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1 TRANSFORMER WINDING ARRANGEMENT ESPECIALLY
 FOR VIDEO DISPLAY

 This invention relates to winding of transformer
 coils, and in particular, to winding techniques for transformers having
5 high voltage stresses such as can occur in television or other video
 display apparatus.

 A high voltage transformer for a video display apparatus, such as
 a television receiver or a computer monitor, commonly comprises one or
 more primary or auxiliary coils wound on a bobbin or coil form. A second
10 bobbin surrounds the primary winding bobbin and receives _____

 tertiary windings which produce a voltage or
 anode potential for a cathode ray tube.

 During operation of the transformer, voltage
 potentials are generated across each of the windings on
15 the primary winding bobbin. The difference between the
 voltage potentials across different windings creates
 voltage stresses between the windings so that insulating
 material, such as mylar, is required to be placed between
 winding layers on the bobbin. The placement of the
20 individual turns of the auxiliary coils with respect to
 the primary winding may result in localized voltage
 stresses between the windings that are undesirably high,
 particularly when the auxiliary windings are heavily
 loaded, such as when the high voltage transformer is used
25 with a resonant retrace deflection circuit. Additionally,
 loading of the primary winding by the auxiliary windings
 affects the loading of the tertiary winding by the primary
 winding which in turn may influence the harmonic tuning of
 the transformer. Tuning of the transformer can influence
30 the high voltage level and the high voltage circuit output
 impedance. If the spatial relationship of the windings is
 not carefully controlled, additional transformer tuning
 components may be required to obtain the desired operating
 characteristics for the transformer.

35 In accordance with an aspect of the present
 invention, a high voltage transformer for a video display
 apparatus comprises a tertiary coil form having a tertiary
 winding wound on the coil form. A magnetically permeable
 core is disposed within the tertiary coil form. A primary



- 1 winding assembly is disposed between the tertiary coil
form and the core and comprises a coil form with a primary
winding wound on the coil form. The primary winding
occupies a predetermined winding region. At least one
5 additional winding overlaps the primary winding and
comprises a plurality of winding turns evenly distributed
over the predetermined winding region.

In the accompanying drawing: FIGURE 1 is a
schematic and block diagram of a portion of a video
10 display apparatus;

FIGURE 2 is a cross-sectional view of a
transformer bobbin and coil assembly constructed in
accordance with the present invention;

FIGURE 3 is a cross-sectional view of a high
15 voltage transformer constructed in accordance with the
present invention; and

FIGURE 4 is a cross-sectional view of a wire such
as that used to wind the transformer windings shown in
FIGURE 3.

20 FIGURE 1 illustrates in schematic form a portion of
a video display apparatus in which an unregulated DC voltage
is applied to regulator circuit 5, which may illustratively
be of an SCR type or a switching-type regulator, to produce
a regulated B+ voltage that is applied to one terminal of a
25 primary winding 201 of high voltage transformer 21. The other
terminal of primary winding 201 is coupled to a horizontal
deflection circuit 6 which may illustratively be of the
resonant retrace type. High voltage transformer 21
produces, via high voltage or tertiary winding 23, a high
30 voltage level at a terminal U, which is applied to the
cathode or anode terminal of a cathode ray tube (not
shown). Transformer 21 is illustratively of the type that
produces a plurality of supply voltages for some of the
other load circuits (not shown) of the video display apparatus.
35 Auxiliary transformer windings 202, 203 and 204, along
with power supply circuits 7, 8 and 9, respectively,
generate the desired voltage levels for their associated
load circuits. The construction of transformer 21 will be
explained in greater detail later in conjunction with the



1 description of FIGURE 3.

FIGURE 2 shows a transformer winding coil form or bobbin 10, illustratively made of a plastic material, such as plastics sold under the names of Noryl or Valox.

5 Bobbin or coil form 10 comprises a base 11 and a cylindrical body 12 about which transformer windings are wound. Bobbin 10 also incorporates an upper winding stop 13 and a lower winding stop 14 which contain the transformer windings within a winding region 15. Base 11
10 incorporates a plurality of radial elements 16, each of which illustratively incorporates an electrical terminal, designated 17a-17h. The interior of bobbin 10 is shaped to receive a magnetically permeable core (not shown).

A plurality of transformer windings 20 are shown
15 wound on bobbin 10. Each winding will comprise a plurality of wire turns having two terminals for coupling the winding to a load circuit. One terminal is coupled to respective ones of bobbin terminals 17a-17h. The wire turns that comprise each of the windings on bobbin 10 are
20 shown in an exaggerated manner for illustrative purposes. The actual number of turns in each winding is determined using conventional transformer design criteria. Each of the transformer windings 20 is wound in layer fashion within winding region 15 on bobbin 10. The individual
25 windings may each comprise one or more layers of wire turns, but in the assembly shown in FIGURE 1, each winding is illustratively comprised of only one layer of wire turns for simplicity. Additional windings may also be wound on bobbin 10.

30 The wire turns that are designated in FIGURE 2 by the identifying numeral "1" comprise the wire turns of primary winding 201. The wire turns that are designated in FIGURE 2 by the identifying numerals "2", "3" and "4" comprises the wire turns of auxiliary windings 202, 203
35 and 204, respectively. Windings 201, 202, 203 and 204 are respectively connected to terminals 17f, 17c, 17b and 17a via conductors 201c, 202c, 203c and 204c. In accordance with a feature of the present invention, primary winding 201 and auxiliary windings 202, 203 and 204 are uniformly



1 distributed over the winding region 25, such that the
spacing between individual wire turns is substantially
constant for a given winding. In FIGURE 2, each of
windings 202, 203 and 204 extend over the complete
5 traverse (i.e., winding region 15) of the primary winding
201. This permits a uniform or constant degree of
magnetic coupling between each of windings 202, 203 and
204 and primary winding 201 over the entire length of the
windings. This causes the primary winding 201 to be
10 uniformly loaded by each of windings 202, 203 and 204.
When bobbin 10 comprises a portion of a television
receiver or video monitor high voltage transformer, as
shown in FIGURE 3, uniform loading of the primary winding
by the auxiliary windings results in uniform loading of
15 the tertiary or high voltage winding 23 by the primary winding
201, since energization of the auxiliary windings loads
the primary winding, which is reflected to the tertiary
winding 23. A constant network resonance from the primary
winding to each coil of the transformer tertiary winding
20 is maintained, which advantageously permits the tuning of
the tertiary winding to a single harmonic pole, which may
illustratively be a high harmonic of the order of the
ninth harmonic or above.

According to a preferred feature of the present
25 invention, each of the windings 202, 203 and 204 overlay
the previous windings directly, without the placement of
any insulating material between the winding layers.
FIGURE 4 illustrates a typical insulated wire 35, which
may be used to wind any of windings 201, 202, 203 or 204.
30 Wire 35 comprises a conductive wire core 36 surrounded by an
insulating jacket or coating 37. Because of the high AC voltage
stress between wire turns of different windings, it is
important that the thickness and electrical property
requirements of insulating jacket 37 be carefully determined.
35 Using wire that has more insulation than is necessary
increases the size and cost of the transformer, and may
degrade coupling between windings. Too little insulation
increases the chance of arcing and transformer failure.

An analysis of the wire insulation on a molecular



- 1 level yields information with respect to voltage stress tolerance and the length of time before the insulation fails. The coupling energy between molecules of a material is a function of the material composition and the process used in
- 5 its formation. There can be one or more coupling poles between molecules, each containing a discrete amount of coupling energy. The molecules of the wire insulation have all of their coupling poles coupled, making for very high resistance.
- 10 There are stresses, however, that are placed upon the molecular bonds of the insulator during each period of AC field change. These stresses reduce the coupling energy during each stress cycle. The greater the voltage stress, the greater amount of coupling energy lost during
- 15 each AC cycle. This eventually causes the coupling bond on the molecules to break. At this time the molecules become sources, as in a conductor, being able to pass electric current continuously at some resistance level. An analysis of this voltage stress-induced bond breakdown
- 20 reaction for transformer wire insulation yields the relationship:

$$t_f = \frac{K}{(s) (e^{5.4366}) (T^{29.5562})}$$

- 25 where t_f is the insulation time to failure in hours;
 K is a constant determined from insulation property data supplied by the wire manufacturer;
 s is a function of the AC voltage waveform, that for a waveform having an unbalanced duty cycle,
- 30 such as the flyback pulse voltage, is substantially equal to unity;
 e is the applied voltage value in Vrms/mil; and
 T is the operating temperature in Kelvin.
- 35 Using the previously described analysis, it is possible to determine, for a given wire gauge, the optimum wire insulation characteristics, such as thickness and type of material necessary to insure reliable transformer operation. By using the analysis, it is possible to wind the transformer windings without the placement of



1 insulating sheets, such as Mylar, between the individual
winding layers, while maintaining reliable operation
without significant risk of transformer failure. The
omission of the insulation between layers of windings
5 improves magnetic coupling between windings which improves
power transfer and load circuit output impedance
characteristics.

10 A transformer 21, embodying the previously
described winding techniques, is shown in FIGURE 3.
Transformer 21 comprises bobbin 10 having windings 201,
202, 203 and 204 wound thereon. Surrounding bobbin 10 is
a tertiary winding bobbin 22, upon which is wound the high
voltage or tertiary winding 23. A magnetically permeable
15 core 24, comprising upper and lower core segments 25 and
26, with an intermediate core spacer 27, is disposed
within the interior of bobbin 10. The winding assemblies
are disposed within a transformer housing 30 and are
desirably potted within housing 30 with an epoxy compound
20 40. A high voltage or anode lead 31 is coupled to the
high voltage end of tertiary winding 23 and supplies the
high voltage level to the anode terminal of a cathode ray
tube (not shown).

The previously described transformer therefore
25 incorporates advantageous winding techniques in which
subsequent winding layers on the primary winding bobbin
are wound directly over previous layers without
intermediate layers of insulation, which optimizes power
transfer and output impedance characteristics. The
30 winding turns of the auxiliary windings are distributed
evenly over the full traverse of the primary winding, which
permits tuning of the transformer to a single harmonic,
for example a high harmonic such as the ninth harmonic.
These techniques therefore simplify tuning of the
35 transformer, provide a reliable assembly, and aid in
reducing the size and cost of the transformer.



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1 CLAIMS:

1. A high voltage transformer (21)
characterized by the combination of:

5 a tertiary coil form (22) having a tertiary
winding (23) wound thereon;

a magnetically permeable core (24) disposed
within the interior of said tertiary coil form (22); and
disposed between said tertiary coil form (22)
and said core (24) a primary winding assembly comprising:

10 a primary coil form (10);

a primary winding (201) wound on said primary
coil form (10) over a predetermined winding region (15);
and

15 at least one additional winding (202;203;204)
wound on said coil form (10) and overlaying said primary
winding (202), said additional winding (202;203;204)
comprising a plurality of winding turns (2;3;4) evenly
distributed over said predetermined winding region (15).

20 2. A transformer as defined in claim 1
designed for connection of a said additional winding
(202) to a load circuit (7) which will heavily load said
additional winding (202), said even distribution of said
additional winding (202) preventing degradation of the
25 harmonic tuning of said transformer (21) due to said
heavy loading of additional winding (202).

3. A transformer as defined in claim 1 or 2
wherein said additional winding (202) is wound directly
30 over said primary winding (201) without any insulation
between said primary winding (201) and said additional
winding (202) other than insulating coating (37) on the
wire of the windings (201,202).

35 4. A transformer as defined in claim 2 or 3
wherein said transformer (21) is tuned to a single
harmonic pole.



- 1 5. A transformer as defined in claim 4,
wherein said signal harmonic pole is a high harmonic of
the order of the ninth or greater harmonic.
- 5 6. A transformer as defined in any preceding
claim including one said additional winding (203) having
a plurality of winding turns (3) interleaved with the
winding turns (4) of another additional winding (204),
said winding turns (3) of said one additional winding
10 (203) and the winding turns (4) said other additional
winding (204) being evenly distributed independent of
any other of said additional windings.
- 15 7. A transformer as defined in any preceding
claim including a transformer housing (30) in which is
disposed at least said tertiary coil form (22) with the
tertiary winding (23) thereon.
- 20 8. A transformer as defined in any preceding
claim, being a high voltage winding for a video display
apparatus.
- 25 9. A transformer comprising:
a bobbin (10);
a first transformer winding (201) wound on
said bobbin (10) and occupying a winding region (15)
thereon; characterized by a second transformer winding
(202) wound on said bobbin (10) directly overlaying said
first transformer winding (201), said second winding
30 (202) comprising a plurality of winding turns (2) evenly
distributed over said winding region (15).