Design of Low-Power TFT-LCD Source Driver

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Abstract

A low-power source driver for TFT-LCDs has been proposed using the triple charge sharing method that enhances the AC power saving efficiency of the prior charge sharing method. The AC power saving efficiency of the proposed source driver reaches 66.6%. In addition, a novel OP-AMP with low-quiescent current has been developed. The measured quiescent current of the OP-AMP is 5μA~7μA at VDD=5V and VSS=0V with load resistance of 2kΩ and load capacitance of 300pF.

Introduction

Panel AC power consumption caused by charging the source lines of the TFT-LCD panel and analog DC power caused by quiescent current of the OP-AMP are two major portions of power consumption of the TFT-LCD source driver[1]. Charge sharing method was introduced as the reduction method of panel AC power consumption[2][3]. But the maximum AC power saving efficiency of the charge sharing method is limited to 50%. So we propose a triple charge sharing method that enhances the panel AC power saving efficiency up to 66.6%. And low-quiescent current OP-AMPs for TFT-LCD source driver have been reported for reducing the analog DC power[4][5]. But the quiescent current of Itakura's OP-AMP[4] with slew-rate enhancement circuit is 10.1μA at VDD=3.3V and that of Yu's OP-AMP[5] with class-B push-pull output stage is 24μA at VDD=5V. The proposed OP-AMP has the quiescent current of 5μA~7μA at VDD=5V and VSS=0V with very simple structure.

Triple Charge Sharing Method

The architecture of the proposed source driver using triple charge sharing is shown in Fig.1. That consists of analog switches, one external capacitor for triple charge sharing and conventional source driver. SEL1, 2 and 3 are control signals of the analog switches for triple charge sharing. The signal AMP controls the output of the conventional source driver. The external capacitor, C_{EXT}, which acts as a power supply, is a large one.

$$C_{EXT} \gg N \cdot C_L \quad (1)$$

where N is the number of the outputs being driven.

In triple charge sharing method, one row line time is divided into triple charge sharing time and gray scale decision time, and the triple charge sharing time is composed of three charge sharing periods. Because C_{EXT} is initially not charged, V_{EXT}, the voltage of C_{EXT} is equal to ground level at the beginning. However, while the source lines are driven by the triple charge sharing method, V_{EXT} rises up by charge sharing between C_{EXT} and C_L whose voltage is going down from the positive to the negative video range. As a result, V_{EXT} settles down near $V_L+(1/3)V_{SWING}$ where V_L is a voltage level of the negative video signal range, V_H is a voltage level of the positive video signal range, and V_{SWING} is a difference between V_H and V_L after thousands of row line time.

Applying this triple charge sharing method to drive the TFT-LCD panel, voltage swing of the output buffers to charge the source line capacitance is reduced to a third of that of the conventional source driver, thus allowing AC power consumption of the proposed driver to be reduced to 1/3 that of the conventional driver. Because two-thirds of the swing is accomplished through triple charge sharing between source lines and the external capacitor.

Low-Quiescent Current OP-AMP

The proposed low-quiescent current OP-AMP is constructed by the modified folded-cascode block and push-pull output stage as shown in Fig.3. Fig.4 is the microphotograph of the proposed low-quiescent current OP-AMP. Fig.5 is the input and output waveform of the OP-AMP when we apply the 1V~4V pulsed input and Fig.6 is the measured quiescent current of the OP-AMP with various input voltage and VDD. The measured slew rate is over 6V/μsec and the measured quiescent current is 5μA~7μA at VDD=5V, VSS=0V, load resistance of 2kΩ and load capacitance of 300pF.

Power Consumption Analysis

To analyze the power saving efficiency of the proposed low-power source driver using triple charge sharing method and the low-quiescent current OP-AMP, we have to determine the gray scale decision time first, then assign the rest of the row line time for triple charge sharing. The gray scale decision time is defined as the time spent for charging the pixel electrode up to 99.9% of the applied input voltage level. The simulation conditions for power consumption analysis are summarized in Table.1. The simulated gray scale decision time and the triple charge sharing time with respect to the source line resistance, R_L, are presented in Table 2. As the R_L grows larger, longer time should be assigned for the gray scale decision time, which might deteriorate the power saving efficiency due to the insufficient triple charge sharing time. However, as shown in Fig.7, the power saving efficiency is still higher than 62% even when the R_L is 30kΩ. Fig.8 shows the measured output waveforms of the source driver using the triple charging method. As explained earlier, it is found that charging and discharging are achieved in three phases.

Conclusions

The low power TFT-LCD source driver using the triple charge sharing method and the low-quiescent current OP-AMP are proposed. The triple charge sharing method provides the power saving efficiency of 66.6%, while that of the prior charge sharing method is limited to only 50%. The measured quiescent current of the proposed OP-AMP is 5μA~7μA at VDD=5V. It has been also confirmed that this proposed low-power source driver is applicable to the 30-inch UXGA TFT-LCDs through SPICE simulation. Even though the source line resistance increases to 30kΩ as the display size gets larger, the power saving efficiency is still higher than 62%.

References

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[2] S.T. Kim et al., IDW 97. pp. 155-158, 1997.
[3] A. Erhart et al., SID 97 . pp. 23-26. 1997.
[4] Tetsuro Itakura et al., AM-LCD 1996, pp. 305-308.
[5] Pang-Cheng Yu et al., IEEE JSSC, jan. 1999, pp.116-119.

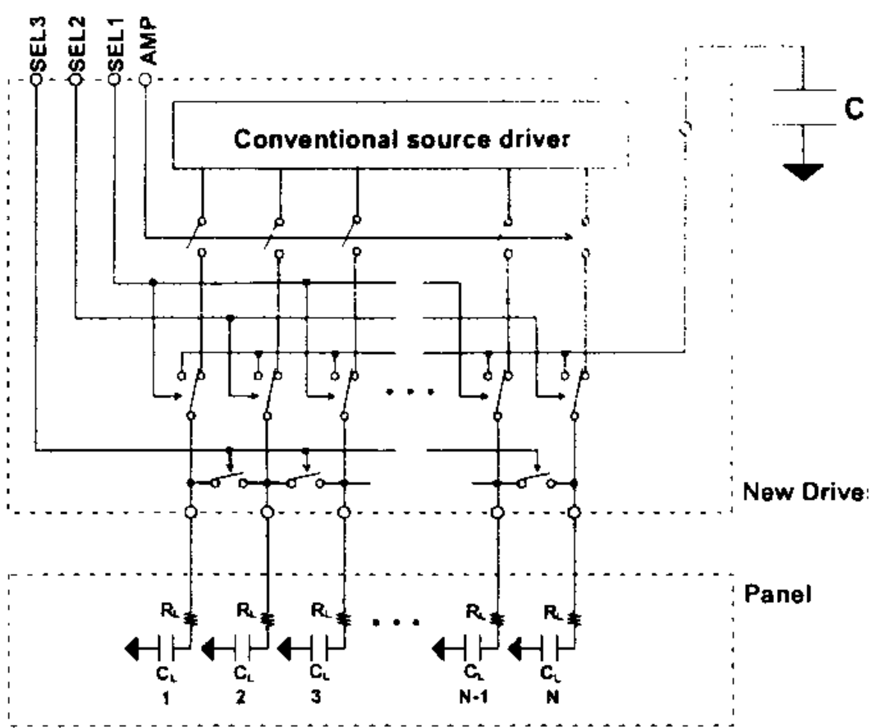

Fig.1. Proposed source driver using triple charge sharing.

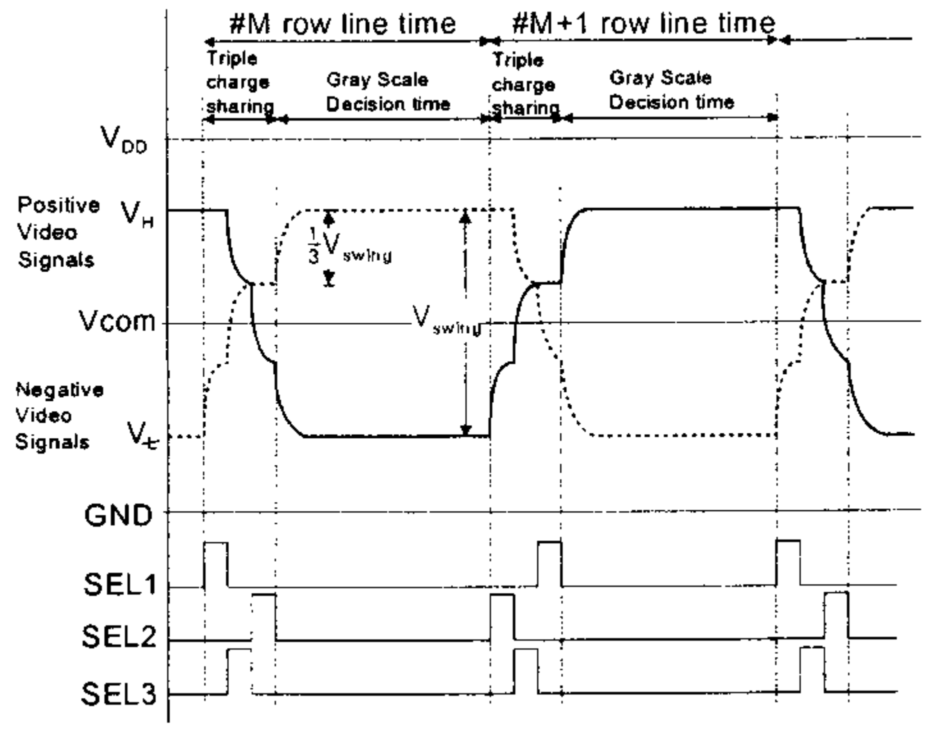

Fig.2. Timing diagram and output waveform of the proposed source driver (Solid line is voltage of the even-numbered C_L, dotted line is voltage of the odd-numbered C_L and Vswing is difference between V_H and V_L).

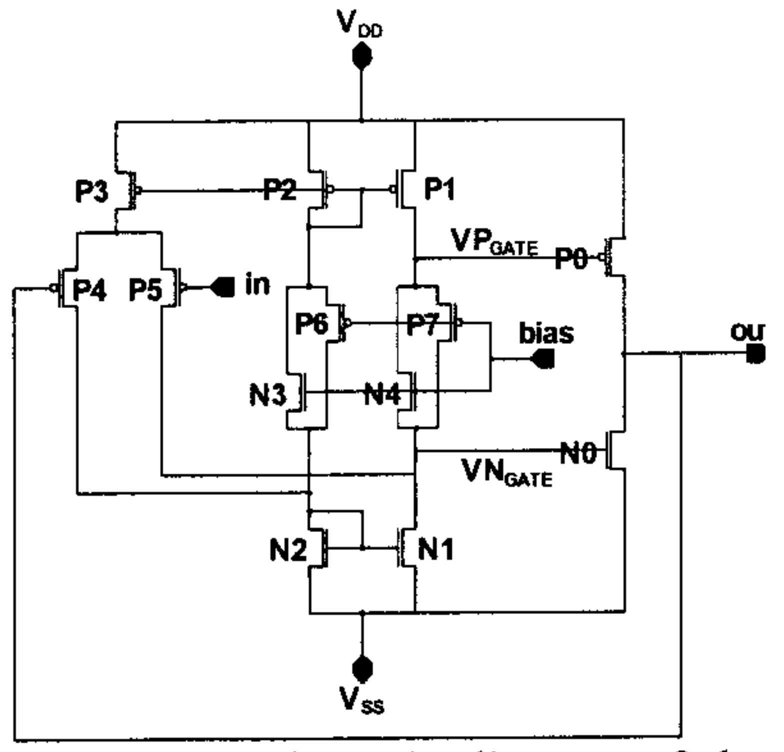

Fig.3. The schematic diagram of the proposed low-quiescent current OP-AMP.

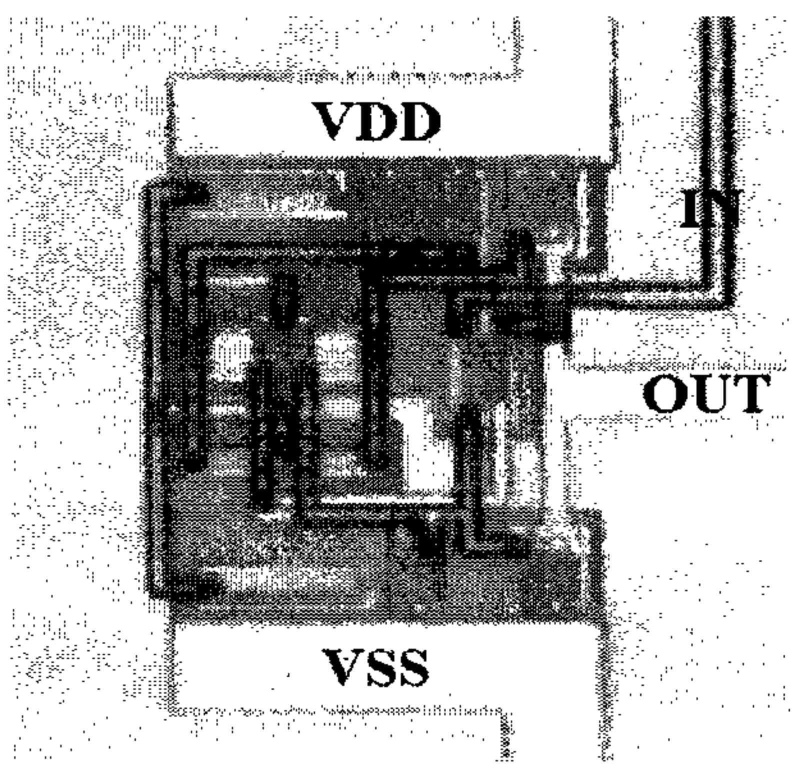

Fig.4. The microphotograph of the proposed low-quiescent current OP-AMP.

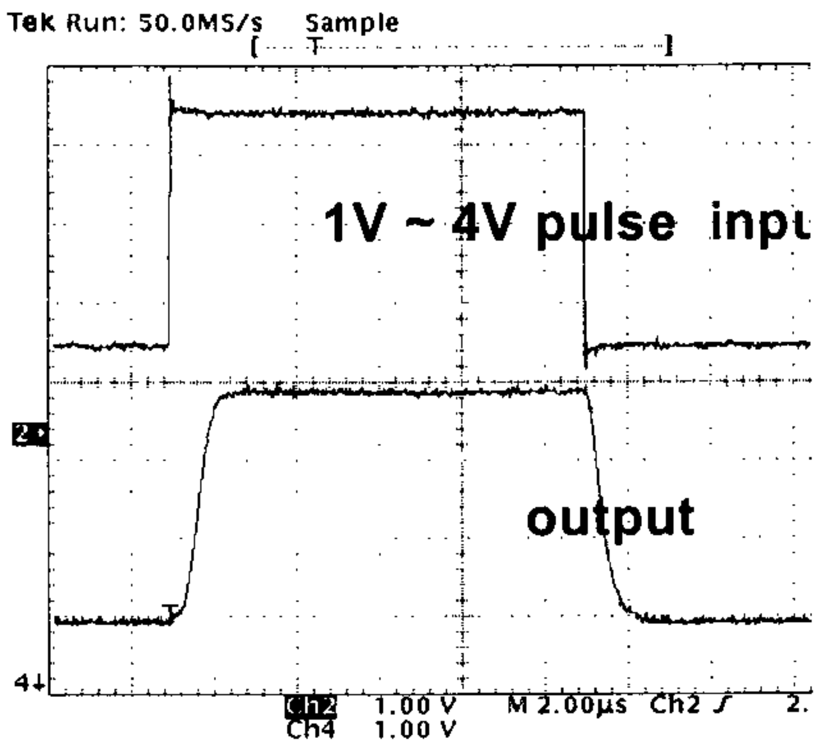

Fig. 5. The measured waveform of the proposed OP-AMP.

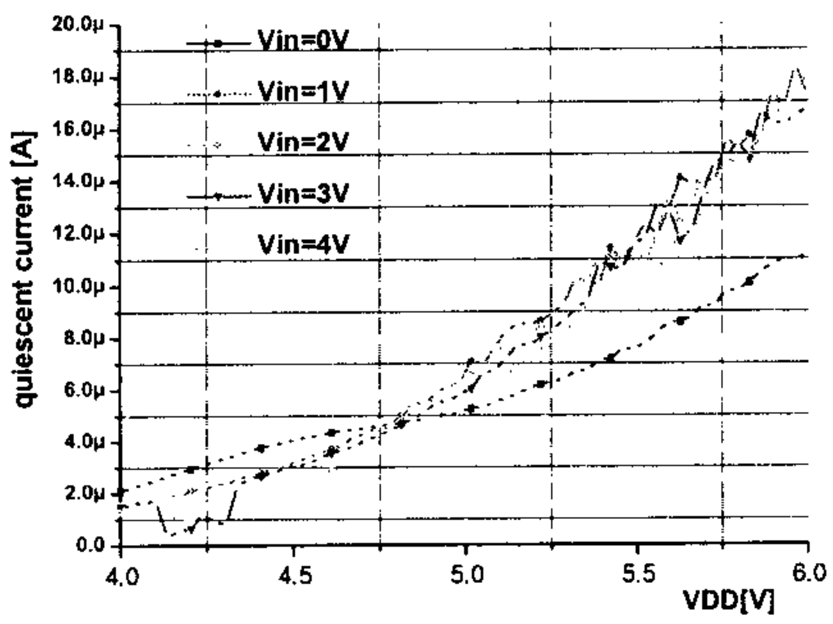

Fig.6. The measured quiescent current of the proposed OP-AMP with various input voltage

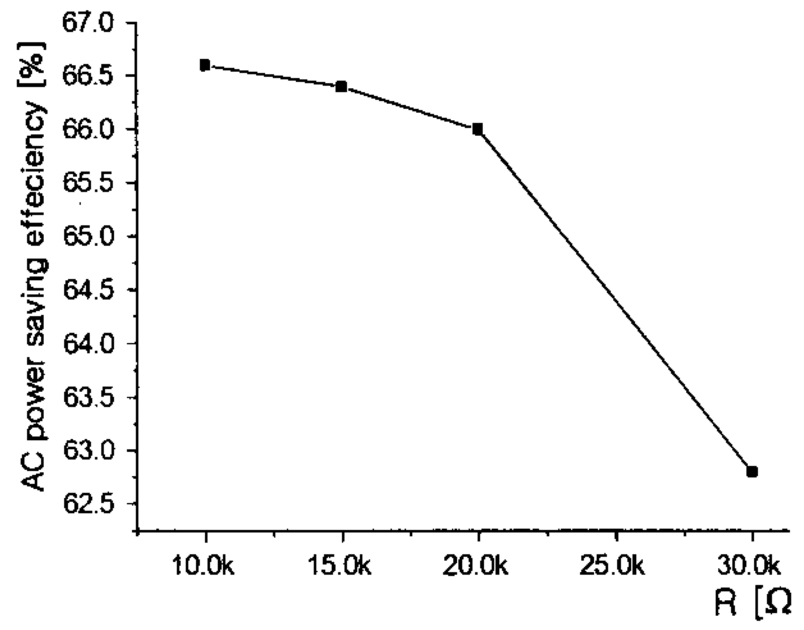

Fig.7. AC power saving efficiency of the proposed triple charge sharing with C_L of 125pF and varing R_L from 10kΩ to 30kΩ.

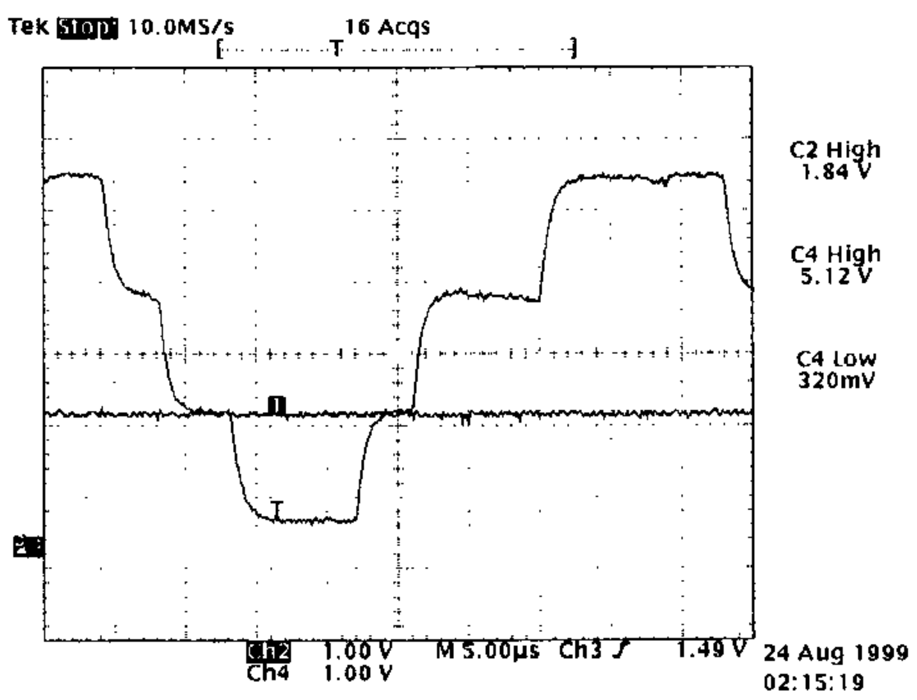

Fig.8. Measured waveform of the proposed source driver.

Table 1. Simulation condition.

Display Size	30-inch	Resolution	UXGA
Frame Freq.	75Hz	Row line time	22μsec
C_{EXT}	10μF	C_L	125pF
Capacitance of Gate line	500pF	Resistance of Gate line	3kΩ
TG* (W/L)	100μm/ 0.6μm	Pixel TFT (W/L)	20μm/ 6μm
		C_{STG}	1pF
		C_{LC}	0.3pF

*TG : Transmission Gate

Table 2. Simulated gray scale decision time and calculated triple charge sharing time.

	R_L = 10kΩ	R_L = 15kΩ	R_L = 20kΩ	R_L = 30kΩ
Gray scale decision time	6.7μsec	7.6μsec	8.5μsec	10.5μsec
Triple charge sharing time	15.3μsec	14.4μsec	13.5μsec	11.5μsec