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(54) Regulated power supplies.

(57) A regulated power supply operable to produce a regulated DC output from an AC input and comprising voltage regulator means (1) and bridge rectifier means (11) having one pair of terminals connected across the voltage regulator means, the AC input being a reactive current source (13) connected across a second pair of terminals of the bridge rectifier means (11), whereby current is limited by reactance having low loss. The reactive current source may be a leaky transformer or a generator having a high leakage reactance.

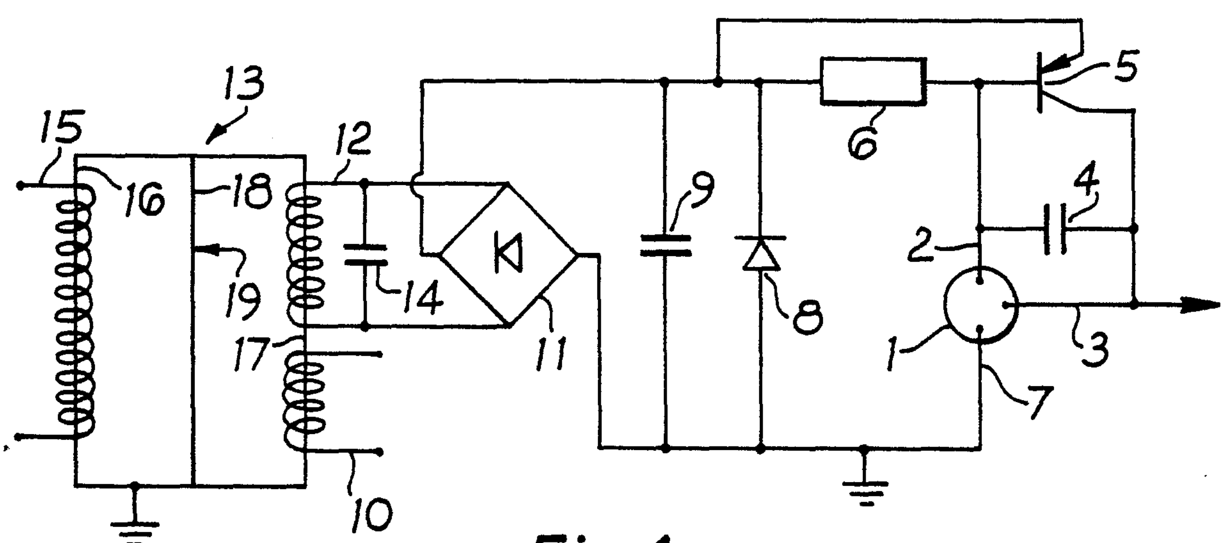

Fig.1

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REGULATED POWER SUPPLIES

This invention relates to regulated power supplies particularly, although not exclusively, for use in aircraft.

Power supplies in aircraft which serve the flight deck have to be regulated to within very tight tolerances to ensure that any voltage excursions are not present which might otherwise affect the operation of one or more instruments which could be critical to flight control and hence to passenger safety.

It is known to employ a voltage regulator in an aircraft power supply to which the input current is stablised by using a series impedance which dissipates excess voltage in the form of power, namely heat. The dissipation of heat in the context of an aircraft can be a major problem. For example, modern aircraft often require that a given piece of equipment must be within a temperature range of -55°C to +85°C, non-operational. Accordingly, it is virtually impossible to design equipment the temperature of which falls within this range when actually operational when it is of the type which dissipates heat. The constraint on temperature is, of course, with reliability in mind as failure cannot be risked with highly critical components in aircraft or other types of sensitive control systems. It will be appreciated that failure is a sensitive function of temperature.

Another problem arises out of a specific aircraft application, namely that of an emergency power supply which needs to be available in the event of failure of the main supply and clearly, in this context, there is an even more stringent technical specification laid down. Such an emergency power supply is conveniently generated from a ram air turbine which drives an hydraulic pump which supplies pressure fluid for the control of the aircraft ailerons, etc., and for driving an hydraulic motor. The hydraulic motor drives a constant speed generator which incorporates a permanent magnet generator from which the emergency electrical supply is derived. However, the voltage produced by the permanent magnet generator is dependent on the rotational speed of the hydraulic motor and inevitably, this means that there is a relatively wide range of frequency and hence voltage during start up. Accordingly, it is not uncommon for the nominal DC output voltage of 28 volts derived from the permanent magnet generator to be as high as 64 volts under overspeed conditions and known regulators cannot cope with this if there is a constraint on the temperature of the equipment as discussed above. It is, therefore, an object of the present invention to overcome the aforementioned problems.

According to the present invention, there is provided a regulated power supply operable to produce a regulated DC output from an AC input and comprising voltage regulator means and bridge rectifier means having one pair of terminals connected across the voltage regulator means, characterised in that the Ac input is a reactive current source connected across a second pair of terminals of the bridge rectifier means, whereby current is limited by reactance having low loss.

The reactive current source may be in the form of a transformer comprising a core having at least three limbs, a primary winding disposed on one limb of the core, and at least one secondary winding disposed on another limb of the core, with the remaining core limb or limbs effectively being free of windings.

Thus, the or each effectively free limb of the transformer core provides a magnetic shunt and by this simple but highly effective expedient, leaky transformer means is provided which provides a relatively stable current output, thus enabling the voltage regulator to operate satisfactorily.

The magnetic shunt provided by the or each effectively free limb of the transformer means core may be provided with an air gap in order to control the flux leakage. The core is not intended to be saturated during normal operation. In addition, or instead, the wound limbs of the core may be provided with an air gap although it is most convenient to provide this gap in the effectively free limb or limbs. The air gaps may be made adjustable.

Alternatively, the reactive current source may be in the form of a high leakage reactance generator, such as a permanent magnet generator configured, by way of magnets and stator windings, to provide the required high reactance.

The present invention will now be described in greater detail by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a circuit diagram of a regulated power supply in accordance with the present invention,

Figure 2 is a more detailed drawing of a transformer forming part of Figure 1,

Figure 3 is a block circuit diagram showing the regulated power supply of Figure 1 in the context of an aircraft control system,

Figure 4 shows an alternative form of transformer to that of Figure 2, and

Figure 5 is an explanatory diagram.

Referring first to Figure 1, the regulated power supply comprises a standard voltage regulator 1 having an input 2 and an output 3. The input and output 2,3 are shunted by a capacitor 4 and a transistor 5, and the input 2 has a series resistance 6. The transistor 5 and resistance 6 are used to augment the limited current capability of the regulator 1 but can be omitted if a regulator of sufficient current capacity is employed. The capacitor 4 ensures the stability of the voltage regulator 1 but can be omitted when certain types of voltage regulator are employed. The regulator 1 has a further terminal 7 which is connected to ground, with the input terminal 2 and ground terminal 7 shunted by a zener diode 8 and a capacitor 9 via the series resistance 6. The junction of the transistor 5 and the resistor 6, and the terminal are shunted by a rectifier bridge 11 which is connected to a reactive current source in the form of a transformer 13 having a secondary winding 12 across which the rectifier bridge is connected. A further capacitor 14 is also connected across the secondary winding 12 to prevent the current rising due to over-frequency/over-voltage conditions, i.e. run-away conditions. This capacitor also assists in providing differential mode lightning suppression. Additional differential mode lightning suppression is provided by the capacitor 9, the principle function of which is to smooth the rectified output from the bridge rectifier 11. Still further differential mode lightning suppression is afforded by the Zener diode 8 which basically protects the regulator 1 from any excess voltage. Instead of a Zener diode, an equivalent electrical device may be employed. A second secondary winding 10 is also provided. The transformer has a primary winding 15 and a core comprising three limbs, an input limb 16 around which the primary winding 15 is disposed, an output limb 17 around which the secondary windings 10 and 12 are disposed, and a further limb 18 which is free of all windings and is provided with an air gap 19. This construction of the transformer 13 is best shown in Figure 2 and it will be seen that the core is constructed in two parts such that each limb 16, 17 and 18 is in fact split but there is only an air gap in the limb 18 and this is of a precisely machined width in accordance with the amount of leakage required for a given power supply.

The first secondary winding 12 is used to provide the input signal to the voltage regulator 1, and the second secondary winding 10 is used to provide a "clean" or low noise signal representative of speed for use by the frequency/speed control. The waveform on the second secondary winding 10 varies little in amplitude as the speed of the generator increases from zero to running speed. The information from the signal provided by the second secondary winding 10 is derived from the frequency thereof and not the amplitude. It will be noted that the core of the transformer 13 is connected to ground and this is to ensure that the output signal to the voltage regulator is less affected by any induced voltage/current surges due to lightning which the aircraft may be subjected, i.e. the ground connection provides common mode lightning suppression whilst components 8, 9 and 14 provide differential mode lightning suppression as already discussed above. This is an important feature because lightning is likely to cause heavy voltage excursions resulting in mis-operation of, or catastrophic damage to, the instruments to which the voltage supply is connected.

It will also be seen from Figure 2 that the core of the transformer 13 is made up of two E-shaped portions which enables ease of winding and location of the various coils and also enables the precise air gap 19 to be provided. The joints 20 between the two E portions of the core are held by adhesive which has no effect on the magnetic properties of the limbs 16 and 17 of the transformer. The transformer has a class B nickel iron laminated E core type EK25 of A_L value 250nH. The primary coil 15 has 1,250 turns, the first secondary coil (12) providing the output to the voltage regulator has 315 turns, and the second secondary coil 10 has 40 turns.

Turning now to Figure 3, this shows the overall system which is used to provide an emergency electrical supply for an aircraft. The system comprises a ram air turbine 21 which produces a mechanical output connected to an hydraulic pump 22 which in turn provides fluid pressure which is used to actuate the mechanical controls, such as ailerons, of the aircraft indicated by box 23 and also used to drive an hydraulic motor 24. The mechanical output from the hydraulic motor 24 is applied to a constant speed motor generator (CSMG) 25. The CSMG 25 comprises a permanent magnet generator (PMG) which is used inter alia to energise the primary winding 15 of the transformer 13. The CSMG 25 also comprises an alternator which produces the standard 400 Hz, 3-phase electrical supply for the electrical systems of the aircraft indicated at 27 and to the GCU 26 for control purposes. The GCU 26 comprises the regulated power supply of Figure 1, together with other units which are not shown.

Figure 4 shows an alternative form of tranformer 13 which utilises four C cores 28,29,31,32 arranged essentially as two separate oval cores which provide four limbs of the overall transformer core. One limb is provided with the primary winding 15 and adjacent limbs of the cores 33 and 34 are provided with the two secondary windings 12 in a manner similar to that shown in Figure 2. The fourth limb is left unwound and it will be noted that the two C cores forming the core 34 are arranged with an air gap 35 between their ends so as to provide an air gap similar to that indicated at 19 in Figures 1 and 2 to provide the magnetic shunt. The C cores of the core 33 are joined at their ends by an adhesive although it may be required in some applications to provide an air gap betwen these C cores as well as an airgap between the C cores of the core 34.

The primary and secondary windings 15; 10, 12 may be interchanged, if such an arrangement is more convenient.

Turning now to Figure 5 this illustrates the equivalent circuit of a transformer having a primary winding L_1, secondary winding L_2 with the mutual inductance between these two windings represented by M. The primary winding current is I_1 and the secondary winding current I_2 with series impedances in the primary and secondary circuits indicated by R_1 and R_2, respectively. The input voltage to the primary circuit is V at a frequency $\omega/2\pi$.

With the constraints that:-

$$\omega L_2 >> R_2$$
$$R_1 = 0$$

$$M^2 << L_1 L_2$$
$$I_2 = \frac{jVM}{L_1 L_2}$$

where $j = \sqrt{-1}$

Since the PMG voltage is proportional to frequency, then V is K , where K is a constant. Thus:-

$$I_2 = \frac{jKM}{L_1 L_2}$$

I_2 will be constant with respect to R2 and PMG speed,

The presence of capacitor 14 (Figure 1) adds another pole to the circuit and is chosen to make the current fall with PMG speed after 12,000 rpm which is the operating speed of the illustrated embodiment. This nominally constant current is passed through the zener diode 8 which in the illustrated embodiment is a 15V diode, together with an augmented shunt voltage reference to produce a precise 10V supply at up to 100mA as is required in the particular application illustrated which is that for aircraft control. The input PMG speed at which adequate output is available extends from below 4,000 rpm to above 20,000 rpm. Further increase in PMG speed causes no damage as the output current from the transformer 13 falls with speed. Furthermore, any short circuit of the transformer output will cause no damage. The air gap 19 in the transformer limb 18 was set at 0.2mm in the illustrated embodiment but, as already explained, this gap is varied to suit the particular application, and, as already mentioned, may be zero.

Whilst the illustrated embodiments show the use of a separate transformer 13 to provide the reactive current source, an alternative approach is to employ a high leakage reactance generator such as a permanent magnet generator. In such a case it can be shown that:-

$$I_2 = \frac{K}{jL_G}$$

Where L_G is the inductance of the generator, and assuming the same constraints as in the case of the use of a transformer as the reactive current source.

It will be seen that the present invention provides a regulated power supply capable of meeting stringent specifications, such as prevail in the aircraft indsutry, expedient of providing a reactive current source for the rectifier bridge, whereby a constant current output is produced from a variable voltage input without consuming any significant power, in contrast to the known use of a resistor to achieve the same result but with the consequential production of heat and also giving rise to a larger dropout voltage. Alternatively, or in addition, a near-constant amplitude and/or frequency "clean" (low noise) control signal is available through use of the second secondary winding 10. The use of a transformer provides a high degree of isolation, for both the power and the control signals, from any electrical surges on the input leads.

Claims

1. A regulated power supply operable to produce a regulated DC output from an AC input and comprising voltage regulator means and bridge rectifier means having one pair of terminals connected across the voltage regulator means, characterised in that the AC input is a reactive current source (13) connected across a second pair of terminals of the bridge rectifier means (11), whereby current is limited by reactance having low loss.

2. A regulator power supply according to claim 1, characterised in that the reactive current source is a transformer (13) comprising a core having at least three limbs (16, 17, 18) a primary winding (15) on one limb (16) of the core, and at least one secondary winding (10, 12) disposed on another limb (17) of the core, with the remaining core limb (18) or limbs being effectively free of windings.

3. A regulated power supply according to claim 2, characterised in that the input signal to the primary winding (15) of the transformer means (13) is a signal which varies both as regards voltage and frequency.

4. A regulated power supply according to claim 2 or 3, characterised in that at least one secondary winding (12) is shunted by capacitance means (14) which, in use, limit the current flowing the secondary winding in over frequency/over voltage conditions and also assist in differential mode lightning suppression.

5. A regulated power supply according to any of the preceding claims, characterised in that said one pair of terminals of the bridge rectifier means (11) is shunted by capacitance means (9) which, in use, are operable to smooth the rectified output of the bridge rectifier means and also serve to augment the differential mode lightning suppression.

6. A regulated power supply according to any of the preceding claims, characterised in that said one pair of terminals of the bridge rectifier means (11) is shunted by limiting means which, in use, protect the voltage regulator means (1) from excess voltage should the load of the regulator means be disconnected, and also serve to provide differential mode lightning suppression.

7. A regulated power supply according to claim 6, characterised in that the limiting means comprises a Zener diode (8).

8. A regulated power supply according to any of the preceding claims, characterised in that means (5, 6) are provided for augmenting the current capability of the voltage regulator means.

9. A regulated power supply according to any of the preceding claims, characterised in that an input terminal (20 and output terminal (3) of the voltage regulator means (1) are shunted by capacitance means (4) to augment the stability of the voltage regulator means.

10. A regulated power supply according to claim 2 and any of claim 3 to 9 appended thereto, characterised in that the core of the tranformer (13) is at ground potential.

11. A regulated power supply according to claim 2 and any of claim 3 to 10 appended thereto, characterised in that the effectively free limb (18) of the core of the transformer is provided with an air gap (19) in order to control the flux leakage.

12. A regulated power supply according to claim 2 and any of claim 3 to 11 appended thereto, characterised in that the or each wound limb (16,17) of the core is provided with an air gap in order to control the flux leakage and inductance values.

13. A regulated power supply according to claim 2 and any of claims 3 to 11 appended thereto, characterised in that the core comprises two E-shaped portions, with the centre limb (18) thereof being provided with an air gap (19), and with the two core portions being secured together by an adhesive which has no effect on the magnetic properties of the associated limbs (16,17) of the core.

14. A regulated power supply according to claim 2 and any of claims 3 to 12 appended thereto, characterised in that the core comprises four C-shaped portions (28,29,30,31,32) arranged as essentially two separate oval cores (33,34) which provide four limbs for the overall transformer core.

15. A regulated power supply according to claim 14, characterised in that one limb of the transformer core is provided with the primary winding (15), and adjacent limbs of the two cores (33,34) are provided with the two secondary windings (10,12), with the fourth limb being effectively free of windings.

16. A regulated power supply according to claim 14, characterised in that the secondary windings (10,12) are provided on one limb, and the primary winding (15) is provided on adjacent limbs of the two cores (33,34), with the fourth limb being free of windings.

17. A regulated power supply according to any of the claims 14 to 16, characterised in that an air gap is provided between the two C-shaped cores of at least one core of the transformer.

18. A regulated power supply according to claim 2 and any of claims 3 to 17 appended thereto, characterised in that the transformer (13) comprises a second secondary winding (10) the output of which provides a low noise control signal.

19. A regulated power supply according to claim 1, characterised in that the reactive current source comprises an AC generator having a high leakage reactance.

20. A regulated power supply according to claim 18, characterised in that the generator is a permanent magnet generator.

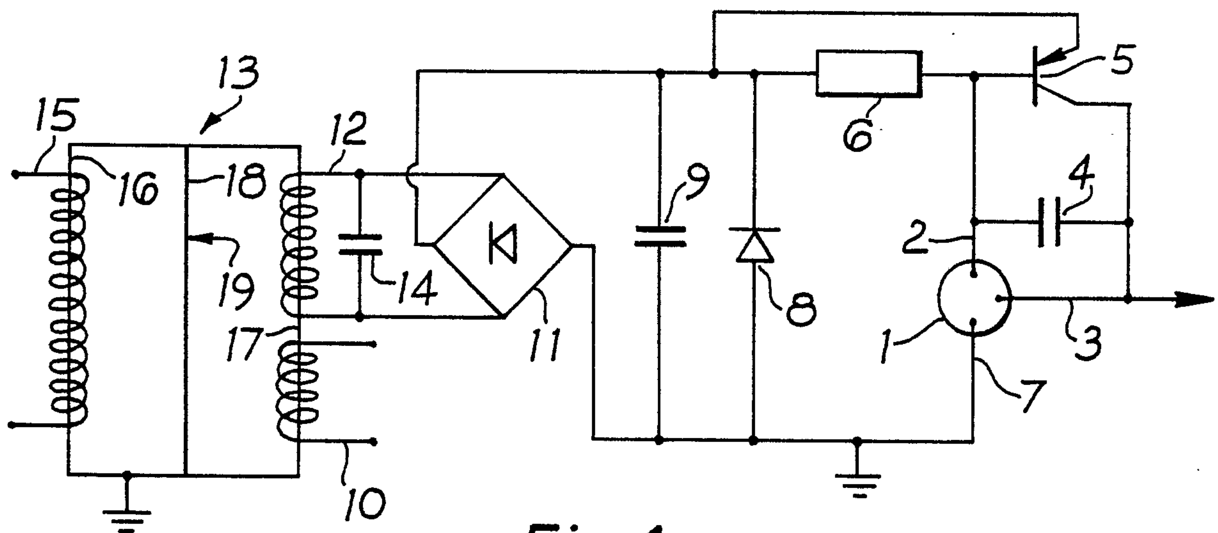
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Fig.1

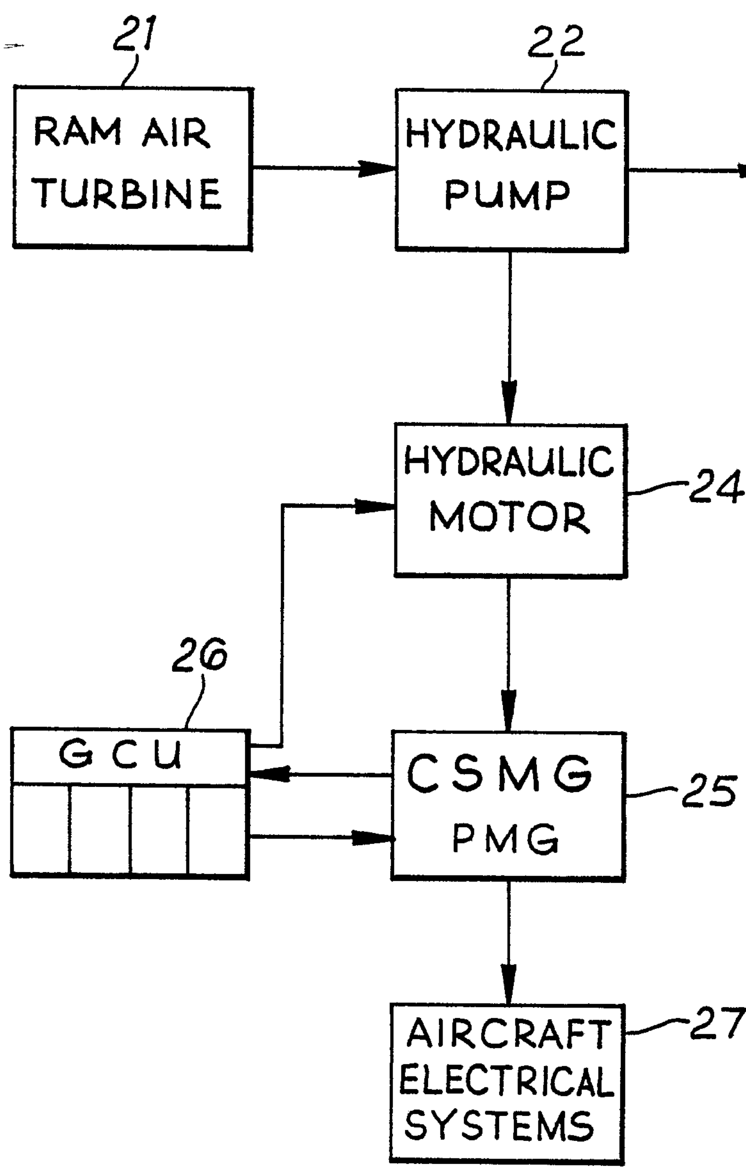
21
RAM AIR TURBINE
22
HYDRAULIC PUMP
23
AIRCRAFT MECHANICAL CONTROLS
HYDRAULIC MOTOR
24
26
GCU
CSMG PMG
25
AIRCRAFT ELECTRICAL SYSTEMS
27

Fig. 3

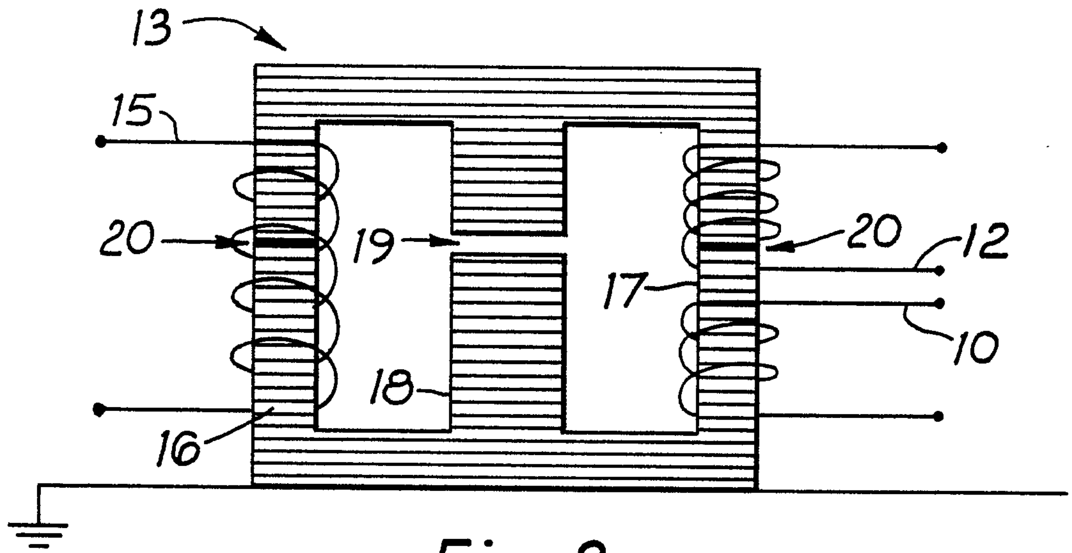

Fig. 2

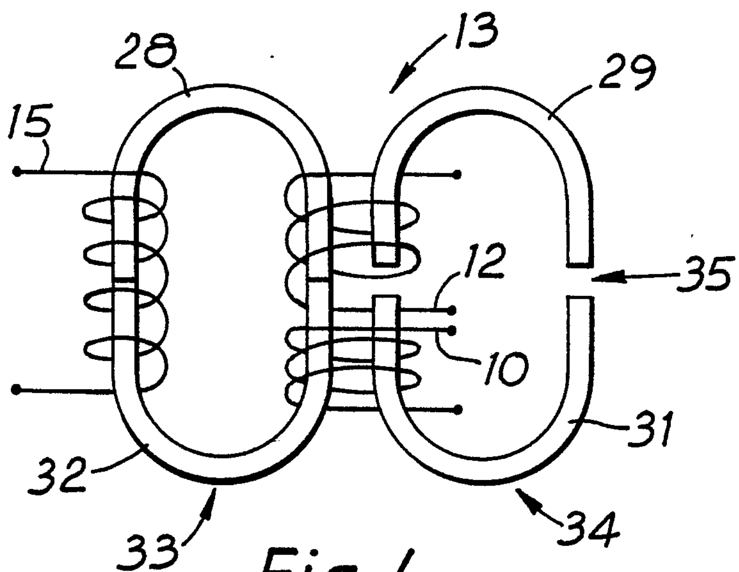

Fig. 4

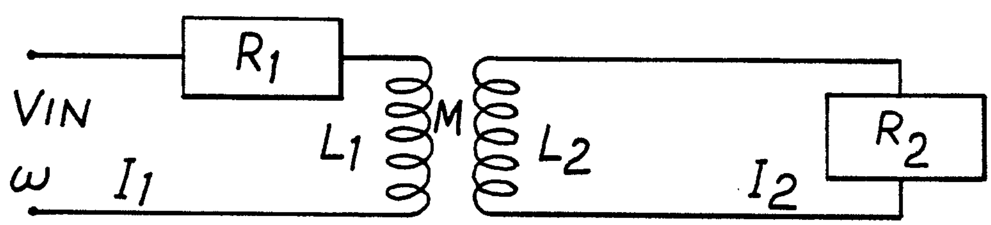

Fig. 5

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EUROPEAN SEARCH REPORT

Application number

EP 87 30 6188

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	US-A-3 921 055 (UNION CARBIDE CORP.) * Column 2, lines 1-57 * ---	1,2,5	H 01 F 31/06
A	US-A-3 135 894 (WESTINGHOUSE ELECTRIC CORP.) * Column 2, lines 57-63 * ---	2,4	
A	US-A-2 792 556 (WESTINGHOUSE ELECTRIC CORP.) * Column 2, line 39 - column 3, line 61 * ---	2,11, 12,14, 15,17	
A	GB-A-2 018 520 (GENERAL ELECTRIC CORP.) * Page 2, line 110 - page 3, line 91 * ---	2,11, 13	TECHNICAL FIELDS SEARCHED (Int. Cl.4) H 01 F 31/00
A	US-A-3 699 385 (SYLVANIA ELECTRIC PRODUCTS) * Column 3, lines 44-57 * ---	2,4,16	
A	US-A-3 247 449 (FOX PRODUCTS CO.) -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-10-1987	VANHULLE R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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