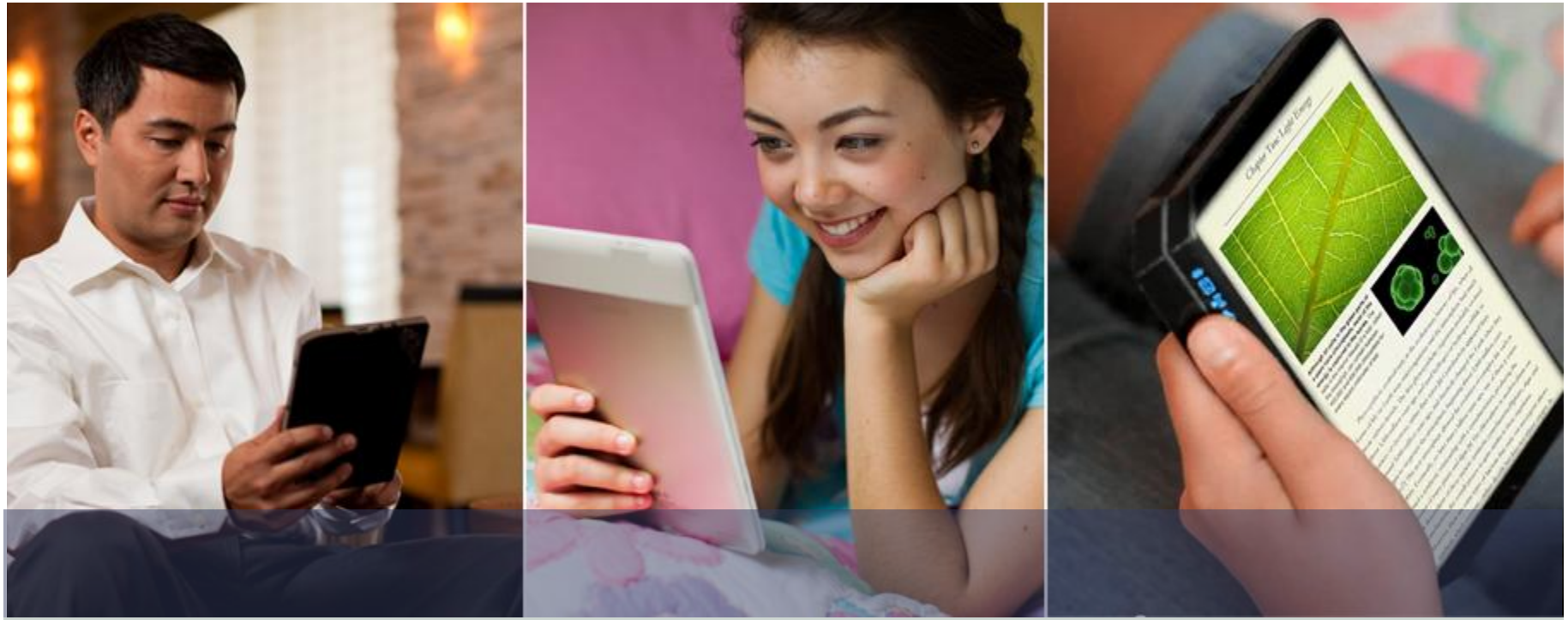

August, 2010

Designing an eReader Solution Using the i.MX508

CON-F0989

Derek Phillips

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What You Will Learn

- Overview on display technology
- eReader system design tradeoffs with i.MX508
- eReader system example using i.MX508
- OS support for the i.MX508
- SW implications of eReader design
- Challenges of low frame rate EPD screens and current software

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Freescale Multimedia Markets

Automotive

- Historic leadership in Telematics
- Ramping in radio and infotainment
- Initial designs in advanced clusters

OnStar by GM · SYNC Powered by Microsoft · KIA

eReaders

- Dominant market share in the emerging eReader market
- Aligned with market leaders

amazon · SONY · E·INK

Smart Mobile Devices

- Pioneer in portable media players
- Thought leader for smartbooks
- Focused investment in tablets

PHILIPS · Google · SHARP

Embedded Multimedia

- Broad traction in the embedded market
- Connected display based devices in consumer and industrial markets



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What is Special about an eReader?

▶ A Microencapsulated Electrophoretic Display (EPD)

- Also known as Electronic Paper Display or bubbles
- E Ink Vizplex® is the leading panel solution

▶ Low Power

- Weeks v. hours

▶ Sunlight Readable

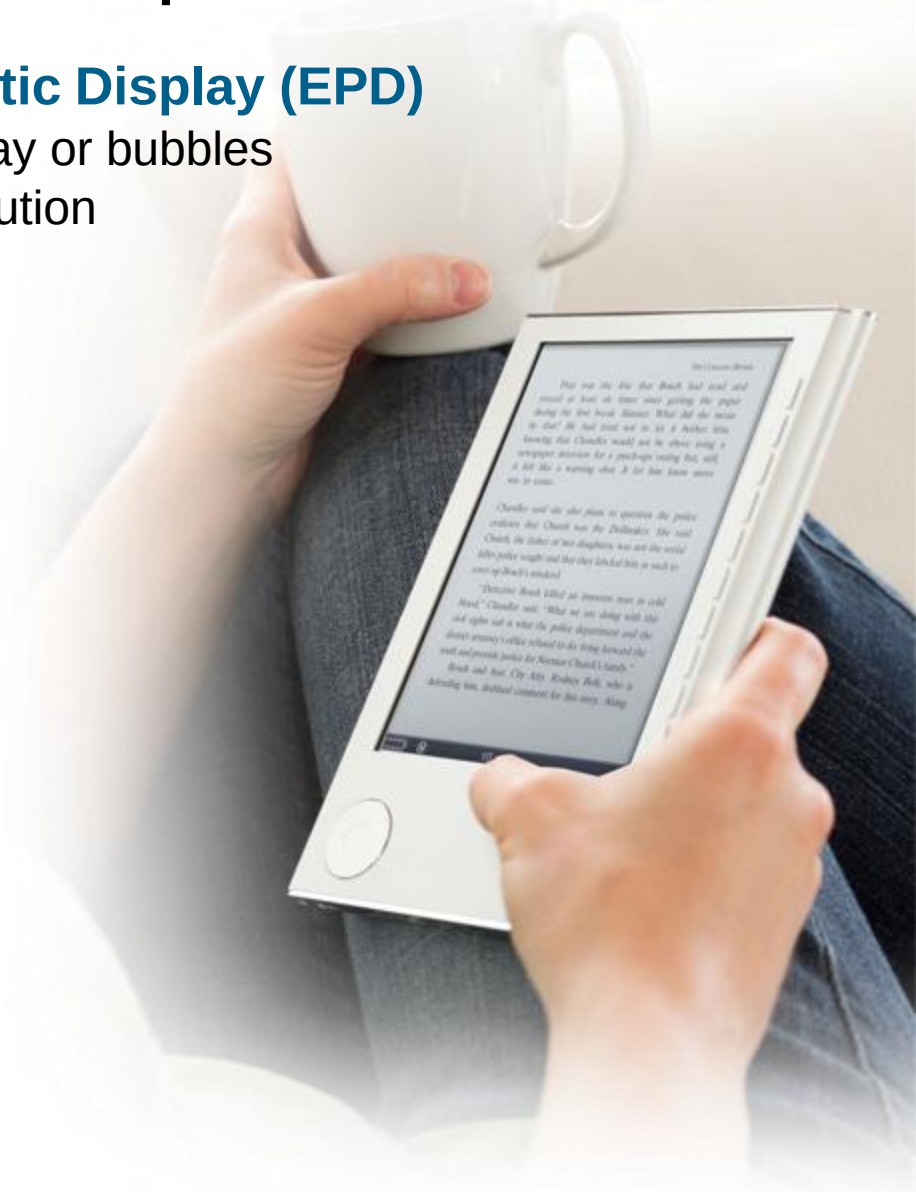
- Reflective v. backlight

▶ Thin and light

- Hold it in one hand

▶ Simple to use

- Some 3G enabled
- No monthly fee
- Easy to download new books



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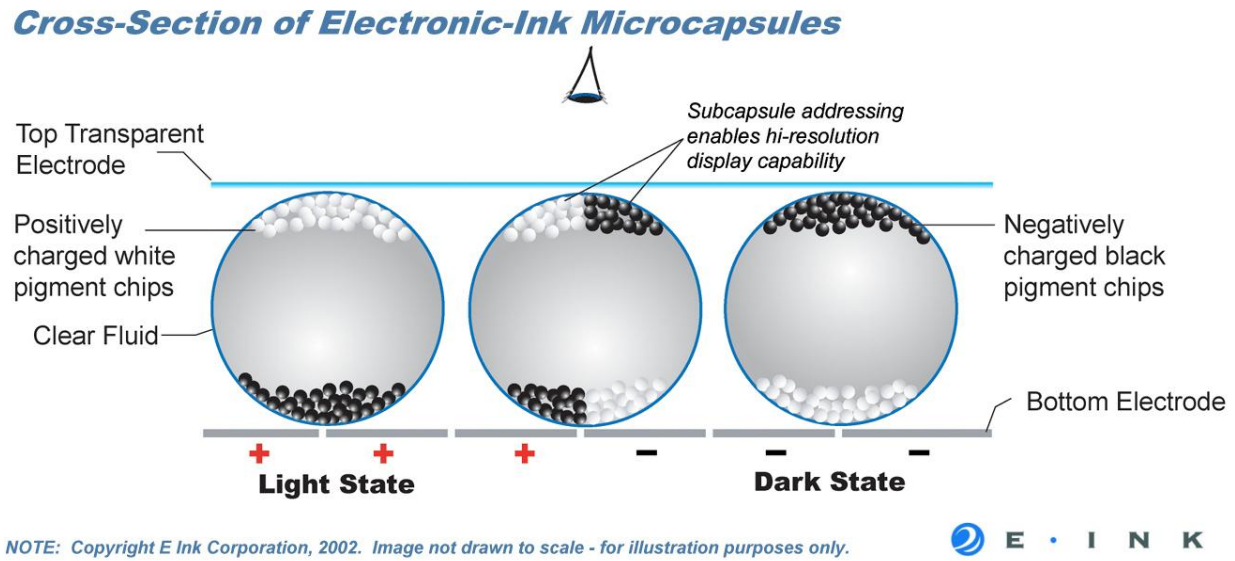
Display Requirements



- **Panel PMIC:** Must support bi-polar high voltage to move charged particles
- **Temp Sensor:** Movement of particles are temperature dependent so a temp sensor is required
- **EPDC controller:** Manipulating display requires special controller
  - This controller can be implemented in SW or hardware

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i.MX508 Block Diagram

▶ Specifications:

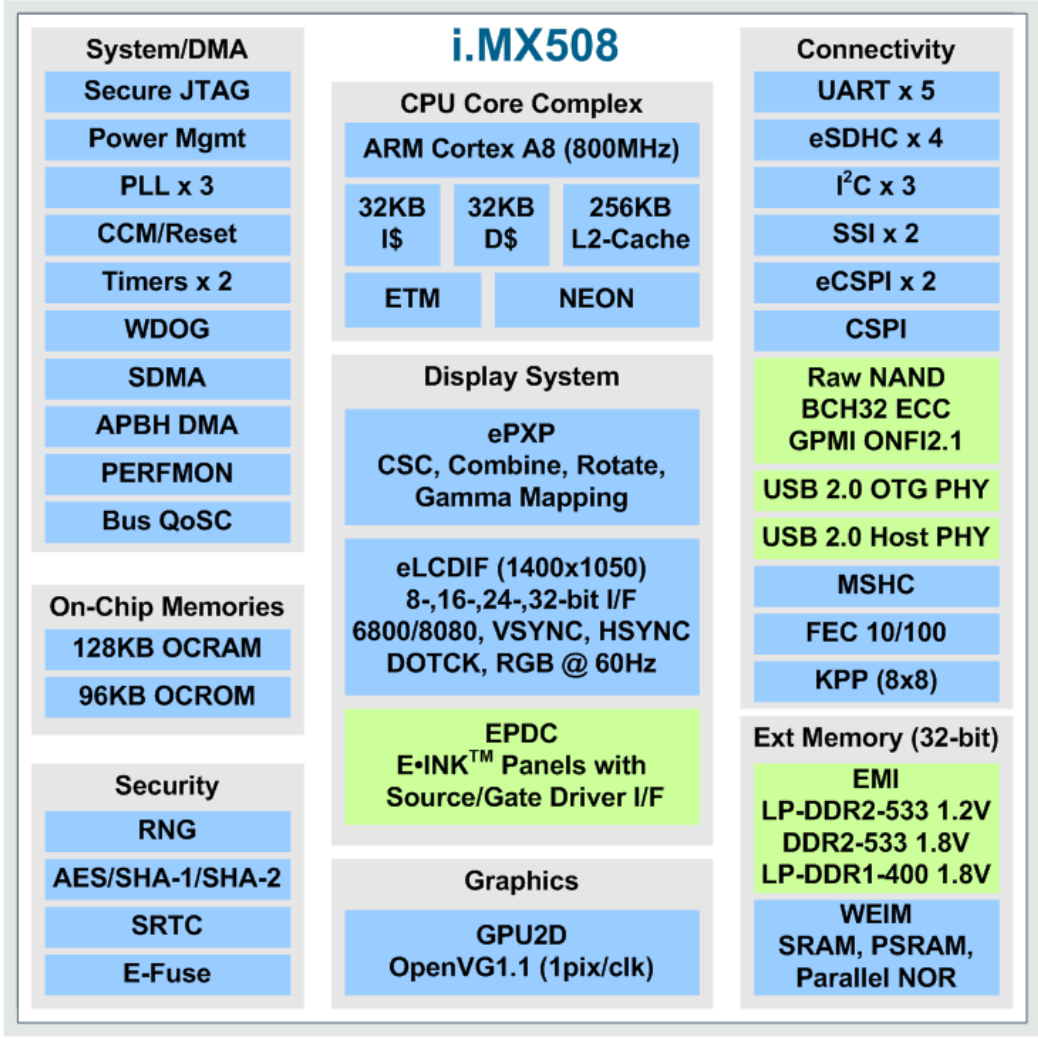
- **CPU:** ARM Cortex-A8 800MHz
- **Process**: 65nm, LP/GP
- **Core Voltage**: 0.7-1.1V
- **Temp Range:** 0 to 70C
- **Package**: 12x12 0.5mm

▶ Features and Advantages

- High Performance CPU : Cortex-A8
- Advanced power management features
- Integrated E-INK EPD Controller
- LP-DDR2 support for low-power applications
- Managed NAND Flash Support with eMMC 4.4/SDIO
- Raw NAND with up to 32-bit ECC and ONFI2.1/Toggle
- Dual USB PHY support (HS OTG, HS Host)
- Flexible LCD display support up to 1400x1050 @ 60Hz

▶ Schedule:

- Samples Q310
- Production Q410



Features to lower system cost

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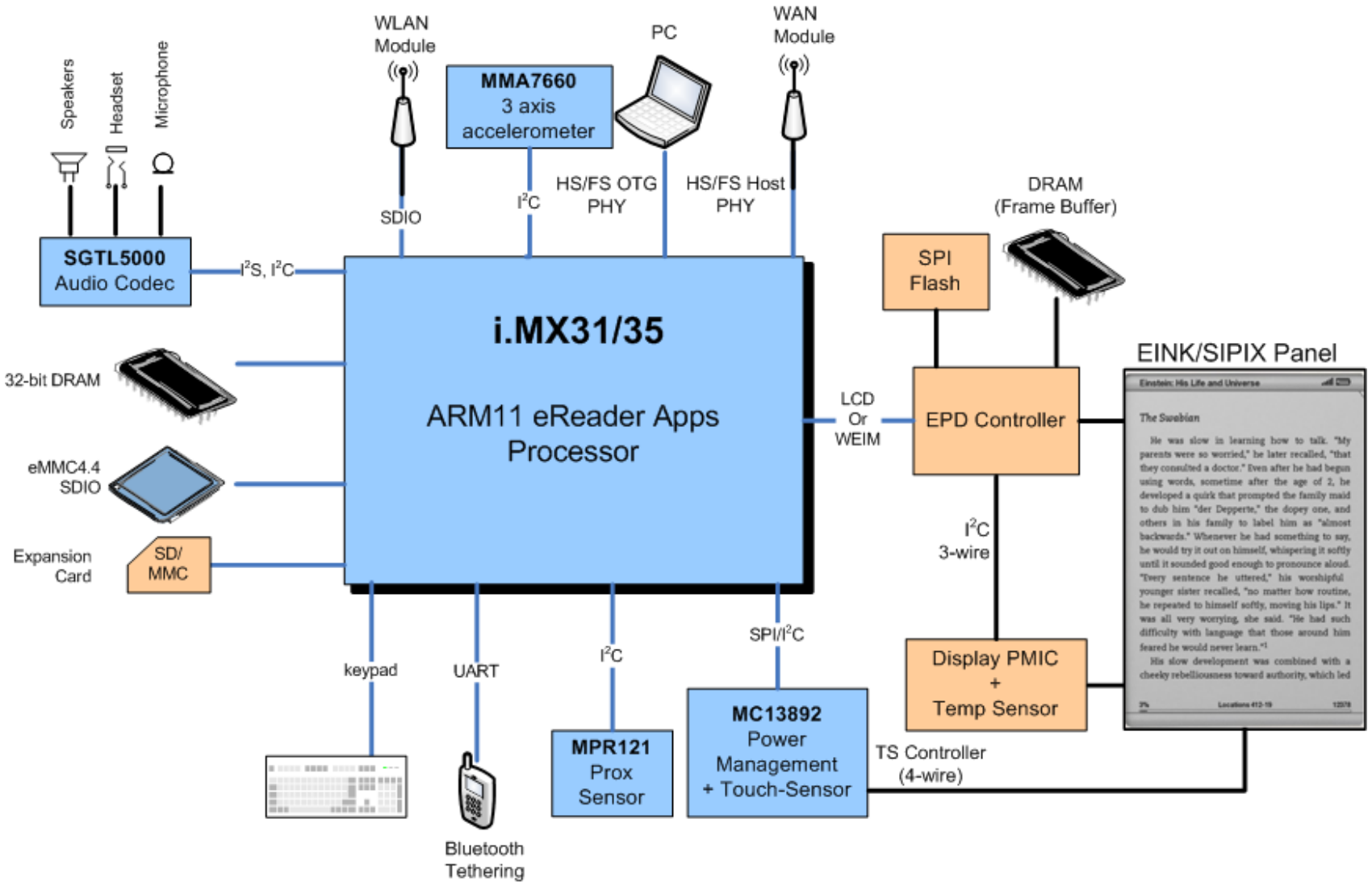
Current Generation eReader System



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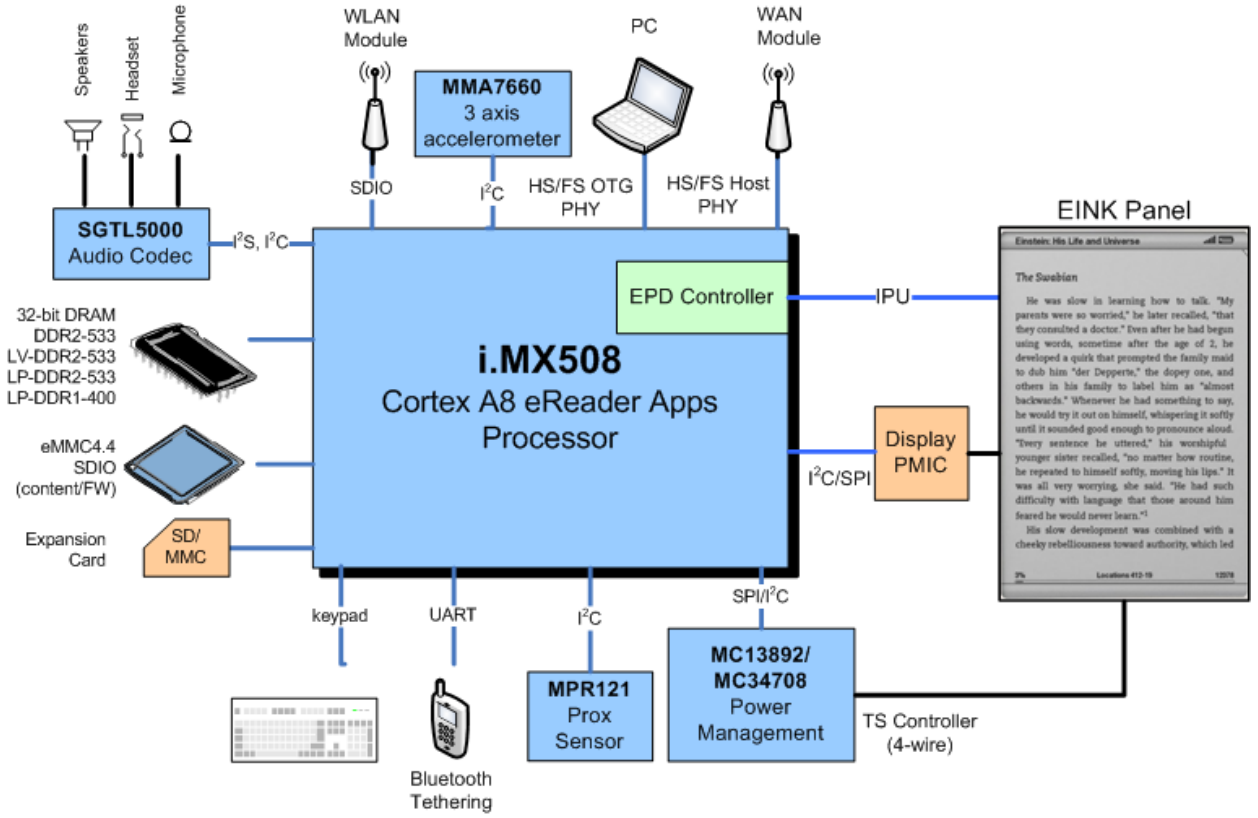
Next Gen i.MX508 eReader Solution



- **Advantages**:
- **Best Performance:** Cortex-A8 with dedicated Internal controller
- **Best Power:** Quickest to do work and turn off
- **Lowest system cost:**
  - No external controller (EPDC) or EPDC memory
  - Targeted eReader apps processor with integration to lower system cost

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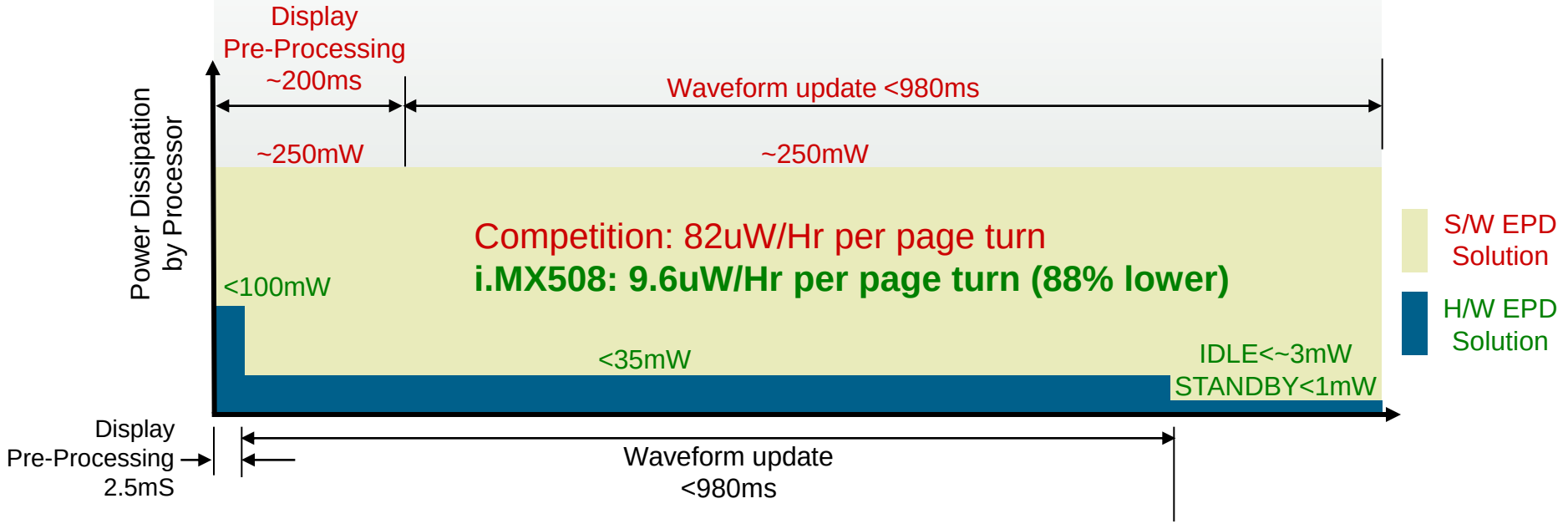
HW EPD: Ultra Low Power Consumption on Page Turn

i.MX508 **accelerates display pre-processing** steps resulting in lower power and lower latency between framebuffer update and final display



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Key iMX508 Features for eReader

▶ iMX508 Low Power Features

- Support for low power DRAM technology (mDDR and LPDDR2)
- Support for low power ARM Core modes such as Stop and SRPG (State Retention Power Gating)
- Dynamic clock gating of SOC peripherals
- Dynamic voltage and frequency scaling supported to reduce power during lower MIPS intensive activities

▶ ePXP (Enhanced Pixel Pipeline)

- HW assist for RGB to Greyscale color space conversion, rotation, scaling and blending
- Greyscale histogram to support auto-waveform mode detection

▶ EPDC Controller

- Supporting direct-driver TFT backplanes beyond 2048 × 1536 at 106 Hz refresh
- Up to 16 concurrent update regions
- HW collision detection

Memory Features

- **Reference design:** LPDDR2 and MMC will be utilized by default, but drivers will be available for alternative options.

- **Available DRAM options**
  - Lowest Power: 1.2V 16/32-bit LPDDR2 up to 266-MHz
    - Higher bus speed and lower power , but at a higher cost. Required for ultra-high resolution panels.
  - Balanced power/cost: 1.8V 16/32bit mDDR up to 200-MHz
    - Capable of supporting most EPD panels (9.7” and lower) at a lower cost
  - Low Cost: 1.8V DDR2
    - Not ideal for eReader solutions due to higher power.

- **Available Storage Media options**
  - Low Cost: 8-bit SLC/MLC NAND flash support with error correction up to ECC32
  - Ease of use: 1, 4 or 8 bit SD or eMMC support including v4.4 with DDR support

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Package Options

▶13x13, .5mm pitch, POP for LPDDR2

- POP allows for lower PCB layer count (no need to route memory)
- Only LPDDR2 is supported. LPDDR2 has limited support for lower memory densities so this may only be viable for higher tier designs
- Allows for smallest footprint

▶13x13, .5mm pitch

- Small footprint, support for all memory types

▶17x17, .8mm pitch

- Larger footprint, allows for easier fan out which translates into lower PCB count and lower cost.

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MC34708 Introduction

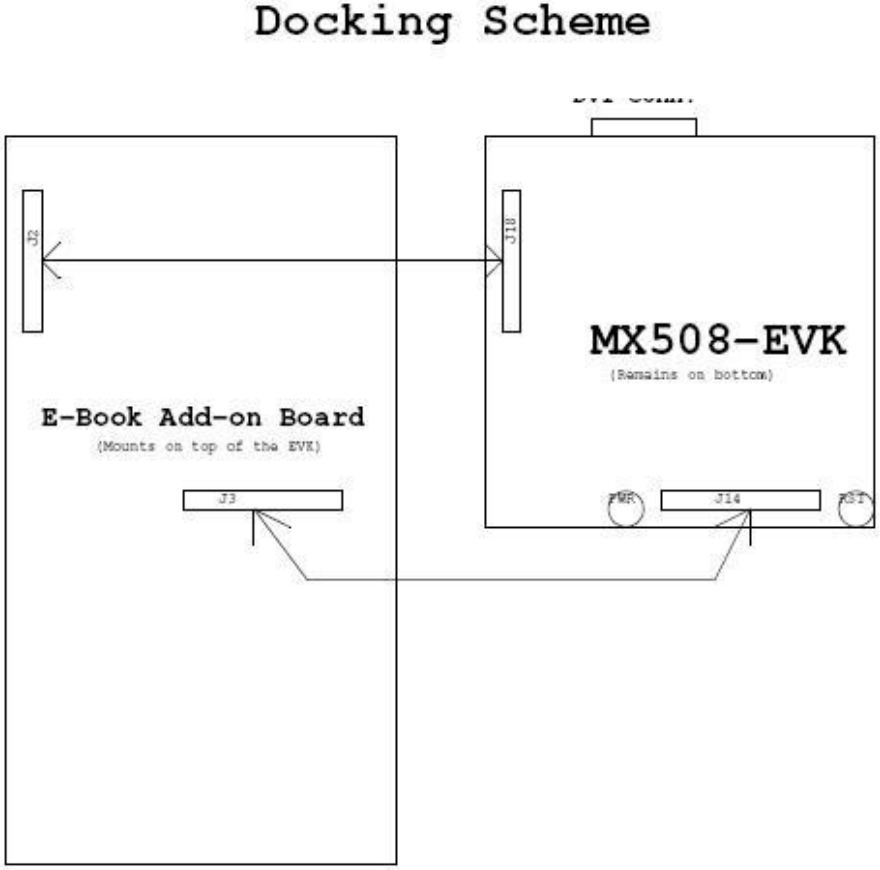
- Ripley represents **next generation i.MX** power architecture from Freescale
- Designed to meet needs of **i.MX508**
- Improved focus on power efficiency results in **longer battery life** and **reduced heat** during operation
- Higher output current capability supports **higher speed processor cores**, and **multi-core devices**
- Improved battery management with **switching charger**, **dual path design**, **USB-OTG power** and **aux-power output capability**. Offers faster battery charging than previous PMIC devices
- **Integrated USB switching** for USB, UART and audio, with universal charging standard (CEA936 support)
- **iMX508** reference design will include **MC34708** support by default with a **MC13892** driver option available with the BSP.

EPD and Display Support

- **iMX508 Reference design** will include E-Book Add-on Board along with the iMX508 EVK.

- **E-Book Add-on Board Includes:**
  - Touch panel connectivity
  - Maxim MAX17135 EPD PMIC
  - 6” EINK Display Panel
  - MMA8450Q Accelerometer

- **iMX508-EVK** has headers for both EPDC and LCDIF ports provide flexible display connectivity options.



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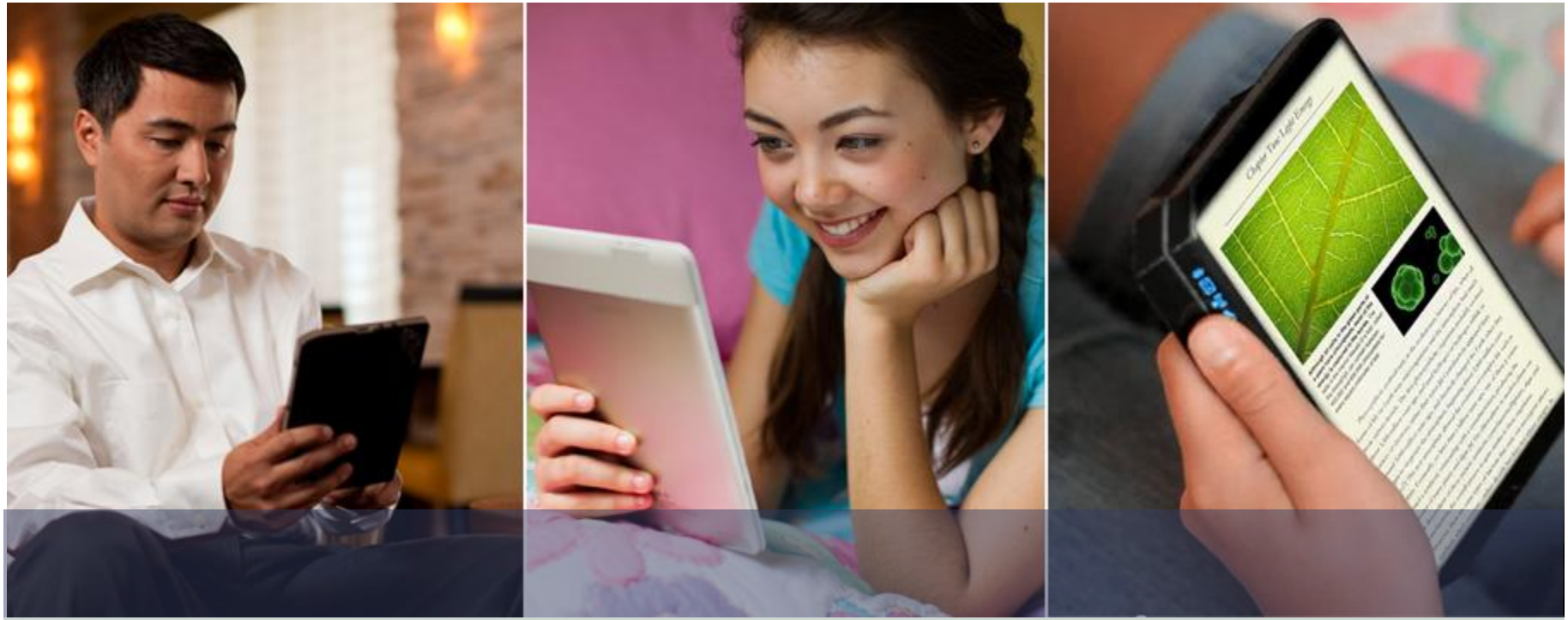

SW Design Considerations for eReaders

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OS Support

Windows® Embedded CE

Linux®

Android™

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FSL EINK BSP Solution

- **Supported OS's** – Linux, Android, WinCE


- **Simple Programming Model** – Standard Framebuffer call with extensions for control over update
  - Allows application control over screen region, update mode (full or partial) and waveform mode
  - Framebuffer driver manages active update lists and collision events
  - Wait for completion available for synchronization of updates
  - PXP hardware acceleration
    - RGB to greyscale color space conversion
    - Rotation, scaling and blending
    - Histogram to support automatic waveform mode detection

- **Android Modifications** – Modifications to display framework, surface flinger and views to allow application control over display updates

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Android w/eReader

- Android was designed for smartphones with LCD interfaces which does not allow for application decisions to overcome the EINK challenges.
  - Screen size is limited to phone resolutions (<6"); eReaders are much larger (6"-11")
  - EPD displays have very slow refresh rates (~1s); Android requires 3D rendering and other graphics required for a rich internet experience.
  - Android Applications can not run on eReaders due to slow screen refresh rates
  - All eReader Apps must be tuned to function on the slow screen
- Developers of eReaders in Android must modify the framework and application to work smoothly on an eINK display. By the time the modifications are complete, it is no longer looks like ‘Android’.
- Developers prefer Android for the following reasons:
  - Development platform for tools and community involvement
  - Easy integration of network stacks and other services
  - Leverage applications

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EINK Terminology

- **Update** – Grey-level state change to an regional or global area of the display
  - **Partial** – Applying the waveform to only the pixels that change in a given region
  - **Full** – Applying a waveform to all pixels in a give region (Often confused with Global)
- **Regional Update** – Only update a portion of the screen
- **Global Update** – Entire screen area is updated
- **Concurrent Update** – Multiple updates processed asynchronously
- Waveform Modes (EINK 50-Hz Update Times)
  - **INIT** – Initialization waveform (~2-sec)
  - **DU** – Black/White (300-ms)
  - **GC4** – 4 level greyscale (600-ms)
  - **GC16** – 16 level greyscale (980-ms)
- **Frame** – A single TFT frame scan of all pixels' waveform state data at the panel frequency; every 50-Hz or 20-ms apply 1, -1 or 0
- **Collision** – Attempting to update pixel(s) that are currently being processed

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EINK CHALLENGE #1 – Slow Display Frame Rate

1

▶ Waveform Selection

- EINK has several waveform modes which are used for different greyscale depth and different update times
- Longer waveform times will produce better greyscale accuracy
- Waveform update characteristics are dependant upon the panel technology and may vary based on product generation or model

Application development has a trade-off between update speed and greyscale accuracy

Black

- All pixels are black or white in update Region
- DU waveform should be selected (300-ms)

Black Greyscale

- Example update region with 4 greyscale levels
- GC4 waveform should be selected (600-ms)

- Maximum pixel depth with all 16-levels used
- Accurate grey level required
- GC16 waveform should be selected (980-ms)

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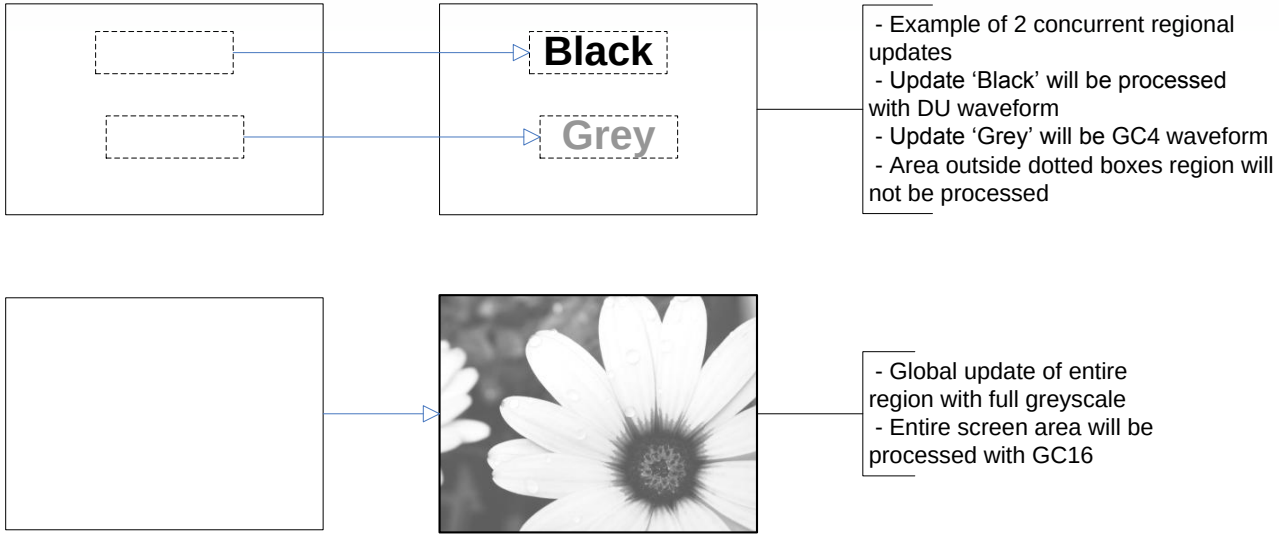
EINK CHALLENGE #1 – Slow Display Frame Rate (2)

1

▶ Global and Regional Updates

- A global update refers to updating the entire display while regional refers to updating only a porting of the screen
- Up to 16 concurrent update regions can be processed asynchronously
- Each regional update can select its own waveform

Application can utilize regional updates to improve the effective frame rate of the display



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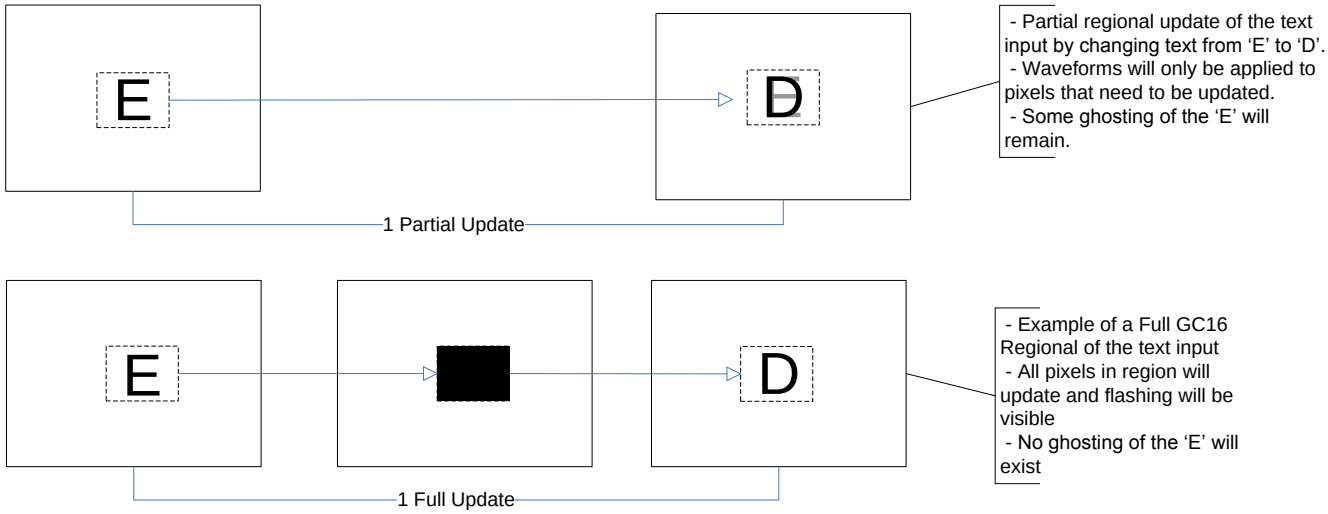
EINK CHALLENGE #2 – Ghosting and Flashing Effect

2

► Utilizing Partial and Full Update Modes

- Partial Update mode can be used to only update pixels that change for the update region.
- A Full update is often confused with Global. Full refers to applying a waveform to all the pixels for a global or regional update.
- Ghosting may occur when using Partial updates.
- Shorter waveforms will produce more ghosting than longer waveforms.
- GC16 Full updates are used to remove any ghosting by driving the pixels to a known state (such as all black) before the final state.
- A side effect of Full GC16 updates is a flashing effect that makes the update appear to flash during the transition.

Application will need to decide the usage of Full or Partial based on the user experience expectations.



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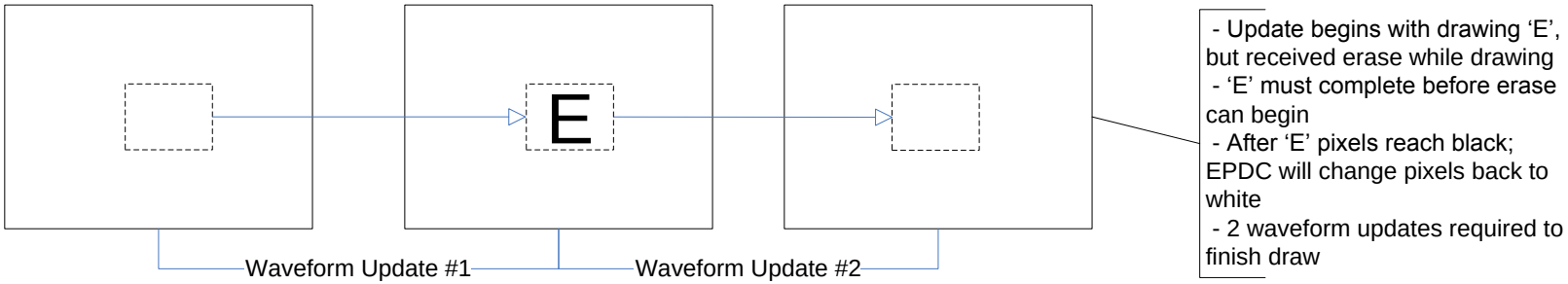
EINK CHALLENGE #3 – Collision Events

3

▶ Collision Handling

- A pixel must complete its transition before starting a new update
- A collision will occur when attempting to change a pixel that is already in the update process
- EPDC driver will resolve collisions for the application
- Application will experience a longer delay to the final image if collision occurs
- Collision example – User presses key entry and immediately presses erases character; total update time will be 2X waveform update time

Application should be designed to limit overlapping regions on a screen



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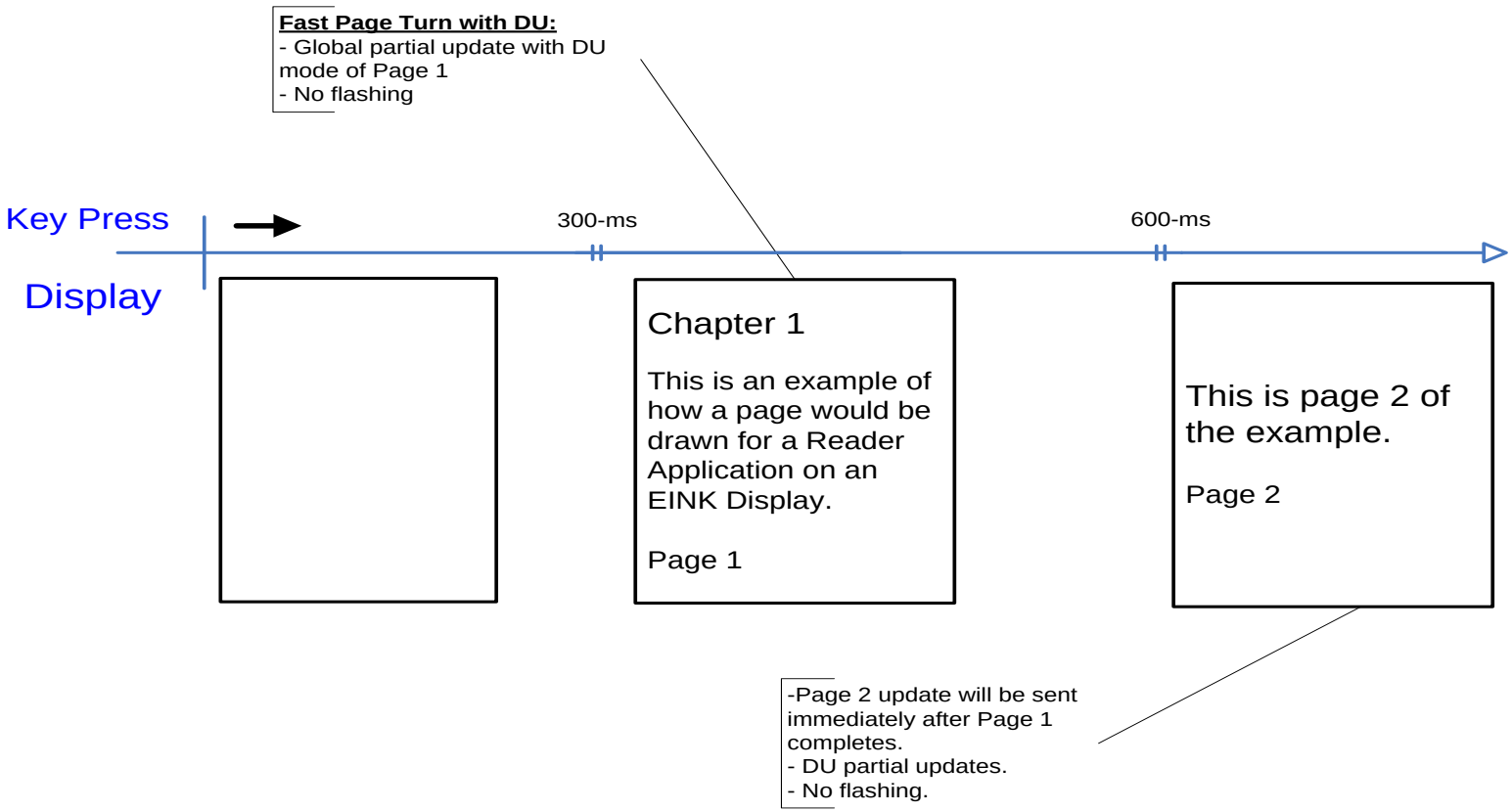
Waveform Example – Fast Page Turn

The fast page turn use case allows the users to quickly seek through the eBook. The page turn speed is limited by the EINK waveform update time. Selecting DU mode will provide ~3fps.



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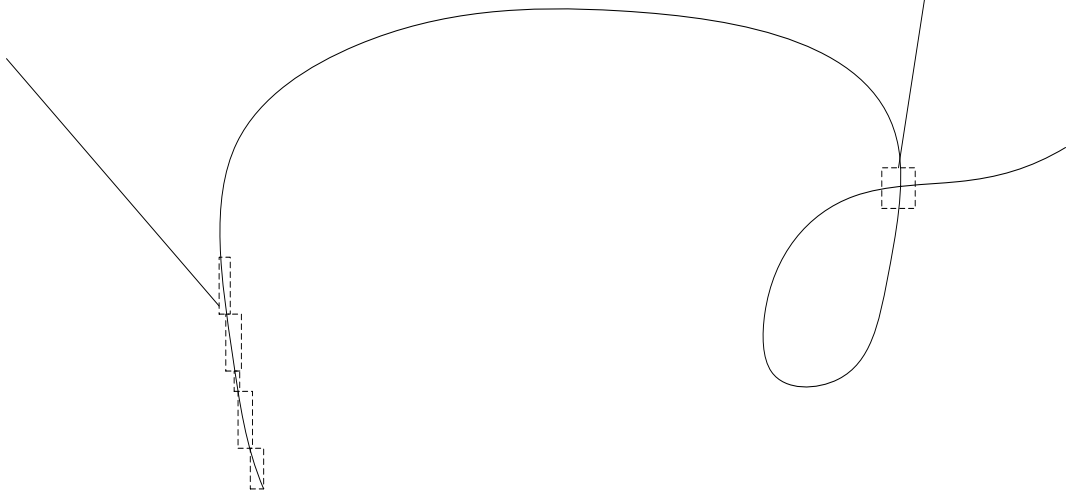
Regional Update – Handwriting Example

- Crossover points would send a new update to a pixel being updated
- Collision event would not trigger since pixel is already moving to black

- DU waveform mode used for maximum throughput
- Regional updates broken into small areas
- EPDC supports up to 16 concurrent updates
- Theoretical framerate would be 48-fps (16 DU regional updates every 300-ms)



Small regional updates can be sent to the screen at the panel refresh rate (ie 50-Hz or 85-Hz) providing user an 'LCD-like' experience.

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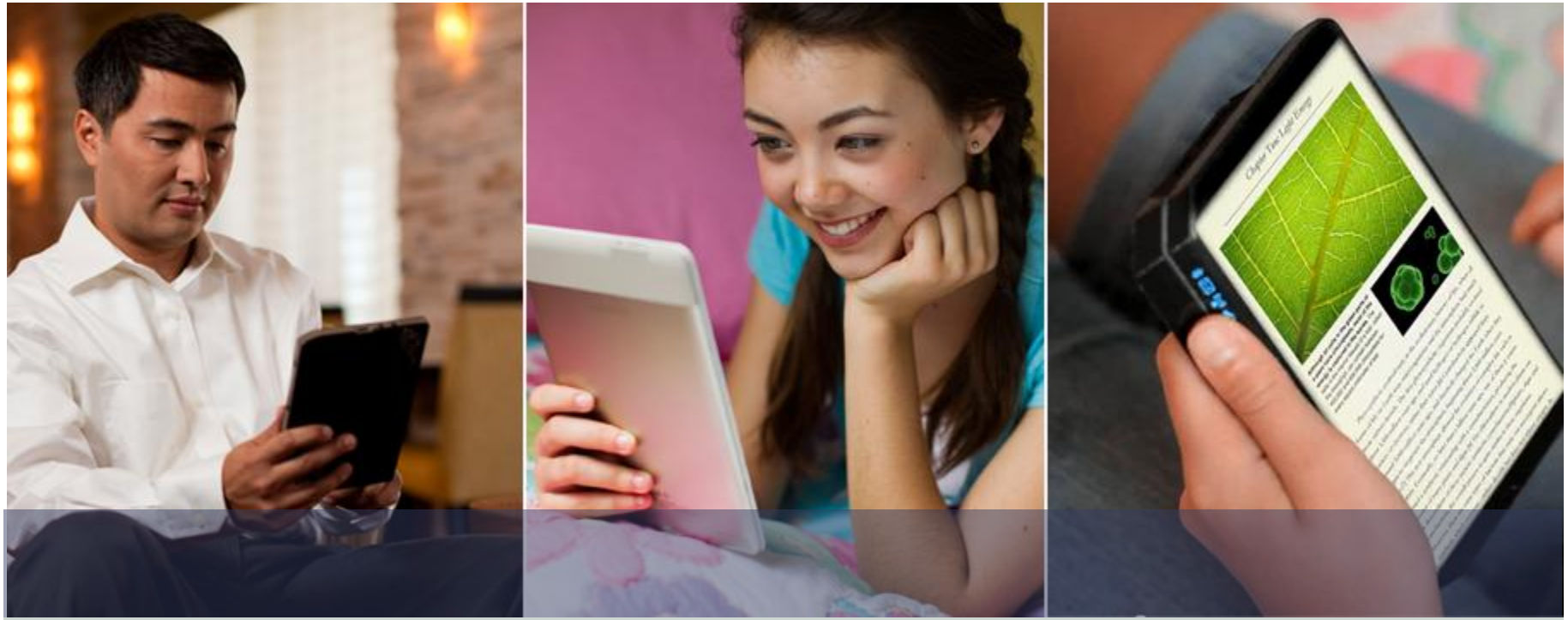

Summary of eReader Designs

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Summary

- **FSL offers a complete portfolio of solutions for the eReader market**
  - i.MX508 introduces integrated EPD controller for BOM optimization and performance
- **eReader Reference Solutions are available today**
  - i.MX508 reference solutions for next generation designs
- **Designing with EPD presents unique design considerations**
  - Must design for different refresh rate, ghosting/flashing effect and collision events
  - Software must be designed with EPD considerations in mind to provide full user experience

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