Session 1 Starts: 8 AM PDT | 11 AM EDT | 5 PM CEST
Session 2 Starts: 11 AM PDT | 2 PM EDT | 8 PM CEST

Ensuring Safety for Autonomous Vehicles with Advanced Voltage Supervision

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- Ph.D. degree from the Ohio State University, 2022
- Joined MPS in 2021 as an intern
- Currently a Technical Marketing Engineer (Product Definer) for the Automotive product line
- Focus on advanced driver-assistance system (ADAS) products including voltage monitors, power sequencers, and system-on-chip (SoC) power management ICs (PMICs)

Agenda

Background

- Autonomous Driving (AD) Statistics
- Autonomous Driving (AD): Enabled by Advanced Driver-Assistance Systems (ADAS)
- Autonomous Driving (AD): High-Performance Computer Block Diagram

Traditional vs. Advanced Voltage Supervision

- Voltage Supervision Overview
- Limitations of Traditional Voltage Supervisors
- Advanced Voltage Supervision

Advanced Voltage Supervision Design

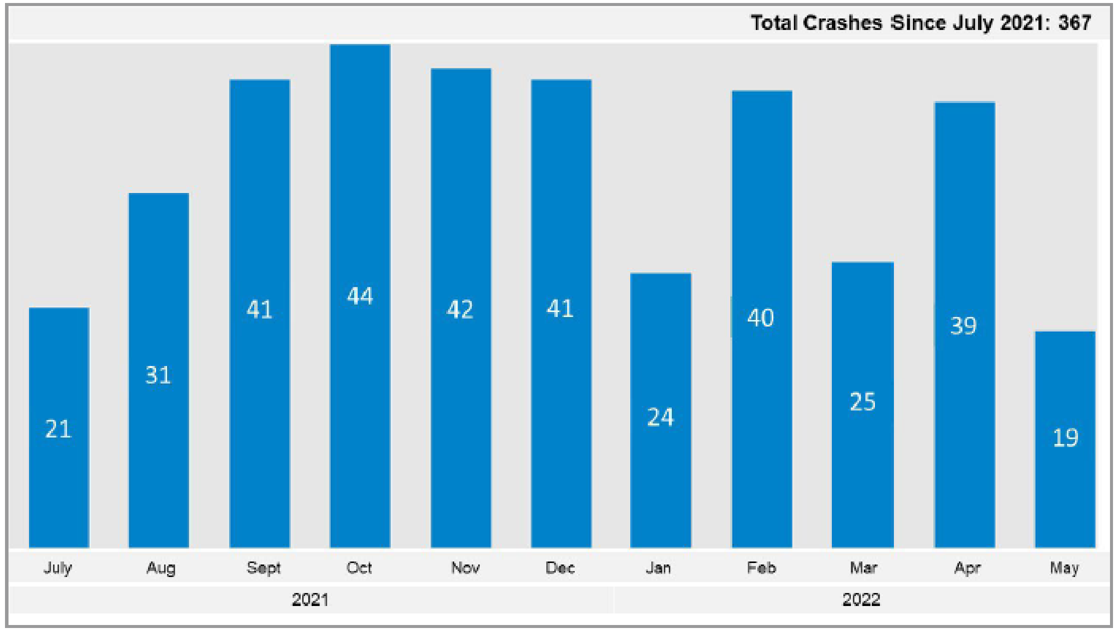
- Functional Safety Capability
- Voltage Monitoring (Drift)
- Voltage Monitoring (Noise)
- Voltage Threshold Setting
- Sequence Recording

Test Results

Summary

Autonomous Driving (AD) Statistics

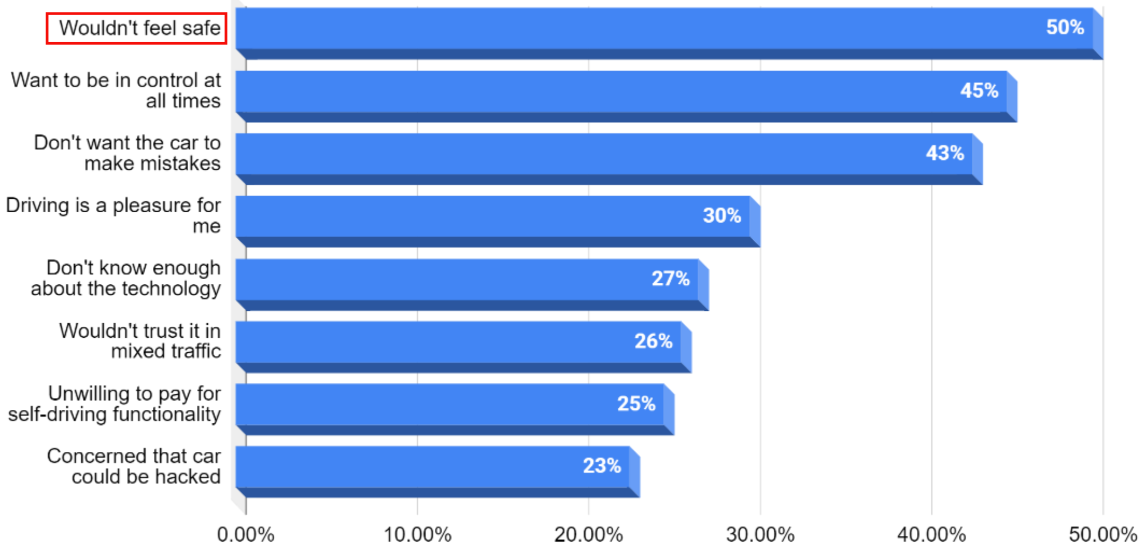
Level 2 ADAS Crashes by Month



Source: National Highway Traffic Safety Administration (NHTSA), “Summary Report: Standing General Order on Crash Reporting for Level 2 Advanced Driver Assistance Systems.” June 2022.

Consumer Concerns About Self-Driving Cars

% of respondents naming the following reasons for their reluctance to use self-driving cars



Source: BCG and World Economic Forum
Base: 1,260 consumers from 10 countries

The safety of autonomous driving systems is mission critical

AD: Enabled by Advanced Driver-Assistance Systems (ADAS)

Long-Range Radar and LiDAR
- Adaptive cruise control

Ultrasound
- Parking assistance

Short-/Medium-Range Radar
- Emergency braking
- Pedestrian detection
- Cross-traffic alert
- Collision warning/avoidance
- Blind spot detection

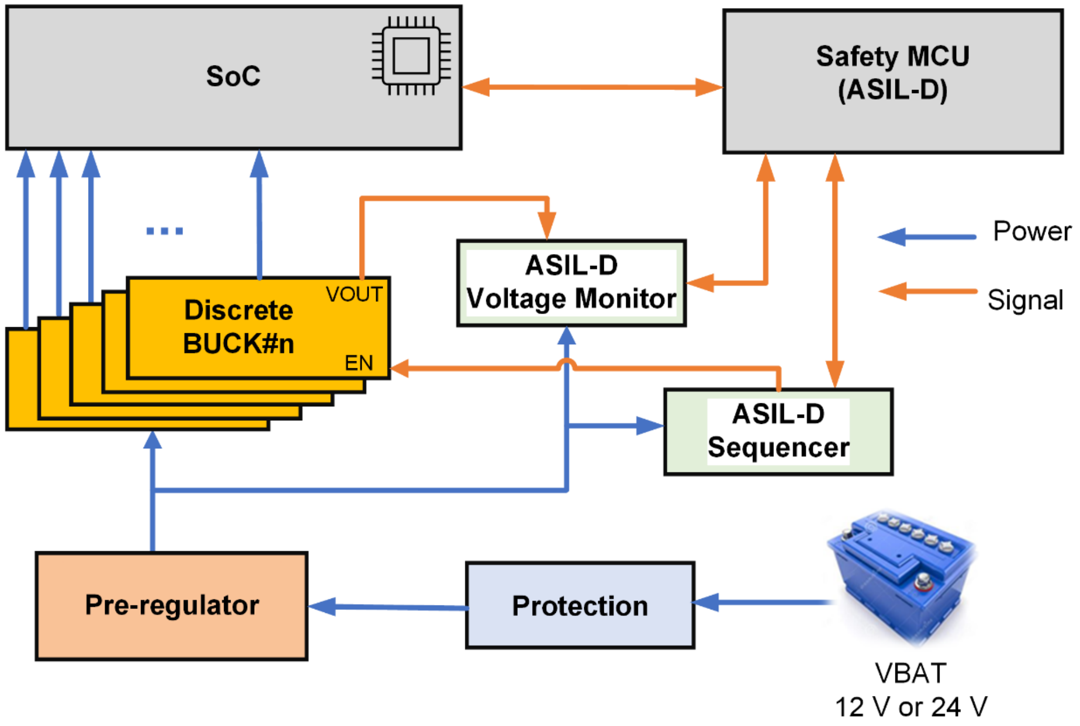
High-Performance Computers
- Sensor fusion
- AI learning
- Computation tasks required for perception, cruising, and parking

Cameras
- Traffic sign recognition
- Lane departure warning
- Parking assistance
- Surround view

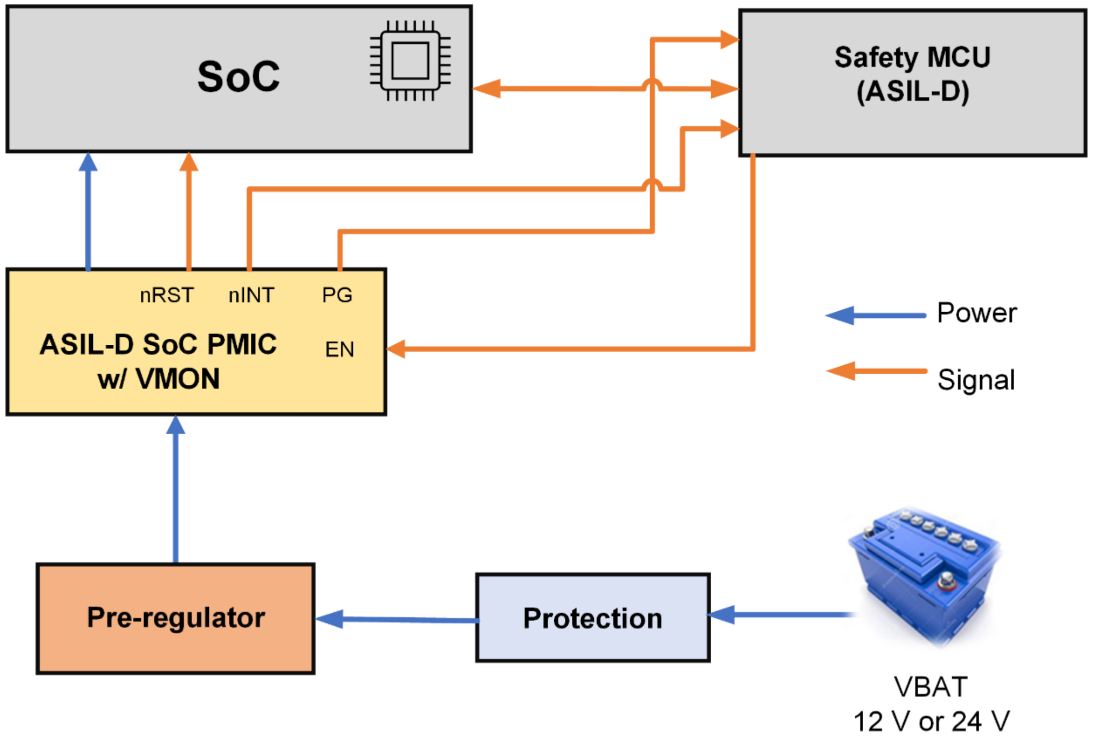
Supervision is mandatory to ensure the functionality of each ADAS subsystem

AD: High-Performance Computer Block Diagram

SoC Powered by Discrete Devices



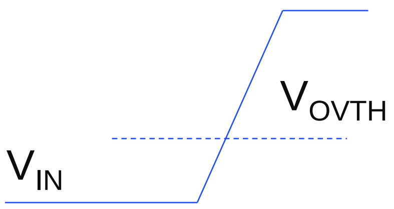
SoC Powered by PMIC



Voltage Supervision Overview

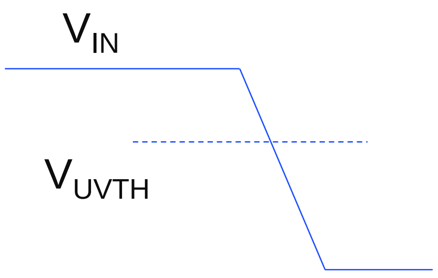
- **Voltage supervision** plays a key role in meeting stringent functional safety requirements
- Supply voltages out of tolerance can cause the SoC/processor in the system to malfunction, resulting in system failure
- Voltage supervisors/monitors are responsible for **over-voltage/under-voltage (OV/UV) event supervision** for a voltage rail
- In addition to supervising the system voltage, voltage monitors should report diagnostic information in systems requiring functional safety

Over-Voltage (OV) Event



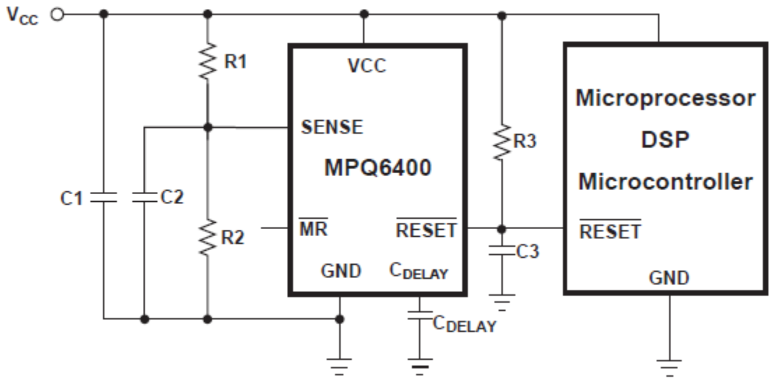
Input voltage (V_{IN}) > OV threshold (V_{OVTH})

Under-Voltage (UV) Event



Input voltage (V_{IN}) < UV threshold (V_{UVTH})

Typical Application



Limitations of Traditional Voltage Supervisors

Lacking Functional Safety Capability

No on-chip diagnostics to implement functional safety features. Lacks compliance with automotive safety integrity level (ASIL).

No Safety Reporting

Traditional supervisors have an analog reset pin to indicate a fault condition. ASIL-compliant systems require fault conditions to be stored to the memory (e.g. time of event, voltage level, type of fault) and read back by a safety MCU.

Limitations

Restricted Voltage Monitoring Range

The voltage monitoring range is restricted to the preset choices. There is no flexibility for user configuration.

Restricted Voltage Threshold Configurability

The threshold values are preset and fixed to limited options. The over-/under-voltage thresholds are not configurable.

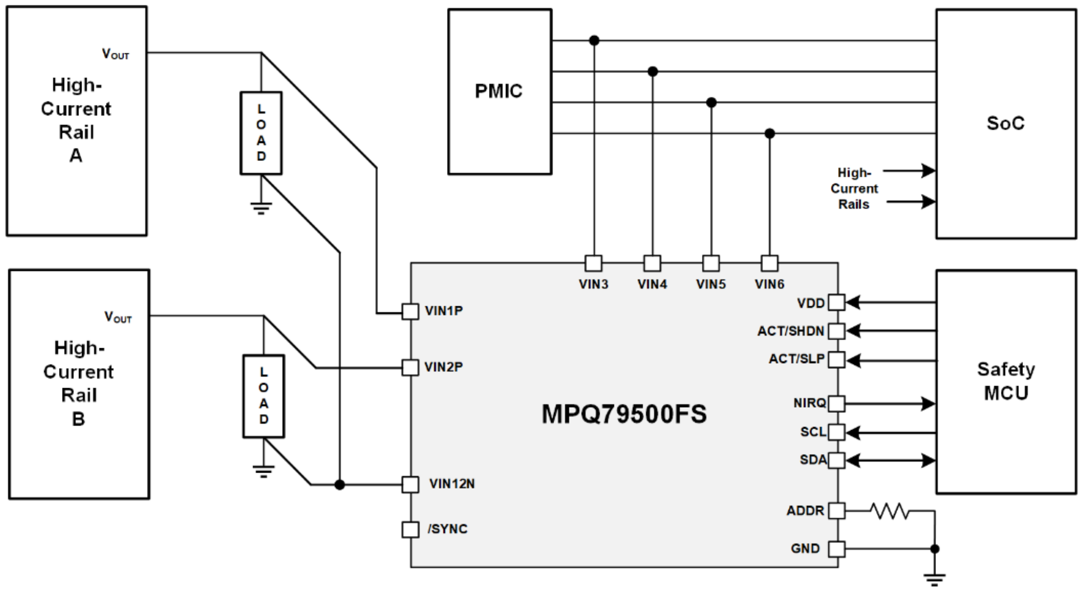
Advanced Voltage Supervision

Traditional	Voltage Monitor	Advanced
Limitations		Improvements
Lacking functional safety capability	1	Includes functional safety capability
No safety reporting	2	Includes safety reporting
Restricted voltage monitoring range	3	Wide voltage monitoring range
Limited voltage threshold configurability	4	Configurable voltage thresholds

MPS

Advanced Voltage Supervision Design

- Includes Functional Safety Capability:
  - Built-In Self-Testing (BIST)
  - Interrupt Output Pin (Fault Reporting)
  - I²C Interface with Cyclic Redundancy Check (CRC)
  - ASIL-D Compliant, ISO26262 Certified
- Multiple Monitoring Channels: 6 (2 Differential Remote Sensing)
- Wide Monitoring Range and Configurable Absolute OV and UV Thresholds:
  - 1x Scaling: 0.2V to 1.475V Range, 5mV/Step
  - 4x Scaling: 0.8V to 5.5V Range, 20mV/Step
- AEC-Q100 Qualified
- Sequence Recording (SYNC Pin for Sequence Recording by Synchronizing Multiple Devices)



6-Channel Voltage Monitor (MPQ79500FS) in a Typical Application Circuit

Functional Safety Capability

1 Built-In Self Testing (BIST)

Logic BIST (LBIST), analog BIST (ABIST), and volatile memory (VM) BIST diagnostics from the non-volatile memory (NVM) ensure reliability for every drive cycle.

2 NIRQ Fault Reporting Pin

An interrupt NIRQ pin is used for fault reporting to the higher-level safety microcontroller (MCU) for fault handling.

3 Reference Voltage Monitor

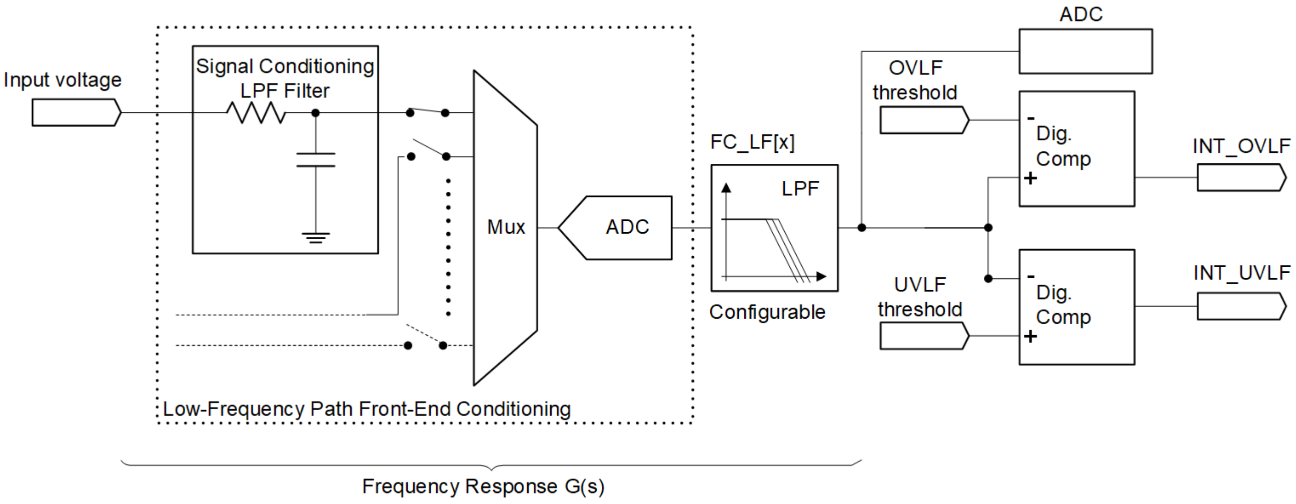
Use a redundant independent voltage reference to cross-check the reference voltage. If one voltage reference is out of range, the device should report reference voltage failures to the system and the system needs to take necessary actions.

4 System Clock Monitor

Use independent clock sources to provide cross-check. If one clock is out of range, the device should report clock failures to system and the system needs to take necessary actions.

Voltage Monitoring (Drift)

The monitored rails where voltages drift (low frequency, LF) are converted to digital signals by a high-accuracy **analog-to-digital converter (ADC)**. Over-voltage/under-voltage low-frequency (UVLF/OVLF) fault events are reported.



Over-Voltage/Under-Voltage Low-Frequency (UVLF/OVLF) Monitoring Structure

Enable/Disable UVLF/OVLF Monitoring via the I²C

IEN_UVLF(0x14)Bank1	
UVLF_VIN[1]	Enable
UVLF_VIN[2]	Enable
UVLF_VIN[3]	Enable
UVLF_VIN[4]	Enable
UVLF_VIN[5]	Disable
UVLF_VIN[6]	Disable

IEN_OVLF(0x16)Bank1	
OVLF_VIN[1]	Enable
OVLF_VIN[2]	Disable
OVLF_VIN[3]	Enable
OVLF_VIN[4]	Disable
OVLF_VIN[5]	Disable
OVLF_VIN[6]	Enable

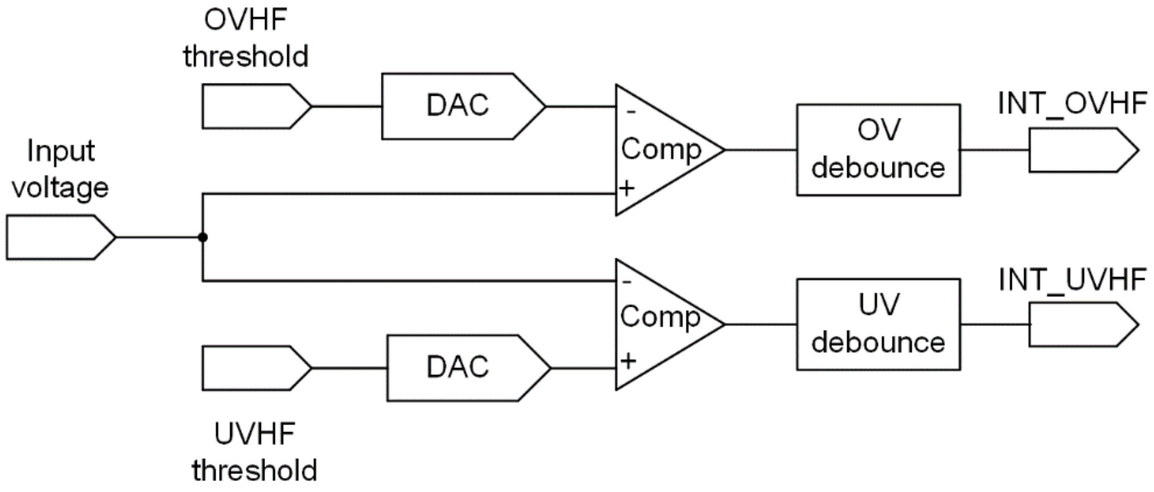
Monitoring Range, Threshold, and Cutoff Frequency Configuration via the I²C

VRANGE_MULT(0x1F)Bank1	
VRANGE_MULT_VIN[1]	1x scaling
VRANGE_MULT_VIN[2]	4x scaling
VRANGE_MULT_VIN[3]	4x scaling
VRANGE_MULT_VIN[4]	1x scaling
VRANGE_MULT_VIN[5]	1x scaling
VRANGE_MULT_VIN[6]	1x scaling

Monitor Registers-CH1(0x20-0x25)Bank1	
UV_HF[1]	0.2 V
OV_HF[1]	1.475 V
UV_LF[1]	0.2 V
OV_LF[1]	1.475 V
FLT_HF_UV[1]	0.1 µs
FLT_HF_OV[1]	0.1 µs
FC_LF_THREEDB[1]	500 Hz

Voltage Monitoring (Noise)

High-accuracy comparators monitor voltage noise (high frequency, HF) for over-voltage and under-voltage events, and include a debounce time that is configurable down to 100ns. Over-voltage/under-voltage high-frequency (UVHF/OVHF) fault events are reported.



Over-Voltage/Under-Voltage High-Frequency (UVHF/OVHF) Monitoring Structure

Enable/Disable UVHF/OVHF Monitoring via the I²C

IEN_UVHF(0x13)Bank1	
UVHF_VIN[1]	Enable
UVHF_VIN[2]	Enable
UVHF_VIN[3]	Enable
UVHF_VIN[4]	Enable
UVHF_VIN[5]	Disable
UVHF_VIN[6]	Disable

IEN_OVHF(0x15)Bank1	
OVHF_VIN[1]	Enable
OVHF_VIN[2]	Enable
OVHF_VIN[3]	Enable
OVHF_VIN[4]	Enable
OVHF_VIN[5]	Enable
OVHF_VIN[6]	Disable

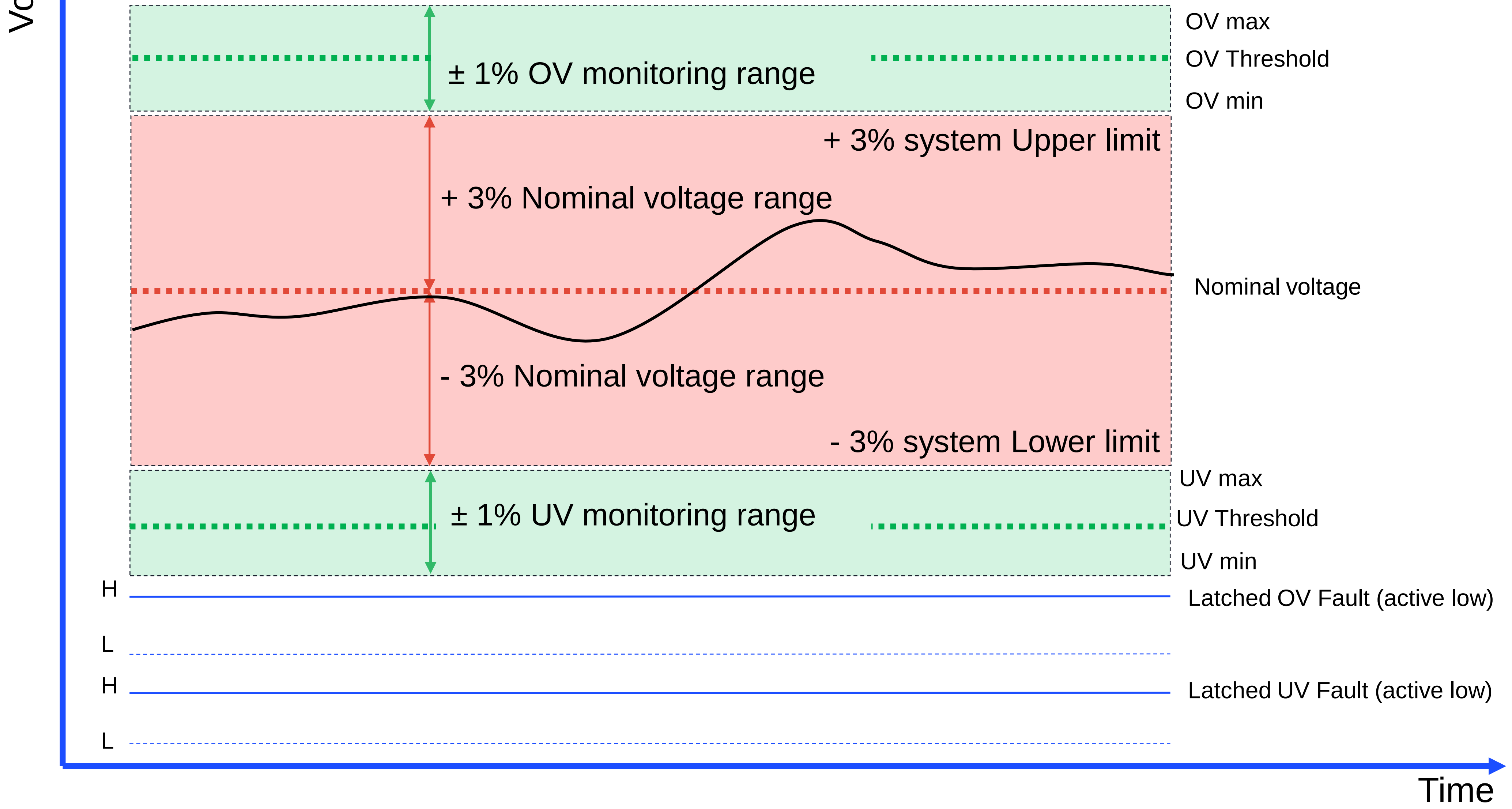
Monitoring Range, Threshold, and Debounce Time Configuration via the I²C

VRANGE_MULT(0x1F)Bank1	
VRANGE_MULT_VIN[1]	1x scaling
VRANGE_MULT_VIN[2]	4x scaling
VRANGE_MULT_VIN[3]	4x scaling
VRANGE_MULT_VIN[4]	1x scaling
VRANGE_MULT_VIN[5]	1x scaling
VRANGE_MULT_VIN[6]	1x scaling

Monitor Registers-CH1(0x20-0x25)Bank1	
UV_HF[1]	0.2 V
OV_HF[1]	1.475 V
UV_LF[1]	0.2 V
OV_LF[1]	1.475 V
FLT_HF_UV[1]	0.1 µs
FLT_HF_OV[1]	0.1 µs
FC_LF_THREEDB[1]	500 Hz

Normal Operation

- OV/UV monitoring range: OV/UV threshold range with tolerance over temperature
- This is applicable for both DC (low frequency) and AC (high frequency) monitoring.



Normal Operation

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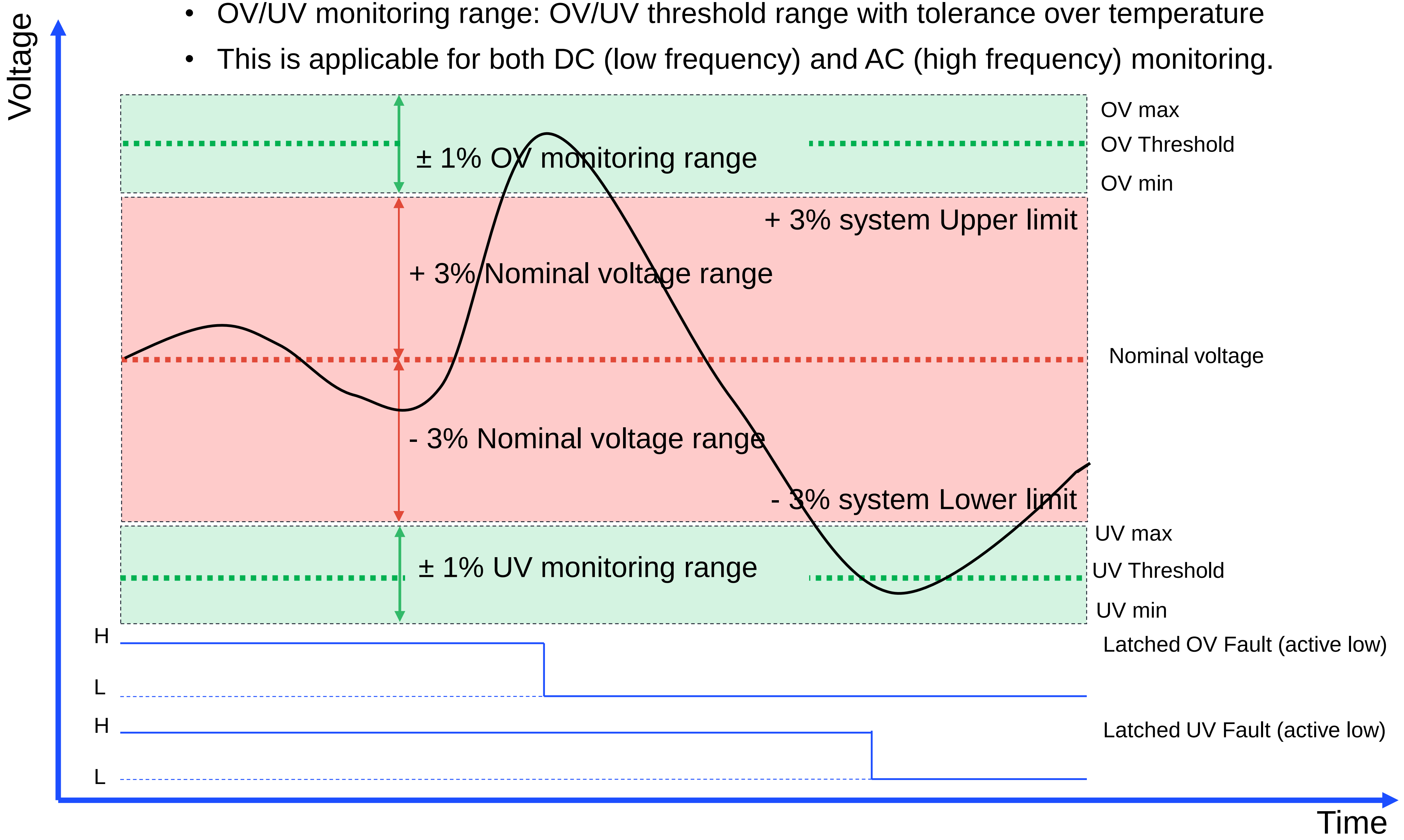
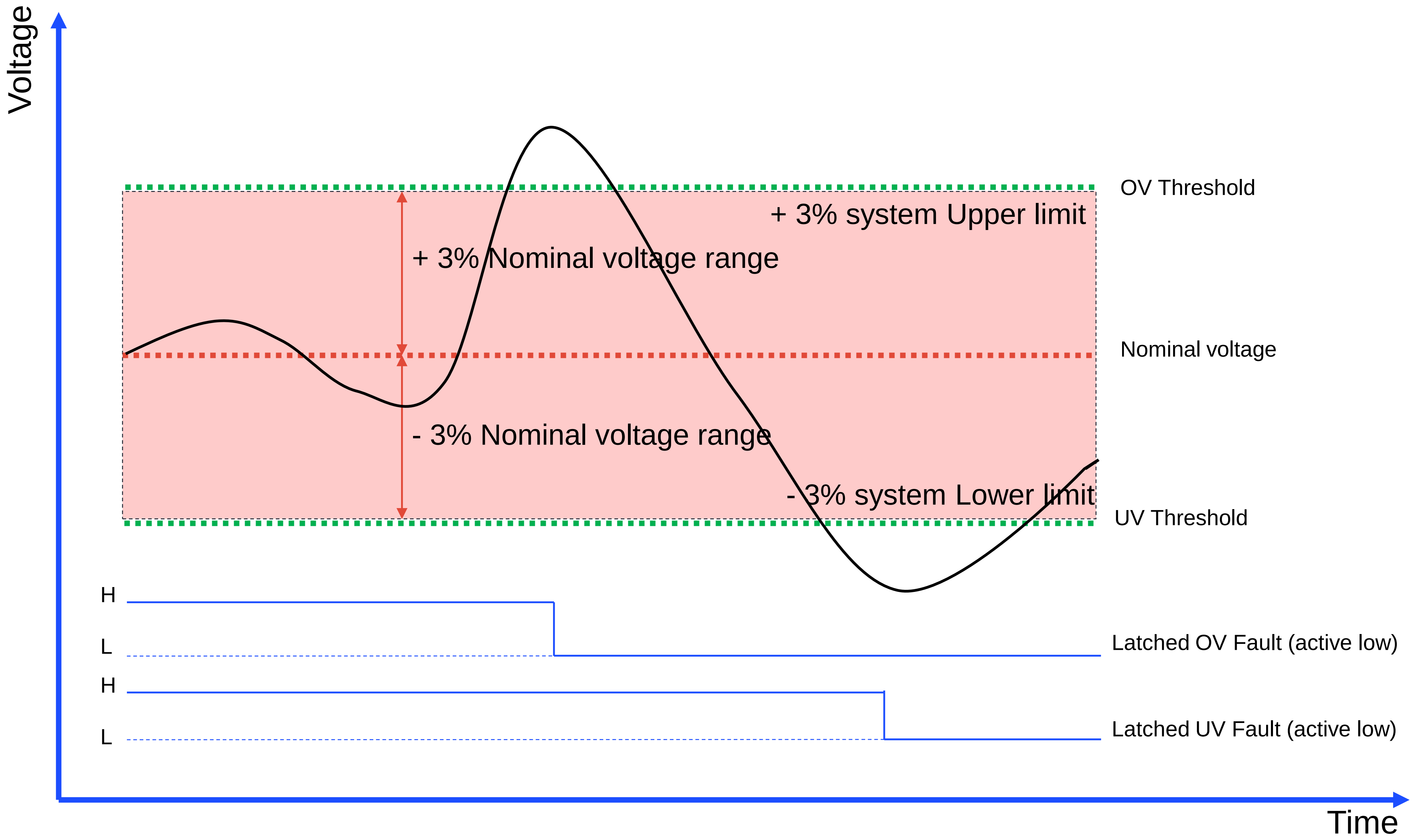
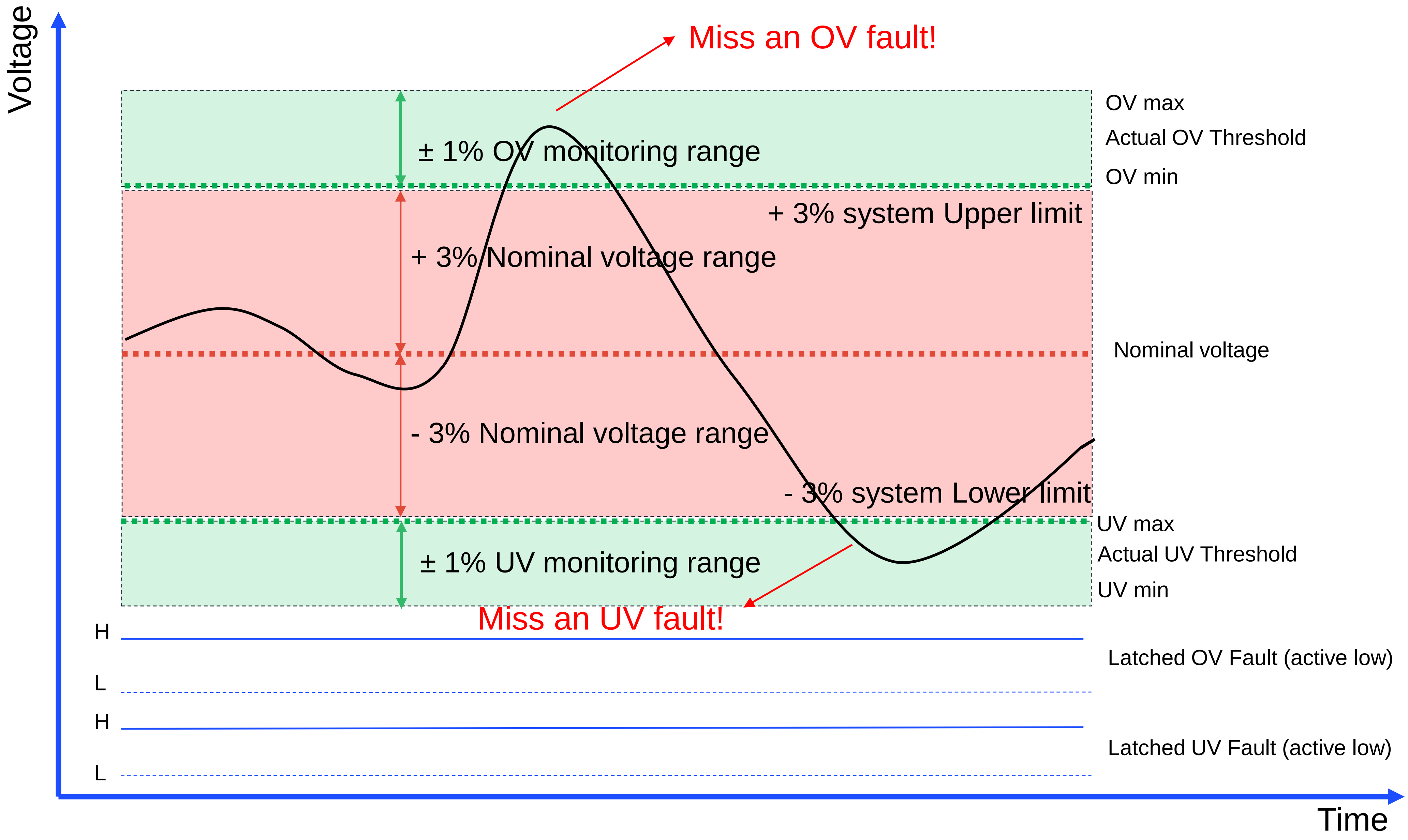


Ideal Case

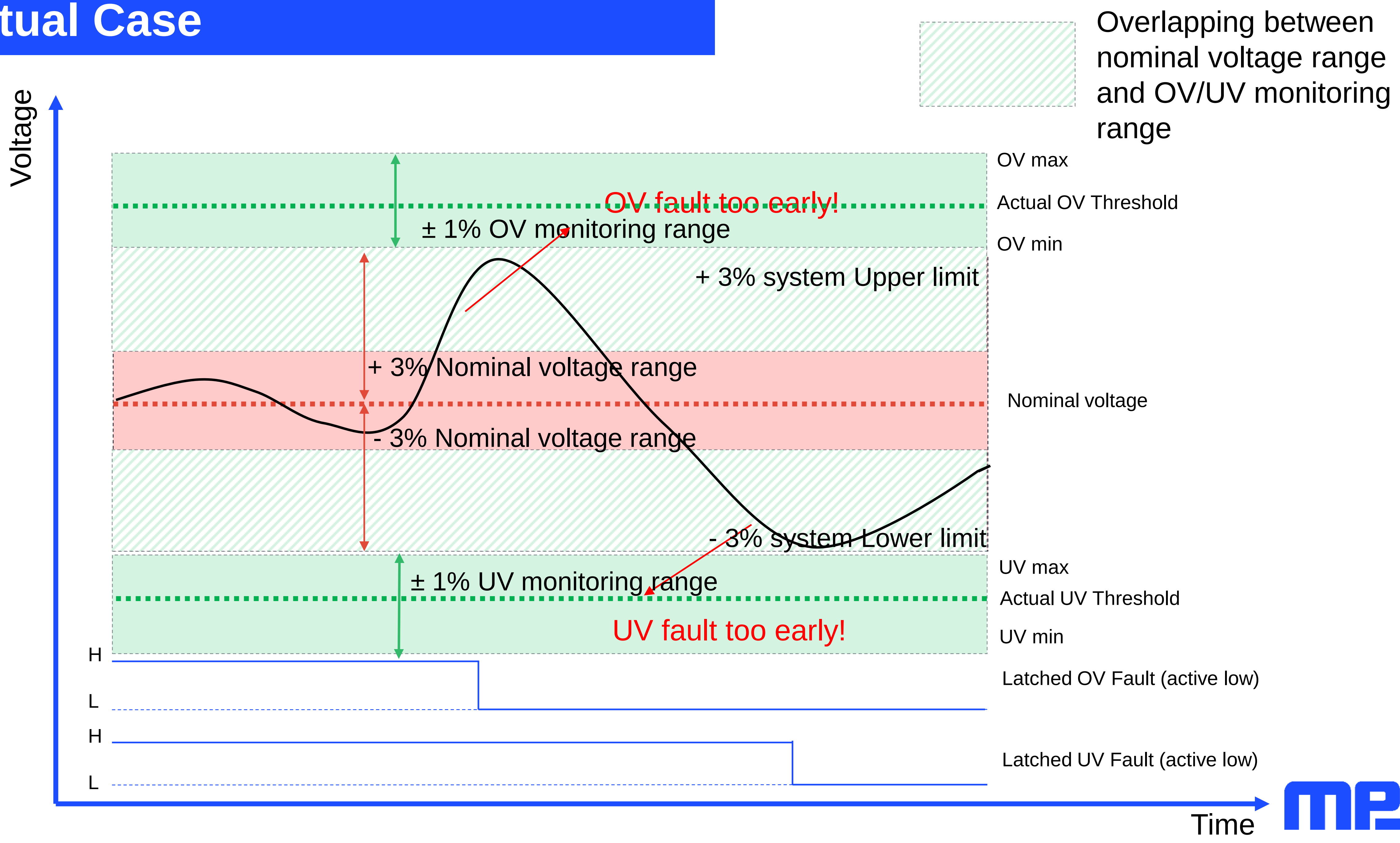

Voltage
OV Threshold
+ 3% system Upper limit
+ 3% Nominal voltage range
Nominal voltage
- 3% Nominal voltage range
- 3% system Lower limit
UV Threshold
H
L
Latched OV Fault (active low)
H
L
Latched UV Fault (active low)
Time

Actual Case

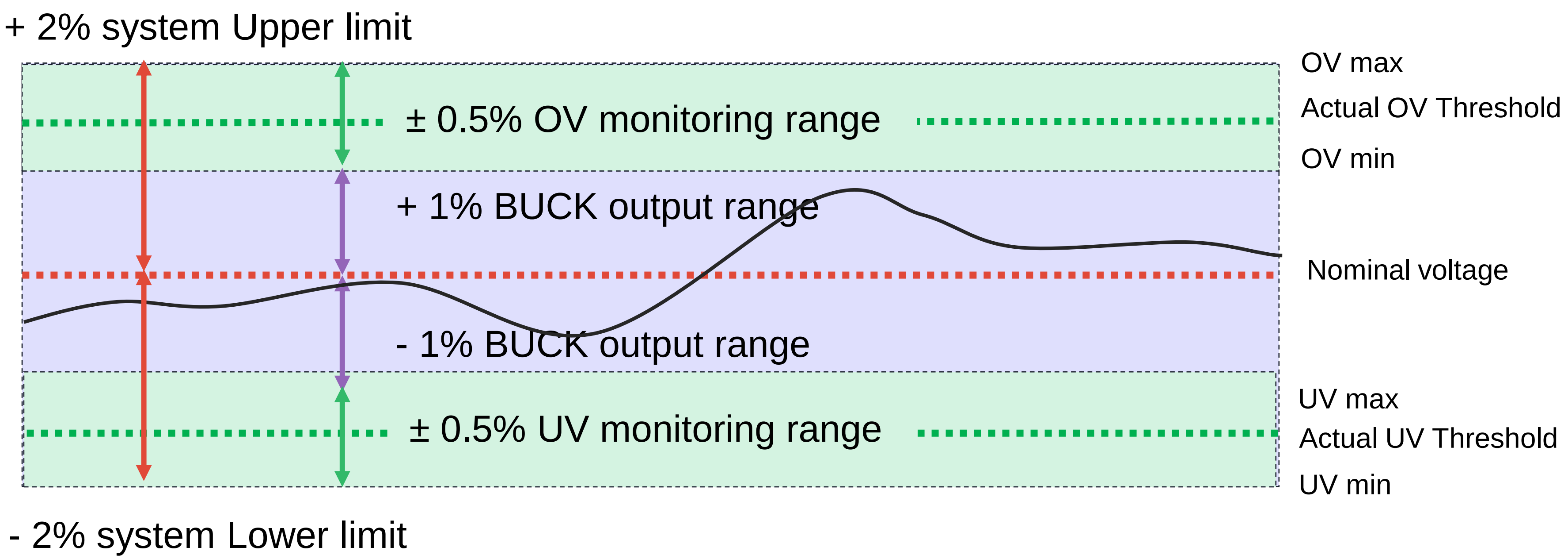


Voltage
Miss an OV fault!
± 1% OV monitoring range
+ 3% system Upper limit
+ 3% Nominal voltage range
- 3% Nominal voltage range
- 3% system Lower limit
± 1% UV monitoring range
Miss an UV fault!
OV max
Actual OV Threshold
OV min
Nominal voltage
UV max
Actual UV Threshold
UV min
H
L
Latched OV Fault (active low)
H
L
Latched UV Fault (active low)
Time

Actual Case

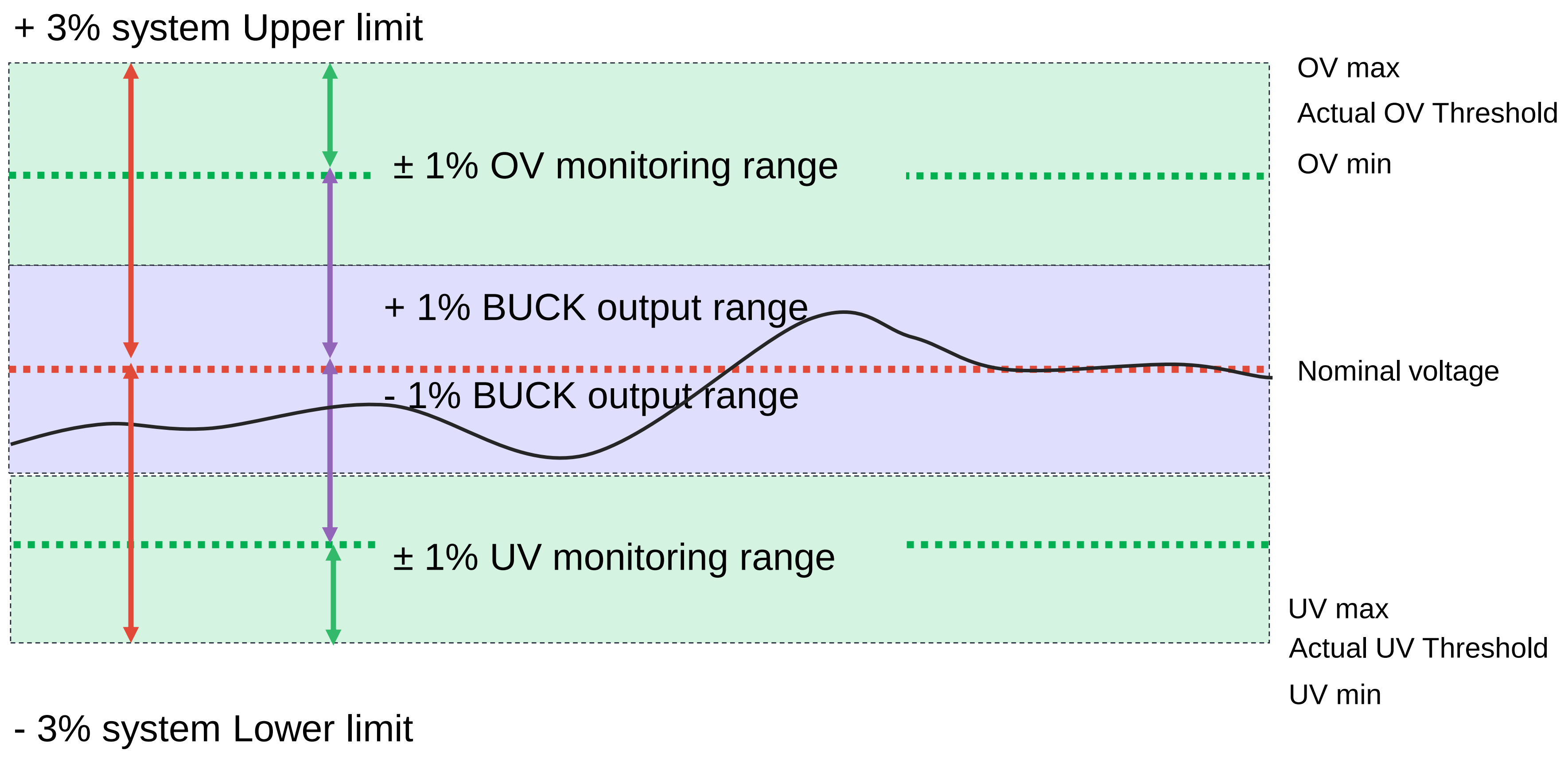

Overlapping between nominal voltage range and OV/UV monitoring range
Voltage
OV max
Actual OV Threshold
OV min
OV fault too early!
± 1% OV monitoring range
+ 3% system Upper limit
+ 3% Nominal voltage range
Nominal voltage
- 3% Nominal voltage range
- 3% system Lower limit
UV max
± 1% UV monitoring range
Actual UV Threshold
UV fault too early!
UV min
H
L
Latched OV Fault (active low)
H
L
Latched UV Fault (active low)
Time

How to Correctly Setup Thresholds



- Higher accuracy buck regulator and more accurate voltage monitors are required to meet total system tolerance.

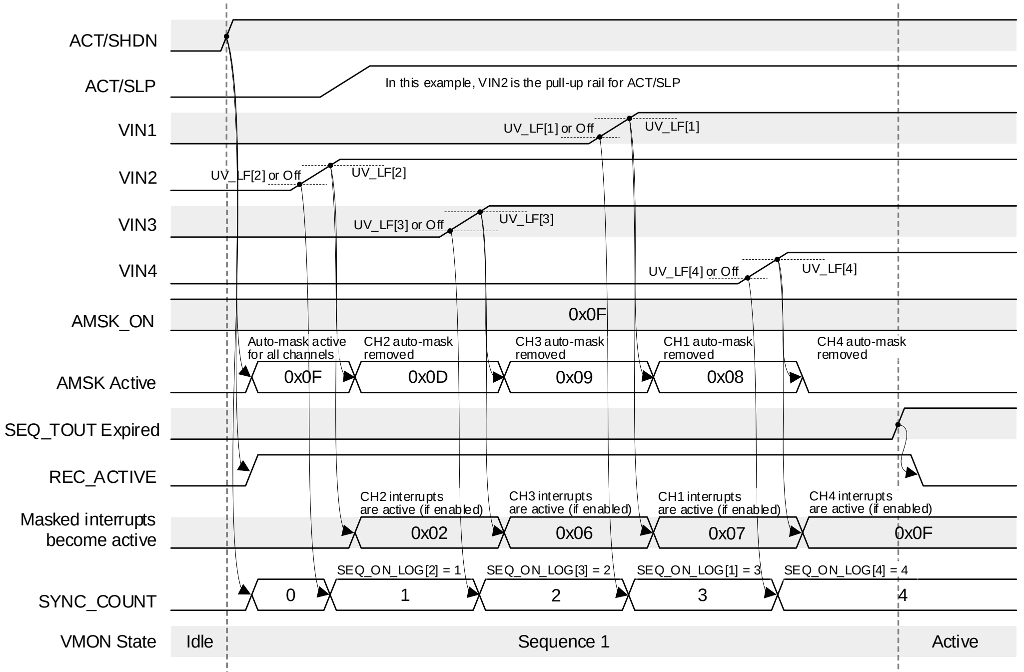
How to Correctly Setup Thresholds



- System tolerance must be loosened to accommodate tolerances of the Monitor and Buck regulator.

Sequence Recording

The power-on, power-off, sleep entry, and sleep exit sequences can be recorded to monitor a correct and safe sequence. Sequence recording with more than one voltage (>6 rails) can be achieved via the /SYNC pin with all voltage rails sharing a synchronous domain.



Sequence Monitoring Using a Single MPQ79500FS Voltage Monitor

Enable/Disable Sequence Monitoring via the I²C

IEN_SEQON(0x17)_Bank1	
ON_VIN[1]	Disable
ON_VIN[2]	Disable
ON_VIN[3]	Disable
ON_VIN[4]	Disable
ON_VIN[5]	Disable
ON_VIN[6]	Disable

IEN_SEQOFF(0x18)_Bank1	
OFF_VIN[1]	Disable
OFF_VIN[2]	Disable
OFF_VIN[3]	Disable
OFF_VIN[4]	Disable
OFF_VIN[5]	Disable
OFF_VIN[6]	Disable

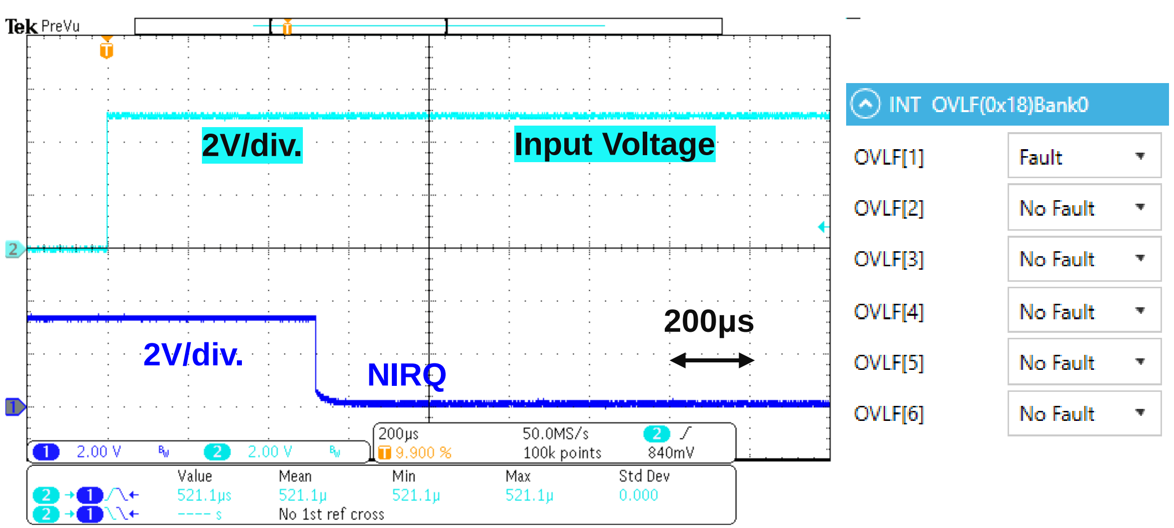
User-Expected Sequence, Actual Logged Sequence, and Timestamp via the I²C

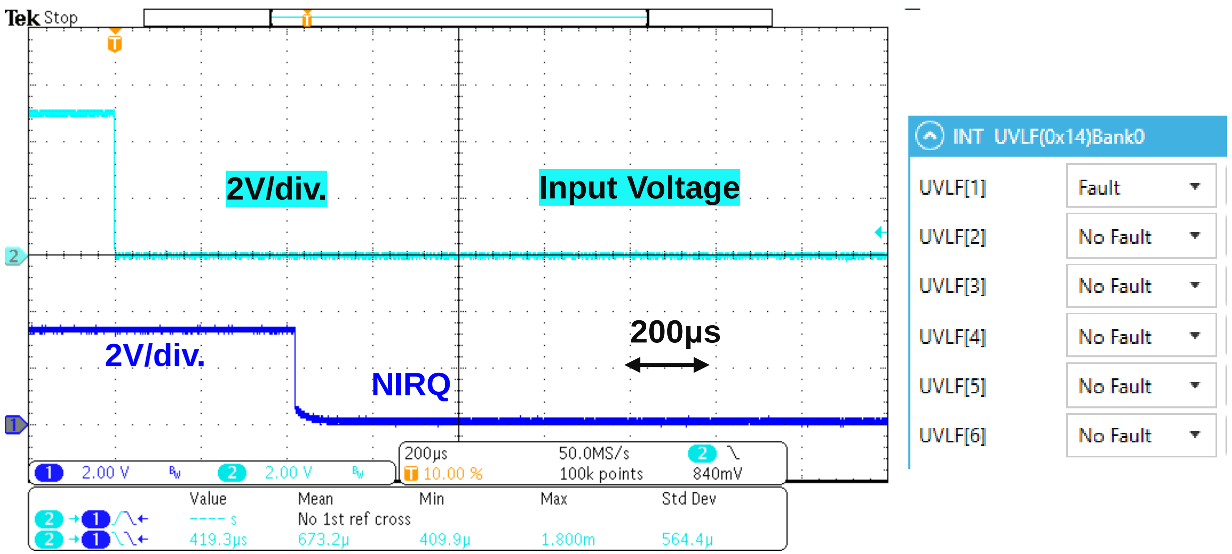
SEQ_ONEXP(0xB0-0xB5)_Bank1	
ON_EXP[1]	3
ON_EXP[2]	4
ON_EXP[3]	1
ON_EXP[4]	2
ON_EXP[5]	3
ON_EXP[6]	2

SEQ_ONLOG(0x50-0x55)_Bank0	
ON_LOG[1]	03
ON_LOG[2]	04
ON_LOG[3]	01
ON_LOG[4]	02
ON_LOG[5]	03
ON_LOG[6]	02

SEQ_TIME(0x90-0x9B)Bank0		
SEQ_TIME[1]	14.8	ms
SEQ_TIME[2]	23.9	ms
SEQ_TIME[3]	1.3	ms
SEQ_TIME[4]	6.1	ms
SEQ_TIME[5]	13.95	ms
SEQ_TIME[6]	5.7	ms

Test Results: Voltage Monitoring (Drift) for OV/UV

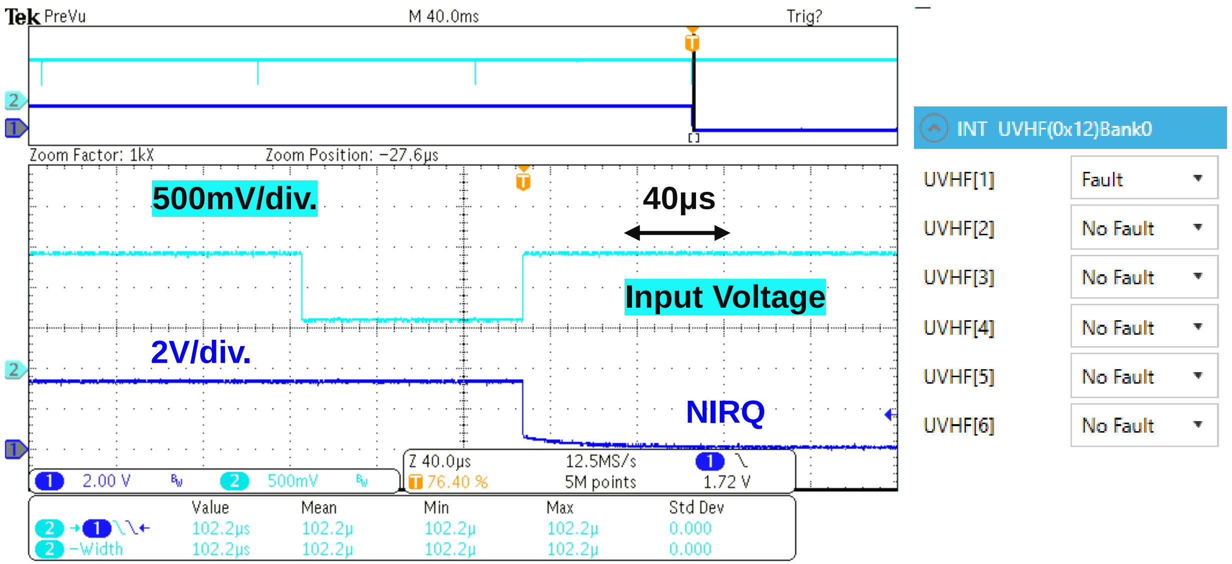


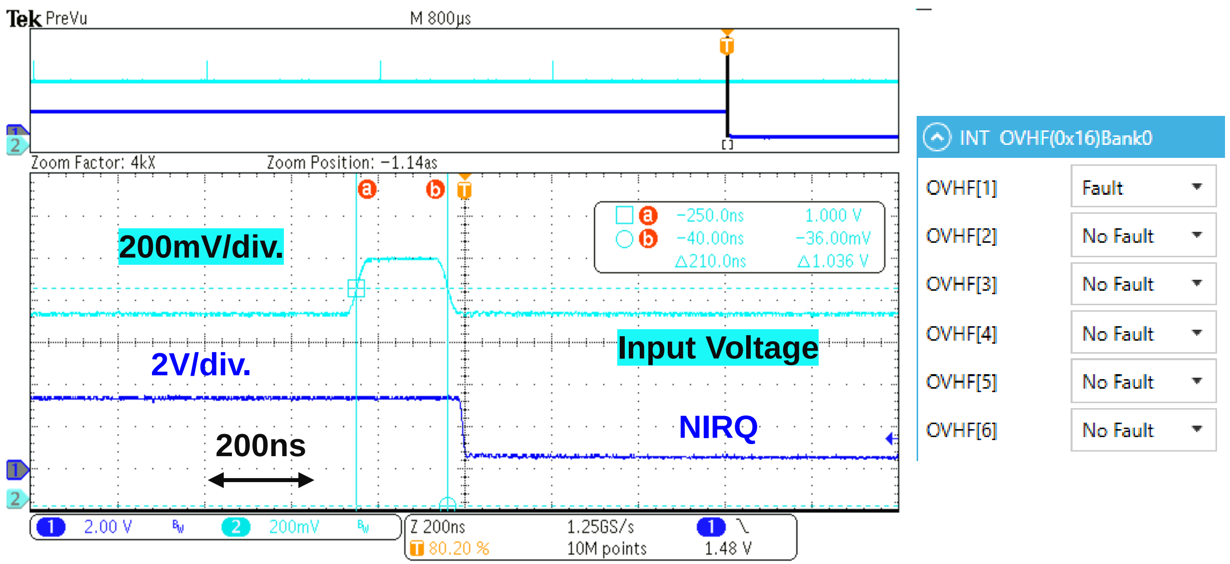


- OVLF threshold = 1V (where the voltage increases from 0V to 5V)
- The fault pin (NIRQ) is pulled low, and the OVLF fault register is set (OVLF, bit[1]) after an OVLF fault occurs
- The fault bit cannot be written to 1 to be cleared until the fault condition is removed

- UVLF threshold = 1V (where the voltage falls from 5V to 0V)
- The NIRQ fault pin is pulled low, and the UVLF fault register is set (UVLF, bit[1]) after a UVLF fault occurs
- The fault bit cannot be written to 1 to be cleared until the fault condition is removed

Test Results: Voltage Monitoring (Noise) for OV/UV

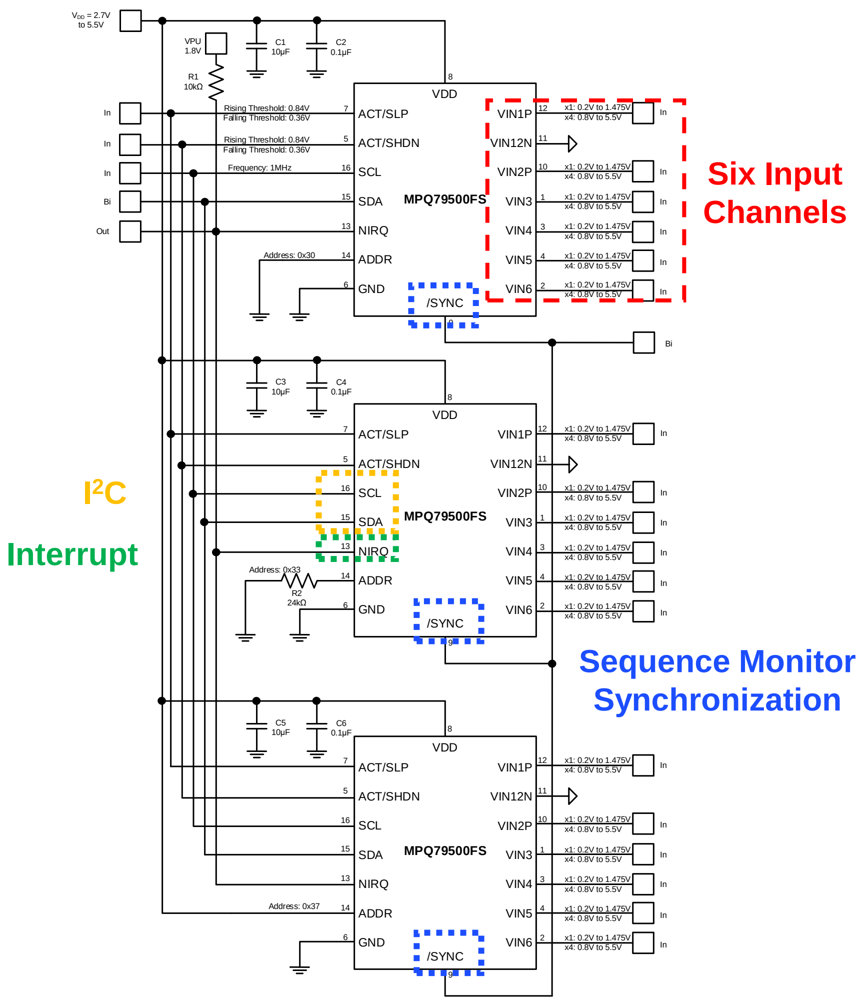




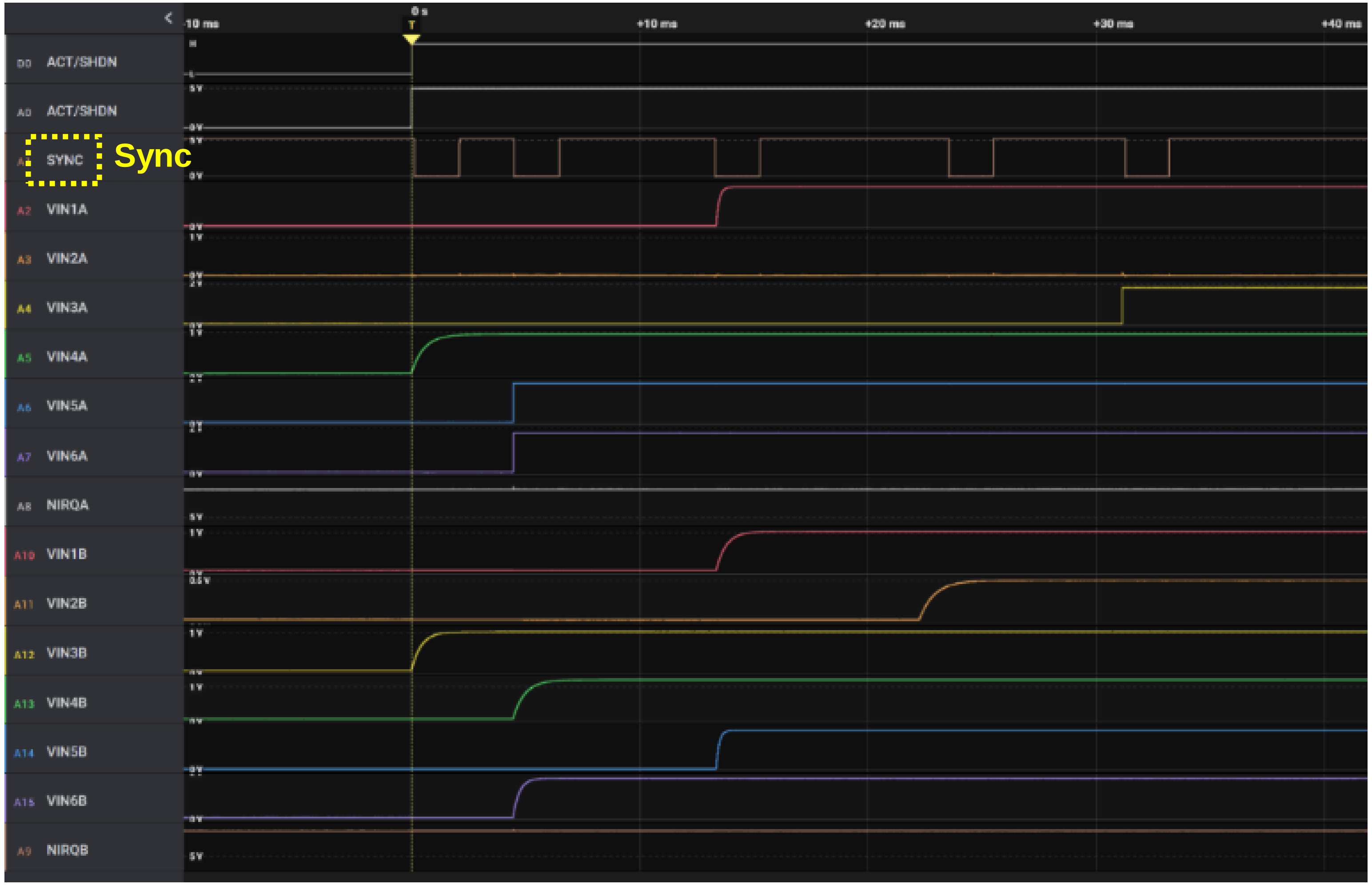
- UVHF threshold = 1V (where the input voltage falls from 1.4V to 0.6V for a short pulse)
- The NIRQ fault pin is pulled low, and the UVHF fault register is set (UVHF, bit[1]) after a UVHF fault occurs
- The fault bit cannot be written to 1 to be cleared until the fault condition is removed

- OVHF threshold = 1V (where the input voltage increases from 0.7V to 1.2V for a short pulse)
- The NIRQ fault pin is pulled low, and the OVHF fault register is set (OVHF, bit[1]) after a OVHF fault occurs
- The fault bit cannot be written to 1 to be cleared until the fault condition is removed

Test Results: Sequence Recording (Multiple Devices)

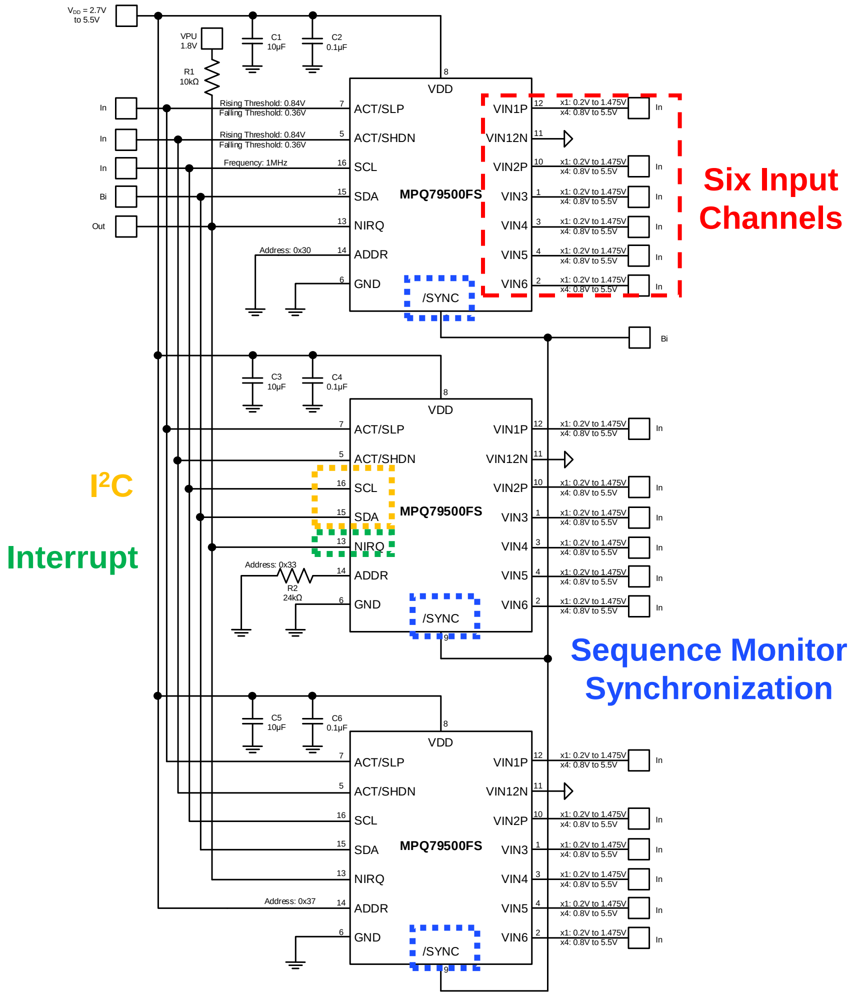


Sequence Monitoring of Three Synchronized MPQ79500FS Devices

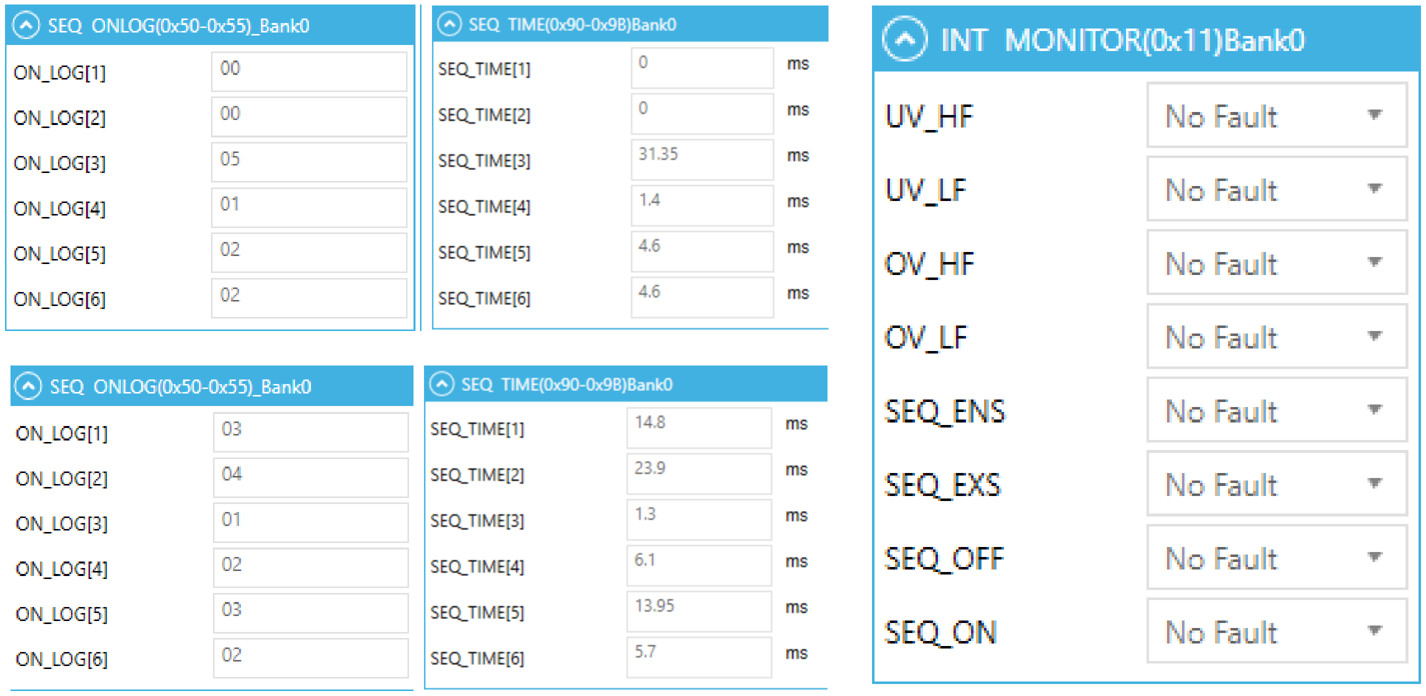


Power-Up Sequence Recording Using Two MPQ79500FS Voltage Monitors (SYNC Pin to Synchronize Both Devices to the Same Domain)

Test Results: Sequence Recording (Multiple Devices)



Sequence Monitoring of Three Synchronized MPQ79500FS Devices



Sequence Recording | Timestamp Logging | Fault Reporting

GUI Reading: On Sequence Recording and Fault Monitoring (Two MPQ79500FS Devices)

Summary

- As ADAS technology achieves higher levels of vehicle autonomy, **functional safety** is mandatory
- **Voltage supervision** plays a critical role in achieving functional safety
- Advanced voltage supervision can target stringent voltage rail monitoring requirements in autonomous vehicle platforms with the following features:
  - **Functional safety capability:** On-chip diagnostics (e.g. LBIST, ABIST, CRC, ECC) to avoid malfunctions
  - **Multiple** channels monitored: Using a single chip to monitor up to 6 channels helps reduce overall cost and size
  - **Reporting** of safety faults (stored in the memory) via the I^2C
  - **Wide** voltage monitoring range: Flexibility to monitor a wide voltage range with high-resolution steps
  - **Configurable** voltage thresholds: Flexibility to configure the OV/UV threshold on demand.
  - **Sequence recording**: Sequence monitoring via one or multiple voltage monitors can be achieved to supervise a safe power-on/-off sequence.
- Voltage monitor has tolerance. There are **trade-offs (either early OV/UV faults or miss some OV/UV faults)** when setting up thresholds for system voltage monitoring.

Thank You!

Questions?