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[54] **SWITCHING REGULATOR**

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[51] **Int. Cl.**[6] **G05F 1/56**

[52] **U.S. Cl.** **323/282**; 323/285

[58] **Field of Search** 323/282, 284–287; 363/21, 23, 25

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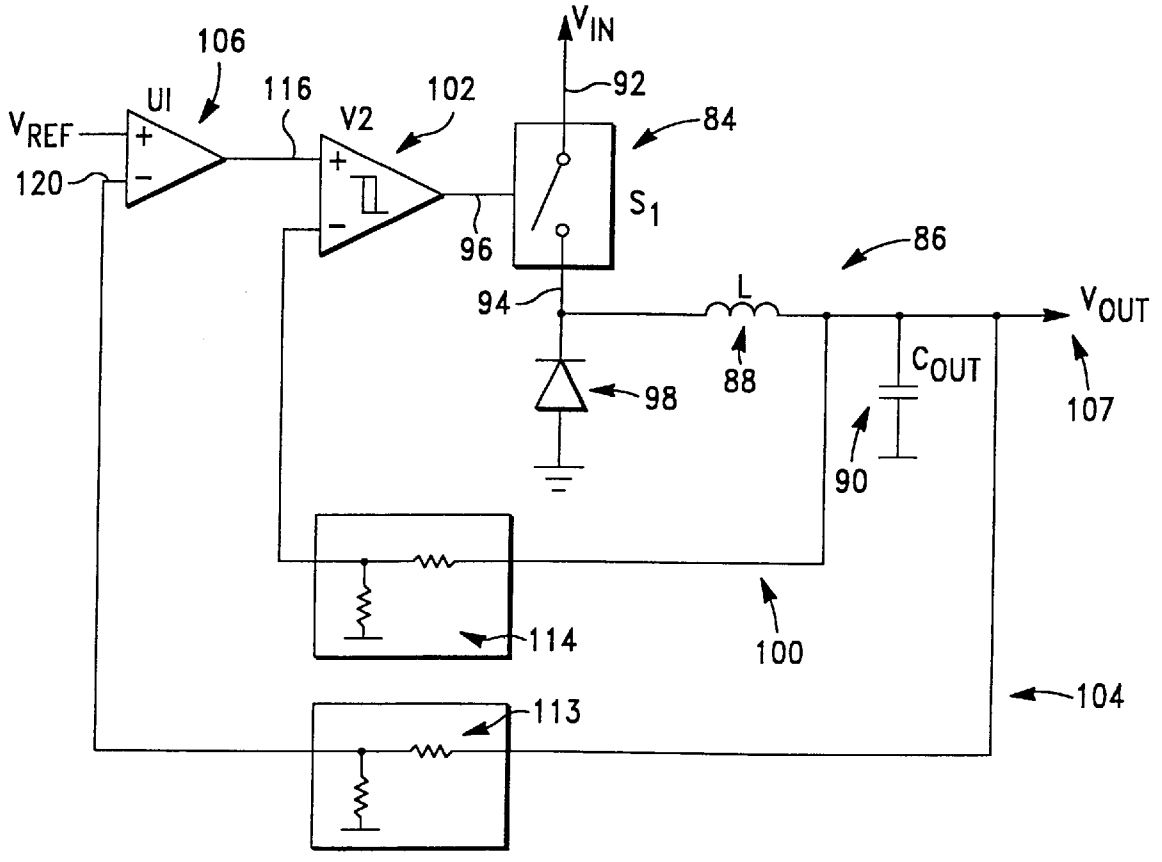
Attorney, Agent, or Firm—William B. Walker

[57] **ABSTRACT**

A switching regulator and a method of regulating voltage by means of a switching regulator, includes a regulator switch, a smoothing filter, and a first voltage feedback loop from an output of he regulator to a control line of the switch. The first feedback loop may include a hysteresis comparator or a comparator and a frequency reference connected to the control line of the switch. The first feedback loop uses the A.C. ripples at the output of the smoothing filter as a ramp signal feedback to substantially instantaneously correct output voltage. A second voltage feedback is further employed to stabilize the output voltage. The smoothing filter employs an LC circuit and the regulator is provided with means for providing an inductor current path when the switch is opened. The regulator may, further, include a current feedback loop.

28 Claims, 6 Drawing Sheets



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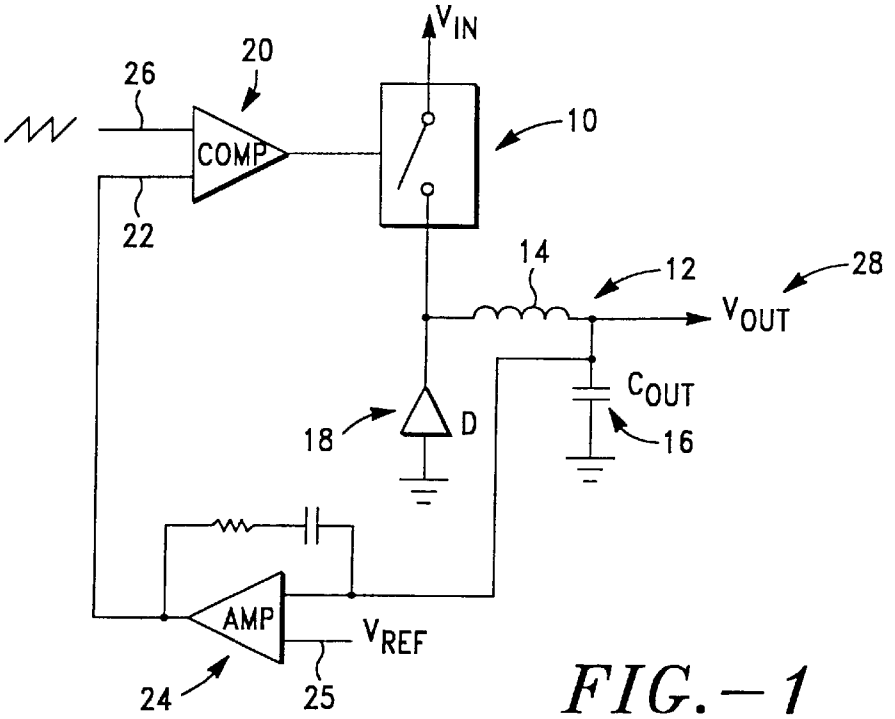

FIG.—1

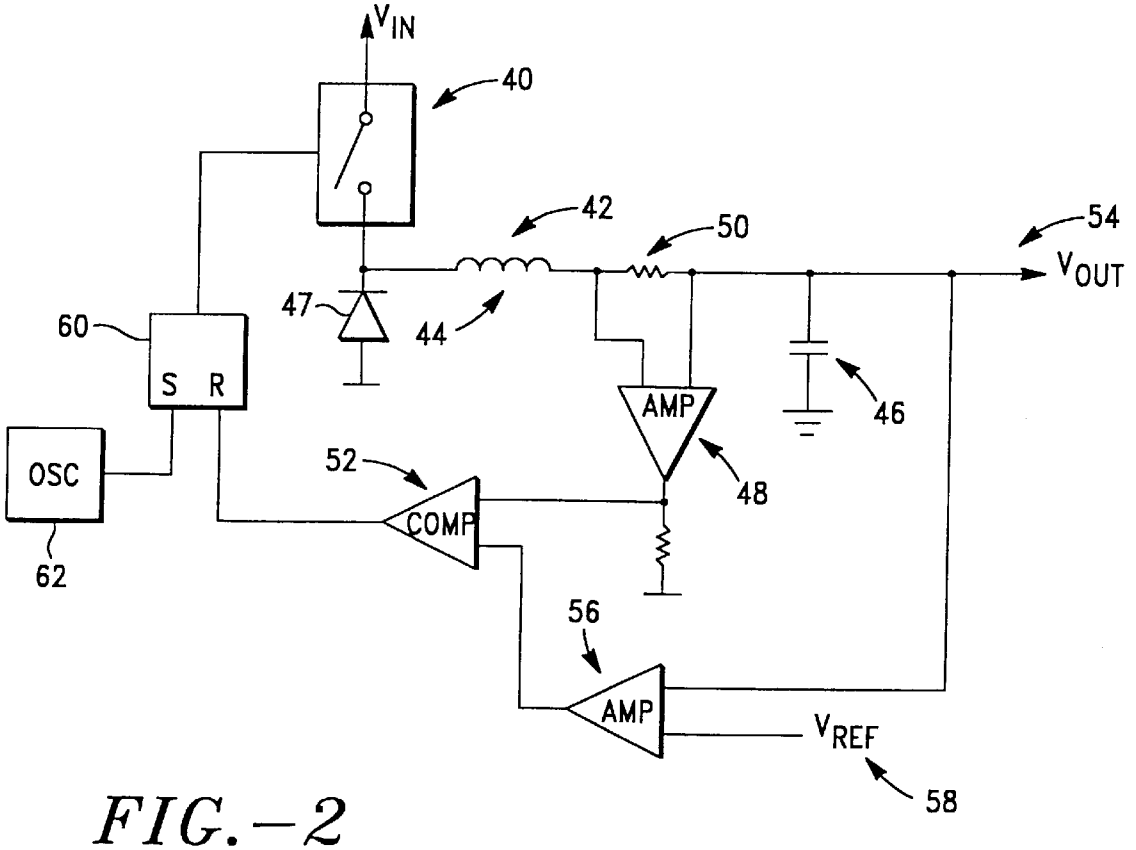

FIG.—2

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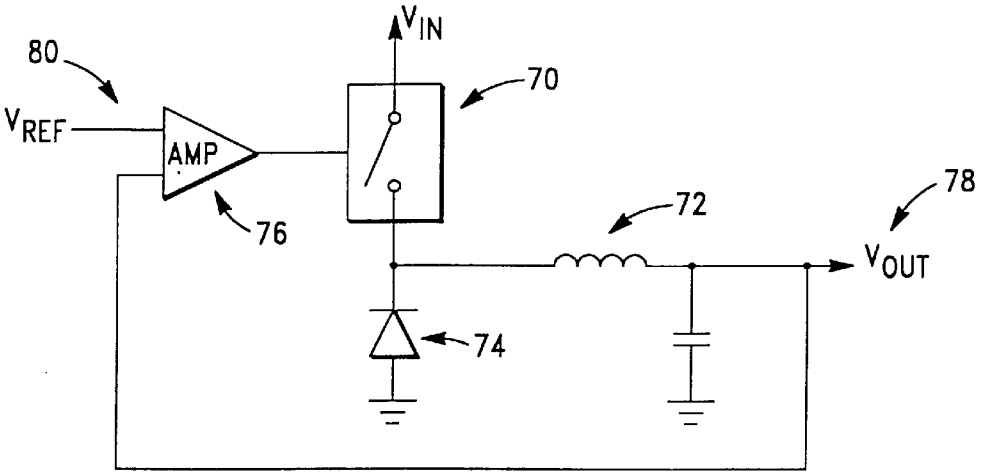

FIG.—3

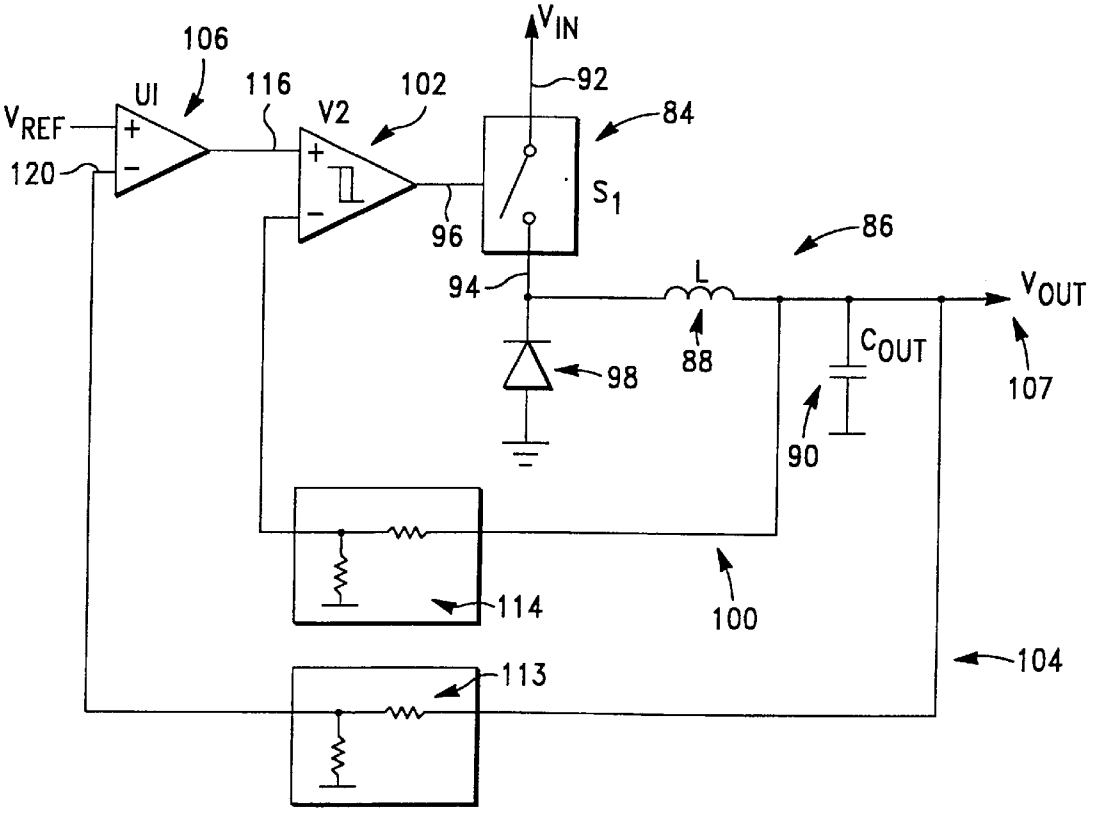

FIG.—4

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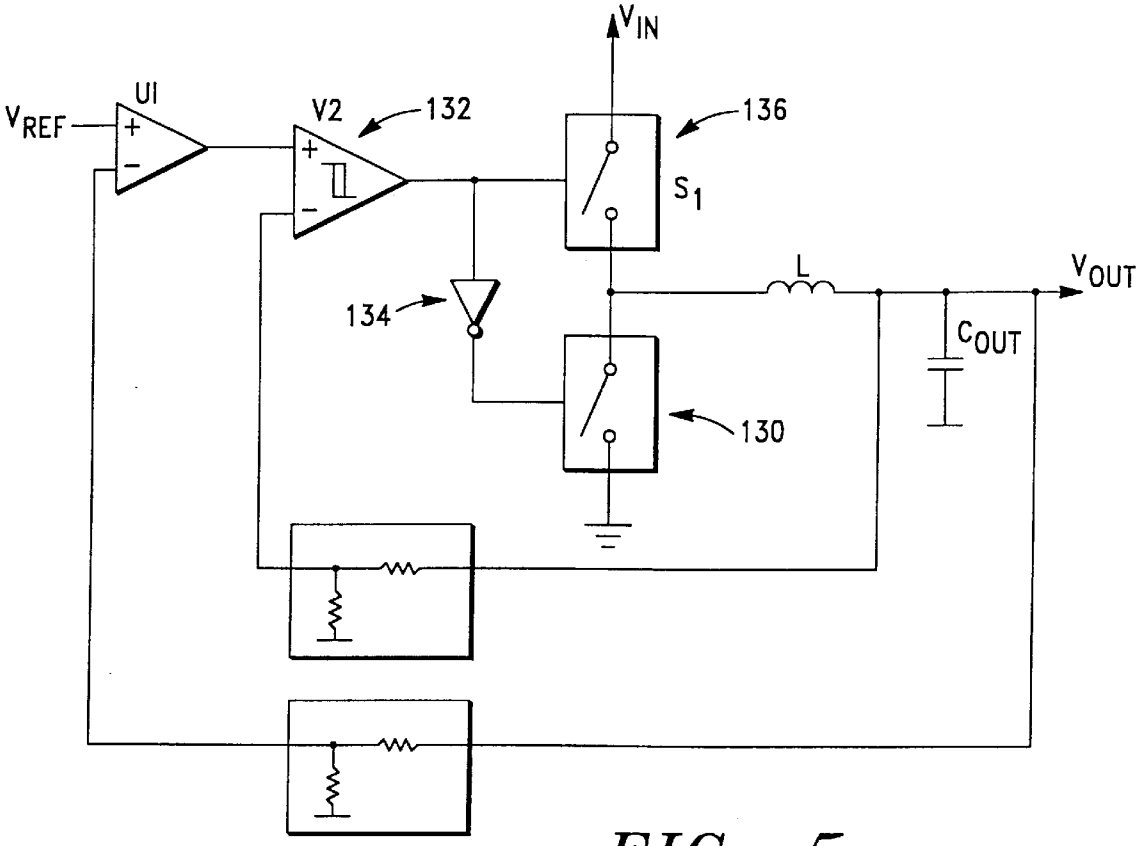

FIG.–5

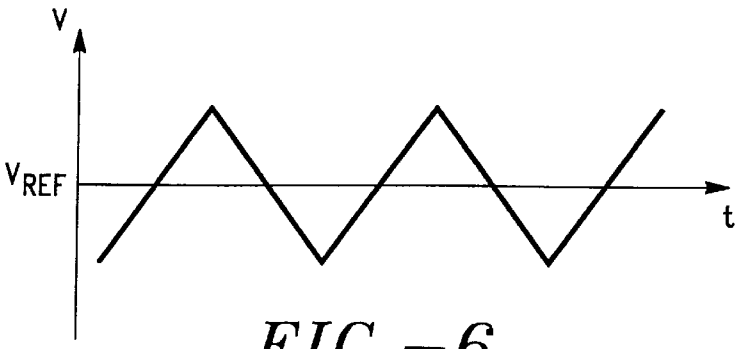

FIG.–6

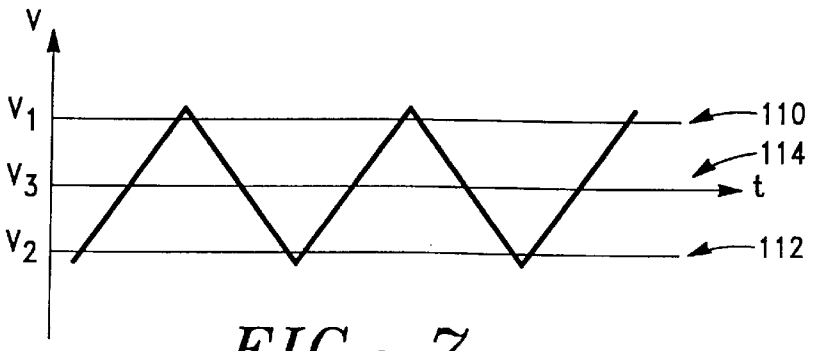

FIG.–7

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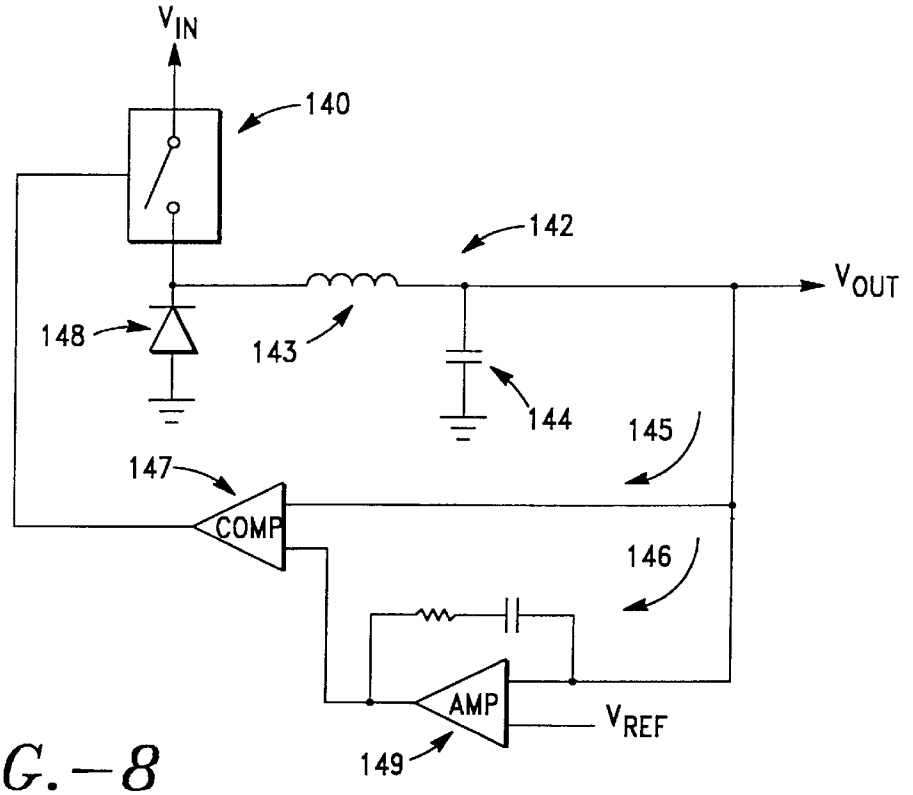

FIG.–8

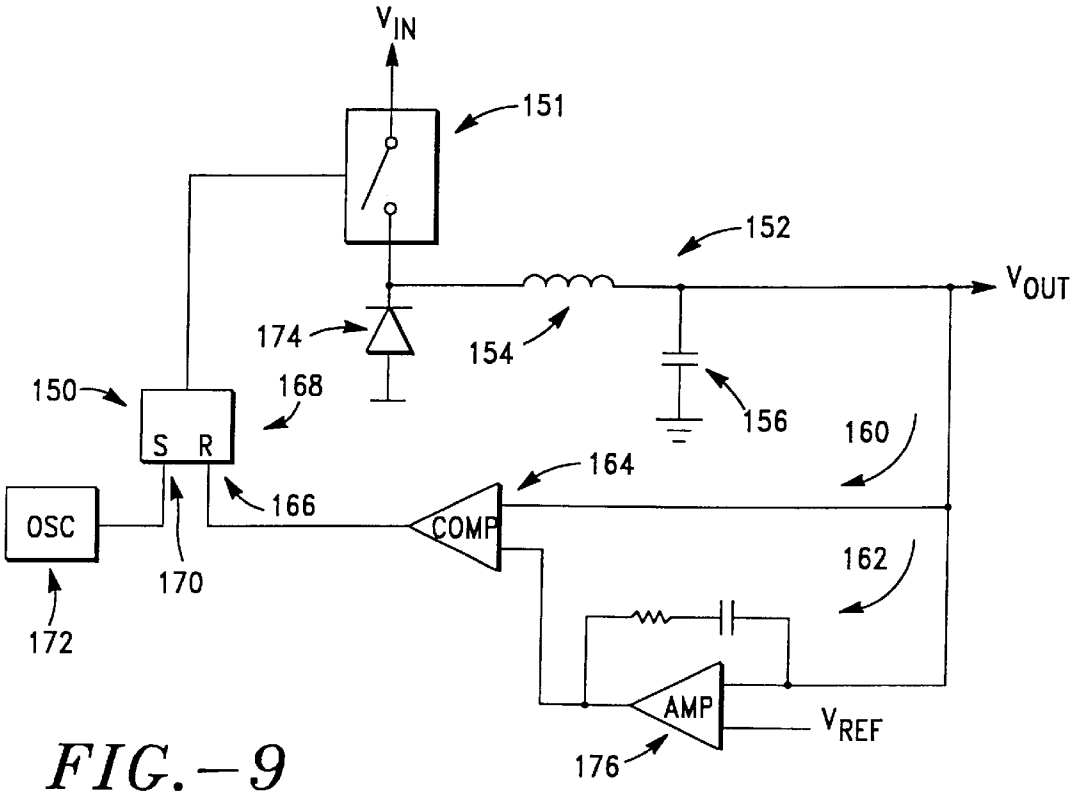

FIG.–9

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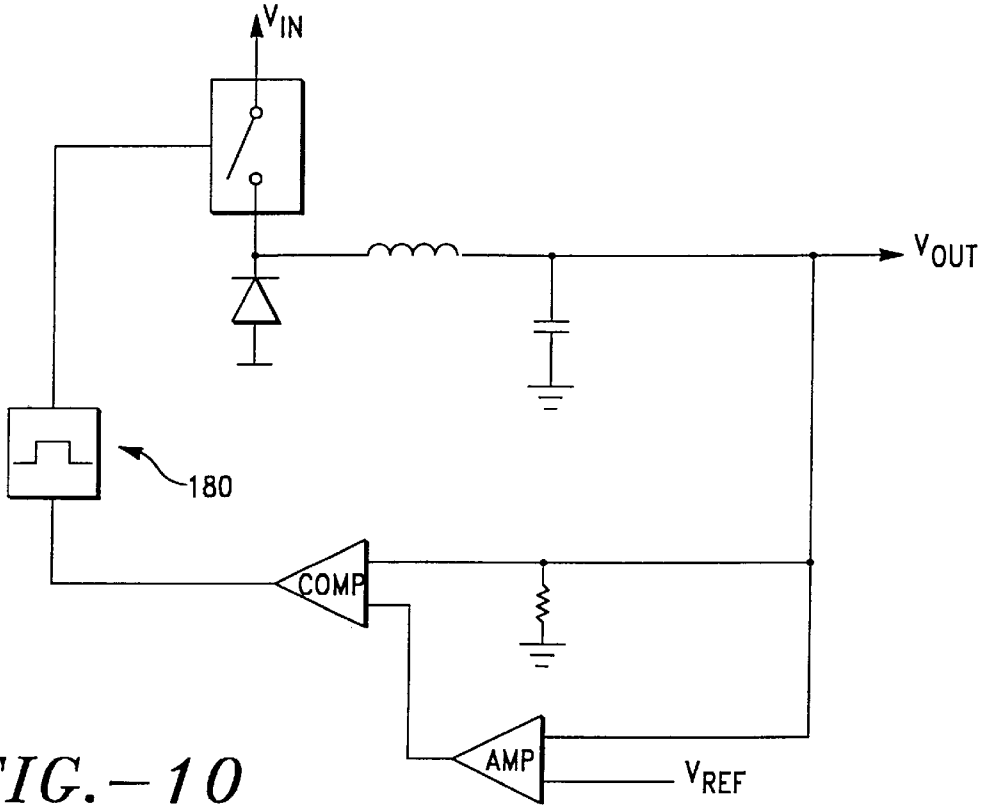

FIG.—10

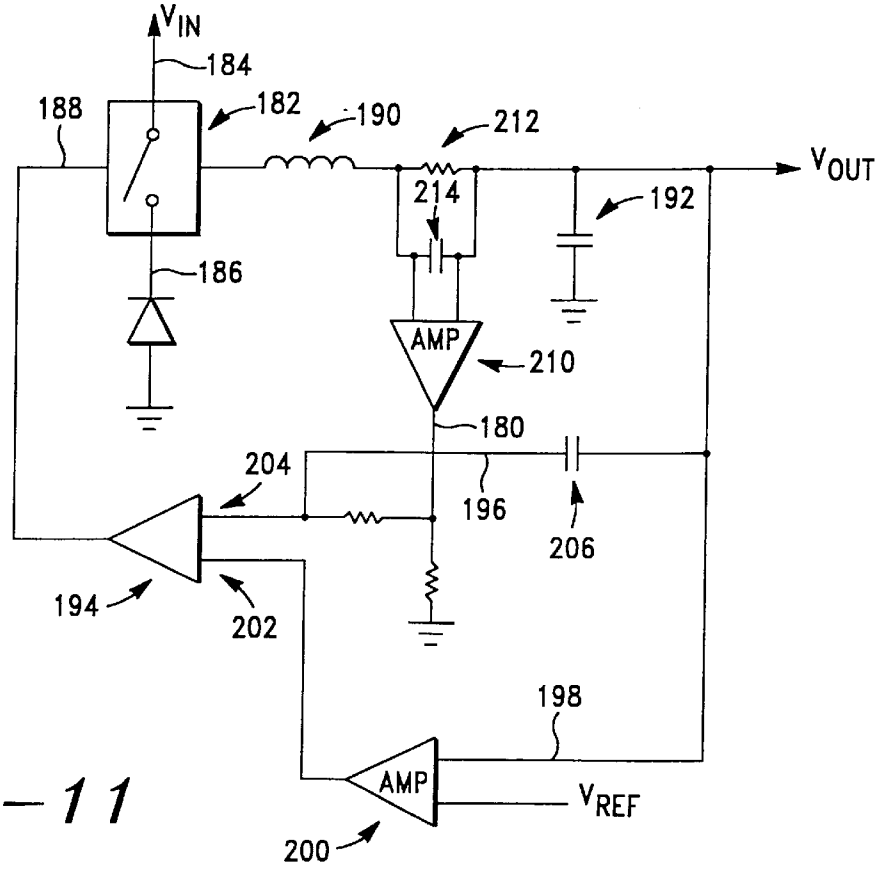

FIG.—11

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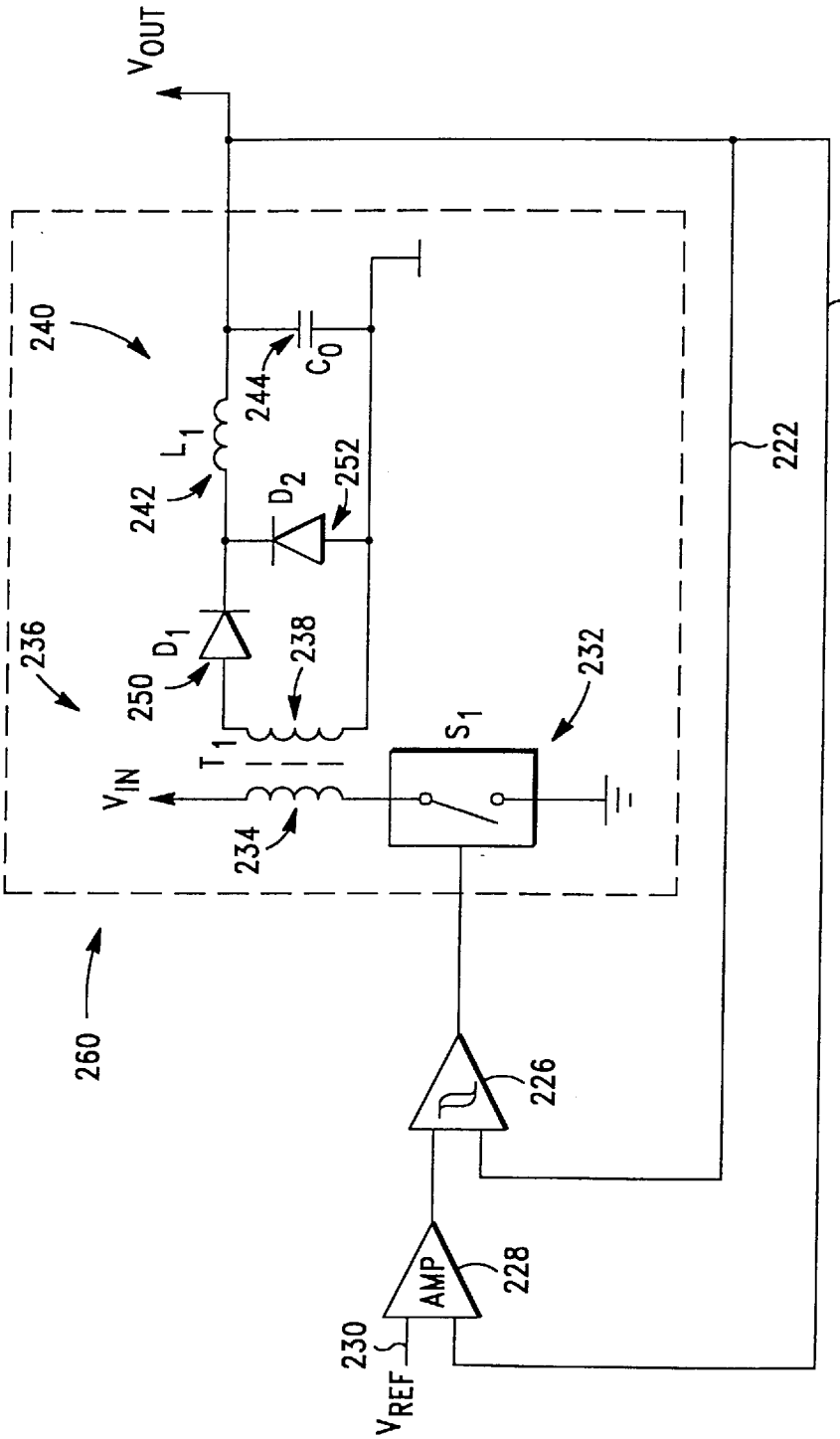

FIG.—12

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SWITCHING REGULATOR

FIELD OF THE INVENTION

This invention relates to a switching regulator.

BACKGROUND OF THE INVENTION

Switching regulators are commonly used for providing a regulated power supply. They typically include an input switch which receives the unregulated power and is intermittently turned on and off. By suitably adjusting the duty cycle of the input switch, the regulated output voltage can be controlled to lie within a certain range. The regulator typically also includes a low pass filter, for instance an LC circuit comprising an inductor and a capacitor, to smooth the output voltage. Typically a free wheeling diode or synchronous switch is connected between ground and the inductor to provide a current path when the input switch is opened.

Various prior art switching regulators have been developed. These include a voltage mode step-down regulator in which a sawtooth waveform is generated and compared to the output voltage of an error amplifier, connected to the output of the regulator circuit. The feedback from the output line is amplified using an amplifier, before the voltage is fed to the comparator. The response time is dictated largely by delays in the amplifier. As a result, any input line transients or load transients remain unregulated for the duration of the delay.

In an attempt to address the delay in response to input transients, another prior art device uses current mode control. Instead of generating an artificial sawtooth waveform, the comparator receives a waveform based on the inductor current. As a result of the regulator switching action, the inductor current takes a sawtooth waveform, and is therefore well suited as a ramp source for the control circuit. The advantage of the circuit is noticeable during input line transients; the current slope changes within one cycle, being determined by the voltage across the inductor. Thus, correction for input line transients commences within one cycle of the oscillator signal. Since no error amplification is required, no delays are caused due to loop response time. Thus a faster response is obtained for input line transients. However, load transients remain undetected by this circuit. These transients are, therefore, still compensated by an error amplifier, again causing significant delays due to loop response time.

Yet another prior art switching regulator uses a circuit in which the output is connected directly to the input of an error amplifier that controls an input switch. Since the opening and closing of the input switch is dictated directly by a feedback loop, the circuit oscillates about a reference point at a frequency depending on the total loop delay. While the circuit provides for a much faster transient response, it is less stable, since its frequency is dependent on the total loop delay.

The present invention seeks to provide an improved switching regulator.

OBJECTS AND SUMMARY OF THE INVENTION

It is an object of the invention to provide a switching regulator with a well defined operating frequency.

It is a further object of the invention to provide a switching regulator that provides a fast transient response.

It is yet a further object of the invention to provide a switching regulator having two separate feedback paths to provide for a fast response and to sense output voltage at a remote location to compensate for power line voltage loss.

According to the invention there is provided a switching regulator comprising:

a first switch having an input, an output and a control line;

a low pass filter connected to an output of the regulator; and

a feedback loop from an output of the regulator to the control line of the switch, the feedback loop including a comparator with built in hysteresis, for providing a well defined switching frequency of the first switch, the comparator having a reference voltage input, and an output connected to the control line.

The feedback loop can extend from a remote point along an output line of the regulator.

The regulator can comprise a second feedback loop from the output of the regulator, the second feedback loop including an amplifier, having a DC voltage input, and an output which is connected to the reference voltage input of the comparator.

The regulator can comprise a free wheeling diode connected to ground and providing a current path for the inductor when the first switch is opened.

The regulator can comprise a second switch connected to ground to provide a current path for the inductor when the first switch is opened, the second switch being controlled by a signal that is inverted relative to the signal switching the first switch, to insure that only one of the switches is closed at any one time.

The regulator can comprising a transformer, wherein the voltage across a primary winding of the transformer is controlled by the switch, and wherein a secondary winding is connected to the low-pass filter.

Further, according to the invention there is provided a switching regulator comprising:

a switch, having an input, an output and a control line;

a low pass filter connected to an output of the regulator;

a voltage feedback loop from an output of the regulator to the control line of the switch, wherein the feedback loop includes a comparator having an output, a first input connected to the output of the regulator, and a reference voltage input, the feedback loop further including a frequency reference connected to the control line of the switch for regulating the switching of the switch.

The regulator can comprise a second feedback loop from the output of the regulator, the second feedback loop including an amplifier having a voltage input, and an output which is connected to the reference voltage input of the comparator.

The frequency reference can comprise an oscillator and a flip flop, wherein the oscillator is connected to a first input of the flip flop, and the output of the comparator is connected to a reset input of the flip flop, an output of the flip flop being connected to the control line of the switch.

The frequency reference can comprise a one shot connected between the output of the comparator and the control line of the switch.

Still further, according to the invention there is provided a step down switching regulator comprising:

a first switch having an input, an output and a control line;

a low pass filter connected to an output of the regulator;

a first feedback from an output of the regulator to the control line of the switch, the first feedback including a comparator having first and second inputs, and an output which is connected to the control line of the switch; and

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a second, voltage feedback from the output of the regulator, wherein the second, voltage feedback includes an amplifier having a reference voltage input and an output connected to the first input of the comparator.

The regulator can comprise a current feedback that is DC coupled to the second input of the comparator, and wherein the first feedback is AC coupled to the second input of the comparator.

Still further, according to the invention there is provided a method of regulating voltage by means of a step-down switching regulator that includes a regulator switch, the method comprising the steps of monitoring the output voltage of the regulator; regulating the switching of the regulator switch by means of a comparator output signal, the comparator receiving a first input signal based on the output voltage of the regulator and a second input signal from an amplifier output, the inputs of the amplifier being based on the output voltage of the regulator and a reference voltage.

The comparator can have built-in hysteresis.

The control voltage can be a DC reference voltage.

The comparator output signal can be fed to a frequency reference, which is connected to a control line of the regulator switch.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic circuit diagram of a prior art switching regulator;

FIG. **2** is a schematic circuit diagram of another type of prior art switching regulator;

FIG. **3** is a schematic circuit diagram of yet another prior art switching regulator;

FIG. **4** is a schematic circuit diagram of a step-down switching regulator in accordance with the invention;

FIG. **5** is schematic circuit diagram of another embodiment of a step-down switching regulator in accordance with the invention;

FIG. **6** is a representation of an output voltage ripple in a circuit not making use of a hysteretic comparator;

FIG. **7** is a representation of an output voltage ripple when a hysteretic comparator is used;

FIG. **8** is a schematic circuit diagram of yet another embodiment of a step-down switching regulator in accordance with the invention;

FIG. **9** is a schematic circuit diagram of yet another embodiment of a step-down switching regulator in accordance with the invention;

FIG. **10** is a schematic circuit diagram of yet another embodiment of a step-down switching regulator in accordance with the invention; and

FIG. **11** is a schematic circuit diagram of yet another embodiment of a step-dow n switching regulator in accordance with the invention; and

FIG. **12** is a schematic circuit diagram of a forward mode regulator in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

A schematic circuit diagram of a prior art step-down switching regulator is illustrated in FIG. **1**. It includes a switch **10** and an LC circuit **12** comprising a n inductor **14** and a capacitor **16**. A free wheeling diode **18** is connected between the ground and the switch **10**. The free wheeling diode **18** provides a current path for the inductor **14** when the switch **10** opens. The circuit further includes a comparator **20** having a first input **22** connected to the circuit output via an amplifier **24** . The second input of the comparator, indicated by reference numeral **26**, receives a separately generated sawtooth input signal. It will be appreciated that as the voltage level at the circuit output **28** changes the level at the input **22** changes accordingly. The artificially generated sawtooth signal at the input **26**, on the other hand, remains constant so that the voltage changes at the input **22** cause a corresponding change in the duty cycle of the switch **10**. This change in the on time of the switch **10** causes a corresponding change in the output voltage **28**. In order to adjust the output voltage level, the amplifier **24** is provided with a reference voltage input **25**. It should be noted that the circuit of FIG. **1** has various drawbacks. In the case of input line transients or load transients, the response time depends on the total loop speed, which is **30** dictated largely by the amplifier **24**. This causes significant response time delays, causing the output to remain unregulated for relatively long periods of time.

FIG. **2** is a circuit diagram of another prior art step-down switching regulator, which uses a current mode control. It includes a switch **40** and an LC circuit **42** comprising an inductor **44** and a capacitor **46**. Again, a free wheeling diode **47** is included to provide a current path for the inductor **44** when the switch **40** is turned off. The circuit further includes an inductor current sensor, which in this circuit comprises an amplifier **48** connected across a resistor **50**. Other prior art circuits exist that make use of different current sensing means such as a current sensing transformer. The circuit in FIG. **2**, further includes a comparator **52**, receiving its inputs from the output of the amplifier **48** and from the circuit output **54**, via an error amplifier **56**. As in the previous circuit, the error amplifier receives a reference voltage, which, in this example, is indicated by reference numeral **58**. The output of the comparator is fed to a frequency reference, which in this circuit comprises an oscillator/flip flop circuit. The output of the comparator **52** is fed the reset pin of an R-S flip flop **60**, the set input of which is connected to an oscillator **62**. Instead of having an artificially generated sawtooth waveform fed directly into the comparator, as in the previous circuit, the comparator **52** receives its input from the amplifier **48**. The oscillator **62** provides a set frequency to the flip flop **60**, which in turn controls the switch **40**. The voltage across the inductor **44** therefore comprises a substantially square waveform. Since the current through the inductor **44** is given by $I=L\int V\,dt$, the current waveform through the inductor **44** will be a sawtooth waveform, the slopes of the waveform ramps depending on the voltage across the inductor **44**. The voltage waveform across the resistor **50** is a corresponding sawtooth waveform. This is fed into the amplifier **48**, the output of which provides a sawtooth input for the comparator **52**. Thus the advantage of the circuit of FIG. **2**, is that input voltage transients cause the slopes of the saw tooth current waveform to change according to the expression $V=LdI/dt$. These are thus quickly detected, thereby resulting in rapid compensation. On the other hand, load transients are still dictated by the error amplifier **56**, resulting in a slow response time.

Yet another prior art step-down switching regulator circuit is illustrated in FIG. **3**. This circuit again includes a switch **70** and a filtering LC circuit **72**. The free wheeling diode **74** provides a current path when the switch **70** is open. In this circuit the amplifier **76** is connected directly to the output **78**, the other input **80** of the amplifier **76**, receiving a reference voltage. The response time depends directly on the delay in

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the loop. The delay is short, resulting in a quick response to both input and load fluctuations. In this circuit, the delay in the circuit itself determines the magnitude of the sawtooth ripple. When the circuit output reaches the desired reference voltage level, the switch **70** is turned off, allowing the output voltage to ramp down. Delays in the feedback loop cause the output voltage to oscillate about the reference voltage as indicated by the wave diagram of FIG. **6**. Since the response time dictates the frequency of the oscillation, the circuit is prone to instability.

Referring now to FIG. **4**, a step-down switching regulator, in accordance with the invention, is shown. The switching regulator comprises a main, input switch **84** and a low pass filter, which, in this particular circuit, comprises an LC circuit **86** that includes an inductor **88** and a capacitor **90**. The switch **84** includes an input **92**, an output **94**, and a control line **96**. The switch **84** can comprise any suitable controllable switch, for example a bipolar transistor or a FET device. A free wheeling diode **98** provides a current path for the inductor **88** when the switch **84** is opened. The circuit includes two feedback loops. The first feedback loop **100** is a quick response feedback that includes a comparator **102**. It will be appreciated that the feedback loop **100** will include an appropriate driver (not shown) which can, for example, be included in the circuitry of the comparator **102**. The second feedback loop **104** is a relatively slow response feedback that includes an error amplifier **106**. The slow response feedback can be used to sense the voltage at a point external to the switching circuit, and can, for instance, be used to sense the voltage at a remote location to detect power line fluctuations. In contrast, the feedback loop **100** is a fast feedback loop connected to the output line. The comparator **102** includes built-in hysteresis, thereby providing a hysteretic window defining an upper voltage limit V_1, indicated by reference numeral **110** in FIG. **7**, and a lower voltage limit V_2 indicated by reference numeral **112**. The voltage limits V_1 and V_2 can be located on either side of a voltage V_3 that corresponds to the output of the amplifier **106**. In FIG. **7** the voltage limits V_1, and V_2 are shown to be symmetrically located on either side of V_3. This need not be the case. The voltage limits V_1, and V_2 could be asymmetrically located with respect to V_3. Either V_1 or V_2 could, for example, coincide with V_3. Since the delay time of the feedback loop **100** is relatively small, any switching delay due to the delay in the feedback loop **100** is insignificant in comparison with the effect of hysteresis. Furthermore, the hysteretic affect can be accurately determined in the comparator **102**. Thus the frequency of the switching circuit is extremely will defined and remains virtually unaffected by loop delays. The comparator **102** seeks to keep the circuit output voltage, at the circuit output **107**, at a fixed value. In the absence of resistor ladders **113**, **114**, the comparator **102** seeks to keep the circuit output voltage equal to the level at its positive terminal **116**, the hysteresis causing a constant peak-to-peak ripple in the output voltage at the circuit output **107**. In the case of input line or output load transients, the comparator **102** quickly detects output voltage changes and switches the switch **84** either on or off to compensate for the voltage fluctuation. Since the first feedback loop **100** operates independently of the error amplifier **106**, no delay is caused by the response time of the error amplifier **106**. Therefore, by choosing a fast comparator **102**, a circuit with a well defined operating frequency and a quick response time is provided.

The second feedback loop **104**, which includes the error amplifier **106**, provides improved output set point accuracy, and can be used for remote sensing. It serves to compensate for voltage fluctuations at the point along the output line from which the feedback is taken. The loop **104** is significantly slower than the loop **100**, but does not interfere with the speed of the loop **100**. The amplifier **106** compares the output voltage against a reference voltage and ensures output accuracy under all load and other variations. The amplifier **106** can be used to sense the output voltage at a remote location and compensate for power line voltage loss. The negative input **120** to the amplifier **106** comprises a sawtooth waveform superimposed on a DC voltage. This signal is derived from the charging and discharging of the capacitor **90**. In practice the output capacitor **90** of the LC circuit **86** is typically implemented using electrolytic or tantalum capacitors. At the switching frequency the impedance of these capacitors is dominated by their parasitic series resistance. Thus, at the switching frequency, these capacitors have the characteristics of a resistor. The sawtooth current of the inductor thus produces an output voltage having a sawtooth waveform proportional to the inductor current. However, even if a "pure" capacitor were to be used, its charging and discharging exponential waveform could be considered as linear in the first order approximation. Any variations in the power line voltage thus shift the DC base of the signal on line **120** to cause a change in the output voltage of the amplifier **106**. Due to the slow response time of the amplifier **106**, it is easy to filter out any noise that may be imposed on long, remote sensing lines. Thus the output of the amplifier **106** can be approximated as a DC signal. As mentioned above, the second feedback loop provides improved compensation for voltage fluctuations along the output line. It will be appreciated that the switching regulator circuit could be used without the second feedback loop **104**, making use merely of the first feedback loop **100**, with its hysteretic comparator **102** receiving a DC reference voltage at its positive terminal **116**. Clearly the absence of the second loop **104** will, however, reduce the compensation accuracy for voltage fluctuations along the output line.

FIG. **5**. illustrates another embodiment of a step-down switching regulator in accordance with the invention. The circuit is virtually identical to that illustrated in FIG. **4**. However, the free wheeling diode is replaced by a second switch **130**. The switch **130** is controlled by an output from the comparator **132**, via an invertor **134**. Thus when the main, input switch **136** is on, switch **130** is off, and vice versa. While a simple invertor is illustrated in FIG. **5**, more complex circuitry could be provided to prevent simultaneous conduction of switches **130** and **136**. In order to avoid the possibility of both switches **130**, **136**, conducting simultaneously, the circuits of FIGS. **4** and **5** can be combined by connecting a free wheeling diode in parallel to the switch **130**.

Yet another embodiment of the invention is illustrated in FIG. **8**. The circuit includes a switch **140** and a low pass filter, in this case an LC filter **142** comprising an inductor **143** and a capacitor **144**. The circuit includes a first feedback loop **145**, and a second feedback loop **146**. The first feedback loop **145** includes a comparator **147**, the output of which is connected to the control line of the switch **140**. This switch **140** includes a free wheeling diode **148**. The loop response of the feedback loop **145** is relatively fast, since it directly senses the output voltage. It, thus, provides rapid compensation for both input line and load voltage fluctuations. The feedback loop **146**, once again, includes an error amplifier **149**, which provides for a longer loop response time.

The loop **146**, however, does not affect the response time of the loop **145**. The circuit is distinguishable over the prior art circuit illustrated in FIG. **3** insofar as it includes a second

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voltage feedback loop for providing improved voltage compensation. Another embodiment of the invention is illustrated in FIG. **9**. This circuit is similar to the circuit of FIG. **8**, but further includes a frequency reference **150**. The circuit includes a switch **151**, and a low pass filter, in this case an LC filter **152** comprising an inductor **154** and a capacitor **156**. The circuit further includes a first feedback loop **160**, and a second feedback loop **162**. The first feedback loop **160** includes a comparator **164** which is fed into the frequency reference **150**, which in this embodiment comprises an oscillator and flip flop circuit. The output of the comparator **164** is fed into the reset input **166** of the R-S flip flop **168**. The set input **170** of the flip flop **168** is connected to the oscillator **172**. The output from the flip flop **168** controls the switch **151** which includes a free wheeling diode **174**. The loop response of the feedback loop **160** is relatively fast, since it directly senses the output voltage. It, thus, provides rapid compensation for both input line and load voltage fluctuations. The feedback loop **162**, once again, includes an error amplifier **176**, which provides for a longer loop response time. The loop **162**, however, does not affect the response time of the loop **160**. The circuit is distinguishable over that of the prior art illustrated in FIG. **2** insofar as it eliminates the current sensor of the prior art circuit. This provides for a superior voltage transient response.

Another embodiment in accordance with the invention is shown in FIG. **10**. Instead of the oscillator and flip flop arrangement, a one shot **180** is provided. This serves as a frequency reference by establishing a constant off time.

Another embodiment of the invention is illustrated in FIG. **11**. This circuit is similar to the one illustrated in FIG. **8**. It, however, further includes a current feedback loop **180**. As in the circuit illustrated in FIG. **8**, the circuit illustrated in FIG. **11** includes a switch **182** having an input **184**, an output **186**, and a control line **188**. It includes a low pass filter which, in this embodiment, takes the form of an LC filter comprising an inductor **190** and a capacitor **192**. The comparator **194** is shown as being directly connected to the control line **188** of the switch **182**. Clearly, a frequency reference could be included in a manner similar to that illustrated and described with respect to FIGS. **9** and **10**. The circuit includes a first feedback loop **196**, a second feedback **198**, and the current feedback **180**. As in the circuit illustrated in FIG. **8**, the feedback **198** includes an amplifier **200**, the output of which is connected to a first input **202** of the comparator **194**. The first feedback loop **196** is fed into a second input **204** of the comparator **194**. The current feedback loop is also connected to the second input **204** of the comparator **194**. In order to accommodate both the first feedback loop and the current feedback **180**, the feedback loop **196** includes a capacitor **206** to block the DC offset, thereby AC coupling the first feedback loop **196** to the comparator **194**. The current feedback loop **180** includes an amplifier **210** connected across a resistor **212** thereby establishing a voltage waveform corresponding to the current through the inductor **190**. The feedback **180** further includes a capacitor **214** for eliminating the AC element of the load current. Thus the output of the amplifier corresponds to the DC output and provides a rapid response to load current fluctuations.

The embodiments described above all comprised step-down switching regulators. The invention is, however, not limited to step-down regulators, but extends also to forward mode regulators, for example, buck regulators. These have the advantage of allowing voltage to be stepped up or down. They make use of a transformer to optimize the input/output ratio by virtue of the transformer winding ratio.

Referring specifically to FIG. **12**, there is shown a forward mode regulator in accordance with the invention. The regulator is indicated generally by reference numeral **220** and includes features similar to the step-down switching regulator of FIG. **4**. Like the regulator of FIG. **4**, the forward mode regulator of FIG. **12** includes a fast feed back loop **222** and a slow feed back loop **224**. The fast feed back loop **222** extends from the output to a hysteretic comparator **226**. The slow feed back loop **224** extends from the output to an amplifier **228**, the other input **230** of which receives a reference voltage. The comparator **226** controls a switch **232**. In this circuit, however, the switch is not directly connected to the output, but controls the voltage across the primary winding **234** of a transformer **236**. The secondary winding **238** of the transformer **236** is, in turn, connected to a low pass filter, which in this case, comprises an LC circuit **240**. The LC circuit **240** includes an inductor **242** and a capacitor **244**. A diode **250** provides half-wave rectification of the signal, while the diode **252** provides a current path for the inductor **242** when the switch **232** is opened. The power block **260** is therefore slightly different to the corresponding circuitry described in the step-down switching regulators of FIGS. **4–11**. The rest of the circuitry is, however, similar to that illustrated in FIG. **4**. In the circuit of FIG. **12**., when the switch **232** turns on, the diode **250** is forward biased and the current builds up in the inductor **242**. The voltage across the inductor may be given by the equation:

$$V_L = V_{in} \times n - V_{out},$$

where V_L is the inductor voltage;

V_{in} is the voltage across the primary winding;

V_{out} is the output voltage; and

n is the transformer ratio.

When the switch **232** turns off, the diode **250** is reverse biased and the diode **252** conducts to provide a current path for the inductor **242**. The behavior of the circuit is therefore similar to the step-down regulator of FIG. **4**, with the exception that during the time that the switch **232** is closed, the inductor voltage is dependent upon the transformer ratio. While only one switch is shown, more switches could be used for increased power.

It will be appreciated that a power block similar to the one indicated by reference numeral **260** could be used in circuits similar to those illustrated in FIGS. **5–11**. Since those circuits would, apart from the power block, remain substantially the same as illustrated in FIGS. **5–11**, the circuits have not been repeated.

Clearly the circuits discussed and illustrated above, are merely illustrative of the invention. Other circuits may be devised without departing from the scope of the invention.

I claim:

1. A switching regulator comprising:

a first switch, having an input, an output and a control line;

a low pass filter connected to an output of the regulator;

a first voltage feedback loop from an output of the regulator to the control line of the switch, wherein the feedback loop includes a comparator having an output, a first input connected to the output of the regulator, and a reference voltage input, the feedback loop further including a frequency reference connected to the control line of the switch for regulating the switching of the switch; and

a second feedback loop from the output of the regulator, the second feedback loop including an amplifier having

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a DC voltage input, and an output which is connected to the reference voltage input of the comparator.

2. A regulator of claim **1**, further comprising a free wheeling diode connected to ground and providing a current path for the inductor when the first switch is opened.

3. A regulator of claim **1**, further comprising a second switch connected to ground to provide a current path for the inductor when the first switch is opened, the second switch being controlled by a signal that is inverted relative to the signal switching the first switch, to insure that only one of the switches is open at any one time.

4. A regulator of claim **1**, wherein the frequency reference comprises an oscillator and a flip flop, wherein the oscillator is connected to a first input of the flip flop, and the output of the comparator is connected to a reset input of the flip flop, an output of the flip flop being connected to the control line of the switch.

5. A regulator of claim **1**, wherein the frequency reference comprises a one shot connected between the output of the comparator and the control line of the switch.

6. A regulator of claim **1**, further comprising a transformer, wherein the voltage across a primary winding of the transformer is controlled by the switch, and wherein a secondary winding is connected to the lowpass filter.

7. A switching regulator comprising:

a first switch having an input, an output and a control line;

a low pass filter connected to an output of the regulator;

a first voltage feedback from an output of the regulator to the control line of the switch, including a comparator having first and second inputs, and an output which is connected to the control line of the switch, the first voltage feedback being AC coupled to the second input of said comparator; and

a second, voltage feedback from the output of the regulator, wherein the second, voltage feedback includes an amplifier having a reference voltage input and an output connected to the first input of the comparator.

8. A regulator of claim **7**, further comprising current feedback that is DC coupled to the second input of the comparator.

9. A switching regulator for supplying a stable output voltage to an output terminal from a supplied input source, comprising:

a switch selectively switching the input source to an output terminal thereof to form a modulated switch output under control of a control line, the modulated switch output being composed of a D.C. offset voltage with a superimposed ripple voltage;

a low pass filter connected between the output of said switch and the output terminal of said regulator and smoothing the modulated switch output to develop said output voltage;

a pulse modulator supplying a pulse train to the control line of said switch to selectively connect said switch;

a first voltage feedback loop comparing the D.C. output voltage of said switching regulator to a desired voltage reference to develop a voltage error signal; and

a second voltage feedback loop, operatively connected to said pulse modulator and supplying the ripple voltage to said pulse modulator;

said pulse modulator varying the duty cycle of said switch based on said ripple voltage to quickly control the output voltage of said switching regulator;

variations in the load or voltage of said output developing a substantially instantaneous variation in said ripple voltage to stabilize said output voltage by quickly correct errors sensed therein.

10. The regulator of claim **9**, further comprising a transformer, wherein the voltage across a primary winding of the transformer is controlled by the switch, and wherein a secondary winding is connected to the low pass filter.

11. The switching regulator of claim **9** wherein said switch switches the input source to the output terminal thereof at a switch frequency, said ripple voltage being related to said switch frequency.

12. The switching regulator of claim **9** wherein said first voltage feedback loop stabilizes the output voltage of said switching regulator.

13. The switching regulator of claim **9** wherein said first voltage feedback loop monitors the D.C. offset voltage at said output terminal.

14. The switching regulator of claim **9** wherein said first voltage feedback loop monitors the output voltage of said switching regulator remote from said switching regulator.

15. The switching regulator of claim **9** wherein said pulse modulator comprises a comparator comparing the ripple voltage with an error voltage, the ripple voltage further supplying a ramp signal to said pulse modulator.

16. The switching regulator of claim **15** wherein said first feedback loop comprises an error amplifier receiving a reference voltage at one input thereof and the D.C. output voltage of said switching regulator as a second input thereof to produce said error voltage.

17. The switching regulator of claim **16** wherein said error amplifier includes an integrating feedback path.

18. The switching regulator of claim **16** wherein said switch includes first and second switch devices each having a switch control terminal, one of said switch devices having its control terminal directly connected to said control line while the other of said switch devices being connected to said control line through an inverter.

19. The switching regulator of claim **16** further comprising a current feedback path monitoring output current at said output terminal and providing inherent current limiting to said switching regulator.

20. The switching regulator of claim **9** wherein said low pass filter includes an inductor serially connected between said switch and said output terminal and a capacitor connected between said output terminal and ground.

21. The regulator of claim **20**, further comprising a free wheeling diode connected to ground and providing a current path for the inductor when the first switch is opened.

22. The switching regulator of claim **9** wherein said pulse modulator includes,

a flip flop having a set terminal and a reset terminal and being connected to said control line of said switch,

an oscillator for setting the flip flop at a controlled frequency, and

a comparator comparing the ripple voltage with an error voltage, the ripple voltage further supplying a ramp signal to the reset terminal of said flip flop.

23. The switching regulator of claim **9** wherein said pulse modulator includes,

a one shot producing a constant duration pulse and being connected to said control line of said switch, and

a comparator comparing the ripple voltage with an error voltage, the ripple voltage further supplying a ramp signal to the one shot at a periodically varying interval.

24. A method of converting an input voltage into a stable output voltage supplied to an output terminal from a supplied input source, comprising:

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a) selectively switching the input source to form a modulated switch output composed of a D.C. offset voltage with a superimposed ripple voltage using a switch having a pulse modulatable control line;

b) smoothing the modulated switch output to develop said output voltage;

c) supplying a pulse train to the control line of said switch to selectively connect said switch;

d) comparing the D.C. output voltage to a desired voltage reference to develop a voltage error signal in a first voltage feedback loop; and

e) supplying the ripple voltage to said pulse modulator in a second voltage feedback loop to aid in the development of said pulse train;

said step c) of supplying varying the duty cycle of said switch based on said ripple voltage to quickly control the output voltage of said switching regulator;

variations in the load or voltage of said output developing a substantially instantaneous variation in said ripple voltage to stabilize said output voltage by quickly correcting errors sensed therein.

25. The method of claim **24** wherein said pulse train is supplied by said step c) of supplying at the output of a comparator comparing the ripple voltage with a second voltage.

26. A method of claim **25**, wherein the comparator has built-in hysteresis.

27. The method of claim **25** wherein said step e) of supplying compares the D.C. output voltage to a reference voltage in a differential amplifier and supplies the difference to the second input of the comparator of said step c).

28. A method of claim **27**, wherein the reference voltage is a DC reference voltage.

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