LCDs simplified

Editor's Note. Ray Holdren drew a large crowd at his technical seminars during the Amusement and Music Operators Association (AMOA) International Expo in September 2007 Holdren, whose knowledge of LCDs is extensive, will cover this topic in a new quarterly technical series for Play Meter starting in this issue.

Ray Holdren

LCD technology displays originated in military displays in the 1960s. LCD displays hit the consumer market in watches and calculators in the early 1970s. Since its advent in 1971 as a display medium, LCDs have moved into a lot of different areas, including portable televisions, digital still and video cameras, and monitors.

Understanding LCD display technology in the arcade industry.

For many years in the arcade, casino gaming, and consumer electronics industry, CRTs have been the standard display device. The development of the first LCD (liquid crystal display) by RCA Laboratories in 1968 ushered in a new era of displays.

Since then LCDs have been incorporated into all types of digital devices, from small watches and calculators to video displays and projection televisions. Early LCD displays suffered from limited gray scale graduations, poorly saturated colors, narrow viewing angles, and slow response times.

Today's LCD panels have greatly improved and are beginning to beat CRTs. In terms of performance and in size, weight, and power consumption LCD displays are far superior.

This article and others to follow will introduces you to LCD technology displays, how they work, and how to repair them.

LCD COLOR MONITOR INTRODUCTION

The LCD "flat panel" display is a display newcomer to many consumer products as far as picture tubes or CRT's are concerned.

It's my belief that the LCD is replacing the CRT monitor in the arcade industry, just as it has in the casino gaming and other industries. It certainly has a good start and holds an apparently unassailable position in notebook and handheld PCs and now with televisions and desktop monitors.

Today's current state of-the-art LCD panels are evolving rapidly and exceeding CRT performance in all categories. Additional improvements are always coming in. Even work on Flexible LCD Displays should be finished very soon and find its place in the market.

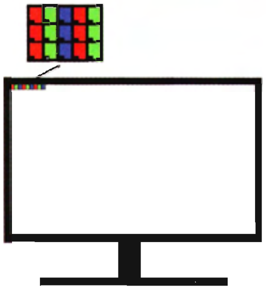
LCD Color Displays, when compared to other display technologies, are thin and lightweight and run on low voltage power supplies and drive signals.

Low voltage drive signals enable LSI (large scale integration) circuitry to drive the display directly. The LCD display panel uses very little power, making portable, battery operation possible. Mass manufacturing techniques have reduced the cost of the displays and lowered consumer pricing.

HOW LCD PANELS WORK

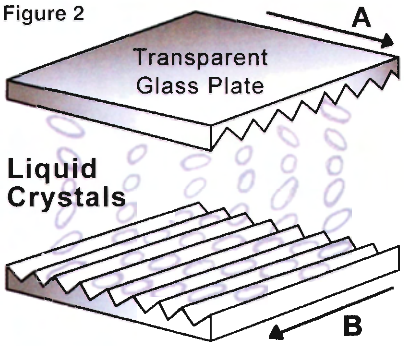
The basic function of the LCD is a

Figure 1



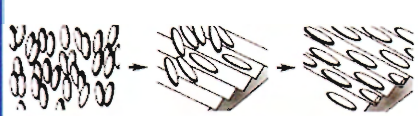
The basic function of the LCD is a "light valve," either blocking light or allowing light to pass through.

Figure 2



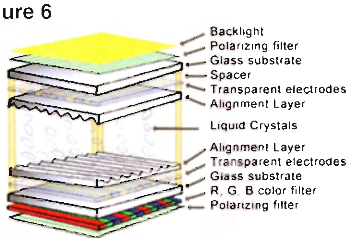
A liquid crystal is an intermediary substance between a liquid and a solid state of matter. *(All images are courtesy of Sencore Inc.)*

Figure 3 Figure 4 Figure 5



Molecules are arranged in a loosely ordered fashion with their long axes parallel. When coming into contact with a finely grooved surface (alignment layer) molecules line up parallel along the grooves.

Figure 6



"light valve," either blocking light or allowing light to pass through.

LCD displays are transmissive, meaning that an LCD is an active filter that works by varying the amount of light (from a fluorescent light source called the backlight) that is able to pass through to the viewing screen.

An LCD display is really a large collection of millions of these really tiny filters called liquid crystal cells. Arranged in columns and rows, these cells form an LC panel. Cells are combined into groups of three containing a uniquely addressable "red," "green," and "blue." (Figure 1)

These cells, or subpixels, working together create one pixel or picture element. A complete LCD display contains millions of these tiny liquid crystal panels or cells.

To produce color, every pixel location in an LCD display needs three LC cells: one each for red, green, and blue. Each LC cell, or subpixel, can be individually addressed with a control voltage. This means, for example, that a 15" 1,024 x 768 video display contains 2,359,296 subpixels (1,024 x 768 x 3). This is why they're sometimes called "Addressable Displays."

Fixed pixel displays such as LCD displays (all present display types except CRTs are fixed pixel displays) can provide the best image only in their native resolution. While you can input an image having a resolution other than the display native resolution, the display can only reproduce a white or colored dot at the fixed physical pixel locations. To view an image at some other resolution, it needs to be "scaled" up or down in order to fill the screen.

Its native resolution refers to the resolution that the LCD monitor is designed for (i.e. 800 x 600 or 1024 x 768) and is determined by the actual number of liquid crystal cells in the display.

WHAT IS LIQUID CRYSTAL?

Liquid crystal is a term that indicates the status of a substance that isn't a solid or liquid, but contains properties of both, kind of like soapy water.

In 1963, it was discovered at RCA the way light passes through liquid crystal changes when it is stimulated by an electrical charge. (Figure 2)

It took over four years for another group of RCA researchers to make a display prototype that applied this concept. This prototype's success was the beginning of today's modern liquid crystal display (LCD) technology.

LCD DISPLAY T4ECHNOLOGY

Most liquid crystals are either rectangular or rod-shaped. Many other types are being found and developed with different properties all the time.

One of the world's greatest research and development centers is Kent State University in Ohio where newer liquid crystals, products, and uses are being discovered and developed every day (Figure 3, 4, 5)

LCD PANELS: CONSTRUCTION AND CONTROL

Now that we've got an idea about liquid crystals, let's jump right into how the panels are put together and how we control them. Each LCD panel is made up of layers of different materials. We'll go through how some are done. (Figure 6)

If we look into a cross section of most of today's LCD panels we see that they get the light from behind or the back. This is called backlighting. Here is the structure: a Polarizing Filter, glass for strength, transparent electrodes, finely grooved glass, the liquid crystals, more grooved glass and transparent electrodes, and then a color filter before the last polarizing filter.

One of the problems in earlier displays was difficulty in controlling the backlighting to get good contrast ratios (transitions from light to dark).

It's really hard to control light coming from so many directions. By using a Polarizing Filter there were less angles of light to worry about controlling. One way to look at it is like crowd control. When you have a lot of people coming at a gate or doorway from all directions it's really hard to maintain control, but if you funnel them down into single file lines you can easily handle what's coming at you. That's what they've done here.

They've taken a "slice of light" rather than try to control all this backlight coming at the panel. This Polarizing filter only allows light to come through at specific angles. The light is allowed to pass through the filter greatest at the angle it was designed for and will still pass light through in lesser quantities for a few degrees either side of that angle. (Figure 7)

If we combine this with the other process of changing a voltage across the crystals, we can "twist" the light through the liquid crystals and that way be able to control it better. (Figure 8)

One other problem encountered on early backlit displays was that it was always brighter on the sides of the panel closest to the lights. To correct this issue Defuser Film (similar to panels used for fluorescent light fixtures in offices) was used to disperse the light as evenly as possible across the back of the panel. That way it looks even across the front to us.

Now how do we control the sub-pixels? Etched onto one of the layers of glass are TFTs (thin film transistors) and anther capacitive material. This is going to be arranged and connected together with the transparent electrodes. (Figure 9)

This type of control system is called an Active Matrix. In this way we don't have to use three wires from each transistor and it's a lot less circuitry to control them.

Next time we'll cover what an A/D circuit is, inverters, and much more.

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Figure 7

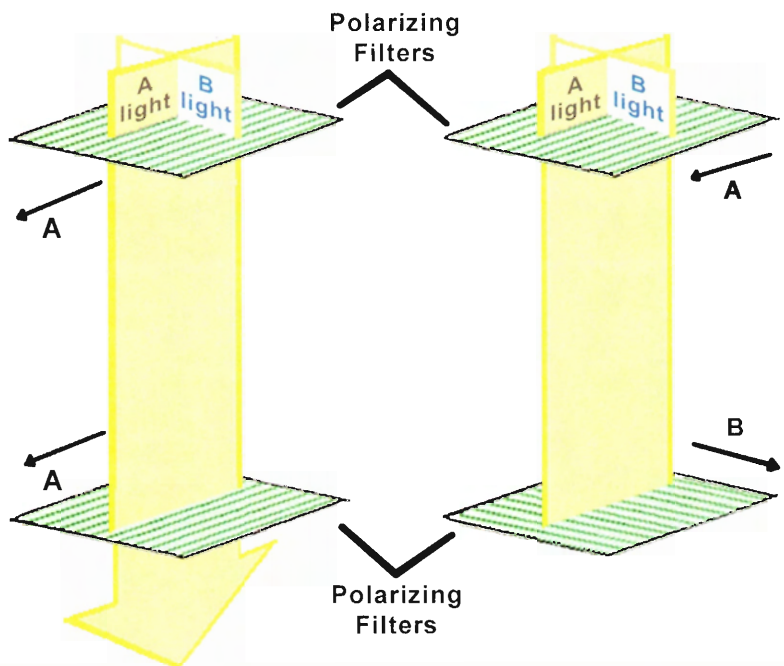


Figure 8

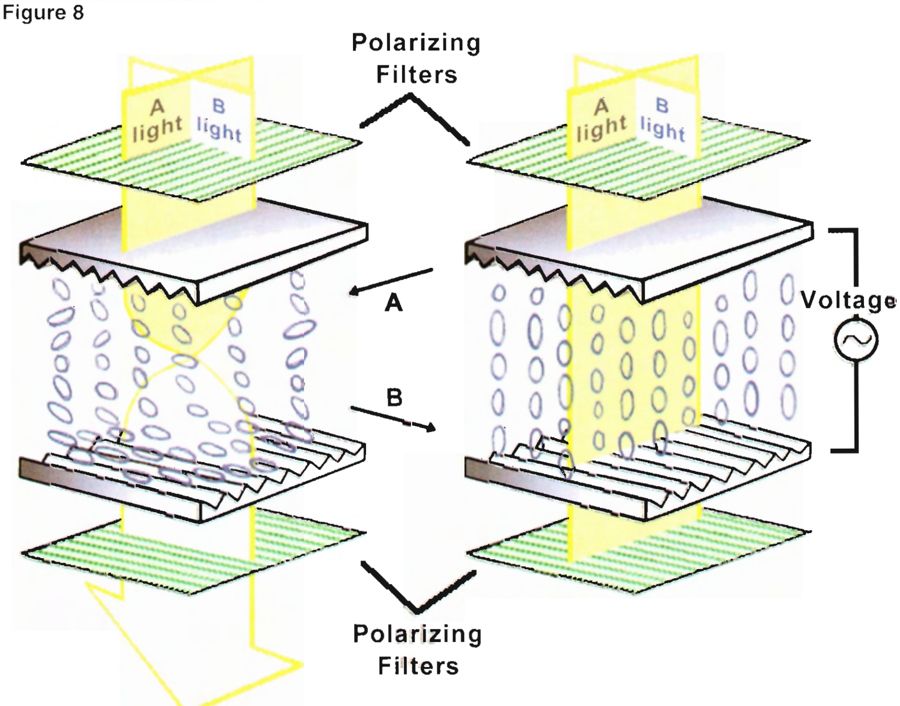
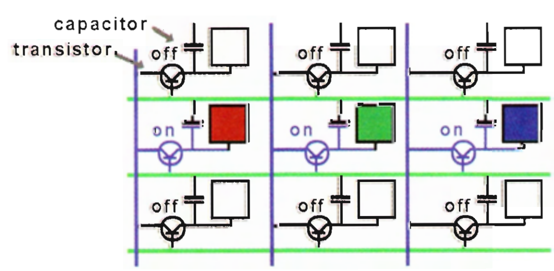


Figure 9

Active Matrix LCD (AMLCDs): Tiny transistors and capacitors control the charge on each liquid crystal cell in an active matrix.



Understanding LCD Monitors, Part 2

Ray Holdren

Education is vital when dealing with a new world of monitors coming to the coin-op market.

In the first part of this series we detailed the ways in which the LCD Panel functions. And now we'll look at some differences between CRT (Cathode Ray Tube) Monitors and LCD Monitors.

LCD Monitors are not affected by the same things that affect CRT Monitors. For example: LCDs are not affected by magnetic fields like CRT Monitors because they do not use a magnetic field to deflect a beam to make a picture. They don't have to be Focused [sic] or have a Convergence done. They also do not have Burn In like CRTs, though they may have a problem know as Image Retention, which is very rare.

Their Contrast Ratios now exceed that of CRTs and their Color Intensity is gaining on CRTs. Their Light Intensity may vary from the top to the bottom of the screen. This is because they don't produce the light; it's supplied from a source know as a backlight, and must be dispersed to cover the screen. They do use a little less power and produce less heat. In addition, they take up less physical space (they're much thinner than CRT Monitors). And one thing's for sure: they weigh a lot less.

The first step in working on an LCD Monitor is to break it down into smaller sections. Just like CRT Monitors have their separate sections (Power Supply, Vertical and Horizontal Sync, and Video Sections), the LCD Monitor also has sections. This will make it a lot easier to troubleshoot when we discern which section is bad. In Figure 1 we see this breakdown.

Figure 1: The breakdown of an LCD Monitor. *(All illustrations courtesy of Sencore)*

1. The Power Supply (the highest failure section in any electronic device)
2. The Microprocessor or A/D PCB (Analog to Digital Converter Printed Circuit Board)
3. The Inverter (which makes the higher voltage for the lamps)
4. The LCD Panel

All monitors need a Power Supply to operate, and this one is no different than most of the ones in CRT Monitors. It's going to be a Switch Mode Power Supply or SMPS. This is one of the most well regulated, current limited, and efficient types. It will also be a Pulse Width Modulated, Switch Mode Power Supply to Maintain Frequency. In Figure 2 we see a Simplified Schematic or Block Diagram of this Supply broken down into its most important circuits for easier troubleshooting.

Figure 2: The Simplified Schematic of a Pulse Width Modulated SMPS

This may be a separate power supply for the monitor, or the voltage may be taken right from the gaming machine's Power Supply. This is just for information at this time, and we may detail working on these in a later article.

Right now I will describe the Microprocessor, or A/D, or "A" to "D" PCB.

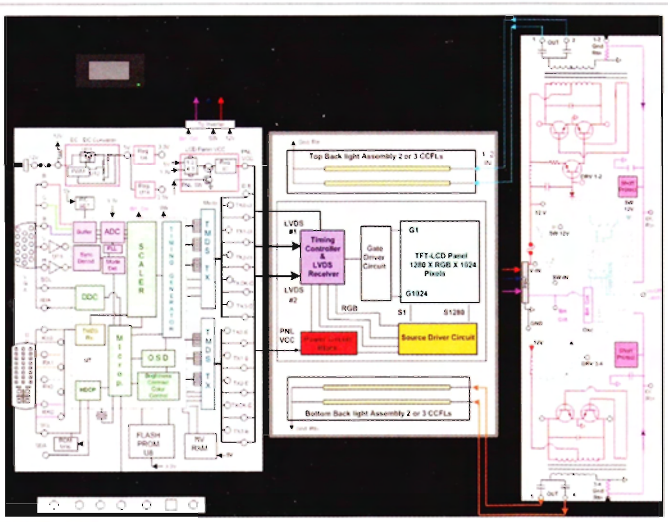


Figure 1: The breakdown of an LCD Monitor.

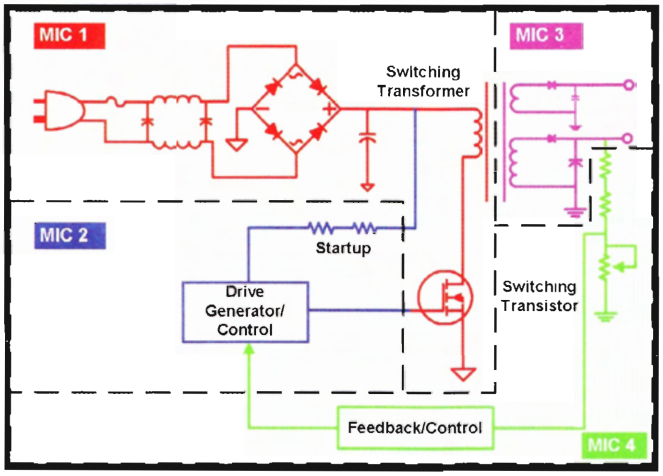


Figure 2: The Simplified Schematic of a Pulse Width Modulated SMPS

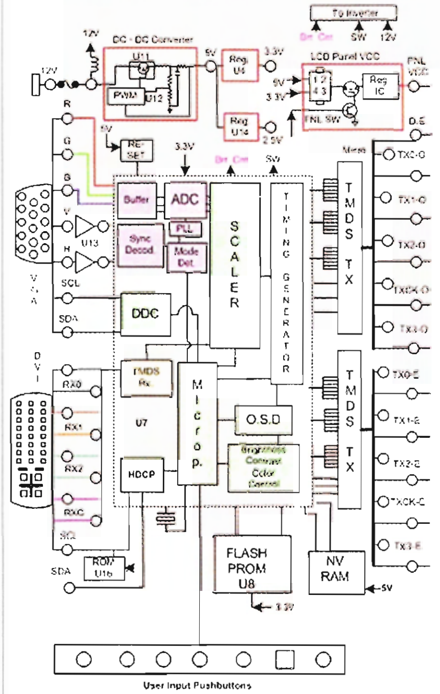


Figure 3: The Microprocessor Block Diagram

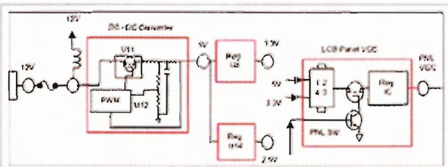


Figure 4: The Micro's Power Supplies

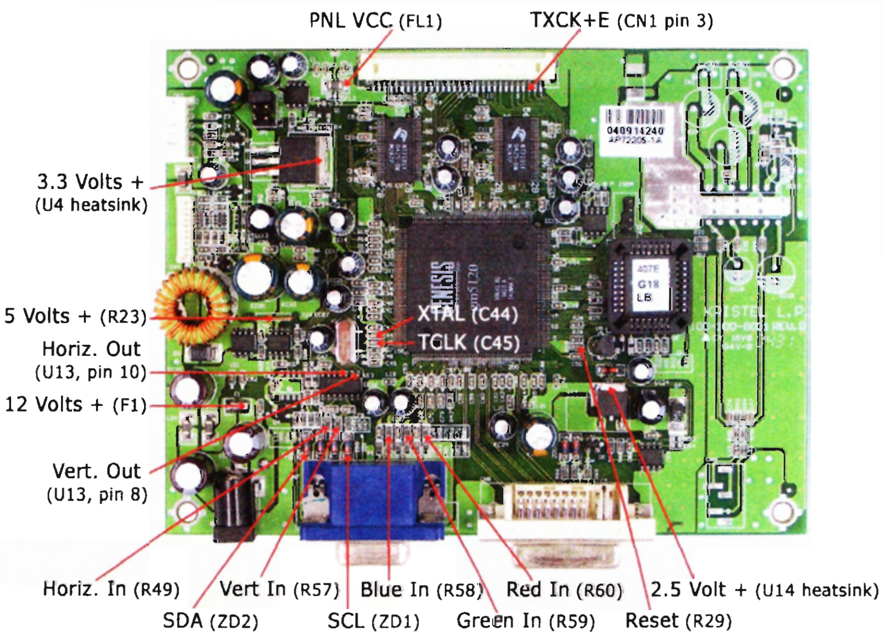


Figure 5: Test Points on a Kristel LCD Monitor Microprocessor PCB

Again, just like any other electronic device, it also features Power Supplies. (Figure 3 shown in red.)

Figure 3: The Microprocessor Block Diagram

These circuit boards, just like the whole monitor, can also be broken down into sections to aid in troubleshooting. The first section will be Power Supplies. The first section of the power supply is a DC to DC Converter using a Pulse Width Modulator to regulate the 5 Volt DC Supply (Figure 4).

Figure 4: The Micro's Power Supplies

The second and third are the 3.3 Volt and 2.5 Volt Voltage Regulators and the fourth is the LCD Panel Power Supply (Figure 4).

When there's a failure with the monitor and the Power Indicator L.E.D. (Light Emitting Diode) doesn't light, these would be the first to test. These Test Points, and other Test Points on a Real Microprocessor PCB, are located in Figure 5.

Figure 5: Test Points on a Kristel LCD Monitor Microprocessor PCB

After some time doing this, you will become familiar with how the power regulators look, and be able to locate them on the different manufacturers' circuit boards with no problem.

On to the second section of the Microprocessor PCB: the Inputs. Most of the LCD Monitor A/D PCBs feature an Analog or VGA input. We will most likely also find another input. This will be the DVI input (Digital Video Interface).

The VGA or Analog Input will have to be changed from to a different form to accommodate this PCB's formats. Back in Figure 3, if we look at the VGA input we see that the Video Signal (the red, green, and blue) go right into the Microprocessor IC Chip.

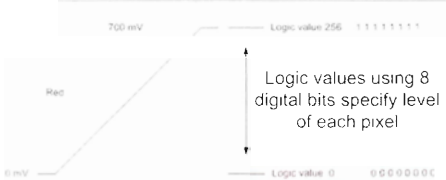


Figure 6: Video Analog to Digital Conversion

We'll also notice that the Vertical and Horizontal Sync Signals go into a different IC first. This IC is known as a Buffer IC. A Buffer IC changes either the impedance of the incoming signal, its voltage size or polarity, to accommodate the main circuit board's needs. In this case it's going to lower the voltage of the signal so it can be accepted by the Microprocessor IC. This can be a failure item to check when troubleshooting this circuit. Make sure you have the signal going into the IC and coming out.

(See Figure 3 again)

After the Video (the red, green, and blue, or the RGB) enters the Micro IC (in Figure 3) you'll see that it goes into a Buffer. This is to give the incoming signals a little bit higher impedance (or resistance) to start out with, and also protects against a short circuit on the input to stop any board damage that might occur. Next, it's on to the "ADC," the analog to digital converter. Here is where the fun starts.

In order for the micro to understand what you want it to do, you have to change this signal from an analog to a digital format. To do this we know that Analog Video has a minimum of "0" volts and a maximum voltage of 700 mv (or 700 millivolts) and that a microprocessor only understands Binary or Digital Information. So, if we give the lowest point a digital address "0" (00000000) and the maximum "256" (11111111), we can accomplish this goal. Take a look at Figure 7 and see exactly what we've done.

Figure 6: Video Analog to Digital Conversion

We also notice that out of the ADC we see that some of the signal goes to the Scaler and a part goes to the PLL (Phase Locked Loop Circuit). The PLL makes a clock pulse from the Sync so the video information matches up at the proper frame rate.

Next, we'll notice that the two Sync Signals, when entering the Micro IC, go into a Sync Decoder. This part Buffers the Sync Signals by changing their duty cycle and polarity, and sends its information to the microprocessor section so it can be analyzed and processed properly for determining how to Scale or Size the incoming Picture. A part also goes to the PLL.

Then there's the Mode Detect section; this takes the Vertical and Horizontal Frequency and their Polarity to determine what Resolution of picture is being sent.

The Microprocessor Section is the workhorse of the chip. Here we do a lot of the functions and controlling. We have the User Controls (brightness, contrasts, and color), OSD (ON Screen Display), DDC (Data Display Channel), and other input controls. The Read and Write features of the board are also processed here.

The Scaler is next; it takes the ADC signals along with information from the Microprocessor and Scales, or Sizes the picture to match the Native Resolution of the LCD Panel.

Now the Timing Generator, the second workhorse of this chip. It takes the information from the Processor, ADC and the OSD, puts it all together, and makes a timing signal send this information in and out of the memory and on to the LVDS Transmitter and finally to the LCD Panel.

If we look closely at this board we'll notice that the DVI Input or Digital Video Interface takes a different path in the Micro IC. It's already a Digital Signal, so it doesn't have to go through all that stuff the VGA went through. It goes right into a TMDS Receiver. Let's see what all this is about.

The DVI Signal is a special type of digital signal that was designed to travel through wire at a high rate of speed, without the problems brought about, such as with normal signals through wire.

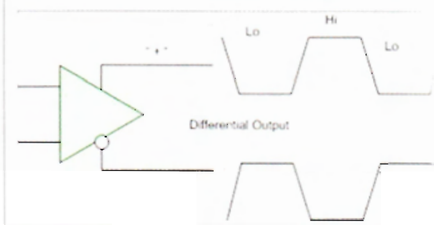


Figure 7: Differential Signaling

The first problem is that we're going to be sending a digital pulse. which looks like a square wave through a wire. Anytime we send a current or signal through wire it creates a magnetic field. This is OK until it collapses. Then it will Induce a Current in any wire next to it. This is known as Electro Magnetic Induction. or EMI for short (a form of interference in the electronics field).

One thing we can do is use Twisted Pair Wire by using a Differential Signal (Figure 7). A Differential Signal uses a positive and a negative signal; that way we help to cancel out some of the EMI. We're going to combine this with a second signal method.

Figure 7: Differential Signaling

This EMI causes all kinds of problems when we're trying to get a signal through wire. So, what the Digital Display Working Group (DDWG) did was to make a whole new way to send the signal through the wire and reduce this EMI without using special coax.

What they came up with was a way to minimize the Transition from High to Low and get this signal through a fast as possible without causing theses problems. They call it Transition Minimized Deferential Signaling, or TMDS for short. Basically, what they're doing is flattening out the square wave there by Minimizing the Transitions and the EMI it creates, and then bringing it back to normal after it's received.

The other process they'll use is changing the digital word from a Parallel Signal Format to a Serial Signal Format. This will also allow them to be able to use less wire and run this

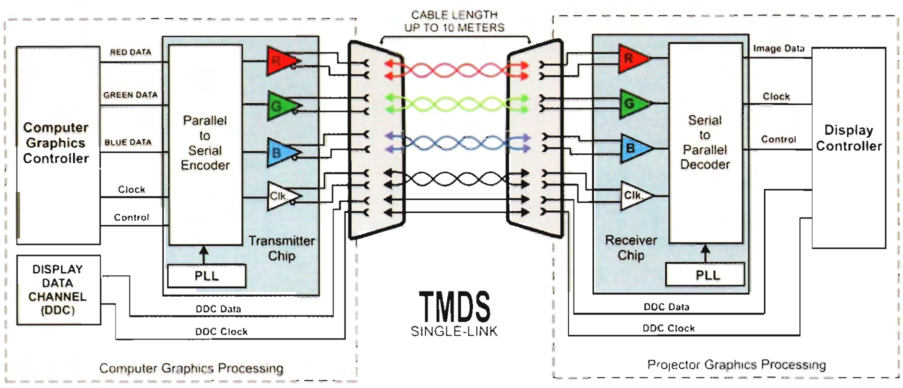


Figure 8: The TMDS Circuitry

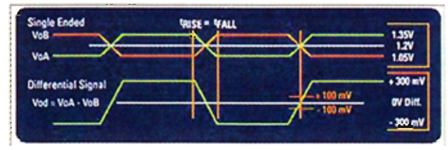


Figure 9: LVDS Signal Method

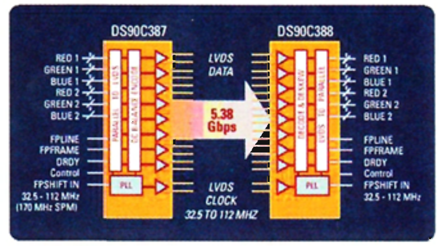


Figure 10: LVDS Transmission and Reception

down longer lengths of wire without amplifying it. So, they're encoding the signal into the wire and decoding it on the other side. If we look at Figure 7 we can see what circuitry is involved for this to happen.

Figure 8: The TMDS Circuitry

By using this we take this signal into the Processor IC straight into the TMDS Receiver, and from there into the Scaler without going through the other sections.

Having been through that, we can go into how we send all this information to the LCD Panel. So we have the digital information ready and coming out of the Timing Generator. What do we do with it now? The signal is quite big at this point, 24 bits plus Clock pulses and PLL pulses, but it's so big we have to split it up. The other problem is, again, what to do about the Transitions to reduce the EMI for the way we are going to Transmit it to the LCD Panel.

Now we're up against the same old EMI troubles as before. Again we will have to minimize those Transitions and do it further than before, so we can send it even faster through wire.

We're going to use a process known as Low Voltage Differential Signaling. First, change it from a Parallel Signal Format to a Serial Signal Format, which again uses less wire and a differential signal through twisted pair wire. But we're going to lower the signal's voltage to get it through the wire quicker.

Figure 9: LVDS Signal Method

By doing this, and splitting up the digital word into two sections (odd and even), we can get this signal through the wire faster than before. We only have to encode it one way to send it, and decode it on the other end to use it.

Quick Microprocessor and LCD Troubleshooting

(See Figure 3 again)

Quick test for the Microprocessor PCB or A/D Card

1. Test for Power on the In-Put and on the other side of the Fuse.

2. Test the 5 Volt DC Supply. If it's not working, replace the 5 Volt Regulator.

3. Test the 3.3 Volt DC and the 2.5 Volt DC Regulators. If either one is not working, replace it.

4. Test the Panel VCC.

5. If you don't have Panel VCC, check the Analog In-Put (VGA). You don't have to look for Video, just Vertical and Horizontal Sync.

6. If there is a Sync Signal on the In-Put, check the Buffer IC for an Out-Put. If there is no Out-Put, make sure the IC has power. If it does, change the Buffer IC.

7. If you have the Sync Signal's In and Out of the Buffer IC, check LVDS Out-Puts for Life. You're not going to try to lock in on the signal; it's too fast. You're just checking to see if there is a signal. If there is none, the Micro is not running. Go to step 9.

8. If there is a signal out of the LVDS Transmitters, then check the Panel VCC Switching Circuitry and replace the defective components.

9. With the Microprocessor not running, first check the Reset and see if it's functioning. If not, check and replace the Reset Device and related circuitry. It could be an IC or a Transistor.

10. If you have Reset, check the Oscillator and the Crystal to see if they're working properly. If they are, then the Micro is bad; either replace the Micro or the A/D Card.

11. Once you've verified that the Micro is working, check the Inverter and see if you have an Out-Put.

12. If you have one, then either the LVDS cable going to the LCD Panel is bad or the LCD Panel is bad and has to be replaced. There are no repairs that can be made to the LCD Panel LVDS Receiver PCB or the other related parts.

13. If there is no output from the Inverter, check the Inverter Circuitry for defects.

Next time we'll talk about the CCFLs (Cold Cathode Fluorescent Lamps) and the Inverter Power Supply that powers them. Good troubleshooting to all. ▲

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