EMI shielding and optical enhancement to touch screens

Incorporation of a circular polarizer is a powerful option for enhancing LCD contrast.

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ABSTRACT

Electromagnetic attenuation features can be incorporated as an integral part of touch screens rather than as a separate component in those display applications requiring shielding for EMI/EMC compliance. Various enhancement techniques and design considerations will be reviewed. Features and methods employed will vary with particular touch screen enhancements and will include conductive layer, encapsulation, termination, and touch screen mounting. Possible enhancements to optical performance including opportunities for contrast enhancement through reflection reduction techniques will also be presented.

INTRODUCTION

Electronic displays are now commonplace in many demanding environments where both high ambient light readability and electromagnetic compatibility (EMC) can be achieved only through enhancements to commercial-off-the-shelf (COTS) components. It is also common that touch screens are integrated into display systems as they are a very efficient user interface, especially in the case of portable electronics. EMC denotes the ability of an electronic system to function within its operational environment without emitting unacceptable levels of electromagnetic (EM) radiation or failing to perform because of an external EM field. The dilemma for system designers is that COTS touch screens typically degrade the high ambient readability of high performance displays to an unusable level. However, the technology to modify a display for high ambient light readability is readily available. Touch screens integrated into display assemblies can be configured with an electromagnetic interference (EMI) shielding conductive ground plane (CGP) and contrast enhancement features to address two performance issues with one part. It is assumed that the reader understands the basic principles behind touch panel technology. The enhancements described focus on resistive touch screen technology and their integration into a high ambient light readable liquid crystal display (LCD) assembly. However, these features can be applied to other touch screen technologies as well.

ELECTROMAGNETIC INTERFERENCE SHIELDING

A Faraday cage is a continuous electrically conductive enclosure that surrounds the equipment and attenuates transmitting electric fields to a desired level. Metalized enclosures form most of a Faraday cage in typical display assemblies, but obviously must leave the display face open and viewable. Therefore, CGPs with satisfactory transparent properties must be installed in the display optical path to complete the Faraday cage and to function as an EMI shield. If this element of the Faraday cage is not properly terminated (*e.g.*, the shielded touch screen is terminated only on one or two corners), this portion of the shield could act as an antenna and could re-radiate an undesired field.

Common techniques for adding conductive properties to an optical substrate include vacuum deposited transparent conductive coatings and integration of fine wire meshes. Electrically conductive, optically transparent ground planes pass a dominant portion of the visual spectrum (*i.e.*, 380 nm to 780 nm). The properties of transmittance and conductivity can be adjusted or tuned to fit the needs of the specific application. All transparent conductive materials require an optical substrate as a carrier. It is important to review and understand the properties of the optical materials that comprise a touch screen as they relate to the CGP because performances of the individual elements, added or inherent, are interrelated.

Transparent Thin Film Conductive Coatings

Transparent thin film conductive coatings offer excellent optical and moderate EMI shielding properties. See Table 1 for relative shielding values. A transparent thin film conductive coating is typically deposited onto an optical medium using a high vacuum coating process (*e.g.*, ion enhanced e-beam evaporation or DC magnetron sputtering). These are high-energy processes that can create very dense films. The durability of a specific coating is largely dependent upon the optical substrate, the specific materials deposited, and the deposition method. The base material of optical plastic substrates often must be enhanced with a hard coating for the conductive coating to have adequate durability and conductivity properties.

Typical transparent conductive films include transparent conductive oxides (TCOs), such as indium tin oxide (ITO), and metal alloyed films (*e.g.*, alternating layers consisting of Ag & ITO). Increasing the conductivity of the coating will increase the average EMI attenuation level over the frequency range of 100 KHz through 20 GHz. Typical conductivities for transparent thin film conductive coatings for this purpose range from 1 O/sq to 100 O/sq. Unfortunately, there is an inverse relationship between light transmittance and conductivity. Metal alloyed films offer better cost/performance options over TCOs, especially when applied to plastics. They can be cost effectively deposited in resistances down to 2 O/sq. while maintaining moderate total luminous light transmittance performance (*i.e.*, > 68% T_L). The photopic transmission of metallic coatings quickly decreases as the conductivity increases. Additionally, metal alloys have an inferior mechanical and galvanic durability.

By contrast, TCOs become very costly to apply to plastics for resistances below 30 O/sq., but can be applied to glass to values below 1 O/sq. A low resistance coating on glass will offer high performance but will cost more because it is deposited in a batch vacuum process rather than a web or continuous process. Additionally, most TCOs can be fully integrated into a multi-layer dielectric stack as part of a broadband anti-reflection (AR) coating. An AR coating reduces surface reflection losses and increases transmitted light. A fully enhanced TCO can have a total luminous reflection of a broadband white light source (*e.g.*, illuminant D65) of less than 0.5%. Furthermore, the photopic absorption of TCOs tends to be very low, often less than a few percent at fairly high conductivities (*i.e.*, < 10 O/sq.).

Fine Wire Mesh

Fine wire mesh CGPs offer excellent EMI shielding and good optical properties. (See Table 1 for relative shielding values.) Fine wire mesh is a grid pattern with high open area and excellent conductivity (*e.g.*, < 30 mO/sq.). The material is typically stainless steel or copper. For higher shielding applications, it is created by weaving fine wires (*e.g.*, 0.0008" to 0.002") in a plain weave format. Plain weave mesh is constructed with wires crossing alternately over and then under one another with adjacent wires 180 degrees out of phase (similar in construction to a window screen but significantly finer). The mesh must be conductively plated to fuse the wire crossovers for very high shielding (*e.g.*, silver conductive plating). The mesh can then be blackened with a black conductive corrosion resistant plating to improve galvanic stability and optical performance (by reducing reflections).

Frequency	80 Mesh Plated	10 O/sq ITO
H Field		
100 KHz	15 dB	0 dB
1 MHz	32 dB	1 dB
E Field		
100 KHz	86 dB	72 dB
10 MHz	81 dB	36 dB
Plane Wave		
100 MHz	71 dB	24 dB
1 GHz	58 dB	25 dB
10 GHz	34 dB	18 dB

Table 1.

The mesh is typically specified by the number of strands per inch in the x and y directions (*e.g.*, 100 x 100 mesh) or openings per inch (OPI). Often the number of strands per inch is stated only once (*e.g.*, 100 mesh) because most of the weaves used in the optical industry are square (*i.e.*, the same number of wires per inch in both x and y directions). The minimum wire diameter and the number of strands per inch will vary with the physical properties of the base material. Standard mesh counts range from 50 to 255 strands per inch. Different mesh count options are available for increased shielding needs and for moiré control options. Whenever two light transmitting matrices are overlaid, there is a potential for a moiré pattern to be generated. The moiré pattern will hinder display readability if the mesh interferes with active-matrix display pixels. Therefore, a touch screen with a mesh CGP must be optically fitted to the specific electronic display (*e.g.*, LCD) to minimize or eliminate this phenomenon. EMI/EMC performance will not change when the mesh orientation is adjusted. The necessity of creating a good "optical fit" makes the remote design process more challenging compared to designing with transparent film processes. Empirical optical testing may be required.

CONTRAST ISSUES WITH COTS TOUCH SCREEN

A contrast measurement of an electronic display will gauge how readable a display is in a demanding high ambient light environment. This test measures the relation between the activated or "on" areas of a display and the dark or "off" areas. High ambient contrast is a function of the inherent display performance, ambient environment, display luminance, and reflections from the display. Contrast performance will decrease significantly as the display reflection increases. There will be reflections at interfaces where light transfers from one medium to another caused by index of refraction changes. Resistive touch screens have four major interfaces, each of which either goes from air to an optical medium or, conversely, from the optical medium to air. Reflection problems are further compounded because the resistive touch screen is comprised of plastic substrates with hard coatings and thin film coatings on both rigid and flexible optical materials (either glass or plastics) that create many additional material interfaces and sources of reflection.

$$R = R_s = R_p = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$

Equation 1. *Fresnel equation for normal reflections.*

A better understanding of the cumulative effects of surface reflection can be attained using the Fresnel equation above. When applied for normal incident light to the first surface interface where the initial medium is air ($n_1 = 1.0$) and the exit medium is an acrylic hard coating ($n_2 = 1.5$), the result is a value of 4% for the first surface reflection. The reflection issues become further compounded when the ¼ wave effects of the thin film coating (*i.e.*, the conductive layer inside the touch screen) are entered into the equation. The total luminous reflection for a COTS touch screen can exceed 20%, a value which would destroy the contrast of almost any display in a high ambient light environment. See Figure 1 for a surface reflection summary of a typical resistive touch screen.

DESIGN CONSIDERATIONS

AR Enhancement of Outer Surfaces

An anti-reflective coating applied to both the front and rear surfaces of the touch screen would reduce the reflections by approximately 50%. Direct enhancements to the internal ITO components of the touch screen cannot be performed on a COTS touch screen. Although indirect solutions are possible, it should be noted that fully optimizing the internal ITO coating would be impossible under current technology constraints. While integrating the TCO into an AR coating, which is index-matched to air, the final layer would need to be a dielectric that is not conductive and, therefore, would render the resistive touch screen electrically inoperative. These factors aside, reasonable levels of optimization can still be achieved. Note that there is a wide range of internal reflection present in COTS touch screens (*i.e.*, < 2% to greater than > 8% per interface).

A thin film coating cannot be directly deposited in a vacuum to the completed COTS resistive touch screen. The direct deposit coating process would cause the air gap between the flexible membrane and the carrier or support layer to collapse. This would result in varying degrees of plastic deformation around the spacers and degradation of either the optics or touch screen electrical performance. For this reason, it is common to apply the conductive coating to an optical substrate and then to laminate it onto a surface of the touch screen. The most cost effective lamination is a flexible film lamination (0.003" to 0.009" in total thickness) to one or both surfaces of the touch screen. Note that a flexible film is the only suitable option for the front surface of the touch screen. Common film optical substrates include polyethylene terephthalate (PET), cellulose triacetate (TAC), cyclo-olefin and poly-olefin substrates. Again, the flexible substrates can be hard coated with a thick film system (*e.g.*, acrylic or silane) with the thin film coatings applied over top to improve mechanical durability. The conductively coated carrier film can be easily applied with an optical adhesive.

Considerations for carrier film selection are index of refraction, durability, cost, and birefringent properties.

EMI Shielding

The EMI shield can be applied to the front, rear, or both surfaces of the touch screen. Care must be taken not to interfere with the resolution or sensitivity of the touch screen if the touch screen itself must be shielded (*i.e.*, the CGP is on the outer most surface). Thin film conductive coatings applied to the rear surface of the touch screen offer a simple cost effective way to achieve EMI attenuation. The degree of index matching of the rear surface is dependent upon the contrast required or the amount of rear surface reflection that can be tolerated.

Grounding of the thin film coating can be readily achieved by using an electrically conductive pressure sensitive adhesive (PSA) and attaching the touch screen to the metal perimeter of the LCD, or to a bezel or housing to complete the Faraday cage. A conduc-

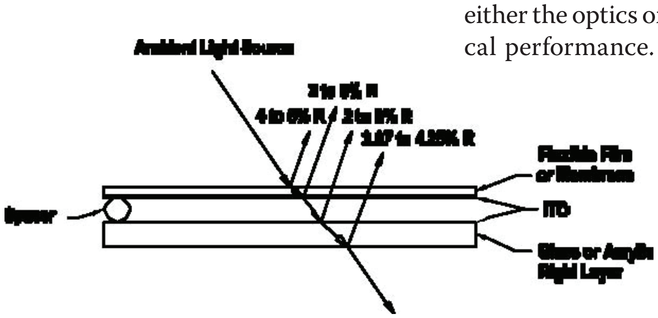

Figure 1. *Ambient reflections magnitudes, COTS resistive touch screen.*

Figure 2. *Termination example.*

tive adhesive or gasket could also be employed to terminate the CGP. The gasket should be placed under compression with mechanical clamping. See Figure 2 for additional details.

It is common to apply a conductive buss (*e.g.*, Ag epoxy or acrylic buss) over the thin film conductive coating CGP to provide mechanical durability when utilizing a compression gasket. The shock and vibration associated with normal use can cause the thin film coating (typical thickness ranging from hundreds to thousands of angstroms) to wear and be compromised. Additionally, the buss can be used to wrap the termination around to the other side of the touch screen. In some touch screen designs, the EMI conductive buss can readily make contact with one of the internal conductive layers of the touch screen that is brought out to the edge causing interference with the touch operation. In these cases, an insulating layer must be added to prevent operational interference.

Touch screen designs with fine wire mesh shielding must consider mesh encapsulation, mesh orientation (*i.e.*, an element of moiré control), and mesh termination. Applying the mesh to the rear surface of the touch screen offers the simplest and a very cost effective way to achieve EMI attenuation. The first step would be to treat the outer surfaces as described before with AR coatings and then to apply the properly oriented mesh under tension to the rear surface of the touch screen. The edges can be secured around the perimeter with an adhesive. The major drawback of this approach is that the mesh must be handled with extreme care to prevent damage during installation. The product should be assembled in a clean room environment because of the dificultly in cleaning exposed mesh.

Encapsulating the mesh is strongly recommended to ease handling. This can be done in conjunction with the optical enhancement to the rear surface of the touch screen. For example, with a glass touch screen, an extra layer of glass with an AR coating can be added with the mesh laminated in between. The mesh can be terminated with a conductive buss around the perimeter or can be allowed to extend. Extended mesh would allow for the highest shielding as the transfer impedance to adjacent conductive surfaces would be minimized. However, this technique poses more difficulties in the packaging of the touch screen display assembly and should be considered early in the design. Again, if the mesh shield were required to be on the front of the touch screen, it would have to be embedded in a thin flexible membrane.

Full Enhancement of the Touch Screen

A circular polarizer (CP) can be integrated into the front membrane to suppress the internal reflections of a touch screen. A CP is a linear polarizer combined with a ¼ wave retarder. The retarder is used to introduce a phase shift between the orthogonal components of the polarized light. In this way, two equal components of light oscillating perpendicular to each other with a relative phase difference act as vectors to yield a rotating linear polarization state. The field inverts, and the light wave begins rotating in the opposite direction when the circularly polarized light reflects off of a conductive surface interface. When this light passes through the retarder again, it is now linearly polarized 90 degrees out of phase with the linear polarizer element of the CP, and a majority of the energy is absorbed. In summary, a CP can eliminate over 99% of the internal reflections. With a CP integrated into the touch screen, the outer surface would then be the only surface which would require the AR coating for refection control. Index-matching other surfaces would only improve display readability. Total absorption of the reflected energy will never be achieved as there is always a small portion of light that will have reflected an even number of times, preventing the proper circular polarization. Additionally, the polarization will become elliptical as angles deviate from normal incidence.

There are two challenges that are presented to the designer when integrating a CP. First, the most common first surface membrane or flexible carrier film of a touch screen is PET. PET has significant birefringent properties that greatly interfere with the proper function of the ¼ wave retarder. Therefore, the PET component must be removed from the touch screen and must be replaced with a non-birefringent component for a CP to be utilized. The second challenge is that a CP in the most ideal situation will remove 50% of unpolarized light and must be properly configured not to interfere with polarized display lighting. In the case of a plasma display (an unpolarized light source), the CP will drop the luminous output of the display by over 50%, and there is nothing that can be done to regain this lost energy. In an LCD, the output of the display is polarized. Firstly, a CP would have to be oriented so as to maximize transmission when used over a polarized light modulator such as an LCD. However, maximized transmission of linearly polarized light through a CP is slightly less than 50% as the display output becomes circularly polarized.

Circularly polarized light does not efficiently transmit thorough a linear polarizer. To overcome this challenge, another retarder is required on the inner surface of the touch screen, that converts the display's output back to linearly polarized light. Transmission of polarized light through a properly oriented linear polarizer can exceed 95%. Theoretically it could rise to to greater than 99%. Performance is greatly dependent upon the polarizing efficiency of the LCD and the linear polarizer component of the CP, the quality of the retarders, and the overall alignment of the optics. In the end, incorporation of a CP is a very powerful option for enhancing the contrast of an LCD without impacting its output luminance. Optical fitting must be performed to each display to ensure proper performance. Usability must also be considered as the CP adds thickness and, hence, reduces touch sensitivity. It is also the most costly of reflection reduction solutions. Incorporation of a CP is a major change to the touch screen design and should be considered prior to manufacture.

CONCLUSION

Touch screens are suitable user interfaces for high ambient light readability applications. The performance of COTS touch screens varies. It is best to start with a product that has properties close to those required in the end application. It is important to select touch screen attributes that will not interfere with any required enhancements. EMI shielding can be readily incorporated into either the front or rear surface of the touch screen using a lamination process of secondary materials. However, application of a CGP is more readily applied to the rear of the touch screen. Transparent thin film conductive coatings are recommended for applications requiring low levels of EMI shielding, and fine wire meshes are the material of choice for very high levels of shielding. Both materials should be considered for moderate levels of shielding. Contrast enhancing properties of a touch screen can be improved during subsequent EMI shield incorporation or during initial product design. There is no one solution that works best for all applications. Each application should be considered unique, and features should be selected for specific end program suitability.

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