

conditions are the reality! And how does the mains transformer react on all this mess? It starts to make acoustical noise. We researched which mains conditions generate noise inside power transformers and found three major causes:

1: The mains 'sinusoid' is not symmetrical. This is identical to a DC-voltage on the mains. A very nice example is: the single phase rectifier used in hair dryers at lower power by means of one series diode. The combination of this rectifier with the actual load resistance and the resistance of the mains wires create an effective DC-voltage on the mains. See Figure 13 for an explanation of this effect of hair dryers.

(It is very easy to test a particular transformer for noise under this "DC on mains" condition. Connect a 100 or 200 W light bulb in series with a proper diode to the same mains socket of the transformer under test and check for transformer noise by listening).

Our measurements indicate that only a few mV-DC can be large enough to bring a transformer into its noisy region. We did many tests to determine the amount of DC-voltage on the mains by means of the light bulb and other loads in series with a diode and by observing the DC content on the mains due to asymmetrical loading elsewhere in our or other buildings connected to the same distribution transformer. We found a DC-component smaller than 100 mV for 120 V at 60 Hz mains. However, by experience we know that bad conditions today surely will be worse tomorrow. We therefore propose to take an extra margin and to use 250 mV-DC as our standard condition for "adverse" mains. (For 230 V at 50 Hz mains, the standard adverse mains condition equals the same 250 mV-DC).

2: Over voltage brings the transformer into its saturation region as well. Example: in Europe the transfer from 220 V to 230 V @ 50 Hz mains voltage takes place in a period of several years, combined with a certain plus/minus deviation. Now suppose, an older 220 V transformer design, having to operate at 230 V (and sometimes in practice up to 240 V). When such a design is constructed with no safety margin of magnetic headroom, saturation will occur at larger input voltages. Our research showed us that 10 % over voltage is a good margin for testing a transformer under conditions of over voltage.

3: Transformers designed for 60 Hz mains frequency can be used in a 50 Hz mains frequency environment. When no magnetic headroom is available, a 60 Hz transformer will saturate at 50 Hz and become noisy. However, it is our opinion that manufacturers clearly should identify on their transformers the mains frequency of safe and silent operation. In this research we assume that all transformers are operating at the right mains frequency of design.

Contrary to popular belief the other effects of mains signal distortion are not included in our list of major noise causes. In the case of sags and surges, a very short momentary saturation of the core can occur. The burst of sound emitted has such a short duration that seldom this will be a problem. Spikes do not produce noise due to their limited time length, and their limited amount of energy will be absorbed inside the conducting shielding inside the transformer. Very high frequencies (Radio and TV, GSM, computers) can not excite the transformer acoustically because it is a mechanical vibrating device with a rather large mass and therefore a limited emitting frequency range. Our measurements showed that above 10 kHz almost no sound is emitted. When considering lower frequency harmonics, for instance the 2-nd and 3-rd ... of the mains frequency: the second harmonic distortion is equivalent to a residual DC-voltage on the mains, while the 3-rd and higher harmonics have a much smaller amplitude than the mains fundamental. This fundamental (50 or 60 Hz) is using most of the magnetic headroom inside the core and is most prone to lead to core saturation. This is not the case with harmonics. The amplitude of the magnetic flux density inside the core is inversely proportional to the frequency of the voltage applied. Harmonics have smaller amplitudes, larger frequencies and consequently create negligible flux densities inside the core. Therefore we omit their influence in audio and video equipment. Above said is certainly not the case for transformers used in switching Triac lighting equipment. However, the study of the effects of such equipment is outside the scope of this research.

Based on above given experience and understanding of the noise generating mechanism inside transformers, we now can define a measurement setup for making "adverse" mains conditions. Figure 14 shows the schematics in a simple form. Through a variac or variable voltage power supply a pure and undistorted mains voltage can be set at the "nominal level" and at a "10 % over voltage level". By means of another variac plus transformer, a rectifying circuit and a buffering capacitor, a "DC-voltage" can be added to the mains voltage.