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☒	Claim(s)	: paged ...9... to paged ...14...
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A LEVEL SHIFTER FOR A POWER SUPPLY, FOR EXAMPLE
IN A TELEVISION APPARATUS

The invention relates to a level shifter as
 5 used for example in an input stage of a power supply
 regulator of a television apparatus, in particular to a
 circuit arrangement that combines an input signal with
 a reference signal to produce an output signal that is
 level shifted relative to that of the input signal.

10 In a power supply arrangement of, for example, a
 television receiver, a voltage representative of a DC,
 regulated supply voltage B+ is coupled to, for example, an
 inverting input terminal of a B+ voltage regulator. A
 reference voltage is coupled to, for example, a
 15 noninverting input terminal of the regulator. The
 feed-back voltage that is representative, for example, of
 regulated supply voltage B+ is compared, in the input
 stage, with the reference voltage to generate an output
 voltage that is coupled to a controllable arrangement. The
 20 controllable arrangement regulates voltage B+ at a level
 that is determined by the reference voltage. Voltage B+
 may be used, for example, to energize a deflection circuit
 output stage for a cathode ray tube (CRT).

In one prior art circuit, a voltage
 25 representative of, for example, a level of the beam current
 in the CRT is summed with the reference voltage, such that
 the sum of both, instead of the reference voltage alone, is
 applied to the noninverting input terminal of the input
 stage. A variation of the beam current representative
 30 voltage varies voltage B+ so as to maintain constant the
 raster width in the CRT when the beam current changes.

The summation of the constant reference voltage
 and the variable beam current representative voltage is
 done, in such prior art circuit, by coupling the beam
 35 current representative voltage via a zener diode to the
 noninverting input terminal. The zener diode develops
 between its anode and cathode electrodes the reference
 voltage. Thus, the reference voltage that level shifts the



beam current representative voltage is series coupled with the beam current representative voltage.

A disadvantage of such zener diode level shifting is that a change in the zener voltage due to temperature, aging or an inherent noise in the zener diode, causes the level to change.

It may be desirable to sum the beam current representative voltage with a reference voltage to generate a sum voltage that is applied to the noninverting input terminal of the input stage without using such zener diode.

In an embodiment of the invention, the reference voltage is produced by a voltage source of, for example, the well known bandgap type. The beam current representative voltage is summed with, or level shifted by, the reference voltage that is produced by the bandgap type source. Advantageously, the bandgap type source is less susceptible than the zener diode to temperature changes, component aging or noise.

In a circuit embodying an aspect of the invention, an input signal, such as a beam current representative voltage, is coupled in series with an emitter electrode of a first transistor that operates as a common base amplifier. A second transistor, operating as a current source, and having its collector coupled to the collector of the first transistor, supplies the collector current of the first transistor. A current mirror arrangement, that includes the first transistor, causes the collector current in the first transistor to be equal to that supplied by the collector current of the second transistor, when the input signal is at a predetermined magnitude such as zero. A first voltage, such as produced by a bandgap type source, is coupled via a resistor to a junction terminal between the collectors of the first and second transistors. The collector currents of the first and second transistors produce a difference current that develops a voltage across the resistor that is summed with the first voltage to produce a second signal that is



developed at the junction terminal. The second signal is at a magnitude that is determined by the first voltage and not by the collector currents in any of the first and second transistors, when the magnitude of the input signal is predetermined such as zero. When the magnitude of the input signal is different from the predetermined magnitude, the second signal is different from the first voltage by an amount that is proportional to the magnitude of the input signal.

10 In accordance with an aspect of the invention, a power supply includes a level shifter level that shifts an input voltage used for controlling an output supply voltage of the power supply. A controllable conductive element is coupled to the input supply voltage for generating, from
15 the input supply voltage, the output supply voltage. The power supply includes a comparator, coupled to the conductive element, for varying, in accordance with an output signal of the comparator, the conduction of the conductive element to control the output supply voltage. A
20 current mirror arrangement that includes a transistor is responsive to a current in a first circuit branch for generating in a first main current conducting electrode of the transistor a current that is the current mirror of the current in the first circuit branch. The first main current
25 conducting electrode is coupled at a junction terminal to a second circuit branch for conducting at least a portion of a current in the second circuit branch. A source of the input voltage is coupled to the transistor for varying the current in the first main current conducting electrode to
30 produce a difference related current that varies in accordance with the input voltage. The difference current is related to a difference between the current in the first main current conducting electrode and the current in the second circuit branch. A first resistance is coupled to
35 the junction terminal for conducting the difference related current to develop a voltage across the resistance that varies in accordance with the input voltage. A source of temperature compensated first voltage is coupled via the



resistance to the junction terminal such that the voltage across the resistance is combined with the first voltage for developing a temperature compensated second voltage at the junction terminal. The second voltage varies in accordance with the input voltage. The second voltage is level shifted in accordance with the first voltage. The temperature compensated, level shifted, second voltage is coupled to an input of the comparator for varying the output signal of the comparator to control the output supply voltage.

In the Drawing:

FIGURE 1 illustrates a simplified schematic diagram of a power supply regulator circuit that includes a level shifter, embodying an aspect of the invention;

FIGURE 2 illustrates a detailed schematic diagram of the level shifter of FIGURE 1; and

FIGURES 3, 4, 5 and 6 illustrate level shifters embodying different aspects of the invention, respectively.

FIGURE 1 illustrates a simplified schematic diagram of a power supply of a television receiver, not shown in the FIGURES, that includes a regulator 100 that is an integrated circuit that regulates a supply voltage B+. Voltage B+ may be used, for example, to energize a horizontal deflection circuit or output stage 99 of the television receiver.

A voltage V+, representative of voltage B+, is obtained from output stage 99. Voltage V+ is coupled to a voltage divider 605 that includes series coupled resistors 601, 604 and 602. Resistor 604 includes a wiper k for developing at wiper k a voltage that is representative of, for example, voltage B+. The voltage at wiper k, that is adjustable by varying the position of wiper k, is coupled to an inverting input terminal 608 of an error amplifier 610 via a resistor 607.

A small voltage that is proportional to the beam current in the CRT of the receiver is coupled from a



tertiary winding of transformer T to a terminal 611 to form a voltage V_{NINI} that is indicative of the beam current.

Voltage V_{NINI} that varies when a variation of the beam current occurs, is coupled via a level shifter 600, embodying an aspect of the invention, to a noninverting input terminal 609 of error amplifier 610 to produce an input voltage V_{NIN} . Level shifter 600 establishes a fixed offset voltage between terminals 611 and 609 that is determined by a voltage V_{BG} . Voltage V_{BG} is generated in a bandgap type voltage source 699. Bandgap type voltage source 699 advantageously maintains voltage V_{BG} constant such that voltage V_{BG} is affected significantly less by component aging or tolerance than would have occurred had a zener diode been used. As explained later on the feed back arrangement of regulator 100 causes voltage B+ to be such that voltage V_{IN} becomes equal to voltage V_{NIN} .

An integrating filter 612 is coupled between inverting input terminal 608 and an output terminal 618 of amplifier 610 to provide the loop filter of regulator 100. A filtered error voltage V_0 , developed at terminal 618 is coupled to a first input terminal of an adder 613. A horizontal rate sawtooth generator 98 develops a horizontal rate signal, having an upramping portion, which is added to error voltage V_0 in adder 613. The sum signal that is also upramping, is applied to an inverting input terminal (614) of a comparator 615 functioning as a pulse width modulator.

When, during its upramping portion, the output of adder 613 becomes more positive than a constant DC voltage V_{REF} , that is coupled to a noninverting input terminal of comparator 615, a negative going transition at an output terminal 615a of comparator 615 is coupled via a buffer amplifier 616 to a control terminal 617a of a switch 617b of a switch mode power supply output stage 617 to turn on switch 617b of output stage 617.

An input terminal 617c of output stage 617 is coupled to unregulated voltage V_{UR} . Regulated voltage B+



is developed at an output terminal 617d of output stage 617.

The duration, during each horizontal period, H , in which switch 617b conducts is determined by the level of error voltage V_0 of error amplifier 610. Thus, regulated voltage $B+$ is determined by voltage V_{NIN} . As indicated before, voltage V_{NIN} is produced by level shifter 600, embodying an aspect of the invention, that is described now in detail.

FIGURE 2 illustrates a schematic diagram of level shifter 600 of FIGURE 1 and of error amplifier 610.

Similar numbers in FIGURES 1 and 2 represent similar items or functions. Level shifter 600 of FIGURE 2 is temperature compensated over a wide range of ambient operating temperatures, such as between 0°C and 70°C , to produce voltage V_{NIN} that is substantially unaffected by a change in the temperature within such range.

A temperature compensated current control arrangement 650 generates a control voltage V_{BR} on a rail signal line 900. Rail signal line 900 is coupled to the base electrode of each of transistors Q142, Q725, Q727, Q736 and Q737. The emitter electrodes of the above-mentioned transistors are coupled through corresponding resistors to a fixed DC voltage V_{CC} . Current control arrangement 650 controls voltage V_{BR} in such a way that the collector current in each of the above-mentioned transistor stays substantially constant when the temperature changes. An example of an arrangement that is similar to current control arrangement 650 is described in detail in U.S. Patent No. 3,886,435, in the name of S. A. Steckler, entitled VBE VOLTAGE SOURCE TEMPERATURE COMPENSATION NETWORK.

Level shifter 600 includes transistors Q736 and Q737. The emitter currents in transistors Q736 and Q737 are controlled by resistors R728 and R69, respectively, having the same value, so as to cause the respective collector currents of transistors Q736 and Q737, that are temperature compensated, to be equal. The collector of



transistor Q737 is coupled to a current mirror arrangement that includes transistors Q733, Q734 and Q735. The collector of transistor Q737 is coupled to the collector of transistor Q734. The emitter of transistor Q735 is coupled to each of the bases of transistors Q733 and Q734. Transistor Q735 provides the base current drive to each of transistors Q733 and Q734. The emitter of transistor Q734 is coupled to ground via a resistor R732. The P-N junction of transistor Q734 between the base and emitter electrodes of transistor Q734, provides temperature compensation that compensates for a temperature related variation of the base-emitter voltage of transistor Q733. The emitter of transistor Q733 is coupled through resistor R731 to terminal 611, where voltage V_{NINI} of FIGURE 1 is developed. The value of resistor R731 is equal to that of resistor R732. Voltage V_{NINI} is prevented from exceeding predetermined limits in either polarity by a diode network 675. The collector of transistor Q733 is coupled to the collector of transistor Q736 at a junction terminal 733A.

Assume that voltage V_{NINI} is zero. In this case, the current mirror arrangement of transistors Q733, Q734 and Q735, produces a collector current i_{Q733} in transistor Q733 that is equal to the collector current i_{Q734} in transistor Q734 because the base current of transistor Q735 is negligible. As explained before, when voltage V_{NINI} is zero, collector current i_{Q736} in transistor Q736 is equal to collector current i_{Q737} in transistor Q737 over a wide temperature range. Also, when voltage V_{NINI} is zero, each of collector current i_{Q734} and its mirror the collector current i_{Q733} is equal to current i_{Q737} over such wide temperature range. It follows that current i_{Q733} is also equal to current i_{Q736} .

Bandgap type voltage source 699 supplies temperature compensated reference voltage V_{BG} that is coupled via a resistor R729 to terminal 733A. Because, as described before, when voltage V_{NINI} is zero, current i_{Q733} is supplied entirely by current i_{Q736} , and because the impedance at terminal 733A, that is contributed by the



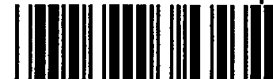
collectors of transistors Q733 and Q736 is high, a current i_{R729} in resistor R729 is zero; therefore, voltage V_{NIN} at terminal 733A is equal to voltage V_{BG} . Thus, in accordance with an aspect of the invention, when voltage V_{NINI} is zero, voltage V_{NIN} is level shifted by an amount that is equal to voltage V_{BG} .

When voltage V_{NINI} at terminal 611 is different from zero, currents i_{Q736} and i_{Q737} will not be equal. The difference current between currents i_{Q733} and i_{Q736} will cause a voltage to develop across resistor R729 that, in turn, will cause a corresponding change in voltage V_{NIN} at terminal 733A. Because transistor Q733 is coupled, relative to voltage V_{NINI} , as a common base amplifier, and because resistors R731 and R729 are, illustratively, equal, the gain, or the ratio between voltage V_{NIN} and voltage V_{NINI} , is one, resulting in an amplifier having a unity gain.

In carrying out another aspect of the invention, voltage V_{NIN} , that is level shifted relative to voltage V_{NINI} by an amount that is equal to voltage V_{BG} , follows variations of voltage V_{NINI} that occur in a range between positive and negative values.

Voltage V_{BG} is temperature compensated and has a tolerance range that is narrow relative to, for example, a zener diode. Furthermore, component aging affects voltage V_{BG} substantially less than it affects, for example, the breakdown voltage of a zener diode. Moreover, the level shifting caused by level shifter 600 is, advantageously, less susceptible to temperature, aging and noise when compared with that produced by a corresponding level shifter in the prior art that utilizes a zener diode interposed between a beam current input terminal and a noninverting input terminal of a differential amplifier to perform such level shifting.

Should a temperature change cause a corresponding change in current i_{Q736} , for example, that, as indicated before, would be relatively small, transistors Q737, Q733, Q734 and Q735 will cause a proportional change in current



i_{Q733} to occur that will prevent even such small change in temperature from affecting the difference current between currents i_{Q736} and i_{Q733} . Therefore, when voltage V_{NINI} is zero, voltage V_{NIN} is, advantageously, not affected by collector currents i_{Q736} and i_{Q737} , but is entirely determined by voltage V_{BG} that is temperature compensated.

It should be understood that temperature compensation may be adequate even when voltage V_{NINI} is significantly different from zero. If temperature compensation, in this case, is inadequate, a further improvement in temperature compensation may be obtained by coupling the terminal of, for example, resistor R732, that in FIGURE 2 is grounded, to a voltage that is different from zero and that is related to, for example, voltage V_{NINI} .

Advantageously, voltage V_{BG} , as explained before, is maintained at tight tolerances, is temperature compensated and is substantially unaffected by components aging. Therefore, advantageously, no factory temperature burn-in process is required prior to the installment of regulator 100 of FIGURE 1 in the television receiver. Furthermore, voltage divider 605 that includes resistors 601, 604 and 602 is required to compensate, advantageously, only for a narrower tolerance range than in prior art circuits in which a zener diode is used for performing the level shifting function of level shifter 600 of FIGURE 2.

Voltage V_{IN} is coupled to the base of a transistor Q721. The clamping operation of a pair of transistors Q145 and Q146 prevents voltage V_{IN} from being above voltage V_{BG} or from being below voltage V_{BG} by more than a predetermined magnitude. Voltage V_{IN} is coupled to inverting input terminal 608 and voltage V_{NIN} is coupled to noninverting input terminal 609 of error amplifier 610. Amplifier 610 includes a current source formed by a transistor Q142 that provides the combined emitter currents of a transistor Q148 and of a transistor Q149, coupled as a differential amplifier. The bases of transistors Q148 and Q149 are coupled to the emitters of transistors Q721 and



Q723 respectively. Transistors Q721 and Q723 operate as emitter followers to couple voltages V_{IN} and V_{NIN} to the bases of transistors Q148 and Q149, respectively.

A current mirror arrangement 610b that is coupled to the collectors of transistors Q148 and Q149 causes a current i_{610} , coupled to integrating filter 612 of FIGURE 1, to be equal to the difference between the collector currents in transistors Q148 and Q153. Consequently, current i_{610} that is coupled to filter 612 of FIGURE 1, is proportional to the difference between voltages V_{IN} and V_{NIN} . The proportionality factor is determined by the gain of error amplifier 610.

FIGURES 3, 4, 5 and 6 illustrate level shifters 600a, 600b, 600c and 600d, respectively, embodying other aspects of the invention, respectively. In FIGURES 2-6, numbers and symbols of similar items or functions are similar except that they include the letters a, b, c and d, in FIGURES 3, 4, 5 and 6, respectively.

In FIGURE 3, resistors R731 and R732, that are used in the circuit of FIGURE 2, were eliminated. Without resistors R731 and R732, the gain of amplifier 600a of FIGURE 3 is, advantageously, higher than unity.

In FIGURE 3, a diode D_{cma} and a temperature compensated current source I_{1a} cause the collector currents in transistors Q737a and Q736a to be, for example, equal. Similarly, transistor Q734a causes the collector current in transistor Q733a to be, for example, equal to that in each of transistors Q737a and Q736a when voltage V_{NINI} is zero.

In FIGURE 4, voltage V_{NINIb} is applied differentially between the emitters of transistors Q733b and Q734b. Such arrangement provides, advantageously, an improved common mode rejection.

In FIGURE 5 the type, N-P-N or P-N-P, of the corresponding transistors is opposite than that in FIGURE 2 so that voltage V_{NINIC} may, if desired, be referenced to voltage V_{CC} , instead of to ground.

In FIGURE 6, the input impedance to voltage V_{NINId} is, advantageously, higher than to voltage V_{NINI} of



FIGURE 2 because of the usage of a transistor Q750 that is coupled as an emitter follower.

CLAIMS:

1. An amplifier comprising:
first (Q149) and second (Q148) transistors that are coupled to form a differential amplifier (610);
an input stage (Q721) coupled at a first junction
5 terminal (base of Q148) to a control electrode (base) of said second transistor (Q148) for establishing a voltage level at said control electrode of said second transistor (Q148) in accordance with a voltage (V_{in}) that is developed at an input terminal (608) of said input stage such that an
10 output current flowing in said input stage is coupled to said first junction terminal;
a source (Q727) of a first current; characterized by
a third transistor (Q726) having a current gain
15 characteristic that is representative of a current gain characteristic of said second transistor (Q148); and
a current mirror arrangement (Q722, Q730) coupled to said third transistor (Q726) and responsive to said first current (from Q727) and to a control electrode
20 current of said third transistor (Q726) for generating at an output terminal of said current mirror arrangement (Q722, Q730) a second current (at collector of Q722) that is coupled to said first junction terminal (base of Q148), said second current having a first portion derived from
25 said first current (from Q727) that generates said output current of said input stage and a second portion derived from said control electrode current of said third transistor (Q726) that generates said control electrode current of said second transistor (Q148), wherein a
30 deviation of said current gain characteristic of said second transistor (148) from a nominal value thereof that produces a corresponding deviation in said control electrode current of said second transistor (Q148) is compensated by said control electrode current of said third
35 transistor (Q726) so as to substantially prevent such current deviation from affecting said output current of said input stage.





2. An amplifier according to Claim 1, characterized in that said input stage comprises a fourth transistor (Q721) coupled as an emitter follower, and said output current of said input stage flows in an emitter electrode of said fourth transistor (Q721).

3. An amplifier according to Claim 1, characterized in that said first current source (Q727) generates said first current having a value that is independent of said variation in said current gain characteristic of at least one of said second (Q148) and third (Q726) transistors.

4. An amplifier according to Claim 1, characterized in that said current mirror arrangement (Q722, Q730) prevents said variation in said current gain of said second transistor (Q148) from affecting an offset voltage at said input terminal (608) of said input stage (Q721).

5. An amplifier according to Claim 1 characterized by second means (Q142) coupled to a second junction terminal between corresponding main current conducting electrodes (emitters) of said first (Q149) and second (Q148) transistors for generating a current that varies in the same sense as said first current (from Q727) independently of said current gain characteristic of said second transistor (Q148).

6. An amplifier according to Claim 1, characterized in that said first (Q149), second (Q148) and third (Q726) transistors are bipolar transistors of the same type.

7. An amplifier according to Claim 1, characterized in that said current mirror arrangement (Q722, Q730) includes a fourth transistor (Q722) that generates said second current that flows in the same direction as said first current (in Q727) and that is equal to the sum of said first current and said control electrode current of said third transistor (Q726).

8. An amplifier according to Claim 1, characterized in that said third transistor (Q726) is





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coupled outside a signal path formed between an input terminal (608) and an output terminal (610a) of said amplifier.

9. An amplifier according to Claim 1,
5 characterized by means (699) for generating a temperature compensated control voltage (V_{BG}) that is coupled to a control electrode of a bipolar, further transistor (Q273) for generating said first current at a collector electrode of said further transistor (Q273) that is unaffected by a
10 variation of a current gain characteristic of said further transistor (Q273).

10. An amplifier according to Claim 9,
characterized in that said current mirror arrangement further comprises an additional transistor (Q730) coupled
15 in a diode configuration for conducting therethrough a current that is equal to a sum of said first current (from Q727) and said control electrode current of said third transistor (Q276).

11. An amplifier according to Claim 10,
20 characterized in that said current mirror arrangement includes another transistor (Q722) having a base electrode that is coupled to said additional transistor (Q730) and a collector electrode that is coupled to said control electrode of said second transistor (Q148).

25 12. An amplifier according to Claim 11 further comprising a second additional transistor (Q724) having a base electrode that is coupled to said additional transistor (Q730) and a collector electrode that is coupled to a base electrode of said first transistor (Q149).

30 13. An amplifier according to Claim 1, characterized in that said amplifier forms an error amplifier in a regulator of a television apparatus power supply.



ABSTRACT

A LEVEL SHIFTER FOR A POWER SUPPLY, FOR EXAMPLE
IN A TELEVISION APPARATUS

5 A level shifter (600) receives a variable input
- voltage (V_{NINI}), such as a beam current representative
voltage of a cathode ray tube in a television receiver,
and produces an output voltage (V_{NIN}) that changes when
the input voltage changes, such that the output voltage
10 (V_{NIN}) is level shifted relative to the input voltage
(V_{NINI}). The output voltage (V_{NIN}) is coupled to an
input terminal (+) of an error amplifier (610) of a
power supply voltage regulator. The level shifter
(600) includes a current mirror arrangement responsive
15 to the input voltage. A band gap type voltage source
(699) determines the amount of level shifting that is
produced by the level shifter (600).

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FIG. 1

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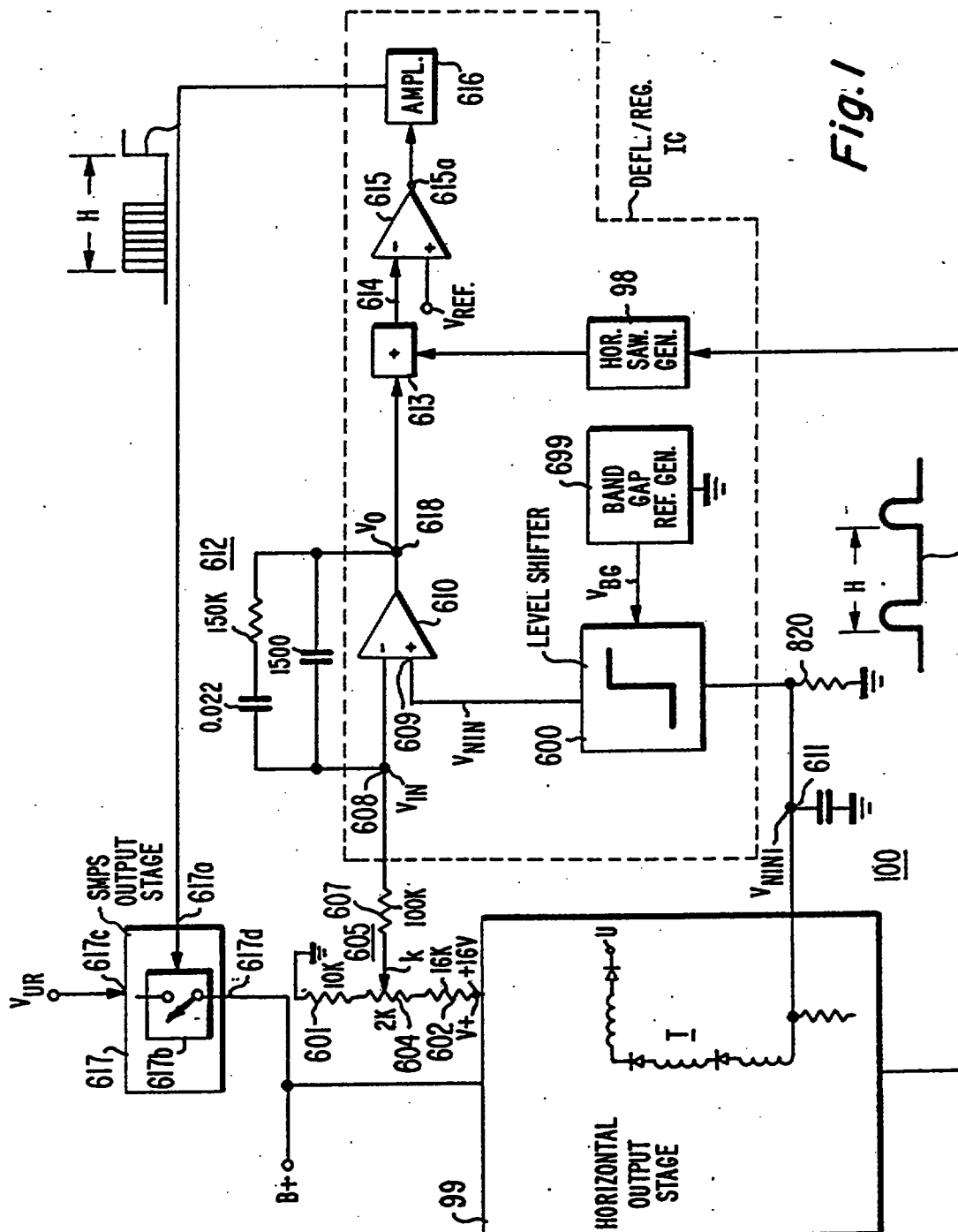


Fig. 1

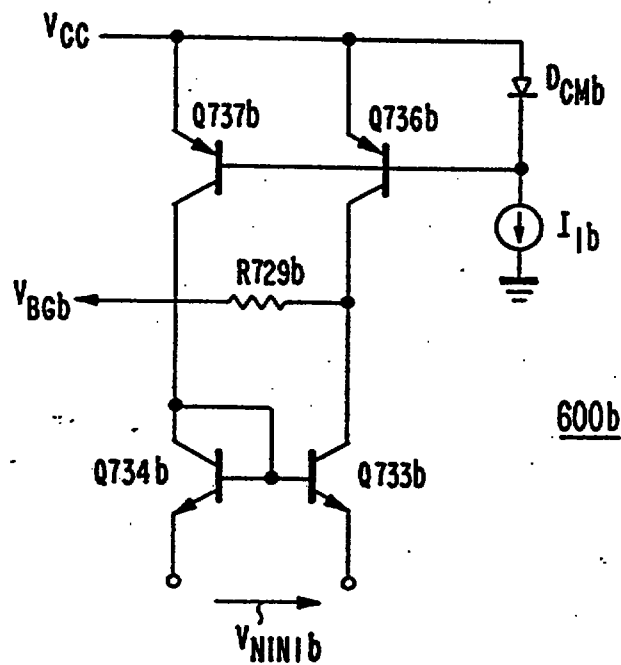
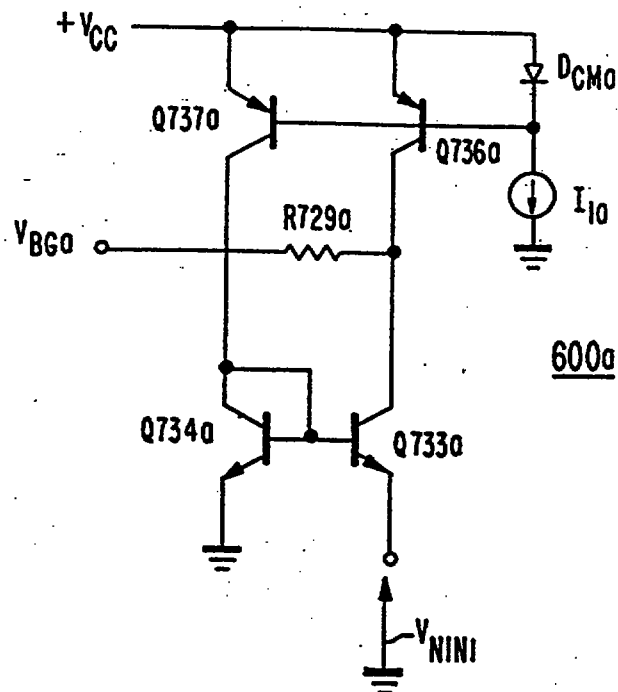




Fig. 2



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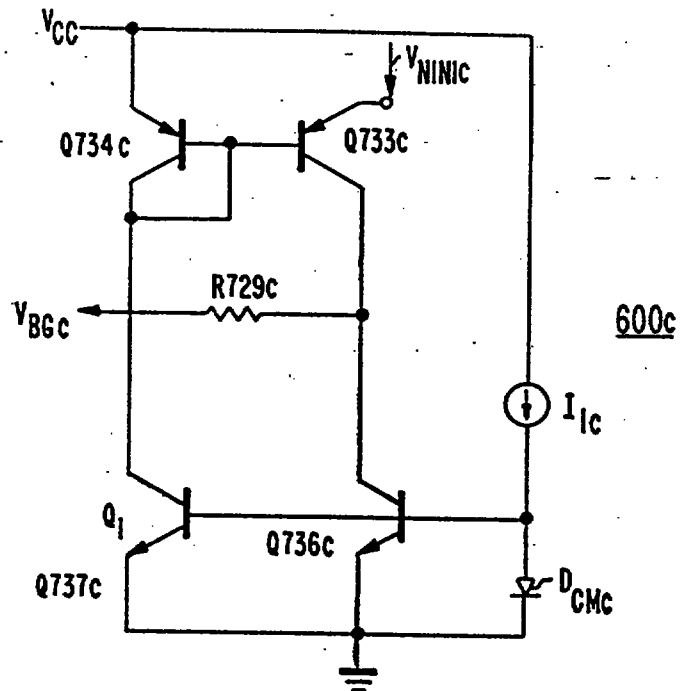


Fig. 5

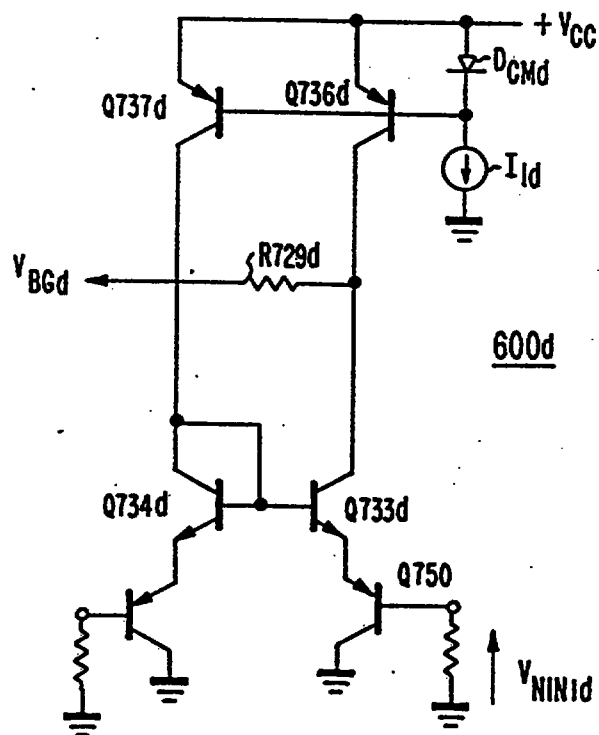


Fig. 6

✓ Description : paged 1. to paged 11.
✓ Claim(s) : paged 12. to paged 14.
✓ Drawing(s) : paged 14a. to paged 14a.
✓ Abstract : paged 15. to paged 15.

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A LEVEL SHIFTER FOR A POWER SUPPLY, FOR EXAMPLE
IN A TELEVISION APPARATUS

5 The invention relates to a level shifter as
used for example in an input stage of a power supply
regulator of a television apparatus, in particular to a
circuit arrangement that combines an input signal with
a reference signal to produce an output signal that is
level shifted relative to that of the input signal.

10 In a power supply arrangement of, for example, a
television receiver, a voltage representative of a DC,
regulated supply voltage B+ is coupled to, for example, an
inverting input terminal of a B+ voltage regulator. A
reference voltage is coupled to, for example, a
15 noninverting input terminal of the regulator. The
feed-back voltage that is representative, for example, of
regulated supply voltage B+ is compared, in the input
stage, with the reference voltage to generate an output
voltage that is coupled to a controllable arrangement. The
20 controllable arrangement regulates voltage B+ at a level
that is determined by the reference voltage. Voltage B+
may be used, for example, to energize a deflection circuit
output stage for a cathode ray tube (CRT).

In one prior art circuit, a voltage
25 representative of, for example, a level of the beam current
in the CRT is summed with the reference voltage, such that
the sum of both, instead of the reference voltage alone, is
applied to the noninverting input terminal of the input
stage. A variation of the beam current representative
30 voltage varies voltage B+ so as to maintain constant the
raster width in the CRT when the beam current changes.

The summation of the constant reference voltage
and the variable beam current representative voltage is
done, in such prior art circuit, by coupling the beam
35 current representative voltage via a zener diode to the
noninverting input terminal. The zener diode develops
between its anode and cathode electrodes the reference
voltage. Thus, the reference voltage that level shifts the

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beam current representative voltage is series coupled with the beam current representative voltage.

A disadvantage of such zener diode level shifting is that a change in the zener voltage due to temperature, aging or an inherent noise in the zener diode, causes the level to change.

It may be desirable to sum the beam current representative voltage with a reference voltage to generate a sum voltage that is applied to the noninverting input terminal of the input stage without using such zener diode.

In an embodiment of the invention, the reference voltage is produced by a voltage source of, for example, the well known bandgap type. The beam current representative voltage is summed with, or level shifted by, the reference voltage that is produced by the bandgap type source. Advantageously, the bandgap type source is less susceptible than the zener diode to temperature changes, component aging or noise.

In a circuit embodying an aspect of the invention, an input signal, such as a beam current representative voltage, is coupled in series with an emitter electrode of a first transistor that operates as a common base amplifier. A second transistor, operating as a current source, and having its collector coupled to the collector of the first transistor, supplies the collector current of the first transistor. A current mirror arrangement, that includes the first transistor, causes the collector current in the first transistor to be equal to that supplied by the collector current of the second transistor, when the input signal is at a predetermined magnitude such as zero. A first voltage, such as produced by a bandgap type source, is coupled via a resistor to a junction terminal between the collectors of the first and second transistors. The collector currents of the first and second transistors produce a difference current that develops a voltage across the resistor that is summed with the first voltage to produce a second signal that is

developed at the junction terminal. The second signal is at a magnitude that is determined by the first voltage and not by the collector currents in any of the first and second transistors, when the magnitude of the input signal is predetermined such as zero. When the magnitude of the input signal is different from the predetermined magnitude, the second signal is different from the first voltage by an amount that is proportional to the magnitude of the input signal.

10 In accordance with an aspect of the invention, a power supply includes a level shifter level that shifts an input voltage used for controlling an output supply voltage of the power supply. A controllable conductive element is coupled to the input supply voltage for generating, from
15 the input supply voltage, the output supply voltage. The power supply includes a comparator, coupled to the conductive element, for varying, in accordance with an output signal of the comparator, the conduction of the conductive element to control the output supply voltage. A
20 current mirror arrangement that includes a transistor is responsive to a current in a first circuit branch for generating in a first main current conducting electrode of the transistor a current that is the current mirror of the current in the first circuit branch. The first main current
25 conducting electrode is coupled at a junction terminal to a second circuit branch for conducting at least a portion of a current in the second circuit branch. A source of the input voltage is coupled to the transistor for varying the current in the first main current conducting electrode to
30 produce a difference related current that varies in accordance with the input voltage. The difference current is related to a difference between the current in the first main current conducting electrode and the current in the second circuit branch. A first resistance is coupled to
35 the junction terminal for conducting the difference related current to develop a voltage across the resistance that varies in accordance with the input voltage. A source of temperature compensated first voltage is coupled via the

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resistance to the junction terminal such that the voltage across the resistance is combined with the first voltage for developing a temperature compensated second voltage at the junction terminal. The second voltage varies in accordance with the input voltage. The second voltage is level shifted in accordance with the first voltage. The temperature compensated, level shifted, second voltage is coupled to an input of the comparator for varying the output signal of the comparator to control the output supply voltage.

In the Drawing:

FIGURE 1 illustrates a simplified schematic diagram of a power supply regulator circuit that includes a level shifter, embodying an aspect of the invention;

FIGURE 2 illustrates a detailed schematic diagram of the level shifter of FIGURE 1; and

FIGURES 3, 4, 5 and 6 illustrate level shifters embodying different aspects of the invention, respectively.

FIGURE 1 illustrates a simplified schematic diagram of a power supply of a television receiver, not shown in the FIGURES, that includes a regulator 100 that is an integrated circuit that regulates a supply voltage B+. Voltage B+ may be used, for example, to energize a horizontal deflection circuit or output stage 99 of the television receiver.

A voltage V+, representative of voltage B+, is obtained from output stage 99. Voltage V+ is coupled to a voltage divider 605 that includes series coupled resistors 601, 604 and 602. Resistor 604 includes a wiper k for developing at wiper k a voltage that is representative of, for example, voltage B+. The voltage at wiper k, that is adjustable by varying the position of wiper k, is coupled to an inverting input terminal 608 of an error amplifier 610 via a resistor 607.

A small voltage that is proportional to the beam current in the CRT of the receiver is coupled from a

tertiary winding of transformer T to a terminal 611 to form a voltage V_{NINI} that is indicative of the beam current.

Voltage V_{NINI} that varies when a variation of the beam current occurs, is coupled via a level shifter 600, embodying an aspect of the invention, to a noninverting input terminal 609 of error amplifier 610 to produce an input voltage V_{NIN} . Level shifter 600 establishes a fixed offset voltage between terminals 611 and 609 that is determined by a voltage V_{BG} . Voltage V_{BG} is generated in a bandgap type voltage source 699. Bandgap type voltage source 699 advantageously maintains voltage V_{BG} constant such that voltage V_{BG} is affected significantly less by component aging or tolerance than would have occurred had a zener diode been used. As explained later on the feed back arrangement of regulator 100 causes voltage B+ to be such that voltage V_{IN} becomes equal to voltage V_{NIN} .

An integrating filter 612 is coupled between inverting input terminal 608 and an output terminal 618 of amplifier 610 to provide the loop filter of regulator 100. A filtered error voltage V_0 , developed at terminal 618 is coupled to a first input terminal of an adder 613. A horizontal rate sawtooth generator 98 develops a horizontal rate signal, having an upramping portion, which is added to error voltage V_0 in adder 613. The sum signal that is also upramping, is applied to an inverting input terminal (614) of a comparator 615 functioning as a pulse width modulator.

When, during its upramping portion, the output of adder 613 becomes more positive than a constant DC voltage V_{REF} , that is coupled to a noninverting input terminal of comparator 615, a negative going transition at an output terminal 615a of comparator 615 is coupled via a buffer amplifier 616 to a control terminal 617a of a switch 617b of a switch mode power supply output stage 617 to turn on switch 617b of output stage 617.

An input terminal 617c of output stage 617 is coupled to unregulated voltage V_{UR} . Regulated voltage B+

is developed at an output terminal 617d of output stage 617.

The duration, during each horizontal period, H, in which switch 617b conducts is determined by the level of error voltage V_0 of error amplifier 610. Thus, regulated voltage B+ is determined by voltage V_{NIN} . As indicated before, voltage V_{NIN} is produced by level shifter 600, embodying an aspect of the invention, that is described now in detail.

FIGURE 2 illustrates a schematic diagram of level shifter 600 of FIGURE 1 and of error amplifier 610. Similar numbers in FIGURES 1 and 2 represent similar items or functions. Level shifter 600 of FIGURE 2 is temperature compensated over a wide range of ambient operating temperatures, such as between 0°C and 70°C, to produce voltage V_{NIN} that is substantially unaffected by a change in the temperature within such range.

A temperature compensated current control arrangement 650 generates a control voltage V_{BR} on a rail signal line 900. Rail signal line 900 is coupled to the base electrode of each of transistors Q142, Q725, Q727, Q736 and Q737. The emitter electrodes of the above-mentioned transistors are coupled through corresponding resistors to a fixed DC voltage V_{CC} . Current control arrangement 650 controls voltage V_{BR} in such a way that the collector current in each of the above-mentioned transistor stays substantially constant when the temperature changes. An example of an arrangement that is similar to current control arrangement 650 is described in detail in U.S. Patent No. 3,886,435, in the name of S. A. Steckler, entitled VBE VOLTAGE SOURCE TEMPERATURE COMPENSATION NETWORK.

Level shifter 600 includes transistors Q736 and Q737. The emitter currents in transistors Q736 and Q737 are controlled by resistors R728 and R69, respectively, having the same value, so as to cause the respective collector currents of transistors Q736 and Q737, that are temperature compensated, to be equal. The collector of

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transistor Q737 is coupled to a current mirror arrangement that includes transistors Q733, Q734 and Q735. The collector of transistor Q737 is coupled to the collector of transistor Q734. The emitter of transistor Q735 is coupled to each of the bases of transistors Q733 and Q734. Transistor Q735 provides the base current drive to each of transistors Q733 and Q734. The emitter of transistor Q734 is coupled to ground via a resistor R732. The P-N junction of transistor Q734 between the base and emitter electrodes of transistor Q734, provides temperature compensation that compensates for a temperature related variation of the base-emitter voltage of transistor Q733. The emitter of transistor Q733 is coupled through resistor R731 to terminal 611, where voltage V_{NINI} of FIGURE 1 is developed. The value of resistor R731 is equal to that of resistor R732. Voltage V_{NINI} is prevented from exceeding predetermined limits in either polarity by a diode network 675. The collector of transistor Q733 is coupled to the collector of transistor Q736 at a junction terminal 733A. Assume that voltage V_{NINI} is zero. In this case, the current mirror arrangement of transistors Q733, Q734 and Q735, produces a collector current i_{Q733} in transistor Q733 that is equal to the collector current i_{Q734} in transistor Q734 because the base current of transistor Q735 is negligible. As explained before, when voltage V_{NINI} is zero, collector current i_{Q736} in transistor Q736 is equal to collector current i_{Q737} in transistor Q737 over a wide temperature range. Also, when voltage V_{NINI} is zero, each of collector current i_{Q734} and its mirror the collector current i_{Q733} is equal to current i_{Q737} over such wide temperature range. It follows that current i_{Q733} is also equal to current i_{Q736} .

Bandgap type voltage source 699 supplies temperature compensated reference voltage V_{BG} that is coupled via a resistor R729 to terminal 733A. Because, as described before, when voltage V_{NINI} is zero, current i_{Q733} is supplied entirely by current i_{Q736} , and because the impedance at terminal 733A, that is contributed by the

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collectors of transistors Q733 and Q736 is high, a current i_{R729} in resistor R729 is zero; therefore, voltage V_{NIN} at terminal 733A is equal to voltage V_{BG} . Thus, in accordance with an aspect of the invention, when voltage V_{NINI} is
5 zero, voltage V_{NIN} is level shifted by an amount that is equal to voltage V_{BG} .

When voltage V_{NINI} at terminal 611 is different from zero, currents i_{Q736} and i_{Q737} will not be equal. The difference current between currents i_{Q733} and i_{Q736} will
10 cause a voltage to develop across resistor R729 that, in turn, will cause a corresponding change in voltage V_{NIN} at terminal 733A. Because transistor Q733 is coupled, relative to voltage V_{NINI} , as a common base amplifier, and because resistors R731 and R729 are, illustratively,
15 equal, the gain, or the ratio between voltage V_{NIN} and voltage V_{NINI} , is one, resulting in an amplifier having a unity gain.

In carrying out another aspect of the invention, voltage V_{NIN} , that is level shifted relative to voltage
20 V_{NINI} by an amount that is equal to voltage V_{BG} , follows variations of voltage V_{NINI} that occur in a range between positive and negative values.

Voltage V_{BG} is temperature compensated and has a tolerance range that is narrow relative to, for example, a
25 zener diode. Furthermore, component aging affects voltage V_{BG} substantially less than it affects, for example, the breakdown voltage of a zener diode. Moreover, the level shifting caused by level shifter 600 is, advantageously, less susceptible to temperature, aging and noise when
30 compared with that produced by a corresponding level shifter in the prior art that utilizes a zener diode interposed between a beam current input terminal and a noninverting input terminal of a differential amplifier to perform such level shifting.

35 Should a temperature change cause a corresponding change in current i_{Q736} , for example, that, as indicated before, would be relatively small, transistors Q737, Q733, Q734 and Q735 will cause a proportional change in current

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i_{Q733} to occur that will prevent even such small change in temperature from affecting the difference current between currents i_{Q736} and i_{Q733} . Therefore, when voltage V_{NINI} is zero, voltage V_{NIN} is, advantageously, not affected by collector currents i_{Q736} and i_{Q737} , but is entirely determined by voltage V_{BG} that is temperature compensated.

It should be understood that temperature compensation may be adequate even when voltage V_{NINI} is significantly different from zero. If temperature compensation, in this case, is inadequate, a further improvement in temperature compensation may be obtained by coupling the terminal of, for example, resistor R732, that in FIGURE 2 is grounded, to a voltage that is different from zero and that is related to, for example, voltage V_{NINI} .

Advantageously, voltage V_{BG} , as explained before, is maintained at tight tolerances, is temperature compensated and is substantially unaffected by components aging. Therefore, advantageously, no factory temperature burn-in process is required prior to the installment of regulator 100 of FIGURE 1 in the television receiver. Furthermore, voltage divider 605 that includes resistors 601, 604 and 602 is required to compensate, advantageously, only for a narrower tolerance range than in prior art circuits in which a zener diode is used for performing the level shifting function of level shifter 600 of FIGURE 2.

Voltage V_{IN} is coupled to the base of a transistor Q721. The clamping operation of a pair of transistors Q145 and Q146 prevents voltage V_{IN} from being above voltage V_{BG} or from being below voltage V_{BG} by more than a predetermined magnitude. Voltage V_{IN} is coupled to inverting input terminal 608 and voltage V_{NIN} is coupled to noninverting input terminal 609 of error amplifier 610. Amplifier 610 includes a current source formed by a transistor Q142 that provides the combined emitter currents of a transistor Q148 and of a transistor Q149, coupled as a differential amplifier. The bases of transistors Q148 and Q149 are coupled to the emitters of transistors Q721 and

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Q723 respectively. Transistors Q721 and Q723 operate as emitter followers to couple voltages V_{IN} and V_{NIN} to the bases of transistors Q148 and Q149, respectively.

A current mirror arrangement 610b that is coupled to the collectors of transistors Q148 and Q149 causes a current i_{610} , coupled to integrating filter 612 of FIGURE 1, to be equal to the difference between the collector currents in transistors Q148 and Q153. Consequently, current i_{610} that is coupled to filter 612 of FIGURE 1, is proportional to the difference between voltages V_{IN} and V_{NIN} . The proportionality factor is determined by the gain of error amplifier 610.

FIGURES 3, 4, 5 and 6 illustrate level shifters 600a, 600b, 600c and 600d, respectively, embodying other aspects of the invention, respectively. In FIGURES 2-6, numbers and symbols of similar items or functions are similar except that they include the letters a, b, c and d, in FIGURES 3, 4, 5 and 6, respectively.

In FIGURE 3, resistors R731 and R732, that are used in the circuit of FIGURE 2, were eliminated. Without resistors R731 and R732, the gain of amplifier 600a of FIGURE 3 is, advantageously, higher than unity.

In FIGURE 3, a diode D_{cma} and a temperature compensated current source I_{1a} cause the collector currents in transistors Q737a and Q736a to be, for example, equal. Similarly, transistor Q734a causes the collector current in transistor Q733a to be, for example, equal to that in each of transistors Q737a and Q736a when voltage V_{NINI} is zero.

In FIGURE 4, voltage V_{NINIb} is applied differentially between the emitters of transistors Q733b and Q734b. Such arrangement provides, advantageously, an improved common mode rejection.

In FIGURE 5 the type, N-P-N or P-N-P, of the corresponding transistors is opposite than that in FIGURE 2 so that voltage V_{NINIC} may, if desired, be referenced to voltage V_{CC} , instead of to ground.

In FIGURE 6, the input impedance to voltage V_{NINId} is, advantageously, higher than to voltage V_{NINI} of

FIGURE 2 because of the usage of a transistor Q750 that is coupled as an emitter follower.

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CLAIMS:

1. An amplifier comprising:
first (Q149) and second (Q148) transistors that
are coupled to form a differential amplifier (610);
an input stage (Q721) coupled at a first junction
5 terminal (base of Q148) to a control electrode (base) of
said second transistor (Q148) for establishing a voltage
level at said control electrode of said second transistor
(Q148) in accordance with a voltage (V_{in}) that is developed
at an input terminal (608) of said input stage such that an
10 output current flowing in said input stage is coupled to
said first junction terminal;
a source (Q727) of a first current; characterized
by
a third transistor (Q726) having a current gain
15 characteristic that is representative of a current gain
characteristic of said second transistor (Q148); and
a current mirror arrangement (Q722, Q730) coupled
to said third transistor (Q726) and responsive to said
first current (from Q727) and to a control electrode
20 current of said third transistor (Q726) for generating at
an output terminal of said current mirror arrangement
(Q722, Q730) a second current (at collector of Q722) that is
coupled to said first junction terminal (base of Q148),
said second current having a first portion derived from
25 said first current (from Q727) that generates said output
current of said input stage and a second portion derived
from said control electrode current of said third
transistor (Q726) that generates said control electrode
current of said second transistor (Q148), wherein a
30 deviation of said current gain characteristic of said
second transistor (148) from a nominal value thereof that
produces a corresponding deviation in said control
electrode current of said second transistor (Q148) is
compensated by said control electrode current of said third
35 transistor (Q726) so as to substantially prevent such
current deviation from affecting said output current of
said input stage.

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2. An amplifier according to Claim 1, characterized in that said input stage comprises a fourth transistor (Q721) coupled as an emitter follower, and said output current of said input stage flows in an emitter electrode of said fourth transistor (Q721).

3. An amplifier according to Claim 1, characterized in that said first current source (Q727) generates said first current having a value that is independent of said variation in said current gain characteristic of at least one of said second (Q148) and third (Q726) transistors.

4. An amplifier according to Claim 1, characterized in that said current mirror arrangement (Q722, Q730) prevents said variation in said current gain of said second transistor (Q148) from affecting an offset voltage at said input terminal (608) of said input stage (Q721).

5. An amplifier according to Claim 1 characterized by second means (Q142) coupled to a second junction terminal between corresponding main current conducting electrodes (emitters) of said first (Q149) and second (Q148) transistors for generating a current that varies in the same sense as said first current (from Q727) independently of said current gain characteristic of said second transistor (Q148).

6. An amplifier according to Claim 1, characterized in that said first (Q149), second (Q148) and third (Q726) transistors are bipolar transistors of the same type.

7. An amplifier according to Claim 1, characterized in that said current mirror arrangement (Q722, Q730) includes a fourth transistor (Q722) that generates said second current that flows in the same direction as said first current (in Q727) and that is equal to the sum of said first current and said control electrode current of said third transistor (Q726).

8. An amplifier according to Claim 1, characterized in that said third transistor (Q726) is

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coupled outside a signal path formed between an input terminal (608) and an output terminal (610a) of said amplifier.

9. An amplifier according to Claim 1,
5 characterized by means (699) for generating a temperature compensated control voltage (V_{BG}) that is coupled to a control electrode of a bipolar, further transistor (Q273) for generating said first current at a collector electrode of said further transistor (Q273) that is unaffected by a
10 variation of a current gain characteristic of said further transistor (Q273).

10. An amplifier according to Claim 9,
characterized in that said current mirror arrangement further comprises an additional transistor (Q730) coupled
15 in a diode configuration for conducting therethrough a current that is equal to a sum of said first current (from Q727) and said control electrode current of said third transistor (Q276).

11. An amplifier according to Claim 10,
20 characterized in that said current mirror arrangement includes another transistor (Q722) having a base electrode that is coupled to said additional transistor (Q730) and a collector electrode that is coupled to said control electrode of said second transistor (Q148).

25 12. An amplifier according to Claim 11 further comprising a second additional transistor (Q724) having a base electrode that is coupled to said additional transistor (Q730) and a collector electrode that is coupled to a base electrode of said first transistor (Q149).

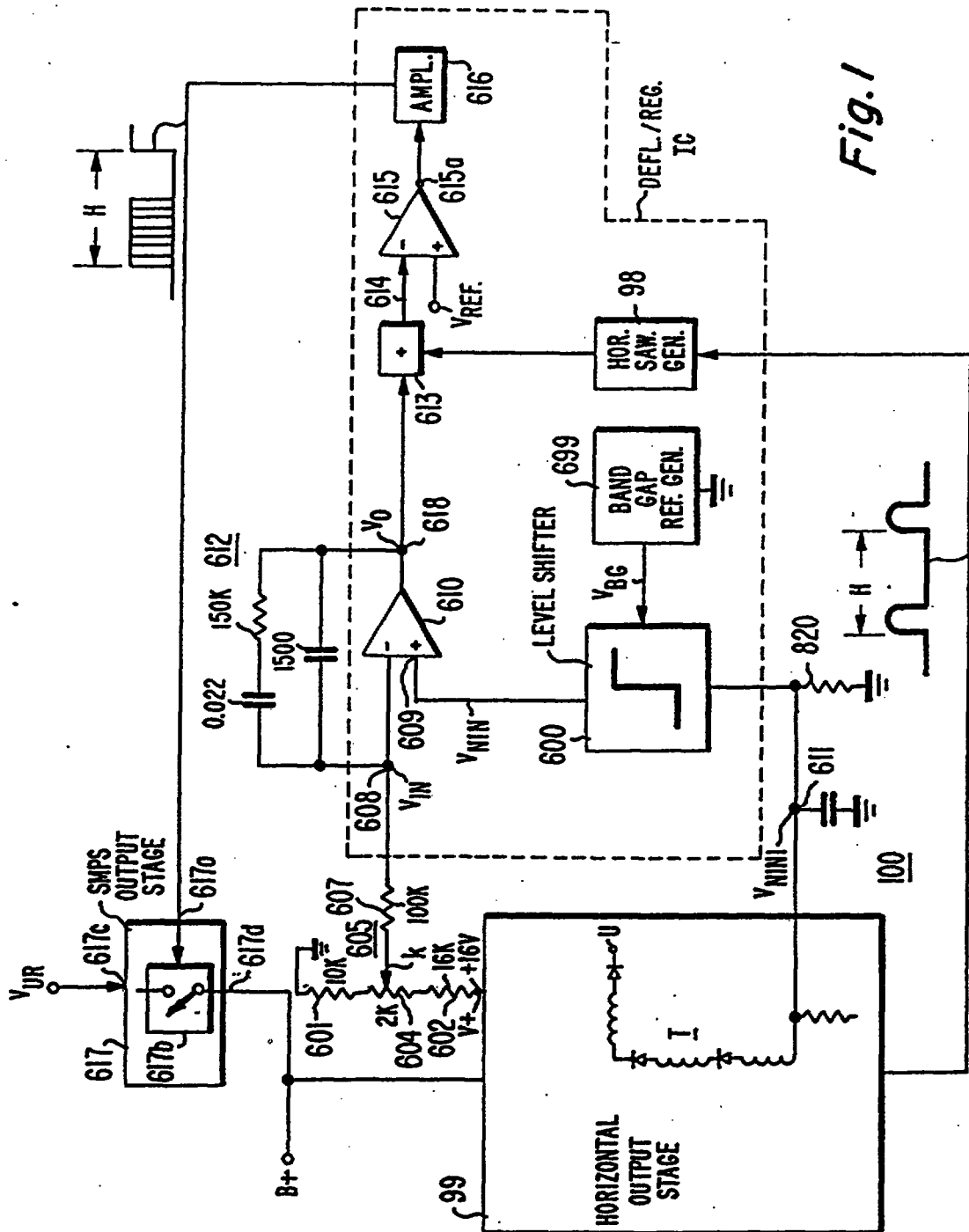
30 13. An amplifier according to Claim 1, characterized in that said amplifier forms an error amplifier in a regulator of a television apparatus power supply.

ABSTRACT

A LEVEL SHIFTER FOR A POWER SUPPLY, FOR EXAMPLE
IN A TELEVISION APPARATUS

5 A level shifter (600) receives a variable input
voltage (V_{NINI}), such as a beam current representative
voltage of a cathode ray tube in a television receiver,
and produces an output voltage (V_{NIN}) that changes when
the input voltage changes, such that the output voltage
10 (V_{NIN}) is level shifted relative to the input voltage
(V_{NINI}). The output voltage (V_{NIN}) is coupled to an
input terminal (+) of an error amplifier (610) of a
power supply voltage regulator. The level shifter
(600) includes a current mirror arrangement responsive
15 to the input voltage. A band gap type voltage source
(699) determines the amount of level shifting that is
produced by the level shifter (600).

FIGURE 1



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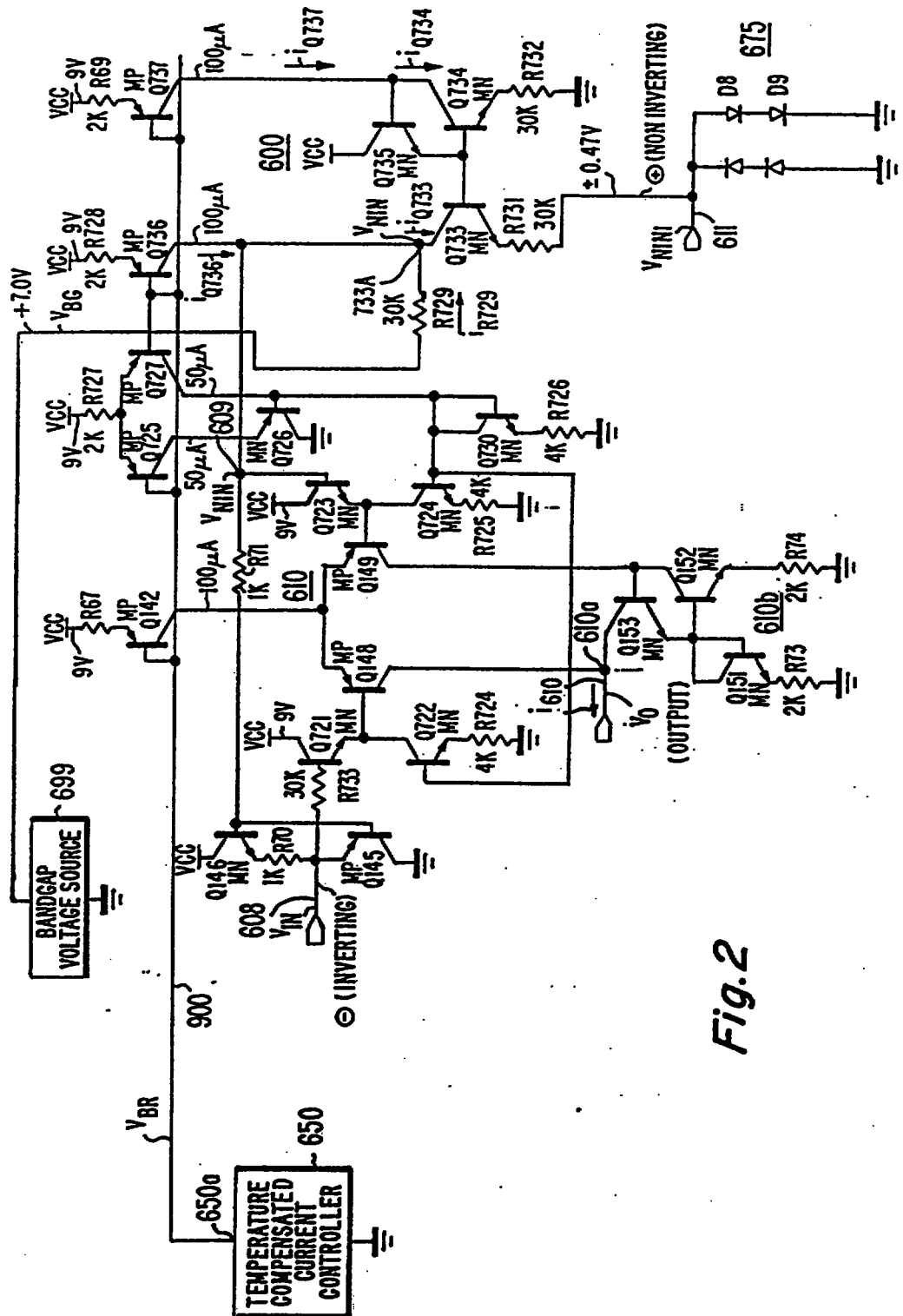


Fig. 2

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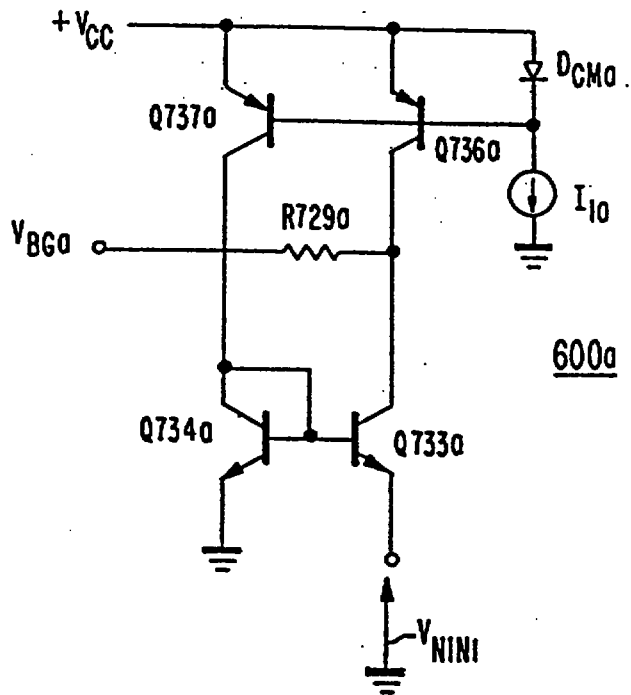


Fig.3

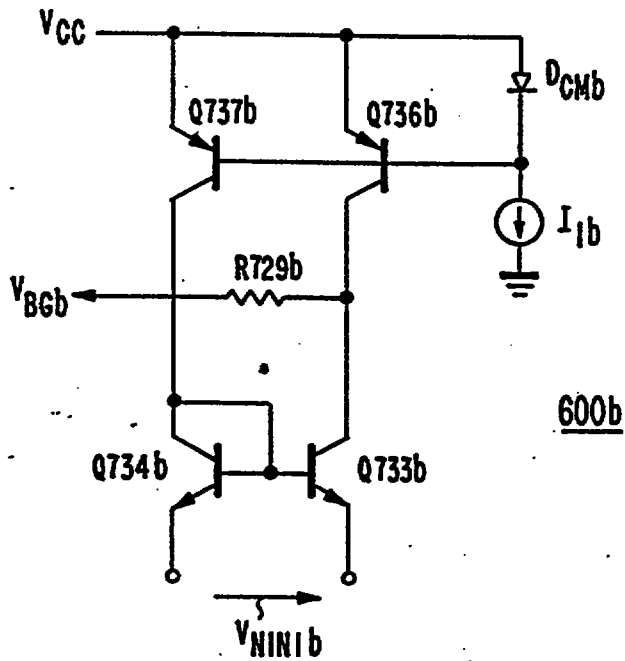


Fig. 4

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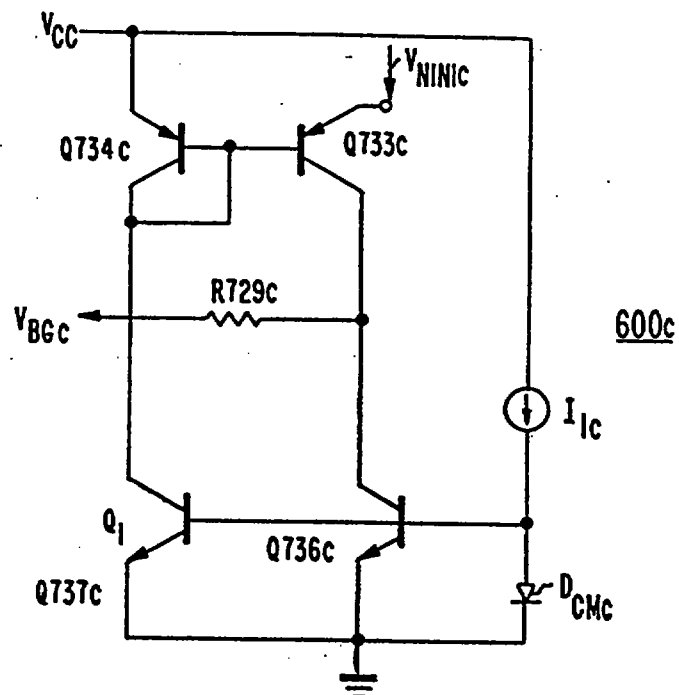


Fig. 5

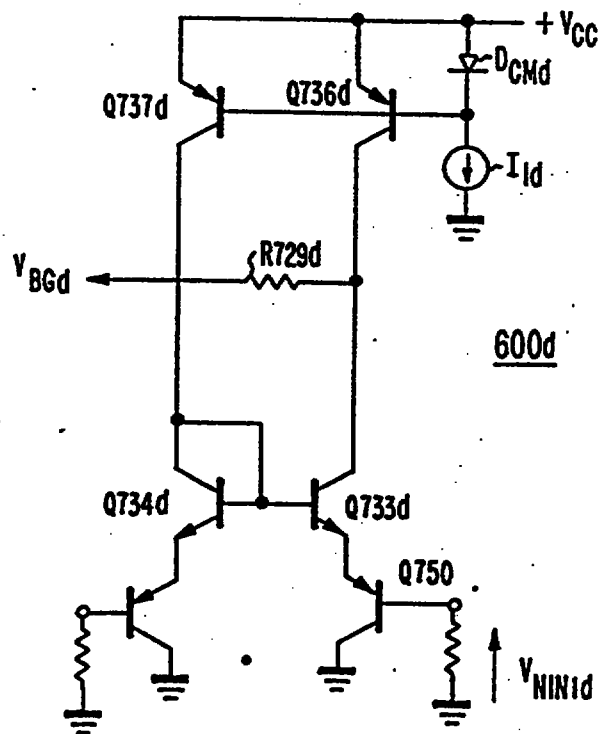


Fig. 6

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