TOREX

Torex...Powerfully Small!

HiSAT-COT® control
Built-in inductor Step-down Micro DC/DC Converter

XCL237 / XCL238 Series (1.5A)
XCL239 / XCL240 Series (1.0A)
XCL241 / XCL242 Series (Ultra Low EMI/0.5A)
XCL243 / XCL244 Series (Low Profile h=0.75mm/0.7A)

March 2024

TOREX Semiconductor Ltd.

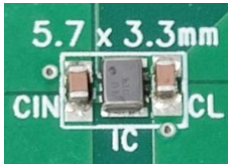
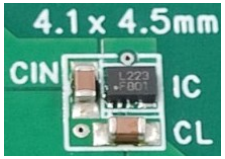
Rev. 1.1

XCL237/238 (1.5A), XCL239/240 (1A), XCL241/242 (0.5A), XCL243/244 (0.7A)
HiSAT-COT® control Built-in inductor Micro DC/DC Converter

Area saving/Fast response with HiSAT-COT/Low EMI/High efficiency and easy to design like an LDO, Built-in inductor DC/DC.

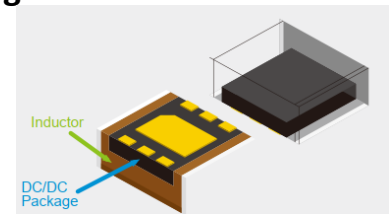
Four types from a balance of I_{OUT}, noise and size, each offering both F-PWM and PWM/PFM auto-switching control.

HiSAT-COT® step-down DC/DC converter with Built-in inductor, XCL series

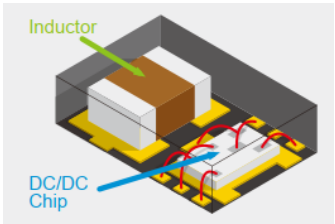
Series		XCL237 / XCL238	XCL239 / XCL240	XCL241 / XCL242	XCL243 / XCL244
Output Current		1.5A	1.0A	500mA	700mA
Selection points		**1.5A**, ideal for POL to such as FPGAs	**XCL standard** for all applications	Pin to Pin for 1A **Ultra-low EMI** For RF and sensors	700mA **Thin, h=0.75mm max**
Package	Name **(Type)**	USP-9B01 (**Multiple**)	CL-2025-02 (**Pocket**)		USP-8B04 (**Multiple**)
	Size	2.5 x 3.2 x 1.05mm	2.5 x 2.0 x 1.04mm		2.25 x 1.5 x 0.75mm
	Solution size				
Input Voltage		2.5V ~ 5.5V (Absolute Max.:6.2V)			
Output Voltage		Internal fixed 0.8V ~ 3.6V (±2.0%)			
Oscillation Frequency (fosc)		3.0MHz	3.0MHz	1.2MHz	3.0MHz
Iq		25µA	25µA	15µA	25µA
Control Method		HiSAT-COT® Fast response control			
		XCL237 F-PWM	**XCL239** F-PWM	**XCL241** F-PWM	**XCL243** F-PWM
		XCL238 PWM/PFM Auto	**XCL240** PWM/PFM Auto	**XCL242** PWM/PFM Auto	**XCL244** PWM/PFM Auto

Built-in inductor packages

Pocket type
Coil over IC structure.
Compact and Low EMI



Multiple type
Shortest/optimal placement of coil and IC
Higher heat dissipation and Thinner profile



Ultra Small / Low EMI / High Speed Transient Response

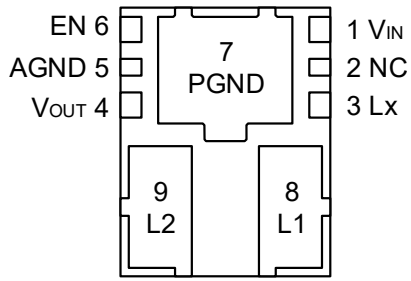
Features

Input Voltage	: 2.5V ~ 5.5V (Absolute Max.:6.2V)
Output Voltage	: 0.8V ~ 3.6V (±2.0%)
Output Current	: 1.5A
Oscillation Frequency	: 3.0MHz
Supply Current	: 25μA
Control Method	: HiSAT-COT Control F-PWM (XCL237) PWM/PFM (XCL238)
Efficiency	: 89% (V_{IN}=3.8V, V_{OUT}=1.8V, I_{OUT}=500mA)
Function	: Soft-start C_L Discharge, UVLO
Protection	: Short Protection Current Limit Thermal Shutdown
Package	: USP-9B01
Operating Ambient Temp.	: -40℃ ~ 105℃

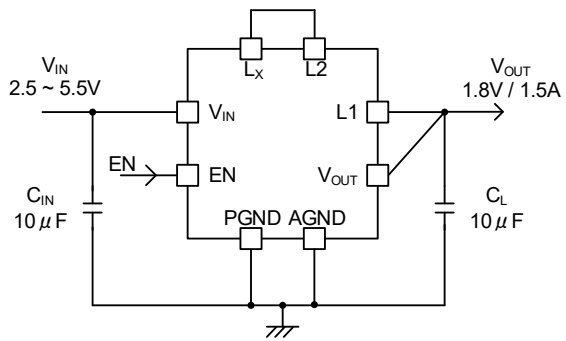
Package

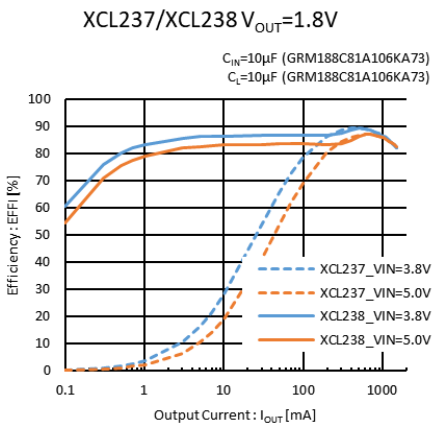
USP-9B01

(2.5x3.2x1.05mm)



Typical Application Circuit





Solution Size

Ultra Small / Low EMI / High Speed Transient Response

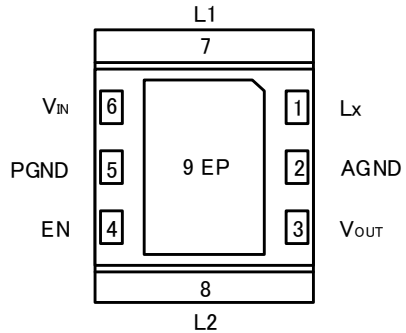
Features

Input Voltage	: 2.5V ~ 5.5V (Absolute Max.:6.2V)
Output Voltage	: 0.8V ~ 3.6V (±2.0%)
Output Current	: 1.0A
Oscillation Frequency	: 3.0MHz
Supply Current	: 25μA
Control Method	: HiSAT-COT Control F-PWM (XCL239) PWM/PFM (XCL240)
Efficiency	: 90% (V_{IN}=3.8V, V_{OUT}=1.8V, I_{OUT}=200mA)
Function	: Soft-start C_L Discharge, UVLO
Protection	: Short Protection Current Limit Thermal Shutdown
Package	: CL-2025-02
Operating Ambient Temp.	: -40℃ ~ 105℃

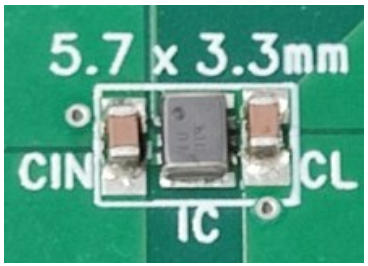
Package

CL-2025-02

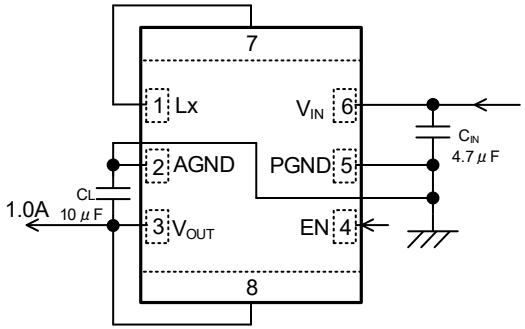
(2.5x2.0x1.04mm)

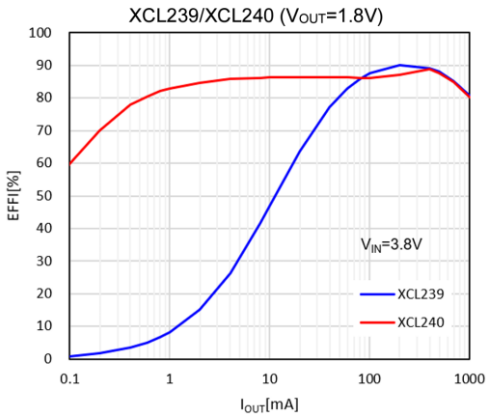


Solution Size



Typical Application Circuit





Ultra Small / Ultra Low EMI / High Speed Transient Response

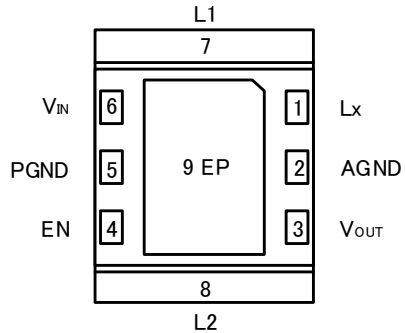
Features

Input Voltage	: 2.5V ~ 5.5V (Absolute Max.:6.2V)
Output Voltage	: 0.8V ~ 3.6V (±2.0%)
Output Current	: 500mA
Oscillation Frequency	: 1.2MHz
Supply Current	: 15μA
Control Method	: HiSAT-COT Control F-PWM (XCL241) PWM/PFM (XCL242)
Efficiency	: 92% (V_{IN}=3.8V, V_{OUT}=1.8V, I_{OUT}=200mA)
Function	: Soft-start C_L Discharge, UVLO
Protection	: Short Protection Current Limit Thermal Shutdown
Package	: CL-2025-02
Operating Ambient Temp.	: -40℃ ~ 105℃

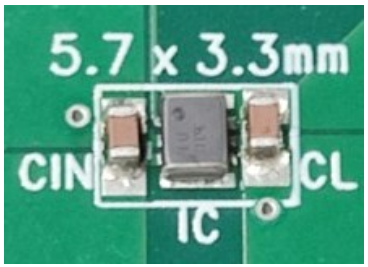
Package

CL-2025-02

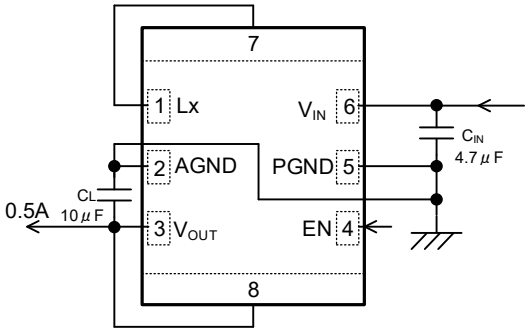
(2.5x2.0x1.04mm)

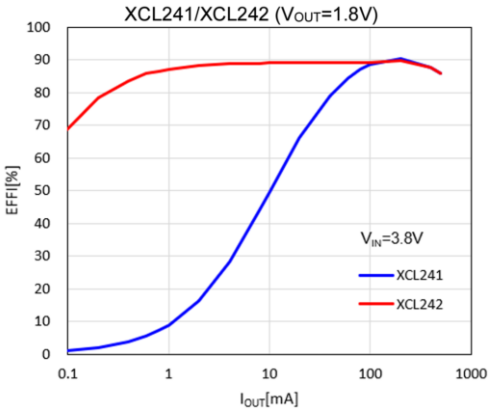


Solution Size



Typical Application Circuit





h=0.75mm max / Low EMI / High Speed Transient Response

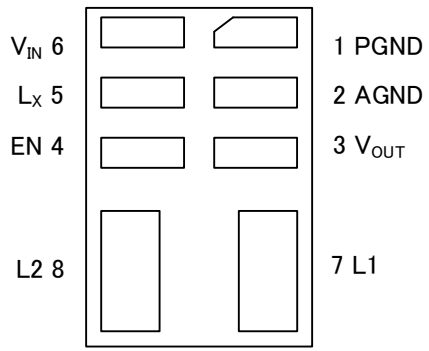
Features

Input Voltage	: 2.5V ~ 5.5V (Absolute Max.:6.2V)
Output Voltage	: 0.8V ~ 3.6V (±2.0%)
Output Current	: 700mA
Oscillation Frequency	: 3.0MHz
Supply Current	: 25μA
Control Method	: HiSAT-COT Control F-PWM (XCL243) PWM/PFM (XCL244)
Efficiency	: 83% (V_{IN}=3.8V, V_{OUT}=1.8V, I_{OUT}=400mA)
Function	: Soft-start C_L Discharge, UVLO
Protection	: Short Protection Current Limit Thermal Shutdown
Package	: USP-8B04
Operating Ambient Temp.	: -40℃ ~ 105℃

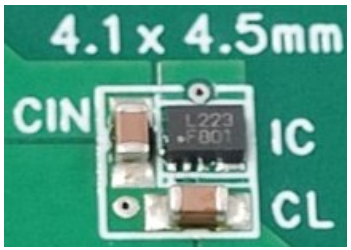
Package

USP-8B04

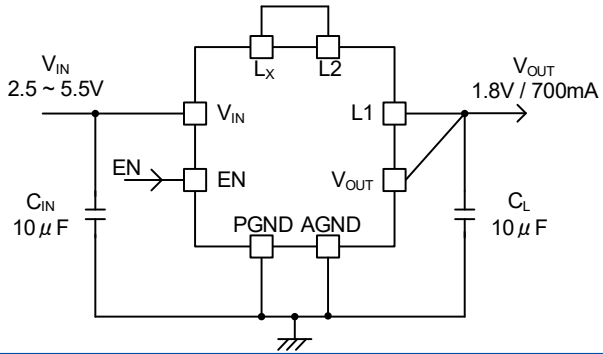
(2.25x1.5x0.75mm)

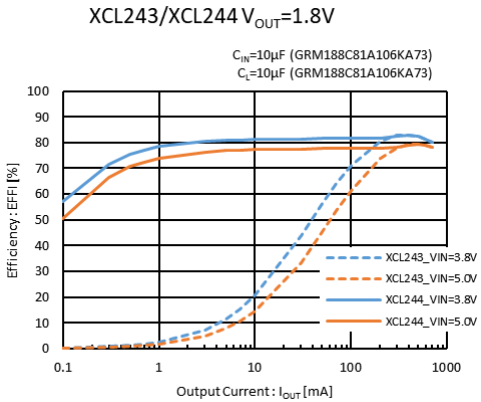


Solution Size



Typical Application Circuit





XCL237/238 (1.5A), XCL239/240 (1A), XCL241/242 (0.5A), XCL243/244 (0.7A)
HiSAT-COT® control Built-in inductor Micro DC/DC Converter

■ HiSAT-COT® and Built-in inductor for Space-saving, Fast response, Low EMI, and High efficiency

HiSAT-COT®
Built in inductor
Micro DC/DC

XCL237/XCL238
XCL239/XCL240
XCL241/XCL242
XCL243/XCL244

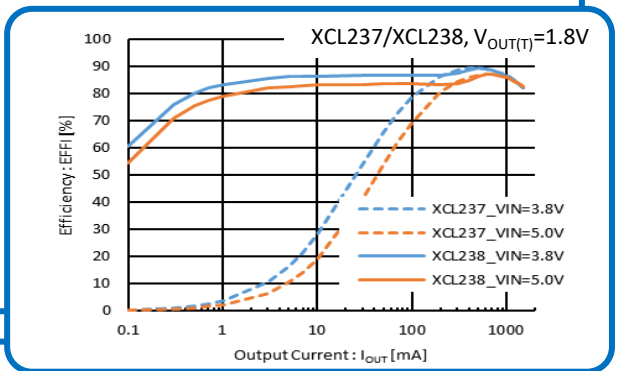
XCL239/XCL240

HiSAT-COT® & Built in inductor for space-saving

①

① Ultra-small DC/DC with built-in inductor usable like an LDO

- ✓ Ultra-compact power supply with TOREX's original built-in inductor structure
- ✓ DC/DC with only input and output capacitors as external components, usable like an LDO

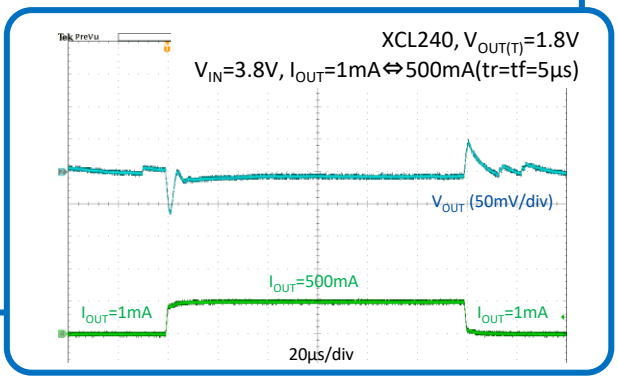


②

Fast transient Low noise

② Fast response, low ripple, and low EMI

- ✓ HiSAT-COT® for fast transient response
- ✓ Low ripple voltage and low EMI further reduced by built-in inductor
- ✓ Suitable for POL power supplies



Suitable for all types of equipment/modules requiring **Fast transient response, High efficiency, Low noise**

- ➢ Industrial Applications/Control Systems : POL power supplies for SoC/FPGA
- ➢ Modules/Sensors : Camera modules, Wireless modules, SSD, Sensors

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

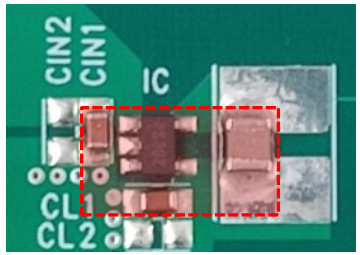
- For stable operation of devices, it is important to place power supply ICs close to MCUs and FPGAs. Especially in cases where multiple power supplies are required, selecting power supply ICs suitable for POL (Point of Load) is a challenge.
- Miniaturization of power circuits including ICs and low EMI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

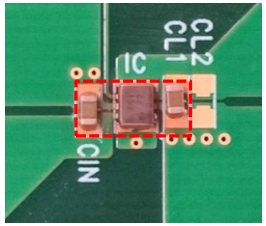
9.6×5.8mm = 56mm²



Stand-alone DC/DC
External parts : 3 pcs

65% reduction

6.5×3.0mm = 19.5mm²



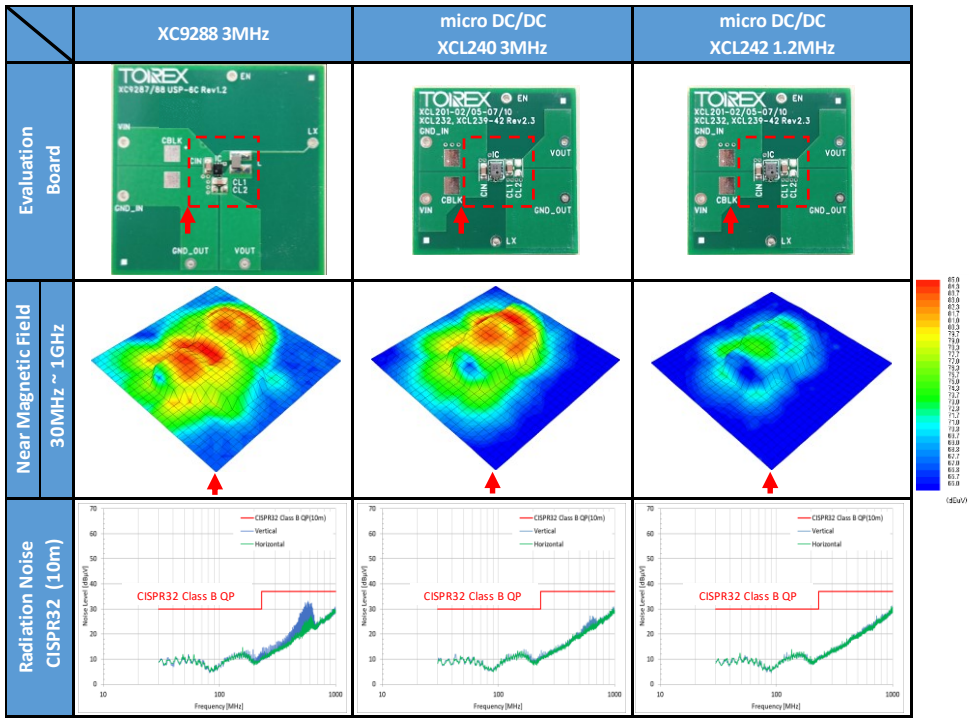
Built-in inductor Micro DC/DC
External parts : 2 pcs

➢**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.

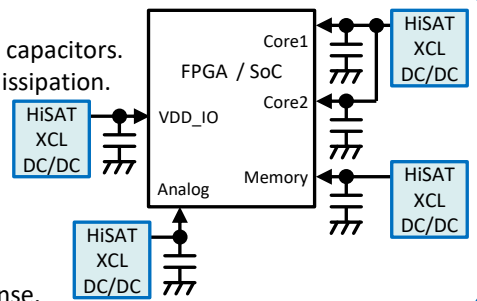
✓Can be placed near RF ICs/Sensors, etc., contributing to miniaturization.

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



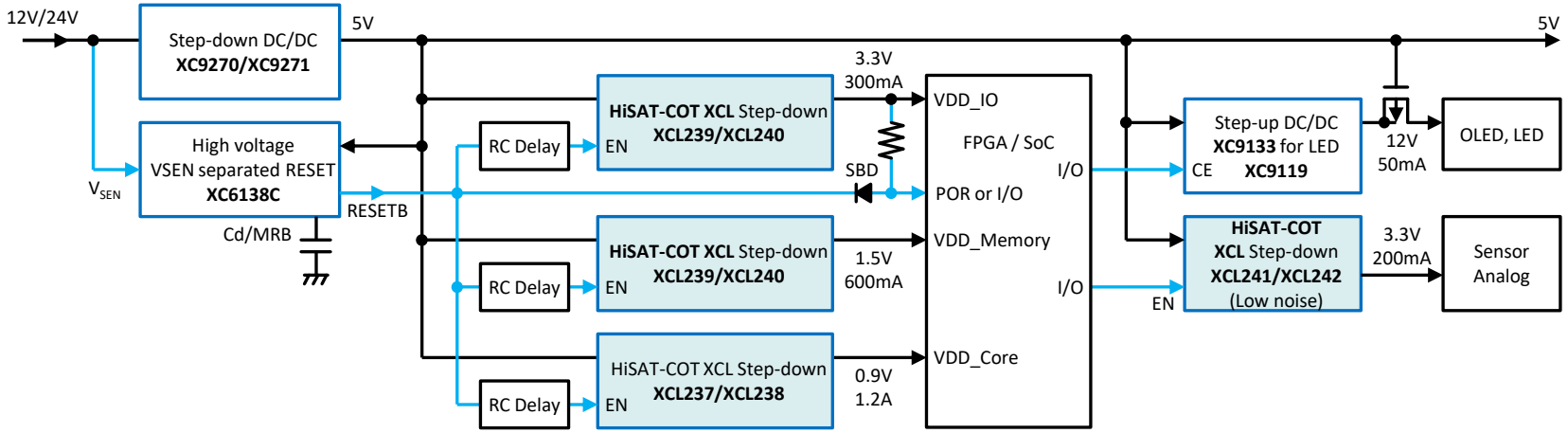
Benefits of POL (Point of Load) power supply and Micro DC/DC & HiSAT-COT®

- 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.

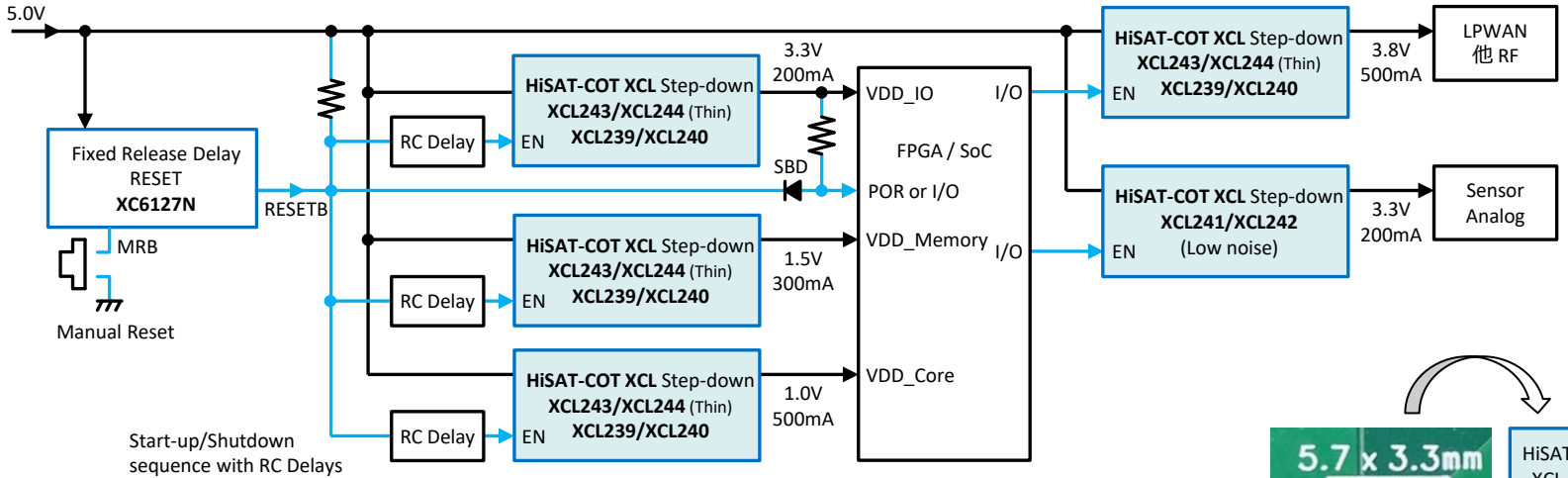


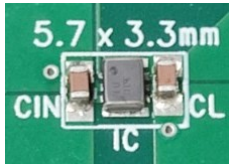
Built-in inductor Micro DC/DC for, XCL series : Multiple power supply solutions

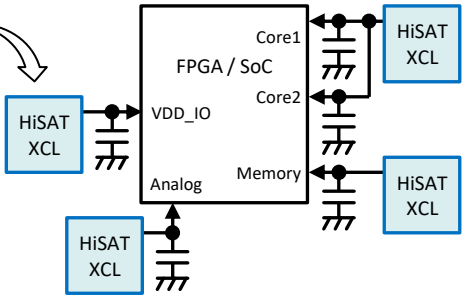
12 V / 24 V input, Example of multiple power supplies



5V input, Example of multiple power supplies







Only two capacitors like LDO
Shortest possible placement as a POL
Contributes significantly to stable operation, space saving and ease of design

HiSAT-COT® control for fast transient response

TOREX original COT control : HiSAT-COT®

Technical trend and challenges

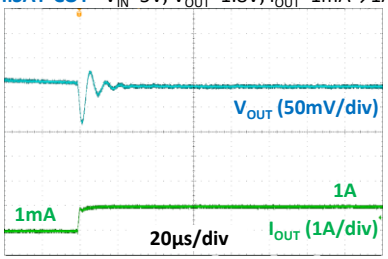
- Stable power supply including transient response to MCU/SoC/FPGA, etc.
- Miniaturization of circuits including peripheral components, and low EMI.

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

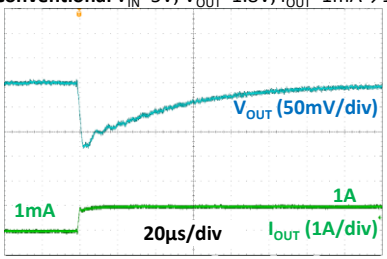
➢Significantly faster transient response

- 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

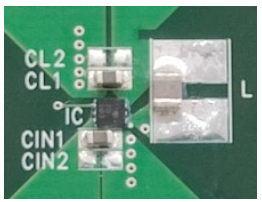


➢Miniaturization including peripheral components

- 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 the 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.