ML9156: A Liquid Crystal Television Driver Enables Display of One Billion Colors

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The popularization of liquid crystal televisions in recent years has generated remarkable momentum. There are two reasons for this. The first reason is due to the progress in research conducted by domestic liquid panel manufacturers in Japan. The angle of visibility and dynamic image qualities improved and the same level of display characteristics that were so familiar in television sets using cathode ray tubes (CRT) are now achieved with liquid crystal television sets. The other reason is the great impact of changes in the market environment arising from the commencement of land-based digital broadcasting (broadcasting started in Kanto, Kinki and Chukyo blocks in December 2003), which increased the number of programs broadcast in the high definition television mode and electrical household appliances have become part of the interior design. Features, such as increasing the screen sizes, thinning profiles and reducing the weight are considered to be of high value in spite of the high prices in the current television replacement market. Furthermore, abolishment of all analog broadcasting by the broadcasting satellites (BS), communication satellites (CS) and land-based broadcasting stations as a national policy is planned for 2011. Therefore, the growth of the large screen liquid crystal television market, which takes into consideration matters such as the switching of television broadcasting and reception methods as well as offering a substantial lineup of land-based broadcast digital tuners and other similar peripheral devices, is expected to continue in the future as well. This trend is no exception in North America, Europe nor in countries of Asia, as the popularization of liquid crystal television is growing on a global scale.

This paper describes the latest technologies and features of the source driver LSI, which drives liquid crystal television sets.

Technological Trends of Source Driver LSI

Thin film transistor (TFT) panels have been adopted for liquid crystal panels used for displaying images in motion including liquid crystal television sets. Display on a TFT panel is achieved by using two types of driver LSIs, a source driver LSI (vertical line gray level driver) and a gate driver LSI (horizontal line selection driver). The technological traits of the source driver LSI are described in this section.

Simply put, the function of the source driver LSI is to perform the following operations:

① Input digital data for display that is acquired from the timing controller.

② Convert the digital data into analog voltage gray levels.

③ Output the analog voltage gray levels to source signal lines (vertical lines of a liquid crystal panel) of individual RGB (three primary colors, red, green and blue) colors.

The following two aspects can be mentioned as features:

- In order to load color gray levels to the TFT panel the output voltage of a certain level, such as from 10V to 16V, is necessary as analog voltage gray levels are output by the source driver (power supply voltage of ordinary logic devices is in the proximity of 3.3V).
- A gray level voltage gamma curve must be built in for the purpose of compensating for RGB colors through the selection of one particular voltage level from among numerous gray voltage levels available in graduating levels created from the aforementioned high voltage through the voltage division. These gray voltage levels are used to express various colors.

Further improvement of the dynamic image quality of liquid crystal television sets is a technical issue that needs to be dealt with using the source driver LSI and the following three aspects are improvement performances for addressing this issue:

(1) Increase the number of gray levels.

(2) Speed up the output of the rising time / falling time.

(3) Add a black image insertion function.

The circumstances that brought up the need to have a black image insertion function and a description of the function are provided in this section. The method used by the CRT for generating light to display images and just for an instant making the luminous body become dark immediately after light is emitted is called the impulse method. This is a display method that provides a light emission and darkness set for one display period, another light emission and darkness set for the next display period and so it keeps repeating in this combination. The luminous picture elements of liquid crystal panels, on the other hand, are constantly in a luminous condition throughout any given display period. It is for this reason that images of changing scenes, such as repeated motion, on liquid crystal panels caused incidental images in the eyes of the viewer and because of this a smooth dynamic image quality could not be attained (this is known as "trailing" and it is a phenomena where objects in motion leave incidental images by apparently dragging the hems, so to speak, as they move).

Black image insertion is a means of improving such dynamic image quality of liquid crystal panel displays using a light emission method that is similar to CRT. Although the picture elements of liquid crystal displays are in a luminous condition at all times during each display period, it is still possible to create a condition resembling the impulse method artificially by periodically inserting black images for short periods of time. The dynamic image characteristics of liquid crystal television sets improved significantly by adopting this kind of black image insertion method.

Functional Summary of ML9156

At Oki Electric we developed the ML9156, a source driver that realizes the kind of performance improvements described above, with mass production and shipping of the product starting in January 2005. This marked the first recorded production and shipment in the world of source driver LSIs that make it possible to display one billion colors. A summary of the functions incorporated into the ML9156 is provided below.

- 10-bit data input = 1,021 level gray output.
- Low power mode availability (charge sharing function).
- Black image insertion function availability.
- Logic voltage: 2.7V to 3.6V.
- RSDS interface availability.
- Liquid crystal driving voltage: 10.0V to 16.5V.
- Output dynamic range: 9.6Vp-p to 16.1Vp-p.
- Data transmission clock frequencies:
  For standard conditions, fmax = 85MHz.
  For high-speed conditions, fmax = 110MHz.
  (High-speed conditions: VCC = 3.2 ± 0.2V, VCM = 1.2 ± 0.15V, RSDS amplitude = 200 ± 20mV.)
- Setting function for multiple outputs including 384ch, 414ch and 420ch.
- TCP and COF dual package, dual purpose chip.

Image Quality Improvement Performance Realized by ML9156

Provided are detailed descriptions of the features realized by the ML9156 for the aforementioned three performances, (1) to (3), to improve the image quality of liquid crystal television sets.

(1) The number of gray level outputs, which is approximately four times that of conventional products, raises the number from 256 gray levels (two to the power of eight) based on 8-bit data input signals to 1,021 gray levels (two to the power of ten minus three) based on 10-bit data input signals. When these figures are converted into the number of colors displayed, there is an increase from 16.77 million colors (8-bit = 256 [R] × 256 [G] × 256 [B]) to over one billion (10-bit = 1,021 [R] × 1,021 [G] × 1,021 [B]), increasing by approximately 60 times the number of colors displayed. This makes it possible to realize a much more detailed color expression for liquid crystal television sets.

By simply installing an analog voltage circuit with 10-bit (two to the power of ten) gray levels in the LSI, however, increases the chip's size. A detailed description of our patented voltage divider method, adopted for this reason for the analog voltage circuit in the ML9156, is provided.

Let us take the example of a magnified view of a portion taken from a gamma curve in the diagram shown on the left in **Figure 1**. The right upper diagram depicts a segment of the curve for conventional 8-bit data, while the right lower diagram depicts a segment of the curve derived from an application of voltage, in which a further voltage division of four has been applied between individual gray level points. The gray level points indicated with larger dots are exactly the same as those on the curve of conventional 8-bit data. Since three additional voltage levels have been added between individual gray levels, as shown with smaller dots, it is possible to obtain approximately four times the number of gray levels by using the voltage levels of the larger and smaller dots combined. The additional three voltage levels are selected by responding to the lower two bits of the 10-bit data. This made it possible to realize a configuration of the analog voltage circuit inside the LSI for the upper eight bits of data, which is identical to the circuit for conventional 8-bit data.

In terms of chip dimensions the method used for the ML9156 reduces the chip size to three-fourths in comparison with conventional methods that involve simply installing an analog voltage circuit for 10-bit

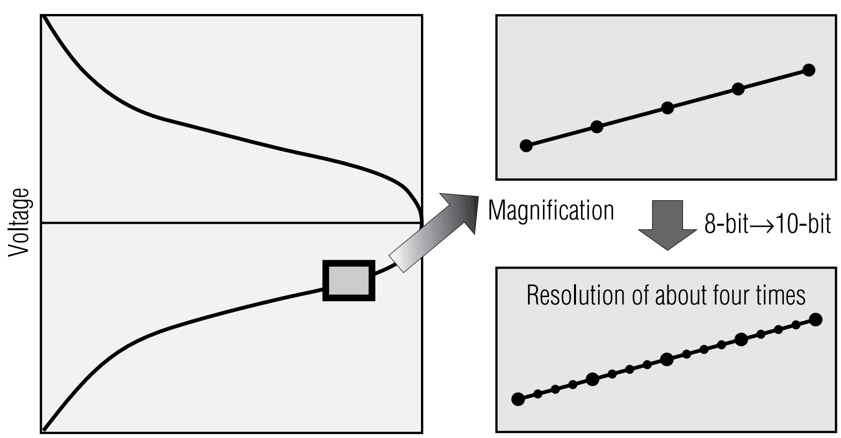

Fig. 1 Difference in display color resolutions of 8-bit and 10-bit data

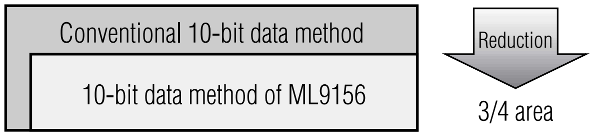

Fig. 2 Reduction of chip dimensions by our patented method

gray levels in the LSI (refer to **Figure 2** on the next page).

(2) A high-speed charge sharing circuit and output buffer are optimized to speed up the rising time and falling time of the output. The former is a charge sharing circuit created by our unique method, which realizes high-speed rising time and falling time operations with a low power consumption by reusing the electric charge stored in the TFT elements of liquid crystal television sets.

The self-heating of chips has become an issue of concern since the screen dimensions of liquid crystal televisions have progressively increased in recent years, resulting in the driving of TFT elements that present a large load capacitance. A significant byproduct of this charge sharing circuit that offers lower electric power consumption is the realization of chip, which reduces self-heating by approximately 40%. The amount of heat generated in a liquid crystal television set, for example, could be reduced by as much as approximately 15 degrees Celsius. This also makes it possible to sustain the high reliability of the LSI as well.

A description of a charge sharing circuit operation is provided in **Figure 3**. The amount of voltage level variations (ΔV) with a conventional source driver output waveform, as represented by the waveform at the bottom, has to be driven entirely by the source driver LSI itself. With the charge sharing waveform represented by the waveform at the middle, however, it is possible to drive up to the mid point (half of ΔV) of the voltage level variation by shorting all source signal lines, without the LSI consuming any electric current itself. The principle behind this is the condition when all source signal lines are shorted, electrical charges transfer freely among individual source signal lines and average out their electrical potential in line with the average level of electrical charge for all TFT elements, even without any from the LSI at all. Since all of the electric current consumption for driving the voltage level up to the mid point of the LSI is eliminated, about half of the electric current charged or discharged to TFT elements and about 40% of electric current consumption for the entire source driver LSI is eliminated.

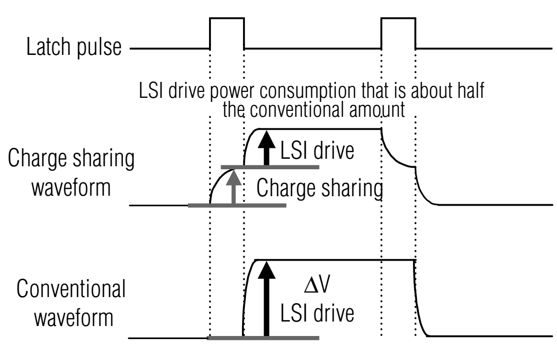

Fig. 3 Conceptual diagram of charge sharing method

(3) The pseudo impulse drive method, which is the black image insertion function, has become essential for liquid crystal television sets. This function can be realized in a variety of ways and with the ML9156 it is possible to support both the normally white and normally black panel methods. As mentioned earlier, this function does not rely on the gray level data of the respective outputs but forcibly outputs a black gray level. It is possible to insert black images at an interval that is controlled by an external signal. Furthermore, although the specifications for black image insertion vary depending on the driving methods of the TFT element, the optional loading of customized black image insertion specifications is available with the ML9156. Support for the various TFT element driving methods of liquid crystal television sets is provided using such optional functions for black image insertions. When dynamic images on crystal liquid television sets of various manufacturers are compared obvious differences emerge among those for which the black image insertion method is suitable for the particular TFT element drive method used and those with a poor compatibility, even to the eyes of a novice viewer. The type of images that bring out this kind of difference in a clear manner are scenes of images where the background transfers at a high speed, such as an image that shows the following of the ball of a home run in a baseball game or a soccer ball in play. As the integration of the black image insertion becomes more complete in liquid crystal television sets, the quality of such dynamic images becomes obviously better.

Other ML9156 Features

The data input method of the ML9156 is the RSDS interface input, which realizes a low EMI. Input data is supplied by 15 paired lines (five pairs of input for each RGB color). In addition to the support of a maximum frequency of 85MHz, operation at a rate of 110MHz is also possible in the range of VCC = 3.0V to 3.4V in

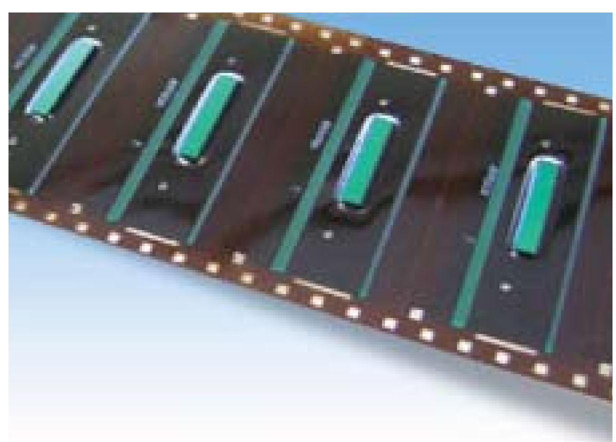

Photo 1 Photograph of TCP mounting of ML9156

response to the high-speed drive required in recent years.

The output dynamic range covers a drive range from 10.0V to 16.5V in order to ensure support for a variety of panel drive methods. A wafer process dedicated to the source driver was developed in order to realize such a broad range of voltage specifications. This resulted in the smallest chip size in the world for a 10-bit equivalent source driver.

Furthermore, in order to meet mounting conditions the device is available both as a tape carrier package-type (TCP) product and also as a chip on film-type (COF) product (**Photo 1**).

Future developments

This paper described the performance of the ML9156 for which mass production and shipping has already begun. Product developments currently ongoing are progressing with the features mentioned in this paper.

Specifically, work is being performed on the following four items:

(1) Optimization of wafer process

A new wafer process is being developed, which is a fusion of a cutting edge process and high-voltage process. This rising time process not only reduces the chip size but also raises the quality levels with consideration for lowering the logic power supply voltage. Shipping of samples for source driver LSIs to which this wafer process has been applied is scheduled to become available from the third quarter of fiscal 2005.

(2) Adoption of individual RGB gamma drive method

This is an approach for faithfully reproducing colors, which differs from simple multiple gray level outputs. With this method outputs are driven using the gamma curves of the three individual colors, red, green and blue. A liquid crystal panel performs color expressions by putting light through color filters for each RGB color. In reality, the permeability of light (the brightness of light visible through color filters) varies individually for each color. For this reason, there will be a deficiency in the color expression performance for skin tones and such images if an identical gamma curve is used to perform gray level expressions for all RGB colors, as is the case at the present time. In order to improve this issue a gamma curve for individual RGB colors can compensate for this by responding to the color filters of individual colors for which the permeability is known. Consequently at Oki Electric, we plan to develop a new drive method with which color compensation for a variety of liquid crystal television sets will be possible.

(3) Increasing Number of Outputs

The ML9156 has 420 channels of source signal outputs. Main stream large liquid crystal television sets at the present time would require ten of these chips per unit, whereas units supporting full high vision broadcasting, to which Japan will be transitioning to very shortly, would require fourteen chips of these source driver LSIs per unit. Out of concern for chip and mounting costs, significant cost reductions can be achieved by increasing the number of output channels per chip, such as increasing the number to 840 channels, which is double what is currently available, then the number of chips that need to be mounted can be reduced to half. The amount of electric current consumed by chips, on the other hand, increases in proportion with the increase in the number of output channels of a chip. This means that the aforementioned self-heating of chips will become a potential problem and, unless this issue can be resolved an increase in the number of outputs will not be possible. Our efforts at Oki Electric are focused on the issue of reducing the self-heating of chips in order to realize an increased number of outputs by source driver LSIs.

(4) Adopting New Interface Method

The two mainstream-types of interface methods currently available for source driver LSIs used in liquid crystal television sets include the RSDS method, which has been adopted for the ML9156 and the mini-LVDS method. We have, however, invented a new interfacing method that reduces the number of wirings on substrates for the purpose of reducing costs relating to the source driver mounted substrates installed in liquid crystal television sets. Although other issues remain, including methods for mounting devices onto TFT panels, we plan to resolve these by conducting joint experiments with panel manufacturers.

Conclusion

In March 2005, we acquired the TFT driver business of TI (Texas Instruments, Inc.). In the future, we plan to develop fused technologies that feature the characteristics of both companies and offer solution proposals, which will also include system integrations.

TIPS Basic Glossary

TFT: Thin Film Transistor.
Gamma curve: Step curve of the gray level voltage used to bring the color on liquid crystal panels closer to natural light colors.
RSDS (Reduced Swing Differential Signaling): A transmission method using digital signals developed by National Semiconductor Corporation.
Normally white: A panel method that allows light to permeate without the application of any voltage to the liquid crystals (white screen).
Normally black: A panel method that prevents light from permeating without the application of any voltage to the liquid crystals (black screen).
mini-LVDS: A transmission method for digital signals jointly developed by Texas Instruments Japan Limited (Japan TI) and IBM Japan Ltd.

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