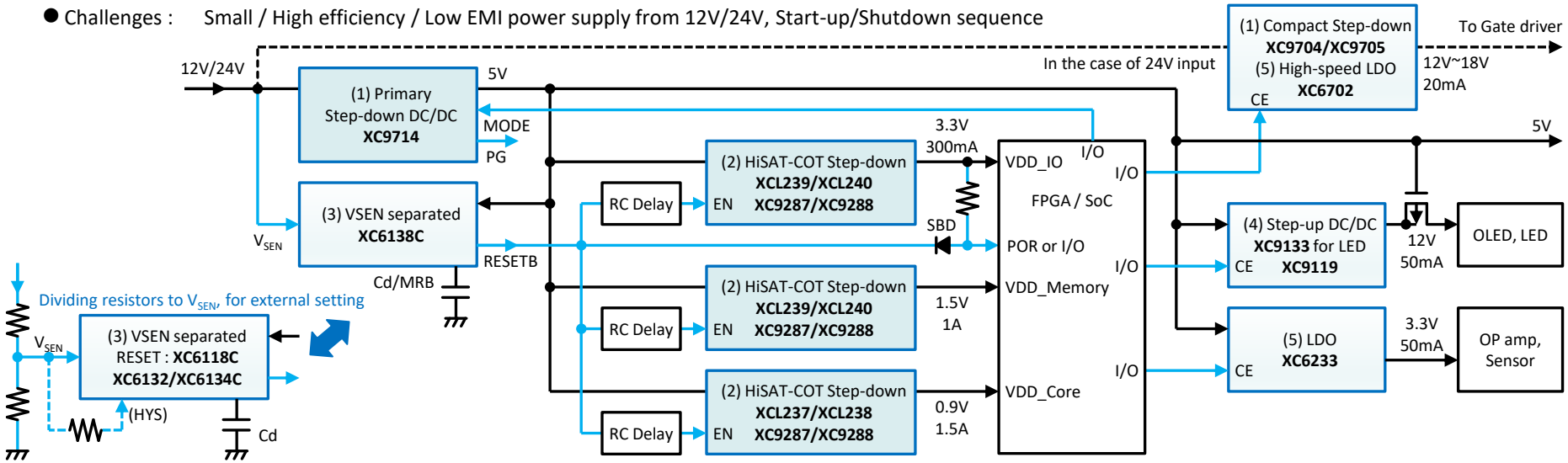
12V/24V : Multiple Power Rail Solutions

12V/24V POL multiple rail power supply

● Challenges : Small / High efficiency / Low EMI power supply from 12V/24V, Start-up/Shutdown sequence



Block1	Product	Features
(1) Primary Step-down DC/DC	**XC9714** NEW	36V, F-PWM - PWM/PFM MODE selectable 800kHz, 2A, Low Iq=9μA
	XC9704 / XC9705 FEATURED	36V, F-PWM, PWM/PFM, 1.2MHz/2.2MHz, 600mA Low Iq=11μA, Space-saving, High efficiency at light load
(2) Step-down DC/DC	**XCL239 / XCL240** **XCL237 / XCL238** FEATURED	Built-in inductor, HiSAT-COT, F-PWM, PWM/PFM 1A (XCL239/XCL240), 1.5A (XCL237/XCL238) **Others : XC9287/XC9288 1.5A,1.2MHz/3MHz**
(3) RESET IC	**XC6138** FEATURED	High Voltage Low Iq Sense pin: 76V, 0.15μA@12V Ultra-low Iq 0.5μA, Release Delay adj., Selectable Hysteresis
	XC6118	Separated Sense pin, Low Iq, Delay adj. **Others : XC6132/XC6134**, Externally adjustable hysteresis
(4) Step-up DC/DC	**XC9119 / XC9133**	~19.5V, PWM, 1MHz, 100mA@5V→12V, For LED: XC9133
(5) LDO	**XC6233**	High-speed PSRR=75dB, 200mA, Inrush prevention
	XC6702	36V, High-speed PSRR=65dB, 300mA, V_{OUT}=1.8V~18V Fixed

(1) Primary Step-down DC/DC for 12V/24V input

Wide input voltage range **to handle input line overshoot**. **Space-saving** including peripheral components. **High efficiency even at light loads**. Low noise by switching between F-PWM and PWM/PFM using the **MODE pin**.

(2) Step-down DC/DC for FPGA/SoC (POL power supply)

High-speed transient response HiSAT-COT controlled DC/DC arranged as POL.
Built-in inductor Micro DC/DC realizes miniaturization and low EMI.
(XCL239/XCL240, XCL237/XCL238)

(3) 12V/24V input monitoring Voltage Detector

12V/24V input monitoring and driving RC delay for Start-up/Shutdown sequence.
Outputs voltage drop signal to FPGA/SoC, then shutdown each DC/DC.

(1)(5) LDO for Gate-Driver Voltage Supply, Space-Saving Step-down DC/DC

High-Voltage LDO : **XC6702**, Step-down DC/DC : **XC9704/XC9705**

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Medium and High Voltage Input Step-down DC/DC

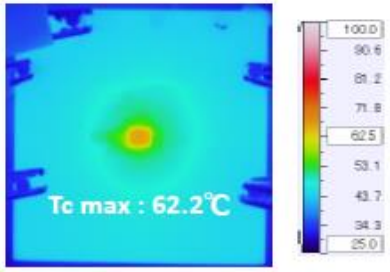
Step-down DC/DC for fluctuating 12V/24V and higher inputs.

Technical trend and challenges

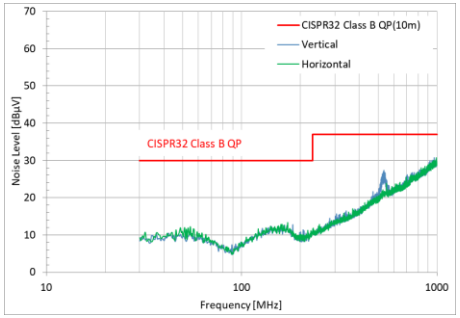
- The increased output current due to the higher functionality of devices makes the heat generated by using LDOs a problem.
- Large fluctuations in the power supply line due to impedance, load fluctuations and induction from motors, etc., must be addressed.

TOREX Proposal : Built-in inductor Micro DC/DC that can be used like an LDO

- Built-in inductor DC/DC can be used like an LDO, and achieves high efficiency. Low EMI, low heat generation, ideal for replacing LDOs.
- **XCL249** 60V Built-in inductor step-down DC/DC that can handle voltage fluctuations such as motor operation



Surface temperature



Radiation Noise CISPR-32(10m)

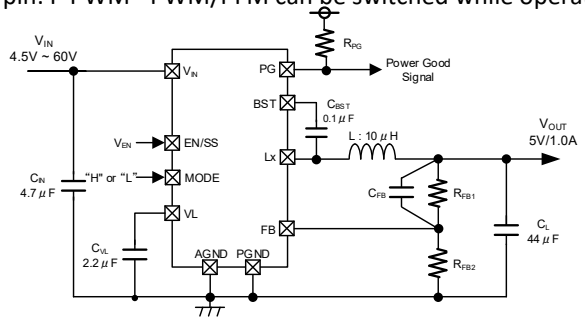
Built-in inductor step-down Micro DC/DC XCL247/XCL248 @12V→5V/600mA

36V/60V Built-in inductor step-down Micro DC/DC

Product	Features	V_{IN} (V)	V_{OUT} (V)	I_{OUT} (mA)	Package
XCL247 **XCL248** FEATURED	Built-in inductor F-PWM, PWM/PFM 1.2MHz	3.0 ~ 36.0	2.8 ~ 6.0	600	DFN3030-10B (3.0x3.0x1.7mm)
XCL249 UNDER DEVELOPMENT	Built-in inductor F-PWM, PWM/PFM	4.5 ~ 60.0	2.5 ~ 6.0	150	CL-3225 (3.2x2.5x2.2mm)

TOREX Proposal : 36V/60V Step-down DC/DC for main power supply.

- World's smallest class of low current consumption at high voltage
- Tj 150°C operation / Low ripple / High step-down ratio
- Large capacitance support (Soft-start external adj. + PG)
- MODE pin: F-PWM - PWM/PFM can be switched while operating.



Step-down DC/DC : XC9711, XC9714

36V/60V Step-down DC/DC

Product	Features	V_{IN} (V)	V_{OUT} (V)	I_{OUT} (mA)	Package
XC9704 **XC9705** FEATURED	F-PWM, PWM/PFM 1.2MHz, 2.2MHz	3.0 ~ 36.0	2.8 ~ 15 2.8 ~ 18	600	SOT-89-5 (4.5x4.6x1.6mm) USP-6C (1.8x2.0x0.6mm)
XC9714 NEW	F-PWM, PWM/PFM 800kHz	4.5 ~ 36.0	2.5 ~ 18	2000	HSOP-8N (6.2x5.2x1.7mm) DFN3030-12A(3.0x3.0x0.75mm)
XC9711 NEW	F-PWM, PWM/PFM 800kHz	4.5 ~ 60.0	2.5 ~ 18	1000	HSOP-8N (6.2x5.2x1.7mm) DFN3030-12A(3.0x3.0x0.75mm)
XC9702 FEATURED	F-PWM, PWM/PFM 1MHz	4.5 ~ 60.0	2.5 ~ 12	300	HSOP-8N (6.2x5.2x1.7mm) DFN3030-12A(3.0x3.0x0.75mm) USP-10B(2.6x2.9x0.6mm)

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HiSAT-COT® Control for Fast Transient Response

TOREX original COT control : HiSAT-COT®

● Technical trend and challenges

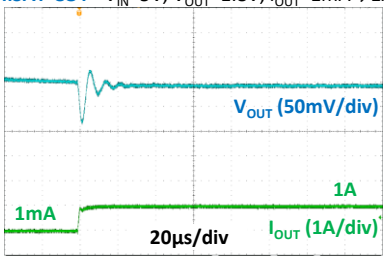
- Stable power supply including transient response to MCU/SoC/FPGA, etc.
- Miniaturization of circuits including peripheral components, and low EMI.

● TOREX Proposal : HiSAT-COT® controlled Step-down DC/DC converter

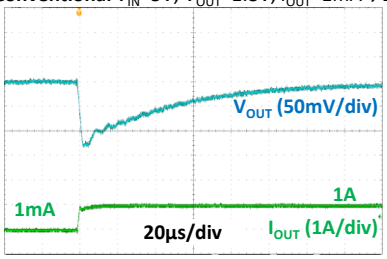
➢ Significantly faster transient response

- Compared to conventional PWM and PWM/PFM control, it achieves **overwhelmingly fast response** and thus **good voltage stability**.

HiSAT-COT® V_{IN}=5V, V_{OUT}=1.8V, I_{OUT}=1mA→1A



Conventional V_{IN}=5V, V_{OUT}=1.8V, I_{OUT}=1mA→1A

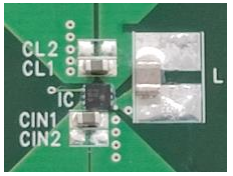


➢ Miniaturization including peripheral components

- High-speed transient response enables **significant reduction of large capacitance** required due to lack of response of conventional PWM.
- Unlike conventional PWM phase compensation, load capacitance CL can be reduced. Also **supports a significant reduction in effective capacitance due to the bias effect of ultra-small Ceramic capacitors.**

HiSAT-COT®

Conventional



➢ Ideal for FPGA/SoC POL power supplies due to its compact size and high-speed response

Overview of COT control and HiSAT-COT®

What is COT (Constant on time) control?

- PFM control with the "ton" determined by V_{IN} and V_{OUT} voltages, resulting that appears to be PWM control with constant frequency (fosc).
  High-speed PFM comparator enables fast transient response.
- Generate **"ton"** in CCM of the targeted fosc from the V_{IN} and V_{OUT} set voltages so that it appears to be a constant frequency PWM control.

● CCM (Continuous Conduction Mode) operation

- Ideal Duty ratio and ton of step-down DC/DC at CCM PWM operation are
  ton = (1/fosc) x Duty = (1/fosc) x (V_{OUT} / V_{IN}) .
  If there is no loss, **Duty ratio is constant** even if I_{OUT} rises.

● How to determine the oscillation frequency of COT control

- Generate the ton of COT control to be the ton of ideal PWM control.
- Continuous mode operation with this ton operates with the same duty as PWM control at the oscillation frequency fosc.

● COT issues and HiSAT-COT®

HiSAT-COT improves the issues of COT control with its own circuits.

- Improved issue of increased oscillation frequency due to output current.
- Improved the deterioration of load stability with an original circuit with an additional amplifier.

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TOREX Built-In Inductor Micro DC/DC for Achieving Small / Low EMI

TOREX original Built-in inductor Micro DC/DC XCL Series

Technical trend and challenges

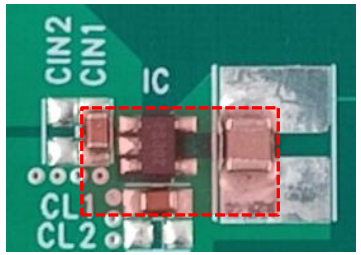
- For stable operation of devices, it is important to place power supply ICs close to MCUs and FPGAs. Especially in cases where multiple power supplies are required, selecting power supply ICs suitable for POL (Point of Load) is a challenge.
- Miniaturization of power circuits including ICs and low EMI are essential.

TOREX Proposal : Built-in inductor Micro DC/DC

➢**Significant miniaturization of power supply circuit**

- Achieves a significant reduction in mounting area and providing smallest class of power supply solution.
- Unique package structure / Optimum inductor for the internal IC.
- Efficient heat dissipation performance with structures that connect IC/coil and substrate with low thermal resistance.

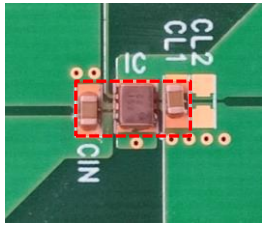
9.6×5.8mm = 56mm²



Stand-alone DC/DC
External parts : 3 pcs

65% reduction

6.5×3.0mm = 19.5mm²



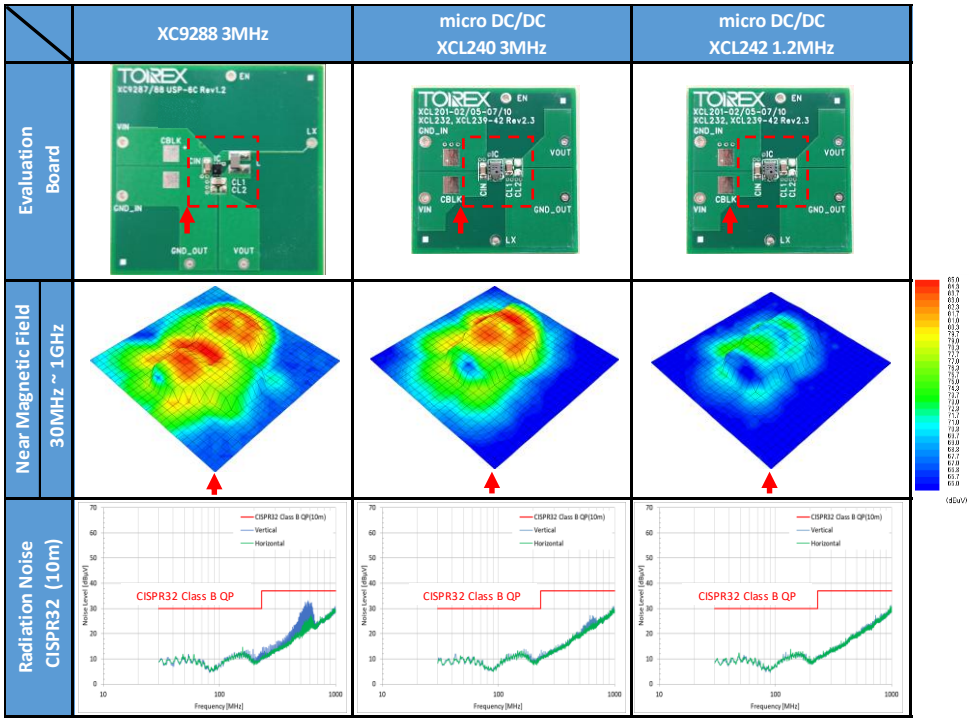
Built-in inductor Micro DC/DC
External parts : 2 pcs

➢**EMI reduction due to unique Built-in inductor structure**

✓The pocket-type structure covering the IC with a coil and the optimum placement of the IC enable a **significant reduction of radiated noise** compared to the stand-alone IC.

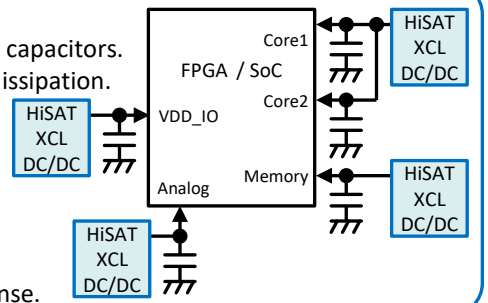
✓Can be placed near RF ICs/Sensors, etc., contributing to miniaturization.

EMI comparison of Built-in inductor Micro DC/DC and stand-alone DC/DC



Benefits of POL (Point of Load) power supply and Micro DC/DC & HiSAT-COT®

- Shorter power supply wiring length.
  In addition to stable operation, reduced capacitors.
  Heat source dispersion facilitates heat dissipation.
- Using **Micro DC/DC XCL Series** with built-in inductor for **POL converter** enables further miniaturization, lower EMI, and easier design.
- **HiSAT-COT** provides highly stable power supply, including transient response.



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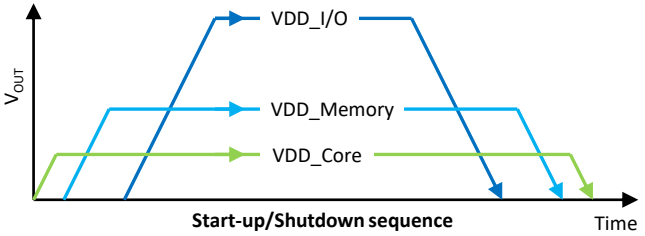
Start-up/Shutdown Sequence Control of Multiple Power Rails

For multiple power rails of SoC/FPGA, Start-up/Shutdown Sequence Control

Technical trend and challenges

- Start-up/shutdown sequences are required for multiple power rails for such as SoC/FPGA.
- As well as starting up using PG of each DC/DC, it is also important to shut down safely under control.

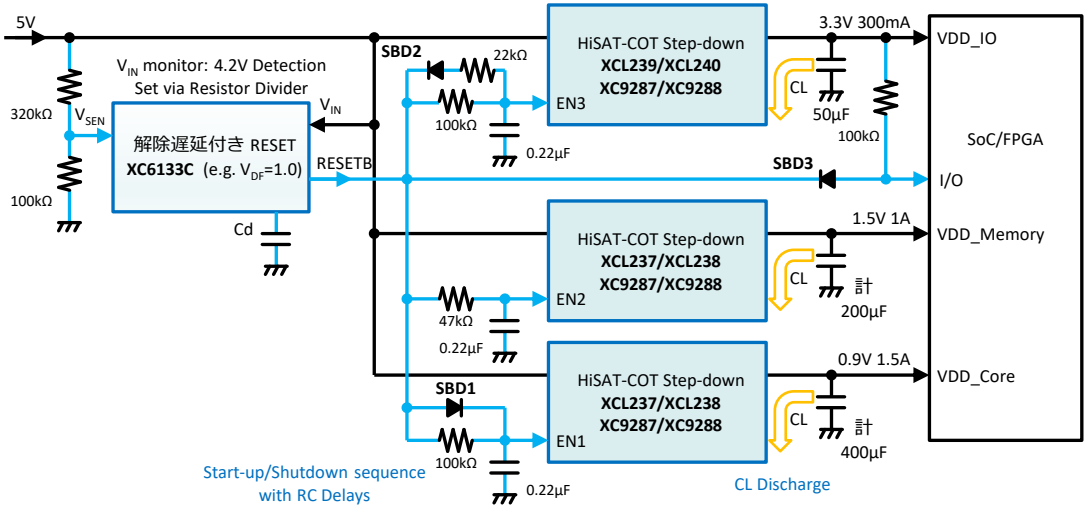


TOREX Proposal : Start-up/shutdown sequence using EN voltage and CL discharge of DC/DC converter

- By applying an RC delay to the EN pin, both start-up and shutdown sequencing can be realized. (Conventional Power Good pin methods typically support start-up sequencing only.)

The rise of each voltage line is via soft start, and the fall is via CL discharge. The timing is controlled by the RC delay at the EN pin of each DC/DC converter.

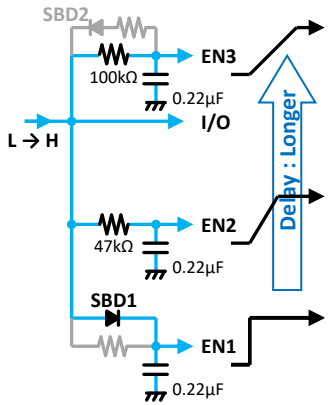
➢ **Circuit Example Using a Reset IC, RC Delays, and DC/DC Converters**



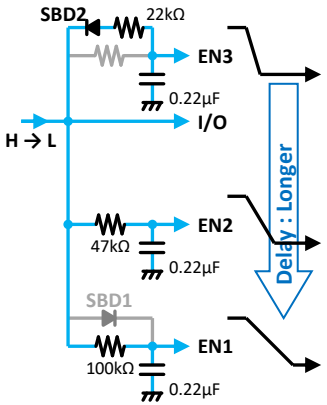
- A RESET IC monitoring the 5V rail drives the RC-delay networks connected to each EN pin. The ON/OFF timing of each EN pin is controlled by the corresponding RC delay.
- **Start-up** : **SBD1** bypasses the RC delay on **EN1**, asserting **EN1** and bringing up **VDD_Core**. Subsequently, **EN2 and EN3** turn ON in order according to their RC delays, powering **VDD_Memory and VDD_IO**.
- **Shutdown** : Through **SBD3**, **the SoC/FPGA I/O** is notified, and the SoC/FPGA executes a shutdown routine. Then **EN3** is driven via **SBD2** through its RC network to turn **VDD_IO** OFF. Following the RC delays, **EN2 and EN1** turn OFF in sequence, shutting down **VDD_Memory and VDD_Core**.

EN Pin ON/OFF Sequencing Control via RC Delays

Startup: RC & EN1–EN3



Shutdown: RC & EN1–EN3



The RC values are switched by the operation of SBD1 and SBD2 during start-up and shutdown.
(**Greyed out** indicates components disabled by SBD operation)

Appendix : The delay time until each DC/DC turns ON/OFF is

$$t_{delay(ON)} = R \times C \times (-\ln((V_{IN} - V_{EN}) / V_{IN}))$$

$$t_{delay(OFF)} = R \times C \times (-\ln(V_{EN} / V_{IN}))$$

V_{EN} : Threshold voltage of EN

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Reset IC Application Examples

Monitoring of 12V/24V input lines with large voltage fluctuations

Technical trend and challenges

- It is necessary to monitor large voltage fluctuations in the power supply line due to loads such as motors and input impedance.
  Set the detect /release voltage to suit the application.

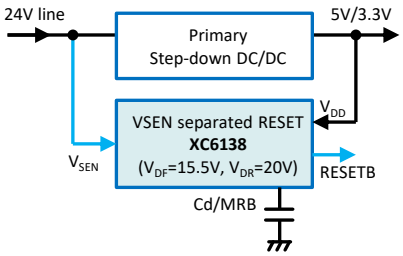
TOREX Proposal : Reset IC with high voltage tolerance and a wide range of detect/release voltages

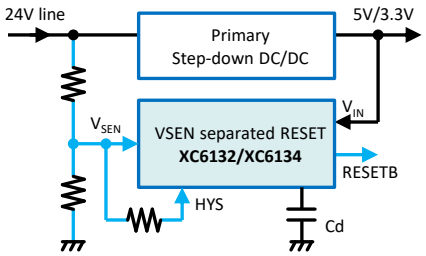
➢ **Wide range of detect/release voltage difference (hysteresis) supported**

- Separate sense pin type, monitoring 12V/24V lines.
- Select a release voltage high enough to ensure a stable rise and select a detect voltage sufficiently different from the release voltage.

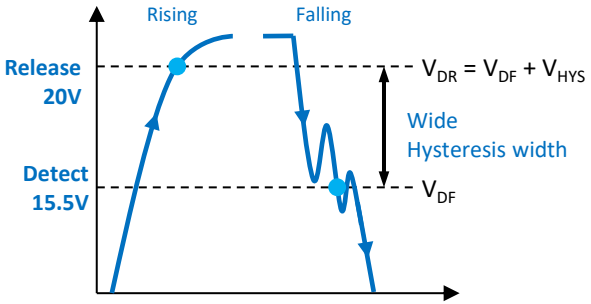
XC6138, XD6138
76V High voltage Sense pin
Wide hysteresis range selectable.

XC6132/XC6134, XD6132/XD6134
Detect and release voltages are set using external resistors.
(**XC/XD6132** has V_{SEN} pin surge protection)





Example of 24V line voltage monitoring



USB port Overvoltage protection (OVP)

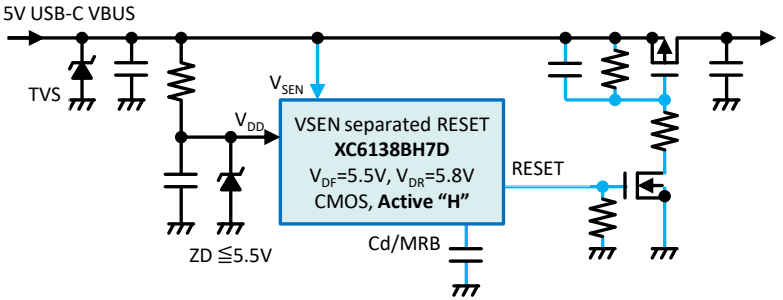
Technical trend and challenges

- The proliferation of low-cost USB-PD adapters poses a challenge, as overshoot on 5V USB or the application of voltages exceeding specifications can damage downstream systems.

TOREX Proposal : Overvoltage protection with a reset IC suitable for 5V USB

➢ **Simple implementation with XC6138BH7D + external Pch FETs.**

- **XC6138BH7D : Outputs 'L' at 5.8V, turning the Pch FET OFF**
  Outputs 'H' at 5.5V, turning the Pch FET ON
- TVS and each FET are selected to match the permissible input voltage.
- Apply <6V to the V_{DD} pin via ZD.
- To counter inrush current during start-up, implement a simple soft-start by adding capacitance between the gate and source of the Pch FET.



Block	Product	Features
RESET IC	**XC6138** FEATURED	High Voltage Sense pin: 76V, Ultra-low Iq V_{DD}: 0.5µA, V_{SEN}: 0.15µA@12V Detect/Release Delay external adj., Selectable Hysteresis
	XC6118 **XC6134**	Separated Sense pin, Low Iq, Adj. Release delay, Hysteresis adj. (XC6134)

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