The Mysterious "Negistor"

BY RICHARD PHARES

A negative-resistance element, disguised as a transistor, with many useful applications.

IT IS known that some transistors, when connected into a circuit in reverse, have a negative resistance similar to that of the tunnel diode. That is, the current through and the voltage across the transistor both increase until the voltage reaches a certain point. Then the transistor breaks down and any further increase in current results in a decrease in voltage. To simplify our discussion, we will call such devices "negistors." In circuit diagrams, we represent it as a conventional transistor with the letter "N" added.

Chances are you can't buy a negistor as such at your local electronics store. (They probably wouldn't know what you were talking about anyway.) However, if you have a few npn silicon transistors, you probably already have a supply on hand without knowing it. (But don't expect to find a negistor among the germanium or the pnp silicon units.)

There are a number of types of npn transistors among which negistors can be found: Motorola's MPS-5172, the 2N2218, 2N2222, 2N697, for example. Transistors which may be useless for anything else may be excellent negistors. We have used negistors to build both crystal-controlled and tunable sine-wave oscillators, variable-width pulse generators, oscilloscope sweeps, and many other circuits. Other suggested applications include timing circuits for SCR power control, latching circuits for power-supply regulator protection, timers, etc.

What Makes It Work. The behavior of the negistor is caused by avalanche multiplication as a result of impact ionization produced by mobile charge carriers. This characteristic is also used to enhance switching speed in some logic circuits.

The negative-resistance characteristic shown in Fig. 1 results when a 2N2218 is connected as shown. In this case the breakdown voltage is about 7.7V. Using this characteristic, the negistor can be used to perform some of the functions of a tunnel diode or a UJT—often with simpler additional circuitry.

When used in tunnel diode applications, the output of a negistor is much greater than that of the diode. As a UJT, the reverse transistor dissipates power only during breakdown and therefore its use is limited only by the peak current.

Applications. A useful circuit employing the negistor is the sawtooth and pulse generator shown in Fig. 2. Output frequency is determined primarily by *R1*, *R2* and *C1*. The current through the negistor is limited by *R2*, which also sets the maximum fre-

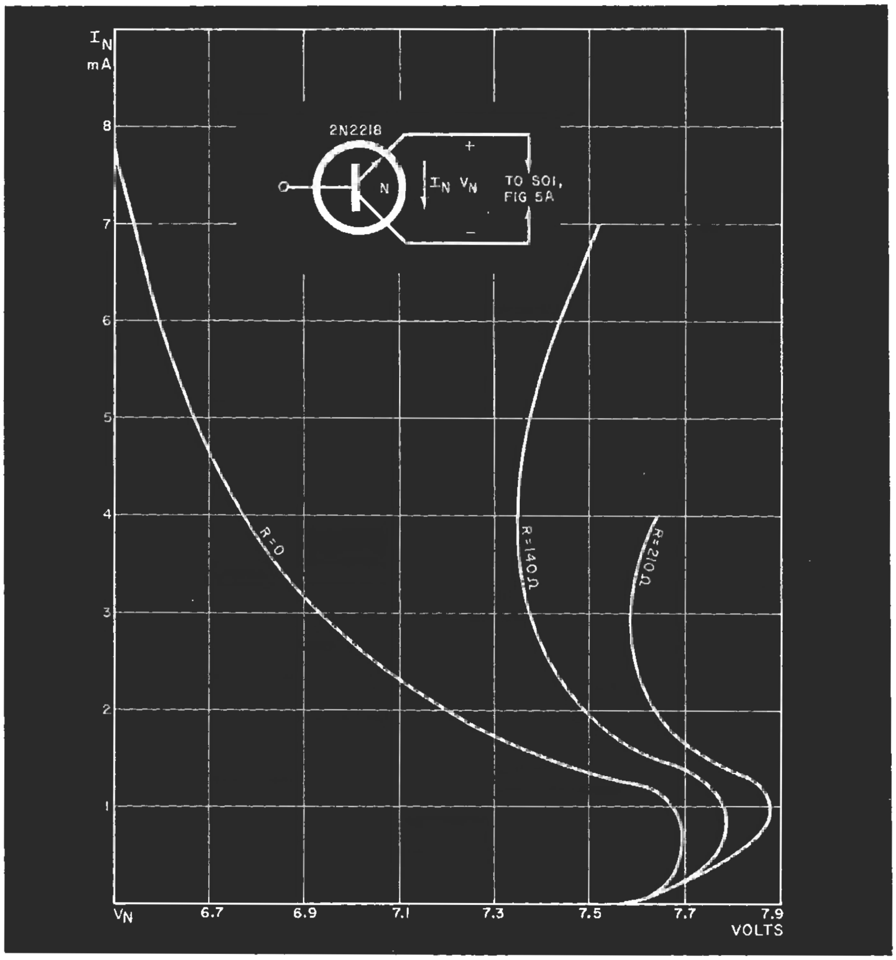


Fig. 1. I-V characteristics of a typical negistor. Many npn transistors exhibit negative-resistance behavior.

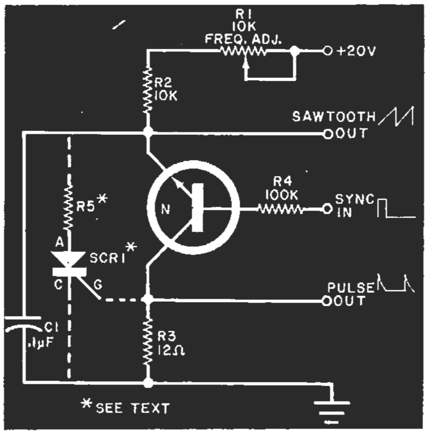


Fig. 2. Sawtooth and pulse generator. SCR circuit increases output.

quency of oscillation. Resistor *R3*, typically 10 to 20 ohms, also affects the frequency somewhat, and decreasing *R3* will lower the rise-time of the pulse and its amplitude. As *C1* increases, the magnitude of the sawtooth will decrease since the resistance of the negistor will rapidly increase once the voltage minimum (also called the "valley point" in UJT circles) is reached. The valley point varies from one negistor to the next, and if they will oscillate at all, peak-to-peak output will generally be greater than 1 volt.

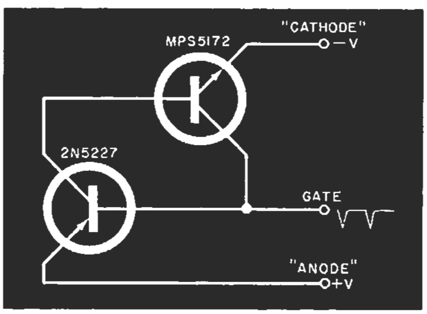


Fig. 3. Reverse-polarity SCR. Transistors simulate SCR.

In some applications, larger output is needed. If this is the case, the SCR-resistor network shown in dashed lines may be added to discharge capacitor *C1*. When the negistor breaks down, the pulse appearing across *R3* will trigger the SCR, discharging *C1* down to the saturation voltage of the SCR. Since *R3* is very small, the SCR will require more holding current than *R1* and *R2* can supply. When *C1* is discharged, the SCR will turn off and *C1* will begin to recharge. The value of *R5* is selected to limit the current through the SCR. A sync input is provided for control purposes. Output will be about 8 volts peak-to-peak with the SCR installed.

An inverse sawtooth may be obtained by reversing the leads of the negistor and polarities of the power supply. However, a conventional SCR cannot be used in this circuit, so the transistor analog of a reverse-polarity SCR (Fig. 3) must be used. This configuration may be used in place of a conventional SCR in any power-control circuit by interchanging the pnp and npn types.

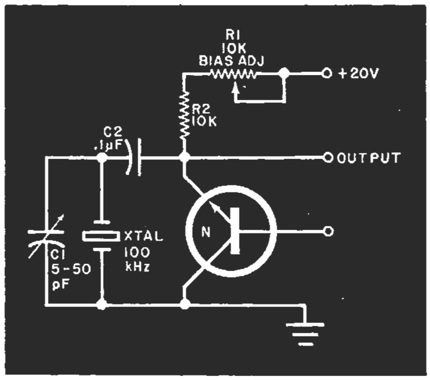


Fig. 4. Negistor used in standard frequency marker generator.

A second negistor application is a series-tuned crystal oscillator, shown in Fig. 4. In this circuit, the negistor is biased into the negative resistance region by *R1*. Capacitor *C1* tunes the oscillator to the operating frequency, and *C2* isolates the crystal from the dc voltage.

Negistor Selection. Three test circuits are shown in Fig. 5 to aid in identifying negistors in your supply of npn transistors. If you have access to an oscilloscope, use the circuits shown in Fig. 5A and 5B. A standard transistor socket can be used. Be sure to insert devices with the emitters and collectors reversed. Figure 5A will give the I-V characteristics of a negistor, as in Fig. 1. Set the vertical sensitivity of your scope to ½ V/cm. Each vertical division will represent 1 mA of negistor current, I_N, when the vertical amplifier input is across the 2000-ohm resistor. Connect the horizontal inputs as shown, setting the sensitivity to 2 V/cm. Vary the 1000-ohm potentiometer through its range, and thereby the voltage applied to the test circuit from 0 to 20 V. Note the movement of the trace. Since resistance is the reciprocal of the slope of the V-I curve shown, a downward (negative) slope means the transistor is displaying a negative resistance.

The circuit in Fig. 5B can be used with a scope, or with a peak-reading VTVM. When inserting or removing a device from socket *S01*, always be sure that switch *S1* is closed. After inserting the transistor and opening *S1*, a linear sawtooth waveform will be seen if the device can function as a negistor. We have found that about half of the npn transistors we test turn out to be negistors.

If a scope or peak-reading VTVM is not available, try the circuit shown in Fig. 5C. This test rig will not give any indication of the quality of the device, but it will indicate whether or not it displays a negative resistance. Connect a dc milliammeter and voltmeter as shown. Slowly advance the potentiometer and observe whether or not current increases while voltage at any point starts to decrease. If this happens, the device is a negistor.

Conclusion. This article has not delved deeply into theory, but rather is intended to be a "hands-on" guide to negistors. Look in your junk box—you'll be surprised how many negistors you have, and what you can do with them! ◈

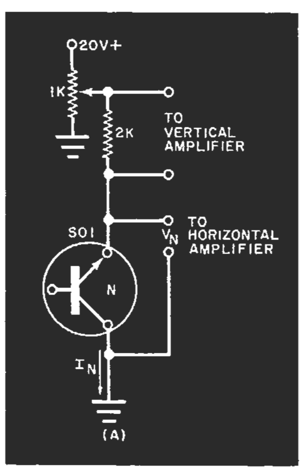
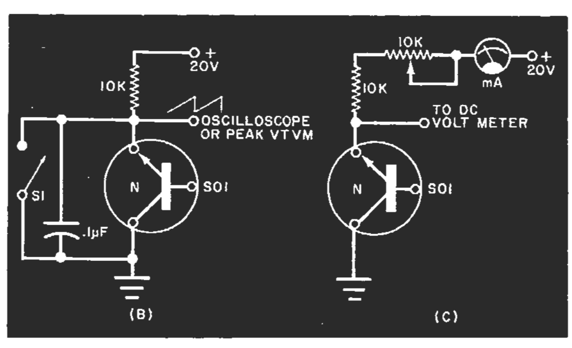
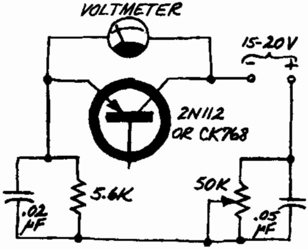


Fig. 5 Test circuits identify negistors using a scope, VTVM, or dc voltmeter.



AN ALTERNATE APPROACH

In the "Negistor" article (December 1975), it was stated that oscillation was obtained from an npn transistor with open base under reverse-bias conditions. I have obtained similar results from the same type of circuit and also from forward-biased *pnp germanium* transistors. One of my pnp circuits is shown below. To test for negative



resistance, I adjust the setting of the potentiometer so that the voltmeter's pointer rises to a peak indication and then begins to fall back toward the zero index. The oscillations I have observed with such a circuit have a sinusoidal waveform and a 0.5-volt peak at about 7000 Hz.—*I. Queen, Brooklyn, N.Y.*