Application Report
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TLIN1441 Failsafe Mode Explanation

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ABSTRACT

The TLIN1441-Q1 and TLIN2441-Q1 are a family of products addressing the need for a LIN transceiver and linear dropout (LDO) regulator integrated into one package. Integrating a power supply into an interface device brings a whole set of potential conditions that can cause damage to the IC and the system as whole. The TLIN1441-Q1 and TLIN2441-Q1 device have a failsafe mode implemented to prevent damage from irregularities in the LDO performance. Failsafe mode as it is implemented on the TLIN1441-Q1 and TLIN2441-Q1 and the potential causes for its use are explained in the following sections.

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Trademarks

1 Introduction

Automotive environments are known to have harsh conditions, especially for electronics. High temperatures, voltage transients, and other volatile conditions can cause damage to ICs which may put the vehicle in a potentially dangerous situation. To avoid these critical cases where catastrophic damage can occur, the TLIN1441-Q1 and TLIN2441-Q1 LIN system basis chips (SBCs) have the failsafe mode feature implemented. Designed with the intention to avoid negatively affecting the safety of the user, the TLIN1441-Q1 and TLIN2441-Q1 automatically transition into failsafe mode when certain conditions are present in the system or on the device.

2 Detailed Description of Failsafe Mode

Failsafe mode is meant to be a state the device transitions into to alleviate the potential for catastrophic damage to the electronic control unit (ECU) the LIN SBC is a part of, as well as the LIN SBC itself. The conditions needed to trigger failsafe mode were chosen as a way to quickly predict dangerous conditions inside the system, like undervoltage on VCC, overvoltage on VCC, and thermal shutdown. Thermal shutdown can and usually is related to the other two conditions, but can also be a condition by itself with the VCC LDO not being the cause.

When any of these conditions are detected by the TLIN1441-Q1/TLIN2441-Q1, the digital core recognizes the unsafe situation and transitions the device into failsafe mode. Once in failsafe mode, all functions of the SBC are disabled except for the digital core, and the low-power receiver to monitor for wake events. The LIMP output is also enabled, pulling up to the battery. Failsafe mode can be thought of as sleep mode with the LIMP output. Since this disables most functions on the device, it significantly decreases the current output from the LIN SBC, and thus allows the junction temperature to reduce.

3 Failsafe Mode Conditions

3.1 VCC Overvoltage

Table 1 shows the conditions to trigger and clear an overvoltage condition. As soon as this condition is detected by the monitoring circuitry of the SBC, the transition into failsafe mode occurs. Once the overvoltage condition is cleared, a wake event transitions the SBC into standby mode. If a wake event occurs while the overvoltage condition is still present, the wake event is ignored.

Table 1. VCC Overvoltage Conditions

DEVICE	OVERVOLTAGE TRIGGER CONDITION	OVERVOLTAGE CLEAR CONDITION
TLIN14413/2413	VCC > 3.79 V	VCC < 3.73 V
TLIN14415/2415	VCC > 5.6 V	VCC < 5.5 V

An overvoltage condition on the integrated VCC LDO can be caused by damage to the LDO pass circuit internally, a sudden loss of load current, or a short to a higher voltage on the electronic control unit (ECU). In any case, an overvoltage on the LDO output can not only damage the LIN SBC by dissipating too much power through the IC, it can also damage the device it is supplying through electrical overstress, whether that is an MCU, a sensor, or something else. This is why it is necessary to immediately transition to failsafe mode when the overvoltage condition is detected. Failsafe mode shuts off the LDO, stopping it from damaging the load or the SBC itself.

3.2 VCC Undervoltage

Table 2 shows the conditions to trigger and clear an undervoltage condition. The undervoltage condition must persist for 250 ms before the SBC transitions into failsafe mode. Once the undervoltage condition is cleared, a wake event transitions the SBC into standby mode. If a wake event occurs while the undervoltage condition is still present, the device transitions into standby mode, and after 250 ms, the device transitions back to failsafe mode.

Table 2. VCC Undervoltage Conditions

DEVICE	UNDERVOLTAGE TRIGGER CONDITION	UNDERVOLTAGE CLEAR CONDITION
TLIN14413/2413	VCC ≤ 2.75 V	VCC > 2.9 V
TLIN14415/2415	VCC ≤ 4.45 V	VCC > 4.7 V

An undervoltage condition on the integrated VCC LDO is typically caused by drawing too much current from the LDO. The TLIN1441-Q1 and TLIN2441-Q1 integrated LDOs are specified to handle loads up to 125 mA at a VSUP of 12 V and an ambient temperature of 100 °C. Any load higher than this and the LDO may not be able to provide to correct amount of current with sacrificing the output voltage level.

A condition that can cause this is either a short-to-ground directly at the output of the LDO, or some kind of damage on the load (an MCU, a sensor, etc.) is creating a low-impedance path or short-to-ground. In either of these cases, too much current is pulled from the LDO, and cause the output voltage to drop. The reason this is potentially damaging is the amount of power being driven through the SBC from the LDO raising the temperature of the entire SBC. If the overcurrent or undervoltage condition is allowed to maintain, further damage may occur on the LIN SBC and cause more low-impedance paths within the IC. The temperature also continues to rise, causing further damage to the LIN SBC, and a potential fire hazard.

Failsafe mode mitigates this potential by detecting the undervoltage, and 250 ms later transitioning to a safe state. Since failsafe mode is similar to sleep mode, the LDO is disabled, and thus the source of the temperature rise is eliminated immediately. If the IC has not been damaged throughout all of this, once the conditions that caused failsafe mode are gone, it can be brought back to standby mode through a wake event.

3.3 Thermal Shutdown

Table 3 shows the conditions to trigger and clear a thermal shutdown condition. Tj refers to the junction temperature of the IC, which is the temperature internal to the SBC itself. As soon as this condition is detected by the temperature monitoring circuit of the SBC, the transition into failsafe mode occurs. Once the thermal shutdown condition is cleared, a wake event transition the SBC into standby mode. If a wake event occurs while the thermal shutdown condition is still present, the wake event is ignored.

Table 3. Thermal Shutdown Conditions

DEVICE	THERMAL SHUTDOWN TRIGGER CONDITION	THERMAL SHUTDOWN CLEAR CONDITION
TLIN14413/24413	Tj > 165 °C	Tj ≤ 150 °C
TLIN14415/24415		

Thermal shutdown can be caused by several things inside the vehicle, but is typically due to a combination of a relatively high ambient temperature in combination with too much power being consumed by the IC, though it can just be overconsumption of power by itself. The VCC overvoltage and undervoltage cases can play a part in this, leading to thermal shutdown, but there are other sources. The LIN bus can have transients damaging the LIN pin, creating a low impedance path or short-to-ground, dissipating power through the transceiver and causing a rise in temperature. Other causes can be VSUP getting shorted to ground internally from electrical overstress, the MCU failing and causing a logic output short to ground,Any cases where excessive power is being dissipated through the LIN SBC is potential for thermal shutdown to occur.

To mitigate this, the device is transitioned into failsafe mode as soon as the junction temperature is detected above 165 °C. Disabling all functions besides the low-power receiver, digital core, and LIMP output eliminates the possibility for the SBC to dissipate more power through itself, and thus lowers the overall current consumption and junction temperature.

4 Conclusion

The main idea of failsafe mode is to stop all current-driving sources internal to the chip to eliminate any possibility of the SBC dissipating more power. Not only does this save the IC, but it also stops the IC from being the cause of further damage within the ECU. It is important to note that though all of these overvoltage, undervoltage, over current, and over temperature conditions have a potential for damage on the TLIN1441-Q1 and TLIN2441-Q1. The LIN SBCs have many other fault protection functions in place to limit current and power dissipation through the device. Failsafe is a last effort to stop any damage from happening. For more information on the LDO performance and its limitations based on supply voltage, temperature, and load current, read the *TLINx441 LDO Performance Application Report*.

5 References

The following can be used to supplement the information provided in this application report.

- *TLINx441 LDO Performance Application Report*
- *TLIN1441-Q1 Product Folder*
- *TLIN2441-Q1 Product Folder*

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