A New Voltage Driving Pixel Circuit for Active Matrix Organic Light Emitting Diodes

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Organic Light Emitting Device

Characteristics

- Light
- Thin
- Self emissive
- Wide viewing angle
- Fast response time
- High contrast ratio
- Low voltage DC drive
- Simple device structures

From: www.auo.com
## Comparison of Driving Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Principle</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
</table>
| **Voltage Driving** | 1. Self-Com. (Cvt)  
2. Match TFT  
3. Clamped Inverter  
4. AC Driving  
5. R, Active load | 1. Great tolerance of variations of Vth  
2. Compatible with data drivers  
3. Simple architecture of drivers | 1. Non-uniformity of gray level due to $\mu$ variation |
| **Current Driving** | 1. Current Copy  
2. Current Mirror  
3. Current Scaling | 1. Great tolerance of variations of Vth and $\mu$  
2. Control the brightness of OLED directly | 1. Driving speed is too slow  
2. Complex driver circuit |
| **Digital Driving** | 1. Time period  
2. Area period | 1. Great tolerance of variations of Vth and $\mu$ | 1. Need very fast addressing speed (low resolution)  
2. Complex process |
AMOLED Driving Methods

Self-Com.(Cvt)
- Dawson IEDM98 Kodak
- Goh SID03 EDL03 Type A, B
- Kim SID03 Sam.
- Kwak SID03 Epson
- Tam SID04 Type-A Sam.
- Choi SID04 Epson
- Choi SID04 Sam.
- Komiya IDW03 Type-B Sam.
- Komiya IDW04 Sam.
- Park IDW04
- Gar IDW04

Voltage
- Match TFT
- AC Driving
- Resistor
- Active load
- Copy
- Mirror
- Scaling
- Time, Area
- Novel
- Clamped Inverter

Digital

Wallpaper

Cover

New

Current

Lee IDW02 EDL04
- Bae IDR00 LG.Ph
- Sasaoka SID01 EDL00 T-ED01
- Lee SID02
- Lee SID03
- Lee SID04
- Lin EDL04
- Lee IDW04
- Lin EDL04
- You SID04
- Sanford SID03 IBM
- Kim SID02
- Wang ASID00 ITRI
- Dawson IEDM98 Kodak
- He EDL00 JJAP01 T-ED01
- Wang EDL01 ITRI
- Hong SID02 ITRI
- Lee IDW02 EDL04
- Kim SID02
- Wang ASID00 ITRI
- Dawson IEDM98 Kodak
- He EDL00 JJAP01 T-ED01
- Wang ASID00 ITRI
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Device Modeling

$I_D$-$V_{GS}$ curves of poly-Si TFTs

$I$-$V$ characteristics of an OLED

Design & Analysis for Display System Lab.
# Parameters used in the pixel circuit simulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{DV}$ W/L</td>
<td>7 $\mu$m/5 $\mu$m</td>
</tr>
<tr>
<td>$T_{sw}$ W/L</td>
<td>7 $\mu$m/5 $\mu$m</td>
</tr>
<tr>
<td>Cst</td>
<td>0.5pF</td>
</tr>
<tr>
<td>Cvt</td>
<td>0.5pF</td>
</tr>
<tr>
<td>Vdd</td>
<td>10V</td>
</tr>
<tr>
<td>Vscan1, Vscan2</td>
<td>0-10V</td>
</tr>
<tr>
<td>Vscan3</td>
<td>0-15V</td>
</tr>
<tr>
<td>$\Delta V_{TH}$ of $T_{DV}$</td>
<td>+/- 0.33V</td>
</tr>
</tbody>
</table>
Conventional 2T1C Pixel Circuit

Design & Analysis for Display System Lab.

Variations of threshold voltage ($V_{TH}$) can affect the output current of Driving TFT ($T_{DV}$).

$\rightarrow$ Non-uniformity problems of display images
Variation of \( V_{\text{out}} \) due to \( V_{\text{th}} \)
Goh’s Pixel Circuit (Voltage Driving)

4T2C

1. The gate and the source of $T_{DV}$ are initialized to ground.

2. $C_{VT\_stored} \Delta V = \frac{a}{1 + a} \times V_{TH\_TDV} - \frac{1}{1 + a} \times V_{TH\_OLED} + \frac{1}{1 + a} \times V_{in}$

3. $I_{OLED} = K(V_{GS} - V_{TH\_TDV})^2 = K(V_{in} + \Delta V - V_{out} - V_{TH\_TDV})$

IDW’01 IEEE EDL’02

Design & Analysis for Display System Lab.
The unnecessary OLED current during the compensation period.

The output voltage cannot be completely compensated by the voltage stored in Cvt, unless the parameter a is very large.
Modified Komiya’s Pixel Circuit (Voltage Driving)

1. N-type TFT is used for $T_DV$.

2. Additional Scan line 3 is used to increase the driving capability of $T_{sw1}$.

$\text{I}_{\text{OLED}} = K \left( V_{dd} - V_{in} \right)^2$

Design & Analysis for Display System Lab.
1. $C_{VT\text{-}stored} \Delta V = V_{TH\text{-}TDV}$

2. $I_{OLED} = K(V_{GS} - V_{TH\text{-}TDV})^2 = K(V_{in} + V_{TH\text{-}TDV} - V_{out} - V_{TH\text{-}TDV})$
Transient simulation result

Graph showing:
- (1) compensation period
- (2) data-input period
- Voltage (V) on the y-axis
- Time (μs) on the x-axis
- Scan line 2
- Data line
- Anode of OLED (ΔVth=0V)
- Anode of OLED (ΔVth=0.33V)
- Anode of OLED (ΔVth=-0.33V)

Design & Analysis for Display System Lab.
Proposed Pixel Circuit (Voltage Driving)

- $C_{ST}$ : sustain the gate voltage of $T_{DV}$ against the leakage currents of $T_{SW}$ during a frame time.

5T2C

- $C_{VT}$ : store the $V_{TH}$ of $T_{DV}$.

- $T_{Sw4}$ : prevents the current from flowing through the OLED during initialization and compensation period.

1. improve the dark gray level
2. increase the contrast ratio
3. decrease power consumption of the panel
Proposed Pixel Circuit (Voltage Driving)

1. The gate and the source of $T_{DV}$ are initialized to ground.

2. $C_{VT} \Delta V = V_{TH_{TDV}}$

3. $I_{OLED} = K(V_{GS} - V_{TH_{TDV}})^2 = K(V_{in} + V_{TH_{TDV}} - V_{out} - V_{TH_{TDV}})$
Transient simulation result

(1) initialization period  (2) compensation period  (3) data-input period

![Diagram showing voltage over time with labels for scan line 2, data line, and anode of OLED with threshold variations.](image)
Non-uniformity of Output Current

\[ \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{avg}}} \]
Conclusions

• A new voltage driving pixel circuit composed of five TFTs and two capacitors for AMOLED is proposed.
• Simulation results indicate that the pixel circuit is effective to provide a uniform output characteristic against the variation in the Poly-Si TFTs performances.
Thank You