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AMPLIFIER HAVING INPUT POWER PROTECTION

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Application No. 63/009,442 filed April 13, 2020, entitled AMPLIFIER HAVING INPUT POWER PROTECTION, the disclosure of which is hereby expressly incorporated by reference herein in its respective entirety.

BACKGROUND

Field

[0002] The present disclosure relates to power protection for amplifiers.

Description of the Related Art

[0003] In electronics applications, an amplifier is utilized to amplify a signal such as a radio-frequency (RF) signal. Such an amplified signal can be further processed in, for example, a receiver circuit.

SUMMARY

[0004] In one aspect~~accordance with some implementations~~, the present disclosure relates to an amplifier circuit that includes an input node and an output node, and an amplifier implemented between the input node and the output node. The amplifier circuit further includes a bias circuit configured to provide a bias signal to the amplifier, and a protection circuit configured to generate a detected voltage representative of a peak of a radio-frequency signal present at the input node. The protection circuit is further configured to enable a protection mode when the detected voltage is greater than a first threshold value and to disable the protection mode when the detected voltage is less than a second threshold value that is less than the first threshold value.

[0005] In some examples~~embodiments~~, the input node can be configured to be coupled to an antenna. The amplifier can be a low-noise amplifier configured to support a receive operation.

[0006] In some examples~~embodiments~~, the amplifier can include a cascode arrangement of a first transistor and a second transistor, with the first transistor

having an input coupled to the input node, and the second transistor being coupled to the first transistor and having an output coupled to the output node. Each of the first and second transistors can be a field-effect transistor having a gate, a drain and a source. The first transistor can be implemented as a common source device, and the second transistor can be implemented as a common gate device, such that the gate of the first transistor is coupled to the input node, the drain of the first transistor is coupled to the source of the second transistor, and the drain of the second transistor is coupled to the output node. The source of the first transistor can be coupled to ground, and the gate of the second transistor can be coupled to a node having a gate potential.

[0007] In some examples~~embodiments~~, the protection circuit can include an assembly switches configured to implement the enablement and disablement of the protection mode. The assembly of switches can include a shunt switch configured to allow switchable shunting of the radio-frequency signal from the input node to ground. The shunt switch can be configured to be open when the protection circuit disables the protection mode, and to be closed when the protection circuit enables the protection mode.

[0008] In some examples~~embodiments~~, the assembly of switches can include an inter-transistor switch configured to provide a switchable coupling of the first and second transistors. The inter-transistor switch can be configured to be closed when the protection circuit disables the protection mode to allow a partially amplified signal from the first transistor to be provided as an input for the second transistor, and to be open when the protection circuit enables the protection mode to disconnect the second transistor from the first transistor.

[0009] In some examples~~embodiments~~, the bias circuit can be configured to provide the bias signal to the input of the first transistor through a bias resistance. The bias circuit can include a current mirror, such that the bias signal is representative of an output of the current mirror.

[0010] In some examples~~embodiments~~, the assembly of switches can include one or more switches implemented in the current mirror. The one or more switches of the current mirror can be configured to enable operation of the current mirror when the protection circuit disables the protection mode, and to disable operation of the current mirror when the protection circuit enables the protection mode.

[0011] In some examples~~embodiments~~, the assembly of switches can include a bias shunt switch implemented between ground and a node between the current mirror and the bias resistance. The bias shunt switch can be configured to be open when the protection circuit disables the protection mode, and to be closed when the protection circuit enables the protection mode.

[0012] In some examples~~embodiments~~, the assembly of switches can include a bypass switch implemented to be electrically parallel with the bias resistance. The bypass switch can be configured to be open when the protection circuit disables the protection mode, and to be closed when the protection circuit enables the protection mode.

[0013] In some examples~~embodiments~~, the protection circuit can include a detector coupled to the input node to allow sampling of the radio-frequency signal. The detector can be configured to generate the detected voltage based on the peak of the sampled radio-frequency signal. In some examples~~embodiments~~, the detector can include a diode configured to limit a current associated with the sampled radio-frequency signal in one direction, and a resistance-capacitance circuit configured to generate the detected voltage. The resistance-capacitance circuit can include a parallel arrangement of a resistance and a capacitance between an output of the diode and ground.

[0014] In some examples~~embodiments~~, the detector can include a comparator configured to generate an enable output to enable the protection mode when the detected voltage is greater than the first threshold value, and to generate a disable output to disable the protection mode when the detected voltage is less than the second threshold value. In some examples~~embodiments~~, the comparator can include a Schmitt trigger.

[0015] In some examples~~embodiments~~, the protection circuit can further include a control logic circuit configured to generate a first set of control signals to enable the protection mode based on the enable output of the comparator, and to generate a second set of control signals to disable the protection mode based on the disable output of the comparator. Each of the first and second sets of control signals can include switch control signals.

[0016] In some examples~~embodiments~~, the amplifier circuit can further include an electrostatic discharge circuit coupled to the input node and configured to provide a discharge path to ground when a voltage at the input node is greater than a

discharge threshold value. The electrostatic discharge circuit can include a plurality of diodes each configured as multi-stack device having a reduced size to meet lower electrostatic discharge protection requirement, to thereby provide a reduced parasitic capacitance.

[0017] In another aspectsome implementations, the present disclosure relates to a die that includes a semiconductor substrate and an amplifier circuit implemented on the semiconductor substrate. The amplifier circuit includes an input node and an output node, and an amplifier implemented between the input node and the output node. The amplifier circuit further includes a bias circuit configured to provide a bias signal to the amplifier. The amplifier circuit further includes a protection circuit configured to generate a detected voltage representative of a peak of a radio-frequency signal present at the input node. The protection circuit is further configured to enable a protection mode when the detected voltage is greater than a first threshold value and to disable the protection mode when the detected voltage is less than a second threshold value that is less than the first threshold value.

[0018] In some examplesembodiments, the semiconductor substrate can be configured to support CMOS processes.

[0019] In another aspectAccording to a number of implementations, the present disclosure relates to a packaged module that includes a packaging substrate configured to receive a plurality of components, and an amplifier circuit implemented on the packaging substrate. The amplifier circuit includes an input node and an output node, and an amplifier implemented between the input node and the output node. The amplifier circuit further includes a bias circuit configured to provide a bias signal to the amplifier. The amplifier circuit further includes a protection circuit configured to generate a detected voltage representative of a peak of a radio-frequency signal present at the input node. The protection circuit is further configured to enable a protection mode when the detected voltage is greater than a first threshold value and to disable the protection mode when the detected voltage is less than a second threshold value that is less than the first threshold value.

[0020] In some examplesembodiments, substantially all of the amplifier circuit can be implemented on a semiconductor die that is mounted on the packaging substrate. In some examplesembodiments, the amplifier circuit can be configured to

support a receive operation. In some examplesembodiments, the packaged module can be a receive module. In some examplesembodiments, the receive module can be a diversity receive module.

[0021] In another aspectsome teachings, the present disclosure relates to a wireless device that includes an antenna, a transceiver, and an amplifier circuit implemented between the antenna and the transceiver. The amplifier circuit includes an input node and an output node, and an amplifier implemented between the input node and the output node. The amplifier circuit further includes a bias circuit configured to provide a bias signal to the amplifier. The amplifier circuit further includes a protection circuit configured to generate a detected voltage representative of a peak of a radio-frequency signal present at the input node. The protection circuit is further configured to enable a protection mode when the detected voltage is greater than a first threshold value and to disable the protection mode when the detected voltage is less than a second threshold value that is less than the first threshold value.

[0022] In some examplesembodiments, the input node of the amplifier circuit can be coupled to the antenna, and the output node of the amplifier circuit can be coupled to the transceiver. In some examplesembodiments, the wireless device can be a cellular phone configured to operate in one or more cellular bands.

[0023] For purposes of summarizing the disclosure, certain examplesaspects, advantages and novel features of the disclosureinventions have been described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular exampleembodiment of the disclosureinvention. Thus, the disclosureinvention may be exemplifiedembodied 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 depicts an amplifier circuit having an amplifier and an input power protection circuit.

[0025] Figure 2 shows an amplifier circuit that can be a more specific example of the amplifier circuit of Figure 1.