BUILD this COLOR TV CAMERA for about $400

Having only two channels of video, this camera produces remarkable color pictures. Any amateur or experimenter can build it for about $400

by GARY DAVIS

INCREASING INTEREST IN CLOSED-CIRcuit TV and the public acceptance of color have created a need for a low-cost color camera. A complex, high-quality broadcast color camera can cost $90,000 or more. Although recent developments have brought the cost down for educational and industrial use, prices are still out of range for most amateurs and experimenters.

The camera described in this article was developed on the premise that an advanced experimenter or amateur could build a color camera without getting into extremely complex mechanical, optical, or electrical problems. All parts are easy to obtain. The two vidicon tubes are standard low-cost black and white types. Color filters are low-cost and available at any glass company. To keep the cost, weight, and size to a minimum, a small black and white TV set is used to supply all voltages and scanning signals to the camera head. The camera uses only 12 transistors in addition to the black and white TV set. The optical system is extremely simple. The cost of the camera, excluding the case, is approximately $400.

Color processing

There is a little known process of using only two colors instead of three to generate color images. This theory dates back to 1914 when William F. Fox and William H. Hickley patented a color motion picture process involving a red filtered scene shown alternately with a green filtered scene projected in black and white only while the red filtered scene was projected through a red filter. The effect was later independently re-discovered by Dr. Edwin H. Land in 1955. This phenomenon has since become known as the Land Color Theory after articles by Land appeared in the proceedings of the *National Academy of Science* in 1959 and the May, 1959 issue of *Scientific American*. Dr. Land found that the human eye can perceive scenes in full color when the image is filtered through long- and short-wavelength filters, then recorded separately on black and white photographic film.

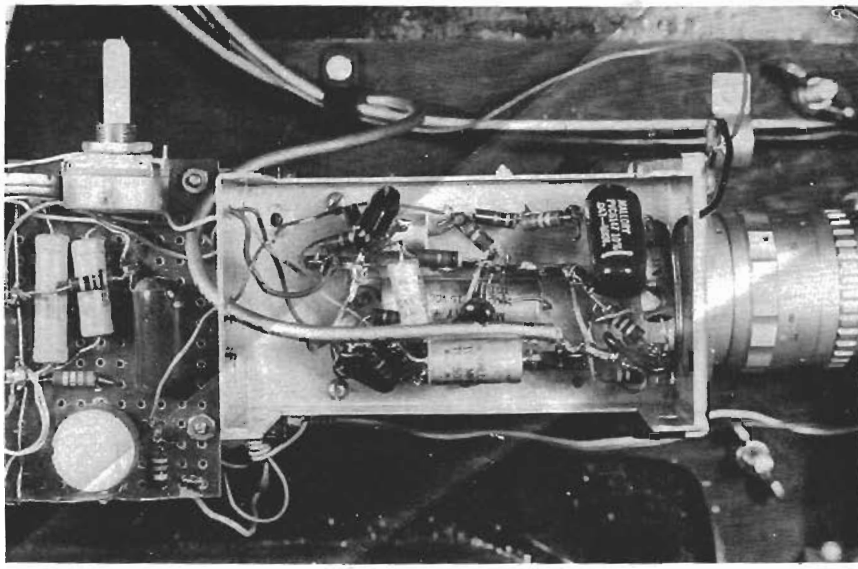
To recover the scene in full color, it is then only necessary to project the scene recorded on the two separate photographs, with a long wavelength light source illuminating the long wavelength photograph, and a short wavelength light source illuminating the short wavelength photograph. In Land's process, the colors in the scene arise not from the choice of wavelengths, filters, or overall brightness levels, but rather from the interplay of longer and shorter wavelengths over the entire scene.

My camera system is similar to Land's process. The two color filter wave lengths correspond to the wave length or combination of wave lengths, generated by the three illuminating phosphor colors in a conventional color picture tube. The filter for the long wavelength image, centered at approximately 650 millimicrons, is red. The short wavelength filter, centered at approximately 475 millimicrons is cyan, a bluish-green. In effect the two color channels are a combination of the three primary colors. Inputs to the green and blue color difference amplifiers of the color monitor are combined, allowing the blue-green phosphor dots to produce cyan, corresponding to the cyan or short wavelength filter in the camera head. The red color difference amplifier and the red phosphor dots of the color monitor handle only the signal from the red or long-wavelength tube.

Colors hold true over a wide range of different red, green and blue images due to the interplay of the red and cyan signals. In fact, the only camera operating color controls are the red and cyan lens iris adjustments. The receiver contrast control may also have to be re-adjusted depending upon lighting conditions. The color receiver tint and color-level controls have no effect in this arrangement since the signal is not encoded to a NTSC signal.

Tests indicate that NTSC color encoding can be done by feeding the cyan signal to the combined blue and green color inputs, and sending the red to the normal red input of a commercial NTSC color encoder. With this arrangement, the camera output could be video taped or transmitted by a ham TV transmitter.

Extensive testing of both the conventional three-tube color system and the simpler two-tube system indicates of course, that the two-tube system cannot duplicate three-tube performance in all respects. The main difference being some averaging of colors along the junction point of the blue-green spectrum, some difficulty with shades of yellow and some hues of magenta. However, the system produces surprisingly good color. The colors are rich and vivid. Blues are blue, greens are green, and reds are red. Complex colors such as skin tones, browns, hair colors, etc. are reproduced well.



Close-up view of one of the preamplifier circuits that are mounted over the vidicon tubes.

The advantage of using only two tubes instead of three, at least for the home experimenter or low-cost application, far outweighs the relatively minor additional color discrepancies encountered with the two-color process. These advantages include:

Camera registration, the art of overlapping images to perfectly coincide, is much simpler.

The camera can be built with one-third less parts.

Camera sensitivity is greater since light must be divided only two ways instead of three.

Optics are much simpler allowing the use of a simple cube prism to split the incoming light in two directions.

How it works

Figure 1 is a block diagram of the entire camera system. Light from the scene first passes through a cube prism. The prism itself absorbs approximately 40% of the light. Approximately 50% of the remaining light is bent 90 degrees to the red lens. The prism is available from Edmunds Scientific Co. The cyan camera lens gets a straight through view of the scene. Both camera lenses are Cosmicar 25 mm, available from Denson Electronics Corp. The prism must be placed before the objective lens so the glass in the prism won't affect the focal length of the lens. The color filters are placed between the lens and vidicon face plate. The cyan filter consists of two layers of Plexiglas green No. 2414. The red

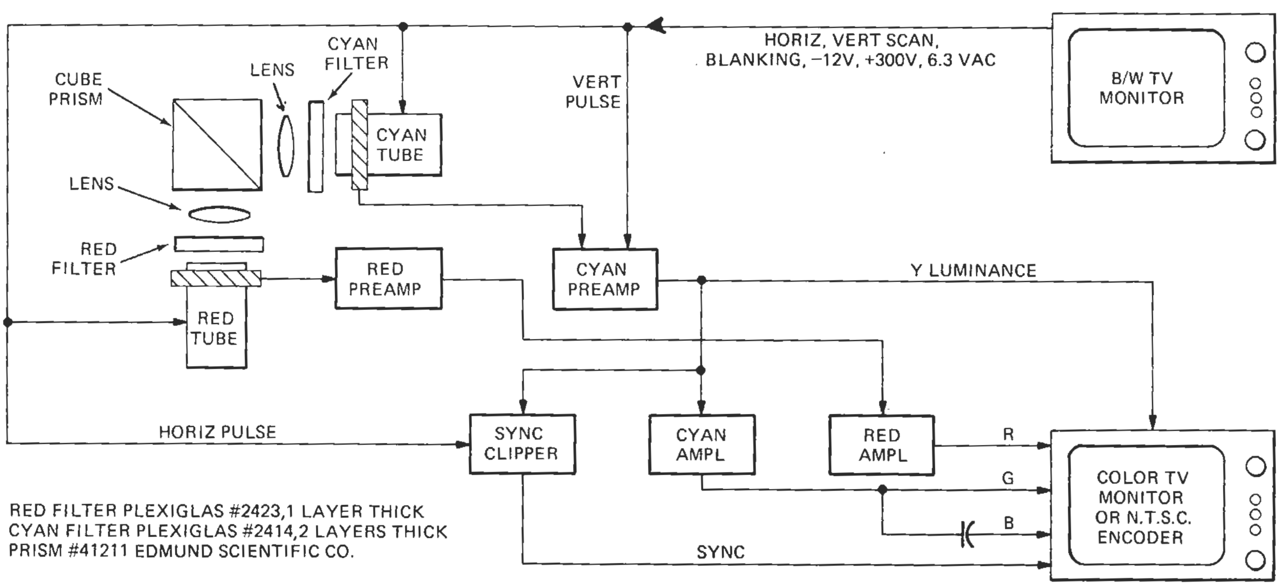
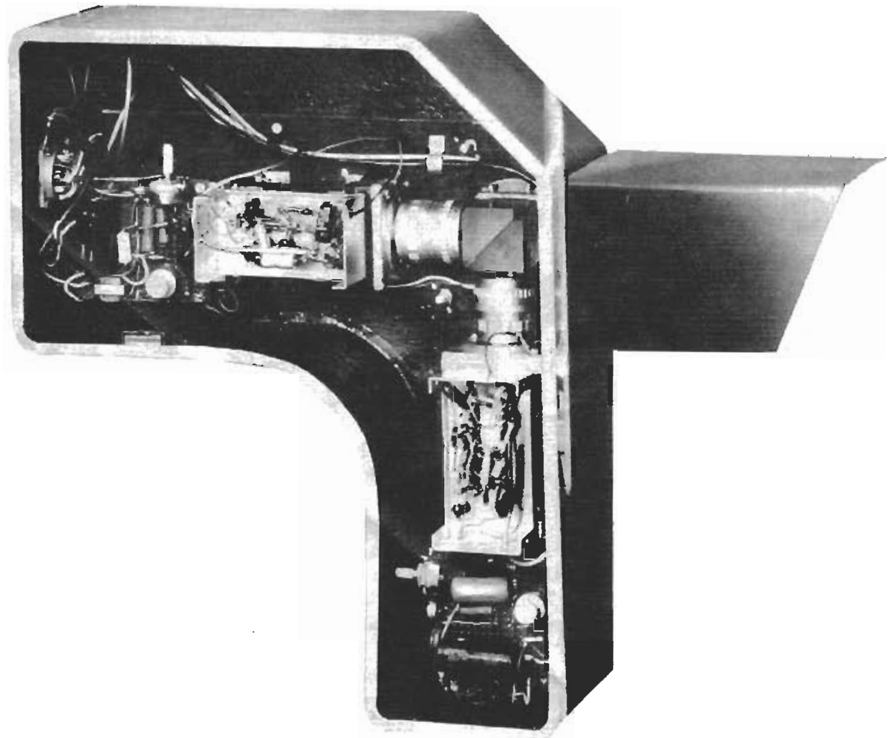


FIG. 1—BLOCK DIAGRAM of the camera head. Operating voltages and sync signals are supplied by a black-and-white TV receiver.

filter is Plexiglas red No. 2423, one layer thick. Both yoke and focus coil assemblies are available from Denson Electronics. This assembly also contains the alignment magnets which are used to register the two images. These yokes are built to very close tolerances and register well. Don't be tempted to substitute another type of yoke.

Again, referring to the block diagram, the black and white TV feeds horizontal, vertical, scan, blanking, −12 volts, +300 volts, and 6.3 VAC to the camera heads. The output of the cyan vidicon is fed to the cyan preamp. A vertical sync pulse is added and the video amplified to approximately 1 volt VP-P. This output also forms the luminance signal and is fed to the color monitor's luminance amplifier to provide the black and white information. The cyan preamp also feeds the cyan amplifier where the signal is inverted and raised in amplitude to drive the grids of the G − Y and B − Y amplifiers. The grids are coupled together with a .5 μF capacitor.

The cyan preamp output is also fed to the sync clipper where the vertical sync pulse is inverted and sent to the color monitor's sync separator. The horizontal sync pulse is fed separately to the sync clipper in order to prevent contamination of the blue and green amplifier in the monitor. The red preamp output drives the red amplifier which in turn drives the R − Y amplifier. The sync clippers, cyan amplifier, red amplifier and a −18 volt power supply are located in the color monitor so that all signals may be sent to the color monitor on a single 4-conductor cable. A multi-conductor cable is used between the black and white TV set and the camera head. This 2-piece configuration also allows the camera to be used hand-held. The camera head weighs 18 lbs.

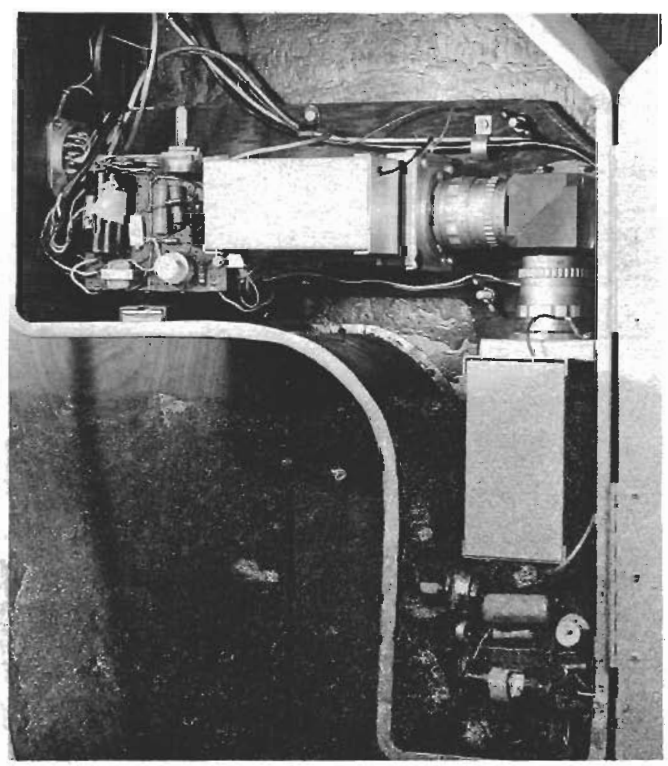


LAYOUT OF THE CAMERA HEAD is shown. Camera case was constructed from sheet metal.

Many camera builders will want to include the small black and white TV in the camera case to act as a view finder. The horizontal sync will have to be re-applied to the TV sync separator for operation as a view finder. Do not use an AC-DC type TV with this project because of the shock hazard involved. A square sun shade on the front of the camera prevents stray light from striking the prism in bright sunlight. Paint the inside of the camera case black. The camera case is not commercially available and may be constructed out of sheet aluminum.

I found the easiest method of mounting the parts for mechanical alignment is to build each camera head as a separate unit. After both heads are tested and operate correctly, lay both heads and the prism on a wood mounting board. The camera is initially registered and adjusted mechanically, optically, and electrically while laying on its side. Remember, for good registration, every optical and electrical parameter—focal length distance, scan amplitude, yoke alignment, optical and electrical focus adjustments—must exactly match the other channel. Finally, when all electrical adjustments and tests are complete, screw down the heads and mount the prism. The whole camera assembly is then placed inside the camera case. All camera tests and registration adjustments are made using a standard TV test pattern with a series of vertical color stripes glued to the top of the test pattern. The colors I use are red, orange, yellow, dark green, light blue, dark blue, and magenta.

Next month we will cover the camera heads, circuit details, modification of the two TV sets, adjustments registration, and final check out. **R-E**



CLOSE-UP VIEW of camera head shows details of layout and optic system.

COLOR TV CAMERA

The article by Gary Davis on building a color TV camera for about $400 published in July, August and September 1975 issues has encouraged me to try a similar project. This is an alternate approach that eliminated the need to build the video circuitry and, in view of a recent bankruptcy sale of black-and-white TV cameras, should cost about the same. These cameras weigh 2.7 lbs, are solid-state, use an Eumig Viennon lens, are new and cost $125 each.

For purposes of a quick preliminary test, I have synchronized two cameras, Scotch-taped the Plexiglas filters in place, and run their video outputs to a color TV monitor connecting the blue and green guns together through a capacitor as suggested in Gary's article. I placed the cameras side-by-side and registered the returns from a color chart. The colors obtained, although not studio quality, were good enough to encourage me to proceed with the registration of the two cameras through the cube prism beamsplitter.

The parts list is included in the event some of your readers would like to try this approach.

Two TV cameras with service manual, sync instructions and 14-ft. cables at $125 each.	$250.00	Automation Systems 124 Lundy Lane Palo Alto, CA 94306
One 18-VDC, 15-watt power supply for the two cameras.	$ 39.00*	Automation Systems
One ⅛-inch thick by 2-inch square red filter, Plexiglas #2423.	$ 1.00	Corth Plastics 532 Howland St. Redwood City, CA 94063
Two ⅛-inch thick by 2-inch square green filters, Plexiglas #2414.	$ 2.00	Corth Plastics
One beam-splitter cube-prism, 40-mm, stock #41211.	$ 20.50	Edmund Scientific Co. Edscorp Building Barrington, NJ 08007
Total:	$312.50	

*The power supply can be built at a savings from information supplied with the cameras.

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