WHAT IS THE PURPOSE OF THE CM-1?

To produce a visible display of ordered dots. Each dot is to be in the position and of the color specified by the Tandy 2000.

HOW IS THIS ACCOMPLISHED?

Each dot is given a row, column, and color value by the software in the 2000. This information is supplied to the High Resolution Color Cathode Ray Tube Controller (CRTC) circuitry of the High Resolution Color Upgrade. It is the job of the CRTC to produce the proper signals for the CM-1. It is the job of the CM-1 to produce a visible display from these signals.

SPECIFICALLY, WHAT ARE THESE SIGNALS?

There are six separate signals needed by the CM-1.

Horizontal sync (HS)- TTL level, negative going
Vertical sync (VS)- TTL level, negative going
Red drive (R)- TTL level, positive going (1 = ON)
Green drive (G)- TTL level, positive going (1 = ON)
Blue drive (B)- TTL level, positive going (1 = ON)
Intensity (I)- TTL level, positive going (1 = active)

All six signals are Transistor-Transistor Logic (TTL) level signals.

These are the same signals required by a normal Color Television, except that the Horizontal sync is much faster (greater frequency). Note, too, that each signal is supplied separately to the CM-1 and not mixed together into one video signal. This is known as DIRECT DRIVE. Supplying only one video signal is known as COMPOSITE VIDEO. Using direct drive decreases the complexity of both the computer and the monitor since it is not necessary to "assemble" a complete video signal inside the computer and then "disassemble" the composite video signal inside the monitor to produce the necessary individual signals. The display produced by a direct video monitor is usually sharper than the composite video monitor since the signals are usually degraded somewhat by the "assembling" and "disassembling" process in the composite video system.

The vertical and horizontal sync signals are used to synchronize the circuits internal to the CM-1 with the signals produced by the CRTC inside the computer. A properly adjusted CM-1 will produce a horizontal sweep rate of APPROXIMATELY 26.4 KHz and a vertical sweep rate of APPROXIMATELY 60 Hz. However, these figures may drift slightly as the units warms up. This would cause the display to drift from side to side and up and down, requiring the user to constantly manipulate the vertical and horizontal controls. By supplying the sync signals the CM-1 internal signals are locked EXACTLY to the desired frequency, producing a solid RASTER and eliminating further adjustment by the user.

The R, G, B, and I signals are used to specify the color of each individual dot. The position of the dot on the screen is determined by the timing of these signals in relationship to the vertical and horizontal sync. This is controlled by the CRTC inside the computer. Since the RGB signals are supplied as separate signals the CM-1 can also be called an RGB MONITOR.

WHAT DO THESE SIGNALS LOOK LIKE?

In general, each signal is a TTL level signal so it will look like many of the other TTL level signals found anywhere inside the computer. Each signal should swing from a level of less than Ø.8 volts to a level of greater than 3.Ø volts. These signals are never tri-stated.

Specifically, only the vertical and horizontal sync can be strictly determined. The vertical sync is a fixed, cyclic (repetitive) signal with a pulse repetition rate of 6Ø Hz. The horizontal sync is also fixed and cyclic, but with a pulse repetition rate of 26.4 KHz.

The R, G, B, and I signals are used to describe each individual dot. Since the dots on the screen are different for each desired display, the R, G, B, and I signals can not be predicted without knowing what is being displayed. They should exhibit all the qualities of a proper TTL level signal, but their repetition rate will most likely not be constant or predictable.

We have determined that the CM-1 does not use a composite video signal, but this does not mean that there is no video used at all. In fact, each of the R, G, B, and I signals contain all the properties of a separate, very specific video signal, and can be referred to as video signals. However, while a "normal" video signal is usually limited to frequencies below 4.5 MHz, the R, G, B, and I signals from the 2ØØØ can contain frequencies greater than 2Ø MHz.

WHAT IS A RASTER?

The elements inside the Cathode Ray Tube (CRT) used in the CM-1 are designed to produce a very narrow electron beam that is aimed to strike the phosphor coating on the face of the tube. This electron beam is guided electromagnetically in such a manner that is is swept both horizontally and vertically across the face of the tube.

The beam is swept horizontally by a roughly sawtooth-shaped signal at a 26.4 KHz rate. It is simultaneously swept vertically by a 6Ø Hz sawtooth. The result is that the electron beam is swept to almost completely cover the face of the CRT.

A little elementary mathematics will show that 44Ø horizontal sweeps, or lines, are produced for every 1 vertical sweep. These 44Ø horizontal lines are known as the RASTER.

THE CM-1 INFORMATION SAYS THE WE HAVE ONLY 400 LINES.

This is correct. Figure 1 is derived from the illustrations on page 34 of the CM-1 Service Manual, and shows the timing expected by the CM-1. The timing starts just after the Vertical Synch Pulse. Note that 24 Horizontal sweep (lines) are "wasted" before the display starts. This gives us a black border at the top of the screen.

Next, the 400 lines of dots are displayed. After the display is finished another 8 lines are "wasted" for a border at the bottom of the screen. The vertical sync pulse is then produced. It is 8 lines wide.

The timing of these signals is a function of the CRTC inside the computer. The CM-1 still produces 440 horizontal lines, but only 400 of them are used as the ACTIVE DISPLAY AREA.

Each dot displayed on the screen is one horizontal line high, producing the vertical specification of the CM-1 -- 400 dots vertically.

PAGE 34 OF THE CM-1 SERVICE MANUAL SAYS WE HAVE 106 CHARACTERS PER LINE.

Correct again, but only 80 are used. Figure 2 is also derived from the CM-1 Service Manual. Again, we "waste" 12 characters for the left hand border. The 80 characters are displayed, and 6 characters are "wasted" for the right border. The horizontal synch pulse is then produced, and is 8 characters wide.

Again, these timings are handled by the CRTC inside the computer. While the CM-1 sweeps for 106 characters, only 80 are used in the active display area.

Note that each character is 8 dots wide. This gives use the horizontal specification for the CM-1 -- 80 characters by 8 dots = 640 horizontal dots.

WE CAN SEE HOW THE RASTER IS PRODUCED AND THAT THE CRTC INSIDE THE COMPUTER IS RESPONSIBLE FOR DISPLAY TIMING. WE ALSO SEE THAT THE R, G, B, AND I SIGNALS CONTROL THE COLOR OF THE DOT. SPECIFICALLY, THOUGH, HOW ARE THE DOTS PRODUCED?

Remember, the electron beam inside the CRT is being swept across the face of the tube. If the beam strikes the phosphor on the face of the tube a lighted streak is produced. Obviously, if the beam were ON all of the time the screen would appear white, or "lit".

To produce a dot we need to control the electron beam, turning it ON for a lit dot and OFF for an unlit (black) dot. Since we need only ON or OFF a digital signal will be just great.

To make any sense of the dots, that is, to make visible characters on the screen, we must precisely and repetitively control when a dot is ON and when a dot is OFF. For instance, we must know that the first dot on scan line one is to be OFF, the second dot on scan line one is to be ON, and the first dot on scan line two is to be ON to produce a specific character. Keeping track of which dot on which scan line is to be ON or OFF is the job of the CRTC inside the computer.

The CRTC must keep a count of which scan line it is on. Is it in the upper or lower boarder, in the active display area, or during a vertical sync pulse? Additionally, it must know what dot row of what character it is displaying so that it can get the proper information from the character generator. The CRTC must also know which dot on the horizontal line it is displaying. Again, is it in the left or right border, the active display area, or during a horizontal synch pulse? As you can see, the CRTC is quite busy.

Once the CRTC determines which dot it is displaying at any one instant, it must determine whether the dot is ON or OFF. The CRTC then generates a TTL level (digital) signal to tun the electron beam ON or OFF.

Simply put, the CM-1 supplies signals that sweep the electron beam across the face of the CRT. These signals are synchronized to the CRTC. The CRTC then generates a signal to turn the electron beam ON for a lit dot or OFF for a dark dot.

HOW ARE COLORED DOTS PRODUCED?

The electron beam inside the CRT is not one, but three individual beams, one each for the Red, Green, and Blue signals. Also, each dot on the screen is made up of three different phosphors, one for the Red, Green, and Blue beams.

In a properly operating CM-1 the beams are aligned such that each beam will strike only its associated phosphor color. This is known as PURITY. As well, the beams are aligned such that each beam strikes the same dot area. This is called CONVERGENCE.

If we turn on only the RED beam all our dots will be red. If we turn on only the GREEN or the BLUE beam all out dots will be GREEN or BLUE respectively. However, if we turn on all three beams at once our eyes mix the three colors to produce a WHITE dot. If we turn on any two beams simultaneously our eyes again mix the colors. GREEN and RED simultaneously produce YELLOW, RED and BLUE simultaneously produce MAGENTA, and BLUE and GREEN simultaneously produce CYAN. Therefore, we can produce eight colors with just three beams: BLACK (all beams OFF), RED, BLUE, GREEN, YELLOW, MAGENTA, CYAN, and WHITE (all beams ON).

We also have the I (intensity) input available. This signal can be used to make the three beams dimmer or brighter. The colors are not changed, only the intensity of the beam is changed. Colors produced when the beams are dimmed are called DARK colors. Colors produced when the beams are brightened are called LIGHT colors. The light colors are considered NORMAL.

Using the I signal allows us to produce 15 colors. Actually, we have 8 colors with two intensities each. DARK WHITE is called GRAY. There is no difference between LIGHT BLACK and DARK BLACK.

You may guess that this, too, calls for very precise timing. You may also guess (correctly) that this timing is handled by the CRTC inside the computer. Not only must it handle the timing of the dots, but it must also supply the correct signal (R, G, B, and I) to produce the desired color.

Figure 3 illustrates the relationships between the three beams, the "I" signal, and the color produced. This is NOT a timing diagram. The actual timing will depend on the desired color of the dot on the screen.

WHY ARE THE VIDEO PULSE RESPONSE TIMES IMPORTANT?

We have already determined that the R, G, B, and I signals can be considered video signals with a very high bandwidth. To handle them we need video amplifiers with the ability to operate higher than the "normal" 4.5 MHz. The video pulse response times are simply the RISE and FALL times of the video circuit. Indirectly, they effect the bandwidth of the video amplifiers. The rise and fall times directly effect the clarity of the display.

To see these effects, we must first produce a display example of alternating green and black dots. This means that the RED and BLUE beams will always be OFF, and the GREEN beam will be alternately turned ON and OFF. Figure 4A is what we would expect to see on the G signal. This signal is produced only during the 28 microseconds that the display is active in the horizontal sweep. Since we are producing 320 green dots (640/2) the period of this signal is 28.59 microseconds/320, or 89 nanoseconds. This is approximately 11.2 MHz in frequency.

This means that we must have at least an 11.2 MHz bandwidth on the video amplifiers inside the CM-1. It would be better still to have 2, 3, or more times this frequency if we are to produce a good display.

The video amplifiers also acts as sort of a low-pass filter to the video signals. Figure 4B shows the effects of a slight low pass filter on the GREEN signal in Figure 4A. Note the rounding of the rising and falling edges. Figure 4C shows the effects of a severely low-pass filtered signal. Note that the signal is no longer square, but is triangular in shape. One of the factors contributing to the low-pass filter effect of the video amplifiers is rise and fall time.

The rise and fall time measurements give a more realistic measurement of the monitor than does simple frequency response. It is comparatively easy to build a video amplifier with a frequency response in the 100's of megahertz, but there is no guarantee that that amplifier would work quite so well on sharp-edged digital signals. The pulse rise and fall times give a much better indication of the ability of the video amplifiers to handle digital signals than does the standard frequency response measurement.

WHAT EFFECTS DOES RISE AND FALL TIMES HAVE ON THE DISPLAY?

Figure 4A is an ideal ON/OFF, beam/no beam signal. It typically has rise and fall times of about 5-10 nanoseconds. If this signal could be applied directly to the CRT we would have nice, clear, sharp dots displayed.

However, if we begin to limit the rise time of the signal, as in Figure 4B and 4C, each dot begins to get smeared. The dots appear as ovals which blend into each other. To prevent this, and produce a sharp display, we must have video amplifiers with good pulse response times.

Generally, this smearing would go relatively unnoticed. You usually can not distinguish the individual dots the the cross of a "T", for instance, and a slight smear may be helpful.

In the CM-1, however, we have more than just one dot to smear. Each dot may be made up from as many as 3 different beams, each beam being controlled by a separate video amplifier. If one video amplifier "smears" dots this may cause slight color impurities, a white screen with a slightly green tint, etc.

Please note that the average eye can not distinguish between a CM-1 having, say, 25 nanosecond rise times, and one have 1Ø nanoseconds rise time. Color impurities are more likely caused by mechanical misalignment of the CM-1 than by video amplifiers with faulty response times.