UM3551

User manual

Getting started with the AEK-POW-LDOV02X dual linear voltage regulator evaluation board with configurable output voltage and diagnostic features based on automotive-grade L99VR02XP

Introduction

In the automotive industry, a low-dropout linear regulator (LDO) provides effective voltage ripple suppression and electromagnetic compatibility (EMC) performance, particularly when compared to DC-DC converters.

LDOs are crucial for systems operating in harsh environments, such as vehicles.

In modern automotive designs, a 12 V battery typically powers the system. While a stable lower-voltage supply is required for system operation, constantly changing load conditions and environmental factors cause variations in the 12 V supply. An automotive battery-direct-connect LDO converts a harsh high-voltage supply into a stable lower-voltage output.

Moreover, thermal performance is always a critical concern for battery-direct-connection LDOs. The LDO connected to a car battery needs to convert the battery voltage down to 5 V, 3.3 V, or even lower voltage for powering MCU, CAN bus, and other devices. In these situations, the voltage drop on the LDO might be very high, and power dissipation on the LDO might even exceed 1 W for a 100-mA loading current. If the system demands several hundred milliamps of current, a single LDO cannot handle the power dissipation.

For automotive off-board sensors and small current off-board modules, systems must consider their power supplies with respect to both protection and output accuracy. In these systems, the power supply runs through a long cable from the main board. The long cable might be damaged in the harsh automotive environment, potentially causing short-to-ground or short-to-battery conditions on the power supply output. In such cases, the system must implement a protection mechanism to safeguard on-board components from damage.

Additionally, it is essential to minimize the voltage-tracking tolerance between the off-board sensor power supply and the MCU/ADC power supply. An ultra-low tolerance tracking voltage for the off-board sensor power supply is critical in achieving high-quality data acquisition. A voltage-tracking LDO is an ideal solution for driving the off-board loads. Voltage-tracking LDOs provide comprehensive protection features, including short-to-ground, short-to-battery, overload protection, thermal protection, and ultra-accurate output tracking voltage.

Our AEK-POW-LDOV02X evaluation board addresses this challenge, thanks to the L99VR02XP dual linear voltage regulator, reaching a higher output current and distributing power consumption among multiple devices.

The L99VR02XP operates with reduced input voltage, minimizing internal power dissipation and maximizing the sourcing current capability. Output current limitation protects the regulator and the application from overload conditions, such as short to ground.

Thanks to its operating temperature range (Tj=-40°C to 175°C), the device is suitable for electronic applications with high temperature environments and for applications that require stable power supplies (for example, navigation systems, microcontroller supplies, audio systems, automotive display drivers, sensors, infotainment processors, and powertrain systems).

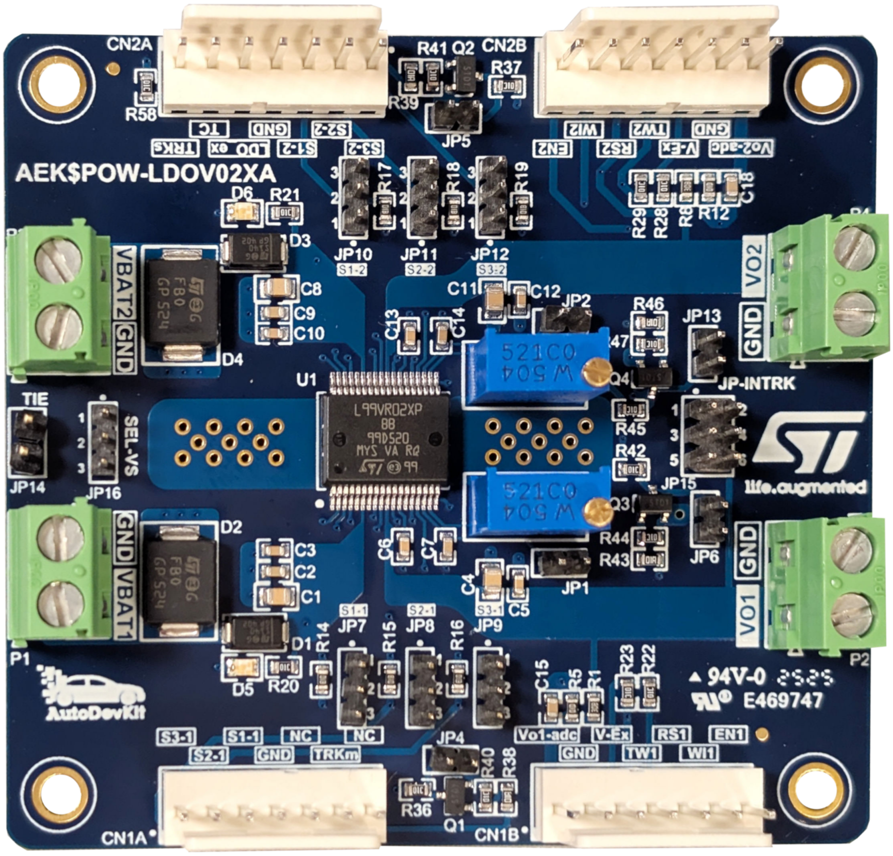
The board features two output voltages, with two LDOs (LDO1 and LDO2), providing low ripple and excellent noise immunity.

LDO2 performs automatic voltage tracking and de-tracking of LDO1, or of an external LDO voltage, thus representing an accurate solution for automotive off-board sensors and small current off-board modules.

This feature is important in complex systems with multiple power supply voltages where it is necessary for one voltage to reach its value before another, or for two voltages to reach the same value simultaneously. Additionally, this feature helps minimize high voltage differences between connected power supplies, reducing inrush currents.

The board also features some automotive safety mechanisms, such as a watchdog per LDO, generated from an external MCU, which allows real-time monitoring of device correct operation. Another key safety feature is advanced on-chip temperature control. In fact, the L99VR02XP outputs are split into two different temperature clusters with dedicated thermal sensors. If the temperature of a cluster reaches the thermal protection threshold, only the relevant output is turned off while the other one remains active.

Figure 1. AEK-POW-LDOV02X evaluation board



Warning: *The AEK-POW-LDOV02X evaluation board is designed for R&D laboratory use only. It is not intended for field use in vehicles. Moreover, it is not a reference design. Its purpose is evaluation and not production as stated in Terms of use license.*

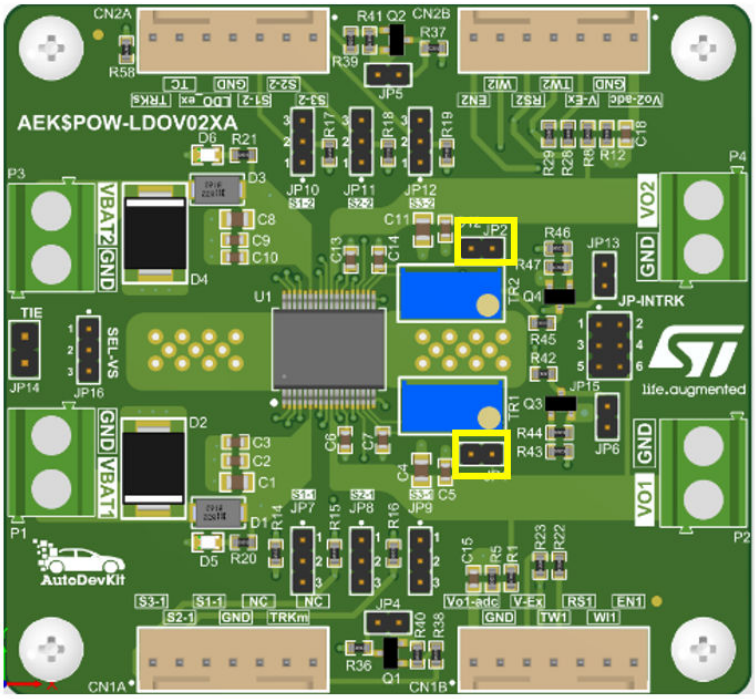
Note: For dedicated assistance, please submit a request in ST AutoDevKit Community.

1 Safety mechanisms

The AEK-POW-LDOV02X evaluation board implements the following automotive safety mechanisms:

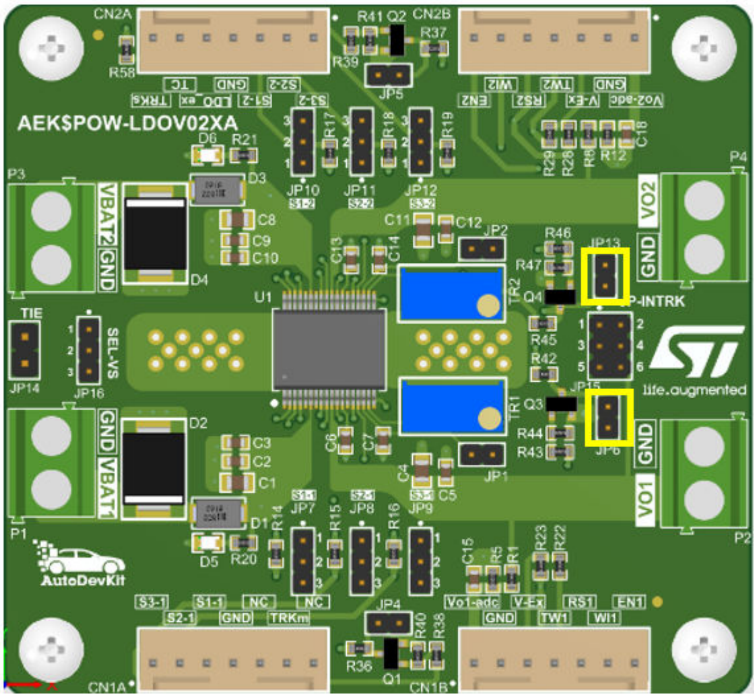
- Output voltage monitoring
  Two independent reset circuits supervise the $V_{O\_LDO1,2}$ output voltages. If at least one output voltage falls below $V_{o\_th\_LDO1,2}$ threshold (equal to V_o-10% $V_{o1,2}$), the $R_{ST\_LDO1,2}$ pins are pulled low.
- Active connection monitoring (MCU-connected configuration only)
  For continuous connection monitoring between the MCU and the two LDOs, a watchdog is employed. The watchdog signal (generated by the MCU and applied to the AEK-POW-LDOV02X $WI_{1,2}$ pins) is a square wave with 50%. duty cycle. The frequency value depends on both the output voltage and the chosen C7 capacitor value for LDO1 and C14 capacitor value for LDO2 (see the AEK-POW-LDOV02X schematics). The LDO devices monitor the watchdog signal provided by the MCU. If the signal frequency is outside the range described above, the $RST_{1,2}$ pins are pulled low. You can disable the watchdog by placing a jumper on JP1 for LDO1 and a jumper on JP2 for LDO2.
  The figure below highlights jumper positions.

Figure 2. Watchdog jumper position



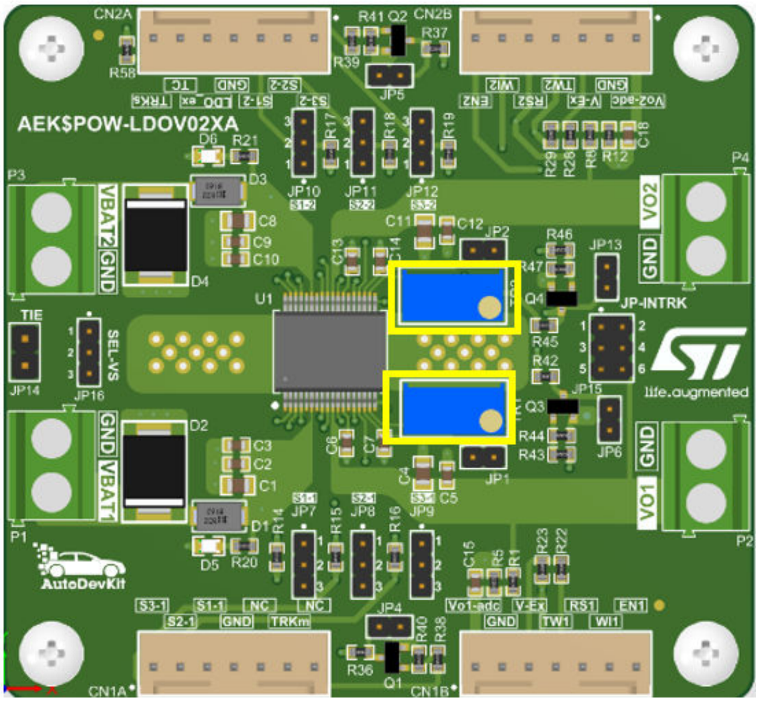
- Regulator enabling and disabling
  The L99VR02XP voltage regulator is enabled/disabled through two independent enable pins, $EN_{1,2}$.
  Remove JP6 and JP13 jumpers to enable $LDO_{1,2}$ output voltage.
  Put JP6 and JP13 jumpers to disable $LDO_{1,2}$ output voltage.

Figure 3. Enable jumper positions



- Output current limitation
  The current output limitation protects the regulator in case of current overload or short-to-ground.
  The overcurrent limit is set by regulating the value of a multiturn variable resistor (trimmer) on the AEK-POW-LDOV02X I_{short} pins.
  To increase or decrease I_{short_LDO1}, turn TR1 trimmer, respectively in counterclockwise or clockwise direction.
  To increase or decrease I_{short_LDO2}, turn TR2 trimmer, respectively in counterclockwise or clockwise direction.

Figure 4. Trimmer positions

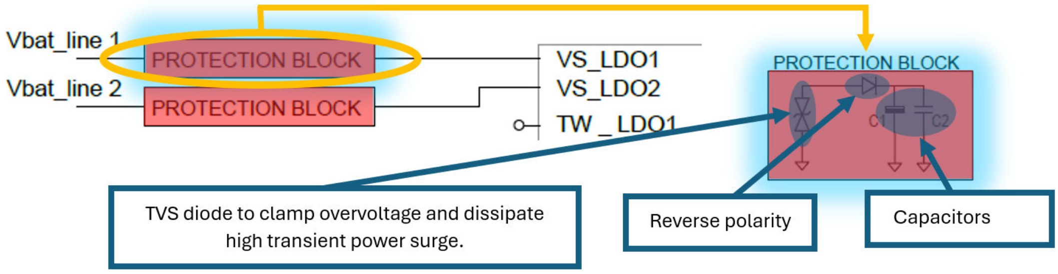


If the $LDO_{1,2}$ overcurrent limit is reached, the $RST_{1,2}$ pins are pulled low.

- Thermal warning detection
  To warn the microcontroller about a severe temperature increase of the LDO, two thermal warning outputs have been implemented (one for each regulator). If the device detects a junction temperature above 150°C, the related advanced thermal warning ($TW_{\_LDO1,2}$) pin is pulled low, while the specific voltage regulator and its features remain active.
- Overvoltage warning detection
  The $TW_{\_LDO1,2}$ pins also provide diagnostics about the output overvoltage. To distinguish between a thermal and an overvoltage warning event, two different signals are generated on the same $TW_{\_LDO1,2}$ output pin. A thermal warning event detection sets the $TW_{\_LDO1,2}$ pins low, whereas an output overvoltage event generates a square wave (duty cycle = 50% and period = 300 microseconds) on the $TW_{\_LDO1,2}$ pins.

- Reverse polarity protection
  To prevent reverse battery polarity, a protection block has been added to rail input lines (VS_LDO$_{1,2}$).
  The following scheme shows the implemented circuit.

Figure 5. VS_LDO1,2 protection block position



2 Overview

2.1 Board features

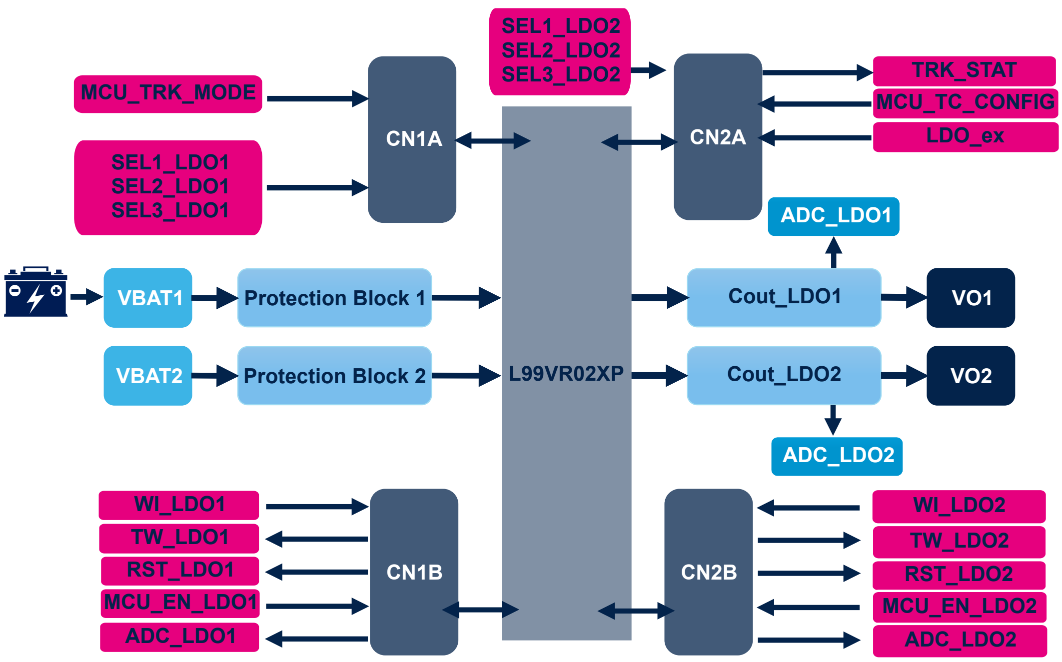
The board key features are:

- L99VR02XP dual automotive-grade linear voltage regulator
- User-selectable output voltages (0.8, 1.2, 1.5, 1.8, 2.5, 2.8, 3.3, and 5 V) with up to 250 mA load current capability per channel (LDO1 and LDO2)
- Protection and diagnostic features:
  - Enable pin for enabling/disabling the voltage regulator
  - Reset
  - Watchdog
  - Advanced thermal warning with output overvoltage detection
  - Undervoltage lockout
  - Programmable short-circuit output current (I_{short})
  - Fast output discharge
  - Short-to-battery output protection
- The two internal LDOs have separate thermal clusters and temperature sensors
- Thermal shutdown and short-circuit protection
- LDO2 automatic voltage tracking and de-tracking with respect to LDO1, or to an external voltage regulator

2.2 Block diagram

The figure below shows the AEK-POW-LDOV02X overall architecture diagram, related to the two LDOs, with protection blocks (detailed in Figure 5. VS_LDO1,2 protection block position), power supplies (VBAT1,2 for LDO1,2), connectors (CN1A, CN2A, CN1B, CN2B), capacitors for supply backup and high-frequency noise filtering (Cout_LDO1,2), and signals (tracking mode, watchdog, thermal warning, overvoltage, enable, reset and ADC).

Figure 6. AEK-POW-LDOV02X block diagram



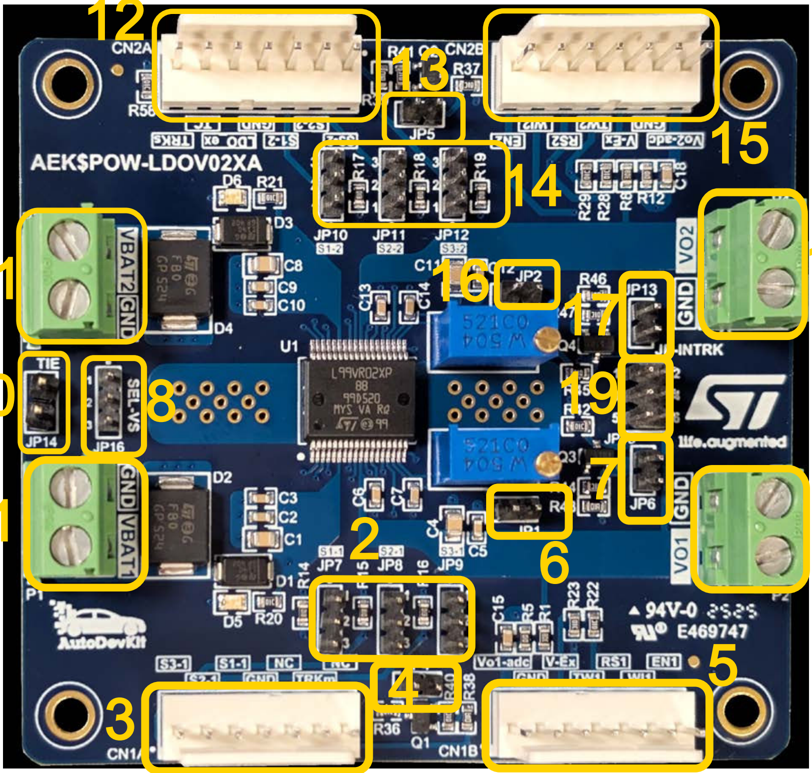
3 Hardware overview

3.1 Hardware description

3.1.1 Hardware overview

Figure 7. AEK-POW-LDOV02X main components

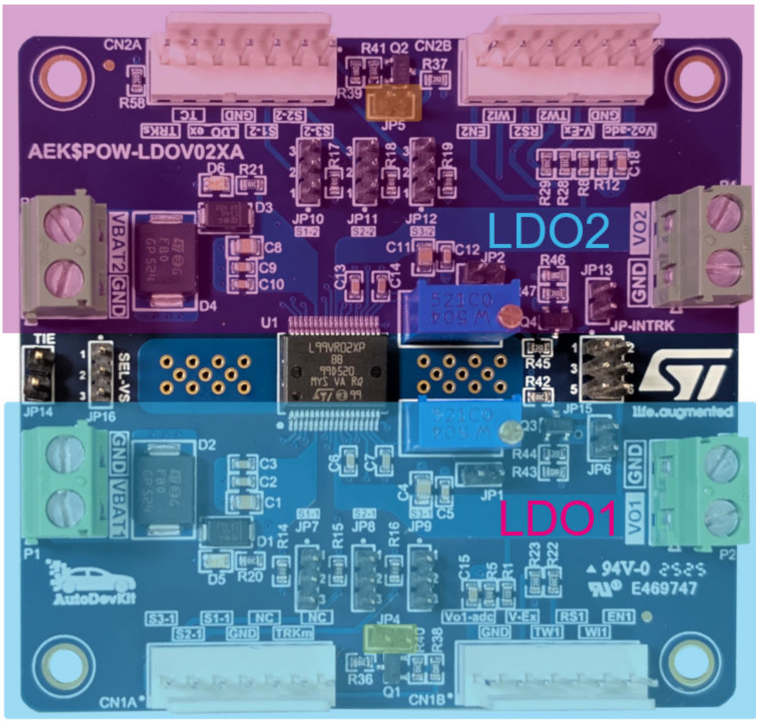
1. VBAT1 input to supply LDO1 (12 V_{DC} battery or power supply)
2. JP7,8,9 jumpers to select LDO1 output voltage
3. CN1A 7-pin KK254 male connector to plug the AEK-POW-LDOV02X to an external MCU board
4. JP4 jumper to disable/enable tracking mode
5. CN1B 7-pin KK254 male connector to plug the AEK-POW-LDOV02X to an external MCU board
6. JP1 jumper to disable/enable the watchdog signal to check VO1 in LDO1
7. JP6 jumper to disable/enable LDO1
8. JP16 jumper to select VS1 or VS2
9. VO1 LDO1 output voltage
10. JP14 jumper to tie VBAT1 and VBAT2
11. VBAT2 input to supply LDO2 (12 V_{DC} battery or power supply)
12. CN2A 7-pin KK254 male connector to plug the AEK-POW-LDOV02X to an external MCU board
13. JP5 jumper for thermal shutdown configuration
14. JP10,11,12 jumpers to select LDO2 output voltage
15. CN2B 7-pin KK254 male connector to plug the AEK-POW-LDOV02X to an external MCU board
16. JP2 jumper to disable/enable the watchdog signal to check VO2 in LDO2
17. JP13 jumper to disable/enable LDO2
18. VO2 LDO2 output voltage
19. JP15 jumper to select the source for IN_TRK (LDO1 or External LDO)



3.1.2 Functional blocks

As shown in the figure below, the board is functionally divided into two blocks along the horizontal axis: the lower part manages LDO1, while the upper part manages LDO2.

Figure 8. AEK-POW-LDOV02X functional blocks



3.1.3 Hardware architecture

The AEK-POW-LDOV02X evaluation board is equipped with four connectors for MCU-connected mode only:

- CN1A and CN1B related to LDO1
- CN2A and CN2B related to LDO2

Table 1. CN1A pin description

Pin	Description
MCU_TRK_MODE	Tracking mode on indicator
GND	Ground reference
SEL1_LDO1, SEL2_LDO1, SEL3_LDO1	Output voltage selectors for LDO1

Table 2. CN1B pin description

Pin	Description
MCU_LDO1_EN	Enable input for LDO1
Wi_LDO1	Watchdog input for LDO1
RS1	Reset output for LDO1
TW1	Thermal warning output and overvoltage warning output for LDO1
V-Ex	Input external voltage reference (5 V)
GND	Ground reference
ADC_LDO1	Output voltage for LDO1. This pin can be used to read the output voltage via a configured external ADC peripheral from an MCU

Table 3. CN2A pin description

Pin	Description
TRK_STAT	Tracking status indicates to MCU that LDO2 is in tracking
MCU_TC_CONF	Thermal cluster configuration pin that selects thermal cluster (LDO1,2 thermal shutdown tied, or thermal shutdown untied)
LDO_ex	External LDO connection pin (put a voltage, selected in the Sel1,2,3 configuration table)
GND	Ground reference
SEL1_LDO2, SEL2_LDO2, SEL3_LDO2	Output voltage selectors for LDO2

Table 4. CN2B pin description

Pin	Description
MCU_LDO2_EN	Enable input for LDO2
Wi_LDO2	Watchdog input for LDO2
RS2	Reset output for LDO2
TW2	Thermal warning output and overvoltage warning output for LDO2
V-Ex	Input external voltage reference (5 V)
GND	Ground reference
ADC_LDO2	Output voltage for LDO2. This pin can be used to read the output voltage via a configured external ADC peripheral from an MCU

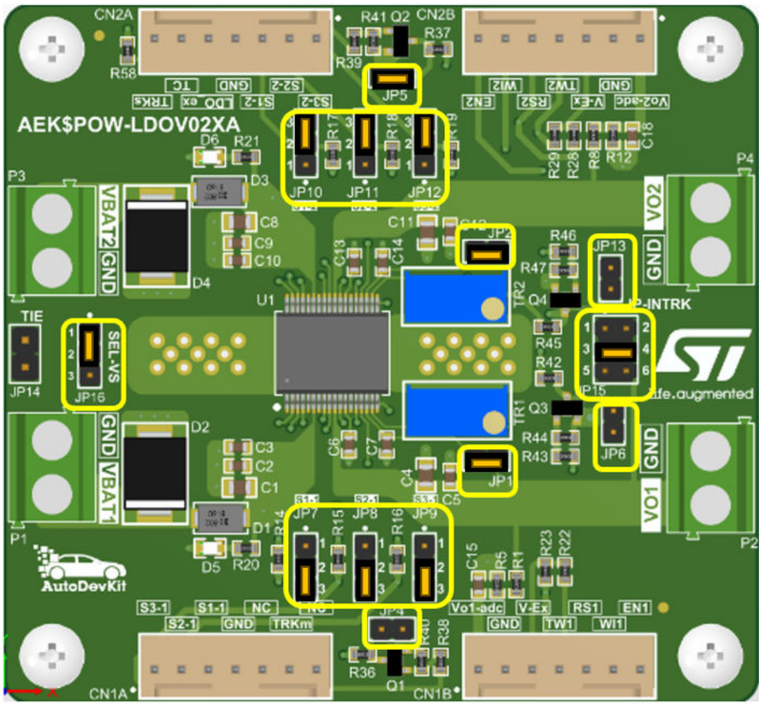
- Jumpers: to be used in standalone working mode only.

Table 5. Jumper description

Jumper	Description
JP1, JP2	LDO1/LDO2 watchdog enable/disable jumpers. Put a jumper on JP1 to disable LDO1 watchdog and remove the jumper to enable it. Put a jumper on JP2 to disable LDO2 watchdog and remove the jumper to enable it.
JP4	Jumper to set TRK_MODE. Default: remove the jumper.
JP5	Thermal cluster configuration for LDO1, LDO2 Put a jumper on JP5 to use LDO1 and LDO2 thermal clusters separately. Remove the jumper to use both clusters as thermally tied.
JP6, JP13	LDO1,2 enable/disable jumpers. Put a jumper on JP6 to disable LDO1 and remove the jumper to enable it. Put a jumper on JP13 to disable LDO2 and remove the jumper to enable it.
JP7, JP8, JP9	Sel1,2,3 – LDO1 output voltage selection (Sel1,2,3_LDO1= GND, jumper in position 2-3, default 0.8 V)
JP10, JP11, JP12	Sel1,2,3 – LDO2 output Voltage selected (Sel1,2,3_LDO2= GND, jumper in position 2-3, default 0.8 V)
JP15	Jumper to select the source to track. Put a jumper in positions 1-2 to activate external LDO tracking. Put a jumper in positions 3-4 for GND (no tracking active). Put a jumper in positions 5-6 to activate LDO1 tracking.
JP16	Jumper to set power rail VS1 or VS2. Default position 1-2.

The figure below shows the jumper position on the board.

Figure 9. Jumper position



- Voltage connectors

Table 6. Voltage connector details

Connector	Description
$V_{S\_LDO1,2}$	Operating DC power supply voltage ranges from 2.15 to 28 V
$V_{O\_LDO1,2}$	LDO output voltages

3.1.4 Enable pins

Two independent enable inputs (EN_LDO$_{1,2}$) enable/disable the L99VR02XP.

A high-voltage signal switches the regulator on. When the enable pins are set to low, the VO1 and VO2 outputs are switched off. The current consumption of the device is about 1 μA and the fast output discharge circuit is activated.

When using an external MCU board, signals coming from the MCU must be:

- MCU_LDO1,2_EN = 0 to enable the LDOs
- MCU_LDO1,2_EN = 1 to disable the LDOs

To change the output voltages while the regulators are on, apply a pulse signal to the EN_LDO$_{1,2}$ input pins after setting SELx_LDOY pins (see table 25).

The L99VR02XP needs a low enable signal (En_LDO1,2) to acquire the input level of SELx_LDOY and select the output voltage accordingly.

3.1.5 Output voltage selection

The L99VR02XP provides up to eight different output voltage options for each output. The combination of its three digital input selectors (SELx_LDOY) determines the output voltage according to the following truth table.

Table 7. **LDO1,2 truth table**

$V_{O\_LDO1,2}$	SEL1_LDOY	SEL2_LDOY	SEL3_LDOY
5	1	1	1
3.3	1	1	0
2.8	1	0	1
2.5	1	0	0
1.8	0	1	1
1.5	0	1	0
1.2	0	0	1
0.8 (default)	0	0	0

The SELx_LDOy pin configuration is acquired at the device startup (in about 500 µs).

Once the configuration is set, the output voltage cannot be changed until the next EN_LDO1,2 pin transition. If all SELx_LDOy pins are left unconnected, the default configuration is applied.

3.1.6 Reset pins

Two independent reset circuits supervise the output voltages VO1,2.

The reset circuit is active when EN_LDO1,2 is high.

As the reset pin (RS 1,2) is an open-drain output, a 10 KΩ resistor, connected to Vext, is used to pull it up (refer to AEK-POW-LDO02X schematic).

When VO1,2 falls below the threshold (= VO1,2 -10% of VO1,2), the reset RS 1,2 signal generates a low logic level.

C6 and C13 capacitors are used to increase the delay after VO1,2 > (VO1,2-10% of VO1,2), holding the RS signal down (to GND).

The delay time is calculated through the following equation:

$$T_{rd} = \frac{2.2\ V}{I_{cr\_LDO1,2}} C_{tr}$$

Where:

Trd = 16µs if Vcr_LDO1,2 pins are floating

I cr_LDO1,2 = 8µA to 30µA (from datasheet)

We selected 2.2 nF for C_{tr} (C6=C13 in the board schematic diagrams) with a delay time in the range:

Trd = 162µs to 605µs (measured at about 300µs).

Note: When the RST pin is pulled low, be aware that the current flowing through the RST pin may affect the watchdog activation or deactivation.

3.1.7 Autonomous watchdog

The L99VR02XP features an autonomous watchdog, which is an automotive safety mechanism used to monitor continuous connection with an external MCU.

Up to two supplied microcontrollers are monitored by the watchdog inputs, Wi_LDO1,2. The watchdog signals are generated by the MCU and provided as inputs to the AEK-POW-LDOV02X Wi_LDO1,2 pins, respecting a specific time window.

If this window is not respected, the MCU triggers a reset signal that indicates a malfunction and resets the device.

If pulses are missing, the relative $R_{ST\_LDO1,2}$ output pins are set low. The watchdog timeout can be set within a wide range with the external capacitor, C_{tw}. The watchdog circuits discharge the capacitor C_{twx}, with the constant current $I_{CWd\_LDO1,2}$.

If the lower threshold ($V_{wlth\_LDO1,2}$) is reached, a watchdog reset is generated. To prevent this from happening, the microcontroller must generate a positive edge during the discharge of the capacitors before the voltage reaches the threshold $V_{wlth\_LDO1,2}$.

The time window is calculated through the following equations:

$$(V_{whth\_LDO1,2} - V_{wlth\_LDO1,2}) \times C_{tw} = I_{CWd\_LDO1,2} \times T_d$$

$$(V_{whth\_LDO1,2} - V_{wlth\_LDO1,2}) \times C_{tw} = I_{CWc\_LDO1,2} \times T_{wol}$$

$$T_{wop} = T_d + T_{wol}$$

Where:

$V_{whth\_LDO1,2}$ = $VO_{1,2}$ high threshold (50% of $VO_{1,2}$)

$V_{wlth\_LDO1,2}$ = $VO_{1,2}$ low threshold (16% of $VO_{1,2}$)

C_{tw} = external capacitor value

$I_{cWc\_LDO1,2}$ = C_{tw} current

T_d = C_{tw} charging time

T_{wol} = C_{tw} discharging time

The sum of T_d and T_{wol} determines the time window T_{wop}. During this time window, the watchdog signal must change state. The rising edge triggers the capacitor to transition from discharge to charge.

The images below highlight how, in the absence of a watchdog signal, LDO1 and LDO2 are repeatedly reset (green and purple signals) each time the low threshold value is reached.

Figure 10. RS1,2 signal without watchdog

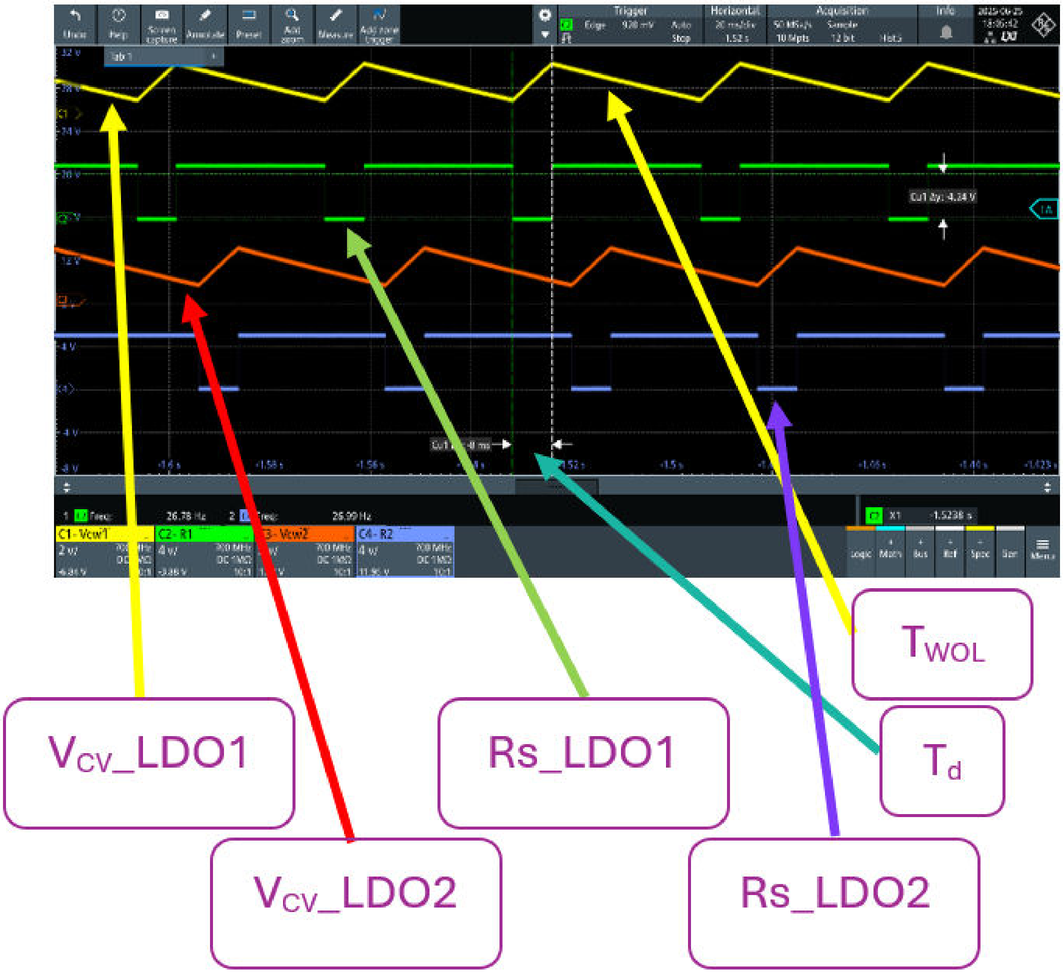
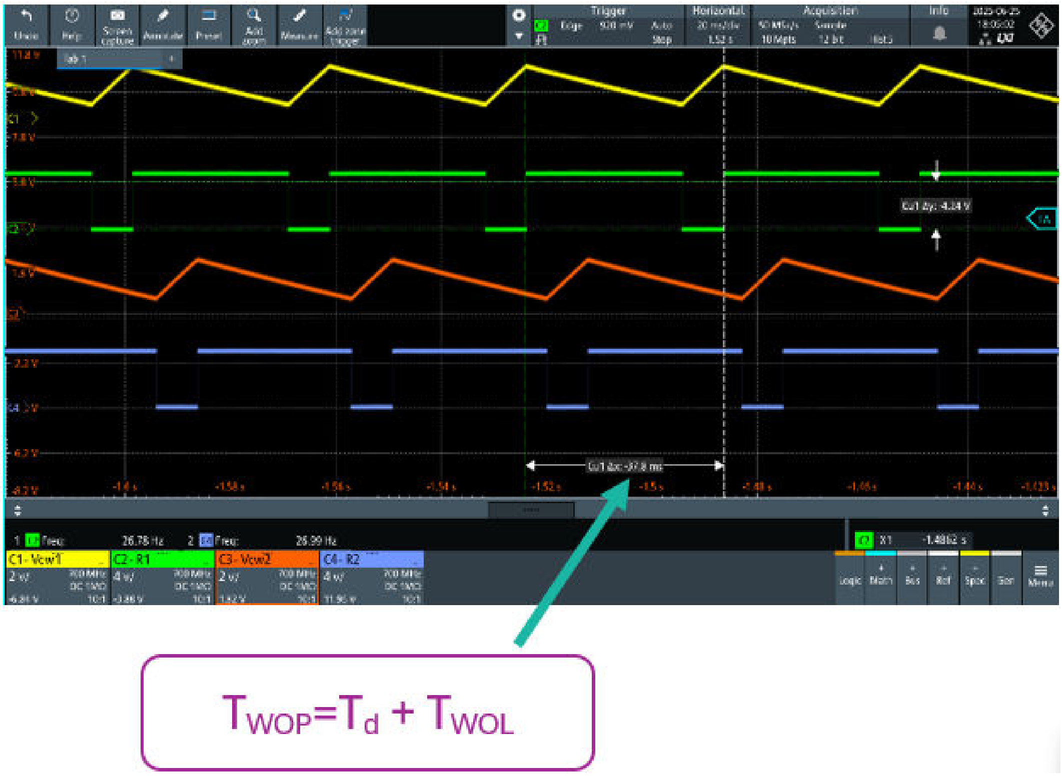
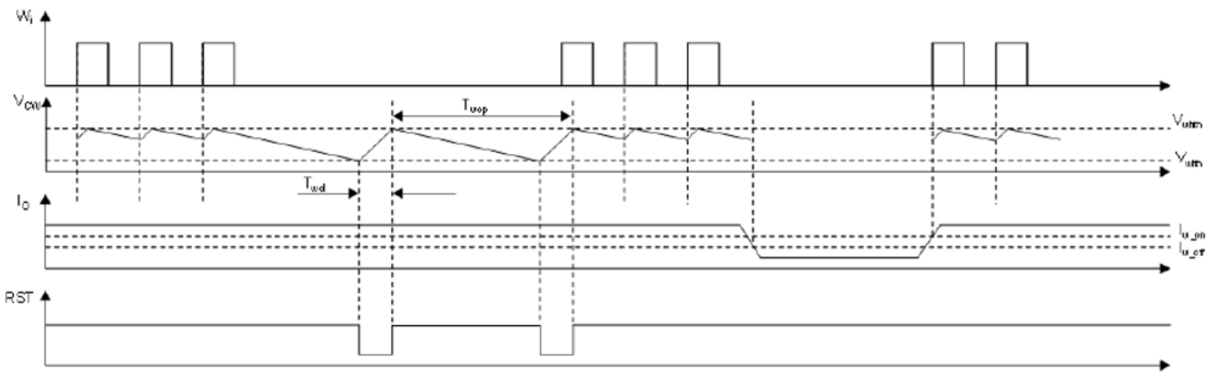


Figure 11. T_{wop} time window



If within the discharge time Twol there is no change in the watchdog state and the discharge signal falls below the low threshold (Vwlth_LDO), the reset signal (RST) transitions from high to low, resetting the system and thereby indicating a fault. The figure below shows this transition.

Figure 12. Watchdog timing diagram



3.1.8 Thermal warning and thermal shutdown

To warn the microcontroller about a severe temperature increase, two thermal warning outputs have been implemented (one for each regulator).

Through TC_CONF it is possible to set the management of a thermal shutdown event.

Table 8. TC_CONF setup

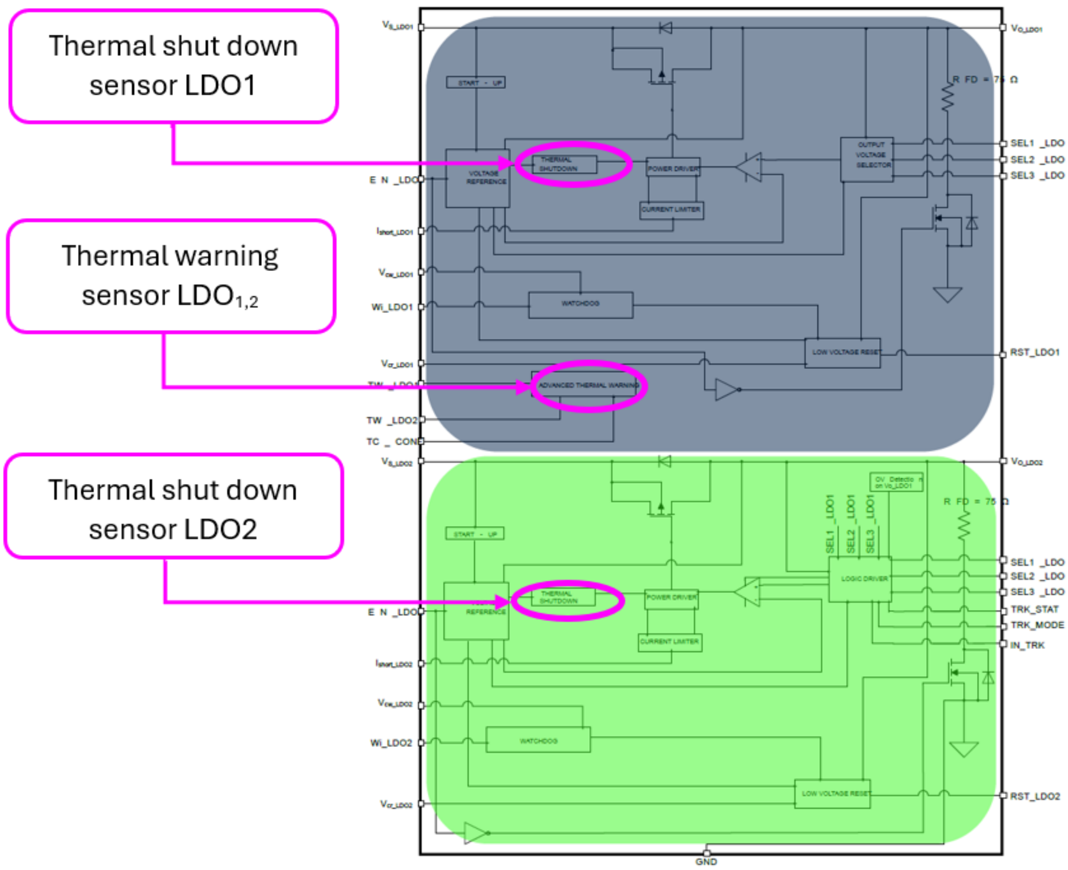
Event	TC_CONF in DEFAULT conf. (TC_CONF = GND)	TC_CONF in OR conf. (TC_CONF= VS_LDO1)
THERMAL SHUTDOWN	LDO1 and LDO2 are fully independent of each other and monitored by two different thermal clusters In tracking mode: if LDO1 is in thermal shutdown and TRK_MODE = GND, LDO2 is untied by LDO1 and keeps the normal activity. In case TRK_MODE = VS, LDO2 is fully independent by LDO1 and keeps the normal activity according to the behavior of an external voltage regulator	If LDO1 is in thermal shutdown, also LDO2 is switched off If LDO2 is in thermal shutdown, LDO1 keeps the normal activity
OVERVOLTAGE/ THERMAL WARNING	Events indicated respectively on the TW_LDO1 and TW_LDO2 pins	Events indicated respectively on the TW_LDO1 and TW_LDO2 pins

Table 8.

3.1.9 Thermal clusters

To provide advanced on-chip temperature control, the L99VR02XP outputs are split into two different temperature clusters with dedicated thermal sensors.

Figure 13. LDO1,2 thermal clusters



If the temperature of a cluster reaches the thermal protection threshold, only the relevant output is turned off while the other one remains active.

Thermal clusters can be configured using TC_CONF pin, as follows:

- When the TC_CONF pin is high, the two clusters are linked to each other:
  - If LDO1 is in thermal shutdown, LDO2 also is switched off
  - If LDO2 is in thermal shutdown, LDO1 keeps the normal activity
- When the TC_CONF pin is low, only the cluster that reached protection temperature is switched off:
  - LDO1 and LDO2 are fully independent of each other and monitored by two different thermal clusters
  - In tracking mode: if LDO1 is in thermal shutdown and TRK_MODE = GND, LDO2 is untied from LDO1 and keeps the normal activity.

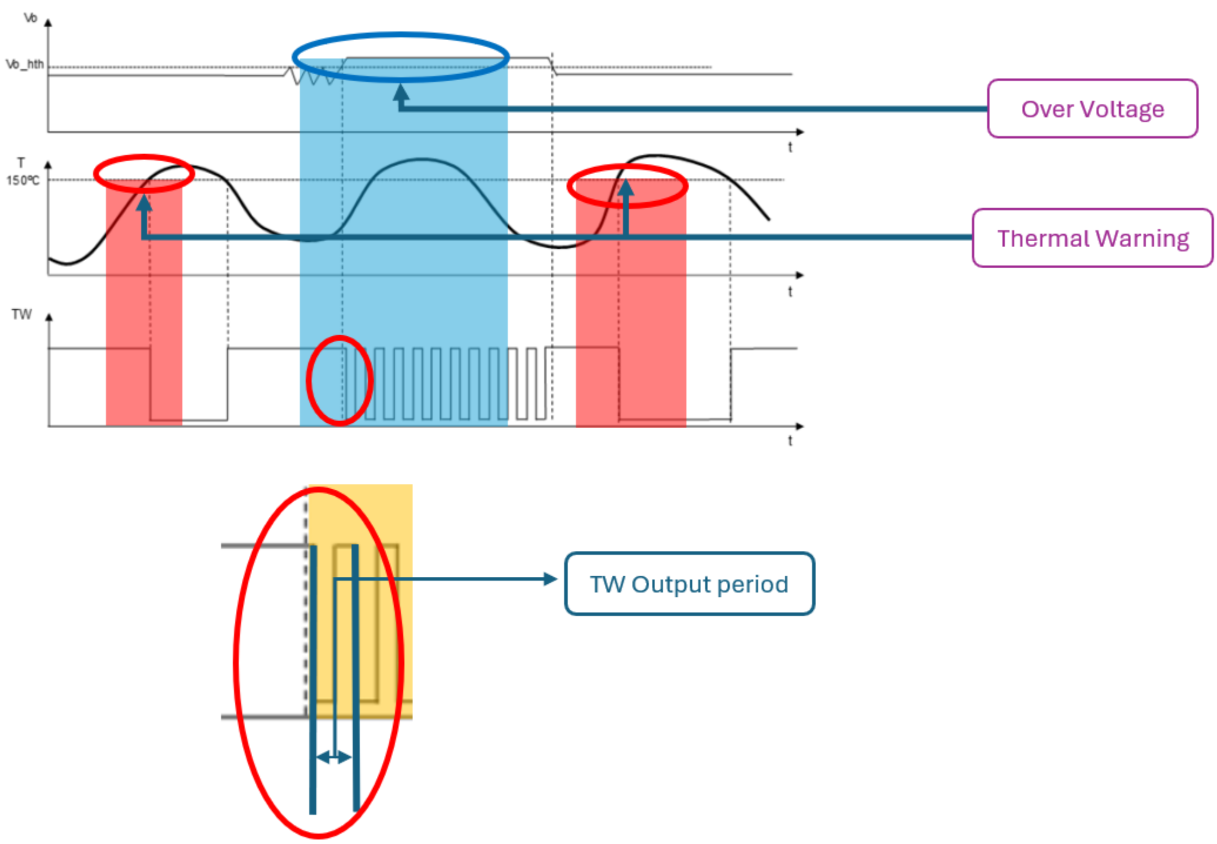
3.1.10 Overvoltage detection and thermal warning

The TW_LDO1,2 pins provide output overvoltage (OV_LDO1,2) diagnostics. To distinguish between a thermal warning event and an output overvoltage event, two different signals are generated on the same TW_LDO1,2 output pins. A thermal warning event detection sets the TW_LDO1,2 pins low.

An output overvoltage event generates a square wave on the TW_LDO1,2 pins. Overvoltage detection has a higher priority than thermal warning detection. Therefore, if both protections are triggered, the generated signal is a square wave.

The following figure shows overtemperature and overvoltage management.

Figure 14. Overvoltage and thermal warning management



The period of signal in TW in the over voltage status is: 160µs ≤ $T_{w\_per\_LDO1,2}$≤ 350µs with frequency: 2.8KHz ≤ $T_{w\_fre\_LDO1,2}$ ≤ 6.25KHz.

3.1.11 Fast output discharge

To ensure a quick discharge of the external capacitors (tied on the output pins) down to around 1.3 V, the L99VR02XP uses two internal pull-down circuits. When the $EN_{\_LDO1,2}$ pins go low, during thermal shut-down and undervoltage lockout, the output currents flow to the ground through the pull-down resistors of the fast output discharge circuit.

The fast output discharge feature is available for the following output voltages:

- $V_{O\_LDO1,2}$ = 2.5 V (SEL_x = [1;0;0])
- $V_{O\_LDO1,2}$ = 2.8 V (SEL_x = [1;0;1])
- $V_{O\_LDO1,2}$ = 3.3 V (SEL_x = [1;1;0])
- $V_{O\_LDO1,2}$ = 5 V (SEL_x = [1;1;1])

Note: For further information, refer to DS14686

3.1.12 Automatic voltage tracking and de-tracking of LDO1 or tracking of an external LDO

Voltage tracking and de-tracking are solutions adopted when long cables supply off-board loads with voltage regulators located on the main module. Under these operating conditions, short-to-ground and short-to-battery protections oppose possible electrical failures caused by cable damage.

In the L99VR02XP, LDO2 can be a tracker of LDO1 or of an external voltage regulator.

This function is enabled by TRK_MODE pin, IN_TRK pin and TRK_STAT, as detailed in the following table.

Table 9. Tracking mode configuration

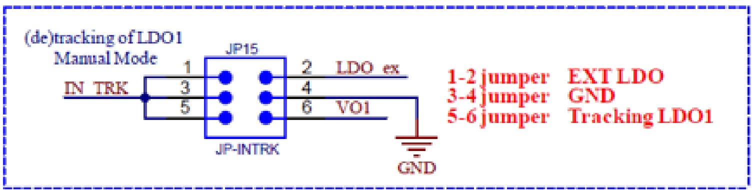
Pin	Function
TRK_MODE = GND IN_TRK = LDO1 TRK_STAT = High	LDO2 automatically tracks LDO1 if SELx_LDO1 = SELx_LDO2 in case of SELx_LDO1 ≠ SELx_LDO2, LDO2 becomes a fully independent regulator
TRK_MODE = VS IN_TRK = external LDO TRK_STAT = High	LDO2 is tracking to an external voltage regulator output. The user MUST guarantee the same rails for the external output voltage regulator and LDO2. Also, if SELx_LDO1 = SELx_LDO2 such internal voltage regulators (LDO1 and LDO2) are always untied.
TRK_MODE = VS IN_TRK = GND TRK_STAT = Low	LDO2 works as a fully independent regulator.

The IN_TRK (input pin) is used to select LDO1, an external LDO, or GND.

Put a jumper on JP15 to select:

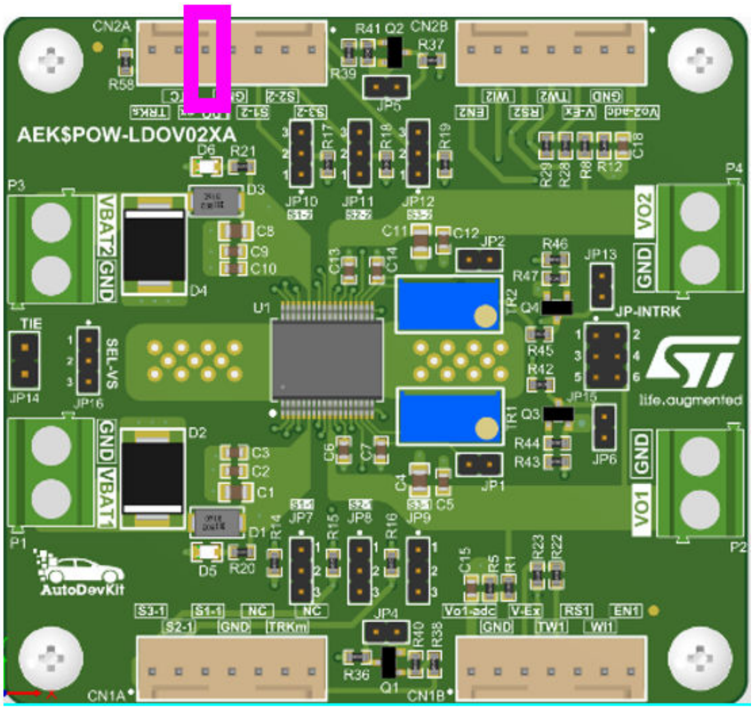
- LDO1 (positions 5-6):
- Ext_LDO (positions 1-2): in this case, LDO2 tracks an external LDO
- GND (positions 3-4)

Figure 15. IN_TRK pin



When using Ext_LDO, connect an external LDO or a stable power supply to the input pin highlighted in the image below.

Figure 16. **Ext_LDO pin**



The TRK_STAT pin indicates to the MCU if the LDO2 is in tracking mode or working as an independent regulator.

During the startup phase (soft start), if the tracking mode is disabled or LDO2 is in UV/OV, the TRK_STAT pin is set to low.

After startup, without UV/OV faults, when the tracking mode is activated, the TRK_STAT pin goes high.

If the device is configured with LDO2 tracking LDO1 and the LDO1 soft-start signal is high, the tracking comparators are ignored to avoid unwanted transient effects during standard startup in the tracking with LDO1.

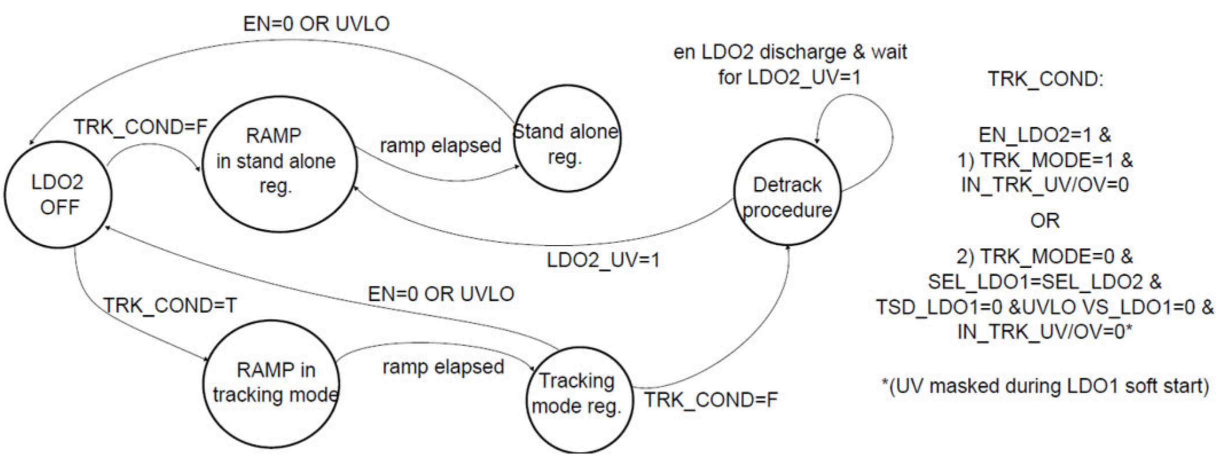
When the TRK_STAT (output pin) is high, the LDO2 is in tracking state. If the output pin is low, the LDO2 is in de-tracking state.

The high logic level depends on the V-Ex voltage (5 V_{DC}).

In tracking mode, if the jumper position of Sel1,2,3_LDO1 ≠ Sel1,2,3_LDO2 (see Table 5. Jumper description and Figure 9. Jumper position), the LDO2 acts as a fully independent regulator.

The figure below shows the tracking mode state machine.

Figure 17. **Tracking mode state machine**



If the ramp-up phase is successful, the state machine transitions from the “RAMP in standalone reg.” state to the “Standalone reg. state”.

If EN pin is equal to 0 or an undervoltage occurs, the state machine enters “LDO2 OFF” state and LDO2 is switched off.

If TRK_COND is true, the device enters “RAMP in tracking mode” state. Then, it enters the “RAMP in tracking mode” state and finally the “Tracking mode reg.”.

According to the image above, TRK_COND is true when all the following conditions occur:

- EN_LDO2=1
- TRK_MODE=1
- IN_TRK_UV/OV=0
- $Sel_{1,2,3}$_LDO1 = $Sel_{1,2,3}$_LDO2
- Thermal fault LDO1=0
- UVLO VS_LDO1=0

Note: During the sof-start phase, IN_TRK_UV/OV logic state is not considered.

If TRK_COND is false, the device goes back to the “Detrack procedure” state.

According to the image above, TRK_COND is false when the following conditions occur:

- EN_LDO2=0
- TRK_MODE=0
- IN_TRK_UV/OV=1
- $Sel_{1,2,3}$_LDO1 ≠ $Sel_{1,2,3}$_LDO2
- Thermal fault LDO1=1
- UVLO VS_LDO1=1

The device remains in “Detrack procedure” state until a fast discharge condition (EN_LDO2=0) or an undervoltage occurs on LDO2. In these cases, the device enters the “RAMP in standalone reg.” state, and the state machine cycle starts again.

Note: For further information, refer to DS14686

4 AutoDevKit ecosystem

The application development employing our AEK-POW-LDOV02X evaluation board takes full advantage of the AutoDevKit ecosystem, whose basic components are:

- AutoDevKit Studio IDE (STSW-AUTODEVKIT)
- OpenOCD programmer and debugger

4.1 AutoDevKit demo application

The upcoming AutoDevKit version 2.7.0 includes a demo application whose goal is to vary the output voltage of both channels of the device among the 8 different supported levels in a cycle, with a delay of 3 seconds between each transition. The `L99VR02XP_dev_init()` and `L99VR02XP_dev_powerOn()` functions require the device name as argument and perform, respectively, the initialization and the start-up of both device channels at the default operation mode (0.8 V).

The `L99VR02XP_ch_changeVOut()` function requires the channel name and an operation mode. This function changes the channel output voltage by applying the given operation mode.

Figure 18. Demo code

```
/*
 * Application entry point.
 */
int main(void) {

  /* Initialization of all the imported components in the order specified in
     the application wizard. The function is generated automatically.*/
  componentsInit();

  irqIsrEnable();

  L99VR02XP_dev_init(L99VR02XP_DEV0);

  L99VR02XP_dev_powerOn(L99VR02XP_DEV0);

  /* Application main loop.*/
  for ( ; ; ) {
      osalThreadDelayMilliseconds(3000);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH1, L99VR02XP_CH_VOLTAGE_1_2_V);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH2, L99VR02XP_CH_VOLTAGE_1_2_V);

      osalThreadDelayMilliseconds(3000);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH1, L99VR02XP_CH_VOLTAGE_1_5_V);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH2, L99VR02XP_CH_VOLTAGE_1_5_V);

      osalThreadDelayMilliseconds(3000);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH1, L99VR02XP_CH_VOLTAGE_1_8_V);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH2, L99VR02XP_CH_VOLTAGE_1_8_V);

      osalThreadDelayMilliseconds(3000);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH1, L99VR02XP_CH_VOLTAGE_2_5_V);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH2, L99VR02XP_CH_VOLTAGE_2_5_V);

      osalThreadDelayMilliseconds(3000);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH1, L99VR02XP_CH_VOLTAGE_2_8_V);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH2, L99VR02XP_CH_VOLTAGE_2_8_V);

      osalThreadDelayMilliseconds(3000);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH1, L99VR02XP_CH_VOLTAGE_3_3_V);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH2, L99VR02XP_CH_VOLTAGE_3_3_V);

      osalThreadDelayMilliseconds(3000);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH1, L99VR02XP_CH_VOLTAGE_5_V);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH2, L99VR02XP_CH_VOLTAGE_5_V);

      osalThreadDelayMilliseconds(3000);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH1, L99VR02XP_CH_VOLTAGE_0_8_V);
      L99VR02XP_ch_changeVOut(L99VR02XP_DEV0, L99VR02XP_CH2, L99VR02XP_CH_VOLTAGE_0_8_V);
  }
}
```

5 APIs

- `void L99VR02XP_dev_init(L99VR02XP_dev_name_t devName);`
  This function initializes the AEK-POW-LDOV02X device
- `void L99VR02XP_dev_powerOn(L99VR02XP_dev_name_t devName);`
  This function turns on both channels of a specific AEK-POW-LDOV02X device
- `void L99VR02XP_ch_enable(L99VR02XP_dev_name_t devName, L99VR02XP_ch_name_t chName);`
  This function enables a specific channel of a specific AEK-POW-LDOV02X device
- `void L99VR02XP_ch_disable(L99VR02XP_dev_name_t devName, L99VR02XP_ch_name_t chName);`
  This function disables a specific channel of a specific AEK-POW-LDOV02X device
- `L99VR02XP_ch_sts_t L99VR02XP_ch_getEnablingSts(L99VR02XP_dev_name_t devName, L99VR02XP_ch_name_t chName);`
  This function returns the enabling status of a channel (DISABLED, ENABLED) of a specific AEK-POW-LDOV02X device
- `L99VR02XP_ch_vout_chng_retCode_t L99VR02XP_ch_changeVOut(L99VR02XP_dev_name_t devName, L99VR02XP_ch_name_t chName, L99VR02XP_ch_opMode_t opMode);`
  This function sets the output voltage of a specific channel of a specific AEK-POW-LDOV02X device
- `void L99VR02XP_dev_startLDO1Tracking(L99VR02XP_dev_name_t L99VR02XP_dev_name);`
  This function makes LDO2 tracker of LDO1 Out Voltage (if the JP-INTRK jumper JP15 is set accordingly in position 5-6) in a specific AEK-POW-LDOV02X device
- `void L99VR02XP_dev_startExtTracking(L99VR02XP_dev_name_t L99VR02XP_dev_name, L99VR02XP_ch_opMode_t L99VR02XP_ch_opMode);`
  This function makes LDO2 tracker of an external regulator in a specific AEK-POW-LDOV02X device, if the following conditions are verified:
  – the JP-INTRK jumper JP15 is set accordingly in position 1-2
  – an external voltage, equal to one of those supported by the device, is supplied in LDO-ex pin in connector CN2A
  – the `L99VR02XP_ch_opMode` argument is equal to the supplied external voltage
- `L99VR02XP_ch_fsm_sts_t L99VR02XP_ch_getFsmState(L99VR02XP_dev_name_t devName, L99VR02XP_ch_name_t chName);`
  This function returns the status of a channel (POWER_OFF, DISABLED, NORMAL, CHANGING_VOUT, UNKNOWN) of a specific AEK-POW-LDOV02X device
- `L99VR02XP_ch_error_fsm_t L99VR02XP_ch_getErrorFsmState (L99VR02XP_dev_name_t devName, L99VR02XP_ch_name_t chName);`
  This function returns the error status of a channel (NONE, WARNING, ERROR, UNKNOWN) of a specific AEK-POW-LDOV02X device
- `L99VR02XP_ch_rst_fsm_t L99VR02XP_ch_getRSTFsmState (L99VR02XP_dev_name_t devName, L99VR02XP_ch_name_t chName);`
  This function returns the status related to the RST pin of a channel (IDLE, NORMAL, WD_MISSING, UNDERVOLTAGE, UNKNOWN) of a specific AEK-POW-LDOV02X device
- `L99VR02XP_ch_tw_fsm_t L99VR02XP_ch_getTWFsmState (L99VR02XP_dev_name_t devName, L99VR02XP_ch_name_t chName);`
  This function returns the status related to the TW pin of a channel (NORMAL, THERMAL_WARNING, OVERVOLTAGE, UNKNOWN) of a specific AEK-POW-LDOV02X device

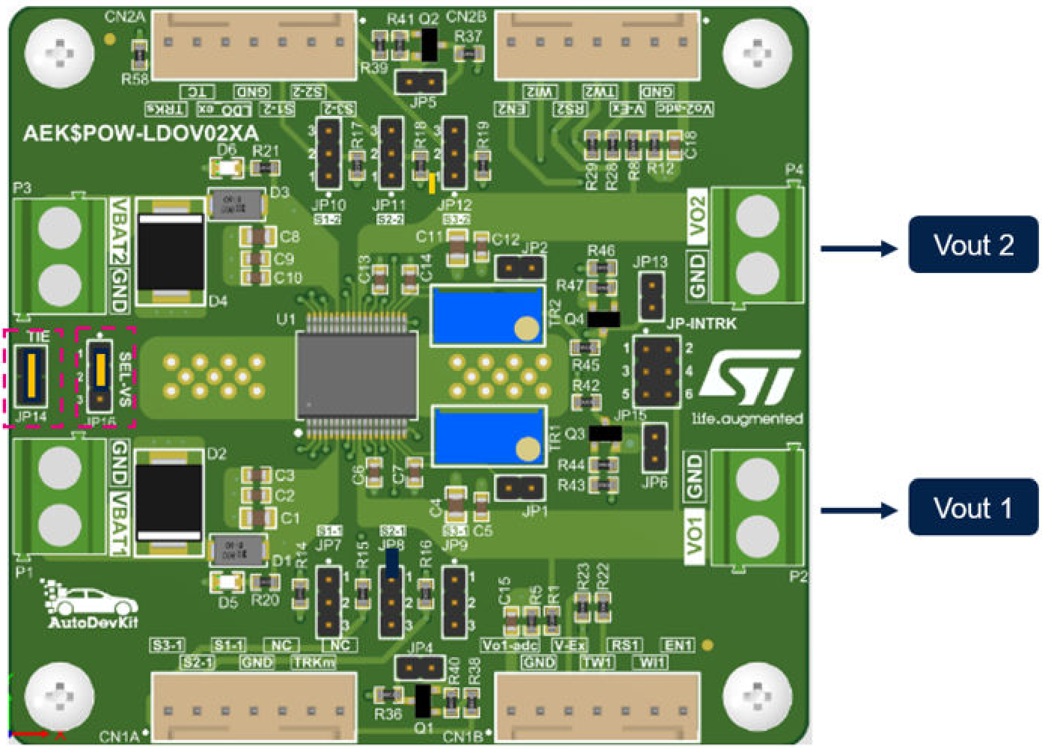
6 How to configure the AEK-POW-LDOVO2X evaluation board

The AEK-POW-LDOV02X board operates in two modes:

- Auto mode or MCU-connected configuration: the board settings are managed through an external microcontroller unit (MCU)
- Manual mode: the board works standalone, that is, without an MCU, and settings are defined via dedicated jumpers.

In both modes, place jumpers on JP16 and JP14, as shown in the figure below.

Figure 19. JP14 and JP16 jumper positions



Placing a jumper on JP14 electrically connects VBAT1 to VBAT2. Therefore, supplying power to either VBAT1 or VBAT2 is sufficient to power all the circuitry associated with both LDOs.

To use two separate power supplies for VBAT1 and VBAT2, simply remove the jumper from JP14.

6.1 Auto mode

In auto mode, the board is configured and controlled by an external MCU through CN1A, CN2A, CN1B, and CN2B connectors.

To use the board in this mode, simply remove all jumpers, except the ones on JP14 and JP16.

6.2 Manual mode

To use the board in this mode, follow the procedure below:

Step 1. Place/remove jumpers on JP6 and JP13 to disable/enable LDO1 and LDO2, respectively.

Step 2. Place jumpers on JP1 and JP2 to disable the watchdogs for both LDOs.

Step 3. Select the output voltage values (Vout1 and Vout2) for LDO1 and LDO2 according to table 7 and jumpers on:

- JP7, JP8, JP9 for LDO1
- JP10, JP11, JP12 for LDO2

Step 4. LDO2 can work in tracking or de-tracking modes:

- Tracking mode:
  - Place a jumper on JP4.
  - Place a jumper on JP15:
  - Position 1-2 to make LDO2 track an external LDO.
  - Position 5-6 to make LDO2 track LDO1.
- De-tracking mode:
  - If present, remove the jumper from JP4.
  - Place a jumper on JP15 in positions 3-4.

Step 5. To make the LDO2 shut down in case of LDO1 thermal shut down, remove a jumper on JP5.

7 Test results

The figures below show an example of Enable transaction from the high level to the low level and back to the high level (blue arrows).

When $EN_{1,2}$ goes low (GND), $VO_{1,2}$ = 0 V.

Figure 20. Enable pulse signal waveforms for LDO1 and LDO2 generated by an external MCU connected to the AEK-POW- LDOV02X

The images below show the reset signal of VO1 and VO2 without watchdog activated, considering two different voltage levels.

Figure 21. RS_LDO1 without Wi_LDO1 for VO1 output (VO1= 0.8V F=153.97Hz)

Figure 22. **RS_LDO1 without Wi_LDO1 for VO1 output (VO1= 5V F=26.50Hz)**

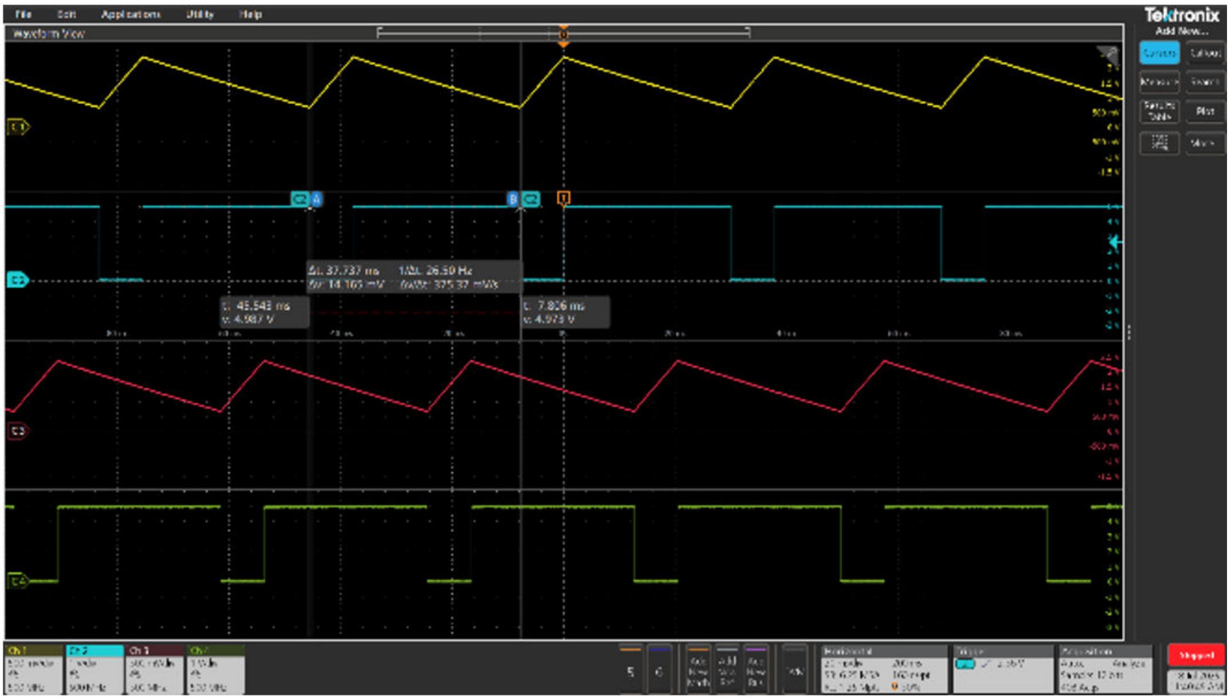


Figure 23. **RS_LDO2 without Wi_LDO2 for VO2 output (VO2= 0.8V F=158.44Hz)**

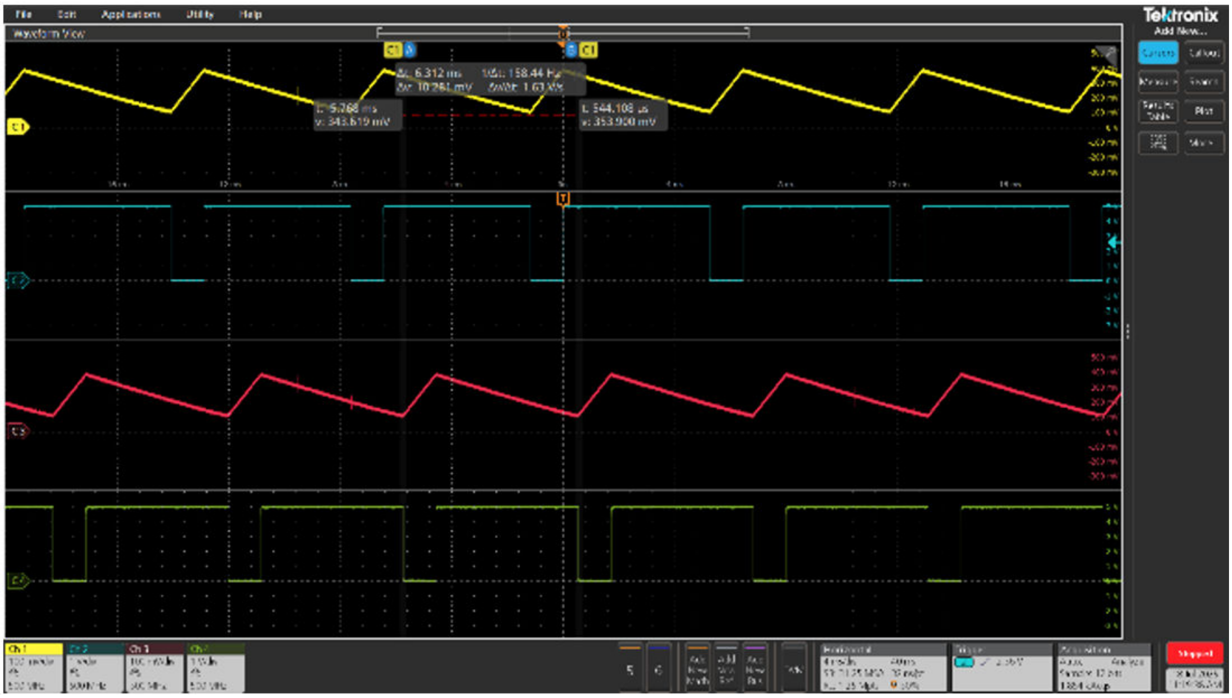
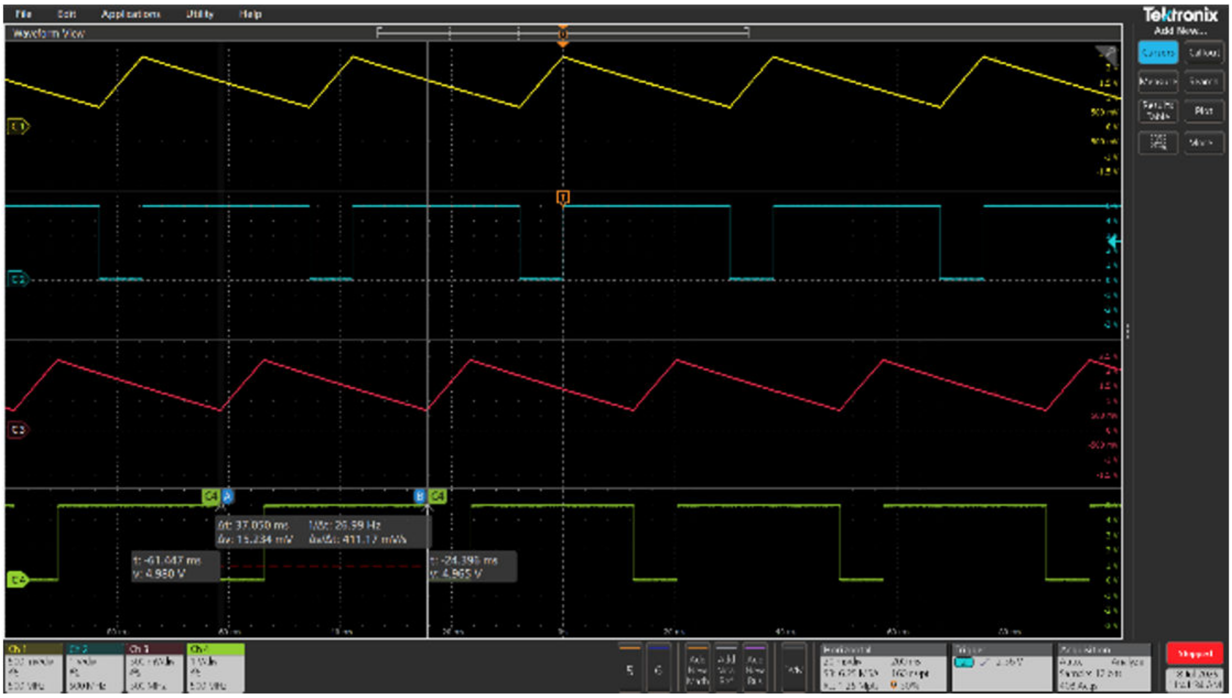
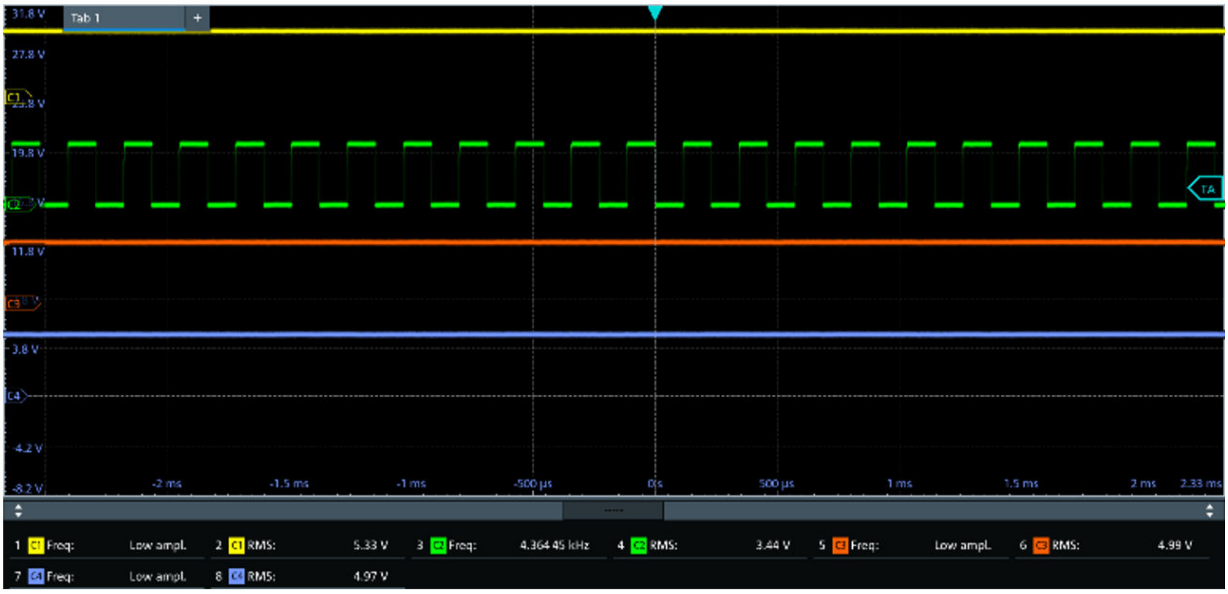


Figure 24. **RS_LDO2 without Wi_LDO2 for VO2 output (VO2= 5V F=26.99Hz)**



The following figure shows the VO_LDO1 in the overvoltage condition (yellow track) and the TW1 pin square wave of about 4.3KHz (green track).

Figure 25. **Overvoltage status for LDO1**



The following figure shows the VO_LDO2 in the overvoltage condition (red track) and the TW2 pin square wave of about 4.1KHz (blue track).

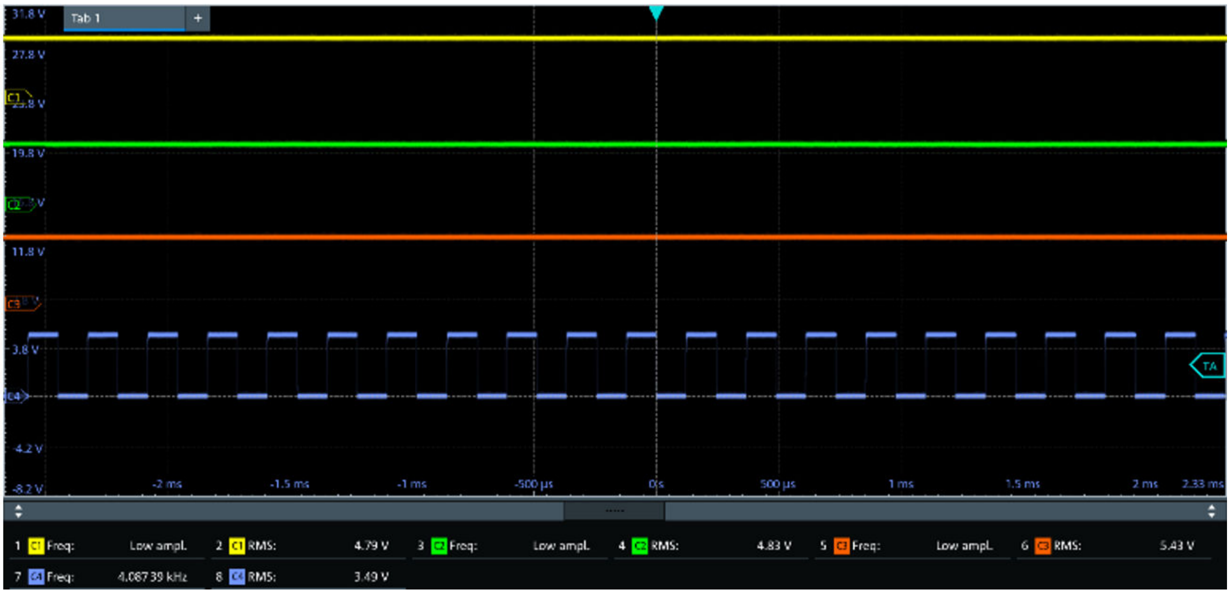


Figure 26. **Overvoltage status for LDO2**

The following figures show examples of thermal warning and thermal shutdown, with an ambient temperature of 23.5°C and an operating voltage of 5 V.

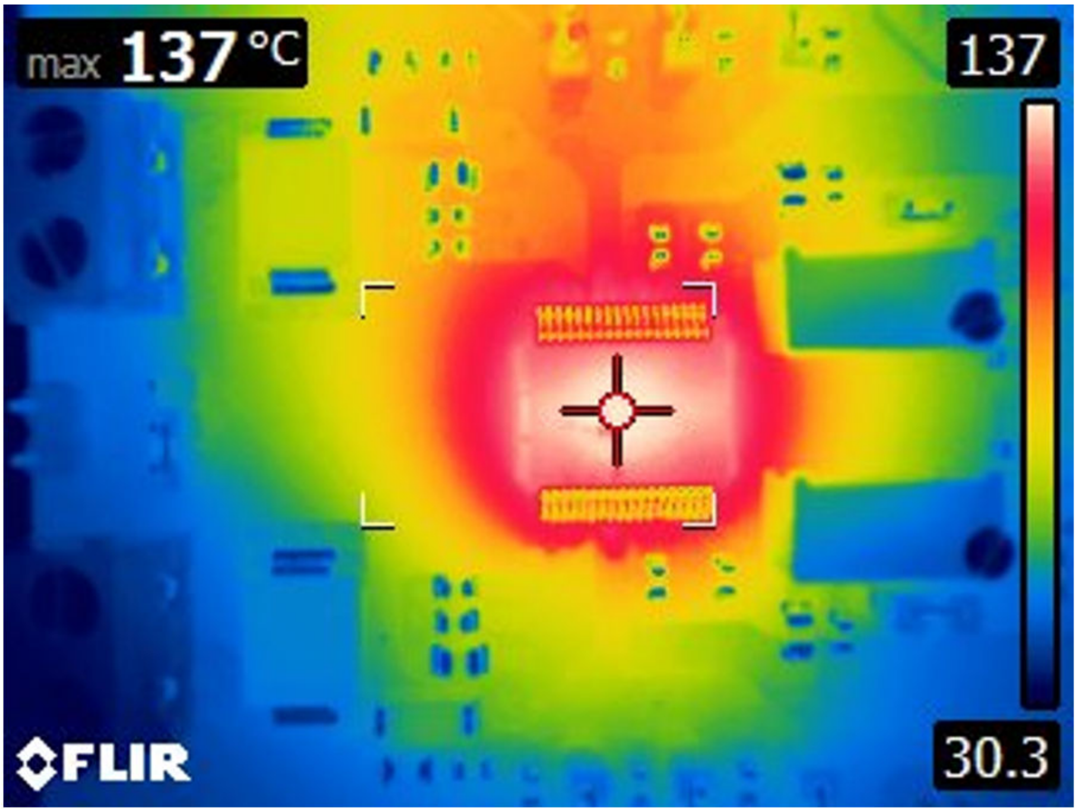
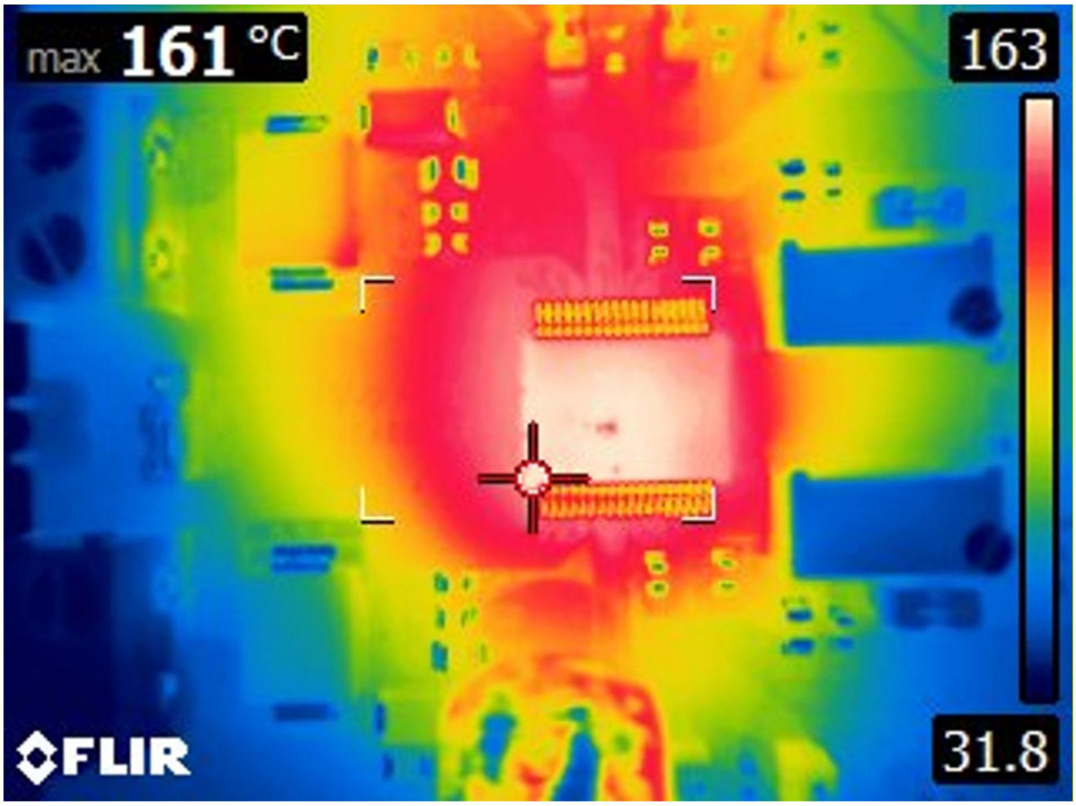


Figure 27. **LDO1,2 thermal warning**

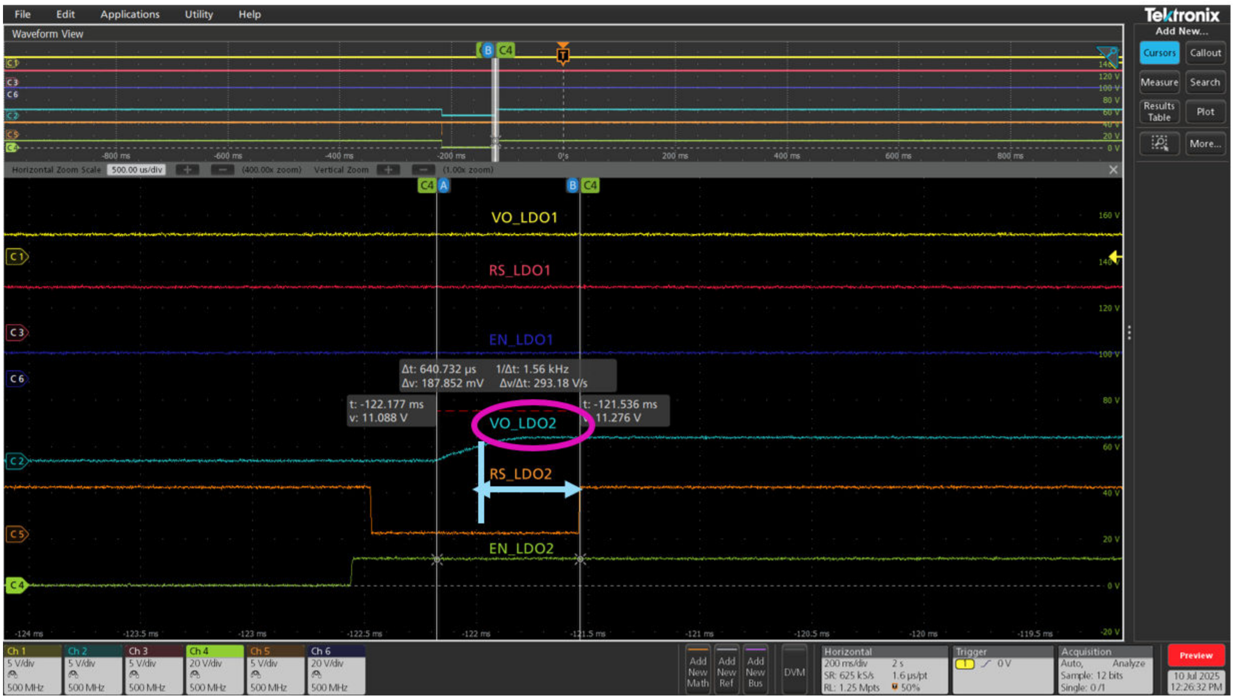
Figure 28. LDO1,2 thermal shutdown



Note: For further details on thermal warning and thermal shutdown reference values, see DS14686, table 3.

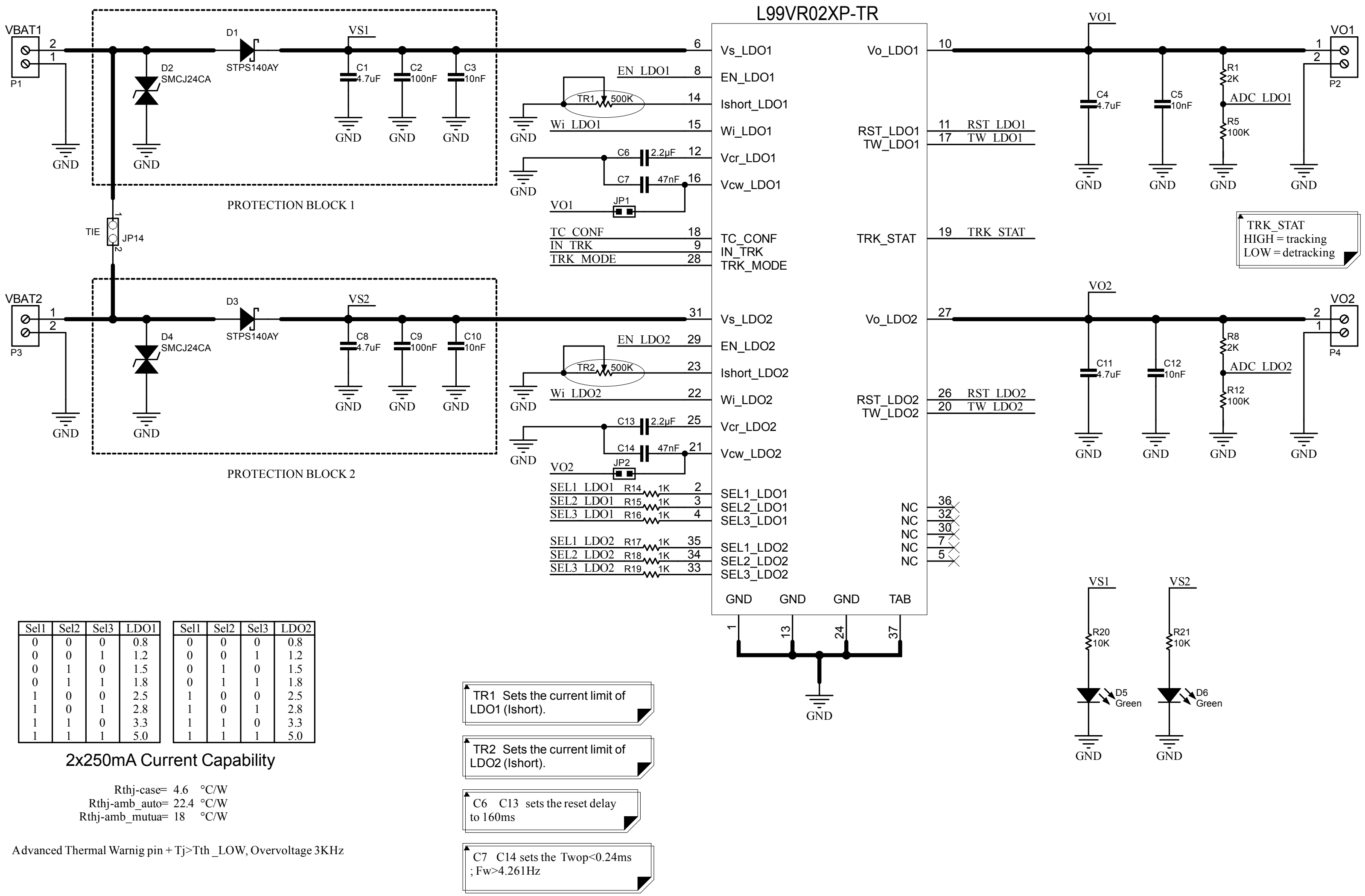
The figure below shows a reset signal example.

Figure 29. RS_LDO2 reset signal



8 Schematic diagrams

Figure 30. **AEK-POW-LDOV02X circuit schematic (1 of 3)**



Sel1	Sel2	Sel3	LDO1
0	0	0	0.8
0	0	1	1.2
0	1	0	1.5
0	1	1	1.8
1	0	0	2.5
1	0	1	2.8
1	1	0	3.3
1	1	1	5.0

Sel1	Sel2	Sel3	LDO2
0	0	0	0.8
0	0	1	1.2
0	1	0	1.5
0	1	1	1.8
1	0	0	2.5
1	0	1	2.8
1	1	0	3.3
1	1	1	5.0

Figure 31. **AEK-POW-LDOV02X circuit schematic (2 of 3)**

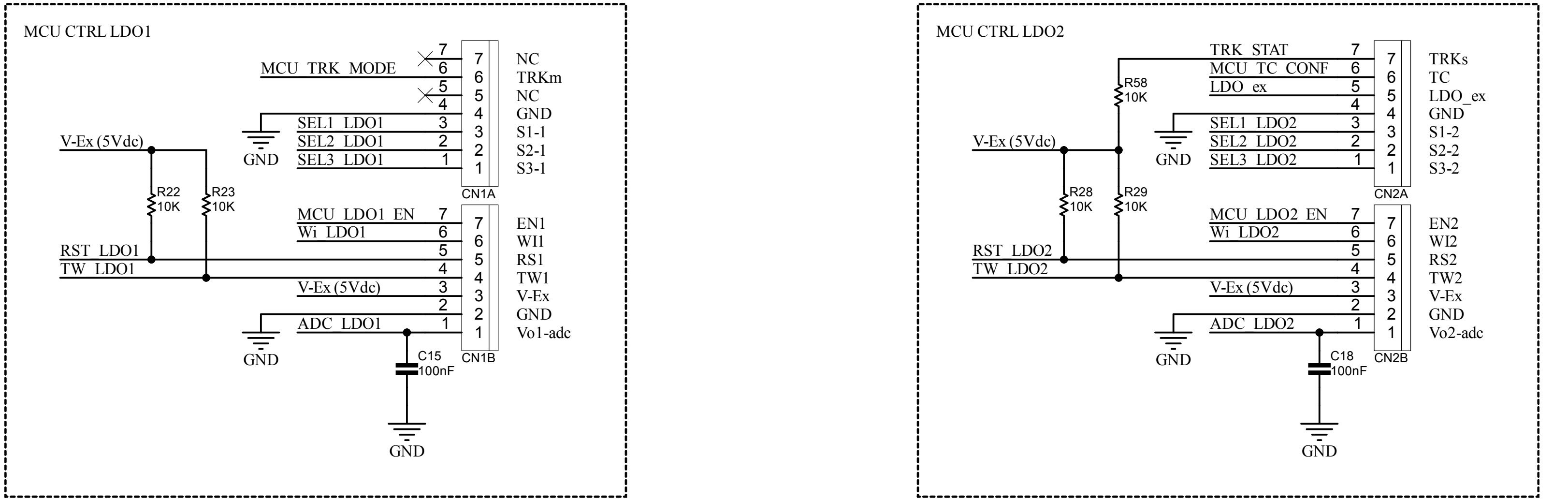
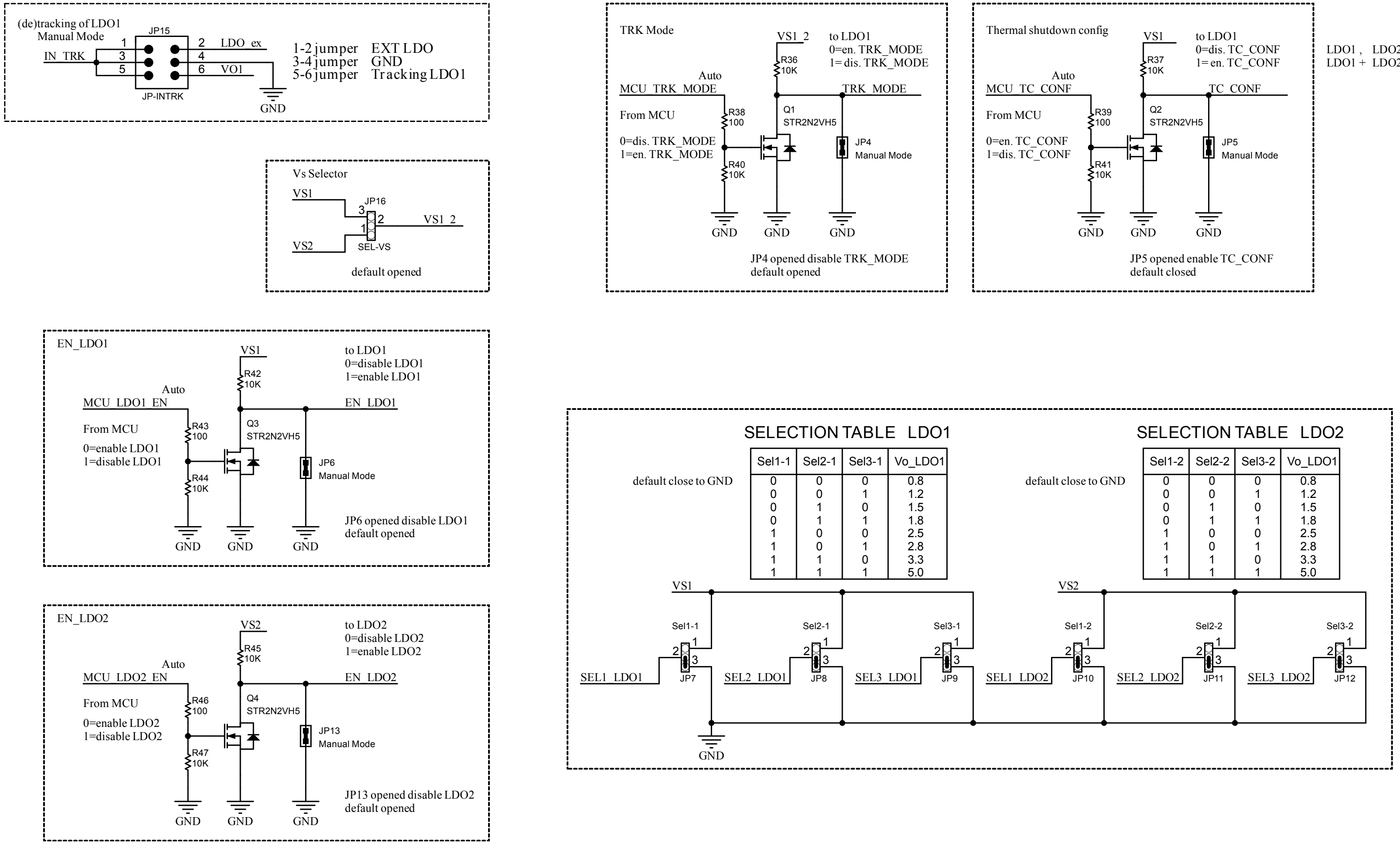


Figure 32. AEK-POW-LDOV02X circuit schematic (3 of 3)



SELECTION TABLE LDO1 (default close to GND)

Sel1-1	Sel2-1	Sel3-1	Vo_LDO1
0	0	0	0.8
0	0	1	1.2
0	1	0	1.5
0	1	1	1.8
1	0	0	2.5
1	0	1	2.8
1	1	0	3.3
1	1	1	5.0

SELECTION TABLE LDO2 (default close to GND)

Sel1-2	Sel2-2	Sel3-2	Vo_LDO1
0	0	0	0.8
0	0	1	1.2
0	1	0	1.5
0	1	1	1.8
1	0	0	2.5
1	0	1	2.8
1	1	0	3.3
1	1	1	5.0

9 Bill of materials

Table 10. AEK-POW-LDOV02X bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	4	C1, C4, C8, C11	4.7uF	0805 - 25V - X5R Class II	WE	885012107018
2	4	C2, C9, C15, C18	100nF	0603 - 50V - X7R Class II	WE	885012206095
3	4	C3, C5, C10, C12	10nF	0603 - 50V - X7R Class II	WE	885012206089
4	2	C6, C13	2.2nF	0603 - 50V - X7R Class II	WE	885012206085
5	2	C7, C14	47nF	0603 - 50V - X7R Class II	WE	885012206093
6	4	CN1A, CN1B, CN2A, CN2B	Con 7P	2.54mm - 1 row - KK254 - Male	WE	61900711121
7	2	D1, D3	STPS140AY	Automotive power Schottky rectifier 40V, 1A Vf=0.5V	STMicroelectronics	STPS140A
8	2	D2, D4	SMCJ24CA	SMC TVS - 24VDC - Bidirectional	STMicroelectronics	SMCJ24CA-TR
9	2	D5, D6	Green	0805 - Led Green - 3.2V	WE	150080GS75000
10	6	JP1, JP2, JP4, JP5, JP6, JP13	Jumper 2p Closed	2mm - WR-PHD 2.00 mm THT Pin Header Single Row, Vertical, 2p, Closed	WE	62000211121
11	7	JP7, JP8, JP9, JP10, JP11, JP12, JP16	Jumper 3p	THT Vertical 3 pins Header, Pitch 2.mm, Single Row	WE	62000311121
12	1	JP14		THT Vertical 2 pins Header, Pitch 2.54 mm, Single Row	WE	61300211121
13	1	JP15	Jumper dual 3p	WR-PHD Pin Header, THT, Vertical, pitch 2mm, 2 Row, 6P	WE	62000621121
14	4	P1, P2, P3, P4	Con 2p 5.08_green	5.08mm - WR-TBL Series 2135 - Horizontal Entry Modular	WE	691213510002
15	4	Q1, Q2, Q3, Q4	STR2N2VH5, SOT23	N-channel 20 V, 0.025 Ω typ., 2.3 A STripFET™ H5 Power MOSFET in a SOT-23 package	ST	STR2N2VH5
16	2	R1, R8	2K	0603 - ±1% - 0.2W	Panasonic	ERJP03F2001V

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
17	2	R5, R12	100K	0603 - ±1% - 0.2W	Panasonic	ERJP03F1003V
18	6	R14, R15, R16, R17, R18, R19	1K	0603 - ±1% - 0.25W	Panasonic	ERJPA3F1001V
19	15	R20, R21, R22, R23, R28, R29, R36, R37, R40, R41, R42, R44, R45, R47, R58	10K	0603 - ±1% - 0.2W	Panasonic	ERJP03F1002V
20	4	R38, R39, R43, R46	100	0603 - ±1% - 0.125W	Panasonic	ERJH3EF1000V
21	2	TR1, TR2	500K	Trimmer - ±10% - 0.5W	Bourns	3296W-1-504LF
22	1	U1	L99VR02XP-TR, POWERSSO-36 EP	Dual Automotive Linear Voltage Regulator with Configurable Output Voltage (2x250mA Current Capability)	ST	L99VR02XP-TR
23	4			WA-SCRW Pan Head Screw w. cross slot M3	WE	97790603211
24	4			WA-SPAII Plastic Spacer Stud, metric, internal/ internal	WE	970060365
25	15			WR-PHD 2.00 mm Jumper with Test Point	WE	60800213421
26	2			WR-PHD 2.54 mm Multi-Jumper Jumper with Test Point	WE	60900213621
27	4			WR-WTB 2.54 mm Female Terminal Housing	WE	61900711621
28	30			WR-WTB 2.54 mm Female Crimp Contact	WE	61900113722DEC

10 Board versions

Table 11. AEK-POW-LDOV02X versions

Finished good	Schematic diagrams	Bill of materials
AEK$POW-LDOV02XA(1)	AEK$POW-LDOV02XA schematic diagrams	AEK$POW-LDOV02XA bill of materials

1. *This code identifies the AEK-POW-LDOV02X evaluation board first version.*

11 Regulatory compliance information

Notice for US Federal Communication Commission (FCC)

For evaluation only; not FCC approved for resale

FCC NOTICE - This kit is designed to allow:

(1) Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine

whether to incorporate such items in a finished product and

(2) Software developers to write software applications for use with the end product.

This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter 3.1.2.

Notice for Innovation, Science and Economic Development Canada (ISED)

For evaluation purposes only. This kit generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to Industry Canada (IC) rules.

À des fins d'évaluation uniquement. Ce kit génère, utilise et peut émettre de l'énergie radiofréquence et n'a pas été testé pour sa conformité aux limites des appareils informatiques conformément aux règles d'Industrie Canada (IC).

Notice for the European Union

This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2011/65/EU (RoHS II), including subsequent revisions and additions, as well as amended by the Delegated Directive 2015/863/EU (RoHS III). Compliance to EMC standards in Class A (industrial intended use).

Notice for the United Kingdom

This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2011/65/EU (RoHS II), including subsequent revisions and additions, as well as amended by the Delegated Directive 2015/863/EU (RoHS III). Compliance to EMC standards in Class A (industrial intended use).

Revision history

Table 12. **Document revision history**

Date	Revision	Changes
28-Jul-2025	1	Initial release.
30-Jul-2025	2	Updated title on cover page.

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