

Shunt Regulators

5 This invention relates to shunt regulators which can
be used to maintain a power supply at a desired voltage
level over a wide range of input current. A key performance
parameter is the ratio of the minimum operating current of
the regulator to the maximum current it can absorb. For
10 example, in an electronic telephone, a shunt regulator may
need to be able to absorb more than 100 mA but should be
able to operate on less than 1 mA to allow the instrument to
function with total currents of only a few mA. In addition
the regulator must provide a low output impedance over its
15 whole operating range and its a.c. stability must be readily
assured.

It is thus an object of the present invention to
provide such a low output impedance wide current range shunt
regulator. Accordingly, a shunt regulator for regulating
20 the voltage level of a power supply comprises a pair of
input nodes for coupling across the power supply, a
reference voltage generator providing a reference voltage, a
potential divider network coupled between the regulator
input nodes and providing an output to a first input of a
25 comparator, the comparator having a second input coupled to
receive the reference voltage and an output and a shunt
element for absorbing current from the power supply in
dependance on an output signal from the comparator, wherein
there is provided a positive feedback path between the shunt
30 element and the comparator for controlling the gain of the
comparator in dependence on the current flowing in the shunt
element.

In one embodiment of the invention, the positive
feedback path includes a current mirror having an input for
35 receiving a signal representative of the current flowing in
the shunt element and an output coupled to a bias input of
the comparator for providing a bias signal proportional to
the current flowing in the shunt element. Preferably, the
shunt element provides an output signal to the current

mirror which comprises an image of the current flowing in the shunt element. The shunt element thus preferably
5 comprises a first transistor having a control electrode coupled to the comparator output, a first current electrode coupled to the control electrode of a second transistor, and a second current electrode coupled to a first current
10 electrode for a third transistor, the second transistor having first and second current electrodes coupled to the regulator input nodes and the third transistor having a second current electrode coupled to a regulator input node and a control electrode coupled to the current mirror input. Preferably, the current mirror also includes a
15 start-up current source for providing a start-up current to the current mirror.

One embodiment of the invention will now be more fully described by way of example with reference to the drawings, of which:

20 Figure 1 shows a known basic shunt regulator arrangement; and

Figure 2 shows a shunt regulator arrangement according to the invention.

Thus, a standard, known shunt regulator may be
25 considered to comprise the arrangement shown in Figure 1. The regulator receives an input current from a power supply to be regulated represented by current generator 1 coupled to input terminals 2,3. A reference voltage generator 4, also coupled to input terminals 2,3 provides an output at
30 node 5 to one input of a voltage comparator 9. The second input of comparator 9 receives a fraction of the voltage developed between terminals 2,3 via a resistive potential divider network composed of resistors 7,8. The comparator output at node 11 is coupled to a control electrode of a
35 shunt element 10, which, in this example, is illustrated as bipolar transistor. The shunt element 10 has its current electrodes coupled to the input terminals 2,3 of the regulator.

In operation, assuming that the input current exceeds that required to operate the shunt regulator and any other circuits coupled to terminals 2,3, then the voltage developed between the terminals will rise to a level at which the shunt element 10 is brought into conduction by the negative feedback loop established via the potential divider network 7,8 and comparator 9 so as to absorb the excess current available. It will be understood that the voltage developed between terminals 2,3 can thus be regulated to a value determined by the reference voltage produced at node 5 by the reference voltage generator 4 and the ratio of the resistors 7,8 of the potential divider network.

The performance of a known shunt regulator, such as that described above, may become inadequate if the current to be absorbed varies over a very wide range. The maximum gain of comparator 9 must usually be restricted to avoid high frequency stability problems which are inherent in any feedback system. It may therefore develop significant input offset voltage variations if the control signal it must supply to the shunt element 10 varies widely. These offset variations cause variations in the regulated voltage and thus cause the regulator to present a finite resistance between terminals 2,3 instead of the ideal zero resistance.

Additionally, the comparator 9 must be able to supply a control signal to the shunt element 10 corresponding to the maximum current to be absorbed. If the shunt element is a bipolar transistor, as in this arrangement, then the control signal is the base current of the transistor. The comparator must then be biased at an appropriate current level which may be too high for operation at the minimum input current level.

To overcome the above problems, the invention provides a shunt regulator having the arrangement shown in Figure 2. This shows only the part of the regulator between nodes 2,3 and 5,6 of Figure 1, that is the comparator 9 and shunt element 10, which are indicated in Figure 2 by dashed-outline boxes. The remainder of the arrangement of

Figure 1 is applicable in an analogous way to that of Figure 2.

Thus, in the arrangement of Figure 2, the comparator 9 is biased at a current level related to the current flowing in the shunt element 10. The control signal required from the comparator will then remain in a fixed relationship with the bias current independently of the shunt current flowing. The comparator offset thus becomes independent of the shunt current so that the regulator output resistance becomes very low. Furthermore, when the shunt current is low, the comparator consumes a very low current so that the low current performance of the regulator is not compromised.

In the embodiment of Figure 2, the comparator and shunt element of a regulator are realised in bipolar IC technology. The comparator 9 comprises a pair of transistors 90,91 having their control electrodes coupled to receive comparator inputs 5,6 respectively, and their emitters coupled together and to receive a bias current I_B . The collector of transistor 90 is coupled via a diode 92 to the regulator input node 3 and to the base of transistor 93 whose emitter is coupled to the regulator input node 3 and whose collector is coupled to the collector of transistor 91. The control signal from the comparator is then taken from the junction of the collectors of transistors 91 and 93.

The bias current I_B is generated by a p.n.p. current mirror composed of transistors 94 and 95 which are arranged to provide a gain N of more than unity e.g. 3 defined by the emitter areas of the transistors 94 and 95. The bias current I_B is thus an image of the current flowing at the input of the current mirror but is N times the value. The current mirror is also coupled to a current source 96 which provides a starting current I_0 which may be made arbitrarily small.

The shunt element 10 is composed of transistors 100, 101 and 102. Transistor 100 has its current electrodes coupled between regulator input nodes 2 and 3 to absorb

current I and is controlled by the current flowing in the emitter of transistor 101. Transistor 101 is controlled by the comparator control signal and has its collector coupled to the emitter of transistor 102. Transistor 102 has its collector coupled to regulator input terminal 2 and its base coupled to the base of transistor 95 forming part of the current mirror.

Thus, when the shunt element absorbs current I, the base current at transistor 100 will be $\frac{I}{\beta}$, the base current at transistors 101 and 102 will be $\frac{I}{\beta^2}$ and the bias current will be:

$$I_B = \frac{NI}{\beta^2} + NI_0$$

where B is the current gain of npn transistors 93, 100, 101 and 102 which are assumed to be matched in an IC. From this, it can be seen that the comparator offset V is given by

$$V = \frac{KT}{q} \ln \frac{N + 1 + \frac{NI_0\beta^2}{I}}{N - 1 + \frac{NI_0\beta^2}{I}}$$

which varies from zero for very small values of I to a virtually constant value of

$$\frac{KT}{q} \ln \frac{N + 1}{N - 1} \quad \text{for} \quad I \gg \beta^2 I_0$$

Thus by adjusting the appropriate values, the normal operating range can be made to comply with these conditions and the control signal will then remain independent of the current flowing in the shunt element.

Claims

5 1. A shunt regulator for regulating the voltage level of
a power supply comprises a pair of input nodes for coupling
across the power supply, a reference voltage generator
providing a reference voltage, a potential divider network
coupled between the regulator input nodes and providing an
10 output to a first input of a comparator, the comparator
having a second input coupled to receive the reference
voltage and an output, and a shunt element for absorbing
current from the power supply in dependence on an output
signal from the comparator, wherein there is provided a
15 positive feedback path between the shunt element and the
comparator for controlling the gain of the comparator in
dependence on the current flowing in the shunt element.

2. A shunt regulator according to claim 1, wherein said
20 positive feedback path includes a current mirror having an
input for receiving a signal representative of the current
flowing in the shunt element and an output coupled to a bias
input of the comparator for providing to the comparator a
bias signal proportional to the current flowing in the shunt
25 element.

3. A shunt regulator according to claim 2 wherein said
shunt element provides an output signal to the current
mirror which comprises an image of the current flowing in
30 the shunt element.

4. A shunt regulator according to either claim 2 or claim
3 wherein said shunt element comprises a first transistor
having a control electrode coupled to the comparator output,
35 a first current electrode coupled to the control electrode
of a second transistor, and a second current electrode
coupled to a first current electrode of a third transistor,
the second transistor having first and second current
electrodes coupled to the regulator input nodes and the



third transistor having a second current electrode coupled
to a regulator input node and a control electrode coupled to
5 the current mirror input.

5. A shunt regulator according to any one of claims 2 to
4 wherein said current mirror further comprises a starting
current source coupled to provide a starting current to the
10 current mirror.

6. A shunt regulator substantially as hereinbefore
described by way of example with reference to Figure 2 of
the drawings.

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