Introduction

Flat Panel Displays (FPDs) have come to dominate the display field with more than half of the $30B display marketplace. If it is not flat, hardly anyone wants it today. Laptops, Flat Panel monitors and Flat Screen televisions are everywhere.

The majority of these FPDs are Liquid Crystal Displays, which by now is a mature industry. You all know the definition of a mature industry. An industry where, if you do everything right, it is still hard to make a dime. To competitively manufacture flat panel televisions, Samsung just spent more than $3B for their newest LCD factory.

It is useful to think of a display in two parts. The part you see is the Display Media, or as we call it, the light bulb. In back of the display media is a matrix of switches that tell the display media which lights to turn on. That switch matrix is called the backplane and until very recently was by far the major cost of an FPD.

Many companies are actively seeking the next great light bulb for applications as diverse as electronic paper to outdoor displays for cheap. Many are on the verge of success in their efforts to reduce the cost of the display media. The trouble is that the display media is only half of an FPD.

The standard backplane for almost any FPD today is the active matrix silicon thin film transistor (TFT) on a glass sheet. Fragile, expensive, prone to low yields unless billions are spent on the factories, overall a challenging technology. The question is what can work as well and NOT cost billions?

And then there is the question of flexibility. Glass backplanes are not very flexible and not very robust. Several groups around the world have attempted to replace the TFT on glass with something else. Most are focused on putting TFTs on a plastic substrate. Sony has a process of scrapping TFTs off of a glass substrate and sticking them on a polymer foil. The process is as barbaric as it sounds, the yields are low and the costs are high.

Philips and Rolltronics have investigated processes that deposit amorphous silicon on plastic foils, with disappointing results. Silicon depositions want to take place at
temperatures of 250C+ and most polymer foils find the deposition environment hostile. Worse, the polymer foil must not take a permanent set after the deposition process, which involves several high temperature steps, or the shape of the matrix is distorted and the transistors don’t work.

Faced with the reality of spiraling development costs, we at Rolltronics decided to give up on silicon on plastic. Which is to say we decided to go back to first principles and try to figure out if there was something we were missing in the design of backplanes. Our president asked the critical question, are transistors the only kind of switches? A quick look around the room confirmed that there were switches on the wall that were not based on silicon transistors, but used your thumb for activation. Micro Electromechanical switch arrays on silicon or glass substrates are well known, but have all of the constraints and costs of transistors on glass substrates because they are manufactured using the same semiconductor equipment. What was needed was to break the silicon manufacturing paradigm and come up with a switch array that could be flexible, cheap and manufacturable in high volumes.

Our invention, FASwitch®, is our solution to the TFT backplane problem. By using unconventional materials, in this case metallized polymer foils, and unconventional manufacturing processes, sheet and roll-to-roll production; we can manufacture MEMS backplanes that are both cheap and flexible.

What is FASwitch® and how does it work?

FASwitch® is a laminated stack of polymer foils. Exactly the same processes and materials that are used to make flexible printed circuits are used in the manufacture of FASwitch®. This was no accident, we wanted to be able to come to the flex-PC board industry with every expectation that they could manufacture this product easily and in high volumes.

The heart of the technology is two foils that have been patterned and laminated together with a spacer layer between. The foil that will contact the display media is called the rigid layer, and a thinner layer that is made to electrostatically deform is called the flexible layer. These two layers are polymer foil, metal foil laminates and are patterned with one via per pixel through the rigid layer. At this point we usually have to go into some detail about how the manufacturing process takes place, but in this group, I am sure that you could instruct me on how it should be made.

Rather than explaining how to make it, let me go into how it works. The separation between the two foils is on the order of 12-30um. When a voltage is applied to the two foils an electrostatic attraction is created and the flexible foil bends toward the rigid layer. We have inserted a pair of metal contacts that touch before the electrostatic foils touch. The contacts are connected to a power source and through the electrical via in the rigid layer to the display media. When the contacts touch, the display pixel is lit and when they release the display pixel is dark.
If the laminated foil backplane did nothing more than this it would be useful and would duplicate much of the functionality of the TFT on glass, but by slightly changing the metal foil layout and (optionally) adding an extra contact, a backplane design that can latch an image is available. This latching function, a capability that is intrinsic in the design of the backplane, is a significant improvement over conventional TFT on glass backplanes.

This technology is based on a metallic contact switch. As such it can switch AC or DC. With careful design it can switch up to at least 100VDC. It can be a momentary or a latched (Bi-stable) switch. We have computer models that show us how to design switches that are from 70um up to any size you wish. We can power voltage driven (electrophoretic displays) or current driven (LED displays) devices. In fact the FASwitch array can interface to just about any display media.

Details of the layout are seen in Figures 1, 2, and 3. Figure 1 is the “A” rigid layer and contacts the display media. Figure 2 is the “B” layer window frame pattern of the spacer layer. Figure 3 is the “C” flexible layer that deforms under the influence of the electrostatic charge.

Figure 4 is similar to Figure 1, but adds the optional latching structure.

This technology typically uses two voltages. An external X and Y driver creates the electrostatic field that pulls the intersecting foils into contact. A second voltage powers the display media and also powers the latching structure.

The 8 generations of prototypes have been manufactured with off-the-shelf materials and their performance has been unexpectedly good. With minor tweaking of the designs, we have met our initial goals for electrical performance for both the matrix addressing voltages and the contact resistance and contact lifetime. Every group of prototypes we have made has had working cells, and several protos have had 100% working cells. This bodes well, since we are hand building these prototypes and have little control of foil tension during the manufacturing steps.

FASwitch® APPLICATIONS

The key benefit of a FASwitch array in the marketplace is that it can be manufactured in sizes that are difficult if not impossible to make by conventional TFT on glass technology, and that the manufacturing costs are low. As expensive as something from Heidelberg is, it is a small fraction of any of the semiconductor manufacturing-derived process equipment used for TFT on glass manufacturing.

Another advantage of FASwitch technology is the possibility to manufacture a display backplane that is flexible. The glass used in TFT on glass display backplanes doesn’t
flex. The laminated plastic foils of FASwitch can be designed to have significant “bendability”.

Advertising signs for both indoor and outdoor use are a perfect fit for FASwitch array backplanes. The signs are required to be large, cheap, light in weight, and able to be powered by batteries. For the small signs, there may be some competition from TFT on glass technologies, but by the time that the sign’s size is measured in square feet, and especially for billboard applications, the low cost of FASwitch arrays provides the only reasonable option. To get a sense of the scale of the market for such signs, it should be noted that one of the big three major billboard advertising companies has committed itself to replacing 50,000,000 square feet of paper billboards with electronic billboards in the next 4 years. It should also be noted that there is no way to do this with the current economics of TFT on glass backplanes and there is a two year manufacturing backlog for the LED jumbotron signs.

Figure 5 shows a table of the design variants available for a FASwitch backplane array and the pixel size and expected difficulty of development into manufacturing. In addition to these variants, there are three not yet announced, that can function as a backplane or as a complete display assembly, with no display media required. You will be able to manufacture complete displays using conventional roll-to-roll equipment and metallized foils.

Fig 1 “A” layer layout

![Fig 1 “A” layer layout](image)

Fig 2 “B” layer layout. The spacer is the red picture frame around each metal square
Fig 3 “C” layer flexible structure

Fig 4 “A” layer with latching “Hairpin”
# FASwitch designs to fit various product applications:

<table>
<thead>
<tr>
<th>Design</th>
<th>Pixel Size (µm)</th>
<th>Manufacturability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>600 to 10,000+</td>
<td>1 (baseline)</td>
</tr>
<tr>
<td>2</td>
<td>200 to 10,000+</td>
<td>1.5</td>
</tr>
<tr>
<td>3</td>
<td>75 to 500</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Sensor arrays</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>200 to 10,000+</td>
<td>1.5</td>
</tr>
<tr>
<td>7</td>
<td>75 to 10,000</td>
<td>Flexible</td>
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