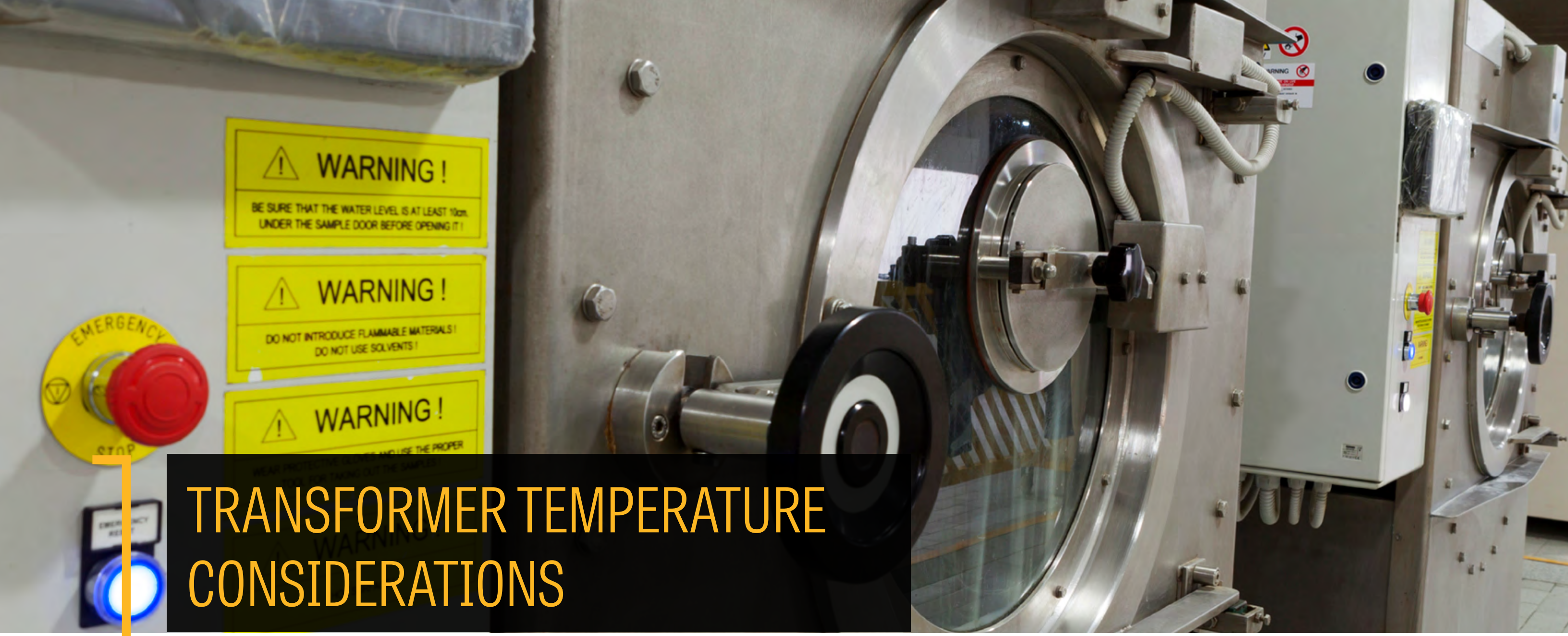
TRIAD MAGNETICS

Transformer Temperature Considerations



TRANSFORMER TEMPERATURE CONSIDERATIONS

A transformer is an electromagnetic device that changes the voltage level of an alternating current (AC) in a circuit. The transformer consists of at least a primary winding and a secondary winding wrapped around a single magnetic core. The primary winding connects to the incoming voltage source, while the secondary winding connects to a load. The transformer's core supports the two windings and provides the magnetic field to either step-up or step-down the voltage levels.

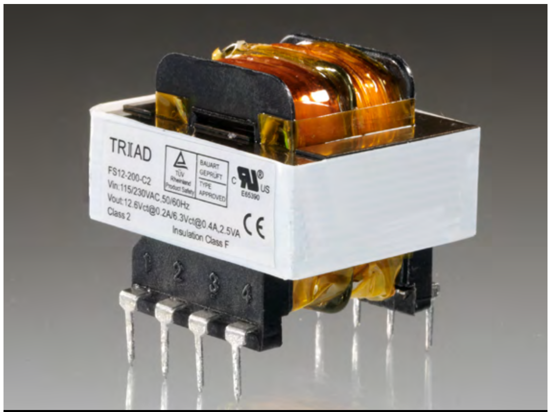
Any device that uses electricity inherently generates a certain amount of wasted heat as an operational byproduct. In transformers, this waste heat increases the device's internal temperature, which can reduce its efficiency and shorten its lifespan. Given the growing importance of energy efficiency in modern electrical power applications, temperature considerations are critical when selecting a transformer for an operation.

This eBook covers some of the most important temperature-related considerations to keep in mind during the transformer selection process.

Temperature Rise vs. Insulation Class

When selecting a transformer for an application, consider temperature rise and insulation class.

- **Temperature rise.** Temperature rise refers to the average temperature increase of the transformer above ambient temperature when the device is fully loaded according to the rating. This self-heating occurs due to conductor and core power losses. The transformer's capacity or rating is limited by the maximum temperature tolerated by the insulation system.



Triad's -C2 Series power transformers uses Kapton® insulation tape to achieve a Class F rating.

- **Insulation class.** A transformer's insulation system receives a class number according to the highest temperature at which it can operate. Based on NEMA-established standards, this class number is equivalent to the transformer’s maximum full load temperature rise plus its maximum allowable ambient temperature in degrees Celsius. For example, a transformer with a Class B insulation system rated for 130°C would allow for a maximum 40°C temperature rise and 90°C ambient. Insulation system ratings also dictate the transformer's overload capacity. For safety and long-term reliability, it is important to keep the transformer operating below the insulation system's temperature maximum rating.

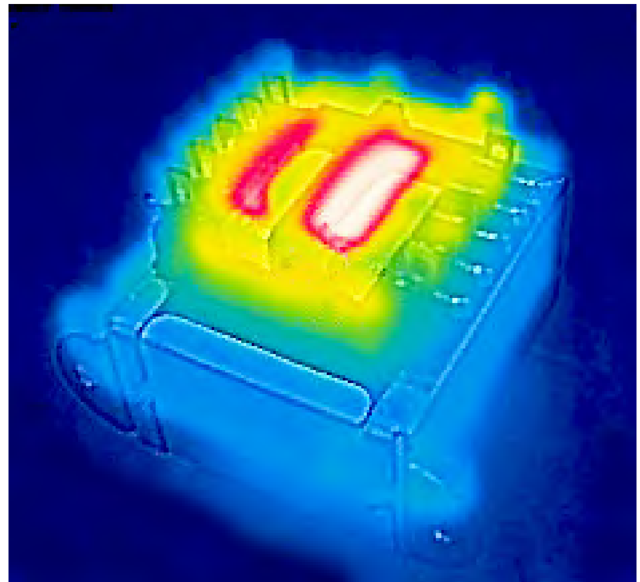
Insulation Class	Maximum Permissible Temparature (° C)
Y	90
A	105
E	120
B	130
F	155
H	180
C	>180

Temperature Rise and Efficiency

One of the main factors influencing a transformer's efficiency and lifespan is temperature. While most transformers are designed to operate for a few decades, regular exposure to temperatures above the device's tolerable limit can lead to rapid degradation of insulating materials and a reduced lifespan. Transformers with low efficiencies tend to generate more waste heat, which results in a higher temperature rise. In general, the more efficient the transformer is, the lower its temperature rise.

Highly efficient transformers with low temperature rise are ideal for applications where long-term reliability and performance are important such as industrial, medical, communication, alternative energy and automotive equipment. Units that can operate more efficiently will generate less waste heat, which reduces cooling and ventilation requirements. Making sure the transformer is appropriately designed, sized, and rated to meet the application's load requirements will help maximize efficiency and life expectancy.

Estimating the Temperature Rise of a Transformer



A thermal image of a power transformer.

A transformer's acceptable temperature rise depends on several factors including cost, physical space limitations, types of materials used in the device, relevant safety regulations, and temperature tolerances of other components near the device. Most of a transformer's temperature rise is attributable to power losses in the core and the windings, which are dissipated in the form of heat.

During the design process, the temperature rise of a transformer can be difficult to predict with absolute accuracy; one estimation method involves combining the core loss with the conductor losses. This method assumes that the transformer's heat energy is evenly dispersed across the core and coil surfaces at all temperatures within the ambient temperature range. For an existing transformer it is possible to fairly accurately measure a transformer’s internal temperature rise by measuring the change in winding DC resistance in the transformer between cold and under load. Simply measuring the transformer surface temperature does not provide an accurate measurement of the transformer’s internal temperature rise.

Core and conductor losses each have distinct impacts on a transformer's temperature rise, which are detailed below.

Core Losses

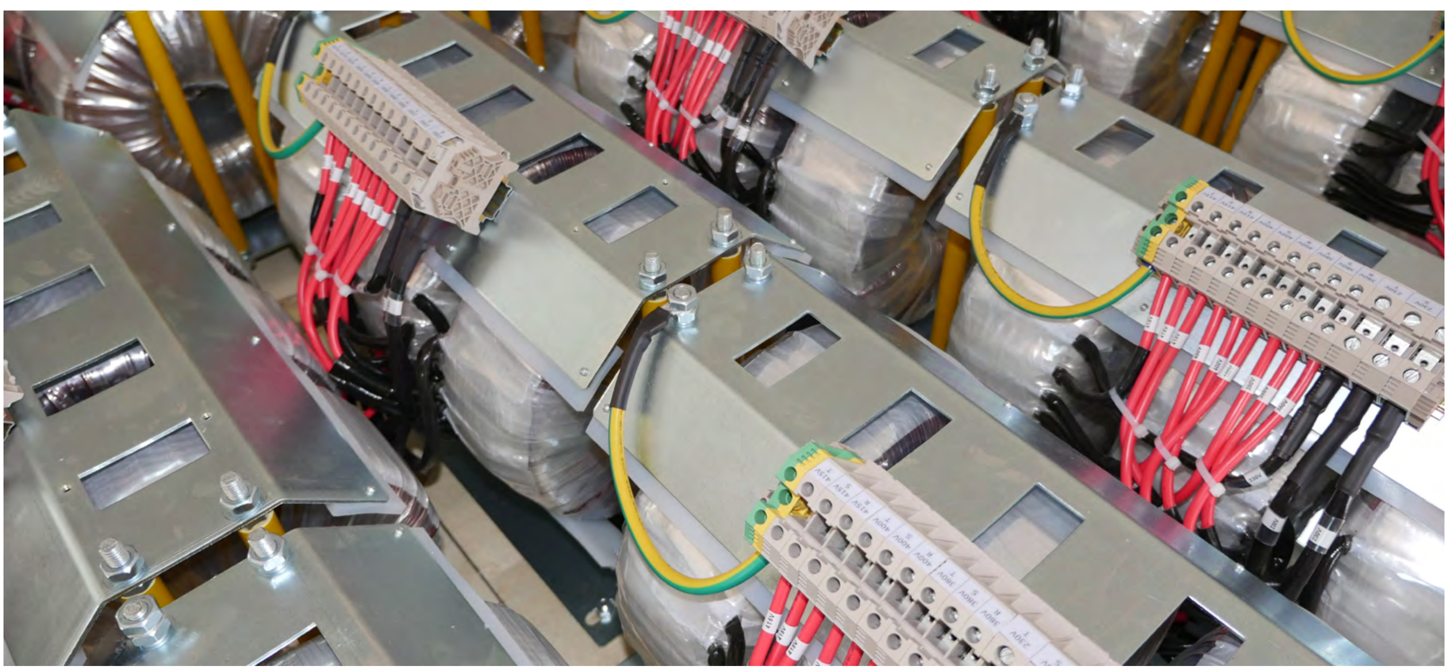
Energy loss from the transformer's electromagnetic core has a substantial impact on the device's temperature rise. Core losses mainly occur in the form of hysteresis loss and eddy current loss, with a small amount of residual loss.

- **Hysteresis loss.** Hysteresis loss occurs as a result of a lag or delay of the magnetic molecules within the core. During operation, the flow of current in forward and reverse directions causes magnetization and demagnetization in the transformer's core. This creates friction in the core's molecules, which results in heat generation and an undesirable increase in temperature.
- **Eddy current loss.** Eddy currents are induced within conductors as a result of a changing magnetic field. These currents circulate within the magnetic core, dissipating energy as heat.

Winding Conductor Losses

Losses from the transformer's primary and secondary windings also contribute to total energy loss and temperature rise. Winding losses are influenced by a combination of factors, including:

- **Skin effects**
- **Proximity effects**
- **Edge effects**
- **Conductor effects**
- **Eddy currents in the windings**
- **Fringing flux intersecting with the windings close to the core gap**



Other Factors to Consider When Choosing Transformers for Your Application

In addition to temperature, the following selection criteria should also be kept in mind to ensure successful transformer implementation:

- **Insulation type.** Different insulation materials can transfer and dissipate internal transformer losses at different rates thereby affecting the transformer's internal temperature rise.
- **Winding material and techniques.** A transformer's coils can be wound using either aluminum or copper conductors. The best material for an application will depend on several factors, including transformer size and weight limitations, material availability, and budget. While copper is the more conductive and compact material choice, aluminum windings are significantly less expensive and perform well in large power transformers. In addition, different winding techniques and spacing between winding layers can be used to reduce the transformer's internal temperature rise.
- **Load requirements.** The selected transformer must be compatible with the load requirements of the given application. Transformers are rated in VA (volt-ampere), where one VA is the product of one volt and one ampere. This rating provides information regarding the transformer's size and its ability to supply the required amount of power to the load when used according to standard guidelines.
- **Installation space.** The space in which the transformer will be installed should be kept in mind during the selection process, since proper transformer specifications are often highly dependent on the conditions of their surrounding environment.

Power Transformers from Triad Magnetics

Transformers improve the efficiency and safety of electrical power systems by accurately adjusting voltage levels to meet output needs. Given the impact of temperature on transformer performance and longevity, it is important to be aware of a transformer's acceptable temperature rise and the factors that contribute to waste heat generation.

Triad Magnetics has over 75 years of experience in designing and constructing high-quality transformers for competitive and fast-paced industries around the world. With a focus on continuous improvement, our quality control process ensures that our products will provide maximum safety, efficiency, and reliability even in the toughest operating environments. Whether you require a slight modification to an existing product or a completely customized design, we have the experience and flexibility to help you find a transformer solution that meets all your application requirements.

To learn more about transformer temperature considerations or to receive personalized guidance for transformer selection, please contact us today or request a quote.

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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