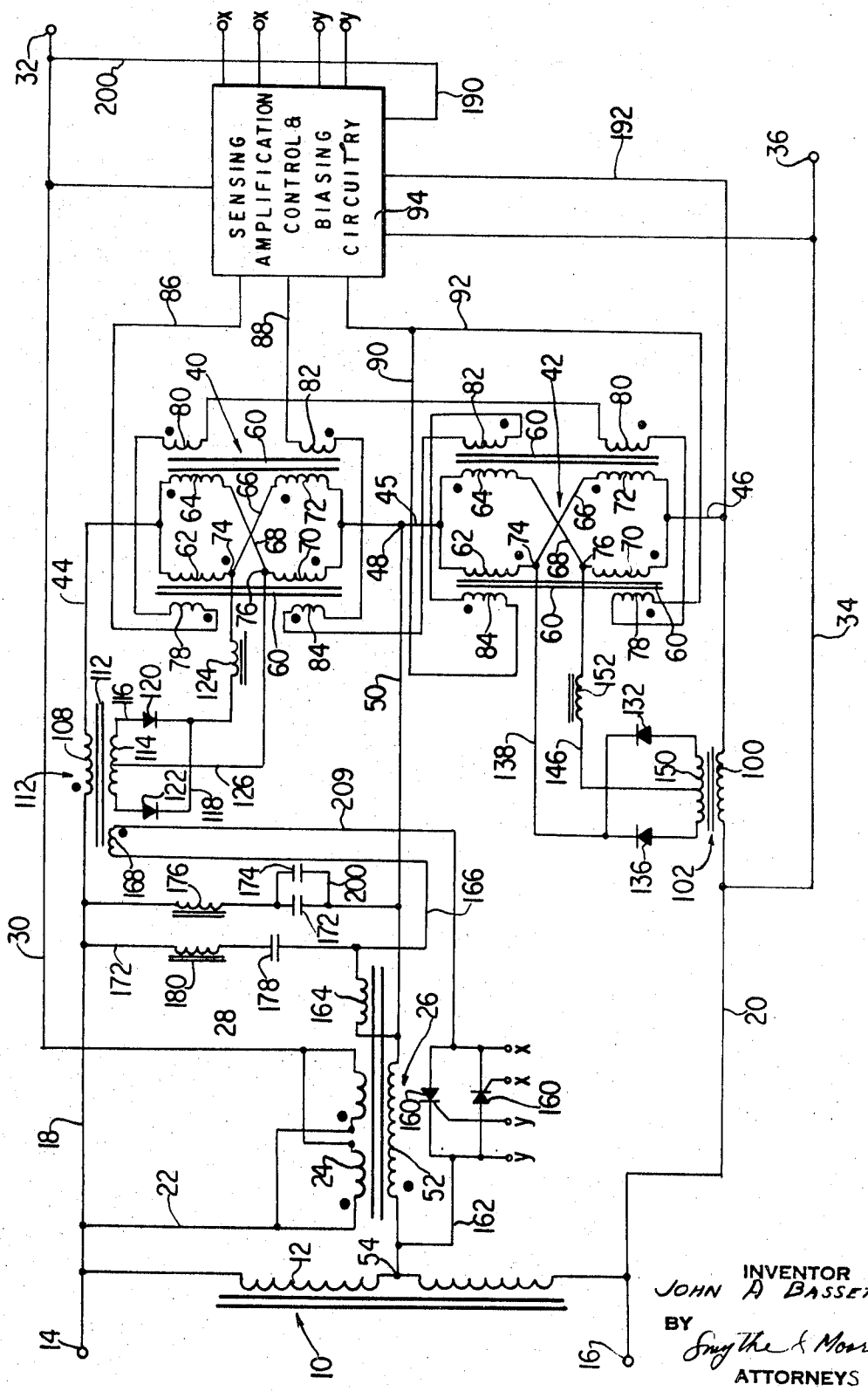
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BUCK/BOOST VOLTAGE REGULATOR EMPLOYING SHUNT MAGNET AMPLIFIER

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BUCK/BOOST VOLTAGE REGULATOR EMPLOYING SHUNT MAGNET AMPLIFIER

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ABSTRACT OF THE DISCLOSURE

A voltage regulator having a pair of magnetic amplifiers connected in shunt across the supply transformer with a connection between the two magnetic amplifiers and the transformer, said connection having a transformer winding therein connected in one of the leads to the load so that the direction of current in said connection will provide a bucking or boosting voltage to the load.

This invention relates to alternating current voltage regulators and more particularly to a regulator of the buck-boost type employing magnetic amplifiers or saturable reactors to provide the desired regulation.

A number of voltage regulators for maintaining substantially constant load voltage despite changes in line voltage, load and frequency have been proposed in the past. Some of these have also utilized saturable reactors or magnetic amplifiers as part of the regulating system. Such reactors or amplifiers, as is well known in the art, often control transformer windings which give an airing (boosting) or opposing (bucking) effects to the voltage normally supplied by the main transformer winding of the regualtor.

An object of the present invention is to provide a new and improved voltage regulator or voltage regulating system of the above described buck-boost type.

Another object of the invention is to provide a magnetic amplifier voltage regulating system in which the amplifiers are supplied with external feedback proportional to the load.

A further object of the invention is to provide a magnetic amplifier voltage regulating system in which load controlled feedback is supplied directly to the load or gate coils of the amplifiers.

A further object of the invention is to provide a regulating circuit in which the requirement for balancing or matching the magnetic characteristics of the cores of the magnetic amplifiers is obviated.

A still further object of the invention is to provide a regulating system in which a tuned circuit means connected across one of a plurality of magnetic amplifiers provides additional range to the regulator.

In one aspect of the invention, a transformer winding in series with an auxiliary transformer winding provides an output voltage. Connected across the input voltage are two series connected magnetic amplifiers. Connected between a tap on the first mentioned transformer winding and a midpoint of the series connected magnetic amplifiers is a primary for the auxiliary winding. The magnetic amplifiers are provided with D.C. bias and control windings, the first of which is connected to a source of D.C. current, and the second to a load voltage sensing device. Instead of being self-saturating, however, the extra D.C. saturating or gain current needed for efficient operation of the magnetic amplifiers is supplied by external feedback transformers connected in the load circuit.

In a second aspect, the gate or load connected windings of the magnetic amplifiers are divided into pairs and each pair is crisscross connected so as to provide a bridge circuit to which the D.C. feedback is connected, thereby permitting use of the common windings for both the gate and feedback circuits and obviating the necessity for magnetically balancing the mag-amp cores.

The foregoing and other objects, features and advantages of the invention will become apparent from the following description and accompanying drawing which are merely exemplary.

In the drawing:

The single figure is a schematic wiring diagram of an embodiment of the invention.

Referring to the drawing, there is shown a transformer **10** having a winding **12** which in the illustrated embodiment comprises an autotransformer. The winding **12** is connected across input line terminals **14** and **16** by lines **18** and **20**. The line **18** is connected to a conductor **22** leading to the secondary **24** (shown split in the illustrated embodiment) of an auxiliary transformer **26**. A conductor **28** connects the secondary **24** to a load line **30** having a load or output terminal **32**. The other input line **20** is connected by a lead **34** to a load or output terminal **36**.

Two magnetic amplifiers **40** annd **42** are connected in series across the input lines **18** and **20** by leads **44**, **45** and **46**. The midpoint **48** of lead **45** is connected through a conductor **50** and the primary **52** of auxiliary transformer **26** to a tap **54** on winding **12**. Each of the magnetic amplifiers **40** and **42** comprises two cores **60** upon which a pair of coils **62** and **64** are crisscross connected by conductors **66** and **68** to a pair of coils **70** and **72**. The coils **62**, **64**, **70** and **72** are so wound, as indicated by black dots, as to form a bridge having intermediate terminals **74** and **76**. The magnetic amplifiers **40** and **42** are provided with series connected D.C. bias windings **78** and **80** and series connected control windings **82** and **84** which are connected by conductors **86**, **88**, **90** and **92** to suitable sensing, amplification, control and biasing circuitry indicated generally by the box **94**.

Included in the lead **46** connected to input line **20** is the primary **100** of a current transformer **102**. Also included in the lead **44** connected to input line **18** is the primary **108** of a current transformer **112**. The transformer **112** has a secondary **114** provided with terminal leads **116** and **118** passing through diodes **120** and **122** and choke **124** to the terminal **74** of the crosscrossed coils of the magnetic amplifier **40**. The secondary **114** of transformer **112** is also provided with a mid-tap connected by line **126** to the crisscrossed terminal **76** of amplifier **40**. In like manner, the transformer **102** is provided with a secondary **130** having its terminals connected through diodes **132** and **136** and connector **138** to the terminal **74** of magnetic amplifier **42**, and a lead **146** connects the terminal **76** of magnetic amplifier **42** to the midpoint **150** of the secondary **130** of transformer **102** through a choke **152**.

Clipper and filter circuits are also preferably provided. As shown in the drawing, the clipper circuit comprises a pair of silicon-controlled rectifiers **160** connected in parallel or full-wave relationship with the box **94** by conductors (not shown) connecting the terminals X—X and Y—Y. The silicon-controlled rectifiers **160** are connected across the primary **52** of transformer **26** through a lead **162**, winding **52**, a winding **164** on the core of transformer **26**, lead **166**, clipper winding **168** on the core of current transformer **112**, and lead **170**. One of the filter circuits comprises a third harmonic filter having a pair of parallel connected capacitors **172** and **174** connected in series with a choke **176** across the lines **18** and **50**. A second filter circuit for fifth harmonics comprises a capacitor **178** and a choke **180** connected in series across the extension winding **164** of transformer **26** and the line **18**.

The operation of the foregoing system is as follows. The input voltage is divided across lines **18** and **20** by the magnetic amplifiers **40** and **42**. The voltage thus derived at midpoint **48** is applied to the primary **52** of transformer **26**. As the other end of winding **52** is connected to a tap **54** on transformer **10**, the voltage at point **48** can be either above or below the voltage at point **54**. Thus, the voltage across the primary winding **52** of transformer **26** can vary in magnitude and polarity depending upon the ratio of the divider formed by magnetic amplifiers **40** and **42**. This voltage is transferred to the secondary **24** of transformer **26** which is connected in series with the output or load and thus adds to (boosts) or subtracts from (bucks) the input voltage to hold the output voltage at a constant level.

The gain of the system is largely controlled by the current transformers **102** and **112** having their primaries **100** and **108** connected in series with the amplifiers **40** and **42**. Due to the crisscrossed bridge connection of the load or gate coils **62, 64, 70** and **72** of these amplifiers, the current from the transformers **102** and **112** can be directly introduced into the gate coils and mixed with the A.C. current flowing therethrough. The chokes **124** and **152** help to control the harmonic content of the divided voltage.

The voltage ratio of the divided magnetic amplifiers **40** and **42** is controlled by the bias and control windings **78, 80, 82** and **84**. Current in the control windings **82** and **84** tends to turn magnetic amplifier **40** "on" and magnetic amplifier **42** "off." Bias current through the windings **78** and **80** turns magnetic amplifier **40** "off" and magnetic amplifier **42** "on," the instantaneous polarity of the current through the several control and bias windings being indicated by black dots. The bias windings **78** and **80** are provided with a D.C. current which is constant in value. The current through the control windings **82** and **84** is varied by the control circuitry in box **94** which senses the output voltage through lines **190** and **192**.

The clipper circuit including the silicon-controlled rectifiers **160** is fired whenever the output voltage exceeds a preset level. Such firing causes the primary winding **52** of transformer **26** to be shorted through extension winding **164**, lead **166**, winding **168**, and lines **170** and **162**. This shorting of primary winding **52** is reflected in the secondary **24** of transformer **26**. The reflected load current flows in the winding **168** of transformer **112**, thereby effecting degeneration of the feedback on magnetic amplifier **40** and ensuring that magnetic amplifier **40** is in an "off" state when the clipper fires.

The feedback transformers **102** and **112** which control the gain of magnetic amplifiers **40** and **42**, respectively do so through D.C. current fed into the gate windings **62, 64, 70** and **72** and mixed with the A.C. components through the center tap connections **126** and **146** of diodes **120, 122, 132** and **136**. This center tap connection regulates the response time of the system since it provides no low impedance conduction path for D.C. when primary current in winding **108** does not flow. The ratio of these transformers is 1:1, providing close to 100% feedback to the magnetic amplifiers, raising the gain so that control current can be extremely low.

It should be noted that the control current flows in both magnetic amplifiers **40** and **42** through windings in series and that this control current turns one magnetic amplifier "on" while the other is turned "off," thereby preventing operation of both magnetic amplifiers at the same time. This ensures a very minimal no load input current. The bridge connections on magnetic amplifiers **40** and **42** provide a crisscrossed connection between the separate magnetic assemblies which obviates the requirement for balancing the two cores, or matching the magnetic characteristics of the two cores.

The capacitors **172** and **174** which are included in the third harmonic filter circuit connected across magnetic amplifier **40** provide at the fundamental frequency a parallel tuned circuit which tends to increase the impedance in this arm of the divider previously described, thus increasing the amount of voltage which can be present across this arm and adding range to the regulator.

What is claimed is:

1. A voltage regulator having input and output terminals, a first transformer winding connected across said input terminals, an auxiliary transformer means connected in series between a terminal of said first transformer winding and one of said output terminals, a connection between a second terminal of said first transformer winding and the other of said output terminals, a pair of series connected variable impedances providing a voltage divider connected in shunt across said first transformer winding and said input terminals, means connecting a winding of said auxiliary transformer means to a midpoint of said series connected variable impedances and an intermediate point of said first transformer winding, and circuit means including a pair of current transformers connected in said shunt circuit means for providing feedback current to said variable impedances.

2. A voltage regulator as set forth in claim **1** in which said variable impedances comprise a pair of magnetic amplifiers.

3. A voltage regulator as set forth in claim **2** in which said magnetic amplifiers include two pairs of gate windings connected in crisscrossed bridge relationship, and said feedback circuit means is connected to said gate windings at the crisscrossed bridge of said windings.

4. A voltage regulator as defined in claim **3** in which said feedback circuit means includes a transformer secondary having terminals connected through diode means to one part of said bridge connection and a center tap connected to a second part of said bridge connection.

5. A voltage regulator as defined in claim **1** in which a clipper circuit including a winding on one of said feedback transformers provides for shorting said auxiliary transformer means upon the output voltage reaching a preset level.

6. A voltage regulator as defined in claim **5** in which said clipper circuit includes a controlled rectifier means.

7. A voltage regulator as defined in claim **1** in which a filter circuit means having capacitance and reactance means tuned to a harmonic of the applied voltage is connected in parallel with one of said variable impedances.

8. A voltage regulator as defined in claim **7** in which a second capacitance and reactance circuit tuned to a different harmonic is connected in parallel with said first filter circuit.

9. The voltage regulator of claim **5** in which said clipper circuit includes an extension winding on said auxiliary transformer and at least one filter circuit.

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