June 18, 1968 E. J. QUIRK ETAL 3,389,329

CONSTANT OUTPUT VOLTAGE TRANSFORMER

Filed June 22, 1965 2 Sheets-Sheet 1

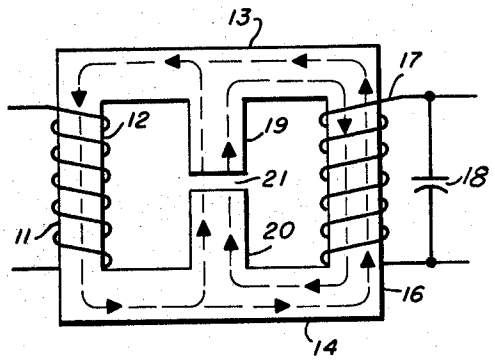



FIG. 1

(PRIOR ART)

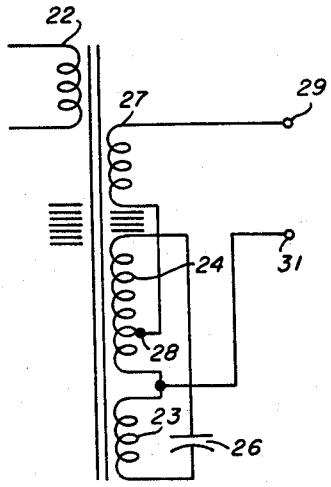



FIG. 2

(PRIOR ART)

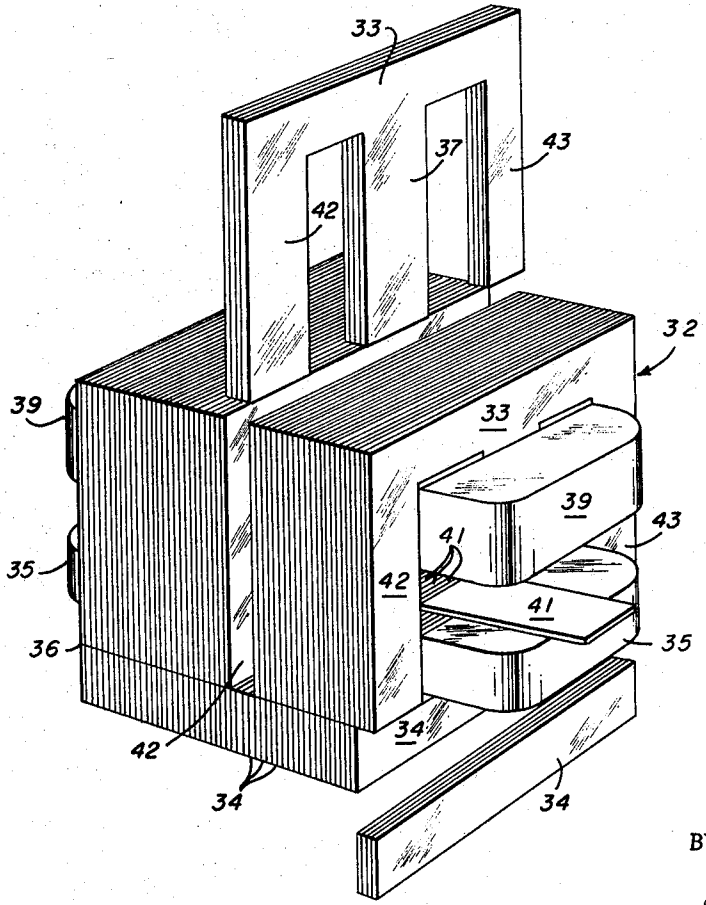



FIG. 3

INVENTORS
EDWARD J. QUIRK
WILLIAM W. FINCH

BY

Richard K. Macneill

June 18, 1968 E. J. QUIRK ETAL 3,389,329

CONSTANT OUTPUT VOLTAGE TRANSFORMER

Filed June 22, 1965 2 Sheets-Sheet 2

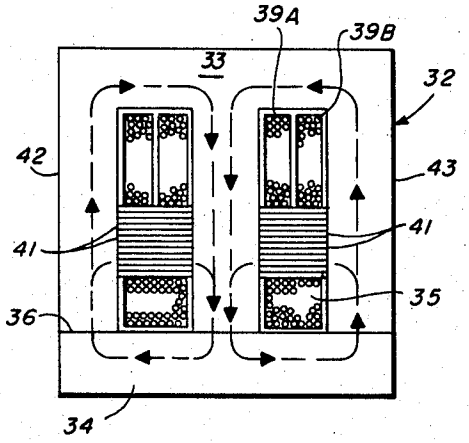



FIG. 4

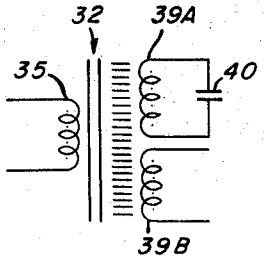



FIG. 6

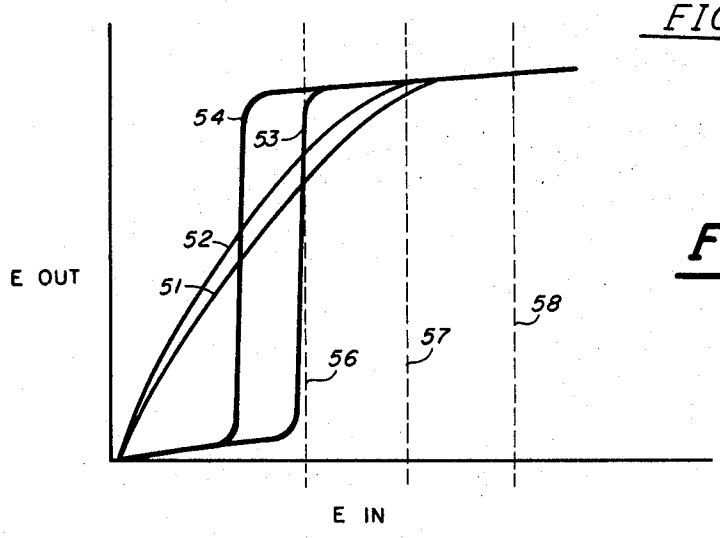



FIG. 5

INVENTORS
EDWARD J. QUIRK
BY WILLIAM W. FINCH

Richard K. Macneill

United States Patent Office 3,389,329 Patented June 18, 1968



3,389,329

# CONSTANT OUTPUT VOLTAGE TRANSFORMER

Edward J. Quirk, Arcadia, and William W. Finch, Manhattan Beach, Calif., assignors to Transformer Engineers, Inc., San Gabriel, Calif., a corporation of California

Filed June 22, 1965, Ser. No. 465,968
7 Claims. (Cl. 323—45)

## ABSTRACT OF THE DISCLOSURE

A constant voltage output transformer having a core consisting of E laminations and I laminations but stacked against each other for the completion of magnetic loops, a primary winding and first and second secondary windings carried by the center leg of the E laminations, and a plurality of shunt laminations press fit between the center leg of the E laminations and each outside leg with no air gaps, said shunt laminations being disposed between the primary winding and the first and second secondary windings.

The present invention relates to a constant output voltage transformer and more particularly to a constant output voltage transformer utilizing shorted shunt techniques.

Prior art constant output voltage transformers have utilized shunt techniques for shunting a predetermined amount of primary flux away from the secondary windings. These shunts all utilize an air gap which is varied to control the amount of flux shunted through this leg. This type of arrangement, however, necessitates a compensating winding which is wound over the primary winding and connected in opposition to the load secondary winding. Naturally, this feedback or compensating winding increases the size and cost of the over-all transformer. Furthermore, the prior art transformers utilizing E laminations I laminations shorting their ends have all been constructed by interleaving the E and I laminations for better control over exciting current. This too, is an expensive process and raises the cost proportionately of the over-all transformer.

According to the invention, a constant output voltage transformer is provided having a core comprising a plurality of E and I laminations. The I laminations are butt stacked, as opposed to interleaving, against the E laminations for the completion of the magnetic loops. The transformer windings are all carried by the center leg of the E laminations, the primary being next to the I laminations, and a capacity and secondary windings stacked away from the primary windings. In between the primary and secondary windings a plurality of shunt laminations are press fit between the center leg of the E laminations and each outside leg, with no air gap. It has been found that this construction results in a transformer, not only less expensive than the prior art transformers mentioned, but yields a broader range of regulation both with line variations and load variations. A further economy is effected through the use of grain oriented steel in all of the laminations, heretofore considered unfeasible in constant output voltage transformers. Grain oriented steel has a higher flux saturation point resulting in a saving of material, weight and size. Another economy is effected through the use of bobbin secondary windings which do not require layer insulation as the prior art constant voltage transformers are constructed.

It is an object of the present invention to provide a constant output voltage transformer having negative regulation characteristics without use of feedback turns.

A further object is the provision of a constant output voltage transformer utilizing shorted shunt techniques.



Another object of the present invention is to provide a constant output voltage transformer utilizing grain oriented steel laminations throughout the core and shunt construction.

Still another object of the invention is to provide a constant output voltage transformer utilizing butt stack construction.

Yet another object of the invention is to provide a constant output voltage transformer which is compact, inexpensive and has superior output voltage regulation.

Other objects and many of the attendant advantages of the present invention will be more readily apparent with reference to the following detailed description taken in conjunction with the drawings in which like reference numerals designate like parts throughout the Figures thereof and wherein:

FIG. 1 shows in schematic form the magnetic circuit of a prior art constant output voltage transformer;

FIG. 2 shows a schematic of a prior art constant output voltage transformer having compensating winding;

FIG. 3 shows a perspective of the assembled transformer of the present invention;

FIG. 4 is a sectional view of the assembled transformer of FIG. 3; and

FIG. 5 is a graphic illustration of the regulation characteristics of a transformer incorporating the features of the present invention as opposed to the prior art constant output voltage transformer regulation characteristic curves; and

FIG. 6 is a schematic representation of the transformer of the present inveniton.

Referring to FIG. 1, the basic magnetic circuit of the prior art type of constant voltage transformer is shown having a primary winding **11** wound on leg **12** which is integral with legs **13**, **14** and **16**, all of the said legs forming a yoke of the transformer. Capacity winding **17** is wound on leg **16** and has capacitor **18** connected in parallel therewith. Shunt legs **19** and **20** are shown integral with legs **13** and **14** and have air gap **21** separating them.

Referring to FIG. 2, a prior art constant output voltage transformer shown in schematic form having primary winding **22** and secondary windings **23** and **24** connected in series. Capacitor **26** is connected in parallel with the series combination of secondary windings **23** and **24**. Secondary winding **27** has one side constructed to tap **28** of secondary winding **24** and the other side connected to output terminal **29**. Output terminal **31** is connected between secondary windings **23** and **24**.

Referring to FIG. 3, a transformer **32** has E laminations **33** and I laminations **34** butt stacked at **36**. The inner leg **37** of E laminations **33** has primary winding **35** and secondary windings **39** carried thereon. Shunts **41** are press fit in between primary winding **38** and secondary windings **39**, and the center portion **37** of E laminations **33** and outside legs **42** and **43** of E laminations **33**.

Referring to FIG. 4, the transformer FIG. 3 is shown sectionally again having E laminations **33** butt stacked to I laminations **34** at **36**. Center portion **37** of E laminations **33** has primary winding **35**, load winding **39***a* and capacity winding **39***b* carried thereon. Shunt laminations **41** are press fit between the primary winding **35** and secondary windings **39** and center leg **37** of E laminations **33** and the outside legs **42** and **43** of E laminations **33**.

Referring to FIG. 5 a graph is shown having E out plotted vertically and E in plotted horizontally with curves **51**, **52**, **53** and **54** plotted thereon. Also shown are dotted lines **56**, **57** and **58**.

Referring to FIG. 6 the transformer constructed according to FIGS. 3 and 4 is shown in schematic form. Primary winding **34** and secondary windings **39A** and **39B** are all wound on core **32**. Secondary winding **39A** has a capacitor

40 in parallel therewith. Shunt laminations are indicated by horizontal lines disposed between secondary windings 39A and 39B and core 32.

*Construction and operations*

Referring back to FIG. 1 the general magnetic loop between primary and secondary comprising legs 12, 13, 14 and 16, of the core, is shunted with additional magnetic shunt legs 19 and 20, containing air gap 21. By controlling the dimensions of the shunt and the width of the air gap, the amount of flux shunted through this leg can be regulated. The magnetic shunt, in effect, loosens the coupling between the primary and secondary. Some of the primary flux is passed back to the primary winding 11 through the shut and this portion does not affect secondary winding 17. Similarly, some of the secondary flux does not oppose the primary flux. With a resistive load, the counter flux created by the secondary is opposed to primary flux. With a resistive load, the counter flux created by the secondary is opposed to primary and cancels part of it.

When capacitor 18 is connected across secondary 17 this is no longer true. The phase of the secondary current, and therefore the flux has now shifted by 180° so that the flux in the shunt leg consists of the primary flux and is brought beyond the knee of the normal transformer characteristic curve. The arrows in FIG. 1, illustrating flux flow through the core, show that the portion of the secondary flux which passes through the rest of the core opposes the primary. Since the shunt portion of the secondary flux path is now operated in the flat portion of the transformer characteristic curve, a relatively large change in primary voltage will not have as much effect on the secondary voltage, but, because the total flux increases, the secondary voltage will increase slightly. This increase of the secondary voltage could be higher than would be expected from the turns ratio, as the secondary and capacitor form a resonant circuit.

Referring to FIG. 2, a compensating winding shown at 27 is utilized to obtain additional reduction of secondary voltage variation. This winding is normally wound directly over the primary. The voltage from this winding will vary with the primary voltage. It is connected in opposition to the secondary and the actual amount of voltage variation in the compensating winding is determined by its ratio to the primary. As the primary voltage increases slightly, the secondary voltage increases very slightly, and the compensating winding voltage also increases slightly. This last voltage increase opposes the second voltage increase and the net result is less change in the secondary voltage than would be the case if no compensating winding were utilized. These prior art constant output voltage transformers suffer from many disadvantages, mainly size and cost.

Referring back to FIG. 1, leg 17 of the core is actually provided by I laminations and legs 11, 13, and 14 by E laminations. These laminations are normally interleaved for better control over core exitation current. This interleaving process is one of the cost raising factors. Another cost raising factor is created by the necessity to vary air gap 21 of shunt legs 19 and 20 for control over shunted flux. A further cost and size increasing factor is the neces sity of compensating winding 27 (FIG. 2) which also increases the bulk and complexity of the transformer.

Referring now to FIGS. 3 and 4, the instant invention is shown as an assembled transformer in perspective in FIG. 3 and sectioned in FIG. 4. Core 32 comprises a butt stack of E laminations 33 and I laminations 34 held together with varnish. These stacks are not cemented until after test adjustments. This method of assembly permits expeditious tuning or adjusting. The output voltage is controlled by adding or removing E laminations, the number of I laminations not being critical. Shunts 41 are press fit between primary winding 35 and secondary winding 39 in a direction perpendicular to center portion 37 of E laminations 33. This construction has been heretofore considered unfeasible, and permits much better control of the transformer short circuit current load and line regulation. The slope of the regulation curve and the degree of regulation is controlled by adding or removing shunts. It has been found that this design also eliminates the need for feedback or compensating windings utilized in the prior art to control the slope of regulation and short circuit current.

Other novel features of the instant invention consist of the utilization of grain oriented steel for all laminations including the shunts 41, and the utilization of bobbin wound secondary coils 39, which eliminates the necessity of layer insulation and thereby reduces the overall size of the transformer. Both of these features have heretofore been considered unfeasible in constant output voltage transformer construction.

The theory of operation is not fully known but, as far as understood, is as follows: As primary voltage is increased from zero, a flux is set up in the primary portion of the core. This flux has two paths, one through shunts 41, and another through the secondary portion of the core legs 42, 37 and 43 of E laminations 33. Current set up by the secondary windings 39, owing to the small induced voltage due to increasing primary flux, increases the reluctance of the secondray portion of the core far above the lower reluctance value of the shunt path with no air gap. Therefore, almost all of the primary flux initially flows through the shunts.

When the reluctance of the shunt path becomes close to the reluctance of the secondary, flux starts dividing more evenly between the shunt and the secondary magnetic loop. The ampere-turns of capacitor winding 39*b* serve to increase the primary flux which causes the secondary flux to avalanche and the unit suddenly moves into saturation. Since the secondary flux no longer changes, the secondary voltage tends to drop to zero, but the capacitor in parallel with capacitor winding 39*b* has been charged up to saturation voltage and supplies energy back to the secondary. This results in a quasi square wave of substantially constant amplitude of the saturation voltage. With proper selection of the parallel capacitor vs. load values, this square wave can be controlled to have an RMS value constant within 0.5% for large variations in input voltage.

Referring to FIG. 5, a graph is shown comparing the input-output voltage variations of the instant invention against that of the conventional prior art transformer utilizing feedback windings. These later variations are shown as curves 51 and 52. As the input voltage is increased the output voltage increases as shown in curve 51 up to a leveling off point shown by dotted line 57. This leveling off point represents about 90% of the rated input voltage at the rated output voltage. When the input voltage is then decreased from the 90% level at dotted line 57, the output voltage follows curve 52 back down to zero.

In the transformer of instant invention, the increasing input voltage curve is shown at 53. Thus, when the input voltage begins to increase, the output voltage stays relatively insignificant up to about the dotted line marked as 56. It suddenly avalanches into saturation resulting in the rated output voltage at that point. This represents about 40% of the rated input voltage. When the input voltage is decreased, the output voltage follows curve 54 back down to zero and the reverse avalanche effect takes place at about 40% of the rated input voltage. Dotted line 58 shows a full rated input and output voltage levels.

It has been found that the instant transformer will regulate within 0.5% of rated output from 0.6 of the rated input through the rated input. Conventional designs regulate from approximately 0.84 of the rated input voltage to the rated input, requiring feedback circuits for this performance.

It should be understood, of course, that the foregoing disclosure relates to only a preferred embodiment of the invention and that it is intended to cover all changes and modifications of the invention herein chosen for the purposes of the disclosure which do not constitute departures from the sprit and scope of the invention.

What is claimed is:

1. A constant output voltage transformer comprising:
(a) a core having a plurality of E laminations and I laminations;
(b) said E laminations having two outside legs and a center portion parallel thereto, said outside legs and center portion being integral with an end portion at right angles thereto;
(c) said I lamination magnetically connected across said E laminations outside legs and center portion opposite said end portion;
(d) a primary winding carried by said center portion;
(e) a capacitor winding carrier by said center portion and having a capacitor connected in parallel therewith;
(f) a load winding carried by said center portion; and
(g) a plurality of shunt laminations magnetically shorted between said center portion and said outside legs of said E laminations and positioned between said primary winding and said capacitor and load windings.

2. The constant output voltage transformer of claim 1 wherein said E laminations and said I laminations are butt stacked against each other.

3. The constant output voltage transformer of claim 1 wherein said shunt laminations are press fitted between the center portion and outside legs of said E laminations.

4. The constant output voltage transformer of claim 1 wherein said primary winding is positioned adjacent said I laminations.

5. The constant output voltage transformer of claim 1 wherein said capacitor winding and said load winding are bobbin wound without layer insulation.

6. The constant output voltage transformer of claim 1 wherein said E laminations and said I laminations are constructed of grain oriented steel.

7. The constant output voltage transformer of claim 1 wherein said shunt laminations are constructed of grain oriented steel.




**References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,064,771 | 12/1936 | Vogt | 336—198 X |
| 2,121,592 | 6/1938 | Gough | 323—48 |
| 2,825,024 | 2/1958 | Berghoff | 323—61 |
| 2,996,656 | 8/1961 | Sola | 323—45 |
| 3,205,561 | 9/1965 | Brutt et al. | |

OTHER REFERENCES

Mittermaier, Abstract of Application Ser. No. 6,687, Pub. Feb. 5, 1952, 655 O.G. 274.



JOHN F. COUCH, *Primary Examiner.*

WARREN E. RAY, *Examiner.*