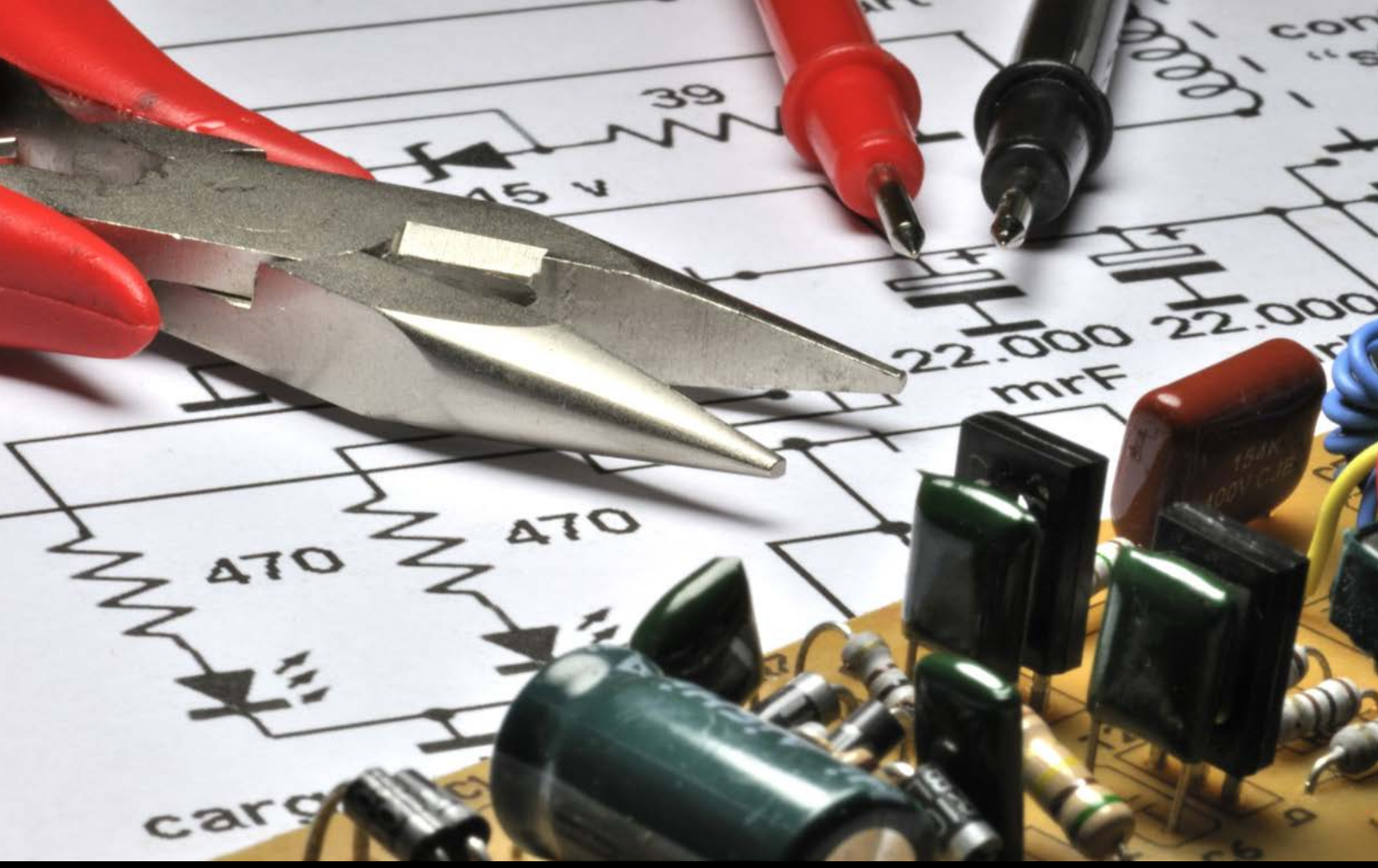
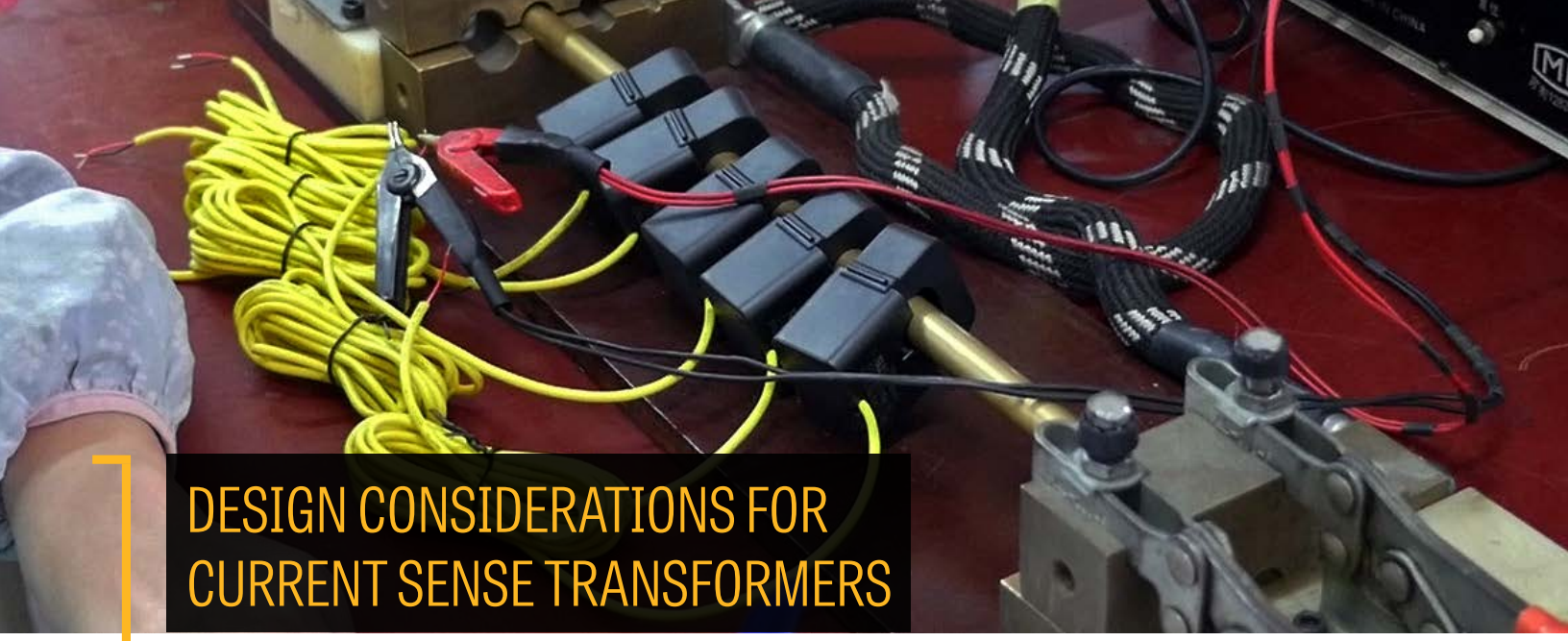


TRIAD MAGNETICS

Design Considerations for Current Sense Transformers



DESIGN CONSIDERATIONS FOR CURRENT SENSE TRANSFORMERS

Current sense transformers are instrument transformers designed to detect (i.e., sense) electrical current and convert (i.e., transform) it into a more usable and safe form for the connected device(s). They perform this function by measuring the current flow in the primary winding and producing a proportional current in the secondary winding, enabling the reduction of high-voltage current in the primary winding to a lower value in the secondary winding.

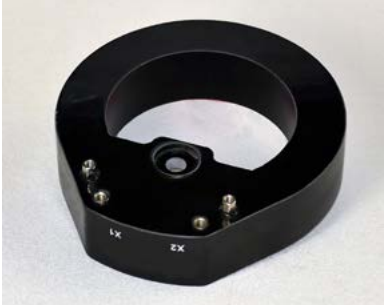
Compared to standard voltage transformers, current sense transformers vary slightly with regard to the principle of operation. The key differences between the two are the primary winding design and the relationship between the primary current and the secondary load current. In current transformers, the primary winding only has a few turns (one to three), and the primary current is controlled by an external load rather than dependent on the secondary load current. This design enables them to reduce currents of thousands of amperes down to 1 or 5 amperes reliably and safely, making them highly suitable for use alongside devices with low amperage ratings.

Current sense transformers find use in a wide range of instrument monitoring, control, protection, and metering applications. For this reason, they come in a variety of designs and configurations to accommodate different application requirements and restrictions. Ensuring the device operates and performs as intended necessitates careful consideration during the design stage.

The following eBook provides an overview of the types of current sense transformers available and discusses the factors to consider when designing one for an application.

Types of AC Current Sense Transformers

The precision of a current sense transformer describes how accurately it detects a current over a specified range. The more proportional the output voltage is to the primary current, the more precise the current sense transformer.



The level of accuracy exhibited by a current sense transformer varies depending on its design. As such, it is important to consider an application's precision requirements before designing a transformer for it.

Current sense transformers can be classified into three broad categories based on precision:

High-precision current sense transformers: High-precision current sense transformers are used in applications requiring the highest degree of accuracy in current detection and/or control. A common example is electric metering current sense transformers—also known as revenue-grade current sense transformers.

Medium-precision current sense transformers: Medium-precision current sense transformers—commonly referred to as industrial-grade or commercial-grade current sense transformers—are used in applications where precision is required but not critical.

Low-precision current sense transformers: Low-precision current sense transformers are used in simple applications such as detecting the on/off status of a connected device. One example is a fault detection current sense transformer.

Key Factors Impacting Current Sense Transformer Design

There are many factors to consider when designing a current sense transformer. Below, we highlight some of the key design considerations to keep in mind.

Turns Ratio

The **turns ratio** refers to the ratio of the number of turns in the secondary winding to the number of turns in the primary winding (N_{sec}:N_{pri}). In current sense transformers, it sets the voltage across the burden resistor (if one is integrated into the design) and the flux density across the transformer. Ideally, the turns ratio should result in a current sense transformer with a flux density that is sufficiently low enough for best performance.

Standard current sense transformers have turns ratios between 1:10 to 1:1000. Higher ratios translate to higher current measurement resolutions. However, it is important to note that a turns ratio that is too high necessitates an increase in distributed capacitance and leakage inductance, which can negatively impact the transformer's accuracy and ability to operate at higher frequencies. On the other hand, a turns ratio that is too low can result in distorted or drooping output signals, which can also negatively impact the transformer's accuracy as well as its control circuit stability.

Many current sense transformers feature single-turn primary windings to achieve a simpler design. However, transformer manufacturers generally include additional turns on the primary winding to improve the transformer accuracy when needed.

Excitation Current:

The **excitation current** refers to the amount of current needed to create and sustain a magnetic field inside of the transformer's core. Regarding this element, the primary goal in current sense transformer design is minimizing what percentage it makes up of the total current measured. The main factors influencing it are the number of turns in the primary winding and the core's permeability.
The excitation current of a current sense transformer is inversely proportional to the number of turns in the primary winding—i.e., the greater the number of turns, the lower the excitation current.

Core Material:

The **core** of a current sense transformer can be made from a variety of laminated or sintered materials, each of which exhibits different properties that make them suitable for different current sensing and transforming applications. The two key considerations to keep in mind when choosing a core material and designing the core are material permeability and cross-sectional area size.

Material permeability influences how much or how little energy is required to create and sustain a magnetic field inside of the core. Materials with low permeability require more energy than materials with high permeability. Ideally, the material chosen should have the smallest input energy requirement that is practically possible as the energy expended for input purposes takes away from the output.

The *cross-sectional area* refers to the area at the center of the core. The size of this area is inversely proportional to the flux density of the core. Doubling it reduces the flux density by half. This relationship is advantageous as manufacturers can leverage it to reduce the number of turns needed to avoid core saturation.

The two main types of core materials utilized are powder (ferrite) and nanocrystalline. Ferrite materials have lower permeability compared to nanocrystalline materials, so they are commonly used for high-frequency applications, such as switch-mode or fault detection operations. Nanocrystalline materials have high permeability, so they are typically used for high-accuracy applications, such as metering operations.

Temperature:

As the resistance of the core material affects the output of the transformer, it is important to consider how operational and environmental conditions can influence it during use. One of the key factors to keep in mind is **temperature**. The temperature of a material can significantly alter its resistance, which, if unaccounted for, can negatively impact output.

Temperature changes in core materials are primarily caused by heat generated in the windings. The wires utilized in windings always offer some degree of resistance to current, which results in the generation of heat. While ambient temperature can also affect the temperature of the core material and the performance of the transformer, it is less influential on design than current flow.

Output Voltage and Burden Resistor:

A current sense transformer's **output voltage** should be established as low as reasonably possible to minimize insertion loss. In a circuit with an input current of 20 A and an optimal secondary output voltage of 0.5 V, a transformer with a 1:100 ratio will provide a secondary current of 200 mA. In this situation, to efficiently convert the current to the output voltage, the recommended **burden resistor** is 0.5 V/200 mA or 2.5 ohms (Ω). When selecting a burden resistor, both its accuracy and temperature behavior should be considered.

Current Sense Transformers From Triad Magnetics

Triad Magnetics is an industry leader in the design and manufacture of standard and custom magnetic products. One of our core product offerings is current sense transformers. We engineer these products for precision, reliability, and ease of use, even in some of the most demanding applications. Since 2005, we've manufactured all of our products to meet RoHS 2015/863/EU standards.

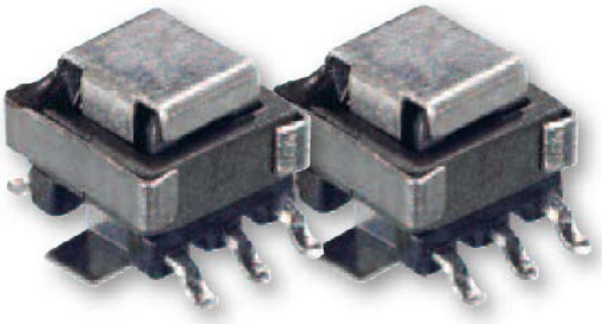
We currently offer five standard current sense transformer product lines, all of which can be custom-tailored to meet unique application requirements:

CST206/CST306 Series High-Frequency Current Sense Transformers –

The CST206/306 series is extremely reliable for operations across a frequency range of 20 kHz to 200 kHz. These models are specifically designed for detecting the current passing through a conductor in switching power supply applications. Constructed of materials UL-rated to 130 ºC (266 ºF), these transformers are also available with a center tap option. The rated primary current creates a temperature rise of approximately 40 °C (104 ºF), the maximum recommended terminating resistance is 1 ohm per turn, and the primary is inserted through-hole in the unit's casting.

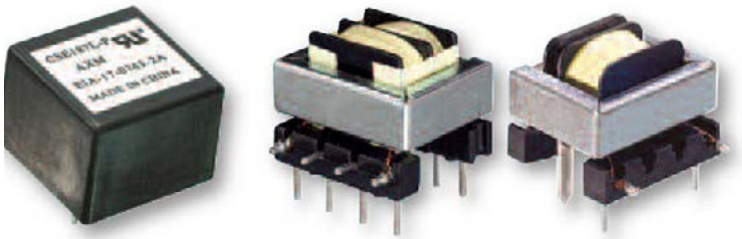
CSE5 Series High-Frequency Current Sense Transformers –

The CSE5 series is specifically designed to monitor electrical currents at 250 kHz and higher. With a primary current rating of 10 amps, these surface-mounted transformers have an operating temperature range of -15 °C (5 ºF) to 105 °C (221 ºF). Common applications include AC current detection, output supply for control circuit, and switching power supply.



CSE Series Low-Frequency Current Sense Transformers –

The CSE series is expertly designed to monitor electrical currents in low-frequency applications. These transformers are provided with a Recognized Component electrical insulation system (OBJY2), Class 130 (B), designated B3.



CST Series Low-Frequency Current Sense Transformers –

The CST series operates effectively from 50 Hz to 60 Hz. These models are constructed with materials UL-rated to 130 ºC (266 ºF). The third pin on these transformers is for mechanical support only. Pin diameters are 0.8±0.1 mm, and pin lengths are 5±1 mm.

CST25 Series Current Sense Transformers –

The CST25 series is ideal for monitoring currents in high-frequency applications such as switch-mode power supplies and LED lighting. These transformers feature a built-in sense winding, allowing for optimal ease of use, and are fully encapsulated to facilitate a high isolation of 4000 VAC between primary and secondary windings. Users can choose from four popular turn ratios: 1:50, 1:100, 1:200, and 1:500.

Additionally, we maintain a line of current sense transformers developed for specific customer applications, which includes a 1 amp variation (CSE184L), a 3 amp variation (CSE185L), a 10 amp variation (CSE196L), and a 30 amp variation (CSE187L). These variations differ with regard to the number of turns and the wire size in the primary. The smaller sizes were developed to reduce excitation current and achieve better accuracy.

Custom Current Sense Transformers from Triad Magnetics

In addition to our standard current sense transformer products, we offer a broad range of custom transformer design and manufacturing services to accommodate highly specific or unique customer applications. Our ISO 9001:2015 certified U.S. Design Center houses all of the equipment we need to offer complete custom current sense transformer solutions. Our capabilities include:

- Rapid design, prototyping, and testing
- Wire preparation and wire harness assembly
- Core creation (ferrite, amorphous, nanocrystalline, powdered iron, and tape-wound)
- Winding creation (52ga-8ga and foil magnetic component)
- Winding and assembling (all core shape and types including laminated)
- Molding and 3D printing

To learn more about current sense transformer design principles or our standard and custom current sense transformer products and services, contact our experts today.

ABOUT TRIAD MAGNETICS

EXPERIENCE

With more than 500 transformer manufacturers in the world, we realize you have a choice. Why choose Triad Magnetics? Having served the needs of our industry for more than 75 years, we believe our experience makes the difference. If there is one point our experience has taught us, it is that we must remain flexible and adaptable to the changing needs of the market.

STANDARD OR CUSTOM

Over 1,000 part numbers mean you will probably find the component you need in our standard product line. If not, the creative thinkers of Triad Magnetics can offer powerful custom solutions. Whether it's Switchmode/High Frequency, Wall Plug-In, Power Transformers, Inductors or Audio Transformers, each product is backed by the industry's most resourceful and organized magnetics manufacturer.

DESIGN INNOVATION

Triad Magnetics' pioneering design process promotes innovation. There are thousands of Triad Magnetics designs providing application solutions throughout the world, from data processing to telecommunications to power conversion. Our engineers are experienced in all packaging styles, from traditional paper-section stick winding to the latest hi-frequency planar construction technology.

WORLD-CLASS MANUFACTURING

Our cellular production techniques provide the flexibility of both high and low volume production, capable of handling one piece to 10 million pieces, making us the perfect supplier for customers who have a "high-mix" of product requirements. The industry's most comprehensive array of production tools include automated fly winding and stick winding processes for bobbin and paper type construction. State-of-the-art welding and impregnation facilities add speed and flexibility.

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View Our Product Demonstrations

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