Development of Organic Light Emitting Diode (OLED) Driver for Automotive Components

Naoya Kimura　Shuji Furuichi

The OLED self luminous display device features high brightness, high contrast, a wide field of vision with a rapid response and is compact as well as light-weight. At the present time the device is implemented in sub-main displays for mobile phones along with other mobile devices, such as portable audio systems, as well as small to medium size displays for automotive components, including car audio and instrument panels. A lot of activities are proceeding to create large size versions of these displays, with announcements being made regarding plans to adopt them for television products. The displays, therefore, are becoming a focal point of attention with a high potential for the future.

OLED displays can be categorized into passive drive and active drive methods. The dot matrix structure and segment structure are passive drive method OLED panels.

Passive drive method panels are comprised of an OLED element located at the cross point of the anode and cathode. The drive method adopted uses anodes and cathodes to drive elements to emit light. Active drive method OLED panels, on the other hand, are comprised of transistors allocated for driving OLED elements inside the panel. This structure is identical to the structure of generic TFT liquid crystal displays[1].

Passive drive method OLED panels were launched in the market before active drive method OLED panels as they are easier to manufacture and the manufacturing costs are lower in comparison with active drive method panels. OKI started mass producing drivers for passive drive method OLED displays in 2002 and the development of OLED drivers is ongoing for automotive components, the growth of which is expected to continue in the market well into the future.

Photo 1 Example of application for automotive instrument panel (provided by Nippon Seiki Co., Ltd.).

This paper describes activities carried out by OKI with regards to technology development for drivers and controllers for passive drive method OLED, which are required for automotive components, as well as activities intended to reduce electromagnetic interference (EMI), considered to present technical challenges of a high degree. Furthermore, a product summary of single chip OLED drivers include controllers, developed by OKI for OLED displays of passive drive method featuring a dot matrix structure, is also provided.

Technology developments of OLED driver for automotive components

High visibility is required of displays for vehicle mounted devices to enable drivers to instantaneously identify displays while driving. For this reason some characteristics, such as high brightness, a high contrasting ratio and wide field of vision have been emphasized, resulting in the conventional use of fluorescent display tubes, which are self-illuminating displays. Nowadays, however, demand for high precision displays have risen significantly, resulting in an increase in the number of display devices incorporating OLED displays, which are self-illuminating and offer high visibility (**Photo 1**).

The following qualities are essential for vehicle mounted devices, due to the characteristics of their use:

- High visibility (high brightness, high contrasting ratio, wide field of vision, etc.).
- Wider operating temperature range in comparison with consumer products.
- Low EMI characteristics.

As for OLED elements current drive methods are often adopted for passive drive method OLED panels in order to maintain the following types of characteristics:

- Brightness of generated light proportional to the input current density.
- Electrical characteristics similar to those of diodes.
- Brightness-voltage characteristics vary depending on the temperature, whereas brightness-current characteristics vary little depending on the temperature.

The drive circuits of the OLED drivers described below, intended for automotive components, were developed with consideration for such display requirements for vehicle mounted devices and the characteristics of OLED elements:

(1) Anode driver with high current drive capacity

Anode driver with a high current drive capacity was developed in order to improve visibility for automotive components, thereby making it possible to brightly display large image elements.

(2) Anode driver of small between adjacent output current variations

A high precision constant current driven anode driver of amall between adjacent output current variation of 2% or less was developed to inhibit linear irregularities of brightness, since such irregularities are recognized quite easily on the display[2)].

(3) Cathode driver of Low ON resistance

The drive voltage level of cathode rises, since a large amount of concentrated drive current flows in to the cathode driver from the anode driver. When the drive voltage level of cathode is high, the power consumption is increased and the output voltage of the anode driver via the display also increases. Irregularities occur with the drive current due to dependence on the output voltage in the constant current output circuit. Increases in power consumption and a rise of voltage level at the cathode driver were inhibited by the realization of a cathode driver with a Low ON resistance with a resistance of 12 ohms or lower.[3)]

Technology development of OLED driver include controller for automotive components

Single chip OLED drivers include controllers, which can be mounted with high density, are required of small to medium size displays intended for application in mobile devices and automotive components. Technology developments to realize controllers that can be built in OLED drivers intended for automotive components are described below:

(1) A variety of display image processing functions

A variety of display image processing functions, listed below, was realized for automotive components:

- Host interface.
- Power saving modes and display on and off functions.
- Built in graphic RAM, and GRAM access to window for control graphic RAM.
- Partial display function for a display size adjustment.
- Horizontal and vertical display direction turn, start point change display functions.
- Multi-layer display function.
- Screen saver function with a burn prevention for scroll bars, etc.

(2) Flexible timing control of display

In terms of structure, passive drive method OLED displays can be considered to be parallel plate capacitors with OLED elements sandwiched between a cathode and anode. The parasitic capacitance value is usually in the order of nF/cm^2, therefore, consideration for the area of picture elements as well as the number of pixels cannot be ignored.

The following functions were realized and a flexible timing setting was made available in order to control the necessary brightness and gray scale without influence by the parasitic capacitance of the OLED element.

- Multiple pre-charging and discharging drive method.
- Controled function for pre-charging and discharging timing.
- Setting function for pulse width modulation (PWM) data.
- Setting function for brightness current.

(3) Particularity of cutting-edge high voltage process

The OLED drivers include controllers for automotive components are comprised of circuits that require a high voltage process, such as an anode driver, a cathode driver and a voltage regulator, as well as digital circuits, such as a controller and graphic RAM, which must be created on a large scale through microfabrication and a low voltage power supply. It is for these reasons that we developed a cutting-edge high voltage process that can satisfy the contradicting requirements of the high voltage process and cutting-edge microfabrication process.

Activities for reducing EMI

Electromagnetic interference, which electromagnetically impacts the surroundings with unnecessary electromagnetic noise emitted by LSIs, is known as EMI. Such noise intensifies with the added amount of power supplied due to an increase in the sizes of electronic devices, faster clock speeds and more sophisticated functions provided by LSIs. Therefore, demand for EMI countermeasures for vehicle mounted devices is increasing as well.

LSIs installed in automotive components, in particular, need to have substantial low EMI strategies implemented for bandwidths between 76 MHz to 108 MHz range, which may deteriorate the sound quality of FM radio and car audio systems, as well as the bandwidth range that may impact keyless entry systems, etc.

Activities by OKI to reduce EMI emitted by OLED drivers include controllers for automotive components are described below.

The following are two primary routes in which EMI noise is emitted:

- Electromagnetic wave noise emitted from signal lines wired on printed circuit boards by the high harmonic wave components of input and output signals of an LSI.
- Electromagnetic wave noise emitted due to the parasitic inductance of an LSI package and from power supply lines wired on printed circuit boards by the power supply current of an LSI.

OLED drivers include controllers for vehicle mounted devices generate large quantities of EMI noise through large amounts of current driven output and switching operations of digital circuitry.

(1) EMI reduced of anode driver and cathode driver

The spike current on power supply, as well as the high harmonic wave components of the input and output signals, are generated through switching operations of the anode driver and cathode driver. It is for this reason the following strategies were implemented in order to reduce EMI noise:

- Insertion of timing control circuit to prevent generation of pass-through current in anode driver and cathode driver.
- Insertion of through rate control circuit for controlling through rates of output signals to limit high harmonic wave components of output signals.

- Insertion of circuit for dispersing output timing to prevent generation of spike power supply current exceeding simultaneous operation current.

(2) Reduction of EMI from controller

The digital circuits of the controller and graphic RAM, etc., operate in synchrony with clock used to display. This causes the generation of large spikes in the power supply current. Because of this the following steps have been taken to reduce EMI noise:

- Dispersed clock timing with the application of a non-synchronous circuit to inhibit spiking power supply current.
- Optimized access timing of the graphic RAM to inhibit the spike power supply current.
- Built in de-coupling capacity.

It is not possible to eliminate EMI noise generated by the excitation of the parasitic inductance of a package triggered by a spiking power supply current in the LSI, with a de-coupling capacity located externally in the vicinity of an LSI. Therefore, a de-coupling capacity was provided to eliminate EMI noise generated by the parasitic inductance and inhibit the spiking current of the digital circuit at the same time.

The provided decoupling capacity, C, necessary for eliminating EMI noise, was obtained from the relationship between the total amount of charge, ΔQ (calculated from the forecasted current consumption, I, and clock frequency, f) and the allowable power supply voltage range for circuit operations, ΔV.

$$C = \Delta Q / \Delta V = I / (f \times \Delta V)$$

(3) Evaluation results

By reducing EMI noise product development was shortened through a reduction in the frequency of the developmental design returned for redesign. This was realized by simulating the power supply noise for each circuit design block starting at the early stages of development.

The results of the spectrum simulation for the power supply current following implementation of EMI reduction strategies on the driver are shown in **Fig. 1**, the results of the spectrum simulation for the power supply current on the digital circuit with and without a built in de-coupling capacity are shown in **Fig. 2** and the results of spectrum measurements for the power supply voltage after implementation of EMI reduction strategies on the driver are shown in **Fig. 3**. The effects of the power supply current noise reduction can be verified using these figures.

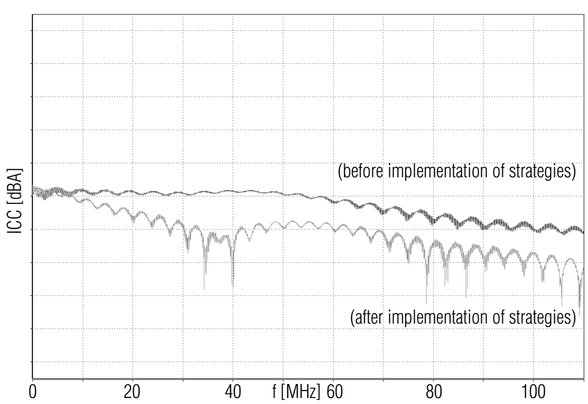

Fig. 1 Power supply current of drive circuit Results of spectrum simulation

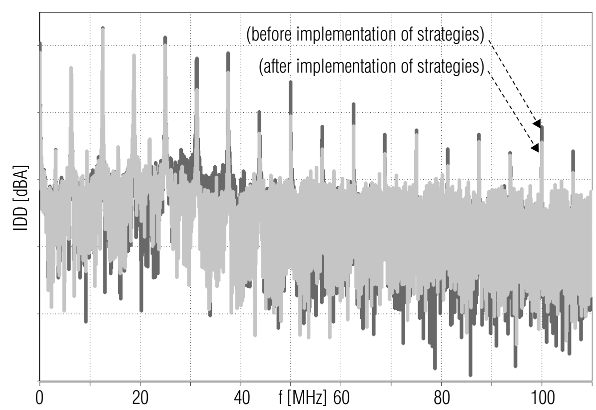

Fig. 2 Power supply current of digital circuit Results of spectrum simulation

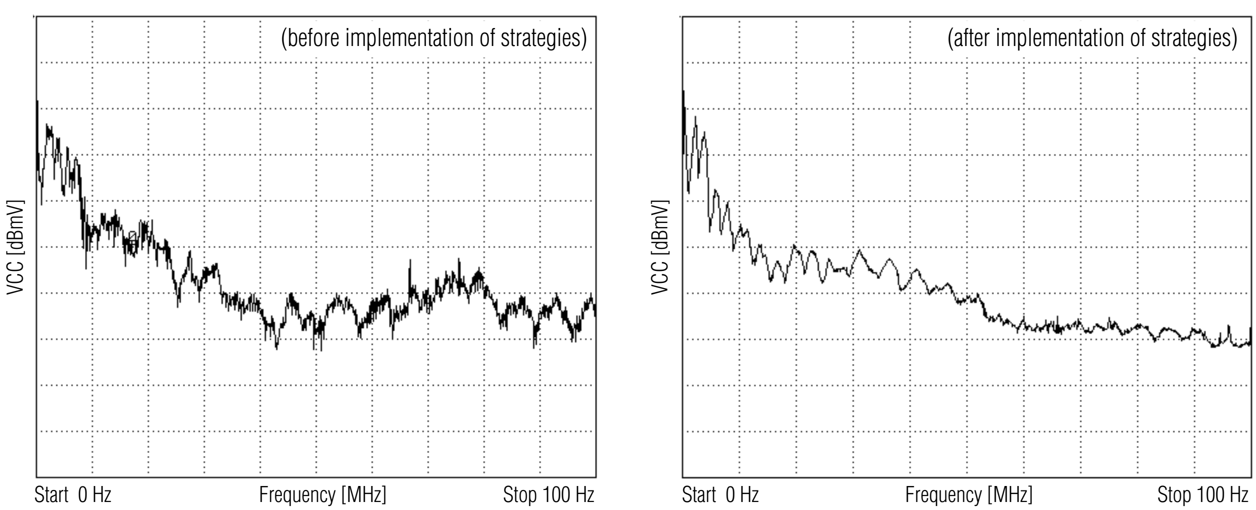

Fig. 3 Results of spectrum measurements for power supply voltage on driver

Table 1 Lineup of single chip OLED drivers include controllers for automotive components

Product name		ML9351	ML9352
Number of display drive outputs	Number of anode drivers	156	128
	Number of cathode drivers	38	32+1 (for static display)
Power supply voltage	OLED drive voltage	12 to 20 V	18 to 30 V
	Digital power supply voltage	2.7 to 3.3 V	3 to 5 V
Graphic RAM capacity		23,712 bit	4,096 bit
Operating temperature range (Tj)		-40 to +125 degrees Celsius	-40 to +125 degrees Celsius
Anode driver output current		0.3 mA (max.)	0.8 mA (max.)
Anode driver adjacent output current error rate		±1 %	±1 %
Cathode driver on resistance		12 Ω (max.)	10 Ω (max.)
Host interface		80/68 system 8/16 bit parallel	80/68 system 8 bit parallel serial
Supported gray scales	Current level	128 steps	2 steps
	Data level	4 gray scales 254 steps	2 gray scales 241 steps
Display image processing functions		Horizontal/vertical/offset display, partial display, window access setting, memory display range setting	Horizontal/vertical/offset display, partial display, window access setting, static display
Display timing control functions		Anode pulse width setting, pre-charging period setting, discharging period setting, built in oscillator	Anode pulse width setting, pre-charging period setting, discharging period setting, built in oscillator

OKI's single chip OLED drivers include controllers for automotive components

OKI's line of single chip OLED drivers include controllers with characteristics and functions necessary for the displays of automotive components, is shown in **Table 1** and features of these OKI products are described below.

(1) ML9351

This is capable of providing a constant current drive output of up to a maximum of 0.3 mA, which is suitable for automotive components, such as car audio systems. It offers a four gray scale 254 step brightness control function and display control function for one screen display into two screen display data, both of which are built in.

This single chip OLED driver include controllers supports displays with a maximum of 156 anodes and 38 cathodes. It incorporates a reference voltage regulator for reference current generate of anode driver and a Low voltage regulator for a digital circuit, which are both built in.

(2) ML9352

This product is capable of providing a constant current drive output up to a maximum of 0.8 mA, which is suitable for automotive components that require an high brightness for the instrument panel and other display devices. It also provides a built in dimmer switch function for night modes that links up with the turning on of the headlights.

This single chip OLED driver include controllers supports the display of up to a maximum of 128 anodes and 32 cathodes, as well as static displays. A reference voltage regulator for reference current generate of anode driver is built in.

Conclusion

Descriptions of the development for elemental technologies required of OLED drivers intended for automotive components, as well as single chip OLED drivers include controllers available from OKI have been provided in this paper. Activities intended to increase the functional levels are currently under way through such means as realizing high resolution images through further reductions of EMI to make it suitable for the spectrum dispersed clock, including increasing the number of gradations and number of resolutions, as well as the incorporation of graphic engines.

Furthermore, we intend to make positive endeavors to develop the driver include controllers for active matrix OLED panels in the future.

References

1) Mayuko Uno, "Passive Matrix OLED Display", Nikkei Electronics, No. 946, February 26, 2007.
2) Shinichi Fukuzako, et., al: "Development of OLED Driver and Future Outlook", Oki Technical Review, Issue 196, Vol. 70, No. 4, pp. 32 to 35, 2003.
3) Masami Tsuchida, "OLED Made Easy: For Beginners to Experts" from "Display Drive Circuit: FY2004 OLED Seminar Collection of Lecture Notes", pp. 27 to 31, 2004.

Authors

Naoya Kimura: Oki Network LSI Co., Ltd., Design Solution Business Group

Shuji Furuichi: Silicon Solution Company, Custom Business Div., Consumer LSI Design Dept.-2.