

TRACKING RUN/STANDBY POWER SUPPLIES

Background of the Invention

The invention relates to voltage regulated power supplies for television apparatus and the like, wherein separate power
5 supplies must energize different loads at substantially the same regulated voltage level, despite load variations.

Televisions, video cassette recorders and the like, herein generally termed television apparatus, often include circuits which must remain energized when the television apparatus is
10 turned off, for example, instant-on circuits, clocks and timers, remote controls having on/off power switching capability, sophisticated control or tuning functions, digital memories and the like. These elements are usually energized whenever the television apparatus is coupled to an active AC mains supply.

15 In the run mode, a television apparatus can be powered from the horizontal deflection circuits and the flyback transformer, operative during horizontal scanning. A standby power supply is provided for powering the standby loads when not scanning, that is, when in standby. It is also possible to employ a switched
20 mode power supply, which can be switched between modes of operation for run and standby, to accommodate different current requirements in the standby and run modes.

A standby supply is usually unswitched, having a transformer with a primary winding coupled to the power plug of
25 the apparatus, and a secondary winding coupled to the input terminals of a rectifier such as a full wave bridge. The output terminals of the rectifier are coupled to a storage or filter capacitor which is charged to an unregulated voltage level related to the AC mains voltage by the turns ratio of the transformer. A
30 voltage regulator is coupled to the filter capacitor and regulates the supply voltage applied to those loads which are to remain constantly powered, i.e., the standby loads.

The standby loads are often control circuits and may include integrated circuits such as microprocessors, random access
35 memories and the like. A remote control receiver may be provided to monitor constantly for a startup signal, for switching from the standby mode to the run mode. It is possible to deactivate the standby power supply or to block all or part of the

current from the standby power supply when switching into the run mode. Many television apparatus, however, use the standby power supply to power the standby loads when in the run mode as well as in the standby mode. In that case, the run mode loads
5 (that is, the loads which are not powered in standby) are powered by one or more separate power supplies, for example from the switched mode power supply associated with the horizontal deflection circuits.

It is desirable to minimize the number of loads which are
10 powered by the standby supply, to reduce unnecessary power consumption as well as the cost of the components needed (especially the cost of the standby power supply transformer), and to reduce stress on the standby power supply components. Control circuits which do not have to be powered in the standby
15 mode are powered from the run supply. However, providing different power supplies for some of the control circuits than for others causes a problem because the separately powered control circuits are coupled to one another. The control circuits used in run and in standby communicate with one another over common
20 signal lines when in the run mode. It is necessary to cause the run and standby regulated voltages to remain substantially equal. However, this can be a complicated problem because the loading of the standby and run supplies varies greatly.

A standby supply, for example at 5 V (volt) DC, may need to
25 supply only 40 mA (milliampere) of current. The run supply at the same voltage may need to supply current up to 1 A (ampere). A fundamental problem with known schemes for maintaining equal regulated voltages for the run and standby supplies is that variations in the base-emitter voltage of the regulating
30 transistor of the run supply is on the order of 200 mV (millivolts).

Control circuits such as CMOS integrated circuits are suitable for fast switching characteristics and reliable long term performance. Large scale integration of CMOS circuits, and in
35 particular microprocessor control of television apparatus, is used widely. It is a characteristic of CMOS circuits that where commonly connected circuits are powered from different power supplies, the voltage regulation of the respective supplies

becomes critical. A problem known as SCR latching can be caused by exceeding the tolerance of a CMOS circuit for differences between the VDD supply for the integrated circuit and the maximum voltage applied to the inputs of the integrated circuit.

- 5 SCR latching can occur because the supply voltage coupled to a first integrated circuit in a common communication path produces a signal on its output that exceeds the supply voltage coupled to a second integrated circuit having an input coupled to the output of the first integrated circuit. A circuit with some
- 10 integrated circuits coupled to the standby supply and others coupled to the run supply, wherein respective input and output signal lines are coupled, for example, over a communications bus, needs some provision to ensure that the supply voltages are equal.

- Most CMOS integrated circuits in production specify a
- 15 maximum input pin voltage of $V_{DD} + 0.3 \text{ V}$, to guarantee that the integrated circuits will operate as specified. At greater than $V_{DD} + 0.3 \text{ V}$, unguarded flip/flops, RAM cells and other integrated functions may change state and cause anomalous operation, or an SCR latch may occur which blocks further operation of the
- 20 affected circuit until the power is turned off.

- Variations in components and conditions are such that the typical voltage regulator cannot be expected to match the nominal output voltage, or even if made manually adjustable by a potentiometer or the like, indefinitely to maintain the nominal
- 25 output voltage to the required tolerance. A typical series regulator uses a series power transistor having a collector coupled to the unregulated voltage input, and a base coupled to a reverse biased Zener diode and by a resistor to the unregulated input. The voltage across the Zener diode defines a reference that
- 30 in conjunction with the base-emitter voltage drop determines the regulated output voltage on the emitter of the power transistor. Assuming two CMOS integrated circuits driven respectively from a 5 V run supply and a 5 V standby supply, and assuming that both have Zener diodes of 5% tolerance, one of the supplies may
- 35 regulate to 5.25 V and the other to 4.75 V. The difference, namely 0.5 V, is enough to violate the $V_{DD} + 0.3 \text{ V}$ maximum input voltage rule.

It is possible to use the regulated level of one power supply to affect the regulation of another power supply. Circuits of this type may require potentiometers to set the coupling between the supplies when the apparatus incorporating the supplies is
5 manufactured. Potentiometers can be expensive. Furthermore, the optimal relationship between the two regulators may be affected by the current loading of one supply or the other. Where the current loading of a series regulated supply is increased, the base-emitter voltage of the series pass transistor in the
10 regulator increases. The loading thus produces a load-dependent variation between the emitter voltage (that is, the regulated output) and the base of the series pass transistor, which typically is coupled to a source of a reference voltage level.

When temperature drift tolerance as well as the Zener
15 nominal tolerance are factored together, the regulated supply voltage easily can vary by ten percent. Moreover, the reference voltage level established by a Zener diode can vary with the magnitude of the current biasing the Zener diode. The reference voltage level can fall as the biasing current falls. Using the
20 nominal 5 V supply voltage example, an input to a CMOS circuit coupled to the lower supply voltage, driven by an output from a CMOS circuit coupled to the higher supply voltage, could exceed the lower VDD by one volt. When one further considers the variations resulting from loading-induced variations in the base-emitter voltage of the run supply regulator, the risk of anomalous
25 operation, for example SCR latching, is a serious problem.

Summary of the Invention

According to the present invention, there is provided a power supply system, comprising: an
30 unswitched voltage source energized during first and second modes of operation; first voltage regulating means energized by said unswitched voltage source for energizing a first variable load at a first regulated voltage level and generating a first control current
35 which varies with said first variable load; a source of a reference voltage level coupled to said first voltage regulating means for establishing said first regulated

voltage level, said reference voltage level being biased by said first control current; a switched voltage source energized only during said second mode of operation; second voltage regulating means energized by said switched voltage source for energizing a second variable load at a second regulated voltage level and generating a second control current which varies with said second variable load; and said source of said reference voltage level also being coupled to said second voltage regulating means for establishing said second regulated voltage level, said source of said reference voltage level also being biased by said second control current, each one of said first and second regulated voltage levels tracking variations of the other one of said first and second regulated voltage levels.

The first voltage level tracks _____ variations of the second voltage level, as the second voltage level changes due to variations of the second variable load, and at the same time, the second voltage level tracks the first voltage level as the first voltage level changes due to variations of the second variable load. The tracking therefore works in both directions at all times during which both the first and second loads are energized. In a television apparatus, for example, the first voltage regulator is operable only during a run mode of operation and the second voltage regulator is operable during a standby mode of operation and during the run mode of operation.

The first and second loads may be interconnected integrated circuits of a kind subject to SCR latching when a difference between respective supply voltages exceeds a tolerance. The first and second regulated voltage levels in this system will not differ from one another by more than the tolerance.

The first and second voltage regulators may be characterized as comprising respective active feedback circuits for generating the first and second control currents. The first and second voltage regulators may also be characterized as comprising respective comparators for generating the control currents at magnitudes related to a difference between the

reference voltage level and the first and second voltage levels respectively as the first and second loads vary. Each of the voltage regulators may also be characterized as generating the respective control currents by variably diverting respective parts of respective input currents flowing into the voltage regulators as the first and second loads vary. The source of the reference voltage level may comprise a Zener diode, the reference voltage level varying with a sum of the first and second control currents.

Brief Description of the Drawings

FIGURE 1 is a simplified schematic diagram illustrating the invention as applied to a television;

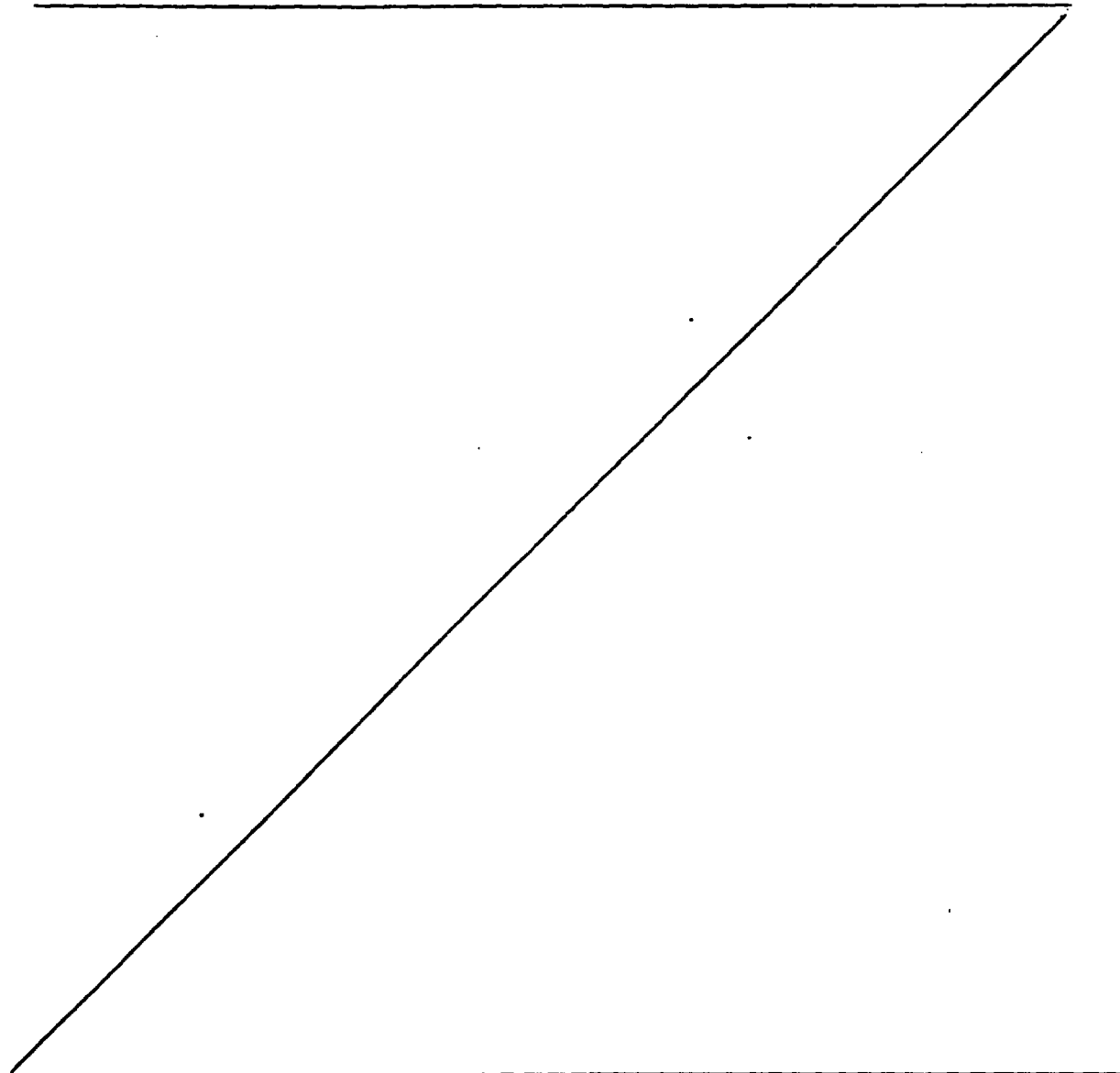


FIGURE 2 is a schematic block diagram showing the relationship of the standby and run power supplies and loads; and,

FIGURE 3 is a partial schematic diagram showing another embodiment of the standby/run voltage regulators.

5 Detailed Description of the Preferred Embodiments

In FIGURE 1, the television apparatus is powered from AC mains, typically wired to a plug 22 inserted in a wall outlet which is always energized. When the television is "off," i.e., not receiving or displaying a signal, some elements of the apparatus
10 are still powered from the AC mains by the standby power supply 30. Without limitation, examples of circuits which remain powered in the standby mode are instant-on circuits, clocks and timers, remote controls having on/off power switching capability, sophisticated control or tuning functions, volatile
15 digital memories and the like. For purposes of illustration, such circuits are represented in FIGURE 1 by standby load 32, which comprises an infrared receiver 42 responsive to a remote control 44. These same circuits are also powered in the run mode, but according to the invention the circuits are segregated into
20 standby loads, powered from the standby regulator 45, and run loads, powered from a separate run regulator 55.

Means are provided for generating an unregulated DC standby voltage V_1 whenever the television apparatus is coupled to active AC power mains, and a standby regulator 45 is coupled to the
25 unregulated DC standby voltage V_1 , operable to produce a regulated standby voltage V_{STBY} . The particular regulated voltage may be, for example, 5 V DC, as appropriate to power CMOS integrated circuits and the like. A standby transformer 60 has a primary winding 62 coupled across the AC mains, and a secondary
30 winding 64 coupled to a rectifier such as full wave bridge rectifier 66. Fuses, chokes, current limiting resistors and the like can be included, but are not shown to avoid overburdening the drawing. The full wave rectified output of the bridge rectifier 66 is coupled to a filter capacitor 68, which charges to the
35 unregulated voltage V_1 . This voltage is somewhat higher than the desired regulated voltage, providing sufficient range for regulation. V_1 can be, for example, 12 V to 16 V for obtaining a regulated output voltage of 5 V.

The unregulated voltage V_1 is coupled to the collector of a series pass transistor 72 of the standby regulator 45. This transistor 72 conducts sufficient current to maintain the voltage at its emitter at the desired output level, being controlled by a feedback or control transistor 74 and a Zener diode 80 in series. Zener diode 80 is a source of a reference voltage level V_Z . The base of the feedback or control transistor 74 is coupled to the regulated output V_{STBY} through feedback resistor 82. The collector of the feedback or control transistor 74 is coupled to the base of the series pass transistor 72 and to resistor 84, which biases the circuit, providing current from the unregulated supply voltage. A filter capacitor 86 is coupled between the base of feedback transistor 74 and ground.

The emitter of the feedback-control transistor 74 is coupled to the anode of the reverse biased Zener diode 80, whose cathode is coupled to ground. A Zener diode has a steep current vs. voltage characteristic at its reverse breakdown voltage. The Zener 80 thus substantially defines the regulation voltage which is maintained at the emitter of the series pass transistor 72.

However, control or feedback transistor 74 improves regulation by feeding back the actual level at the regulated output, making the regulator less sensitive to current loading variations which may produce a corresponding variation in the base-emitter voltage at series pass transistor 72. A control current I_1 generated by transistor 74 biases the reference voltage level of the Zener diode 80.

Means are also provided for generating an unregulated voltage for the run regulator, active upon changing from a standby mode to a run mode. There are a number of possible techniques for generating the unregulated run voltage. For example, a power supply such as a switched mode supply 100 can be switchable so as to provide certain outputs in the run mode only, i.e., to disable certain of its outputs V_A , V_B , V_C in the standby mode, which can then be used as unregulated run voltages.

In the embodiment shown in FIGURE 1, the unregulated voltage is derived from the flyback transformer 106, which is only active during horizontal deflection. It is also possible to draw current from a "standby" supply for input to the run mode

regulator, provided switched means are available to disable such current draw when in the standby mode. The invention is applicable to any voltage source which is available only in the run mode, and is to be regulated to a lower voltage.

5 The AC mains are coupled to a second bridge rectifier 102, the output of which is coupled to a filter capacitor 104, which charges to the B+ voltage. This voltage is coupled to the primary winding of the flyback transformer 106 and is available whenever the television is coupled to the AC mains, in a manner similar to
10 the standby unregulated voltage. However, no current is drawn from the B+ supply unless the horizontal deflection circuits are active.

 The horizontal oscillator and drive circuit 150, which drives the horizontal deflection circuit, is enabled or disabled
15 when changing into the run mode or the standby mode, respectively. This is a convenient means for providing a run mode power supply, and is illustrated by way of example.

 An output from a standby load which changes from standby to run is coupled to the horizontal drive circuit 150, which
20 comprises a horizontal oscillator coupled to suitable synchronization means (not shown). The horizontal drive circuit is coupled to a horizontal output transistor 152, which is coupled between the primary winding of the flyback transformer and ground. According to the simplified embodiment shown, a
25 clamping diode DC and retrace capacitor CR are coupled between the collector of the horizontal output transformer (and to the primary winding of the flyback transformer) and ground. The horizontal deflection coils YH and the trace capacitor CS are coupled in series with one another, and in parallel with the
30 horizontal output transistor. During horizontal scanning, retrace pulses or flyback pulses occur on the primary winding of the flyback transformer and on the secondary windings 108. Various secondary windings can be employed for different purposes such as providing the high voltage output U, as well as providing
35 unregulated run mode voltages at various voltage levels as needed.

 The standby load responsive to the remote control is operable to turn the horizontal deflection circuits on (in the run

mode) and off (in the standby mode). The unregulated DC run voltage is derived from one of the secondary windings 108 of the flyback transformer. A secondary winding 108 is coupled to a rectifier, shown as series diode 122, which charges filter capacitor 124 to the unregulated DC run voltage V2. A run regulator 55 is coupled to the unregulated DC run voltage V2, and is operable to produce a regulated run voltage VRUN. The run regulator 55 is similar to the standby regulator 45, namely having a series pass transistor 126 whose collector is coupled to the unregulated run voltage, and which conducts sufficient current to maintain the voltage at its emitter at the desired output level. The base of the series pass transistor 126 is coupled to a feedback or control transistor 128 and to the same Zener diode 80 which provides a reference to the standby regulator 45. A control current I_2 generated by transistor 128 also biases the reference voltage level of the Zener diode 80. The base of the feedback or control transistor 128 is coupled to the regulated output VRUN through feedback resistor 132. The collector of the feedback or control transistor 128 is coupled to the base of the series pass transistor 126 and to resistor 136, which biases the circuit, providing current from the unregulated run supply voltage. A filter capacitor 138 is coupled between the base of transistor 128 and ground.

Accordingly, the emitters of the control transistors 74, 128 for both the run and standby regulator are coupled together at a summing junction, namely at the anode of reverse biased Zener diode 80, whose cathode is coupled to ground. The Zener diode has a steep current vs. voltage characteristic at its reverse breakdown voltage. The Zener 80 thus substantially defines the regulation voltage which is maintained at the emitter of both the series pass transistors 72, 126. However, the two control or feedback transistors 74, 128 improve regulation by feeding back the actual level at the respective regulated output, and accommodate current load variations while causing the run and standby regulated output voltages to track one another.

In FIGURE 1, the standby and run loads 32, 52 can be considered as two integrated circuits, one powered by the regulated standby voltage VSTBY and the other powered by the

regulated run voltage VRUN. The standby and run loads 32, 52 are coupled by signal lines 142 for operation in the run mode, i.e., at least one output of one of the circuits is coupled to at least one input of the other. Whereas the standby regulator 45 and the run regulator 55 are coupled via feedback paths that cause the regulated DC voltage produced by one of the standby regulator and the run regulator to be factored into the regulation of the other, in the run mode the regulated standby voltage and the regulated run voltage track one another and remain very nearly equal notwithstanding variations in loading.

The operation of the tracking regulators can be appreciated from FIGURE 2, which shows the power supply, regulation and load sections according to FIGURE 1 in block form. The standby and run mode unregulated supplies 16, 18 are coupled to the AC mains 22, but the run supply can be enabled or disabled. The run supply can be a separate supply as in FIGURE 1, or can be simply provided by a certain output of a switched mode power supply, for example operated by a switched mode controller. The unregulated outputs V1 and V2 are regulated by the standby and run regulators 45, 55 to produce regulated power to the respective standby and run loads 32, 52, which have coupled signal lines 142. Tracking is achieved by coupling the reference inputs to the two regulators 45, 55 together, and in particular to the same reference Zener diode 80. This provides conductive paths for control currents I_1 and I_2 . Since the communicating load circuits 32, 52 are powered from equal voltages, the inputs to either one cannot substantially exceed its supply voltage. The load circuits remain functional, for operations in the run mode, as well as for standby operations such as switching into the run mode by enabling the run mode supply.

FIGURE 3 illustrates another embodiment of the invention, showing a number of run and standby supply voltages which are preferably generated for operation of various loads. FIGURE 3 shows voltage regulators of a higher tolerance which can be coupled into the circuit in place of the simplified regulators shown in FIGURE 1, including particular component values which are such as to provide a nominal $5.15 \text{ V} \pm 3\%$ with loading of the standby supply of about 40 mA, and the run supply up to 1 A. The

run and standby supplies shown have regulated outputs that track each other to within 150 mV.

5 The unregulated standby supply voltage and the run voltages in this embodiment are not shown in FIGURE 3, for purposes of clarity. This circuit accommodates the very different current requirements in the run mode and the standby mode. In the run mode, the nominal 16 V standby unregulated input to the standby regulator is at 16 V, but in the standby mode it may drop to 12 V due to action of the switched mode power supply controller. This
10 level is still sufficient to provide regulated standby voltages of 5 V, 12 V and 4.6 V, with suitable accuracy in both the run mode and the standby mode. The current for the run mode regulator in the embodiment shown is substantially derived from the 7.5 V standby supply. However, a 12 V unregulated run supply, which
15 appears only in the run mode, is coupled to the base of transistor Q07 via resistor R00, and enables or disables the series pass transistors Q00 and Q07 of the run regulator as a function of whether the 12 V run supply is present or not. The series pass transistor Q00 regulates the 7.5 V STBY supply to a run supply
20 voltage of 5 V in the run mode, and does not conduct in the standby mode. The 12 V and 4.6 V standby voltages are provided from reverse biased Zener diodes CR09 and CR02, respectively, the latter being the reference Zener for the tracking regulators providing the 5 V standby and 5 V run regulated outputs. The
25 reference voltage level V_Z of Zener diode CR02 will vary with the current supplied to it. The reference voltage level V_Z will be 4.6 V at 5 ma, but will fall to 4.5 V at 4.5 ma and 4.0 V at 0.25 ma. Diode CR09 is coupled by resistor R01 to the nominal 16V unregulated standby voltage, and also by resistor R17 to the
30 anode of Zener diode CR02. Capacitor C08 is a relatively large storage capacitor coupled in parallel with Zener diode CR02. Capacitors C01 and C14 are filter capacitors in parallel with the 4.6 V and 12 V regulated outputs.

35 In the embodiment according to FIGURE 3, the series pass transistors are arranged as Darlington pairs, with small resistances R18, R19 coupled between the emitter of the respective Darlington transistor Q09, Q07 which is coupled to the feedback transistor Q11, Q10, and the base of the other coupled

Darlington transistor Q04, Q00, which carries a greater amount of current. The small resistors R18, R19 help to roll off high frequency noise and prevent possible oscillation. A 1 μ F (microfarad) capacitor C15 coupled to the base of the run

5 regulator Darlington pair helps to filter out noise from the unregulated 12 V run supply, which provides a current supply to transistor Q10 through resistor R00. Current supply to the standby regulator is provided from the 16 V standby supply through resistor R02

10 The variations in base-emitter voltages for the power devices Q00 and Q04 are eliminated by feedback from the feedback transistors Q11, Q10 in the form of the control currents I_1 and I_2 respectively. Only the two feedback transistors Q11, Q10 contribute to an error due to base-emitter voltage variations
15 with changes in loading. However, the collector-emitter current for the feedback transistors Q11, Q10 is small, and is of the same order of magnitude. Therefore, variation of the regulated output voltages is minimal.

The nominal 16 V unregulated standby supply voltage can
20 drop to about 12 V in the standby mode, and is 16V in the run mode, which is handled by using a second Zener diode CR09 at 12 V, to regulate the voltage supplied to the 4.6 V Zener diode CR02. Zener diode CR02 is preferably a 2% Zener.

In the circuit of the invention, the regulated run and standby
25 voltages are insensitive to almost all variations between the elements. Supply variations do not affect tracking, only the voltage offsets. Variations should be less than 2%, the tolerance of the Zener reference diode CR02. The two regulated supply voltages track within 100 mV to 150 mV in the worst case.



14

CLAIMS:

1. A power supply system, comprising:

an unswitched voltage source energized during first
5 and second modes of operation;

first voltage regulating means energized by said
unswitched voltage source for energizing a first variable
load at a first regulated voltage level and generating a
first control current which varies with said first
10 variable load;

a source of a reference voltage level coupled to
said first voltage regulating means for establishing said
first regulated voltage level, said reference voltage
level being biased by said first control current;

15 a switched voltage source energized only during said
second mode of operation;

second voltage regulating means energized by said
switched voltage source for energizing a second variable
load at a second regulated voltage level and generating a
second control current which varies with said second
20 variable load; and

said source of said reference voltage level also
being coupled to said second voltage regulating means for
establishing said second regulated voltage level, said
25 source of said reference voltage level also being biased
by said second control current, each one of said first
and second regulated voltage levels tracking variations
of the other one of said first and second regulated
voltage levels.

30 2. The system of claim 1, wherein said first mode
of operation corresponds to a standby mode and said
second mode of operation corresponds to a run mode of
operation.

35 3. The system of claim 1, wherein said first and
second voltage regulating means comprise respective
active feedback circuits for generating said first and



15

second control currents.

4. The system of claim 1, wherein said first and second voltage regulating means comprise respective comparators for generating said control currents at magnitudes related to a difference between said reference voltage level and said first and second voltage levels respectively as said first and second loads vary.

5. The system of claim 1, wherein each of said voltage regulating means comprises means for generating said respective control currents by variably diverting respective parts of respective input currents flowing into said voltage regulating means as said first and second loads vary.

6. The system of claim 1, wherein said source of said reference voltage level comprises a Zener diode, said reference voltage level varying with a sum of said first and second control currents.

7. The system of claim 1, wherein said first and second loads are interconnected integrated circuits of a kind subject to SCR latching when a difference between said voltage levels generated by said first and second voltage regulating means exceeds a tolerance, said voltage levels generated by said first and second voltage regulating means not differing from one another by more than said tolerance during said second mode of operation.

8. A power supply system substantially as hereinbefore described with reference to the accompanying drawings.