BUILD A ZENER DIODE SUBSTITUTION BOX

SIMULATES A ZENER DIODE FROM 1.2 TO 18 VOLTS WITH POWER DISSIPATION TO SIX WATTS

BY STANLEY SULA

MOST experimenters are aware of the zener diode's usefulness and versatility. However, the fact that a single zener diode can provide only one value of zener voltage is a characteristic which may discourage experimentation with this very useful device. The trouble of buying a new diode every time a different voltage is required in an experimental circuit can be quite expensive and frustrating.

The Zener Diode Substitution Box described here is a very worthwhile project for those who experiment with circuits involving zener diodes. The substitution box provides a continuously variable zener breakdown from approximately 1.2 to 18 volts, with a power dissipation of up to six watts. Using all new parts, it can be constructed easily for less than $10. The device's electrical characteristics are identical to those of a high-quality zener diode.

Construction. Due to the simplicity of the circuit (Fig. 1), point-to-point wiring can be used. Parts layout is not critical. The maximum power dissipation of the circuit varies from ½ watt to 6 watts, depending on whether or not *Q1* is provided with a heat sink. With no heat sink, maximum dissipation is approximately ½ watt. With a "slip-on" fin-type heat sink, dissipation is about 1 watt; and for six watts, a heavy-duty heat sink is necessary.

If power dissipation is to be no more than 1 watt, the unit can be built in a 4" × 2⅞" × 1½" plastic enclosure. For a higher dissipation, a larger enclosure will be required.

Do not use a carbon-composition potentiometer for *R2*. Even the so-called "linear taper" potentiometers of this type can be grossly nonlinear and their use can lead to a very nonlinear voltage scale. For reasonable linearity at low cost, a wirewound pot must be used. For a small enclosure, be sure to use the miniature VW-type Mallory potentiometer given in the Parts List to leave enough room for the battery.

Theory of Operation. The circuit is a high-gain Darlington amplifier, with a negative bias supply which normally keeps the transistors in their nonconducting state. The bias is varied by *R2* from 1.2 to 18 volts. Note that one end of the bias supply (the wiper arm of *R2*) is connected to *Q2*'s base, while the other end is connected to one of the input terminals. Thus, the voltage across the input terminals is bucked by the bias voltage so that, as long as the bias exceeds the input, the net voltage on *Q2* is negative and the transistors do not conduct. However, as soon as the positive input exceeds the negative bias by 1.2 volts, the transistors turn on and present a very low resistance between the input terminals.

Transistors *Q1* and *Q2* will not conduct until a positive voltage of 0.6 appears across each of their emitter-base junctions. This sets the minimum of 1.2 volts for the lowest zener voltage attainable with this circuit.

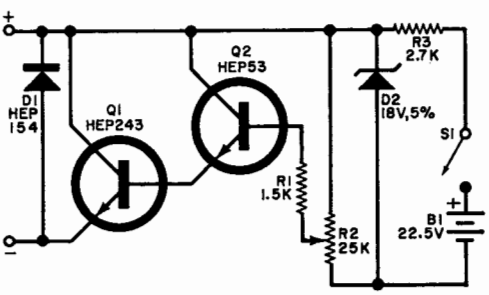

Fig. 1. Darlington amplifier switches on when voltage at the input bucks out preset bias. With proper heat sink on Q1, dissipation can be 6 watts.

PARTS LIST

B1—22½-volt battery (Eveready #412)
D1—1-A, 50-volt diode (HEP154)
D2—18-volt zener diode (HEPZ2522)
Q1—Transistor (HEP243)
Q2—Transistor (HEP53)
R1—1500-ohm, ½-watt resistor
R2—25,000-ohm, 5-watt wirewound potentiometer (Mallory VW-25K)
R3—2700-ohm, ½-watt resistor
S1—Spst slide switch
Misc.—Enclosure, 5-lug terminal strip, heat sink (see text), knob, battery holder (Keystone #177), hardware, etc.

Diode *D1* simulates the forward characteristics of a zener diode and also protects *Q1* and *Q2* from reverse polarity voltages.

Calibration. The calibration circuit is shown in Fig. 2. The voltmeter should be capable of measuring down to one volt accurately. Turn the voltage-selector dial (*R2*) on the substitution box fully clockwise (minimum resistance). This should give a meter reading close to 1.2 volts. Slowly turn the dial until the meter reads 2 volts. Make a graduation mark on the dial at this point. Continue rotating the dial until the meter indicates 3 volts and make another dial marking. Continue until you reach the highest attainable voltage. This maximum voltage will be between 18 and 20 volts, depending on the exact value of *D2*. To complete the dial marking at the lower end, make a mark for 1 volt a distance below 2 volts that is approximately the average of the distance between other voltage markings.

Operation. Since the circuit of the substitution box duplicates the characteristics of a zener diode so closely, it is used exactly as you would use a regular zener diode. As

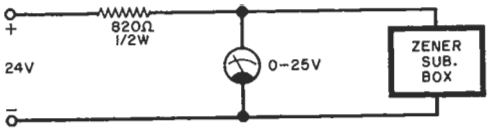

Fig. 2. To calibrate the dial on R2, use dc voltmeter capable of indicating down to about 1 volt accurately.

with any such diode, when connecting it into a circuit, always be sure that there is sufficient series resistance to prevent exceeding the power dissipation limits. This minimum series resistance can be calculated from the formula $R=E_zE_d/P$, where R is the minimum series resistance, E_z is the zener voltage, E_d is the difference between the zener voltage and the source voltage, and P is the maximum power dissipation in watts.

Needless to say, switch *S1* should be turned off when the unit is not in use, though the battery drain is only about 2.5 mA. Incidentally, with *S1* turned off, the device acts as a 1.2-volt zener regardless of the setting of the voltage dial. However, the zener voltage knee in this case is not as abrupt as it is with the switch on and the voltage dial set to 1.2 volts. ◈

LUGGAGE INSPECTION SYSTEM

A system that uses a low-dose, short-pulse X ray to detect illegal guns, explosives, etc. in airplane luggage has been developed by the Bendix Corporation's Aerospace Systems Div. The portable Bendix-Ray Inspection System is easily operated by one person. An example of baggage contents can be seen on the video monitor at upper left.