

# An Emission Control Driver Using P-type TFTs for AMOLED Displays

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**Abstract:** We designed an emission control driver using P-type TFTs to adjust the light emission period of an active matrix organic light emitting diode (AMOLED) displays. The P-TFT emission control driver has achieved rail-to-rail driving and low power consumption. Using this circuit, we can control peak brightness dynamically to reduce panel power consumption and motion blur. We developed 4.3 inch WQVGA AMOLED panel with the integrated proposed circuit. The output rising and falling times of P-TFT emission control driver measured on panel are 300 ns and 1.2  $\mu$ s, respectively. The power consumption of the emission control driver with 272 stages is 0.2 W according to the measurement data.

## 1. Introduction

AMOLED displays are expected as promising next generation display applications because of strong point such as fast response time, thin, light, wide viewing angle, good color gamut, and bright luminance compared to liquid crystal displays (LCDs) and plasma display panels (PDPs) [1].

However, AMOLED displays have some problems, which should be solved for the mass production. Most of all, TFT backplane of AMOLED displays is very big issue. Hydrogenated amorphous silicon thin film transistors (a-Si:H TFTs) are considered as the backplane of the AMOLED due to low manufacturing cost and well matured technology. However, the threshold voltage ( $V_{th}$ ) shifts remarkably from initial value by gate bias stress. In addition, the turn on voltage of OLEDs also shifts considerably during the operating and the shift rates of  $V_{th}$  have been reported 0.1 – 0.25 mV/h [2]. So, without a compensation scheme, a-Si:H TFTs are not suitable for AMOLED displays because the poor reliability in short life time.

On the other hand, the characteristics of low temperature poly silicon (LTPS) TFTs are better than those of a-Si:H TFTs such as  $V_{th}$ , mobility, reliability and so on. However, the fabrication process of LTPS TFTs is more complicated and expensive in comparison with that of a-Si:H TFTs. Therefore, the cost reduction is a critical issue of LTPS TFT fabrication. Therefore, P-TFT only process has an advantage of the low cost as well as the simple process in comparison with both N- and P-TFT process. From the background above, we have developed only P-TFT emission control driver to adjust light emission period. This

new proposed emission control driver will help to solve the high power consumption and the non-uniformity in panel with controlling the light emission time.

## 2. Conventional P-TFT Emission Driver

LTPS TFTs have the process problems such as the variations of threshold voltage and mobility in comparison with single crystal silicon devices. So, compensation method for threshold voltage ( $V_{th}$ ) variation is generally applied to the pixel circuit to drive AMOLED panel using LTPS TFT. In order to compensate  $V_{th}$  variation, the emission control driver needs to cut off the current flowing into the OLED during the period of  $V_{th}$  compensation or the period of data writing time to improve contrast ratio of the panel. In addition, we have to control the peak brightness dynamically to improve the uniformity and decrease the power consumption of the panel. Therefore, a new emission control driver that can control the period of light emission is required.

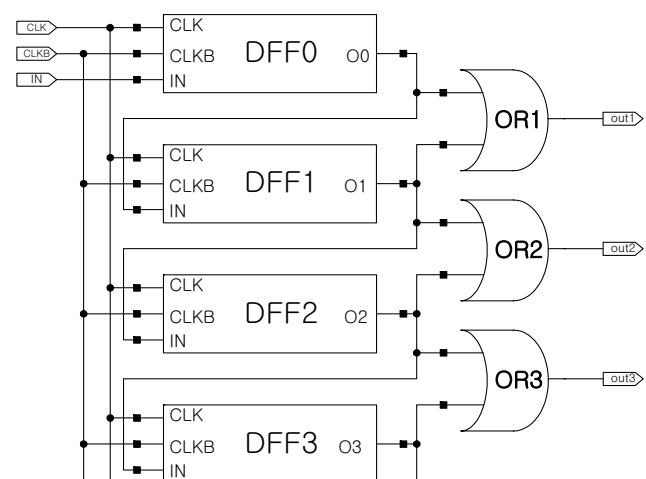


Figure 1. Block diagram of conventional emission driver.

Figure 1 is the block diagram of the conventional emission control driver, which is composed of D flip-flop (D-FF) and OR-gate, and all circuits consist of P-TFT. Mostly a master-slave pseudo static D flip-flop is used to obtain the stability. D flip-flop schematic is shown in Figure 2. This circuit has 4 inverters and 4 switching PTFTs. The inverters in the D flip-flop are also using PTFTs. In comparison with both N- and P-TFT process, p-type inverters cause high power during outputting high voltage level because the

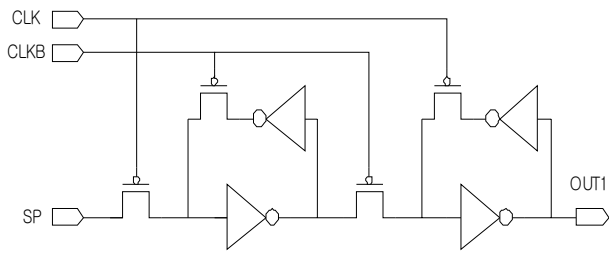


Figure 2. Schematic of a pseudo static D flip-flop.

static current path exists.

Consequently, if we use the pseudo static D flip-flop, power consumption considerably becomes high due to the static current path. The principle of operation is as follows. If *clk* is low level (0) and *clkb* is high level (1), new input signal is written to the master and output node maintains the previous signal stored in the slave. In opposition, if *clk* is high level (1) and *clkb* is low level (0), output node changes to the new signal stored in the master.

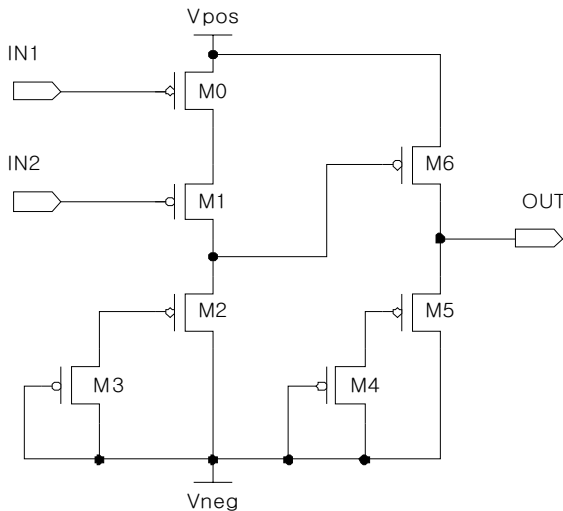


Figure 3. Schematic of P-TFT 2 input OR-Gate logic circuit.

The two inputs OR-Gate logic circuit is also composed of 7 PTFTs as shown in Fig. 3. If two input signals are all zero (low voltage level), static current path exists due to the M2 TFT, in the other cases, static current path exists due to the M5 TFT. The principle of the operation is as follows. If two input signals are all zero (low level voltage), M0 and M1 TFTs are turned on, M6 TFT is turned off, and the output node becomes low voltage level as M4 and M5 TFTs pull down the output node. In the other cases, M2 and M3 TFTs are turned on, and then the output node becomes high voltage level as M6 TFT pulls up the output node. In order to prevent high power consumption caused by the static current path, which is a conventional problem, we developed a new proposed emission control driver.

### 3. New P-TFT Emission Driver

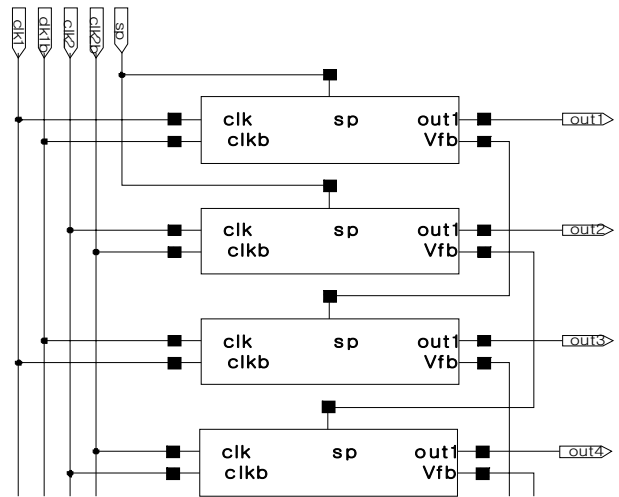


Figure 4. Block diagram of the proposed P-TFT emission Driver.

Figure 4 shows the block diagram of the proposed P-TFT emission control driver. This circuit has an advantage that allows the speed of the clock to slow, because the output signal is created in every half period of the clock. In addition, there is also another strong point. It is possible to reduce the RC-delay caused by input clock loads to half using the 4 input clocks separately.

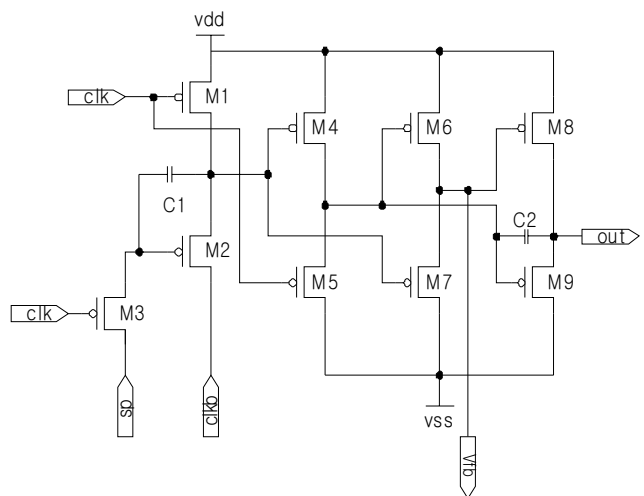


Figure 5. Schematic of proposed emission control driver.

Figure 5 shows the schematic of the proposed emission control driver. It consists of 9 TFTs and 2 capacitors. The input signals are two opposite phase signals such as *clk* and *clkb*, and one start pulse such as *sp*.

Generally speaking, it is more difficult to design the driving circuits by using only P-TFT because of the high power consumption due to the static current and the difficulty in pulling down the low voltage level perfectly.

However, the proposed circuit as shown in Fig. 5 is able to achieve not only the low power consumption by reducing the static current path, but also fully pulling down the output node by using the capacitor bootstrap.

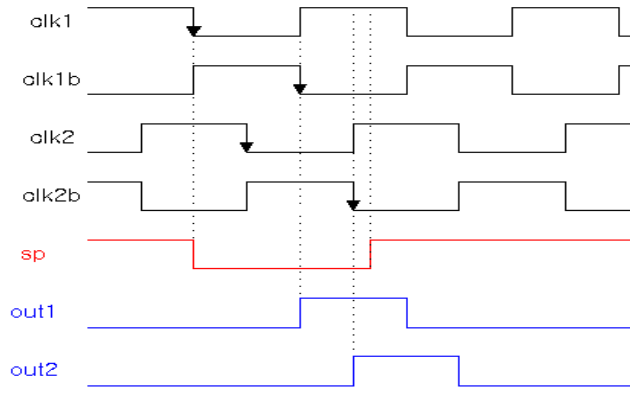


Figure 6. Driving waveform of emission control driver.

The driving waveforms of input and output signals for the emission control driver are shown in Fig. 6.

The driving principle of the new proposed circuit is as follows. If the clock (clk) signal and the start pulse (sp) signal are all low voltage level (0), M1 and M3 TFTs are turned on, and then C1(capacitor) is charged. At the same time, the output node becomes low voltage level as M5, M6, and M9 TFTs are turned on, M4, M7, and M8 TFTs are turned off. After this if clk signal is high level and clk b signal is low level, M1 and M3 TFTs are turned off, M2 TFT is turned on due to the C1 (capacitor) is charged, and then the source of M2 TFT comes to the low voltage level. Simultaneously, the output node becomes high voltage level as M4, M7, and M8 TFTs are turned on, and M5, M6, and M9 TFTs are turned off.

#### 4. Simulated and Measured Results

We have designed new proposed P-TFT emission control driver. Table 1 shows the simulation results of the conventional emission control driver and the proposed one. The conditions of the simulation are as follows. The rising and falling times of clk, clk b and sp signals are 50ns, and the driving voltage level of these circuits is 12V. The line resistance of output load is 10.3kohm, and the parasitic capacitance is 233pF. The driving voltage of emission control driver is 12V, and we simulated these circuits connected with 10 stages for 1 frame time.

Table 1. Simulated results of the conventional emission control driver and the proposed one.

	Conventional case	Proposed case
Rising time (μsec)	3.40	4.31
Falling time (μsec)	32.10	7.86
Driving Current (μA)	144.53	1.99
Current Ratio (%)	100.0%	1.4%

The rising and falling times of the conventional emission control driver are 3.4μsec and 32.1μsec, respectively. The average current of this circuit connected with 10 stages is about 145μA. On the other hand, the rising and falling times of the proposed one are 4.31μsec and 7.86μsec,

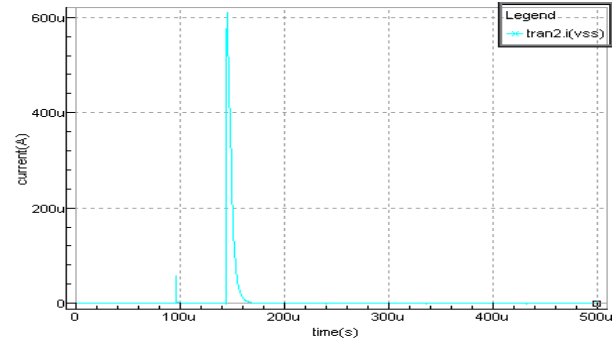


Figure 7. Current waveform of the proposed emission control driver.

respectively. The average current of this circuit connected with 10 stages is about 2μA. We have successfully reduced the average current by 98.6% in comparison with the conventional case as shown in the simulation results. Consequently, the power consumption of new proposed one is about a quarter of that of the conventional one.

Figure 7 shows the average current waveform of the proposed emission control driver. In the Fig. 7, the static current is extremely zero except that the dynamic current caused by the switching TFT turned on simultaneously flows for a moment.

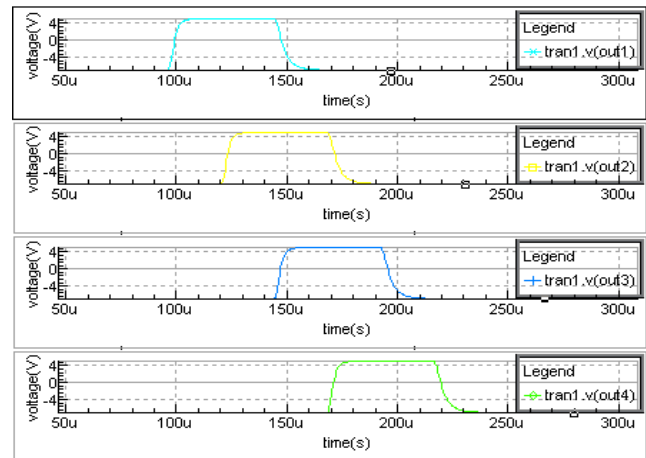


Figure 8. Output voltage waveform of proposed emission control driver.

There are the output voltage waveforms of the 4 stages of the proposed emission control driver as shown in Fig. 8.

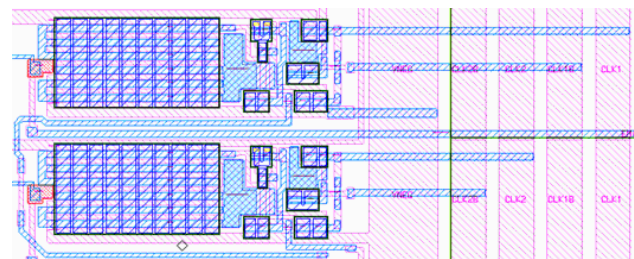


Figure 9. Layout of proposed emission control driver.

Fig. 9 shows the layout of P-TFT emission control driver integrated in 4.3 inch WQVGA AMOLED panel.

The line resistance of output load is  $3.2k\Omega$  and the parasitic capacitance is  $61pF$ . The emission control driver consists of 272 stages and the horizontal line time is about  $59\mu s$ . The driving voltage of new circuit is 12V.

We have measured the driving speed and logic power consumption of the proposed P-TFT emission control driver integrated in 4.3 inch WQVGA AMOLED panel.

The output rising and falling times were about 300ns and  $1.2\mu s$  respectively. The falling time was larger than the rising time in the measurement data. However, this is not a critical issue because the emission driver just controls the start of light emission. The power consumption of this circuit was about 0.2mW in the measurement data.

## 5. Conclusions

We developed 4.3 inch WQVGA AMOLED panel integrated new proposed emission control driver, which adjusts the light emission period to reduce panel power consumption and motion blur with only P-TFT fabrication process.



Figure 10. Display image of 4.3 inch WQVGA AMOLED.

The new proposed P-TFT emission control driver has achieved rail-to-rail driving and low power consumption by removing static current path. The output rising and falling times of proposed new circuit measured on panel were about 300ns and  $1.2\mu s$  respectively. The power consumption is 0.2 mW in the measurement data. We also succeeded to decrease the power consumption of the panel and to improve of luminance and contrast ratio by changing the light emission period according to the image load in the 4.3-inch WQVGA AMOLED panel.

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