TOREX

Torex...Powerfully Small!

HiSAT-COT® control

600mA Synchronous Step-down DC/DC converters

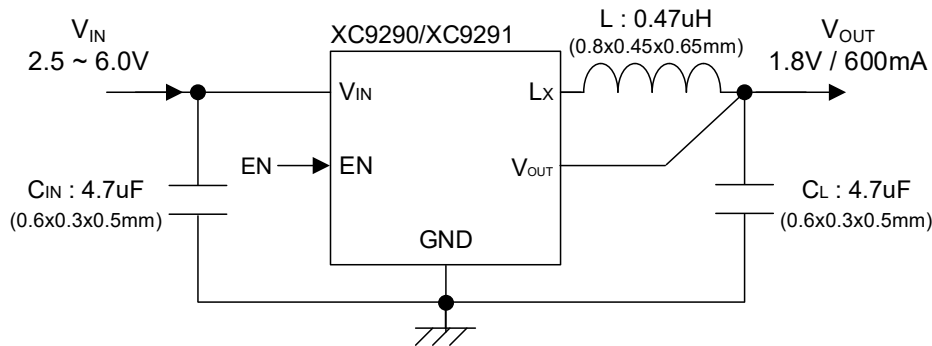# XC9290/XC9291 Series

May. 2024

TOREX Semiconductor Ltd.

Rev. 1.2

XC9290/XC9291 : HiSAT-COT® control 600mA step-down DC/DC converter

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World's smallest solution area / Low consumption

■ Features

Input Voltage	: 2.5V ~ 6.0V (Absolute Max.: 7.0V)
Output Voltage	: 0.7V ~ 3.6V (Accuracy: ±2.0%)
Output Current	: 600mA
Oscillation Frequency	: 4.0MHz, 6.0MHz
Efficiency	: 90% (V_{IN}=3.7V, V_{OUT}=1.8V, I_{OUT}=200mA)
Control Method	: HiSAT-COT
	F-PWM (XC9290)
	PWM/PFM (XC9291)
Functions	: Soft-Start
	UVLO
	C_L Discharge (Type B)
Protection	: Current Limit
Packages	: LGA-6B01, WLP-5-08
Operating Ambient Temp.	: -40℃ ~ 105℃

■ Typical Application Circuit

■ Packages

LGA-6B01
(1.2x1.2x0.3mm)

```
GND 6  [ ]   [ ]  1 VOUT
Lx  5  [ ]   [ ]  2 NC
VIN 4  [ ]   [ ]  3 EN
```
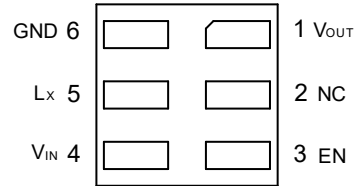
WLP-5-08
(0.96x0.88x0.3mm)

```
EN 1  ○ ○  2 VIN
        ○ 5 ← Lx
VOUT 4  ○ ○  3 GND
```
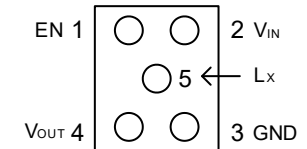
■ Ultra Small Size

- World's smallest solution 3.15mm^2
- 0.6 x 0.3mm Ceramic Capacitors
- 0.8 x 0.45mm Inductor

Mount Area
1.5x2.1mm=3.15mm^2

XC9290/XC9291 : Ultra-small HiSAT-COT 600mA Step-down DC/DC

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■ World's smallest solution area with fast transient response / Low noise / High efficiency

Ultra small HiSAT-COT® 600mA Step-down DC/DC
XC9290 / XC9291

Mount Area 1.5x2.1mm=3.15mm²
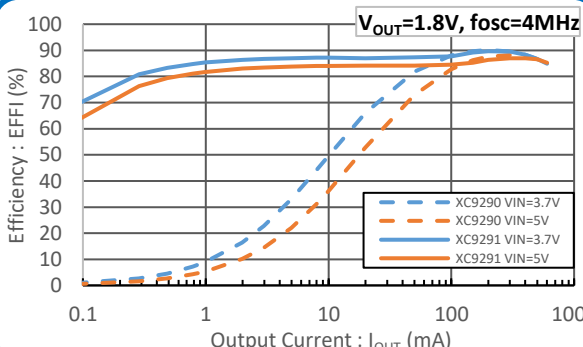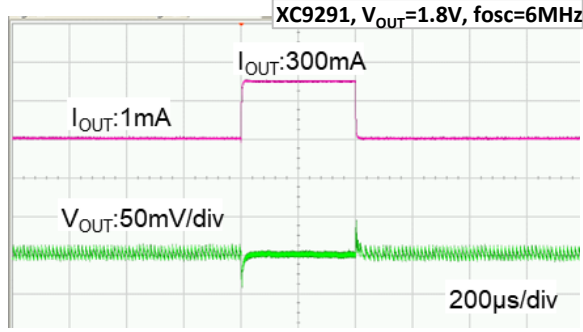
SOT-25

World's smallest 2.1 x 1.5 mm = 3.15mm²

Fast transient Low noise

① ① Adapted to the smallest external components.

✓ 0.8x0.45mm Inductor (world-first)

✓ 0.6x0.3mm Ceramic Capacitor

✓ High efficiency despite being the world's smallest and 6MHz.

V_{OUT}=1.8V, fosc=4MHz

Efficiency : EFFI (%)

Output Current : I_{OUT} (mA)

XC9290 VIN=3.7V
XC9290 VIN=5V
XC9291 VIN=3.7V
XC9291 VIN=5V

② ② Fast transient, Low ripple, Low EMI

✓ High speed transient response with HiSAT-COT control

✓ Low ripple voltage even with 0.6x0.3mm size low effective ceramic capacitor

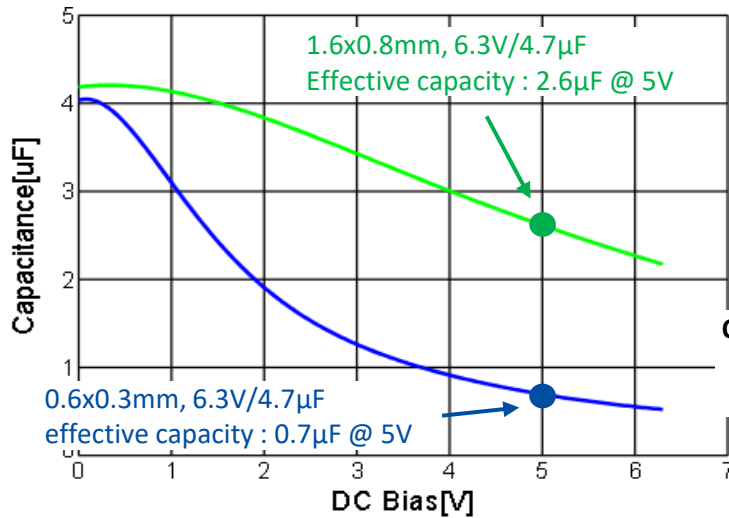✓ Ultra-low EMI equivalent to Built-in inductor DC/DC due to minimized layout.

XC9291, V_{OUT}=1.8V, fosc=6MHz

I_{OUT}:300mA

I_{OUT}:1mA

V_{OUT}:50mV/div

200µs/div

The world's smallest solution for further miniaturization of equipment/modules requiring high efficiency and low noise.

➢ Wearable/Hearable devices : TWS, Hearing aid, Headset, VR, Tracker, Medical monitoring

➢ Modules/Sensors : Camera modules, Wireless modules, SSD, Miniature sensors

XC9290/XC9291 : World's smallest solution size

- ## 0.6 x 0.3mm ceramic capacitors

  ➤ Stable operation even with ultra-small ceramic capacitors with small effective capacitances.

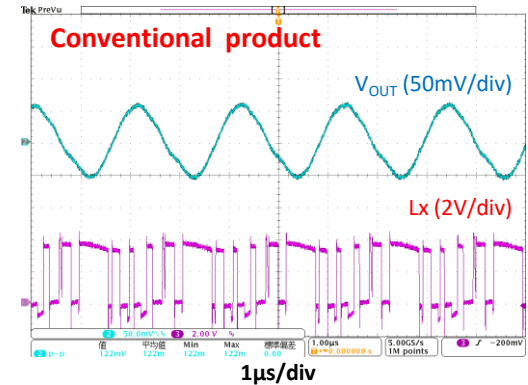Graph: Capacitance[μF] vs DC Bias[V]
- 1.6x0.8mm, 6.3V/4.7μF, Effective capacity : 2.6μF @ 5V
- 0.6x0.3mm, 6.3V/4.7μF, effective capacity : 0.7μF @ 5V

Operates with low effective capacity

DC/DC output voltage with 0.6x0.3mm ceramic capacitors

XC9290/XC9291
V_{OUT} (50mV/div)
Lx (2V/div)
200ns/div
stable operation
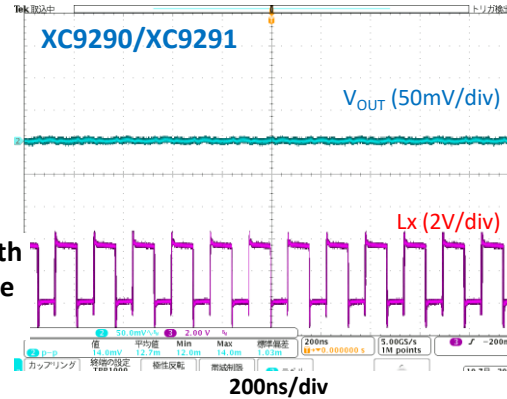
Conventional product
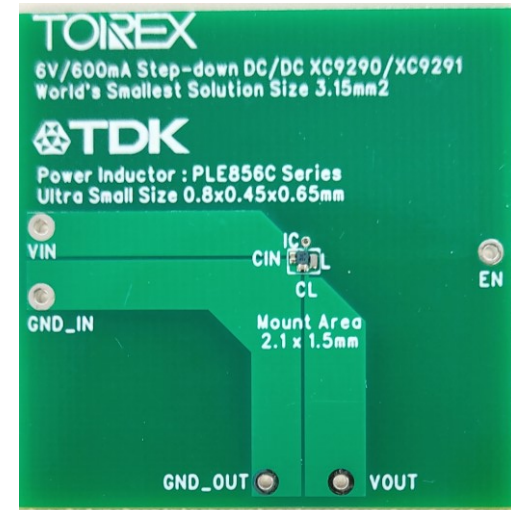V_{OUT} (50mV/div)
Lx (2V/div)
1μs/div
abnormal oscillation

- ## World's smallest 0.8 x 0.45mm Inductor

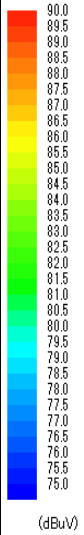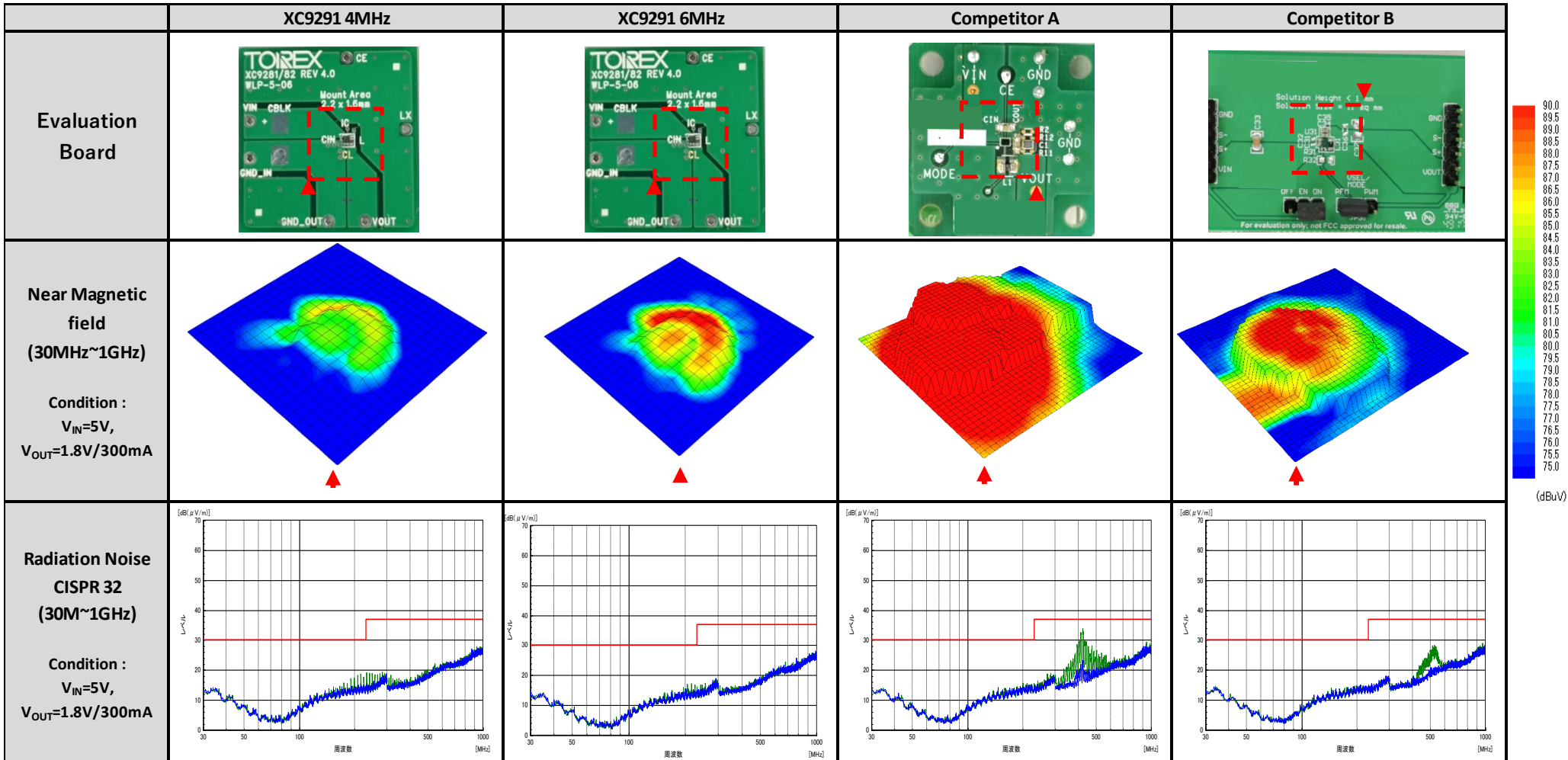 ● Stable operation with low inductance, so it can be used with ultra-small inductors.

  * 0.8 x 0.45mm Inductor : TDK, PLE856CBAR47M-1PT

TOREX
6V/600mA Step-down DC/DC XC9290/XC9291
World's Smallest Solution Size 3.15mm2
⊛TDK
Power Inductor : PLE856C Series
Ultra Small Size 0.8x0.45x0.65mm
VIN   IC CIN L EN
GND_IN   CL   Mount Area 2.1 x 1.5mm
GND_OUT   VOUT

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Low EMI & Low noise

- Low magnetic field leakage to the surroundings and minimal influence on peripheral devices during high-density mounting.

	XC9291 4MHz	XC9291 6MHz	Competitor A	Competitor B
Evaluation Board				
Near Magnetic field (30MHz~1GHz) Condition : V_{IN}=5V, V_{OUT}=1.8V/300mA				
Radiation Noise CISPR 32 (30M~1GHz) Condition : V_{IN}=5V, V_{OUT}=1.8V/300mA				

HiSAT-COT® for fast transient response and Miniaturization

■ **TOREX original COT control : HiSAT-COT®**
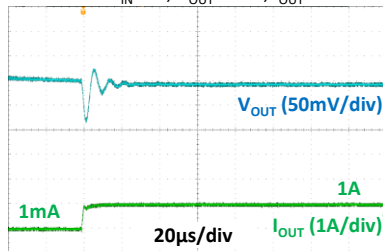
● **Technical trend and challenges**

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

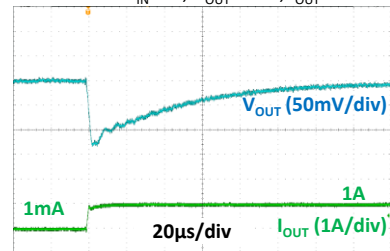● **TOREX Proposal : HiSAT-COT® controlled Step-down DC/DC converter**

➢ **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
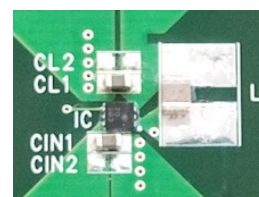
Overview of COT control and HiSAT-COT®

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**

- Duty ratio of step-down DC/DC PWM operation above a certain I_{OUT} is
  Duty ratio = V_{OUT}/V_{IN},   ton = 1/fosc x Duty ratio.
  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.