(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 756 222 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
29.01.1997 Bulletin 1997/05

(51) Int. Cl.[6]: **G05F 1/569**

(21) Application number: **96110932.9**

(22) Date of filing: **06.07.1996**

(84) Designated Contracting States:
DE ES FR GB IT

(30) Priority: **25.07.1995 US 507690**

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(54) Clamp circuit for remotely sensed voltage

(57) An apparatus provides power to a remote load (R_{LOAD}), such as a plurality of digital integrated circuits. The power is routed to the load through a first plurality of pins of a connector (P1), which is mounted, for example, on a periphery of the apparatus's printed circuit board. A feedback path (FB) is provided from the load to the apparatus in order to monitor a voltage (V_{LOAD}) at the load. The feedback path is routed to the apparatus through a second plurality of pins of the connector. In order to facilitate testing of the apparatus, the output of the apparatus is isolated from the feedback path by a resistance (R2). A switch device (D2) is coupled in parallel with the resistance to prevent the output voltage of the apparatus from exceeding a level which the load can safely tolerate.

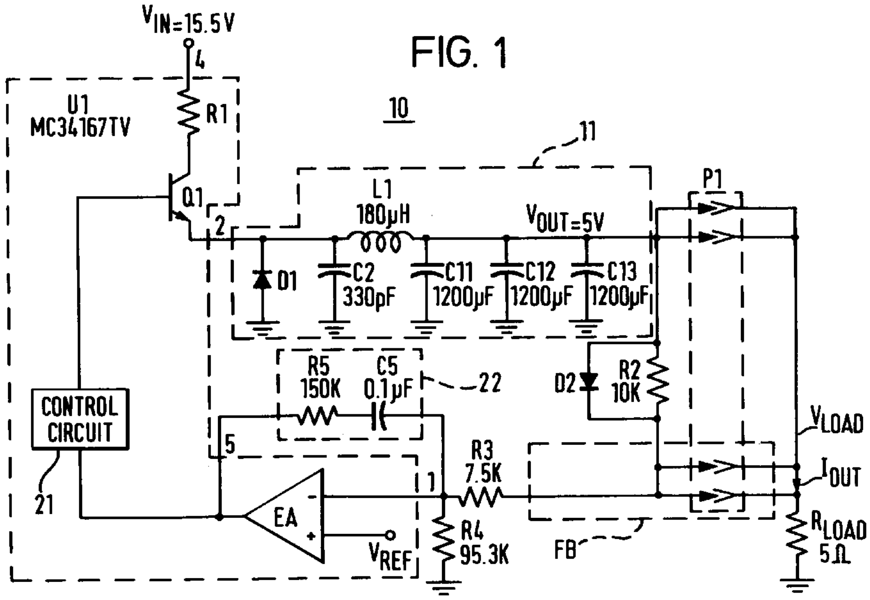

FIG. 1

EP 0 756 222 A2

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Description

This invention relates generally to the field of power supplies, and, in particular, to power supplies which use a feedback path to remotely sense an output voltage at a load.

In the manufacture of an electronic device, it may be desirable to situate different circuits and subsystems on separate printed circuit boards. If the electronic device requires several printed circuit boards, it may be advantageous to dedicate one printed circuit board for the device's power supply. The remaining printed circuit boards may comprise a load, which may include, for example, a plurality of digital integrated circuits.

A prior-art power supply 20 is shown in FIGURE 2. Power can be routed from an output of power supply 20 to a load R_{LOAD}, which may comprise the plurality of digital loads, through a connector P1, which may be mounted on a periphery of the power supply's printed circuit board.

It may be useful to know an actual output voltage V_{LOAD} at a point near load R_{LOAD} so that power supply 20 can raise an output voltage V_{OUT} to compensate for a voltage drop between output voltage V_{OUT} and the load voltage V_{LOAD}. This may be done by providing a remote sensing feedback path FB from a point near load R_{LOAD} to an input of an error amplifier EA through connector P1, as shown in FIGURE 2. If the load voltage V_{LOAD} is not within its allotted tolerance, error amplifier EA and control circuit 21 can adjust the conduction time of a switch device Q1 so as to raise output voltage V_{OUT} and, consequently, load voltage V_{LOAD}.

It may be beneficial to test each printed circuit board separately prior to final assembly within the electronic device. Power supply 20, for example, can be tested under simulated load conditions. To facilitate such testing, power supply 20 may include, as shown in FIGURE 2, a resistance R2 coupled between an output of the power supply and the remote sensing feedback path FB. Resistance R2 provides a feedback path for the output voltage V_{OUT} to error amplifier EA, thereby allowing error amplifier EA to sense and regulate output voltage V_{OUT} in the event of a no-load condition at the output of power supply 20. In addition, resistor R2 is sufficiently large that it does not interfere with the remote sensing function provided by remote sensing feedback path FB when power supply 20 is assembled within the electronic device.

A situation may develop wherein load voltage V_{LOAD} may be interrupted by a fault condition, for example, an intermittent connection at connector P1, transients or spikes on remote sensing feedback path FB or a short circuit load condition. In any such event, or because of other mechanisms, load voltage V_{LOAD} at remote sensing feedback path FB may drop to a low level because output voltage V_{OUT} is isolated from remote sensing feedback path FB by resistor R2. In that case, error amplifier EA causes power supply 20 to compensate for the decrease in load voltage V_{LOAD} by increasing output voltage V_{OUT} to a potentially unacceptably high level, thereby possibly damaging the load that is coupled to the output of power supply 20.

In an apparatus according to an inventive arrangement taught herein, the output voltage potential of a power supply, as described above, is held below a predetermined voltage potential in the event that the apparatus attempts to increase its output voltage potential in response to a fault condition.

According to an aspect of the inventive arrangement, such an apparatus comprises: a source of voltage potential; means for sensing the voltage potential at a load; means for isolating the sensing means from the source; means for adjusting the voltage potential having an input coupled to the sensing means; and, clamping means coupled to the source and to the sensing means.

The clamping means may comprise a diode having an anode coupled to the source of voltage potential and a cathode coupled to the sensing means.

The isolating means may comprise a resistance.

The adjusting means may comprise an amplifier having a non-inverting input coupled to an amplifier reference voltage potential and an inverting input, and a switch device coupled to an output of the amplifier.

The sensing means may comprise a feedback path coupled from the load to the inverting input of the amplifier.

According to another aspect of the inventive arrangement taught herein, such an apparatus comprises: a source of voltage potential; means for sensing the voltage potential at a load; means for isolating the sensing means from the source; and, a switch device coupled to the source and to the sensing means.

The switch device may comprise a diode having an anode coupled to the source of voltage potential and a cathode coupled to the sensing means. The switch device may conduct a current after a difference in the voltage potential between the source and the load exceeds a predetermined value. While the switch device conducts the current, it may render the isolating means inoperative. The isolating means may comprise a resistance.

In each of the embodiments of the inventive arrangement taught herein, the use of a diode as a clamping means or as a switch device has been found to be particularly advantageous for at least two reasons. First, the diode provides a low-resistance path for a current to flow from the apparatus to the load without affecting a remote sensing function provided by the sensing means during normal operation of the apparatus. Second, the diode consumes relatively little space on the apparatus's printed circuit board in relation to the amount of power that the diode is required to dissipate.

The above, and other features and advantages of the present invention will become apparent from the following description read in conjunction with the accompanying drawings, in which like reference numerals designate the same elements.

FIGURE 1 is a schematic diagram of a power supply circuit according to an inventive arrangement.

FIGURE 2 is a schematic diagram of a prior-art buck-topology power supply circuit.

A buck-topology power supply 10, shown in FIGURE 1, derives an input voltage V_{IN} of 15.5 V from a secondary winding of a flyback power transformer (not shown). Power supply 10 provides a substantially regulated output voltage V_{OUT} of 5 V to a load comprising a plurality of digital integrated circuits, represented in FIGURE 1 by a resistor R_{LOAD}, through a connector P1.

A power switching regulator U1 includes an error amplifier EA, a switch device Q1, a reference voltage V_{REF} for a non-inverting input of error amplifier EA and a control circuit 21 for switch device Q1. Power switching regulator U1 is represented in FIGURE 1 by an integrated circuit which has the industry part number MC34167TV and which is manufactured by Motorola. Power switching regulator U1 can, however, comprise any integrated circuit that is functionally compatible with the MC34167TV, such as, for example, the integrated circuit which has the industry part number L4960 and which is manufactured by SGS Thomson Electronics.

A power stage 11 of power supply 10 comprises diode D1, inductor L1, and capacitors C11, C12 and C13, which correspond in function to capacitor C1 of FIGURE 2. A first terminal of inductor L1 is coupled to pin 2 of power switching regulator U1. Diode D1 has a cathode coupled to the first terminal of inductor L1 and an anode coupled to a reference voltage potential of power supply 10. Capacitor C2 is coupled in parallel with diode D1. First terminals of capacitors C11, C12 and C13 are coupled to a second terminal of inductor L1, and second terminals of capacitors C11, C12 and C13 are coupled to the reference voltage potential of power supply 10.

Resistor R2 has a first terminal coupled to the first terminals of capacitors C11, C12 and C13, and a second terminal coupled to a first terminal of resistor R3. Diode D2 has an anode coupled to the first terminal of resistor R2 and a cathode coupled to the second terminal of resistor R2.

Resistor R3 has a second terminal coupled to a first terminal of resistor R4. The first terminal of resistor R4 is also coupled to pin 1 of power switching regulator U1. A second terminal of resistor R4 is coupled to the reference voltage potential of power supply 10.

The first terminal of resistor R2 is coupled to a first plurality of pins of connector P1. The second terminal of resistor R2 is coupled to a second plurality of pins of connector P1. A first terminal of digital loads R_{LOAD} is coupled to the first and second pluralities of pins of connector P1. A second terminal of digital loads R_{LOAD} is coupled to the reference voltage potential of power supply 10. The effective load resistance of digital loads R_{LOAD} may be approximately 5Ω, as shown in FIGURE 1.

A compensation network 22 for error amplifier EA is formed by capacitor C5 and resistor R5. Capacitor C5 has a first terminal coupled to a second terminal of resistor R3 and a second terminal coupled a first terminal of resistor R5. A second terminal of resistor R5 is coupled to pin 5 of power switching regulator U1.

Power switching regulator U1 and power stage 11 convert input voltage V_{IN} into output voltage V_{OUT} in a manner that is well known in the art. The load voltage V_{LOAD} can be measured at a point near the digital loads R_{LOAD} to ensure that load voltage V_{LOAD} is within its allotted tolerance. Load voltage V_{LOAD} is fed back through the second plurality of pins of connector P1 and along remote sensing feedback path FB. Voltage V_{LOAD} is then divided by the voltage divider network formed by resistors R3 and R4, before being applied to pin 1 of power switching regulator U1. No load current flows back to power supply 10 through the remote sensing feedback path FB. If load voltage V_{LOAD} is not within its allotted tolerance, error amplifier EA and control circuit 21 adjust the conduction time of switch device Q1, thereby adjusting output voltage V_{OUT} such that load voltage V_{LOAD} returns to a level that is within its allotted tolerance.

Resistor R2 is included in power supply 10 to facilitate testing of power supply 10 prior to final assembly. During testing of power supply 10, resistor R2 provides a feedback path from output voltage V_{OUT} to pin 1 of power switching regulator U1, thereby allowing power switching regulator U1 to sense and regulate output voltage V_{OUT} in the event of a no-load condition at the output of power supply 10. Resistor R2 is sufficiently large that it does not interfere with the remote sensing function provided by remote sensing feedback path FB when power supply 10 is assembled within an electronic device.

Diode D2 protects digital loads R_{LOAD} from a situation wherein output voltage V_{OUT} rises to the level of input voltage V_{IN}. Such a situation might arise if load voltage V_{LOAD} on the remote sensing feedback path FB drops to a value which is too low. This may occur, for example, because of an intermittent connection at the first plurality of pins of connector P1. Regardless of the particular mechanism whereby load voltage V_{LOAD} is caused to drop, such a condition can result in resistor R2 undesirably forming a voltage divider network with the digital loads R_{LOAD}. The load voltage V_{LOAD} at the first terminal of digital loads R_{LOAD} thus becomes

$$5V*\left(\frac{5\Omega}{10k\Omega+5\Omega}\right),$$

or approximately 2.5 mV. Load voltage V_{LOAD} can drop to an unacceptably low level because the effective load resistance of digital loads R_{LOAD} is small in relation to the value of resistor R2. Thus, the effective load resistance of digital loads R_{LOAD} can be significantly greater than the 5Ω value shown in FIGURE 1, so long as the effective load resistance of digital loads R_{LOAD} remains small in relation to resistor R2.

Sensing this drop in load voltage V_{LOAD}, power switching regulator U1 attempts to compensate by raising output voltage V_{OUT} to a level that can become as high as input voltage V_{IN}. Such a rise in output voltage V_{OUT} may damage the plurality of digital integrated circuits that comprises digital loads R_{LOAD}.

As output voltage V_{OUT} begins to rise, diode D2 becomes forward biased, thereby clamping output voltage V_{OUT} to the load voltage V_{LOAD} plus the forward voltage drop of diode D2. Once diode D2 is forward biased, it also provides a low-resistance path for an output current I_{OUT} to flow to digital loads R_{LOAD}.

The use of diode D2 in such a manner is advantageous for at least two reasons. First, during normal operation of power supply 10, diode D2 is non-conducting and thus has no deleterious effect on the remote sensing function provided by remote sensing feedback path FB. Second, diode D2 also consumes relatively little space on the power supply's printed circuit board in relation to the amount of power that the diode is required to dissipate.

Claims

1. An apparatus, comprising:

    a source (V_{OUT}) of voltage potential;
    means (FB) for sensing said voltage potential at a load (R_{LOAD});
    means (R2) for isolating said sensing means (FB) from said source (V_{OUT}); and,
    means (U1) for adjusting said voltage potential having an input coupled to said sensing means (FB);
    characterized by:
    clamping means (D2) coupled to said source (V_{OUT}) and to said sensing means (FB).

2. The apparatus of claim 1, characterized in that said voltage potential (V_{OUT}) does not exceed a predetermined value.

3. The apparatus of claim 1, characterized in that said clamping means (D2) provides a low-resistance path for a current to flow from said apparatus to a load (R_{LOAD}).

4. The apparatus of claim 1, wherein said clamping means is characterized by a diode (D2) having an anode coupled to said source (V_{OUT}) and a cathode coupled to said sensing means (FB).

5. The apparatus of claim 1, wherein said adjusting means (U1) is characterized by:

    an amplifier (EA) having a non-inverting input coupled to an amplifier reference voltage potential and an inverting input; and,
    a switch device (Q1) coupled to an output of said amplifier (EA).

6. The apparatus of claim 5, wherein said sensing means (FB) is characterized by a feedback path coupled from said load (R_{LOAD}) to said inverting input of said amplifier (EA).

7. The apparatus of claim 1, wherein said isolating means is characterized by a resistance (R2).

8. An apparatus, comprising:

    a source (V_{OUT}) of voltage potential;
    means (FB) for sensing said voltage potential at a load (RLOAD); and,
    means (R2) for isolating said sensing means (FB) from said source (V_{OUT});
    characterized by:
    a switch device (D2) coupled to said source (V_{OUT}) and to said sensing means (FB).

9. The apparatus of claim 8, characterized in that said switch device (D2) conducts a current after a difference in said voltage potential between said source (V_{OUT}) and said load (R_{LOAD}) exceeds a predetermined value.

10. The apparatus of claim 9, characterized in that said switch device (D2) renders said isolating means (R2) inoperative.

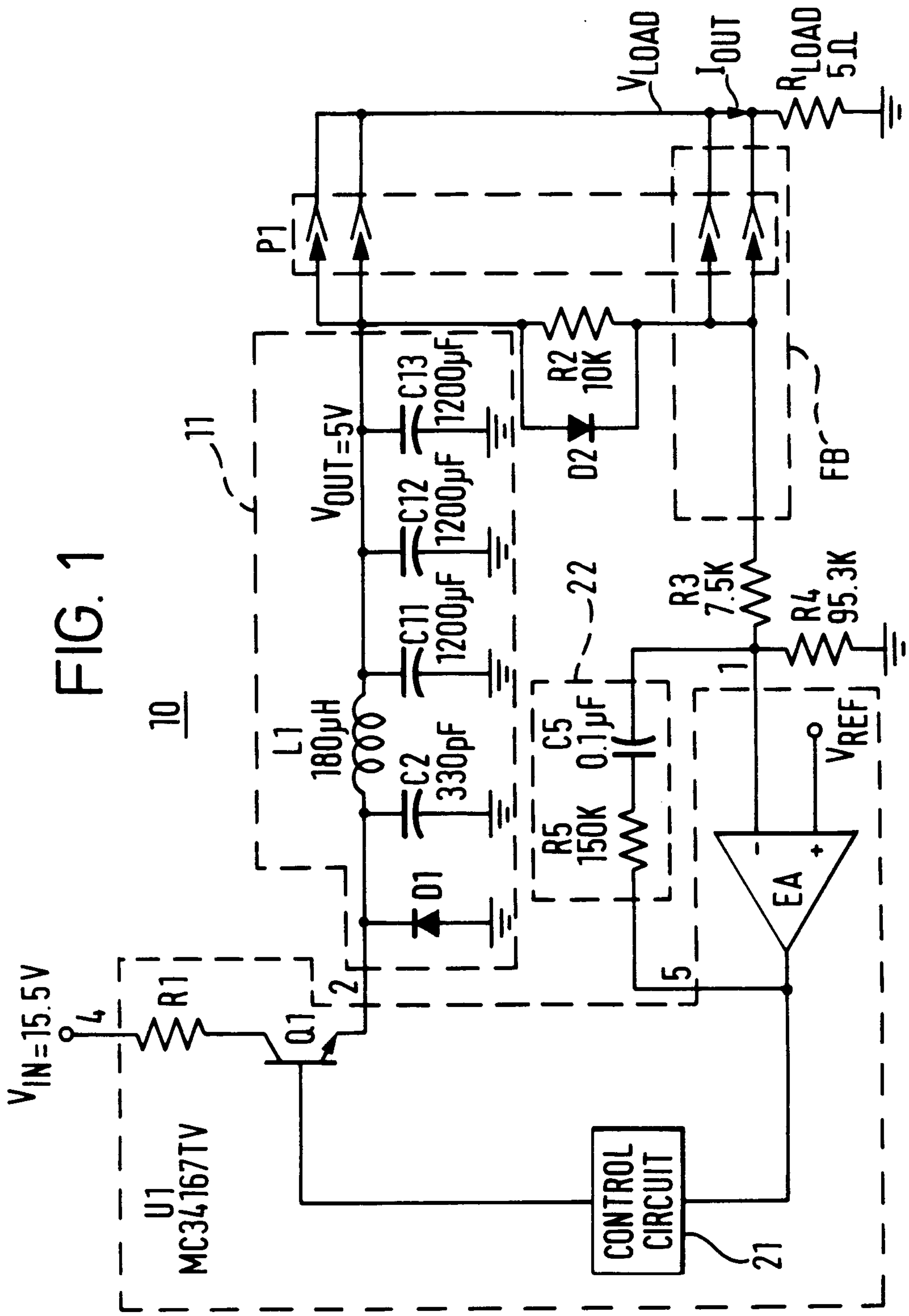
11. The apparatus of claim 8, wherein said switch device (D2) is characterized by a diode (D2) having an anode coupled to said source (V_{OUT}) and a cathode coupled to said sensing means

12. The apparatus of claim 8, wherein said isolating means (R2) is characterized by a resistance (R2).

13. An apparatus, comprising:

    a source (V_{OUT}) of voltage potential;
    a feedback path (FB) for sensing a load voltage potential (V_{LOAD}); and,
    a resistance (R2) coupled between said source and said feedback path;
    characterized by:
    a diode (D2) coupled in parallel with said resistance.

14. The apparatus of claim 13, characterized in that said diode (D2) conducts a current after said voltage potential of said source (V_{OUT}) exceeds said load voltage potential (V_{LOAD}) by a predetermined value.


10
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4
R1
Q1
2
U1
MC34167TV
CONTROL
CIRCUIT
21
D1
L1
180µH
C2
330pF
C11
1200µF
C12
1200µF
C13
1200µF
VOUT=5V
11
R5
150K
C5
0.1µF
22
EA
VREF
5
1
R3
7.5K
R4
95.3K
R2
10K
D2
FB
P1
VLOAD
IOUT
RLOAD
5Ω

FIG. 1

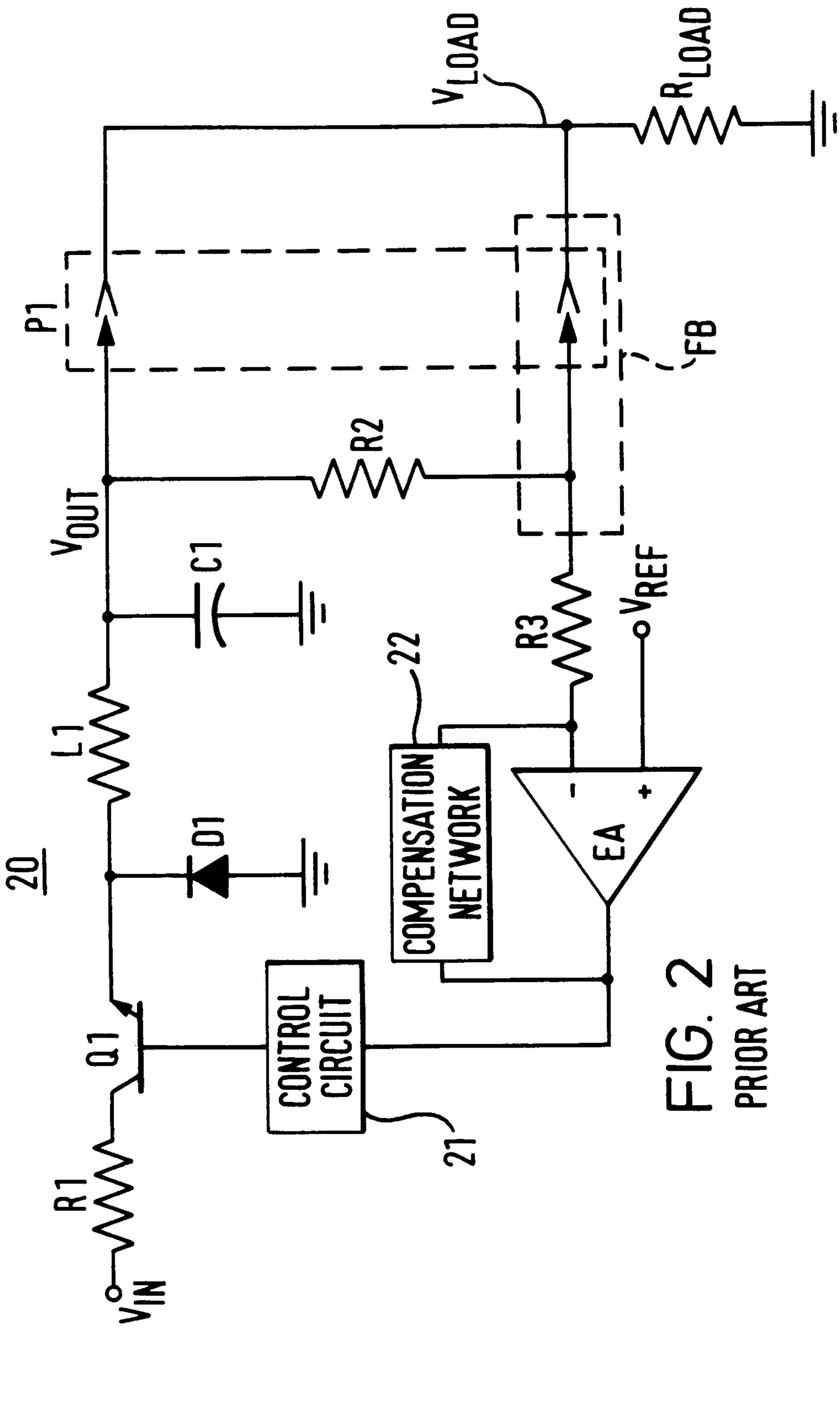

FIG. 2
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