limits, or to avoid interference with other local circuitry. Such circuits must also be efficient in terms of integrated circuit area consumed, and, especially for battery operated devices such as cellular telephones, must be efficient in terms of power consumption.

[007] Additionally, it is often useful to control an output voltage of a charge pump by means of a feedback control loop that includes a differential-input operational transconductance amplifier ("OTA"). OTA output common mode voltages include the effects of various offsets, including input signal misalignment, differential input offset voltages, finite gain of input common mode signals, and other mismatches that may occur throughout the OTA. Nulling the effect of such offsets is particularly useful for amplifying small signals. Adjusting output voltage levels is also useful for permitting maximum gain before the signal is clipped.

[008] The method and apparatus presented herein address the need for low-noise, high efficiency bias generation circuits, including charge pumps, regulation control and amplification circuits, bias level setting circuits and, particularly for the capacitive coupling of low-noise clocking waveforms, efficient active bias circuits. Various aspects of the bias generation method and apparatus described herein will be seen to provide further advantages, as well.

SUMMARY

[009] A bias generation method and apparatus is set forth that may generate bias voltage supplies quietly and efficiently by means of a charge pump that alternately couples charge from an input supply to a transfer capacitor and then couples the charge to an output, and may couple bias voltages to nodes requiring biasing by means of "active bias resistor" circuits. A variety of novel features are described and employed to achieve such bias generation. Many charge pump topologies are possible, some of which are set forth in U.S. Patent Application 10/658,154, which is incorporated by reference; many charge pump clock oscillators are suitable, especially that produce waveforms having limited harmonic content above a fundamental frequency, which may be substantially sine-like, and which moreover may include two waveforms substantially symmetric and in phase opposition. Such charge pump clocks may be coupled to transfer coupling switch control nodes via capacitance, and the nodes may be biased to selected levels by means of charge conducted by active bias resistors that may not have any substantial resistance at all. Moreover, the bias voltage generation may be controlled by an amplifier loop that includes an operational amplifier circuit having a controllable current mirror ratio, which may permit common mode control of differential outputs from the amplifier.

[010] One important aspect of the bias generation circuits and method is a focus on minimizing the extent to which a charge pump creating bias voltages generates and transfers electrical noise to nearby circuits and devices with which the charge pump is associated. Some features of the bias generation circuits and method aid in reducing such noise generation and conduction, while others serve to permit bias generation to be efficient in terms of integrated circuit area and power consumption while employing such noise reduction features. Any one or more of these various features may be combined in bias generation circuits and methods that generate reduced interference.

[011] Because the clock that controls a charge pump or other clocked bias generation circuits is both a direct and an indirect source of undesirable electrical noise currents, characteristics of the clock define some embodiments of the bias generation circuits and method. Embodiments may be defined by the clock they employ