Driving E Ink Displays
Renesas Technology & Solution Portfolio

Enabling the Smart Society

Microcontrollers
No.1 Market Share Worldwide

Advanced and Proven Technologies

Extensive, High-quality Portfolio

System LSIs

Analog & Power
Agenda

- E Ink Background and Overview
- Display Options
- Comparison to LCD
- Display Construction
- Technical Stuff
  - Display Structure
  - How does it switch
  - Display terms
  - Driving and Electronics
  - Integration
  - Standard Reliability testing
- Contact
- Addendum – Display concepts
E Ink at a Glance

- E Ink Corporation spun out of MIT Media Lab in 1997
- E Ink Holdings formed by 2009 combination of E Ink Corporation and PVI
Market Overview

- Active Matrix Business Unit
  - Triton and Pearl

- Segmented Business Unit
  - SURF Segmented Displays
  - High Channel Segmented Displays (Q4 12’)

- Ink in Motion
  - Point of Purchase
## Display Options

<table>
<thead>
<tr>
<th></th>
<th>Active Matrix</th>
<th>SURF Segmented</th>
<th>High Channel Segmented</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Backplane</strong></td>
<td>Glass</td>
<td>Polymer</td>
<td>Glass</td>
</tr>
<tr>
<td><strong>Shape</strong></td>
<td>Square/rectangular</td>
<td>Any 2D Shape 99% Custom</td>
<td>Square/rectangular</td>
</tr>
<tr>
<td><strong>Minimum Size</strong></td>
<td>4”</td>
<td>4mm^2</td>
<td>2.5”</td>
</tr>
<tr>
<td><strong>Thickness</strong></td>
<td>1.5mm</td>
<td>380 microns</td>
<td>1.5mm</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>160 – 200 Dpi</td>
<td>~ 200 Segments</td>
<td>Up to 600 segments</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>$$$$$$</td>
<td>$</td>
<td>Q4 2012</td>
</tr>
</tbody>
</table>
SURF Display Options

- Segmented Display Cell (SDC)
  - Customer integrates the display with electronics

- Segmented Display Module (SDM)
  - Display driver is bonded to the SDC
  - SDM is then connected to the MCU
# E Ink Segmented vs. TN-LCD

<table>
<thead>
<tr>
<th>Feature</th>
<th>E Ink</th>
<th>TN-LCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infinite viewing angle</td>
<td>🎉</td>
<td>🤕</td>
</tr>
<tr>
<td>Bi-Stable</td>
<td>🎉</td>
<td>🤕</td>
</tr>
<tr>
<td>Shatterproof</td>
<td>🎉</td>
<td>🤕</td>
</tr>
<tr>
<td>Any 2D shape</td>
<td>🎉</td>
<td>🤕</td>
</tr>
<tr>
<td>Reflective</td>
<td>🎉</td>
<td>🤕</td>
</tr>
<tr>
<td>Brighter White State</td>
<td>🎉</td>
<td>🤕</td>
</tr>
<tr>
<td>Darker Dark state</td>
<td>🎉</td>
<td>🤕</td>
</tr>
<tr>
<td>Daylight readable</td>
<td>🎉</td>
<td>🤕</td>
</tr>
</tbody>
</table>
Display construction

- Flexible backplane is made of either Polyimide or PET
  - PET ~ carbon based (200 um design rules)
  - Polyimide ~ copper or gold based (100 um design rules)

- Displays across a broad range of sizes
  - From 1 segment to 200+ segments
  - Alpha-numeric, and iconic, virtually any shape

- Almost unlimited design potential
  - LCD is glass based
  - Not limited to 90 degree angles

_The opportunity to use displays where they have not previously existed_
Best Applications for E Ink

- Power requirements have made a display unfeasible
  - Novatel Wireless

- Form factor limitations have made the incorporation of a display impractical
  - Lexar
Lets Get Technical
Display Cell Structure

Front Electrode
- 188 um PET with conductive ITO coating.

Back Electrode
- PET / FR4 / Polyimide
- pixel electrode layers (not shown)

Lamination Adhesive
- 25 um polyurethane

Microcapsule (~30 micron sphere)

Binder
- thermoplastic polyurethane
  (note, this material also surrounds microcapsules)

Front Barrier
- PET / FR4 / Polyimide
- pixel electrode layers (not shown)
- 2 mils EVA adhesive
- 1.25 mil PE
- thin PE tie layer (not shown)
- 0.3 mil AL foil
- thin PE tie layer (not shown)
- 0.5 mil PET

Back Barrier
- 2 mils EVA adhesive
- 1.25 mil PE
- thin PE tie layer (not shown)
- 0.3 mil AL foil
- thin PE tie layer (not shown)
- 0.5 mil PET

Inactive area on backplane

1.5 mm
How does it work?

• Each area needing to be switched must have its own dedicated drive line.
• To drive the display the top electrode and any bottom electrode or segment must be in opposite states.

  • When charged the pigment moves up or down in the capsule.
  • If the charge does not change the pigment remains in place.
• A capsule can display a black and white state at the same time.

Capsules are 30-70um in diameter
Display Terms

- **Segment** – Any Character or characters which need to change state. Note: Multiple segments can be tied to the same line.

- **Background/Field** – Essentially a segment, but is defined as the largest segment which is typically held in the opposite state to other segments.

- **Front/Top Electrode** – Drive line connection to the top electrode layer. This creates the DC potential for any segment to switch.
SURF Segmented Display Cell

- Display Driver
- MCU
- 1.8 - 3.3 VBat
- SPI or I^2C Interface options
  - FPC Connector
  - ACF bonding
  - Hot bar bonding

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SURF Segmented Display Module

1.8 - 3.3 VBat

Interface options
- FPC Connector
- ACF bonding
- Hot bar bonding

SPI or I^2C
## Driving E Ink Displays

<table>
<thead>
<tr>
<th></th>
<th>15 Volt</th>
<th>5 Volt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fastest Update Time</strong></td>
<td>240 milliseconds (Range 50-400ms @ 25C)</td>
<td>720 milliseconds (Range 500 - 2000ms @ 25C)</td>
</tr>
<tr>
<td><strong>Percent of available Contrast</strong></td>
<td>100%</td>
<td>80 - 90%</td>
</tr>
<tr>
<td><strong>Display Drivers</strong></td>
<td>E Ink Specific display driver</td>
<td>MCU</td>
</tr>
<tr>
<td><strong>Vendors</strong></td>
<td>Dialog Semiconductor</td>
<td>Renesas</td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>.5ua cm^2</td>
<td>.5ua cm^2</td>
</tr>
</tbody>
</table>
Waveforms

In its simplest form we drive the display with a square wave operating between 0 – 5V or 0 – 15V.

To drive all segments and field black – Segments and field =5V Top electrode =0V
5V
Top Electrode
0V

5V
All Segments
0V 500ms – 2 sec

To drive all segments and field white – Segments and field =0V Top electrode =1V
5V
Top Electrode
0V

5V
All Segments
0V
Global Update

- **Global update** - all segment switch during update
  - Even if it reverts to its original state
- Global Update provide a pleasant appearance
  - Even objects that do not change will flash
  - Global update waveforms can switch from B->W or from W->B

In this transition all segments which are not black are driven black
We then drive to white any segments not needed to complete the “5”
Note: The background/field is switched in this update
Global Update, cont

Image: Black to White update:

- In this transition all segments which are not white are driven white
- We then drive to black any segments needed to complete the “5”
- Note: The background/field is switched in this update
Local Update

- In this transition the segments needed to complete the “5” are driven black
- We then drive to white any segments not needed to complete the “5”
- Note: The background/field is not switched in this update

Image: White to Black update:
Local Update Waveforms, cont

Image: Black to White update:

- In this transition all the segments not needed to complete the “5” are driven white
- We then drive to black any segments needed to complete the “5”
- Note: The background/field is not switched in this update
Key Driving Points

- Do drive the ink to a saturated optical state
- Do drive the ink in a DC-balanced manner
  - Net impulse across ink should sum to zero
  - At constant-voltage, this means equal pulses in opposite directions.

- Do Not overdrive the ink
  - Do Not apply pulses longer than needed to reach saturated optical states.
  - Do Not re-drive ink in the same direction.
Integration

- Can E Ink displays be used with touch screens?
  - Yes, E Ink displays have been used with
    - Capacitive touch screens on top
    - Resistive touch screens
    - IR

- Can alternative lighting be used?
  - Yes
    - Side lighting and front lighting are commonly used with our displays.

- Can alignment features be added to the display?
  - Yes
    - Positioning features such as holes or notches are commonly added to assist in the positioning of displays in housings.

- Is passive Matrix possible?
  - No
## Standard Testing Environments

<table>
<thead>
<tr>
<th>Name</th>
<th>Test Items</th>
<th>Test Details</th>
<th>Pass Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RTO</strong></td>
<td>Room Temperature Operating</td>
<td>25°C/30% RH for 240 hours</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
<tr>
<td><strong>HHO</strong></td>
<td>High Humidity Operating</td>
<td>40°C and 90% RH for 240 hours</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
<tr>
<td><strong>HHS</strong></td>
<td>High Humidity Storage</td>
<td>60°C and 80% for 100 hours</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
<tr>
<td><strong>HTO</strong></td>
<td>High Temp Operating</td>
<td>50°C and 28% for 240 hours</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
<tr>
<td><strong>HTS</strong></td>
<td>High Temp Storage</td>
<td>70°C and 23% RH for 240 hours</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
<tr>
<td><strong>LTS</strong></td>
<td>Low Temperature Storage</td>
<td>-25°C for 240 hours</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
<tr>
<td><strong>LTO</strong></td>
<td>Low Temperature Operating</td>
<td>0°C for 240 hours</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
<tr>
<td><strong>TCT</strong></td>
<td>Thermal Cycle</td>
<td>[-25°C, 30 mins] to [70°C, 30 mins] 100 cycles</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
<tr>
<td><strong>SUN</strong></td>
<td>UV / Solar</td>
<td>768 W/m² for 7-days [Temp &lt;= 40°C]</td>
<td>less than 20% change in L* less than 250% increase in drive current</td>
</tr>
</tbody>
</table>
Contact Info

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Questions?
Driving the Display
Zones and Digits

- A digit is a collective group of segments

- Zone is a logical collection of digits or segments or icons
On board resources

- One timer operating at 5 ms
- Pins configured as output
- One routine call to EinkDisplayFSM to manage the screen (usually in the main while loop or using a regular timer interval).
Controlling the display using a finite state machine

- The **EinkDisplay FSM** handles every detail about turning the segments black or white.
- CurrDisplay array holds the current segments turned ON/OFF. nextDisplay holds the new segments to be turned ON/OFF. A “1” indicates turned ON, “0” indicates OFF.
- FSM has four states. START_UPDATE, WAIT, UPDATE_COMPLETE, and IDLE
- In order to start an update to the screen, set variable “updateRequest” to TRUE and the FSM switches to WAIT after setting the flag “changingState” as TRUE. It is recommended to not make any changes to the nextDisplay array while this flag is true.
- The FSM continues to update the screen while in the WAIT state by making calls to **updateScreen**.
- Once all steps required to update the screen using a particular waveform are done, the FSM switches to UPDATE_COMPLETE and the FSM returns to IDLE.
Defining a Screen using data structures

- **Screen name**
  - Used to identify the structure

- **Number of display zones**
  - Used to identify the number of logical zones on screen

- **Display Zone information**
  - Used to identify the number of segments per digit and number of digits in a zone

- **Number of pin connections**
  - Used to indicate the number of pins (including dummy segments) used by the display

- **Pin Connection information**
  - Used to identify which pin is connected to which digit segment. (grouped by zones)

- **Number of Valid ASCII to Segment mappings**
  - Used to indicate the number of valid mapping tables available in memory

- **ASCII to Segment mapping table 01**
  - Pointer to the segment mapping table for ASCII characters

- **ASCII to Segment mapping table 02**
  - Second pointer to the segment mapping table for ASCII characters
Using the “DisplayNumber” API

- Provide the DisplayNumber routine with the following:
  - An integer or message to display (8, 16 or 32-bit)
  - A location or zone number
  - Formatting options
  - Information about the screen using the display structure

- The DisplayNumber API will set the corresponding pins/segments to be turned ON by indexes in nextDisplay array
- Set the updateRequest flag to TRUE.

Advantages:
- Ease of setting up numbers/ alphabets
- Uses a look up table indexed by ASCII values to select the segments in a digit to turn ON
- Supports 256/128 mappings depending upon the number of pins/segments per digit
- Setup is required only once
- Error checking
- Easily support multiple screen definitions
Questions?