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TRANSFORMER SWITCHING MATRIX

Filed June 4, 1963 2 Sheets-Sheet 1

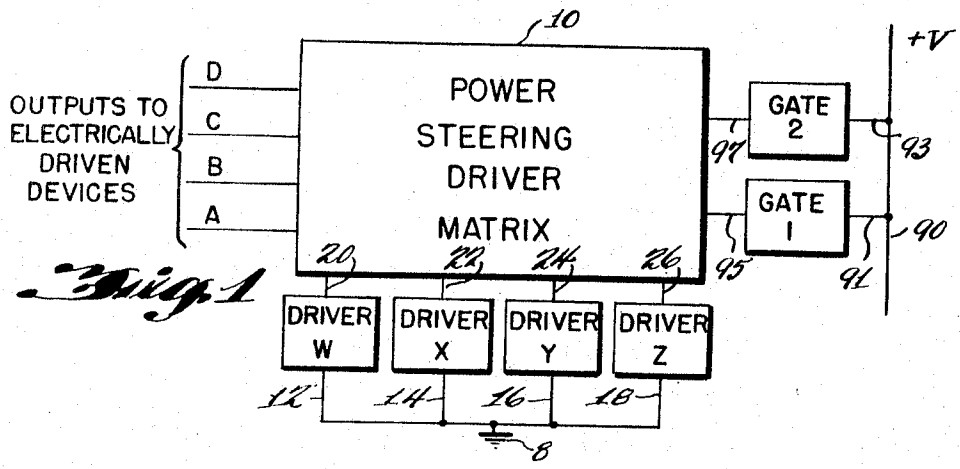


Fig. 1

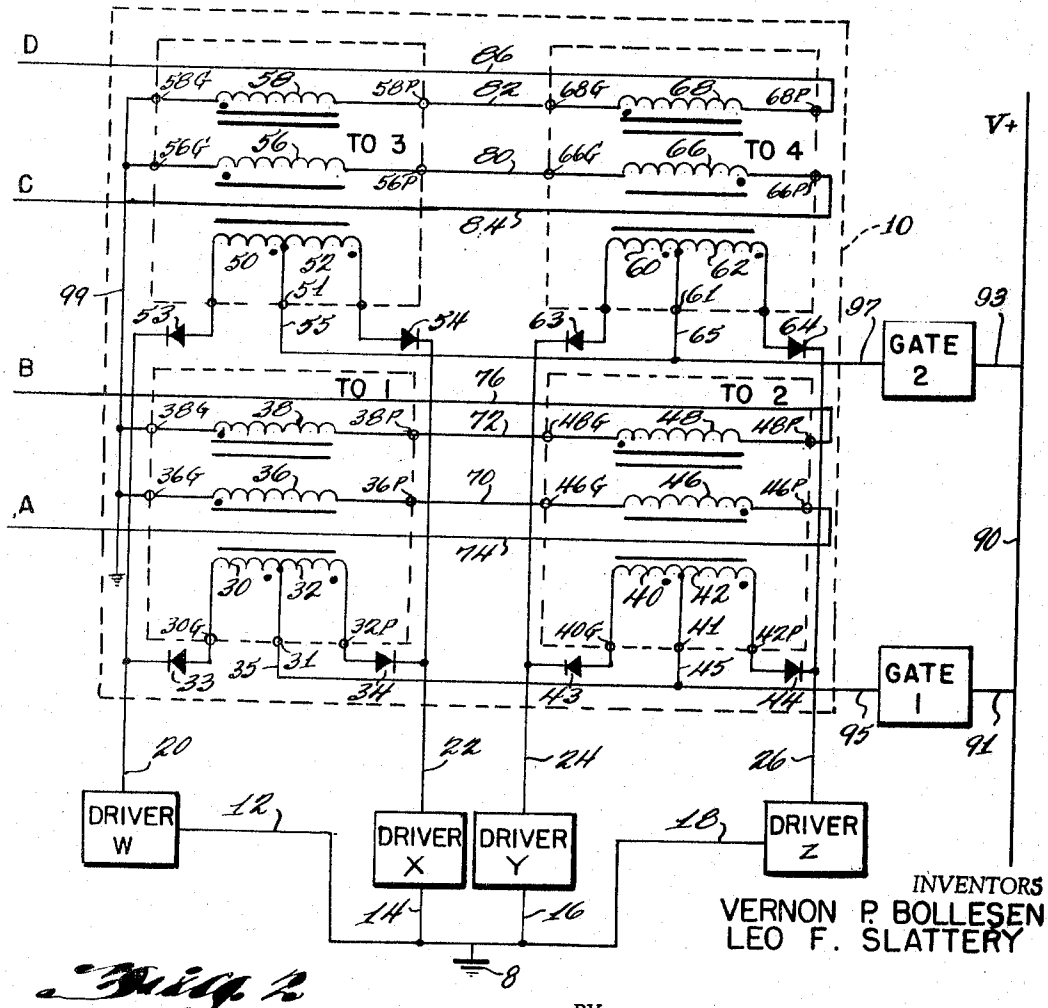


Fig. 2

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Filed June 4, 1963 2 Sheets-Sheet 2

	GATE	DRIVER	MATRIX OUTPUT A	MATRIX OUTPUT B	MATRIX OUTPUT C	MATRIX OUTPUT D
LEVEL 1 OPERATION	1	W&Z	+ 2 V.			
	↓	X&Y	- 2 V.			
		W&Y		+ 2 V.		
	↓	X&Z		- 2 V.		
LEVEL 2 OPERATION	2	W&Y				+2V.
	↓	X&Z				-2V.
		W&Z			+2V.	
	↓	X&Y			-2V.	

Fig. 3

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TRANSFORMER SWITCHING MATRIX

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This invention relates to a power steering driver for use as a selective power driving system in a digital computer and more particularly to a means of generating bi-polar power pulses from a matrix of diodes and transformers.

Previous methods known in the art for successfully generating power pulses from a transformer matrix have encountered several limitations. These limitations include the means available for increasing the number of outputs from a given matrix. As the number of outputs is increased, the complexity of individual components is increased. Each additional output from a matrix requires the addition of separate transformer windings to the matrix thus resulting in a complex matrix if a large number of outputs are required.

As a further limitation, some power steering systems utilize magnetic core material which exhibits a square hysteresis loop. This square hysteresis loop makes the pulse outputs from the matrix dependent upon the core material thereby increasing the difficulty of pulse shaping.

It is therefore an object of this invention to provide a power steering matrix system which can easily be expanded to provide a greater number of outputs without increasing the complexity of individual components.

It is another object of this invention to provide a power steering matrix system in which a bi-polar pulse is generated having a voltage level which is twice that of the output of a single power steering transformer within the matrix.

A further object of this invention is to provide a power steering transformer matrix utilizing a transformer driving means which is separate from the transformer matrix.

A still further object of this invention is to provide a power steering transformer matrix which utilizes a core material capable of allowing the shaping of the output pulse.

Further objects and the entire scope of the invention will become more fully apparent when considered in light of the following detailed description of illustrative embodiment of this invention and from the appended claims.

The illustrative embodiment may best be understood by reference to the accompanying drawings wherein:

FIGURE 1 is a schematic block diagram illustrating the various elements associated with the power steering driver matrix;

FIGURE 2 is a schematic diagram of the electrical circuitry within the power steering driving matrix, the external elements associated with the matrix being shown in block form; and

FIGURE 3 is a chart illustrating the various combinations of gates and drivers for selecting particular matrix outputs.

Briefly, the invention comprises the use of a plurality of transformers which, in the illustrative embodiment, are associated in pairs. The transformers are paired by the interconnection of secondary windings. The voltage source is selectively connected to center tapped primary windings of the associated pairs of transformers. Voltages are thereby generated across the secondary windings in a manner determined by the way which the individual secondaries are wound to produce resultant power pulses.

FIGURE 1 illustrates by means of a block diagram the inventive power steering driver system. This power

steering driver includes a power steering driver matrix **10**, input control means including gates **1** and **2** and drivers W, X, Y, and Z, and matrix output lines A, B, C, and D. An output from the power steering driver is obtained at one of the plurality of matrix output lines. The selection of an output line A, B, C or D, and the polarity of an output signal appearing thereon, is dependent on the input control means. The input control means produces a selected matrix output signal of a certain magnitude and polarity by the operation of the gates and drivers in a predetermined manner. The activation of a single matrix output requires the activation of a single gate simultaneously with the operation of two drivers. By the proper combination of gates and drivers, an output signal of a certain polarity is produced upon any selected matrix output. Therefore it is possible to obtain a bi-polar pulse at each matrix output line A, B, C and D. A bi-polar pulse is defined as a voltage which appears upon a matrix output line when the matrix is driven, which voltage may be of a value of plus (+) two times the supply voltage, +V, volts (+2V volts) or minus (—) two times the supply voltage, +V, volts (—2V volts), wherein a transformer turn ratio of 1:1 is assumed. Thus matrix outputs on lines A, B, C and D have two operating voltages which thereby result in eight selective output conditions. The input means requires six separate elements to produce the eight selective output signals. The inventive arrangement thereby reduces the number of control means necessary to obtain a determined number of outputs. Although the matrix outputs of this embodiment are second multiples of the supply voltage, it will be understood that any proportion or multiple may be achieved by appropriate transformer turn ratios.

The gates of the input means are used to apply a supply voltage to the matrix. The drivers of the input means are used to complete matrix circuits by connecting them between the supply voltage and ground. Gates **1** and **2** are connected to the supply voltage line **90** by means of lines **91** and **93**, respectively. Gate **1** connects the supply voltage to the power steering driver matrix via line **95**. Gate **2** connects the supply voltage to the matrix via line **97**. Drivers W, X, Y and Z are connected to a ground terminal **8** via lines **12**, **14**, **16** and **18** respectively. Driver W connects a circuit of the power steering driver matrix to ground via line **20**. Similarly, driver X connects a matrix circuit to ground via line **22**, driver Y connects a matrix circuit to ground via line **24**, and driver Z connects a matrix circuit to ground via line **26**.

FIGURE 2 illustrates in detail the arrangements of the transformers and diodes within the power steering driver matrix **10**. The transformers and diodes within the matrix are stablished in two levels. The first level corresponds to the transformers and diodes energized by gate **1** and the second level corresponds to the transformers and diodes energized by gate **2**. Each level comprises two transformer components. Each transformer component is identical and includes four windings and seven connecting terminals as shown in FIGURE 2. The four windings include two primary windings and two secondary windings. Each primary winding has an end terminated with a non-linear diode thereby providing two diodes per transformer component.

Considering now the first level of FIGURE 2, this level includes two transformer components TO1 and TO2. Transformer component TO1 has four windings, two primary windings **30** and **32** and two seconadry windings **36** and **38**. Primary windings **30** and **32** are each joined at one end thereof at point **31**, which point is essentially the center tapped point of a large primary winding. The other end of primary winding **30**, joined to terminal **30G**, is connected through diode **33** to line **20**. Line **20** ema-

nates from driver W. The other end of primary winding 32, joined to terminal 32P, is connected through diode 34 to line 22. Line 22 emanates from driver X. Center tapped terminal point 31 is connected via line 35 to line 95. Line 95 emanates from gate 1. Referring now to the secondary windings 36 and 38, each secondary winding is a separate and independent winding. Secondary winding 36 has one end terminal, 36G, connected to ground line 99. The other end of secondary winding 36, at terminal 36P, is connected via line 70 to terminal point 46G, which point is the terminal of a secondary winding within transformer component TO2. The other secondary winding 38 has one end terminal, 38G, connected to the ground line 99. The other end of secondary winding 38P is connected via line 72 to terminal point 48G, which point is the terminal of the other secondary winding within transformer component TO2. Considering now the transformer component TO2, which is the other transformer component within level 1 controlled by gate 1, this transformer component TO2 has four windings; two primary windings 40 and 42 and two secondary windings 46 and 48. Primary windings 40 and 42 are each joined at one end at point 41, which point may also be considered as a center tapped point of a large primary winding. The other end of primary winding 40 at terminal 40G is connected through diode 43 to line 24. Line 24 emanates from driver Y. The other end of primary winding 42 at terminal 42P is connected through diode 44 to line 26. Line 26 emanates from driver Z. Center tapped terminal point 41 is connected via line 45 to line 95. Line 95 emanates from gate 1. Each secondary winding of TO2 is, as in transformer component TO1, a separate and independent winding. Secondary winding 46 has one end terminal 46G connected via line 70 to terminal point 36P of secondary winding located within transformer component TO1 as described previously. The other end of secondary winding 46 at terminal point 46P is connected to line 74. Line 74 subsequently is identified as matrix output line A. The other secondary winding 48 has its other end terminal point 48G connected via line 72 to terminal points 38P of the other secondary winding of transformer component TO1 as previouly described. The other end of secondary winding 48 terminal point 48P is connected to line 76. Line 76 subsequently is identified as matrix output line B.

In each of the transformer components TO1 and TO2 of level 1, the dots on the transformer windings indicate the *direction* of *current flow*. For example, if current flows *into* the dotted end of the primary winding, current will also flow *into* the dotted end of the secondary winding. This is achieved by appropriate coiling in the required direction. Further, the magnetic cores comprise material which allows the transformers to operate within the linear portion of the magnetic cores' characteristic hysteresis loops. This allows the transformer secondaries to produce a pulse output proportional to the input thereby retaining the same pulse shape.

The transformer components TO3 and TO4 of level 2, which are controlled by gate 2, are identical to the components TO1 and TO2 of level 1. The windings and terminal points of TO3 are identical to those of TO1 with the exception that the numbering scheme is identified as 5X. The primary winding connections TO3 are connected to the same drivers W and X as TO1. The center tapped terminal 51 is connected through line 55 to line 97 emanating from gate 2. Similarly, the windings and identification of transformer component TO4 are identical to those of TO2 with the exception that the number scheme is identified as 6X. The primary winding connections of TO4 are connected to the same drivers Y and Z as TO2. The center tapped terminal 61 is connected through line 65 to line 97 emanating from gate 2. The secondary connections between transformer components TO3 and TO4 are as follows. Secondary winding 56 of

TO3 is connected at terminal point 56P via line 80 to terminal point 66G of secondary winding 66 of TO4. Terminal point 56G of secondary winding 56 is connected to ground line 99. Terminal point 66P of secondary winding 66 is connected to line 84, which line subsequently is identified as matrix output line C. Similarly, secondary winding 58 of transformer component TO3 is connected at terminal point 58P via line 82 to terminal point 68G of secondary winding 68 of transformer component TO4. Terminal point 58G of secondary winding 58 is connected to ground line 99. Terminal point 68P of secondary winding 68 is connected to line 86, which line subsequently is identified as matrix output line D.

Summarizing, the transformer components of each level are so connected that the primary windings are energized in parallel from the voltage supply source and the secondary windings are connected in series thereby making the output voltage from the transformer additive.

The over-all circuit operation is dependent upon the operation of the input control means which includes gates 1 and 2 and drivers W, X, Y and Z. The gate input control means includes switching means which either connect or disconnect circuits within the power steering driver matrix to the supply voltage. Similarly, the driver input control means includes switching means for either connecting or disconnecting windings within the power steering driver matrix to ground. The switching means may comprise any well known electronic switching device such as, but not limited to, a transistor, or any mechanical or other switching control apparatus. Also these switching means may be selected or controlled in a predetermined scheme by any logical control means, configuration or devices, which are well known in the high speed digital computer art. This invention will be described using various combinations of the input control means to select a specific matrix output line and to develop a voltage of a certain polarity thereon.

The over-all operation of the inventive power steering driver includes double level operation, that of levels 1 and 2. Level 1 operation includes the use of gate 1 and drivers W, X, Y and Z. Level 2 operation includes the use of gate 2 and drivers W, X, Y and Z.

As an example of the operation of the power steering driver, level 1 operation will first be considered. During level 1 operation there exists four possible combinations for simultaneously connecting both transformer components of the matrix circuit to the supply voltage and ground via the gate and drivers. FIGURE 3 illustrates these combinations for a level 1 operation. When gate 1 is activated to connect line 95 to the voltage supply +V on line 90 via line 91, energization of the primary windings of the matrix circuit is completed by any one of these four possible combinations. Each combination requires the use of two drivers to select matrix output lines A or B and to generate either a +2V volts or −2V volts upon the selected matrix output line.

Assume that gate 1 is activated to connect line 95 via line 91 to the supply voltage line 90. The supply voltage +V is applied via lines 95 and 35 to terminal point 31 and to terminal point 41 via lines 95 and 45. For the purposes of illustration drivers W and Z are activated. When drivers W and Z are activated, the parallel primary windings of transformer components TO1 and TO2 are energized simultaneously. A voltage of +V is applied to TO1 primary winding 30 through a path from the voltage supply line 90, through gate 1 via line 91, through lines 95 and 35 to terminal 31 of TO1. Since terminal 30G is effectively grounded, current passes through primary winding 30 into the end of the winding with the dot. The current flows out of primary winding 30 at terminal point 30G, through diode 33 to line 20 and via line 20 through driver W and line 12 to ground terminal 8. During this current flow, diode 53 of level 2 transformer component TO3 is back-biased thereby preventing the possibility of any current flowing within level 2 due to the operation

of level **1**. Referring now to transformer component TO2, a voltage of +V is simultaneously applied to the TO2 primary winding **42** from the voltage supply line **90**, through gate **1** via lines **91** and **95** to line **45** whereupon the terminal point **41** is energized. Since terminal **42P** is effectively grounded, the current through primary winding **42** passes into the end of the winding without the dot. The current flows *out of* primary winding **42** at the end with the dot via terminal point **42P** through diode **44** to line **26**, and via line **26** through driver Z and line **18** to ground terminal **8**. Diode **64** is back biased during this current flow to prevent current through level **2** due to the operation of level **1**. Summarizing, with gate **1** and drivers W and Z activated, current flows *into* primary winding **30** at the dotted end and *out of* primary winding **42** at the dotted end.

Referring now to the secondary windings of each transformer component, both secondary windings of each transformer component are energized when either primary winding is energized. The direction of current flow within the secondary winding and the voltage applied thereon is a function of which primary winding is energized. The rule which governs the direction of current flow in the secondary winding as they are wound in this embodiment is: if the current flows *into* the dotted end of the primary winding, current will also flow *into* the dotted end of the secondary windings; also if the current flows *out of* the dotted end of the primary winding, current will also flow *out of* the dotted end of the secondary windings.

Applying these rules to the illustrative case, with driver W activated, current flows *into* the dotted end of primary winding **30**. Therefore the current flow in each secondary winding **36** and **38** must be *into* the dotted end of the secondary winding. Considering secondary winding **36**, the current flow is *into* the dotted end of **36**, i.e., current flows from terminal point **36G**, via secondary winding **36** to terminal point **36P**. The voltage thereby appearing upon the secondary winding **36** has a magnitude of V volts, and the sense of the voltage is such that point **36P** is positive with respect to point **36G**, which point is essentially grounded. Considering now secondary winding **38**, the current also flows *into* the dotted end end of **38**, i.e., current flows from terminal point **38G** via secondary winding **38** to terminal point **38P**. The magnitude and sense of the voltage appearing upon the secondary winding is the same as that appearing upon winding **36**. The sense of the voltage is such that terminal point **38P** is positive with respect to point **38G**, which point is essentially grounded. The output of the secondary winding **36** is applied via terminal point **36P** and line **70** to the secondary winding **46** of transformer component TO2. Also the output of the secondary winding **38** is applied via terminal point **48P** and line **72** to the secondary winding **48** of transformer component TO2.

Consider now the secondary windings **46** and **48** of TO2. Current flows *out of* primary winding **42** at the dotted end since driver Z is activated. Therefore the current flowing in each secondary winding **46** and **48** flows *out of* the dotted end thereof. Referring to secondary winding **46**, the current moves in a direction to flow *out of* the dotted end of **46**, i.e., current flows from terminal **46G**, via secondary winding **46** to terminal point **46P**. The magnitude of the voltage appearing across the secondary winding **46** is V volts and this voltage has a sense such that point **46P** is positive with respect to point **46G**, which point is connected via line **70** to secondary winding **36** of transformer component TO1. Considering now secondary winding **48**, current flows *out of* the dotted end of **48**. Therefore, the current flows from terminal point **48P** via secondary winding **48** to terminal point **48G**. Terminal point **48G** is connected to secondary winding **38** of transformer component TO1. The magnitude of the voltage appearing on winding **48** is V volts but its sense is opposite to that of the voltage appearing on winding **46**. The sense of the voltage is such that terminal **48G** is more positive than terminal point **48P**.

Considering the resultant operation of the transformer components TO1 and TO2, terminal **46P** of TO1 is connected to line **74** which is subsequently identified as matrix output line A. The voltage appearing between terminal point **46P** and ground line **99** is the sum of the voltages appearing on each secondary winding. Therefore, the voltage between point **46P** and ground line **99** includes the voltages on secondary winding **36** and secondary winding **46**. Since terminal point **36P** is more positive than point **36G** and since terminal point **46P** is more positive than terminal point **46G**, the two voltages of magnitude V impressed upon the secondary windings **36** and **46** are additively related resulting in a voltage between matrix output line A and the ground line **99** of +2V volts since line A is at a higher potential than ground line **99**. As stated previously, the current flow is from the power steering matrix driving a predetermined electrical load connected to line A.

Referring to the other matrix output B connected to terminal **48P**, the voltage between terminal point **48P** and ground line **99** is the sum of the voltages appearing across secondary windings **38** and **48**. Since terminal point **38P** is more positive than terminal point **38G** and since terminal point **48G** is more positive than terminal point **48P**, the addition of the voltages between terminal point **48P** and the ground line **99** is zero. Accordingly, no current flows from within the matrix to the load, and the voltage appearing at matrix output line B is zero.

Summarizing, when gate **1** and drivers W and Z are energized, the supply voltage +V is applied in parallel to the appropriate primary windings of transformer components TO1 and TO2. Both secondary windings of transformer component TO1 produce an output of V volts, the outputs having the same sense. The secondary windings of transformer component TO2 also produce an output of V volts on their secondary windings but these are of opposite sense. Since the secondary windings of one component are paired with those of the other component, the addition of the secondary voltages produces a +2V volts output with a current flow from one matrix output line, line A, and a zero volt output and no current flow at the other matrix output line, line B.

If a voltage of −2V volts is required at matrix output line A, drivers X and Y are activated simultaneously with gate **1**. Similarly, to produce a +2V volts at matrix output line B, drivers W and Y are activated simultaneously with gate **1**, and to produce a −2V volts at matrix output line B, drivers X and Z are activated simultaneously with gate **1**.

The chart of FIGURE 3 illustrates the combination of gates and drivers necessary to obtain a level **2** operation. The level **2** operation affects the matrix outputs C and D and determines which matrix output line is to be selected and the magnitude of the voltage appearing thereon. The level **2** operating scheme is similar to that for a level **1** operation.

The power steering driver can be expanded for more outputs by adding more gates and transformers in the upward direction. For each additional two outputs, a single gate and two transformer components are necessary. An increase of two additional matrix output lines provides an increase of four additional operating conditions.

Also the power steering driver can be expanded by adding drivers and transformers to the left. For each additional two outputs, a group of four drivers and two transformer components must be added. Similarly, an increase of two additional matrix output lines provides for an increase of four additional operating conditions.

When the power steering driver matrix outputs are increased by the addition of gates, drivers and transformer components, the increase is accomplished without in-

creasing the complexity of any of the matrix components.

Generally, the number of matrix outputs may be expressed as a function of the number of drivers and the number of gates in an equation format as follows:

$$\text{No. of matrix outputs} = \frac{(\text{No. of drivers})(\text{No. of gates})}{2}$$

Similarly, the number of operating conditions may be expressed as a function of the number of drivers and the number of gates in an equation format as follows:

$$\text{No. of operating conditions} = (\text{No. of drivers})(\text{No. of gates})$$

It will be also understood that any appropriate power steering device may be utilized with the inventive power steering driver.

The above illustrative embodiment comprises a preferred embodiment of the invention. However, this embodiment is not intended to limit the possibilities of insuring the improved features of the power steering driver. The power steering driver disclosed herein is an example of an arrangement in which the inventive features of this disclosure may be utilized and it will become apparent to one skilled in the art that certain modifications may be made within the spirit of the invention as defined by the appended claims.

What is claimed is:

1. A power steering driver for selectively generating a voltage on one of a plurality of output lines, comprising: a power steering drive matrix including a plurality of transformer components, each of said components having a pair of primary windings effectively wound in opposite sense and a plurality of secondary windings, the individual secondary windings of each component being connected in series with at least one secondary winding of another transformer component and with an output line; input control means selectively actuated to connect an external voltage source to said matrix to energize single primary windings of more than one transformer component thereby inducing voltages across the secondary windings associated with said energized primary windings, the secondary windings being wound such that the induced voltages in one series connection are additive to produce a resultant voltage on the output line in said series connection.

2. A power steering driver as set forth in claim **1**, further comprising means for electrically isolating the non-energized primary windings during selective energization of said single primary windings.

3. A power steering driver as set forth in claim **1**, wherein said pair of primary windings in each transformer component comprises a center-tapped primary winding, said input control means connecting the external voltage source to the center-tap and selectively completing electrical paths to ground from the ends of the center-tapped winding.

4. A power steering driver as set forth in claim **3**, wherein said input control means includes gates for selectively connecting the external voltage source to the center-taps of the primary windings and drivers connected to the ends of the center-tapped primary windings for selectively completing electrical paths from the primary windings to ground; the number of output lines available in the combination comprising one half the product of the gates and drivers, and the number of output voltages which can be generated equaling the product of the gates and the drivers.

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