15.13 Amplimo and Plitron

Menno van der Veen [6, van der Veen] has designed in 1998 two toroid step-up transformers for electrostatic loudspeakers, having step-up ratio's of 50× and 75×.
The Dutch company Amplimo [7, Amplimo] used to have these transformers in their program. They do not appear on their website anymore, but Amplimo might still be able to supply them.
The same transformers are still available from a Canadian company called Plitron [8, Plitron].

Plitron supplies the following technical data:

Type Number	PAT4133-ES	PAT4134-ES
Step-up ratio	1:50	1:75
Primary dc resistance	0.1 Ω	0.1 Ω
Secondary dc resistance	190 Ω	273 Ω
Saturation limit	17.9 V_{rms} @ 50 Hz	17.9 V_{rms} @ 50 Hz
Secondary inductance	719H	1600 H
Primary inductance, calculated from step-up ratio	288 mH	284 mH
Secondary Leakage Inductance	15 mH	22 mH
Secondary internal capacitance	700 pF	800 pF
Resonance frequency	32 kHz	25 kHz
Primary impedance at 20kHz	2.272 Ω	1.0 Ω

Discussion

Identical primary windings and identical cores
The specified secondary magnetizing inductance, when transformed back to the primary side using the turns ratio, results for both transformers in almost the same primary magnetizing inductance.
The primary dc resistance and the saturation voltage at 50 Hz are exactly the same.
We therefore suspect that both transformers have identical cores and identical primary windings.

Primary input impedance at 20 kHz
If we calculate the impedance of the secondary internal capacitance at 20 kHz and transform that back to the primary side using the turns ratio, we arrive at 4.5 Ω for the first transformer and 1.8 Ω for the second one.
As the specified input impedances are significantly lower, other effects must play a role too, or the secondary capacitance is larger than specified.

Resonance Frequency
The resonance frequency of the specified leakage inductance and the specified internal capacitance comes to 49 kHz for the first transformer and 38 kHz for the second one. As this is much higher than the specified resonance frequencies we might suspect that the actual internal capacitance is larger than specified.
Even so, the specified resonance frequency is above the audio frequency range.

Combination of two transformers to get a 1:150 step-up ratio
If two of the 1:75 transformers are combined in the way described in section 15.12 we can achieve a total step-up ratio of 1:150. The center taps of both transformers will in that case not be used.
The amplifier must be capable of driving a load that drops to 0.5 Ω at 20 kHz!

We do not know if the construction of the transformer is symmetrical, i.e. if the parasitic capacitance from each end of the secondary winding to the primary is the same.
If this is not the case, it will help to find out which secondary node has the highest capacitance and connect the pair such that these nodes are joined to form the center tap, as discussed in section 15.12.

Saturation voltage
The transformers saturate at a primary voltage of 17.9 V_{rms} at 50 Hz.
This corresponds to a peak voltage of 25.3 V_{peak}.
With a total step-up ratio of 1:150 the peak secondary voltage is 3795 V_{peak}.
The voltage handling capability is proportional to the frequency, so at 100 Hz the transformer can handle a primary voltage of 50.6 V and produces a secondary output voltage of 7590 V_{peak}.
The data sheet does not specify at what increase of the magnetizing current they consider the core to be saturated.

Saturation by dc offset voltage
We can expect that the transformers, being of the toroid type without an air gap, are susceptible to saturation by amplifier output offset.

Let's try to estimate how much offset they can handle.
We know that the transformers saturate at a primary voltage of 17.9 V_{rms} at 50 Hz.
This rms voltage corresponds to a peak voltage of 25.3 V.
With a magnetizing inductance of 286 mH we find that the peak magnetizing current is 281 mA_{peak}.
Therefore a primary dc current of 281 mA will saturate the core.
If we want to loose no more than 10% of voltage handling capability (corresponding to approximately 1 dB) to dc offset, the dc current must be no more then 28.1 mA.
At a dc resistance of 0.1 Ω the dc offset voltage of the amplifier must be no more than 2.81 mV. This is quite a restrictive number to ask of the amplifier.
This is therefore a real problem with this transformer.

The offset problem is often solved by placing a 1 Ω resistor in series with the primary winding. That way, we can allow the amplifier to produce 28.1 mV offset.
As the combined input impedance of two transformers at 20 kHz drops to 0.5 Ω we must bypass the resistor for high frequencies by a capacitor. See Figure 82.
If we want the capacitor to have an impedance of 0.5 Ω at 2000 Hz, it must have a value of 160 μF. Because of the large value, this will be a bipolar electrolytic capacitor.
We must make sure that the ESR (equivalent series resistance) of the capacitor is much smaller than 0.5 Ω.

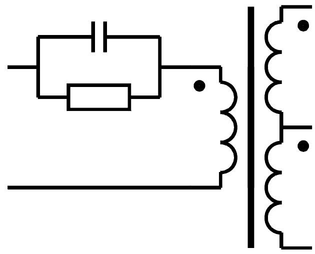

Figure 82 Series resistor, bypassed by a capacitor can help to combat saturation due to amplifier offset.

Even this solution for the offset problem is not without disadvantages.
At bass frequencies the shunt capacitor has negligible effect and the magnetizing current causes a voltage drop over the resistor.
Because the magnetizing current can be rather distorted due to saturation of the core, so is the voltage drop.
The remaining voltage driving the primary of the transformer is then also distorted.

The best solution, therefore, is to somehow control the amplifier offset to less than 2.8 mV.

15.14 DIY Step-up Transformer

The Dutch ESL forum [14, Dutch ESL forum] used to have a participant called Marc Schroeyers, who contributed very valuable information on how to construct your own step-up transformer. Unfortunately, Marc has withdrawn from the forum, but chances are that he is still listening in.