VOLTAGE REGULATOR USING DEPLETION MODE PASS DRIVER AND BOOT-STRAPPED, INPUT ISOLATED FLOATING REFERENCE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of application No. 61/221,042 filed on Jun. 27, 2009.

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[0002] Not Applicable

SEQUENCE LISTING OR PROGRAM

[0003] Not Applicable

BACKGROUND

[0004] 1. Field of the Invention

[0005] The described invention relates to electronic systems, more specifically to linear voltage regulation using analog circuits, either discrete, integrated or a combination thereof.

[0006] 2. Description of Related Art

[0007] Advances in electronic circuits have brought requirements for lower voltages yet higher resolution, for example audio circuits may attempt to resolve one part in 2^{19} over a OV to 5V full scale span, which is an attempt to resolve ones of microVolts. Circuits such as these demand an extremely stable and quiet power supply voltage. Linear voltage regulators are used to provide power to electronic circuits in the form of a constant, stable DC voltage. Various regulator circuits have been created to variously improve line and load regulation and decrease power consumption, so as to provide inexpensive and convenient devices with as few as 2 and 3 terminal connections. Voltage regulators exist as either shunt regulators or series pass regulators, with series pass regulators being the more widely used type due to their higher efficiency. Series pass regulators use feedback as provided by an error amplifier that detects and corrects differences between a ratiometric portion of the output voltage and a fixed, constant voltage reference.

[0008] As is well known to those skilled in the art, voltage regulators function as a means to generate a fixed, stable DC output voltage VOUT from a higher and less stable source voltage VIN. Linear voltage regulators typically use a reference voltage and a scaling factor to create the output voltage. Voltage regulators dissipate power as current out times (input voltage -output voltage) and in general it is desired to dissipate the least power possible. Given that the output voltage and current are set by requirements of a load circuit external to the regulator, the only way to minimize power dissipation is to have VIN as close as possible to VOUT while still maintaining regulation. Voltage regulators that continue to regulate with a small difference between VIN and VOUT are known as low drop out regulators. Drop out is defined as the minimum voltage differential VIN-VOUT in which the circuit continues to operate correctly.

[0009] Another desired characteristic of voltage regulators is the rejection of unwanted perturbations, generally called noise, that may appear as part of the input voltage. This is called line rejection or line regulation. A third desired characteristic is the rejection of noise on the output voltage due to the electrical demands of the load, known as load regulation. Other naturally desirable characteristics of any electronic circuit are a low parts count, low cost, high reliability and potential use in a wide variety of situations.

[0010] Series pass regulators typically use a field effect transistor, known by the acronym FET, or a bipolar transistor series pass element to provide output voltage and current. Sufficient output current can be delivered via the FET source or drain and the bipolar emitter or collector. Delivering output current via the FET drain is known as common source configuration, and via the bipolar collector as common emitter configuration. Common source and common emitter configurations can function with a dropout voltage that depends, for the FET, only on the channel on resistance and, for the bipolar, on the saturation voltage that can reach as low as a few tenths of a volt. The trade off for this low drop out voltage is a relatively high output impedance, resulting in relatively poor load regulation.

[0011] Delivering output current via the FET source is known as source follower configuration. Delivering output current via the bipolar emitter is known as emitter follower configuration. Source and emitter follower configurations require a minimum voltage of the FET threshold or the bipolar VBE plus the voltage across the FET drain-source or bipolar collector-emitter. This results in a higher drop out voltage than the common source and common emitter configurations. A discussion of the advantages and disadvantages of various output configurations can be found in the article by Jung, Walt, "Low-Dropout Regulators", published by Analog Devices Inc., no date.

[0012] The lower the output impedance of a voltage regulator, the better the load regulation. Emitter follower and source follower configurations are the lowest impedance configurations available, with the bipolar device the clear winner at approximately 10 times lower output impedance versus the FET for equivalent geometric area devices delivering the same current. A bipolar output regulator using an emitter follower output yet with the drop out voltage of the common collector configuration is highly desirable.

[0013] Known means exist in prior art for improving line rejection by using the regulated output voltage as power for some internal portions of a regulator such as a reference circuit or difference amplifier. A circuit that supplies power to itself is known in the trade as bootstrapped. Any portion of a regulator powered by VIN is subject to passing some portion of unwanted noise from VIN to VOUT. The more internal elements of a regulator that can be bootstrapped, the better the line regulation. Some prior art that uses bootstrapping has start up problems in which the output voltage may never reach the desired and designed value.

[0014] Many prior art voltage regulator circuits exist in individual form and also in integrated circuit form. These circuits employ various techniques to increase line and load rejection, decrease noise and improve dynamic performance. Often these circuits offer a compromise between one performance characteristic and another. For example, low dropout regulators often use a series pass element in common emitter configuration with bipolar transistors [U.S. Pat. No. 5,274,323, Dobkin et al.] and in common source configuration with metal oxide semiconductor field effect transistors (MOSFET) [U.S. Pat. No. 6,373,233 B2 Bakker et al.].

[0015] A depletion mode FET has been used in a source follower configuration as series pass element to provide low dropout [U.S. Pat. Nos. 6,989,659 Menegoli et al. and **5168175** Endo], but the disadvantage of the FET output impedance remains. The impedance is substantially 10 times