Current Sense Transformer Fundamentals

Application Information

1 Introduction

Current measurement is a fundamental requirement in modern power electronic systems. In switched-mode power supplies (SMPS), motor drives, renewable energy converters, battery charging systems, and industrial power equipment, accurate current sensing supports closed-loop regulation, overcurrent protection, efficiency optimization, and system diagnostics. As switching frequencies and power densities continue to increase, designers require current sensing solutions that provide high bandwidth, galvanic isolation, and reliable performance in electrically noisy environments.

Current sense transformers (CSTs), also referred to as current transformers (CTs) in switching power applications, provide an efficient method of measuring alternating and pulsed currents while maintaining electrical isolation between the power stage and control circuitry. Their passive magnetic construction introduces very low insertion loss, generates minimal heat, and eliminates the need for an external power supply, making them well suited for high-efficiency power conversion systems. Because transformer operation relies on changing magnetic flux, CSTs are intended for AC and pulsed-current measurement rather than true DC current sensing.

This application note explains the operating principles, performance characteristics, and practical design considerations for current sense transformers used in switching power electronics. Topics covered include transformer operation, burden resistor selection, excitation current, frequency response, saturation, transformer errors, PCB layout considerations, and representative applications to help engineers successfully integrate current sense transformers into modern power conversion designs.

2 What Is a Current Sense Transformer?

2.1 Definition

A current sense transformer (CST), also known as a current transformer (CT) in switching power applications, is a passive magnetic component used to measure alternating or pulsed current while providing galvanic isolation between the power stage and the control circuitry. Unlike conventional transformers that transfer power, a CST reproduces the primary current as a proportional secondary current for measurement and protection.

A typical CST consists of a single-turn primary conductor passing through a high-permeability magnetic core and a multi-turn secondary winding. The induced secondary current typically flows through an external burden resistor, producing a proportional voltage that can be monitored by PWM controllers, analog-to-digital converters (ADCs), comparators, or other current sensing circuits.

Because transformer operation depends on changing magnetic flux, current sense transformers are intended for AC and pulsed-current measurement in switched-mode power supplies, inverters, motor drives, battery chargers, and other power conversion systems. They cannot accurately measure true DC current.

Figures 1 and ***2*** illustrate the electrical representation and physical construction of a current sense transformer, including the primary conductor, magnetic core, secondary winding, burden resistor, and resulting output voltage.

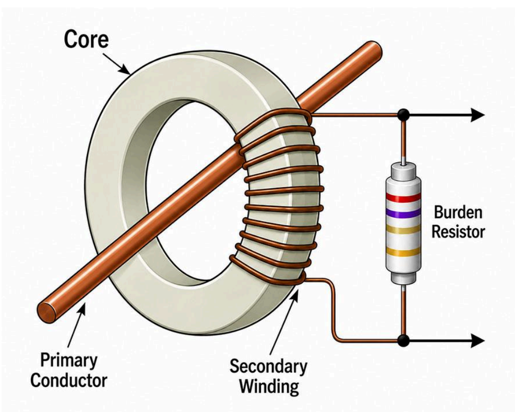

Figure 1. Simplified Physical Construction of a CST.

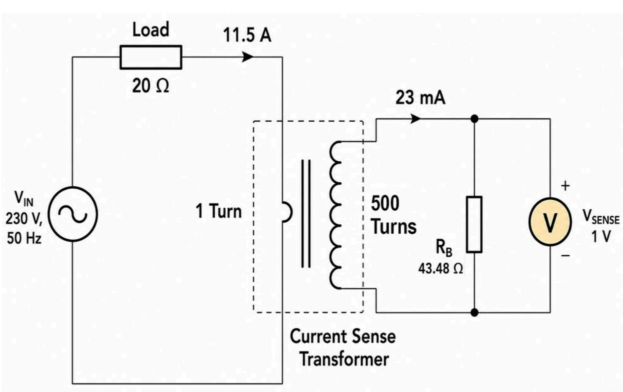

Figure 2. Simplified current sensing circuit using CST.

3 Why Use Current Sense Transformers?

Current sense transformers are widely used in switched-mode power supplies and other power conversion systems because they provide accurate current measurement while maintaining galvanic isolation between the power stage and the control circuitry. Compared to other current sensing methods, they offer several advantages that make them well suited for high-frequency switching applications.

3.1 Typical Advantages in Power Electronics

The combination of galvanic isolation, low insertion loss, and wide frequency response makes current sense transformers an effective solution for current monitoring and protection in modern power conversion systems. Their passive magnetic construction also provides a simple, reliable, and highly efficient sensing method without requiring an external power supply. These advantages explain why current sense transformers continue to be widely adopted across industrial, automotive, renewable energy, telecommunications, and other high-performance power electronic applications.

3.1.1 Galvanic Isolation

Current sense transformers provide electrical isolation between the primary current path and the sensing circuitry. This isolation protects low-voltage control electronics from hazardous voltages while improving system safety and reducing the effects of common-mode noise in electrically noisy switching environments.

3.1.2 Low Insertion Loss

The primary winding is typically a single-turn conductor with very low impedance, introducing minimal voltage drop and power dissipation into the primary circuit. This enables efficient current measurement without significantly affecting converter performance, particularly in high-current applications.

3.1.3 Wide Bandwidth

Current sense transformers respond rapidly to changing current, making them suitable for monitoring the fast switching waveforms found in modern switched-mode power supplies. Their wide frequency response supports accurate current feedback for regulation, monitoring, and overcurrent protection.

3.1.4 Passive Operation

Unlike active current sensing devices, current sense transformers require no external power supply or signal conditioning to generate the sensing current. Their simple magnetic construction provides excellent long-term reliability while reducing component count and system complexity.

3.1.5 Compact Size

Modern current sense transformers are available in compact through-hole and surface-mount packages that occupy minimal PCB area while maintaining high isolation capability and wide frequency response. Their small footprint makes them well suited for high-density power converters where board space is limited without compromising sensing performance.

3.1.6 Excellent Linearity

When operated within their specified current and frequency range, current sense transformers provide a highly linear relationship between the primary and secondary current. This predictable response enables accurate current feedback for converter regulation, current monitoring, and overcurrent protection across a wide operating range.

3.1.7 High Reliability

Current sense transformers contain no active semiconductor devices and require no external power supply for operation. Their simple magnetic construction provides excellent long-term stability, making them highly reliable in demanding industrial, automotive, telecommunications, and renewable energy applications where electrical and thermal robustness are essential.

4 How Current Sense Transformers Work

Current sense transformers operate on the principle of electromagnetic induction, where a changing primary current generates a changing magnetic flux within the transformer core. According to Faraday's law of electromagnetic induction, this changing magnetic flux induces a voltage in the secondary winding, resulting in a proportional secondary current determined by the transformer's turns ratio. Unlike a power transformer, which transfers energy between circuits, a current sense transformer reproduces the primary current as a scaled secondary current for measurement, monitoring, and protection.

4.1 Primary and Secondary Current Relationship

The primary winding of a current sense transformer is typically a single conductor carrying the current to be measured, while the secondary winding consists of multiple turns wound around a high-permeability magnetic core. As alternating current flows through the primary conductor, magnetic flux induced in the core produces a proportional, isolated secondary current. Under normal operating conditions, the transformer maintains ampere-turn balance, allowing large primary currents to be accurately reproduced at a reduced level for low-voltage measurement and control circuitry.

For an ideal current transformer, the relationship between the primary and secondary currents is expressed as:

$$N_P \times I_P = N_S \times I_S$$

Where:

- ***N_P*** *= Number of primary turns*
- ***N_S*** *= Number of secondary turns*
- ***I_P*** *= Primary current (A)*
- ***I_S*** *= Secondary current (A)*

Since the primary winding of most current sense transformers consists of a single conductor passing through the magnetic core,

$$N_P = 1$$

the secondary current becomes:

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

In practice, a small excitation (magnetizing) current is required to establish magnetic flux within the core. This excitation current produces minor ratio and phase errors, particularly at low primary currents, but is typically negligible during normal switching power converter operation.

4.2 Converting Current into Sense Voltage

The secondary winding of a current sense transformer produces a current rather than a directly measurable voltage. To generate a usable sense voltage, the secondary current is passed through an external burden resistor (R_B), which converts the current into a proportional voltage suitable for PWM controllers, comparators, analog-to-digital converters (ADCs), or other control circuitry.

The sense voltage is determined by:

$$V_{SENSE} = I_S \times R_B$$

Substituting the secondary current relationship from the previous section gives:

$$V_{SENSE} = \frac{I_P \times R_B}{TR}$$

Where:

- ***V_{SENSE}*** *= Voltage across the burden resistor (V)*
- ***I_P*** *= Primary current (A)*
- ***I_S*** *= Secondary current (A)*
- ***R_B*** *= Burden resistor (Ω)*

This relationship shows that the sense voltage is determined by the primary current, burden resistance, and transformer turns ratio. These parameters work together to establish the voltage presented to the measurement circuitry while maintaining the galvanic isolation provided by the transformer.

4.3 AC and Pulsed Current Operation

Because current sense transformers rely on changing magnetic flux to induce secondary current, they respond only to alternating or pulsed current. A steady DC current does not produce a changing magnetic field and therefore cannot induce a continuous secondary current. For this reason, current sense transformers are best suited for switched-mode power supplies and other power conversion systems where current continuously changes during switching operation.

Figures 3 and ***4*** illustrate the current transformation process and the conversion of secondary current into a measurable output voltage across the burden resistor.

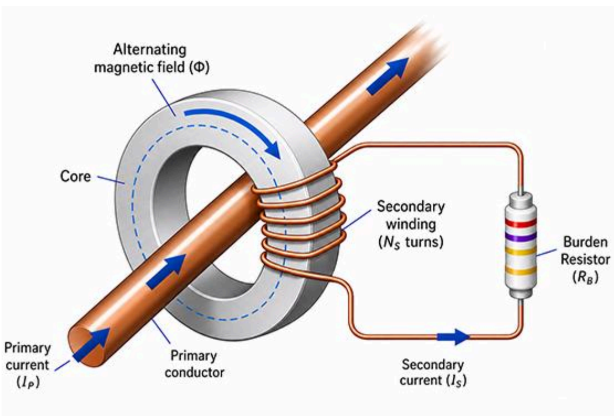

Figure 3. Current Sense Transformer Operating Principle.

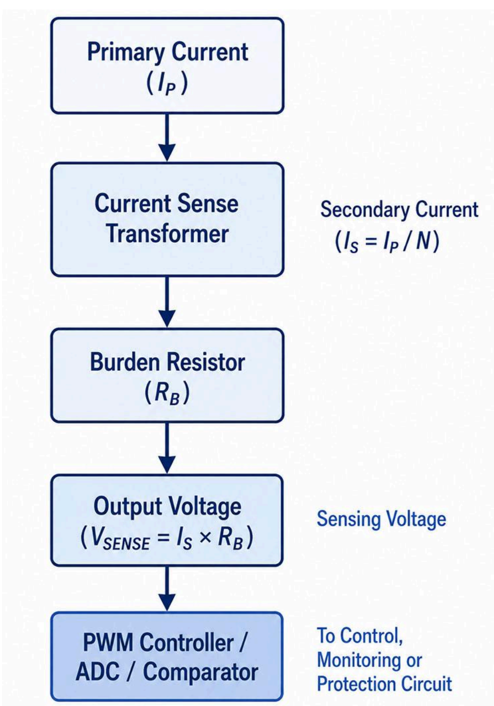

Figure 4. Conversion of Primary Current into an Isolated Output Voltage.

5 Selecting a Current Sense Transformer

Selecting the appropriate current sense transformer requires more than matching the expected current level. Parameters such as current range, turns ratio, burden resistor selection, frequency response, isolation requirements, core characteristics, and package style all influence measurement accuracy, bandwidth, and long-term reliability. Understanding these design considerations helps engineers choose the most suitable transformer for their application.

Figure 5 summarizes a recommended workflow for evaluating the key electrical and mechanical parameters when selecting a current sense transformer.

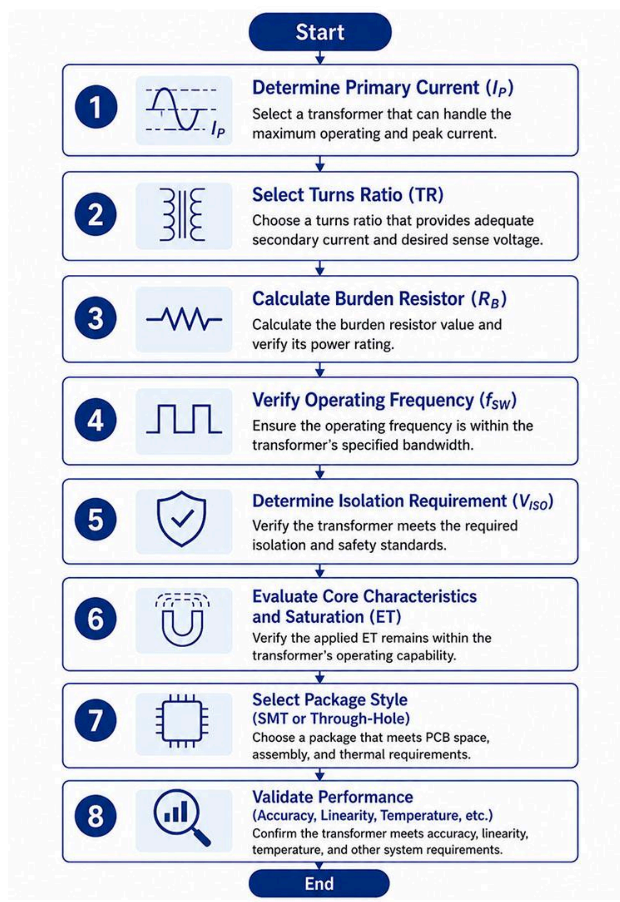

Figure 5. Current Sense Transformer Selection Flow.

5.1 Primary Current Range

The current sense transformer should be selected to accommodate the expected operating current as well as transient overload conditions while maintaining reliable operation under the intended operating conditions. Selecting a transformer with an appropriate current rating helps maintain measurement accuracy while ensuring reliable operation during startup, overload, and fault conditions.

Designers should also consider the maximum peak current rather than only the average or RMS current, particularly in switched-mode power supplies where pulsed currents may be significantly higher than their average value. The selected transformer should also be verified to operate within its specified electrical and thermal limits under all expected operating conditions.

5.2 Turns Ratio

The turns ratio is a primary design parameter of a current sense transformer because it determines how the primary current is scaled into the secondary winding. It is commonly specified as a ratio rather than the number of secondary turns, simplifying comparison between transformer designs and selection for a given application.

The turns ratio is defined as:

$$TR = \frac{N_S}{N_P}$$

Where:

TR *= Turns ratio*
N_S *= Number of secondary turns*
N_P *= Number of primary turns*

As discussed in Section 4.1, most current sense transformers use a single-turn primary conductor, making $N_P = 1$. Therefore, the turns ratio is numerically equal to the number of secondary turns, and the secondary current relationship can be expressed as:

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

Where:

I_P *= Primary current (A)*
I_S *= Secondary current (A)*

Higher turns ratios reduce secondary current, while lower turns ratios increase it. Current sense transformers are commonly specified by turns ratios such as 1:50 or 1:100, which directly indicate the current scaling. Since the turns ratio establishes the secondary current, the burden resistor is selected to produce the required sense voltage while maintaining adequate measurement resolution and transformer accuracy.

5.3 Burden Resistor Selection

The burden resistor converts the transformer's secondary current into a measurable output voltage and is one of the most important design parameters in a current sensing circuit. In the previous section, this voltage was denoted as V_{SENSE} as a general representation of the sensed output. To remain consistent with ICE Components current sense transformer datasheets, the notation E_O is used throughout the remainder of this application note to denote the voltage developed across the burden resistor. In the circuits discussed here, V_{SENSE} and E_O refer to the same voltage.

The required burden resistance can be estimated using:

$$R_B = \frac{E_O}{I_S}$$

or, by substituting the secondary current relationship,

$$R_B = \frac{E_O \times TR}{I_P}$$

Where:

R_B *= Burden resistor (Ω)*
E_O *= Voltage across the burden resistor (V)*
I_S *= Secondary current (A)*
TR *= Turns ratio*
I_P *= Primary current (A)*

These equations provide a practical starting point for selecting the burden resistor based on the desired output voltage and expected maximum primary current. Because the burden resistor and turns ratio together determine the output sensing voltage, both parameters should be selected together.

Increasing the burden resistance raises the secondary output voltage but also increases the voltage developed across the transformer secondary. Excessively large burden resistance may increase measurement error or reduce saturation margin and should remain within the transformer's recommended operating conditions.

5.3.1 Example Calculation

For example, a current sense transformer with a 1:100 turns ratio measuring a 20 A peak primary current produces a peak secondary current of:

$$I_{S(PEAK)} = \frac{I_{P\,(PEAK)}}{TR} = \frac{20}{100} = 0.2A$$

If the desired peak output voltage is E_O = 2.0 V, the required burden resistor is:

$$R_B = \frac{E_O}{I_{S(PEAK)}} = \frac{2.0}{0.2} = 10\Omega$$

This example demonstrates that the selected burden resistor directly determines the output voltage produced for a given primary current and turns ratio.

5.3.2 Burden Resistor Power Rating

The burden resistor should be capable of safely dissipating the expected average power under maximum operating conditions. The required power rating can be estimated using:

$$P_{R_B} = I^2_{S(RMS)} \times R_B$$

Where:
P_{RB} *= Burden resistor power dissipation (W)*
$I_{S(RMS)}$ *= RMS Secondary current (A)*
R_B *= Burden resistor (Ω)*

For pulsed current waveforms, the RMS secondary current depends on the waveform shape and duty cycle and should be used when calculating the burden resistor's average power dissipation.

Selecting a resistor with an adequate power rating and appropriate temperature coefficient improves long-term reliability and measurement stability.

> ⚠️ ***Design Note:*** *Do not operate a current transformer with its secondary open-circuited while primary current is flowing. Always provide a burden, clamp, or other defined secondary-current path. An open secondary may produce excessive secondary voltage, cause core saturation, and damage the transformer or connected circuitry.*

5.4 Frequency Range

Current sense transformers are designed to operate over a specified frequency range that supports accurate current measurement under the intended switching conditions. Because transformer operation depends on changing magnetic flux, performance can vary significantly outside the recommended operating bandwidth.

At lower switching frequencies or longer pulse widths, the applied voltage is present for a longer interval, producing a larger magnetic flux excursion within the transformer core and increasing the likelihood of core saturation. At excessively high frequencies, additional winding and core losses may reduce measurement accuracy. Selecting a transformer with a frequency range appropriate for the converter switching frequency helps maintain reliable current sensing performance.

5.5 Isolation Requirements

Isolation requirements are an important consideration whenever the sensed current path operates at a different electrical potential than the control circuitry. The transformer's insulation system should satisfy the application's electrical safety requirements while providing adequate creepage, clearance, and dielectric withstand capability for the intended operating environment.

Applications operating from high-voltage AC mains or industrial DC bus voltages often require insulation systems that comply with the applicable electrical safety standards. Depending on the application, this may include basic, supplementary, or reinforced insulation, together with appropriate creepage, clearance, and dielectric withstand capability.

5.6 Core Characteristics and Saturation

The magnetic core plays a critical role in determining the transformer's accuracy, bandwidth, excitation current, and saturation performance. Core material and geometry influence how effectively the transformer reproduces the primary current over the intended operating range while maintaining stable electrical characteristics under varying operating conditions.

Excitation current represents the portion of primary current required to establish magnetic flux in the core and contributes to ratio and phase error, particularly at low current levels.

Another important consideration is avoiding core saturation during operation. During each switching cycle, the transformer core experiences an applied volt-time that establishes magnetic flux within the core. If the applied volt-time exceeds the transformer's specified operating capability, the core may saturate, reducing measurement accuracy and distorting the secondary output waveform.

The applied volt-time is generally defined as the integral of the voltage across the transformer winding over the interval during which it is applied:

$$ET_{interval} = \int_{t_1}^{t_2} v_S(t)\,dt$$

Where:

$ET_{interval}$ = Applied volt-time during the evaluated interval (V·s)
$v_S(t)$ = Instantaneous voltage across the secondary winding (V)
t_1, t_2 = Beginning and end of the evaluated interval (s)

For symmetrical bipolar switching waveforms in which each polarity occupies one-half of the switching period, the applied volt-time during each polarity interval can be approximated by:

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

Where the output voltage is:

$$E_O = \frac{I_P \times R_B}{TR}$$

Where:

ET = Applied volt-time (V·s)
E_O = Output voltage across the burden resistor (V)
f = Switching frequency (Hz)
I_P = Primary current (A)
R_B = Burden resistor (Ω)
TR = Turns ratio

For repetitive operation, the transformer core must also be provided with sufficient reset so that the applied positive and negative volt-time remain balanced over successive switching cycles. Inadequate core reset may cause residual magnetic flux to accumulate, eventually driving the core into saturation.

As the burden resistance or primary current increases, the secondary output voltage also increases, resulting in greater applied volt-time for a given pulse duration. Likewise, reducing the switching frequency or increasing the pulse width increases the duration over which voltage is applied to the transformer winding. Designers should verify that the resulting applied volt-time remains within the transformer's specified operating capability and that adequate core reset is maintained to preserve linear transformer operation and accurate current sensing.

When the magnetic core saturates, the transformer can no longer accurately reproduce the primary current. The resulting reduction in secondary current causes measurement errors, distorted output waveforms, and delayed or inaccurate protection responses. Selecting a transformer with suitable core characteristics and operating it within its specified electrical ratings helps maintain linear transformer operation and reliable current sensing.

📝***Design Note:*** *The ET calculation provides a useful estimate of the applied volt-time for evaluating saturation margin. Designers should always verify the transformer's specified electrical ratings, waveform assumptions, and recommended operating conditions provided by the manufacturer before applying ET calculations to a specific design.*

5.7 Package Style

Current sense transformers are available in both through-hole and surface-mount packages. Package selection should consider the available PCB space, primary current path, manufacturing process, and mechanical requirements of the overall power converter. Selecting an appropriate package helps simplify PCB layout while supporting reliable electrical and mechanical performance. The selected package should satisfy both the electrical requirements of the application and the practical constraints of PCB layout, assembly, and long-term mechanical reliability.

Surface-mount devices are often preferred for compact, automated assembly, while through-hole packages may be advantageous in applications requiring greater mechanical robustness or higher-current conductors.

5.8 Design Trade-Offs

Selecting a current sense transformer requires balancing multiple electrical and mechanical design considerations rather than optimizing a single specification. Primary current range, turns ratio, frequency range, isolation requirements, burden resistor selection, core characteristics, and package style all influence overall transformer performance and should be evaluated together during the design process.

The most suitable current sense transformer is one that satisfies the application's electrical, thermal, mechanical, and safety requirements while providing the required measurement accuracy over the intended operating conditions. Careful consideration of these design trade-offs helps ensure reliable current sensing, stable system operation, and long-term product reliability.

Table 1. Current Sense Transformer Selection Checklist

Design Parameter	Verification
Primary Current Range	Verify the transformer accommodates both normal operating current and expected peak current.
Turns Ratio	Confirm the selected turns ratio provides the required secondary current and output voltage.
Burden Resistor	Confirm the selected resistance value and power rating are appropriate for the intended operating conditions.
Frequency Range	Ensure the operating frequency and pulse conditions fall within the transformer's specified operating range.
Isolation Requirements	Verify the insulation system satisfies the application's electrical safety requirements.
Core Saturation	Verify the calculated applied volt-time remains within the transformer's specified operating capability to avoid core saturation.
Package Style	Confirm the selected package satisfies PCB layout, assembly, and mechanical requirements.

Once the appropriate current sense transformer has been selected, the next step is understanding how it is applied within practical power conversion circuits. The following section presents representative applications commonly found in switched-mode power supplies, motor drives, renewable energy systems, battery management systems, and other power electronic equipment.

6 Common Applications of Current Sense Transformers

Current sense transformers are widely used in switched-mode power supplies and other power electronic systems that require isolated, low-loss current measurement for regulation, monitoring, and protection. By converting the primary current into a proportional secondary current and corresponding output voltage across a burden resistor, they provide accurate current feedback for PWM controllers, analog-to-digital converters (ADCs), comparators, digital signal processors (DSPs), and other control or protection circuits.

Although power converter topologies vary, the fundamental operating principle remains the same. Current flowing through the transformer's primary conductor generates a changing magnetic flux that induces a proportional secondary current. The burden resistor converts this secondary current into a measurable voltage for use by the control and protection circuitry.

Figure 6 illustrates a representative implementation of a current sense transformer used for primary-side current monitoring in a flyback switched-mode power supply, while **Table 2** summarizes several common applications and their primary design objectives.

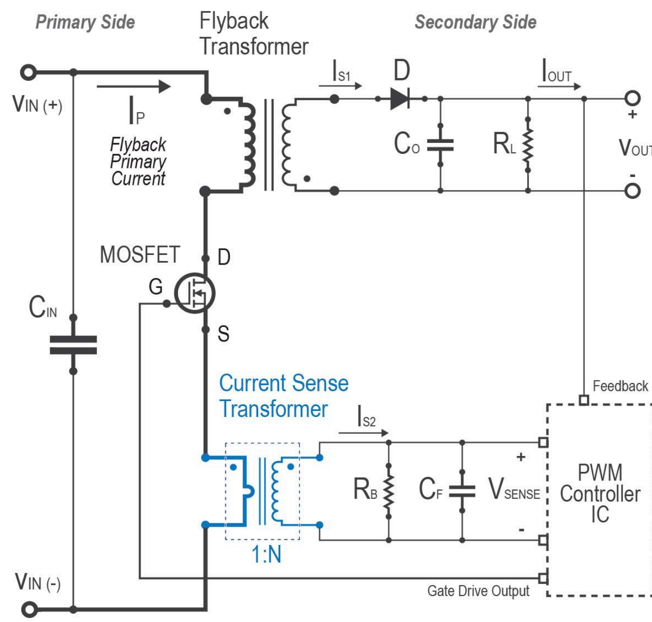

Figure 6. Representative Primary-Side Current Monitoring Using a Current Sense Transformer in a Flyback Switched-Mode Power Supply.

6.1 Typical Current Sense Transformer Applications

Table 2. Typical Implementation and Design Objectives

Application	Primary Function
Switched-Mode Power Supplies	PWM regulation and overcurrent protection
Power Factor Correction	Current shaping and converter protection
DC-DC Converters	Isolated sensing of switch, winding, or rectifier current pulses
Inverters and Motor Drives	AC phase-current or switching-current feedback and protection
Protection Circuits	Fault detection and equipment protection

6.1.1 Switched-Mode Power Supplies (SMPS)

Current sense transformers are widely used in flyback, forward, push-pull, half-bridge, and full-bridge converters to provide isolated primary-current feedback for PWM regulation and overcurrent protection. Their fast response, galvanic isolation, and low insertion loss make them well suited for high-frequency switching applications, where accurate current measurement is essential for stable converter operation and fault protection.

6.1.2 Power Factor Correction (PFC)

In boost power factor correction (PFC) converters, current sense transformers monitor the pulsed inductor or switching-device current and provide isolated feedback to the controller for current shaping and fault protection. Accurate current sensing supports high power factor, low input-current distortion, and reliable converter operation under normal and fault conditions.

6.1.3 DC-DC Converters

Current sense transformers are commonly used in isolated DC-DC converters to measure switch, transformer-winding, rectifier, and other pulsed currents while maintaining galvanic isolation between the power and control circuits. Their fast response and low insertion loss support current regulation, current limiting, and overcurrent protection in industrial, automotive, and distributed power systems. Because conventional current sense transformers respond only to changing current, they are not suitable for directly measuring the continuous DC component of input, output, or intermediate bus current.

6.1.4 Inverters and Motor Drives

Current sense transformers may be used to measure AC motor-phase current, switching-device current pulses, or switching ripple associated with an inverter or DC-link circuit. Their fast response supports torque control, current limiting, overcurrent protection, and fault detection in variable-frequency drives and other motor-control applications. They do not directly measure the continuous or average DC-link current.

6.1.5 Protection Circuits

Current sense transformers are widely used in overcurrent, short-circuit, overload, and inrush-current protection circuits. Because they introduce low insertion loss while providing galvanic isolation, they are well suited for fast fault detection and protective shutdown in power electronic equipment.

7 Comparison of Current Sensing Technologies

Several technologies are available for current measurement in power electronic systems, each offering distinct advantages depending on the application. The choice of sensing method depends on factors such as the type of current being measured, isolation requirements, bandwidth, response speed, accuracy, insertion loss, and overall system complexity.

Table 3 compares current sense transformers with shunt resistors, Hall-effect sensors, and Rogowski coils by summarizing their operating principles, key characteristics, and typical applications

Table 3. Comparison of Common Current Sensing Technologies

Characteristic	Current Sense Transformer	Shunt Resistor	Hall-Effect Sensor	Rogowski Coil
Operating Principle	Electromagnetic induction	Resistive voltage drop	Magnetic field sensing	Air-core mutual induction
Suitable Current Types	AC and switching currents	AC and DC	AC and DC	AC and transient currents
Galvanic Isolation	Yes	No (unless isolated circuitry is added)	Yes	Yes
Insertion Loss	Very low	Power dissipated in resistor	Very low	Negligible
Response Speed	Fast	Fast	Moderate to fast	Very fast
DC Measurement	No	Yes	Yes	No
Saturation	Core can saturate	Not applicable	Device-dependent	No magnetic saturation
Signal Conditioning	External burden resistor	Amplifier often required	Integrated or external circuitry	Integrator required
Typical Applications	SMPS, DC-DC converters, inverters, motor drives, overcurrent protection	Battery systems, DC current monitoring, instrumentation	Motor drives, EV systems, battery monitoring, industrial power electronics	High-current switching, power analyzers, fault-current measurement

7.1 Current Sense Transformer

Current sense transformers are well suited for measuring high-frequency AC and switching currents in isolated power conversion systems. Their low insertion loss, fast response, galvanic isolation, and good common-mode noise rejection make them particularly suitable for switched-mode power supplies, DC-DC converters, inverters, motor drives, and overcurrent protection circuits. Although they provide galvanic isolation and good rejection of DC and low-frequency common-mode disturbances, high-frequency common-mode transients may still couple through parasitic interwinding capacitance. Appropriate transformer construction, PCB layout, and grounding practices help minimize these effects. Because their operation depends on changing magnetic flux, they respond only to AC, pulsed, or other time-varying currents and do not directly measure continuous DC current.

7.2 Shunt Resistor

Shunt resistors provide a simple and economical method of measuring both AC and DC current by sensing the voltage developed across a precision resistor. They are widely used in battery management systems, power supplies, and instrumentation where low cost, simplicity, and high measurement accuracy are important. However, because the measured current flows directly through the resistor, shunt resistors introduce power dissipation into the current path and require additional isolation circuitry when galvanic isolation is needed.

7.3 Hall-Effect Sensor

Hall-effect sensors measure current by detecting the magnetic field surrounding a current-carrying conductor, enabling isolated measurement of both AC and continuous DC current. Their ability to monitor bidirectional current without direct electrical connection makes them well suited for motor drives, battery management systems, electric vehicles, renewable energy systems, and industrial automation. Depending on the device architecture, Hall-effect sensors may integrate signal conditioning and compensation circuitry to improve measurement performance.

ICE Components also offers **programmable Hall-effect current sensors** for applications requiring accurate isolated AC and DC current measurement in a compact PCB-mounted solution.

> 📝***Additional Resource:*** *For more information on Hall-effect current sensing, refer to the* ***ISB Series Current Sense Transducer Application Information (ISB-AN1-R1)***.

7.4 Rogowski Coil

Rogowski coils measure current using an air-core winding surrounding the current-carrying conductor. Because they do not contain a magnetic core, they are immune to magnetic core saturation and provide exceptionally wide bandwidth for measuring rapidly changing currents. However, because their output voltage is proportional to the rate of change of current (*di/dt*), an integrator circuit is required to reconstruct the measured current waveform. Rogowski coils are commonly used for high-current transient measurements, power quality analysis, and fault-current monitoring.

Selection Guideline

Each current sensing technology offers unique advantages and limitations. Selecting the most appropriate solution depends on the type of current being measured, isolation requirements, and the electrical and performance objectives of the application.

8 Design Considerations

Proper implementation is essential for achieving accurate, stable, and reliable current measurement. In addition to selecting an appropriate current sense transformer, designers should consider burden resistor selection, magnetic operating limits, switching frequency, PCB layout, and isolation requirements to optimize measurement performance and long-term reliability.

Table 4-A. Practical Design Guidelines for Current Sense Transformers

Design Consideration	Design Guideline
Burden Resistor	Select a burden resistance that provides the required output voltage while maintaining measurement accuracy and operating within the transformer's recommended conditions.
Core Saturation	Verify that the applied volt-time remains within the transformer's specified operating capability to maintain linear operation and avoid core saturation.
See next page for continuation.	

*Table 4-B. Practical Design Guidelines for Current Sense Transformers - **Continuation***

Design Consideration	Design Guideline
Operating Frequency	Select a transformer whose specified operating frequency range is appropriate for the application's switching frequency and pulse conditions.
PCB Layout	Keep the secondary current loop short and place the burden resistor close to the transformer terminals to minimize noise pickup and parasitic inductance.
Isolation	Verify that the insulation system, creepage, and clearance distances satisfy the applicable electrical safety requirements.
Current Type	Use current sense transformers for AC, pulsed, and high-frequency switching currents. Hall-effect sensors or shunt resistors are more appropriate for applications requiring continuous DC current measurement.

The design recommendations presented above complement the transformer selection guidelines discussed earlier in this application note. Final circuit performance should always be verified under the intended electrical, thermal, and environmental operating conditions to ensure accurate current measurement, reliable operation, and long-term system performance.

9 ICE Current Sense Transformer Solutions

ICE Components offers a comprehensive portfolio of current sense transformers engineered for accurate, isolated current measurement across a broad range of power electronic applications. Designed for high-frequency power conversion systems, these product families support applications including switched-mode power supplies, DC-DC converters, power factor correction (PFC) circuits, inverters, motor drives, battery charging systems, and industrial power equipment.

Available in both surface-mount and through-hole packages, ICE current sense transformers cover a wide range of current ratings, turns ratios, operating frequencies, isolation voltages, and package configurations to accommodate diverse electrical and mechanical design requirements. Whether the design objective is improving measurement accuracy, minimizing PCB area, increasing isolation capability, or supporting higher operating currents, ICE Components offers both standard product families and custom magnetic solutions for modern power conversion systems.

9.1 Standard Product Families

ICE Components offers a broad portfolio of standard current sense transformers optimized for applications ranging from compact, high-frequency switched-mode power supplies to high-current and reinforced-isolation industrial systems. Each product family is designed to address specific electrical, mechanical, and safety requirements encountered in modern power electronics.

Table 5 summarizes the key characteristics of each product series to assist engineers in selecting the most appropriate current sense transformer for their application.

Table 5. ICE Current Sense Transformer Series Overview

Series	Mounting	Key Characteristics	Maximum Primary Current	Operating Frequency	Hi-Pot Rating
CT01 Series	SMT	Low-profile design for compact SMPS	10 A	Up to 1.5 MHz	500 VAC
CT02 Series	SMT	Compact design with higher isolation capability	18 A	Up to 1.5 MHz	1500 VAC
CT03 Series	THT	Vertical tombstone package for space-efficient layouts	25 A	Up to 500 kHz	3750 VAC
CT04 Series	SMT	Higher-current low-profile design	20 A	Up to 1.5 MHz	500 VAC
CT05 Series	THT	High-isolation design for industrial applications	25 A	Up to 500 kHz	4000 VAC
CT06 Series	SMT	Compact design for space-constrained layouts	18 A	Up to 1.5 MHz	1500 VAC
CT07 Series	THT	High-current sensing for line-frequency applications	200 A	40 Hz–3.2 kHz	3750 VAC
CT08 Series	THT	Low-frequency sensing in a vertical package	50 A	40 Hz–4.7 kHz	3750 VAC
CT09 Series	SMT	High-creepage design	6 A	Up to 1.5 MHz	3750 VAC
CT10 Series	THT	General-purpose design for medium-current applications	40 A	Up to 400 kHz	3000 VAC
CT11 Series	SMT	High-isolation design supporting modern IEC insulation requirements	30 A	200 Hz–1 MHz	3000 VAC

9.2 Custom Current Sense Transformers

In addition to its standard product portfolio, ICE Components develops custom current sense transformers tailored to specific electrical, mechanical, thermal, and regulatory requirements. Our **engineering team** works closely with customers to optimize turns ratio, current range, isolation performance, package configuration, operating frequency, and other critical design parameters to meet demanding application requirements.

From prototype development through volume production, ICE Components delivers **custom magnetic solutions** engineered for accurate, reliable, and isolated current measurement, helping customers accelerate product development while achieving long-term system performance.

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