# A Study on the Dual Power Management IC for AMOLED Display

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***Abstract***

*In this this paper, an IP driver block was designed and simulation conducted for an AMOLED display which supplies power as selected by users. The IP driver design focused on the regulation of output power, due to the OLED characteristic for diode electric current according to voltage, to be activate by pulse-skipping mode (PSM) under low loads, and 1.5 MHz pulse-width modulation (PWM) for medium/high loads. The IP driver was designed to eliminate ringing effects appearing from the dis-continue mode (DCM) of the step-up converter. Ringing effects destroy the power switch within the IC, or increase EMI to the surrounding elements. The IP driver design minimized this through a ringing killer circuit. Mobile applications were considered to enable true shut-down capability by designing the standby current to fall below 1uA for disable.*

***Keywords:*** *AMOLED, IP, IC, Driver, DC-DC*

## 1. Introduction

With the rapid development of information technology and rapid growth of consumer electronics market, smaller and more efficient switching power supplies have been widely applied. And the performance of power supply modules will directly influences the overall power consumption, reliability and cost of the electronic system. Therefore, the key specs of a switching power supply such as efficiency, stability, dynamic performance, integration level, *etc.*, have become the focus on which the researchers pay attentions [1-2].

AMOLED possesses excellent qualities of thin structure, vivid color reproduction, light viewing angles, quick response speed, high luminance, and high contrast versus low power usage, for the elements to self-radiate, so requires no back lighting, unlike the LCD.

Since OLED brightness is determined by electric current, and each AMOLED pixel is activated by the current driven method, AMOLED requires power whose current may be adjusted according to the demands of the user [3-4].

Accordingly for this paper, an IP driver block was designed and simulation conducted for an AMOLED display which supplies power according to user settings. The IP driver design focused on the regulation of output power, due to the OLED characteristic for diode electric current according to voltage, to be activated by pulse-skipping mode (PSM) under low loads, and 1.5 MHz pulse-width modulation (PWM) for medium/high loads. For output voltage regulation within 1%, for relatively high frequency of 1.5 MHz and efficiency, was designed as a synchronous rectifier type. Mobile applications were considered for achieving true shutdown by limiting current to under 1uA for turn-off. The soft-start and the thermal shutdown functions protect the IC by preventing in-rush current during IC enable [5-6].

## 2. The Structure and Operation Principle IC Driver

Output voltage regulation is very important for the AMOLED display dual power management IC. For both input voltage and load fluctuations, output voltage regulation within 1% is required. To achieve such specifications, high switching frequency of 1.5 MHz was selected, whereby efficiency was lowered compared to the DC-DC converter in general, but this will be corrected in the future. Output current was designed for a maximum 150mA, and maximum input current limited to 1A. IC protection circuitry includes UVLO (Under Voltage Lock-Out) and thermal shutdown, among others [7-8].

AMOLED display dual power management IP is basically designed as a DC-DC step-up converter, producing an output voltage of 4.9V from input ranges of 2.3 to 4.8 volts. Some step-up converter control techniques include the voltage-mode control and the current-mode control. This IP was designed by applying the current-mode control method with fast response to input voltage and load changes. It was designed by internal compensation to reduce external discrete element size. A high switching frequency of 1.5 MHz was selected for the small ripples in output voltage, thus was lowered in efficiency to below that of ordinary DC-DC step-up converters [9]. To compensate this point, discrete forms of freewheeling diodes were not used, but was designed using synchronous rectification, and efficiency was improved somewhat. The IP design eliminates the ringing effect found in DCM (Dis-Continue Modes) of step-up converters, which destroys the power switch within an IC or increases EMI to the nearby elements [10-11]. The IP design utilized the ringing killer circuit to minimize this. Mobile applications were considered to enable true shut-down capability by designing the standby current to drop below 1uA for disable.

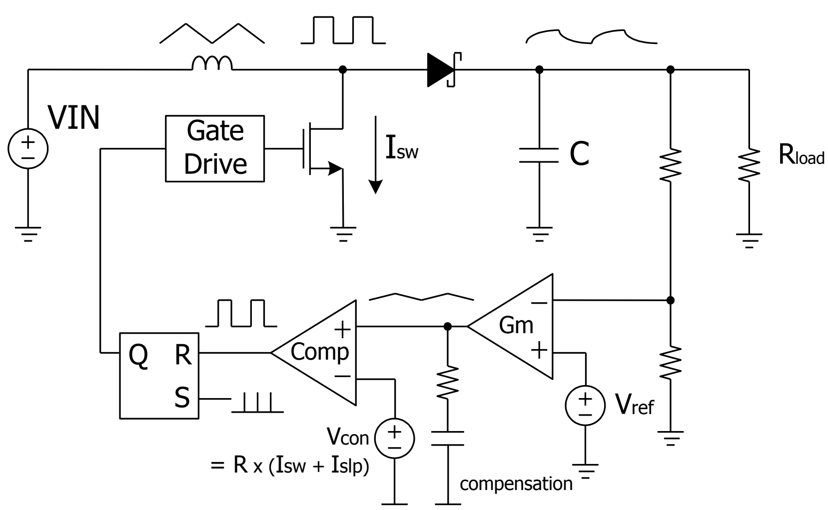


**Figure 1. Current-mode control scheme**

Figure 1 shows a step-up converter's general current-mode control scheme, a method where output voltage is fed back for the Gm amplifier and error comparator, *etc.*, to control the switch duty, to control the inductor current. Compared to the voltage-mode control technique, the current-mode control method is better for compensation, with good response characteristics for input voltage and load fluctuations. This IC design used internal compensation, with sufficient simulation to find a suitable compensation value [12]. Another important aspect of control is inductor current sensing, since only through accurate sensing is it possible to control the current to achieve the designed value for each input voltage and load conditions. Slope compensation is also an important part of the current-mode control method, since with this method, vibrations begin at switching duty values of over 50%. Therefore, inductor slope compensation is required. This IC was designed to compensate 1/2 of the inductor current down slope for safe operation.

## 3. The Design and Simulation of IC Driver for Dual Power Management IP

The most important element to be addressed with regard to LED operation of LCD backlighting system is the loss of electric power. Unless this is not kept minimized, the problem of heat generation may weaken the system competitiveness to a large degree.

This study aims to design an LED driver that controls the output of the boost converter for the optimization of voltage at both sides of the constant current source for LED string operation, in order to maximize the power consumption efficiency of an LED backlight device.

### 3.1. Design of Bias Blocks

Figure 2 is a functional block diagram of dual power management IP. Among the functional blocks in Figure 2, the driver block applies to the gate driver and synchronous driver, ringing-killer driver blocks. Step-up converter power switch uses a 5V 0.5Ω CMOS. Synchronous switch uses a 5V 0.8Ω CMOS. Ringing-killer switch uses a 5V 1Ω CMOS. Each switch was designed for non-overlap to prevent shoot-through. The power switch in particular was designed to reduce leading edge current spike by soft switching for turn-on, and hard switching for turn-off.

### 3.2. Gate Driver

Dual power management IP has a planned voltage output of 4.9V, with power switch element using a 5V 0.5Ω CMOS. Size of the power switch was designed for a width of 14mm and length of 500nm. To operate a power switch of this size, there must be a gate driver with sufficient sourcing/sinking capacity to allow rise & fall in desired time. Also, to reduce peak currents occurring during switching on the gate driver, a non-overlap circuit was selected. With the block designed for rising time of 10nsec and falling time of 3nsec, in order to reduce the leading edge peak current, turn-on uses soft switching and turn-off uses hard switching.

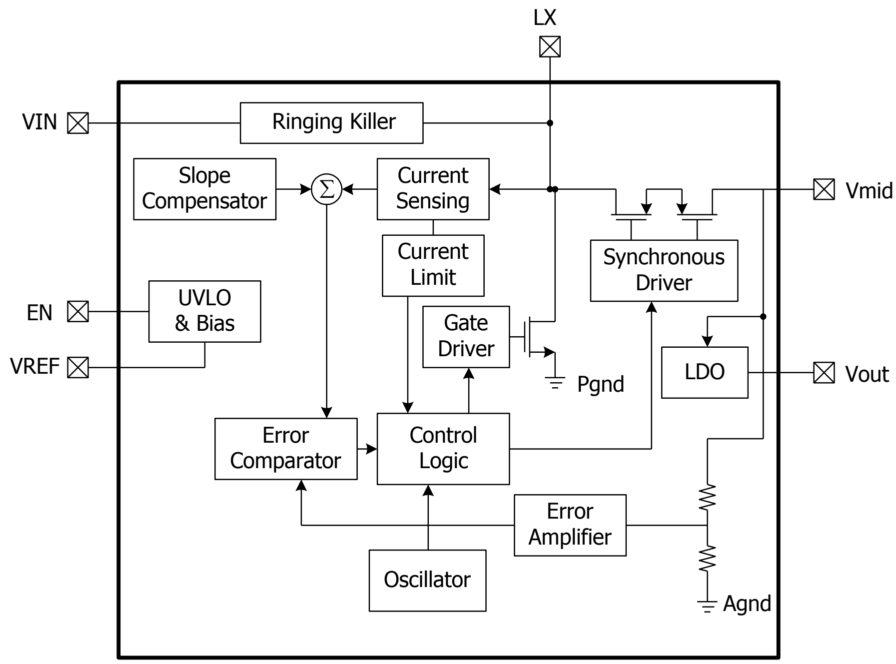


**Figure 2. Functional block diagram**

Figure 3 is the schematic of the designed power switch driver.

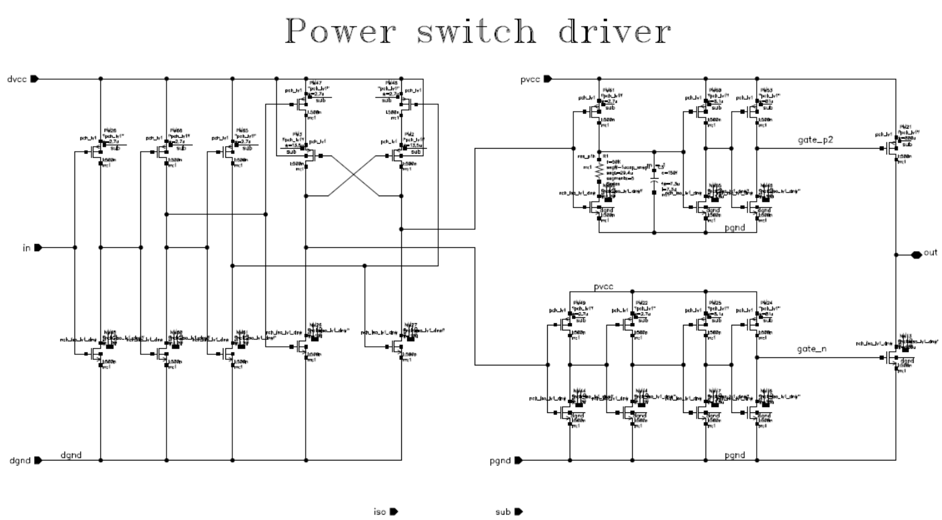


**Figure 3. Power switch gate driver block diagram**

Figure 4 in turn shows the results of simulation from the circuitry design as shown on Figure 3. The simulation conditions were set for Vin = 3.7V, and input pulse rising/falling time = 2nsec.

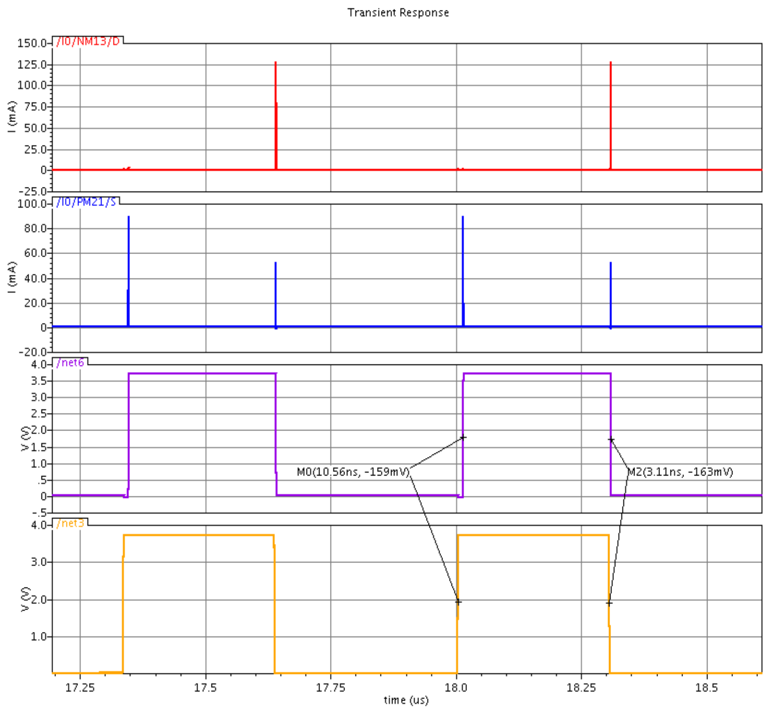


**Figure 4. Delay and current waveform measured of power switch driver**

### 3.3. Synchronous Driver

Figure 5 shows the schematic of the synchronous driver, where the mechanism applied for improving efficiency used a freewheeling diode, by saving power used by the diode and using a high frequency of 1.5 MHz to compensate for the reduced efficiency. There is also the purpose of reducing the external element in reducing the size of the overall application. The element used output voltage of 4.9V, so a 5V 0.8Ω CMOS was used

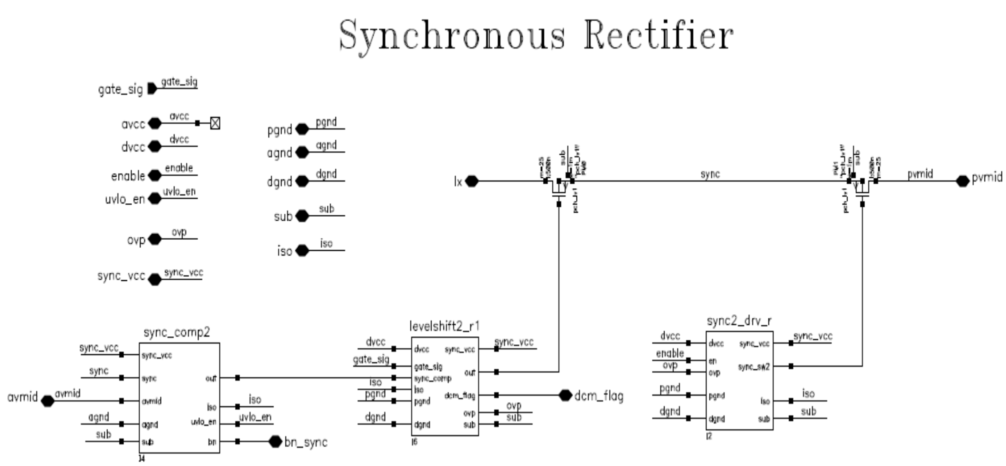


**Figure 5. Schematic diagram of synchronous rectifier switch driver**

Figure 6 is a block diagram of the synchronous rectifier, to prevent parasitic diode reverse current produced in the case of a single transistor design, by the dual transistor design of two parasite diodes facing each other. The transistor on the right is designed to always command turn-on after enable, whereas the left transistor commands turn-on/turn-off in the synchronous rectifier.

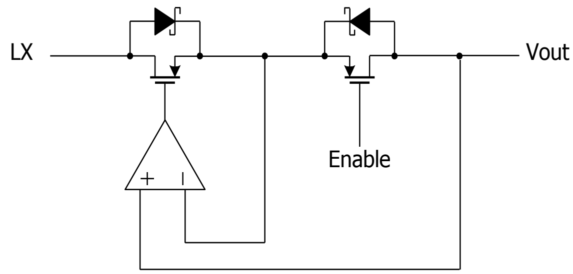


**Figure 6. Block diagram of synchronous rectifier**

Figure 7 shows the results of simulation according to the circuit on Figure 5. Simulation conditions were set for Vin = 3.7V, and input pulse rising/falling time = 2nsec.

Synchronous rectifier driver block's turn-on/turn-off delays were 2.5nsec and 2.1nsec, respectively. We blocked shoot-through of the driver unit through designed for non-overlap.

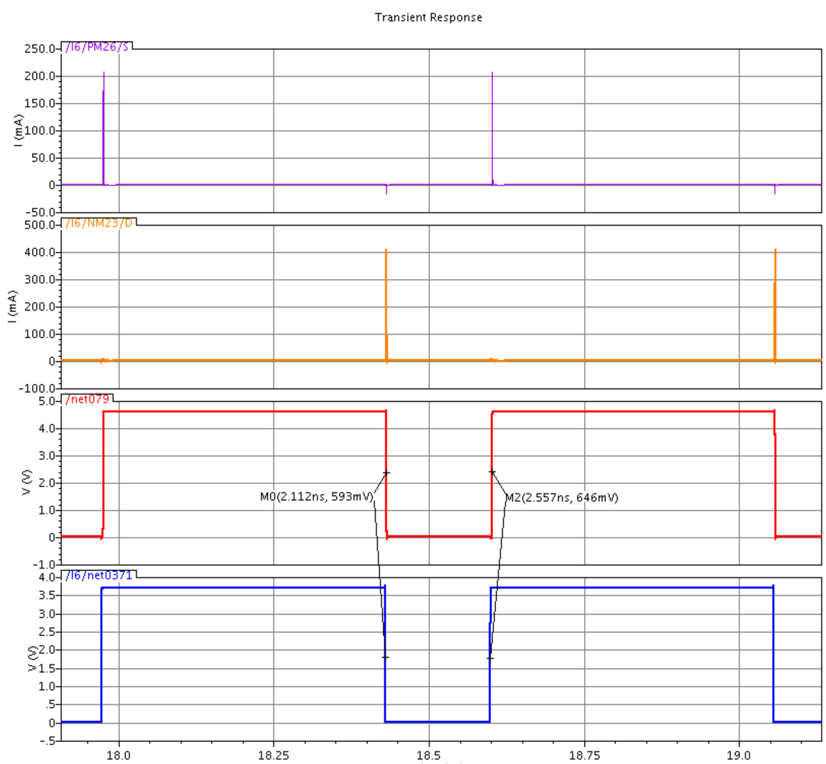


**Figure 7. Simulation result of synchronous rectifier switch driver**

### 3.3. Ringing-Killer Driver

Figure 8 shows the block circuit of the designed ringing-killer driver, and Figure 9 is the block diagram of the ringing-killer driver, with the step-up converter acting in discontinuous mode (DCM) under reduced loads, with ringing oscillation of the inductor. Ringing oscillations destroy the power switch, or may be the source of EMI increase to surrounding elements. A circuit is necessary to prevent ringing oscillation in correcting these problems. For this purpose, this IC used the ringing-killer block to prevent ringing oscillations. When the current built up on the inductor is delivered through the synchronous rectifier as output power to reach 0A, by making the inductor unit voltage to be 0V, inductor induced ringing oscillations can be prevented.

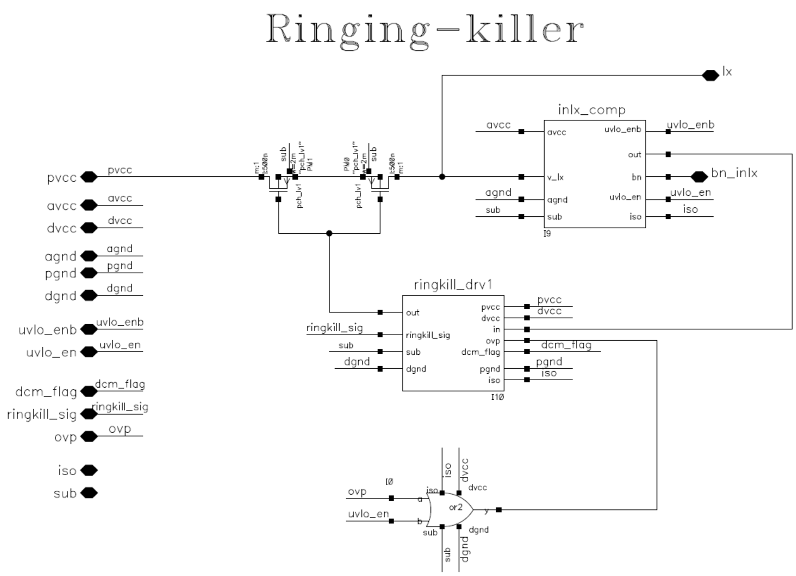


**Figure 8. Schematic diagram of ringing-killer driver**

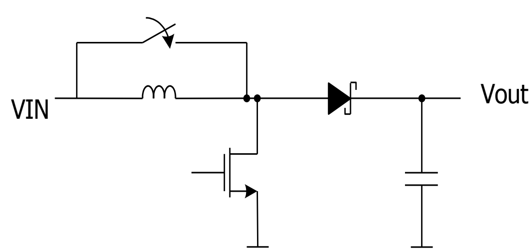


**Figure 9. Block diagram of ringing-killer driver**

The ringing-killer switch used a 5V 2Ω CMOS. The driver unit switch was not large in size, so was activated using the inverter.

Figure 10 and 11 show simulation results from the designed ringing-killer circuit.

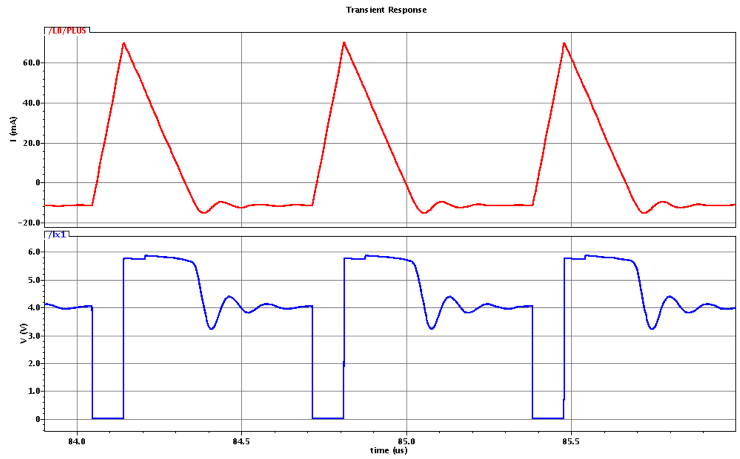


**Figure 10. Simulation result of ringing oscillation without ringing-killer driver**

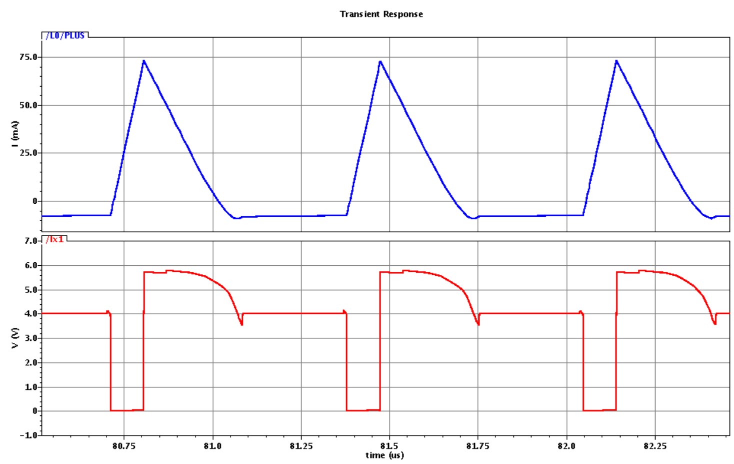


**Figure 11. Simulation result of ringing oscillation with ringing-killer driver**

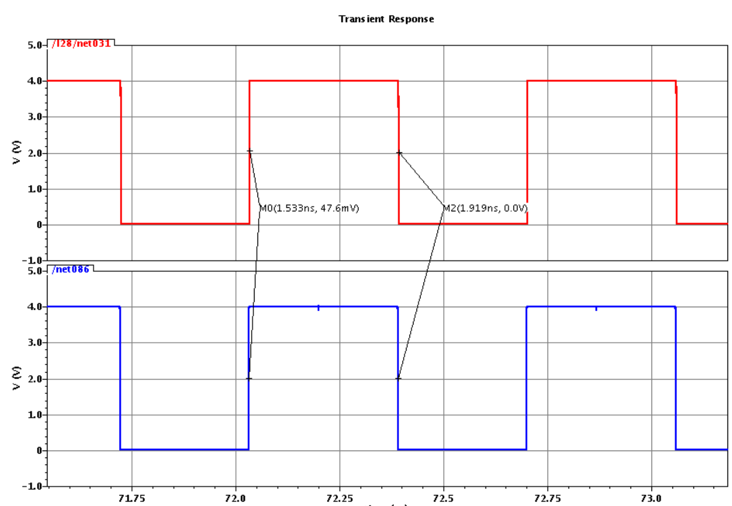


**Figure 12. Simulation result of ringing-killer turn-on/turn-off delay**

Ringing-killer switch size is large because the inverter was driven by each turn-on/turn-off delay time is 1.92nsec, 1.5nsec

## 4. Conclusion

AMOLED LCD and AMOLED brightness of the device does not require a backlight controlled by the current flowing in the OLED. Therefore, each pixel AMOLED behavior depending on the current-driven power, so the amount of current that can be controlled according to the user's needs is required.

This paper examined the AMOLED display IP driver block for design and simulation. An IP driver block was designed and simulation conducted for an AMOLED display which supplies power as selected by users. The IP driver design focused on the regulation of output power, due to the OLED characteristic for diode electric current according to voltage, to be activate by pulse-skipping mode (PSM) under low loads, and 1.5 MHz pulse-width modulation (PWM) for medium/high loads.

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