

## Total Harmonic Distortion (THD): A Lesson for Lighting Harmony

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It's got to be THD at less than 10 percent! Many lighting designers and engineers I consult with everyday are writing master specifications, which include a requirement for THD to be at or less than 10 percent. But what does Total Harmonic Distortion really mean and what is the real impact to project design and cost?

### **Definition:**

According to Wikipedia, the online encyclopedia for all things defined, "Total Harmonic Distortion of a [signal](#) is a measurement of the [harmonic distortion](#) present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the [fundamental frequency](#)." Lesser THD, for example, allows the components in a loudspeaker, amplifier or microphone or other equipment to make a violin sound like a violin when played back and not a cello or simply a distorted noise.<sup>(1)</sup>

As a musician, I typically have learned about harmonics in terms of chords, distortion and found them useful in tuning guitars at various frets across the neck of the guitar.

For those of us in the lighting and electrical world, THD refers to the Harmonic Distortion present with most electrical equipment, and more specifically now, the distortion present with electronic ballasts. THD is the measurement of the distortion created from the equipment's current draw. True resistive loads, such as an incandescent light bulb, do not have THD. Equipment containing coils and capacitors, such as motors, drives, fluorescent lighting and HID lighting, have some measure of THD.

In the true engineering sense; only fundamental frequency current can provide real power. Systems with Power Factor correction capacitors and motors are considered to be "linear loads" with acceptable (negligible) distortion levels. However, solid-state electronic devices have been shown to be the largest contributor to distortion due to the switching of diode bridges producing a discontinuous current, which then causes a distorted sine wave.<sup>(2)</sup>

In four wire WYE systems such as 120/208 and 277/480-volt systems; harmonics may cause a problem with overheating of the neutral wire. The phase wires should also be designed for the increased harmonic current, but since the "triplens" are additive, the problem is especially critical on the neutral. The third harmonic and other "triplens" (9<sup>th</sup>, 15<sup>th</sup>, etc.) are additive. Total Harmonic Distortion is the percentage of all of these additive values in relation to the total load. The sum of triplen harmonics greater than 33 percent will result in neutral current greater than

individual line currents. The resultant current exceeds the neutral conductor's rating and causes overheating of the neutral and/or transformer.

It is a common misconception that electronic ballasts increase THD. Currently available electronic ballasts actually decrease the THD on an electrical system compared to a system applying magnetic ballasts. ANSI C82.11 requires that the maximum THD of electronic ballasts not exceed 32 percent and the maximum triplens not exceed 30 percent. Electronic ballasts today are rated at less than 20 percent, 15 percent, or less than 10 percent THD. The magnetic ballast is rated in the 20 to 28 percent range.

Electronic ballasts reduce THD in two ways.

1. The electronic ballast has a lower THD percentage than the magnetic ballast.
2. The biggest reduction comes from the fact that electronic ballasts reduce the total load.

For lighting systems, the following table provides some comparisons <sup>(3)</sup>:

Total Harmonic Distortion	Wattage	Typical THD	THD Wattage	<b>Total Wattage</b>	Typical THD Amps (watts/277)	THD Amps per 1000 fixtures
4-lamp, 277 volt fixture						
Standard Magnetic Ballast, F40T12	192	23%	44.16	<b>236.16</b>	0.16	159.42
Energy Efficient Magnetic, F34T12	148	23%	34.04	<b>182.04</b>	0.12	122.89
Electronic Ballast, Standard .88 BF, F32T8	114	20%	22.80	<b>136.80</b>	0.08	82.31
Electronic, High Performance .88BF, F32T8	114	10%	11.40	<b>125.40</b>	0.04	41.16
Electronic Ballast, Low Power, F32T8	100	20%	20.00	<b>120.00</b>	0.07	72.20
Electronic, High Performance "L", F32T8	101	10%	10.10	<b>111.10</b>	0.04	36.46
GE UltraMax "4L" .77BF with F32T8, /U	96	<13%	12.48	<b>108.48</b>	0.05	45.05
GE UltraMax "4L" .77BF with F32T8WM, @30w	91	<14%	12.74	<b>103.74</b>	0.05	45.99
GE UltraMax "4L" .77BF with F28T8/UMX	86	<14%	12.04	<b>98.04</b>	0.04	43.47

Note: UltraMax is <10% THD @ 120v & <14% at 277v

The above measurements illustrate the drastic reduction in THD that electronic ballasts can provide.

The GE electronic fluorescent ballast is rated at less than 10 percent THD at 120 volts. It is rated between 8-13 percent THD at 277 volts depending on the lamp type. It surpasses the intent of lowering the THD because they are High Efficiency Ballast design. Maintaining the same light level, the UltraMax uses 5 percent less energy than the standard ballast. Lowering the total load thus reduces the heating effect on wiring and transformers. The GE UltraMax® is tuned for lowest THD at 120 volt because of the various items such as computers on the same line. Except for Motors in an industrial application, i.e.: water/waste-water, typically loads connected to the 277 volt system are lighting, so THD is not as critical to the power system. The THD is less than the ANSI requirement of less than 32 percent.

Several other ballast OEMs do not list THD level by voltage and lamp type and have very similar performance as GE. Our product service team has never received a product failure or complaint of harmonic distortion resulting in inference with other devices, hot neutral lines or not meeting utility rebate requirements.

I mentioned cost to the project in my opening paragraph. The cost adder of high efficient THD reducing electronic ballast is no longer a consideration due to the wide availability of high performance electronic ballasts and the impact of energy legislation. However, life cycle costing when considered as part of the programming design phase could offer bigger savings than first costs. Since harmonics are now reduced, conductors no longer have to be oversized to handle those currents. With greater efficiency the end-user gets more light for a given wire size or transformer rating. Both represent savings.

Ballast pricing has become very competitive today and the ability of the designer or engineer to specify highly efficient ballasts that meet THD specification thresholds will indeed prove to bring a project in on budget.

**Reference:**

1. [http://en.wikipedia.org/wiki/Total\\_harmonic\\_distortion](http://en.wikipedia.org/wiki/Total_harmonic_distortion)
2. Gary Fox, PE, Senior Specification Engineer, GE Consumer and Industrial
3. GE Ballast Manual #2; Courtesy, Mike Smith, Ballast Manager, GE Consumer & Industrial