DEVCON
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HYATT REGENCY ORANGE COUNTY

RENESAS

E ink®

Driving E Ink Displays

Renesas Electronics America Inc.

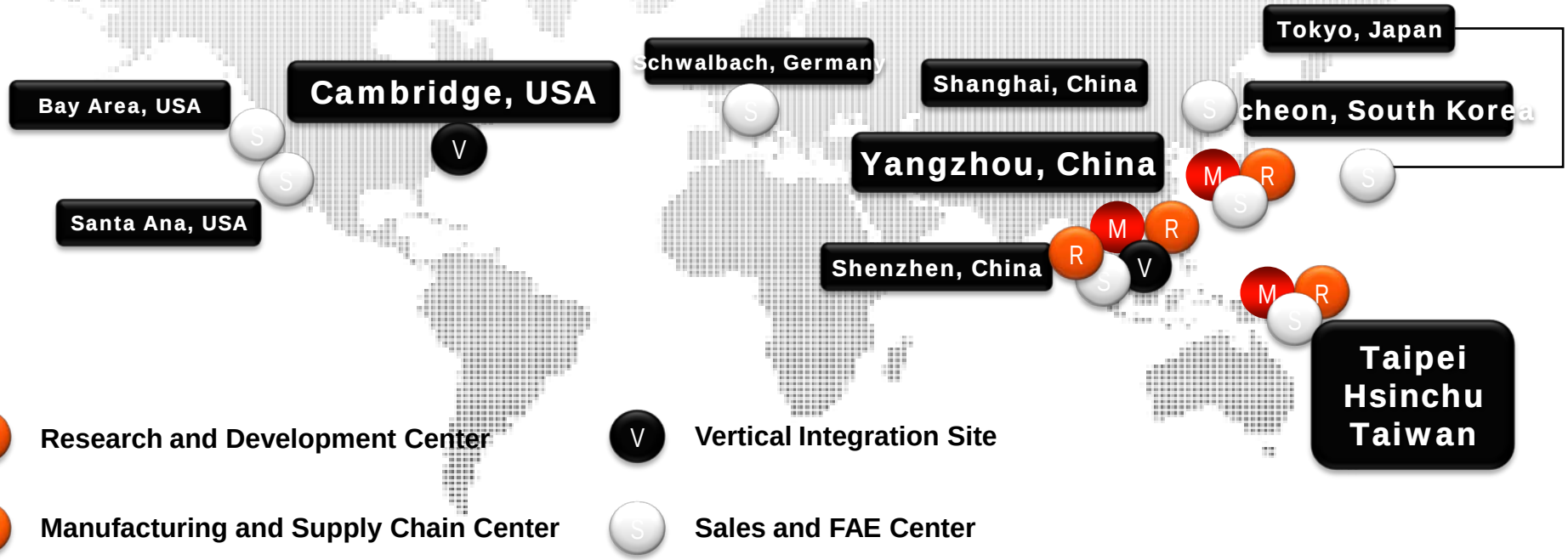
Renesas Technology & Solution Portfolio

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

	Active Matrix	SURF Segmented	High Channel Segmented
Backplane	Glass	Polymer	Glass
Shape	Square/rectangular	Any 2D Shape 99% Custom	Square/rectangular
Minimum Size	4”	4mm^2	2.5”
Thickness	1.5mm	380 microns	1.5mm
Capacity	160 – 200 Dpi	~ 200 Segments	Up to 600 segments
Cost	$$$$$	$	**Q4 2012**

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

Feature	E Ink	TN-LCD
Infinite viewing angle	☺	⊘
Bi-Stable	☺	⊘
Shatterproof	☺	⊘
Any 2D shape	☺	⊘
Reflective	☺	⊘
Brighter White State	☺	⊘
Darker Dark state	☺	⊘
Daylight readable	☺	⊘

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

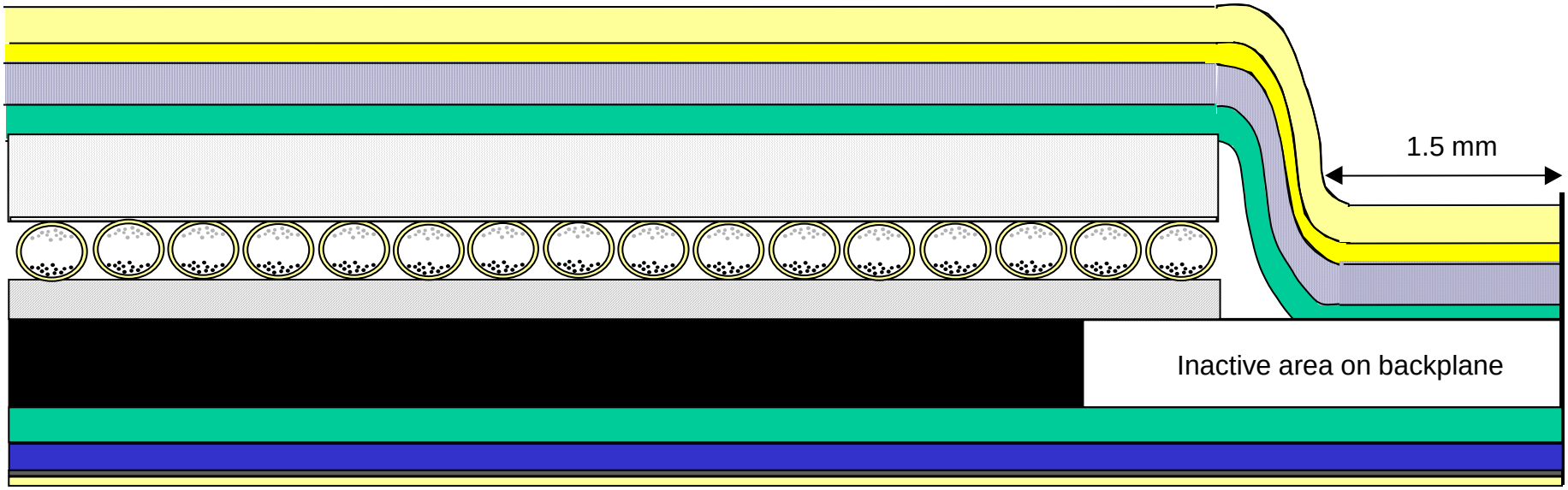
Best Applications for E Ink

- 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.

Lamination Adhesive
- 25 um polyurethane

Microcapsule (~30 micron sphere)

Front Barrier
- 2 mils UV/PET
- 1 mil PSA adhesive
- 2 mils ACLAR
- 2 mils EVA adhesive

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

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

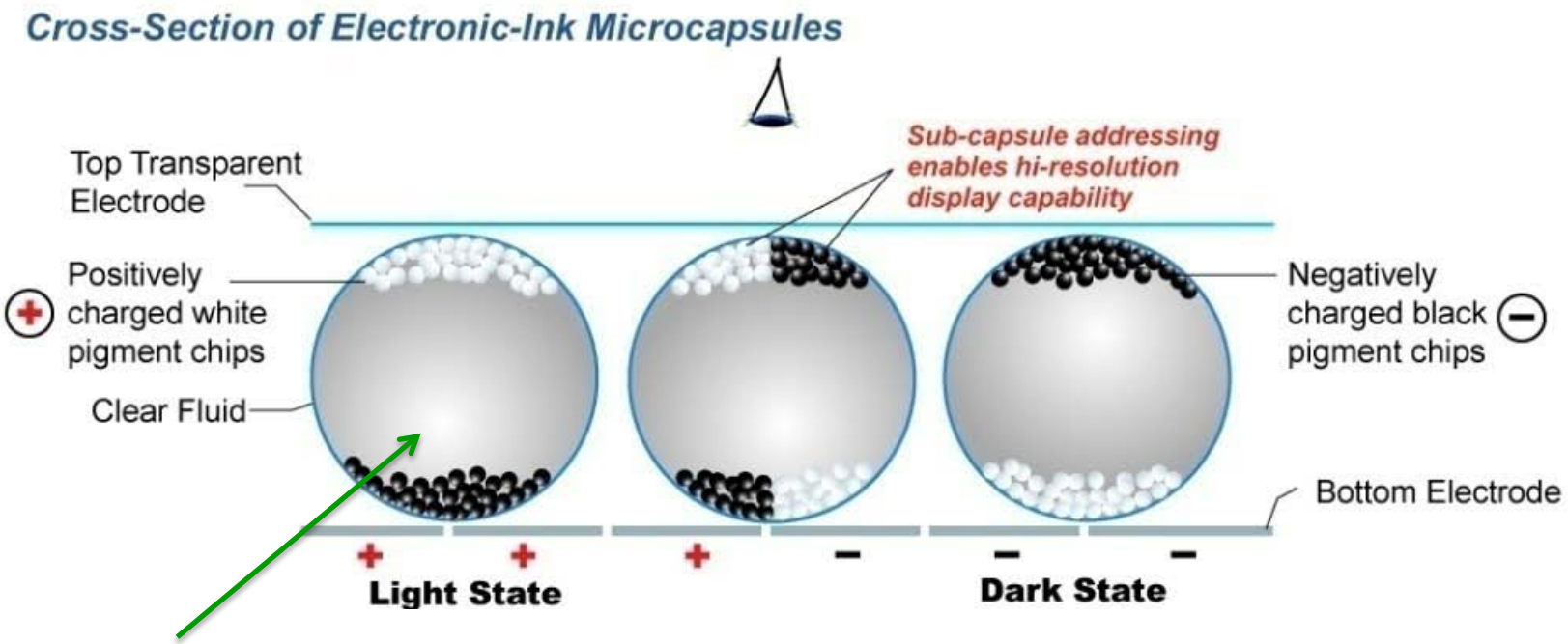
Back Barrier
-2 mils EVA adhesive
-1.25 mil PE
-thin PE tie layer (not shown)
- 0.3 mil AL foil
- thin PE tie layer (not shown)
- 0.5 mil PET

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.

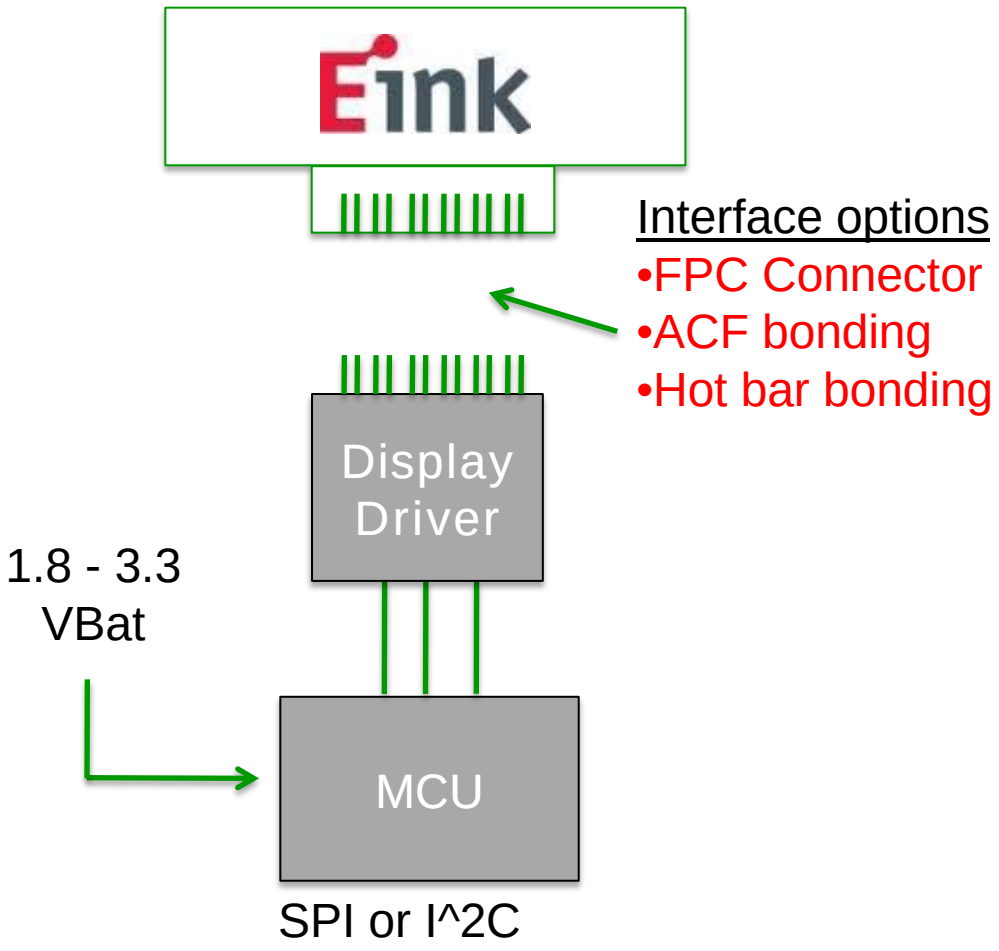


Capsules are 30-70um in diameter

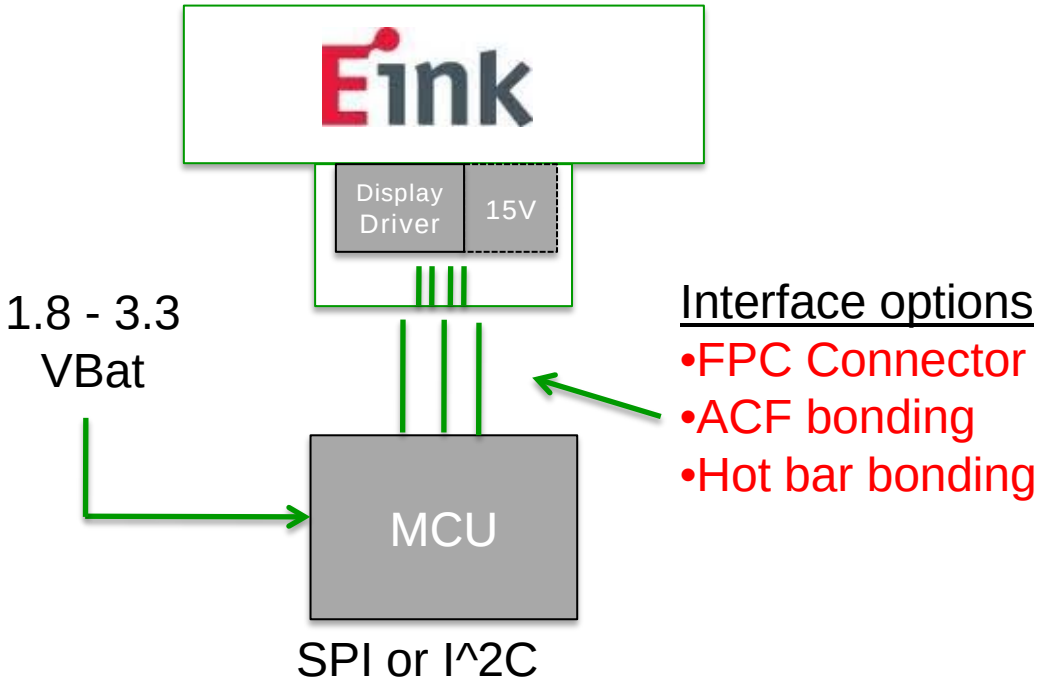
Display Terms

- 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



SURF Segmented Display Module

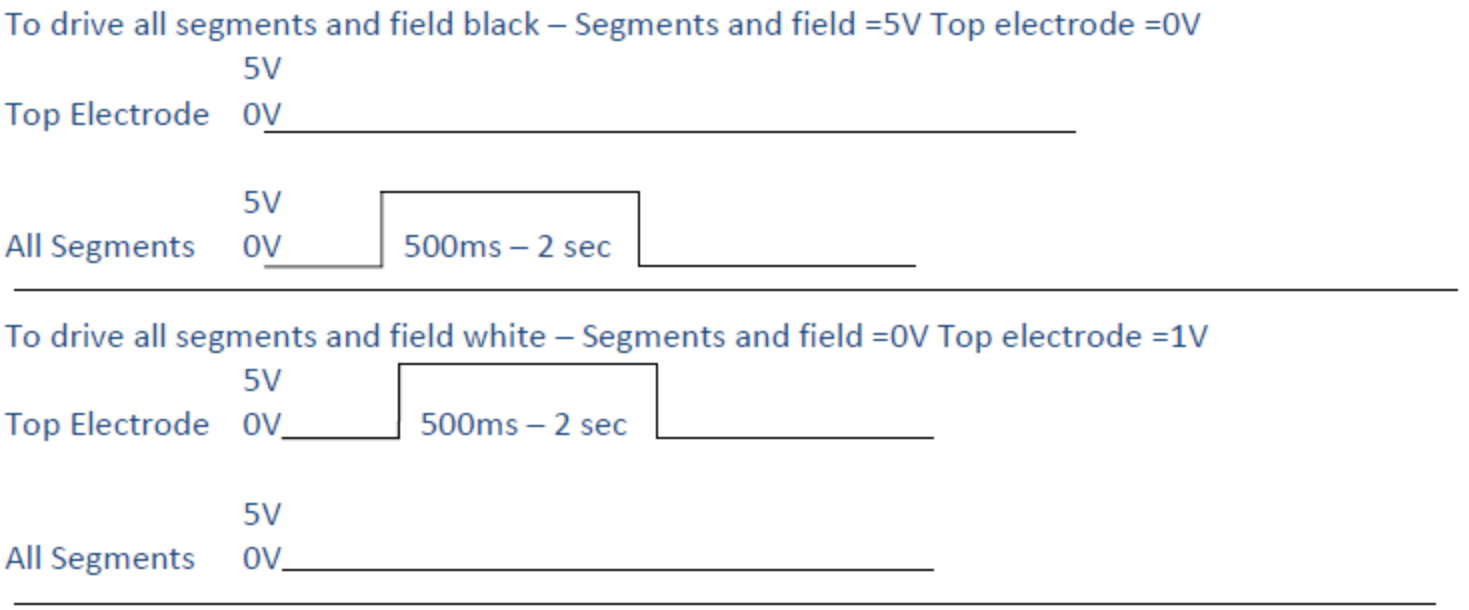


Driving E Ink Displays

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

Waveforms

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

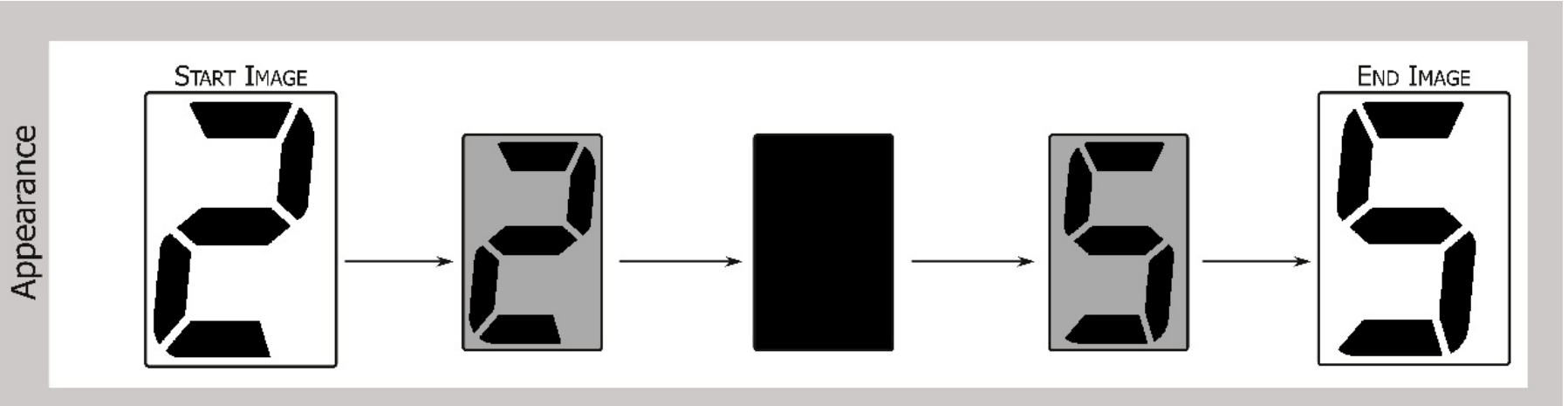


Global Update

- **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

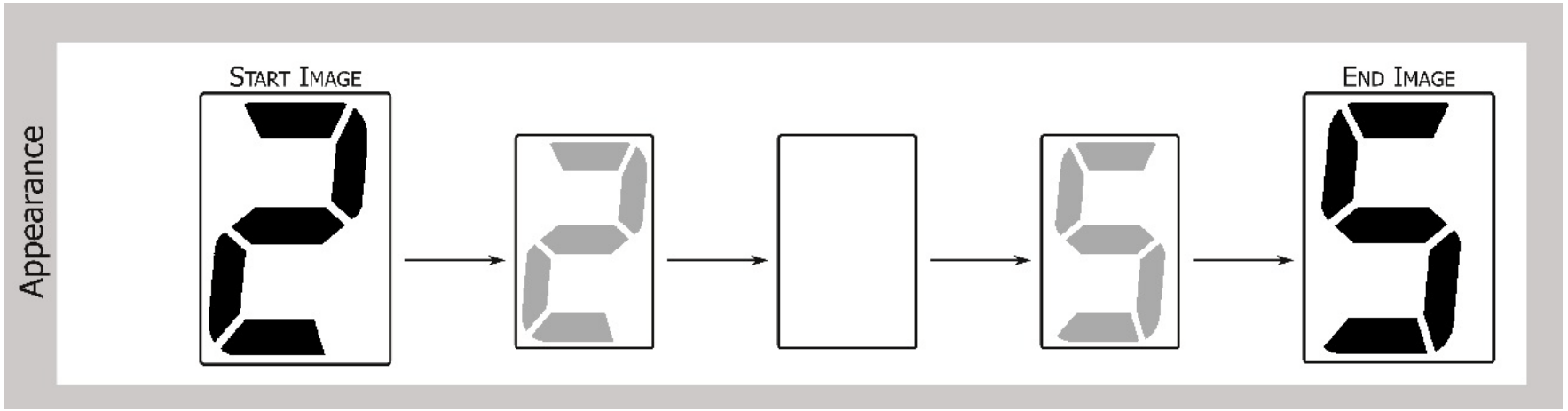
  Global update waveforms can switch from B->W or from W->B



- 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:

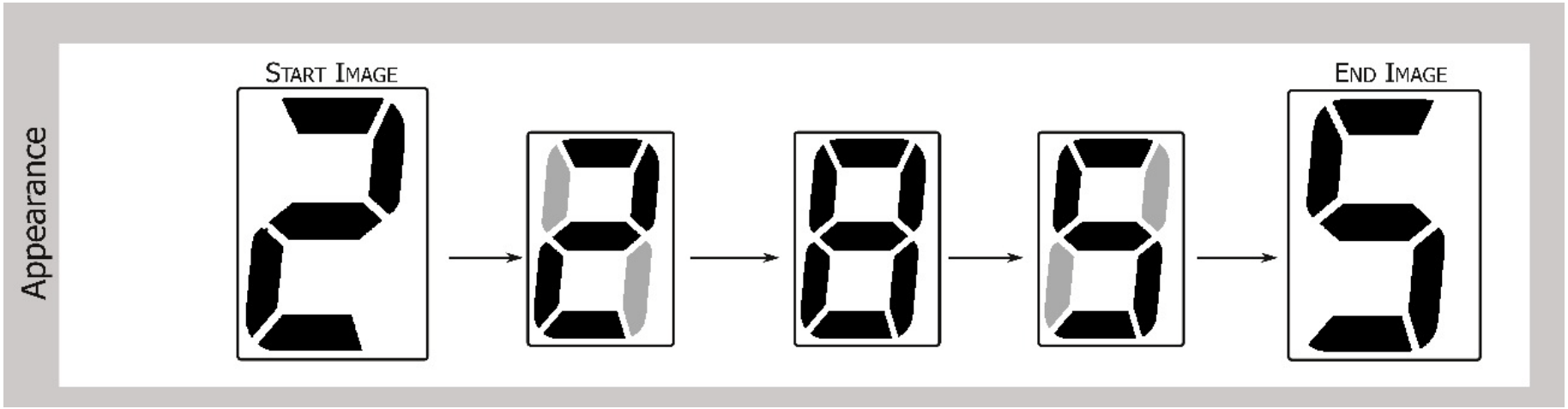


- In this transition all segments which are not white are driven white
- We then drive to black any segments needed to complete the “5”
- Note: The background/field is switched in this update

Local Update

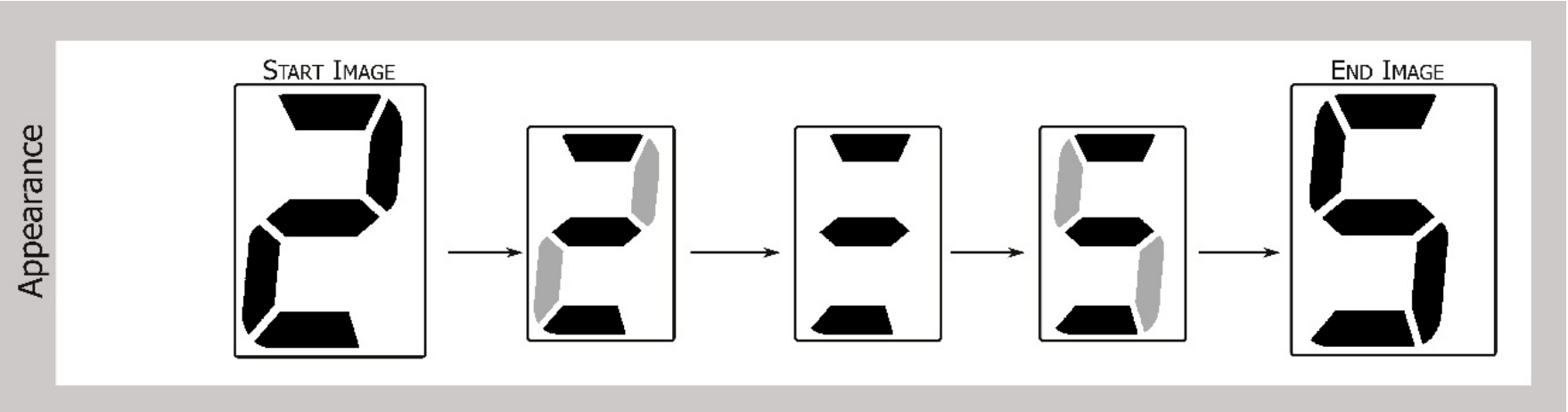
- In this transition the segments needed to complete the “5” are driven black
- We then drive to white any segments not needed to complete the “5”
- Note: The background/field is not switched in this update

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

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

Contact Info

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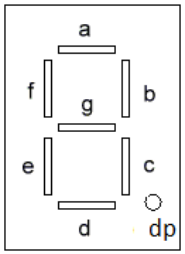
Questions?

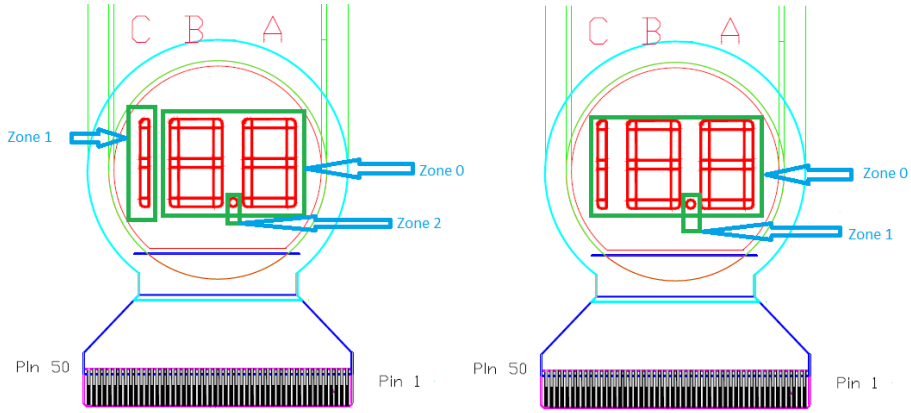
Driving the Display

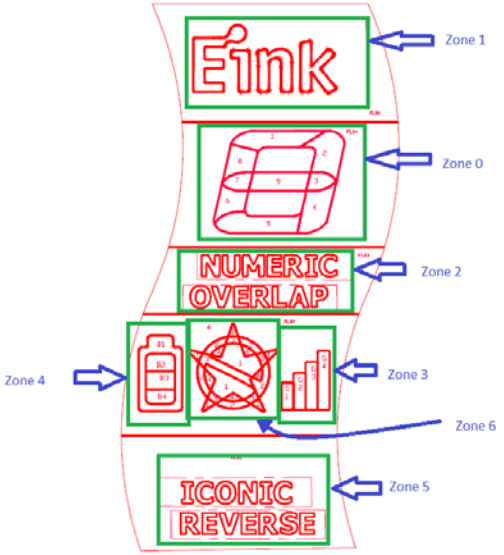
Zones and Digits

- A digit is a collective group of segments



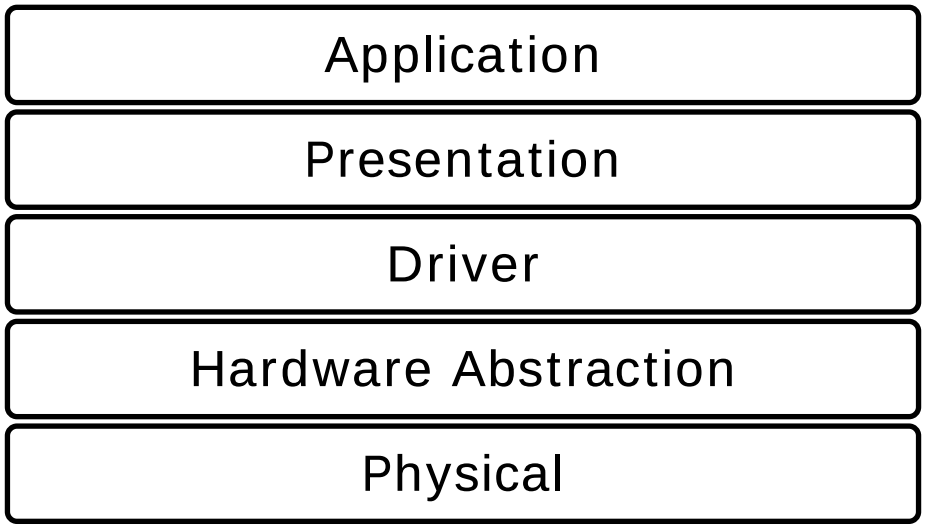
- Zone is a logical collection of digits or segments or icons





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 **EinkDisplayFSM** 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?

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