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The Incredible Lambda Diode

-- you can even make it yourself!

Do you remember the Tunnel Diode of days gone by? You may have seen it used in various oscillator and converter circuits and in other types of high frequency applications. The main reasons for using these devices were low power consumption, good frequency stability, and extremely simple circuitry. In addition to these features, it is also possible to use the Tunnel Diode as a voltage controlled oscillator well up into the VHF range. With all of these features and the availability of low cost devices, it would seem that Tunnel Diodes would find their way into a lot of circuits, right? Wrong. For one reason or another, the Tunnel Diode has not been used to a great extent in everyday electronic circuits. Perhaps they were not sophisticated enough for some designers or maybe the device was not suited for the application at hand. But for whatever the reasons may have been, we have turned to other devices, such as the FET, for oscillator circuits and other high frequency applications.

Just recently, a new circuit device has been developed that behaves like a Tunnel Diode, but has all of the advantages of field-effect transistors. The new device is called a Lambda Diode, for reasons which will become apparent later, and is the subject of this article.

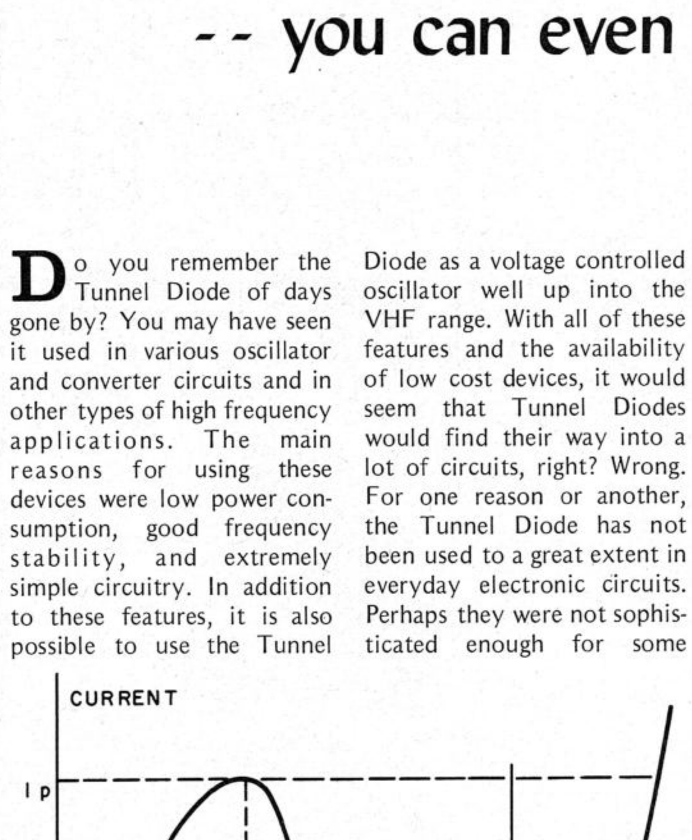

Fig. 1. Typical characteristics of a Tunnel Diode, showing the negative resistance region of the voltage vs. current curve.

Background

Before leaving the Tunnel Diode completely, perhaps a review of its characteristics will help in understanding how the Lambda Diode works and how to apply it properly.

The Tunnel Diode is a basic two terminal device that exhibits a negative resistance at certain voltages. What this means is that as the voltage across the device is increased, the current will also increase up to a point. When the voltage reaches this particular value, the current through the device will level off. Then any further increase in voltage will result in a proportional decrease in current through the device. This characteristic is illustrated in Fig. 1.

The negative resistance is the result of the diode having a small p-n junction with a high concentration of impurities in the p-type and n-type semiconductor materials. Having a high impurity density makes the junction depletion region narrow so that the electrical charges can transfer across the region at almost the speed of light. This effect is called "tunneling" and was first discovered in 1957 by Dr. Leo Esaki when he announced the results of his experiments dealing with highly doped p-n junctions. This was the first time a negative resistance device was produced, although the tunneling effect was predicted mathematically as early as 1929 by three physicists.

It is this tunneling effect in the negative resistance region on the characteristic curve of the device that makes it possible to achieve amplication, pulse generation, and rf energy generation.

While the Tunnel Diode held great promise when it was first introduced, it seems to have been sidestepped in our race for better and more efficient devices. Perhaps it deserves a closer look by many of us who have forgotten how easy it is to use in designing electronic circuits. Coming to our aid in this regard is a new device that brings the negative resistance circuit element into a new realm of activity. The new device is called the Lambda Diode and it appears to have a very exciting future.

The Lambda Diode

Like its tunnel diode counterpart, the Lambda Diode is also a two terminal device, but it is constructed with a pair of complementary depletion-mode junction-field-effect transistors connected as shown in Fig. 2. According to manufacturers of the device, it is easier to fabricate than conventional devices and it can be produced on one chip along with other devices. However, unlike Tunnel Diodes, Lambda Diodes are not limited to a narrow resistance region and consequently can be produced with a wide range of characteristics.

Although these devices are too new to be available on the surplus market, it is possible to build your own Lambda Diode from a complementary pair of JFET transistors. Fig. 3 shows the general layout for the Lambda Diode constructed from an n-channel and a p-channel JFET available from Radio Shack and other suppliers.

The name for the device is derived from the shape of its voltage-current characteristic curve, as shown in Fig. 4. Like the Tunnel Diode, when a positive voltage is applied to the anode of the Lambda Diode, the current through the device increases until the applied voltage reaches the pinch-off voltage of one of the devices. At this point on the curve, the voltage is called the peak voltage, Vp, and the peak current is Ip. Increasing the voltage further will cause the current to decrease until the applied voltage is equal to the sum of the pinch-off voltages of both JFETs. At this point, the voltage is referred to as the valley voltage, Vv, and both of the JFETs are cut off. Current

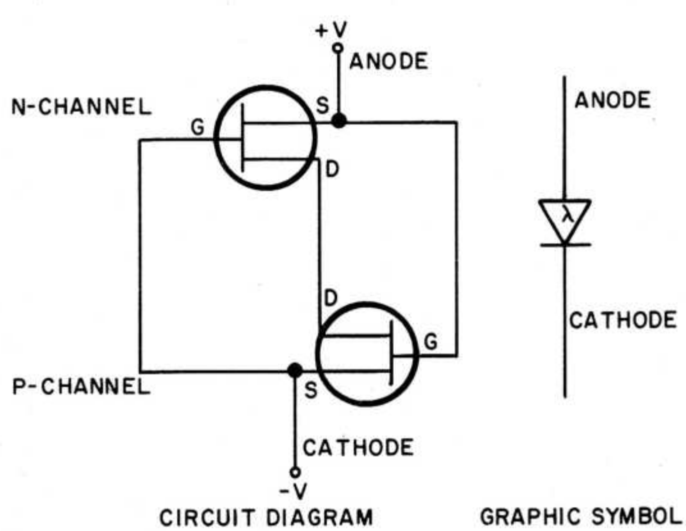

Fig. 2. The Lambda Diode is a two terminal device consisting of a pair of complementary depletion-mode junction-field-effect transistors connected as shown.

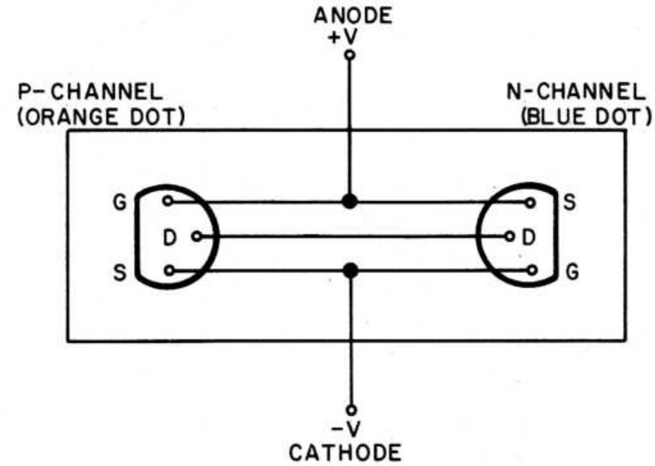

Fig. 3. This is a top view showing how two complementary transistors are connected to form a Lambda Diode. JFETs from Radio Shack (276-112) were used in this instance, although a 2N4360 or similar could be used for the p-channel and a 2N3819 or similar could be used for the n-channel.

draw in this state is low (in the order of a few nanoamps) and this feature makes the device a good choice for low power consumption applications. This minimal current will be limited for further increases in voltage until breakdown of one of the gates occurs.

The basic characteristics of this diode make it useful for many applications including oscillators, transistor protective circuits, battery monitors and many other circuits requiring low "off" states at high voltages.

Lambda Diode Applications

One useful application for the Lambda Diode is an electronic fuse that is non-destructive, fast acting and provides low current protection. Three such protective circuits are shown in Fig. 5. When an abnormally high voltage is applied to the power transistor, the diode will move into its negative resistance region, effectively cutting off bias to the transistor and allowing it to turn off and protect itself. For higher current applications, the diode can be connected in Darlington fashion as shown in Fig. 5(b). Similarly, for higher voltages, it can be connected as a sensing element to control a particular transistor as shown in Fig. 5(c).

Battery Voltage Monitor

Since the diode displays a bistable switching characteristic with almost zero standby current draw, it also makes a good battery voltage monitor. Simply connect the Lambda Diode as shown in Fig. 6, using a 2N2222 transistor and any LED as a low voltage indicator. Voltage measurements on the two JFETs I used resulted in the LED being switched on at 8.7 volts. This "switch on" voltage was found to be ideal for devices powered by a 9 volt transistor battery. However, you can change this transfer point by selecting JFETs with higher or lower pinch-off voltages than the ones I used.

In this particular circuit, as long as the battery stays in its normal operating range, the device will not draw any current due to its excellent "off" state characteristics. For this reason, the Lambda Diode makes an ideal battery voltage monitor.

Power Failure Monitor

Another application for the Lambda Diode is a power failure monitor as shown in Fig. 7. This particular circuit

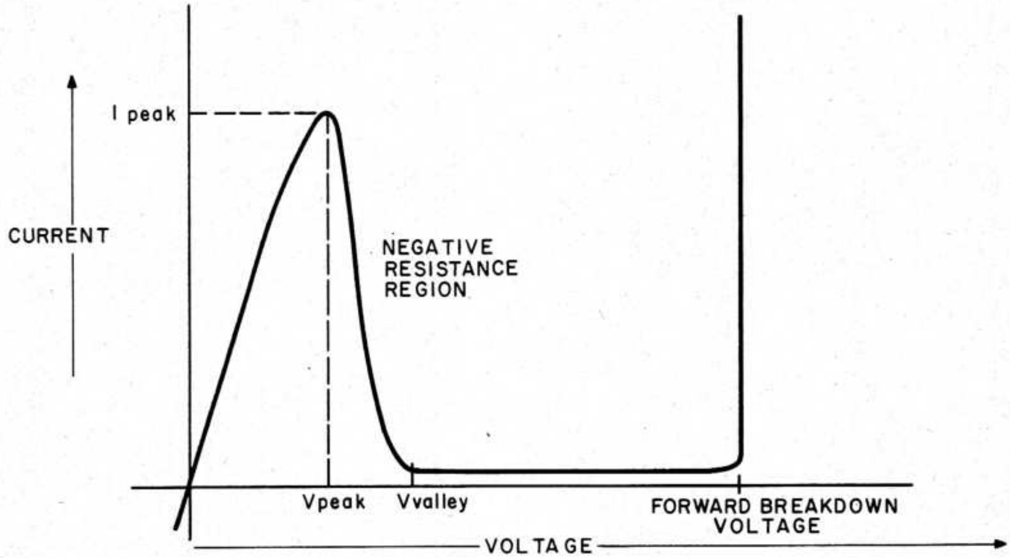

Fig. 4. Like the Tunnel Diode, the Lambda Diode displays a negative resistance characteristic when its bias voltage is increased past the peak shown on the graph.

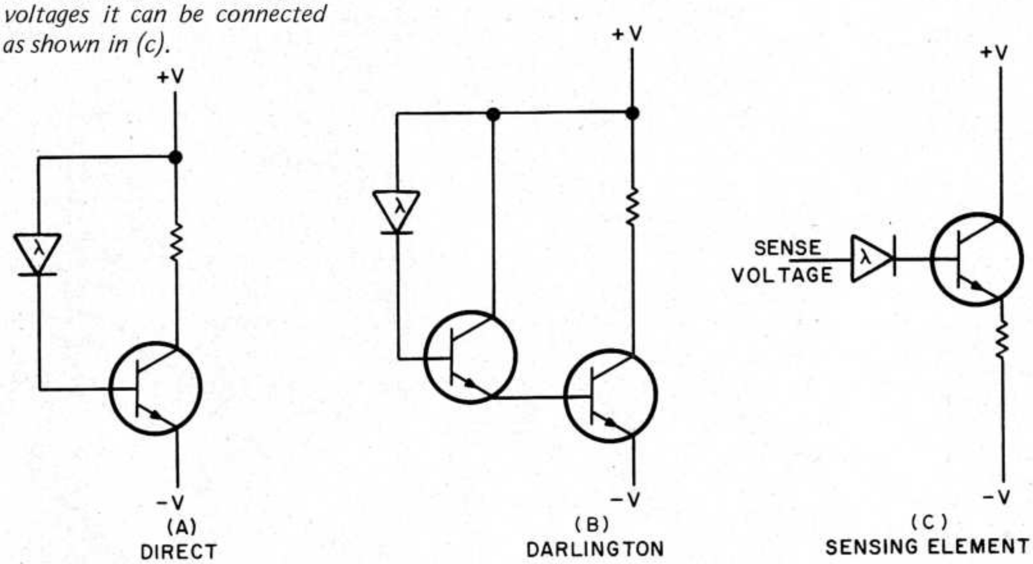

Fig. 5. The Lambda Diode makes an excellent electronic fuse when it is used to supply bias to the transistor it is protecting. An increase in current will cause the voltage drop across the collector resistor to increase, turning the Lambda Diode off. This will in turn cause the transistor to stop conducting. For higher current capabilities, it can be connected in Darlington fashion, and for higher voltages it can be connected as shown in (c).

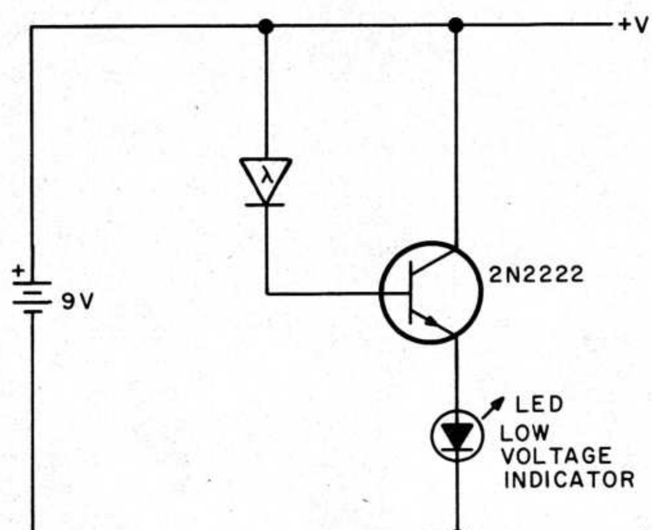

Fig. 6. Battery voltage monitor. With the Lambda Diode I was using, the LED would turn on at 8.7 volts, which makes it ideal for a 9 volt transistor battery. However, by using other JFETs with different pinch-off voltages, it may be possible to raise this transition voltage to monitor other power supplies.

will find application in products such as digital clocks, security systems, and computer operations. Basically, two transistor drivers are connected to LED indicators, with one transistor biased by the Lambda Diode. Under normal operating conditions, the diode is off, keeping transistor #1 turned off. Under these conditions, only transistor #2 is on, with the green LED indicating a "power on" condition. When a power failure occurs, of course, both LEDs will be off for the duration of the power failure. Then when power is restored, the Lambda Diode will be "on" causing the red LED to come on, indicating a power failure has occurred, and the green LED will be off. After the reset button is pushed, the red LED will go off and the green LED will turn on. Since the diode is fast acting, this circuit will also detect momentary outages in the nanosecond range.

Basic Oscillator

Being similar to the Tunnel Diode in many respects, the Lambda Diode will also find many applications as an oscillator in af, rf, and dc-to-ac converters as shown in Fig. 8. Since the diode is so efficient, it draws very little current and consequently there is very little internal heating of the device. This results in excellent temperature stability, and it's a natural as the basic active element in a vfo or local oscillator.

Building a basic oscillator circuit is simple — all you have to do is add an LC tank circuit and a 6 to 12 volt power supply. The actual value of the supply voltage will depend on the particular JFETs you use to make up the Lambda Diode. However, the actual voltage is not critical as long as you bias the device in the negative resistance region of its characteristic curve.

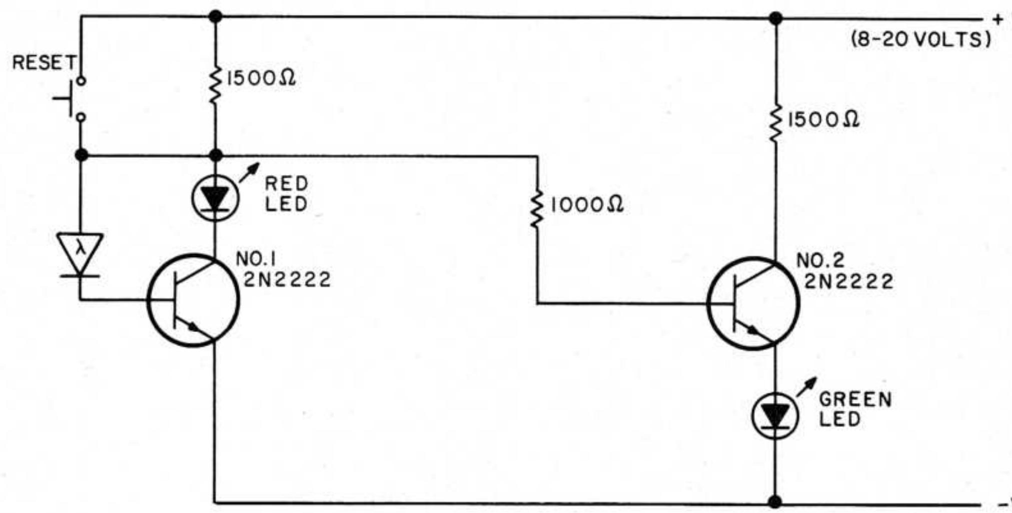

Fig. 7. Power failure monitor. This circuit will indicate a power failure on a bus between 8 to 20 volts. As long as this voltage is maintained, only the green LED will be on. If the power fails and is later restored, the green LED will turn off and the red LED will remain on until the reset button is pressed.

There are many applications for a simple oscillator of this type, from QRP transceivers to dip oscillators, signal generators, antenna testing devices, radio control applications and whatever you want to dream up. It's also possible to amplitude modulate the device, with a tone or voice, with excellent results. Although I have not tried SSB or FM with the device at this time, I feel reasonably sure that the oscillator will work here, too.

Since the Lambda Diode maintains an almost infinite impedance in its valley region, very little energy will be absorbed from the tank circuits. This is the basic reason why the Lambda Diode is so efficient as an oscillator and can produce an output amplitude voltage of twice the supply voltage. Also, because of its efficiency, the output amplitude will remain constant over its operating frequency range, even when the capacitance in the tank circuit is varied to change the frequency. This feature alone would make the device an excellent choice for a dip oscillator circuit.

Future Possibilities

Being a relatively new device, the potential applications are just beginning to emerge. Experimentation is presently being conducted on combining the Lambda Diode with other devices, as well as connecting two devices in series with similar polarity orientation (and also with opposing polarity orientation). The characteristics produced by such circuits are proving to be very interesting.

There is also the possibility of using the diode as the basis of a new memory cell which is only two-thirds the size of conventional CMOS memory cells. Since the Lambda Diode operates as a flip flop, only one bit line is required to activate the cell. By incorporating two additional MOSFETs, a new CMOS memory cell can be made using a total of four transistors as opposed to the six now required for conventional memories.

Regardless of how the Lambda Diode is used, it is evident that this versatile device is capable of performing many useful tasks. How well we use it will depend on our own ingenuity. ■

Reference

Kano, Iwasa, Takagi, Teramoto, "The Lambda Diode: A Versatile Negative Resistance Device," *Electronics*, June 26, 1975, page 105.

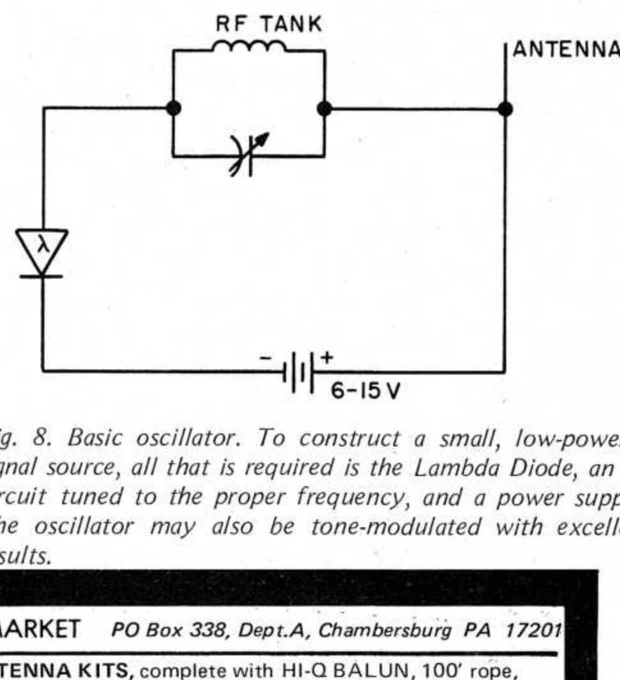

Fig. 8. Basic oscillator. To construct a small, low-powered signal source, all that is required is the Lambda Diode, an LC circuit tuned to the proper frequency, and a power supply. The oscillator may also be tone-modulated with excellent results.