A New External Compensation method for AMOLED Display

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ABSTRACT

The external compensation circuit and method have been used for metal-oxide-compound-semiconductor thin-film-transistor (Oxide TFT) in the active-matrix organic light-emitting diode (AMOLED) display. However, the real time compensation is very difficult, and the number of fan-out lines should be increased for the conventional external compensation. A new compensation circuit and driving scheme are proposed to reduce fan-out lines and to realize a real time compensation. The application of Oxide TFT would be expanded using this method.

1 Introduction

AMOLED (Active-Matrix Organic Light Emitting Diode) display has been expanding its application from mobile phone to large area TV [1].

Two thin film transistor (TFT) technologies have been utilized for AMOLED display. The internal compensation scheme has been mainly used for Low Temperature Polycrystalline Silicon (LTPS) TFT in mobile applications such as smart watches and mobile phones while the external compensation method for Oxide TFT is thought to be suitable for TV applications. These two technologies have their pros and cons. [2][3]. The larger substrate would be suitable for the larger area display. It is very difficult to use LTPS in the larger substrate such as Gen 8.5 (2200x2500 mm^2). So, Oxide TFT would be proper technology for larger area AMOLED display.

It has been known that the shift of threshold voltage (V_{TH}) is one of serious problems for the internal compensation in case of Oxide TFT. In order to solve this problem, the external compensation technology has been used [4]. However, the external compensation requires additional fan-out lines in the panel and pads to read out the pixel characteristics in the driver IC. Generally, the cost of IC is determined by chip area, which is affected by the number of pads, so-called ‘Pad limit’ [5]. Therefore, the cost of IC is cut down if the number of I/O pads is reduced by combining the sensing line and the data line. As well, the conventional external compensation hardly realizes the real time compensation during displaying because the time to extract V_{TH} of driving TFT in every pixel is very long, for about several milliseconds. Therefore, the extraction of V_{TH} would be mainly done in turn-on and turn-off period. We cannot avoid the concerns about degradation of image quality during the displaying without real time compensation.

In this work, a new external compensation scheme has been proposed to reduce fan-out lines and to realize a real time compensation.

2 New Pixel Circuit

Fig.1 shows the OLED pixel circuit for conventional external compensation which requires two vertical signal I/O lines for each pixel. [2] One is for video data input and the other is used to read out the characteristics of driving TFT (Thin film transistor) and OLED in each pixel. As for Fig. 1, several pixels may share the sensing line to reduce the pixel circuit area and the number of I/O pads of the driver IC. However, we still cannot eliminate the additional sensing line. As well, the reduction of sensing line means that the total sensing time for whole panel should be increased. For this reason, the real-time compensation becomes more difficult.

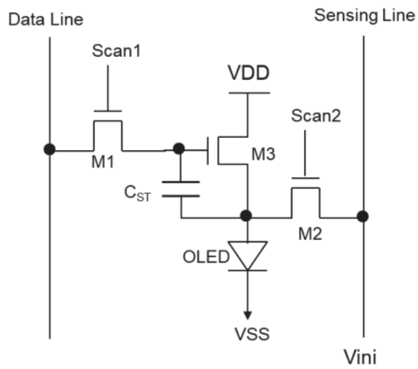

Fig. 1 Conventional pixel circuit for external compensation

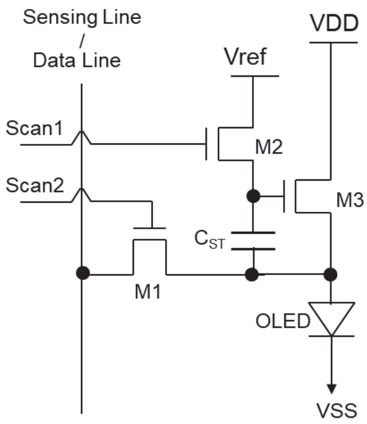

Fig. 2 New pixel circuit for external compensation

	Conventional	New
V_g	$V_{data}+V_{th}$	V_{ref}
V_s	V_{ini}	V_{data}-V_{th}

Table.1 Comparison of M3 V_{GS}

We propose a new pixel circuit in order to further reduce the I/O pads for the external compensation.

Fig. 2 is the schematic diagram of our new pixel circuit. In the conventional pixel circuit of Fig. 1, the V_{GS} of M3 TFT is the difference between V_{data} and V_{ini} of the sensing line, while in our pixel circuit of Fig. 2, that is the difference between V_{ref} and V_{data}. V_{data} is determined based on the characteristics of M3 and the OLED while V_{ref} is a constant bias voltage. As shown in Fig.2, the data line is also used to read-out the characteristics of M3 and the OLED. It means that the pads of IC can also be shared for both writing data and reading characteristics by time dividing. Although the V_{ref} line is still required in Fig. 2. Different from the sensing line in Fig. 1, it can be drawn as a horizontal line through a couple of sub-pixels in the pixel area and converged into a single pad of the driver IC because it is a DC bias voltage. As a result, the area of the pixel circuit is reduced, and the number of IC pads is minimized.

3 Compensation Scheme

As we discussed, the relatively long time is required to extract V_{TH} of M3 depending on the panel load as shown in Fig.3, Generally, several milliseconds should be required to obtain the saturated value. During displaying, the longtime cannot be allowed without any disturbing image quality. Therefore, V_{TH} extraction mainly occurs at turn-on or turn-off period in the conventional method. And the compensation is carried out to compensate for only the

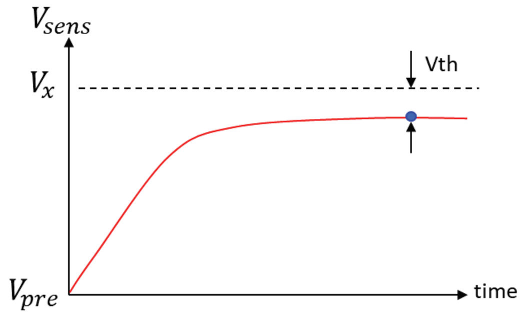

Fig. 3 Sensing time and level

Carrier mobility of M3 during displaying. The carrier mobility is a very important factor, but V_{TH} would be more serious factor to degrade the display quality.

If the sensing can be conducted cumulatively by several steps, each step might require a relatively short time, for about several microseconds, as shown in Fig.4. The V_{sens} reaches a certain value, S1, after completing the 1st sensing step. S1 is stored at the memory. And then, the sensing line is pre-charged by S1. The V_{sens} reaches S2 at the end of 2nd sensing step. The same processes are repeated and finally the saturated V_{sens} can be obtained. The difference between final value and V_{ref} is V_{TH} of M3. The new diving scheme is proposed to use the porch time which is the interval between frames. The V_{TH} of all pixels in one selected horizontal line is extracted during porch, however the porch time is insufficient to obtain the stable V_{TH} as we discussed. Fig.5 shows the driving scheme. If one porch were 300 microseconds, 4 or 5 porches can be required to extract the reliable V_{TH} for 15 inches QHD (2560×1440). The time to extract V_{TH} of all pixels would take about one minute. The update of compensation data can be conducted every minute. It is almost a real time compensation. Of course, it is not perfect real-time compensation, but the V_{TH} hardly changes in several minutes. In case of the conventional method, the frequency of V_{TH} update cannot be set because the displaying time is different by users. However, we can expect the update frequency in the new method, so the characteristics' requirement can become clearer.

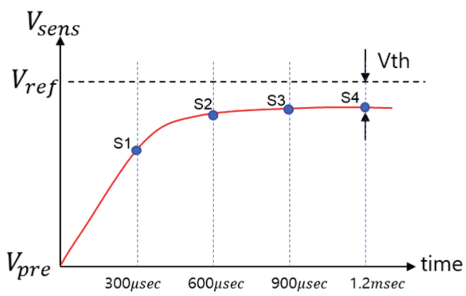

Fig. 4 Concept of multi-step V_{TH} sensing

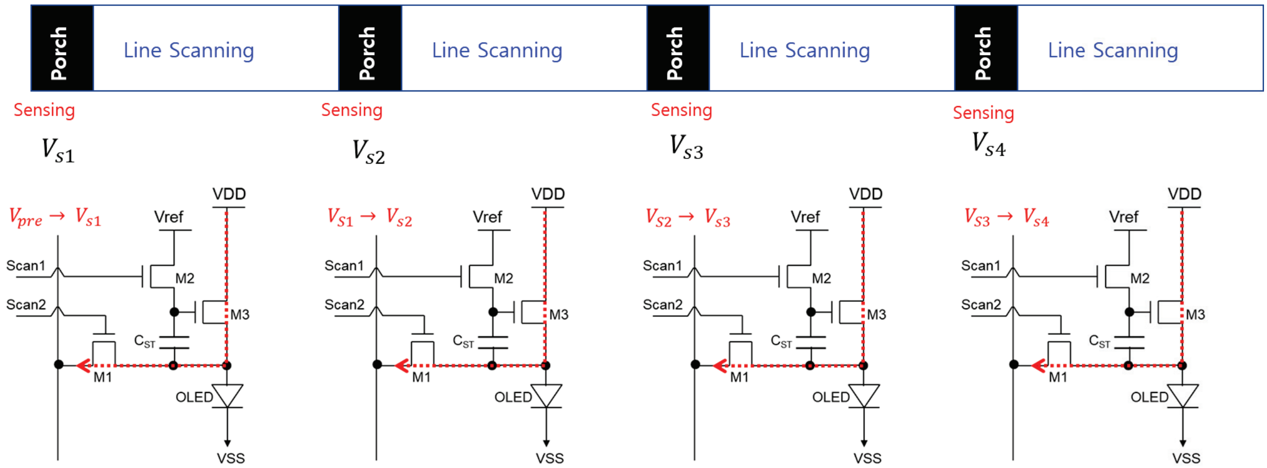

Fig.5 Scheme of circuit operation for V_{TH} extraction

The degradation of OLED can be also detected by the following procedure using the proposed circuit. When Scan1 and Scan2 turn on, the proper voltage applies to the gate electrode of M3. Then, Scan1 turns off, and the voltage level of sensing line slowly rises unitll finally it is saturated at OLED's anode voltage. The difference of anode voltage represents the ratio of degradation. This scheme is similar to the conventional external compensation method.

4 Result and Discussion

Fig.6 shows the simulation result. The simulation has been conducted under 50 pF load and 120 Hz refresh rate. The porch time is 300 microseconds. The V_{sens} rises rapidly in the first sensing step. It is saturated within 5 sensing steps. The extracted V_{TH} is 1.83V and the actual TFT parameter has 1.87V of V_{TH}.

The current of M3 to emit OLED is controlled by not only V_{TH} and the carrier mobility. In order to make the accurate current, the carrier mobility should be extracted. The carrier mobility can be calculated by the first V_{sens}, V_{S1}, after extracting V_{TH}. V_{S1} is determined by the current and the load capacitance, and we can calculate the carrier mobility because the load capacitance and V_{TH} have been obtained. The different method to compensate for the variation of carrier mobility is proposed. The additional one sensing step is set to compensate for V_{TH} variation. If all pixels' V_{TH} could successfully be extracted, the variation of V_{sens} would be due to the carrier mobility deviation. The difference between each pixel's V_{sens} and the average of V_{sens} can be compensated finally.

Increasing the number of sensing step can enhance the accuracy of the extracted data. However, the frequency of update should get longer. As mentioned above, 120 Hz refresh-rate QHD resolution need one minute update time in case of five porches. If the panel load were 5 times and vertical resolution were 2 times, the update interval would be 10 minutes. The degradation of Oxide

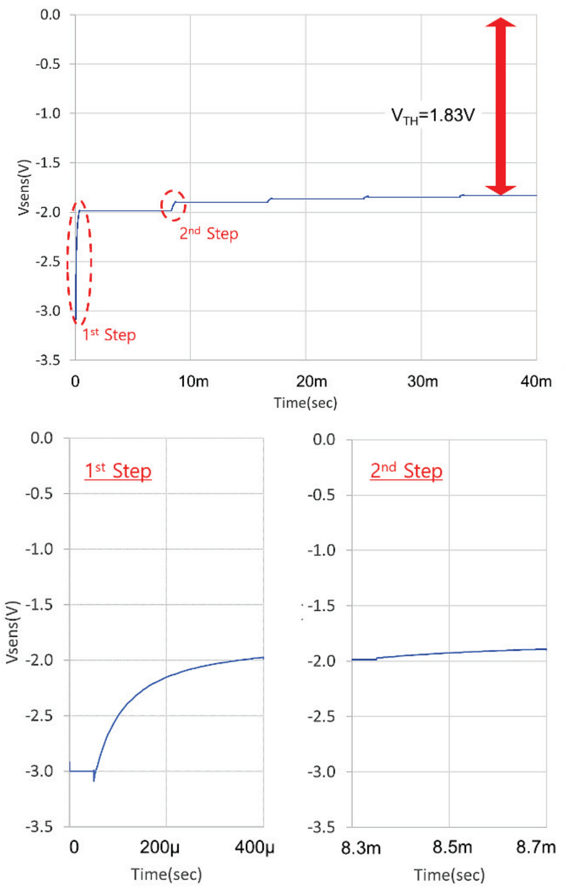

Fig. 6 Simulation Result (Under 50pF load and 120Hz Refresh rate)

TFT cannot be serious within 10 minutes. Therefore, the compensation can be performed almost in real time by our new concept.

5 Conclusions

Our new compensation circuit and driving scheme can successfully reduce fan-out lines and realize a real time compensation. The sensing and data writing are carried out by the same line at the different time. The additional sensing lines are not required, and V_{TH} extraction can be updated within several minutes.

The application of Oxide TFT would be expanded by using this method from OLED TV to IT application.

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