**Popular Electronics**
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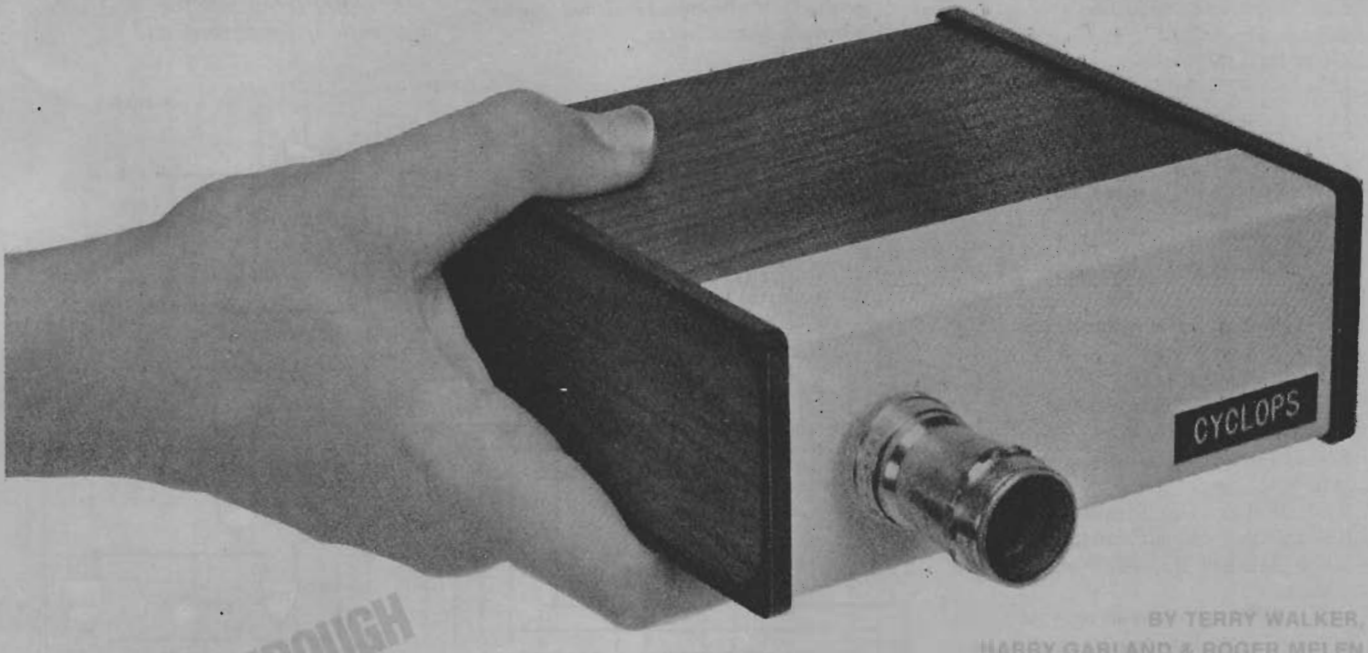

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BREAKTHROUGH PROJECT!

# BUILD CYCLOPS FIRST ALL SOLID-STATE TV CAMERA FOR EXPERIMENTERS

*Using an MOS array and digital electronics eliminates vidicon and yoke.*

SOLID-STATE image sensors, which were discussed in detail last month, may one day supplant vidicon tubes in TV cameras. They promise small size and easy camera construction, have a low power requirement and operate in a wide range of light conditions. Cost, however, has been prohibitive—until now!

Presented here is "Cyclops," the first all-solid-state TV camera project using a special MOS photoelement array as the image sensor—and, it can be built by electronics experimenters at an affordable price. (A complete kit of semiconductors, including the MOS device, is available for $55, for example.)

Any image that can be picked up by a conventional TV (or movie) camera can be picked up by Cyclops. Unlike conventional cameras, however, Cyclops is sensitive to infrared radiation and is thus able to "see" in the dark when an infrared light is used to illuminate the scene.

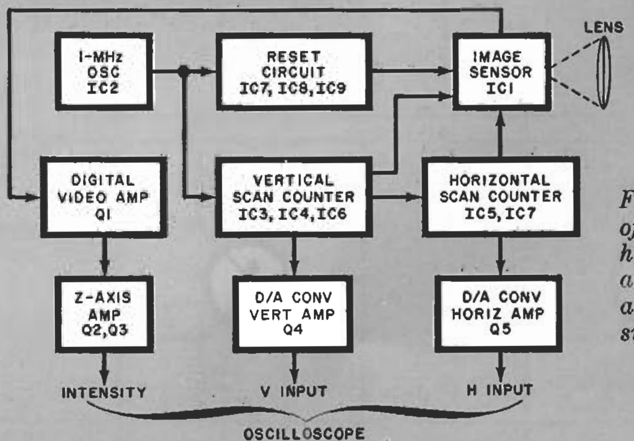


*Fig. 1. Logic diagram of the camera shows how scan counters address camera and also generate sweep signals for the scope.*

## PARTS LIST

C1, C2—0.001-$\mu$F disc capacitor
C3, C4, C5—0.1-$\mu$F disc capacitor
C6—330-pF disc capacitor
C7, C8, C9—0.01$\mu$F disc capacitor
D1 to D4—1N914 diode
D5—1N5242 12-volt zener diode
IC1—1024-element image sensor
IC2, IC9—7402 TTL quadruple 2-input NOR gate
IC3, IC5, IC6, IC7—7493 TTL 4-bit binary counter
IC4—7404 TTL hex inverter
IC8—7400 TTL quadruple 2-input NAND gate
IC10—MC7805CP 5-volt regulator
I1, I2—#47 pilot light
J1 to J4—Banana jacks
Q1, Q2, Q3—2N3640 transistor
Q4, Q5—2N3904 transistor
R1—100-ohm, ½-watt miniature potentiometer
R2—100-ohm, ½-watt resistor
R3—560-ohm, ¼-watt resistor
R4 to R18 and R52—1000-ohm, ¼-watt resistor
R19—15,000-ohm, ¼-watt resistor
R20 to R31—20,000-ohm, ¼-watt 5% resis.
R32 to R39—10,000-ohm, ¼-watt 5% resis.
R40 to R44—100-ohm, ¼-watt resistor
R45, R46—68,000-ohm, ¼-watt resistor
R47, R48—5600-ohm, ¼-watt resistor
R49—1800-ohm, ¼-watt resistor
R50—18,000-ohm, ¼-watt resistor
R51—2200-ohm, ¼-watt resistor
Misc.—IC socket (9), ¾" variable-length spacers, lens (see text), suitable chassis, mounting hardware, line cord, etc.

Note—The following are available from H. Garland and R. Melen, 26655 Laurel Lane, Los Altos, CA 94022: kit of all IC's (including image sensor), diodes, and transistors at $55; pc board at $5; all postpaid. California residents, please add sufficient sales tax.

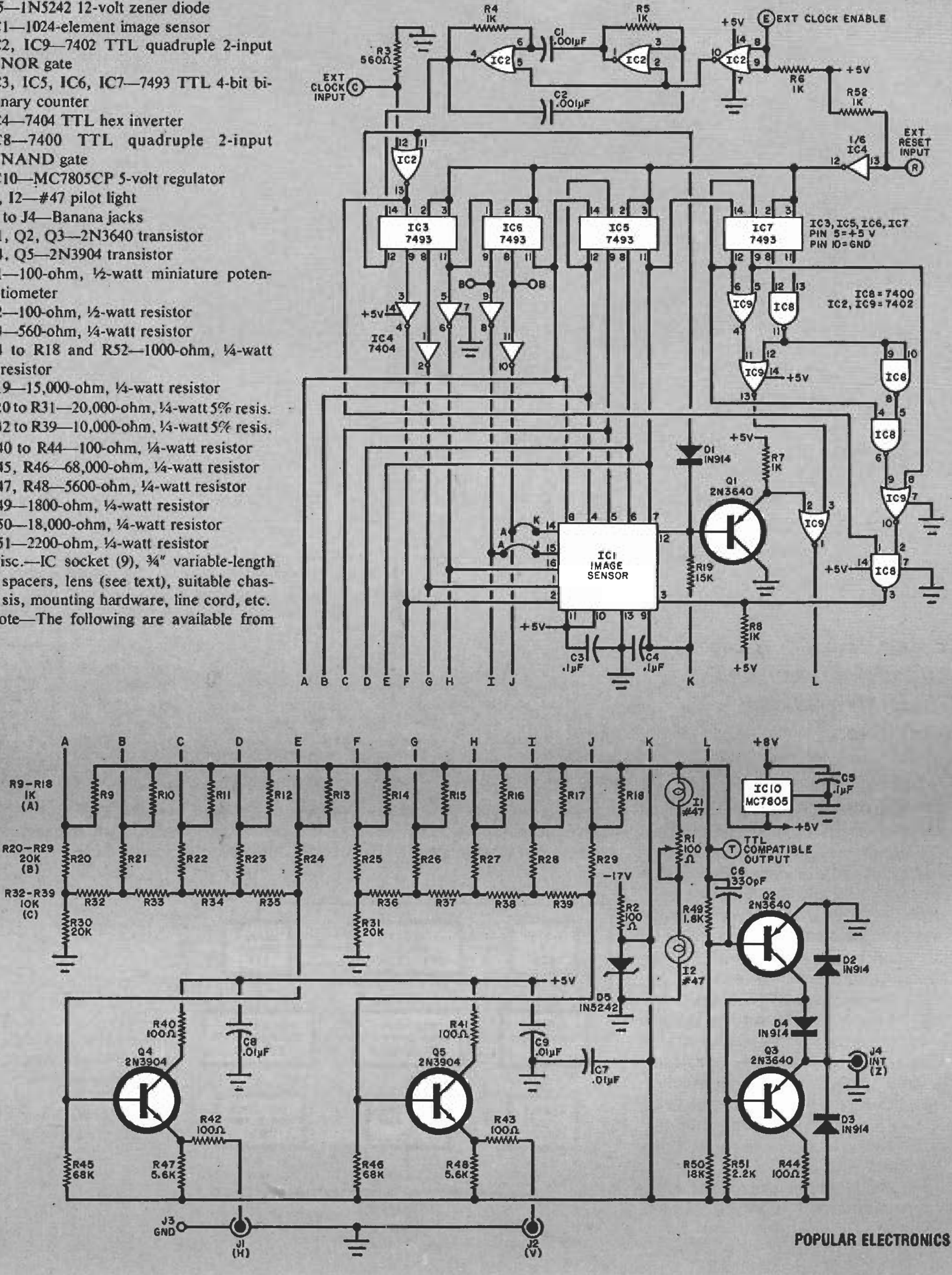


*Fig. 2. Complete schematic of the camera. Letters between sections are merely for showing interconnections. Letters in circles are terminals for use with optional circuits.*

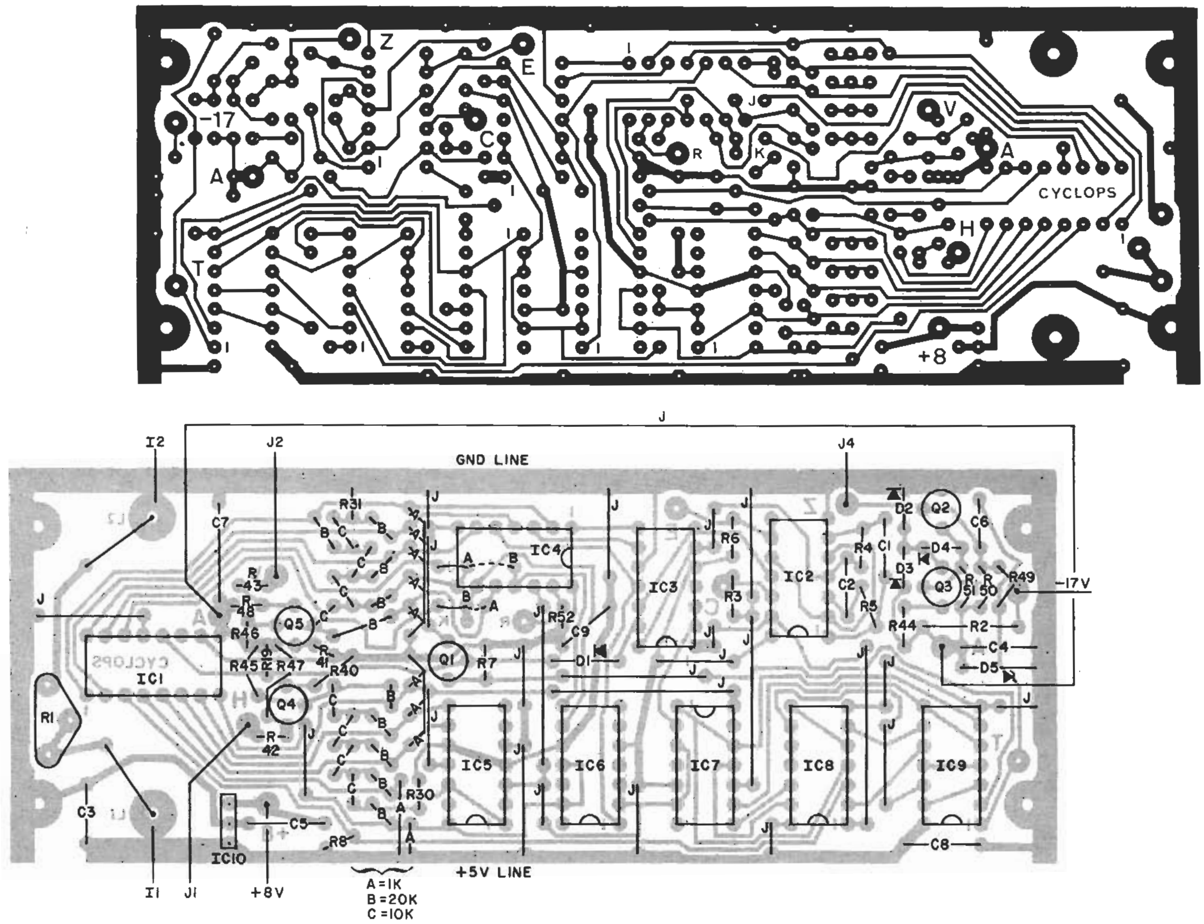


*Fig. 3. Actual-size foil pattern (top) and component placement. Note that most resistors are mounted on end to conserve space.*

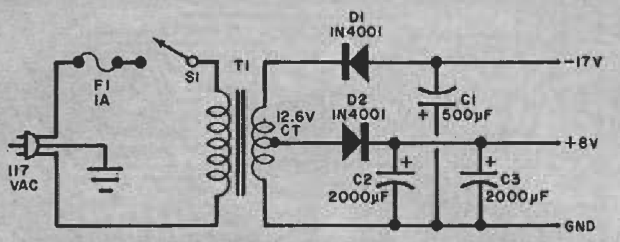
The MOS array has 1024 separate photosensitive elements fabricated on a single chip and mounted in a conventional 16-pin DIP case with a transparent cover. Although similar sensing devices have cost up to several hundred dollars in the past, new techniques and volume production have made it possible to reduce prices. With just 1024 elements (in a 32 by 32 array), Cyclops can't be expected to match the resolution of a vidicon camera; but it is quite useful for many applications. The circuit described here is for using Cyclops with a conventional oscilloscope, but it could be altered for a display on a TV tube. (Among other things, a sync generator would be needed.)

A little imagination will enable the experimenter to come up with a number of novel uses for Cyclops. For example, if a fiber-optic light pipe is used with the sensor, it could pick up conventional printed material for transmission or to excite a type of tactile device for use by the blind. Consider also the possibility of using Cyclops in conjunction with the Altair 8800 Minicomputer (POPULAR ELECTRONICS, January 1975). The combination could be used to build a security system that would operate on the basis of a person's appearance. This approach also opens up a brand new and exciting area for the advanced experimenter—a digital computer that has "vision." For example, the Cyclops/Altair combination, with 256 independent inputs/outputs could be the basis for a robot that could be programmed to do a number of things, while also being able to "see" its environment and make any necessary corrections in its actions.

**Circuit Operation.** The Cyclops logic diagram is shown in Fig. 1. A part of *IC2* is used as a 1-MHz timing oscillator. One output of the oscillator drives the vertical scan counter, which drives the horizontal scan counter. The binary outputs of the scan counters are used to address the rows and columns of the MOS array.

As each of the 1024 elements is addressed, two events occur within a period of less than two microseconds. First, the outputs of the vertical and horizontal scan counters are processed by a ladder-type digital-to-analog (D/A) converter, then amplified by *Q4* and *Q5*, respectively, to produce the scope vertical and horizontal sweep. This creates the raster on the CRT. The second event occurs when the video information on the image sensor is read out, amplified and used to vary the brightness of each of the 1024 dots that make up the raster and produce the intensity-modulated image on the CRT. Since both sweeps (H and V) and the video (brightness) information are "in step" at all times, each of the 1024 elements on the sensor has a corresponding point on the raster, and the charge on each element determines the brightness of its raster dot.

A novel coding scheme is used for the video information. Thirty completely new frames are displayed on the scope each second, with each frame made up of 16 separate and complete scans of the image sensor. The first of these 16 scans is used to reset the 1024 photoelements, with



## PARTS LIST

C1—500-µF, 15-volt electrolytic capacitor
C2, C3—2000-µF, 15-volt electrolytic capacitor
D1, D2—1N4001 diode
F1—1-ampere fuse and holder
S1—Spst switch
T1—12.6-VCT filament transformer (Triad F-25X or similar)

*Fig. 4. Power supply for camera can be wired point-to-point and mounted anywhere in chassis.*

the reset pulses generated by *IC7*, *IC8*, and *IC9*. On subsequent scans, the video information is read out.

When a particular photoelement is illuminated by a bright light (from the image being sensed), a video output pulse is developed each time that element is addressed. The video output pulses are amplified by *Q1* and, after gating, by *Q2* and *Q3* to produce the scope intensity (Z) axis signal. If there is no light on a particular element, no video pulse is generated when that element is addressed. For grey portions of the picture, the number of video pulses generated for each frame is determined by the intensity of the grey in the original image.

Several inputs and outputs are provided on the pc board as shown in Fig. 2. These are for possible use in advanced projects. For normal operation, no connection is necessary at these points. Point "T" provides a TTL-level signal to facilitate interfacing with external digital circuits. By connecting point "E" to ground, the 1-MHz oscillator is disabled and an external oscillator can be applied to point "C". An external reset pulse can be applied through point "R" to reset the scan counters at any point in the scan cycle. Since both position and intensity information are available in digital form, Cyclops can very easily be interfaced with a digital computer.

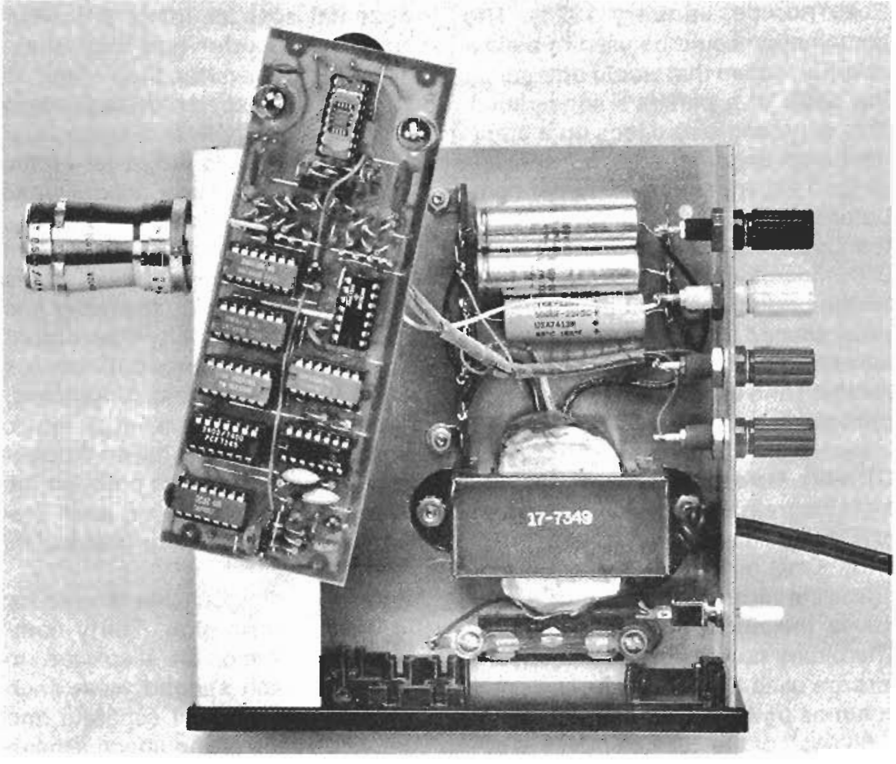


*Photo shows chassis with the printed circuit board pulled out.*

The external oscillator input can be used to synchronize Cyclops with the computer or with a TV display.

**Construction.** The logic circuits of Cyclops are on a single pc board (Fig. 3). Use sockets for all of the IC's except *IC10* which is soldered in place. Be sure to observe the correct polarities on all IC's, diodes, and transistors.

For the pilot lamps (*I1* and *I2*), drill holes in the board just large enough to accommodate the metal portions of the lamps so that, when they are inserted from the nonfoil side, the glass portion just touches the board. The metal portions of the lamps are then soldered to the pads, and small lengths of wire are soldered to the center connectors on the lamps and the appropriate pads.

Miniature potentiometer *R1* is mounted on the foil side of the board so that the two lamps can be adjusted when the pc board is mounted in place. The purpose of *I1* and *I2* is to bias the image sensor with a dim, uniform background light. Although this is not absolutely necessary, the bias light improves the low-light-level sensitivity and provides better picture contrast.

Note that many resistors are mounted on-end to conserve space on the board.

The power supply circuit is shown in Fig. 4. This supply is wired point-to-point (using a terminal strip) and can be mounted anywhere within the selected chassis.

The pc board is mounted on ¾" adjustable standoffs behind the front of the chassis. Mount the board temporarily and mark a spot on the front panel that is directly in line with the center of the image sensor *(IC1)*. Remove the board and drill (or cut) a hole just large enough to accommodate the selected lens. Before mounting the board permanently, make sure that the distance between it and the lens can be adjusted slightly to permit focussing.

Connect the ground, +8-volt and −17-volt lines from the power supply to the board. Connect the four leads from the board (ground, vertical, horizontal, and intensity) to their respective color-coded jacks on the rear panel. The power switch *(S1)* is also mounted on the rear panel, and the line cord goes through a grommeted hole in the same panel.

Either one of two image sensors

*Jacks for scope connections and on/off switch are on chassis rear.*

may be supplied for use in Cyclops. The two are identical except for the way pins 14 and 15 are connected to the circuit. Note that, on the pc board, *IC1* pin 15 goes to pad J, and pin 14 goes to pad K. If your image sensor is marked "Type A," connect pad J to pin 8 of *IC4* and pad K to pin 10 of *IC4*. If the image sensor is marked "Type B," connect pad J to pin 9 of *IC4* and pad K to pin 11 of *IC4*.

**Lens Selection.** Almost any movie camera lens will work with Cyclops. The two important factors to consider in choosing a lens are focal length and *f*-number. The focal length determines the viewing angle of the camera, while the *f*-number determines how much light can be collected.

The lens used with Cyclops should have a variable aperture so that the *f*-number can be adjusted to suit the lighting conditions. The minimum *f*-number, when the aperture is wide open, determines the lowest light level at which Cyclops will operate. An *f*-2.8 lens should be adequate for most applications, though some additional lighting may be required for indoor operation. (We purchased an under-$10 used *f*-2.8 normal motion-picture-camera lens with variable stops for this project.)

Both new and used movie camera lenses are available from photography stores and mail-order houses. A 12.5-mm, *f-27* lens is available from Edmund Scientific (300 Edscorp Bldg., Barrington, NJ 08007) for less than $10 (stock No. 41,146).

**Setup and Operation.** Connect Cyclops to an oscilloscope (set to external horizontal) as follows: *J1* to horizontal input, *J2* to vertical input, *J3* to ground, and *J4* to intensity input. If your scope does not have provision for an intensity input, modify it according to Fig. 5.

With power applied to both Cyclops and the scope, adjust the scope's horizontal and vertical gain until a 32-by-32 pattern of dots forms a square array on the screen. Cover the lens of Cyclops and then turn the scope's intensity control down until the dots just disappear. Now, expose the lens to a lamp. The dots on the CRT will illuminate.

To adjust the focus between the image sensor and lens, turn the bias lamps down *(R1* at maximum resistance) and expose the lens to a simple, illuminated test pattern such as a black cross on a white background. If the lens can be focussed, adjust it for the distance between the lens and the test pattern. Set the lens to its widest opening (smallest *f*-number). Use a 50-watt lamp to illuminate the test pattern and position the lamp until an image appears on the screen. Adjust the distance between the image sensor and the lens by varying the spacers until the test pattern is in the sharpest focus. Then secure the pc board in place.

To adjust the bias lamps, darken the room so that no ambient light reaches the image sensor. Make sure that *R1* is at maximum resistance (lamps out). Adjust the scope's brightness control until the dot pattern can just be seen, and then increase the brightness of the bias lamps until the scope pattern just starts to get brighter. This is the correct setting of *R1*. Place the cover on the chassis so that no ambient light reaches the image sensor.

Cyclops is now ready for use. Although the resolution may seem to be on the low side for observing fine details, you will note that the apparent resolution seems to increase when viewing a "live" scene—especially one with motion.

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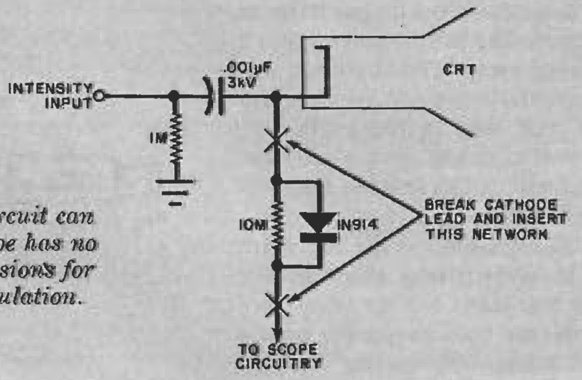

*Fig. 5 This circuit can be used if scope has no internal provisions for intensity modulation.*