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APPLICATION NOTE
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Designing LDO Power Rails for IEC 61508 Compliant Systems

Mitigating Systematic Failures Through Controlled Power-Down, Brown-Out Control, and Power-Good Monitoring

AND90423/D

Executive Summary

onsemi’s LDO portfolio addresses a wide range of industrial and automotive power-rail requirements, including applications where functional safety and deterministic behavior are critical. In IEC 61508 compliant systems, the power supply must do more than deliver voltage under normal conditions—it must also ensure predictable behavior during faults, brown-out events, and shutdown. Poorly controlled power-down and brown-out behavior in linear regulators can create systematic failures that may not be detected by testing alone.

This application note uses representative **onsemi** LDO features to examine common failure mechanisms in safety-related power rails, with emphasis on active output discharge, undervoltage lockout (UVLO), and proper use of Power-Good (PG) signals. These techniques ensure that safety-related circuitry transitions through defined states and provide practical context for selecting suitable **onsemi** LDO devices for IEC 61508-oriented designs.

Abstract

In safety-related electronic systems, power supplies are often treated as supporting infrastructure rather than contributors to the overall safety function. However, experience from field returns and failure analysis shows that a significant number of systematic failures originate from poorly defined power sequencing, incomplete discharge of supply rails, or brown-out events that leave digital and mixed-signal circuits operating outside their specified limits.

This document focuses on low-dropout (LDO) regulators used to supply safety-critical loads such as microcontrollers, sensors, and communication interfaces. Through simplified block diagrams and timing waveforms, it illustrates how controlled power-down and brown-out handling can be achieved. The examples are intended to support functional safety analysis and to provide practical design guidance for engineers developing IEC 61508-compliant systems.

LDO Power Architecture in Safety Systems

LDO regulators are widely used in safety-related systems due to their simplicity, low noise, and predictable behavior under normal operating conditions. However, not all LDOs provide the same level of control during power-down or fault scenarios. In many designs, the output capacitor of an LDO can hold the supply voltage for tens or hundreds of milliseconds depending on output capacitance, load current, and leakage paths after the input supply has been removed.

If this residual voltage is not actively discharged, downstream circuitry may remain partially powered. During this interval, internal logic may violate reset thresholds, memory contents may become corrupted, and external interfaces may drive undefined levels. From a functional safety perspective, such behavior represents a systematic failure because it is repeatable and originates from design or specification deficiencies rather than in random hardware faults.

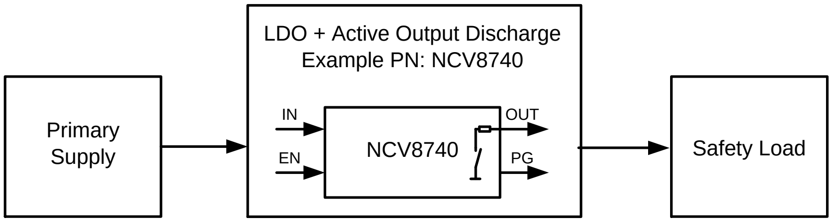

Figure 1. LDO Power Rail with Controlled Power-Down

Failure Scenario: Uncontrolled Power-Down

Figure 2 illustrates a common failure scenario in which an LDO without active output discharge relies solely on load current, leakage paths, and parasitic elements to discharge its output capacitor once the input supply is removed. In lightly loaded or intermittently active systems, this natural discharge mechanism can be extremely slow, allowing the output voltage to persist for tens or even hundreds of milliseconds. During this interval, the supply rail may remain within a range that is insufficient for correct operation but high enough to partially bias internal circuitry.

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From a functional safety perspective, this uncontrolled decay represents a significant risk. Safety-related components such as microcontrollers, communication interfaces, and mixed-signal devices may remain partially powered and operate outside their specified voltage limits. Internal reset circuits may not assert reliably, clock oscillators may start and stop unpredictably, and memory elements may enter undefined states. Because this behavior is repeatable and inherent to the design, it constitutes a systematic failure rather than a random hardware fault.

In addition, uncontrolled power-down can result in inconsistent behavior across power cycles. Depending on temperature, leakage currents, or residual load conditions, the discharge time may vary significantly, leading to non-deterministic startup behavior during the subsequent power-up. Such variability complicates system-level safety analysis and undermines assumptions made during Failure Modes and Effects Analysis (FMEA) or Fault Tree Analysis (FTA). Without a defined and bounded power-down sequence, it becomes difficult to guarantee that all safety-critical elements reach a known and fully unpowered state before the next operating cycle begins.

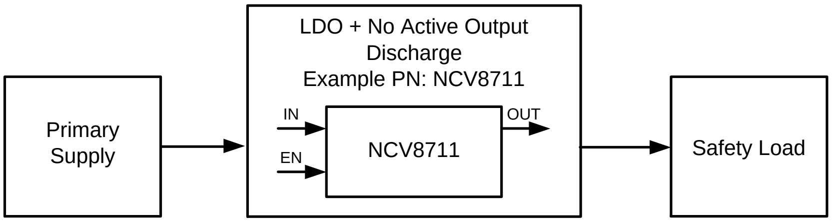

Figure 2. Uncontrolled Power-Down Without Active Output Discharge

Output Voltage Timing During Power-Down

Figure 3 compares the output voltage decay of an LDO with and without active discharge circuitry, highlighting the importance of controlled power-down timing in safety-related systems. When active discharge is implemented, the output voltage is forced rapidly toward ground once the regulator is disabled or the input supply collapses. This creates a short, well-defined discharge interval that is largely independent of load conditions, output capacitance, or environmental factors.

A controlled and repeatable discharge profile ensures that all downstream circuitry experiences a complete and reliable power-off event. Digital logic is driven cleanly below its reset threshold, internal states are cleared, and no residual voltage remains that could influence subsequent behavior. This deterministic timing simplifies system verification and allows power-down behavior to be explicitly documented as part of the functional safety concept.

In contrast, passive discharge results in a slow and poorly defined voltage decay that may traverse regions where digital and mixed-signal circuits are neither fully on nor fully off. Operation in this indeterminate voltage range increases the likelihood of unintended resets, metastable logic states, or partial retention of memory contents. For safety-critical systems, avoiding these regions is essential, as undefined internal states may persist undetected and only manifest as faults during later operation.

By enforcing a rapid and monotonic transition to ground, active discharge eliminates ambiguity in power-down behavior and ensures consistent system initialization on the next power-up. This predictable timing directly supports the systematic capability requirements of IEC 61508 by reducing design-dependent variability and strengthening confidence in the power supply’s contribution to overall system safety.

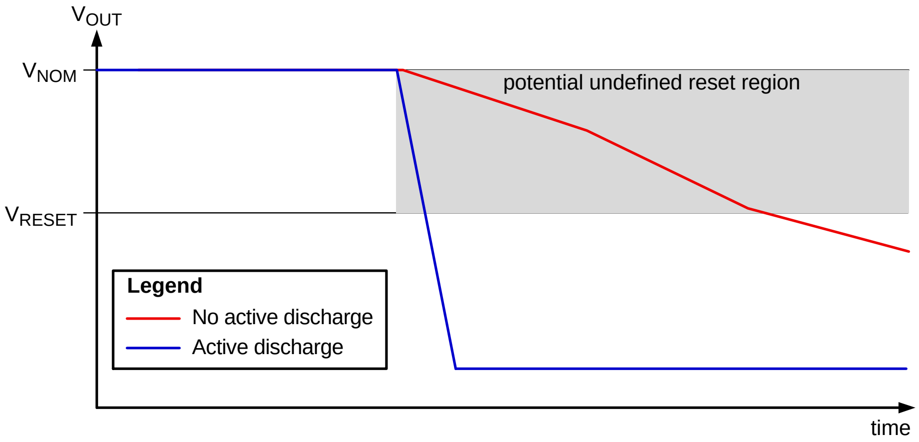

Figure 3. Output Voltage Timing During Power-Down

Brown-Out Scenarios and Power-Good (PG) Behavior

Brown-out events occur when the input supply voltage temporarily drops below its nominal level but does not fully collapse. Such events are common in industrial environments due to load transients, wiring impedance, or upstream power disturbances. If not properly handled, brown-outs can cause safety-related logic to operate outside its specified voltage range.

Figure 4 shows two brown-out scenarios: one without UVLO and one with UVLO enabled. Without UVLO, the LDO output may track or partially follow the input supply depending on dropout conditions, lingering between the reset threshold and the minimum operating voltage. With UVLO, the regulator forces a rapid shutdown once the input falls below a defined threshold. Figure 5 shows a similar situation as Figure 4; however, it additionally features a quick, proper VOUT restart event.

The Power-Good (PG) signal provides a diagnostic indication of output validity by indicating whether the output voltage is within its valid operating range. De-asserting PG early during a brown-out allows the system controller to enter a safe state before undefined behavior can occur.

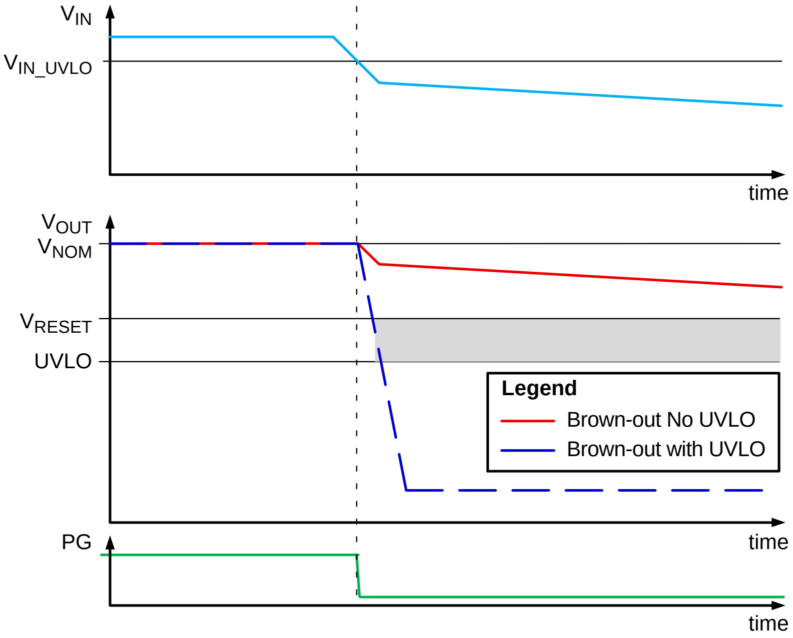

Figure 4. Brown-Out Scenarios with and without UVLO (PG Shown)

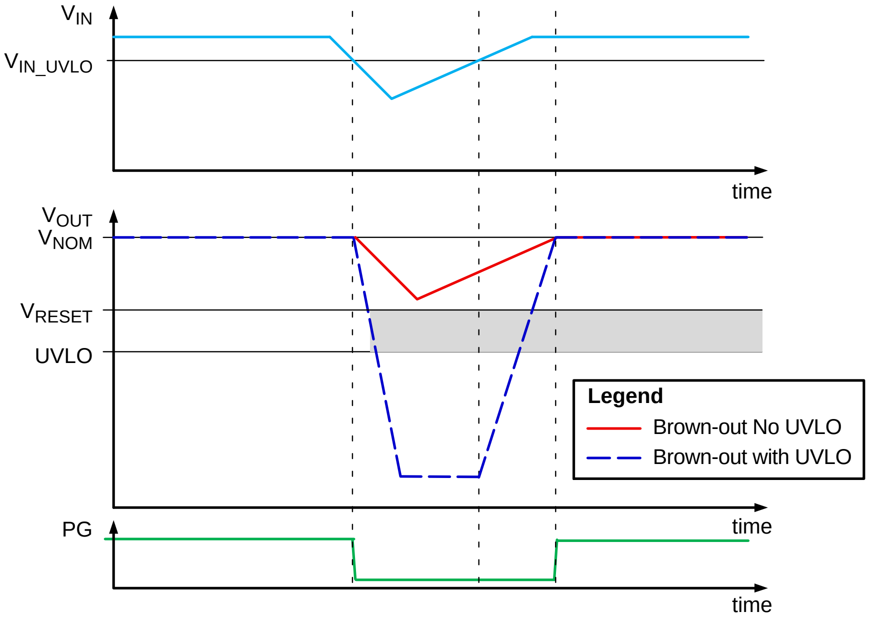

Figure 5. Brown-Out Scenarios with and without UVLO (PG Shown) with Quick V_{OUT} Restart

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Design Checklist for IEC 61508 LDO Power Rails

- Verify that the LDO provides active output discharge or implement an external discharge path if required.
- Ensure that the power-down time is short, well-defined, and independent of load conditions.
- Confirm that all safety-critical loads experience a complete and reliable reset during shutdown.
- Use UVLO to prevent operation during brown-out conditions.
- Connect and monitor the PG signal to enable early detection of invalid supply conditions.
- Document power sequencing, discharge behavior, and brown-out response as part of the functional safety analysis.

Refer to Table 1 for an overview of **onsemi** LDO regulators suitable for use in safety-related supply architectures. The table summarizes key selection parameters—including input voltage range, output voltage options, maximum output current, and available functional safety-relevant features—providing practical guidance for selecting an appropriate device for a given application.

Table 1. onsemi LDOs

LDO P/N	V_{in} (V)	V_{out} (V)	I_{out_max} (mA)	I_q Typ. (µA)	$I_{shutdown}$ Typ. (µA)	Package(s)	Active Discharge	EN	PG
NCV8711A	2.7–18	1.2–17 (fixed / adj)	100	1	<0.1	TSOP-5 WDFN-6 (2x2)	N	Y	Y
NCV8730A	2.7–38	1.2–24 (fixed) 1.2–37 (adj)	150	1	0.1	TSOP-5 WDFN-6 (2x2)	N	Y	Y
NCV8740A	3.0–85	1.2–20 (fixed / adj)	100	2	0.2	TSOP-5 WDFN-6	Y	Y	Y
NCV8163A	2.2–5.5	1.2–5.3	250	12	0.1	TSOP-5 XDFN-4 (1x1)	Y	Y	N
NCV8164A	1.6–5.5	1.2–5.0 (fixed / adj)	300	30	0.1	TSOP-5 WDFN-6 (2x2) DFN-8 (3x3)	Y	Y	Y
NCV8165A	1.9–5.5	1.8–5.2	500	12	0.1	DFN-8 (3x3)	Y	Y	N
NCV8177A	1.6–5.5	0.7–3.6	500	60	0.1	XDFN-4 (1x1) WDFN-8 (2x2)	Y	Y	N
NCV8189	1.6–5.5	0.6–5.0 (fixed / adj)	500	35	0.1	WDFN-6 (2x2) DFN-8 (3x3)	Y	Y	Y
NCV59749	0.8–5.5 (VIN) 2.7–5.5 (VBIAS)	0.8–3.6	3000	1000–2000	1–5	QFN-20 (5x5)	N	Y	Y
NCV59801C	1.6–5.5	0.6–5.0 (fixed / adj)	1000	35	0.1	WDFN-6 (2x2) DFN-8 (3x3)	Y	Y	Y
NCP156A	2.5–16	1.2–12 (fixed / adj)	150	60	1	SOT-23-5	Y	Y	N
T30LMPSR131A	<2.2 (VIN) <3.6 (VBIAS)	0.5–1.8 (fixed, 25 mV step)	1000	85	10	WLCSP6 1.145x0.75x0.33	Y	Y	N
T30LMPSR165A	1.4–3.6	1.0–3.2 (fixed)	300	240	10	WLCSP4 0.64x0.64x0.33	Y	Y	N

Conclusion

Power supply behavior is a foundational element of functional safety, even when the power supply itself is not explicitly defined as part of the safety function. In IEC 61508 systems, predictable and deterministic behavior during all operating conditions—including power-up, normal operation, brown-out, and power-down—is essential to achieving the required level of systematic capability. Poorly defined power rail behavior can introduce repeatable, design-induced failures that are difficult to uncover through testing alone and that can undermine otherwise robust safety architectures.

By implementing controlled power-down mechanisms, designers ensure that all downstream circuitry transitions cleanly and consistently to a fully unpowered state. Active output discharge significantly reduces extended periods of indeterminate voltage, reducing the risk of unintended logic states, corrupted memory, or incomplete resets. Similarly, the use of undervoltage lockout (UVLO) prevents operation during brown-out conditions, forcing a rapid and well-defined shutdown before components are driven outside their specified operating range. Together, these measures significantly improve system determinism and simplify safety analysis.

The proper use of Power-Good (PG) signaling further strengthens the diagnostic coverage of the power subsystem. By providing early and reliable indication of invalid supply conditions, PG enables system controllers to enter a safe state before undefined behavior can propagate through safety-critical logic. When documented and integrated into the overall safety concept, PG signals support clearer assumptions in FMEA and FTA activities and contribute to a more defensible safety case.

Although the examples in this application note focus on LDO regulators, the underlying principles apply broadly to power management in safety-related electronic systems. Treating the power supply as an active contributor to functional safety—rather than as passive infrastructure—allows designers to eliminate an entire class of systematic failures. The techniques discussed here help ensure deterministic system behavior, improve robustness against real-world power disturbances, and ultimately strengthen compliance with IEC 61508 requirements across a wide range of industrial applications.

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[4] *NCV8164 Low-Dropout Regulator Datasheet*, **onsemi**. Example of an LDO providing Power-Good signaling and controlled output behavior relevant to safety-related systems.

REVISION HISTORY

Revision	Description of Changes	Date
0	Initial document release.	6/8/2026

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