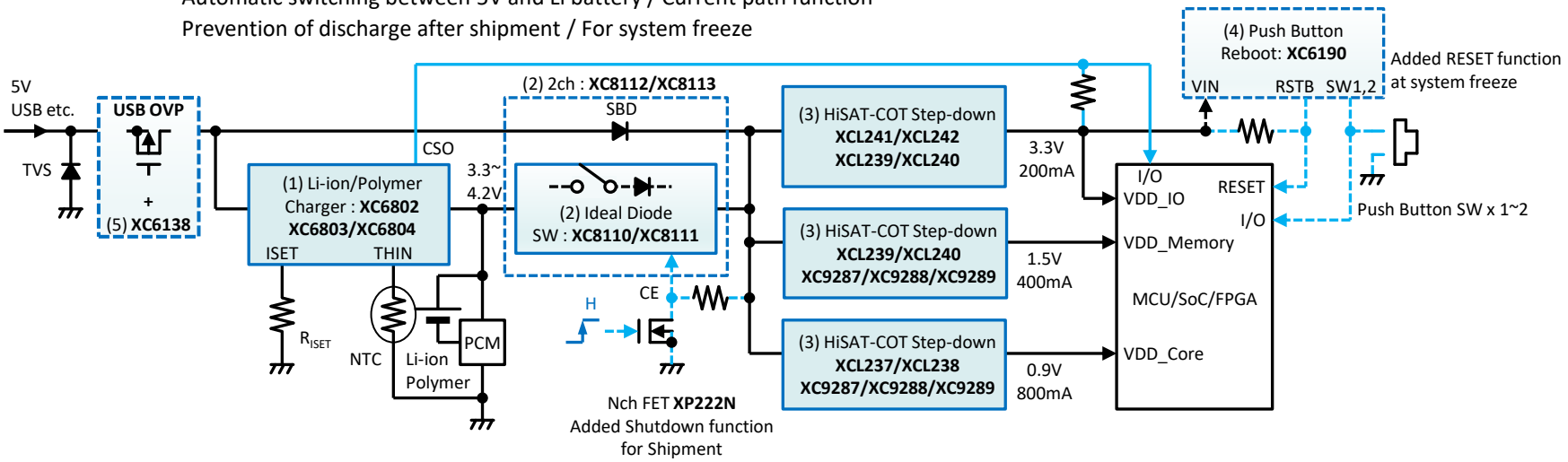
Li Rechargeable Battery : Multiple Power Rail Solutions

■ Products that requires multi-voltage from Li-ion/Polymer Rechargeable battery

● Challenges : Small / High efficiency / High-speed response / Low EMI Step-down DC/DC
Automatic switching between 5V and Li battery / Current path function
Prevention of discharge after shipment / For system freeze



Block	Product	Features
(1) Li Charger IC	XC6803 / XC6804	CC/CV Charger, CC=~280/800mA,Battery Temperature Monitor
(2) Ideal diode SW	XC8110 / XC8111	True Reverse current prevention Ideal Diode Load SW VF=20mV, 500mA (XC8110), 1A (XC8111), IEC 62368-1 certified
	XC8112 / XC8113	2ch True Reverse current prevention Ideal Diode SW, VF=20mV 2ch x 500mA (XC8110), 2ch x 1A (XC8111), IEC 62368-1 certified
(3) Step-down DC/DC	XCL241 / XCL242	Built-in inductor, HiSAT-COT, F-PWM, PWM/PFM 1.2MHz, 500mA, Ultra-low EMI
	XCL239 / XCL240 XCL237 / XCL238	Built-in inductor, HiSAT-COT, F-PWM, PWM/PFM 1A (XCL239/XCL240), 1.5A (XCL237/XCL238)
	XC9287 / XC9288 XC9289	HiSAT-COT, F-PWM, PWM/PFM, Selectable by MODE 1.2MHz/3MHz, 1.5A
(4) Reboot IC	XC6190	For system freeze, Hold SW 1 and 2 "L" to output reset signal
(5) Reset IC	XC6138	High Voltage Sense pin: 76V, Wide hysteresis

(2) Ideal Diode Load SW : XC8110/XC8111

Ideal Diode achieves **automatic switching between 5V input and Li battery**
VF loss is also reduced. Adding Nch FET enables Shutdown function at shipment.
2ch type XC8112/XC8113 achieves low loss for both 5V input and Li-ion battery.

(3) Step-down DC/DC for MPU/Memory/FPGA (POL converter)

HiSAT-COT controlled DC/DC with high-speed transient response
arranged as POL power supply.
Built-in inductor Micro DC/DC achieves miniaturization and low EMI.

(4) Push Button Reboot controller : XC6190

Added Push Button Reboot IC that can **reboot the system by long pressing the physical SW** for freeze countermeasure.
Physical SW can be shared with other uses.

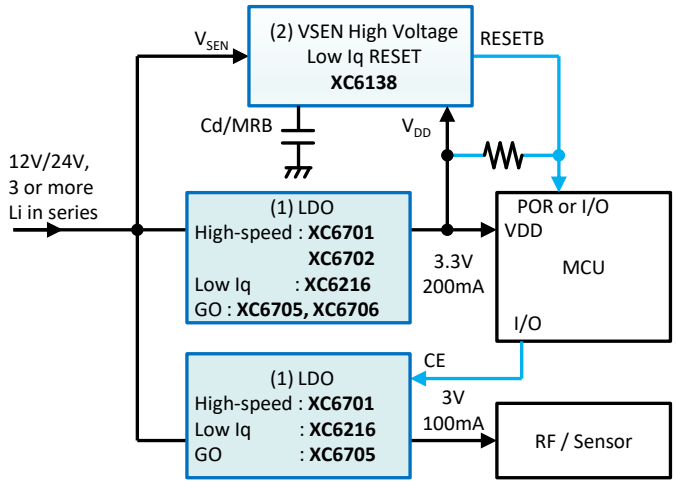
(5) RESET IC for OVP (Over Voltage Protection) of USB input : XC6138

12V/24V, Li Multi-Cell and 4-Dry Cell Solutions

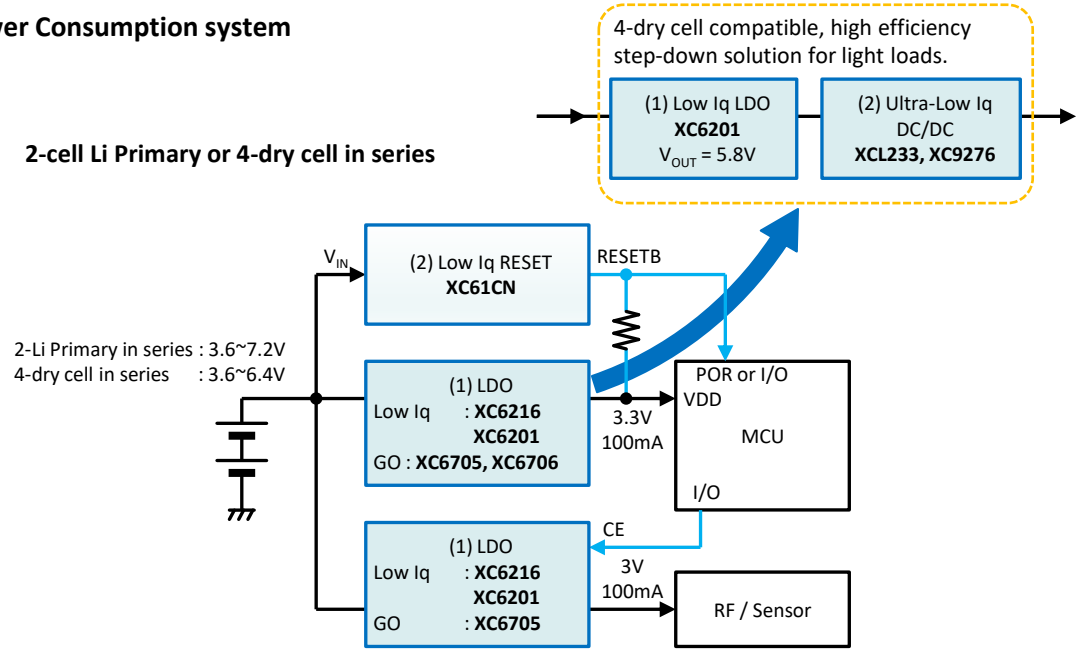
12V/24V input, Li multi-cell and 4-dry cell operation: Low Power Consumption system

● Challenges : Small / Low Iq / Simple
Load transient response to RF/Sensor

12V/24V or 3 or more Li in series input



2-cell Li Primary or 4-dry cell in series



Block	Product	Features
(1) LDO	**XC6701**	28V, High-speed PSRR=50dB, 150mA
	XC6702	36V, High-speed PSRR=65dB, 300mA
	XC6216	28V, Iq=5μA, 150mA
	XC6705 / XC6706	20V, Iq=1.2μA, 200mA PSRR=50dB, Seamless GO, Soft-start, CE (XC6705)
	XC6201	10V, Iq=2.0μA, 200mA
(2) Step-down DC/DC	**XCL233**	Built-in inductor, Iq=200nA, PFM, 150mA, VSET(V_{OUT} selectable)
	XC9276	Iq=200nA, PFM, 150mA, VSET(V_{OUT} selectable)
(3) RESET IC	**XC6138**	High Voltage Sense pin: 76V, Ultra-low Iq V_{DD}: 0.5μA, V_{SEN}: 0.15μA@12V Detect/Release Delay external adj., Selectable Hysteresis
	XC61CN	10V, Iq=0.7μA

(1) Medium Voltage LDO

● **For 12V/24V or 3 or more Li in series input**
Selecting by input voltage range and current consumption.

● **For 2-Li / 4-dry cell in series : XC6705/XC6706**
Seamless GO achieves both low Iq and high-speed response.
Supports high-speed response required by RF and Sensor.

(2) 2-Li and 4-dry cell compatible, high efficiency Step-down solution for light loads

● 10V low Iq LDO **XC6201** + ultra-low Iq step-down **XCL233/XC9276**.

(3) RESET IC

● **Direct monitoring of 12V/24V input with V_{SEN} pin of XC6138**
No dividing resistors required resulting in low Iq and high accuracy.

● For 10V or less, monitoring voltage with low Iq RESET IC **XC61CN**.

Further Lower Consumption / Battery Life : Ideal Diode, Push Button Load SW

Ideal Diode to reduce power loss of diode

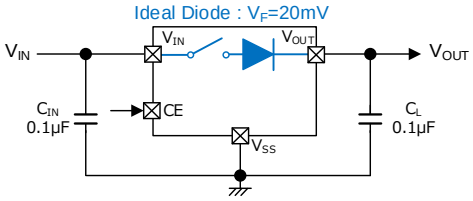
Technical trend and challenges

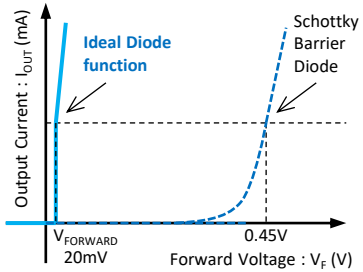
- Many diodes used in each power lines for reverse current prevention, etc.
- SBD generates about 0.4V of VF loss and reverse current due to leakage, and the loss is more than 0.4W at IF=1A, which is an obstacle to high efficiency and miniaturization.

TOREX Proposal : Significantly reducing VF loss

➢ **Ideal Diode Load SW: XC8110 / XC8111, XC8112 / XC8113**

- Achieving **VF=20mV. Loss is 1/20 of SBD**@200mA or less and 1/6@500mA. Parallel connection of XC8112/XC8113 halves VF at high current. Leakage current is 0 µA, preventing reverse current harmful to batteries.
- **IEC 62368-1:2018 certified** with current limit and other protections.





Ideal Diode Load Switch

Product	Features	V_{IN} (V)	Ron	I_{OUT}	Package
XC8110	VF=20mV 3.6µA (Forward bias) 0µA (Reverse bias) IEC 62368-1:2018 certified	1.5 ~ 6.0	120mΩ	500mA	WLP-4-02 (0.82x0.82x0.5mm) SOT-25 (2.9x2.8x1.3mm) USP-6B06 (1.8x1.5x0.33mm)
XC8111				1A	
XC8114			60mΩ	3A	WLP-4-04 (0.82x1.48x0.495mm) SOT-89-5 (4.5x4.6x1.6mm) DFN1820-6G (1.8x2.0x0.6mm)
XC8112	2ch (Parallel is allowed) VF=20mV 3.6µA (Forward bias) 0µA (Reverse bias) IEC 62368-1:2018 certified		2ch x 120mΩ	2 x 500mA	USP-8B06 (2.0x2.0x0.33mm)
XC8113				2 x 1A	

"Ship function" to prevent battery discharge during shipment.

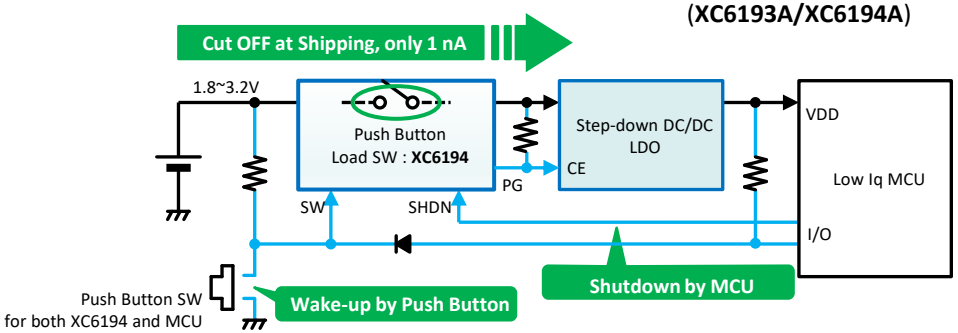
Technical trend and challenges

- Discharge current from the battery after shipment is so large that the battery may not be usable at the time of usage.
- Due to an increase in the number of devices with built-in batteries and the need to ensure water resistance, the conventional method of preventing discharge by using plastic insulating tabs has become difficult.

TOREX Proposal : Preventing battery discharge by Ship function

➢ **Push Button Load SW: XC6194 (1A) / XC6193 (1A + External Pch FET)**

- **Ship function** greatly reduces discharge after shipment to 1nA.
- **Useful as main power switch as well.**
  Turn ON by the push-button, and OFF by the signal from MCU to SHDN after processing termination. Safety shutdown is possible.
- **At system freeze**, long pressing the push button forces OFF.
  (XC6193A/XC6194A)



Push Button Load Switch with Ship function

Product	Features	V_{IN} (V)	Ron	I_{OUT}	Package
XC6193	I_{STB}=1nA Shutdown function (Ship/Main power SW) For system freeze (XC6193A/XC6194A) UVLO: Prevents battery leakage	1.8 ~ 6.0	Internal 1A + External Pch FET		USP-8B06 (2.0x2.0x0.33mm)
XC6194			140mΩ	1A	

HiSAT-COT® Control for Fast Transient Response

TOREX original COT control : HiSAT-COT®

Technical trend and challenges

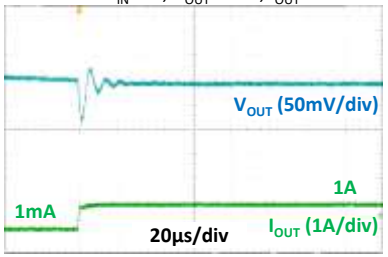
- Stable power supply including transient response to MCU/SoC/FPGA, etc.
- Miniaturization of circuits including peripheral components, and low EMI.

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

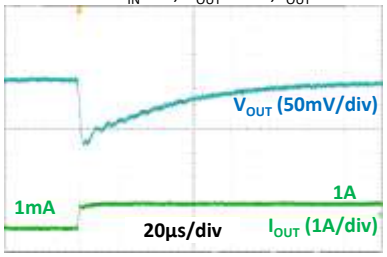
➢ **Significantly faster transient response**

- 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

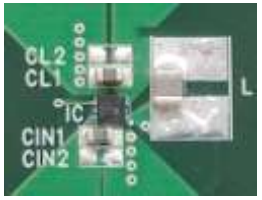


➢ **Miniaturization including peripheral components**

- 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

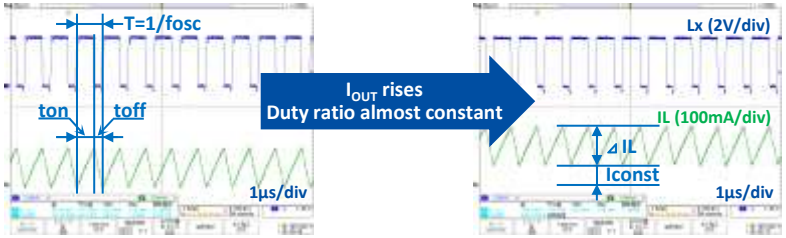


Overview of COT control and HiSAT-COT®

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.

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.

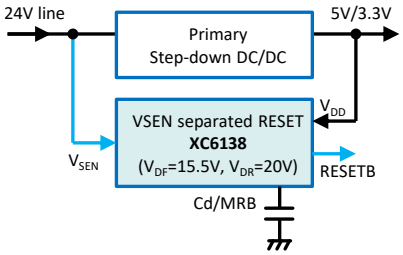
TOREX Proposal : Reset IC with high voltage tolerance and a wide range of detect/release voltages

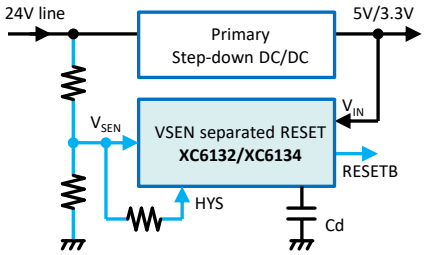
➢ **Wide range of detect/release voltage difference (hysteresis) supported**

- 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.

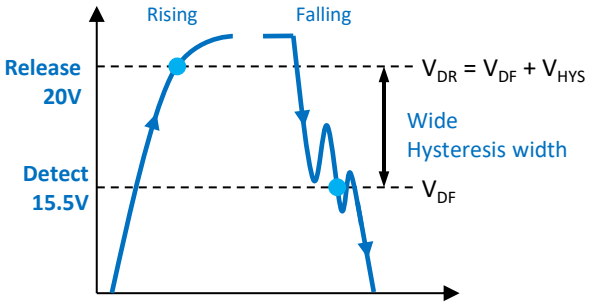
XC6138
76V High voltage Sense pin
Wide hysteresis range selectable.

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





Example of 24V line voltage monitoring



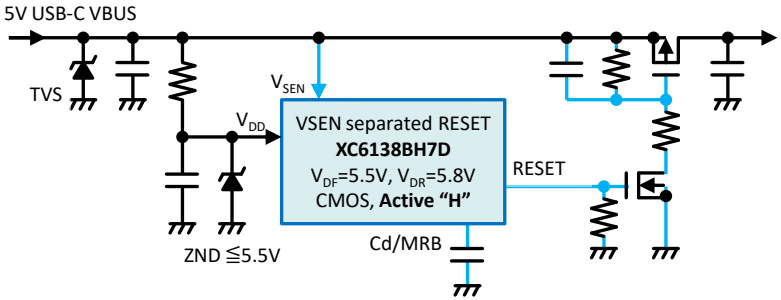
USB port Overvoltage protection (OVP)

Technical trend and challenges

- 5V USB overshoot is an issue due to the spread of low-cost USB-PD adapters.

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

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



Simple MPPT using an ultra-low Iq reset IC and a step-up DC/DC

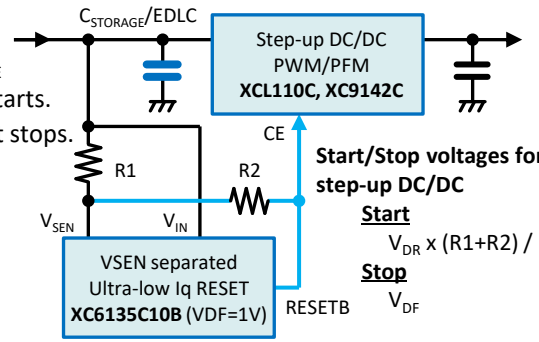
Technical trend and challenges

- ON/OFF control of step-up DC/DC in response to changes in input voltage is important for energy harvesting and backup power supply from EDLC.

TOREX Proposal : Input voltage monitoring using an ultra-low Iq reset IC

➢ **Creating hysteresis with XC6135 + resistors**

- **Energy Harvesting**
  When voltage of $C_{STORAGE}$ rises enough, boosting starts. When the voltage falls, it stops.
- **EDLC for backup**
  When the EDLC voltage rises enough, backup supply starts. When the voltage falls, it stops.



Start/Stop voltages for step-up DC/DC
Start
V_{DR} x (R1+R2) / R2
Stop
V_{DF}