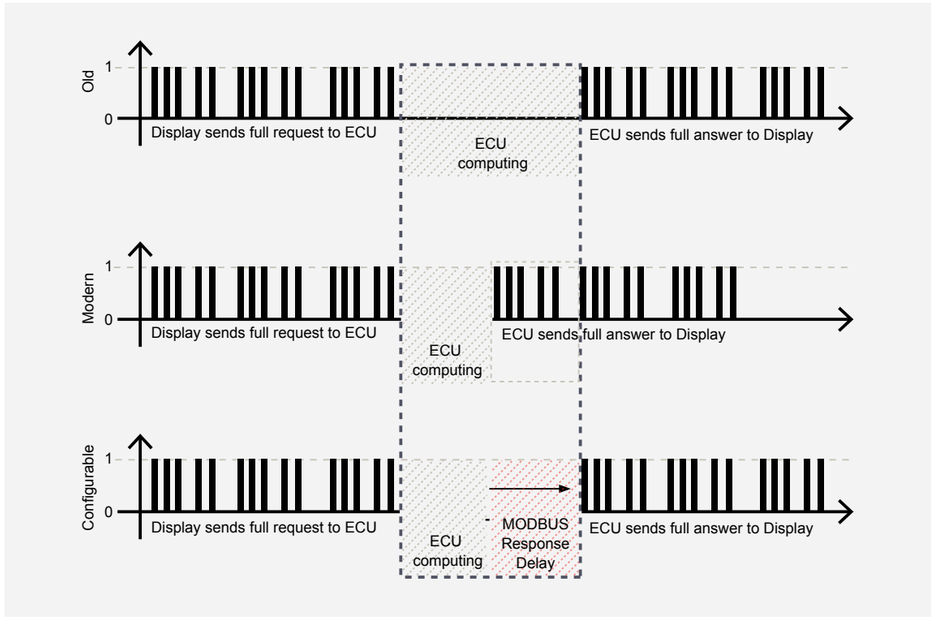


Starting the fan before the compressor and extend its runtime after the compressor has stopped helps to equalize pressures in the refrigeration system. The reduced pressures support a soft and silent start of the compressor.

Thermostat cut-in and cut-out delay help to reduce short operations after door openings, when the cabinet temperature spikes on both thermistor and thermostat based on hot ambient air entering the cabinet.

Battery cut-in/cut-out delays apply when a battery is drained or under load. Configure the battery cut-out delay to a higher value (= longer delay) to ensure the operation of the compressor is not interrupted when, i.e. the engine is started and battery voltage dips below cut out. Configure the cut-in delay to a higher value (= longer delay) to ensure a short burst voltage of an alternator does not immediately start the refrigerator when a battery is empty. See the chapter "Battery Protection" for more details.

The Modbus response delay helps slower thermostats, displays, or master controllers to compute before the modern and fast-responding BD Nano Auto Controller answers to a Modbus request.



The configurable delay ensures backwards compatibility of the modern controller.

Condenser Fan

Fan Speed

The controller features two registers to control the condenser fan speed. One located in an EEPROM cell, intended to be configured once in factory environment. The second is in the controllers RAM, intended to be overwritten by a master controller to actively control the fan speed. Both registers are percent values, 100% equal 12V output, 0% equal 0V. Values between 0% and 40% are not allowed.

Fan Start Delay

The start delay time defines the delay between the thermostat signals cooling demand and the condenser fan starts. To delay the condenser fan, action can be helpful to reduce current spikes when compressor and fan start simultaneously.

Fan Forced State

Via the forced state you can fix the fan state to either normal (auto) mode, forced on or forced off. In normal (auto) mode, the fan starts and stops respecting the delays together with the compressor on a cooling demand.

Note: This is a EEPROM register intended to be factory programmed and should not be overwritten cyclically. (more 10 times/hours

Value	Description
0	Fan in in normal (auto) operation mode
1	Fan is forced on
2	Fan is forced off

Fan Speed Control Mode

The Fan features two new advanced control methods,

a) Fan follows compressor compartment temperature (M input) temperature and

b) Fan follows compressor speed.

c) Fixed fan speed

In Fixed Speed mode, the condenser fan speed is configured one time and stays at the configured speed (fan speed [F2]). It is possible to overwrite the fixed fan speed to overrule the fan speed by a higher-level control algorithm.

In method a) fan follows compressor compartment temperature (M input) temperature (default), the fan speed is adjusted depending on the temperature in the compressor compartment. Min. and max. speed are configurable, min. and max. temperature are inherited from M input cut-in configuration. Fan speed low (F1) and fan speed high (F2) are configurable. The corresponding temperature to fan speed low (F1) is set at 25°C.

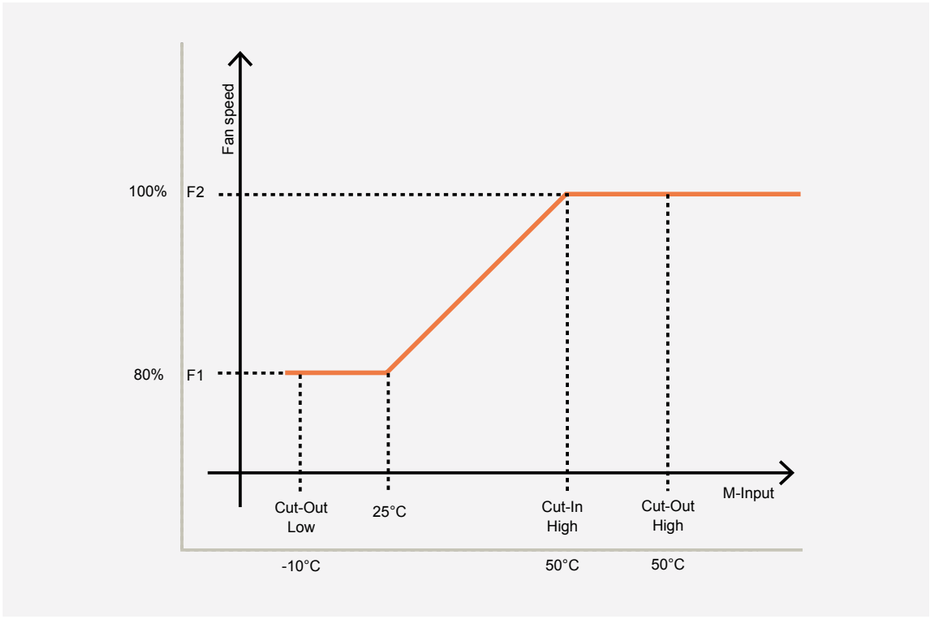
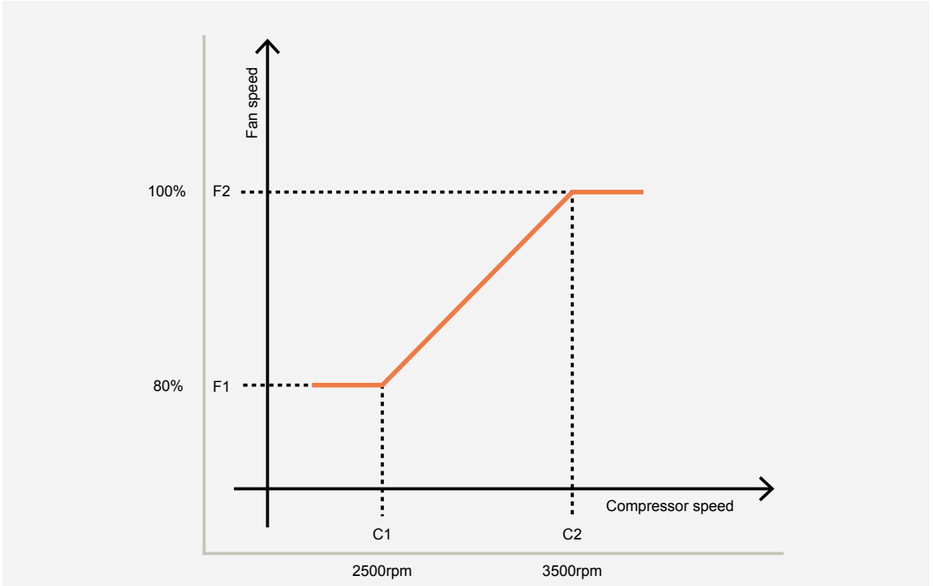


Figure 4- Fan speed depending on compressor compartment temperature (M input)

In b) the fan follows compressor speed control mode (configurable), the fan follows in a defined area the compressors speed, ramping up and down according to the compressors current RPM. The lower and higher intersection of compressor RPM vs. fan RPM can be configured, the points in between are calculated accordingly.



Fan Soft Start

The fan output can be configured to ramp up rather than hard switch on if enabled. This ramp up curve makes it possible to drive demanding fans.

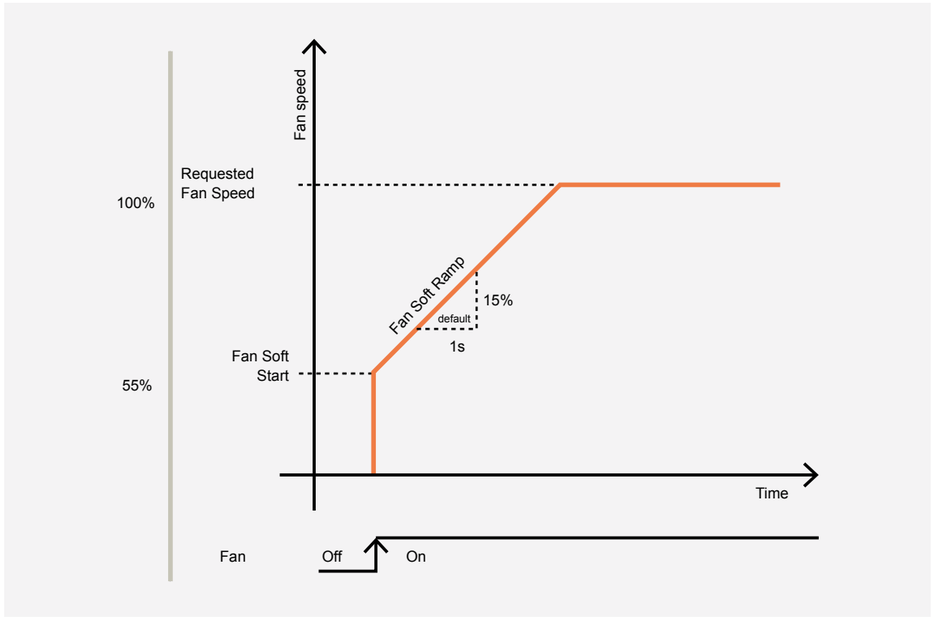


Figure 5- Illustration of a fan soft start

Thermostat

The electronic unit is equipped with a digitally controlled thermostat. To make best use of the thermostat feature, be sure to configure it properly to fit it to the needs of the cooling appliance.

The thermostat is the central state machine for the controller, it signals the cooling demand and therefore the main operating point for the cooling compressor. To configure the target temperature to reach in the cooled chamber, refer to the cut-out temperature. The thermostat will end the cooling demand signal as soon as the cut-out temperature is reached. The thermostat will signal cooling demand again if the temperature has risen to or above the defined cut-out temperature + cut-in difference.

We recommend using the integrated thermostat of the electronic unit, since the values, delays and inertias are factory-tuned for best performance. Nevertheless, it is possible to override the thermostat via a register and force on the cooling demand signal.

Thermostat Type

Via the thermostat type register it is possible to define which temperature sensing element is used. In the default mode, the electronic unit detects automatically if a resistance is connected and decides for NTC thermistor or mechanical thermostat. It is recommended to configure this register if the device is configured using Tool4Cool® or the MODBUS interface, as in auto default (auto) mode, the electronic unit won't detect NTC errors such as shorted or open thermistors, due to considering it a mechanical thermostat.

Value	Thermostat Type	Description
0	Mechanical	Controlling the thermostat is done by shorting terminal C & T of the electronic unit, or by using the "Override (forced on)"-parameter.
1	Electronic	This enables the internal thermostat function, if a NTC is connected between terminal C & T of the electronic unit. If the NTC fails (disconnected or shorted), then it results in an NTC error.
2	Auto	This is a combination of a mechanical and electronic solution, which means that it is possible to run with either a mechanical thermostat or with a NTC. NTC errors cannot be detected and are therefore disabled.

Electronic Thermostat

The controller features a full electronic thermostat implementation, which can detect the current appliance temperature via a connected NTC. It is possible to configure the cut-in and cut-out temperatures via communication interface.

Thermostat Override (forced on)

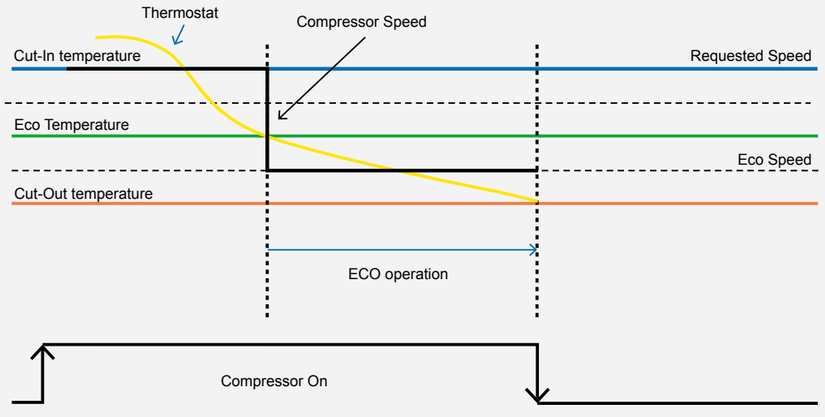
Use this register to control cooling demand and therefore compressor operation externally.

Value	Description
0	Thermostat is in normal operation mode
1	Thermostat is forced on (signals cooling demand)

ECO Mode

For a more economically cooling appliance, the integrated thermostat supports the ECO mode. The idea is to have the compressor running at low rpm during low load conditions and have it run at high rpm at high load conditions. In ECO mode, the compressor's rpm depend on the difference of the current NTC temperature and the actual cut-in temperature. In case the temperature does not exceed the ECO temperature, the compressor stays at the lower ECO speed instead of ramping up to its configured default maximum speed.

On pull-down, the ECO mode will decelerate the compressor as soon as the ECO temperature is reached, to make better use of the inertia of the cooling loop. The slow faded-out motor speed is very beneficial for the energy consumption of the system, as the otherwise undershooting of the temperature would waste energy that is used for normal operation in ECO mode.



After the pulldown succeeds, the appliance will operate in thermostat mode. In this mode, the Eco feature makes use of the variable speed operation of the compressor. The now reduced capacity requirement of the appliance storage compartment allows for a higher evaporating temperature and lower condensing temperature, resulting in a reduced compressor rpm requirement. This reduction allows for a significant improvement on power draw, optimizing the COP of the refrigeration appliance.

Performance Data with Refrigerant R134a

Capacity (ASHRAE LBP) 12 V DC, static cooling watt

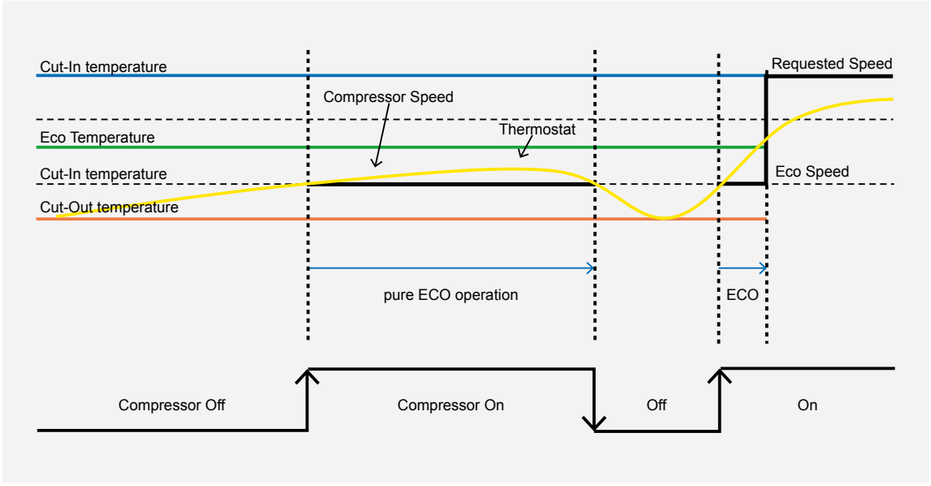
rpm\°C	-30	-25	-23.3	-20	-15	-10	-5	0	5
2,300	17.9	24.9	27.6	33.7	44.8	**58.4**	74.7	94.1	116.7
3,000	23.1	32.7	36.6	45.2	60.8	79.5	101.3	126.3	
4,000	31.4	45.5	51.1	63.1	83.8	107.3	133.3	161.4	
4,500	35.7	52.2	58.7	72.4	**95.9**	122.0	150.4		

Power Consumption 12 V DC, static cooling watt

rpm \ °C	-30	-25	-23.3	-20	-15	-10	-5	0	5
2,300	15.9	19.0	20.2	22.6	26.5	**30.8**	35.3	40.1	45.1
3,000	19.2	23.3	24.8	28.0	33.1	38.4	43.6	48.6	
4,000	25.1	31.3	33.5	37.9	44.7	51.4	57.6	62.9	
4,500	28.8	36.1	38.7	43.9	**51.8**	59.3	66.2		

☐ Pull down condition ☐ Normal operation condition

An additional overall benefit of the ECO mode is the reduced compressor noise at lower speeds. As the ECO mode aims to run the compressor at a lower speed than the configured maximum required speed, the noise is kept low if the compressor stays in the ECO envelope.



Enabling ECO Mode

To enable the ECO mode, you can either factory-enable it when initially programming the device, or on-the-fly enable and disable it using a customer specific display.

Configuring ECO Mode

To configure the ECO mode, it is possible to adjust the setpoint and the eco speed. The set point, configured in percent, is the range between cut-out and cut-in temperature. The speed is the absolute value of the compressors motor speed. ECO set point configuration

The ECO set point is calculated as follows:

Absolute (cut-in – cut-out) * ECO set point register value, i.e.

Cut-out 2°C, cut-in 7°C, Eco 50% => Eco temp 5.5°C

Cut-out 2°C, cut-in 7°C, Eco 20% => Eco temp 3°C

Cut-out 2°C, cut-in 7°C, Eco 80% => Eco temp 6°C

Cut-out -2°C, cut-in 2°C, Eco 50% => Eco temp 0°C

MODBUS Communication

To configure the MODBUS communication according the needs of the cooling appliance, the address of the electronic unit can be changed. To protect the configuration from either being copied or being manipulated, it is possible to set a protective PIN code. To prevent headless operation of the electronic unit when an external display is configured but not sending commands (i.e. defect, broken cable), the register "Set main switch off when communication timeout occurs" can be used to disable the electronic controller after a configurable timeout.

Bus Address

Note: If the bus address is changed, all commands issuing the bus address must also be changed.

Protection PIN

Please refer to "Protecting the System via PIN Code"

Set Main Switch off When Communication Timeout Cccurs

Depending on the configuration of this register, the unit either goes into an error state after a communication timeout to a master controller has occurred or continues to operate normal. This allows the master controller to disable the whole application by stopping the communication.

Please note: If a master controller is used to operate the unit and a timeout and error is configured, cyclic requests must be sent to the controller to keep the communication alive. That is, if timeout is configured to 5 seconds, a command every 4 seconds would keep the communication alive and not trigger the timeout action.

Value	Description
0	Do not switch off but report the error on timeout
1	Switch off and report the error on timeout
2	Do not switch off and do not report the error on timeout
3	Switch off but do not report the error on timeout

Communication Timeout

The communication timeout wait time can be configured, i.e. if a stopped communication is intentional behavior, it can be configured very quickly to allow the motor controller to stop any compressor action as soon as the master controller stopped any communication. If a communication timeout is not expected or not used as a feature, it can be configured rather slowly to ensure cooling even a master controller that might be stalling and is not requesting any information.

Custom Registers

It is possible to store ten times 2-byte information on these addresses. These registers are written to the EEPROM of the electronic unit and are not used or modified by any process. The intended use might be serial numbers, configuration template checksums, template version numbers, temperature offsets for displays, or anything that would need to be stored in an EEPROM. Note: Each write action to these registers decreases the EEPROM's life.

ACCESSIBLE READABLE PARAMETERS

Compressor

Actual Speed

The actual speed register holds the current motor rpms. A deviation of a few rpm to the requested compressor speed is possible and normal due to the inertia of the regulator.

Motor Controller Temperature

It is possible to access the current temperature of the motor controller PCB via two registers. Both the inverter temperature and load dump input protection temperature are available for reading.

Product Information

Product information is available via the read device identification (Encapsulated Interface Transport) Modbus request. Refer to the Modbus Register Information (available from Secop on request) for full documentation.

Available Information:

→ Product Code Nb.

→ Software Version

→ Product Manufacturer

Errors and Events

Actual Error

This register holds, if applicable, the current corresponding error code to the error state. The register is reset to zero if the error is no longer present.

Error Codes

The following codes apply if the electronic unit detects any errors by itself.

Code	Error	Description
0	No error	-
1	Battery protection error	Voltage below cut-out or out of range
2	Fan error	Fan shorted or too much power drawn
3	Compressor error	Compressor failed to start
4	Speed error	The requested speed couldn't be archived.
5	Temperature error	Electronic unit is overheated
6	NTC failure	NTC shorted or open circuit
7	Communication Error	A previously established communication is lost
8	Tilt Error	The controller is tilted further than the configured maximum

Blink Codes

Either on the internal error LED or an externally connected LED, the error codes are shown as blinks. The patterns will blink their corresponding number of blinks regarding the code and afterwards go dark for 1 second. Each blink on duration is approx. 1/5 of a second. Each full blink cycle takes 4 seconds.

Note: The external error LED must be protected with approx. 1.8 kΩ to battery+, cathode to LIN connector.

Logs

Error Logs

Via Tool4Cool®, it is possible to view a table with the recent 255 errors. All errors contain the relative uptime when they have appeared and a reference to the corresponding event.

Event Logs

Via Tool4Cool®, it is possible to view a list with the most recent 255 events. Events are points of interest but do not affect the working state of the system, i.e. a change on EEPROM values is logged to the event list, or a reboot of the whole device.

Encapsulated Interface Transport

The controller supports the Modbus encapsulated interface transport holding its product code number, its firmware version as well as the production date. All data is available via either Tool4Cool or Modbus command 0 × 2 B (43).

Protecting the System via PIN Code

To protect the system against manipulation, theft of configuration values, etc. it is possible to set up a protection PIN (see "Settings Protection Code"). If the settings protection code is factory-programmed to the device, the unit locks the communication with this PIN.

To enable writing parameters to a locked device, the settings protection code must be either entered via Tool4Cool or written once to the corresponding register of the ECU. After unlocking, the unit remains unlocked. If locked, all write requests to parameters are blocked.

NOTE ON EEPROM REGISTERS

EEPROM registers are used to permanently store information, even in case of power outages. The registers located in the controllers EEPROM are intended to be used for factory programming, to allow an initial configuration.

Anyway, also a master controller/display can use these registers to control the system behavior. In the latter case, we recommend keeping the write cycles as reduced as possible. A good measure is to not exceed more than 10 writes per hour.

MODBUS INTERFACE

The device uses a Modbus Interface according to the V1.02 Standard:

www.modbus.org/docs/Modbus_over_serial_line_V1_02.pdf

Supported Modbus Functions

3 (0 × 03)	Read holding registers
4 (0 × 04)	Read input registers
6 (0 × 06)	Write single registers
43 (0 × 2b)	Read device identification (encapsulated interface transport)

For functional description on each function code refer to the Modbus Application Protocol Note:

www.modbus.org/docs/Modbus_Application_Protocol_V1_1b.pdf

Establish a Modbus Connection

Serial Communication Settings

Baud rate	19,200 baud
Duplex	Half
Encoding	8 bit binary
Parity	Even
Stop bits	One
Handshaking	None
Transmission mode	RTU

Please note: The MODBUS application protocol uses a MODBUS specific CRC implementation. See the sample code below for more details.

Hardware Signal Level Requirements

Please refer to the LIN Bus standards for any level and slope-related requirements, i.e. rise and fall times for signals. Absolute maximum and recommended ratings for this controller overrule any LIN standards which might allow for wider ranges.

CRC Calculation

Example CRC 16 Function (in C)

```c
#define             M16                 0xA001
#define             MODBUS_CRC_INIT     0xffff

unsigned short int CalcCRC(unsigned char *pBuf, unsigned char ucLen)
{
  unsigned char ucByte, ucBit, ucShf;
  unsigned short int uiCRC;

  uiCRC = MODBUS_CRC_INIT;
  for(ucByte = 0; ucByte < ucLen; ucByte++)
  {
    ucShf = *pBuf;
    for(ucBit = 0; ucBit < 8; ucBit++)
    {
      if((uiCRC ^ ucShf) & 0x0001)
        uiCRC = (uiCRC >> 1) ^ M16;
      else
        uiCRC >>= 1;
      ucShf >>= 1;
    }
    pBuf++;
  };
  return uiCRC;
}
```

Note: This code returns a reversed CRC, high byte – low byte instead of low byte – high byte and is therefore compliant to the implemented MODBUS interface in Secop controllers.

Example of MODBUS Conversation

Write a MODBUS Parameter

Example: Request to configure the 12V cut-in to 1.0V

Request to send to the electronic unit

Slave Address	Function Code	Starting Address	Register Value		CRC²	
0 × 01	0 × 06	Please request Modbus application note from Secop	0 × 0A	0 × 00	0 × FF	0 × FF

Answer from electronic unit

Slave Address	Function Code	Starting Address	Register Value		CRC²	
0 × 01	0 × 06	Please request Modbus application note from Secop	0 × 0A	0 × 00	0 × FF	0 × FF

Note: On a write request, the electronic unit will answer with the new written register value (this might not be identical to the requested value, i.e., when the requested value is out of range and the max. possible value is chosen)

Writing a MODBUS Parameter

Example: Read the current electronic unit pcb temperature

Request to send to the electronic unit

Slave Address	Function Code	Starting Address	Register Value		CRC²	
0 × 01	0 × 03	Please request Modbus application note from Secop	0 × 00	0 × 01	0 × FF	0 × FF

Note: On a write request, the electronic unit will answer with the new written register value (this might not be identical to the requested value, i.e., when the requested value is out of range and the max. possible value is chosen)

Reading a MODBUS Parameter

Example: Read the current electronic unit pcb temperature

Request to send to the electronic unit

Slave Address	Function Code	Byte Count	Register Value		CRC²	
0 × 01	0x03	0x02	0x01	0xA4	0xFF	0xFF

Note: The unit will return always a byte count of two, because the communication interface is designed to carry two byte data. If the data is just a single byte in size, the high byte carries the information, and the low byte can be ignored (but will be used for CRC calculation).

Note²: CRC values are not actual CRC values but dummy values for visualization purposes only.

Developing an External Display

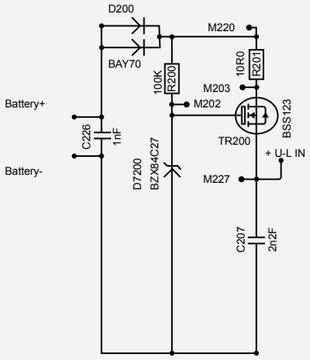
Recommended LIN Interface

While the recommended hardware interface might be a good solution for our use case, it is possible that a display might need different components, especially with automotive classifications behind.

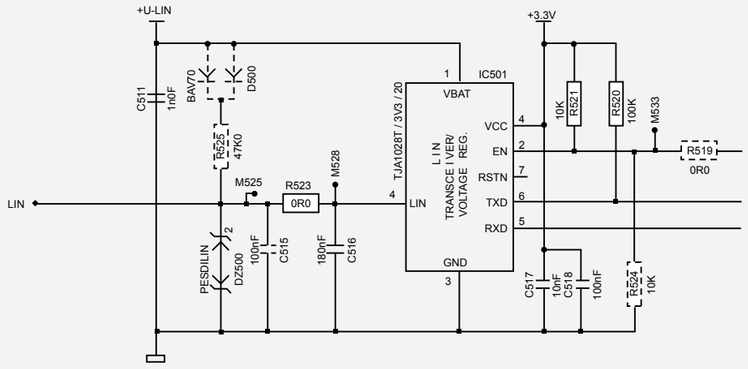
Please note, the maximum logic level voltage supported by the electronic unit is 27 V.

LIN Bus Integration on Electronic Unit

Overvoltage Protection



LIN Bus Transceiver Implementation



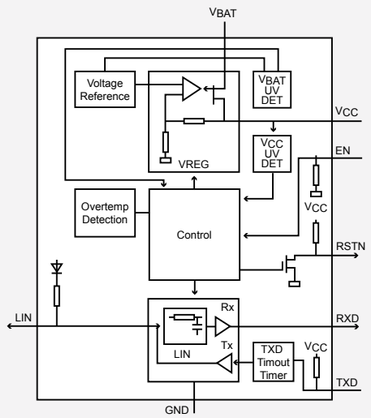
Recommended LIN Bus integration for Display

We suggest adding an identical overvoltage protection to the LIN bus on the display side.

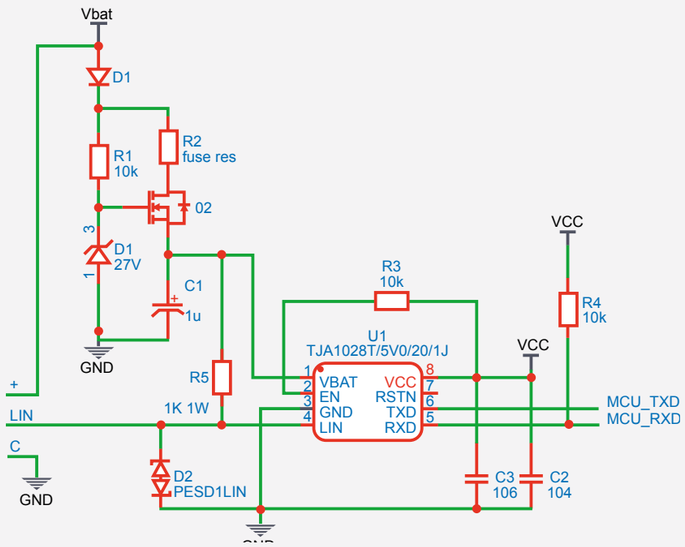
For the transceiver, we recommend a TJA1028T type, which has an integrated linear converter.

For microcontrollers with a supply voltage of 5 V use the TJA1028T/5V0/20, for 3V3 microcontrollers the TJA1028T/3V3/20.

LIN IC Block Diagram



Recommended Display Diagram Implementation



For a detailed description on the TJA1028, please consider the Application Notes provided by NXP:
TJA1028 | LIN Transceiver with Integrated Voltage Regulator | NXP Semiconductors

ORDERING INFORMATION

Packaging Information

The electronic unit is available as single package and in industrial packaging.

The single package is individually boxed together with a short manual and comes with a scannable barcode on the packaging for individual reselling intended to be sold as spare part or demonstration unit.

The industrial package packs 30 electronic units together per box. The packaging is intended to be used in industrial production environments to be an easy solution for stock management and reduce packaging waste.

Ordering Information

Compatible Compressor(s)

Model	Code Nb	Refrigerant	Description
BDN45F-A	109Z0440	R134a, R1234yf	BDN45F OEM Compressor
BDN45F-A	109Z0441	R134a, R1234yf	BDN45F OEM Compressor
BDN45F-A	109Z0442	R134a, R1234yf	BDN45F OEM Compressor

Peripheries ordering information

All peripheries with a Secop article number can be ordered either directly from Secop (industrial quantities) or from our resellers worldwide.

For periphery without a Secop article number, please contact the listed manufacturer for ordering information

Periphery, Single-, and Industrial Packs

Model	Type	Code Nb	Description
BD Nano Leisure Controller	SP	101N2740	Single unit of Leisure Controller
	IP	101N2741	40 units of Leisure Controllers
BD Nano Automotive Controller	SP	101N2720	Single unit of Automotive Controller
	IP	101N2721	40 units of Automotive Controllers
OEM Controller A	SP	101N2710	Single unit of OEM Controller
	IP	101N2711	40 units of OEM Controllers
OEM Controller A1	SP	101N2712	Single unit of OEM Controller
	IP	101N2713	40 units of OEM Controllers
OEM Controller B	SP	101N2700	Single unit of OEM Controller
	IP	101N2701	40 units of OEM Controllers
OEM Controller C	SP	101N2730	Single unit of OEM Controller
	IP	101N2731	40 units of OEM Controllers
OEM Controller C1	SP	101N2732	Single unit of OEM Controller
	IP	101N2733	40 units of Automotive Controllers
NTC Thermistor	PP (IP)	105N9617	Recommended Secop Thermistor for Thermostat Input
Secop Gateway	PP	105N9518	Communication Interface for PC and Controller
SDD Connector Package	PP	105N9030	Includes a set of all connectors for both Leisure Controllers and Solar Direct Drive Power Management Systems.
Snap On Mounting Hardware incl. Rubber Feet	PP (SP)	118-1959	Containing mounting hardware incl. snap-on and rubber feet
Bolt On Mounting Hardware incl. Rubber Feet	PP (SP)	118-1960	Containing mounting hardware incl. screws and rubber feet Recommended for heavy duty environments.
Bolt and Nut Mounting Hardware incl. Rubber Feet	PP (SP)	118-1966	Containing mounting hardware incl. screws, nuts, and rubber feet. Recommended for thin-mounting plates without embedded threading

SP = Single Pack, IP = Industrial Pack, PP = Periphery

PRODUCT INFORMATION

Product Information on 2D DataMatrix **Label**

Labels on electronic units consist of a 2D DataMatrix Code area and several lines with information. The 2D DataMatrix Code always consists of 62 characters containing information about type, code number, product version, product revision, unit ID, supplier, part number, and text.

Text information on the label:

Sample Label

Product Information Registers

Please see "Encapsulated Interface Transport"

DOCUMENT INFORMATION

Revision

Revision	Date	Change
DES.S.100.G1.02	2023-10-12	Initial version
DES.S.100.G2.02	2024-26-11	First revision

SECOP GROUP: AROUND THE WORLD

12
international partners for advanced developments

33
laboratories located in Austria, Germany, Slovakia, China, U.S.A., and Turkey

160
R&D engineers and technicians

440
patents globally

50+
countries with customer support

Secop is the expert for advanced hermetic compressor technologies and cooling solutions in commercial refrigeration. We develop high performance stationary and mobile cooling solutions for leading international commercial refrigeration manufacturers and are the first choice when it comes to leading hermetic compressors and electronic controls for refrigeration solutions for light commercial and DC-powered applications.

Secop was formerly known as Danfoss Compressors and is one of the founding fathers of modern compressor technology with years of experience that goes back to the beginning of the 1950s.

- **Flensburg:** Sales and R&D
- **Turin:** Sales
- **Gleisdorf:** R&D
- **Zlaté Moravce:** R&D, Logistics, and Manufacturing
- **Tianjin:** Sales, R&D, Logistics, and Manufacturing
- **Atlanta:** Sales and Logistics

Stationary Cooling

Mobile Cooling

Medical Cooling

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DES.S.100.G2.02