Switchable View-Angle Control Using LC Technology for Automotive

Wei-Ming Huang, Jia-Hong Ye, Chih-Huang Liao, Min-Hsuan Chiu, Wei-Ming Cheng, Yen-Hua Lo, Chao-Chien Chiu, Chun-Hung Kuo*

AUO Corporation, Hsinchu Science Park, Hsinchu 300, Taiwan, R.O.C.

***E-mail: JiaHong.Ye@auo.com**

ABSTRACT

As technology advances, the demand for privacy protection has evolved from portable display products to automotive panels. AUO Corporation has continuously innovated and developed new solutions to meet this demand. This article primarily discusses AUO's development of Dual VAC technology for automotive privacy protection, utilizing the unique characteristics of liquid crystals and rotation angles to achieve an asymmetrical viewing design. Unlike previous privacy filter technologies that restricted viewing angles, this technology achieves the effect of wide viewing angle while simultaneously reducing side window reflection issues. It meets the stringent requirements of automotive applications, enhancing the driving experience for passengers and creating new opportunities and challenges within the market. We expect that this technology will bring transformation to the automotive industry, improving overall driving safety and entertainment experiences.

Author Keywords

Active Privacy, LC Technology Automotive

1. INTRODUCTION

AUO has been continuously developing LCD privacy technology to meet market demands. Since the introduction of the Dual Light Guide backlight privacy technology in 2016 to the three-electrode privacy technology in 2018, the design of privacy technology has evolved from backlight design to cell design. From 2021 to 2022, AUO's independently developed VAC technology achieved success in the Touch TW DEMO and performed exceptionally well in the notebook market, solidifying its leadership position in the global commercial laptop market.

With the increasing demand for automotive privacy solutions, AUO launched Dual VAC technology, eliminating traditional privacy films and leveraging liquid crystal properties to create an asymmetrical wide-view privacy solution. This technology addresses the image parallax issues caused by traditional symmetrical designs and incorporates AmLED backlight and local dimming design to achieve high-contrast image quality, as shown in Figure 1.

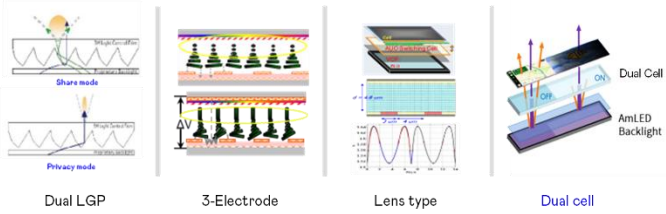

Figure 1 AUO Privacy Tech. Milestone

Due to the distinct designs employed by various automobile manufacturers in installing dashboards inside vehicles, there is a significant variation in the line of sight angle of the human eye toward the panel. This characteristic results in a clear difference in the optical design for anti-peeping features of automotive panels compared to general commercial panels, ultimately leading to the distinction between axial and off-axial designs. Specifically, when the dashboard forms a 90-degree angle with the driver's line of sight, it is referred to as an axial design; conversely, if the angle of the dashboard relative to the driver's line of sight is non-90 degrees, it is termed a off none-axial design, as shown in Figure 2.

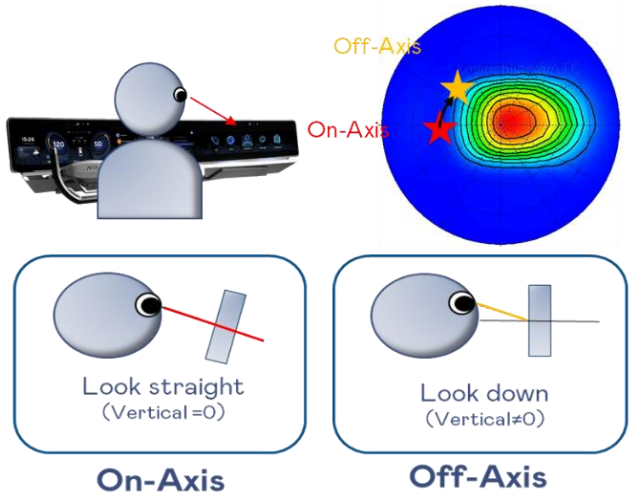

Figure 2 Off-Axis & On-Axis with isoluminance contour

2. Experiment and Results

2.1 Design principles

Based on existing technical evaluations, it is evident that Dual Cell has the potential to meet various structural needs. Its technical principle utilizes the asymmetric characteristics of the LC's grayscale viewing angles.

The cause of its asymmetry must be quantitatively analyzed through simulation software to observe the variation of retardation at different viewing angles. Qualitatively, we can use a simple example for illustration: in the VAC Cell, the liquid crystal is rotated 90 degrees from the bottom substrate to the top substrate. Therefore, when a vertical electric field is applied causing the liquid crystal to tilt, we can roughly visualize it as a whole structure tilted at 45 degrees. At this point, when the human eye observes the panel from the left side, the polarization will align with the short axis of the liquid crystal, resulting in no retardation. Conversely, when the human eye views the panel from the left side, the polarization will align with the long axis of the liquid crystal, leading to retardation and causing light to penetrate, which results in the asymmetrical phenomenon where the left side appears darker and the right side appears brighter. We take advantage of this phenomenon to achieve asymmetric privacy, thereby meeting the automotive market demand for different special angle privacy solutions, as shown in Figure 3.

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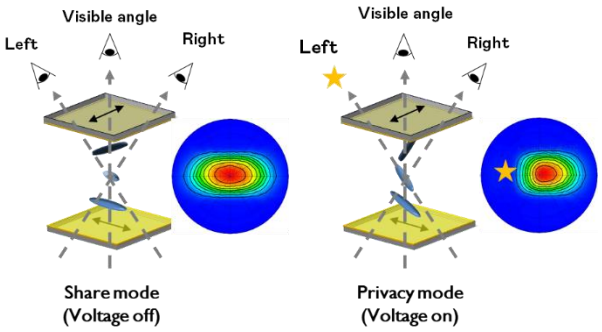

Figure 3 Viewing angle with isoluminance contour

However, due to insufficient privacy capabilities of a single-layer structure, we stacked an additional cell layer rotated by 90 degrees relative to the first layer. This configuration can achieve a privacy capability at theta=45° with a brightness relative to the center brightness of less than 1%, which is comparable to the capabilities of privacy films. However, when the Dual Cell is not driven (L255), it does not limit the viewing angle in the same way as light control films (LCF), thus achieving a wide viewing angle effect, as compared in Figure 4.

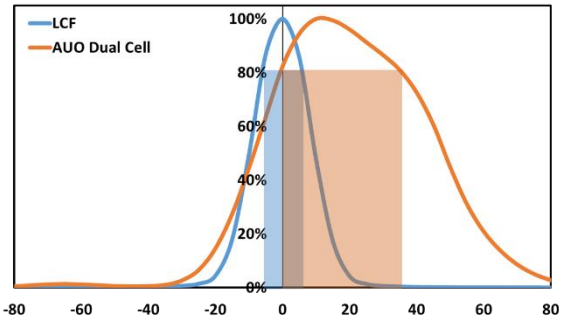

Figure 4 LCF & Dual Cell FWHM comparison

2.2 AUO Dual Cell

In automotive applications, the demand for off -axial designs is particularly important, as the dashboard designs of many modern vehicles do not always align at a right angle with the driver's line of sight. Therefore, effectively addressing the impact of angular variations on optical performance in off -axial designs becomes crucial for enhancing driving safety and passenger experience.

Furthermore, in addition to utilizing the aforementioned liquid crystal characteristics to achieve an asymmetrical wide-view privacy solution, the Dual Cell design must also integrate effectively with the Display Cell. Therefore, the upper and lower Cells of the Dual Cell have distinct functions; the lower Cell is critical for influencing privacy capability and special viewing angles, as both privacy and viewing angles are related to LC design. By rotating the LC in the lower Cell, we optimize the Dual Cell's privacy capabilities and viewing angles.

The upper Cell is key to the non-orthogonal design of the Dual Cell. To ensure compatibility with the topmost Display Cell, the angle of the polarizer in the upper Cell and the rotation angle of the LC are designed to align with the Display Cell. This design results in a rotation angle for the upper Cell that is less than 90°, ensuring that the final polarization of the emitted light matches that of the Display Cell's polarization. This approach not only reduces the loss of transmittance but also prevents the degradation of color deviation. More importantly, it eliminates the need for additional wave plates to match the polarization direction of the Display Cell's lower polarizer, thereby avoiding cost increases. The overall structural design is shown in Figure 5.

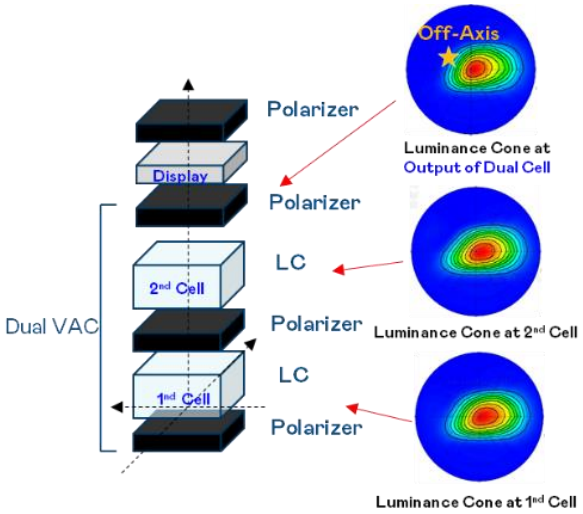

Figure 5 AUO Dual Cell structure & isoluminace contour

2.3 LC rotated changing simulation

As previously mentioned, we utilize the characteristic of the LC mode's grayscale viewing angle asymmetry to achieve privacy. This characteristic is based on the angle of our view and the LC. Therefore, we extend this feature to address the privacy needs from different viewing angles by changing the rotation angles of the liquid crystals. To verify this design idea, we conducted simulations to change the rotation angles, as shown in Figure 6. We simulated three different rotation angles, and from the results, we observed that as the LC rotation angles changed, the isoluminance contour diagram also varied. This simulation result allows us to make better design adjustments to meet the privacy needs of different manufacturers for special viewing angles.

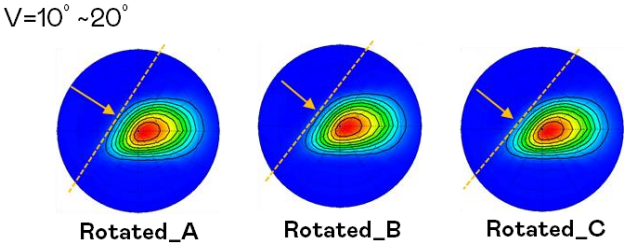

Figure 6 isoluminace contour at different rotated angles.

rotated_A, rotated_B, rotated_C respectively represent different liquid crystal rotation angles.

2.4 LC rotated actual optical verification

To verify the above simulation results, we actually tested three different LC rotation angles to assess their privacy effects on the actual Dual Cell. As shown in Table 1, the designs with different rotation angles can indeed alter the privacy effects. If the customer's privacy protection requirement is around H = -30, there is better optical performance in the Rotated_C design; or if the customer requires optimal privacy protection around H = -40 due to structural design needs, we can choose the Rotated_B

design to achieve the customer's goals. The reason for this is related to the varying amounts perceived by the human eye in relation to the liquid crystal's long and short axes, indicating that different LC rotation angles have their own advantages at different viewing angles and can meet various special angle privacy requirements through this characteristic.

Table 1 Privacy capabilities at different rotated angles

H	Rotated _A	Rotated _B	Rotated _C
-30	1.08%	0.86%	0.74%
-40	0.56%	0.45%	0.49%

3. Compare with commercial products

To easier understanding of the advantages of AUO Dual Cell technology, we compared it with the more commonly used technology in the automotive privacy market, Dual LGP and Dual cell. As seen in Table 2, AUO Dual Cell utilizes direct type Backlight (AmLED) technology, resulting in superior performance in contrast ratio. Additionally, by leveraging the properties of liquid crystals, Dual Cell offers enhanced privacy capabilities and improves the image parallax caused by traditional symmetric viewing angles, achieving a wider viewing angle for privacy. Furthermore, in share mode, it reduces power consumption by nearly half. Based on XOEM requirements, Dual Cell also demonstrates better contrast ratio performance in ID18, ID19, and ID20.

Table 2 Compare with Dual LGP & Dual Cell

Item		Dual LGP (Product)	Dual cell (Product)	AUO Dual cell (New Design)
Privacy mechanism		LCF	LC Cell	LC Cell
Backlight		Edge type	Direct type	Direct type
Contract Ratio		2,000:1	100,000:1	100,000:1
Privacy mode (V around 10˚ ~20˚)	Privacy ability @H=-30˚ (Ref. Center Luminance 100.0%)	1.0%	0.9%	0.7%
	Visible angle range (Ref. Luminance 80.0%)	~10˚	~20˚	~40˚
Public mode (Based on XOEM requirements)	@H=-40˚	50%	40%	50%
	ID 18 (H-10, V8)	85%	90%	90%
	ID 19 (H-40, V20)	55%	35%	45%
	ID 20 (H-50, V20)	60%	20%	30%
Power	Privacy mode	100%	140%	120%
	Public mode	100%	55%	55%

Public mode Contrast ratio (Based on XOEM requirements)			
Item	Dual LGP (Product)	Dual cell (Product)	AUO Dual cell (New Design)
ID 18 (H-10, V8)	1300	1400	1400
ID 19 (H-40, V20)	600	600	650
ID 20 (H-50, V20)	500	400	450

4. Side window reflection issue

Under the mechanisms designed by some car manufacturers, the window next to the front passenger seat may reflect the PID image in Privacy mode. Therefore, the aim is to reduce the brightness range of the window display in Privacy mode to minimize the possibility of distracting or affecting the driver while driving, as shown in Figure 7.

Figure 7 side window reflection

4.1 Side window reflection simulation

Due to the issue of side window reflection primarily occurring at large viewing angles, we adjusted the BLU structure to improve the side window reflection problem. By using the film to block only large-angle light, we not only maintained the driver's privacy protection but also significantly reduced the side window reflection issue. As shown in Figure 8, after changing the structure (Type_2), we effectively blocked large-angle light, greatly reducing the side window problem.

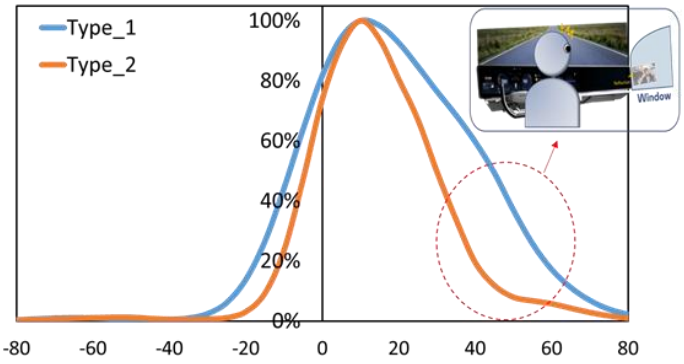

Figure 8 Type1 and Type2 privacy capability simulation

5. SUMMARY

We have successfully developed the Dual Cell technology, which utilizes an LC rotated design to not only meet the customized privacy angle requirements of the automotive market but also effectively reduce the reflection issue of the side windows in privacy mode, thereby enhancing driver safety and comfort. In addition, we leverage the unique characteristics of liquid crystal to create an asymmetric viewing angle design for privacy, successfully overcoming the viewing angle limitations of

traditional privacy films and achieving a wide viewing angle effect. Furthermore, it is equipped with AmLED backlight local dimming design, which achieving high contrast image quality and providing customers with more competitive products in the market, as shown in Figure 10. In the future, AUO will continue to optimize LC technology and integrate axial and off-axial designs to continually create innovative solutions in the field of LCD privacy technology, providing high-quality privacy solutions that promote industry advancement and development.

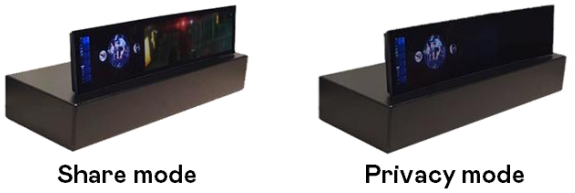

Figure 9 Demo photo

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