NIGHT-VISION SCOPES WERE DEVELOPED AS MILITARY SURVEILLANCE DEVICES TO PERMIT VIEWING ENEMY ACTIVITIES AND AIMING WEAPONS AT NIGHT WITHOUT REVEALING THE OBSERVER'S PRESENCE. THE SENSITIVITIES OF THEIR PRINCIPAL COMPONENTS, IMAGE TUBES, HAVE BEEN IMPROVED WITH FIBER-OPTIC LENSES, MORE GAIN STAGES AND BETTER PHOTOCATHODES. IN ADDITION, MINIATURE, SOLID-STATE, EXTRA HIGH-VOLTAGE POWER SUPPLIES HAVE REDUCED THEIR SIZE, WEIGHT, AND POWER NEEDS.

Two night-vision scopes are described in this article. One is passive, meaning that it will work in faint natural light, and the other is active, meaning that it requires supplemental infrared illumination. They include surplus first-generation imaging tubes. Although, they have been superseded by more advanced devices, they will, nevertheless, provide adequate sensitivity for most hobbyists and science experimenters.

The active scope will permit police to observe suspected criminal activity at night and citizens to monitor their homes or property without being detected. The scope will also permit hunting, nature study, marine navigation, and many other slight-time applications. The active scope is suitable for some of these activities, but the scene must be illuminated by an infrared source. Neither will disturb the eyes' adaptation to darkness.

The first night vision scopes were designed for use by for-havo observers, snipers, aviators, and tank crews. Some that were made as monoscopes to mount on rifles looked like the devices shown in Fig. 1: others were made as binoculars. The most sensitive passive units are called starlight scopes. Night-vision goggles are lightweight binoculars for helicopter crews that mount on their helmets.

Active night-vision scopes, such as the one shown in Fig. 2, depend on infrared illumination from sources such as lasers for aiming artillery guided missiles, and "smart" bombs. Night-vision systems were considered military secrets for many years. After they were declassified, they could be sold as military surplus and commercial versions based on the technology were offered for police surveillance and as nighttime marine navigational aids at prices that often exceed $2000.

Both of the night-vision scopes described in this article are based on military surplus equipment that includes both an image tube and optics. The parts for the active unit cost $90, and parts for the active unit cost 6220.

Night-vision scopes

Figure 3 illustrates a typical night-vision scope. The objective lens, positioned at the cathode end of the tube, focuses the image on the photocathode. It is selected for its intended application—long-distance or short-range viewing. The eyepiece at the anode is for viewing the enhanced image. If is a simple lens that magnifies the image on the screen. It can be removed and replaced by a television camera, camcorder, or film camera for transmitting or recording the image.

The image tubes are the hearts of the night-vision scopes. Before you start building one (or both), you might want to learn more about how they work. See the sidebar entitled "Image Converter and Intensifier Tubes."

The only electronics needed...
in both projects described in this article is a high-voltage power supply capable of providing a typical working voltage of 13.5 kilovolts. This efficient and compact regulated supply operates satisfactorily from a 9-volt, alkaline battery. The current drain of both tubes described here is small, so that their power consumption is low.

The compact power supply is built into a small plastic project case that is fastened directly to the surplus night-vision scope that contains the imaging tube. The Russian-made monocular viewer shown in Fig. 1 is actually one half of a binocular. It is complete with an objective lens and an eyepiece. This assembly includes a first-generation, single-stage image intensifier tube.

The active night-vision scope shown in Fig. 2 contains a single-stage image converter tube. Instructions on how to make several different low-cost infrared illumination sources are described in this article.

Active military night-vision weapons aiming systems typically include an infrared-emitting laser. It pinpoints the target for a heat-seeking weapon or for aiming other kinds of guns or missiles while also acting as a non-visible searchlight for the observer (bombardier or gunner) with an active scope. Various systems have been built for use on land, in the air, or on the sea at night.

Infrared-sensing missiles and “smart” bombs actually “home” on the IR-illuminated target which has been identified by the observer who directs the laser beam and watches it with the active scope. Needless to say, aiming and firing must be fast because enemy gunners with active scopes can also see the laser illumination and take evasive action or retaliate.

**Power supply design**

Figure 4 is the schematic for a high-voltage power supply that will power both night-vision scopes described here. It produces about 13.5 kilovolts from a 9-volt battery. The tubes draw about 20 milliamperes so about
36 hours of useful life can be obtained from a 9-volt alkaline battery. The output voltage will remain essentially constant for battery voltages of 6 to 12 volts.

The power supply has three sections: the inverter, the converter, and the voltage multiplier. The inverter section, a ringing-choke oscillator, consists of transformer T1, resistor R1, diode D1, and transistor Q1. Resistor R1 provides bias current for starting the oscillator, and it also supplies the feedback to maintain oscillation.

Diode D1 protects the base-emitter junction of Q1 when the base voltage swings negative. The oscillator operates at about 120 Hz, set principally by the transformer. The resulting AC voltage at the primary of T1 is stepped up by the secondary turns. The secondary voltage, which is rectified by diode D2, charges C2 through the primary (low-resistance) winding of transformer T2.

When the voltage across C2 exceeds the breakdown voltage of the two series-connected neon lamps NE1 and NE2 (about 150 volts) the lamps turn on. This conduction triggers SCR1, and C2 is quickly discharged through SCR1 and the primary winding of T2. When C2 is discharged, the lamps extinguish. SCR1 turns off, and the charge cycle starts again.

During the discharge cycle of C2, a pulse with a peak-to-peak voltage of 4.5 kilovolts is produced at the secondary of trigger transformer T2. This pulse is applied to the three-stage Cockcroft-Walton or Greinacher voltage-multiplier circuit consisting of diodes D3 to D8 and capacitors C3 to C8.

The multiplier triples the 4.5-kilovolt input to provide the 13.5-kilovolt output with very low current. The capacitors and
The neon lamps regulate the output so that the voltage applied to the primary of T2 is constant at 150 volts, peak. Although the power supply output is nearly constant for DC input voltage from 6 to 12 volts, the operating frequency of the inverter/oscillator increases with the DC input voltage. The waveforms and frequencies shown on Fig. 4 were obtained with a 9-volt input.

Building the power supply
All the electronic components of the power supply except the capacitors and diodes in the voltage tripler are mounted on a 115/16 × 115/16-inch printed-circuit board that will fit with a 9-volt rectangular battery inside a 2 × 31/4 × 1-inch plastic project case. A foil pattern has been provided here for those who want to make their own circuit boards.

Refer to parts placement diagram Fig. 5. Insert SCR1 so that its metal heatsink faces neon lamp NE2. When inserting electrolytic capacitor C1 and diodes D1 and D2, observe their polarities. Mount resistor R1 vertically on the circuit board. Solder all components and trim excess lead lengths.

Refer back to the schematic Fig. 4, and wire the leads of capacitors C3 to C8 and diodes D3 to D8 together mechanically to form a rigid unit according to the schematic. Keep all exposed lead lengths about 1/4-inch long. Then solder the network together as rapidly as possible to avoid applying damaging excessive heat to the capacitors and diodes. The cathodes of some diodes are identified with a red dot on the cathode lead.

Figure 6 shows the completed power supply with the tripler network to the right of the board. Battery B1 and switch S1, both off-board components, are not shown. Solder one lead from C3 and one lead from C6 in the tripler network to the terminal points on the circuit board, as shown in Fig. 5. (The tripler will be potted in silicone after the system has been tested.)

NOTE: The image converter tube in the active night-vision scope shown in Fig. 2 requires a positive ground. If you build this unit, reverse diodes D3 to D8 to convert the supply from one with a positive to a negative output with respect to ground.
**Mechanical assembly.**

Drill a hole in the body of the plastic project case for mounting the miniature toggle switch S1. The location of the switch is not critical, but it should not interfere with the other components. In the passive night-vision scope, it was positioned at the end of the case facing the eyepiece.

Drill the hole in the case for mounting it to the passive scope body with a single screw. The hole for this screw, already drilled and tapped in the body of the scope, is located under the coupling bracket. Drill another hole large enough to pass the power cable to the image tube. Its location will depend on the project you build. Mount switch S1 in the sidewall of the case. Fasten the case to the passive viewer with a screw. If you build the active viewer, cement the case to the scope body with epoxy, as shown in Fig. 2.

Cut the supply lead from the scope about 6 inches long, and strip back about 1 inch of the jacket to expose the braid and the insulated central conductor. Twist the braid into a lead and insulate it with a length of plastic tubing. Insert the cable lead into the project box, solder the braid to the ground connection of the circuit board, and solder the inner conductor to the high-voltage terminal of the tripler network, as shown in Fig. 4.

Verify that there are no short circuits in the construction of the tripler and that the leads are spaced by at least ¼-inch from each other. Wire toggle switch S1 in series with the positive lead from the battery clip. Cut the battery leads from the circuit board so they are long enough to permit lifting the circuit board out of the case. Insert the battery and wiring in the case, but leave the tripler network and circuit board outside temporarily.

**Test and checkout**

After rechecking your work and verifying the polarities and orientation of all components, snap the battery to the battery clip. The current drain on a 9-volt alkaline transistor battery should be about 20 milliamperes in a correct circuit.

WARNING! The power supply described in this article produces an output voltage of about 13.5 kilovolts, and is capable of giving you a startling electric shock. While not normally life-threatening, it can have a temporarily debilitating effect. Consequently, treat it
with respect and always make sure switch S1 is off and the capacitors are discharged before handling the circuit board.

When you switch on S1, a corona discharge might appear around the tripler network. This is non-destructive, but avoid electrical shock by keeping your hands away from that part of the circuit.

Alternatively, you can test the power supply by placing a wire connected to the circuit's ground bus close to the high-voltage output lead. It should produce an arc as much as ¼-inch long.

When the switch is off, connect the ground wire directly to the high-voltage output to discharge all the capacitors. Because of the short-duty cycle discharge pulses, the illumination of neon lamps NE1 and NE2 will be visible only in darkness.

If power supplies have been built and installed correctly, the phosphor screen of the image tube should emit a green glow, whether or not light is incident on the cathode. The green glow persists for about a minute after the power has been switched off, indicating that sufficient voltage still exists between the anode and cathode to form an image.

If, after following the directions closely and checking your workmanship, the scope still doesn’t work, check the voltages at the base and collector of transistor Q1 with a digital volt-meter. The values shown on the schematic, Fig. 4, are DC values expected with a 9-volt power supply.

Do not attempt to measure the high-voltage output directly unless you have a suitable high-voltage probe on your meter. The waveforms shown were also obtained with a 9-volt supply. If you don’t have an oscilloscope available, measure the AC voltage at the test points shown on Fig. 4.

The reading on most digital voltmeters will be RMS values, but they will give you a valid indication if there is a signal. The AC voltage at the cathode of D2 (to ground) of the prototype measured about 45 volts RMS on a DMM. The AC voltage at the base of Q1 was about 0.45 volt RMS.

When the scope is working properly, switch off the power and wait for the tube to discharge completely. Insert the tripler section carefully inside the case as shown at the right side of Fig. 7. Encapsulate it with neutral-cure, room-temperature vulcanizing (RTV) silicone potting compound to prevent high-voltage corona and discharge, which increases with relative humidity. The compound will also fasten the tripler network inside of the case.

Viewing with the scope

The lens of the surplus Russian passive night-vision scope specified in this article is focused to infinity, making it useful for viewing images more than a few meters away. By loosening a small locking screw, the lens can be adjusted. This will permit viewing objects more than 100 meters away under near starlight illumination.

Imaging tubes will be damaged if they are exposed to bright light for long periods. Don’t use either scope in sunlight, or even in well lighted rooms. Always cover both ends of a night-vision scope with suitable lens caps when it is not in use to keep the imaging tube in darkness. The monocular passive scope offered by the source given in the parts list has a rubber lens cap that can be snapped in place. It also has a focusing eyepiece.

Both of the night-vision scopes will detect IR energy, so they can verify the operation of stereo and TV remote controls. In a darkened room, point the emitting face of the control at the scope. A pulsing green light will be seen when any of the remote control’s keys are pressed. A TV remote control can also serve as a temporary IR illuminator.

IR light source

A better IR source can be made by covering a flashlight with an IR filter. You can pur-
with the component values shown in Fig. 12. The circuit can only lock to input signals within this frequency range.

Figures 13 and 14 are schematics for several practical frequency multiplier circuits. The circuit in Fig. 13 serves as a multiply by 100 frequency multiplier/prescaler that can change 1 Hz to 150 Hz input signals into 150 Hz to 15 kHz output signals.

The circuit in Fig. 14 is a simple frequency synthesizer. It is fed with a precise (crystal-derived) 1-kHz input signal, and its output is a whole-number multiple (in the range \( x \times 1 \) to \( x \times 9 \)) of this signal. The CD4017B is organized as a programmable divide-by-N counter in this application. A single CD4017B can be replaced by a series of programmable decade counters to form a wide-range (10 Hz to 1 MHz) synthesizer.

**NIGHT VISION SCOPES**

*continued from page 62*

chase a suitable IR filter at most retail camera stores, or you can stack four or five layers of completely exposed, developed film negatives between the incandescent lamp and flashlight lens. This film can be obtained as scrap from local photo developing shops. Cut four or five disks from this exposed film to fit inside the plastic or glass lens cap of your flashlight.

A complete kit of parts to build both of the scopes described in this article can be obtained from the source given in the parts list. If you elect to buy a surplus image tube to make a night-vision scope from scratch, purchase or obtain a "fast" camera lens and a magnifying glass for use as an eyepiece. You can then assemble all of these parts in a suitable metal or plastic tube. The power supply described here will power most imaging tubes, regardless of their size or country of origin.

**FUNCTION GENERATORS**

*continued from page 50*

nature represents the forward voltage drop. The vertical part of the signature represents the forward current, and the horizontal part represents the reverse voltage drop.

In the waveform for the Zener diode in Fig. 9-d, the forward current is a function of the forward voltage. But when the reverse voltage equals the PN junction breakdown voltage, reverse current increases rapidly, producing a vertical line in the lower left quadrant of the screen. This line is the break-over point or Zener voltage, and it is established by the knee in the signature.

The signature technique can be applied to test and explain the operation of all electronic components. It is simple to use, it can speed troubleshooting, and it works well on unpowered circuit boards. Even electronic service centers operating under tight budget constraints can afford this method.

It is worth noting that two functionally identical ICs which seem to be operating normally can have different pin signatures because of differences in chip fabrication. You might encounter this when testing functionally identical IC's from different manufacturers. Different signatures do not necessarily indicate a device fault.

With experience in the careful interpretation of signatures, signature analysis can help you to identify defective components quickly—even those with marginal problems. Defective ICs (open-circuited or short-circuited) can be isolated rapidly by persons with little or no experience doing this.

**FIG. 9—NORMALIZED CURRENT VS. VOLTAGE SIGNATURES for electronic components: resistor (a), inductor or capacitor (b), silicon signal diode (c), light-emitting diode (d), and Zener diode (e).**