

Fig. 1A—The horseshoe comprises all the visible colors; the triangle includes all colors reproducible in color TV. Colors shown in this triangle are recognizable to the eye when they cover large areas. B—When medium-small areas are viewed, blues and yellows appear gray, and only cyan and orange are clearly distinct. Two areas rather than one are shown as gray. This is so because yellow and purple—the colors really present in these areas—will look gray if the observer's distance from them is great enough. C—The eye cannot distinguish between colors and black-and-white when small objects are viewed; only intensity variations—referred to as varying shades of gray—are visible.

## More About

# Color TV Fundamentals

*How the Eye Sees Color. What "Q," "Y" and "I" Signals Are. Sub-carrier Modulation Explained*

BY PETER ORNE  
AND  
SOL HELLER  
MANAGING EDITOR, TECHNICIAN

• Last month, we tried to clarify how room was found in the black-and-white spectrum for color signals. In this month's article, we will review the next problem surmounted by NTSC researchers—i.e., their determination of the minimum information required to obtain a satisfactory color picture. The problem was briefly discussed in the Oct. '53 issue of *TECHNICIAN* (*Serviceman's Analysis of the New*

*TV Color System*), and will be considered in greater detail in this piece.

The less information that has to be transmitted in addition to the luminance information (luminance refers to the color signal component that corresponds to the black-and-white video signal) the less chance there will be of interaction taking place among the different signals sent out. In order to determine the minimum bandwidths to which color signals could be reduced, many investigations were made into how well the eye sees small areas of color. The result of these investiga-

tions may be summed up as follows:

The eye cannot see color—i.e., distinguish between colors or black-and-white—when the object inspected is very small (see Fig. 1C). The eye has "three-color" vision, on the other hand, for large objects (Fig. 1A). "Three-color vision" means that we can, by mixing lights of three colors in the proper amount, cause the eye to see practically any color. This duplication is called color matching.

There are many ways of obtaining a color match. Almost any three widely-separated colors may be used (as we shall see later). In the

color picture tube, red, green and blue lights (given off by phosphors on the screen) are employed for this purpose.

How about cases that fall in between the extremes of no color and three-color vision—i.e., the instances when medium-small objects are being viewed? What the average person sees in these instances may be reproduced by the mixture of two colors (see Fig. 1B). Some color-blind people, incidentally, see both large and medium-sized objects in this way.

In viewing medium-small objects, most of us readily differentiate between cyan (a bluish green) and orange. Blues and greens, however, look like cyan, and reds and yellows look like orange. We can experience this effect if we try to match a single fine strand of colored thread to a correspondingly-colored spool of thread.

It appears, therefore, that we need three components of information to get proper coloring for large areas; two pieces of information are required to get satisfactory color on "medium-small" areas; we only need to know the luminance for very small areas.

#### "Q", "Y" and "I" Signals

The way we see small detail, in monochrome that is, and the fact that we want a compatible system, makes it necessary that one of the components be the luminance or "Y" signal. From the fact that we can distinguish cyan and orange best in medium-small areas, it would be an advantage to choose as one of the other components of information a signal that distinguishes between these colors. This signal is called the "I" signal.

For large areas, where the eye can distinguish between all colors, another piece of intelligence must be added which is called the "Q" signal. This signal distinguishes between green and purple. If the information present in the "I," "Q" and "Y" signals is combined, any visible color can be effectively reproduced, thus permitting "three-color" viewing.

Summing up: "Y" is the luminance information; it is transmitted for the full 4 mc. "I" is the information that can tell cyan from orange, and is transmitted to 1.5 mc. "Q" is the information that, in conjunction with the "I" and "Y" signals, provides the three components for "three-color" vision; it is transmitted for only .5 mc (see Fig. 2).

Readers may wonder why the

colors in Fig. 1 are grouped in a horse-shoe form. The theory behind this may be summarized as follows:

Any color can be reproduced by mixing three colors together. The three colors used are known as the *primaries* of the system. The only restriction regarding the choice of colors is that a primary color must not be reproducible by any mixture of the other two primaries.

#### Color Designation Systems

Visible colors can be represented in different ways. Most readers are probably familiar with the fact that colors can be designated by their wavelength. Scientists concerned with the study of color have found it convenient to use another method of representing visible colors. They (arbitrarily) choose three colors that are *supersaturated*—i.e., unmixed with white—and define any other color by giving the amount of each supersaturated color necessary to reproduce it.

The supersaturated or reference colors are non-existent in nature and cannot be seen by the eye. They provide arbitrary standards for comparing colors.

One of the reference colors is so chosen that its amount affects only the brightness (not the hue or saturation) of the color to be defined. The other two colors are capable of representing any definite color (except with respect to brightness). The system is essentially the same as the one used in color TV, in which two signals—"Q" and "I"—determine the color, while the third one—"Y"—reports on its brightness.

When the two supersaturated or

reference colors are used as axes (vertical and horizontal axes, of course) any color visible to the eye may be plotted as a point on this diagram. The height of the point (or its distance above the X axis) indicates the amount of one reference color present; the distance of the point from the Y axis indicates how much there is of the other reference color.

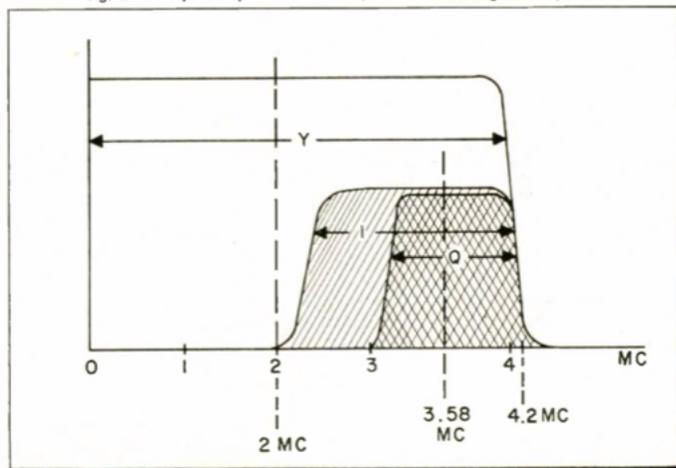
When such a diagram is made, it is found that visible colors fall into an area that looks like an inverted horse-shoe. The nearer we come to the center of the horse-shoe, the less saturated the colors get—i.e., the whiter they get. The area at the center is what most people consider white.

#### Subjective Aspects of Color

Color is subjective—that is, different people give different names to the same shade of color. In addition, colors look different when their surrounding color is changed. White is a wide area (in Fig. 1) because desaturated shades of any color (i.e., color mixed with white) will look white if looked at for some time without comparison. This is the reason, incidentally, that the shade of white used on a black-and-white crt screen turned out to be much less important than originally expected; only when a number of b & w sets are put next to each other does the difference in screen whiteness become apparent.

A final note on the horse-shoe patterns of Fig. 1: There are actually no sharp divisions between colors, such as those that seem to be present in these sketches. Different

Fig. 2—Bandpass requirements for "Q," "Y" and "I" signal components.



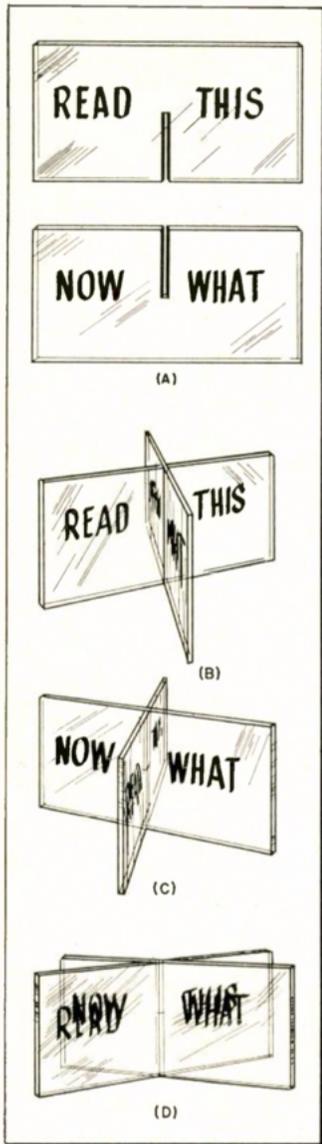


Fig. 3—Mechanical analogy to phase-shifting of color subcarrier. Two signs, painted on glass and mounted at right angles, represent subcarrier at 0 and 90 degrees.

people will place the dividing lines between colors at different points. The colors in Fig. 1A are most saturated (i.e., intense) on the rim of the horse-shoe; these intensities are largely beyond the range of the present-day TV color system. The dotted-line area in the white section will be seen as white, or white with a hue of the adjacent color added, depending on the vision characteristic of the viewer.

With the problem of how much color information to transmit surmounted, the next difficulty that arises is how to transmit two different pieces of color information, "Q" and "I," on one subcarrier. If we could use two different subcarriers, "Q" could be modulated on one and "I" on the other. This is effectively done, but the two carriers are at the same frequency. Since this may sound like double talk, let's see whether we can clear it up.

#### Mechanical Analogy

Assume that two transparent sections of glass are available (Fig. 3A). On one of them are printed the words READ THIS; on the other, NOW WHAT. Suppose we get our favorite glasscutter to join these two pieces of glass at right angles, as shown in Fig. 3B. If we look at this combination from one angle (Fig. 3B), we can see the words READ THIS. If we look at it from another angle (Fig. 3C), we can read the words NOW WHAT. If we look at the unit from the angle shown in Fig. 3D, however, we can decipher neither phrase, since one set of words falls over the other, obscuring both groups of words.

An analogous situation is present with respect to the use of the color subcarrier. The "Q" signal (similar to READ THIS) is modulated on the color subcarrier (equivalent to one glass section); the "I" signal (similar to NOW WHAT) is modulated onto the subcarrier after the latter has been shifted in phase 90°

(or quadrature-shifted). The second glass section, which makes an angle of 90° with the first one, may be compared to the phase-shifted color subcarrier.

If the exact phase of the carrier when the signal was modulated onto it is known, the modulation can be removed or detected (just as the glass sections can be read, if we know the angle to read them by). This type of detection is known as synchronous detection. It requires exact knowledge of the subcarrier phase; a subcarrier sync burst is transmitted after each regular horizontal sync pulse as a phase reference for the receiver, to provide this desired phase information.

AND WAS HIS FACE RED! Technician we know was asked to install an outdoor antenna on the roof of a fourteen-story building in New York. Job took almost all day because the superintendent insisted on lead-in being fastened to outside wall at each floor. This necessitated going into each apartment from top to second floor (and finding the super each time another floor was reached.) New antenna set-up provided a mediocre picture, which owner didn't squawk about since most tenants on his particular side of the building got poor reception also. The pay-off: A few weeks later the owner called the TV man and said that an outdoor aerial which he'd purchased solved his problem, bringing in an acceptable picture.

"For years I broadcast my morning setting up exercises—did fine—then they put me on TV"

