1.   Description and Scope

This document applies to the AF E Ink waveform flash memory file. The waveform flash file is designed for use with an E Ink approved compatible controller (with advanced Generation II capabilities), an E Ink approved Power Management Integrated Circuit (PMIC), and an Active Matrix Electronic Paper Display (AMEPD) panel using E Ink Carta Imaging Film. Verified AMEPDs are listed in Section 5. The AF waveform is a high performance 4-bit (16-level) grayscale waveform. The AF waveform look-up tables are defined in a 5-bit (32-level) pixel state representation where the 16 graytones are assigned to the even pixel states (0, 2, 4, … 30), where 0 is black and 30 is white.

The waveform flash memory file contains temperature look-up tables (LUTs), waveform sequence data, algorithm data, voltage data, controller settings, and manufacturing data. Each AF waveform is specifically adjusted for a particular display module lot. This specification document is for use by E Ink Corporation and their customers under non-disclosure agreements. E Ink Corporation will be responsible for maintaining and controlling specification revisions.

2.   Waveform Flash File Format

2.1 Introduction

The controller generates display waveforms using an internal or external flash file. The waveform flash file contains multiple temperatures look-up-tables (LUTs). Each temperature LUT contains the waveform sequence information to allow the controller to properly construct a waveform used to generate images on the display. Several update modes are encoded in the AF waveform within each temperature LUT.

2.2 Pixel State Usage

For the AF waveform, the LUTs are defined for a 5-bit (32-level) pixel state representation. Graytones 1-16 are assigned to the even pixel states (0, 2, 4, … 30), respectively. The odd pixels states (1, 3, 5, … 27) are not used. Odd pixel states 29 and 31 (along with state 30) are used to denote graytone 16; states 29 and 31 are used to invoke special transitions to graytone 16.

2.3 Display Update Modes

2.3.1   INIT

The initialization (INIT) mode is used to completely erase the display and leave it in the white state. It is useful for situations where the display information in memory is not a faithful representation of the optical state of the display, for example, after the device receives power after it has been fully powered down. This waveform switches the display several times and leaves it in the white state.

2.3.2   DU

The direct update (DU) is a very fast, non-flashy update. This mode supports transitions from any graytone to black or white only. It cannot be used to update to any graytone other than black or white.   The fast update time for this mode makes it useful for response to touch sensor or pen input or menu selection indictors.

2.3.3 GC16

The grayscale clearing (GC16) mode is used to update the full display and provide a high image quality. When GC16 is used with Full Display Update the entire display will update as the new image is written. If a Partial Update command is used the only pixels with changing graytone values will update. The GC16 mode has 16 unique gray levels.

2.3.4 GL16

The GL16 waveform is primarily used to update sparse content on a white background, such as a page of anti-aliased text, with reduced flash. The GL16 waveform has 16 unique gray levels.

2.3.5 GLR16

The GLR16 mode is used in conjunction with an image preprocessing algorithm to update sparse content on a white background with reduced flash and reduced image artifacts. The GLR16 mode supports 16 graytones. If only the even pixel states are used (0, 2, 4, … 30), the mode will behave exactly as a traditional GL16 waveform mode. If a separately-supplied image preprocessing algorithm is used, the transitions invoked by the pixel states 29 and 31 are used to improve display quality. For the AF waveform, it is assured that the GLR16 waveform data will point to the same voltage lists as the GL16 data and does not need to be stored in a separate memory.

2.3.6 GLD16

The GLD16 mode is used in conjunction with an image preprocessing algorithm to update sparse content on a white background with reduced flash and reduced image artifacts. It is recommended to be used only with the full display update. The GLD16 mode supports 16 graytones. If only the even pixel states are used (0, 2, 4, … 30), the mode will behave exactly as a traditional GL16 waveform mode. If a separately-supplied image preprocessing algorithm is used, the transitions invoked by the pixel states 29 and 31 are used to refresh the background with a lighter flash compared to GC16 mode following a predetermined pixel map as encoded in the waveform file, and reduce image artifacts even more compared to the GLR16 mode. For the AF waveform, it is assured that the GLD16 waveform data will point to the same voltage lists as the GL16 data and does not need to be stored in a separate memory.

2.3.7 DU4

The DU4 is a fast update time (similar to DU), non-flashy waveform. This mode supports transitions from any gray tone to gray tones 1,6,11,16 represented by pixel states [0 10 20 30]. The combination of fast update time and four gray tones make it useful for anti-aliased text in menus. There is a moderate increase in ghosting compared with GC16.

2.3.8 A2

The A2 mode is a fast, non-flash update mode designed for fast paging turning or simple black/white animation. This mode supports transitions from and to black or white only. It cannot be used to update to any graytone other than black or white. The recommended update sequence to transition into repeated A2 updates is shown in Figure 1. The use of a white image in the transition from 4-bit to 1-bit images will reduce ghosting and improve image quality for A2 updates.
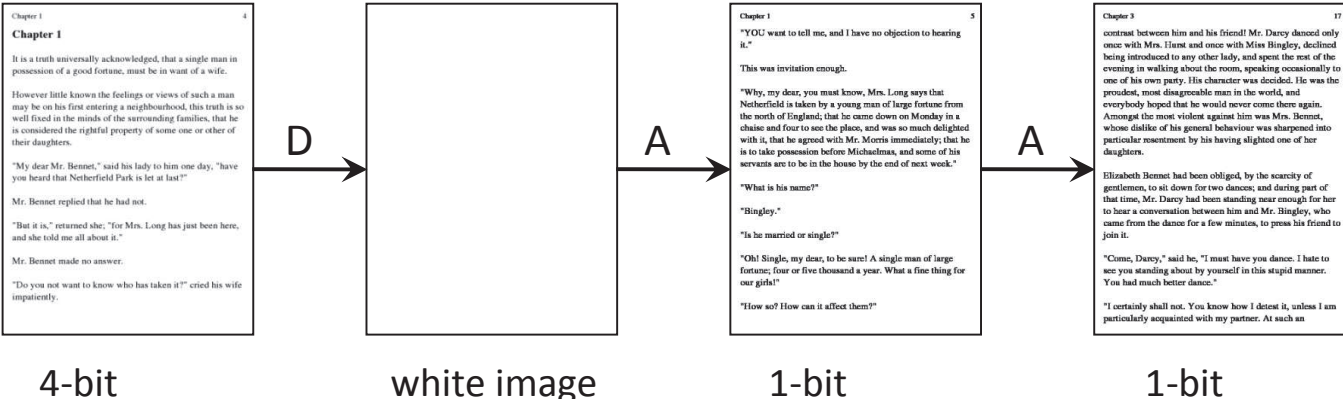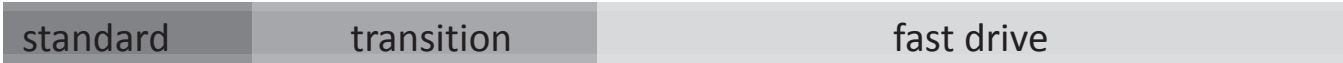
standard	transition	fast drive

4-bit	white image	1-bit	1-bit

Figure 1 Recommended update sequence for transitioning into A2

It is also recommended to use a white image after a sequence of A2 updates as shown in Figure 2

fast drive	transition	standard drive

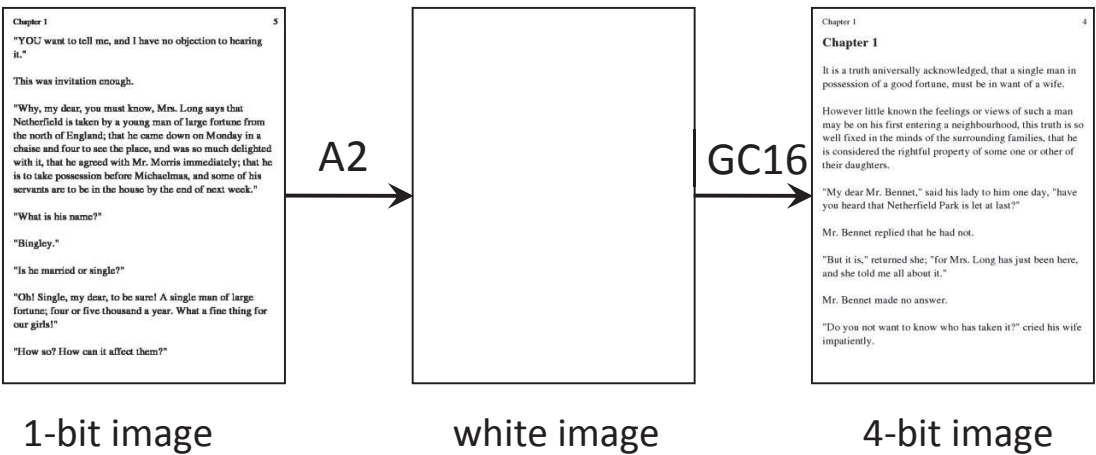| 1-bit image	white image	4-bit image

Figure 2 Recommended update sequence for transitioning out of A2

2.4 Mode Version

Table 1 and Table 2 defines the mode and what mode versions available.

Table **4** lists which mode version is available for each AMEPD part number.

Table 1 Waveform Mode Summary

Mode	Supported pixel state transitions	Ghosting	Usage	Typical update time at 25 C 85 Hz (ms)
INIT	[0 1 2 3 … 31]→ 30	N/A	Display initialization	2000
DU	[0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 29 30 31]→ [0 30]	Low	Monochrome menu, text input, and touch screen/pen input	260
GC16	[0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 29 30 31]→ [0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30]	Very Low	High quality images	450
GL16	[0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 29 30 31]→ [0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30]	Medium	Text with white background	450
GLR16	[0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 29 30 31]→ [0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 29 30 31]	Low	Text with white background	450
GLD16	[0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 29 30 31]→ [0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 29 30 31]	Low	Text and graphics with white background	450
A2	[0 29 30 31]→ [0 30]	Medium	Fast page flipping at reduced contrast	120
DU4	[0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 29 30 31] → [0 10 20 30]	Medium	Anti-aliased text in menus / touch and screen/pen input	290

Table 2 Mode Version Description

Offset 0x16 Value	Offset 0x10 Value	Mode 0	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7
0x00	**0x19**	INIT	DU	GC16	GL16	GLR16	GLD16	A2	DU4

3.   Controller settings and manufacturing data

The information section describes the information held in the first 24 bytes of the flash file. The bytes are defined in Table 3.

Table 3 Waveform Header Information

Offset (bytes)	Size (bytes)	Data	Allowed Values	Comments
0x00	4	CHECKSUM	0x00000000– 0xFFFFFFFF	CRC32 Checksum calculated on the entire binary data file, assuming a value of 0x00000000 for the checksum bytes.
0x04	4	FILE LENGTH	0x00000000– 0xFFFFFFFF	File length in bytes (32-bit little-endian value).
0x08	4	SERIAL #	0x00000000 – 0xFFFFFFFF	Unique 32-bit little-endian value assigned to each released waveform file. 0x00000000 = no serial # assigned.
0x0C	1	RUN TYPE	0x11 -0xFF	8-bit value representing the type of FPL runs. R = 0x11
0x0D	1	RESERVED	0x00-0xFF	RESERVED
0x0E	2	FPL LOT	0x0000 – 0xFFFF	FPL lot number, (16-bit value, little-endian).
0x10	1	MODE VERSION	See Table 2	See Table 2. (Mode descriptions can be found in Table 2.)
0x11	1	WF VERSION	0x00-0xFF	Waveform version
0x12	1	WF SUBVERSION	0x00-0xFF	Waveform subversion
0x13	1	WF TYPE	0x51	Waveform type: 0x51= AF
0x14	1	RESERVED	0x00-0xFF	RESERVED
0x15	1	AMEPD Part Number	See Table 4	
0x16	1	WFM REV	0x00	0x00 = AF WFM Rev00;
0x17	1	FRAME RATE	0x85	0x85 = 85 Hz [*Field definition deprecated in 0x02 WBF Header Revision, Do Not Use field on future designs*]
0x18	1	FRAME RATE	0x00-0xFF	Frame rate converted to Hex, i.e. (0x55 = 85Hz)
0x19	1	VCOM OFFSET	0x00	**0x00 =** User should set the Vcom (VCOM(applied)) to VCOM stored in the module flash plus the VCOM_OFFSET specified in the Voltage Control Information(VCI). ***0x01 value is reserved (for customer compatibility with the VCOM OFFSET field)***
0x1C	3	XWIA	0x000000- 0xFFFFFF	Extra Waveform Information (XWI) address. The XWI contains the waveform filename. (see Section 3.1)
0x1F	1	CS1	0x00-0xFF	Checksum of bytes 0-30 with bytes 0-7 set to 0x00.
0x27	1	AWV	0x00-0xFF	0x00= No Advance WFM information is included; Gen I compatible 0x01= Voltage Control format V2 0x02= Algorithm Control only; 0x03= Voltage Control and Algorithm Control;