

# Narrow Bandwidth Technology

## A PLITRON White Paper



**Keywords**

- Toroidal Transformers
- Noise Reduction Transformers
- Narrow Bandwidth Transformers
- High Frequency Damping

### Abstract

Narrow Bandwidth Technology (NBT) reduces line distortion within isolation or power transformers. NBT transformers restrict electromagnetic energy to a very narrow passing frequency band. This patented technology gives the transformer the ability to dampen distortion on the line due to harmonics and spikes. It is very effective for attenuating high and very high frequency signals whether the origin is on the line or generated due to asymmetrical loads. NBT can be adapted to most transformer-based power applications.

An NBT transformer performs as a low pass filter with a selected corner frequency. The system is based on two principles, which involve an increase of the internal series inductance, as well as the phase cancellation principle. Phase cancellation is obtained by connecting a bifilar control winding in contraposition through a capacitor. At low frequencies the capacitor acts as an open switch allowing the power frequency (50/60 Hz) to freely cross the transformer. At high frequencies, the capacitor behaves as a closed switch. Therefore, the magnetic flux of the two windings cancel one another and full deletion of high frequency signals occurs. By adjusting the series inductance and the capacitor, the passing bandwidth of the transformer can be controlled.



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# Introduction

Power lines not only contain pure undistorted 50 or 60 Hz sine wave voltages, but other signals as well. The sine wave is distorted, and consequently harmonics of the 50/60 Hz fundamental are found up to 10 kHz. At higher frequencies, switching transients appear from rectifiers, motor drives, etc. At frequencies above 50 kHz, strong HF signals from radio, TV, and computers are superimposed on the line and appear across the primary winding of a transformer.

All these extra signals, called noise or distortion, appear in two ways on the power lines. At frequencies above one MHz, noise is mostly common mode - which refers to both line and neutral containing an equal amount of amplitude and phase distortion. For frequencies below 1 MHz, the major component of the noise is typically differential mode - lines where the noise on both sides' amplitudes are equal and the phase reversed. Differential mode noise generates a real noise voltage difference between line and neutral.

NBT resolves both differential and common mode noise, with the help of increased series inductance, phase cancellation principle, and a reduction in primary to secondary capacitance.

Electronic equipment is sensitive to noise entering through the power line. This unwanted noise can affect the product in many ways, including performance degradation, and even result in malfunctions. Typically, high frequency filters are applied to remove the noise before the line voltage enters the power transformer that supplies the electronic equipment. However, with NBT the power transformer becomes an effective noise rejection filter and the external components to remove the high frequency component are not longer required.

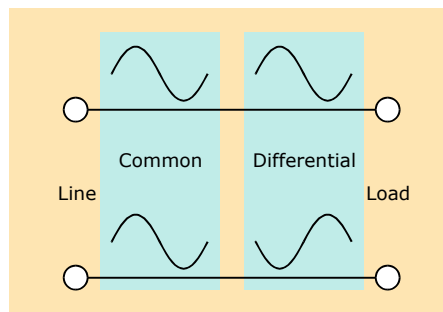


Figure 1. Common and differential noise

The elimination of components has many advantages including reduced parts count and cost. Also, the reduction of primary circuit components will expedite safety agency and approvals certifications. Improved leakage current results by eliminating line-to-ground components.

## Comparing Other Technologies

Effective noise rejection filters should pass the 50/60 Hz fundamental, and remove all higher frequencies. However because the line source impedance, combined with the impedance of the actual load, is low (between 1 to 100 Ohms at 50/60 Hz), for optimum attenuation, the impedance of the filter should be low as well. This would require impractical large and expensive capacitors and inductors.

A less costly approach is to start filtering noise at frequencies above 1 kHz, where most of the unwanted noise is found and which causes malfunction of electronic equipment. The filter should be of the low-pass type with second or higher order slopes. The internal capacitance and inductance inside the transformer are the tools to create the desired filter.

Leakage inductance between the primary and secondary windings in all transformers already functions as a first order low pass filter. Its corner frequency is high, 20 kHz for EI-transformers and 200 kHz for toroidals (due to the toroid's inherently low leakage inductance). Previously, leakage inductance and

interwinding capacitance were viewed as simply a bi-product of the design of line frequency transformers, a function of spacings and dielectrics. NBT exploits these characteristics to attenuate all unwanted frequencies.

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PLITRON has developed the means to accurately calculate specifications, and to construct transformers to meet specified corner frequencies.

## Principle

Figures 2a and 2b give the essentials of the NBT filter technique. Figure 2a shows the secondary winding being extended with an extra winding (control winding), with equal number of turns, connected in reverse phase to the existing secondary winding through a capacitor (control capacitor). At low

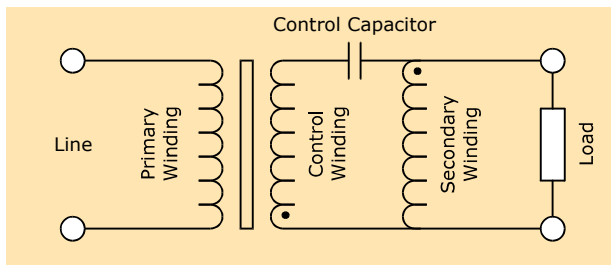


Figure 2a. Phase Cancellation Principle

frequencies, the impedance of the control capacitor is high, the capacitor acts as an open switch, only one secondary winding functions and the 50/60 Hz is free to cross the transformer. At higher frequencies (above 1 kHz), the control capacitor begins to act as a closed switch. Both secondary windings now generate magnetic flux in the transformer core, however, with 180 degrees phase difference. Therefore the magnetic flux of the two windings cancel one another and full cancellation of high frequency signals occurs. Then there is no magnetic transfer of energy through the core to the secondary.

Figure 2b shows the equivalent circuit of a NBT transformer. The increased leakage inductance,  $L$ , is the prime factor in the performance of the NBT design,  $C$  is the transformed capacitance from secondary to primary and  $R$  is the Primary DC-resistance. The combination of  $L$ ,  $C$  and  $R$  react as a second order low pass filter. The corner frequency of the filter is determined by the combination of the values of these elements along with the load impedance  $Z_L$ .

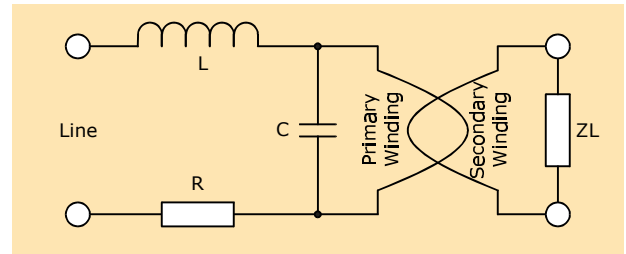


Figure 2b. Equivalent circuit (from primary side)

One of the advantages of this approach is the large impedance of  $L$  at high frequencies. Noise from the line will not be reflected at the input terminals of the transformer, but absorbed in  $L$ . At high frequencies, the NBT transformer will deliver no load to the power lines.

## Distributed phase cancellation

When the control winding is used to deliver energy to an extra secondary load, more efficient use of copper (winding wire) is made, see Figure 3.

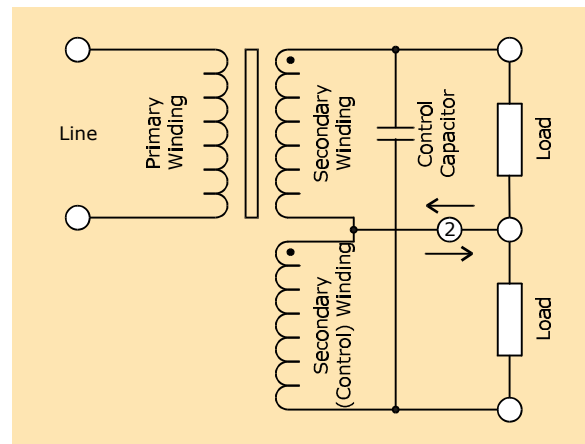


Figure 3. Control winding delivering power

When the loads are equal, the total effective current through connection (2) becomes zero (Phase cancellation). When connecting (2) to ground, a clean ground reference is created without high frequency noise.

# Frequency Response Measurements

To verify the performance of the NBT transformer and observe its advantage over other transformer designs, frequency response tests were carried out and the results are shown in Figure 4. The primary of the transformers are fed by an oscillator and the voltages of the primaries and the loaded secondaries are measured at frequencies, ranging from 50Hz to 1GHz. The ratio of the

secondary to primary voltage, in decibels, versus frequency is plotted for each transformer.

Four different toroidal transformer constructions were compared; a) Standard toroidal transformer, b) Balanced Power, (biflar centre tapped secondary connected to ground), c) Standard Toroid with an externally connected commercial filter\* d) Toroid incorporating NBT Technology.

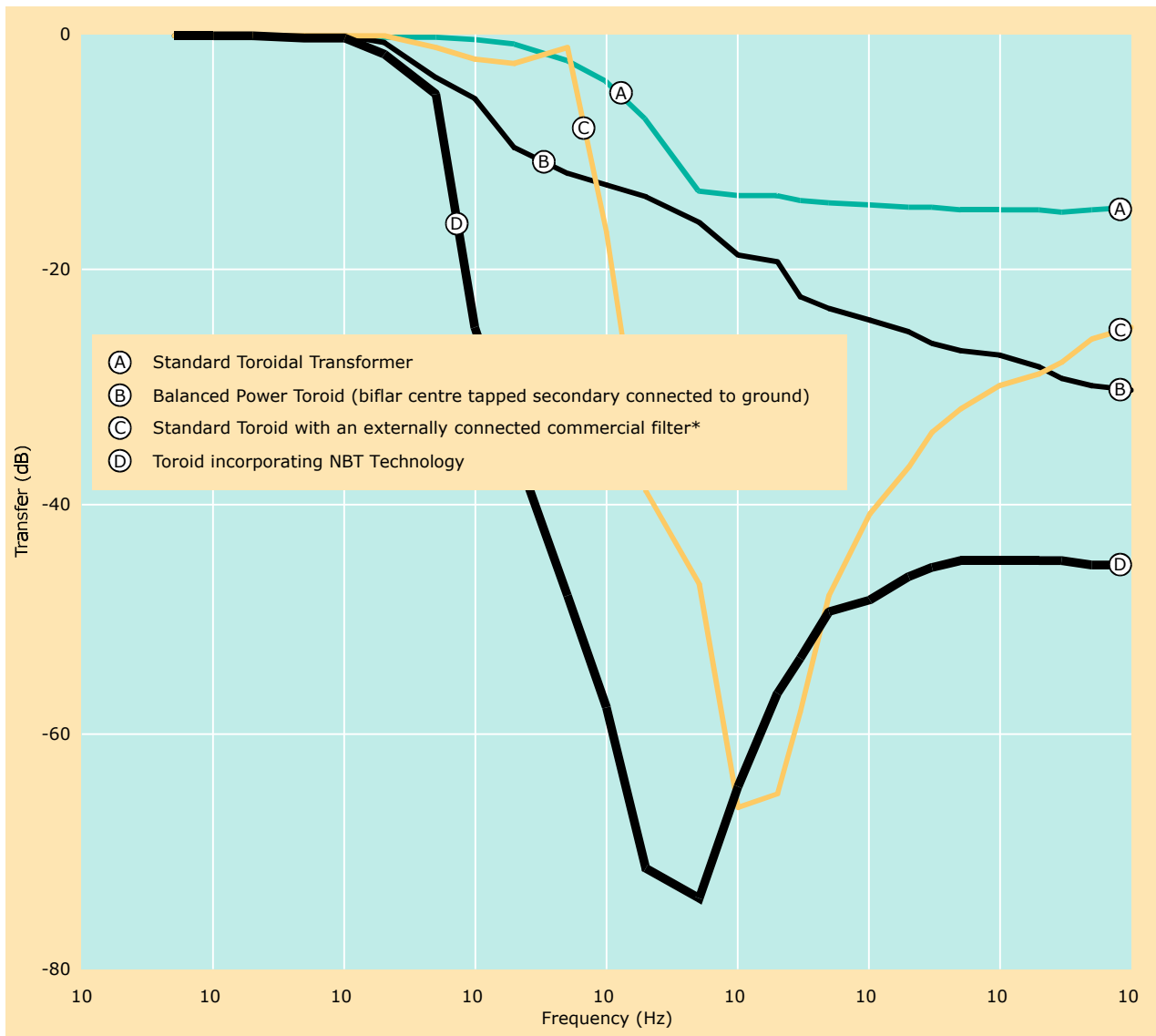


Figure 4 Performance comparisons

\* Corcom P/N 20VV1

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The standard Toroid (a) has a high corner frequency of about 50kHz and low attenuation rate. Balanced power (b) has better performance with reasonably low corner frequency of about 3kHz, attenuation of about -15db around 100kHz and -30db close to 1GHz. The standard toroid with an external commercial filter\* (c) performs much better in the range of 50kHz to 40MHz in comparison with the balanced power, but it has poor corner frequency of about 60kHz.

NBT (d) clearly out-performs other designs in terms of both corner frequency and attenuation. It has a low corner frequency of about 1kHz, which can be design-adjusted to any reasonable value, with db attenuation in excess of 60db around 1MHZ and 35db at 1GHZ.

## Applications

The applications of NBT in power supply transformers are various. A clear example is audio applications, where it is important that differential high frequency noise not enter the sensitive audio equipment. A second application is found in general power supply transformers in any electronic equipment, where differential noise filtering is mandatory. The choice for an NBT-transformer is then based on the balance of costs for a NBT transformer compared to a standard power transformer with external differential mode filters.

In IT applications with uninterrupted data transport over long distances, the advantages of clean power lines are obvious. Medical applications, especially safety-critical patient connected devices, NBT transformers with electrostatic shields, provide clean power with low leakage currents. In large power applications, NBT can remove the higher harmonics, starting with the 5th up to the 50th - with no external filters.

## Summary

Power lines can contain electromagnetic noise. Noise can appear in differential (below 1 MHz) or common (above 1 MHz) mode. NBT effectively removes differential mode noise up to a frequency of about 1MHz. It also reduces the common mode noise considerably between 1MHz to 1GHz. The control capacitor and the internal leakage inductance between primary and secondary windings of the power transformer determine the frequency at which the reduction of noise starts.

## References

This paper describes a portion of the inventions and research performed at PLITRON Manufacturing by the team of Francisco de Leon, Brian Gladstone, Menno van der Veen, and Val Tatu from 1999 to 2001, and Henry Pajooman who joined in late 2001. Written by Francisco DeLeon, Menno Vanderveen and Brian Gladstone in 2001. Edited and updated by Henry Pajooman in 2002.

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# PLITRON R&D



PLITRON has a research team dedicated to improving and expanding toroidal technology. We engage in fundamental research and have developed new methods to quantify transformer performance. In addition to NBT, here are some of the other projects we have introduced for use in standard and custom toroidal applications.



LOW INRUSH TECHNOLOGY

PLITRON's Imin technology reduces in-rush currents to the level of load currents. This eliminates the need for soft-start circuits, relays, PTCs or large breakers.



LOW NOISE TECHNOLOGY

LONO technology from our research program effectively eliminates any audible noise in the power transformer regardless of line conditions, including DC offset and overvoltage. PLITRON can quantify and specify noise performance to NC (noise criterion) standard curves.



LOW STRAY FIELD TECHNOLOGY

Toroidal transformers are typically 1/10th the magnetic field of standard EI transformers. Yet another research output, PLITRON's LoSTRAY technology further reduces magnetic emissions from the transformer without the use of shields, or "belly-bands".

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