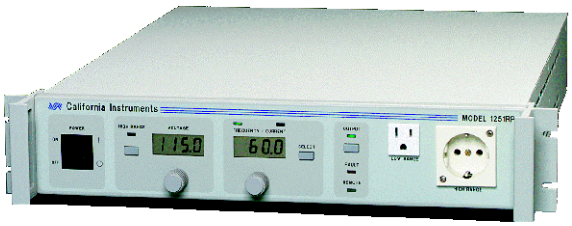
Application Note #112

Using the 1001P or 1251RP for IEC1000-3-2 Testing

Introduction

This application note describes the use of the California Instruments 1001P or 1251RP programmable AC power source for IEC 1000-3-2 harmonics emissions testing. Topics covered include IEC 1000-3-2 background, AC source requirements, differences between full compliance and pre-compliance testing and the conditions under which the 1001P or 1251RP can be used.

The argument presented in this application note is substantiated by test data on a variety of typical consumer product loads powered by the 1251RP. The 1001P is nearly identical in performance to the 1251RP and can be used in its place in most cases.



IEC 1000-3-2 Compliance Testing

Mandatory CE marking of products destined for sale in the European Community requires compliance to the Low Voltage Directive (LVD). However, product development engineers may not necessarily require a full verification system, as the CE product mark testing is often performed by third party testing agencies. To reduce the high cost of agency testing, in-house pre-compliance testing can prevent repeated tests. The cost effective 1001P or 1251RP power source is ideal for in-house pre-compliance testing, and can even be used for compliance verification of many medium power electrical products.

IEC1000-3-2 Test Considerations

The IEC1000-3-2 standard covers all electrical or electronic products with nominal currents up to 16 A rms. The standard defines four (4) different test classes, Class A, B, C, and D. Each class has its own limits for harmonic currents. Class A is the "catch all" category; Class B deals mainly with portable electric tools; Class C covers lighting products with a power consumption of 25 Watt and up, and Class D provides limits for products with a special current waveshape and power level from 75 - 600 Watt. Class D is primarily aimed at consumer products, especially those with low cost switching power supplies. Anything that does not fit in either of the other three classes is automatically categorized as Class-A equipment. Table 1 shows the maximum allowed current harmonics for each class.

Harmonic no. (n)	Class A	Class B	Class C	Class D
	A rms	A rms	% of fund. rms current	mA/Watt input pwr (75-600 W)
2	1.080	1.620	2	-
3	2.300	3.450	30 x PF	3.400
4	0.430	0.645	-	-
5	1.440	2.160	10	1.900
6	0.300	0.450	-	-
7	0.770	1.155	7	1.000
8	0.230	0.345	-	-
9	0.400	0.600	5	0.500
10	0.184	0.276	-	-
11	0.330	0.495	3	0.350
12	0.153	0.230	-	-
13	0.210	0.315	3	0.296
Even 14-40	1.84 / n	2.760 / n	-	-
Odd 15-39	2.25 / n	3.338 / n	3	3.850 / n

Table 1 IEC 1000-3-2 Product Class Limits

Even though the maximum rms current level for covered products is 16 Amp, peak current levels can be in the order of 40 Amp. Verification systems used by official testing agencies have to be powerful enough to test a variety of products, including those with high peak currents. Since a Class B product with 40 Amp peak may still pass IEC 1000-3-2, a full compliance verification system has to be able to supply even higher peak current levels.

Many consumer product companies manufacture only low/medium power products. Examples are PC's, audio equipment, VCR's, TV's, monitors, kitchen appliances, etc. Even most light industrial electronic products consume less than a few hundred Watts. Therefore, development and production test engineers dealing with those low power products may not need a high power general purpose test system. The 1001P and 1251RP are very cost effective power sources for these applications.

Why use an AC Source?

There are several reasons to use a "clean" power source. First, the IEC 1000-3-2 standard requires that products are tested for the full

operating voltage range. If a product has an input voltage operating range of 220 to 240 V, it must be tested at those levels. Secondly, the operating frequency has to be 50 Hz. Most important however, is that the standard demands that compliance is verified using a power source which itself has negligible voltage distortion and a very low output impedance. This low output impedance and distortion requirement ensures that the tested product is permitted to "draw the maximum level of harmonic currents", but is not affected by harmonics caused by other equipment present on the same circuit.

Alternately, the product may pass the line voltage test while failing verification, because the higher impedance of the 230 Vac line "masks" (attenuates) some of the higher harmonics. Annex A of the IEC1000-3-2 standard defines the power quality for compliance verification. Table 2 shows these rather stringent power quality requirements, as given in Annex A of the standard.

While the measurements are being made, the test voltage at the terminals of the equipment under test shall meet the following requirements:

- *Test voltage of 230 Vac nominal is to be maintained within +/- 2 % , and the frequency shall be maintained within 0.5 % of the nominal (50 Hz) value.*
- *For 3 phase supplies/test the phase angle between phases shall be 120° +/- 2°*
- *The harmonic ratios of the test voltage U shall not exceed the following values with the EUT connected as in normal operation.*

0.9 % for harmonic of order 3;
0.4 % for harmonic of order 5;
0.3 % for harmonic of order 7;
0.2 % for harmonic of order 9;
0.2 % for even harmonics of order 2 - 10;
0.1 % for odd harmonics of order 11 - 40;

- *The voltage Crest Factor shall be 1.40 - 1.42, and the peak value shall be reached within 87 - 93° after the zero crossing*

Table 2 Power Quality Requirements for IEC1000-3-2 Testing (Annex-A)

1001P and 1251RP Performance Characteristics

Whereas the distortion specifications in Table 2 may not seem difficult to meet, they actually represent a significant challenge. After all, many consumer products use switching AC/DC power supplies, with highly non-linear power consumption. Following are different types of loads and their impact on AC source requirements.

Non linear load that fails IEC 1000-3-2

Figure 1 shows the current waveform of a typical switching power supply having a power

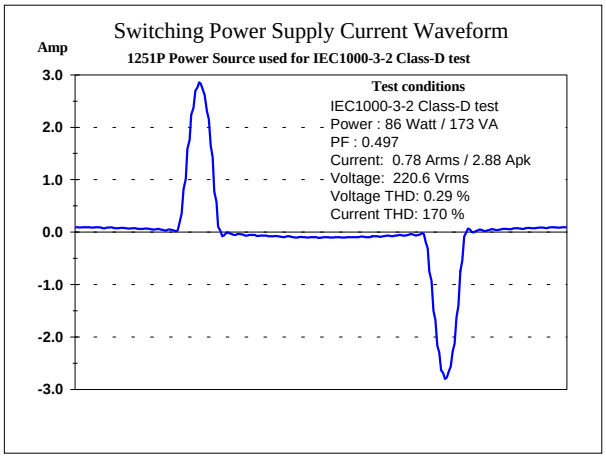


Figure 1 : Current waveform of a typical low cost switching power supply

consumption of about 86 Watts. Peak current in this example reaches almost 2.9 Amp, while the RMS level is only 0.78 Amp. This 86 Watt power supply therefore demands 896 VA of instantaneous power (2.88 x 220 x 1.414).

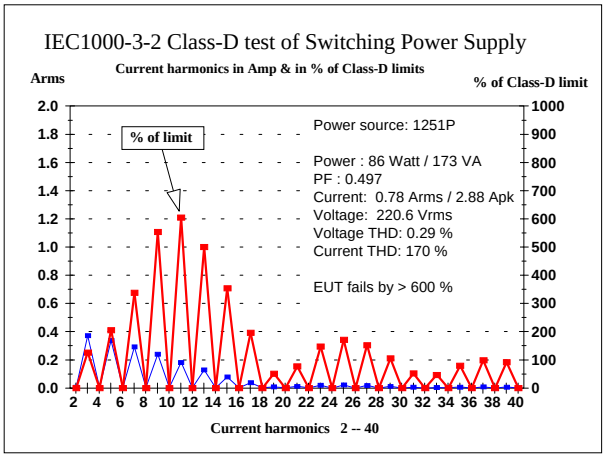


Figure 2 : Current harmonics of the 86 Watt Switching Power Supply

Figure 2, shows the current harmonics of this device against the limits of IEC1000-3-2 Class-D. As follows from the percentage scale, the 11th harmonic exceeds the limit slightly more than 6 times, hence this device would fail the IEC1000-3-2 compliance test by a wide margin. Even with excessive current harmonics, the AC source used should not affect the readings.

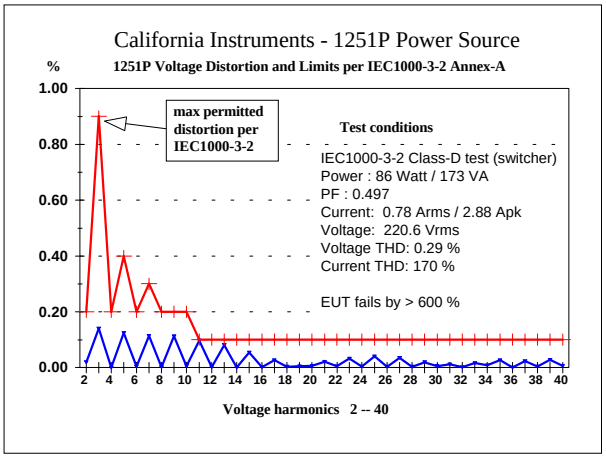


Figure 3 : 1251RP voltage distortion for the 86 Watt switching power supply load.

Figure 3 shows the voltage distortion of the 1251RP, which was used during this test. Note that the voltage distortion of the 11 th harmonic is just under the permissible 0.1 % level. The standard does not specify voltage distortion levels for even harmonics above order 10, but the graph's limit is kept at 0.1 % . From this test data it is clear that, at these power levels, the 1251RP easily meets the AC source requirements as specified for IEC1000-3-2 compliance verification.

Linear loads

Linear loads generally don't represent problems for most power sources and meeting the IEC 1000-3-2 AC source requirements is much easier when testing these types of loads. Figure 4

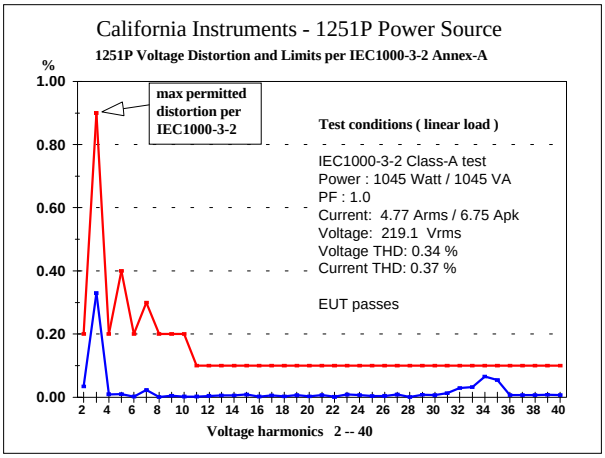


Figure 6 : 1251RP Voltage distortion for 1045 Watt linear load

shows the voltage distortion of the 1251RP for a linear load of 1045 Watt. Note that the peak current is still √2 x 4.774, or about 6.75 Amp peak. Even though the 1251RP is rated for 1250 VA, it performs very well at this instantaneous power level of almost 2100 VA (6.75 x 220 x √2 = 2099).

Higher power non-linear loads, which fail the standard by wide margins, may cause the 1251RP voltage harmonics to fall outside the permitted limits in Annex A of the standard. Even in those cases however, the distortion contributed by the source is so low, that the test results are virtually the same. Moreover, if the unit under test is improved and comes closer to meeting the harmonics limits, the 1251RP will perform fine.

Severely failing loads

What happens if the load being tested causes severe current harmonics that far exceed the IEC 1000-3-2 class limits?

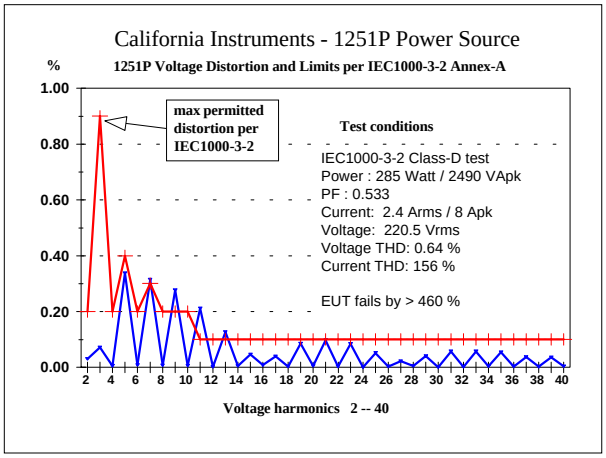


Figure 4 : 1251RP Voltage distortion with highly non-linear load as shown in Fig. 6

Figure 5 shows the voltage distortion of the 1251RP when subjected to a highly non-linear load such as one with a current waveform shown in Figure 6. This non-linear load (an older model color TV) causes peak currents of about 8 Amp, which equates to a worst case power demand of almost 2490 VA peak. Even though the 1251RP voltage distortion is slightly higher than the maximum levels permitted in IEC1000-3-2, the harmonic analysis is still highly accurate. Note that the harmonic levels of the tested TV exceed the

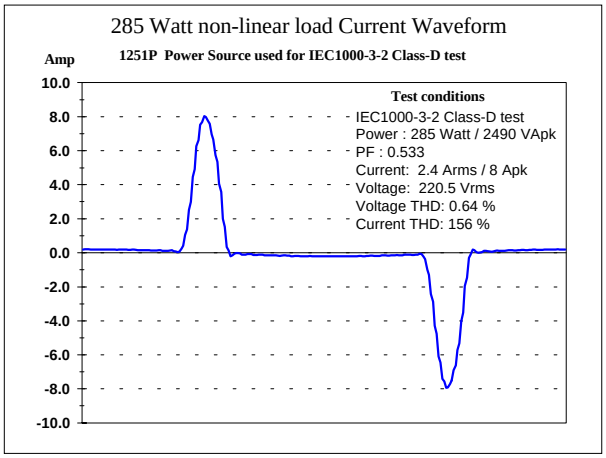


Figure 5 : Current waveform of highly non-linear load with 8 Amp peak current

permitted levels by 460 %. The slightly higher level of 1251RP voltage distortion actually causes the reported harmonic levels to be slightly lower than they would have been with a fully compliant AC source such as the California Instruments 3001i or 5001i. These sources are recommended for higher power demands. The difference however is insignificant. This load will fail IEC 1000-3-2 either way.

The 1001P and 1251RP are more than acceptable power sources for this application. After all, it is hardly relevant whether this TV fails by 460 % or 463 % ! If the tested product comes close to meeting the IEC1000-3-2 specification, the current distortion is less severe, and the voltage distortion of the 1251RP will remain within the permitted range, as is illustrated in Figure 4 with a linear load.

What about IEC 1000-3-3 Flicker?

Carefully reading the standard reveals that Flicker testing is often not necessary, and that just measuring the inrush current will suffice in many cases. In order to evaluate flicker, a number of parameters are measured. These are momentary voltage dips due to high inrush currents (d_t and d_{max}), voltage sags of several seconds duration (d_c) due to high currents, and the longer term effect of repeated voltage fluctuations and their resulting annoying light flicker on humans (P_{st} and P_{lt}). The IEC 1000-3-3 standard states the following in section 6 under general test conditions:

"Tests shall not be made on equipment which is unlikely to produce significant voltage fluctuations or flicker."

And in section 5, the standard states:

"If voltage changes are caused by manual switching or occur less frequently than once per hour, the Pst and Plt requirements shall not be applicable. The three requirements related to voltage changes shall be applicable with the previously mentioned voltage values multiplied by a factor of 1.33."

Therefore, unless the product under consideration has an autonomous power cycle or switches power levels more than once per hour, it is exempt from both P_{st} and P_{lt} tests. There are still other limits that need to be met before testing can be eliminated. This involves the maximum values for d_c and d_{max}. The standard states specifies the test limits for these parameters:

"- the relative steady state voltage change, d_c, shall not exceed 3 %"

"- the maximum relative voltage change, d_{max}, shall not exceed 4 %."

In other words, for low power equipment that is turned on less than once per hour, the inrush current is permitted to cause momentary voltage dips of max. 1.33 x 4 = 5.32 %, while voltage sags of up to 4 % are permitted.

Using a storage oscilloscope and a current clamp to evaluate the inrush current allows calculation of the voltage drops. The IEC1000-3-3 standard requires the use of a Reference Impedance for Flicker testing. This impedance has a resistive portion of 400 mOhm, and a reactive element of 250 mOhm. For a first order approximation, one can simply calculate the voltage drop across the impedance, and compare this against the limits.

Because the nominal test voltage is 230 V_{rms}, the 3 % and 4 % limits equate to 3 x 2.3 = 6.9 V_{rms} and 4 x 2.3 = 9.2 V_{rms}. The 5.32 % would equate to 12.236 V_{rms}. Just considering the resistive element of the impedance, this means that the current would have to exceed 6.9 / 0.4 = 17.25 A_{rms} in order to cause a voltage sag exceeding 3 %. To exceed the higher percentages requires even higher inrush/start-up currents.

Therefore, if inrush currents are below 17 Arms, and thereafter the power level fluctuates less than 350 Watts, the equipment can be deemed to meet the requirements of IEC1000-3-3. This relatively simple analysis, which is particularly applicable for low power products, avoids the need for testing with an expensive Flicker meter.

Conclusions

The 1001P and 1251RP are low cost power sources for (pre-) compliance testing per IEC1000-3-2. Either unit is ideally suited for testing of low to medium power consumer products and light industrial products.

For products having a power demand of less than 1250 VA, both units meet the voltage distortion limits given in Annex A of the standard. Even for non-linear loads, the 1001P and 1251RP maintain low voltage distortion, thus providing the basis for accurate harmonic current analysis.

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