

Wide-Angle LCDs and the Tablet PC

A discussion of wide-angle display technologies

by Geoff Walker

Have you ever used a Tablet PC in portrait mode and had trouble reading the screen unless you held it at exactly the right angle? That's because most Tablet PCs today use standard notebook screens that have been modified mechanically but not optically for use in a Tablet PC.

Notebook screens usually have a wide horizontal viewing angle (typically 120°) and a narrow vertical viewing angle (typically 45°). Although 45° doesn't sound like a very small angle, it's an absolute-maximum specification that doesn't take into account the gray-scale inversion (photographic negative effect), color shift and large decrease in contrast that occurs near the edge of the viewing cone. The usable portrait-mode viewing cone is actually only about 15° - 20°.

The reasons notebook screens are designed with these viewing angles are (1) multiple people often view a notebook screen in a horizontal group around the screen, and (2) it's very easy to adjust a hinged notebook screen to the best vertical viewing angle, so a wide vertical viewing angle isn't necessary. Notebook screens are therefore all optimized for horizontal rather than vertical viewing.

A Tablet PC, however, is used in both landscape (horizontal) and portrait (vertical) modes. Ideally the screen should have equal viewing angles in both directions. So why don't more Tablet PCs have wide-angle screens? The answer is a complex blend of technical and business factors.

Table 1: Possible Tablet PC LCD sizes

Size	Resolution	Pixels	DPI	Microsoft's View (1)	Current Tablet PC LCD Vendors
8.4"	SVGA	800 x 600	119	Sub-optimal	AUO
8.4"	XGA	1024 x 768	152	Optimal (+L)	None
8.9"	WSVGA	1024 x 600	129	Sub-optimal	None
10.4"	XGA	1024 x 768	123	Optimal	Toshiba & Hydis (2)
10.0"	WXGA	1280 x 800	144	Optimal (+L)	None
12.1"	XGA	1024 x 768	106	Sub-optimal	Toshiba & Hydis (2)
12.1"	WXGA	1280 x 800	124	Optimal	None
12.1"	SXGA+	1400 x 1050	145	Optimal (+L)	Toshiba
14.1"	XGA	1024 x 768	91	Sub-optimal	AUO & CMO
14.0"	WXGA	1280 x 800	108	Sub-optimal	None
14.1"	SXGA+	1400 x 1050	124	Optimal	None
14.1"	UXGA	1600 x 1200	145	Optimal (+L)	None
15.4"	WSXGA+	1680 x 1050	128	Optimal	None
15.4"	WUXGA	1920 x 1200	147	Optimal (+L)	None

Note (1): "Sub-optimal" means that Microsoft believes the LCD's pixel resolution or dpi are too low for acceptable Tablet PC performance. "(+L)" means that Microsoft considers the LCD optimal for use with Longhorn due to the new Windows operating system's resolution independence.
Note (2): Hydis is currently the only LCD vendor supplying wide-angle Tablet PC LCDs

This article attempts to make some sense out of those factors.

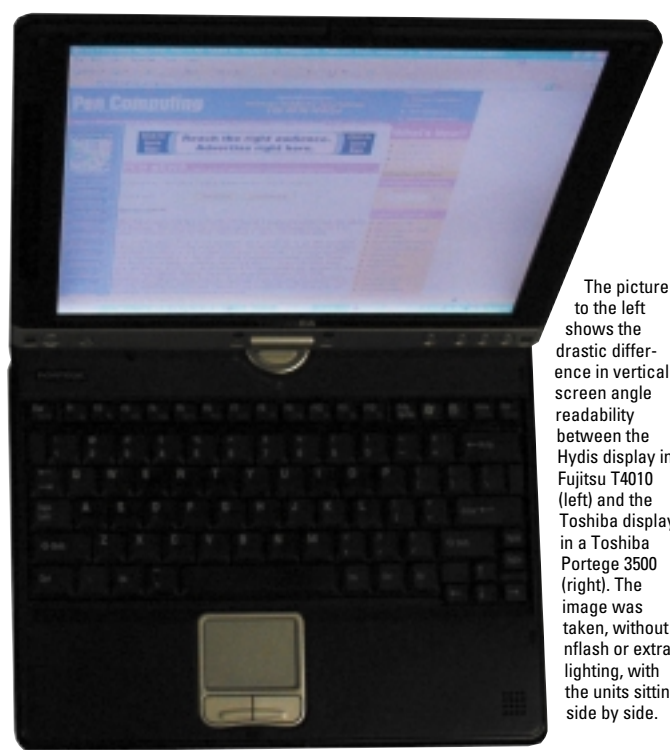
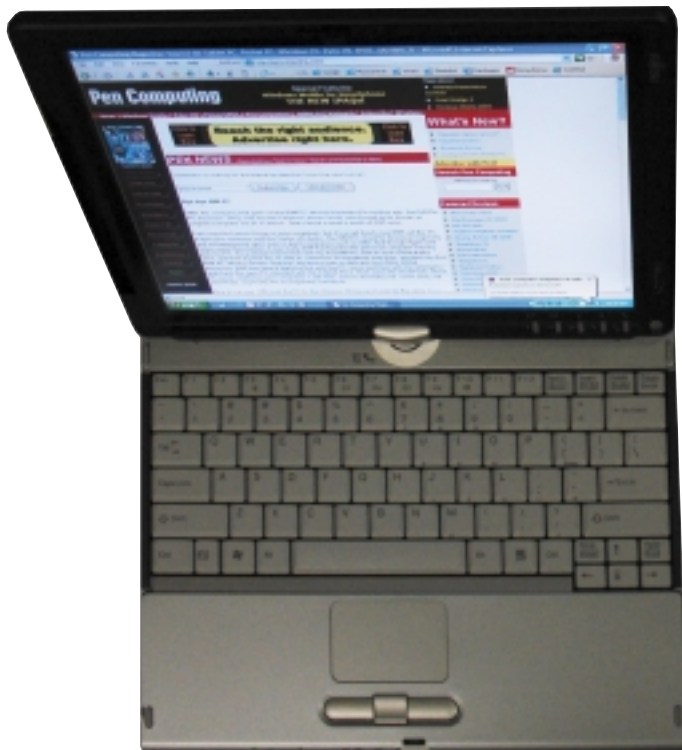
WIDE-ANGLE TABLET PCs

There are a growing number of Tablet PCs on the market with wide-angle screens (defined as having a viewing angle equal to or greater than 100° in both directions). As of mid-December 2004, the list includes the following products:

- Fujitsu T4000 convertible
- HP TC1100 slate
- Motion M1400 slate
- LG-IBM T20 convertible
- Sharp TN10W convertible

At least six or seven more Tablet PCs with wide-angle screens will be added to this list during 2005.

Once you've used a Tablet PC with a wide-angle screen, you'll never want to go back to notebook screens. A wide-angle screen makes an amazing difference in the ease of use. You can show a portrait-mode image to a group of people with absolutely no problem. You can look over someone's shoulder and see the screen perfectly. You can use the Tablet PC on your lap or read it in bed with much less fatigue. A wide-angle screen doubles the value of a Tablet PC.



The picture to the left shows the drastic difference in vertical screen angle readability between the Hydis display in a Fujitsu T4010 (left) and the Toshiba display in a Toshiba Portege 3500 (right). The image was taken, without nflash or extra lighting, with the units sitting side by side.

WIDE-ANGLE TECHNOLOGIES

In late 1995, Hitachi invented “in-plane switching” (IPS), the first technology used to accomplish wide-angle viewing. IPS is a method of aligning the liquid crystals in the LCD horizontally so that there is less variation in the optical characteristics due to viewing angle. In a standard LCD, the liquid crystals are twisted and tilted such that the light that travels through them is restricted to a relatively narrow angle.

In 1996, Fujitsu invented “vertical alignment” (VA) and then enhanced it into “multi-domain vertical alignment” (MVA) in 1997. MVA is the other main technology used to accomplish wide-angle viewing. In MVA, liquid crystals are aligned vertically in several horizontal planes (“domains”). The end result is essentially the same as IPS – increased viewing angle, high contrast and no color shift.

Both Hitachi and Fujitsu licensed their technology to other LCD vendors, many of whom made their own improvements. Two examples are LG.Philips and Samsung, the two largest LCD vendors in the world. The former uses a version of IPS, while the latter uses a version of MVA. Both claim their wide-angle technology is the best; in reality, they’re converging on the same point.

When wide-angle LCD PC monitors were first introduced, a viewing angle of 130° was considered state-of-the-art. Today, the latest monitors are all between 170° and 180°, which doesn’t leave much room for improvement!

Until recently, PC monitors were the target on which the LCD vendors focused their wide-angle technology. However, in the last two years, the LCD-TV has become the newest hot target for the LCD vendors. Wide-angle viewing is certainly very important in an LCD-TV, but other factors have been added to the mix, such as fast response time (required for “no-smear” full-motion video). This has created another competitive battleground for the LCD vendors, causing most of them to move beyond competing on viewing angle, since there isn’t much perceptible difference between 170° and 180°.

ONE MORE WIDE-ANGLE TECHNOLOGY

There’s one more wide-angle technology that’s worth mentioning (particularly with regard to Tablet PCs), and that’s “film compensation”. In this technology, special films are added above and below the LCD. The films’ chemical structure mimics the twisted and tilted alignment of liquid crystals, but in the opposite direction, thus “compensating” for the narrow viewing angle of normal liquid crystals. Compensation films can extend the viewing angle up to 100° - 120° in both directions.

However, there’s a fundamental difference between film compensation and the IPS/MVA liquid-crystal-alignment methods. Film compensation can be applied to an existing LCD with only a small material cost increment (about 1%) and little effect on yield. If a particular market demands wide viewing angles (e.g., the Tablet PC market), an LCD vendor can develop new models of existing LCDs with little investment and still remain competitive.

On the other hand, the IPS/MVA liquid-crystal-alignment methods significantly increase the cost of an LCD. The reason isn’t material cost, but instead, process yields. Adding IPS or MVA to a standard LCD decreases the yield by as much as 30%, which increases the cost of an LCD to the point where it becomes non-competitive. In addition, both IPS and MVA increase the power consumption of an LCD, which also makes the LCD less competitive in battery-powered applications. The result is that it’s impractical to apply IPS/MVA liquid-crystal-alignment methods to notebook-size LCDs when none of the competitors are using them. In the monitor/TV market, it’s a more level playing field, since the majority of the LCD vendors are using IPS or MVA.

WHAT ABOUT MOBILE PC LCDS?

Where are mobile PCs (notebooks or Tablet PCs) in all this discussion about wide-angle technologies? Nowhere. There has never been any demand for symmetrical wide viewing angles in notebooks, so none of the LCD vendors have had any motivation to spend time or resources developing wide-angle, notebook-sized LCDs. Tablet PCs are so new that there’s not enough demand to drive any of the LCD vendors to do anything special for them – with two significant exceptions, Toshiba and BOE Hydis.

TOSHIBA MATSUSHITA DISPLAYS

Toshiba is the #1 supplier of LCDs for Tablet PCs. When Microsoft started building their first Tablet PC prototype in 2000, they needed a 10.4” XGA (1024 x 768, 123 dpi) LCD with mechanical modifications for the active digitizer. The vendor that had the best technology match and was the most willing to get involved in the project was Toshiba. Toshiba called their initial Tablet PC LCD the “Kangaroo” model because it had a “pouch” to hold the active digitizer. It was really just a 10.4” notebook LCD with minor mechanical modifications. Toshiba’s close relationship with Microsoft during the Tablet PC development period gave them a head start on the Tablet PC LCD market. Every Tablet PC sold during all of 2003 used a Toshiba LCD. Any differences in screen appearance between different models of Tablet PC during 2003 were due mostly to different

treatments on the cover glass over the LCD.

Toshiba has a relatively high tolerance for risk. Unlike most other LCD vendors, Toshiba is willing to develop new LCD models in anticipation of a future market or in response to an unproven customer demand. Accordingly, Toshiba next developed a 12.1” XGA Tablet PC LCD, again right at the beginning of the demand for 12.1” Tablet PCs. As a result, all of the initial 12.1” Tablet PCs used the Toshiba LCD.

Next, Toshiba’s notebook PC division wanted a higher-resolution 12.1” LCD for their new M200 Tablet PC. The Toshiba LCD division’s LTPS (Low Temperature Polysilicon) LCD technology was ideally suited for high-resolution notebook screens, so they developed a 12.1” SXGA+ (1400 x 1150, 144 dpi) Tablet PC LCD to meet Toshiba PC’s need. Also, it didn’t hurt that Microsoft was pushing the Tablet PC OEMs at the same time to move to higher-resolution LCDs in their products. This was Toshiba’s third Tablet PC LCD; by this time they were getting a very firm grip on the Tablet PC LCD market.

At the beginning of the Tablet PC, nobody really understood how important a wide viewing angle would become. Toshiba’s 10.4” notebook LCD was the accepted standard, and while users complained about the narrow viewing angle in portrait mode, Toshiba didn’t take any action to improve it. After all, when you’re the dominant (almost monopoly) supplier, there’s not much motivation to improve your product.

BOE HYDIS

BOE Hydis is currently the #2 supplier of LCDs for Tablet PCs, with about 18% of the Tablet PC LCD market (calculated by the number of unique models of Tablet PCs, not sales volumes). Hydis is a relatively small player in the LCD industry, with 2003 sales of only 3.1M LCDs (3% of the total large-format LCD market), split 70-30 between monitor and notebook LCDs [data from DisplaySearch].

In 1996, shortly after Hitachi announced the development of IPS, Hydis announced the development of “fringe field switching” (FFS), their own wide-angle viewing technology. In FFS, the liquid crystals are aligned horizontally through the use of a modified cell structure and “wedges” (cell dividers) between pixels. When Hydis developed FFS, they made a critical strategic decision to focus all of their development effort on FFS LCDs, and to be prepared to use the technology not just in monitors, but also in other LCD sizes as the market demanded.

Hydis made another critical strategic decision in 2001 when they decided to enter the then-unknown Tablet PC market with their FFS wide-angle technology. This was the key decision that no other LCD vendor made. Hydis was both very smart and very lucky. They invested early, had the right techno-

The difference is even more drastic when the tablets are used in portrait mode. The Hydis display remains completely readable whereas the Toshiba display washes out.



12.1" wide-angle LCD with a bonded cover glass. Hydis has the only pooling-free LCDs available in today's Tablet PCs.

TOSHIBA VERSUS HYDIS

Once the Hydis LCDs started gaining traction in the Tablet PC market, Toshiba began to feel the pressure. Toshiba's only option for increasing the viewing angle of their Tablet PC LCDs was the film compensation method, which they call ACIT (Anti Color Inversion with TN). After Hydis took Toshiba's LCD business away from the five Tablet PC OEMs listed on the first page of this article, Toshiba modified their

logy, gambled well and caught the Tablet PC wave at just the right time. Another beneficial decision they made in 2001 was to duplicate Toshiba's LCD mechanical dimensions and mounting-hole pattern, so that a Hydis LCD could directly replace a Toshiba LCD with no changes.

As is often the case with any new product or technology, the Tablet PC OEMs and ODMs were a little slow to accept Hydis' new LCDs. In addition, there were some initial performance issues such as a "gray trace ghosting problem" where pen strokes sometimes left a temporary gray trace on the screen. Those problems are all resolved now and the Hydis wide-angle LCDs are in five current Tablet PC models. Microsoft has identified wide-angle viewing as the #1 enhancement needed in Tablet PC LCDs and the market has acknowledged the strong desirability of wide-angle viewing. The result is that Hydis' sales are beginning to accelerate. Hydis has the only wide-angle LCDs available in today's Tablet PCs.

FFS TECHNOLOGY AND THE TABLET PC

FFS technology is rapidly becoming more important in the market. In 2004, Hitachi initiated a cross-licensing agreement with Hydis, where each company will license their technology (IPS and FFS) to each other. This puts FFS on an equal footing with IPS.

FFS technology has an impressive list of characteristics, including the following:

- 180° horizontal and vertical viewing angles
- High transmittance (optical efficiency)
- Absence of any color shift at the edge of the viewing cone
- Very high contrast ratio
- Low power consumption, especially when compared with IPS
- Absence of any pooling (also called "ripple" or "blooming")

The absence of pooling is very important in a Tablet PC. Pooling is the expanding blue "shadow" that you see when you press on most LCDs (including those using IPS or MVA). If you press hard with the stylus while you're writing on a Tablet PC screen, you'll often see pooling, which can be quite distracting. One of the side benefits of Hydis' FFS technology is that it completely eliminates pooling. This means that the cover glass on a Hydis-equipped Tablet

PC can be bonded directly on top of the LCD, rather than leaving an air space between the cover glass and the LCD as is always the case with a standard LCD. The substantial benefits include the following:

- The pen tip is closer to the LCD, which decreases the parallax error and makes the Tablet PC easier to use
- The entire Tablet PC can be made 1-2 mm thinner
- The lamination of the cover glass on top of the LCD tends to increase the durability of the LCD
- The elimination of two air-to-glass interfaces reduces reflections and makes the screen more readable outdoors

The Motion M1400 slate is an example of a current Tablet PC that uses the Hydis

Tablet PC LCDs to compete more effectively by adding compensation films. So far, Toshiba has added compensation films to their 10.4" XGA and 12.1" SXGA+ Tablet PC LCDs. As of the end of 2004, these en-

hanced LCDs have not yet appeared in any Tablet PCs.

As previously noted, film compensation can only widen the viewing angle to 100° - 120° (Toshiba's specification for their enhanced LCDs is 100°). It will be interesting to see whether Toshiba's or Hydis' LCD will appear in more Tablet PCs in 2005. You should be able to tell which wide-angle LCD is in a given Tablet PC just by holding it at an acute angle, since 180° is noticeably wider than 100°.

OTHER TABLET PC LCD VENDORS

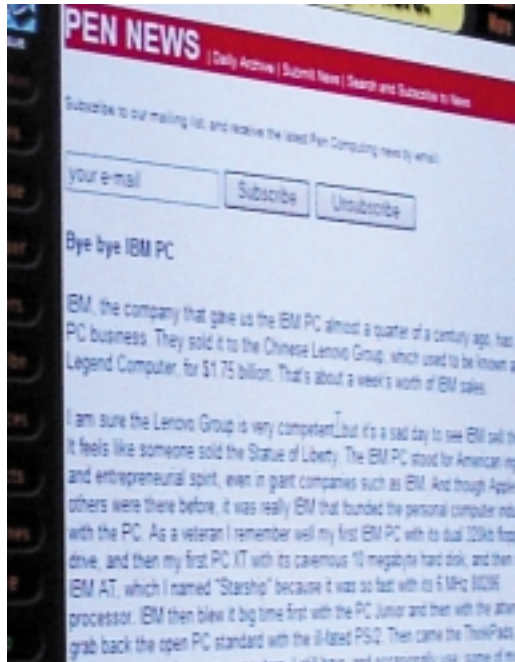
Toshiba and Hydis together have about

Table 2: The 15 major Notebook LCD vendors

LCD Vendor	Wide-Angle Technology	URL
1 Samsung	MVA	www.samsung.com/Products/TFTLCD/index.htm
2 LG.Philips (LPL)	Super-IPS	www.lgphilips-lcd.com
3 AU Optronics (AUO)	MVA	www.auo.com/auoDEV/
4 Quanta Display (ODI)	Film	http://www.qdi.com.tw/
5 Toshiba Matsushita Display (TMD)	Film	www3.toshiba.co.jp/tm_dsp/index.htm
6 Hitachi	Super-IPS	www.hedus.com/productpage04.html
7 Sharp	ASV (MVA)	www.sharpsma.com/sma/products/display.htm
8 IDTech	IPS	http://www.idtech.co.jp/en/index.html
9 Chi Mei Optoelectronics (CMO)	Super-MVA	www.cmo.com.tw/cmo/english/index.jsp
10 HannStar	IPS	www.hannstar.com/index.html
11 Chunghwa Picture Tubes (CPT)	Film	www.cpt.com.tw
12 BOE Hydis	FFS	www.boehydis.com
13 Tottori Sanyo	Film	http://www.torisan.co.jp/English_frame.html
14 Toppoly	Film	http://www.toppoly.com.tw/
15 Fujitsu Displays	MVA	http://www.fme.fujitsu.com/products/displays/lcd.html

Note: The 15 notebook LCD vendors above accounted for more than 99% of the notebook market in 2003 (ranked by volume), along with their wide-angle technology and URL. Many of these websites include interesting descriptions and illustrations of LCD technology.

This is a rotated zoom-in on the picture shown on page 66. Even though this wasn't a good picture, you can still read the text at this severe angle. That is remarkable.



THE BOTTOM LINE

Because there is no demand for wide-angle LCDs in notebooks, wide-angle LCDs have been uncommon in Tablet PCs until recently. BOE Hydis with their FFS wide-angle technology is currently the only supplier, due to their smart strategic decisions and the conservativeness of the other LCD vendors. Toshiba is the dominant supplier with approximately 75% of the Tablet PC LCD market (calculated by the number of unique models of Tablet PCs, not sales volumes). Toshiba is trying to compete with Hydis by using film compensation technology, but Toshiba's viewing angle is only 56% as wide as Hydis' viewing angle. AUO and CMO together are supplying about 7% of the market with mechanical modifications of narrow-angle notebook LCDs that were request-

ed by their OEM/ODM customers. The remaining notebook LCD vendors believe that the Tablet PC market isn't yet large enough to warrant creating products for it. If and when other LCD vendors create new Tablet PC LCDs, due to economic reasons they won't be able to use IPS or MVA technology to produce wide viewing angles.

The bottom line: Although the demand for wide viewing angles is very likely to increase, it's unlikely that any other supplier of wide-angle Tablet PC LCDs will enter the market in the next two years. The probable result is that Hydis with their FFS wide-angle technology will replace Toshiba as the dominant supplier of Tablet PC LCDs.

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93% of the Tablet PC LCD market (calculated by the number of unique models of Tablet PCs, not sales volumes). There are only two other Tablet PC LCD vendors, AUO (AU Optronics) and CMO (Chi Mei Optoelectronics).

AUO is the #3 supplier of LCDs for Tablet PCs. AUO has an 8.4" SVGA (800 x 600) Tablet PC LCD, used in the Itronix GoBook rugged slate and in the ECS (EliteGroup Computer Systems) EZ30 slate, and a 14.1" XGA LCD used in the Acer C300 convertible Tablet PC. Both of these LCDs were developed upon request from AUO's OEM/ODM customers. Both are really just standard narrow-angle notebook LCDs with mechanical modifications for the active digitizer.

AUO is more conservative than Toshiba, so it's unlikely that AUO will develop another Tablet PC LCD unless one of their customers asks them for it. AUO's production lines aren't optimized for standard-format 10.4" or 12.1" LCDs, so it's also unlikely that they will introduce new Tablet PC LCDs in those sizes.

While AUO uses MVA wide-angle technology in their monitor/TV LCDs, as previously described it's not economical to apply it to notebook-sized LCDs. It's therefore unlikely that AUO will introduce any very-wide-angle Tablet PC LCDs to compete with Hydis in the near future, although it's possible that they might add compensation film to a Tablet PC LCD if one of their customers asks for it.

CMO is the #4 supplier of LCDs for Tablet PCs. CMO has only a 14.1" XGA Tablet PC LCD, used in the Gateway M275 convertible. CMO developed this LCD upon request from their OEM/ODM customer. Like AUO's Tablet PC LCDs, CMO's LCD is a mechanical modification of a standard narrow-angle notebook LCD. Also like AUO, while CMO uses MVA wide-angle technology in their monitor/TV LCDs, it's not economical to apply it to notebook-sized LCDs. It's unlikely that CMO will introduce any new Tablet PC LCDs unless one of their customers asks for it, and any new Tablet PC LCD from CMO is very unlikely to have very-wide-angle viewing.

LOOKING AHEAD

The Tablet PC market is of limited interest to all the other LCD vendors, for the following two basic reasons:

- There is insufficient demand (i.e., the Tablet PC market is too small) to justify the investment necessary to create and market a new LCD product, particularly one with wide-angle viewing
- The Tablet PC market is too risky and its growth is too slow; it's unclear if the product category will even survive

As an example, consider that LG.Philips sold more than 21M notebook, monitor and TV LCDs in 2003. They're simply not interested in a hundred thousand Tablet PC LCDs, especially when 93% of the market is held by only two competitors. When the Tablet PC market grows to several million units, then they will probably enter the market with a Tablet PC LCD. At that time, given LG.Philips' resources, their new product will probably meet all of the market requirements, including wide-angle viewing, absence of pooling, etc.

Table 3: Tablet PCs mentioned in this article

Tablet PC	Product URL
Acer C300 convertible	http://global.acer.com/products/tablet_pc/tmc300.htm
Elitegroup Computer Systems (ECS) EZ30 slate	http://www.ecs.com.tw/ECSWeb/Products/ProductsDetail.aspx?detailid=386&MenuID=56&LanID=0
Fujitsu T4000 convertible	http://webshop.fujitsu.com/fpc/Ecommerce/buildseriesbean.do?series=T4
Gateway M275 convertible	http://products.gateway.com/products/goonfig/prodseries.asp?seg=cp&gcseries=gtwrym275b&clv=LVan
Hewlett-Packard TC1100 slate	http://h18000.www1.hp.com/products/tabletpc/
Itronix GoBook slate	http://www.itronix.com/products/tablet/GoBooktablet.asp
LG-IBM LT20 convertible	http://www.lge.com/catalog/prodlist?categoryId=CTG1000651&modelCategoryId=CTG1000654&parentId=CTG1000439
Motion Computing M1400 slate	http://www.motioncomputing.com/
Sharp TN10W convertible	http://www.sharpsystems.com/products/pc_notebooks/actius/tn/10w/
Toshiba M200 convertible	http://www.toshibadirect.com/td/b2c/cmод.то?coид=-26373&sel=0&rcid=-26367&ccid=1291021&seg=SMB&sel=1