

**Subject: The Performance Of
Shielded Isolation Transformers
Class 7400**

OVERVIEW

Since the early beginnings of computer power isolation, Square D has supplied shielded transformers for reducing common mode noise and transients. Some applications, however, require additional protection from across-the-line, or transverse mode power disturbances. Although transverse mode transients are usually the least troublesome to sensitive loads, line filtering and across-the-line transient protection can offer added protection. This bulletin introduces a new line of shielded isolation transformers containing these additional features, and provides comparison information evaluating this product with the standard, single shield isolation transformer.

The explanatory diagrams shown in this bulletin are single phase for clarity. The performance characteristics of three phase transformers are identical to those shown in the graph illustrations.

**THE ELECTROSTATIC
SHIELD**

Common Mode

Common-mode, or line to ground transients, (see Figure 1), are the most troublesome of all line disturbances because they bypass equipment power supply filters and more easily penetrate sensitive electronic grounding systems. This often directly affects digital signal levels vitally critical to proper equipment operation. Common mode signals can travel from the primary to the secondary of an unshielded isolation transformer by electrostatic coupling through the capacitance that exists between the input and output windings (see Figure 1).

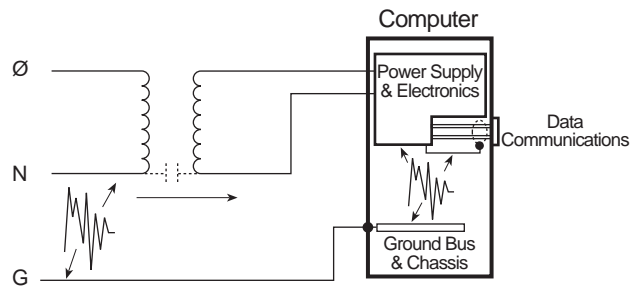


Figure 1. Illustration of common mode noise passing through the interwinding capacitance of a transformer.

Noise Attenuation

An isolation transformer with an electrostatic shield, (in the form of a thin sheet of foil separating the primary from the secondary), can capacitively "short circuit" to ground most spikes and noise arriving at the primary common mode (see Figure 2). In this way, standard, electrostatically shielded transformers have helped to solve the vast majority of power problems.

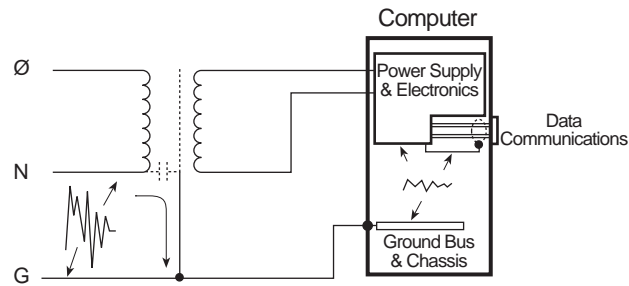
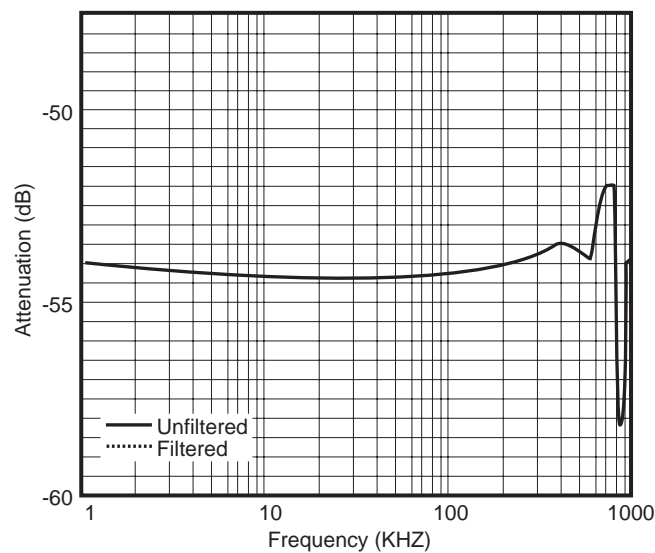


Figure 2. Illustration of common mode noise attenuation values for shielded isolation transformer.

Graph A shows an example curve of attenuation values for shielded isolation transformers with ungrounded secondaries.

It should be noted that the vast majority of applications require that the secondary be grounded in accordance with National Electrical Code requirements.¹ It would be reasonable to think that common mode noise could not be induced into a grounded secondary. However, the AC resistance and inductance of even short ground straps or conductors can present a surprisingly high impedance to high frequency transients and noise. Since the length, size and type of grounding conductors are installation dependent factors, it is impractical to attempt to predict the amount of noise that can be coupled into this external ground.

Graph A



Obviously, however, more efficient electrostatic shielding will decrease whatever common mode signal is available to couple into grounded windings. The values of attenuation shown in Graph A are shown only for illustration purposes, and are measured using methods common to most manufacturers for evaluating shield performance. Thus, these common-mode curves are useful in comparing shield performance with other manufacturers, but do not show, other than in a *relative* way, the performance of the shielding for normal, grounded secondary systems.

¹NEC Article 250-5(b).

TRANSVERSE MODE NOISE

Another type of power problem is in the form of transverse mode, or across-the-line disturbances (see Figure 3). This is the type of noise that most people think of as line noise, but it is least often the cause of equipment malfunction, or failure. Transverse mode spikes and transients are not as effectively dealt with by electrostatic shielding because they are transformed from the primary to the secondary mainly by electromagnetic coupling rather than through capacitance between the windings.

Equipment power supplies are specifically designed to filter out transverse mode disturbances. If proper grounding and wiring techniques are used, including isolation of sensitive loads to dedicated branch circuits, additional protection is usually unnecessary. However, in the event that transverse mode noise has proven to be a problem, additional suppression and filtering must be added to the isolation transformer.

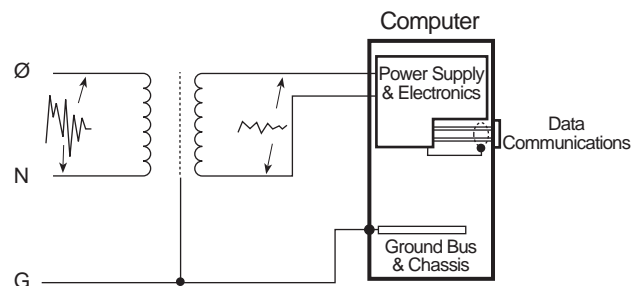


Figure 3. Illustration of transverse-transverse attenuation through an isolation transformer.

TRANSIENT SUPPRESSION AND LINE FILTERING

It is the primary purpose of a transformer to transfer power, as faithfully as possible, from the primary to the secondary. Unfortunately, this often means coupling into the load input transients and other troublesome deviations from the ideal, clean power wave. A transformer couples power most efficiently at its design frequency, (usually 60HZ). Since the transformer reactive impedance increases with frequency, the higher order harmonics and high frequency waveform spikes are greatly attenuated with the transformer under load. This is simply because they are dissipated across the X_L component of the transformer impedance. However, under lightly loaded conditions, the reactive drop may not provide sufficient voltage reduction, or attenuation. Additionally, not all troublesome noise can be classified as high frequency. Therefore, if transverse noise has shown itself to be a problem in a given application, then clearly some remedy, other than relying on isolation transformer impedance, may be required.

Square D isolation transformers with surge suppression and filtering can solve the problem in two ways (see Figure 4):

1. Very fast acting metal-oxide varistor type surge suppression is provided at the primary in order to chop very high amplitude, potentially damaging transient levels.
2. Filtering is provided on each secondary phase to neutral leg to present a “roll-off”, or very low impedance to high frequency signals, thus providing very large attenuation of transverse noise regardless of load on the transformer.

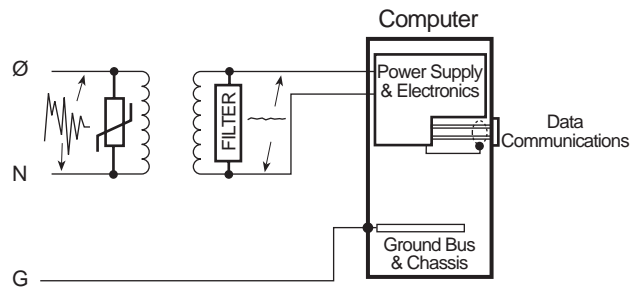
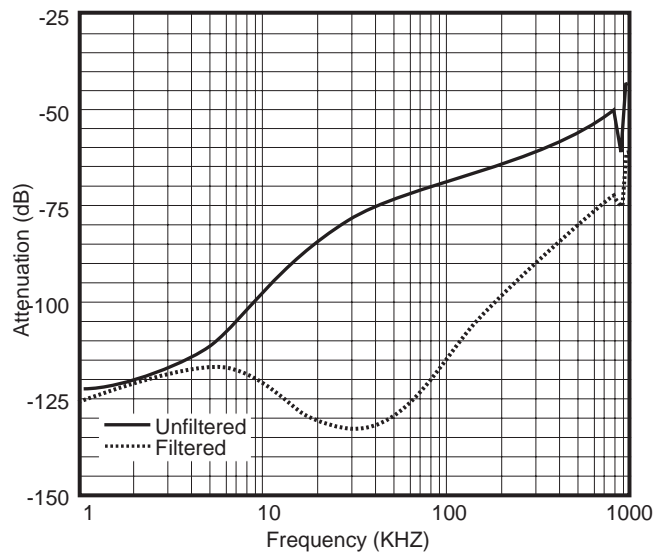


Figure 4. Illustration of transverse-transverse attenuation through a filtered isolation transformer.

Capacitive Coupling

Graph B shows the typical amount of transverse (line-to-neutral) signal which can be impressed into a grounded secondary as a result of common mode signal into the primary. The capacitive coupling between the primary and secondary of a transformer is not uniform for all turns of the coils. The unequal coupling results in the development of a differential, or transverse signal on the secondary. Here the benefits of the line filter on the secondary are evident when comparing unfiltered vs. filtered isolation transformers.

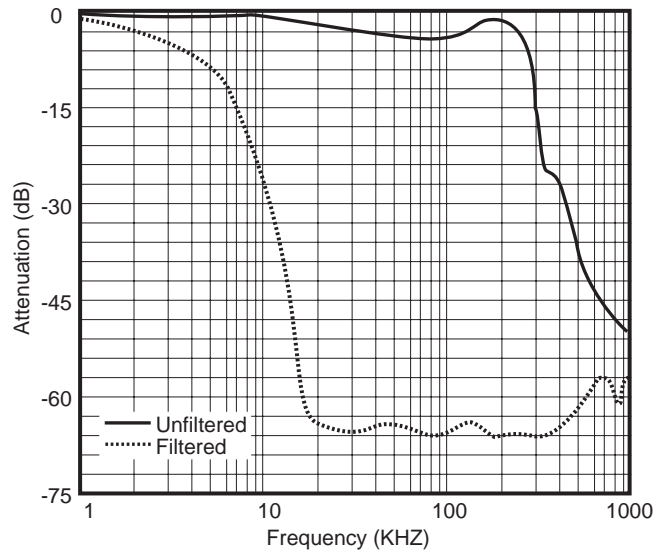
Graph B



FILTERED VS. UNFILTERED

Finally, Graph C illustrates the typical performance of filtered vs. unfiltered isolation transformers in an unloaded, or lightly loaded condition, in attenuating transverse mode (across line) signals into the line-to-line (or line-to-neutral) secondary circuit. Here the advantage of the line filter is very apparent. At 100KHZ the filtered design produces 60 dB (1000 times) more attenuation than the unfiltered transformer. In addition, primary surge suppression provides protection against catastrophic impulses from the service line due to lightning and switching surges.

Graph C



SUMMARY

This bulletin serves not only to explain the operation of Square D isolation transformers, with and without filter and suppressor options, but also to illustrate the relative complexity in the way noise and transients, of various types and frequencies, pass through an isolation transformer. Specifications containing broad statements such as “common mode attenuation shall be 120dB minimum” should be shown to be totally uninterpretable, especially in the case of grounded secondaries. Such specification statements neglect defining if attenuation is common mode to common mode, (such as in graph A), common mode to transverse mode, (such as in graph B), or transverse mode to transverse mode, (such as in graph C). In addition, there is a limit to how far in the frequency spectrum that an isolation transformer can provide a given attenuation. Therefore, a specification neglecting frequency limits is equally open to interpretation.

Standards do not exist for defining terms, test methods, or suitability to application. Therefore, many manufacturers are using various terms describing attenuation in different ways. Thus, competitive advantage can be gained by choosing unrealistic test parameters, selecting advantageous portions of attenuation curves, and making statements which are vague, or are true only in a limited scope or special circumstance. Interpretation of specifications citing attenuation values usually requires additional investigation in order to determine which of the three types of isolation transformers a customer is attempting to specify.

Dictating guidelines for specification interpretation is far too complex an undertaking. Contact the appropriate product headquarters for interpretation of all specifications requiring specific attenuation values.

The addition of Square D’s filtered isolation transformer line completes a trinity of general types of shielded isolation transformers: (1) The single shield transformer, (2) The single shield transformer with additional suppressors and filtering, and

(3) the multiple, box-shielded design with suppressors and filtering. Products (1) and (2) are available as the class 7450 product from the Square D Low Voltage business, and product (3) is available as various Power Protection isolation products.² The three product types represent a range of isolation protection from good to excellent. The choice is highly dependent on many factors, a few of which are:

- Energy, frequency and type of existing noise and/or transients
- Magnitude of reduction required
- Liability, or cost of down time
- Experience with similar installations
- Sensitivity of equipment to be protected

²Contact Power Protection Marketing Headquarters for product information.

Printed in U.S.A.

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