

Mianyang BOE Optoelectronics Technology Co., Ltd. (BOE”); Wuhan China Star Optoelectronics Semiconductor Display Technology Co., Ltd.; Tianma Microelectronics Co. Ltd.; and Visionox Technology, Inc.

v.

Samsung Display Co., Ltd.

Case No. IPR2023-00941

U.S. Patent No. 7,414,599

Patent Owner’s Demonstratives

September 16, 2024 Oral Hearing

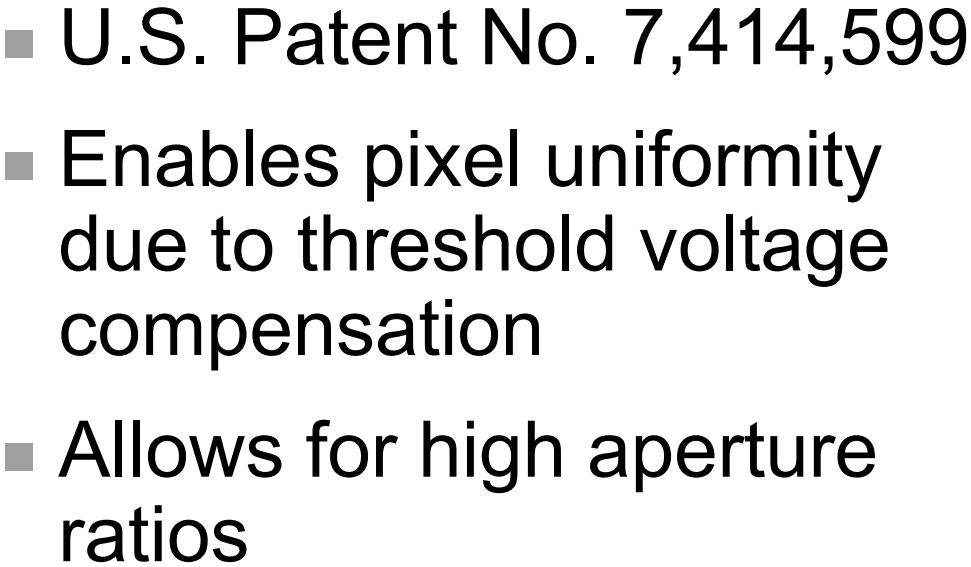
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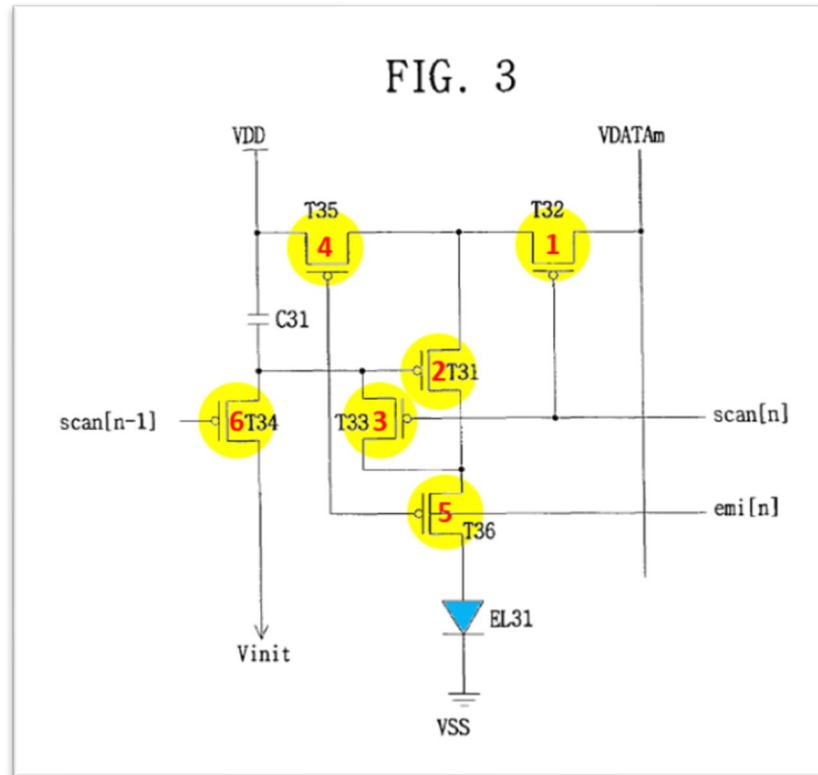
SDC EX. 2056

- U.S. Patent No. 7,414,599
- Enables pixel uniformity due to threshold voltage compensation
- Allows for high aperture ratios



The '599 Patent's Pixel Circuit

'599 Patent Fig. 3 as Annotated by Petitioner



Pet. at 7

A pixel circuit in an organic light emitting device capable of realizing high gradation representation by **self-compensating a threshold voltage**, and a method for driving the same. The

'599 Patent at Abstract

the fifth transistor. **The third transistor connects the second transistor in the form of a diode** in response to the current scan signal, so that the second transistor detects and **compensates its threshold voltage deviation in itself**.

'599 Patent at 4:24–27

As described above, driving transistor T31 in the present invention can **self-compensate the threshold voltage** deviation by detecting its own threshold voltage.

'599 Patent at 8:30–32

'599 Pixel Circuit Enabled Pixel Uniformity and High Aperture Ratio

2005 SID Paper on '599 Pixel Circuit Benefits

38.2 / K.-J. Yoo

38.2: 302-ppi High-Resolution AMOLED using Laser-Induced Thermal Imagi

Kyung-Jin Yoo, Seung-Hyun Lee, An-Su Lee, Choong-Youl Im,
Tae-Min Kang, Wang-Jo Lee, Seong-Taek Lee, Hye-Dong Kim, Ho-Kyoon Chung
TD-1 team, Corporate R&D Center, Samsung SDI Co., Ltd.,
428-5, Gongse-Ri, Kiheung-Eup, Yongin-City, Kyunggi-Do, 449-577, KOREA

Abstract

Samsung SDI has developed 2.6-inch full color VGA Active Matrix Organic Light-Emitting Diode (AMOLED) display with the world's highest resolution of 302ppi using Laser Induced Thermal Imaging (LITI) method with the top emission structure. A voltage compensating pixel circuit with 2μm design-rule in low-temperature poly-Si (LTPS) thin film transistors (TFTs) was introduced to compensate the variation of the threshold voltage (V_{th}) in order to improve the image quality. Moreover, an aperture ratio of ~40% was obtained for each pixel even though the sub-pixel pitch was 28μm. The luminance for the white color was 206cd/m² and color gamut was 74% compared to national television standard committee (NTSC) standards. These results show the possibility of high-resolution AMOLED display incorporating the LTPS technology and LITI method for digital mobile-era applications in the near future.

1. Introduction

In recent year, AMOLED display has attracted great attention due to many advantages such as wide viewing angle, fast response time, high brightness, vivid images, low power consumption and thin structure. The commercialization of small AMOLEDs has already been proceeding in spite of several issues still to be resolved. One of the important issues is the pixel resolution limitation of AMOLED display caused by the conventional evaporation method, which uses a fine metal mask (FMM). Even though FMM is the most common method for patterning primary colors for full color AMOLED, it is almost impossible to realize a resolution higher than 230ppi in a mass production environment. The other issue is the use of voltage compensation circuit that AMOLED needs to compensate for the V_{th} variation originating from laser crystallization process. Although many groups are developing compensation circuits, it is more difficult to integrate such circuits in the case of higher pixel density display due to restricted pixel area. However, there is a demand for improved image quality requiring higher resolution. The products for multimedia applications such as DSC (Digital Still Camera), cellular phones and DMB (Digital Multi-media Broadcasting) etc. will be merged in the mobile space in the near future. The digital convergence of mobile devices will lead to rapidly increasing demand for higher resolution display products¹⁻⁶.

We have developed the AMOLED display with resolution higher than 230ppi by optimizing the panel design, improving the TFT fabrication process and utilizing the LITI⁷⁻⁹ method. To realize higher resolution display, each red, green and blue sub-pixel requires 28μm pitch which is lower than conventional FMM limit of 35 μm. Furthermore the photolithography design rule in this panel must be 2μm for a pixel circuit with V_{th} compensation circuit consisting of 6TFTs and 1 capacitor. In order to form three

different OLED colors in the 28μm sub-pixel pitch, we utilized LITI method on the top emission structure and achieved adequate patterning accuracy.

By incorporating these technologies, we developed the first 2.6 inch full color VGA AMOLED display with a resolution of 302ppi.

2. LTPS Substrate Design

In order to achieve high resolution AMOLED display, we realized compensation circuit with 2μm design rule, 5 resistance metallization to minimize signal delay and top emission structure with flatness for LITI process. The LTPS TFT substrate of the newly developed 2.6-inch (302ppi) VGA AMOLED consists of 480 X RGB X 640 voltage programming pixel and peripheral circuits as shown in Figure 1. The scan driver is integrated by LTPS TFTs on the glass substrate and data driver directly connected to external driver ICs. We have applied own 6 TFTs and 1 capacitor structure to compensate the variation of the driving TFT in the pixels. This pixel circuit suitable to realize a high image quality and high resolution AMOLED panel. The transistor and capacitor size of each pixel is optimized by simulation. We have also used 2μm design rule and 28μm sub-pixel pitch to fabricate active matrix substrate with very high resolution. Due to limited sub-pixel area adopted switching transistors with short channels and dual structure in order to reduce the leakage current. We obtained stable TFT characteristics by properly engineering Lightly Doped Drain (LDD) structure, which reduced short channel effect caused by hot carrier. It was controlled by LDD length and concentration and we also improved the reliability by optimizing the activation condition. Figure 2 shows a schematic diagram each RGB sub-pixels with 28μm pitch and cross sectional view of the top emission device¹⁰ used to realize high resolution. This structure has excellent flatness as shown in Figure 2(b).

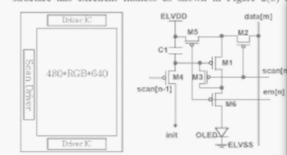
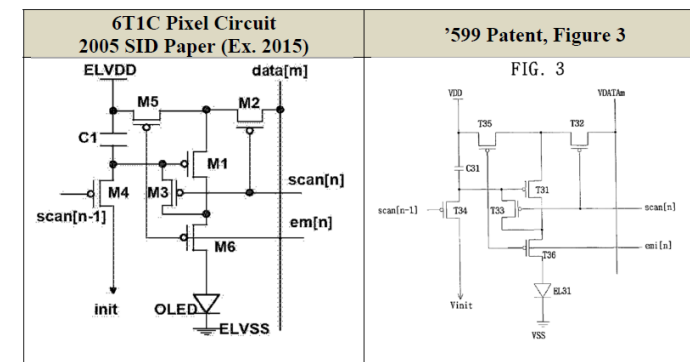


Figure 1. Block diagram of the LTPS substrate and pixel circuit for the 2.6-inch AMOLED display

In order to achieve high resolution AMOLED display, we need to realize compensation circuit with 2μm design rule, lower resistance metallization to minimize signal delay and top emission structure with flatness for LITI process. The LTPS TFT substrate of the newly developed 2.6-inch (302ppi) VGA AMOLED panel consists of 480 X RGB X 640 voltage programming pixel array and peripheral circuits as shown in Figure 1. The scan driver is integrated by LTPS TFTs on the glass substrate and data driver is directly connected to external driver ICs. We have applied our own 6 TFTs and 1 capacitor structure to compensate the V_{th} variation of the driving TFT in the pixels. This pixel circuit is suitable to realize a high image quality and high resolution for AMOLED panel. The transistor and capacitor size of each sub-pixel is optimized by simulation. We have also used 2μm design

We have developed 2.6-inch full color VGA AMOLED display with the highest resolution to date of 302ppi. We used V_{th} compensating pixel circuit to improve image quality and 2μm design rule in LTPS TFT fabrication process to realize the 28μm sub-pixel pitch with 40% aperture ratio. In spite of employing



Ex. 2015 at 1, 3

Overview of Challenge

- The petition proposed one ground of unpatentability: obviousness of claims 1–18 over Kimura

Primary Issues in Dispute

- Whether a POSITA would have been motivated to change Kimura Figure 33 to use a shared light-emitting signal (claims 1–6 and 13–18)
- Whether a POSITA would have been motivated to change Kimura Figure 33 to add the claimed initialization transistor (claims 2, 8, 16, and 18)
- Whether a POSITA would have been motivated to change Kimura Figure 33 to an all-PMOS circuit
- Whether the objective evidence reinforces the non-obviousness of the claims

Shared Light-Emitting Signal

Claims 1–6 and 13–18

The Petition's Theory

- The Petition relied on Kimura Fig. 33 as the “baseline circuit” for its obviousness arguments

The baseline circuit for Petitioners' patentability analysis is Kimura Fig. 33³ which, with only minor modifications taught by Kimura and known to POSITAs (e.g., replacing NMOS transistors with PMOS), renders all Challenged Claims obvious. These modifications (and reasons for them) are discussed after reviewing

Petition at 15

The Petition's Theory

- The Petition proposed a single modification to Figure 33, and did not seek to incorporate an “additional transistor”

controlled by the “current light emitting signal.” Dec. Inst. 49. The Petition explains that although the Figure 33 embodiment of Kimura shows the fourth and fifth transistors controlled by different signals, the Figure 36 embodiment of Kimura uses shared light-emitting signal to control the fourth and fifth transistors. Pet. 64–65. On the basis of the use of a shared light emitting signal in the Figure 36 embodiment to control the fourth and fifth transistors, Petitioner concludes that it would have been obvious to use a shared light emitting signal in the Figure 33 embodiment to control the fourth and fifth transistors. *Id.* No other modification to the Figure 33 embodiment was proposed by Petitioner to account for this feature.

Order Denying Motion to Supplement, Paper 27 at 7–8 and 10

Ex. 1019, ¶ 10. *Neither the Petition nor Dr. Foty's original declaration described any “additional transistor” in the proposed modification of Figure 33 for claim 13.*

Opp. 4–5 (emphasis added).

The emphasized portions of the above-quoted statements in the Opposition are essentially correct and we are in agreement therewith. Neither the Petition nor the first declaration of Dr. Foty proposed any modification of the Kimura's Figure 33 embodiment, in connection with the shared light emitting signal feature of claim 13, beyond simply applying the same light emitting-signal to the gates of transistors 4 and 5.

All of the opinions in the proposed supplemental declaration of Dr. Foty with regard to additional modifications including adding another transistor, are new and not in any way addressed or referred to in the Petition or Dr. Foty's first declaration. The proposed supplemental declaration changes Petitioner's theory of obviousness and the citation to Sakamoto

It Is Undisputed the Petition's Modification Would Render Fig. 33 Inoperable

Dr. Foty's Admissions

modification. DI at 51–52. That is because Petitioner's proposed modifications would, in fact, render the circuit inoperable. Indeed, Petitioner's expert, Dr. Foty, conceded in deposition that turning on transistor 3307 at the same time as transistor 3310 during the operation shown in Figure 33B “would make no sense” and “would be a bad idea,” as it may cause “too much current through the electroluminescent element and damage it.” Ex. 2050 at 76:12–77:5. A POSITA would have had no reason to make such a modification. For this reason alone, Petitioner's challenge as to claims 1–6 and 13–18 necessarily fails.

PO Response at 4–5

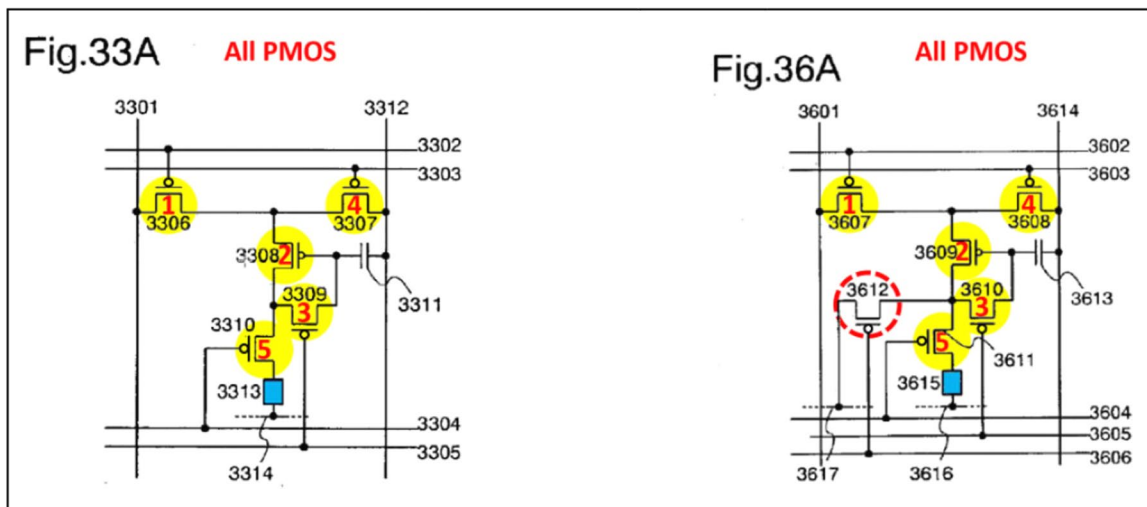
Petitioner's Admissions

Samsung's sole argument against a shared light-emitting signal is that bodily incorporation into Fig. 33 renders the circuit inoperable. POR, 38-44.⁷ That is true, but irrelevant because Petitioner never proposed such a change. In fact, the Petition acknowledged unmodified Fig. 33 did not permit a shared light-emitting signal because the two relevant transistors have different ON/OFF states during initialization, as Fig. 33B shows below.⁸ Pet., 64.

Pet. Reply at 10

Petitioner Is Again Seeking to Add the “Additional Transistor”

Accordingly, Petitioner’s claim 7 analysis applies in all relevant respects to claim 13. A side-by-side comparison of Fig. 33A and Fig. 36A shows all five transistors in Fig. 33 (and their respective connections) are the same in Fig. 36. The only structural difference in Fig. 36 is the addition of transistor 3612, but all Challenged Claims are “comprising” claims that permit additional elements.



Pet. Reply at 15

The Board Did Not “Invite” This Change in Theory

Petitioner’s Argument

At institution, the Board agreed but observed that Fig. 36 “[uses] six transistors, not five as in the case of the Figure 33 embodiment,” and invited the parties to develop the record on whether the “Figure 36 embodiment, would still meet all the requirements of the first, second, third, fourth, and fifth transistor” in base claim 7. ID, 51-52. The unequivocal answer is “yes.”

Pet. Reply at 14

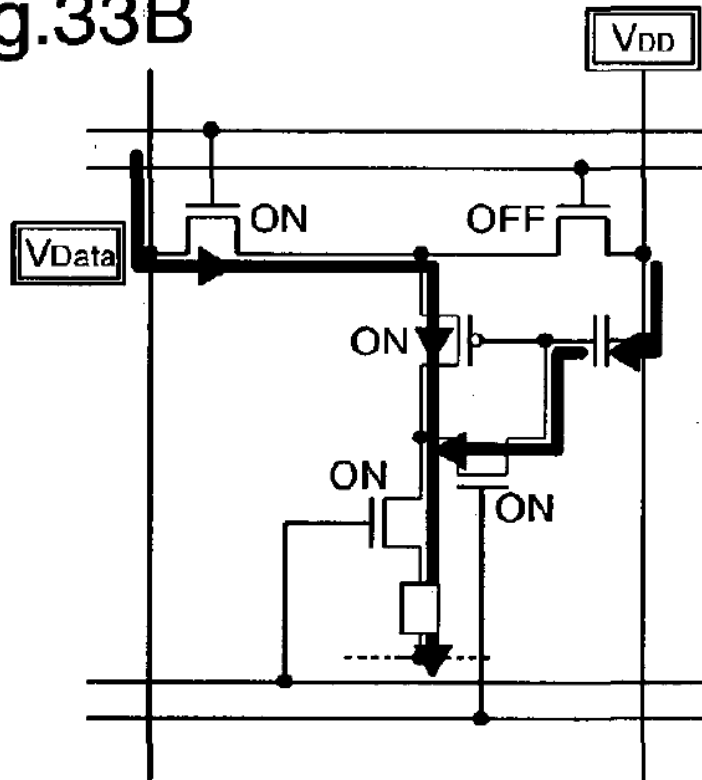
The Board’s Institution Ruling

The Figure 36 embodiment is also different structurally from the Figure 33 embodiment in that it makes use of six transistors, not five as in the case of the Figure 33 embodiment. In accounting for claim 7, Petitioner relied on the Figure 33 embodiment to meet each of the limitations regarding the first, second, third, fourth, and fifth transistors. It is questionable whether the Figure 33 embodiment, after being modified to make the fourth and fifth transistor always turn on and off together, as Petitioner proposes based on the Figure 36 embodiment, would still meet all the requirements of the first, second, third, fourth, and fifth transistor, as recited in claim 7. Based on the present record, we find that Petitioner has not provided an adequate explanation as to this potential discrepancy.

Institution Decision at 51–52

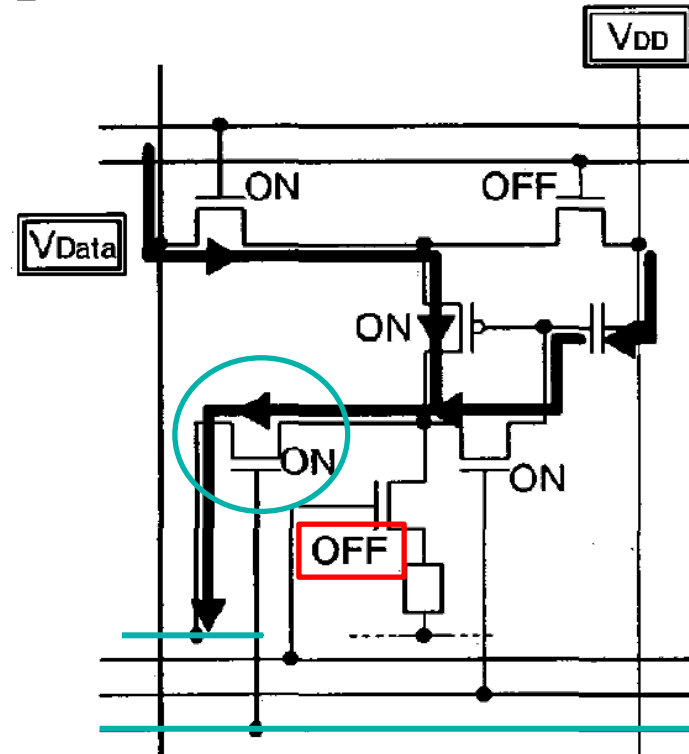
Fig. 36 Is Not “Merely an Extension of Fig. 33”

Fig.33B



Kimura Fig. 33B

Fig.36B



Kimura Fig. 36B

Additional circuit elements, additional lines, and different timing

Initialization Transistor

Claims 2, 8, 16, and 18

The Petition's Theory Hinged on Conflating Erasure with Initialization

- The Petition's theory was that the “initialization” transistor 1607 and “erasure TFT” 3310 were analogous as they both allegedly serve to reset the capacitor to a default initialization voltage

Just like Fig. 17B, during initialization in Fig. 33A the sixth transistor [added from Figs 16/17] turns on and creates a current path (shown by purple arrow) that discharges the capacitor to an *initialization/reset value* EX1002, ¶[0666]; *see also id.*, [0425] (discussing “VReset” voltage); EX1003, ¶¶221-230 and ¶¶155-158.

Kimura discloses that the fifth transistor in Fig. 33 [TFT 3310] “can also be used as an erasure [transistor]” that resets the capacitor voltage to a *default initialization value*. EX1002, [0658]....

When the initialization transistor is added to Fig. 33A, the resulting circuit is shown below where the sixth transistor's source is coupled to one capacitor terminal and its drain connects an “*initialization voltage*” EX1003, ¶¶318-322.

Petition at 51

Petition at 53, 79

Erasure and Initialization Are Distinct Operations

- Erasure in Kimura means forcibly placing the EL device in a non-light-emitting state

[0410] Electric current corresponding to the voltage between the gate and the source of the TFT 907 flows in an EL device 909 after image signal input is complete, as shown in FIG. 9B, and the EL device 909 emits light. A pulse is then input to the third gate signal line 913 when the timing for completion of the sustain (light emitting) period is reached, the erasure TFT 914 turns on, and the voltage between the gate and the source of the TFT 907 is set to zero, as shown in FIG. 9C. The TFT 907 therefore turns off, electric current flow to the EL device 909 is cutoff, and the EL device 909 is forcibly placed in a non-light emitting state.

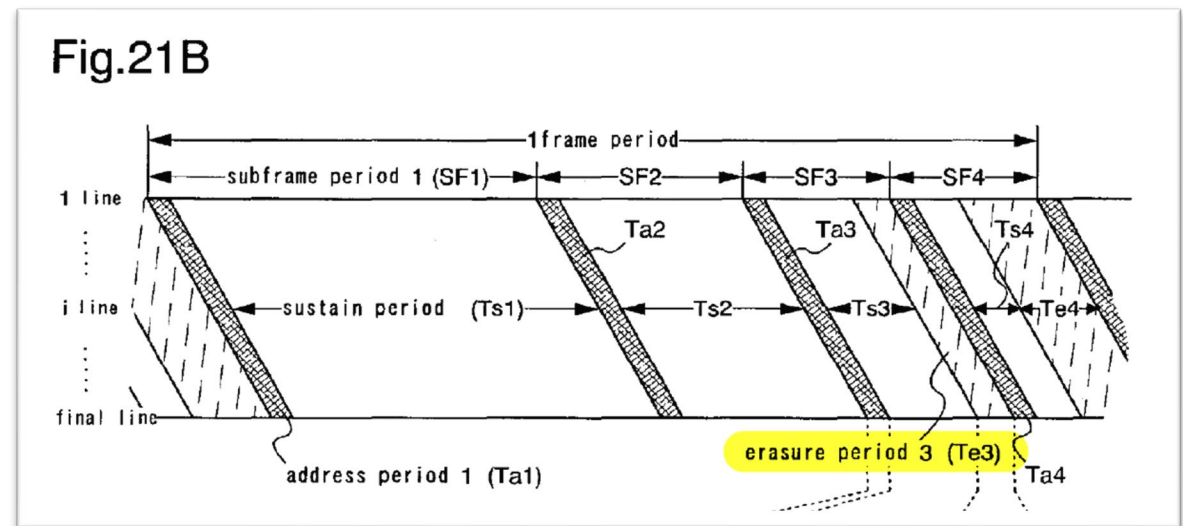
See also Kimura at ¶ 658 (“erasure TFT can be placed in any location, provided that it is a location at which electric current supplied to the EL device can be cut off at an arbitrary timing.”)

Kimura at ¶ 410

Erasure and Initialization Are Distinct Operations

- Erasure is used to resolve timing issues in Kimura's digital gray scale method

[0406] The lengths of the sustain periods of the less significant bits become short when realizing multiple gray scales by using a time gray scale method, and therefore an overlapping period develops if an address period begins immediately after the previous sustain (light emitting) period is complete, wherein the address (write in) periods of different subframe periods overlap. An image signal input to a certain pixel is also input to different pixels at the same time in this case, and therefore normal display becomes impossible. The erasure period is formed in order to resolve these kinds of problems, and is formed so that two different address (write in) periods do not overlap after sustain (light emitting) periods Ts3 and Ts4, as shown in FIG. 21B. The



Kimura at Fig. 21

Kimura at ¶ 406

Erasure and Initialization Are Distinct Operations

Importantly, Kimura discusses “erasure” and “initialization” as separate operations and concepts. Whereas “initialization” in Kimura entails applying a reset voltage (“VReset”) to a capacitor or gate electrode (*see, e.g.*, Kimura at ¶¶ 425–426), Kimura describes “erasure” as “forcibly plac[ing] [the EL device] in a non-light-emitting state.” Kimura at ¶ 410. Indeed, as shown below, Kimura depicts “erasure” and “initialization” as distinct operations in its Figure 16B. Despite this

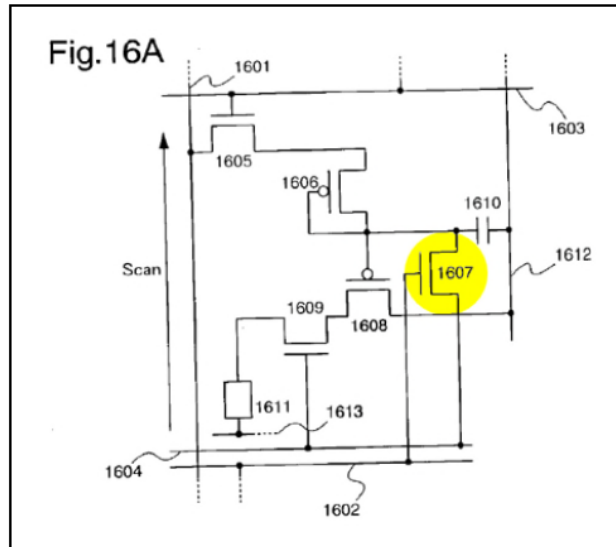
PO Preliminary Response at 14

Institution Decision at 47–48

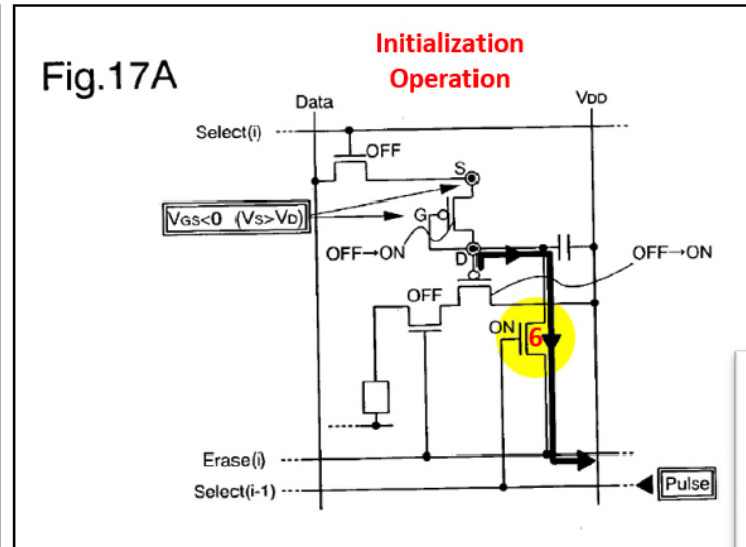
Patent Owner asserts that Petitioner “Conflates ‘Initialization’ with ‘Erasure.’” Prelim. Resp. 16. On this record, that appears to be true. The

Ex. 1002 ¶ 658. Based on the preliminary record, we agree with Patent Owner that “Kimura uses ‘erasure’ to mean ‘forcibly plac[ing] [the EL device] in a non-light-emitting state.’” Prelim. Resp. 16 (alterations in original). In that regard, Kimura describes the following:

Petition Seeks to Use Initialization or “Reset” Transistor from Figs. 16/17



Petition at 51



Petition at 51–52

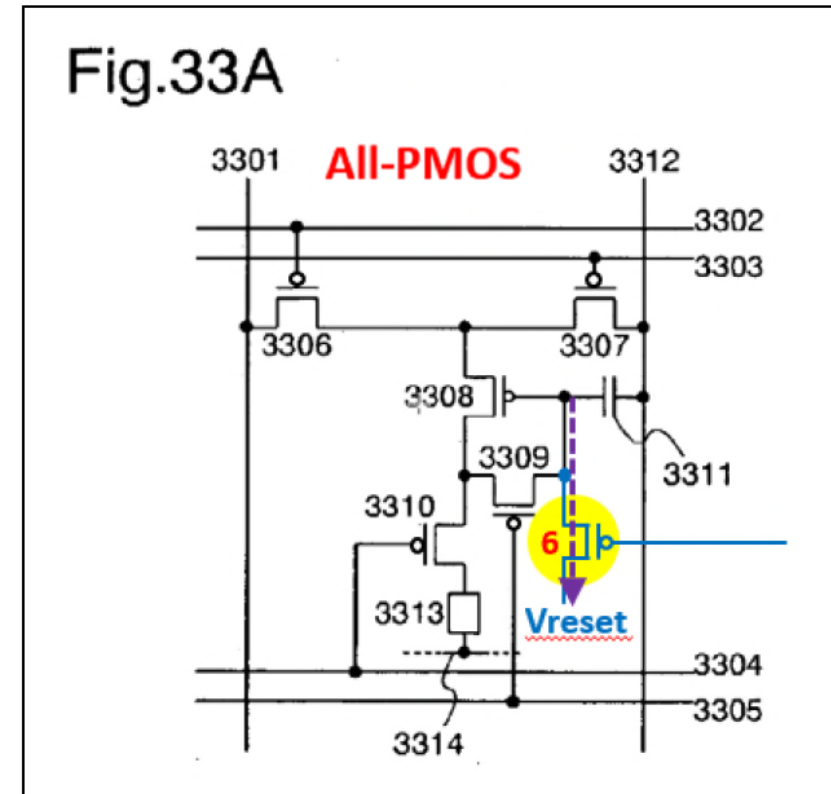
Operation of the initialization transistor (1607) is discussed in Kimura [0422]-[0429]. In summary, transistor 1607 resets the voltage on capacitor 1610. *Id.*, [0429]. The “gate electrode of the TFT 1607 is connected to the gate signal line 1602 of an (i-1)th row.” EX1002, [0423]. Just like the capacitor in Fig. 33, the capacitor in Figs. 16-17 “stores [a voltage] applied to the gate electrode of the TFT 1608 during the sustain (light emitting) period.” *Id.*; EX1003, ¶¶221-223. The function of transistor 1607 is to initialize/reset the capacitor by discharging it, as shown in Fig. 17A. EX1002, [0426]; *see also id.*, [0425] (referring to the initialization voltage as “VReset”).

Petitioner Asserts the Initialization Transistor Is “Readily Applicable” to Fig. 33

Petitioner’s Argument

A POSITA would have been motivated to combine the initialization approach disclosed in Kimura Figs. 16-17 with Kimura Fig. 33 by adding a dedicated initialization transistor (*i.e.*, the sixth transistor as illustrated below). EX1003, ¶¶221-230 and ¶¶155-158. Such an approach is readily applicable to the baseline circuit of Fig. 33. *Id.*; see also *id.*, ¶¶141-143. Indeed, when discussing Fig. 33, Kimura expressly teaches that “the erasure [transistor] can be placed in any location, provided that it is a location at which electric current supplied to the EL device can be cut off at an arbitrary timing.” EX1002, [0658]. Thus, a POSITA would have been motivated to place the initialization transistor discussed in Figs. 16-17 in the same location (*i.e.*, directly connected to the capacitor) in Fig. 33. EX1003, ¶¶221-230 and ¶¶155-158. Modified Fig. 33 below shows the “sixth transistor” (*i.e.*, initialization transistor) in blue as a PMOS device. Given that all

Petitioner’s Added Transistor



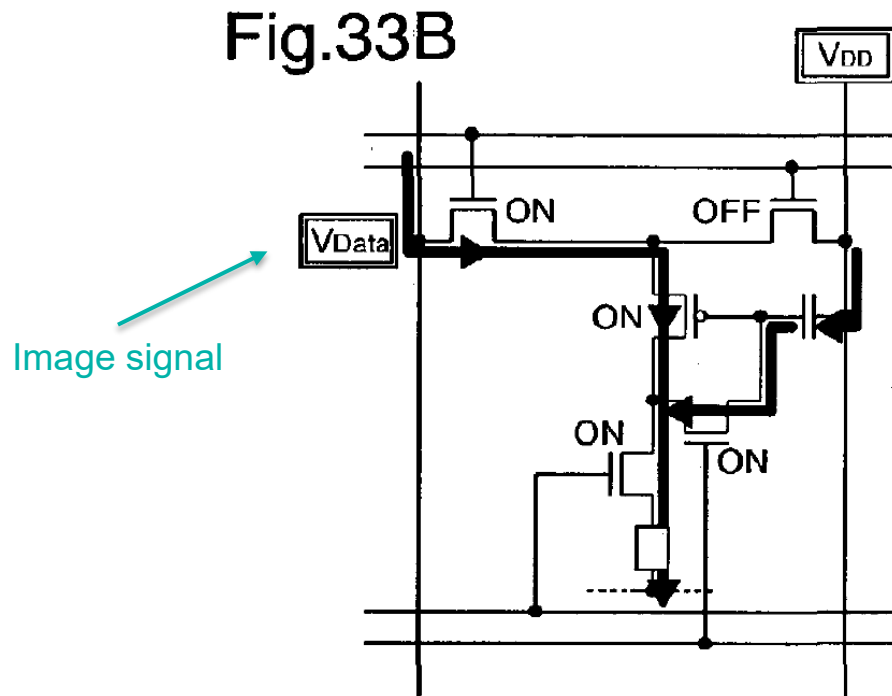
Petition at 54

Petition at 52–53

Yet Fig. 33 Does Not Involve Initialization or a “Reset” Voltage

Petitioner alleges that Fig. 33B shows “initialization”...

... but Fig. 33B is part of programming phase.



Kimura Fig. 33B

[0655] Operation is explained. First, the TFT 3306 turns on, and an image signal VData is input as shown in FIG. 33B. In addition, the TFT 3309 and a TFT 3310 turn on, and the TFT 3308 thus behaves as a diode connected TFT. When the TFT 3310 then turns off electric charge moves as shown in FIG. 33C. The voltage between the source and the drain of the TFT 3308, in other words the voltage between the gate and the source of the TFT 3308, eventually becomes equal to the threshold voltage, at which point the TFT 3308 turns off as shown in FIG. 33D.

Kimura at ¶ 655

⁴ As Dr. Wolfe explained, Figure 33B shows “the first phase of the capacitor programming” in which “there appears to be some discharging of that node [the capacitor]” but “there’s also this VData coming in” (i.e., the programming data voltage). Ex.1028, 203:4-5, 203:20, 205:6. Hence, the current flow (and the voltage on the capacitor) “depends on the value of Vdata and the relative resistivity of the four transistors.” *Id.*, 205:15-206:2. The result of Figure 33B is an indeterminate capacitor voltage.

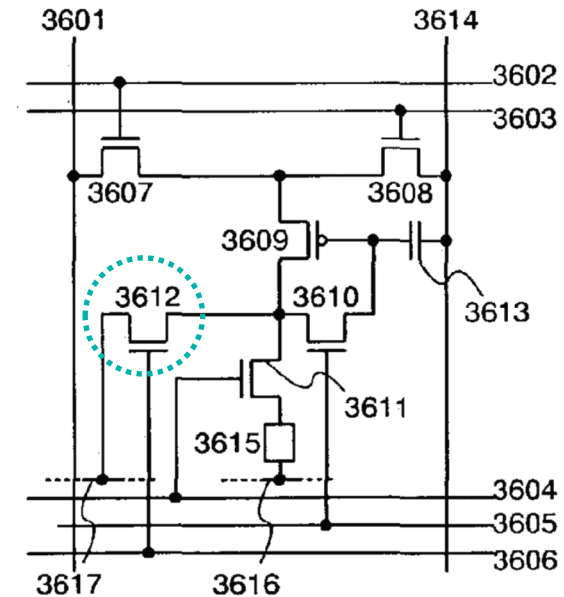
PO Surreply at 13 n.4

Kimura Fig. 36 Already Solves the Problem of Fig. 33

[0665] In the structures shown FIGS. 33 to 35, there are cases in which electric current flows in the EL device to cause light emission, before or after threshold voltage acquisition, that is during a period that is not the normal light emitting period. In these cases the value of the electric current flowing in the EL device is not necessarily equal to the image signal plus the correct threshold value, and this therefore causes errors to develop between the actual brightness and the target brightness.

[0666] A TFT 3612 is therefore added as shown in FIG. 36A. Electric current flowing in the TFT 3609 during input of the image signal flows through the TFT 3612 and to an electric power source line 3617. An electric current path to the EL device 3615 is cut off by a TFT 3611, and therefore the EL device 3615 does not emit light. Light emission by the EL device during unnecessary periods can thus be prevented by using this type of structure.

Kimura at ¶¶ 665–666

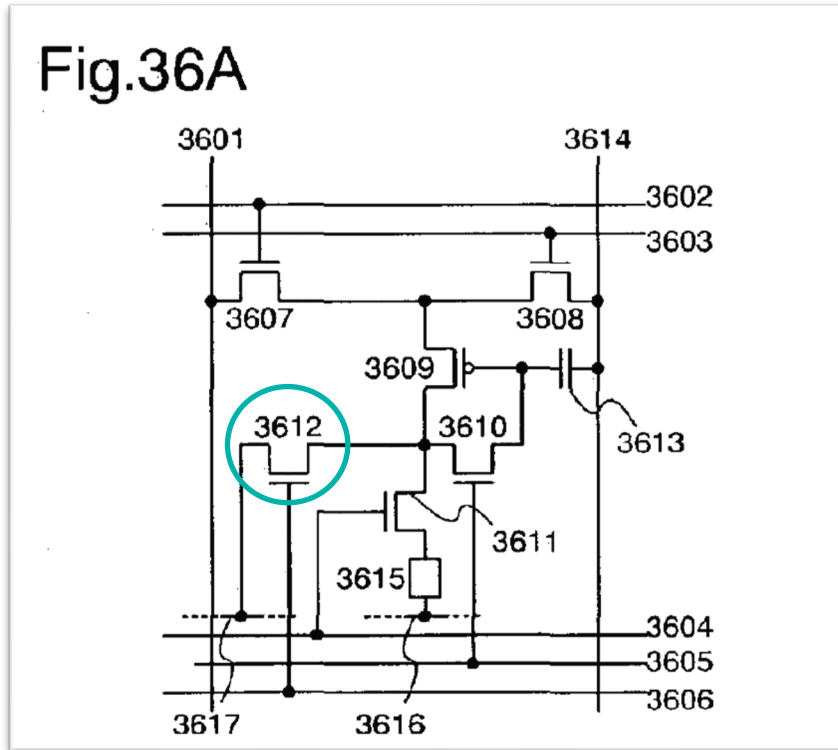


Kimura
Fig. 36A

See *also* Petition at 19 (“Kimura solves this problem ... as shown in Fig. 36B.”)

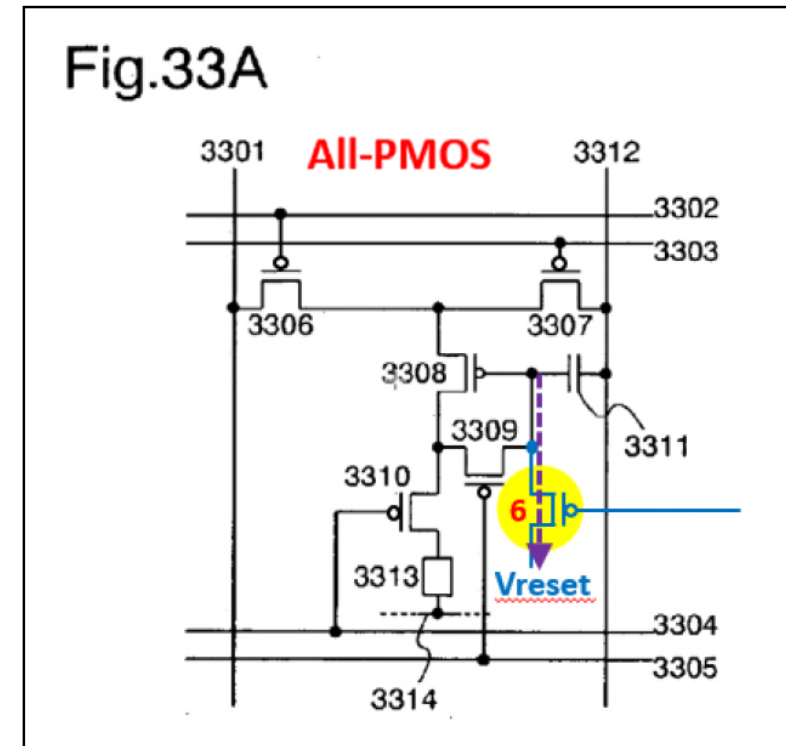
Petitioner's Modification Disregards the Solution of Fig. 36

Kimura's Solution to Fig. 33



Kimura Fig. 36A

Petitioner's Added Transistor



Petition at 54

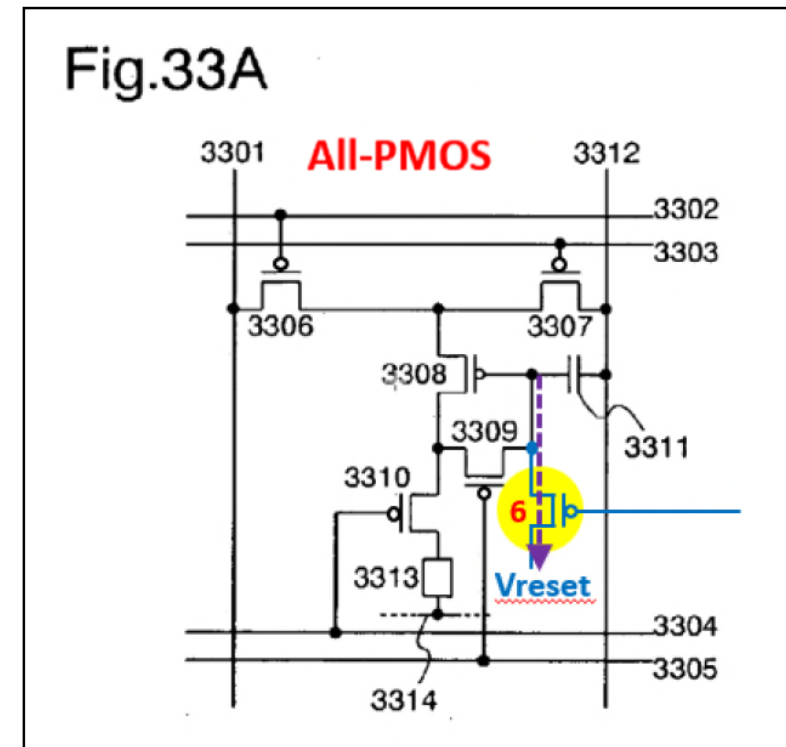
Petitioner's Transistor Could Not Even Perform Erasure

- Petitioner relies on Kimura's teaching that "the erasure TFT can be placed in any location, *provided that it is a location at which electric current supplied to the EL device can be cut off at an arbitrary timing*" (Kimura at ¶ 658; see Pet. at 52)
- But Petitioner's transistor could *not* "cut off" current flow

But as Dr. Foty admitted in deposition, when Kimura describes "cut[ting] off" current flow, it means preventing current from flowing to the EL element. Ex. 2050 at 112:11–113:7. He further admitted that the additional transistor he proposes adding would not "cut off" current flow to the EL element. Ex. 2050 at 120:1–15 (Q... "[T]here's no current path through Transistor 6 that also leads through the EL element. Right? A. Yes. That's the point of the modification, to have that capacitor be drained without having it go through the electroluminescent element."); *see also*

PO Response at 32

Petitioner's Added Transistor



Petition at 54

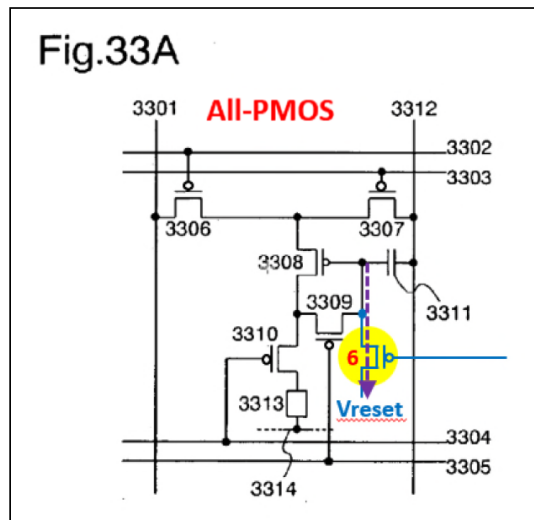
The Petition Did Not Seek to Combine Figs. 16/17 and 36

The Petition proposed adding the “initialization transistor” to Figure 33

... but the Reply suggests a new theory of adding it to Figure 36

Turning now to Kimura, incorporating the initialization transistor from Figs. 16-17 into Fig. 33 renders claim 8 obvious. EX1003, ¶¶221-230. Kimura

Petitioner applied Kimura’s reset/initialization transistor 1607 to Kimura Figs. 33/36 as the claimed “initialization transistor” that discharges the capacitor. See Pet., 51-56. Petitioner provided numerous reasons for doing so. See *id.*, 54-55



Pet. Reply at 19

Petition at 50–51, 54

All-PMOS Circuit Modification

All Challenged Claims

Petitioner Advances a “General Interchangeability” Theory

Some (but not all) Challenged Claims require PMOS transistors. ID, 19.

Petitioner used “all-PMOS” implementations of Kimura Fig. 33/36 to meet such requirements and presented multiple rationales for doing so. *See, e.g.*, Pet., 19-23.

To streamline proceedings, Petitioner focuses its reply on the “general interchangeability” rationale.² ID, 23-31.

Pet. Reply at 4

The Evidence Shows Material NMOS/PMOS Differences

- Dr. Wolfe demonstrated that NMOS transistors were known to have:
 - less susceptibility to leakage current
 - smaller size
 - faster speed

Ex. 2008 at ¶¶ 63–68

- “[A] finding of obviousness based on design choice is precluded where the difference between the claimed feature and prior art results in a functional difference”

Lumenis Be Ltd. v. BTL Healthcare Technologies A.S., IPR2021-01275, Paper 8, at 30 (Feb. 8, 2022) (citing *In re Gal*, 980 F.2d 717, 719 (Fed. Cir. 1992))

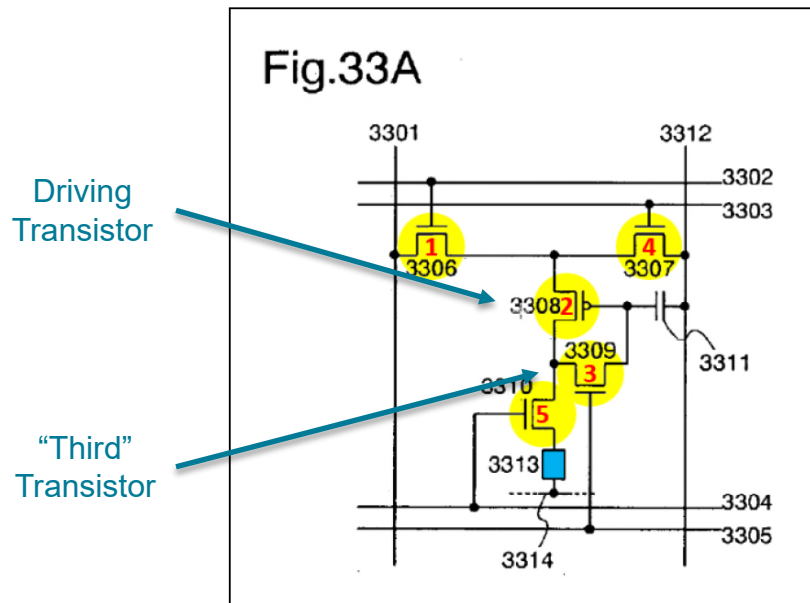
Dr. Foty on Leakage Current

When PMOS transistors in some -- in the older technologies used all N plus polysilicon gates, the slope of the PMOS transistor was less steep. So for the same threshold voltage in N and P would have a higher leakage current. But you could compensate for that by slightly increasing the threshold.

Ex. 2050 at 98:14–20

Kimura Does Not Teach Interchangeability for All Transistors

- Certain transistors in Kimura's pixel circuits do not function as *simple switching devices*



Kimura Fig. 33A (Petition at 16)

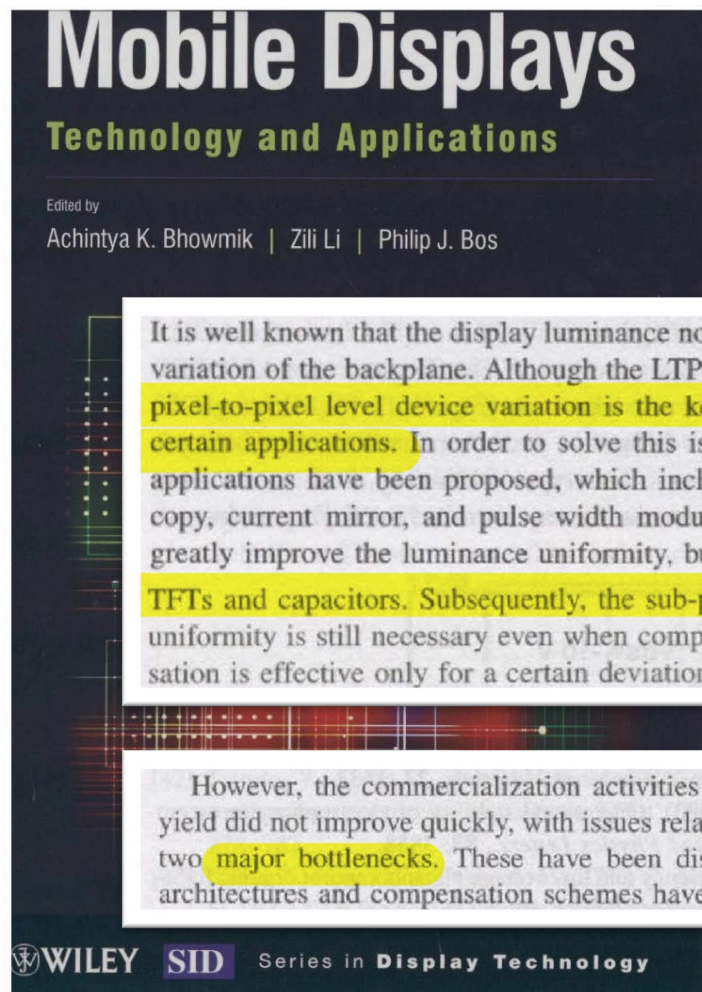
Dr. Wolfe's Testimony

70. As shown in Figure 33, the "third" transistor is located within the pixel circuit such that it controls the flow of charge to the capacitor during programming and holds charge on the capacitor during emission. Kimura Fig. 33. The charge on the capacitor in turn determines the brightness of the pixel. In this context, ensuring that the correct value is placed on, and held on, the capacitor is essential to the correct operation of the pixel circuit. Given the location of the third transistor and the role it plays in the circuit, a POSITA would have recognized that leakage current in the third transistor could alter the charge stored on the capacitor, thereby changing the brightness of the pixel from its intended value. It would thus be particularly important to mitigate any potential leakage current for this transistor, to ensure that the intended charge is placed on, and held on, the capacitor. Accordingly, it is unsurprising that Kimura never suggests that this transistor (or its counterpart in any other embodiment) may be switched from NMOS to PMOS, as this would lead to a higher susceptibility to leakage current.

Ex. 2008 at ¶ 70

Objective Evidence of Non-Obviousness

Pixel Uniformity and Aperture Challenges Are Well Documented



It is well known that the display luminance non-uniformity on AMOLED panels generally results from variation of the backplane. Although the LTPS TFT device is capable of driving an OLED device, the pixel-to-pixel level device variation is the key issue that makes the AMOLED panel a concern for certain applications. In order to solve this issue, several pixel compensation circuits for AMOLED applications have been proposed, which include the threshold voltage compensation circuit, current copy, current mirror, and pulse width modulation [36–39]. Most of the compensation circuits can greatly improve the luminance uniformity, but, nevertheless, complicated pixel circuits require more TFTs and capacitors. Subsequently, the sub-pixel aperture ratio is reduced. In addition, good device uniformity is still necessary even when compensation circuits are implemented, because the compensation is effective only for a certain deviation range.

However, the commercialization activities slowed down considerably after 2003. The production yield did not improve quickly, with issues relating to fine shadow mask and TFT non-uniformity being two major bottlenecks. These have been discussed extensively in this chapter. Alternative device architectures and compensation schemes have been widely studied and implemented.

Ex. 2010 at 29–30, 52

1. Introduction

Organic light emitting diode (OLED) displays are known to have a simple thin structure, fast response, wide viewing angle, and high contrast ratio. Adding to these merits, active matrix driving has lower power consumption than passive one because OLEDs can be driven using their more power-efficient condition. However, some challenges remain with active matrix OLED displays. Among them, inter-pixel uniformity is one of the most important for a picture quality as well as gamma correction.

Several pixel-driving methods have been proposed for suppressing inter-pixel non-uniformity, which is mainly caused by a deviation in poly-Si TFTs performance. The pixel circuit for V_{th} variation-compensation with autozero [1] was shown to suppress the V_{th} variation effectively, but it cannot compensate for a mobility variation [2]. Time-ratio gray scaling [3][4] performs very good uniformity because TFTs are driven only as switches. However, it is obvious that this digital driving method does not perform gamma correction, and frame memories are required in a sub-frame data generator [2]. Another driving method, such as adaptive current mode driving [2][5], requires the same characteristics in pair TFTs [6]. In this paper, we propose an

Ex. 2012 at 1

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There are two ways to compensate the TFT threshold voltage variation, current-program [2] and voltage-program [3]. Both of them needed more than four TFTs and four bus-lines for each pixel in general, which is too complicated in driving scheme and too busy in pixel area to achieve the high reliability and large aperture ratio. Simpler circuit design and driving scheme are expected in a-Si TFT driving AM-OLED. In SID'03 three TFT voltage-program pixel circuit was presented using in 20 inch a-Si TFT AM-OLED [4]. This driving technology makes possible to drive large-sized AM-OLED utilizing a-Si TFT.

Ex. 2013 at 1

Many Tried But Failed to Make Suitable Pixel Circuits

Mobile Displays

Technology and Applications

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during operation, leading to differential aging from pixel to pixel. To overcome the non-uniformity issues for both LTPS and a-Si driven AMOLED displays, several compensation approaches have been proposed and will be discussed in the following sections.

14.4.1.3 Voltage Compensation

Dawson *et al.* [50] from the Sarnoff Corporation proposed a voltage-driven pixel compensation circuit which contains four transistors and two capacitors. The circuit and its corresponding timing are shown in Figure 14.25 below. The additional transistors, M3 and M4, automatically zero the threshold voltage of the driving transistor, M2. During this period, M4 turns off and M3 turns on. M2 and M3 form a diode-connected structure and the disconnection of M4 forces the voltage at the gate of M2 to be $V_g = V_{DD} - V_{th}$. V_{th} is the threshold voltage of M2. Now the voltage across the capacitor C1 is V_{th} . In the second period, M3 is disconnected and V_{data} is applied. The voltage across C1 now becomes

Ono *et al.* [51], from IDT, proposed a voltage-controlled 4T1C pixel circuit for an a-Si AMOLED. Figure 14.27 shows the proposed pixel circuit and its corresponding timing. There are four control lines: MRG, RST, SCT, and COM. These control lines can be generated externally in the driver IC or power IC. During the compensation cycle, the OLED device serves as a capacitor, C_{OLED} . The pixel operation can be divided into four periods, as indicated in the timing in Figure 14.27. The operation of each period will be analyzed as follows:

Sanford and Libsch [52], from IBM T. J. Watson Research Center, proposed a simple V_{th} correcting circuit. Figure 14.30 shows the proposed pixel circuit and its corresponding timing. The circuit is simple with three TFTs, one capacitor, and two control lines. The operating principle is similar to the

Du-Zen Peng *et al.* [53, 54] from Toppoly Optoelectronics Corp, proposed another pixel compensation circuit, which compensates not only the threshold voltage of the driving TFT, but also the EL power voltage drop on the power lines. The pixel circuit contains five transistors and one capacitor and is shown in Figure 14.32 below together with its corresponding timing. The operation of

14.4.1.4 Current Compensation

Since the OLED is driven by a current and its luminance is proportional to that current, it is logical to apply current data to the pixel. Dawson *et al.* [55] from the Sarnoff Corporation proposed a current-driving pixel compensation circuit. Figure 14.35 depicts the pixel circuit and its corresponding timing.

This normal procedure, however, is not suitable for current-driven AMOLEDs, since too many pads are required for driving the panel, which is not practical for mass production and inspection. The issues described above can be tackled by applying the current-mirror type of pixel compensation circuit, and will be described as follows.

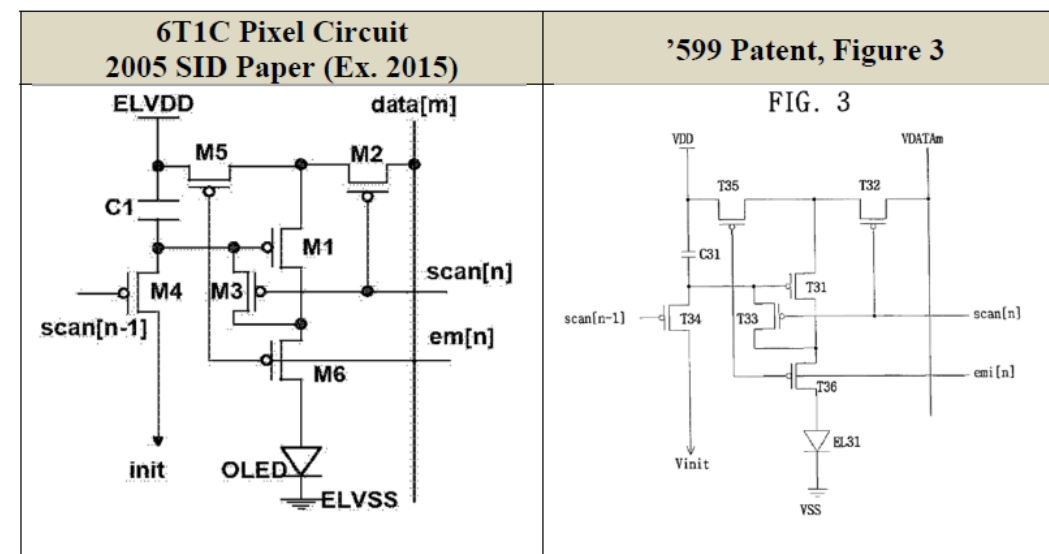
Sasaoka *et al.* [56], from Sony Corporation, developed a current-driven pixel compensation circuit. The pixel contains four transistors and one capacitor, and is illustrated in Figure 14.36. The pixel

Ex. 2010 at 36, 37, 39, 41, 42, 44, 45

'599 Pixel Circuit Solved the Uniformity and Aperture Challenges

In order to achieve high resolution AMOLED display, we need to realize compensation circuit with 2 μ m design rule, lower resistance metallization to minimize signal delay and top emission structure with flatness for LITI process. The LTPS TFT substrate of the newly developed 2.6-inch (302ppi) VGA AMOLED panel consists of 480 X RGB X 640 voltage programming pixel array and peripheral circuits as shown in Figure 1. The scan driver is integrated by LTPS TFTs on the glass substrate and data driver is directly connected to external driver ICs. We have applied our own 6 TFTs and 1 capacitor structure to compensate the V_{th} variation of the driving TFT in the pixels. This pixel circuit is suitable to realize a high image quality and high resolution for AMOLED panel. The transistor and capacitor size of each sub-pixel is optimized by simulation. We have also used 2 μ m design

We have developed 2.6-inch full color VGA AMOLED display with the highest resolution to date of 302ppi. We used V_{th} compensating pixel circuit to improve image quality and 2 μ m design rule in LTPS TFT fabrication process to realize the 28 μ m sub-pixel pitch with 40% aperture ratio. In spite of employing

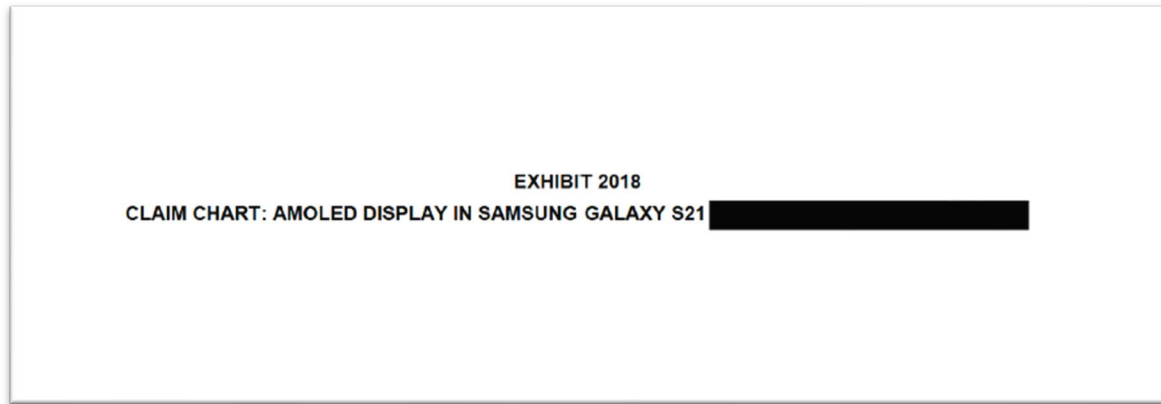


PO Response at 53

Ex. 2015 at 1, 3

'599 Pixel Circuit Has Been Used Ubiquitously

Galaxy S21 Circuit Analyzed by Dr. Wolfe

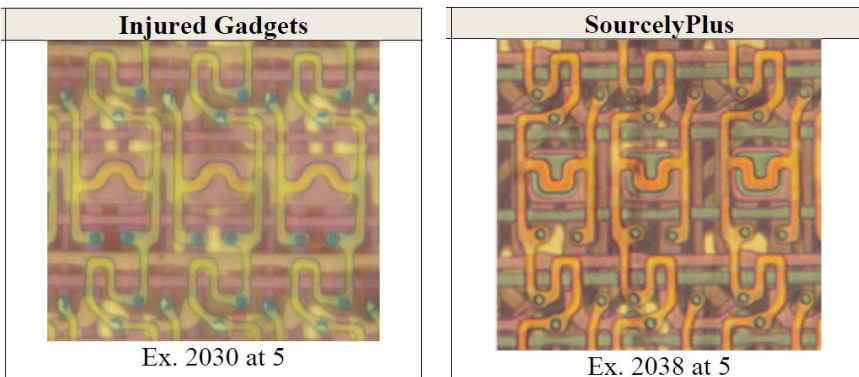
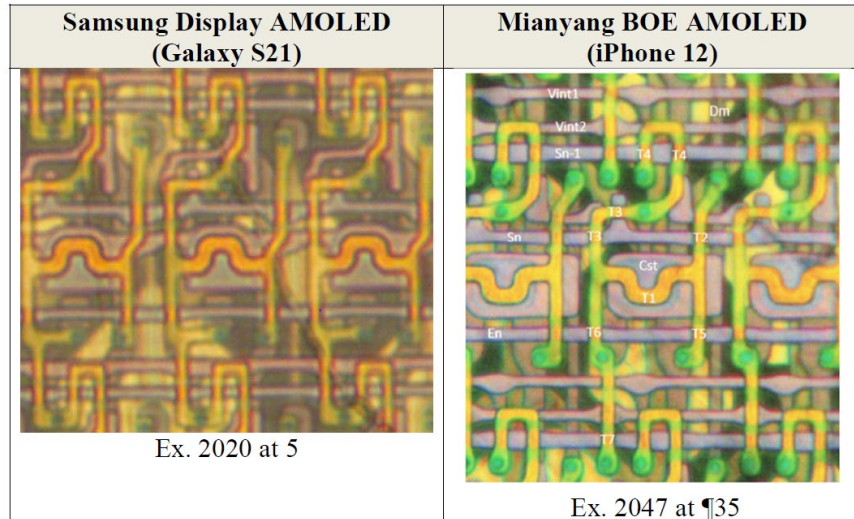


Ex. 2018

- Petitioner does not dispute:
 - that any claim element is not met by Samsung Display's AMOLED displays, or
 - that benefits of display uniformity and high aperture ratios result from the claimed structures

- No evidence that any of the alternative pixel circuits proposed by others have been successfully implemented in commercialized AMOLED displays for mobile devices

Widespread Copying of SDC's Patented Circuit Is Clear



- Petitioner does not rebut Dr. Wolfe's analysis showing that representative displays from Sourcely Plus and Injured Gadgets practice the claims in the same manner as SDC
Ex. 2018; Ex. 2021; Ex. 2022; Ex.2008, ¶¶ 137–138, 158–159
- Nor does Petitioner rebut Dr. Wolfe's testimony that the copied products are so similar in physical layout that they can only be explained by deliberate copying
Ex.2008, ¶¶156-160; see *Institut Pasteur v. Focarino*, 738 F.3d1337, 1347-48 (Fed. Cir. 2013)

Success of the '599 Circuit Has Been Validated by Industry Praise

He became the first Hanyang University professor to be selected as Korea's top scientist and engineer for contributing to the growth of the domestic display and semiconductor businesses.

The Republic of Korea's Best Science and Technology Award is an award given to scientists and engineers who have contributed to national development through world-class research and development achievements. Oh-Kyung Kwon, Distinguished Professor of Convergence Electronic Engineering, received the 2021 Korea Best Science and Technology Award on September 9. Professor Kwon said, "I am sincerely grateful to everyone who helped with the research," and added, "I feel honored and proud to be able to contribute to raising the status of Korea's display and system semiconductor businesses."



▲ Oh-Kyung Kwon,
Distinguished Professor of
Convergence Electronic
Engineering

Professor Kwon developed the world's first active organic light emitting diode (AMOLED) display technology for mobile and TV. He explained the reason for his research, saying, "Existing displays had difficulty controlling the current of the subpixels, making it difficult to express the intended color and luminance." To solve the problem, Professor Kwon developed internal compensation methods and external compensation methods. He said, "This method enabled accurate current level control and long-term use, and made mass production of AMOLED displays a reality."

Pixel circuit research is also one of Professor Kwon's major achievements. The existing pixel circuit structure had uneven luminance and low yield. Professor Kwon talked about the development process, saying, "We solved the problem by inserting a circuit inside the pixel circuit that can compensate for the deviation in the characteristics of the TFT for current control." He then replied, "Through research on pixel circuit structure, we have been able to increase the resolution of displays even with low current levels. I also remember that this technology was mass-produced at Samsung Mobile Display."

Ex. 2022 at 1

See also Ex. 2023 (awards for Dr. Ho Kyoong Chung from President of South Korea and the Society for Information Display; highlighting his "contributions to the large-scale commercialization and technical development of AMOLED displays")