United States Patent [19]

Swisher et al.

[11] **4,327,319**

[45] **Apr. 27, 1982**

[54] **ACTIVE POWER SUPPLY RIPPLE FILTER**

[75] Inventors: **Scott N. Swisher**, Elk Grove, Ill.; **Edward L. Furman**, Omaha, Nebr.

[73] Assignee: **Motorola, Inc.**, Schaumburg, Ill.

[21] Appl. No.: **178,490**

[22] Filed: **Aug. 15, 1980**

[51] **Int. Cl.**³ **G05F 5/00**

[52] **U.S. Cl.** **323/303**; 323/275

[58] **Field of Search** 323/275, 281, 299, 303; 363/39, 47

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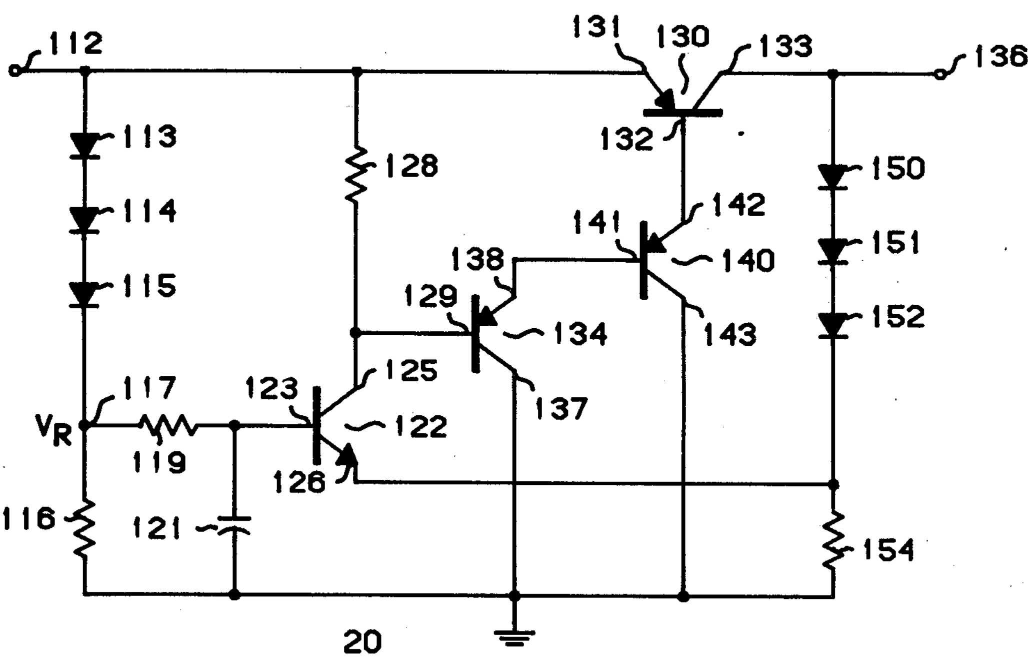
Primary Examiner—William M. Shoop
Assistant Examiner—Peter S. Wong
Attorney, Agent, or Firm—James A. Scheer; James W. Gillman

[57] **ABSTRACT**

An active power supply ripple filter with low noise and low power dissipation characteristics, which tracks the voltage of the power source with low voltage drop and high current capability. The circuit consists of a control transistor connected between one terminal of a power source and one terminal of a load, a reference circuit which tracks the supply voltage, a low pass filter which filters the reference voltage and an amplifier for driving the control transistor in response to the filtered reference voltage and a feedback voltage from the load. The circuit minimizes the voltage drop across the control transistor as well as minimizing the capacitance values required for the filter capacitors.

4 Claims, 2 Drawing Figures



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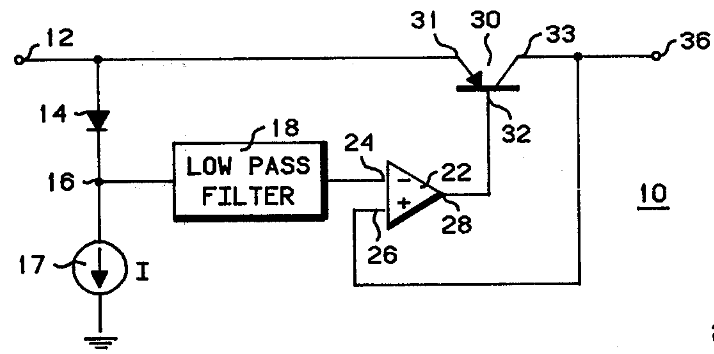
12
14
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LOW PASS
FILTER
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36
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FIG. 1

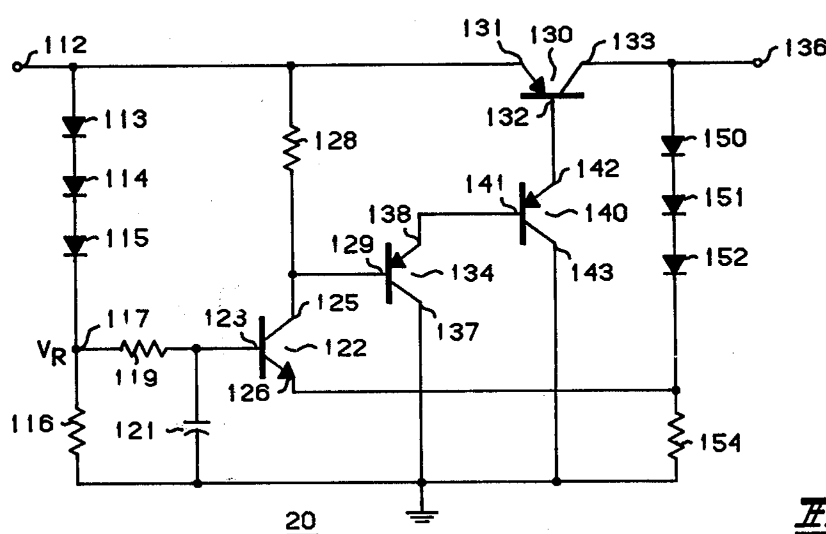
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FIG. 2

ACTIVE POWER SUPPLY RIPPLE FILTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to power supply circuitry and, in particular, to a low noise, low voltage drop, active power supply filter suitable for monolithic fabrication.

2. Description of the Prior Art

In conventional communication circuitry it is often desirable to employ a power supply ripple filter which will provide a well filtered, low noise supply voltage capable of high output current and which drops as small a voltage as possible across the filter. Ripple filters known in the prior art do not maintain a minimum voltage drop nor minimal noise levels. Further, prior art circuits require relatively large capacitance values to achieve a desired cut-off frequency and are not highly suitable for monolithic integration.

Accordingly, it is an object of the invention to provide a low noise active power supply ripple filter capable of high output currents while maintaining low voltage drop across the filter.

It is another object of the invention to provide a low noise active power supply ripple filter which minimizes the capacitance values required to achieve desired frequency rejection characteristics.

It is yet another object of the invention to provide a low noise active power supply ripple filter which is particularly suitable for monolithic integration.

Briefly, in accordance with the invention a low noise active power supply filter capable of high output current is provided for eliminating alternating current components from a direct current voltage, with a minimal input-output voltage drop. A control device such as a bipolar transistor is utilized with an input terminal coupled to the power supply and an output terminal coupled to a load. The control device controls and therefore to the power supply the current from the input terminal to the output terminal via a signal coupled to a control terminal. A reference circuit coupled to the input terminal of the control device provides a reference voltage which approximately tracks the power supply input voltage. An amplifier having its output coupled to the control terminal of the control device amplifies a signal applied across first and second input terminals. A filter is coupled to the reference means to low pass filter the reference voltage and then couple the filtered reference voltage to the first input of the amplifier means. A feedback loop couples the control means output terminal to the second input of the amplifier means.

The invention herein disclosed provides a low noise active power supply ripple filter capable of high output current which tracks the direct current supply voltage thereby maintaining a minimum voltage drop across the filter and low power dissipation. The filter also provides some temperature compensation, permits the use of small value filter capacitors and is particularly suitable for monolithic fabrication.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention itself, together with further objects, features and advantages thereof, may best be understood by reference to the following description when taken in conjunction with the accompanying drawings.

FIG. 1 is a simplified schematic diagram of the novel power supply ripple filter circuit according to the invention.

FIG. 2 is a detailed schematic diagram of the preferred embodiment of the novel power supply ripple filter circuit according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, there is shown a simplified schematic diagram of an active power supply ripper filter **10** constructed in accordance with the present invention (and shown with a positive supply of voltages). The output of a DC power supply (not shown) is applied to the active filter input terminal **12**. The anode of a diode **14** is coupled to the input terminal **12**, as shown, and the cathode of the diode **14** is coupled to a node **16**. Also coupled to the node **16** is a current source **17** which is coupled from the node **16** to ground, as shown, to provide a current through the diode **14** when a DC voltage is applied to the input terminal **12**. This results in a voltage at the node **16** which is one diode drop (approximately 0.7 volt) below the applied DC voltage. Thus, a reference voltage tracking one diode drop below the input DC voltage is generated at node **16**.

The reference node **16** is coupled to the input of a low pass filter **18**, which filters the DC reference voltage. A simple RC filter can be used to provide a high degree of filtering, however, multiple pole networks can also be used to provide additional filtering. The output of the low pass filter **18** is coupled, as shown, to the inverting input **24** of a gain stage **22**. The output **28** of the gain stage **22** is coupled to the control terminal **32** (i.e., the base) of a control transistor **30**. The emitter **31** of the control transistor **30** is coupled, as shown, to the input terminal **12**, while the collector **33** of the transistor **30** is coupled to an output terminal **36**. Also coupled to the output terminal **36** is the non-inverting input **26** of the gain stage **22**, thereby providing negative feedback.

In operation, the circuit of FIG. **1** functions as described below. The output of a DC power supply (not shown), having a small ripple component, is applied to the input terminal **12**. This voltage, together with the current source **17**, forward biases the diode **14** resulting in a DC reference voltage with ripple at the node **16** which tracks one diode drop below the input DC voltage. This reference voltage is filtered by the low pass filter **18** providing a filtered DC reference to the inverting input **24** of the gain stage **22**. The output voltage at the collector **33** of the control transistor **30** is fed back to the non-inverting input **26** of the gain stage **22**. Thus, the gain stage **22** acts as a comparator with its output coupled to the base **32** of the control transistor **30**, thereby controlling the current through the control transistor **30**. If the output voltage at the output terminal **36** drops, the voltage on the noninverting input **26** of the gain stage **22** will drop, causing the difference between the reference voltage at the inverting input **24** and the non-inverting input **26** to increase. This will result in a decrease in the output voltage of the gain stage **22** applied to the base **32** of the control transistor **30**, and will drive the control transistor harder, pulling up the output voltage of the output terminal **36**.

Since the reference voltage at the inverting input **24** of the gain stage **22** tracks one diode drop below the input voltage, the voltage across the transistor **30** is maintained at approximately one diode drop, independent of the input voltage. This provides the advantage of maintaining a low input-output voltage drop for the circuit, as well as minimizing the power dissipation of the control transistor **30**. In addition, the control transistor **30** is kept out of saturation over a wide temperature range. Finally, since the gain stage **22** can have a very low input bias current and good noise characteristics, great flexibility is possible in the choice of the values of resistance and capacitance for the low pass filter **18**, while still providing a high degree of supply filtering.

Referring now to FIG. **2**, there is shown a detailed schematic diagram of the preferred embodiment of the novel power supply filter according to the invention. An input terminal **112** is coupled to a reference node **117** via a series string of diodes **113**, **114**, **115**, as shown. The reference node **117** is coupled to ground via a current source resistor **116**. The reference node **117** is also coupled to a resistor **119**, which is connected to the base **123** of a transistor **122**, and to one electrode of a filter capacitor **121**. The second electrode of the capacitor **121** is coupled to ground. The emitter **126** of the transistor **122** is coupled to ground via a resistor **154** and the collector **125** is coupled to the input terminal **112** via a resistor **128**, as shown. Also coupled to the collector **125** of the transistor **122** is the base **129** of a transistor **134**. The collector **137** of the transistor **134** is coupled directly to ground, while the emitter **138** is connected to the base **141** of a transistor **140**. The collector **143** of the transistor **140** is connected to the base **132** of a control transistor **130**. It can be seen that this arrangement of the transistors **134** and **140** forms a Darlington pair configuration. The emitter **131** of the control transistor **130** is connected to the input terminal **112**, and the collector **133** is connected to an output terminal **136**, as shown. A series string of three diodes, **150**, **151** and **152**, are coupled from the output terminal **136** to the resistor **154**, as shown, thereby providing a negative feedback connection to the emitter **126** of the transistor **122**.

In operation, a DC power supply voltage having a small AC ripple component is applied to the input terminal **112**. This DC voltage applied across the series combination composed of the diodes **113**, **114**, **115** and the resistor **116**, will forward bias the diodes **113**, **114**, **115**. This will result in a reference voltage V_R generated at the reference node **117**, which tracks three diode drops below the input DC voltage at the input terminal **112**. This reference voltage V_R is filtered by the low pass filter formed by the resistor **119** and the capacitor **121**. The filtered reference voltage is applied to the base of the transistor **123**. The voltage generated at the collector **125** is coupled to the base **132** of the control transistor **130** via the Darlington pair composed of the transistors **134** and **140**. The Darlington pair provides a high degree of current gain. Thus, the transistors **122**, **134** and **140** form a high gain stage with a high output current capability and an added two diode voltage drop. The reference voltage at the base **123** of the transistor **122** is approximately three diode drops below the input DC voltage. In addition, the feedback through the three diodes **150**, **151**, **152** will cause the voltage of the emitter **126** of the transistor **122** to be three diode drops below the voltage at the output terminal **136**. Therefore, the voltage across the control transistor **130** will be maintained at approximately one diode drop. An additional consequence of the feedback loop is that an output voltage drop will cause the voltage at the emitter **126** to drop, causing the transistor **122** to turn on more. This will drive the transistor **130** harder, pulling up the output voltage at the output terminal **136**.

Since this novel active power supply ripple filter tracks the input voltage by maintaining approximately one diode drop across the control transistor **130**, it therefore has the dual advantage of low input-output voltage differential and low power dissipation. Also, since the voltage across the reference and feedback diode strings change with temperature in the same manner, the circuit provides the advantage of compensating for temperature changes within the circuit. In addition, since only the base current of the transistor **122** goes through the filter resistor **119**, a pinch resistor can be used for the resistor **119** and an NPN transistor can be used for the transistor **122** when the circuit is integrated. A pinch resistor is an integrated circuit resistor with high value of resistance that tracks the NPN beta of the circuit transistors. Thus, a constant voltage drop across the high value resistor can be obtained. This permits the use of a larger value of resistance than could otherwise be utilized, allowing smaller values of capacitance to achieve a desired filter cut-off frequency. Also of importance when integrating this circuit is the fact that no lateral PNP transistor would be required in the signal path since the PNP control transistor **130** is required to be external to the integrated circuit when using standard processing technology due to the high current requirement. In integrated circuits this reduces frequency compensation problems and provides improved noise characteristics over a circuit requiring a lateral PNP in the signal path. Thus, this novel circuit is highly suitable for monolithic integration.

It can be seen from the above description that an active power supply ripple filter has been provided which maintains minimum voltage drop across it and minimum power dissipation in the control device. In addition, the invention provides temperature compensated operation, permits the use of smaller capacitances and is particularly suitable for monolithic fabrication.

While a preferred embodiment of the invention has been described and shown, it should be understood that other variations and modifications may be implemented. It is therefore contemplated to cover by the present application any and all modifications and variations that fall within the true spirit and scope of the basic underlying principles disclosed and claimed herein.

What is claimed is:

1. A low noise electronic power supply filter circuit capable of high output currents for eliminating alternating current components from a direct current power supply and for tracking the direct current voltage of said power supply, comprising:

(a) control means having a control terminal, an input terminal and an output terminal, said input terminal coupled to the power supply and said output terminals adapted to be coupled to a load, said control means controlling current from the input terminal to the output terminal;

(b) reference means, coupled to the control means input terminal for generating a reference voltage which tracks approximately three diode drops below the power supply voltage;

(c) amplifier means having an output coupled to the control terminal and having first and second input terminals, for amplifying a signal applied across the input terminals comprising an input transistor coupled to a darlington pair;

(d) filter means, having an input coupled to the reference means for low pass filtering the reference voltage, and having an output coupled to the first input of the amplifier means thereby coupling the filtered reference voltage to said amplifier means; and

(e) feedback means, coupled from the control means output terminal to the second input of the amplifier means, comprising three diodes in series such that approximately one diode drop is maintained across the control means.

2. The low noise electronic power supply filter circuit of claim **1**, wherein the control means is a bipolar transistor.

3. The low noise electronic power supply filter circuit of claim **1** fabricated in integrated form wherein the filter means comprises a pinch resistor coupled from the reference means to the amplifier means.

4. The low noise electronic power supply filter circuit of claim **3** wherein the amplifier means comprises an npn input transistor coupled to a pnp darlington pair.

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