ENVELOPE FOLLOWING VOLTAGE CONVERTER

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Application No. 63/216,374 filed June 29, 2021, entitled ENVELOPE FOLLOWING BOOST CONVERTER, the disclosure of which is hereby expressly incorporated by reference herein in its respective entirety.

BACKGROUND

Field

[0002] The present disclosure relates to voltage converters such as boost converters

Description of the Related Art

[0003] A voltage converter receives an input voltage and generates an output voltage that is typically greater than or less than the input voltage in magnitude. The former type of voltage converter is sometimes referred to as a step-up or boost converter, and the latter type of voltage converter is sometimes referred to as a step-down or buck converter.

[0004] A voltage converter having either or both of the step-down (buck) and step-up (boost) functionality is utilized in many electronic applications such as radio-frequency (RF) applications. In such applications, a desired output voltage can be generated for operation of a circuit based on an input voltage such as a battery voltage.

SUMMARY

[0005] According to an aspect, the present disclosure relates to a power supply system for a power amplifier. The power supply system comprises a voltage converter implemented generate a first voltage at an output node, and an envelope following circuit implemented to generate and combine a second voltage with the first voltage to provide a combined output voltage for the power amplifier.

The combined output voltage has a waveform that follows one or more peaks of an envelope of a radio-frequency signal above the first voltage.

[0006] In some examples, the voltage converter can include an input node configured to receive a DC input voltage Vin. The first voltage can include a boosted DC voltage having a magnitude greater than that of Vin. The boosted DC voltage can be selected to be lower than an average power tracking (APT) level. The boosted DC voltage can be selected to provide a back-off that is less than a back-off associated with the APT level. The back-off associated with the boosted DC voltage can be less than or equal to, for example, 3dB, 2dB, or 1dB.

[0007] In some examples, the power supply system can further include a controller configured to control operations of the voltage converter and the envelope following circuit. The voltage converter can be configured to include a synchronous boost functionality, and include a boost hold capacitor C_B coupled to the output node. The voltage converter can be further configured to include a bypass functionality such that the first voltage is substantially the same as the DC input voltage Vin. The voltage converter can be configured such that the envelope following circuit is disabled when the bypass functionality is enabled.

[0008] In some examples, the voltage converter can be further configured to generate a reduced voltage as the first voltage. The voltage converter can include a divide-by-N circuit to generate the reduced voltage, with the quantity N being a positive integer, such that the reduced voltage has a value of approximately Vin/N, such as a value of approximately Vin/2. The voltage converter can be configured such that the envelope following circuit is disabled when the divide-by-N circuit is enabled.

[0009] In some examples, the envelope following circuit can include a following amplifier configured to receive information representative of the envelope of the radio-frequency signal and generate the second voltage. An output of the following amplifier can be coupled to the output node of the voltage converter through the boost hold capacitor C_B. The second voltage generated by the following amplifier can be AC-coupled to the first voltage at the output node of the voltage converter. The information representative of the envelope of the radio-frequency signal can include differential signals provided by the controller. The differential signals can have a MIPI format.

[0010] In some examples, the controller can be configured to generate the differential signals for the following amplifier based on differential envelope tracking (ET) signals. The envelope following circuit can further include a feedback path between the output of the following amplifier and the controller. The controller can be further configured to utilize the feedback path adjust the differential signals provided to the following amplifier based on a frequency associated with the envelope of the radio-frequency signal. The differential signals provided to the following amplifier can be adjusted to maintain a desired voltage across the boost hold capacitor C_B if the frequency is less than or equal to a selected frequency, and to provide a reference for the following amplifier feedback to facilitate cancellation of ripples associated with the first voltage output by the voltage converter if the frequency is greater than the selected frequency. The selected frequency can be, for example, approximately 200 KHz.

[0011] In another aspect, the present disclosure relates to a method for generating a supply voltage for a power amplifier. The method comprises converting an input voltage into a first voltage at an output node of a voltage converter, and generating a second voltage associated with an envelope of a radio-frequency signal. The method further comprises combining the second voltage with the first voltage to provide a combined output voltage for the power amplifier, such that the combined output voltage has a waveform that follows one or more peaks of the envelope of the radio-frequency signal above the first voltage.

[0012] In yet another aspect, the present disclosure relates to a semiconductor die that includes a semiconductor substrate and a power supply system implemented on the semiconductor die. The power supply system further comprises a voltage converter configured to generate a first voltage at an output node. The power supply system further comprises an envelope following circuit implemented to generate and combine a second voltage with the first voltage to provide a combined output voltage for the power amplifier, such that the combined output voltage has a waveform that follows one or more peaks of an envelope of a radio-frequency signal above the first voltage.

[0013] In yet another aspect, the present disclosure relates to a radio-frequency module that comprises a packaging substrate configured to receive a plurality of components, and a power supply system implemented on the packaging substrate. The power supply system comprises a voltage converter configured to

generate a first voltage at an output node, and an envelope following circuit implemented to generate and combine a second voltage with the first voltage to provide a combined output voltage for the power amplifier, such that the combined output voltage has a waveform that follows one or more peaks of an envelope of a radio-frequency signal above the first voltage.

[0014] In some examples, the voltage converter can be configured to include a synchronous boost functionality with a boost hold capacitor C_B coupled to the output node. In some examples, the boost hold capacitor C_B can be implemented on the packaging substrate. In some examples, the voltage converter can be configured such that the output node is coupled to the boost hold capacitor C_B external to the radio-frequency module.

[0015] In yet another aspect, the present disclosure relates to a wireless device that includes a transceiver configured to generate a radio-frequency signal, and a power amplifier in communication with the transceiver and configured to amplify the radio-frequency signal. The wireless device further comprises a power supply system implemented to provide a supply voltage to the power amplifier. The power supply system includes a voltage converter configured to generate a first voltage at an output node, and an envelope following circuit configured to generate and combine a second voltage with the first voltage to provide the supply voltage for the power amplifier, such that the supply voltage has a waveform that follows one or more peaks of an envelope of the radio-frequency signal above the first voltage. The wireless device further comprises an antenna in communication with the power amplifier, and the antenna is configured to transmit the amplified radio-frequency signal.

[0016] For purposes of summarizing the disclosure, certain examples, advantages and novel features of the disclosures have been described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular example of the disclosure. Thus, the disclosure may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.