Why choose a toroidal transformer?

In the past, only the most exotic power application justified the use and cost of a toroidal transformer, as they were in limited supply due to the cost of winding toroidals. However, technical advances in winding and production techniques have lowered the cost and increased the availability of toroidal transformers, making them a desirable and cost-efficient alternative to laminated transformers in a wide variety of applications.

Benefits of toroidal transformer design:

Efficiency: The toroidal form of transformer offers excellent efficiency for a given size and weight. The toroidal core provides a virtually perfect magnetic circuit, eliminating the inherent air gaps of conventional laminated-bobbin transformers. Higher flux densities, along with full utilization of the core area, result in a smaller component—typically 50% of the size and weight of laminated components. The overall efficiency of toroidals is typically 90 to 95%, and with custom design can be even higher. Due to the high quality, tightly wound, grain-oriented silicon steel core, very low core losses and off-load magnetizing currents can be achieved, adding to the overall efficiency.

Low noise and low stray flux field: Because the magnetic circuit is so complete, and due to the uniform distribution of the windings over the core, a toroidal transformer is very quiet in operation—with low or even zero mechanical hum caused by magnetostriction. Toroidal transformers also exhibit very low levels of noise-inducing stray magnetic fields (typically 8 times lower than laminated stack type transformers). This makes the toroid the perfect choice for sensitive electronic systems such as high-gain preamplifiers and instrumentation.

Good regulation: The winding configuration of toroidal transformers results in very low leakage inductance. This inductance is produced when a percentage of the magnetic flux produced by the primary is not utilized by the secondary, therefore not generating any voltage—a common characteristic of laminated stack transformers. Because toroidal winding results in tight coupling, virtually all the flux is utilized (and not left to radiate and interfere with circuitry). This enables tight regulation, with off-load secondary voltages lower than laminates. In addition, lower copper loss results in less power being wasted as heat.

Ease of mounting: The majority of toroidal transformers are mounted with one central screw, speeding production time and lowering the parts count of mounting hardware. For special applications, custom mounting methods can easily be provided for greater production efficiency.

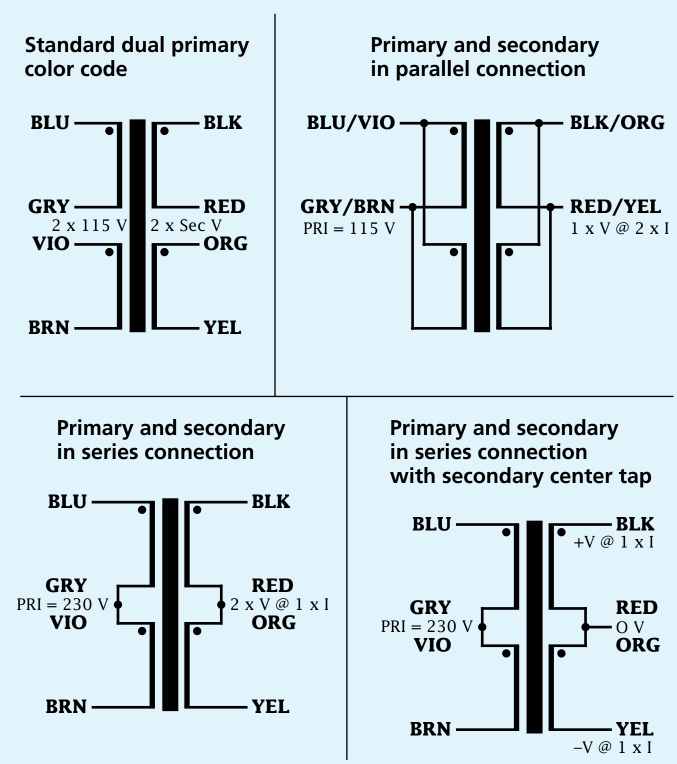
Packaging versatility: A toroidal transformer with specific characteristics can be varied in height and diameter to meet product-design requirements. This enables the transformer to meet enclosure space constraints. Tall cylinder or flat disc styles can be produced to meet retrofit space requirements or low-profile applications.

Approvals: Avel Lindberg Standard Toroidal Transformers comply with most of the world's major safety standards (including UL506, UL2601, UL1411, and UL1950) and are built under our UL- and CSA-recognized design and construction files. Custom designs can be manufactured to comply with most other standards, whether European, medical, military, or commercial. All Avel transformers are CE marked.

Guide to transformer selection and specifications:

Avel's standard general-purpose transformers are available with dual primary windings for operation at 50/60 Hz, and series or parallel connection. They incorporate dual secondaries that can be used in series, parallel or independently, in a range of voltages and VA ratings to suit most power and electronic applications.

Primary / Secondary configurations



This combination of windings enables one component to be specified both for domestic use or for export to other countries where line voltages differ, as well as providing several secondary power configurations.

If your application requires a power supply configuration that cannot be met with our standard range of transformers, our custom transformer service is ready to design a transformer to your precise needs. This may be just a slight modification to our standard range or a unique custom design.

Following is a general guide to some of the criteria that should be considered when specifying a custom transformer.

Power rating:

Transformers are rated in Volt Amps (VA), which is the product of rms AC voltage and rms AC current for a predominantly resistive load.

Example 1: A heating element requires 4 Amps at 24 volts AC and is to be driven from a 115 or 230v, 60 Hz mains supply.

A 115 + 115v to 24v step down transformer is therefore required, with a VA rating of 4 x 24 = 96 VA (100 VA will therefore be suitable)

Example 2: Two 50 watt Halogen Lamps are to be connected in parallel, and require 12v AC to obtain full brightness. A 115v fan is also required to be run, which draws 182 milliamps. This combination is to be driven from 115v 60 Hz supply.

A 115v step down transformer with 2 separate secondary windings is therefore required.

Secondary 1 should be rated at 12v, 100 VA (8.33 Amps)

Secondary 2 should be rated at 115 x 0.182 = 20 VA

The transformer total rating is 100 + 20 = 120 VA

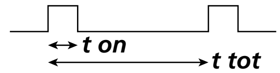
A transformer supplying reactive or rectifier loads needs to be rated according to the load characteristic

Our engineers are pleased to offer guidance regarding ratings for any application (see also the section on rectifier transformers)

Duty cycle:

If the load is not continuous and is much shorter than the thermal time constant (the time taken to reach steady on-load temperature, which can be several hours), a smaller transformer can often be specified. The following formula is helpful in calculating the rating needed.

$$\text{Power Nom} = \text{Power Load}\sqrt{t\ on / t\ tot}$$



Where: Power Nom. = Nominal transformer rating
Power Load = Actual power in the load
t on = Load on time
t tot = Total cycle time

Operating frequency:

The operating frequency determines the transformer size and weight for a given output power—higher frequency generally means a smaller transformer. A transformer designed for 60 Hz operation only will therefore be smaller and lighter than one designed for 50/60 Hz operation, though this size reduction will not be considerable for a difference of only 10 Hz. However, a transformer for 400 Hz operation may be up to 80% smaller than a 50/60 Hz transformer. It is important to specify the minimum expected operating frequency of transformers, as operation is possible above the designed frequency but not below.

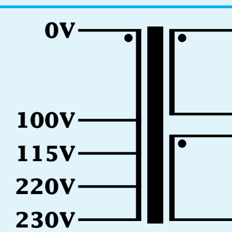
Primary configuration:

It is preferable to try to obtain the required secondary voltages using separate identical primaries to be used in series or parallel. For example, two identical 115v 50 Hz primaries would be connected in series to obtain 230v 50 Hz, or in parallel to obtain 115v, 50 Hz. This arrangement is the most economical in both price and transformer size. A more versatile arrangement would be 2 identical primaries of, for example, 0–100–115V. This will provide 100, 115, and 230V, covering input voltages for places such as Japan, USA, and Europe.

(*The unused taps must then be insulated well, as these will be at their stated voltages above ground and to the other windings when the transformer is in use.*)

Another option (which generally requires a larger and more expensive transformer), is a multi-tapped or ladder primary.

Multi-tapped primary



Primary Voltage:

The Primary voltage(s) stated in standard transformer specifications (or customer-specified in an inquiry) are the nominal voltages. These voltages may vary during times when line supplies are at heavy loads (nearly always around dinnertime), or light loads (when most people are asleep). Drops or rises in this voltage can be as much as 10% of the nominal and vary considerably from country to country. This change in voltage will be reflected on the secondary voltage (on and off-load) by the standard transformation relationship:

$$\text{Sec Voltage} = \left(\frac{\text{Nominal Sec Voltage}}{\text{Nominal Primary Voltage}}\right) \text{X Actual Primary Voltage}$$

Example: A toroidal transformer is rated at 12v and the primary is rated at 117v 60 Hz. The line supply regulation is stated as ± 6% by the utility company.

The secondary voltage when the line is at its lowest voltage will be:

$$\text{Sec Voltage} = \left(\frac{12.0}{117.0}\right) \text{X } 109.98 = 11.28\text{v}$$

Regulation:

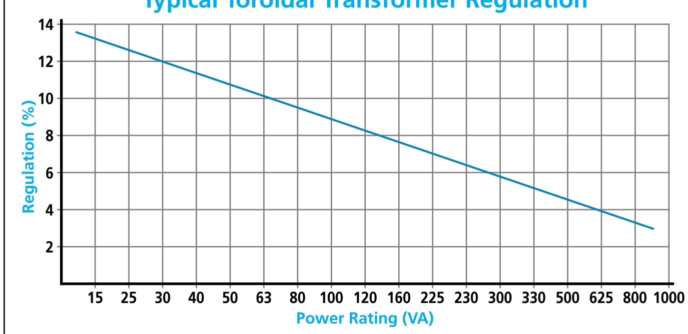
Transformer regulation is a measure of the voltage rise on the secondary due to off-load or light-load conditions with the primary input voltage remaining constant. This measure is expressed as a percentage of the secondary voltage; for example, a transformer with 10% regulation and rated at 12v at full load will have an off-load voltage of 13.2v.

Regulation is calculated as:

$$\left(\frac{\text{No load voltage–Full load voltage}}{\text{No load voltage}}\right) \text{X } 100$$

Due to the design characteristics of transformers, regulation varies inversely with power rating (VA) and is approximately linear for any given loading on the secondary. In the above example, if the load was 50% of full load, the voltage would be 5% higher, or 12.6v. This regulation figure must be borne in mind when designing rectifier power supplies, etc. as it will affect the voltage rating of reservoir capacitors, voltage regulators, etc.

Custom transformers can be designed with very low regulation figures but only at the expense of size and weight, as larger cores and wire gauges must be used. Following are some typical regulation figures for standard transformer VA ratings.



Temperature rise:

Avel's standard toroidal transformers are designed for a temperature rise of a maximum of 60˚C, and have a material rating of Class A (105˚C), although the winding wire used has a rating of Class F (155˚C) for additional reliability. This temperature rise is above the ambient temperature of approximately 30-35˚C.

If a higher temperature rise can be tolerated by surrounding components and enclosures, then a reduction in transformer size may be considered. Avel can manufacture to most standard temperature classes, although the cost of the transformer will rise considerably due to the higher-cost materials that would be required. It is important to furnish expected ambient temperatures in a custom inquiry for any temperature class, as the running temperature of the transformer will be the ambient temperature plus the transformer temperature rise.

Below are some standard temperature classes.

Insulation Classes:

Y = 90˚ C
A = 105˚ C
E = 120˚ C
B = 130˚ C
F = 155˚ C
H = 180˚ C

Capacitive shielding:

Transformers by nature are wide band devices regarding stray signal coupling. Where a transformer is required to operate in electrically noisy environments, a conducting shielding layer can be interposed between the primary and secondary windings (or between individual secondaries) to minimize the capacitance between them. This can reduce (or even eliminate) some types of common mode noise, but its effectiveness depends on the noise characteristic as

well as the transformer's overall surface area.
This type of shield is sometimes required to satisfy certain safety regulations and circuit configurations. Capacitive screens add layers and cost to a toroid's build, because if they are required, a larger core may have to be specified with a large enough inner diameter to complete the windings. This type of shielding should supplement and not replace the usual line filters and suppressor networks that may be required for circuit operation or EMC compliance.

Magnetic shielding:

Although toroidal transformers emit minimal stray magnetic fields by their nature, a certain amount will always be present as with all magnetic devices. For the vast majority of applications, toroidal emissions are far too low to affect circuit operation, but there are some applications that are especially sensitive.

These include wideband, high-gain instrumentation and preamplification, high-end audio, and high resolution CRT circuits. In this case, magnetic shielding can be applied around the toroid in the form of a high-permeability metal band. This can be Silicon Steel for the majority of cases or Mu Metal for sensitive applications. For extremely sensitive circuits, total encapsulation in a steel can or case may be the only option. There are ways to reduce emissions by design (before any protection is added to the transformer), so if your circuit is prone to magnetic interference, please include this information in specifications when requesting a quotation.

Inrush currents:

Due to the excellent magnetic circuit that toroidal cores create, and also due to the remanence that results from the more square hysteresis loop that these cores possess, high inrush currents can be encountered when switching on large toroidal transformers. These are higher than in laminated stack transformers and can last for a few half-cycles of the mains voltage. This is caused by the core saturating for a split second and is quite normal. However, this means that larger toroidals (1.5 KVA and higher) should not be switched on without some precautions. It is recommended that slow-blow (type T) fuses be used in the primary circuits of all transformers over 100 VA. For larger toroids, either NTC thermistors or circuit breakers designed for motors and transformers (with type D delay characteristics, for example) should be incorporated. Simple relay-switched resistor soft start circuits can also be used effectively, and a delay of between about 30 to 300 mS will usually work effectively (some relays themselves have pull-in delays of approximately this time). Soft start circuits of this kind should be implemented with, and never replace, the proper circuit protection provided by fuses or circuit breakers.

Mounting:

The standard method of mounting toroidal transformers to a chassis is with a dished steel washer, with the transformer interposed between cushioning gaskets, with this hardware held in place by a single bolt passed through the central hole of the toroid. These mounting kits are supplied with standard transformers. For other mounting options, please see the custom transformers section beginning on page 11.

Caution: *The metal chassis should not touch both ends of the mounting bolt. This causes a shorted turn, which would overheat the transformer rapidly and cause its destruction.*

Varnishing and vacuum impregnation:

Avel offers full vacuum and pressure varnish impregnation, as well as envelope dipping with mold-resistant polymers and protective barriers. Impregnation and dipping can be carried out with either standard solvent-based coil varnishes or solventless epoxy varnishes. Contact Avel for further information, or where you feel you may have an unusual environmental requirement.

Thermal protection:

Thermal protection can be built in to our toroidal transformers in the form of thermal sensitive fuses and switches (thermostats). These protectors are generally built inline into the primary winding, and are in close thermal contact with the windings. Thermal fuses are not resettable and once blown cannot be replaced. Thermal switches are designed to open at a set temperature and will close again upon cooling, reforming the primary circuit (with slight hysteresis). These protectors may be required to satisfy certain safety approvals. Customer specified protection can be added in the form of Normally Open switches, as well as incorporation into specific windings. Thermal protection always adds to the cost of toroidals and can affect the transformer geometry slightly. Our engineers are pleased to advise on protection issues.

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