EMI Issues for Flat Panel Displays

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by

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Abstract

EMI for Flat panel Displays

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High technology flat panel displays, such as high resolution AM-TFT-LCD's, mean more Electromagnetic noise is inherently produced than from their smaller, lower resolution counterparts. This unfortunate characteristic makes it more difficult to contain the potential to radiate within acceptable regulation limits.

This tendency of higher emission is a serious problem whose difficulty is underestimated by many, and it must be controlled before large, high resolution flat panel displays become commonplace and low in cost.

This presentation will discuss EMI issues and how they apply to flat panel displays, most notably for digitally interfaced LCD's. It will start with the basics, by defining EMI. Then it will show how clocks and other digital signals may be analyzed for radiation in terms of their analog structure and signal components. After that, issues of flat panel interface, layout, and general techniques to help identify radiation mechanisms will be discussed. The goal is to define EMC guidelines for building and packaging flat panel displays and associated drive and interface systems.

Outline

- **Introduction to EMI**
  - Overview
  - What is EMI, really?
- **How to analyze EMI characteristics**
  - By breaking it down for analysis in terms of its components
    - *EMI is really an Analog Phenomenon produced in Digital Systems by digital Signals*
  - Flat Panels and other digital systems are primarily Digital systems
- **EMI Issues With Flat Panel Displays**
  - Transmission Paths
  - Coupling
  - Wavelength Dependencies
  - LVDS

Overview

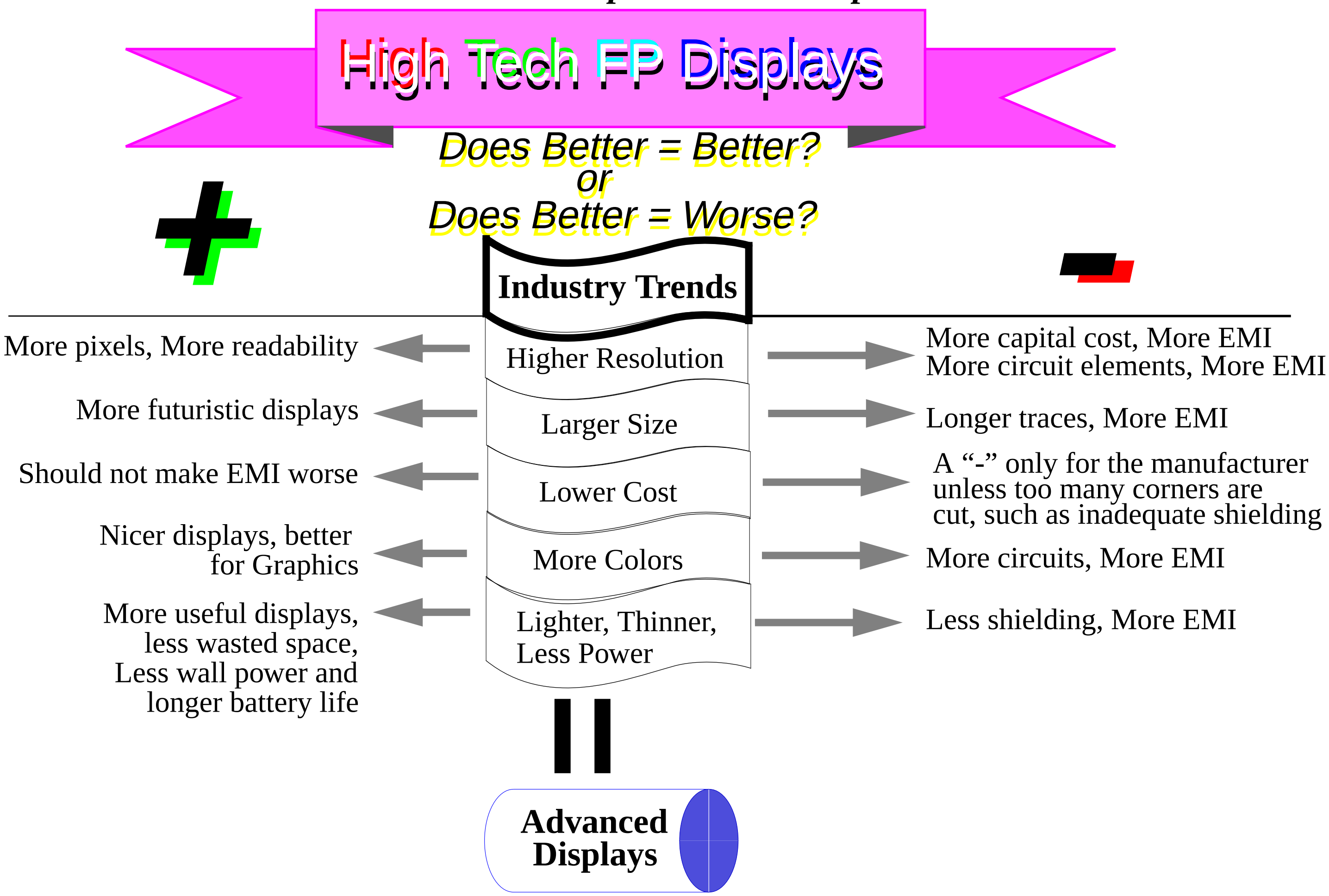
- **EMI (ElectroMagnetic Interference), or radiated emissions, must be controlled, or there will be unnecessary problems**
  - Product Delays
  - Lots of Extra $$$$$

- **All electrical systems produce EMI**
  - Agencies such as FCC/VCCI, et. al., determine acceptable radiated emissions level
  - Meeting the requirements of FCC/VCCI, etc. produces Compliance or EMC.

- **Flat Panel Displays are windows for a computer and for EMI**
  - They are separate products from an electrical system
    - *They produce their own sets of signals which can radiate*
    - *They introduce new geometry which can act like a radiating antenna*
  - EMI gets worse for higher performance display
    - *Better Displays produce Worse EMI*

The EMI Enigma for Flat Panels

- **Higher technology flat panel displays means they get better**
  - ***...but it also means there is more potential to have problems with EMI.***



EMI Precautions

-EMI
Provisions must be taken at the beginning of the project to build in EMI reduction countermeasures. Some issues which should be considered are as follows.

1) Overall
   - -Controlled impedance paths from the frame buffer to the panel
   - -Lower drive signals, so that proper terminations can be achieved on the panel without requiring a great deal of drive from the frame buffer

2) Frame Buffer
   - -Pi grounding on all supplies
     C's, RF choke, C's`
   - -Filter clock and data lines
   - -Keep clock line as isolated as possible from data lines

3) Frame Buffer to Panel Interface
   - -Controlled impedance signal lines
     - -Minimal interconnects
     - -Minimal cable types (same from input to output)
   - -Adequate ground returns (at least 1 per signal, and multiple for power)
   - -Shielding over data/clock/sync paths
   - -Separate power lines from signal lines
   - -Separate clock line

4) Flat Panel
   - -Terminations for all signals
   - -Adequate ground planes on all boards
   - -Metal bezel with numerous tie points from board ground

Types of Electromagnetic Radiation

- **Conductive Emissions**
  - Primarily 30MHz and below
- **Radiated Emissions**
  - Differential Mode
    - *Radiation from normal circuit operation*
    - *Much less of a problem then Common Mode*
  - Common Mode ← **This one is the main problem** ← ***Smaller currents produce more radiation***
    - *Radiation from paths that are not properly terminated and act like dipole antennas.*
    - *This is the worst case radiation mode for flat panels*
      - Difficult to detect
      - More radiation than Differential Mode Radiation for the same current
      - It is the hardest to control
      - Normally determines the overall emission performance of the product (Ott)
      - Often comes from cables in a system
      - Often from a signal coupling from one source to another, such as a trace, cable, or chassis

How and why does a signal radiate?

- **The Problem: We have to generate signals in an electrical system, and send them from one location to another.**
  - Via wires, printed circuit board traces, component leads, connectors, etc.
  - This is the phenomenon of transferring charge from one point of a circuit to another, and is described as *electric current*. (Valkenburg)
    - *An electric current is the time rate of net motion of electric charge across a cross-section boundary (that is, a conductor). Therefore, current is defined as follows.*

$$i = \frac{dq}{dt}$$

Eq. 1: Electric Current flow in terms of charge (q) over time (Valkenburg)

    - *Radiation is proportional to current (ref: Eq. 15:- Eq. 20:)*
- **Intentional or normal circuit operation can cause radiation**
  - As Differential Mode radiation, in which current is contained within a signal path (e.g. source-to-termination-to-return path back to source) and can radiate only at unbalanced areas, such as trace leads, certain planes, etc.
    - *An improperly terminated, or unbalanced signal path can produce reflections which go back toward the source, and can provide more current to radiate in small loop areas.*
    - *loops of area can act as small antennas*
- **Accidental circuit operation can also cause radiation**

❏ As Common Mode radiation in which current goes down a path where it has no direct return path, such as the shield of a cable which is not supposed to contain the signal

- *Accidental signal paths*
- *Paths which do not have real signal return paths*
- *Paths which have improper shielding or balance*
- *These behave like radiating antennas*
- *These are often unpredictable and may be very difficult to find.*
- *These can radiate from cables, wires, areas of a chassis, metal frames, trace leads, etc.*
- *Paths in which current flows in the same direction, that is, there is no apparent return path*
- *Most similar to a dipole antenna*
- *Reflections from improperly terminated transmission lines, causing VSWR.*

The Foundations of Electromagnetic Wave Generation

Voltage between 2 conductors can be formed in the way of a field if there are free charges of equal and opposite polarity on both wires as described by Coulomb's law.

$$E = \frac{q}{4\pi\varepsilon r^2}$$

Eq. 2: Coulomb's Law (Repulsive Force)

Where
- E = Electric field in Volts per meter
- q = Charge in Coulombs
- ε = Dielectric constant
- r = Distance in meters

Charge is determined by the current as follows.

$$q = \int i\,dt$$

Eq. 3: Charge as a Function of Current Strength

Capacitance can be determined in terms of charge and Voltage.

$$C = \frac{q}{V}$$

Eq. 4: Capacitance as a Function of Charge

It is known that a current flow in conductors introduces a magnetic field or flux. This is determined by either Ampere's law (Fairchild).

$$\oint H dl = i$$

Eq. 5: Ampere's Law

or the Biot-Savart law (Fairchild)

$$dB = \frac{\mu I dl \times r}{4\pi r^3}$$

Eq. 6: Biot-Savart law

Where
- r = Radius vector (meters)
- l = Length vector (meters)
- B = Magnetic Flux density (Webers per meter)
- H = Magnetic field (amps per meter)
- μ = Permeability

If the magnetic flux (ϕ) linking 2 wires is variable with time, then induced voltage results from the flux variation with respect to time

$$V = \frac{d\phi}{dt}$$

Eq. 7: Faraday's Law

Sections of the line or wire can exhibit a voltage drop not only due to intrinsic resistance drop, but also due to the changing magnetic flux within a section loop.

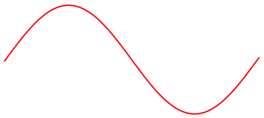
$$V = L\frac{di}{dt}$$

Eq. 8: Faraday's Law

Therefore, transmission lines or paths should be considered in terms of their inductance and resistance, which influences current flow and magnetic radiation, and their capacitance, which influences the electric field propagation.

Dissection of a Digital Signal

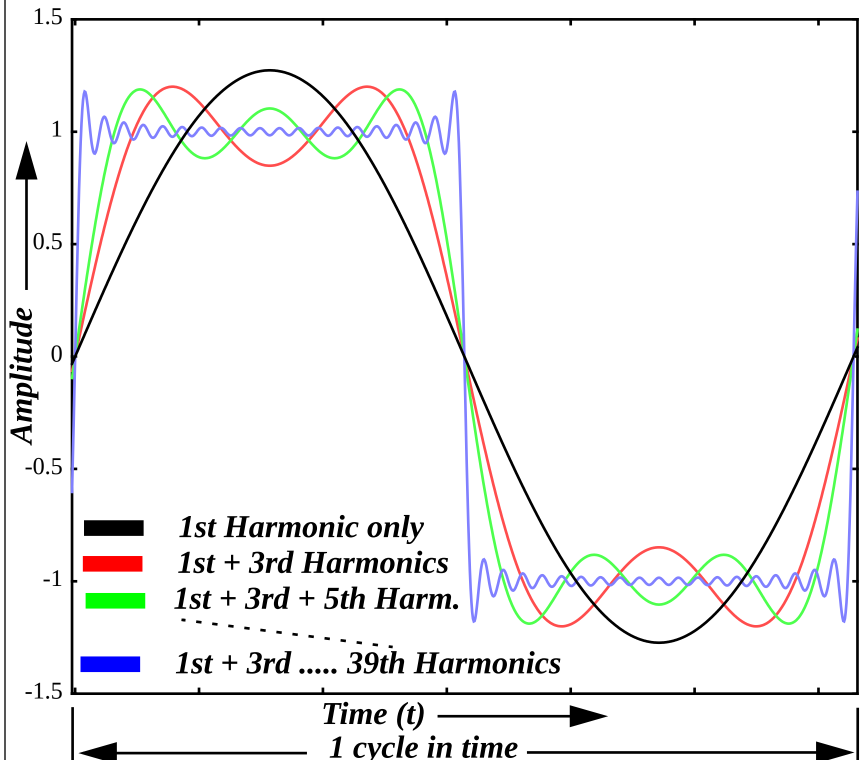
- **The fundamental electrical signal is a sine wave.**
  - All Signals, Analog or Digital, are composed of sine waves.
    - *A sine wave in time =* $A \sin(\omega t + \theta)$



- Where
  - A = the amplitude of the voltage, current, etc.,
  - $\omega = 2\pi f$, or the radian frequency,
  - θ = the phase in degrees.

- All signals are composed of sine waves added together.
  - *It is the number of sine waves, and the frequency, amplitude, and phase of each that determine a signal's identity.*
- Analysis of a signal from its sine wave components provides a method to help understand the EMI puzzle
  - *Defines the fundamental and harmonic frequency components of a digital signal analyzed by use of Fourier methods*
  - *Provides a method in which frequency dependent EMI problems may be assessed*

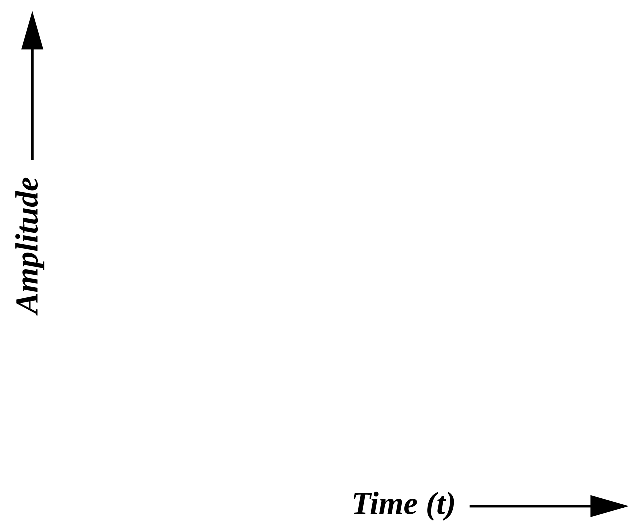
Components of a Square Wave Digital Signal

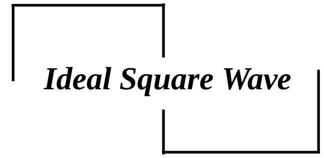


Fourier series representation of the sinusoidal components of a square wave:

$$\frac{4}{\pi}\sum_{n=0}^{\infty}\frac{1}{2n+1} + \sin(2n+1)t$$

The above waveforms are the solution of the Fourier series for limits of 1, 3, 5, & 39 rather than ∞.



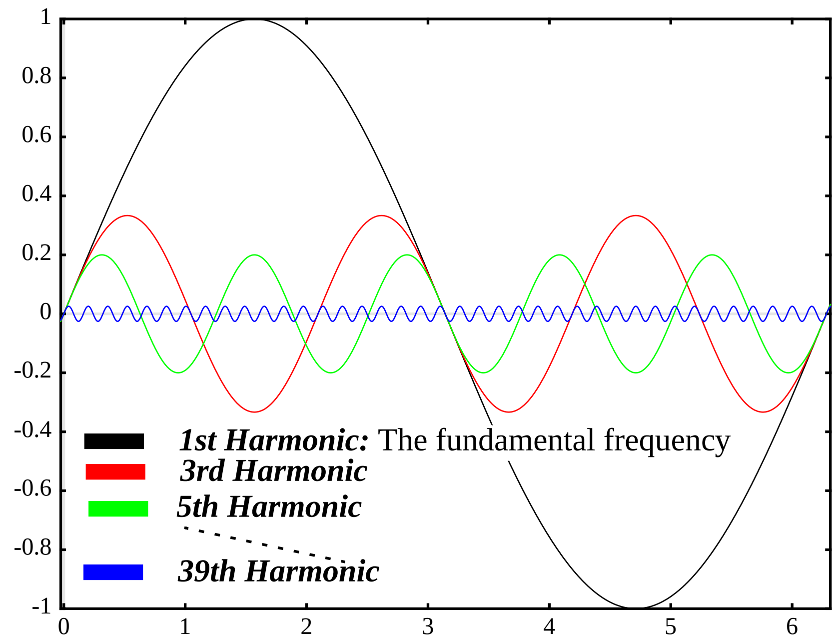


A Square Wave Digital Signal is many sine waves combined in a special way.

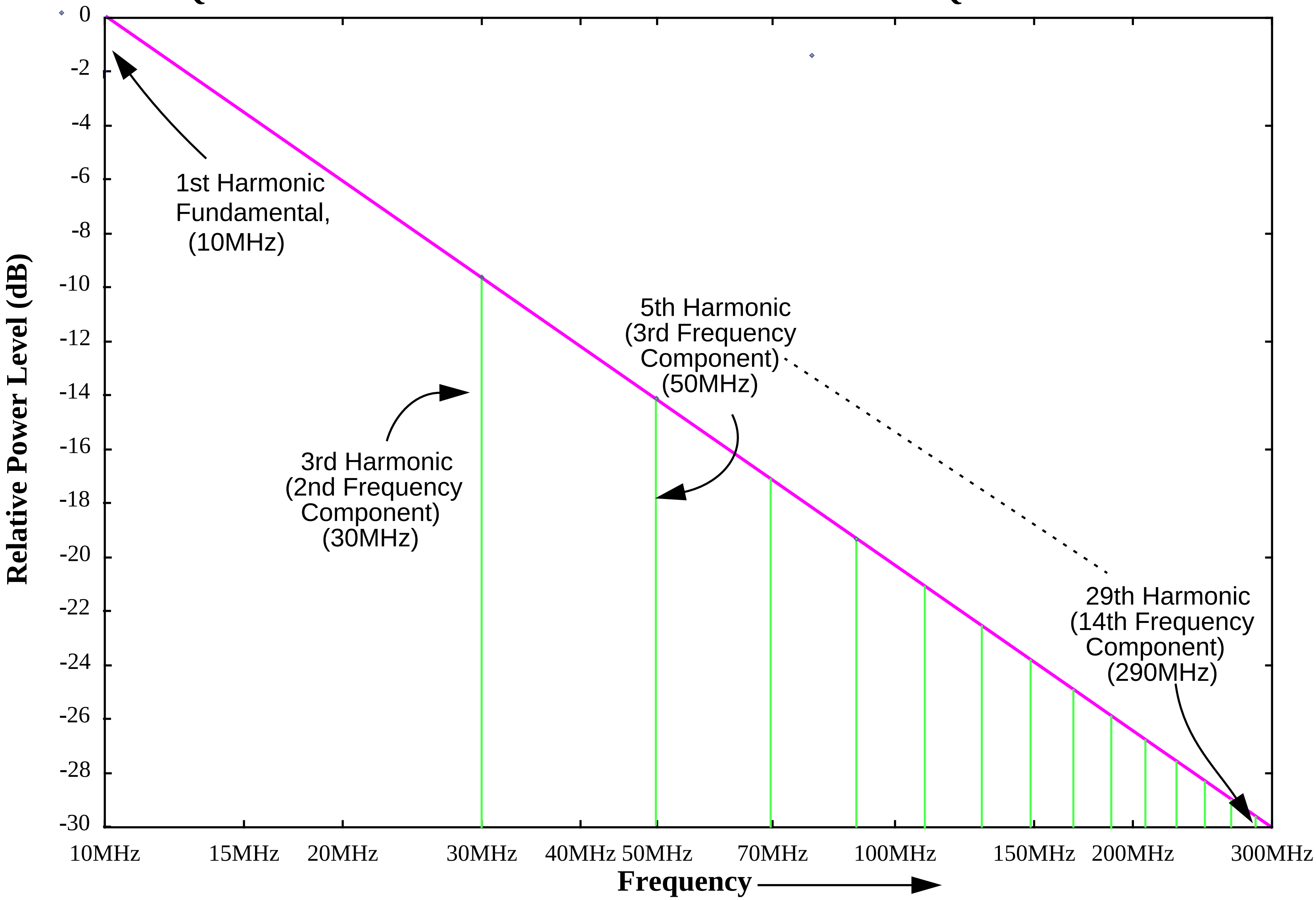
The sine wave components of a square wave are called harmonics. For a square wave, they are always odd. That is, they will be the 1st, 3rd, 5th, etc. harmonics.

The more odd harmonics added to the fundamental (with the right amplitude and phase) the more the signal approaches a true square wave.

Frequency of the fundamental = frequency of the square wave

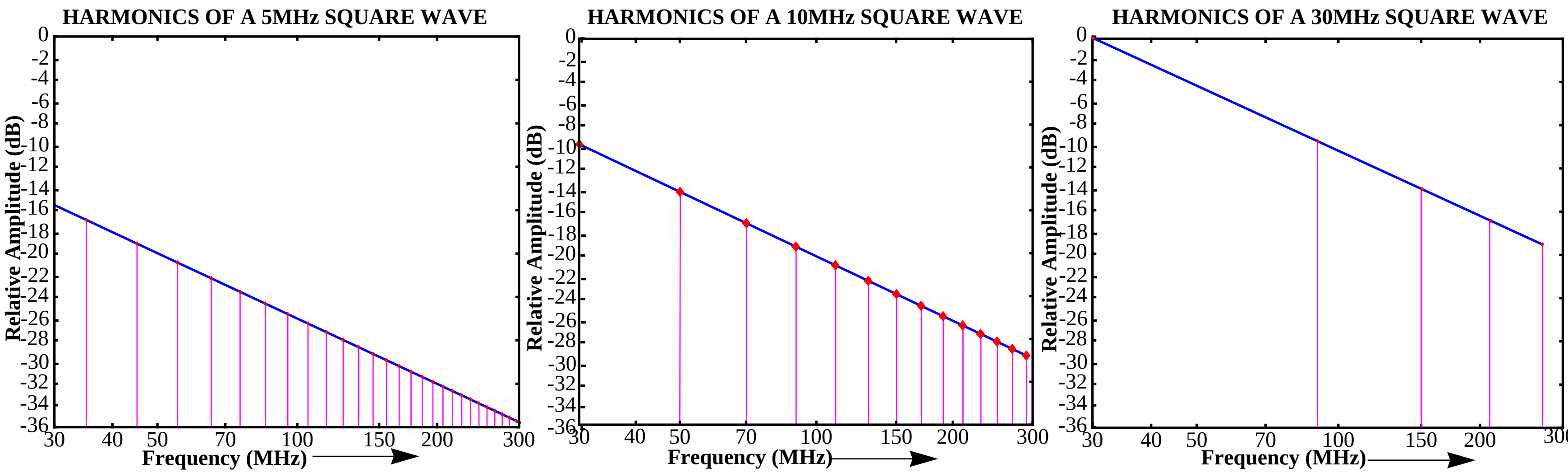


FREQUENCY PLOT OF THE COMPONENTS OF A 10MHz SQUARE WAVE



How Clock Harmonics for Various Clock Rates Compare

- **They vary in amplitude and quantity of harmonics within a given range**



- **Clock frequencies of 5MHz, 10MHz, and 30MHz are shown for comparison**
- **Shown in 30MHz to 300MHz Bandwidth**
  - The frequency window for common EMI measurement

Electrical Systems: Size Matters

- **Any electrical systems can act as a selective filter for the plane wave**
  - An electrical system may have radiation mechanisms in which any component of a complex signal, such as a digital signal, can escape as electromagnetic radiation.
- **EMI is really just radiation of radio waves from antennas that we don't want to be there.**
  - All we have to do is eliminate the antennas or cover them up with shielding.
- **How do we make antennas look like bad antennas?**
  - Reduce current
  - Detune the antenna
    - *By controlled inductance or capacitance. This can also help filter the signal.*
    - *Golden Rule: Shorter antennas need shorter wavelengths (that is higher frequencies) to radiate. Therefore, keep all the antennas short.*
      - *Use short leads, short traces, short wires, short separations for cables as they attach to connectors, etc.*

❏ What are antennas in circuits?

- *Any of the following can be antennas if not handled properly.*
- *The better they are handled, such as by proper ground planes, shielding, being kept short, balancing, etc., the less they act like antennas, or allow higher frequencies to radiate.*
  - *Leads of components, such as IC's, transistors, resistors, etc.*
  - *Printed circuit board traces*
  - *Connector pins*
  - *Wires*

Why is radiation a problem in Liquid Crystal Displays?

- **A: The Source**
  - This one is owned by the Computer Mfg.
  - The computer generates signals that can radiate.
- **B: The Signal Transmission Path**
  - This one is owned by both
  - Wires, connectors, traces, etc. are needed to carry signals to the displays
    - *These can act as antennas for radiation, and they exist only due to the display.*
  - Multiples of signals are needed (e.g. RGB x 8 bits/color = 24 bits + clock and other signals) to get the signals to the flat panel display.
- **C: The Destination: The LCD's**
  - This one is owned by the Flat Panel Mfg.
  - They receive the signals then reprocess them
  - They have many wires and traces which can produce Common Mode Radiation
  - They generate many new sources signal sources.

All must be solved by both parties together

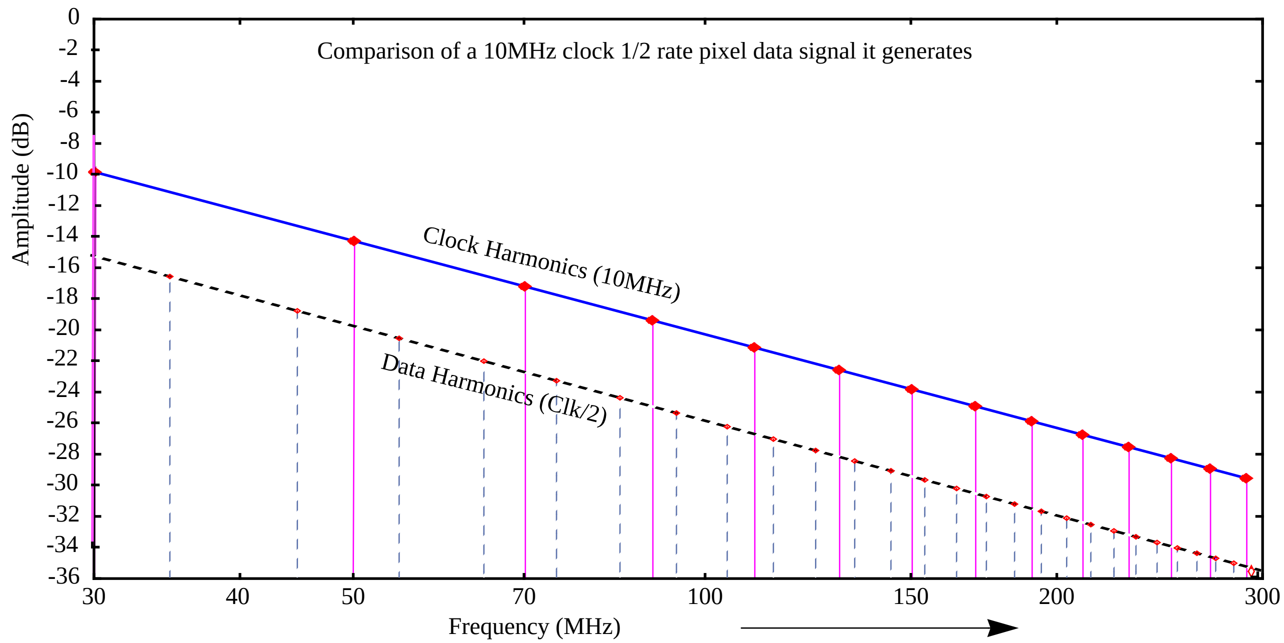
Radiation of a frequency component is quite dependent on numerous circumstances to make them available to radiate. These are often wavelength dependencies. A frequency, when travelling through a medium, has a wavelength that is dependent on both frequency and the density of the medium in which it is travelling.

Electromagnetic waves can be called plane waves or radio waves. They travel at the same speed as light. Light travels in free space at 186, 282.423 miles/second, or about 300,000,000m/sec. The wavelength of a frequency in space ( ) is equal to the velocity of light divided by the frequency, or

$$\lambda(m) = \frac{300,000,000}{F} = \frac{300}{F(MHz)}$$ (rounded off from 299,793,077 meters per second in free space),

The Relationship Between Data and Clock Harmonics

❍ For Amplitudes and Quantity for Alternating Pixel Video



- ❑ For an alternating pixel display, a square wave equal to 1/2 the clock is produced.
- ❑ This produces a new signal at half the frequency of the original clock
  - *New timing at half the frequency of the original frequency*
  - *Twice as many frequencies are generated within the EMI measurement window*
  - *All are about 6dB lower than the pixel clock levels*

Power Calculations within a Given Frequency Band

To calculate the total power of all the frequencies from a square wave, we start by first determining an arbitrary power level for 0dB.

Let $V_{ref} = 5.0V$
Let $Z_{ref} = 25k\Omega$

For the above reference values, an arbitrary Reference Power Level (P_0) can be determined as follows:

$$P_0 = \frac{Vref^2}{Z_{ref}} = \frac{5V^2}{25000\Omega} = 0.001W$$

Eq. 9: Calculation of Reference Power Level (P_0)

The absolute Voltage Level (V) can then be determined for any dB level by Eq. 5.

$$V = \sqrt{\log{-1}\left(\frac{dB}{10}\right) \cdot Z_{ref} \cdot 0.001 \cdot P_0}$$

Eq. 10: Absolute Voltage Level (V) for any dB level

Real Power for a specific dB level (P_1) can then be calculated as follows:

$$P_1 = \frac{V^2}{Z}$$

Eq. 11: Real Power Level for V found from Eq. 5:

Power Calculations within a Given Frequency Band, Cont.

$$\sum_{n = 30MHz}^{300MHz} P_1$$

The total power calculation of the frequency content within the given bandwidth of 30MHz to 300MHz can be calculated from P_1.

Eq. 12: Total Harmonics Power Calculation, 30MHz to 300MHz.

In the extended form this would appear as follows.

$$\sum_{n = 30MHz}^{300MHz} \frac{\left(\sqrt{\log{-1}\left(\frac{dB}{10}\right) \cdot Z_{ref} \cdot 0.001 \cdot P_0}\right)^2}{Z}$$

Eq. 13: Total Extended Harmonics Power Calculation, 30MHz to 300MHz.

Table of Relative EMI Relationships

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The Mechanisms as follow show relationships of signal levels

These mechanisms indicate sources of signal energy which could potentially radiate at levels with respect to the reference. In all cases, the ability to have the radiation as a function of the given changes is strictly a function of the overall system design.

The assumption is that changes in levels are changes in voltage or current with respect to a similar impedance.
This is a worst case scenario, assuming equal radiating conditions

-dB means the radiation got better.

Reference Condition	Ref Level	Comment	Alternate Case	Comment	Change Level	Better/Worse
5.0V Logic	0 dB		3.3V Logic		-3.609dB	better
No of signal lines	0 dB		1/2 no of signal lines		-6dB	better
4 Bits/color	0 dB		6 Bits/color		+3.52dB	worse
6 Bits/color	0 dB		8 Bits/color		+2.5dB	worse
VGA (640 x 480)	0 dB	307k pixels	SVGA (800 x 600)	480k pixels	+3.876dB	worse
VGA (640 x 480)	0 dB	307k pixels	XGA (1024 x 768)	786k pixels	+8.65dB	worse
VGA (640 x 480)	0 dB		SUN (1152 x 900)	1.04M pixels	+10.57dB	worse
VGA (640 x 480)	0 dB		EWS (1280 x 1024)	1.31M pixels	+12.6dB	worse
VGA (640 x 480)	0 dB		Hi Res (1600 x 1280)	2.05M pixels	+16.5dB	worse
VGA (640 x 480)	0 dB		HDTV (1920 x 1080)	2.07M pixels	+16.58dB	worse

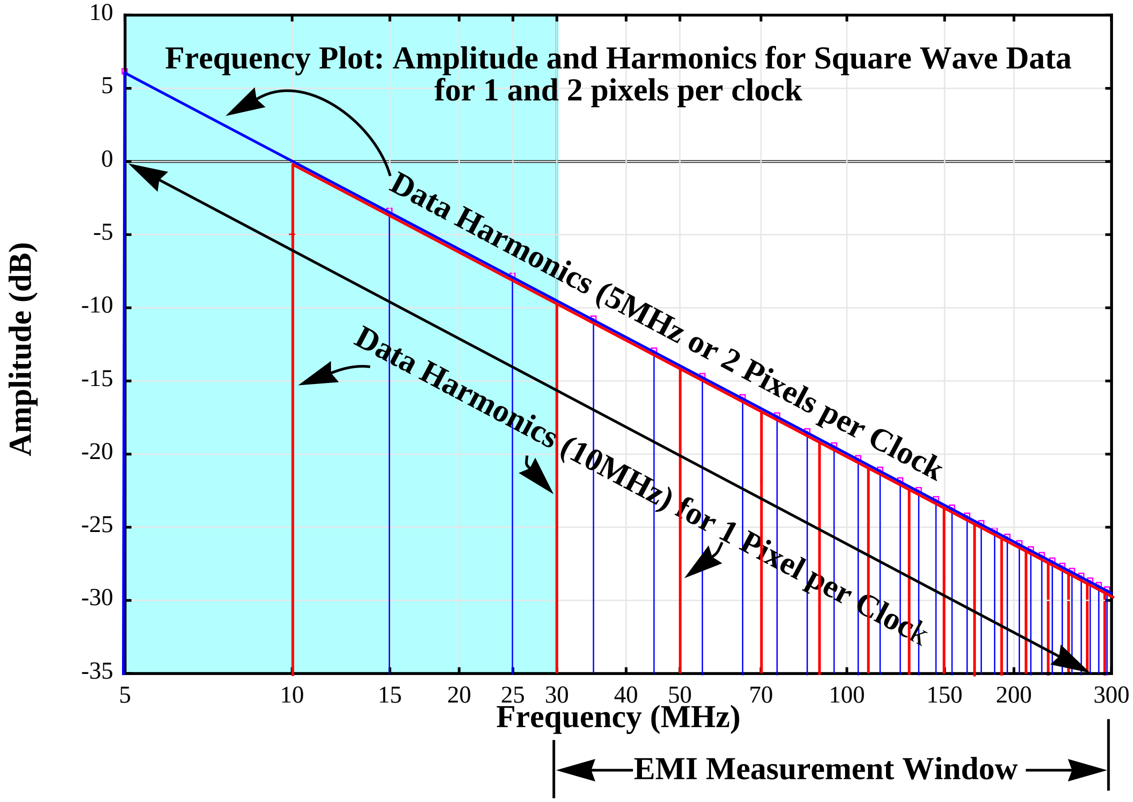
Flat Panel Interface Issues: Pixels per Clock

- **1 Pixel Per Clock vs. 2**
- **Flat Panels for Computer Displays will require primarily a digital interface**
- **If 2 pixels per clock are sent to a flat panel, vs. 1 pixel per clock, the following changes occur.**
  - There harmonic content will be rearranged in a specified bandwidth.
  - There will be at least twice as many harmonics.

							1 Pixel per Clock		2 Pixels per Clock	
Display Size (Diagonal)	**Resolution**	**Name**	**Bits/ Color**	**% Blanking Time**	**Vertical Freq**	**No. of Full Pixels**	**Total # of Pixel Data Bits**	**Clock Frequency**	**Total # of Pixel Data Bits**	**Clock Frequency**
10.4”	640 x 480	VGA	8	2.5%	60Hz	.307M	24	18.9MHz	48	9.5MHz
11.3”	800 x 600	SVGA	8	2.5%	60Hz	.48M	24	29.5MHz	48	14.8MHz
12.1”	1024 x 768	XGA	8	2.5%	60Hz	.786M	24	48.5MHz	48	24.2MHz
15” & up	1280 x 1024	EWS	8	2.5%	60Hz	1.3M	24	80.6MHz	48	40.3MHz

Table 1: Clock Rates for Various Flat Panels

Flat Panel Interface Issues: 1 or 2 Pixels per Clock

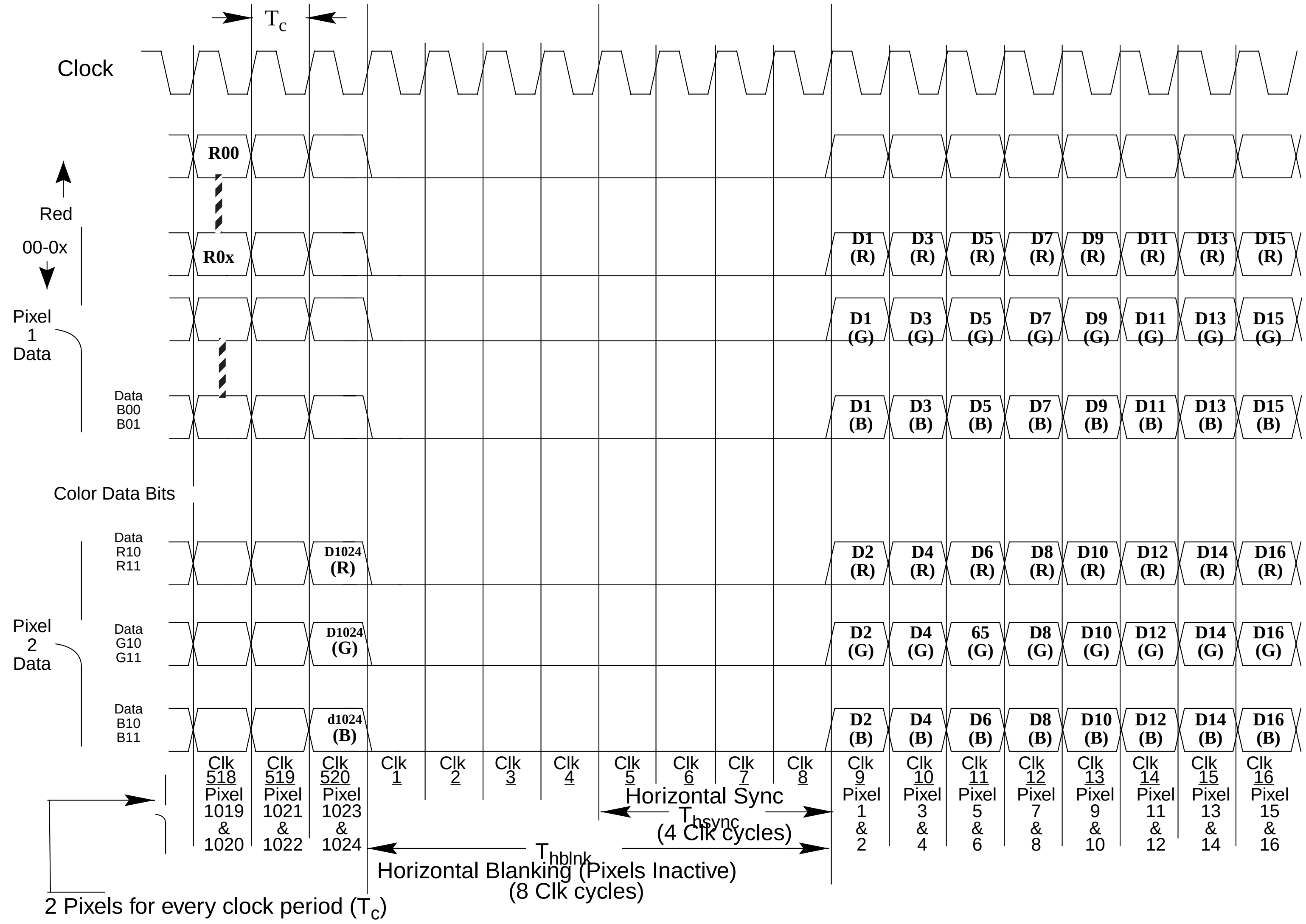


❍ **Two pixels per clock can produce double power of transferring the signal from the driver to the load**

❑ This could double the power in any data harmonic, if the signals are the same

- *EMI reduction may be dependent on other issues such as skin effect, parasitics, phase variations, etc.*

- **What does 2 pixels per clock do?**



T_c
Clock
R00
Red
00-0x
R0x
Pixel 1 Data
Data B00 B01
Color Data Bits
Data R10 R11
Pixel 2 Data
Data G10 G11
Data B10 B11
D1024 (R)
D1024 (G)
d1024 (B)
D1 (R) D3 (R) D5 (R) D7 (R) D9 (R) D11 (R) D13 (R) D15 (R)
D1 (G) D3 (G) D5 (G) D7 (G) D9 (G) D11 (G) D13 (G) D15 (G)
D1 (B) D3 (B) D5 (B) D7 (B) D9 (B) D11 (B) D13 (B) D15 (B)
D2 (R) D4 (R) D6 (R) D8 (R) D10 (R) D12 (R) D14 (R) D16 (R)
D2 (G) D4 (G) 65 (G) D8 (G) D10 (G) D12 (G) D14 (G) D16 (G)
D2 (B) D4 (B) D6 (B) D8 (B) D10 (B) D12 (B) D14 (B) D16 (B)
Clk 518 Pixel 1019 & 1020
Clk 519 Pixel 1021 & 1022
Clk 520 Pixel 1023 & 1024
Clk 1
Clk 2
Clk 3
Clk 4
Clk 5
Clk 6
Clk 7
Clk 8
Clk 9 Pixel 1 & 2
Clk 10 Pixel 3 & 4
Clk 11 Pixel 5 & 6
Clk 12 Pixel 7 & 8
Clk 13 Pixel 9 & 10
Clk 14 Pixel 11 & 12
Clk 15 Pixel 13 & 14
Clk 16 Pixel 15 & 16
Horizontal Sync
T_{hsync}
(4 Clk cycles)
T_{hblnk}
Horizontal Blanking (Pixels Inactive)
(8 Clk cycles)
2 Pixels for every clock period (T_c)

Flat Panel Interface Issues: LVDS

- **What is LVDS?**
  - Low Voltage Differential Signaling
    - *EIA-644 Interface Standard*
- **What is the significance of LVDS**
  - It has been accepted as the Interface Architecture for the flat panel display interface standard in development at VESA
- **Why LVDS?**
  - It Solves several major problems for high technology, high resolution LCD's

1) It enables a very wide digital video bus to be serialized and be reduced

2) It helps reduce EMI

3) It helps control grounding issues

4) It enables data to be transmitted longer distances than on a parallel data bus

LVDS: High Speed Serial Link

- **Serialization means higher frequencies.**

- **If higher frequencies mean worse EMI, and LVDS produces higher frequencies, then how does LVDS work to reduce EMI?**

    - By lowering the voltages, rearranging the harmonics, and controlling the impedance signals path using differential pairs

- **The current hardware implementation of LVDS works as follows:**

Base Band (Clock & Data before and after LVDS processing)			**Serialized (as LVDS Signal)**			
LVDS Processing Range	**Clock Rate**	**Maximum Video Rate***	**LVDS Clock**	**LVDS Data Rate**	**LVDS Frequency**	**Multiplexing Factor**
Minimum	20MHz	10MHz max (clk/2)	20MHz	140Mbits/s	70MHz	7:1
Maximum	65MHz	32.5MHz max (clk/2)	65Mhz	455Mbit/s	227.5MHz	7:1

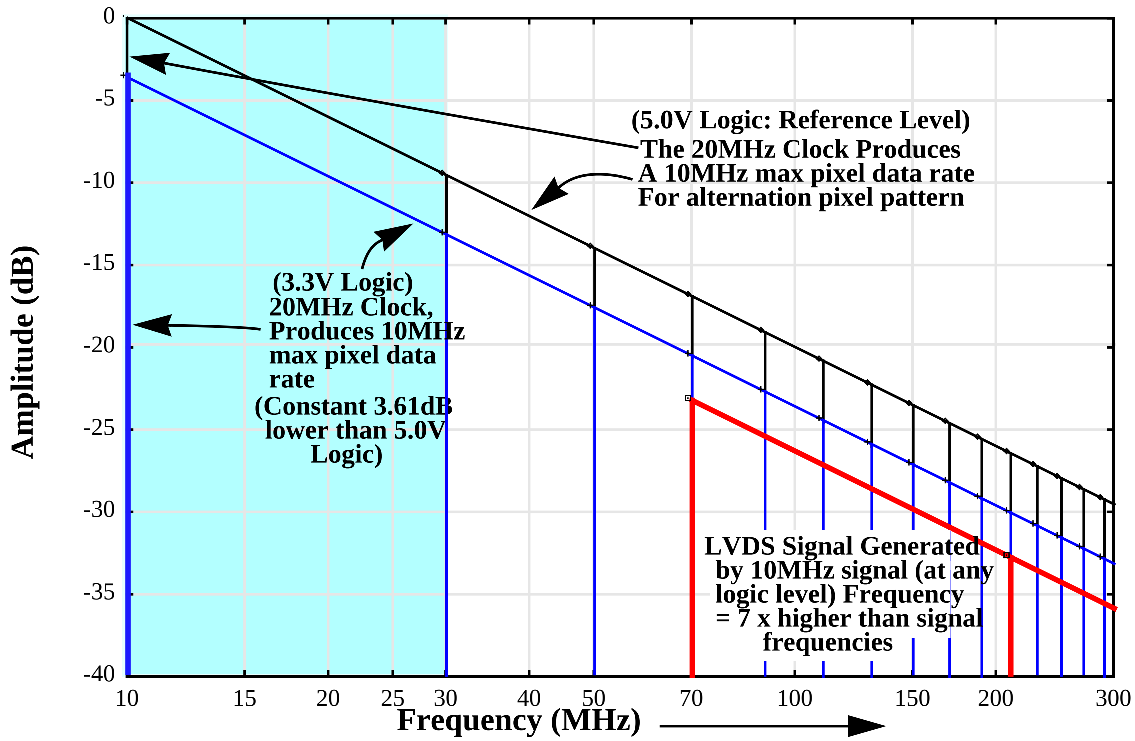
Table 2: LVDS Signal Processing, Current Implementation

*The highest frequency video signal a data clock can produce is the clk/2, for alternating pixels.

- **This implementation of LVDS is being used by major LCD suppliers today.**

LVDS Frequency Analysis

- **Frequency and amplitude for a current implementation of LVDS**
  - Hardware only, with a 7:1 signal multiplex/demultiplex ratio.



FREQUENCY PLOT: 20MHz 5.0V and 3.3V Logic Levels, and LVDS Processed Frequencies

  - 10MHz maximum data rate is shown

Advantages & Disadvantages of LVDS

✔ Reduction of EMI

- As per analysis and lab data showing spectral content with respect to other Logic types (National)

✔ One Implementation reduces the number of data lines by as much as 5.8:1†

✔ Eliminates needs for grounds, and thus reduces ground-induced EMI mechanisms

✔ Reduces connector pin count by as much as 58 pins reduced to 10†

- *Solves ground problems, since grounds are often not 1:1 for parallel data busses. Often times there are shared ground for several bits, and this can make EMC more difficult.*

✔ Controls Impedance of Digital Signal Lines

- *Digital signals normally have minimal impedance control on their transmission paths*
- *Digital Signal Lines are normally not well balanced*

✘ Skew sensitivity

✘ DC balance sensitivity†

✘ Frequency limitations: 7:1 multiplexing factor is not good enough†

✘ It adds power to the system*†

✘ It adds cost to the system*†

✘ It requires additional space for the system*†

*These may be short-term problems only. As systems are redesigned with LVDS architecture in mind, LVDS may become part of the controlling IC's, thus reducing or eliminating these factors.
†As per the current implementation hardware.

How LVDS Reduces EMI for Flat Panels

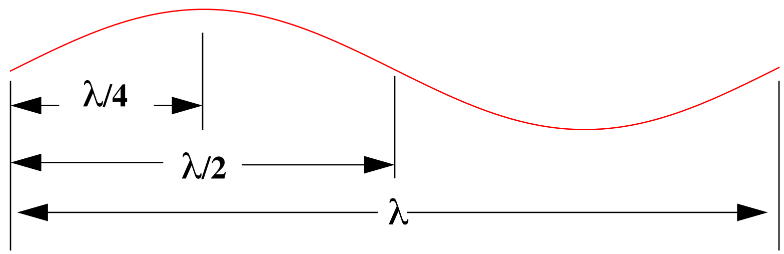
- ✰ By reducing the number of signal lines
- ✰ By controlling grounds
- ✰ By providing balanced transmission paths
- ✰ By providing impedance control for digital signals
- ✰ By producing low voltage levels

Is LVDS the best solution?

- ✰ The current implementation has some limitations, but it has offer the following advantages
  - It is available now
  - It does the job of solving major interface problems for flat panels

Relative Radiation Strength for Wavelengths

Relative Field Radiation Strength of an antenna for frequencies varying from 1/4 wavelength.



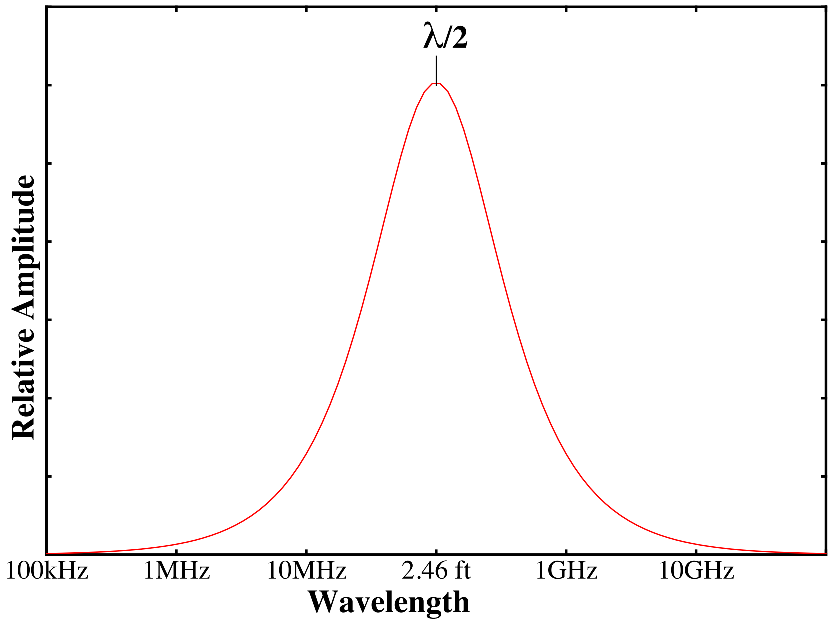
Radiation can take place for 1/2 or 1/4 wavelength.

<u>For freq = 227MHz</u>

λ = 4.336ft (52.01")

λ/2 = 2.168ft (26.015")

λ/4 = 1.084ft (13.0")



$$V\left(\frac{dB\mu v}{m}\right) = 20\log\left(\frac{12.6 \times 10^{-7}(f\,l\,I)\left(\frac{1}{r}\right)}{1\,\mu V}\right)$$

$$\lambda = \frac{300(m)}{f(Mhz)}$$

*estimated horizontal size of a 12.1" LCD (Estimated to be 13.0")

Differential Mode Radiation

Differential Mode Radiation can be defined as follows:

$$E = 131.6 \times 10^{-16}(f^2 A I)\left(\frac{1}{r}\right)\sin\theta$$

Eq. 14: Differential Mode Radiation in Free Space (Weeks, Ott)

Where

E = volts/meter
f = frequency in Hertz
A = area in square meters
I = current in Amperes
r = distance in meters

Compensating for additional radiation magnitude when measurements are made in an open field over a ground plane, rather than in free space. Additional radiation results from reflections from the ground surface.

$$E = 263 \times 10^{-16}(f^2 A I)\left(\frac{1}{r}\right)$$

Eq. 15: Differential Mode Radiation over a Ground Plane (Ott)

Since levels of radiation will produce values of E which will be very small, it is scaled by 1 million to be in dB microvolts.

$$dB\mu V = 20\log\left(\frac{E}{1\mu V}\right)$$

Eq. 16: E to dBμV Conversion

This puts the equation for differential mode radiation in the following form:

$$\left(\frac{dB\mu V}{m}\right) = 20\log\left(\frac{263 \times 10^{-16}(f^2 A I)\left(\frac{1}{r}\right)}{1\mu V}\right)$$

Eq. 17: Differential Mode Radiation in dBμV

Common Mode Radiation

Common Mode Radiation in free space

$$E\frac{v}{m} = \frac{4\pi \times 10^{-7}(fAlI)\sin\theta}{r}$$

Eq. 18: Common Mode Radiation in Free Space (Weeks)

Where
- E = volts/meter
- f = frequency in Hertz
- l = length in meters
- I = current in Amperes
- r = distance in meters

$$E = 12.6 \times 10^{-7}(flI)\left(\frac{1}{r}\right)$$

Eq. 19: Common Mode Radiation

Compensating for additional radiation magnitude when measurements are made in an open field over a ground plane, rather than in free space. Additional radiation results from reflections from the ground surface.

This makes the equation for differential mode radiation be as follows

$$\left(\frac{dB\mu v}{m}\right) = 20\log\left(\frac{12.6 \times 10^{-7}(flI)\left(\frac{1}{r}\right)}{1\mu V}\right)$$

Eq. 20: Common Mode Radiation in dBμV

Differential And Common Mode Radiation in Volts (e)

Sometimes it may be more helpful

Comparison of Differential and Common Mode Radiation

❍ Differential Mode Radiation

$$\left(\frac{dB\mu V}{m}\right) = 20\log\left(\frac{263\times 10^{-16}(f^{2}AI)\left(\frac{1}{r}\right)}{1\mu V}\right)$$

❍ Common Mode Radiation

$$\left(\frac{dB\mu v}{m}\right) = 20\log\left(\frac{12.6\times 10^{-7}(flI)\left(\frac{1}{r}\right)}{1\mu V}\right)$$

❍ Example Case:

Assume the following conditions:

l = length in meters = .330m (from a estimate of a 12.1” LCD horizontal size) = 13.0”
I = current in Amperes = 10mA
r = distance in meters = 3m
A = area in square meters = 524.2x10-6m^2 (13”/4 x 1/4” from a 12.1” LCD geometry)
f = 227.135MHz (the λ/4 frequency for l = 13.0”)

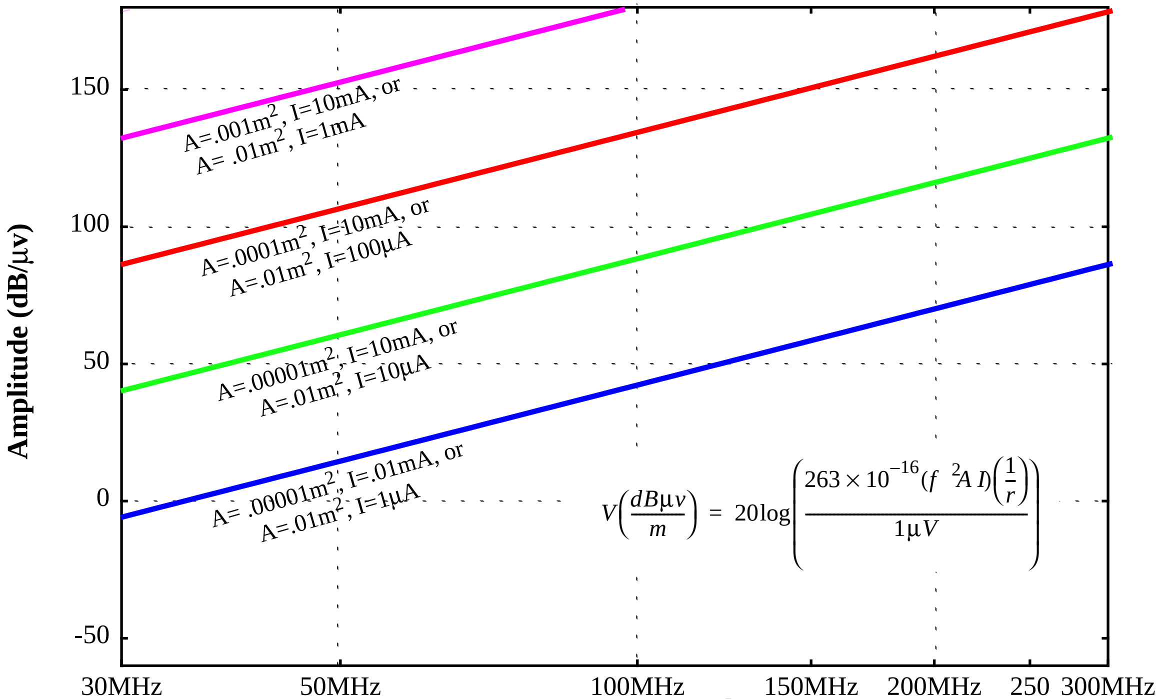
What is the level of radiation for the Differential and Common Mode Cases?

Differential Mode Radiation = 67.5dBμv/m
Common Mode Radiation = 110dBμv/m
or 42.5dB worse for somewhat similar conditions on an LCD.

Differential vs. Common Mode Radiation

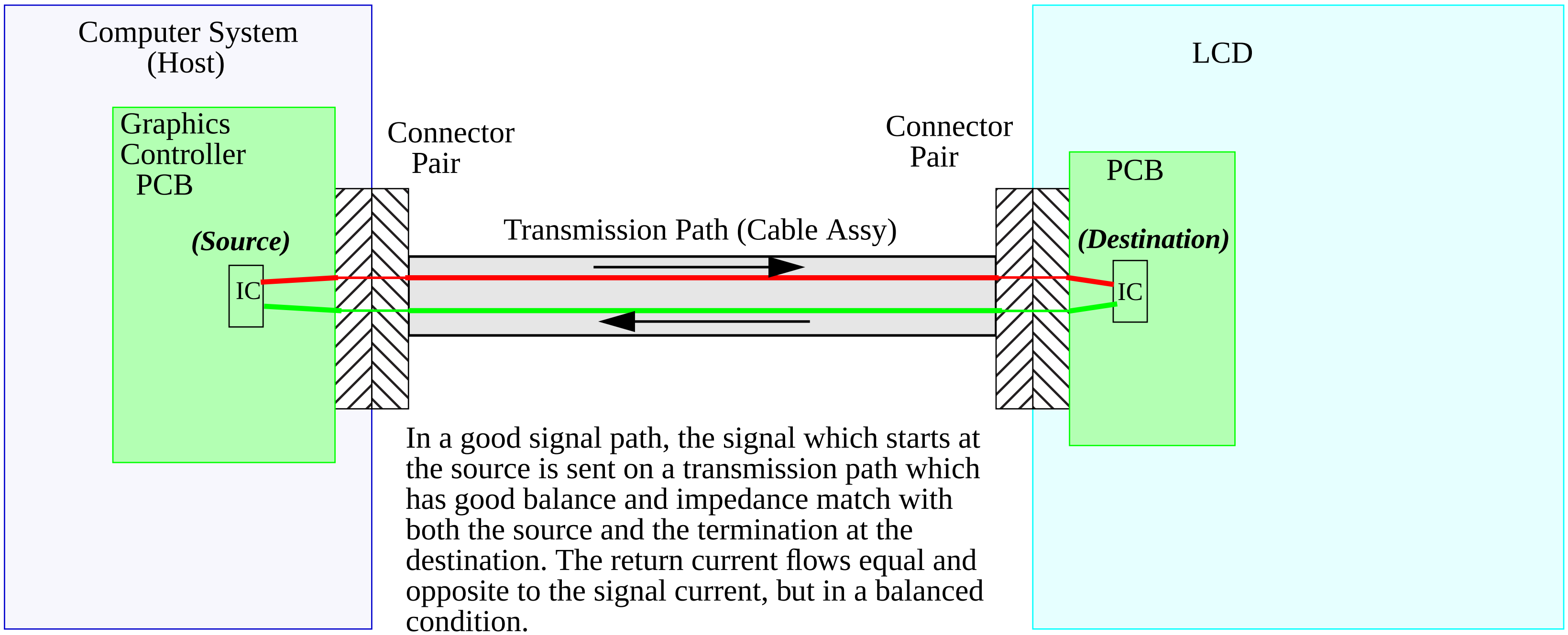
Mechanism	Differential Mode	Common Mode
Balanced Transmission Path	*Maybe*	*No*
Unbalanced Transmission Path	*Maybe*	*Yes*
Ground Loop	*No*	*Yes*
Open circuits	*No*	*Yes*
Long leads	*Yes*	*No*
Large Circulating current loops	*Yes*	*No*
Coupling between lines	*Yes*	*Yes*
Unshielded chassis	*Yes*	*Yes*
High Currents	*Yes*	*Yes*
High Frequencies	*Yes*	*Yes*

Differential Mode Radiation Curve, Open Field Over a Ground Plane



The Relationship of Signal Integrity to EMI

- **Good Signal Integrity means minimal EMI.**
  - Why? Let’s consider the following situation.



In a good signal path, the signal which starts at the source is sent on a transmission path which has good balance and impedance match with both the source and the termination at the destination. The return current flows equal and opposite to the signal current, but in a balanced condition.

When the balance or impedance is not correct, then the circuit flow is not balanced, and reflections can occur. These reflection will cause unbalanced current to flow and be able to radiate as differential mode radiation in places where it can build up, such as at the source or the termination.

The Effect of Cross talk

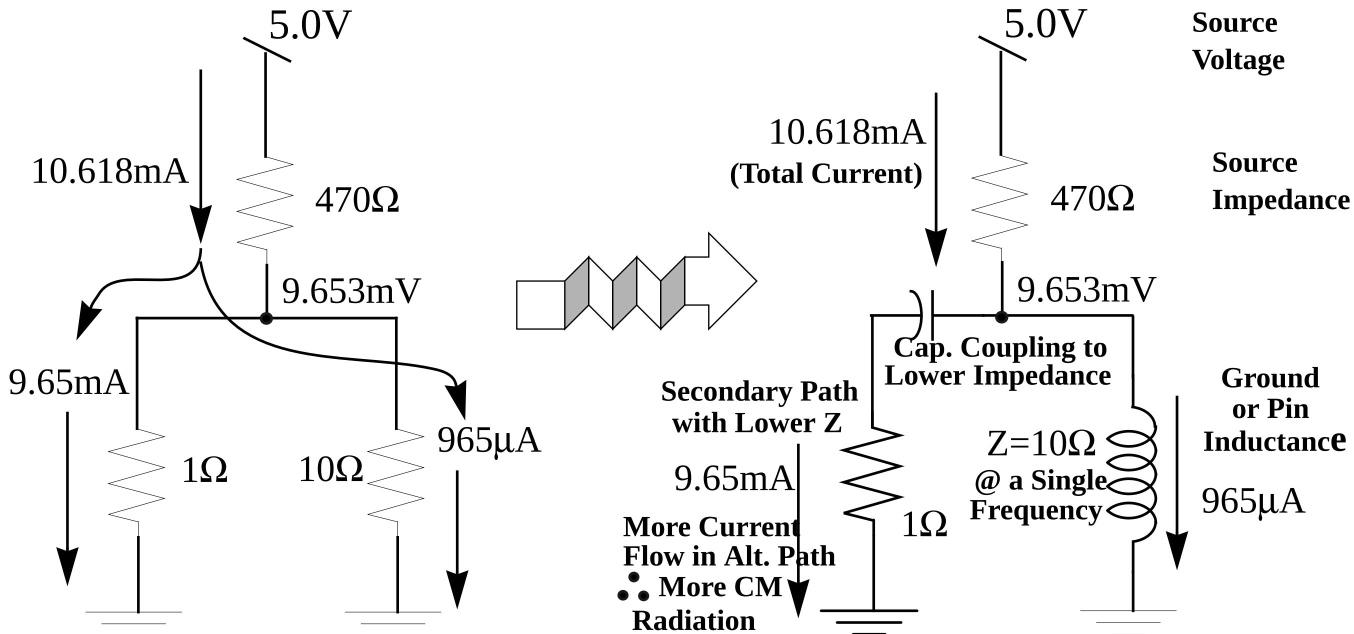
- **Cross talk is coupling of signal components from one transmission path to another**
  - It can occur among any two or more conductors when parasitic capacitance exists
  - It can degrade signals
  - It can produce Common Mode Radiation

Why Grounds Are Important for EMC for Flat Panels

- **Good grounds provide an adequate return path for the signal current**
  - They give signal current the proper path to follow
  - Keeps the current contained within that path and unable to flow to other lines where they can radiate
  - They help keep Differential Mode Current from becoming Common Mode radiation
- **Good grounds keep signals in a transmission path balanced**
  - They maintain the differential signal flow in which the signal and return path are equal, but in opposite directions, causing the E & H fields to cancel.
- **Careful attention should be paid to ground impedance**
  - Signals propagate along the lowest impedance path
  - Grounds have inductance. Impedance of inductors go up as frequency goes up.

Current Flow With Respect to Ground Potential

❍ **The lower the impedance of the ground, the less the CM radiation**



Resistive Model of Ground Impedance to show Current Analysis

Example of How this might apply for a real flat panel case

- ❑ 10 times more current flows in the lower impedance path

❍ **Conclusion: Large grounds are needed (or more pins for connectors) to help reduce EMI in Flat Panels**

The Potential EMI Problems with Connectors

- **Why are connectors a potential disaster for EMI, if not controlled?**
  -

Summary: EMI Issues for Flat Panels

- **We have looked at defining EMI**
  - In terms of its radiating properties from E & H components as Waves in space
- **We have looked at how sine waves are the fundamental part of all signals**
  - Whether as electrical signals or EMI radiated waves
- **We have looked at analyzing digital data by its frequency content**
  - In terms of numbers of sine waves, and their individual characteristics
    - *Frequency, amplitude, and phase*
- **We have shown how frequency relates to wavelength**
  - And how lengths of parts of flat panels determine what frequencies can radiated
- **We have looked at the modes of radiation, and their relative strengths**

Summary, Pg 2: EMI Issues for Flat Panels

- **We have looked at how these issues apply to EMI for flat panels.**
  - The EMI Enigma for flat panels
  - Wavelength dependencies
  - Coupling, and common mode radiation as a result
  - LVDS
  - Interface issues
    - *Two Pixels per clock*
    - *LVDS*
  - Grounding issues
- **Conclusions**
  - Flat Panels are a tough case for EMC
  - They will get worse as they become better displays
    - *It is important to leverage off what will be learned on every iteration of FP EMI qualification*
  - VESA will tackle some of these issues for the flat panel interface standard

Conclusions

- **High resolution, high technology flat panel displays are the way of the future**
    - These pose more difficult EMI challenges
- **Are there special tricks to enable them to easily become EM compliant?**
    - Most tricks either produce operation problems, or else wind up not needed
  - **No, only good engineering practice**
    - Good Grounds
    - Good Shielding
    - Good Transmission Paths
    - Filtering of data/clock signals
    - Filtering on power supplies
  - **The more one understands about the phenomena surrounding EMI, the easier it is to get to the root cause of the problem**
- **The interface is important**
    - LVDS serialization of the flat panel data may be a good solution

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