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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Electrical Reactance Amplifiers

We TEXAS INSTRUMENTS INCORPORATED, 13500 North Central Expressway, Dallas, Texas, United States of America, a corporation organized and existing under the laws of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to electrical reactance amplifiers having a resistive load. Considering any network which has some optimum characteristic such as gain, input impedance, frequency response, etc. when loaded with a conductance, noise will be generated in the network.

Typically reactance amplifiers are networks which have been designed for amplifying signals with a low signal to noise ratio. One such reactance amplifier is referred to as a negative-resistance type. Basically, such a reactance amplifier comprises three tank circuits and varactor diode or non-linear component such as a variable capacitor all in a series circuit. One of the tanks is tuned to the signal frequency desired to be amplified, another tank circuit provides a constant frequency alternating voltage or pump frequency. The third tuned circuit is known as the idle tank and it is tuned to the sideband frequency generated by mixing the signal frequency and the pump frequency together. Since a non-linear impedance is interposed in the circuit, if power is dissipated in the idle tank, it will reflect a negative resistance to the signal frequency thus providing a power gain. The usual method of achieving power dissipation in the idle tank is by a resistive termination. The use of a resistor or resistive element as a power dissipator in the idle tank is

undesirable inasmuch as the resistor will add Johnson noise to the circuit.

A forward-biased P—N junction at low frequency has a conductance given by

$$g = \frac{e(I + I_s)}{mkT} \approx \frac{eI}{mkT} \quad (1)$$

where e is the electronic charge, I is the net dc current, I_s is the diode saturation current, K is Boltzman's constant, T is the absolute temperature, and m is a constant between 1 and 2.

For a resistance element with the same value of conductance the mean square noise current (Johnson noise) is given by

$$i_n^2 = 4kT\Delta f g \quad (2)$$

In "Theory and Experiments on Shot noise in Silicon P—N Junction Diodes and Transistors" by B. Schneider and M. J. O. Strutt (Proc. IRE, Vol 47, No. 4 pp 546—554; April 1959), the diode noise current is given as,

$$i_n^2 = 4kT\Delta f \text{Re}(Y) - \frac{2e\Delta f I}{m} \quad (3)$$

where $\text{Re}(Y)$ denotes the real part of the junction admittance, Y , substituting eq. (1) into eq. (3) to eliminate I gives

$$i_n^2 = 4kT\Delta f \text{Re}(Y) - 2kT\Delta f g \quad (4)$$

At low frequencies

$$\text{Re}(Y) = g,$$

and equation (4) becomes:

$$i_n^2 = 2kT\Delta f g,$$

which is seen to be half the mean square noise current originating in the equivalent resistor as given in equation (2).

At high frequency the $\text{Re}(Y)$ increases as $\omega^{1/2}$ and the first term of equation (4) would ultimately prevail, resulting in diode noise equal to resistor noise; however, at all fre-

quencies below this frequency of equality, the diode will have less noise than the resistor.

5 The present invention is an electrical reactance amplifier having a resistive load and having an arrangement for improving the noise level comprising a forward biased P—N junction device as the load, said P—N junction device having a conductance
10 equivalent to said resistive load.

The present invention is also an electrical reactance amplifier having a tuned circuit and requiring a resistive load in which power is dissipated at the idle frequency of
15 said amplifier, including an arrangement for improving the noise level comprising a forward biased P—N junction device as the load coupled to said tuned circuit to dissipate power at the idle frequency, said P—N junction
20 device having a conductance equivalent to said resistive load.

The present invention is also an electrical reactance amplifier having a transformer with a pair of windings, a capacitor connected
25 across one of the windings to form a tuned circuit, a non-linear reactive component coupled to said tuned circuit, and a pump signal source inductively coupled through said transformer to said nonlinear reactive
30 component, said amplifier requiring a resistive load in which power is dissipated at the idle frequency of said amplifier, said amplifier including an arrangement for improving the noise level comprising a forward
35 biased P—N junction device as the load coupled to said tuned circuit to dissipate power at the idle frequency, said P—N junction device having a conductance equivalent to said resistive load.

40 Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawing, in which—

45 FIG. 1 illustrates a reactance amplifier of the negative-resistance type with the output at the signal frequency and the idle tank terminated with a forward-biased diode; and

50 FIG. 2 illustrates a low-frequency reactance amplifier in which the frequency output is terminated into a forward-biased P—N junction of a transistor amplifier.

Referring specifically to Fig. 1 there is illustrated a reactance amplifier according to the invention. The reactance amplifier
55 consists of a closed loop series circuit comprising a signal frequency tank circuit containing a capacitor 50 in parallel with inductance 51; an idle tank having capacitor 52 in parallel with an inductance 53, the
60 idle tank being terminated by diode 54 forward biased by a current source 56; and a pump tank circuit containing a capacitor 57 in parallel with an inductance 58, and a varactor diode 59. The pump frequency
65 tank has a pump signal source 61 inductively

coupled to the pump tank. The signal tank has an input tap 62 to the inductor 51 and an output tap 63 to the inductor 51. The output from the inductor tap 63 is applied through a receiver load 64 to
70 ground.

The circuit incorporates a forward bias diode 54 across the idle tank instead of a resistor as heretofore proposed. The circuit
75 provides amplification by reflecting a negative resistance in the output from the signal tank by dissipating power at the difference side band or idle tank frequency.

Referring specifically to Fig. 2 of the drawing, a preferred embodiment of the
80 invention is illustrated. This embodiment of the invention relates to a double sideband upconverter which has an improved noise performance.

The pump frequency of pump source 100 is coupled through winding 101 into winding 102 of a transformer. Winding 102 has a centre tap 103 to ground. Winding 102 is part of a bridge network 128 containing
85 non-linear impedance.

One half of the bridge network 128 comprises the upper half of winding 102 centre tapped to ground, nonlinear impedance diode 104 and a reverse biasing potential 107
90 coupled to the top of tank circuit 110. The other half of the bridge network 128 includes the lower half of winding 102 centre tapped to ground, non-linear impedance diode 106 and a reverse biasing potential 109 coupled to the top of tank circuit 110. The biasing potentials 107 and 109 are chosen to reflect a low impedance to the output frequency from the pump
95 source 100 either inherently or by providing a by-pass capacitor for the purpose.

The tank circuit 110 consists of a capacitor 111 in parallel with a winding 112 which is the primary of an output transformer and in parallel with the average capacitance of the bridge network 128. The bottom of tank 110 is coupled to ground by a capacitor 113. A signal source 116 injects the signal frequency into the circuit through terminals 114 and 115 across capacitor 113. The DC return for the pump frequency bridge network is provided by the signal source thus
105 avoiding the need to use a resistor to shunt capacitor 113 and adding undesired noise into the circuit. The output from the reactance amplifier is coupled by the secondary winding 124 of the output transformer into the amplifier circuit of transistor 120 which has a base 121, collector 122, and an emitter 123. Transistor 120 has collector 122 coupled through resistor 126 to a positive supply of potential. The emitter 123 is coupled through a variable resistor 127 to a negative supply of potential. The variable resistor 127 provides a forward bias to the base-emitter PN junction. Be-
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cause transformer secondary winding 124 forms part of the tuned tank circuit 110, it must be isolated from variable resistor 127. Capacitor 129 provides this isolation. The

5 output tank 110 is tuned to the frequency of the pump source 100 hence to the nearby upper and lower sideband frequencies generated by the non-linear impedance bridge network impressing a variable capacitance across the tank 110 at the pump frequency and by the signal frequency applied to capacitor 113. The output signal is taken from the tank 110 and inductively coupled into the forward biased base-emitter, PN junction of transistor 120. Further amplification is achieved by the amplifier circuit of transistor 120. The output of the transistor amplifier is taken from the collector 122 at terminal 130 and may then be further applied into other amplifying stages or utilized in any desired manner.

From the foregoing description, it will be recognized that the output of the double sideband up converter is terminated effectively by the forward biased PN junction of the transistor 120, thus providing a low noise termination which is much less than the equivalent resistive load termination.

Among the advantages of the invention is that it provides an improved noise figure to a resistance amplifier the noise performance is critical and the noise arises in the conductance of the load which is a significant contribution to the noise of the network; it provides an improved low-noise reactance amplifier by utilizing a forward-bias diode as the termination for the idle tank; it provides a low-noise negative-resistance type reactance amplifier with a forward-bias diode as the idle tank termination to reflect a negative resistance to the input signal frequency; it provides a low-noise input to a transistor amplifier at the idle tank frequency by terminating the idle tank as the input to a transistor amplifier having a forward-biased base to emitter thereby providing a high signal to noise input to the transistor amplifier.

WHAT WE CLAIM IS:—

- 50 1. An electrical reactance amplifier having a resistive load and having an arrangement for improving the noise level comprising a

forward biased P—N junction device as the load, said P—N junction device having a conductance equivalent to said resistive load. 55

2. An electrical reactance amplifier having a tuned circuit and requiring a resistive load in which power is dissipated at the idle frequency of said amplifier, including an arrangement for improving the noise level comprising a forward biased P—N junction device as the load coupled to said tuned circuit to dissipate power at the idle frequency, said P—N junction device having a conductance equivalent to said resistive load. 60 65

3. An amplifier according to claim 1 or 2 wherein the P—N junction device is a diode. 70

4. An amplifier according to claim 1 or 2 wherein the P—N junction device is the base-emitter junction of a transistor.

5. An electrical reactance amplifier having a transformer with a pair of windings, a capacitor connected across one of the windings to form a tuned circuit, a non-linear reactive component coupled to said tuned circuit, and a pump signal source inductively coupled through said transformer to said non-linear reactive component, said amplifier requiring a resistive load in which power is dissipated at the idle frequency of said amplifier, said amplifier including an arrangement for improving the noise level comprising a forward biased P—N junction device as the load coupled to said tuned circuit to dissipate power at the idle frequency, said P—N junction device having a conductance equivalent to said resistive load. 75 80 85 90

6. An electrical reactance amplifier as substantially described herein with reference to FIG. 1 of the accompanying drawing.

7. An electrical reactance amplifier as substantially described herein with reference to FIG. 2 of the accompanying drawing. 95

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cause transformer secondary winding 124 forms part of the tuned tank circuit 110, it must be isolated from variable resistor 127. Capacitor 129 provides this isolation. The output tank 110 is tuned to the frequency of the pump source 100 hence to the nearby upper and lower sideband frequencies generated by the non-linear impedance bridge network impressing a variable capacitance across the tank 110 at the pump frequency and by the signal frequency applied to capacitor 113. The output signal is taken from the tank 110 and inductively coupled into the forward biased base-emitter, PN junction of transistor 120. Further amplification is achieved by the amplifier circuit of transistor 120. The output of the transistor amplifier is taken from the collector 122 at terminal 130 and may then be further applied into other amplifying stages or utilized in any desired manner.

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WHAT WE CLAIM IS:—

1. An electrical reactance amplifier having a resistive load and having an arrangement for improving the noise level comprising a

forward biased P—N junction device as the load, said P—N junction device having a conductance equivalent to said resistive load.

2. An electrical reactance amplifier having a tuned circuit and requiring a resistive load in which power is dissipated at the idle frequency of said amplifier, including an arrangement for improving the noise level comprising a forward biased P—N junction device as the load coupled to said tuned circuit to dissipate power at the idle frequency, said P—N junction device having a conductance equivalent to said resistive load.

3. An amplifier according to claim 1 or 2 wherein the P—N junction device is a diode.

4. An amplifier according to claim 1 or 2 wherein the P—N junction device is the base-emitter junction of a transistor.

5. An electrical reactance amplifier having a transformer with a pair of windings, a capacitor connected across one of the windings to form a tuned circuit, a non-linear reactive component coupled to said tuned circuit, and a pump signal source inductively coupled through said transformer to said non-linear reactive component, said amplifier requiring a resistive load in which power is dissipated at the idle frequency of said amplifier, said amplifier including an arrangement for improving the noise level comprising a forward biased P—N junction device as the load coupled to said tuned circuit to dissipate power at the idle frequency, said P—N junction device having a conductance equivalent to said resistive load.

6. An electrical reactance amplifier as substantially described herein with reference to FIG. 1 of the accompanying drawing.

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