Understanding and using Power System Reliability Modeling

About this document

Scope and purpose

This document introduces Power System Reliability Modeling (PSRM), an integrated feature in Infineon's XDP™-series digital power controllers that addresses a common blind spot for customers. Once a converter is deployed in the field; its actual reliability is largely unknown. PSRM closes this gap by continuously calculating the converter's in-field reliability — failure rate, failure probability, and operating time — from high-resolution telemetry such as current, voltage, and temperature, and making these reliability parameters available via PMBus®.

This document helps you to understand and use the PSRM and explains how the reliability calculation works and what it assumes and does not cover, shows what the resulting data can be used for in practice, and provides the configuration and PMBus® integration steps needed to deploy and read out PSRM in an application.

PSRM is integrated directly into Infineon's XDPP and XDPE controllers.

Intended audience

This document is intended for system architects deciding whether to adopt PSRM, and for developer/integration engineers those need to understand how to implement PSRM into the electronic system.

Keypoints

- Explains Power System Reliability Modeling (PSRM) for in-field reliability assessment using real operating-condition telemetry
- Describes failure-rate and accumulated failure-probability calculations based on reliability models and measured stress conditions
- Demonstrates converter reliability analysis through threshold comparison, health scoring, fleet comparison, and load balancing use cases
- Provides guidance for configuring design-specific reliability models using component grouping, telemetry mapping, and unit definitions
- Details PMBus® interfaces and integration methods for accessing and restoring reliability parameters in deployed systems

About this product family

Product family

Infineon's XDP™-series digital power controllers

Target applications

- Datacenters
- Telecommunication

Table of contents

About this document **1**
About this product family **1**
Table of contents **2**
1 Introduction **3**
1.1 Implementation quick guide 4
2 Power system reliability patch **6**
2.1 Telemetry compression 7
2.2 Calculation of the failure rate λ 7
2.3 Calculation of the failure probability CDF 10
2.3.1 System- vs. unit-level granularity 11
2.4 Start-up behavior 12
2.5 Assumptions and limitations of the reliability model 12
2.5.1 Failure rate model: constant hazard rate within each interval 12
2.5.2 Stressors not covered 13
2.5.3 Series reliability model 13
2.5.4 Telemetry mapping approximations 13
2.5.5 Accuracy and measurement error 14
2.5.6 Model validation 14
3 Use cases derived from the reliability parameters **16**
3.1 Definition of Fleet 16
3.2 Comparison against reliability thresholds 16
3.2.1 Defining the upper and lower bound 17
3.3 Health status derived from converter reliability 18
3.4 Comparison against fleet reliability 19
3.5 Load balancing based on reliability 19
3.6 Supporting wear-out analysis 20
3.6.1 Correlating CDF with field failure events 20
3.6.2 PSRM as the foundation for component-specific wear model extensions 20
4 Configuration of a design-specific reliability model **21**
5 PSRM PMBus® commands description **26**
5.1 System-level reliability readout 26
5.1.1 MFR_RELIABILITY_CALC (OP_code: 0xB2) 27
5.1.2 MFR_CDF_TIME_VALUE (OP_code: 0xB6) 28
5.2 Unit-level reliability readout 28
5.2.1 MFR_CMD_AND_UNIT_SEL_PARAM (OP_code: 0xE7) 30
5.2.2 MFR_READ_WRITE_REL_PARAM (OP_code: 0xEF) 31
5.2.2.1 PSRM_CMD_UNIT_REL (Subcode: 0x01) 32
5.2.2.2 PSRM_CMD_LOOP_CDF (Subcode: 0x02) 33
5.2.2.3 PSRM_CMD_LOOP_FIT (Subcode: 0x03) 34
6 Summary **36**
References **37**
Revision history **38**
Disclaimer **39**

1 Introduction

Power system reliability modeling (PSRM), a functional block in Infineon's XDP™ digital power controllers, enables in-situ and in-field reliability assessment of power converters, by using measured operating conditions instead of relying on assumed mission profiles.

A major benefit of PSRM is its integration directly into the power controller. Reliability-relevant operating conditions can change quickly and may be missed when telemetry is read out slowly or only processed outside the controller. PSRM evaluates continuously measured telemetry at millisecond level before compressing it into reliability-relevant average values, allowing short-term stress variations to be considered in the reliability calculations.

Together with an embedded reliability model of the complete DC-DC converter, PSRM calculates in-field reliability parameters directly in the deployed system. These parameters extend the controller's register map and can be accessed via PMBus® by application controllers such as a baseboard management controller (BMC), as shown in Figure 1. This enables reliability information to be used for infrastructure control and maintenance at server-board or datacenter level.

The use cases derived from the in-field reliability parameters of the power converter are:

- Comparison of one specific converter's reliability against reliability limits (Section 3.2)
- Deriving health status from converter reliability (Section 3.3)
- Comparison of one specific converter's reliability against fleet (*the population of identical converters deployed across the infrastructure*) reliability (Section 3.4)
- Load balancing based on reliability between converters in redundant or multiphase systems, or balancing computational load at the datacenter level (Section 3.5)
- Supporting wear-out analysis (Section 3.6)

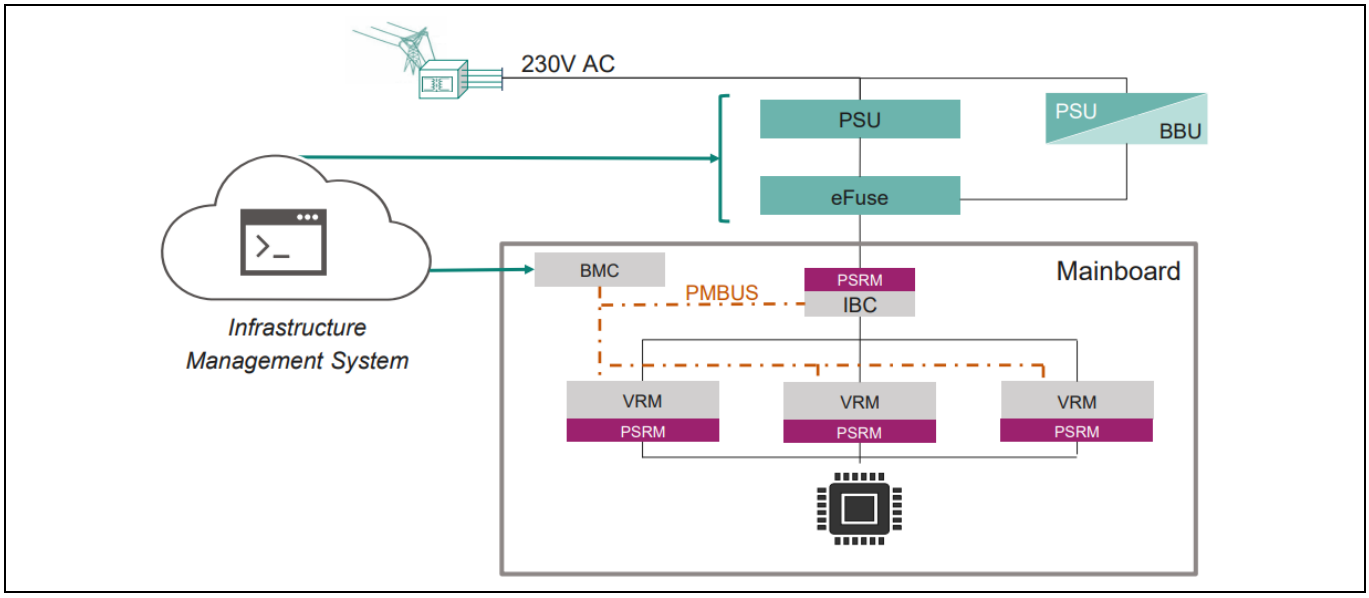


Figure 1 PSRM as part of the infrastructure

PSRM continuously measures the available telemetry parameters, compresses the telemetry inputs using built-in low-pass filters and a defined compression routine, and creates a one-second representation of the signal (Figure 2).

Introduction

Using the design-specific reliability model, PSRM executes the PSRM library to calculate the in-field converter failure rate (λ_{sys}) and the failure probability via the cumulative distribution function (CDF) of either the whole design or specific functional blocks. $\lambda_{sys}, CDF\ and\ operating\ time$ are added to the register map of the power controller and can be read out via dedicated PMBus® commands.

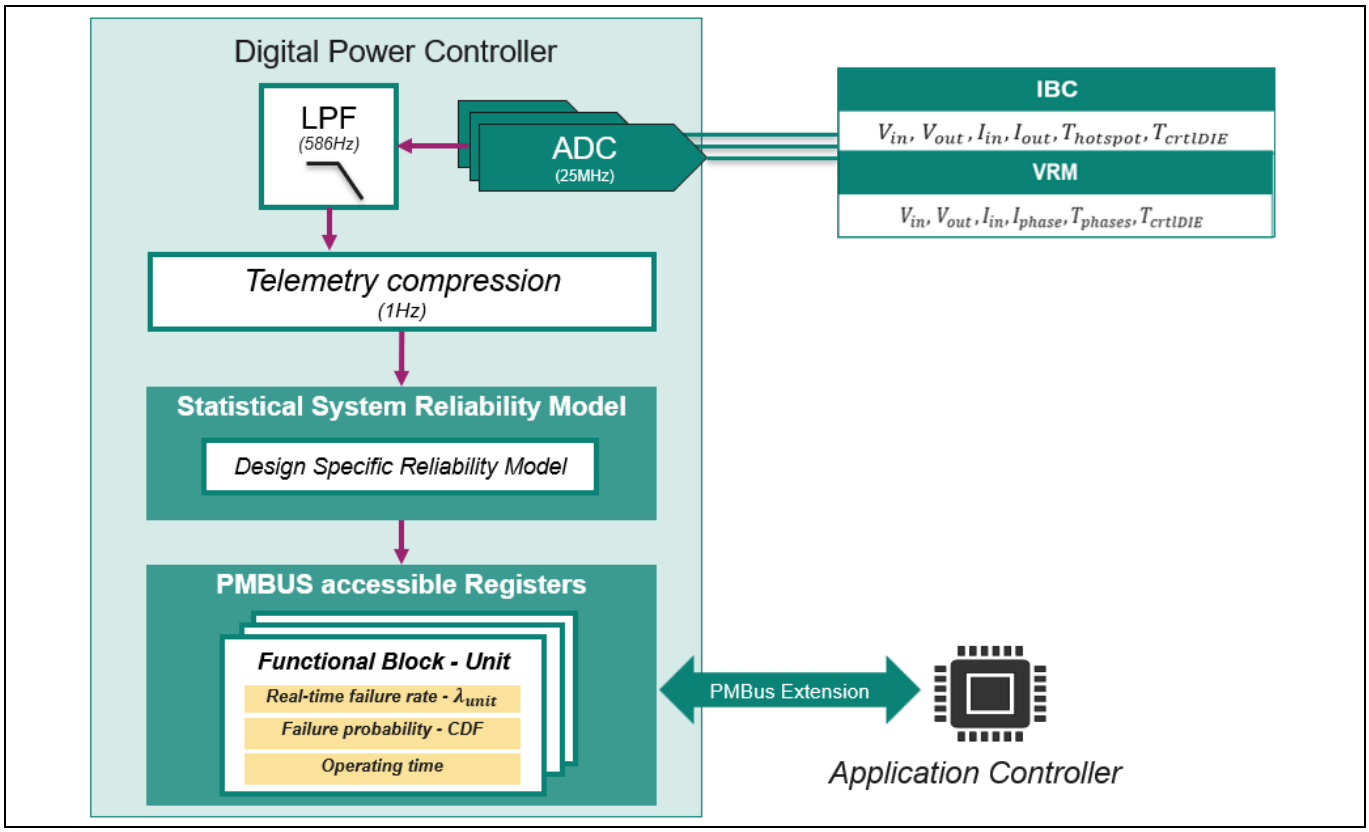


Figure 2 Block diagram of the PSRM feature

To explain the parameters calculated by PSRM, Section 2 describes telemetry compression, reliability calculation, and reliability-model assumptions. Section 3 describes use cases that can be implemented in the application controller or infrastructure management tool. Section 4 uses a 600 W full-bridge evaluation board based on the XDPP1100 as a practical guide for integrating the feature into a controller. Finally, Section 5 documents the interfaces and explains how to integrate PSRM into an application.

1.1 Implementation quick guide

The delivery method is either to have PSRM pre-flashed as part of the controller or to receive a firmware patch for integration into the user flashing flow. Currently, this feature is only accessible with the support of Infineon Application Engineers. If you would like to implement this feature or learn more about it, contact your Infineon Account Manager.

Prerequisites:

- Infineon power controller (XDP™, XMC™, PSOC™)
- ~15 KB of free memory space

To deploy PSRM, the following steps are required:

- Design the DC-DC converter as usual. PSRM can be added to new designs and retrofitted to existing designs

Introduction

- Collaborate with Infineon to configure the system reliability model based on high-level design information and the bill of materials (see Section 4)
- Receive a custom patch for your power controller which includes the reliability model
- Load the custom patch onto the controller
- Implement custom PMBus commands in your application controller (see Section 5)
- PSRM is deployed automatically once the controller enters the regulation state
- Read reliability data via custom PMBus® commands

The feature can be customized for various designs, topologies, and converter types such as IBCs, VRMs, and AC-DC converters. As each design requires a correct configuration, the design configurator must be completed during the development process with the required design-specific information. This configuration sheet is used to generate header files that are compiled into the final firmware patch. This enables reuse of the existing patch programming flow available via XDP™ Designer GUI.

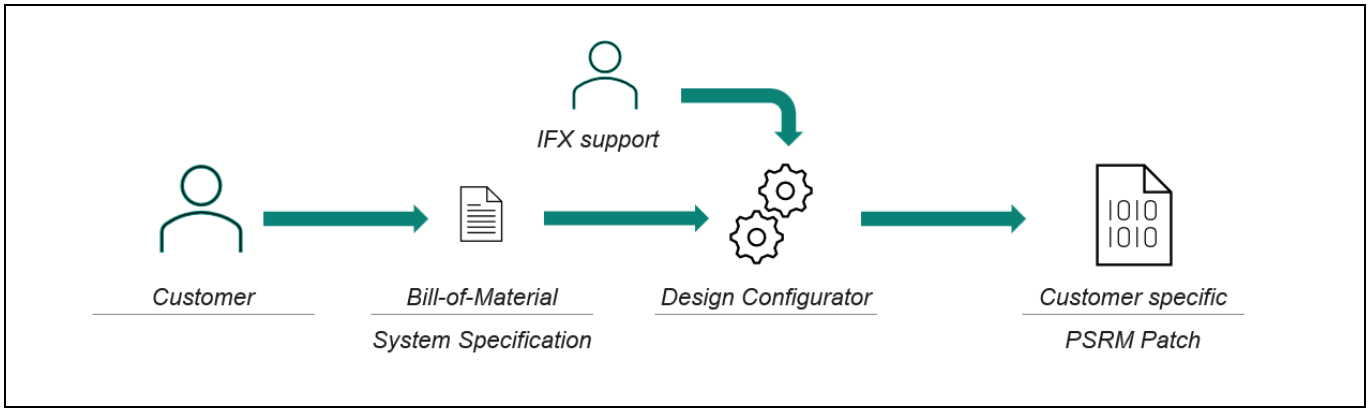


Figure 3 Block diagram of the PSRM feature deployment

2 Power system reliability patch

Currently, PSRM can be implemented on XDPP1100 and XDPE1B2C4B controllers. Additional controllers can be supported on request if the required telemetry and memory resources are available.

Table 1 System requirements

System and design requirement	Description	
Controller	XDPP1100, XDPE1B2C4B Rollout to further controllers on request	
Required memory size	OTP: ~15 KB	RAM: ~2 KB
Design telemetry information	Minimum: one measurement point for temperature, voltage, and current More measurement points enable a more refined reliability prediction.	

Table 2 PSRM output parameters

Output parameter	Failure rate λ_{sys}	Failure probability: CDF	Operatng time
Description	Estimated rate of failures in an interval adjusted by the operating conditions of the converter.	Probability the converter has failed until operating time based on all experienced operating conditions.	Time the converter has been powered on
Interpretation	Approximation of stress over the interval of 1 s	Approximation of stress accumulation over converter lifetime	
Unit	$FIT = \frac{1\ Failure}{10^9 h}$	%	h, ms
Data Type	Float32	Float32	Float32, uint32
Update rate	1 Hz	1 Hz	1 kHz

Table 3 Algorithm specification

Algorithm specification	Description
Memory size	Base firmware: ~8 KB Reliability model dependent on component number: ~1 KB – 5 KB
Runtime	~0.4 ms -2 ms

PSRM produces λ, CDF, and operating time at two granularities: **system level** (whole converter: λ_{sys}, CDF_{sys}) and **unit level** (per functional block $\lambda_{unit}, CDF_{unit}$).

Power system reliability patch

Definition: Unit
Within the context of this document, a unit is a cluster of components that are either electrically connected or in thermal proximity.
The appropriate granularity is selected at model configuration time and determines which PMBus® commands are used (see Section 5). The rationale for selecting the appropriate granularity is provided in Section 2.3.1. For readability, the document uses the generic terms λ and CDF when referring to both system- and unit-level reliability parameters. Cases that apply only to system- or unit-level granularity are stated explicitly.

The following sections describe telemetry compression, the output parameters, the patch start-up behavior, and the practical usage and limitations of the reliability models.

2.1 Telemetry compression

PSRM uses compressed telemetry values to construct the stress vector that is used for the FIT calculation. The compression routine builds on the existing hardware filters provided by the XDP™ controller (see Figure 4).

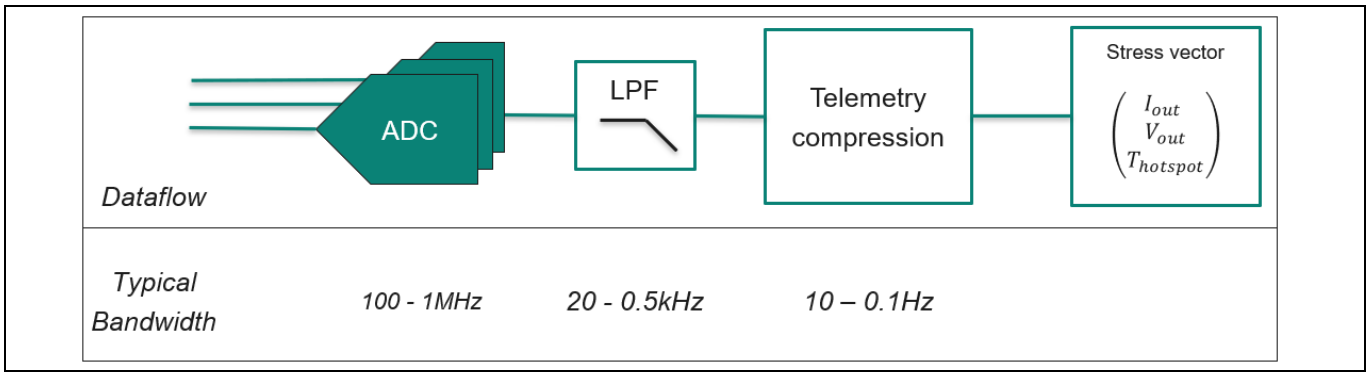


Figure 4 Bandwidth of the telemetry path

As the current PSRM implementation focuses on average lifetime operation rather than individual reliability-deteriorating events such as SOA exceedances, telemetry compression uses a cascaded averaging scheme.

The hardware low-pass filter is set to 586 Hz, and the telemetry thread samples its output every 1 ms. This two-stage arrangement separates the filtering and averaging functions: the firmware accumulator provides long-term averaging for signal content below 500 Hz, while the hardware low-pass filter acts as an anti-aliasing filter at the 1 kHz sampling boundary, reducing the risk that switching-frequency ripple and high-frequency noise alias into the telemetry band.

2.2 Calculation of the failure rate λ

This section provides the fundamental background to understand the λ calculation. A more applied view and what you have to do to configure the model is described in Section 4.

As a reliability metric, PSRM calculates the in-field failure rate and failure probability of the power converter based on the measured operating conditions and converter reliability models derived from the parts count methods defined in the reliability handbooks (MIL-HDBK-217F, Telcordia SR-332, etc.).

These methods postulate that the converter failure rate can be approximated by combining the failure rates of individual components with their mission profile—average operating conditions of devices over their lifetime. The handbooks are used for design evaluation and assume that all converters within a fleet have the same

mission profile. However, as identical converters will experience different operating conditions, those handbooks are not suited for calculating the failure rate of a single converter.

Since PSRM is integrated into the power controller, it can directly measure the thermal and electrical stress of the deployed DC-DC converter while it is operational. Therefore, it calculates the failure rate of each individual converter directly. This allows the converter's reliability to be compared against other converters in the fleet, since the assessment is no longer based on assumed operating conditions but on the converter's actual, effective operating conditions.

To calculate λ, the feature calculates the individual component failure rates by mapping the compressed operating conditions — such as voltage, current, and temperature — to the individual components of the converter. Further information regarding the nature of the failure rate and its value is provided in the white paper [1].

The basic formula to reflect the thermal and electrical load dependency of a component (for example, capacitor) failure rate is:

$$\lambda_{comp} = \lambda_{base}\, \pi_T\, \pi_S$$

Equation 1 Calculation of the component failure rate

The base failure rate λ_{base} can come from different sources:

- A vendor FIT rate report, if a specific component has already been selected
- Reliability handbooks (for example, Telcordia SR-332, MIL-HDBK-217F) for standardized component data

The acceleration factor for temperature (π_T) is typically defined as:

$$\pi_T = e^{\frac{E_a}{k_b}\left(\frac{1}{T_0}-\frac{1}{T}\right)}$$

Equation 2 Arrhenius equation for thermal stress calculation

where:

$\boldsymbol{E_a}$: *component − specific activation energy in eV*
$\boldsymbol{T}$: *operating temperature of the component in °K*
$\boldsymbol{T_0}$: *reference temperature of the component in °K*
$\boldsymbol{k_b}$: *Boltzmann constant* $= 8.62\ x\ 10^{-5}\frac{eV}{°K}$

Similarly, the electrical stress factor (π_s) is given by:

$$\pi_s = Ae^{B(S_x - S_0)}$$

Equation 3 Electrical stress calculation

where:

$\boldsymbol{A}$ *and* $\boldsymbol{B}$ *usually denote component − specific shape parameters considering device specific behavior*
$\boldsymbol{s_x}$: *electrical stress parameter of component in %*
$\boldsymbol{s_0}$: *reference electrical stress parameter of component in %*

The electrical stress parameter is defined as the ratio of an applied stress parameter to a rated parameter. Together with the component-specific variables for stress sensitivity, such as activation energy, a reliability model is constructed:

Power system reliability patch

Table 4 Component model examples

Component type	λ_{base}	E_a	A	S_x	Dynamic stress Parameter
Electrolytic Capacitor	1.5	0.4	0.2	V_applied/V_rated	V_applied,T
Ceramic capacitor	0.1	0.05	1		
MOSFET	1.77	0.7	1	V_applied/V_rated	V_applied,T
Transformer	5	0.15	-		

With these formulae established, the feature uses the compressed telemetry values — such as $V_{applied}, I_{applied}$ *or* T — to recalculate the acceleration factors (π_T, π_s) and the in-field component failure rate.

However, in a real converter design, the operating conditions across each individual component are not available. Therefore, the model groups a set of components into a Unit (see Figure 5). A unit shall always group components which are either electrically connected or in thermal proximity. Grouped correctly the compressed telemetry parameters can be shared among the components of a unit.

Which telemetry parameters are being associated with one unit is defined in the unit type. The unit type defines the maximum electrical ratings of the unit, and which telemetry parameters are being used to calculate S_v, S_I *and* S_P (see Section 4 for a concrete example). A component linked to a specific unit will always use the S_v, S_I *and* S_P of the unit type associated with the unit.

As you can see in Figure 5, the unit types can be shared among different units that allows a more flexible partitioning of the components into units and if the λ_{unit} *and* CDF_{unit} is of interest to the user. If the stress of a component is independent of the operation, for example, bypass capacitor of an IC, the electrical stress can be assumed static.

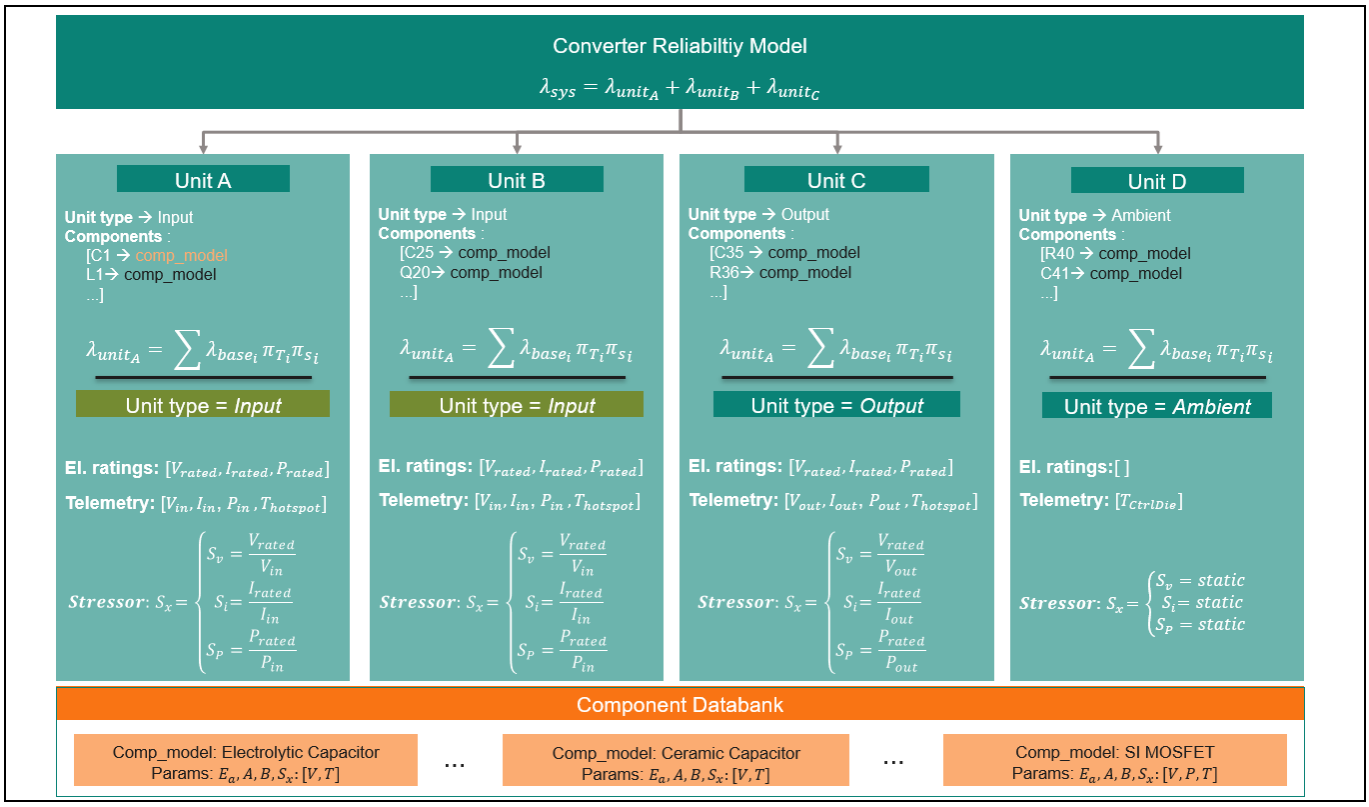


Figure 5 General structure of the converter reliability model

Power system reliability patch

PSRM assumes a series reliability model, meaning that one component failure causes the entire unit to fail, and one unit failure causes the entire converter to fail. Consequently, the failure rate of the whole converter can be represented as the sum of the individual component FIT rates.

Clustering the components into the right units and assigning the right unit types requires some engineering decision. To make this more tangible Section 4 works through a complete example of this model structure using a 600 W full-bridge evaluation board, showing how to define units, assign components, and map telemetry to units.

2.3 Calculation of the failure probability CDF

The in-field system failure rate is an estimate of the expected rate at which failures would occur if many converters were operated according to the measured operating conditions. From this parameter, a calculation of the failure probability is possible. There are two different representations of the failure probability which have to be differentiated:

- **Accumulated failure probability**: Calculating the probability the device **has failed** until now based on all the experienced operating conditions
- **Forecasted failure probability**: Calculating the probability the device **will fail** within a certain time interval based on assumptions of the future operating conditions within this interval

The latter method is not implemented, as unforeseen operating conditions could significantly alter the failure probability within the given time interval, and the failure rate has only limited capability to predict concrete failures resulting from overstress events. For a discussion of stress events that fall outside the model's scope, see Section 2.5.

PSRM implements the accumulated failure probability. The assumption is that continuous high stress increases stress accumulation in the devices and thus increases the probability of the device having failed up to the current point in time. Transparency about which stress has accumulated in which converter can be achieved by incorporating every operating condition that the converter experienced into the calculation. This way the dependency on operating condition assumptions is removed and a model-based estimate of the in-field failure probability is obtained.

At each calculation interval Δt, PSRM computes the marginal increase in failure probability attributable to the operating conditions observed during that interval. This increment is derived from the current λ and is accumulated onto the failure probability from all previous intervals. The steeper the CDF curve in Figure 6, the higher the stress experienced in that interval.

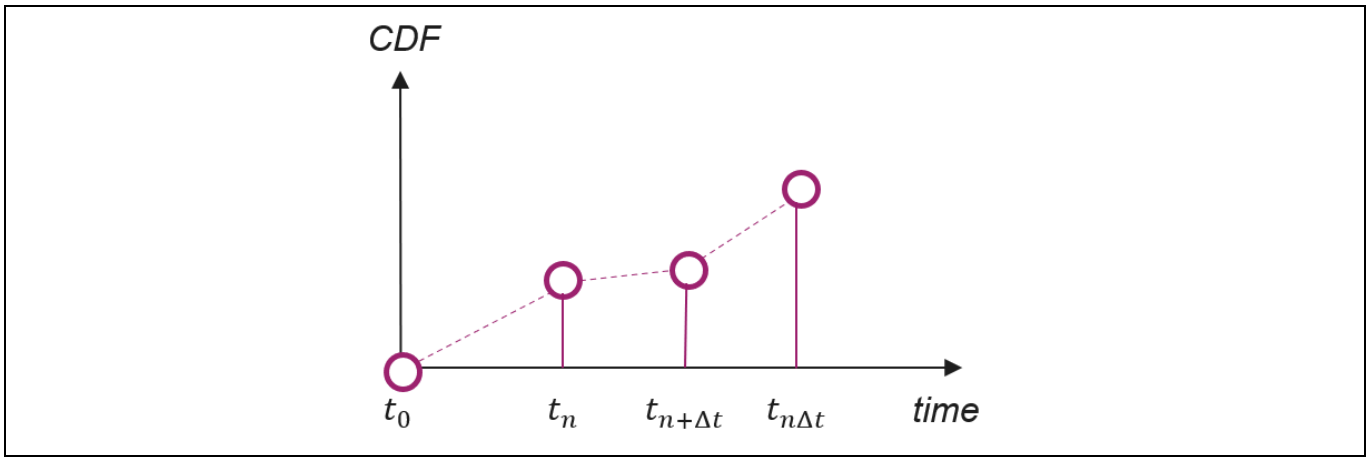


Figure 6 Iterative calculation of the CDF values

The interval Δt can be configured, but its default value is 1 s as an optimum of reduced computational load for the CPU and accuracy of the reliability prediction.

The calculation is executed iteratively, meaning the ΔCDF is always added to the last valid CDF. This approach is used to save on memory usage as only the telemetry information of the last sample interval (e.g. 1 s) must be stored and to reduce calculation effort.

To restore the CDF after a VDD reset a special PMBus® command is implemented to load the last valid CDF (see Section 5.2).

2.3.1 System- vs. unit-level granularity

There are two implementations of PSRM available:

1. FIT/CDF parameter for the whole system
2. FIT/CDF parameters on a unit level

Referring to Figure 5, the major difference between the two flavors are the parameters which can be accessed via PMBus®.

Option 1 is preferred for systems in which the reliability of individual units is of less interest than the holistic system reliability, such as for the 600 W IBC described in the previous section. For other systems such as multi-phase designs like voltage regulation modules (VRMs), individual phase reliability is more relevant (where a phase constitutes one unit), since individual phase currents may differ and an uneven accumulation of failure probability is therefore possible.

The greater insight into system reliability comes at the cost of higher communication overhead from the BMC side. To read the full set of reliability parameters ($\lambda, \lambda_{std}, CDF, op_{time_h}, op_{time_{ms}}$) a 28-byte block read is required. In case of the unit-level granularity, those parameters are available for each unit increasing the number of parameters which are readable.

To ease the communication effort on unit-level granularity, the option is given to read only the CDF or FIT values in bulk (subcodes 0x02/0x03). A detailed description is given in Section 5.

Table 5 PMBus® commands for PSRM parameter access

System level reliability information			**Bytes**
0xB2	MFR_RELIABILITY_CALC	Read the reliability parameters of the whole system	28
Unit level reliability information			
0xE7	MFR_CMD_AND_UNIT_SEL_PARAM	Selection of the unit and the subcode to define the type of data of next 0xEF	5
0xEF	MFR_READ_WRITE_REL_PARAM	0x01: Read unit reliability parameters	28
		0x02: Read selected Unit CDF values only	4+ 4n
		0x03: Read selected Unit FIT values only	4+ 4n

2.4 Start-up behavior

As the operating time and the CDF are parameters that are incremented or accumulated over the whole lifetime of the DC/DC converter, a mechanism must be established to recover the CDF and operating time information in the event of such a power cycle, during which the volatile memory is reset. One limitation of the XDP™ controller series is that it uses OTP memory, limiting the amount of data that can be stored before a power cycle.

Therefore, during startup of the controller, the CDF values of units/system and the time must be written into the correct registers using the PMBus® commands defined in Section 5. The initialization parameter can be either 0 or the last logged CDF value from the BMC controller.

Upon startup, XDP™ controller will start the PSRM module/calculations with values initialized to 0. Once the XDP™ controller receives the old values, it will combine the CDF and operating time with its current values. It is expected that this operation will be done only once at every cold reset of the controller by the BMC host.

The expected behavior is:

- The BMC will write the CDF value using the PMBus® commands only once at every cold reset of the XDP™ controller
- Subsequent receipt of the commands to change the CDF from the BMC will be rejected by the XDP™ controller
- The update of the CDF/op_time registers is time independent as the newly calculated values are combined with last valid CDF/op_time values.

2.5 Assumptions and limitations of the reliability model

Understanding what PSRM models — and equally what it does not model — is essential for correct interpretation of λ_{sys} and CDF outputs.

2.5.1 Failure rate model: constant hazard rate within each interval

The reliability calculation uses the exponential failure distribution, under which the instantaneous failure rate λ is treated as **constant within each 1-second calculation interval**. This lets PSRM continuously re-evaluate λ from the latest measured operating conditions, so the model tracks random, condition-driven failure contributions (the flat region of the bathtub curve) with high time resolution.

Two mechanisms sit outside this interval-wise random-failure model and are not separately represented:

- **Wear-out acceleration.** λ is derived purely from current operating conditions, not from how much a component has already aged. Consequently, the failure-rate rise typically associated with accumulated wear is not reflected in the calculated CDF.
- **Infant mortality.** Early-life failure rates from latent manufacturing defects ($\beta < 1$) are likewise outside scope; PSRM targets converters that have passed initial screening and are operating in the random-failure phase.

In practice, the CDF is best used as a **condition-weighted, comparative stress indicator**. For example, tracking one converter against a fleet or against qualification bounds (Section 3.1) rather than as a standalone remaining-useful-life prediction. Combining it with wear-out analysis gives the most complete lifetime picture.

2.5.2 Stressors not covered

PSRM does not model discrete failure mechanisms in the classical sense, and it does not simulate the physical degradation process behind a specific failure mode. Instead, λ reflects how sustained thermal and electrical operating stress elevates a component's random failure rate relative to a reference condition, following the parts-count approach (Section 2.2). Consequently, specific stress conditions associated with distinct failure mechanisms are not individually resolved in the calculation of λ. The following mechanisms are notable examples:

Table 6 List of stressors not reflected in reliability calculations

Failure mode	Description	Effect
Instantaneous overstress (SOA exceedance / EOS)	Transient excursions beyond the safe operating area or absolute maximum ratings.	Controller protection (OVP/OCP/OTP) should mitigate the wear effect of those events.
Electrostatic discharge (ESD)	Latent damage from an ESD event.	Mitigated at hardware design level via standard ESD protection; not operating-condition-driven.
Thermomechanical fatigue	Thermomechanical fatigue on bond wires or solder joints from repeated temperature and power cycling.	Thermal and power cycling are not reflected in current calculation but could be added[1].
Mechanical stress	Vibration, shock, connector fretting.	Requires accelerometer/mechanical sensor input not available on the controller.
Humidity and corrosion	Long-term degradation from moisture ingress.	Requires a humidity sensor not available on the controller.

2.5.3 Series reliability model

PSRM assumes a **series reliability network**: a single component failure causes its unit to fail, and a single unit failure causes the entire converter to fail. Redundant topologies (active parallel operation, N+1 power stages) are not represented. For multi-phase or redundant designs, the system λ will be conservatively high because the model does not reduce the effective failure rate for redundant paths. Unit-level CDF parameters should be used for unit-level comparisons in such designs.

2.5.4 Telemetry mapping approximations

All components within a unit share the same telemetry stress vector for voltage, current, power, and temperature. This is a necessary simplification, since only a limited number of telemetry measurement points are available on the controller and individual per-component sensing is not practical. Two related approximations follow from this:

[1] PSRM's existing unit/component and telemetry structure provides a reusable foundation for a dedicated thermal/power cycling fatigue model; reach out to your Infineon contact if this is required by your design

- **Position-dependent stress**: Components within a unit that are physically distant from a measurement point or exposed to a different local current/voltage path, are assigned the same stress vector as the rest of the unit. This introduces an error proportional to the electrical or thermal gradient across the unit.
- **Component rating vs. unit rating:** A component's own rated voltage/current/power may differ from the maximum electrical rating assigned to its unit (Section 4). Since the stress ratio S_x is calculated against the unit rating, not the individual component rating, a component with a lower or higher rating than its unit will have its stress ratio over- or under-estimated accordingly.

As λ and CDF are primarily used as **relative, comparative parameters** (Section 3.1 to Section 3.4), the resulting error is systematic across the fleet. Since every converter of a given design shares the same unit definitions and mappings and has limited impact on relative comparisons.

2.5.5 Accuracy and measurement error

The accuracy of λ and CDF depends on two factors; the accuracy of the underlying telemetry (voltage, current, temperature), and how telemetry errors propagate through the reliability model. Two complementary approaches are used to characterize this:

- Bench characterization on physical hardware
- A telemetry error-propagation simulation

Bench characterization: measures real, not assumed, accuracy — its main limitation is that testing a large enough sample size to establish a realistic error distribution is difficult.

Error-propagation simulation (Monte Carlo): Each telemetry channel's error is modeled from its known accuracy distribution — ADC accuracy and maximum resolution, ADC non-linearities, bias current- and sense network tolerances — and propagated through the full reliability calculation across a representative stress grid of load current and temperature. The strength is that a very holistic error analysis can be made but the error estimation could be very conservative.

Verifying the accuracy: Use bench measurements to characterize telemetry errors over the relevant operating range and define realistic error distributions. Apply these distributions in a Monte Carlo simulation of the complete PSRM calculation and then compare simulated and measured outputs at matching operating points. Deviations can reveal missing effects or telemetry channels requiring further characterization.

The combined approach provides both realism and coverage: bench measurements anchor the analysis in the actual converter and telemetry implementation, while the Monte Carlo simulation extends the assessment to operating points, tolerance combinations, and device populations that are impractical to test exhaustively. The results should be used to quantify the expected uncertainty of FIT and CDF values, determine the dominant error contributors, and assess whether the accuracy is sufficient for the intended comparative use case.

Reach out to your Infineon contact to learn more about the details of this approach.

2.5.6 Model validation

The component failure rate parameters ($\lambda_{base}, E_a, A, B$) are derived from established reliability handbooks (Telcordia SR-332, MIL-HDBK-217F) and component vendor FIT reports, providing an industry-standard foundation for the reliability model.

Validation against field failure data from deployed Infineon converters has not yet been performed and is planned as part of the productization roadmap, alongside continued model calibration against field and lifetime test data.

Power system reliability patch

This does not preclude deployment ahead of full field validation. PSRM is based on standard or vendor-supplied FIT rates, it is not intended to predict concrete, absolute failure events in which highest accuracy is required, but rather to provide a relative, condition-weighted comparison of stress across the population — a comparison that remains meaningful as long as the model is rolled out consistently across all units.

Deploying PSRM early also creates a direct benefit: collecting the system-specific failure statistics at an early stage enables fine-tuning and calibrating the model against your own fleet's operating and failure history — i.e. the specific population of converters deployed in your infrastructure.

This fleet-specific calibration can produce a more accurate validation than reliance on Infineon's validation alone, since it reflects the actual field conditions, usage patterns, and component population of your deployment.

If you would like to learn more about ongoing model validation efforts, contact your Infineon Account Manager.

3 Use cases derived from the reliability parameters

The five use cases introduced in Section 1 all derive from the same two primary PSRM outputs: the current failure rate λ and the accumulated failure probability CDF. Each case maps these parameters to a specific operational decision at the application controller or infrastructure management layer. It is important to note that the applications are best implemented on the infrastructure level as information about fleet is required.

3.1 Definition of Fleet

A **fleet** is the population of same-design, converters deployed across a customer's infrastructure. For example, all DC-DC converters of a given design are installed across a datacenter or telecom site. Because every unit in a fleet shares the same reliability model, unit definitions, and mappings, their λ and CDF values are directly comparable to one another, which is what makes the fleet-level comparison described in this section meaningful.

Table 7 Applications derived from PSRM output parameters

Use case	Required infrastructure	Primary PSRM output used	NOTES
Threshold comparison	BMC	**CDF** **operating time**	Requires qualification bounds
Health score	BMC Fleet database		Thresholds require calibration
Fleet comparison	Fleet database		Needs comparable model/configuration
Load balancing	Control layer Fleet database	**Unit FIT/CDF**	Requires capabilites for xPU computational job distirbution
Wear-out support	Fleet analytics	**CDF + failure tags**	Not direct RUL prediction

3.2 Comparison against reliability thresholds

The most direct use of PSRM is benchmarking a converter's in-field accumulated failure probability against bounds established during qualification testing. To establish these bounds, PSRM is run during the qualification test campaign under at least two stress scenarios: one representing nominal operating conditions and one representing worst-case conditions as defined by the qualification team. For each scenario, the CDF accumulation rate over the test duration is recorded and extrapolated to the intended system lifetime, producing two bounding curves.

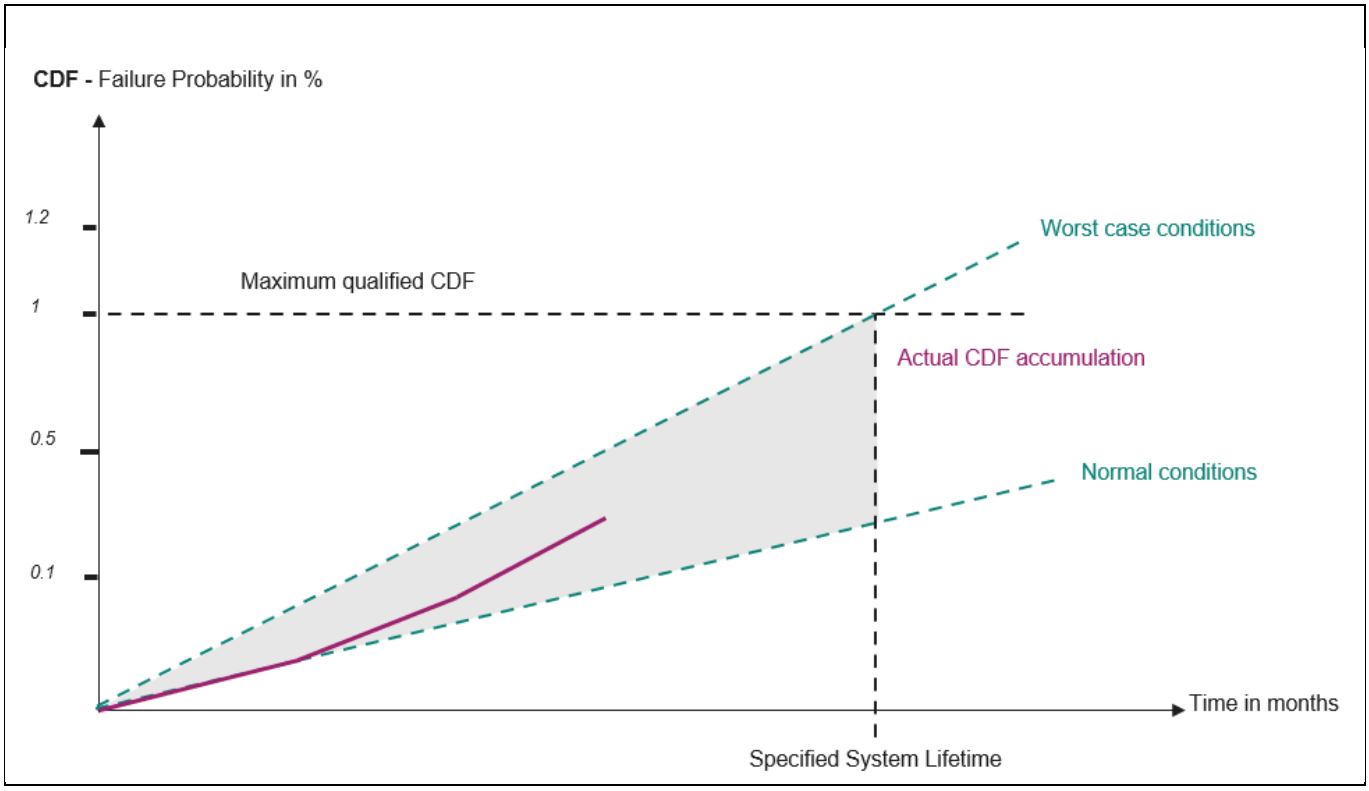


Figure 7 View of PSRM CDF accumulation in relationship to probability thresholds

The worst-case and nominal qualification curves establish an operating envelope, as illustrated above. The X-axis displays operating time, and the Y-axis displays failure probability. In the field, the BMC reads the CDF and operating time from the converter at regular intervals using custom PMBus commands (e.g. `MFR_RELIABILITY_CALC`) and tracks the converter's CDF trajectory against this envelope.

A converter whose trajectory approaches or exceeds the worst-case bound is experiencing operating conditions more stressful than the qualification worst-case. A converter tracking below the nominal bound is operating well within expectations.

This use case requires no additional infrastructure beyond the power controller and the BMC, making it the baseline use case for any PSRM deployment.

3.2.1 Defining the upper and lower bound

Three methods are available to establish the bounding curves, suitable for different stages of the product lifecycle.

Table 8 Methods to determine the threshold

Method	When to use	Characteristics
Qualification bench measurement	Hardware available	• Most accurate captures design-specific effects
Offline calculation with digital twin	Pre-qualification	• Conservative • Produces linear bounds

Use cases derived from the reliability parameters

Method	When to use	Characteristics
	Profile-governed applications	• Scenario-tied • hardware-revision independent
Empirical fleet percentile	Mature deployment (>= ~100 units)	• Data-driven • self-updating • detects systemic shifts

The preferred approach is to activate PSRM on the qualification test bench and log the CDF trajectory directly for each stress scenario. This method requires no additional computation: the bound is produced by the same component model and telemetry path used in the field, so design-specific effects such as component placement, thermal resistance, and measurement offsets are automatically included.

Before qualification hardware is available, an offline calculation can substitute. Feeding the maximum rated telemetry values into the PSRM digital twin produces a conservative worst-case CDF accumulation rate; integrating this at a constant rate over the intended service life gives an upper bound. For applications with known mission profiles a normative mission profile can instead be replayed through the PSRM digital twin to produce a bound tied to a specific operating scenario rather than to hardware revision.

Once enough converters have been deployed, a third approach becomes available; deriving the bound empirically from the fleet database. The BMC collects CDF and operating time from all systems at regular intervals. A high percentile of the resulting CDF distribution, typically the 95th or 99th, defines a data-driven worst-case bound that self-updates as the fleet grows.

This method captures real-world variability such as airflow and workload that controlled qualification tests cannot fully replicate and is particularly effective for detecting systematic shifts in fleet stress level such as a cooling degradation event.

Note: *Regardless of which method is used, the bounds must be generated with the exact same reliability model, the same component database and unit type configurationas the firmware loaded on the field device. Any model update requires the bounds to be recomputed.*

3.3 Health status derived from converter reliability

The CDF value provides a dimensionless, condition-aware measure of a converter's accumulated failure probability. Unlike a simple operating-hour counter, the CDF accounts for the actual severity of the experienced operating conditions: a converter that has operated at high temperature and load accumulates a higher CDF than one that has operated at low stress for the same duration.

A health score can be derived by normalizing the converter's current CDF against the worst-case qualification bound at the **same operating time**, established using the method described in the qualification comparison use case above:

$$\text{Health score} = 1 - \frac{CDF_{\text{field}}}{CDF_{\text{worst-case qual}}|_{t\,=\,t_{\text{op}}}}$$

Equation 4 Health status calculation

A health score approaching zero indicates that the converter's accumulated stress has reached the level observed at the end of worst-case qualification testing. Tiered thresholds based on this score can drive maintenance workflows.

Use cases derived from the reliability parameters

Table 9 Qualitative examples for health status thresholds

Healthscore thresholds	Recommended action
> 0.5	Normal operation; no action required
0.2 – 0.5	Schedule inspection at next maintenance window
0.05 – 0.2	Flag for priority maintenance; review operating environment
< 0.05	Initiate planned replacement before next extended operating period

These thresholds are indicative and should be calibrated to the specific reliability requirements, maintenance cost model, and redundancy configuration of the target application.

3.4 Comparison against fleet reliability

In datacenter or telecommunication applications, where multiple identical converters operate in the same infrastructure, PSRM enables cross-converter comparison without relying on external sensors or assumptions about operating conditions.

The application controller periodically reads CDF and operating time from each converter using the custom PMBus® commands (e.g. `MFR_RELIABILITY_CALC`). Since operating time may differ between converters due to maintenance events or a stepwise roll out of the infrastructure, the relevant comparison metric is the average lambda λ_{avg}:

$$\lambda_{avg} = \frac{-\ln(1-CDF_t)}{t}$$

Equation 5 Calculating λ_{avg} based on CDF and operating time

A converter accumulating CDF significantly faster than the fleet average is experiencing elevated stress relative to its peers. Root causes may include:

- **Elevated thermal environment**: Insufficient airflow, proximity to a heat source, or a failed cooling fan
- **Higher average load**: Uneven distribution of computational workload across servers

Early detection of fleet outliers enables targeted preventive maintenance rather than reactive replacement after failure.

3.5 Load balancing based on reliability

For multi-phase voltage regulation modules (VRMs) and redundant power supply configurations, PSRM provides per-phase reliability data that can directly inform load balancing decisions.

A common source of imbalance arises between separate rails on the same converter. Since computational workload is rarely distributed evenly across cores, the rail supplying a heavily loaded core draws more current, and therefore accumulates CDF faster, than the rail supplying an idle or lightly loaded core. Rail-to-rail differences in accumulated CDF can be read synchronously using PSRM_CMD_LOOP_CDF (Subcode: 0x02).

If one rail's CDF diverges significantly from the others, workload can be redirected away from the associated core to prevent that rail from reaching its reliability limit prematurely.

Use cases derived from the reliability parameters

Note: PSRM itself does not perform load balancing. The XDP™ controller only measures and reports the per-phase/per-rail reliability data; the balancing decision and its execution must be implemented by an external control layer (e.g. the BMC, host OS/hypervisor, or datacenter orchestration software).

At the data center level, the same principle applies to server-level workload steering: computational loads can be directed toward servers whose DC/DC stages show lower CDF accumulation rates, distributing wear evenly across the installed base.

3.6 Supporting wear-out analysis

PSRM is confined to the random failure region of the bathtub curve and cannot perform wear-out prediction on its own (see Section 2.5). However, the CDF and λ parameters it already exposes via PMBus® can support wear-out analysis in two complementary ways.

3.6.1 Correlating CDF with field failure events

The CDF is a condition-weighted accumulator: it grows faster under high stress and slower under low stress. This means that at the moment a component failure occurs in the field, the CDF value of the corresponding unit is a proxy for the accumulated stress that unit has experienced up to that point. If failure events — tagged by component type and unit — are recorded alongside the CDF and operating time at the time of failure, an empirical picture emerges over the fleet: electrolytic capacitors in each design may consistently fail at CDF values in a narrow band, while MOSFETs exhibit a different pattern. Once sufficient failure statistics have been collected, these empirical CDF thresholds become condition-aware early-warning levels for that specific failure mode — a data-driven complement to the analytical model.

Prerequisite to this approach is a statistically useful failure dataset from a sufficiently large, deployed fleet and consistent failure attribution. For small fleets or designs with low absolute failure rates, the sample size may be insufficient to establish reliable CDF thresholds within a practical timeframe.

3.6.2 PSRM as the foundation for component-specific wear model extensions

The unit and component structure that PSRM already establishes, each component assigned to a unit with a defined stress vector (S_V, S_I, S_P, T) is the same structure that a wear-out extension would require. Adding component-specific wear models to the PSRM framework therefore does not require new data architecture: it means adding a new calculation alongside the existing λ_{comp} computation, consuming the same compressed telemetry values that PSRM already produces. The component database, unit grouping, and telemetry mapping that Infineon configures as part of the PSRM deployment are directly reusable inputs for a wear model. This makes PSRM a natural integration point for future lifetime estimation capability, and reduces the incremental effort of adding wear-out tracking to a system that already has PSRM deployed

4 Configuration of a design-specific reliability model

One of the fundamental benefits of PSRM is that it can be applied to existing designs and all topologies; however, it must be configured based on the components used in the system. In this section, an example is given on how a reliability model is configured for the PSRM patch. As an example configuration, a 600 W Full Bridge – Full Bridge (FBFB) evaluation board for XDPP1100 is used. For more information, see [2].

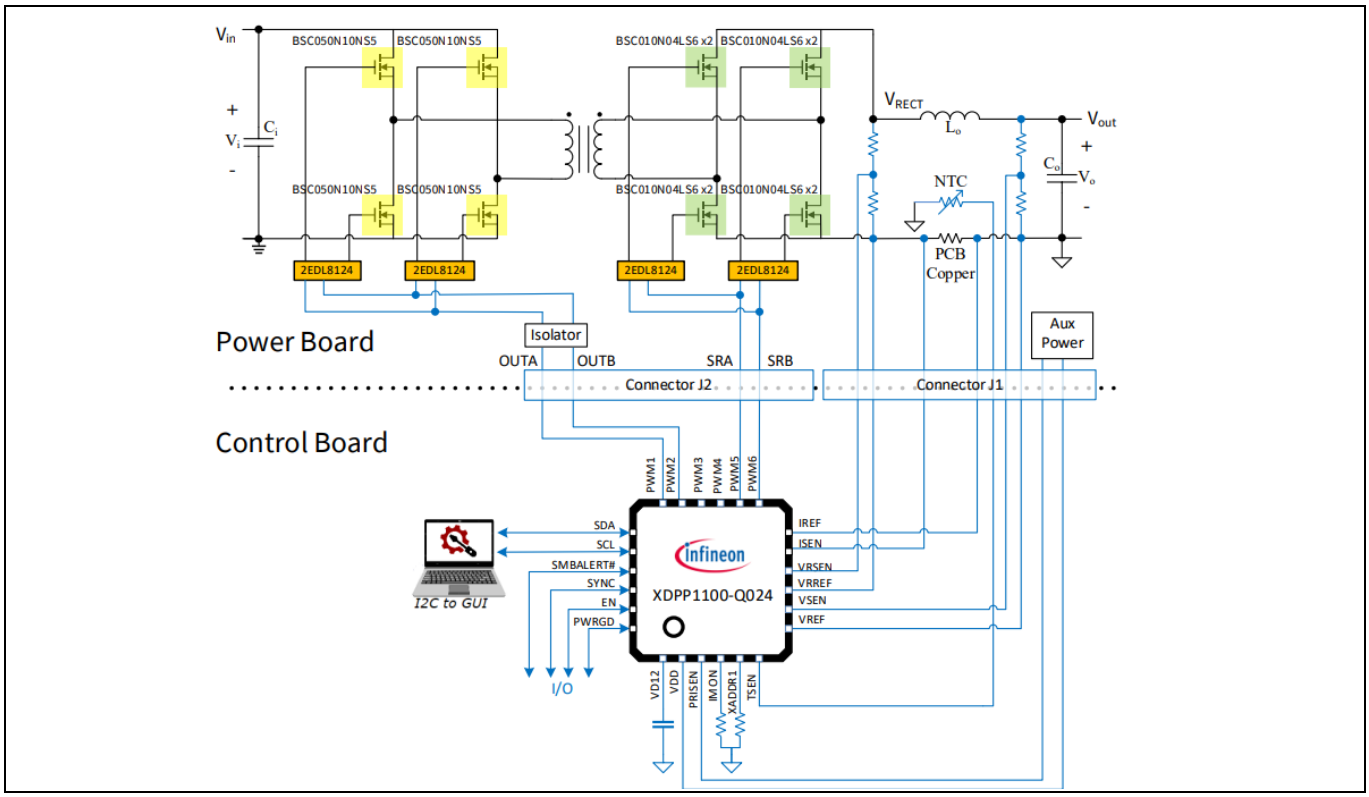


Figure 8 Diagram of 600W FBFB reference board

This example demonstrates how a model can be configured. The same methodology applies to other designs. Contact your Infineon Account Manager to obtain access to and support for the model configurator.

To configure the model, the following steps are required:

1. Cluster your design in units (see Figure 9)
2. Map the components to your units (see Figure 10/Figure 11)
3. Specify the maximum electrical ratings of your system or your units (see Figure 12)
4. Select the applicable pre-defined unit type and map them to unit (see Figure 12)

By analyzing the schematic and PCB of the evaluation board, the following sub-circuits can be identified for the 600 W FBFB evaluation board: an auxiliary power supply, an input filter, a full-bridge on the primary side, a full-bridge on the secondary side, and an output filter for smoothing the output voltage. The available telemetry for the system comprises the output voltage, the rectification voltage, the output current via the PCB Cu shunt, the output stage temperature, and the XDPP1100 internal temperature. These telemetry parameters and register contents are used to derive the input current and input voltage. A more detailed description can be found in the application note for the evaluation board.

Configuration of a design-specific reliability model

As a first step, the system is clustered into units. A **unit** groups components that can be approximated by the same electrical and thermal telemetry/parameters. For the evaluation board described above, the derived units are:

- Input Stage: Groups the components that form the IBC input filter and are exposed to the input voltage and input current
- Primary Side: Groups the components that form the power train on the primary side of the FBFB topology
- Secondary Side: Groups the components that form the power train on the secondary side of the FBFB topology
- Output Stage: Groups the components that form the IBC output filter and are exposed to the output voltage and output current
- Ambient Devices: Groups of components that are not part of the regular power train
- Auxiliary Stage: Groups components that form the 3.3 V and 15 V supply voltages at power-up

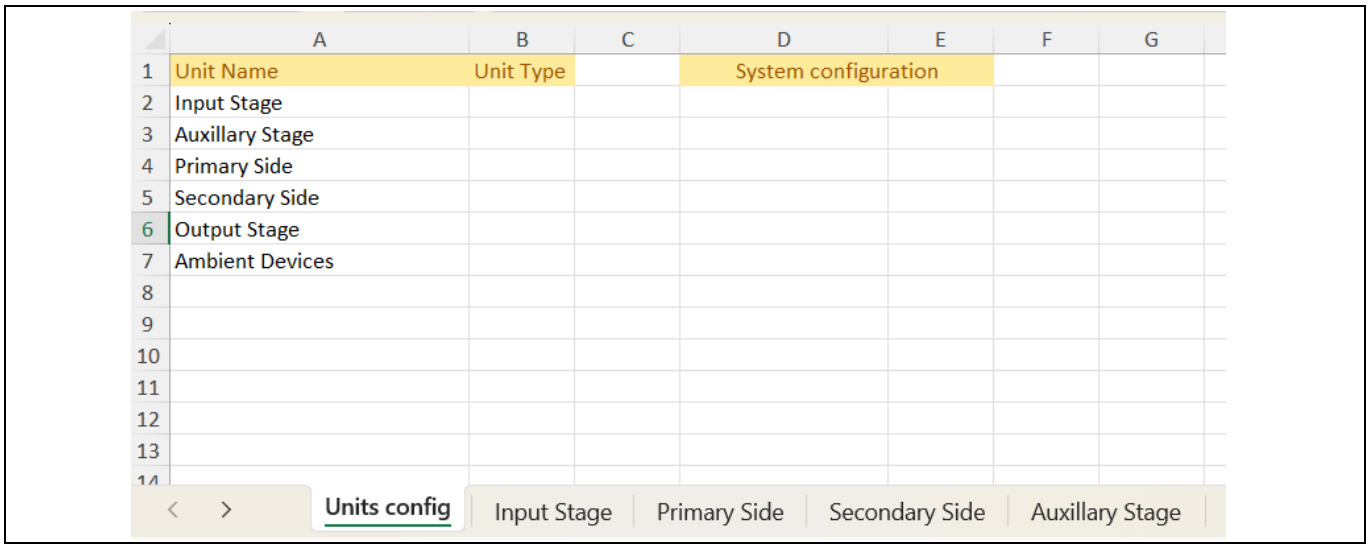


Figure 9 Defining the different units in the Excel-based Design Configurator

In the second step the components must be mapped to the units. This is typically done using the Bill of Materials, distributing components among the units. The "Input Stage" unit of the evaluation board is used as an example below.

Configuration of a design-specific reliability model

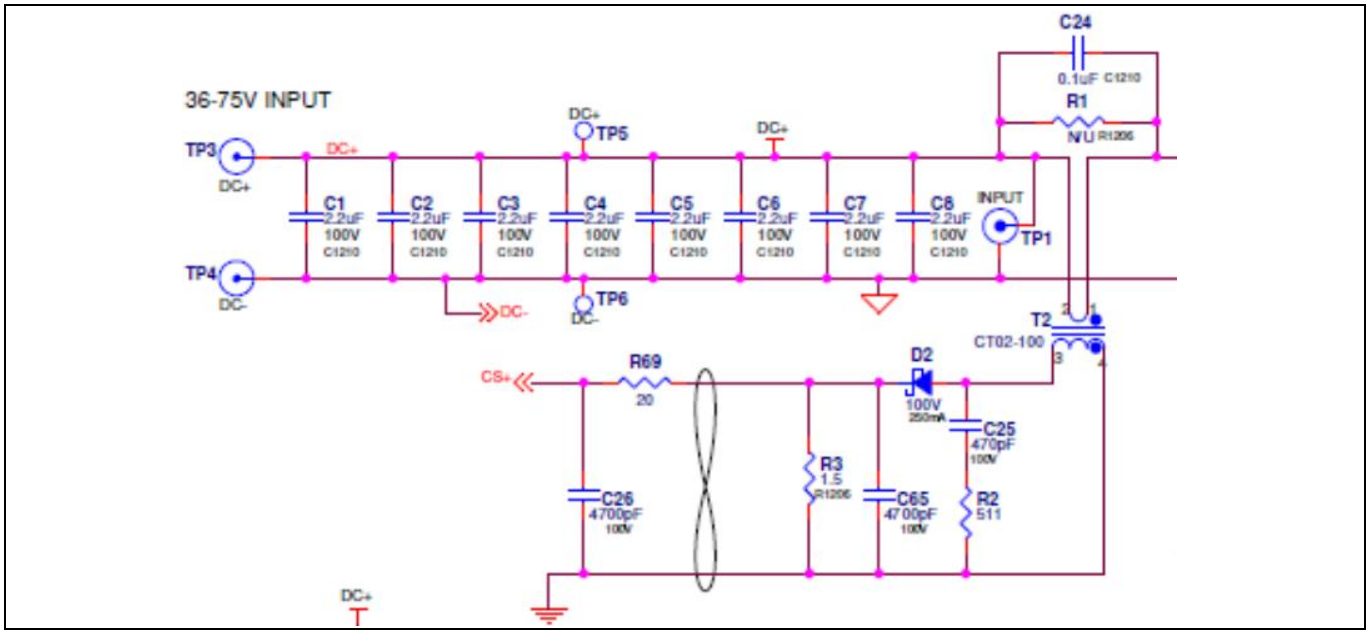


Figure 10 Schematic of the input filter stage of the 600W FBFB evaluation board

The schematic shows that the evaluation board includes a variety of ceramic capacitors, and an input current measurement circuit.

To simplify model configuration, the component category can be selected from a drop-down menu offering a wide range of component types. If required component types are not already present in the catalogue, they can be added upon request.

Unit Type	Input	Quality Level	II			II		
Category	Sub-category	Quantity	Quality Level	Device Complexity or Chip Complexity	Units of Complexity		Mean Failure Rate	Std. Dev.
Capacitor	Fixed, Ceramic	8	II			Capacitor, Fixed, Ceramic	0,1	0,01
Capacitor	Fixed, Ceramic	1	II			Capacitor, Fixed, Ceramic	0,1	0,01
Capacitor	Fixed, Ceramic	1	II			Capacitor, Fixed, Ceramic	0,1	0,01
Capacitor	Fixed, Aluminum, Electrolytic, Fixed, <	2	II			Capacitor, Fixed, Aluminum,	0,73	0,17
Capacitor	Fixed, Ceramic	1	II			Capacitor, Fixed, Ceramic	0,1	0,01
Diode	Silicon, General Purpose, <= 20 AMP	1	II			Diode, Silicon, General Purp	0,33	0,23
Resistor	Fixed, Film (Carbon, Oxide, Metal), <=	1	II			Resistor, Fixed, Film (Carbon	0,08	0,02
Resistor	Fixed, Film (Carbon, Oxide, Metal), <=	1	II			Resistor, Fixed, Film (Carbon	0,08	0,02
Inductor	Transformer, Pulse Low Level	1	II			Inductor, Transformer, Pulse	3	0,9

Figure 11 Excel based Design Configurator for the unit “Input Filter”

Each distinct component occupies one row in the Excel sheet. For identical components, a quantity parameter can be specified. If parameters from the reliability handbooks such as Telcordia SR-332 or MIL-HDBK-217F are to be used, additional information such as the quality level or device complexity must be provided. In those cases, the mean failure rate from the relevant standard is populated automatically. If the component vendor provides FIT data in their datasheet or reliability report, the component FIT rate can be entered directly into the sheet.

This procedure must be repeated for all the different units of your design. Currently, this configurator is only accessible via direct support by Infineon. If you are interested in building a reliability model for your system, contact your Infineon Account Manager.

Configuration of a design-specific reliability model

As a third step, the maximum rated values must be specified. The maximum ratings can be specified either at the unit level or at the system level. If the stress within a system can be asymmetric. For example, in multi-phase or redundant designs, it is advisable to specify unit-based maximum ratings and map them to unit-specific telemetry, e.g. phase current. The calculated reliability parameters can be accessed on unit and system level – not on component level. In the context of this 600W FBFB, this is not the case, and therefore the system-level electrical ratings are used.

Table 10 Rating for 600W FBFB evaluation board

$V_{in(max)}$ [V]	$I_{in(max)}$ [A]	$P_{in(max)}$ [W]	$V_{out(max)}$ [V]	$I_{out(max)}$ [A]	$P_{out(max)}$ [W]
75	16	600	12	50	600

As a fourth step the unit types must be mapped to the units. A **Unit Type** defines a load vector that is applied to the components of the respective unit and its maximum ratings. Since the components of one unit are approximated by the same stress parameters, common current, voltage, power, and temperature stress parameters —S_I, S_V, S_P, T — can be used. In the evaluation board example, the input/output current, input/output voltage, as well as the temperature measured at the hotspot and on the XDPP1100 itself, are used.

$$S_V = \left(\frac{V_{out}}{V_{ratedOutputVoltage}}\right), S_I = \left(\frac{I_{out}}{I_{ratedOutputCurrent}}\right), S_P = \left(\frac{P_{out}}{P_{ratedOutputPower}}\right), T_{hotspot}$$

Equation 6 Unit Type: Output

$$S_V = \left(\frac{V_{in}}{V_{ratedInVoltage}}\right), S_I = \left(\frac{I_{in}}{I_{ratedInCurrent}}\right), S_P = \left(\frac{P_{in}}{P_{ratedInPower}}\right), T_{hotspot}$$

Equation 7 Unit Type: Input

$$T_{CtrlDie}$$

Equation 8 Unit Type: Ambient

The unit types listed above are pre-defined in the current version of the PSRM feature. Various additional unit types can be added by Infineon based on your system requirements.

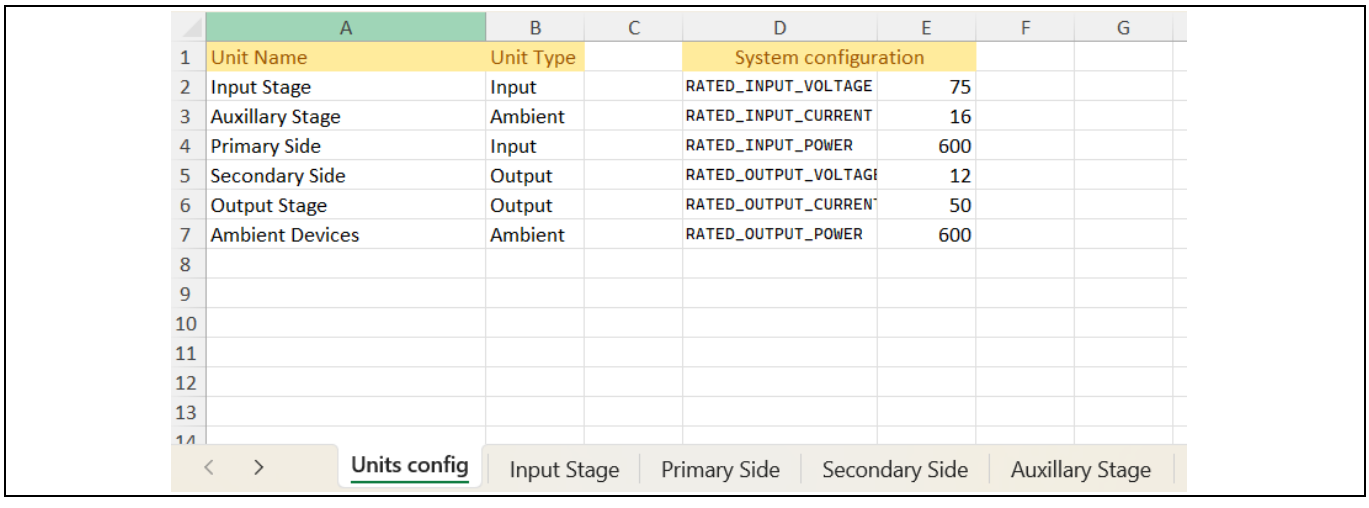


Figure 12 Unit <--> Unit Type mapping within Excel-based Design Configurator

Configuration of a design-specific reliability model

The next step is mapping the units to the unit types. The Excel-based Design Configurator provides a convenient way to specify this mapping, allowing you to assign existing unit types to units via a drop-down menu.

5 PSRM PMBus® commands description

Once PSRM is configured and you receive your customized FW patch or pre-flashed controller, the output parameters can be accessed via PMBus®.

As stated in Section 2.3, reliability information can be read out at two levels: the system level and the unit level. As for the unit-level granularity, significantly more data can be read out via PMBus®. Therefore, the protocol was adjusted, and the BMC integration will be slightly different.

To interact with both versions, two sets of operation code are implemented, as described in the high-level table below:

Table 11 PSRM PMBus® overview

System-level reliability information		
0xB2	MFR_RELIABILITY_CALC	Read the reliability parameters of the whole system
0xB6	MFR_CDF_TIME_VALUE	Set time and CDF information after power cycle
Unit-level reliability information		
0xE7	MFR_CMD_AND_UNIT_SEL_PARAM	Selection of the unit and the subcode to define the type of data of next 0xEF
0xEF	MFR_READ_WRITE_REL_PARAM	0x01: Read unit reliability parameters 0x02: Read synchronized Unit CDF value or write CDF/time values after power cycle 0x03: Read synchronized Unit FIT value

In the following sections, the BMC control flow and the explicit PMBus® commands are explained.

5.1 System-level reliability readout

The BMC-side integration for the system-level granularity requires two scenarios to be handled: First deployment and warm restart after a power cycle, followed by periodic readout. All interactions use two commands: 0xB2 for reading and 0xB6 for the optional CDF restore. The diagram below shows the required BMC-side sequence.

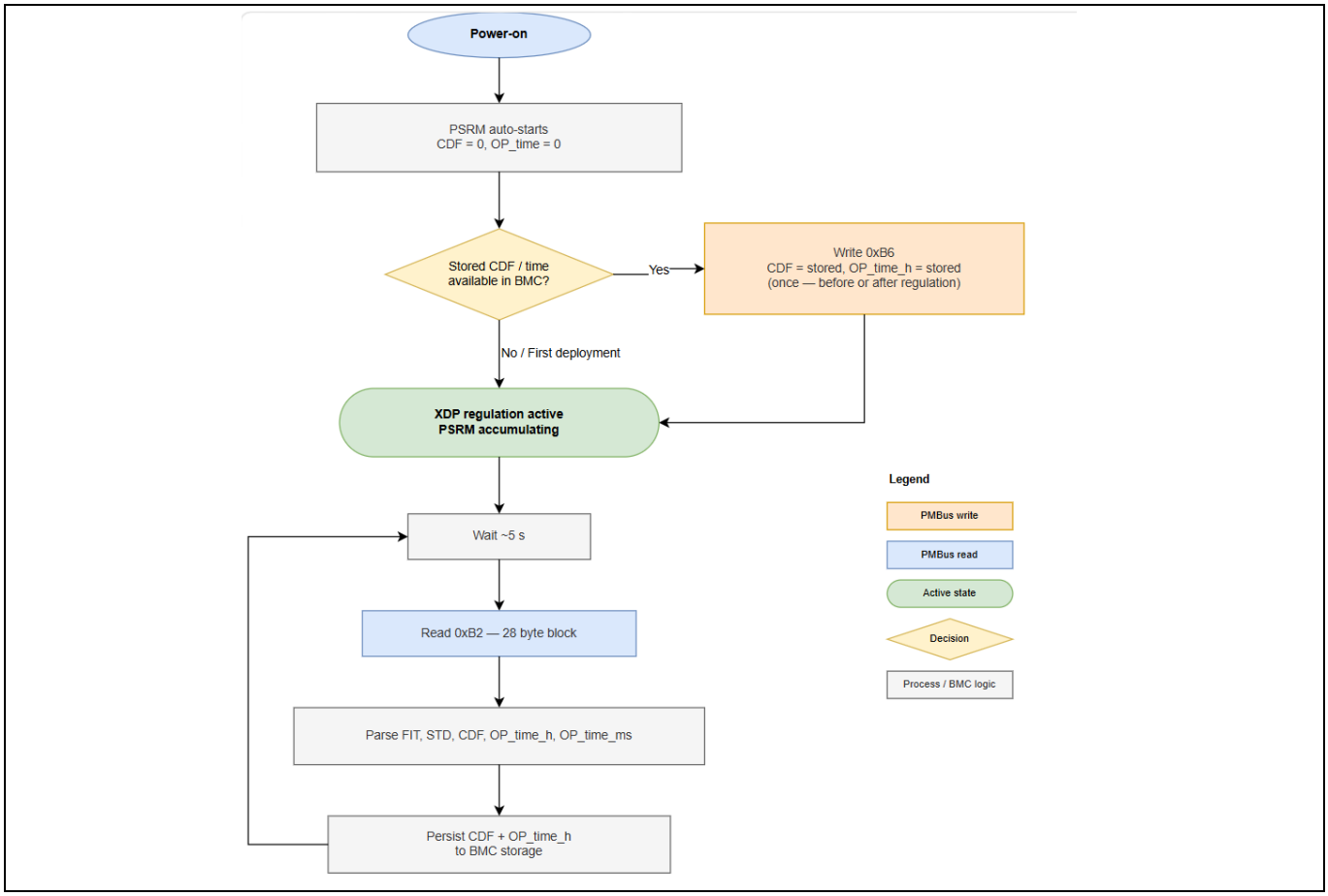


Figure 13 BMC flow to interact with PSRM with system level granularity

Integration notes:

- On first deployment, no BMC action is needed at startup. PSRM initializes CDF and operating time to zero automatically
- After a power cycle, write 0xB6 once to restore the previously stored CDF and OP_time_h. This write is accepted before the XDP™ controller enters regulation state, as well as after PSRM has started running. Subsequent writes of 0xB6 are rejected by the firmware via NACK on the PMBus®
- Persist CDF and OP_time_h to BMC non-volatile storage after every successful 0xB2 read so that the values are available for the next warm restart.

5.1.1 MFR_RELIABILITY_CALC (OP_code: 0xB2)

Table 12 MFR_RELIABILITY_CALC data format

Byte Nr	Byte Name	Operation	Description
[27:24]	Reserved	-	Not used
[23:20]	FIT	R	Failure rate of the last time interval of the selected Unit
[19:16]	STD	R	Standard deviation of FIT parameter of last

Byte Nr	Byte Name	Operation	Description
			time interval of the selected Unit
[15:12]	CDF	R	Accumulated failure probability based on experienced operating conditions [%]
[11:8]	OP_time_ms	R	Operational time in milliseconds.
[7:4]	OP_time_h	R	Operational time in hours.

5.1.2 MFR_CDF_TIME_VALUE (OP_code: 0xB6)

Table 13 MFR_CDF_TIME_VALUE data format

Byte Nr	Byte Name	Operation	Description
[7:4]	CDF	W/R	Last stored CDF value from the BMC
[3:0]	OP_time_h	W/R	Operating time in hours

5.2 Unit-level reliability readout

The unit-level granularity exposes individual failure rate and CDF values per unit. All interactions require a two-step transaction; first write 0xE7 to select the target unit and subcode, then read or write 0xEF to transfer the data. Subcode 0x01 reads the full parameter set for one unit; subcodes 0x02 and 0x03 read synchronized bulk CDF or FIT snapshots across multiple units in a single transaction. The diagram below shows the required BMC-side sequence.

PSRM PMBus® commands description

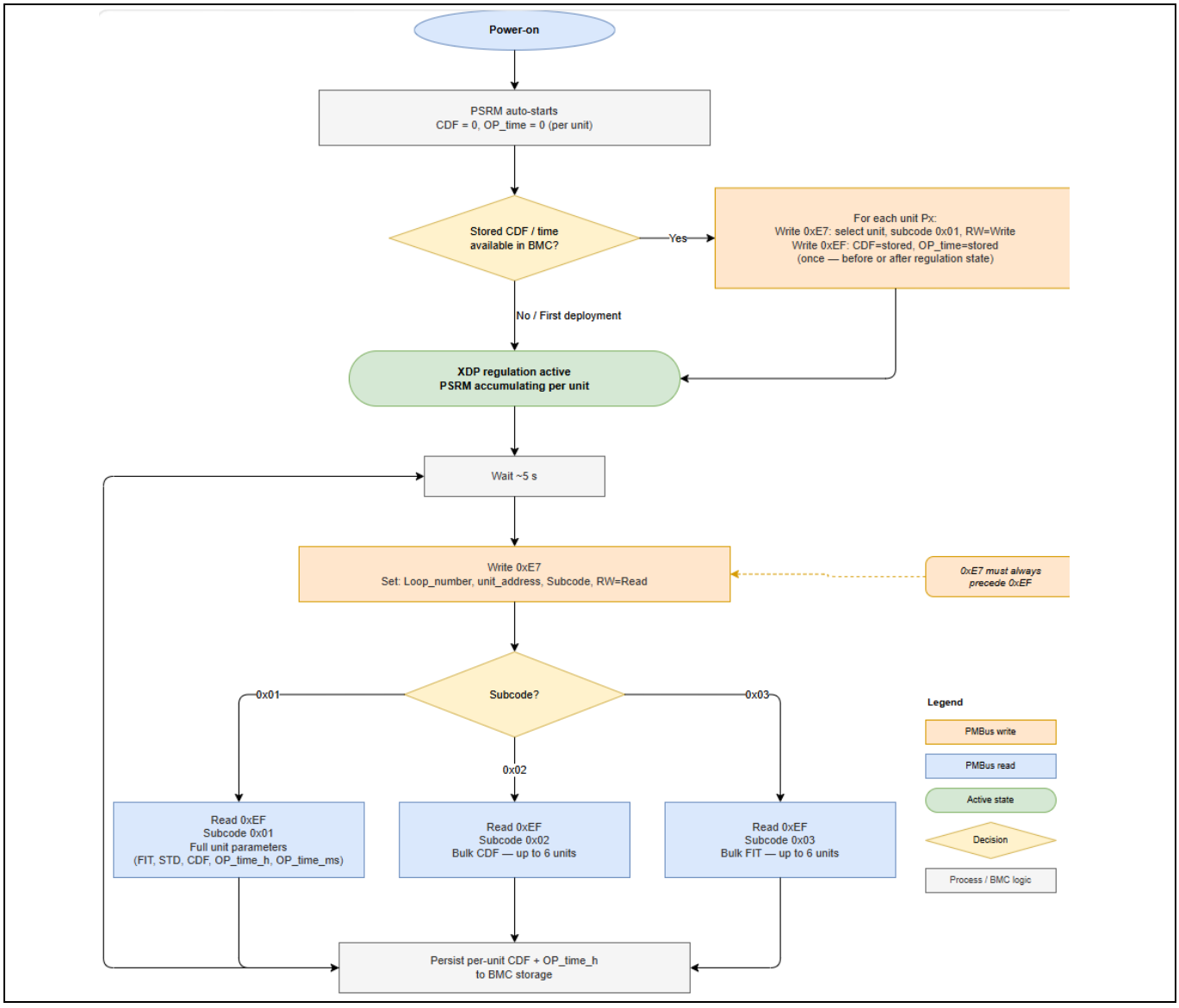


Figure 14 BMC flow to interact with PSRM with system level granularity

Integration notes:

- On first deployment, no BMC action is needed at startup — PSRM initializes all unit CDF values and operating time to zero automatically
- After a power cycle, restore each unit individually: write 0xE7 (select unit x, subcode 0x01, RW=Write) followed by 0xEF with the stored CDF and op_time. This sequence is accepted before or after the XDP enters regulation state. System operating time must be restored using Unit address 0x00
- In the periodic readout loop, **0xE7 must always precede 0xEF**. 0xE7 selects which unit and which subcode the following 0xEF transaction applies to
- **Inter-unit reads with subcode 0x01 do not need to be synchronous.** Use subcodes 0x02 or 0x03 only when a simultaneous unit snapshot is required — for example, for the load-balancing use case in Section 3.4
- **Maximum 6 units per bulk read.** If a loop has more than 6 units, issue consecutive reads with incremented Start_Unit values
- **LoopA and LoopB require separate transactions.** The 31-byte PMBus® block-read limit prevents reading both loops in a single 0xEF operation

- The mapping between units addresses and design-specific unit names is provided by Infineon as part of the firmware patch delivery documentation

Table 14 Unit decoding

Unit address	Unit name
0x00	System Reliability Parameter
0x01	Input Stage
0x02	Auxiliary Stage
0x03	Primary Side
0x04	Secondary Side
0x05	Output Stage
0x06	Ambient Devices

5.2.1 MFR_CMD_AND_UNIT_SEL_PARAM (OP_code: 0xE7)

Write operation:

PSRM_CMD_UNIT_REL (0x01):

```
// Example: select unit 1 of LoopA for a full-parameter read
write_0xE7(
    PSRM_CMD_ID = 0x01,     // subcode: PSRM_CMD_UNIT_REL
    RW_operation = 1,       // 1 = read, 0 = write
    Loop_number = 0x00,     // LoopA
    unit_address = 0x01,    // Unit 1 (see Table 5 for all addresses)
    Reserved = 0x00
)
// Immediately follow with 0xEF to execute the selected operation (see Table 4)
```

Figure 15 Psuedocode for configuring MFR_CMD_UNIT_SEL_PRAM

Table 15 PSRM_CMD_UNIT_REL data format

Byte Nr	Byte name	Description
[4]	Reserved	Not used.
[3]	unit_address	Unit address defined in PSRM_CMD_UNIT_REL description.
[2]	Loop_number	Loop number.
[1]	RW_operation	Flag to indicate whether Read or Write operation is going to happen. 0 - Write 1 - Read
[0]	PSRM_CMD_ID	Subcode of the next PSRM PMBus® command to indicate

Byte Nr	Byte name	Description
		which operation is going to happen.
[4]	Reserved	Not used.

```
// Example: select Units 1-3 of LoopA for a bulk CDF read
write_0xE7(
    PSRM_CMD_ID = 0x02,           // subcode: PSRM_CMD_LOOP_CDF,
                                  // subcode: 0x03 for PSRM_CMD_LOOP_FIT
    RW_operation = 1,             // 1 = read, 0 = write
    Loop_number = 0x00,           // LoopA, 0x01 for LoopB
    Start_Unit_address = 0x01,    // start at Unit 1
    Number_of_Units = 3           // read 3 consecutive Units (max 6)
)
// Immediately follow with 0xEF to execute the selected operation (see Table 6 / Table 7)
```

Figure 16 Pseudocode for configuring MFR_CMD_AND_UNIT_SEL_PARAM for subcode 0x02 and 0x03

Table 16 PSRM_CMD_LOOP_CDF & PSRM_CMD_LOOP_FIT data format

Byte Nr	Byte name	Description
[4]	Number_of_Units	Number of Units to read/write. Maximum allowed is 6.
[3]	Start_Unit_address	Unit address of starting Unit to read/write from. 0x01 to max number of Units in LoopX. refer to PSRM_CMD_UNIT_REL operation description.
[2]	Loop_number	Loop number.
[1]	RW_operation	Flag to indicate whether Read or Write operation is going to happen. 0 - Write 1 - Read
[0]	PSRM_CMD_ID	Subcode for the next PSRM PMBus® command to indicate which operation is going to happen.

5.2.2 MFR_READ_WRITE_REL_PARAM (OP_code: 0xEF)

This command is used to read/write the reliability specific parameters. The definition varies based on the last subcode selected.

5.2.2.1 PSRM_CMD_UNIT_REL (Subcode: 0x01)

Reliability parameters:

Table 17 PSRM_CMD_UNIT_REL data format

Byte Nr	Byte name	Operation	Description
[27:20]	Reserved	-	Not used
[19:16]	FIT	R	Failure rate of the last time interval of the selected Unit
[15:12]	STD	R	Standard deviation of last time interval of the selected Unit
[11:8]	CDF	W/R	Accumulated failure probability based on experienced operating conditions [%]
[7:4]	OP_time_ms	W/R	Operational time in milliseconds.
[3:0]	OP_time_h	W/R	Operational time in hours.

```
write_0xE7(PSRM_CMD_ID=0x01, RW_operation=1, Loop_number=loop, unit_address=unit_addr);
response = read_0xEF();       // 28-byte block read (subcode 0x01)
fit = response[19:16];        // current failure rate [FIT]
std = response[15:12];        // standard deviation of FIT
cdf = response[11:8];         // accumulated failure probability
op_time_h = response[7:4];    // operating time (hours)
op_time_ms = response[3:0];   // operating time (milliseconds)
// Note: all fields within one unit are captured atomically.
```

Figure 17 Read – retrieve all reliability parameters for one unit

```
// Step 1: restore operating time ONCE via system address (unit_address=0x00)
write_0xE7(PSRM_CMD_ID=0x01, RW_operation=0, Loop_number=0x00, unit_address=0x00);
write_0xEF(CDF=0x00, OP_time_ms=stored_ms, OP_time_h=stored_h);

// Step 2: restore CDF per unit - repeat for every active unit address
for (unit_addr : {0x01, 0x02, ..., 0x06, 0x40, 0x41}) {
    write_0xE7(PSRM_CMD_ID=0x01, RW_operation=0, Loop_number=loop, unit_address=unit_addr);
    write_0xEF(CDF=stored_cdf[unit_addr], OP_time_ms=0, OP_time_h=0);
}
write_0xE7(PSRM_CMD_ID=0x01, RW_operation=0, Loop_number=0x00, unit_address=0x00);
write_0xEF(CDF=0, OP_time_ms=stored_optime_ms, OP_time_h=stored_optime_h);
```

Figure 18 Write operation – restore operating time and CDF after cold reset

Note: Operation times (ms, hrs) needs to initialize only once using the "System" (Unit address 0x00) as it is assumed that all the reliability parameters of all units are in sync.

5.2.2.2 PSRM_CMD_LOOP_CDF (Subcode: 0x02)

Command is needed if a synchronous comparison between the individual CDF parameters is needed. So, this command is used for "bulk" read/write.

Table 18 PSRM_CMD_LOOP_CDF data format

Byte Nr	Byte Name	Operation	Description
[27:4]	CDF	W/R	[27:24] → PVDD_loopX_PHs+5 [23:20] → PVDD_loopX_PHs+4 [19:16] → PVDD_loopX_PHs+3 [15:12] → PVDD_loopX_PHs+2 [11:8] → PVDD_loopX_PHs+1 [7:4] → PVDD_loopX_PHs
[3:0]	OP_time_ms	R	Operational time in milliseconds.

```
write_0xE7(PSRM_CMD_ID=0x02, RW_operation=1, Loop_number=loop, Start_Phase_address=start_phase, Number_of_phases=n);
response = read_0xEF();       // 28-byte block read (subcode 0x02)
op_time_ms = response[3:0];   // operating time (ms) at snapshot
cdf_PHs = response[7:4];      // CDF for Start_Phase (PHs)
cdf_PHs1 = response[11:8];    // CDF for Start_Phase + 1
cdf_PHs2 = response[15:12];   // CDF for Start_Phase + 2
// ... up to response[27:24] for Start_Phase + 5 (max Number_of_phases = 6)
// Unused phase slots are 0x0.
// LoopA and LoopB require separate calls (31-byte block-read limit).
```

Figure 19 Read – synchronous bulk CDF snapshot for up to 6 consecutive units:

As the block read limit of XDP is 31 bytes, a readout of both loops is not possible in a single operation. To read out both Loop parameters, the operation must be executed twice.

Usage:

- Send MFR_CMD_AND_UNIT_SEL_PARAM command before with PSRM_CMD_ID field with the subcode of PSRM_CMD_LOOP_CDF,
- RW_operation with "1" for read operation,
- loop_number,
- Start_Unit_address
- Number_of_Units

*Note: Maximum value of n is **6**; Unit selection must stay within the valid Unit range of the selected loop. If n < 6, unused MSB slots in the response are set to 0x0.*

```
write_0xE7(PSRM_CMD_ID=0x02, RW_operation=0, Loop_number=loop, Start_Phase_address=start_phase, Number_of_phases=n);
// Precondition: write_0xE7 already sent (see Table 3 above)
write_0xEF(CDF_PHs = stored_cdf[Start_Phase], CDF_PHs1 = stored_cdf[Start_Phase + 1], CDF_PHs2 =
stored_cdf[Start_Phase + 2]); // repeat up to +5
// Note: OP_time in the write payload is ignored.
// Restore it once via PSRM_CMD_UNIT_REL (0x01), unit_address = 0x00.
```

Figure 20 Write – bulk CDF restore after cold reset:

This is used for initialization, to restore the CDF (accumulated stress) if the XDP™ controller undergoes a cold reset.

Note: Operation time in write operation is ignored and can only be set using PSRM_CMD_UNIT_REL operation with the Unit address of "system".

5.2.2.3 PSRM_CMD_LOOP_FIT (Subcode: 0x03)

Command is needed if a synchronous comparison between the individual FIT parameters is needed. So, this command is used for "bulk" read/write.

Table 19 PSRM_CMD_LOOP_FIT data format

Byte Nr	Byte Name	Description
[27:4]	FIT	[27:24] → PVDD_loopX_unit+5 [23:20] → PVDD_loopX_unit+4 [19:16] → PVDD_loopX_unit+3 [15:12] → PVDD_loopX_unit+2 [11:8] → PVDD_loopX_unit+1 [7:4] → PVDD_loopX_unit
[3:0]	OP_time_ms	Operational time in milliseconds.

```
write_0xE7(PSRM_CMD_ID=0x03, RW_operation=1, Loop_number=loop, Start_Phase_address=start_phase, Number_of_phases=n);
response = read_0xEF();       // 28-byte block read (subcode 0x03)
op_time_ms = response[3:0];   // operating time (ms) at snapshot
fit_PHs = response[7:4];      // FIT rate for Start_Phase (PHs)
fit_PHs1 = response[11:8];    // FIT rate for Start_Phase + 1
fit_PHs2 = response[15:12];   // FIT rate for Start_Phase + 2
// ... up to response[27:24] for Start_Phase + 5 (max Number_of_phases = 6)
// Unused phase slots are 0x0.
// LoopA and LoopB require separate calls (31-byte block-read limit).
// Note: there is no write operation for this subcode - FIT is computed by PSRM
```

Figure 21 Read operation

As the block read limit of XDP is 31 bytes, a readout of both loops is not possible in a single operation. To read out both Loop parameters, the operation must be executed twice.

PSRM PMBus® commands description

Usage:

- Send MFR_CMD_AND_UNIT_SEL_PARAM command before with PSRM_CMD_ID field with the subcode of PSRM_CMD_LOOP_FIT,
- RW_operation with “1” for read operation,
- loop_number,
- Start_Unit_address
- Number_of_Units

Note: *Maximum value of n is **6**; Unit selection must stay within the valid Unit range of the selected loop. If n < 6, unused MSB slots in the response are set to 0x0.*

6 Summary

PSRM brings in-field, condition-aware reliability estimation directly into Infineon's digital power controllers. By continuously measuring real operating conditions and mapping them through a parts-count reliability model, it produces two key outputs — failure rate (λ) and accumulated failure probability (CDF) — without requiring external sensors, additional hardware, or assumptions about how the converter is used in the field.

These outputs enable a range of use cases at the application-controller or infrastructure level; benchmarking a converter against qualification limits, deriving a health score, comparing reliability across a fleet, balancing load across phases or servers, and laying the groundwork for future wear-out analysis.

Integration requires only a firmware patch and a one-time, design-specific reliability model configuration, carried out together with Infineon based on your bill of materials and design topology.

Ready to get started?

- Reach out to your Infineon representative to discuss integrating PSRM into your design
- Get in touch via Infineon support
- Learn more about the benefits of health monitoring in our webinar

References

[1] Infineon Technologies AG: Power System Reliability Modeling with In-Situ MTBF Calculations whitepaper; Available online.

[2] Infineon Technologies AG: EVAL_600W_FBFB_XDPP user guide; Available online.

Revision history

Document revision	Date	Description of changes
1.0	2026-07-29	Initial release

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