LCD Monitors: Why we're stuck at 100 ppi

Why, When & How it's going to change

By Geoff Walker

This article attempts to answer the question of why LCD monitors remain stuck at ~100 ppi (pixels per inch) while notebooks are at ~115 ppi and rising. Please be forewarned: while this article contains quite a bit of factual information, it also contains a large amount of opinion and speculation.

Today's Monitor Landscape: Table 1 lists the basic specifications of all monitor LCDs offered by the top six panel suppliers that accounted for 90% of the monitor LCD market in 2Q05 (according to iSuppli). The most important columns in Table 1 are the diagonal size and the ppi (pixels per inch). PPI ranges from 86 to 101; the average for the whole table is 94. The average of just the wide-format LCDs is 96, indicating that the transition to wide is having only a small effect on ppi so far. Note that this table does not relate to the number of units shipped in each size category; it just shows the range of products that the LCD panel vendors are offering to the monitor makers. The table does, however, give a good indication of where the panel vendors are heading: towards wide-aspect in every size category except 15 inch and 17 inch (so far). While writing this article I spoke with the product planner for all LCD monitors at one of the major monitor makers; he predicted that 50% of all monitors shipping at the end of 2007 will be wide-aspect. I've heard this sentiment echoed in several places, but neither iSuppli nor DisplaySearch are on this bandwagon. iSuppli forecasts that only 7% of monitors will be wide-format in 2009, while DisplaySearch's forecast is 9%. I think they're both behind the curve here.

Table 1: Monitor LCD Sizes and Resolutions

Diagonal	Pixels	Pitch	PPI
15.0"	1024 x 768	0.297	86
17.0"	1280 x 1024	0.264	96
19.0"	1440 x 900	0.285	89
19.0"	1280 x 1024	0.294	86
20.0"	1680 x 1050	0.258	98
20.1"	1400 x 1050	0.292	87
20.1"	1680 x 1050	0.258	98
20.1"	1600 x 1200	0.255	100
21.0"	1680 x 1050	0.270	94
21.3"	1600 x 1200	0.270	94
23.0"	1920 x 1200	0.258	98
24.0"	1920 x 1200	0.270	94
30.0"	2560 x 1600	0.251	101

It's important to understand that 82% of all LCD monitors sold worldwide in 2005 (86M units!) were 17 inch and 19 inch (according to iSuppli). This is a very large, very stable, very well-defined market. Essentially all of those 86 million monitors were sold with a single resolution: SXGA (1280 x 1024), in only two physical sizes (17 inch and 19 inch), resulting in only two pixel densities (96 and 86). That's an incredibly solid base. Nevertheless, the panel vendors have strong economic motivation to move to wide-aspect displays. In general, doing so improves the utilization of their motherglass (although it varies by the fab generation), and thus their profitability. It's the same force that's driving notebook LCDs towards wide-aspect. (Note that iSuppli forecasts that nearly 70% of notebooks will be wide-aspect in 2009.)

How Will Monitors Change As They Go Wide? As stated earlier, I believe that all LCD monitors will experience a broad movement towards wide-aspect ratios, so 17 inch and 19 inch will go wide eventually. One question is whether the buyer will accept less height in exchange for greater width. Consumers are already accepting this tradeoff in some notebooks, but in the HDTV world things are different. In general, consumers are buying LCD TVs where the vertical dimension is the same or larger than their old CRT TV. This drives a significant increase in the average diagonal – e.g., the owner of a 27 inch CRT TV typically replaces it with a 32 inch or larger LCD TV.

Tables 2 and 3 below show what I believe are three plausible ways that 17 inch and 19 inch monitors could migrate to wide-aspect in the future. Solution (1) is a change from today's 5:4 to 4:3; this is probably the least

Table 2: Possible Migrations from 17" to 17"-Wide

Size & Resolution	Aspect Ratio	Dimensions	Area(in^2)	PPI
Today's 17" 1280 x 1024	5:4	13.3" x 10.6"	141.0	96
(1) 17" 1400 x 1050	4:3 (wider)	13.6" x 10.2"	138.7	103
(2) 17" 1680 x 1050	16:10 (widest)	14.4" x 9.0"	129.9	117
(3) 18" 1680 x 1050	16:10 (widest)	15.3" x 9.5"	145.6	110

likely possibility. Solution (2) is a change from 5:4 to 16:10, the growing standard for wide-aspect ratios in the PC market. The problem with (2) is that it reduces the total area of the screen by about 8%. Solution (3) handles this problem by increasing the diagonal at the same time as changing the aspect ratio. This is what notebook LCD vendors have done, for example, by moving from 15 inch at 4:3 (107.6 in^2) to 15.4 inch" at 16:10 (106.3" in^2), an area loss of only about 1%.

Table 3: Possible Migrations from 19" to 19"-Wide

Size & Resolution	Aspect Ratio	Dimensions	Area(in^2)	PPI
Today's 19" 1280 x 1024	5:4	14.8" x 11.9"	176.1	86
(1) 19" 1400 x 1050	4:3 (wider)	15.2" x 11.4"	173.3	92
(2) 19" 1680 x 1050	16:10 (widest)	16.1" x 10.1"	162.2	105
(3) 20" 1680 x 1050	16:10 (widest)	17.0 x 10.6	179.8	99

Why Are We Stuck At 100 PPI? It seems clear from Table 1 that monitors are stuck at less than 100 ppi. They've been there for a long time, on the order of 5 to 10 years, and there's no change looming on the horizon. I suggest there are several reasons:

1. *There is no meaningful demand for higher-ppi monitors*. As a reader of this High Resolution newsletter, you probably want a higher-ppi monitor very badly – but you're atypical! Both consumers and business users tend to buy monitors on the basis of size, not resolution or ppi. There is simply no market sensitivity to the issue of ppi. Microsoft has been pushing higher ppi in WinHEC (PC hardware engineering) conferences for more than 7 years, with little or no results. None of the monitor-oriented presentations at DisplaySearch's 2005 FPD or iSuppli's 2005 FID conference even mentioned the subject of monitor ppi. When presenters spoke of "higher resolution", what they meant is a physically larger screen containing more pixels – at the existing <=100 ppi! Some of the reasons that there's no demand include the following:
    - 100 ppi is "good enough" for the majority of PC applications
    - There are almost no examples of monitors over 100 ppi to create desire
    - Most consumers and business users have never experienced a high-ppi monitor
    - There's no broadly applicable "killer app" for high-ppi monitors
    - Because the Windows UI doesn't scale well, higher ppi makes Windows harder to use
    - Higher-ppi LCDs are more expensive

    The 19" UXGA (1600 x 1200, 105 ppi) LCD monitors that were on the market in 2003-2004 provide some good evidence for the lack of demand. These monitors were priced about 30% above a 19 inch SXGA (86 ppi) monitor. According to iSuppli, the total sold worldwide in 2004 was only 245,000 units. In a 70M-unit market, this is negligible. None of these monitors remain on the market today.

    Additional evidence is provided by the steadily growing market share of 19 inch SXGA monitors vs. 17 inch SXGA monitors. According to iSuppli, the market share of 19 inch SXGA grew from 13% in 2004 to 21% in 2005. iSuppli's market share forecast for 19 inch SXGA in 2009 is 31%; astonishingly, DisplaySearch's forecast is 55%. And that's for an 86 ppi display!
2. *With no visible demand, LCD panel suppliers have absolutely no motivation to develop higher-ppi monitor panels*. Higher-ppi panels are more costly and less profitable for LCD makers due to decreasing yield as ppi increases. This is a significant factor. With monitor LCD panel prices currently approaching the panel makers' BOM costs (i.e., zero profit); they are unwilling to do anything that might increase cost.
3. *The startup cost of creating a new size/resolution combination is relatively high (around $1M)*. LCD panel vendors are very reluctant to make this investment without some reasonable chance of return.
4. *Proliferating SKUs (unique size/resolution combinations) is always seen as undesirable.*

What About Notebooks? None of the above takes into account the possible effect that notebooks could have on monitor ppi specs. Before examining that, let's take a look at the notebook LCD landscape. Table 4 below lists the

basic specifications of all notebook LCDs offered by the top eight panel suppliers that accounted for 91% of the notebook LCD market in 2Q05 (according to iSuppli).

PPI in the table ranges from 86 to 147 (far wider than for monitors). The average ppi for the whole table is 115; for just the wide-aspect LCDs it's 116, and for just the 4:3 LCDs it's 114. Again this shows that the ongoing transition to wide-format (which is happening in all size categories except 10.4 inch) is having relatively little effect on ppi.

Pixel formats for notebook LCDs are more varied than for monitor LCDs. Instead of one resolution in two sizes accounting for 82% of shipments, the market is spread across eight sizes with multiple resolutions in most size categories. Table 5 lists the notebook LCD sizes shipped in 2005 with their respective market shares (iSuppli data).

Within the mainstream size categories of 14 inch and 15 inch, at least three different pixel densities are offered at each size, providing different functionality at different price points. This practice has existed for at least five years and is to some degree a result of the continually evolving capability of TFT LCDs. The difference in the cost of the different pixel density displays is small compared to the total system cost, so it's easy for the notebook OEM to create different models with slightly different prices. In a monitor, the LCD is a much larger share of the total product cost, so pixel density differences cause much larger swings in the product price, which makes the variant products harder to position and sell. iSuppli's data shows that the percentage of notebooks sold in 2005 with >100 ppi screens is between 30% and 40%. (Unfortunately, iSuppli doesn't break out resolutions within the 15.4 inch size category, so it's impossible to determine the exact percentage.) Nevertheless, that's a substantial number of notebooks.

Table 4: Notebook LCD Sizes and Resolutions

Diagonal (in)	Pixels	Pitch (mm)	PPI
10.4	1024 x 768	0.206	123
12.1	1024 x 768	0.240	106
12.1	1280 x 800	0.204	125
12.1	1400 x 1050	0.176	144
13.3	1280 x 800	0.224	114
14.0	1024 x 768	0.297	86
14.0	1280 x 768	0.238	107
14.0	1400 x 1050	0.204	125
14.1	1024 x 768	0.279	91
14.1	1280 x 800	0.237	107
14.1	1440 x 900	0.211	121
14.1	1400 x 1050	0.204	124
15.0	1024 x 768	0.297	86
15.0	1400 x 1050	0.218	117
15.0	1600 x 1200	0.190	134
15.4	1280 x 800	0.259	98
15.4	1440 x 900	0.231	110
15.4	1680 x 1050	0.197	129
15.4	1920 x 1200	0.173	147
17.0	1440 x 900	0.255	100
17.0	1680 x 1050	0.218	117
17.0	1920 x 1200	0.191	133
19.0	1680 x 1050	0.243	105

Will Notebooks Drive Demand for Higher-PPI Monitors? I suggest that the answer to this question is no (at least in the next few years), and that there are several reasons, as follows:

Table 5: Notebook LCD Market Share by Diagonal (data from iSuppli)

Notebook LCD Diagonal	2005 Share
10.4"	1%
12.1"	7%
12.1" Wide	<1%
14.x"	26%
14.x" Wide	3%
15.x"	34%
15.4" Wide	25%
17.0" Wide	3%

1. *When the ppi gets up around 120-125, Windows' inability to scale the UI starts to become obvious.* At >140, it's VERY obvious. The desktop and application icons, toolbars and menu items become quite small. While it's nice to have the additional document workspace that a high-ppi screen creates, it comes at a cost of decreased ease-of-use. It is for this reason that some notebook OEMs ship Portrait Displays' Liquid View screen-scaling utility with every high-ppi system. The utility puts a friendly interface on Windows' ability to scale the system font, but it doesn't actually solve the underlying problem. According to iSuppli, the percentage of notebooks shipped in 2005 with >120 ppi screens is 10%-15%, which means that only a small fraction of notebook owners are in a position to experience the advantages and disadvantages of higher ppi screens.
2. *Not all notebooks are used regularly with monitors.* I haven't been able to find a published number for the monitor attach rate, but I'm guessing it's less than 75% and maybe even less than 50%. This attach rate then

must be multiplied by the percentage of monitors that are LCDs, which in 2005 was 66% (according to DisplaySearch).

3. *The difference in ppi between the monitor and the notebook may be less significant than the difference in the number of pixels*. For example, in my own situation, I use a notebook with a 14.1 inch UXGA (1600 x 1200, 142 ppi) screen – that isn't sold any more due to consumer complaints about small icons! – and a $200 LCD monitor with a 17 inch SXGA (1280 x 1024, 96 ppi) screen. Basically, the monitor at 96 ppi is good enough in terms of sharpness and readability at my average viewing distance. What I would like, however, is more pixels. These would be readily available if I was willing to step up to a $400, 20.1 inch WSXGA+ (1680 x 1050, 98 ppi) monitor, or to a $550, 20.1 inch UXGA (1600 x 1200, 100 ppi) monitor. Unfortunately, the additional 320-400 horizontal pixels simply aren't worth $400-$550 to me.

Will Anything Ever Drive Demand for Higher-PPI Monitors? I believe that Windows Vista, scheduled for shipment at the end of 2006, will start to create more demand for higher-ppi screens. Vista is "resolution independent". What that means is that the entire Windows UI is scaleable. Assuming that your computer has sufficient graphics processing power and memory, you will be able to drag a corner of a window on your desktop and the entire window will scale evenly. All the icons, fonts, graphics and other UI elements will change size uniformly. This will allow you to easily adjust the size of any window until the content looks just right to you. The more pixels you have on your screen, the sharper and clearer everything will look. This is a very different dynamic than today, where "more pixels makes everything smaller". Instead, the dynamic will become "more pixels makes everything clearer". However, Windows Vista won't happen overnight. I predict that the adoption of Windows Vista will be the slowest that Microsoft has ever experienced. The change in hardware requirements is so substantial that taking full advantage of Vista is almost guaranteed to require new hardware. This means that the migration at best will be at 50% after three or four years.

A Vision of the Future: Let's assume that most monitors go wide-aspect (16:10) in the next few years, and that Windows Vista is launched more or less on schedule and has three years of successful adoption under its belt. That takes us to the beginning of 2010. At that point it's reasonable to expect to see some increase in demand for higher-ppi monitors. Consumers will still need to be able to purchase different physical size monitors to suit their environments, so we will probably need 17 inch, 19 inch and 21 inch monitors as mainstream sizes. Within each size, demand will probably grow for at least two "performance" (ppi) levels. These levels are similar in concept to the difference today between a 15" XGA notebook (low-end) and a 15 inch UXGA notebook (high-end). Ideally the low end should be a little higher than today's monitor ppi levels, perhaps in the range of 100-105. The high end can't go much above 140 ppi due to amorphous-silicon LCD fab limitations (as the ppi goes above ~140, the cost starts to rise much faster). Table 6 shows my concept of what an ideal mainstream monitor lineup might look like in 2010. By 2010, Vista should begin to drive the ancient IBM VGA-based resolution nomenclature out of the monitor market (similar to the way HDTV vocabulary is slowly driving it out of the TV market, replacing it with 720p, 1080p and similar designations). PPI is a good intermediate nomenclature; eventually it should be possible to identify displays by their megapixel numbers (like digital cameras) and their physical size.

Table 6: Ideal Mainstream Monitor Product Lineup in 2010

Diagonal (in)	PPI	Pitch (mm)	Pixels [MP]	Dimensions (in)
17 Wide	100	0.254	1440 x 900 [1.3]	14.4 x 9.0
17 Wide	142	0.191	2048 x 1280 [2.6]	14.4 x 9.0
19 Wide	104	0.243	1680 x 1050 [1.8]	16.1 x 10.1
19 Wide	139	0.183	2240 x 1400 [3.1]	16.1 x 10.1
21 Wide	107	0.237	1920 x 1200 [2.3]	17.9 x 11.2
21 Wide	143	0.178	2560 x 1600 [4.1]	17.9 x 11.2

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