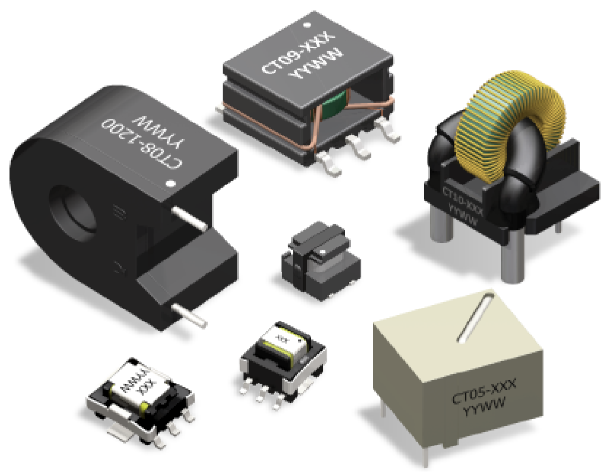
Applying Current Sense Transformers in Isolated DC-DC Converters

Application Information

1 Introduction

Current Sense Transformers (CTs) are widely used in isolated DC-DC converters for accurate current measurement, control, and protection. Their compact form factor, high isolation capability, and compatibility with automated assembly make them ideal for modern power electronics designs. This application note outlines key considerations for selecting, integrating, and optimizing **SMT** and **THT** current sense transformers in isolated converter topologies.



2 Role of Current Sense Transformers in Isolated Converters

In isolated DC-DC converters, current sense transformers are typically used to:

- **Monitor primary or secondary winding current** for control loop feedback.
- **Enable overcurrent protection** to safeguard power switches and magnetics.
- **Support current-mode control** for improved transient response and stability.
- **Provide galvanic isolation** between the sensing circuitry and high-voltage domains.

3 Selection Criteria

When choosing a current sense transformer, consider the following:

- **Turns Ratio** – Determines the scaling between the primary current and the secondary output voltage.
- **Isolation Voltage** – Must meet or exceed the safety standards for the converter's operating voltage.
- **Low Loss**: Unlike shunt resistors, CTs introduce negligible conduction loss.
- **Size and Footprint** – Must fit within the PCB layout and mechanical constraints.
- **Temperature Range** – Should match or exceed the converter's expected operating temperature range.

4 Integration Guidelines

Circuit Interface

- **Signal Conversion**
  Place a burden resistor (R_B) across the secondary winding to convert secondary current (I_S) into a measurable output voltage (E_O).

- **ET Product Definition**
  A key parameter that defines the maximum voltage deliverable from the secondary winding over time without core saturation. It is defined by the following relationship:

$$ET = \frac{E_O}{2f}$$

- **Secondary Current Calculation**
  It refers to the current flowing through the secondary winding. It is typically calculated using the formula:

$$I_S = \frac{I_P}{TR}$$

- **Burden Resistor Selection**
  The burden resistor (***R**$_B$*) converts secondary current into output voltage (***E**$_O$*) and must be sized to avoid core saturation. Its maximum value is defined by:

$$R_B \leq \frac{2f \cdot ET \cdot TR}{I_S} \quad \therefore \quad R_B = \frac{E_O \cdot TR}{I_P}$$

- **Voltage Calculation**
  The output voltage (***E**$_O$*) across the burden resistor (***R**$_B$*) is determined by the current flowing through the transformer, scaled by the winding ratio. It can be expressed as:

$$E_O = \frac{I_P \cdot R_B}{TR} \quad \text{or} \quad E_O = I_s \cdot R_B$$

- **Filtering Considerations**
  Add RC or active filtering if needed to suppress high-frequency noise and maintain signal integrity.

Symbol Definitions	
ET	Voltage-Time Product
***E**$_O$*	Peak Output Voltage
f	Operating Frequency
***I**$_P$*	Primary Current
***I**$_S$*	Secondary Current
***R**$_B$*	Burden Resistor
TR	Turns Ratio (N_S/N_P)

Placement

- Position the transformer close to the switching device or winding being monitored to minimize parasitic inductance and noise pickup.
- Keep the sense signal path short and shielded where possible.

Isolation & Safety

- Ensure creepage and clearance distances meet IEC/UL safety requirements.
- Verify the transformer's insulation system rating for reinforced or basic isolation as required.

5 Example Application

Topology: Forward converter, 48 V input, 5 V output, 200 kHz switching frequency.

Implementation:

- Primary-side current sense transformer with ***TR*** = 100 (N_P = 1; N_S = 100).
- Desired output voltage at peak load current ***I**$_P$* = 5 A; ***R**$_B$* = (1 V x 100) / 5 A = 20 ohms.
- RC filter tuned to pass up to 1 MHz for accurate pulse shape reproduction.
- Transformer placed adjacent to the MOSFET drain connection to minimize loop area.

Part Recommendation: A good choice would be ICE's **CT02-100**. It is rated for 18 A and has an ET rating of 140 V-μs which is greater than the ET product requirement of 12.5 V-μs in the application.

7 Common Pitfalls and Solutions

- **Signal Distortion**
  - *Cause:* Bandwidth of the transformer is too low.
  - *Solution:* Select a transformer with a higher frequency response.

- **Overheating**
  - *Cause:* Excessive power dissipation in the burden resistor.
  - *Solution:* Reduce the burden resistor value or improve thermal management.

- **Noise Pickup**
  - *Cause:* Long secondary winding traces acting as antennas.
  - *Solution:* Shorten the secondary traces, use twisted pairs, or add shielding.

- **Saturation**
  - *Cause:* Primary current exceeds the transformer's saturation current rating.
  - *Solution: Choose a transformer with a higher saturation current capability.*

8 Validation and Performance Testing

- Validate the sensed waveform against a calibrated current probe.
- Check linearity across the full load range.
- Perform isolation testing per applicable safety standards.
- Verify thermal performance under maximum load and ambient conditions.

9 Conclusion

SMT and THT current sense transformers offer a compact, reliable, and accurate solution for current measurement in isolated DC-DC converters. By applying the formulas above, carefully selecting the transformer, optimizing PCB layout, and validating performance, designers can achieve precise control and robust protection in high-density power systems.

To explore ICE's full range of high-performance current sense transformers, including SMT, THT, and custom design options, you may visit:
https://www.icecomponents.com/product-category/transformers/current-sense-transformers/