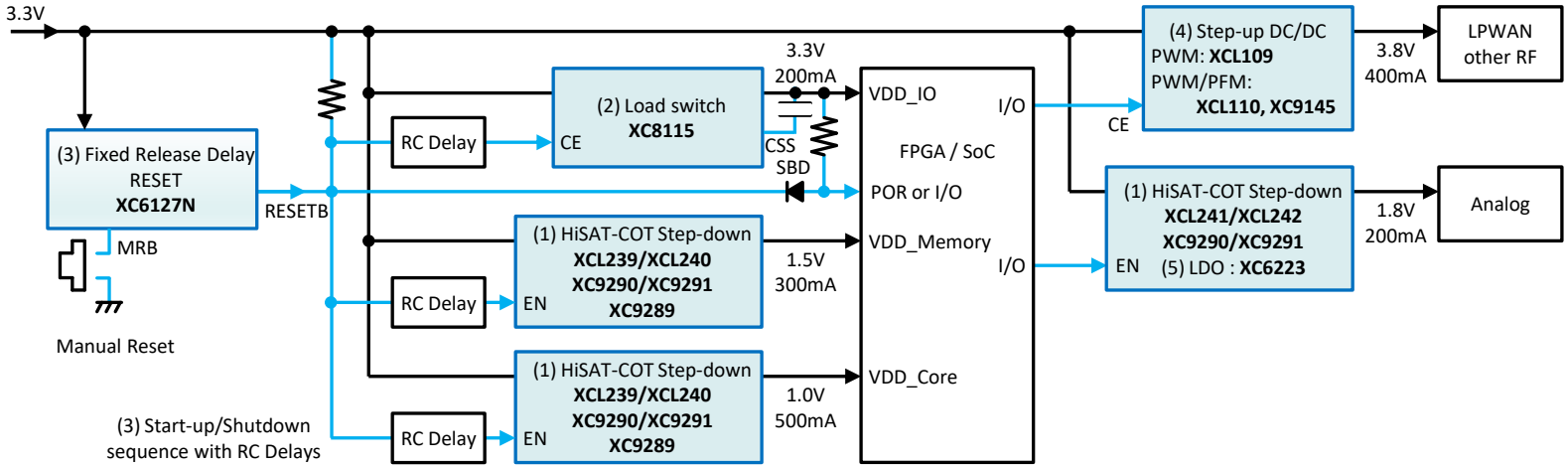
3.3V : Small Solutions for Multiple Power Rails

■ Compact multiple power supplies for MCU/SoC/FPGA, sensors, and various modules

● Challenges : Fast transient response/High stability, Small size/High efficiency/Heat dispersion/Low EMI, Start-up/Shutdown sequence



Block	Product	Features
(1) Step-down DC/DC	**XCL241 / XCL242** FEATURED	Built-in inductor, HiSAT-COT, F-PWM, PWM/PFM 1.2MHz, 500mA, Ultra-low EMI
	XCL239 / XCL240 FEATURED	Built-in inductor, HiSAT-COT, F-PWM, PWM/PFM 3MHz, 1A
	XC9289 FEATURED	HiSAT-COT, Ultra-small, F-PWM-PWM/PFM MODE selectable 1.2MHz/3MHz, 1.5A
	XC9290 / XC9291 FEATURED	HiSAT-COT, Smallest area, F-PWM, PWM/PFM 4MHz/6MHz, 600mA
(2) Load Switch	**XC8115** UNDER DEVELOPMENT	Ultra-low Iq Iq=0μA, Adj. soft start, 1A
(3) RESET IC	**XC6127**	Low Iq, High accuracy, Selectable Release delay, Manual reset
(4) Step-up DC/DC	**XCL109 / XCL110** FEATURED	Built-in inductor, Small but high current, F-PWM, PWM/PFM 1.2MHz, 610mA@3.3V→5V
	XC9145 FEATURED	Ultra-low Iq: 400nA, PWM/PFM 1.2MHz, 430mA@3.3V→5V, V_{ST}=1.6V
(5) LDO	**XC6223**	High speed PSRR=80dB, 300mA, Inrush prevention

(1) Step-down DC/DC for MCU/SoC/FPGA, RF/Sensor (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.
(XCL241/XCL242, XCL239/XCL240)

For RF and other analogs requiring even lower noise
Ultra-low EMI Built-in inductor **Micro DC/DC XCL241/XCL242,**
World's smallest solution size XC9290/XC9291.

(2)(3) 3.3V input monitoring and Start-up/Shutdown Power supply sequence

Monitored by voltage detector with Manual reset function : **XC6127**
RC delay to the EN(CE) pin of each DC/DC is **driven by XC6127**
for start-up/shutdown sequence.
Ultra-low Iq load switch with soft-start external control and built-in CL discharge
for 3.3V line sequencing: **XC8115**

(4) Step-up DC/DC for LPWAN and other RF

Low ripple/Low EMI Built-in inductor **Micro DC/DC XCL109/XCL110** and **XC9145**

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HiSAT-COT® Control for Fast Transient Response

TOREX original COT control : HiSAT-COT®

● Technical trend and challenges

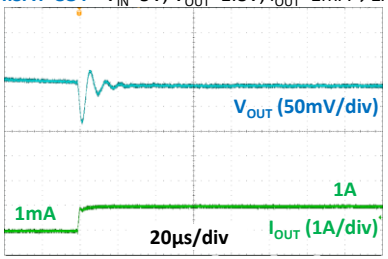
- Stable power supply including transient response to MCU/SoC/FPGA, etc.
- Miniaturization of circuits including peripheral components, and low EMI.

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

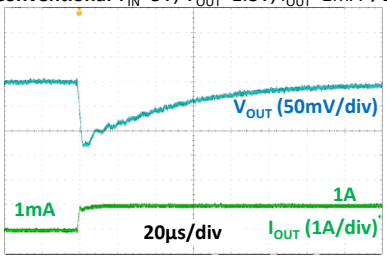
➢ Significantly faster transient response

- 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

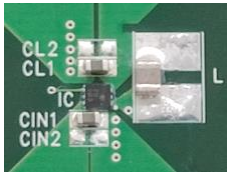


➢ Miniaturization including peripheral components

- 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

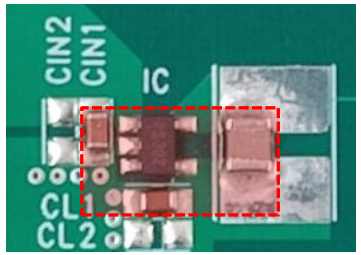
- For stable operation of devices, it is important to place power supply ICs close to MCUs and FPGAs. Especially in cases where multiple power supplies are required, selecting power supply ICs suitable for POL (Point of Load) is a challenge.
- Miniaturization of power circuits including ICs and low EMI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

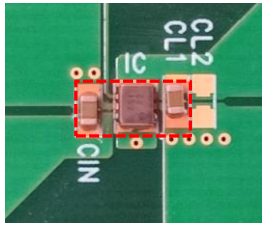
9.6×5.8mm = 56mm²



Stand-alone DC/DC
External parts : 3 pcs

65% reduction

6.5×3.0mm = 19.5mm²



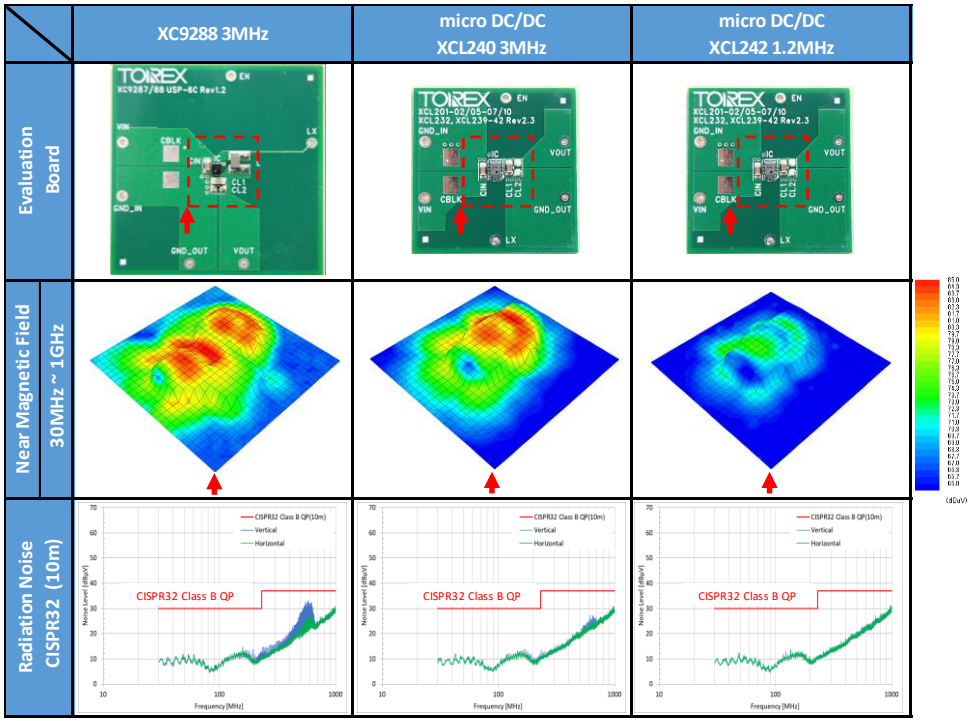
Built-in inductor Micro DC/DC
External parts : 2 pcs

➢**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.

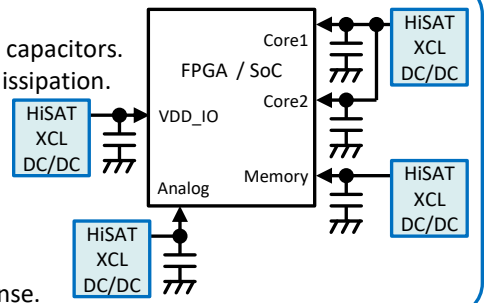
✓Can be placed near RF ICs/Sensors, etc., contributing to miniaturization.

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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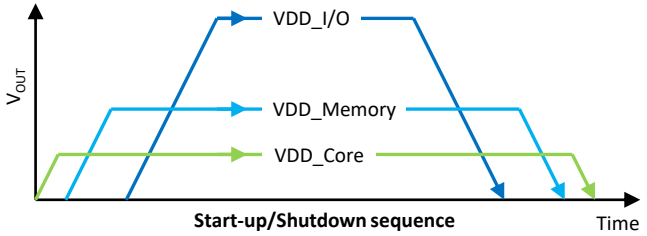
Start-up/Shutdown Sequence Control of Multiple Power Rails

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.

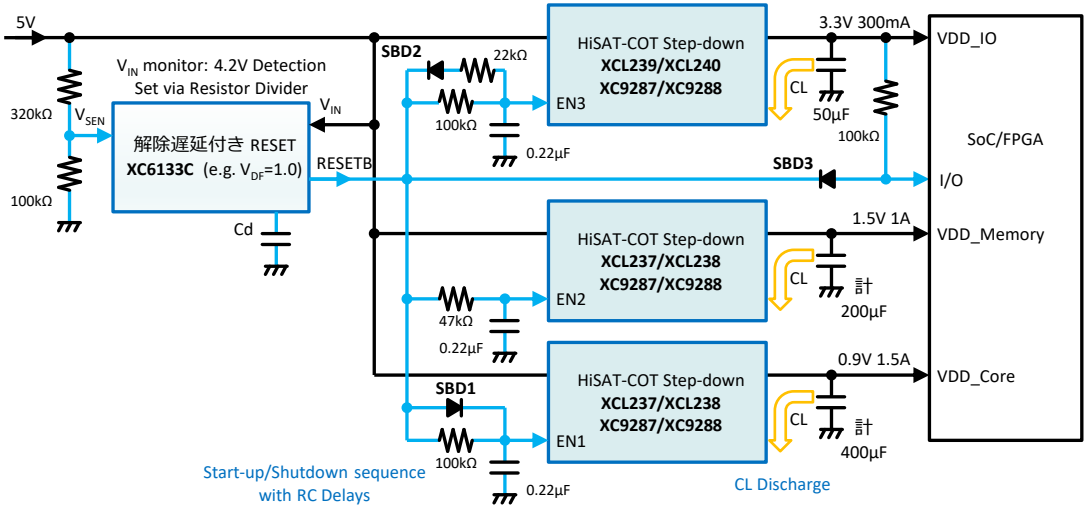


TOREX Proposal : Start-up/shutdown sequence using EN voltage and CL discharge of DC/DC converter

- 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.

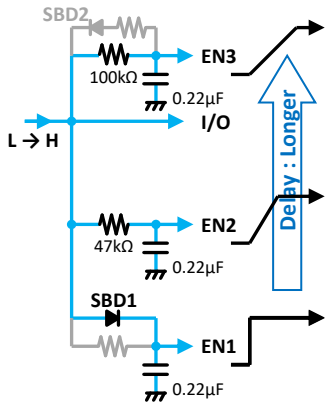
➢ **Circuit Example Using a Reset IC, RC Delays, and DC/DC Converters**



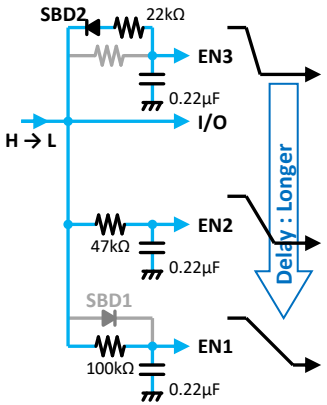
- A RESET IC monitoring the 5V rail drives the RC-delay networks connected to each EN pin. The ON/OFF timing of each EN pin is controlled by the corresponding RC delay.
- **Start-up** : **SBD1** bypasses the RC delay on **EN1**, asserting **EN1** and bringing up **VDD_Core**. Subsequently, **EN2 and 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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All-in-one Charger IC and Ultra-Low Iq Load Switch

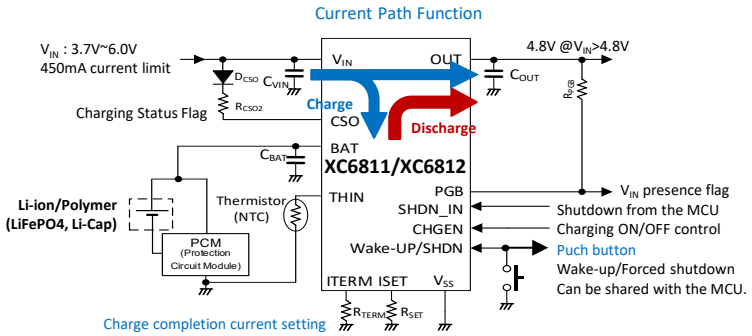
All-in-one Charger IC with Push Button Control and Current Path

Technical trend and challenges

- Miniaturization and higher performance in IoT sensors, wearables, and trackers
- Longer battery life and stable operation getting more critical: Precise charge control, discharge prevention(Ship Mode), and freeze-recovery measures

TOREX Proposal : All-in-one Charge Control in an Ultra-Compact Package

➢ **All-in-one Charger IC with Integrated Power-Path & Push-Button Control : XC6811/XC6812** UNDER DEVELOPMENT



Precise Charge Settings

CV : 3.1V~4.5V, **supports solid-state batteries, LiFePO4, and Li-Cap**
Externally Adj. CC : 1mA~50mA **(XC6811)**, 25mA~400mA **(XC6812)**。
Externally Adj. charge completion current : 0.1mA~10mA **(XC6811)**, 1mA~50mA **(XC6812)** Enables wide battery coverage and long-life design

Current Path

Separate control of battery charging and power supply to OUT
After full charge, powers OUT from V_{IN} without drawing from the battery

Wake-Up / Shutdown

Wake-up: Push button, or V_{IN} applied.
Shutdown: Signal from MCU to SHDN_IN. Also supports Ship mode.
Push button long press, as a countermeasure during freeze.

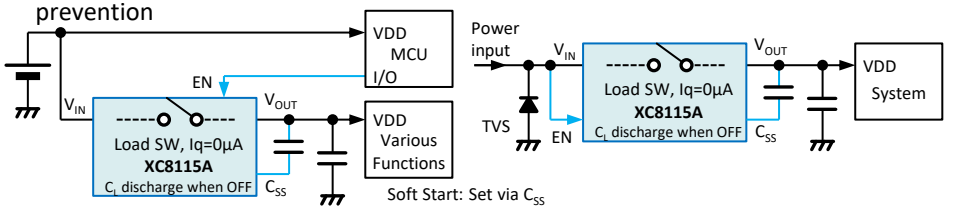
Ultra-Low Iq 0μA Load Switch

Technical trend and challenges

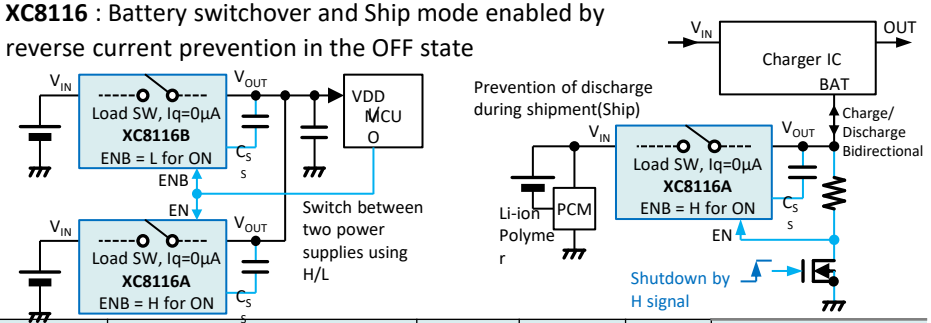
- Power distribution and line-by-line ON/OFF control with ultra-low power consumption.
- Inrush current prevention is essential to prevent voltage drops in battery or power lines.
- Battery/power line selection and battery disconnection (Ship mode) are essential for IoT devices.

TOREX Proposal : Ultra-low Iq I_{STB} / Iq = 0μA Load Switch IC : XC8115/XC8116

XC8115 : Power line ON/OFF and externally adj. soft start for inrush current prevention



XC8116 : Battery switchover and Ship mode enabled by reverse current prevention in the OFF state



Product	Features	V_{IN} (V)	Ron	I_{OUT}	Package
XC8115 UNDER DEVELOPMENT	I_{STB}/Iq = 0μA **Externally adj. soft start** **C_L discharge**	1.5 ~ 6.0	150mΩ	1.0A	DFN1515-6A (1.5x1.5x0.38mm) SOT-25 (2.8x2.9x1.3mm)
XC8116 UNDER DEVELOPMENT	I_{STB}/Iq = 0μA **Externally adj. soft start** **Reverse current prevention @OFF** Both EN/ENB type available				

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