Monitor fundamentals

We sure do get a lot of computer-monitor and TV compatibility calls. Let's start off with the obvious: The performance and bandwidth of an ordinary TV or VCR using *composite NTSC* video is severely limited. That is why all the computer folks went to special RGB monitors in the first place. And that is why nearly all the computers are *totally incompatible* with ordinary television gear.

Yes, there now are all sorts of ways you can use your computer for real video editing or to record computer screens on a VCR. But note that there is *no way* I know of that you can record plain old 80-column text as composite video on your VCR. Or display it on any unmodified TV set.

How does a monitor work? Inside is a cathode ray "picture tube" with one or more guns that squirt lots of electrons at a phosphor screen. At

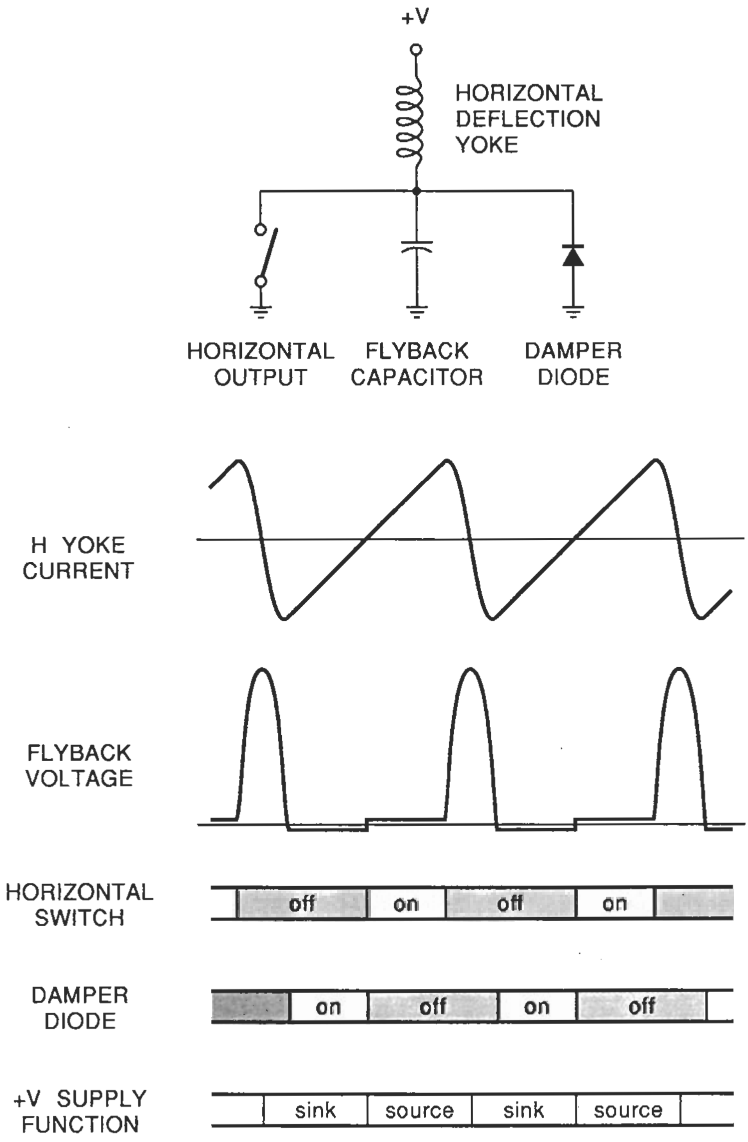

FIG. 3—THE RECURRENT FLYBACK SWEEP on television sets and computer monitor displays is extremely energy efficient, but will only work over a VERY limited range of horizontal scan rates.

any instant, *only one single dot* appears on the screen. That dot gets moved around by the scanning process, and will get brightened and dimmed by rapidly setting its intensity at a *video* modulation rate.

To build up the *illusion* of a full picture, that scanned dot is moved rapidly and *horizontally* from left to right and more slowly *vertically* from the top to bottom. The decay characteristics of the phosphors selected and your human persistence of vision combine to create the *illusion* of a total picture.

Television uses what is known as an *interlaced* scan. To build up a TV *frame*, the dot starts at the upper left and rapidly scans to the right and slowly on downward, painting every *second* scan line. When it gets to the bottom of this *field*, it goes back to the top and picks up what it missed, painting a second field. The normal field rate is usually 60 hertz for black and white or 59.94 hertz for color.

The NTSC (National Television Standards Committee) standard uses 512 lines per frame, or 262.5 lines per field. That leads to standard horizontal scan rates of 15750 Hertz for black and white or 15735 Hertz for color. The two numbers end up slightly different to get all the rest of those color magic numbers to properly drop in place.

Interlaced scan is used by NTSC to minimize flicker. But *interlaced scan is totally unsuitable for data displays, especially small text!* The reason is that interlace works only if successive lines are more or less the same. This is clearly *not* the case between dot lines of finer text. Thus, most computer screens *demand* a *noninterlaced* display where each field is complete and identical.

Most computer monitors also will use a 59.94- or a 60-hertz vertical scan rate. Less than that and you'll end up with too much flicker. If you try to lengthen the phosphor persistence you may end up with "comets" for traveling balls.

The horizontal scan rate is decided by how many horizontal lines you are using per field. *As you increase the number of lines in a display, the horizontal scan rate goes up.* Scan rates from 22 to 45 kilohertz are typical, with some exotic displays going much higher.

Now for the kicker: *Most monitors will work only over a VERY limited range of horizontal scan frequencies!* Unless you go to some *very* fancy *multi-sync* techniques.

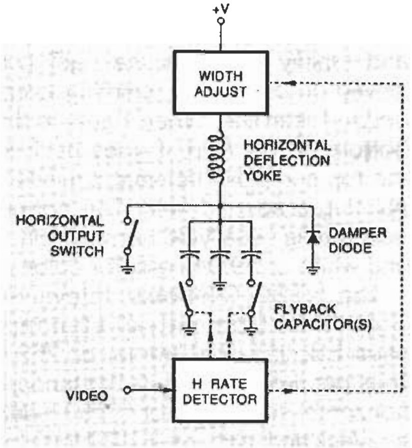

FIG. 4—MULTI-SYNCING MONITORS change their sweep values to try and match an input horizontal scanning rate. But once selected, they still operate only over a very limited frequency range.

Flyback deflection

Why can't someone just build a monitor that accepts an ultra-wide range of horizontal scan frequencies and be done with it? The answer to that has much to do with both energy conservation and the way things have been done in the past.

A set of coils known as a *deflection yoke* normally goes on the neck of the display tube. These are plain old coils that will move your electron beam to wherever you want it to go. Normally, the horizontal yoke is where all the action is, since it does things several hundred times faster than the vertical one.

Since several kilowatts or more of deflection power are involved in the horizontal deflection of a larger color display, sneaky tricks will have to be played to reuse and recycle all of the energy involved. These sneaky tricks go by the name of *recurrent flyback deflection*, and are shown to you in Fig. 3

The basic rule of any inductor is

that...

$$e = L\Delta i/\Delta t$$

Let's rearrange things a tad...

$$\Delta i/\Delta t = e/L$$

Now Δi is the change in current and Δt is the change in time, so $\Delta i/\Delta t$ will be a *linear current ramp* whose rate of change should equal your supply voltage divided by the inductance of your horizontal yoke.

Say that the switch in Fig. 3 is now open and has been that way for a long time. There is no current in the yoke, and no deflection. The spot will still be in the middle of the line.

Now, close the switch, but just for around *one-half* of the live scan time. What happens? We now apply a positive voltage to an inductor, and start building a linear current ramp. That current ramp in the deflection yoke creates one linearly increasing magnetic field, and the spot moves to the right. When you get to the right side of the screen, you'll have bunches of energy stored in the horizontal yoke's magnetic field.

What are you going to do with it? If you just burn it up as heat, you'll end up with bad reliability and high power consumption. Besides needing *far* tougher electronics. Instead, let's work smarter instead of harder.

Open your switch. Your equivalent circuit now consists of a yoke coil in series with the *flyback* capacitor. A standard and high-Q series-resonant circuit. But one that started out with zero volts on your capacitor and a strong current through the coil.

At this time, all of the energy is in the coil and none is in the capacitor. Let the circuit resonate for a while, exactly like any other series-resonant circuit. In one quarter of a cycle, the capacitor will be charged up to a large positive voltage, often in the 800–1200 volt range. At the peak, the current will be zero, and the inductor will be "empty" and field-free.

You have now transferred all of the magnetic energy that was in the yoke into electrical energy stored in the flyback capacitor! And done so with very little loss.

Let the circuit continue to resonate. The current will *reverse* in direction, and energy will start transferring back *into* the inductor. Note that the current is now going in the *opposite direction.*

Let the circuit resonance continue until the capacitor gets to zero volts. You will now have placed all of the original magnetic energy right back into the deflection yoke, with one very important difference: Since the current is going in the opposite direction, you're now at the *maximum left* spot position, compared to the maximum right that you were half a resonance cycle ago. And, again, you have done this with very little loss.

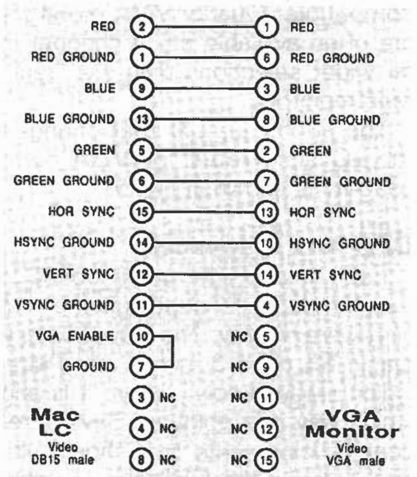

FIG. 5—THE MACINTOSH LC definitely can NOT be used with a NTSC monitor. But this simple cable and jumpering lets you use it with most VGA color monitors. The configuration jumper from pin 7 to pin 10 selects VGA scan rates and standards.

This process is known as a *flyback*, and the retrace interval is called the *flyback time*. The beam is turned off during the flyback time so the retrace is invisible.

Let the circuit resonance try and continue. The flyback capacitor will try and go negative but, at that time, a *damper diode* will turn itself on. Your circuit now consists once again of a coil connected between a positive voltage and ground. It will once again start generating a positive current ramp. Only this time, it starts from a *negative* initial current. Thus, your sweep starts linearly moving from the left to the center. As you move on towards the center of your scan line, the yoke energy gets sent back *into* the positive supply.

When you get to the center of the screen, you once again close your switch to repeat everything for the next cycle. The damper diode shuts down just as soon as you cross center screen. Automatically.

Once again: Close your switch to move from center to right. Transfer the coil energy to a flyback capacitor. Resonate half a cycle and transfer the flyback capacitor energy back to the coil *inverting its sign* and putting you far left. Turn on the damping diode to move from left to center. And repeat the process once each scan line.

Several details I've omitted: That flyback pulse also gets sensed and routed to a current step-up transformer called a *flyback transformer.* The flyback transformer steals a minor part of the energy and uses it to create the high voltage DC supply that is needed by the display tube. Other windings can be used for blanking, horizontal phase comparison, and boosted supply voltages elsewhere in the TV or monitor. And games have to be played to keep any uncenter DC bias out of the horizontal yoke. But regardless of these details, the basic concept of recycling your deflection energy remains.

This very elegant, highly tested, and ultra conservative flyback scheme inherently works best only at *one* horizontal scan frequency. And that is why you can't normally get a monitor that can accept any old horizontal rate.

Yes, there are multi-sync monitors. These usually work by measuring the intended input scan frequency and then switching in one or more flyback capacitors and adjusting the supply voltage accordingly. Figure 4 shows one multisync scheme. Once switched, a multisync monitor is a narrowband system just like any other flyback-driven circuit.

VGA for the Mac LC

The Macintosh LC computer was designed for use with the Mac color monitors to the Mac color standards. Since these can be expensive, lots of hackers are often on the lookout for lower-cost substitutes. But note that you definitely can *not* use an NTSC color monitor because of the higher scan rates on the LC.

And also do note that you should *never* buy a substitute monitor without making certain it works and is good enough for your uses.

Happily, there is a hidden "secret" provision on the Mac LC that lets you change your LC output so it is VGA-compatible. Quality VGA monitors are often available much cheaper in far wider selections than are "real" Mac monitors.

The secret jumper that changes the LC scan rates for VGA compatibility is shown in Fig. 5.