ApwmU
Universal PWM adapter for standard car fan control units

v1.0.4

IMPORTANT!!!

The author has completed the electrical circuit as close as possible to modern standards of power electronics, but the device is not certified, assembled and tested manually.
Therefore, the **AUTHOR DOES NOT COMPENSATE ANY MATERIAL AND MORAL RESPONSIBILITY** in the event of damage to the electrical parts of your car, as well as in the event of failure of the PWM adapter itself due to non-compliance with the installation and configuration rules!
When handing over the device for installation to a third party (electrician), make sure that he carefully reads the instructions and follows all the recommended rules! For some reason, many specialists do not consider it necessary to study the manual and rely only on personal experience, in which there is often no understanding of the specifics of the installation and configuration of such controllers. A lot of work and time has been invested in the creation of these devices, so I, as an author, want them to work for a long time, without interruption and satisfy all the requirements of their owners, that is - You!

SPECIFICATIONS

Case dimensions	**40x50x20 mm**
Case type	**Z74U (KRADEX) (non-waterproof!)**
Case material	**ABS-пластик**
Connector	**Standard 7pin x 2.54mm**
PCB-board dimensions	**30.5 x 40.5 mm**
Supply voltage	**+12V**
Supply current	**< 50mA**
Communication/power ports	**5/2**
Control signals	**- analog 0 ... + 5V - PWM (10...1000Hz)**
Output PWM Frequencies	**10/25/50/100/250/500/1000Hz**
PWM-output maximum load	**200mA**
PWM-output signal amplitude	**+5V/+12V (switch on PCB-board)**
Input PWM Frequencies	**from 10 to 1000 Hz**
PWM-intput signal amplitude	**+5V/+12V**
Interaction	**Button on PCB-board**
Indication	**LED on PCB-board**

* under voltage «+12V» means the vehicle voltage (+10...15V)

OPERATING DESCRIPTION

The adapter is an microcontroller device, and is designed to control the onboard (built-in) car fan control modules of the engine cooling system.
The working principle is the generation of a PWM (pulse width modulation) signal of need parameters (frequency, duty cycle, polarity) for smooth RPM-control of the fan speed with a built-in control unit. FAN-speed is calculated based on the readings of an additional temperature sensor, or an external PWM signal from a standard ECU, as well as in accordance with the selected "cooling strategy".

CONSTRUCTION

Device can work with **"+12V"** onboard voltage only! Power is supplied from the "POWER IGNITION CIRCUIT". The adapter is protected against polarity reversal; the board also has a 200mA self-healing fuse at the +12V input.
Device has five IO-ports onboard:

S1, S2 – temperature sensor connection;
A/C1 – "+"(+12v) connection from the air conditioning compressor clutch;
A/C2 – "-"(GND) connection from the refrigerant pressure sensor, or external PWM control signal (PWM-input);
PWM – PWM output;

The adapter can generate a PWM signal with an amplitude of +5 or +12 volts

direct  or

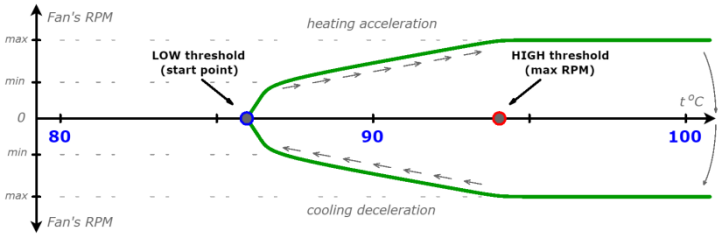
inverse  polarity with a duty cycle of 10% to 90%.

The amplitude of the signal at the PWM output is switched by a toggle switch on the board to the "+ 5V" or "+ 12V" position.
PWM frequency, inversion, and other parameters and functions are switched in the "OPTIONS SETTING" mode.

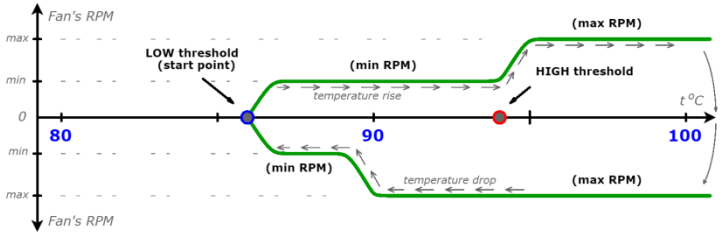
COOLING STRATEGIES

Strategies are algorithms for starting and controlling the fan speed based on the values of an NTC sensor or an external PWM control signal.

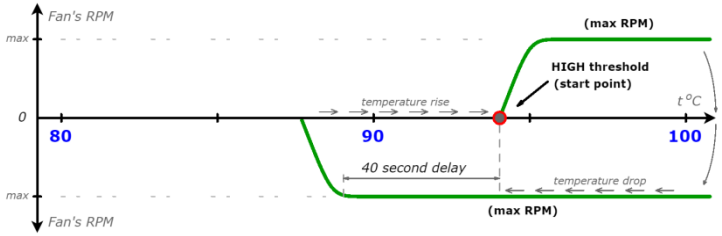
1. **Maintain temperature** – user in real time, on a running motor, at the moments of warming up to the desired temperature values, performs programming the **LOW** and **HIGH** thresholds, thus creating a range for smooth temperature control by means of accelerating / decelerating the fan spinning. The fan starts to spin smoothly at the moment the temperature overcomes by **LOW** threshold, and continues to accelerate to maximum speed when the **HIGH** threshold is reached; and vice versa - when the temperature drops, the speed decreases smoothly, and when the **LOW** threshold is overcome, the fan turns off. That's algorithm does not allow the coolant to heat up above the average value of the programmed temperature range. For example, in the 86-94°C range, the coolant will not heat above 90°C.



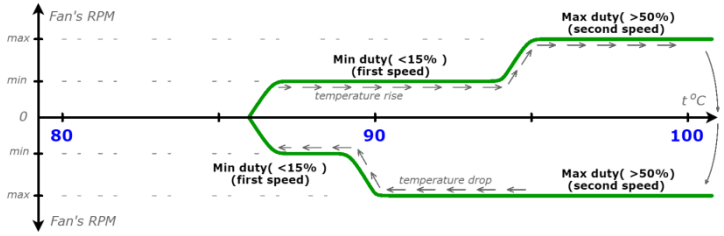
2. **Standard mode (2 speeds)** – user in real time, on a running motor, at the moments of warming up to the required temperatures, programs the **LOW** and **HIGH** thresholds, thus creating moments for turning on the fan, respectively, with MINIMUM and MAXIMUM speeds. The fan starts smoothly when the temperature reaches the **LOW** threshold. Further, the minimum rotation speed is maintained until the temperature overcomes the **HIGH** threshold, after which the fan smoothly and quickly spins up to the maximum speed, maintaining high speed until the coolant temperature drops to the **LOW** threshold, after which the speed gradually drops to minimum, or the fan stops when the temperature drops for the **LOW** threshold.



3. **Soft start (max.speed)** – user in real time on the running motor and warming up to the required temperature programs the moment of starting the fan (**HIGH** threshold). Upon reaching the set temperature, the fan smoothly accelerates to maximum speed. When the temperature drops below the set value, the fan will continue to spinning at a maximum speed for another 40 seconds, after which it will stop if the coolant temperature continues to decrease.



4. **PWM adaptation** – fan speed is calculated based on the duty cycle of the PWM signal from the standard ECU. The fan schedule will be similar to the strategy schedule "Standard mode (2 speeds)". At duty values above 15%, the fan will start smoothly at minimum speed, at duty values above 50%, the fan will smoothly accelerate to maximum speed.

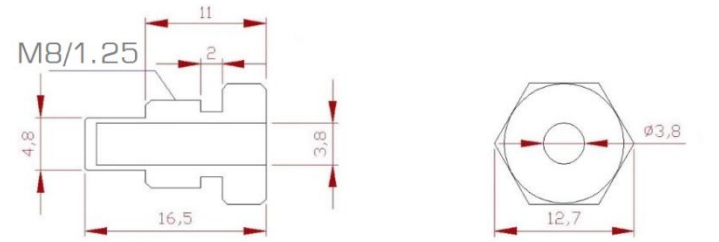


For this mode, use the **"Standard PWM"** temperature signal connection diagram. It is also worth considering that the PWM signal from the standard ECU can be inverted, and for this you need to activate the next strategy **"PWM adaptation (inversion)"**. Adapter version 1.0.3 is capable of processing an external PWM signal with frequencies not exceeding 1000Hz!

5. **PWM adaptation (inversion)** – This strategy is completely similar to the previous one, with the difference that the PWM input receives an INVERTED PWM signal from the standard engine ECU.

MEASURING THE COOLANT TEMPERATURE

To monitor the engine temperature, ApwmU can use any NTC-type sensor, or an analog signal with a voltage of 0 to 5 volts from other temperature measurement sources. Interaction with almost any temperature value is possible and this makes the device UNIVERSAL and adaptable for different purposes (for example, to simulate the operation of a viscous coupling, control the intercooler blowing, etc.). The set with the adapter includes a standard M8 insertion type NTC sensor with the following parameters:



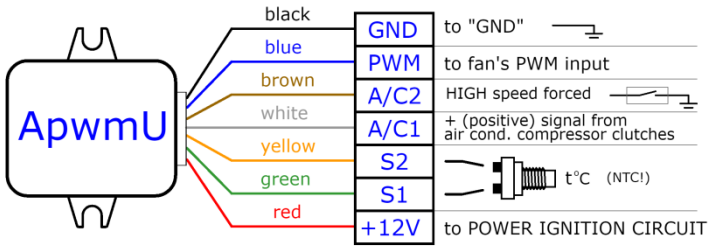
t°C	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	100
kΩ	1.42	1.38	1.34	1.3	1.26	1.22	1.18	1.14	1.11	1.08	1.05	1.02	0.99	0.96	0.94	0.91	0.88	0.8

The sensor SHOULD be installed as close as possible to the coolant outlet from the cylinder head for maximum contact with the hot coolant. This will provide the most accurate temperature measurement and therefore more efficient cooling!
The sensor SHOULD NOT be installed in the radiator or the lower radiator pipe, as this leads to a large error in temperature measurements at different times of the year and under different operating conditions of the vehicle!

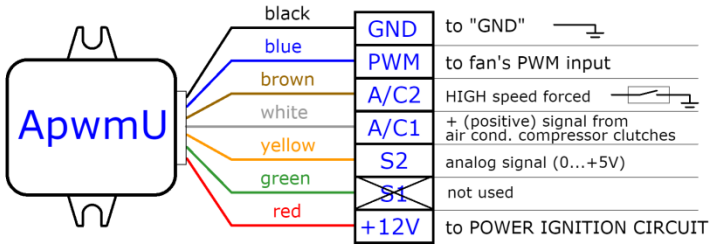
CONNECTION

A The adapter can use 3 temperature signal connection schemes:

1. **"With separate sensor"** - the circuit uses a separate independent resistive sensor (any 2-pin, NTC-type), which is connected to ports **S1** and **S2**.

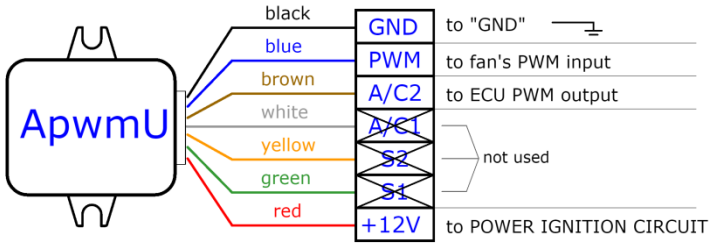


2. **"Analog input"** - an external analog temperature signal from 0V to 5V is connected to the **S2** port. The **S1** port is not used in this case!



An "external" temperature signal can be used from a standard ECU sensor*, or a special temperature monitoring sensor following on the dashboard. The reference voltage of the standard sensor should not exceed + 5.2V, **otherwise the adapter will go into error, or it may be destroyed!**
To be sure that the signal is correct, before connecting, you should measure the voltage on the signal wire of the sensor relative to "GND", on a cold and warm engine, and if the voltage changes (increases or decreases in the range of 0 ... + 5V), then a signal is correct! You also need to measure the voltage at the moments of warming up the motor to the LOWER and UPPER thresholds, so that the voltage difference between them is not less than **200mVolst!**
For this connection scheme, you need removed soldering jumper **"J1"** from the PCB-board.
**** This connection scheme should be checked only empirically, since errors in the ECU or interference in the operation of the adapter are possible. Stable operation with this connection method is NOT GUARANTEED !!!!!!***

3. **"Standard PWM"** - an external PWM signal from the standard engine ECU is connected to port **A/C2**, while the strategies **"PWM adaptation"** or **"PWM adaptation (inversion)"** must be activated!



OPERATING MODES. *Indication*

Modes are the events described below, to which the adapter reacts, giving an appropriate response to the LED indicator, starting fan or writing various parameters into the memory (do not confuse OPERATING MODES with COOLING STRATEGIES).

1. **"Temperature settings"**- temperature range thresholds programming mode. It is active when the device is first started, when there is no data in the memory, or at the time of reconfiguration, when the values of the previous thresholds are erased and new ones are expected to be written (available for strategies 1-3). It has 3 indication states (for more details, see the START-UP and TEMPERATURE SETTINGS sections).

2. **"Main"**- a mode in which the adapter smoothly controls the fan speed, generating a PWM signal of the calculated duty cycle, based on the temperature settings (for 1-3 strategies), or the duty cycle of an external PWM control signal (for 4-5 strategies). After the motor heats up above the **LOW** threshold of the range or after a control signal appears on the **A/C2** port, a signal starts to be generated on the **PWM** port, spinning the fan to the desired speed. *LED indicator periodically emits a short flash, or lights up constantly if the engine temperature is at the **HIGH** threshold of the range.*

3. **"Climate control"** - after the +12V signal from the air conditioner compressor is applied to the **white** wire, after 2 seconds the fan will smoothly accelerate to "minimum" or "maximum" RPM (depending on the port setting, see the OPTIONS SETTINGS section), and will spinning at this speed until the temperature enters the operating range or the signal from the **white** wire is turned off. This mode works even without temperature calibration. *LED indicator periodically emits a short flash (this mode is active for 1-3 strategies)*. After disconnecting the signal from the **white** wire, the fan will continue to spinning for another 20 seconds, excluding false stops when the air conditioner compressor is turned off for a short time.

4. **"HIGH speed forced "** - when connecting the **brown** wire (A/C2) to "GND", regardless of the temperature coolant, the fan will start smoothly to maximum RPM and spinning at maximum until the signal to "GND" is disconnected. this mode can be used with refrigerant pressure sensors of the air conditioning system or for forced start of the fan from a button inside the passenger compartment. It is also possible to set the shutdown delay (10/20 sec). For strategy 4-5, **brown** wire is used as external PWM input.

5. **"Save mode"** - it starts when the temperature signal is incorrectly connected, or if the sensor contacts are missing, short, or open. Adapter detects an error; smoothly start up the fan to 50% speed and *LED blinks at 1 second intervals*. This mode will be activated until the sensor error is eliminated and the adapter is restarted by a power reset (available for 1-3 strategies).

6. **"Test run"** - available only for the 1st strategy and empty data of temperature settings (or after a "full reset"). It's activated by **five quick clicks of the button**. The fan start up smoothly to 50% speed, holds the speed for 10 seconds, after which it smoothly decelerates and turns off. *LED blinks at 1 second intervals as in "Save mode".*

7. **"Options Settings"** - this mode is different from the others that can be activated only when power is supplied with the button pressed. In this mode, you can configure various parameters, as well as do a "full reset". In this mode, the adapter will not respond to events described in other modes until the button is released or until a "full reset" is completed. For more details, see the OPTIONS SETTINGS section.

START UP

If the adapter is installed and connected according to the selected diagram, then you can trigger and set temperature thresholds.

First start. By default, the "1 PRESET" with the settings and the strategy **"1. Maintain temperature"** will be activated. After powering on the adapter, after 2 seconds the *LED will blink 2 times* - this means the device has turned on. The delay is needed so that the "hot" engine has time to start before the fan starts to spin. Then we wait a couple more seconds. If the temperature signal or sensor is connected correctly, the device will not perform any action, waiting for the temperature thresholds to be set. If a signal or sensor is not connected, or is connected incorrectly, the adapter will immediately switch to **"Save mode"** (see section OPERATING MODES. Indication).

If the **"Standard PWM"** connection diagram is used, then 4 or 5 strategies should be activated, respectively.

If you have chosen other connection schemes, then you need to activate strategies 1 to 3 of your choice. It is worth noting that cooling strategies 2 and 3 are best suited for the **"Analog input"** circuit.

If strategy 4 or 5 is activated, then, accordingly, no actions will be performed until a PWM signal with a duty cycle of more than 15% appears on the **A/C2** port.

You can also check if the fan reads the PWM signal generated by the adapter correctly. To do this, make a **"Test run"** (see the section OPERATING MODES. Indication). If "Test run" is successful, then the PWM signal is compatible with the fan. If the fan starts up intermittently or keeps the spinning unstable or starts at maximum speed and does not turn off, then the PWM frequency is not compatible and you should change it to a suitable one (see the OPTIONS. SETTINGS section). The default PWM frequency is set to **10Hz.**

If the fan immediately starts to spinning after power is applied, then it is possible that either the PWM port is connected incorrectly, or it is required to activate the **"inversion"** or **"idle" PWM** in the options settings (some fan control units in idle mode require constant activity of the PWM signal from minimum duty cycle).

TEMPERATURE SETTINGS

For the 1st and 2nd cooling strategies, we perform the following actions: warm up the engine to the desired **LOW** threshold temperature value (for example: 86°C); press the button and hold it for 3 seconds until the LED lights up; release the button; the LED blinks quickly for a while; The **LOW** threshold is saved; warm up the engine to the desired **HIGH** threshold (for example: 94°C); press the button and hold it for 3 seconds until the LED flashes; release the button; LED will still light up for 2 seconds, confirming the entry of the **HIGH** temperature threshold. Then the fan starts to spin up smoothly to maximum speed, and as the engine cools down, the controller will switch to the "**Main**" operating mode (see section OPERATING MODES. Indication).

For the 3rd cooling strategy, we only program the **HIGH** threshold: we warm up the engine to the temperature value we need (for example: 94°C); press the button and hold it for 3 seconds until the LED flashes; release the button; LED will still light up for 2 seconds, confirming the entry of the **HIGH** temperature threshold. OK! Temperature range is saved in the memory of the current PRESET (default is **1st**). Then you can adjust the fan speed for different modes, and other options (see the OPTIONS SETTINGS section).

IMPORTANT!!! The desired cooling strategy must be activated before making temperature settings. Active by default: **"1.Maintain temperature"** (most effective). Also, before activating the desired strategy, you should reset the temperature settings in the current PRESET, if it was done earlier (see the OPTIONS SETTINGS section).

For strategies 4th and 5th accordingly, temperature settings are not required!

You need to understand that the internal combustion engine of a car has a large thermal inertia, which depends directly on the mass, type of metal and design features. Heat from combustion chambers and exhaust gases from the cylinder head takes some time to be distributed throughout the "body" of the engine. Each motor has unique temperature characteristics, so temperature settings are always highly individual! When choosing a temperature, it is best to start from the **"thermostat opening point"**, and if this, for example 85°C, then the **LOW** threshold should be set no higher than 90°C, and the **HIGH** threshold is not higher than 95°C**.** If you set the **LOW** threshold too high, then at moments of critical thermal loads (heat in traffic jams with active climate control, long climb uphill, etc.), it is possible that the motor heating speed is higher than the speed of soft start of the fan to the maximum. From here we get the effect of "undercooling" and the average operating temperature will rise by several degrees, which in a short moment can lead to a very rapid temperature rise with engine loads.

If we set the **LOW** threshold too high, we get about the same effect of "undercooling". The fan simply will not have time to accelerate fast enough to blow off excess heat from the radiator and prevent further temperature rise. The season should also be taken into account. The higher the air temperature, the longer it takes for the radiator to remove heat from the engine. Therefore, in the summertime, the operating temperature range should be shifted lower so that the fan starts earlier and reaches maximum speed faster, preventing a rapid rise in temperature.

OPTIONS SETTINGS

MEMORY	1 **PRESET**	● Temperature settings; ● PWM frequency; ● A/C1 port management; ● A/C2 port management; ● LOW threshold delay; ● MIN fan RPM; ● MAX fan RPM;	● Smooth start; ● Cooling strategy; ● "Idle" PWM; ● PWM inversion; ● Reset temperature settings for current preset
	2 **PRESET**	● Temperature settings; ● PWM frequency; ● A/C1 port management; ● A/C2 port management; ● LOW threshold delay; ● MIN fan RPM; ● MAX fan RPM;	● Smooth start; ● Cooling strategy; ● "Idle" PWM; ● PWM inversion; ● Reset temperature settings for current preset
	3 **PRESET**	● Temperature settings; ● PWM frequency; ● A/C1 port management; ● A/C2 port management; ● LOW threshold delay; ● MIN fan RPM; ● MAX fan RPM;	● Smooth start; ● Cooling strategy; ● "Idle" PWM; ● PWM inversion; ● Reset temperature settings for current preset

It is possible to save 3 independent PRESETS with individual settings of options and temperature in the device memory. This is done for the convenience of quick switching of fan modes, for example, for periods of *winter / summer / off-season*. It is enough to configure each of the PRESETS separately once and in the future just switch between them at any time.

The **OPTIONS** are configured as follows:

press and hold the button; we connect the power; wait for a series of LED blinks corresponding to the selected option; release the button; we observe the reaction of the adapter in the form of a short series of flashes according to the number of corresponding to the selected setting (see table); then the adapter is rebooted (double blinking of the LED). Each series of flashes toggles the corresponding OPTION:

- **1 blink** – switching PRESET with settings [1/2/3] (switch one by one);
- **2 blinks** – switching PWM frequency [10/25/50/100/250/500/1000Hz]**;** (switch one by one);
- **3 blinks** – rpm setting for active A/C1 port [MIN/MAX/OFF] (switch one by one);
- **4 blinks** – setting the forced start port A/C2 [ON/+10sec/+20sec/OFF] (switch one by one);
- **5 blinks** – delay LOW threshold [10/15/20sec]
- **6 blinks** – MINIMUM fan speed setting [15/20/30%duty] (switch one by one);
- **7 blinks** – MAXIMUM fan speed setting [60/75/90%duty] (switch one by one);
- **8 blinks** – fan smoothness start setting [1/2/3/4 types] (switch one by one);
- **9 blinks** – switching cooling strategy [1/2/3/4/5] (switch one by one);
- **10 blinks** – "idle" PWM [ON/OFF] (switch one by one);
- **11 blinks** – inverted PWM signal [ON/OFF] (switch one by one);
- **12 blinks** – deleting temperature settings for the current PRESET;
- **many short flashes** – FULL RESET by "default" for adapter setups - in all PRESETS all OPTIONS take the 1st positions of their settings, and the temperature data is erased!

Further, for convenience of perception, a table with a step-by-step algorithm for setting OPTIONS is presented.

Moving down the "steps" and performing the described actions, we get the appropriate response of the LED and the desired setting of the option. To switch to the next value of the same option, you need to repeat the sequence of all actions again starting from STEP 1.

The process requires concentration and adherence to a clear sequence of actions, but is not something complicated and does not require special knowledge.

SETTINGS OPTION. TABLE ALGORITHM

"Out of the box", as well as after "FULL RESET", the options in all PRESETS are set to "default" and are marked in the table with the icon "●" then it should be borne in mind that when further configuring the desired option
It's value switches to the NEXT in the list after "●"

STEP	ACTION		PCB's LED RESPONSE
1	*hold down the button*		
2	*power ON*		
3	**1 blink**	*release the button*	***1 short blink*** – выбор 1-го ПЕРСЕТА с настройками ●
			2 short blinks – выбор 2-го ПЕРСЕТА с настройками
			3 short blinks – выбор 3-го ПЕРСЕТА с настройками
4	*hold the button*		
5	**2 blinks**	*release the button*	***1 short blink*** – PWM frequency set – **10Hz** ●
			2 short blinks – PWM frequency set - **25Hz**
			3 short blinks – PWM frequency set - **50Hz**
			4 short blinks – PWM frequency set - **100Hz**
			5 short blinks – PWM frequency set - **250Hz**
			6 short blinks – PWM frequency set - **500Hz**
			7 short blinks – PWM frequency set - **1000Hz**
6	*hold the button*		
7	**3 blinks**	*release the button*	***1 short blink*** – *MINIMUM* speed set when port **A/C1** is activated ●
			2 short blinks – *MAXIMUM* speed set when port **A/C1** is activated
			3 short blinks – **A/C1** port OFF (deactivate)
8	*hold the button*		
9	**4 blinks**	*release the button*	***1 short blink*** – **A/C2** port active ●
			2 short blinks – **A/C2** port active + **10 seconds** OFF delay
			3 short blinks – **A/C2** port active + **10 seconds** OFF delay
			4 short blinks – **A/C2** port OFF (deactivate)
10	*hold the button*		
11	**5 blinks**	*release the button*	***1 short blink*** – *LOW threshold delay* **10 seconds** ●
			2 short blinks – *LOW threshold delay* **15 seconds**
			3 short blinks – *LOW threshold delay* **20 seconds**
12	*hold the button*		
13	**6 blinks**	*release the button*	***1 short blink*** – MINIMUM fan speed **15%** (duty) ●
			2 short blinks – MINIMUM fan speed **20%** (duty)
			3 short blinks – MINIMUM fan speed **30%** (duty)
14	*hold the button*		
15	**7 blinks**	*release the button*	***1 short blink*** – MAXIMUM fan speed **60%** (duty) ●
			2 short blinks – MAXIMUM fan speed **75%** (duty)
			3 short blinks – MAXIMUM fan speed **90%** (duty)
16	*hold the button*		
17	**8 blinks**	*release the button*	***1 short blink*** – smooth start mode 1 ●
			2 short blinks – smooth start mode 2
			3 short blinks – smooth start mode 3
			4 short blinks – smooth start mode 4
18	*hold the button*		
19	**9 blinks**	*release the button*	***1 short blink*** – **"Maintain temperature"** strategy ●
			2 short blinks – **"Standard mode (2 speeds)"** strategy
			3 short blinks – **"Soft start (max.speed)"** strategy
			4 short blinks – **"PWM adaptation"** strategy
			5 short blinks – **"PWM adaptation (inversion)"** strategy
20	*hold the button*		
21	**10 blinks**	*release the button*	***1 short blink*** – **"iddle"** PWM OFF ●
			2 short blinks – **"iddle"** PWM ON
22	*hold the button*		
23	**11 blinks**	*release the button*	***1 short blink*** – inverted PWM OFF ●
			2 short blinks – inverted PWM ON
24	*hold the button*		
25	**12 blinks**	*release the button*	***Fast blinking series*** – reset temperature settings for the current PRESET
26	*hold the button*		
27	**many short flashes**	***FULL RESET to default settings*** (all options are set to position "●") and full clearing of temperature data in all PRESETS	
28	*release the button*		