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 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.

[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 to 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

WHAT IS CLAIMED IS:

1. A power supply system for a power amplifier, comprising:

a voltage converter implemented 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, the combined output voltage having a waveform that follows one or more peaks of an envelope of a radio-frequency signal above the first voltage.

2. The power supply system of claim 1 wherein the voltage converter includes an input node configured to receive a DC input voltage Vin.

3. The power supply system of claim 2 wherein the first voltage includes a boosted DC voltage having a magnitude greater than that of Vin.

4. The power supply system of claim 3 wherein the boosted DC voltage is selected to be lower than an average power tracking (APT) level.

5. The power supply system of claim 4 wherein the boosted DC voltage is selected to provide a back-off that is less than a back-off associated with the average power tracking level.

6. The power supply system of claim 5 wherein the back-off associated with the boosted DC voltage is less than or equal to 3dB, 2dB, or 1dB.

7. The power supply system of claim 2 further comprising a controller configured to control operations of the voltage converter and the envelope following circuit.

8. The power supply system of claim 7 wherein the voltage converter is configured to include a synchronous boost functionality, and including a boost hold capacitor C_B coupled to the output node.

9. The power supply system of claim 8 wherein the voltage converter is further configured to include a bypass functionality such that the first voltage is substantially the same as the DC input voltage Vin.

10. The power supply system of claim 9 wherein the voltage converter is configured such that the envelope following circuit is disabled when the bypass functionality is enabled.

11. The power supply system of claim 8 wherein the voltage converter is further configured to generate a reduced voltage as the first voltage.

12. The power supply system of claim 11 wherein the voltage converter includes a divide-by-N circuit to generate the reduced voltage, the quantity N being a positive integer, such that the reduced voltage has a value of Vin/N.

13. The power supply system of claim 12 wherein the reduced voltage has a value of Vin/2.

14. The power supply system of claim 12 wherein the voltage converter is configured such that the envelope following circuit is disabled when the divide-by-N circuit is enabled.

15. The power supply system of claim 8 wherein the envelope following circuit includes a following amplifier configured to receive information representative of the envelope of the radio-frequency signal and generate the second voltage.

16. The power supply system of claim 15 wherein an output of the following amplifier is coupled to the output node of the voltage converter through the boost hold capacitor C_B.

17. The power supply system of claim 15 wherein the second voltage generated by the following amplifier is AC-coupled to the first voltage at the output node of the voltage converter.

18. The power supply system of claim 15 wherein the information representative of the envelope of the radio-frequency signal includes differential signals provided by the controller.

19. The power supply system of claim 18 wherein the differential signals have a MIPI format.

20. The power supply system of claim 18 wherein the controller is configured to generate the differential signals for the following amplifier based on differential envelope tracking (ET) signals.

21. The power supply system of claim 20 wherein the envelope following circuit further includes a feedback path between the output of the following amplifier and the controller.

22. The power supply system of claim 21 wherein the controller is further configured to utilize the feedback path to adjust the differential signals provided to the following amplifier based on a frequency associated with the envelope of the radio-frequency signal.

23. The power supply system of claim 22 wherein the differential signals provided to the following amplifier are 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.

24. The power supply system of claim 23 wherein the selected frequency is approximately 200 KHz.

25. A method for generating a supply voltage for a power amplifier, the method comprising:

converting an input voltage into a first voltage at an output node of a voltage converter;

generating a second voltage associated with an envelope of a radio-frequency signal; and

combining the second voltage with the first voltage to provide a combined output voltage for the power amplifier, the combined output voltage having a waveform that follows one or more peaks of the envelope of the radio-frequency signal above the first voltage.

26. A semiconductor die comprising:

a semiconductor substrate; and

a power supply system implemented on the semiconductor die, the power supply system including a voltage converter configured to generate a first voltage at an output node, the power supply system further including 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 having a waveform that follows one or more peaks of an envelope of a radio-frequency signal above the first voltage.

27. A radio-frequency module comprising:

a packaging substrate configured to receive a plurality of components; and

a power supply system implemented on the packaging substrate, the power supply system including a voltage converter configured to generate a first voltage at an output node, the power supply system further including 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 having a waveform that follows one or more peaks of an envelope of a radio-frequency signal above the first voltage.

28. The radio-frequency module of claim 27 wherein the voltage converter is configured to include a synchronous boost functionality with a boost hold capacitor C_B coupled to the output node.

29. The radio-frequency module of claim 28 wherein the boost hold capacitor C_B is implemented on the packaging substrate.

30. The radio-frequency module of claim 28 wherein the voltage converter is configured such that the output node is coupled to the boost hold capacitor C_B external to the radio-frequency module.

31. A wireless device comprising:

a transceiver configured to generate a radio-frequency signal;

a power amplifier in communication with the transceiver and configured to amplify the radio-frequency signal;

a power supply system implemented to provide a supply voltage to the power amplifier, the power supply system including a voltage converter configured to generate a first voltage at an output node, the power supply system further including 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, the supply voltage having a waveform that follows one or more peaks of an envelope of the radio-frequency signal above the first voltage; and

an antenna in communication with the power amplifier, the antenna configured to transmit the amplified radio-frequency signal.