

On-Panel Analog Output Buffer with Level Shifting Function in LTPS Technology

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An analog output buffer with level shifting function containing the digital-to-analog converter (DAC) of gamma correction, which is suitable for integrated on glass substrate for panel application, has been designed and verified in a 3- μ m low temperature poly-silicon (LTPS) technology. The new proposed circuit utilizes DAC with gamma correction of 3-V liquid crystal (LC) specification, but it can also drive the 5-V liquid crystal to meet the desired 5-V gamma curve without redesigning the DAC with 5-V gamma correction parameters.

1. Introduction

LTPS technology with its higher mobility characteristic, which has been widely applied in active matrix liquid crystal display (AMLCD), is conceived as one of most desirable technology to accomplish system-on-panel (SOP) integration for portable systems, such as digital camera, mobile phone, personal digital assistants (PDAs), notebook, and so on. SOP application has the potential to realize compact, highly reliable, and high resolution display by integrating functional circuits within a display. With all sub-circuits integrated on panel, the cost of panel becomes lower as well as the higher yield rate can be achieved [1]. Furthermore, some poly-Si TFT characteristics, such as high carrier mobility, low threshold voltage, high stability, and high reliability, are required to fulfill the SOP application. The carrier mobility depends on the grain size of the active poly-Si layer, and the deviation of the characteristic of the TFT is related to the quality of the poly-Si layer [2]. Some recent literature had been reported to suppress the variation of poly-Si TFT characteristics to further redeem SOP application. In [3], a class-B output buffer with offset compensation had been proposed to compensate the offset of output buffer to provide high resolution display and uniform brightness display. In [4], a new gate-bias generating technique with threshold-voltage compensation had been presented to reduce the impact of threshold-voltage variation on analog circuit performance in LTPS technology.

The periphery circuit blocks of LCD panel are roughly composed of four parts: display panel, timing

control circuit, scan driver circuit, and data driver circuit. Display panel is constructed of the active matrix liquid crystals and the operation of the active matrixes is similar to DRAM (dynamic random access memory) which is used to charge and discharge the capacitor of the pixel. Timing control circuit is responsible for transmitting RGB (red, green, and blue) signals to the data driver and controlling the behavior of scan driver. Data driver circuit, shown in Fig. 1, is composed of shifter register (S/R), data latch, level shifter (L/S), DAC, and analog output buffer. Shifter register and data latch are used to transit and store the RGB signals while level shifter translates the RGB signal to a higher voltage level due to the higher operating voltage of active matrixes. In addition, DAC is used to convert the digital RGB signal to analog gray level with consideration of gamma correction. The LCD panel with larger panel size or higher resolution display results in larger load, so the analog output buffer is essential to provide the driving capability of the data driver [5].

Some kinds of circuits had been successfully integrated on TFT-LCD substrates for SOP application. In [6], a low power consumption TFT-LCD with dynamic memory embedded in each pixel has been proposed to hold a digital data corresponding to display image in the memory, so the operation of data driver can be stopped to reduce power consumption. In [7], it reported the first LCD equipped with all the circuits to display static images continuously for up to one year powered with only a button battery. In [8], an 8-bit CPU containing 13,000 TFTs on a glass substrate suitable for LCD mass production was reported to demonstrate the feasibility of the SOP.

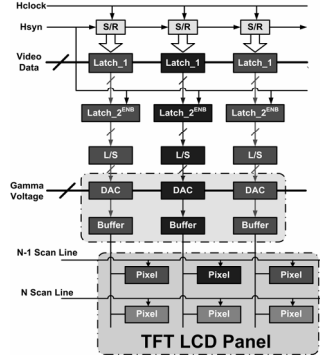


Fig. 1. The basic diagram of data driver circuits for TFT LCD Panel.

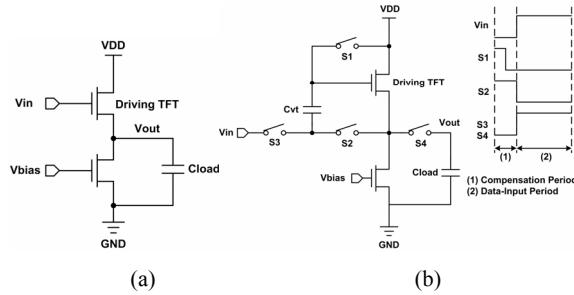


Fig. 2. (a) Conventional source follower analog output buffer with active load, and (b) the modified source follower analog output buffer with compensation capacitor [9].

In this work, an analog output buffer with level shifting function containing the DAC circuit with gamma correction, which is suitable for data driver circuits integrated on glass substrate for panel application, has been designed and fabricated in a 3- μm low temperature poly-silicon (LTPS) technology. The new proposed circuit realizes the DAC with gamma correction of 3-V liquid crystal (LC) specification, but it can also drive the 5-V liquid crystal with the desired 5-V gamma curve without re-designing the DAC with 5-V gamma correction parameters.

2. Conventional On-Panel Analog Output Buffers

Source follower is one of the most popular analog output buffers integrated on the glass substrate for data driver duo to its high input impedance and low output impedance. For such simple architecture, some drawbacks are found such as smaller output swing and higher input offset voltage. Fig. 2(a) shows the conventional source follower of analog output buffer with active load [9]. The final output voltage in Fig. 2(a) with different input voltage is kept constant but has an offset voltage from the input value, in which the offset is

determined mainly by the threshold voltage of the driving TFT. Besides, the threshold voltage is not a constant in different panel locations due to the LTPS device variation. To balance the input offset voltage, Fig. 2(b) shows the modified source follower of analog output buffer with compensation capacitor. In the compensation period (1), S1 and S2 are turned on, so the voltage drop is stored in compensation capacitor (C_{vt}). In the data-input period (2), S1 and S2 are turned off while S3 and S4 are turned on. At the meanwhile, the gate voltage of the driving TFT is applied with the voltage difference hold in C_{vt} added to the input voltage V_{in} . Thus, the output voltage is compensated by the voltage stored in C_{vt} .

The offset voltage was decreased by the aforementioned compensation technique. However, the offset voltage, which is predominantly governed by the threshold voltage of TFT, may not be stored exactly in the capacitor due to the subthreshold leakage current. The large subthreshold current of poly-Si TFTs increases the offset voltage of analog buffers [10]. In addition, compensation capacitor utilized in this technique may also consume larger area. Therefore, Fig. 3 shows the analog buffer of source follower type with device matching technique and its timing diagram of operation. When the reset signal (Reset) is low, the voltage in output loading capacitor (C_{panel}) is reset. The input signal (V_{data}) is applied when the Reset becomes high, so the voltage in node A (V_a) grows to $V_{data} + |V_{th}|$ due to the diode connection of P1. (V_{th} is the threshold voltage of PTFT.) After that, P4 is turned on with the active signal and V_a decreases due to bootstrapping effect, as well as V_{ss} is transferred to C_{panel} . As V_a decreases to $V_{data} - |V_{th}|$, diode-connected P2 is turned on to hold this voltage. Therefore, the source voltage of P3 is about V_{data} and the threshold voltage is compensated by device matching. This analog buffer with device matching technique can reduce the offset by the subthreshold current of poly-Si TFT without using additional capacitor to store the threshold voltage of a poly-Si TFT.

Compared with the analog output buffer of source follower type, the unity-gain analog output buffer with an OP amp has higher on-panel analog driving capability [11]. Fig. 4 shows the two-stage OP amp utilized for unity-gain analog output buffer. The two-stage OP amp has larger unity-gain frequency, better slew rate, lower input offset voltage, better immunity to noise, and more steady circuit performance, as comparing to the analog output buffer of source follower.

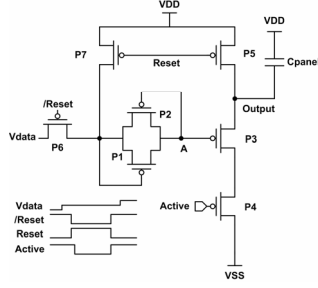


Fig. 3. An analog buffer of source follower with device matching technique and its timing diagram of operation [10].

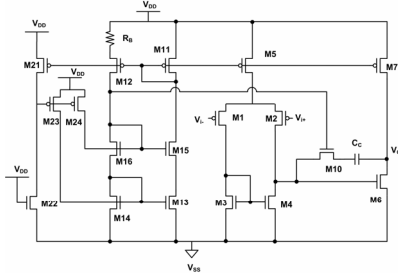


Fig. 4. Two-stage OP amp utilized for unity-gain analog output buffer [11].

3. New Proposed Analog Output Buffer with Level Shifting Function

In this work, a new analog output buffer with level shifting function is proposed to realize the DAC with gamma correction of 3-V liquid crystal (LC) specification, but it can drive the 5-V liquid crystal with the desired 5-V gamma curve without re-designing the DAC with gamma correction parameters. Fig. 5 shows the new proposed analog output buffer with level shifting function on glass substrate for panel application in 3- μm LTPS technology. R-string (RS00-RS64) and decoder 1 with digital input code Din are 6-bit R-string DAC circuit with gamma correction implemented by the R-string for 3-V liquid crystal panel application. When Din is 000000, decoder 1 transforms the digital input code to only turn on MS01 and V0 is assigned to Vin+ of OPAMP in Fig. 5. In the meantime, all the other voltages (V1-V63) are not transmitted to Vin+. Therefore, with proper digital input code, the corresponding voltage level is correctly chosen to meet each gray level in Vin+ for DAC circuit with gamma correction for 3-V liquid crystal panel application.

Fig. 6 shows two gamma curves for the liquid crystal panel under different operating voltages (3-V or 5-V). For different liquid crystal display, such as 5-V liquid crystal panel, the gamma curves are not only different to that under 3-V operation but also nonlinear in each gray level. In the new proposed circuit, 6-bit R-string DAC with gamma correction for 3-V liquid crystal display is not needed to re-design. OPAMP, decoder 2, R1, R201-R237, and MR01-MR37 are proposed to operate the analog output buffer with level shifting

function for 5-V operation. Decoder 2 receives the input signal from decoder 1 to turn on only one switch of MR01-MR37 at the same time. For example, if MR01 is turned on, the OPAMP behaves like a non-inverting amplifier with its function shown below

$$V_{out} = V_{in} \left(1 + \frac{R1}{R201} \right), \quad (1)$$

where $V_{in} = V_{in+} = V_{in-}$ if the gain of OPAMP is large enough. Therefore, with suitable design of R201-R237, gamma curve for 5-V liquid crystal panel can be achieved without redesigning the 6-bit R-string DAC that has been realized with 3-V gamma correction parameters. Fig. 7 shows the simulated gamma curves of the proposed circuit in a 3- μm LTPS technology for liquid crystal panel under 3-V or 5-V operations. Vin+ is the output gamma curve of 3-V liquid crystal panel and Vout is the output gamma curve of 5-V liquid crystal panel.

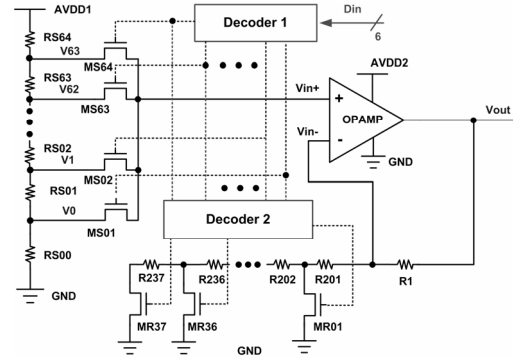


Fig. 5. The new proposed analog output buffer with level shifting function on glass substrate.

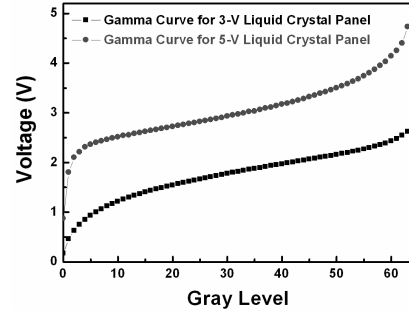


Fig. 6. Gamma curves for 3-V and 5-V liquid crystal panels.

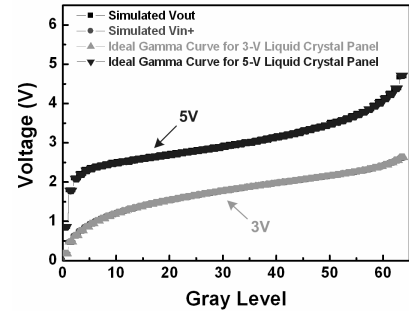


Fig. 7. Simulated gamma curves of the new proposed circuit for the liquid crystal panel under 3-V or 5-V operations.

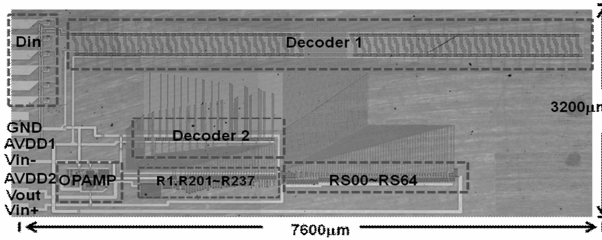


Fig. 8. Die photo of the fabricated analog output buffer with level shifting function on glass substrate in a 3- μ m LTPS technology.

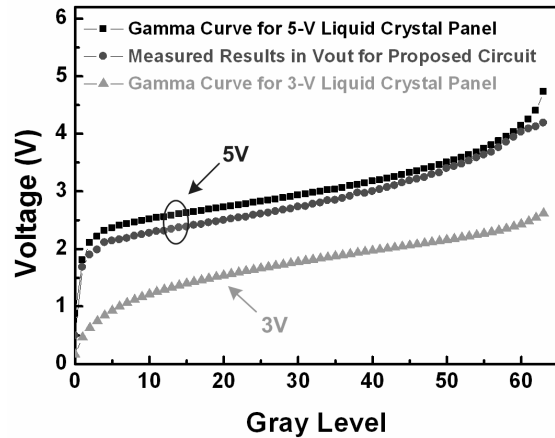


Fig. 9. Measured results of the new proposed circuit with gamma curve for 5-V liquid crystal panel but designed with the resistance ratio of 3-V gamma correction.

4. Experimental Results

The new proposed circuit has been designed and fabricated in a 3- μ m LTPS technology. Fig. 8 shows the die photo of the fabricated analog output buffer with level shifting function on glass substrate, where the area is 3200 μ m x 7600 μ m. Fig. 9 shows the measured result of the proposed circuit with gamma curve for 5-V liquid crystal panel but designed with the resistance ratio of 3-V gamma correction, where Vout is the output gamma curve for 5-V liquid crystal panel. With the transform function and proper resistance ratio, the simulated result is near to the ideal gamma curve with gamma value of 2.2. Somewhat, the measured result is not so well matching with the simulated result due to the variation of on-glass resistance after fabrication in LTPS process. Suitable adjustment on the layout of R-string resistance in the LTPS process, a more precise result of the proposed circuit can be achieved.

5. Conclusions

An analog output buffer with level shifting function on glass substrate for panel application has been successfully designed and fabricated in a 3- μ m LTPS technology. By using OPAMP, decoder 2, R1, R201-R237, MR01-MR37, and DAC with 3-V gamma correction parameters, the new proposed

analog output buffer can drive 5-V liquid crystal panel without re-designing the DAC with 5-V gamma correction parameters. This new proposed circuit architecture can be applied to different kinds of liquid crystal panels by modifying the corresponding resistance and the decoder.

Acknowledgments

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