Oscillations and Regenerative Amplification using Negative Resistance Devices

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The usual procedure for the production of sustained oscillations in tuned L-C networks is to overcome circuit losses through the use of designed-in positive feedback or regeneration. Then, during the circuit's on-transient oscillations will build up triggered by the thermal noise of circuit elements.

Two possible situations may arise for a potential oscillator. The tuned active network may have excess loss, in which case the circuit will refuse to oscillate (Fig.1-a). Nevertheless, it may still work as a regenerative or high-gain narrow-band tuned amplifier. The second situation that may arise is that of a successful oscillator. In this case, excess loss will have been compensated for (Fig.1-b) and a sustained oscillation is obtained at the circuit's output.

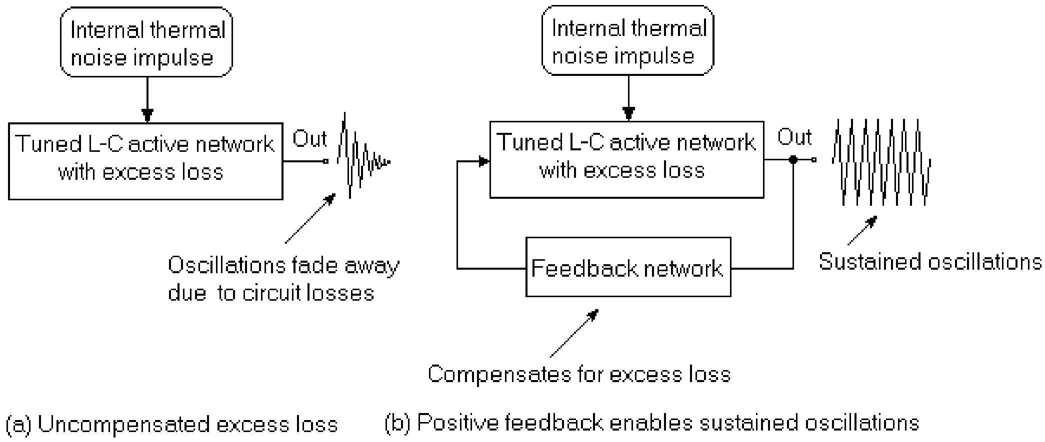

Fig.1 A potential oscillator faces two situations

In the analog realm, two sine-wave oscillator types are distinguished: the feedback and the negative-resistance oscillator. Regarding cancellation of resistive losses, both types may be shown to be equivalent, losses being effectively cancelled out by the negative resistance contributed by the active device and associated reactive components.

Two ways of carrying out this process are shown in simplified form in Fig.2 for a series and a parallel L-C circuit.

In Fig.2-a the negative resistance is series connected with the L-C tuned network. Rs represents the tuned circuit's series loss. The net resistive loss is R_T = Rs – r, and clearly, it may be nulled out.

The negative resistance in Fig.2-b is parallel connected to the tuned network. R_P represents the tuned circuit's parallel loss. The net conductance is $G_T = -\frac{1}{r} + \frac{1}{R_P}$ and it also may be nulled out. In this particular case, the net parallel resistive loss would be infinity, meaning zero power losses in the tuned L-C circuit.

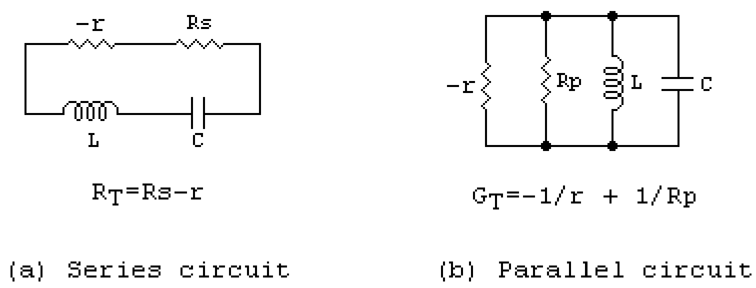

Fig.2 Loss cancellation

If loss cancellation is incomplete, the loop-gain of a sine-wave oscillator will be less than unity and oscillations will not start building up. On the other hand, if the gain is close to unity the circuit will behave as a regenerative or high-gain narrow-band tuned amplifier.

There are a number of single and compound active devices that exhibit negative resistance regions on their static I-V characteristic curves. These devices can be successfully employed in the construction of L-C oscillators and regenerative amplifiers. One of these devices is the Lambda diode, whose basic configuration is shown in Fig.3. It makes use of an N-channel and a P-channel JFET, connected in such a way that the drain to source voltage drop of either transistor is the gate to source voltage applied to the other device.

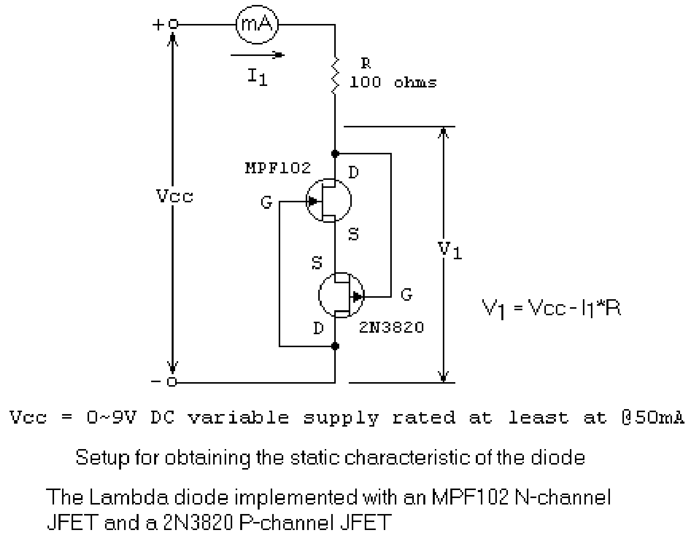

Fig.3 The basic Lambda diode and test setup

Figure 4 shows the measured I-V static characteristic of a Lambda diode implemented by the author with an MPF102 N-channel JFET and a 2N3820 P-channel JFET. The form of the curve resembles the symbol of the Greek letter lambda. Current sense and voltage polarity are as shown in Fig.3. Thus, it is a unidirectional device.

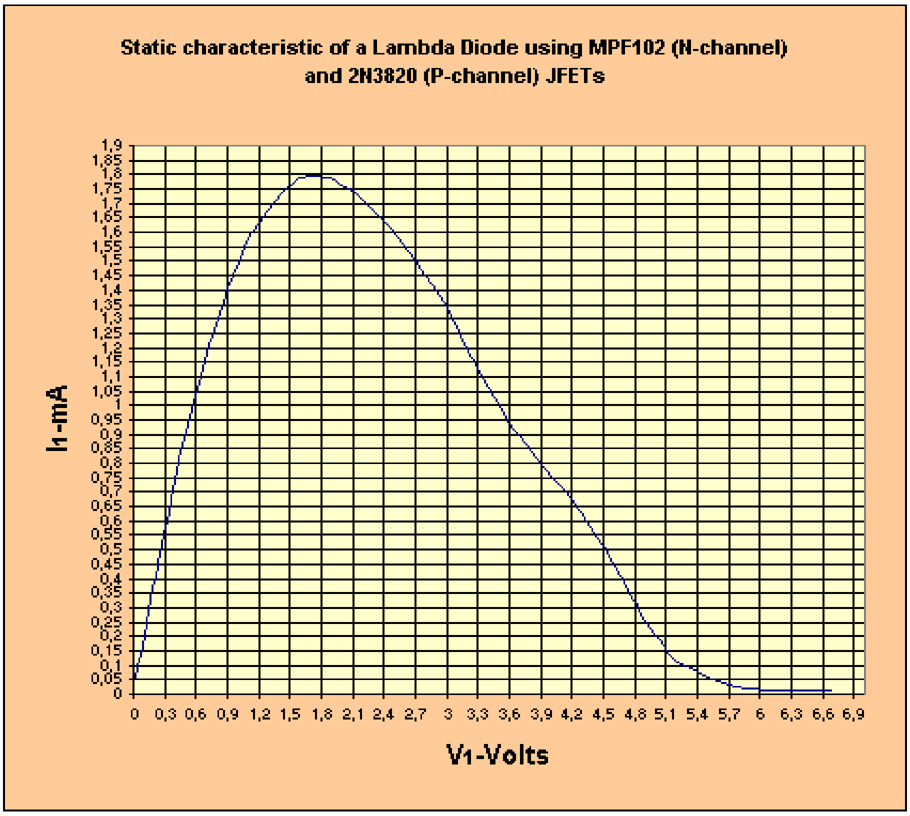

Fig.4 Measured I-V curve of Lambda diode

The author also tested a modified version of the Lambda diode in which a 2N3906 PNP silicon bipolar transistor substituted for the P-channel JFET. The test setup is shown in Fig.5 and the measured I-V characteristic in Fig.6. A negative resistance region can be observed to exist between 2Volts and 9Volts (region with a negative $\Delta V_1/\Delta I_1$).

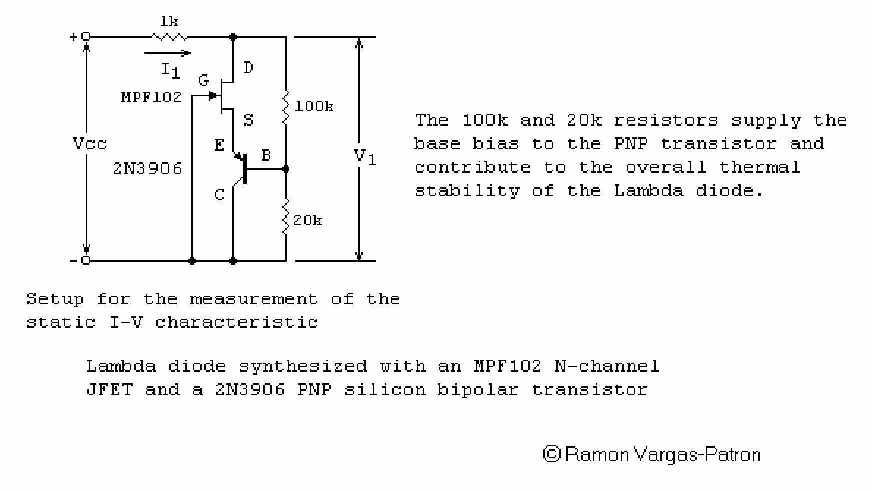

Fig.5 A modified version of the Lambda diode and test setup

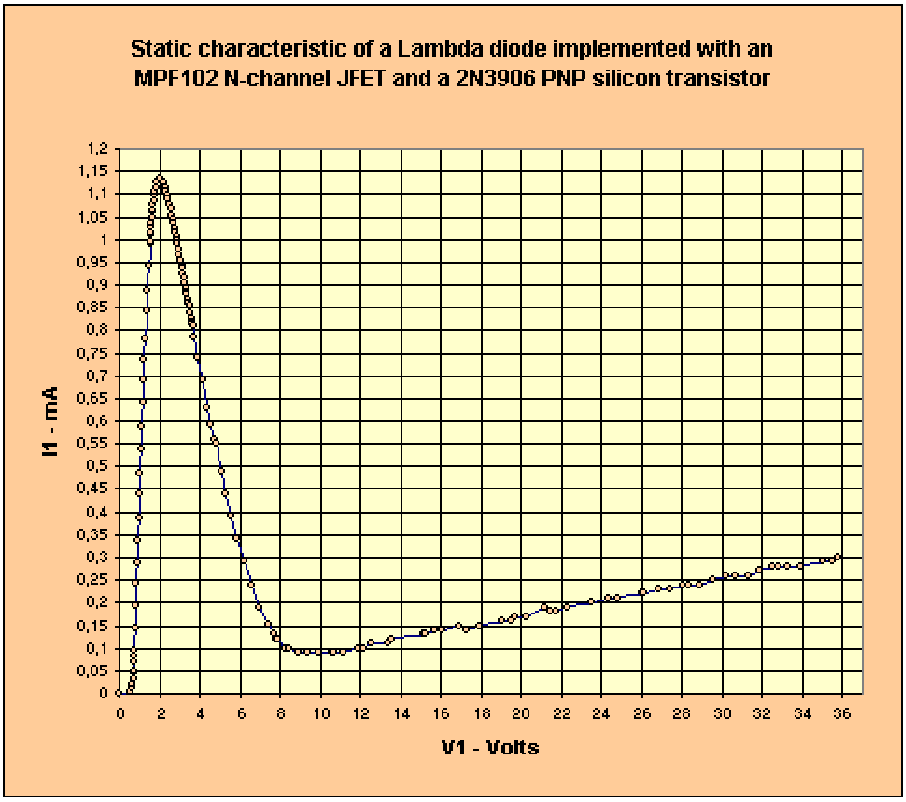

Fig.6 Measured I-V curve of modified Lambda diode

Two interesting applications

Interesting uses for the Lambda diode arise when it is biased on its negative resistance region. Straightforward applications include oscillator circuits and regenerative amplifiers.

To prove the usefulness of the modified configuration a simple sine-wave audio oscillator was built around the Lambda diode using an iron-cored inductor and a piezoelectric earphone (Fig.7). The inductance and the intrinsic capacitance of the earphone tuned the oscillation.

The circuit oscillated for power supply values between 3.2Volts DC and 4.68Volts DC. The best waveform was obtained for 4.25Volts DC. A low-distortion sine wave having 2Volts peak was measured across the Lambda diode at a frequency of 909Hz.

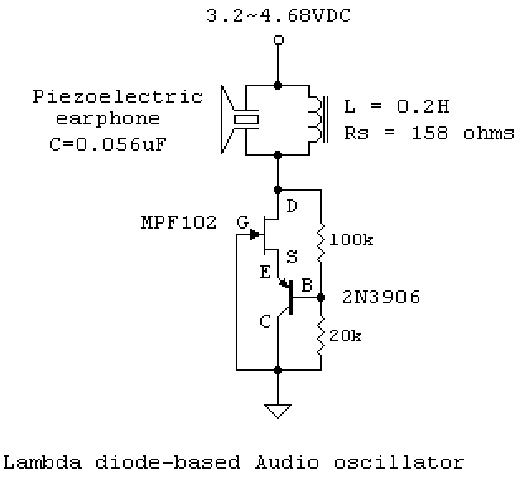

Fig.7 Sine wave audio oscillator

The second interesting and successful application was that of a regenerative receiver for the 530kHz~1620kHz MW AM broadcast band. Excellent selectivity and sensitivity, and a smooth regeneration control are appreciated features of this receiver. The schematic diagram for this circuit is shown in Fig. 8.

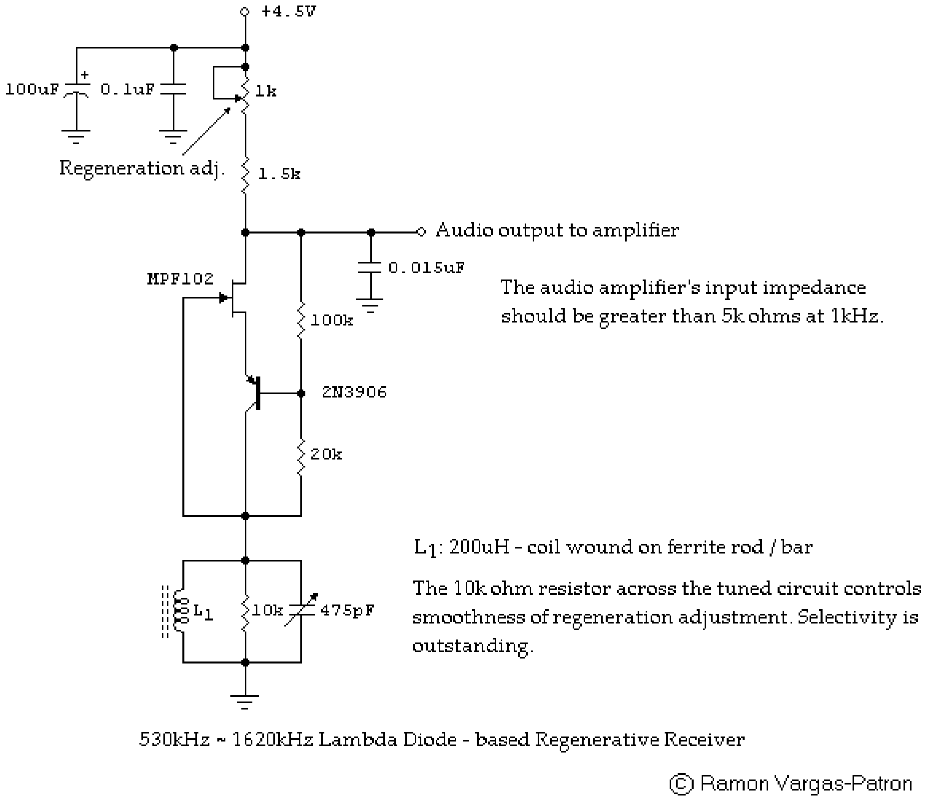

Fig.8 Regenerative receiver for the MW AM broadcast band

The Lambda diode is biased on its negative resistance region by the power supply and series resistors, and the circuit adjusted to the threshold of oscillation for best sensitivity and selectivity. As the efficiency of the ferrite antenna changes with frequency, some regeneration adjustment is required as the receiver is tuned throughout the band. The 10k ohm resistor in parallel with the tuned circuit contributes to the smoothness of regeneration settings.

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