DRAWING BOARD

Let's build our own video scrambler!

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We haven't seen very much circuitry yet on our journey through videoland. That's to be expected, though, because video is a subject whose theory you should understand before you start building hardware. As I've already written countless times before, a video signal (shown in Fig. 1) is very complex, with many separate components that are mathematically related to one another.

If you look at a video signal on an oscilloscope, it will appear more or less like the lower waveform in Fig. 1. The most important component of the waveform is the horizontal sync pulse; if you do away with it, the TV won't have any reference for the beginning of a video line, and the resulting image will be misaligned vertically. (See our September column for more on the subject.) The color will also be messed up—without the horizontal sync pulse, the TV won't be able to find the colorburst signal.

Altering horizontal synch

Suppressing the horizontal sync is a simple, inexpensive, and relatively safe way to keep "unauthorized" viewers from receiving a coherent signal. So, to understand better how scrambling works, let's build a circuit that can alter the horizontal sync.

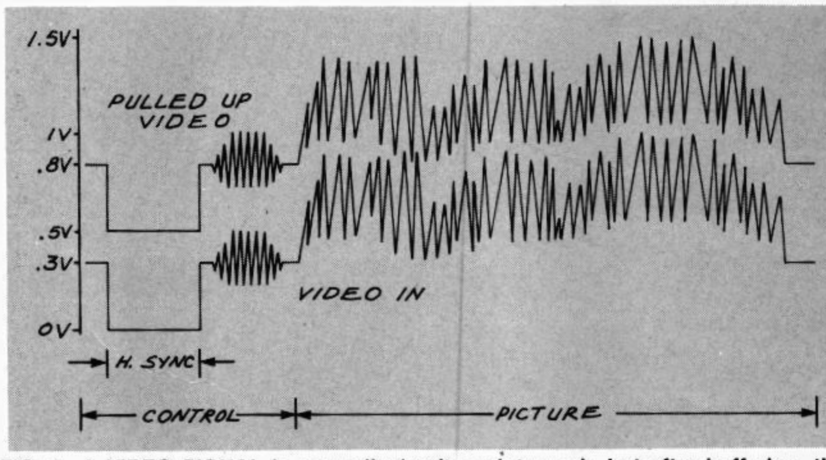

FIG. 1—A VIDEO SIGNAL is normally 1-volt peak-to-peak, but after buffering, the relative voltage level of the signal is raised by 0.5 volts. Then, the only part of the pulled-up video signal that falls below the TTL threshold of 0.8 volts is the horizontal sync signal.

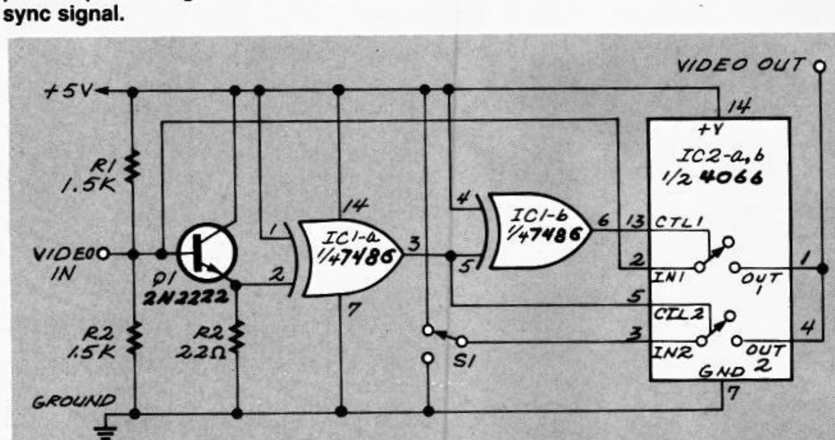

FIG. 2—WHEN S1 PULLS PIN 3 of IC2 high, the video signal loses its sync. When S1 pulls pin 3 low, sync is restored.

Because we're dealing with composite video, and we intend to play games with horizontal sync, the first thing we have to do is isolate the sync from the rest of the signal. That isn't very difficult—every TV in the universe can do it. Most modern TV's either use a discreet sync separator chip or have the needed circuitry buried in the innards of some custom silicon. That makes things cheaper for TV manufacturers, but it's murder for people like us who have a hard time buying the chip in single quantities.

Fortunately, there's always more than one way to get the job done. In this case, it means looking at the voltage definitions inherent in the video signal, and seeing what we can do with them. Standard video has very strict voltage divisions; everything above 0.3 volts is picture information and everything below 0.3 volts has to be a control signal. (We haven't talked about vertical sync yet, but you'll find that the same voltage levels apply to it, too.)

When you have a 5-volt supply and a signal voltage with a 0.3-volt knee, you should immediately think about standard TTL logic. In that family, everything below 0.8 volts is low, which is exactly what we're looking for. That might not be immediately obvious, so let's go through it.

A video signal is 1-volt peak-to-peak but, by buffering it, the relative voltage level of the signal is raised by 0.5 volts. So, instead of ranging from 0 to 1 volt, the signal ranges from about 0.5 to 1.5 volts. The translated level of the control/picture voltage point is now about 1 volt (see the upper waveform in Fig. 1). You can see that the only part of the pulled-up video signal that falls below the TTL threshold of 0.8 volts is the horizontal sync signal.

The bottom line here is that we can build a sync separator from a standard TTL gate—in this case we'll use a 7486 exclusive-or (XOR) gate. All we have to do, as shown in Fig. 2, is feed the translated and buffered video from Q1 to one input of the gate, and tie the other input of the gate high. (Q1 is part of the buffer that we put together in September to keep your video generator or VCR from being damaged.)

Suppression circuit

If you work out the truth table for yourself, you'll see that the only time the output of the gate is high is during horizontal sync. The output at pin 3 of the 7486 is a TTL-level inverted version of the horizontal sync. That output is fed to another XOR gate, which inverts the signal and gives us a negative-going sync signal. Ability to provide both a positive and negative sync signal is the key attribute of the suppression circuit. We want to build a switch that passes video during the picture portion of the signal and be able to alter the signal during the horizontal sync period. That's what the rest of the circuit does.

The first part of the circuit is a picture/sync separator, and the last part is a picture/sync combiner—sort of. Even though we can put the sync back in, we also have the option of sticking in just about anything else we want in place of horizontal sync.

The combiner uses half of a 4066 analog switch as a double-pole, double-throw switch. (The analog switch contacts close when the control voltage is high.) The outputs of the switch (pins 1 and 4) are combined, but because the control lines of the switches (pins 13 and 5) are connected to mirror images of the horizontal sync signal, we can route the picture portion of the video signal to the switch output when sync is low (pin 6 of the 7486) and route horizontal sync to the switch output when sync is high (pin 3 of the 7486).

The single-pole, single-throw switch (S1) controls the input to pin 3 of the 4066. While it's neat to see the effect S1 has on the video signal when seen on an oscilloscope, this is one of those cases when you're better off seeing the effect on a TV.

Whenever S1 pulls pin 3 of the 4066 high (anything above the expected sync level), the video signal loses its sync and the picture on the TV goes totally haywire. If you've seen scrambled pictures before, you'll recognize it immediately. The left side of the picture will be on the right half of the screen, the right side of the picture will be on the left half. Down the middle of the screen will be the horizontal interval. When S1 pulls pin 3 low, sync is restored and so is the TV picture.

Putting it together

We are not ready to go into the details of the scrambling business just yet, though. A successful scrambler not only has to take the video apart, but it also has to put it back together again. That is quite a bit more difficult. There has to be a way to encode the video signal so that the horizontal sync signal is restored at the right time, and for the right length of time. One outdated way that this can be accomplished is to bury the information in the 31.5-kHz audio subcarrier.

That's not so surprising when you realize that half that frequency is 15.75 kHz—exactly the same as the scan rate of the video lines on a standard color TV. There's not much point in going through all the gory details of recovering suppressed-sync video since it's about as useful as presenting a full tutorial on repairing telegraph lines.

Since suppressed-sync scrambling was figured out by signal pirates about five minutes after it appeared, the people in the television signal scrambling business moved on to more complex methods of screwing up the video signal. The most common method now in use combines a variation on the suppressed-sync method, inverting the video, and performing a lot of weird other stuff. **R-E**