Evolution or revolution?

The future looks bright for liquid crystal displays for avionics

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The aircraft is experiencing the greatest quantum change since the introduction of the jet engine. But many observers do not see it in such terms because the changes are so conservative that they appear more Darwinian than revolutionary; they are in the flight deck and not in the performance envelope, and they are not yet complete.

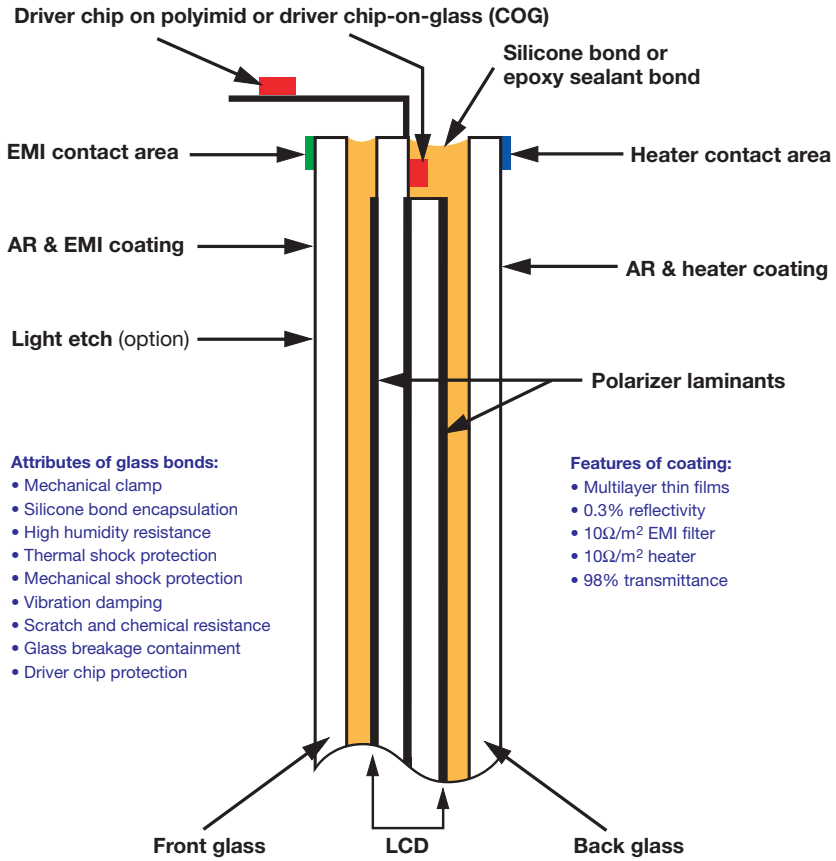

Figure1: **Ruggedized avionics LCD sandwich**

The changes referred to are the infusion of microelectronics into the flight deck and the resulting applications such as GPS navigation, satellite communications, real-time weather and weather maps, real-time traffic, advisories, and electronic maps and plates. The single display with integrated navigation, weather, traffic and terrain is the Holy Grail for pilot situation awareness. It is coming, and the benefits are lower cost of ownership and improved flight safety.

Changes are not complete yet because of the limited availability of the cornerstone component – the liquid crystal display (LCD). Further it is not clear how best to integrate the situational issues of navigation, terrain, traffic and weather. Should the image be inside out or outside in; horizontal, perspective or vertical; display head up, head down or helmet mounted; color or monochrome; stereo or non-stereo, etc? Regardless, everyone will agree that the navigation situation is instantly apparent after seeing the present position relative to desired flight path and navigational checkpoints on a horizontal situation display. Add traffic, weather and terrain and you are in pilot heaven.

The LCD is the display of choice and is widely used on the flight deck – but only at the high end of aviation in airlines, business jets and military aircraft. Most of the more than 200,000 aircraft worldwide have not seen an LCD except perhaps in a new GPS box.

The barrier to the LCD has been availability in the size needed at an acceptable price. Military aircraft pilots get the best at whatever the cost, but even that has its limits as the industry

has been experiencing. In the civilian avionics marketplace cost is always an issue as there are options. The cathode-ray tube (CRT) and classical servos, galvanometers and barometric instruments have dominated the flight deck and are not instantly replaced by something 10 times the price. At the single-engine, general-aviation end of the spectrum, one LCD-based digital avionics box can cost more than a rebuilt engine.

However the LCD is the key to flight deck evolution. LCD technology is the only solution known to completely couple the pilot to digital electronics images in all environmental situations. CRTs were the first displays in the digital glass cockpit and have performed admirably but with limitations – they are difficult to read in color in bright sunlight, are difficult to dim and have poor image quality in the corners and at low light levels. The other limitations of the CRT have been met by improved designs but with increased weight, power, volume and cost.

The good news

LCDs and CRTs use completely different technology. The performance and operation of the LCD is based on different materials, electronics, physics and optics. In its application to the flight deck it requires much less weight, power and volume, and is practically immune to shock, vibration, ambient pressure and illumination. It does have limits in temperature and humidity but things can be improved through ruggedization. The viewing angle, speed of response and temperature range of LCDs have always been less than that of CRTs, but these parameters have improved markedly and now are good enough for the cockpit environment. The new generation of commercial-off-the-shelf (COTS) LCDs now exceeds many of the performance parameters of custom-made avionics LCDs.

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The bad news

Yet LCDs are not a slam-dunk due to lack of availability in the desired form factor and acceptable cost. Most primary flight instruments are square. For historical reasons most LCDs are rectangular with a 3:4 aspect ratio as required in the TV and computer markets. With an LCD production line costing over US$100 million and NRE tooling costing over US$1 million, factories cannot be engaged to make a few hundred LCDs of a custom size for aviation. Custom aviation LCDs have been made, for example, by American Corporation of Atlanta, Georgia, and the price is correspondingly high.

Custom LCDs are being manufactured, but only under special arrangements and in most cases as a sole source. There is a long and turbulent history in manufacturing custom LCDs for aerospace. Most custom display manufacturers have seen financial failure with aircraft deliveries delayed and avionics business plans destroyed. Most airframe manufacturers and avionics manufacturers say "No" to sole source of avionics components in general and LCDs in particular.

The good news

A new approach to sourcing LCDs has evolved – resizing COTS LCDs and ruggedizing them for the avionics environment. The ruggedization needed for resized COTS LCDs is the same as that needed for any custom or COTS LCD. Two entities that can resize COTS LCDs have evolved – Tannas Electronic Displays in California, with patents in the USA, and BAE Systems, in Scotland, with patents in the UK.

As reported in technical papers[1, 2], both entities describe the resizing process as straightforward, cost-effective and reliable. Resized COTS LCDs have been tested to aviation environmental requirements and have passed DO-160 temperature and humidity requirements. COTS LCDs are getting better and the new generation of COTS displays has, in several ways, better performance than custom avionics LCDs. In particular the viewing angles for many COTS products are ±70° in the horizontal axis, +15° and -35° in the vertical axis, and 80° in all axes for the larger COTS LCDs such as those needed to resize 8in x 8in D-size avionics.

There are two alternatives to custom LCDs. One is to use COTS displays, ruggedize them for avionics and change the panel as needed; the other is to resize (cut and reseal) an appropriate COTS LCD to the size desired to fit the panel. The first option is appropriate for new aircraft and the second is appropriate for a retrofit. Regardless of the size of custom, COTS or resized COTS LCDs, the LCD industry may stop manufacturing the selected size over the 20- or 30-year life of the aircraft. Therefore the solution is to make lifetime buys or consider resizing COTS LCDs – in whatever sizes are then available – to the desired size.

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Ruggedized for avionics

Custom, COTS and resized COTS LCDs need to be ruggedized, giving several areas of concern:

- Antireflective coating on the front surface;
- EMI filter on the front surface;
- Heating of the LCD and backlight for rapid start at low temperatures;
- Sealant to protect from humidity, the polarizers, silicon chips and anisotropic conductive adhesive.

The ruggedized sandwich is shown in Figure 1. Glass plates carry the performance enhancements and protective features and are laminated to the original LCD. The glass plates make a rugged package. The environmental issue of shock and vibration are a function of the mounting of the glass sandwich in the box. Shock, vibration and breakage are not such a problem in LCDs as they are in CRTs. The LCD sandwich is solid and there is nothing to implode. If breakage occurs the pieces are held in place by the sealants and polarizer laminants.

Display module

The avionics LCD is an assembly of two components – the backlight and

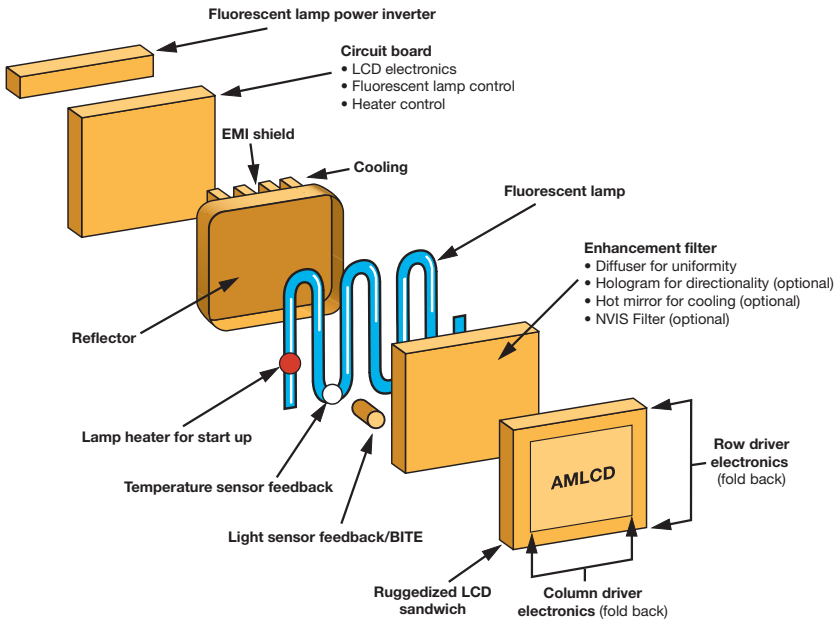

Figure 2: **High-performance avionics LCD**

the LCD. The key component is the LCD panel where the electrical signal of the image is converted into an optical effect. The optical effect is a change in birefringence due to a rotation of the liquid crystal material at each pixel, controlled electrically by the charge on the pixel. To see the contrast between the thousands of individual pixels that form the image, the LCD panel with polarizers must be illuminated from the rear.

The complete assembly is shown in Figure 2. An industry avionics infrastructure has emerged to custom build the backlight assembly. The backlight is designed to give the unique performance of wide dimming ratio, high brightness and night vision goggles compatibility needed in avionics. No other display technology has the brightness capability and dimming range of the avionics LCD.

The fluorescent lamp with the triband phosphor is uniquely suited to avionics applications with its high efficiency and red, green and blue spectral emission. Straight, bent and flat fluorescent lamps are used. The bent version is shown in Figure 2. The lamps are usually redundant for reliability purposes. Lamps with over 50,000 hours to half brightness are now available. The performance life characteristic of a fluorescent lamp is an exponential decay in luminance with operating time. The luminance decay can be compensated for electronically with feedback. To reduce cost and electromagnetic interference the avionics simulator industry is using LEDs as backlights, but their efficiency is much less than that of fluorescent lamps. The heat from the backlight becomes critical when packaged for the flight deck and operating at high luminance levels and a heat sink must be included in the box design.

The really good news is that the COTS LCD can be resized to fit the box or panel

The most important feature of LCDs in their application to avionics is their immunity to high ambient illumination. This is accomplished because of three factors:

• The display when off is truly black. The polarizers absorb all the light either from the back or front. The LCD is optimized to absorb all the light uniformly throughout the panel area and over a wide viewing angle. All CRTs suffer from the phosphors being white and the only way to make them dark and minimize refection is by filtering, but this absorbs the image light as well as the ambient light.

• The LCD reflects the image and is the only electronic display technology to do so. The ambient light passes through the pixels that are open – or turned on – to produce the image. The ambient light is then reflected and added to the backlight and passes through the pixels. Thus the ambient illumination adds to the image brightness.

• As with all avionics instrument glass, an antireflective coating is needed on the front surfaces.

There are three areas of concern about LCDs when applied to avionics:

• Off-axis image quality is poorer than in the normal axis. CRTs are lambertian emitters and have no variation in image quality off axis. However parallax problems exist with older mechanical instruments and CRTs.

• Speed of response is less than that of CRTs. LCDs can be refreshed at 60Hz with 20Hz image change to alleviate the slow response if necessary with no adverse effect.

• Temperature range is limited but most LCDs now exceed the required operating range for avionics. COTS LCDs are not tested for the avionics range so they need to be tested during qualification to confirm proper performance. Reliable ranges of between -40°C to 80°C and wider can be expected.

Summary

High-performance avionics LCDs can be made by ruggedizing COTS or resized COTS LCDs. The COTS LCD must be ruggedized in a sandwich and integrated with an avionics grade backlight. The complete assembly is normally designed, tested and qualified together just as with custom LCDs.

The really good news is that the COTS LCD can be resized to fit the box or panel. There are some limitations in resizing but there is a large range of COTS LCDs from which to choose. Resized COTS LCDs can be made at one-tenth the cost of custom LCDs. The evolution will be a revolution and LCDs will lead to a better flight deck at a lower cost with increased safety – the golden goal of avionics.

❖ *Lawrence Tannas is a consultant in electronic displays and avionics, and a pioneer in the development of LCDs and resized LCDs*

1. D. Hogg, et al, "Development of a production process for COTS glass remanufacture for use in avionic displays"; in Proceedings of SPIE, 17-19 April 2001, Volume 4362, p. 278

2. L. E. Tannas, Jr., "AMLCD resizing". ibid, p. 288